AcerDET\[1] : a particle level fast simulation and reconstruction package for phenomenological studies on high $p_T$ physics at LHC.

\[1\] Package is available for the web page \url{http://erichter.home.cern.ch/erichter/AcerDET.html}

\textbf{Elżbieta Richter-Wąs}\[2]

\textit{Institute of Computer Science, Jagellonian University;}
\textit{30-072 Krakow, ul. Nawojki 11, Poland.}
\textit{Institute of Nuclear Physics}
\textit{31-342 Krakow, ul. Radzikowskiego 152, Poland.}

\section*{Abstract}

This paper documents package for the particle level fast simulation. The package is designed to complete the AcerMC generator framework with the easy-to-use simulation and reconstruction algorithms. The package provides, starting from list of particles in the event, the list of reconstructed jets, isolated electrons, muons and photons and reconstructed missing transverse energy. The AcerDET represents a simplified version of the package called ATLFAST, used since several years within ATLAS Collaboration. In the AcerDET version some functionalities of the former one have been removed, only the most crucial detector effects are implemented and the parametrisations are largely simplified. Therefore it is not representing in details neither ATLAS nor CMS detectors. Nevertheless, we believe that the package can be well adequate for some feasibility studies of the high $p_T$ physics at LHC and in future, after some adjustments, of other detectors as well.

\[2\] Supported in part by Polish Government grant KBN 2 P03B 001 22.
PROGRAM SUMMARY

Title of the program: **AcerDET version 1.0**

Operating system: Linux

Programming language: FORTRAN 77 with popular extensions.

External libraries: CERNLIB.

Size of the compressed distribution directory: about 25 kB.

Key words: Fast simulation, Physics at LHC.

Nature of physical problem: A particle level fast simulation and reconstruction package. The package provides, starting from the list of particles in the event, list of reconstructed jets, isolated electrons, muons and photons and reconstructed missing transverse energy. The package is aimed to complete the AcerMC framework [1] with the easy-to-use simulation and reconstruction algorithms. The interface subroutines to PYTHIA 6.2 [2] or HERWIG 6.3 [3] are provided. Distribution version includes also example of the main program for execution with PYTHIA 6.2 generator. Implemented set of parametrisations is not representing in details ATLAS or CMS detectors, some of them are simple and can be considered rather as place-holders for future adaptation of any detector. Nevertheless, we believe that the package will be well adequate for some feasibility studies on the high \( p_T \) physics at LHC.

[1]. B. Kersevan and E. Richter-Was, *The Monte Carlo event generator AcerMC version 1.0 with interfaces to PYTHIA 6.2 and HERWIG 6.3*, [hep-ph/0201302](http://kersevan.home.cern.ch/borut). Comp. Phys. Commun. in print., [http://kersevan.home.cern.ch/borut](http://kersevan.home.cern.ch/borut)

[2]. T. Sjostrand et al., *High energy physics generation with PYTHIA 6.2*, eprint [hep-ph/0108264](http://arxiv.org/abs/hep-ph/0108264), LU-TP 01-21, August 2001.

[3]. G. Marchesini et al., Comp. Phys. Commun. **67** (1992) 465, G. Corcella et al., JHEP **0101** (2001) 010.
1 Introduction

The potential of the LHC detectors for physics at high $p_T$ will be very rich, see [1] for comprehensive review. Prospects for observability of e.g. the Higgs boson(s), Supersymmetry particles, Exotic particles, New Vector Bosons is very impressive. All these thanks to the high sensitivity of the detectors in terms of acceptance and identifying efficiencies to variety of signatures: photons, electrons, muons, multi-b-jets, tau-jets, missing transverse energy.

Those high sensitivities will allow to study very exclusive signatures and so the discovery potential will be limited in some cases by the rare background processes. It is becoming evident that the multi-jet and multi-b-jet production in association with known vector bosons, W and/or Z, or with top-quark pair will be the serious background to the several observables as well. As so, should be understood beyond the leading order. One will likely need to understand well effects coming from the finite width or angular spin correlations (e.g. from the intermediate resonances decays). Moreover one should be able to understand limitations and complementarity of the matrix element and parton shower predictions for the diversity of signatures.

The package for particle-level simulation and reconstruction is one of the intermediate steps between simple parton-level analysis and very sophisticated and CPU consuming full detector simulation. The package provides, starting from list of particles in the event, list of reconstructed jets, isolated electrons, muons and photons and reconstructed missing transverse energy. It can serve for several phenomenological feasibility studies on the prospects for observability of a given signature. One of the example of such application reported in [4] are studies on prospects for observability of the invisibly decaying Higgs boson in the $t\bar{t}H$ production process. Our package can be also useful for the dedicated comparisons between matrix element and parton shower predictions. In that case one can compare experimental signatures (reconstructed jets, leptons, photons) to quantify size of the discrepancies between different predictions in straightforward way. Such comparison was recently reported in [5] for $Wb\bar{b}$, $Zb\bar{b}$ and $t\bar{t}$ processes.

The package simulates some key features of the LHC detectors like ATLAS and CMS. It is based on the calorimetric energy deposition for jets reconstruction and tracks reconstruction for electrons and muons. It takes into account very high granularity of the electromagnetic calorimetry for the photon reconstruction. The missing transverse energy is calculated for the total energy balance of the reconstructed objects. The capability for the identification of b-jets and tau-jets is also explored. Implemented set of parameterisations is not representing in details performance of neither ATLAS nor CMS detectors. Nevertheless, we believe that the package will be adequate for some feasibility studies on the high $p_T$ physics at LHC and offer option also for LC.

The paper is organised as follows. In Section 2 we discuss algorithms used for objects reconstruction and show benchmarking distributions. Section 3 gives an outlook. Some comparison numbers with the performance of the ATLAS detector are collected in Appendix A. In the Appendixes B-F we give more technical details concerning input parameters and output structure. In Appendix G we show control output.
2 Simulation and reconstruction

Fully or partially generated event i.e. event generated including or not QED/QCD initial and final state radiation, fragmentation, hadronisation and decays of unstable particles can be analysed by this package. The list of the partons/particles of the generated event should be rewritten (including information on their history) from the event record, filled by the event generator, to the COMMON /ACMCEVENT/. Stored there information is used by the AcerDET algorithms for event simulation and reconstruction.

Events simulation is limited to the following steps:

- Deposition of the particles energies in the calorimetric cells.
- Smearing of the energy of electrons, photons, muons with the parametrised resolutions.
- Smearing of the energy of hadronic clusters and not-clustered cells with the parametrised resolution.

Events reconstruction is limited to the following steps:

- Reconstruction of the calorimetric clusters.
- Verification of the isolation criteria for electrons/photons/muons.
- Rejection of clusters associated with electrons and photons.
- Acceptation of remaining clusters as hadronic jets and identification (labeling) of those associated with b-quarks, c-quarks, tau-leptons.
- Jets energy calibration.

There is no clear separation between the simulation and reconstruction parts in the structure of algorithms. Some larger blocks (subroutines) might realise both tasks.

As a final result provided are four-momenta of reconstructed electrons, photons, muons, labeled and calibrated jets and calculated is total missing transverse energy.

2.1 Calorimetric clusters

The transverse energy of all undecayed particles stored in COMMON /ACMCEVENT/, except for muons, neutrinos and other invisible particles\(^3\) eg. the lightest SUSY particle, are summed up in the map of calorimetric cells with a given granularity in \((\eta \times \phi)\) coordinates (default: \(0.1 \times 0.1\) for \(|\eta| < 3.2\) and \(0.2 \times 0.2\) for \(|\eta| > 3.2\), with the calorimetric coverage up to \(|\eta| = 5.0\)). As an effect of the solenoidal magnetic field in the inner part of the detector we assume that the \(\phi\) position of charged particles with transverse momenta above the threshold (default: \(p_T > 0.5\) GeV) will be shifted as parametrised in function FLDPHI. The contribution from all charged particles with transverse momenta below that threshold is neglected.

\(^3\)User may want to make any particle invisible to the detector. For this one should redefine its code in the COMMON /ACMCEVENT/ to that specified for the invisible particles in acerdet.dat file.
All calorimetric cells with the transverse energy greater than a given threshold (default: $E_T > 1.5$ GeV) are taken as possible initiators of clusters. They are scanned in order of decreasing $E_T$ to verify whether the total $E_T$ summed over all cells in a cone $\Delta R = \sqrt{\Delta^2 \eta + \Delta^2 \phi}$ exceeds the minimum required threshold for the reconstructed cluster (default $E_T > 5$ GeV). Cells with deposited transverse energy below the threshold (default: $E_T = 0$) are not accounted for. As a coordinates $(\eta^{clu} \times \phi^{clu})$ of the reconstructed cluster taken are the coordinates of the bary-center of the cone weighted by the cells $E_T$ for all cells inside the cone around the initiator cell.

All reconstructed clusters are stored in the COMMON /CLUSTE/. Fig. 1 shows the $\Delta \eta$ (left) and $\Delta \phi$ (right) distribution between the reconstructed bary-center of particles falling within the geometrical cluster cone and the reconstructed cluster position.

2.2 Isolated muons

Algorithm reconstructing isolated muons uses information of the generated muons, reconstructed calorimetric clusters and the cells map.

Isolated muon candidates are searched for in the COMMON /ACMCEVENT/. The inverse muon four-momentum is smeared according to the Gaussian resolution parametrised with function RESMUO (default: $\sigma = 0.05 \% \cdot p_T$). The muon direction remains unsmeared.

For all muons which pass selection criteria in $p_T$ and $\eta$ (default: $p_T > 6$ GeV and $|\eta| < 2.5$ GeV), isolation criteria, in terms of the distance from calorimetric clusters and of maximum transverse energy deposition in cells in a cone around the muon, are then applied (defaults: separation by $\Delta R > 0.4$ from other clusters and $\sum E_T < 10$ GeV in a cone $\Delta R = 0.2$ around the muon). All muons passing the isolation criteria are stored in COMMON /ISOMUO/ and those not passing are stored in COMMON /NIOMUO/.

As a control physics process the $gg \rightarrow H \rightarrow ZZ^* \rightarrow 4\mu$ production with the Higgs boson mass of 130 GeV is used. The default isolation selection has 97.8% efficiency for...
muons passing kinematical selection with $p_{T}^{\mu_{1}, \mu_{2}} > 20 \text{ GeV}$ and $p_{T}^{\mu_{3}, \mu_{4}} > 7 \text{ GeV}$. As the predicted intrinsic width of the Higgs boson of this mass is very small, the resolution is completely dominated by the resolution assumed for the single muon reconstruction. Fig. 2 (left) shows the reconstructed distribution of the 4-muon system. The assumed single muon transverse momenta resolution of $\sigma = 0.05\% \cdot p_{T}$ leads to the $\sigma_{m} = 1.57 \text{ GeV}$ resolution for the invariant mass of the four-muon system originating from the $H \rightarrow ZZ^{*} \rightarrow 4\mu$ decay. Please note that the photon bremsstrahlung was omitted in the event generation.

The second control physics process is the di-jet production. Here we don’t expect isolated muons to be present, just muons from the semileptonic cascade within the jets. Nevertheless some of those muons will also pass isolation criteria. Fig. 2 (right) shows the $p_{T}$ distribution of the true (dashed) and classified as isolated (solid) muons passing the default selection criteria.

Figure 2: Left: The reconstructed mass, $m_{4\mu}$, for $H \rightarrow ZZ^{*} \rightarrow 4\mu$ events with $m_{H} = 130 \text{ GeV}$; Right: the transverse momenta spectrum of true (solid) and reconstructed isolated (dashed) muons in the di-jet sample generated with $p_{T}^{\text{hard}} > 17 \text{ GeV}$.

2.3 Isolated electrons

Algorithm reconstructing isolated electrons uses information of the generated electrons, reconstructed calorimetric clusters and the cells map.

Isolated electron candidates are searched for in the COMMON /ACMCEVENT/. The electron four-momentum is smeared according to the Gaussian resolution parametrised with function RESELE (default: $\sigma = 12\%/\sqrt{E}$). The electron direction remains unsmeared.

For all electrons which pass selection criteria in $p_{T}$ and $\eta$ (default: $p_{T} > 5 \text{ GeV}$ and $|\eta| < 2.5 \text{ GeV}$), the associated reconstructed calorimeter cluster is identified (default: $\Delta R_{e,\text{cluster}} < 0.1$). Electron isolation criteria, in terms of the distance from other clusters and of maximum transverse energy deposition in cells in a cone around the electron, are then applied (defaults: separation by $\Delta R > 0.4$ from other clusters and $\sum E_{T} < 10 \text{ GeV}$ in a cone $\Delta R = 0.2$ around the electron). All electrons passing the isolation criteria are
stored in COMMON /ISOELE/ and the clusters associated with them are removed from the COMMON /CLUSTE/.

As a control physics process the $gg \rightarrow H \rightarrow ZZ^* \rightarrow 4e$ production with the Higgs boson mass of 130 GeV is used. The default isolation selection has 95.2% efficiency for electrons passing kinematical selection with $p_{T}^{e_1,e_2} > 20$ GeV and $p_{T}^{e_3,e_4} > 7$ GeV. As the predicted intrinsic width of the Higgs boson of this mass is very small, the resolution is completely dominated by the resolution assumed for the single electron reconstruction. Fig. 3 (left) shows the reconstructed distribution of the 4-electron system. The assumed single electron energy resolution of $\sigma = 12%/\sqrt{E}$ leads to the $\sigma_m = 1.26$ GeV resolution for the reconstructed invariant mass of the four-electron system originating from the $H \rightarrow ZZ^* \rightarrow 4e$ decay. Please note that the photon bremsstrahlung was omitted in the events generation.

The second control physics process is the di-jet production. Here we don’t expect isolated electrons to be present, just electrons from the semileptonic cascade or Dalitz decays within the jets. Nevertheless some of these electrons will also pass isolation criteria. Fig. 3 (right) shows the $p_T$ distribution of the true (dashed) and classified as isolated (solid) electrons passing the default selection criteria.

Figure 3: Left: The reconstructed mass, $m_{4e}$, for $H \rightarrow ZZ^* \rightarrow 4e$ events with $m_H = 130$ GeV; Right: the transverse momenta spectrum of true (solid) and reconstructed isolated (dashed) electrons in the di-jet sample generated with $p_{T}^{\text{hard}} > 17$ GeV.

2.4 Isolated photons

Algorithm reconstructing isolated photons uses information of the generated photons, reconstructed calorimetric clusters and the cells map.

Isolated photon candidates are searched for in the COMMON /ACMCEVENT/. The photon four-momentum is smeared according to the Gaussian resolution parametrised with function RESPHO (default: $\sigma = 10%/\sqrt{E}$). The photon direction remains unsmeared.

For all photons which pass selection criteria in $p_T$ and $\eta$ (default: $p_T > 5$ GeV and $|\eta| < 2.5$ GeV), the associated reconstructed calorimeter cluster is identified (default:
Photon isolation criteria, in terms of the distance from other clusters and of maximum transverse energy deposition in cells in a cone around the photon, are then applied (defaults: separation by $\Delta R > 0.4$ from other clusters and $\sum E_T < 10 \text{ GeV}$ in a cone $\Delta R = 0.2$ around the photon). All photons passing the isolation criteria are stored in COMMON /ISOPHO/ and the clusters associated with them are removed from the COMMON /CLUSTE/.

As a control physics process the Standard Model $gg \to H \to \gamma\gamma$ production with the Higgs boson mass of 100 GeV is used. The isolation selection has 98.0\% efficiency for photons passing the kinematical selection of $p_T^1 > 40 \text{ GeV}$ and $p_T^2 > 25 \text{ GeV}$. As the predicted intrinsic width of the Higgs boson of this mass is much below 1 GeV, the resolution of the reconstructed invariant mass of the di-photon system is completely dominated by the resolution assumed for the single photon reconstruction. Fig. 4 (left) shows the reconstructed distribution of the di-photon system of photons passing selection criteria. The assumed energy resolution of $\sigma = 10\%/\sqrt{E}$ leads to the $\sigma_m = 0.85 \text{ GeV}$ resolution for the reconstructed invariant mass of the di-photon system originating from the $H \to \gamma\gamma$ decay.

The second control physics process is the di-jet production. Here we don’t expect isolated photons to be present, just photons from the radiative cascade or $\pi'$s decays within the jets. Nevertheless, some of those photons will also pass isolation criteria. Fig. 4 (right) shows the $p_T$ distribution of the true (dashed) and classified as isolated (solid) photons passing the default selection criteria.

![Figure 4](image)

**Figure 4:** *Left:* The reconstructed mass, $m_{\gamma\gamma}$, for $H \to \gamma\gamma$ events with $m_H = 100 \text{ GeV};$ *Right:* the transverse momenta spectrum for true (solid) and reconstructed isolated (dashed) photons in the di-jet sample generated with $p_T^{\text{hard}} > 17 \text{ GeV}.$

### 2.5 Jets

Clusters which have not been selected as associated with electrons or photons are smeared with Gaussian resolution parametrised in function RESHAD (default: $\sigma = 50\%/\sqrt{E}$ and $100\%/\sqrt{E}$).
Figure 5: The ratio of \( p_{T}^{u-jet} / p_{T}^{u-quark} \) (left) and \( p_{T}^{b-jet} / p_{T}^{b-quark} \) (right) for events generated with hard process only (top), hard process and ISR/FSR (middle) and full generation (hard process + ISR/FSR + hadronisation) (bottom). Events are calibrated only in case of the full generation (bottom plots). The HP denotes hard process, ISR/FSR initial and final state radiation respectively and HD denotes hadronisation.
If the non-isolated muon falls into the cone of a cluster its 4-momenta is added to
the cluster 4-momenta and the cluster direction is recalculated. The resulting clusters are
classified as jets if their transverse momentum is greater than a given threshold (default: $p_T > 15 \text{ GeV}$). They are removed from the common `/CLUSTE/` and stored in the common
common `/JETALL/`

The jets reconstruction efficiencies and di-jet mass resolution have been studied using
control physics process of the $WH$ production with $m_H = 100 \text{ GeV}$ and forcing the Higgs
boson decay into specific partons, namely $H \rightarrow u\bar{u}$, $H \rightarrow c\bar{c}$ and $H \rightarrow b\bar{b}$. We used
also process $gg \rightarrow H \rightarrow \tau\tau$ for estimating tau-jet reconstruction efficiency (we forced
tau-leptons decay into hadrons). For estimating reconstruction efficiency we consider
only jets which have been reconstructed within the cone $\Delta R = 0.4$ from the primary
parton (particle) and we require that the primary parton (particle) has passed the same
kinematical selection as required for reconstructed jets.

2.5.1 Labeling

Very important for the physics at LHC are jets originating from b-quarks (so called b-jets)
which can be identified in the detector using b-tagging technique (vertex or soft-lepton
tags). The package labels a jet as a b-jet if it is reconstructed within a limited rapidity
range (default: $|\Delta \eta| < 2.5$) and if a b-quark of a transverse momenta (after FSR) above
the threshold (default: $p_T > 5 \text{ GeV}$) is found within the cone (default: $\Delta R = 0.2$) around
the axis of reconstructed jet. The similar criteria are used for labeling the c-jets.

Equivalently important are also jets originating from the hadronic $\tau$-decay (so called
$\tau$-jets) which can be identified using dedicated algorithms. The package labels jet as
a tau-jet if the hadronic decay product is relatively hard (default: $p_T^{\tau-\text{had}} > 10 \text{ GeV}$),
inside limited rapidity range (default: $|\eta| < 2.5$), dominates reconstructed jet transverse
momenta (default: $p_T^{\tau-\text{had}}/p_T^{\text{jet}} > 0.9$), and is within the cone (default: $\Delta R_{\text{jet,}\tau-\text{had}} < 0.3$)
around the axis of a jet.

Table 1 summarises the jets reconstruction+labeling efficiencies as obtained for the
$WH, H \rightarrow b\bar{b}, c\bar{c}, u\bar{u}$ and $gg \rightarrow H \rightarrow \tau\tau$ events. Jets labeling is optional, can be switched
off for b- and c-jets and/or separately for tau-jets (default: ON).

Table 1: Efficiency for jet reconstruction+labeling for different types of initial partons with $p_T^{\text{parton}} > 15 \text{ GeV}$ (required $p_T^{\text{jet}} > 15 \text{ GeV}$). The rapidity coverage is limited to $|\eta| < 2.5$.
The $\Delta R_{\text{cone}} = 0.4$ is used for cluster reconstruction and $\Delta R_{\text{cone}} = 0.2$ is used for matching
criteria. The $WH, H \rightarrow b\bar{b}, c\bar{c}, u\bar{u}$ and $gg \rightarrow H \rightarrow \tau\tau$ processes were generated with
$m_H = 100 \text{ GeV}$. In case of tau-jets only hadronic tau decays were generated.

| Parton type | Reconstruction + Labeling |
|-------------|---------------------------|
| u-quark     | 95%                       |
| b-quark     | 81%                       |
| c-quark     | 87%                       |
| tau-jet     | 80%                       |
2.5.2 Calibration

The reconstructed jets four-momenta need to be corrected for the out-cone energy loss (cascade outside the jet-cone) and for the loss of the particles escaping detection (those below threshold at $p_T = 0.5$ GeV, neutrinos, invisible particles, muons outside acceptance range or below the observability threshold). Such correction, called calibration, can be performed on the statistical basis only. The single default calibration function (the same for any type of jets), as a function of transverse momenta of reconstructed jet, $p_T^{\text{jet}}$, is provided in the package. The calibration algorithm corrects jets four-momenta without altering their direction. Calibration can be switched off (default: ON).

The quality of the calibration algorithm can be verified by monitoring the ratio of $p_T^{b\text{-quark}} / p_T^{b\text{-jet}}$, taking into account a hard-process quark which originates a given jet. One can note, (see Fig. 5, bottom plots) that the implemented calibration function has a tendency to undercalibrate b-jets while calibrates reasonably well u-jets. We can observe also rather large tail in the $p_T^{\text{jet}} / p_T^{b\text{-quark}}$ distribution, caused by the semileptonic b-quarks decays and larger spread of the cascading particles than in the case of light jets.

2.5.3 Reconstruction of the resonance

As an effect of the hadronisation and cascading decays, the expected resolution for the resonance reconstruction in the hadronic channels will be much worse than in the leptonic ones. The precision for reconstructing the peak position of the invariant mass of the di-jet system will relay on the precision of the calibration procedure. Fig. 6 shows two examples of the reconstruction of invariant mass of the di-jet system in the $WH$ production with $H \rightarrow u\bar{u}$ and $H \rightarrow b\bar{b}$ decays. The long tail at the lower side of the invariant mass distribution is an effect of hadronisation and cascading decays which was not sufficiently corrected by the imposed calibration. One may also notice the effect of the ISR/FSR originated jets contributing to the distribution in the low mass range for the $H \rightarrow u\bar{u}$ case where jets identification is more ambiguous.

![Figure 6: Left: The reconstructed mass, $m_{jj}$, for the $WH$ with $H \rightarrow u\bar{u}$ (left) and $H \rightarrow b\bar{b}$ (right) events with $m_H = 100$ GeV.](image-url)
2.6 Missing transverse energy

The missing transverse energy is calculated by summing the transverse momenta of identified isolated photons, electrons and muons, of jets and clusters not accepted as jets and of non-isolated muons not added to any jet. Finally, the transverse energies deposited in cells not used for clusters reconstruction are also included in the total sum. Transverse energies deposited in unused cells are smeared with the same energy resolution function as for jets, and cells with deposited transverse energy below a given threshold (default: 0 GeV) are excluded from the sum. From the calculation of the total sum $E_{T}^{\text{obs}}$, the missing transverse energy is obtained, $E_{T}^{\text{miss}} = E_{T}^{\text{obs}}$ as well as the missing transverse momentum components $p_{x}^{\text{miss}} = -p_{x}^{\text{obs}}$, $p_{y}^{\text{miss}} = -p_{y}^{\text{obs}}$. The total calorimeter transverse energy, $\sum E_{T}^{\text{calo}}$, is calculated as the sum of all the above transverse energies except that of muons. Please note, that missing transverse energy is calculated from the energy balance before jets calibration is performed, as the possible out-cone energy loss is already taken into account by summing up energy deposition of unused cells/clusters.

Fig. 7 shows the resolution of the transverse missing energy obtained for the di-jet events generated with the transverse momenta of the hard process above 17 GeV.

![Figure 7: The $p_{x}^{\text{miss}}$ and $p_{y}^{\text{miss}}$ resolutions for the di-jet events.](image)

2.7 Additional efficiencies

The algorithms of the AcerDET package are not correcting for inefficiencies of photon, electron and muon reconstruction and identification. To be more realistic, one should apply a weighting factor of 70%-90% for each isolated lepton used in the analysis and of 80% for each isolated photon.

The package is also not correcting for tagging-efficiencies, namely the labeling procedure is not equivalent to the b- and tau-jet identification in the experiment. One can assume b-tagging efficiency of 60% per b-labeled jet with mistagging probability of 10% for c-labeled jet and 1% for the light jet. For the tau-jets using efficiency of 50% (per tau-labelled jet) and 5 - 10 % mistagging probability for other jets could be a reasonable
assumptions. One should be well aware that what proposed above represents quite crude estimates.

The package is also not correcting for trigger efficiencies which has to be applied in addition if a given reconstructed object is foreseen to trigger an event.

2.8 OUTPUT format

By the end of the simulation and reconstruction algorithm, reconstructed entities: photons, electrons, muons, jets, transverse missing energy are rewritten to the set of COMMON BLOCKS. Provided is algorithm to store this information in the PAW HBOOK [6] data-base, so called PAW NTUPLE. However, the user might decide to use his preferred data-base technology for storing output from the simulation and reconstruction algorithms.

3 Outlook

We presented package which can be useful for several phenomenological studies on the high $p_T$ physics at LHC. One of the favoured application might be the comparison studies on the matrix element and parton shower Monte Carlo predictions for different background processes at LHC, like eg. presented in [6]. It is not the aim of the package to represent in details performance of neither ATLAS nor CMS detectors, nevertheless some global features of these would be reproduced well. In particular we believe that the analyses performed with the package for physics at LHC will be more realistic than parton-level studies alone. The package allows also for rather flexible adjusting of several key parameters which characterise features of any detector for LHC or LC experiments.

Acknowledgments

This work was inspired by the several years of my involvement in the activity of the Physics Working Groups of the ATLAS Collaboration. I am grateful to all colleagues for a very creative atmosphere. In particular for several suggestions and inspiring discussions to Daniel Froidevaux, who some years ago initiated and guided my work on the first version of the fast simulation package.
References

[1] ATLAS Collaboration, ATLAS Detector and Physics Performance TDR, ATLAS TDR 15, CERN/LHCC/99-15, 25 May 1999.

[2] E. Richter-Was, D. Froidevaux and L. Poggioli, ATLAS Internal Note ATL-PHYS-98-131 (1998).

[3] B. Kersevan and E. Richter-Was, The Monte Carlo event generator AcerMC version 1.0 with interfaces to PYTHIA 6.2 and HERWIG 6.3, hep-ph/0201302, Comp. Phys. Commun. in print.

[4] B. Kersevan, M. Malawski and E. Richter-Was, Prospects for observing an invisibly decaying Higgs boson in the $t\bar{t}H$ production at the LHC, hep-ph/0207014.

[5] B. Kersevan and E. Richter-Was, What is the $Wb\bar{b}$, $Zb\bar{b}$ and $t\bar{t}b\bar{b}$ background at LHC, hep-ph/0203148, JHEP in print.

[6] CERN program Library Long Writeups Y250. HBOOK Statistical Analysis and Histogramming, Reference Manual.

[7] T. Sjostrand et al., High energy physics generation with PYTHIA 6.2, eprint hep-ph/0108264, LU-TP 01-21, August 2001.

[8] G. Marchesini et al., Comp. Phys. Commun. 67 (1992) 465, G. Corcella et al., JHEP 0101 (2001) 010.
A  AcerDET versus ATLAS detector fast and full simulation

Below we compare few benchmarking numbers obtained with the AcerDET code, the fast simulation of ATLAS detector ATLFAST[2] and the results from the full simulation/reconstruction expected with ATLAS detector[1] at the luminosity of $10^{33} cm^{-2}s^{-1}$. Numbers are given after event selection as foreseen for the analysis in the specific channel[1].

Table 2: Benchmarking numbers for fast simulation AcerDET, ATLFAST package and results from full simulation of ATLAS detector at the luminosity of $10^{33} cm^{-2}s^{-1}$

| Parton type | AcerDET $\sigma_m$ | ATLFAST $\sigma_m$ | ATLAS full sim. $\sigma_m$ |
|-------------|---------------------|---------------------|-----------------------------|
| $H \rightarrow \gamma\gamma$ ($m_H = 100$ GeV) | 0.85 GeV | 1.0 GeV | 1.1 GeV |
| $H \rightarrow ZZ \rightarrow 4e$ ($m_H = 130$ GeV) | 1.26 GeV | 1.45 GeV | 1.5 GeV |
| $H \rightarrow ZZ \rightarrow 4\mu$ ($m_H = 130$ GeV) | 1.57 GeV | 1.34 GeV | 1.4 GeV |
| $H \rightarrow ZZ \rightarrow 2e2\mu$ ($m_H = 130$ GeV) | 1.40 GeV | 1.40 GeV | 1.5 GeV |
| $WH, H \rightarrow bb$ ($m_H = 100$ GeV) | 10 GeV | 12.5 GeV | 14.7 GeV |
| $E_T^{miss}$ resolution (di-jet events $p_T^{hard} > 17$ GeV) | 5.0 GeV | 5.7 GeV | 6.3 GeV |

B  General informations

The simulation and reconstruction algorithm is executed by a call to the routine ACERDET. The events which is going to be processed should be stored in the COMMON /ACMCEVENT/:

```
INTEGER N, K
REAL P, V
COMMON/ACMCEVENT/N,K(10000,5),P(10000,5),V(10000,5)
```

The convention for the particles status, mother-daughter relations, particles codes, etc. should be the same as in the COMMON /PYJETS/ of the PYTHIA 6.2 event generator[7].

The input/output logical identifiers should be defined in COMMON /ACDNOUT/:

```
INTEGER NINP,NOUT
COMMON/ACDNOUT/ NINP,NOUT
```

The package reads single input file acerdet.dat which contains parameters for events simulation and reconstruction and write out single control output file acerdet.out. If initialised by the user in the main program, control histograms and ntuple with reconstructed events will be stored in the acerdet.ntup file.
B.1 Subroutine ACERDET

This is the main subroutine, called to execute simulation and reconstruction algorithms. The following modes of executing this subroutine are implemented:

- **MODE=-1** – initialisation, which should be called before the first event is processed.
- **MODE= 0** – simulation and reconstruction, should be called event by event.
- **MODE= 1** – finalisation, should be called after last event is processed.

This subroutine invokes other subroutines: ACDINF, ACDINI, ACDCEL, ACDCLU, ACDELE, ACDMUO, ACDPHO, ACDJET, ACMIS, ACDBJE, ACDCJE, ACDTAU and ACDCAL.

B.2 Interfaces to Event Generators

The event, which is going to be processed, should be stored in the COMMON /ACMCEVENT/. In the source code of the program provided are subroutines ACDPYTHIA6 and ACDHERWIG6 which respectively fill the COMMON /ACMCEVENT/ with the event content from COMMON /PYJETS/ (for PYTHIA generator) and COMMON /HEPEVT/ (for HERWIG generator [8]). In the second case also the convention for status of the particles is modified and made consistent with that used by the ACERDET.

B.3 External calling sequence

The following calling sequence should be provided in the main program

```fortran
Initialise Generator
CALL ACERDET(-1)
CALL ACERDETNTUP(-1)
DO II= 1,NEVENT
   Generate Event (PYTHIA) or Generate Event (HERWIG)
   CALL ACDPYTHIA6 or CALL ACDHERWIG6
   CALL ACERDET(0)
   CALL ACERDETNTUP(0)
ENDDO
Finalise Generator
CALL ACERDET(1)
CALL ACERDETNTUP(1)
```

Invoking subroutine ACERDETNTUP is optional. It stores data-base with processed events in the HBOOK NTUPLE [6] from cernlib library. It creates also output file for storing control histograms and ntuple in acerdet.ntup. User however may decide on a different output format.

If user do not wish, the dependencies on cernlib could be easily removed. It requires linking into executable the respective library and providing very simple conversion package where the existing calls to cernlib functions for random number generation and histograming are used to fill information into the user’s preferred ones.

B.4 Execution sequence

After the initialisation phase, the event by event execution sequence is a following one:
- Map of the cells energy deposition is created: **SUBROUTINE ACDCEL**.
- Calorimetric clusters are reconstructed: **SUBROUTINE ACDCLU**.
- Isolated and non-isolated muons are reconstructed: **SUBROUTINE ACDMUO**.
- Isolated electrons are reconstructed: **SUBROUTINE ACDELE**.
- Isolated photons are reconstructed: **SUBROUTINE ACDPHO**.
- The remaining calorimetric clusters are identified as jets: **SUBROUTINE ACDJET**.
- Missing transverse is calculated for the reconstructed event: **SUBROUTINE ACDMIS**.
- Optionally, if specified in the acerdet.dat file, algorithms for jets labeling and calibration of jets are executed (default=ON): **SUBROUTINE ACDBJE**, **SUBROUTINE ACDCJE**, **SUBROUTINE ACDTAU**, **SUBROUTINE ACDCAL**
- Reconstructed event is stored in the final common blocks: **SUBROUTINE ACDOUT**.

The respective sequence of calls is executed in the **SUBROUTINE ACERDET**.

### B.5 Structure of the distribution version

The distribution version consists of the source code of the AcerDET and example of the main program for execution with PYTHIA 6.2 generator. The **acerdet.dat** file resides in subdirectory **acerdet.dat**. Source code resides in **acerdet_src** with includes files stored in **acerdet_inc**. The library will be created in **acerdet_lib**. provided is also example of the main program **demo.f** to execute AcerDET algorithms with PYTHIA 6.2 generator.

To execute the package following actions should be taken:

- In subdirectory **acerdet_src** type: `make install`. It will compile the code and create the **libacerdet.a** library in **acerdet_lib** subdirectory.
- Edit **makefile** in main directory to define PYPATH and CERNLIB environmental variables.
- In main directory type: `make`. It will create **demo.exe** executable.
- Optional: Edit **run.dat** file in subdirectory **prod** to redefine generated process, number of events, random seed, etc.
- In main directory type: `make run`. It will create link to the **acerdet.dat** file in **prod** subdirectory and will execute the executable. Output will be stored in subdirectory **prod**.
C List of input parameters: acerdet.dat file

C-------- flags and switches -----------------------
  10000 --- LPAR(1) ....id for histograms
           1 --- LPAR(2) ....smearing on=1, off=0
           1 --- LPAR(3) ....B-field on=1, off=0
           66 --- LPAR(4) ....code for invisible particle
           1 --- LPAR(5) ....b- and c-labeling on=1, off=0
           1 --- LPAR(6) ....tau-labeling on=1, off=0
           1 --- LPAR(7) ....calibration on=1, off=0

C-------- parameters for ACDCEL -------------------
           5.000 --- YPAR(1) ....rapidity coverage
           0.500 --- YPAR(2) ....min p_T for B-field
           0.000 --- YPAR(3) ....min E_T for cell
           3.200 --- YPAR(4) ....eta transition in cells granularity
           0.100 --- YPAR(5) ....granularity in eta (within YPAR(17)), 2x outside
           0.100 --- YPAR(6) ....granularity in phi (within YPAR(17)), 2x outside

C-------- parameters for ACDCLU -------------------
           5.000 --- YPAR(10) ....minimum E_T for cluster
           0.400 --- YPAR(11) ....cone R for clustering
           5.000 --- YPAR(12) ....rapidity coverage
           1.500 --- YPAR(13) ....min E_T for cluster initiator

C-------- parameters for ACDMUO -------------------
           6.000 --- YPAR(20) ....minimum muon-momenta to be detected
           2.500 --- YPAR(21) ....maximum muon eta to be detected
           0.400 --- YPAR(27) ....min R_lj for muon-isolation
           0.200 --- YPAR(28) ....R_cone for energy deposition
           10.000 --- YPAR(29) ....max energy deposition for isol

C-------- parameters for ACDPHO -------------------
           5.000 --- YPAR(30) ....minimum photon-momenta to be isol
           2.500 --- YPAR(31) ....maximum photon eta to be isol
           0.150 --- YPAR(35) ....min R_lj for photon-jet
           0.400 --- YPAR(37) ....min R_lj for photon-isolation
           0.200 --- YPAR(38) ....R_cone for energy deposition
           10.000 --- YPAR(39) ....max energy deposition for isol

C-------- parameters for ACDELE -------------------
           5.000 --- YPAR(40) ....minimum electron-momenta to be isol
           2.500 --- YPAR(41) ....maximum electron eta to be isol
           0.150 --- YPAR(45) ....min R_lj for electron-jet
           0.400 --- YPAR(47) ....min R_lj for electron-isolation
           0.200 --- YPAR(48) ....R_cone for energy deposition
           10.000 --- YPAR(49) ....max energy deposition for isol

C-------- parameters for ACDEJET ------------------
           10.000 --- YPAR(51) ....jets energy_min threshold
           5.000 --- YPAR(52) ....rapidity coverage for jets

C-------- parameters for ACDJET -------------------
           5.000 --- YPAR(61) ....minimum b-quark pT (after FSR) momenta for b-jet label
           2.500 --- YPAR(62) ....maximum b-quark eta for b-jet label
           0.200 --- YPAR(63) ....max R_bj for b-jet label

C-------- parameters for ACDJET -------------------
           5.000 --- YPAR(71) ....minimum c-quark pT (after FSR) momenta for c-jet label
           2.500 --- YPAR(72) ....maximum c-quark eta for c-jet label
           0.200 --- YPAR(73) ....max R_cj for c-jet label

C-------- parameters for ACDJET -------------------
           10.000 --- YPAR(90) ....minimum tau-had pT for tau-jet label
           2.500 --- YPAR(91) ....maximum tau-eta for tau-jet label
           0.300 --- YPAR(92) ....max R_tauj for tau-jet
           0.900 --- YPAR(93) ....max R_tauj for tau-jet

C-------- parameters for ACDMIS -------------------
           0.000 --- YPAR(80) ....min E_T for energy in cell to count unused cell

C-------- end of data files -----------------------
D Reconstructed entities

Isolated photons are stored in COMMON /ACDPHOT/, given are 4-momenta in the laboratory frame $\text{P}_{X\text{PHOT}}, \text{P}_{Y\text{PHOT}}, \text{P}_{Z\text{PHOT}}, \text{E}_{\text{EPHOT}}$, and code for the photon $\text{KFPHOT} = 22$. Photons are ordered with the decreasing transverse momenta.

```
INTEGER MAXPHOT
PARAMETER(MAXPHOT=12)
INTEGER NPHOT,KFPHOT
REAL PXPHOT,PYPHOT,PZPHOT,EEPHOT
COMMON /ACDPHOT/ NPHOT,KFPHOT(MAXPHOT),
+ PXPHOT(MAXPHOT),PYPHOT(MAXPHOT),PZPHOT(MAXPHOT),
+ EEPHOT(MAXPHOT)
```

Isolated leptons are stored in COMMON /ACDLEPT/, given are 4-momenta in the laboratory frame $\text{P}_{X\text{LEPT}}, \text{P}_{Y\text{LEPT}}, \text{P}_{Z\text{LEPT}}, \text{E}_{\text{ELEPT}}$, and code for the lepton $\text{KFLEPT} = \pm 11, \pm 13$. Leptons are ordered with the decreasing transverse momenta.

```
INTEGER MAXLEPT
PARAMETER(MAXLEPT=12)
INTEGER NLEPT,KFLEPT
REAL PXLEPT,PYLEPT,PZLEPT,EELEPT
COMMON /ACDLEPT/ NLEPT,KFLEPT(MAXLEPT),
+ PXLEPT(MAXLEPT),PYLEPT(MAXLEPT),PZLEPT(MAXLEPT),
+ ELEPT(MAXLEPT)
```

Reconstructed jets stored in COMMON /ACDJETS/, given are 4-momenta in the laboratory frame $\text{P}_{X\text{JETS}}, \text{P}_{Y\text{JETS}}, \text{P}_{Z\text{JETS}}, \text{E}_{\text{EEJETS}}$, and code for the jet $\text{KFJETS} = 5, 4, 15, 98$; respectively for b-jets, c-jets, tau-jets and light-jets. Jets are ordered with the decreasing transverse moment.

```
INTEGER MAXJET
PARAMETER(MAXJET=20)
INTEGER NJETS,KFJETS
REAL PJETS,PYJETS,PZJETS,EEJETS
COMMON /ACDJETS/ NJETS,KFJETS(MAXJET),
+ PJETS(MAXJET),PYJETS(MAXJET),PZJETS(MAXJET),
+ EEJETS(MAXJET)
```

Information on the reconstructed missing transverse energy is stored in COMMON /ACDMISS/. Given are both transverse components $\text{P}_{X\text{MISS}}, \text{P}_{Y\text{MISS}}$, sum of transverse momenta components of neutrinos and invisible particles (as defined by the user) present in the event $\text{P}_{X\text{NUES}}, \text{P}_{Y\text{NUES}}$ and finally sum of the total transverse energy components deposited in the calorimeter $\text{P}_{X\text{CALO}}, \text{P}_{Y\text{CALO}}$.

```
REAL PXMISS,PYMISS,PXNUES,PYNUES,PXCALO,PYCALO
COMMON /ACDMISS/ PXMISS,PYMISS,PXNUES,PYNUES,PXCALO,PYCALO
```

For the convenience stored is also information on the history of all particles participating in the hard-scattering in which event was created. Included are those with the status code $= 21$ (convention of PYTHIA generator). Given is: status of particle $\text{KSPART}$, its flavour code $\text{KFPART}$ and 4-momenta in the laboratory frame $\text{P}_{X\text{PART}}, \text{P}_{Y\text{PART}}, \text{P}_{Z\text{PART}}, \text{E}_{\text{EPART}}$.
E Parametrisation for energy/momenta resolution

E.1 Function RESPHO

The parametrisation for photon energy resolution assumes only energy dependence and the Gaussian smearing with 10%/$\sqrt{E_\gamma}$ resolution.

$$E_{\gamma}^{\text{smeared}} = E_{\gamma}^{\text{true}} \cdot (1 + r_n \cdot 0.10 \sqrt{E_{\gamma}^{\text{true}}}).$$  \hspace{1cm} (1)

Where $r_n$ is the random number generated according to the Gaussian distribution (function RANNOR from cernlib library is used). All 4-momenta components of the photon are smeared with the same resolution so the direction of the photon is not altered.

E.2 Function RESELE

The parametrisation for electron energy resolution assumes only energy dependence and the Gaussian smearing with 12%/$\sqrt{E_e}$ resolution.

$$E_e^{\text{smeared}} = E_e^{\text{true}} \cdot (1 + r_n \cdot 0.12 \sqrt{E_e^{\text{true}}}).$$  \hspace{1cm} (2)

Where $r_n$ is the random number generated according to the Gaussian distribution (function RANNOR from cernlib library is used). All 4-momenta components of the electron are smeared with the same resolution so the direction of the electron is not altered.

E.3 Function RESHAD

The parametrisation for clusters momenta resolution assumes only energy dependence and Gaussian smearing with 50%/$\sqrt{E_{\text{clus}}}$ or 100%/$\sqrt{E_{\text{clus}}}$ resolution. The transition region, $|\eta^{\text{clus}}| = \text{CALOTH}$ is the same as the transition of the cells granularity.

For $|\eta^{\text{clus}}| < \text{CALOTH}$:

$$E_{\text{clus}}^{\text{smeared}} = E_{\text{clus}}^{\text{true}} \cdot (1 + r_n \cdot 0.50 \sqrt{E_{\text{clus}}^{\text{true}}}).$$  \hspace{1cm} (3)

For $|\eta^{\text{clus}}| > \text{CALOTH}$:

$$E_{\text{clus}}^{\text{smeared}} = E_{\text{clus}}^{\text{true}} \cdot (1 + r_n \cdot 1.00 \sqrt{E_{\text{clus}}^{\text{true}}}).$$  \hspace{1cm} (4)
Where \( r_n \) is the random number generated according to the Gaussian distribution (function \texttt{RANNOR} from \texttt{cernlib} library is used). All 4-momenta components of the muon are smeared with the same resolution so the direction of the muon is not altered.

### E.4 Function RESMUO

The parametrisation for muon momenta resolution assumes only transverse momenta dependence and Gaussian smearing with 0.0005 \( \cdot \) \( pT_\mu \) resolution.

\[
pT_\mu^{\text{smeared}} = \frac{pT_\mu^{\text{true}}}{(1 + r_n \cdot 0.0005 \cdot pT_\mu^{\text{true}})}.
\]

(5)

Where \( r_n \) is the random number generated according to the Gaussian distribution (function \texttt{RANNOR} from \texttt{cernlib} library is used). All 4-momenta components of the muon are smeared with the same resolution so the direction of the muon is not altered.

### E.5 Function FLDPHI

The effect of the magnetic field is included by simple shifting the \( \phi \) position of the charged particles respectively to its transverse momenta, parametrised as following:

\[
\delta \phi = 0.5 / pT_{\text{part}}.
\]

(6)

The \( \delta \phi \) is calculated in radians and \( pT_{\text{part}} \) is given in \( GeV \). The sign of the \( \delta \phi \) is the same as the sign of the particle charge. Charged particles with \( pT_{\text{part}} < 0.5 \) GeV are assumed to be looping in the detector and not depositing energy in the calorimeter.

### F Some formulas

We work with the assumptions of massless reconstructed objects. The following relations were used to translate between \((p_T, \eta, \phi)\) coordinates and four-momenta \((p_x, p_y, p_z, E)\).

\[
p_x = p_T \cdot \cos(\phi)
\]

(7)

\[
p_y = p_T \cdot \sin(\phi)
\]

(8)

\[
p_z = p_T \cdot \cosh(\eta)
\]

(9)

\[
E = p_T \cdot \sinh(\eta)
\]

(10)

\[
p_T = \sqrt{p_x^2 + p_y^2}
\]

(11)

\[
\eta = \text{sign}(\ln \frac{\sqrt{p_T^2 + p_z^2} + |p_z|}{p_T}, p_z)
\]

(12)

\[
\phi = \text{asinh}(p_y / \sqrt{p_x^2 + p_y^2})
\]

(13)
G. Output content

G.1 Output ntuple content: acerdet.ntup file

The content of the ntuple is exactly as described in the previous section. As an auxiliary info, within the stored information, could be provided code on the generated process, IDPROC.

| Ntuple ID | Entries | ACERDET |
|-----------|---------|---------|
| 3333      | 100000  |         |

| Var numb | Type | Packing | Range | Block | Name          |
|----------|------|---------|-------|-------|---------------|
| 1        | I    | 4       |       | ACDINFO | IDPROC      |
| 1        | R    | 4       |       | ACDMISS | PXMISS      |
| 2        | R    | 4       |       | ACDMISS | PYMISS      |
| 3        | R    | 4       |       | ACDMISS | PXNUES      |
| 4        | R    | 4       |       | ACDMISS | PYNUES      |
| 5        | R    | 4       |       | ACDMISS | PXCALO     |
| 6        | R    | 4       |       | ACDMISS | PYCALO     |
| 1        | I    | 4       | [0,12]| ACDLEPT | NLEPT       |
| 2        | I    | 4       |       | ACDLEPT | KFLEPT(NLEPT) |
| 3        | R    | 4       |       | ACDLEPT | PXLEPT(NLEPT) |
| 4        | R    | 4       |       | ACDLEPT | PYLEPT(NLEPT) |
| 5        | R    | 4       |       | ACDLEPT | PZLEPT(NLEPT) |
| 6        | R    | 4       |       | ACDLEPT | EELLEPT(NLEPT) |
| 1        | I    | 4       | [0,12]| ACDPHOT | NPHOT      |
| 2        | I    | 4       |       | ACDPHOT | KFPHOT(NPHOT) |
| 3        | R    | 4       |       | ACDPHOT | PXPHOT(NPHOT) |
| 4        | R    | 4       |       | ACDPHOT | PYPHOT(NPHOT) |
| 5        | R    | 4       |       | ACDPHOT | PZPHOT(NPHOT) |
| 6        | R    | 4       |       | ACDPHOT | EEPHOT(NPHOT) |
| 1        | I    | 4       | [0,20]| ACDJETS | NJETS       |
| 2        | I    | 4       |       | ACDJETS | KFJETS(NJETS) |
| 3        | R    | 4       |       | ACDJETS | PJETS(NJETS) |
| 4        | R    | 4       |       | ACDJETS | PYJETS(NJETS) |
| 5        | R    | 4       |       | ACDJETS | PZJETS(NJETS) |
| 6        | R    | 4       |       | ACDJETS | EEJETS(NJETS) |
| 1        | I    | 4       | [0,40]| ACDPART | NPART      |
| 2        | I    | 4       |       | ACDPART | KFPART(NPART) |
| 3        | I    | 4       |       | ACDPART | KPART(NPART) |
| 4        | R    | 4       |       | ACDPART | PXPART(NPART) |
| 5        | R    | 4       |       | ACDPART | PYPART(NPART) |
| 6        | R    | 4       |       | ACDPART | PZPART(NPART) |
| 7        | R    | 4       |       | ACDPART | EEPART(NPART) |

| Block | Entries | Unpacked | Packed | Packing Factor |
|-------|---------|----------|--------|---------------|
| 1     | 100000  | 4        | 4      | 1.000          |
| 2     | ACDMISS | 100000   | 24     | 24            | 1.000          |
| 3     | ACDLEPT | 100000   | 244    | Var.          | Variable       |
| 4     | ACDPHOT | 100000   | 244    | Var.          | Variable       |
| 5     | ACDJETS | 100000   | 404    | Var.          | Variable       |
| 6     | ACDPART | 100000   | 964    | Var.          | Variable       |
| Total | ---     | 1884     | Var.   | Variable       |

| Blocks | 6    | Variables | 32    | Max. Columns | 471 |

---

21
G.2 Control printout: acerdet.out file

***************************************************************************
* * *
* ************************** *
* AcerDET, version: 1.0 *
* Released at: 30.07.2002 *
* ************************** *
* Simplied event simulation and reconstruction package *
* by E. Richter-Was *
* Institute of Computer Science *
* Jagellonian University, Cracow, Poland *
***************************************************************************
***************************************************************************
* ********************************* *
* * ***************** * *
* * *** ACDCEL *** * *
* * ***************** * *
* ********************************* *
* clusters definition .... *
* 5.00000 eta coverage ETACEL *
* 3.20000 eta gran. transition CALOTH *
* 0.10000 gran in eta(central) DBETA *
* 0.10000 gran in phi(central) DBPHI *
* B field apply .... *
* 1 B-field on/off KEYFLD *
* 0.50000 p_T min non looping PTMIN *
* invisible particles ..... *
* 66 KF code for invis KFINVS *
***************************************************************************
***************************************************************************
* ********************************* *
* * ***************** * *
* * *** ACDCLU *** * *
* * ***************** * *
* ********************************* *
* clusters definition .... *
* 5.00000 E_T_min cluster ETCLU *
* 1.50000 E_T_min cell initia ETINI *
* 0.40000 R cone RCONQ *
* 5.00000 eta coverage ETACLU *
* 3.20000 eta gran. transition CALOTH *
***************************************************************************
***************************************************************************
* ********************************* *
* * ***************** * *
* * *** ACMDMU *** * *
* * ***************** * *
* ********************************* *
* muon isolation .... *
* 6.00000 min. muon p_T PTUMIN *
* 2.50000 max. muon eta ETAMAX *
* 0.40000 min R_lj for isolat. RISDLJ *
* 0.20000 R for energy deposit RDEP *
* 10.00000 max E_dep for isolat EDMAX *
* 0.00000 min. muon p_T unsmea PTUMIT *
* 1 smearing on/off KEYSME*
***************************************************************************
electron isolation ....
- 5.00000 min. lepton p_T PTLMIN
- 2.50000 max. lepton eta ETAMAX
- 0.15000 max R_ej for ele-clu RJE
- 0.40000 min R_lj for isolat. RISDLJ
- 0.20000 R for energy deposit RDEP
- 10.00000 max E_dep for isolat EDMAX
- 1 smearing on/off KEYSME

photon isolation ....
- 5.00000 min. photon p_T PTLMIN
- 2.50000 max. photon eta ETAMAX
- 0.15000 max R_gam-clust RJE
- 0.40000 min R_isol RISOLJ
- 0.20000 R for energy deposit RDEP
- 10.00000 max E_dep for isolat EDMAX
- 1 smearing on/off KEYSME

clusters definition ....
- 0.40000 R cone RCDONE
- 10.00000 E_T_jets [GeV] ETJET
- 5.00000 eta coverage jets ETAJET
- 1 smearing on/off KEYSME

muon coverage ....
- 6.00000 min. muon p_T PTUMMIN
- 2.50000 max. muon eta ETAMAX
- 1 unused cells KEYSME
- 0.00000 cells threshold ETCCELL
- 66 KF code for invis KFINVS
jets labeling ....
 1  labeling on/off KEYBCL
jets definition ....
  10.0000  E_T_jets [GeV] ETJET
   b-jets............. ....
     5.00000  min b-quark p_T PTBMIN
     2.50000  max b-quark eta ETBMAX
     0.20000  max R_bj for b-jet RJB
jets labeling ....
 1  labeling on/off KEYBCL
jets definition ....
  10.0000  E_T_jets [GeV] ETJET
   c-jets.............
     5.00000  min c-quark p_T PTCMIN
     2.50000  max c-quark eta ETCMAX
     0.20000  max R_cj for c-jet RJC
jets labeling ....
 1  labeling on/off KEYBCL
jets definition ....
  10.0000  E_T_jets [GeV] ETJET
  tau-jets.............
    10.00000  min tau-had p_T PTTAU
    2.500000  max tau-had eta ETATAU
    0.300000  max R_tauj for tau-j RJTAU
    0.900000  tau-had frac. of jet PTFRAC
jets calibration ....
 1  calibration n/off KEYCAL
### G.3 Control histograms: acerdet.ntup file

Below is the list of control histograms which monitors performance of the simulation/reconstruction. They are stored together with `ACERDET` ntuple in file `acerdet.ntup`.

| Number | Description |
|--------|-------------|
| 10001  | ACDCEL: cells multiplicity |
| 10010  | ACDCLU: clusters multiplicity |
| 10111  | ACDCLU: delta phi clu-barycentre |
| 10112  | ACDCLU: delta eta clu-barycentre |
| 10113  | ACDCLU: delta r clu-barycentre |
| 10123  | ACDCLU: delta r clu-parton |
| 10144  | ACDCLU: pTclu/SumpTparticle |
| 10124  | ACDCLU: pTclu/pTparton |
| 10210  | ACDMUO: muon multiplicity NOISOLATED |
| 10211  | ACDMUO: muon multiplicity ISOLATED |
| 10221  | ACDMUO: muon multiplicity HARD |
| 10231  | ACDMUO: muon multiplicity HARD+isol |
| 10311  | ACDELE: electron multiplicity ISOLATED |
| 10321  | ACDELE: electron multiplicity HARD |
| 10331  | ACDELE: electron multiplicity HARD+isol |
| 10411  | ACDPHO: photon multiplicity ISOLATED |
| 10421  | ACDPHO: photon multiplicity HARD |
| 10431  | ACDPHO: photon multiplicity HARD+ISO |
| 10501  | ACDJET: jets multiplicity |
| 10511  | ACDJET: delta phi jet-barycentre |
| 10512  | ACDJET: delta eta jet-barycentre |
| 10513  | ACDJET: delta r jet-barycentre |
| 10523  | ACDJET: delta r jet-parton |
| 10514  | ACDJET: pTjet/SumpTparticle |
| 10524  | ACDJET: pTjet/pTparton |
| 10611  | ACDMIS: reconstructed p_T |
| 10612  | ACDMIS: reconstructed p_T +cells |
| 10613  | ACDMIS: pTmiss |
| 10621  | ACDMIS: p_T nu |
| 10711  | ACDJBE: b-jets multiplicity |
| 10721  | ACDJBE: b-quarks HARD multiplicity |
| 10723  | ACDJET: delta r bjet-bquark |
| 10724  | ACDJET: pTbjet/pTbquark |
| 10811  | ACDJE: c-jets multiplicity |
| 10821  | ACDJE: c-quarks HARD multiplicity |
| 10823  | ACDJET: delta r cjet-cquark |
| 10824  | ACDJET: pTcjet/pTcquark |
| 10911  | ACDCAU: tau-jets multiplicity |
| 10921  | ACDCAU: taus multiplicity |
| 11010  | ACDCAL: calibration entry |
| 11011  | ACDCAL: calibration factor |
| 11020  | ACDCAL: pTjetCALIB/pTparton |
| 11030  | ACDCAL: pTjetNONCALIB/pTparton |