Photon identification in the MPD-ECAL with V3 geometry

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Previous presentations:

V. Riabov, https://indico.jinr.ru/event/899/ (16 may 2019)

Photon identification
- Charged track veto
- Time of Flight
- Shower shape

- **D. Blau, https://indico.jinr.ru/event/899/https://indico.jinr.ru/event/914/ (29 may 2019)**

Proposals for photon PID studies with MPD ECal. Introduction to two-dimensional dispersion cut.

Simulation setup

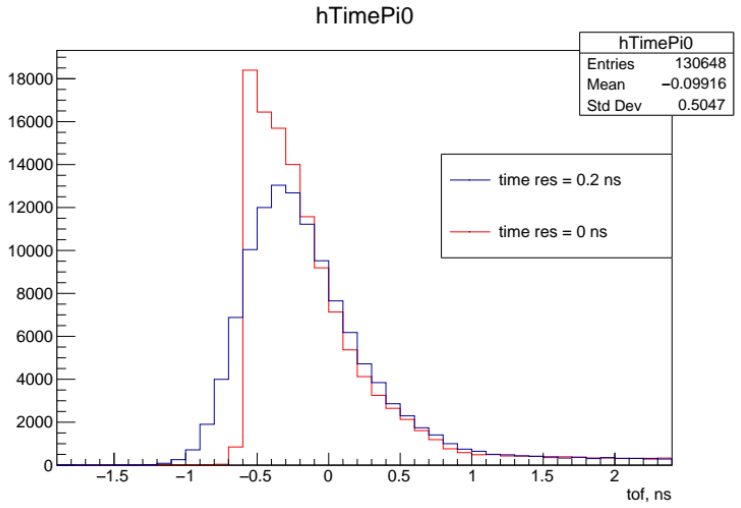
- I have used NICA cluster for simulation of UrQMD events (my own sim-reco files, and those provided by Viktor). 11 GeV UrQMD min bias with EOS 0.
- Also for some studies 100 events with 50 pi0 or pi+ were generated with BOX generator. pT: 0.25-2.5 GeV/C
- In reco.C (doesn't it should be in runMC.C?)

```
MpdEmcSimParams * par = MpdEmcSimParams::GetInstance() ;
par->fSmearLightCollection = false; // Emulate smearing and collecting light using
fEdepToLightYield photoelectrons per GeV
par->fSimulateNoise = false ;       // Simulate electronic noise in HitCreation
par->fApplyNonlinearity = false;    // Apply energy non-linearity in HitCreation
par->fApplyDigitization = false ;   // Apply digitization of energy in HitCreation
par->fApplyTimeResolution = false ; // Apply time resolution in HitCreation
par->fZSthreshold=0.;
```

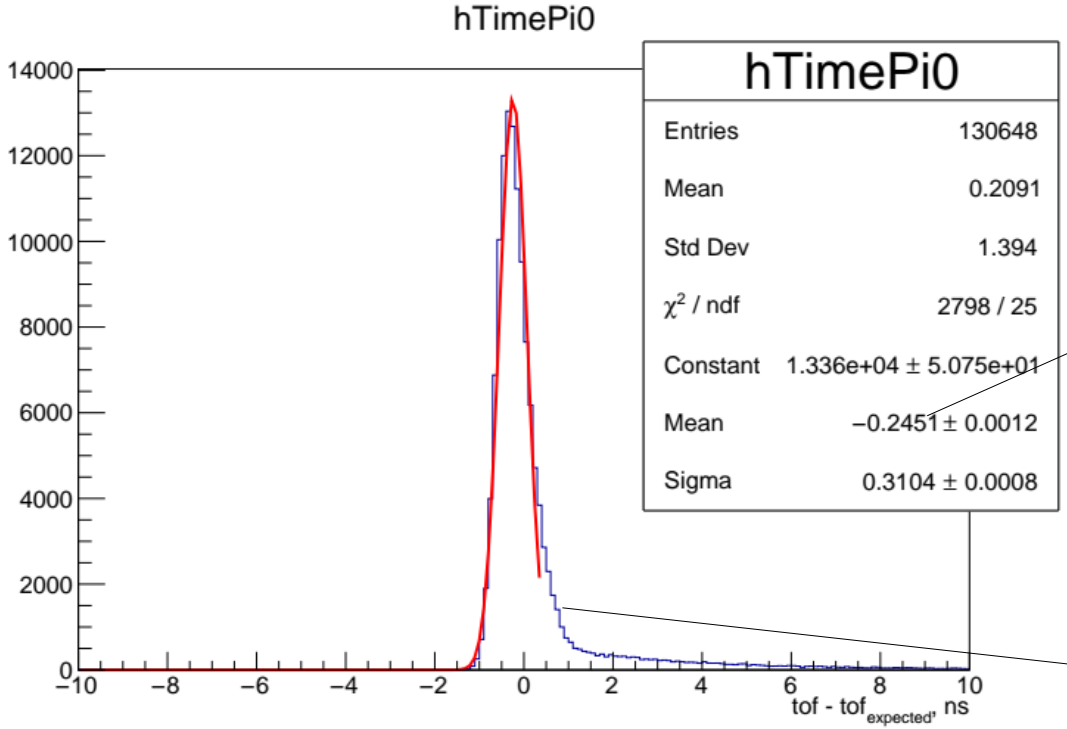
Time resolution is applied in post-processing macros as Gaussian smearing of cluster→GetTime() value:
time=gRandom->Gaus(clu->GetTime(), 0.2)

Time of flight

Time of flight is very useful for photon (massless) and other particles separation required that we have good timing resolution of FEE. It was quoted that with MPD ECal we can achieve as good as 0.2 ns resolution. So, 0.2 ns smearing of Time of flight is applied.



Time for clusters which correspond to pi0 mothers from UrQMD events



Offset is coming from the fact that time is calculated in simulations when particle is crossing front surface of the calorimeter, while length is calculated to the cluster coordinates which are inside module

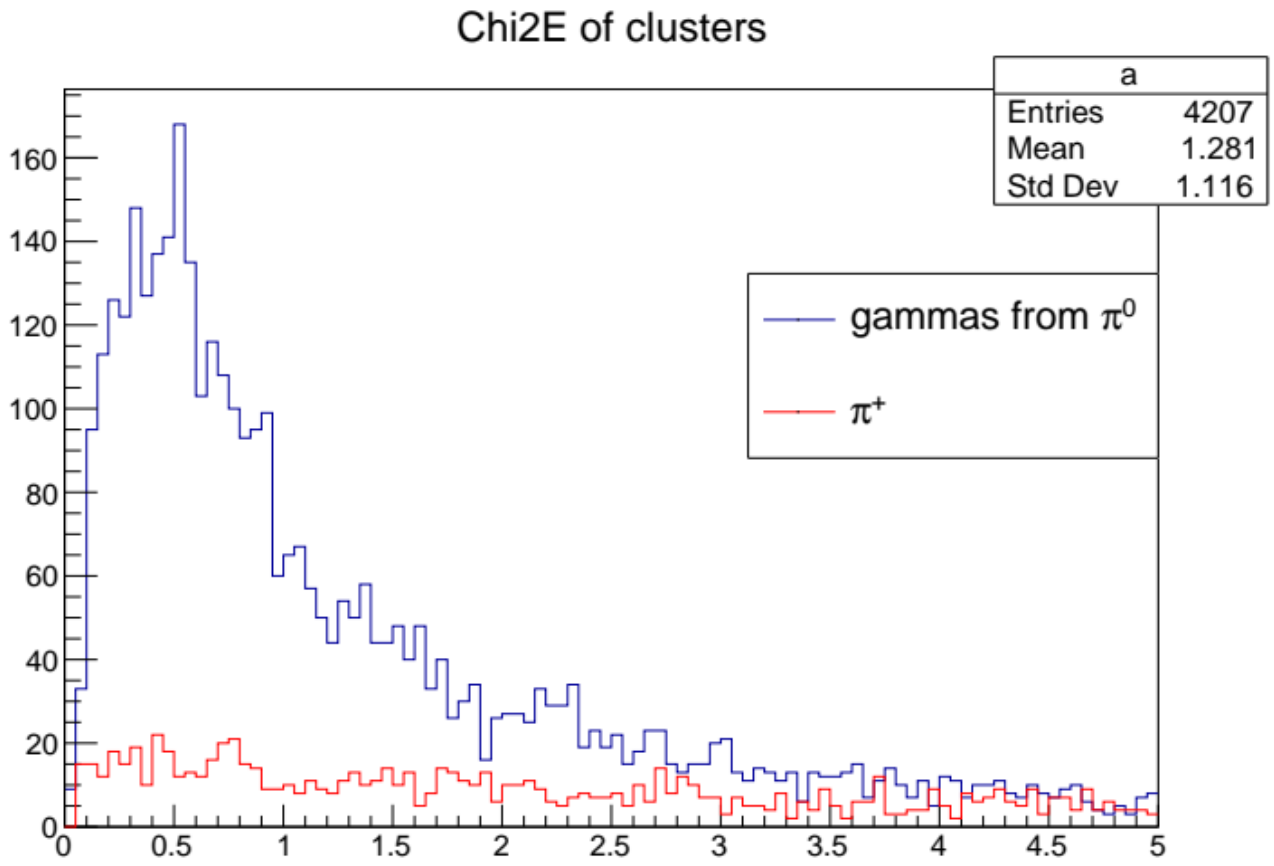
Probably clusters from converted photons

```
bool TestTime(float time,float rad){
float res = 0.3104; //in ns; for electronics resolution 0.2 ns
float offset = -0.245;
return time < rad/29.98 - offset + res*2.;
}
```

Rad = sqrt((x_cl-x_primvtx)^2+(y_cl-y_primvtx)^2+(y_cl-y_primvtx)^2)

Cluster shape chi2 cut

It was shown by PHENIX collaboration that chi2 cut of cluster shape fit to electromagnetic-shower parameterization is useful for separation of photons from hadrons (for example, pions)



100 events with 50 pi0 or 50 pi+ were simulated

Cut E>0.1 GeV

Note different normalization! (pions are about 5 times less)

```
bool TestChi2(float chi2,float e){
return chi2<1.;
}
//very-very rough cut!
```

Cluster shape dispersion cut

It was shown by ALICE collaboration (PHOS spectrometer) that 2-dimensional cluster dispersion is useful for photon-hadron separation (ALICE PPR vol. 2).

REMINDER: (see D.Blau presentation from 29.05.2019)

- The lateral dispersion, d, in the (x, z) plane measured on the surface of EMC:

$$d = \frac{\sum_{\text{digits}} w_i \left[(x_i - x)^2 + (z_i - z)^2\right]}{\sum_{\text{digits}} w_i} .$$

$$S = \begin{pmatrix} s_{xx} & s_{zx} \\ s_{xz} & s_{zz} \end{pmatrix} ,$$

where

$$s_{xx} = \left\langle (x - \bar{x})^2 \right\rangle = \frac{\sum_{\text{digits}} w_i x_i^2}{\sum_{\text{digits}} w_i} - \left(\frac{\sum_{\text{digits}} w_i x_i}{\sum_{\text{digits}} w_i} \right)^2 ,$$

$$s_{xz} = \langle (x - \bar{x})(z - \bar{z}) \rangle = \frac{\sum_{\text{digits}} w_i x_i z_i}{\sum_{\text{digits}} w_i} - \frac{\sum_{\text{digits}} w_i x_i \times \sum_{\text{digits}} w_i z_i}{\left(\sum_{\text{digits}} w_i \right)^2} ,$$

and corresponding definitions for s_{zz}, s_{zx}. Here $\langle\ \rangle$ denotes averaging with logarithmic weights w_i (Eq. (5.29)), $\bar{x}$ and $\bar{z}$ are the centre of gravity of the cluster (Eq. (5.28)), (x_i, z_i) are the positions of a crystal i belonging to the cluster. Diagonalization of this covariance matrix defines the main axes of the shower surface, λ_1 and λ_2, as the square root of the eigen vectors of the covariance matrix.

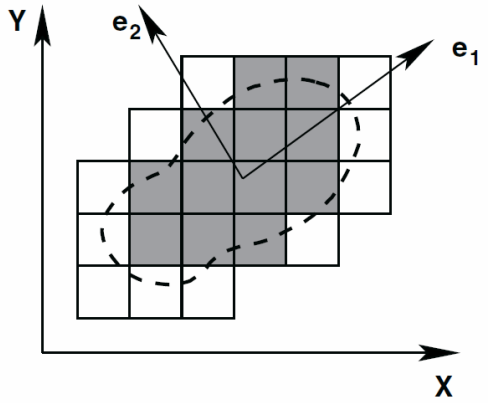
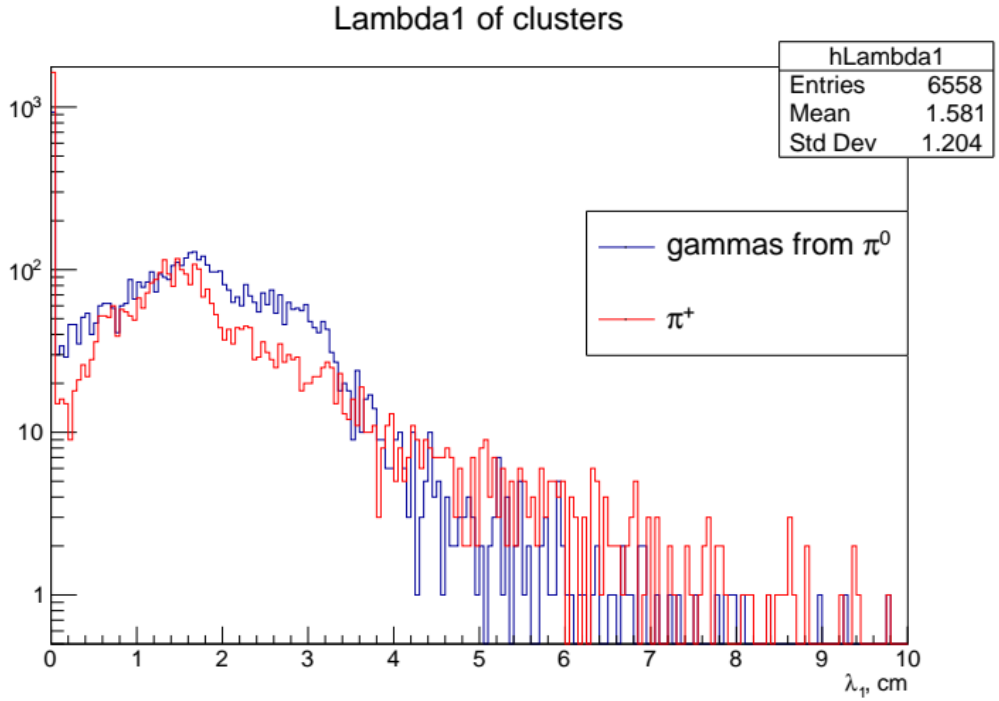
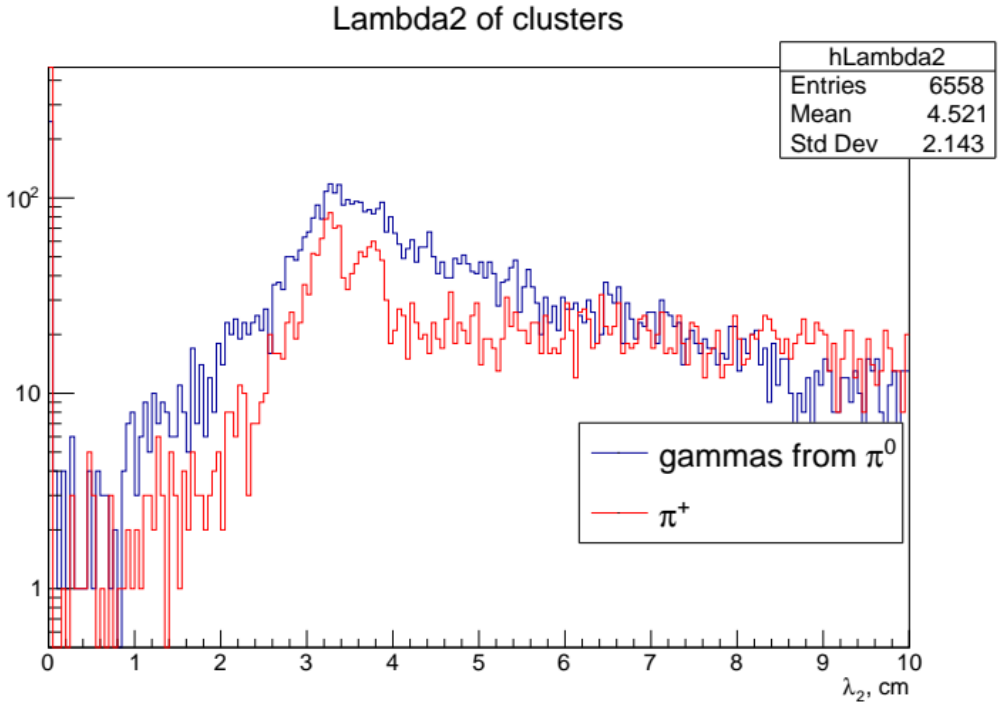


Figure 5.129. Example of a shower profile and its main axes e_1 and e_2.

Lambda1 and lambda2 are filled in MpdEmcClusterKI object. There is also fDisp for 1-dim dispersion, but it is not filled. Do we need it? I think it could be useful for PID studies

Cluster shape dispersion cut



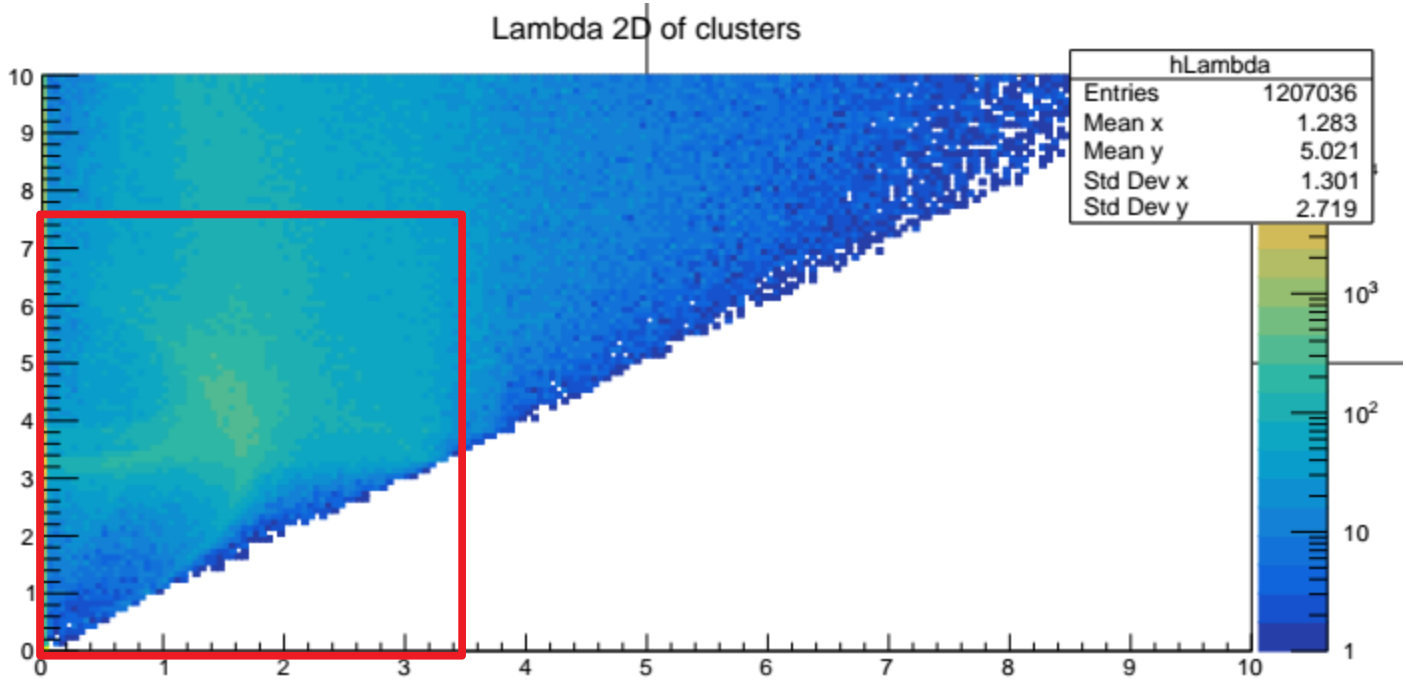


100 events with 50 pi0 or 50 pi+ were simulated

No cut on E

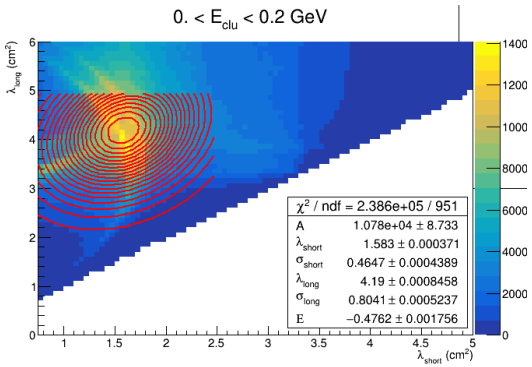
Note different normalization! (pions are about 5 times less)

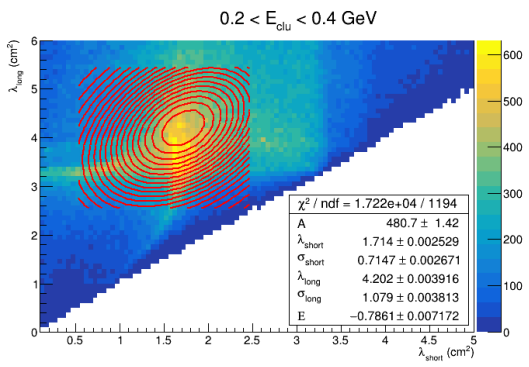
Cluster shape dispersion cut

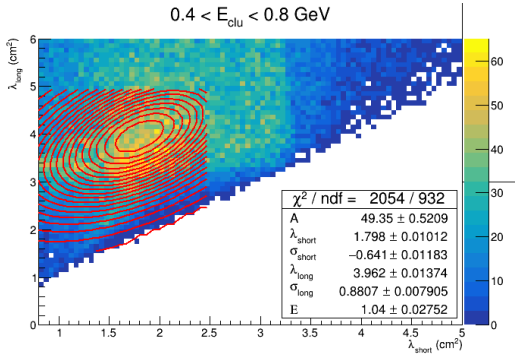


UrQMD events

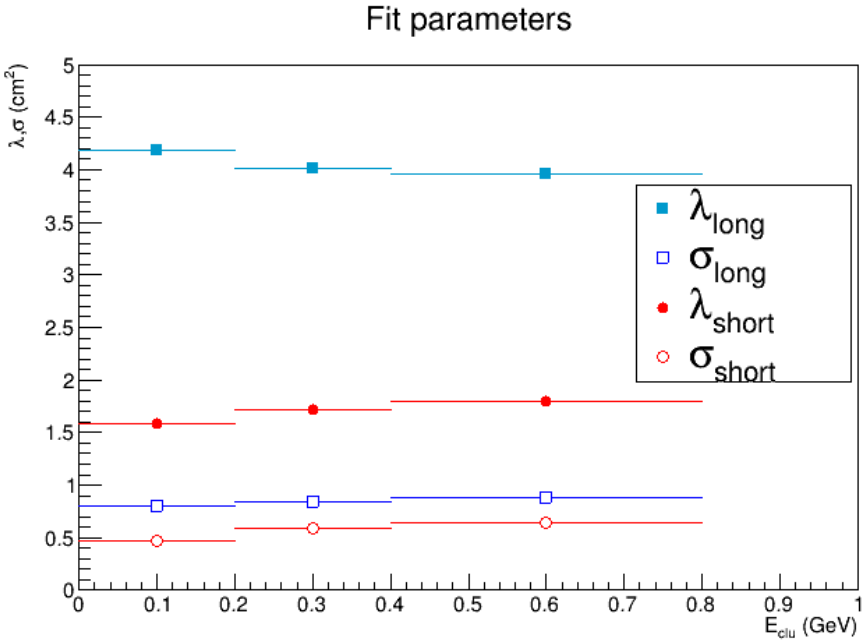
As in the other cases, 2 sigma cut from (two-dimensional) Gaussian fit is used as a PID criterion





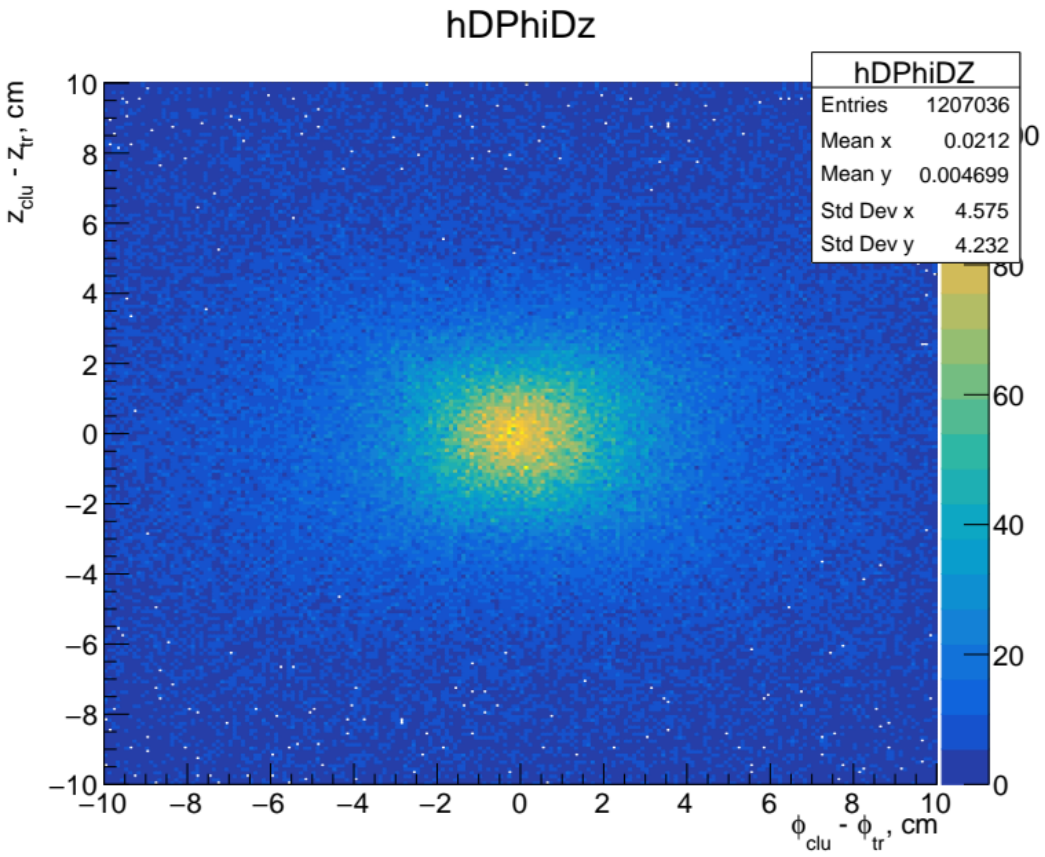


Disp cluster cut still to be optimized!

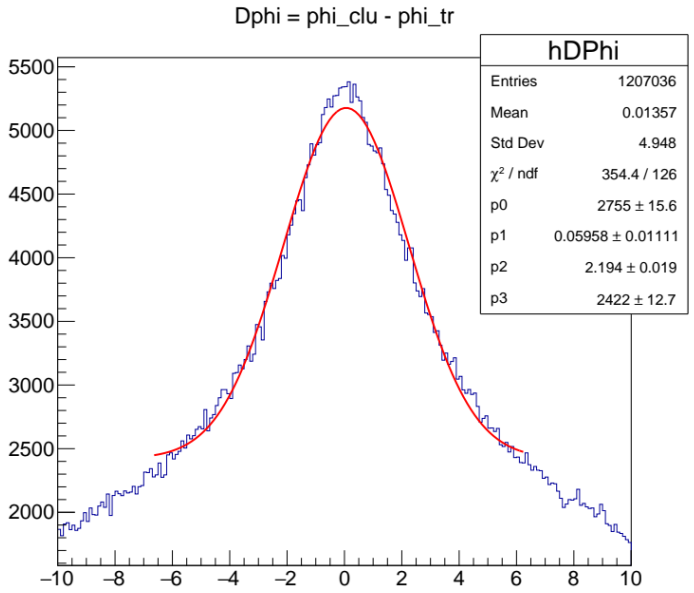


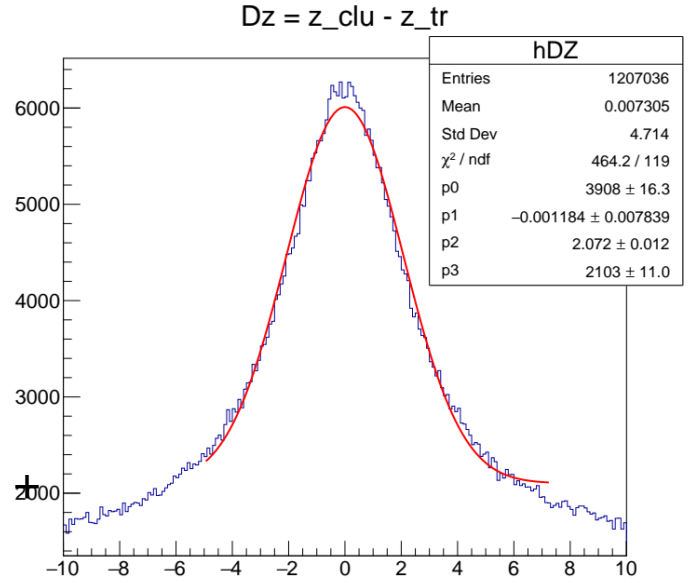
Anti-track matching cut

During reconstruction a track matching procedure is done – it matches cluster to the nearest track extrapolated from the tracking system to the calorimeter.



UrQMD events





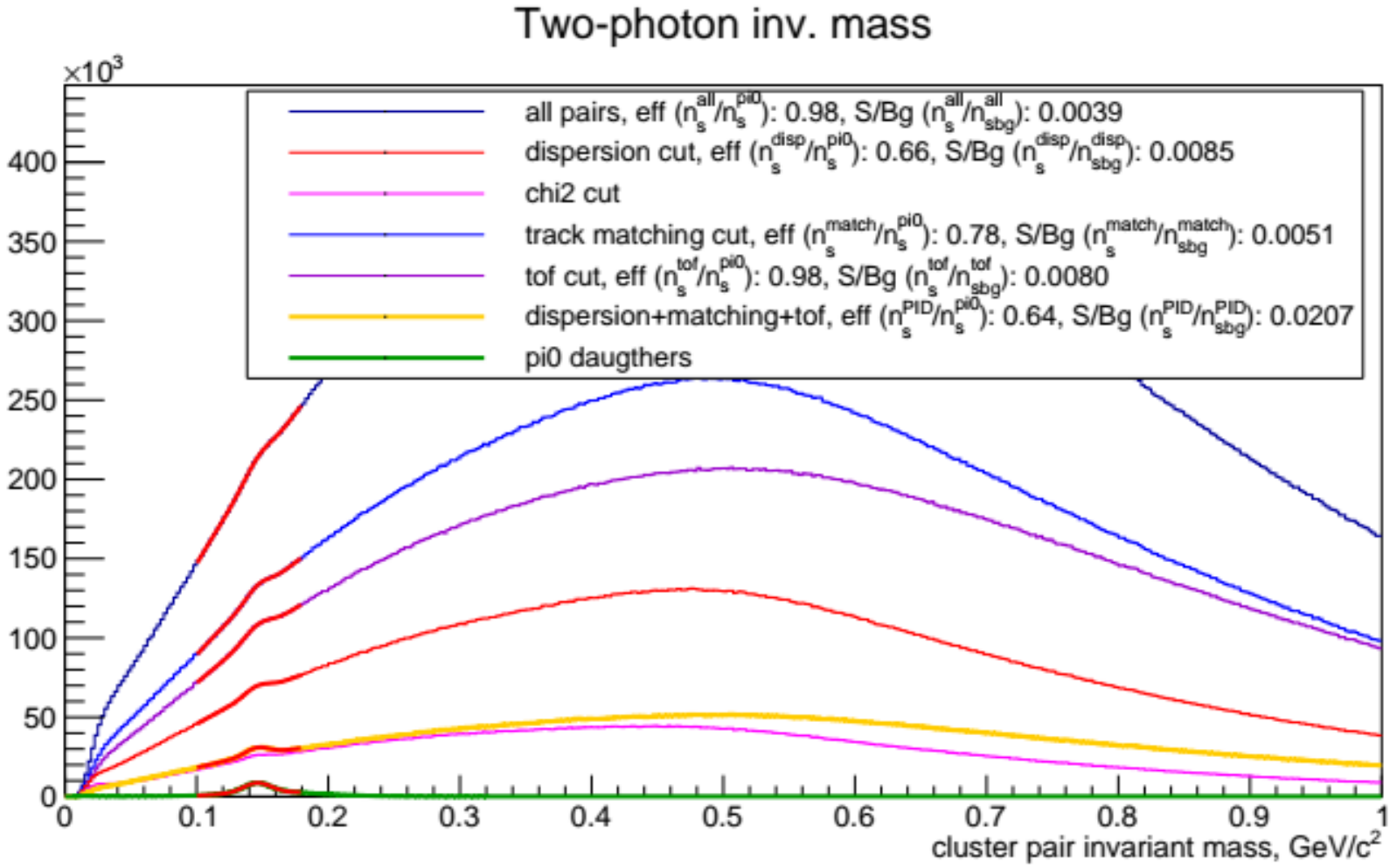

```
bool TestDphiDz(float dphi,float dz,float e){
Double_t sigma_dz = 2.072;
Double_t sigma_dphi=2.194;
        return (TMath::Sqrt(dphi*dphi/sigma_dphi/sigma_dphi +
dz*dz/sigma_dz/sigma_dz)>2.);
}
```

Two-cluster invariant mass distributions

Cuts: b>5 fm (most central events are not processed), E>0.05 GeV, lambda1>0

100k UrQMD events

Chi2 cut is not working, others are useful. Efficiency and purity to be optimized.



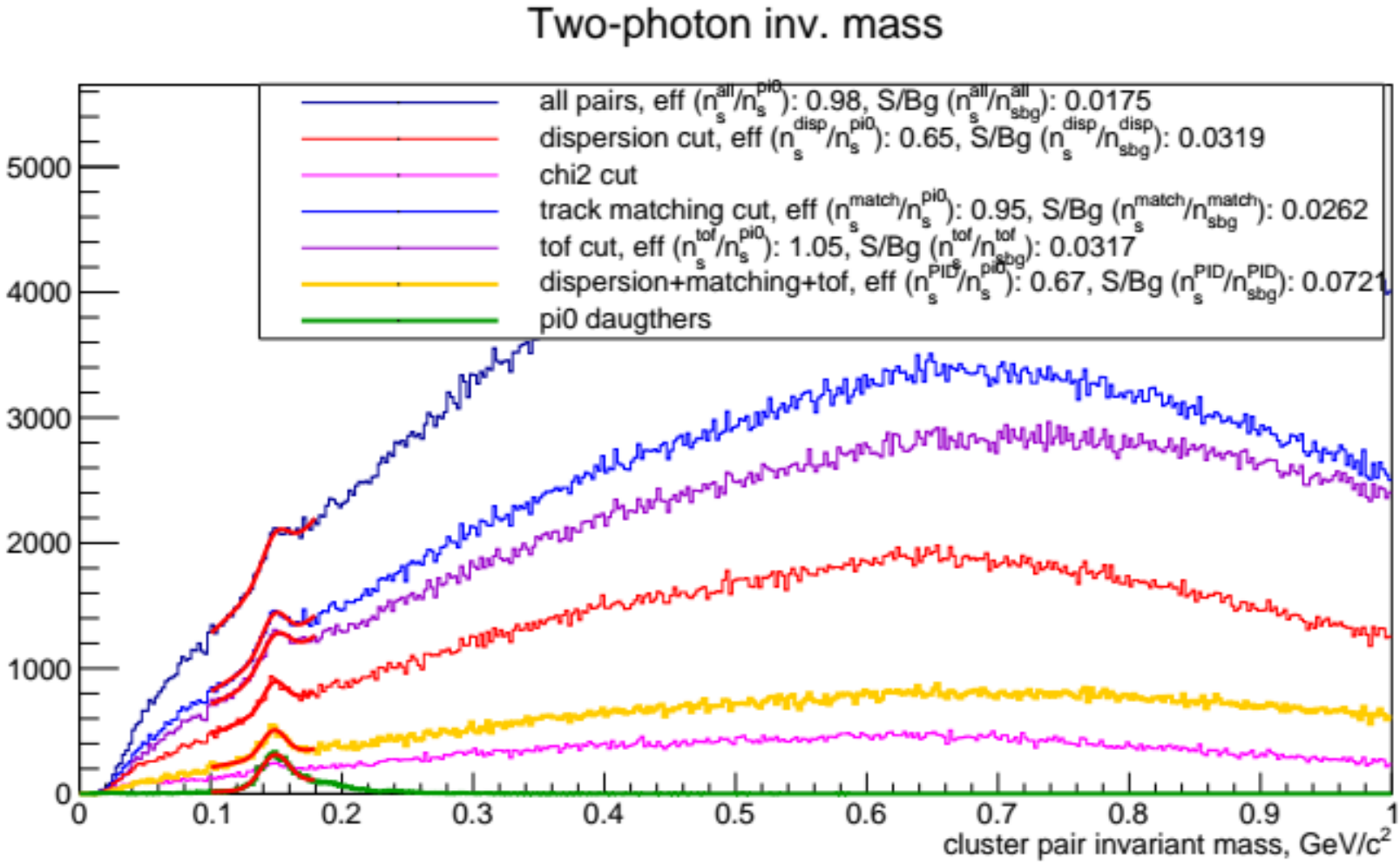
1 < pT < 2 GeV/c

Two-cluster invariant mass distributions

Cuts: b>5 fm (most central events are not processed), E>0.05 GeV, lambda1>0

100k UrQMD events

Chi2 cut is not working, others are useful. Efficiency and purity to be optimized.



2 < pT < 3 GeV/c

Summary

- Photon PID was studied for MPD ECal with v3 geometry. Small set of UrQMD events was used, more will follow for more detailed PID efficiency and purity calculations.
- 1 student from MEPhI is currently working with NRC KI group with this task for his diploma thesis (to be defended in summer 2020).

- Todo plans:
- Mixing event code to be implemented
- Cuts optimization