Investigations of AHCAL Test Beam Data (June 2018) from a new Master's student

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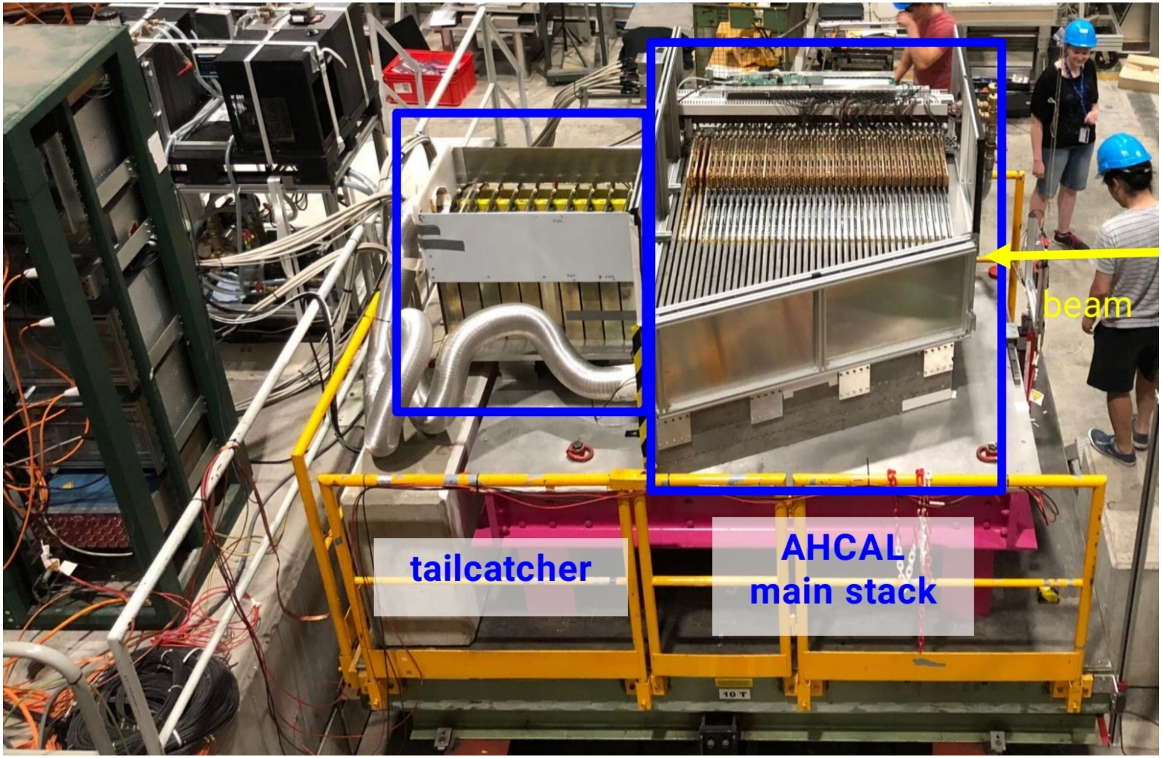
About Me

- Master's student at the Georg-August-University Göttingen
- Working on CALICE/AHCAL since October 2021
- Plan to investigate simulation techniques of high-granularity calorimetry
- First exercise: Investigate June 2018 AHCAL test beam data
  $\Rightarrow$ Familiarize with CALICE/AHCAL

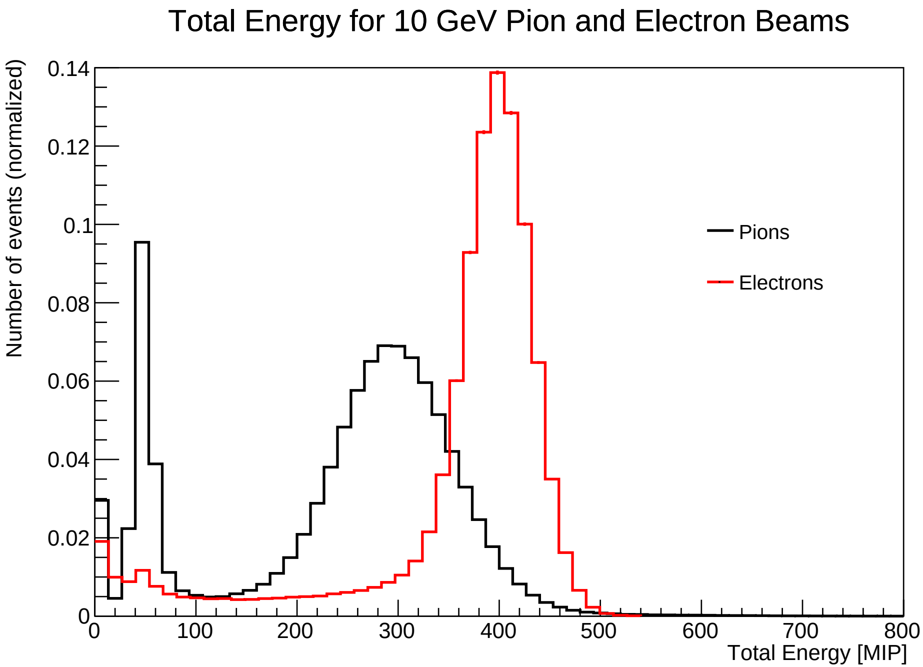
Test Beam Data Acquisition

- Data taking in June 2018 at CERN
- Exposition of physics prototype to electron and pion test beams



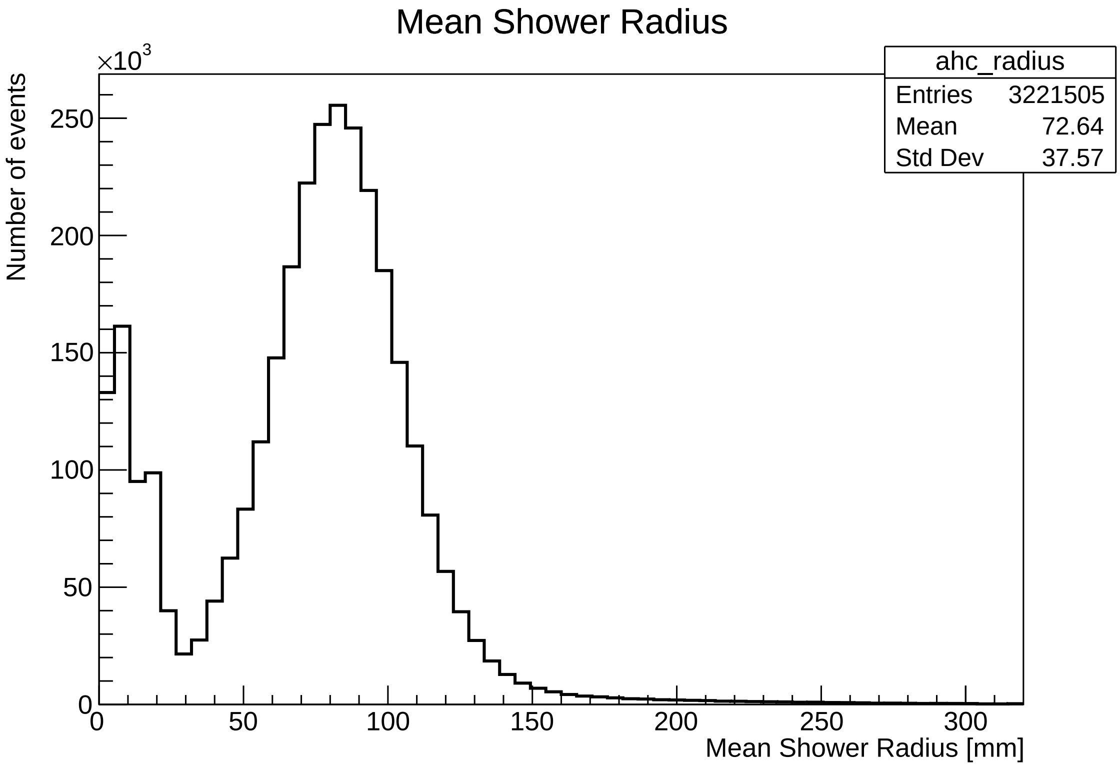
Energy Distributions

- Electron peak narrower than pion peak at about 400 MIP
- Energy resolution better for electrons
- Second pion peak probably due to $\pi^{\pm} \to \mu^{\pm} \overset{(-)}{\nu}_{\mu}$



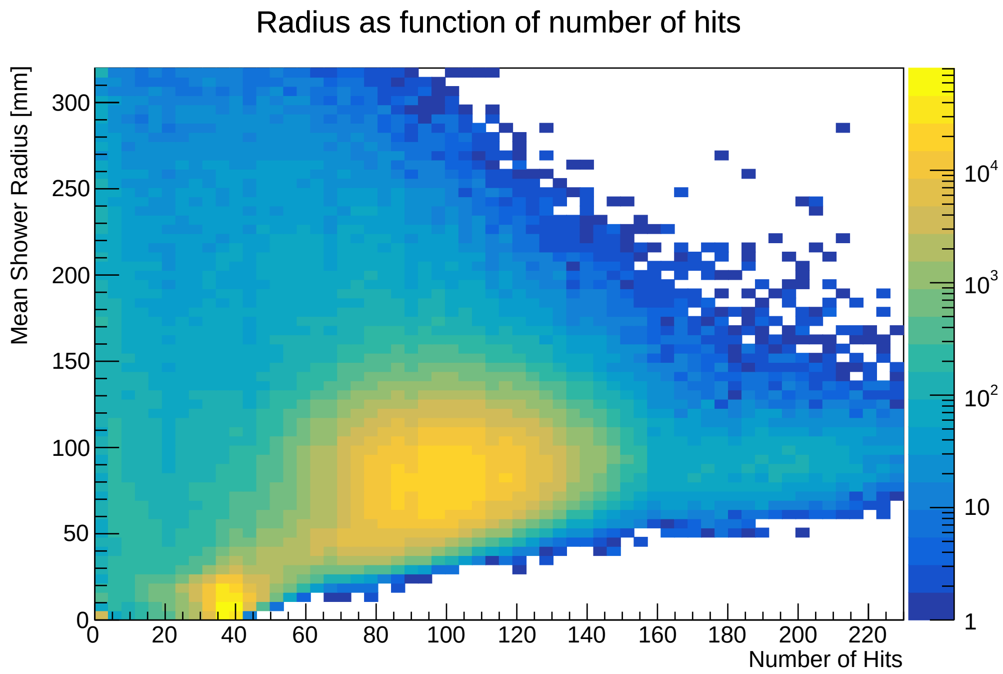
Transversal Shower Radius (only Pions)

- Expected behavior for hadronic showers
- Peak at $\sim 0\,\mathrm{mm}$ supports muon hypothesis



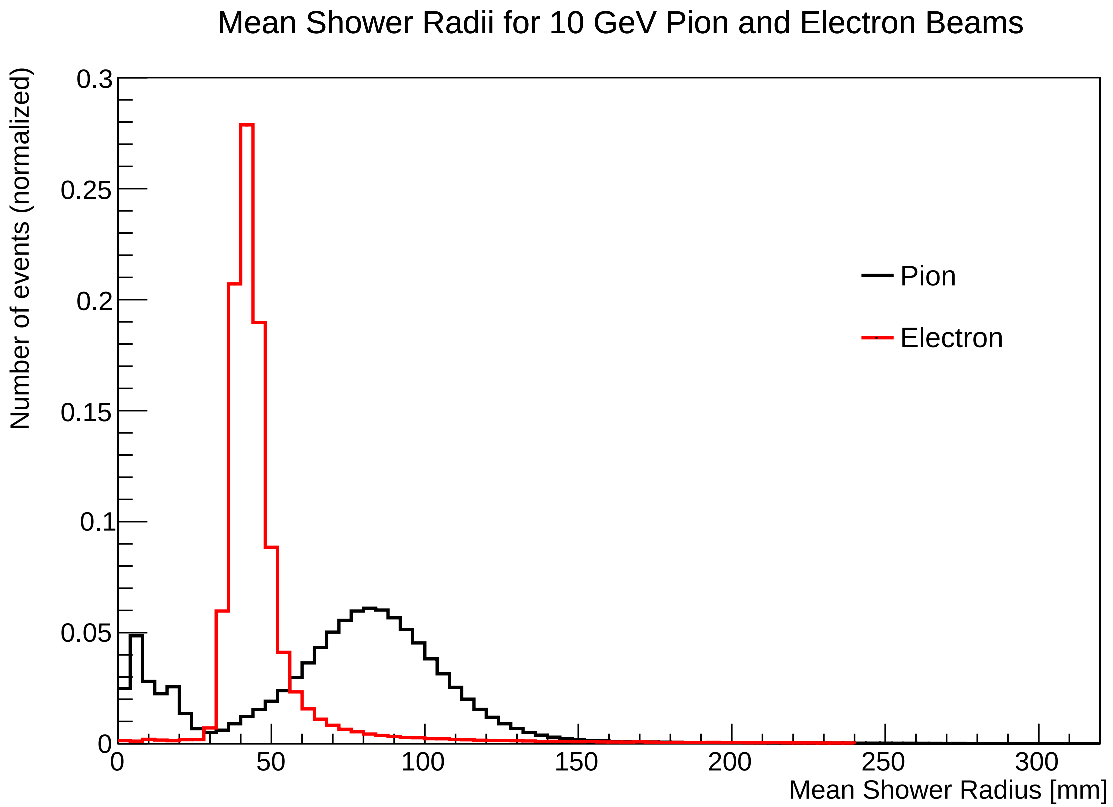
Transversal Shower Radius vs. Number of Hits

- Large range of radii for large range of number of hits (caused by showers)
- Small radii at around 38 hits
  $\Rightarrow$ Consistent with muon hypothesis (only $\sim$ 1 hit per layer)



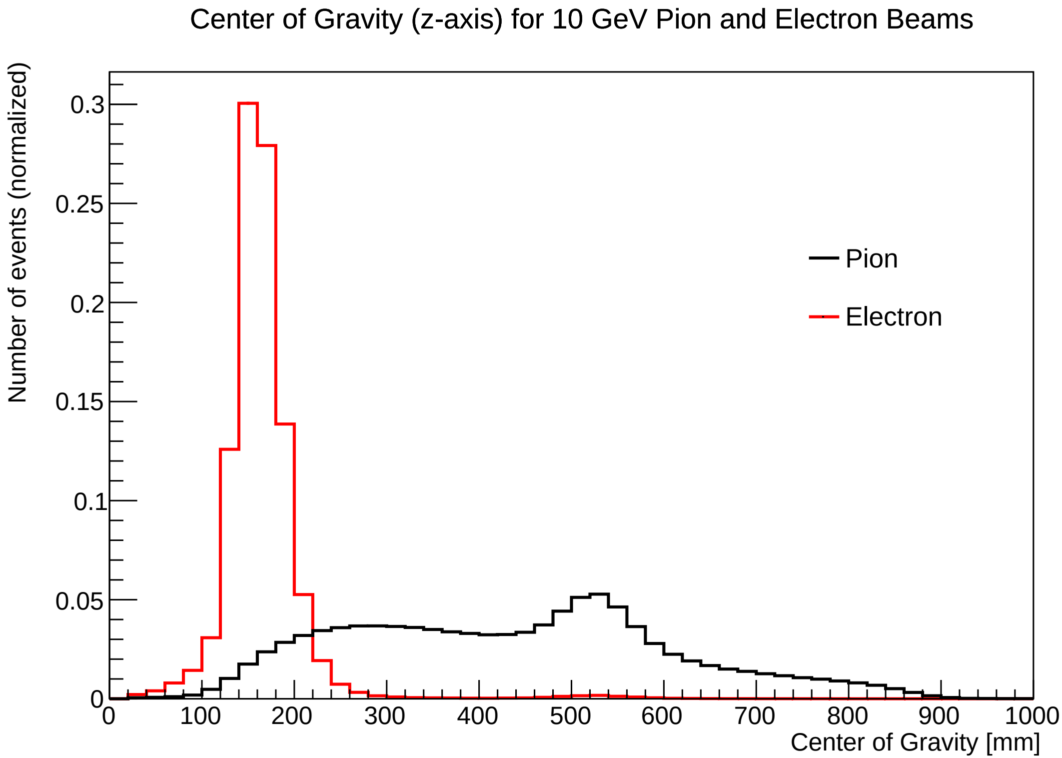
Transversal Shower Radius (Electrons and Pions)

- Electromagnetic showers narrower than hadronic showers



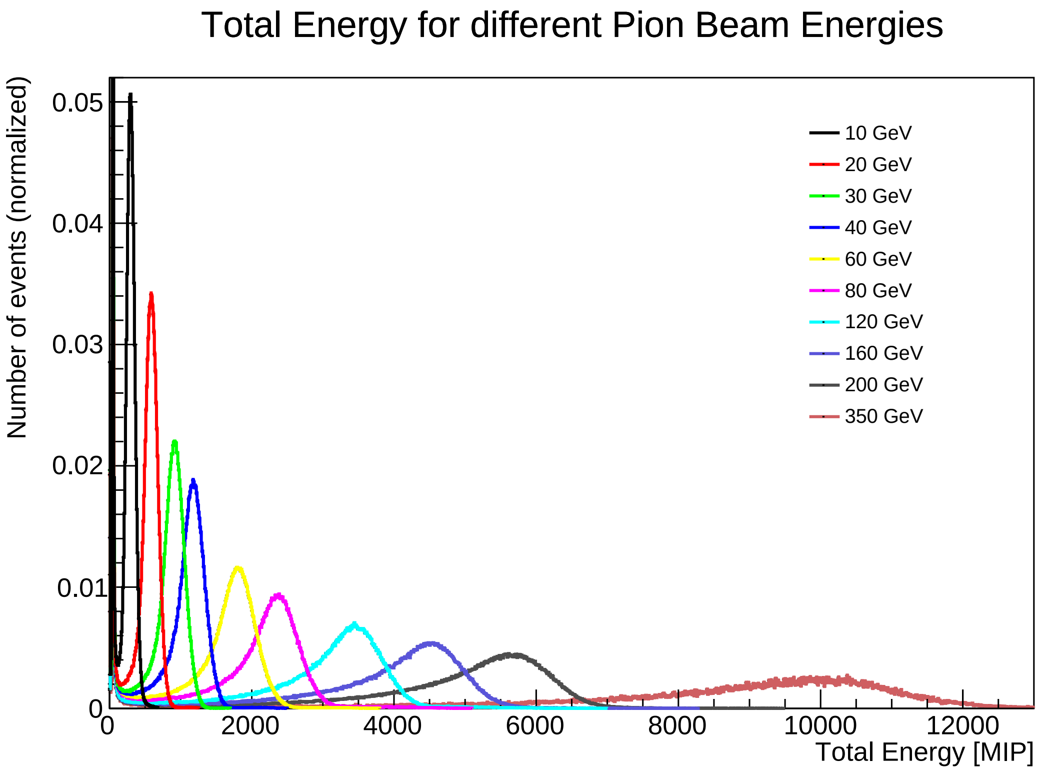
Longitudinal Center of Gravity

- Electromagnetic showers obviously much shorter
  $\Rightarrow$ Electrons deposit energy within first 20 cm



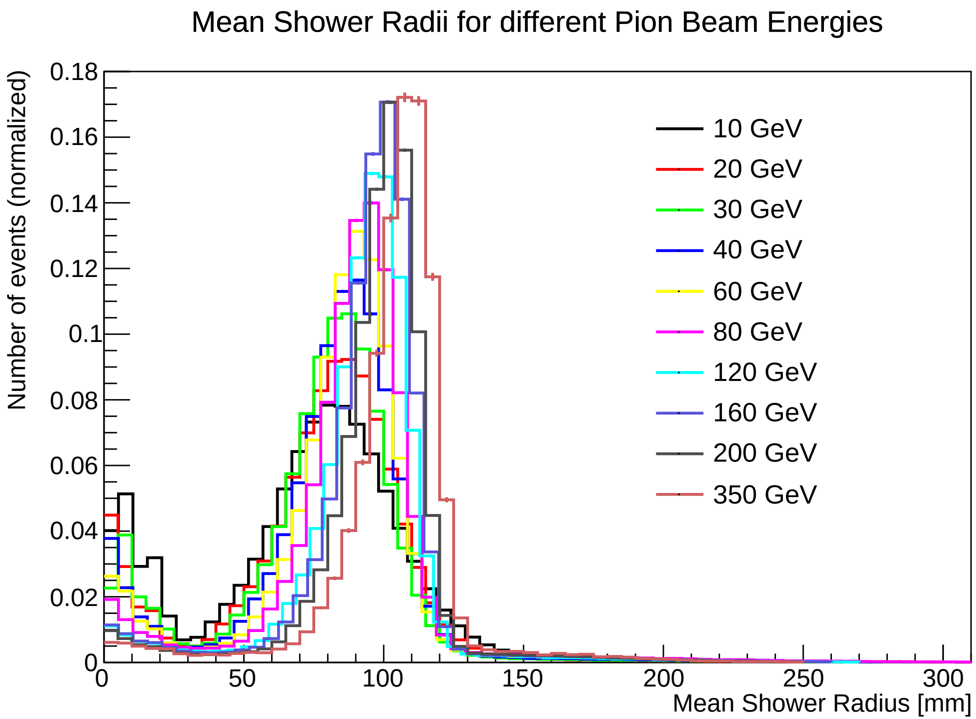
Energy Distributions

- Measured energy varies more intensely for higher beam energies
  $\Rightarrow$ Broader distributions with smaller peaks



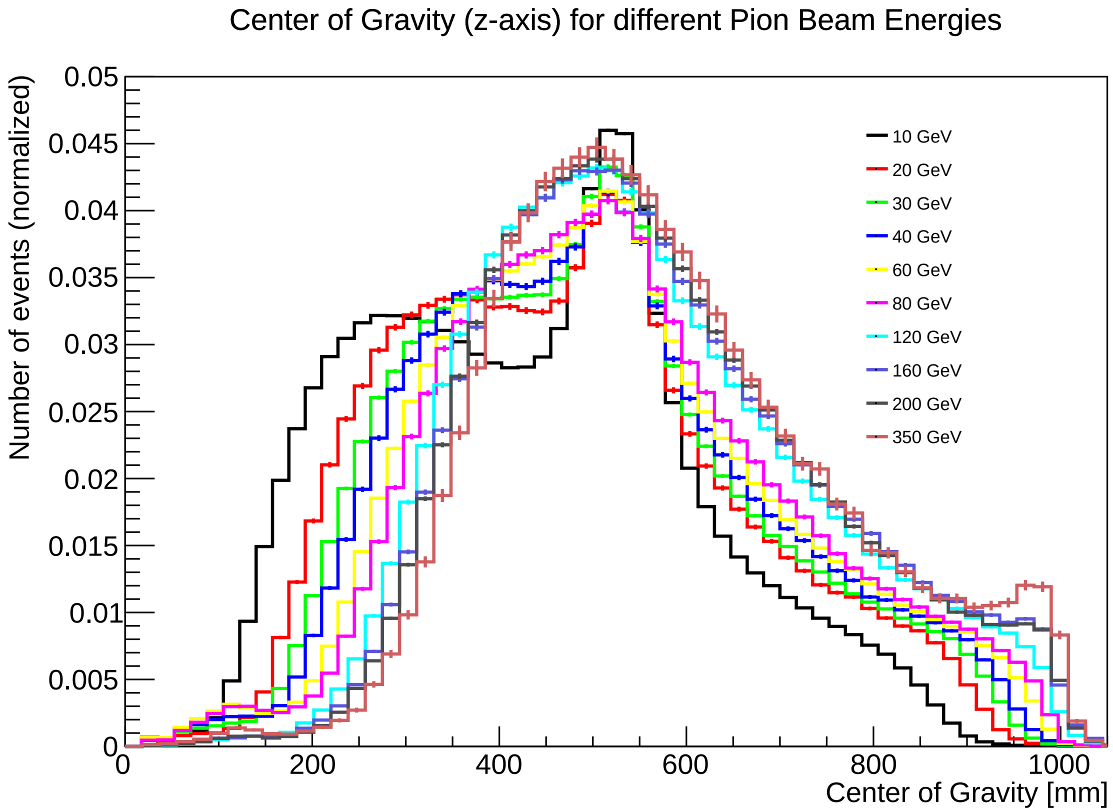
Transversal Shower Radii

- Shower radii show similar behavior, but grow at higher energies
  $\Rightarrow$ But fluctuations become less
- Also less muons at higher energies



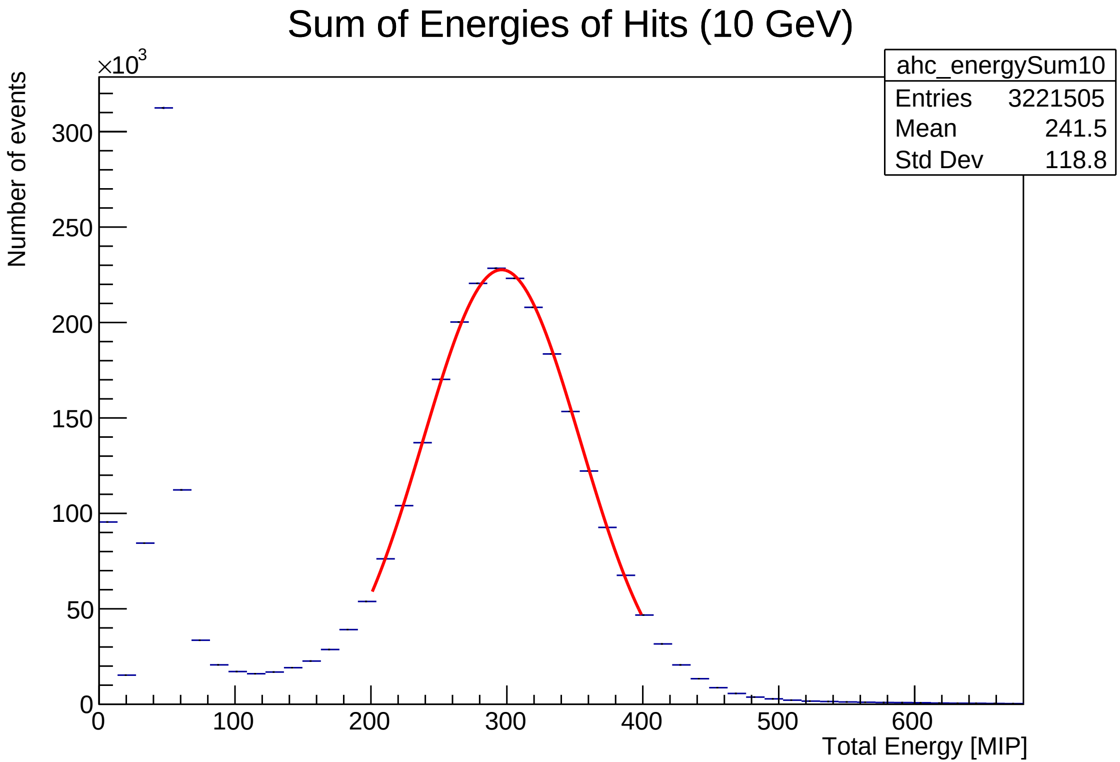
Longitudinal Centers of Gravity

- Energy is deposited over large range of layers



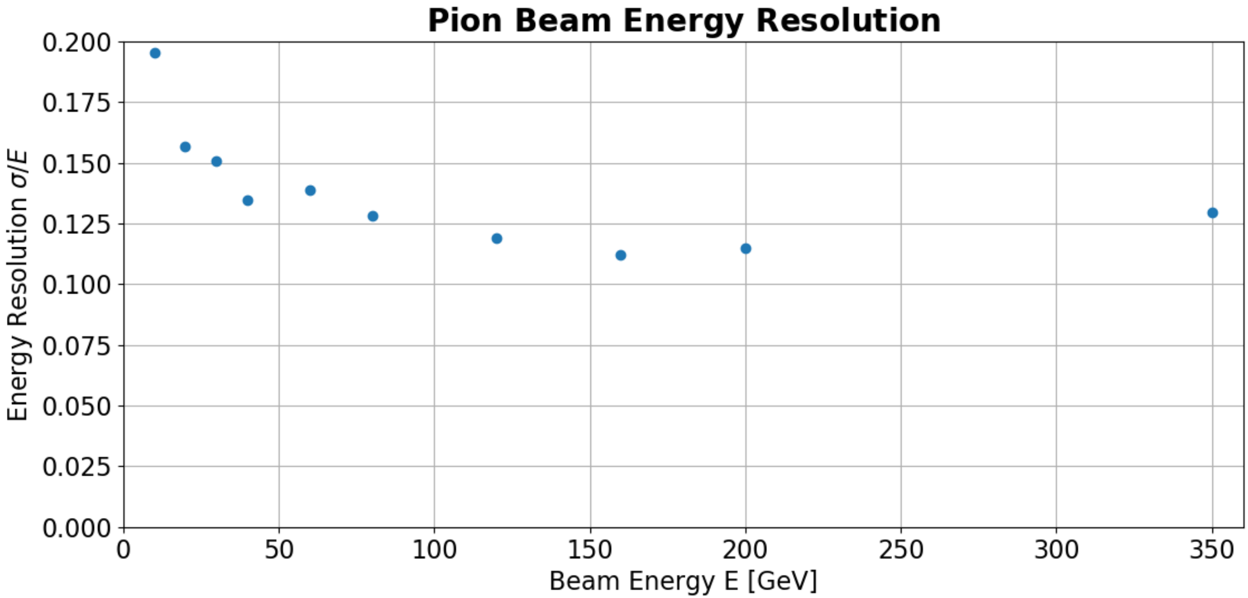
Fit Curves for Pions

- Fit Gaussian bell curve to data within certain interval
  ⇒ Determine mean and standard deviation



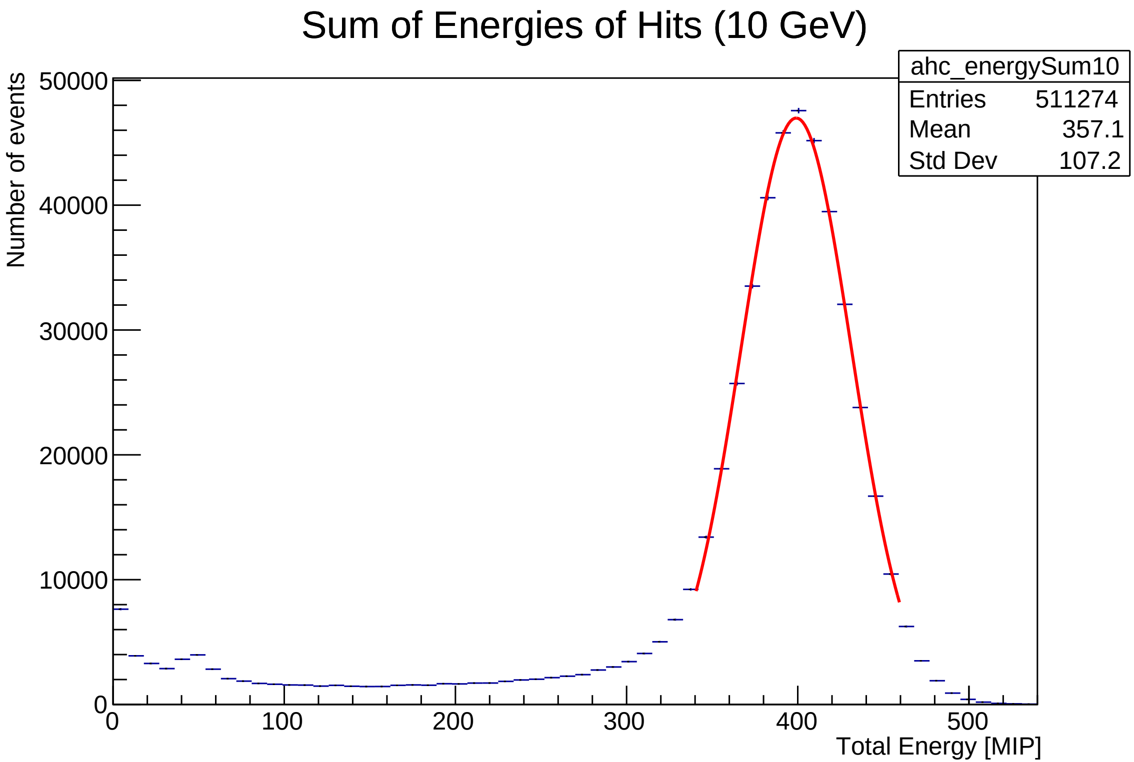
Pion Beam Energy Resolutions

- Expected falling behavior for higher energies
- Resolution ranging between $\sim 20\,\% - 11\,\%$



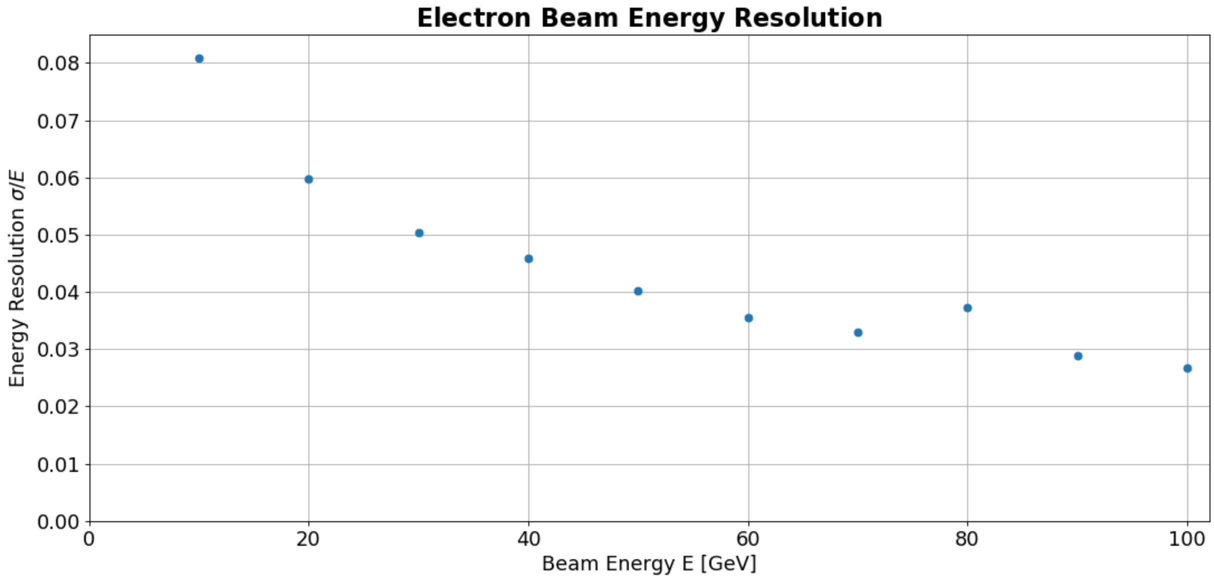
Fit Curves for Electrons

- Same fitting procedure as for pions



Electron Beam Energy Resolutions

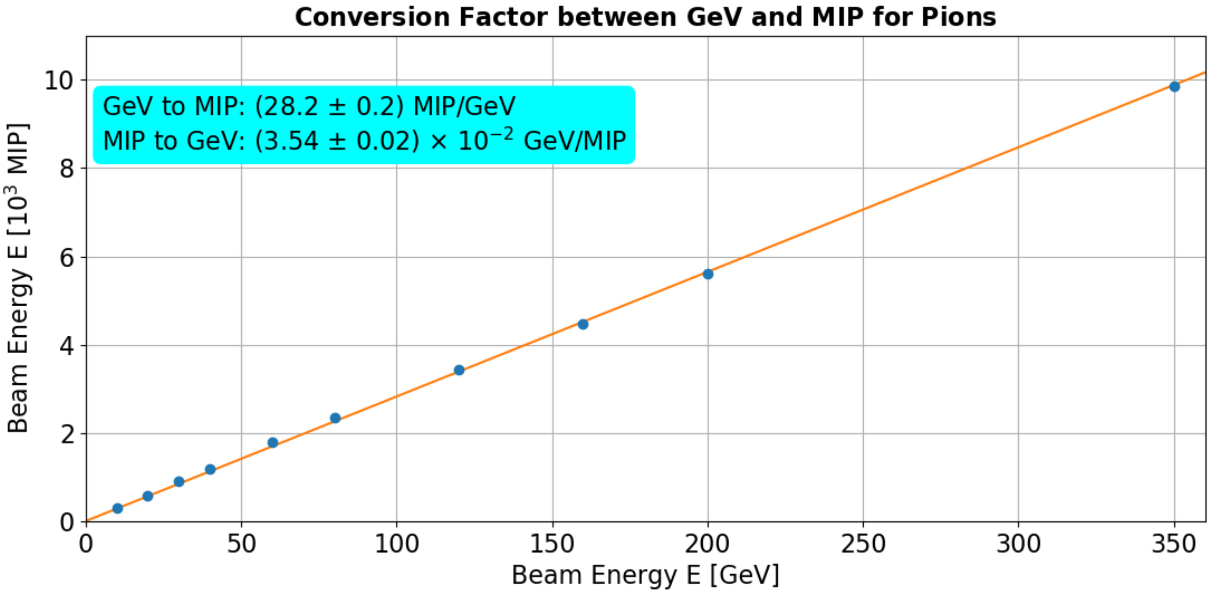
- Resolution far better than for pions (as expected)
- Resolution ranging between $\sim 8\,\% - 3\,\%$



Conversion Factors - Pions

- Plot mean (from fits) versus beam energy
- Fit linear function of form $f(x) = mx$
- Nominal conversion factors: $2.68 \times 10^{-2}\,\mathrm{GeV\,MIP^{-1}}$ or $37.3\,\mathrm{MIP\,GeV^{-1}}$

  $\Rightarrow$ Results less accurate due to worse energy resolution

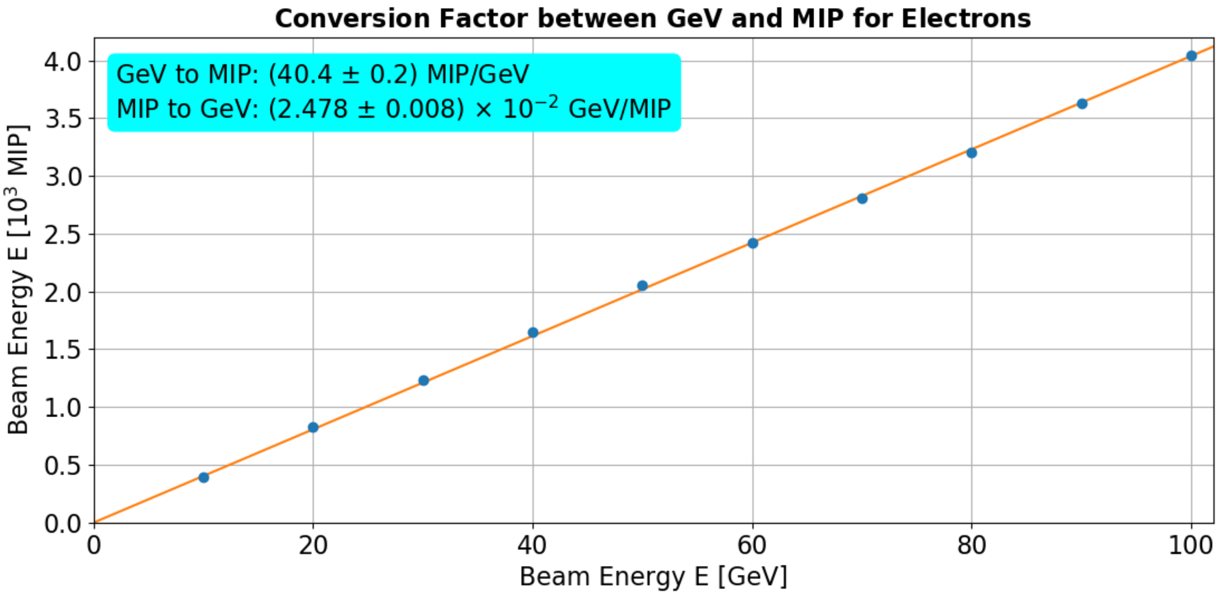


Conversion Factors - Electrons

- Also fit $f(x) = mx$ for electron data
- Compare again with $2.68 \times 10^{-2}\,\mathrm{GeV\,MIP^{-1}}$ and $37.3\,\mathrm{MIP\,GeV^{-1}}$

  $\Rightarrow$ Conversion factors more precise than those from pion fits

  $\Rightarrow$ Still room for improvement, though



Conclusions and Outlook

Conclusions:

- First look for myself at AHCAL test beam data
- Features make sense and match expectations
- Obtained good understanding how to analyze AHCAL data format

Outlook:

- Parametrize pion showers analytically (i.e. Olin's studies)
- Create probability density distributions of fit parameters
- Investigate fit parameter distributions
  $\Rightarrow$ Extrapolate to different energies
- Build Fast Simulation based on analytical functions
  $\Rightarrow$ Simulate pion showers and compare with data
  $\Rightarrow$ Investigate mismodeling
  $\Rightarrow$ Will allow tuned simulation without using GEANT4
  $\Rightarrow$ Possibly extend to electron showers

The End

Thanks for your attention!