FCC hadron detector meeting

Preliminary studies of boosted hadronic τ leptons and W bosons using high-granularity calorimeter at FCC

by

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Introduction

- detection of boosted objects will be important at FCC-hh experiment
  - heavy resonances decaying to WW, ZZ, HH and $t\bar{t}$ well-motivated in many BSM models
- detecting hadronic τ decays from $H \to \tau\tau$ could also be important for reconstructing di-τ and di-higgs resonances
- preliminary studies of hadronic τ identification variables from simulated Z' (1 TeV) $\to$ ττ events are presented
- preliminary studies of jet response and resolution for boosted $W \to$ dijets from Z'(10 TeV) $\to$ WW simulation are also presented

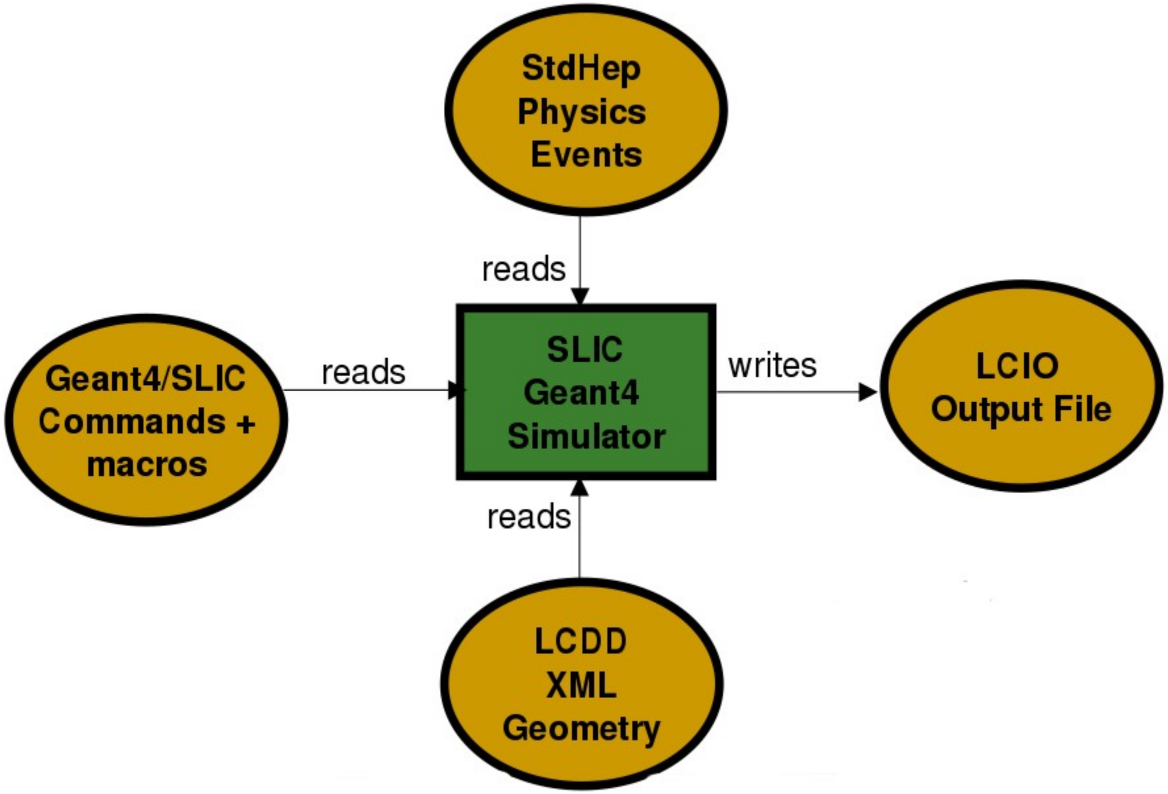
A framework for boosted particle studies

- Using HepSim public repository with EVGEN and full simulations
  - http://atlaswww.hep.anl.gov/hepsim/

- EVGEN Madgraph files were created with MG5/Pythia6

- Files are being processed with a full detector simulation which includes high-granularity calorimeter (1x1 cm cell size in HCAL)

- Detector geometry can be changed using XML files



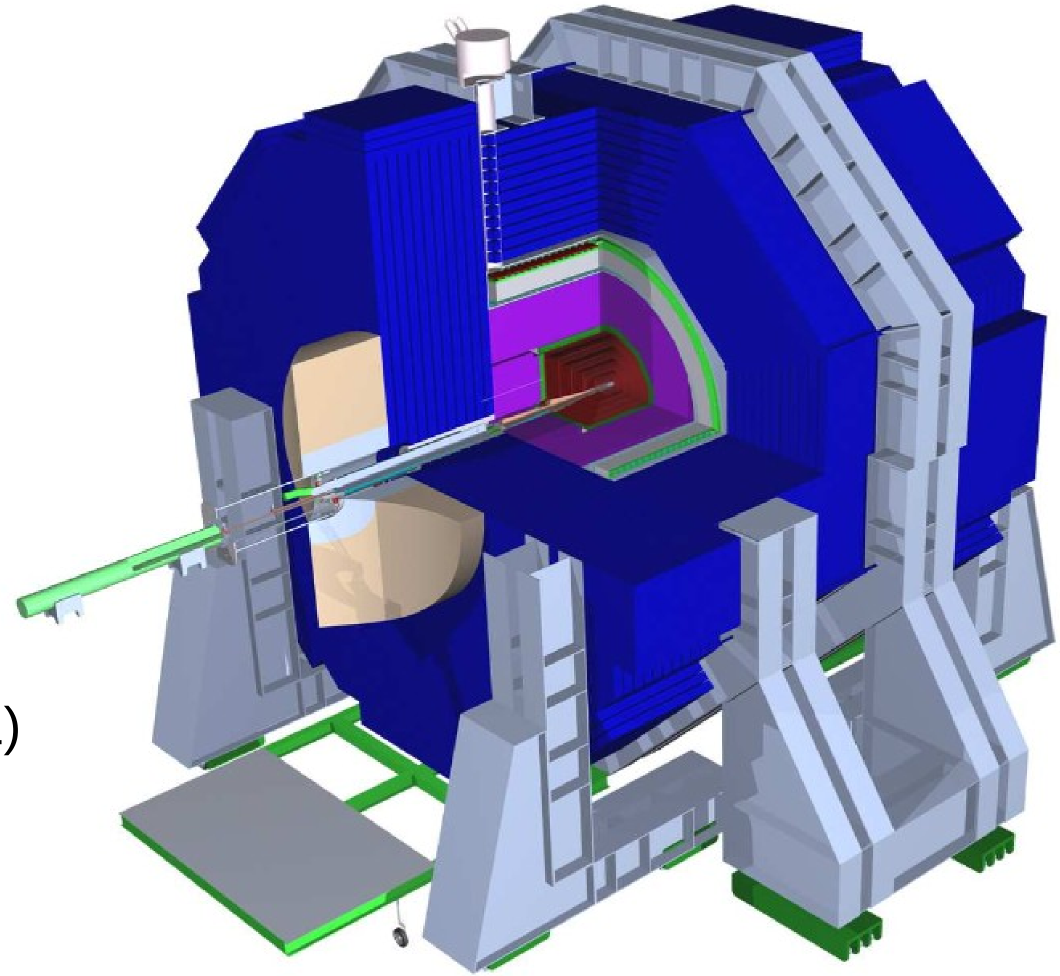
Designing a high-granularity calorimeter for FCC-hh energies

SiD detector

- A multi-purpose detector for ILC

- The key characteristics:
  - 5 Tesla solenoid & silicon tracker
  - 3.5 mm cell size for ECAL
    - Tungsten absorber
    - silicon sensors
  - 10x10 mm cell size for HCAL :
    - Steel absorber
    - RPC sensors
    - 40 layers for barrel (HCAL)

- Optimized for particle-flow algorithms.



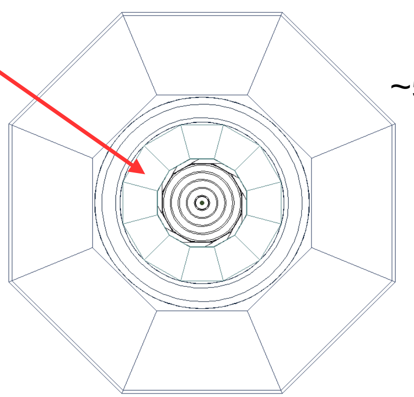
Designing a detector for TeV-scale boosted physics

SiD detector was designed for ~500 GeV jets

A FCC-like detector for studies of CAL transverse and longitudinal granularity, depth, material, magnetic fields, pixel sizes etc, responses to particles etc.

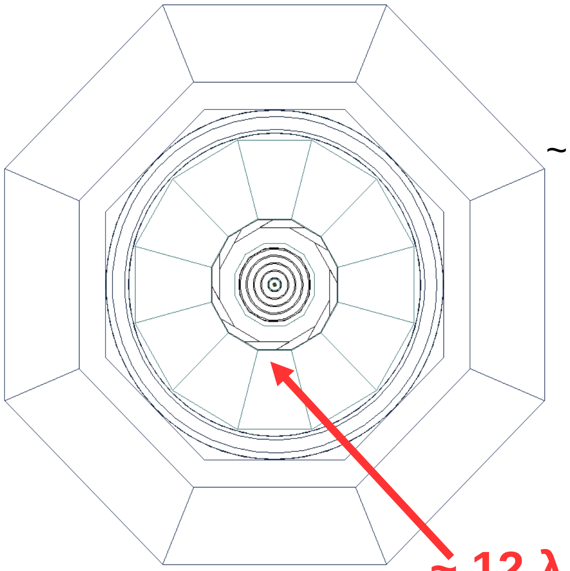
SiD

~ 5.1 λ_I



~5m

expanding to FCC-hh (pp at 100 TeV)



~10m

~ 12 λ_I

Designing a Geant4 simulation for high-granularity calorimeter (1 cm x 1 cm) with 12 λ to contain 20-30 TeV jets

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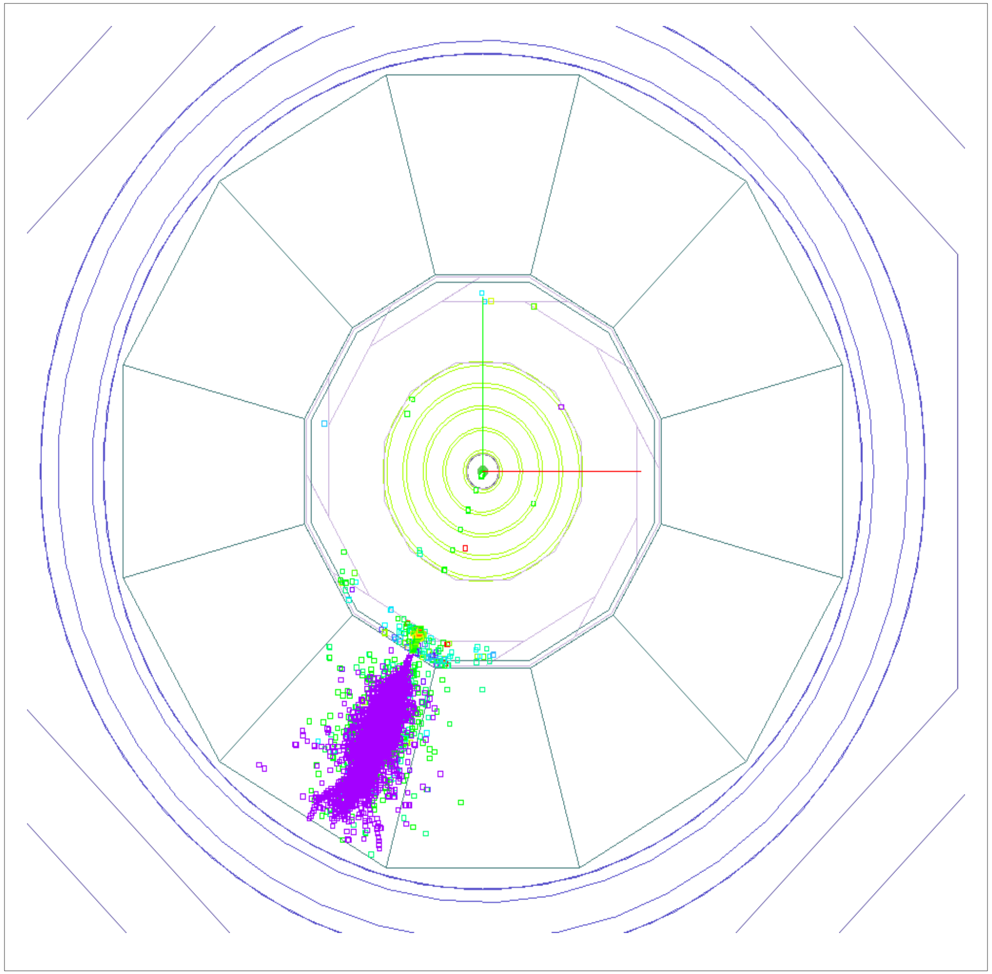
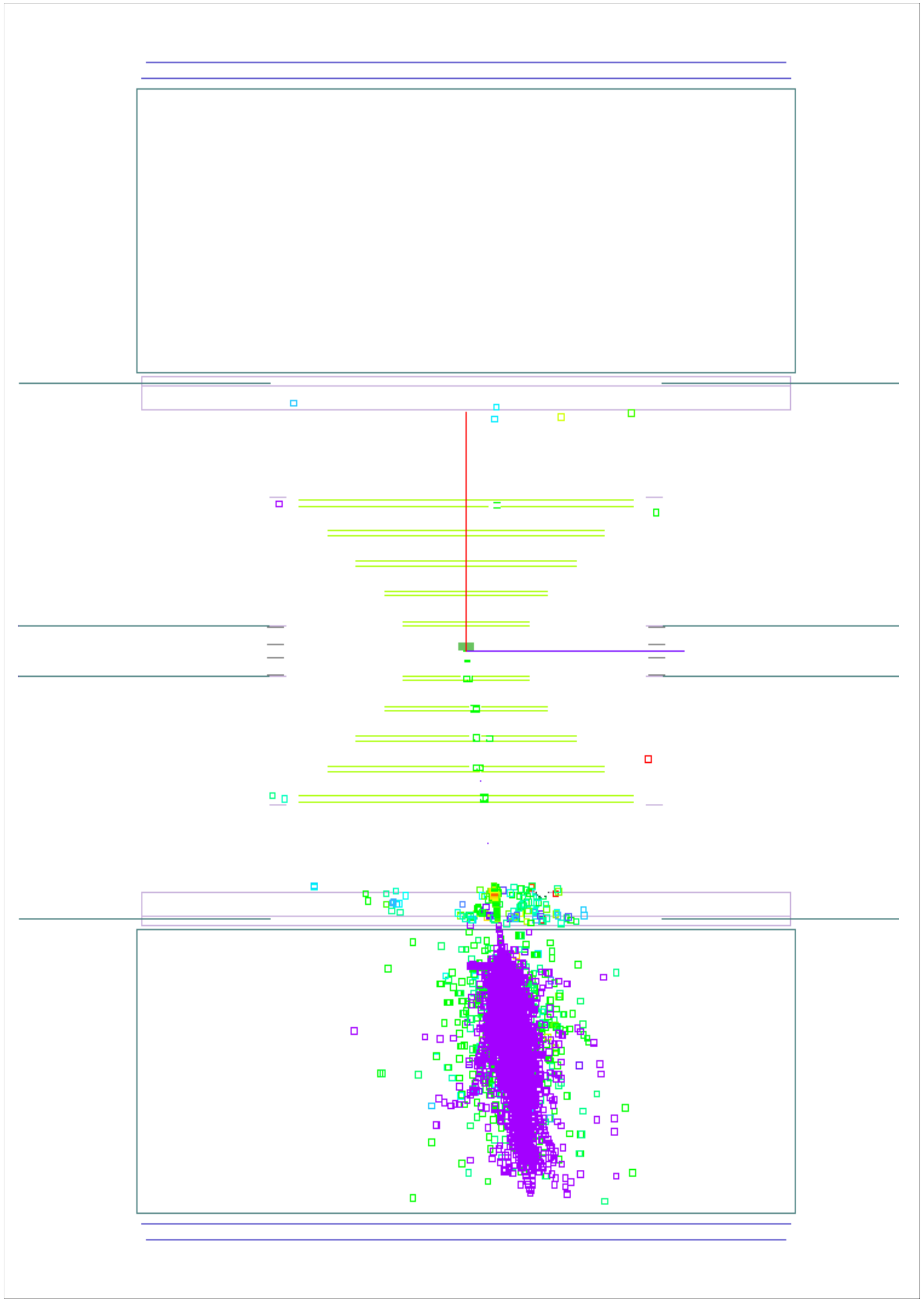
A typical response to 1000 GeV single pion





Pandora Particle Flow algorithm reconstructs
1000 GeV single pion

Boosted τ → hadrons studies

Sample: Z'(1TeV) → ττ (19980 events)

Sanity Check

MC level

1-prong = 20602 (= 51.5%)

3-prong = 4848 (= 12.1%)

Detector level:

1-prong = 18637 (= 46.6%)

3-prong = 5177 (= 12.9%)

The one prong can further be improved by π^0 recontruction

$\tau_{had\text{-}vis}$ identification variables

Reference:

ATLAS collaboration. "Identification and energy calibration of hadronically decaying tau leptons with the ATLAS experiment in pp collisions at √s= 8 TeV." arXiv preprint arXiv:1412.7086 (2014).

Core=0.1, Isolation region=0.4

f_{cent} (Central energy Fraction)= (total E_T deposited in ΔR < core/2)/ (total E_T deposited in ΔR < core)

N_{track}^{iso} (number of tracks in the isolated region)=Number of tracks in the region: core < ΔR < 0.4

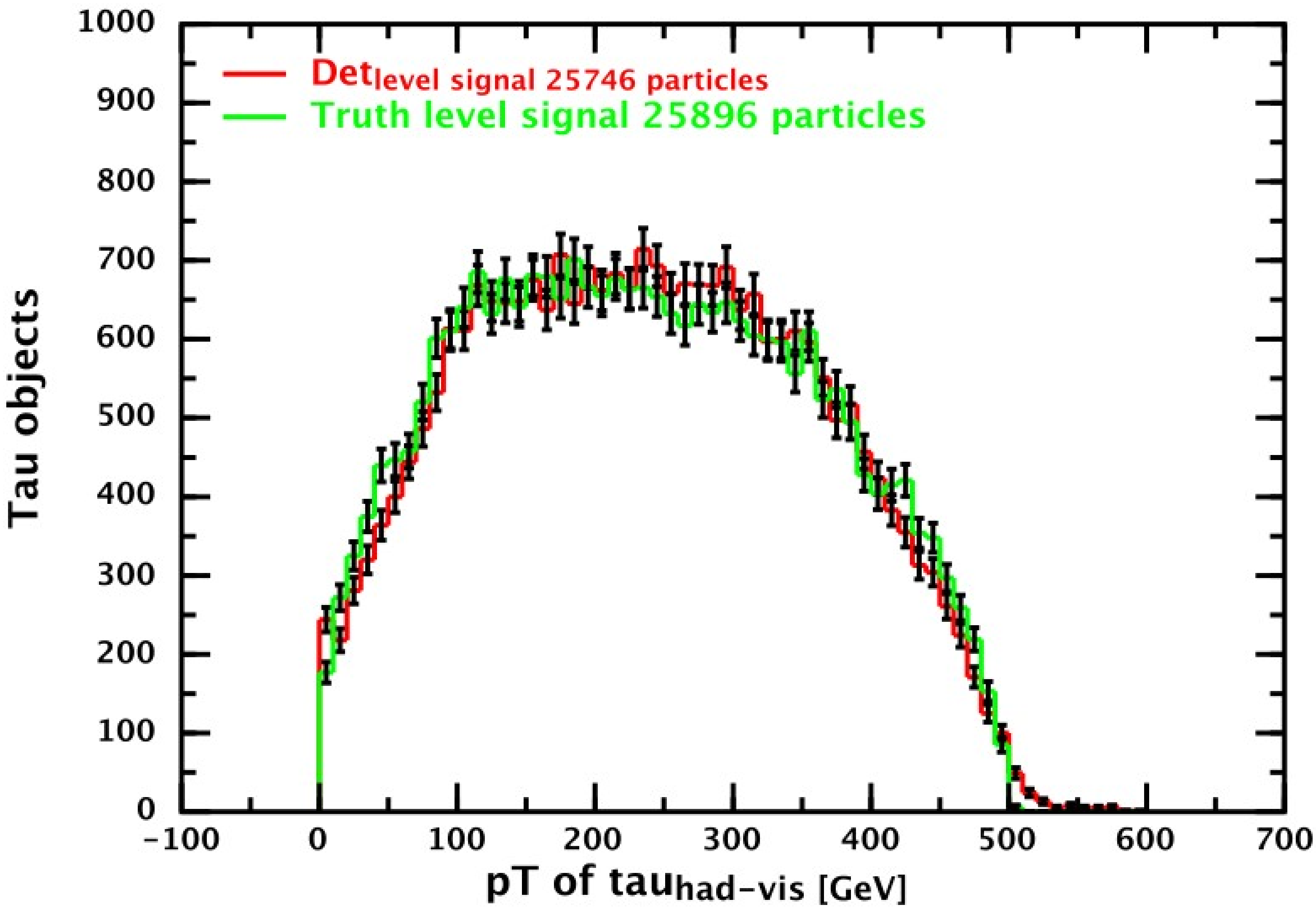
f_{track} (leading track momentum fraction) =(pT of highest pT track in core region (ΔR < core)) / (Total E_T deposited in ΔR <core)

ΔR_{max}(Max ΔR)= max ΔR between a track and $\tau_{had\text{-}vis}$ direction in ΔR < core

R_{track} (Track radius)= pT weighted average of ΔR to the $\tau_{had\text{-}vis}$ direction in ΔR < 0.4

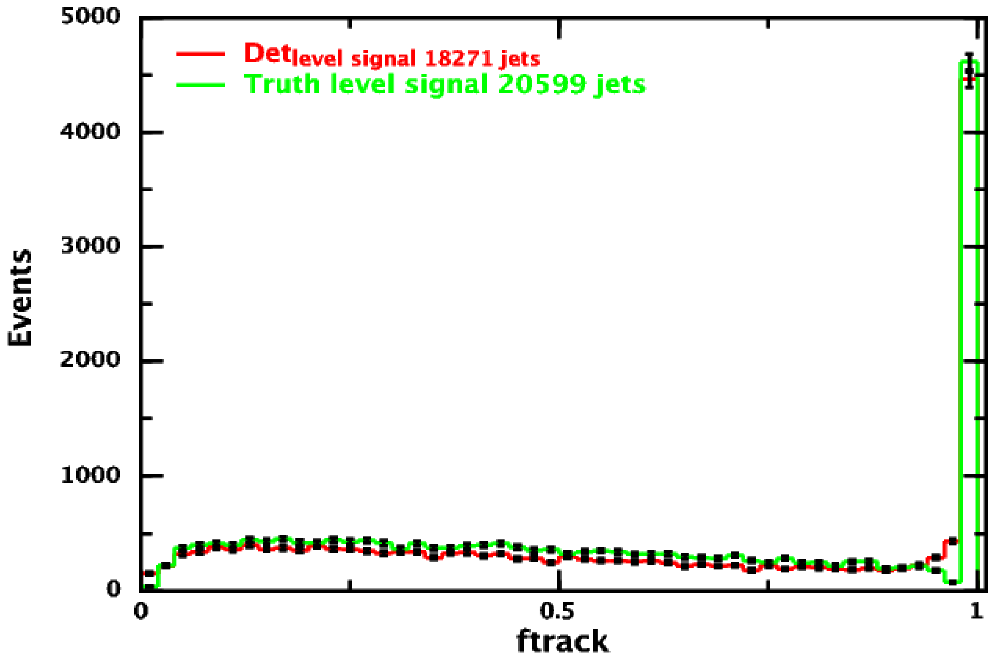
M_{track}(Track mass)= Invariant mass calculated using tracks in ΔR < 0.4, assuming pion mass for each track

P_T of $\tau_{had\text{-}vis}$

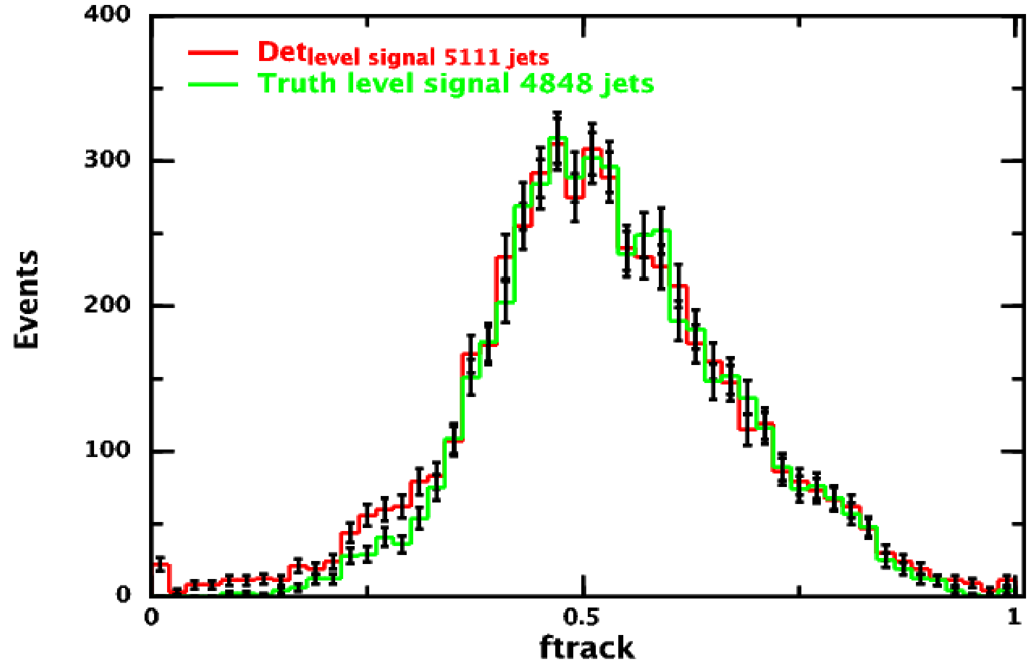


f_{track} (leading track momentum fraction)

=(pT of highest pT track in core region (ΔR < core)) / (Total E_T deposited in ΔR <core)

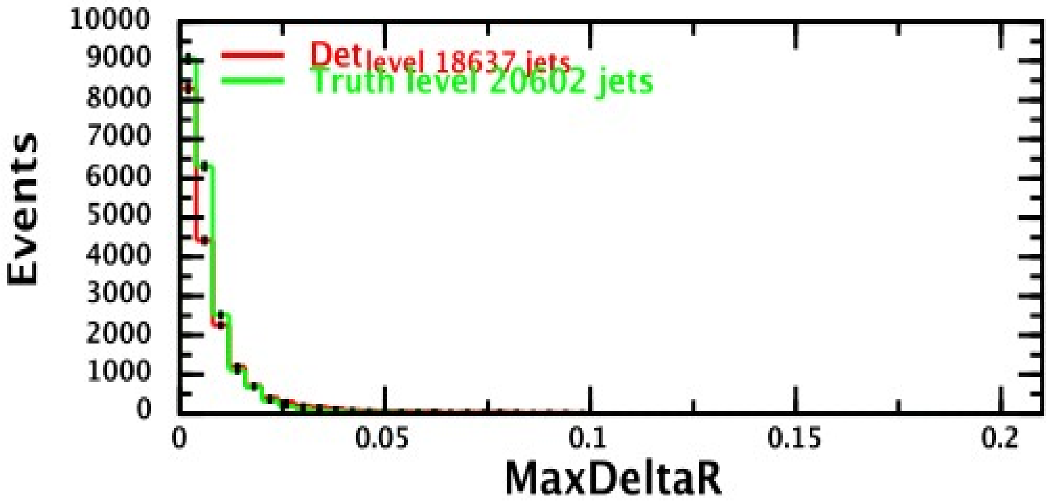


1 prong

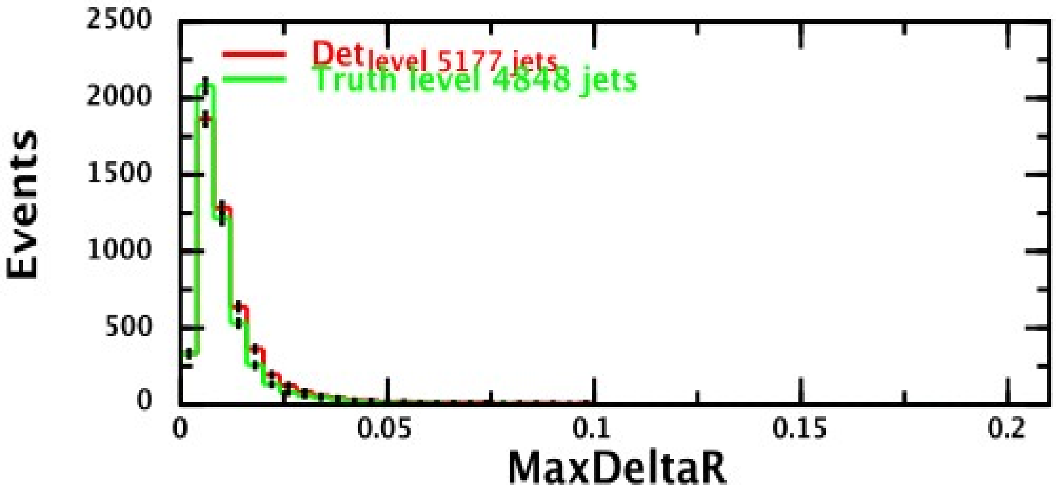


3 prong

ΔR_{max}(Max ΔR)= max ΔR between a track and $\tau_{had\text{-}vis}$ direction in ΔR < core

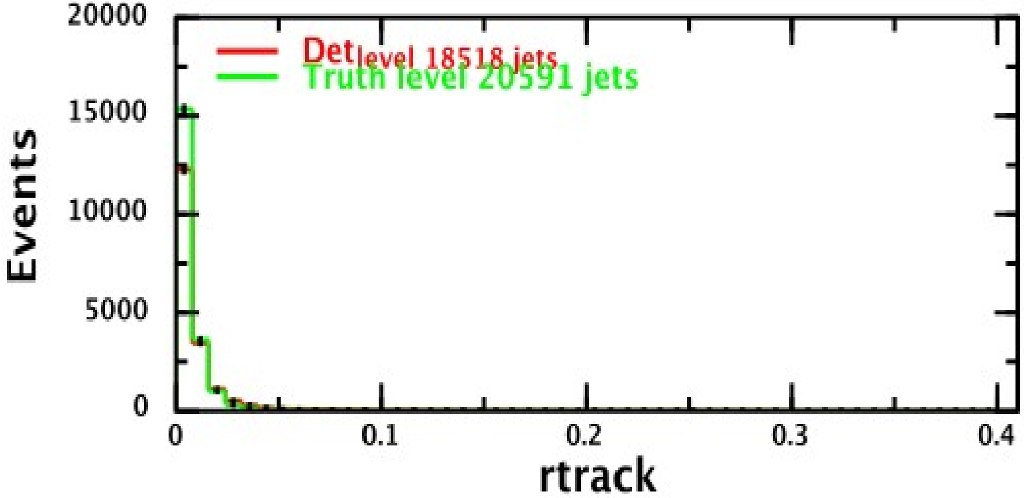


1 prong

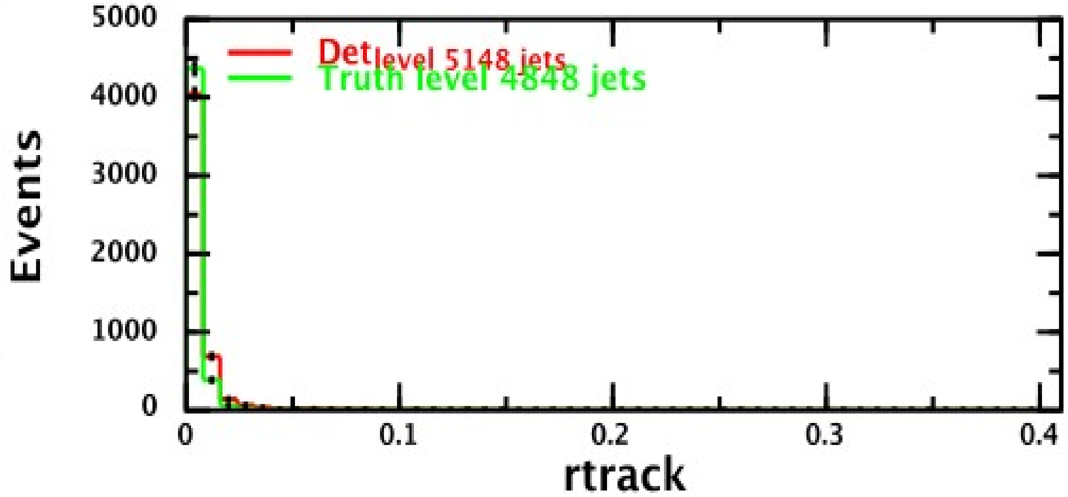


3 prong

R_{track} (Track radius)= pT weighted average of ΔR to the $\tau_{had\text{-}vis}$ direction in $\Delta R < 0.4$



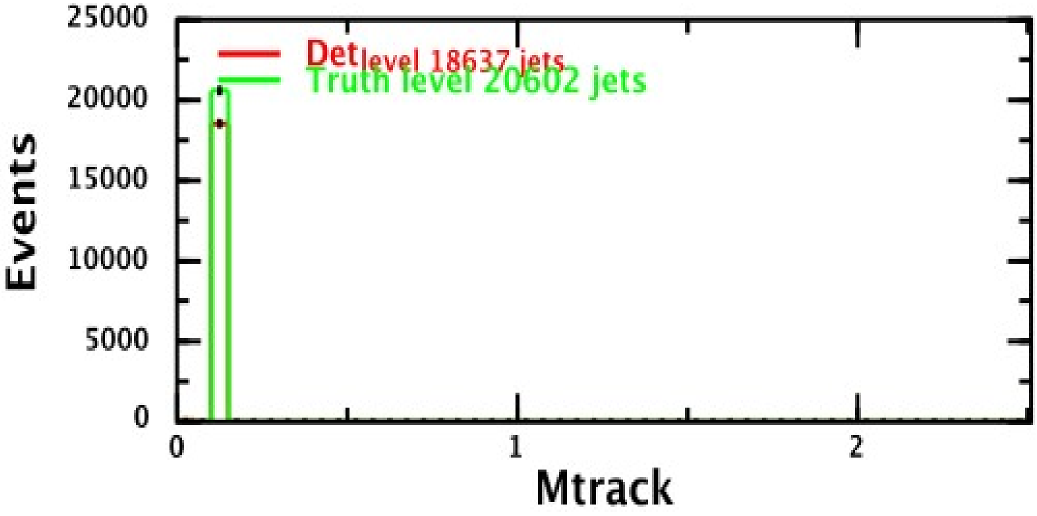
1 prong



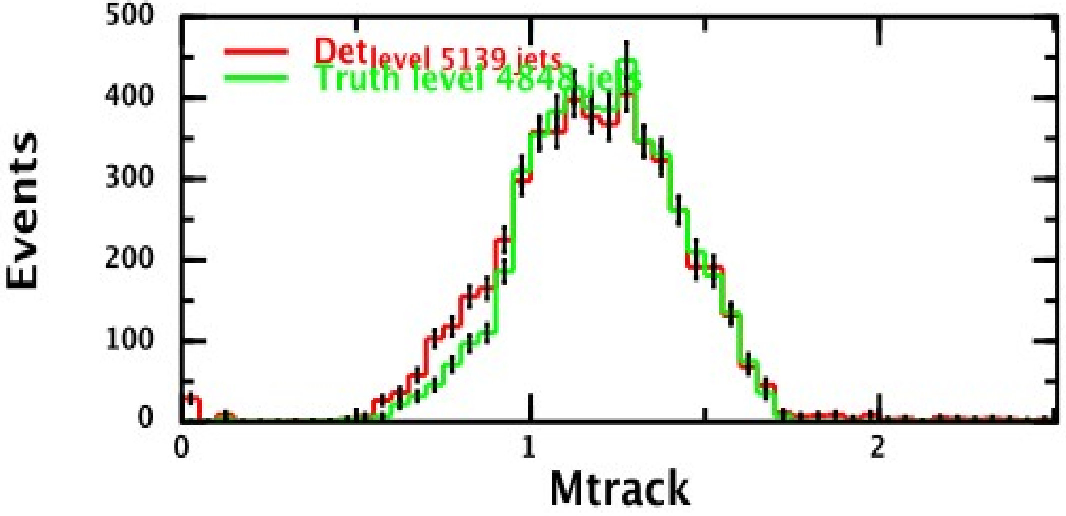
3 prong

M_{track}(Track mass)

= Invariant mass calculated using tracks in ΔR < 0.4, assuming pion mass for each track

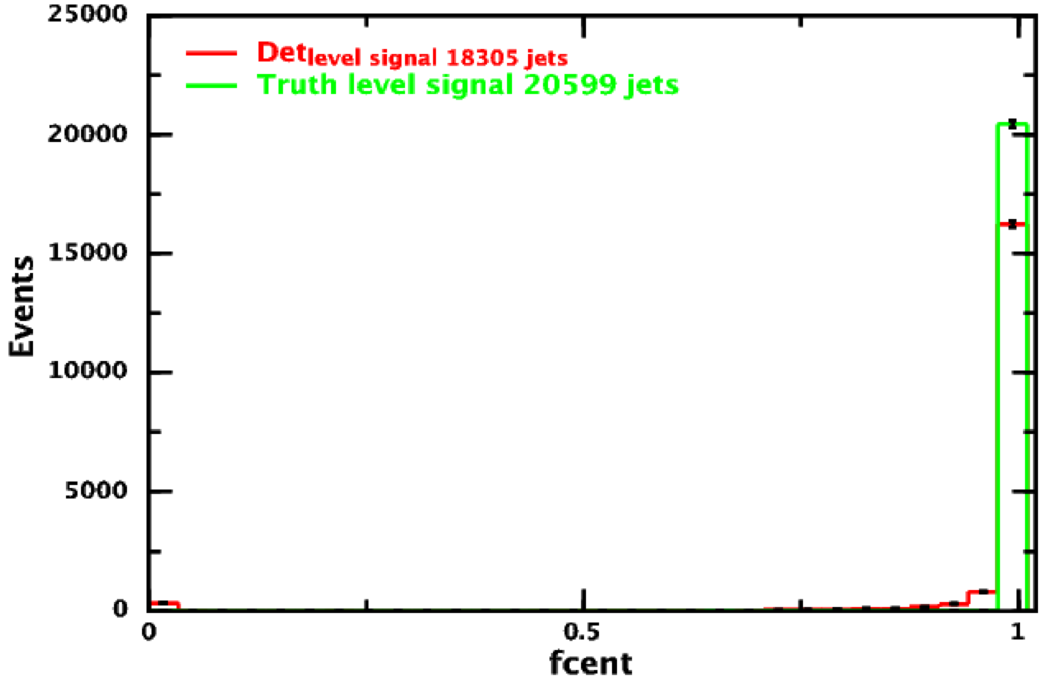


1 prong

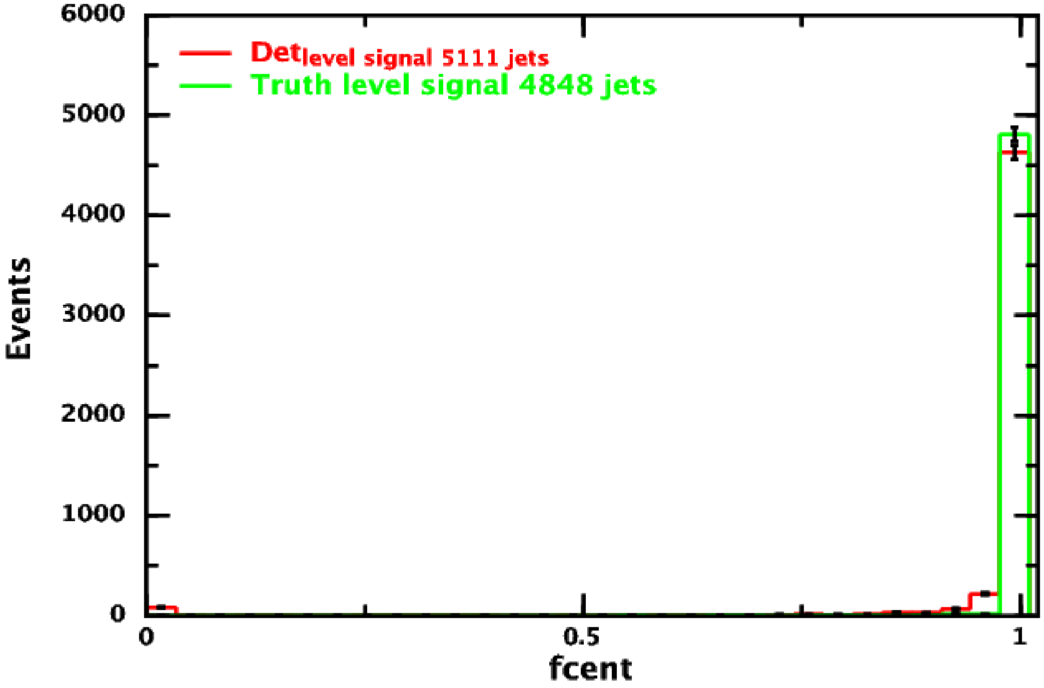


3 prong

f_{cent} (Central energy Fraction)= (total E_T deposited in ΔR < core/2)/ (total E_T deposited in ΔR < core)



1 prong

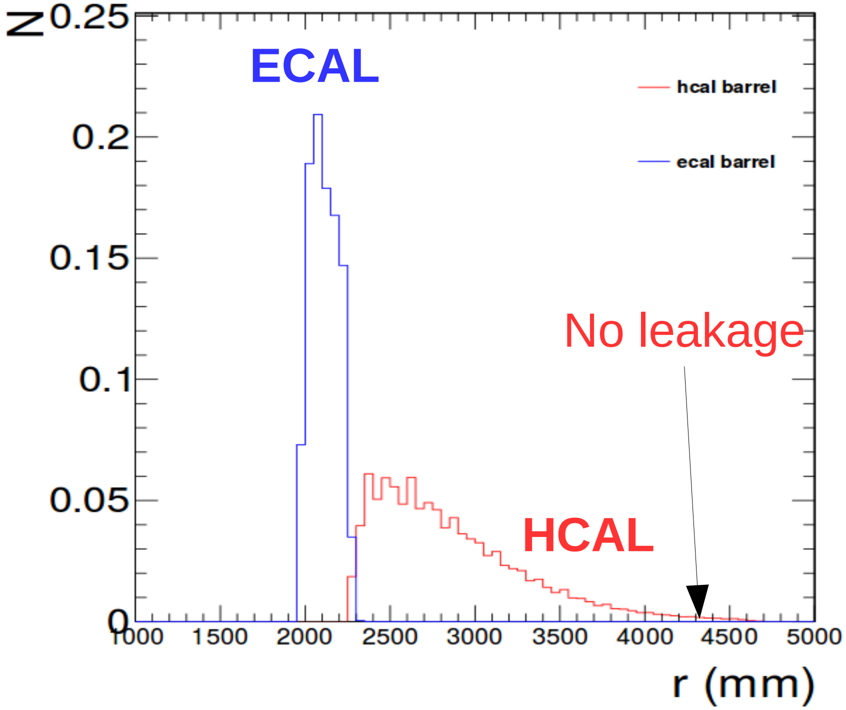


3 prong

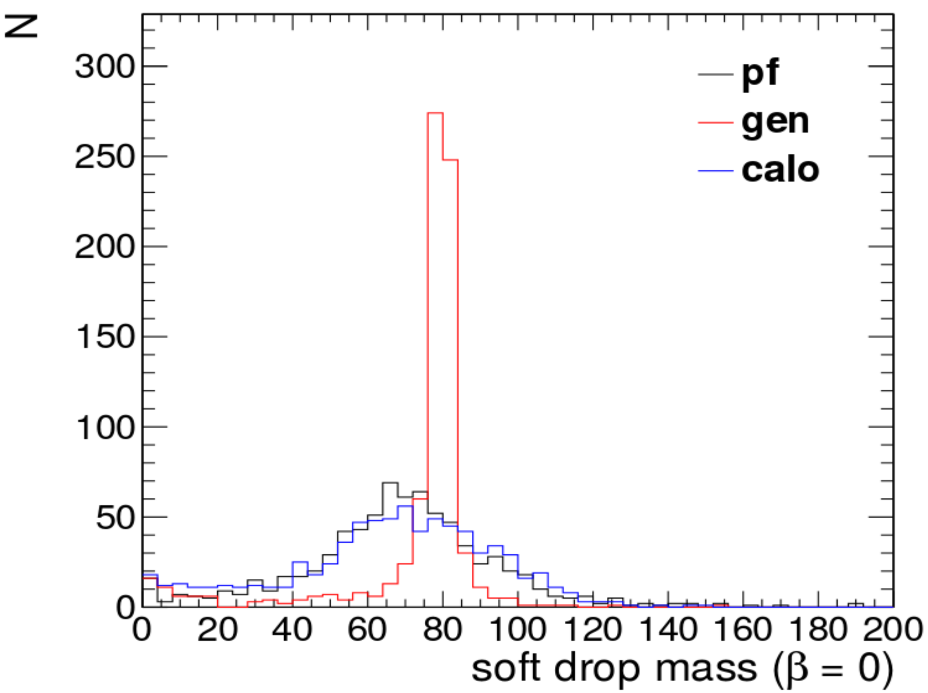
Boosted W → dijet studies

Sample: Z'(10TeV) → WW

(64 layers of HCAL used)



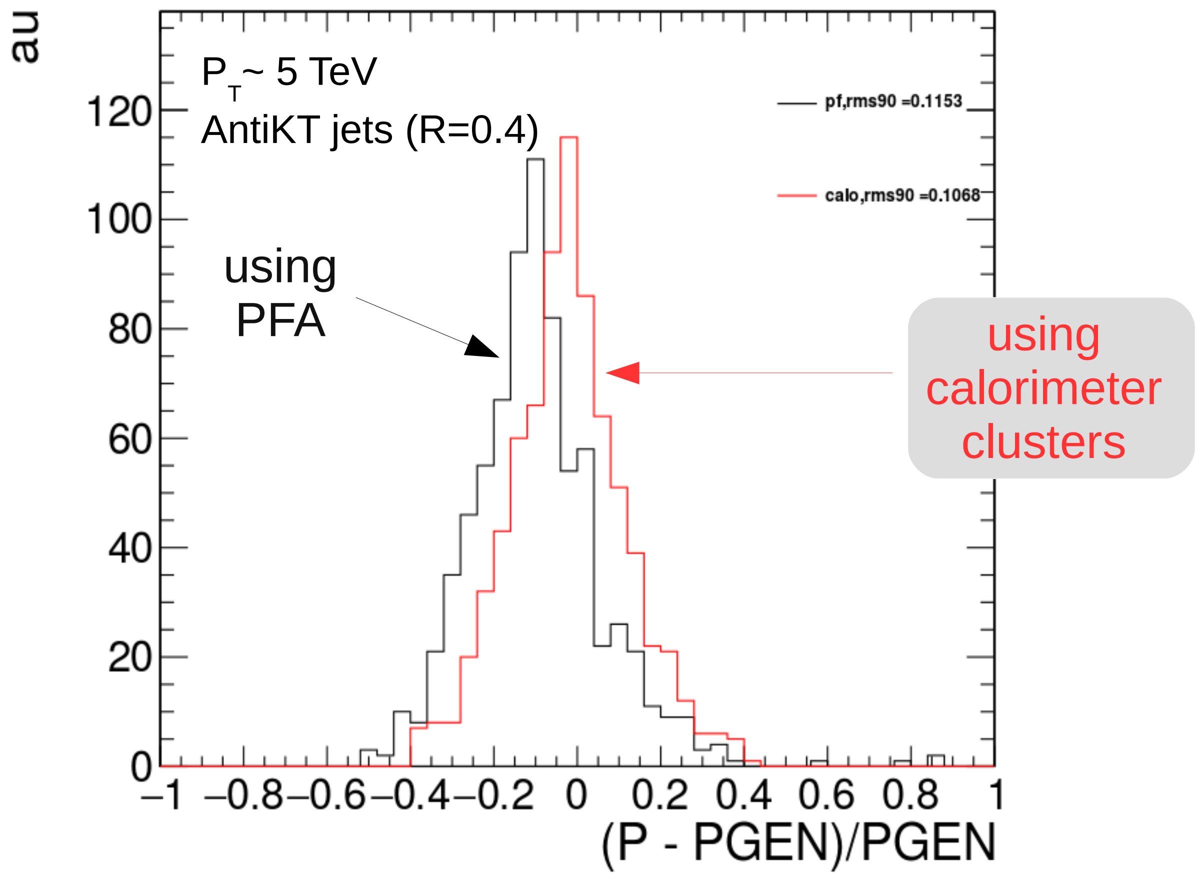
Radial distribution of calorimeter hits



Soft drop declustering condition: Given a jet of radius R_0 with only two constituents, the soft drop procedure removes the softer constituent unless:

$$\min(pT_1, pT_2)/(pT_1 + pT_2) > z_{cut} * (\Delta R_{12}/R_0)^{\beta}$$

Jet response: P(rec) -P(gen)/P(gen)



Shift for PFA jets is due to tracking or imaging HCAL? (under investigation)

Conclusion

- Progress with the Geant4 simulation to understand calorimeter reponse for multi-TeV particles
- Several physics processes in the boosted regime (Z' to WW, ττ, qq) after full simulations are available
- Preliminary studies of boosted hadronic taus (at 500 GeV) and W's (at 5 TeV) have been presented
- Reasonable agreement between truth-level and detector-level tau identification variables
- Designing a calorimeter which will better match the FCC-hh specifications

End