ATLAS Tau Reconstruction – Status and Plans

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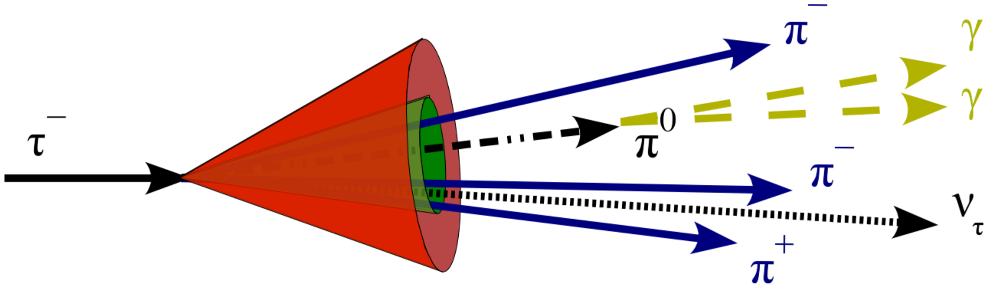
Overview

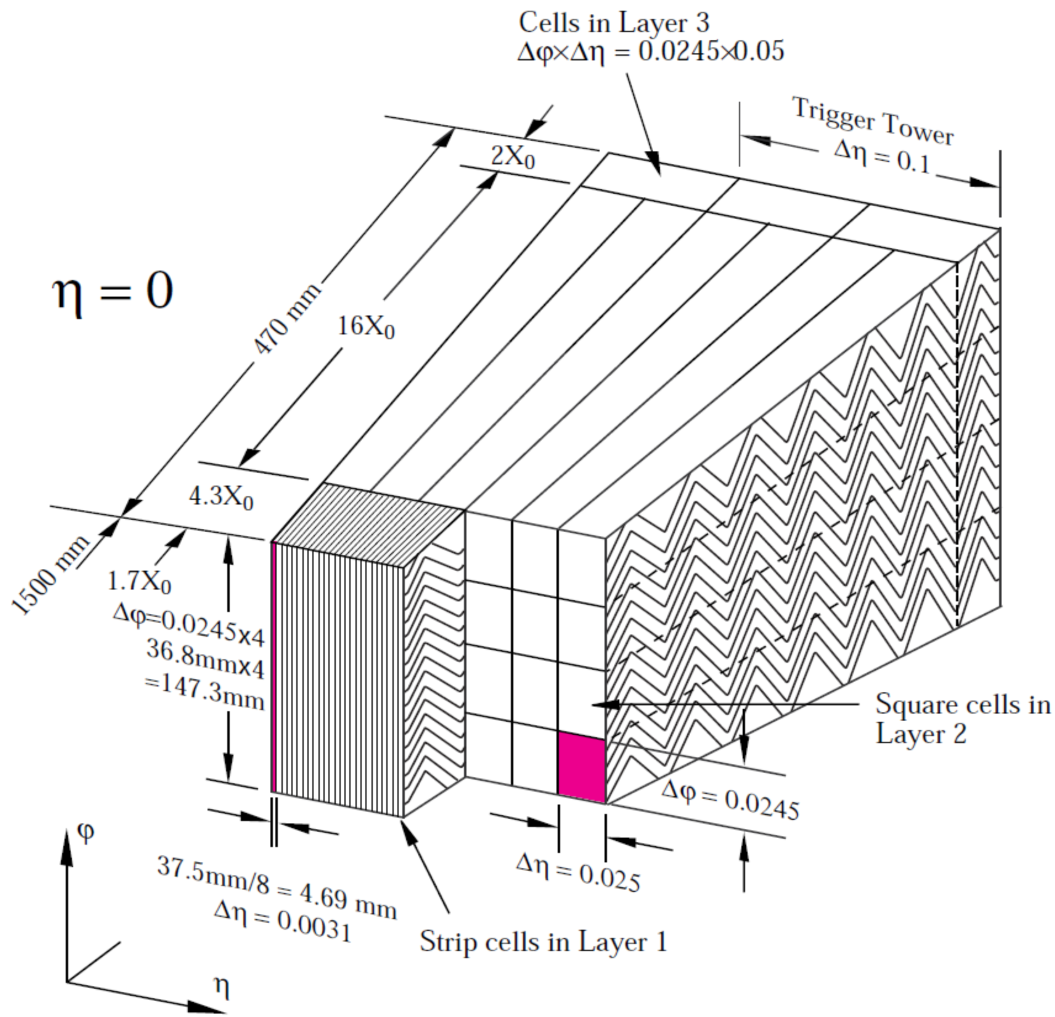
- Performance in Run I
- Major Tau Upgrade for Run II: Substructure reconstruction
- Conclusion

"τ_h" = hadronically decaying tau



Run I Tau Reconstruction

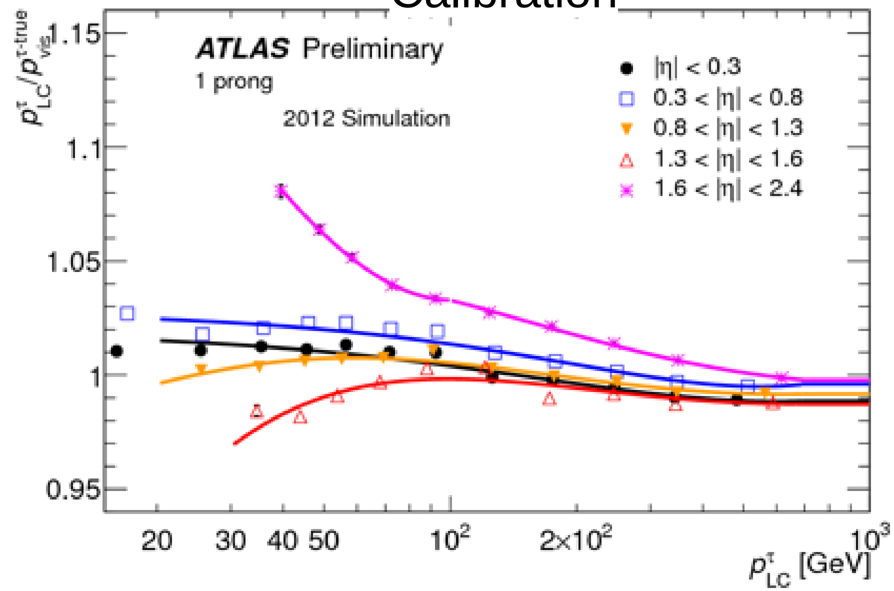
- τ_h : narrow, isolated jet from neutral (e.g. π^0) and charged particles (e.g. $\pi^\pm$)
- Calorimeter seed: anti-kT jet with R=0.4, p_T > 10 GeV, $|\eta|$<2.5
  - Classify in number of tracks ("prongs") in ΔR=0.2 of jet seed
  - τ_h energy = energy of topological clusters within ΔR=0.2, with tau-specific calibration ("TES")
  - Discrimination against jets, electrons and muons using calo and tracker measurements



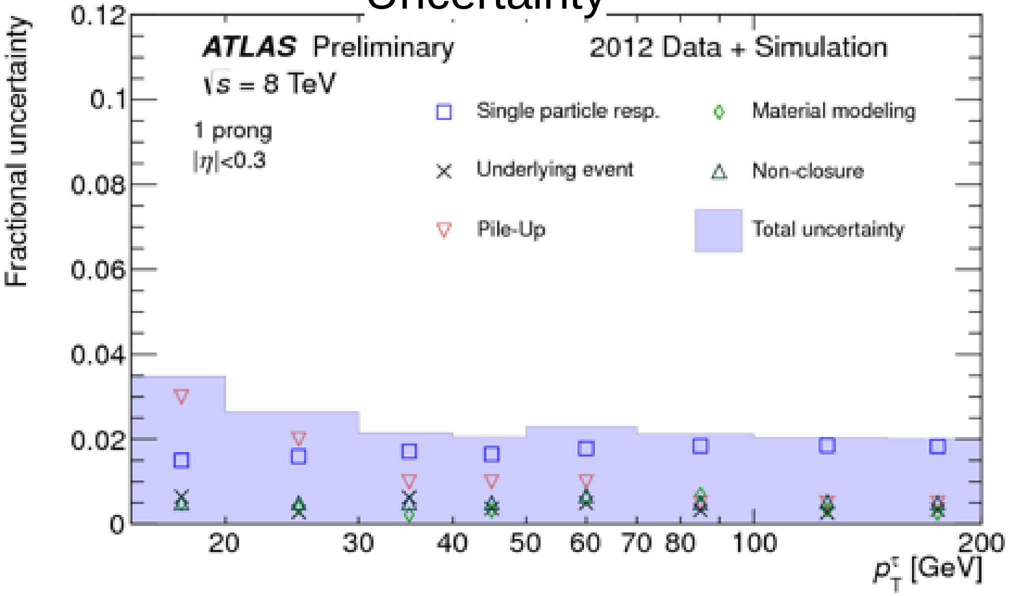
Run I Tau Reconstruction

- TES calibration using MC including pileup correction
- Major uncertainties from single-particle response (mainly from data), pileup sensitivity (MC)

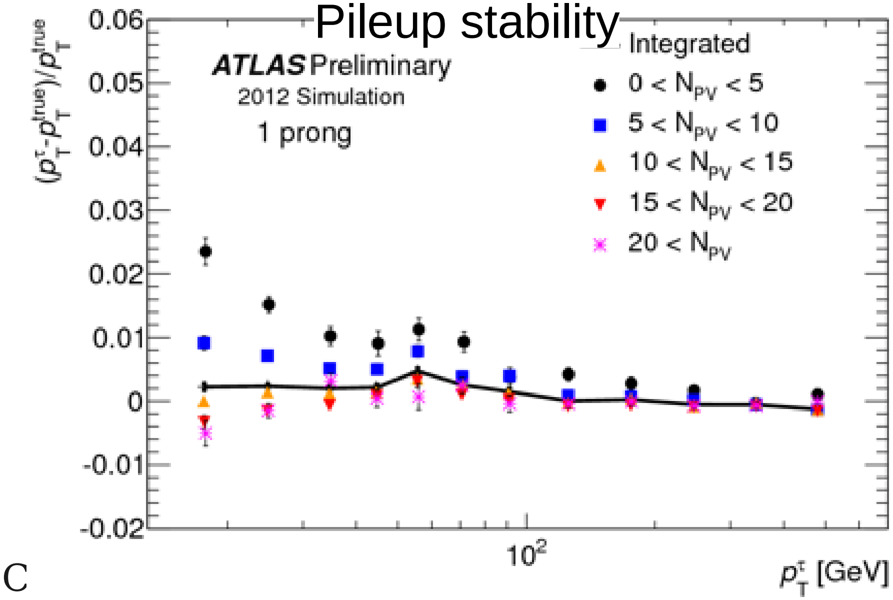
Calibration



Uncertainty



Pileup stability



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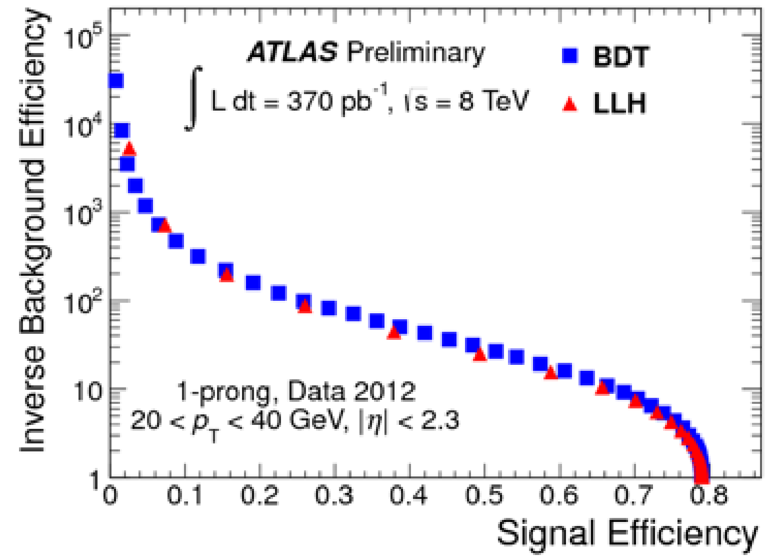
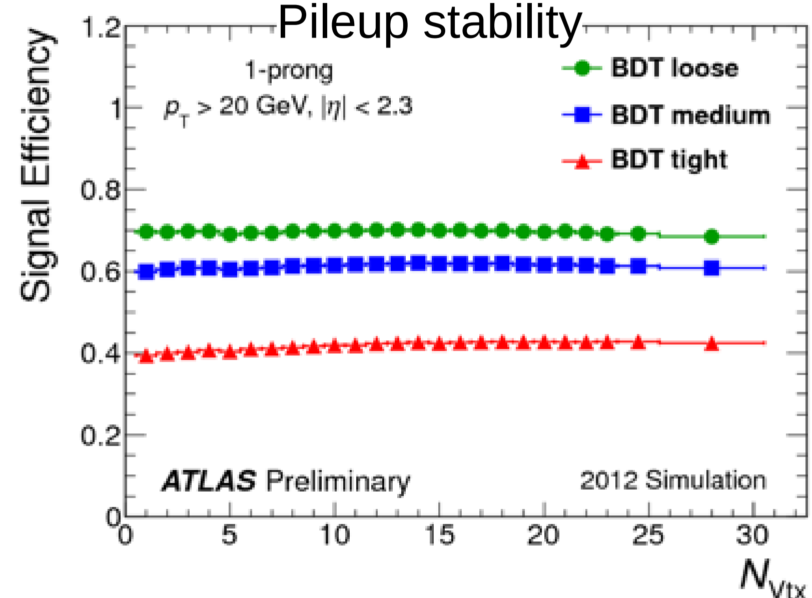
Run I Jet Discrimination

- Jet discrimination critical at LHC
- Need both **power** and **pileup stability**
- Use MVA to combine track and calorimeter variables that exploit collimation and low multiplicity of τ_h decays
- ATLAS philosophy:
  - focus primarily on tracking variables which are inherently pileup robust
  - use only a few pileup-corrected calo variables

Rejection power



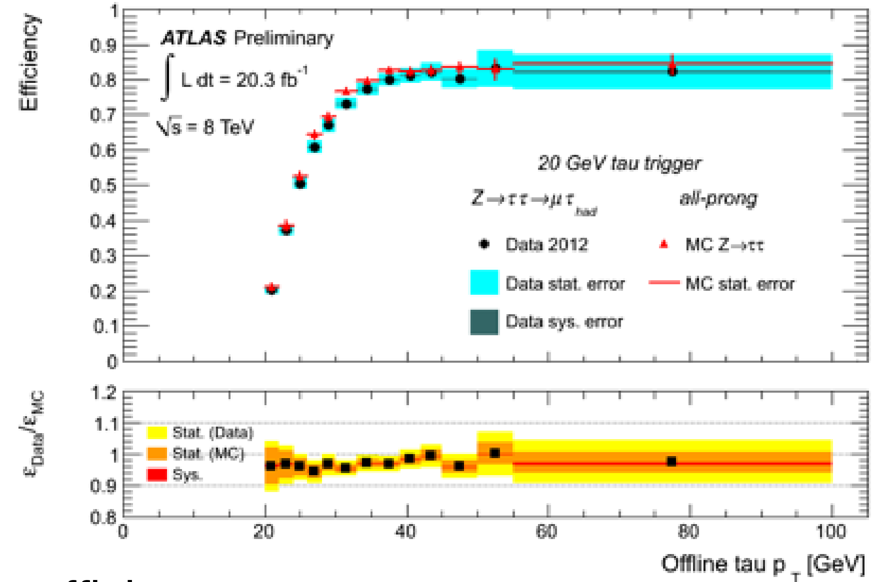
Pileup stability



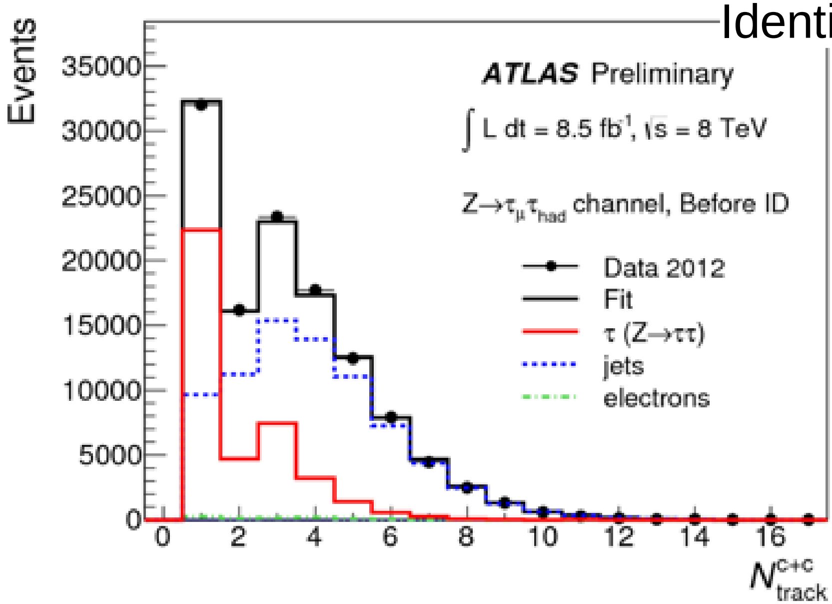
Run I Tau Identification

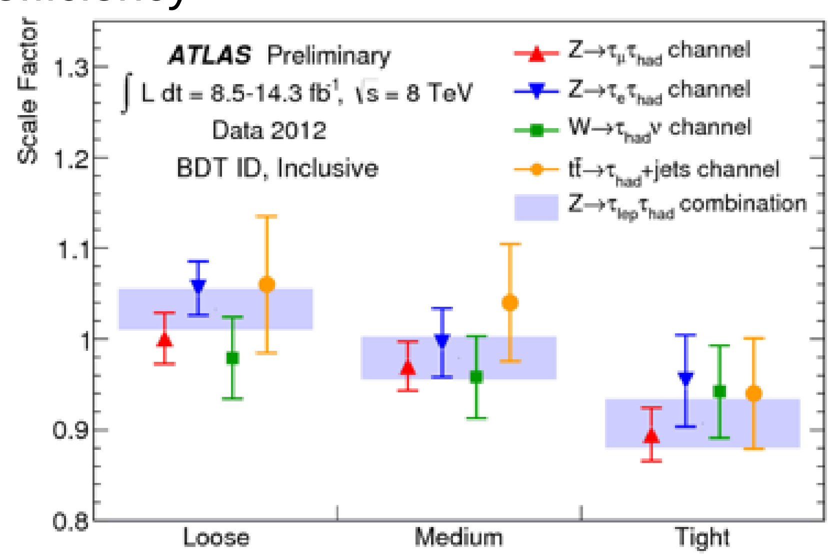
- Measured using $Z \rightarrow \tau\tau$ events
- Good agreement between MC and data
- Trigger and identification uncertainties down to a few %

Trigger efficiency



Identification efficiency

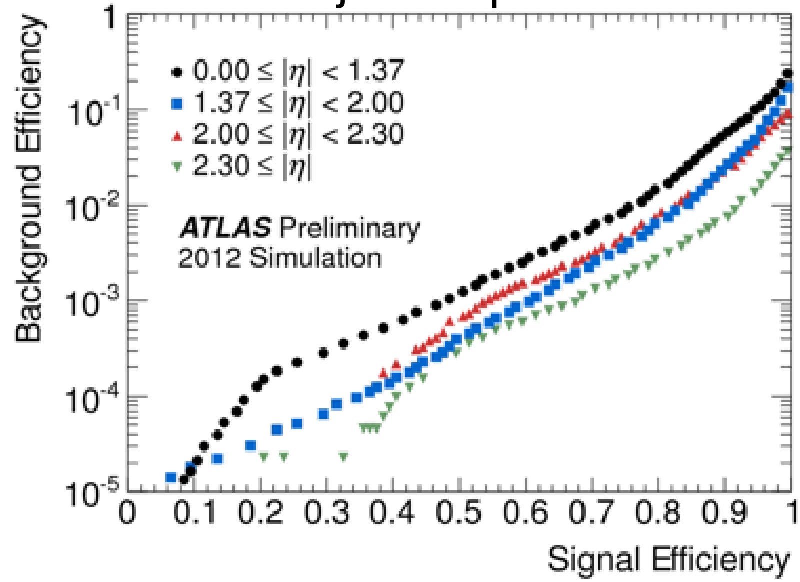




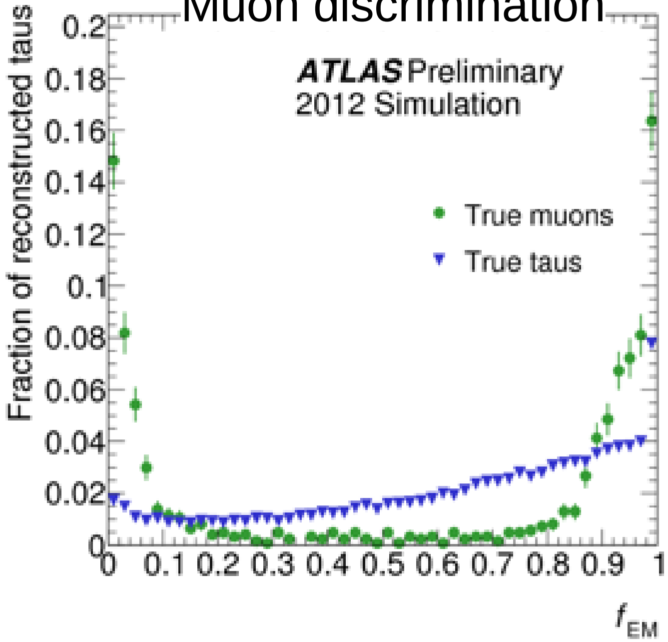
Run I Electron Discrimination

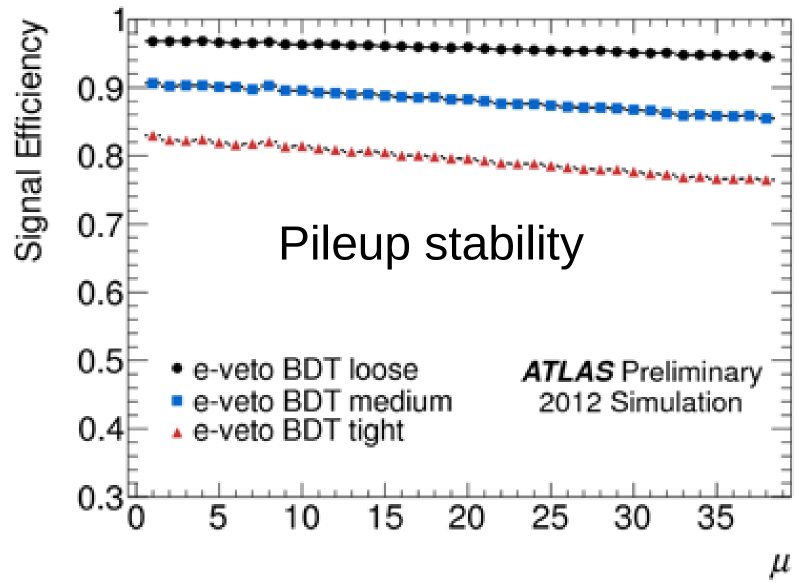
- ATLAS has powerful and pileup robust electron rejection for τ_h
- Best discrimination comes from transition radiation and shower shape

Rejection power



Muon discrimination





Remarks on Run I

• Good performance of rejection of jets, electrons and muons with remarkable robustness in the varying pileup conditions

• Good understanding of efficiencies and energy scales with uncertainties down to a few %

Things to keep in mind for τ_h's Run I:

• Completely calo-based 4-momentum calculation

• Fixed size $\Delta R<0.2$ core cone (not momentum-dependent)

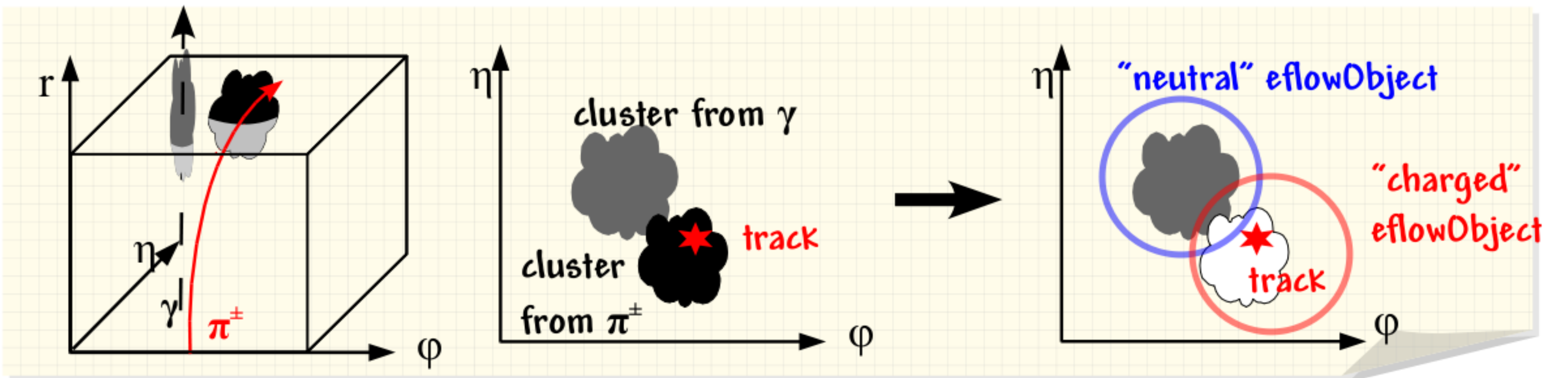
• Neutral pion reconstruction not fully exploited

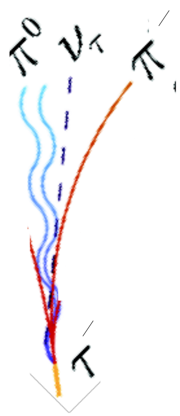
Major Tau Upgrade for Run 2 – Substructure Reconstruction

- Idea: Use high resolution tracking detector measurement for $\pi^{\pm}$ instead of calorimeter-only
- To achieve this need to tell apart calorimeter energy deposits from $\pi^{\pm}$'s and π^{0}'s then substitute $\pi^{\pm}$ calorimeter deposits with track
- Result: 4-vector of each $\pi^{\pm}$ and π^{0} $\Rightarrow$
    - Higher τ_h energy resolution
    - Higher τ_h position resolution
    - Potentially higher mass resolution in di-tau events
    - Decay mode classification
    - Allows for polarization measurement

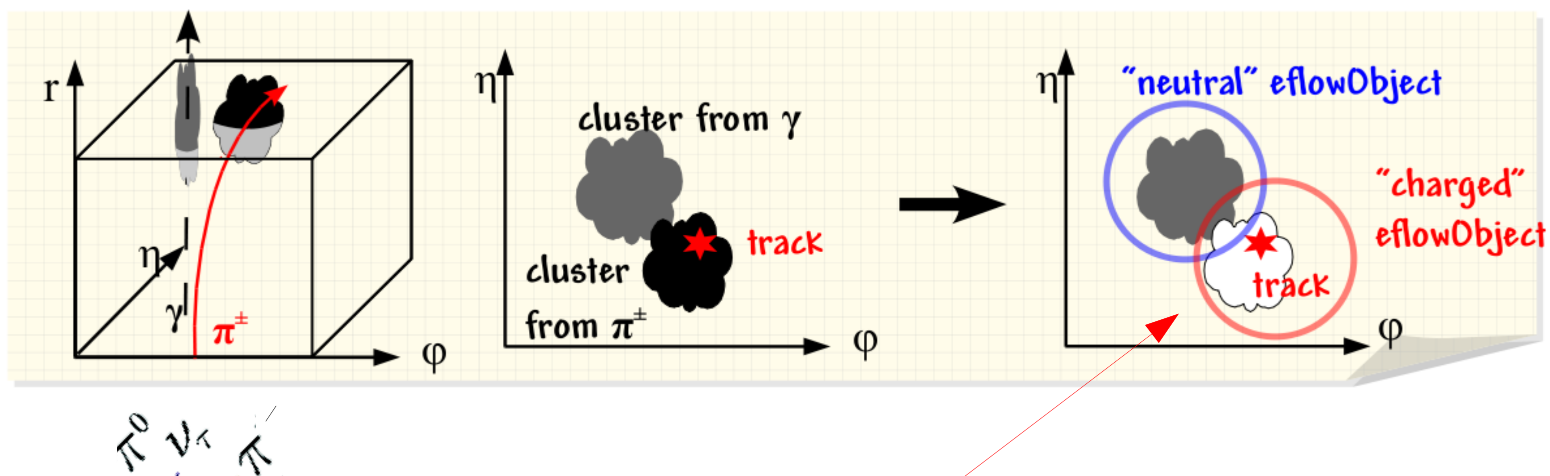
(Note: Current tau identification is already using substructure information – number of pi0s, evaluated by MVAs using global tau information)

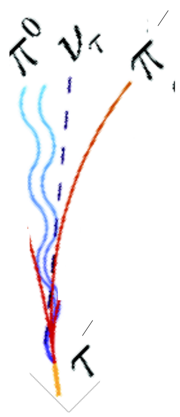
Major Run 2 Upgrade –
Tau Substructure Reconstruction





Major Run 2 Upgrade – Tau Substructure Reconstruction



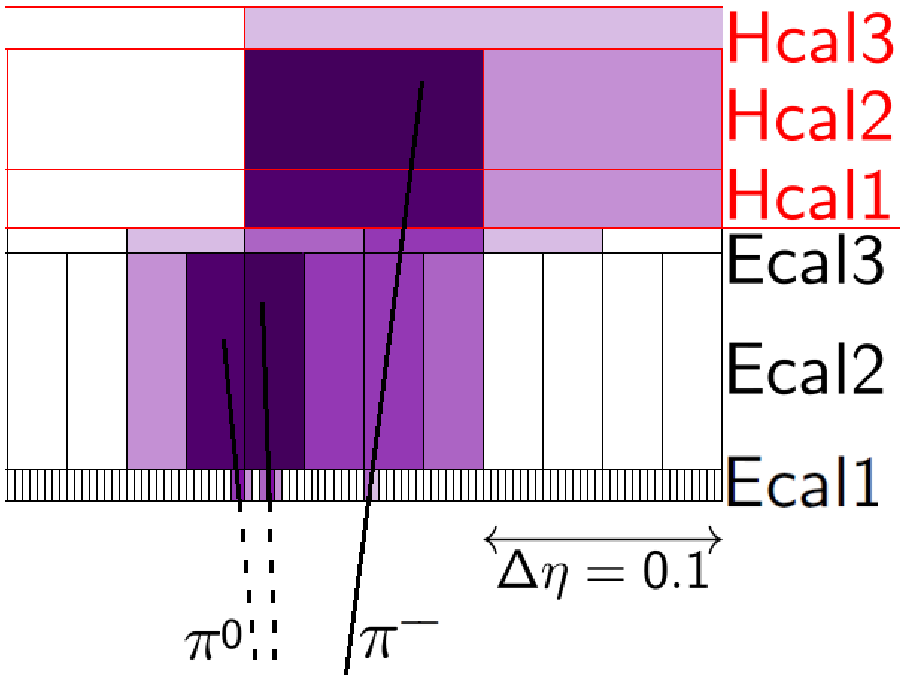


Difficult: π^0-$\pi^\pm$ separation

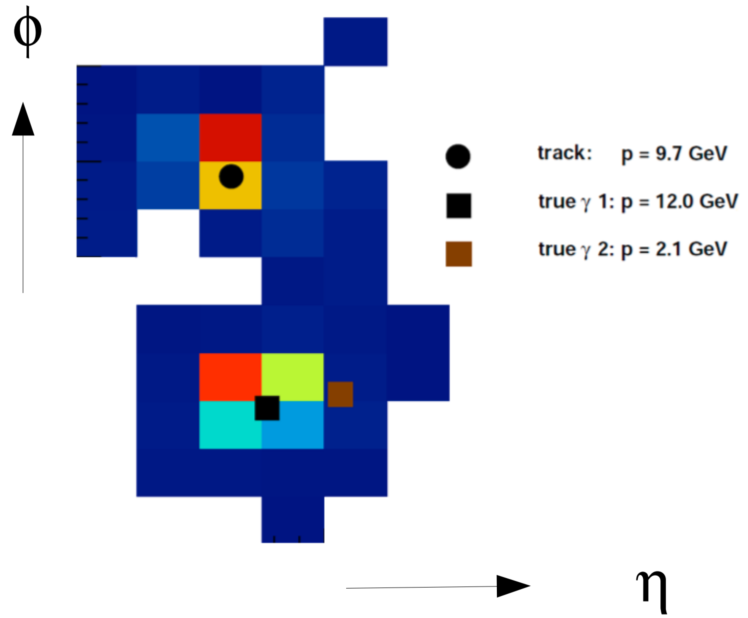
Cannot just use available Topo-clusters

- $\pi^\pm$ and π^0 often overlap
- $\pi^\pm$ often fragment into multiple clusters
- difficult to accurately recover pi0 energy deposit

Charged pion subtraction

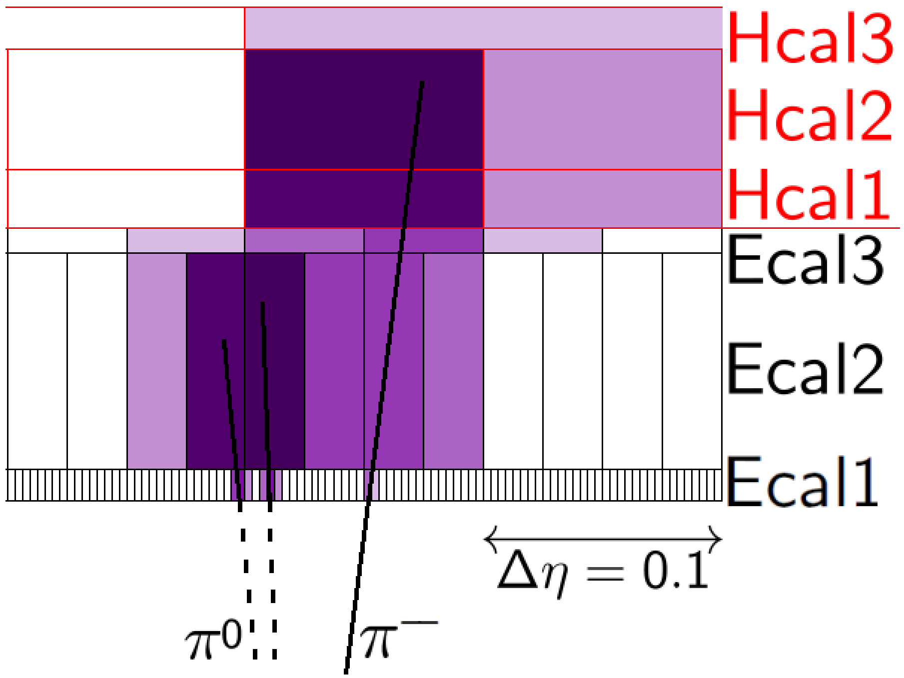


Before subtraction

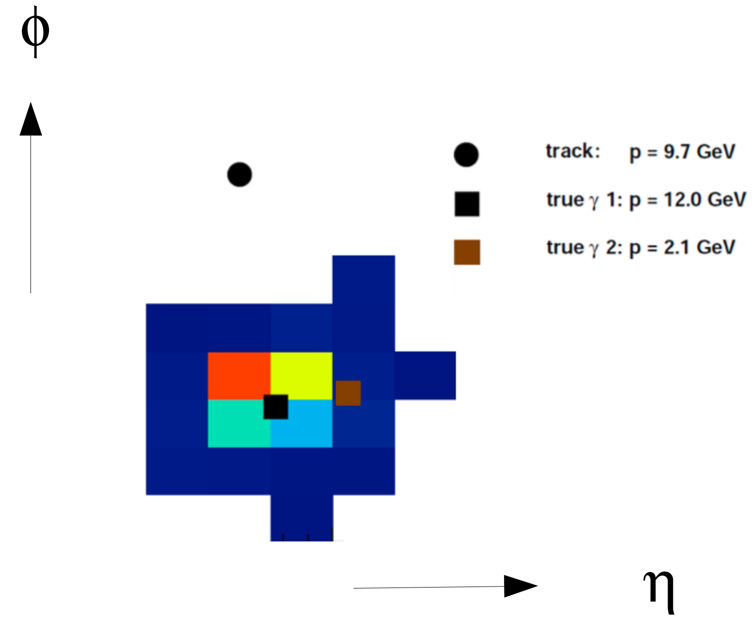


- Estimate longitudinal position and energy of $\pi^{\pm}$ in calorimeter

Charged pion subtraction



After subtraction



- Estimate longitudinal position and energy of $\pi^{\pm}$ in calorimeter
- Subtract out cell energies consistent with parametrized $\pi^{\pm}$ shower shapes
- Use shower shape info using MVA to identify π^{0} clusters and suppress fake-clusters from non-ideal subtraction, pileup etc…

Tau decay mode classification

- Could naively count tracks and π^0 candidates to identify decay mode
- However using information on all reconstructed decay products simultaneously (e.g. kinematics) can improve classification
- Example: 1 charged cluster + 1 π^0-identified neutral cluster + 1 neutral cluster that failed π^0 identification → could be ρ-decay or a_1-decay
- Example variables: energy fraction of charged clusters, BDT scores of neutral clusters, angular distance between charged and neutral clusters, ...

Reco nProng	Reco nPi0	Reco nNon-pi0	Action
1	0	> 0	BDT 1p0n vs. 1p1n
1	1	0	BDT 1p0n vs. 1p1n
1	1	> 0	BDT 1p1n vs. 1pXn
1	> 1	any	BDT 1p1n vs. 1pXn
3	0	> 0	BDT 3p0n vs. 3pXn
3	> 0	any	BDT 3p0n vs. 3pXn

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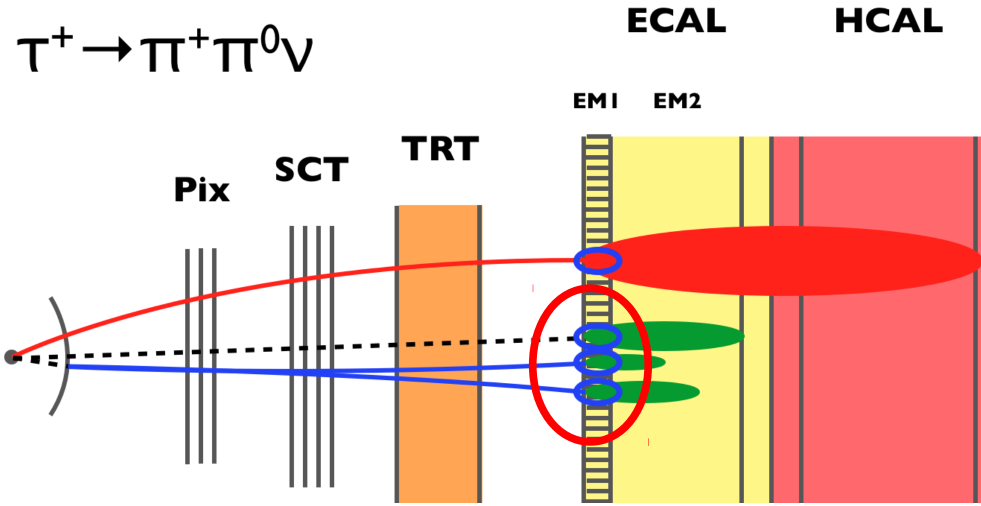
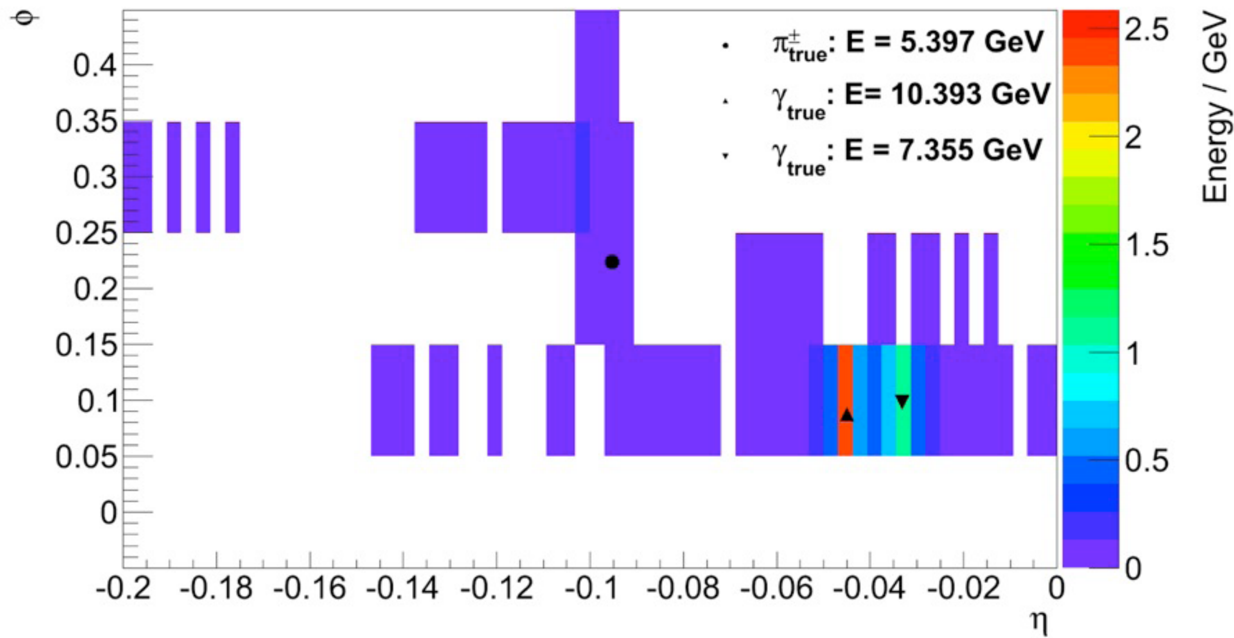
Result: decay mode and 4-vectors of decay particles and tau candidate

Recent Developments & Future Upgrades

EM-cal strip layer

- ATLAS calorimeter features finely segmented "strip layer"
- Useful for
    - distinguishing whether neutral cluster was created by single or multiple photons (one or multiple π^0's)
    - Identifying π^0's hiding in charged clusters

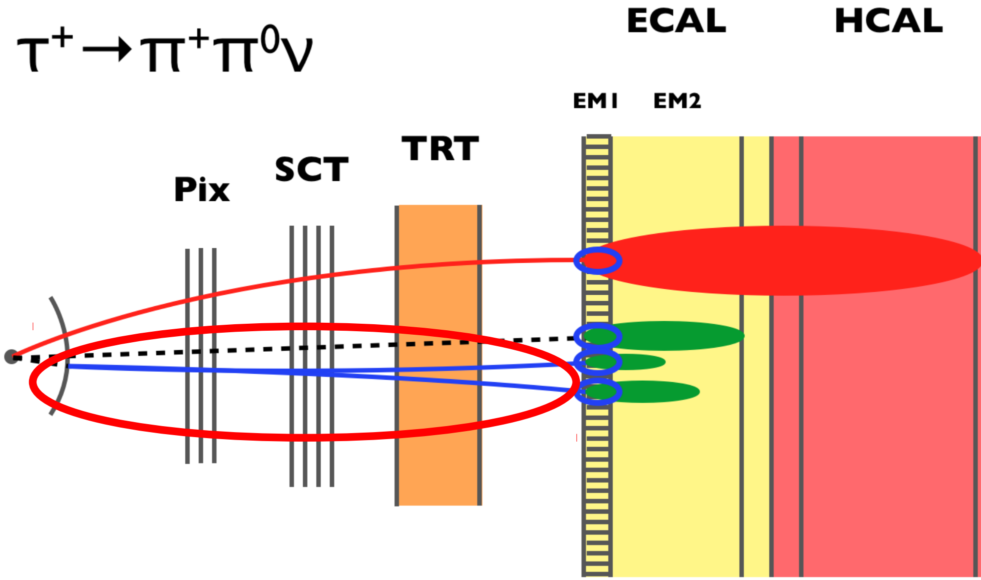




Recent Developments & Future Upgrades

Conversion track identification

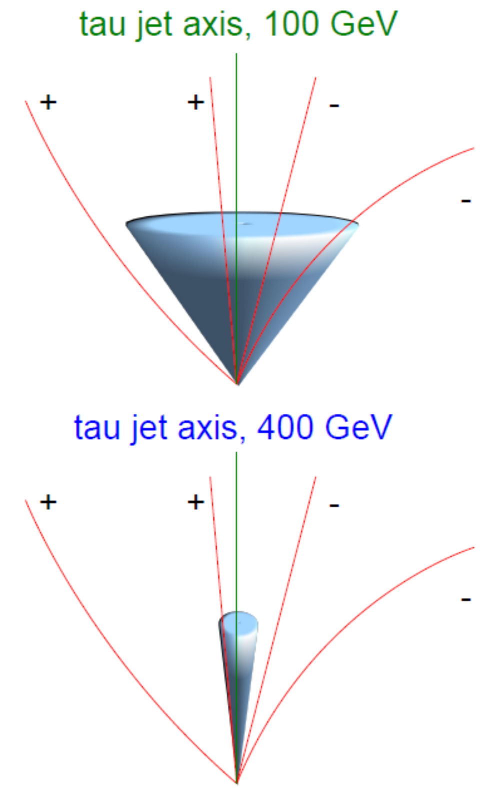
- Decay photons from π^0's can convert before they reach calorimeter
- Identify tracks from conversion electrons against charged pions
- Identify neutral clusters with a track stub as conversion electrons
- Possibly useful for tau-electron discrimination

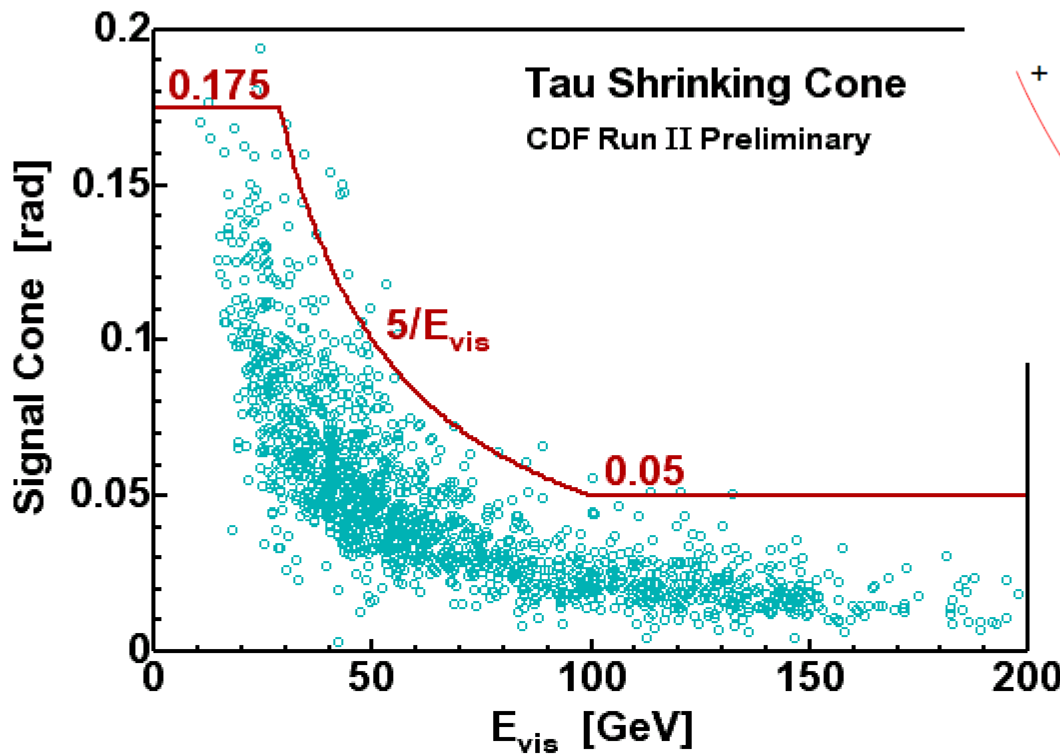


Recent Developments & Future Upgrades

Momentum-dependent cone

- Tau decay products more collimated as a function of tau momentum
- Potentially useful for jet rejection
- Just to give you an idea – a public plot by CDF:





Conclusions

- Tau performance during Run I very successful
- Major tau upgrade for Run 2: substructure reconstruction, looks very promising
- Allows for decay mode classification and polarization measurements
- Lots of promising upgrades to come

Bonus