π^0 Reconstruction in Tau Decays

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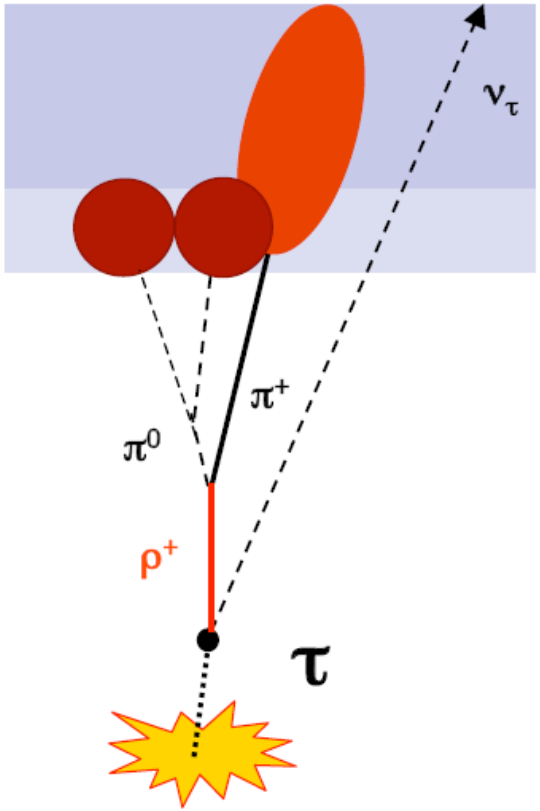
Status of π^0 Reconstruction

- Goal: reconstruct π^0 showers in τ decays
  - Improve τ identification
  - Decay mode specific analyses (i.e. polarization measurements)
- Problem: overlap between neutral and charged components of τ energy deposits
- Status: In Athena Release 15.0.0 two separate algorithms for π^0 reconstruction available
  - "Old" Tau1p3pCreatePi0Clus
  - "New" TauCommonCreatePi0Clus
- Previous study in release 13.0.40



Reminder on tau1P3P π^0 Reconstruction

Reconstruction of π^0 in ECAL:

1. Prepare cellcontainer from ECAL cells with
   $0.0375 < \Delta R$ (track-cell) < 0.4

2. Run Topoclustering on ECAL cell container

3. Required criteria for π^0 clusters
   - $0.0375 < \Delta R$ (track-cluster) < 0.2
   - E_T (cluster) > 1 GeV
   - Energy fraction in first 2 layers of ECAL > 0.1

Reminder on tauCommon π^0 Reconstruction

Reconstruct π^0 in ECAL after subtraction of energy deposits from $\pi^\pm$ (1 prong):

1. Determine $\pi^\pm$ energy in ECAL: $E_{\pi^\pm_{ECAL}} = E_{trk} - E_{\pi^\pm_{HCAL}}$

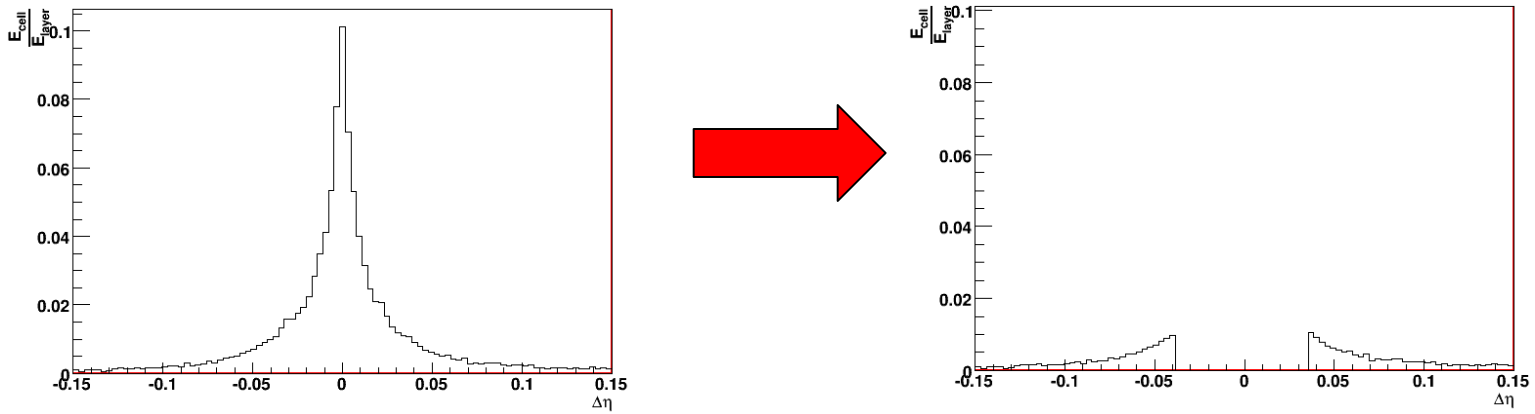
2. Cell-by-cell subtraction of $E_{\pi^\pm_{ECAL}}$ from τ energy in ECAL
   (according to fitted 2-dim hadronic shower shape)

3. Find π^0 candidates in remaining ECAL energy distribution

4. Suppress fake π^0 candidates with cuts on cluster shape variables

Differences in Charged Energy Subtraction

- tau1p3p removes charged energy by removing cells closer than ΔR = 0.0375 to track, before clustering



- TauCommon does cell-energy subtraction according to parametrized shower development

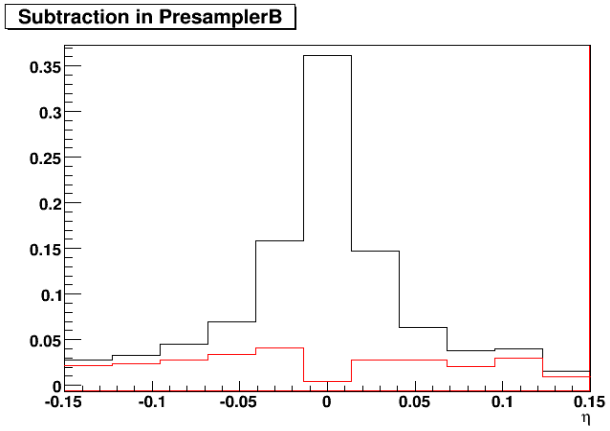
Lateral (f_L) : 2D

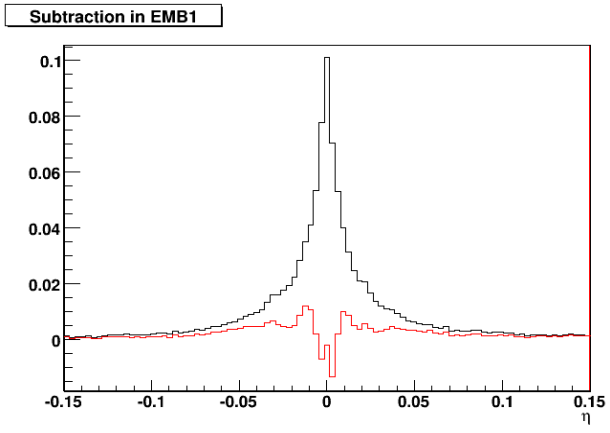
$$w_i = c_L \cdot \int_{\text{volume cell i}} \mathrm{f}_L\left(\eta - \eta_{trk}, \phi - \phi_{track}\right) \cosh(\eta) d\eta d\phi$$

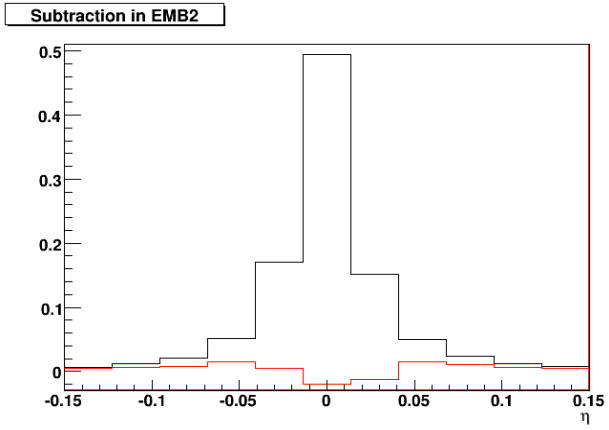
Longitudinal (c_L): weights per ECAL layer

Shower Subtraction

- Shower parametrization using single tau samples
- Validation using independent $Z \rightarrow \tau\,\tau$ sample
- Here energy profiles from $\tau \rightarrow \pi^{\pm}\nu$ decays (no π^0´s) before and after subtraction







Comparison of Athena Implementations

- apply same cuts as 1P3P algorithm, compare #π^0 for different decay modes
- 1P3P:

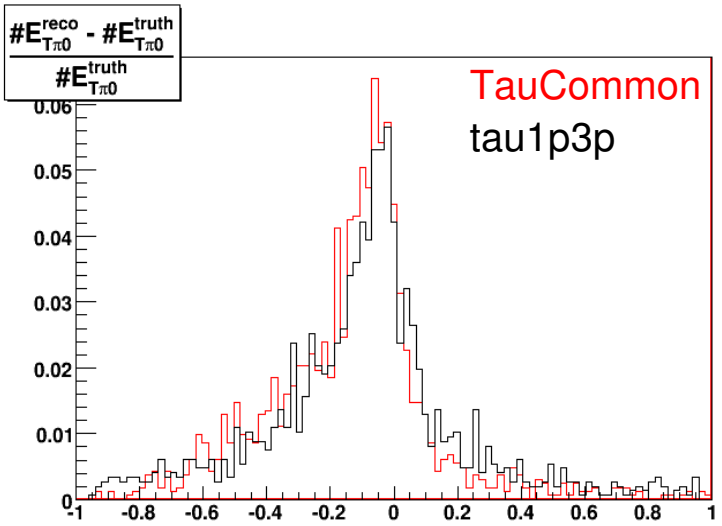
decay mode	zero pi0	one pi0	two pi0	three pi0	four pi0	five pi0	more than five
true pinu	72.4%	19.5%	6.3%	1.2%	0.5%	0.0%	0.1%
true rho	21.8%	55.3%	18.0%	4.1%	0.8%	0.1%	0.0%
true a1	12.4%	42.0%	30.5%	12.3%	2.5%	0.3%	0.0%

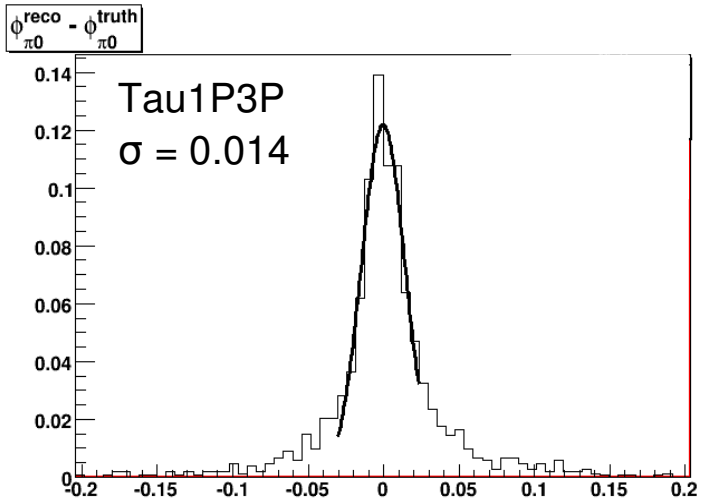
- TauCommon:

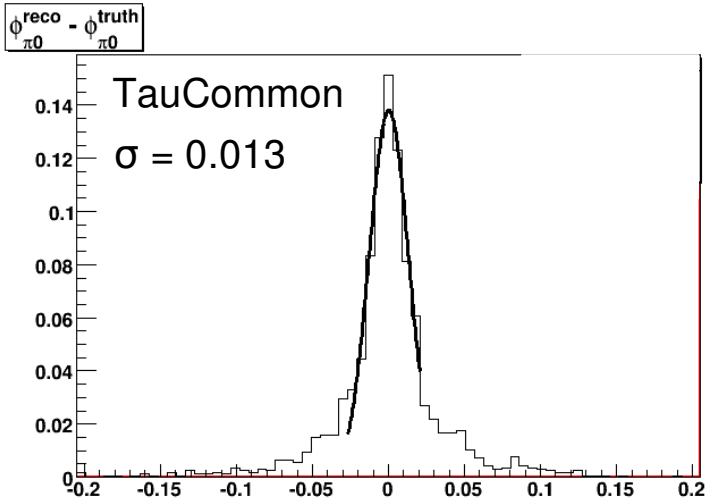
decay mode	zero pi0	one pi0	two pi0	three pi0	four pi0	five pi0	more than five
true pinu	82.6%	14.5%	2.5%	0.3%	0.1%	0.0%	0.0%
true rho	18.3%	60.0%	18.4%	2.9%	0.3%	0.0%	0.0%
true a1	6.7%	42.7%	35.6%	11.9%	2.8%	0.2%	0.0%

Comparison: Resolutions Central Barrel

- Look at truth matched $\tau \rightarrow \rho\nu$ decays:







Comparison: “Efficiencies” Endcap

- apply same cuts as 1P3P algorithm, compare #π^0 for different decay modes
- 1P3P:

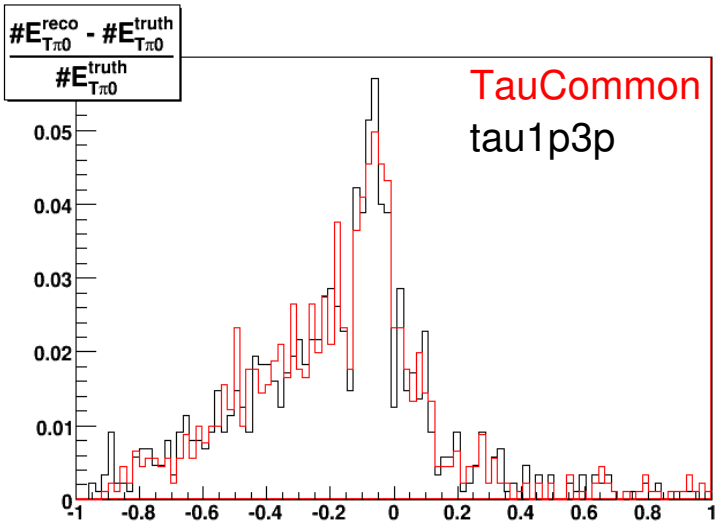
decay mode	zero pi0	one pi0	two pi0	three pi0	four pi0	five pi0	more than five
true pinu	65.9%	18.3%	10.5%	3.3%	1.2%	0.5%	0.3%
true rho	18.8%	44.8%	25.4%	8.0%	2.3%	0.4%	2.3%
true a1	10.2%	30.4%	32.8%	19.8%	5.3%	1.2%	0.3%

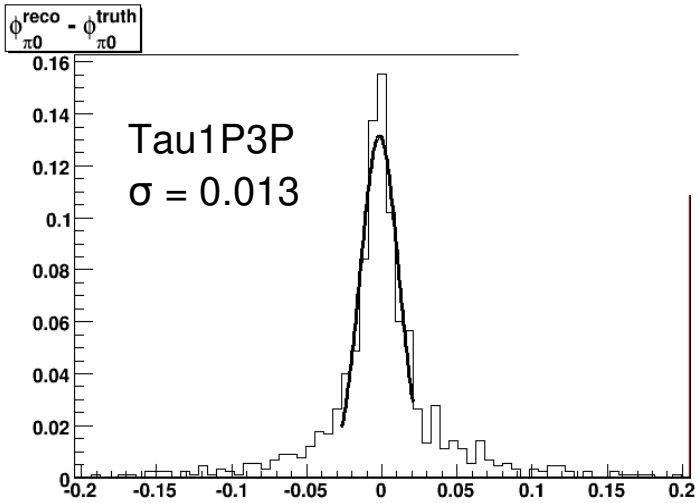
- TauComon:

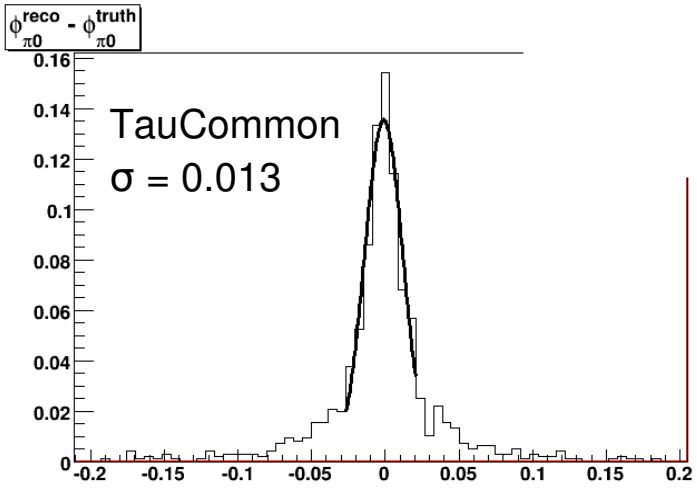
decay mode	zero pi0	one pi0	two pi0	three pi0	four pi0	five pi0	more than five
true pinu	65.9%	23.3%	5.9%	1.8%	0.8%	0.3%	0.1%
true rho	16.3%	49.0%	24.8%	7.7%	1.7%	0.3%	0.2%
true a1	8.2%	30.8%	32.9%	20.5%	5.7%	1.5%	0.4%

Comparison: Resolutions Endcap

- Look at truth matched $\tau \rightarrow \rho\nu$ decays:



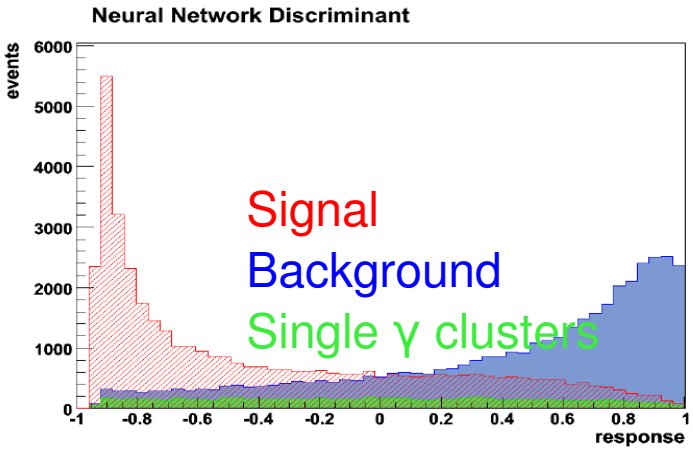




Fake π^0 suppression

- Tau1p3p cuts
  - E_T (cluster) > 1 GeV
  - 0.0375 < ΔR (track-cluster) < 0.2
  - Energy fraction in first 2 layers of ECAL > 0.1

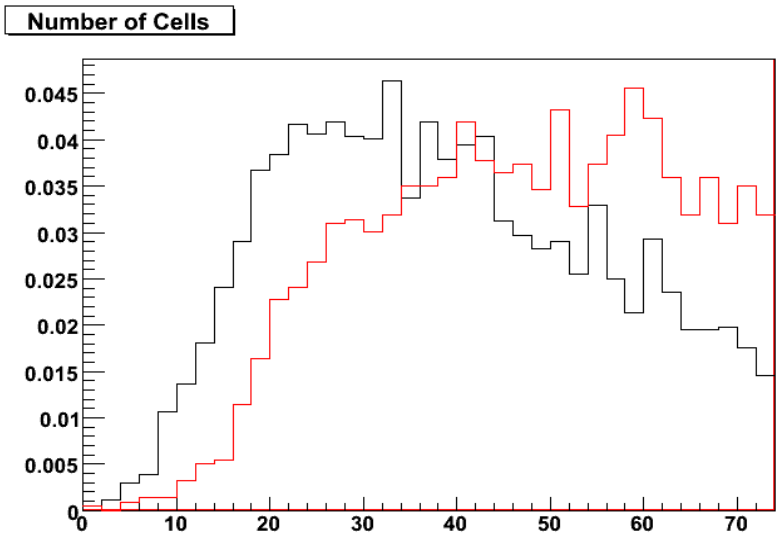
- Taucommon cuts (shower shapes with best separation power selected)
  - ET > 500 MeV
  - ΔR (track-cluster) < 0.2
  - ln(1st moment in E/V)
  - 2nd moment in eta
  - Number of Cells

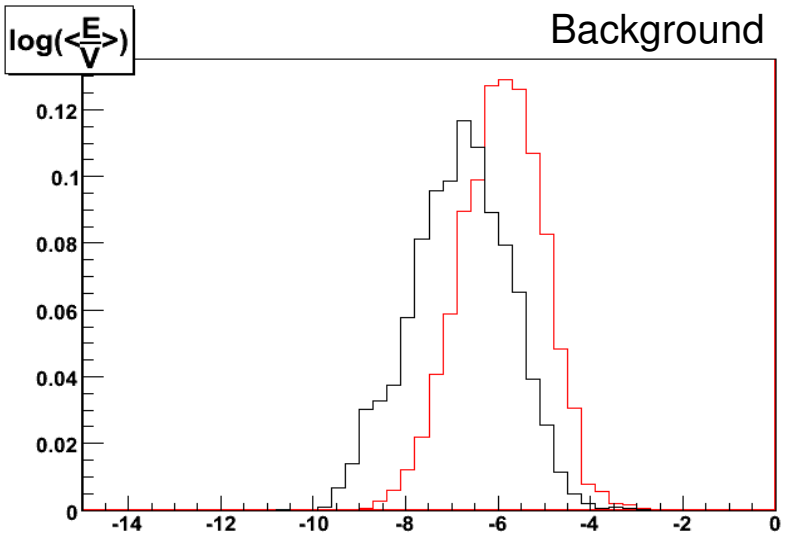


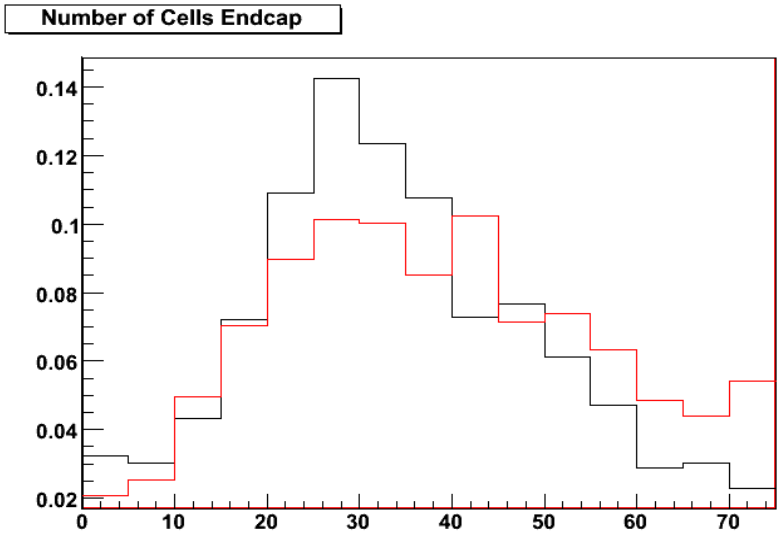
- (Re)tune fake suppresion cuts
- Cross check with Bjoern´s safe variables

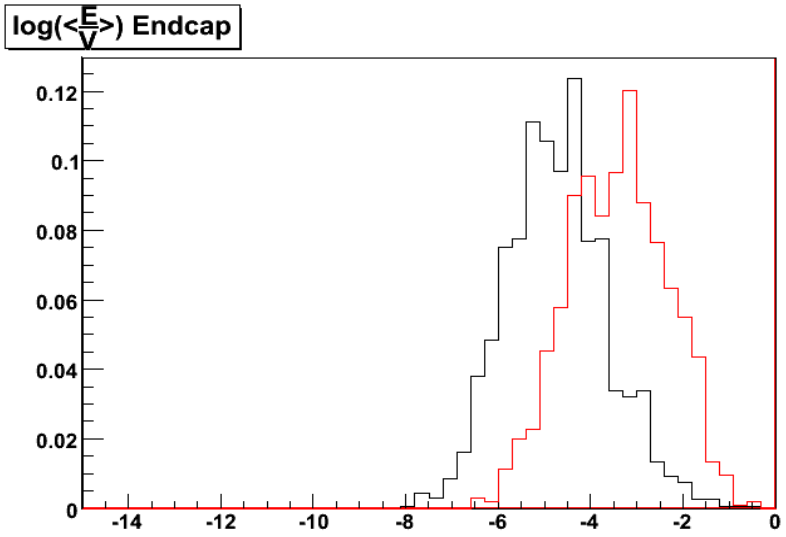
Background suppression variables

Signal
Background









Status summary and Current work

Status:

- Validation for single prong nearly completed
  - Subtraction performance validated
  - Extension to Endcaps looks OK

Current Work on:

- TauCommon π^0 id-cuts being optimized now
- Study p_T-dependence of method and extension of study to larger p_T (e.g. $A \rightarrow \tau\tau$)

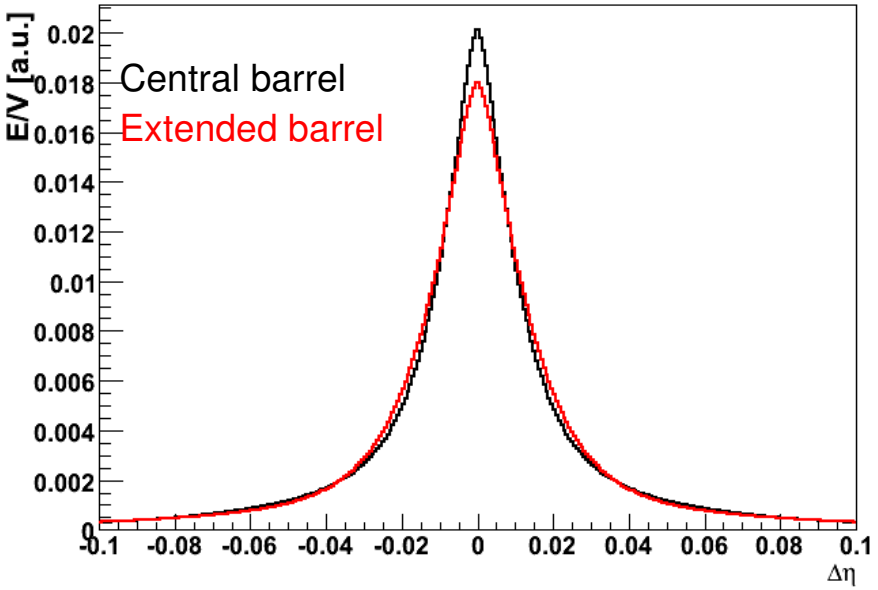
Thank you for your attention!

- Backup

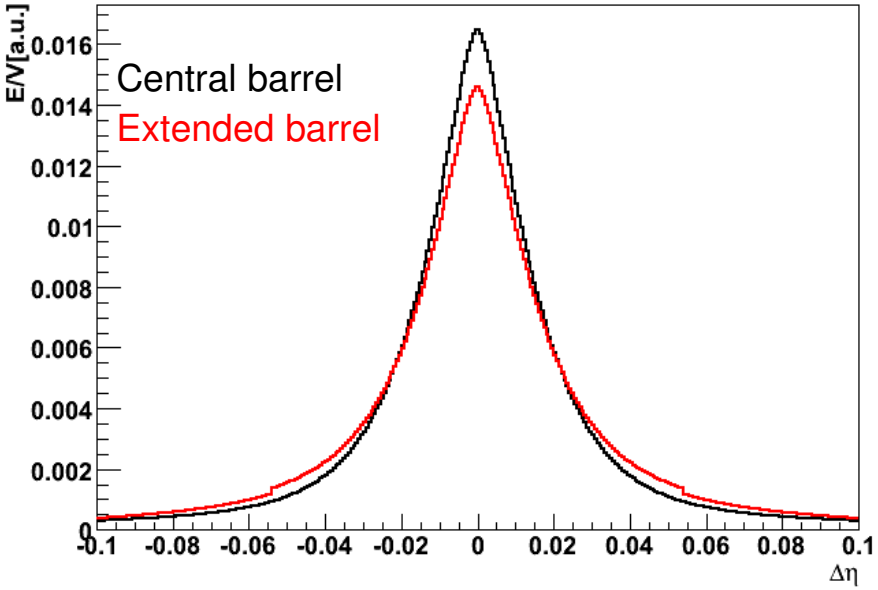
Recent developments of algorithm

- Extended η range (from 1.4 to 2.5)
- Adjustments for extended barrel:
  - different cell geometry
  - Different lateral shower shapes

Fit for eta strip layer



Fit for Presampler



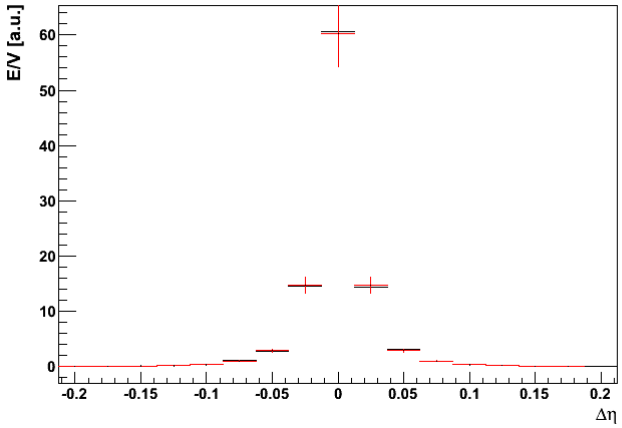
new shower shape fits for extended barrel region

Recent developments of algorithm

- Bug Fix for Cell hash mapping
  - before: cluster loss after several 100 evts

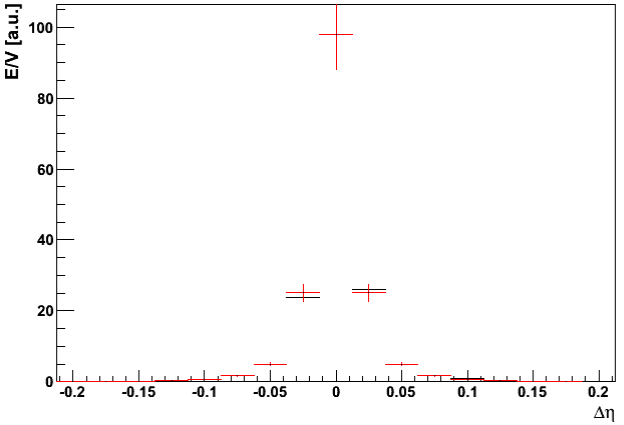
- Implemented 2-Dimensional Shower Shape Fits, both for central and extended barrel

Fit for EMB layer 2



Simulated τ → ρν
histogramm filled
according to fit

Fit for EME layer 2



- To Do: extension to muti-prong case
  - postponed until validation for 1-prong complete

Modifying the cut selection

- Efficiency table already shifted towards low #π^0

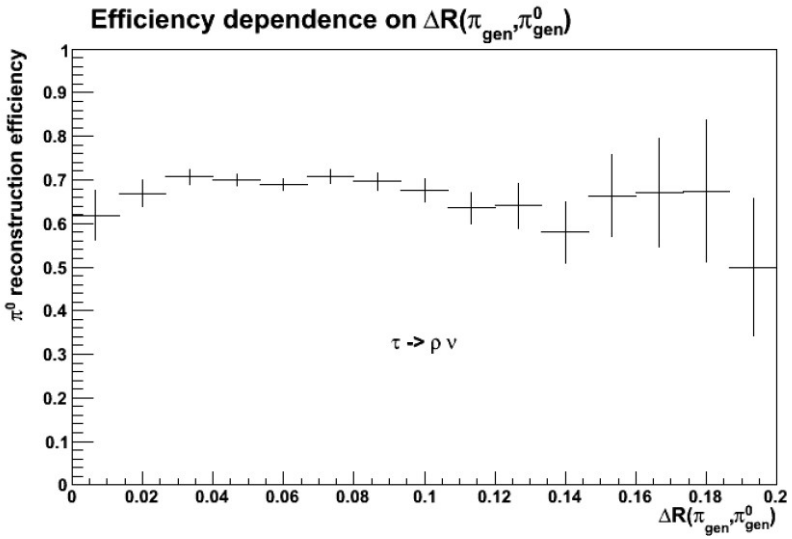
decay mode	zero pi0	one pi0	two pi0	three pi0	four pi0	five pi0	more than five
true pinu	0.826	0.145	0.025	0.003	0.001	0.000	0.000
true rho	0.183	0.600	0.184	0.029	0.003	0.000	0.000
true a1	0.067	0.427	0.356	0.119	0.028	0.002	0.000

- Loosen cut on cluster Et to 500 MeV

decay mode	zero pi0	one pi0	two pi0	three pi0	four pi0	five pi0	more than five
true pinu	0.719	0.220	0.052	0.008	0.001	0.000	0.000
true rho	0.131	0.578	0.235	0.049	0.007	0.001	0.000
true a1	0.042	0.390	0.375	0.151	0.034	0.008	0.000

Strategy for validation of 1 prong

- Validate energy subtraction
  - apply same cuts as 1P3P algorithm
  - drop $\Delta R > 0.0375$ cut (gain in $\#\pi^0$ close to track ?)
  - compare $\#\pi^0$ for different decay modes



- Look at truth matched $\tau \rightarrow \rho\nu$ decays for:
  - η- ,φ- and E_T resolutions
- Comparison with 1D cuts from Common method

Performance comparable with results previously shown for NN

(numbers from athena implementation coming soon)

property	selection
E_T	$> 1\,\mathrm{GeV}$
$\Delta R(\mathrm{track}, \pi^0_{\mathrm{cand}})$	< 0.2
$\langle \eta^2 \rangle$	< 0.0007
$\log\left(\langle \frac{E}{V} \rangle\right)$	> -7
N_{cells}	> 12

Future Developments

- Extension of method to multiple tracks in progress

- Look into recovery of single photon clusters
- Efficiency of π^0 reconstruction drops with distance between the two photons from π^0 decay

  - Not highest priority
    - Only about 5% of π^0 candidates come from single photon clusters