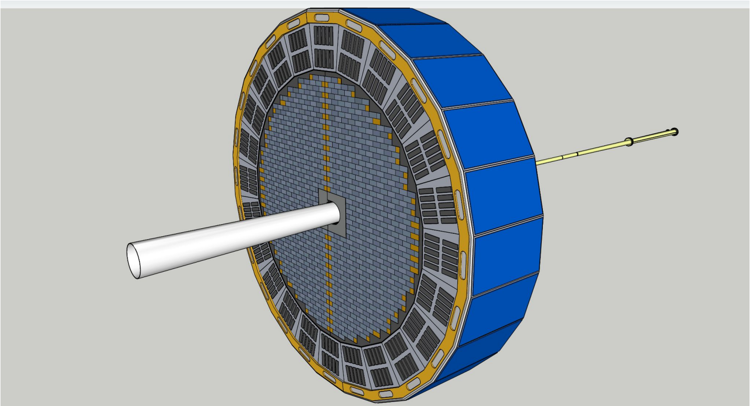
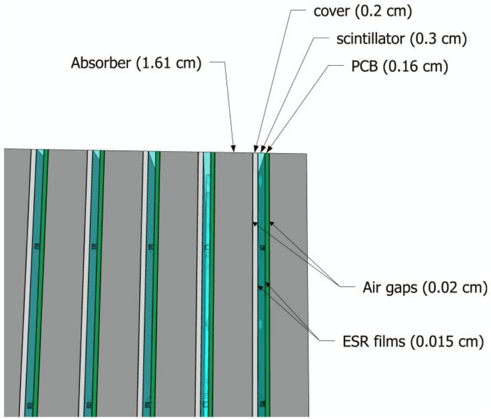
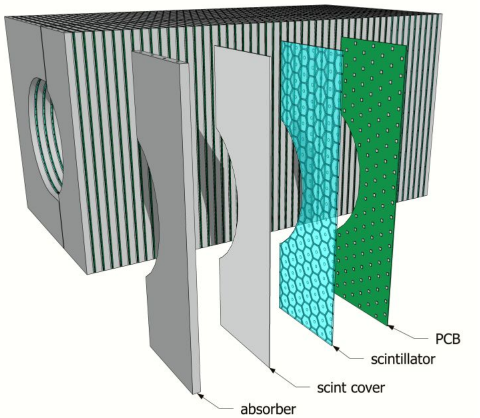
Performance and Validation of HG-CALI Simulation







Bishnu Karki

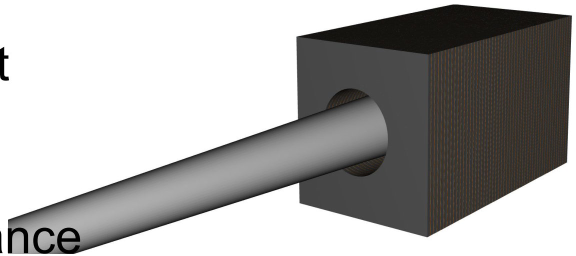
UC RIVERSIDE

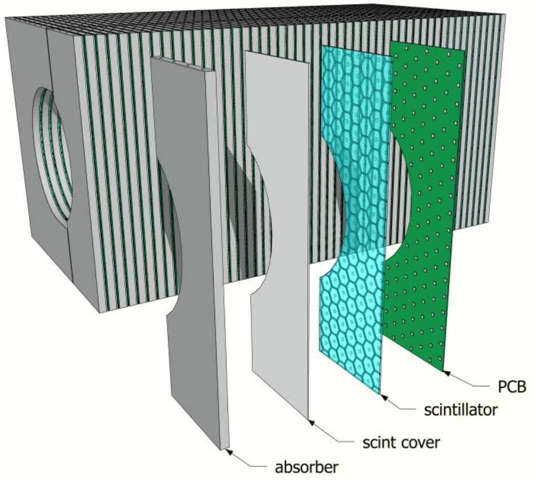
CALIFORNIA EIC CONSORTIUM

07/19/2022

Goals

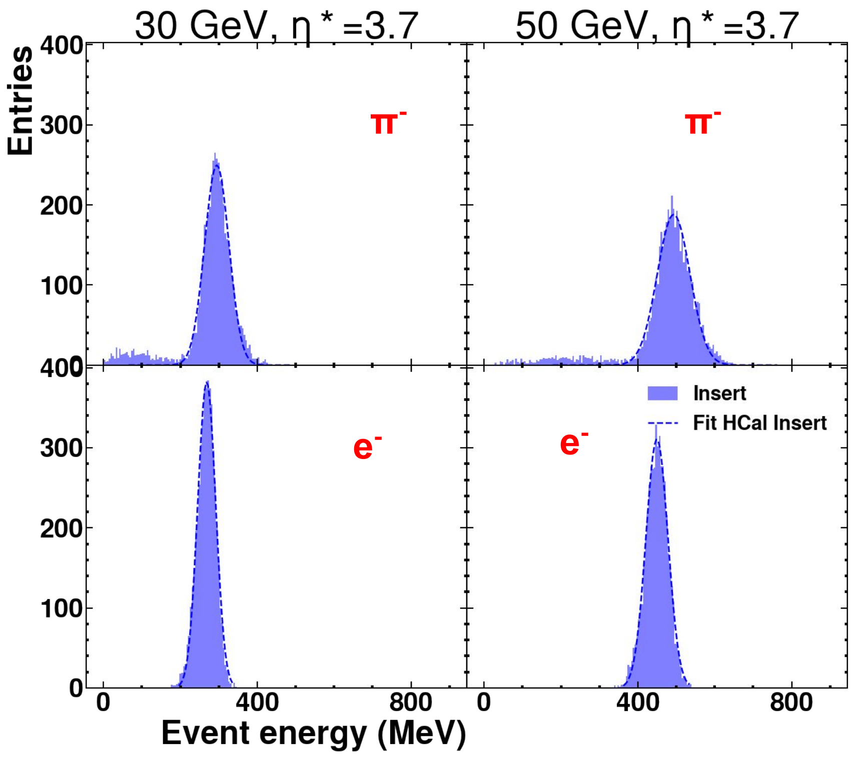
- Validate G4, digitization reconstruction, selection against test-beam data
- Ultimately, we want to yield a credible baseline performance to be compared with AI reconstruction & codesign
- In this presentation, I will focus on energy response and resolution for both electrons and pions
- In the future, we'll include shower-shape and time information





Performance

Shower energy distribution



Cuts:

- E > 0.1 x E $_{MIP}$ (E_{MIP} = 0.8 MeV)
- time < 150 ns

Reconstruction strategy:

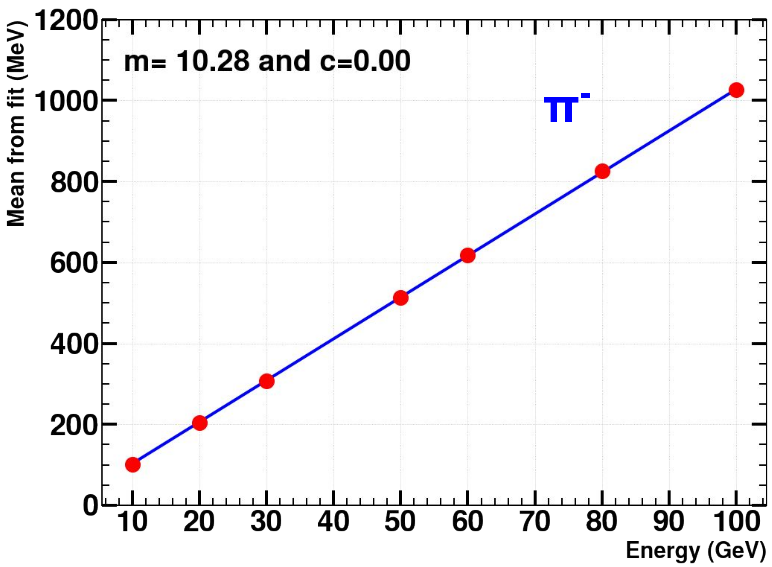
Sum of all hits passing the threshold (“strawman”)

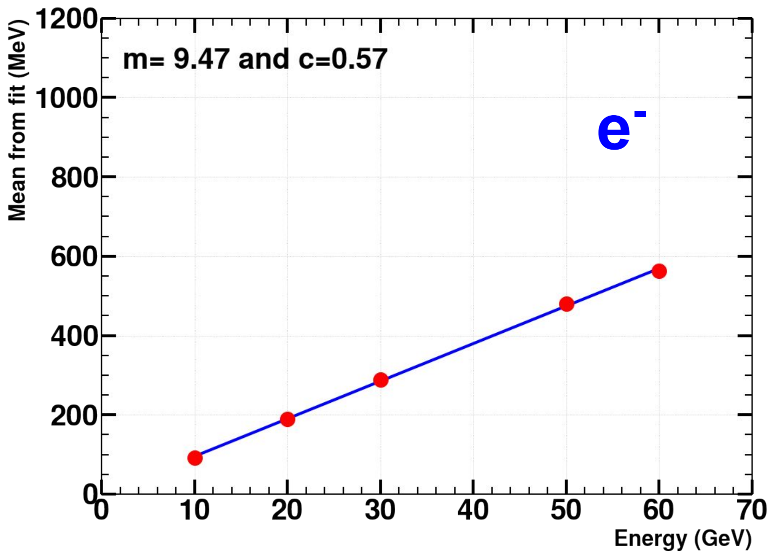
$$\text{Resolution} = \frac{\sigma}{\text{mean (E)}}$$

- Mostly Gaussian response even at high rapidity (η* = 3.7)
- EM core of hadronic showers are well contained due to short X_0 in W

Performance

Linearity



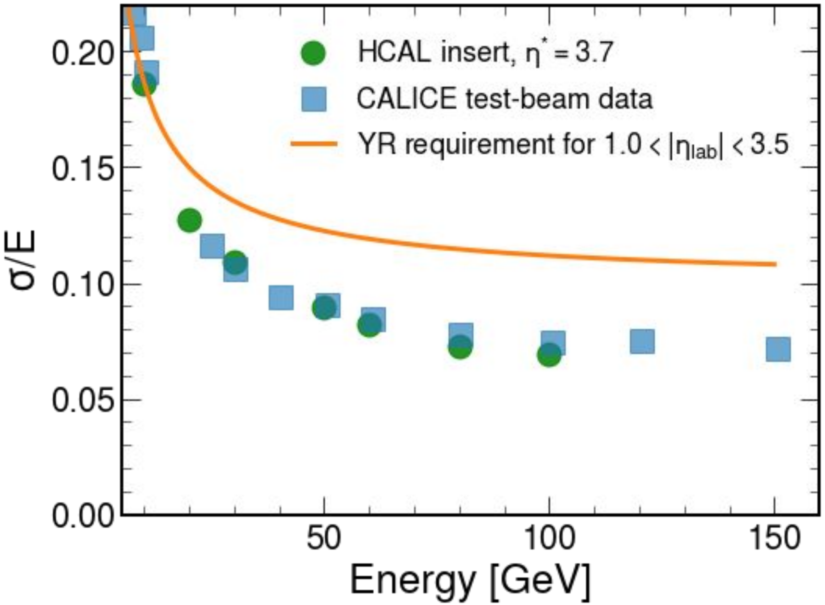


Linear fit: y=mx +c

Very linear for pions and electrons upto relevant energy range

Performance

Resolution (π^-)



- Meets YR requirement on resolution even beyond required acceptance.
  (event with most rudimentary reconstruction algorithm; much more is yet to come from our AI project)

- With credibility given similarity with CALICE W-AHCAL data (reproduced that separately as well)

Validation of Simulation with test-beam data

Validation

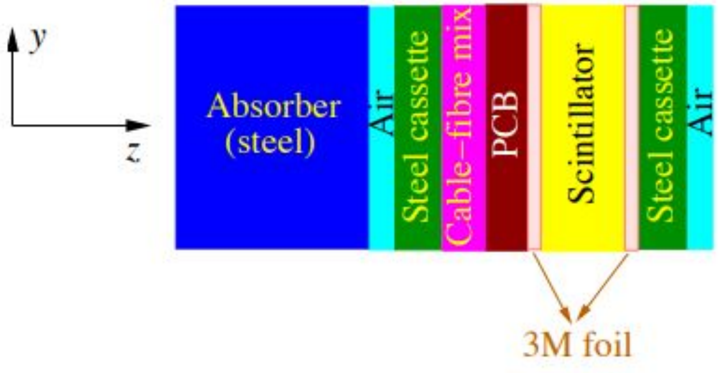
Adopting CALICE HCAL Setup in our Simulation

C Adloff *et al* 2014 *JINST* 9 P07022

T-AHCAL

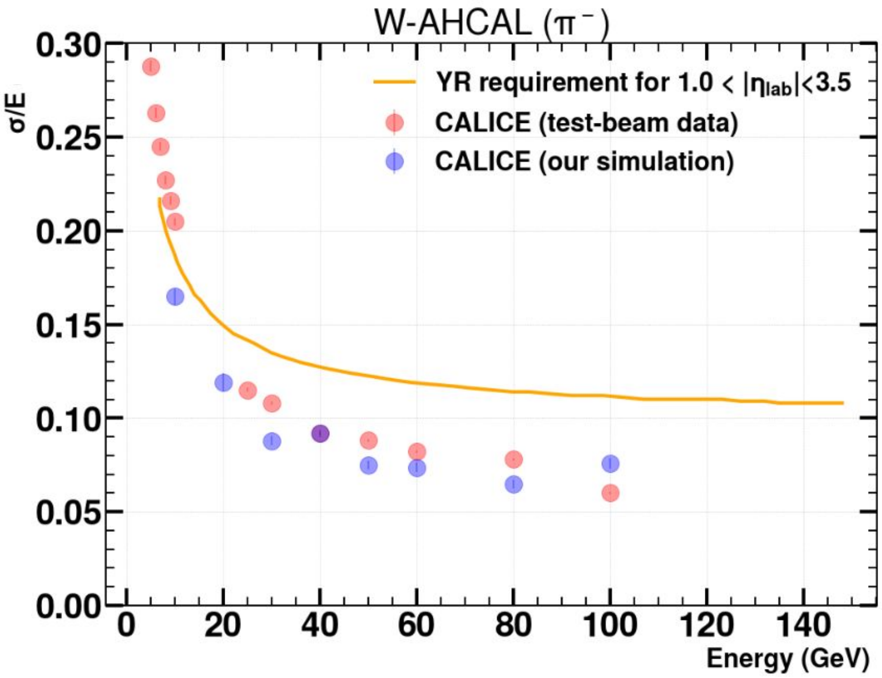
Component	d [mm]
Steel Support	0.5
Tungsten	10
Air	1.25
Steel Cassette	2.0
Cable Mix	1.5
PCB	1.0
Scintillator	5.0
Steel Cassette	2.0
Air	1.25
Total	24.5

Transverse dimensions:72 x 72 cm^2
Longitudinal dimension: 90 cm



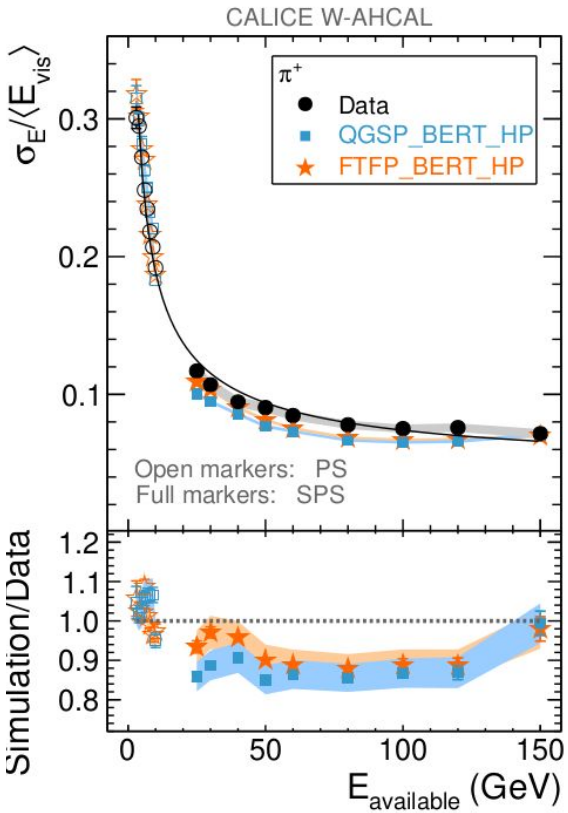
- DD4HEP framework for geometry
- FPFP_BERT_HP list of G4 for particle shower
- Adopted CALICE setup for both Tungsten and steel prototype
- Compare the CALICE test-beam data

Validation
T-HCAL Resolution

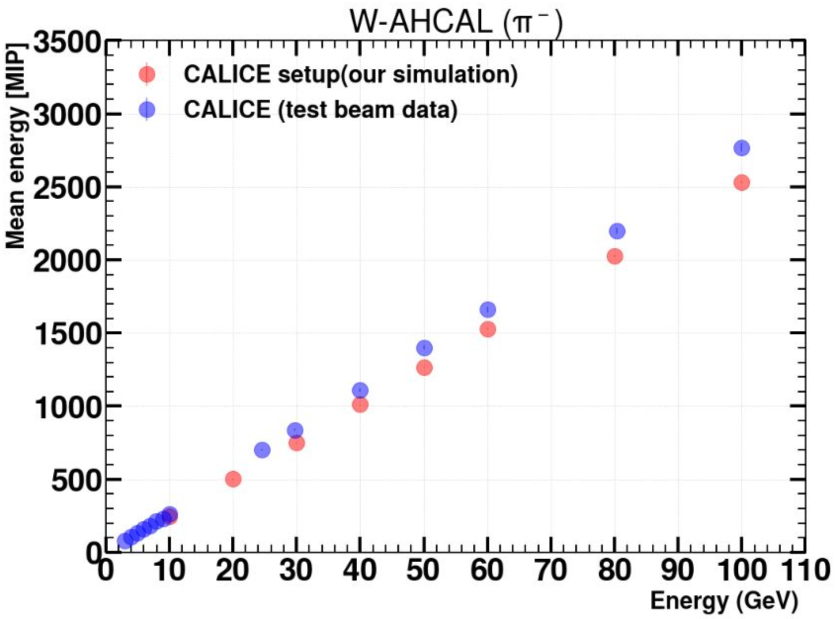


2014 JINST 9 P01004

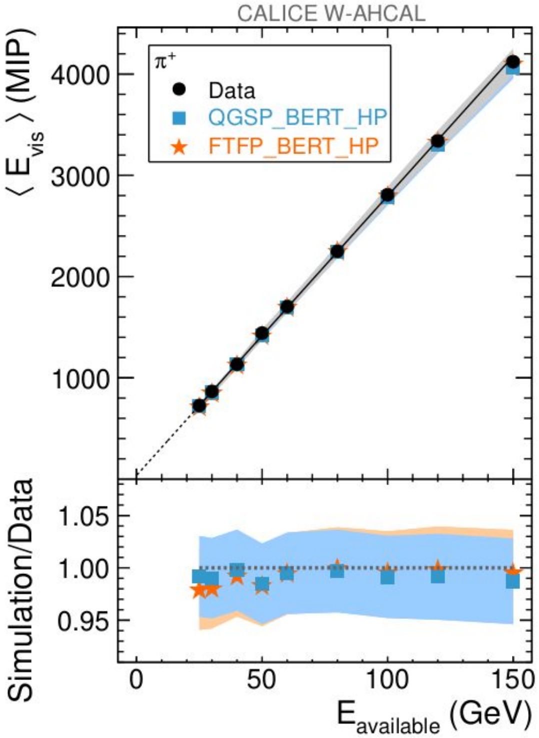
2015 JINST 10 P12006



Average energy deposition



[2015 JINST 10 P12006]

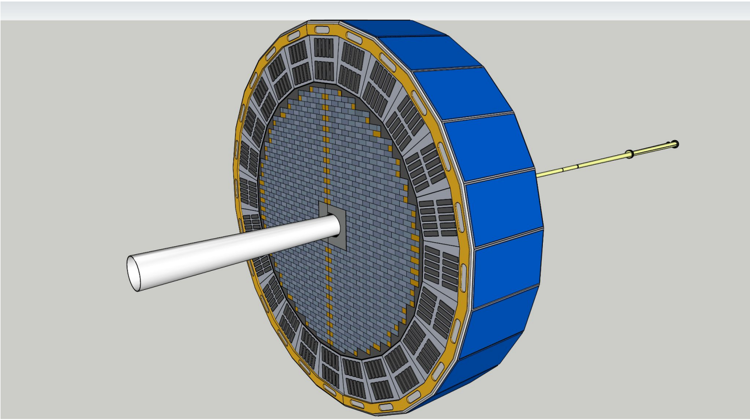


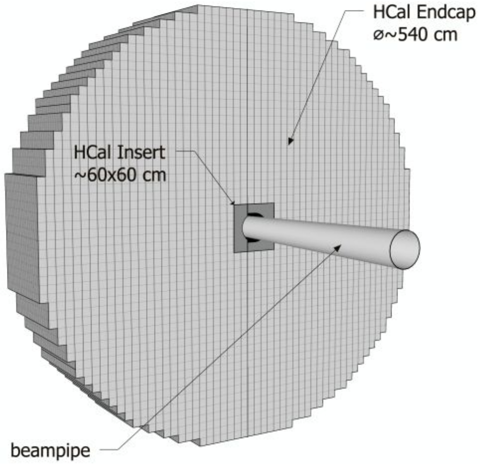
- Similar study adopting CALICE Steel HCal
- Able to reproduce both linearity and resolution within 10% as reported by CALICE using test beam data

Validation with HCAL

Validate Fe/Sc calorimeters simulation in DD4Hep against test beam data

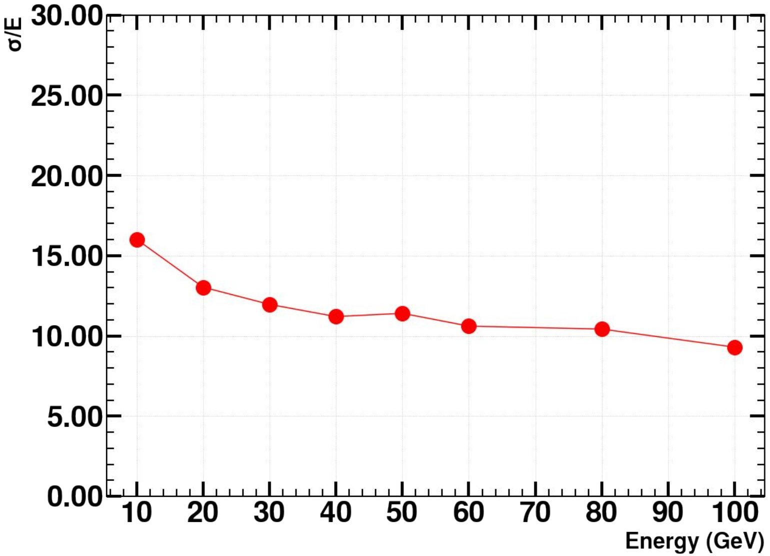
This is an extension of our validation effort for insert simulation against CALICE data

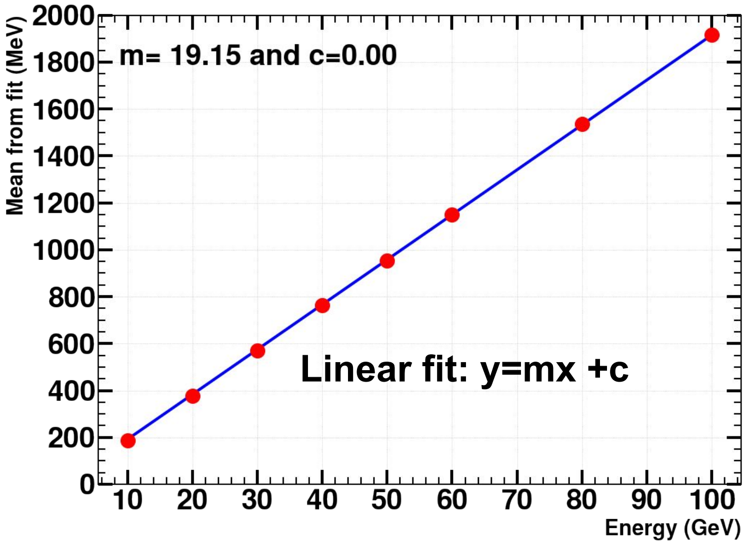




Fe/Sc HCAL (STAR / ATHENA design)
Resolution and mean energy

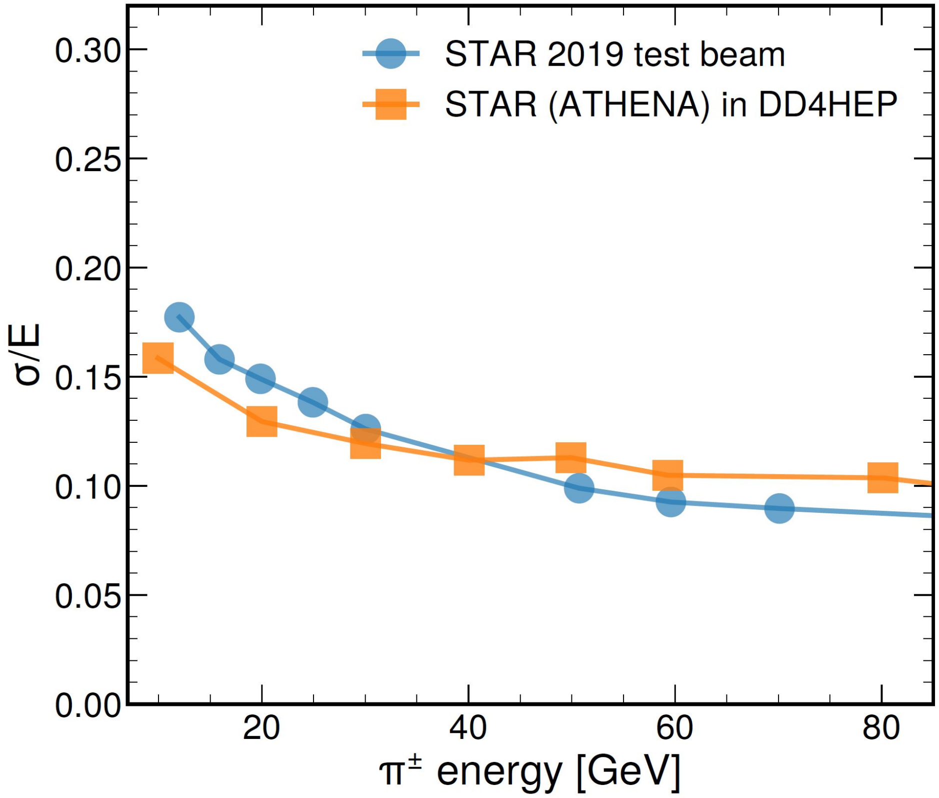
- DD4HEP framework for geometry
- Absorber (Fe) thickness=20 mm
- Scintillator thickness=3 mm
- π^- fired at 30 deg





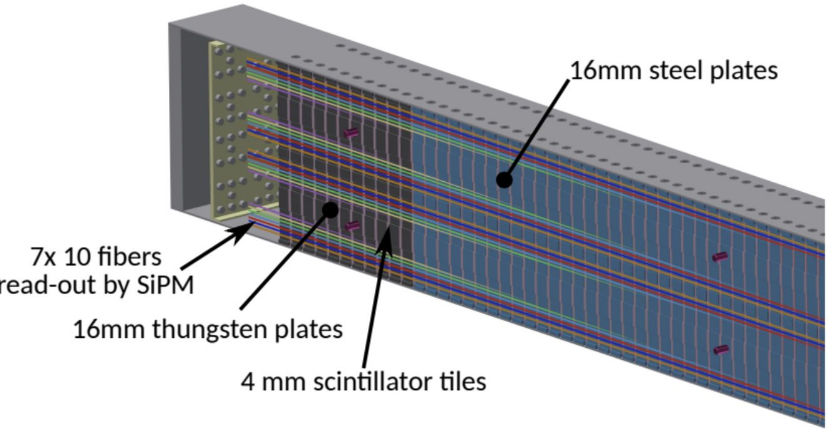
Linear Energy response

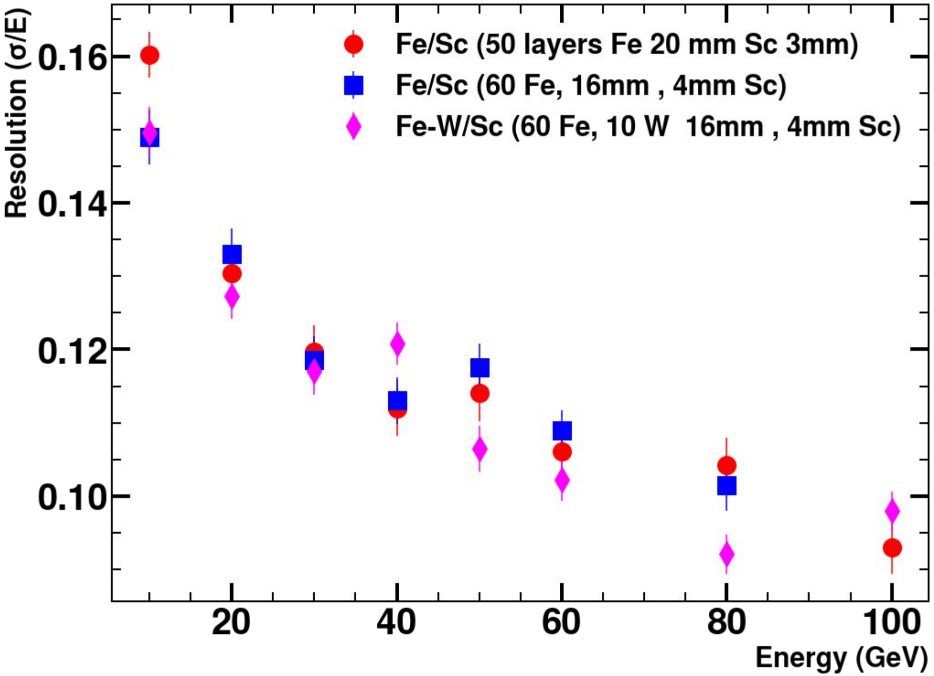
Validation of STAR (ATHENA) simulation in DD4Hep



Fair agreement with STAR test-beam data

ECCE Design in DD4Hep

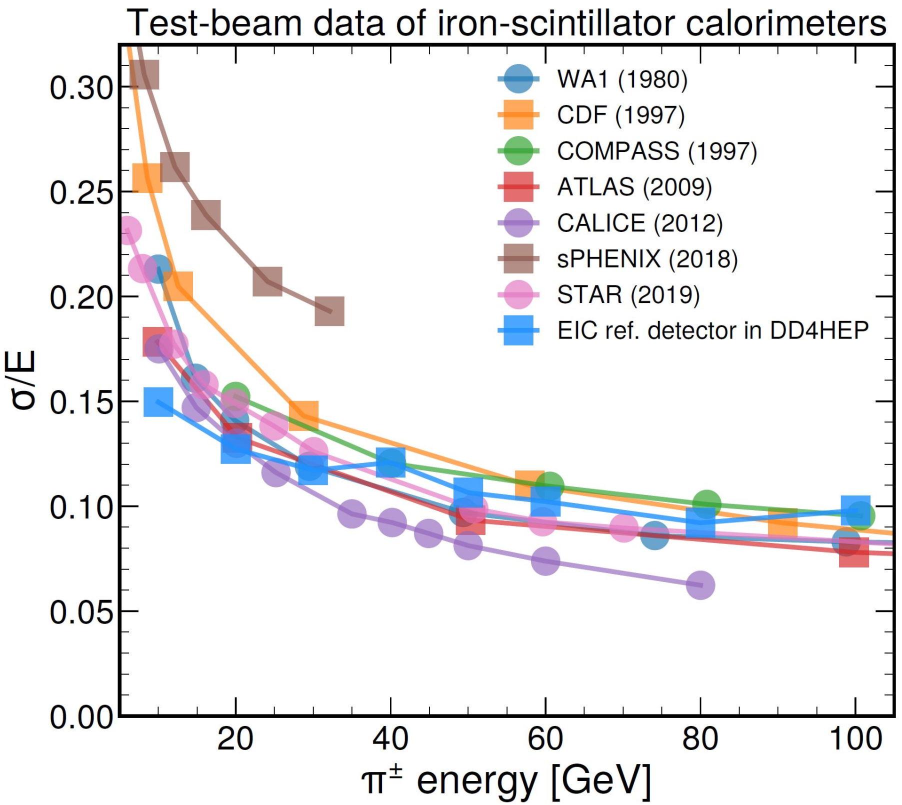




- Implemented a version of the ECCE HCAL in DD4Hep as well.
  Sampling structure but not WLS fiber or SiPM details or varied granularity

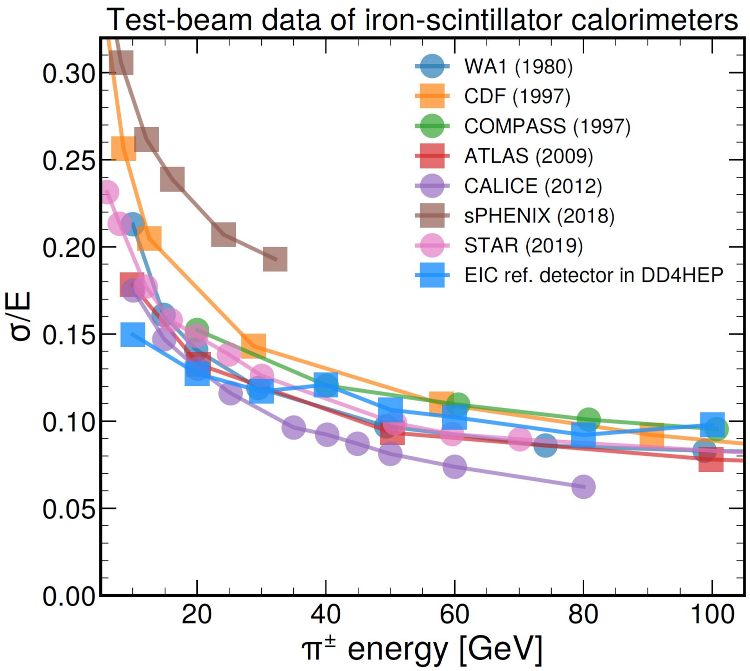
https://github.com/rymilton/eic_endcap_insert/blob/main/compact/hcal_ECCE.xml

Comparison of EIC reference (ECCE) to other Fe/Sc calorimeters

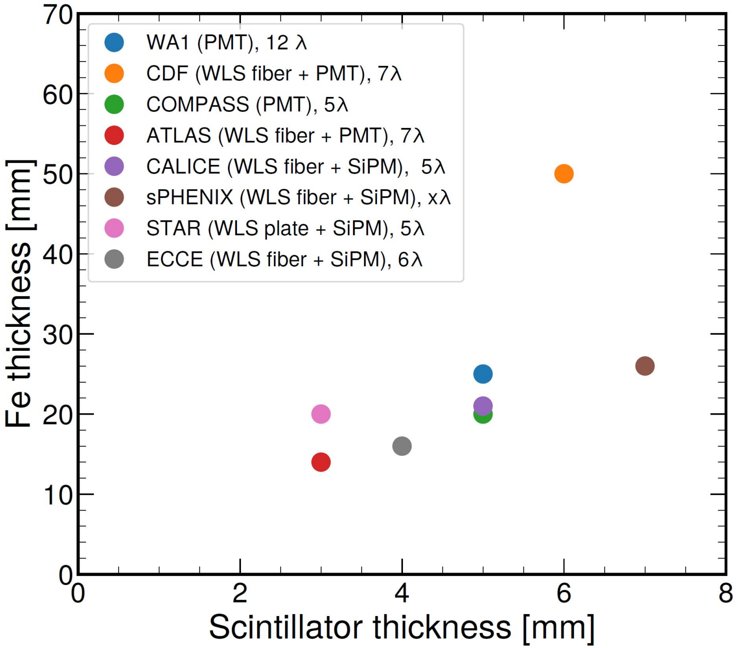


DD4Hep simulation results are compatible with expectation from previous experiments

Resolution study of Fe/Sc calorimeters



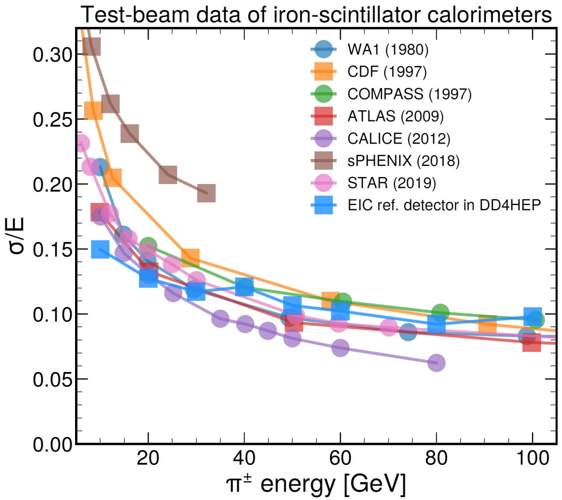
Comparison of parameters used in other Fe/Sc calorimeters

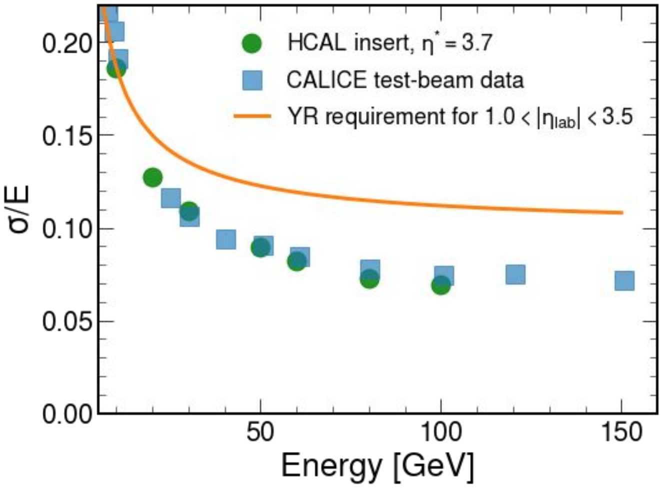


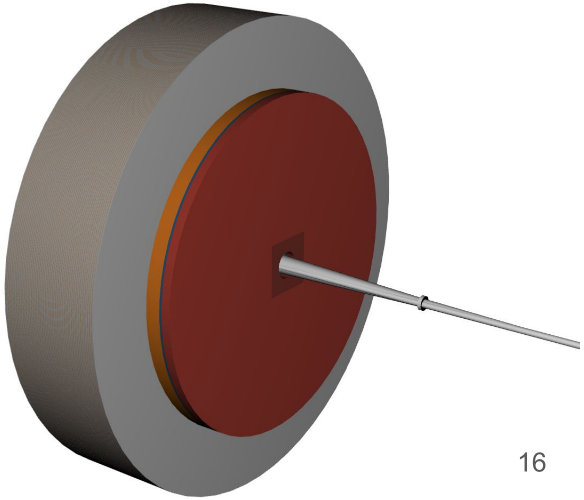
- Various possible combinations of readout have been tried over time. It seems that resulting changes in resolution are modest at best. Expected as resolution is not driven by photo-statistics but sampling fluctuations and total thickness.
- We think that refining simulation to include the readout details are unlikely to change results much, so it does not seem a good investment of time

Summary

- We have established a “strawman” baseline reconstruction with high-granularity insert
- Strawman is a fair representation because design is compensated
- GNN should improve performance
- DD4Hep simulation of HCAL and HCAL Insert are validated against data and thus “realistic”
- DD4Hep model for all forward calorimeter subsystems (ECAL, ECAL insert + HCAL + HCAL insert) is complete and ready to use for physics simulations



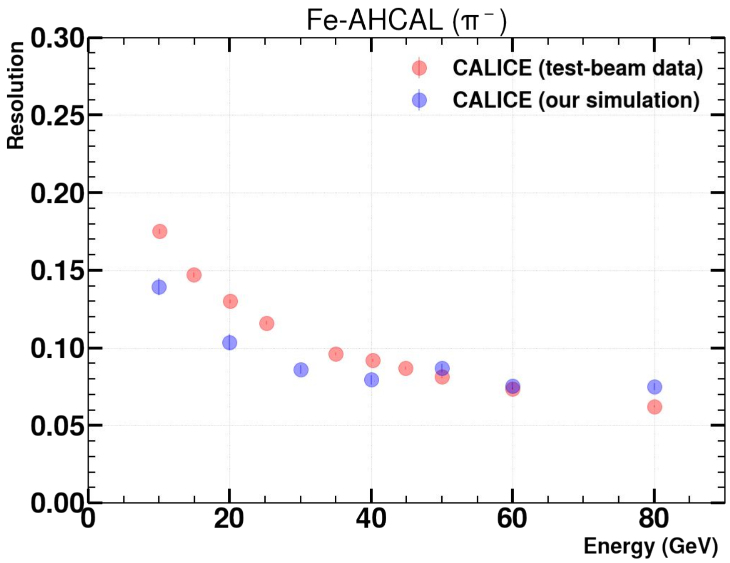




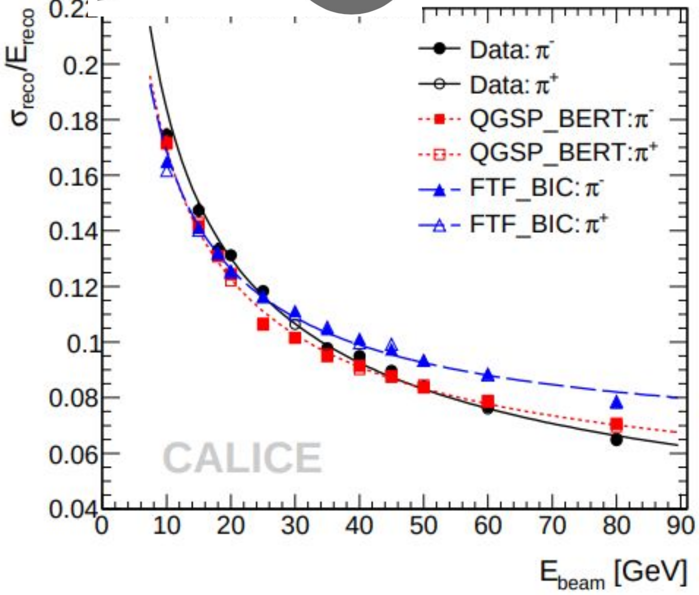
Backup

Validation

Resolution (π^-)

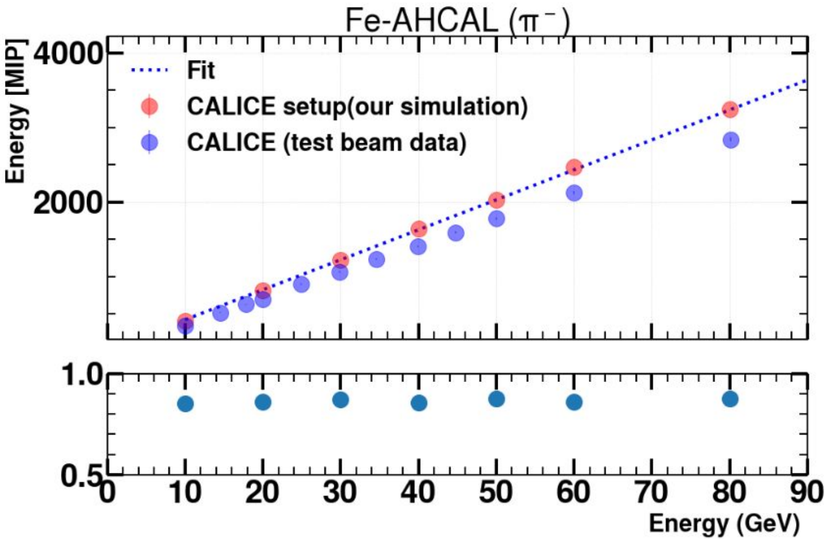


[2012 JINST 7 P09017](#)

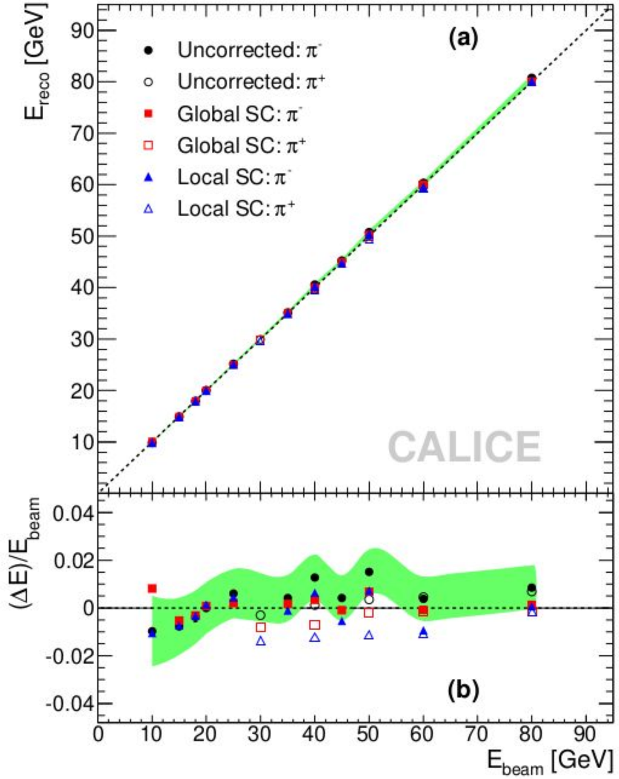


Adopting CALICE setup in our simulation yields similar resolution as reported by CALICE JINST 7 P09017

Linearity for Fe-AHCAL



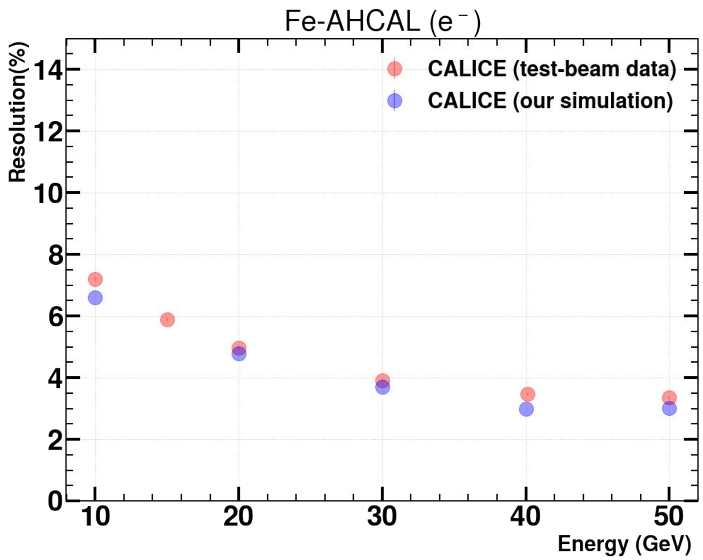
2012 JINST 7 P09017

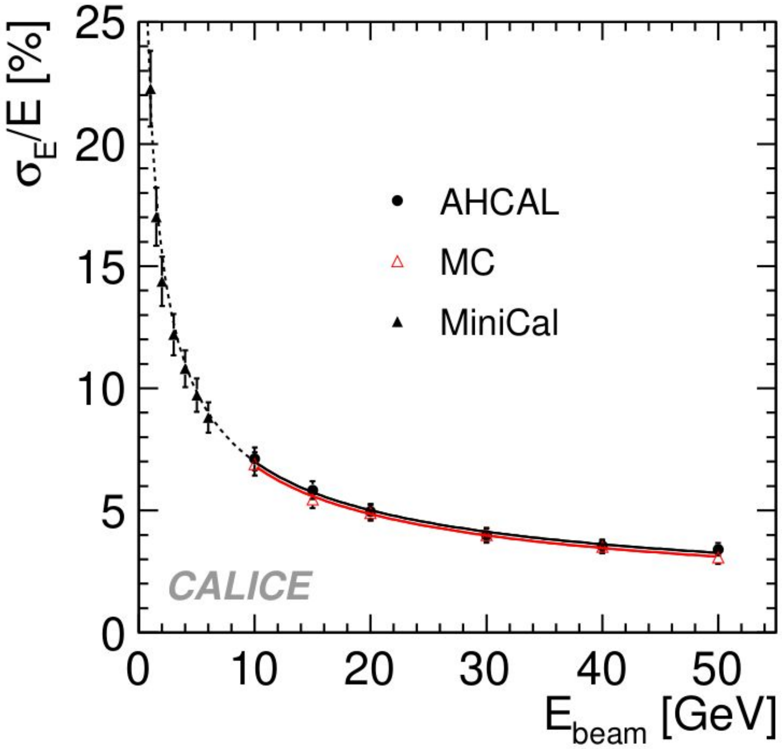


Similar test performed with W-AHCAL yielded similar agreement

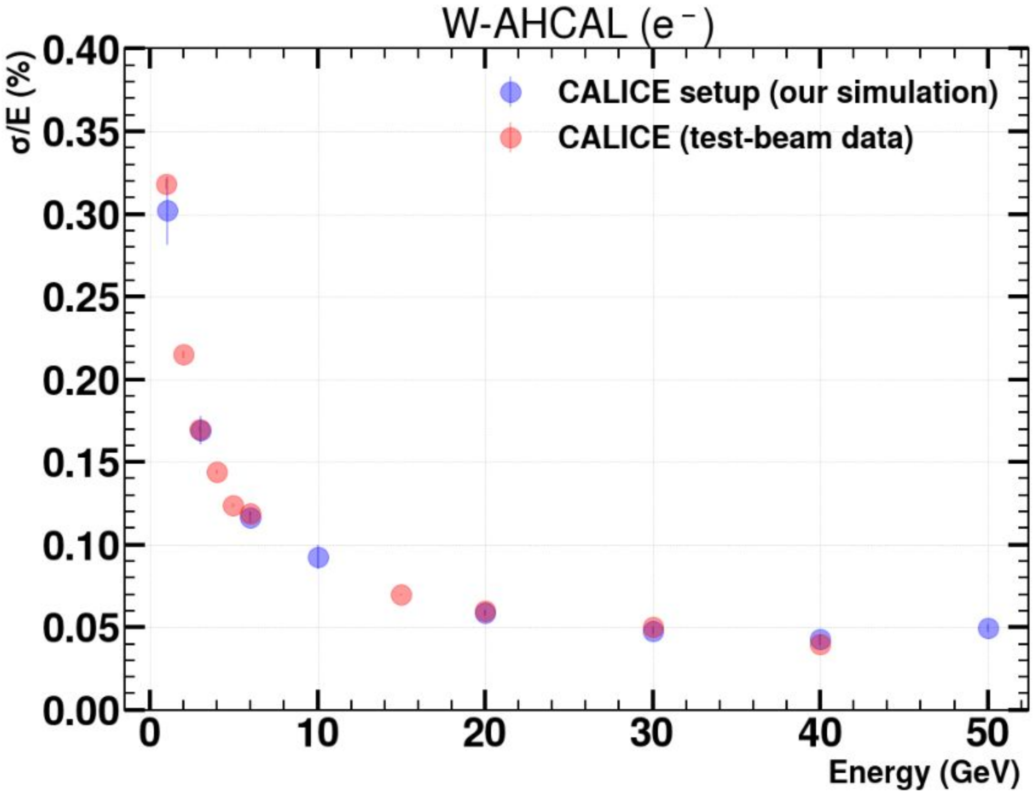
CALICE Fe-AHCAL
Resolution (e^-)

[2011 *JINST* 6 P04003]

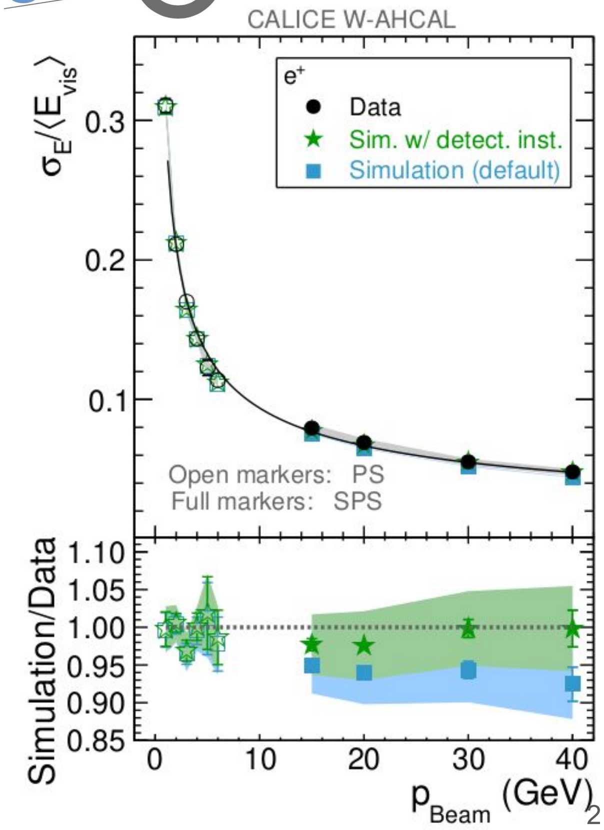




T-AHCAL Resolution



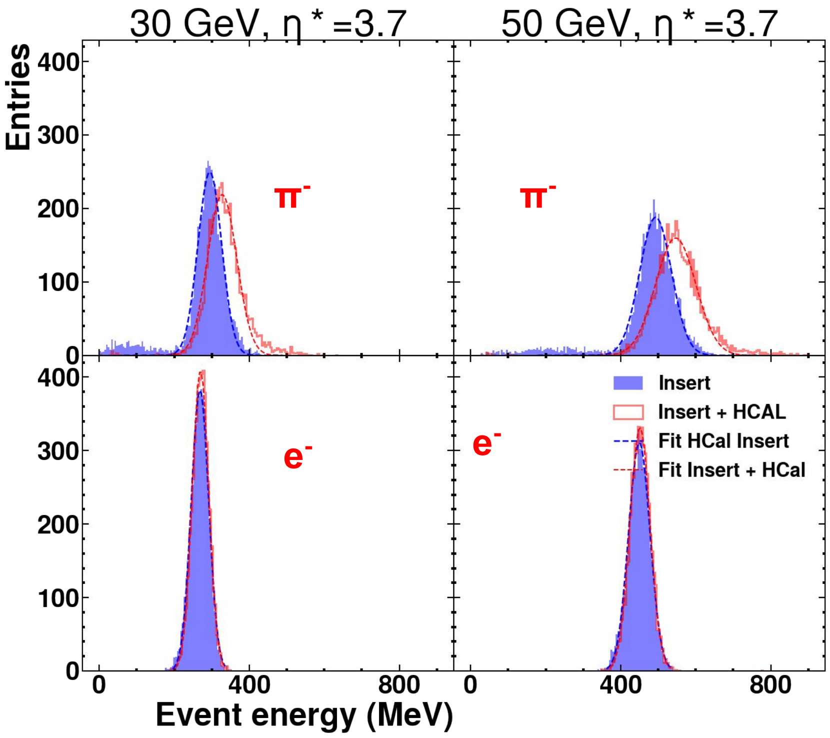
[2015 JINST 10 P12006]



Shower energy distribution (HCAL + HCAL Insert)

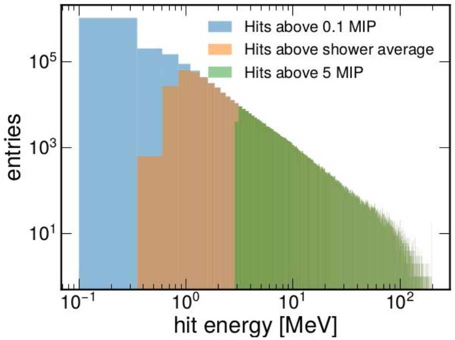
Reconstruction

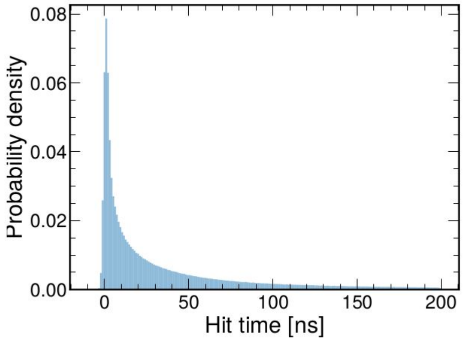
Sum of energy of HCAL insert hits + energy of HCAL hits (passing selection cut)

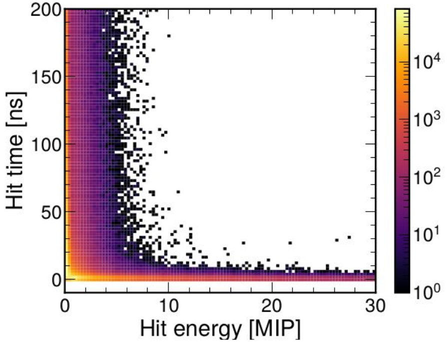


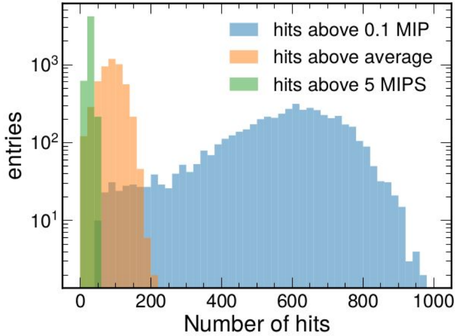
- Left tail is recovered by adding HCAL. No any significant leakage through the beam pipe hole
- Neutrons traverse hole and are measured, rather than being lost in small solid angle of beampipe exit
- Next steps: quantify this for a variety of angles and energies

Reconstructed hit energy and time distributions









Cuts:

- E> 0.1 x MIP (MIP = 0.6 MeV)
- t< 200 ns

Reconstruction strategy:

Sum of all hits passing the threshold ("strawman")