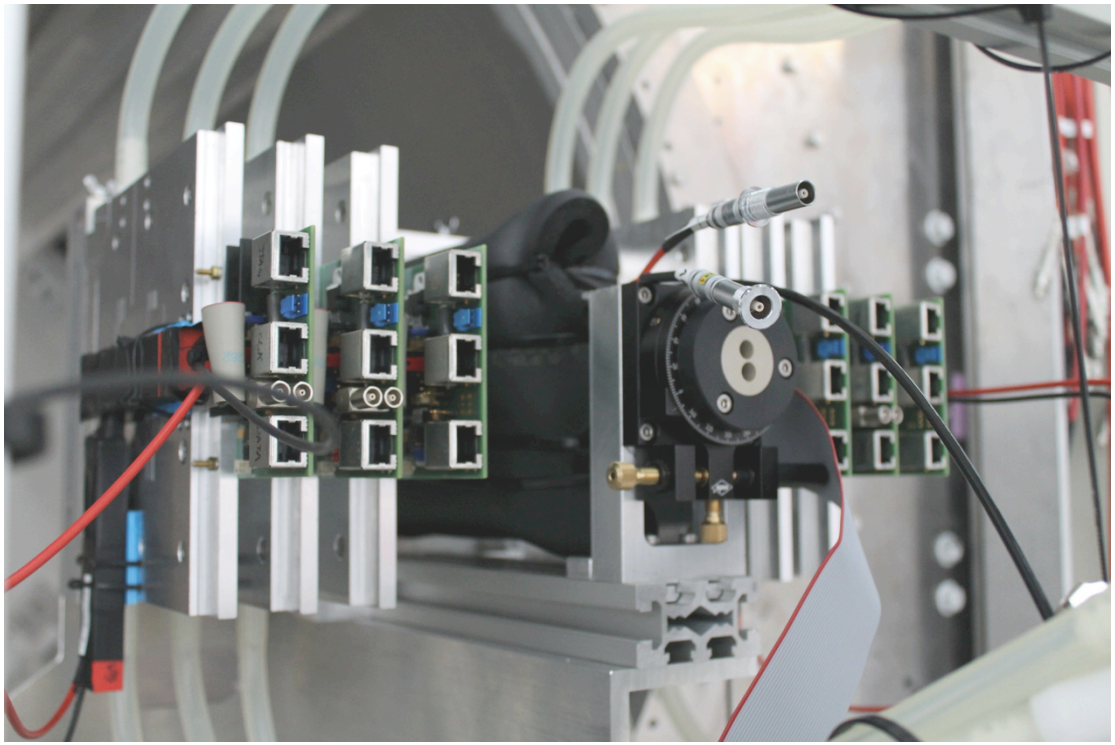
Lorentz Angle Measurement

On Future ATLAS Silicon Strip Sensors



Eda Yildirim, DESY
Student Seminar
June 20, 2013

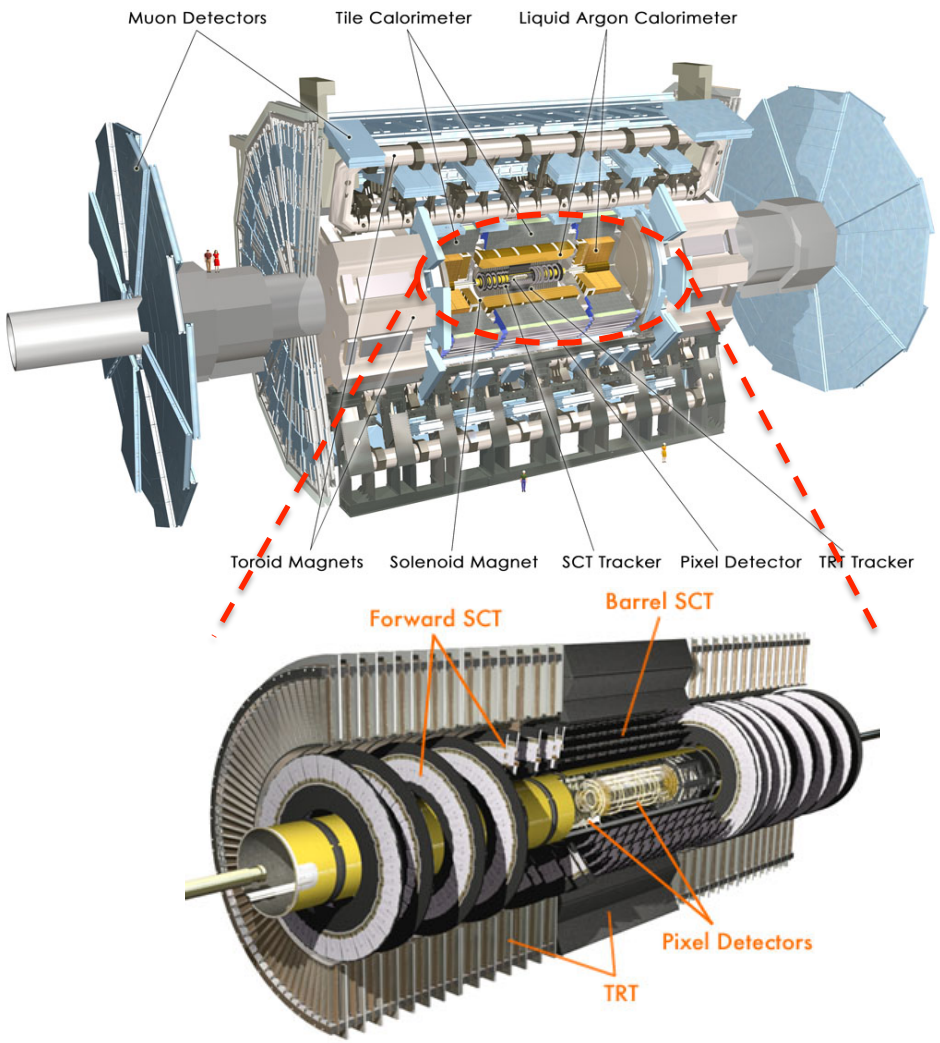
HELMHOLTZ ASSOCIATION

UHH

ATLAS

DESY

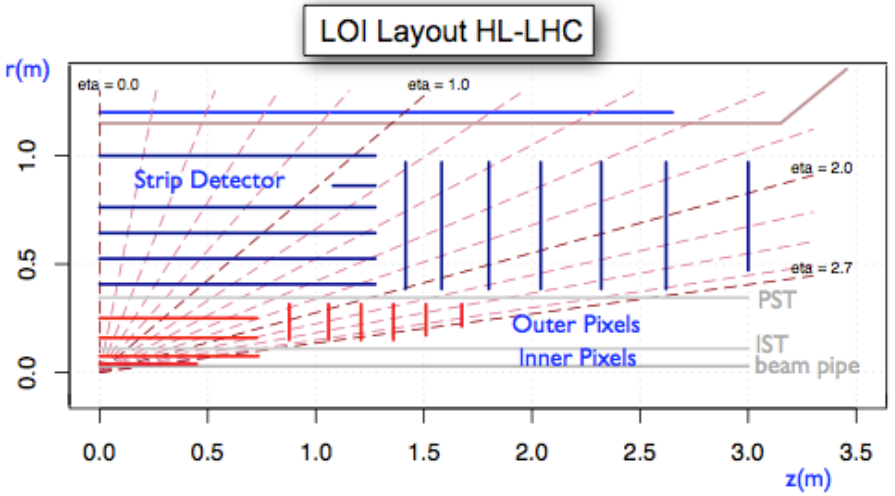
The ATLAS Detector

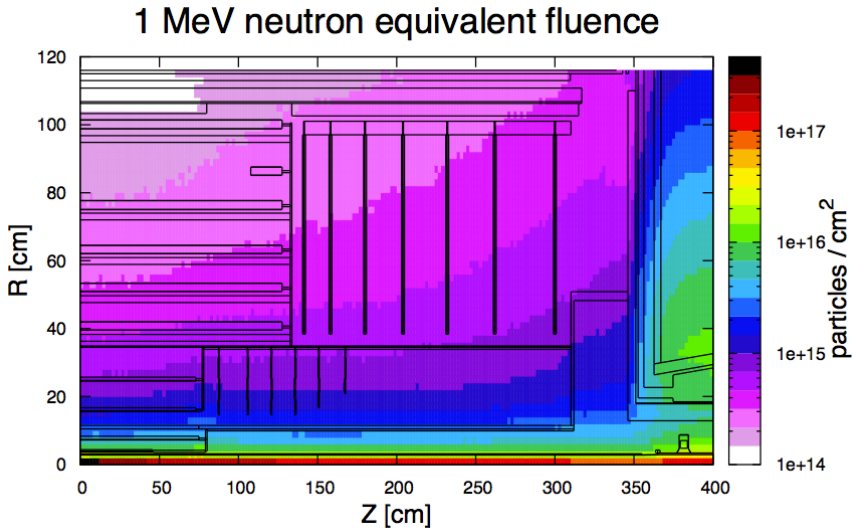


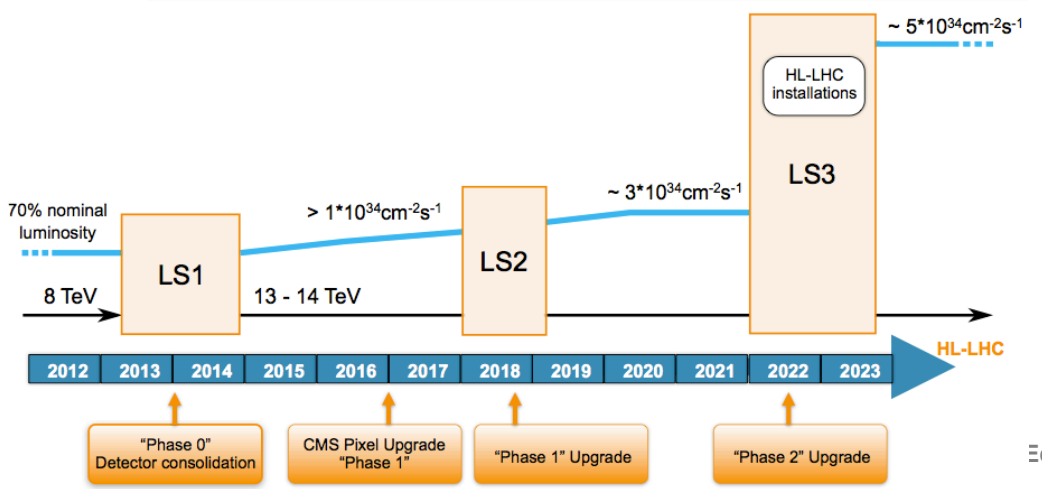
- ATLAS is one of the two general purpose detectors at the Larger Hadron Collider (LHC)
- Inner detector
  - used to track charged particles and find their momentum
  - consists of silicon (pixel and strip) detectors and drift-tube tracker (with transition radiation)
  - closest to the collision region
  - experience the highest radiation levels

High Luminosity LHC

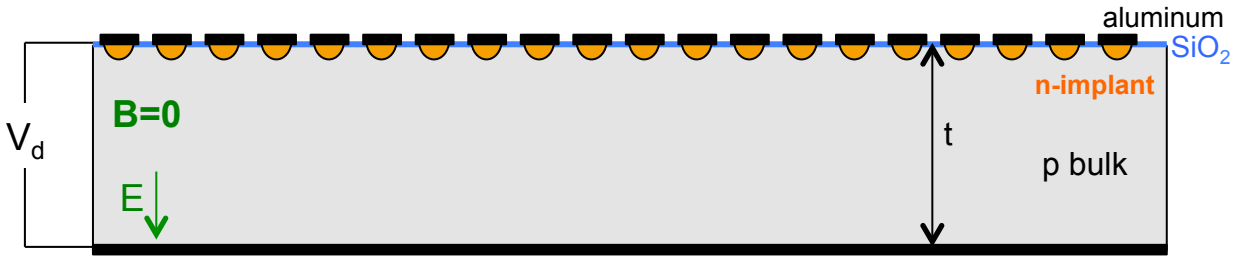
- In ~10 years from now, it is planned to upgrade LHC to High Luminosity LHC [1]
  - Inner detector will be replaced with silicon pixel and silicon microstrip system
  - LHC luminosity will be increased to $5x10^{34}$ $cm^{-2}s^{-1}$ which will lead to increased radiation damage in the inner detector





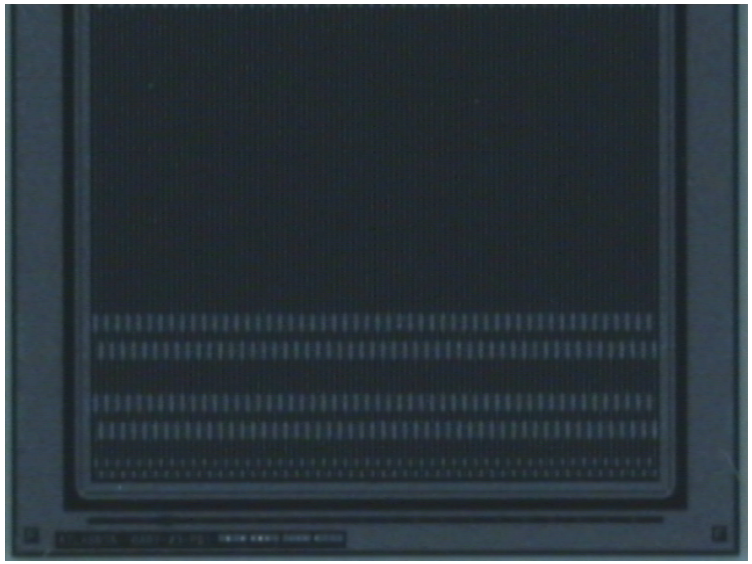


Silicon Microstrip Sensors



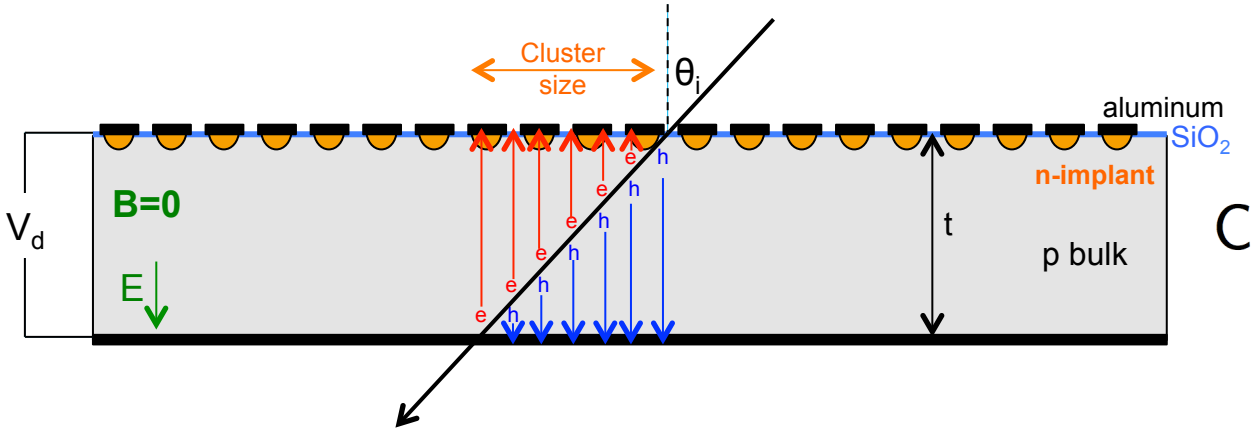
V_d : depletion voltage
E : Electric field
t : thickness

ATLAS12 miniature test sensors



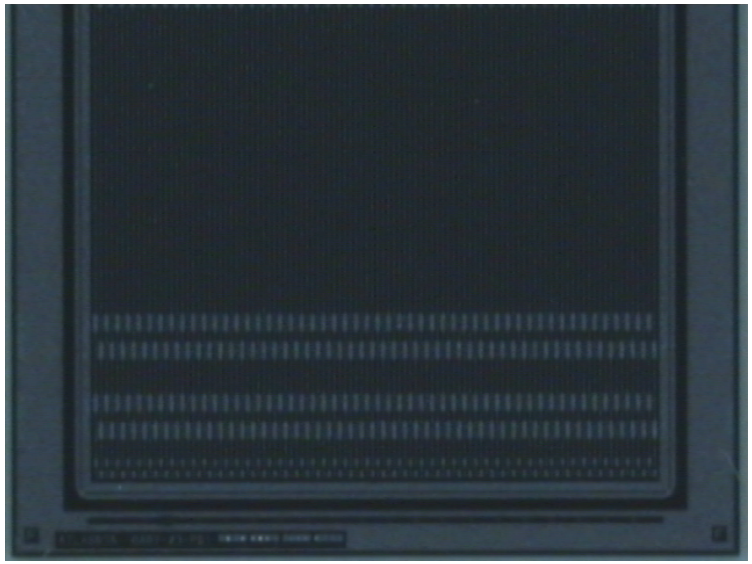
Type	n in p
Collects	electrons
Thickness	320 um
Depletion Voltage	-170 V
Bias Voltage	-500 V
Outer dimension	10x10 mm
Active area	~ 8x8 mm
Number of channels	104
Pitch size	74.5 um

Silicon Microstrip Sensors



$$\text{Cluster Size} \approx t \cdot \tan\theta_i$$

ATLAS12 miniature test sensors



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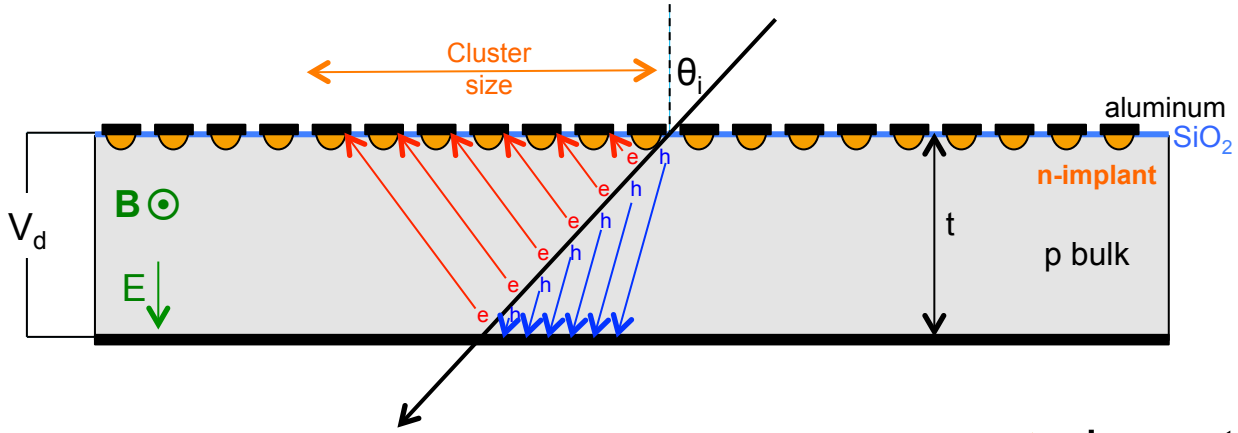
Lorentz Angle



$$\tan\theta_L = \mu_H B = r_H \mu_d B \quad [2]$$

Hall mobility | Hall factor | Drift mobility

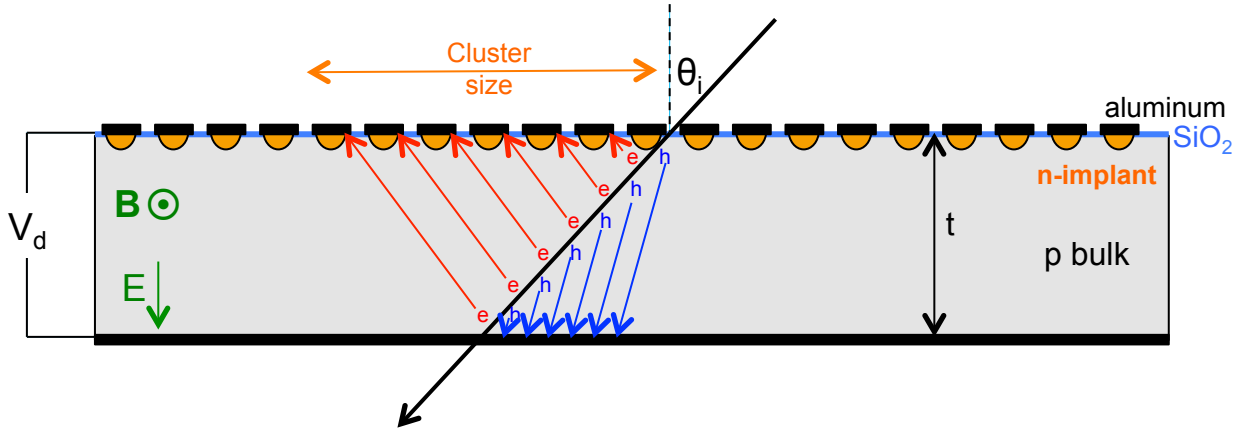
$$\mu_d = \frac{v_s/E_c}{[1+(E/E_c)^{\beta}]^{1/\beta}}$$

	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.

- Lorentz Angle needs to be taken into account in order to reconstruct track information correctly
- Lorentz angle estimated for ATLAS12 silicon microstrip sensor (B= 1T, T= -25°C)
  - θ_L ~ 3.80 degrees

Lorentz Angle in Irradiated Silicon Sensor



$$\tan\theta_L = \mu_H B = r_H \mu_d B \quad [2]$$

Hall mobility | Hall factor | Drift mobility

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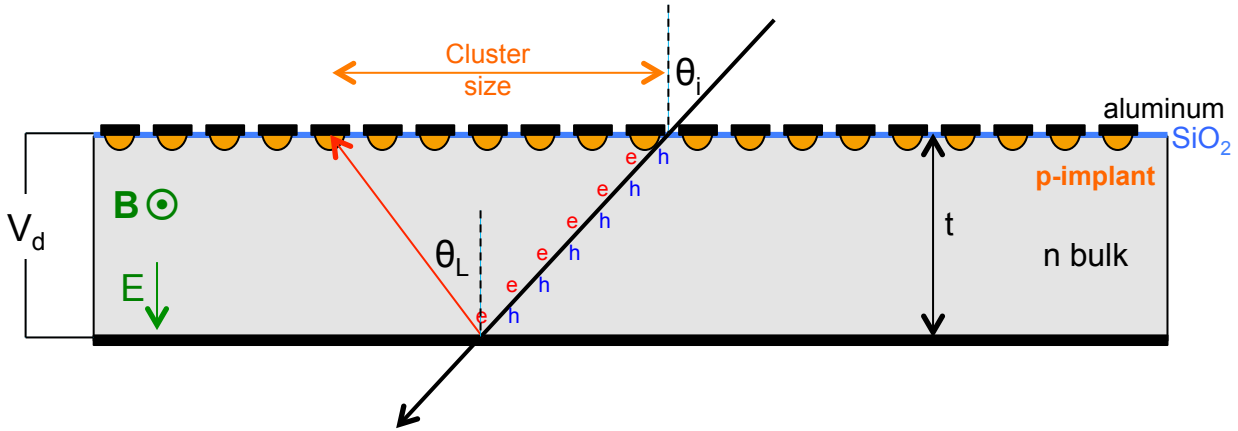
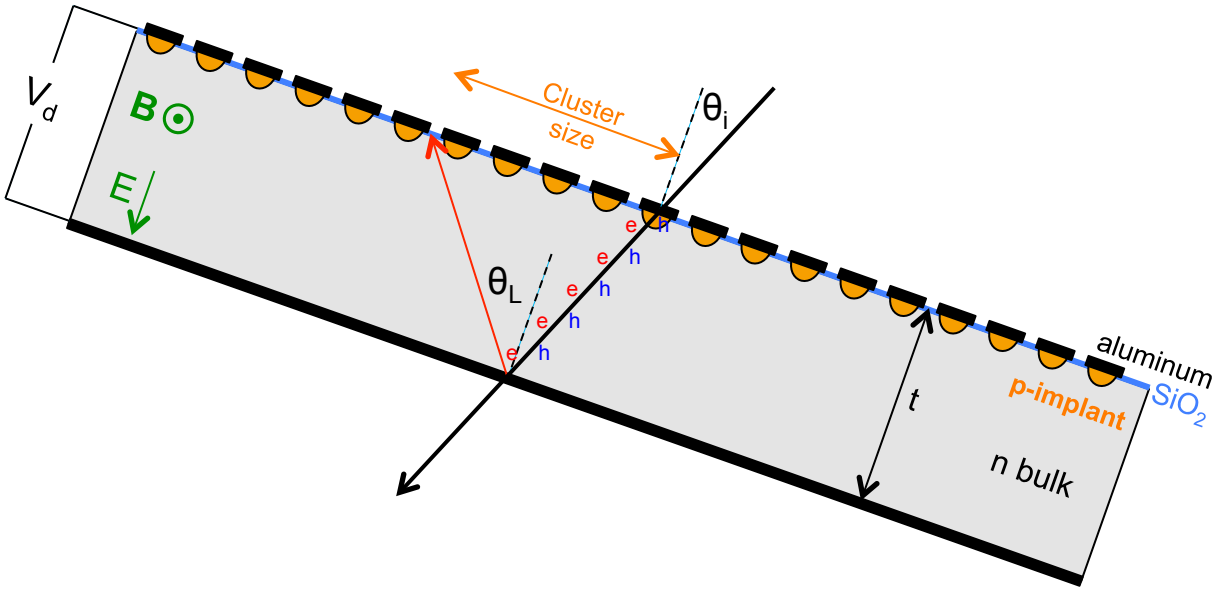
where v_s is drift velocity, E is electric field and T is the absolute temperature.

- Drift velocity and depletion voltage will change with irradiation
- The effect of radiation damage on Lorentz angle is not well understood

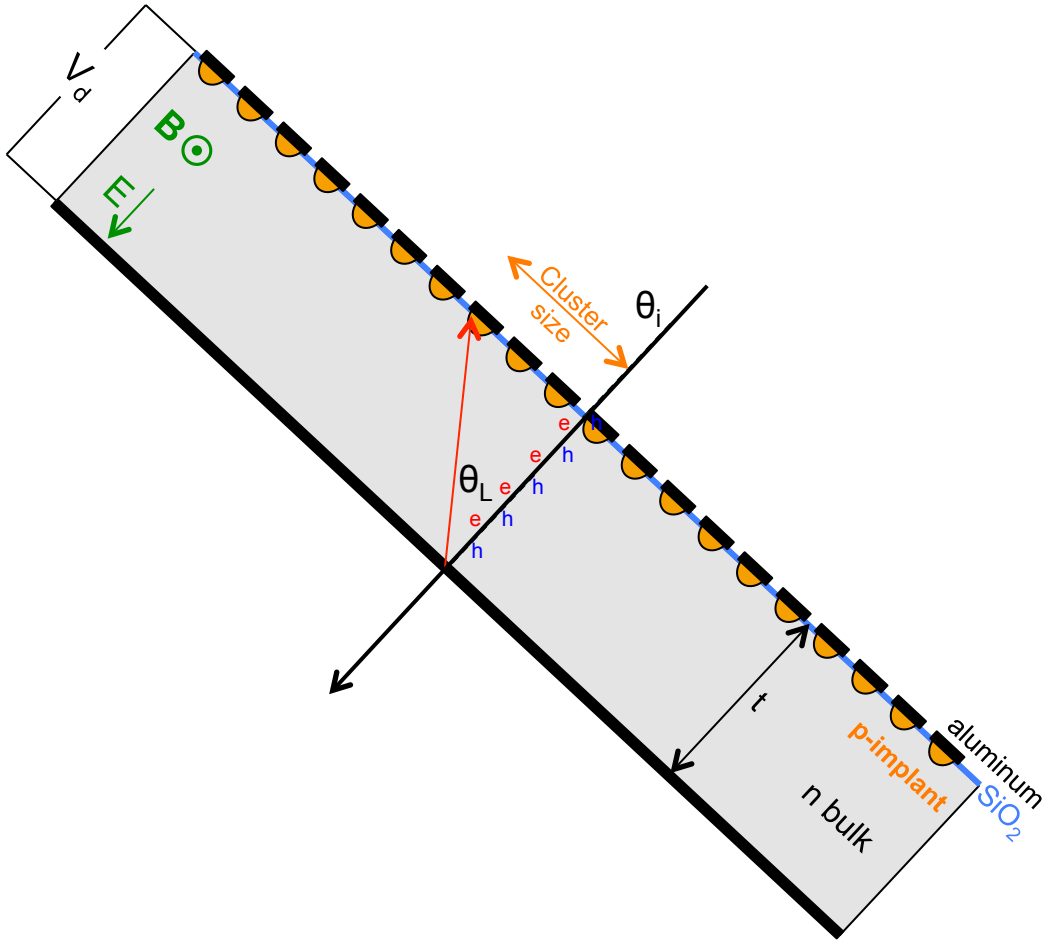
Lorentz Angle Measurement



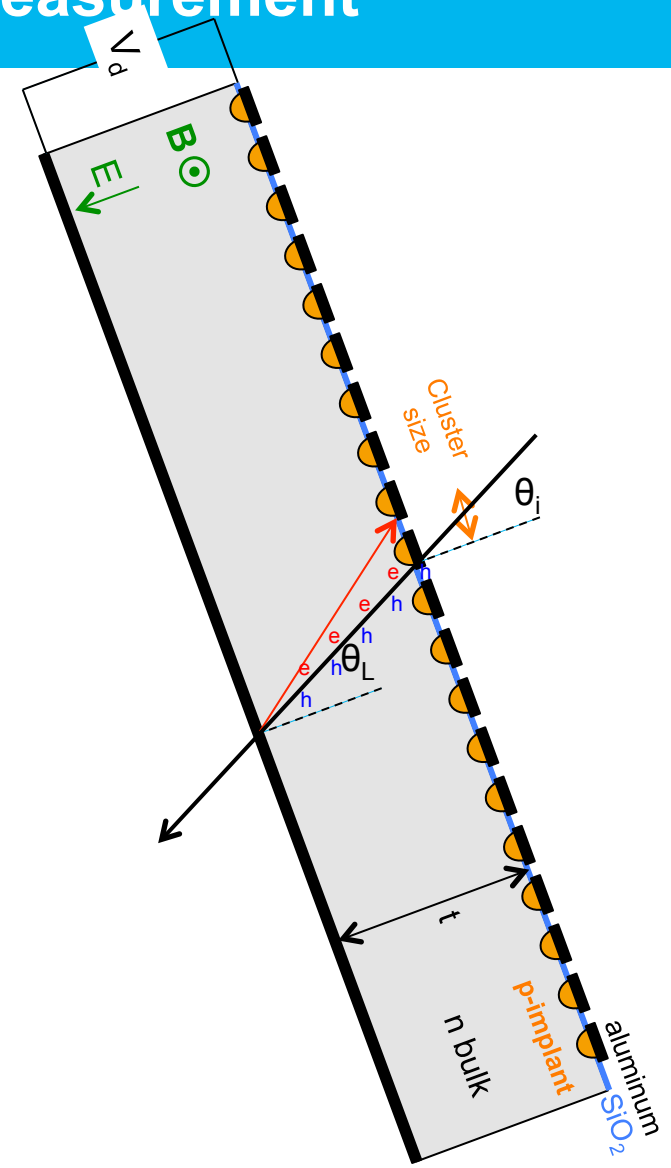
Lorentz Angle Measurement



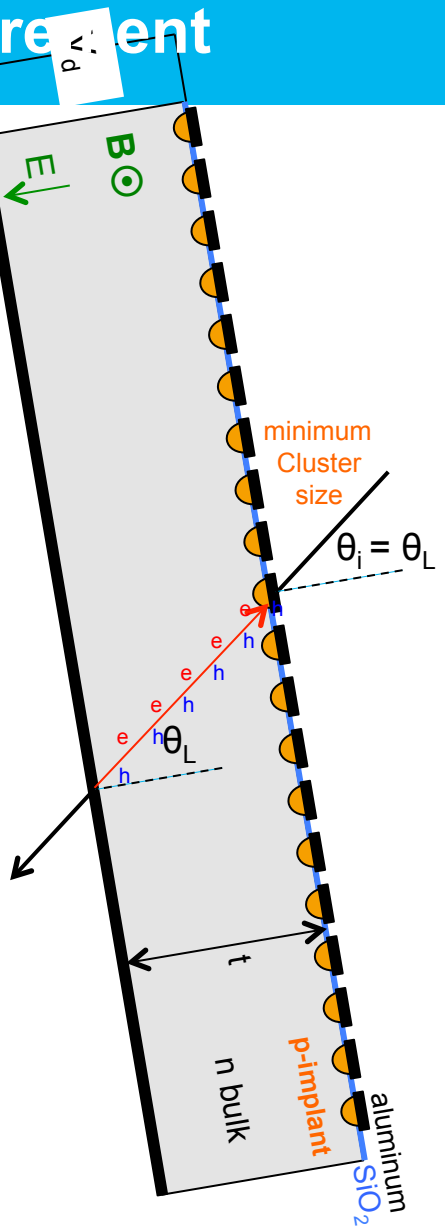
Lorentz Angle Measurement



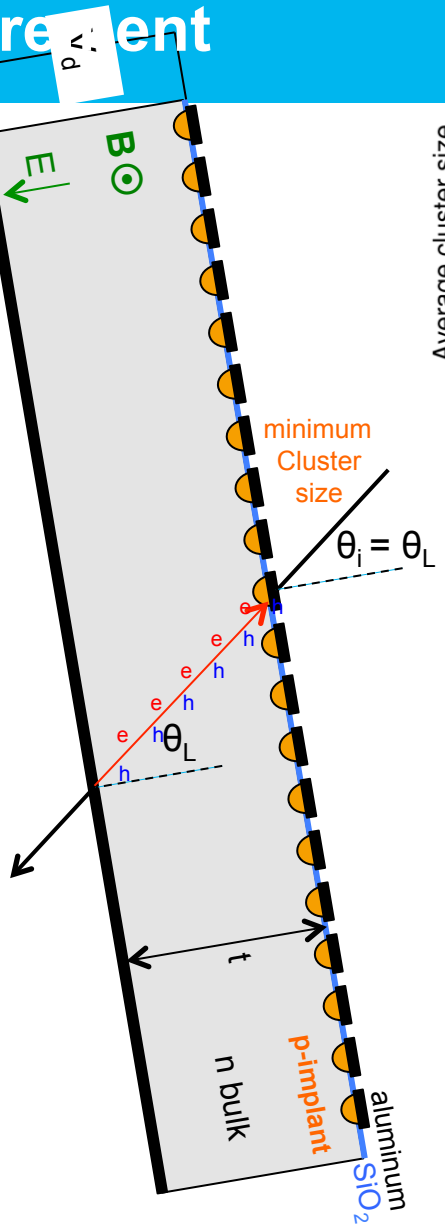
Lorentz Angle Measurement

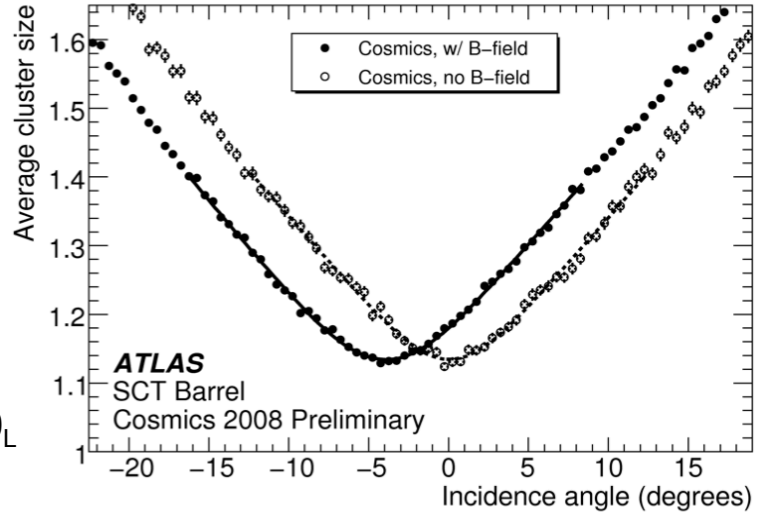


Lorentz Angle Measurement



Lorentz Angle Measurement

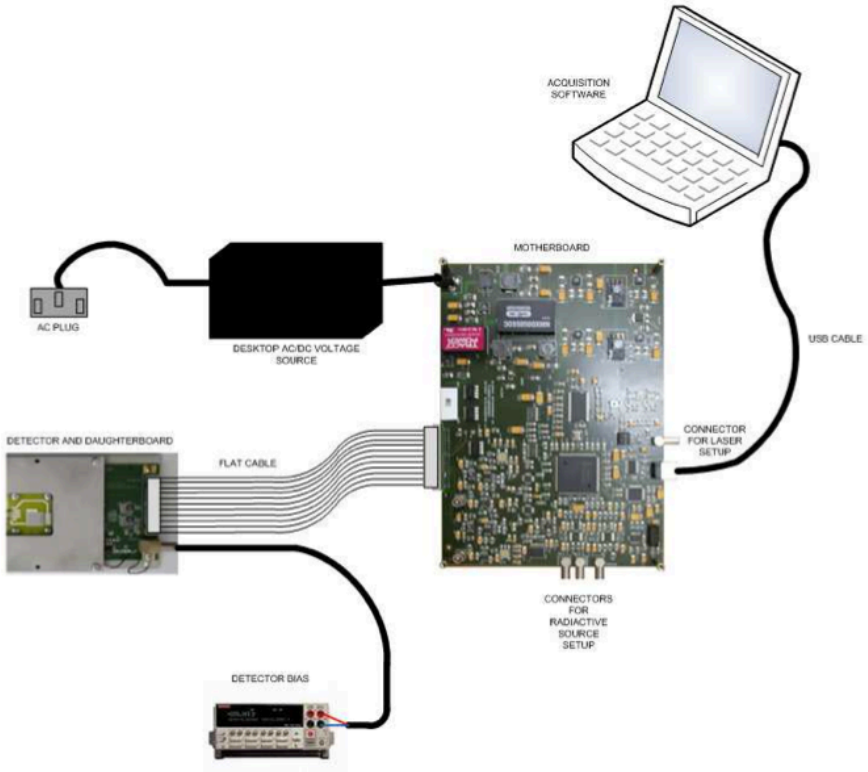


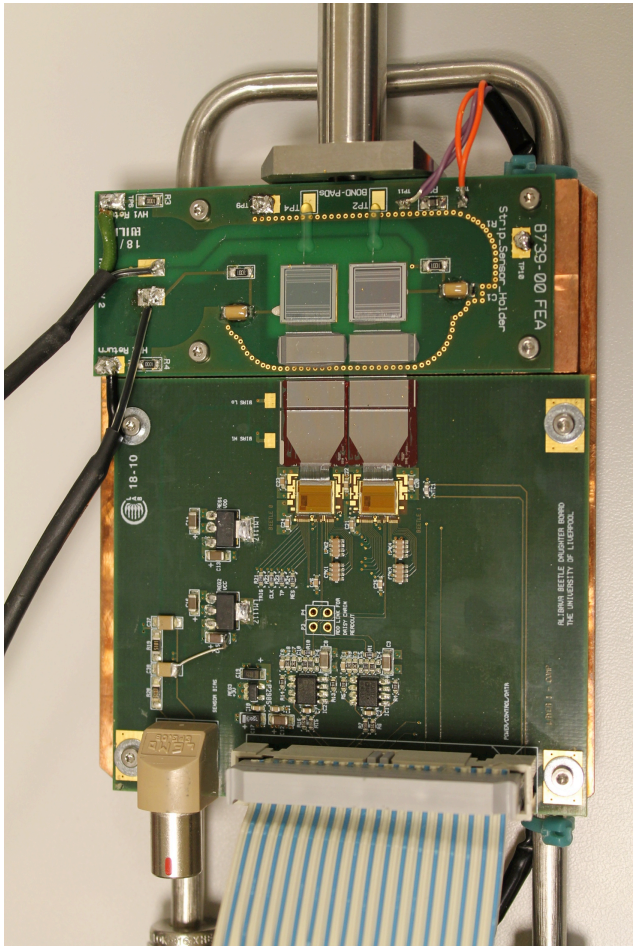


Lorentz angle measurement on ATLAS SemiConductor Tracker (SCT)

Setup: Device Under Test (DUT)

- Readout System: Alibava
  - 2 Beetle chips, 256 channels
  - Clock rate: 40 MHz
  - Output: Analogue





Alibava Daughter Board

Setup: Device Under Test (DUT)

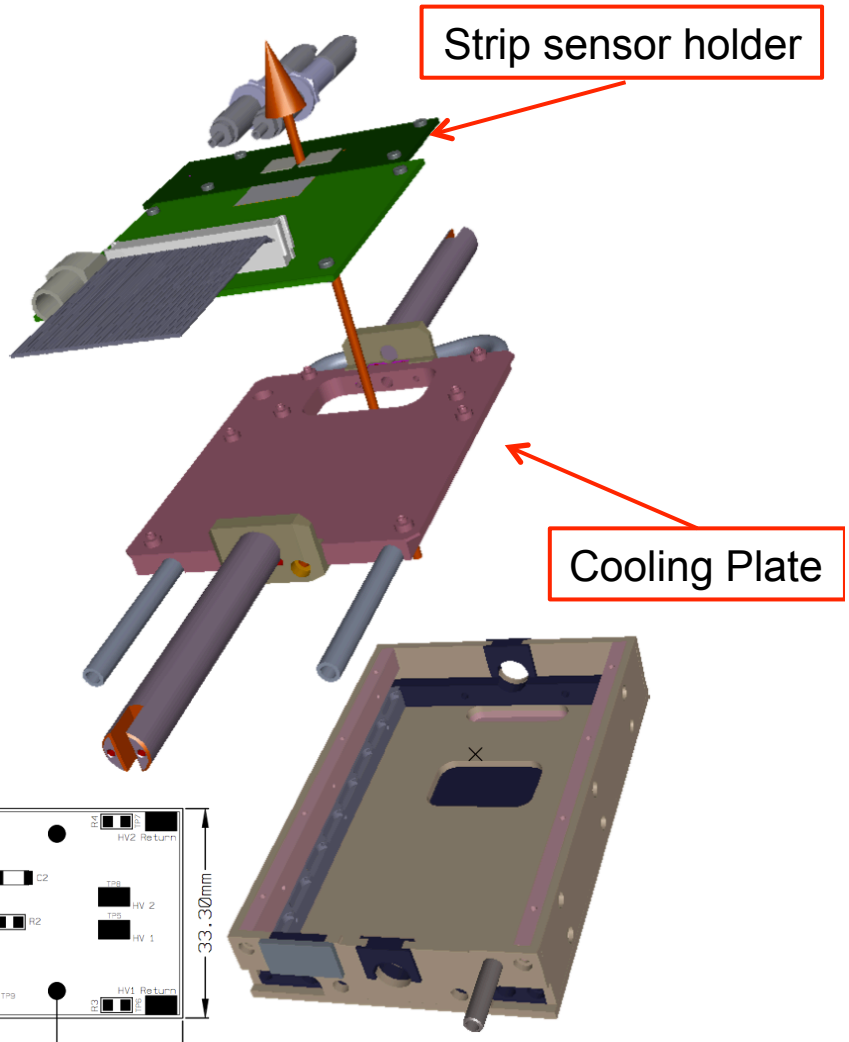
- Cooling:

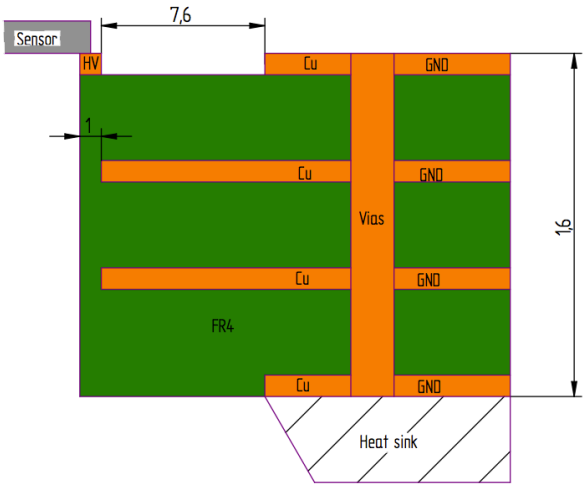
  We will use irradiated sensors

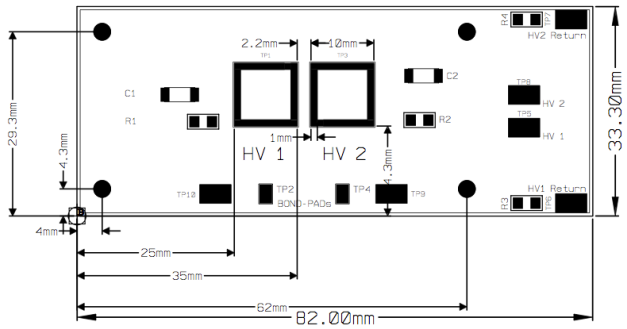
  - To avoid leakage current
  - To prevent annealing
  - Cooling down to - 25 degrees using silicone oil

- Strip sensor holder

  - Needs good thermal conductivity







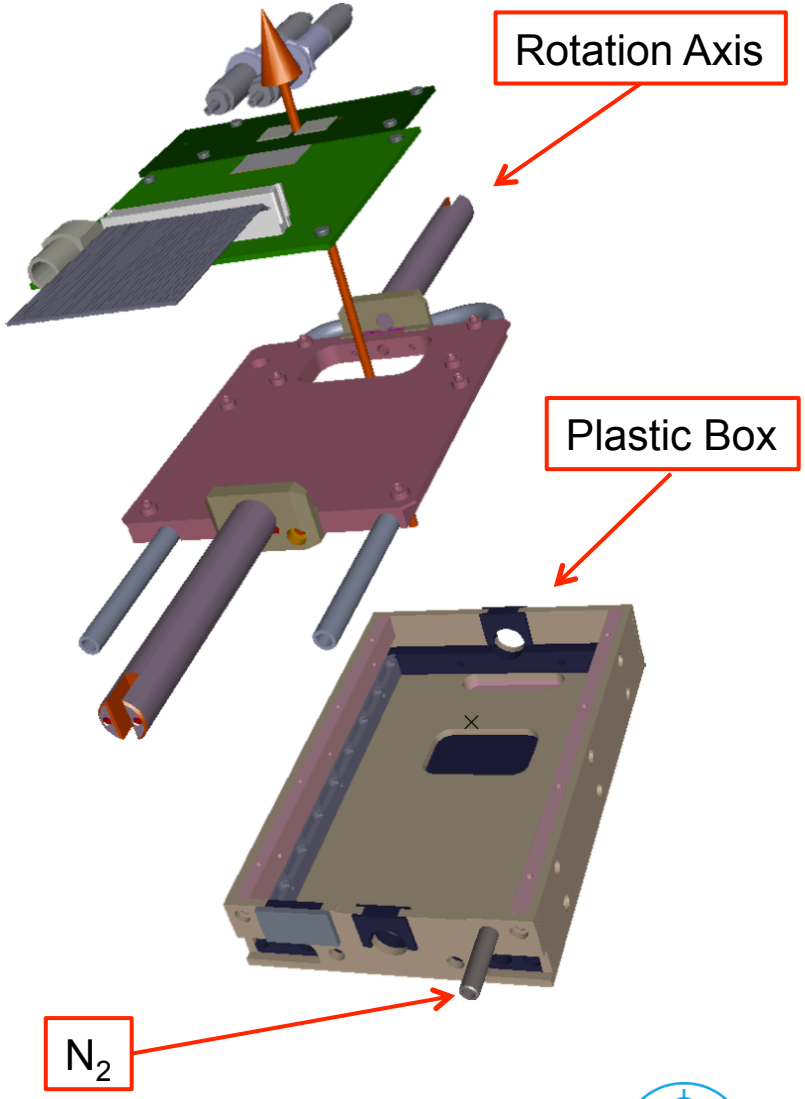
Setup: Device Under Test (DUT)

- Box:

  To avoid humidity

  - Flush inside with N_2
  - Cover with styrofoam

  Should be rotatable

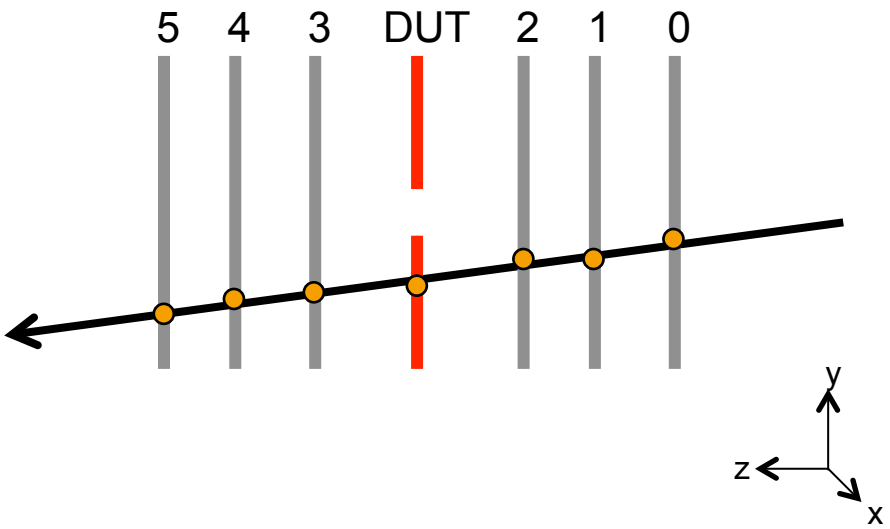


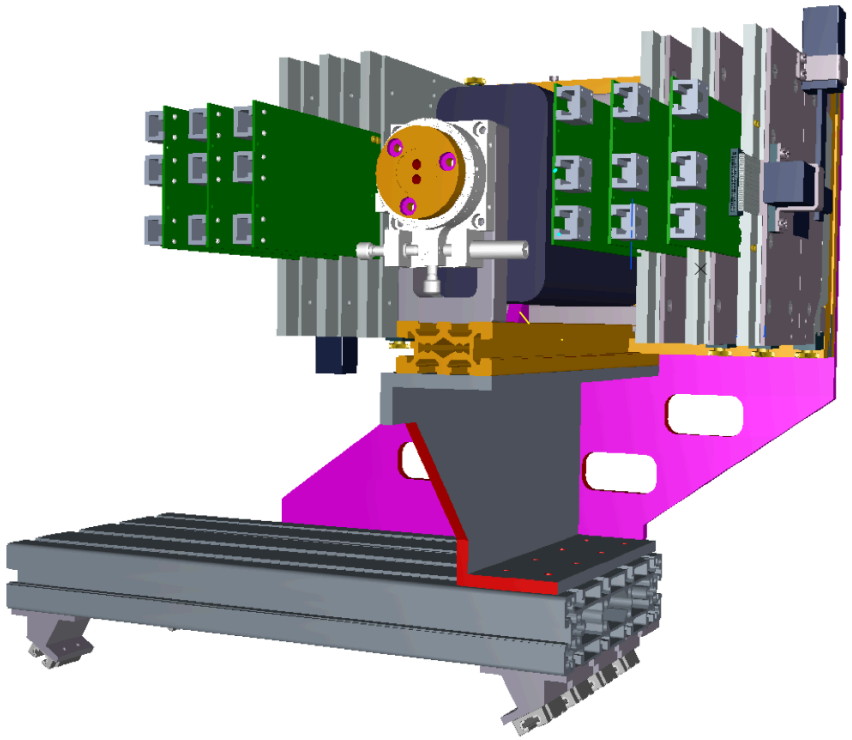
Setup: EUDET Beam Telescope

- EUDET Telescope:
  - Consists of 6 pixel sensors
  - Pointing resolution ~2 um

    without any DUT
  - In our case without DUT

    intrinsic resolution ~4um

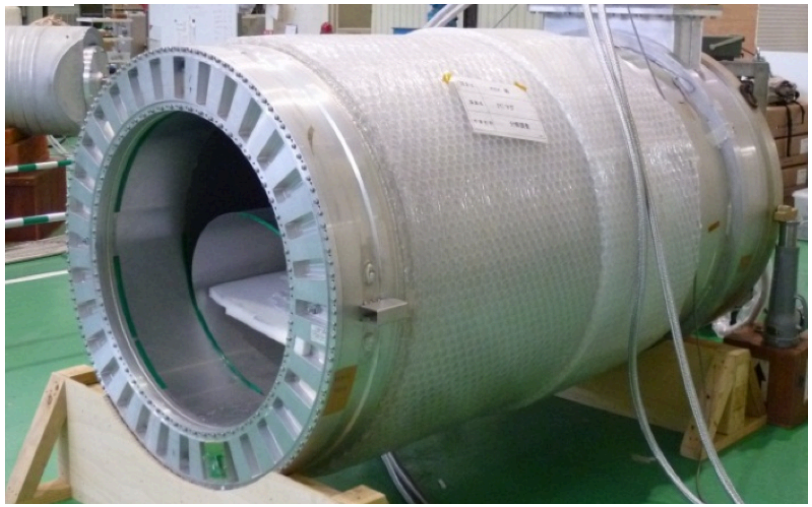




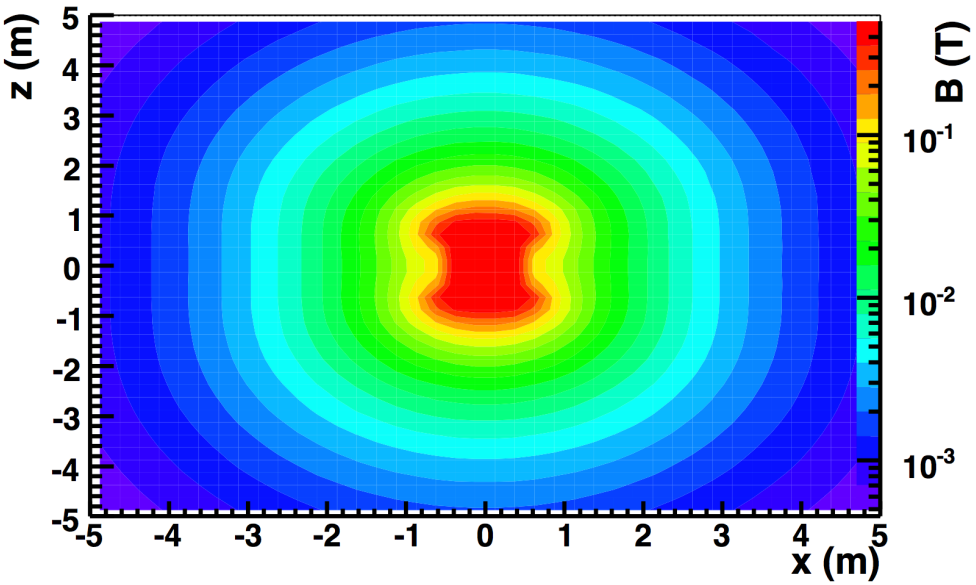
Setup: The Magnet

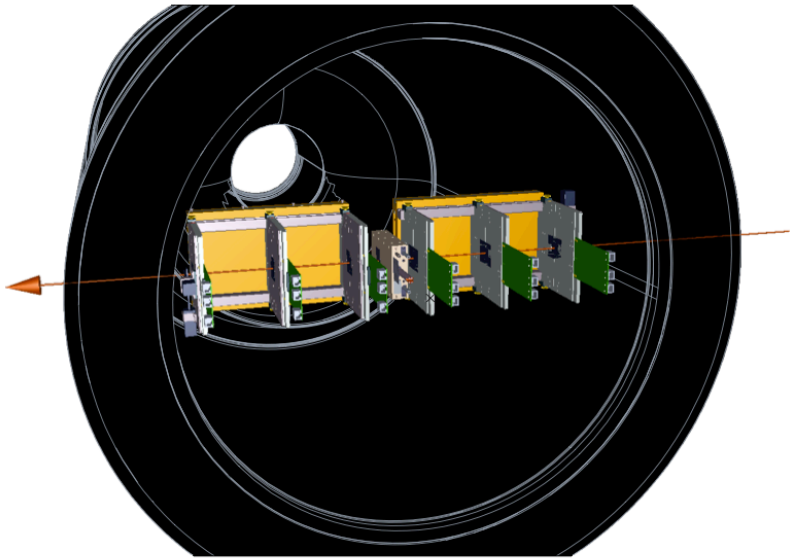
- PCMAG:
  - B field up to 1Tesla
  - Measurement will be done in various magnetic fields

    0.25T, 0.50T, 0.75T, 1.00T
  - Extrapolate results to 2T



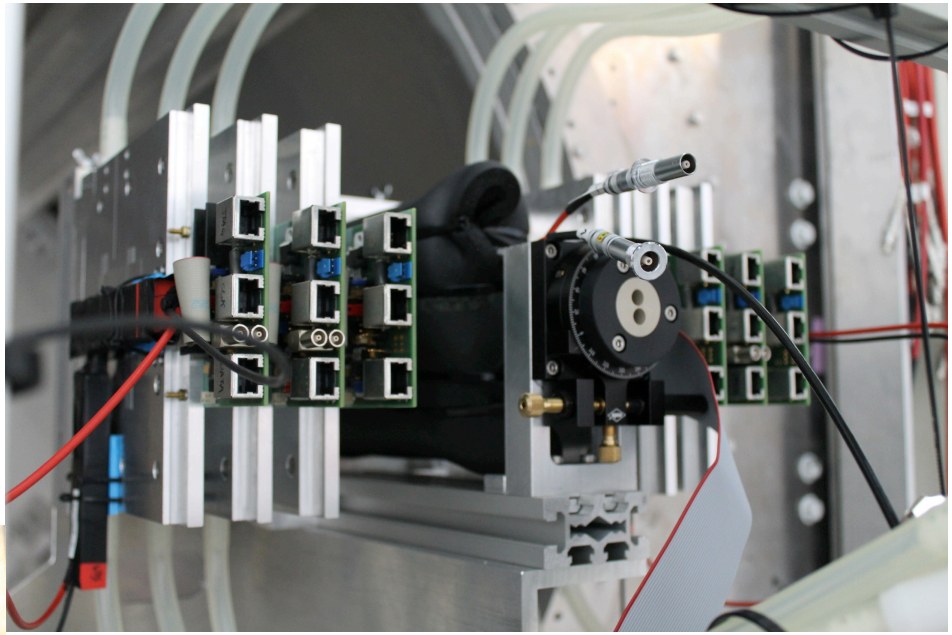
Magnetic field in ATLAS Inner detector

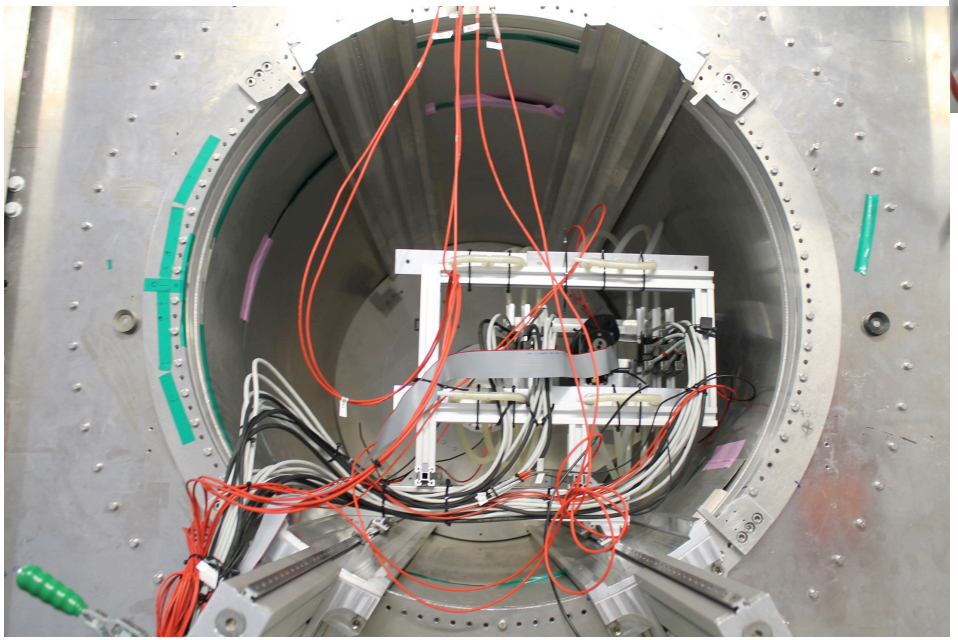




Setup

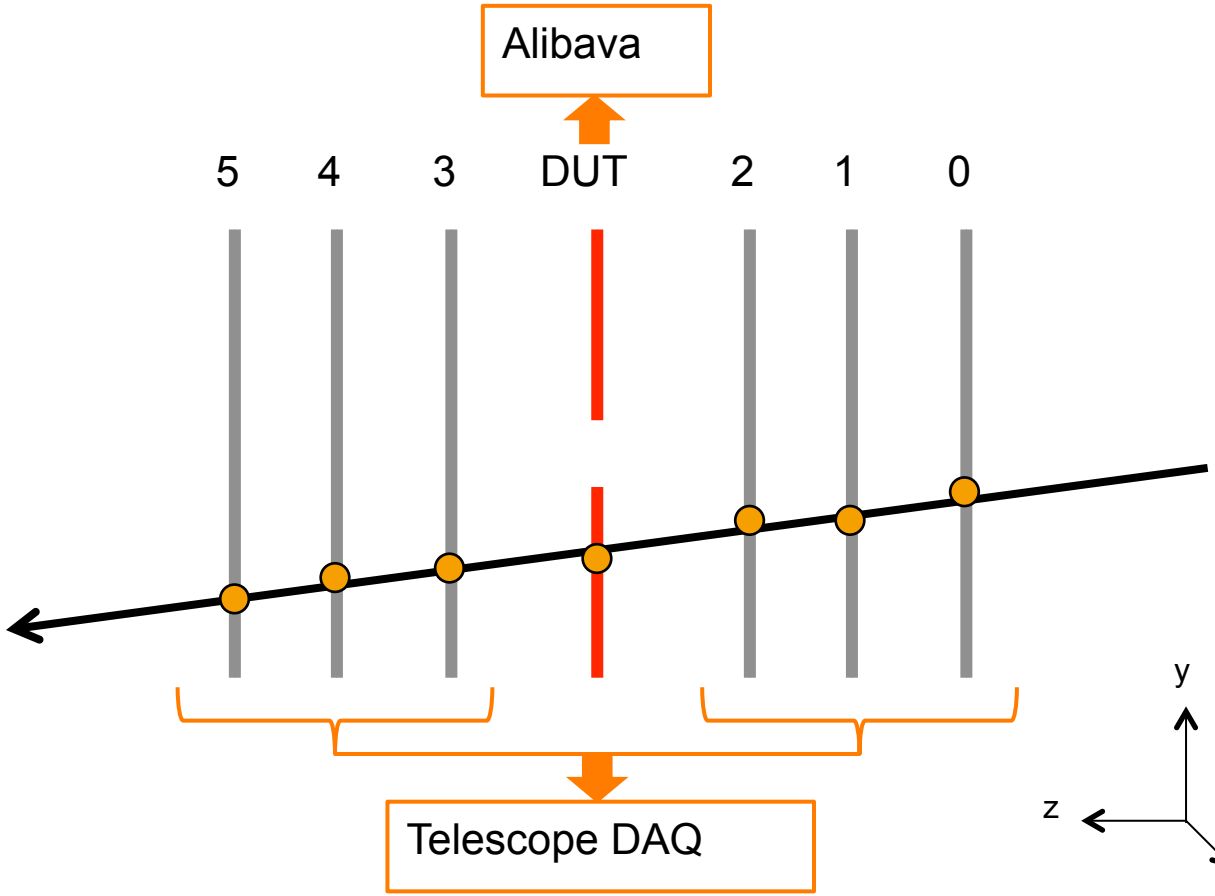
- Beam
- Magnetic field
- Track of particle
- Device Under Test (DUT)

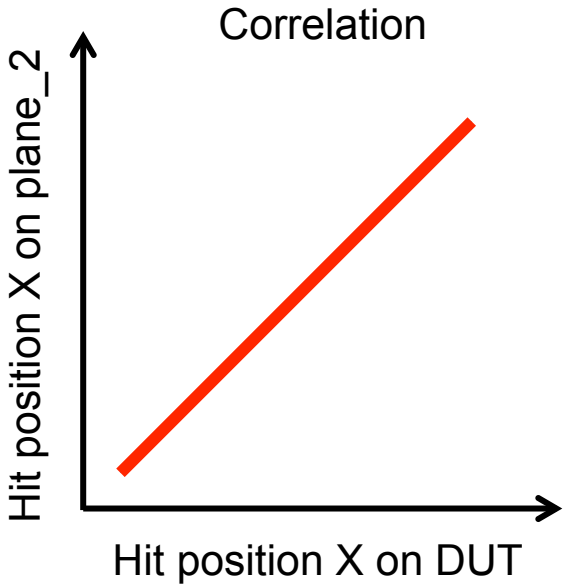




Measurements

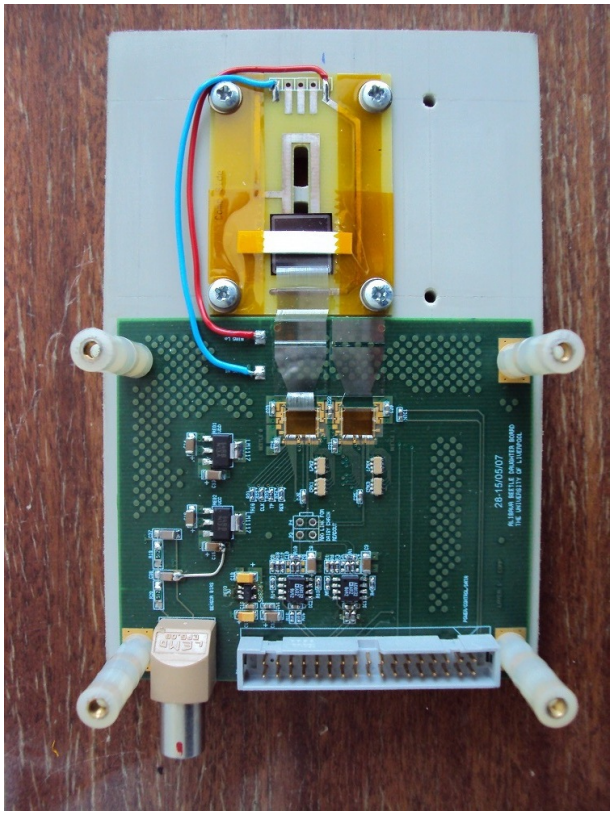
- DUT will be read by Alibava
- Telescope planes will be read by Telescope DAQ
- One needs to check synchronization between Alibava data and telescope data



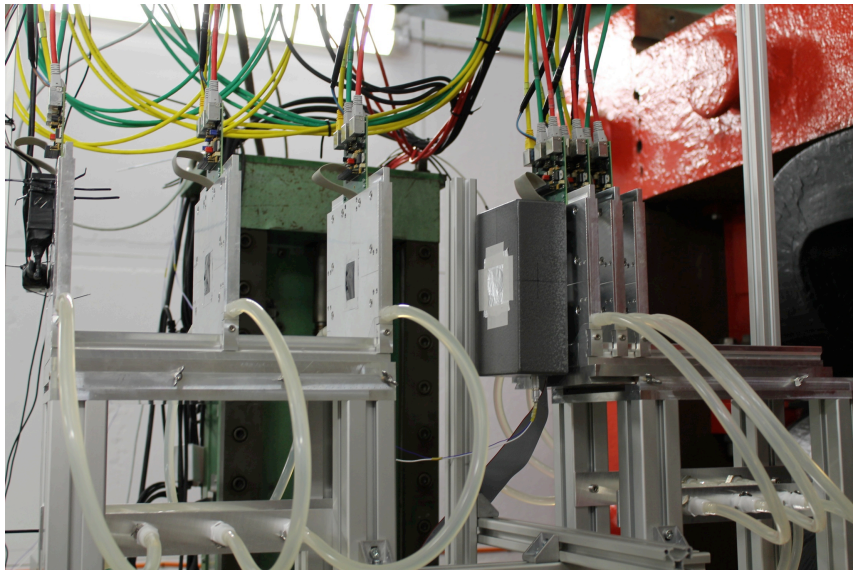


Synchronization Check

- Synchronization was checked in May 2012
- Setup of Charles University (Prague) was used with Alibava readout system.



- First test beam setup



- No B field!

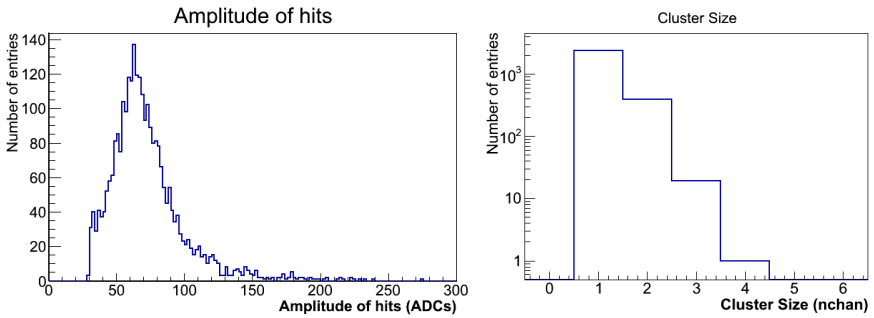
Prague Sensor:

Type	n in p
Thickness	300 μm
Depletion Voltage	80 V
Bias Voltage	100 V
Number of channels	131
Pitch size	80 μm

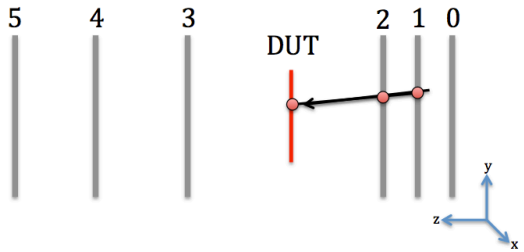
Synchronization Check

- Hits on DUT

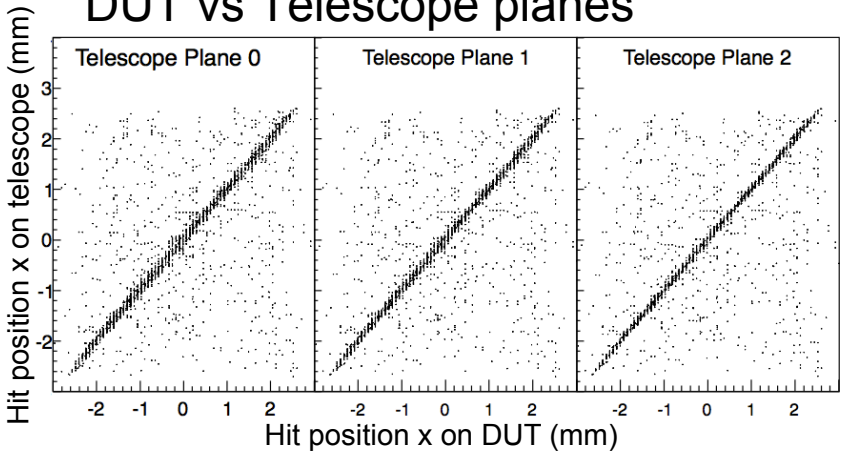
Average cluster size = 1.16



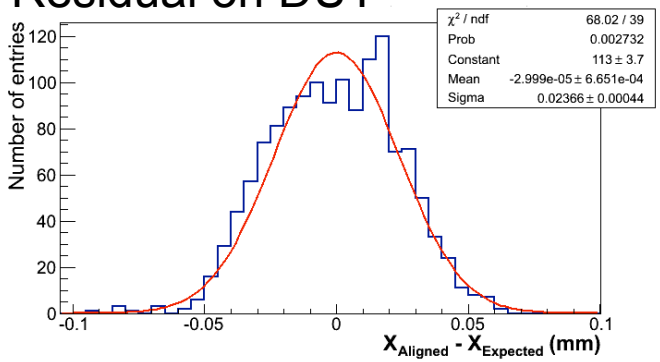
- Tracks on DUT found by using only two telescope sensors (will be improved)



- Correlation plot: DUT vs Telescope planes

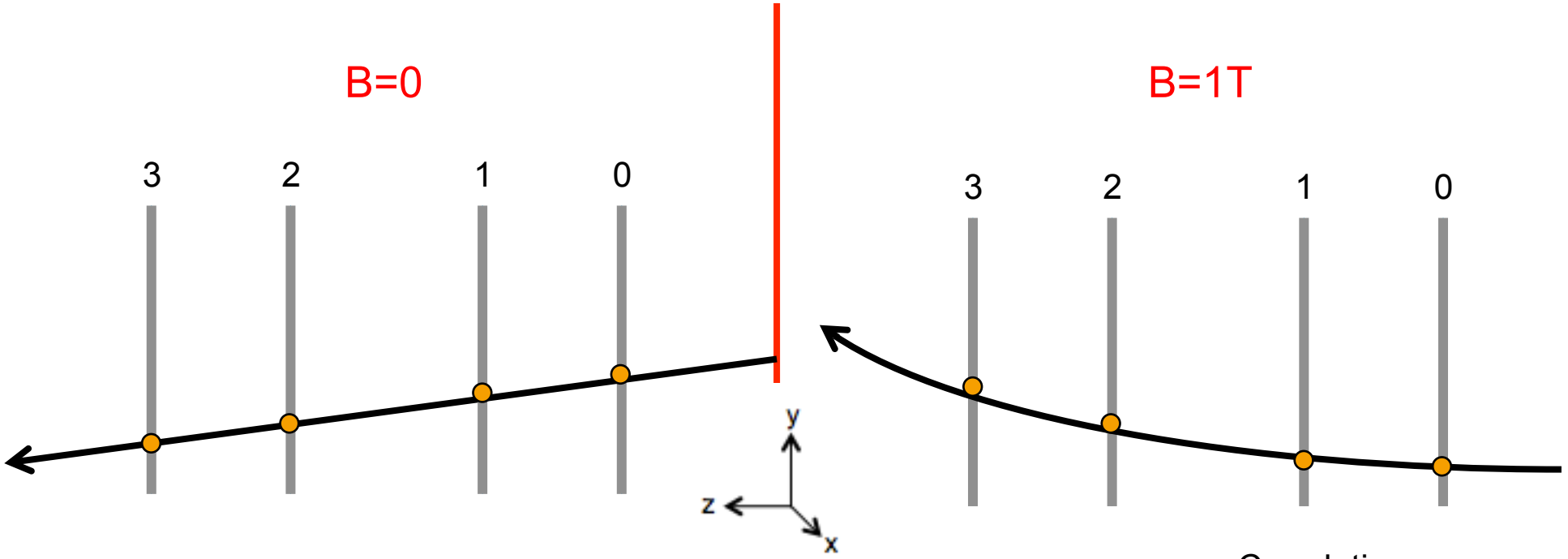


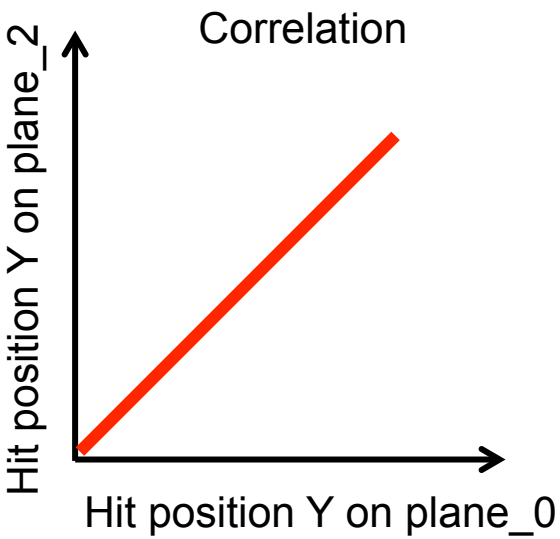
- Residual on DUT

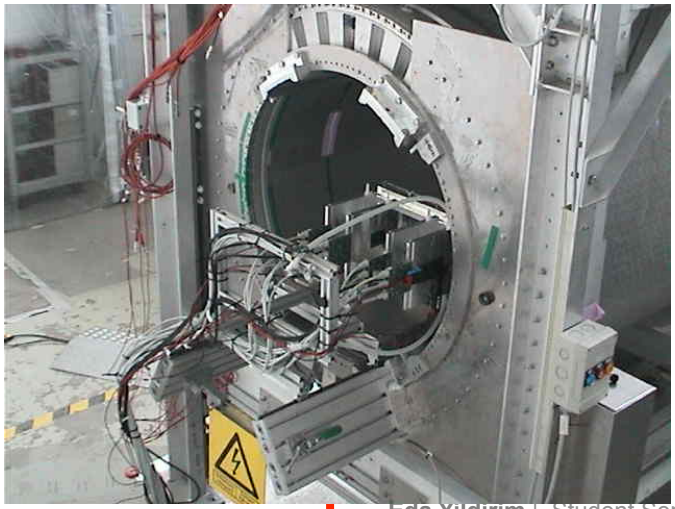


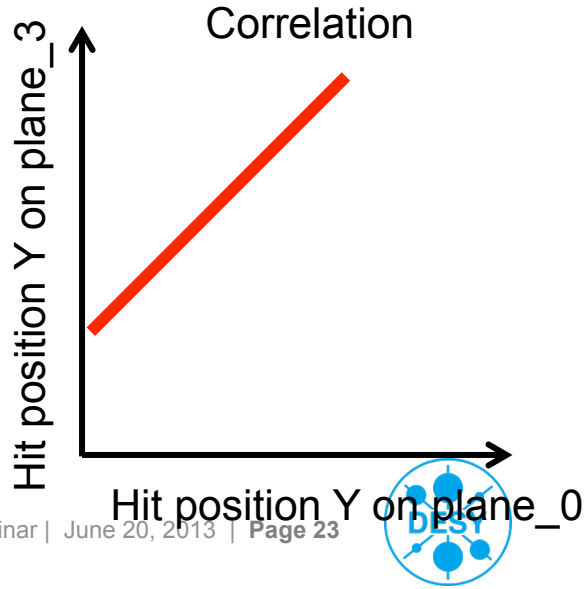
  - Resolution on DUT = 23.7 µm
  - Average incident angle = 6.05 degrees

Telescope in Magnetic Field



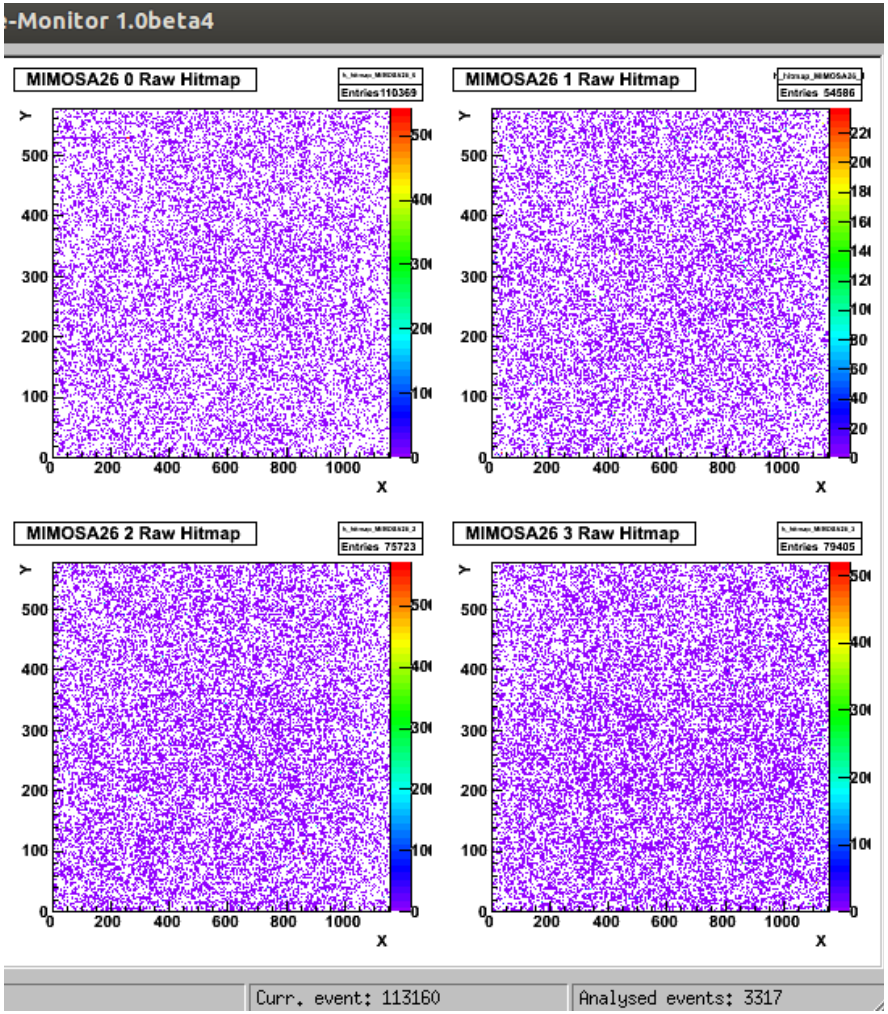




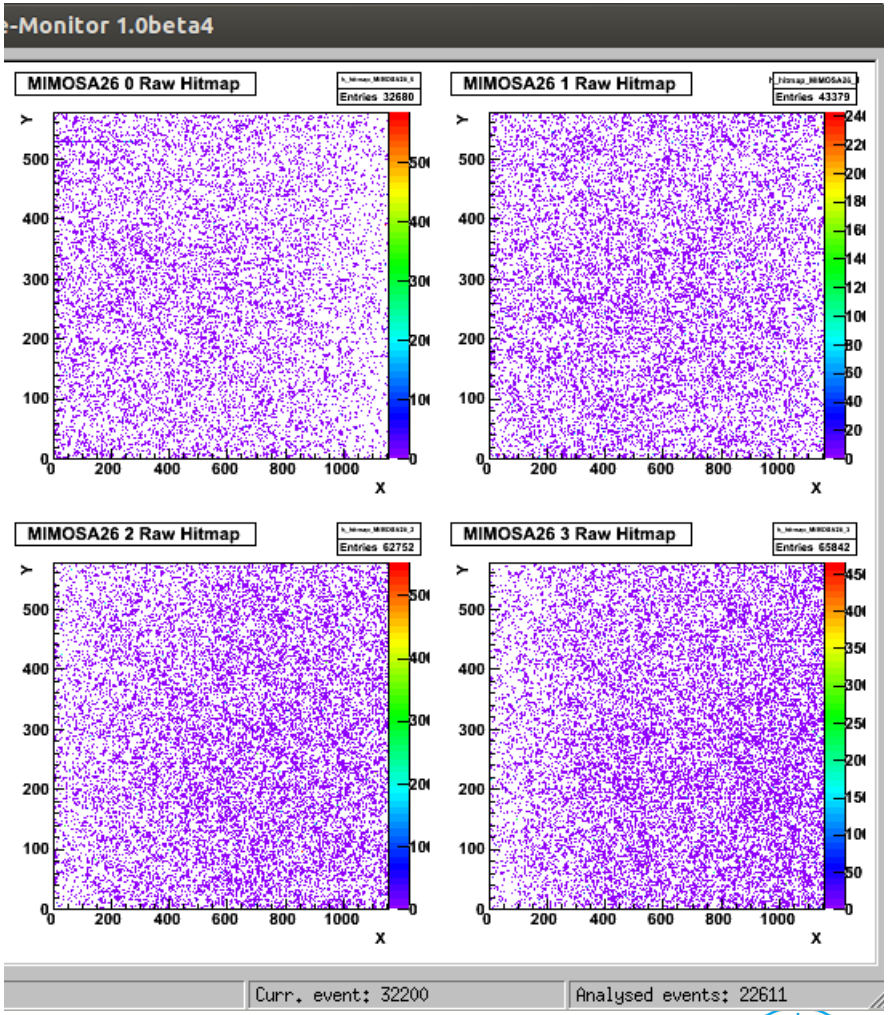


Telescope in Magnetic Field: Hit Maps

E= 4GeV, B=0

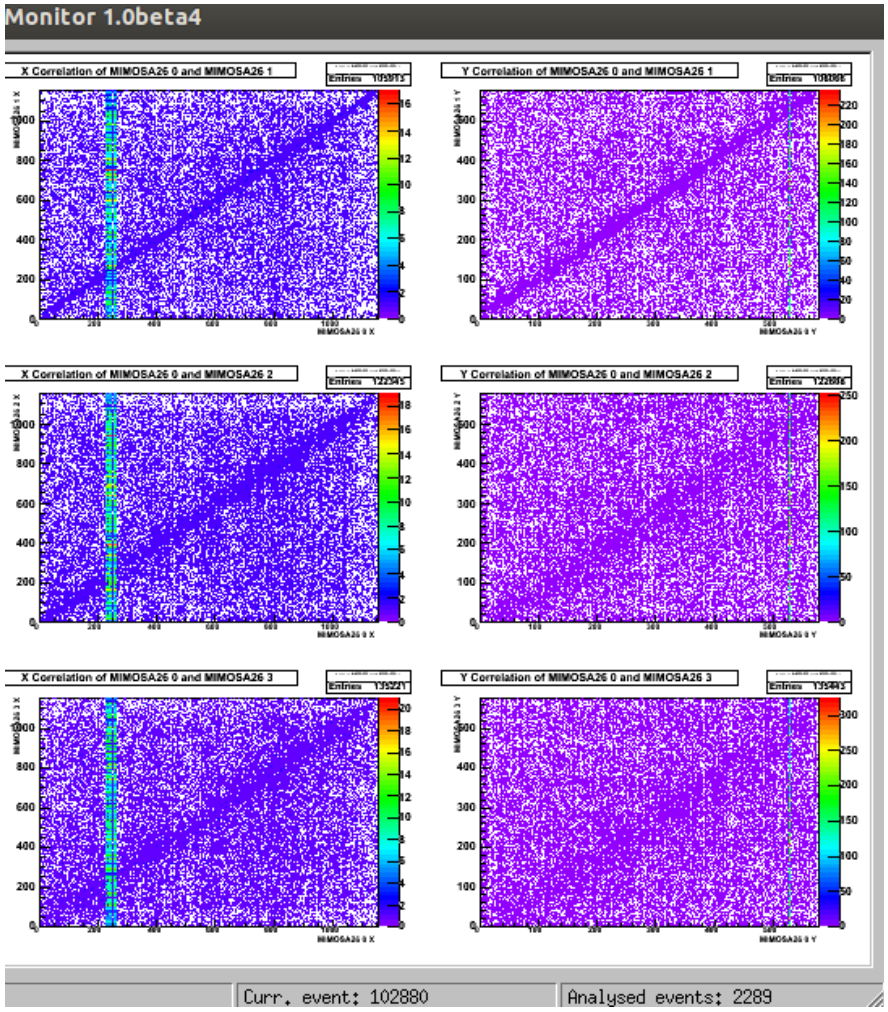


E= 4GeV, B=1T

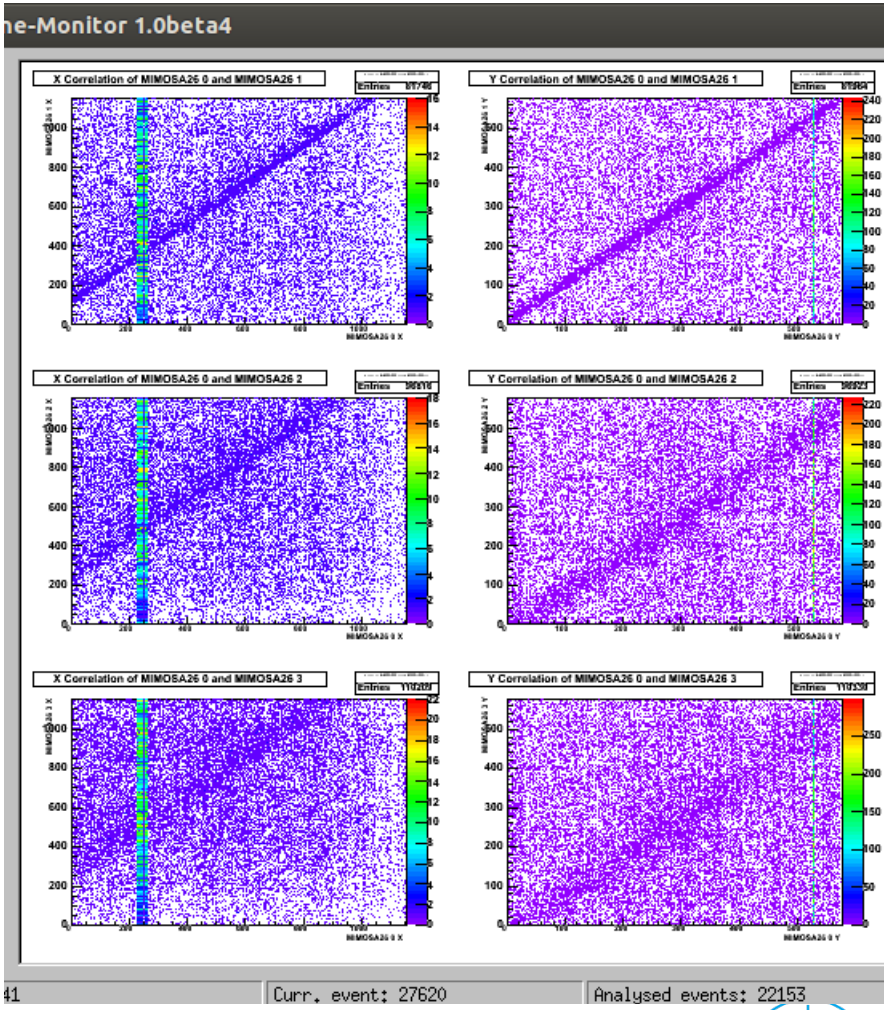


Telescope in Magnetic Field: Correlation Plots

E= 4GeV, B=0

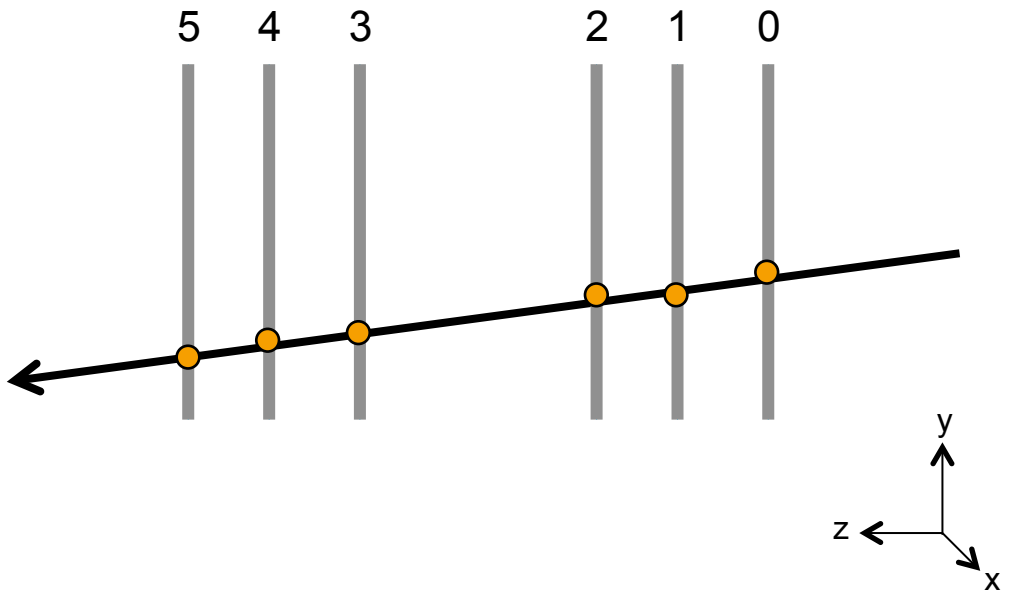


E= 4GeV, B=1T



Telescope in PCMAG

- Because of the cooling pumps, the magnet vibrates. One needs to check if this vibration affects resolution of the telescope
- We took data with/without vibration and compared the alignment and resolutions on each sensor.



Telescope in PCMAG

- Because of the cooling pumps, the magnet vibrates. One needs to check if this vibration affects resolution of the telescope
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		run357 (vibration on)		run360 (vibration off)	
Plane	Axis	Resolution (um)	ResErr (um)	Resolution (um)	ResErr (um)
0	X	3.49	0.02	3.55	0.02
0	Y	3.50	0.02	3.54	0.02
1	X	2.91	0.01	2.92	0.01
1	Y	2.97	0.01	2.93	0.01
2	X	3.69	0.02	3.77	0.02
2	Y	3.64	0.02	3.79	0.02
3	X	3.78	0.02	3.95	0.02
3	Y	3.78	0.02	3.95	0.02
4	X	2.93	0.01	2.96	0.01
4	Y	2.95	0.01	3.00	0.01
5	X	3.59	0.02	3.74	0.02
5	Y	3.62	0.02	3.73	0.02

Summary & Future Plans

- Setup is ready
- We confirmed that
  - Alibava and telescope DAQ can be synchronized
  - Vibration of the magnet do not affect our measurement
  - Everything works with magnetic field
- We are ready to measure Lorentz angle!

August Test Beam:

- We will have the latest ATLAS strip test sensors
- Lorentz angle measurement with non-irradiated sensors

Future Test Beams

- Irradiated sensor with B field
  - Various radiation doses

    up to 2 x 10^{15} n_{eq}/cm^2
  - Various magnetic fields

    0.25T, 0.50T, 0.75T, 1.00T

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DESY

Thank You !

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Backup

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Magnetic Field