The New CALICE SiPM-on-Tile HCAL Prototype: Software and First Look into Test Beam Data

May 29th, 2018

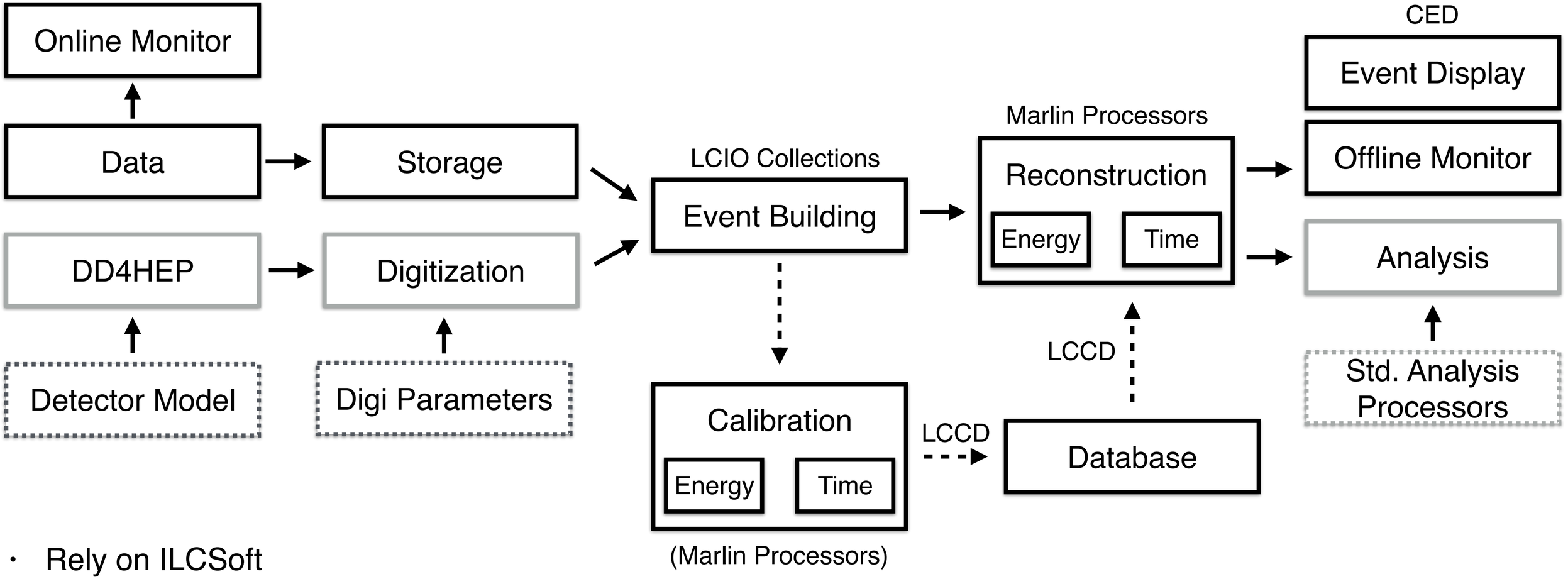
Asian Linear Collider Workshop 2018, Fukuoka

Christian Graf

On behalf of the CALICE Collaboration

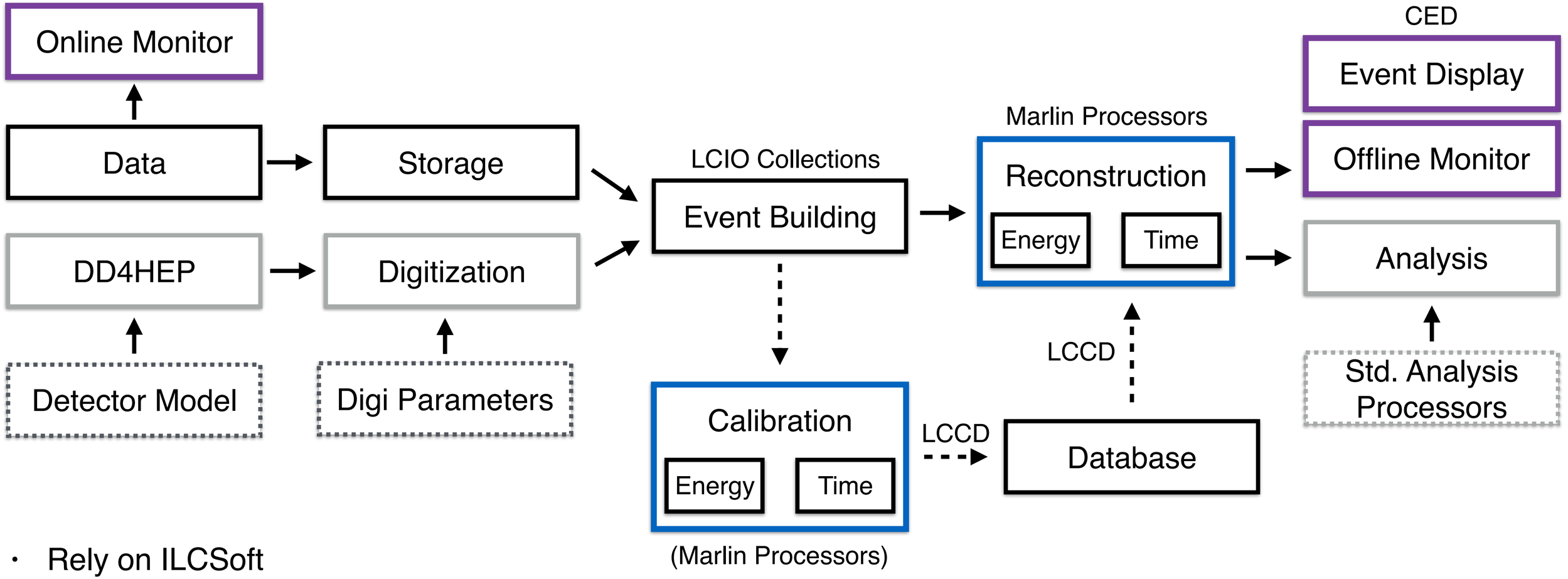
Max-Planck-Institut für Physik
(Werner-Heisenberg-Institut)

Overview - Software Workflow



- Rely on ILCSoft
- Software chain build with future linear collider experiment in mind
  - validation of simulations
- Data and simulation are processed by the same pipeline

Overview - Software Workflow



- Rely on ILCSoft
- Software chain build with future linear collider experiment in mind
  - validation of simulations
- Data and simulation are processed by the same pipeline

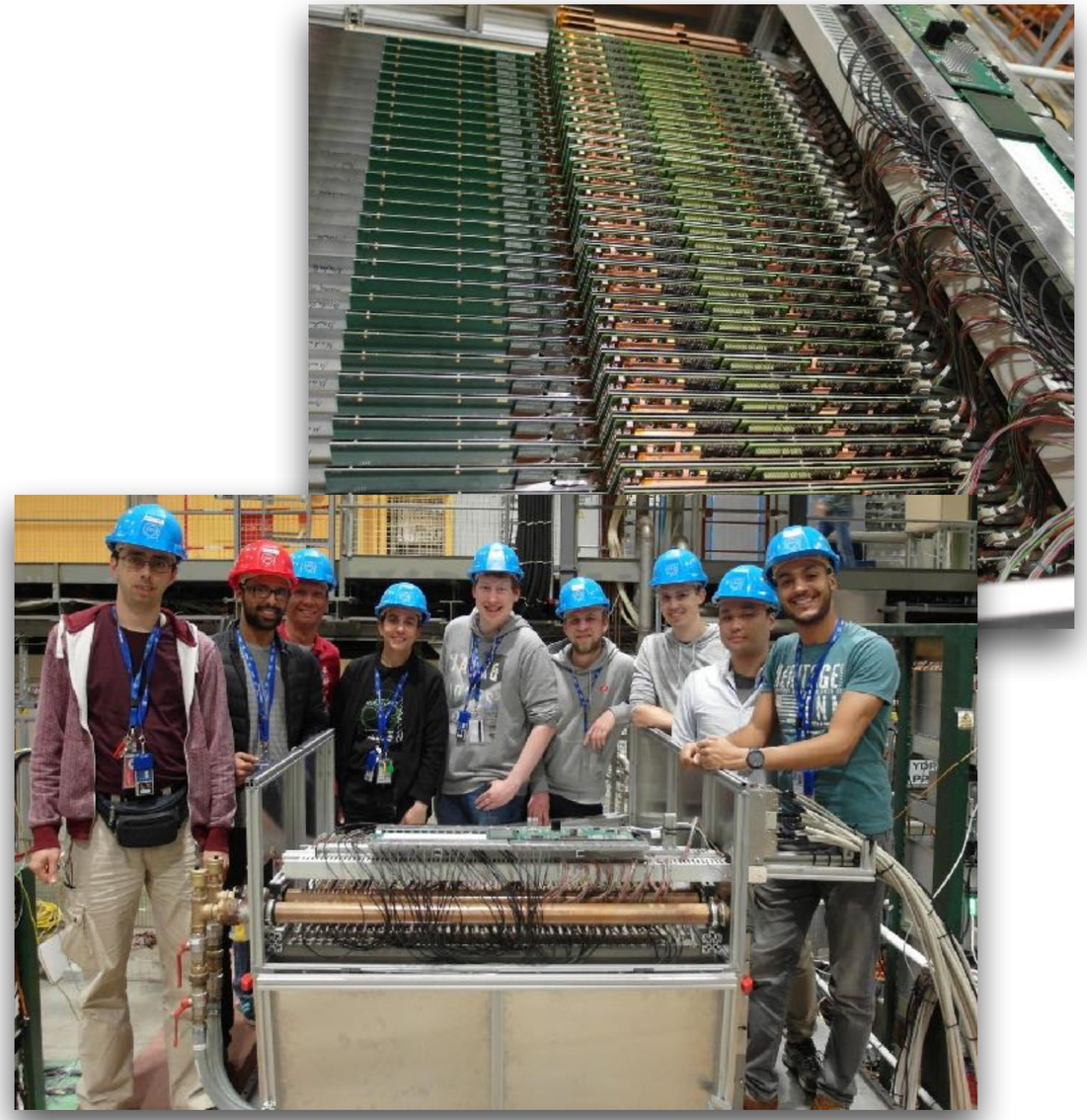
Test Beam Campaign at CERN / SPS

- CERN / SPS H2 beam line (9.5. - 23.5.18)

- Installation of 38 layers, nearly 22,000 channels

  - **Technical Objectives:**
    - prove concept of scalable scintillator on tile design
    - reliable operation of large prototype

  - **Scientific Objectives:**
    - energy linearity
    - hit time analysis
    - shower profiles



Run Program

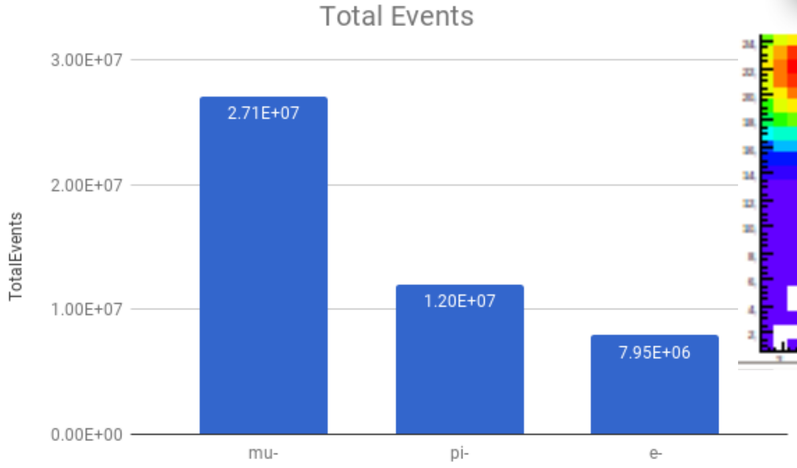
- **Muon:**
  - 40GeV and 120GeV scans with movable stage
  - at least 5000 hits per channel for time calibration and to cross-check MIP calibration

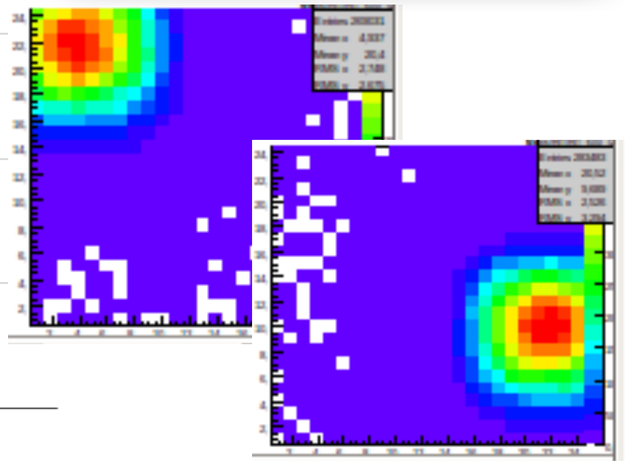
- **Electrons:**
  - 10GeV - 100GeV

- **Hadrons:**
  - 10GeV - 160GeV

- LED runs for gain calibration

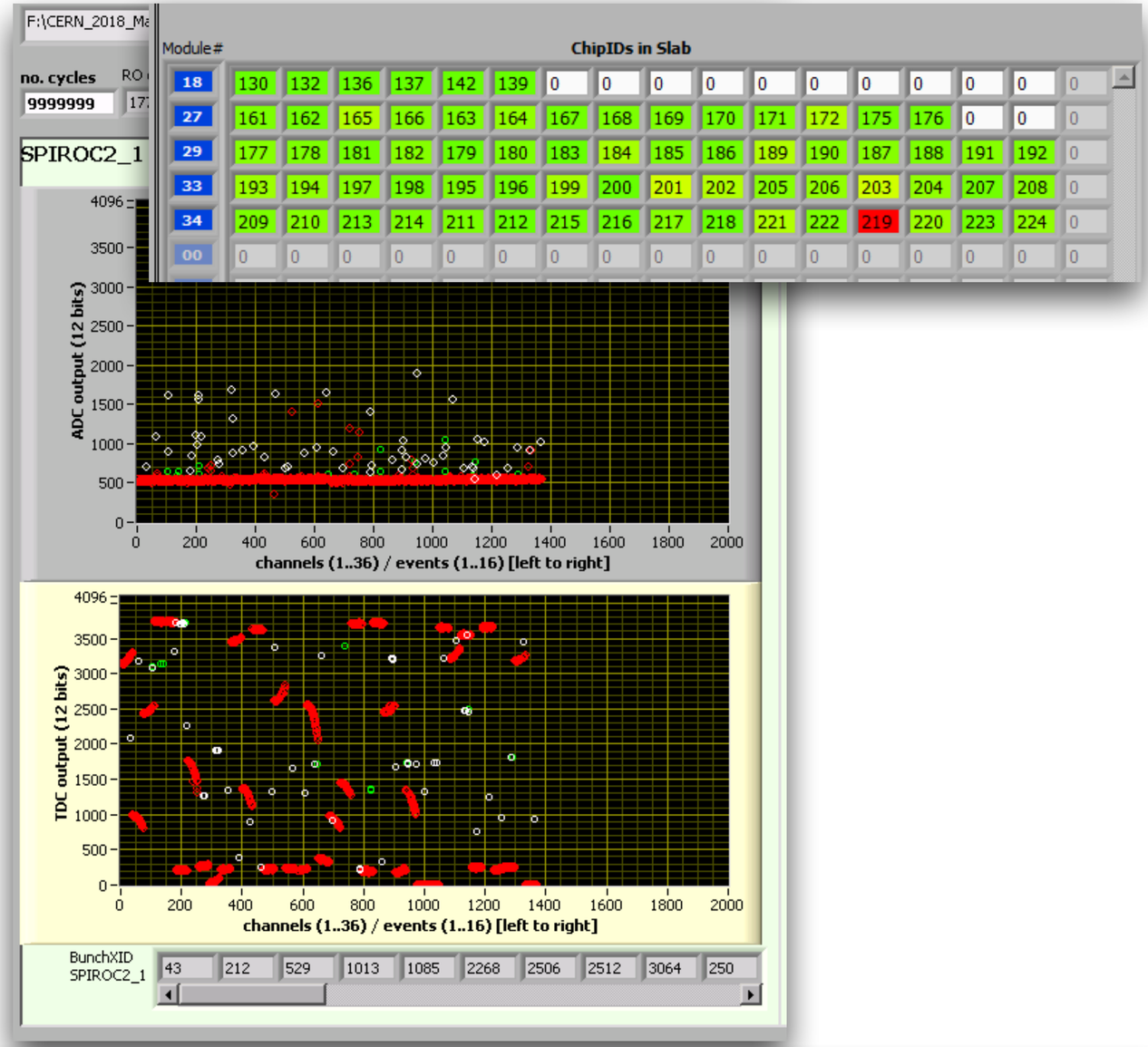
- Running with and without power pulsing





Monitoring

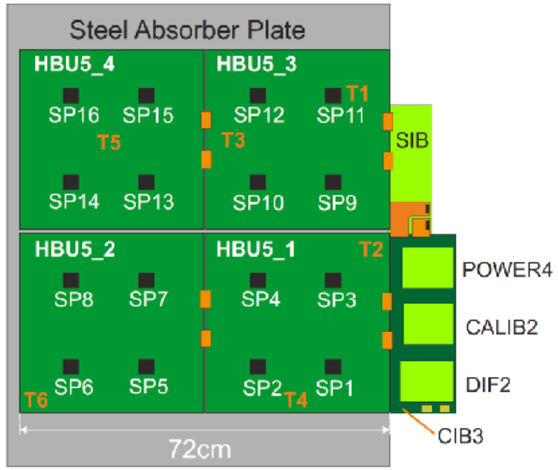
- **Labview:**
  - first impressions on data completeness

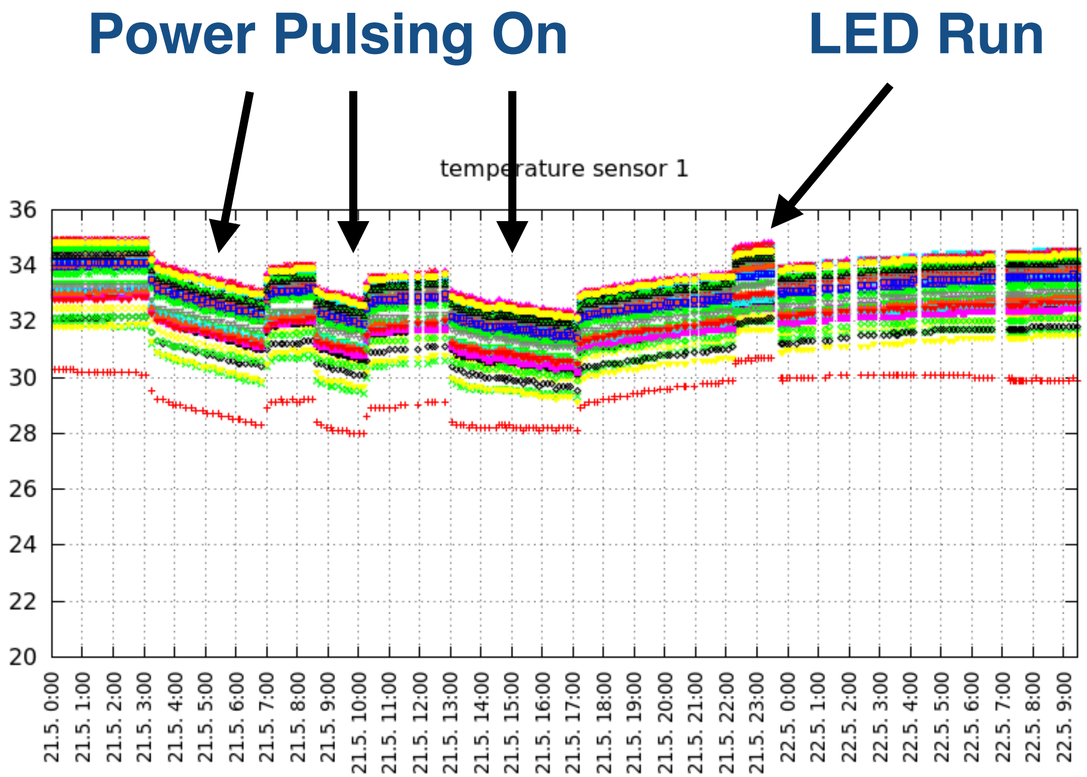


Monitoring

- **Labview**

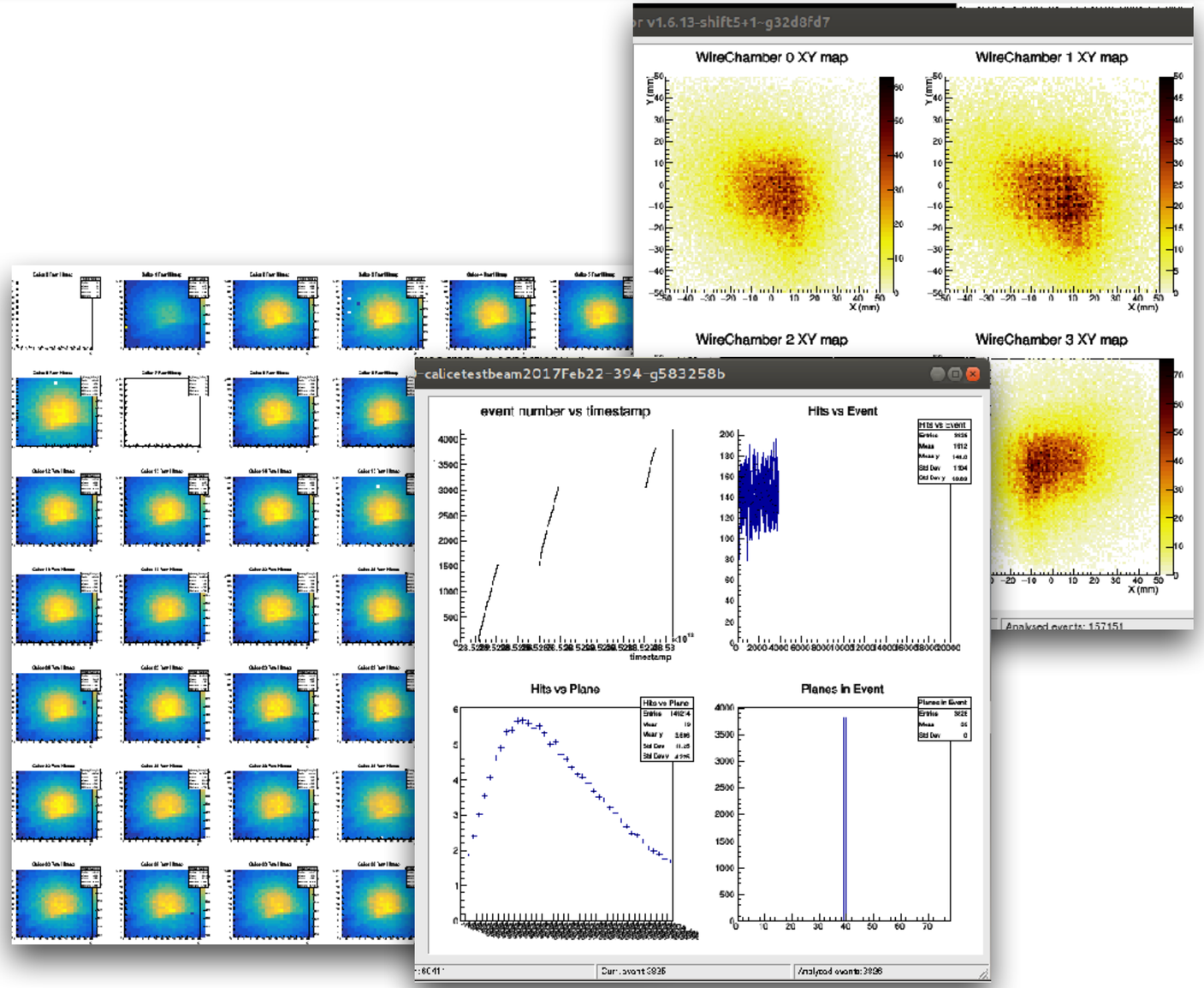
- **Temperature Monitoring:**
  - temperature decrease for power pulsing
  - temperature increase for LED runs





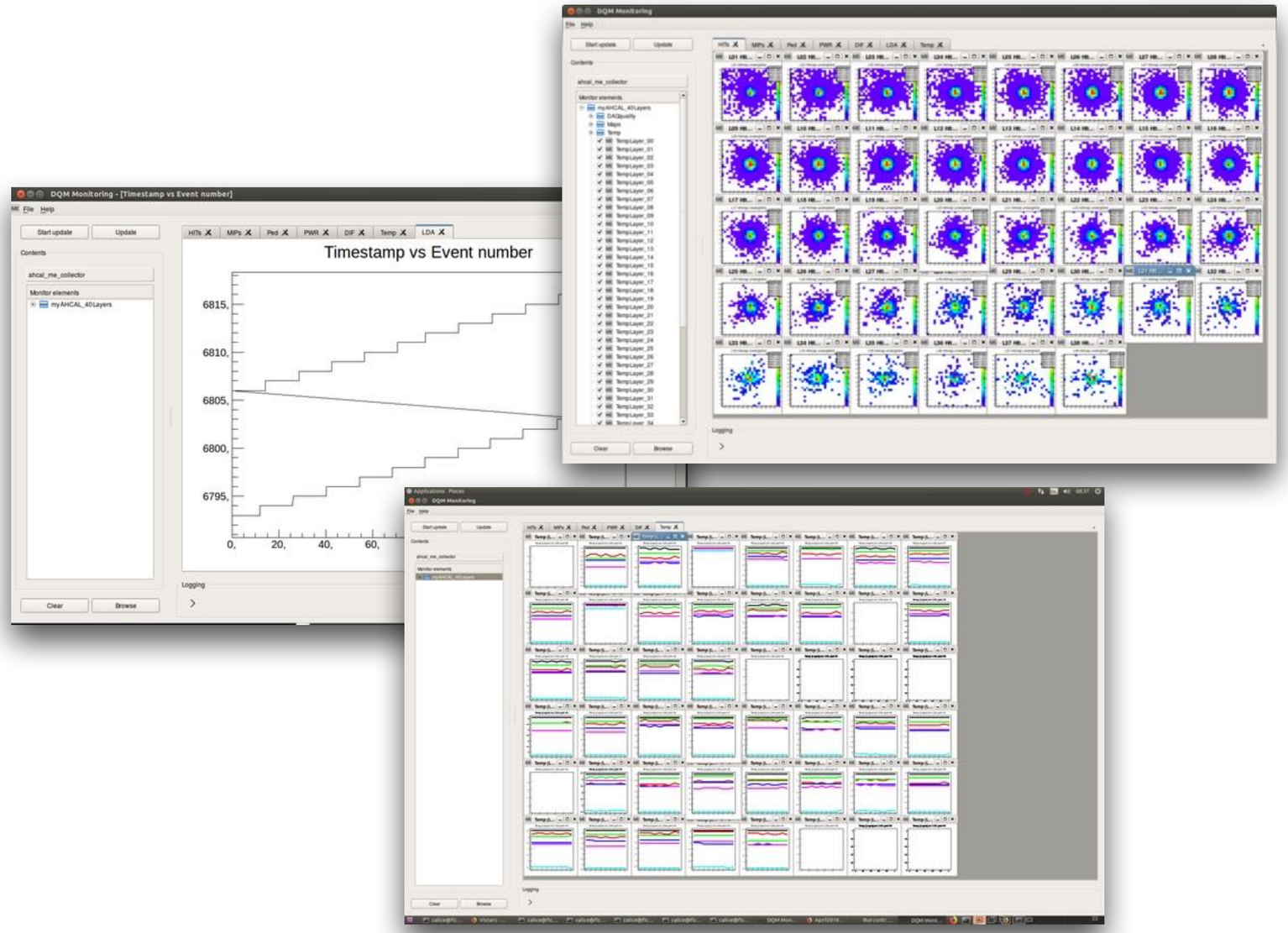
Monitoring

- **Labview**
- **Temperature Monitoring**
- **EUDAQ Monitors:**
  - wire chamber hit maps
  - AHCAL hit maps
  - low level plots



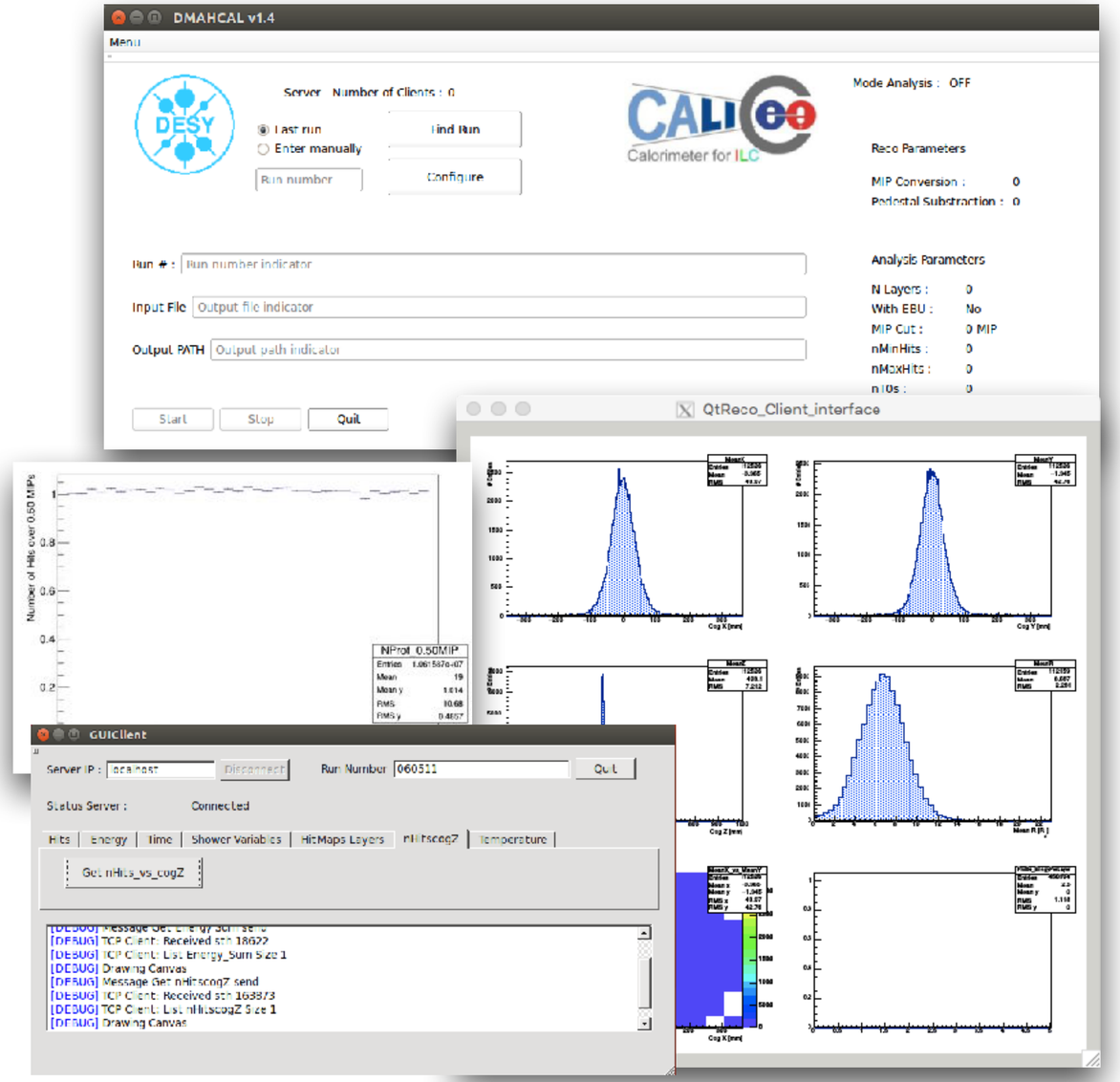
Monitoring

- **Labview**
- **Temperature Monitoring**
- **EUDAQ Monitors**
- **DQM4HEP:**
  - online monitor
  - hit maps, temperature, …
  - more to be implemented



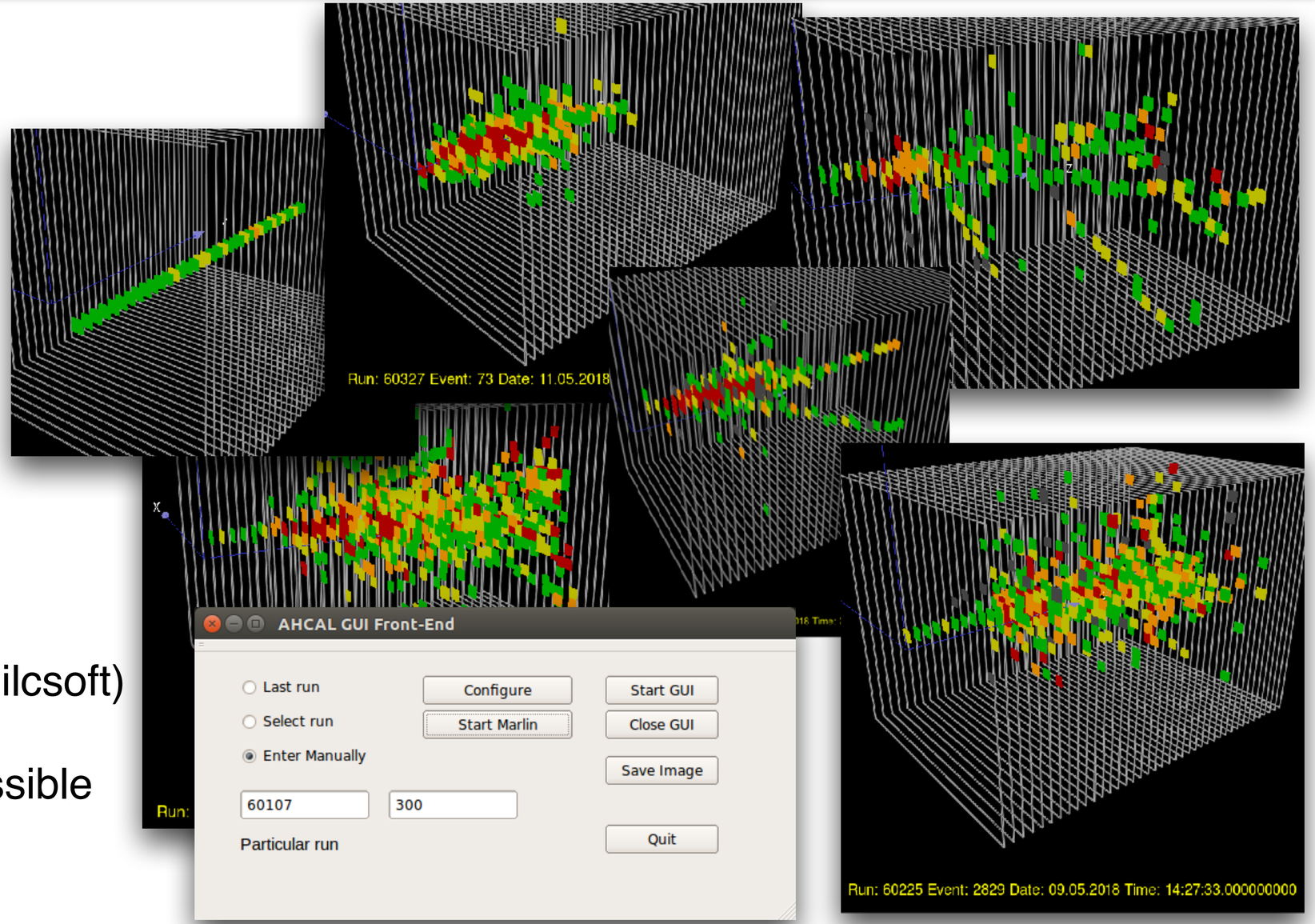
Monitoring

- **Labview**
- **Temperature Monitoring**
- **EUDAQ Monitors**
- **DQM4HEP**
- **Quasi-Online Monitor:**
  - fast reconstruction of files (even while data taking)
  - access to full root tree
  - easy GUI Access to many plots as:
    number of hits distributions, energy distributions, hit maps, shower variables, time distribution, …

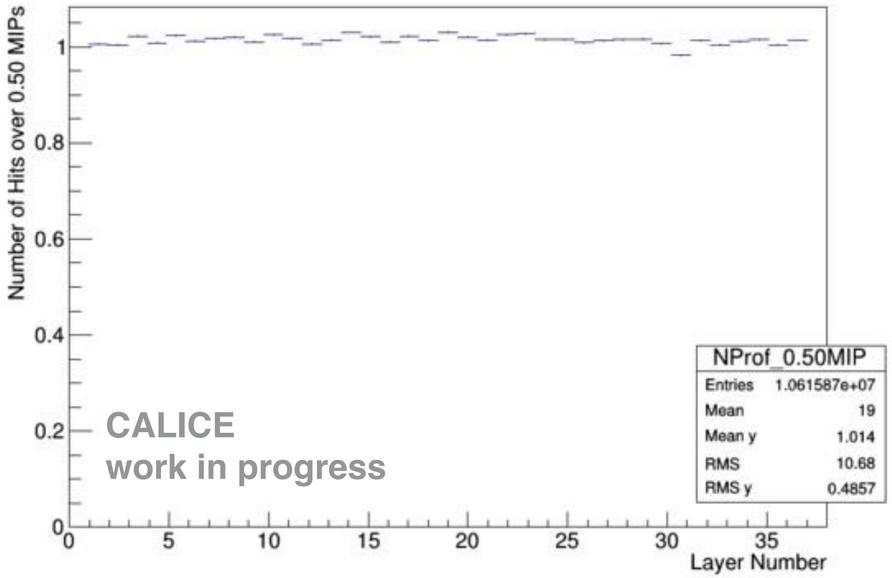


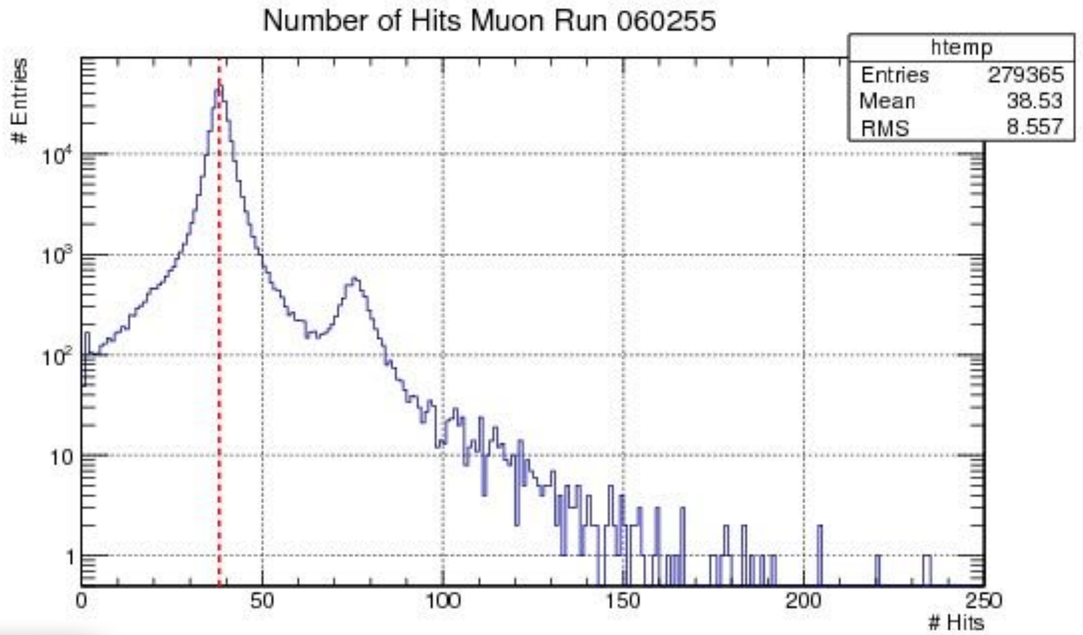
Monitoring

- **Labview**
- **Temperature Monitoring**
- **EUDAQ Monitors**
- **DQM4HEP**
- **Quasi-Online Monitor**
- **Event Display:**
  - easy to use GUI
  - based on CED (C event display, ilcsoft)
  - runs on reconstructed slcio files
  - energy or time color scheme possible

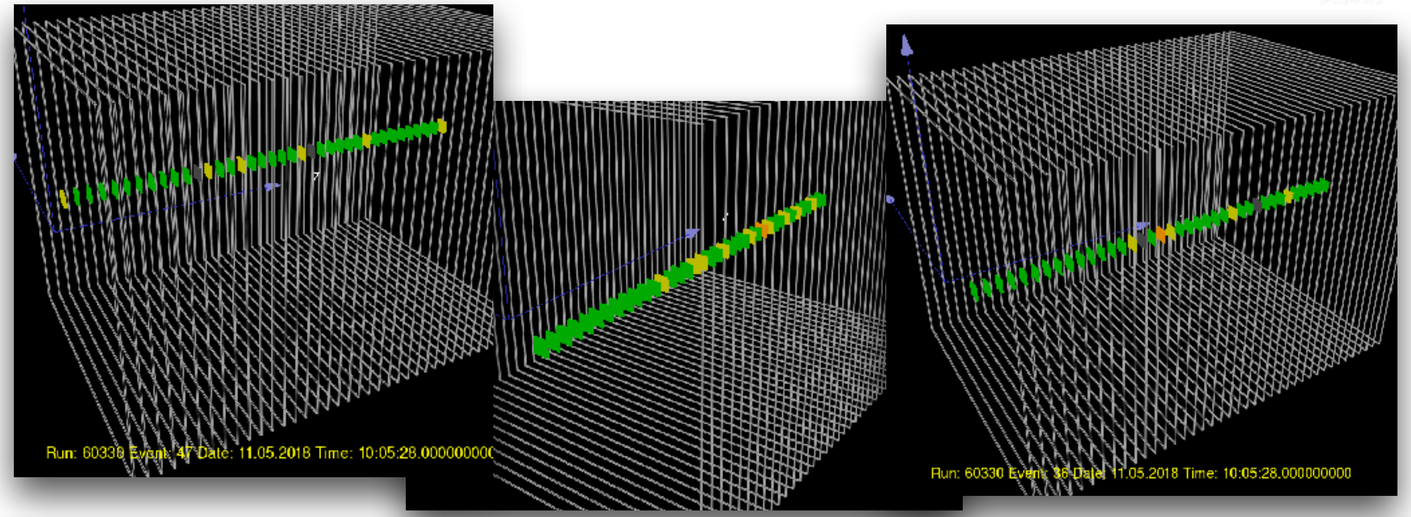


Muon Beam

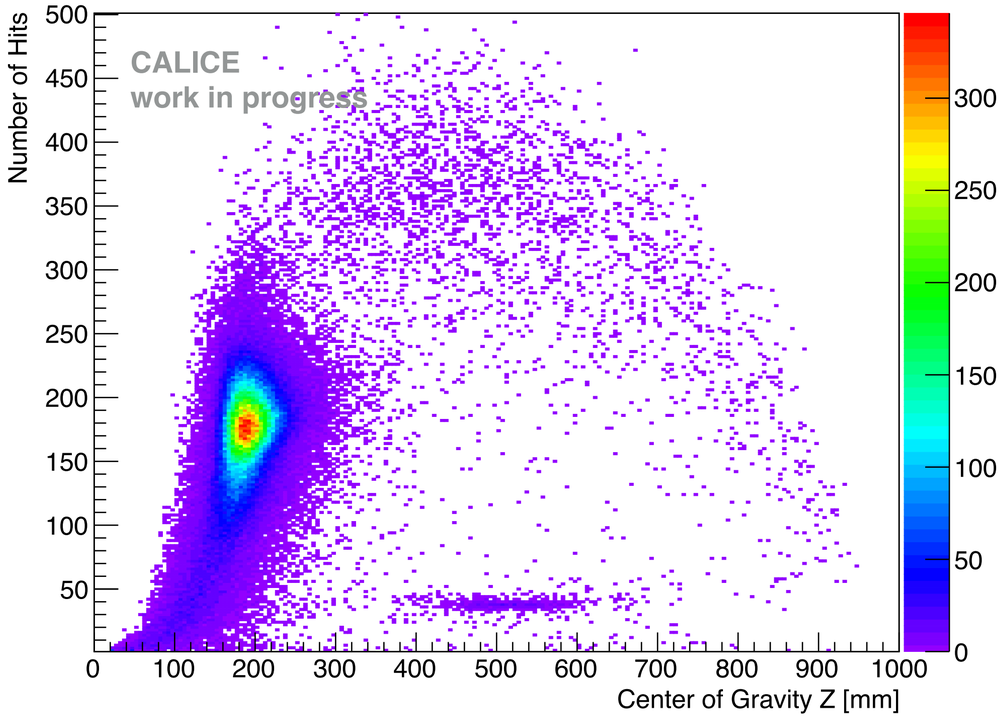




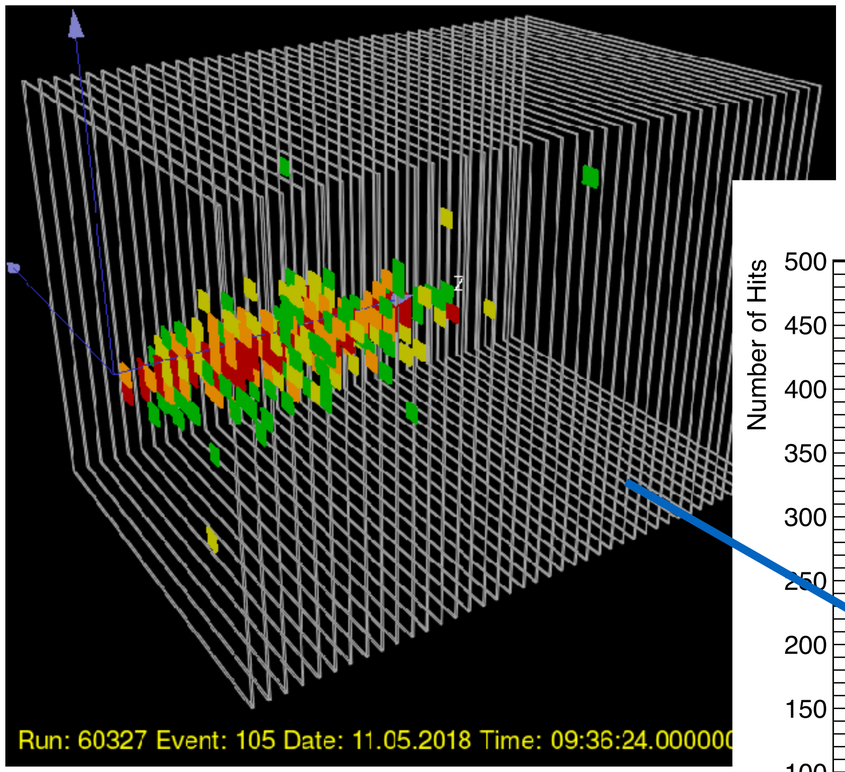
- Hits per event peak at 38 for muons
- ~1% two muon events
- High efficiency, low noise

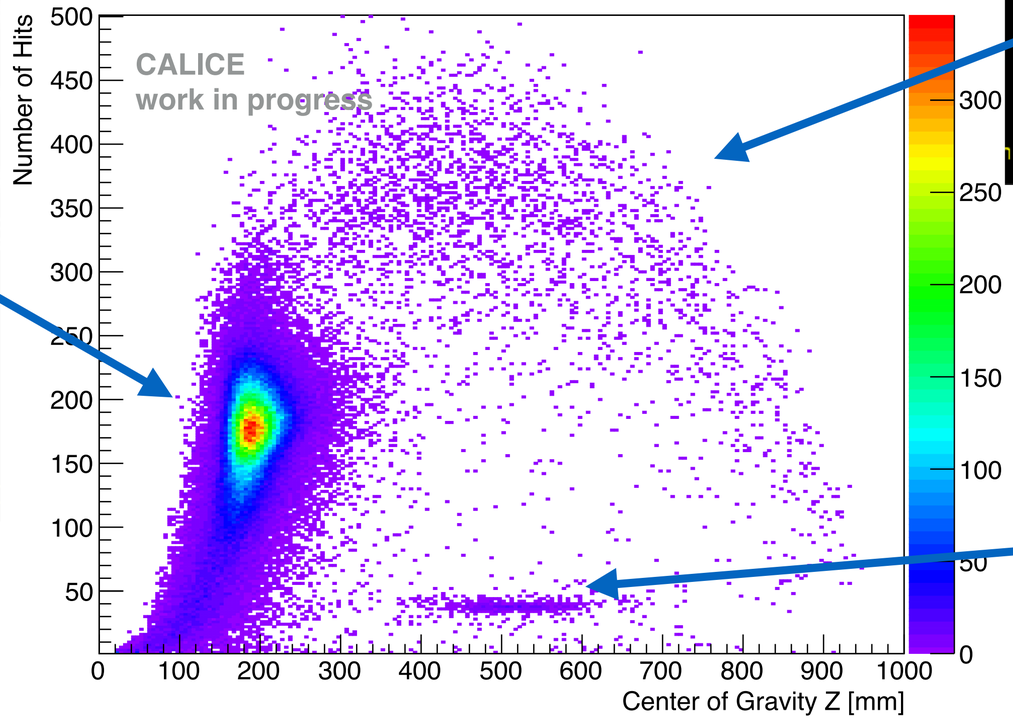


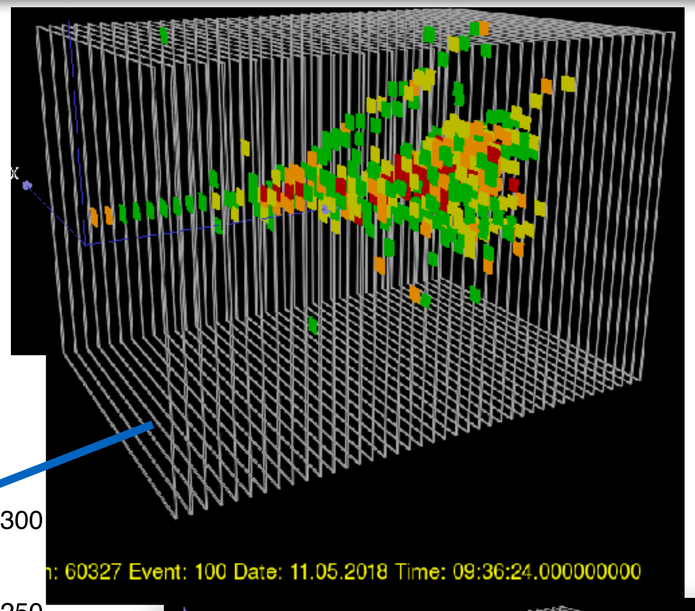
Beam Composition - Electron Beam

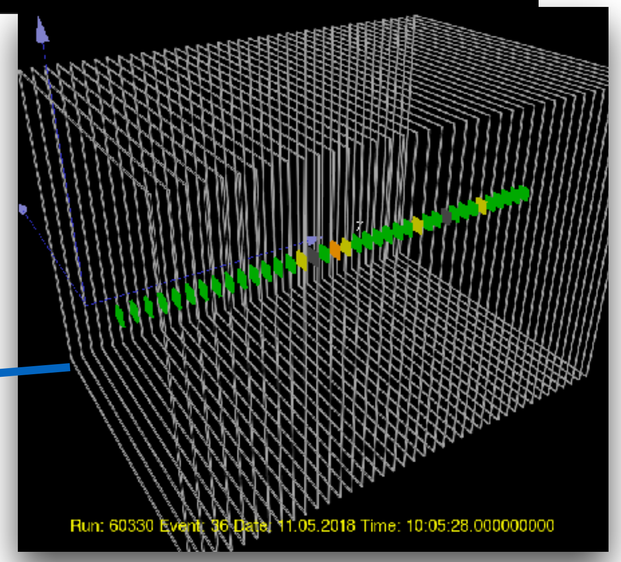


Beam Composition - Electron Beam

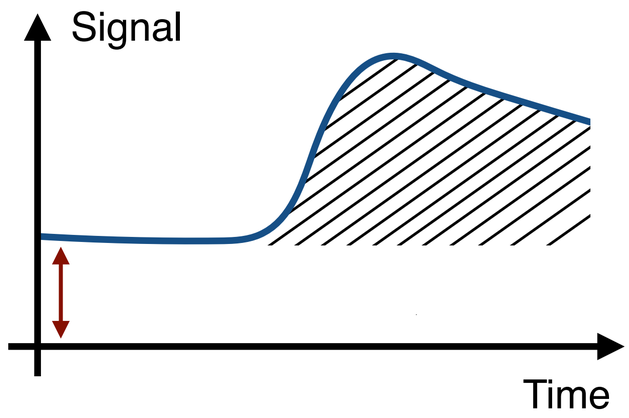


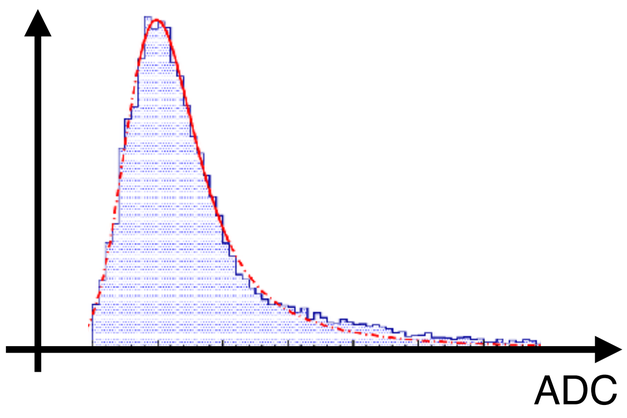


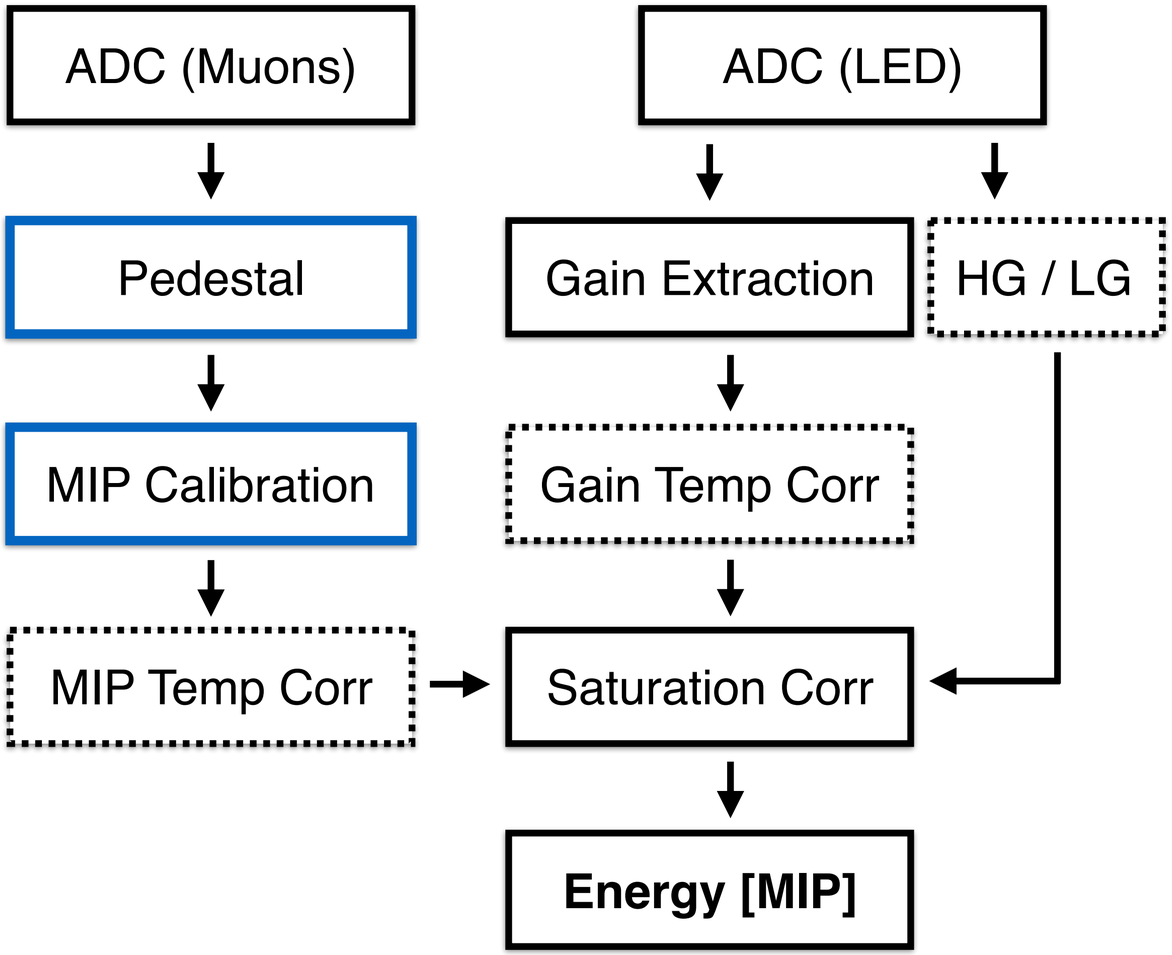




Energy Reconstruction

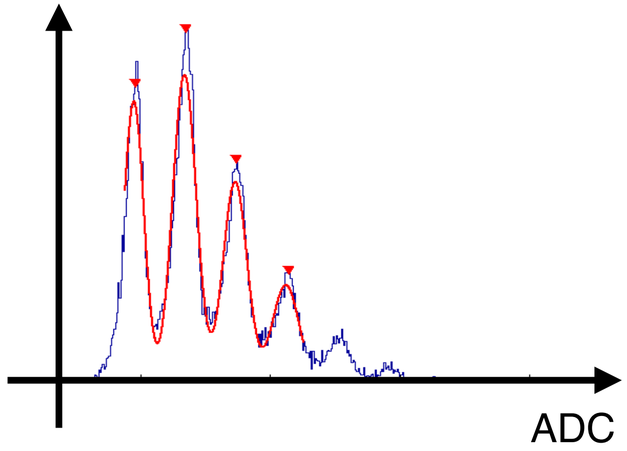






- **First step:**
  - determine pedestal
  - what is the signal of a MIP?
- Calibration done in commissioning phase at DESY using low energetic electrons
- Cross-check calibration with CERN data

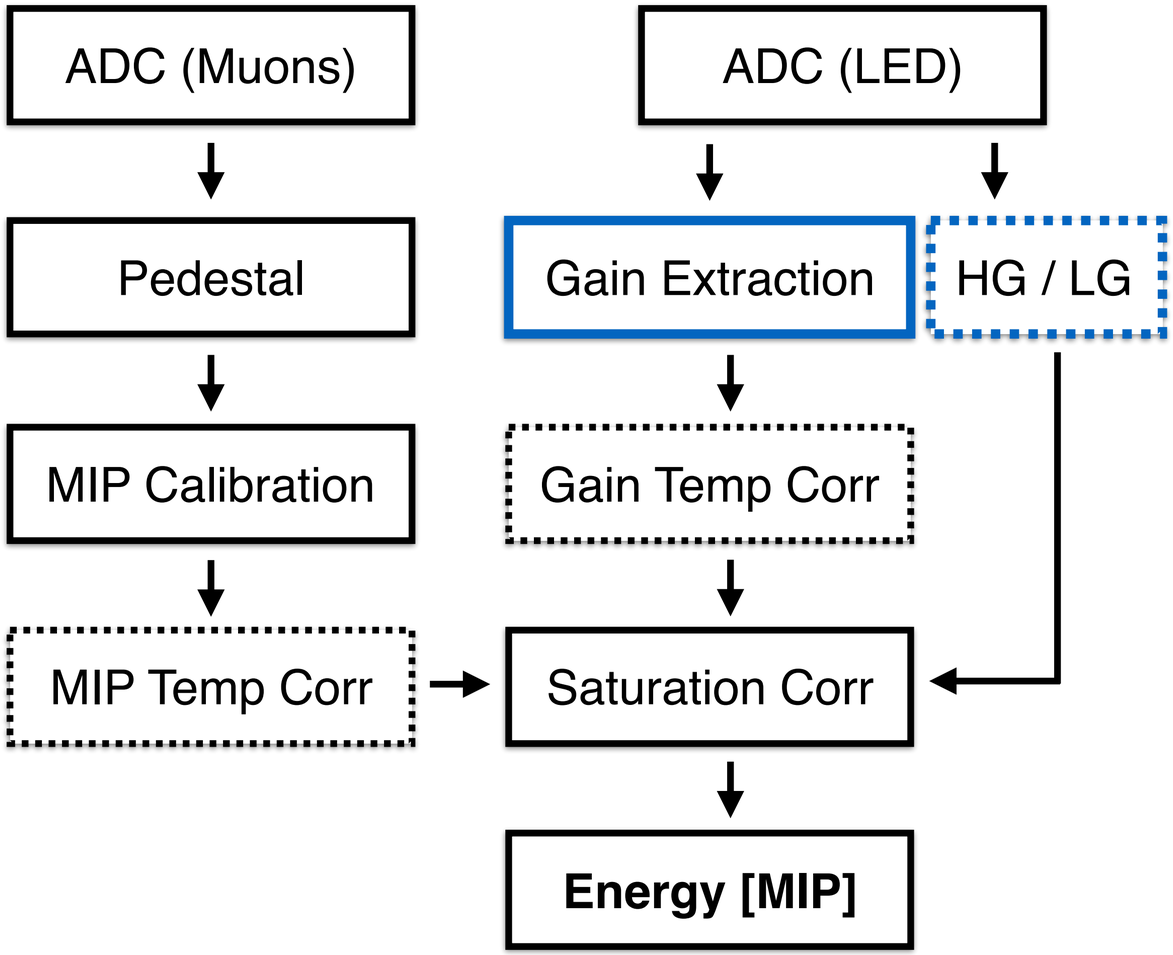
Energy Reconstruction



- **Second step:**
  - High gain / low gain inter-calibration

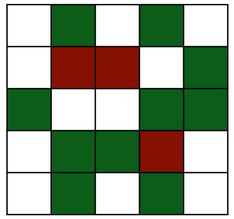
- Two amplification modes to enhance dynamic range while maintaining good low energy resolution

- High gain: calibration done during commissioning
  Low gain: currently, approximate values

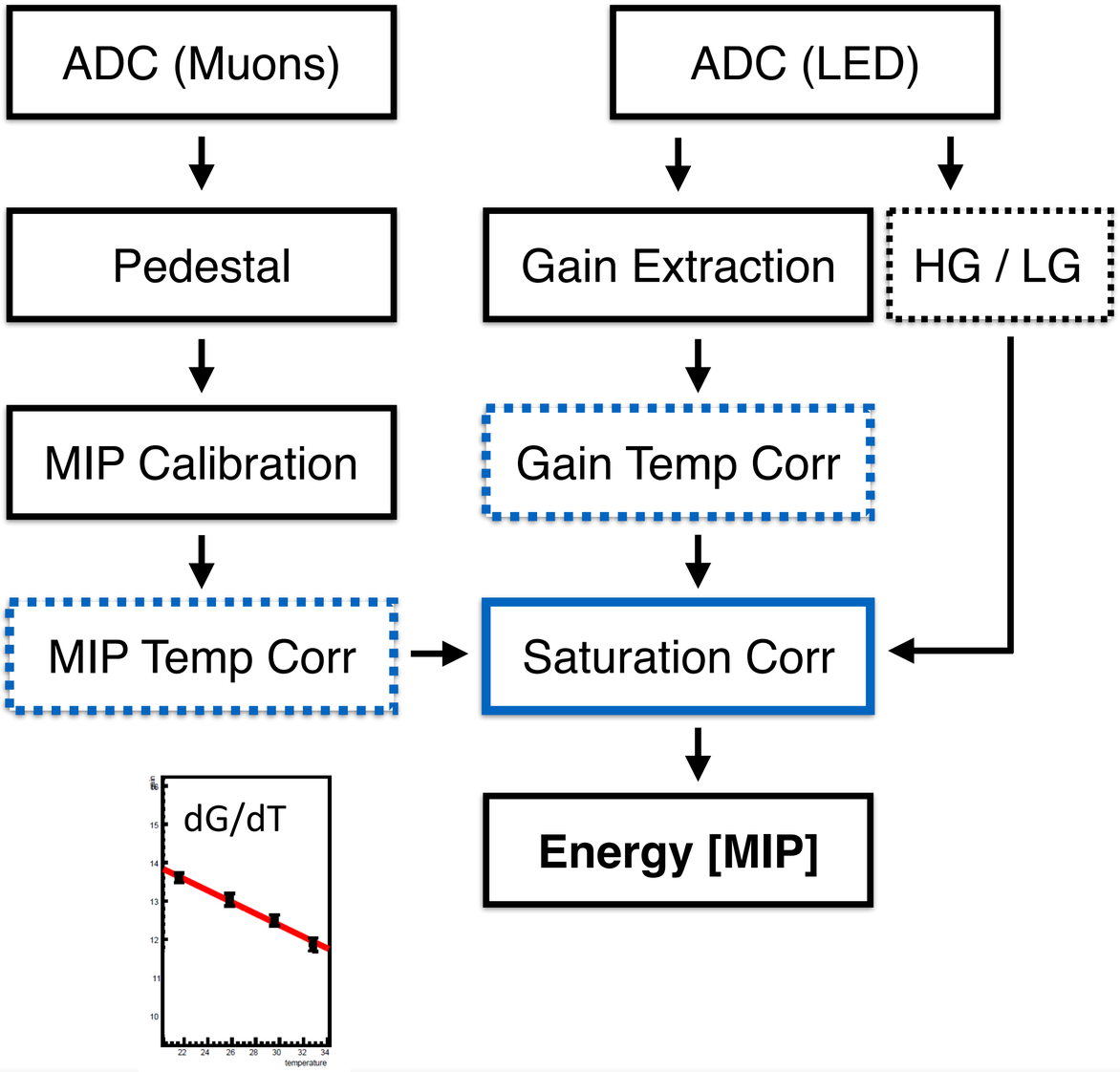


Energy Reconstruction

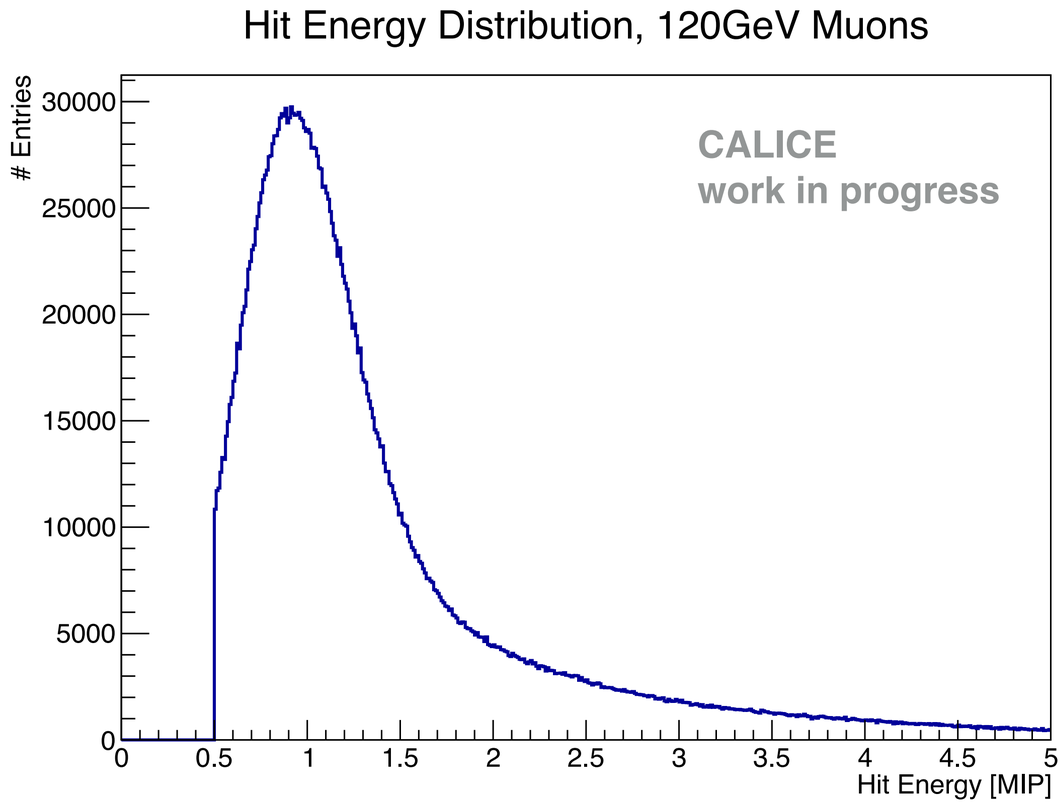
$$f_{\text{saturation}}(N_{\text{fired}}) = N_{\text{total}} \cdot \exp\left[-\frac{N_{\text{fired}}}{N_{\text{total}}}\right]$$



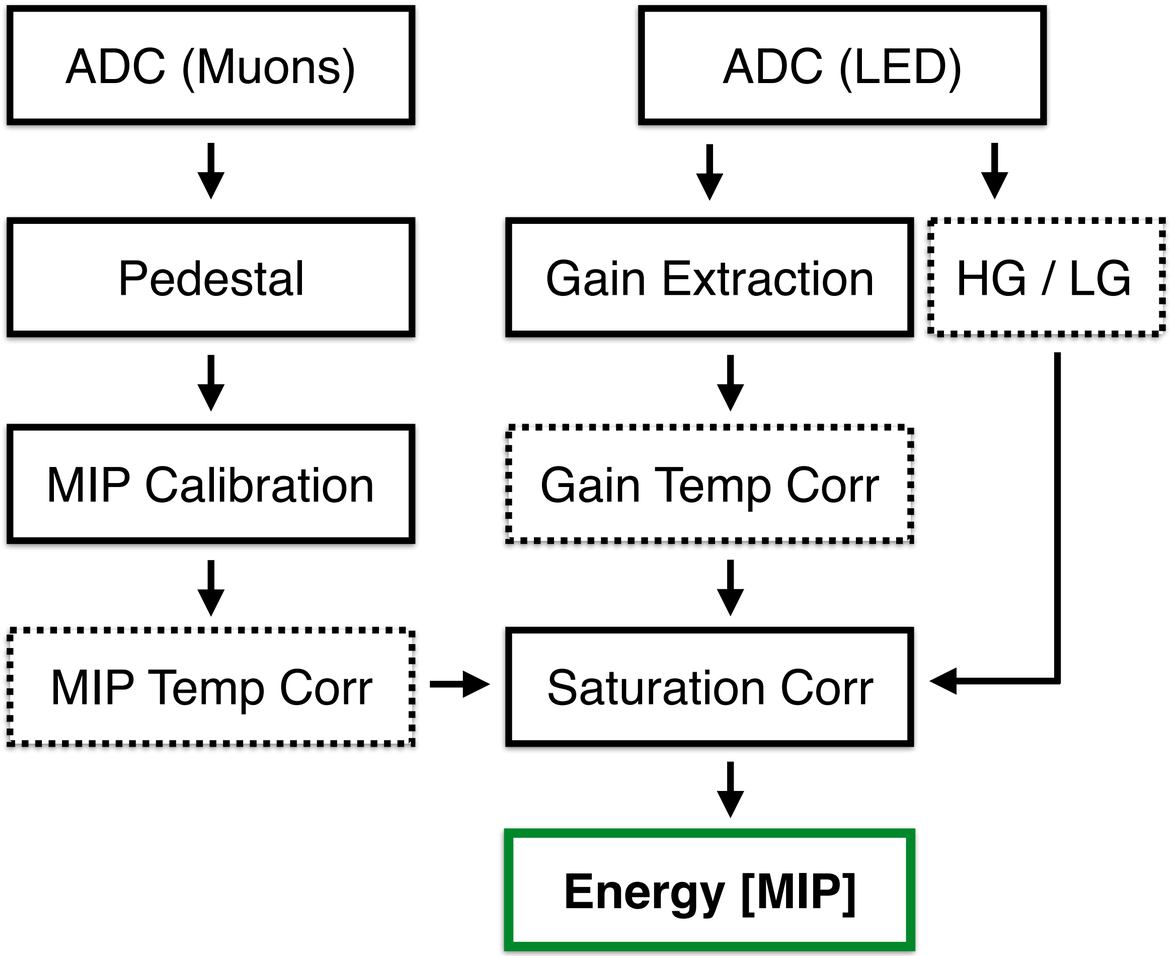
- **Further corrections:**
  - Account for SiPM Effects
- Saturation correction: simple exponential model
  - only important for high energy depositions
- Temperature dependence of gain (MIP): not yet used
  - *temperature compensation:*
    adjust SiPM voltage with temperature change
  —> only residual corrections needed (if at all)



Energy Reconstruction

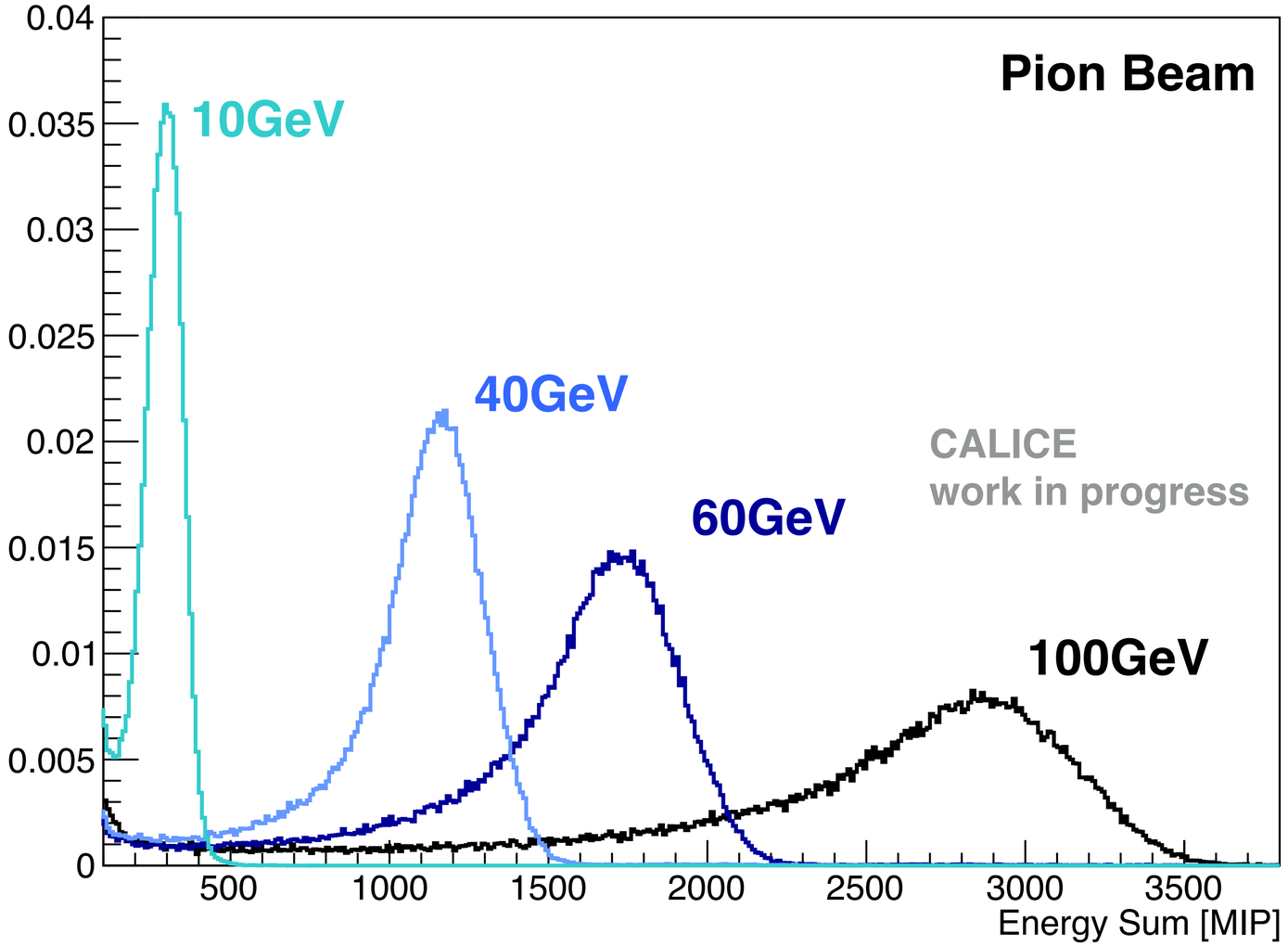


$$E_{\text{calibrated}} = \frac{A}{A_{\text{MIP}}} * f_{\text{saturation}}\left(\frac{A}{A_{\text{pixel}}}\right)$$



Hadron Beams

- Preliminary energy reconstruction
- Only basic muon rejection



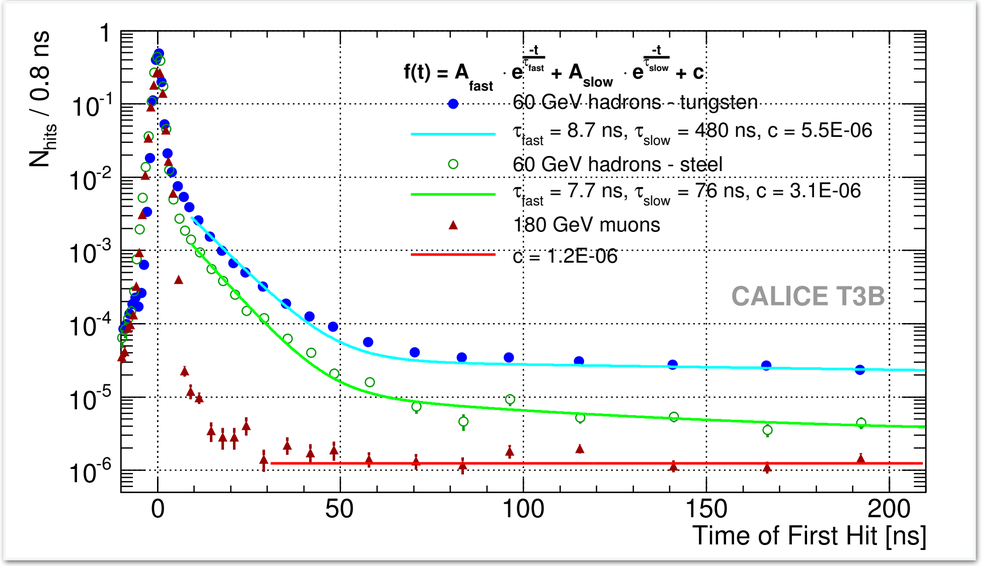
Timing

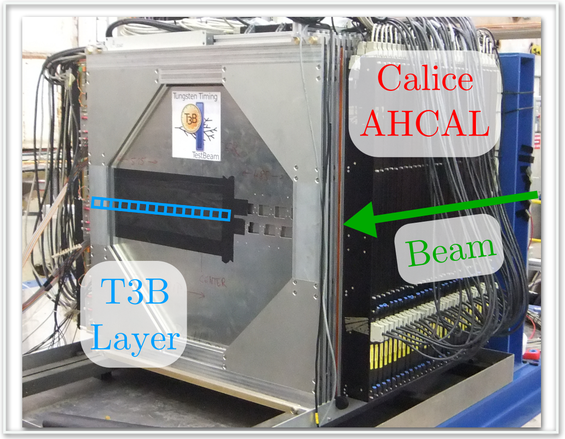
- Complex time structure of hadronic showers:
  Slow neutrons from hadronic processes produce late energy depositions

- Previous measurements:
  T3B parasitic to physics prototype

- Now: Timing capabilities in whole prototype

- Readout ASIC (SPIROC 2E) has two timing modes:
  - test beam mode: ~1.2ns / TDC
  - ILC mode (80ps / TDC) possible

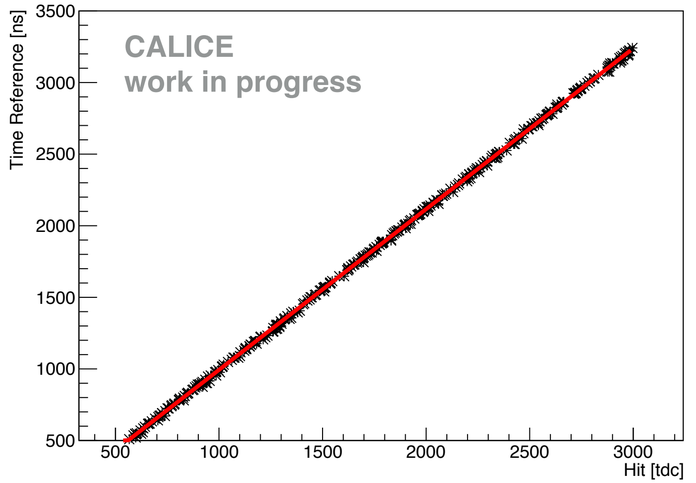


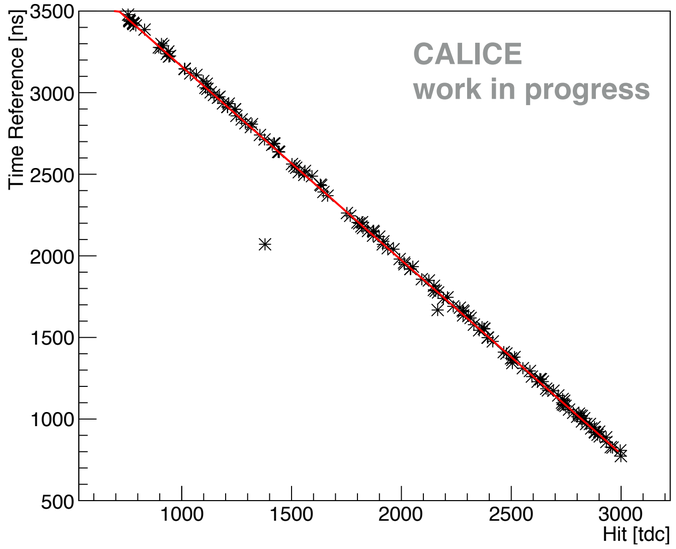


T3B behind physics prototype

Time Calibration

- Muon scan used for calibration
- Trigger scintillator for time reference is managed by beam interface board (BIF)
- Time calibration procedure established
- Two slopes per chip,
  fit with per mille precision needed
- Offset for each memory cell (16 per channel)
  700’000 calibration constants
- Corrections missing:
  - time walk
  - non-linearity





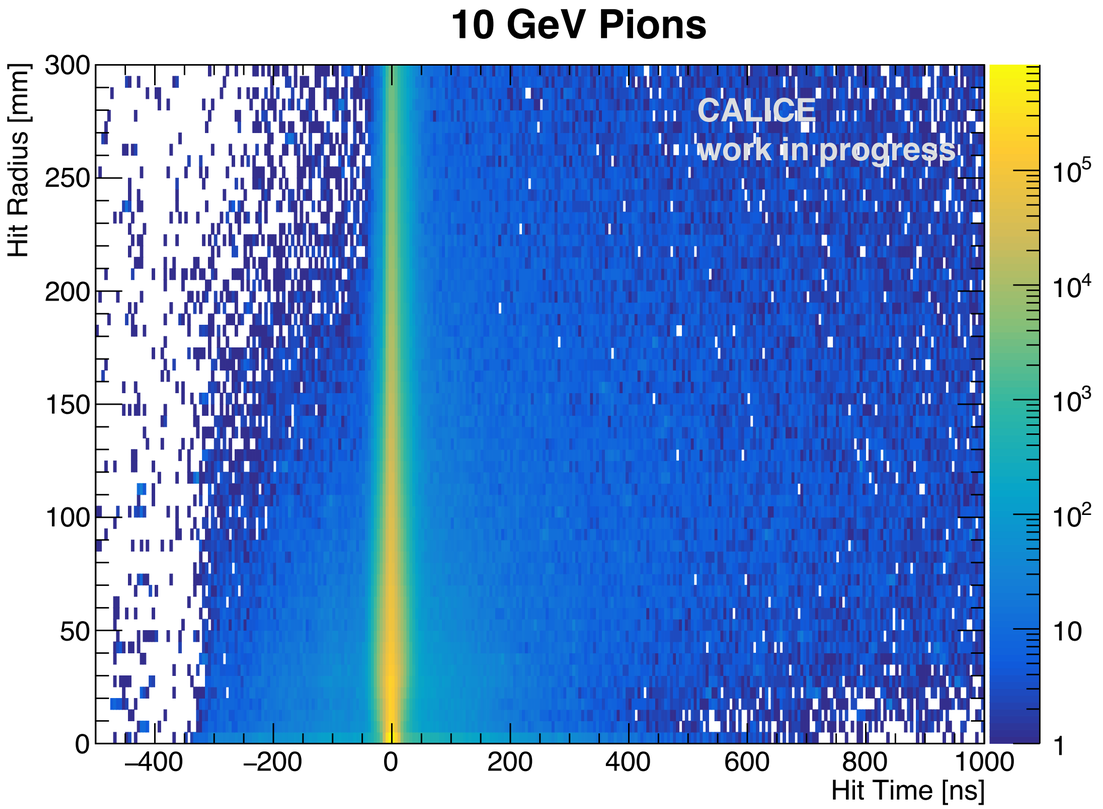
Time Reconstruction

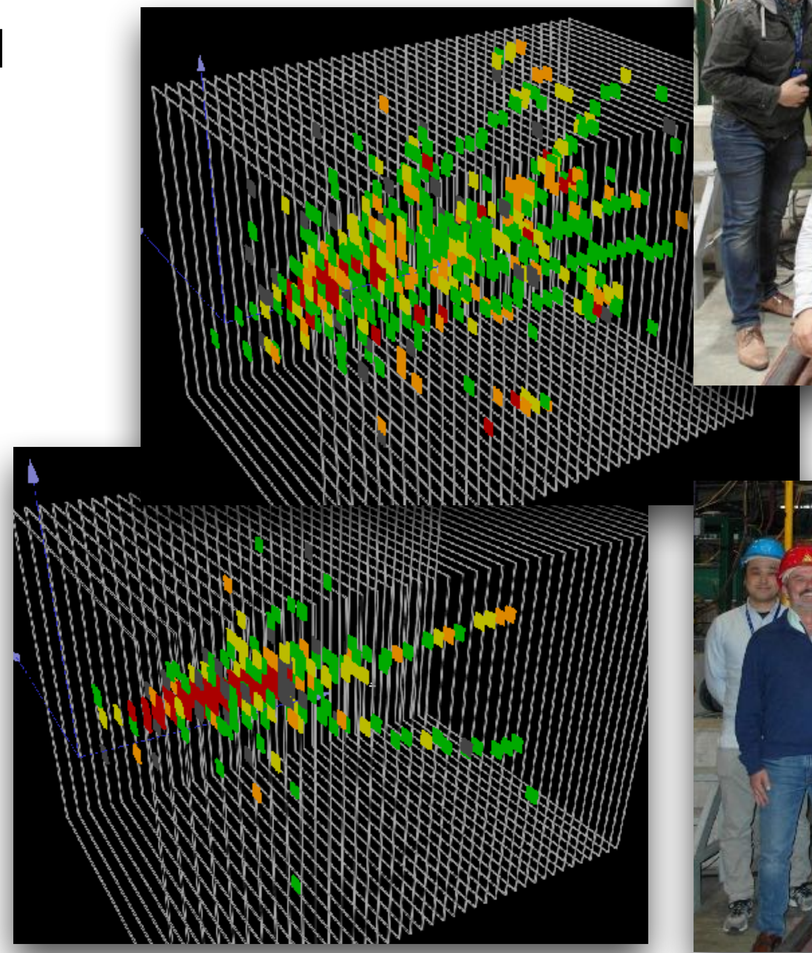
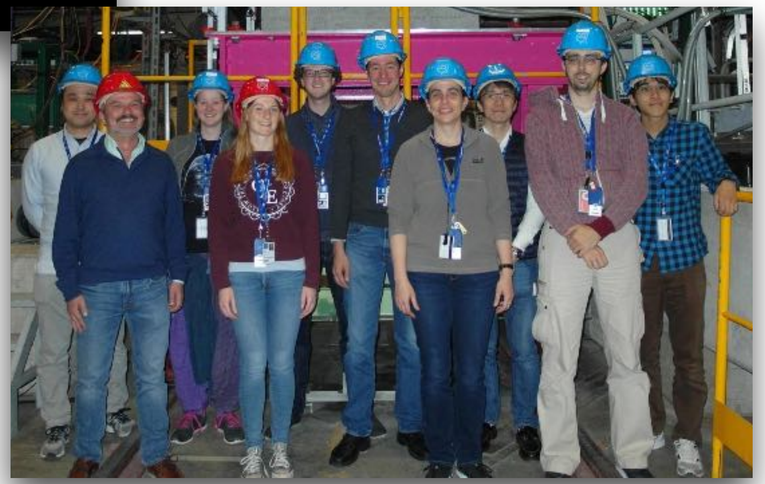
- Preliminary time reconstruction:
  - time calibration not complete
  - corrections missing

- Readout ASIC shows problems for high rates
  - hopefully recoverable; analysis ongoing

- Late energy depositions visible

- Outlook: investigate complex time structure of hadronic showers



Summary

- Successful test beam campaign at CERN
- Detector prototype is in good shape:
  - reliable operation
  - few dead channels, low noise
- Full software chain from raw to reconstructed data available
- First look into data looks promising
- Many analyses to follow…