Study Of Boosted W-Jets And Higgs-Jets With the SiFCC Detector

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WITH
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Outline

- Introduction of the SiFCC detector at a 100-TeV pp collider
- Full GEANT simulation of SiFCC detector on Open Science Grid
- Single particle response and resolution
- Jet response and resolution
- Reconstructed mass of the Higgs-jet
- Two-jet separation in highly-boosted W→qq' and Higgs→bb
- Conclusion

Calorimeters For Colliders At 100 TeV

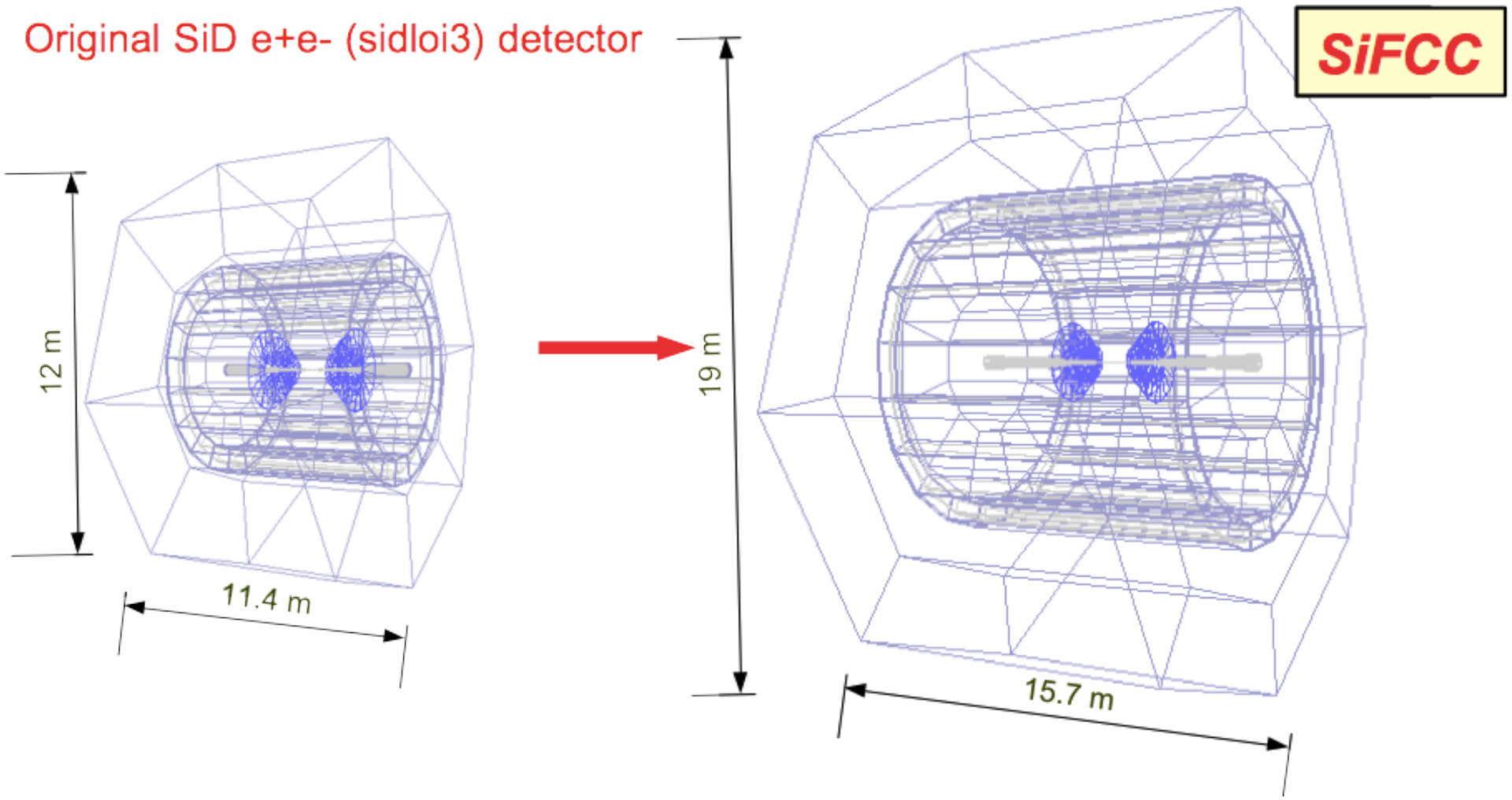
- Very-high-energy colliders can produce particles with:
  - Large mass
  - Large energy of decay products
  - Large jet transverse momentum

See more discussions in the talks at BOOST 2015/2016 by G. Perez, S. Chekanov, and N. Tran

- Requirement of calorimeters
  - Good containment up to p_T(jet)~30 TeV: **12 λ_I** for ECAL+HCAL
  - Small constant term for HCAL energy resolution: **c < 3%** (dominates jet resolution for p_T>5 TeV)
  - Sufficient transverse segmentation for resolving boosted particles
  - Longitudinal segmentation

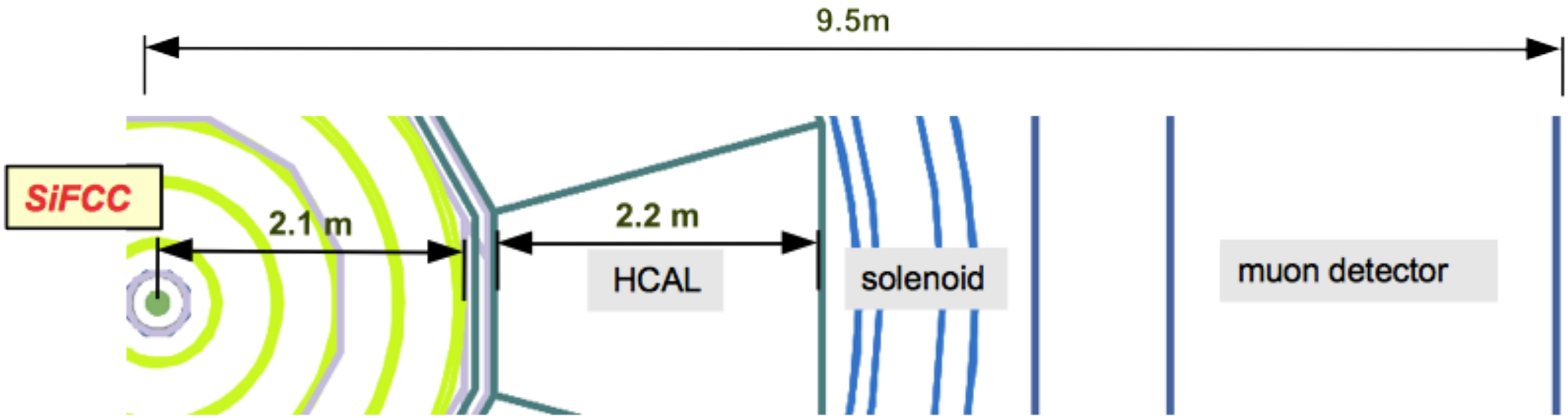
SiFCC Detector For Performance Studies

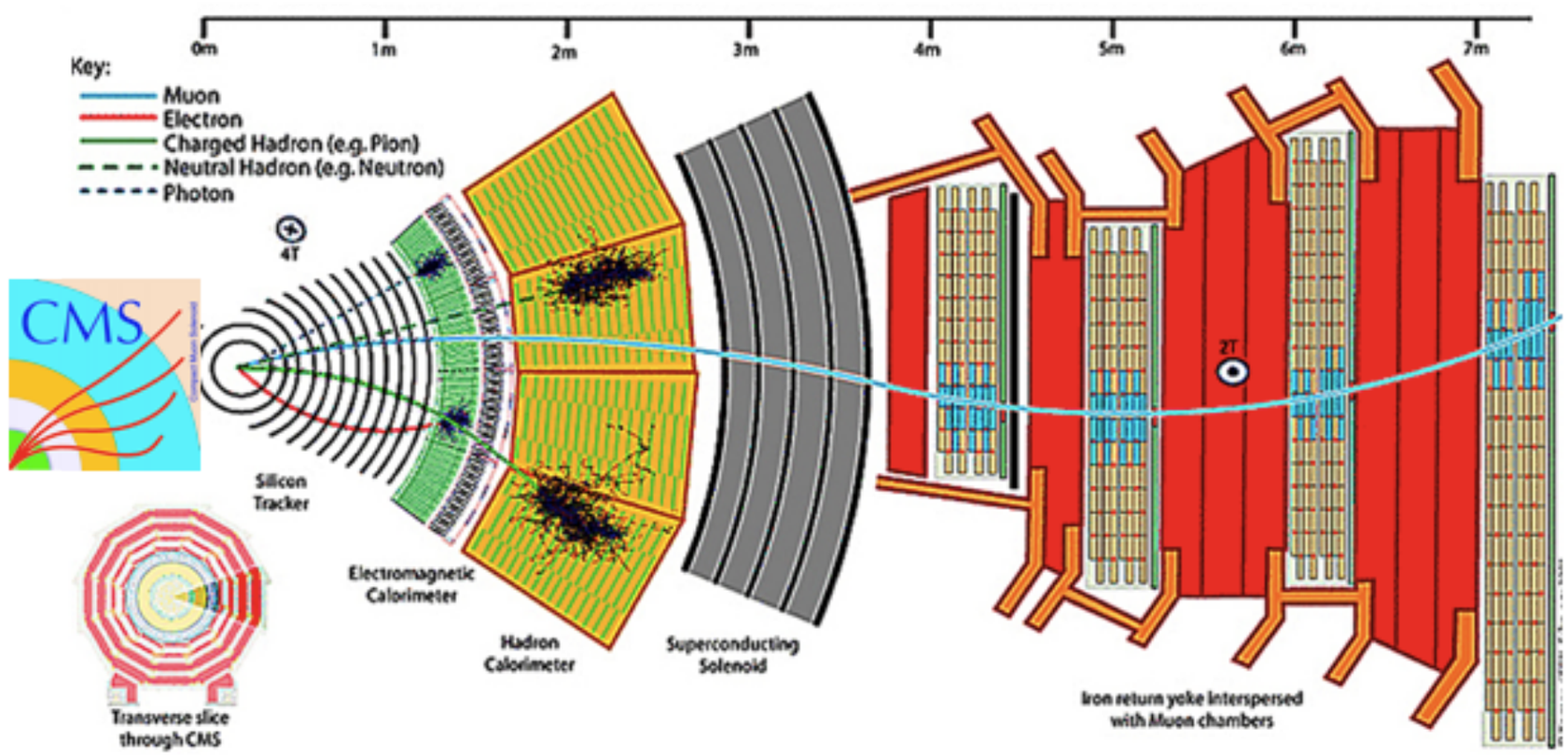
- Re-purpose SiD (ILC) detector and SLIC software

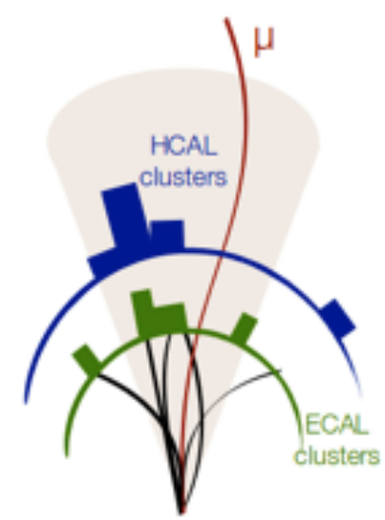


- SiFCC: multipurpose, high granularity, compact detector
  - 30% smaller than ATLAS (D=25 m vs D=19 m)
  - 30% larger than CMS (D=14.6 m vs D=19 m)

SiFCC detector vs CMS



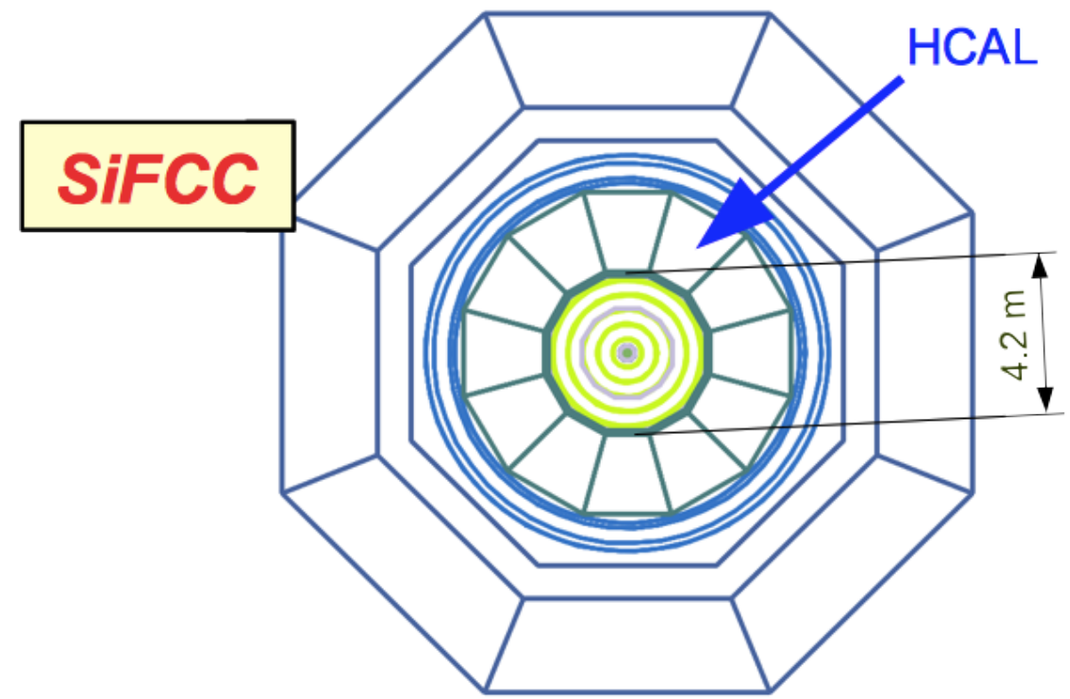


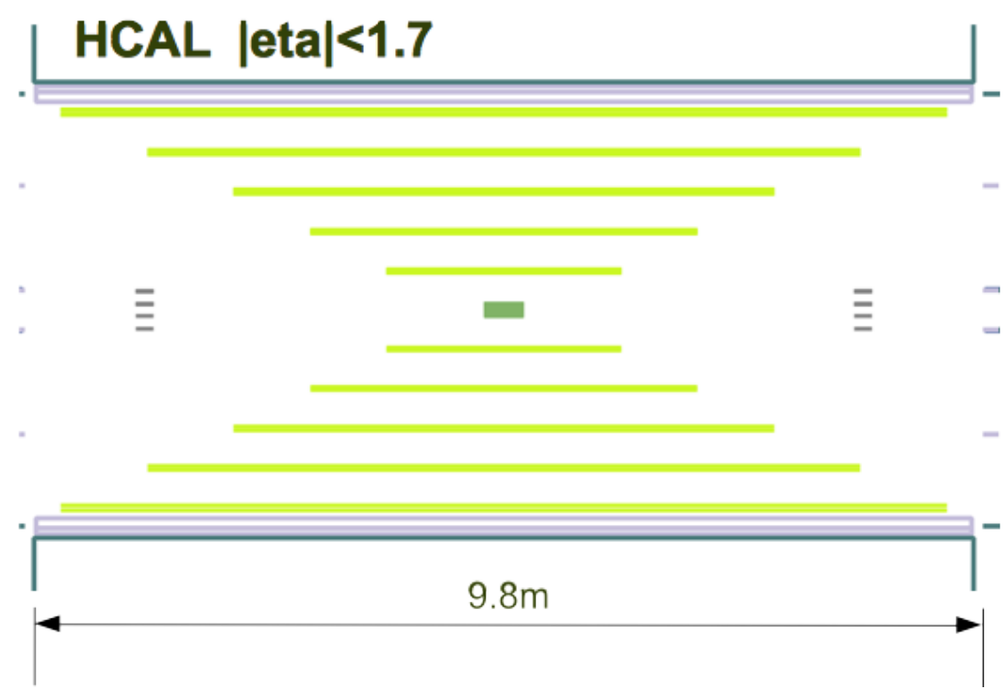


Characteristics Of SiFCC Detector

- 5 T solenoid outside HCAL
- Pixel and Outer trackers:
  - 20 μm pixel (inner), 50 μm(outer)
- ECAL (Silicon+W): 2x2 cm. 32 layers, ~35 X_0
- HCAL (Scint+Fe)
  - 5x5 cm cells: $\Delta\eta x \Delta\varphi$=0.022 x 0.022
  - CMS: $\Delta\eta x \Delta\varphi$=0.087x0.087
  - ATLAS: $\Delta\eta x \Delta\varphi$=0.1x0.1
  - Longitudinal: 64 layers, 11.3 λ_I
  - 27.5 mm Steel, 5 mm Polystyrene active material, 2.5 mm G10 (3.1% sampling fraction)
  - > 150 million cells, non-projective

Detector Information

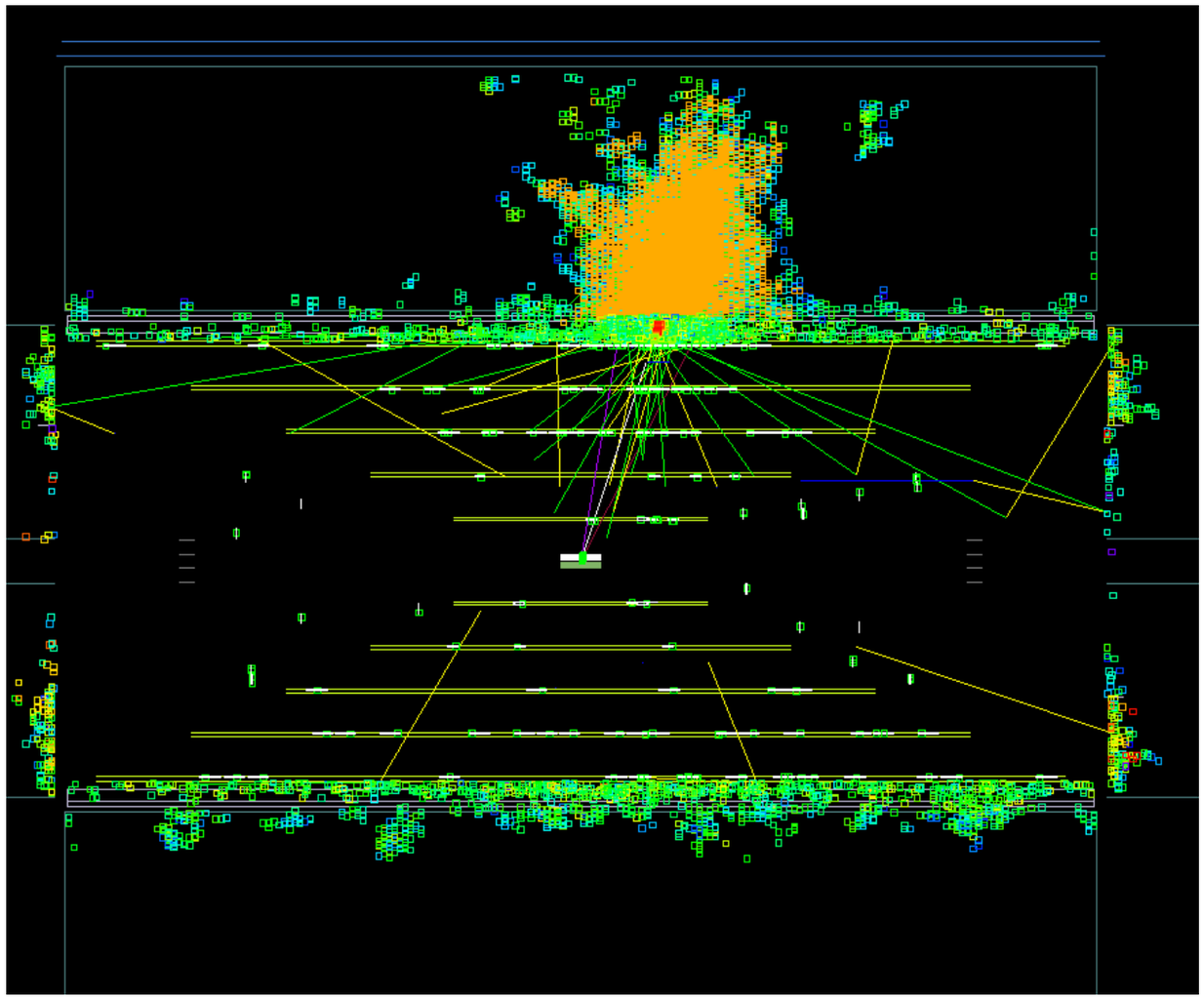


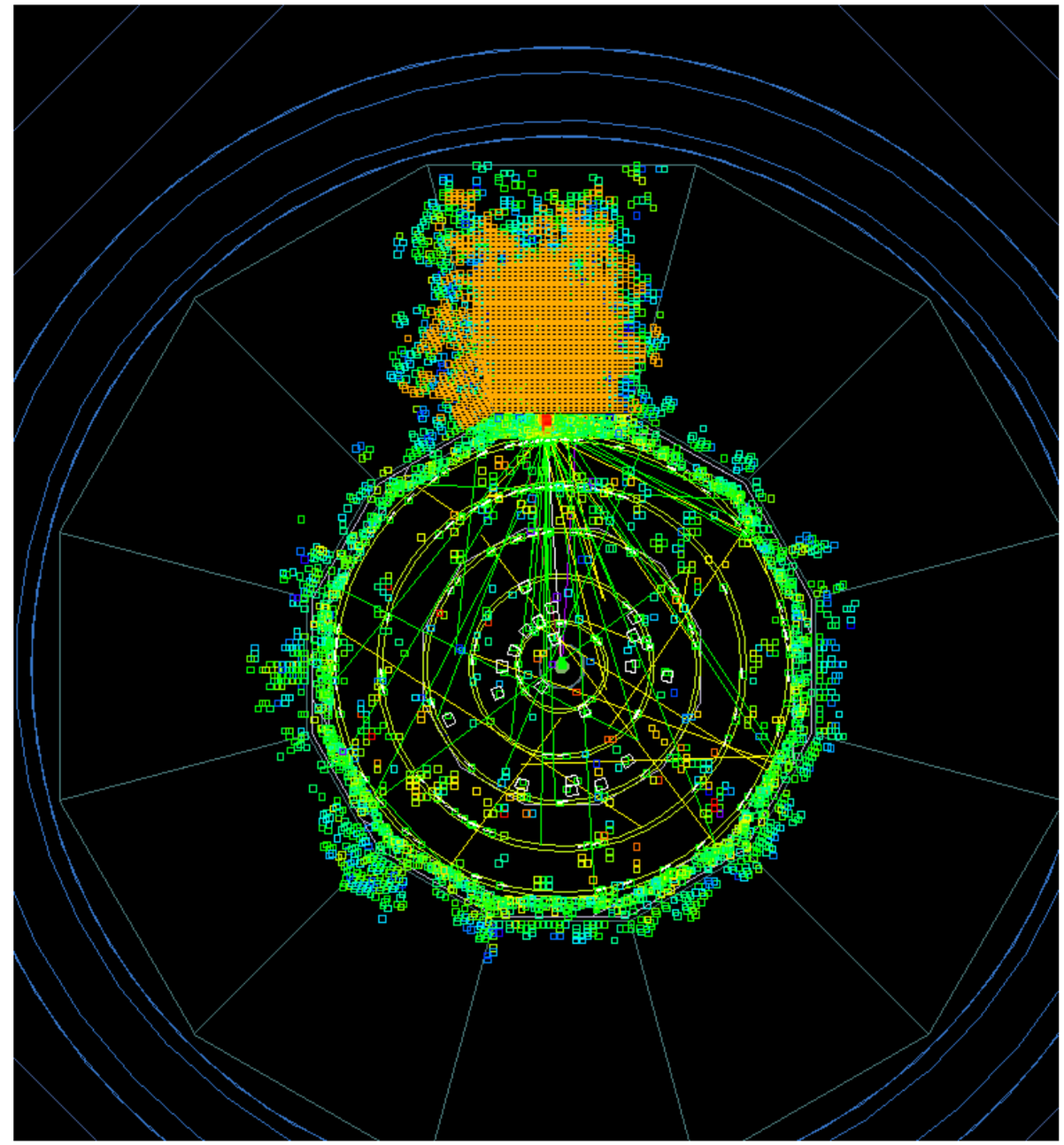


Event Display Of 1 TeV Single Charged Pion

- 7300 calorimeter hits, 440 SiTracker hits
- 1 reconstructed PFA object (π+)=998 GeV
- 1 reconstructed CaloCluster at 1058 GeV
- Many back-splash interactions

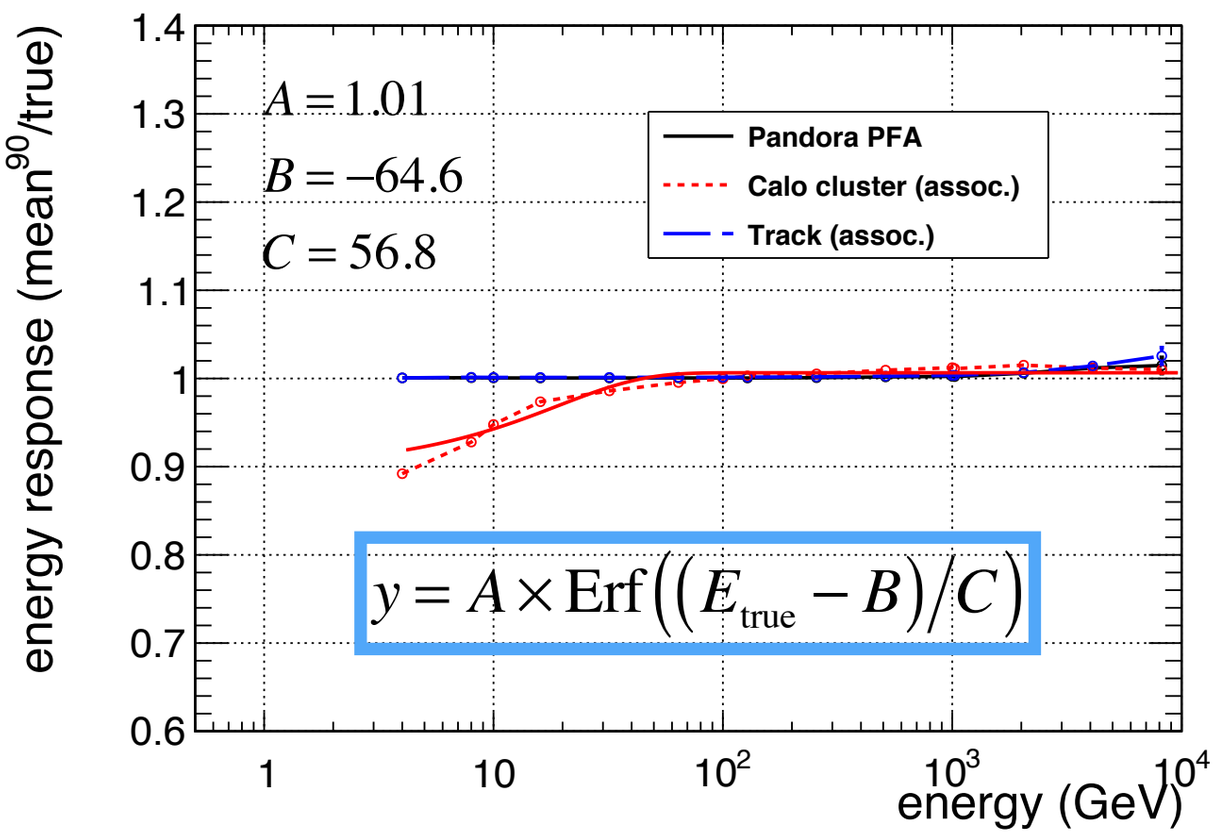
PFA=Particle Flow Algorithm

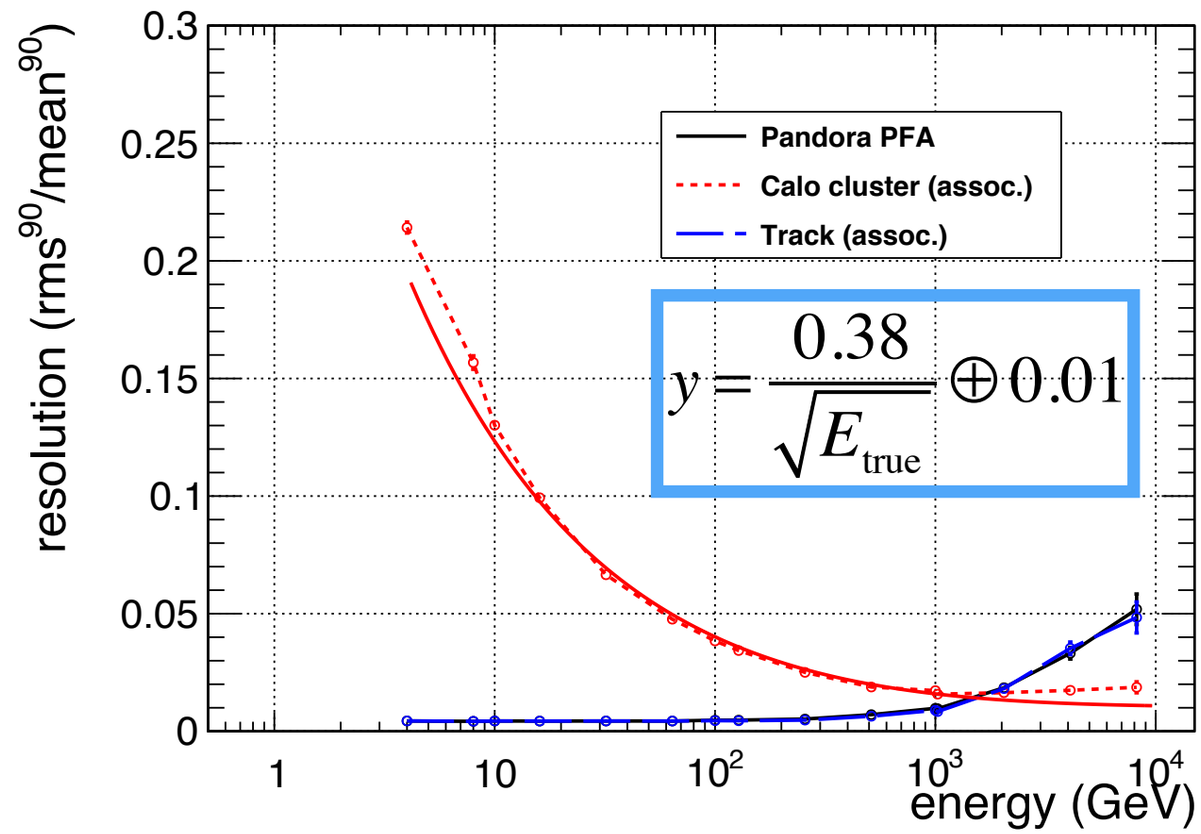




Single-Pion Response And Resolution

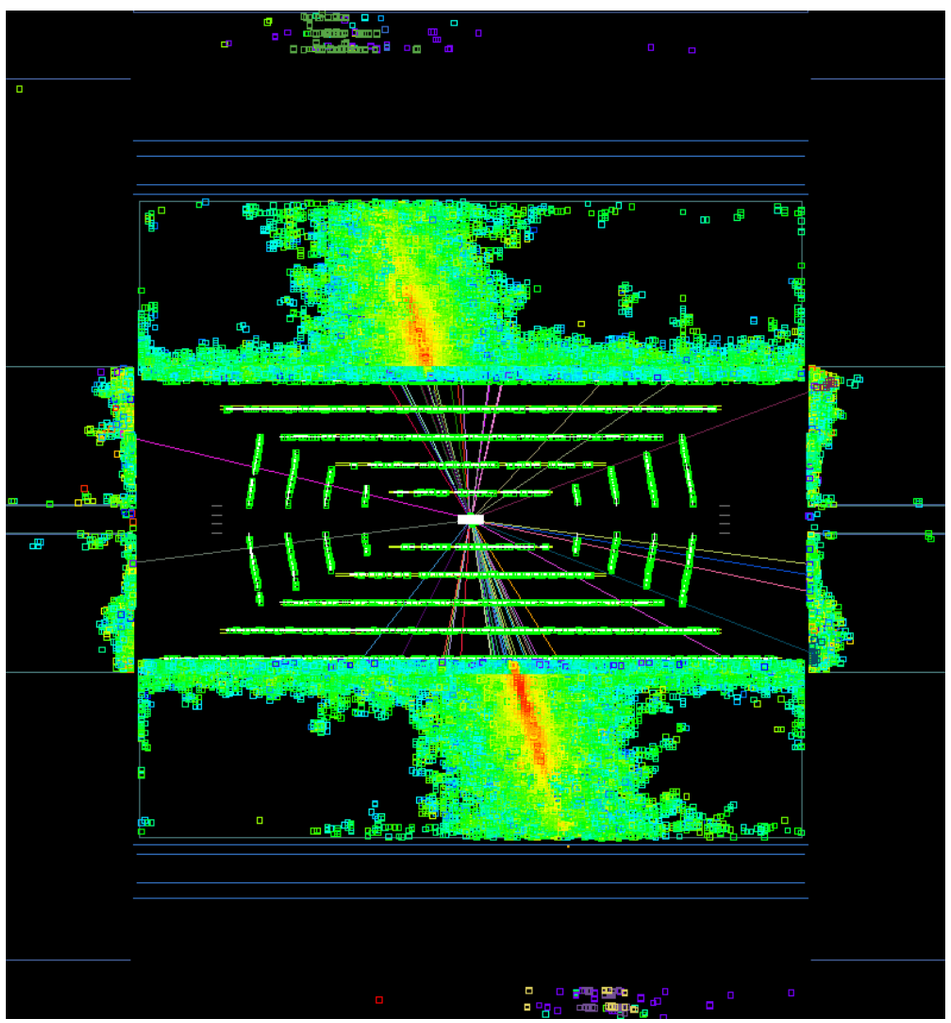
- Loss of acceptance for low-p_T tracks due to 5T magnetic field
- Resolution of tracks getting worse with energy
- Resolution for CaloClusters is better than tracks for E> 2 TeV

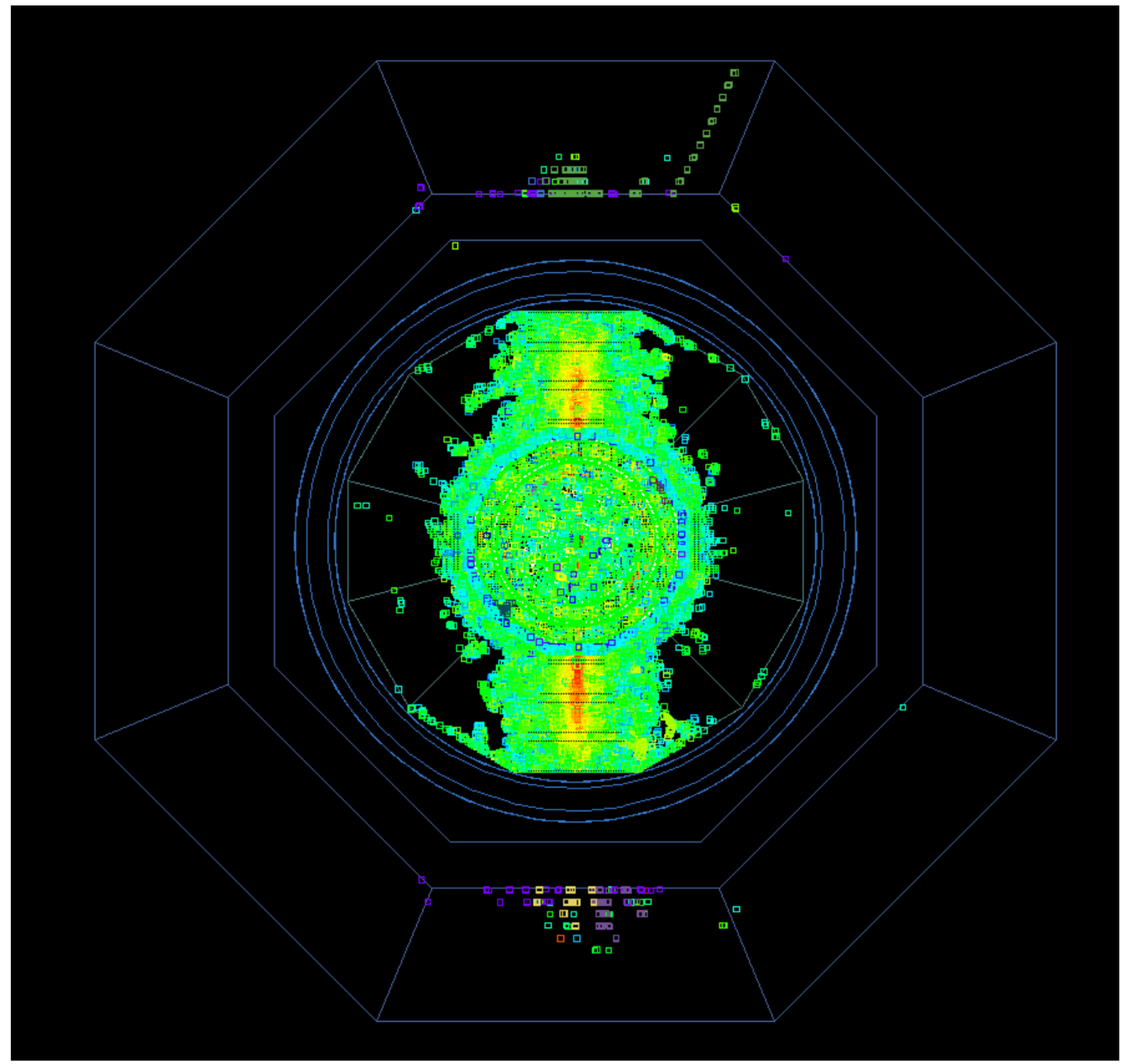




Event Display Of 40 TeV Z'→WW

10,000 hits in ECAL
46,000 hits in HCAL
12,000 hits in outer tracker
1,000 hits in pixel tracker



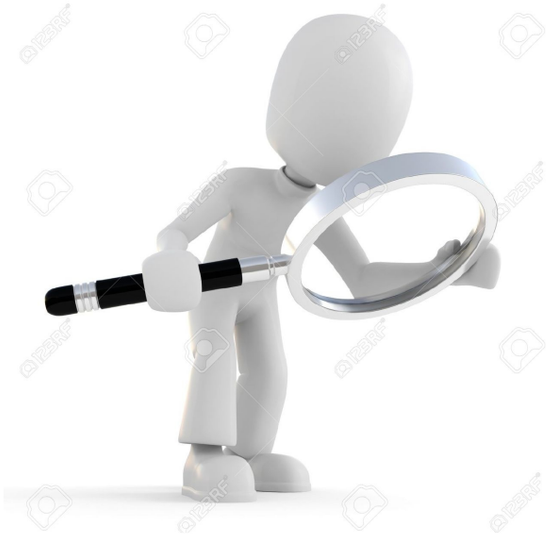


Simulated Physics Events

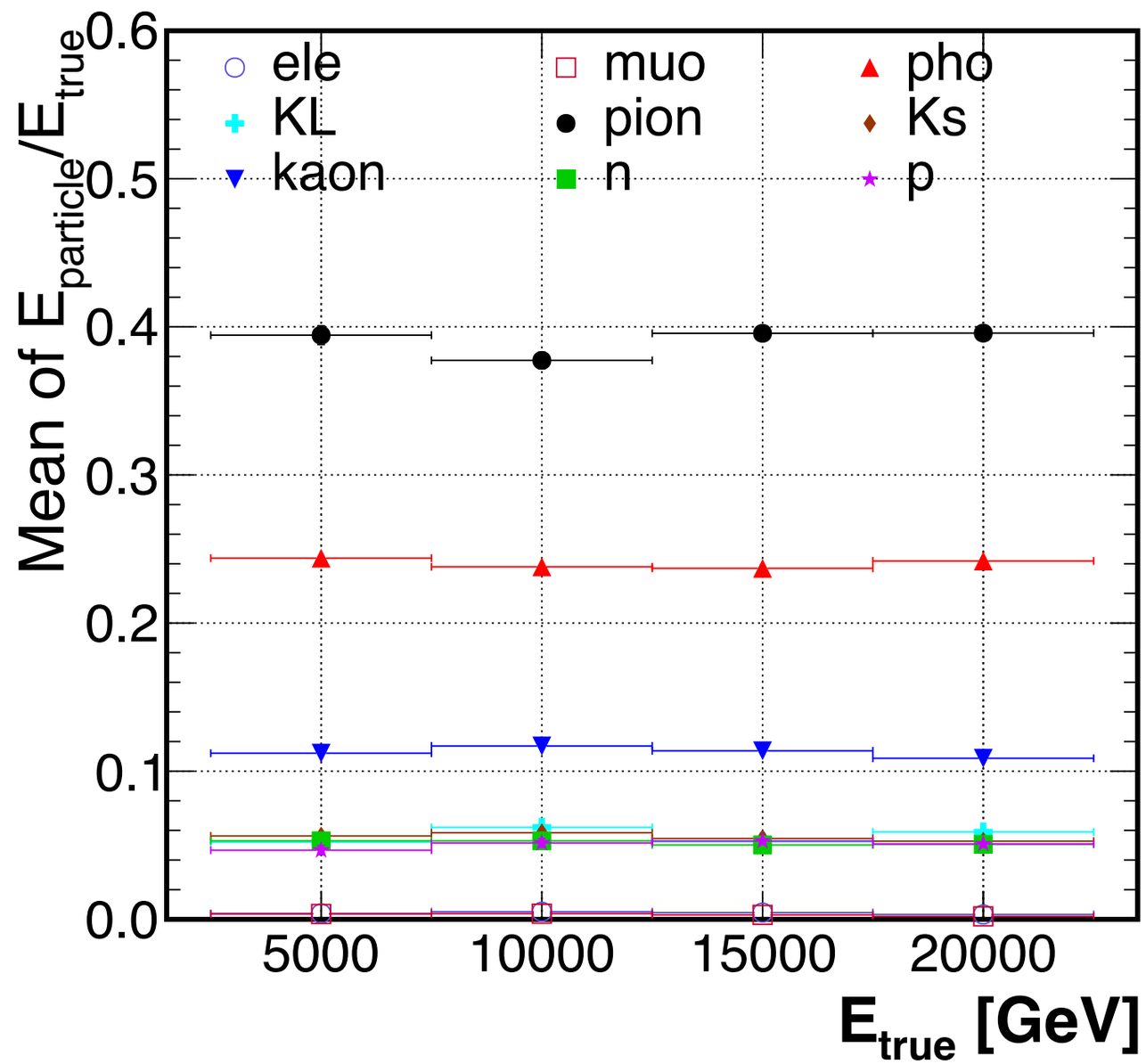
Start with μμ collider events to eliminate pileup effects
and reduce simulation time
Focus on the detector performance

Physics Process	Generator	μμ √s [TeV]	Resonance Mass [TeV]	Link to sample
2HDM H2	MADGRAPH + PYTHIA6	5	5	ID 178
Z' (filtered)	PYTHIA6	10	10	ID 179
Z' (filtered)	PYTHIA6	40	10	ID 206
Z' (filtered)	PYTHIA6	40	20	ID 206
Z' (filtered)	PYTHIA6	40	30	ID 206
Z' (filtered)	PYTHIA6	40	40	ID 206

What Is Inside A Jet?



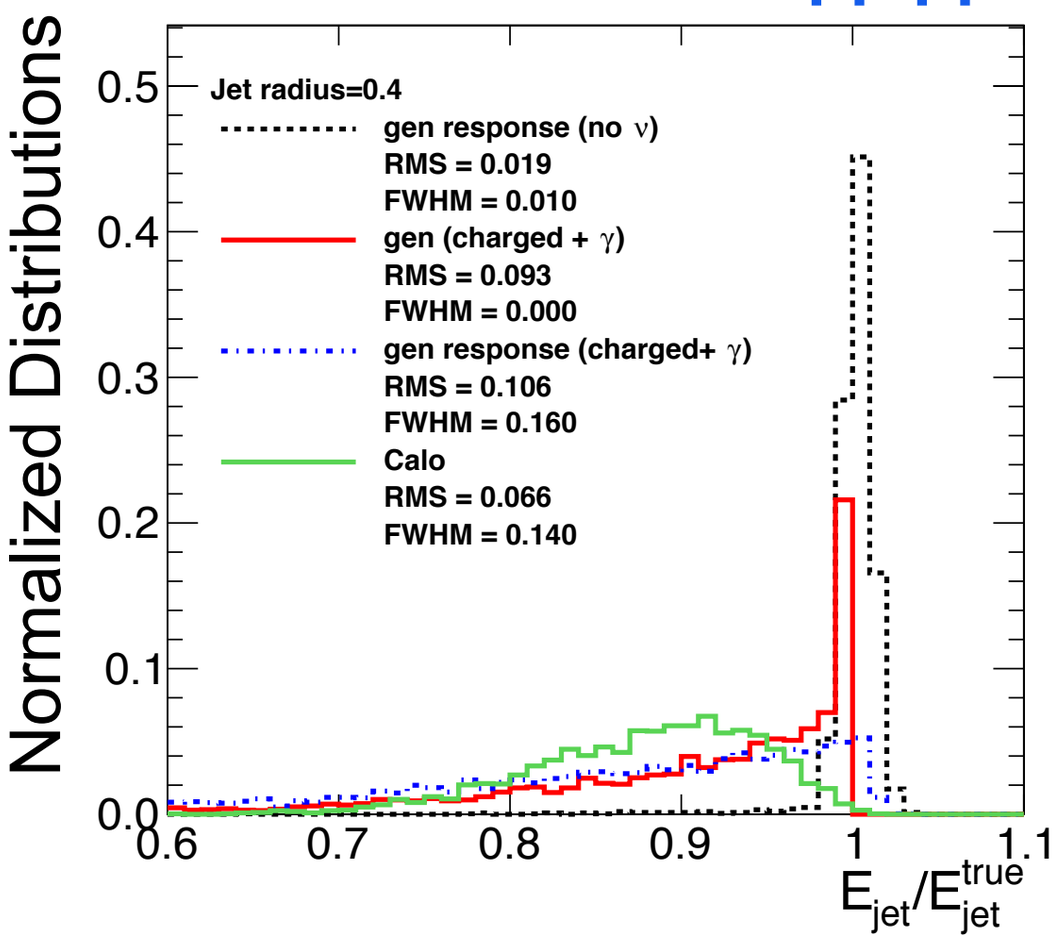
- Generator-level jets clustered with anti-k_T algorithm and $\Delta R=0.4$ ($Z' \rightarrow WW$ sample)
- Neutrinos are excluded in the calculation of E_{true}
- Overall fractions
  - $\pi^{\pm}$: 40%
  - γ: 24%
  - $K^{\pm}$: 11%
  - p, n, K_S, K_L: 5% each
  - Rest (Λ,Ξ,Σ): 5%



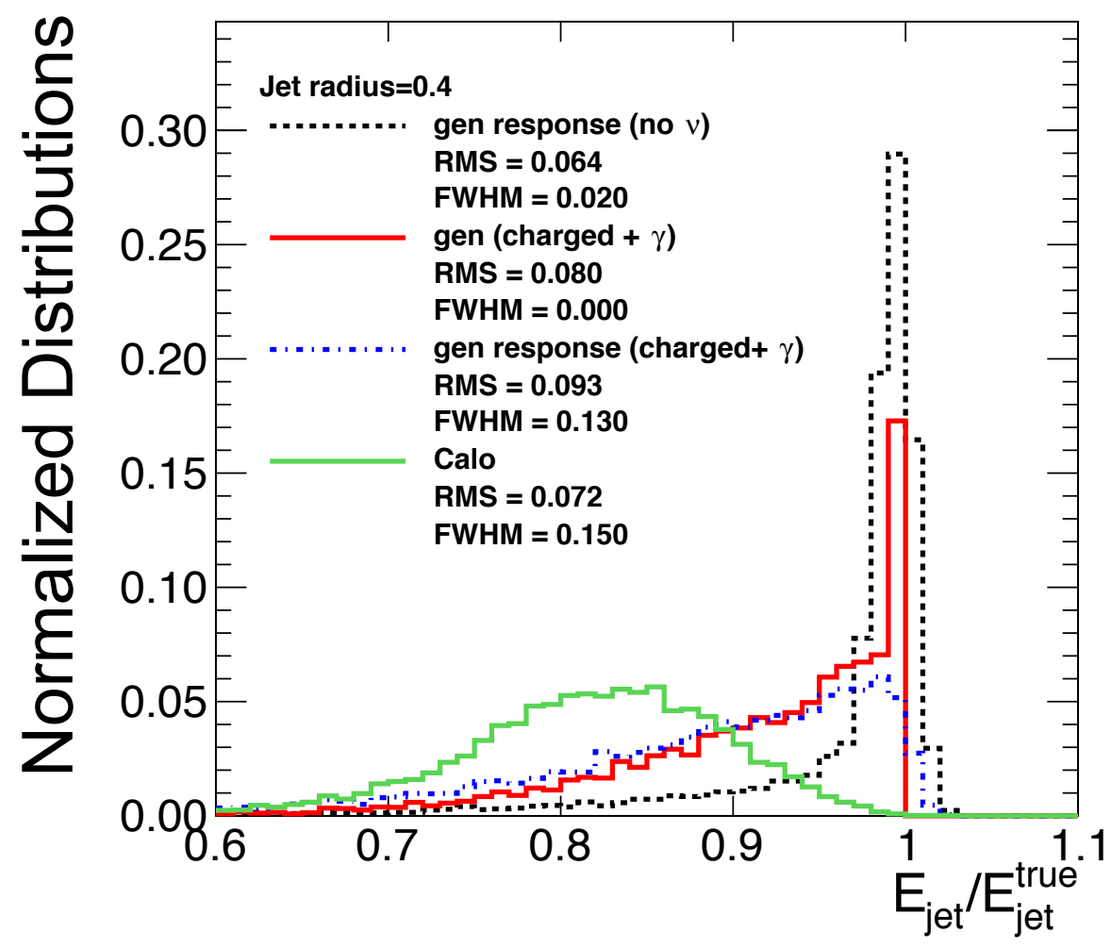
Comparison Of Energy Response

- Weight generator-level particles with single-particle response and smear with single-particle resolution
  - response = 0 for charged particles with E < 3 GeV, eγ response mean=1, RMS/Mean = 0.15/√E ⊕ 0.01
  - gen (charged + γ): include only charged particles and photons

10-TeV Z'→WW→qq'qq'

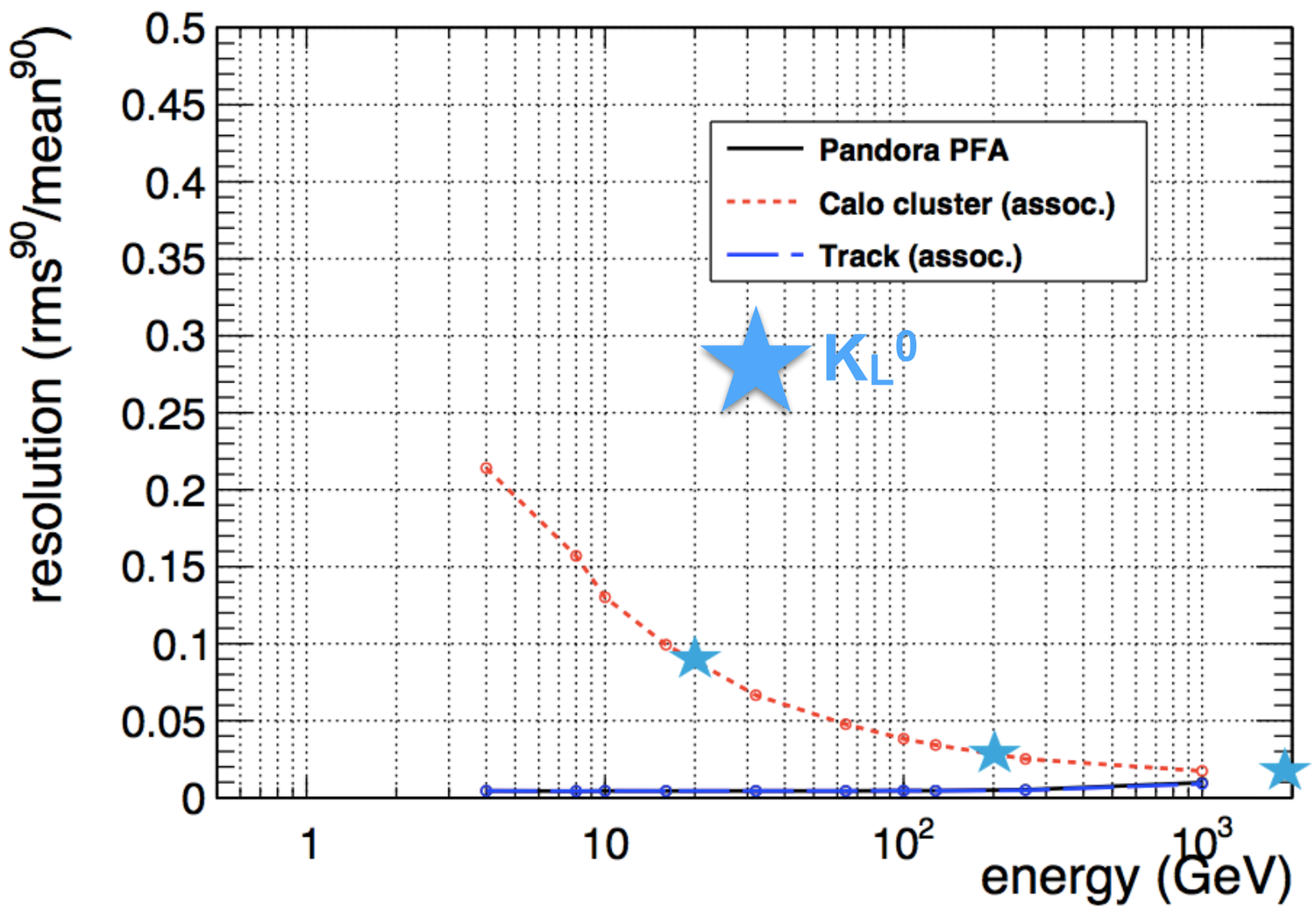


5-TeV H2→hh→bbbb



Single-K_L^0 Response and Resolution

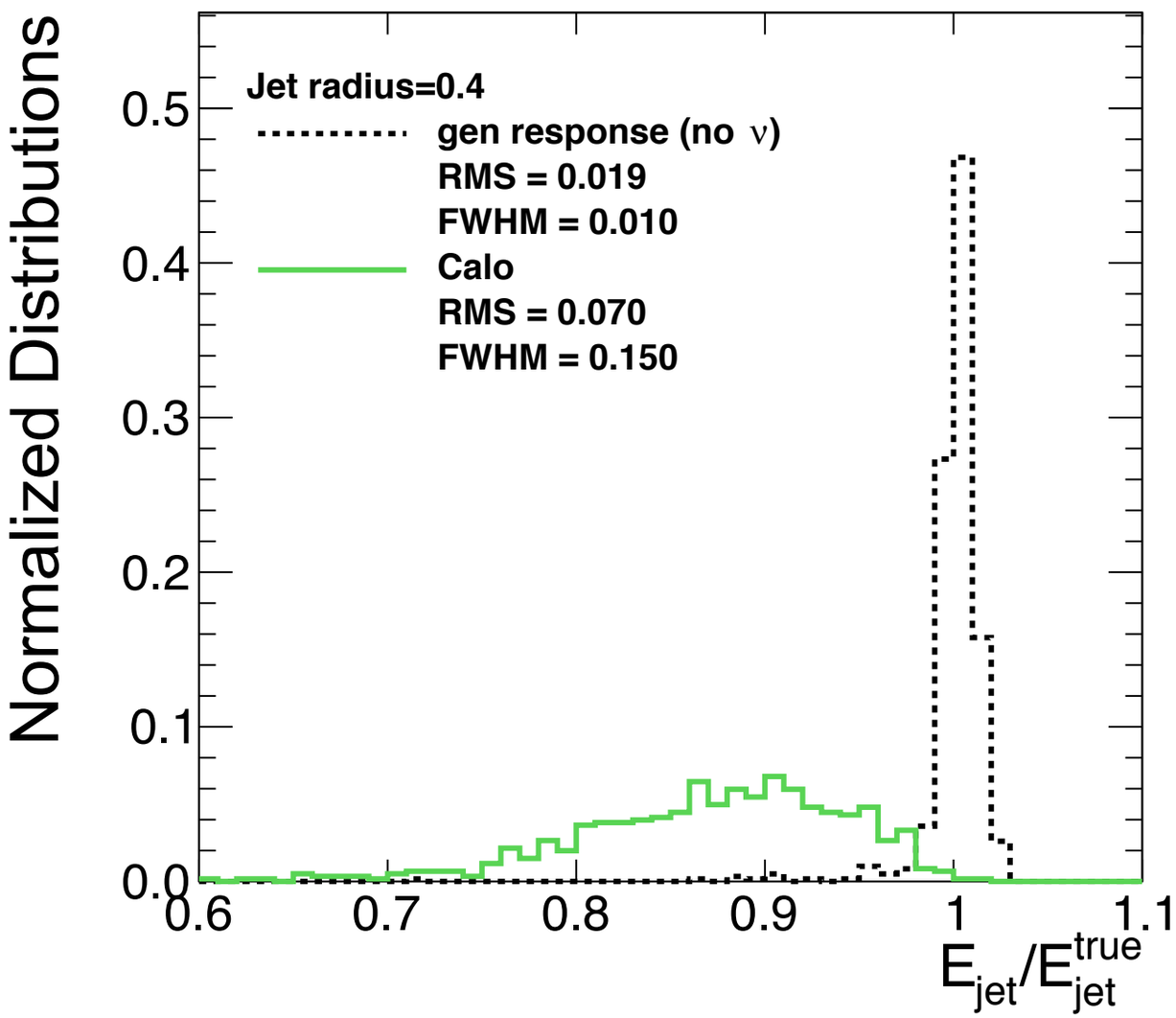
- Is it possible that K_L^0 has very different response or resolution?
  - The response and resolution of single K_L^0 are actually similar to those of single pion



Jet Response And Resolution

- Study the calorimeter jet energy response as a function of generator-level jet energy with Z'→WW samples

10-TeV Z'→WW→qq'qq'



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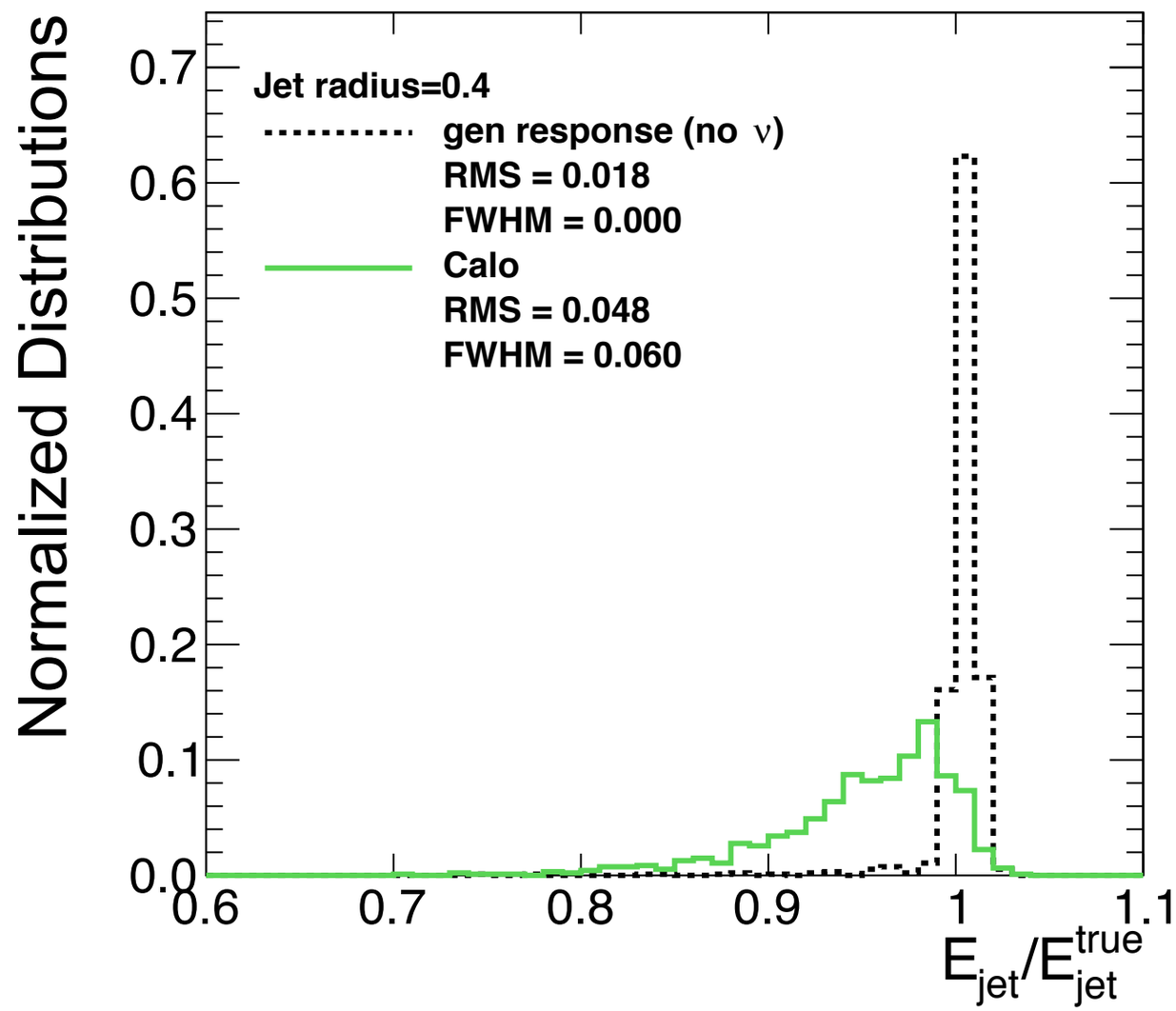
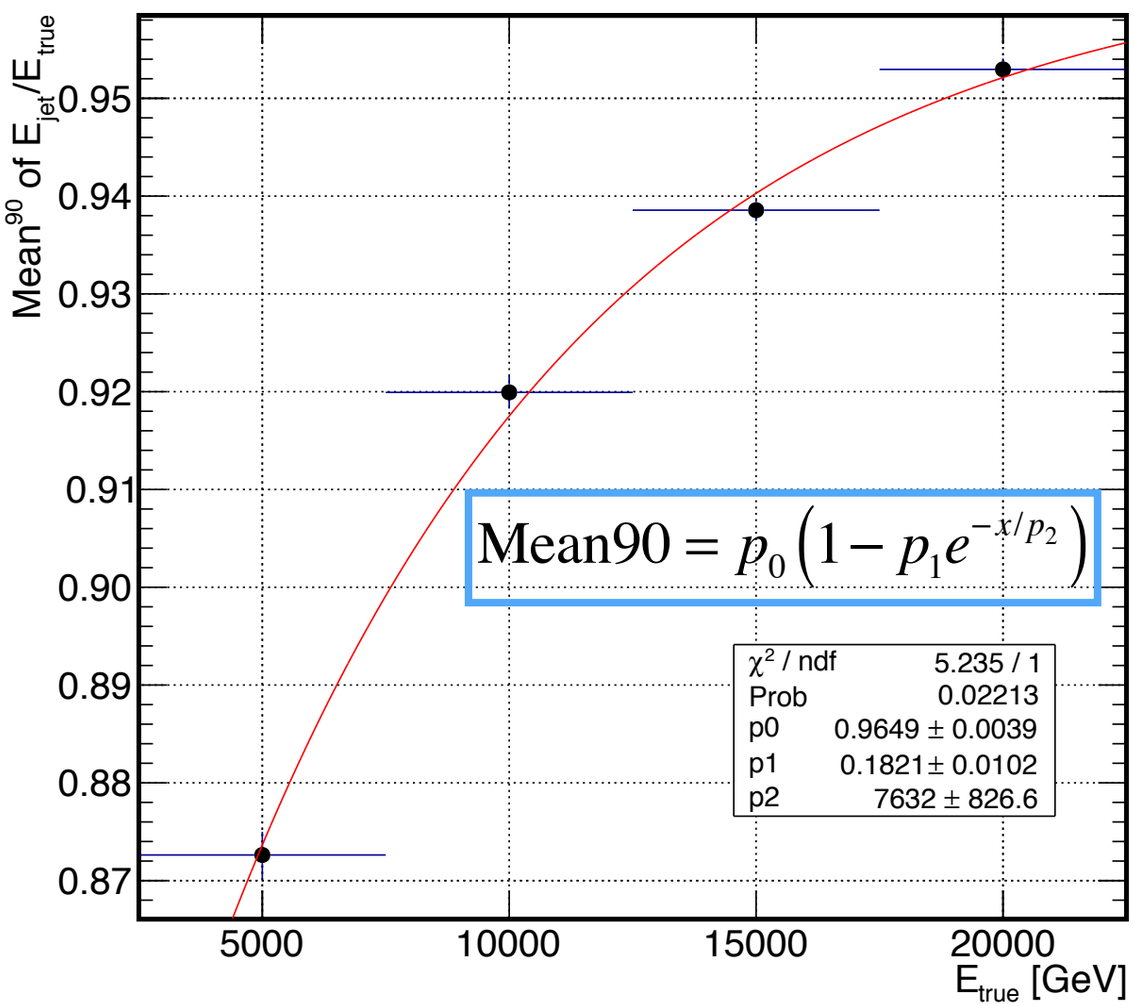
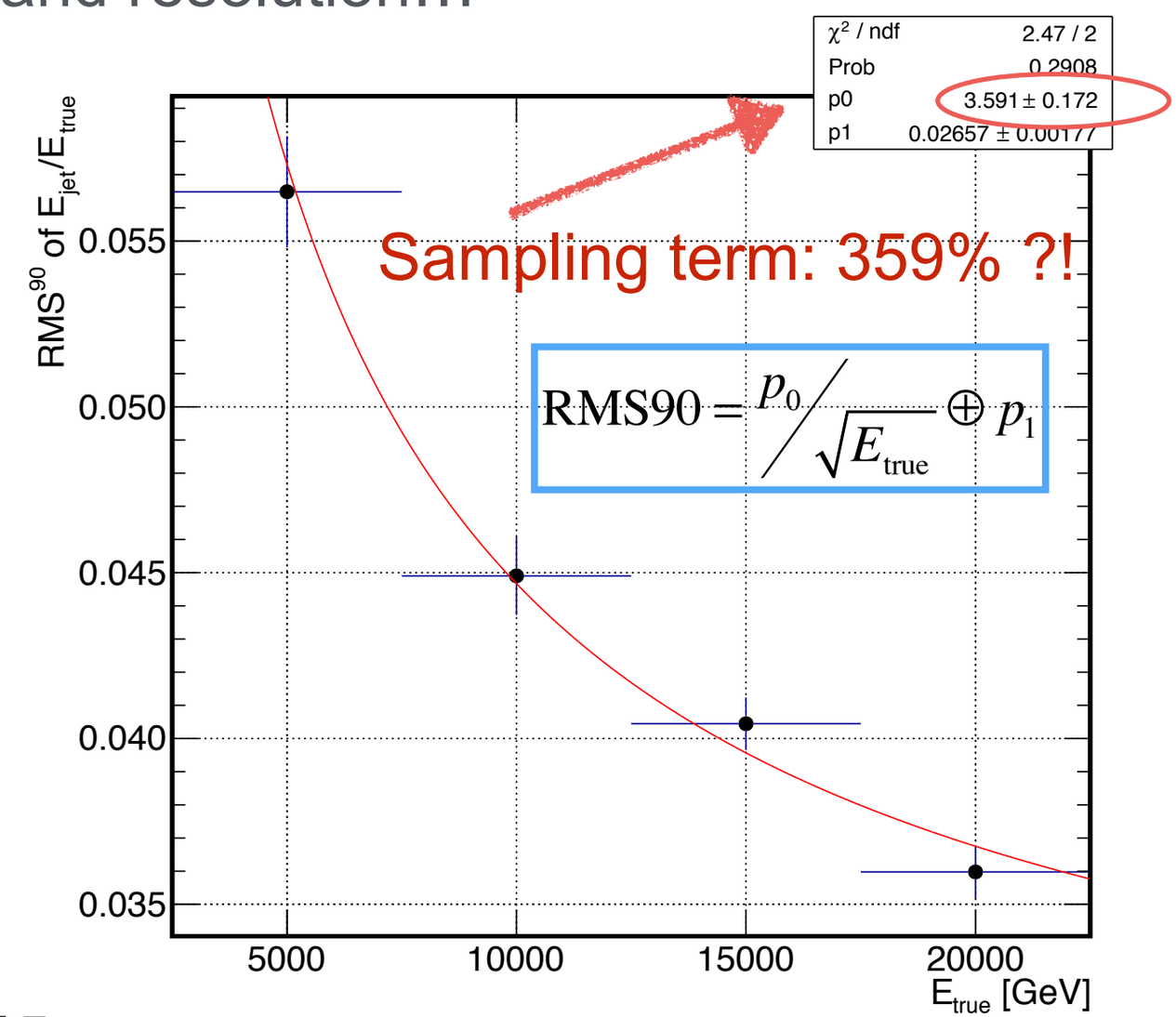


Jet Response And Resolution

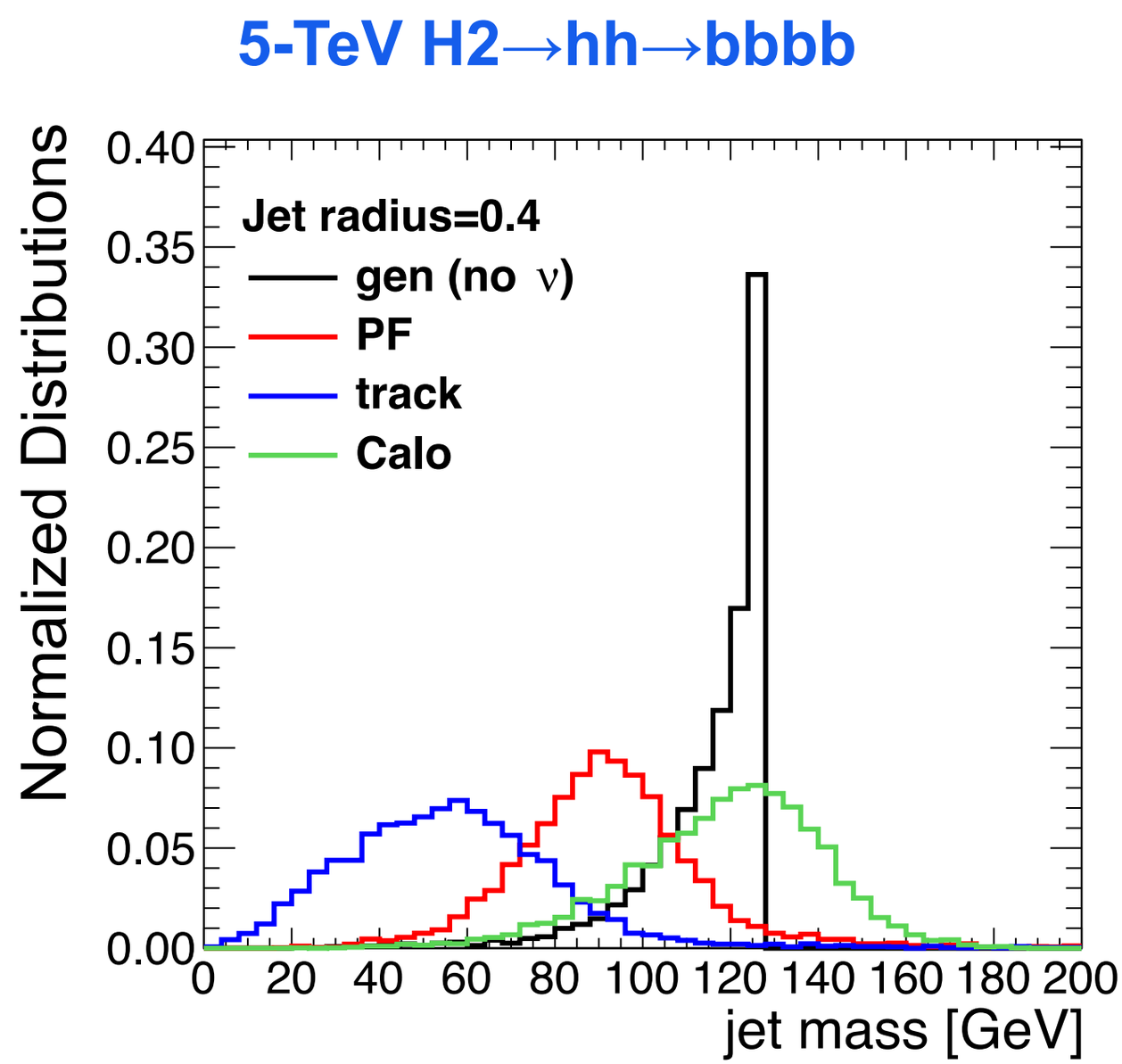
- First study of calorimeter energy response and resolution for 5-20 TeV jets using realistic GEANT4 simulation
  - Also tried clustering of calorimeter hits around the generator-level W direction, results are very similar
  - Continuing study of jet response and resolution…





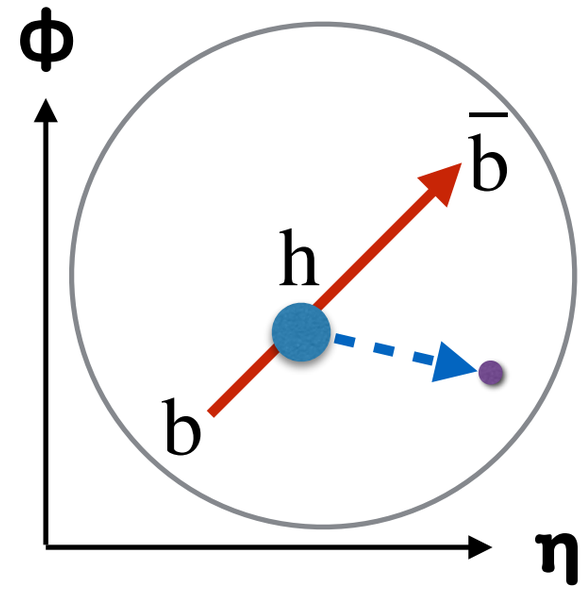
Reconstructed Mass Of the Higgs-Jets

- Study of the mass distributions is in progress
  - Reconstruction-level jets matched to generator-level with $\Delta R < 0.1$
  - PF-jet mass is about 30 GeV lower than the nominal mass



Two-Jet Separation In Boosted Bosons

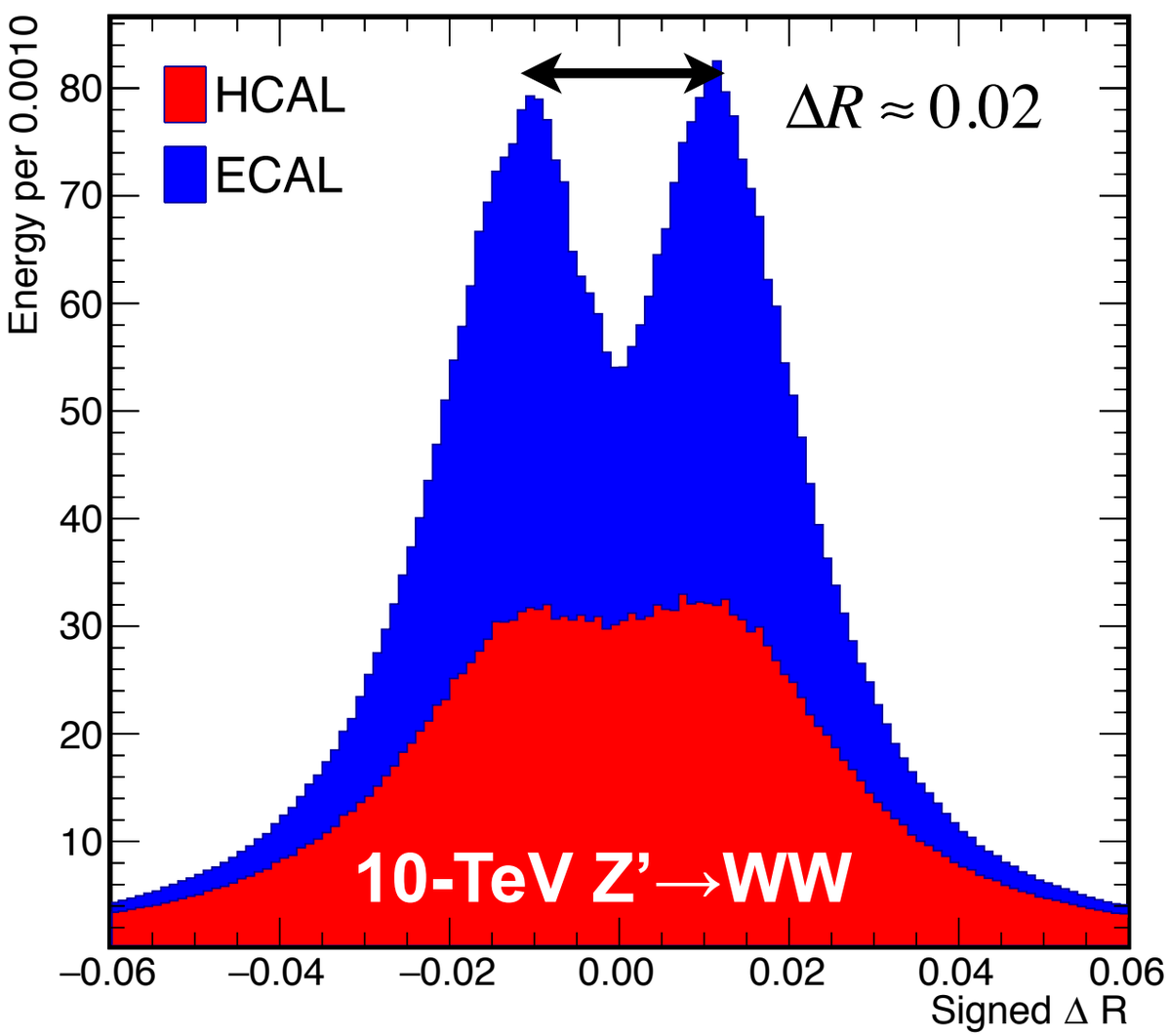
- The high-granularity calorimeter makes it possible to see the separation of jets within highly-boosted bosons

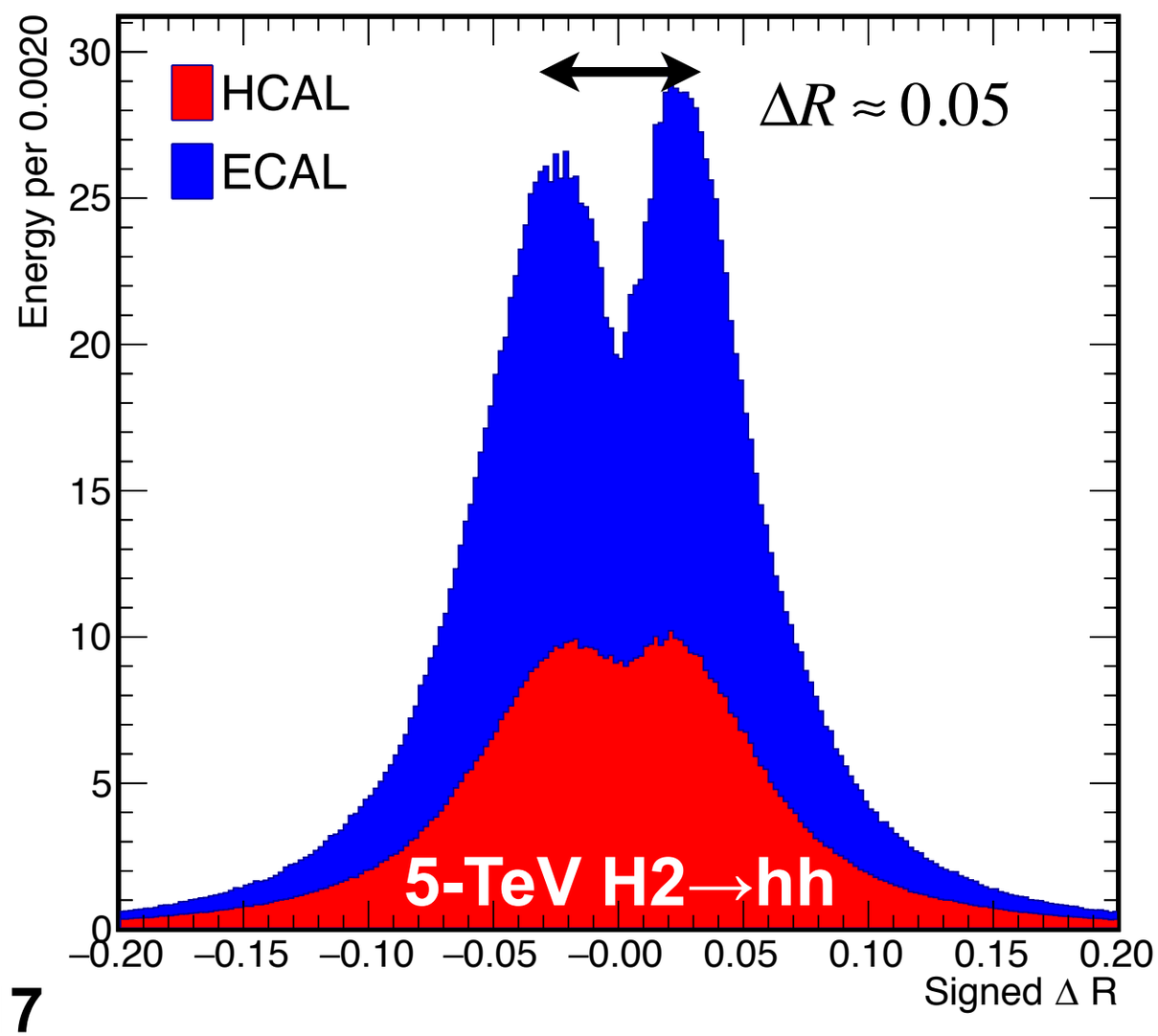


- **calorimeter hit**

signed ΔR

$$\equiv \frac{\overrightarrow{D_{b\bar{b}}} \bullet \overrightarrow{D_{h-calo}}}{\left|\overrightarrow{D_{b\bar{b}}}\right|}$$





Conclusion

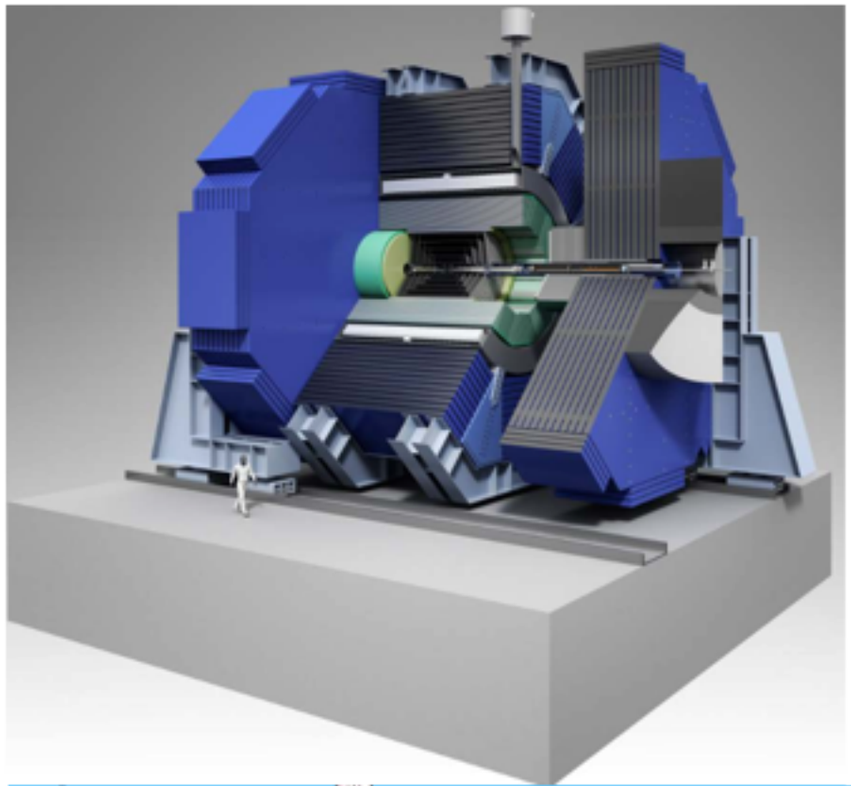
- We present a first study of the boosted W-jets and Higgs-jets with the SiFCC detector using full GEANT4 simulation
  - Response and resolution of single particles follow the expected performance of the designed detector
  - Resolution of calorimeter jet energy has a very big sampling term, will continue the study using lower-energy jets from 100 GeV upwards
  - The high granularity of the calorimeter shows the possibility to separate energy clusters within a jet from a 2.5-5 TeV boosted boson
- We are geared towards the study of high-level variables, such as jet substructures, jet grooming…
- Collaborators are always welcome!

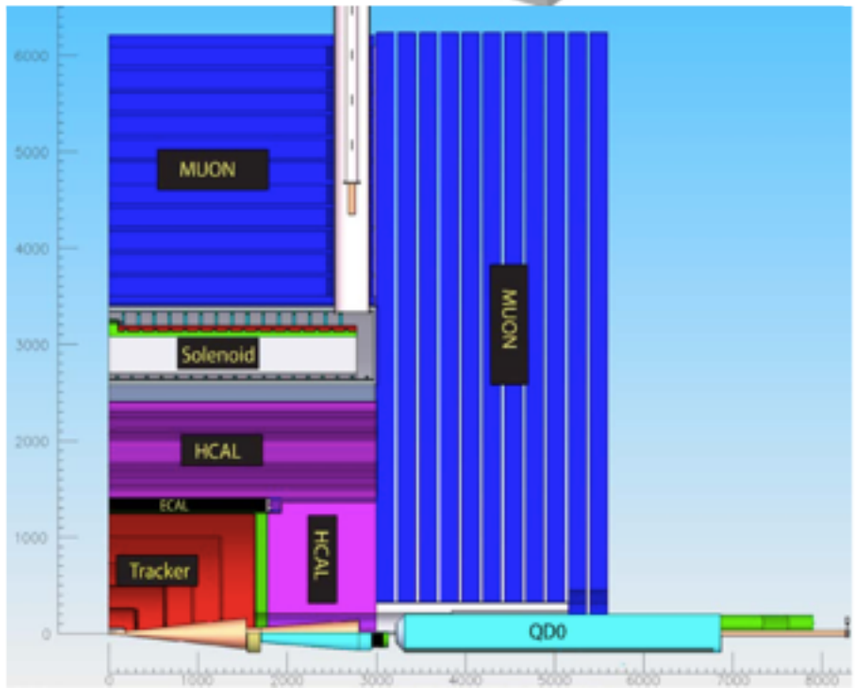
Talk:Sergei Chekanov, “Monte Carlo simulations for future collider studies”
Poster: Nhan Tran, “Detectors for Superboosted Jet Substructure at Future Circular Colliders”
Poster: Sourav Sen, ”Detectors for Superboosted tau-leptons at Future Circular Colliders"

Backup Slides

SiD detector for ILC

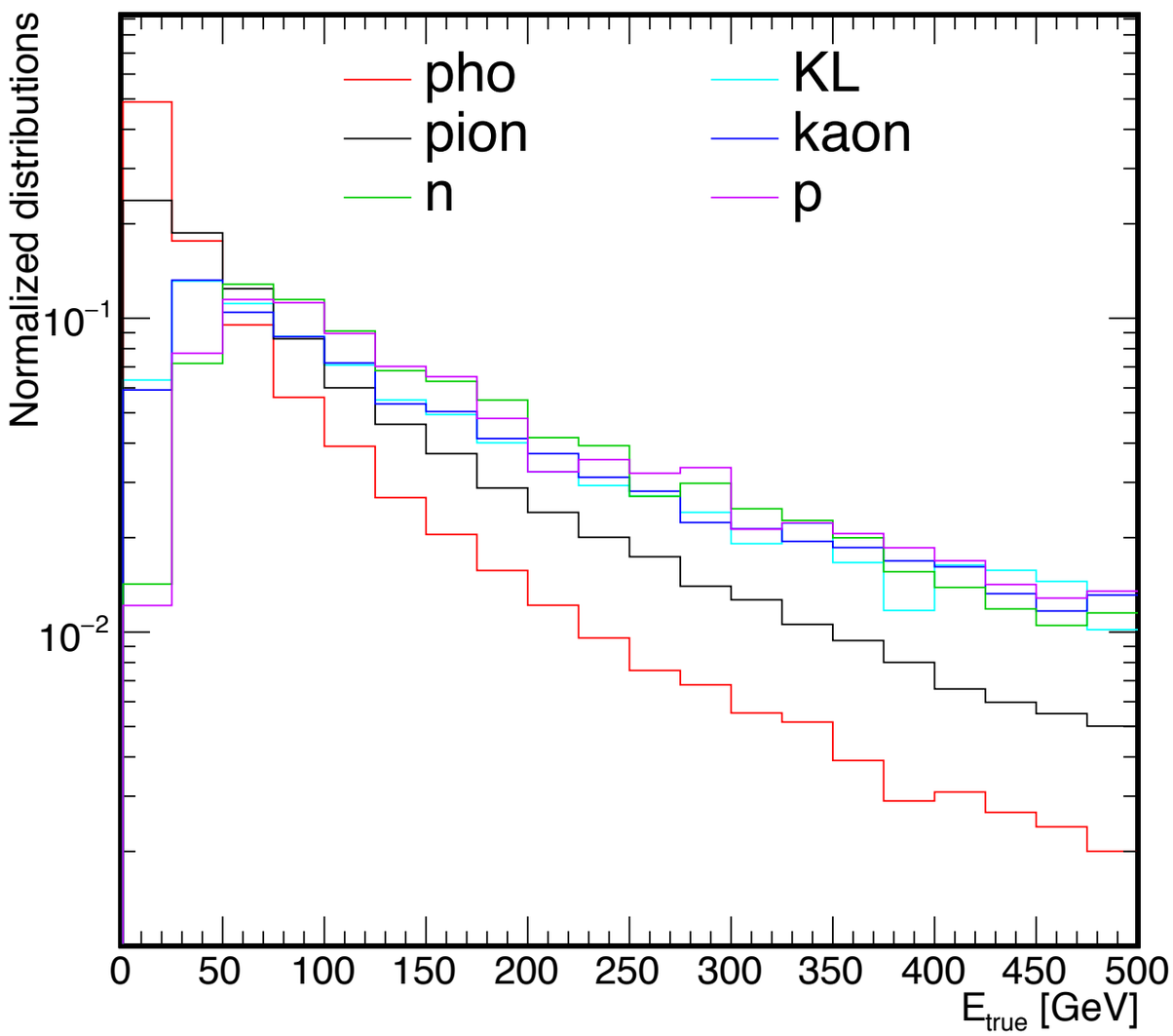
- Multi-purpose detector for the ILC
- The key characteristics of the SiD detector:
  - 5 Tesla solenoid
  - Silicon tracker: 50 um readout pitch
  - ECAL: (0.35 cm cell size, W / silicon)
  - HCAL:
    - 1x1 cm cell size (RPC)
    - 40 layers for barrel (HCAL) ~4.5 λ_I
- Optimized for particle-flow algorithms (PFA)
- Fully configurable using SLIC software





Energy Distributions Of Particles In A Jet

10-TeV Z'→WW→qq'qq'



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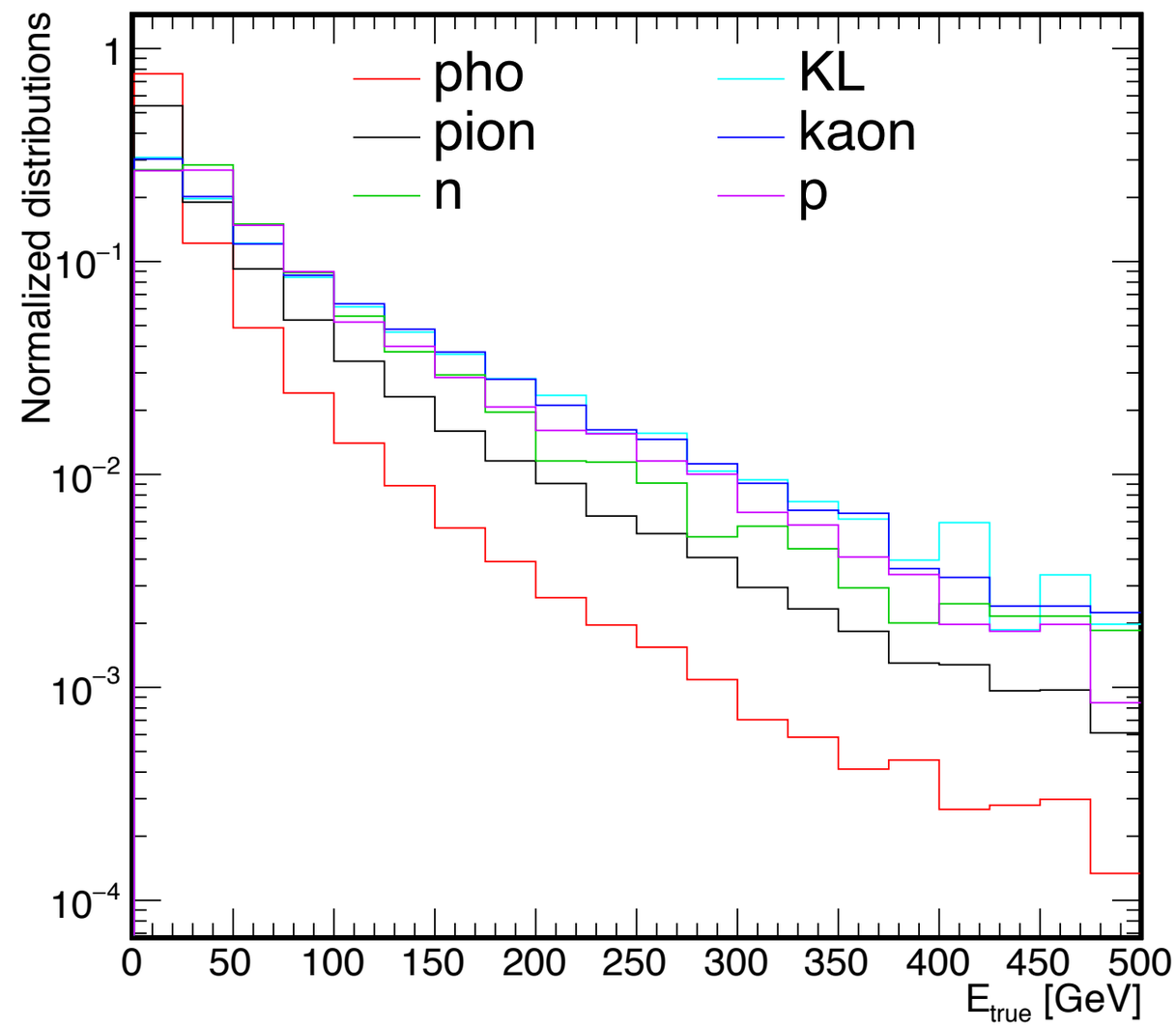

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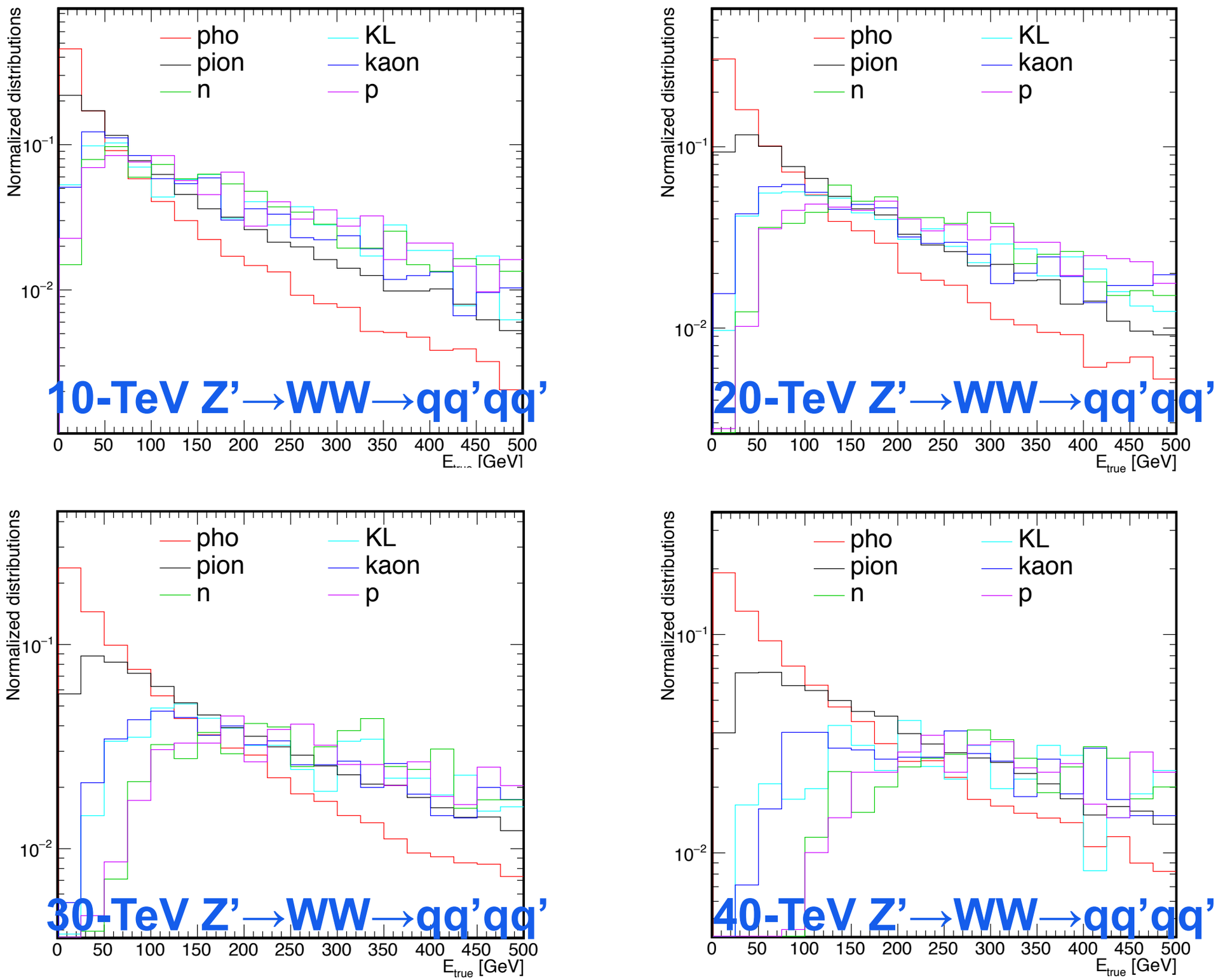

Single-Photon Response Resolution