Optimization of photon PID in EMC

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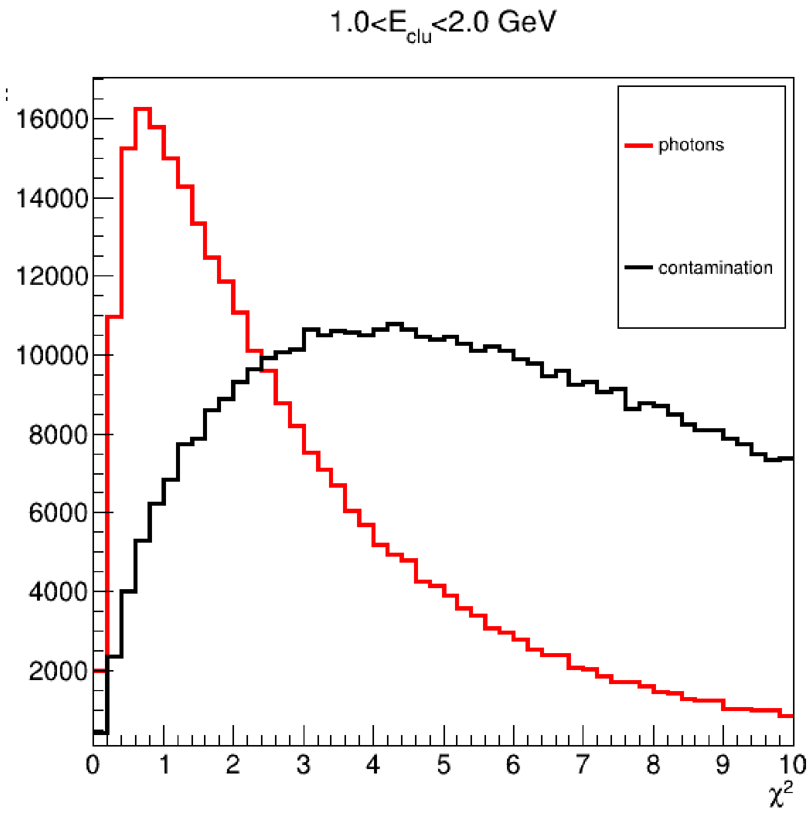
Data analyzed

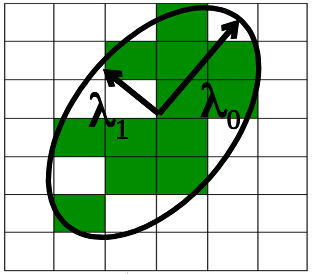
- URQMD, min. bias, 10000 events
  - The first centralized production, AuAu@11 G4
  - https://mpdforum.jinr.ru/t/the-first-centralized-production-auau-11/219
- Git branch ID provided, analyzed with same version of mpdroot without problems.

Photon shower shape: χ^2

- Fit shower shape with parameterized EM shower and calculate χ^2 of the fit
- Result provided by MpdEmcClusterKI::GetChi2()
- Vary threshold to change efficiency and purity



Photon shower shape: (λ_{short},λ_{long})



- Calculate eigenvalues of the dispersion matrix
- Most complete information for 2-d momenta

- Dispersion

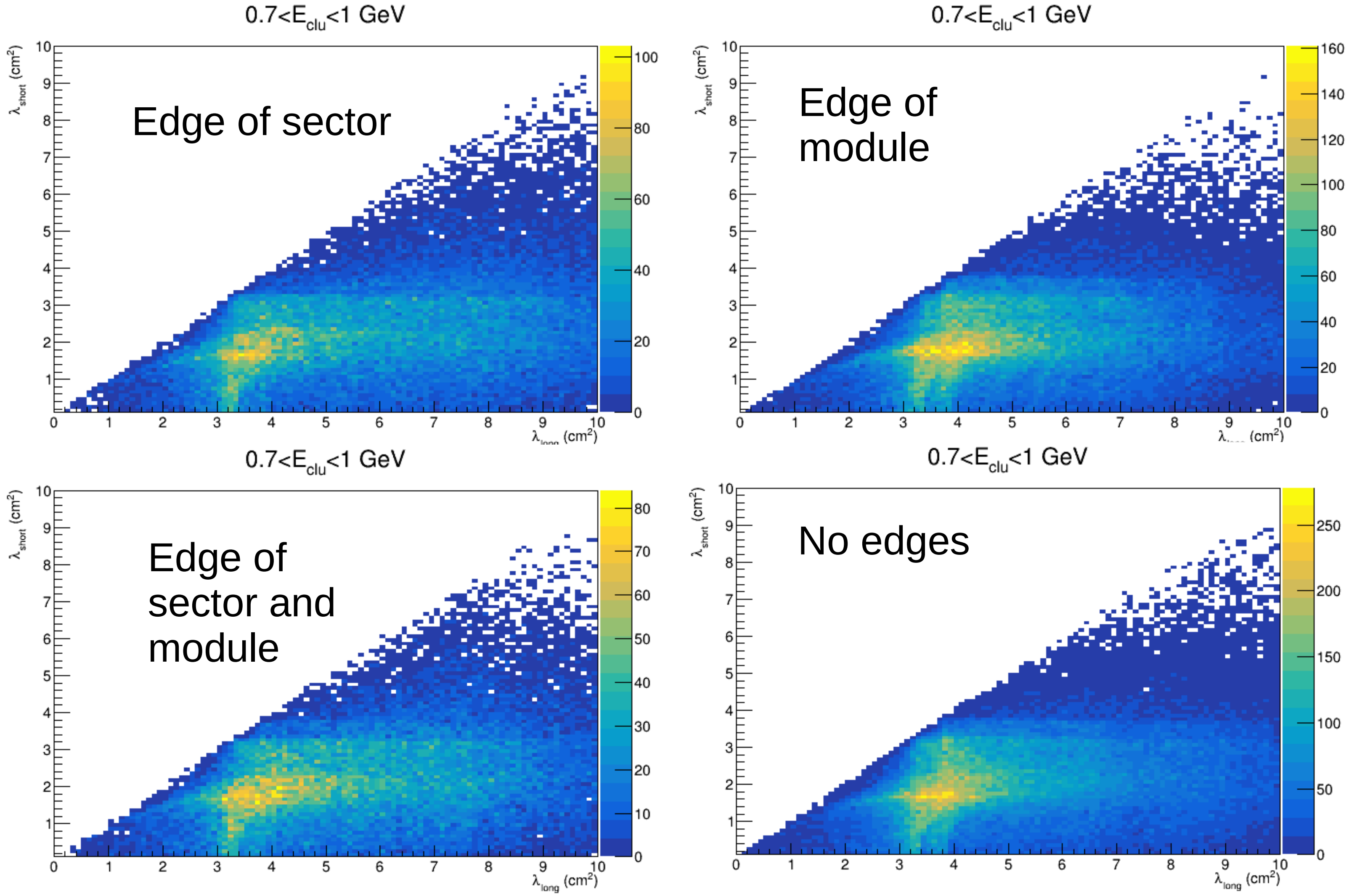
$$D^2 = \frac{\sum\left((x_i - \bar{x})^2 + (y_i - \bar{y})^2\right) w_i}{\sum w_i}$$

- Eigenvalues of second momenta tensor

$$D^{ij} = \frac{\sum_k w_k (x_k^i - \bar{x^i})(x_k^j - \bar{x^j})}{\sum_k w_k}$$

$$\lambda_{1,2} = \frac{1}{2}(D_{xx} + D_{zz}) \pm \sqrt{(D_{xx} - D_{zz})^2/4 + D_{xz}^2}$$

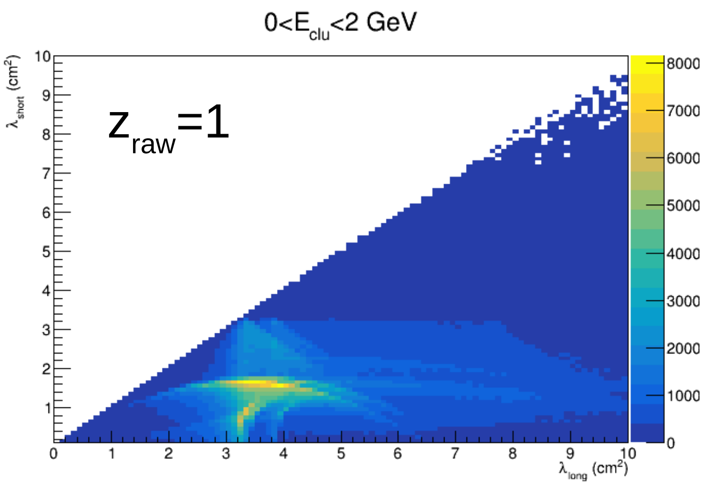
Influence of support structures

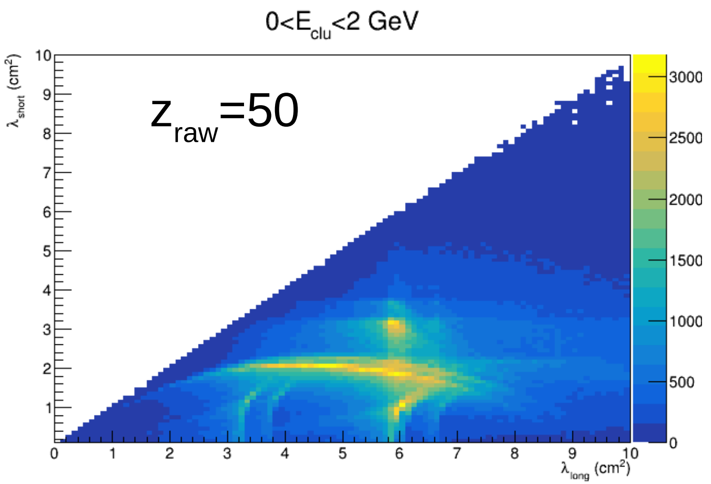


Compare dispersion of clusters, including edges of sector, module and no support structures:

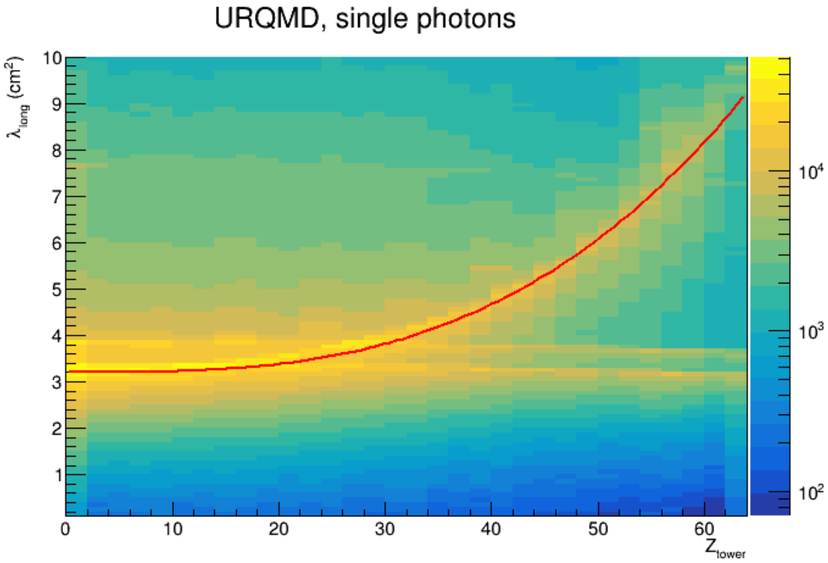
No dramatic difference between cases

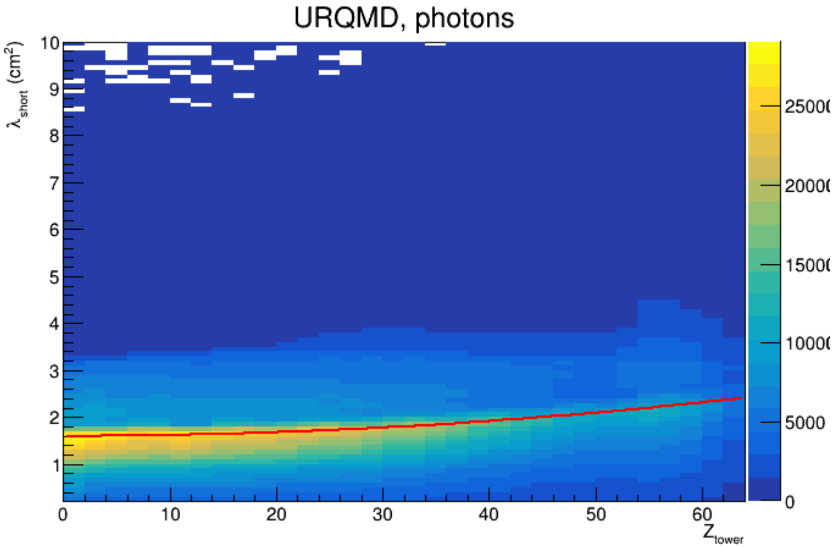
Dependence on z coordinate





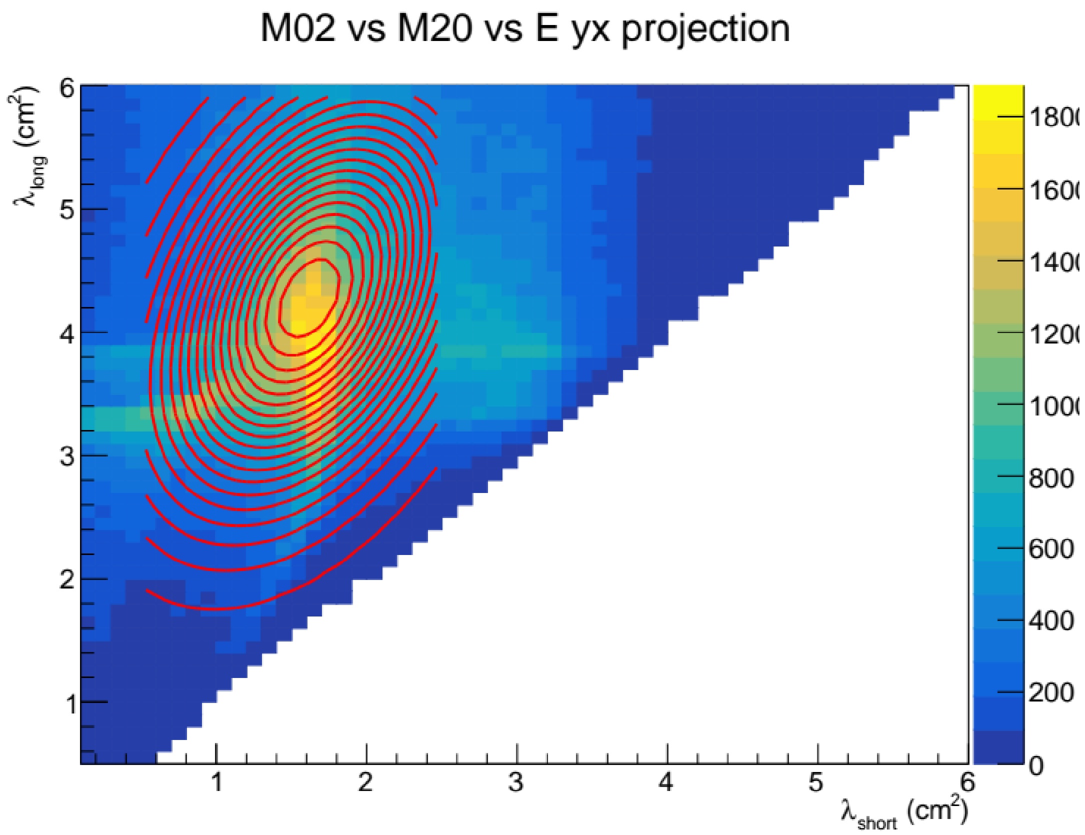
Strong dependence of the shower shape on tower index (z_{raw}) due to protective geometry/material/...

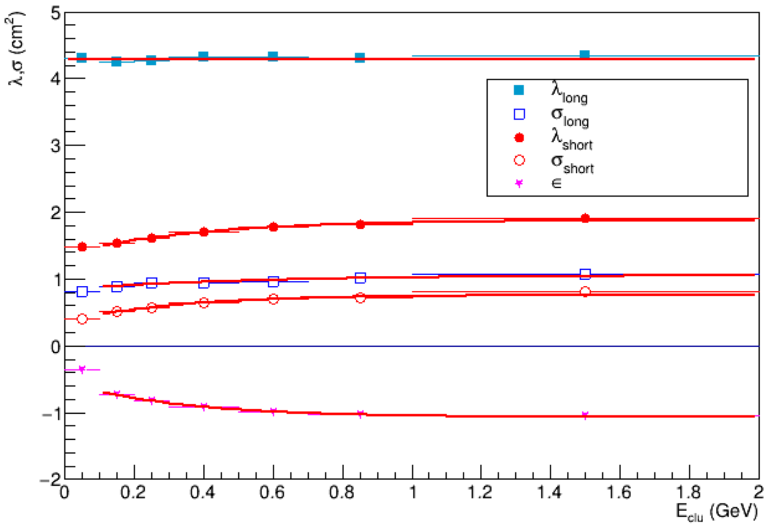




Correct by scaling lambdas with parameterization (red lines)

Fit of (λ_{short},λ_{long})





Fit (z-corrected) distribution for photons with

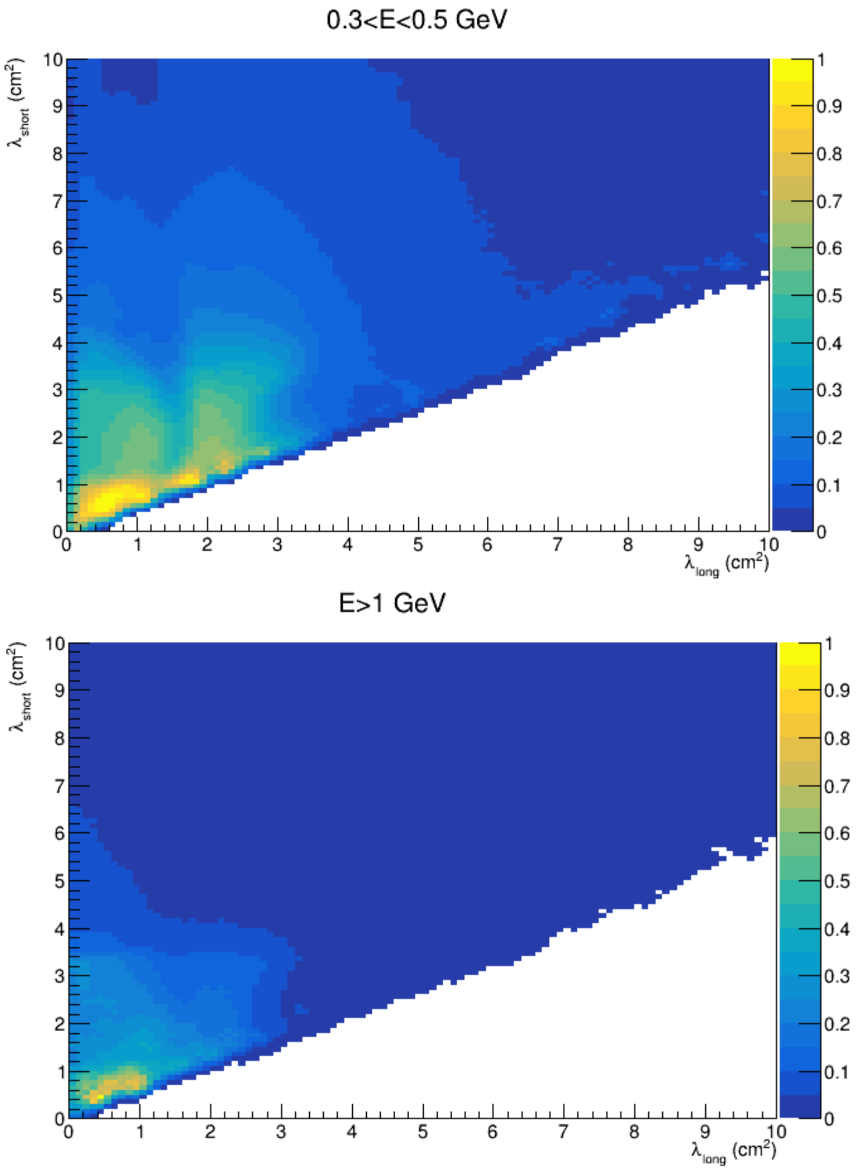
$$\exp\left(-\frac{(\lambda_{long}-\lambda_{long}^{mean})^2}{2\sigma_{long}^2}-\frac{(\lambda_{short}-\lambda_{short}^{mean})^2}{2\sigma_{short}^2}-c\frac{(\lambda_{long}-\lambda_{long}^{mean})(\lambda_{short}-\lambda_{short}^{mean})}{2\sigma_{long}\sigma_{short}}\right)$$

```
float EvalLambdaCut(float l1,float l2,float E){
  float longM = 4.28333 ;
  float shortM= 1.88168-5.06456e-01*exp(-E/3.83640e-01) ;
  float longS = 1.05616-2.12212e-01*exp(-E/5.46530e-01) ;
  float shortS= 7.58640e-01-3.97720e-01*exp(-E/3.18150e-01) ;
  float c = -1.0+5.42460e-01*exp(-E/3.22982e-01) ;
  return sqrt((l1-longM)*(l1-longM)/(longS*longS*2.)
          +(l2-shortM)*(l2-shortM)/(shortS*shortS*2.)
          +c*(l1-longM)*(l2-shortM)/(longS*shortS*2.));
}
```

Photon shower shape: **ratio**

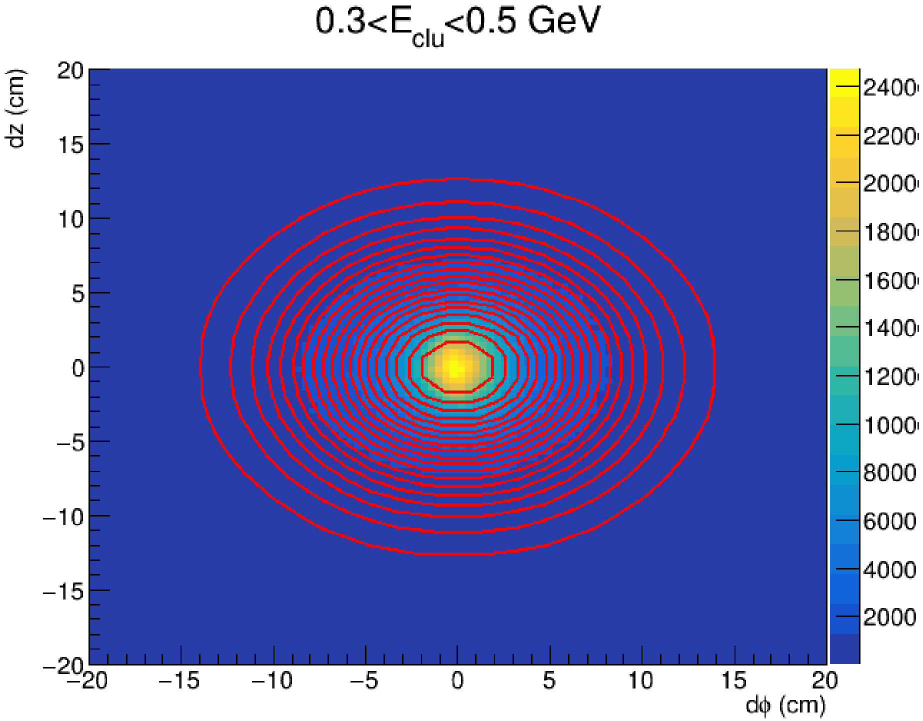
- Make ratio of (λ_{short},λ_{long}) distribution of photon and of contamination
- Find a region in (λ_{short},λ_{long}) plane where photon/contamination ratio is maximal
- Return ratio photons/contamination R normalized to 1 at maximum (0..1)
- Accept particle if R>threshold

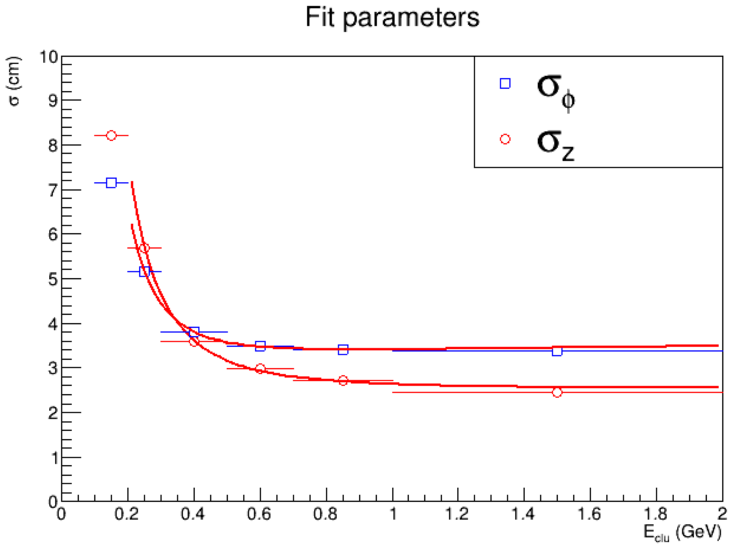
Pro: better discriminating power
Contra: depends also on description of calorimeter response to hadrons



Neutrality cut

- Calculate distance to closest track
- Fit distance for pion tracks:

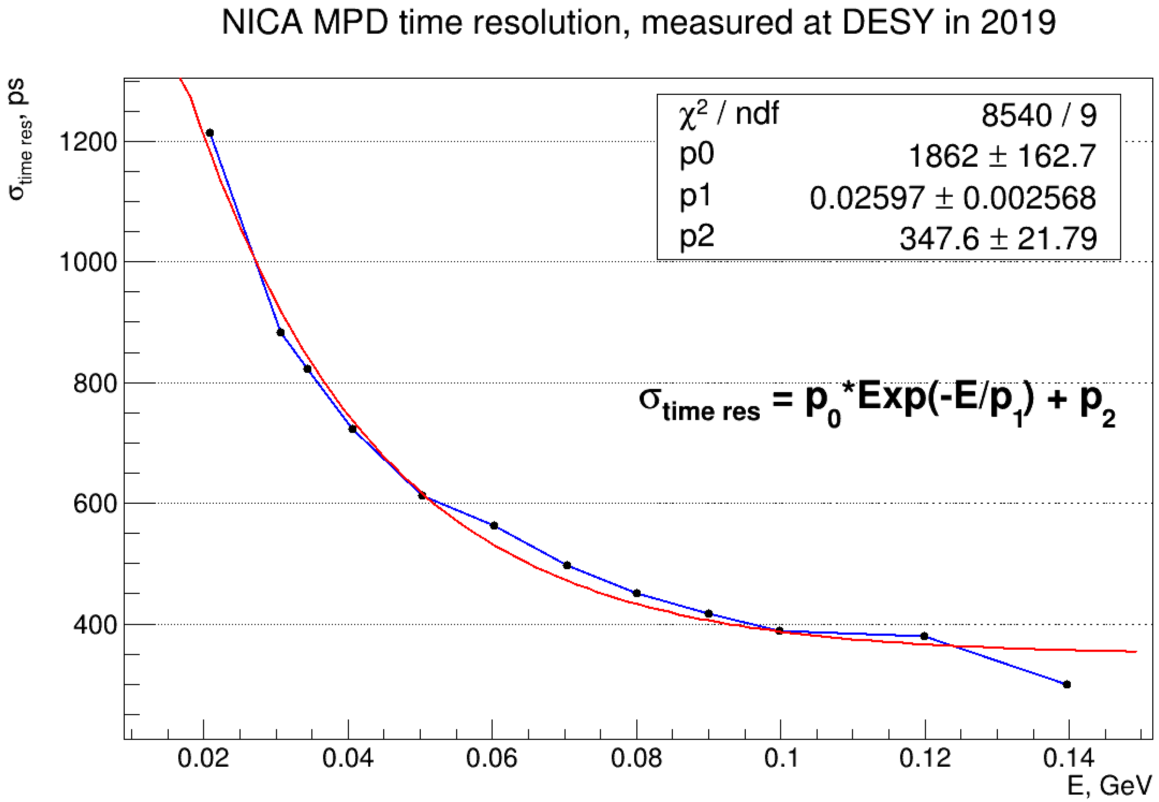




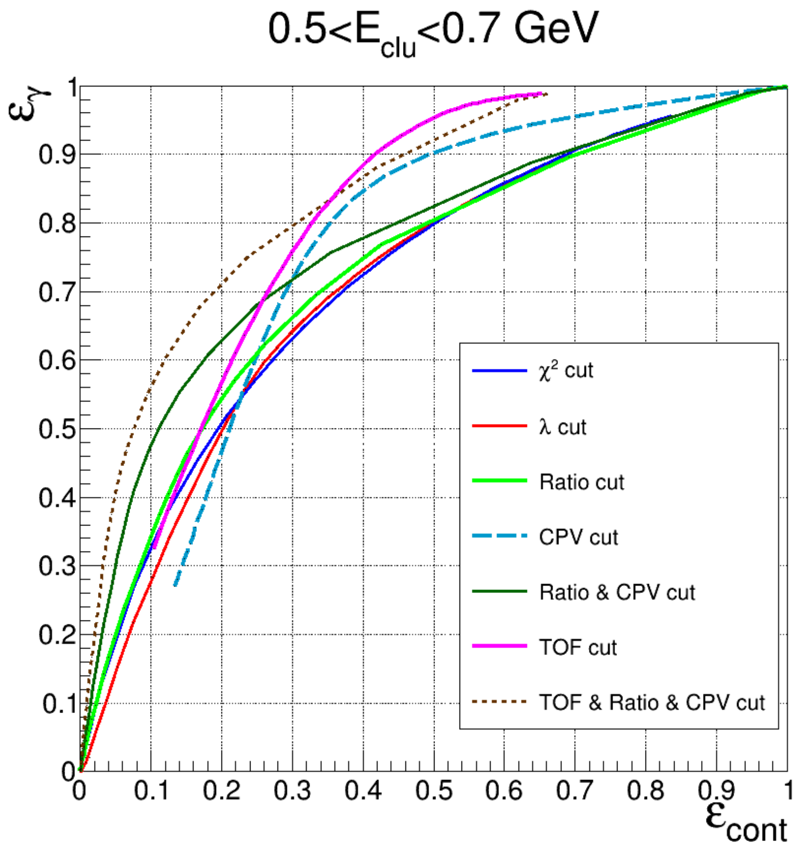

```
float EvalDistCPV(float dphi, float dz, float E){
  //returns distance in sigma
  float sigmaPhi = 3.66601-4.63964e-01/E+2.08779e-01/E/E ;
  float sigmaZ   = 2.58409-1.87502e-01/E+2.40143e-01/E/E ;
  dphi=dphi/sigmaPhi ;
  dz=dz/sigmaZ ;
  return sqrt(dphi*dphi + dz*dz) ;
}
```

Time cut

- Parameterize time resolution (thanks to Andrey Semenov)
- Smear arrival time
- Calculate dt = arrival time – expected photon arrival time.
- Cut: dt<-1σ...nσ



Receiver Operating Characteristic (ROC)-curve



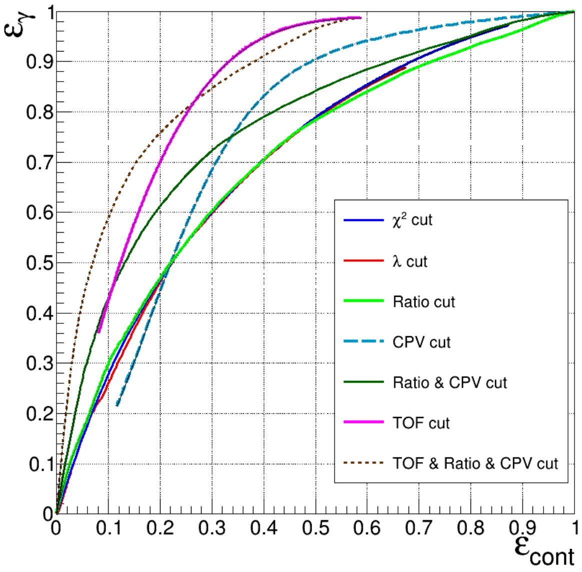
Quality of cuts:
Probability to pass cut for a photon vs probability to pass cut for a contamination (electrons, pions, protons etc.). NB!This is not contamination of photon spectrum!

χ^2 and (λ_{short},λ_{long}) cuts show similar results
“Ratio” shows slightly better performance
CPV and TOF cuts show better performance at low E

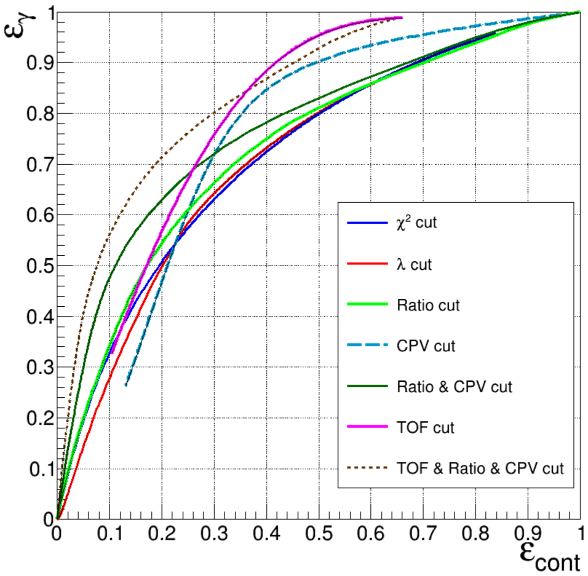
Many options how to calculate ROC for combined cuts (a&b). To be optimized

ROC: Other energies

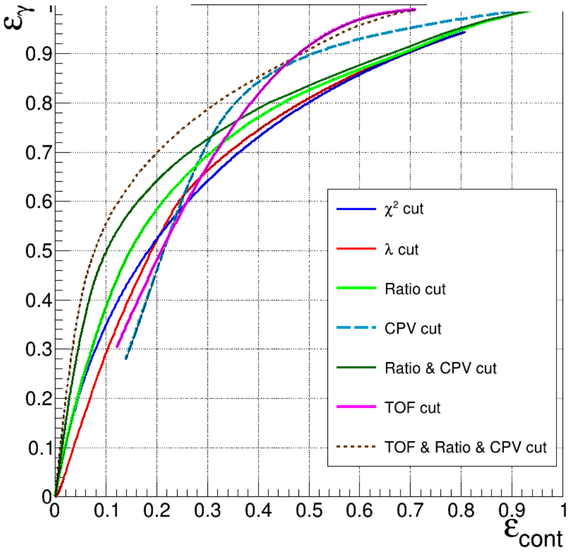
0.3<E$_{clu}$<0.5 GeV



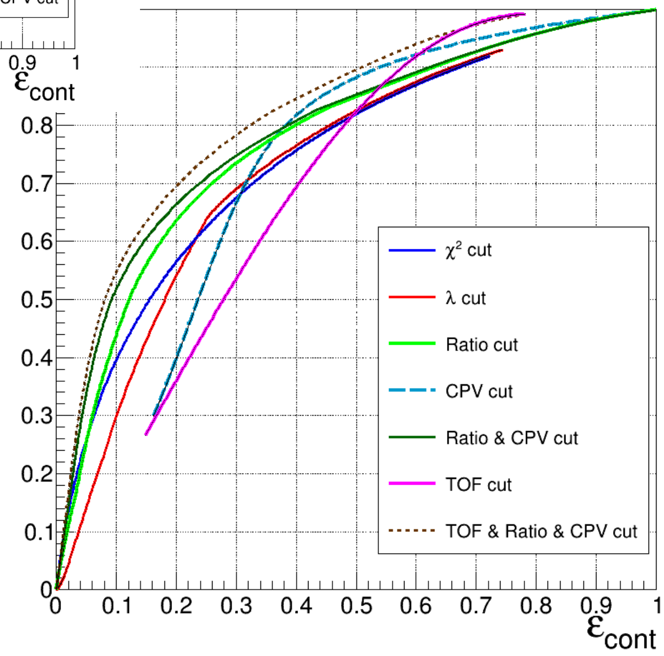
0.5<E$_{clu}$<0.7 GeV



0.7<E$_{clu}$<1.0 GeV



1.0<E$_{clu}$<2.0 GeV



Conclusions

- Dispersion cuts not efficient at E~<0.5 GeV (too few cells in cluster)
  - Improve PID at higher energies
  - "Ratio" slightly better than χ^2 or λ cuts
- TOF cut efficient at low E
- Define several sets (efficient, clean) using ROC