Analysis of AHCAL Electron Data

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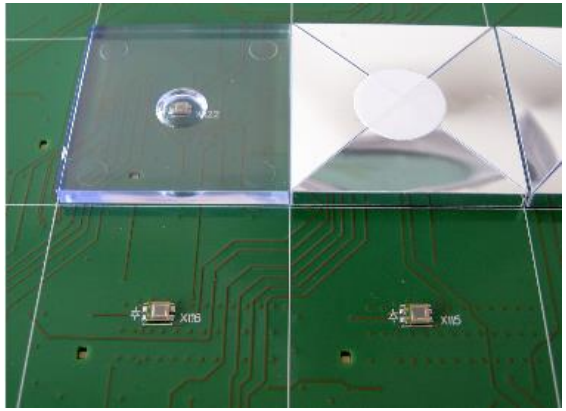
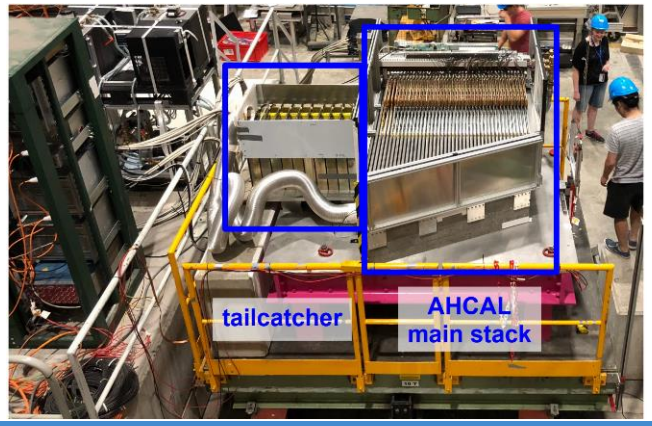
CALICE Main Meeting 2019

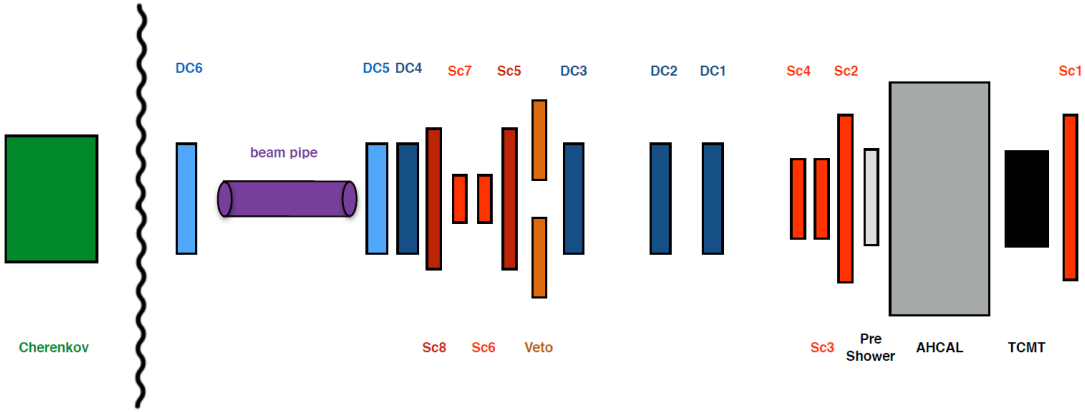
12.04.2019

2018 Test Beams



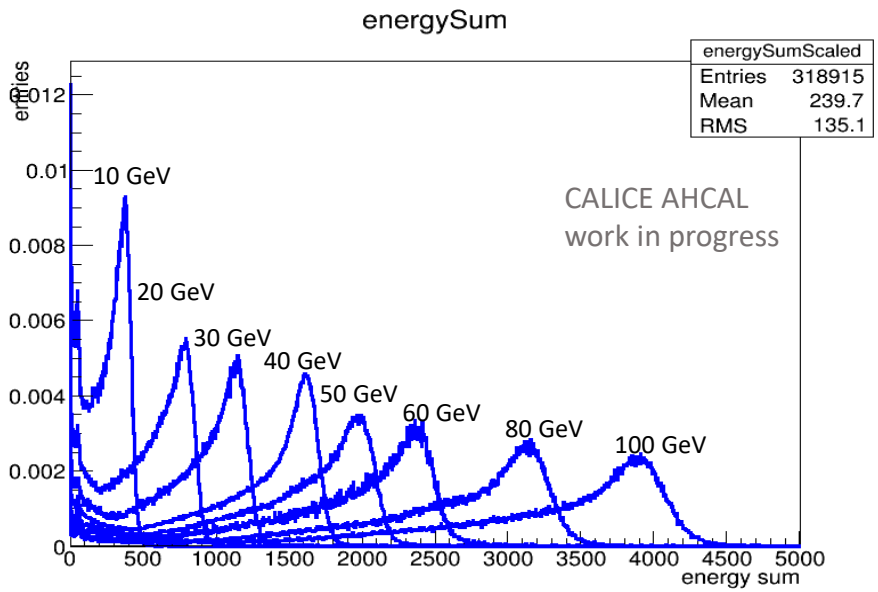
- At CERN SPS
- ~ 40 layers in steel stack with 4x144 individually wrapped channels each
- Runs with muons, electrons, and pions with several 10^7 events
- In May: Runs with and without power pulsing
- June: only power pulsing used





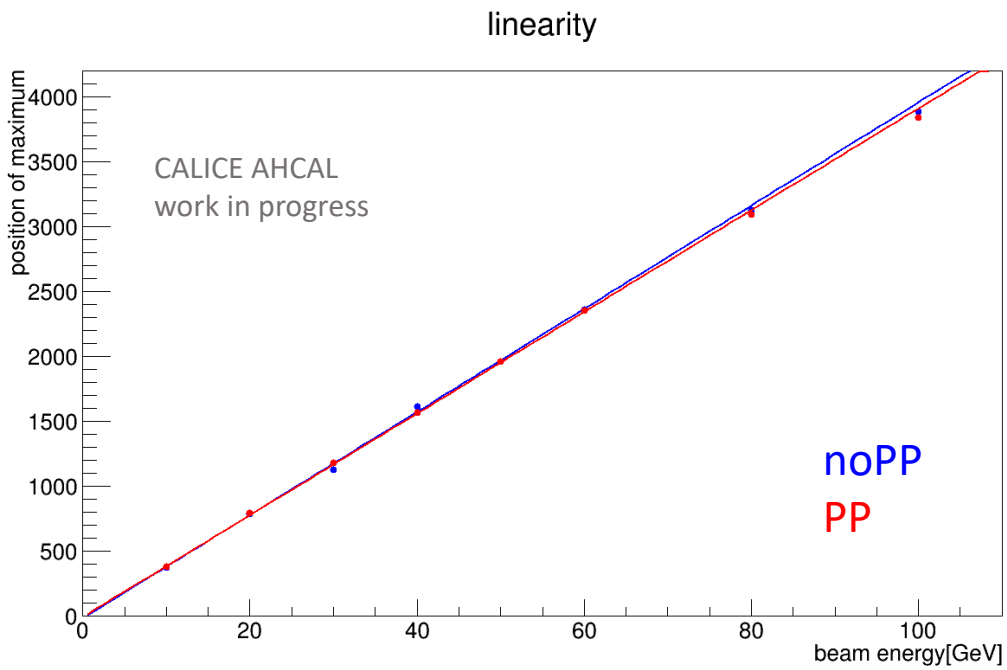
May; e-: Total Energy

- Eventwise sum over hit energies
- Peaks position is expected to scale linearly with beam energy
- Gaussian fits over peaks to determine position



May; e-: Linearity of Total Energy

- Good agreement of noPP and PP within expected precision



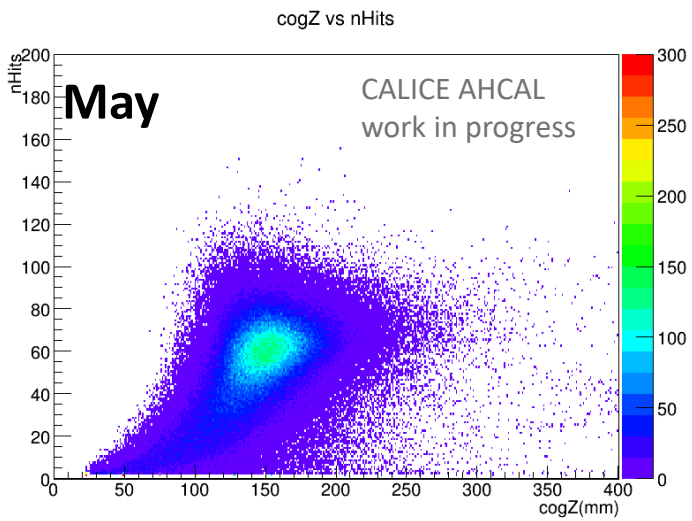
Fit variables:

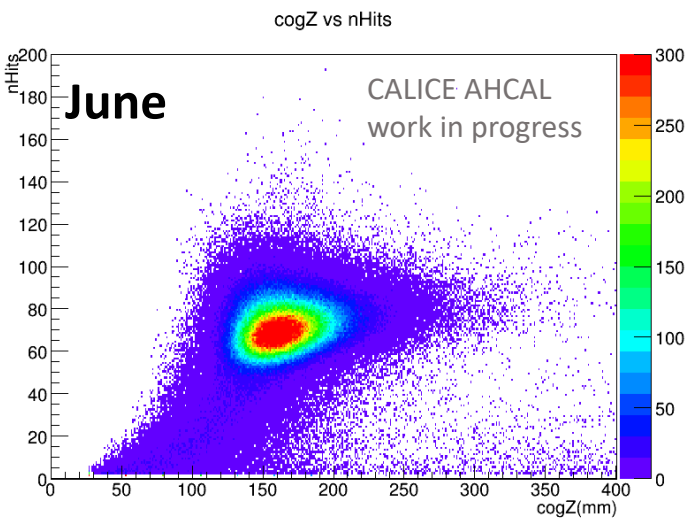
	noPP	PP
offset	-17,8±0,6	-8,7±0,5
slope	39,80±0,01	39,27±0,02

More information: https://agenda.linearcollider.org/event/8082/#day-2018-12-13; Comparison of the May Electron Data With and Without Power Pulsing

May; e-: Tail of Total Energy

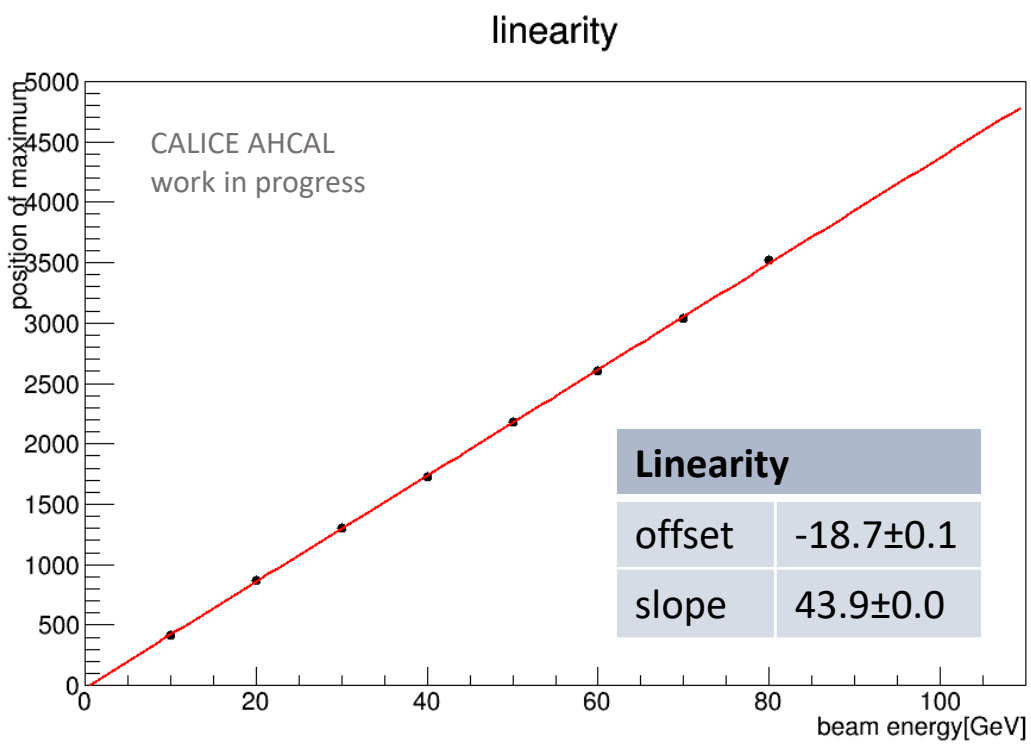
- May electron data has tail of low energy events
- All attempts to remove it unsuccessful
- Beam probably already showering before detector
- Leads to problems with Gaussian fit
- Comparison of data with simulation impossible





June; e-: Linearity of Total Energy

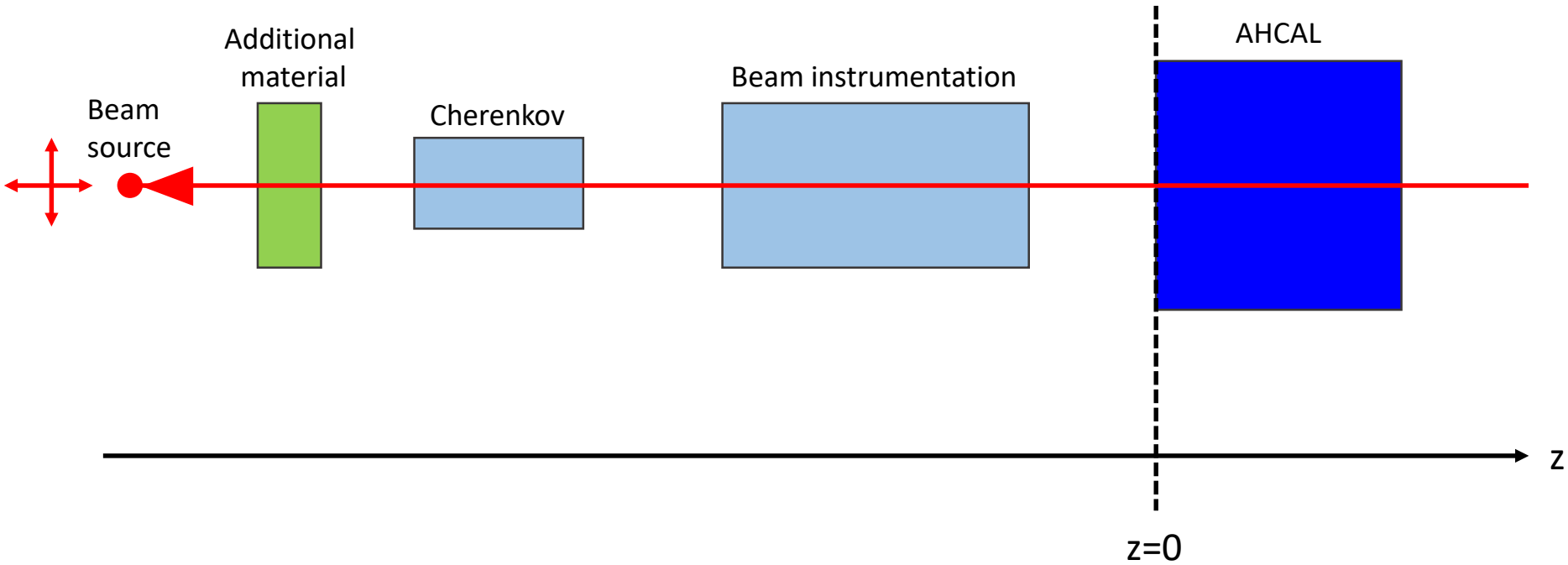
- June data taken with power pulsing
- Good linearity without additional cuts



Linearity	
offset	-18.7±0.1
slope	43.9±0.0

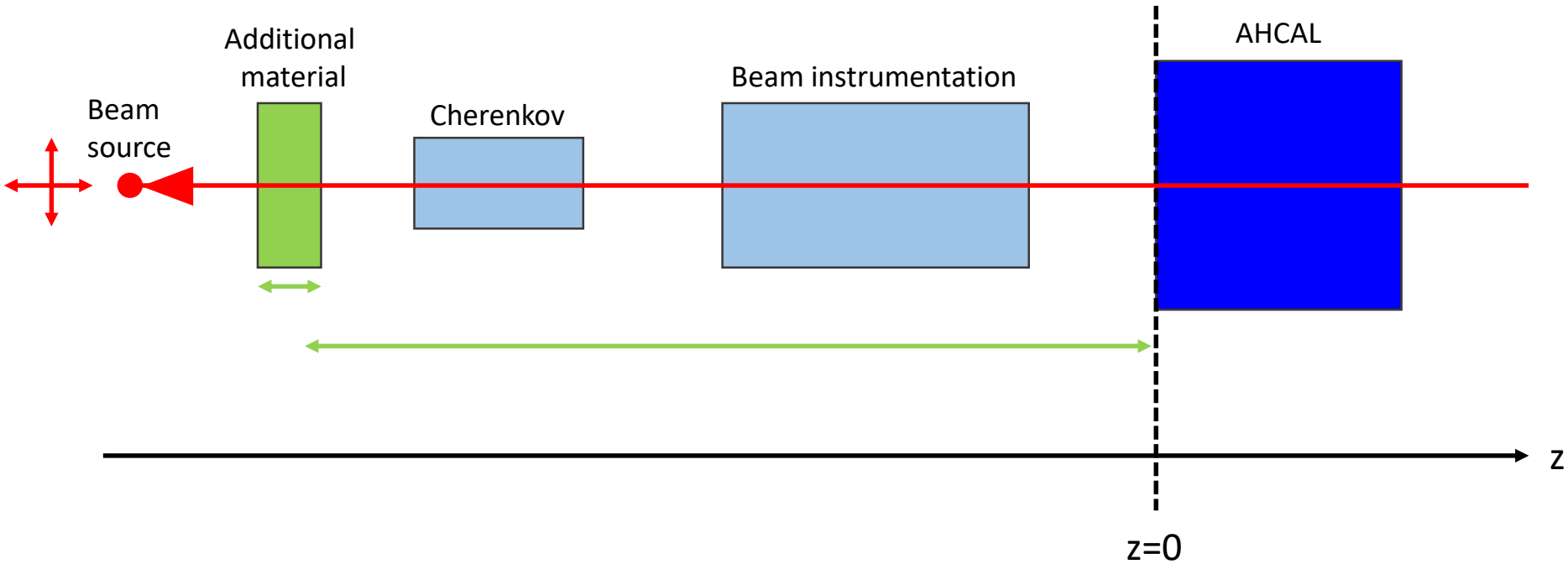
June; e-: Simulation

- 9 parameters tuned:
  - Beam source: position in x, y, z; beam width in x, y



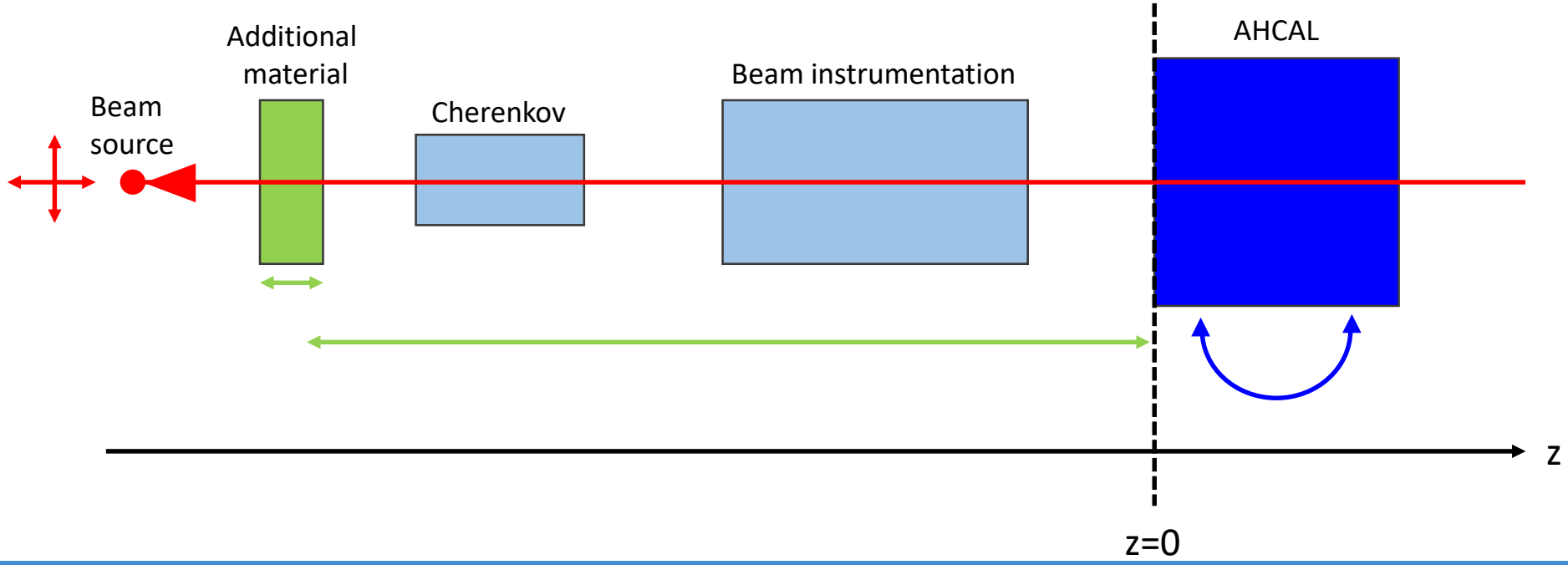
June; e-: Simulation

- 9 parameters tuned:
  - Beam source: position in x, y, z; beam width in x, y
  - Additional material: position and thickness



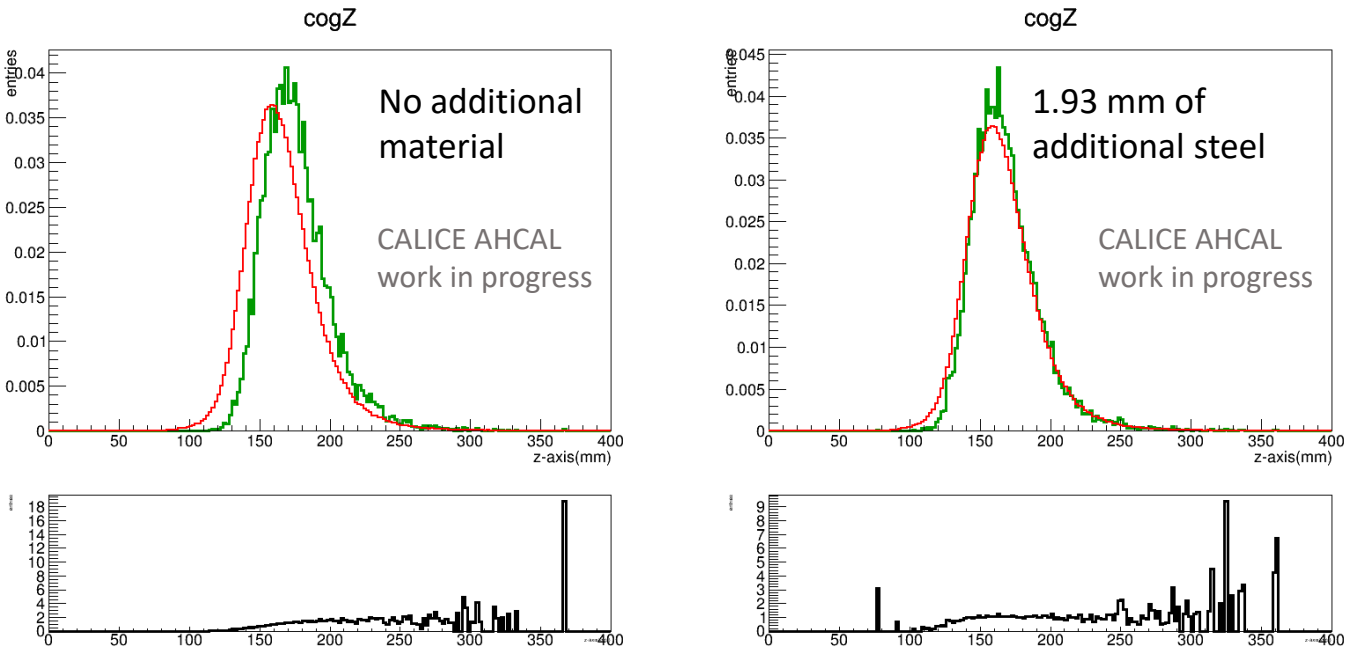
June; e-: Simulation

- 9 parameters tuned:
  - Beam source: position in x, y, z; beam width in x, y
  - Additional material: position and thickness
  - Rotation of AHCAL in x and y



June; e-; 10GeV; CoG Z

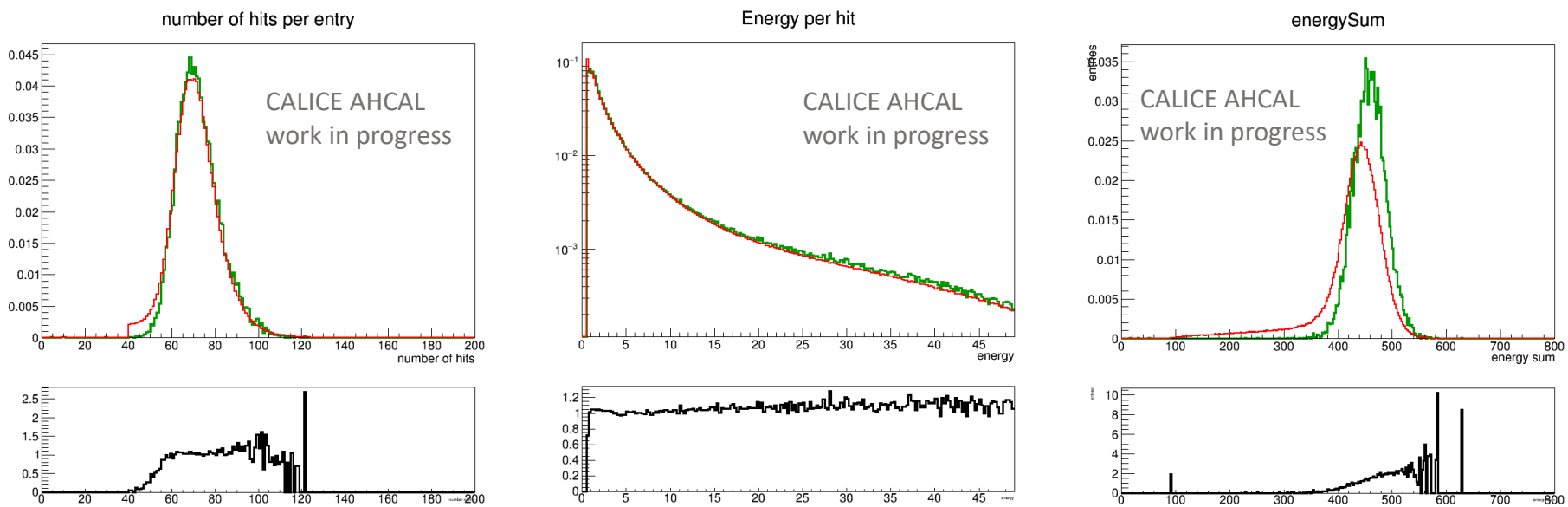
- CoG Z dependent of material in beam line
  - ⇨Check for description of detector material
- Beam is hitting extra material
  - ⇨Extra material needed



Data
Simulation

June; e-; 10 GeV; General Variables

- Number of hits looks fine
- Simulation has more high energy hits
  - ⇨Total energy is higher

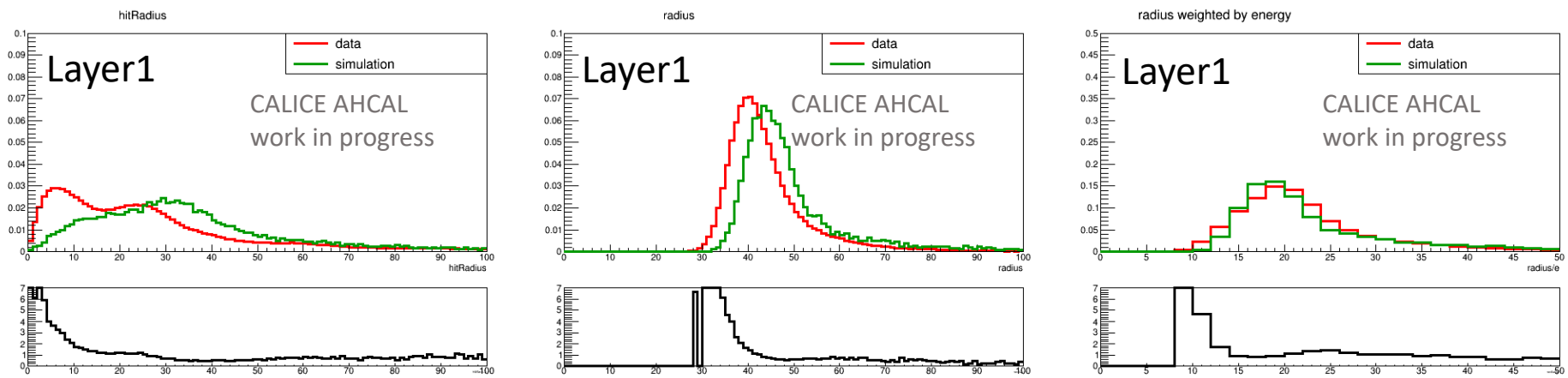


Data

Simulation

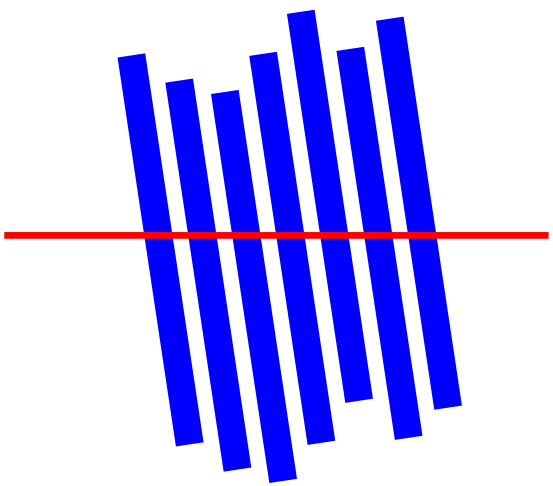
June; e-; 10 GeV; Problems with Radii

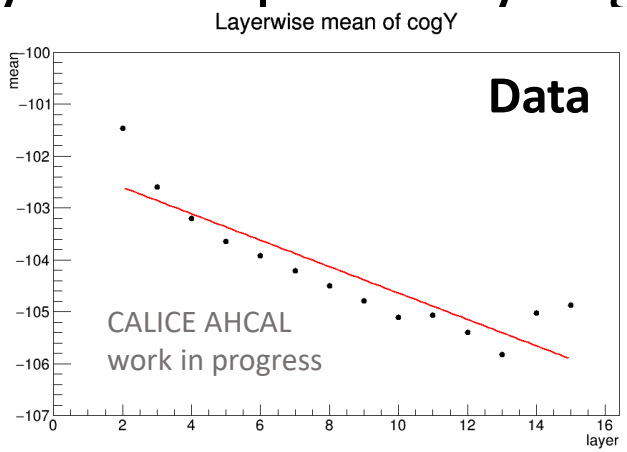
- Hit radius: distance of CoG and hit
- Radius: Mean radius per event
- Energy weighted radius: Eventwise sum over hit radii weighted by energy density

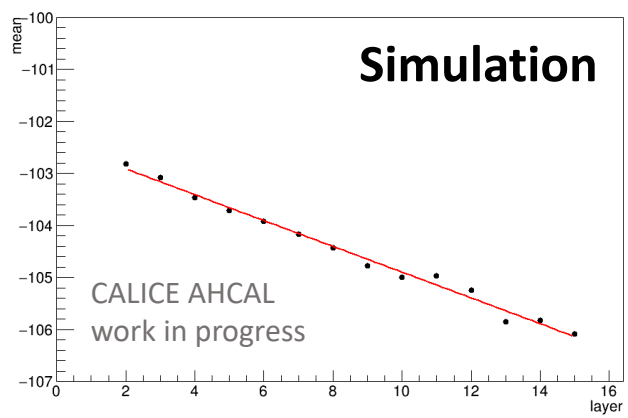


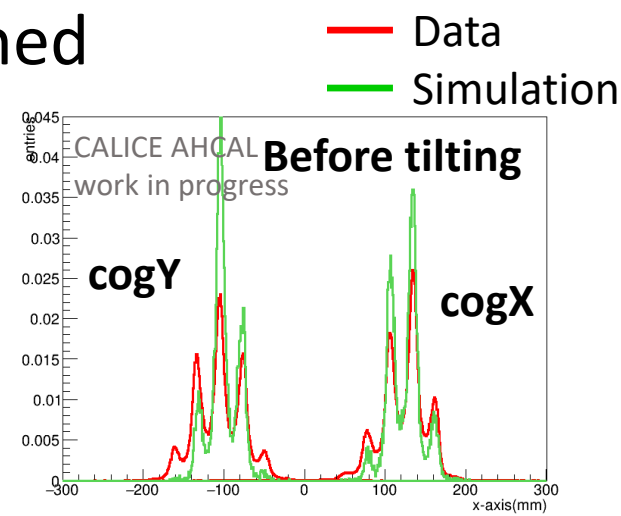
June; e-; 10 GeV; CoG X, Y

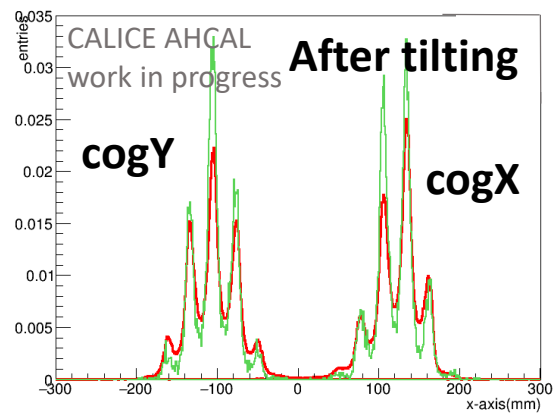
- Important for adjusting beam position in simulation
- Challenge: layers not perfectly aligned





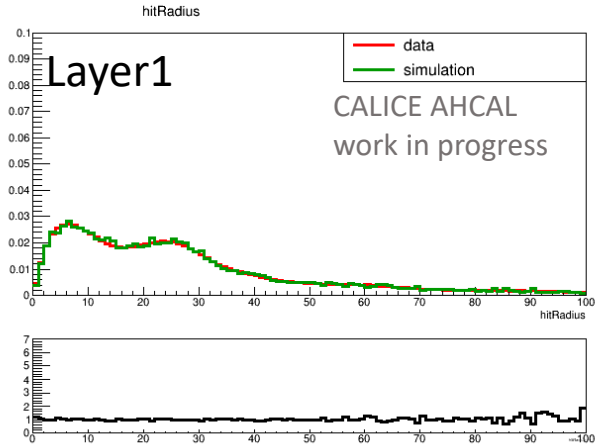


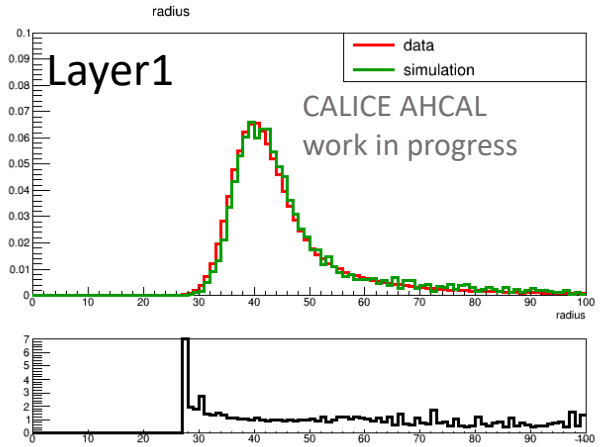


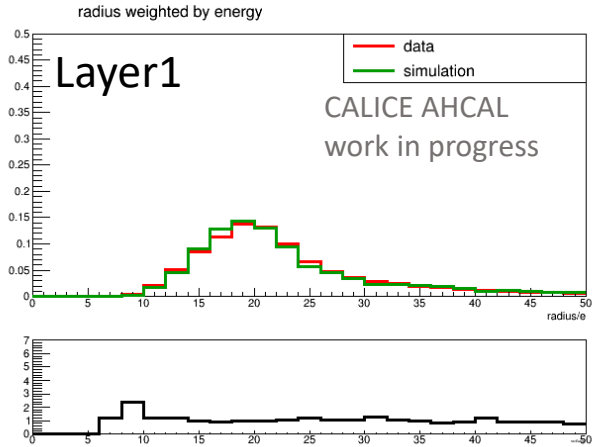


June; e-; 10 GeV; New Radii

- Radii now agree well



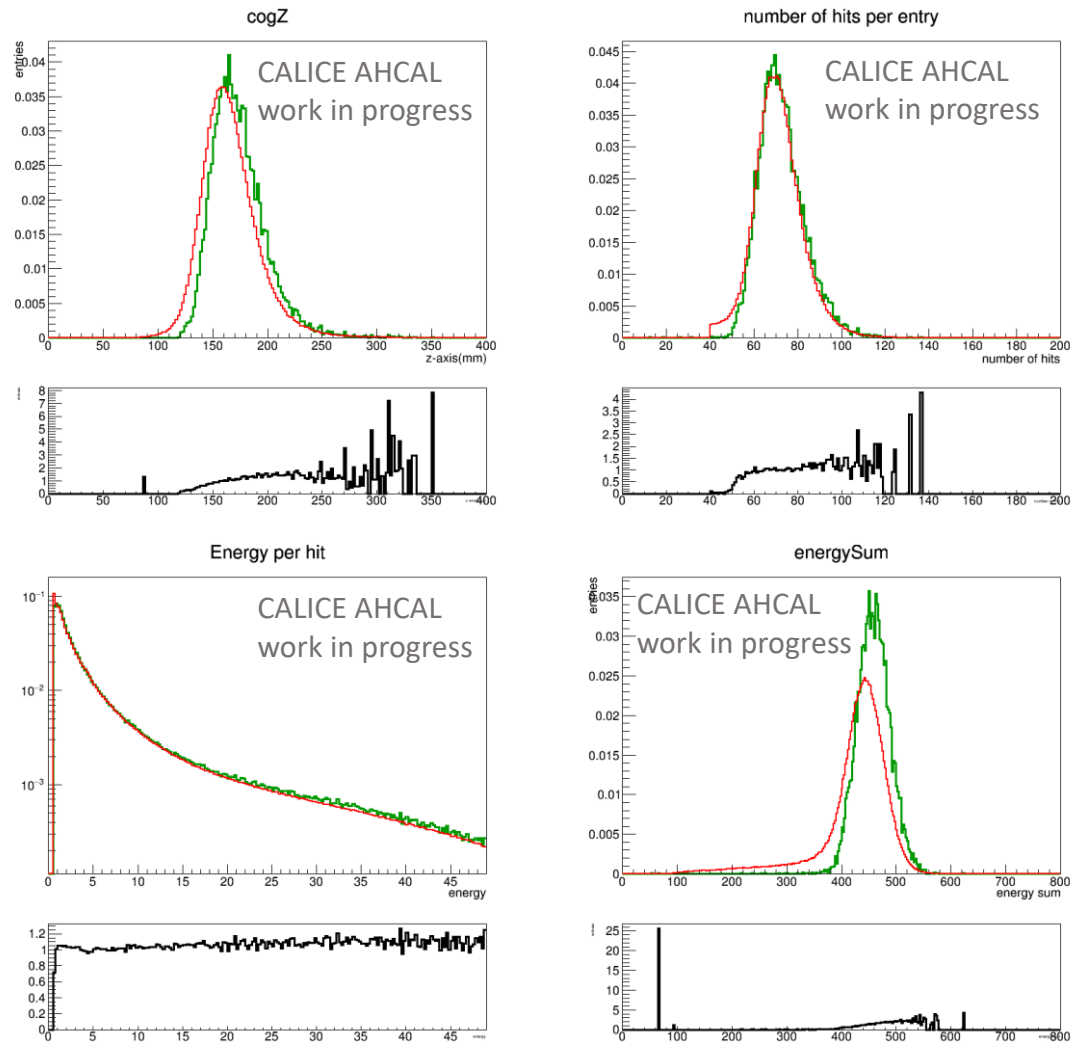




Data
Simulation

June; e-; 10 GeV; New General Variables

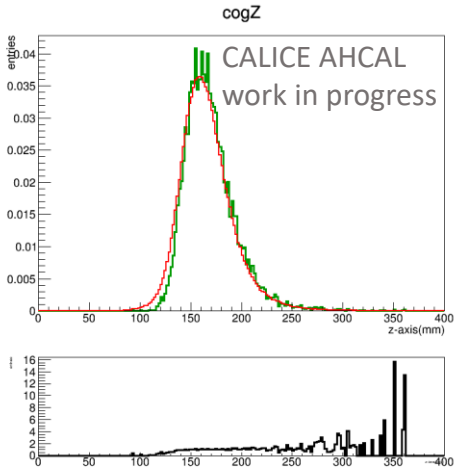
- nHit distribution agrees well
- CogZ worse
- Total energy still off
- More investigation needed



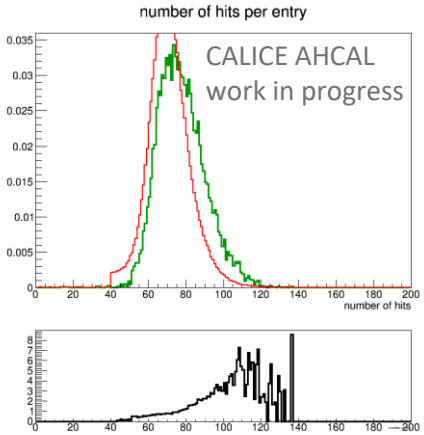
Data
Simulation

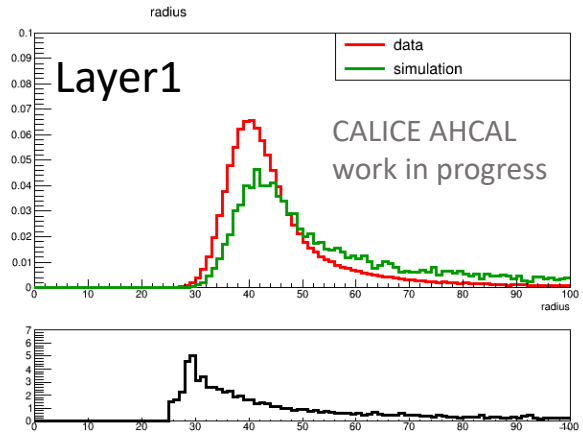
June; e-; 10 GeV; More Material

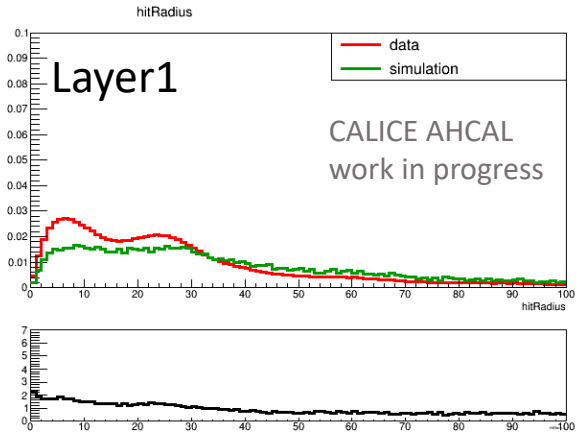
- Increase material to 5 mm to improve cogZ
  - ⇨nHits and radii get worse
  - ⇨1.93 mm of additional material is fine



Data
Simulation

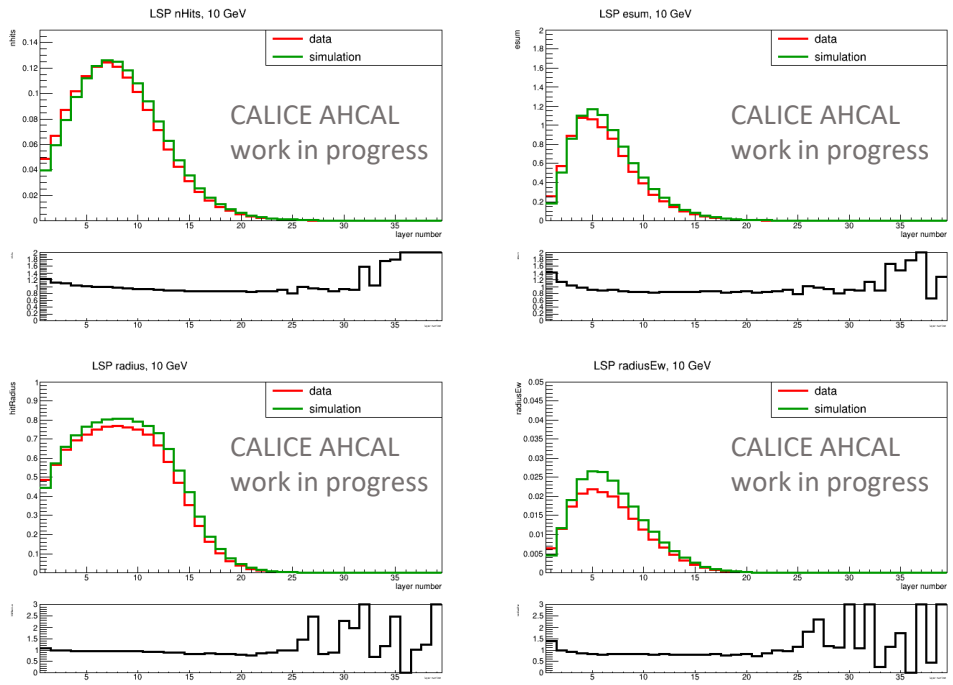






June; e-; 10 GeV; LSP; 1.93 mm steel

- Longitudinal Shower Profile for nHits and radius agree reasonably well
- Still some differences
  ⇨Will improve hopefully with further fine tuning of simulation



Conclusion and Outlook

Conclusion:

- Power pulsing thoroughly tested: improvement in temperature stability with identical performance confirmed
- Good linearity for May and June
- June data suitable for comparison with simulation
- Excellent agreement in radii and number of hits between data and simulation
  - ⇨Radii and number of hits agree well

Outlook:

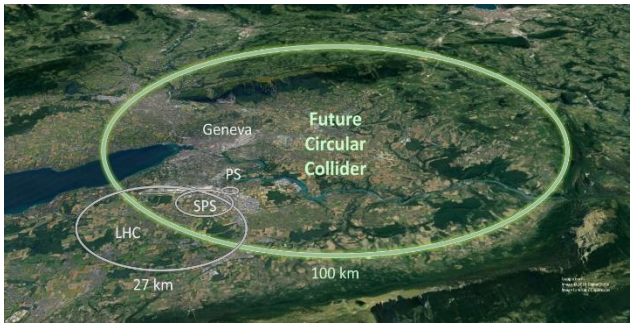
- Fine tuning of simulation and selection cuts to improve agreement
- Comparison of shower shapes and energy response with simulation

Thank you for your attention!

Backup

Future e+e- Collider

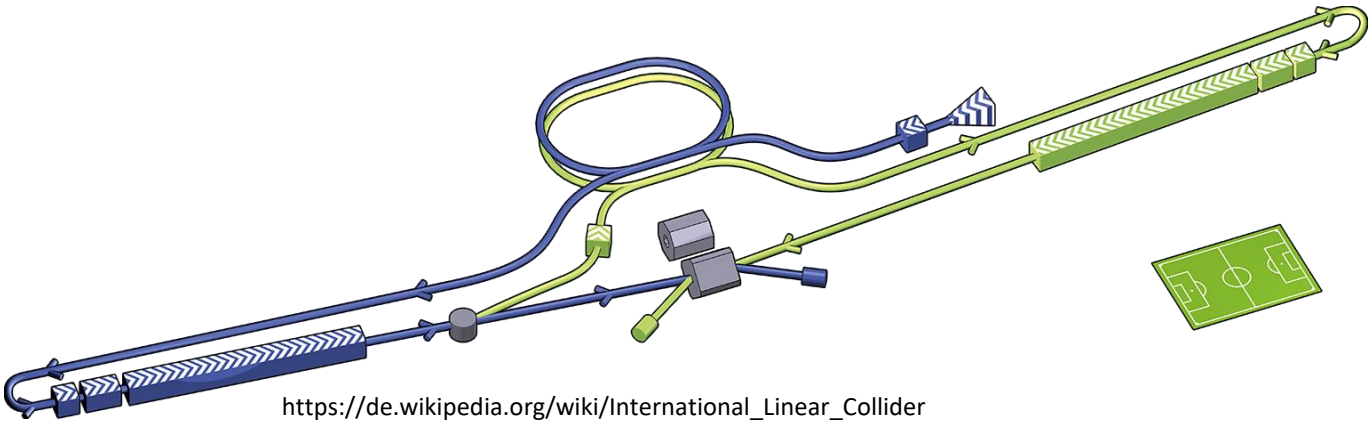
- Future high energy colliders need high energy resolution detectors
- Different concepts:
  - CEPC
  - CLIC
  - FCC
  - ILC



- Energy resolution achieved by use of particle flow algorithm
  - ⇨High granularity needed

ILC

- International Linear Collider (ILC) to investigate properties of Higgs-Boson and top quark, and search for new particles
- Electron-Positron-Collisions at 250 – 500 GeV



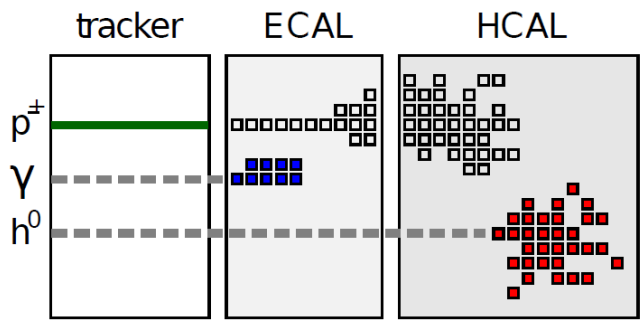
https://de.wikipedia.org/wiki/International_Linear_Collider

CALICE

- **Ca**lorimeter for **Li**near **C**ollider **E**xperiment (CALICE) Collaboration
- Over 300 members from 17 countries
- Development of ECAL, HCAL and tail catcher/muon tracker
- Test beam activities for over 10 years

Particle Flow Algorithms (PFA)

- PFA uses most precise detector component for measurement of different particles:
  - Tracker: charged particles
  - ECAL: photons
  - HCAL: neutral hadrons
- Resolution degrades when particle clusters overlap
- Highly granular calorimeters neccessary for use of PFA

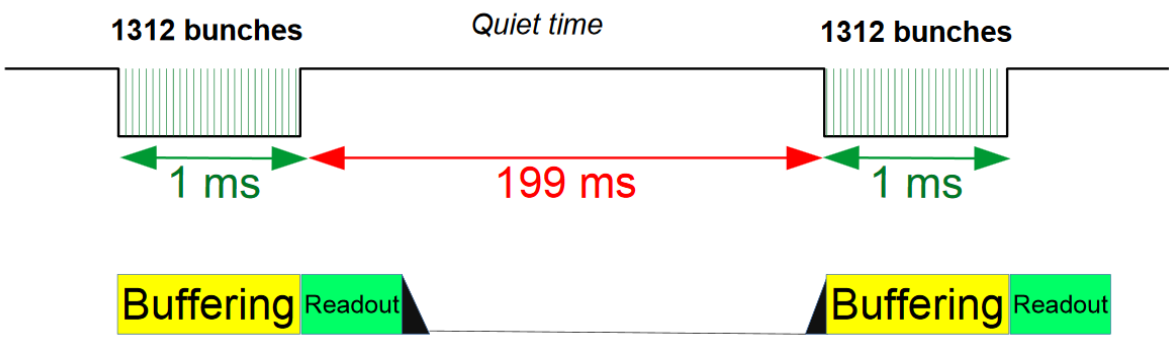


Oskar Hartbrich - Commissioning and LED System Tests of the Engineering Prototype of the Analog Hadronic Calorimeter of the CALICE Collaboration

Power Pulsing

- New concept tested for ILC
- Detector only switched on when particle bunch arrives
- Possible because of time structure of beam:
  - 1 ms bunch trains at 5 Herz
- Reduces heating and power consumption

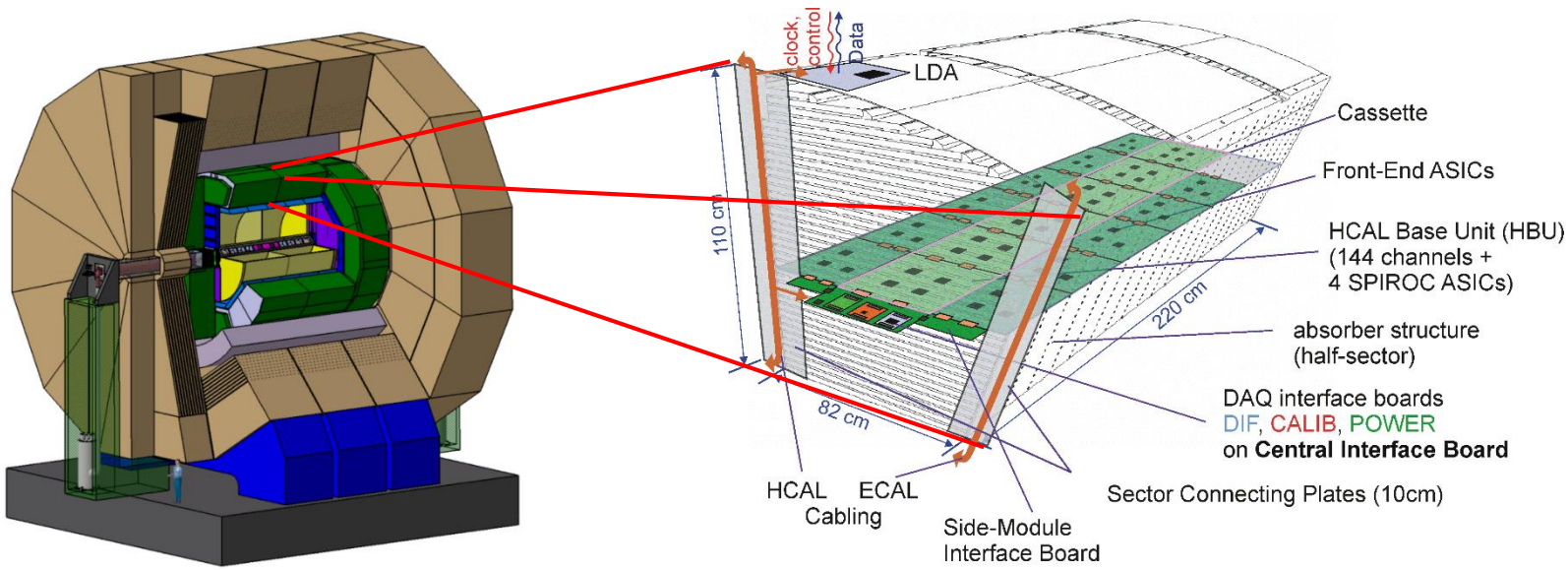
  ⇨Allows for compact detector design



Marcel Stanitzki - 103rd Plenary ECFA

AHCAL

- Development of calorimeter prototype: **A**nalogue **H**adronic **Ca**Lorimeter (AHCAL); Sampling calorimeter

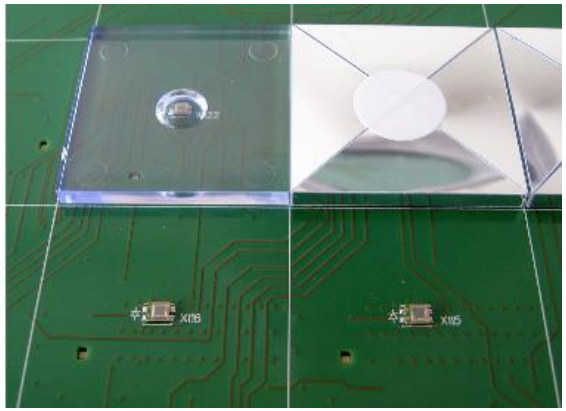


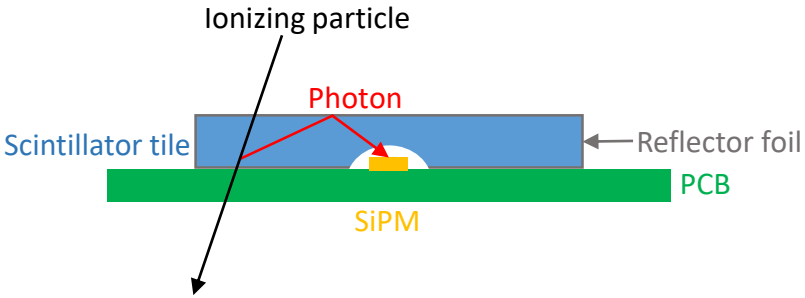
ILD-Letter of Intent

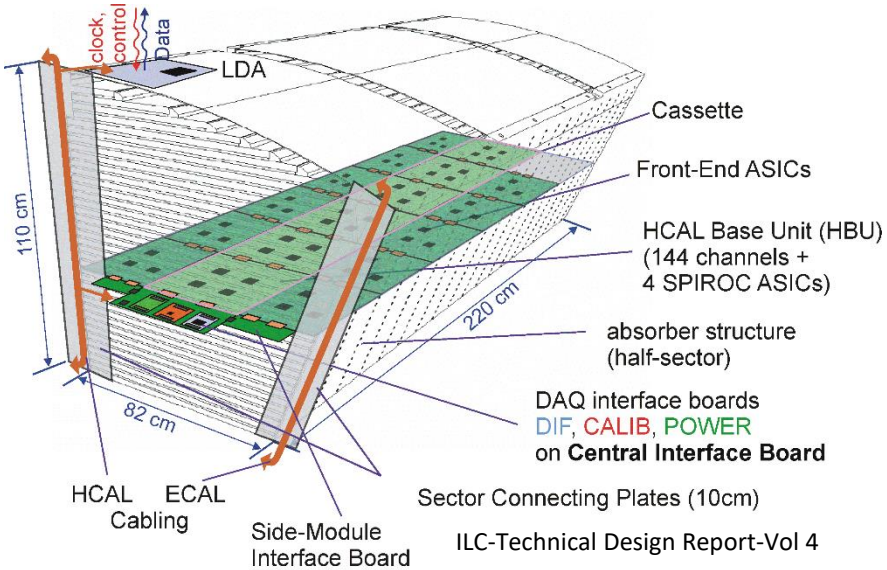
ILC-Technical Design Report-Vol 4

CALICE AHCAL

- Individually wrapped 3 x 3 cm^2 scintillator tiles
- Read out with SiPMs
- 144 channels form HBU



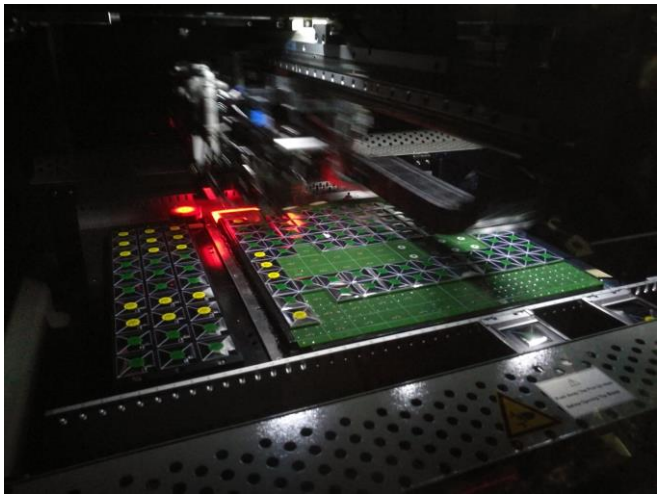




Technological Prototype

- 40 fully equipped layers with 4x144 channels each
  - ⇨~22k channels total
- Mass assembly in a reasonable time

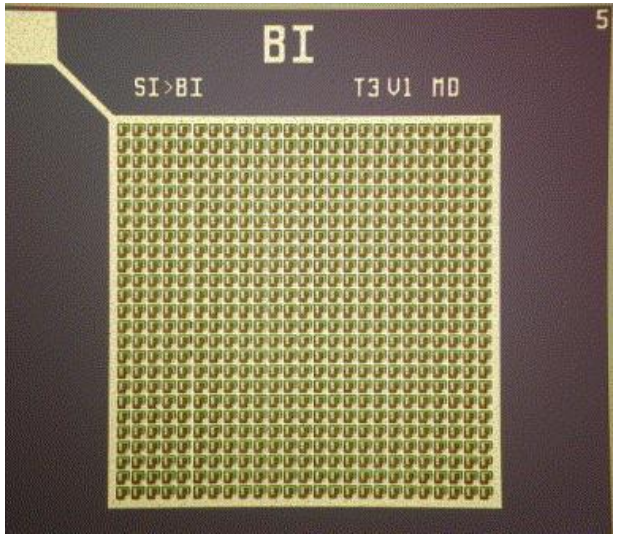
  (See: A design of scintillator tiles read out by surface-mounted SiPMs for a future hadron calorimeter, Phi Chau)
- Test beams with newly assembled boards with improved design and low noise SiPMs
- Comparison with GEANT4 simulation



Tile assembly at University Mainz

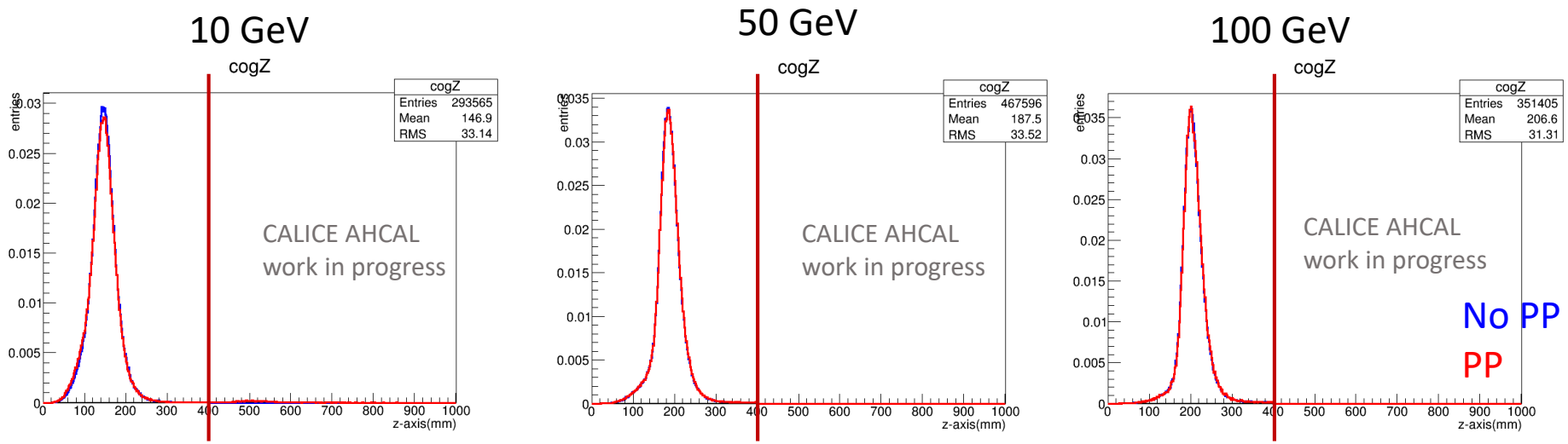
AHCAL Working Principle

- Scintillator tiles produce photons when ionizing particles cross
- Silicon photomultiplier (SiPM) consists of grid of photo diodes
- Photon produces signal in pixel of SiPM:
  - Creates electron-hole pair
  - Charge drifts trough high electric field
    - ⇨ Creates avalache
    - ⇨ Signal
  - Probability for creation of electron-hole pair highly dependent of temperature
  - Output is sum over all pixels
  - Number of fired pixels proportional to energy deposited in tile



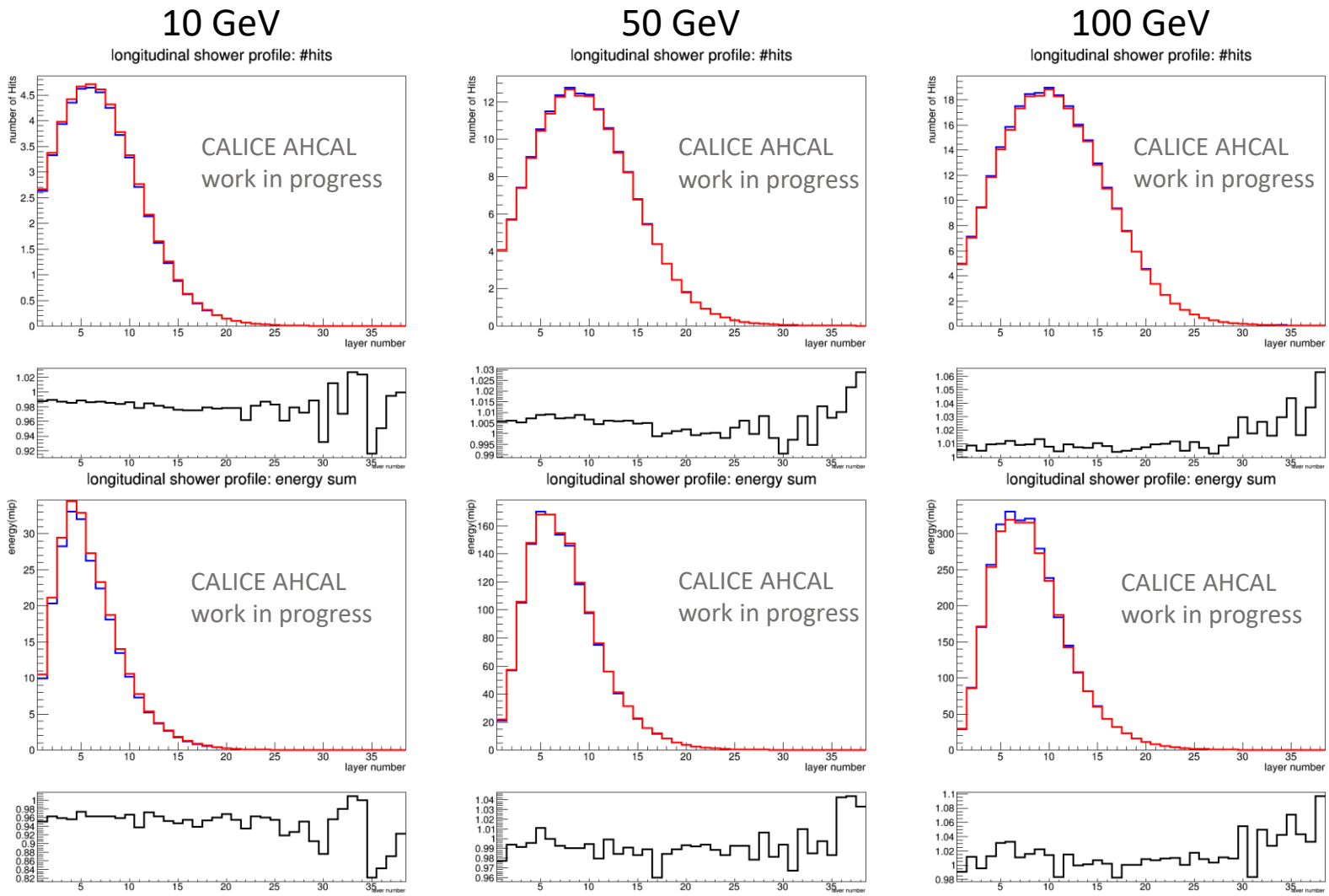
http://www.sciencedirect.com/science/article/pii/S0168900206021462

Comparison of PP/no PP: CoG Z



- Muons visible in cogZ ⇨ cut at 400 mm
- Shower development similar for both

Longitudinal Shower Profiles



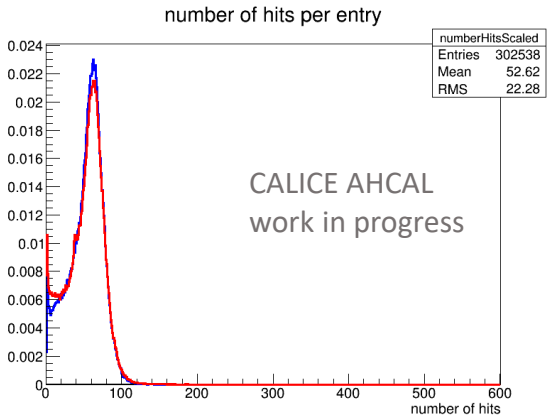
No PP
PP

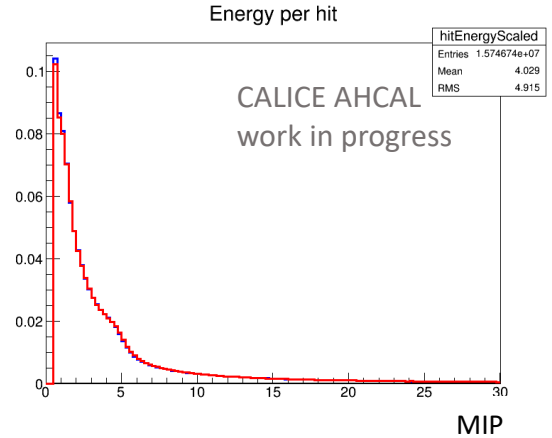
Longitudinal Shower Profiles

- Number of hits distributions with and without power pulsing nearly identical (differences of up to <2%) in the first layers
- Fluctuations in later layers higher because of lower statistics
- Energy sum distributions also agree well
- Temperature differences probably resulting from temperature changes in detector ⇨ general shift per layer

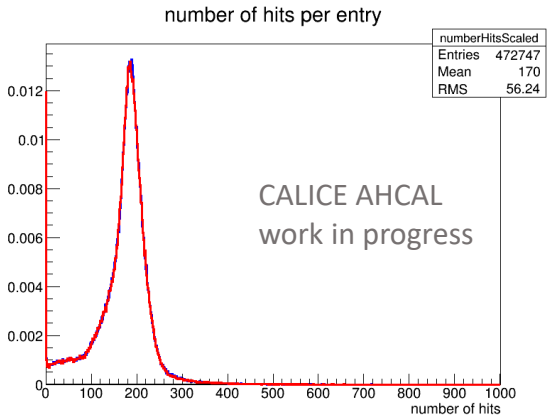
Number of Hits Per Event and Energy Per Hit

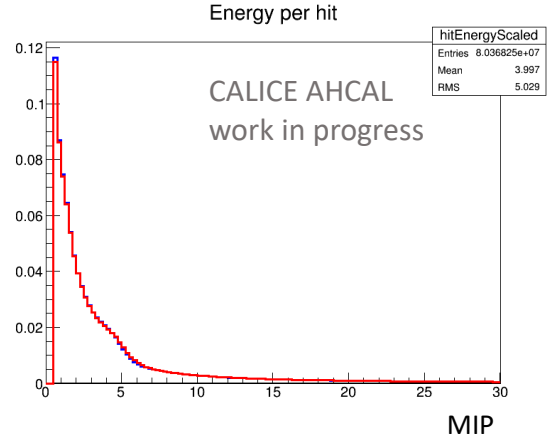
10 GeV



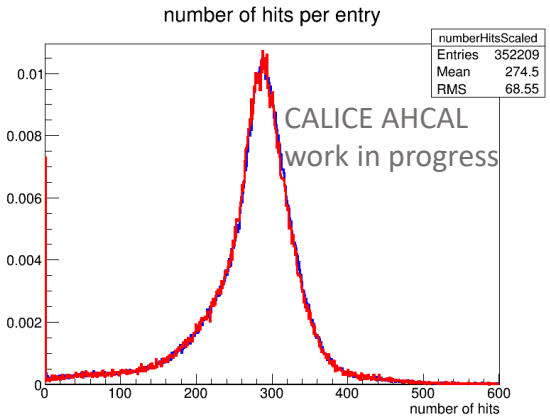


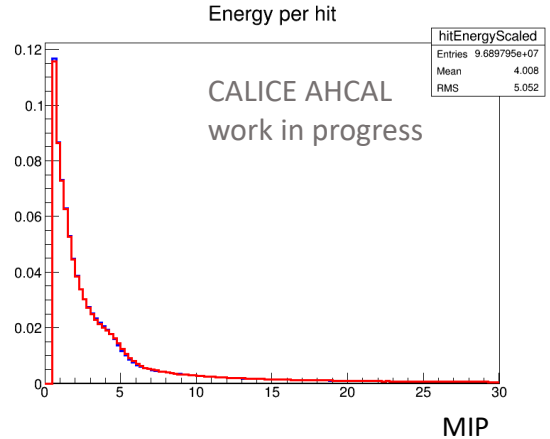
50 GeV





100 GeV





No PP

PP