ITk Strip with Beam Test

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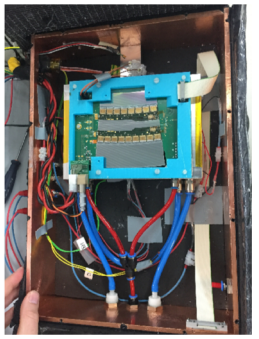
IHEP
LHC detector upgrade workshop
29 June 2018

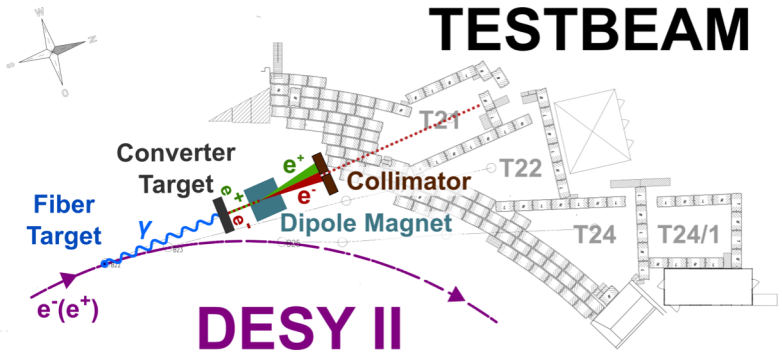
Outline

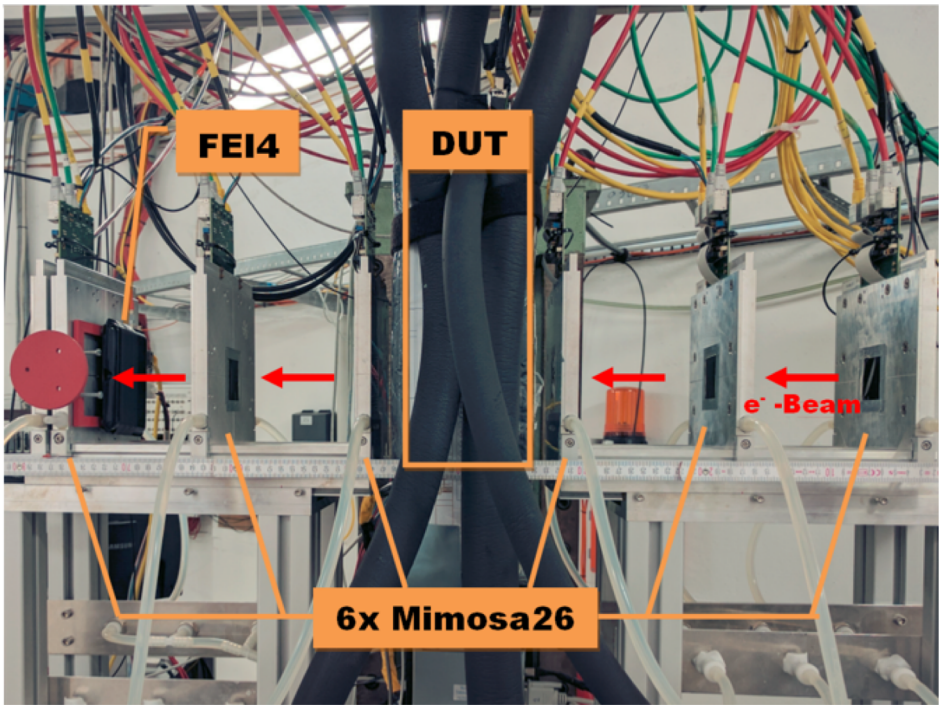
- DESY EUDET-type telescope
- ITk upgrade module
- EUDAQ and EUTelescope
- Test results
- Conclusion

DESY EUDET-type Telescope

- **Beam:** 1-6 GeV e^-
- **Reference planes**: 6 MIMOSA-26 pixel sensors -> 3 µm
- **Timing**: FE-I4 plane -> 25 ns
- **Trigger**: Scintillator/PMT + TLU

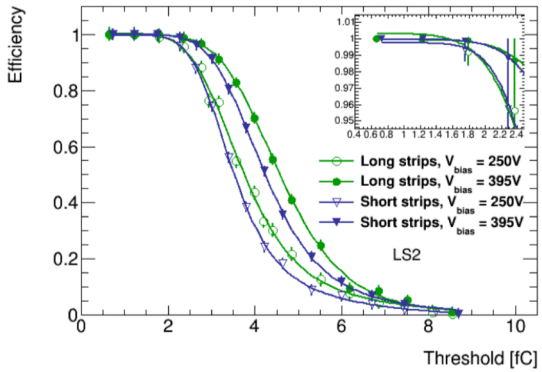


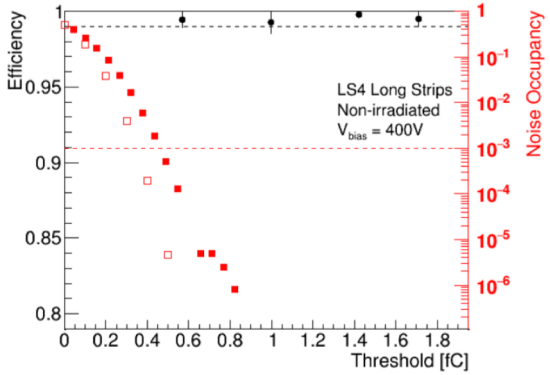


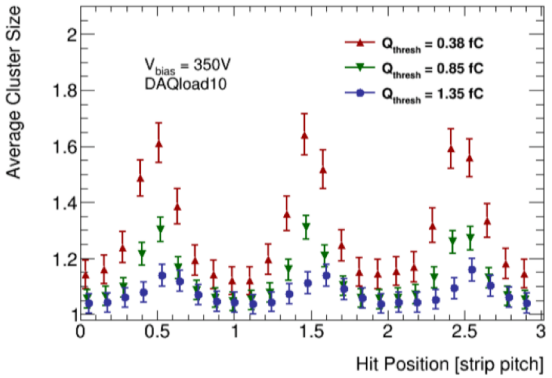


Telescope Application and Development

- Beam tests enable various characterization for full size sensor + readout in most realistic environment:
  - detection efficiency, noise occupancy
  - resolution, inter-strip behavior allowed by excellent spatial resolution







- EUDET, MIMOSA-26 based, 7 built in DESY
  - AIDA, commuting between DESY and CERN SPS-H6.
  - ANEMOME (6-MIMOSA+1-FEI4+2), Bonn-ELSA.
  - ACONITE, copy for ATLAS used at CERN-SPS-H6, DESY, SLAC.
  - DATURA, copy for DESY, at the TB21 area.
  - CALADIUM, ESA, SLAC, USA
  - DURANTA, copy for DESY, at the TB22 area
  - AZALEA, used at the CERN PS

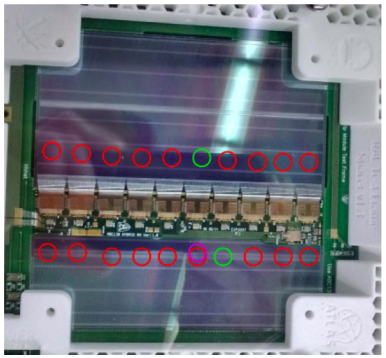
ATLAS ITk Strip Detector/Module

- DUT at 2017 May DESY testbeam(unirradiated)

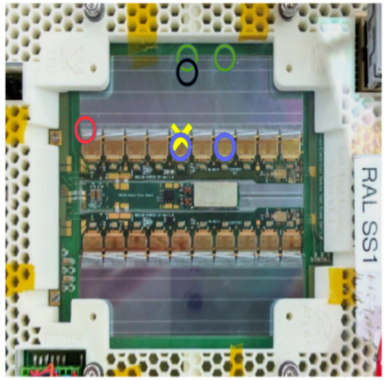
Endcap R0 module, Barrel Short Strip module

- DUT at 2018 June DESY testbeam (unirradiated)

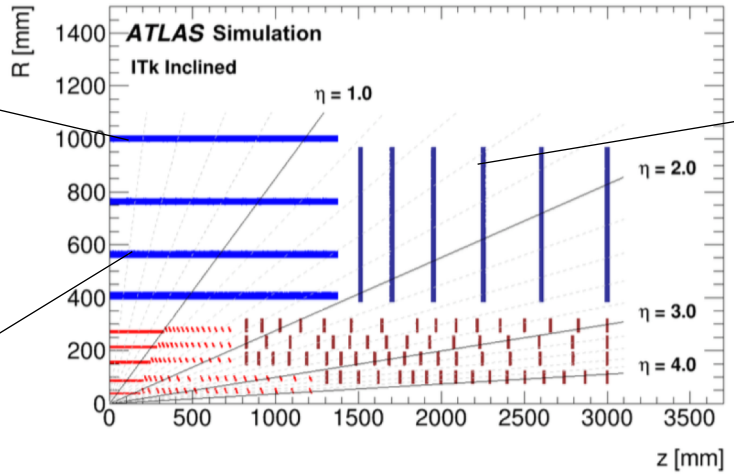
Barrel Long Strip module, Double-sided R0 module

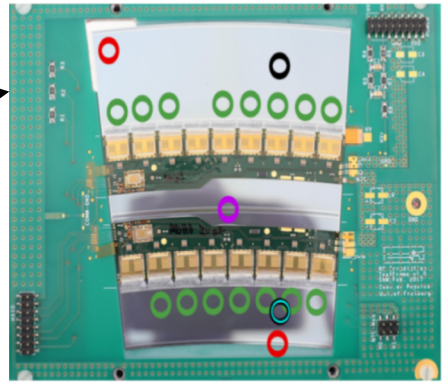


Long strip module



Short strip module

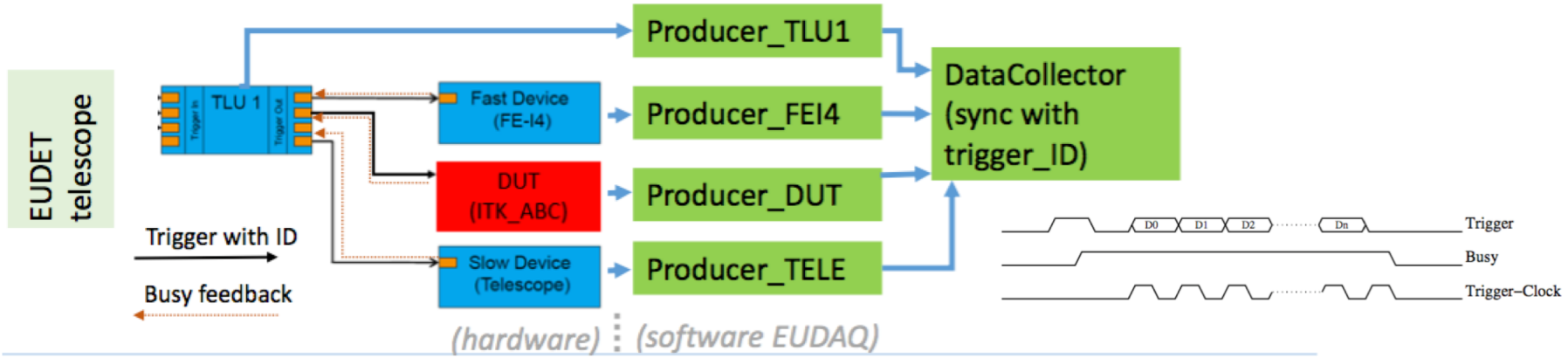


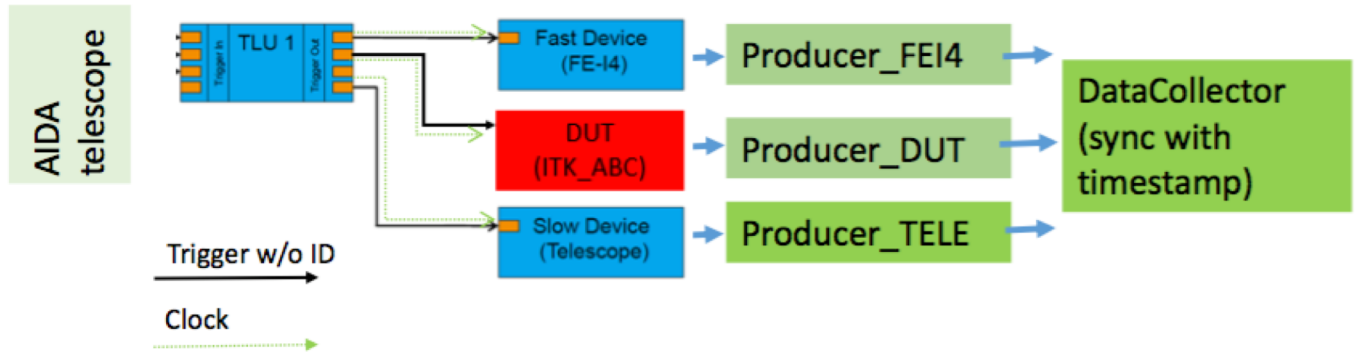


R0 module

EUDAQ2 Upgrade Motivation

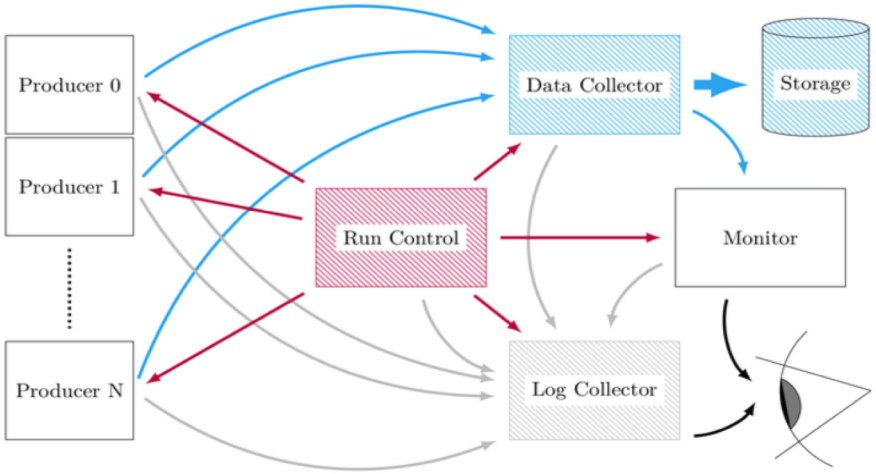
- **Upgrade by Yi Liu from EUDAQ1**
- Significate change of interface, more common code not heavily related to TLU
- Important components for EUDET-type telescope upgrading to AIDA telescope

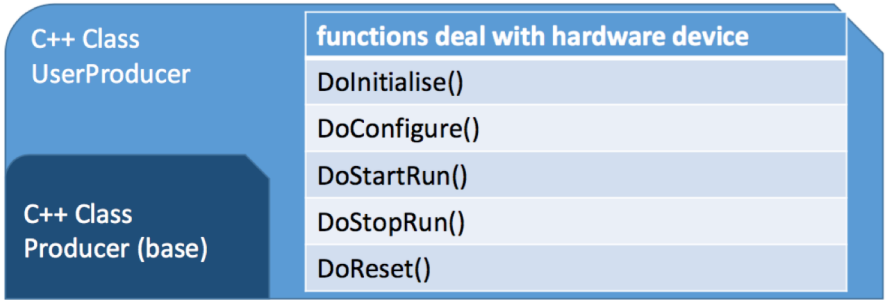




EUDAQ2

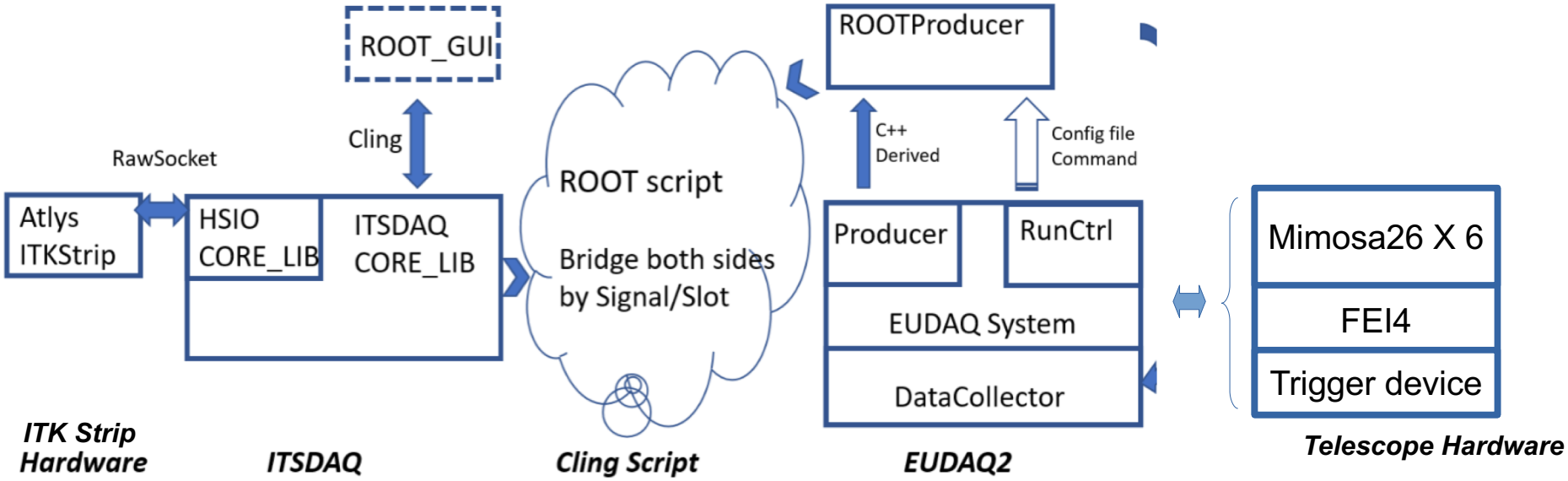
- Producers are the binding part between a user DAQ and the central EUDAQ RunControl.
- A Producer base class is provided in order to simplify the integration. The base class do all the common tasks for the derived Producer.





ITk Strip Testbeam Data Acquisition

- **EUDAQ2**: the beam telescope DAQ
- **ITSDAQ**: ITK strip module DAQ, integrated as a subsystem in EUDAQ2
- **ROOT/Cling script**: bridge between EUDAQ2 and ITSDAQ



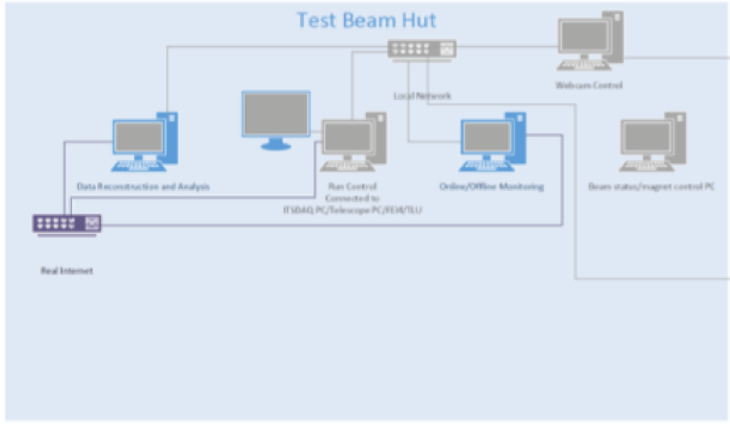
2017 May Testbeam

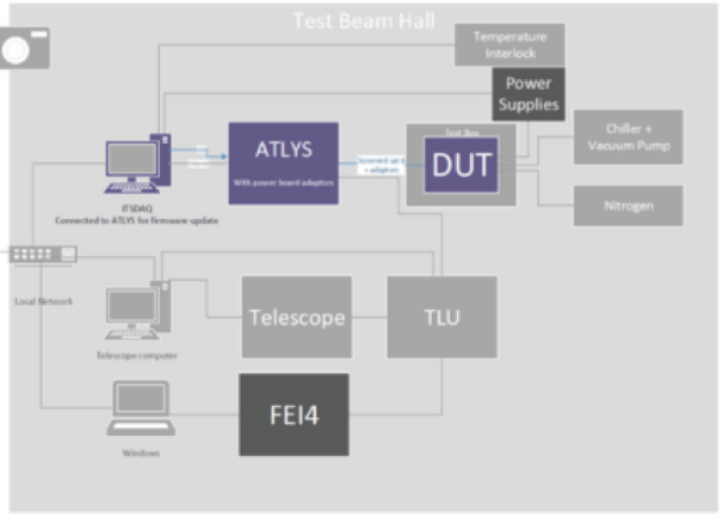
Hardware	Comments	Status	R0	SS
Install updates to ITSDAQ on PC	working on SS + nexys	Done	Dennis	
Check ATLYS f/w is correct		Done	Dennis, Yi	
Setup LV, HV and Cabling for Lab tests		Done	Sergio	
Setup of temp/humid readout (sensors, cabling and interlock)		Done	Juergen	
DUT and box				
Testing of SS module and R0 module in lab (without cooling)		Done	Dennis	Craig
Buy dry ice			probably not needed	
Cooling tests in lab of cold box			Sergio, Uli	
Infrastructure				
Move setup to test beam hall		Done		
testing of DUTs in hall (both modules)	R0 done. Now for SS	Done		
buy food and drinks		Done	Luise. Andy	
Setup runlist and runlog		Done	Andy	
Setup CERNBox for data storage		Done	Dennis	
Understand and run the scripts for latency and beam position		Done	Edo	
Print Order of scans and shift plans				
Telescope				
Test Fe-i4		Done	Yi, Jan DE	
Mount Fe-i4 to plane 5 of telescope		Done		
Mount DUT box to telescope		Done		
Check plane positions		Done		
Cold running of module in testbeam infrastructure		Done		
Confirm T.H readout		Done		
DUT: IV scan		Done		
Run with R0 module		Done		

Day	Date	# Attendees on doodle	8am-2pm	2pm-8pm	8pm-2am	2am-8am
Sunday	21/05/2017	11			Jiri, Edo	Jiri, Edo
Monday	22/05/2017	14	Edo, Mortiz	Francesco, Ryan, Christoph	Andy, Jiri, Christoph	Jiri, Edo
Tuesday	23/05/2017	14	Mortiz, Francesco, Liejian, Xiaocong	Graham, Luise, Christoph	Andy, Ryan, Christoph	Jiri, Francesco, Edo (2am-7am)
Wednesday	24/05/2017	14	Mortiz, Graham, Liejian (9am-2pm)	Andy, Xiaocong, Christoph	Francesco, Ryan, Christoph	Liejian, Jiri,Edo
Thursday	25/05/2017	13	Graham,Edo, Francesco	Liejian, Xiaocong, Christoph	Andy,Christoph	Francesco, Moritz, Jiri
Friday	26/05/2017	14	Mortiz,Liejian	Graham, Andy, Christoph	Francesco, Jiri , Andy, Christoph	Jiri,Edo
Saturday	27/05/2017	11	Mortiz, Graham			
Sunday	28/05/2017	11	Mortiz,	Andy, Ryan, Christoph	Francesco, Graham	Jiri,Edo
DUT Change	DUT Change	DUT Change	DUT Change	DUT Change	DUT Change	DUT Change
Monday	29/05/2017	12	Graham, Moritz, Christoph	Francesco, Ryan, Christoph	Andy, Jiri	Edo, Jiri
Tuesday	30/05/2017	12	Francesco, Moritz, Christoph, Edo	Andy,Ryan, Christoph	Jiri, Graham	Edo, Jiri
Wednesday	31/05/2017	11	Graham, Francesco (power off)	Dino, Moritz, Francesco	Jiri, Ryan	Edo, Jiri
Thursday	01/06/2017	10	Dino, Graham	Dino, Ryan	Jiri, Edo, Francesco	Edo, Jiri
Friday	02/06/2017	10	Dino, Graham	Jens, Moritz	Jens, Jiri	Edo, Jiri
Saturday	03/06/2017	8	Dino, Moritz	Jens, Dino	Jens, Jiri, Graham	Edo, Jiri
Sunday	04/06/2017	8	Dino, Moritz	Jens, Graham	Jens, Jiri	Edo, Jiri
Monday	05/06/2017	7	Jens, Graham, Dino, Moritz	Juergen, Graham, Moritz		
			Need to be finished by Mon 9am			

Important events		
NBA	23/05/2017	3:00:00 AM
NBA	24/05/2017	2:30:00 AM
UEFA Europa League	24/05/2017	8:45:00 PM
UEFA Champions League	03/06/2017	8:45:00 PM
NHL	23/05/2017	2:00:00 AM
NHL	24/05/2017	2:00:00 AM
NHL	26/05/2017	2:00:00 AM
World Cricket League	(24/7)	
Scottish Cup	27/05/2017	4:00 PM

Yi, Liu taking charge in DAQ and FEI4

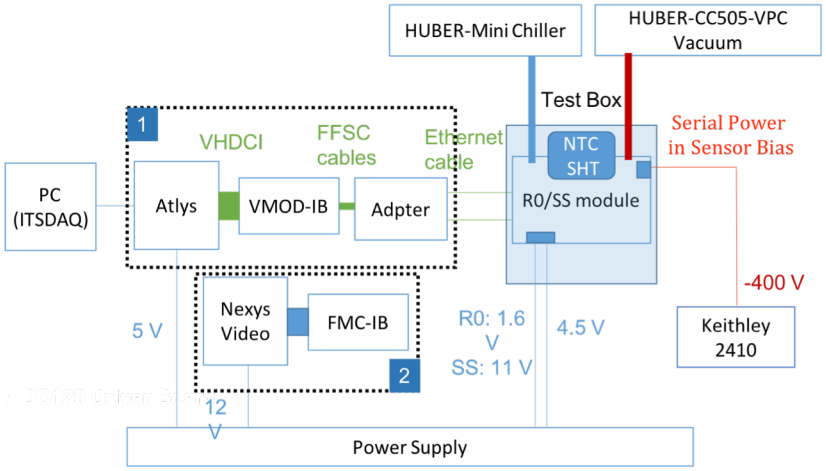


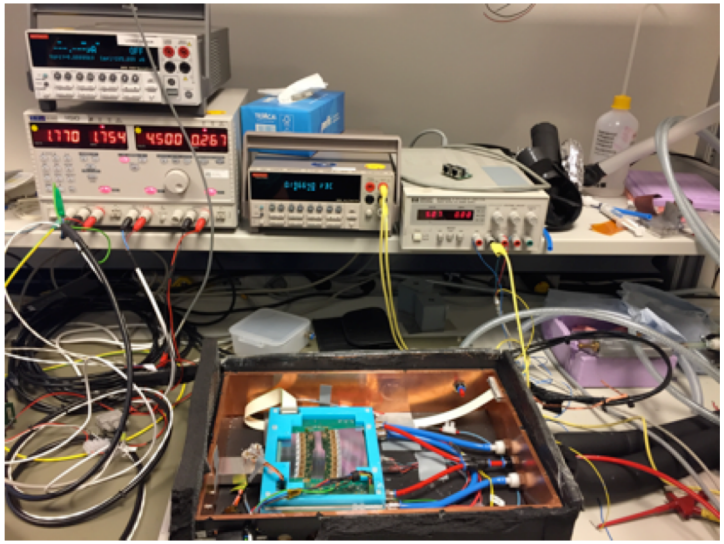


RAL | DESY (Z) | Testbeam Team

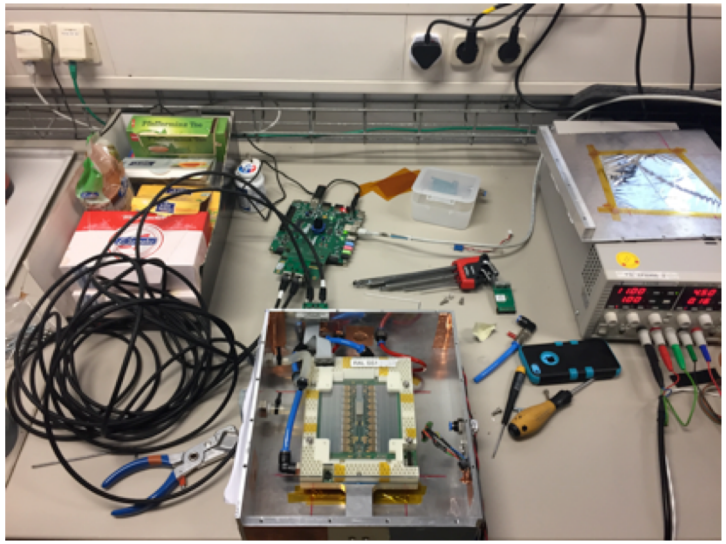
Lab Test

- Basic electron test
  - IV curve
  - Response curve
- Many unexpected problems occurred after transferring to DESY even those modules are tested well in local lab
  - ITSDAQ configure failed
  - Wire boding lines broken





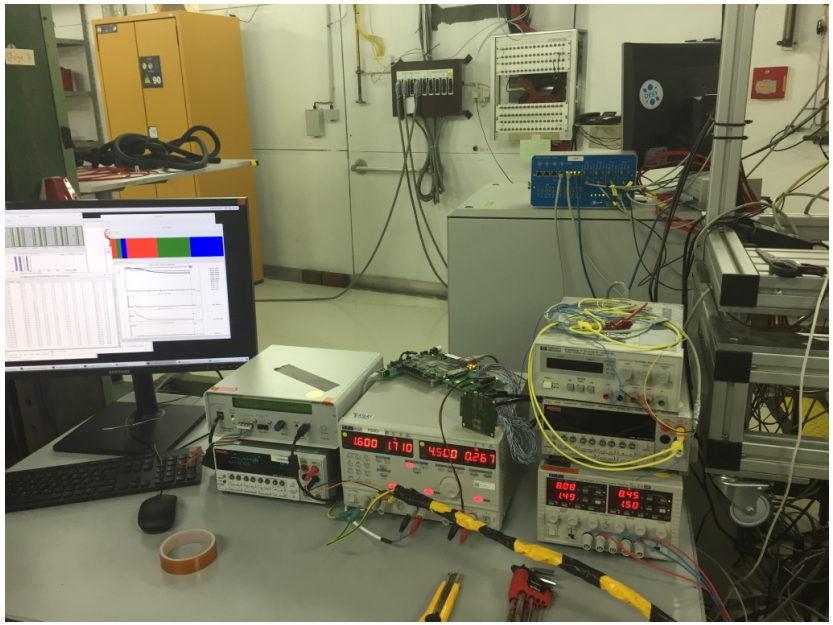
Ro module test in E-Lab



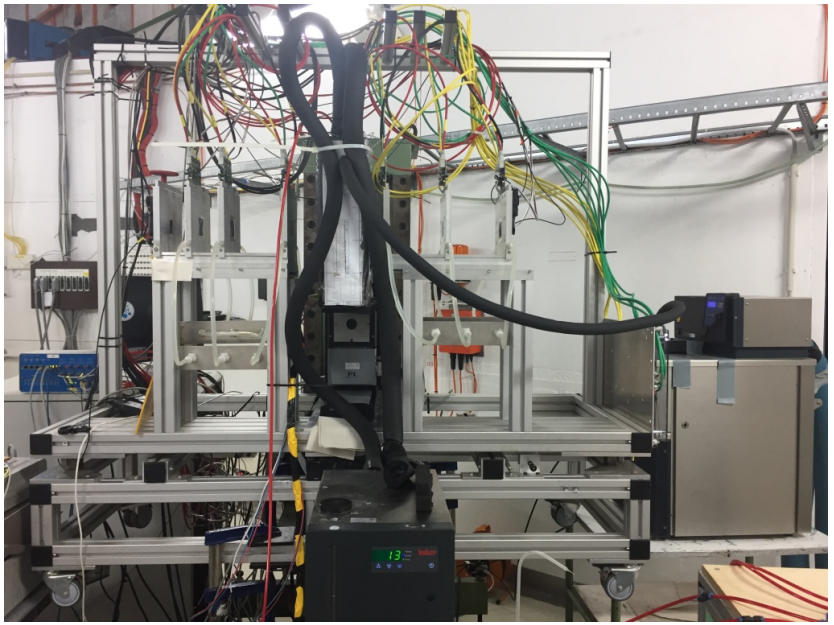
SS module test in E-Lab

Beam Test

- Long time (Over 8 hours) to cool down



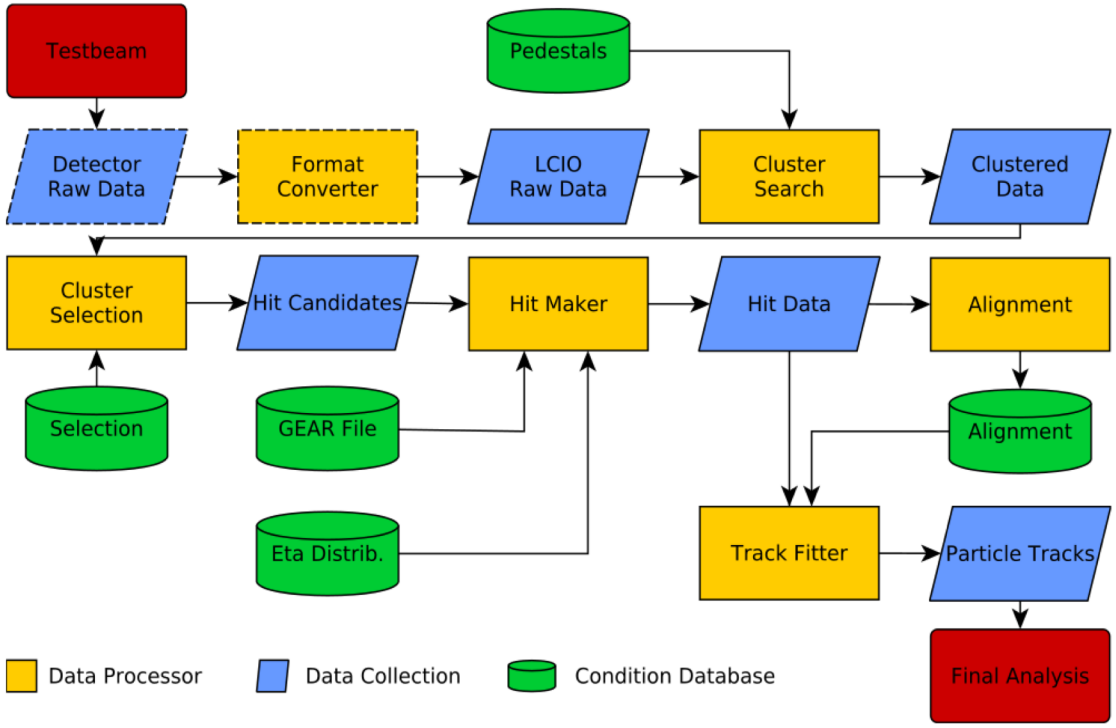
Power supply, bias voltage, temperature monitor, etc



SS/R0 module (DUT), MIMOSA-26 (Reference plane), FEI4 scintillators (trigger), chiller and vacuum

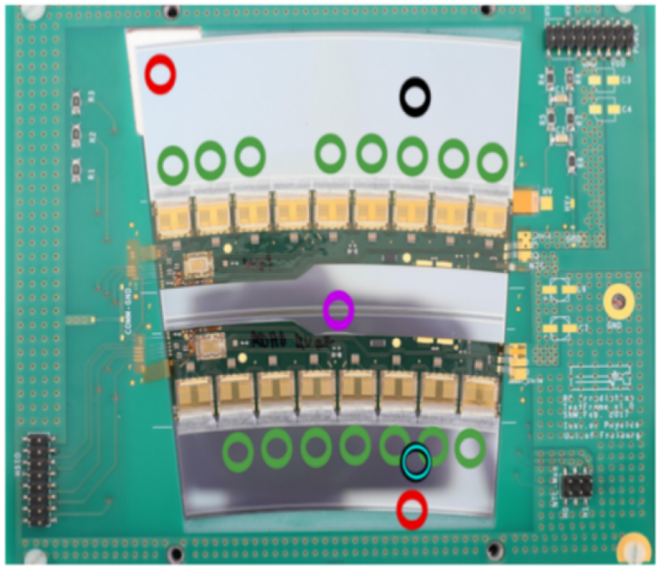
Offline Data Reconstruction/Analysis

- **EUTelescope**: based on ILCSoft framework (MARLIN, GEAR, LCIO …)
- **Millepede, General Broken Lines algorithm**: integrated for track fitting and alignment
- **Radial strips**: **developed by X.C Ai for ATLAS ITk Strip endcap sensors**.

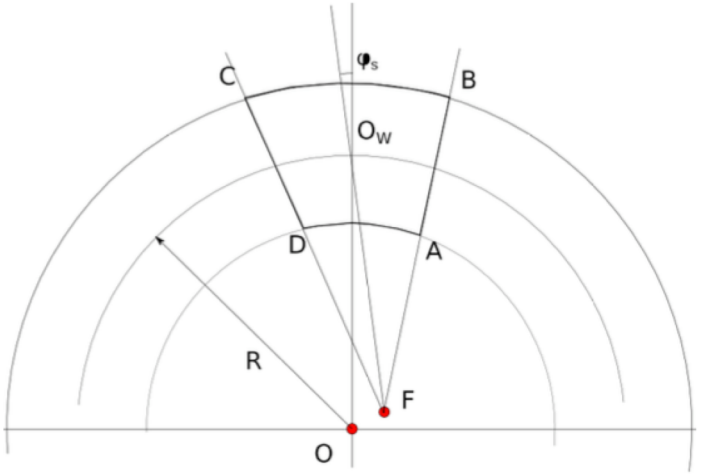


Radial Reconstruction

- End-cap R0 module has radial strips with rotated annulus shape
  - measurement frame is orientated differently to local frame
- Modifications to GBL code for radial geometry:
  - **Clustering:** using polar coordinates (strip radius r/ angle ϕ) in DUT local plane
  - **Pattern Recognition**: using the difference of orientation as the criterion to attach the hit on DUT to the track instead of the difference of coordinate
  - **Track Fitting/Alignment:** the residuals are calculated in radial coordinates



The inner and outer edges are concentric arcs of circles, centered at the center of the wheel

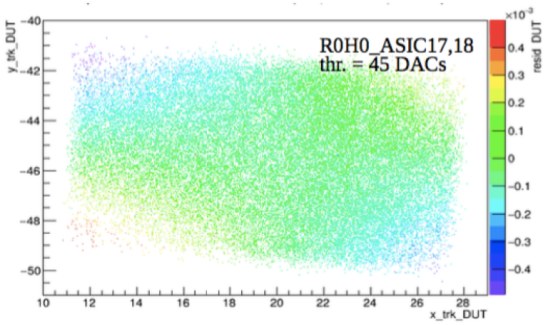


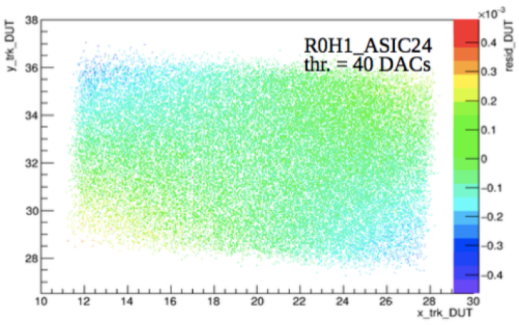
The two sides are straight, but rotated away from the wheel center by the stereo angle

Indexing Problem

Funny dependence of the residual on the local (x,y) position:

- larger residual lies in the four corners of the beam region
- opposite sign of residuals at the two ends of a strip at the corner



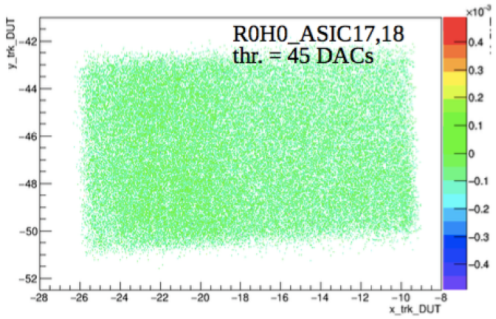


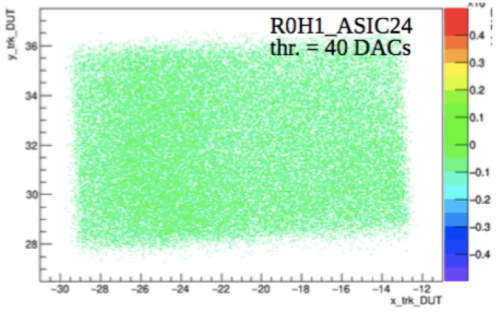
No dependence of residual on the local (x,y) position any more

How to solve?

Just reverse the strip index!

- Motivated by the fact that the strips seem to have a focus overhead, not downward...
- Probably have the DUT front and back ward reversed (not important for parallel strips)





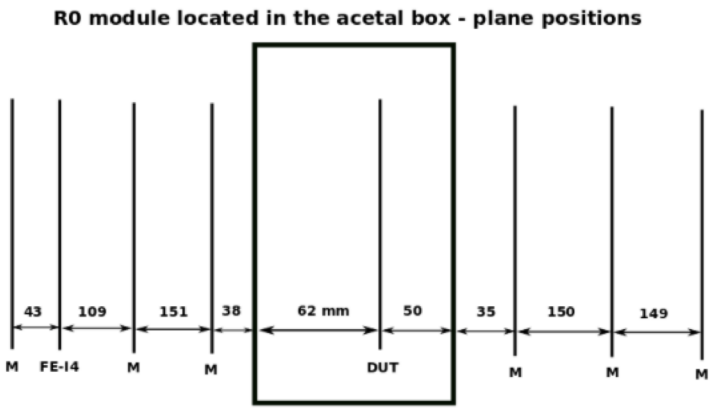
Residual and Tracking Resolution

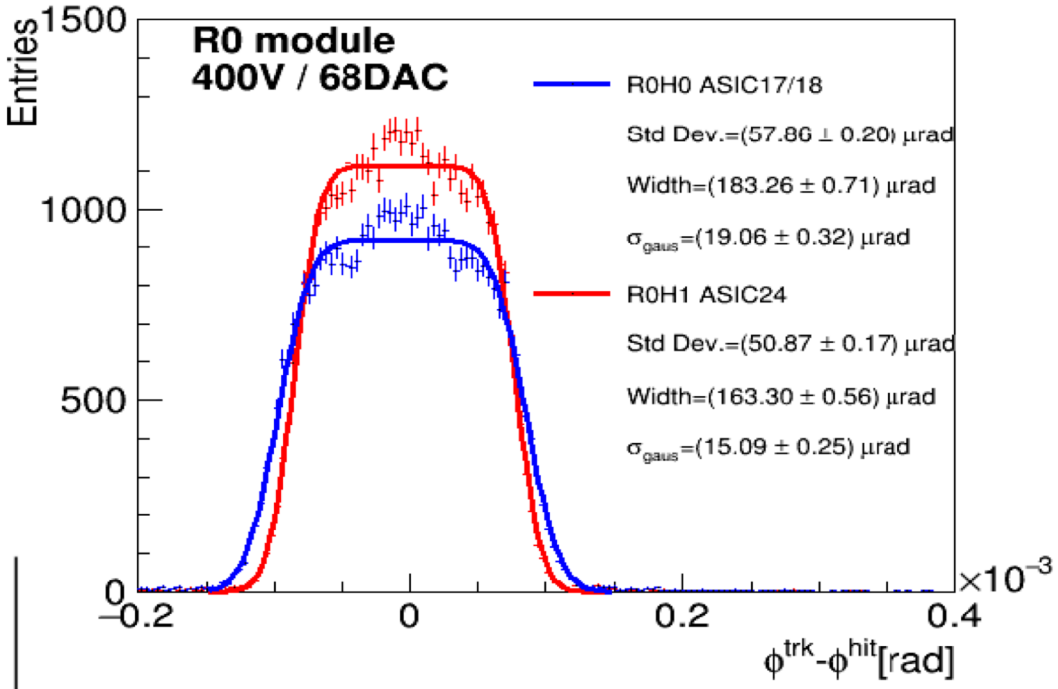
- Tracking resolution estimated from residuals of track fit
- Residual fitted with convolution of rectangular function with gaussian

$$r_{DUT} = \phi_{trk} - \phi_{DUT}$$

$$\sigma^2_{r_{DUT}} = \sigma^2_{\phi_{trk}} + \sigma^2_{\phi_{DUT}}$$

$$\sigma_{\phi_{DUT}} = \sqrt{\sigma^2_{r_{DUT}} - \sigma^2_{\phi_{trk}}}$$





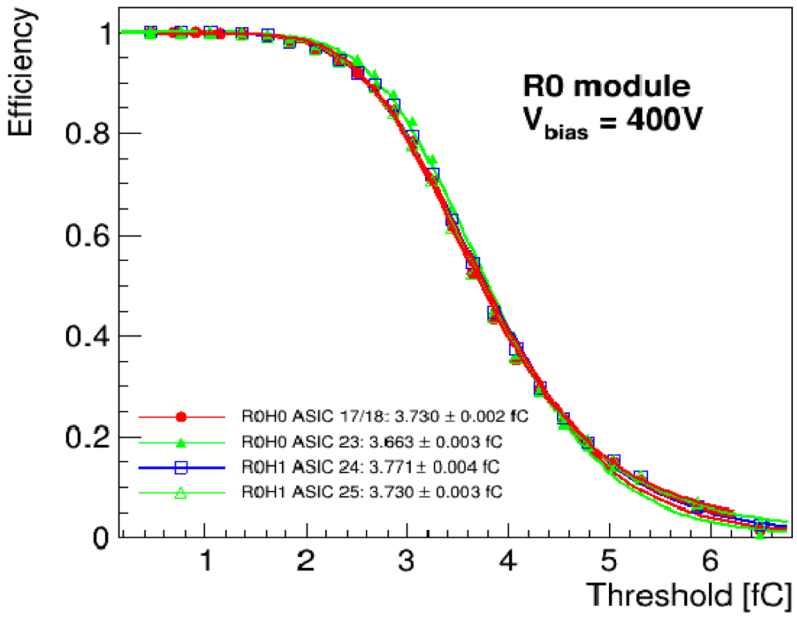
Efficiency

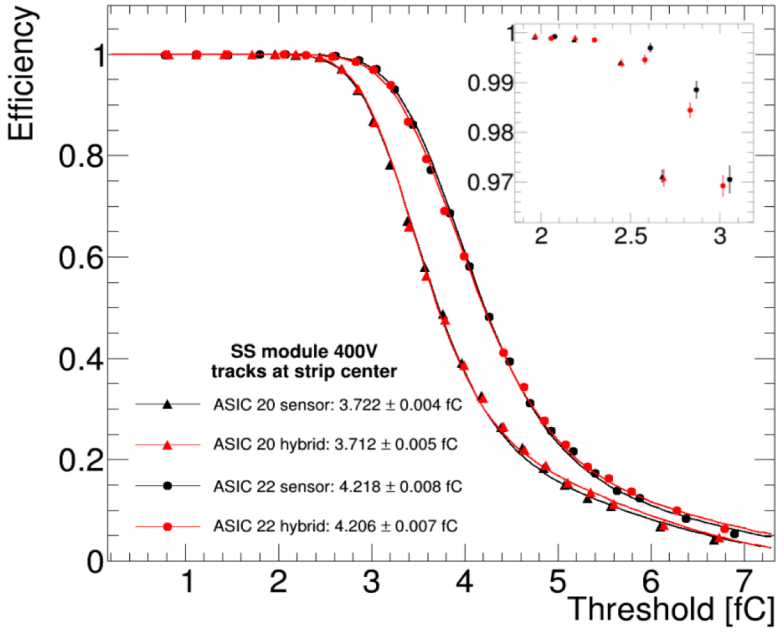
- Efficiency comparable in all the positions for both DUTs
- Efficiency vs threshold is S-curve, fitted with skewed error function

$$\epsilon = \frac{tracks\ with\ FEI4 + DUT\ hits}{tracks\ with\ FEI4\ hits}$$

$$\epsilon = \epsilon_{max} \cdot \mathrm{erfc}[x(1 + 0.6\frac{e^{-\xi x} - e^{\xi x}}{e^{-\xi x} + e^{\xi x}})]$$

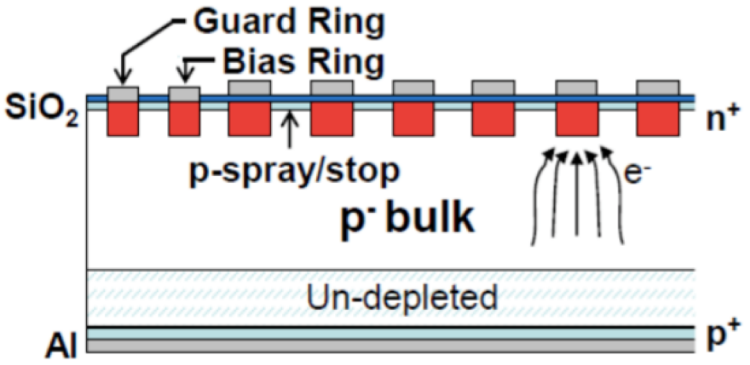
$$x = \frac{q_{thr} - \mu}{\sqrt{2}\sigma}$$

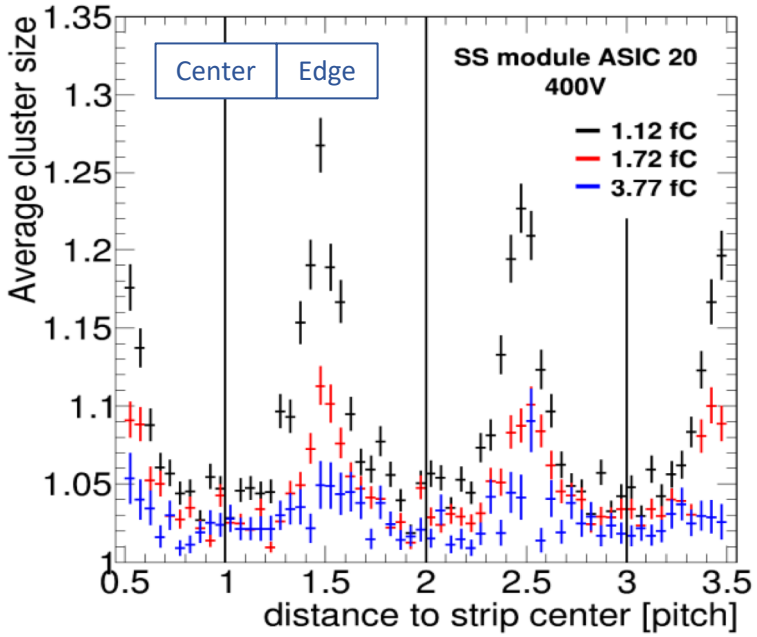


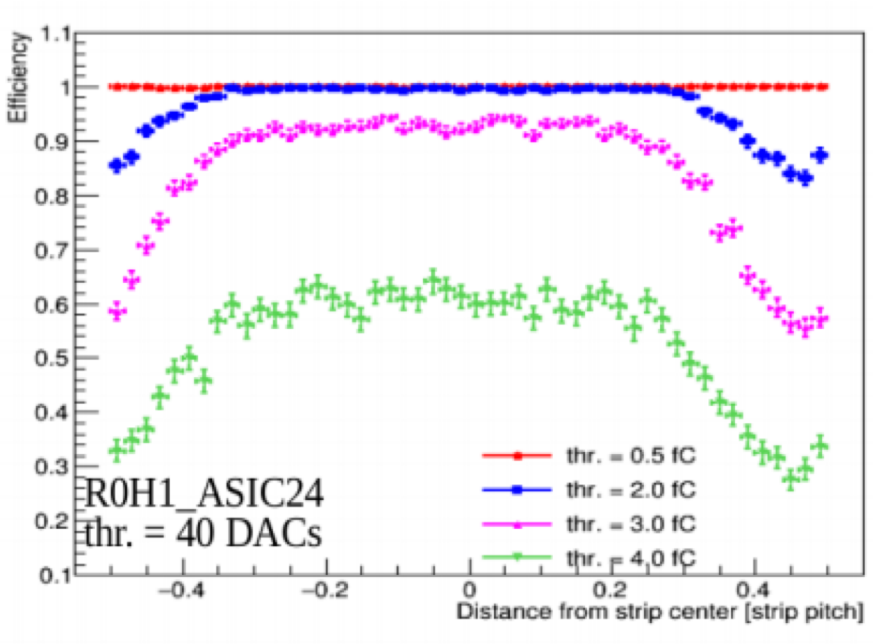


Inter-strip Cluster Size and Efficiency

- Inter-strip cluster size larger in edge
- Inter-strip efficiency decrease in edge







Conclusion

- A series of tests have been performed at the DESY-II test beam facilities to investigate the detailed performance of the ATLAS ITk strip module

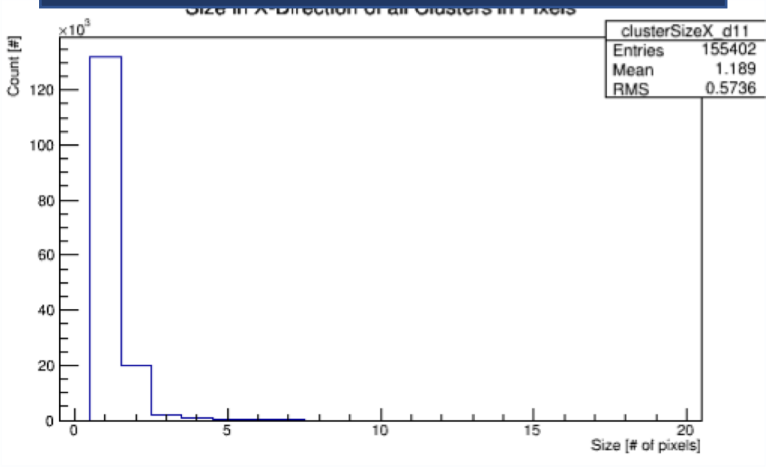
- IHEP is making import contributions on module beam tests

Thanks for your attention

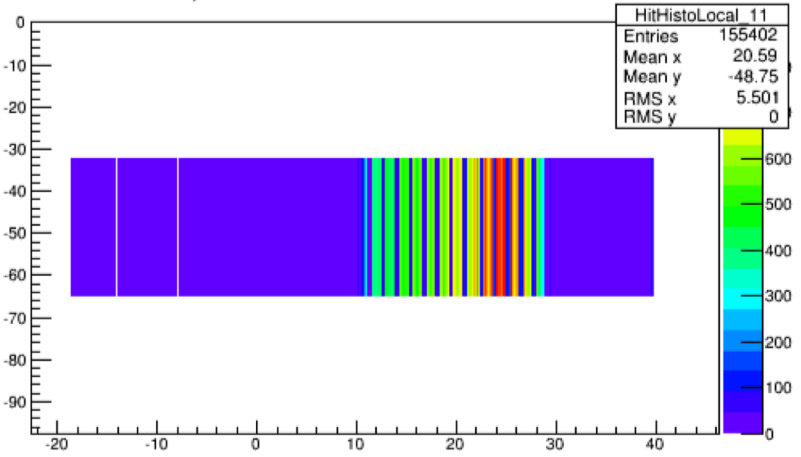
Backups

Validation of the New Eutelescope Code

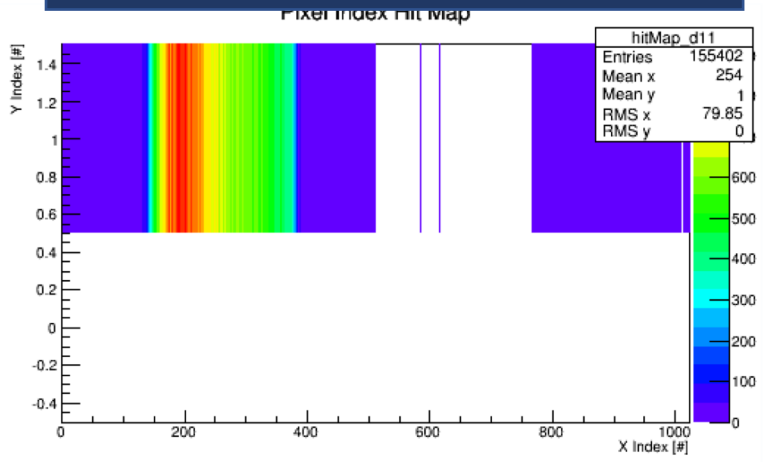
cluster size of DUT in X-direction



Pixel index hitmap of the DUT



Hit map of the DUT in local frame



Hit X Correlation : Mimosa1_DUT