Study of photons selection in the HERA-B electromagnetic calorimeter

Maxim Korotkov
Moscow Institute for Physics and Technology (State University)
Institutskii per.,6, Dolgoprudnii, Russian Federation
Email: maxim_korotkov@mail.ru

The selection of photons using parameters of reconstructed clusters in the electromagnetic calorimeter has been investigated. Photons from $\pi^0 \rightarrow \gamma\gamma$ decay were used in the analysis. For comparison the study was made also for pions from $K_s \rightarrow \pi^+\pi^-$ decay.

1 Introduction

1.1 The electromagnetic calorimeter(ECAL) of the HERA-B experiment

HERA-B is a fixed target experiment at the 920 GeV/c proton beam of the HERA ep collider at DESY in Hamburg, Germany(Fig.2). The detector was designed and optimised to deal with high rates for the study of the CP symmetry violation in the B Mesons system. The trigger and the data acquisition system are flexible enough to access physics topics ranging from B hadron spectroscopy to detailed investigations of heavy quark, J/ψ and Upsilon production mechanisms.

The main task of the ECAL subsystem is to provide a fast pretrigger signal for the First Level Trigger (FLT) on electron/positron candidates coming from J/ψ decay. Moreover it must supply positron measurements, an electron-hadron separation, and photon trigger and detection.

To fulfil these requirements a sampling calorimeter of the *shashlik* type has been designed. The detector is located at ∼13.5 m distance from the target and is made by a matrix of 56 columns times 42 rows of *shashlik* modules. Each calorimeter module is made of a square cross-section tower, where active scintillator layers alternate with the converter ones, all being crossed by optical fibers light guides. The granularity of the detector is increasing for decreasing distances from the beam axis, in order to keep the maximum occupancy at a level smaller than 10. Therefore ECAL has been subdivided into three sections: *Inner, Middle* and *Outer*(Fig.1). In the *Inner* region the converter material is a (W-Ni-Fe) metal alloy, in order to have a small Moliere radius (∼1.3 cm) and the containment depth is ∼23 radiation length (X_o). In the *Middle* and *Outer* sections, where the track density decreases, the converter is lead, the Moliere radius is (∼3.5 cm) and the containment is ∼20 X_o.

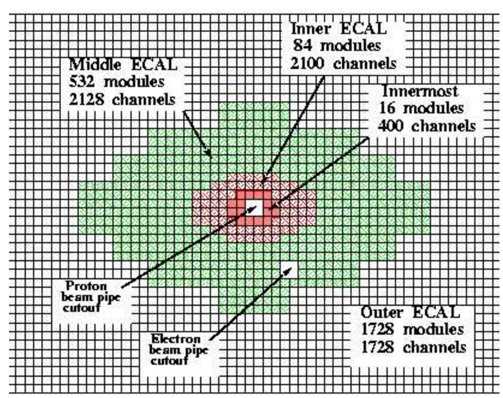

Fig. 1: *HERA-B electromagnetic calorimeter.*

1.2 Definition of variables for further analysis

Reconstruction of π^0 and K_s mesons was performed by their decay products, $\pi^0 \rightarrow \gamma\gamma$ and $K_s \rightarrow \pi^+\pi^-$. The data from physics runs with selected J/ψ were used for further analysis. Information on the electromagnetic clus-

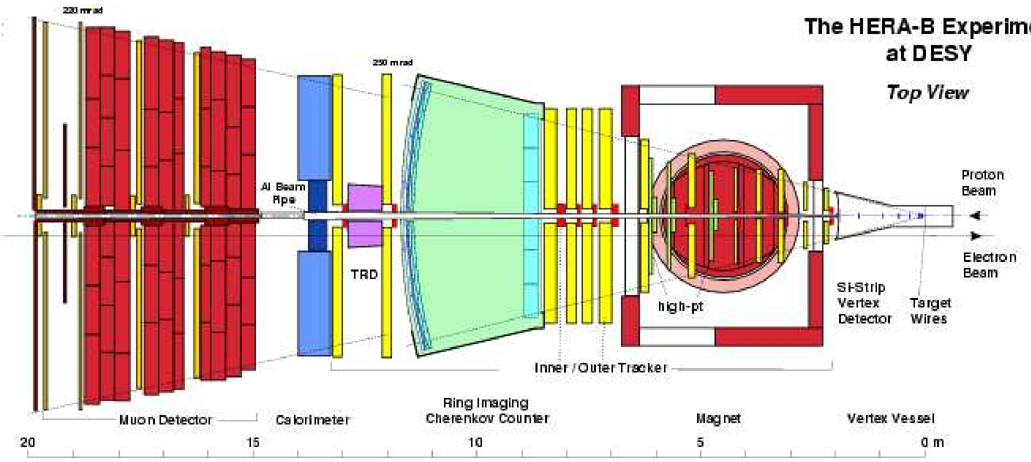

Fig. 2: *HERA-B detector components.*

ters and reconstructed tracks was taken from the RCCL(cluster table) and RTRA(reconstructed tracks) tables (of the HERA-B DST), respectively. Some definitions used in the study (names are taken from the table RCCL) are following: Asymmetry is the sum of energy in 3 cells with maximum energy divided by total energy of the cluster:

$$Asymmetry = \sum_{i=1}^{3} E_{cell}^{max} / E_{cluster},$$

Width of cluster is the number of cells included in cluster. E_t is the transverse energy:

$E_t = \sqrt{P_x^2 + P_y^2}$, where P_x, P_y are x,y component of photon momentum.

$Significance = \frac{N_{Signal}}{\sqrt{N_{Signal}+N_{Background}}}$, where N_{signal} - number of events in the π^0 or K_s peak, $N_{background}$ - number of events under $\pi^0(K_s)$ peak.

2 Data analysis

2.1 Invariant mass reconstruction

The amount of $\pi^0 \to \gamma\gamma$ decays produced in the interactions of a proton with the target of the HERA-B detector provides a big sample of data. In most cases the photons from π^0 decay are reconstructed as two independent ECAL *clusters.* The cluster consists usually from several neigboring cells (the typical example is a matrix of 3×3 cells). Energy distribution of clusters for photons is shown in Fig.5.

For fitting of the π^0 mass distribution(Fig.3) we used fitting function: Gaussian + $a \cdot x^2 + b \cdot x + c$. The signal and background were measured

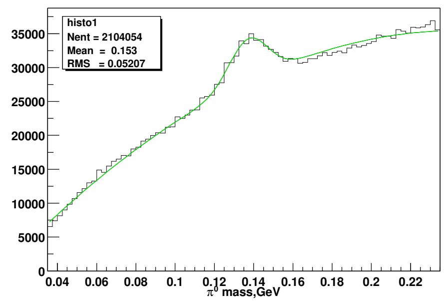

Fig. 3: *The invariant mass distribution of* π^0.

in the region: $0.107 < \pi^o mass < 0.167$ GeV.

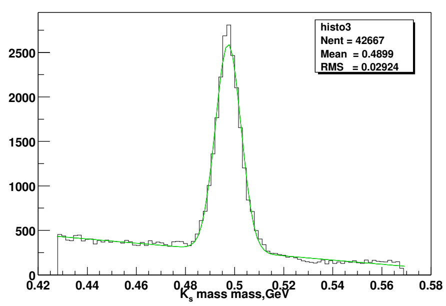

Fig. 4: *The invariant mass distribution of* K_s.

For fitting of the K_s mass distribution(Fig.4) the function is: Gaussian $+ a \cdot x + b$. The signal and background were measured in the range: $0.482 < K_s mass < 0.512$ GeV.

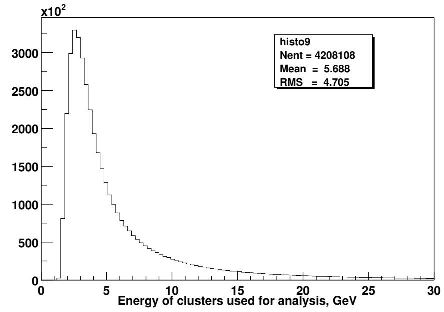

Fig. 5: *Distribution of energy of clusters used in analysis.*

2.2 A study of cut on width of cluster

In the following analysis clusters with $E_t > 0.35$ were used. A distribution of *width of clusters* in different parts of ECAL for photons and hadrons is presented in fig's.6-11. As one may observe the distributions for photons in different parts look similar, but differ from distributions for hadrons.

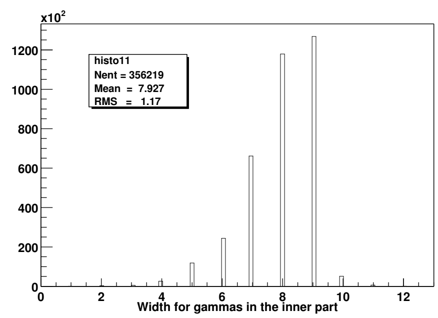

Fig. 6: *Distribution of the width of cluster for γ in the Inner part of ECAL.*

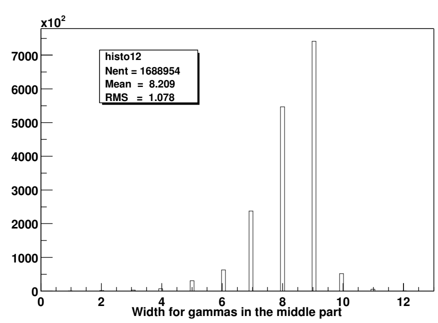

Fig. 7: *Distribution of the width of cluster for γ in the Middle part of ECAL.*

We make different cuts on *width of cluster* and *cluster energy* to study effects for gammas

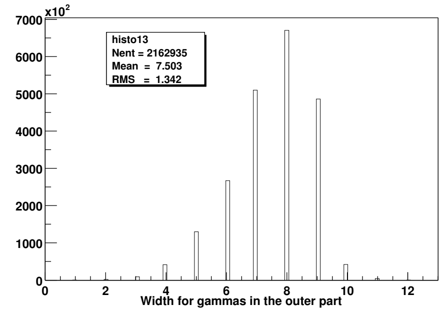

Fig. 8: *Distribution of the width of cluster for γ in the Outer part of ECAL.*

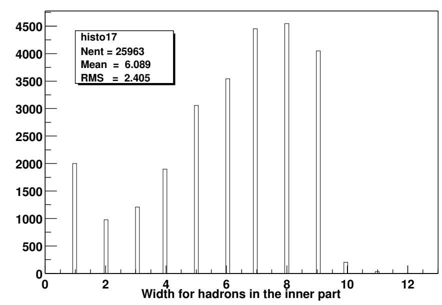

Fig. 9: *Distribution of the width of cluster for hadrons in the Inner part of ECAL.*

and hadrons. The average energy of all clusters used in π^0 analysis was 6 GeV, and 13 GeV and 21 GeV with cuts $E_\gamma > 5$ GeV and $E_\gamma > 10$ GeV, correspondingly. The fraction of decays extracted with given cut with respect to the number of decay reconstructed without cut was evaluated. Therefore each curve for different *cluster energy* starts at point where the *fraction* is equal to 1, but the number of particles analysed with different cuts on *cluster energy* are not the same. From figures 12-15 one can see that cut on *width of cluster* > 5 gives us: for π^0 *fraction and significance* stay almost at the same level as without cut. But for K_s we reject about 70% of hadrons when we make no cut on *cluster energy*, and about 15-20% with cuts on *cluster energy* more than 5 GeV and 10 Gev. The cut on *width of cluster* > 5 looks reasonable.

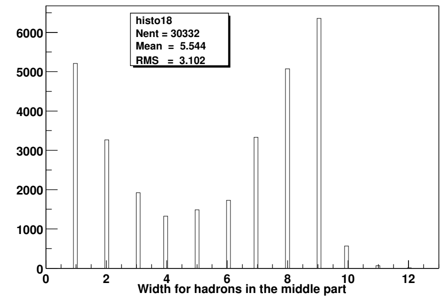

Fig. 10: *Distribution of the width of cluster for hadrons in the Middle part of ECAL.*

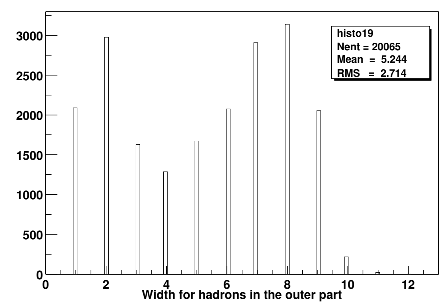

Fig. 11: *Distribution of the width of cluster for hadrons in the Outer part of ECAL.*

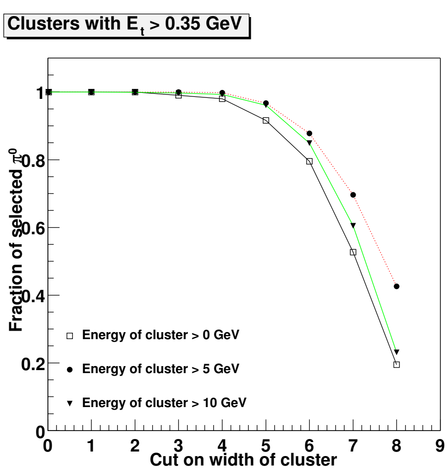

Fig. 12: *The fraction of π^0 signal as a function of the cut on the width of cluster.*

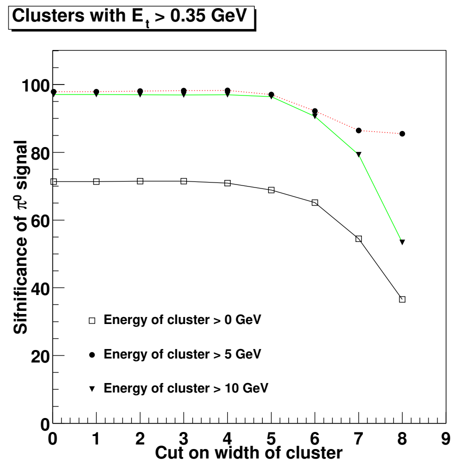

Fig. 13: *The significance of π^0 signal as a function of the cut on the width of cluster.*

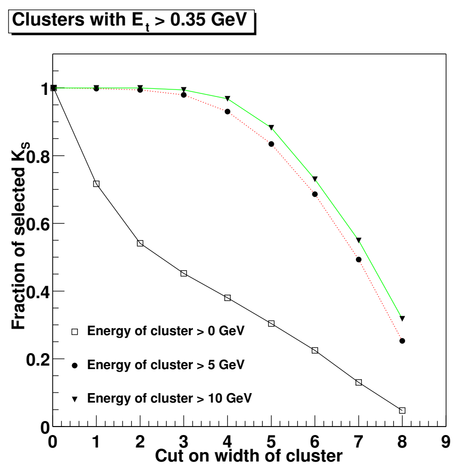

Fig. 14: *The fraction of K_s signal as a function of the cut on the width of cluster.*

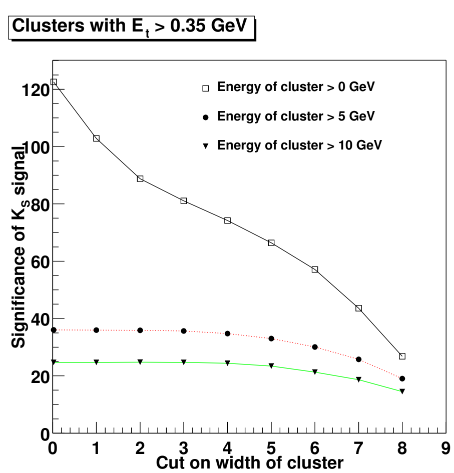

Fig. 15: *The significance of K_s signal as a function of the cut on the width of cluster.*

2.3 A study of cut on asymmetry

A distribution of the *cluster asymmetry* in different parts of the ECAL for photons and hadrons is presented in Fig.16-21. The distributions for photons (hadrons) detected in different parts of the ECAL look quite similar. At the same time, the distributions for photons and hadrons are very different.

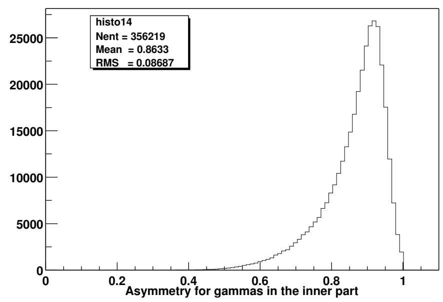

Fig. 16: *Distribution of the cluster asymmetry for* γ *in the Inner part of ECAL.*

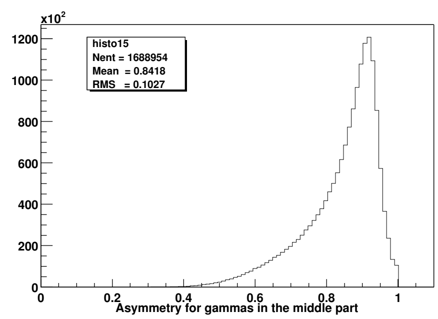

Fig. 17: *Distribution of the cluster asymmetry for* γ *in the Middle part of ECAL.*

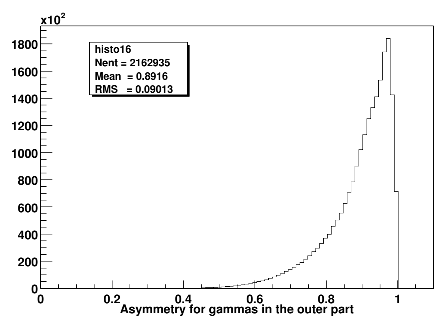

Fig. 18: *Distribution of the cluster asymmetry for* γ *in the Outer part of ECAL.*

The fraction and the significance of the π^0, K_s signal are studied as a function of the *asymmetry*

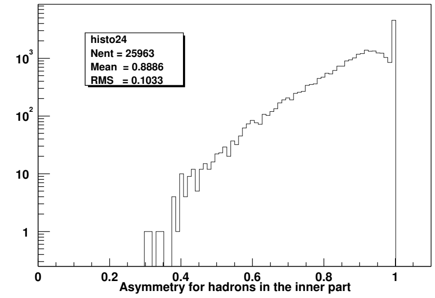

Fig. 19: *Distribution of the cluster asymmetry for hadrons in the Inner part of ECAL.*

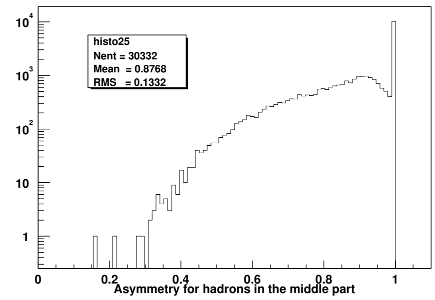

Fig. 20: *Distribution of the cluster asymmetry for hadrons in the Middle part of ECAL.*

of cluster for various energy of the clusters and presented in fig.22-25. From fig.23 one may see that a cut, cluster asymmetry > 0.8, provides the significance of the π^0 signal to be higher than without any cut. As a conclusion, the cut, cluster asymmetry > 0.8, rejects about 40-50% particles from K_s signal while preserve about 80-95% of particles from π^0 signal.

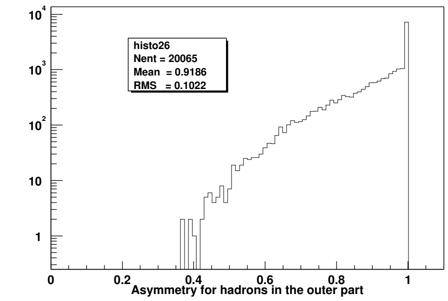

Fig. 21: *Distribution of the cluster asymmetry for hadrons in the Outer part of ECAL.*

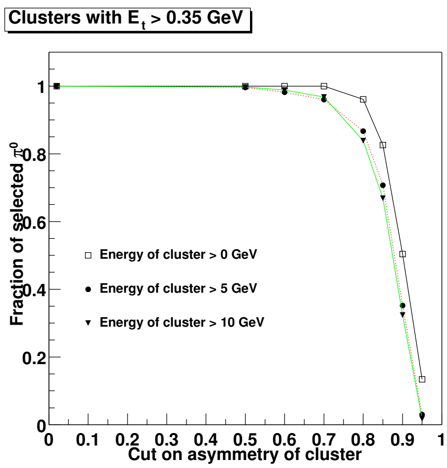

Fig. 22: *The fraction of π^0 signal as a function of the cut on the asymmetry of cluster.*

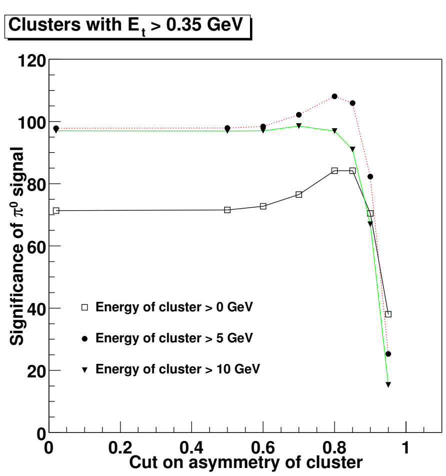

Fig. 23: *The significance of π^0 signal as a function of the cut on the asymmetry of cluster.*

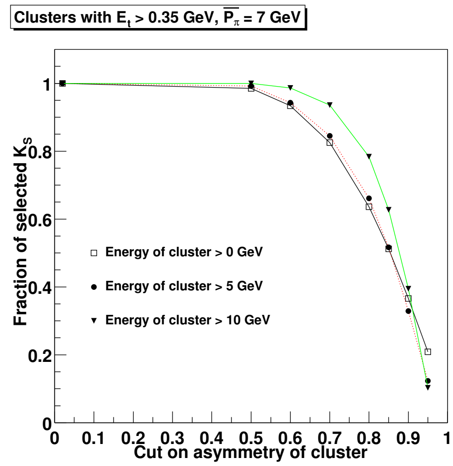

Fig. 24: *The fraction of K_s signal as a function of the cut on the asymmetry of cluster.*

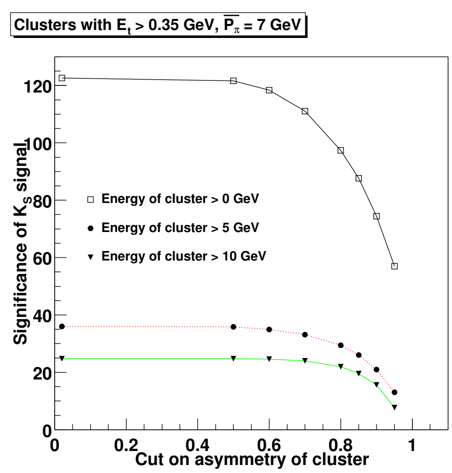

Fig. 25: *The significance of K_s signal as a function of the cut on the asymmetry of cluster.*

2.4 Cut on E_t

In this section clusters with width > 5 and asymmetry >0.8 are analysed. The fraction and the significance for the π^0 signal as a function of the cut on the transverse energy, E_t, are shown in fig.26 and 27, respectively. One may see that if a cut on the transverse energy, E_t, is take to be more than 0.2 GeV, this would lead to a lost of 30-90% of particles of π^0 signal and the significance of the signal becomes much lower. Therefore, one may conclude, that a lower cut on E_t is preferable.

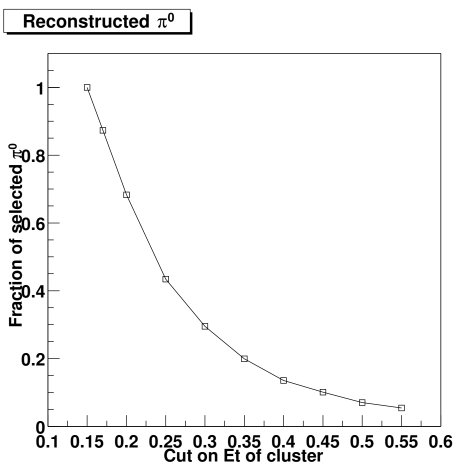

Fig. 26: *The fraction as a function of the cut on E_t.*

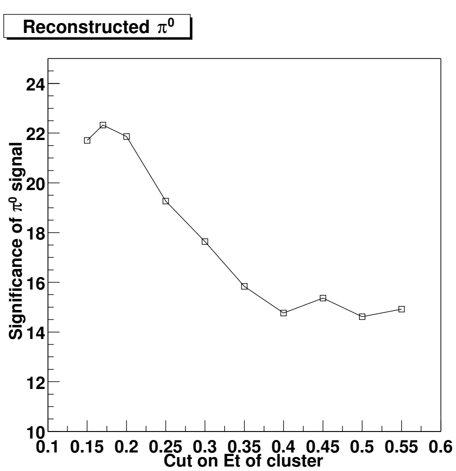

Fig. 27: *The significance as a function of the cut on E_t.*

3 Conclusion

The study of photons selection using a various cuts on the *width of cluster*, the it asymmetry of cluster and the transverse energy was carried out. Using the fraction of the reconstructed particles and the significance of the signal as criterions one may recommend the following cuts for photons selection: it width of cluster > 5, *asymmetry of cluster* > 0.8, transverse energy $E_t >$ 0.2 GeV.

Acknowledgements

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