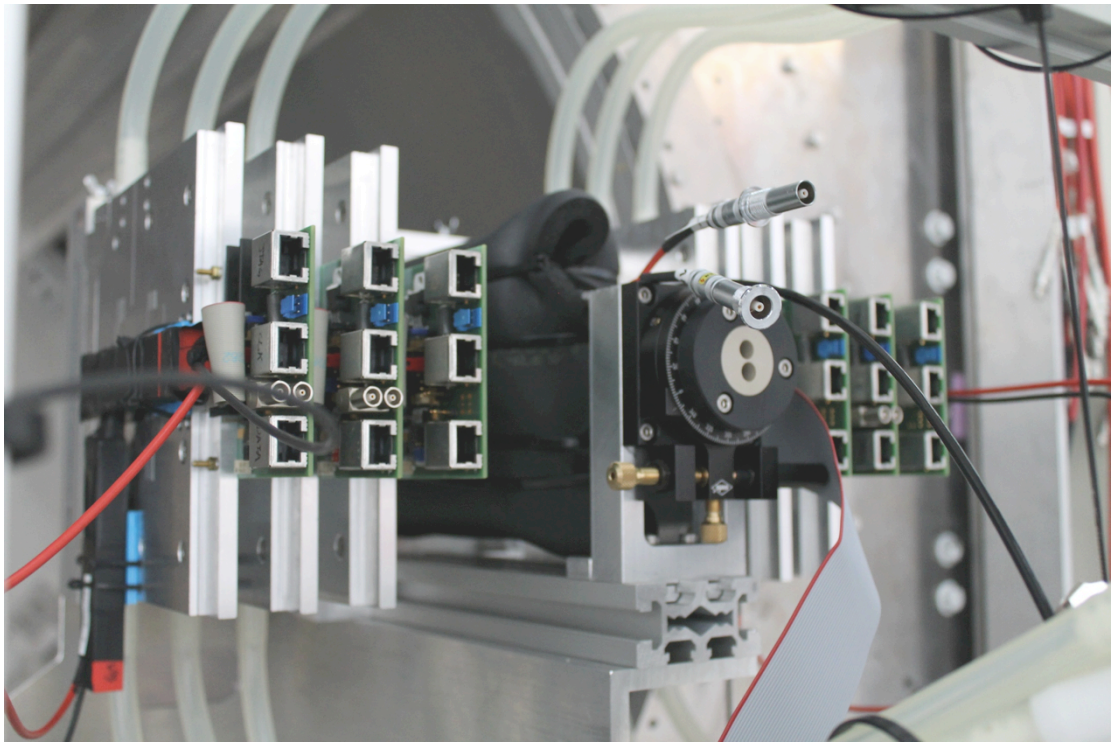
Lorentz Angle Measurement

On Future ATLAS Silicon Strip Sensors



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RD50, Bucharest
June 12, 2014

HELMHOLTZ ASSOCIATION

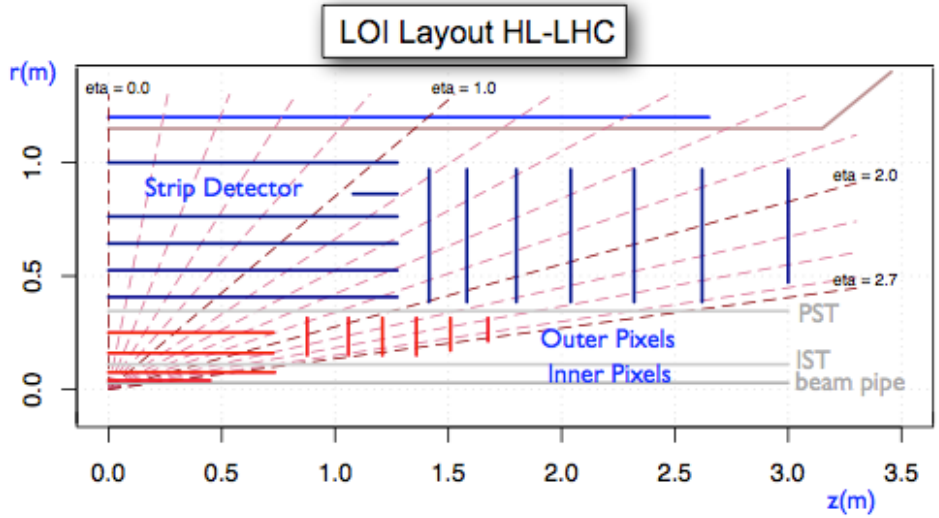
UHH

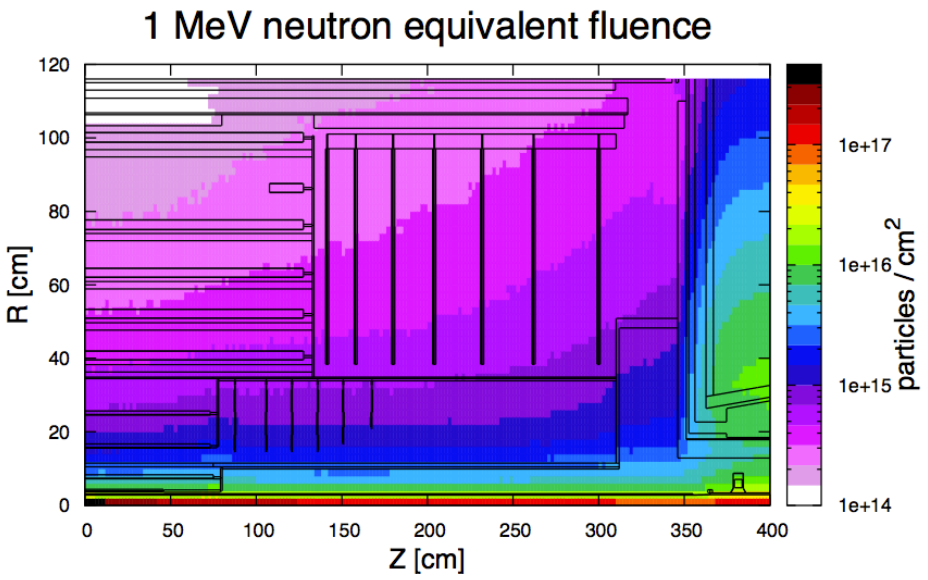
ATLAS

DESY

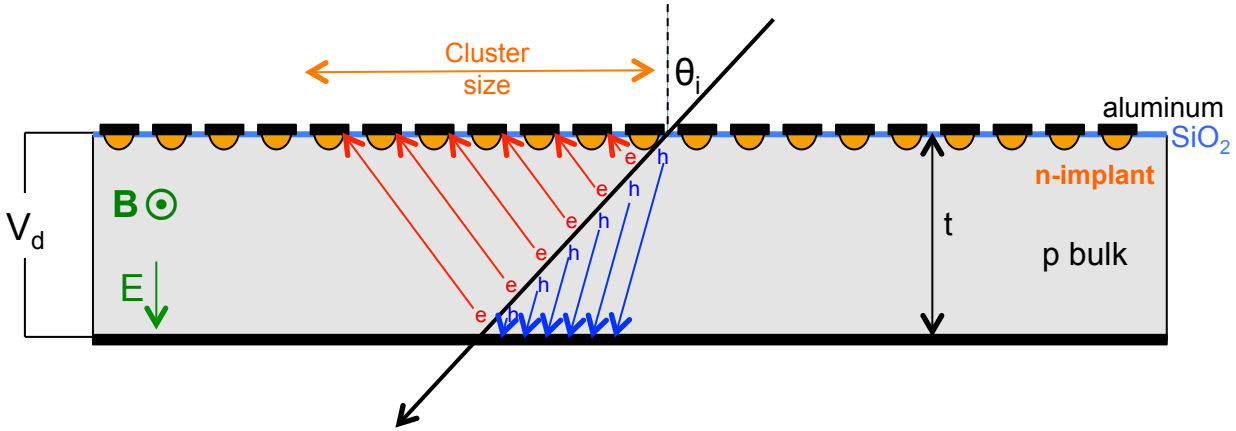
Motivation

- Upgrade of LHC to High-Luminosity LHC in ~10 years
- ATLAS inner tracker to be replaced by an all silicon tracker (pixel and strip detectors).
- During HL-LHC running, radiation doses on strip detector in ATLAS will reach to 10^{15} 1MeV neq/cm^2
- Lorentz angle in silicon sensors will change due to radiation damage
- Knowledge of Lorentz angle is important for track reconstruction.



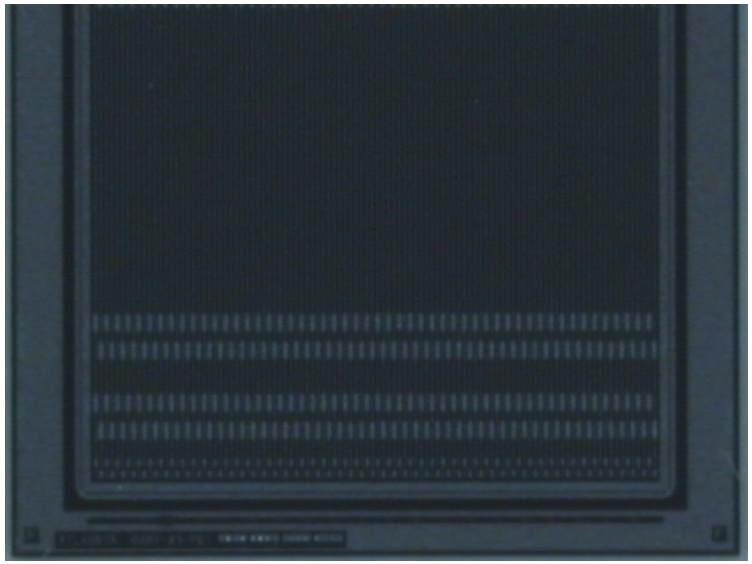


Test Sensors for Future ATLAS Strip Detector



V_d : depletion voltage
E : Electric field
B: Magnetic Field
t : thickness

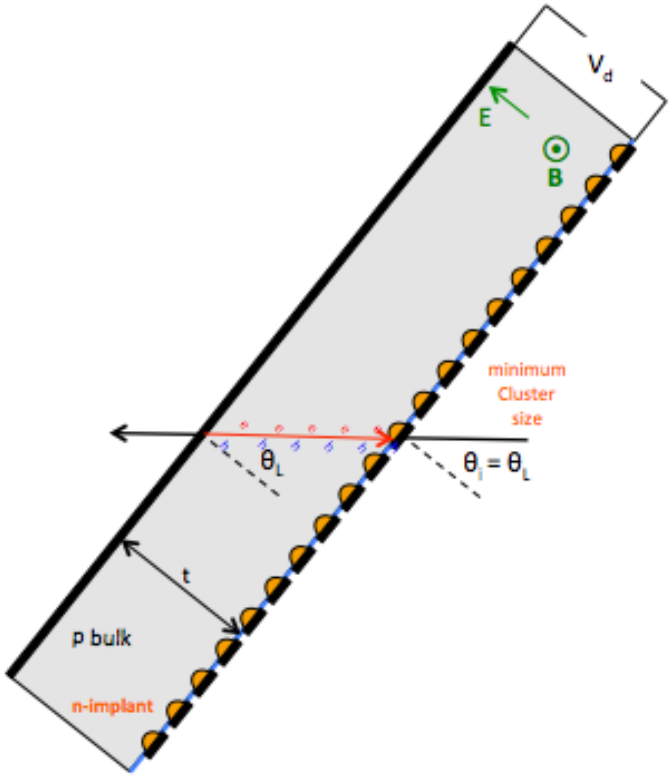
ATLAS12 miniature test sensors

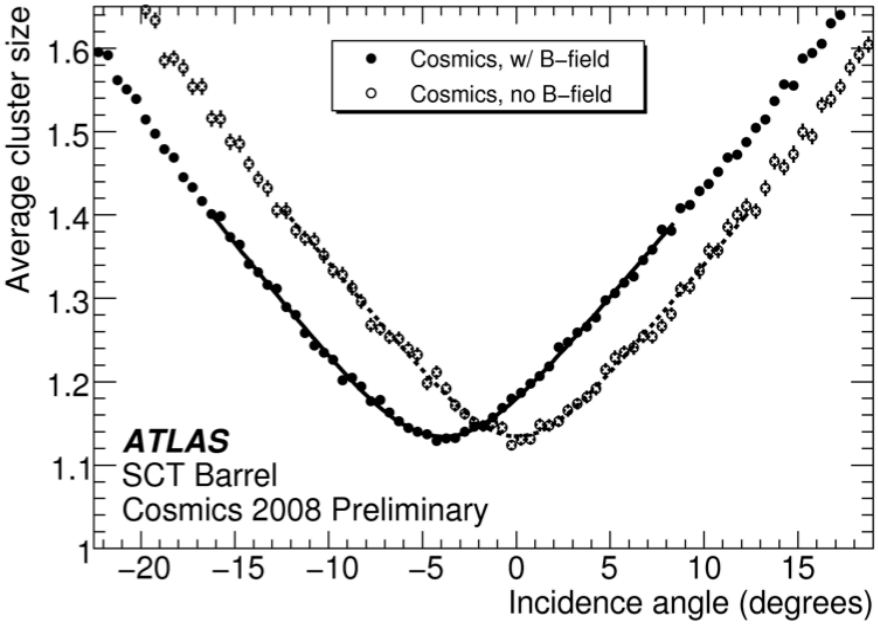


Type	n in p
Collects	electrons
Thickness	320 um
Depletion Voltage	-170 V
Bias Voltage	-500 V
Outer dimension	10x10 mm
Active area	~ 8x8 mm
Number of channels	104
Pitch size	74.5 um

Lorentz Angle Measurement Method

- Measurement carried out at DESY test beam
- Cluster size measured as a function of track incidence angle on the sensors

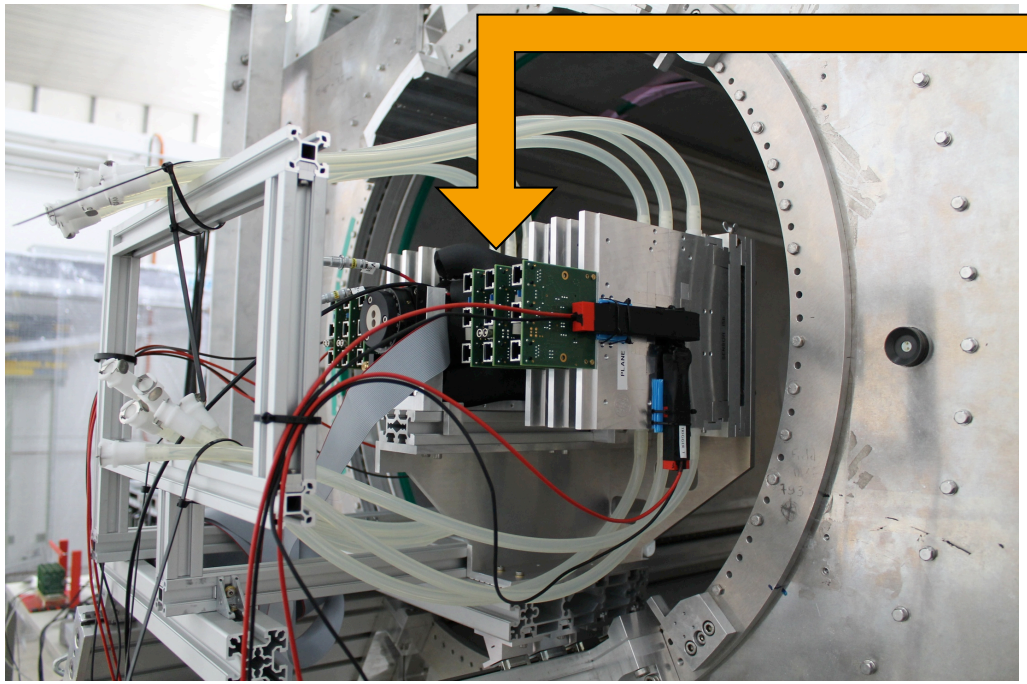




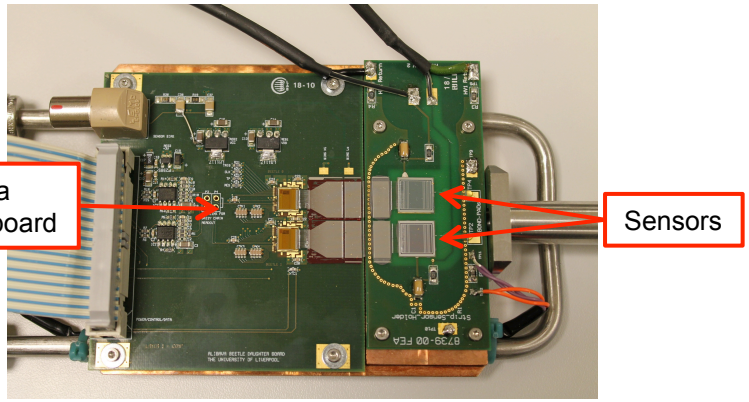
Lorentz angle measurement on ATLAS SemiConductor Tracker (SCT)
ATL-COM-INDET-2009-039

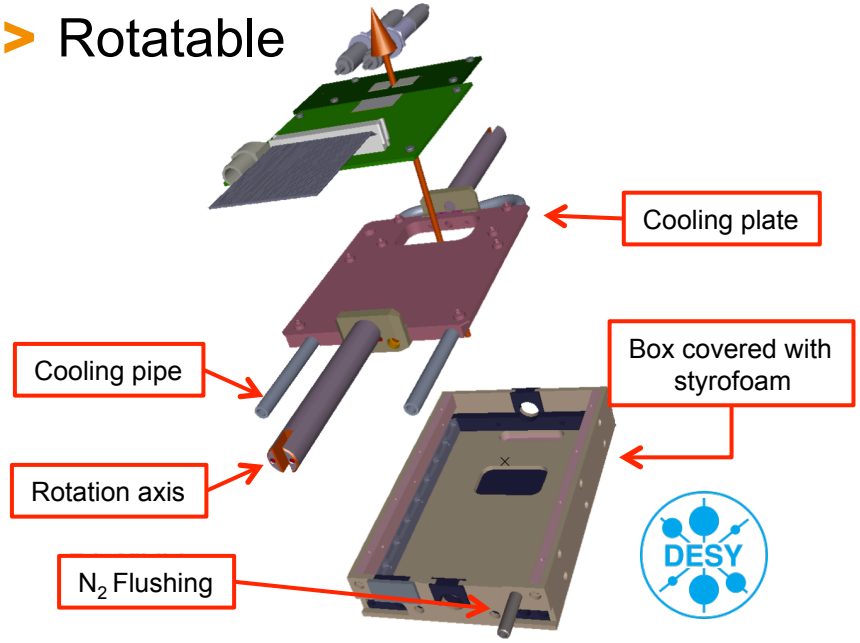
- Lorentz angle = incidence angle at minimum cluster size

Setup

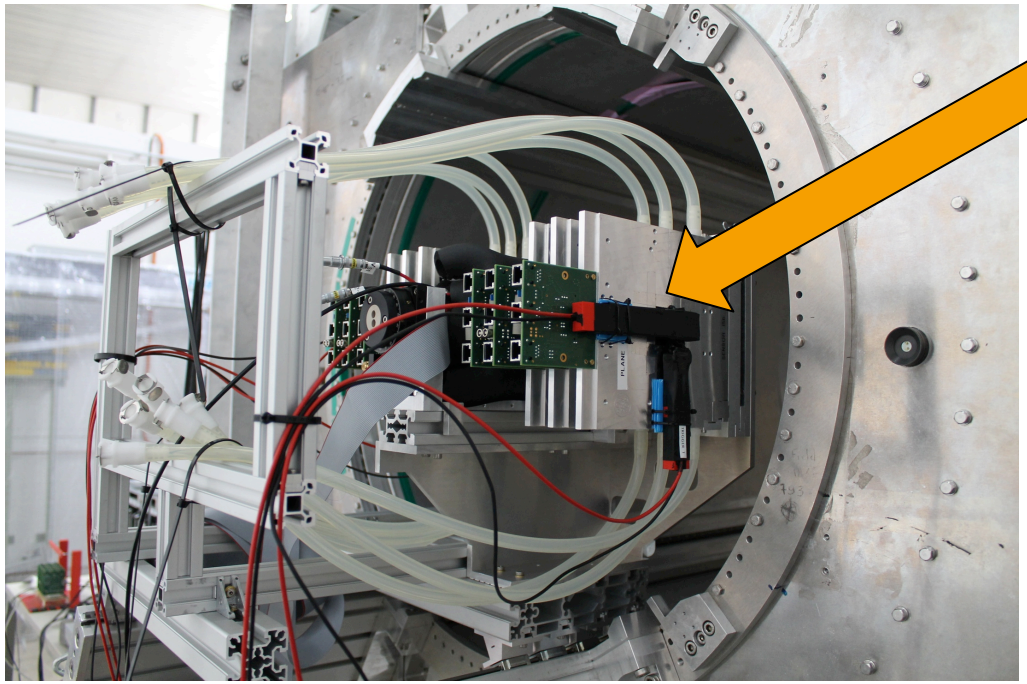


- Device Under Test (DUT)
- 2 strip sensors
  - attached to an Alibava daughter board
- Cooled down to -25C using silicone oil
  - To avoid leakage current and prevent annealing
- Rotatable





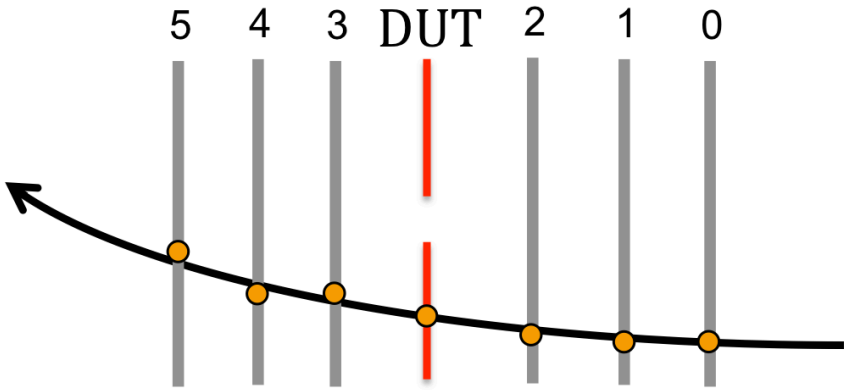
Setup

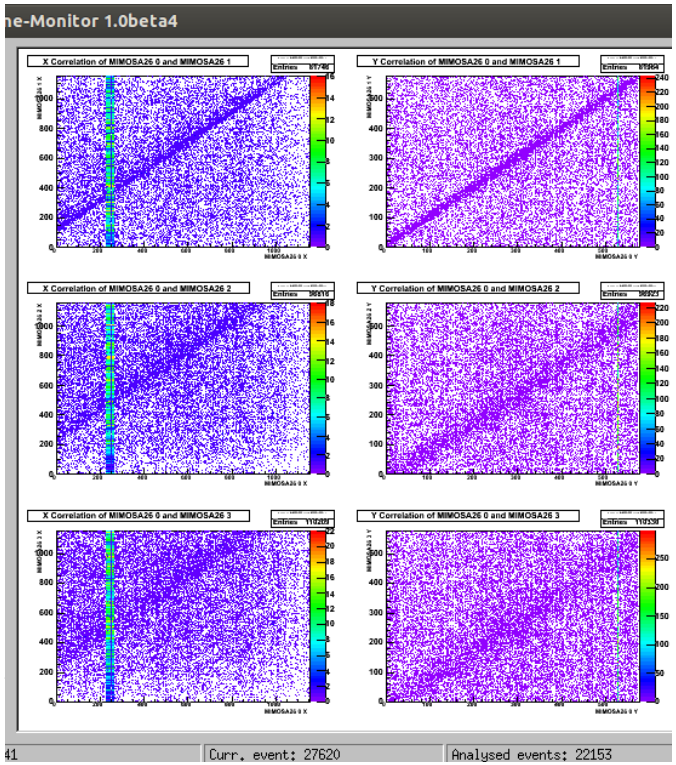


EUDET Beam Telescope

- Consists of 6 pixel sensors
- Pointing resolution can reach up to 2um without any DUT

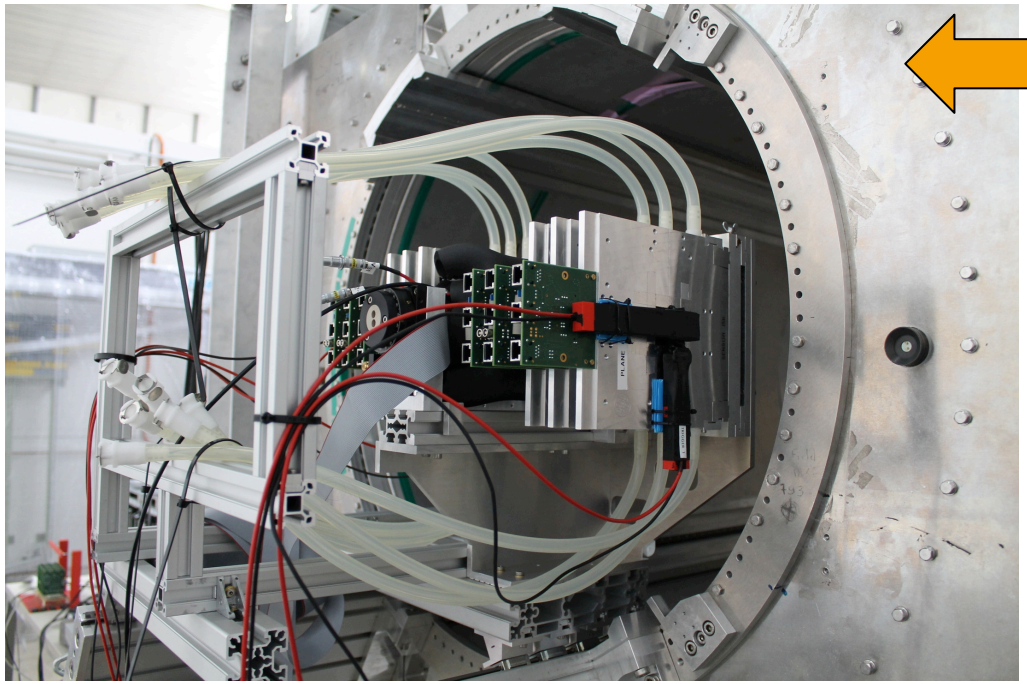
> Used to track particles and find the incidence angle on DUT



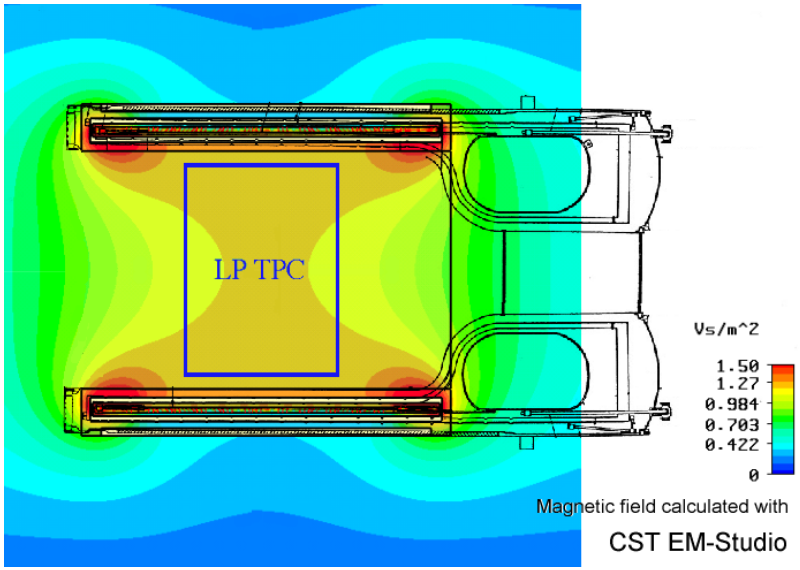


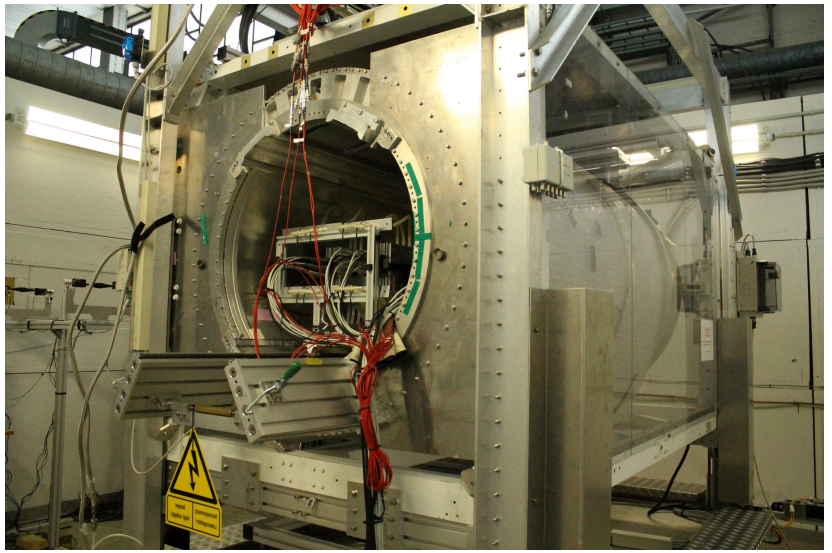
Eda

Setup : Magnet



- Solenoid Magnet
  - Magnetic field up to 1T
- Measurements are done in various magnetic fields
  - 0, 0.25T, 0.50T, 0.75T, 1.0T
- Extrapolate results to 2T
  - ATLAS inner detector has 2T magnetic field





Measured doses

- During 2013 and 2014 test beams, data taken for Lorentz angle measurement on non-irradiated and neutron irradiated ATLAS12 sensors.

doses (1MeV n_{eq} cm^{-2})		Magnetic Field (T)				
		0	**0.25**	**0.50**	**0.75**	**1.00**
Bias Voltage (V)	**-300**	X	X	X	X	$1.2x10^{14}$ $2x10^{14}$
	-500	non-irradiated $1.2x10^{14}$ $1.2x10^{14}$ an. $2x10^{14}$ $2x10^{14}$ an. $5x10^{14}$ $5x10^{14}$ an. $1x10^{15}$ $1x10^{15}$ an. $2x10^{15}$ $5x10^{15}$	non-irradiated $5x10^{14}$ $5x10^{14}$ an. $1x10^{15}$ $1x10^{15}$ an. $2x10^{15}$ $5x10^{15}$	non-irradiated $1.2x10^{14}$ $1.2x10^{14}$ an. $2x10^{14}$ $2x10^{14}$ an. $5x10^{14}$ $5x10^{14}$ an. $1x10^{15}$ $1x10^{15}$ an. $2x10^{15}$ $5x10^{15}$	non-irradiated $1.2x10^{14}$ $1.2x10^{14}$ an. $2x10^{14}$ $2x10^{14}$ an. $5x10^{14}$ $5x10^{14}$ an. $1x10^{15}$ $1x10^{15}$ an. $2x10^{15}$ $5x10^{15}$	non-irradiated $1.2x10^{14}$ * $1.2x10^{14}$ an. $2x10^{14}$ * $2x10^{14}$ an. $5x10^{14}$ $5x10^{14}$ an. $1x10^{15}$ $1x10^{15}$ an. $2x10^{15}$ $5x10^{15}$
	-700	X	X	X	X	$1.2x10^{14}$ $2x10^{14}$
	-1000	X	X	X	X	$1.2x10^{14}$ $2x10^{14}$

- Temperature

between -20C to -26C

- Beam energy

4.4GeV

* few runs at different beam energy

Irradiations done at Ljubljana

an. = annealed at 60C for 80min

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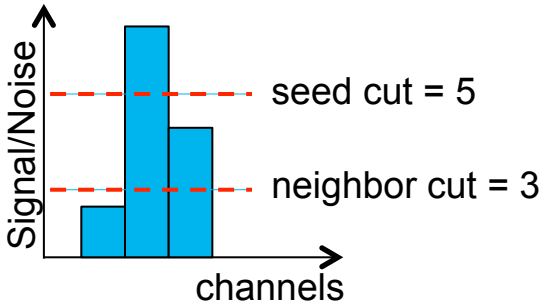
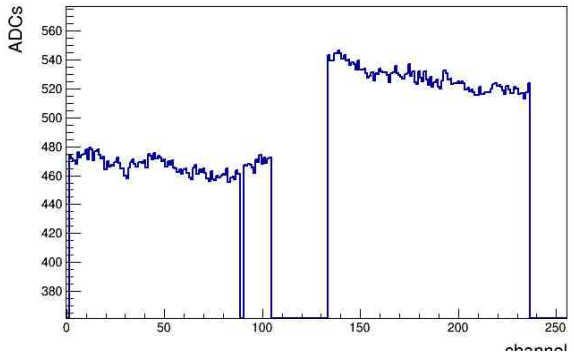
First look at data

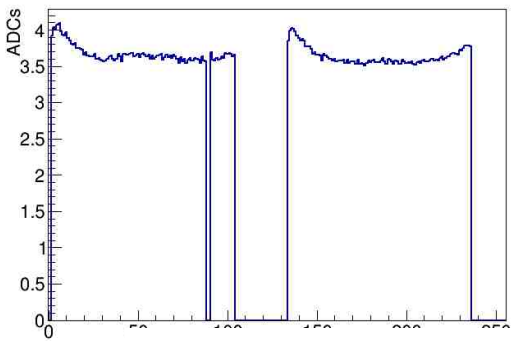
- Analysis of the data is ongoing.
- First look at non-irradiated sensor B=0, Tilt angle=0



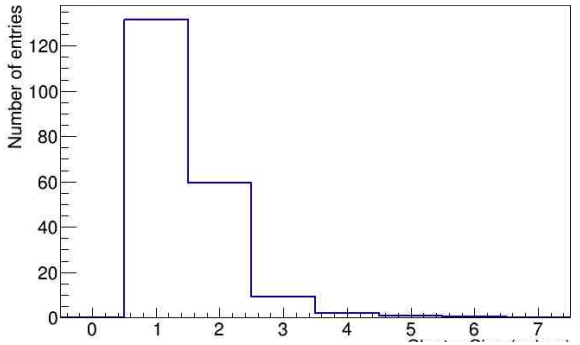
Pedestal



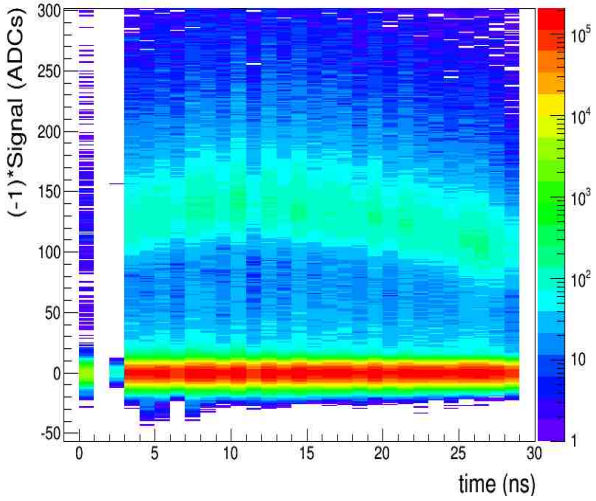
Noise



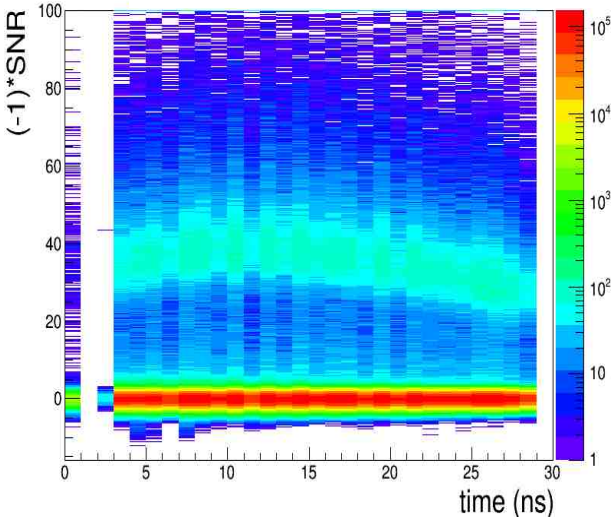
Cluster size



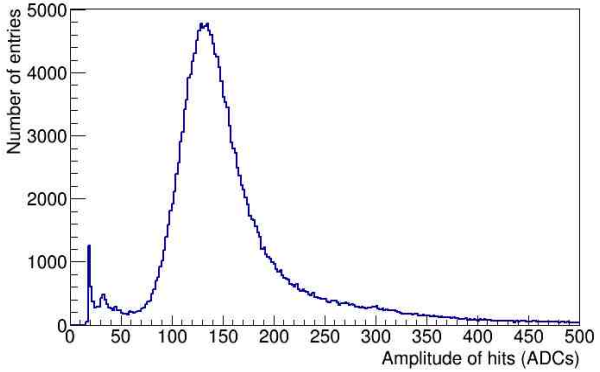
Signal vs time



Signal/Noise vs time



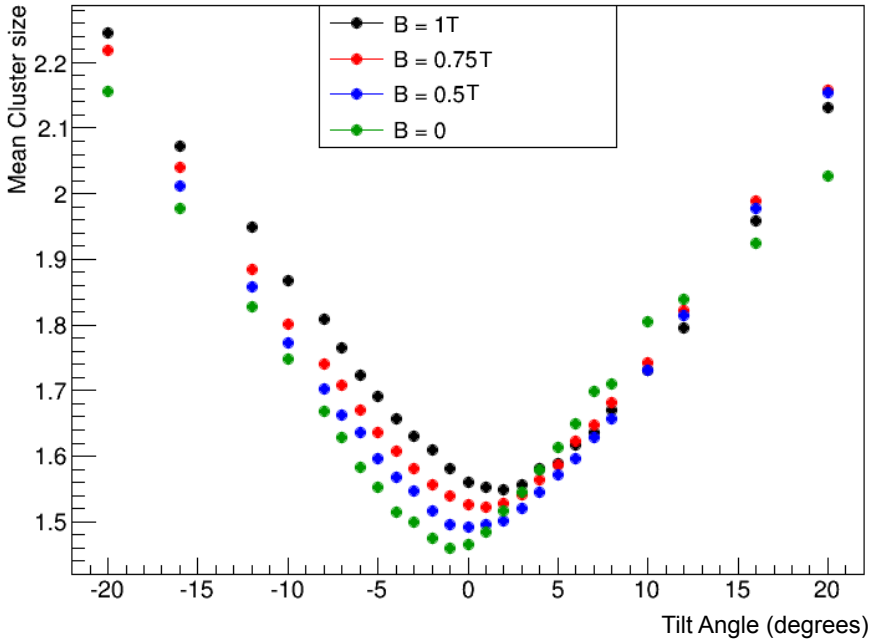
Hit amplitude



First look at data – nonirradiated

- Analysis of the data is ongoing. The plot is the first look at dependence of cluster size on tilt angle.
  - Telescope information is not included
  - Tilt angle is not the incidence angle but the tilt angle of the box
  - Tilt angle measurement clearly has an offset
  - Clustering algorithm and the cuts applied will be changed and improved
- Shows qualitatively the expected shape

Control plot for non-irradiated sensor

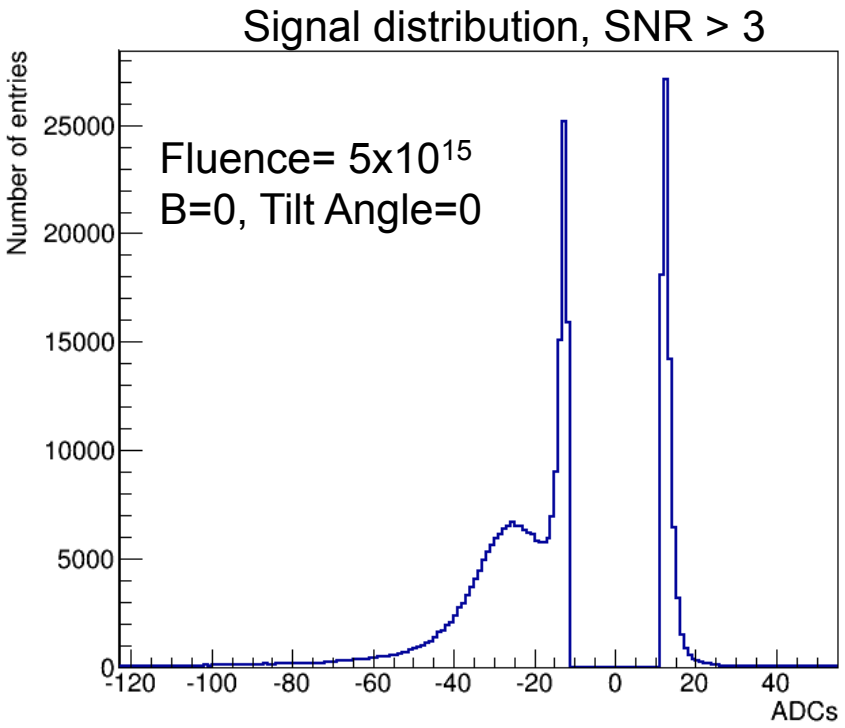


- Lorentz angle estimated for ATLAS12 silicon microstrip sensor

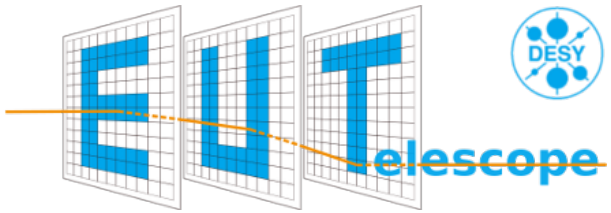
  (B= 1T, V=-500V T= -25^{o}C)
  - θ_L ~ 3.80 degrees

Use of Tracking

- Data taken with highly irradiated samples



  - The signal gets significantly low
  - Need to reduce noise 'hits'



- Noise reduction
  - Using tracking from EUDET beam telescope to identify hits consistent with telescope track.
- The analysis will be done in EUTelescope* framework.
  - EUTelescope is the software package used to analyze data from EUDET beam telescopes
  - General Broken Line (GBL) is being implemented to be able to track particles in magnetic field.
  - Analysis tools for Alibava data are also being implemented.

* http://eutelescope.web.cern.ch/

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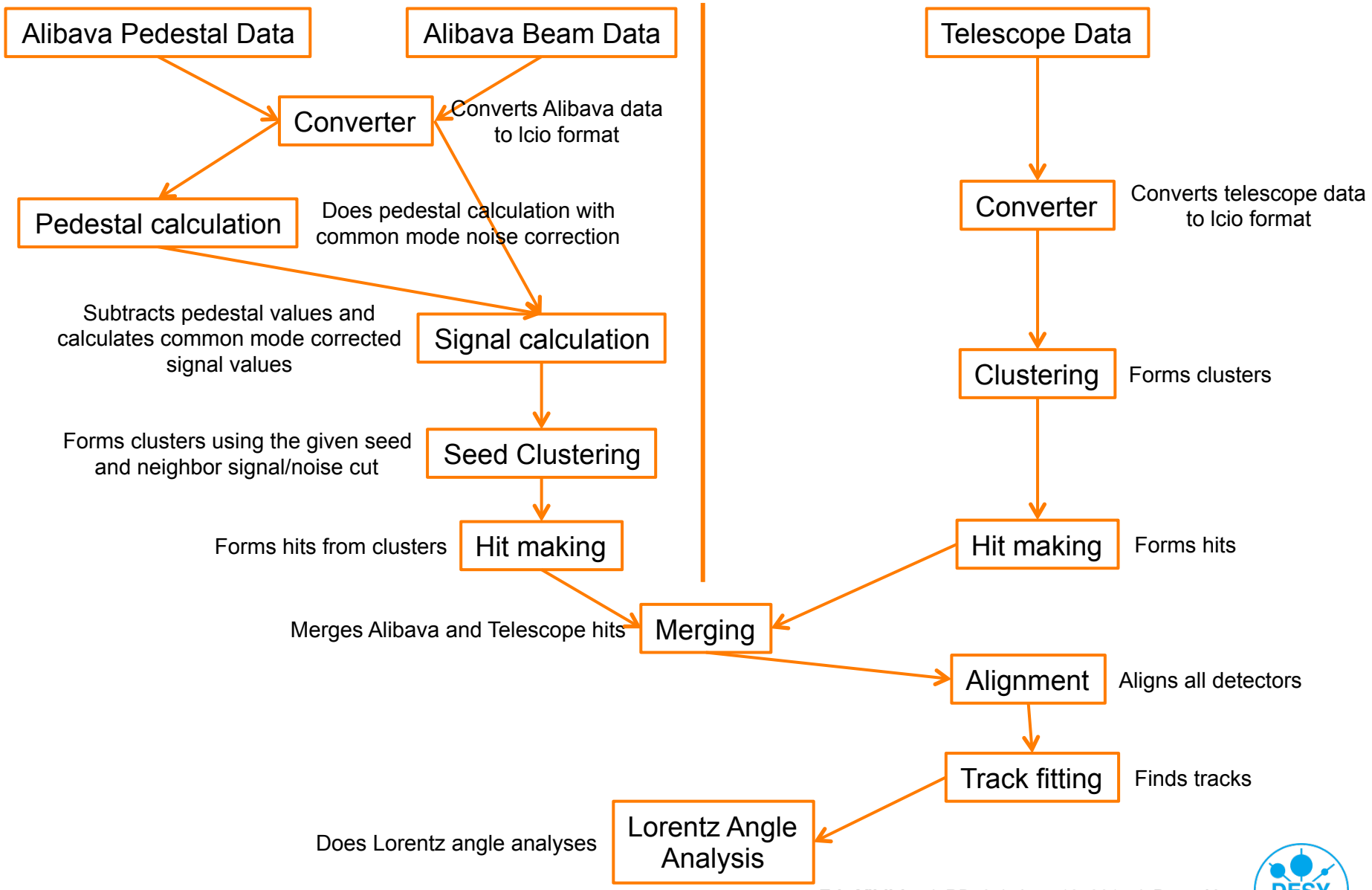
Analysis


Alibava Pedestal Data
Alibava Beam Data
Converter
Converts Alibava data to lcio format
Pedestal calculation
Does pedestal calculation with common mode noise correction
Subtracts pedestal values and calculates common mode corrected signal values
Signal calculation
Forms clusters using the given seed and neighbor signal/noise cut
Seed Clustering
Forms hits from clusters
Hit making
Merges Alibava and Telescope hits
Merging
Does Lorentz angle analyses
Lorentz Angle Analysis
Telescope Data
Converter
Converts telescope data to lcio format
Clustering
Forms clusters
Hit making
Forms hits
Alignment
Aligns all detectors
Track fitting
Finds tracks

Summary & Future Plans

- Developed setup for Lorentz angle measurement at test beam
- Data for Lorentz angle measurement is taken from 12 sensors (10 neutron irradiated)
  - 2 non-irradiated

  Neutron irradiated (1MeV n_{eq} cm^{-2})
  - $1.2x10^{14}$, $2x10^{14}$, $5x10^{14}$, $1x10^{15}$, $2x10^{15}$, $5x10^{15}$

  Neutron irradiated and annealed at 60C for 80min (1MeV n_{eq} cm^{-2})
  - $1.2x10^{14}$, $2x10^{14}$, $5x10^{14}$, $1x10^{15}$
- Data analysis is ongoing
  - Using the EUTelescope framework and the newly implemented General Broken Line (GBL) algorithm for track fitting.
  - Developing Alibava data analysis tools for EUTelescope which can be used by other groups
  - The signal and clustering algorithm will be studied in detail, including checking the dependence on incidence angle, radiation dose, temperature, magnetic field … etc

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Thank You !

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Backup

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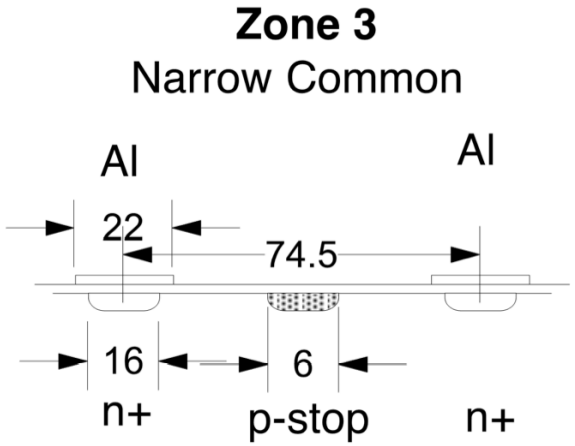
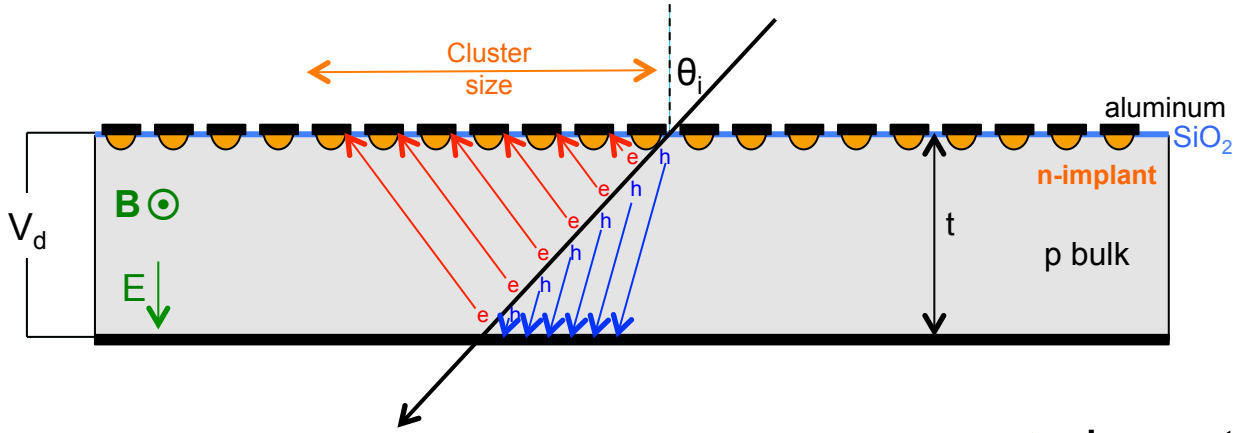
Sensor properties

ATLAS12 Miniature sensor (BZ3)	
Type	P
Thickness	320um
Strip implant	N
Pitch size	74.5um
Orientation	<100>
Outer dimension	10x10mm
Strip length	8mm
Number of channels	104



Lorentz Angle



$$\tan\theta_L = \mu_H B = r_H \mu_d B \quad *$$

Hall mobility — Hall factor — Drift mobility

$$\mu_d = \frac{v_s/E_c}{[1+(E/E_c)^{\beta}]^{1/\beta}}$$

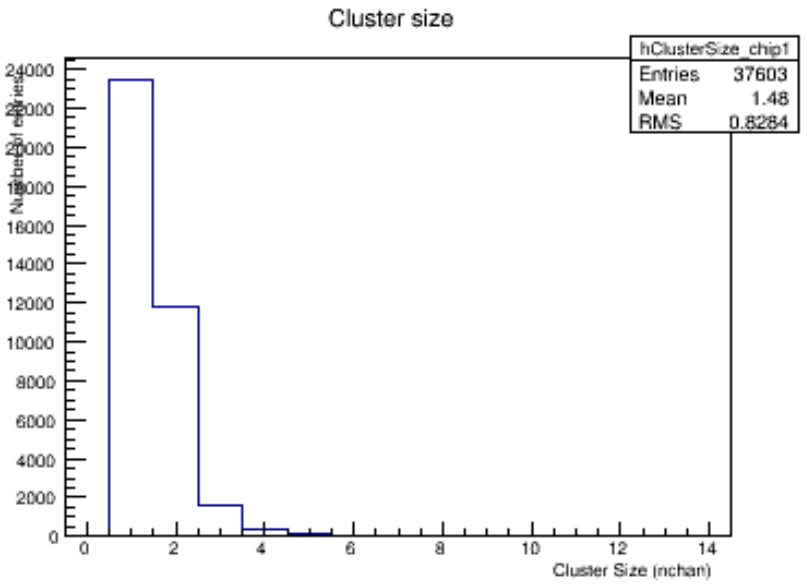
	Electrons	Holes
$v_s(cm\,s^{-1})$	$1.53\times10^{9}\times T^{-0.87}$	$1.62\times10^{8}\times T^{-0.52}$
$E_c(V\,cm^{-1})$	$1.01\times T^{1.55}$	$1.24\times T^{1.68}$
β	$2.57\times10^{-2}\times T^{0.66}$	$0.46\times T^{0.17}$
r_H	$1.13+0.0008(T-273)$	$0.72-0.0005(T-273)$

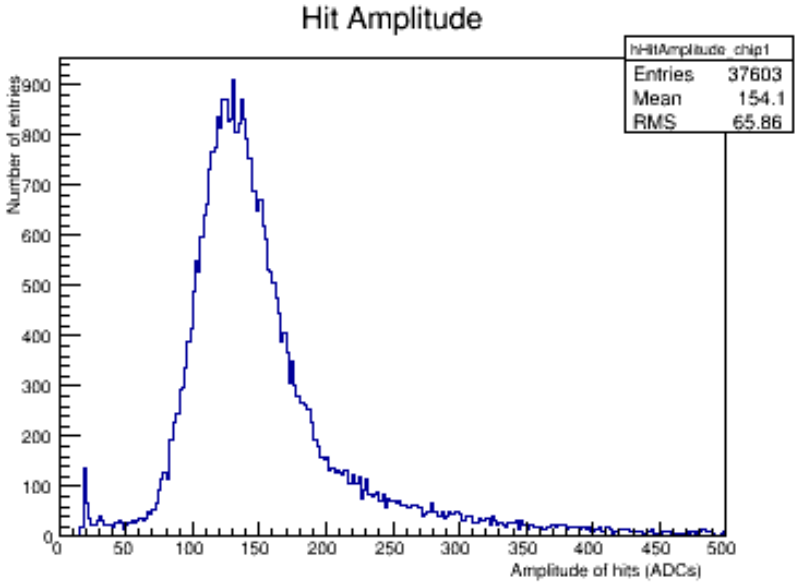
where v_s is drift velocity, E is electric field and T is the absolute temperature.

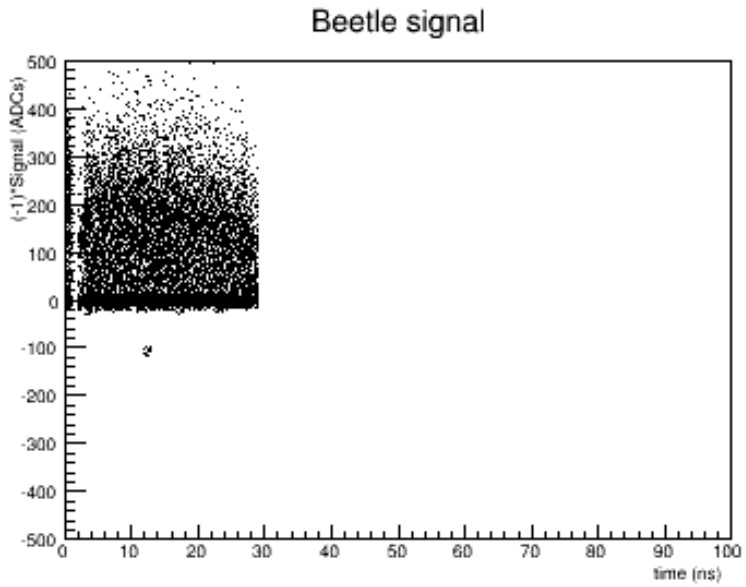
* *ATL-INDET-2001-004*

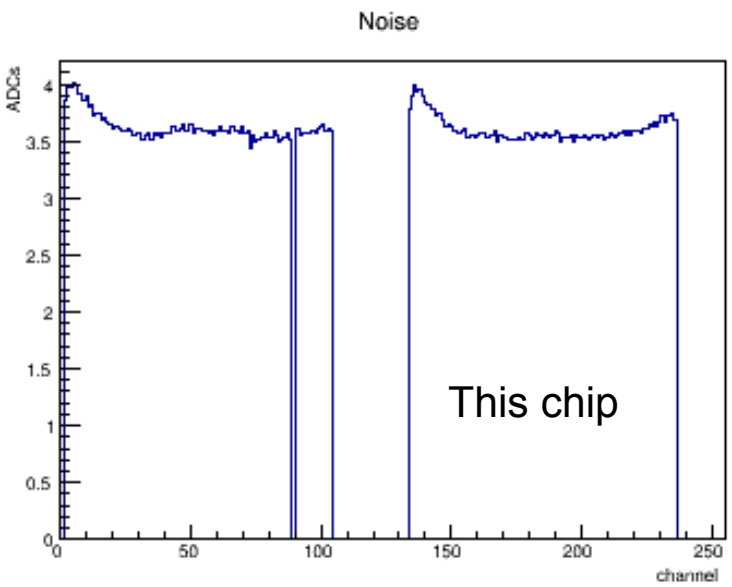
- Lorentz Angle needs to be taken into account in order to reconstruct track information correctly
- Drift velocity and depletion voltage will change with irradiation
- The effect of radiation damage on Lorentz angle is not well understood

Control plots: Fluence=0, B=0, Tilt angle=0

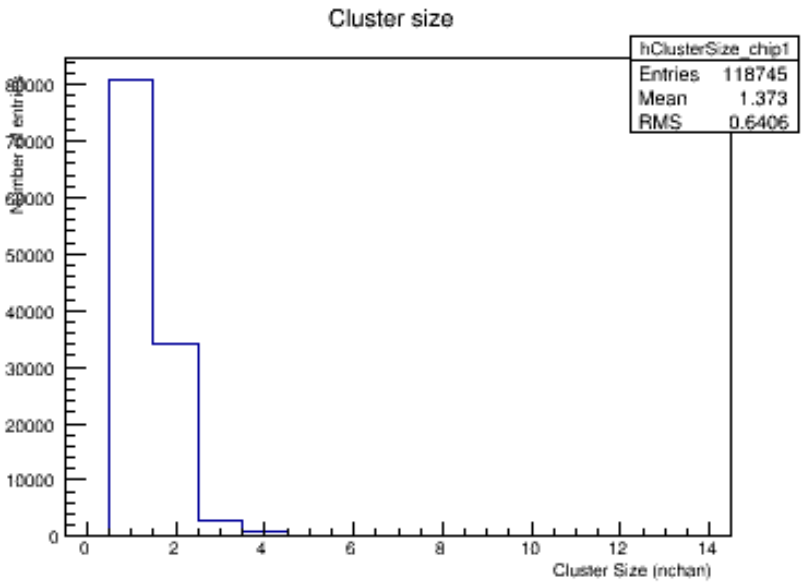


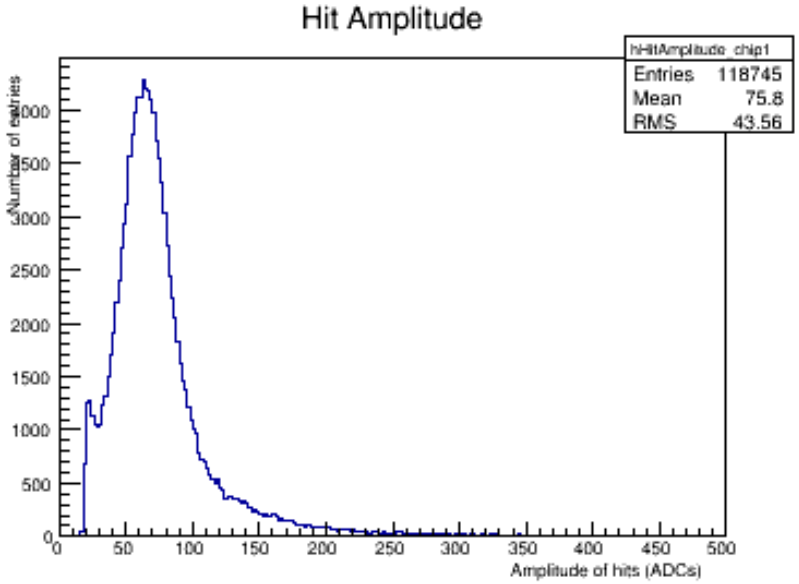


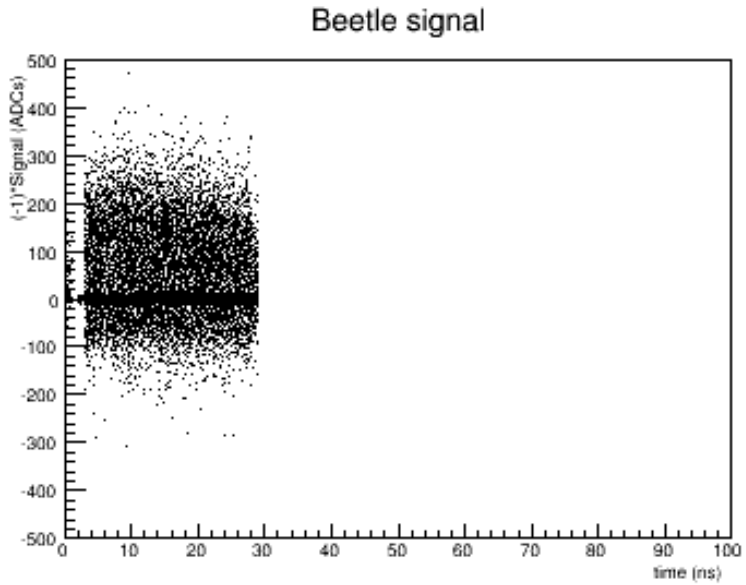


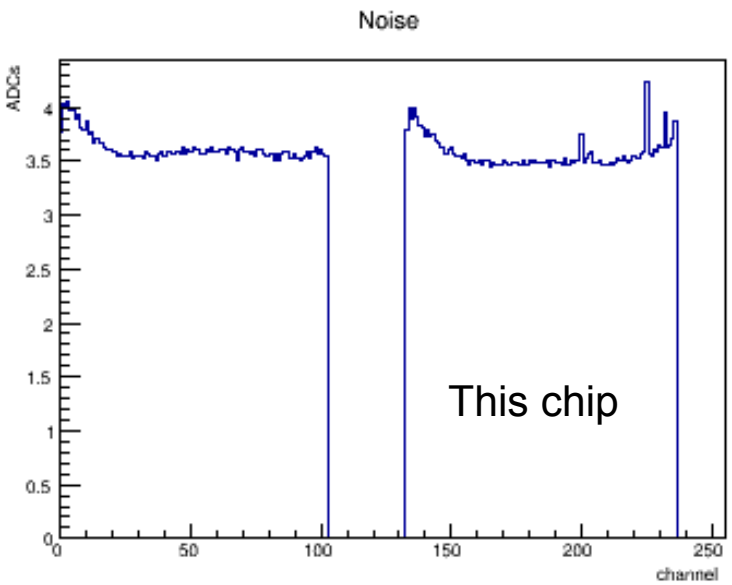


Control plots: Fluence=5E14, B=0, Tilt angle=0

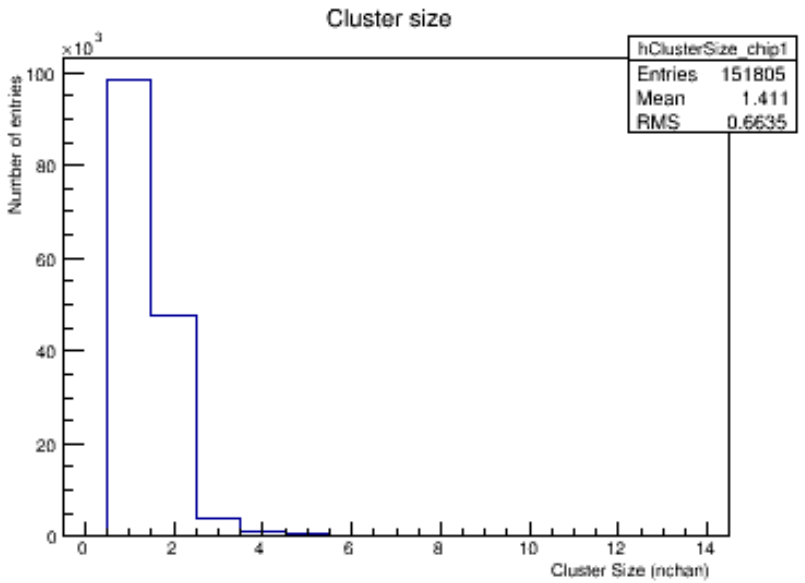


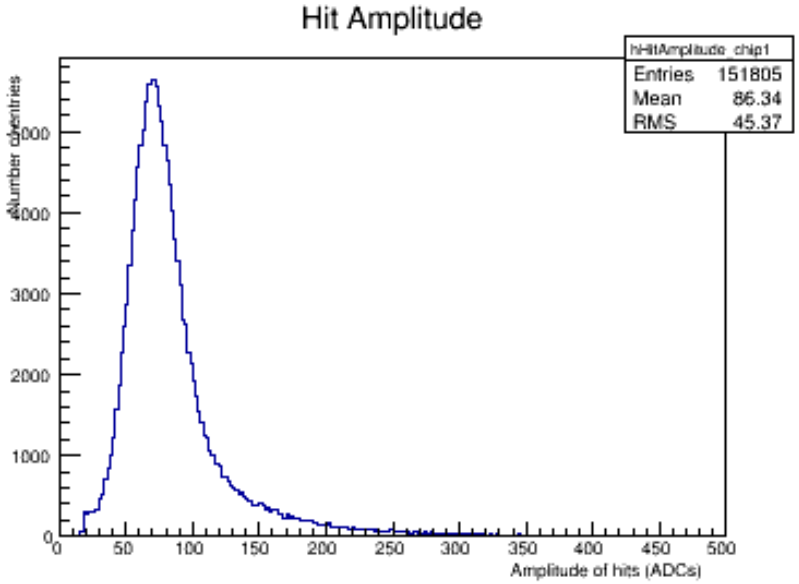


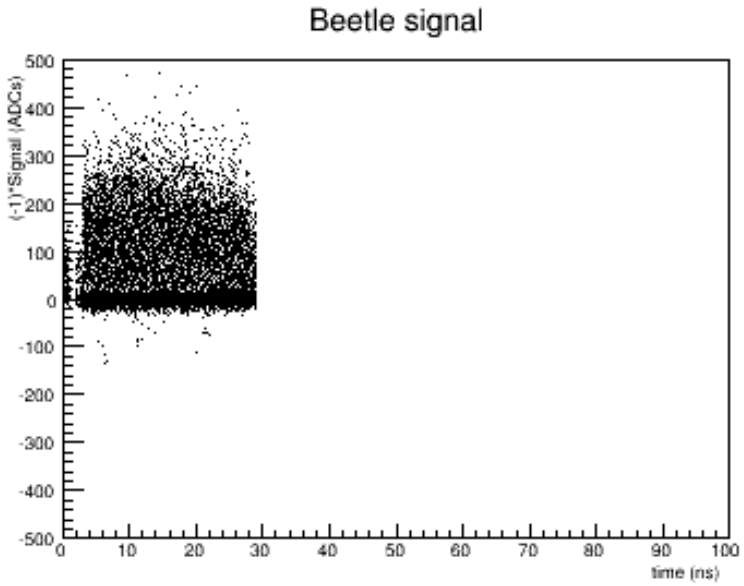


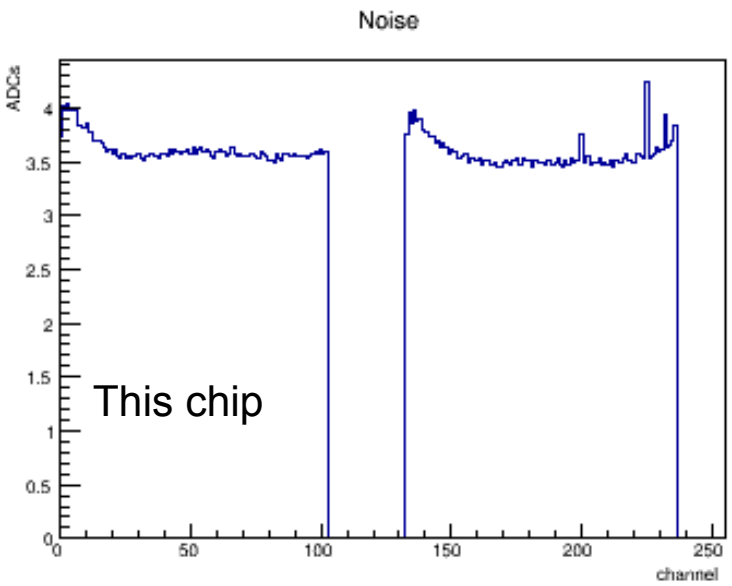


Control plots: Fluence=5E14 annealed, B=0, Tilt angle=0

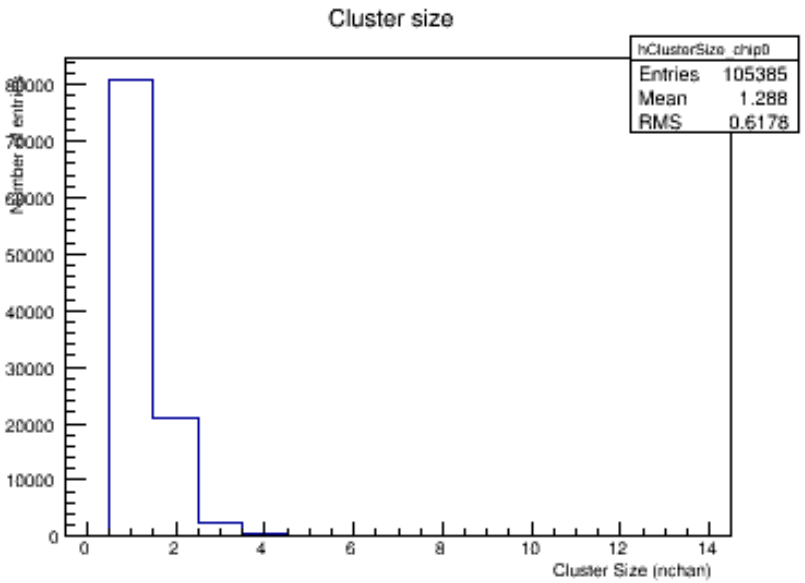


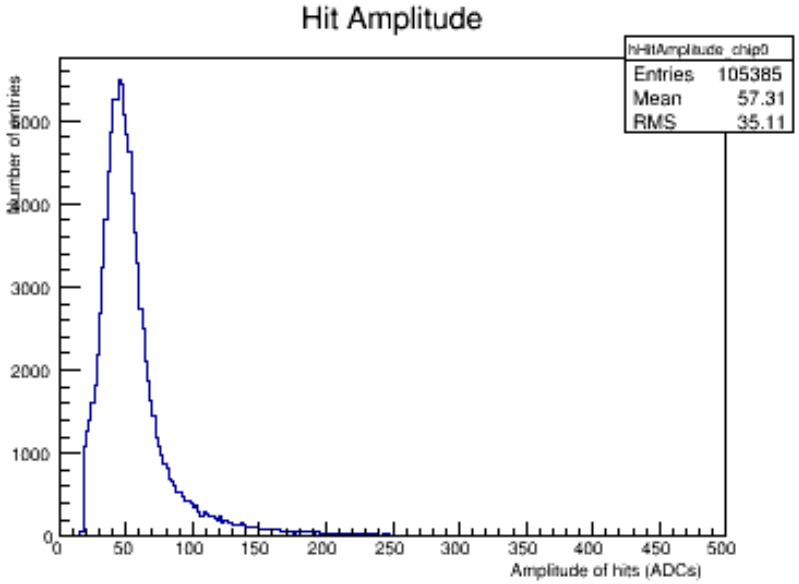


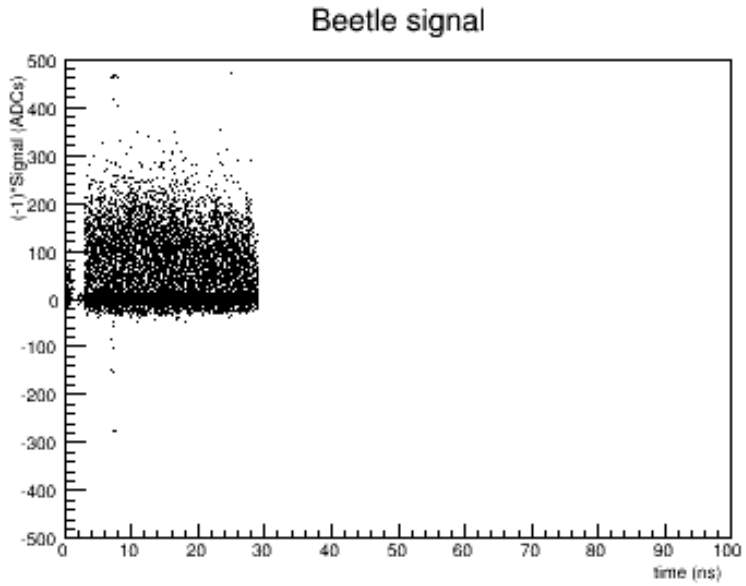


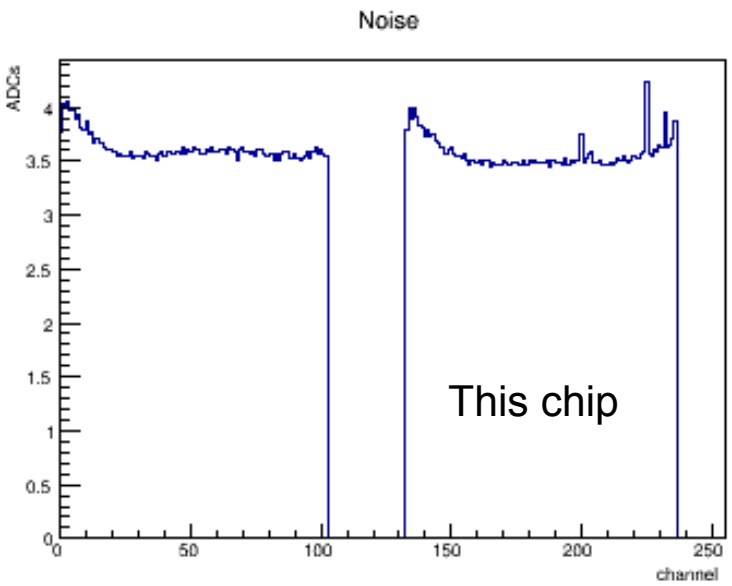


Control plots: Fluence=1E15, B=0, Tilt angle=0

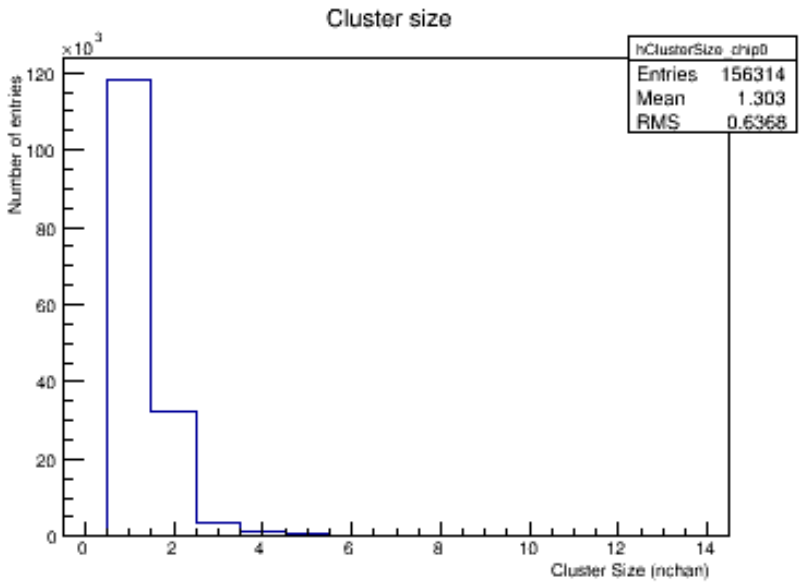


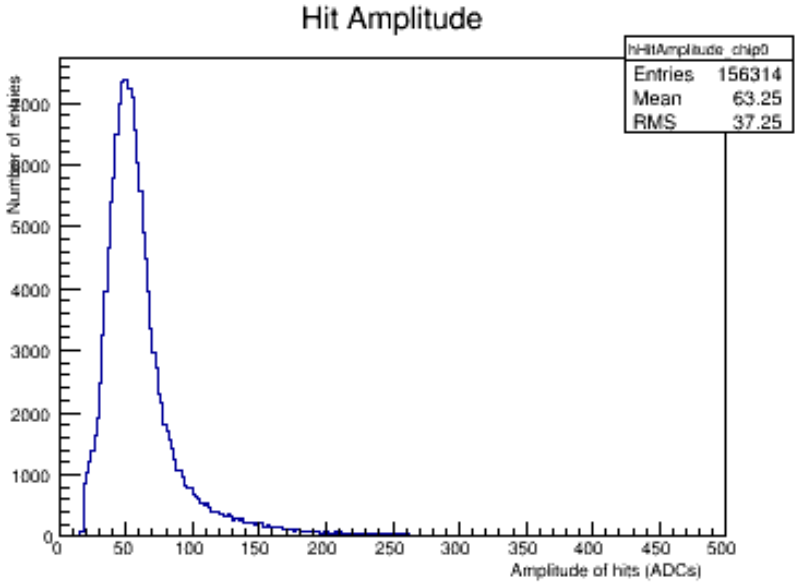


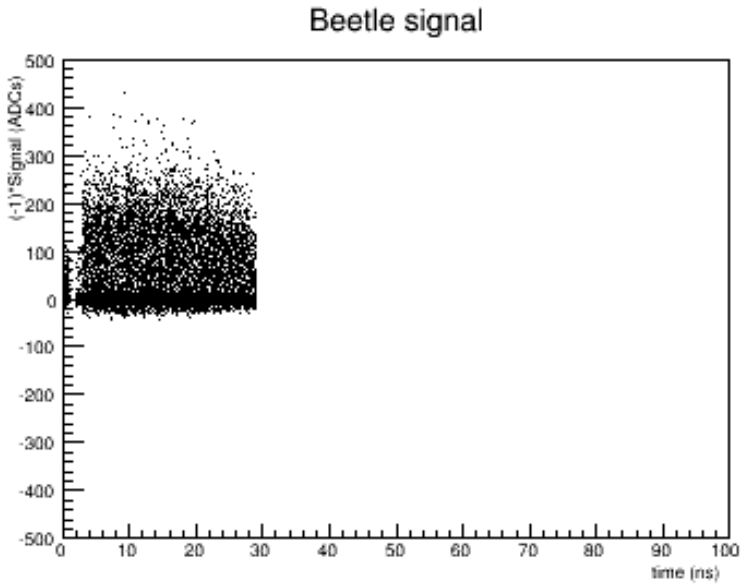


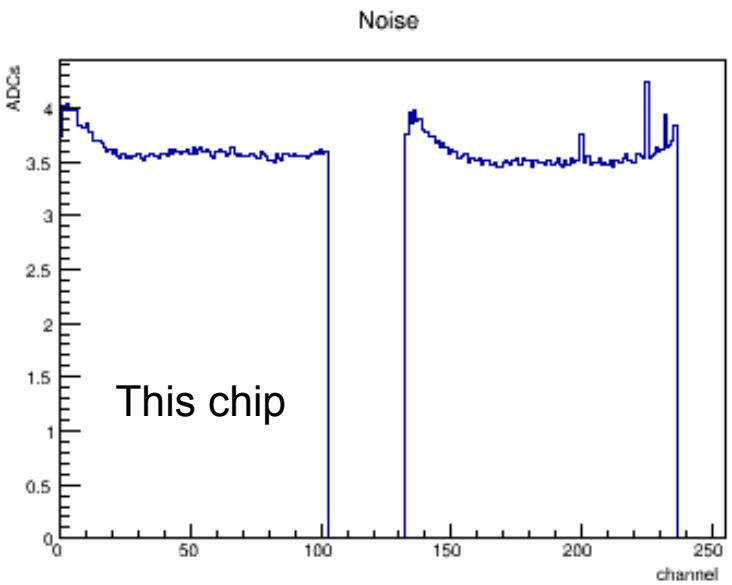


Control plots: Fluence=1E15 annealed, B=0, Tilt angle=0

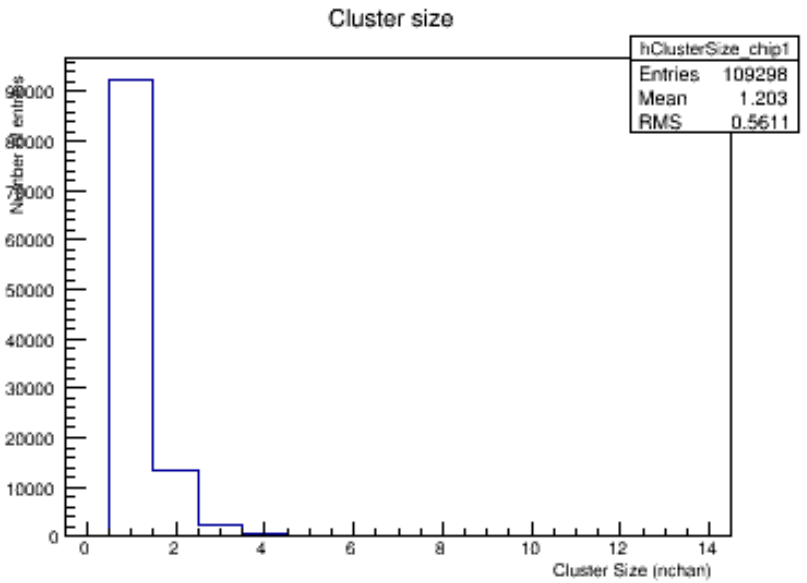


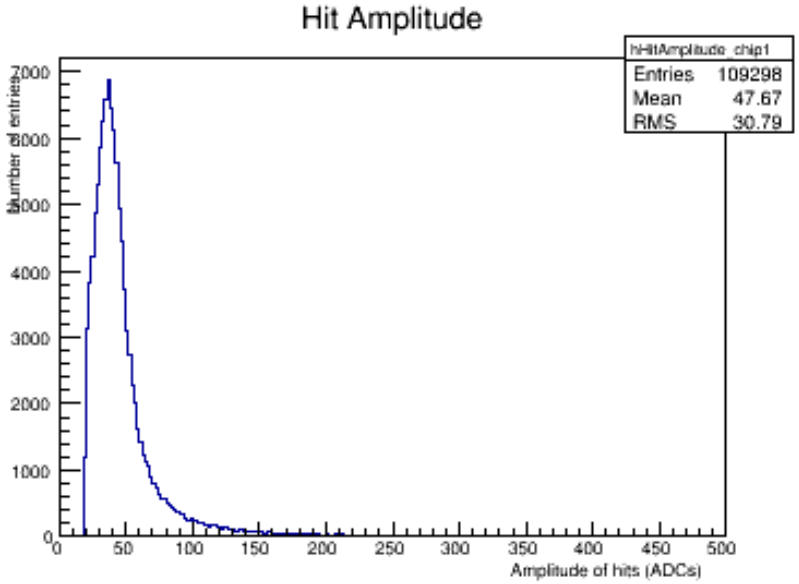


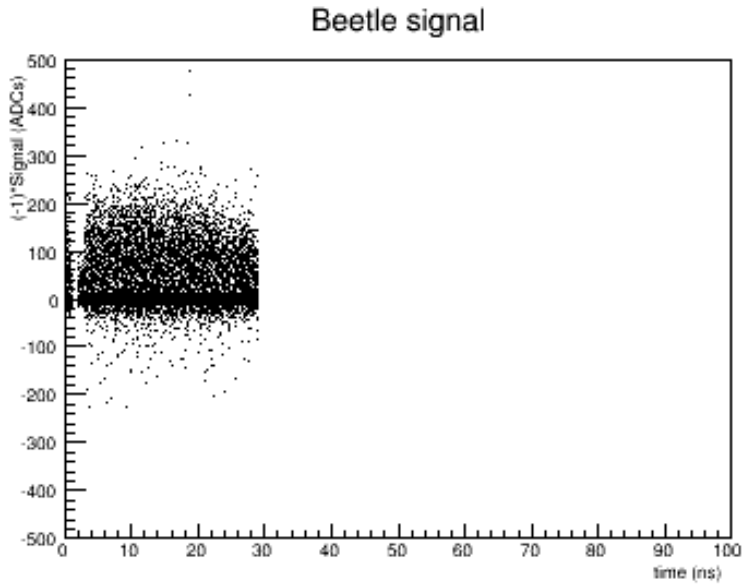


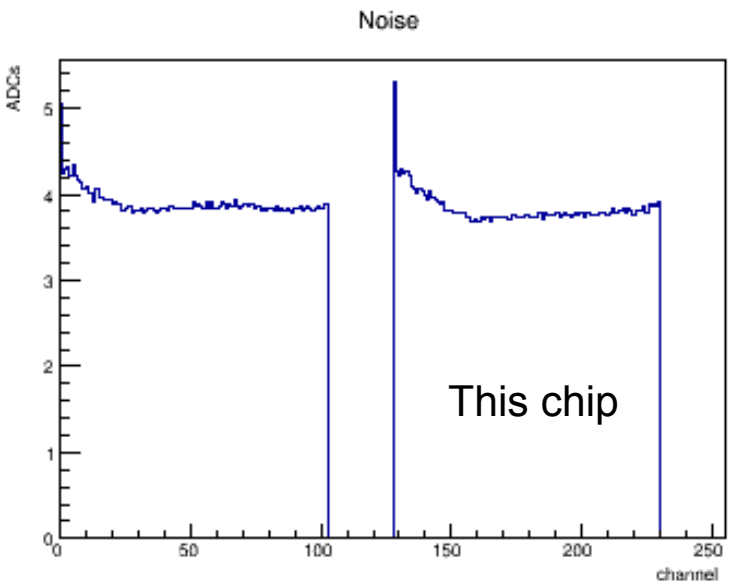


Control plots: Fluence=2E15, B=0, Tilt angle=0









Control plots: Fluence=5E15, B=0, Tilt angle=0