TEST BEAM STUDIES FOR THE ATLAS TILE CALORIMETER READOUT ELECTRONICS

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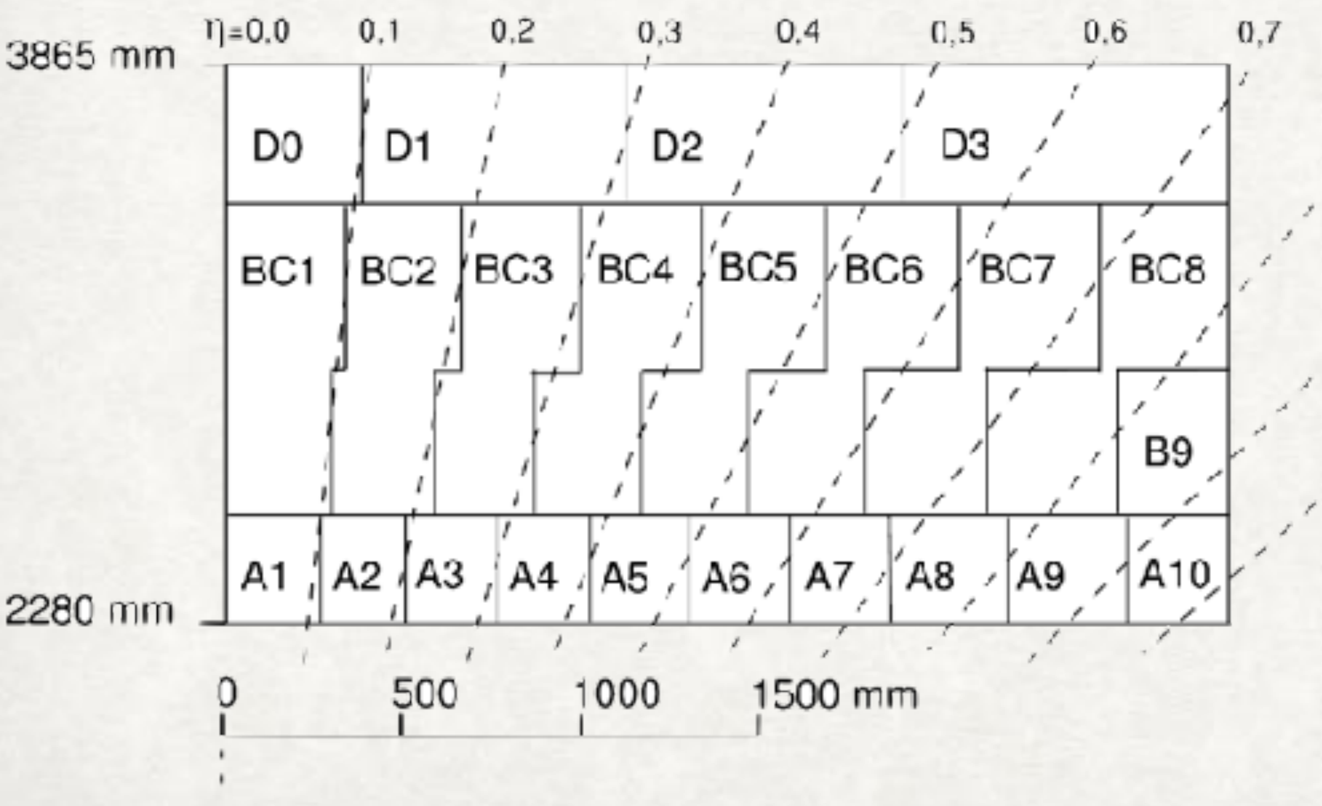
OUTLINE

- The ATLAS Tile Calorimeter
- TileCal upgrade
- Test beam setup
- Results with muons
- Results with electrons
- Results with hadrons
- Conclusions

TILE CALORIMETER

- TileCal is the hadronic calorimeter of the ATLAS detector
- Made of scintillating material and iron plates
- Structured in 4 barrels (2 Long, 2 Extended) with 64 modules each
- Particle detection through plastic scintillators



Cell layout in Long barrel C-side (see slide 5)

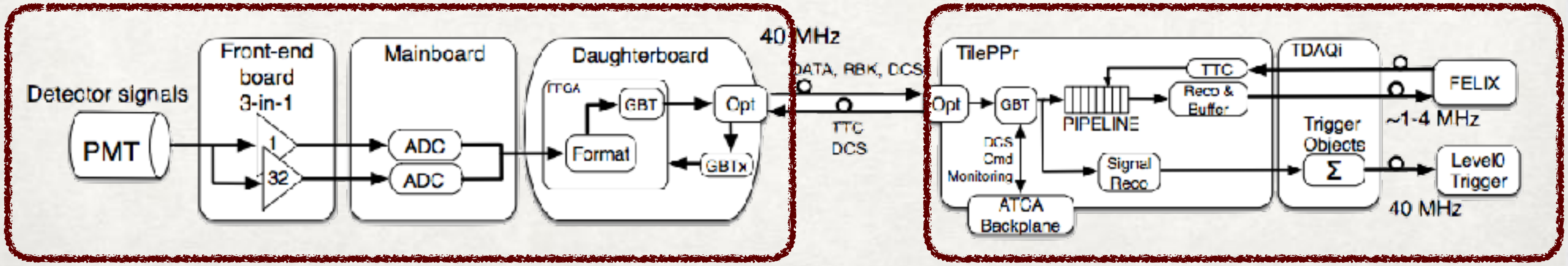
- Light collected by optic fibers and delivered to PMTs
- Modules are organized in 3 longitudinal layers (A, BC, D) and projective cells
- Calibrated at the EM scale

TILECAL UPGRADE

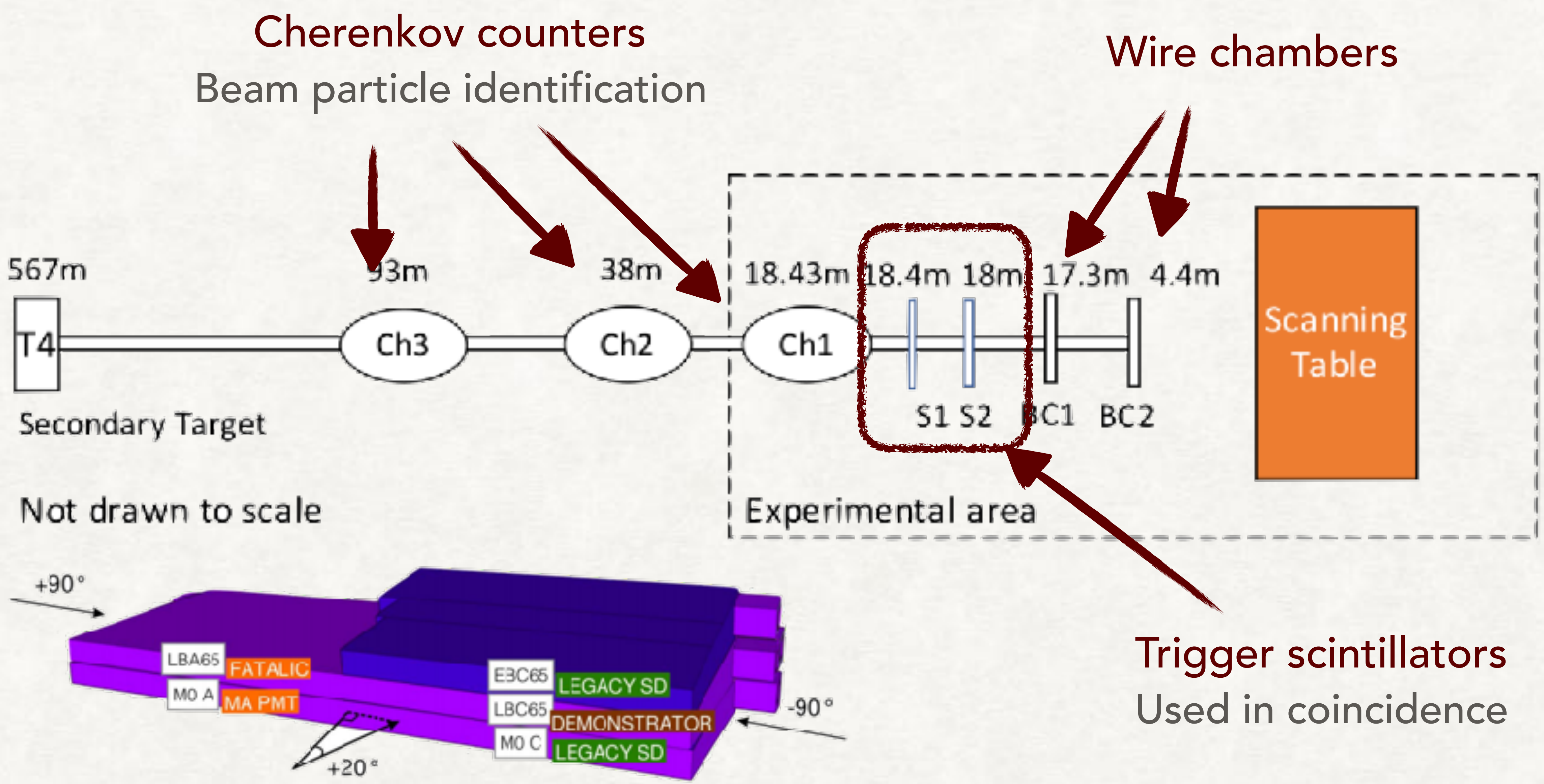
- LHC Phase II upgrade in 2026 will increase luminosity to up to 7 times the LHC design luminosity
- Upgrades for the Tile Calorimeter readout electronics (see F. Scuri's talk)
  - Substitute outdated and damaged electronics
  - Improve tolerance to radiation
  - Fully digital trigger data, with higher granularity and precision
- Test beam studies done to check performance of new electronics

In-Detector

Out-Detector



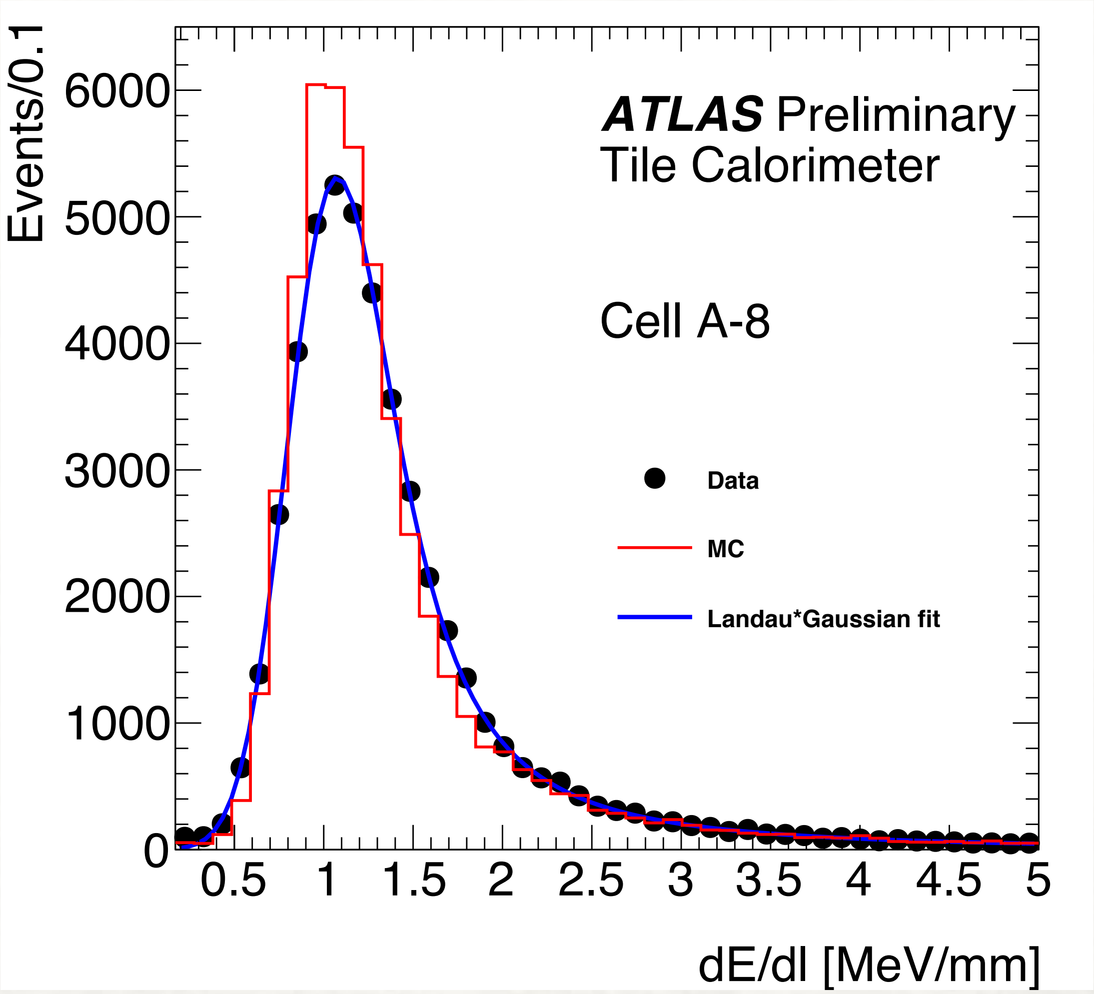
TEST BEAM SETUP



- Three modules (two long and one extended barrels) used in the test beam
  - Data collected with "demonstrator", long barrel module equipped with 3-in-1 front end electronics for the upgrade
- Beams of hadrons, electrons and muons used to study response

TEST BEAM RESULTS: MUONS

- Data collected with muon beam at 165 GeV incident at 90 degrees
- Deposited muon energy follows a Landau distribution
- Muon energy lost in ionization is proportional to path length
- Response studied in terms of deposited energy over track length



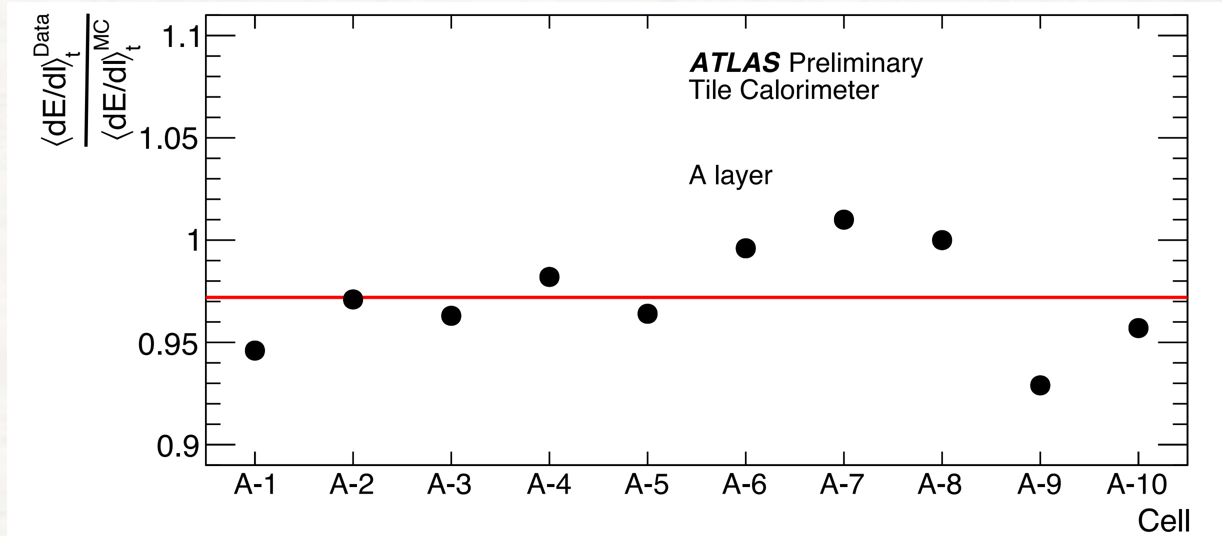
TEST BEAM RESULTS: MUONS

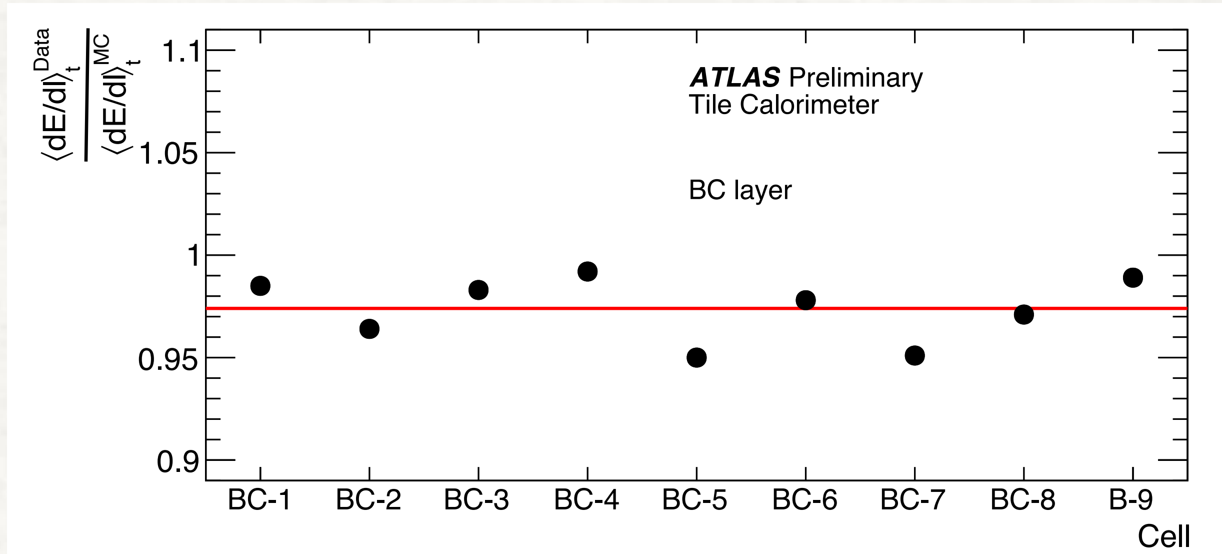
- Event selection: Total energy deposited between 700 and 15000 MeV
- Truncated mean of the distribution (97.5%) used for the calculation
- Ratio of data over simulation result used in the studies:

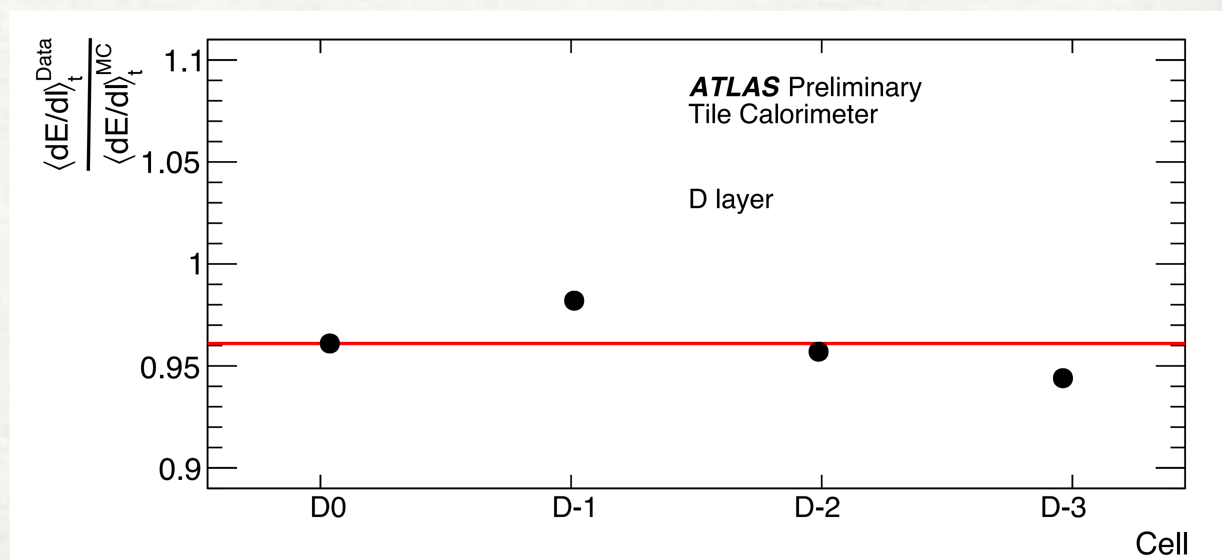
$$R = \frac{(\langle dE \rangle / dl)^{Data}}{(\langle dE \rangle / dl)^{MC}}$$

- Red line represents layer mean
- Data/MC within 4% and Layer uniformity of 2%

Layer	mean	rms
A	0.972	0.025
BC	0.974	0.016
D	0.961	0.016







TEST BEAM RESULTS: ELECTRONS

- Data collected for electron beams of 20, 50 and 100 GeV incident at 20 degrees
- Total energy deposited in the calorimeter is expected to be equal to beam energy
- Electron identification done using shower profile variables (see paper)

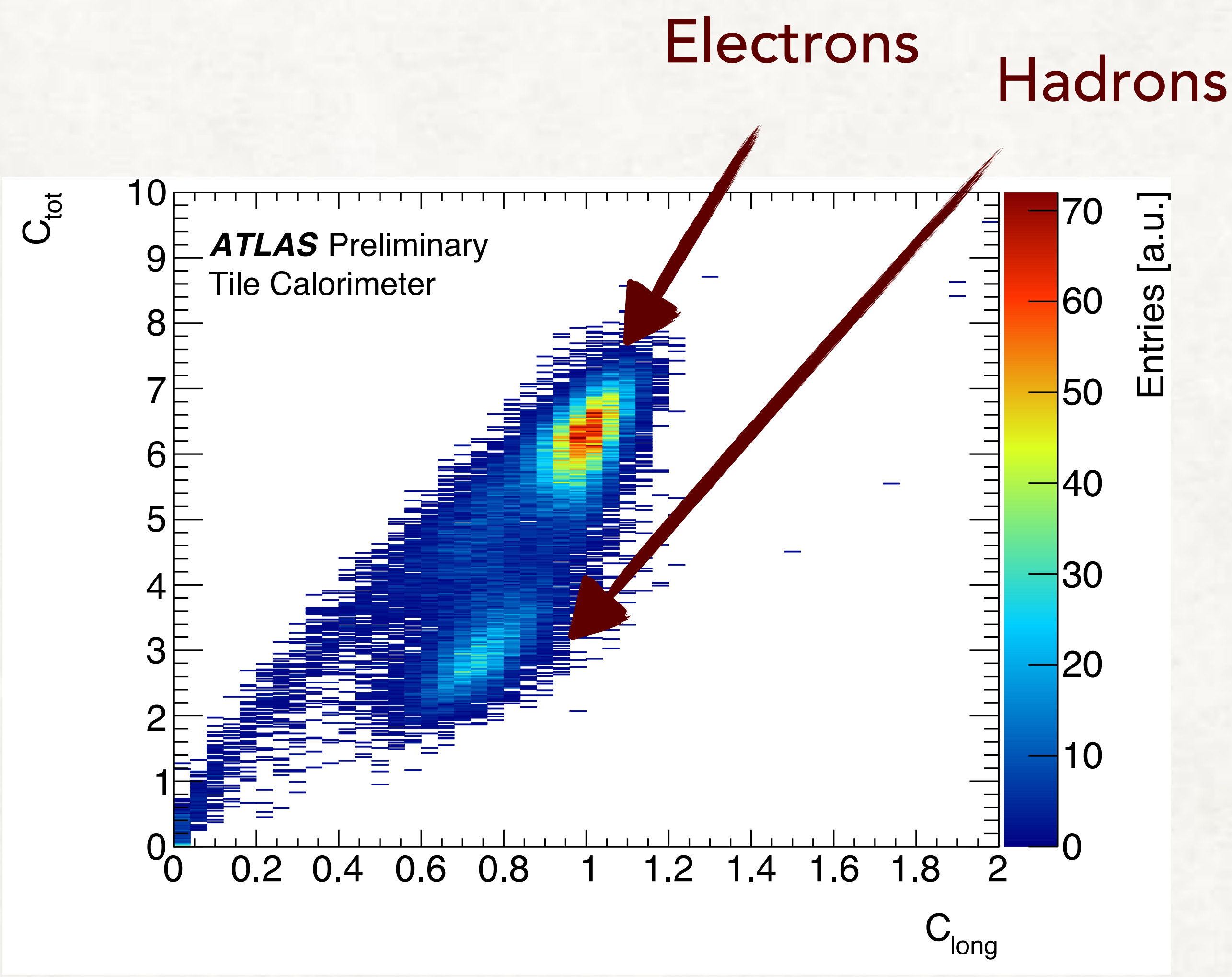
$$C_{\text{long}} = \sum_{i=1}^{2}\sum_{j=1}^{3}\frac{E_{ij}}{E_{\text{beam}}}$$

Fraction of energy deposited in the first two layers of the demonstrator

$$C_{\text{tot}} = \frac{1}{\sum_c E_c^{\alpha}}\sqrt{\frac{1}{N_{\text{cell}}}\sum_c\left(E_c^{\alpha} - \frac{1}{N_{\text{cell}}}\sum_c E_c^{\alpha}\right)^2}$$

Spread of the energy deposited in a certain cell

TEST BEAM RESULTS: ELECTRONS

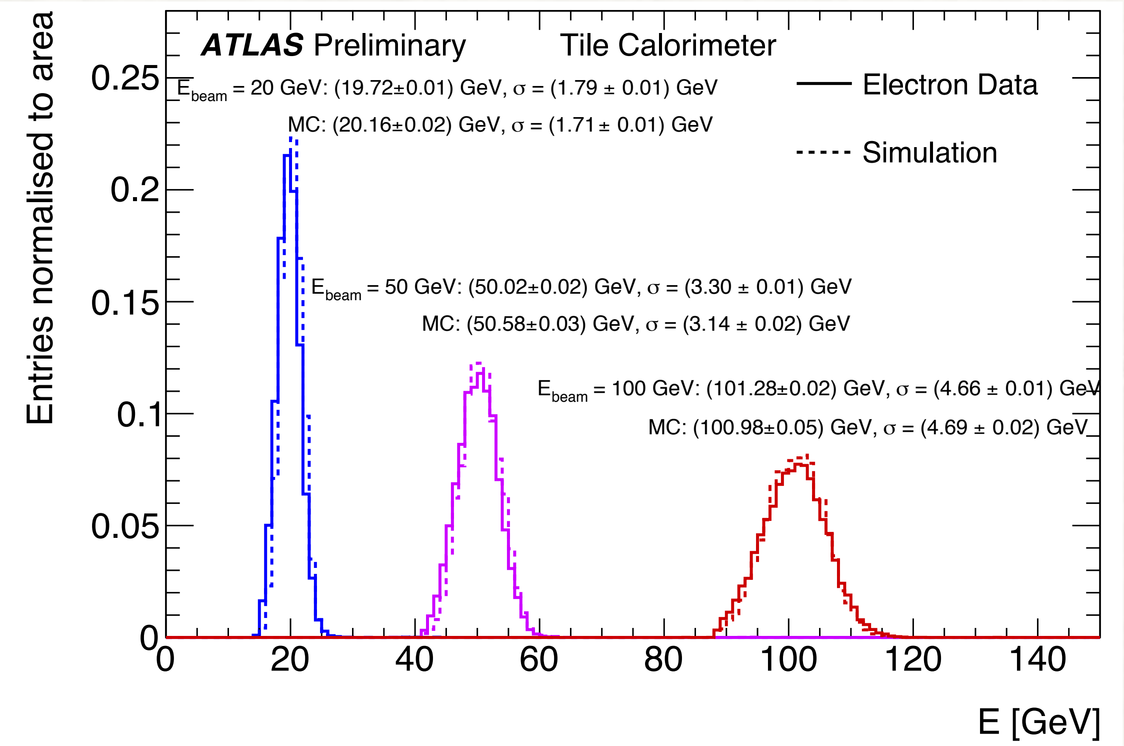


- Cuts applied depend on energy
- Cut on $C_{\rm tot}$ ranges from 2.1 at 20 GeV and 6.5 at 100 GeV
- Cut on $C_{\rm long}$ ranges from 0.75 at 20 GeV and 0.88 at 100 GeV

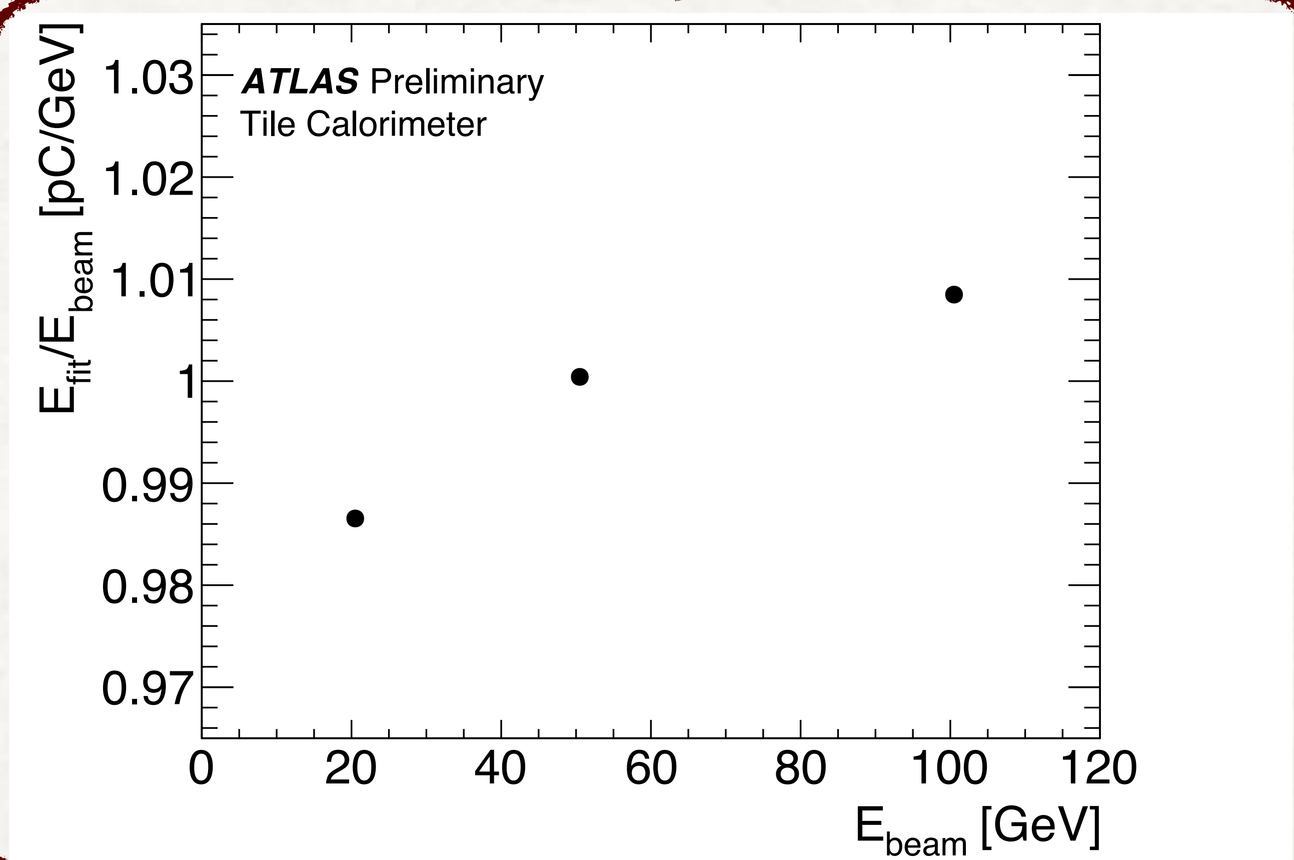
- In low energy runs, purity is improved by requiring Cherenkov 1 and 3 signals to be higher than 500 ADC counts

TEST BEAM RESULTS: ELECTRONS

- Total deposited energy obtained summing energies of the cells
- Data and simulation agree nicely for all energies



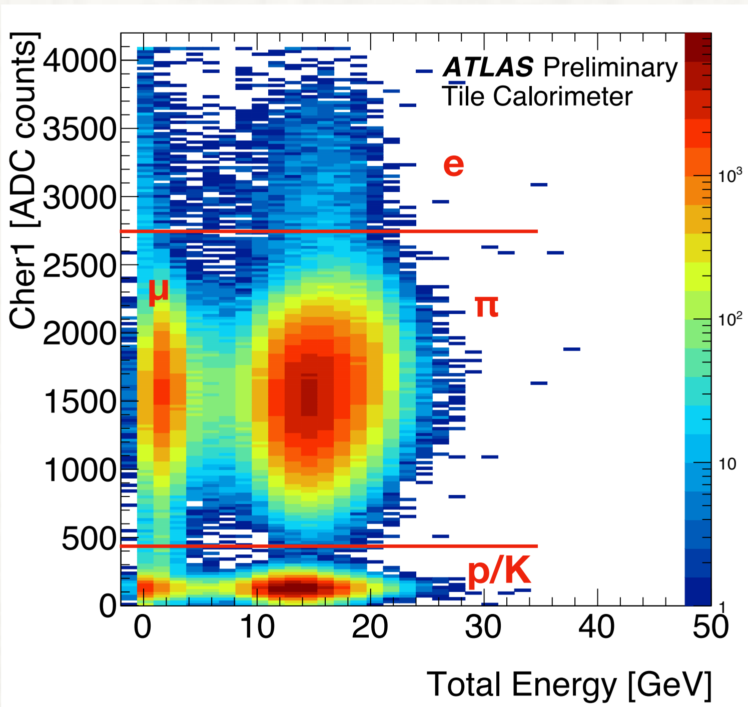
Mean of Gaussian fit to total energy distribution

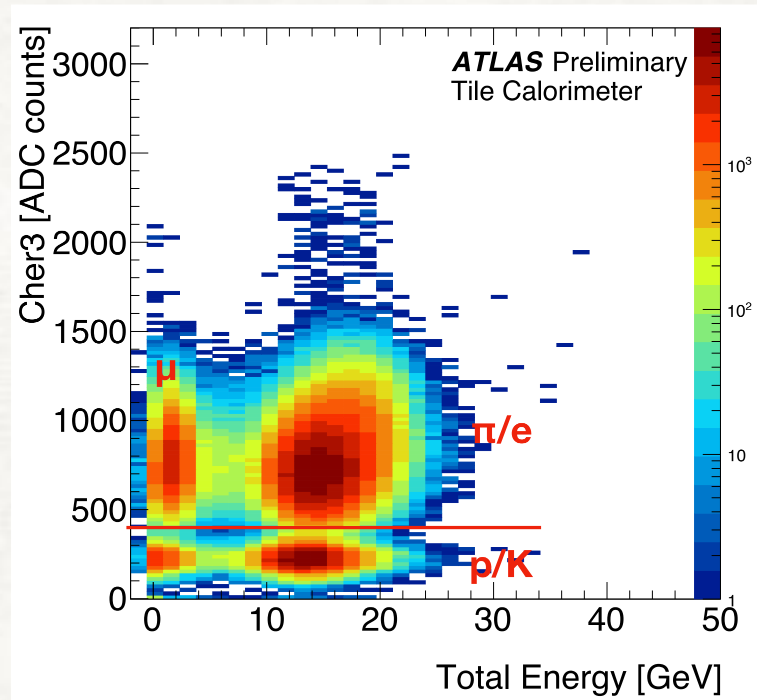


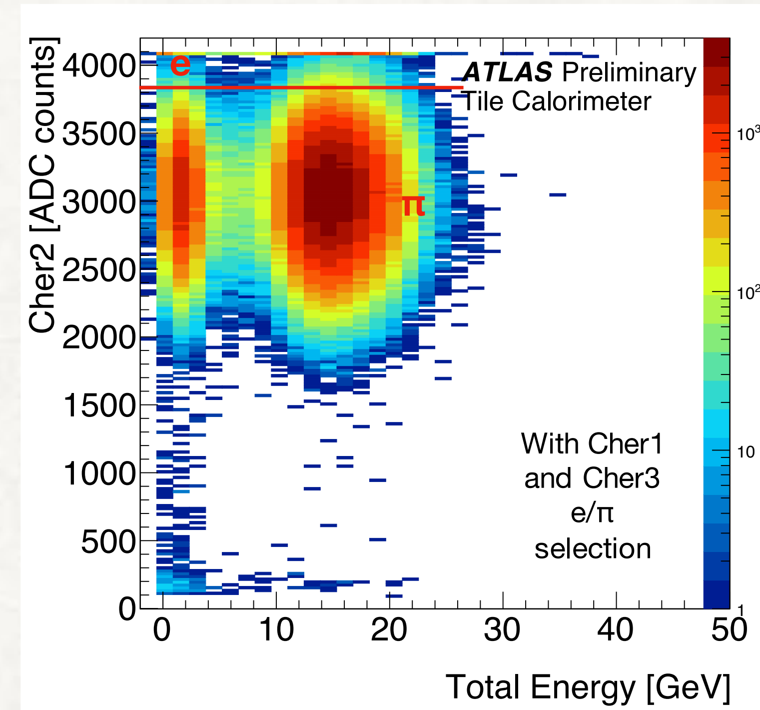
Beam pointing to A4

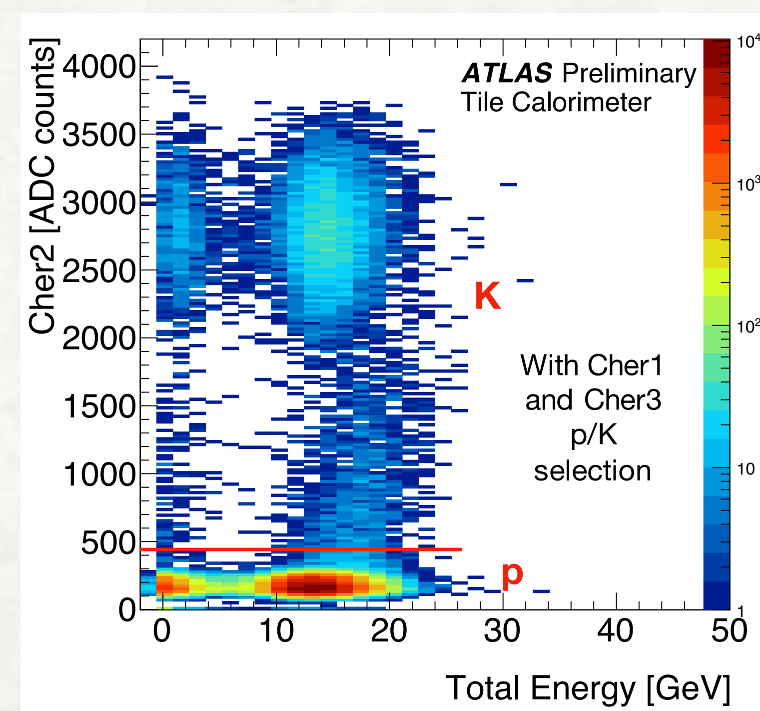
TEST BEAM RESULTS: HADRONS

- Data collected for hadron (p, π, K, e, μ) beams at 16, 18, 20 and 30 GeV with a projective angle for A-3 cell
- Cherenkov counters used for selection





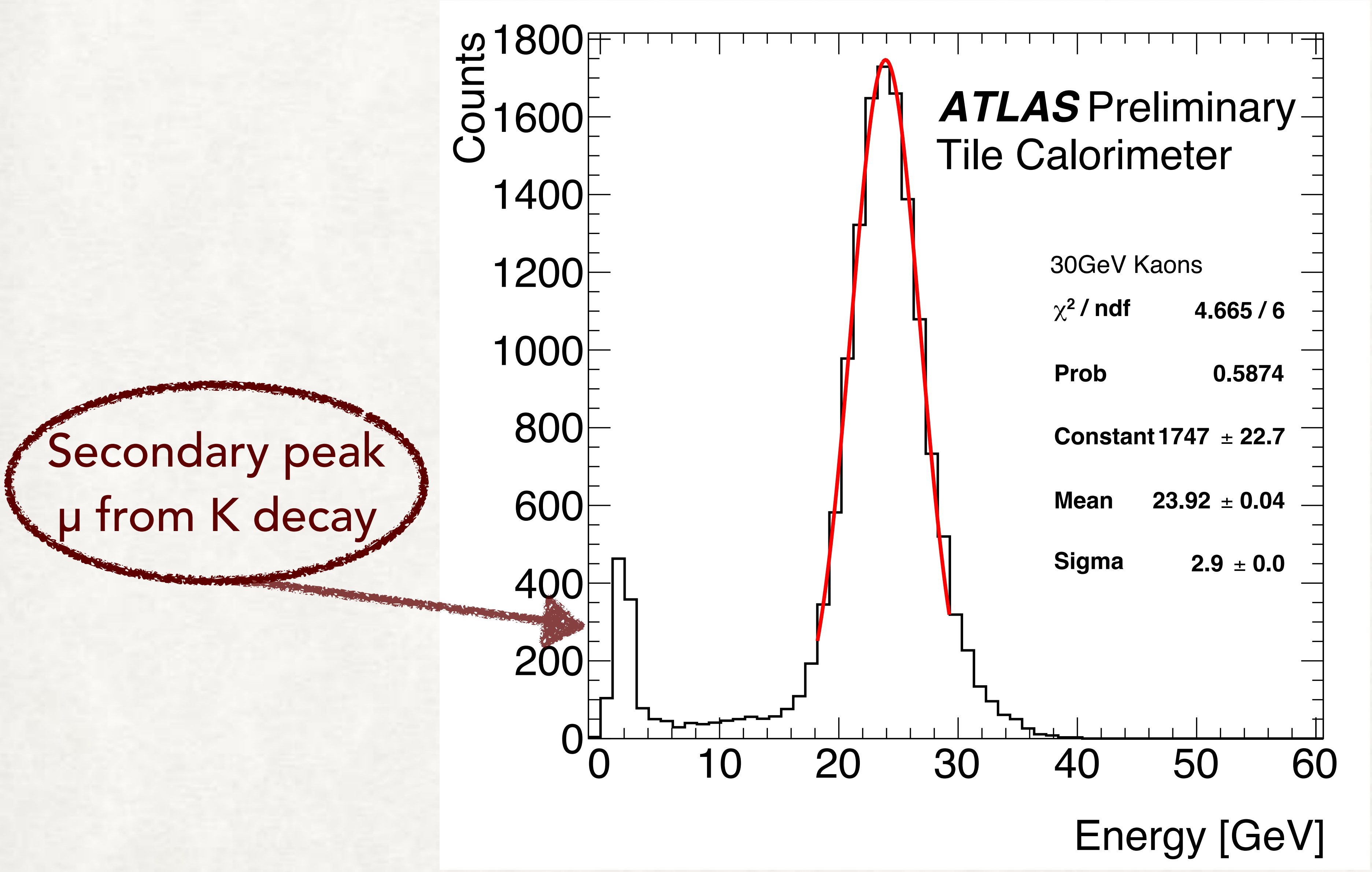




	p	K	π
Cher1	<400	<400	[400,2600]
Cher2	<460	>460	<3900
Cher3	<420	<420	>420

TEST BEAM RESULTS: HADRONS

- Response calculated as mean of gaussian fit to the total energy distribution within 2σ of the peak

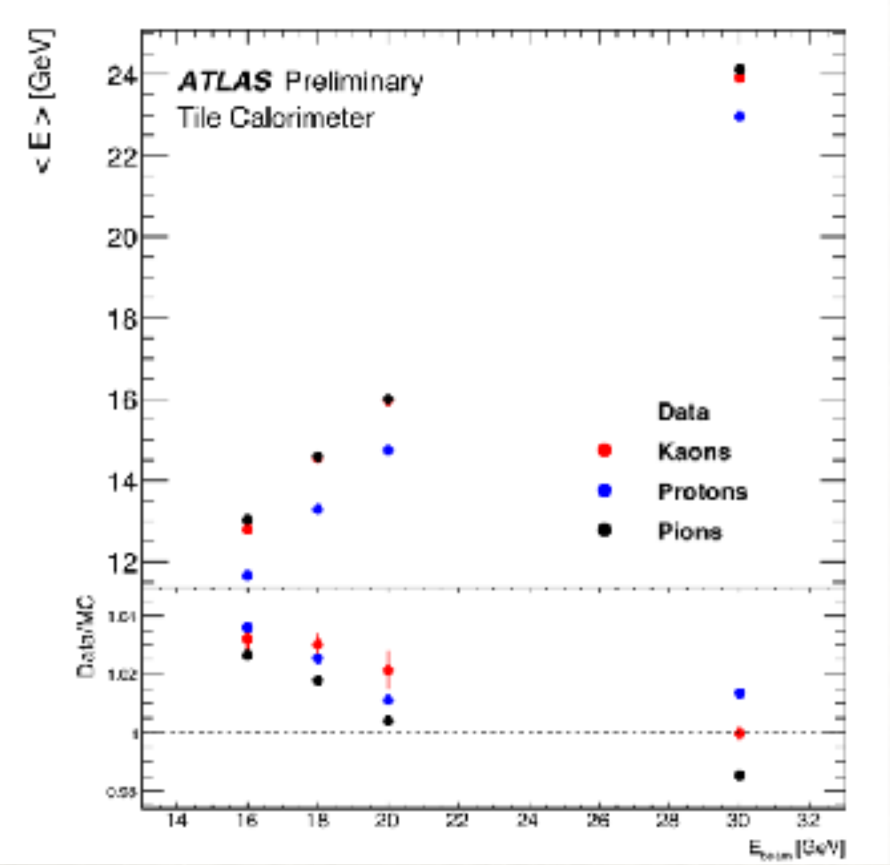


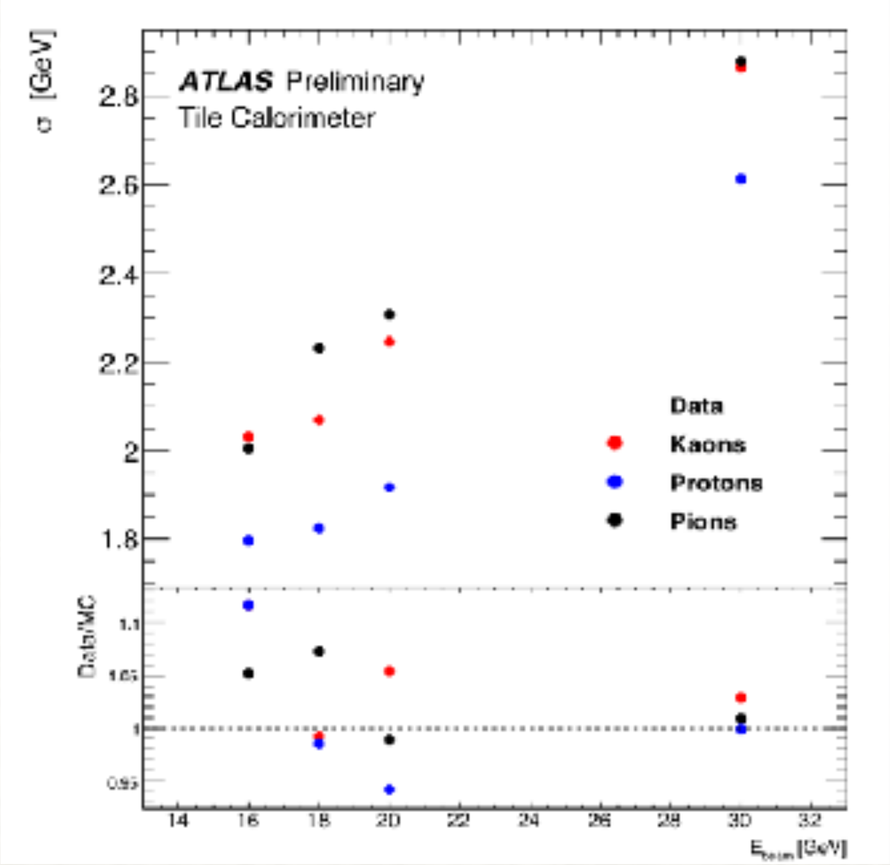
TEST BEAM RESULTS: HADRONS

- Distribution of response as a function of the beam energy for kaons, protons and pions

- Response to pions and kaons higher than to protons

- Agreement with Geant4 FTFP_BERT_ATLMC simulation improves with increasing energy (lower contamination from electrons and muons)





- Better energy resolution to protons

CONCLUSIONS

- The LHC Phase II upgrade will require TileCal to substitute old electronics and improve radiation hardness
- Prototype with new electronics exposed to test beam
- Results obtained with muons agree with simulation and show expected linearity of response with path length
- Electron results with data agree with simulation closely, and show that the total energy deposited is within 2% of the beam energy
- Results from hadron beams confirm good agreement with simulation
    - Response to pions and kaons higher than protons
- The test beam results confirm good performance of new electronics, and agreement with calibration and simulated data