Silicon Pixel R&D with EUDET Telescope in ESA

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on behalf of the the T-539 and T-545 experiments
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https://confluence.slac.stanford.edu/display/Atlas/TestBeam

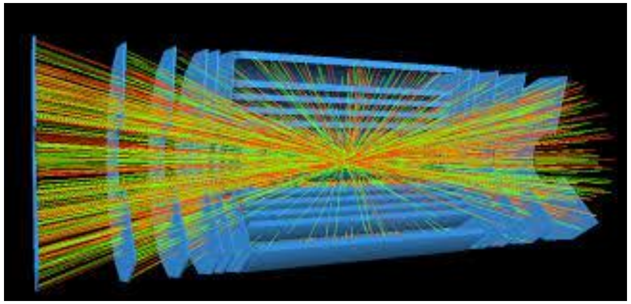
Scope

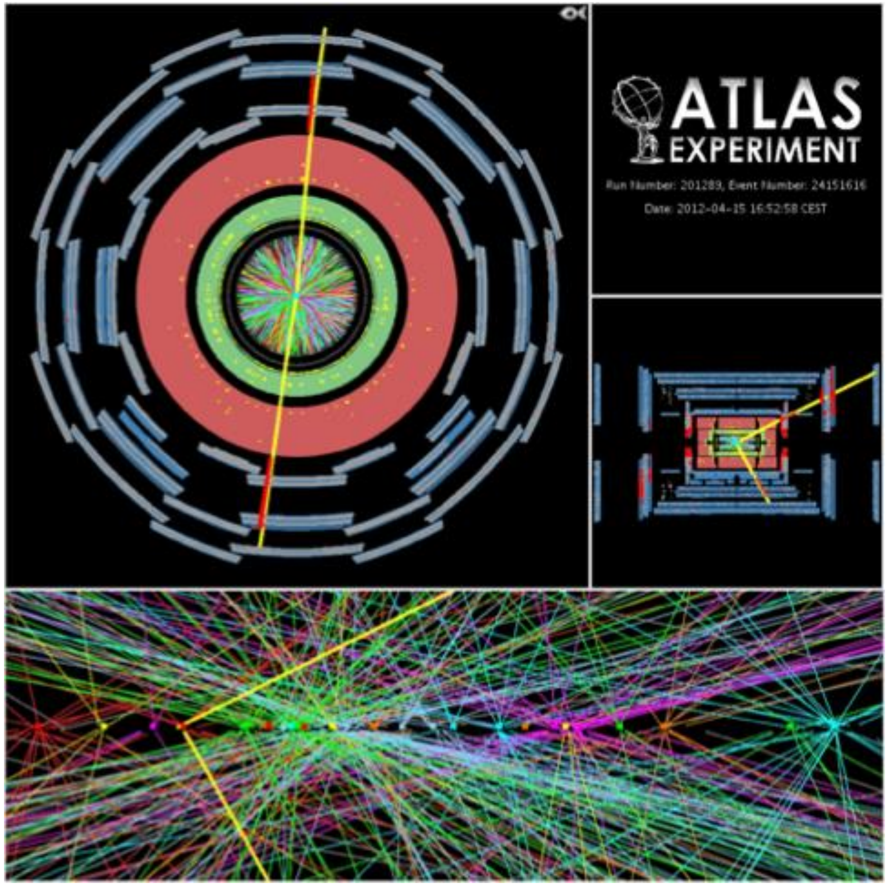
As part of the ATLAS collaboration at CERN, we are using the ESTB to study silicon detectors used for charged particle tracking:

- Precision momentum and direction measurements of tracks
- Tagging of short lived b quark decay secondary vertices coming from decays of Higgs and potential new particles

IBL insertion 2014

1. Test the performance of irradiated devices in order to validate and improve our models
   - 15 times more data (and radiation dose) to go with current detector until 2022
2. Study new devices that can be used in the upgrade of the ATLAS all silicon tracker in 2023
   - 100 times more data than today
   - 10 times instan. luminosity and radiation level
   - 100 times data rate
   - $30m^2$ pixels + $164m^2$ Si-strips



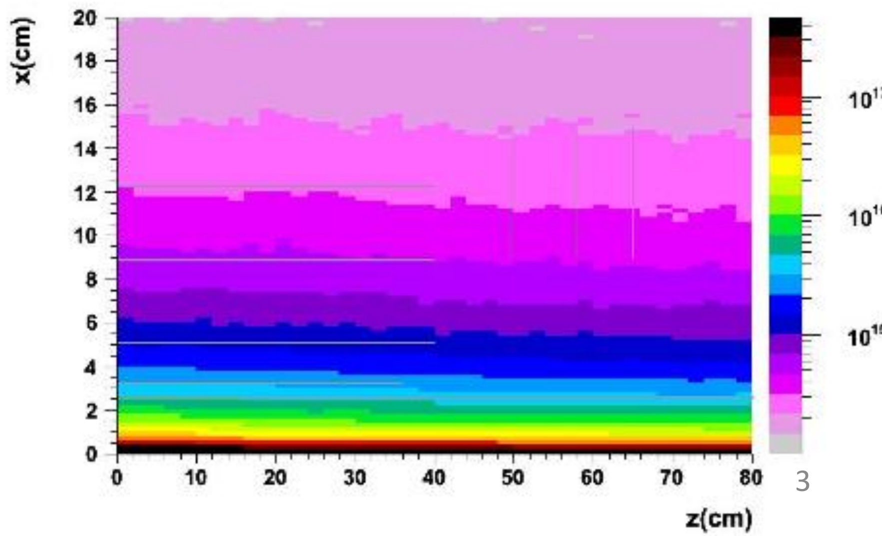


Radiation Damage

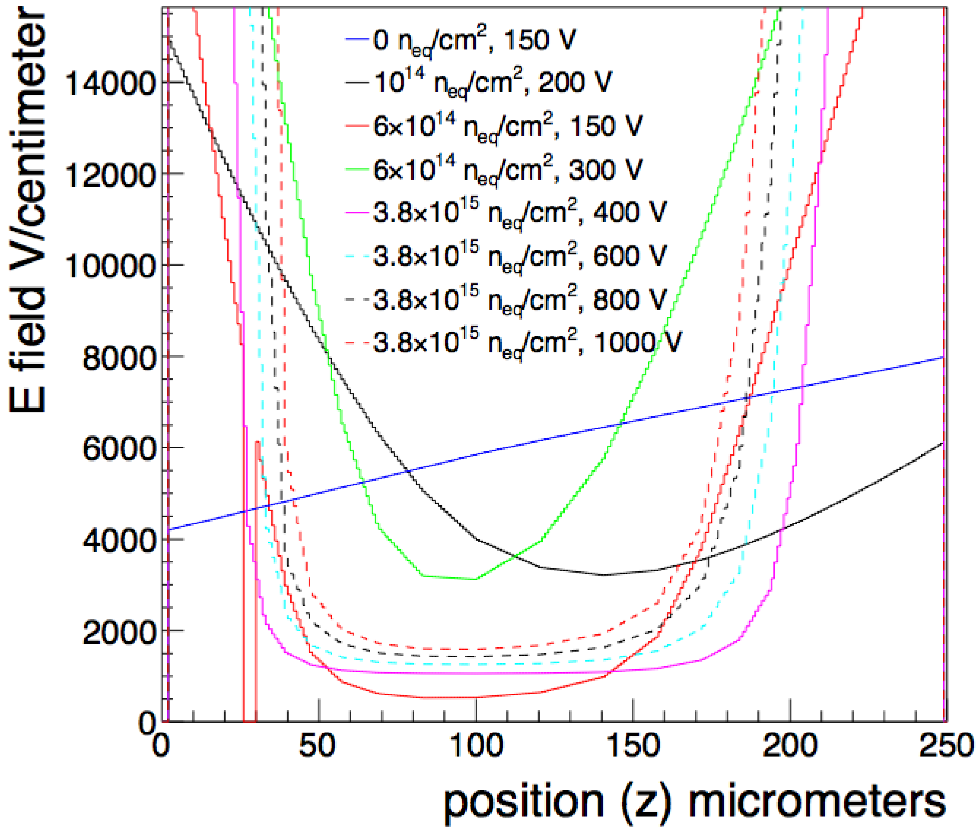
The use of radiation hard technology in the ATLAS inner detector is and will be crucial to maintain performance in Run II and beyond.

However, significant performance degradation is inevitable and we must be prepared with proper simulation!

550/fb: ~3e15 n_{eq}/cm^2 for the IBL



We have empirical models for rad. damage, but we need to validate them with TB data.



$$\tau_{e,h}^{-1} = \beta\Phi$$

fluence

$$\beta = 3 \cdot 10^{-16}\ \mathrm{cm^2/ns}$$

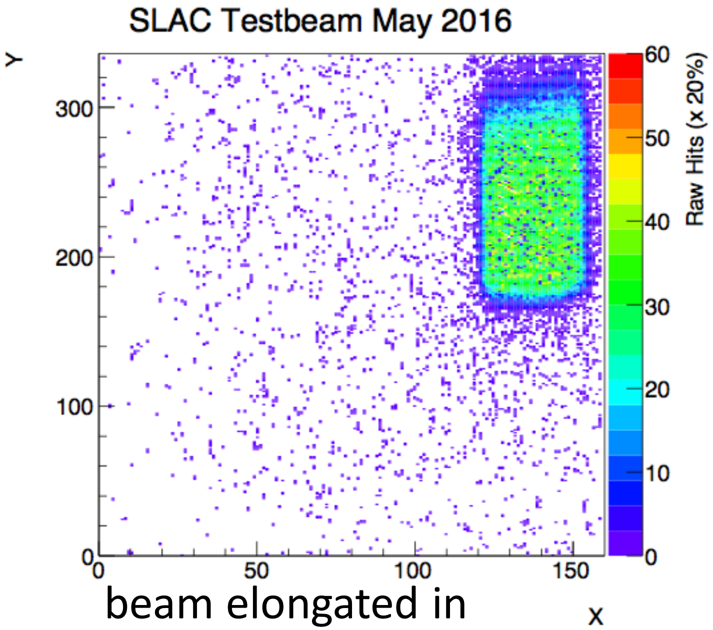
For example, radiation reduces the E field in the center of the pixel and causes charge trapping (signal loss)

ESTB Setup with EUDET Telescope

- 6 planes of precision CMOS EUDET pixel telescope (Caladium) from Carleton Univ.
- 18.5μm pixels with ~3μm spatial resolution
- ~ 2cm x 1cm beam aperture
- Integrated Device Under Test (DUT) readout and XY/rotation adjustment.

Allows selection of good tracks through whole telescope and less sensitive to beam debris contamination

We took data with a reference (unirradiated) sensor in May.



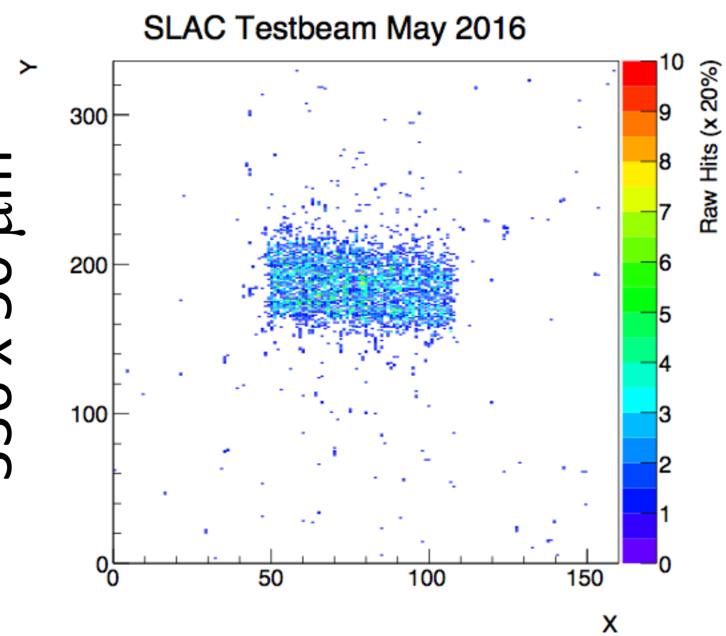
beam elongated in the direction of the rotated DUT

Close communication with MCC has been very beneficial.

The efficiency of our beam time has significantly increased due to a custom beam shape and size.

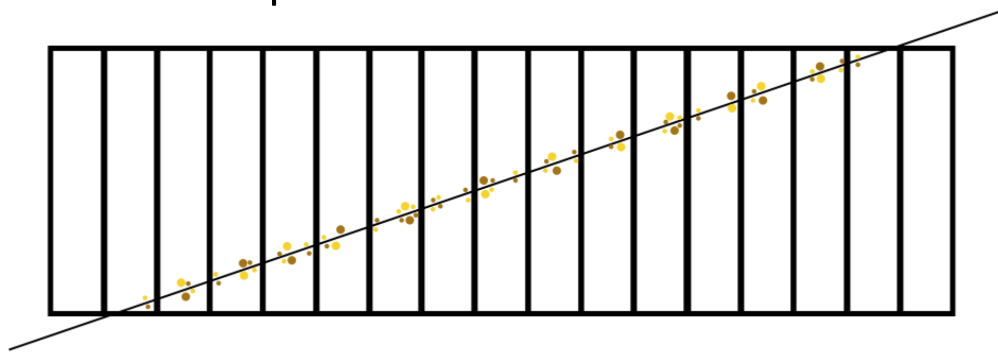
The DUT's are small and so is the beam spot; useful analysis is possible because of the 18.5 μm pixels from the Caladium telescope with ~3 μm resolution.

336 x 50 μm

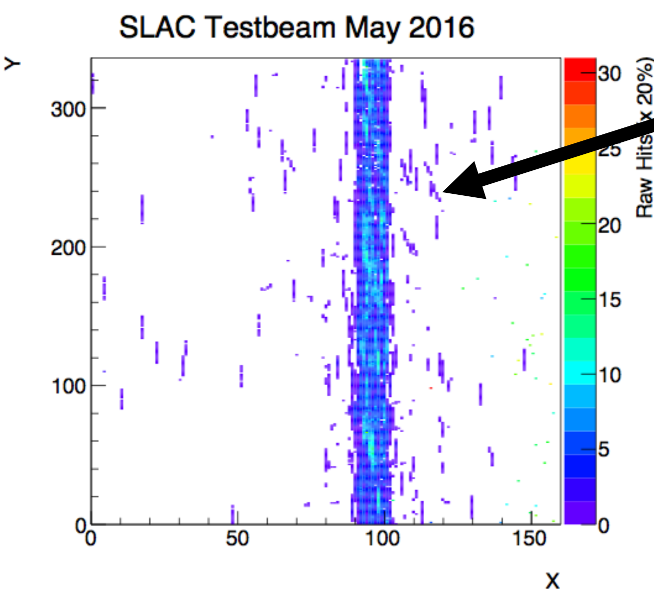


160 x 250 μm

DUT at high angles to probe charge collection as a function of depth in the sensor.



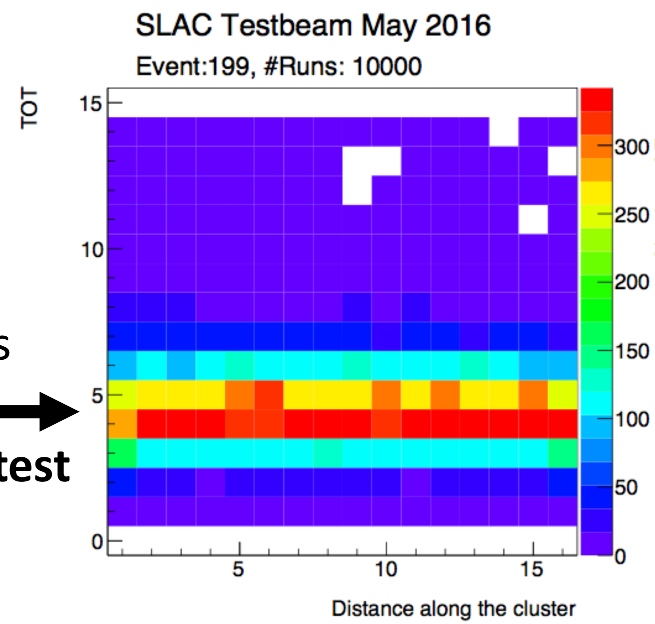
Critical for studying radiation damage effects and validating / improving our models.



DUT occupancy: long clusters (~15 pixels)

Charge collection versus depth (unirradiated)

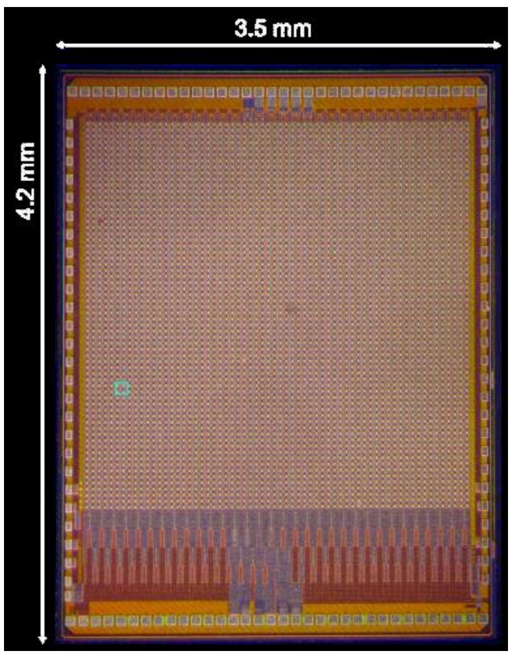
This week (hopefully): test our irradiated sensors



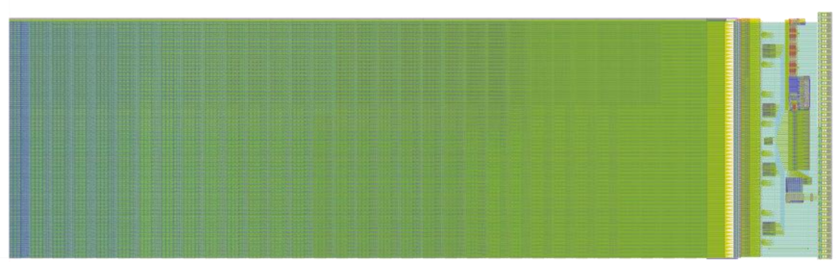
This will have a significant impact on ATLAS performance in the (near) future.

Future Upgrade Devices to Come

RD53 FE65-P2 prototype
- 50μm x 50μm pixels
- Readout ASIC with TSMC 65nm technology



LBNL SBIR CMOS sensor with Sensor's Creation Inc. (ESTB last week)



CHESS2 MAPS Pixelated 'strip' like device with AMS-35 technology

Beam Requirements

- Parasitic ESA secondary electrons at the rate of a few electrons per beam crossing typically, and sometimes up to a few hundreds per crossing during setup tuning
- Prefers high energy beam >10 GeV to reduce multiple scattering but don't care about exact energy or moderate energy spread
- Beam spot size preferably to cover large fraction of test device ~1x1cm – only worth fine tune for long data taking runs.
- Beam cleanness not crucial – we have EUDET telescope for offline quality selection