Time Measurements with the CALICE Analog Hadronic Calorimeter

DPG Frühjahrstagung
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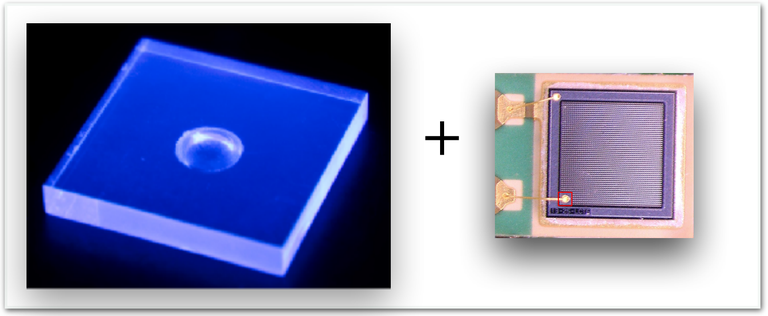
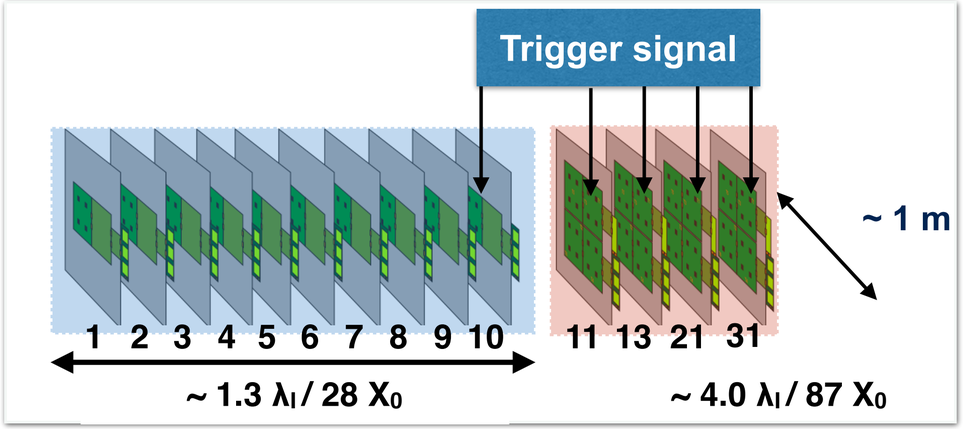
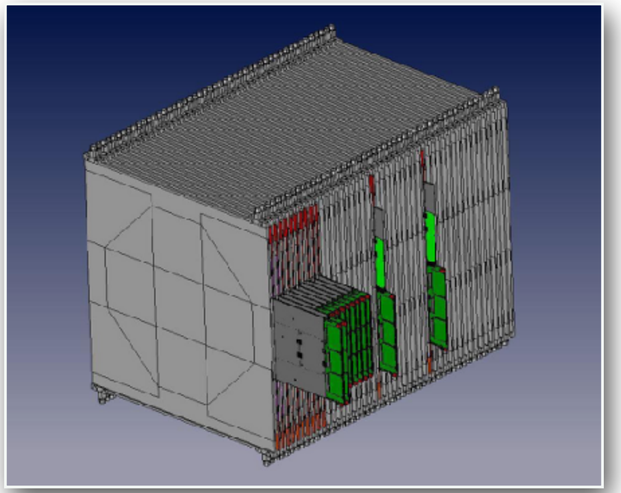
CALICE AHCAL Technological Prototype

2001	2006	2015	2015 - Present	Present	???
CALICE founded	Physics prototype	Technological prototype	**Prove concept of techn. prototype**	Large techn. prototype	Full Detector
	Talk by Y. Israeli			**Talk by P. Chau** **Talk by S. Martens**	

- tungsten absorber stack
  λ_I: 10.8 cm, X_0: 0.4 cm
- 3x3cm scintillating tiles with SiPM readout
- 8 small layers (4x36 channels), 4 big layers (16x36 channels)
- 3456 total channels
- H6 at SPS beam line







Data:

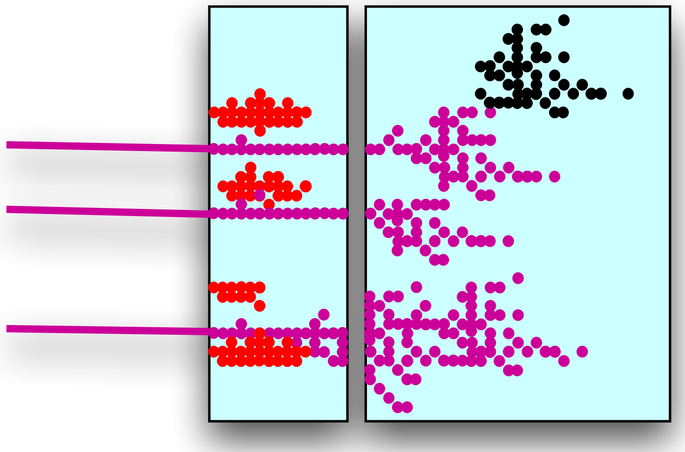
- 120 GeV Muons
- 20 GeV Electrons
- 10, 30, 50, 70, 90GeV Pions

Motivation: Time Analysis

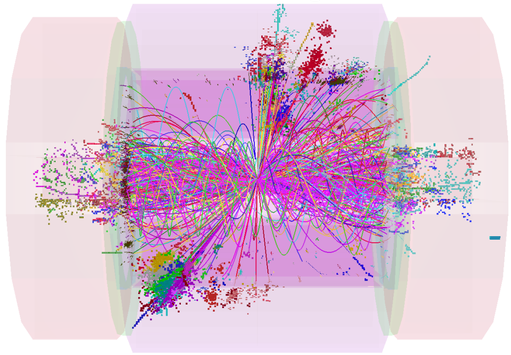
1) Time based clustering
2) Background rejection (CLIC)
3) Discriminate components in hadronic showers by time
   "Software-compensation-like"

   Complex time structure of hadronic showers due to slow neutrons

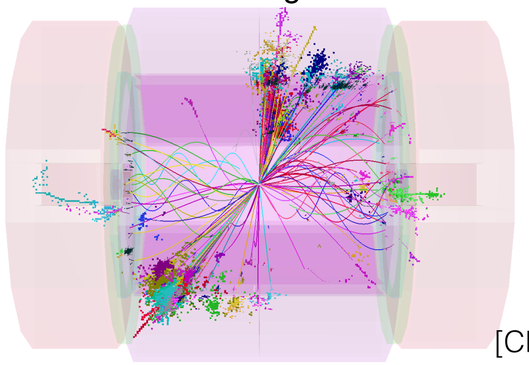
—> Time Resolution ~1ns needed



Before timing cut



After timing cut

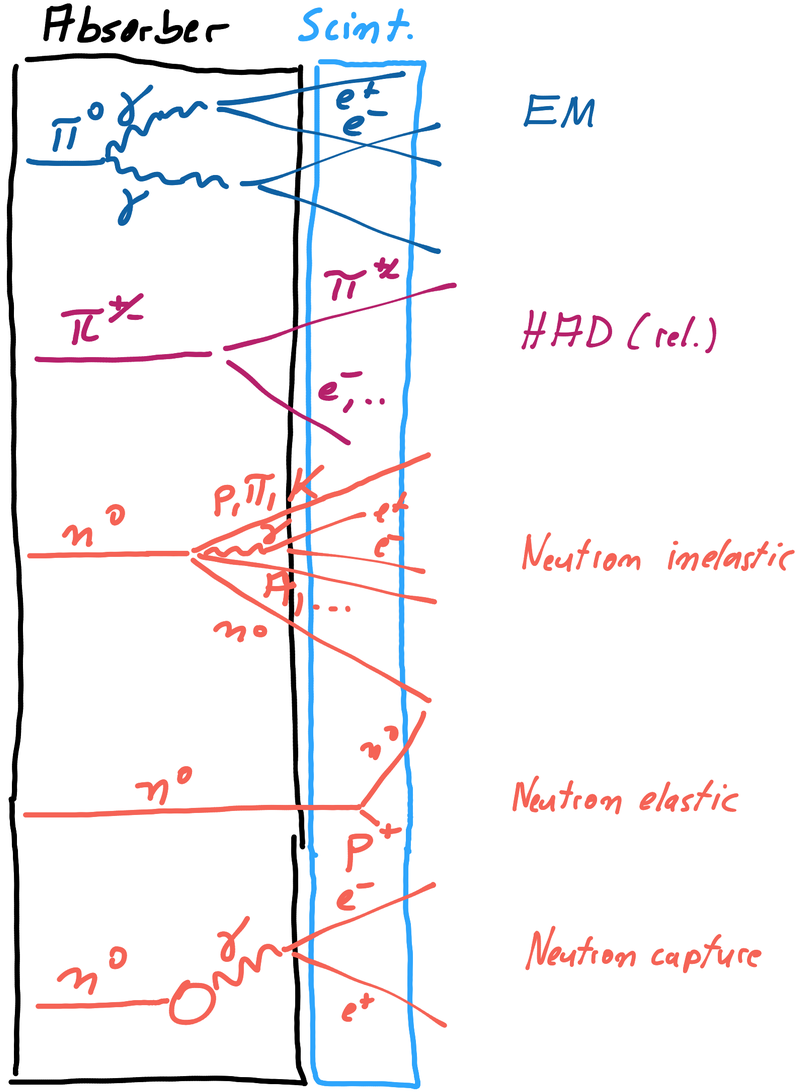


[CLIC CDR: 1202.5940]

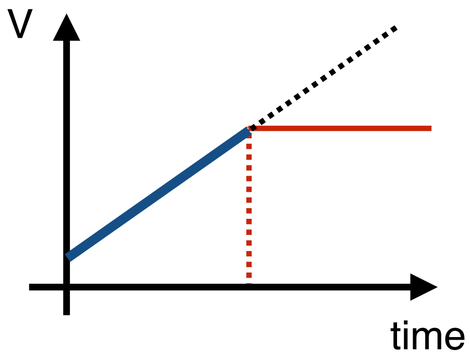
Quasi instantaneous

Intermediate ~10ns - 50ns

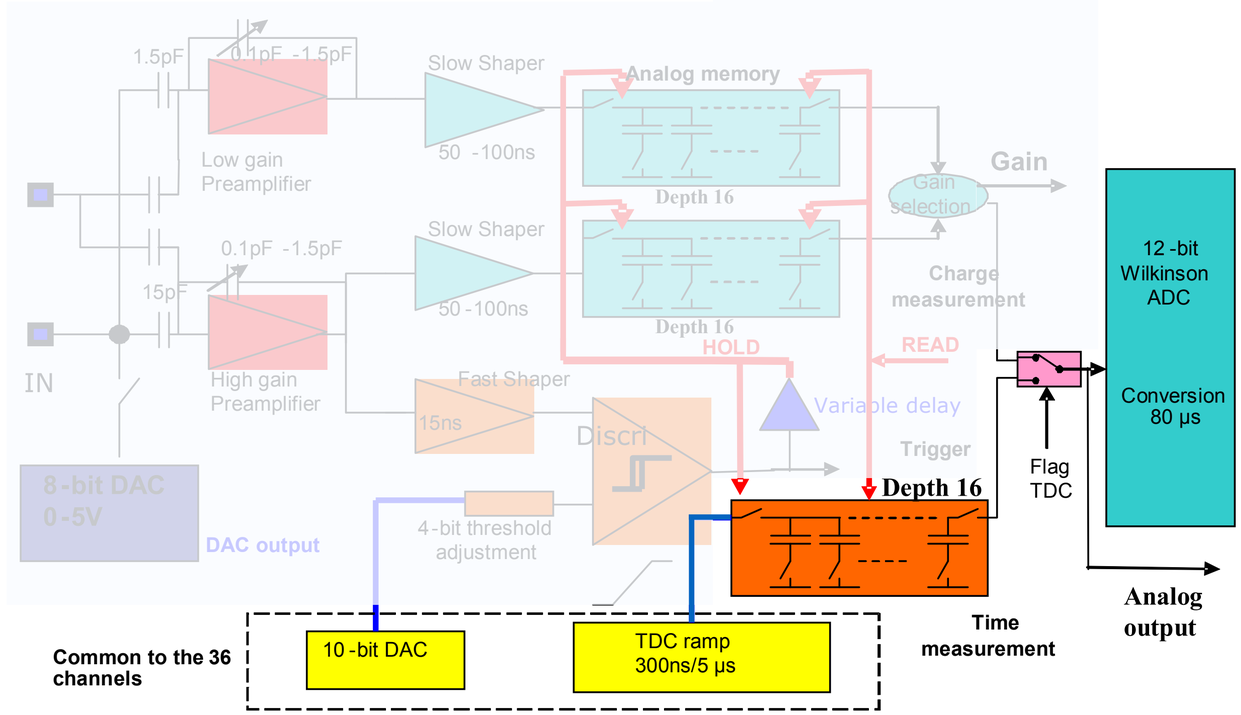
Late > ~50ns



Timing with Spiroc2B

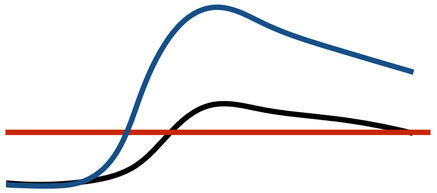


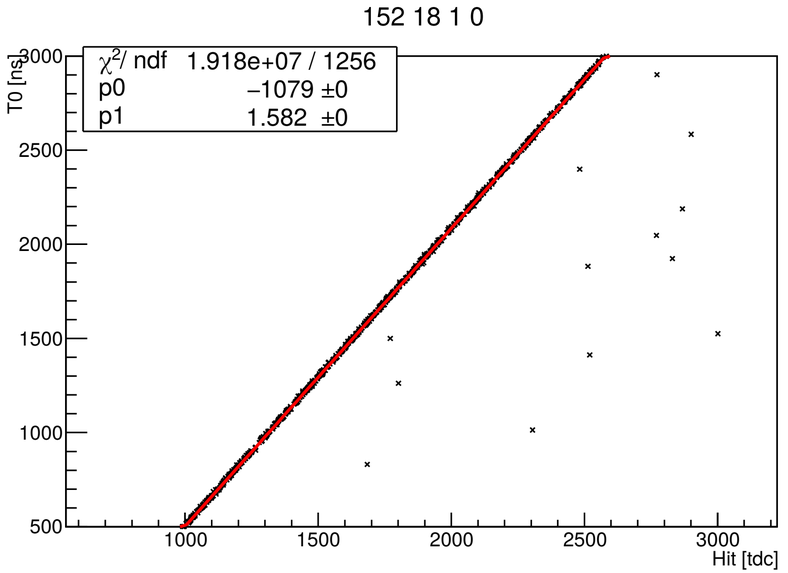
- Voltage ramps up linear in time
- Two ramps are used alternately to avoid edge effects
- On a hit, the ramp voltage is stored in one of 16 memory cells.
- Digitized by ADC -> ***TDC* values**
- Slope:
  ~1.6 ns / TDC (test beam mode)
  ~ 80 ps / TDC (ILC mode)

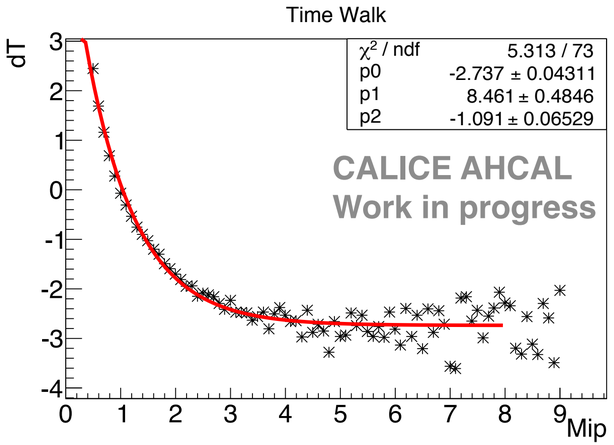


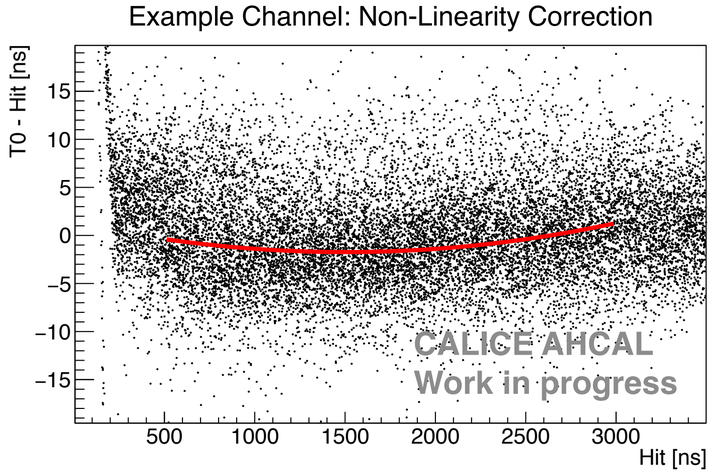
Time Calibration

- Calibrate all other channels with respect to time reference (T0s, or BIF)
  - *TDC* to *ns* conversion
    - linear fit (precision on per mill level needed)
    - 2 slopes for each chips
    - pedestal for each channel and memory cell
  - Non-linearity correction
    - quadratic fit for each slope
  - Time-walk correction

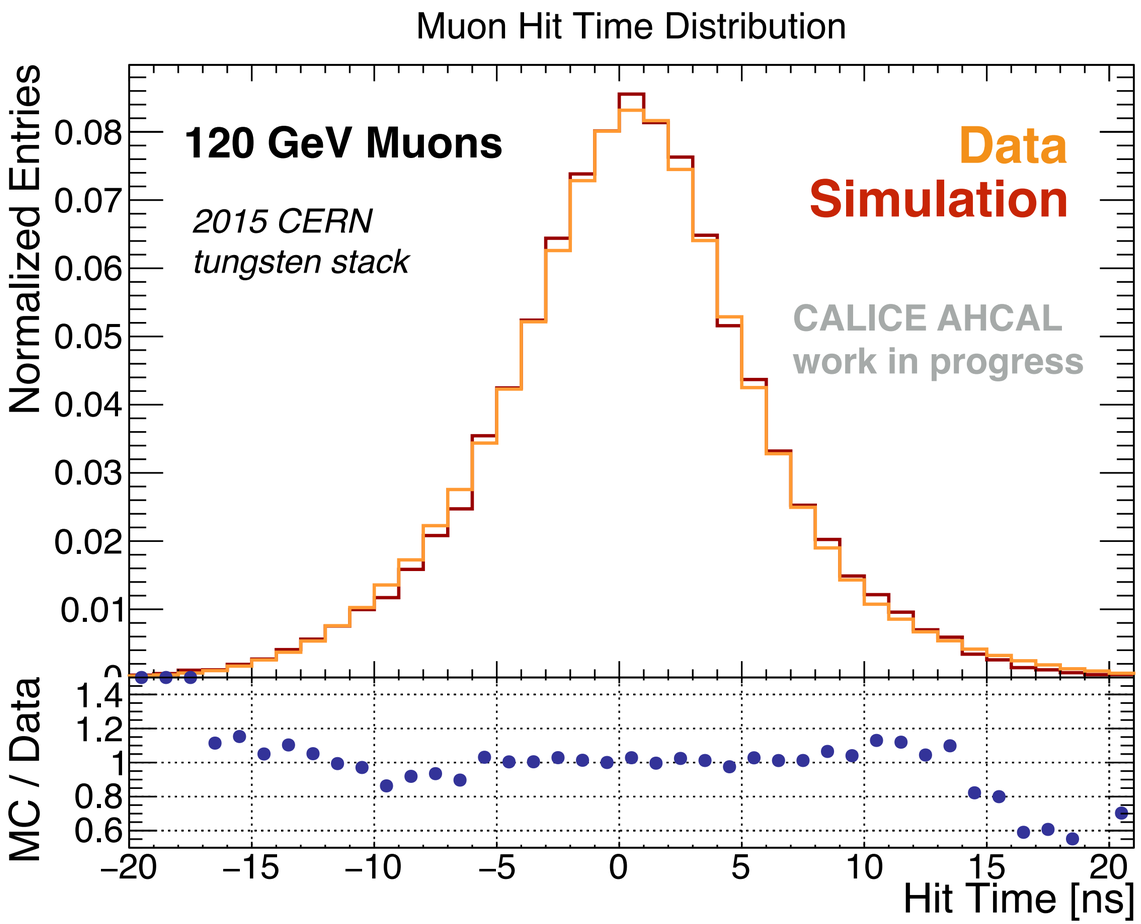


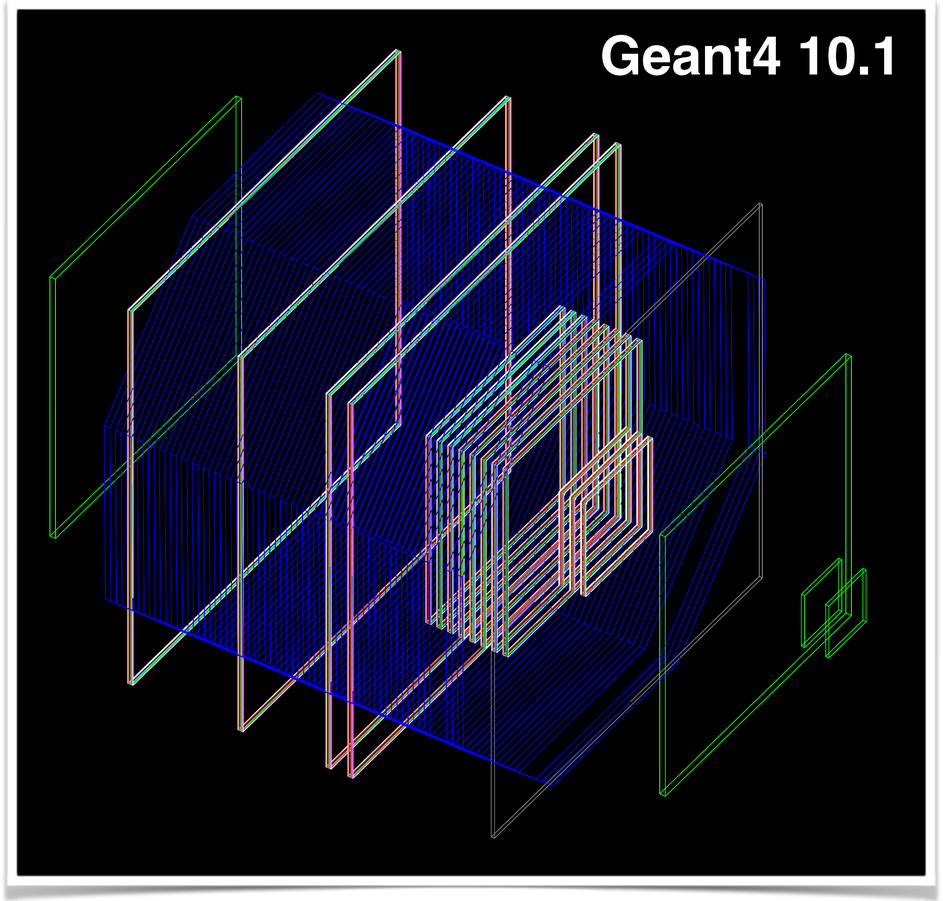






Muon Time Resolution

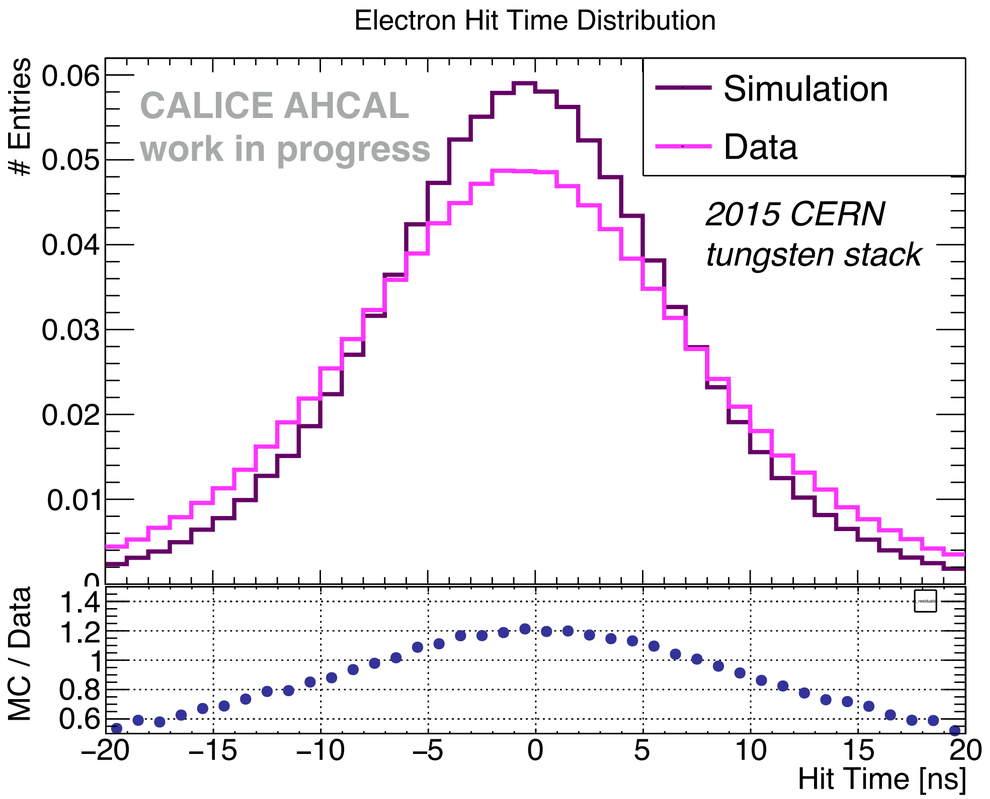




Time Resolution:
~10ns (FWHM), 5.6ns (RMS)

Used as input for MC time smearing

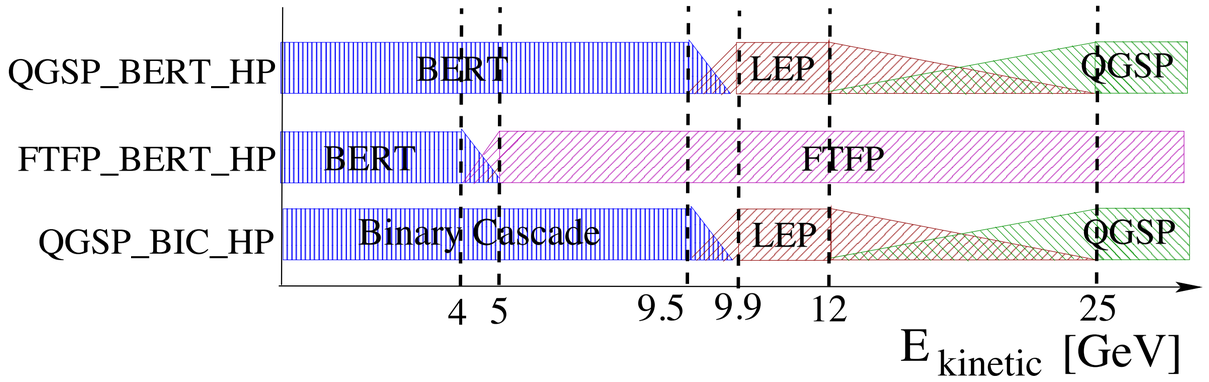
Electromagnetic Showers

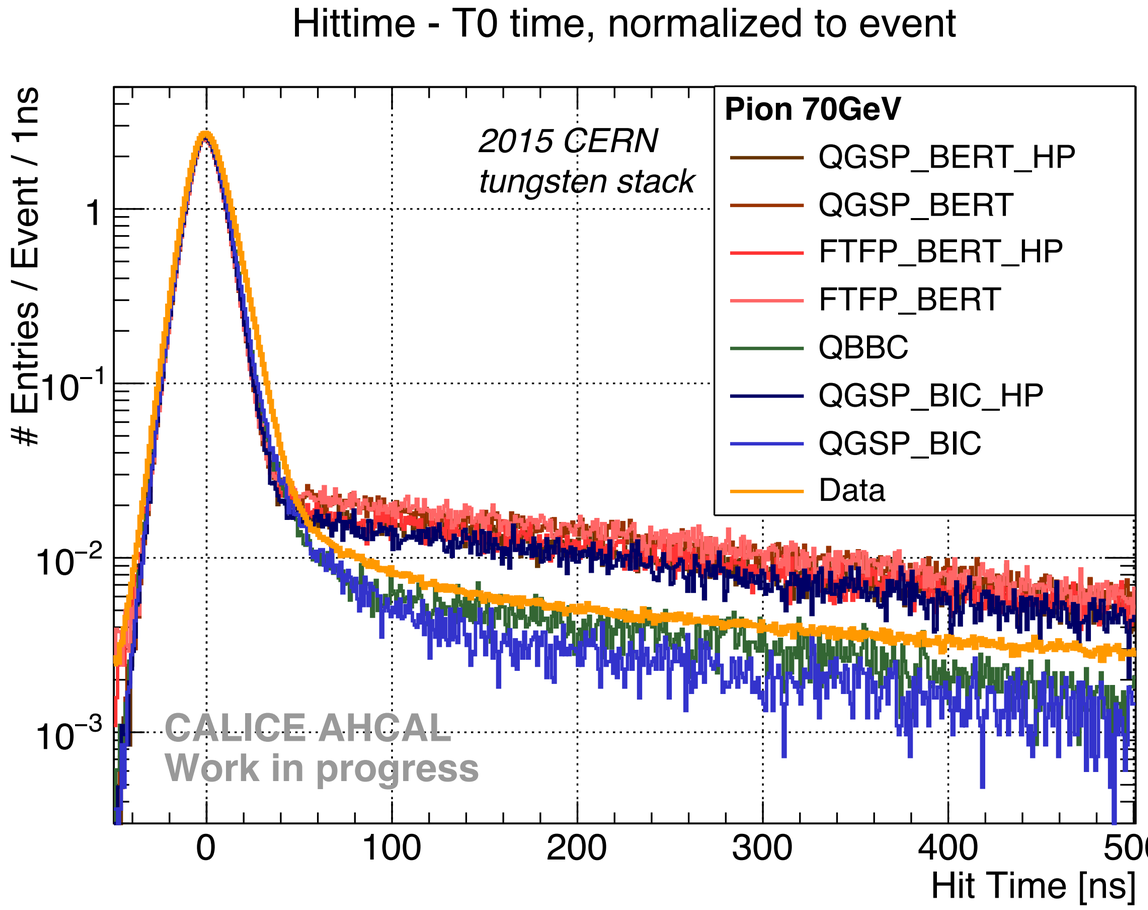


- Time resolution of electromagnetic showers gets worse
- Effect of the electronics: base-line shift and worse resolution for **high occupancy in chips**
- Mismatch between data and simulation can be explained by higher occupancy in first layer of simulation

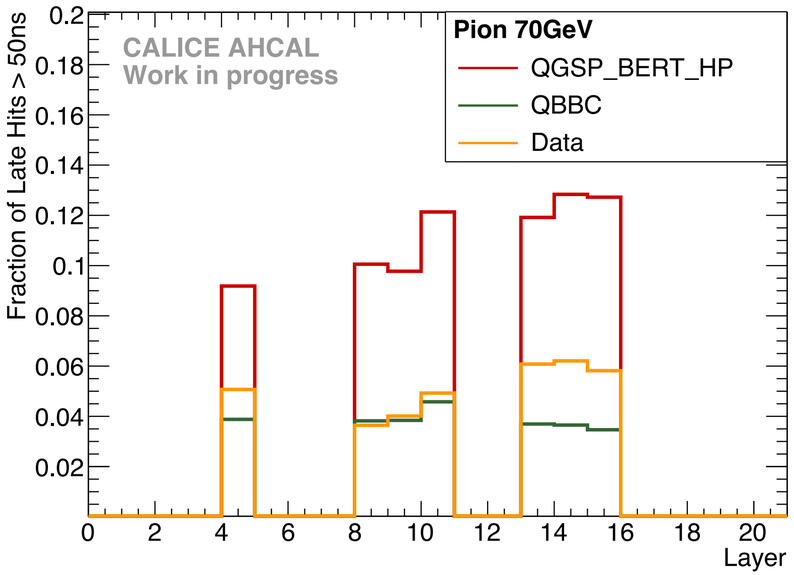
Time Measurement of Hadronic Showers

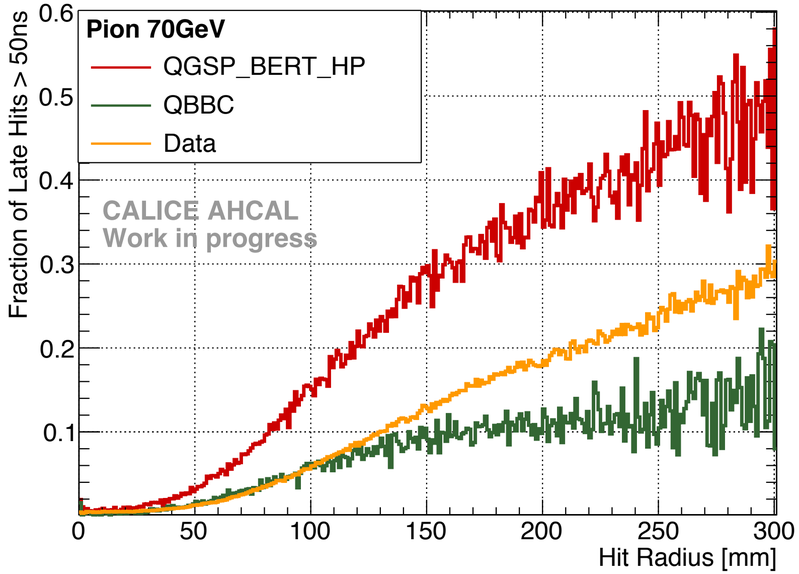
- Pion time distribution compared to several physics lists
- Bertini and HP physics lists overestimate late tail by factor ~2

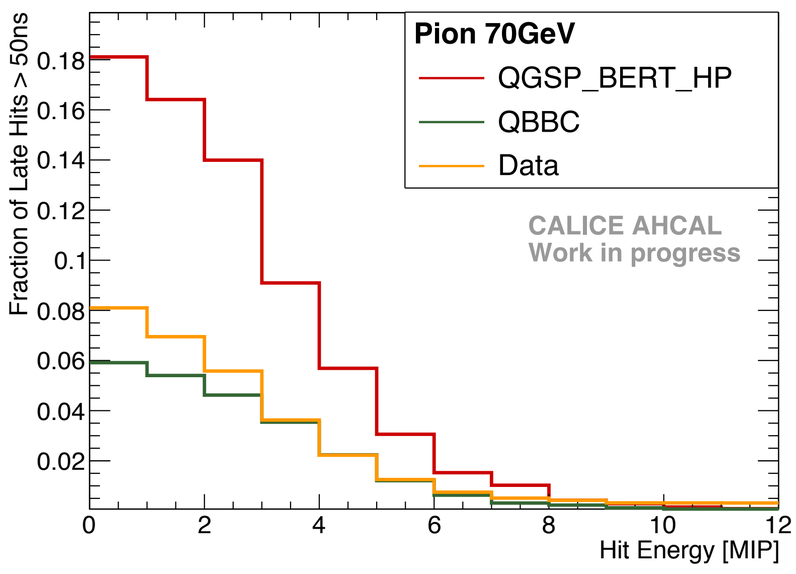




Time Measurement of Hadronic Showers



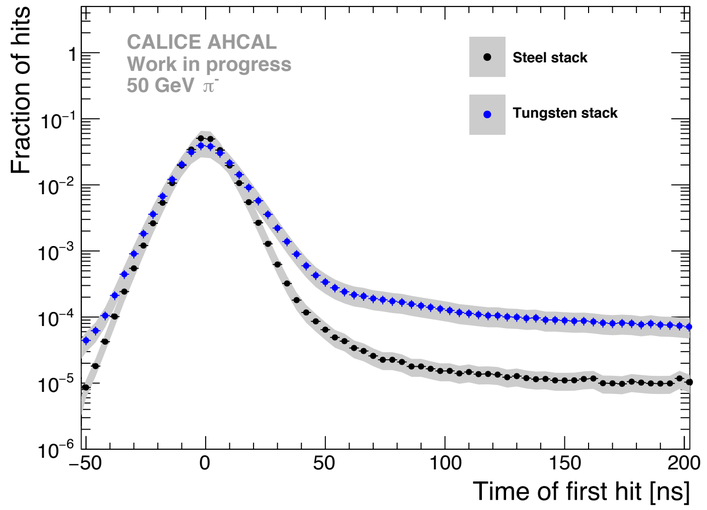




- Consistently more late hits for QGSP_BERT_HP
- QBBC is missing some late hits at bigger radii and lower energies

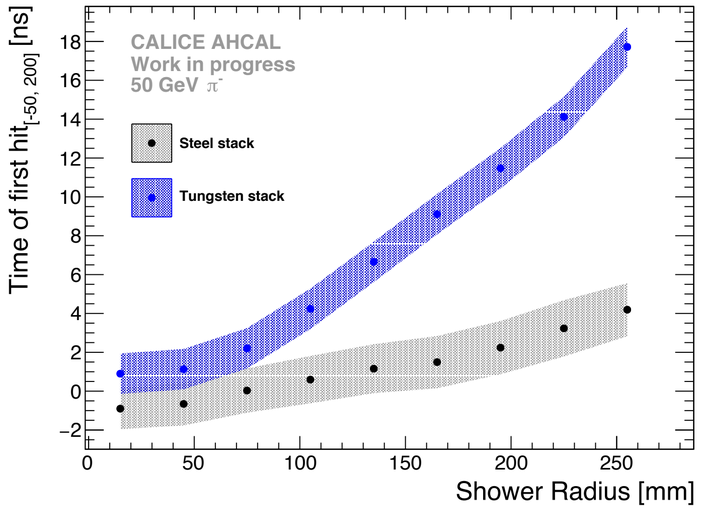
Time Measurement of Hadronic Showers

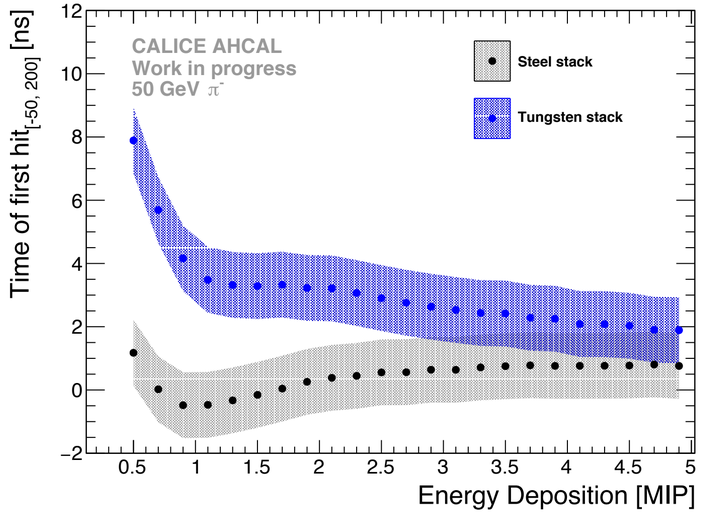
- Steel data: Independent analysis by E. Brianne
- ~10 times more hits for tungsten absorber compared to steel
- Later low energy depositions
- Later hits with large distance to shower axis



More late low energy hits at larger hit radii in tungsten

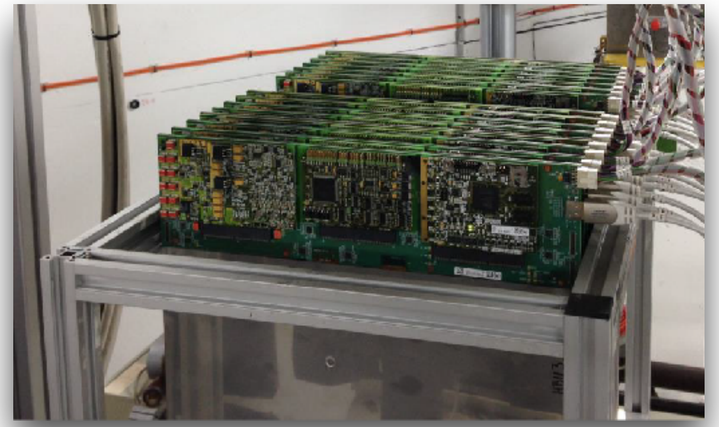
—> More slow neutrons

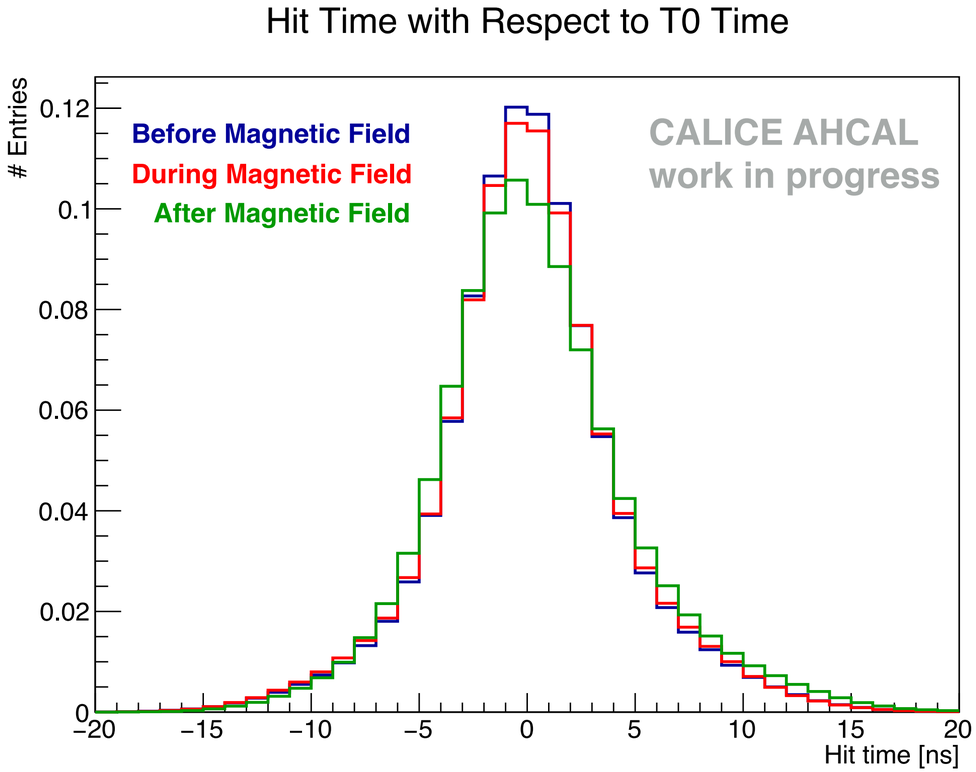




Time measurements in magnetic field

- Test beam with 15 layers in small steel stack in 2017
- Test detector performance in magnetic field
- Beam Interface Board (BIF) gives time reference
- Time distribution stays stable in magnetic field
- **Better time resolution with BIF**





Time Resolution: **5ns (FWHM)**, **4.3ns (RMS)**

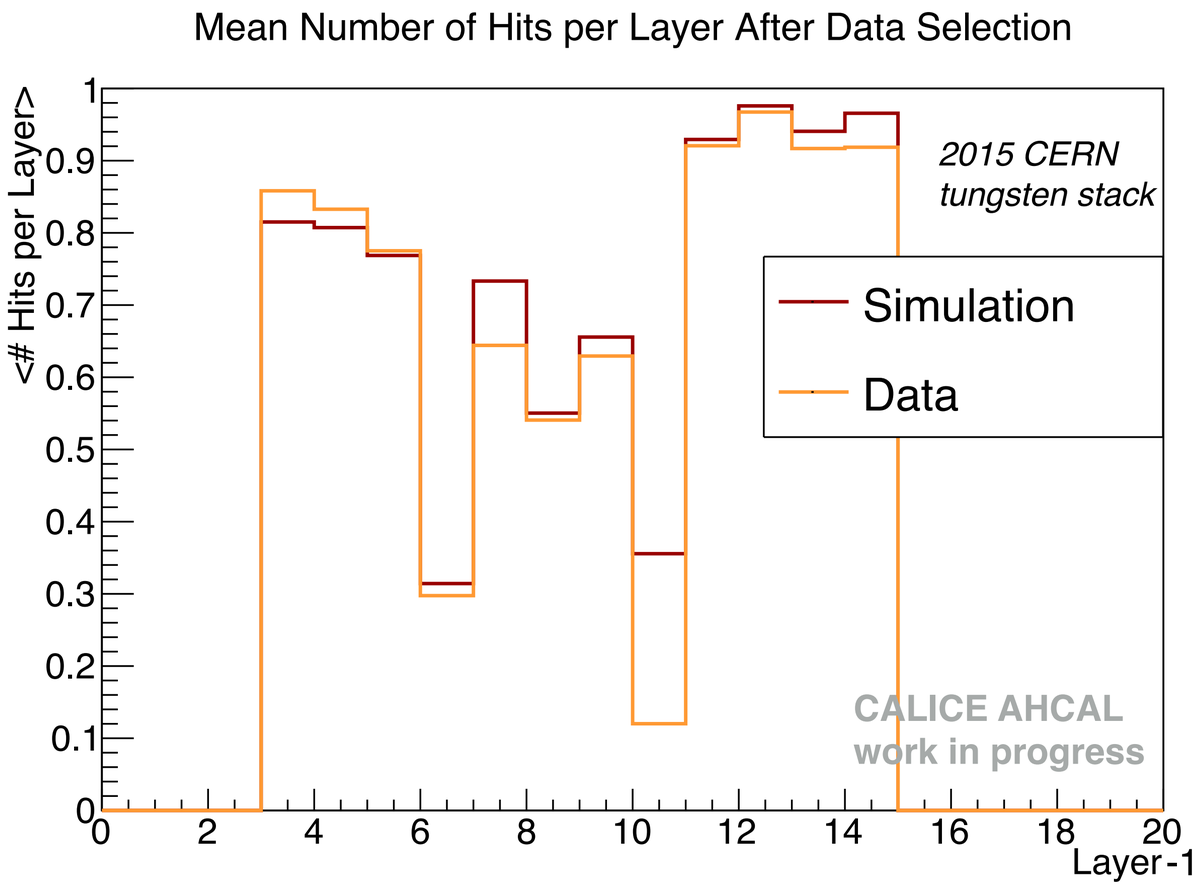
Conclusion

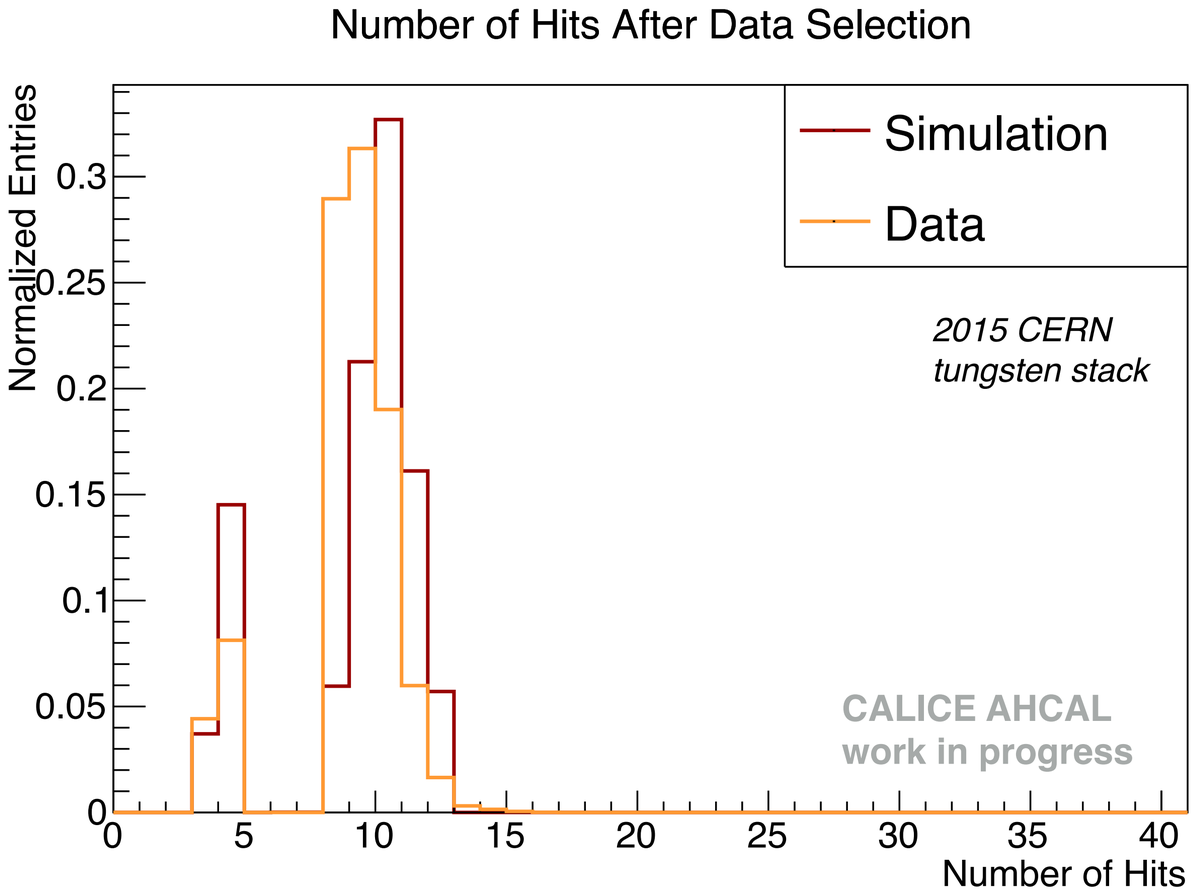
- Working calibration procedure
- Muon time resolution: 10ns (FWHM), 5.6ns (RMS)
- We are able to perform time analysis of hadronic showers with the AHCAL technological prototype

- Two times more late hits seen in QGSP_BERT_HP (and similar) physics lists for tungsten
- Late hits due to slow neutrons with low energy deposition mainly at the outer part of the shower
- Looking forward to data taking of new large prototype this year!

Backup

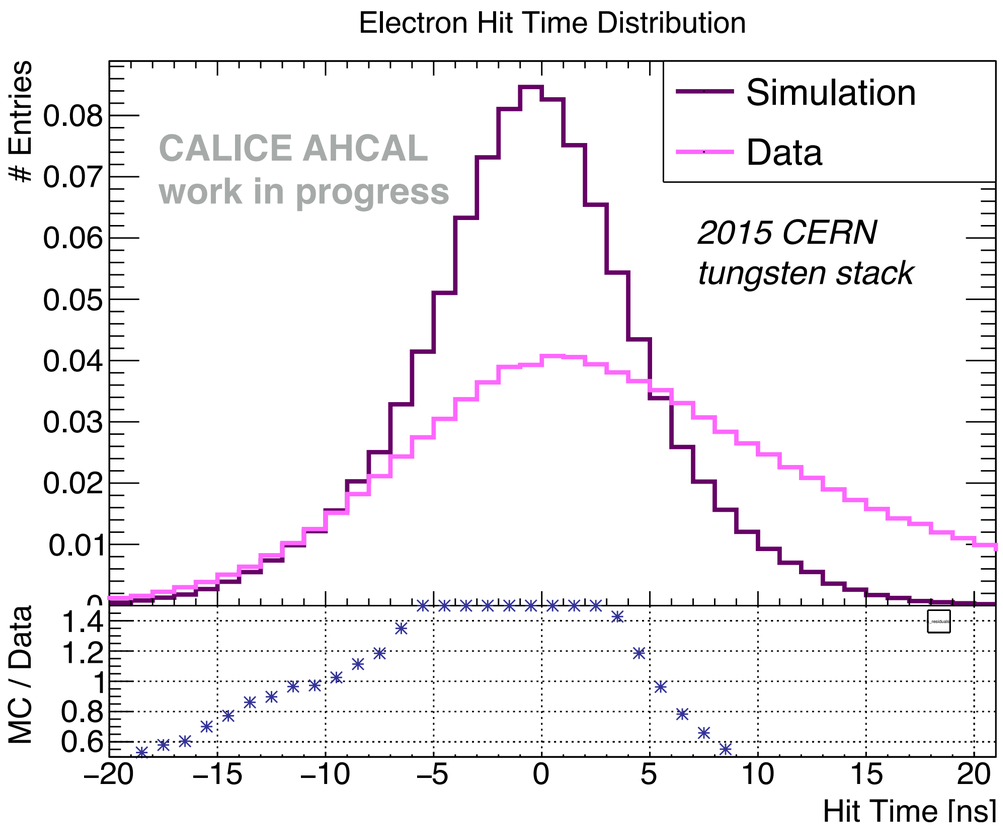
Data Quality Muons





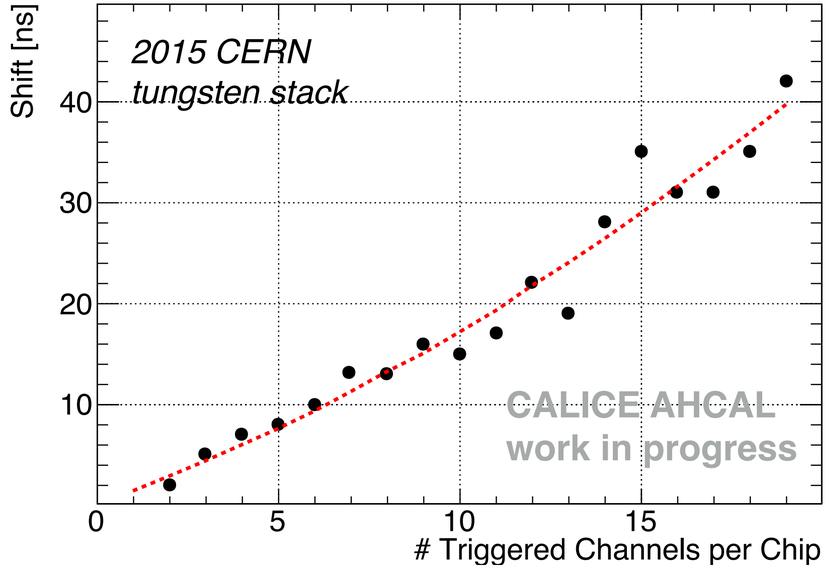
- Inefficiencies especially in Layer 11
- **ToDo**: Update map of dead channels. **Currently**: just exclude layer 11

Electromagnetic Showers



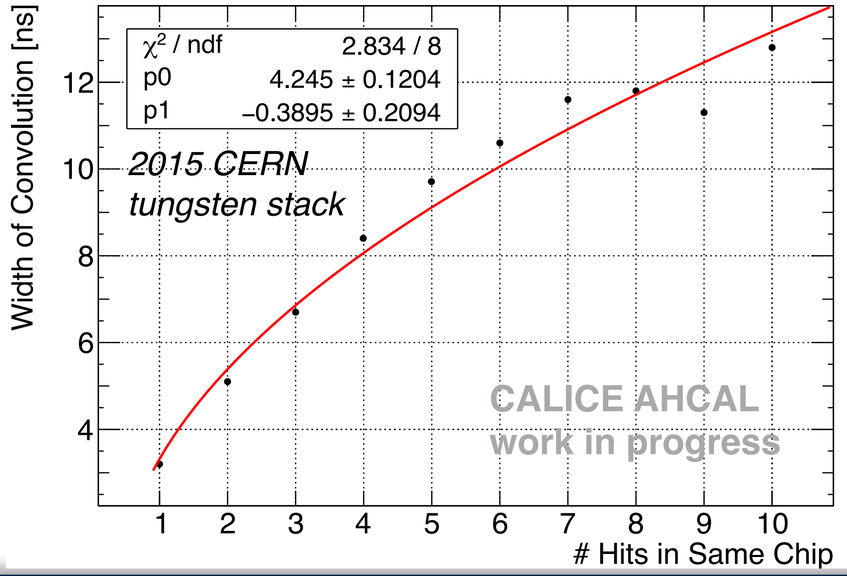
Shift

(Can be corrected)



Worse Resolution

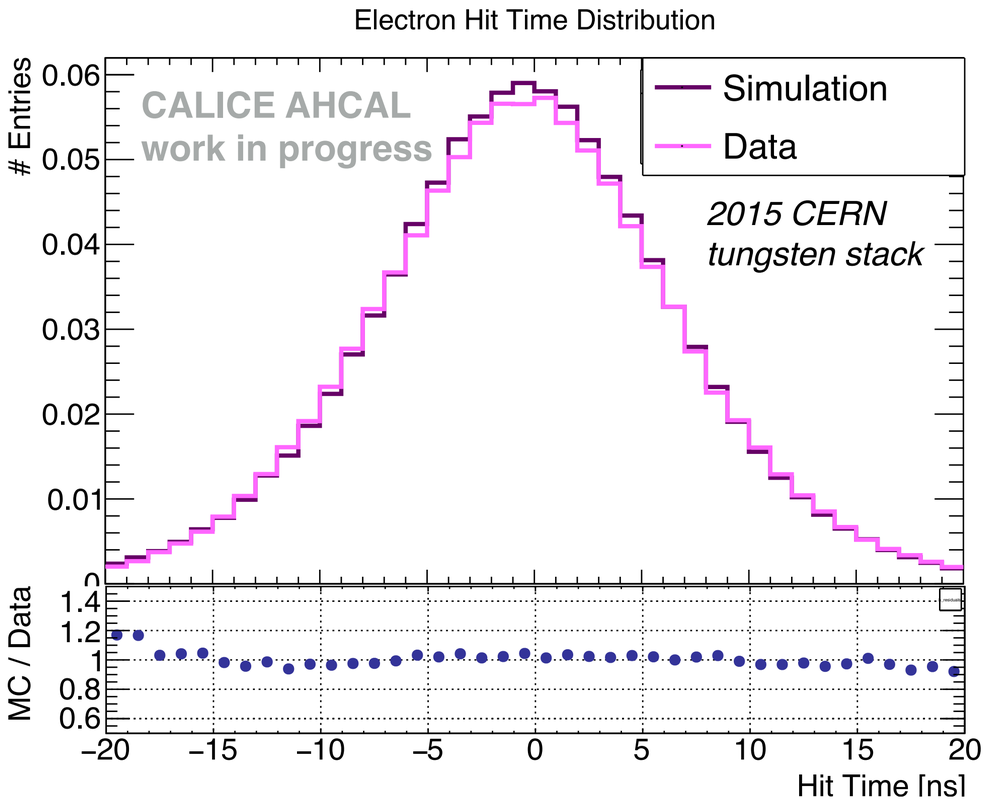
(Input for MC)

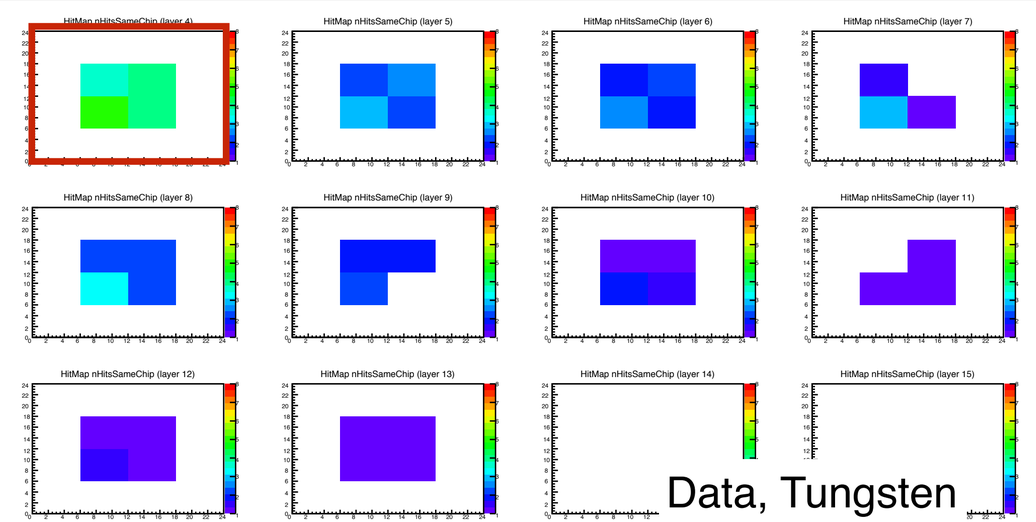


High occupancy in a chip degrades time resolution

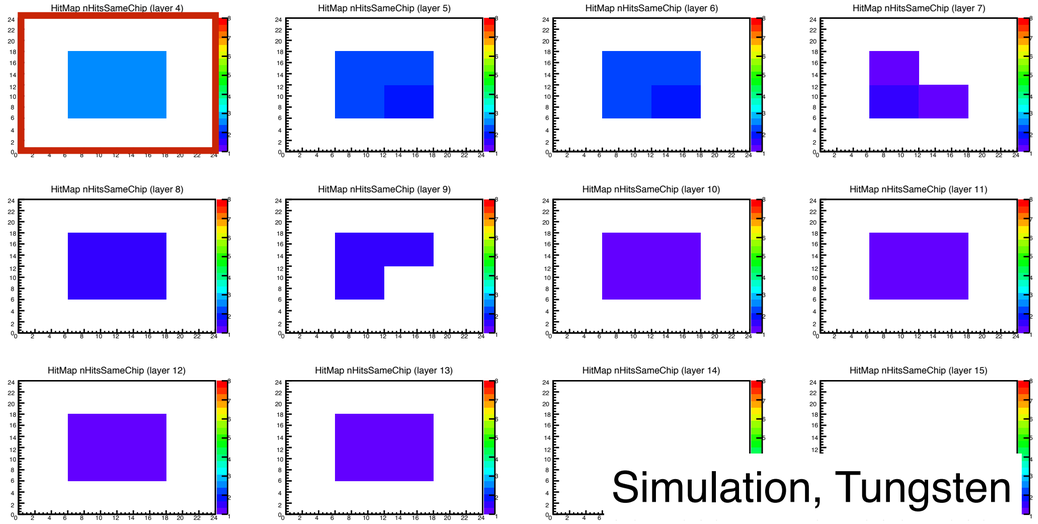
(Will be fixed in new chips)

Electromagnetic Showers





Mean number of hits in each chip per event. Scale from 1 to 8.

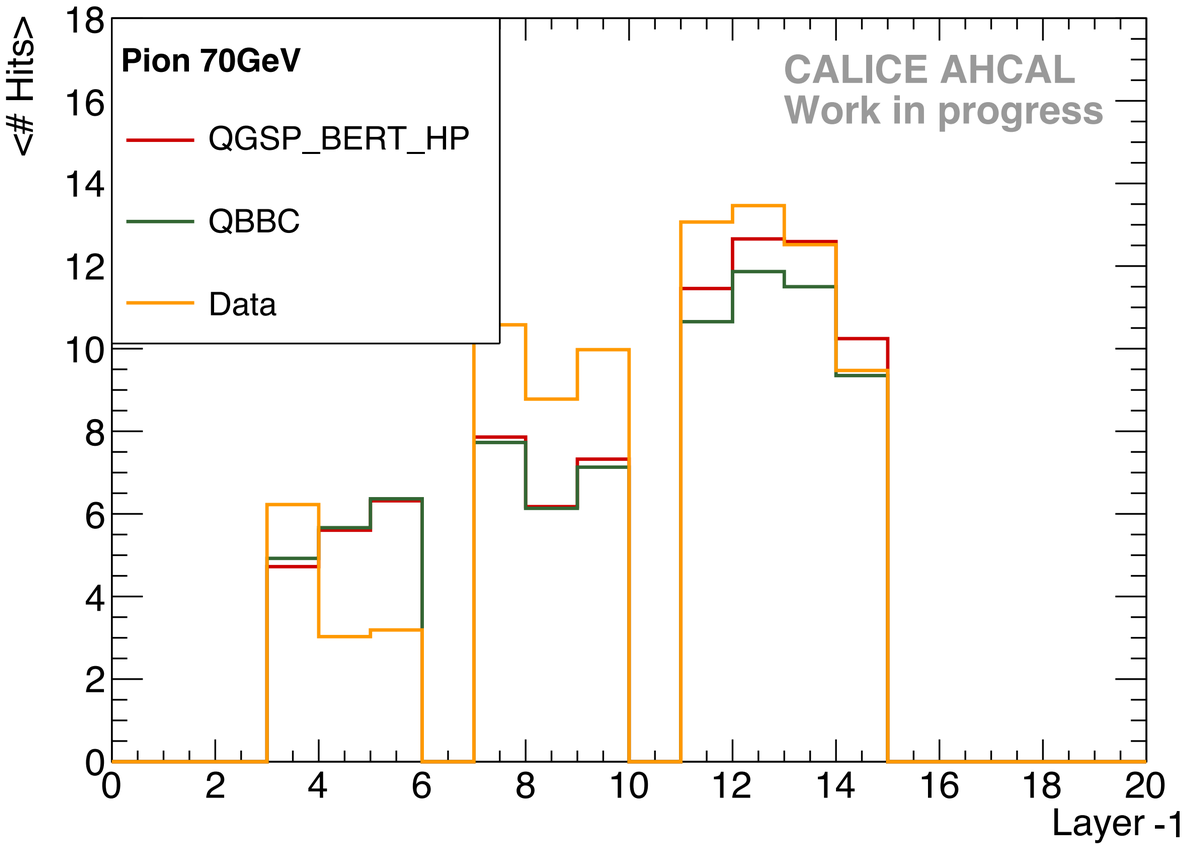


- Difference in number of hits per chip between data and simulation for first layer

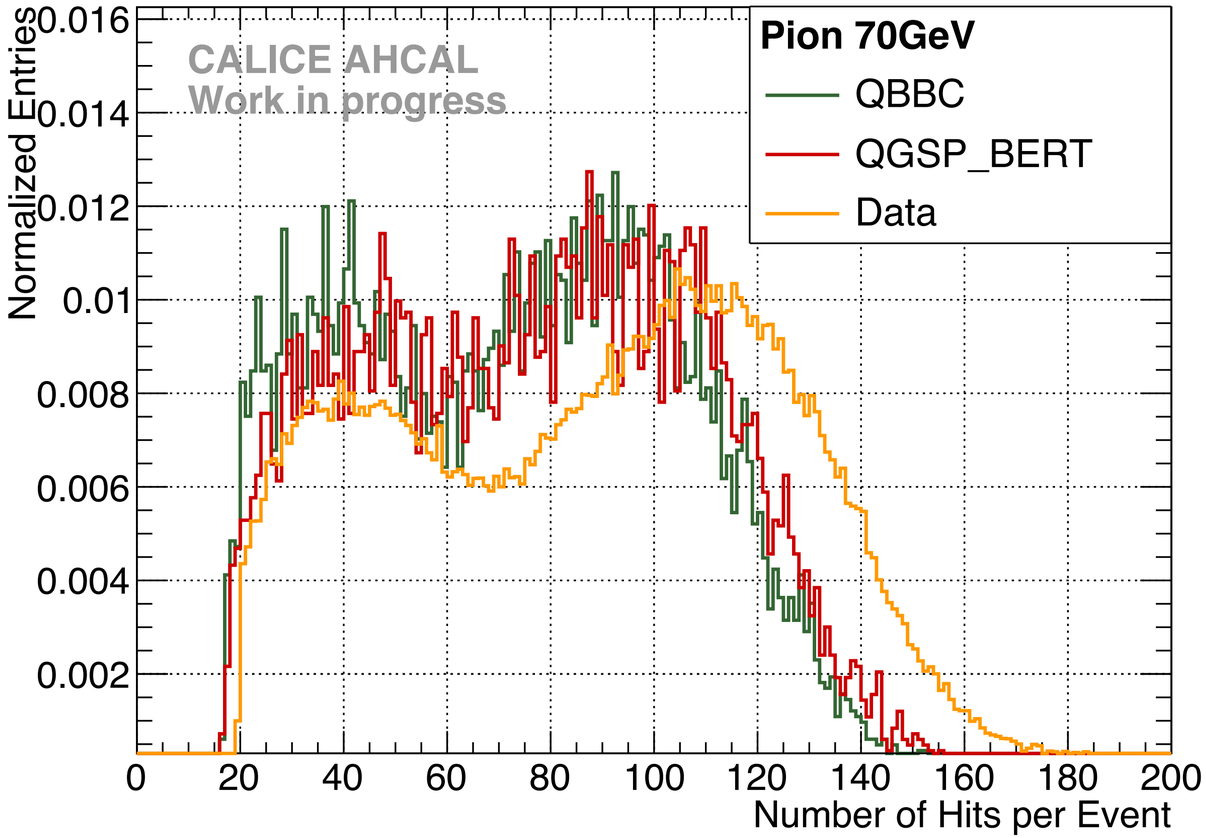
Hadronic Showers

- Less hits in data in layers 5&6 (problematic layers)
- More events with high number of hits in data

Mean Number of Hits per Layer

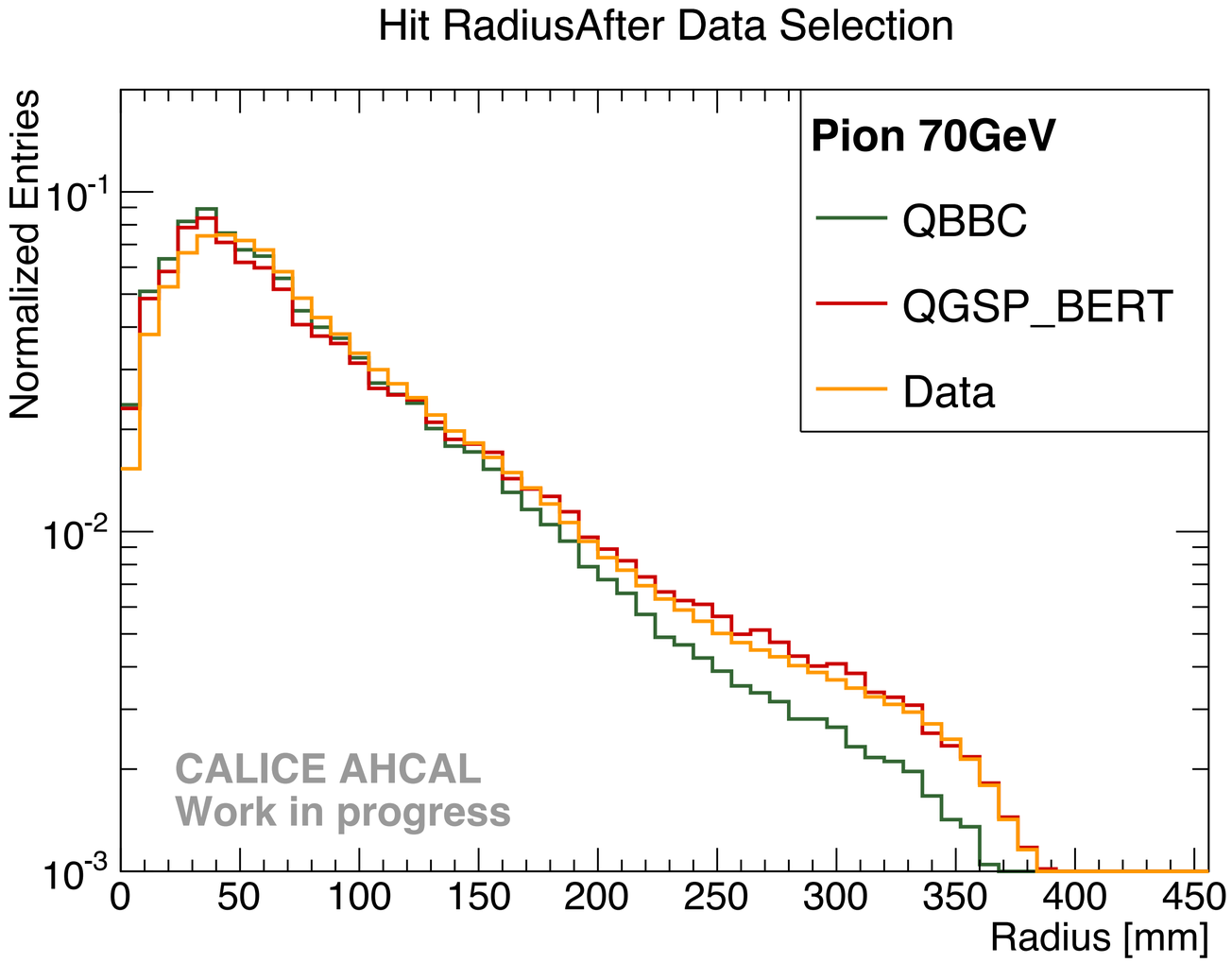


Number of Hits After Data Selection

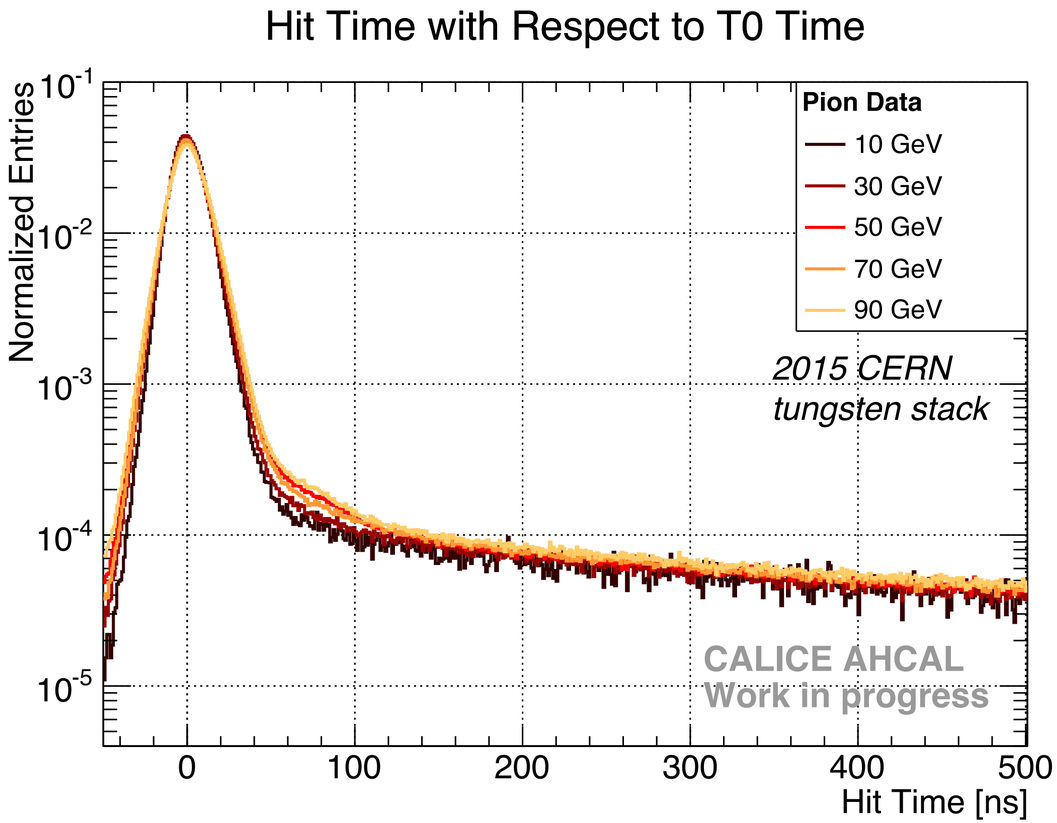


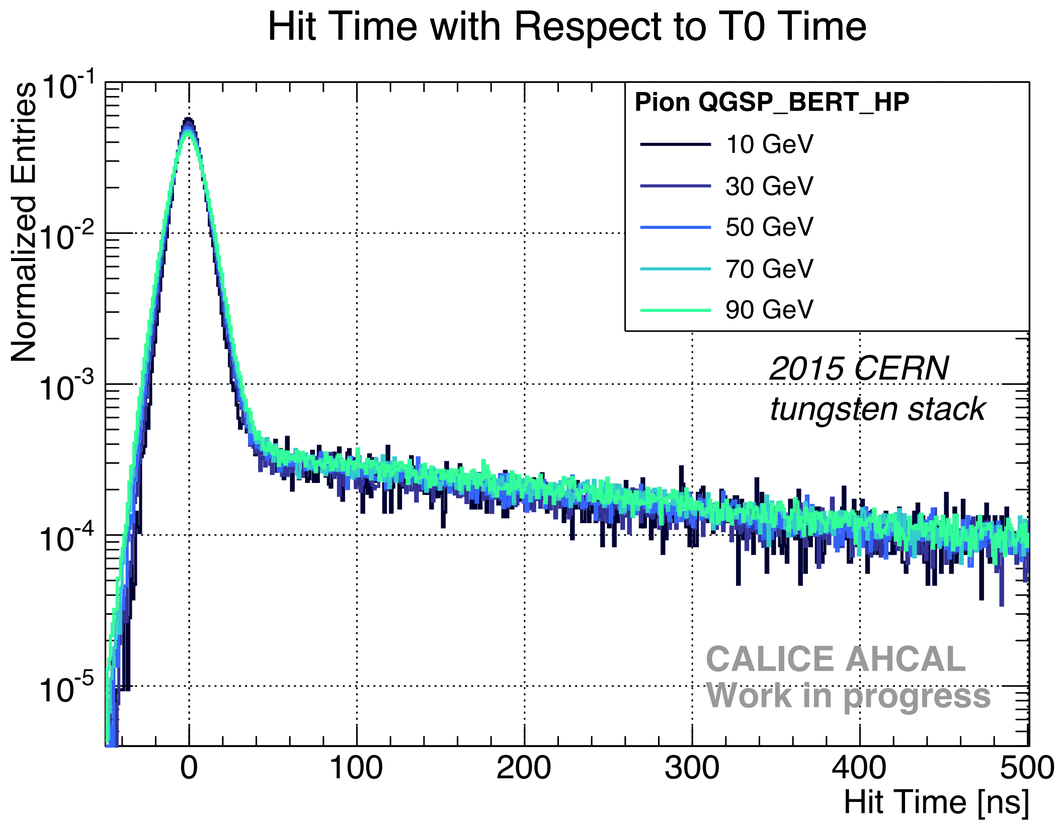
Hadronic Showers

- Distribution of distance of hit to CoG of event is well described by QGSP_BERT_HP



Time Measurement of Hadronic Showers

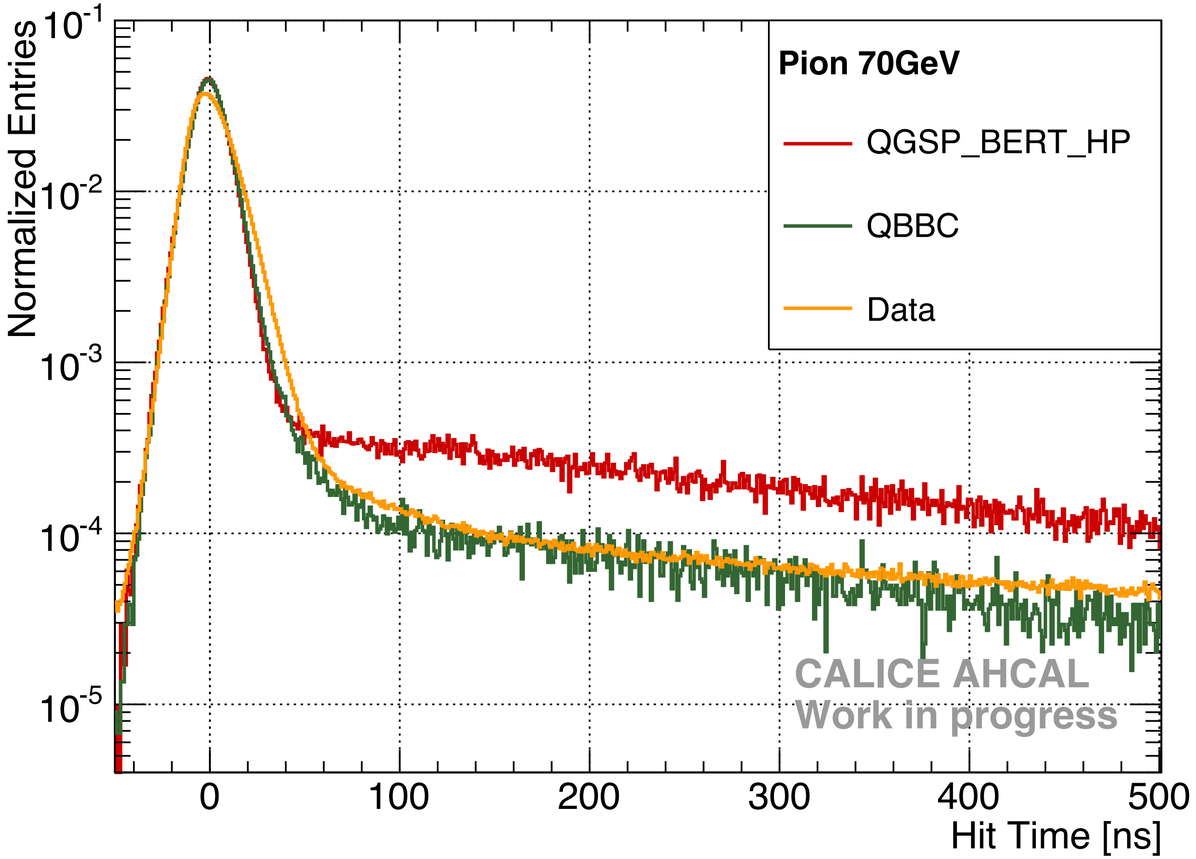




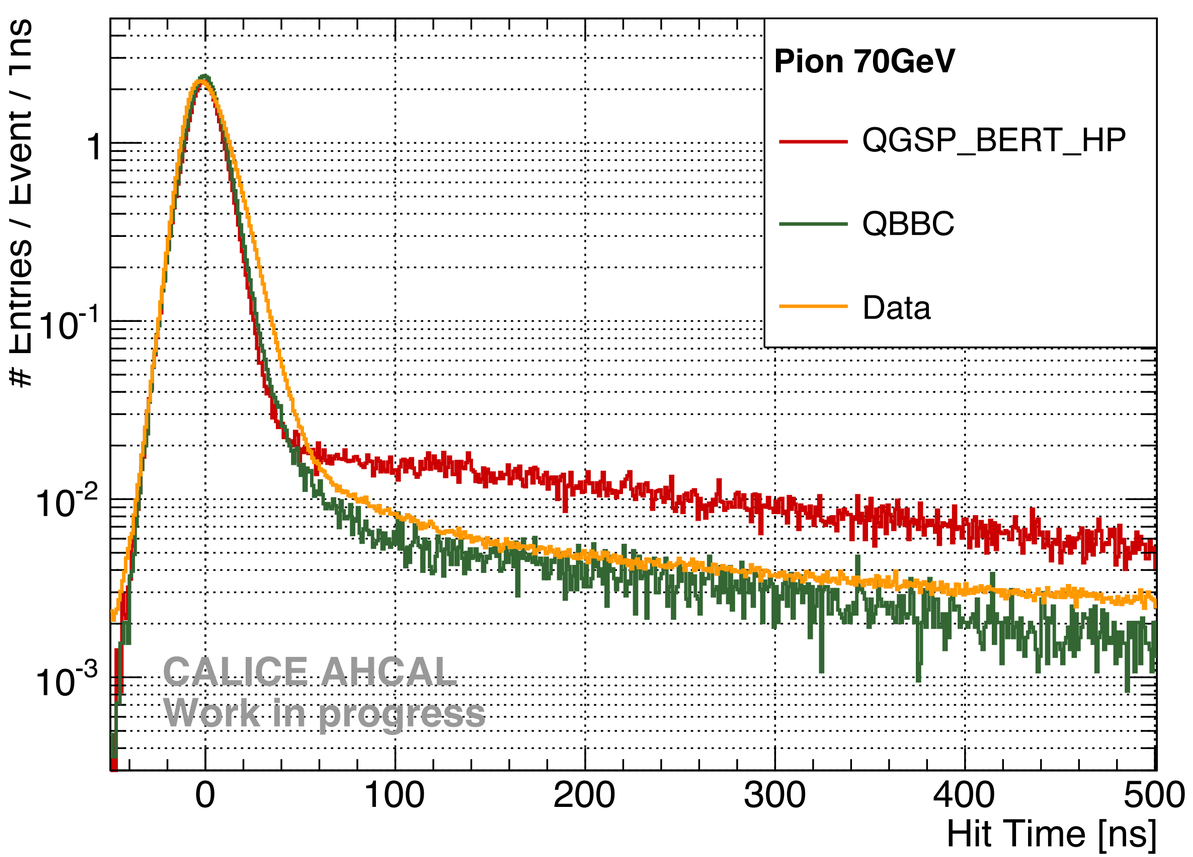
Late hits clearly visible in pion data, consistency over whole energy range

Backup

Hit Time with Respect to T0 Time

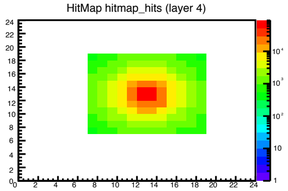


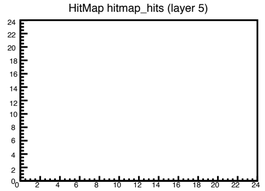
Hittime - T0 time, normalized to event

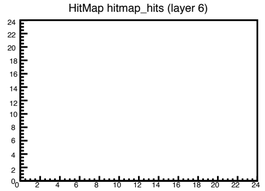


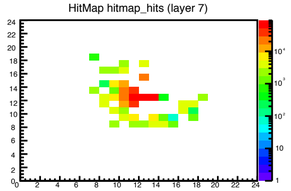
Backup

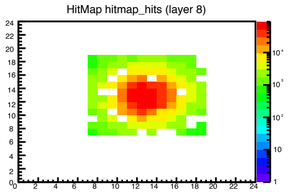
Data

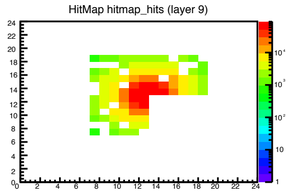


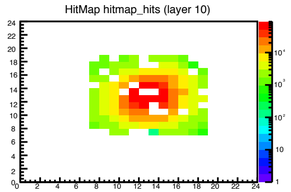


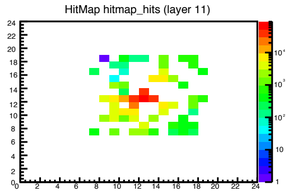


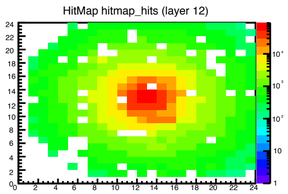


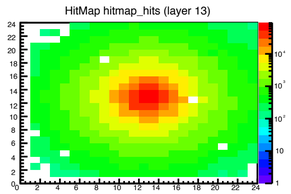


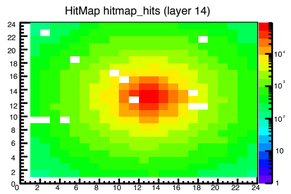


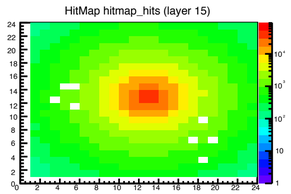












MC