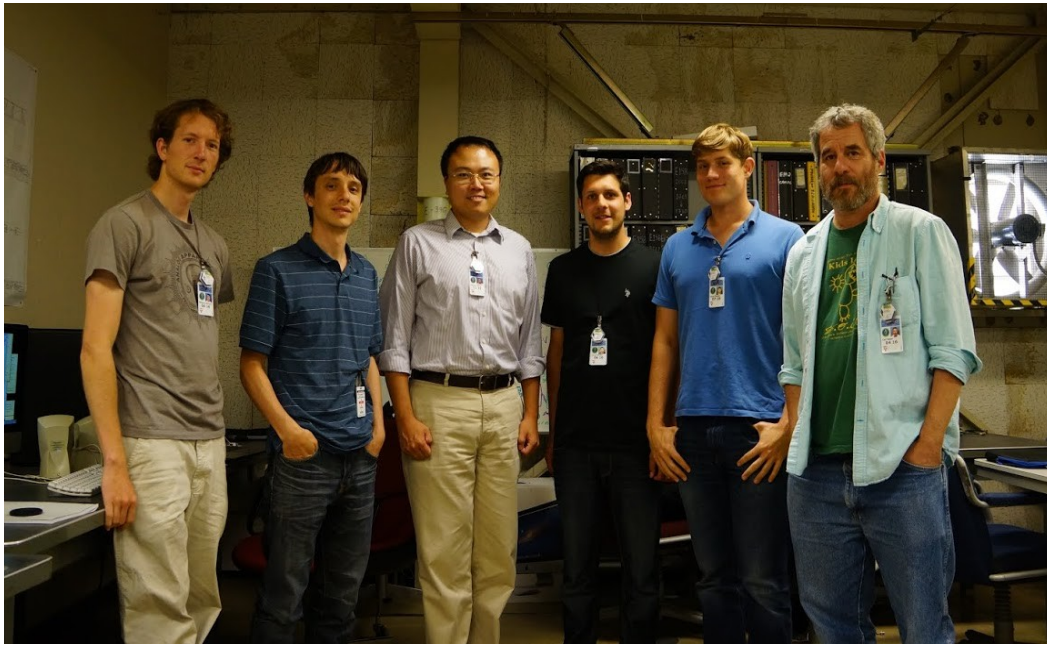
ATLAS Silicon strip upgrade: Results with the SLAC testbeam and AIDA telescope

John Keller (DESY)
on behalf of many people

The team

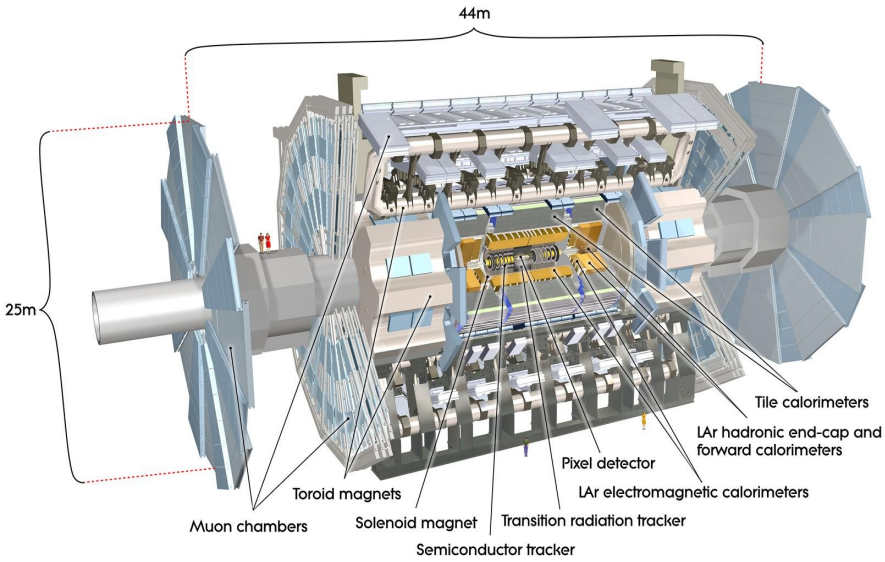


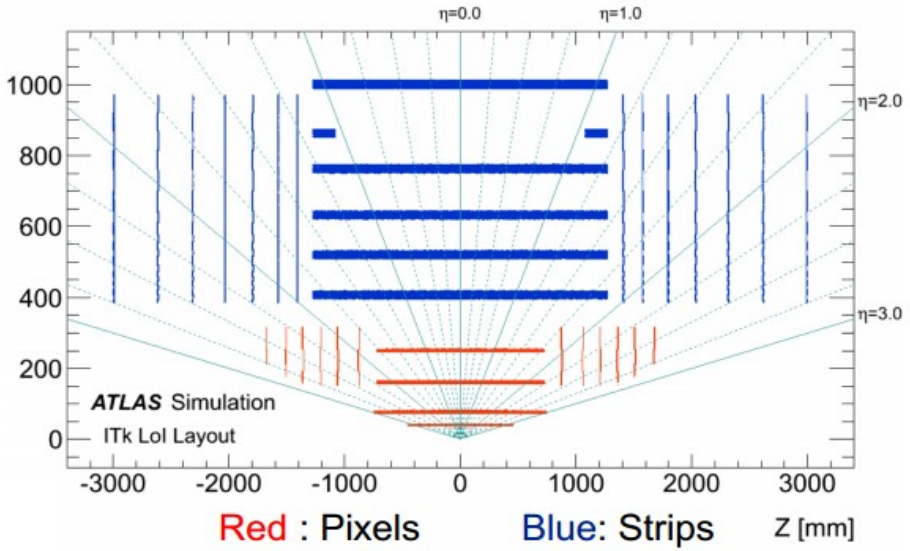
Niklaus Lehmann (LBNL) | JK (DESY) | Haichen Wang (LBNL) | Jonas Stalder (LBNL) | Jacob Pasner (UCSC) | Carl Haber (LBNL)

- Not pictured: Lorenzo Pirrami, Amar Risbud (LBNL), Richard Peschke, Igor Rubinsky, Sergio Diez (DESY), Max Swiatlowski (SLAC), Bruce Gallop, Peter Phillips (RAL), Andrew Blue (Glasgow), Matt Warren (UCL), Ashley Greenall (Liverpool)

ATLAS tracker upgrade

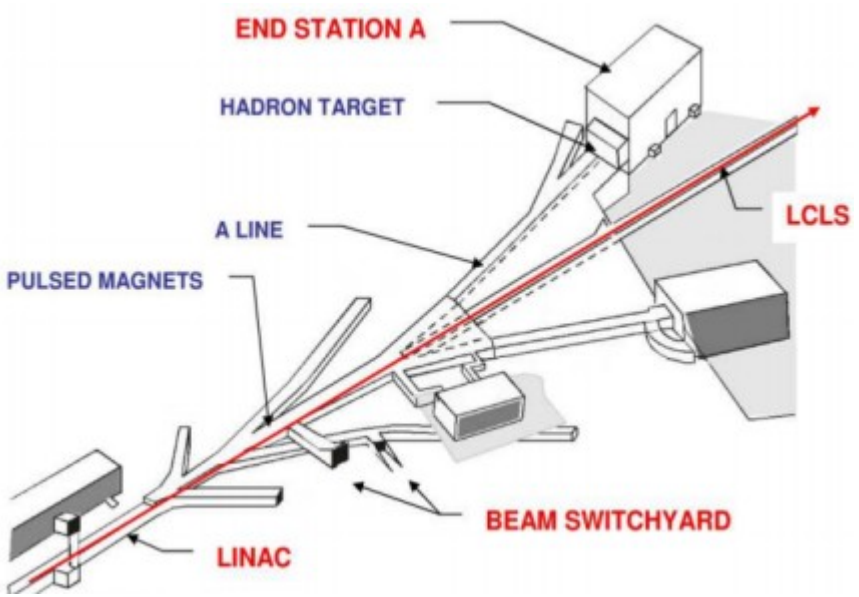
- Tracking detector forms innermost part of ATLAS.
- During “LS3” (2023-24), current ID will be replaced with all-silicon Integrated Tracker (ITk), to prepare for High-Lumi LHC.
- ITk consists of silicon pixels and strips surrounding the interaction point.



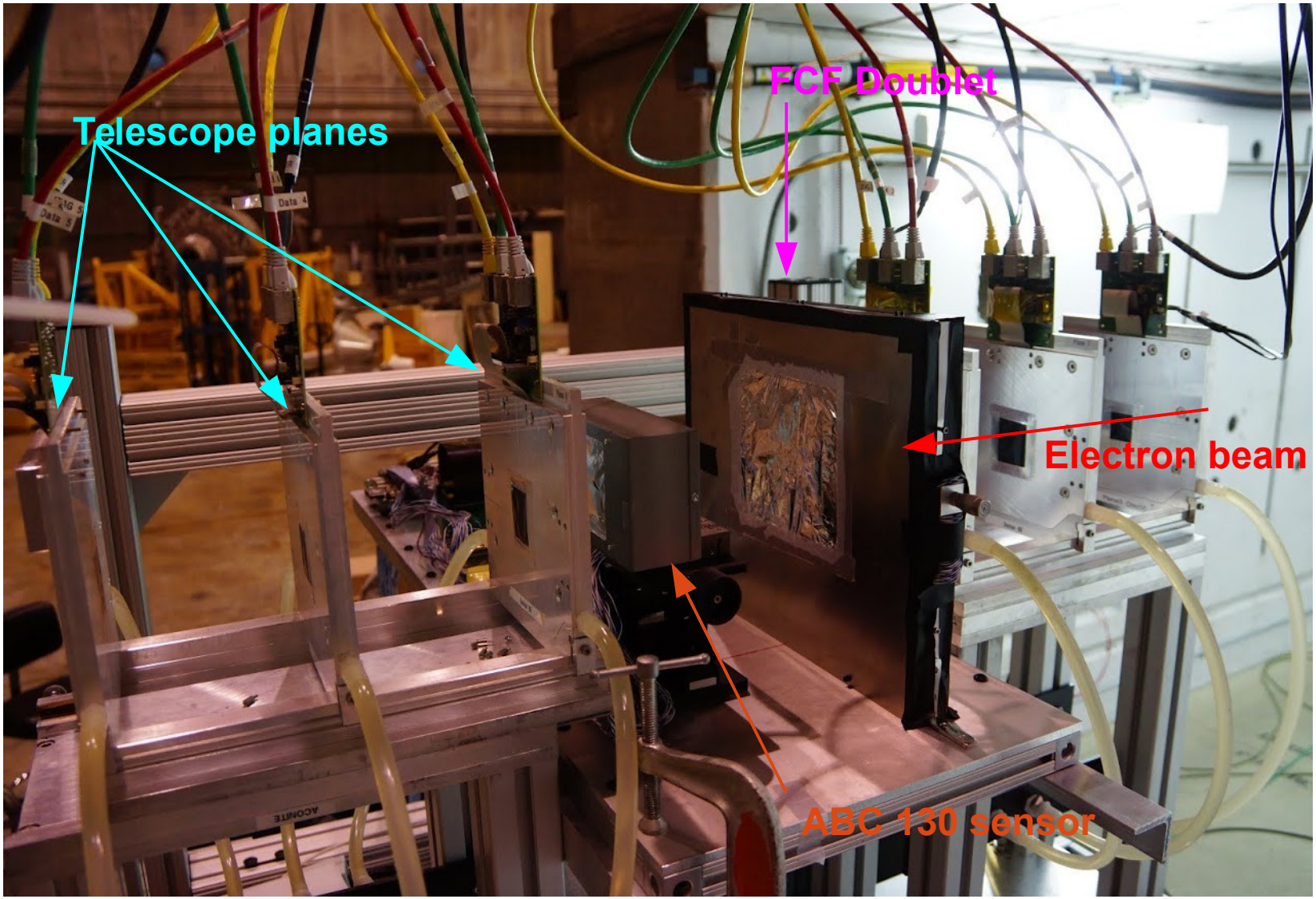


This testbeam

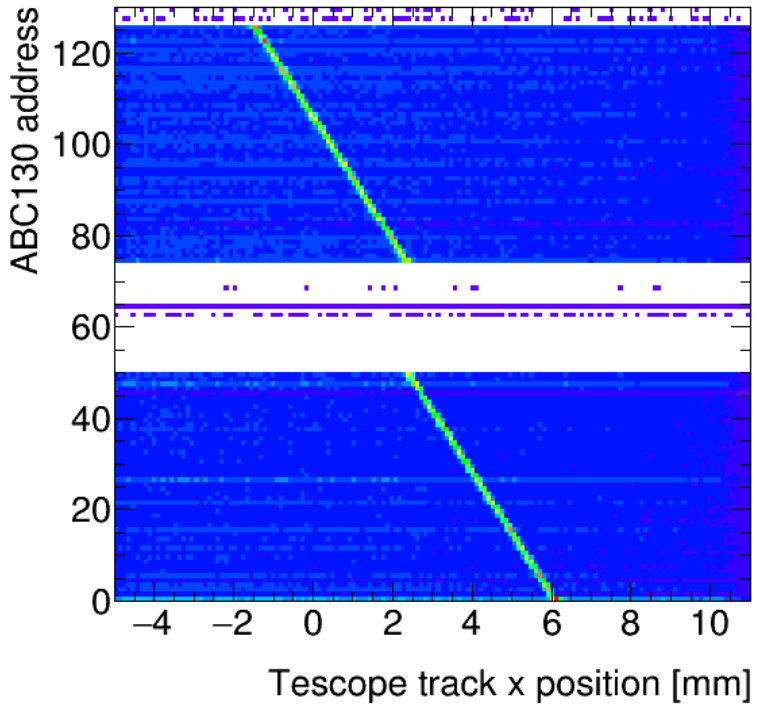
- Had beam at SLAC End Station A from 2nd – 16th July 2014.
- ~9 GeV, 5 Hz, O(100) electrons/bunch.
- Two measurements performed at once:
  - ABC 130: Measure the gain of new ATLAS binary chip.
  - Fast Cluster Finder: Demonstrate new readout technique for use in self-seeded trigger.
- Both being tested with beam for the first time.

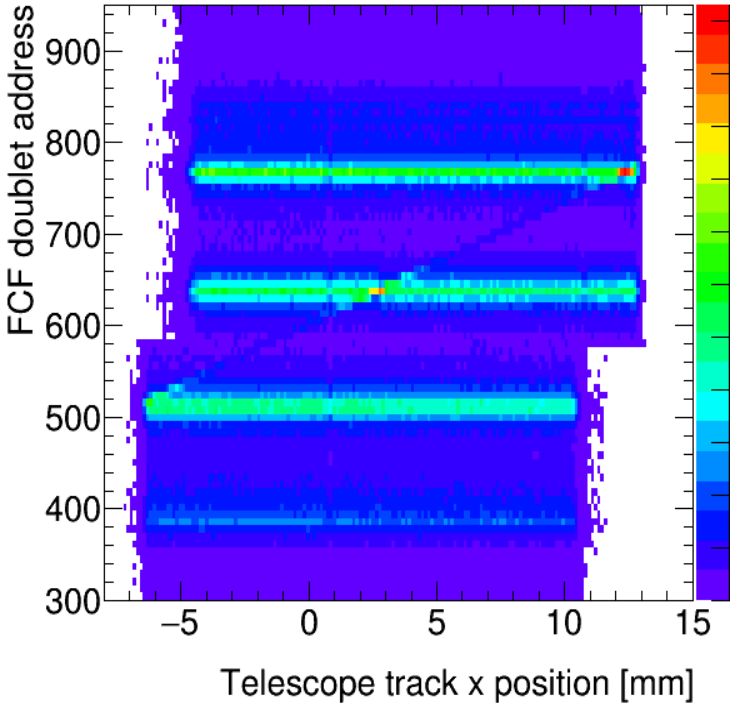


The setup



Integration with telescope



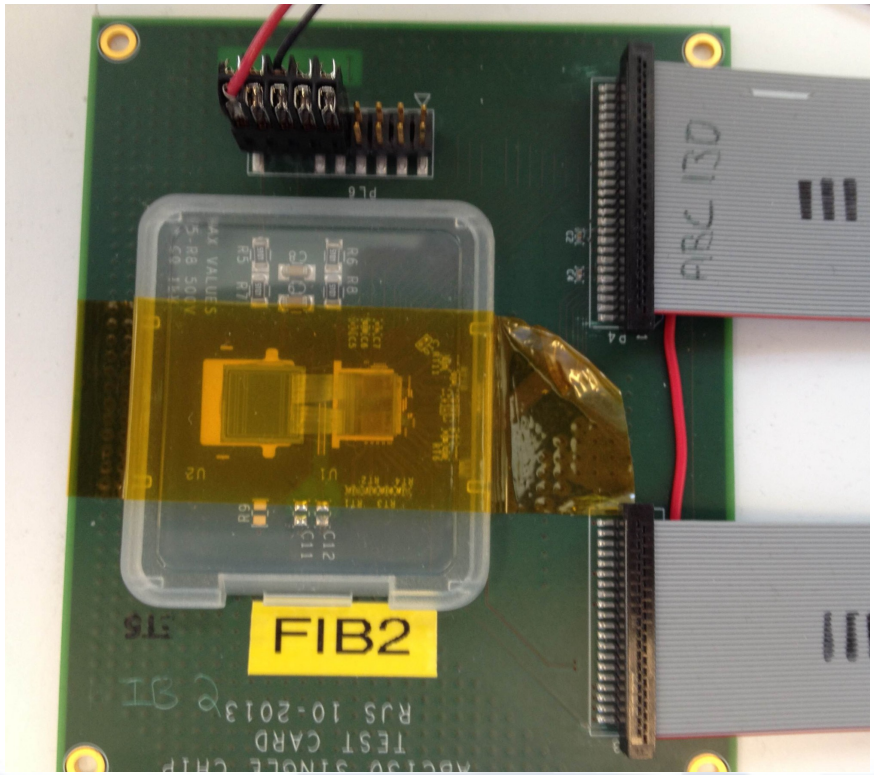


- Both DUT's are in-sync with telescope.

ABC 130

ABC 130

- New ATLAS Binary Chip ABC 130 intended to be used as default.
- First prototypes show lower gain than expected.
- However these measurements depend on internal calibration capacitor: want to use test beam as external calibration.



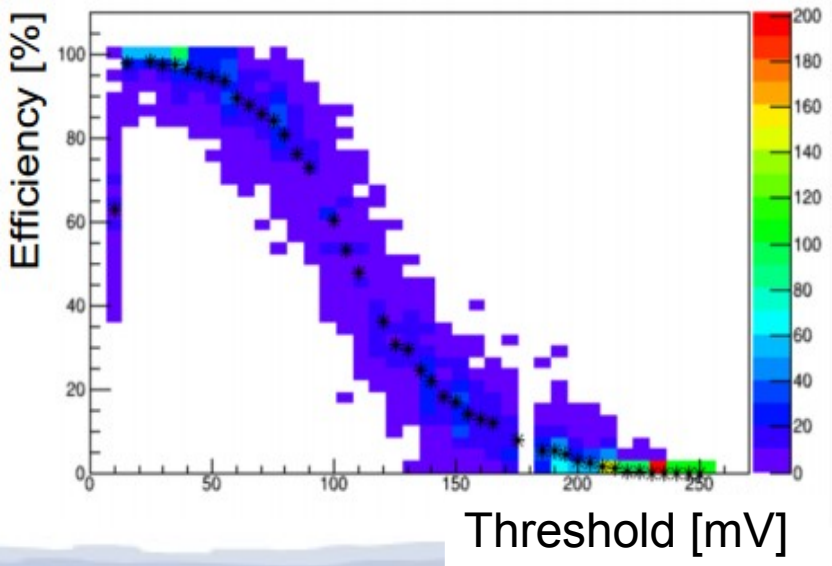
Gain Measurement

- Given the known beam energy and sensor thickness, the most probable charge deposit due to ionization may be calculated: 3.6 fC.
- Cannot calculate voltage gained due to only binary readout: instead do a threshold scan counting events at each level.
- Differential of threshold scan should correspond to Landau curve of charge deposition.

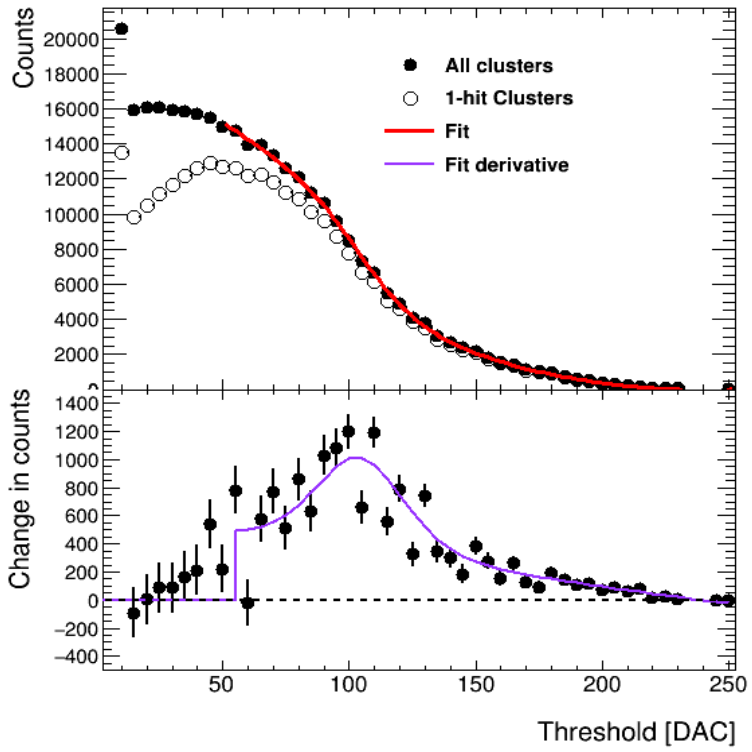
The most probable ionization energy

Thickness [um]	E [MeV]	Theory[KeV]	Exp.[KeV]
148	0.976	38.4	40.3
148	199	40.4	41.4
148	9 999	40.6	39.6
148	9 999	40.6	39.5
148	50 000	40.6	39.7
290	199	82.2	80.9
1 007	199	306	323

Moller et al. (1982)



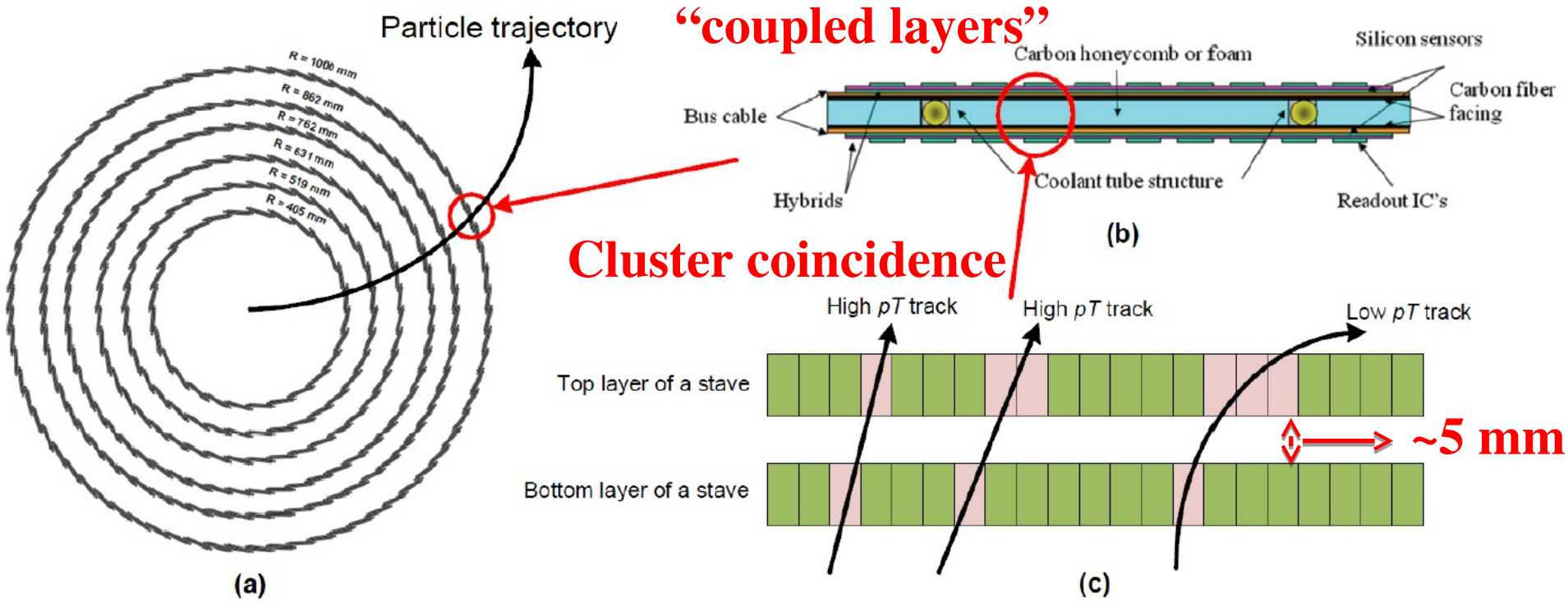
Gain results



- Preliminary result indicates maximum of threshold curve at around 314 mV.
- This would correspond to a gain of 88 mV/fC, in good agreement with the specification of 90 mV/fC.
- However there are many subtleties to the analysis: charge-sharing effects, DAC-mV conversion, etc.
- We are awaiting complementary measurements with a source before reaching a firm conclusion.

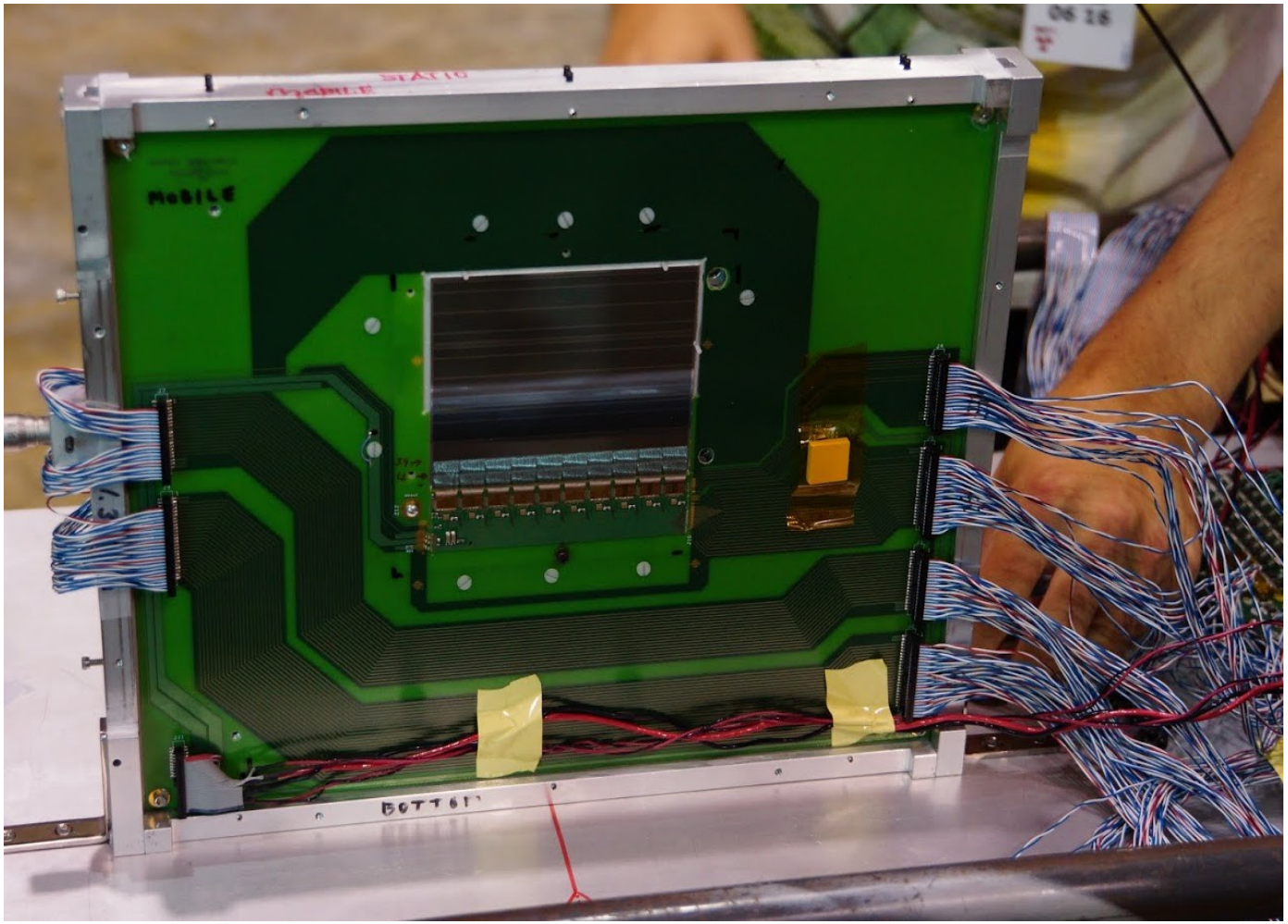
Fast Cluster Finder

Fast Cluster Finder



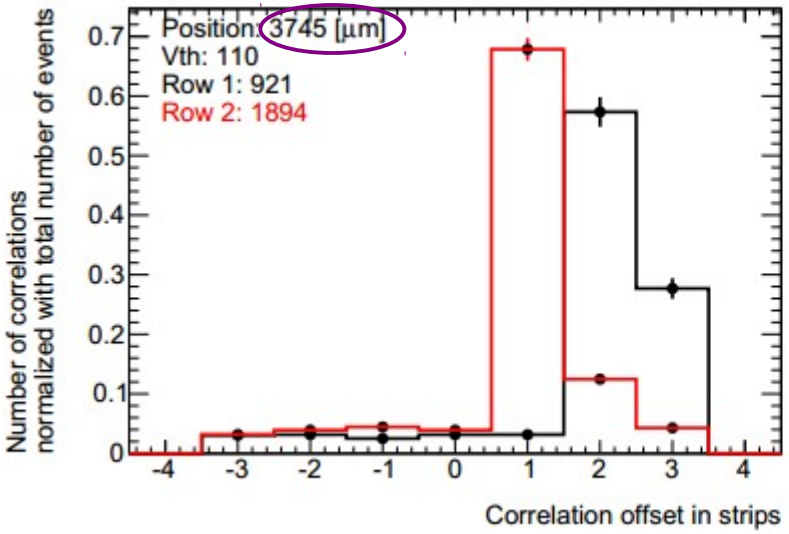
- FCF readout finds coincidence between hits on two layers of silicon strips.
- Can be used as input for self-seeded track trigger algorithm.

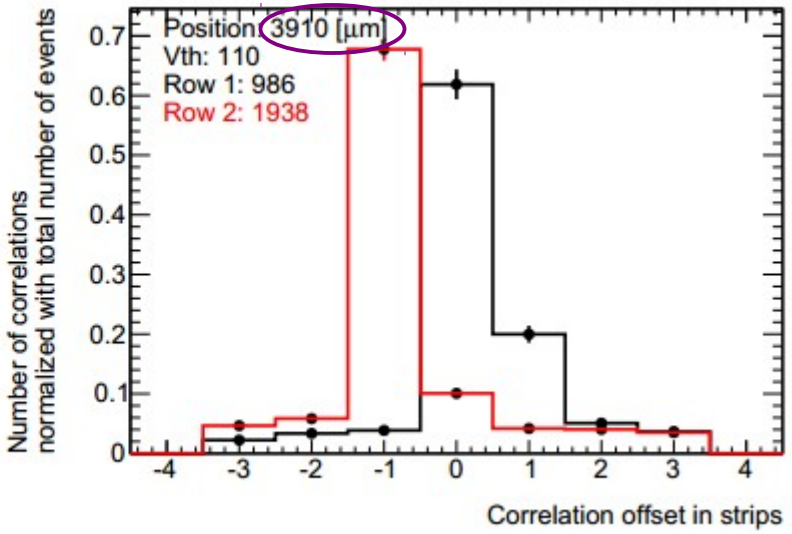
FCF doublet



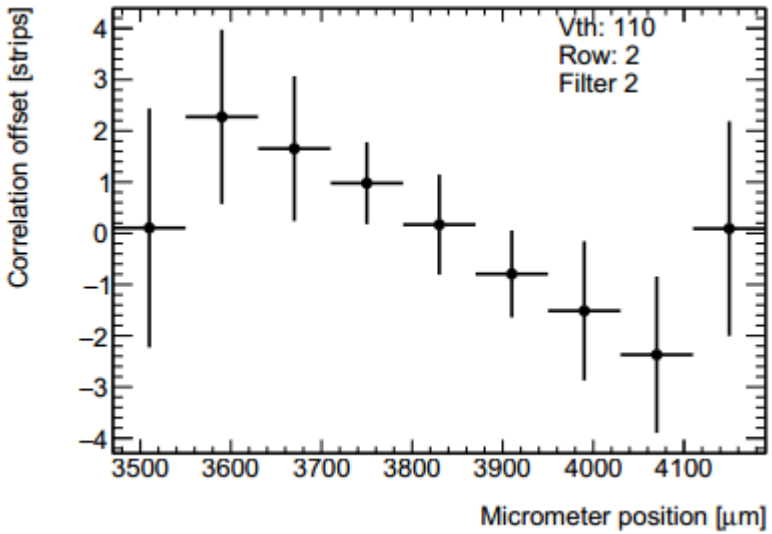
- No B field in test beam: instead slide sensors relative to one another to simulate effect of curved trajectory.

FCF correlations





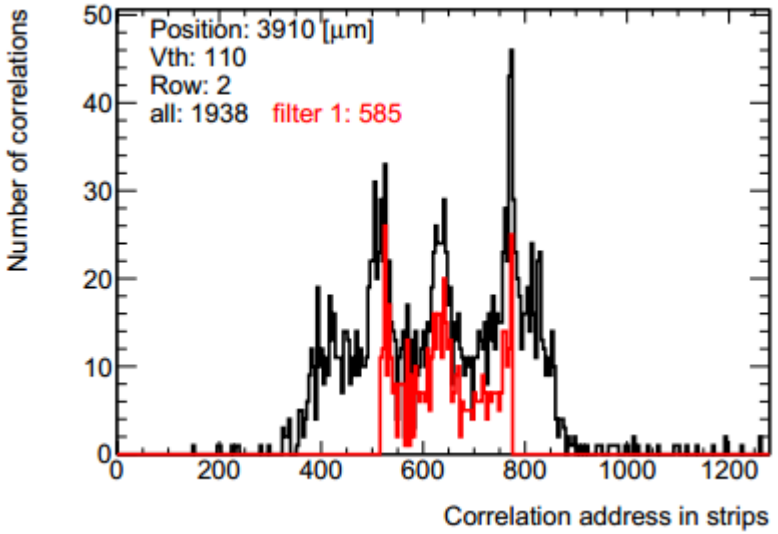
- When the layers are aligned within 3 strips, peak of correlations is clearly visible.
- Peak position moves just as expected as doublet is slid.

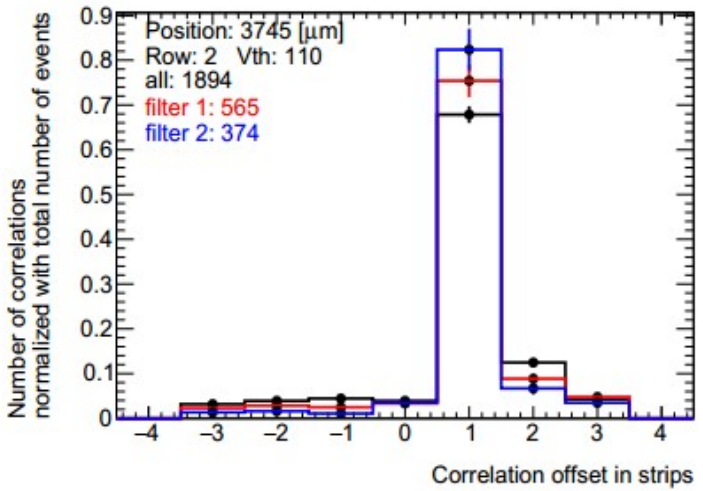


FCF and tracks

- Integrating FCF with telescope is complicated by smaller telescope coverage, and slight mis-alignment with beam.
  - Partially overcome using 4-plane tracking.
- Applying isolation from multiple tracks suggests most of the "background" correlations are due to two nearby electrons.

filter 1: one track within 0.08 μm.
filter 2: also no other track within 0.3 μm.





Conclusions

- Two successful and exhilarating weeks of testbeam occurred at SLAC End Station A last July.
- External calibration of ABC 130 gain provided valuable input to the strip community, awaiting further corroboration from source tests.
- Fast Cluster Finder successfully demonstrated using data for the first time.
- AIDA telescope tracks correlated with DUT's and used to assist in the measurements.

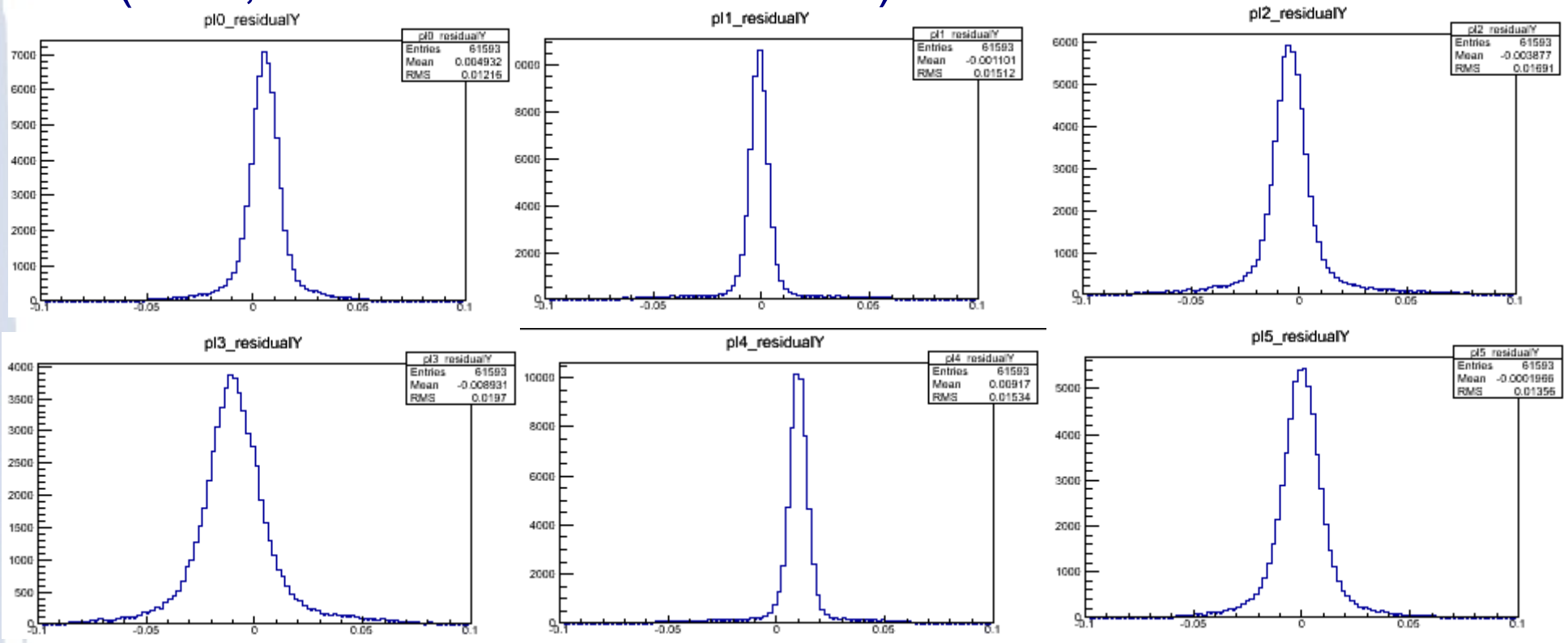
Backup slides

Track reconstruction details

- We mostly used the default settings in the datura_noDET example of the EUTelescope package.
- DUT's not included in track reconstruction.
- Residual cut at alignment step set to 150.
- Use only plane 0 as fixed for ABC runs.
- Maximum chi2 of 1000.
- Maximum 300 clusters per plane for filter.
- For ABC runs, require only 5 of the 6 planes to have hits.
- For FCF runs, do tracking with either first or last 4 planes.

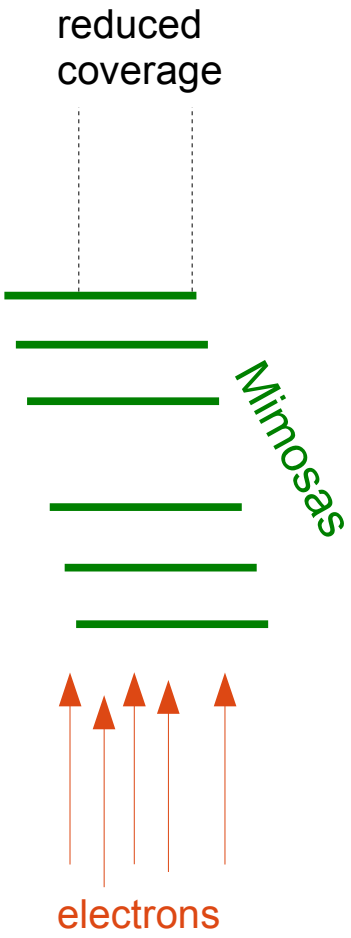
Residuals

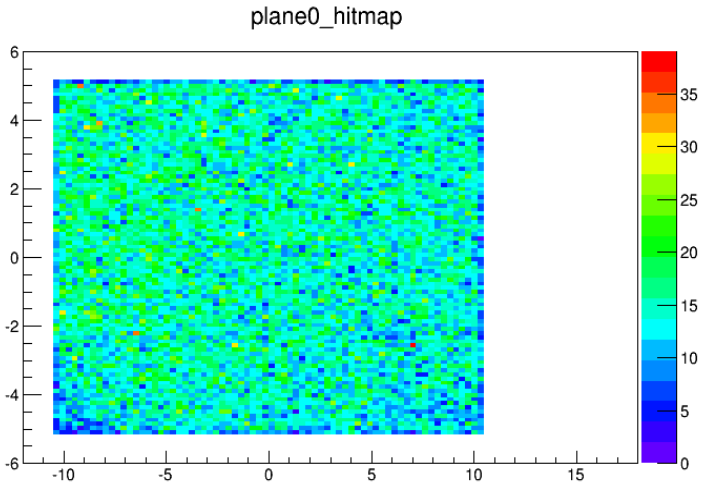
- A look at the fit residuals (i.e. track position – hit position) from a typical run.
- The x axis is in mm.
- (Note, these are biased residuals).

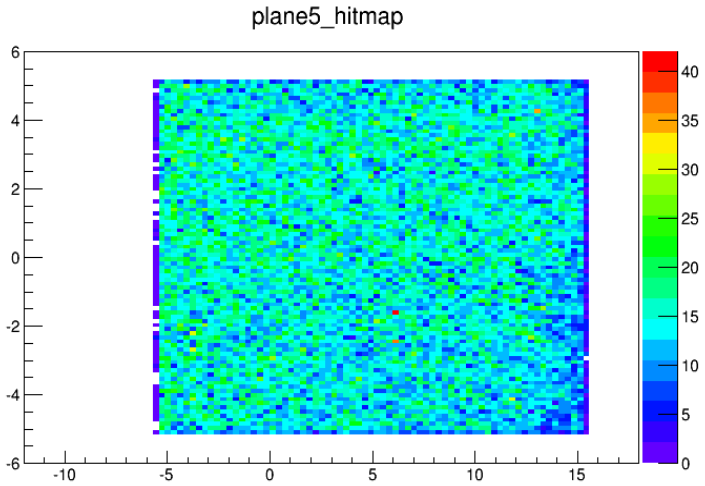


Coverage issue

- The telescope was slightly rotated with respect to the incoming beam.
- This reduces the effective area of the sensors by about 5 mm (20 → 15)
- All of ABC chip is still inside coverage, but for FCF we miss two of the 3 big peaks.

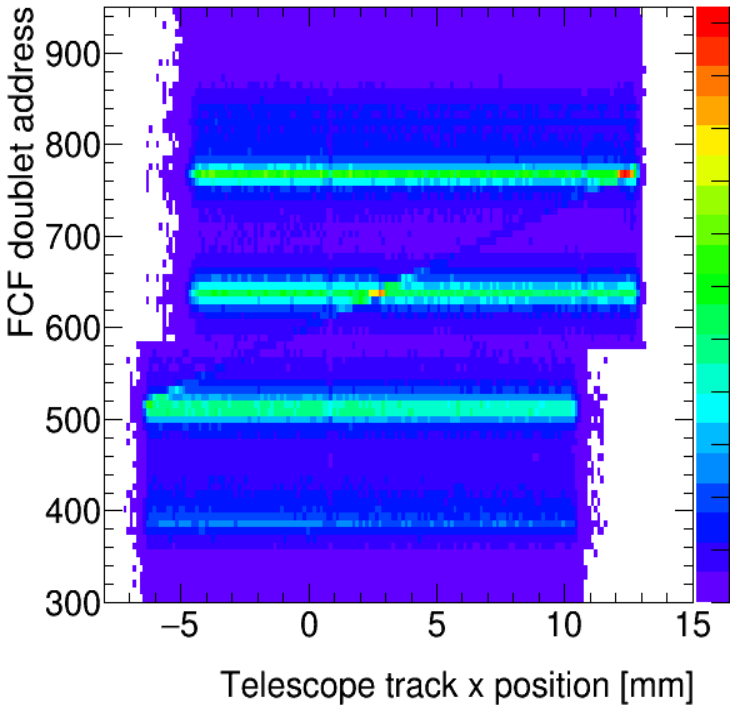




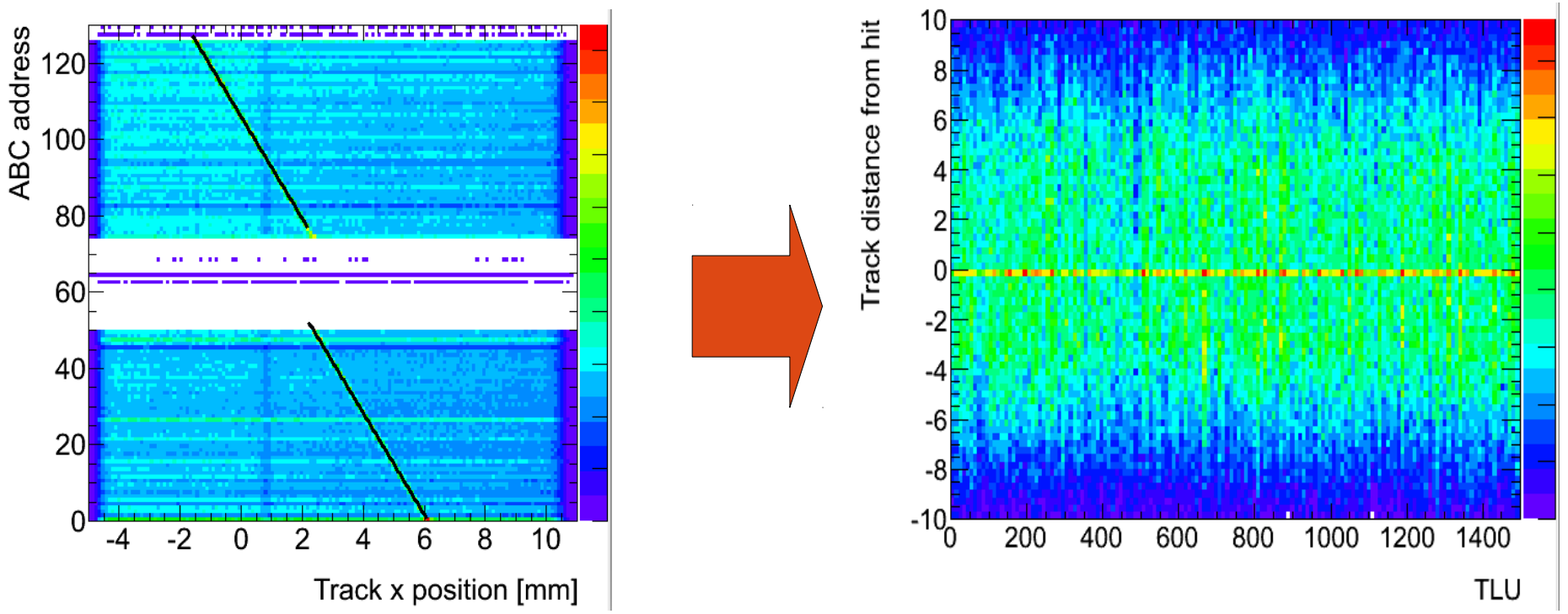


Coverage issue

- Coverage in x direction is only an issue for the FCF; single-chip ABC is still totally covered.
- Mostly recovered by running track reconstruction twice, with either first or last 4 planes.
- Which set to use determined by address on FCF doublet.

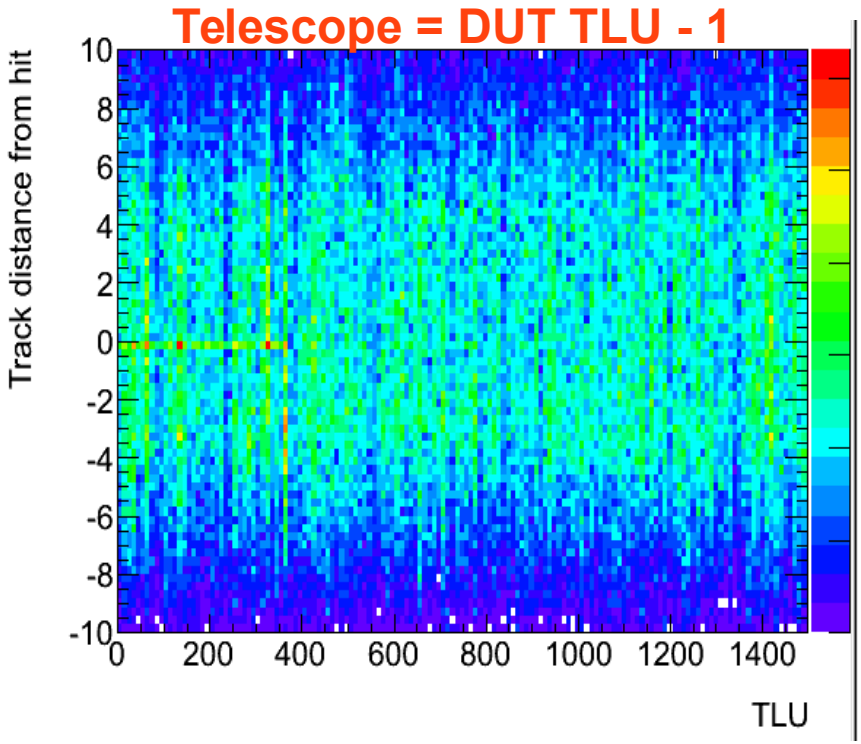


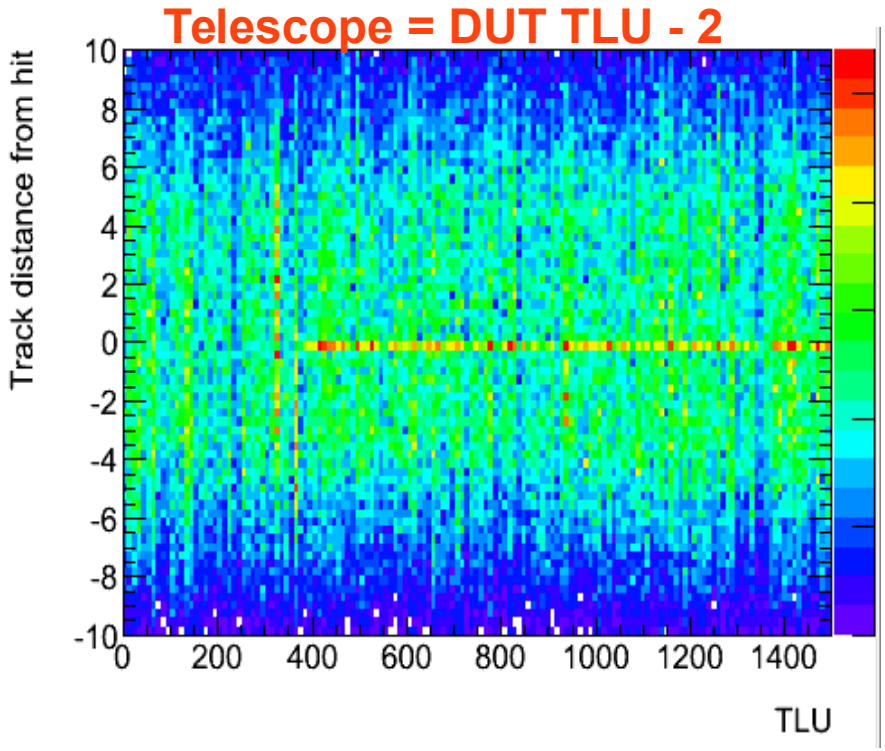
Correlation vs. time



- We can check to make sure the correlation is working as expected by plotting the track's distance from the expected line, as a function of time (or TLU ID number).
- This is an example of a run that is good the whole way through.

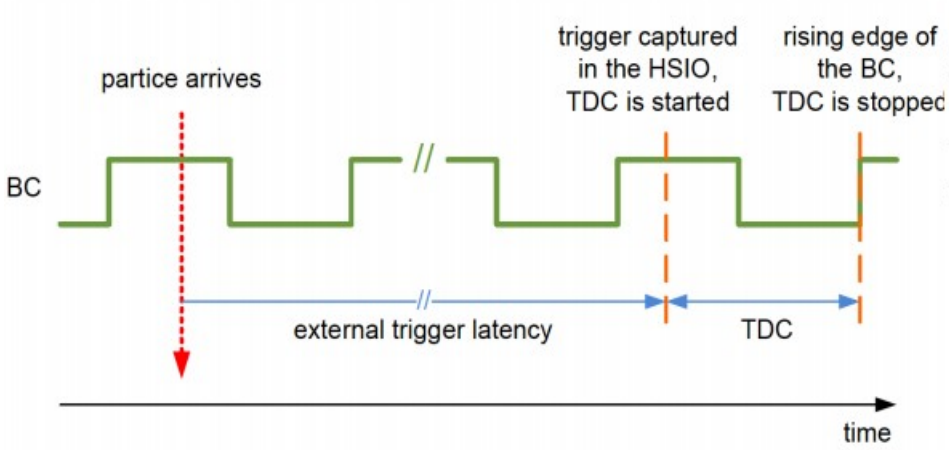
Correlation vs. time

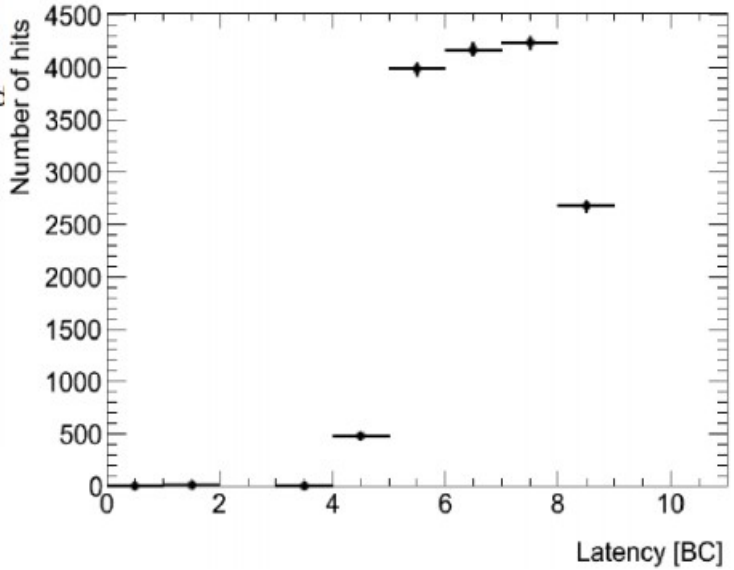




- In some cases, the telescope gets “off” from the DUT, usually by one TLU ID.
- Simple correlation plot may not catch this.
- Usually can be recovered.

Latency





When the TLU trigger arrives at HSIO, it's already a few BC cycles behind the actual event. A latency can be set to read out the right event.

Before data taking, a latency scan was done to find the right latency to use.