On the application of “$Z^0 + \text{jet}$” events for setting the absolute jet energy scale and determining the gluon distribution in a proton at the LHC.

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Abstract

A possibility of jet energy scale setting by help of “$pp \rightarrow Z^0 + \text{jet} + X$” process at LHC is studied. The effect of new set of cuts, proposed in our previous works, on the improvement of $P_{tZ} - P_{t\text{jet}}$ balance is demonstrated. The distributions of the selected events over $P_{tZ}$ and $n_{\text{jet}}$ are presented. A possibility of background events suppression by use of the “$Z^0 + \text{jet}$” events selection criteria is shown.

It is also found that the samples of “$Z^0 + \text{jet}$” events, gained with the cuts for the jet energy calibration, may have enough statistics for determining the gluon distribution inside a proton in the region of $2 \cdot 10^{-4} \leq x \leq 1.0$ with $0.9 \cdot 10^4 \leq Q^2 \leq 4 \cdot 10^4$ (GeV/c)$^2$.

Monte Carlo events produced by the PYTHIA 5.7 generator are used here.
1 Introduction.

A precise reconstruction of the jet energy is the extremely important task in many high energy physics experiments. The previous studies of possibilities to apply for this aim different physical processes (like \( Z^0/\gamma + \text{jet} \) and others), done in D0, CDF, CMS and ATLAS collaborations may be found in [1]–[16].

\( Z^0 + \text{jet} \) events with one high-\( P_t \) jet can provide a useful sample to perform \textit{in situ} determination of a jet transverse momentum via a transverse momentum of \( Z^0 \) boson reconstructed from the precisely measured leptonic \( Z^0 \) decay \((Z^0 \rightarrow \mu^+ \mu^-, e^+ e^-)\).

In this paper we limit our consideration to \( Z^0 \rightarrow \mu^+ \mu^- \) decay only. The amount of material in front and inside the muon detector system guarantees absorbing most hadronic background. Besides, by using the track segments matching between the muon system and the tracker one can reach a high enough reconstruction efficiency of a muon detector system guarantees absorbing most hadronic background. Besides, by using the track segments matching between the muon system and the tracker one can reach a high enough reconstruction efficiency of a muon jet reconstruction. The consequent decay \( Z^0 \rightarrow e^+ e^- \) would require a supplementary introduction of isolation criteria for \( e^\pm \) tracks to perform a confident reconstruction of \( e^\pm \) signal in the cells of electromagnetic calorimeter (ECAL).

Our study has shown that a background to the \( Z^0 + \text{jet} \) events with \( e^+ e^- \) decay channel of \( Z^0 \) boson is about the same as one to the \( Z^0 + \text{jet} \) events with \( \mu^+ \mu^- \) decay channel.

\( Z^0 + \text{jet} \) events is a useful tool to cross-check a setting an absolute jet energy scale with help of other processes like \( \gamma + \text{jet} \) [12]–[16] and \( W \rightarrow 2 \text{jets} \) events [8], for example.

Here we present results of the analysis of \( Z^0 + \text{jet} \) events generated by using PYTHIA 5.7 Monte-Carlo event simulation package [19].

Section 2 is an introduction into the problem. General features of \( Z^0 + \text{jet} \) processes at LHC energies as well as the sources of the disbalance between transverse momenta of \( Z^0 \) and jet are presented here. We list here a set of the selection cuts used to identify signal \( Z^0 + \text{jet} \) events (implying subsequent \( Z^0 \) decay to the muon pair). New criteria (introduced for the first time in [12]) of \( Z^0 + \text{jet} \) events with \( \mu^+ \mu^- \) decay channel of \( Z^0 \) boson is about the same as one to the \( Z^0 + \text{jet} \) events with \( \mu^+ \mu^- \) decay channel.

Section 4 is devoted to the study of the influence of \( P_t^\text{clust} \) and \( P_t^\text{out} \) on the initial state radiation (ISR) suppression. The rates of \( Z^0 + \text{jet} \) events with jet covering Barrel, Endcap and Forward parts of the calorimeter are also given in this section.

In Sections 5 and 6 we confine ourselves by consideration of \( Z^0 + \text{jet} \) events with the jet entirely contained in the Barrel region. The dependences of various physical variables on \( P_t^\text{clust} \) and \( P_t^\text{out} \) are analyzed there and shown in the tables of Appendixes 2–5. The values of the disbalance between \( P_t^Z \) and \( P_t^\text{jet} \) with for three \( P_t^Z \) intervals and various \( P_t^\text{clust} \) and \( P_t^\text{out} \) values are presented in Appendix 6.

In Section 7 we study a possibility of background events suppression for different \( P_t^Z \) intervals. The number of events for determination of the gluon density in a proton by using \( Z^0 + \text{jet} \) events is estimated in Section 8. The event rates and contributions of various processes are calculated there for different \( x \) and \( Q^2 \) intervals. It is shown that the kinematic region for the gluon density determination in the intervals: \( 2 \cdot 10^{-4} \leq x \leq 1.0 \) with \( 0.9 \cdot 10^3 \leq Q^2 \leq 4 \cdot 10^4 \text{(GeV/c)}^2 \) can be covered by studying the \( Z^0 + \text{jet} \) events.

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1) see [17]

2) For instance, by requiring (1) a total transverse momentum \( E_t^{\text{tot}} \) around an electron with \( E_t^e \) in the cone with \( R = 0.3 \) to be \( E_t^{\text{tot}} < 5 \text{ GeV} \) and (2) \( E_t^{\text{tot}}/E_t^e < 0.1 \) (e.g. see [18]) we additionally reduce a number of signal events by \( 2 – 4\% \).
2 Generalities of the “$Z^0 + jet$” process.

2.1 Leading order picture and sources of $P_{tZ}$ and $P_{tJet}$ disbalance.

In this section we observe briefly the main effects that lead to the disbalance between $P_{tZ}$ and $P_{tJet}$.

The process of $Z^0 + jet$ production

$$pp \rightarrow Z^0 + 1 jet + X$$

(1)

is caused at the parton level by two subprocesses: Compton-like scattering

$$qg \rightarrow q + Z^0$$

(2a)

and the annihilation process

$$q\bar{q} \rightarrow g + Z^0.$$  (2b)

Some leading order Feynman diagrams of these processes are shown in Fig. 1.

Figure 1: Some leading order Feynman diagrams for $Z^0$ production.

If the initial state radiation (ISR) is absent, the total transverse momentum of the final state in the subprocesses (2a) or (2b) is equal to zero, i.e. the $P_t$ balance equation for $Z^0$ and final parton would look as

$$\vec{P}_{tZ}^{part} + \vec{P}_{tZ}^{part} = 0.$$  (2)

Thus, having neglected hadronization effect we could expect that a jet transverse momentum $P_{tJet}$ is close enough to $Z^0$ boson transverse momentum, i.e. $P_{tJet} \approx -\vec{P}_{tZ}^{part}$.

A radiation of a gluon in the initial state with a non-zero transverse momentum $P_{tISR} \neq 0$ can produce a disbalance between $P_{tZ}$ and $P_{tpart}$ and, thus, between transverse momenta of $Z^0$ boson and the jet originated from this proton. The corresponding next-to-leading order diagrams are shown in Fig. 2.

Following [12], we choose the sum of the modulus of the transverse momentum vectors $P_t^5$ and $P_t^6$ of the incoming (into $2 \rightarrow 2$ fundamental QCD subprocesses $5 + 6 \rightarrow 7 + 8$) partons (lines 5 and 6 in Fig. 2):

$$P_{t56} = |P_t^5| + |P_t^6|.$$  (3)

as a quantitative measure to estimate the $P_t$ disbalance caused by ISR.

The numerical notations in the Feynman diagrams shown in Figs. 1 and 2 and in formula (2) are chosen to be in correspondence with those used in the PYTHIA event listing for description of the parton–parton subprocess displayed schematically in Fig. 3. The “ISR” block describes the initial state radiation process that can take place before the fundamental hard $2 \rightarrow 2$ process.

Figure 2: Some Feynman diagrams of $Z^0$ production including gluon radiation in the initial state.

3) The more detailed consideration is given in our papers [12, 22] devoted to the jet energy calibration by using “$\gamma + jet$” events.
Figure 3: PYTHIA “diagram” of a fundamental $2 \to 2$ process ($5+6 \to 7+8$) following the block ($3+4 \to 5+6$) of initial state radiation (ISR).

Let us consider fundamental subprocesses in which there is no initial state radiation but instead final state radiation (FSR) takes place. Some Feynman diagrams of the signal subprocesses with the FSR are shown in Fig. 4. An appearance of a gluon in the final state may also cause a disbalance between transverse momenta of $Z^0$ and jet. But because it manifests itself as some extra jets or clusters, like in the case of ISR, the same selection criteria (see below) as for suppression of ISR can be used.

A possible non-zero value of the intrinsic transverse momentum of a parton inside a colliding proton ($k_T$) may be another source of the $P_t^{Z}$ and $P_t^{Jet}$ disbalance in the final state. Its reasonable value is supposed to lead to the value of $k_T \leq 1.0 \text{ GeV/c}$. In what follows we shall keep the value of $k_T$ to be fixed by the PYTHIA default value $\langle k_T \rangle = 0.44 \text{ GeV/c}$. The dependence of the disbalance between $P_t^{Z}$ and $P_t^{Jet}$ on a possible variation of $k_T$ is discussed in detail in [16, 22]. The general conclusion is that the variation of $k_T$ within reasonable boundaries does not produce a large effect when the initial state radiation is taken into account. The latter makes a dominant contribution.

Another non-perturbative effect that results in the $P_t^{Z}$ and $P_t^{Jet}$ disbalance is an hadronization of the parton, produced in the fundamental $2 \to 2$ subprocess, into a jet. The contribution of the hadronization to this disbalance is calculated within the Lund string fragmentation scheme used by default in PYTHIA. The mean values of the relative $P_t^{Jet} - P_t^{part}$ disbalance are presented in the tables of Appendices 2 – 5 for three different jetfinders (UA1, UA2 and LUCELL 4) as a function of the variable which limit a cluster activity beyond the “$Z^0 + jet$” system (see Section 2.2 and [14]).

2.2 Definition of selection cuts.

1. We shall select the events with $Z^0$ boson 5) and one jet with

$$P_t^{Z} \geq 40 \text{ GeV/c} \quad \text{and} \quad P_t^{Jet} \geq 30 \text{ GeV/c}. \quad (4)$$

For most of our applications the jet is defined according to the PYTHIA jetfinding algorithm LUCELL. The jet cone radius $R$ in the $\eta - \phi$ space counted from the jet initiator cell (ic) is taken to be $R_{ic} = (\Delta \eta)^2 + (\Delta \phi)^2)^{1/2} = 0.7$.

Comparison with the UA1 and UA2 jetfinding algorithms is presented in Sections 5 and 6.

2. To guarantee a clear identification of a muon track from $Z^0$ decay in the muon and tracker systems and determination of its parameters we put the following restrictions on muons 6):

(a) on the $P_t$ value of any considered muon:

$$P_t^\mu \geq 10 \text{ GeV/c}; \quad (5)$$

(b) on the $P_t$ value of the most energetic muon in a pair:

$$P_{t_{max}}^\mu \geq P_{t_{CUT}}^\mu \quad (6)$$

($P_{t_{CUT}}^\mu \geq 20 \text{ GeV/c}$ and depends on the energy scale; see Fig. 6 of Section 4.3);

4) UA1 and UA2 algorithms are taken from the CMSJET program of fast simulation [18], while LUCELL is the PYTHIA’s default jetfinding algorithm [19].

5) Here and below in the paper speaking about $Z^0$ boson we imply a signal reconstructed from the muon pair with muons selected by the criteria $2 - 4$ of this section.

6) Most of the muon selection cuts are taken from [17, 18].

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(c) on the value of the ratio of $P_t^{isol}$, i.e., the scalar sum of $P_t$ of all particles surrounding a muon, to $P_t^{\mu}$ ($P_t^{isol}/P_t^{\mu}$) in the cone of radius $R = 0.3$ and on the value of maximal $P_t$ of a charged particle surrounding a muon in this cone:

$$P_t^{isol}/P_t^{\mu} \leq 0.10, \quad P_t^{ch} \leq 2\,\text{GeV}/c. \quad (7)$$

The isolated high-$P_t$ tracks can be reconstructed with a good efficiency (at least 98% over all pseudorapidity region $|\eta| < 2.4$; see [17]) and with generation of a low number of fake and ghost tracks.

3. A muon is selected in the region of the muon system acceptance:

$$|\eta^\mu| < 2.4. \quad (8)$$

4. To select muon pairs only from the $Z^0$ decay we limit the value of invariant mass of a muon pair $M_{inv}^{ll}$ by:

$$|M^Z - M_{inv}^{ll}| \leq 5\,\text{GeV}/c^2. \quad (9)$$

5. We select the events with the vector $\vec{P}_t^{Z,jet}$ being “back-to-back” to the vector $\vec{P}_t^Z$ (in the plane transverse to the beam line) within $\Delta\phi$ defined by the equation:

$$\phi(Z,jet) = 180^\circ \pm \Delta\phi \quad (10)$$

where $\phi(Z,jet)$ is the angle between the $\vec{P}_t^Z$ and $\vec{P}_t^{Z,jet}$ vectors: $\vec{P}_t^Z \cdot \vec{P}_t^{Z,jet} = P_t^Z P_t^{Z,jet} \cos(\phi(Z,jet))$, where $P_t^Z = |\vec{P}_t^Z|$, $P_t^{Z,jet} = |\vec{P}_t^{Z,jet}|$. $\Delta\phi$ defined in the interval $5 – 15^\circ$ is the most effective choice.

6. The initial and final state radiations (ISR and FSR) manifest themselves most clearly as some final state mini-jets shown in [12] – [16] and in [22]. In Sections 5 and 6 it will be demonstrated once again for the case of “$Z^0 + \text{jet}$” events. The set of selection cuts 1 – 7 we call as “Selection 1”.

7. We limit the value of the modulus of the vector sum of $\vec{P}_t$ of all particles that do not belong to the “$Z^0 + \text{jet}$” system but fit into the region $|\eta| < 5$ covered by the calorimeter system, i.e., we limit the signal in the cells “beyond the jet and $Z^0$” regions by the following cut:

$$\left| \sum_{i \notin \text{Jet, Z}^{out}} |\vec{P}_t^i| \right| = P_{t^{out}} \leq P_{t^{cut}}^{out}, \quad |\eta| < 5. \quad (12)$$

The importance of $P_{t^{cut}}$ and $P_{t^{cut}}^{out}$ for selection of events with a good balance of $P_t^Z$ and $P_t^{\text{Jet}}$ was already shown in [12] – [16] and in [22]. In Sections 5 and 6 it will be demonstrated once again for the case of “$Z^0 + \text{jet}$” events. The set of selection cuts 1 – 7 we call as “Selection 1”.

8. By analogy with [12] – [16] and [22] we use a “jet isolation” requirement (introduced for the first time in [12]), i.e. the presence of a “clean enough” (in the sense of limited $P_t$ activity) region inside the ring of $\Delta R = 0.3$ around the jet. Following this picture, we restrict the ratio of the scalar sum of transverse momenta of particles belonging to this ring, i.e.,

$$P_t^{ring}/P_t^{jet} \equiv \varepsilon^{jet}, \quad \text{where} \quad P_t^{ring} = \sum_{i \in 0.7 < R < 1} |\vec{P}_t^i| \quad (13)$$

with $\varepsilon^{jet} \leq 3 – 8\%$ (see Sections 6 and 7). The set of events that pass cuts 1 – 7 will be called “Selection 2”.

9. As in [12] [22] in the following “Selection 3” we shall keep only those events in which one and the same jet (i.e. up to good accuracy having the same values of $P_t^{jet}$, $R^{jet}$ and $\Delta\phi$) is found simultaneously by every of three jetfinders used here: UA1, UA2 and LUCCELL. For these jets (and also clusters) we require the following conditions:

$$P_t^{jet} > 30\,\text{GeV}/c, \quad P_t^{clust} < P_{t^{cut}}^{clust}, \quad \Delta\phi < 15^\circ, \quad \varepsilon^{jet} \leq 5\%. \quad (14)$$
10. As we shown in [12, 22] One can expect reasonable results of modeling the jet energy calibration procedure and subsequent practical realization only if one uses a set of selected events with small missing transverse momentum $P^\text{miss}_t$. We define it here as a $P_t$ vector sum of all the particles flying mostly in the direction of the non-instrumented region $|\eta| > 5.0$ and neutrinos with $|\eta| < 5.0$:

$$P^\text{miss}_t = \vec{P}_t^{|\eta|>5.0} + \sum_{i\in|\eta|<5.0} \vec{P}_t^i. \tag{15}$$

Here $\vec{P}_t^{|\eta|>5}$ is the total transverse momentum of non-observable particles $i$ flying in the direction of the non-instrumented forward part of the CMS detector ($|\eta| > 5$):

$$\sum_{i\in|\eta|<5} \vec{P}_t^i = \vec{P}_t^{|\eta|>5}. \tag{16}$$

We shall use the following cut on $P^\text{miss}_t$:

$$P^\text{miss}_t \leq P^\text{miss}_{t,CUT}. \tag{17}$$

The aim of the event selection with small $P^\text{miss}_t$ is quite obvious: we need a set of events with a reduced $P_t^\text{jet}$ uncertainty due to a possible presence of a non-detectable neutrino contribution to a jet, for example.

The exact values of the cut parameters $P^\mu_{t,CUT}$, $\epsilon^\text{jet}$, $P^\text{clust}_{t,CUT}$, $P^\text{out}_{t,CUT}$ will be specified below, since they may be different, for instance, for various $P_t^Z$ intervals.

### 2.3 The $P_t$-balance equation of “$Z^0 + jet$” event.

The conservation law for “$Z^0 + jet$” events as a whole can be written in the following vector form [12, 22]:

$$\vec{P}_t^Z + \vec{P}_t^\text{Jet} + \vec{P}_t^O + \vec{P}_t^{|\eta|>5} = 0. \tag{18}$$

$\vec{P}_t^{|\eta|>5}$ is defined in [16] and $\vec{P}_t^O$ is a total transverse momentum of all other (O) particles besides “jet particles and muons from $Z^0$ decay” (“$Z^0 + jet$” system) in the $|\eta| < 5$ region and defined as:

$$\vec{P}_t^O = \vec{P}_t^\text{out} + \vec{P}_t^{(\nu)} + \vec{P}_t^{(\mu,|\eta|>2.4)}. \tag{19}$$

In its turn, $\vec{P}_t^\text{out}$ is a sum of clusters $P_t$ (with $P_t^{\text{clust}}$ smaller than $P_t^\text{Jet}$) and $P_t$ of single hadrons ($h$), photons ($\gamma$) and electrons ($e$) with $|\eta| < 5$ and muons ($\mu$) with $|\eta^\mu| < 2.4$ that are out of the “$Z^0 + jet$” system:

$$\vec{P}_t^\text{out} = \vec{P}_t^{\text{clust}} + \vec{P}_t^{(h)} + \vec{P}_t^{(\gamma)} + \vec{P}_t^{(e)} + \vec{P}_t^{(\mu,|\eta|>2.4)}, \quad |\eta| < 5. \tag{20}$$

The last two terms in equation (19) are the transverse momentum carried out by the neutrinos that do not belong to the jet but that are contained in the $|\eta| < 5$ region ($\vec{P}_t^{(\nu)}$) and non-detectable muons flying with $|\eta^\mu| > 2.4$ ($\vec{P}_t^{(\mu,|\eta|>2.4)}$).

To conclude this section, let us rewrite the basic vector $P_t$-balance equation in the following scalar form, more suitable to present the final results:

$$\frac{P_t^Z - P_t^\text{Jet}}{P_t^Z} = (1 - \cos \Delta \phi) + P_t(\Omega + \eta > 5)/P_t^Z, \tag{21}$$

where $P_t(\Omega + \eta > 5) \equiv (\vec{P}_t^O + \vec{P}_t^{(\text{out},|\eta|>5)}) \cdot \vec{\eta}^\text{Jet}$ with $\vec{\eta}^\text{Jet} = P_t^\text{Jet}/P_t^\text{Jet}$ and $\Delta \phi$ is the angle that enters equation [11].

As will be shown in Section 6, the first term on the right-hand side of equation (21) is negligibly small and tends to decrease fast with growing $P_t^\text{Jet}$. So, the main contribution to the $P_t$ disbalance in the “$Z^0 + jet$” system is caused by the term $P_t(\Omega + \eta > 5)/P_t^Z$ [12–16, 22].
3 Estimation of a non-detectable part of $P_t^{jet}$.

This subject is considered in detail in [12]. Here we outline the main results for the case of “$Z^0 + jet$” events. One of the main sources of this part, that can be estimated on the particle level, is non-detectable particles (like neutrinos and muons with $|\eta| > 2.4$) \(^7\)

The missing transverse momentum $P_t^{miss}$ (see [15]) and a $P_t$ contribution to a jet from non-detectable particles are estimated here in the framework of simulation with PYTHIA \(^8\). The detailed information about the transverse momenta of non-detectable neutrinos $P_{t(\nu)}^{jet}$ averaged over all events (no cut on $P_t^{miss}$ was used) as well as about mean $P_t$ values of muons belonging to jets ($P_{t(\mu)}^{jet}$) is presented in Tables 1–12 of Appendix 1 for the sample of events with jets which are entirely contained in the barrel region of the calorimeter ($|\eta| < 1.4$, “HB-events”, see Section 4 and 5). In these tables the ratio of number of the events with non-zero $P_{t(\nu)}^{jet}$ to the total number of events is denoted by $P_{event}^{\nu}$ and the ratio of the number of events with non-zero $P_{t(\mu)}^{jet}$ to the total number of events is denoted by $P_{event}^{\mu}$.

A wide variation of $P_t^{miss}$ as well as the case of allowed $K^\pm$ decays in the calorimeter volume were presented in detail in [12]. We choose here for the following analysis $P_{t,CUT}^{miss} = 10 \text{ GeV/c}$ found to be optimal in [12].

4 Event rates for different $P_t^Z$ and $\eta^Z$ intervals.

4.1 Dependence of the distribution of the number of events on the ”back-to-back” angle $\phi(Z,\text{jet})$ and on $P_t^{ISR}$.

Here we study the spectrum of the variable $P_{t,56}$ for the sample of signal events \(^9\). For this aim four samples of “$Z^0 + jet$” events (each by $5 \cdot 10^9$) were generated by using PYTHIA with 2 subprocesses (2a) and (2b) and with minimal $P_t$ of hard $2 \rightarrow 2$ scattering \(^{10}\) $P_{t,min} = 20, 35, 50, 75 \text{ GeV/c}$ to cover four $P_t^Z$ intervals: 40–50, 70–85, 100–120, 150–200 $\text{ GeV/c}$, respectively. The obtained cross sections for these subprocesses are given in Table 1.

Table 1: The cross sections (in microbarns) of the $qg \rightarrow q + Z^0$ and $q\bar{q} \rightarrow g + Z^0$ subprocesses for four $P_{t,min}$ values.

| Subprocess type | $\hat{p}_{t,min}$ values (GeV/c) |
|-----------------|---------------------------------|
| $qg \rightarrow q + Z^0$ | 3.83-10^-4, 1.71-10^-4, 9.14-10^-5, 3.80-10^-5 |
| $q\bar{q} \rightarrow g + Z^0$ | 1.20-10^-4, 0.42-10^-4, 1.93-10^-5, 0.69-10^-5 |
| Total           | 5.03-10^-4, 2.13-10^-4, 1.11-10^-5, 4.59-10^-5 |

For our analysis we used cuts \([3] \rightarrow [12] \) and the following cut parameters:

$$P_{t,max}^h > 20 \text{ GeV/c}, \quad \Delta \phi < 15^\circ, \quad P_{t,CUT}^{clus} = 30 \text{ GeV/c}.$$ \hspace{1cm} (22)

In Tables 2 and 5 we study (as in [12]) $P_{t,56}$ spectra for two most illustrative cases of $P_t^Z$ intervals $40 < P_t^Z < 50 \text{ GeV/c}$ (Tables 2 and 5) and $100 < P_t^Z < 120 \text{ GeV/c}$ (Tables 3 and 6). The distributions of the number of events for the integrated luminosity $L_{int} = 10 \text{ fb}^{-1}$ in different $P_{t,56}$ intervals and for different “back-to-back” angle intervals $\phi(Z,\text{jet}) = 180^\circ \pm \Delta \phi$ (with $\Delta \phi = 15^\circ, 10^\circ$ and $5^\circ$ as well as without any restriction on $\Delta \phi$, i.e. for the whole $\phi$ interval $\Delta \phi = 180^\circ$) are given there. The LUCELL jetfinder was used to find jets and clusters. Tables 4 and 6 correspond to the events selected with cuts $P_{t,clus}^h < 30 \text{ GeV/c}$ and without any limit on $P_{t,clus}$ value, while Tables 5 and 6 correspond to more restrictive selection cuts $P_{t,clus}^h < 10 \text{ GeV/c}$ and $P_{t,clus}^h < 10 \text{ GeV/c}$.

First, from the last summary lines of Tables 2, 4 and 5 we can make a general conclusion about the $\Delta \phi$ dependence of the event spectrum. In the case when no restriction is used we can see that for the $40 < P_t^Z < 50 \text{ GeV/c}$

\(^7\) In a real experiment, of course, it can be also conditioned by many other reasons as, for instance, the energy leakage due to constructive features of the detector, magnetic filed effects and so on.

\(^8\) We have considered the case of switched-off decays of $\pi^\pm$ and $K^\pm$ mesons (according to the PYTHIA default agreement, $\pi^\pm$ and $K^\pm$ mesons are stable).

\(^9\) $P_{t,56}$ is approximately proportional to $P_{t,ISR}^h$ up to the value of intrinsic parton transverse momentum $k_T$ inside a proton ($\langle k_T \rangle$ was taken to be fixed at the PYTHIA default value, i.e. $\langle k_T \rangle = 0.44 \text{ GeV/c}$).

\(^{10}\) CKIN(3) parameter in PYTHIA
Table 2: Number of events dependence on $P_t^{56}$ and $\Delta \phi$ for $40 \leq P_t^{Z} \leq 50$ GeV/c and $P_t^{clust}$ = 30 GeV/c for $L_{int}=10$ fb$^{-1}$.

| $P_t^{56}$ (GeV/c) | $\Delta \phi_{max}$ | 180° | 15° | 10° | 5° |
|-------------------|-------------------|------|-----|-----|----|
| 0 – 5             |                   | 18525| 16965| 15880| 12708|
| 5 – 10            |                   | 29094| 26671| 23419| 15579|
| 10 – 15           |                   | 24192| 19935| 14042| 7033 |
| 15 – 20           |                   | 18168| 10910| 7088 | 3481 |
| 20 – 25           |                   | 13424| 5833 | 3924 | 1968 |
| 25 – 30           |                   | 10169| 3604 | 2380 | 1172 |
| 30 – 40           |                   | 14070| 4114 | 2677 | 1311 |
| 40 – 50           |                   | 7544 | 1833 | 1184 | 618  |
| 50 – 100          |                   | 5904 | 1727 | 1097 | 550  |
| 100 – 300         |                   | 8    | 3    | 2    | 0    |
| 300 – 500         |                   | 0    | 0    | 0    | 0    |
| 30 – 500          |                   | 141095| 91594| 71694| 42423|

Table 3: Number of events dependence on $P_t^{56}$ and $\Delta \phi$ for $100 \leq P_t^{Z} \leq 120$ GeV/c and $P_t^{clust}$ = 30 GeV/c for $L_{int}=10$ fb$^{-1}$.

| $P_t^{56}$ (GeV/c) | $\Delta \phi_{max}$ | 180° | 15° | 10° | 5° |
|-------------------|-------------------|------|-----|-----|----|
| 0 – 5             |                   | 1849 | 1837| 1790| 1616|
| 5 – 10            |                   | 3798 | 3770| 3667| 3247|
| 10 – 15           |                   | 3635 | 3600| 3477| 2542|
| 15 – 20           |                   | 3065 | 3025| 2847| 1592|
| 20 – 25           |                   | 2491 | 2424| 1976| 986 |
| 25 – 30           |                   | 2115 | 2000| 1418| 709 |
| 30 – 40           |                   | 2507 | 2039| 1398| 721 |
| 40 – 50           |                   | 1061 | 744 | 527 | 289 |
| 50 – 100          |                   | 1105 | 768 | 582 | 325 |
| 100 – 300         |                   | 194 | 147 | 107 | 63  |
| 300 – 500         |                   | 2     | 2   | 1   | 0   |
| 0 – 500           |                   | 21826| 20356| 17797| 12094|

Table 4: Number of events dependence on $\Delta \phi$ and on $P_t^{Z}$ for $L_{int} = 10$ fb$^{-1}$.

| $P_t^{Z}$ (GeV/c) | $\Delta \phi_{max}$ | 180° | 15° | 10° | 5° |
|------------------|------------------|------|-----|-----|----|
| 40 – 50          |                  | 141095| 91591| 71694| 42423|
| 70 – 80          |                  | 40032 | 32551| 26710| 16794|
| 100 – 120        |                  | 2182 | 20356| 17797| 12094|
| 150 – 200        |                  | 8649 | 8558 | 8134 | 6182|
Table 5: Number of events dependence on $P_{t56}$ and $\Delta\phi$ for $40 \leq P_{tZ} \leq 50\,\text{GeV}/c$ and $P_{tclust}^{\text{cut}} = 10\,\text{GeV}/c$ and $P_{t\text{out}}^{\text{cut}} = 10\,\text{GeV}/c$ for $L_{\text{int}}=10\,\text{fb}^{-1}$.

| $P_{t56}$ (GeV/c) | $\Delta\phi_{\text{max}}$ | 180° | 15° | 10° | 5° |
|-------------------|--------------------------|------|-----|-----|-----|
| 0 – 5             |                          | 11619| 11603| 11409| 9603|
| 5 – 10            |                          | 15329| 15258| 14288| 8767|
| 10 – 15           |                          | 6787 | 6479 | 5156 | 2768|
| 15 – 20           |                          | 1810 | 1533 | 1204 | 645 |
| 20 – 25           |                          | 677  | 527  | 432  | 253 |
| 25 – 30           |                          | 305  | 238  | 195  | 119 |
| 30 – 40           |                          | 277  | 222  | 193  | 111 |
| 40 – 50           |                          | 127  | 111  | 91   | 44  |
| 50 – 100          |                          | 36   | 32   | 24   | 12  |
| 100 – 300         |                          | 0    | 0    | 0    | 0   |
| 300 – 500         |                          | 0    | 0    | 0    | 0   |
| 0 – 500           |                          | 36967| 35996| 32987| 22315|

Table 6: Number of events dependence on $P_{t56}$ and $\Delta\phi$ for $100 \leq P_{tZ} \leq 120\,\text{GeV}/c$ and $P_{tclust}^{\text{cut}} = 10\,\text{GeV}/c$ and $P_{t\text{out}}^{\text{cut}} = 10\,\text{GeV}/c$ for $L_{\text{int}}=10\,\text{fb}^{-1}$.

| $P_{t56}$ (GeV/c) | $\Delta\phi_{\text{max}}$ | 180° | 15° | 10° | 5° |
|-------------------|--------------------------|------|-----|-----|-----|
| 0 – 5             |                          | 1133 | 1133| 1133| 1121|
| 5 – 10            |                          | 1932 | 1932| 1932| 1877|
| 10 – 15           |                          | 1002 | 1002| 1002| 867 |
| 15 – 20           |                          | 309  | 309 | 309 | 234 |
| 20 – 25           |                          | 95   | 95  | 91  | 63  |
| 25 – 30           |                          | 49   | 49  | 45  | 33  |
| 30 – 40           |                          | 48   | 44  | 40  | 32  |
| 40 – 50           |                          | 27   | 25  | 25  | 25  |
| 50 – 100          |                          | 44   | 44  | 44  | 40  |
| 100 – 300         |                          | 5    | 5   | 5   | 5   |
| 300 – 500         |                          | 0    | 0   | 0   | 0   |
| 0 – 500           |                          | 4641 | 4637| 4621| 4293|

Table 7: Number of events dependence on $\Delta\phi$ and on $P_{tZ}$ for $L_{\text{int}} = 10\,\text{fb}^{-1}$.

| $P_{tZ}$ (GeV/c) | $\Delta\phi_{\text{max}}$ | 180° | 15° | 10° | 5° |
|------------------|--------------------------|------|-----|-----|-----|
| 40 – 50          |                          | 36967| 35996| 32987| 22315|
| 70 – 80          |                          | 8688 | 8657| 8542| 7033 |
| 100 – 120        |                          | 4641 | 4637| 4621| 4293 |
| 150 – 200        |                          | 1746 | 1746| 1742| 1719 |
An increase in the interval about 65% of events are concentrated in the $\Delta \phi < 15^\circ$ range, while 30% of events are in the $\Delta \phi < 5^\circ$ range. At the same time the analogous summary line of Table 2 shows us that for $100 < P_t^Z < 120$ GeV/c the event spectrum moves noticeably to the small $\Delta \phi$ region: more than 94% of events have $\Delta \phi < 15^\circ$ and 56% of them have $\Delta \phi < 5^\circ$.

We observe a tendency of the distributions of the number of signal “$Z^0 + jet$” events to be concentrated in a rather narrow back-to-back angle interval $\Delta \phi < 15^\circ$ with $P_t^Z$ growing. It becomes more distinct with a more restrictive cuts $P_{t\text{out}} = 10$ GeV/c and $P_{t\text{cut}} = 10$ GeV/c (Tables 3 and 5). From the last summary line of Table 5 we see that in the case of $40 < P_t^Z < 50$ GeV/c more than 96% of the events have $\Delta \phi < 15^\circ$, while 60% of them are in the $\Delta \phi < 5^\circ$ range. For $100 < P_t^Z < 120$ GeV/c (see Table 6) more than 92% of the events, subject to these cuts, have $\Delta \phi < 5^\circ$. It means that while suppressing $P_t$ activity beyond the “$Z^0 + jet$” system by imposing $P_{t\text{cut}} = 10$ GeV/c and $P_{t\text{cut}} = 10$ GeV/c we can select the sample of events with a clean back-to-back ($\Delta \phi < 15^\circ$) topology of $P_t^Z$ and $P_t^\text{jet}$ orientation.

The other lines of Tables 2, 3 and 5, 6 contain the information about the $P_t^{Z6}$ spectrum (or, up to $k_T$ effect, $P_t^{ISR}$ spectrum).

From the comparison of Table 2 with Table 5 (as well as from Tables 3 and 6) one can conclude that the width of the most populated part of the $P_t^{Z6}$ (or $P_t^{ISR}$) spectrum is noticeably reduced with restricting $P_{t\text{cut}}$ and $P_{t\text{cut}}$

We supply Tables 2, 4 and 5 with summarizing Tables 4 and 7 containing an illustrative information on $\Delta \phi$ dependence of the total number of events. They include more $P_t^Z$ intervals and contain analogous numbers of events that can be collected in different $\Delta \phi$ intervals for $P_{t\text{cut}}$, $P_{t\text{cut}}$ and other cuts, defined by |Z|, at $L_{int} = 10$ fb$^{-1}$.

We can conclude from Tables 2, 4 that restriction on the $P_{t\text{cut}}$ and $P_{t\text{cut}}$ variables are good tools to reduce ISR while by limiting $\Delta \phi$ angle the ISR remains, in fact, without a change. Meanwhile, in spite of about twofold spectra reduction of the ISR (or $P_t^{Z6}$), see Tables 4 and 7, it continues to be noticeable at the LHC energies.

4.2 $P_t^Z$, $\eta^Z$ and $P_t^\mu$ dependence of rates.

In Table 2 we present the number of events calculated after passing selection cuts 4–12 for different $P_t^Z$ and $\eta^Z$ intervals (lines and columns of the table, respectively). The last column of this table contains the total number of events (at $L_{int} = 10$ fb$^{-1}$) at $|\eta^Z| < 5.0$ for a given $P_t^Z$ interval. We see that the number of events decreases fast with growing $P_t^Z$ (but it decreases much slower as compared with decrease in $P_t^\gamma$ spectrum in the case of “$\gamma + jet$” events, see Fig. 12). It also drops with growing $|\eta^Z|$ starting from $|\eta^Z| \approx 2.0$ and has weak dependence on $\eta^Z$ in the interval $|\eta^Z| < 2.0$. The analogous information is illustrated by Fig. 5 for three $P_t^Z$ intervals.

In Fig. 5 we have plotted a normalized distributions of the number of events over $P_t$ of muons from $Z^0$ decay for two $P_t^Z$ intervals: $40 < P_t^Z < 50$ and $100 < P_t^Z < 120$ GeV/c. The muon spectra are limited by the condition (4) $P_t^Z > 10$ GeV/c. We also see that the spectra with muons having maximal $P_t$ in the pair starts at $20$ GeV/c for $40 < P_t^Z < 50$ GeV/c and at $50$ GeV/c for $100 < P_t^Z < 120$ GeV/c. It explains our choice in (5) for $P_t^\mu_{max}$ restriction.

11) An increase in $P_t^Z$ produces the same effect, as is seen from Tables 3 and 4 and will be demonstrated in more detail in Section 6 and Appendices 2–5.

12) The analogous conclusion was done by studying “$\gamma + jet$” events in [12].

13) We have limited $Z^0$ pseudorapidity spectrum from above in Fig. 5 and Table 5 only to give understanding about the its behavior inside this $\eta^Z$ interval and, certainly, have not used those limits as cuts anywhere in this paper.
Table 8: Rates for $L_{int} = 10 \text{ fb}^{-1}$ for different intervals of $P_t^Z$ and $\eta^Z$ ($P_{t\text{cut}} = 10 \text{ GeV/c}$, $P_{t\text{cut}} = 10 \text{ GeV/c}$ and $\Delta \phi \leq 15^\circ$).

| $P_t^Z$ (GeV/c) | $|\Delta \eta^Z|$ intervals | all $|\eta^Z|$ |
|----------------|-----------------------------|---------------|
|                | 0.0-0.5                     | 0.0-5.0       |
| 40 – 50        | 4594                        | 5425          |
| 50 – 60        | 5128                        | 4397          |
| 60 – 70        | 4218                        | 2934          |
| 70 – 80        | 2598                        | 1948          |
| 80 – 90        | 1580                        | 1236          |
| 90 – 100       | 741                         | 808           |
| 100 – 110      | 582                         | 546           |
| 110 – 120      | 384                         | 412           |
| 120 – 140      | 523                         | 531           |
| 140 – 170      | 392                         | 341           |
| 170 – 200      | 170                         | 170           |
| 200 – 240      | 111                         | 99            |
| 240 – 300      | 71                          | 44            |

Figure 6: A normalized distributions of the number of events over $P_t$ of muons from $Z^0$ decay: for a muon with maximal $P_t$ (full line) and for a muon with minimal $P_t$ (dashed line) in the pair.

4.3 Estimation of “$Z^0 + \text{jet}$” event rates for the HB, HE and HF regions.

Since a jet is a wide-spread object, we present the $\eta^{jet}$ dependence of rates (for different $P_t^Z$ intervals) in a different way. Namely, Tables 9–12 include the rates of events (at $L_{int} = 10 \text{ fb}^{-1}$) for different $\eta^{jet}$ intervals, covered by the Barrel, Endcap and Forward (HB, HE and HF) parts of the calorimeter. The events are selected after the cuts (4) – (12) (Selection 1) with the following values of the cut parameters:

$$\Delta \phi < 15^\circ, \quad P_{t\text{cut}} = 10 \text{ GeV/c}, \quad P_{t\text{cut}} = 10 \text{ GeV/c}. \quad (23)$$

The first columns of these tables give the number of events with jets (found by the LUCELL jetfinding algorithm of PYTHIA), all particles of which are comprised entirely (100%) in the Barrel part (HB) and there is a 0% sharing ($\Delta P_t^{jet} = 0$) of $P_t^{jet}$ between the HB and the neighboring HE part of the calorimeter. The second columns of the tables contain the number of events in which $P_t$ of the jet is shared between the HB and HE regions. The same sequence of restriction conditions takes place in the next columns. Thus, the HE and HF columns include the number of events with jets entirely contained in these regions, while the HE+HF column gives the number of events where the jet covers both the HE and HF regions. From these tables we can see what number of events can, in principle, be suitable for the most precise jet energy calibration procedure, carried out separately for the HB, HE and HF parts of the calorimeter in different $P_t^Z$ ($\approx P_t^{jet}$) intervals. Less restrictive conditions, when up to 10\%
of the jet $P_t$ are allowed to be shared between the HB, HE and HF parts of the calorimeter, are given in Tables 10 and 12. Tables 9 and 10 correspond to the case of Selection 1. Tables 11 and 12 contain the number of events collected with the added Selection 2 restriction (with $\epsilon_{\text{jet}} < 5\%$), i.e. they include only the events with “isolated jets” (defined in Section 2.2). The reduction factor of about 2 for the number of events can be found by comparing Tables 9 and 10 with Tables 11 and 12.

From the last summarizing line of Table 9 we see that for the whole interval $40 < P_t^Z < 300 \text{ GeV/c}$ PYTHIA predicts about 45 000 events for HB, 16 000 events for HE and about 2 000 events for HF at $L_{\text{int}}=10 \text{ fb}^{-1}$.

| $P_t^Z$ | HB     | HB+HE  | HE     | HE+HF  | HF      |
|---------|--------|--------|--------|--------|---------|
| 40 - 50 | 15072  | 11179  | 5417   | 3045   | 729     |
| 50 - 60 | 9076   | 7037   | 3231   | 1734   | 376     |
| 60 - 70 | 5813   | 4447   | 2055   | 1030   | 218     |
| 70 - 80 | 3726   | 2903   | 1275   | 669    | 123     |
| 80 - 90 | 2542   | 1901   | 847    | 432    | 67      |
| 90 - 100| 1711   | 1243   | 558    | 246    | 44      |
| 100 - 110| 1263   | 879    | 352    | 150    | 12      |
| 110 - 120| 836    | 681    | 289    | 107    | 20      |
| 120 - 140| 1085   | 836    | 400    | 154    | 8       |
| 140 - 170| 752    | 626    | 218    | 71     | 8       |
| 170 - 200| 348    | 261    | 103    | 44     | 0       |
| 200 - 240| 206    | 139    | 75     | 20     | 0       |
| 240 - 300| 111    | 95     | 28     | 4      | 0       |
| 40 - 300 | 44554  | 34076  | 15789  | 8510   | 2020    |

| $P_t^Z$ | HB     | HB+HE  | HE     | HE+HF  | HF      |
|---------|--------|--------|--------|--------|---------|
| 40 - 50 | 19610  | 3251   | 10328  | 887    | 1366    |
| 50 - 60 | 12161  | 1667   | 6439   | 420    | 768     |
| 60 - 70 | 7797   | 950    | 4166   | 202    | 444     |
| 70 - 80 | 5077   | 570    | 2633   | 162    | 253     |
| 80 - 90 | 3453   | 372    | 1734   | 83     | 147     |
| 90 - 100| 2261   | 242    | 1152   | 48     | 95      |
| 100 - 110| 1683   | 170    | 729    | 32     | 40      |
| 110 - 120| 1176   | 87     | 582    | 16     | 45      |
| 120 - 140| 1465   | 139    | 816    | 36     | 43      |
| 140 - 170| 1026   | 115    | 511    | 12     | 12      |
| 170 - 200| 475    | 48     | 222    | 5      | 8       |
| 200 - 240| 273    | 17     | 147    | 3      | 4       |
| 240 - 300| 158    | 15     | 59     | 0      | 0       |
| 40 - 300 | 59392  | 8169   | 31395  | 2127   | 3861    |
An additional information on the numbers of “$Z^0 + jet$” events with jets produced by $c$ and $b$ quarks (see also [12] and [42, 43]), given for the integrated luminosity $L_{int} = 10 \, fb^{-1}$ for different $P_t^Z(\approx P_t^{jet})$ intervals 45–55, 70–85, 100–120 and 150–200 GeV/c is contained in Tables 1–12 of Appendix 1 (they denoted as $N_{event c}$ and $N_{event b}$ there). They also show the ratio of the number of events caused by gluonic Compton-like subprocess (2a) to the number of events due to the sum of subprocesses (2a) and (2b) ($30_{sub/all}$) and averaged jet radii $<R_{ge}>$. 

Table 11: Selection 2. $\Delta P_t^{jet}/P_t^{jet} = 0.00$ ($L_{int}=10 \, fb^{-1}$). 

| $P_t^Z$ | HB | HB+HE | HE | HE+HF | HF |
|---------|----|-------|----|-------|----|
| 40 – 50 | 6039 | 4221 | 2364 | 1152 | 352 |
| 50 – 60 | 4578 | 3398 | 1810 | 847 | 182 |
| 60 – 70 | 3461 | 2637 | 1319 | 645 | 154 |
| 70 – 80 | 2542 | 2020 | 915 | 447 | 91 |
| 80 – 90 | 1936 | 1382 | 681 | 329 | 55 |
| 90 – 100 | 1390 | 962 | 475 | 190 | 36 |
| 100 – 110 | 1093 | 717 | 305 | 123 | 13 |
| 110 – 120 | 744 | 614 | 273 | 79 | 15 |
| 120 – 140 | 990 | 760 | 376 | 158 | 9 |
| 140 – 170 | 713 | 602 | 210 | 71 | 7 |
| 170 – 200 | 341 | 257 | 103 | 45 | 1 |
| 200 – 240 | 206 | 131 | 75 | 19 | 0 |
| 240 – 300 | 111 | 95 | 28 | 4 | 0 |
| 40 – 300 | 24912 | 18489 | 9393 | 4499 | 1169 |

Table 12: Selection 2. $\Delta P_t^{jet}/P_t^{jet} \leq 0.10$ ($L_{int}=10 \, fb^{-1}$). 

| $P_t^Z$ | HB | HB+HE | HE | HE+HF | HF |
|---------|----|-------|----|-------|----|
| 40 – 50 | 7770 | 1148 | 4297 | 309 | 602 |
| 50 – 60 | 6083 | 729 | 3425 | 190 | 384 |
| 60 – 70 | 4629 | 554 | 2602 | 119 | 305 |
| 70 – 80 | 3465 | 388 | 1885 | 99 | 178 |
| 80 – 90 | 2610 | 249 | 1350 | 59 | 115 |
| 90 – 100 | 1806 | 190 | 950 | 37 | 79 |
| 100 – 110 | 1434 | 139 | 610 | 23 | 36 |
| 110 – 120 | 1057 | 85 | 635 | 31 | 40 |
| 120 – 140 | 1338 | 117 | 656 | 21 | 37 |
| 140 – 170 | 974 | 111 | 491 | 12 | 11 |
| 170 – 200 | 467 | 48 | 218 | 4 | 9 |
| 200 – 240 | 273 | 18 | 143 | 4 | 3 |
| 240 – 300 | 158 | 14 | 59 | 0 | 0 |
| 40 – 300 | 33117 | 3952 | 18224 | 990 | 2174 |
5 Features of “$Z^0 + \text{jet}$” events in the Barrel region.

5.1 Influence of the $P_t^{\text{clust}}$ parameter on the balance between $Z^0$ and jet transverse momenta and on the initial state radiation suppression.

Here we shall study a correlation of $P_t^{\text{clust}}$ with $P_t^{\text{ISR}}$. The samples of 1-jet “$Z^0 + \text{jet}$” events, gained from the PYTHIA simulation of $5 \times 10^6$ signal “$Z^0 + \text{jet}$” events in two $P_t^Z$ intervals 45 – 55 and 100 – 120 GeV/c, will be used here. The observables defined in Section 2 will be restricted here by Selection 1 cuts (4) – (12) of Section 2.2 with $P_t^{\text{CUT}} = 30$ GeV/c. $P_t^{\text{CUT}}$ is not limited here.

The influence of the $P_t^{\text{clust}}$ variation on the distribution of some important physical variables is shown in Fig. 4 for $45 < P_t^Z < 55$ GeV/c and in Fig. 5 for $100 < P_t^Z < 120$ GeV/c. Besides of distributions for three auxiliary variables $P_{t56}$, $P_t^{\phi 5}$, $P_t^{\text{out}}$ (defined by (2), (16), (18)) we present distributions for $P_t(O+\eta > 5)$ and $\langle 1 - \cos \Delta \phi \rangle$ which define the right-hand side of equation (21). The distribution of the back-to-back $\Delta \phi$ angle (10), defining the second variable $\langle 1 - \cos \Delta \phi \rangle$, is also presented in Figs. 4, 5.

The $P_{t56}$ variable and both components defining $P_t^Z$ and $P_t^{\text{Jet}}$ disbalance, $(1 - \cos \Delta \phi)$ and $P_t(O+\eta > 5)$, as well as two others variables, $P_t^{\text{out}}$ and $\Delta \phi$, show a tendency to become smaller (as the mean values of the widths of distributions) by restricting an upper limit on the $P_t^{\text{clust}}$ value (see also tables of Appendices 2–5). It means that the precision of jet energy setting may increase with decreasing $P_t^{\text{clust}}$. The origin of this improvement becomes clear from the $P_t^{\text{56}}$ density plot which demonstrates ISR suppression (or $P_t^{\text{ISR}}$) as a more restrictive cut is imposed on $P_t^{\text{clust}}$.

Comparison of Fig. 7 (for $45 < P_t^Z < 55$ GeV/c) and Fig. 8 (for $100 < P_t^Z < 120$ GeV/c) shows that $\Delta \phi$ as a degree of back-to-backness of $Z^0$ boson and jet $P_t$ vectors in the $\phi$-plane decreases with increasing $P_t^Z$. At the same time $P_t^{\text{ISR}}$ distribution becomes wider, while the $P_t^{\phi 5}$ and $P_t^{\text{out}}$ distributions practically do not depend on $P_t^Z$ (see for details Appendices 2–5).

It should be mentioned that the results presented in Figs. 7 and 8 were obtained with the LUCELL jetfinder of PYTHIA 14).

5.2 $P_t$ distribution inside and outside of a jet.

Now let us see how the space outside the jet may be populated by $P_t$ in the “$Z^0 + \text{jet}$” HB events. For this purpose we calculate a vector sum $\vec{P}_t^{\text{sum}}$ of individual transverse momenta of the calorimeter cells included by a jetfinder into a jet and of cells in a larger volume that surrounds a jet. In the latter case this procedure can be viewed as straightforward enlarging of the jet radius in the $\eta - \phi$ space.

The plots that present the ratio $P_t^{\text{sum}}/P_t^Z$ as a function of the distance $R(\eta, \phi)$ counted from a jet gravity center towards its boundary and further into the space outside a jet are shown in the left-hand columns of Figs. 2 and 10 for two $P_t^Z$ intervals ($45 < P_t^Z < 55$ GeV/c and $100 < P_t^Z < 120$ GeV/c) and three jetfinding algorithms (UA1, UA2 and LUCELL).

From these figures we see that the space surrounding the jet is in general far from being empty. We also see that the average value of $P_t^{\text{sum}}$ increases with increasing volume around a jet and it exceeds $P_t^Z$ at $R = 0.7 - 0.8$ (see Figs. 9 and 10).

From the right-hand columns of Figs. 11 and 12 we see that the vector disbalance measure

$$P_t^{Z,+\text{sum}} = |\vec{P}_t^Z + \vec{P}_t^{\text{sum}}|$$

achieves its minimum again at $R \approx 0.7 - 0.8$ for all jetfinding algorithms. (The minimum of the vector sum $P_t^{Z,+\text{sum}}$ can serve as an illustration of the $P_t^Z - P_t^{\text{Jet}}$ disbalance minimum.)

The value of $P_t^{Z,+\text{sum}}$ (as well as $P_t^{\text{sum}}/P_t^Z$) continues to grow rapidly for $40 < P_t^Z < 50$ GeV/c and more slowly for $100 < P_t^Z < 120$ GeV/c with increasing $R$ after the point $R = 0.7 - 0.8$ (see Figs. 8 and 10). This means that at higher $P_t^Z$ (or $P_t^{\text{Jet}}$) the topology of “$Z^0 + \text{jet}$” events becomes more distinct and we get a clearer picture of an “isolated” jet. This feature clarifies the motivation of introducing the “Selection 2” criteria in Section 2.2 for selection of events with isolated jets.

14) The results obtained with all jetfinders and $P_t^Z$ and $P_t^{\text{Jet}}$ balance will be discussed in Sections 7 in more detail.
Figure 7: LUCELL algorithm, $\Delta \phi < 15^\circ$, $45 < P_t^Z < 55 \text{ GeV/c}$. Selection 1.
Figure 8: LUCHELL algorithm, $\Delta \phi < 15^\circ$, $100 < P_t^Z < 120 \text{ GeV/c}$. Selection 1.
Figure 9: LUCELL, UA1 and UA2 algorithms, $\Delta \phi < 15^\circ$, $45 < P_t^Z < 55 \text{GeV/c}$. 
Figure 10: LUCELL, UA1 and UA2 algorithms, $\Delta \phi < 15^\circ$, $100 < P_t^Z < 120 \text{ GeV/c}$. 
6 Dependence of the disbalance between $P_t^Z$ and $P_t^{Jet}$ on the $P_t^{CUT}$ and $P_t^{out}$ parameters.

Here we shall study in detail a dependence of the $P_t^Z - P_t^{Jet}$ disbalance on the values of $P_t^{CUT}$ and $P_t^{out}$. For this aim the four samples of “$Z^0 + jet$” events described in the beginning of Section 4 were used.

The mean values of the most important variables used in our analyses that reflect the main features of “$Z^0 + jet$” events with the jet completely contained in the Barrel region, i.e. “HB events” (see Section 5) are given in the tables of Appendices 2–5.

Appendix 2 contains the tables for events inside $45 < P_t^Z < 55$ GeV/c interval. In these tables we present the values of interest found with UA1, UA2 and LUCCELL jetfinders for three different Selections mentioned in Section 2.2. Each page corresponds to a definite value of $\Delta \phi$ as a measure of deviation from the absolute back-to-back orientation of $P_t^Z$ and $P_t^{Jet}$ vectors. The first four pages of each Appendix contain the information about variables that characterize the $P_t^Z - P_t^{Jet}$ balance for events passed the cuts (15) (Selection 1).

On the fifth page of each of Appendices 2–5 we present Tables 13–15 (for the cut $\Delta \phi < 15^\circ$) that correspond to Selection 2 (see Section 2.2). We have limited $\varepsilon^{Jet} \leq 9\%$ for $45 < P_t^Z < 55$ with a gradual change to $\varepsilon^{Jet} \leq 3\%$ for $P_t^Z \geq 100$ GeV/c. The best result for UA2 in the case of $45 < P_t^Z < 55$ is obtained with $\varepsilon^{Jet} \leq 6\%$ instead of the cut $\varepsilon^{Jet} \leq 9\%$ chosen for UA1 and LUCCELL algorithms. The results obtained with Selection 3 are given on the sixth page of Appendices 2–5 (10), while on the seventh page Selection 3 is used to find jets found simultaneously by UA1 and LUCCELL jetfinders only.

The columns in tables of Appendices 2–5 correspond to five values of $P_t^{CUT} = 30, 20, 15, 10$ and 5 GeV/c. The upper lines of these tables contain the expected numbers $N_{event}$ of “HB events” for the integrated luminosity $L_{int} = 10$ fb$^{-1}$.

In the next four lines of the tables we put the values of $P_t^{56}$, $\Delta \phi$, $P_t^{out}$, $P_t^{q5}$ defined by formulas (2), (9), (18) and (16), respectively, and averaged over the events selected with a chosen $P_t^{CUT}$ value. From the tables we see, firstly, that the averaged values of $P_t^{q5}$ show very weak dependence on it (practically constant) (17), what is in complete agreement with behavior of these variables in the case of “$\gamma + jet$” events. At the same time, the values of $P_t^{56}$, $\Delta \phi$, $P_t^{out}$ decrease fast with decreasing $P_t^{CUT}$. The $P_t^{56}$ variable (non-observable one) that serves, according to (2), as measure of the initial state radiation transverse momentum $P_t^{ISR}$, i.e. one of the main sources of the $P_t$ disbalance in the subprocesses (2a) and (2b). So, variation of $P_t^{CUT}$ from 30 to 10 GeV/c for $\Delta \phi < 15^\circ$ leads to suppression of the $P_t^{56}$ value (or $P_t^{ISR}$) approximately by $\approx 40 - 45\%$ for all $P_t^Z$.

The following three lines (from 6-th to 8-th) show the average values of the variables $(P_t^Z - P_t^{part})/P_t^Z$, $(P_t^{Jet} - P_t^{part})/P_t^Z$, $(P_t^Z - P_t^{Jet})/P_t^Z$ (here $J$=Jet). These lines correspond to the relative $P_t$ balance at the $Z^0$-parton level (final state of the fundamental subprocess $2 \rightarrow 2$), the relative difference of the parton $P_t$ and the jet $P_t$ (parton hadronization effect) and the relative $P_t$ balance of the jet and $Z^0$ boson. The lines 9 and 10 include the averaged values of $P_t(O+\eta > 5)/P_t^Z$ and $(1 - \cos(\Delta \phi))$ that appear on the right-hand side of the $P_t$-balance equation (21).

As a rule, the value of $(1 - \cos(\Delta \phi))$ is smaller than the value of $\langle P_t(O+\eta > 5)/P_t^Z \rangle$ for the cut $\Delta \phi < 15^\circ$ and tends to decrease more with growing energy. So, we can conclude that the main source of the $P_t$ disbalance in the “$Z^0 + jet$” system is defined by the term $P_t(O+\eta > 5)/P_t^Z$.

The following line contains the averaged values of the standard deviations of $(P_t^Z - P_t^{Jet})/P_t^Z (\equiv D_b[Z,J])$. The values of this variable drop approximately by a factor of two (and even more for all intervals with $P_t^Z > 100$ GeV/c) while moving from $P_t^{CUT} = 30$ GeV/c to $P_t^{CUT} = 5$ GeV/c for all jetfinding algorithms.

The last lines of the tables present the number of generated events, i.e. entries left after cuts.

A decrease in $P_t^{CUT}$ leads to a decrease in the $(P_t^Z - P_t^{Jet})/P_t^Z$ ratio (mean values as well as standard deviations), i.e. we select the events that can be used to improve the jet energy calibration accuracy. For instance, in the case

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15) In [12] – [16] the Selection 2 criterion was considered with a more severe cut $\varepsilon^{Jet} \leq 2\%$.

16) Selection 3 (see Section 2.2) leaves only those events in which jets are found simultaneously by UA1, UA2 and LUCCELL jetfinders i.e. events with jets having up to a good accuracy equal coordinates of the center of gravity, $P_t^{Jet}$ and $\phi(Z,Jet)$.

17) Compare with Figs. 7 and 8.
of \(70 < P_T^Z < 85 \text{ GeV/c}\) the mean value of \((P_T^Z - P_T^j)/P_T^Z\) drops from \(4.5 - 4.9\%\) to \(0.9 - 1.5\%\) (see Tables 4, 6 of Appendix 3) and in the case of \(100 < P_T^Z < 120 \text{ GeV/c}\) the mean value of this variable drops from \(3.4 - 3.7\%\) to less than \(0.6 - 1.0\%\) for UA1 and LUCELL jetfinders (Tables 4, 6 of Appendix 4). A worse situation is seen for the \(45 < P_T^Z < 55 \text{ GeV/c}\) interval, where the disbalance changes, e.g. for LUCELL algorithm, as \(2.1 \rightarrow 1.8\%\). Meantime, RMS values with the same variations of \(P_{CUT}^{\text{clust}}\) (from 30 to 10 GeV/c) decrease by 40 – 50\%.

After imposing the jet isolation requirement (see Tables 13 – 15 of Appendices 2–5) we observe that for \(P_T^Z \geq 100 \text{ GeV/c}\) the mean values of \((P_T^Z - P_T^j)/P_T^Z\) are contained inside the 1\% window for any \(P_{CUT}^{\text{clust}}\). For \(45 < P_T^Z < 55 \text{ GeV/c}\) we see that with Selection 1 \(P_{CUT}^{\text{clust}}\) works more effectively than in the case of Selection 1. Thus, \(P_{CUT}^{\text{clust}} = 15 \text{ GeV/c}\) allows to reduce \((P_T^Z - P_T^j)/P_T^Z\) to less than 1\% level for all algorithms. The Selection 2 criterion leaves quite a sufficient number of events with a jet contained completely in the barrel region: about 10 000 \(- 18 000\) for \(45 < P_T^Z < 55 \text{ GeV/c}\) with \(P_{CUT}^{\text{clust}} = 15 \text{ GeV/c}\) and about 4 500 for \(100 < P_T^Z < 120 \text{ GeV/c}\) with \(P_{CUT}^{\text{clust}} = 20 \text{ GeV/c}\) at \(L_{int} = 10 fb^{-1}\) (see Tables 13 – 15 of Appendices 2, 3).

The analogous results for Selection 3 are presented in Tables 16–18 of Appendices 2–5. Let us consider first the most difficult interval \(45 < P_T^Z < 55 \text{ GeV/c}\). From the tables of Appendix 2 one can see that this selection leads to approximately 20\% reduction of the number of selected events as compared with the case of Selection 2. A combined usage of all three jetfinders (Tables 16–18) worsens the balance values. A requirement of simultaneous jet finding by only UA1 and LUCELL algorithms practically does not change values of the \(P_T^Z - P_T^j\) balance as compared with the case of combined usage of all three jetfinders for this aim. This fact stresses a good compatibility of UA1 and LUCELL jetfinders. For other considered \(P_T^Z\) intervals UA1, UA2 and LUCELL algorithms give more or less close results and a passage to Selection 3 does not worsen a situation.

We also can note that Selections 2 and 3, besides improving the \(P_T^Z\) and \(P_T^j\) balance value, are important for selecting events with a clean jet topology and rising the confidence level of a jet determination.

The influence of a wide variation of cuts \(P_{CUT}^{\text{clust}}\) and \(P_{CUT}^{out}\) on
(a) the number of selected events (for \(L_{int} = 10 fb^{-1}\)),
(b) the mean value of \(F \equiv (P_T^Z - P_T^j)/P_T^Z\) and
(c) the standard deviation value \(\sigma(F)\)
is presented in rows and columns of Tables 1–9 for Selection 1 of Appendix 6. The set of selection cuts (4)–(10) (Section 2.2) was applied to preselect \(\{Z^0 + \text{jet}\}\) events for the tables of Appendix 6. The jets (as well as clusters) in these events, unlike the jets in the events analyzed in Appendices 2–5, were found by LUCELL jetfinder for the whole \(\eta\) region \(|\eta^{\text{jet}}| < 5.0\).

Tables 1–3 of Appendix 6 correspond to the \(\{Z^0 + \text{jet}\}\) events selection in the interval \(40 \leq P_T^Z \leq 70 \text{ GeV/c}\) Tables 4–6 to that for \(70 \leq P_T^Z \leq 100 \text{ GeV/c}\) and Tables 7–9 to that for \(100 \leq P_T^Z \leq 140 \text{ GeV/c}\).

We see that the restriction of \(P_{CUT}^{\text{clust}}\) and \(P_{CUT}^{out}\) are necessary to improve the jet energy setting accuracy. So, Tables 2 (for \(40 \leq P_T^Z \leq 70 \text{ GeV/c}\)) and 8 (for \(100 \leq P_T^Z \leq 140 \text{ GeV/c}\)) of Appendix 6 show that the mean values of the fraction \(F \equiv (P_T^Z - P_T^j)/P_T^Z\) decreases with variation of the two cuts from \(P_{CUT}^{\text{clust}} = 30 \text{ GeV/c}\) and \(P_{CUT}^{out} = 1000 \text{ GeV/c}\) (i.e. without limits) to \(P_{CUT}^{\text{clust}} = 10 \text{ GeV/c}\) and \(P_{CUT}^{out} = 10 \text{ GeV/c}\) at 0.049 to 0.018 and as 0.036 to 0.012, respectively. At the same time this restriction noticeably decreases the width of the Gaussian \(\sigma(F)\) (see Tables 3, 6 and 9 of Appendix 6). So, it drops from 0.200 to 0.103 for \(40 \leq P_T^Z \leq 70 \text{ GeV/c}\) and from 0.138 to 0.066 for \(100 \leq P_T^Z \leq 140 \text{ GeV/c}\) (i.e. about in a factor of two) for the same variation of \(P_{CUT}^{\text{clust}}\) and \(P_{CUT}^{out}\).

Again, the reason is caused by the term \(P_1(\cos \Delta \phi > 5)/P_T^Z\) of the \(P_T\)-balance equation (19) (as we noted above, the contribution of \((1 - \cos \Delta \phi)\) to the \(P_T^Z - P_T^j\) disbalance is negligibly small). This term can be decreased by decreasing \(P_T\) activity in the space \(out\) of the \(\{Z^0 + \text{jet}\}\) system, i.e. by limiting \(P_{CUT}^{\text{clust}}\) and \(P_{CUT}^{out}\).

The numbers of events at the integrated luminosity \(L_{int} = 10 fb^{-1}\) for different \(P_{CUT}^{\text{clust}}\) and \(P_{CUT}^{out}\) are given in Tables 1, 5 and 9 of Appendix 6. One can see that even with such strict \(P_{CUT}^{\text{clust}}\) and \(P_{CUT}^{out}\) values as 10 GeV/c for both, for example, we would have 69 600, 18 100 and 6 860 for \(40 \leq P_T^Z \leq 70 \text{ GeV/c}\), 70 \(\leq P_T^Z \leq 100 \text{ GeV/c}\) and 100 \(\leq P_T^Z \leq 140 \text{ GeV/c}\) respectively.

In addition, we present in Tables 10–18 of Appendix 6 the results obtained with Selection 2. They contain the

\(^{18}\) the lower value corresponds to UA2 algorithm for which the stricter isolation cut was used.
information analogous to that in Tables 1–12 but for the case of imposing jet isolation requirement: \( \epsilon^{jet} = 8\% \) at \( 40 \leq P_t^Z \leq 70 \) GeV/c and \( \epsilon^{jet} = 5\% \) at \( 70 \leq P_t^Z \leq 100 \) GeV/c and \( 100 \leq P_t^Z \leq 140 \) GeV/c. From these tables we see that with the same (and with even weaker) cuts \( P_{t,\text{CUT}} = P_{t,\text{out}} = 10 \) GeV/c one can obtain a much better fractional balance \( F \), less than 1\% for all \( P_t^Z \) intervals (with almost the same values of \( \sigma(F) \)), at the statistics of about 50 800, 13 200 and 6 150 events for intervals \( 40 \leq P_t^Z \leq 70 \) GeV/c, \( 70 \leq P_t^Z \leq 100 \) GeV/c and \( 100 \leq P_t^Z \leq 140 \) GeV/c, respectively.

The behavior of number of the selected events for \( L_{\text{int}} = 10 \) fb\(^{-1}\), the mean values of \( (P_t^Z - P_t^{\text{jet}})/P_t^Z \) and its standard deviation \( \sigma(F) \) as a function of \( P_{t,\text{CUT}} \) for \( P_{t,\text{CUT}} = 20 \) GeV/c is displayed in Fig. 11 for non-isolated (left-hand column) and isolated jets with \( \epsilon^{jet} = 8\% \) at \( 40 \leq P_t^Z \leq 70 \) GeV/c and \( \epsilon^{jet} = 5\% \) at \( 70 \leq P_t^Z \leq 100 \) GeV/c and \( 100 \leq P_t^Z \leq 140 \) GeV/c (right-hand column).

Figure 11: Number of events at \( L_{\text{int}} = 10 \) fb\(^{-1}\), mean value \( (P_t^Z - P_t^{\text{jet}})/P_t^Z \) (\( \equiv F \)), its standard deviation \( \sigma(F) \) as a function of \( P_{t,\text{CUT}} \) value. \( P_{t,\text{CUT}} \) value is limited by 20 GeV/c. Full line corresponds to the event selection with \( 40 \leq P_t^Z \leq 70 \) GeV/c, dashed line to that with \( 70 \leq P_t^Z \leq 100 \) GeV/c and dotted line to that with 100 \( \leq P_t^Z \leq 140 \) GeV/c (\( \epsilon^{jet} = 8\%, 5\%, 5\% \) in these \( P_t^Z \) intervals, respectively).
7 The study of background suppression.

In principle, there is a probability, that some combination of muons in the events, based on the QCD subprocesses with much larger cross sections (by about 5 orders of magnitude) than ones of the signal sub-processes, can be registered as the \( Z^0 \) signal. This type of background we call as "combinatorial background". To study a rejection possibility of such type of events by about 40 million events with a mixture of all QCD and SM subprocesses with large cross sections existing in PYTHIA 19) including also the signal subprocesses (2a) and (2b) were generated. Three generations were performed with different minimal \( P_t \) of the hard \( 2 \to 2 \) subprocess 20) \( \hat{p}_\perp \) values: \( \hat{p}_\perp \) \( = 40, 70 \) and \( 100 \) \( \text{GeV/c} \). The cross sections of different subprocesses serve in simulation as weight factors and, thus, determine the final statistics of the corresponding physical events. The generated events were analyzed by use of the cuts given in Table 13 (see also Section 2.2).

To trace the effect of their application let us consider first the case of one (intermediate) energy, i.e. the generation with \( \hat{p}_\perp = 70 \) \( \text{GeV/c} \). Each line of Table 14 corresponds to the respective cut of Table 13. The numbers in columns “Signal” and “Bkgd” show the number of signal and (combinatorial) background events remained after a cut. Column “Eff” demonstrates the efficiency of a cut. The efficiencies \( E f f \) with their errors are defined as a ratio of the number of signal (background) events that passed under a cut (1–6) to the number of the preselected events after the first cut of Table 13. The number of events after the first cuts is taken as 100%.

Table 14: A demonstration of cut-by-cut efficiencies and \( S/B \) ratios for generation with \( \hat{p}_\perp = 70 \) \( \text{GeV/c} \).

| Selection | Signal | Bkgd | \( E f f_S(\%) \) | \( E f f_B(\%) \) | \( S/B \) |
|-----------|--------|------|----------------|----------------|--------|
| 0         | 401    | 850821 | 100.00±0.00 | 100.00±0.00 | 5 \cdot 10^{-4} |
| 1         | 245    | 15842 | 92.24±8.51 | 2.948±0.138 | 0.5    |
| 2         | 226    | 467   | 0.076±0.022 | 8.3           |
| 3         | 99     | 12    | 0.063±0.020 | 8.1           |
| 4         | 81     | 10    | 0.025±0.013 | 18.0          |
| 5         | 72     | 4     | 0.000±0.000 | –             |
| 6         | 62     | 0     | 0.000±0.000 | –             |

Table 15: Values of efficiencies and \( S/B \) ratios for generations with \( \hat{p}_\perp = 40, 70 \) and \( 100 \) \( \text{GeV/c} \).

| \( \hat{p}_\perp \) (\( \text{GeV/c} \)) | Cuts | Signal | Bkgd | \( E f f_S(\%) \) | \( E f f_B(\%) \) | \( S/B \) |
|--------------------------------------|------|--------|------|----------------|----------------|--------|
| 40 (\( \text{GeV/c} \))              | Preselection (1) | 89 | 1090 | 100.00±0.00 | 0.08 |
|                                       | Main (1–5) | 30 | 0    | 33.71±7.12 | 0.00±0.00 | – |
| 70 (\( \text{GeV/c} \))              | Preselection (1) | 245 | 15842 | 100.00±0.00 | 0.02 |
|                                       | Main (1–5) | 72 | 4    | 29.39±3.94 | 0.025±0.013 | 18.0 |
| 100 (\( \text{GeV/c} \))             | Preselection (1) | 497 | 37118 | 100.00±0.00 | 0.01 |
|                                       | Main (1–5) | 127 | 4    | 25.55±2.54 | 0.011±0.005 | 31.8 |

We see from Table 14 that initial ratio of \( \mu^+ \mu^- \) pairs in signal and background events is very small (5 \cdot 10^{-4}) 21). A weak restriction of the muon transverse momentum and pseudorapidity in the 1st selection increase \( S/B \) by

19) (namely, ISUB=11–20, 28–31, 53, 68)
20) i.e. \( C K I N(3) \) parameter in PYTHIA
about 2 order (as $5 \cdot 10^{-4} \rightarrow 2 \cdot 10^{-2}$). The invariant mass criterion and one-jet events selection make $S/B = 18.0$ and the last criterion on the azimuthal angle between $Z^0$ and jet ($\Delta \phi < 15^\circ$) suppresses the background events completely.

The information on other intervals (i.e. on the event generations with $P_{t, \min}^\mu = 40$ and $P_{t, \min}^\mu = 100$ GeV/c) is presented in Table 15. Line “Preselection (1)” corresponds to the first cuts in Table 15 ($P_t^\mu > 10$ GeV/c, $|\eta| < 2.4$) while line “Main (1—5)” corresponds to the result of application of criteria from 1 to 5 of Table 15. After application of all six criteria of Table 15, we have observed no background events in all of the $P_t^Z$ intervals with the signal events selection efficiency of 25 — 33%.

The practical absence of a background to the “$Z^0$ + jet” events allow to use them for an extraction of the gluon distribution in a proton $f_\gamma^p(x, Q^2)$.

## 8 Estimation of rates for gluon distribution determination at the LHC using “$Z^0$ + jet” events.

Many theoretical predictions for production of new particles (Higgs, SUSY) at the LHC are based on model estimations of the gluon density behavior at low $x$ and high $Q^2$. Thus, determining the proton gluon density $f_\gamma^p(x, Q^2)$ for this kinematic region directly in LHC experiments would be obviously very useful.

One of the channels for this determination is a high $P_t$ direct photon production $pp \rightarrow \gamma^{\text{dir}} + X$ (see [24]). The region of high $P_t$, reached by UA1 [25], UA2 [26], CDF [27] and D0 [28] extends up to $P_t \approx 60$ GeV/c and recently up to $P_t = 105$ GeV/c [29]. These data together with the later ones (see references in [30]—[39]) and recent E706 [40] and UA6 [41] results give an opportunity for tuning the form of gluon distribution (see [33], [36]).

The rates and estimated cross sections of inclusive direct photon production at the LHC are given in [24].

A more promising process that can be used for measuring $f_\gamma^p(x, Q^2)$ is $pp \rightarrow \gamma^{\text{dir}} + 1 \text{ jet} + X$ defined at the leading order by two QCD subprocesses $qg \rightarrow q + \gamma$ and $q\bar{q} \rightarrow g + \gamma$ was considered in [20], [21] (see also [42] and for experimental results see [43], [44]).

Here to estimate a possibility of extraction of information on the gluon density in a proton we shall consider the “$Z^0$ + jet” production process [1] (analogous to the “$\gamma + jet$” process above), where $Z^0$ boson decays to the muon pair, a signal from which can be perfectly measured in the detector.

In the case of $pp \rightarrow Z^0/\gamma^{\text{dir}} + 1 \text{ jet} + X$ for $P_t^{\text{jet}} \geq 30$ GeV/c (i.e. in the region where $k_T$ smearing effects are not important), see [37] the cross section is expressed directly in terms of parton distribution functions $f^a(x_a, Q^2)$ (see, for example, [34]):

$$
\frac{d\sigma}{d\eta_1 d\eta_2 dp_t^\mu} = \sum_{a,b} x_a f^a(x_a, Q^2) x_b f^b(x_b, Q^2) \frac{d\sigma}{dt}(a b \rightarrow 1 2)
$$

(25)

where $x_{a,b}$ are defined by

$$
x_{a,b} = P_t/\sqrt{s} \cdot (\exp(\eta_1) + \exp(\eta_2)).
$$

(26)

We also used the following designations above: $\eta_1 = \eta^Z$, $\eta_2 = \eta^{\text{jet}}$, $P_t = P_t^Z$; $a, b = q, \bar{q}, g$; $1, 2 = q, \bar{q}, g, Z^0$.

Formula (25) and the knowledge of the results of independent measurements of $q, \bar{q}$ distributions [42] allow the gluon distribution $f_\gamma^p(x, Q^2)$ to be determined with an account of the selection efficiencies of “$Z^0 + jet$” events.

In Table 16 we present the $Q^2 (= (P_t^Z)^2)$ and $x$ distribution (with $x$ defined by [46]) of the number of all events, i.e. the events, based on the subprocesses $qg \rightarrow Z^0 + q$ and $q\bar{q} \rightarrow g + Z^0$ (with the decay $Z^0 \rightarrow \mu^+ \mu^-$) for integrated luminosity $L_{\text{int}} = 20$ $fb^{-1}$. These events satisfy the cuts (4)—(12) of Section 2.2 with the parameter values:

$$
|\eta^{\text{jet}}| < 5.0, \quad P_{t, \max}^\mu \geq 20 \text{ GeV/c}, \quad \Delta \phi < 15^\circ, \quad P_{t, \text{CUT}}^\mu = 10 \text{ GeV/c}, \quad P_{t, \text{CUT}}^{\text{clus}} = 10 \text{ GeV/c}.
$$

(27)

The contributions (in %) of the events originated from the subprocesses (2a) and (2b) (and passed the cuts (4)—(12) of Section 2.2) as functions of $P_t^Z$ are presented in Fig. 12. From this figure one can see that the contribution of the events from the Compton scattering (2a) varies from 67% at $P_t^Z \approx 40$ GeV/c to 85% at $P_t^Z \approx 120$ GeV/c.\footnote{That is mainly due to the huge difference in the cross sections of “$Z^0 + jet$” events (from subprocesses (2a), (2b)) and the QCD events.}
The area that can be covered by studying the process \( \mu^+\mu^- \) with the subsequent decay \( Z^0 \rightarrow \mu^+\mu^- \) is shown in Fig. 13. The number of events in different \( x \) and \( Q^2 \) intervals of this area is given in Table 16. From this figure (and Tables 16) it is seen that during first two years of LHC running at low luminosity \( (L = 10^{33} \text{cm}^{-2}\text{s}^{-1}) \) it would be possible to extract an information for the gluon distribution determination \( f^g(x, Q^2) \) in a proton in the region of \( 0.9 \cdot 10^3 \leq Q^2 \leq 4 \cdot 10^4 \text{(GeV/c)}^2 \) with as small \( x \) values as accessible at HERA but at higher \( Q^2 \) values (by 1–2 orders of magnitude). It is also worth emphasizing that the sample of the “\( Z^0 + \text{jet} \)” events selected for this aim can be used to perform a cross-check of \( f^g(x, Q^2) \) determination with help of “\( \gamma + \text{jet} \)” events [20, 21].

The area covered with “\( \gamma + \text{jet} \)” events is also shown in Fig. 13 by dashed lines.

Table 16: Numbers of “\( Z^0 + \text{jet} \)” events (with \( Z^0 \rightarrow \mu^+\mu^- \)) in \( Q^2 \) and \( x \) intervals for \( L_{\text{int}} = 20 \text{fb}^{-1} \).

| \( Q^2 \) \( (\text{GeV/c})^2 \) | \( x \) values of a parton | \( t \) | \( t \) | \( t \) | \( t \) | \( t \) | \( t \) | \( t \) | \( t \) | \( t \) |
|---|---|---|---|---|---|---|---|---|---|---|
| \( 900-1600 \) | 18409 | 45844 | 47453 | 2479 | 114185 | 30–40 |
| \( 1600-2500 \) | 7417 | 28361 | 28702 | 1854 | 66333 | 40–50 |
| \( 2500-3600 \) | 2479 | 16574 | 19015 | 1533 | 39599 | 50–60 |
| \( 3600-5000 \) | 1097 | 10406 | 12941 | 1533 | 25977 | 60–71 |
| \( 5000-6400 \) | 227 | 5846 | 6944 | 1022 | 14039 | 71–80 |
| \( 6400-8100 \) | 170 | 4238 | 5430 | 624 | 10463 | 80–90 |
| \( 8100-10000 \) | 19 | 2989 | 4049 | 719 | 7776 | 90–100 |
| \( 10000-14400 \) | 19 | 2819 | 4579 | 908 | 8325 | 100–120 |
| \( 14400-20000 \) | 0 | 1400 | 2781 | 454 | 4635 | 120–141 |
| \( 20000-40000 \) | 0 | 908 | 2195 | 719 | 3822 | 141–200 |

| \( P_t^Z \) \( (\text{GeV/c}) \) | \( \text{Events fraction (\%)} \) | \( \text{Events type:} \) |
|---|---|---|
| --- | --- | ---|
| 20 | 100 | \( q \bar{q} \rightarrow g + Z^0 \) |
| 40 | 60 | \( g g \rightarrow q + Z^0 \) |
| 60 | 20 | \( q g \rightarrow q + Z^0 \) |
| 80 | 0 | \( g q \rightarrow q + Z^0 \) |

Figure 12: The contributions of the events originated from the subprocesses (2a) and (2b) as a function of \( P_t^Z \). Full line corresponds to the “\( qg \rightarrow q + Z^0 \)” events, dashed line – to the “\( q\bar{q} \rightarrow g + Z^0 \)” events.

9 Summary.

A possibility of the absolute jet energy scale setting with help of “\( Z^0 + \text{jet} \)” events based on the \( qg \rightarrow q + Z^0 \) and \( q\bar{q} \rightarrow g + Z^0 \) subprocesses with subsequent \( Z^0 \) decay to the muon pair is studied. The PYTHIA event generator is applied here to find the selection criteria of the “\( Z^0 + \text{jet} \)” events that would provide a good \( P_t^Z - P_t^{\text{jet}} \) balance.

It is shown here (by analogy with [12–16]) that the limitation of the clusters \( P_t \) that may be found in an event in addition to the main jet as well as the limitation of \( P_t \) activity of all particles beyond the “\( Z^0 + \text{jet} \)” system (see Section 2) leads to an improvement of the \( P_t^Z - P_t^{\text{jet}} \) balance value. A further improvement of the \( P_t^Z - P_t^{\text{jet}} \) balance can be reached by selection of events having the isolated jets only. Besides, this criterion (as well as the simultaneous jet finding by two or three algorithms; see Selection 3 in Section 2.2) is also important for selecting events with a clean jet topology and rising the confidence level of a jet determination. The summarizing results of our study of the jet energy scale setting are presented in Appendices 2–6 (see also Fig. 11).

It is demonstrated (Section 7) that the used selection criteria guarantee practically complete suppression of the combinatorial background from the QCD events.
Figure 13: LHC \((x, Q^2)\) kinematic region for the process \(pp \rightarrow Z^0 + \text{jet} + X\) \((\text{with } Z^0 \rightarrow \mu^+\mu^-)\).

It is worth emphasizing that the number of events presented here were not our main goal as they may depend on the used event generator and on the particular choice of a long set of its parameters. The most important result of our work is demonstration that the set of new selection criteria (limitation of \(P_t^{\text{clus}}, P_t^{\text{out}}\) and jet isolation found earlier in [12]–[16]) are also very useful for the jet energy scale determination by help of "\(Z^0 + \text{jet}\)" events.

It is also shown that the selected sample of the "\(Z^0 + \text{jet}\)" events, most suitable for the absolute jet energy scale setting at the LHC energy, can provide useful information for the gluon density determination inside a proton in the kinematic region with \(x\) values as small as accessible at HERA but at much higher \(Q^2\) values (by about 1–2 orders of magnitude): \(2 \cdot 10^{-4} \leq x \leq 1.0\) with \(0.9 \cdot 10^3 \leq Q^2 \leq 4 \cdot 10^4 \text{ (GeV/c)}^2\). This sample of "\(Z^0 + \text{jet}\)" events can be used to perform a cross-check of the \(f^p_\gamma(x, Q^2)\) determination by help of "\(\gamma + \text{jet}\)" events [20, 21]. The \(x - Q^2\) kinematic area that can be covered by the "\(Z^0 + \text{jet}\)" events (with \(Z^0 \rightarrow \mu^+\mu^-\)) as well as by the "\(\gamma + \text{jet}\)" events is shown in Fig. 13.

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**Appendix 1**

$45 < P_t^Z < 55 \text{ GeV/c}$

**Table 1:** Selection 1. $\Delta\phi(Z,\text{jet}) = 180^\circ \pm 15^\circ$. UA1 algorithm.

| $P_t^{\text{cut}}$ | 30    | 20    | 15    | 10    | 5    |
|-------------------|-------|-------|-------|-------|------|
| $P_t^{\text{jet}}$ | 48.145 | 47.600 | 47.417 | 47.334 | 47.323 |
| $P_t^{\text{jet}} - P_{t(j)}^{\text{min}}$ | 0.140 | 0.129 | 0.122 | 0.106 | 0.084 |
| $R_{\text{jet}}^{\text{min}}$ | 0.027 | 0.026 | 0.025 | 0.023 | 0.022 |
| $P_{t(j)}^{\text{min}}$ | 0.046 | 0.042 | 0.043 | 0.038 | 0.029 |
| $R_{\text{jet}}^{\text{min}}$ | 0.011 | 0.011 | 0.010 | 0.009 | 0.010 |
| $P_t^{\text{max}}$ | 5.009 | 4.897 | 4.777 | 4.577 | 4.239 |
| $P_{t(\nu)}^{\text{max}}$ | 9.016 | 8.843 | 8.517 | 7.653 | 6.880 |
| $N_{\text{event}}(c)$ | 2774 | 2300 | 1763 | 1027 | 201 |
| $N_{\text{event}}(b)$ | 2129 | 1677 | 1257 | 626 | 80 |
| $R_{\text{gc}}^{30}$ | 0.71 | 0.70 | 0.69 | 0.68 | 0.65 |
| Entries | 33240 | 29704 | 25482 | 17162 | 3842 |

**Table 2:** Selection 1. $\Delta\phi(Z,\text{jet}) = 180^\circ \pm 15^\circ$. UA2 algorithm.

| $P_t^{\text{cut}}$ | 30    | 20    | 15    | 10    | 5    |
|-------------------|-------|-------|-------|-------|------|
| $P_t^{\text{jet}}$ | 47.520 | 46.883 | 46.520 | 46.296 | 46.254 |
| $P_t^{\text{jet}} - P_{t(j)}^{\text{min}}$ | 0.129 | 0.116 | 0.106 | 0.096 | 0.085 |
| $R_{\text{jet}}^{\text{min}}$ | 0.026 | 0.023 | 0.023 | 0.022 | 0.021 |
| $P_{t(j)}^{\text{min}}$ | 0.048 | 0.045 | 0.044 | 0.042 | 0.038 |
| $R_{\text{jet}}^{\text{min}}$ | 0.010 | 0.010 | 0.009 | 0.009 | 0.010 |
| $P_t^{\text{max}}$ | 5.012 | 4.890 | 4.765 | 4.571 | 4.221 |
| $P_{t(\nu)}^{\text{max}}$ | 8.635 | 8.336 | 8.008 | 7.290 | 6.366 |
| $N_{\text{event}}(c)$ | 2774 | 2300 | 1763 | 1027 | 201 |
| $N_{\text{event}}(b)$ | 2129 | 1677 | 1257 | 626 | 80 |
| $R_{\text{gc}}^{30}$ | 0.56 | 0.56 | 0.55 | 0.55 | 0.56 |
| Entries | 33240 | 29704 | 25482 | 17162 | 3842 |

**Table 3:** Selection 1. $\Delta\phi(Z,\text{jet}) = 180^\circ \pm 15^\circ$. LUCELL algorithm.

| $P_t^{\text{cut}}$ | 30    | 20    | 15    | 10    | 5    |
|-------------------|-------|-------|-------|-------|------|
| $P_t^{\text{jet}}$ | 47.326 | 46.854 | 46.677 | 46.732 | 47.016 |
| $P_t^{\text{jet}} - P_{t(j)}^{\text{min}}$ | 0.144 | 0.133 | 0.128 | 0.118 | 0.095 |
| $R_{\text{jet}}^{\text{min}}$ | 0.028 | 0.027 | 0.026 | 0.025 | 0.023 |
| $P_{t(j)}^{\text{min}}$ | 0.049 | 0.048 | 0.043 | 0.040 | 0.034 |
| $R_{\text{jet}}^{\text{min}}$ | 0.010 | 0.010 | 0.009 | 0.009 | 0.010 |
| $P_t^{\text{max}}$ | 5.007 | 4.902 | 4.791 | 4.600 | 4.255 |
| $P_{t(\nu)}^{\text{max}}$ | 9.104 | 8.871 | 8.666 | 8.140 | 7.124 |
| $N_{\text{event}}(c)$ | 2793 | 2322 | 1792 | 1057 | 187 |
| $N_{\text{event}}(b)$ | 2354 | 1856 | 1386 | 693 | 91 |
| $R_{\text{gc}}^{30}$ | 0.69 | 0.68 | 0.66 | 0.64 | 0.61 |
| Entries | 33240 | 29057 | 25154 | 17041 | 3706 |

Note: The entries in the tables represent the selection criteria and observed values for different algorithms and cuts.
$70 < P_t^Z < 85$ GeV/c

Table 4: Selection 1. $\Delta \phi (Z, \text{jet}) = 180^\circ \pm 15^\circ$. UA1 algorithm.

| $P_{tclust}^{UA1}$ | 30 | 20 | 15 | 10 | 5 |
|---------------------|----|----|----|----|----|
| $P_t^{jet}$         | 71.309 | 72.833 | 73.509 | 74.073 | 74.192 |
| $P_t^{jet} - P_{tclust}^{UA1}$ | 0.339 | 0.326 | 0.319 | 0.270 | 0.271 |
| $P_t^{(u)}$         | 0.341 | 0.328 | 0.321 | 0.271 | 0.272 |
| $R_{\nu \rightarrow \text{jet}}^{\text{UA1}}$ | 0.039 | 0.037 | 0.036 | 0.031 | 0.027 |
| $R_{\mu \rightarrow \text{jet}}^{\text{UA1}}$ | 0.147 | 0.144 | 0.141 | 0.124 | 0.126 |
| $P_t^{\text{miss}}$ | 5.480 | 5.324 | 5.230 | 5.056 | 4.662 |
| $P_t^{\text{miss}}^{\nu \rightarrow \text{jet}}$ | 14.357 | 14.273 | 14.484 | 14.504 | 15.842 |
| $N_{\text{event}}(c)$ | 1478 | 1025 | 710 | 396 | 62 |
| $N_{\text{event}}(b)$ | 1173 | 787 | 528 | 263 | 35 |
| $R_{\gamma \rightarrow \text{jet}}^{\text{sub/all}}$ | 0.81 | 0.80 | 0.79 | 0.77 | 0.74 |
| Entries             | 21649 | 17169 | 13309 | 8132 | 1628 |

Table 5: Selection 1. $\Delta \phi (Z, \text{jet}) = 180^\circ \pm 15^\circ$. UA2 algorithm.

| $P_{tclust}^{UA2}$ | 30 | 20 | 15 | 10 | 5 |
|---------------------|----|----|----|----|----|
| $P_t^{jet}$         | 71.065 | 72.035 | 72.483 | 72.896 | 72.976 |
| $P_t^{jet} - P_{tclust}^{UA2}$ | 0.329 | 0.319 | 0.316 | 0.274 | 0.319 |
| $P_t^{(u)}$         | 0.331 | 0.322 | 0.318 | 0.276 | 0.320 |
| $R_{\nu \rightarrow \text{jet}}^{\text{UA2}}$ | 0.039 | 0.037 | 0.036 | 0.031 | 0.030 |
| $R_{\mu \rightarrow \text{jet}}^{\text{UA2}}$ | 0.147 | 0.144 | 0.141 | 0.124 | 0.138 |
| $P_t^{\text{miss}}$ | 5.465 | 5.308 | 5.216 | 4.999 | 4.577 |
| $P_t^{\text{miss}}^{\nu \rightarrow \text{jet}}$ | 13.783 | 13.586 | 13.684 | 13.688 | 15.203 |
| $N_{\text{event}}(c)$ | 1557 | 1114 | 787 | 440 | 67 |
| $N_{\text{event}}(b)$ | 1349 | 924 | 624 | 324 | 40 |
| $R_{\gamma \rightarrow \text{jet}}^{\text{sub/all}}$ | 0.79 | 0.75 | 0.77 | 0.75 | 0.71 |
| Entries             | 22238 | 17993 | 14199 | 8656 | 1719 |

Table 6: Selection 1. $\Delta \phi (Z, \text{jet}) = 180^\circ \pm 15^\circ$. LUCCELL algorithm.

| $P_{tclust}^{LUCELL}$ | 30 | 20 | 15 | 10 | 5 |
|-----------------------|----|----|----|----|----|
| $P_t^{jet}$           | 71.054 | 72.235 | 72.910 | 73.608 | 73.869 |
| $P_t^{jet} - P_{tclust}^{LUCELL}$ | 0.334 | 0.328 | 0.318 | 0.264 | 0.258 |
| $P_t^{(u)}$           | 0.336 | 0.330 | 0.319 | 0.265 | 0.258 |
| $R_{\nu \rightarrow \text{jet}}^{\text{LUCCELL}}$ | 0.038 | 0.037 | 0.035 | 0.031 | 0.026 |
| $R_{\mu \rightarrow \text{jet}}^{\text{LUCCELL}}$ | 0.151 | 0.150 | 0.148 | 0.126 | 0.129 |
| $P_t^{\text{miss}}$   | 5.480 | 5.336 | 5.229 | 5.040 | 4.615 |
| $P_t^{\text{miss}}^{\nu \rightarrow \text{jet}}$ | 14.412 | 14.301 | 14.423 | 14.095 | 15.959 |
| $N_{\text{event}}(c)$ | 1488 | 1057 | 735 | 401 | 64 |
| $N_{\text{event}}(b)$ | 1166 | 812 | 547 | 270 | 34 |
| $R_{\gamma \rightarrow \text{jet}}^{\text{sub/all}}$ | 0.81 | 0.80 | 0.79 | 0.78 | 0.75 |
| Entries              | 22439 | 18123 | 14046 | 8434 | 1600 |
100 < P_tZ < 120 GeV/c

Table 7: Selection 1. $\Delta \phi (Z,jet) = 180^\circ \pm 15^\circ$. UA1 algorithm.

| $P_{t_{clust}}$ | 30 | 20 | 15 | 10 | 5 |
|----------------|----|----|----|----|---|
| $P_{t_{clust}}$ | 105.311 | 106.781 | 107.596 | 108.186 | 108.211 |
| $P_{t_{jet}}-P_{t_{clust}}$ | 0.579 | 0.536 | 0.503 | 0.464 | 0.306 |
| $P_{t_{jet}}$ | 0.582 | 0.538 | 0.505 | 0.465 | 0.308 |
| $R_{c_{cent}}$ | 0.043 | 0.040 | 0.038 | 0.035 | 0.027 |
| $P_{t_{clust}}$ | 0.256 | 0.236 | 0.229 | 0.248 | 0.190 |
| $R_{c_{cent}}$ | 0.021 | 0.021 | 0.020 | 0.019 | 0.017 |
| $P_{t_{miss}}$ | 6.021 | 5.773 | 5.565 | 5.410 | 4.998 |
| $P_{t_{miss}}$ | 21.291 | 20.555 | 19.968 | 19.964 | 20.603 |
| Nevent(c) | 1101 | 837 | 611 | 348 | 71 |
| Nevent(b) | 804 | 584 | 418 | 214 | 27 |
| 30sub/all | 0.84 | 0.83 | 0.82 | 0.81 | 0.78 |
| R_{gc} | 0.65 | 0.65 | 0.65 | 0.65 | 0.65 |
| Entries | 26365 | 19658 | 14669 | 8491 | 1690 |

Table 8: Selection 1. $\Delta \phi (Z,jet) = 180^\circ \pm 15^\circ$. UA2 algorithm.

| $P_{t_{clust}}$ | 30 | 20 | 15 | 10 | 5 |
|----------------|----|----|----|----|---|
| $P_{t_{clust}}$ | 105.053 | 106.086 | 106.624 | 107.032 | 107.226 |
| $P_{t_{jet}}-P_{t_{clust}}$ | 0.584 | 0.536 | 0.499 | 0.458 | 0.300 |
| $P_{t_{jet}}$ | 0.587 | 0.539 | 0.502 | 0.461 | 0.302 |
| $R_{c_{cent}}$ | 0.045 | 0.041 | 0.038 | 0.036 | 0.028 |
| $P_{t_{clust}}$ | 0.258 | 0.236 | 0.229 | 0.218 | 0.209 |
| $R_{c_{cent}}$ | 0.022 | 0.022 | 0.021 | 0.018 | 0.017 |
| $P_{t_{miss}}$ | 5.998 | 5.781 | 5.578 | 5.430 | 5.000 |
| $P_{t_{miss}}$ | 20.530 | 19.980 | 19.456 | 19.427 | 18.699 |
| Nevent(c) | 1136 | 881 | 652 | 372 | 76 |
| Nevent(b) | 881 | 658 | 478 | 250 | 31 |
| 30sub/all | 0.84 | 0.82 | 0.81 | 0.80 | 0.76 |
| R_{gc} | 0.59 | 0.60 | 0.59 | 0.59 | 0.59 |
| Entries | 28311 | 21607 | 16358 | 9541 | 1845 |

Table 9: Selection 1. $\Delta \phi (Z,jet) = 180^\circ \pm 15^\circ$. LUCELL algorithm.

| $P_{t_{clust}}$ | 30 | 20 | 15 | 10 | 5 |
|----------------|----|----|----|----|---|
| $P_{t_{clust}}$ | 104.919 | 106.238 | 107.024 | 107.700 | 108.019 |
| $P_{t_{jet}}-P_{t_{clust}}$ | 0.579 | 0.539 | 0.511 | 0.468 | 0.318 |
| $P_{t_{jet}}$ | 0.581 | 0.541 | 0.514 | 0.470 | 0.319 |
| $R_{c_{cent}}$ | 0.043 | 0.040 | 0.038 | 0.035 | 0.026 |
| $P_{t_{clust}}$ | 0.264 | 0.247 | 0.244 | 0.222 | 0.188 |
| $R_{c_{cent}}$ | 0.022 | 0.022 | 0.021 | 0.019 | 0.018 |
| $P_{t_{miss}}$ | 6.014 | 5.787 | 5.602 | 5.424 | 4.991 |
| $P_{t_{miss}}$ | 21.514 | 20.833 | 20.528 | 20.390 | 21.456 |
| Nevent(c) | 1131 | 878 | 641 | 354 | 71 |
| Nevent(b) | 818 | 612 | 438 | 219 | 25 |
| 30sub/all | 0.84 | 0.83 | 0.82 | 0.82 | 0.80 |
| R_{gc} | 0.66 | 0.66 | 0.66 | 0.65 | 0.64 |
| Entries | 26920 | 20362 | 15184 | 8643 | 1636 |
\[150 < P_t^Z < 200 \text{ GeV/c}\]

Table 10: Selection 1. $\Delta \phi(Z,\text{jet}) = 180^\circ \pm 15^\circ$. UA1 algorithm.

| $P_{t, \text{cut}}^{\mu, \nu}$ | 30    | 20    | 15    | 10    | 5    |
|-------------------------------|-------|-------|-------|-------|------|
| $P_{t, \text{cut}}^{\mu, \nu}$ | 166.611 | 167.904 | 168.504 | 168.711 | 169.574 |
| $P_{t, \text{cut}}^{\mu, \nu} - P_{t, \text{cut}}^{\nu, \mu}$ | 0.808 | 0.763 | 0.732 | 0.652 | 0.548 |
| $P_{t, \text{cut}}^{\mu, \nu}$ | 0.811 | 0.766 | 0.734 | 0.655 | 0.551 |
| $P_{t, \text{cut}}^{\mu, \nu}$ | 0.043 | 0.041 | 0.041 | 0.038 | 0.034 |
| $P_{t, \text{cut}}^{\mu, \nu}$ | 0.368 | 0.357 | 0.348 | 0.302 | 0.261 |
| $R_{\text{cut}}^{\mu, \nu}$ | 0.021 | 0.021 | 0.021 | 0.020 | 0.019 |
| $P_{t, \text{cut}}^{\mu, \nu}$ | 6.647 | 6.468 | 6.306 | 6.086 | 5.462 |
| $P_{t, \text{cut}}^{\mu, \nu}$ | 29.802 | 29.934 | 29.081 | 28.699 | 22.469 |
| Nevent$_{(c)}$ | 629 | 429 | 306 | 173 | 29 |
| Nevent$_{(b)}$ | 459 | 305 | 201 | 97 | 14 |
| 30sub/all | 0.85 | 0.84 | 0.83 | 0.81 | 0.77 |
| $R_{gc}$ | 0.66 | 0.66 | 0.66 | 0.66 | 0.65 |
| Entries | 27148 | 19298 | 14089 | 8022 | 1517 |

Table 11: Selection 1. $\Delta \phi(Z,\text{jet}) = 180^\circ \pm 15^\circ$. UA2 algorithm.

| $P_{t, \text{cut}}^{\mu, \nu}$ | 30    | 20    | 15    | 10    | 5    |
|-------------------------------|-------|-------|-------|-------|------|
| $P_{t, \text{cut}}^{\mu, \nu}$ | 166.410 | 167.275 | 167.612 | 167.794 | 168.177 |
| $P_{t, \text{cut}}^{\mu, \nu} - P_{t, \text{cut}}^{\nu, \mu}$ | 0.797 | 0.736 | 0.722 | 0.648 | 0.486 |
| $P_{t, \text{cut}}^{\mu, \nu}$ | 0.801 | 0.740 | 0.725 | 0.652 | 0.490 |
| $P_{t, \text{cut}}^{\mu, \nu}$ | 0.044 | 0.041 | 0.041 | 0.037 | 0.035 |
| $P_{t, \text{cut}}^{\mu, \nu}$ | 0.377 | 0.352 | 0.344 | 0.322 | 0.237 |
| $P_{t, \text{cut}}^{\mu, \nu}$ | 0.023 | 0.022 | 0.022 | 0.021 | 0.020 |
| $P_{t, \text{cut}}^{\mu, \nu}$ | 6.616 | 6.385 | 6.250 | 6.042 | 5.382 |
| $P_{t, \text{cut}}^{\mu, \nu}$ | 28.727 | 28.831 | 28.168 | 28.360 | 20.770 |
| Nevent$_{(c)}$ | 698 | 476 | 348 | 193 | 33 |
| Nevent$_{(b)}$ | 545 | 364 | 247 | 119 | 15 |
| 30sub/all | 0.84 | 0.83 | 0.82 | 0.80 | 0.76 |
| $R_{gc}$ | 0.62 | 0.62 | 0.62 | 0.62 | 0.63 |
| Entries | 30379 | 22130 | 16501 | 9520 | 1731 |

Table 12: Selection 1. $\Delta \phi(Z,\text{jet}) = 180^\circ \pm 15^\circ$. LUCELL algorithm.

| $P_{t, \text{cut}}^{\mu, \nu}$ | 30    | 20    | 15    | 10    | 5    |
|-------------------------------|-------|-------|-------|-------|------|
| $P_{t, \text{cut}}^{\mu, \nu}$ | 166.046 | 167.273 | 167.865 | 168.298 | 169.319 |
| $P_{t, \text{cut}}^{\mu, \nu} - P_{t, \text{cut}}^{\nu, \mu}$ | 0.800 | 0.739 | 0.714 | 0.629 | 0.594 |
| $P_{t, \text{cut}}^{\mu, \nu}$ | 0.803 | 0.742 | 0.716 | 0.631 | 0.596 |
| $P_{t, \text{cut}}^{\mu, \nu}$ | 0.043 | 0.040 | 0.040 | 0.036 | 0.036 |
| $P_{t, \text{cut}}^{\mu, \nu}$ | 0.396 | 0.361 | 0.352 | 0.326 | 0.297 |
| $R_{\text{cut}}^{\mu, \nu}$ | 0.022 | 0.021 | 0.021 | 0.019 | 0.018 |
| $P_{t, \text{cut}}^{\mu, \nu}$ | 6.644 | 6.466 | 6.292 | 6.072 | 5.555 |
| $P_{t, \text{cut}}^{\mu, \nu}$ | 29.840 | 30.057 | 29.270 | 29.107 | 22.946 |
| Nevent$_{(c)}$ | 626 | 434 | 313 | 169 | 28 |
| Nevent$_{(b)}$ | 457 | 304 | 200 | 91 | 13 |
| 30sub/all | 0.85 | 0.84 | 0.83 | 0.82 | 0.79 |
| $R_{gc}$ | 0.66 | 0.66 | 0.65 | 0.65 | 0.64 |
| Entries | 27334 | 19833 | 14494 | 8069 | 1430 |
### Appendix 2

$45 < P_t^Z < 55$ GeV/c

#### Table 1: Selection 1. $\Delta\phi(Z, jet) = 180^\circ \pm 180^\circ$. UA1 algorithm.

| $P_{t,CUT}$ | 30   | 20   | 15   | 10   | 5    |
|--------------|------|------|------|------|------|
| Nevent*      | 44812| 33355| 25413| 15342| 3246 |
| $P_{5,6}$    | 19.6 | 15.0 | 12.4 | 9.9  | 7.4  |
| $\Delta\phi$| 13.8 | 9.8  | 7.9  | 6.0  | 4.2  |
| $P_{t,\text{out}}$ | 15.3 | 11.9 | 10.0 | 7.9  | 5.6  |
| $P_{t,\text{clust}}$ | 5.1  | 4.9  | 4.9  | 4.8  | 4.3  |
| $(P_t^Z-P_{t,\text{part}}^Z)/P_t^Z$ | 0.0487 | 0.0315 | 0.0189 | 0.0113 | 0.0026 |
| $(P_t^Z-P_{t,\text{clus}}^Z)/P_t^Z$ | 0.0140 | -0.0016 | -0.0069 | -0.0032 | -0.0057 |
| $(P_t^Z-P_t^Z)/P_t^Z$ | 0.0243 | 0.0202 | 0.0200 | 0.0109 | 0.0064 |
| $P_t(O+p>5)/P_t^Z$ | -0.0300 | -0.0005 | 0.0031 | 0.0011 | 0.0014 |
| $1-\cos(\Delta\phi)$ | 0.0543 | 0.0267 | 0.0170 | 0.0098 | 0.0050 |
| $\sigma(DB[Z, J])$ | 0.2140 | 0.1814 | 0.1591 | 0.1304 | 0.1010 |
| Entries       | 18857 | 14036 | 10694 | 6456  | 1366 |

#### Table 2: Selection 1. $\Delta\phi(Z, jet) = 180^\circ \pm 180^\circ$. UA2 algorithm.

| $P_{t,CUT}$ | 30   | 20   | 15   | 10   | 5    |
|--------------|------|------|------|------|------|
| Nevent       | 43198| 32713| 25458| 15489| 3189 |
| $P_{5,6}$    | 19.3 | 14.8 | 12.4 | 10.0 | 7.6  |
| $\Delta\phi$| 13.3 | 9.6  | 7.7  | 5.9  | 4.1  |
| $P_{t,\text{out}}$ | 15.0 | 11.8 | 10.0 | 8.0  | 5.8  |
| $P_{t,\text{clus}}$ | 5.0  | 4.9  | 4.9  | 4.8  | 4.4  |
| $(P_t^Z-P_{t,\text{part}}^Z)/P_t^Z$ | 0.0399 | 0.0239 | 0.0153 | 0.0119 | 0.0080 |
| $(P_t^Z-P_{t,\text{clus}}^Z)/P_t^Z$ | -0.0048 | -0.0257 | -0.0333 | -0.0295 | -0.0259 |
| $(P_t^Z-P_t^Z)/P_t^Z$ | 0.0330 | 0.0405 | 0.0405 | 0.0357 | 0.0302 |
| $P_t(O+p>5)/P_t^Z$ | -0.0175 | 0.0152 | 0.0241 | 0.0263 | 0.0254 |
| $1-\cos(\Delta\phi)$ | 0.0505 | 0.0253 | 0.0165 | 0.0094 | 0.0048 |
| $\sigma(DB[Z, J])$ | 0.2088 | 0.1773 | 0.1563 | 0.1305 | 0.1009 |
| Entries       | 18178 | 13766 | 10713 | 6518  | 1342 |

#### Table 3: Selection 1. $\Delta\phi(Z, jet) = 180^\circ \pm 180^\circ$. LUCCELL algorithm.

| $P_{t,CUT}$ | 30   | 20   | 15   | 10   | 5    |
|--------------|------|------|------|------|------|
| Nevent       | 48402| 36720| 27923| 16411| 3296 |
| $P_{5,6}$    | 19.4 | 15.2 | 12.6 | 10.0 | 7.3  |
| $\Delta\phi$| 13.6 | 10.0 | 8.0  | 6.1  | 4.3  |
| $P_{t,\text{out}}$ | 15.2 | 12.2 | 10.2 | 8.0  | 5.7  |
| $P_{t,\text{clus}}$ | 5.0  | 4.9  | 4.9  | 4.8  | 4.4  |
| $(P_t^Z-P_{t,\text{part}}^Z)/P_t^Z$ | 0.0552 | 0.0378 | 0.0250 | 0.0142 | 0.0009 |
| $(P_t^Z-P_{t,\text{clus}}^Z)/P_t^Z$ | 0.0043 | -0.0120 | -0.0170 | -0.0123 | -0.0119 |
| $(P_t^Z-P_t^Z)/P_t^Z$ | 0.0413 | 0.0420 | 0.0355 | 0.0223 | 0.0105 |
| $P_t(O+p>5)/P_t^Z$ | -0.0108 | 0.0143 | 0.0182 | 0.0122 | 0.0047 |
| $1-\cos(\Delta\phi)$ | 0.0521 | 0.0278 | 0.0173 | 0.0102 | 0.0058 |
| $\sigma(DB[Z, J])$ | 0.2121 | 0.1842 | 0.1626 | 0.1337 | 0.1031 |
| Entries       | 20368 | 15452 | 11750 | 6906  | 1387 |

*Number of events (Nevent) is given in this and in the following tables for integrated luminosity $L_{int} = 10 fb^{-1}$

** $DB[Z, J] \equiv (P_t^Z - P_t^J)/P_t^Z$
Table 4: Selection 1. $\Delta \phi(Z, \text{jet}) = 180^\circ \pm 15^\circ$. UA1 algorithm.

| $P_{\text{clust}}^{\text{cut}}$ | 30  | 20  | 15  | 10  | 5  |
|-------------------------------|-----|-----|-----|-----|----|
| Nevent                        | 29624 | 26022 | 21782 | 14320 | 3189 |
| $P_{\text{mix}}$              | 14.5 | 12.5 | 11.0 | 9.3  | 7.2 |
| $\Delta \phi$                 | 6.1  | 5.9  | 5.6  | 4.9  | 3.9 |
| $P_{\text{mix}}$              | 10.5 | 9.6  | 8.7  | 7.4  | 5.5 |
| $P_{\text{mix}}^{\text{pt}}$  | 4.9  | 4.8  | 4.7  | 4.6  | 4.2 |
| $P_{\text{mix}}^{\text{pt}}$  | 0.0156 | 0.0156 | 0.0107 | 0.0078 | 0.0004 |
| $P_{\text{mix}}^{\text{pt}}$  | 0.0015 | -0.0047 | -0.0062 | -0.0033 | -0.0054 |
| $P_{\text{mix}}^{\text{pt}}$  | 0.0051 | 0.0140 | 0.0120 | 0.0077 | 0.0039 |
| $P_{\text{mix}}^{\text{pt}}$  | -0.0033 | 0.0060 | 0.0047 | 0.0019 | 0.0001 |
| $1 - \cos(\Delta \phi)$       | 0.0084 | 0.0080 | 0.0073 | 0.0058 | 0.0039 |
| $\sigma(Db[Z,J])$             | 0.2025 | 0.1745 | 0.1543 | 0.1282 | 0.0992 |
| Entries                       | 12466 | 10950 | 9166  | 6026  | 1342 |

Table 5: Selection 1. $\Delta \phi(Z, \text{jet}) = 180^\circ \pm 15^\circ$. UA2 algorithm.

| $P_{\text{clust}}^{\text{cut}}$ | 30  | 20  | 15  | 10  | 5  |
|-------------------------------|-----|-----|-----|-----|----|
| Nevent                        | 29089 | 25734 | 21915 | 14491 | 3144 |
| $P_{\text{mix}}$              | 14.3 | 12.4 | 11.0 | 9.4  | 7.4 |
| $\Delta \phi$                 | 6.0  | 5.9  | 5.5  | 4.9  | 3.9 |
| $P_{\text{mix}}$              | 10.4 | 9.5  | 8.7  | 7.5  | 5.8 |
| $P_{\text{mix}}^{\text{pt}}$  | 4.9  | 4.8  | 4.7  | 4.6  | 4.3 |
| $P_{\text{mix}}^{\text{pt}}$  | 0.0087 | 0.0093 | 0.0081 | 0.0093 | 0.0064 |
| $P_{\text{mix}}^{\text{pt}}$  | -0.0203 | -0.0292 | -0.0324 | -0.0293 | -0.0262 |
| $P_{\text{mix}}^{\text{pt}}$  | 0.0187 | 0.0302 | 0.0335 | 0.0332 | 0.0289 |
| $P_{\text{mix}}^{\text{pt}}$  | 0.0105 | 0.0225 | 0.0264 | 0.0275 | 0.0252 |
| $1 - \cos(\Delta \phi)$       | 0.0082 | 0.0078 | 0.0071 | 0.0057 | 0.0038 |
| $\sigma(Db[Z,J])$             | 0.1972 | 0.1704 | 0.1513 | 0.1286 | 0.0998 |
| Entries                       | 12241 | 10829 | 9166  | 6098  | 1323 |

Table 6: Selection 1. $\Delta \phi(Z, \text{jet}) = 180^\circ \pm 15^\circ$. LUCHELL algorithm.

| $P_{\text{clust}}^{\text{cut}}$ | 30  | 20  | 15  | 10  | 5  |
|-------------------------------|-----|-----|-----|-----|----|
| Nevent                        | 32153 | 28405 | 23849 | 15294 | 3237 |
| $P_{\text{mix}}$              | 14.5 | 12.6 | 11.2 | 9.3  | 7.0 |
| $\Delta \phi$                 | 6.2  | 6.0  | 5.7  | 5.0  | 4.0 |
| $P_{\text{mix}}$              | 10.6 | 9.7  | 8.9  | 7.5  | 5.6 |
| $P_{\text{mix}}^{\text{pt}}$  | 4.9  | 4.8  | 4.8  | 4.6  | 4.2 |
| $P_{\text{mix}}^{\text{pt}}$  | 0.0213 | 0.0206 | 0.0164 | 0.0103 | -0.0013 |
| $P_{\text{mix}}^{\text{pt}}$  | -0.0081 | -0.0145 | -0.0161 | -0.0120 | -0.0118 |
| $P_{\text{mix}}^{\text{pt}}$  | 0.0207 | 0.0281 | 0.0268 | 0.0184 | 0.0082 |
| $P_{\text{mix}}^{\text{pt}}$  | 0.0122 | 0.0200 | 0.0195 | 0.0124 | 0.0043 |
| $1 - \cos(\Delta \phi)$       | 0.0085 | 0.0081 | 0.0074 | 0.0060 | 0.0039 |
| $\sigma(Db[Z,J])$             | 0.2017 | 0.1768 | 0.1578 | 0.1312 | 0.1009 |
| Entries                       | 13530 | 11953 | 10036 | 6436  | 1362 |
### Table 7: Selection 1. $\Delta \phi(Z, \text{jet}) = 180^\circ \pm 10^\circ$. UA1 algorithm.

| $P_{\text{clust}}^{\text{cut}}$ | 30 | 20 | 15 | 10 | 5 |
|-----------------|----|----|----|----|----|
| Nevent          | 23075 | 20713 | 17892 | 12512 | 2985 |
| $P_{56}$        | 13.0 | 11.3 | 10.1 | 8.6 | 6.8 |
| $\Delta \phi$   | 4.3 | 4.3 | 4.2 | 3.9 | 3.4 |
| $P_{\text{out}}$ | 9.4 | 8.6 | 7.9 | 6.9 | 5.3 |
| $P_{\eta>5}$    | 4.8 | 4.8 | 4.7 | 4.5 | 4.1 |
| $\frac{(P_{Z} - P_{\text{part}})}{P_{Z}}$ | 0.0079 | 0.0091 | 0.0069 | 0.0048 | -0.0024 |
| $\frac{(P_{J} - P_{\text{part}})}{P_{J}}$ | -0.0009 | -0.0053 | -0.0061 | -0.0027 | -0.0061 |
| $\frac{(P_{Z} - P_{J})}{P_{Z}}$ | 0.0011 | 0.0085 | 0.0070 | 0.0044 | 0.0018 |
| $P_{(O+\eta>5)/P_{Z}}$ | -0.0030 | 0.0045 | 0.0032 | 0.0009 | -0.0009 |
| $1 - \cos(\Delta \phi)$ | 0.0041 | 0.0040 | 0.0038 | 0.0034 | 0.0026 |
| $\sigma(DB(Z, J))$ | 0.1944 | 0.1691 | 0.1496 | 0.1255 | 0.0980 |
| Entries         | 9710 | 8716 | 7529 | 5265 | 1256 |

### Table 8: Selection 1. $\Delta \phi(Z, \text{jet}) = 180^\circ \pm 10^\circ$. UA2 algorithm.

| $P_{\text{clust}}^{\text{cut}}$ | 30 | 20 | 15 | 10 | 5 |
|-----------------|----|----|----|----|----|
| Nevent          | 22965 | 20713 | 18196 | 12780 | 2966 |
| $P_{56}$        | 13.0 | 11.3 | 10.1 | 8.8 | 7.1 |
| $\Delta \phi$   | 4.3 | 4.3 | 4.2 | 3.9 | 3.4 |
| $P_{\text{out}}$ | 9.3 | 8.6 | 8.0 | 7.1 | 5.6 |
| $P_{\eta>5}$    | 4.8 | 4.8 | 4.7 | 4.6 | 4.2 |
| $\frac{(P_{Z} - P_{\text{part}})}{P_{Z}}$ | 0.0050 | 0.0069 | 0.0070 | 0.0063 | 0.0046 |
| $\frac{(P_{J} - P_{\text{part}})}{P_{J}}$ | -0.0226 | -0.0294 | -0.0308 | -0.0296 | -0.0260 |
| $\frac{(P_{Z} - P_{J})}{P_{Z}}$ | 0.0183 | 0.0285 | 0.0309 | 0.0307 | 0.0271 |
| $P_{(O+\eta>5)/P_{Z}}$ | 0.0142 | 0.0245 | 0.0271 | 0.0273 | 0.0245 |
| $1 - \cos(\Delta \phi)$ | 0.0041 | 0.0040 | 0.0038 | 0.0035 | 0.0026 |
| $\sigma(DB(Z, J))$ | 0.1895 | 0.1643 | 0.1468 | 0.1258 | 0.0983 |
| Entries         | 9664 | 8716 | 7657 | 5378 | 1248 |

### Table 9: Selection 1. $\Delta \phi(Z, \text{jet}) = 180^\circ \pm 10^\circ$. LUCELL algorithm.

| $P_{\text{clust}}^{\text{cut}}$ | 30 | 20 | 15 | 10 | 5 |
|-----------------|----|----|----|----|----|
| Nevent          | 25028 | 22564 | 19532 | 13332 | 3035 |
| $P_{56}$        | 13.1 | 11.5 | 10.3 | 8.7 | 6.7 |
| $\Delta \phi$   | 4.4 | 4.3 | 4.2 | 4.0 | 3.4 |
| $P_{\text{out}}$ | 9.5 | 8.8 | 8.1 | 7.0 | 5.4 |
| $P_{\eta>5}$    | 4.8 | 4.8 | 4.7 | 4.5 | 4.1 |
| $\frac{(P_{Z} - P_{\text{part}})}{P_{Z}}$ | 0.0140 | 0.0147 | 0.0129 | 0.0070 | -0.0035 |
| $\frac{(P_{J} - P_{\text{part}})}{P_{J}}$ | -0.0102 | -0.0141 | -0.0144 | -0.0118 | -0.0115 |
| $\frac{(P_{Z} - P_{J})}{P_{Z}}$ | 0.0166 | 0.0225 | 0.0220 | 0.0151 | 0.0058 |
| $P_{(O+\eta>5)/P_{Z}}$ | 0.0125 | 0.0185 | 0.0181 | 0.0116 | 0.0032 |
| $1 - \cos(\Delta \phi)$ | 0.0042 | 0.0041 | 0.0039 | 0.0035 | 0.0027 |
| $\sigma(DB(Z, J))$ | 0.1944 | 0.1721 | 0.1515 | 0.1282 | 0.0997 |
| Entries         | 10532 | 9495 | 8219 | 5610 | 1277 |
Table 10: Selection 1. $\Delta \phi(Z,jet) = 180^\circ \pm 5^\circ$. UA1 algorithm.

| $P_{\text{clust}}^{\text{cut}}$ | 30 | 20 | 15 | 10 | 5 |
|-----------------|-----|----|----|----|----|
| Nevent          | 14078 | 12852 | 11364 | 8477 | 2246 |
| $P_{56}$        | 11.6 | 10.1 | 9.1 | 7.8 | 6.2 |
| $\Delta \phi$  | 2.4 | 2.4 | 2.3 | 2.3 | 2.2 |
| $P_{\text{cut}}$ | 8.4 | 7.7 | 7.1 | 6.2 | 4.9 |
| $P_{\text{cut}}^{\text{clos}}$ | 4.8 | 4.7 | 4.6 | 4.4 | 4.0 |
| $(P_{Z}^{2} - P_{\text{part}}^{2}) / P_{Z}^{2}$ | 0.0082 | 0.0090 | 0.0074 | 0.0038 | -0.0029 |
| $(P_{J}^{2} - P_{\text{part}}^{2}) / P_{J}^{2}$ | 0.0070 | -0.0035 | -0.0028 | -0.0025 | -0.0065 |
| $(P_{Z}^{2} - P_{J}^{2}) / P_{Z}^{2}$ | 0.0013 | 0.0057 | 0.0055 | 0.0031 | 0.0013 |
| $P_{t}(O + \eta > 5) / P_{Z}^{2}$ | 0.0001 | 0.0059 | 0.0044 | 0.0020 | 0.0003 |
| $1 - \cos(\Delta \phi)$ | 0.0012 | 0.0012 | 0.0012 | 0.0011 | 0.0010 |
| $\sigma(Db[Z,J])$ | 0.1847 | 0.1611 | 0.1432 | 0.1203 | 0.0938 |
| Entries         | 5924 | 5408 | 4782 | 3567 | 945 |

Table 11: Selection 1. $\Delta \phi(Z,jet) = 180^\circ \pm 5^\circ$. UA2 algorithm.

| $P_{\text{clust}}^{\text{cut}}$ | 30 | 20 | 15 | 10 | 5 |
|-----------------|-----|----|----|----|----|
| Nevent          | 13961 | 12775 | 11511 | 8607 | 2243 |
| $P_{56}$        | 11.5 | 10.0 | 9.1 | 8.0 | 6.5 |
| $\Delta \phi$  | 2.4 | 2.4 | 2.3 | 2.3 | 2.2 |
| $P_{\text{cut}}$ | 8.4 | 7.6 | 7.1 | 6.3 | 5.2 |
| $P_{\text{cut}}^{\text{clos}}$ | 4.8 | 4.7 | 4.6 | 4.5 | 4.0 |
| $(P_{Z}^{2} - P_{\text{part}}^{2}) / P_{Z}^{2}$ | 0.0033 | 0.0048 | 0.0060 | 0.0046 | 0.0032 |
| $(P_{J}^{2} - P_{\text{part}}^{2}) / P_{J}^{2}$ | -0.0242 | -0.0301 | -0.0307 | -0.0300 | -0.0271 |
| $(P_{Z}^{2} - P_{J}^{2}) / P_{Z}^{2}$ | 0.0186 | 0.0275 | 0.0300 | 0.0292 | 0.0264 |
| $P_{t}(O + \eta > 5) / P_{Z}^{2}$ | 0.0174 | 0.0263 | 0.0289 | 0.0281 | 0.0254 |
| $1 - \cos(\Delta \phi)$ | 0.0012 | 0.0012 | 0.0011 | 0.0011 | 0.0010 |
| $\sigma(Db[Z,J])$ | 0.1832 | 0.1583 | 0.1414 | 0.1216 | 0.0936 |
| Entries         | 5875 | 5376 | 4844 | 3622 | 944 |

Table 12: Selection 1. $\Delta \phi(Z,jet) = 180^\circ \pm 5^\circ$. LUEcell algorithm.

| $P_{\text{clust}}^{\text{cut}}$ | 30 | 20 | 15 | 10 | 5 |
|-----------------|-----|----|----|----|----|
| Nevent          | 15114 | 13840 | 12286 | 8930 | 2272 |
| $P_{56}$        | 11.7 | 10.3 | 9.2 | 7.8 | 6.1 |
| $\Delta \phi$  | 2.4 | 2.4 | 2.4 | 2.3 | 2.2 |
| $P_{\text{cut}}$ | 8.5 | 7.8 | 7.2 | 6.3 | 5.0 |
| $P_{\text{cut}}^{\text{clos}}$ | 4.7 | 4.7 | 4.6 | 4.5 | 4.0 |
| $(P_{Z}^{2} - P_{\text{part}}^{2}) / P_{Z}^{2}$ | 0.0121 | 0.0124 | 0.0111 | 0.0053 | -0.0032 |
| $(P_{J}^{2} - P_{\text{part}}^{2}) / P_{J}^{2}$ | -0.0097 | -0.0129 | -0.0138 | -0.0119 | -0.0127 |
| $(P_{Z}^{2} - P_{J}^{2}) / P_{Z}^{2}$ | 0.0146 | 0.0194 | 0.0197 | 0.0135 | 0.0070 |
| $P_{t}(O + \eta > 5) / P_{Z}^{2}$ | 0.0134 | 0.0183 | 0.0185 | 0.0123 | 0.0060 |
| $1 - \cos(\Delta \phi)$ | 0.0012 | 0.0012 | 0.0012 | 0.0011 | 0.0011 |
| $\sigma(Db[Z,J])$ | 0.1849 | 0.1639 | 0.1470 | 0.1225 | 0.0959 |
| Entries         | 6360 | 5824 | 5170 | 3758 | 956 |
Table 13: Selection 2. $\Delta \phi(Z, jet) = 180^\circ \pm 15^\circ$, $\epsilon^{jet} < 9\%$. UA1 algorithm.

| $P_{T,Z,jet}^{\text{init}}$ | Nevent | $P_{T,56}$ | $\Delta \phi$ | $P_{T,\text{min}}$ | $P_{T,\text{part}}^\phi$ | $(P_{T,\phi}^Z - P_{T,\text{part}}^\phi)/P_{T,\phi}^Z$ | $(P_{T,\phi}^Z - P_{T,\text{part}}^\phi)/P_{T,J}^Z$ | $(P_{T,\phi}^Z - P_{T,\text{part}}^\phi)/P_{T,J}^Z$ | $(P_{T,\phi}^Z - P_{T,\text{part}}^\phi)/P_{T,J}^Z$ | $P_{T}(O + \eta > 5)/P_{T,\phi}^Z$ | $1 - \cos(\Delta \phi)$ | $\sigma(Db(Z, J))$ | Entries |
|-----------------------------|--------|------------|----------------|-------------------|------------------------|------------------------------------|------------------------------------|------------------------------------|------------------------------------|------------------------------------|---------------------|------------------|
|                             |        |            |                |                   |                       |                                    |                                    |                                    |                                    |                                    |         |          |
| 30                          | 23186  | 13.8       | 5.9            | 10.2              | 4.9                   | -0.0088                            | -0.0057                            | -0.0060                            | -0.0023                            | -0.0042                            | 0.0408   | 0.1986  | 9757    |
| 20                          | 20758  | 11.9       | 5.8            | 9.2               | 4.8                   | -0.0136                            | 0.0048                             | -0.0002                            | -0.0004                            | -0.0042                            | 0.0800   | 0.1632  | 8735    |
| 15                          | 17966  | 10.6       | 5.5            | 8.5               | 4.6                   | -0.0299                            | -0.0153                            | -0.0098                            | -0.0048                            | 0.0000                             | 0.0467   | 0.1487  | 7556    |
| 10                          | 12419  | 9.0        | 4.8            | 7.2               | 4.2                   | -0.0379                            | -0.0229                            | -0.0168                            | -0.0105                            | -0.0037                           | 0.0570   | 0.1246  | 5226    |
| 5                           | 3011   | 7.1        | 3.9            | 5.5               | 4.2                   |                                    |                                    |                                    |                                    |                                    | 0.0038   | 0.0984  | 1267    |

Table 14: Selection 2. $\Delta \phi(Z, jet) = 180^\circ \pm 15^\circ$, $\epsilon^{jet} < 6\%$. UA2 algorithm.

| $P_{T,Z,jet}^{\text{init}}$ | Nevent | $P_{T,56}$ | $\Delta \phi$ | $P_{T,\text{min}}$ | $P_{T,\text{part}}^\phi$ | $(P_{T,\phi}^Z - P_{T,\text{part}}^\phi)/P_{T,\phi}^Z$ | $(P_{T,\phi}^Z - P_{T,\text{part}}^\phi)/P_{T,J}^Z$ | $(P_{T,\phi}^Z - P_{T,\text{part}}^\phi)/P_{T,J}^Z$ | $(P_{T,\phi}^Z - P_{T,\text{part}}^\phi)/P_{T,J}^Z$ | $P_{T}(O + \eta > 5)/P_{T,\phi}^Z$ | $1 - \cos(\Delta \phi)$ | $\sigma(Db(Z, J))$ | Entries |
|-----------------------------|--------|------------|----------------|-------------------|------------------------|------------------------------------|------------------------------------|------------------------------------|------------------------------------|------------------------------------|---------------------|------------------|
|                             |        |            |                |                   |                       |                                    |                                    |                                    |                                    |                                    |         |          |
| 30                          | 12671  | 13.6       | 5.6            | 10.2              | 4.9                   | -0.0467                            | -0.0385                            | -0.0314                            | -0.0213                            | -0.0175                            | 0.0677   | 0.2024  | 5332    |
| 20                          | 11321  | 11.5       | 5.5            | 8.3               | 4.6                   | -0.0118                            | -0.0229                            | -0.0272                            | -0.0290                            | -0.0341                            | 0.0072   | 0.1694  | 4764    |
| 15                          | 9895   | 10.2       | 5.3            | 7.1               | 4.3                   | -0.0421                            | -0.0206                            | -0.0083                            | 0.0042                             | 0.0103                             | 0.0066   | 0.1494  | 4164    |
| 10                          | 6946   | 8.7        | 4.7            | 7.1               | 3.7                   | -0.0379                            | -0.0229                            | -0.0168                            | -0.0105                            | -0.0037                           | 0.0053   | 0.1252  | 2923    |
| 5                           | 1811   | 6.8        | 3.7            | 5.5               | 4.3                   |                                    |                                    |                                    |                                    |                                    | 0.0350   | 0.0992  | 762     |

Table 15: Selection 2. $\Delta \phi(Z, jet) = 180^\circ \pm 15^\circ$, $\epsilon^{jet} < 9\%$. LUCELL algorithm.

| $P_{T,Z,jet}^{\text{init}}$ | Nevent | $P_{T,56}$ | $\Delta \phi$ | $P_{T,\text{min}}$ | $P_{T,\text{part}}^\phi$ | $(P_{T,\phi}^Z - P_{T,\text{part}}^\phi)/P_{T,\phi}^Z$ | $(P_{T,\phi}^Z - P_{T,\text{part}}^\phi)/P_{T,J}^Z$ | $(P_{T,\phi}^Z - P_{T,\text{part}}^\phi)/P_{T,J}^Z$ | $(P_{T,\phi}^Z - P_{T,\text{part}}^\phi)/P_{T,J}^Z$ | $P_{T}(O + \eta > 5)/P_{T,\phi}^Z$ | $1 - \cos(\Delta \phi)$ | $\sigma(Db(Z, J))$ | Entries |
|-----------------------------|--------|------------|----------------|-------------------|------------------------|------------------------------------|------------------------------------|------------------------------------|------------------------------------|------------------------------------|---------------------|------------------|
|                             |        |            |                |                   |                       |                                    |                                    |                                    |                                    |                                    |         |          |
| 30                          | 24510  | 13.6       | 6.0            | 10.1              | 4.9                   | -0.0089                            | -0.0054                            | -0.0055                            | -0.0026                            | -0.0039                            | 0.0081   | 0.2079  | 10314   |
| 20                          | 22048  | 11.9       | 5.8            | 9.3               | 4.8                   | -0.0192                            | -0.0058                            | -0.0104                            | -0.0089                            | -0.0098                            | 0.0071   | 0.1705  | 9278    |
| 15                          | 19047  | 10.5       | 5.5            | 8.5               | 4.6                   | -0.0179                            | -0.0049                            | 0.0003                             | 0.0029                             | 0.0038                             | 0.0071   | 0.1510  | 8015    |
| 10                          | 13027  | 9.0        | 4.9            | 7.3               | 4.2                   | -0.0259                            | -0.0125                            | -0.0067                            | -0.0029                            | 0.0000                             | 0.0057   | 0.1263  | 5482    |
| 5                           | 3068   | 7.0        | 3.9            | 5.5               | 4.2                   |                                    |                                    |                                    |                                    |                                    | 0.0039   | 0.0993  | 1291    |
Table 16: Selection 3. $\Delta \phi(Z, jet) = 180^\circ \pm 15^\circ$, $\epsilon^{jet} < 9\%$. UA1 algorithm.

| $P_{T,a}^{cut}$ | 30  | 20  | 15  | 10  | 5   |
|-----------------|-----|-----|-----|-----|-----|
| Nevent          | 17640 | 15872 | 13835 | 9541 | 2224 |
| $P_{T,56}$      | 13.4 | 11.6 | 10.3 | 8.8  | 7.0  |
| $\Delta \phi$   | 5.8 | 5.6  | 5.4  | 4.7  | 3.8  |
| $P_{T,20}$      | 10.0 | 9.0  | 8.3  | 7.1  | 5.4  |
| $P_{T,180}$     | 4.9 | 4.8  | 4.7  | 4.6  | 4.3  |
| $(P_{T,2} - P_{T,part1})/P_{T,2}$ | -0.0221 | -0.0171 | -0.0153 | -0.0083 | -0.0059 |
| $(P_{T,2} - P_{T,part2})/P_{T,2}$ | 0.0132 | 0.0046 | -0.0006 | -0.0007 | -0.0061 |
| $(P_{T,2} - P_{T,jet})/P_{T,2}$ | -0.0422 | -0.0261 | -0.0182 | -0.0102 | -0.0016 |
| $P_{T}(O+\eta>5)/P_{T,2}$ | -0.0498 | -0.0334 | -0.0249 | -0.0155 | -0.0051 |
| $1 - \cos(\Delta \phi)$ | 0.0076 | 0.0073 | 0.0067 | 0.0054 | 0.0037 |
| $\sigma(Db(Z, J))$ | 0.1948 | 0.1646 | 0.1460 | 0.1225 | 0.0971 |
| Entries         | 7423 | 6679 | 5822 | 4015 | 936  |

Table 17: Selection 3. $\Delta \phi(Z, jet) = 180^\circ \pm 15^\circ$, $\epsilon^{jet} < 6\%$. UA2 algorithm.

| $P_{T,a}^{cut}$ | 30  | 20  | 15  | 10  | 5   |
|-----------------|-----|-----|-----|-----|-----|
| Nevent          | 17640 | 15872 | 13835 | 9541 | 2224 |
| $P_{T,56}$      | 13.4 | 11.6 | 10.3 | 8.8  | 7.0  |
| $\Delta \phi$   | 5.8 | 5.6  | 5.4  | 4.7  | 3.8  |
| $P_{T,20}$      | 10.0 | 9.0  | 8.3  | 7.1  | 5.4  |
| $P_{T,180}$     | 4.9 | 4.8  | 4.7  | 4.6  | 4.3  |
| $(P_{T,2} - P_{T,part1})/P_{T,2}$ | -0.0221 | -0.0171 | -0.0153 | -0.0083 | -0.0059 |
| $(P_{T,2} - P_{T,part2})/P_{T,2}$ | 0.0174 | 0.0266 | -0.0319 | -0.0320 | -0.0339 |
| $(P_{T,2} - P_{T,jet})/P_{T,2}$ | -0.0124 | 0.0037 | 0.0115 | 0.0166 | 0.0217 |
| $P_{T}(O+\eta>5)/P_{T,2}$ | -0.0200 | -0.0036 | 0.0048 | 0.0113 | 0.0181 |
| $1 - \cos(\Delta \phi)$ | 0.0077 | 0.0073 | 0.0068 | 0.0054 | 0.0038 |
| $\sigma(Db(Z, J))$ | 0.1958 | 0.1688 | 0.1475 | 0.1243 | 0.0992 |
| Entries         | 7423 | 6679 | 5822 | 4015 | 936  |

Table 18: Selection 3. $\Delta \phi(Z, jet) = 180^\circ \pm 15^\circ$, $\epsilon^{jet} < 9\%$. LUCELL algorithm.

| $P_{T,a}^{cut}$ | 30  | 20  | 15  | 10  | 5   |
|-----------------|-----|-----|-----|-----|-----|
| Nevent          | 17640 | 15872 | 13835 | 9541 | 2224 |
| $P_{T,56}$      | 13.4 | 11.6 | 10.3 | 8.8  | 7.0  |
| $\Delta \phi$   | 5.8 | 5.6  | 5.4  | 4.7  | 3.8  |
| $P_{T,20}$      | 10.0 | 9.0  | 8.3  | 7.1  | 5.4  |
| $P_{T,180}$     | 4.9 | 4.8  | 4.7  | 4.6  | 4.3  |
| $(P_{T,2} - P_{T,part1})/P_{T,2}$ | -0.0221 | -0.0171 | -0.0153 | -0.0083 | -0.0059 |
| $(P_{T,2} - P_{T,part2})/P_{T,2}$ | 0.0065 | 0.0024 | 0.0076 | 0.0070 | 0.0096 |
| $(P_{T,2} - P_{T,jet})/P_{T,2}$ | -0.0355 | -0.0194 | -0.0116 | -0.0041 | 0.0019 |
| $P_{T}(O+\eta>5)/P_{T,2}$ | -0.0431 | -0.0268 | -0.0183 | -0.0095 | -0.0016 |
| $1 - \cos(\Delta \phi)$ | 0.0077 | 0.0074 | 0.0068 | 0.0055 | 0.0037 |
| $\sigma(Db(Z, J))$ | 0.1950 | 0.1653 | 0.1469 | 0.1237 | 0.0975 |
| Entries         | 7423 | 6679 | 5822 | 4015 | 936  |
Table 19: Selection 3. $\Delta \phi_{(Z,\text{jet})} = 180^{\circ} \pm 15^{\circ}$, $\epsilon_{\text{jet}} < 9\%$. UA1 algorithm.

| $P_{t_{\text{clust}}}$ | 30 | 20 | 15 | 10 | 5 |
|------------------------|----|----|----|----|---|
| Nevent                 | 22010 | 19805 | 17153 | 11818 | 2795 |
| $P_t^{56}$             | 13.5 | 11.8 | 10.4 | 8.9 | 7.0 |
| $\Delta \phi$         | 5.9 | 5.7 | 5.4 | 4.8 | 3.9 |
| $P_{t_{\text{out}}}$  | 10.1 | 9.2 | 8.4 | 7.2 | 5.5 |
| $P_t^{\eta>5}$        | 4.9 | 4.8 | 4.8 | 4.6 | 4.2 |
| ($P_t^{Z} - P_t^{part}$) / $P_t^{Z}$ | -0.0125 | -0.0089 | -0.0086 | -0.0040 | -0.0044 |
| ($P_t^{J} - P_t^{part}$) / $P_t^{J}$ | 0.0107 | 0.0028 | -0.0018 | -0.0017 | -0.0055 |
| ($P_t^{Z} - P_t^{J}$) / $P_t^{Z}$ | -0.0302 | -0.0165 | -0.0108 | -0.0052 | -0.0009 |
| $P_t^{(O+\eta>5)} / P_t^{Z}$ | -0.0383 | -0.0243 | -0.0179 | -0.0111 | -0.0045 |
| $1 - \cos(\Delta \phi)$ | 0.0079 | 0.0075 | 0.0069 | 0.0056 | 0.0038 |
| $\sigma(Db[Z,J])$     | 0.1971 | 0.1683 | 0.1488 | 0.1246 | 0.0986 |
| Entries                | 9262 | 8334 | 7218 | 4973 | 1176 |

Table 20: Selection 3. $\Delta \phi_{(Z,\text{jet})} = 180^{\circ} \pm 15^{\circ}$, $\epsilon_{\text{jet}} < 9\%$. LUCELL algorithm.

| $P_{t_{\text{clust}}}$ | 30 | 20 | 15 | 10 | 5 |
|------------------------|----|----|----|----|---|
| Nevent                 | 22010 | 19805 | 17153 | 11818 | 2795 |
| $P_t^{56}$             | 13.5 | 11.8 | 10.4 | 8.9 | 7.0 |
| $\Delta \phi$         | 5.9 | 5.7 | 5.4 | 4.8 | 3.9 |
| $P_{t_{\text{out}}}$  | 10.1 | 9.2 | 8.4 | 7.2 | 5.5 |
| $P_t^{\eta>5}$        | 4.9 | 4.8 | 4.8 | 4.6 | 4.2 |
| ($P_t^{Z} - P_t^{part}$) / $P_t^{Z}$ | -0.0125 | -0.0089 | -0.0086 | -0.0040 | -0.0044 |
| ($P_t^{J} - P_t^{part}$) / $P_t^{J}$ | 0.0041 | -0.0040 | -0.0087 | -0.0078 | -0.0089 |
| ($P_t^{Z} - P_t^{J}$) / $P_t^{Z}$ | -0.0237 | -0.0099 | -0.0042 | 0.0005 | 0.0024 |
| $P_t^{(O+\eta>5)} / P_t^{Z}$ | -0.0318 | -0.0178 | -0.0114 | -0.0054 | -0.0012 |
| $1 - \cos(\Delta \phi)$ | 0.0080 | 0.0076 | 0.0070 | 0.0057 | 0.0038 |
| $\sigma(Db[Z,J])$     | 0.1971 | 0.1689 | 0.1495 | 0.1257 | 0.0993 |
| Entries                | 9262 | 8334 | 7218 | 4973 | 1176 |
Appendix 3

70 < P_t^Z < 85 GeV/c

Table 1: Selection 1. \( \Delta \phi(Z,jet) = 180^\circ \pm 180^\circ \). UA1 algorithm.

| \( P_{t \text{cut}} \) | 30   | 20   | 15   | 10   | 5    |
|-----------------|------|------|------|------|------|
| Nevent\(^*\)    | 17258| 12124| 8956 | 5313 | 1058 |
| \( P_t \)       | 21.0 | 16.0 | 13.3 | 10.7 | 8.0  |
| \( \Delta \phi \) | 9.0  | 6.4  | 5.1  | 3.9  | 2.8  |
| \( P_t^{\text{out}} \) | 17.3 | 12.8 | 10.3 | 8.0  | 5.7  |
| \( P_t^{\text{part}} \) | 5.4  | 5.3  | 5.2  | 5.1  | 4.7  |
| \( (P_t^Z - P_t^{\text{part}})/P_t^Z \) | 0.0508 | 0.0227 | 0.0137 | 0.0090 | 0.0049 |
| \( (P_t' - P_t^{\text{part}})/P_t' \) | -0.0273 | -0.0163 | -0.0100 | -0.0037 | -0.0068 |
| \( P_t(O+\eta>5)/P_t^Z \) | 0.0365 | 0.0158 | 0.0072 | 0.0015 | 0.0022 |
| \( 1 - \cos(\Delta \phi) \) | 0.0236 | 0.0113 | 0.0071 | 0.0040 | 0.0023 |
| \( \sigma(Db[Z,J])** \) | 0.1915 | 0.1478 | 0.1219 | 0.0968 | 0.0801 |
| Entries         | 26667| 18734| 13839| 8209 | 1635 |

Table 2: Selection 1. \( \Delta \phi(Z,jet) = 180^\circ \pm 180^\circ \). UA2 algorithm.

| \( P_{t \text{cut}} \) | 30   | 20   | 15   | 10   | 5    |
|-----------------|------|------|------|------|------|
| Nevent          | 17564| 12705| 9563 | 5664 | 1120 |
| \( P_t \)       | 20.9 | 16.2 | 13.6 | 11.0 | 8.5  |
| \( \Delta \phi \) | 8.8  | 6.3  | 5.1  | 3.9  | 2.9  |
| \( P_t^{\text{out}} \) | 16.9 | 12.7 | 10.5 | 8.1  | 5.8  |
| \( P_t^{\text{part}} \) | 5.4  | 5.3  | 5.2  | 5.0  | 4.7  |
| \( (P_t^Z - P_t^{\text{part}})/P_t^Z \) | 0.0489 | 0.0243 | 0.0161 | 0.0128 | 0.0103 |
| \( (P_t' - P_t^{\text{part}})/P_t' \) | -0.0309 | -0.0298 | -0.0226 | -0.0165 | -0.0182 |
| \( P_t(O+\eta>5)/P_t^Z \) | 0.0670 | 0.0421 | 0.0325 | 0.0252 | 0.0240 |
| \( 1 - \cos(\Delta \phi) \) | 0.0224 | 0.0112 | 0.0071 | 0.0041 | 0.0024 |
| \( \sigma(Db[Z,J])** \) | 0.1856 | 0.1450 | 0.1207 | 0.0962 | 0.0792 |
| Entries         | 27139| 19631| 14776| 8752 | 1730 |

Table 3: Selection 1. \( \Delta \phi(Z,jet) = 180^\circ \pm 180^\circ \). LUCELL algorithm.

| \( P_{t \text{cut}} \) | 30   | 20   | 15   | 10   | 5    |
|-----------------|------|------|------|------|------|
| Nevent          | 17643| 12828| 9459 | 5512 | 1041 |
| \( P_t \)       | 20.5 | 16.1 | 13.3 | 10.5 | 7.6  |
| \( \Delta \phi \) | 8.7  | 6.4  | 5.1  | 3.9  | 2.8  |
| \( P_t^{\text{out}} \) | 16.9 | 12.9 | 10.5 | 8.1  | 5.7  |
| \( P_t^{\text{part}} \) | 5.4  | 5.3  | 5.2  | 5.1  | 4.7  |
| \( (P_t^Z - P_t^{\text{part}})/P_t^Z \) | 0.0492 | 0.0249 | 0.0143 | 0.0079 | 0.0012 |
| \( (P_t' - P_t^{\text{part}})/P_t' \) | -0.0302 | -0.0227 | -0.0180 | -0.0108 | -0.0143 |
| \( P_t(O+\eta>5)/P_t^Z \) | 0.0673 | 0.0400 | 0.0267 | 0.0152 | 0.0121 |
| \( 1 - \cos(\Delta \phi) \) | 0.0223 | 0.0116 | 0.0072 | 0.0041 | 0.0024 |
| \( \sigma(Db[Z,J])** \) | 0.1865 | 0.1489 | 0.1232 | 0.0974 | 0.0803 |
| Entries         | 27262| 19821| 14615| 8517 | 1608 |

\(^*\)Number of events (Nevent) is given in this and in the following tables for integrated luminosity \( L_{int} = 10 \text{ fb}^{-1} \)
\(^**\) \( Db[Z,J] \equiv (P_t^Z - P_t^J)/P_t^Z \)
Table 4: Selection 1. $\Delta \phi(Z,\text{jet}) = 180^\circ \pm 15^\circ$. UA1 algorithm.

| $P_{t\text{clust}}^{\text{CUT}}$ | 30 | 20 | 15 | 10 | 5 |
|-------------------------------|----|----|----|----|---|
| Nevent                        | 14012 | 11112 | 8613 | 5263 | 1064 |
| $P_{t56}$                      | 17.5 | 14.6 | 12.7 | 10.5 | 7.9 |
| $\Delta \phi$                 | 5.6 | 5.1 | 4.5 | 3.8 | 2.7 |
| $P_{t\text{min}}$             | 13.7 | 11.5 | 9.8 | 7.9 | 5.7 |
| $P_{t\text{out}}$             | 5.2 | 5.1 | 5.1 | 5.0 | 4.6 |
| $(P_{tZ} - P_{t\text{part}})/P_{tZ}$ | 0.0320 | 0.0171 | 0.0113 | 0.0083 | 0.0042 |
| $(P_{tJ} - P_{t\text{part}})/P_{tJ}$ | -0.0243 | -0.0148 | -0.0094 | -0.0037 | -0.0068 |
| $(P_{tZ} - P_{tJ})/P_{tZ}$    | 0.0447 | 0.0252 | 0.0158 | 0.0085 | 0.0074 |
| $P_{t}(O+\eta>5)/P_{tZ}$      | 0.0330 | 0.0147 | 0.0066 | 0.0014 | 0.0018 |
| $1 - \cos(\Delta \phi)$      | 0.0072 | 0.0061 | 0.0050 | 0.0035 | 0.0020 |
| $\sigma(\Delta \phi)$        | 0.1783 | 0.1420 | 0.1191 | 0.0958 | 0.0787 |
| Entries                       | 21651 | 17170 | 13309 | 8132 | 1628 |

Table 5: Selection 1. $\Delta \phi(Z,\text{jet}) = 180^\circ \pm 15^\circ$. UA2 algorithm.

| $P_{t\text{clust}}^{\text{CUT}}$ | 30 | 20 | 15 | 10 | 5 |
|-------------------------------|----|----|----|----|---|
| Nevent                        | 14394 | 11646 | 9190 | 5603 | 1113 |
| $P_{t56}$                      | 17.5 | 14.9 | 13.0 | 10.8 | 8.4 |
| $\Delta \phi$                 | 5.5 | 5.0 | 4.5 | 3.7 | 2.8 |
| $P_{t\text{min}}$             | 13.5 | 11.5 | 9.9 | 8.0 | 5.8 |
| $P_{t\text{out}}$             | 5.2 | 5.1 | 5.1 | 4.9 | 4.5 |
| $(P_{tZ} - P_{t\text{part}})/P_{tZ}$ | 0.0316 | 0.0189 | 0.0139 | 0.0120 | 0.0094 |
| $(P_{tJ} - P_{t\text{part}})/P_{tJ}$ | -0.0287 | -0.0246 | -0.0219 | -0.0165 | -0.0180 |
| $(P_{tZ} - P_{tJ})/P_{tZ}$    | 0.0494 | 0.0361 | 0.0299 | 0.0244 | 0.0229 |
| $P_{t}(O+\eta>5)/P_{tZ}$      | 0.0379 | 0.0257 | 0.0207 | 0.0173 | 0.0167 |
| $1 - \cos(\Delta \phi)$      | 0.0071 | 0.0061 | 0.0050 | 0.0035 | 0.0020 |
| $\sigma(\Delta \phi)$        | 0.1739 | 0.1491 | 0.1182 | 0.0950 | 0.0772 |
| Entries                       | 22241 | 17995 | 14200 | 8434 | 1720 |

Table 6: Selection 1. $\Delta \phi(Z,\text{jet}) = 180^\circ \pm 15^\circ$. LUCELL algorithm.

| $P_{t\text{clust}}^{\text{CUT}}$ | 30 | 20 | 15 | 10 | 5 |
|-------------------------------|----|----|----|----|---|
| Nevent                        | 14523 | 11730 | 9090 | 5458 | 1035 |
| $P_{t56}$                      | 17.4 | 14.7 | 12.7 | 10.3 | 7.5 |
| $\Delta \phi$                 | 5.6 | 5.1 | 4.6 | 3.8 | 2.7 |
| $P_{t\text{min}}$             | 13.6 | 11.6 | 10.0 | 8.0 | 5.7 |
| $P_{t\text{out}}$             | 5.2 | 5.2 | 5.1 | 5.0 | 4.6 |
| $(P_{tZ} - P_{t\text{part}})/P_{tZ}$ | 0.0322 | 0.0185 | 0.0115 | 0.0072 | 0.0003 |
| $(P_{tJ} - P_{t\text{part}})/P_{tJ}$ | -0.0273 | -0.0214 | -0.0175 | -0.0108 | -0.0142 |
| $(P_{tZ} - P_{tJ})/P_{tZ}$    | 0.0491 | 0.0330 | 0.0237 | 0.0145 | 0.0112 |
| $P_{t}(O+\eta>5)/P_{tZ}$      | 0.0375 | 0.0224 | 0.0144 | 0.0074 | 0.0057 |
| $1 - \cos(\Delta \phi)$      | 0.0072 | 0.0062 | 0.0051 | 0.0036 | 0.0020 |
| $\sigma(\Delta \phi)$        | 0.1744 | 0.1426 | 0.1204 | 0.0965 | 0.0786 |
| Entries                       | 22441 | 18124 | 14046 | 8434 | 1600 |
Table 7: Selection 1. $\Delta \phi_{(Z,\text{jet})} = 180^\circ \pm 10^\circ$. UA1 algorithm.

| $P_{\text{cut}}$ | 30 | 20 | 15 | 10 | 5 |
|-----------------|----|----|----|----|----|
| Nevent          | 11553 | 9597 | 7794 | 5014 | 1039 |
| $P_{56}$        | 16.0 | 13.5 | 11.9 | 10.1 | 7.8 |
| $\Delta \phi$   | 4.1 | 3.9 | 3.7 | 3.3 | 2.6 |
| $P_{\text{out}}$ | 12.2 | 10.4 | 9.1 | 7.6 | 5.7 |
| $P_{\eta>5}$    | 5.2 | 5.1 | 5.0 | 4.9 | 4.6 |
| $(P_{Z} - P_{\text{part}})/P_{Z}$ | 0.0267 | 0.0141 | 0.0091 | 0.0076 | 0.0047 |
| $(P_{J} - P_{\text{part}})/P_{J}$ | -0.0222 | -0.0137 | -0.0089 | -0.0037 | -0.0066 |
| $(P_{Z} - P_{J})/P_{Z}$ | 0.0384 | 0.0214 | 0.0133 | 0.0079 | 0.0077 |
| $P_{(O+\eta>5)/P_{Z}}$ | 0.0303 | 0.0137 | 0.0061 | 0.0017 | 0.0024 |
| $1 - \cos(\Delta \phi)$ | 0.0037 | 0.0035 | 0.0032 | 0.0026 | 0.0017 |
| $\sigma(Db(Z,J))$ | 0.1721 | 0.1382 | 0.1163 | 0.0944 | 0.0778 |
| Entries         | 17852 | 14829 | 12043 | 7748 | 1606 |

Table 8: Selection 1. $\Delta \phi_{(Z,\text{jet})} = 180^\circ \pm 10^\circ$. UA2 algorithm.

| $P_{\text{cut}}$ | 30 | 20 | 15 | 10 | 5 |
|-----------------|----|----|----|----|----|
| Nevent          | 11917 | 10088 | 8332 | 5350 | 1099 |
| $P_{56}$        | 16.1 | 13.8 | 12.2 | 10.5 | 8.3 |
| $\Delta \phi$   | 4.1 | 3.9 | 3.7 | 3.4 | 2.6 |
| $P_{\text{out}}$ | 12.0 | 10.4 | 9.2 | 7.7 | 5.8 |
| $P_{\eta>5}$    | 5.1 | 5.1 | 5.0 | 4.9 | 4.5 |
| $(P_{Z} - P_{\text{part}})/P_{Z}$ | 0.0266 | 0.0162 | 0.0122 | 0.0111 | 0.0093 |
| $(P_{J} - P_{\text{part}})/P_{J}$ | -0.0275 | -0.0238 | -0.0209 | -0.0166 | -0.0181 |
| $(P_{Z} - P_{J})/P_{Z}$ | 0.0441 | 0.0328 | 0.0276 | 0.0237 | 0.0230 |
| $P_{(O+\eta>5)/P_{Z}}$ | 0.0362 | 0.0252 | 0.0203 | 0.0175 | 0.0170 |
| $1 - \cos(\Delta \phi)$ | 0.0037 | 0.0035 | 0.0032 | 0.0026 | 0.0018 |
| $\sigma(Db(Z,J))$ | 0.1655 | 0.1347 | 0.1152 | 0.0938 | 0.0763 |
| Entries         | 18413 | 15588 | 12874 | 8267 | 1698 |

Table 9: Selection 1. $\Delta \phi_{(Z,\text{jet})} = 180^\circ \pm 10^\circ$. LUCELL algorithm.

| $P_{\text{cut}}$ | 30 | 20 | 15 | 10 | 5 |
|-----------------|----|----|----|----|----|
| Nevent          | 11986 | 10121 | 8209 | 5192 | 1021 |
| $P_{56}$        | 15.9 | 13.6 | 11.9 | 9.9 | 7.4 |
| $\Delta \phi$   | 4.1 | 4.0 | 3.8 | 3.4 | 2.6 |
| $P_{\text{out}}$ | 12.2 | 10.5 | 9.2 | 7.7 | 5.7 |
| $P_{\eta>5}$    | 5.2 | 5.1 | 5.0 | 4.9 | 4.5 |
| $(P_{Z} - P_{\text{part}})/P_{Z}$ | 0.0270 | 0.0158 | 0.0093 | 0.0063 | 0.0006 |
| $(P_{J} - P_{\text{part}})/P_{J}$ | -0.0250 | -0.0198 | -0.0161 | -0.0104 | -0.0142 |
| $(P_{Z} - P_{J})/P_{Z}$ | 0.0427 | 0.0291 | 0.0206 | 0.0134 | 0.0114 |
| $P_{(O+\eta>5)/P_{Z}}$ | 0.0347 | 0.0214 | 0.0134 | 0.0073 | 0.0062 |
| $1 - \cos(\Delta \phi)$ | 0.0038 | 0.0035 | 0.0032 | 0.0027 | 0.0017 |
| $\sigma(Db(Z,J))$ | 0.1684 | 0.1391 | 0.1174 | 0.0948 | 0.0771 |
| Entries         | 18520 | 15639 | 12684 | 8023 | 1577 |
Table 10: Selection 1. $\Delta \phi(Z,jet) = 180^\circ \pm 5^\circ$. UA1 algorithm.

| $P_{t \text{clust}}$ | 30  | 20  | 15  | 10  | 5  |
|----------------------|-----|-----|-----|-----|----|
| Nevent               | 7410| 6408| 5471| 3787| 899|
| $\Delta \phi$        | 2.3 | 2.3 | 2.3 | 2.2 | 2.0|
| $P_{t \text{min}}$   | 10.5| 8.9 | 7.9 | 6.7 | 5.3|
| $P_{t \text{out}}$   | 5.0 | 5.0 | 4.9 | 4.8 | 4.3|
| $(P_t^Z - P_t^{\text{part}}) / P_t^Z$ | 0.0221 | 0.0115 | 0.0081 | 0.0061 | 0.0031|
| $(P_t^J - P_t^{\text{part}}) / P_t^J$ | -0.0171 | -0.0091 | -0.0064 | -0.0018 | -0.0053|
| $(P_t^Z - P_t^J) / P_t^Z$ | 0.0302 | 0.0152 | 0.0093 | 0.0047 | 0.0051|
| $P_t(O + \eta > 5) / P_t^Z$ | 0.0252 | 0.0103 | 0.0044 | 0.0006 | 0.0010|
| $1 - \cos(\Delta \phi)$ | 0.0011 | 0.0011 | 0.0011 | 0.0010 | 0.0009|
| $\sigma(Db(Z, J))$  | 0.1597 | 0.1294 | 0.1112 | 0.0905 | 0.0728|
| Entries              | 11449| 9901 | 8454| 5851| 1389|

Table 11: Selection 1. $\Delta \phi(Z,jet) = 180^\circ \pm 5^\circ$. UA2 algorithm.

| $P_{t \text{clust}}$ | 30  | 20  | 15  | 10  | 5  |
|----------------------|-----|-----|-----|-----|----|
| Nevent               | 7657| 6737| 5821| 4029| 942|
| $\Delta \phi$        | 2.3 | 2.3 | 2.3 | 2.2 | 2.0|
| $P_{t \text{min}}$   | 10.3| 8.9 | 8.0 | 6.9 | 5.4|
| $P_{t \text{out}}$   | 5.0 | 4.9 | 4.9 | 4.7 | 4.2|
| $(P_t^Z - P_t^{\text{part}}) / P_t^Z$ | 0.0221 | 0.0127 | 0.0109 | 0.0096 | 0.0087|
| $(P_t^J - P_t^{\text{part}}) / P_t^J$ | -0.0242 | -0.0205 | -0.0181 | -0.0153 | -0.0162|
| $(P_t^Z - P_t^J) / P_t^Z$ | 0.0372 | 0.0270 | 0.0240 | 0.0214 | 0.0209|
| $P_t(O + \eta > 5) / P_t^Z$ | 0.0320 | 0.0219 | 0.0188 | 0.0172 | 0.0163|
| $1 - \cos(\Delta \phi)$ | 0.0011 | 0.0011 | 0.0011 | 0.0010 | 0.0009|
| $\sigma(Db(Z, J))$  | 0.1388 | 0.1270 | 0.1105 | 0.0897 | 0.0733|
| Entries              | 11831| 10409| 8994| 6225| 1456|

Table 12: Selection 1. $\Delta \phi(Z,jet) = 180^\circ \pm 5^\circ$. LUCELL algorithm.

| $P_{t \text{clust}}$ | 30  | 20  | 15  | 10  | 5  |
|----------------------|-----|-----|-----|-----|----|
| Nevent               | 7648| 6700| 5713| 3892| 876|
| $\Delta \phi$        | 2.3 | 2.3 | 2.3 | 2.2 | 1.9|
| $P_{t \text{min}}$   | 10.4| 9.0 | 8.1 | 6.8 | 5.3|
| $P_{t \text{out}}$   | 5.0 | 5.0 | 4.9 | 4.7 | 4.3|
| $(P_t^Z - P_t^{\text{part}}) / P_t^Z$ | 0.0231 | 0.0134 | 0.0083 | 0.0045 | -0.0027|
| $(P_t^J - P_t^{\text{part}}) / P_t^J$ | -0.0196 | -0.0154 | -0.0129 | -0.0089 | -0.0142|
| $(P_t^Z - P_t^J) / P_t^Z$ | 0.0349 | 0.0232 | 0.0167 | 0.0101 | 0.0084|
| $P_t(O + \eta > 5) / P_t^Z$ | 0.0300 | 0.0184 | 0.0118 | 0.0060 | 0.0045|
| $1 - \cos(\Delta \phi)$ | 0.0011 | 0.0011 | 0.0011 | 0.0010 | 0.0008|
| $\sigma(Db(Z, J))$  | 0.1566 | 0.1310 | 0.1127 | 0.0911 | 0.0723|
| Entries              | 11818| 10353| 8827| 6014| 1354|
Table 13: Selection 2. $\Delta\phi(Z,\text{jet}) = 180^\circ \pm 15^\circ$, $\epsilon^{\text{jet}} < 5\%$. UA1 algorithm.

| $P_{t\text{CT}}^{\text{cut}}$ | 30  | 20  | 15  | 10  | 5    |
|-----------------------------|-----|-----|-----|-----|-----|
| Nevent                      | 7623| 6466| 5291| 3473| 818 |
| $P_{56}$                    | 15.8| 13.6| 11.9| 9.9 | 7.5 |
| $\Delta\phi$               | 5.3 | 4.9 | 4.4 | 3.7 | 2.7 |
| $P_{\text{tot}}^{\text{jet}}$ | 12.4| 10.7| 9.4 | 7.7 | 5.7 |
| $P_{30}^{\text{jet}}$       | 5.1 | 5.1 | 5.0 | 4.9 | 4.5 |
| $[P_{tZ}^{\text{jet}}-P_{\text{part}}^{\text{jet}}]/P_{tZ}^{\text{jet}}$ | -0.0125 | -0.0126 | -0.0107 | -0.0069 | -0.0052 |
| $[P_{tJ}^{\text{jet}}-P_{\text{part}}^{\text{jet}}]/P_{tJ}^{\text{jet}}$ | -0.0016 | -0.0031 | -0.0028 | -0.0021 | -0.0052 |
| $[P_{tZ}^{\text{jet}}-P_{\text{jet}}^{\text{jet}}]/P_{tZ}^{\text{jet}}$ | -0.0146 | -0.0125 | -0.0105 | -0.0070 | -0.0018 |
| $P_{t}(O+\eta > 5)/P_{tZ}^{\text{jet}}$ | -0.0246 | -0.0214 | -0.0181 | -0.0129 | -0.0058 |
| $1 - \cos(\Delta\phi)$     | 0.0067 | 0.0058 | 0.0047 | 0.0034 | 0.0020 |
| $\sigma(\Delta\phi(Z,J))$  | 0.1534 | 0.1263 | 0.1085 | 0.0891 | 0.0686 |
| Entries                     | 11778| 9991 | 8175| 5367| 1264 |

Table 14: Selection 2. $\Delta\phi(Z,\text{jet}) = 180^\circ \pm 15^\circ$, $\epsilon^{\text{jet}} < 4\%$. UA2 algorithm.

| $P_{t\text{CT}}^{\text{cut}}$ | 30  | 20  | 15  | 10  | 5    |
|-----------------------------|-----|-----|-----|-----|-----|
| Nevent                      | 4198| 3593| 2975| 1975| 485 |
| $P_{56}$                    | 15.5| 13.3| 11.7| 9.7 | 7.4 |
| $\Delta\phi$               | 5.2 | 4.8 | 4.3 | 3.6 | 2.7 |
| $P_{\text{tot}}^{\text{jet}}$ | 12.2| 10.6| 9.3 | 7.7 | 5.6 |
| $P_{30}^{\text{jet}}$       | 5.1 | 5.0 | 5.0 | 4.9 | 4.4 |
| $[P_{tZ}^{\text{jet}}-P_{\text{part}}^{\text{jet}}]/P_{tZ}^{\text{jet}}$ | -0.0294 | -0.0261 | -0.0215 | -0.0146 | -0.0095 |
| $[P_{tJ}^{\text{jet}}-P_{\text{part}}^{\text{jet}}]/P_{tJ}^{\text{jet}}$ | -0.0205 | -0.0220 | -0.0213 | -0.0192 | -0.0214 |
| $[P_{tZ}^{\text{jet}}-P_{\text{jet}}^{\text{jet}}]/P_{tZ}^{\text{jet}}$ | -0.0127 | -0.0075 | -0.0030 | 0.0025 | 0.0097 |
| $P_{t}(O+\eta > 5)/P_{tZ}^{\text{jet}}$ | -0.0227 | -0.0163 | -0.0108 | -0.0031 | 0.0059 |
| $1 - \cos(\Delta\phi)$     | 0.0065 | 0.0056 | 0.0046 | 0.0032 | 0.0019 |
| $\sigma(\Delta\phi(Z,J))$  | 0.1509 | 0.1260 | 0.1089 | 0.0896 | 0.0695 |
| Entries                     | 6487 | 5552 | 4597 | 3052 | 749 |

Table 15: Selection 2. $\Delta\phi(Z,\text{jet}) = 180^\circ \pm 15^\circ$, $\epsilon^{\text{jet}} < 5\%$. LUCELL algorithm.

| $P_{t\text{CT}}^{\text{cut}}$ | 30  | 20  | 15  | 10  | 5    |
|-----------------------------|-----|-----|-----|-----|-----|
| Nevent                      | 7835| 6688| 5471| 3569| 814 |
| $P_{56}$                    | 15.6| 13.5| 11.8| 9.8 | 7.3 |
| $\Delta\phi$               | 5.3 | 4.9 | 4.4 | 3.7 | 2.7 |
| $P_{\text{tot}}^{\text{jet}}$ | 12.3| 10.8| 9.4 | 7.7 | 5.6 |
| $P_{30}^{\text{jet}}$       | 5.1 | 5.1 | 5.0 | 4.9 | 4.5 |
| $[P_{tZ}^{\text{jet}}-P_{\text{part}}^{\text{jet}}]/P_{tZ}^{\text{jet}}$ | -0.0130 | -0.0131 | -0.0115 | -0.0084 | -0.0066 |
| $[P_{tJ}^{\text{jet}}-P_{\text{part}}^{\text{jet}}]/P_{tJ}^{\text{jet}}$ | -0.0080 | -0.0087 | -0.0085 | -0.0076 | -0.0106 |
| $[P_{tZ}^{\text{jet}}-P_{\text{jet}}^{\text{jet}}]/P_{tZ}^{\text{jet}}$ | -0.0088 | -0.0075 | -0.0056 | -0.0030 | 0.0022 |
| $P_{t}(O+\eta > 5)/P_{tZ}^{\text{jet}}$ | -0.0189 | -0.0165 | -0.0133 | -0.0090 | -0.0019 |
| $1 - \cos(\Delta\phi)$     | 0.0067 | 0.0058 | 0.0048 | 0.0035 | 0.0020 |
| $\sigma(\Delta\phi(Z,J))$  | 0.1523 | 0.1269 | 0.1092 | 0.0894 | 0.0692 |
| Entries                     | 12107| 10334| 8454| 5515| 1258 |
Table 16: Selection 3. $\Delta \phi(Z, jet) = 180^\circ \pm 15^\circ$, $\epsilon^{jet} < 5\%$. UA1 algorithm.

| $P_{Z,jet}^{\text{clust}}$ | 30   | 20   | 15   | 10   | 5    |
|---------------------------|------|------|------|------|------|
| Nevent                   | 4945 | 4250 | 3496 | 2275 | 539  |
| $P_{56}$                   | 15.4 | 13.4 | 11.8 | 9.7  | 7.3  |
| $\Delta \phi$             | 5.1  | 4.8  | 4.3  | 3.6  | 2.7  |
| $P_{\text{clus}}$         | 12.2 | 10.7 | 9.4  | 7.7  | 5.6  |
| $P_{\text{clus}}>5$       | 5.0  | 5.0  | 5.0  | 4.9  | 4.4  |
| $(P_{Z}-P_{\text{clus}})/P_{Z}$ | -0.0233 | -0.0209 | -0.0182 | -0.0126 | -0.0081 |
| $(P_{J}-P_{\text{clus}})/P_{J}$ | -0.0019 | -0.0041 | -0.0032 | -0.0031 | -0.0065 |
| $(P_{Z}-P_{\text{clus}})/P_{Z}$ | -0.0247 | -0.0197 | -0.0174 | -0.0116 | -0.0033 |
| $P_{1}(O+\eta>5)/P_{Z}$   | -0.0344 | -0.0285 | -0.0250 | -0.0175 | -0.0073 |
| $1 - \cos(\Delta \phi)$ | 0.0064 | 0.0056 | 0.0046 | 0.0033 | 0.0020 |
| $\sigma(DB(Z, J))$        | 0.1487 | 0.1287 | 0.1078 | 0.0889 | 0.0684 |
| Entries                   | 7641 | 6567 | 5402 | 3515 | 833  |

Table 17: Selection 3. $\Delta \phi(Z, jet) = 180^\circ \pm 15^\circ$, $\epsilon^{jet} < 5\%$. UA2 algorithm.

| $P_{Z,jet}^{\text{clust}}$ | 30   | 20   | 15   | 10   | 5    |
|---------------------------|------|------|------|------|------|
| Nevent                   | 4945 | 4250 | 3496 | 2275 | 539  |
| $P_{56}$                   | 15.4 | 13.4 | 11.8 | 9.7  | 7.3  |
| $\Delta \phi$             | 5.2  | 4.8  | 4.3  | 3.6  | 2.7  |
| $P_{\text{clus}}$         | 12.1 | 10.6 | 9.3  | 7.7  | 5.7  |
| $P_{\text{clus}}>5$       | 5.0  | 5.0  | 5.0  | 4.9  | 4.4  |
| $(P_{Z}-P_{\text{clus}})/P_{Z}$ | -0.0233 | -0.0209 | -0.0182 | -0.0126 | -0.0081 |
| $(P_{J}-P_{\text{clus}})/P_{J}$ | -0.0201 | -0.0220 | -0.0207 | -0.0204 | -0.0228 |
| $(P_{Z}-P_{\text{clus}})/P_{Z}$ | -0.0070 | -0.0022 | -0.0002 | 0.0053 | 0.0126 |
| $P_{1}(O+\eta>5)/P_{Z}$   | -0.0167 | -0.0111 | -0.0079 | -0.0007 | 0.0085 |
| $1 - \cos(\Delta \phi)$ | 0.0064 | 0.0056 | 0.0046 | 0.0033 | 0.0020 |
| $\sigma(DB(Z, J))$        | 0.1492 | 0.1289 | 0.1081 | 0.0897 | 0.0688 |
| Entries                   | 7641 | 6567 | 5402 | 3515 | 833  |

Table 18: Selection 3. $\Delta \phi(Z, jet) = 180^\circ \pm 15^\circ$, $\epsilon^{jet} < 5\%$. LUCELL algorithm.

| $P_{Z,jet}^{\text{clust}}$ | 30   | 20   | 15   | 10   | 5    |
|---------------------------|------|------|------|------|------|
| Nevent                   | 4945 | 4250 | 3496 | 2275 | 539  |
| $P_{56}$                   | 15.4 | 13.4 | 11.8 | 9.7  | 7.3  |
| $\Delta \phi$             | 5.2  | 4.8  | 4.3  | 3.6  | 2.7  |
| $P_{\text{clus}}$         | 12.2 | 10.7 | 9.4  | 7.7  | 5.6  |
| $P_{\text{clus}}>5$       | 5.0  | 5.0  | 5.0  | 4.9  | 4.4  |
| $(P_{Z}-P_{\text{clus}})/P_{Z}$ | -0.0233 | -0.0209 | -0.0182 | -0.0126 | -0.0081 |
| $(P_{J}-P_{\text{clus}})/P_{J}$ | -0.0063 | -0.0080 | -0.0072 | -0.0065 | -0.0089 |
| $(P_{Z}-P_{\text{clus}})/P_{Z}$ | -0.0205 | -0.0159 | -0.0135 | -0.0082 | -0.0009 |
| $P_{1}(O+\eta>5)/P_{Z}$   | -0.0302 | -0.0247 | -0.0212 | -0.0142 | -0.0050 |
| $1 - \cos(\Delta \phi)$ | 0.0064 | 0.0056 | 0.0046 | 0.0033 | 0.0020 |
| $\sigma(DB(Z, J))$        | 0.1494 | 0.1263 | 0.1085 | 0.0894 | 0.0682 |
| Entries                   | 7641 | 6567 | 5402 | 3515 | 833  |
### Appendix 4

100 < $P_t^Z$ < 120 GeV/c

| $P_{tJ}^{cut}$ | 30  | 20 | 15 | 10 | 5  |
|---------------|-----|----|----|----|----|
| Nevent*       | 9840| 6949| 5114| 2944| 586 |
| $P_5^6$       | 21.9| 17.0| 14.4| 11.7| 8.6 |
| $\Delta \phi$ | 6.0 | 4.4 | 3.6 | 2.8 | 2.1 |
| $P_{t\eta}$   | 17.4| 13.0| 10.6| 8.0 | 5.6 |
| $P_{t\eta}^{>\eta}$ | 5.8 | 5.6 | 5.5 | 5.4 | 5.1 |
| ($P_t^Z - P_{t\eta}^{>\eta}$) / $P_t^Z$ | 0.0322 | 0.0183 | 0.0129 | 0.0104 | 0.0052 |
| ($P_{tJ}' - P_{t\eta}^{>\eta}'$) / $P_{tJ}'$ | -0.0166 | -0.0082 | -0.0035 | 0.0007 | -0.0014 |
| ($P_t^Z - P_{tJ}'$) / $P_t^Z$ | 0.0400 | 0.0208 | 0.0121 | 0.0061 | 0.0040 |
| $P_{tJ}(O+H>5)/P_{tJ}'$ | 0.0244 | 0.0107 | 0.0040 | -0.0002 | -0.0001 |
| $1 - \cos(\Delta \phi)$ | 0.0102 | 0.0052 | 0.0034 | 0.0020 | 0.0013 |
| $\sigma(D\bar{b}[Z,J])^{**}$ | 0.1442 | 0.1093 | 0.0920 | 0.0751 | 0.0602 |
| Entries       | 28431 | 20078 | 14777 | 8505 | 1694 |

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**Table 1:** Selection 1. $\Delta \phi(Z,J_{\text{jet}}) = 180^\circ \pm 180^\circ$. UA1 algorithm.

| $P_{tJ}^{cut}$ | 30  | 20 | 15 | 10 | 5  |
|---------------|-----|----|----|----|----|
| Nevent*       | 10518| 7623 | 5697 | 3306 | 640 |
| $P_5^6$       | 22.2 | 17.6 | 15.1 | 12.5 | 9.5 |
| $\Delta \phi$ | 5.9 | 4.3 | 3.6 | 2.8 | 2.1 |
| $P_{t\eta}$   | 17.0 | 12.9 | 10.6 | 8.2 | 5.8 |
| $P_{t\eta}^{>\eta}$ | 5.8 | 5.6 | 5.5 | 5.4 | 5.0 |
| ($P_t^Z - P_{t\eta}^{>\eta}$) / $P_t^Z$ | 0.0341 | 0.0225 | 0.0184 | 0.0162 | 0.0121 |
| ($P_{tJ}' - P_{t\eta}^{>\eta}'$) / $P_{tJ}'$ | -0.0164 | -0.0110 | -0.0081 | -0.0049 | -0.0043 |
| ($P_t^Z - P_{tJ}'$) / $P_t^Z$ | 0.0422 | 0.0275 | 0.0214 | 0.0169 | 0.0141 |
| $P_{tJ}(O+H>5)/P_{tJ}'$ | 0.0269 | 0.0174 | 0.0135 | 0.0107 | 0.0100 |
| $1 - \cos(\Delta \phi)$ | 0.0098 | 0.0051 | 0.0034 | 0.0020 | 0.0013 |
| $\sigma(D\bar{b}[Z,J])^{**}$ | 0.1394 | 0.1076 | 0.0913 | 0.0759 | 0.0596 |
| Entries       | 30391 | 22026 | 16462 | 9553 | 1848 |

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**Table 2:** Selection 1. $\Delta \phi(Z,J_{\text{jet}}) = 180^\circ \pm 180^\circ$. UA2 algorithm.

| $P_{tJ}^{cut}$ | 30  | 20 | 15 | 10 | 5  |
|---------------|-----|----|----|----|----|
| Nevent*       | 9967 | 7202 | 5295 | 2996 | 568 |
| $P_5^6$       | 21.4 | 17.0 | 14.3 | 11.4 | 8.1 |
| $\Delta \phi$ | 5.8 | 4.4 | 3.6 | 2.8 | 2.1 |
| $P_{t\eta}$   | 17.0 | 13.1 | 10.7 | 8.1 | 5.6 |
| $P_{t\eta}^{>\eta}$ | 5.8 | 5.7 | 5.5 | 5.4 | 5.1 |
| ($P_t^Z - P_{t\eta}^{>\eta}$) / $P_t^Z$ | 0.0311 | 0.0185 | 0.0120 | 0.0083 | 0.0008 |
| ($P_{tJ}' - P_{t\eta}^{>\eta}'$) / $P_{tJ}'$ | -0.0195 | -0.0132 | -0.0099 | -0.0059 | -0.0072 |
| ($P_t^Z - P_{tJ}'$) / $P_t^Z$ | 0.0424 | 0.0259 | 0.0172 | 0.0101 | 0.0053 |
| $P_{tJ}(O+H>5)/P_{tJ}'$ | 0.0275 | 0.0156 | 0.0090 | 0.0038 | 0.0012 |
| $1 - \cos(\Delta \phi)$ | 0.0095 | 0.0053 | 0.0035 | 0.0021 | 0.0013 |
| $\sigma(D\bar{b}[Z,J])^{**}$ | 0.1399 | 0.1101 | 0.0933 | 0.0767 | 0.0609 |
| Entries       | 28798 | 20809 | 15300 | 8658 | 1640 |

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**Table 3:** Selection 1. $\Delta \phi(Z,J_{\text{jet}}) = 180^\circ \pm 180^\circ$. LUCELL algorithm.

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*Number of events (Nevent) is given in this and in the following tables for integrated luminosity $L_{int} = 10 fb^{-1}$

** $D\bar{b}[Z,J] \equiv (P_t^Z - P_{tJ})/P_t^Z$
Table 4: Selection 1. $\Delta \phi_{(Z, \text{jet})} = 180^\circ \pm 15^\circ$. UA1 algorithm.

| $P_{t\text{clust}}^{\text{CUT}}$ | 30   | 20   | 15   | 10   | 5    |
|-------------------------------|------|------|------|------|------|
| Nevent                        | 9125 | 6803 | 5077 | 2939 | 585  |
| $P_{t56}$                      | 20.3 | 16.6 | 14.2 | 11.6 | 8.5  |
| $\Delta \phi$                 | 4.9  | 4.1  | 3.5  | 2.7  | 2.0  |
| $P_{t\text{out}}$             | 15.7 | 12.5 | 10.5 | 8.0  | 5.6  |
| $P_{t\eta>5}$                 |      |      |      |      |      |
| $(P_t^Z - P_{t\text{part}})/P_t^Z$ | 0.0266 | 0.0170 | 0.0132 | 0.0103 | 0.0048 |
| $(P_t^J - P_{t\text{part}})/P_t^J$ | -0.0150 | -0.0080 | -0.0036 | 0.0007 | -0.0014 |
| $(P_t^Z - P_t^J)/P_t^Z$       | 0.0336 | 0.0195 | 0.0115 | 0.0060 | 0.0036 |
| $P_t(O+\eta>5)/P_t^Z$         | 0.0225 | 0.0104 | 0.0038 | -0.0002 | -0.0003 |
| $1 - \cos(\Delta \phi)$      | 0.0058 | 0.0042 | 0.0031 | 0.0019 | 0.0011 |
| $\sigma(Db_{Z,J})$            | 0.1382 | 0.1080 | 0.0916 | 0.0750 | 0.0596 |
| Entries                       | 26365 | 19658 | 14669 | 8491 | 1690 |

Table 5: Selection 1. $\Delta \phi_{(Z, \text{jet})} = 180^\circ \pm 15^\circ$. UA2 algorithm.

| $P_{t\text{clust}}^{\text{CUT}}$ | 30   | 20   | 15   | 10   | 5    |
|-------------------------------|------|------|------|------|------|
| Nevent                        | 9798 | 7478 | 5661 | 3302 | 639  |
| $P_{t56}$                      | 20.6 | 17.3 | 14.9 | 12.5 | 9.5  |
| $\Delta \phi$                 | 4.8  | 4.1  | 3.5  | 2.7  | 2.0  |
| $P_{t\text{out}}$             | 15.4 | 12.5 | 10.5 | 8.2  | 5.8  |
| $P_{t\eta>5}$                 |      |      |      |      |      |
| $(P_t^Z - P_{t\text{part}})/P_t^Z$ | 0.0286 | 0.0215 | 0.0177 | 0.0162 | 0.0119 |
| $(P_t^J - P_{t\text{part}})/P_t^J$ | -0.0152 | -0.0106 | -0.0080 | -0.0049 | -0.0042 |
| $(P_t^Z - P_t^J)/P_t^Z$       | 0.0362 | 0.0262 | 0.0209 | 0.0168 | 0.0139 |
| $P_t(O+\eta>5)/P_t^Z$         | 0.0251 | 0.0171 | 0.0133 | 0.0107 | 0.0100 |
| $1 - \cos(\Delta \phi)$      | 0.0057 | 0.0042 | 0.0031 | 0.0020 | 0.0011 |
| $\sigma(Db_{Z,J})$            | 0.1337 | 0.1064 | 0.0907 | 0.0750 | 0.0593 |
| Entries                       | 28311 | 21607 | 16358 | 9541 | 1845 |

Table 6: Selection 1. $\Delta \phi_{(Z, \text{jet})} = 180^\circ \pm 15^\circ$. LUCELL algorithm.

| $P_{t\text{clust}}^{\text{CUT}}$ | 30   | 20   | 15   | 10   | 5    |
|-------------------------------|------|------|------|------|------|
| Nevent                        | 9317 | 7047 | 5255 | 2991 | 566  |
| $P_{t56}$                      | 20.0 | 16.6 | 14.1 | 11.4 | 8.0  |
| $\Delta \phi$                 | 4.8  | 4.1  | 3.5  | 2.7  | 2.0  |
| $P_{t\text{out}}$             | 15.5 | 12.7 | 10.6 | 8.1  | 5.6  |
| $P_{t\eta>5}$                 |      |      |      |      |      |
| $(P_t^Z - P_{t\text{part}})/P_t^Z$ | 0.0265 | 0.0172 | 0.0115 | 0.0082 | 0.0005 |
| $(P_t^J - P_{t\text{part}})/P_t^J$ | -0.0181 | -0.0128 | -0.0097 | -0.0058 | -0.0072 |
| $(P_t^Z - P_t^J)/P_t^Z$       | 0.0370 | 0.0244 | 0.0166 | 0.0100 | 0.0500 |
| $P_t(O+\eta>5)/P_t^Z$         | 0.0260 | 0.0152 | 0.0087 | 0.0038 | 0.0010 |
| $1 - \cos(\Delta \phi)$      | 0.0057 | 0.0043 | 0.0032 | 0.0020 | 0.0011 |
| $\sigma(Db_{Z,J})$            | 0.1349 | 0.1087 | 0.0927 | 0.0766 | 0.0604 |
| Entries                       | 26920 | 20362 | 15184 | 8643 | 1636 |
Table 7: Selection 1. $\Delta \phi(Z, \text{jet}) = 180^\circ \pm 10^\circ$. UA1 algorithm.

| $P_{T_{\text{clust}}}$ | 30 | 20 | 15 | 10 | 5 |
|-------------------------|----|----|----|----|---|
| Nevent                  | 7979 | 6323 | 4882 | 2897 | 581 |
| $P_{T_{56}}$            | 18.7 | 15.7 | 13.7 | 11.4 | 8.4 |
| $\Delta \phi$          | 3.8 | 3.5 | 3.1 | 2.6 | 2.0 |
| $P_{T_{\text{out}}}$   | 14.0 | 11.7 | 10.0 | 7.9 | 5.6 |
| $P_{T_{\eta>5}}$       | 5.6 | 5.5 | 5.4 | 5.3 | 4.9 |
| $(P_{T_{Z}} - P_{T_{\text{part}}}) / P_{T_{Z}}$ | 0.0233 | 0.0155 | 0.0114 | 0.0098 | 0.0049 |
| $(P_{T_{J}} - P_{T_{\text{part}}}) / P_{T_{J}}$ | -0.0126 | -0.0072 | -0.0032 | 0.0007 | -0.0014 |
| $(P_{T_{Z}} - P_{T_{J}}) / P_{T_{Z}}$ | 0.0288 | 0.0175 | 0.0103 | 0.0055 | 0.0037 |
| $P_{T}(O+\eta>5) / P_{T_{Z}}$ | 0.0204 | 0.0099 | 0.0034 | -0.0004 | -0.0001 |
| $1 - \cos(\Delta \phi)$ | 0.0033 | 0.0029 | 0.0024 | 0.0017 | 0.0010 |
| $\sigma(Db[Z, J])$     | 0.1332 | 0.1061 | 0.0901 | 0.0742 | 0.0591 |
| Entries                | 23056 | 18271 | 14105 | 8371 | 1679 |

Table 8: Selection 1. $\Delta \phi(Z, \text{jet}) = 180^\circ \pm 10^\circ$. UA2 algorithm.

| $P_{T_{\text{clust}}}$ | 30 | 20 | 15 | 10 | 5 |
|-------------------------|----|----|----|----|---|
| Nevent                  | 8590 | 6952 | 5449 | 3256 | 634 |
| $P_{T_{56}}$            | 19.1 | 16.4 | 14.5 | 12.3 | 9.3 |
| $\Delta \phi$          | 3.8 | 3.5 | 3.1 | 2.6 | 2.0 |
| $P_{T_{\text{out}}}$   | 13.8 | 11.7 | 10.1 | 8.1 | 5.8 |
| $P_{T_{\eta>5}}$       | 5.6 | 5.5 | 5.4 | 5.3 | 4.8 |
| $(P_{T_{Z}} - P_{T_{\text{part}}}) / P_{T_{Z}}$ | 0.0250 | 0.0199 | 0.0165 | 0.0157 | 0.0116 |
| $(P_{T_{J}} - P_{T_{\text{part}}}) / P_{T_{J}}$ | -0.0140 | -0.0101 | -0.0080 | -0.0050 | -0.0042 |
| $(P_{T_{Z}} - P_{T_{J}}) / P_{T_{Z}}$ | 0.0319 | 0.0243 | 0.0198 | 0.0164 | 0.0135 |
| $P_{T}(O+\eta>5) / P_{T_{Z}}$ | 0.0235 | 0.0168 | 0.0129 | 0.0106 | 0.0097 |
| $1 - \cos(\Delta \phi)$ | 0.0033 | 0.0028 | 0.0024 | 0.0017 | 0.0010 |
| $\sigma(Db[Z, J])$     | 0.1290 | 0.1044 | 0.0894 | 0.0742 | 0.0574 |
| Entries                | 24819 | 20086 | 15744 | 9407 | 1832 |

Table 9: Selection 1. $\Delta \phi(Z, \text{jet}) = 180^\circ \pm 10^\circ$. LUCCELL algorithm.

| $P_{T_{\text{clust}}}$ | 30 | 20 | 15 | 10 | 5 |
|-------------------------|----|----|----|----|---|
| Nevent                  | 8188 | 6546 | 5051 | 2951 | 563 |
| $P_{T_{56}}$            | 18.5 | 15.7 | 13.6 | 11.2 | 7.9 |
| $\Delta \phi$          | 3.8 | 3.5 | 3.2 | 2.6 | 2.0 |
| $P_{T_{\text{out}}}$   | 14.0 | 11.8 | 10.1 | 8.0 | 5.6 |
| $P_{T_{\eta>5}}$       | 5.6 | 5.5 | 5.4 | 5.3 | 4.9 |
| $(P_{T_{Z}} - P_{T_{\text{part}}}) / P_{T_{Z}}$ | 0.0229 | 0.0155 | 0.0103 | 0.0079 | 0.0007 |
| $(P_{T_{J}} - P_{T_{\text{part}}}) / P_{T_{J}}$ | -0.0163 | -0.0123 | -0.0096 | -0.0058 | -0.0072 |
| $(P_{T_{Z}} - P_{T_{J}}) / P_{T_{Z}}$ | 0.0324 | 0.0224 | 0.0152 | 0.0096 | 0.0052 |
| $P_{T}(O+\eta>5) / P_{T_{Z}}$ | 0.0240 | 0.0148 | 0.0082 | 0.0037 | 0.0012 |
| $1 - \cos(\Delta \phi)$ | 0.0033 | 0.0029 | 0.0024 | 0.0017 | 0.0010 |
| $\sigma(Db[Z, J])$     | 0.1308 | 0.1069 | 0.0915 | 0.0760 | 0.0601 |
| Entries                | 23659 | 18915 | 14593 | 8528 | 1628 |
| $P_{T\text{clust}}^{\text{CUT}}$ | 30  | 20  | 15  | 10  | 5   |
|--------------------------|-----|-----|-----|-----|-----|
| Nevent                  | 5491 | 4657 | 3850 | 2514 | 546 |
| $P_{t56}$               | 16.4 | 14.0 | 12.4 | 10.6 | 8.0 |
| $\Delta \phi$           | 2.2  | 2.2  | 2.1  | 2.0  | 1.7 |
| $P_{t\text{tot}}$       | 11.7 | 9.9  | 8.7  | 7.3  | 5.4 |
| $P_{t\eta>5}$           | 5.5  | 5.3  | 5.2  | 5.1  | 4.7 |
| $(P_{tZ} - P_{t\text{part}})/P_{tZ}$ | 0.0203 | 0.0141 | 0.0108 | 0.0090 | 0.0055 |
| $(P_{tJ} - P_{t\text{part}})/P_{tJ}$ | -0.0090 | -0.0049 | -0.0017 | -0.0007 | -0.0005 |
| $(P_{tZ} - P_{tJ})/P_{tZ}$ | 0.0229 | 0.0141 | 0.0086 | 0.0047 | 0.0038 |
| $P_{t}(O+\eta>5)/P_{tZ}$ | 0.0172 | 0.0087 | 0.0035 | -0.0001 | -0.0005 |
| $1 - \cos(\Delta \phi)$ | 0.0011 | 0.0010 | 0.0010 | 0.0009 | 0.0007 |
| $\sigma(DB[Z,J])$       | 0.1248 | 0.1018 | 0.0869 | 0.0724 | 0.0561 |
| Entries                 | 15866 | 13457 | 11125 | 7263 | 1579 |

| $P_{T\text{clust}}^{\text{CUT}}$ | 30  | 20  | 15  | 10  | 5   |
|--------------------------|-----|-----|-----|-----|-----|
| Nevent                  | 5935 | 5124 | 4285 | 2822 | 597 |
| $P_{t56}$               | 16.7 | 14.7 | 13.2 | 11.5 | 9.0 |
| $\Delta \phi$           | 2.2  | 2.2  | 2.1  | 2.0  | 1.7 |
| $P_{t\text{tot}}$       | 11.5 | 9.9  | 8.8  | 7.4  | 5.6 |
| $P_{t\eta>5}$           | 5.4  | 5.3  | 5.2  | 5.1  | 4.6 |
| $(P_{tZ} - P_{t\text{part}})/P_{tZ}$ | 0.0224 | 0.0185 | 0.0162 | 0.0150 | 0.0127 |
| $(P_{tJ} - P_{t\text{part}})/P_{tJ}$ | -0.0108 | -0.0080 | -0.0060 | -0.0044 | -0.0029 |
| $(P_{tZ} - P_{tJ})/P_{tZ}$ | 0.0271 | 0.0215 | 0.0180 | 0.0155 | 0.0137 |
| $P_{t}(O+\eta>5)/P_{tZ}$ | 0.0213 | 0.0162 | 0.0131 | 0.0110 | 0.0104 |
| $1 - \cos(\Delta \phi)$ | 0.0011 | 0.0010 | 0.0010 | 0.0009 | 0.0007 |
| $\sigma(DB[Z,J])$       | 0.1205 | 0.0999 | 0.0856 | 0.0723 | 0.0545 |
| Entries                 | 17150 | 14806 | 12380 | 8153 | 1726 |

| $P_{T\text{clust}}^{\text{CUT}}$ | 30  | 20  | 15  | 10  | 5   |
|--------------------------|-----|-----|-----|-----|-----|
| Nevent                  | 5621 | 4788 | 3958 | 2556 | 531 |
| $P_{t56}$               | 16.2 | 13.9 | 12.2 | 10.3 | 7.5 |
| $\Delta \phi$           | 2.2  | 2.2  | 2.1  | 2.0  | 1.7 |
| $P_{t\text{tot}}$       | 11.6 | 10.0 | 8.8  | 7.3  | 5.4 |
| $P_{t\eta>5}$           | 5.5  | 5.4  | 5.2  | 5.1  | 4.7 |
| $(P_{tZ} - P_{t\text{part}})/P_{tZ}$ | 0.0195 | 0.0137 | 0.0094 | 0.0067 | 0.0013 |
| $(P_{tJ} - P_{t\text{part}})/P_{tJ}$ | -0.0136 | -0.0101 | -0.0082 | -0.0059 | -0.0061 |
| $(P_{tZ} - P_{tJ})/P_{tZ}$ | 0.0268 | 0.0187 | 0.0132 | 0.0086 | 0.0051 |
| $P_{t}(O+\eta>5)/P_{tZ}$ | 0.0211 | 0.0134 | 0.0081 | 0.0037 | 0.0018 |
| $1 - \cos(\Delta \phi)$ | 0.0011 | 0.0010 | 0.0010 | 0.0009 | 0.0007 |
| $\sigma(DB[Z,J])$       | 0.1228 | 0.1023 | 0.0880 | 0.0738 | 0.0565 |
| Entries                 | 16241 | 13834 | 11437 | 7385 | 1534 |
Table 13: Selection 2. $\Delta \phi_{(Z, jet)} = 180^\circ \pm 15^\circ$, $\epsilon^{jet} < 4\%$. UA1 algorithm.

| $P_{T \text{Clu}}$ | 30 | 20 | 15 | 10 | 5 |
|------------------|----|----|----|----|----|
| Nevent           | 5599 | 4453 | 3499 | 2187 | 493 |
| $P_{T56}$        | 18.3 | 15.2 | 13.1 | 10.8 | 8.0 |
| $\Delta \phi$    | 4.6 | 3.9 | 3.3 | 2.7 | 2.0 |
| $P_{T \text{jet}}$ | 14.2 | 11.7 | 9.9 | 7.8 | 5.5 |
| $P_{T \text{jet}}^{\eta>5}$ | 5.5 | 5.4 | 5.3 | 5.2 | 5.0 |
| $(P_{TZ}^{\phi} - P_{T \text{jet}}^{\phi})/P_{TZ}$ | -0.0041 | -0.0034 | -0.0037 | -0.0009 | -0.0021 |
| $(P_{TJ}^{\phi} - P_{T \text{jet}}^{\phi})/P_{TJ}$ | -0.0037 | -0.0026 | -0.0017 | 0.0001 | -0.0044 |
| $(P_{TZ} - P_{T \text{jet}}^{\phi})/P_{TZ}$ | -0.0038 | -0.0035 | -0.0045 | -0.0029 | 0.0000 |
| $P_{T}(O+\eta>5)/P_{TZ}$ | -0.0130 | -0.0109 | -0.0105 | -0.0076 | -0.0037 |
| $1 - \cos(\Delta \phi)$ | 0.0053 | 0.0039 | 0.0029 | 0.0019 | 0.0011 |
| $\sigma(Db(Z,J))$ | 0.1206 | 0.0963 | 0.0822 | 0.0668 | 0.0575 |
| Entries          | 16173 | 12867 | 10110 | 6319 | 1424 |

Table 14: Selection 2. $\Delta \phi_{(Z, jet)} = 180^\circ \pm 15^\circ$, $\epsilon^{jet} < 4\%$. UA2 algorithm.

| $P_{T \text{Clu}}$ | 30 | 20 | 15 | 10 | 5 |
|------------------|----|----|----|----|----|
| Nevent           | 5859 | 4677 | 3664 | 2290 | 502 |
| $P_{T56}$        | 18.3 | 15.3 | 13.2 | 11.0 | 8.3 |
| $\Delta \phi$    | 4.6 | 3.9 | 3.3 | 2.7 | 2.0 |
| $P_{T \text{jet}}$ | 14.2 | 11.7 | 10.0 | 7.9 | 5.6 |
| $P_{T \text{jet}}^{\eta>5}$ | 5.5 | 5.4 | 5.3 | 5.2 | 4.9 |
| $(P_{TZ}^{\phi} - P_{T \text{jet}}^{\phi})/P_{TZ}$ | -0.0053 | -0.0035 | -0.0032 | 0.0000 | 0.0001 |
| $(P_{TJ}^{\phi} - P_{T \text{jet}}^{\phi})/P_{TJ}$ | -0.0155 | -0.0143 | -0.0131 | -0.0110 | -0.0126 |
| $(P_{TZ} - P_{T \text{jet}}^{\phi})/P_{TZ}$ | 0.0067 | 0.0079 | 0.0074 | 0.0090 | 0.0108 |
| $P_{T}(O+\eta>5)/P_{TZ}$ | -0.0024 | 0.0006 | 0.0016 | 0.0044 | 0.0073 |
| $1 - \cos(\Delta \phi)$ | 0.0053 | 0.0039 | 0.0029 | 0.0019 | 0.0012 |
| $\sigma(Db(Z,J))$ | 0.1181 | 0.0959 | 0.0817 | 0.0672 | 0.0567 |
| Entries          | 16928 | 13513 | 10586 | 6617 | 1450 |

Table 15: Selection 2. $\Delta \phi_{(Z, jet)} = 180^\circ \pm 15^\circ$, $\epsilon^{jet} < 4\%$. LUCELL algorithm.

| $P_{T \text{Clu}}$ | 30 | 20 | 15 | 10 | 5 |
|------------------|----|----|----|----|----|
| Nevent           | 5639 | 4525 | 3554 | 2205 | 493 |
| $P_{T56}$        | 17.9 | 15.0 | 12.9 | 10.5 | 7.8 |
| $\Delta \phi$    | 4.6 | 3.9 | 3.3 | 2.7 | 2.0 |
| $P_{T \text{jet}}$ | 14.1 | 11.7 | 10.0 | 7.8 | 5.5 |
| $P_{T \text{jet}}^{\eta>5}$ | 5.5 | 5.4 | 5.3 | 5.2 | 4.9 |
| $(P_{TZ}^{\phi} - P_{T \text{jet}}^{\phi})/P_{TZ}$ | -0.0046 | -0.0045 | -0.0051 | -0.0029 | -0.0040 |
| $(P_{TJ}^{\phi} - P_{T \text{jet}}^{\phi})/P_{TJ}$ | -0.0083 | -0.0072 | -0.0065 | -0.0043 | -0.0073 |
| $(P_{TZ} - P_{T \text{jet}}^{\phi})/P_{TZ}$ | 0.0004 | -0.0001 | -0.0011 | -0.0005 | 0.0010 |
| $P_{T}(O+\eta>5)/P_{TZ}$ | -0.0088 | -0.0075 | -0.0072 | -0.0053 | -0.0026 |
| $1 - \cos(\Delta \phi)$ | 0.0052 | 0.0039 | 0.0029 | 0.0019 | 0.0011 |
| $\sigma(Db(Z,J))$ | 0.1189 | 0.0966 | 0.0830 | 0.0672 | 0.0572 |
| Entries          | 16292 | 13074 | 10268 | 6371 | 1425 |
Table 16: Selection 3. $\Delta \phi(Z, jet) = 180^\circ \pm 15^\circ$, $\epsilon^{jet} < 4\%$. UA1 algorithm.

| $P_{z, CUT}$ | 30  | 20  | 15  | 10  | 5   |
|-------------|-----|-----|-----|-----|-----|
| Nevent      | 4686| 3785| 2962| 1846| 400 |
| $P_{z, 56}$ | 17.8| 15.0| 12.8| 10.5| 7.7 |
| $\Delta \phi$ | 4.5 | 3.9 | 3.3 | 2.7 | 2.0 |
| $P_{\text{rem}}$ | 13.9| 11.7| 9.9 | 7.8 | 5.5 |
| $P_{z, \text{min}}^\phi$ | 5.5 | 5.4 | 5.3 | 5.2 | 4.9 |
| $(P_{z} - P_{\text{part}})/P_{z}$ | -0.0074 | -0.0067 | -0.0066 | -0.0034 | -0.0058 |
| $(P_{T} - P_{\text{part}})/P_{T}$ | -0.0048 | -0.0042 | -0.0034 | -0.0023 | -0.0061 |
| $(P_{z} - P_{\text{part}})/P_{z}$ | -0.0058 | -0.0052 | -0.0055 | -0.0031 | -0.0015 |
| $P_{i}(O+\eta>5)/P_{z}$ | -0.0149 | -0.0125 | -0.0115 | -0.0079 | -0.0049 |
| $1 - \cos(\Delta \phi)$ | 0.0051 | 0.0038 | 0.0028 | 0.0019 | 0.0012 |
| $\sigma(Db(Z, J))$ | 0.1169 | 0.0960 | 0.0815 | 0.0669 | 0.0553 |
| Entries     | 13541| 10935| 8559| 5333| 1157|

Table 17: Selection 3. $\Delta \phi(Z, jet) = 180^\circ \pm 15^\circ$, $\epsilon^{jet} < 4\%$. UA2 algorithm.

| $P_{z, CUT}$ | 30  | 20  | 15  | 10  | 5   |
|-------------|-----|-----|-----|-----|-----|
| Nevent      | 4686| 3785| 2962| 1846| 400 |
| $P_{z, 56}$ | 17.8| 15.0| 12.8| 10.5| 7.7 |
| $\Delta \phi$ | 4.5 | 3.9 | 3.3 | 2.7 | 2.0 |
| $P_{\text{rem}}$ | 13.9| 11.7| 9.9 | 7.8 | 5.5 |
| $P_{z, \text{min}}^\phi$ | 5.5 | 5.4 | 5.3 | 5.2 | 4.9 |
| $(P_{z} - P_{\text{part}})/P_{z}$ | -0.0074 | -0.0067 | -0.0066 | -0.0034 | -0.0058 |
| $(P_{T} - P_{\text{part}})/P_{T}$ | -0.0048 | -0.0042 | -0.0034 | -0.0023 | -0.0061 |
| $(P_{z} - P_{\text{part}})/P_{z}$ | -0.0058 | -0.0052 | -0.0055 | -0.0031 | -0.0015 |
| $P_{i}(O+\eta>5)/P_{z}$ | -0.0149 | -0.0125 | -0.0115 | -0.0079 | -0.0049 |
| $1 - \cos(\Delta \phi)$ | 0.0051 | 0.0038 | 0.0028 | 0.0019 | 0.0012 |
| $\sigma(Db(Z, J))$ | 0.1171 | 0.0963 | 0.0820 | 0.0673 | 0.0555 |
| Entries     | 13541| 10935| 8559| 5333| 1157|

Table 18: Selection 3. $\Delta \phi(Z, jet) = 180^\circ \pm 15^\circ$, $\epsilon^{jet} < 4\%$. LUCELL algorithm.

| $P_{z, CUT}$ | 30  | 20  | 15  | 10  | 5   |
|-------------|-----|-----|-----|-----|-----|
| Nevent      | 4686| 3785| 2962| 1846| 400 |
| $P_{z, 56}$ | 17.8| 15.0| 12.8| 10.5| 7.7 |
| $\Delta \phi$ | 4.5 | 3.9 | 3.3 | 2.7 | 2.0 |
| $P_{\text{rem}}$ | 13.9| 11.7| 9.9 | 7.8 | 5.5 |
| $P_{z, \text{min}}^\phi$ | 5.5 | 5.4 | 5.3 | 5.2 | 4.9 |
| $(P_{z} - P_{\text{part}})/P_{z}$ | -0.0074 | -0.0067 | -0.0066 | -0.0034 | -0.0058 |
| $(P_{T} - P_{\text{part}})/P_{T}$ | -0.0048 | -0.0042 | -0.0034 | -0.0023 | -0.0061 |
| $(P_{z} - P_{\text{part}})/P_{z}$ | -0.0058 | -0.0052 | -0.0055 | -0.0031 | -0.0015 |
| $P_{i}(O+\eta>5)/P_{z}$ | -0.0149 | -0.0125 | -0.0115 | -0.0079 | -0.0049 |
| $1 - \cos(\Delta \phi)$ | 0.0051 | 0.0038 | 0.0028 | 0.0019 | 0.0012 |
| $\sigma(Db(Z, J))$ | 0.1174 | 0.0964 | 0.0819 | 0.0672 | 0.0556 |
| Entries     | 13541| 10935| 8559| 5333| 1157|
Appendix 5

150 < $P_T^Z$ < 200 GeV/c

Table 1: Selection 1. $\Delta \phi (Z, jet) = 180^\circ \pm 180^\circ$. UA1 algorithm.

| $P_T^{cut}$ | 30  | 20  | 15  | 10  | 5   |
|-------------|-----|-----|-----|-----|-----|
| Nevent*     | 4103| 2886| 2104| 1198| 227 |
| $P_t$       | 23.4| 18.6| 15.8| 13.0| 10.0|
| $\Delta \phi$ | 3.9 | 2.9 | 2.4 | 1.9 | 1.4 |
| $P_T^{out}$ | 17.6| 13.2| 10.8| 8.4 | 6.0 |
| $P_T^{out}$ | 6.4 | 6.3 | 6.2 | 6.0 | 5.5 |
| $\frac{(P_T^Z - P_T^{jet})}{P_T^Z}$ | 0.0186 | 0.0133 | 0.0112 | 0.0104 | 0.0067 |
| $\frac{(P_T^Z - P_T^{jet})}{P_T^Z}$ | -0.0081 | -0.0036 | -0.0009 | 0.0012 | 0.0018 |
| $\sigma (D\phi | 0.0214 | 0.0126 | 0.0085 | 0.0061 | 0.0028 |
| $P_t(O+p>5)/P_T^Z$ | 0.0123 | 0.0058 | 0.0027 | 0.0014 | -0.0011 |
| $1 - \cos(\Delta \phi)$ | 0.0042 | 0.0024 | 0.0015 | 0.0009 | 0.0006 |
| Entries     | 27490| 19335| 14096| 8024 | 1518 |

Table 2: Selection 1. $\Delta \phi (Z, jet) = 180^\circ \pm 180^\circ$. UA2 algorithm.

| $P_T^{cut}$ | 30  | 20  | 15  | 10  | 5   |
|-------------|-----|-----|-----|-----|-----|
| Nevent      | 4585| 3309| 2464| 1421| 259 |
| $P_t$       | 24.2| 19.7| 17.1| 14.3| 11.3|
| $\Delta \phi$ | 3.8 | 2.9 | 2.4 | 1.9 | 1.4 |
| $P_T^{out}$ | 17.1| 13.1| 10.8| 8.5 | 6.0 |
| $P_T^{out}$ | 6.4 | 6.2 | 6.2 | 6.0 | 5.4 |
| $\frac{(P_T^Z - P_T^{jet})}{P_T^Z}$ | 0.0234 | 0.0186 | 0.0173 | 0.0156 | 0.0110 |
| $\frac{(P_T^Z - P_T^{jet})}{P_T^Z}$ | -0.0048 | -0.0023 | -0.0004 | 0.0004 | 0.0013 |
| $\sigma (D\phi | 0.0231 | 0.0168 | 0.0142 | 0.0121 | 0.0082 |
| $P_t(O+p>5)/P_T^Z$ | 0.0142 | 0.0101 | 0.0085 | 0.0074 | 0.0048 |
| $1 - \cos(\Delta \phi)$ | 0.0040 | 0.0023 | 0.0015 | 0.0009 | 0.0006 |
| Entries     | 30179| 22169| 16509| 9522 | 1732 |

Table 3: Selection 1. $\Delta \phi (Z, jet) = 180^\circ \pm 180^\circ$. LUCCELL algorithm.

| $P_T^{cut}$ | 30  | 20  | 15  | 10  | 5   |
|-------------|-----|-----|-----|-----|-----|
| Nevent      | 4123| 2966| 2165| 1205| 214 |
| $P_t$       | 22.8| 18.4| 15.6| 12.5| 9.4 |
| $\Delta \phi$ | 3.8 | 2.9 | 2.4 | 1.9 | 1.4 |
| $P_T^{out}$ | 17.3| 13.4| 11.0| 8.5 | 6.0 |
| $P_T^{out}$ | 6.4 | 6.3 | 6.2 | 6.0 | 5.6 |
| $\frac{(P_T^Z - P_T^{jet})}{P_T^Z}$ | 0.0180 | 0.0125 | 0.0103 | 0.0081 | 0.0039 |
| $\frac{(P_T^Z - P_T^{jet})}{P_T^Z}$ | -0.0115 | -0.0078 | -0.0055 | -0.0036 | -0.0029 |
| $\sigma (D\phi | 0.0205 | 0.0161 | 0.0121 | 0.0087 | 0.0042 |
| $P_t(O+p>5)/P_T^Z$ | 0.0153 | 0.0093 | 0.0064 | 0.0040 | 0.0001 |
| $1 - \cos(\Delta \phi)$ | 0.0040 | 0.0024 | 0.0015 | 0.0009 | 0.0006 |
| Entries     | 27621| 19870| 14502| 8071 | 1431 |

* Number of events (Nevent) is given in this and in the following tables for integrated luminosity $L_{int} = 10 fb^{-1}$

** $D\phi[Z, J] \equiv (P_T^Z - P_T^J)/P_T^Z$
Table 4: Selection 1. $\Delta \phi_{(Z,\text{jet})} = 180^\circ \pm 15^\circ$. UA1 algorithm.

| $P_{T_{\text{clust}}}^{\text{CUT}}$ | 30 | 20 | 15 | 10 | 5 |
|----------------------------------|----|----|----|----|---|
| Nevent                           | 4052 | 2880 | 2103 | 1197 | 226 |
| $P_{T,56}$                       | 22.9 | 18.5 | 15.8 | 13.0 | 10.0 |
| $\Delta \phi$                   | 3.7 | 2.9 | 2.4 | 1.9 | 1.4 |
| $P_{T_{\text{min}}}$            | 17.1 | 13.2 | 10.8 | 8.4 | 6.0 |
| $P_{T_{\text{out}}}$            | 6.3 | 6.3 | 6.2 | 6.0 | 5.4 |
| $(P_{T_{Z}} - P_{T_{\text{part}}})/P_{T_{Z}}$ | 0.0178 | 0.0131 | 0.0111 | 0.0104 | 0.0067 |
| $(P_{T_{J}} - P_{T_{\text{part}}})/P_{T_{J}}$ | -0.0078 | -0.0036 | -0.0009 | 0.0012 | 0.0018 |
| $(P_{T_{Z}} - P_{T_{J}})/P_{T_{Z}}$ | 0.0204 | 0.0124 | 0.0085 | 0.0061 | 0.0028 |
| $P_{T}(O+\eta>5)/P_{T_{Z}}$     | 0.0120 | 0.0057 | 0.0027 | 0.0014 | -0.0010 |
| $1 - \cos(\Delta \phi)$         | 0.0036 | 0.0022 | 0.0015 | 0.0009 | 0.0005 |
| $\sigma(\Delta \phi)$           | 0.0976 | 0.0787 | 0.0683 | 0.0586 | 0.0465 |
| Entries                          | 27148 | 19298 | 14089 | 8022 | 1517 |

Table 5: Selection 1. $\Delta \phi_{(Z,\text{jet})} = 180^\circ \pm 10^\circ$. UA2 algorithm.

| $P_{T_{\text{clust}}}^{\text{CUT}}$ | 30 | 20 | 15 | 10 | 5 |
|----------------------------------|----|----|----|----|---|
| Nevent                           | 4534 | 3303 | 2463 | 1421 | 258 |
| $P_{T,56}$                       | 23.8 | 19.6 | 17.1 | 14.3 | 11.2 |
| $\Delta \phi$                   | 3.6 | 2.9 | 2.4 | 1.9 | 1.4 |
| $P_{T_{\text{min}}}$            | 16.7 | 13.1 | 10.8 | 8.5 | 6.0 |
| $P_{T_{\text{out}}}$            | 6.3 | 6.2 | 6.1 | 6.0 | 5.4 |
| $(P_{T_{Z}} - P_{T_{\text{part}}})/P_{T_{Z}}$ | 0.0227 | 0.0185 | 0.0173 | 0.0156 | 0.0110 |
| $(P_{T_{J}} - P_{T_{\text{part}}})/P_{T_{J}}$ | -0.0044 | -0.0023 | -0.0005 | 0.0004 | 0.0013 |
| $(P_{T_{Z}} - P_{T_{J}})/P_{T_{Z}}$ | 0.0222 | 0.0166 | 0.0142 | 0.0121 | 0.0083 |
| $P_{T}(O+\eta>5)/P_{T_{Z}}$     | 0.0140 | 0.0101 | 0.0085 | 0.0074 | 0.0048 |
| $1 - \cos(\Delta \phi)$         | 0.0035 | 0.0022 | 0.0015 | 0.0009 | 0.0005 |
| $\sigma(\Delta \phi)$           | 0.0906 | 0.0787 | 0.0663 | 0.0580 | 0.0439 |
| Entries                          | 30379 | 22130 | 16501 | 9520 | 1731 |

Table 6: Selection 1. $\Delta \phi_{(Z,\text{jet})} = 180^\circ \pm 15^\circ$. LUCCELL algorithm.

| $P_{T_{\text{clust}}}^{\text{CUT}}$ | 30 | 20 | 15 | 10 | 5 |
|----------------------------------|----|----|----|----|---|
| Nevent                           | 4080 | 2960 | 2163 | 1204 | 213 |
| $P_{T,56}$                       | 22.5 | 18.3 | 15.6 | 12.5 | 9.4 |
| $\Delta \phi$                   | 3.6 | 2.9 | 2.4 | 1.9 | 1.4 |
| $P_{T_{\text{min}}}$            | 16.9 | 13.3 | 11.0 | 8.5 | 6.0 |
| $P_{T_{\text{out}}}$            | 6.3 | 6.3 | 6.2 | 6.0 | 5.5 |
| $(P_{T_{Z}} - P_{T_{\text{part}}})/P_{T_{Z}}$ | 0.0175 | 0.0123 | 0.0102 | 0.0081 | 0.0039 |
| $(P_{T_{J}} - P_{T_{\text{part}}})/P_{T_{J}}$ | -0.0110 | -0.0078 | -0.0055 | -0.0036 | -0.0029 |
| $(P_{T_{Z}} - P_{T_{J}})/P_{T_{Z}}$ | 0.0233 | 0.0159 | 0.0121 | 0.0087 | 0.0043 |
| $P_{T}(O+\eta>5)/P_{T_{Z}}$     | 0.0152 | 0.0093 | 0.0064 | 0.0041 | 0.0002 |
| $1 - \cos(\Delta \phi)$         | 0.0035 | 0.0022 | 0.0015 | 0.0009 | 0.0005 |
| $\sigma(\Delta \phi)$           | 0.0963 | 0.0788 | 0.0689 | 0.0585 | 0.0478 |
| Entries                          | 27334 | 19833 | 14494 | 8069 | 1430 |
### Table 7: Selection 1. $\Delta \phi(Z, \text{jet}) = 180^\circ \pm 10^\circ$. UA1 algorithm.

| $P_{\text{clust}}^{\text{cut}}$ | 30  | 20  | 15  | 10  | 5  |
|-------------------------------|-----|-----|-----|-----|----|
| Nevent                        | 3842 | 2831 | 2091 | 1195 | 226 |
| $P_{56}$                      | 21.9| 18.2| 15.7 | 12.9 | 10.0 |
| $\Delta \phi$                | 3.2 | 2.7 | 2.3  | 1.9  | 1.4  |
| $P_{\text{tot}}^{\text{cut}}$| 16.0 | 12.8 | 10.7 | 8.4  | 6.0  |
| $P_{\text{out}}^{\text{cut}}$| 6.3 | 6.2 | 6.2  | 6.0  | 5.4  |
| $(P_{Z} - P_{\text{part}})/P_{Z}$ | 0.0165 | 0.0127 | 0.0110 | 0.0103 | 0.0068 |
| $(P_{J} - P_{\text{part}})/P_{J}$ | -0.0074 | -0.0034 | -0.0008 | 0.0014 | 0.0019 |
| $(P_{Z} - P_{J})/P_{Z}$          | 0.0188 | 0.0119 | 0.0083 | 0.0060 | 0.0028 |
| $P_{(O+\eta>5)}/P_{Z}$            | 0.0114 | 0.0056 | 0.0026 | 0.0013 | -0.0010 |
| $1 - \cos(\Delta \phi)$         | 0.0026 | 0.0019 | 0.0014 | 0.0009 | 0.0005 |
| $\sigma(Db[Z, J])$             | 0.0959 | 0.0782 | 0.0680 | 0.0583 | 0.0465 |
| Entries                        | 25739 | 18965 | 14012 | 8009 | 1515 |

### Table 8: Selection 1. $\Delta \phi(Z, \text{jet}) = 180^\circ \pm 10^\circ$. UA2 algorithm.

| $P_{\text{clust}}^{\text{cut}}$ | 30  | 20  | 15  | 10  | 5  |
|-------------------------------|-----|-----|-----|-----|----|
| Nevent                        | 4308 | 3245 | 2449 | 1418 | 258 |
| $P_{56}$                      | 22.8| 19.3| 17.0 | 14.2 | 11.2 |
| $\Delta \phi$                | 3.2 | 2.7 | 2.3  | 1.9  | 1.4  |
| $P_{\text{tot}}^{\text{cut}}$| 15.7 | 12.7 | 10.7 | 8.5  | 6.1  |
| $P_{\text{out}}^{\text{cut}}$| 6.3 | 6.2 | 6.1  | 5.9  | 5.3  |
| $(P_{Z} - P_{\text{part}})/P_{Z}$ | 0.0214 | 0.0180 | 0.0171 | 0.0156 | 0.0111 |
| $(P_{J} - P_{\text{part}})/P_{J}$ | -0.0042 | -0.0021 | -0.0004 | 0.0005 | 0.0013 |
| $(P_{Z} - P_{J})/P_{Z}$          | 0.0207 | 0.0160 | 0.0139 | 0.0119 | 0.0083 |
| $P_{(O+\eta>5)}/P_{Z}$            | 0.0136 | 0.0099 | 0.0084 | 0.0073 | 0.0049 |
| $1 - \cos(\Delta \phi)$         | 0.0025 | 0.0019 | 0.0014 | 0.0009 | 0.0005 |
| $\sigma(Db[Z, J])$             | 0.0930 | 0.0763 | 0.0670 | 0.0577 | 0.0439 |
| Entries                        | 28861 | 21739 | 16409 | 9500 | 1727 |

### Table 9: Selection 1. $\Delta \phi(Z, \text{jet}) = 180^\circ \pm 10^\circ$. LUCELL algorithm.

| $P_{\text{clust}}^{\text{cut}}$ | 30  | 20  | 15  | 10  | 5  |
|-------------------------------|-----|-----|-----|-----|----|
| Nevent                        | 3884 | 2907 | 2152 | 1202 | 213 |
| $P_{56}$                      | 21.5| 17.9| 15.5 | 12.5 | 9.4  |
| $\Delta \phi$                | 3.2 | 2.8 | 2.4  | 1.9  | 1.4  |
| $P_{\text{tot}}^{\text{cut}}$| 15.9 | 12.9 | 10.9 | 8.5  | 6.0  |
| $P_{\text{out}}^{\text{cut}}$| 6.3 | 6.2 | 6.1  | 6.0  | 5.5  |
| $(P_{Z} - P_{\text{part}})/P_{Z}$ | 0.0161 | 0.0117 | 0.0100 | 0.0080 | 0.0039 |
| $(P_{J} - P_{\text{part}})/P_{J}$ | -0.0109 | -0.0077 | -0.0055 | -0.0036 | -0.0029 |
| $(P_{Z} - P_{J})/P_{Z}$          | 0.0220 | 0.0153 | 0.0119 | 0.0086 | 0.0043 |
| $P_{(O+\eta>5)}/P_{Z}$            | 0.0148 | 0.0091 | 0.0063 | 0.0040 | 0.0002 |
| $1 - \cos(\Delta \phi)$         | 0.0025 | 0.0019 | 0.0014 | 0.0009 | 0.0005 |
| $\sigma(Db[Z, J])$             | 0.0948 | 0.0783 | 0.0687 | 0.0584 | 0.0478 |
| Entries                        | 26020 | 19473 | 14415 | 8056 | 1428 |
### Table 10: Selection 1. $\Delta \phi(Z, jet) = 180^\circ \pm 5^\circ$. UA1 algorithm.

| $P_t^{clust\, CUT}$ | 30   | 20   | 15   | 10   | 5   |
|---------------------|------|------|------|------|-----|
| Nevent              | 2937 | 2388 | 1884 | 1143 | 223 |
| $P_t^{56}$          | 19.3 | 16.6 | 14.7 | 12.5 | 9.8 |
| $\Delta \phi$       | 2.1  | 2.0  | 1.9  | 1.7  | 1.3 |
| $P_t^{\text{min}}$  | 13.2 | 11.2 | 9.8  | 8.1  | 6.0 |
| $P_t^{q+\bar{q}}$   | 6.2  | 6.1  | 6.0  | 5.8  | 5.2 |
| $(P_t^Z - P_t^{part})/P_t^Z$ | 0.0148 | 0.0118 | 0.0102 | 0.0098 | 0.0064 |
| $(P_t^J - P_t^{part})/P_t^J$ | -0.0052 | -0.0021 | -0.0004 | 0.0012 | 0.0020 |
| $(P_t^Z - P_t^J)/P_t^Z$ | 0.0152 | 0.0101 | 0.0072 | 0.0056 | 0.0023 |
| $P_t(O + \eta>5)/P_t^Z$ | 0.0096 | 0.0049 | 0.0022 | 0.0012 | -0.0012 |
| $1 - \cos(\Delta \phi)$ | 0.0010 | 0.0009 | 0.0008 | 0.0007 | 0.0004 |
| $\sigma(Db[Z, J])$ | 0.0909 | 0.0754 | 0.0665 | 0.0577 | 0.0448 |
| Entries | 19676 | 15996 | 12622 | 7657 | 1495 |

### Table 11: Selection 1. $\Delta \phi(Z, jet) = 180^\circ \pm 5^\circ$. UA2 algorithm.

| $P_t^{clust\, CUT}$ | 30   | 20   | 15   | 10   | 5   |
|---------------------|------|------|------|------|-----|
| Nevent              | 3317 | 2740 | 2204 | 1357 | 254 |
| $P_t^{56}$          | 20.3 | 17.7 | 16.1 | 13.8 | 11.1 |
| $\Delta \phi$       | 2.1  | 2.0  | 1.9  | 1.7  | 1.3 |
| $P_t^{\text{min}}$  | 13.0 | 11.1 | 9.8  | 8.2  | 6.0 |
| $P_t^{q+\bar{q}}$   | 6.1  | 6.0  | 6.0  | 5.8  | 5.1 |
| $(P_t^Z - P_t^{part})/P_t^Z$ | 0.0196 | 0.0172 | 0.0165 | 0.0153 | 0.0113 |
| $(P_t^J - P_t^{part})/P_t^J$ | -0.0026 | -0.0008 | 0.0006 | 0.0009 | 0.0022 |
| $(P_t^Z - P_t^J)/P_t^Z$ | 0.0177 | 0.0141 | 0.0126 | 0.0115 | 0.0080 |
| $P_t(O + \eta>5)/P_t^Z$ | 0.0123 | 0.0092 | 0.0078 | 0.0072 | 0.0049 |
| $1 - \cos(\Delta \phi)$ | 0.0009 | 0.0009 | 0.0008 | 0.0007 | 0.0004 |
| $\sigma(Db[Z, J])$ | 0.0883 | 0.0735 | 0.0665 | 0.0577 | 0.0416 |
| Entries | 22222 | 18359 | 14764 | 9089 | 1705 |

### Table 12: Selection 1. $\Delta \phi(Z, jet) = 180^\circ \pm 5^\circ$. UA2 algorithm.

| $P_t^{clust\, CUT}$ | 30   | 20   | 15   | 10   | 5   |
|---------------------|------|------|------|------|-----|
| Nevent              | 2984 | 2443 | 1931 | 1149 | 210 |
| $P_t^{56}$          | 19.0 | 16.3 | 14.5 | 12.1 | 9.2 |
| $\Delta \phi$       | 2.1  | 2.0  | 1.9  | 1.7  | 1.3 |
| $P_t^{\text{min}}$  | 13.2 | 11.3 | 9.9  | 8.2  | 6.0 |
| $P_t^{q+\bar{q}}$   | 6.2  | 6.1  | 6.0  | 5.8  | 5.3 |
| $(P_t^Z - P_t^{part})/P_t^Z$ | 0.0141 | 0.0106 | 0.0093 | 0.0076 | 0.0040 |
| $(P_t^J - P_t^{part})/P_t^J$ | -0.0091 | -0.0065 | -0.0049 | -0.0036 | -0.0025 |
| $(P_t^Z - P_t^J)/P_t^Z$ | 0.0185 | 0.0133 | 0.0107 | 0.0082 | 0.0041 |
| $P_t(O + \eta>5)/P_t^Z$ | 0.0130 | 0.0083 | 0.0057 | 0.0039 | 0.0002 |
| $1 - \cos(\Delta \phi)$ | 0.0010 | 0.0009 | 0.0008 | 0.0007 | 0.0004 |
| $\sigma(Db[Z, J])$ | 0.0902 | 0.0754 | 0.0672 | 0.0576 | 0.0467 |
| Entries | 19995 | 16364 | 12936 | 7700 | 1409 |
### Table 13: Selection 2. $\Delta \phi(Z, \text{jet}) = 180^\circ \pm 15^\circ$, $\epsilon^{\text{jet}} < 3\%$. UA1 algorithm.

| $P_{T}^{\text{clus}}$ | 30   | 20   | 15   | 10   | 5    |
|-----------------------|------|------|------|------|------|
| Nevent                | 3193 | 2403 | 1835 | 1093 | 217  |
| $P_{T}^{56}$          | 21.4 | 17.5 | 15.0 | 12.3 | 9.6  |
| $\Delta \phi$         | 3.5  | 2.8  | 2.3  | 1.9  | 1.4  |
| $P_{T}^{\text{clus}}$ | 16.0 | 12.6 | 10.5 | 8.3  | 5.9  |
| $P_{T}^{n>\ell}$      | 6.1  | 6.1  | 6.0  | 5.9  | 5.3  |
| $(P_{T}^{Z} - P_{T}^{\text{partj}})/P_{T}^{Z}$ | 0.0049 | 0.0051 | 0.0052 | 0.0058 | 0.0044 |
| $(P_{T}^{J} - P_{T}^{\text{partj}})/P_{T}^{J}$ | -0.0015 | -0.0006 | 0.0000 | 0.0005 | 0.0028 |
| $(P_{T}^{Z} - P_{T}^{J})/P_{T}^{Z}$ | 0.0035 | 0.0029 | 0.0028 | 0.0032 | 0.0009 |
| $P_{T}(O+\eta>5)/P_{T}^{Z}$ | -0.0035 | -0.0028 | -0.0021 | -0.0009 | -0.0020 |
| $1 - \cos(\Delta \phi)$ | 0.0033 | 0.0021 | 0.0014 | 0.0009 | 0.0005 |
| $\sigma(Db(Z, J))$   | 0.0870 | 0.0714 | 0.0625 | 0.0539 | 0.0390 |
| Entries               | 21392 | 16101 | 12291 | 7321 | 1457 |

### Table 14: Selection 2. $\Delta \phi(Z, \text{jet}) = 180^\circ \pm 15^\circ$, $\epsilon^{\text{jet}} < 3\%$. UA2 algorithm.

| $P_{T}^{\text{clus}}$ | 30   | 20   | 15   | 10   | 5    |
|-----------------------|------|------|------|------|------|
| Nevent                | 3458 | 2605 | 2000 | 1198 | 229  |
| $P_{T}^{56}$          | 21.4 | 17.6 | 15.2 | 12.5 | 9.8  |
| $\Delta \phi$         | 3.5  | 2.8  | 2.3  | 1.9  | 1.4  |
| $P_{T}^{\text{clus}}$ | 15.9 | 12.6 | 10.5 | 8.4  | 6.0  |
| $P_{T}^{n>\ell}$      | 6.1  | 6.1  | 6.0  | 5.9  | 5.4  |
| $(P_{T}^{Z} - P_{T}^{\text{partj}})/P_{T}^{Z}$ | 0.0055 | 0.0053 | 0.0059 | 0.0064 | 0.0046 |
| $(P_{T}^{J} - P_{T}^{\text{partj}})/P_{T}^{J}$ | -0.0089 | -0.0082 | -0.0071 | -0.0066 | -0.0046 |
| $(P_{T}^{Z} - P_{T}^{J})/P_{T}^{Z}$ | 0.0111 | 0.0103 | 0.0102 | 0.0105 | 0.0080 |
| $P_{T}(O+\eta>5)/P_{T}^{Z}$ | 0.0040 | 0.0046 | 0.0052 | 0.0062 | 0.0046 |
| $1 - \cos(\Delta \phi)$ | 0.0033 | 0.0021 | 0.0014 | 0.0009 | 0.0006 |
| $\sigma(Db(Z, J))$   | 0.0869 | 0.0721 | 0.0633 | 0.0548 | 0.0428 |
| Entries               | 23169 | 17455 | 13397 | 8023 | 1537 |

### Table 15: Selection 2. $\Delta \phi(Z, \text{jet}) = 180^\circ \pm 15^\circ$, $\epsilon^{\text{jet}} < 3\%$. LUCCELL algorithm.

| $P_{T}^{\text{clus}}$ | 30   | 20   | 15   | 10   | 5    |
|-----------------------|------|------|------|------|------|
| Nevent                | 3184 | 2429 | 1851 | 1095 | 209  |
| $P_{T}^{56}$          | 20.9 | 17.3 | 14.8 | 12.1 | 9.3  |
| $\Delta \phi$         | 3.5  | 2.8  | 2.4  | 1.9  | 1.4  |
| $P_{T}^{\text{clus}}$ | 15.8 | 12.7 | 10.6 | 8.4  | 6.0  |
| $P_{T}^{n>\ell}$      | 6.1  | 6.1  | 6.0  | 5.9  | 5.4  |
| $(P_{T}^{Z} - P_{T}^{\text{partj}})/P_{T}^{Z}$ | 0.0040 | 0.0039 | 0.0041 | 0.0049 | 0.0033 |
| $(P_{T}^{J} - P_{T}^{\text{partj}})/P_{T}^{J}$ | -0.0056 | -0.0047 | -0.0037 | -0.0023 | -0.0004 |
| $(P_{T}^{Z} - P_{T}^{J})/P_{T}^{Z}$ | 0.0068 | 0.0059 | 0.0053 | 0.0052 | 0.0027 |
| $P_{T}(O+\eta>5)/P_{T}^{Z}$ | 0.0000 | 0.0002 | 0.0004 | 0.0012 | -0.0007 |
| $1 - \cos(\Delta \phi)$ | 0.0032 | 0.0021 | 0.0014 | 0.0009 | 0.0005 |
| $\sigma(Db(Z, J))$   | 0.0863 | 0.0720 | 0.0631 | 0.0536 | 0.0410 |
| Entries               | 21330 | 16275 | 12399 | 7339 | 1400 |
Table 16: Selection 3, $\Delta\phi_{(Z,\text{jet})} = 180^\circ \pm 15^\circ$, $\epsilon_{\text{jet}} < 3\%$. UA1 algorithm.

| $P_{\text{clus}}^{\text{clust}}$ | 30 | 20 | 15 | 10 | 5 |
|---------------------------------|----|----|----|----|---|
| Nevent                          | 2770 | 2119 | 1616 | 957 | 179 |
| $P_{56}$                        | 20.6 | 17.1 | 14.6 | 11.9 | 9.3 |
| $\Delta\phi$                    | 3.4 | 2.8 | 2.3 | 1.9 | 1.4 |
| $P_{1 \text{jet}}^{\text{clust}}$ | 15.6 | 12.5 | 10.5 | 8.3 | 6.0 |
| $P_{1 \text{jet}}^{\text{pass}}$ | 6.1 | 6.1 | 6.0 | 5.9 | 5.4 |
| $(P_{Z} - P_{\text{part}})/P_{Z}$ | 0.0024 | 0.0027 | 0.0031 | 0.0038 | 0.0029 |
| $(P_{J} - P_{\text{part}})/P_{J}$ | -0.0032 | -0.0028 | -0.0018 | -0.0011 | 0.0007 |
| $(P_{Z} - P_{\text{jet}})/P_{Z}$ | 0.0027 | 0.0026 | 0.0024 | 0.0028 | 0.0013 |
| $P_{1}(O+\eta>5)/P_{Z}$ | -0.0042 | -0.0031 | -0.0025 | -0.0012 | -0.0021 |
| $1 - \cos(\Delta\phi)$          | 0.0032 | 0.0021 | 0.0014 | 0.0009 | 0.0005 |
| $\sigma(DB(Z,J))$               | 0.0848 | 0.0712 | 0.0626 | 0.0536 | 0.0406 |
| Entries                         | 18559 | 14199 | 10824 | 6409 | 1200 |

Table 17: Selection 3, $\Delta\phi_{(Z,\text{jet})} = 180^\circ \pm 15^\circ$, $\epsilon_{\text{jet}} < 3\%$. UA2 algorithm.

| $P_{\text{clus}}^{\text{clust}}$ | 30 | 20 | 15 | 10 | 5 |
|---------------------------------|----|----|----|----|---|
| Nevent                          | 2770 | 2119 | 1616 | 957 | 179 |
| $P_{56}$                        | 20.6 | 17.1 | 14.6 | 11.9 | 9.3 |
| $\Delta\phi$                    | 3.4 | 2.8 | 2.3 | 1.9 | 1.4 |
| $P_{1 \text{jet}}^{\text{clust}}$ | 15.6 | 12.5 | 10.5 | 8.3 | 6.1 |
| $P_{1 \text{jet}}^{\text{pass}}$ | 6.1 | 6.1 | 6.0 | 5.9 | 5.4 |
| $(P_{Z} - P_{\text{part}})/P_{Z}$ | 0.0024 | 0.0027 | 0.0031 | 0.0038 | 0.0029 |
| $(P_{J} - P_{\text{part}})/P_{J}$ | -0.0110 | -0.0104 | -0.0094 | -0.0086 | -0.0059 |
| $(P_{Z} - P_{\text{jet}})/P_{Z}$ | 0.0101 | 0.0100 | 0.0098 | 0.0102 | 0.0078 |
| $P_{1}(O+\eta>5)/P_{Z}$ | 0.0033 | 0.0043 | 0.0048 | 0.0061 | 0.0044 |
| $1 - \cos(\Delta\phi)$          | 0.0032 | 0.0021 | 0.0014 | 0.0009 | 0.0005 |
| $\sigma(DB(Z,J))$               | 0.0851 | 0.0714 | 0.0628 | 0.0538 | 0.0408 |
| Entries                         | 18559 | 14199 | 10824 | 6409 | 1200 |

Table 18: Selection 3, $\Delta\phi_{(Z,\text{jet})} = 180^\circ \pm 15^\circ$, $\epsilon_{\text{jet}} < 3\%$. LUCELL algorithm.

| $P_{\text{clus}}^{\text{clust}}$ | 30 | 20 | 15 | 10 | 5 |
|---------------------------------|----|----|----|----|---|
| Nevent                          | 2770 | 2119 | 1616 | 957 | 179 |
| $P_{56}$                        | 20.6 | 17.1 | 14.6 | 11.9 | 9.3 |
| $\Delta\phi$                    | 3.5 | 2.8 | 2.3 | 1.9 | 1.4 |
| $P_{1 \text{jet}}^{\text{clust}}$ | 15.7 | 12.6 | 10.5 | 8.4 | 6.0 |
| $P_{1 \text{jet}}^{\text{pass}}$ | 6.1 | 6.1 | 6.0 | 5.9 | 5.4 |
| $(P_{Z} - P_{\text{part}})/P_{Z}$ | 0.0024 | 0.0027 | 0.0031 | 0.0038 | 0.0029 |
| $(P_{J} - P_{\text{part}})/P_{J}$ | -0.0061 | -0.0052 | -0.0040 | -0.0031 | -0.0006 |
| $(P_{Z} - P_{\text{jet}})/P_{Z}$ | 0.0055 | 0.0050 | 0.0047 | 0.0048 | 0.0027 |
| $P_{1}(O+\eta>5)/P_{Z}$ | -0.0014 | -0.0007 | -0.0003 | 0.0007 | -0.0007 |
| $1 - \cos(\Delta\phi)$          | 0.0032 | 0.0021 | 0.0014 | 0.0009 | 0.0005 |
| $\sigma(DB(Z,J))$               | 0.0853 | 0.0714 | 0.0628 | 0.0539 | 0.0408 |
| Entries                         | 18559 | 14199 | 10824 | 6409 | 1200 |
Appendix 6

\[ 40 \leq P_t^Z \leq 70 \text{ GeV/c} \]

Table 1: Number of events per \( L_{\text{int}} = 10 \text{ fb}^{-1} \).

| \( P_t^{\text{clust}} \) (GeV/c) | 5    | 10   | 15   | 20   | 30   | 1000 |
|----------------------------------|------|------|------|------|------|------|
| 5                               | 9700 | 17700| 19200| 19300| 19300| 19300|
| 10                              | 30700| 69600| 87300| 91700| 92400| 92400|
| 15                              | 37700| 92600| 127400| 141500| 146600| 146900|
| 20                              | 40000| 100900| 145400| 167700| 179200| 180300|
| 30                              | 41400| 106600| 157600| 187100| 208900| 213100|

Table 2: \( \langle F \rangle, F = (P_t^Z - P_t^{\text{jet}})/P_t^Z \).

| \( P_t^{\text{clust}} \) (GeV/c) | 5    | 10   | 15   | 20   | 30   | 1000 |
|----------------------------------|------|------|------|------|------|------|
| 5                               | 0.014| 0.015| 0.016| 0.016| 0.016| 0.016|
| 10                              | 0.013| 0.018| 0.023| 0.024| 0.024| 0.024|
| 15                              | 0.014| 0.021| 0.029| 0.033| 0.034| 0.034|
| 20                              | 0.014| 0.022| 0.033| 0.038| 0.041| 0.041|
| 30                              | 0.014| 0.023| 0.034| 0.042| 0.047| 0.049|

Table 3: \( \sigma(F), F = (P_t^Z - P_t^{\text{jet}})/P_t^Z \).

| \( P_t^{\text{clust}} \) (GeV/c) | 5    | 10   | 15   | 20   | 30   | 1000 |
|----------------------------------|------|------|------|------|------|------|
| 5                               | 0.079| 0.088| 0.093| 0.094| 0.095| 0.095|
| 10                              | 0.085| 0.103| 0.115| 0.121| 0.124| 0.124|
| 15                              | 0.086| 0.107| 0.126| 0.140| 0.150| 0.151|
| 20                              | 0.088| 0.109| 0.131| 0.151| 0.168| 0.173|
| 30                              | 0.088| 0.110| 0.134| 0.158| 0.187| 0.200|
$70 \leq P_t^Z \leq 100 \text{ GeV/c}$

Table 4: Number of events per $L_{\text{int}} = 10 \text{ fb}^{-1}$.

| $P_{t\text{max}}$ (GeV/c) | 5   | 10  | 15   | 20   | 30   | 1000 |
|--------------------------|-----|-----|------|------|------|------|
| 5                        | 2500| 4500| 4900 | 5000 | 5000 | 5000 |
| 10                       | 7600| 18100| 23000| 24800| 25200| 25200|
| 15                       | 9500| 24700| 35000| 40700| 43900| 44000|
| 20                       | 10100| 27000| 40300| 50000| 57900| 59200|
| 30                       | 10600| 28700| 44500| 57900| 73200| 79200|

Table 5: $\langle F \rangle$, $F = (P_t^Z - P_t^{jet})/P_t^Z$.

| $P_{t\text{max}}$ (GeV/c) | 5   | 10  | 15   | 20   | 30   | 1000 |
|--------------------------|-----|-----|------|------|------|------|
| 5                        | 0.011| 0.012| 0.012| 0.012| 0.013| 0.013|
| 10                       | 0.012| 0.013| 0.015| 0.018| 0.018| 0.018|
| 15                       | 0.013| 0.015| 0.019| 0.024| 0.028| 0.029|
| 20                       | 0.014| 0.016| 0.021| 0.028| 0.038| 0.043|
| 30                       | 0.014| 0.017| 0.023| 0.033| 0.050| 0.066|

Table 6: $\sigma(F)$, $F = (P_t^Z - P_t^{jet})/P_t^Z$.

| $P_{t\text{max}}$ (GeV/c) | 5   | 10  | 15   | 20   | 30   | 1000 |
|--------------------------|-----|-----|------|------|------|------|
| 5                        | 0.069| 0.070| 0.074| 0.075| 0.077| 0.077|
| 10                       | 0.071| 0.078| 0.088| 0.093| 0.095| 0.096|
| 15                       | 0.071| 0.082| 0.094| 0.105| 0.116| 0.118|
| 20                       | 0.072| 0.083| 0.097| 0.111| 0.131| 0.141|
| 30                       | 0.073| 0.084| 0.100| 0.118| 0.149| 0.178|
$100 \leq P_t^Z \leq 140 \text{ GeV/c}$

Table 7: Number of events per $L_{int} = 10\ f_{b^{-1}}$.

| $P_{t_{\text{max}}}^{\text{clust}}$ (GeV/c) | 5  | 10  | 15  | 20  | 30  | 1000 |
|------------------------------------------|----|-----|-----|-----|-----|------|
| 5                                       | 930| 1710| 1890| 1920| 1920| 1920 |
| 10                                      | 3000| 6860| 9010| 9660| 9910| 9930 |
| 15                                      | 3660| 9320| 13750| 16110| 17700| 17910 |
| 20                                      | 3880| 10320| 15950| 19880| 23600| 24330 |
| 30                                      | 4050| 10970| 17470| 22910| 30640| 34110 |

Table 8: $\langle F \rangle$, $F = (P_t^Z - P_t^{jet})/P_t^Z$.

| $P_{t_{\text{max}}}^{\text{clust}}$ (GeV/c) | 5  | 10  | 15  | 20  | 30  | 1000 |
|------------------------------------------|----|-----|-----|-----|-----|------|
| 5                                       | 0.007| 0.006| 0.009| 0.008| 0.008| 0.008 |
| 10                                      | 0.005| 0.012| 0.014| 0.014| 0.015| 0.015 |
| 15                                      | 0.005| 0.011| 0.015| 0.017| 0.018| 0.019 |
| 20                                      | 0.006| 0.012| 0.017| 0.019| 0.024| 0.026 |
| 30                                      | 0.005| 0.013| 0.017| 0.022| 0.033| 0.036 |

Table 9: $\sigma(F)$, $F = (P_t^Z - P_t^{jet})/P_t^Z$.

| $P_{t_{\text{max}}}^{\text{clust}}$ (GeV/c) | 5  | 10  | 15  | 20  | 30  | 1000 |
|------------------------------------------|----|-----|-----|-----|-----|------|
| 5                                       | 0.046| 0.045| 0.050| 0.051| 0.050| 0.050 |
| 10                                      | 0.054| 0.066| 0.075| 0.076| 0.080| 0.080 |
| 15                                      | 0.054| 0.068| 0.079| 0.084| 0.092| 0.095 |
| 20                                      | 0.056| 0.071| 0.082| 0.088| 0.102| 0.109 |
| 30                                      | 0.055| 0.073| 0.084| 0.092| 0.113| 0.138 |
$40 \leq P_t^Z \leq 70$ GeV/c

$\epsilon^{jet} = 8\%$

Table 10: Number of events per $L_{int} = 10$ fb$^{-1}$.

| $P_{t_{max}}^Z$ (GeV/c) | $P_{t_{max}}^{jet}$ (GeV/c) |
|-------------------------|-----------------------------|
|                         | 5  | 10 | 15 | 20 | 30 | 1000 |
| 5                       | 8200 | 14800 | 16000 | 16100 | 16100 | 16100 |
| 10                      | 23200 | 50800 | 62200 | 64800 | 65100 | 65100 |
| 15                      | 27400 | 64200 | 85300 | 93200 | 95700 | 95900 |
| 20                      | 28700 | 68700 | 94800 | 106900 | 112600 | 113200 |
| 30                      | 29300 | 71300 | 100700 | 116200 | 127200 | 129500 |

Table 11: $\langle F \rangle$, $F = (P_t^Z - P_t^{jet})/P_t^Z$.

| $P_{t_{max}}^Z$ (GeV/c) | $P_{t_{max}}^{jet}$ (GeV/c) |
|-------------------------|-----------------------------|
|                         | 5  | 10 | 15 | 20 | 30 | 1000 |
| 5                       | 0.007 | 0.006 | 0.005 | 0.005 | 0.005 | 0.005 |
| 10                      | 0.006 | 0.003 | 0.002 | 0.001 | 0.000 | 0.000 |
| 15                      | 0.007 | 0.005 | 0.003 | 0.001 | -0.002 | -0.002 |
| 20                      | 0.007 | 0.005 | 0.004 | 0.002 | -0.003 | -0.004 |
| 30                      | 0.007 | 0.006 | 0.006 | 0.004 | -0.003 | -0.010 |

Table 12: $\sigma(F)$, $F = (P_t^Z - P_t^{jet})/P_t^Z$.

| $P_{t_{max}}^Z$ (GeV/c) | $P_{t_{max}}^{jet}$ (GeV/c) |
|-------------------------|-----------------------------|
|                         | 5  | 10 | 15 | 20 | 30 | 1000 |
| 5                       | 0.077 | 0.086 | 0.091 | 0.091 | 0.092 | 0.092 |
| 10                      | 0.080 | 0.096 | 0.108 | 0.114 | 0.116 | 0.116 |
| 15                      | 0.082 | 0.101 | 0.119 | 0.132 | 0.141 | 0.142 |
| 20                      | 0.083 | 0.103 | 0.124 | 0.141 | 0.158 | 0.162 |
| 30                      | 0.084 | 0.104 | 0.127 | 0.148 | 0.178 | 0.192 |
\[70 \leq P_t^Z \leq 100 \text{ GeV/c} \]
\[\epsilon_{jet} = 5\%\]

Table 13: Number of events per \(L_{int} = 10 \text{ fb}^{-1}\).

| \(P_{t_{clus \max}}\) (GeV/c) | \(5\) | \(10\) | \(15\) | \(20\) | \(30\) | \(1000\) |
|-----------------------------|-----|-----|-----|-----|-----|------|
| \(P_{t_{clus \max}}\) (GeV/c) |     |     |     |     |     |      |
| 5                           | 2100 | 3700 | 4000 | 4100 | 4100 | 4100  |
| 10                          | 5800 | 13200 | 16400 | 17400 | 17700 | 17700  |
| 15                          | 7000 | 17000 | 23300 | 26600 | 28100 | 28200  |
| 20                          | 7300 | 18200 | 26100 | 31400 | 35200 | 35600  |
| 30                          | 7600 | 19100 | 28100 | 35300 | 42400 | 44300  |

Table 14: \(⟨F⟩\), \(F = (P_t^Z - P_t^{jet})/P_t^Z\).

| \(P_{t_{clus \max}}\) (GeV/c) | \(5\) | \(10\) | \(15\) | \(20\) | \(30\) | \(1000\) |
|-----------------------------|-----|-----|-----|-----|-----|------|
| \(P_{t_{clus \max}}\) (GeV/c) |     |     |     |     |     |      |
| 5                           | 0.010 | 0.009 | 0.008 | 0.008 | 0.007 | 0.007 |
| 10                          | 0.010 | 0.005 | 0.004 | 0.004 | 0.003 | 0.003 |
| 15                          | 0.009 | 0.006 | 0.005 | 0.005 | 0.003 | 0.003 |
| 20                          | 0.009 | 0.006 | 0.006 | 0.006 | 0.006 | 0.006 |
| 30                          | 0.009 | 0.007 | 0.007 | 0.009 | 0.011 | 0.009 |

Table 15: \(σ(F)\), \(F = (P_t^Z - P_t^{jet})/P_t^Z\).

| \(P_{t_{clus \max}}\) (GeV/c) | \(5\) | \(10\) | \(15\) | \(20\) | \(30\) | \(1000\) |
|-----------------------------|-----|-----|-----|-----|-----|------|
| \(P_{t_{clus \max}}\) (GeV/c) |     |     |     |     |     |      |
| 5                           | 0.074 | 0.070 | 0.073 | 0.073 | 0.074 | 0.074 |
| 10                          | 0.069 | 0.075 | 0.083 | 0.087 | 0.090 | 0.090 |
| 15                          | 0.069 | 0.077 | 0.088 | 0.097 | 0.106 | 0.107 |
| 20                          | 0.068 | 0.077 | 0.090 | 0.102 | 0.119 | 0.124 |
| 30                          | 0.069 | 0.077 | 0.092 | 0.108 | 0.136 | 0.155 |
\[ 100 \leq P_t^Z \leq 140 \text{ GeV/c} \]
\[ \epsilon^{\text{jet}} = 5\% \]

Table 16: Number of events per \( L_{\text{int}} = 10 \text{ fb}^{-1} \).

| \( P_t^{\text{clus max}} \) (GeV/c) | 5     | 10    | 15    | 20    | 30    | 1000 |
|-----------------------------------|-------|-------|-------|-------|-------|------|
| 5                                 | 910   | 1660  | 1810  | 1840  | 1850  | 1850 |
| 10                                | 2730  | 6150  | 7870  | 8390  | 8590  | 8610 |
| 15                                | 3220  | 8050  | 11460 | 13230 | 14380 | 14490|
| 20                                | 3370  | 8720  | 12900 | 15780 | 18300 | 18670|
| 30                                | 3490  | 9120  | 13910 | 17770 | 22860 | 24510|

Table 17: \( \langle F \rangle, F = (P_t^Z - P_t^{\text{jet}})/P_t^Z \).

| \( P_t^{\text{clus max}} \) (GeV/c) | 5   | 10  | 15  | 20  | 30  | 1000 |
|-----------------------------------|-----|-----|-----|-----|-----|------|
| 5                                 | 0.007 | 0.006 | 0.008 | 0.007 | 0.007 | 0.007 |
| 10                                | 0.003 | 0.009 | 0.009 | 0.008 | 0.008 | 0.008 |
| 15                                | 0.002 | 0.008 | 0.009 | 0.008 | 0.007 | 0.007 |
| 20                                | 0.003 | 0.008 | 0.009 | 0.009 | 0.008 | 0.008 |
| 30                                | 0.002 | 0.009 | 0.009 | 0.010 | 0.014 | 0.013 |

Table 18: \( \sigma(F), F = (P_t^Z - P_t^{\text{jet}})/P_t^Z \).

| \( P_t^{\text{clus max}} \) (GeV/c) | 5     | 10    | 15    | 20    | 30    | 1000 |
|-----------------------------------|-------|-------|-------|-------|-------|------|
| 5                                 | 0.046 | 0.045 | 0.049 | 0.049 | 0.049 | 0.049 |
| 10                                | 0.046 | 0.039 | 0.065 | 0.08 | 0.071 | 0.071 |
| 15                                | 0.046 | 0.063 | 0.071 | 0.076 | 0.084 | 0.086 |
| 20                                | 0.049 | 0.063 | 0.072 | 0.080 | 0.093 | 0.098 |
| 30                                | 0.048 | 0.064 | 0.075 | 0.084 | 0.105 | 0.120 |