Particle Shower Development in a W Scintillator HCAL

1-10 GeV/c Momentum Range

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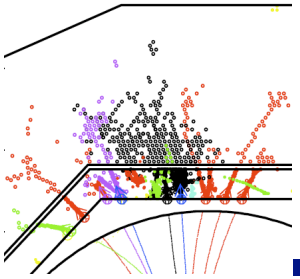
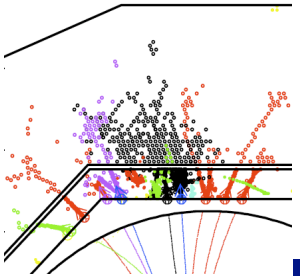


Outline

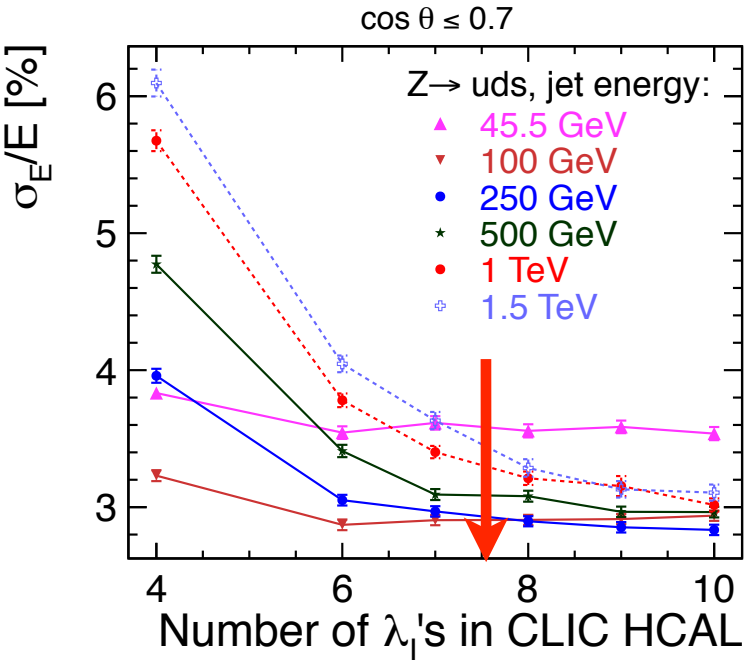
- Motivation
- Installation
- Calibration
- Validation
- Compensation

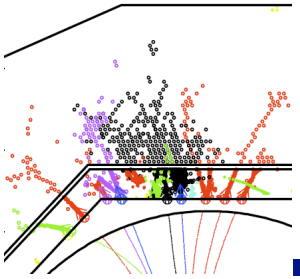
Analysis effort by CERN group, led by A.Lucaci, with support from DESY



Why tungsten?

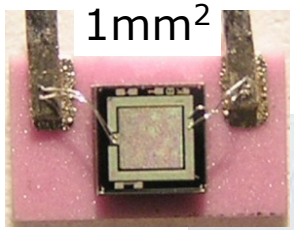
- For jet energies in multi-TeV e+e- collisions, leakage becomes important
- Particle flow calorimeters need to fit inside the solenoid
- Technical and cost limitations for coil: dense absorber like W
- Need to validate simulation
  - larger neutron component: slower response than steel
- Acquire construction experience with tungsten
- Because we can



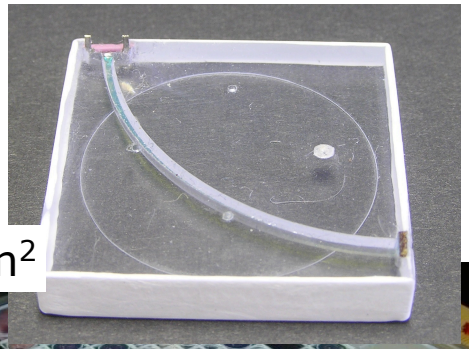


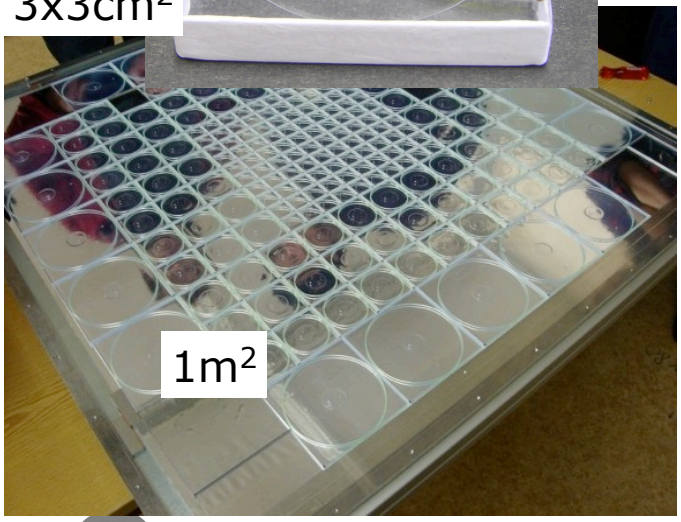
W scintillator HCAL prototype

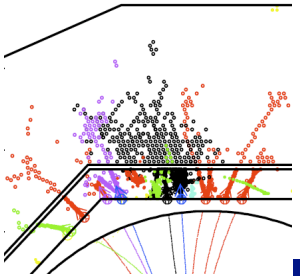
- Existing CALICE scintillator HCAL active layers
- New tungsten absorber stack: 30 - 38 layers, 1cm thick



SiPM

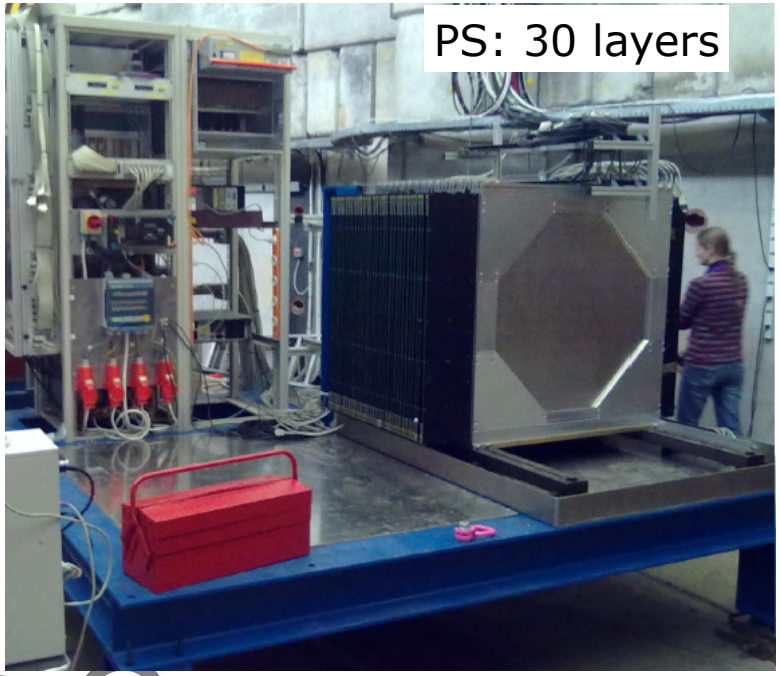


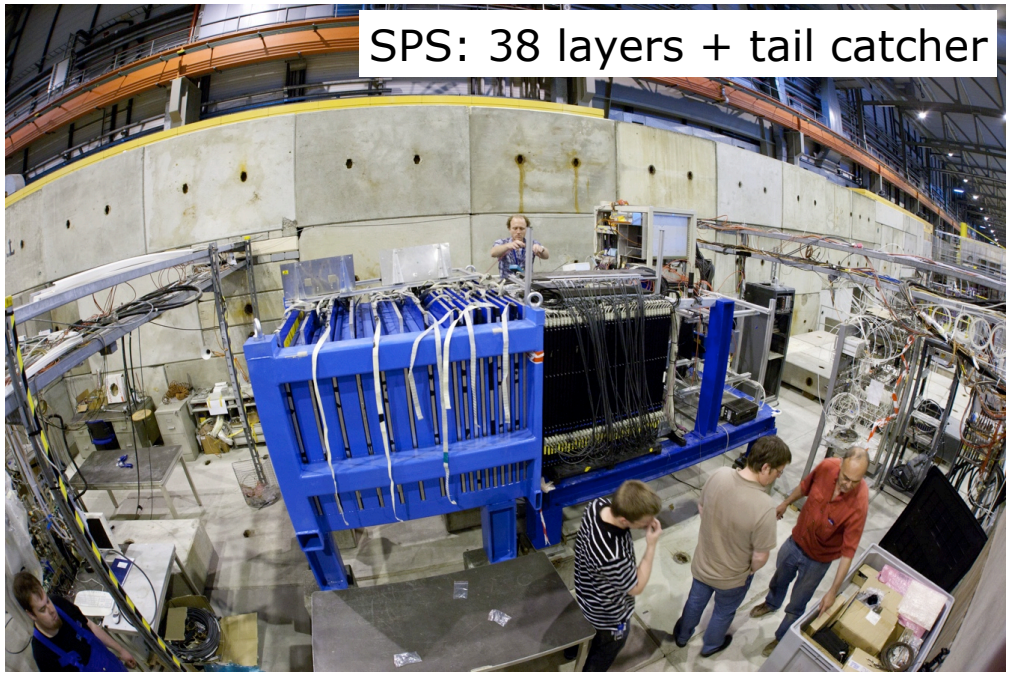


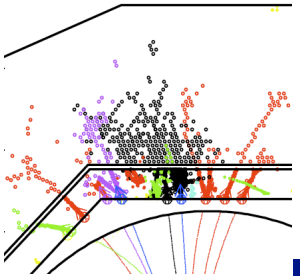


Test beam installations

- 2010: PS, 1 - 10 GeV (this talk)
- 2011: SPS, 10 - 300 GeV (analysis being refined)
- 2012: gaseous DHCAL (J.Repond's talk)
- T3B: Fast timing (F. Simon's talk)



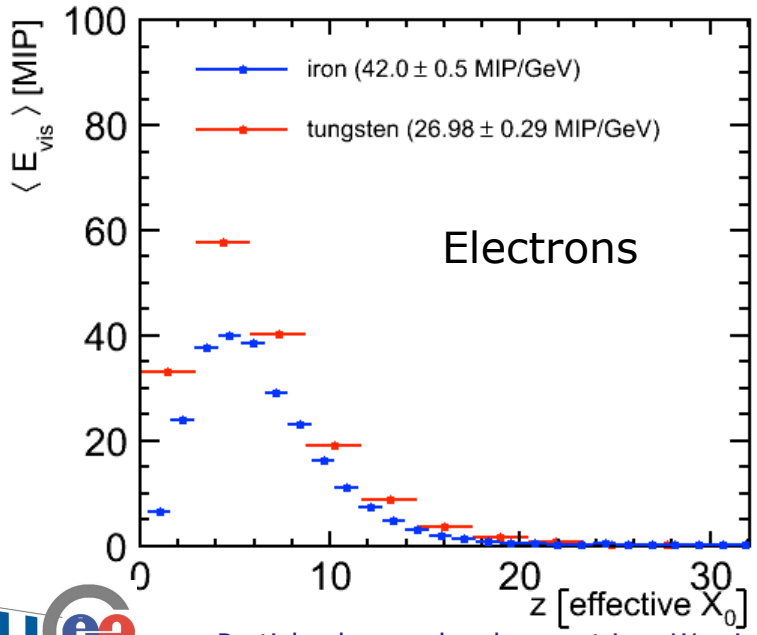




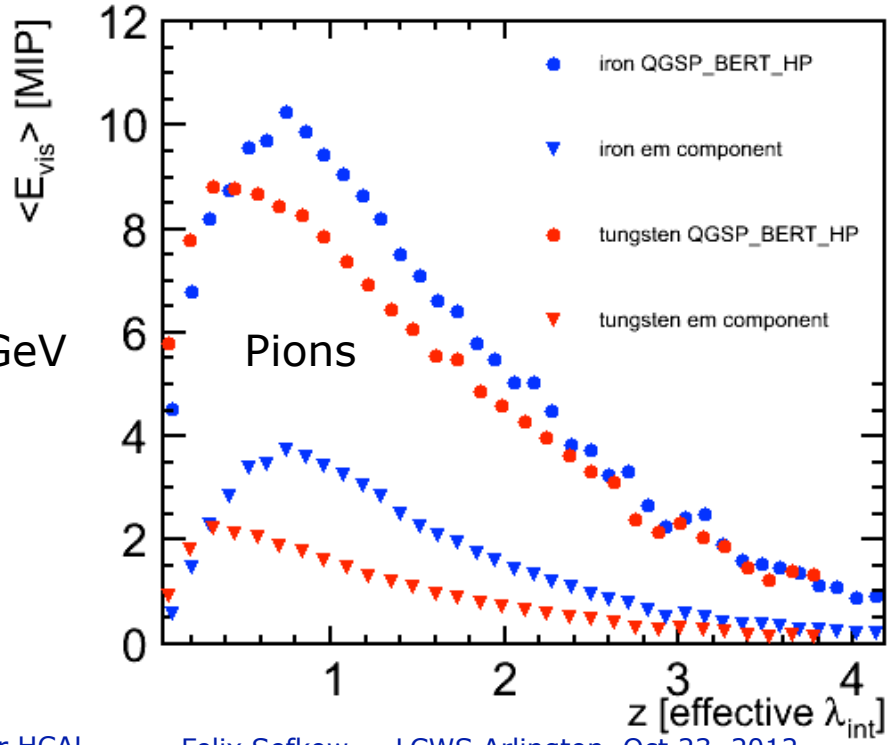
Tungsten vs steel

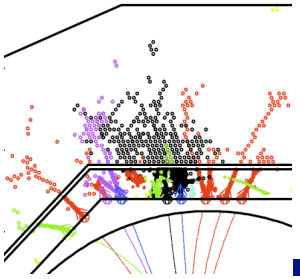
- Electromagnetic part of shower more compactified than hadronic
- Similar sampling in terms of hadronic interaction length - reduced sampling in terms of radiation length

	λ_I	X_0
W	10 cm	0.4 cm
Fe	16.8 cm	1.8 cm



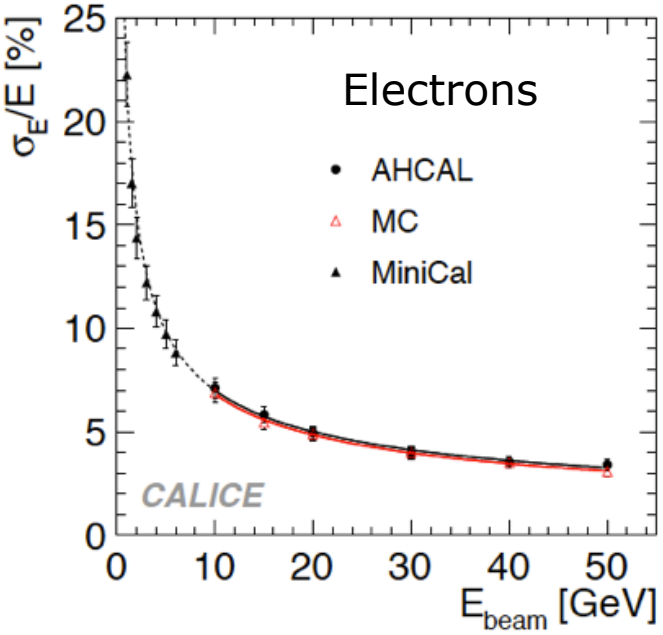
6 GeV





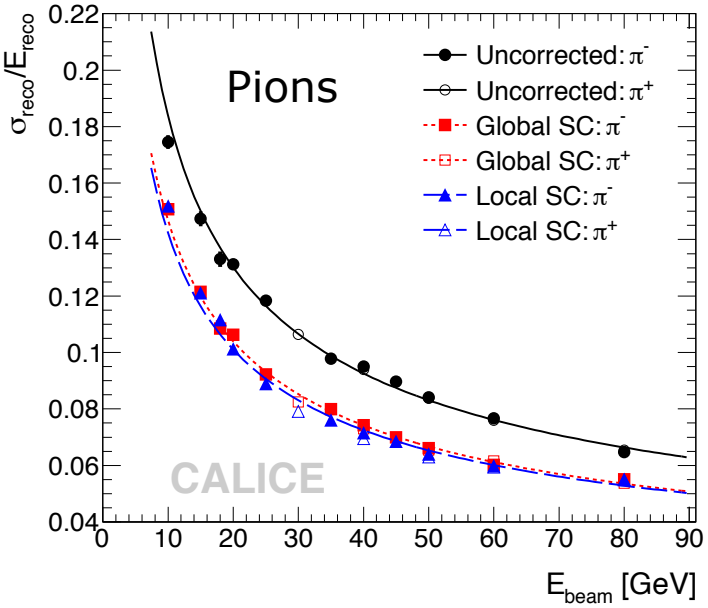
Performance with steel

- Electrons: Validation of calibration and detector simulation
- Pions: establish resolution and compare with simulation
- Excellent performance published, challenge for W analysis



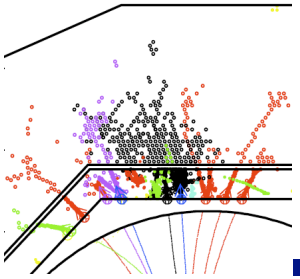
$\sigma/E = 21.9\%/\sqrt{E} \oplus 1\% \oplus 0.058/E$

JINST 6, P04003 (2011)



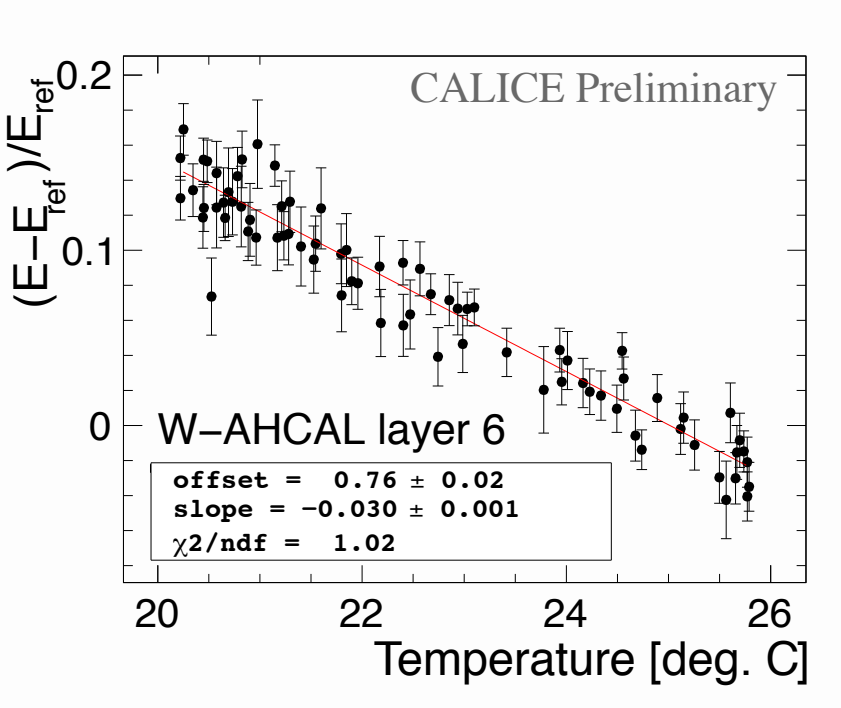
$\sigma/E = 45.1\%/\sqrt{E} \oplus 1.7\% \oplus 0.18/E$

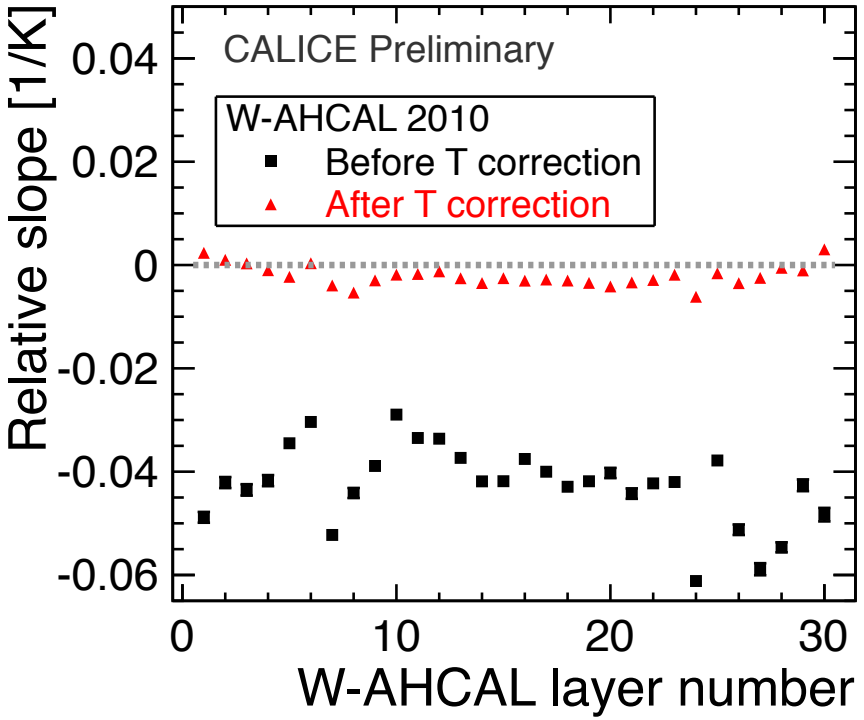
JINST 7, P00917 (2012)

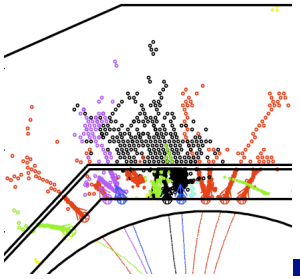


Calibration

- Tungsten runs suffered from large temperature variations
- After layer-wise correction stable to better than 0.2%/K

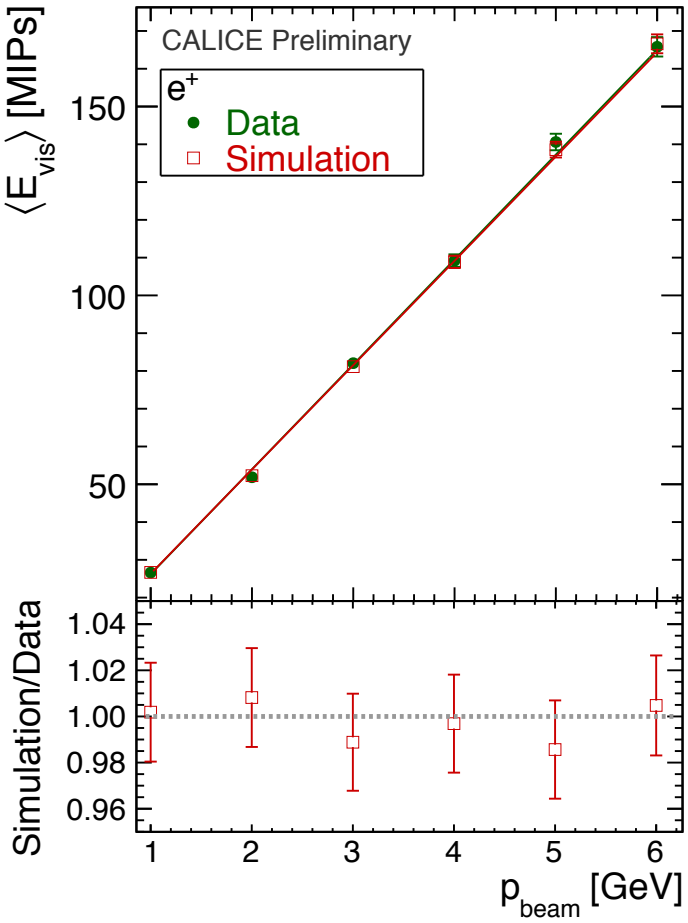


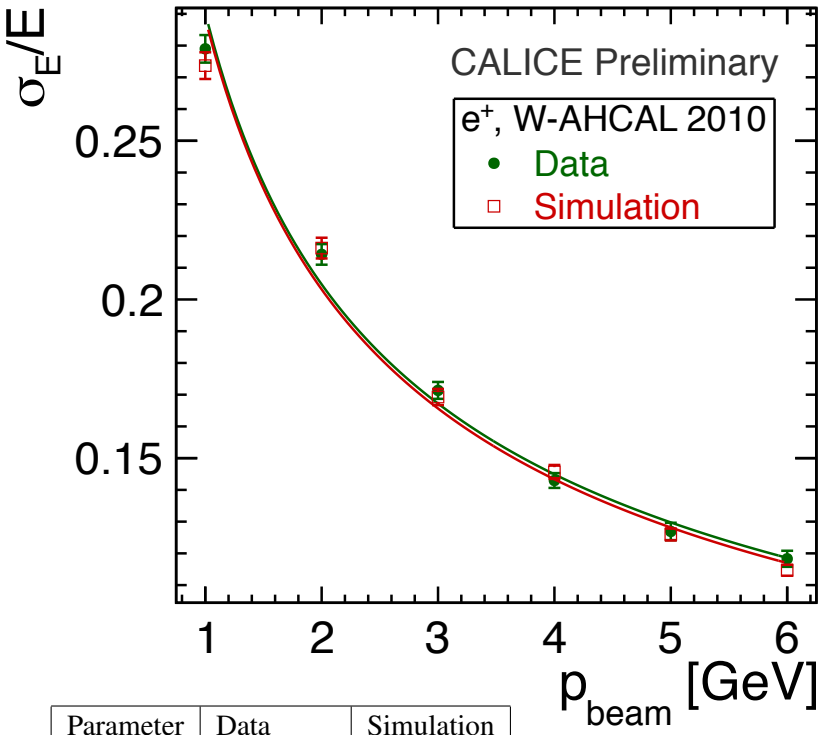




Validation with electrons

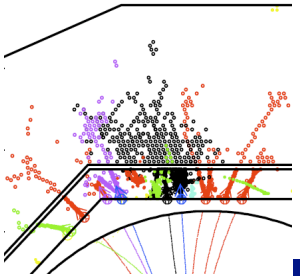
- Data MC difference <2%, constant term <2%





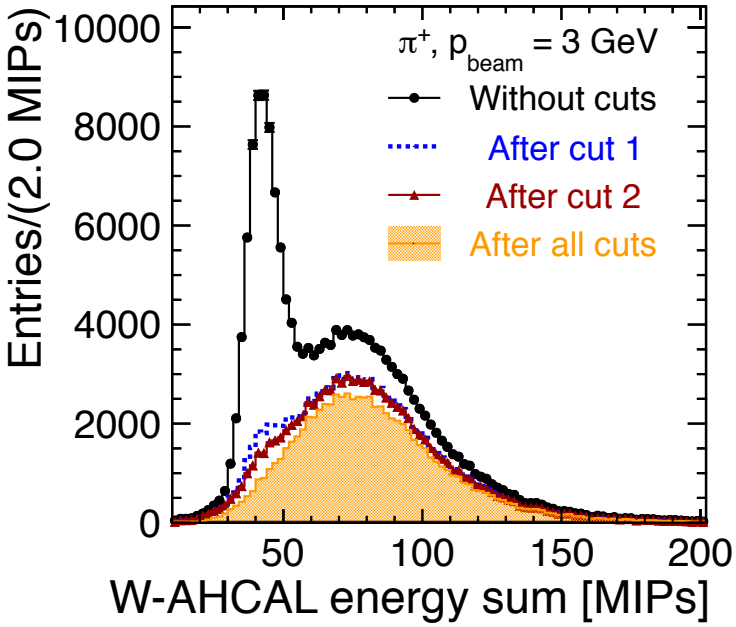
Parameter	Data	Simulation
a [%]	28.7 ± 0.4	28.6 ± 0.2
b [%]	1.6 ± 2.3	0 ± 2.6
c [MeV]	38	38
χ^2/ndf	19.6/4	34.7/4

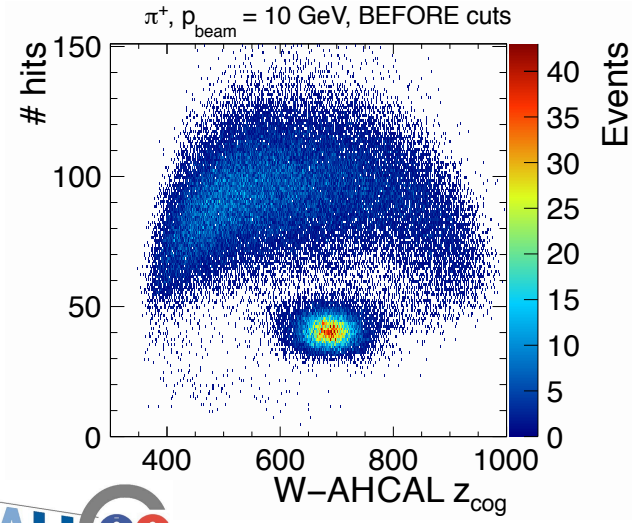
$$\frac{\sigma_E}{E} = \frac{a}{\sqrt{E\ [\mathrm{GeV}]}} \oplus b \oplus \frac{c}{E\ [\mathrm{GeV}]}$$

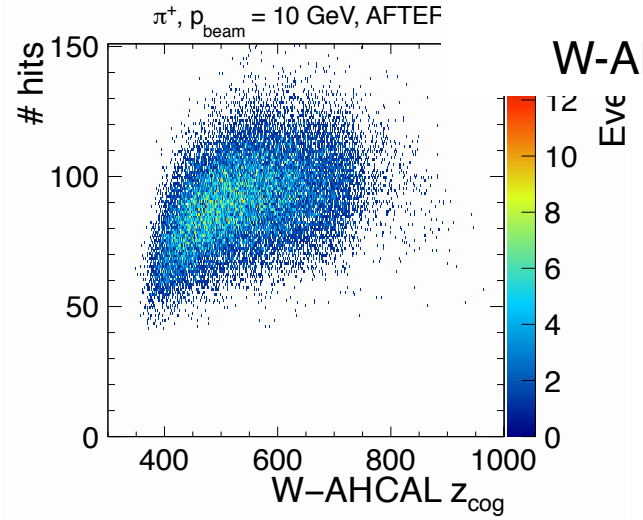


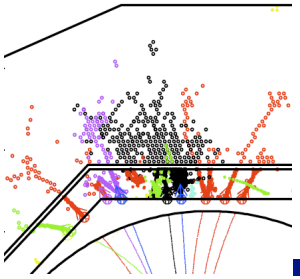
Pion selection

- Cerenkov counter to reject electrons
- But no tail catcher to suppress muons
- identify tracks and clusters in HCAL









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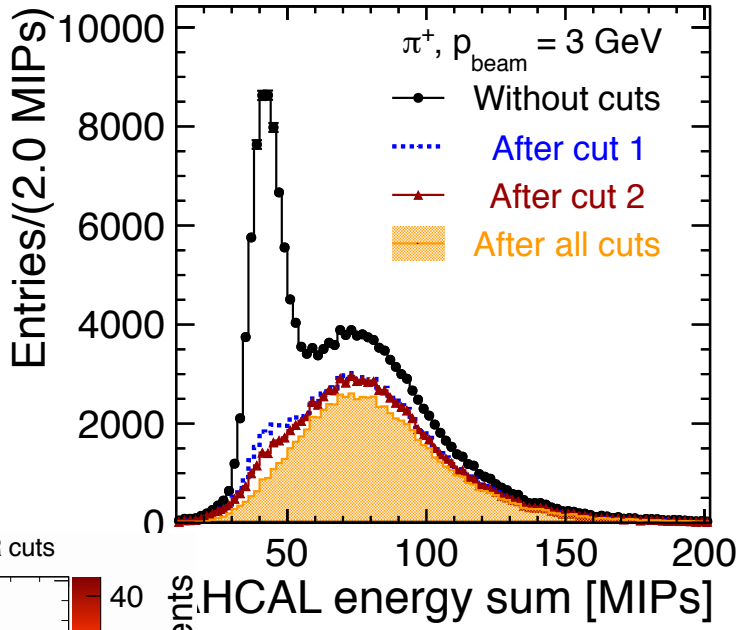
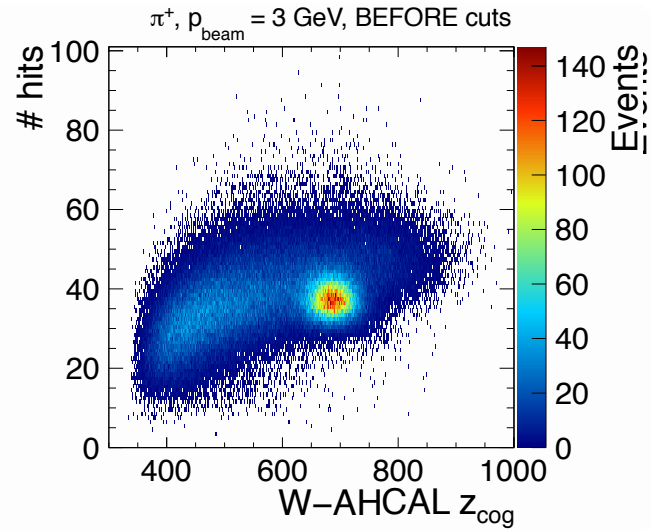
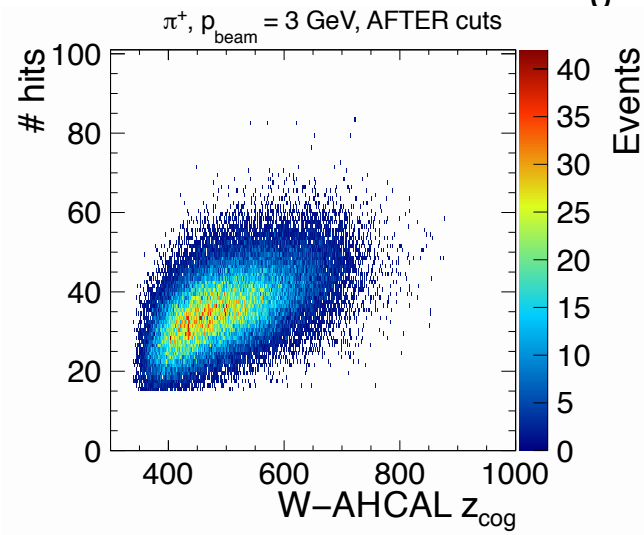
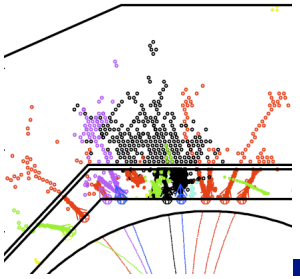


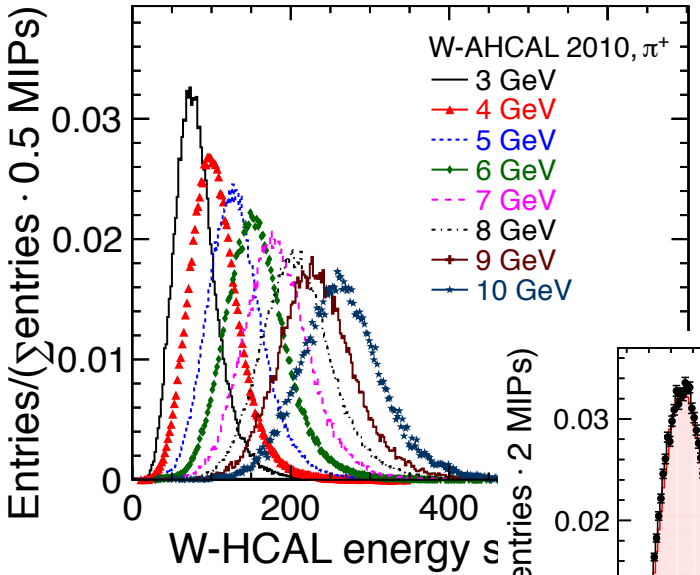


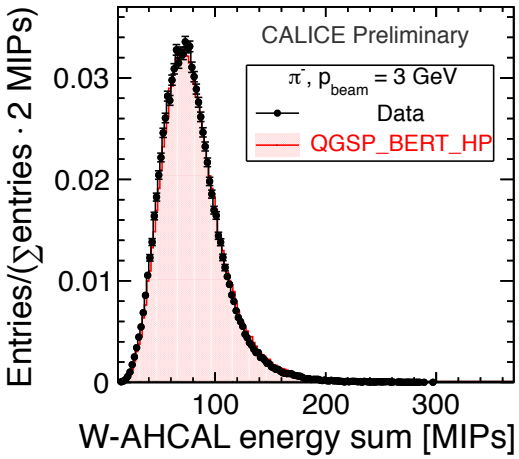


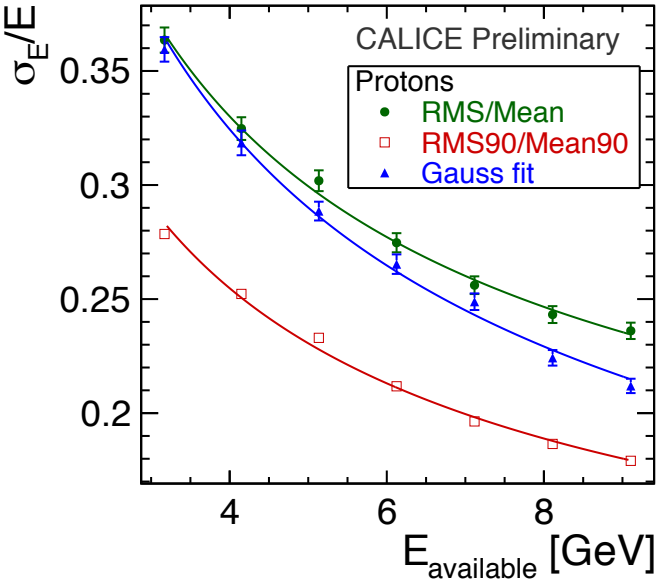


Performance with pions

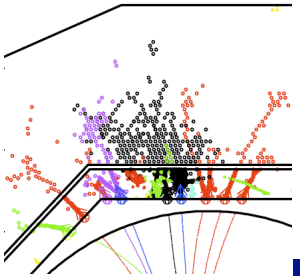
- Non-Gaussian signals at low E (in data and MC) - use RMS to estimate resolution
- Energy range too low to reliably constrain constant term





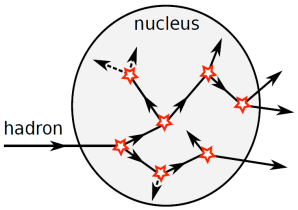


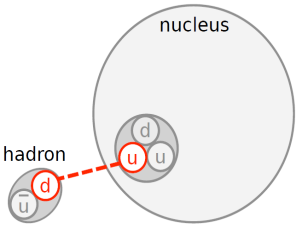
stochastic term ~61%
what matters is
the test of simulations

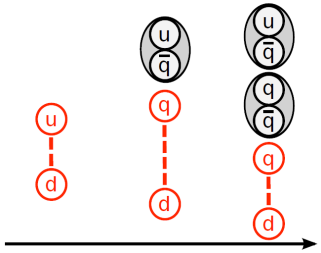


Shower simulation in Geant 4

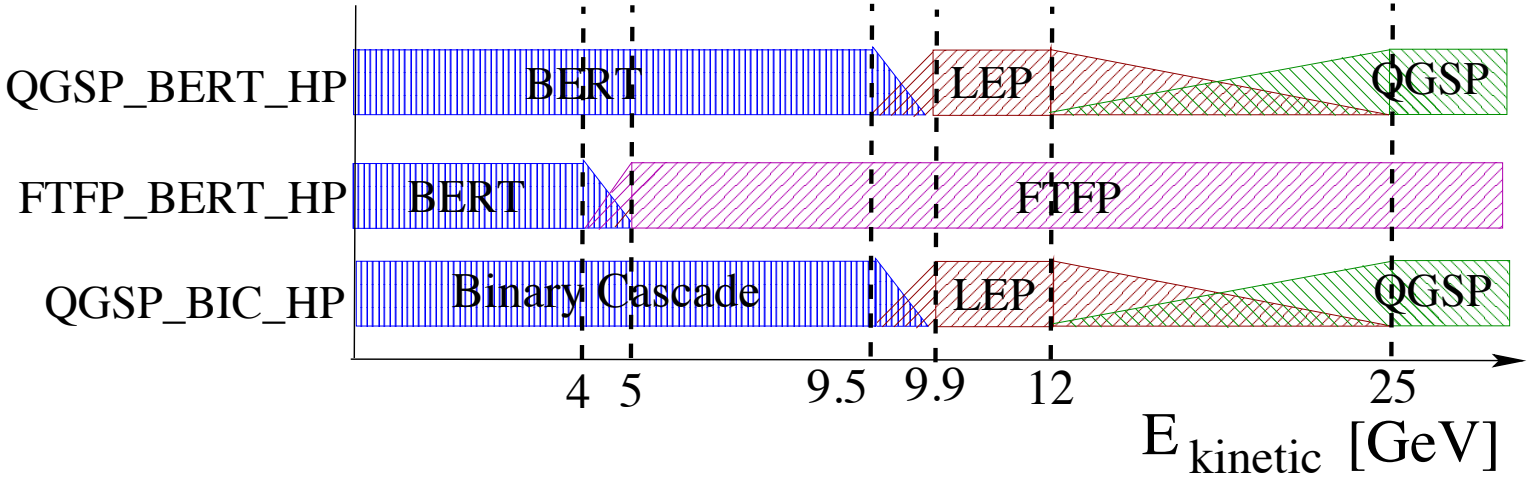
- Low energy: cascade models
- High energy: partonic models



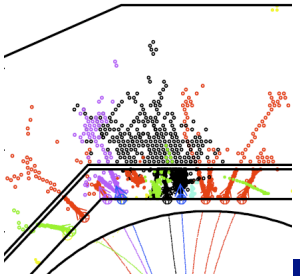




minimize use of phenomenological parameterization

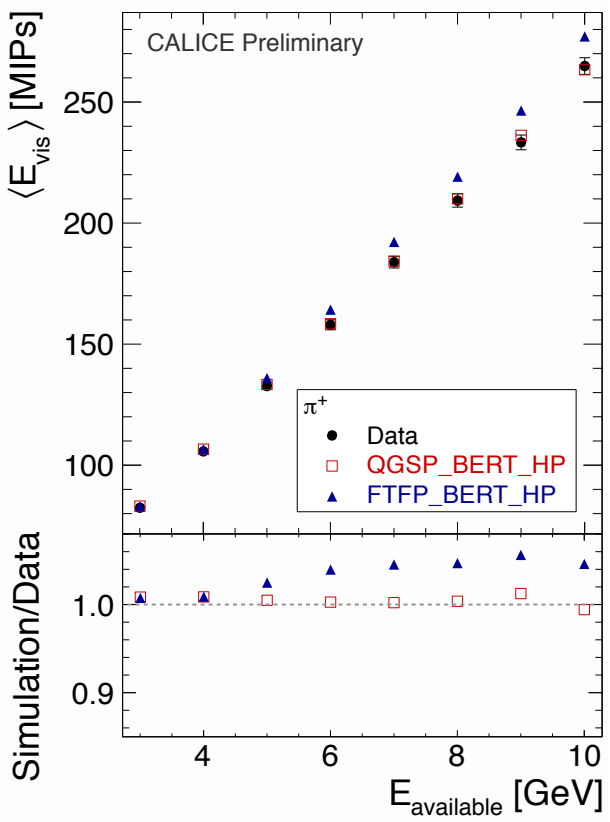


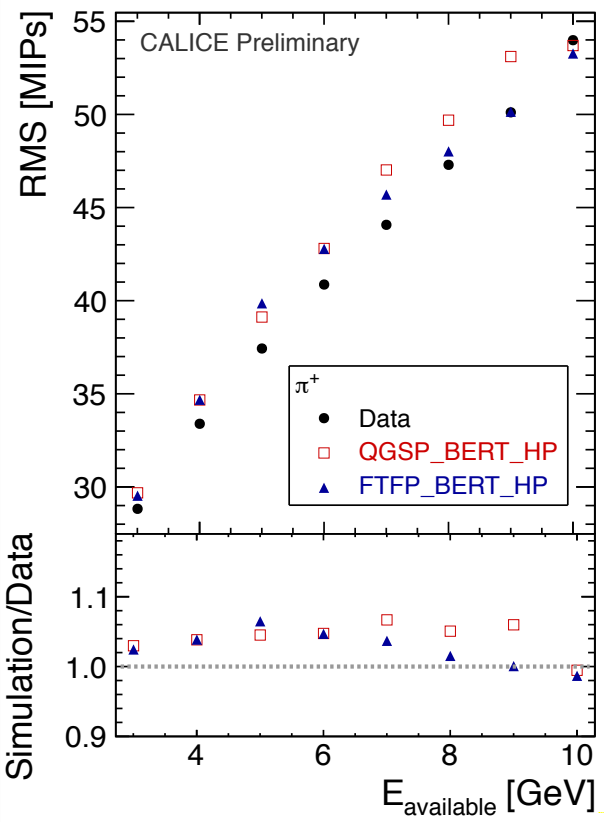
- HP: High Precision simulation of low energy neutron interactions (to be used for tungsten)

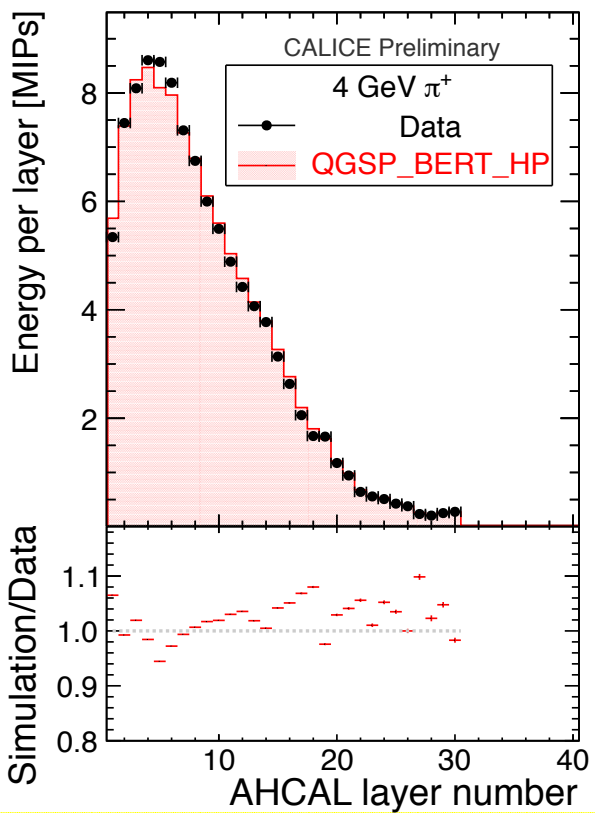


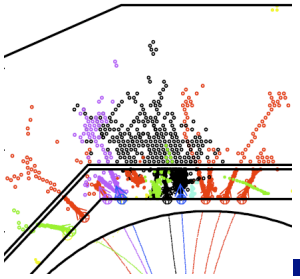
Pion response

- In general reproduced within 2-3% globally, <10% locally
- note transitions between models





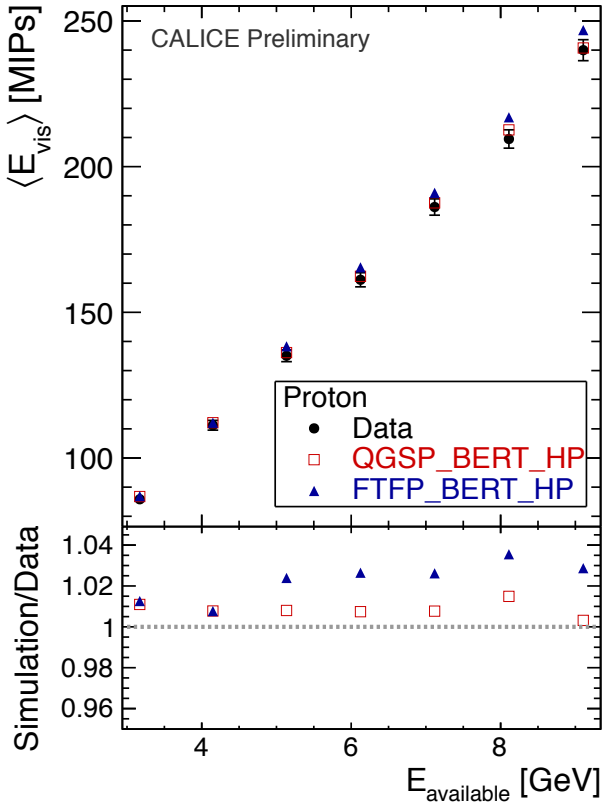


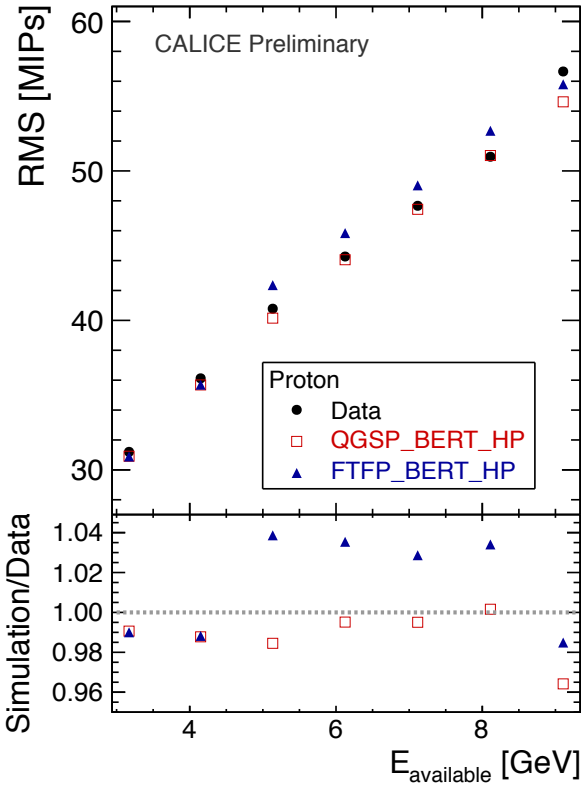


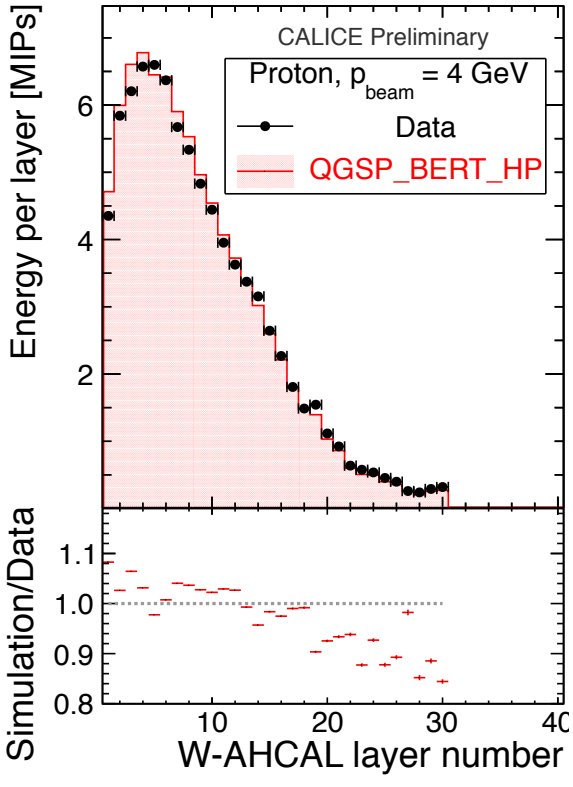
Protons

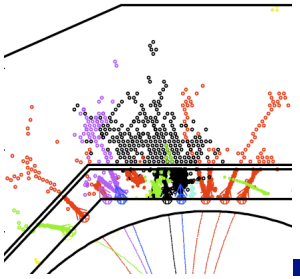
- same picture as for pions
- BIC cascade works well, too

identify by Cerenkov

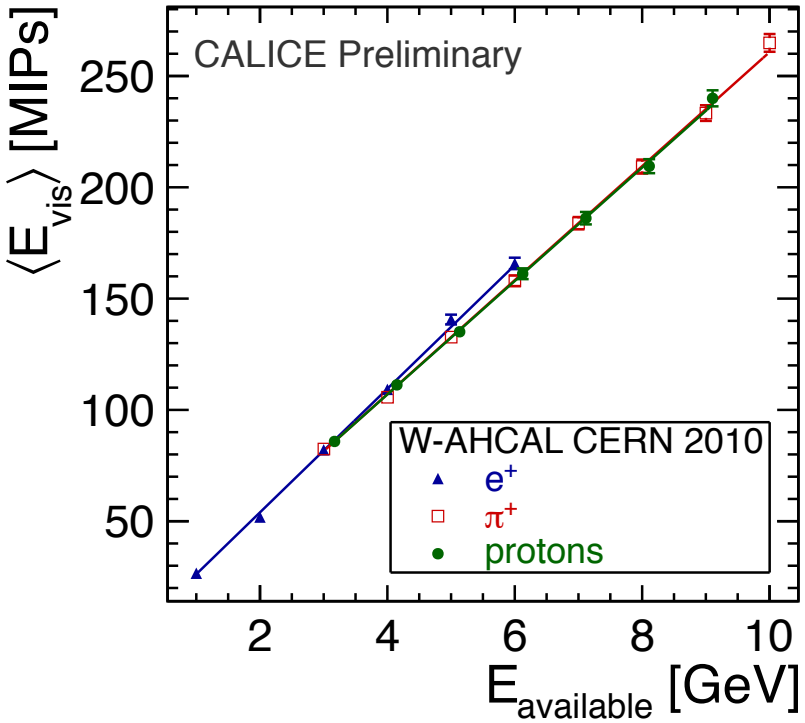


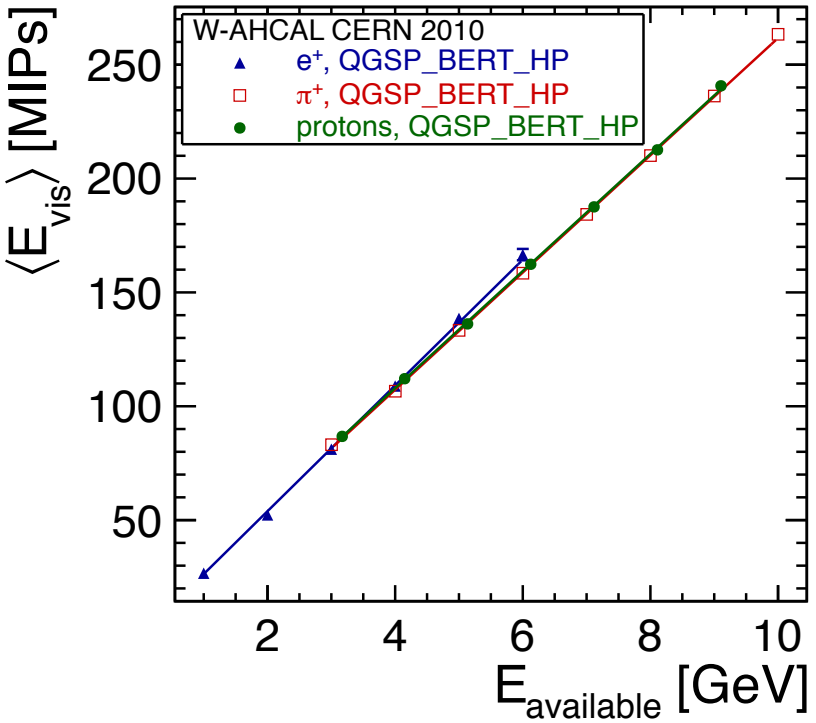




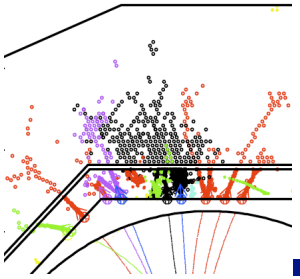


Compensation?





- same response for all particle types in 1-10 GeV range
- Need to probe at higher energies, too



Summary

- Scintillator tungsten HCAL tested with electrons and hadrons
- Technology still proving its robustness, reconstruction refined
- Detector response is very well reproduced by recent Geant 4 physics lists
- In the 1-10GeV range, the WAHCAL is compensating
- Results at higher energy are coming soon