Hybrid method
for the reconstruction of neutral mesons
in the tracking system and the ECAL

D.Peresunko

NRC “Kurchatov institute”

Photon registration in MPD

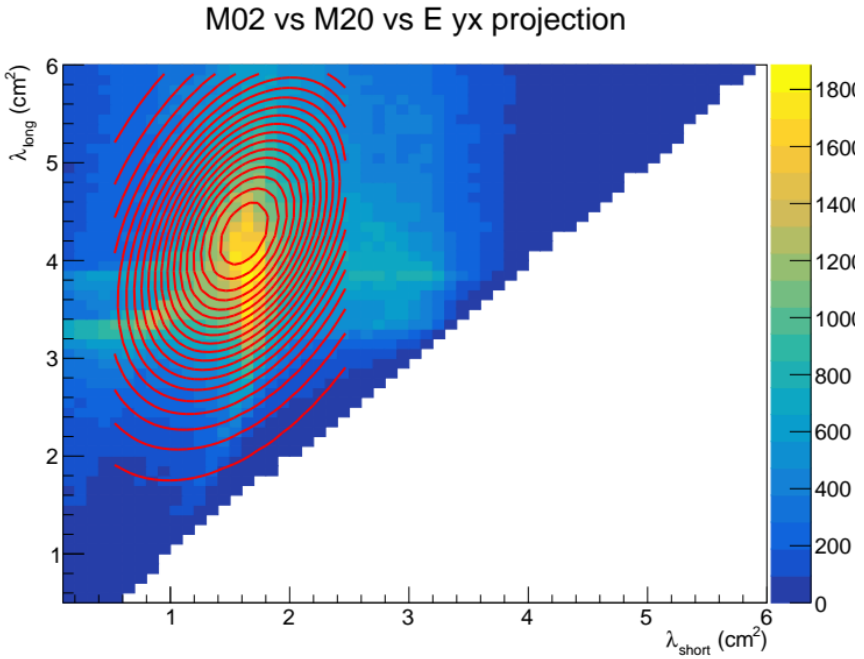
- ECAL
  - (+) High efficiency
  - (-) Low purity especially at low p_T
  - (-) Modest energy and position resolution at low p_T
- V0 reconstruction
  - (+) High purity
  - (+) Good momentum resolution at low p_T
  - (-) Small conversion probability =>small eff.
  - (-) p_T < 300-400 MeV/c not accessible

Completely independent approaches with very different systematic uncertainties. Excellent possibility to cross-check results: e.g. for π^0 3 independent measurements at once.

ECAL: photon identification criteria

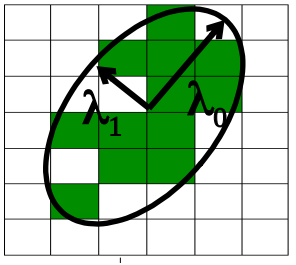
- Cluster multiplicity
- Shower shape
  - 2D dispersion cut
  - χ^2 cut
  - Ratio cut
- Neutrality (charged particles veto)
- Time of flight

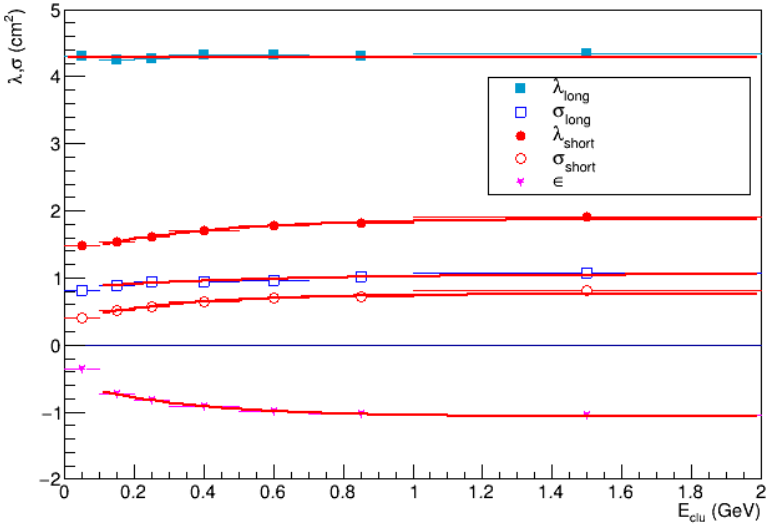
2D dispersion cut



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

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



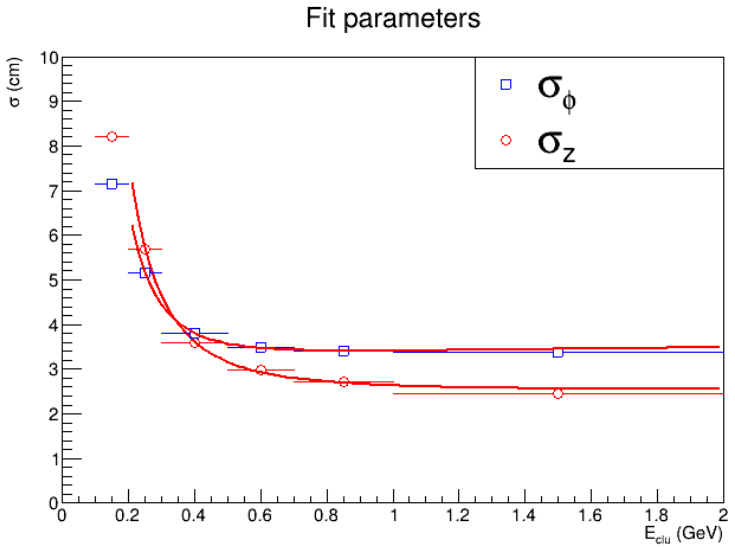


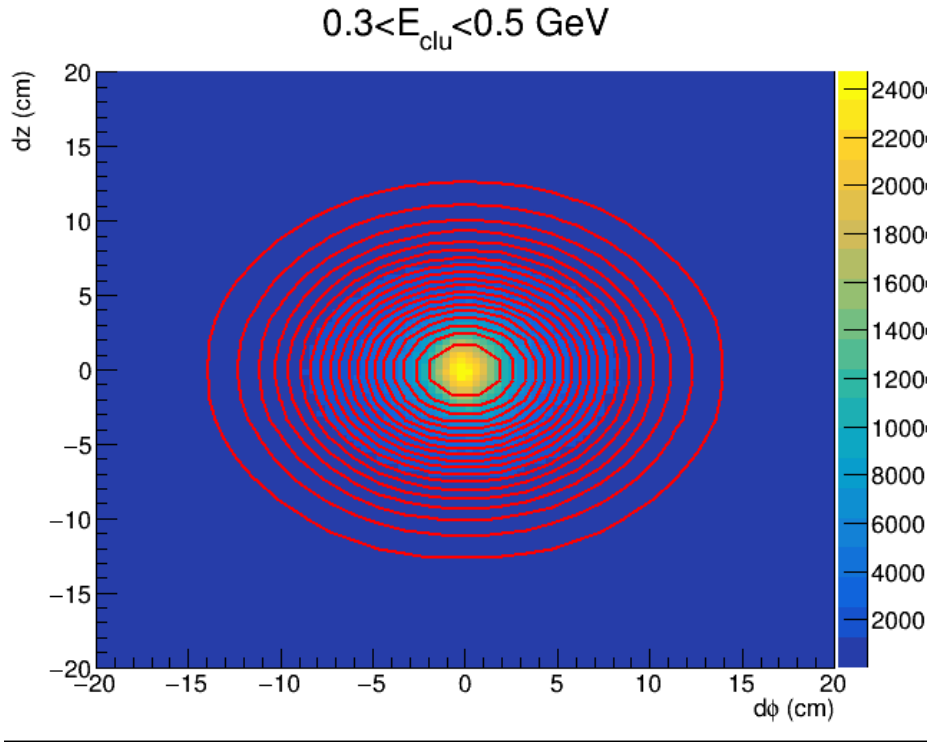
Fit distribution for photons with

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

Neutrality cut

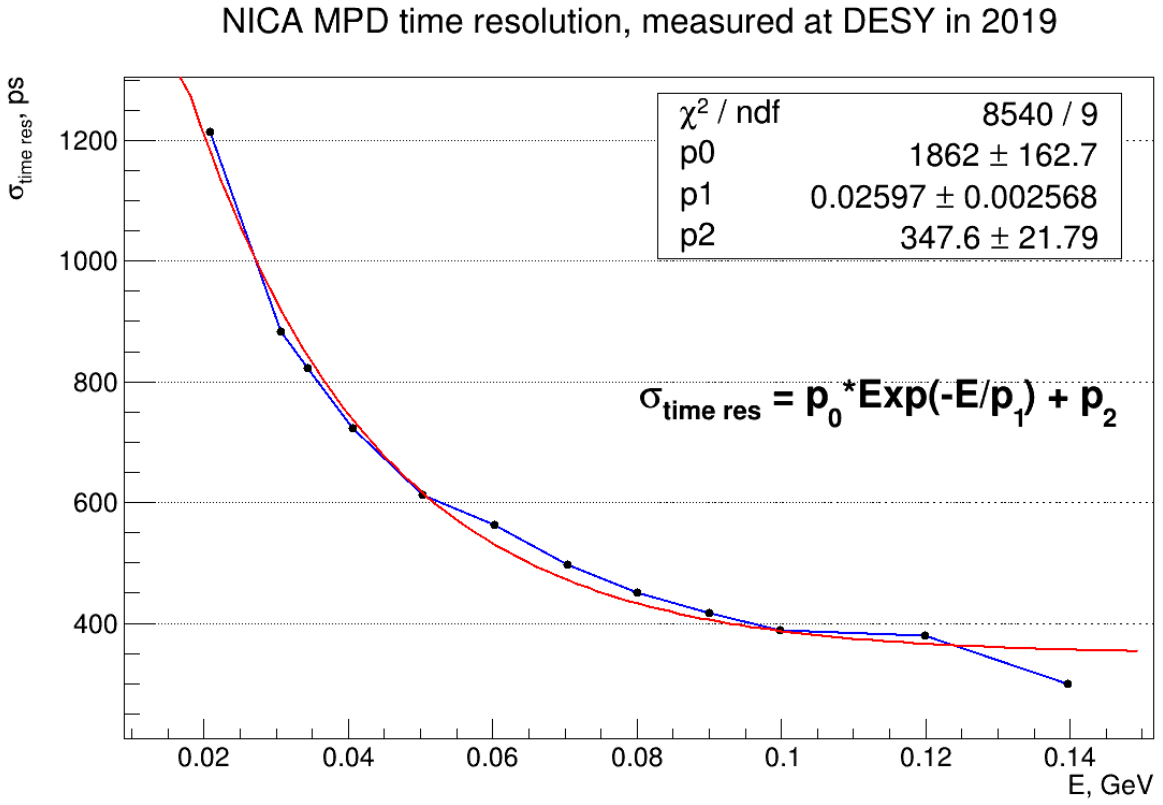
- Calculate distance to closest track
- Fit distance for pion tracks:



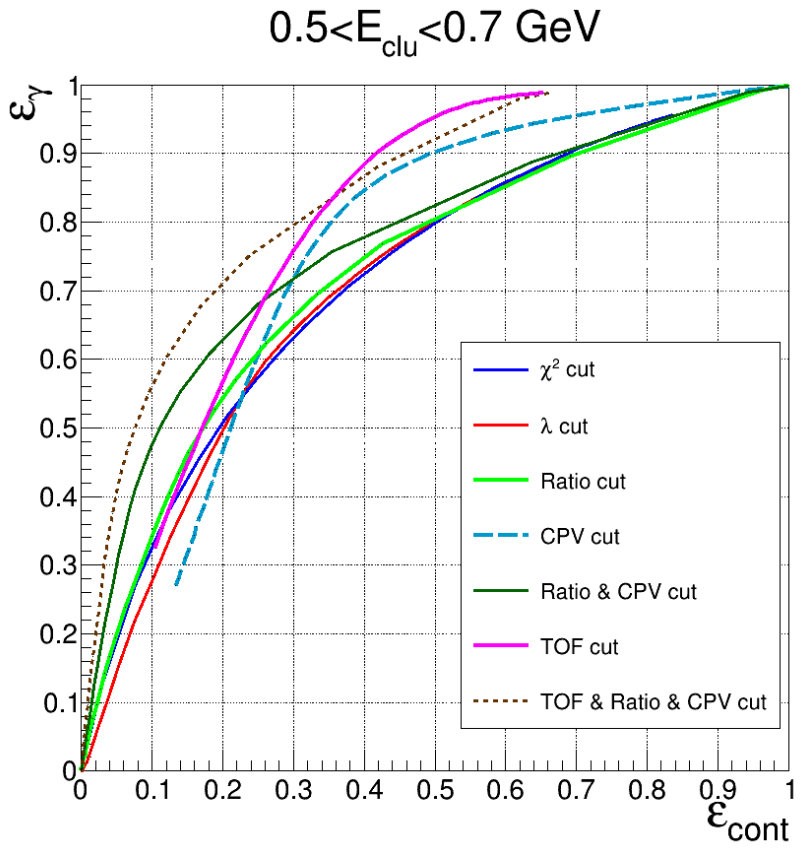


Time cut

- Parameterize time resolution (thanks to Andrey Semenov)
- Smear arrival time
- Calculate dt = arrival time – expected photon arrival time.
- Cut: |dt|< 5 sigma



Receiver Operating Characteristic (ROC)



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!

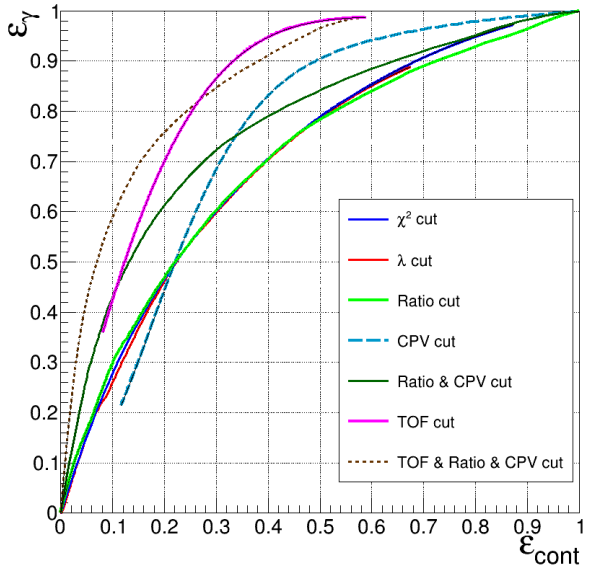
χ^2 and (λ_{short},λ_{long}) cuts show similar results

"Ratio" shows slightly better performance

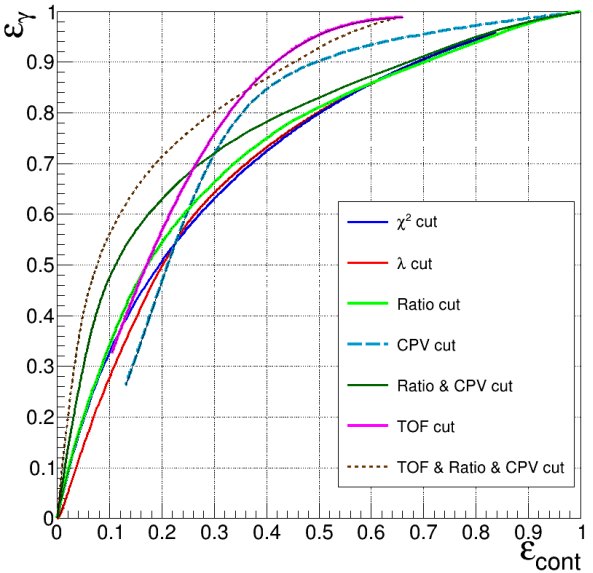
CPV and TOF cuts show better performance at low E

ROC: Other energies

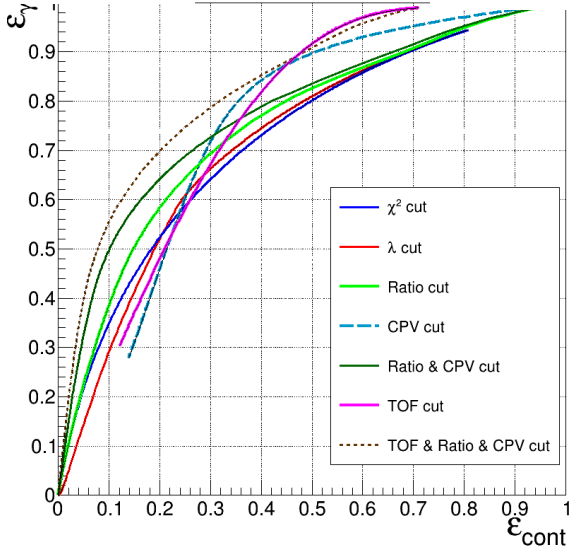
$0.3<E_{clu}<0.5$ GeV



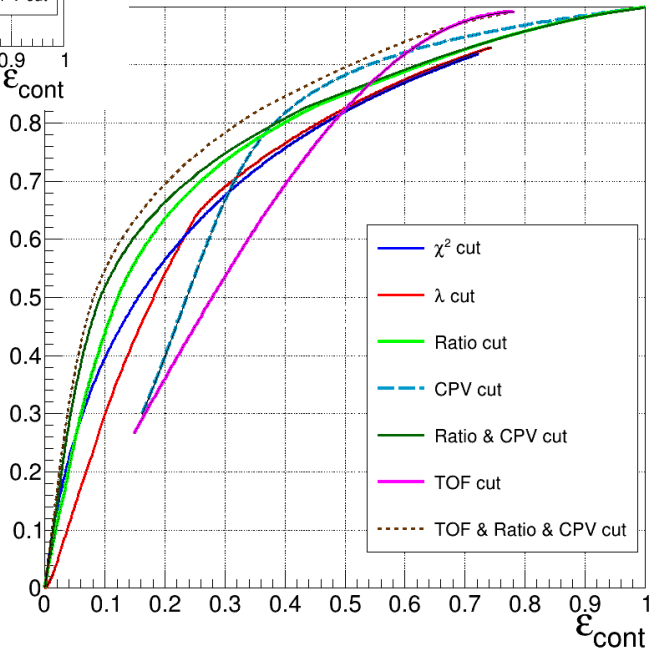
$0.5<E_{clu}<0.7$ GeV



$0.7<E_{clu}<1.0$ GeV



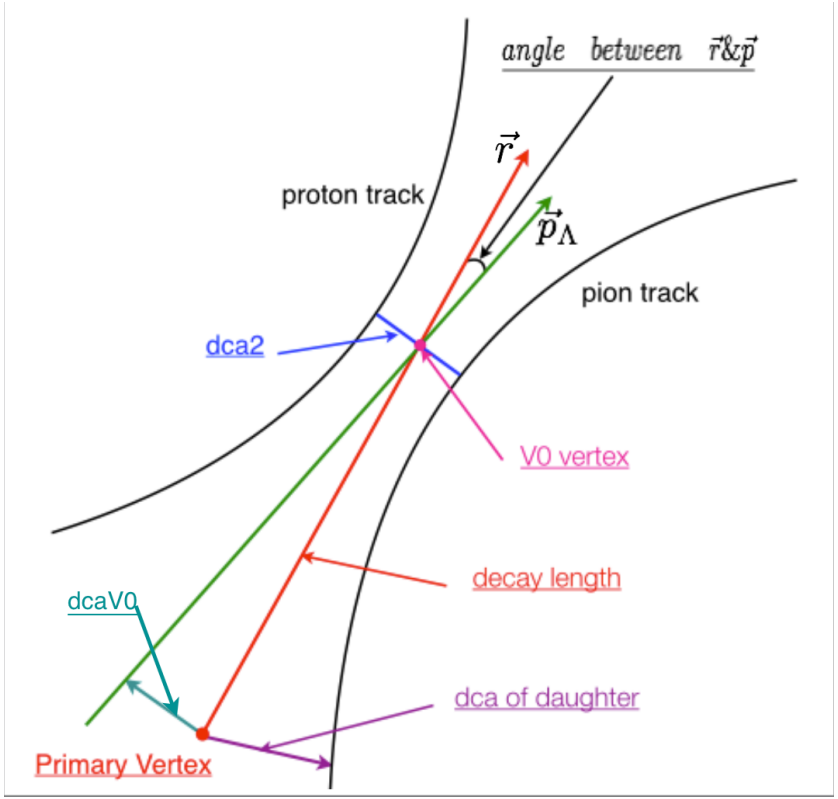
$1.0<E_{clu}<2.0$ GeV



Converted photon reconstruction

Definition of variables for V0 selection

- Tracks with opposite charges
- Conversion radius
- χ^2 of Kalman fit of track pair
- m_{e+e-}
- α = angle between $\bar{r}$ & $\bar{p}$
- Daughter tracks DCA
- Asymmetry
- Ψ-cut (pair orientation w.r.t. B)



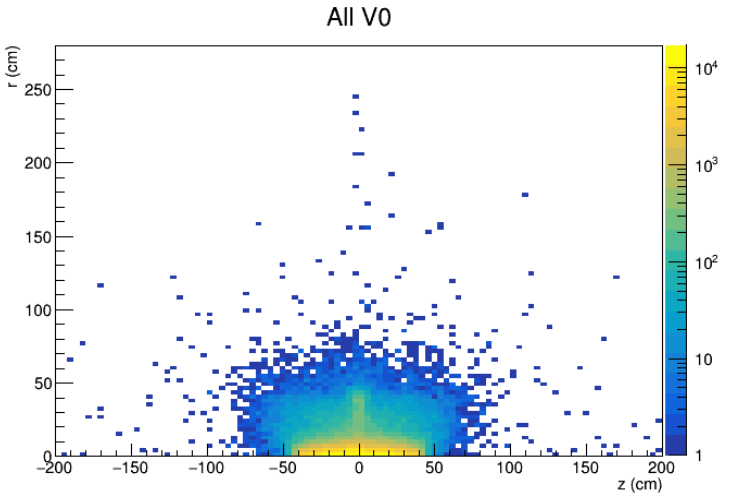
Plot from STAR collaboration

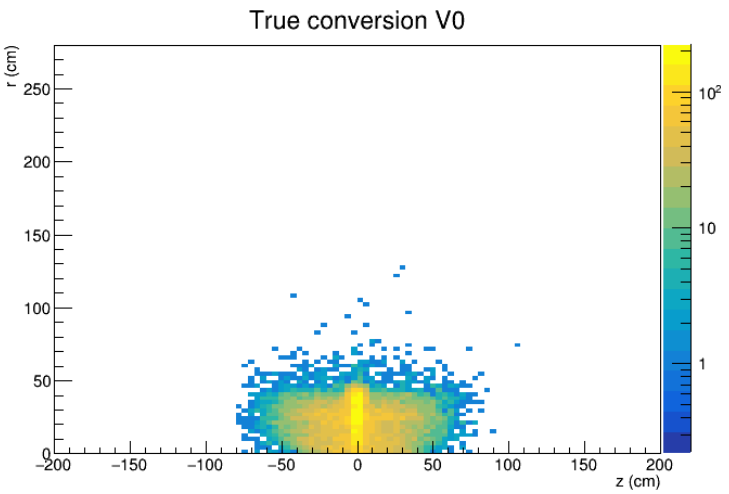
Material budget or conversion map

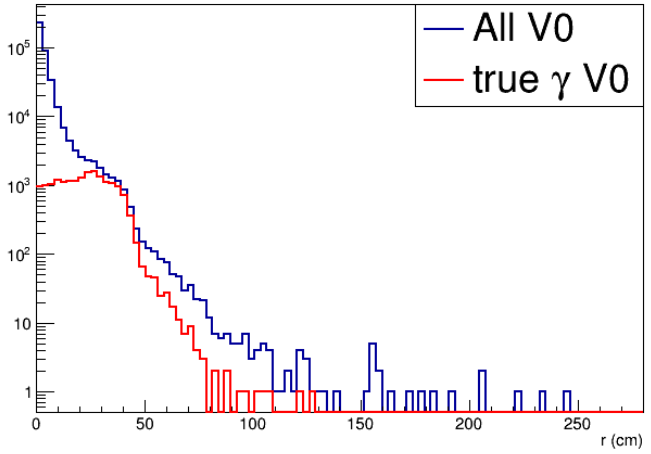
- Cut on minimal conversion radius effective

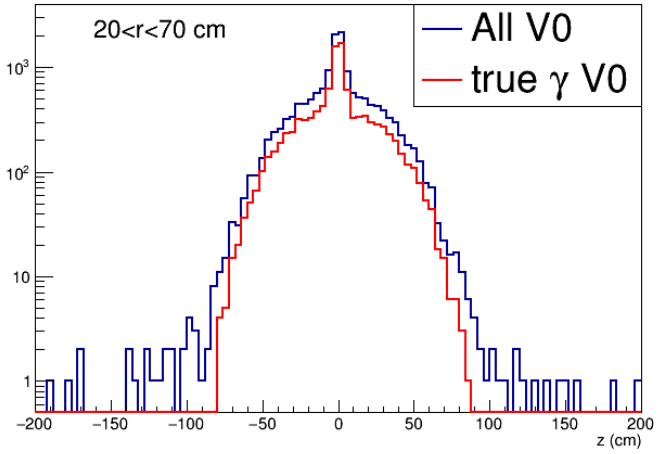
  20<r<100 cm (remove combinatorics and Dalitz decays)
- Cut on

  |z| < 100 cm possibly useful



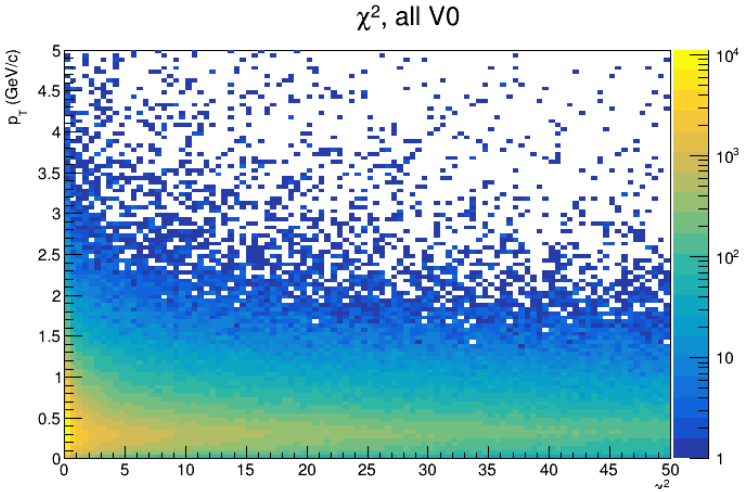


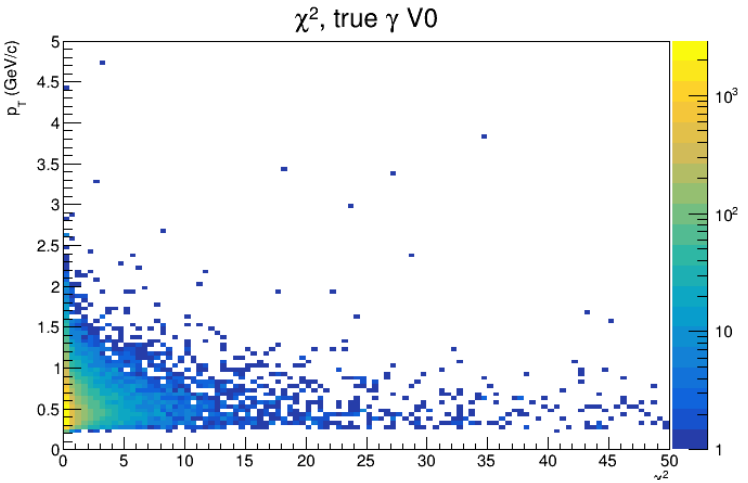


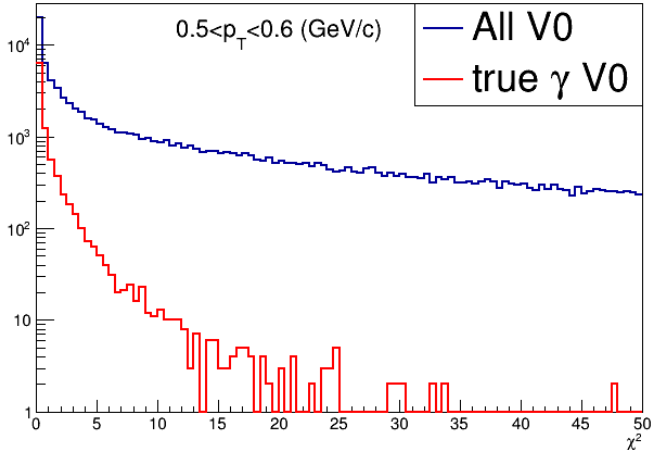


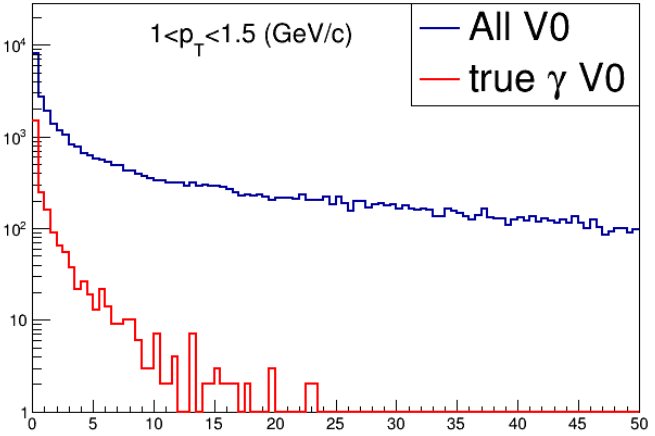
Kalman fit χ^2

- Distribution for true pairs is narrower. Try χ^2<Cut



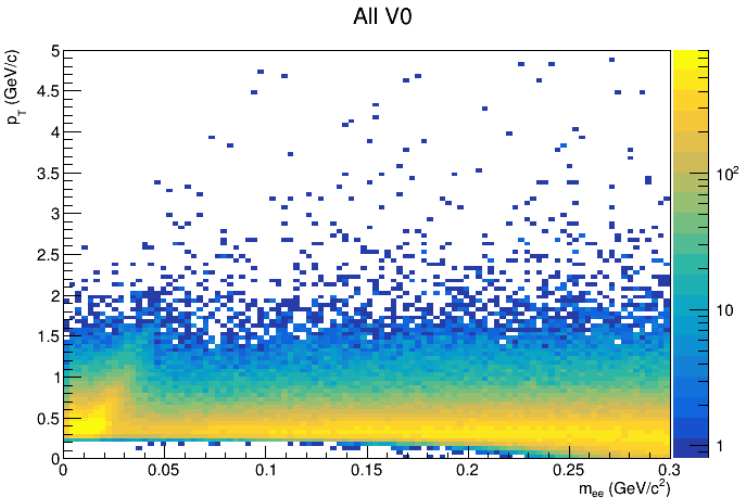


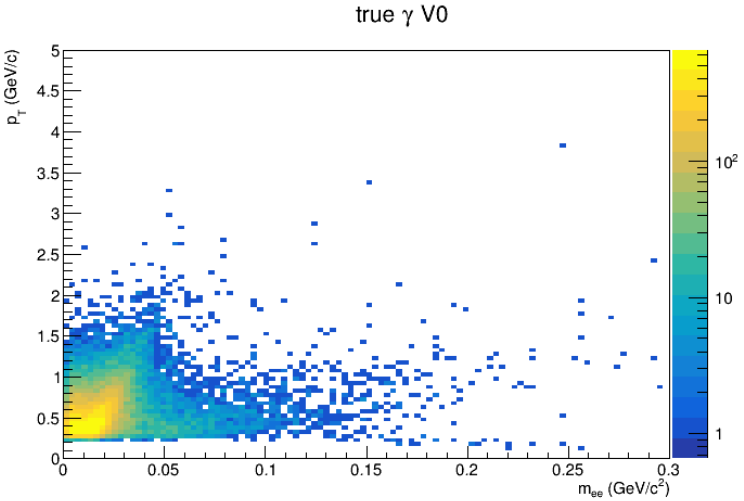


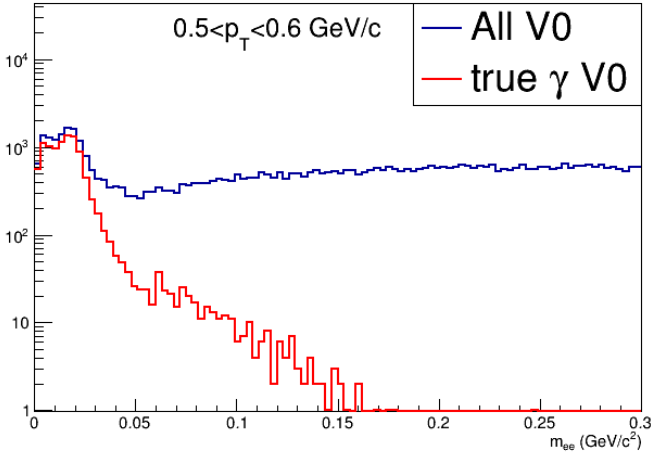


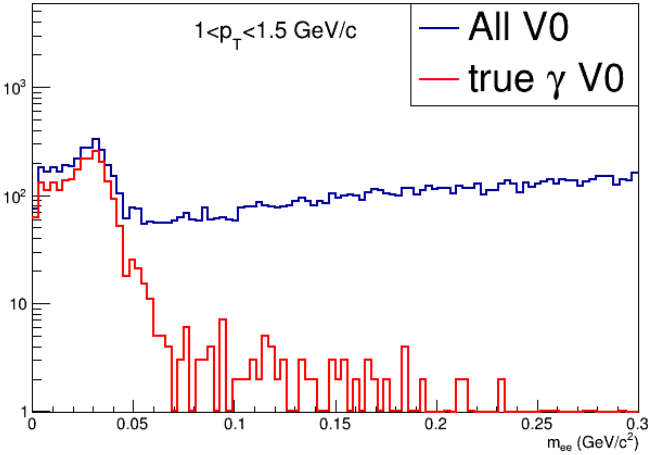
e^+e^- inv. mass

- One of the most effective cuts, use m<cut





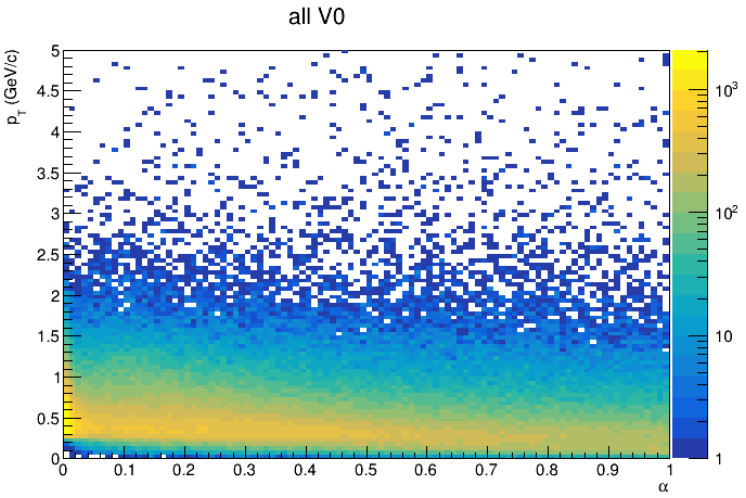


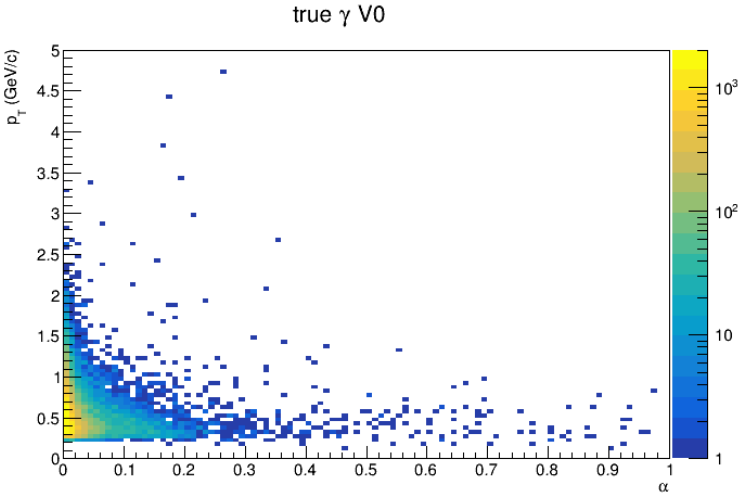


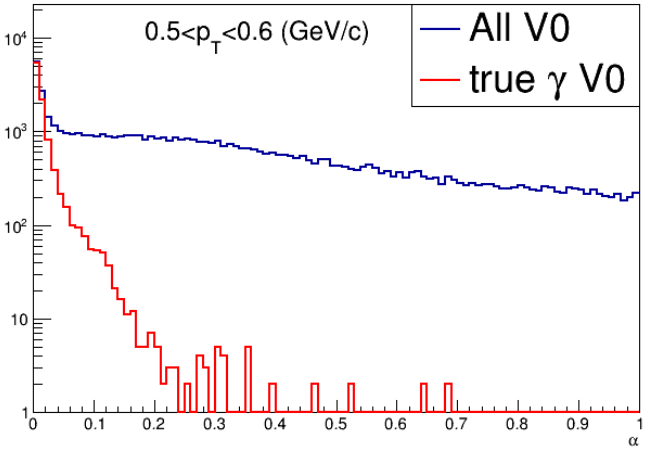
α angle

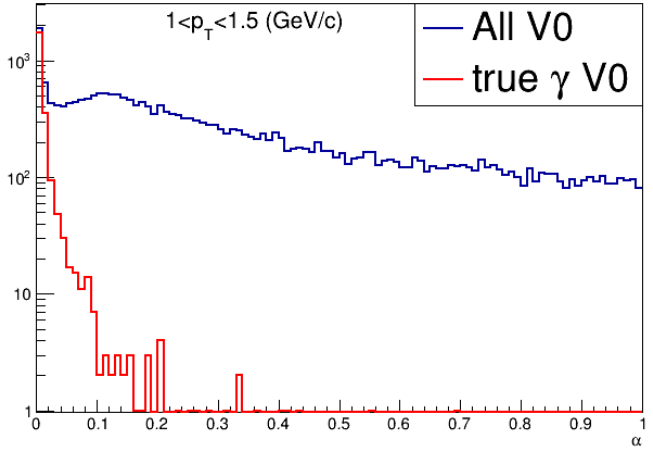
- The most effective cut, use

  α<cut





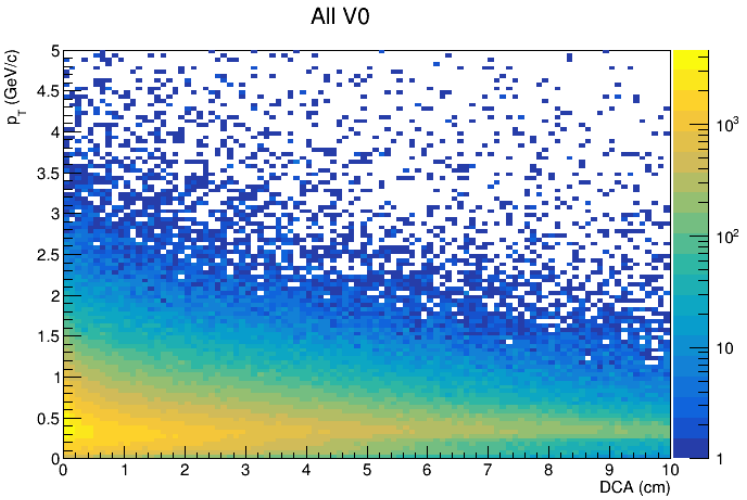


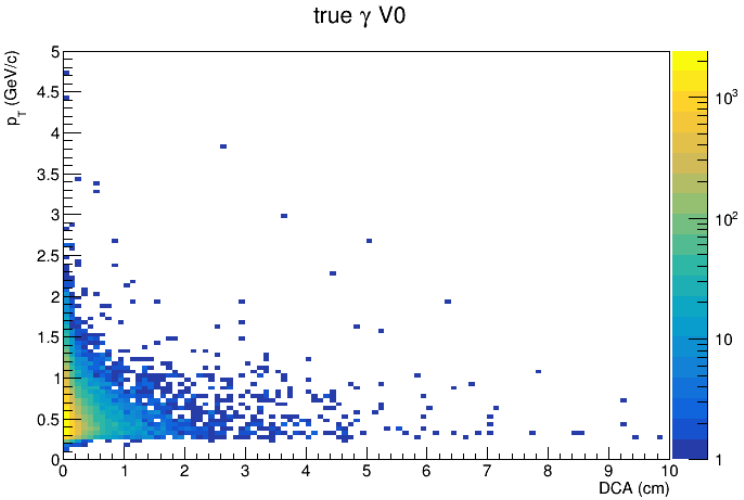


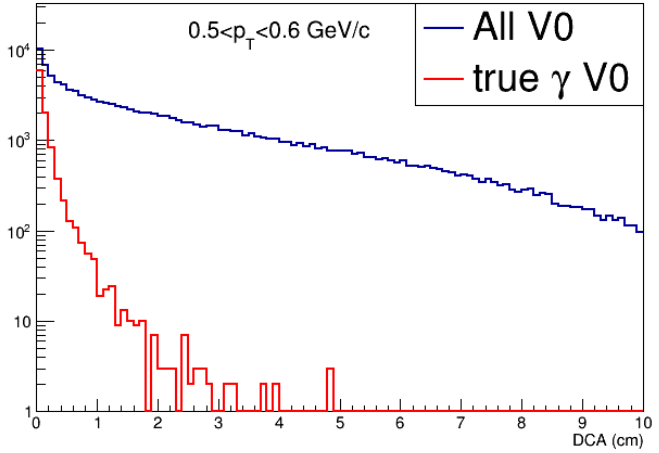
Daughter DCA

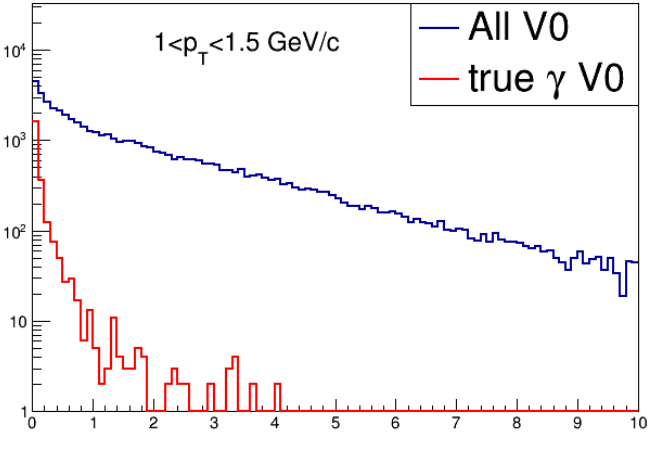
- Reduce combinatorial background, use (p_T-independent)

  dca <cut





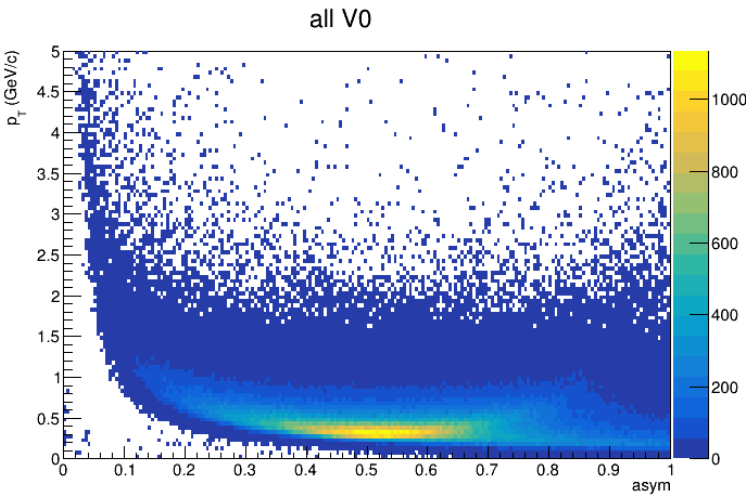


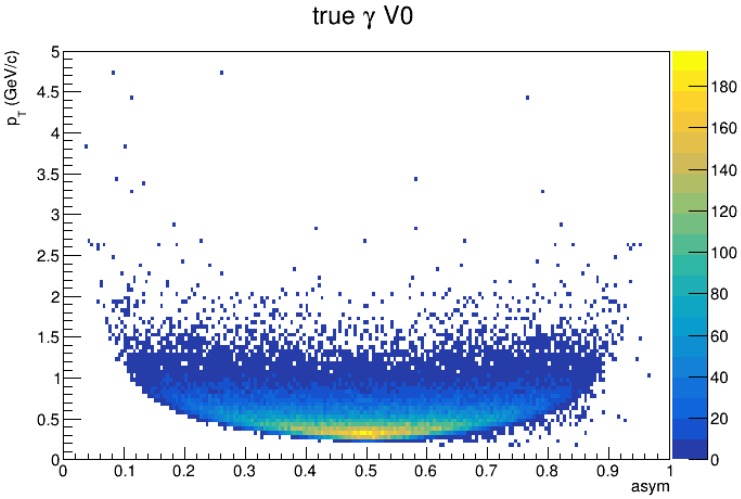


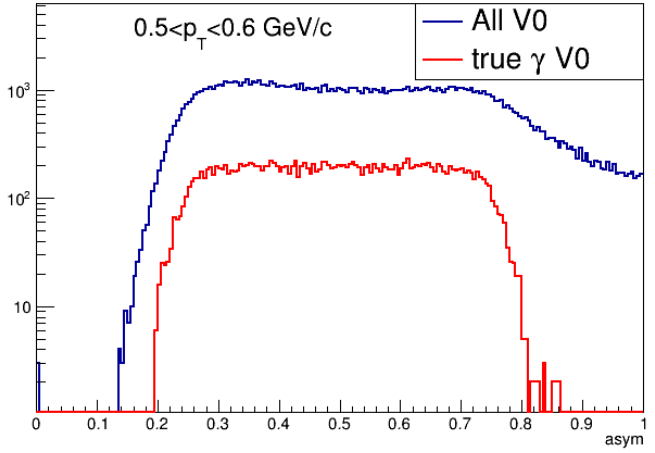
Asymmetry

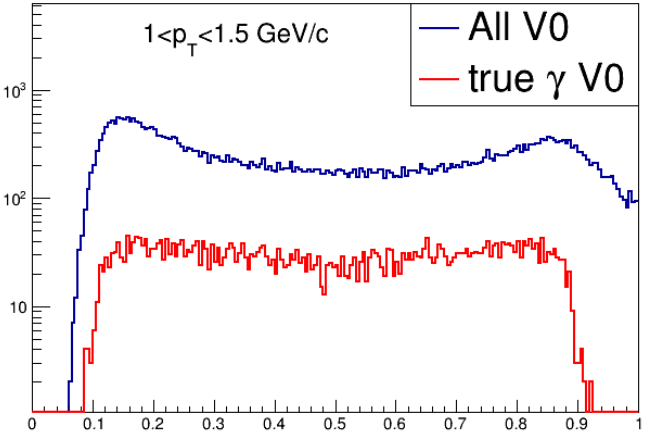
- Useless cut, try

  cut<asym<1-cut









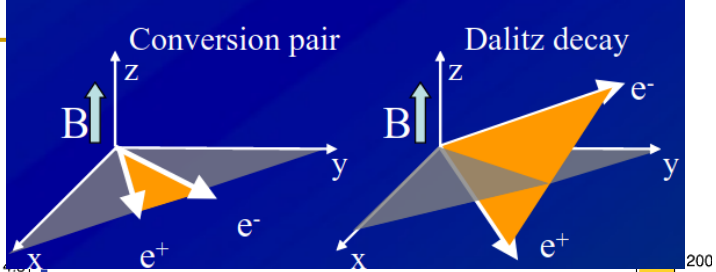
ψ cut

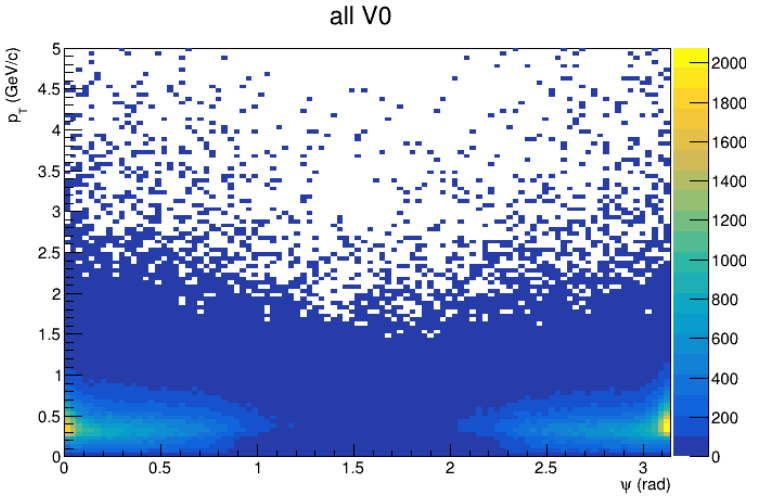
- Pair orientation wrt B-field,

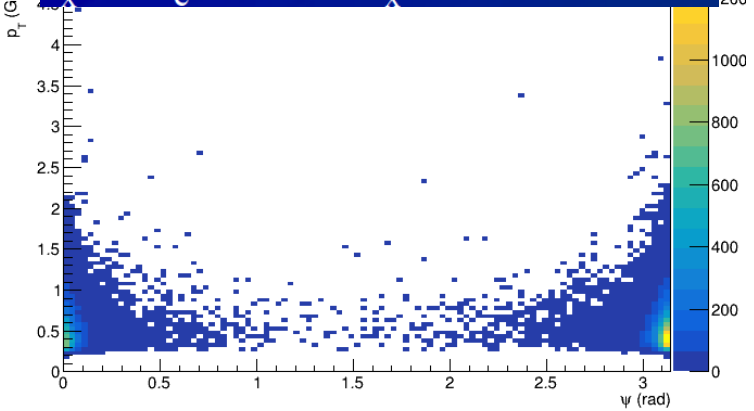
  use

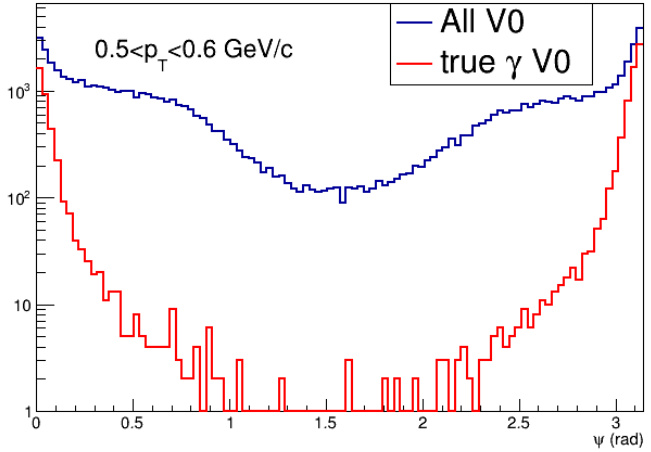
  ψ<cut ||

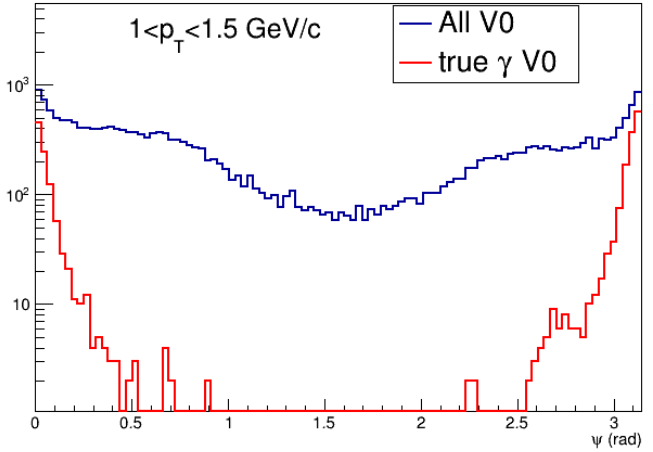
  π-cut <ψ







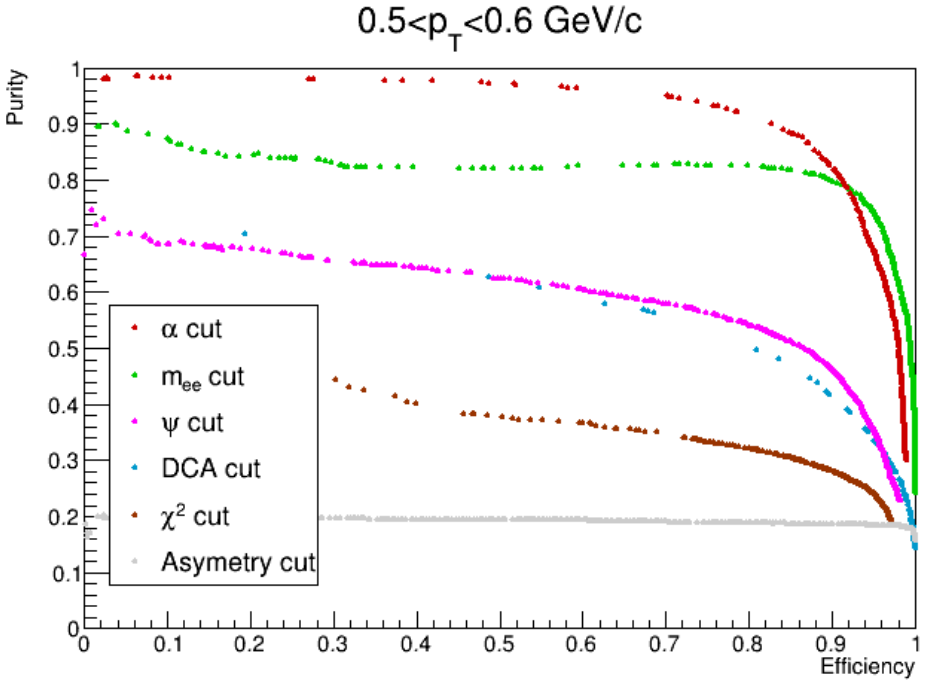


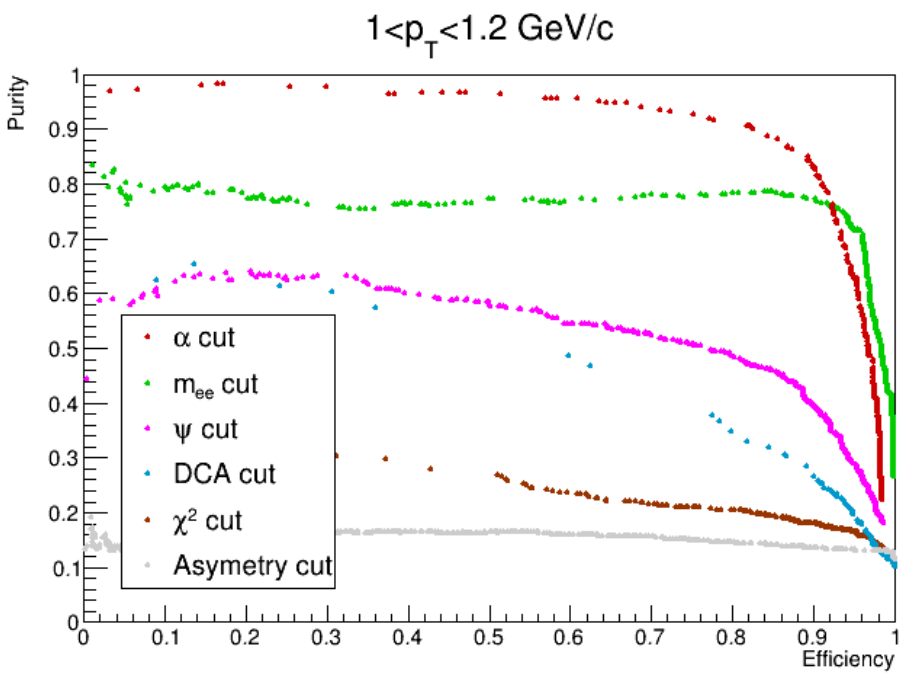


Cut optimization

- 6-7 cuts to be optimized
- Cuts are strongly correlated: optimization of one cut will influence another, e.g. one cut may contradict another and reduce efficiency without improving purity
- Simultaneous optimization
  - For each cut define possible variation range and scale to have $cut_i=f(x)$, x=0..1
  - Scan MC data fill tree with V0 parameters
  - Generate random sets (x_1,...x_n) and for each set calculate pair (Efficiency,Purity)

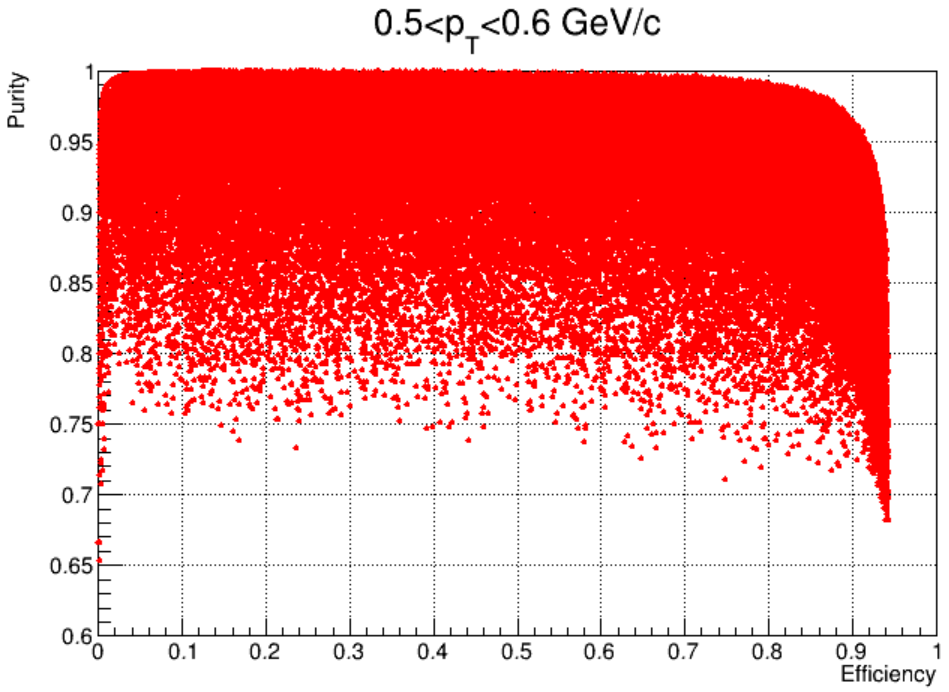
ROC for individual cuts

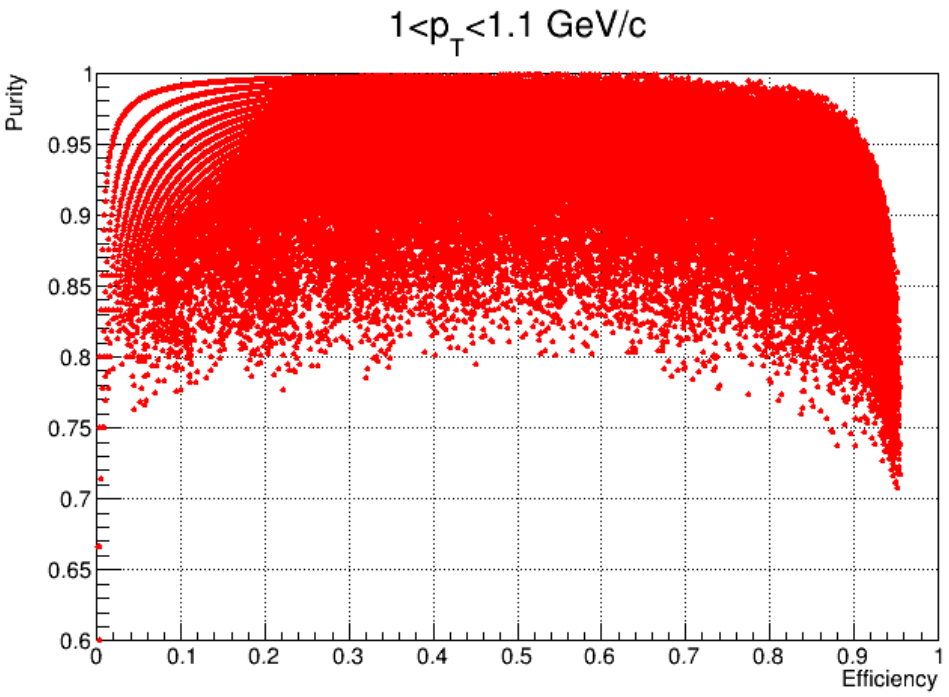




Most effective is α-cut, and cut on m_{ee}. Asymmetry cut has no resolving power

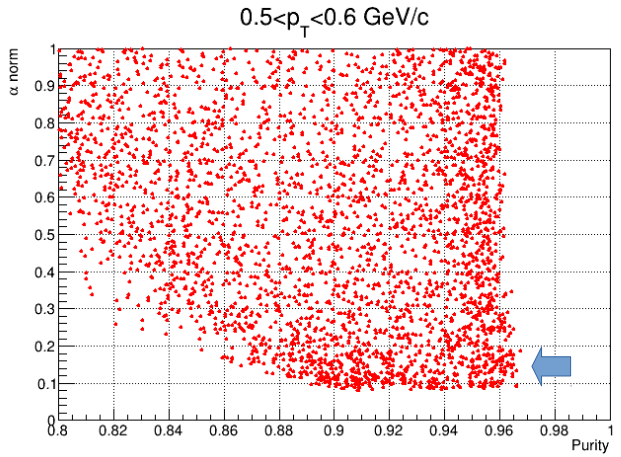
ROC: combined cuts

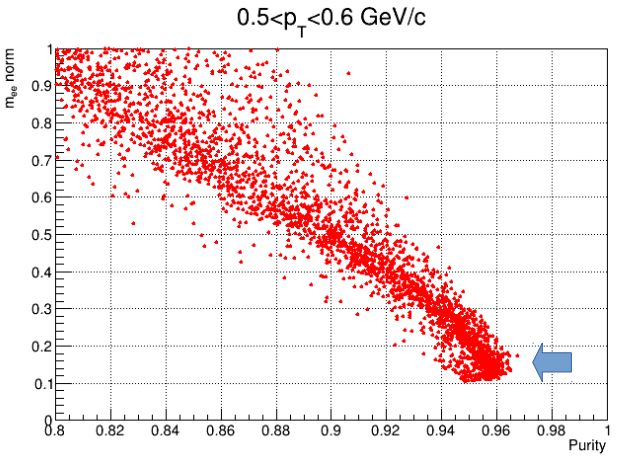


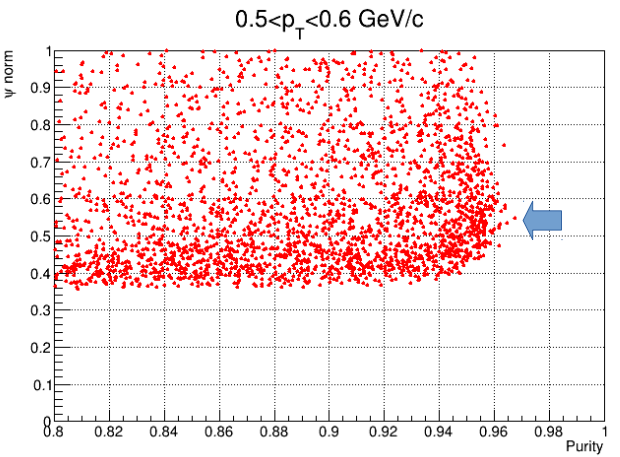


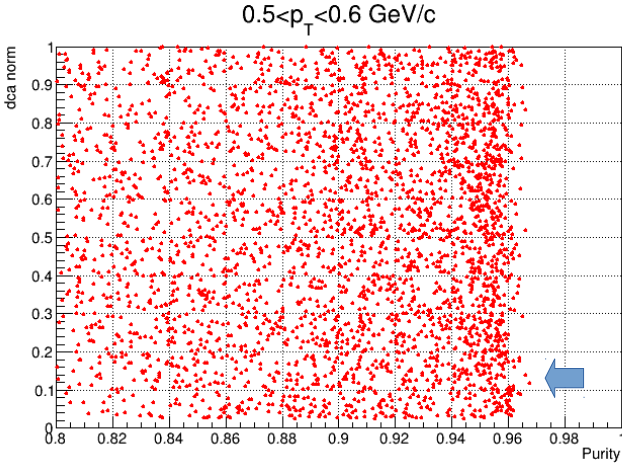
Not optimal combination of cuts can reduce purity for a fixed eff by ~20%.
Find combinations, providing maximal purity for a fixed efficiency

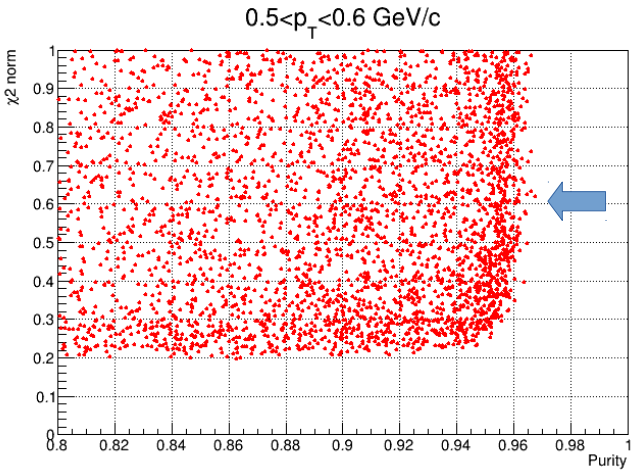
Cut optimization for efficiency=0.9

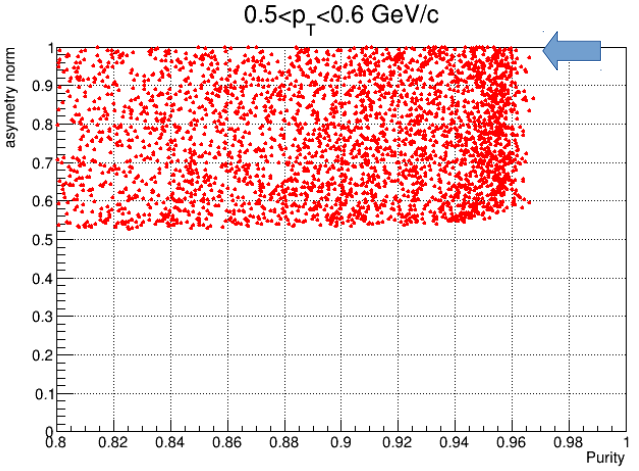






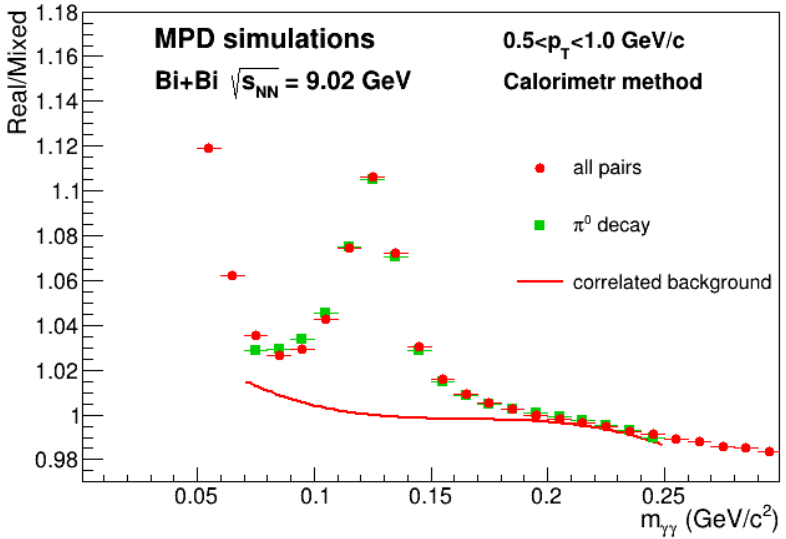


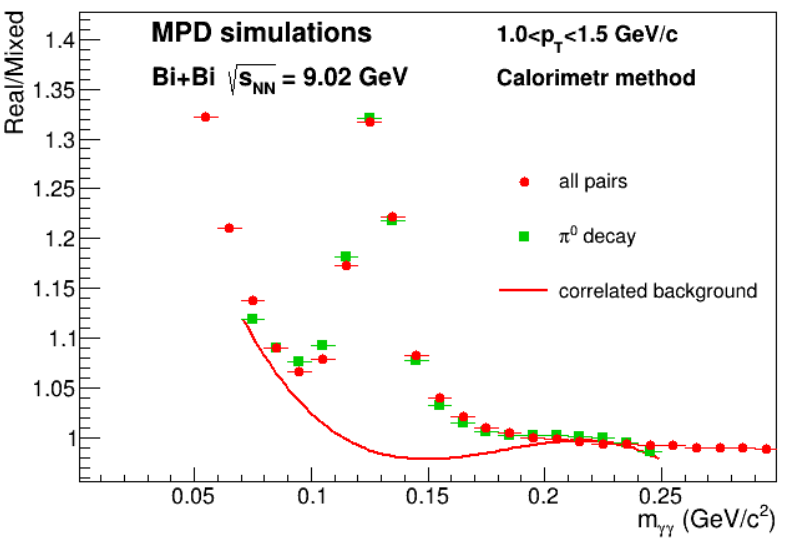




Test with neutral pion peak

Pion peaks: two photons in ECAL



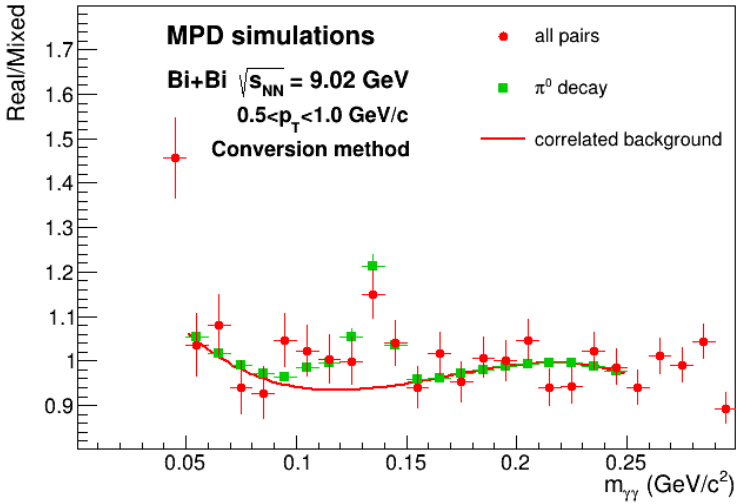


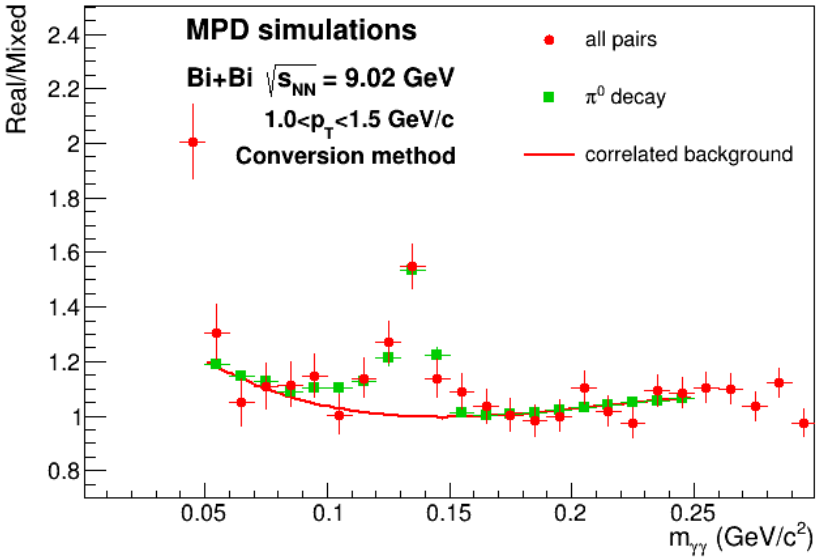
Correlated background calculated so that being added with π^0 pairs reproduce measured Re/Mi ratio

Signal/Background ratio is modest, but statistics is sufficient to extract π^0 spectrum

Shape of the combinatorial background can be improved if use finer centrality and reaction plane binning

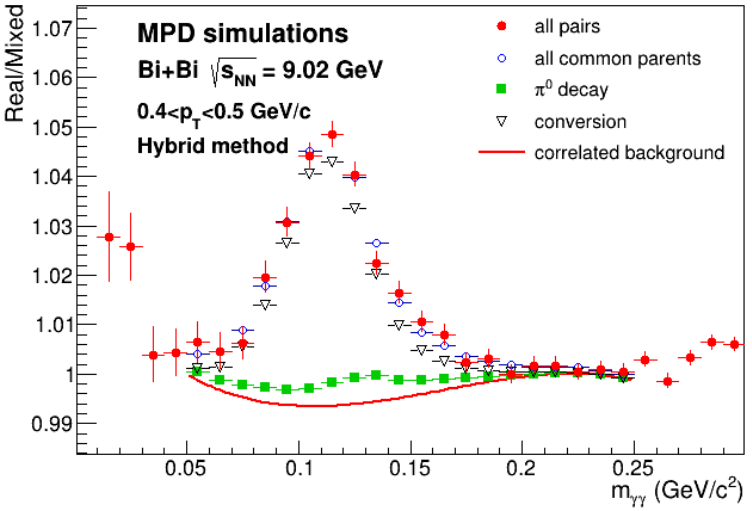
Pion peak: two converted photons

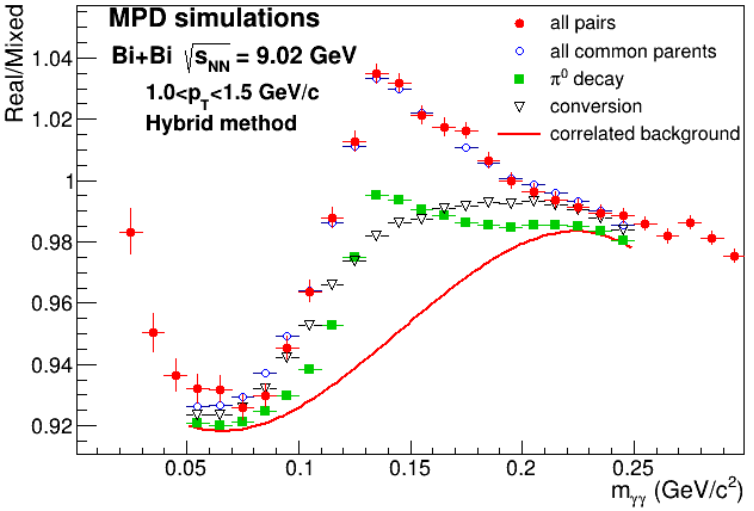


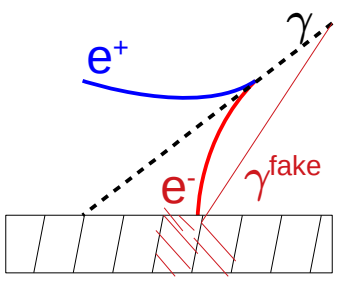


Clear pion peaks, excellent S/Bg ratio.
But very low efficiency.

π^0 peak: hybrid approach







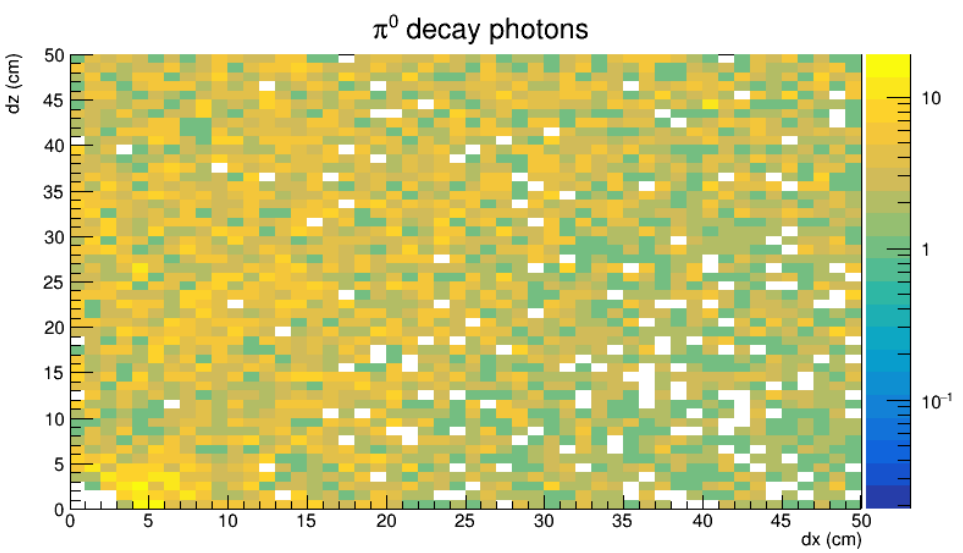
Hybrid approach: combining converted photon with one reconstructed in ECAL.

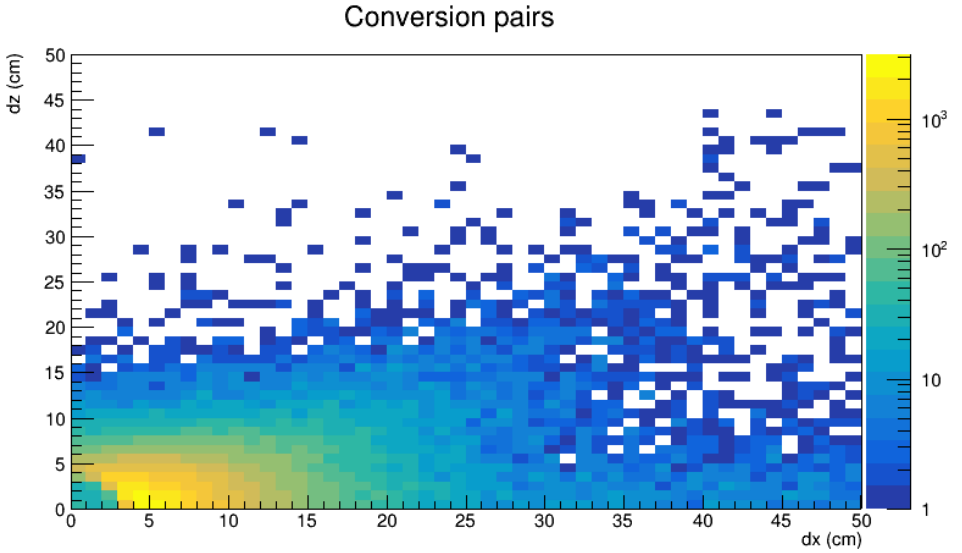
Large background correlations between reconstructed V0 photon and daughter electron/positron cluster in ECAL!
Unfortunate combination of B-field and material budget put contamination peak close to pion one

No time cut applied in ECAL in this exercise

Reducing same tracks contamination

Estimate distance between cluster and V0 tracks extrapolated to EMC



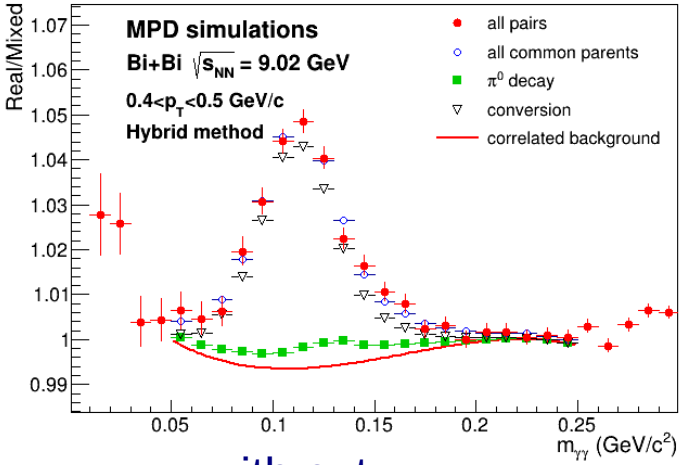


Clusters from different daughter photons uniformly distributed in dx,dz plane.
Clusters from same tracks have narrow distribution along z (B-field) and wider perpendicular to B

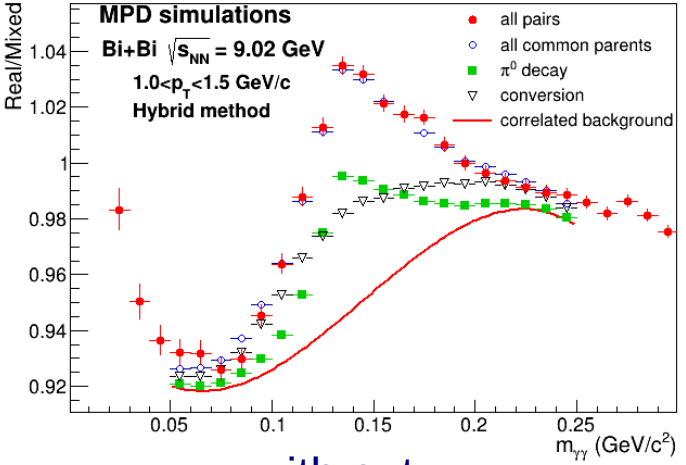
Remove clusters pairs if $r^2 = \left(\frac{dz}{5\,cm}\right)^2 + \left(\frac{dx}{18\,cm}\right)^2 < 1$

π^0 peak: hybrid corrected

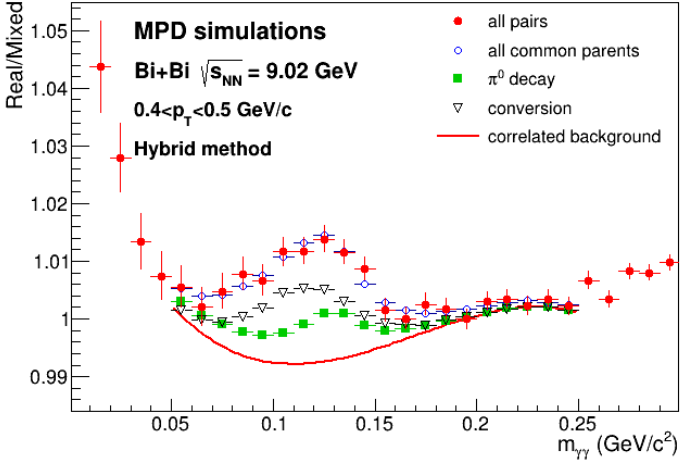
no cut



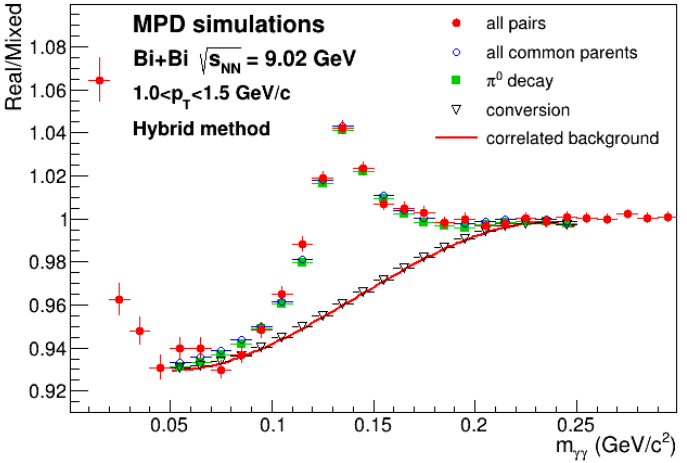
no cut



with cut

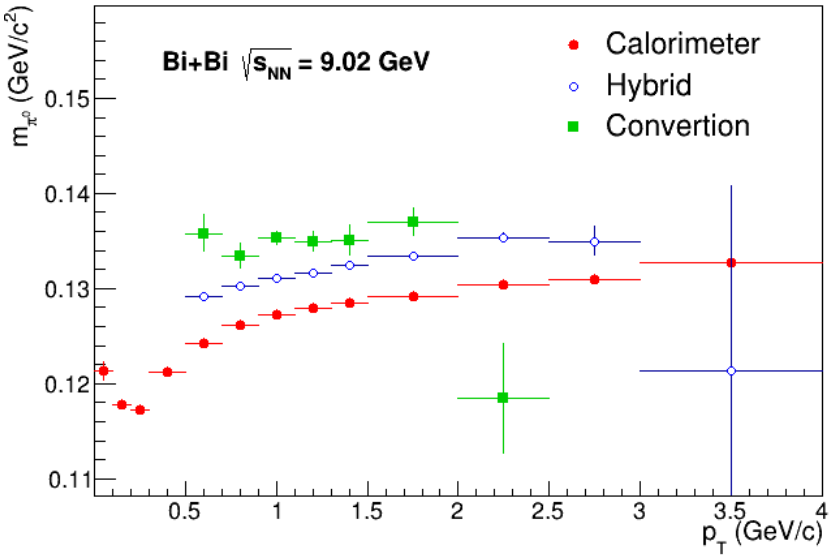


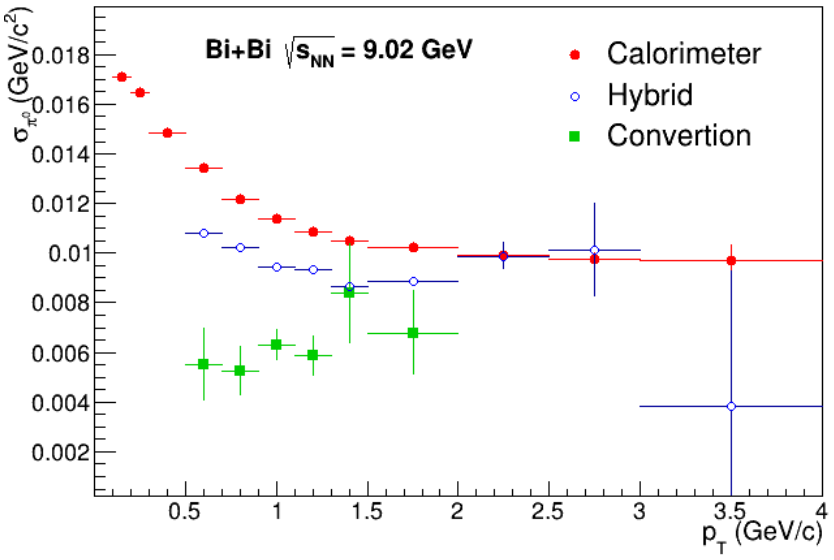
with cut



Cut reduces contamination by factor ~5, probably, more strict cut necessary for low p_T

Peak parameters

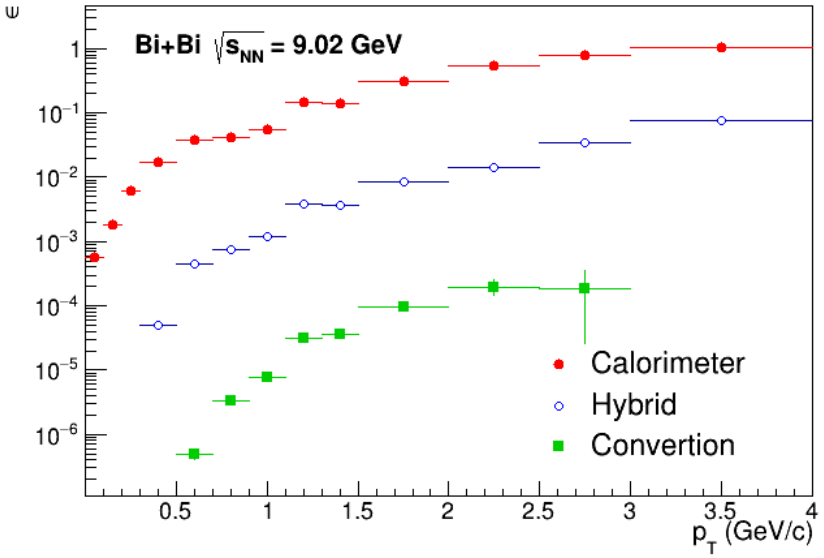


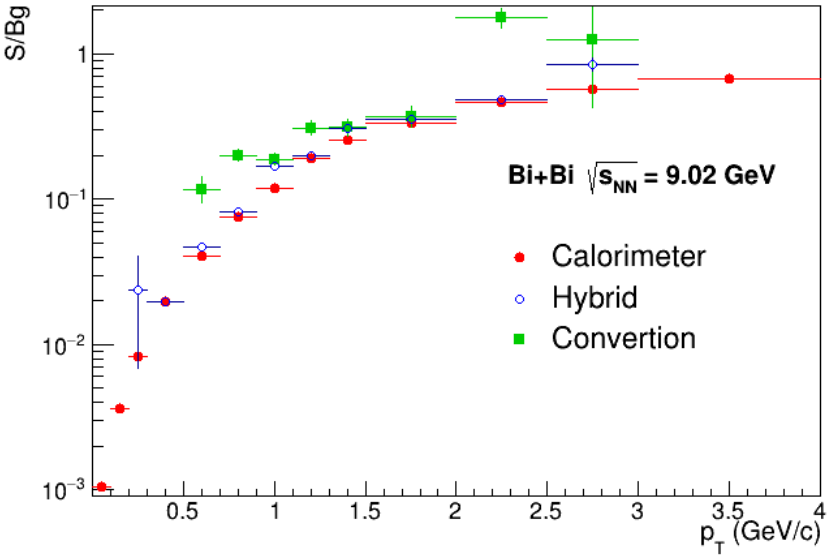


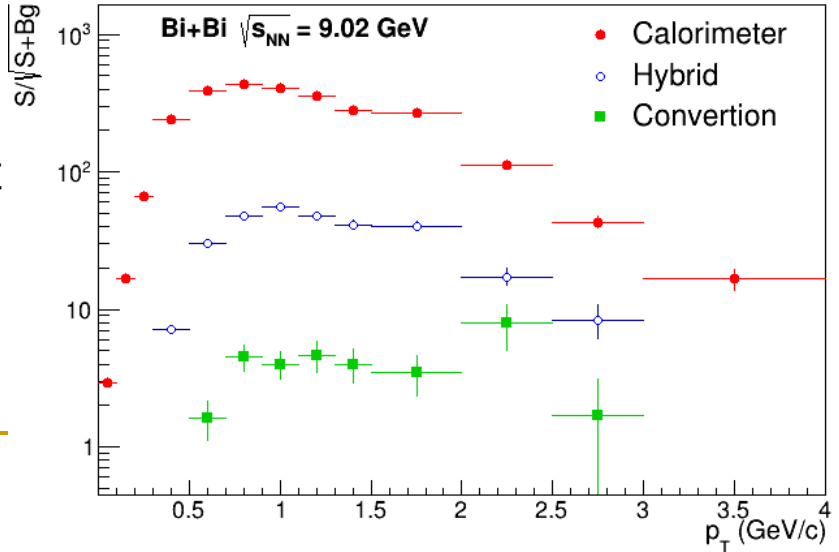
Conversion approach shows best width and stable peak position at expected mass 134 MeV,
Calorimeter - peak position shifts with increase of energy, width is larger at low p_T but gets close to conversion one at high p_T.

Hybrid – between of two approaches.

Efficiency, significance...







Conversion: larger S/Bg at low p_T and close to ECAL at high p_T but worst efficiency.

Expected significance for 10M events is better for ECAL, conversion is at the edge

Conclusions

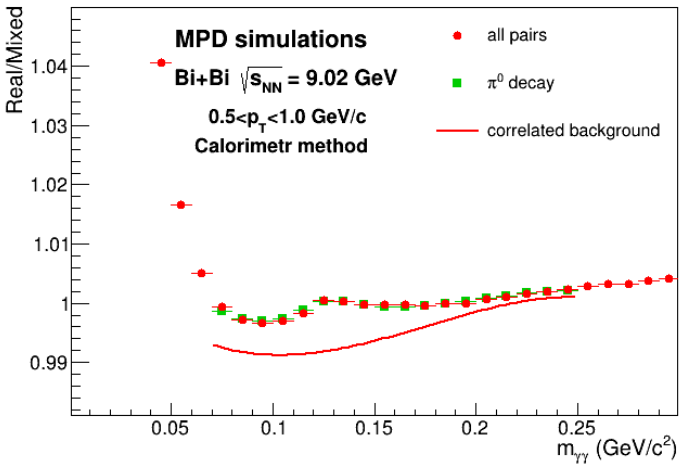
- Photon reconstruction in ECAL and with conversion technique was tested
- Identification criteria were optimized for both techniques
- Expected significance is largest for calorimeter approach and smallest for conversion
- It is important to measure photon and neutral meson spectra with 3 methods simultaneously for cross-check and reducing systematic uncertainties

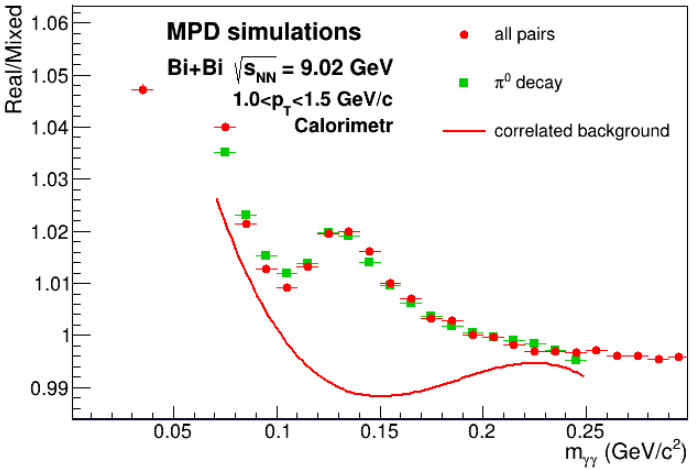
Code implementation

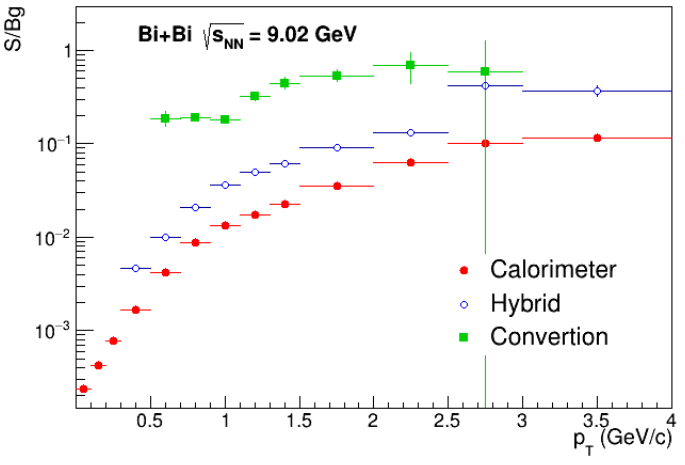
- Cluster and V0 selection implemented in class
  - physics/photons/MpdConvPi0.*
- Set of cuts for photon selection in ECAL and V0 is in the class
  - physics/photons/MpdPhotonAnalysisParams
- To be added to repository

ECAL with and without time cut

No time cut in ECAL







With 5s cut in ECAL