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Towards a Particle Based Tau ID at low energies

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(1) Motivation

(2) Issues with TopoClusters

(3) Optimizing clustering parameters

(4) Cluster moments

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Motivation

A) ATLAS is blessed with a high granularity calorimeter

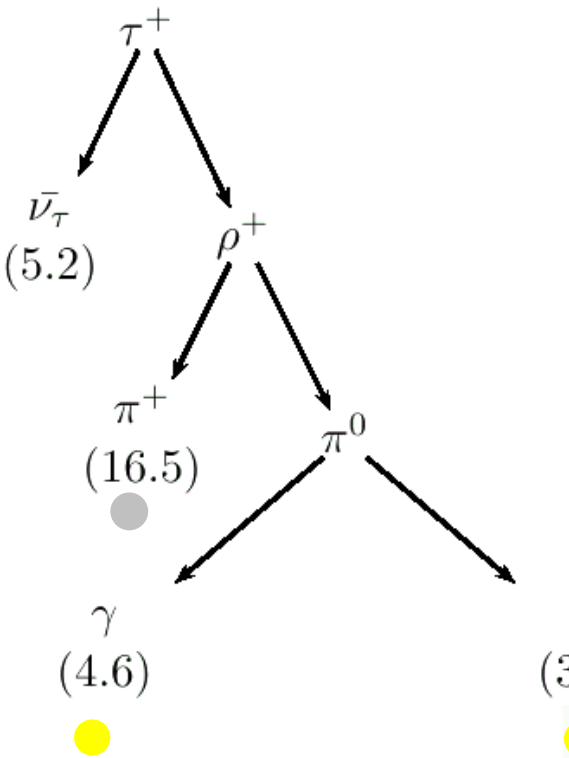
B) Topological clustering provides a window towards resolving the energy depositions of individual particles

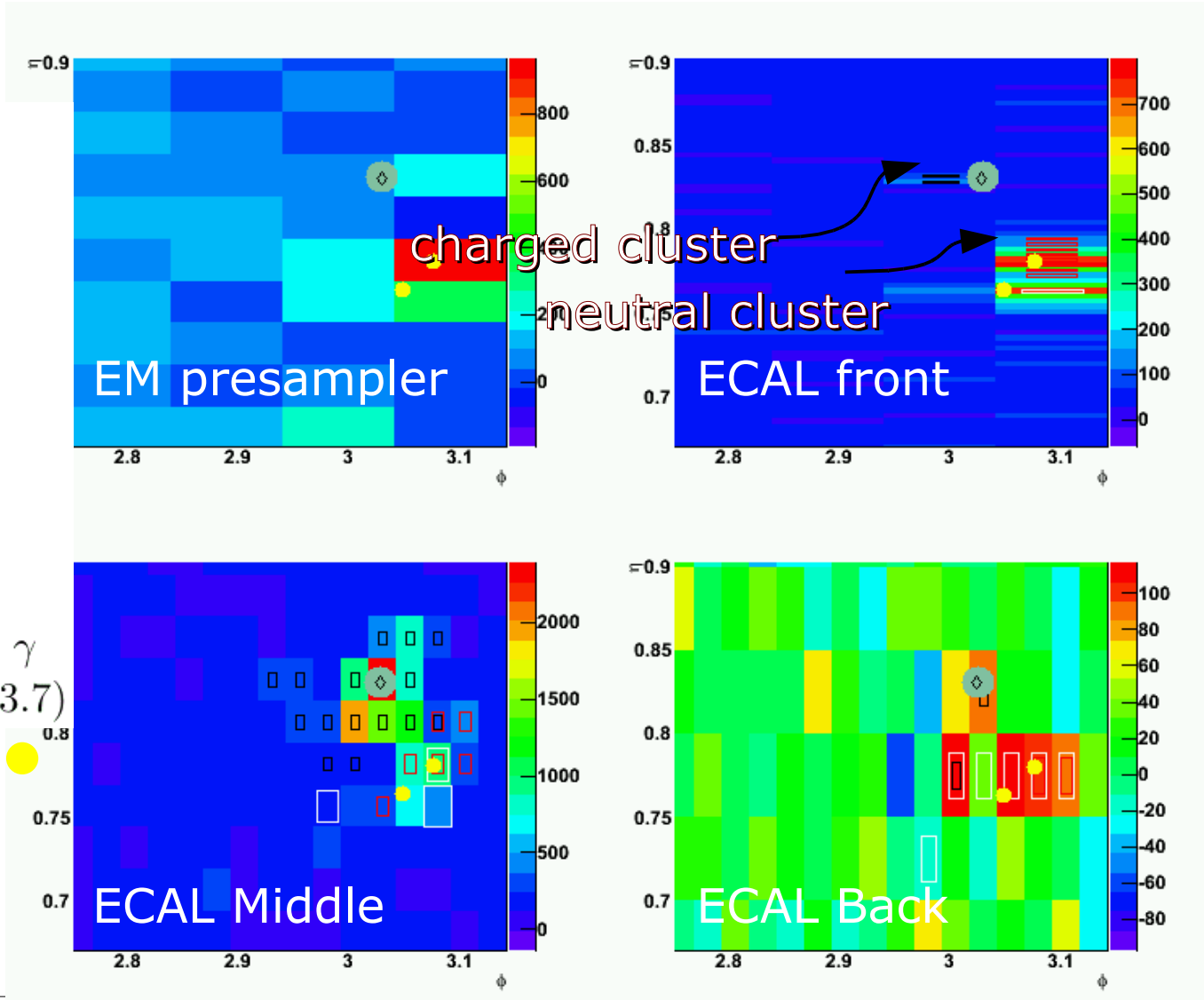
- Is it possible to separately identify and reconstruct the component particles of the tau-decay jet?
  - e.g reconstruct subclusters within the tau-jet cone with explicit π± and π (or γ) ID

  - exploit tau decay kinematics (mass contraints, angles, etc.)
  - exploit calorimeter segmentation, shower profiles

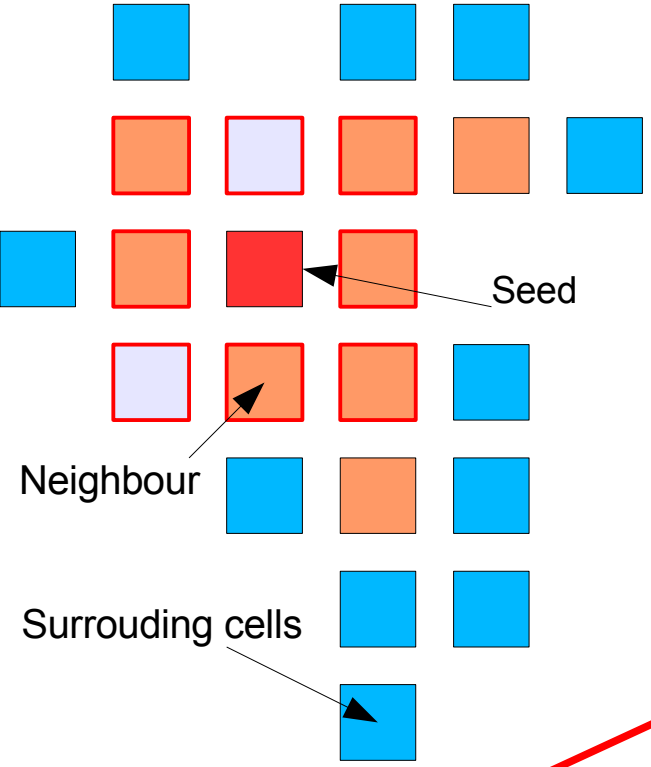
TopoClustering in τ -decays

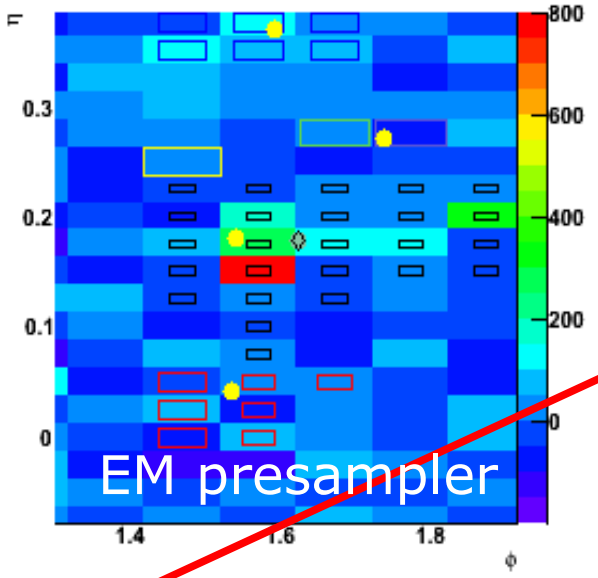
1-prong + 1 π^0

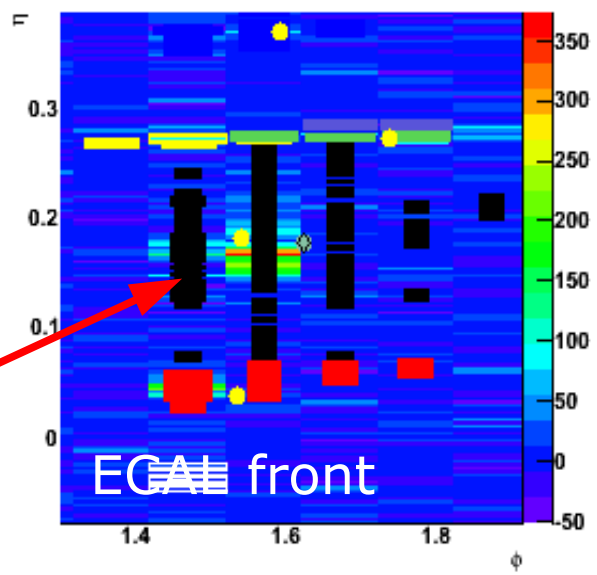


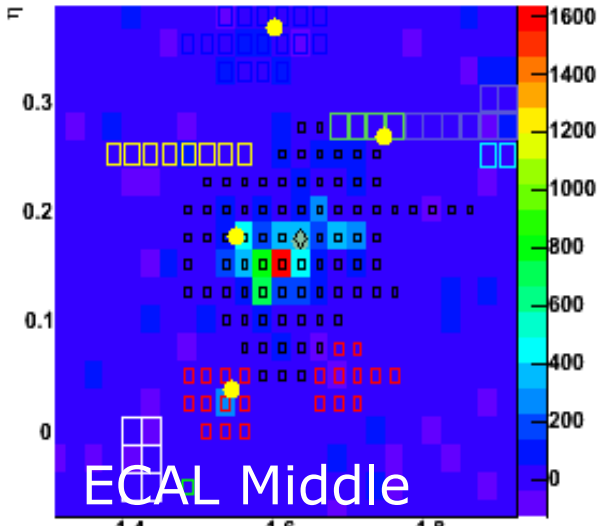


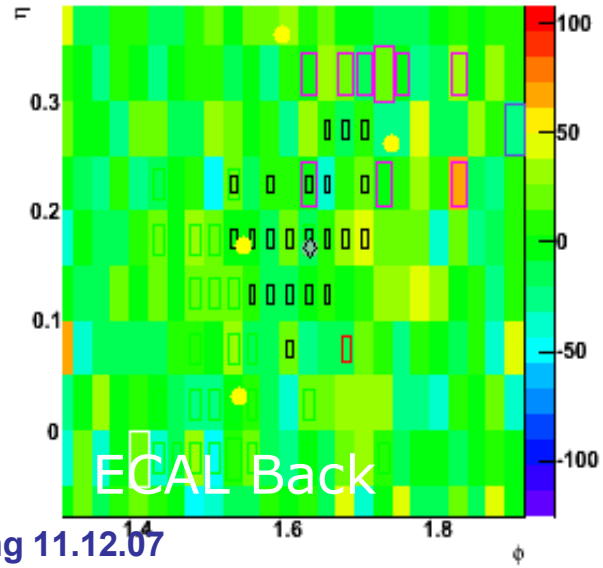
single tau, 20 GeV < pTvis < 25 GeV, 1-prong + 2 π^0











- (Unfortunate) feature of clustering algorithm:
  - fine granularity of front layers maybe washed out by coarser granularity in back layers

TopoCluster settings optimal?

- a single pion “event”, will on average contain 12 TopoClusters (in 4-2-0 configuration)
  - feature of total cell number and seed threshold
    - 1 “signal” cluster
    - 11 noise clusters (randomly scattered across calorimeter?)
- 4-2-0 configuration found to give optimal energy resolution

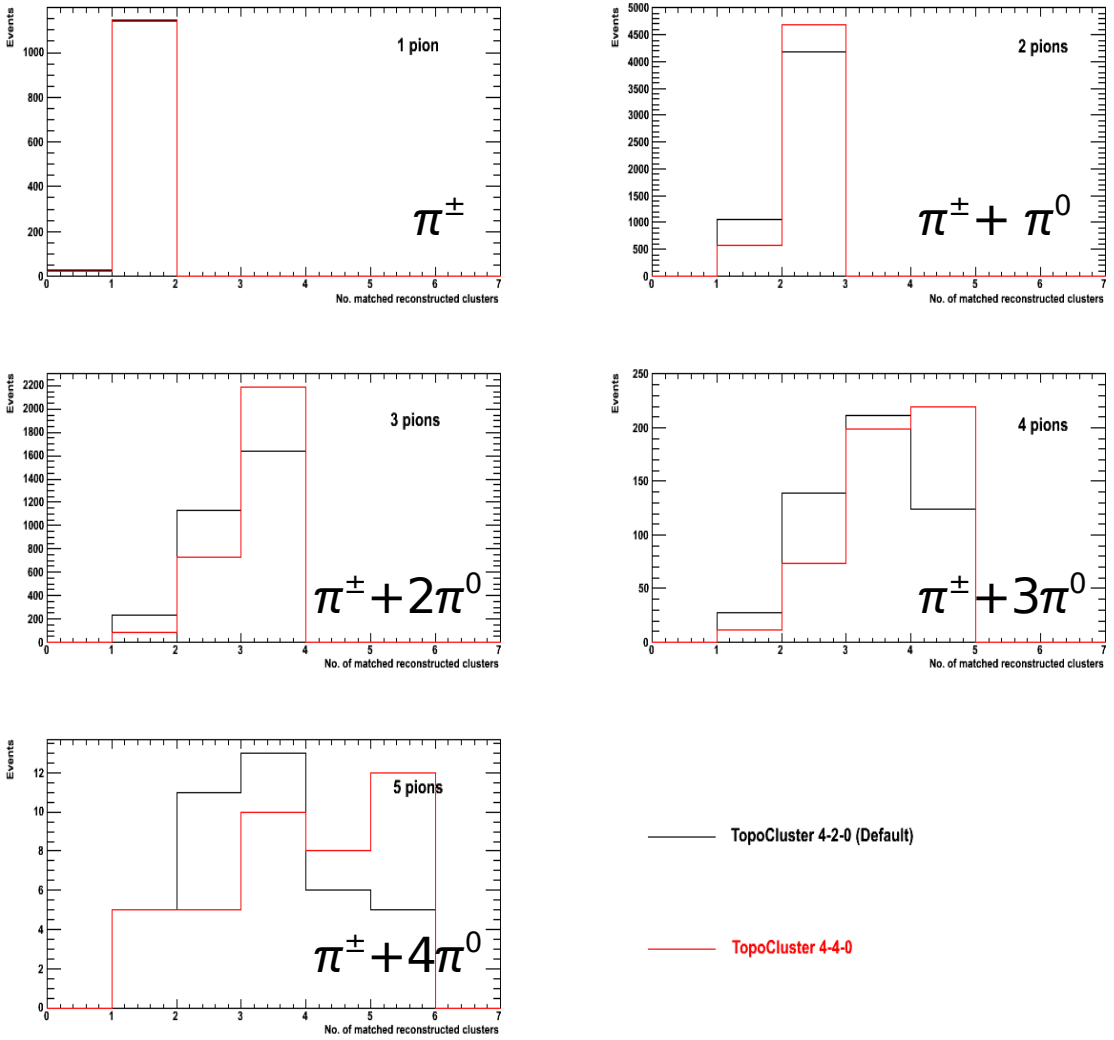
http://indico.cern.ch/getFile.py/access?contribId=s0t7&resId=0&materialId=0&confId=a062374

- Sven Menke: for tau ID/reconstruction study the following configurations:
  - n-n-0 (660,550,440, etc.)
    - second n “restrains” cluster growth
    - last 0 ensures the inclusion of tails needed for good energy resolution
- worry less about energy resolution at the ID step
  - n-n-m configuration may provide improved spatial resolution

Optimizing thresholds...

- Ansatz (first iteration):
  - For each pion in the tau decay, there should be a corresponding spatially resolved cluster
- Number of MC π's in tau decay with cluster match (ΔR < 0.1)
- n-n-0 configuration seen to perform slightly better than 4-2-0

single taus, 20 GeV < pTvis < 25 GeV, 1-prong decays



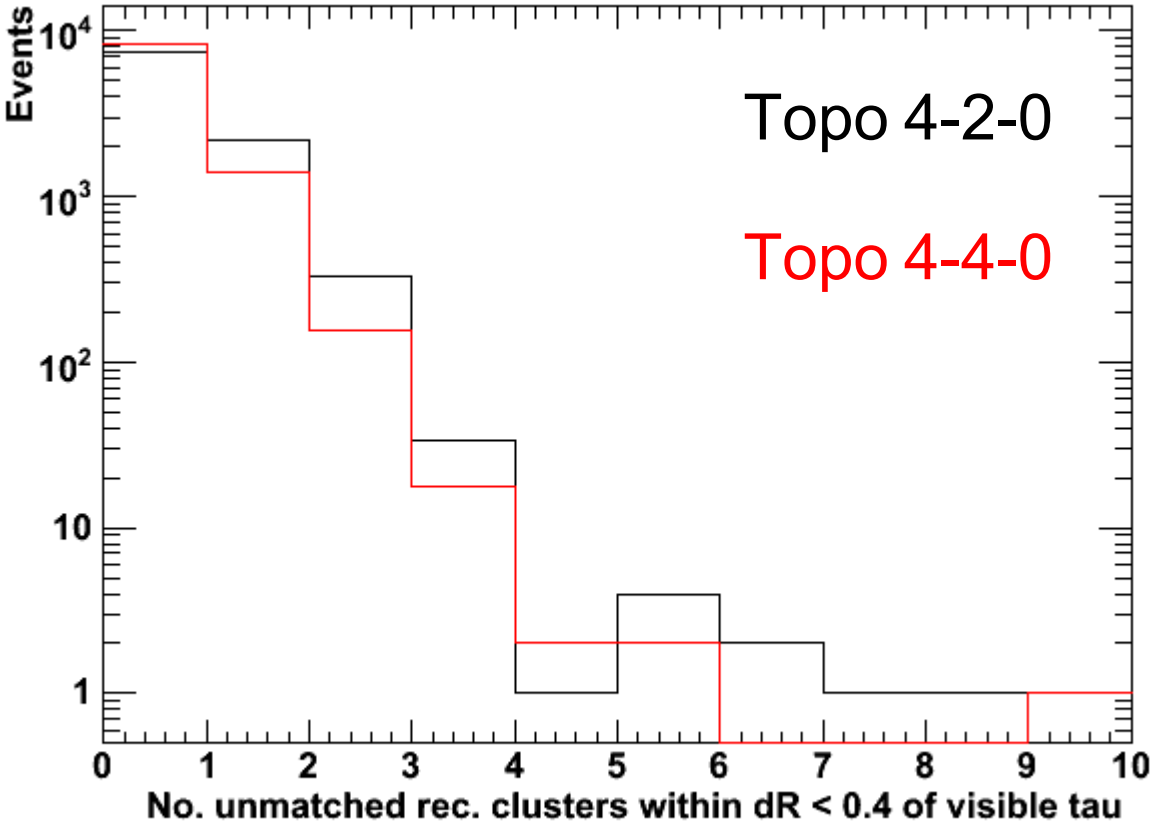
Optimization

single taus, 20 GeV < pTvis < 25 GeV, 1-prong decays

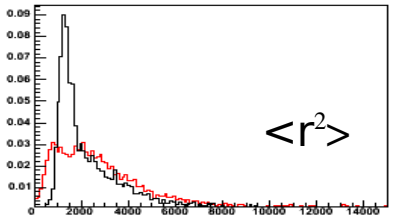
2 pions	0 clusters	1 cluster	2 clusters	3 clusters	4 clusters	5 clusters
topo440	0.02%	10.80%	**89.20%**			
topo430	0.04%	13.70%	86.30%			
topo420	0.02%	20.20%	79.70%			
topo550	0.00%	11.40%	88.60%			
topo540	0.02%	12.90%	87.00%			
topo660	0.00%	11.80%	88.20%			
topo650	0.02%	12.70%	87.30%			
3 pions						
topo440	0.00%	2.80%	24.40%	**72.70%**		
topo430	0.00%	4.10%	29.40%	66.60%		
topo420	0.00%	7.70%	37.80%	54.50%		
topo550	0.00%	3.10%	25.20%	71.70%		
topo540	0.00%	3.80%	28.30%	67.90%		
topo660	0.00%	3.10%	26.40%	70.50%		
topo650	0.00%	3.60%	28.50%	68.00%		
4 pions						
topo440	0.00%	2.30%	14.50%	39.60%	43.70%	
topo430	0.00%	3.20%	17.70%	43.50%	35.60%	
topo420	0.00%	5.60%	27.60%	42.10%	24.70%	
topo550	0.00%	2.40%	15.90%	37.20%	**44.50%**	
topo540	0.00%	3.00%	18.90%	40.40%	37.80%	
topo660	0.00%	2.90%	14.90%	38.40%	44.10%	
topo650	0.00%	2.80%	18.50%	39.60%	39.10%	
5 pions						
topo440	0.00%	12.50%	12.50%	25.00%	20.00%	**30.00%**
topo430	0.00%	12.50%	17.50%	25.00%	17.50%	27.50%
topo420	0.00%	12.50%	27.50%	32.50%	15.00%	12.50%
topo550	0.00%	12.50%	12.50%	32.50%	20.00%	22.50%
topo540	0.00%	12.50%	15.00%	30.00%	27.50%	15.00%
topo660	0.00%	10.00%	5.00%	45.00%	17.50%	22.50%

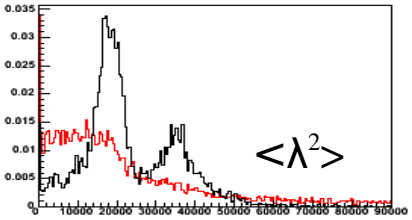
unmatched clusters

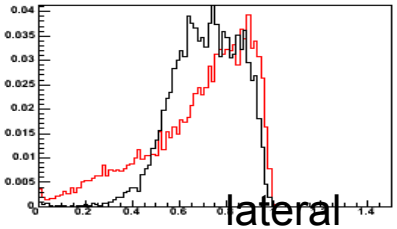
- Number clusters within $\Delta R < 0.4$ of visible tau with no match to tau decay pions
- n-n-0 configuration seen to:
  - increase # clusters matched to tau decay pions
  - decrease # clusters with no match to decay pions
- Note: resolved γ clusters with no match

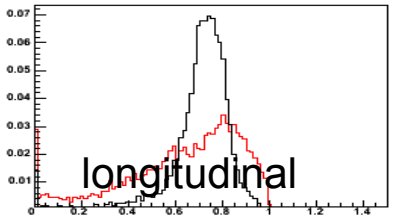


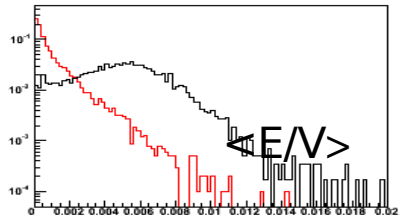
TopoCluster Moments

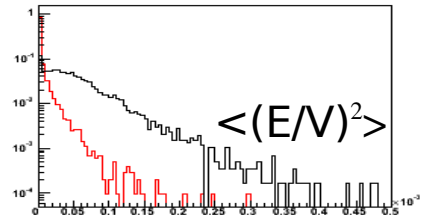


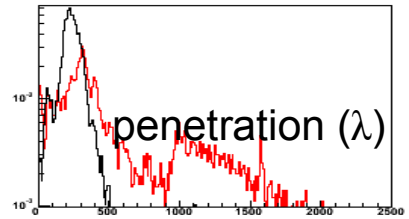


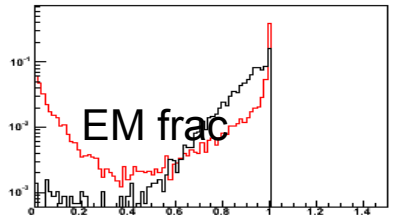


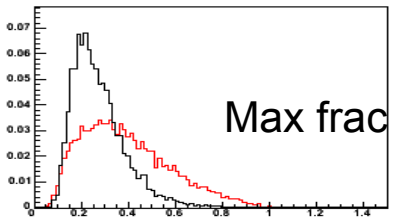


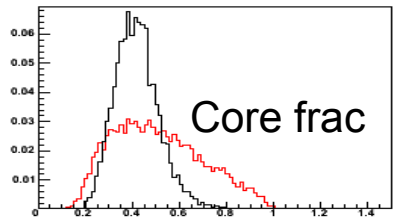


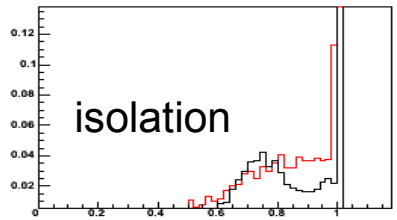






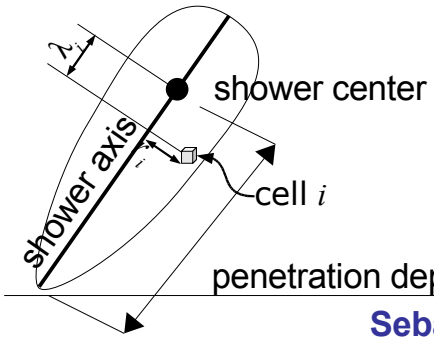






15 GeV Single Pions

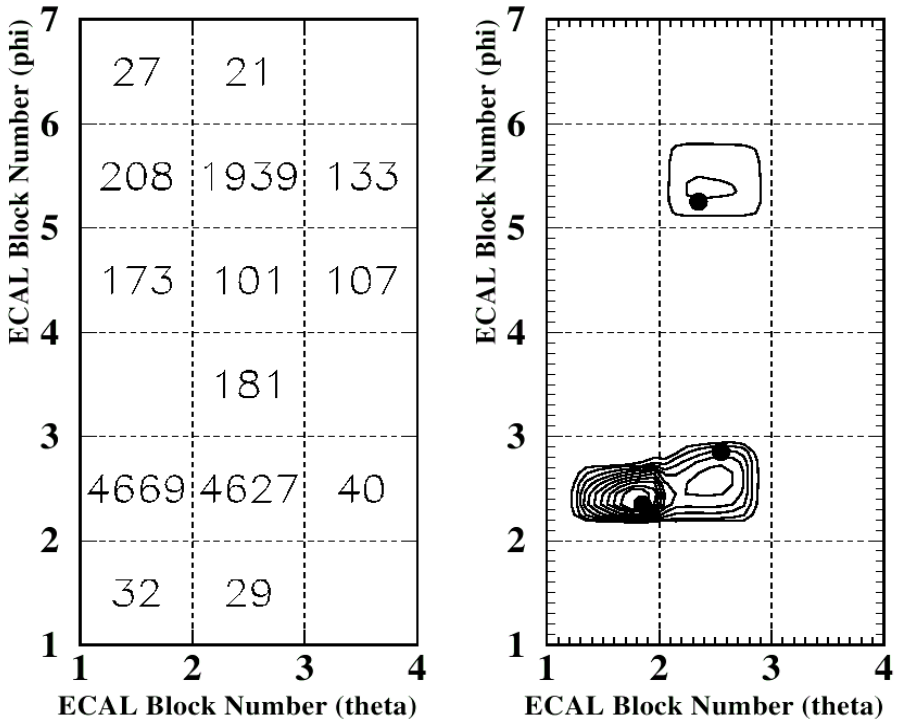
Hadronic
Electromagnetic



- exploit shape differences in likelihood → studies underway
  - charged/neutral cluster ID
  - reject electron clusters with track match?

New approach: Maximum Entropy

- Maximum entropy method investigated in OPAL for enhancement of spatial calorimeter resolution and often used in astronomy:
  - [M.A. Thomson, NIM A382 (1996) 553]
    [J. Skilling & R.K. Bryan, Mon Not R astr Soc 211 (1984) 111]
- Resolutions below detector granularity achieved with response function of detector → Introduce physics knowledge!



from [M.A. Thomson, NIM A382 (1996) 553]

  - Response function: taken from FastCaloSim (to give "inverse FastCaloSim")
    - Currently using single shower shape for all particles and all energies
    - Handle sampling layers separately
- Not only useful for Tau ID, but also for general calo reco (e/γ, …)

Maximum Entropy & Bayesian Networks

- Second step (new idea): Include different response functions for particle types to get a particle hypothesis from fit
  - Problem: Continuous and discrete variables in objective function make optimization more difficult (perhaps use techniques like Deterministic Annealing as used in Tracking to assign measurements to tracks)
  - Information from the Inner Detector may serve as starting point for better convergence
- Third Step: Apply Bayesian Networks
  - Very flexible framework for Pattern Recognition and Machine Learning, many different implementations possible...
  - Started to investigate how to model the system “tau children penetrate through the ATLAS detector”
  - Combine all sources of information: Different sampling layers, tracking, ...
  - Main idea: include all *a priori* knowledge (branching ratios, etc.) rather than just training the system (allthough training is possible)

Summary / Outlook

- TopoClusters properly tuned provide a promising handle on the substructure of the tau decay

- Along with enhanced calorimetric information (shower profiles, etc.), a more “particle-based” approach to tau identification might be possible
  - studies of optimal topocluster settings underway
    - still need to understand impact on energy resolution
  - studies of shower profiles underway
    - cluster moments are promising, but further studies are required

- Draw on experiences from pattern recognition?
  - Maximum Entropy algorithm seems promising
    - studies underway using shower shapes from FastCaloSim