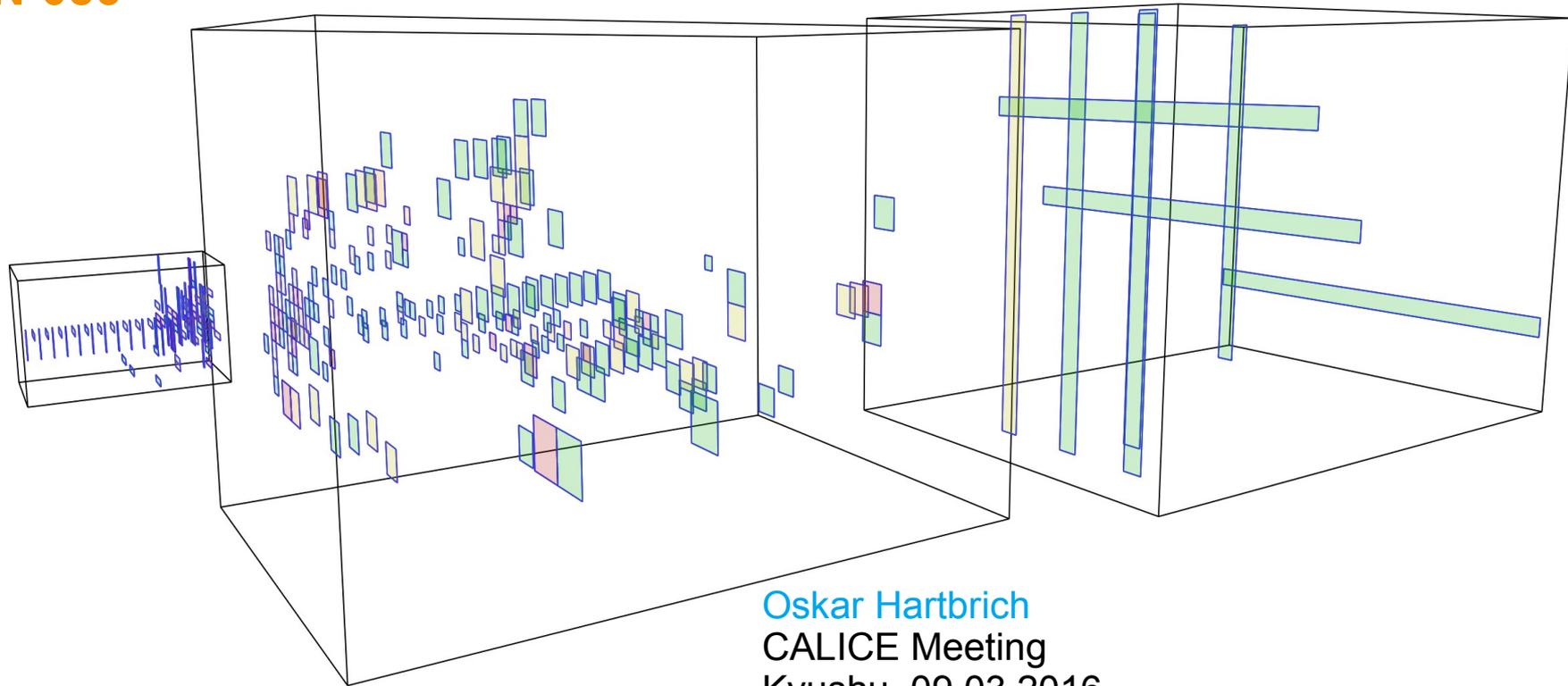


Energy Resolution of ScECAL + AHCAL + TCMT

CAN-056



Oskar Hartbrich
CALICE Meeting
Kyushu, 09.03.2016

FNAL 2009 Combined Scintillator-SiPM system

ScECAL

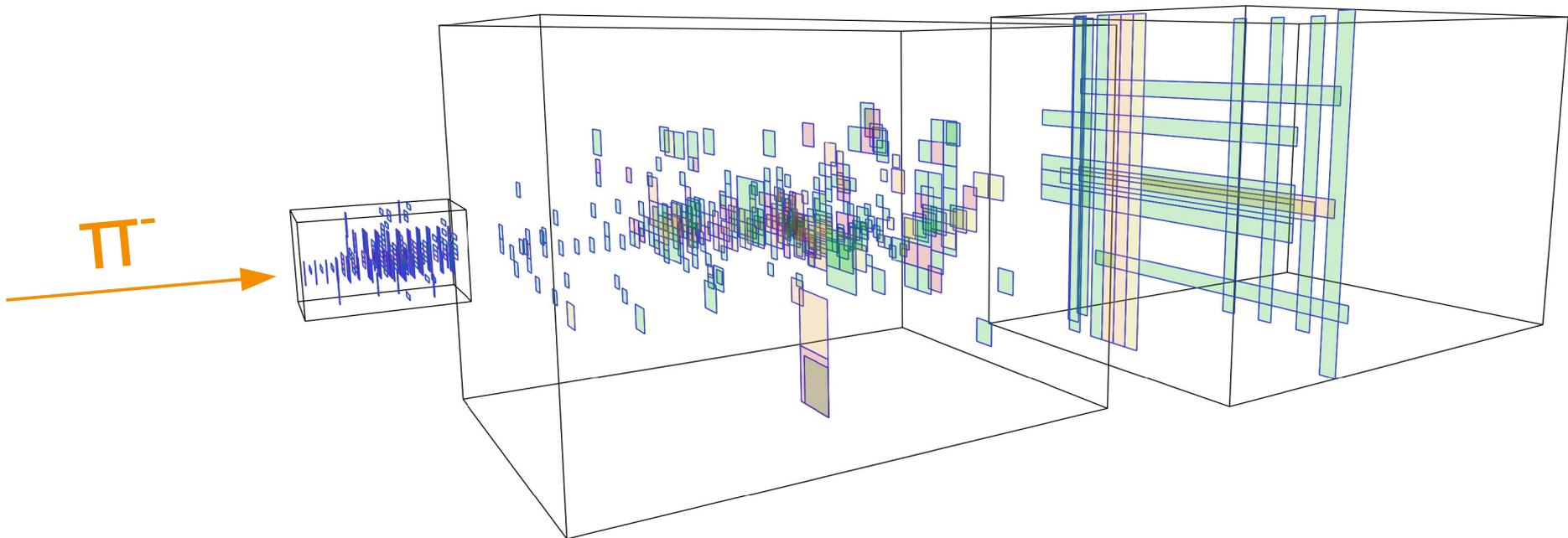
45*10mm² strips

AHCAL

30*30-60*60mm² tiles

TCMT

1000*50mm² strips



Testbeam Analysis

- Energy reconstruction in combined scintillator-SiPM calorimeter
 - Variable longitudinal sampling
 - Making use of granularity apart from particle flow

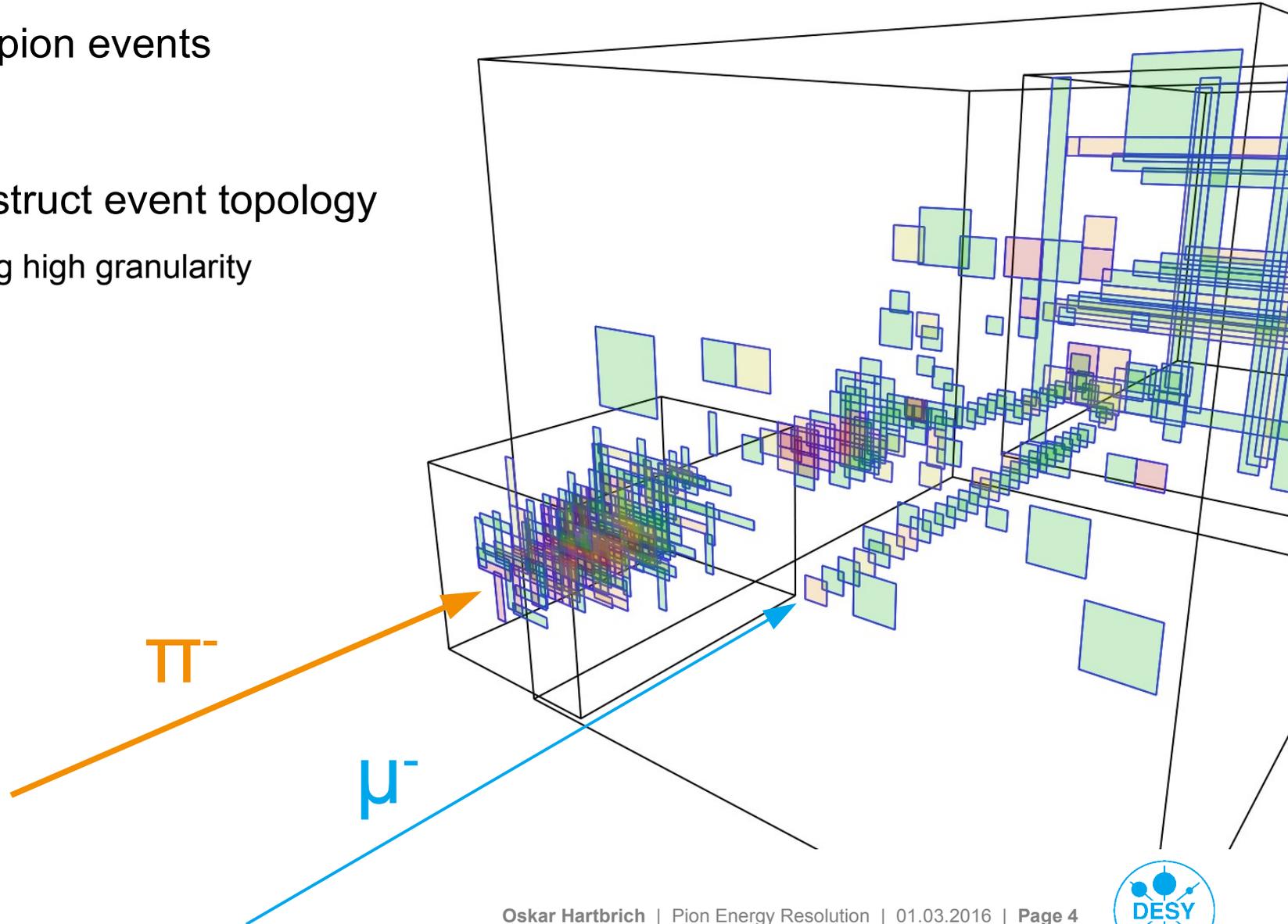
	ScECAL	AHCAL	TCMT
Absorber material	3.5mm W	21mm Fe	21mm (105mm) Fe
Scint. thickness	3mm	5mm	5mm
Sampling Fraction (EM)	17	33	33 (165)

- **Energy resolution of the combined system?**
- **Energy resolution well described in MC?**
- **How is the energy resolution influenced by ScECAL?**



Event Selection

- Single pion events
- Reconstruct event topology
 - Using high granularity



Event Selection

➤ Pion selection

- Beamline instrumentation
- First hadron interaction layer (FHI) ≥ 5
- No tracks parallel to beam axis

➤ Single particle selection

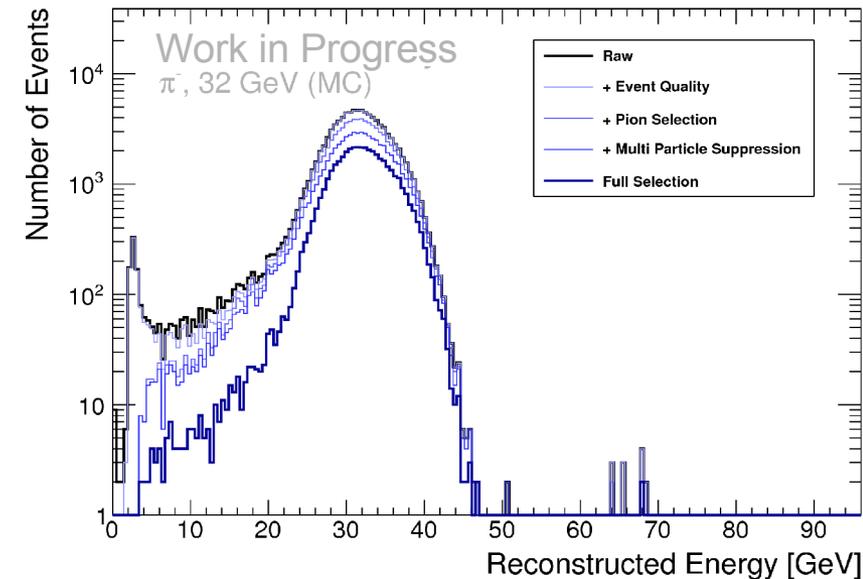
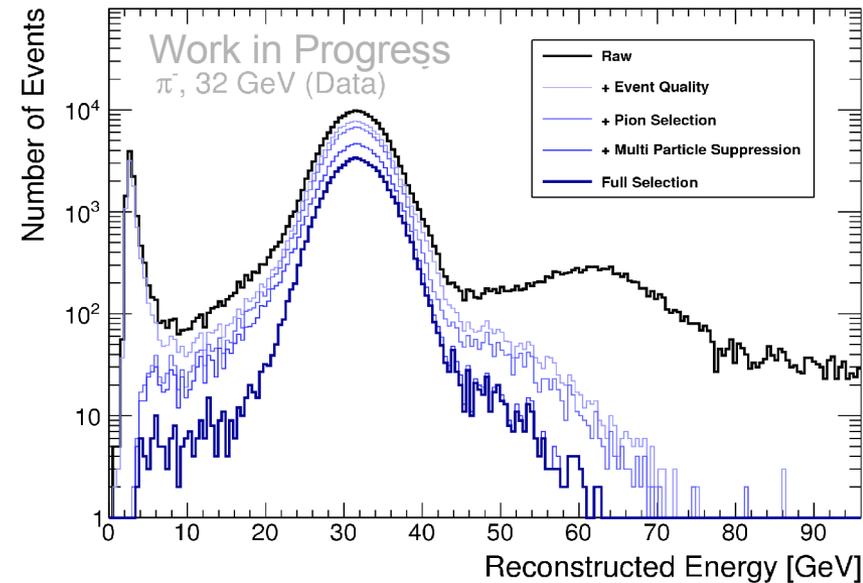
- Single, isolated primary track

➤ Containment selection

- FHI $\leq 5^{\text{th}}$ layer AHCAL

➤ Efficiencies and biases from MC

- No bias on EM-subshower fraction
- No bias on response/resolution



Simulation Comparison – Shower Profiles

➤ Full Mokka+Geant4 detector simulation

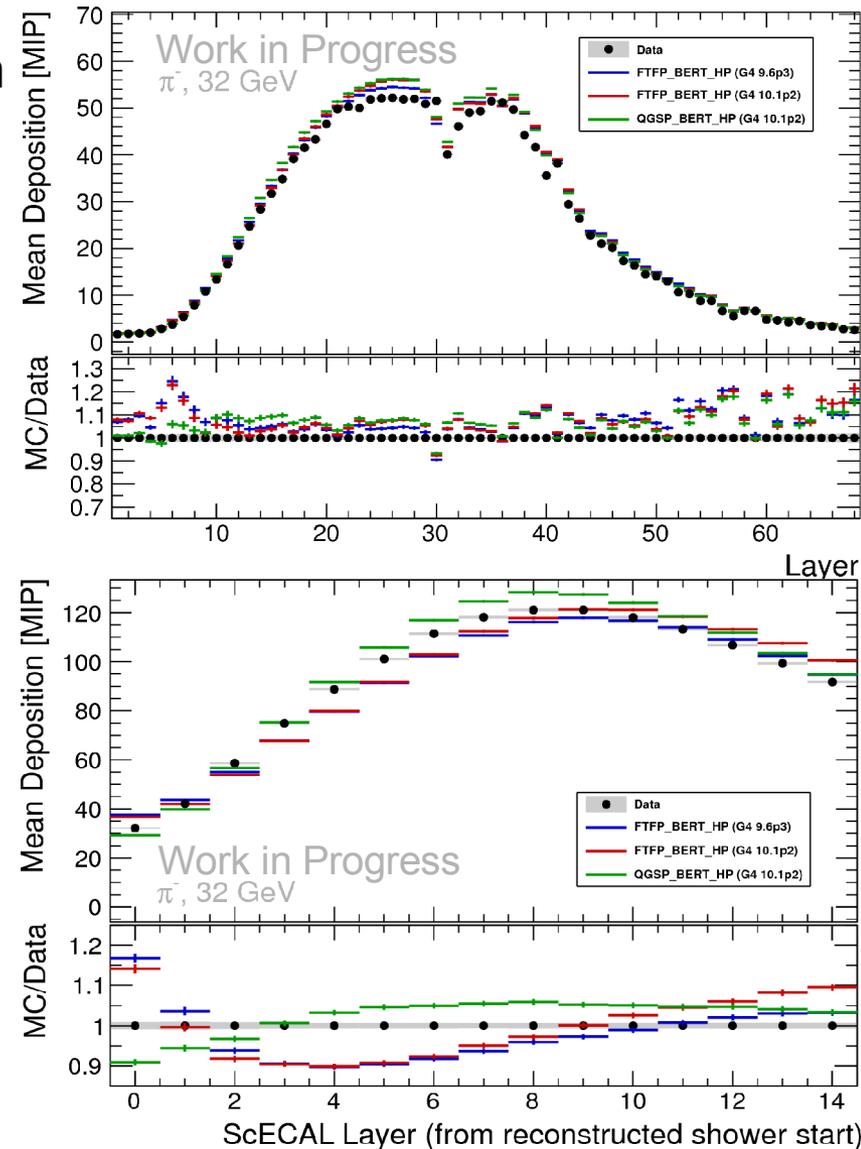
- Detailed geometry, materials
- Realistic digitisation of sensor effects

➤ Full longitudinal pion shower profile in good agreement with simulations

- ~5% excess depositions in MC

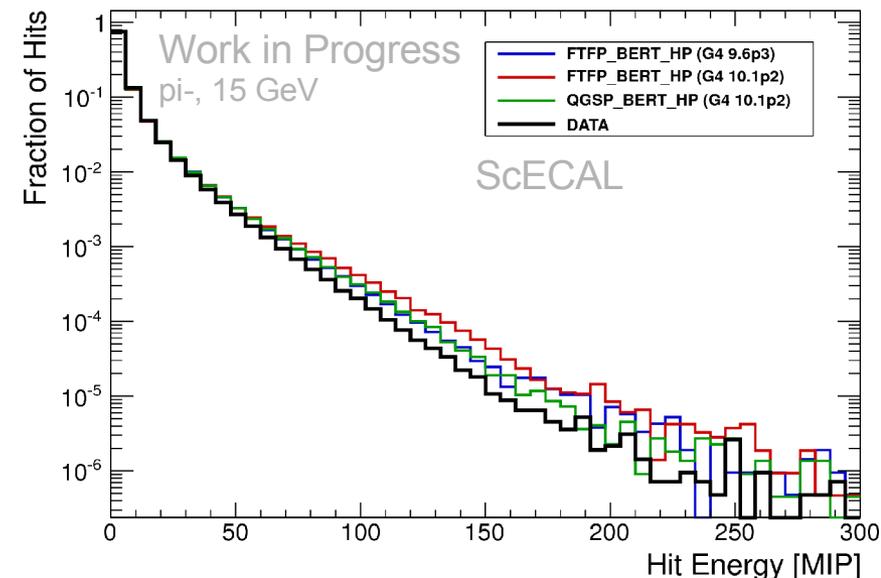
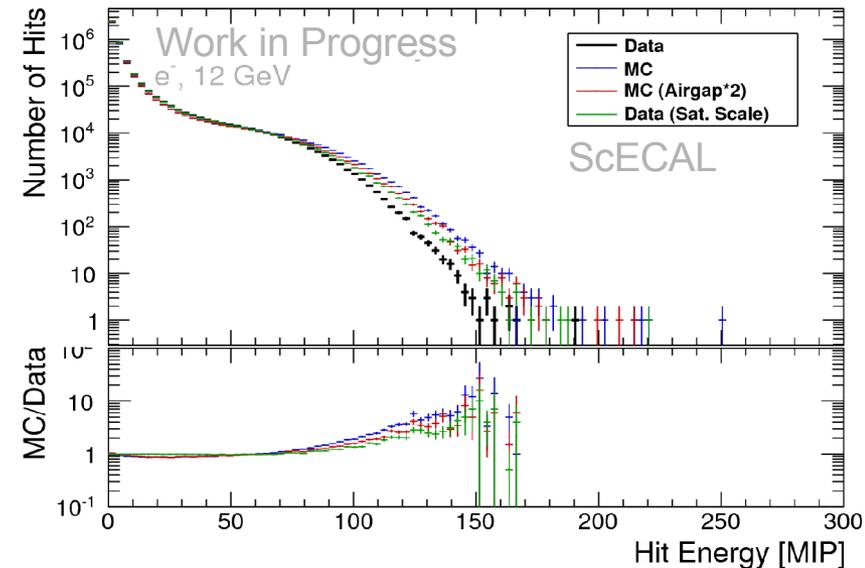
➤ Physics modelling uncertainties in ScECAL shower profile from FHI

- Physics lists show different behaviours
- Data between physics lists



Simulation Comparison – Hit Energy Spectra

- Overestimations in ScECAL hit energy tails
 - Not explained by saturation scale mismatch
Needs more complex saturation modelling?
(See Katsu's talk from monday)
 - Not explained by misdescribed material
- Larger effect in electrons than pions
 - Electron showers also too narrow in MC
- Smaller effect on pions
 - Similar scale to shower modelling spread
- No effects on energy sum



Energy Reconstruction - Standard

- Standard reconstruction: Single constant weight per calo (~1/sampling)

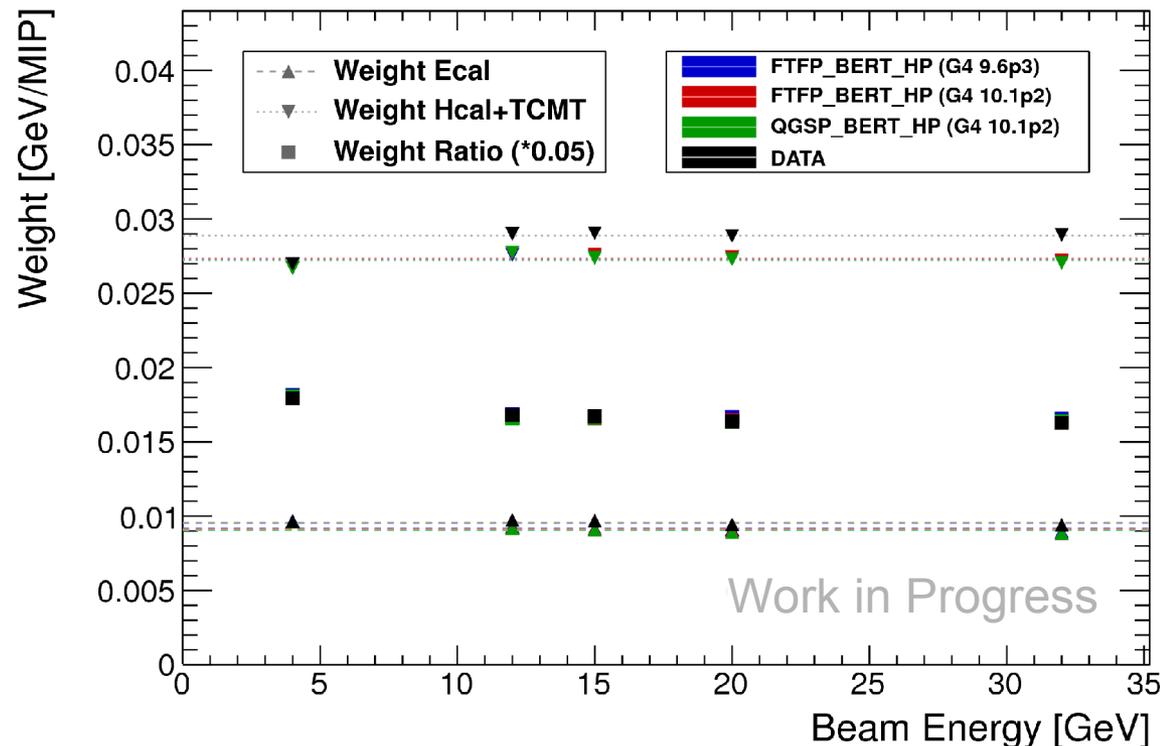
$$E_{\text{rec}}^{\text{classic}} = w_{\text{ECAL}} (E_{\text{sum}}^{\text{ECAL}}) + w_{\text{HCAL}} (E_{\text{sum}}^{\text{HCAL}} + E_{\text{sum}}^{\text{TCMT}})$$

- Weights from χ^2 optimisation

$$\chi^2 = \frac{(E_{\text{rec}} - E_{\text{beam}})^2}{(\sigma_E)^2}$$

- Similar weights in data and simulation

- 5% shift from deposition overestimation in MC
- Ratio identical in data/MC

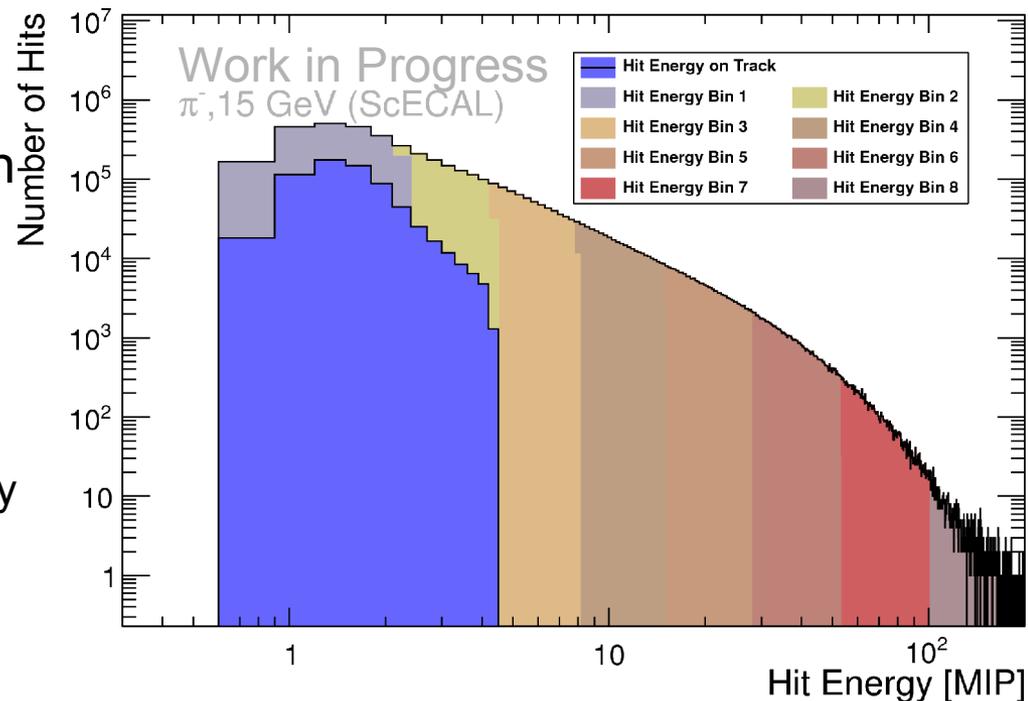


Energy Reconstruction – Software Compensation

- Mean deposition of electrons higher than hadrons
 - e/h ratio > 1 (depending on absorber, active material, geometry)
- Hadron shower: variable energy fraction in EM subshowers
 - Identification of EM subshowers from local deposition density

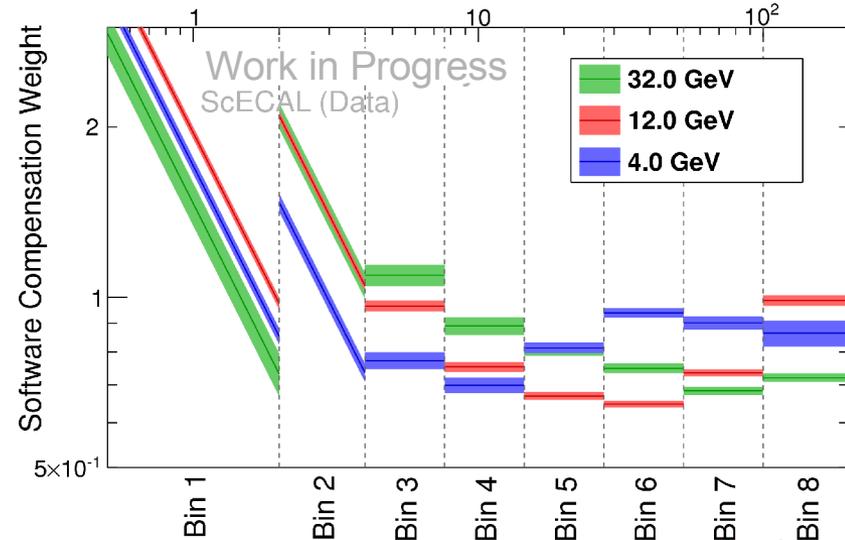
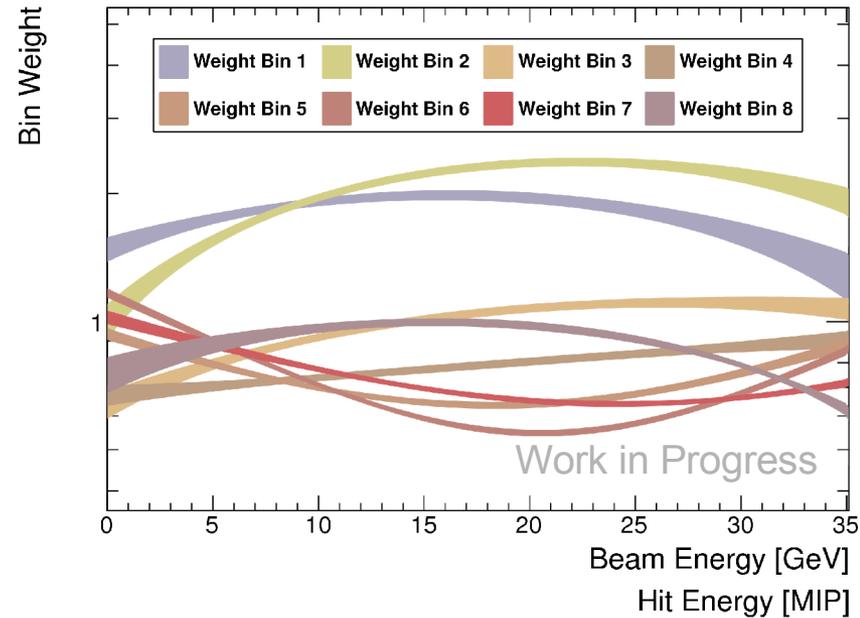
Software Compensation

- Weight each hit in reconstruction
 - Depending on hit energy
 - As function of full shower energy
- Hit energy in 8 bins
 - Primary track hit weighted separately



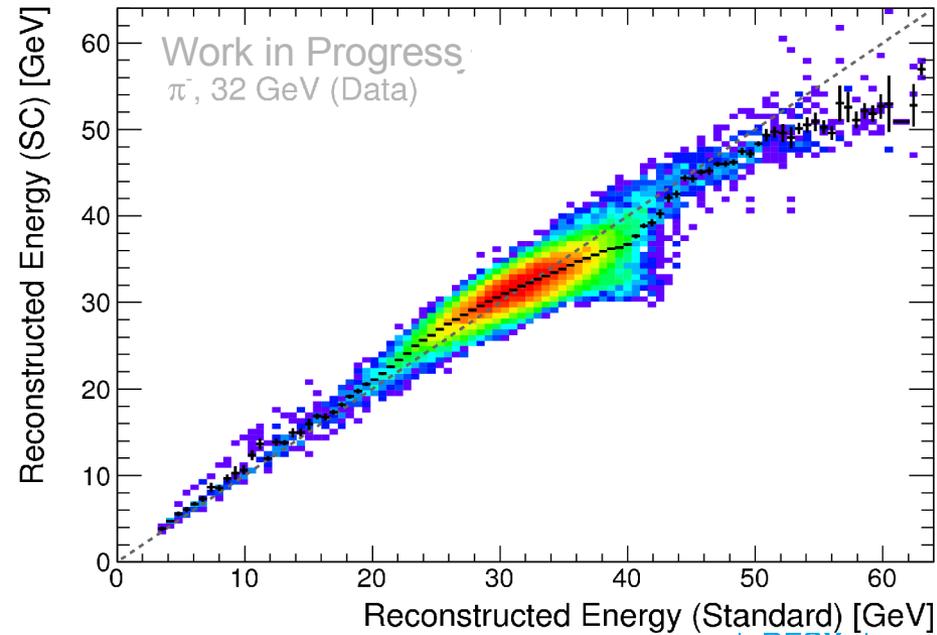
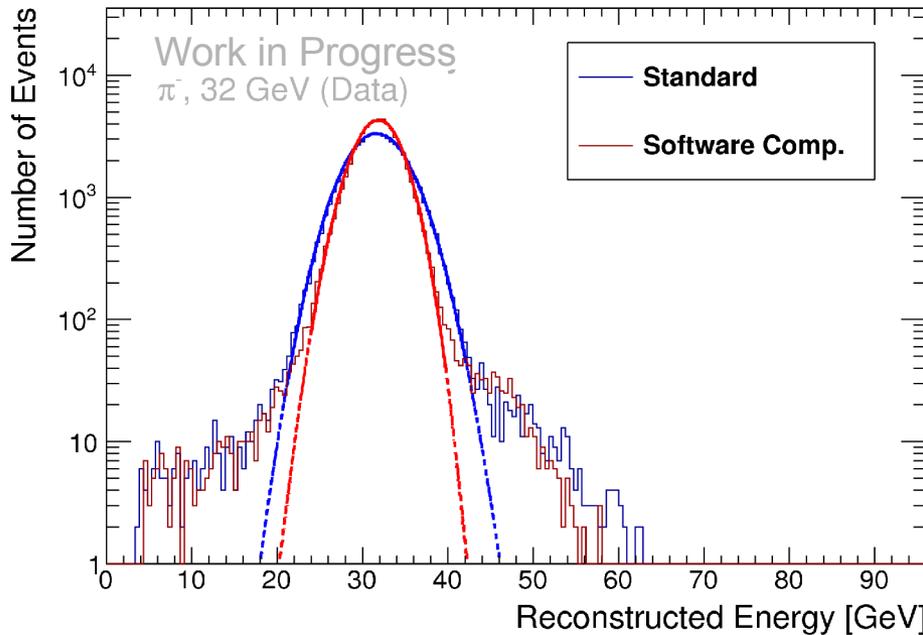
Energy Reconstruction – Software Compensation Weights

- Bin weights parametrised with beam energy
 - 2nd order polynomial, 3 free parameters
- Binary reconstruction in Bins 1-2
 - Only counting number of hits in bin
 - Suppression of Landau fluctuations
- Minimum weight bin energy increases with energy
 - Typical EM hit energy depends on shower energy



Energy Reconstruction – Software Compensation

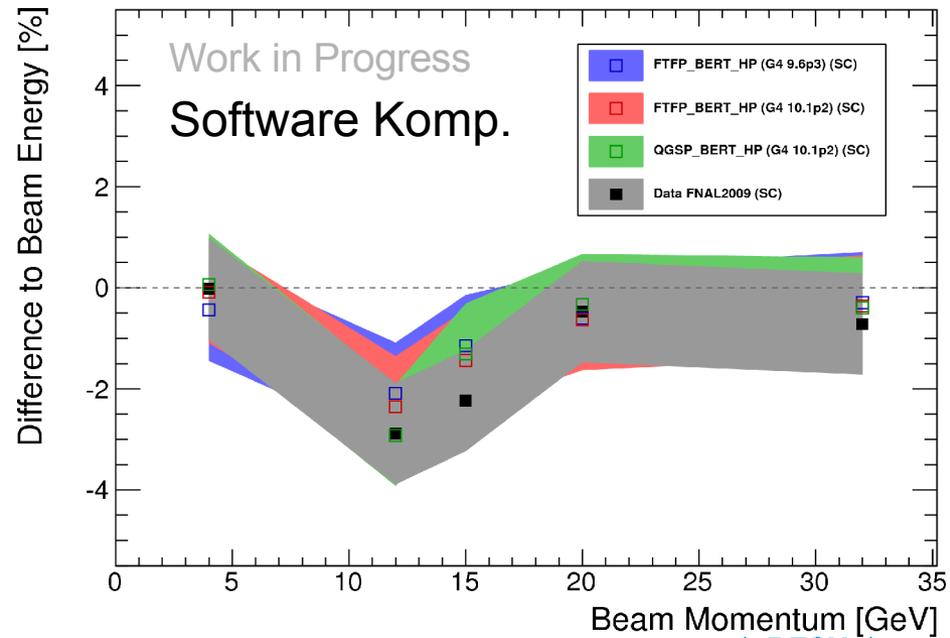
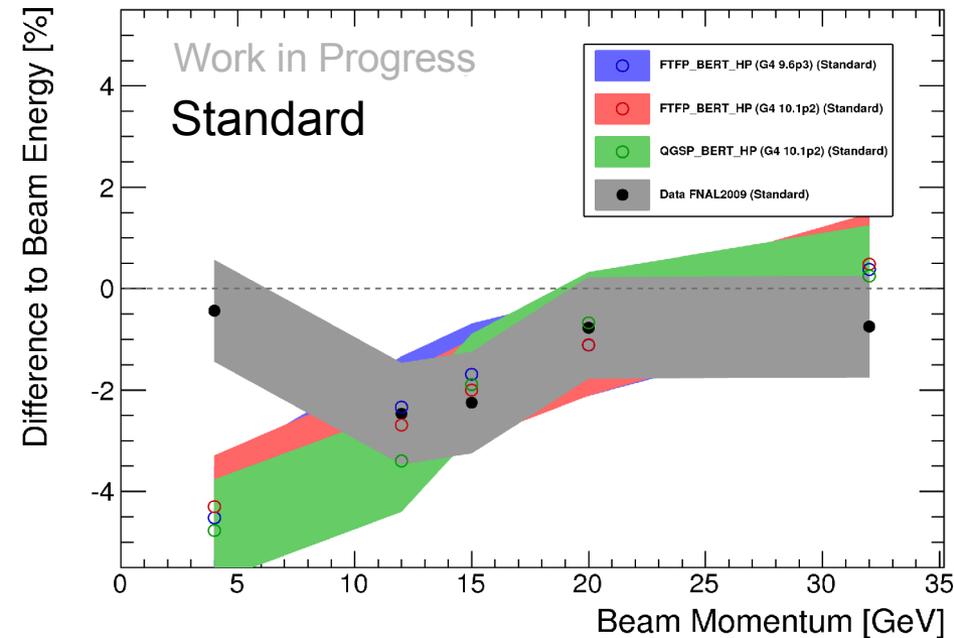
- Strong resolution improvement from software compensation
 - Small change in mean reconstructed energy
- SC weights up too low standard reconstructed energy events, de-weights too high standard reconstructed energies



Linearity

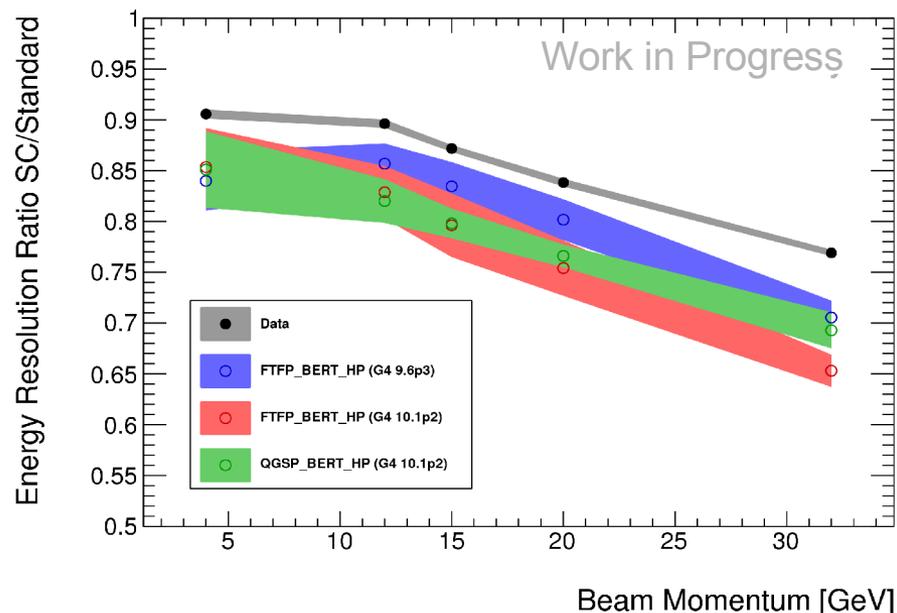
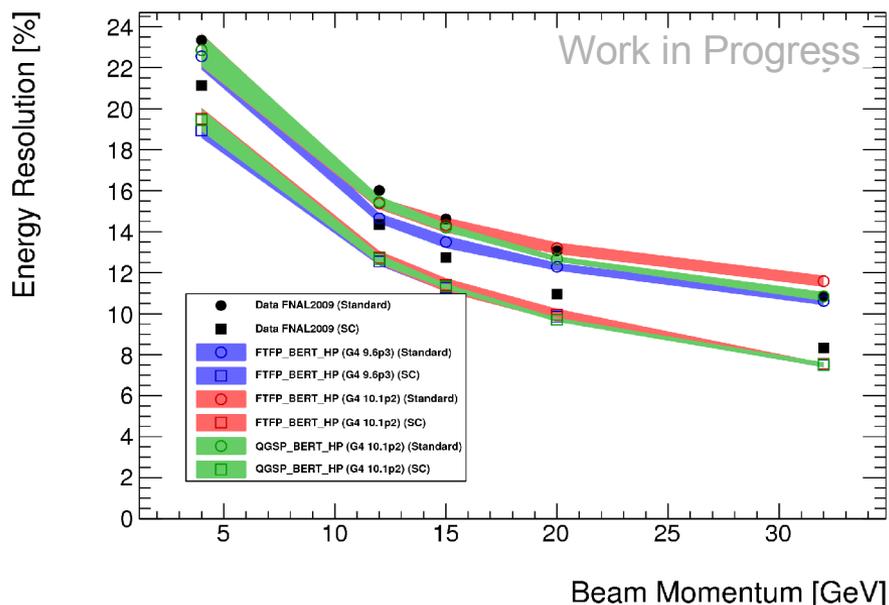
➤ Good linearity in data and simulation (by construction)

- Standard reconstruction: $\leq 4\%$ deviation from linear response
- Software compensation: $\leq 3\%$ deviation from linear response



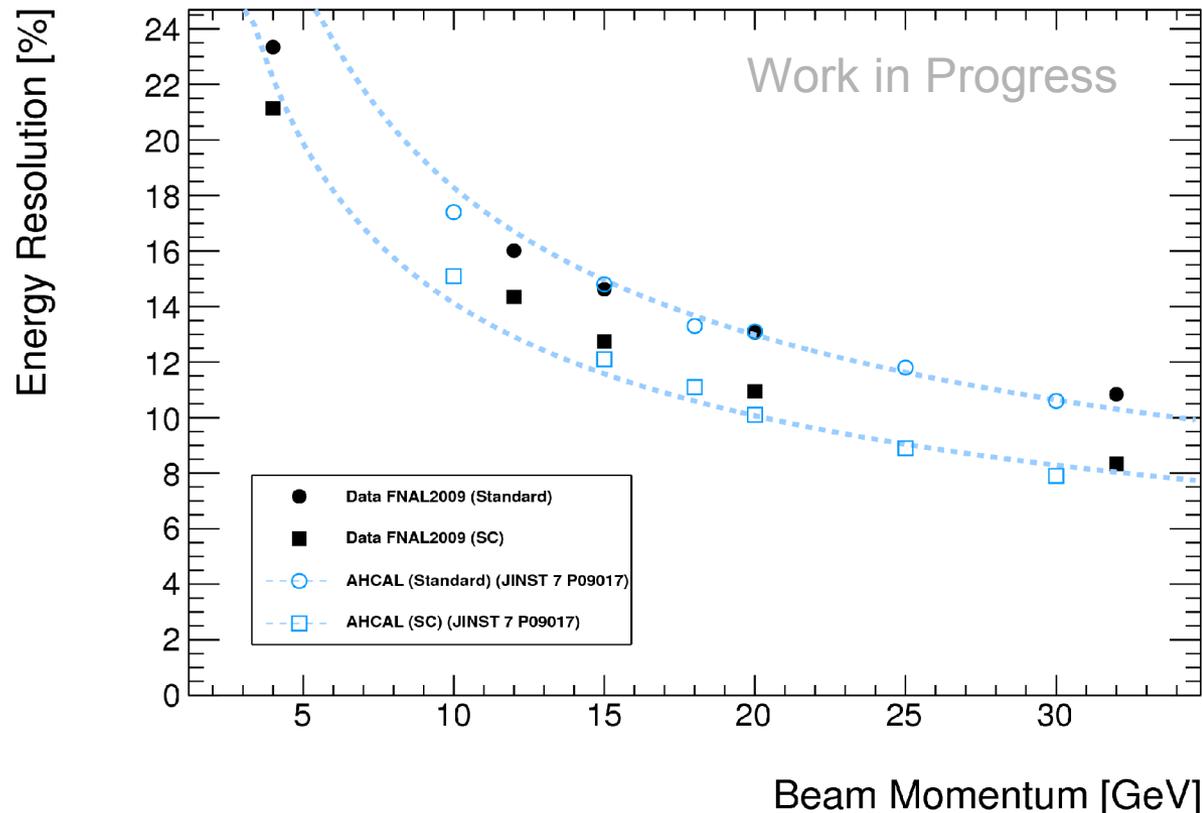
Energy Resolution

- Standard reconstruction: Identical resolution in data and simulations
- Software compensation: Simulation overestimates improvements
 - Resolution improvement in data 10-20%
 - Resolution improvement in simulation 15-30%



Energy Resolution

- Comparing resolutions to reference analysis
 - AHCAL + TCMT (JINST 7 P09017)
- Resolutions identical: AHCAL performance is maintained with ScECAL



Summary

- Combined scintillator-SiPM calorimeter system in FNAL Testbeam
 - ScECAL, AHCAL, TCMT

- Clean selection of single particle events
 - Making full use of high granularity to reconstruct event topology
- Data well described by simulations
 - Deviations in tails of ScECAL hit energy spectra

- Standard energy reconstruction in good agreement
 - Software compensation overestimated in all simulations
- Energy resolution is identical with and without ScECAL

