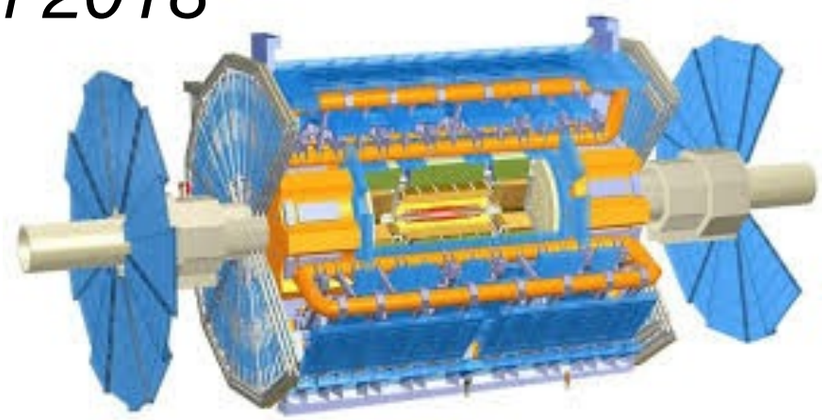
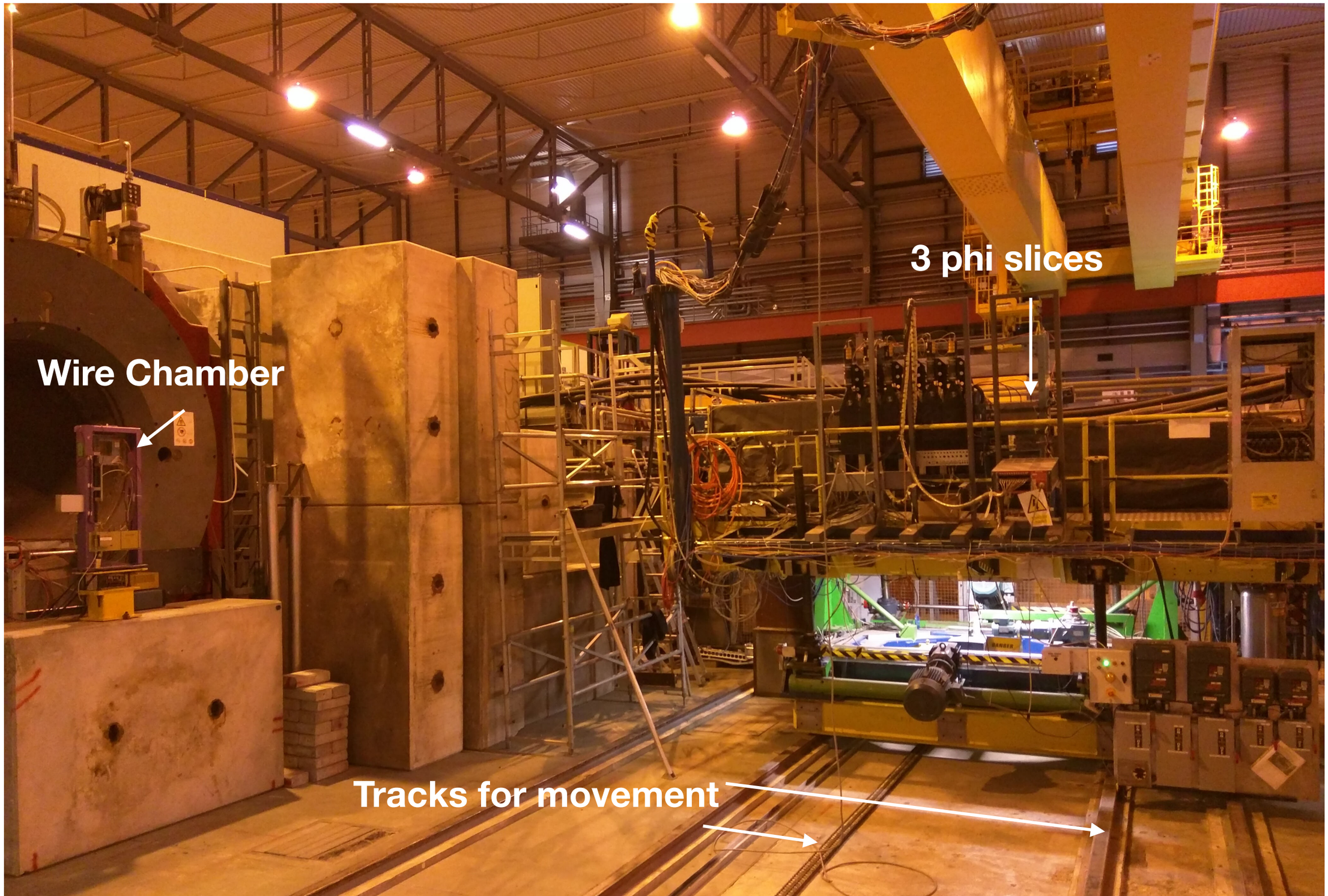
Test Beam Studies for the ATLAS Tile Calorimeter Upgrade Readout Electronics

Doug Schaefer (University of Chicago)
on behalf of the ATLAS Tile Calorimeter System

Test Beam Work Shop Zurich 2018

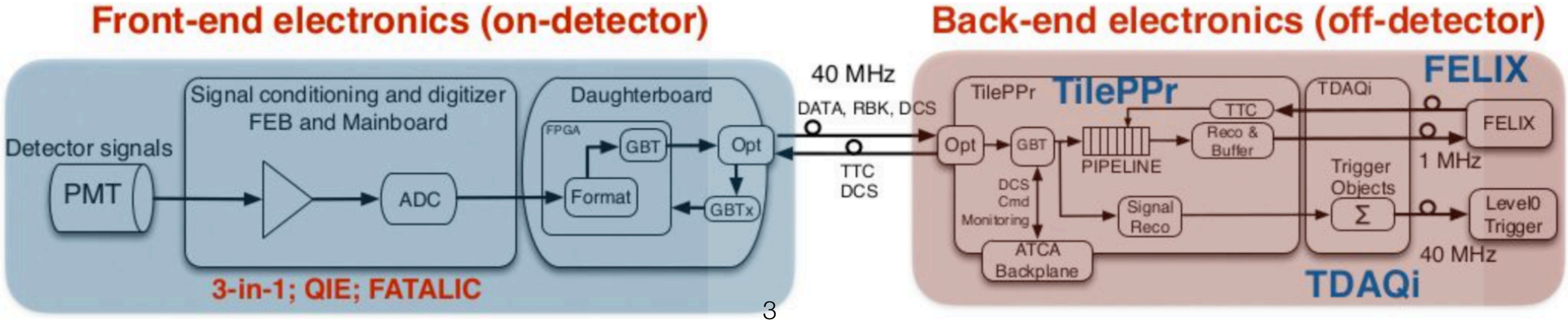


ATLAS Tile Calorimeter Slice at CERN Test Beam



Tile Calorimeter Planned Updates

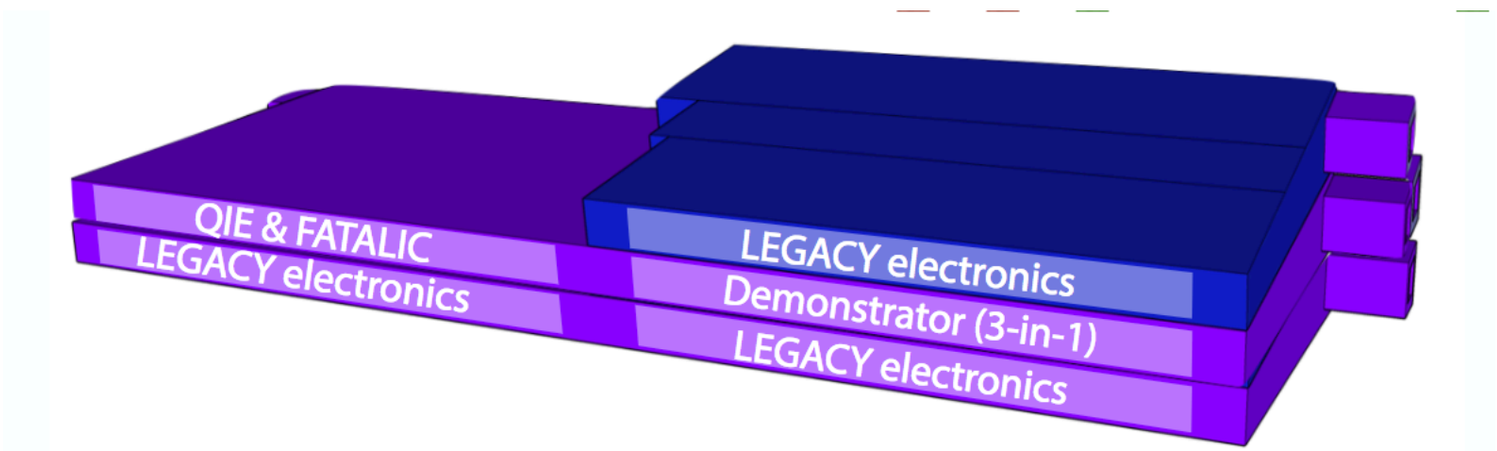
- HL-LHC starting in 2026 expects an increase in instantaneous luminosity by around a factor of 5-7 respect to the nominal LHC
- ATLAS plans upgrades called Phase-II to compensate for the higher rates of pileup with installation from 2024-2025
- The upgrade of scintillating tiles, fibers, and PMTs are not foreseen for the Tile Cal
- The readout electronics will be replaced to adopt the ATLAS full-digital trigger system
  - Provide full-granularity digital data at Level-0/1 (40 MHz)
  - The current electronics do not meet HL-LHC radiation tolerance requirements
  - Degradation (and aging) of electronics due to radiation & time



Testing Readout/Digitization Options for Phase-II upgrade

- Three options were considered for the upgrade of the digitizing front end electronics

3-in-1	Fatalic	QIE
Shaper, bi-gain clamping amplifiers and slow integrator 12bit ADCs. Called the Demonstrator	Front-End ATLAS Tile Integrated Circuit (FATALIC). New technology for TileCal implemented as an ASIC aiming for a low noise chip. FATALIC does signal conditioning by means of a shaper and digitization	Charge Integrator and Encoder. New technology for ATLAS TileCal, but used in other experiments (e.g.CMS). It is an ASIC that does signal conditioning by means of an integrator.



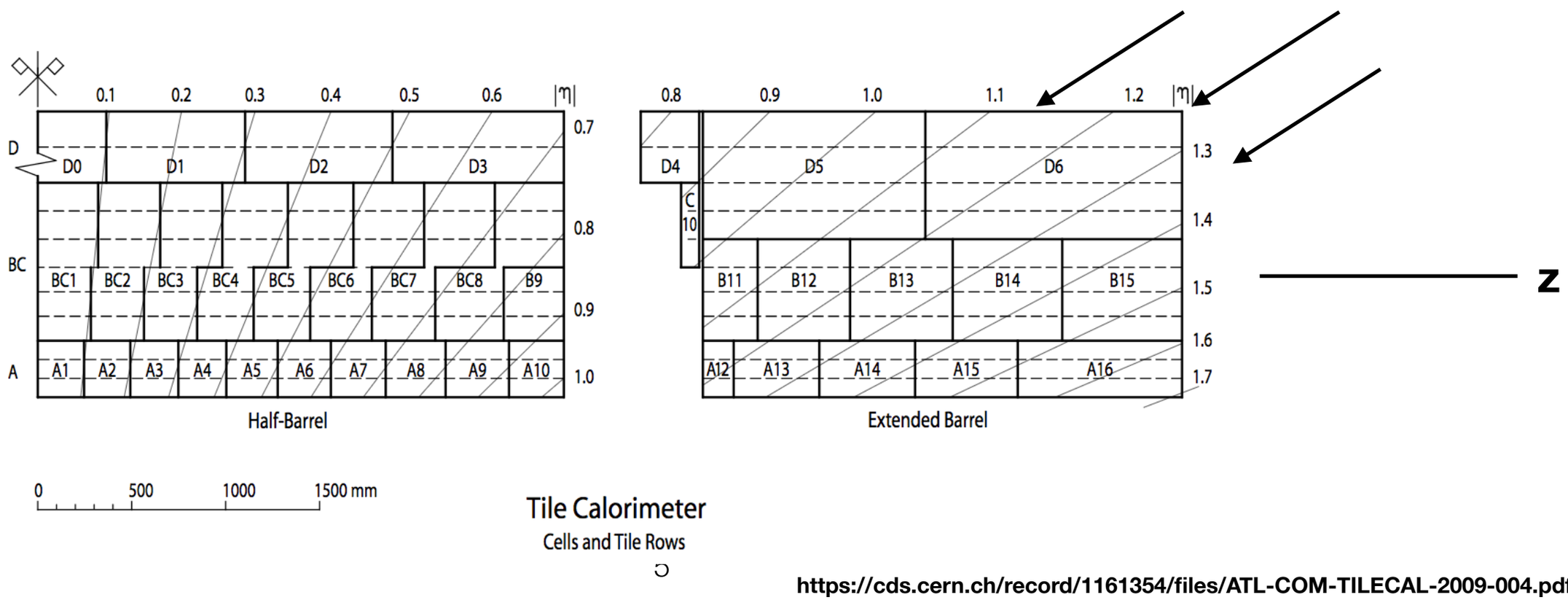
https://cds.cern.ch/record/1161354/files/ATL-COM-TILECAL-2009-004.pdf

Layout of The Calorimeter Layers

- 3 layers (A, BC, and D) in the barrel and end cap of the ATLAS Tile Calorimeter
- Sections in η indicate “towers” used to identify cells of the calorimeter that have their energy summed for a hardware based trigger at 40 MHz
- Each layer was scanned during the test beam in “z” to measure the consistency in response between cells and also in ϕ to measure the energy resolution of hadrons & electrons

Trigger towers

Layers



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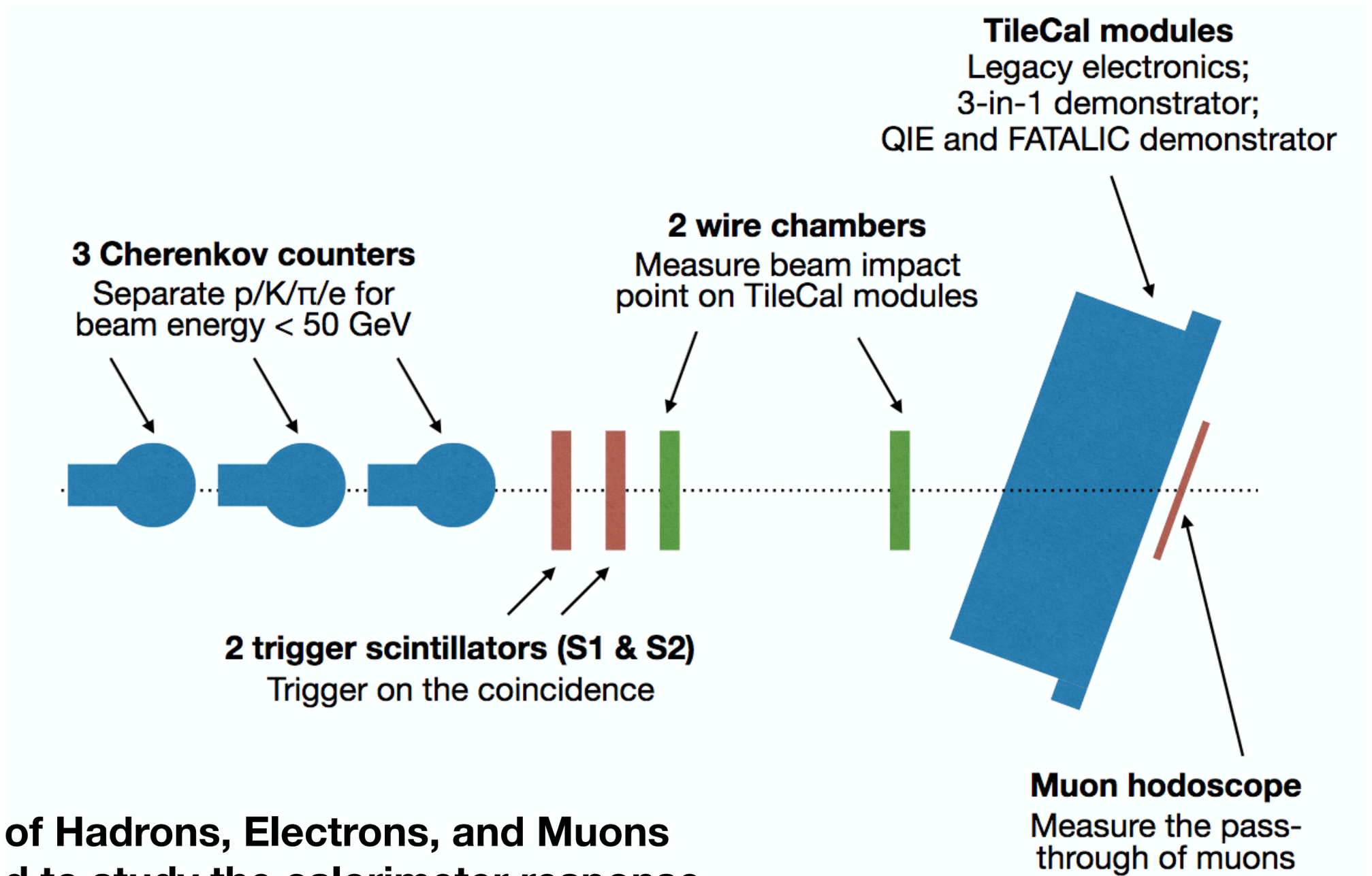
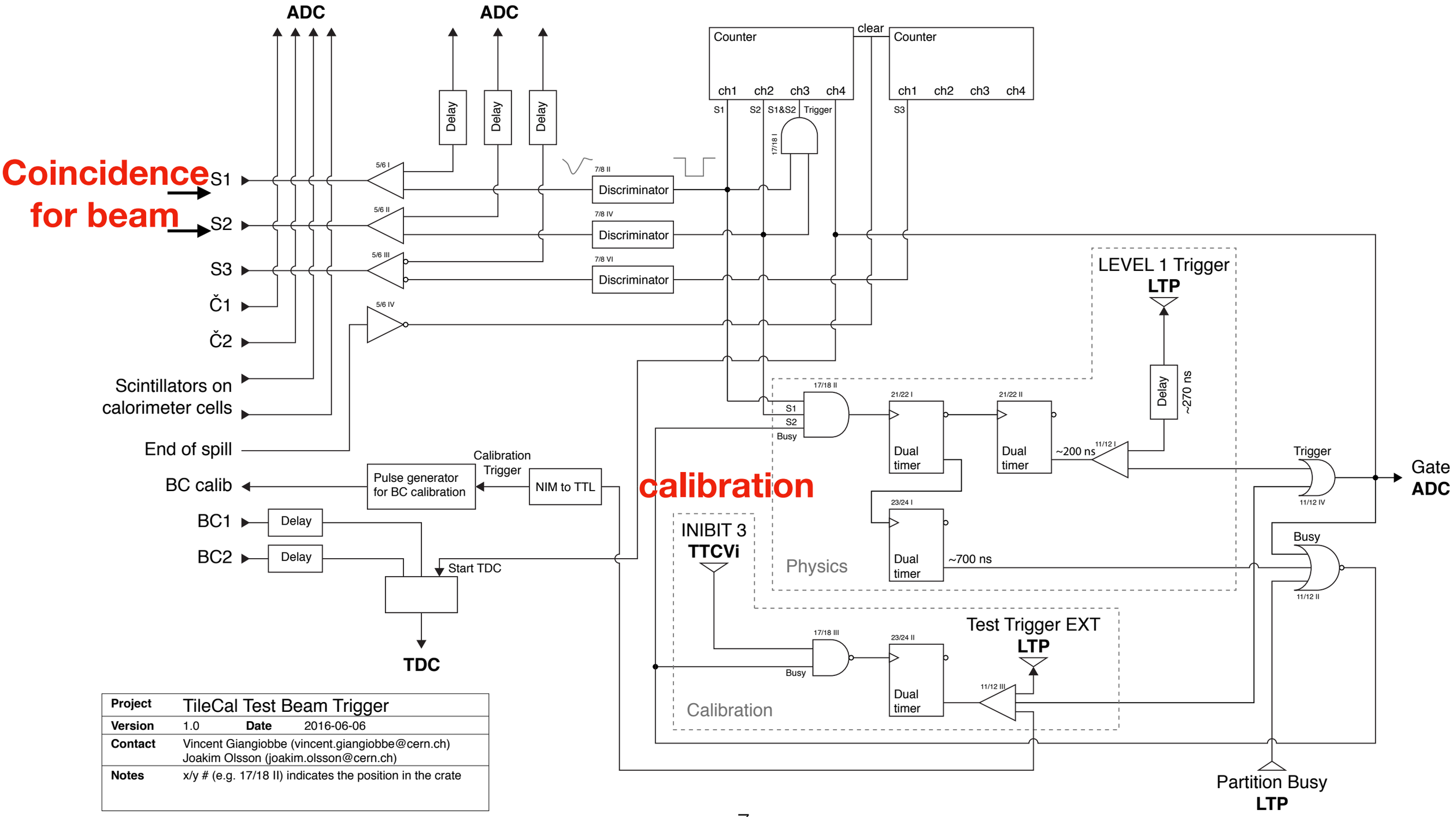
Layout for Particle ID & Beam Positioning



Beams of Hadrons, Electrons, and Muons were used to study the calorimeter response

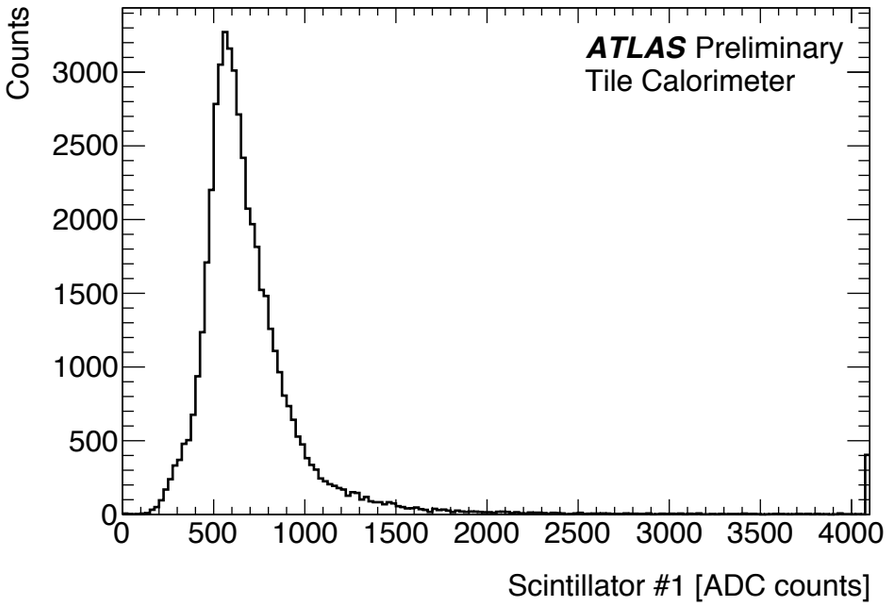
Trigger Setup

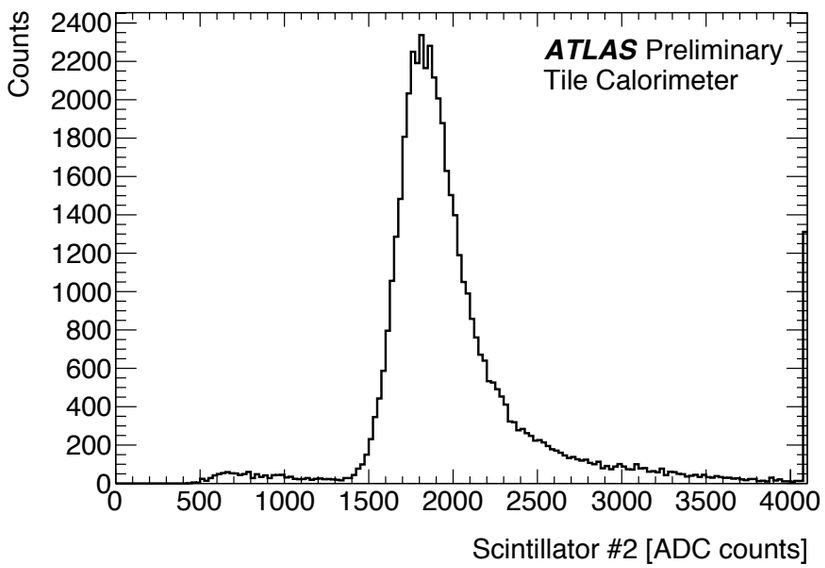


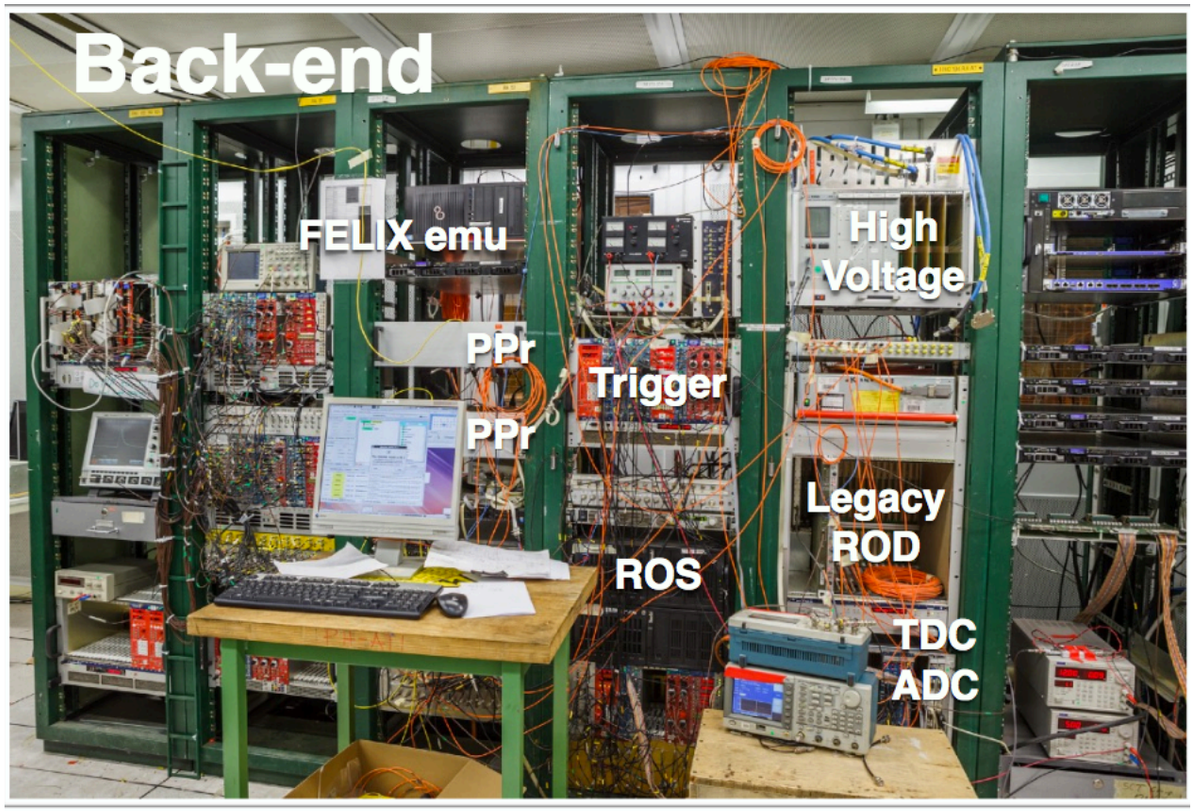
Project	TileCal Test Beam Trigger
Version	1.0 **Date** 2016-06-06
Contact	Vincent Giangiobbe (vincent.giangiobbe@cern.ch) Joakim Olsson (joakim.olsson@cern.ch)
Notes	x/y # (e.g. 17/18 II) indicates the position in the crate

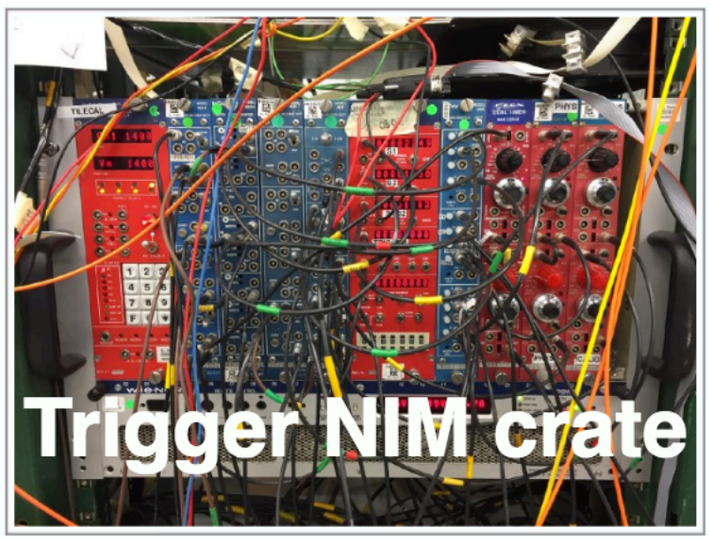
Trigger Setup

Require the coincidence of two scintillators









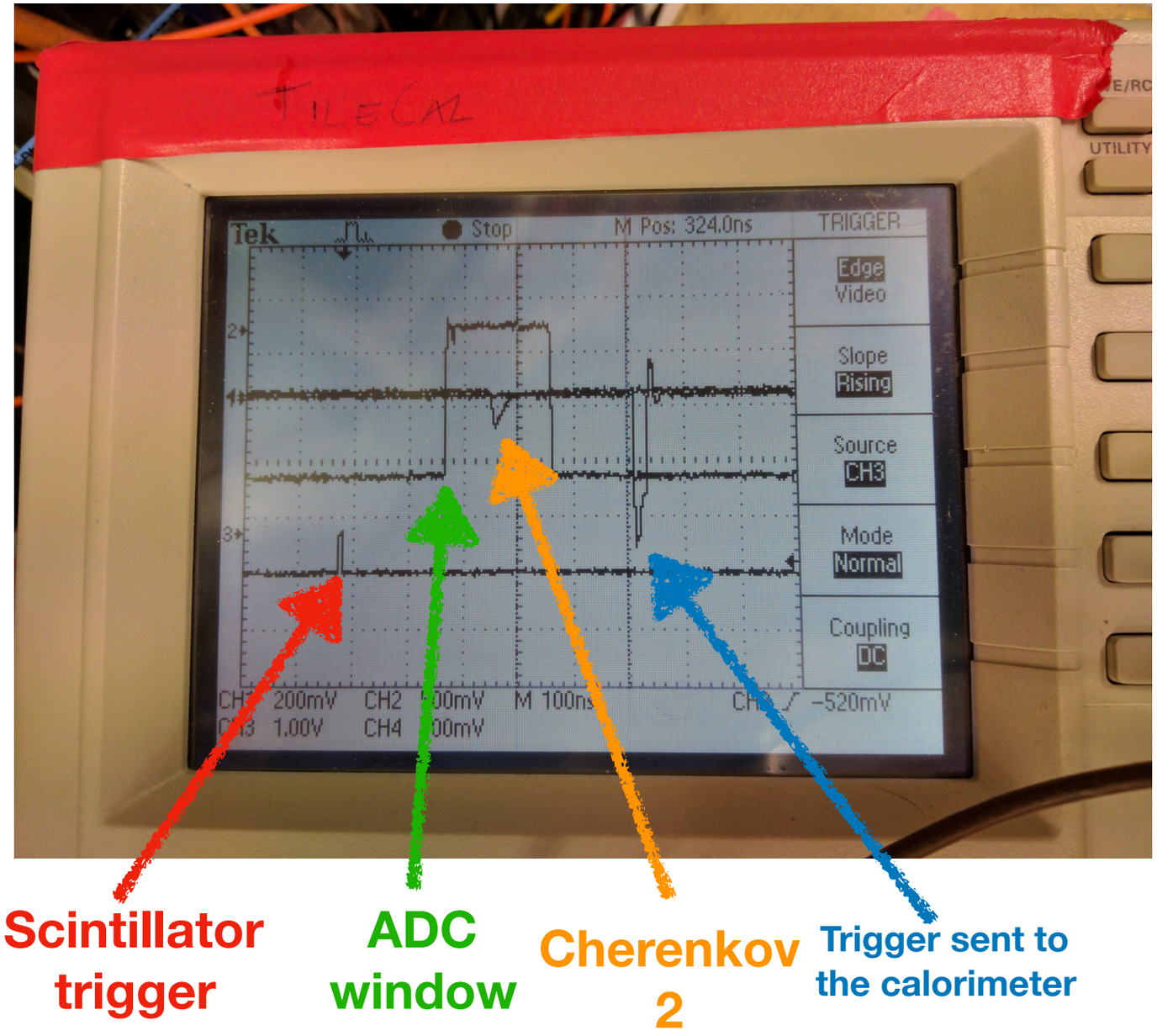
Timing the Triggers

- Trigger on the coincidence of two scintillators intimates the test beam trigger

- 3 cherenkov detectors are used to separate electrons, pions, and kaons. They are readout using an ADC

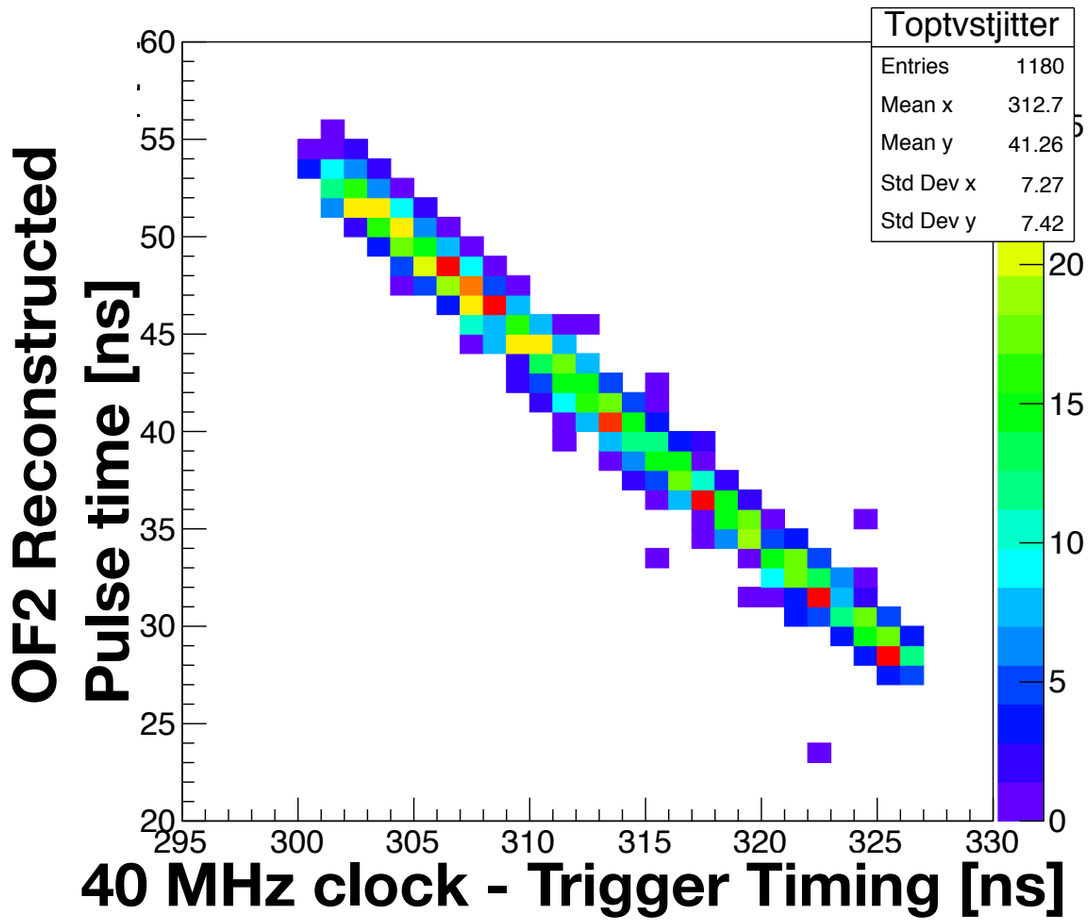
- Beam position is determined with two wire chambers

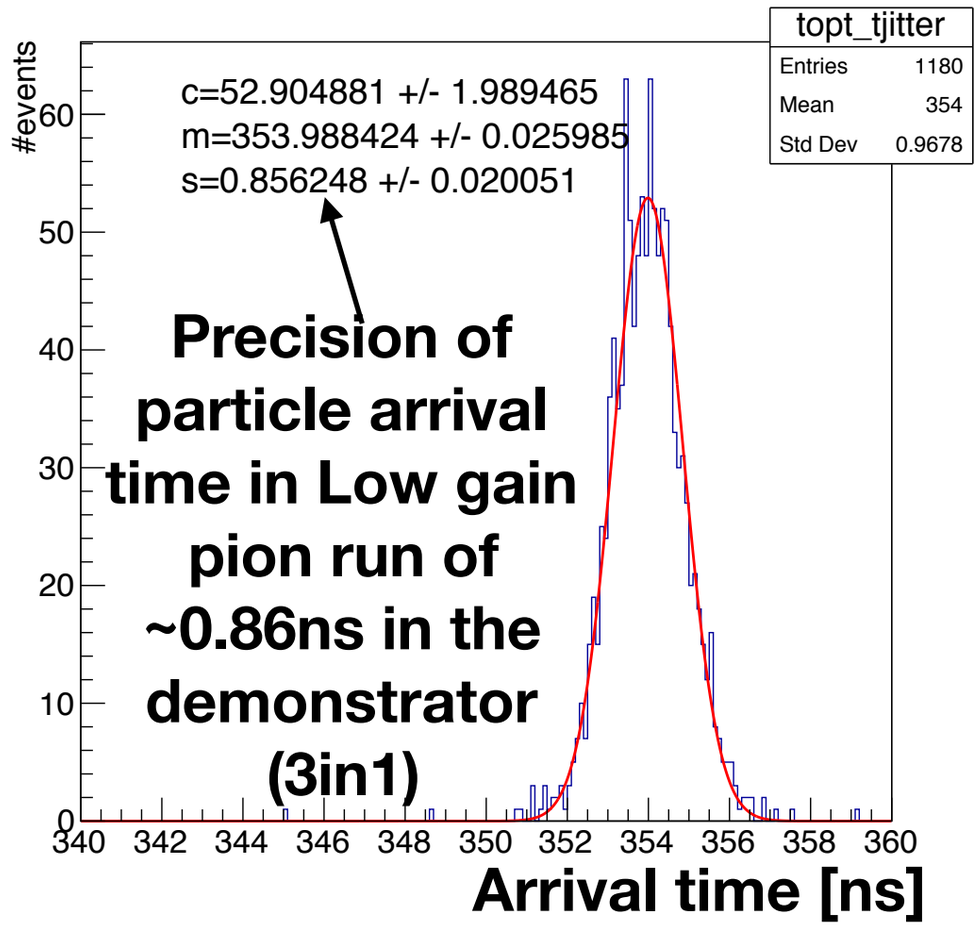
- Finally the trigger is sent to the Tile Calorimeter asking for the signals recorded



Measure of Pulse Timing

- Goal: Measure the timing reconstruction of pulses
  - **Beam arrival time:** The timing difference between the scintillator triggers and the 40 MHz clock was recorded with a TDC. This measures the arrival time of particles with ~1 ns precision
  - Subtracting the (Optimal Filter pulse reconstruction) *OF2 timing* of reconstructed pulses and the *beam arrival time* establishes an upper bound of ~0.86 ns on the timing response of the 3in1, which the limit of the TDC precision

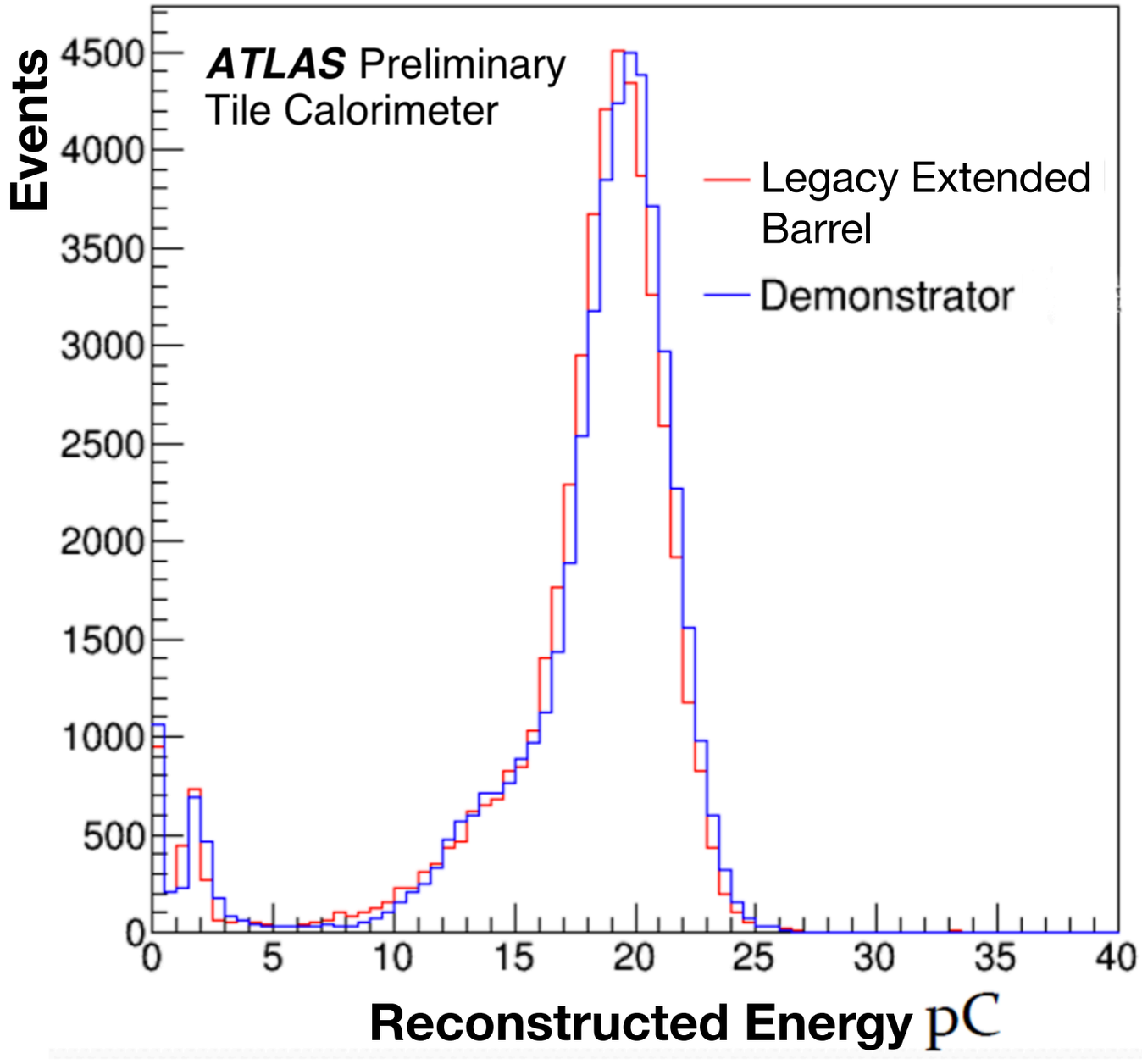




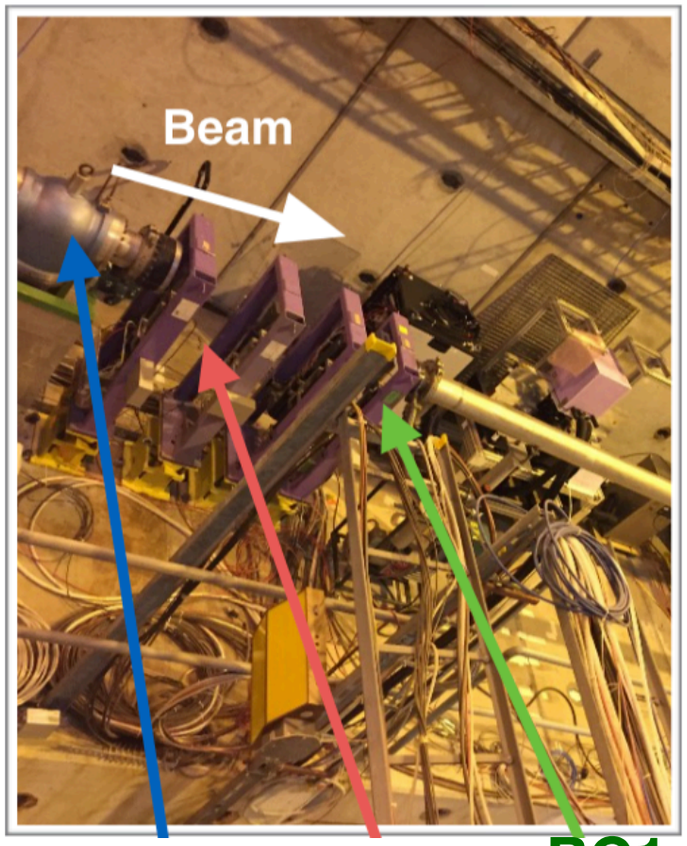
Response of the New System

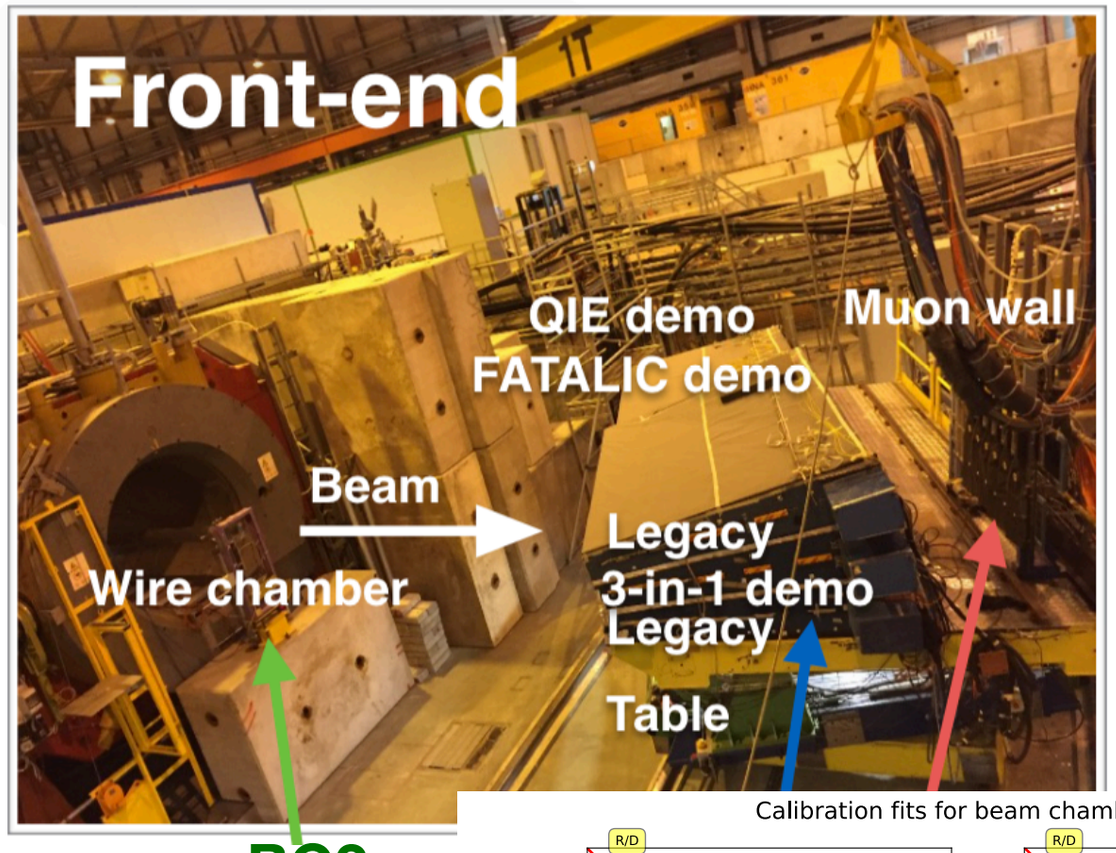
- 20 GeV electron data was used to validate the demonstrator particle response versus the legacy system

- Both systems use an optimal filter algorithm to reconstruct the charge collected



Calibration of the Wire Chambers

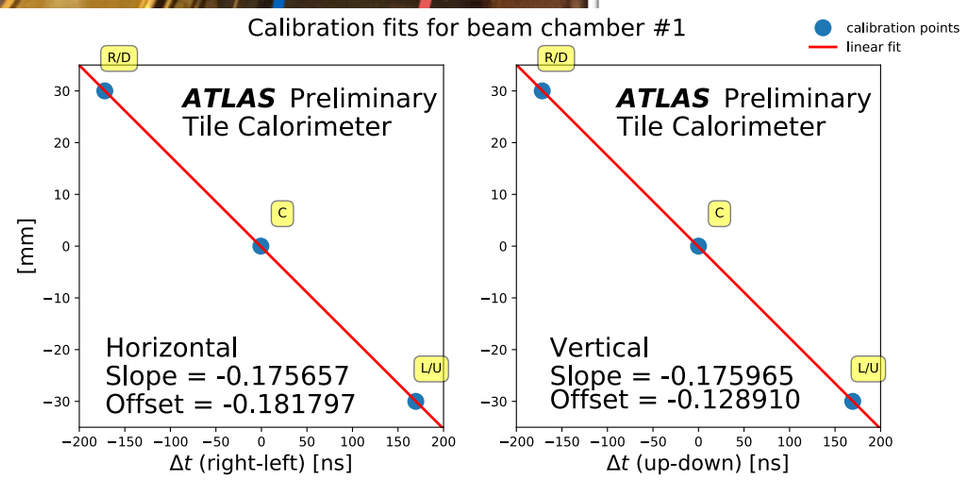




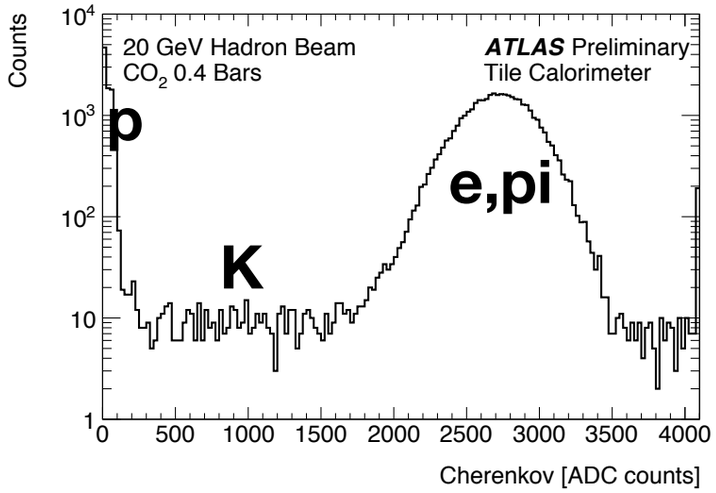
- Two wire chambers were used to measure the incoming particle positions. Their positions were measured within 1mm by a survey crew
- Calibration of the wire chambers by injecting pulses in the left (x=-30mm y=30mm) & right (x=30mm y=-30mm) corners and in the center
  - Measuring the response time allows us to calibrate both wire chambers by fitting for the arrival times, which are shown to the right

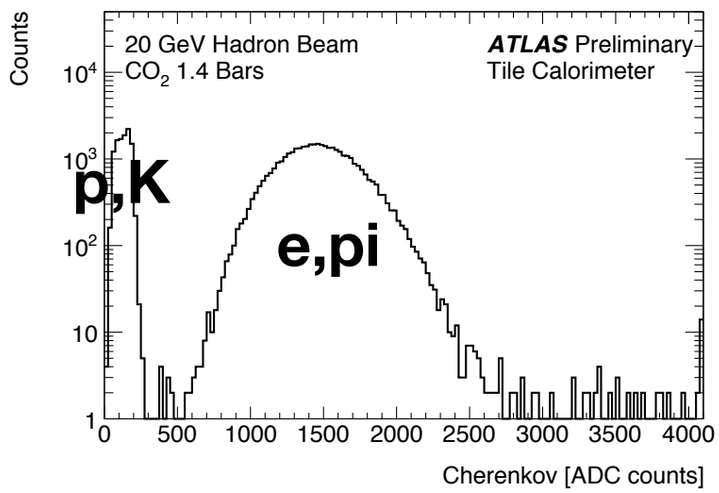
$$x = (t_{\text{right}} - t_{\text{left}}) \times \text{horizontalSlope} + \text{horizontalOffset}$$

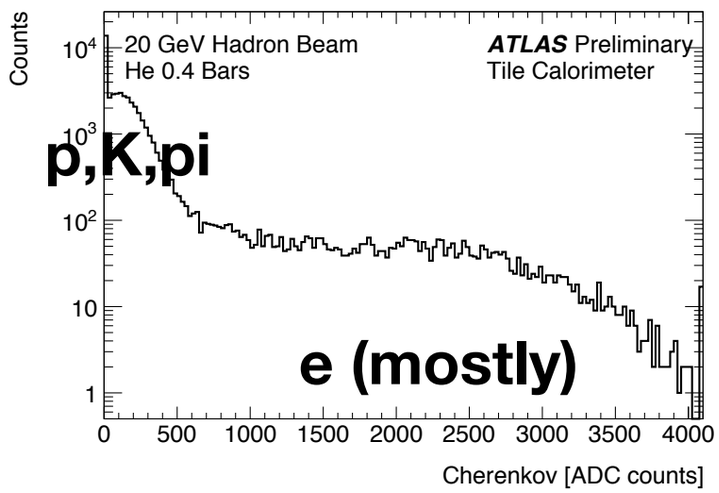
$$y = (t_{\text{up}} - t_{\text{down}}) \times \text{verticalSlope} + \text{verticalOffset}$$

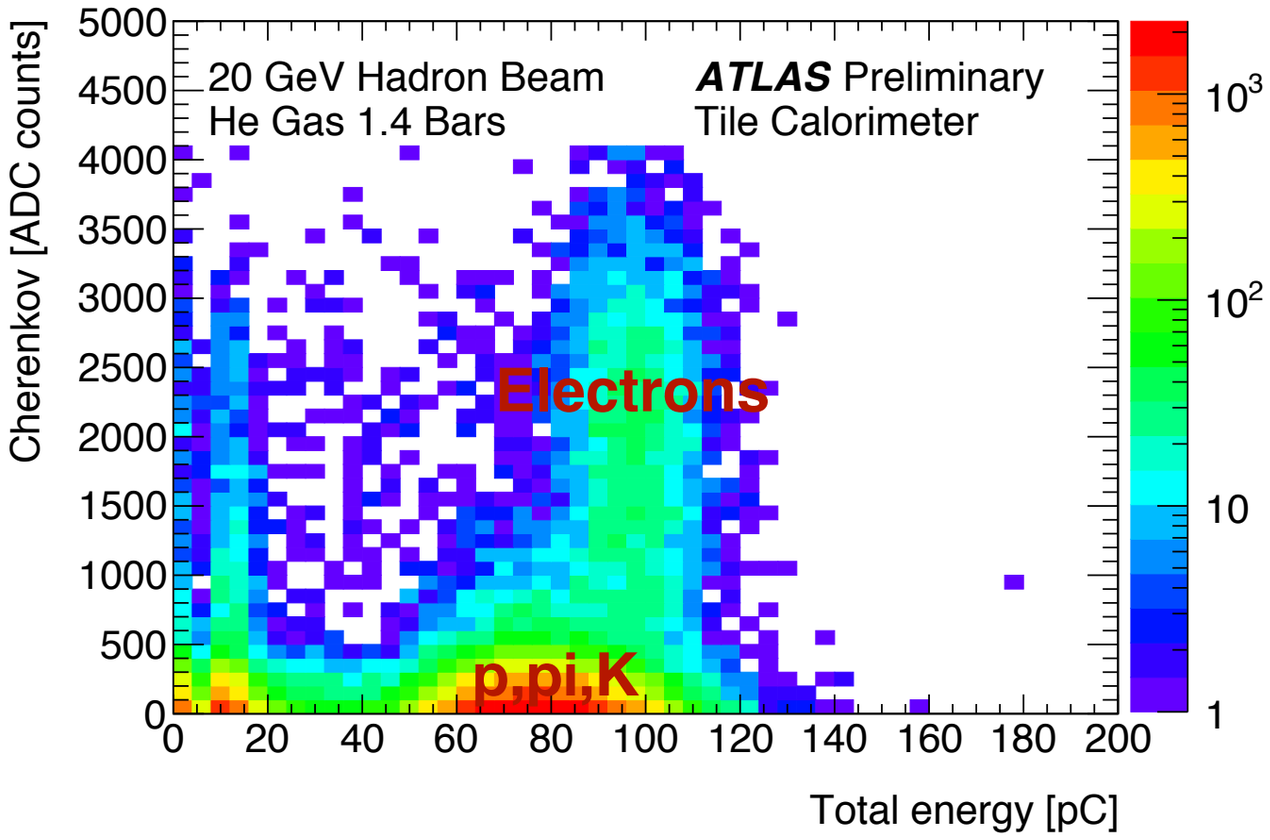


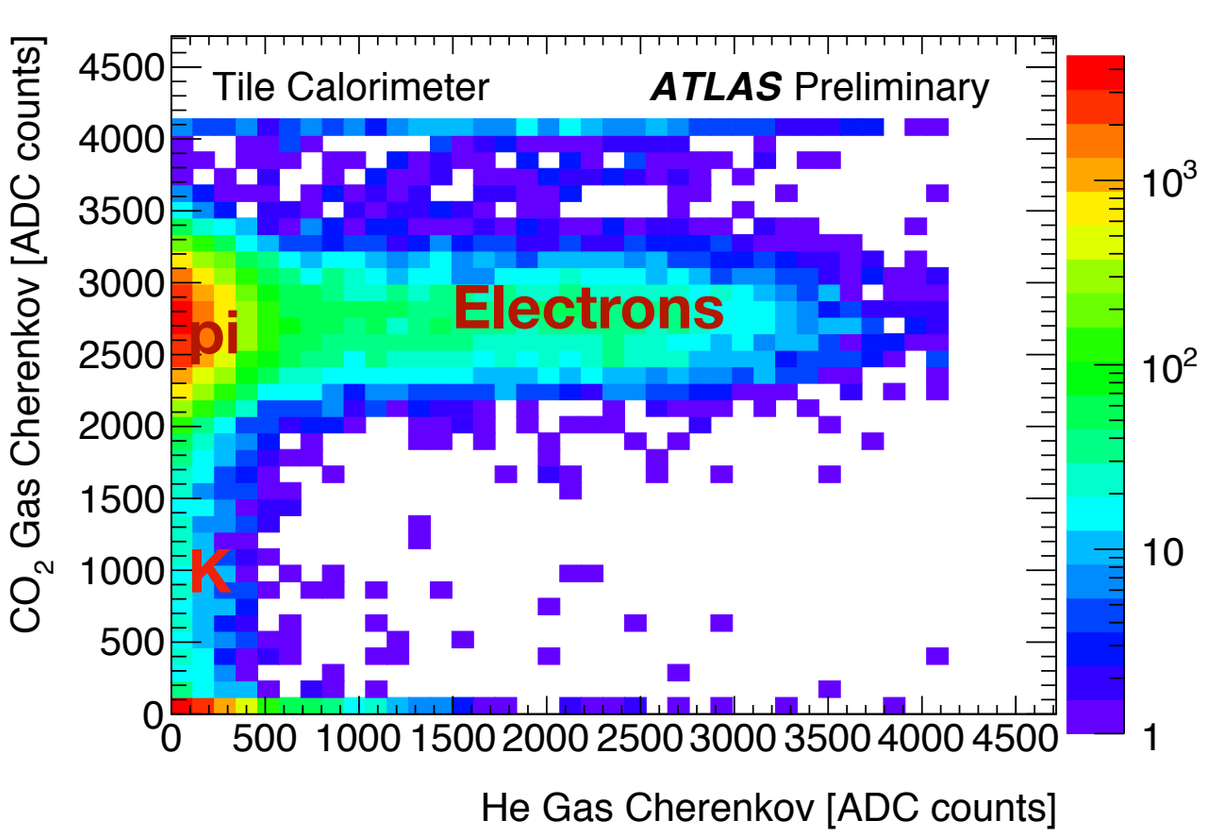
Cherenkov Detectors for 20 GeV Hadrons











PMT with 5xgain

Conclusions

- Tile test beam was conducted over the summer 2015, 2016, and 2017 to validate the functionality of the upgrades of the ATLAS Tile Calorimeter

- Results show excellent signal reconstruction that are agree well with the legacy system

- Future tests will validate the operational stability as well the functionality of the 40MHz triggering system

Backup