Jet energy scale setting with "$\gamma + Jet$" events at LHC energies. Minijets and cluster suppression and $P_t^{\gamma} - P_t^{Jet}$ disbalance.

D.V. Bandourin$^1$, V.F. Konoplyanikov$^2$, N.B. Skachkov$^3$

E-mail: (1) dmv@cv.jinr.ru, (2) kon@cv.jinr.ru, (3) skachkov@cv.jinr.ru

$^\dagger$ Laboratory of Nuclear Problems  
$^\ast$ Laboratory of Particle Physics

Abstract

In this paper the study of "$\gamma + Jet$" events is continued and the event number determination useful for jet energy scale setting with the possible CMS detector hadron calorimeter calibration at LHC is fulfilled. The sources of $P_t^{\gamma}$ and $P_t^{Jet}$ are exposed. It is shown that the cluster $P_t$ limitation, which is found in an event outside of the jet, can be a good criterion for this disbalance decreasing.
1. INTRODUCTION

In this article we continue our study of the $pp \rightarrow \gamma + Jet + X$ process caused by two partonic subprocesses:

$$qg \rightarrow q + \gamma \quad (1a)$$

$$q\bar{q} \rightarrow g + \gamma \quad (1b)$$

The main goal of this paper is to estimate whether there will be a sufficient number of "$\gamma + Jet$" events for setting the mass scale of a jet with a good accuracy and for performing hadron calorimeter (HCAL) calibration at LHC energies. We use the PYTHIA generator as a model for this sort of estimation supposing that the results with other physical event generators like HERWIG, and with GEANT–based simulation packages will be discussed in our further publications.

Here we study in detail the sources of $P_t^{\gamma}$ and $P_t^{Jet}$ disbalance and the impact of the $P_{t\text{cut}}^{\text{clust}}$ parameter [1, 2], imposed as the cut on possible minijets or clusters $P_t$ for the calibration accuracy improvement

2. DETAILED "$\gamma + Jet$" SYSTEM $P_t$ DISBALANCE DEPENDENCE ON $P_{t\text{cut}}^{\text{clust}}$ PARAMETER.

In the previous papers ([1, 2]) we introduced physical observables (variables) for studying "$\gamma + Jet$" events [1] and discussed what cuts for them could lead to a decrease in the $P_t^{\gamma}$ and $P_t^{Jet}$ disbalance [2]. The calibration procedure depends on the gained statistics. One can make these cuts to be tighter if more events would be collected during data taking.

In the tables of Appendices 1–4 for four different $P_t^{\gamma}$ intervals the mean values of the most important variables that reflect the main features of "$\gamma + Jet$" events and the other values that characterize $P_t^{\gamma}$ and $P_t^{Jet}$ balance (as predicted by the PYTHIA model), are presented.

Appendix 1 contains tables for $P_t^{\gamma}$ varying from 40 to 50 GeV/c. In these tables we present the values of interest for three different Selections, mentioned in Section 3.2 [1]. Each page corresponds to a definite value of $\Delta \phi$ (which enters the formula (23) of [1]) as a measure of deviation from the absolute back-to-back orientation of two $\vec{P}_t^{\gamma}$ and $\vec{P}_t^{Jet}$ vectors. So, Tables 1 and 2 on the first page and Tables 3 and 4 on the second one in each of Appendices 1–4 correspond to $\Delta \phi = 180^\circ$ (i.e. to the case of no restriction on the back-to-backness angle choice) and to $\Delta \phi = 15^\circ$, respectively. On the third page of each of Appendices 1–4 we present the Tables 5 and 6 (for the same cut $\Delta \phi = 15^\circ$) that correspond to the Selection 2 case described in [1]. This Selection differs from Selection 1, presented in Tables 1–4, by addition of the cut (26) of [1]. It allows one to select events with the "isolated jet", i.e. events having the total $P_t$ activity in $\Delta R = 0.3$ ring around a jet not exceeding 2% of jet $P_t$. Tables 7, 8, shown on the fourth page in each of Appendices, present results found in the case of Selection 3 for the same cut $\Delta \phi = 15^\circ$. The last sample includes only events having the same jet found simultaneously by both jetfinders UA1 and LUCCELL.

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1 The detailed information on the dependence of the $P_t^{\gamma}$ and $P_t^{Jet}$ disbalance on $P_{t\text{cut}}^{\text{clust}}$ and $P_{t\text{cut}}^{\text{out}}$ in the case of background events can be found in [3, 4].
The columns in Tables 1–6 correspond to five different values of $P_{t\text{clust}^{CUT}} = 30, 20, 15, 10$ and $5 \text{ GeV}/c$. The upper lines of Tables 1–6 from all the Appendices contain the numbers of events $N_{\text{event}}$ expected for “HB events”, i.e. for ”$\gamma + \text{Jet}$” events in which jet is completely fitted into the barrel region of HCAL (see [2]) for the integrated luminosity $L_{\text{int}} = 3 f_{b}^{-1}$ for different values of $P_{t\text{clust}^{CUT}}$ and a fixed value of $\Delta \phi$. The last lines of the Tables present the number of generated events, left after cuts, i.e. entries. In the next four lines of the Tables we put the values of $P_{t56}$, $\Delta \phi$, $P_{tout}$, $P_{t>\eta>5}$ defined by formulae (3), (23), (25) and (5) of [1], respectively, and averaged over the events selected with a chosen $P_{t\text{clust}^{CUT}}$ value.

From the Tables we see that the values of $P_{t56}$, $\Delta \phi$, $P_{tout}$ decrease fast with decreasing $P_{t\text{clust}^{CUT}}$, while the averaged values of $P_{t>\eta>5}$ show very weak dependence on it (practically constant).

In the sixth line the average values of the initial state vector disbalance $P_{t}^{5+6}$ (defined by (3) of [1]) are presented in addition to the rough scalar $P_{t56}$ estimator value. It is seen that they are smaller than $P_{t56}$ value.

The next lines represent the average values of the variables $P_{t}^{\gamma+\text{part}}$, $P_{t}^{\gamma+\text{jet}}$, $P_{t}^{\gamma+\text{Jet}}$ that are defined as averaged values of (2), (12) and (4) from [1] and serve as a measure of the $P_{t}$ disbalance in the ”$\gamma + \text{Jet}$” system. These lines correspond in the following order to: the balance at the parton level, the balance of that part of the ”$\gamma + \text{Jet}$” system which can be measured by calorimeters, i.e. defined by $P_{t}^{\text{Jet}}$ (see (10) of [1]), and the balance of the ”$\gamma + \text{complete jet}$” system. Practically all the values of these three variables drop approximately by a factor of two when we move from $P_{t\text{clust}^{\gamma}} = 30 \text{ GeV}/c$ to $P_{t\text{clust}^{\gamma}} = 5 \text{ GeV}/c$ for all $P_{t}^{\gamma}$ intervals and for both the UA1 and LUCCELL algorithms.

To take into account the part of jet $P_{t}$ carried off by neutrinos, we have introduced in [1] the correction $\Delta \nu$ that should be added to $P_{t}^{\text{Jet}}$ to restore $P_{t}$ of the complete jet in each event:

$$\Delta \nu = P_{t}^{\text{Jet}^{\nu}} - P_{t}^{\text{Jet}} \tag{2}$$

Let us define a new quantity $P_{t}^{J}$, which would serve as an estimator for the total $P_{t}^{\text{Jet}}$ value, by the sum of $P_{t}^{\text{Jet}^{\nu}}$ (a measurable part of $P_{t}^{\text{Jet}^{\nu}}$) and an averaged $\Delta \nu$, correction:

$$P_{t}^{J} = P_{t}^{\text{Jet}^{\nu}} + <\Delta \nu> \tag{3}$$

The comparison of the $P_{t}^{\gamma+\text{part}}$ and $P_{t}^{\gamma+\text{Jet}}$ shows that the fragmentation process contribution into the value of the final state $P_{t}$ disbalance is much more smaller than the contribution of ISR that defines a dominant part of $P_{t}$ disbalance in the ”$\gamma + \text{Jet}$” system. The photon and the jet $P_{t}$ disbalance is defined in fact by the disbalance appearing at the parton level of fundamental $2 \rightarrow 2$ subprocesses (1a) and (1b). The comparison of $P_{t}^{\gamma+\text{Jet}}$ and $P_{t}^{5+6}$ shows that the final state disbalance has, approximately, the value of the initial state $P_{t}$ disbalance of colliding partons.

After the described lines follow three lines below for the averaged values of the $(P_{t}^{\gamma} - P_{t}^{J})/P_{t}^{\gamma}$, $(1 - \cos(\Delta \phi))$ and $P_{t}(O+\eta > 5)/P_{t}^{\gamma}$ quantities that enter equation (29) of [1] which has the meaning of the scalar variant of vector equation (16) of [1] for the total transverse momentum conservation in a physical event. The first quantity characterizes relative $P_{t}$ disbalance in the ”$\gamma + \text{complete Jet}$” system. The second and the third ones have the meaning of the averaged values of two terms in the right-hand part of balance equation.
2. RESULTS

The efficiency of the $P_t^{\text{clust}}$ restriction for the initial state radiation (ISR) suppression and the $P_t$ balance improvement in the "$\gamma + \text{Jet}$" system was demonstrated. For the case of $\Delta \phi \leq 15^\circ$ such a strict limitation as $P_t^{\text{clust}} = 5\text{ GeV}/c$ would allow to reduce $P_t^{\text{ISR}}$ by $25 - 40\%$ (in dependence on $P_t^\gamma$) and simultaneously to obtain the $1\%$ disbalance value.

It is also shown that the number of the events (at $L_{\text{int}} = 3\text{fb}^{-1}$), collected by Selection 2 criteria are not small even at $P_t^{\text{clust}} = 5 - 10\text{ GeV}/c$. These events have a topologically clean jet, whose transverse momentum is good balanced with one of the direct photon.

3. SUMMARY

The efficiency of the $P_t^{\text{clust}}$ restriction for the initial state radiation (ISR) suppression and the $P_t$ balance improvement in the "$\gamma + \text{Jet}$" system is defined by the term $\langle P_t(O + \eta > 5)/P_t^\gamma \rangle$.

We see from the Tables that more restrictive cuts on the $P_t^{\text{clust}}$ observable lead to decreasing in the $P_t56$ and $P_t^{5+6}$ values (non-observable ones) that serve, according to (3) of paper [1], as measures of the initial state radiation transverse momentum $P_t^{\text{ISR}}$, i.e. of the main source of the $P_t$ disbalance in fundamental $2 \rightarrow 2$ subprocesses (1a) and (1b).

Thus, the variation of $P_t^{\text{clust}}$ from $30\text{ GeV}/c$ to $5\text{ GeV}/c$ for $\Delta \phi \leq 15^\circ$ leads to suppression of the $P_t56$ and $P_t^{5+6}$ values (or $P_t^{\text{ISR}}$) approximately by $25\%$ for $40 < P_t^\gamma < 50\text{ GeV}/c$ and by $\approx 40 - 45\%$ for $P_t^\gamma \approx 100\text{ GeV}/c$. This diminishing of $P_t^{\text{clust}}$ value leads to diminishing of $(P_t^\gamma - P_t^J)/P_t^\gamma$ ratio, i.e. we improve the calibration accuracy. For instance, in the case of $100 < P_t^\gamma < 120\text{ GeV}/c$ the mean value of $(P_t^\gamma - P_t^J)/P_t^\gamma$ drops from $4-5\%$ to $0.6-1\%$ (see Tables 3 and 4 of Appendix 2) and in the case of $200 < P_t^\gamma < 240\text{ GeV}/c$ the mean value of this variable drops from $2\%$ to less than $0.5\%$ (see Tables 3 and 4 of Appendix 3).

After requirement the jet to be isolated (see Tables 5, 8 of Appendix 1–4) we observe, starting from $P_t^\gamma = 100\text{ GeV}/c$, that the mean values of $(P_t^\gamma - P_t^J)/P_t^\gamma$ are contained inside the $1\%$ window for any $P_t^{\text{clust}}$ value. In the case of $40 < P_t^\gamma < 50\text{ GeV}/c$ interval, where we have enough events even after passing to Selections 2 and 3, we see that $P_t^{\text{CUT}}$ works most effectively. Thus, $P_t^{\text{CUT}} = 10\text{ GeV}/c$ allows to reduce $(P_t^\gamma - P_t^J)/P_t^\gamma$ value to be less than $1.5\%$ in the case of Selection 3 while a more strict cut $P_t^{\text{CUT}} = 5\text{ GeV}/c$ makes it less than $0.5\%$. Both cuts leave quite a sufficient number of events: about 124 and 35 thousand, correspondingly (see Tables 7, 8 of Appendix 1).

In the following papers [3, 4] we shall show how these results can be improved by imposing the cut on $P_t^{\text{clust}}$ as it enter the expression $P_t(O + \eta > 5)/P_t^\gamma$, which gives a dominant contribution to the right-hand side of $P_t$-balance equation (29) of [1] as we have mentioned above.

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References

[1] D.V. Bandourin, V.F. Konoplyanikov, N.B. Skachkov. “Jet energy scale setting with ”$\gamma + \text{Jet}$” events at LHC energies. Generalities, selection rules”, JINR Preprint E2-2000-251, JINR, Dubna.

[2] D.V. Bandourin, V.F. Konoplyanikov, N.B. Skachkov. “Jet energy scale setting with ”$\gamma + \text{Jet}$” events at LHC energies. Event rates, $P_t$ structure of jet”, JINR Preprint E2-2000-252, JINR, Dubna.

[3] D.V. Bandourin, V.F. Konoplyanikov, N.B. Skachkov. “Jet energy scale setting with ”$\gamma + \text{Jet}$” events at LHC energies. Selection of events with a clean ”$\gamma + \text{Jet}$” topology and $P_t\gamma - P_t\text{Jet}$ disbalance”, JINR Preprint E2-2000-254, JINR, Dubna.

[4] D.V. Bandourin, V.F. Konoplyanikov, N.B. Skachkov. “Jet energy scale setting with ”$\gamma + \text{Jet}$” events at LHC energies. Detailed study of the background suppression”. JINR Preprint E2-2000-255, JINR, Dubna.
Appendix 1

\[ 40 < P_t^\gamma < 50 \text{ GeV/c} \]

Table 1: Selection 1. \( \phi(\gamma,\text{jet}) = 180^\circ \pm 180^\circ \). UA1 algorithm.

| \( P_t^{\text{clust}} \) CUT | 30 | 20 | 15 | 10 | 5 |
|-----------------------------|----|----|----|----|---|
| Nevent\(^*\)               | 2829803 | 2319650 | 1904754 | 1283404 | 296186 |
| \( P_t^{56} \)             | 16.8 | 14.0 | 12.1 | 10.0 | 7.6 |
| \( \Delta \phi \)          | 13.6 | 10.3 | 8.6 | 6.8 | 5.0 |
| \( P_t^{\text{out}} \)     | 13.6 | 11.1 | 9.7 | 8.0 | 5.8 |
| \( P_t^{\gamma>\eta} \)    | 4.6  | 4.6  | 4.5  | 4.5  | 4.3 |
| \( P_t^{\gamma+\text{b}} \) | 14.0 | 11.4 | 9.7 | 7.9 | 6.0 |
| \( P_t^{\gamma+\text{part}} \) | 13.9 | 11.3 | 9.7 | 7.9 | 6.0 |
| \( P_t^{\gamma+\text{jet}} \) | 13.3 | 10.8 | 9.4 | 7.8 | 6.0 |

\( \frac{P_t^{\gamma}-P_t^{\text{out}}}{P_t^{\gamma}} \)

\( \frac{1-\cos(\Delta \phi)}{} \)

\( \frac{P_t(O+\eta>5)}{P_t^{\gamma}} \)

Entries \( 83981 \)

Table 2: Selection 1. \( \phi(\gamma,\text{jet}) = 180^\circ \pm 180^\circ \). LUCCELL algorithm.

| \( P_t^{\text{clust}} \) CUT | 30 | 20 | 15 | 10 | 5 |
|-----------------------------|----|----|----|----|---|
| Nevent\(^*\)               | 2739600 | 2208386 | 1781966 | 1145083 | 267241 |
| \( P_t^{56} \)             | 16.7 | 13.7 | 11.7 | 9.4  | 7.0  |
| \( \Delta \phi \)          | 13.4 | 10.0 | 8.1  | 6.2  | 4.5  |
| \( P_t^{\text{out}} \)     | 13.4 | 10.8 | 9.3  | 7.5  | 5.3  |
| \( P_t^{\gamma>\eta} \)    | 4.6  | 4.6  | 4.5  | 4.4  | 4.2  |
| \( P_t^{\gamma+\text{b}} \) | 13.9 | 11.2 | 9.4  | 7.5  | 5.4  |
| \( P_t^{\gamma+\text{part}} \) | 13.8 | 11.1 | 9.3  | 7.4  | 5.4  |
| \( P_t^{\gamma+\text{jet}} \) | 13.1 | 10.5 | 9.0  | 7.2  | 5.4  |

\( \frac{P_t^{\gamma}-P_t^{\text{out}}}{P_t^{\gamma}} \)

\( \frac{1-\cos(\Delta \phi)}{} \)

\( \frac{P_t(O+\eta>5)}{P_t^{\gamma}} \)

Entries \( 81304 \)

\(^*\)Number of events (Nevent) is given in this and in the following tables for integrated luminosity \( L_{\text{int}} = 3 \text{ } fb^{-1} \)
Table 3: Selection 1. $\phi(\gamma,\text{jet}) = 180^\circ \pm 15^\circ$. UA1 algorithm.

| $P(t)^{\text{cut}}$ | 30 | 20 | 15 | 10 | 5 |
|---------------------|----|----|----|----|---|
| Nevent              | 1904888 | 1771992 | 1583397 | 1160010 | 283752 |
| $P(t)$             | 12.2 | 11.3 | 10.4 | 9.0 | 7.0 |
| $P(t)^{\text{cut}}$ | 9.0 | 8.6 | 8.1 | 7.2 | 5.5 |
| $P(t)^{\eta>5}$   | 4.5 | 4.4 | 4.4 | 4.3 | 4.1 |
| $P(t)^{5+6}$      | 9.3 | 8.7 | 8.0 | 6.9 | 5.4 |
| $P(t)^{\gamma+\text{part}}$ | 9.3 | 8.6 | 7.9 | 6.9 | 5.4 |
| $P(t)^{\gamma+\text{jet}}$ | 8.3 | 7.9 | 7.5 | 6.7 | 5.4 |
| $P(t)^{\gamma+\text{Jet}}$ | 8.3 | 7.9 | 7.5 | 6.7 | 5.4 |
| $(P(t)^{\gamma} - P(t)^{\text{Jet}})/P(t)^{\gamma}$ | 0.0236 | 0.0287 | 0.0290 | 0.0257 | 0.0163 |
| $1 - \cos(\Delta \phi)$ | 0.0080 | 0.0077 | 0.0073 | 0.0063 | 0.0044 |
| $P(t)(O+\eta>5)/P(t)^{\gamma}$ | 0.0156 | 0.0210 | 0.0218 | 0.0196 | 0.0122 |
| Entries            | 54922 | 50723 | 44738 | 31455 | 7751 |

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

| $P(t)^{\text{cut}}$ | 30 | 20 | 15 | 10 | 5 |
|---------------------|----|----|----|----|---|
| Nevent              | 1850638 | 1709150 | 1507481 | 1059900 | 260259 |
| $P(t)$             | 12.2 | 11.2 | 10.3 | 8.8 | 6.7 |
| $P(t)^{\text{cut}}$ | 8.9 | 8.4 | 7.9 | 7.0 | 5.3 |
| $P(t)^{\eta>5}$   | 4.5 | 4.4 | 4.4 | 4.3 | 4.0 |
| $P(t)^{5+6}$      | 9.4 | 8.7 | 7.9 | 6.8 | 5.2 |
| $P(t)^{\gamma+\text{part}}$ | 9.3 | 8.6 | 7.9 | 6.8 | 5.2 |
| $P(t)^{\gamma+\text{jet}}$ | 8.3 | 7.8 | 7.4 | 6.5 | 5.2 |
| $P(t)^{\gamma+\text{Jet}}$ | 8.2 | 7.8 | 7.3 | 6.5 | 5.1 |
| $(P(t)^{\gamma} - P(t)^{\text{jet}})/P(t)^{\gamma}$ | 0.0236 | 0.0287 | 0.0290 | 0.0257 | 0.0163 |
| $1 - \cos(\Delta \phi)$ | 0.0080 | 0.0077 | 0.0073 | 0.0063 | 0.0042 |
| $P(t)(O+\eta>5)/P(t)^{\gamma}$ | 0.0156 | 0.0210 | 0.0218 | 0.0196 | 0.0122 |
| Entries            | 54922 | 50723 | 44738 | 31455 | 7751 |
Table 5: Selection 2. $\phi_{(\gamma,\text{jet})} = 180^\circ \pm 15^\circ$. UA1 algorithm.

| $P_{t_{\text{clust}}}^{\text{CUT}}$ | 30  | 20  | 15   | 10   | 5    |
|-------------------------------|-----|-----|------|------|------|
| Nevent                        | 222459 | 208947 | 190853 | 150148 | 52363 |
| $P_{t_{56}}$                  | 11.4 | 10.4 | 9.6  | 8.4  | 6.7  |
| $\Delta\phi$                 | 5.6  | 5.5  | 5.4  | 4.9  | 4.1  |
| $P_{t_{\text{out}}}$         | 8.9  | 8.2  | 7.7  | 6.8  | 5.3  |
| $P_{t_{\eta>5}}$             | 4.5  | 4.4  | 4.4  | 4.4  | 4.2  |
| $P_{t_{5+6}}$                | 8.6  | 7.9  | 7.3  | 6.4  | 5.1  |
| $P_{t_{\gamma+\text{part}}}$ | 8.7  | 8.0  | 7.4  | 6.5  | 5.2  |
| $P_{t_{\gamma+\text{jet}}}$  | 8.3  | 7.6  | 7.1  | 6.4  | 5.3  |
| $(P_{t_{\gamma}} - P_{t_{\text{out}}})/P_{t_{\gamma}}$ | -0.0469 | -0.0336 | -0.0252 | -0.0187 | -0.0137 |
| $1 - \cos(\Delta\phi)$      | 0.0073 | 0.0070 | 0.0067 | 0.0059 | 0.0041 |
| $P_{t}(O+\eta>5)/P_{t_{\gamma}}$ | -0.0540 | -0.0405 | -0.0318 | -0.0245 | -0.0178 |
| Entries                      | 6602 | 6201 | 5664 | 4456 | 1554 |

Table 6: Selection 2. $\phi_{(\gamma,\text{jet})} = 180^\circ \pm 15^\circ$. LUCELL algorithm.

| $P_{t_{\text{clust}}}^{\text{CUT}}$ | 30  | 20  | 15   | 10   | 5    |
|-------------------------------|-----|-----|------|------|------|
| Nevent                        | 219764 | 205275 | 185394 | 140916 | 46972 |
| $P_{t_{56}}$                  | 11.3 | 10.3 | 9.4  | 8.1  | 6.4  |
| $\Delta\phi$                 | 5.6  | 5.5  | 5.3  | 4.9  | 4.0  |
| $P_{t_{\text{out}}}$         | 8.9  | 8.2  | 7.6  | 6.6  | 5.1  |
| $P_{t_{\eta>5}}$             | 4.5  | 4.5  | 4.4  | 4.3  | 4.1  |
| $P_{t_{5+6}}$                | 8.6  | 7.8  | 7.1  | 6.2  | 4.9  |
| $P_{t_{\gamma+\text{part}}}$ | 8.7  | 7.9  | 7.2  | 6.3  | 4.9  |
| $P_{t_{\gamma+\text{jet}}}$  | 8.2  | 7.6  | 7.1  | 6.2  | 5.0  |
| $(P_{t_{\gamma}} - P_{t_{\text{out}}})/P_{t_{\gamma}}$ | -0.0438 | -0.0289 | -0.0219 | -0.0148 | -0.0073 |
| $1 - \cos(\Delta\phi)$      | 0.0073 | 0.0071 | 0.0067 | 0.0057 | 0.0040 |
| $P_{t}(O+\eta>5)/P_{t_{\gamma}}$ | -0.0510 | -0.0358 | -0.0284 | -0.0204 | -0.0112 |
| Entries                      | 6522 | 6092 | 5502 | 4182 | 1398 |
Table 7: Selection 3. $\phi_{(\gamma,\text{jet})} = 180^\circ \pm 15^\circ$. UA1 algorithm.

| $P_t^{\text{jet}}_{\text{CUT}}$ | 30  | 20  | 15  | 10  | 5    |
|-------------------------------|-----|-----|-----|-----|------|
| Nevent                        | 204381 | 190906 | 170562 | 124006 | 35229 |
| $P_t^{56}$                    | 10.8 | 9.6 | 8.7 | 7.5 | 5.9  |
| $\Delta\phi$                 | 5.5 | 5.3 | 5.1 | 4.6 | 3.6  |
| $P_t^{\text{out}}$            | 8.5 | 7.7 | 7.1 | 6.1 | 4.3  |
| $P_t^{\eta>5}$                | 4.5 | 4.4 | 4.3 | 4.3 | 4.0  |
| $P_t^{5+6}$                   | 8.1 | 7.2 | 6.6 | 5.7 | 4.5  |
| $P_t^{\gamma+\text{part}}$   | 8.3 | 7.3 | 6.7 | 5.8 | 4.5  |
| $P_t^{\gamma+\text{jet}}$    | 7.9 | 7.1 | 6.6 | 5.7 | 4.5  |
| $(P_t^{\gamma}-P_t^{\text{jet}})/P_t^{\gamma}$ | -0.0408 | -0.0268 | -0.0201 | -0.0142 | -0.0042 |
| $1 - \cos(\Delta\phi)$       | 0.0071 | 0.0067 | 0.0061 | 0.0051 | 0.0031 |
| $P_t(O+\eta>5)/P_t^{\gamma}$ | -0.0478 | -0.0334 | -0.0261 | -0.0192 | -0.0072 |
| Entries                       | 6065 | 5604 | 5061 | 3680 | 1049 |

Table 8: Selection 3. $\phi_{(\gamma,\text{jet})} = 180^\circ \pm 15^\circ$. LUCERL algorithm.

| $P_t^{\text{jet}}_{\text{CUT}}$ | 30  | 20  | 15  | 10  | 5    |
|-------------------------------|-----|-----|-----|-----|------|
| Nevent                        | 204381 | 190906 | 170562 | 124006 | 35229 |
| $P_t^{56}$                    | 10.8 | 9.6 | 8.7 | 7.5 | 5.9  |
| $\Delta\phi$                 | 5.5 | 5.3 | 5.1 | 4.6 | 3.6  |
| $P_t^{\text{out}}$            | 8.5 | 7.7 | 7.1 | 6.1 | 4.3  |
| $P_t^{\eta>5}$                | 4.5 | 4.4 | 4.3 | 4.3 | 4.0  |
| $P_t^{5+6}$                   | 8.1 | 7.2 | 6.6 | 5.7 | 4.5  |
| $P_t^{\gamma+\text{part}}$   | 8.3 | 7.3 | 6.7 | 5.8 | 4.5  |
| $P_t^{\gamma+\text{jet}}$    | 7.9 | 7.1 | 6.6 | 5.7 | 4.5  |
| $(P_t^{\gamma}-P_t^{\text{jet}})/P_t^{\gamma}$ | -0.0400 | -0.0260 | -0.0194 | -0.0136 | -0.0036 |
| $1 - \cos(\Delta\phi)$       | 0.0072 | 0.0067 | 0.0062 | 0.0051 | 0.0032 |
| $P_t(O+\eta>5)/P_t^{\gamma}$ | -0.0470 | -0.0326 | -0.0255 | -0.0186 | -0.0066 |
| Entries                       | 6065 | 5604 | 5061 | 3680 | 1049 |
Appendix 2

$100 < P_t^\gamma < 120 \, GeV/c$

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

| $P_t^{clust}$ | 30 | 20 | 15 | 10 | 5 |
|---------------|----|----|----|----|---|
| Nevent        | 133709 | 95415 | 72927 | 45345 | 8654 |
| $P_t56$       | 23.1 | 17.7 | 15.1 | 12.6 | 9.9 |
| $\Delta\phi$ | 6.4 | 4.7 | 3.9 | 3.1 | 2.4 |
| $P_t^{out}$   | 18.5 | 13.6 | 11.3 | 9.1 | 6.7 |
| $P_t^{\gamma>0}$ | 4.8 | 4.8 | 4.7 | 4.7 | 4.6 |
| $P_t^{\gamma+b}$ | 19.3 | 14.3 | 12.1 | 10.0 | 7.9 |
| $P_t^{\gamma+part}$ | 19.1 | 14.3 | 12.1 | 10.1 | 8.0 |
| $P_t^{\gamma+Jet}$ | 18.8 | 14.0 | 11.7 | 9.6 | 7.5 |
| $(P_t^{\gamma}−P_t^{\gamma+jet})/P_t^{\gamma}$ | 0.0589 | 0.0335 | 0.0238 | 0.0170 | 0.0120 |
| $1−\cos(\Delta\phi)$ | 0.0120 | 0.0062 | 0.0042 | 0.0029 | 0.0024 |
| $P_t(O+\eta>5)/P_t^{\gamma}$ | 0.0470 | 0.0273 | 0.0196 | 0.0141 | 0.0097 |
| Entries        | 69710 | 49745 | 38021 | 23641 | 4512 |

Table 2: Selection 1. $\phi(\gamma,jet) = 180^\circ \pm 180^\circ$. LUCELL algorithm.

| $P_t^{clust}$ | 30 | 20 | 15 | 10 | 5 |
|---------------|----|----|----|----|---|
| Nevent        | 124587 | 87645 | 65928 | 38555 | 7720 |
| $P_t56$       | 22.3 | 16.9 | 14.2 | 11.4 | 8.6 |
| $\Delta\phi$ | 6.1 | 4.4 | 3.6 | 2.8 | 2.0 |
| $P_t^{out}$   | 17.6 | 12.8 | 10.5 | 8.1 | 5.7 |
| $P_t^{\gamma>0}$ | 4.8 | 4.7 | 4.7 | 4.7 | 4.6 |
| $P_t^{\gamma+b}$ | 18.5 | 13.6 | 11.3 | 9.0 | 6.7 |
| $P_t^{\gamma+part}$ | 18.4 | 13.6 | 11.4 | 9.1 | 6.7 |
| $P_t^{\gamma+Jet}$ | 18.0 | 13.2 | 10.9 | 8.5 | 6.4 |
| $(P_t^{\gamma}−P_t^{\gamma+jet})/P_t^{\gamma}$ | 0.0504 | 0.0268 | 0.0178 | 0.0104 | 0.0063 |
| $1−\cos(\Delta\phi)$ | 0.0108 | 0.0053 | 0.0035 | 0.0021 | 0.0012 |
| $P_t(O+\eta>5)/P_t^{\gamma}$ | 0.0397 | 0.0215 | 0.0143 | 0.0083 | 0.0051 |
| Entries        | 64954 | 45694 | 34372 | 20101 | 4025 |
Table 3: Selection 1. $\phi_{(\gamma,jet)} = 180^\circ \pm 15^\circ$. UA1 algorithm.

| $P_t^{clust\_CUT}$ | 30 | 20 | 15 | 10 | 5 |
|---------------------|----|----|----|----|---|
| Nevent              | 121445 | 92409 | 71951 | 45021 | 8568 |
| $P_{t56}$           | 20.8 | 16.9 | 14.7 | 12.3 | 9.5 |
| $\Delta \phi$      | 4.9 | 4.2 | 3.7 | 3.0 | 2.2 |
| $P_t^{clust}$       | 16.1 | 12.9 | 11.0 | 8.9  | 6.4 |
| $P_{t>5}$          | 4.7 | 4.7 | 4.7 | 4.7  | 4.5 |
| $P_{t5+6}$         | 16.9 | 13.5 | 11.7 | 9.8  | 7.5 |
| $P_{t\gamma+part}$ | 16.8 | 13.6 | 11.8 | 9.8  | 7.6 |
| $P_{t\gamma+jet}$  | 16.3 | 13.1 | 11.3 | 9.3  | 7.2 |
| $P_{t\gamma+Jet}$ | 16.2 | 13.1 | 11.2 | 9.3  | 7.1 |
| $(P_{t\gamma}-P_{t\gamma+Jet})/P_{t\gamma}$ | 0.0503 | 0.0312 | 0.0228 | 0.0162 | 0.0106 |
| $1-\cos(\Delta \phi)$ | 0.0060 | 0.0045 | 0.0035 | 0.0024 | 0.0015 |
| $P_t(O+\eta>5)/P_{t\gamma}$ | 0.0443 | 0.0268 | 0.0194 | 0.0138 | 0.0092 |
| Entries             | 63316 | 48178 | 37512 | 23472 | 4467 |

Table 4: Selection 1. $\phi_{(\gamma,jet)} = 180^\circ \pm 15^\circ$. LUCELL algorithm.

| $P_t^{clust\_CUT}$ | 30 | 20 | 15 | 10 | 5 |
|---------------------|----|----|----|----|---|
| Nevent              | 114477 | 85721 | 65481 | 38500 | 7703 |
| $P_{t56}$           | 20.4 | 16.4 | 14.1 | 11.4 | 8.5 |
| $\Delta \phi$      | 4.9 | 4.1 | 3.5 | 2.8  | 2.0 |
| $P_t^{clust}$       | 15.6 | 12.3 | 10.4 | 8.1  | 5.7 |
| $P_{t>5}$          | 4.7 | 4.7 | 4.7 | 4.6  | 4.5 |
| $P_{t5+6}$         | 16.6 | 13.1 | 11.2 | 9.0  | 6.6 |
| $P_{t\gamma+part}$ | 16.5 | 13.1 | 11.2 | 9.0  | 6.7 |
| $P_{t\gamma+jet}$  | 15.8 | 12.6 | 10.7 | 8.5  | 6.4 |
| $P_{t\gamma+Jet}$ | 15.7 | 12.5 | 10.6 | 8.4  | 6.3 |
| $(P_{t\gamma}-P_{t\gamma+Jet})/P_{t\gamma}$ | 0.0433 | 0.0254 | 0.0173 | 0.0103 | 0.0061 |
| $1-\cos(\Delta \phi)$ | 0.0059 | 0.0043 | 0.0032 | 0.0020 | 0.0011 |
| $P_t(O+\eta>5)/P_{t\gamma}$ | 0.0374 | 0.0212 | 0.0141 | 0.0083 | 0.0050 |
| Entries             | 59683 | 44691 | 34139 | 20072 | 4019 |
Table 5: Selection 2. $\phi(\gamma, \text{jet}) = 180^\circ \pm 15^\circ$, UA1 algorithm.

| $P_{t_{\text{clust}}}^{\text{CUT}}$ | 30   | 20   | 15   | 10   | 5    |
|-----------------------------------|------|------|------|------|------|
| Nevent                           | 37984| 31376| 25953| 17917| 4672 |
| $P_{t66}$                         | 17.7 | 14.9 | 13.2 | 11.1 | 8.6  |
| $\Delta \phi$                    | 4.6  | 3.9  | 3.5  | 2.9  | 2.1  |
| $P_{t^{\text{out}}}$             | 13.7 | 11.5 | 10.1 | 8.3  | 6.0  |
| $P_{t^{\eta>5}}$                 | 4.7  | 4.7  | 4.7  | 4.7  | 4.5  |
| $P_{t^{5+6}}$                    | 14.0 | 11.7 | 10.3 | 8.7  | 6.7  |
| $P_{t^{\gamma+\text{part}}}$    | 14.3 | 12.0 | 10.5 | 8.8  | 6.9  |
| $P_{t^{\gamma+\text{jet}}}$     | 13.8 | 11.6 | 10.2 | 8.5  | 6.7  |
| $P_{t^{\gamma+\text{Jet}}}$     | 13.8 | 11.7 | 10.2 | 8.5  | 6.7  |
| $(P_{t^{\gamma}} - P_{t^{\text{Jet}}})/P_{t^{\gamma}}$ | -0.0057 | -0.0060 | -0.0052 | -0.0036 | 0.0006 |
| $1 - \cos(\Delta \phi)$        | 0.0053 | 0.0040 | 0.0032 | 0.0022 | 0.0014 |
| $P_{t}(O+\eta>5)/P_{t^{\gamma}}$ | -0.0110 | -0.0100 | -0.0083 | -0.0057 | -0.0007 |
| Entries                          | 19803| 16358| 13531| 9341 | 2436 |

Table 6: Selection 2. $\phi(\gamma, \text{jet}) = 180^\circ \pm 15^\circ$, LUCELL algorithm.

| $P_{t_{\text{clust}}}^{\text{CUT}}$ | 30   | 20   | 15   | 10   | 5    |
|-----------------------------------|------|------|------|------|------|
| Nevent                           | 36338| 29489| 23986| 15690| 4157 |
| $P_{t66}$                         | 17.3 | 14.3 | 12.5 | 10.4 | 7.9  |
| $\Delta \phi$                    | 4.5  | 3.8  | 3.3  | 2.6  | 1.9  |
| $P_{t^{\text{out}}}$             | 13.5 | 11.2 | 9.6  | 7.7  | 5.5  |
| $P_{t^{\eta>5}}$                 | 4.7  | 4.7  | 4.7  | 4.6  | 4.4  |
| $P_{t^{5+6}}$                    | 13.7 | 11.2 | 9.7  | 8.0  | 6.0  |
| $P_{t^{\gamma+\text{part}}}$    | 13.9 | 11.5 | 9.9  | 8.2  | 6.1  |
| $P_{t^{\gamma+\text{jet}}}$     | 13.6 | 11.3 | 9.7  | 7.9  | 6.0  |
| $P_{t^{\gamma+\text{Jet}}}$     | 13.6 | 11.3 | 9.7  | 7.9  | 6.0  |
| $(P_{t^{\gamma}} - P_{t^{\text{Jet}}})/P_{t^{\gamma}}$ | -0.0061 | -0.0063 | -0.0054 | -0.0043 | -0.0013 |
| $1 - \cos(\Delta \phi)$        | 0.0052 | 0.0038 | 0.0029 | 0.0019 | 0.0011 |
| $P_{t}(O+\eta>5)/P_{t^{\gamma}}$ | -0.0113 | -0.0101 | -0.0083 | -0.0061 | -0.0023 |
| Entries                          | 18945| 15374| 12505| 8180 | 2168 |
Table 7: Selection 3, $\phi(\gamma,\text{jet}) = 180^\circ \pm 15^\circ$. UA1 algorithm.

| $P_{T_{\text{clust}}}^{\gamma,\text{Jet}}$ CUT | 30  | 20  | 15  | 10  | 5    |
|-------------------------------------------|-----|-----|-----|-----|-----|
| Nevent                                   | 34158 | 27425 | 22067 | 13807 | 3242 |
| $P_{T56}$                                 | 15.7 | 12.8 | 11.0 | 9.1  | 7.2  |
| $\Delta \phi$                             | 4.2  | 3.4  | 2.9  | 2.3  | 1.8  |
| $P_{T_{\text{out}}}$                      | 12.3 | 9.8  | 8.4  | 6.6  | 4.6  |
| $P_{T_{\eta>5}}$                          | 4.7  | 4.7  | 4.7  | 4.6  | 4.6  |
| $P_{T_{5+6}}$                             | 12.3 | 10.0 | 8.5  | 6.9  | 5.4  |
| $P_{T_{\gamma+\text{part}}}$             | 12.6 | 10.2 | 8.8  | 7.1  | 5.5  |
| $P_{T_{\gamma+\text{jet}}}$              | 12.4 | 10.0 | 8.6  | 7.0  | 5.9  |
| $(P_{T_{\gamma}} - P_{T_{\text{Jet}}})/P_{T_{\gamma}}$ | -0.0060 | -0.0048 | -0.0043 | -0.0017 | 0.0034 |
| $1 - \cos(\Delta \phi)$                  | 0.0045 | 0.0031 | 0.0023 | 0.0015 | 0.0011 |
| $P_{T}(O+\eta>5)/P_{T_{\gamma}}$         | -0.0105 | -0.0079 | -0.0066 | -0.0032 | 0.0023 |
| Entries                                   | 17808 | 14298 | 11505 | 7198 | 1691 |

Table 8: Selection 3, $\phi(\gamma,\text{jet}) = 180^\circ \pm 15^\circ$. LUCELL algorithm.

| $P_{T_{\text{clust}}}^{\gamma,\text{Jet}}$ CUT | 30  | 20  | 15  | 10  | 5    |
|-------------------------------------------|-----|-----|-----|-----|-----|
| Nevent                                   | 34158 | 27425 | 22067 | 13807 | 3242 |
| $P_{T56}$                                 | 15.7 | 12.8 | 11.0 | 9.1  | 7.2  |
| $\Delta \phi$                             | 4.2  | 3.4  | 2.9  | 2.3  | 1.8  |
| $P_{T_{\text{out}}}$                      | 12.3 | 9.9  | 8.4  | 6.7  | 4.6  |
| $P_{T_{\eta>5}}$                          | 4.7  | 4.7  | 4.7  | 4.6  | 4.6  |
| $P_{T_{5+6}}$                             | 12.3 | 10.0 | 8.5  | 6.9  | 5.4  |
| $P_{T_{\gamma+\text{part}}}$             | 12.3 | 10.2 | 8.8  | 7.1  | 5.5  |
| $P_{T_{\gamma+\text{jet}}}$              | 12.4 | 10.1 | 8.6  | 7.0  | 5.9  |
| $(P_{T_{\gamma}} - P_{T_{\text{Jet}}})/P_{T_{\gamma}}$ | -0.0062 | -0.0053 | -0.0049 | -0.0024 | 0.0023 |
| $1 - \cos(\Delta \phi)$                  | 0.0045 | 0.0031 | 0.0023 | 0.0015 | 0.0011 |
| $P_{T}(O+\eta>5)/P_{T_{\gamma}}$         | -0.0107 | -0.0084 | -0.0071 | -0.0038 | 0.0013 |
| Entries                                   | 17808 | 14298 | 11505 | 7198 | 1691 |
Appendix 3

\[200 < P_t^\gamma < 240 \text{ GeV}/c\]

Table 1: Selection 1. \(\phi(\gamma, \text{jet}) = 180^\circ \pm 180^\circ\). UA1 algorithm.

| \(P_t^\text{clust}_{\text{CUT}}\) | 30  | 20  | 15  | 10  | 5    |
|----------------------------------|-----|-----|-----|-----|------|
| Nevent                           | 9389| 6714| 5065| 3057| 559  |
| \(P_t56\)                        | 24.5| 19.7| 17.2| 14.3| 10.8 |
| \(\Delta \phi\)                  | 3.2 | 2.4 | 2.0 | 1.6 | 1.2  |
| \(P_t^{\text{out}}\)             | 18.5| 14.1| 11.7| 9.3 | 6.8  |
| \(P_t^{\gamma+b}\)               | 4.8 | 4.8 | 4.7 | 4.7 | 4.6  |
| \(P_t^{\gamma+\text{part}}\)     | 20.0| 15.9| 13.8| 11.4| 8.7  |
| \(P_t^{\gamma+\text{jet}}\)      | 19.1| 14.8| 12.5| 10.1| 7.8  |
| \((P_t^\gamma - P_t^{\text{jet}})/P_t^\gamma\) | 0.0202| 0.0131| 0.0097| 0.0066| 0.0042|
| \(1 - \cos(\Delta \phi)\)       | 0.0029| 0.0016| 0.0011| 0.0007| 0.0005|
| \(P_t(O+\eta>5)/P_t^\gamma\)    | 0.0173| 0.0115| 0.0086| 0.0059| 0.0037|
| Entries                          | 52803| 37761| 28486| 17192| 3143 |

Table 2: Selection 1. \(\phi(\gamma, \text{jet}) = 180^\circ \pm 180^\circ\). LUCELL algorithm.

| \(P_t^\text{clust}_{\text{CUT}}\) | 30  | 20  | 15  | 10  | 5    |
|----------------------------------|-----|-----|-----|-----|------|
| Nevent                           | 8788| 6185| 4549| 2589| 495  |
| \(P_t56\)                        | 23.9| 18.9| 16.2| 13.1| 9.3  |
| \(\Delta \phi\)                  | 3.1 | 2.3 | 1.9 | 1.5 | 1.1  |
| \(P_t^{\text{out}}\)             | 17.8| 13.3| 10.9| 8.4 | 5.8  |
| \(P_t^{\gamma+b}\)               | 4.8 | 4.8 | 4.7 | 4.7 | 4.5  |
| \(P_t^{\gamma+\text{part}}\)     | 19.5| 15.2| 12.9| 10.3| 7.2  |
| \(P_t^{\gamma+\text{jet}}\)      | 19.6| 15.3| 13.0| 10.5| 7.4  |
| \((P_t^\gamma - P_t^{\text{jet}})/P_t^\gamma\) | 0.0174| 0.0101| 0.0069| 0.0039| 0.0023|
| \(1 - \cos(\Delta \phi)\)       | 0.0026| 0.0014| 0.0009| 0.0006| 0.0003|
| \(P_t(O+\eta>5)/P_t^\gamma\)    | 0.0148| 0.0087| 0.0060| 0.0034| 0.0021|
| Entries                          | 49425| 34786| 25582| 14562| 2786 |
Table 3: Selection 1. $\phi_{(\gamma,\text{jet})} = 180^\circ \pm 15^\circ$. UA1 algorithm.

| $P_{t_{\gamma + \text{Jet}}}^{\text{cut}}$ | 30 | 20 | 15 | 10 | 5 |
|--------------------------------------|----|----|----|----|---|
| Nevent                               | 9343 | 6711 | 5064 | 3056 | 559 |
| $P_{t_{56}}$                          | 24.3 | 19.7 | 17.1 | 14.3 | 10.8 |
| $\Delta \phi$                        | 3.1 | 2.4 | 2.0 | 1.6 | 1.2 |
| $P_{t_{\gamma + \text{part}}}$      | 18.2 | 14.0 | 11.7 | 9.3 | 6.8 |
| $P_{t_{\gamma + \text{jet}}}$       | 4.8 | 4.8 | 4.7 | 4.7 | 4.6 |
| $P_{t_{5+6}}$                        | 19.8 | 15.9 | 13.7 | 11.4 | 8.7 |
| $P_{t_{\gamma + \text{jet}}}$       | 18.9 | 14.7 | 12.4 | 10.1 | 7.8 |
| $P_{t_{\gamma + \text{Jet}}}$       | 18.7 | 14.6 | 12.4 | 10.0 | 7.7 |
| $(P_{t_{\gamma}} - P_{t_{\gamma + \text{Jet}}}) / P_{t_{\gamma}}$ | 0.0198 | 0.0130 | 0.0097 | 0.0066 | 0.0041 |
| $1 - \cos(\Delta \phi)$             | 0.0026 | 0.0016 | 0.0011 | 0.0007 | 0.0005 |
| $P_{t}(O+\eta > 5) / P_{t_{\gamma}}$ | 0.0172 | 0.0115 | 0.0086 | 0.0059 | 0.0037 |
| Entries                              | 52542 | 37741 | 28477 | 17189 | 3142 |

Table 4: Selection 1. $\phi_{(\gamma,\text{jet})} = 180^\circ \pm 15^\circ$. LUCELL algorithm.

| $P_{t_{\gamma + \text{Jet}}}^{\text{cut}}$ | 30 | 20 | 15 | 10 | 5 |
|--------------------------------------|----|----|----|----|---|
| Nevent                               | 8758 | 6183 | 4549 | 2589 | 503 |
| $P_{t_{56}}$                          | 23.8 | 18.9 | 16.2 | 13.1 | 9.3 |
| $\Delta \phi$                        | 3.0 | 2.3 | 1.9 | 1.5 | 1.1 |
| $P_{t_{\gamma + \text{part}}}$      | 17.6 | 13.3 | 10.9 | 8.4 | 5.8 |
| $P_{t_{\gamma + \text{jet}}}$       | 4.8 | 4.7 | 4.7 | 4.7 | 4.5 |
| $P_{t_{5+6}}$                        | 19.3 | 15.1 | 12.9 | 10.3 | 7.2 |
| $P_{t_{\gamma + \text{jet}}}$       | 19.5 | 15.3 | 13.0 | 10.5 | 7.4 |
| $P_{t_{\gamma + \text{Jet}}}$       | 18.2 | 14.0 | 11.6 | 9.1 | 6.7 |
| $(P_{t_{\gamma}} - P_{t_{\gamma + \text{Jet}}}) / P_{t_{\gamma}}$ | 0.0172 | 0.0101 | 0.0069 | 0.0039 | 0.0023 |
| $1 - \cos(\Delta \phi)$             | 0.0025 | 0.0014 | 0.0009 | 0.0006 | 0.0003 |
| $P_{t}(O+\eta > 5) / P_{t_{\gamma}}$ | 0.0147 | 0.0087 | 0.0060 | 0.0034 | 0.0021 |
| Entries                              | 49253 | 34775 | 25582 | 14562 | 2786 |
Table 5: Selection 2. $\phi_{(\gamma, \text{jet})} = 180^\circ \pm 15^\circ$. UA1 algorithm.

| $P_{t_{\text{CLUST}}}^{\text{CUT}}$ | 30  | 20  | 15  | 10  | 5  |
|---------------------------------|-----|-----|-----|-----|----|
| Nevent                          | 5797| 4466| 3558| 2340| 509 |
| $P_{t_{\text{56}}}$            | 21.6| 17.7| 15.5| 13.2| 10.4|
| $\Delta\phi$                   | 2.9 | 2.3 | 1.9 | 1.6 | 1.2 |
| $P_{t_{\text{56}}}^{\text{CLUST}}$ | 16.3| 12.9| 10.9| 8.9 | 6.7 |
| $P_{t_{\text{56}}}^{\text{CLUST}}^{>0}$ | 4.8 | 4.8 | 4.7 | 4.7 | 4.6 |
| $P_{t_{\text{56}}}^{\text{CLUST}}^{5+6}$ | 17.2| 14.0| 12.2| 10.4| 8.3 |
| $P_{t_{\text{56}}}^{\text{CLUST}}^{\gamma+\text{part}}$ | 17.6| 14.3| 12.5| 10.7| 8.5 |
| $P_{t_{\text{56}}}^{\text{CLUST}}^{\gamma+\text{jet}}$ | 16.8| 13.4| 11.5| 9.5 | 7.6 |
| $P_{t_{\text{56}}}^{\text{CLUST}}^{\gamma+\text{Jet}}$ | 16.8| 13.4| 11.5| 9.5 | 7.6 |
| $\frac{(P_{t_{\gamma}}-P_{t_{\text{56}}}^{\text{CLUST}}^{\gamma+\text{jet}})}{P_{t_{\gamma}}}$ | 0.0014| 0.0010| 0.0015| 0.0019| 0.0030 |
| $\frac{1-cos(\Delta\phi)}{P_{t_{\gamma}}}$ | 0.0023| 0.0014| 0.0010| 0.0007| 0.0005 |
| $\frac{Pt(O+\eta>5)}{P_{t_{\gamma}}}$ | -0.0009| -0.0004| 0.0005| 0.0012| 0.0025 |
| Entries                         | 32603| 25116| 20009| 13160| 2862 |

Table 6: Selection 2. $\phi_{(\gamma, \text{jet})} = 180^\circ \pm 15^\circ$. LUCCELL algorithm.

| $P_{t_{\text{CLUST}}}^{\text{CUT}}$ | 30  | 20  | 15  | 10  | 5  |
|---------------------------------|-----|-----|-----|-----|----|
| Nevent                          | 5433| 4114| 3190| 1971| 442 |
| $P_{t_{\text{56}}}$            | 21.0| 17.0| 14.6| 12.0| 8.7 |
| $\Delta\phi$                   | 2.8 | 2.2 | 1.8 | 1.4 | 1.1 |
| $P_{t_{\text{56}}}^{\text{CLUST}}$ | 15.9| 12.4| 10.3| 8.1 | 5.7 |
| $P_{t_{\text{56}}}^{\text{CLUST}}^{>0}$ | 4.8 | 4.7 | 4.7 | 4.7 | 4.5 |
| $P_{t_{\text{56}}}^{\text{CLUST}}^{5+6}$ | 16.7| 13.4| 11.5| 9.3 | 6.7 |
| $P_{t_{\text{56}}}^{\text{CLUST}}^{\gamma+\text{part}}$ | 17.1| 13.7| 11.8| 9.6 | 6.8 |
| $P_{t_{\text{56}}}^{\text{CLUST}}^{\gamma+\text{jet}}$ | 16.4| 12.8| 10.8| 8.7 | 6.6 |
| $P_{t_{\text{56}}}^{\text{CLUST}}^{\gamma+\text{Jet}}$ | 16.4| 12.9| 10.8| 8.7 | 6.6 |
| $\frac{(P_{t_{\gamma}}-P_{t_{\text{56}}}^{\text{CLUST}}^{\gamma+\text{jet}})}{P_{t_{\gamma}}}$ | 0.0005| -0.0002| 0.0001| 0.0000| 0.0009 |
| $\frac{1-cos(\Delta\phi)}{P_{t_{\gamma}}}$ | 0.0022| 0.0013| 0.0009| 0.0005| 0.0003 |
| $\frac{Pt(O+\eta>5)}{P_{t_{\gamma}}}$ | -0.0016| -0.0015| -0.0007| -0.0005| 0.0006 |
| Entries                         | 30556| 23138| 17939| 11085| 2447 |
Table 7: Selection 3. $\phi_{(\gamma, \text{jet})} = 180^\circ \pm 15^\circ$. UA1 algorithm.

| $p_{T,\text{cut}}$ | 30  | 20  | 15  | 10  | 5   |
|-------------------|-----|-----|-----|-----|-----|
| Nevent            | 5053| 3826| 2935| 2735| 327 |
| $p_{T,56}$        | 18.2| 14.6| 12.7| 10.6| 7.9 |
| $\Delta \phi$    | 2.4 | 1.9 | 1.6 | 1.3 | 1.0 |
| $p_{T,\text{cut}}$ | 13.6| 10.5| 8.8 | 7.2 | 4.8 |
| $p_{T,5+6}$      | 4.7 | 4.7 | 4.7 | 4.7 | 4.6 |
| $p_{T,\gamma+\text{part}}$ | 14.4| 11.3| 9.8 | 8.2 | 6.1 |
| $p_{T,\gamma+\text{jet}}$ | 14.7| 11.6| 10.1| 8.4 | 6.2 |
| $p_{T,\gamma+\text{Jet}}$ | 14.2| 11.1| 9.4 | 8.0 | 6.2 |
| $(p_{T,\gamma}-p_{T,\text{cut}})/p_{T,\gamma}$ | 0.0002| 0.0004| 0.0012| 0.0013| 0.0024 |
| $1-\cos(\Delta \phi)$ | 0.0016| 0.0009| 0.0006| 0.0005| 0.0003 |
| $p_t(O+\eta>5)/p_{T,\gamma}$ | -0.0014| -0.0005| 0.0006| 0.0009| 0.0021 |
| Entries | 28417| 21518| 16504| 9755| 1811 |

Table 8: Selection 3. $\phi_{(\gamma, \text{jet})} = 180^\circ \pm 15^\circ$. LUCELL algorithm.

| $p_{T,\text{cut}}$ | 30  | 20  | 15  | 10  | 5   |
|-------------------|-----|-----|-----|-----|-----|
| Nevent            | 5053| 3826| 2935| 2735| 327 |
| $p_{T,56}$        | 18.2| 14.6| 12.7| 10.6| 7.9 |
| $\Delta \phi$    | 2.4 | 1.9 | 1.6 | 1.3 | 1.0 |
| $p_{T,\text{cut}}$ | 13.7| 10.5| 8.8 | 7.1 | 4.7 |
| $p_{T,5+6}$      | 4.7 | 4.7 | 4.7 | 4.7 | 4.6 |
| $p_{T,\gamma+\text{part}}$ | 14.4| 11.3| 9.8 | 8.2 | 6.1 |
| $p_{T,\gamma+\text{jet}}$ | 14.7| 11.6| 10.1| 8.4 | 6.2 |
| $p_{T,\gamma+\text{Jet}}$ | 14.3| 11.1| 9.5 | 8.0 | 6.2 |
| $(p_{T,\gamma}-p_{T,\text{cut}})/p_{T,\gamma}$ | -0.0005| -0.0004| 0.0002| 0.0000| 0.0011 |
| $1-\cos(\Delta \phi)$ | 0.0016| 0.0009| 0.0006| 0.0005| 0.0003 |
| $p_t(O+\eta>5)/p_{T,\gamma}$ | -0.0021| -0.0013| -0.0005| -0.0005| 0.0008 |
| Entries | 28417| 21518| 16504| 9755| 1811 |
Appendix 4

300 < $P_t^\gamma$ < 360 GeV/c

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

| $P_t^{\text{cut}}$ | 30 | 20 | 15 | 10 | 5 |
|------------------|----|----|----|----|---|
| Nevent           | 1872 | 1315 | 977 | 579 | 107 |
| $P_t56$          | 26.7 | 21.7 | 18.8 | 15.7 | 12.7 |
| $\Delta \phi$    | 2.2 | 1.7 | 1.4 | 1.1 | 0.8 |
| $P_t^{\text{out}}$ | 19.0 | 14.5 | 12.1 | 9.7 | 7.0 |
| $P_t^{\gamma+b}$ | 4.8 | 4.7 | 4.7 | 4.7 | 4.6 |
| $P_t^{\gamma+\text{part}}$ | 21.8 | 17.6 | 15.2 | 12.7 | 10.4 |
| $P_t^{\gamma+\text{jet}}$ | 19.9 | 15.5 | 13.1 | 10.7 | 8.6 |
| $P_t^{\gamma+\text{Jet}}$ | 19.8 | 15.4 | 13.0 | 10.6 | 8.6 |
| $(P_t^{\gamma} - P_t^{\gamma+\text{Jet}})/P_t^{\gamma}$ | 0.0124 | 0.0083 | 0.0059 | 0.0042 | 0.0029 |
| $1 - \cos(\Delta \phi)$ | 0.0013 | 0.0008 | 0.0005 | 0.0003 | 0.0002 |
| $P_t(O+\eta>5)/P_t^{\gamma}$ | 0.0111 | 0.0076 | 0.0054 | 0.0039 | 0.0027 |
| Entries          | 46306 | 32515 | 24159 | 14319 | 2642 |

Table 2: Selection 1. $\phi(\gamma,\text{jet}) = 180^\circ \pm 180^\circ$. LUCELL algorithm.

| $P_t^{\text{cut}}$ | 30 | 20 | 15 | 10 | 5 |
|------------------|----|----|----|----|---|
| Nevent           | 1752 | 1204 | 878 | 489 | 94 |
| $P_t56$          | 26.0 | 20.7 | 17.7 | 14.2 | 10.9 |
| $\Delta \phi$    | 2.1 | 1.6 | 1.3 | 1.0 | 0.7 |
| $P_t^{\text{out}}$ | 18.4 | 13.7 | 11.3 | 8.6 | 5.9 |
| $P_t^{\gamma+b}$ | 4.8 | 4.8 | 4.7 | 4.6 | 4.5 |
| $P_t^{\gamma+\text{part}}$ | 21.2 | 16.7 | 14.2 | 11.3 | 8.7 |
| $P_t^{\gamma+\text{jet}}$ | 21.5 | 17.0 | 14.4 | 11.5 | 8.9 |
| $P_t^{\gamma+\text{Jet}}$ | 19.3 | 14.7 | 12.3 | 9.7 | 7.4 |
| $(P_t^{\gamma} - P_t^{\gamma+\text{Jet}})/P_t^{\gamma}$ | 0.0107 | 0.0066 | 0.0046 | 0.0027 | 0.0016 |
| $1 - \cos(\Delta \phi)$ | 0.0012 | 0.0007 | 0.0004 | 0.0003 | 0.0001 |
| $P_t(O+\eta>5)/P_t^{\gamma}$ | 0.0095 | 0.0060 | 0.0041 | 0.0025 | 0.0015 |
| Entries          | 43323 | 29783 | 21707 | 12104 | 2334 |
Table 3: Selection 1. $\phi_{\gamma,\text{jet}} = 180^\circ \pm 15^\circ$. UA1 algorithm.

| $P_t^{\gamma\text{clust}}$ | 30   | 20   | 15   | 10   | 5   |
|---------------------------|------|------|------|------|-----|
| Nevent                    | 1872 | 1315 | 977  | 579  | 107 |
| $P_t^{\delta}$            | 26.7 | 21.7 | 18.8 | 15.7 | 12.7|
| $\Delta \phi$             | 2.2  | 1.7  | 1.4  | 1.1  | 0.8 |
| $P_t^{\text{cut}}$        | 19.0 | 14.5 | 12.1 | 9.7  | 7.0 |
| $P_t^{\eta>5}$            | 4.8  | 4.7  | 4.7  | 4.7  | 4.6 |
| $P_t^{5+6}$               | 21.8 | 17.6 | 15.2 | 12.7 | 10.4|
| $P_t^{\gamma+\text{part}}$| 22.1 | 17.9 | 15.5 | 12.9 | 10.6|
| $P_t^{\gamma+\text{jet}}$ | 19.9 | 15.5 | 13.1 | 10.7 | 8.6 |
| $P_t^{\gamma+\text{Jet}}$ | 19.7 | 15.4 | 13.0 | 10.6 | 8.6 |
| $(P_t^{\gamma} - P_t^{\text{jet}})/P_t^{\gamma}$ | 0.0124 | 0.0083 | 0.0059 | 0.0042 | 0.0029 |
| $1 - \cos(\Delta \phi)$   | 0.0013 | 0.0008 | 0.0005 | 0.0003 | 0.0002 |
| $P_t^{(O+\eta>5)}/P_t^{\gamma}$ | 0.0111 | 0.0076 | 0.0054 | 0.0039 | 0.0027 |
| Entries                   | 46297 | 32513 | 24157 | 14318 | 2642 |

Table 4: Selection 1. $\phi_{(\gamma,\text{jet})} = 180^\circ \pm 15^\circ$. LUCELL algorithm.

| $P_t^{\gamma\text{clust}}$ | 30   | 20   | 15   | 10   | 5   |
|---------------------------|------|------|------|------|-----|
| Nevent                    | 1752 | 1204 | 878  | 489  | 96  |
| $P_t^{\delta}$            | 26.0 | 20.7 | 17.7 | 14.2 | 10.9|
| $\Delta \phi$             | 2.1  | 1.6  | 1.3  | 1.0  | 0.7 |
| $P_t^{\text{cut}}$        | 18.4 | 13.7 | 11.3 | 8.6  | 5.9 |
| $P_t^{\eta>5}$            | 4.8  | 4.8  | 4.7  | 4.6  | 4.5 |
| $P_t^{5+6}$               | 21.1 | 16.7 | 14.2 | 11.3 | 8.7 |
| $P_t^{\gamma+\text{part}}$| 21.5 | 17.0 | 14.4 | 11.5 | 8.9 |
| $P_t^{\gamma+\text{jet}}$ | 19.2 | 14.7 | 12.3 | 9.7  | 7.4 |
| $P_t^{\gamma+\text{Jet}}$ | 19.1 | 14.6 | 12.2 | 9.6  | 7.4 |
| $(P_t^{\gamma} - P_t^{\text{jet}})/P_t^{\gamma}$ | 0.0107 | 0.0066 | 0.0046 | 0.0027 | 0.0016 |
| $1 - \cos(\Delta \phi)$   | 0.0012 | 0.0007 | 0.0004 | 0.0003 | 0.0001 |
| $P_t^{(O+\eta>5)}/P_t^{\gamma}$ | 0.0095 | 0.0060 | 0.0041 | 0.0025 | 0.0015 |
| Entries                   | 43320 | 29783 | 21707 | 12104 | 2334 |
Table 5: Selection 2. $\phi(\gamma,\text{jet}) = 180^\circ \pm 15^\circ$. UA1 algorithm.

| $P_{t,\text{cut}}$ | 30 | 20 | 15 | 10 | 5 |
|-------------------|----|----|----|----|---|
| Nevent            | 1464 | 1096 | 854 | 538 | 106 |
| $P_{t,56}$        | 24.5 | 20.3 | 17.9 | 15.2 | 12.5 |
| $\Delta \phi$     | 2.1 | 1.6 | 1.4 | 1.1 | 0.8 |
| $P_{t,\text{out}}$ | 17.4 | 13.7 | 11.6 | 9.5  | 7.0  |
| $P_{t,\eta>5}$    | 4.7 | 4.7 | 4.7 | 4.7  | 4.6  |
| $P_{t,5+6}$       | 19.7 | 16.3 | 14.3 | 12.2 | 10.2 |
| $P_{t,\gamma+\text{part}}$ | 20.2 | 16.7 | 14.7 | 12.5 | 10.5 |
| $P_{t,\gamma+\text{jet}}$ | 18.2 | 14.5 | 12.6 | 10.5 | 8.6  |
| $P_{t,\gamma+\text{Jet}}$ | 18.2 | 14.5 | 12.5 | 10.4 | 8.6  |
| $(P_{t,\gamma}-P_{t,\text{cut}})/P_{t,\gamma}$ | 0.0034 | 0.0032 | 0.0028  | 0.0029 | 0.0028 |
| $1 - \cos(\Delta \phi)$ | 0.0012 | 0.0007 | 0.0005  | 0.0003 | 0.0002 |
| $P_{t}(\Omega+\eta>5)/P_{t,\gamma}$ | 0.0022 | 0.0025 | 0.0023  | 0.0026 | 0.0026 |
| Entries           | 36198 | 27104 | 21115 | 13303 | 2610 |

Table 6: Selection 2. $\phi(\gamma,\text{jet}) = 180^\circ \pm 15^\circ$. LUCELL algorithm.

| $P_{t,\text{cut}}$ | 30 | 20 | 15 | 10 | 5 |
|-------------------|----|----|----|----|---|
| Nevent            | 1359 | 993 | 756 | 448 | 94  |
| $P_{t,56}$        | 23.6 | 19.2 | 16.6 | 13.6 | 10.8 |
| $\Delta \phi$     | 2.0  | 1.5  | 1.3  | 1.0  | 0.7  |
| $P_{t,\text{out}}$ | 16.9 | 13.0 | 10.8 | 8.4  | 5.9  |
| $P_{t,\eta>5}$    | 4.7  | 4.7  | 4.7  | 4.6  | 4.5  |
| $P_{t,5+6}$       | 19.0 | 15.3 | 13.2 | 10.7 | 8.6  |
| $P_{t,\gamma+\text{part}}$ | 19.4 | 15.7 | 13.5 | 11.0 | 8.8  |
| $P_{t,\gamma+\text{jet}}$ | 17.8 | 13.9 | 11.8 | 9.4  | 7.3  |
| $P_{t,\gamma+\text{Jet}}$ | 17.7 | 13.9 | 11.8 | 9.4  | 7.3  |
| $(P_{t,\gamma}-P_{t,\text{cut}})/P_{t,\gamma}$ | 0.0024 | 0.0020 | 0.0017  | 0.0014 | 0.0014 |
| $1 - \cos(\Delta \phi)$ | 0.0011 | 0.0006 | 0.0004  | 0.0003 | 0.0001 |
| $P_{t}(\Omega+\eta>5)/P_{t,\gamma}$ | 0.0013 | 0.0014 | 0.0013  | 0.0011 | 0.0013 |
| Entries           | 33599 | 24547 | 18686 | 11070 | 2287 |

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Table 7: Selection 3. $\phi(\gamma,jet) = 180^\circ \pm 15^\circ$. UA1 algorithm.

| $P_t^{clust}$ | 30  | 20  | 15  | 10  | 5   |
|---------------|-----|-----|-----|-----|-----|
| Nevent        | 1264| 925 | 696 | 394 | 70  |
| $P_t^{56}$    | 20.0| 16.3| 14.2| 11.7| 8.8 |
| $P_t^{out}$   | 14.4| 11.0| 9.2 | 7.3 | 5.2 |
| $P_t^{\eta>5}$| 4.7 | 4.7 | 4.7 | 4.6 | 4.7 |
| $P_t^{5+6}$   | 15.8| 12.9| 11.2| 9.2 | 6.7 |
| $P_t^{\gamma+part}$ | 16.3| 13.2| 11.5| 9.4 | 6.9 |
| $P_t^{\gamma+jet}$ | 15.3| 12.0| 10.4| 8.5 | 7.4 |
| $P_t^{\gamma+Jet}$ | 15.3| 12.0| 10.4| 8.5 | 7.3 |
| $(P_t^{\gamma}-P_t^{Jet})/P_t^{\gamma}$ | 0.0010| 0.0016| 0.0021| 0.0026| 0.00323 |
| $1-\cos(\Delta\phi)$ | 0.0008| 0.0005| 0.0003| 0.0002| 0.0001 |
| $P_t((O+\eta>5)/P_t^{\gamma}$ | 0.0002| 0.0011| 0.0018| 0.0025| 0.00312 |
| Entries       | 31247| 22829| 17991| 10301| 1692 |

Table 8: Selection 3. $\phi(\gamma,jet) = 180^\circ \pm 15^\circ$. LUCELL algorithm.

| $P_t^{clust}$ | 30  | 20  | 15  | 10  | 5   |
|---------------|-----|-----|-----|-----|-----|
| Nevent        | 1264| 925 | 696 | 394 | 70  |
| $P_t^{56}$    | 20.0| 16.3| 14.2| 11.7| 8.8 |
| $P_t^{out}$   | 14.5| 11.0| 9.2 | 7.2 | 5.1 |
| $P_t^{\eta>5}$| 4.7 | 4.7 | 4.7 | 4.6 | 4.7 |
| $P_t^{5+6}$   | 15.8| 12.9| 11.2| 9.2 | 6.7 |
| $P_t^{\gamma+part}$ | 16.3| 13.2| 11.5| 9.4 | 6.9 |
| $P_t^{\gamma+jet}$ | 15.4| 12.0| 10.3| 8.5 | 7.3 |
| $P_t^{\gamma+Jet}$ | 15.4| 12.0| 10.3| 8.4 | 7.2 |
| $(P_t^{\gamma}-P_t^{Jet})/P_t^{\gamma}$ | 0.0005| 0.0008| 0.0013| 0.0016| 0.0023 |
| $1-\cos(\Delta\phi)$ | 0.0008| 0.0005| 0.0003| 0.0002| 0.0001 |
| $P_t((O+\eta>5)/P_t^{\gamma}$ | -0.0003| 0.0004| 0.0010| 0.0014| 0.0022 |
| Entries       | 31247| 22829| 17991| 10301| 1692 |