Characterisation & testing at LAL

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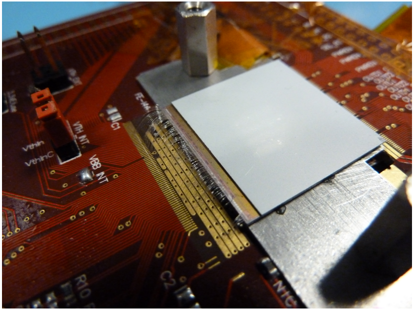
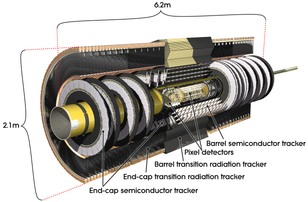
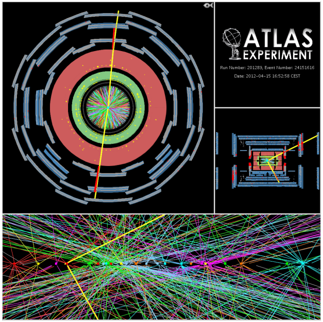


Motivation



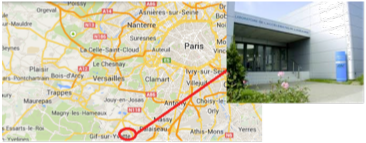


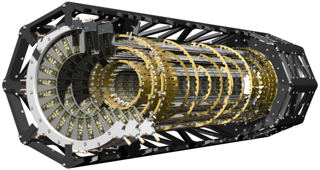
- HL-LHC phase II upgrade in $\sim$ 2022
- Expected fluence of 10^{-16}
  - Includes a new ATLAS tracker $\rightarrow$ requires improved pixel devices (**radiation hard**, slimmer edges, better granularity...).
- Results obtained from test structures can be used to develop reliable simulations of devices.
- Simulations, in turn, drive the development of new sensor layouts.
  - Quicker and less expensive than building multiple prototypes.

Laboratoire de L'accelerateur Lineaire

What is LAL?

- Mixed research laboratory between CNRS and University Paris XI
- Situated at Orsay (south of Paris)
- Originally an accelerator laboratory, claiming first e-e^- collisions
- Several Physics Groups (ATLAS, LHCb, NeMO, PLANK, ILC)
- Roughly 200 people including researchers, PhD students & engineers

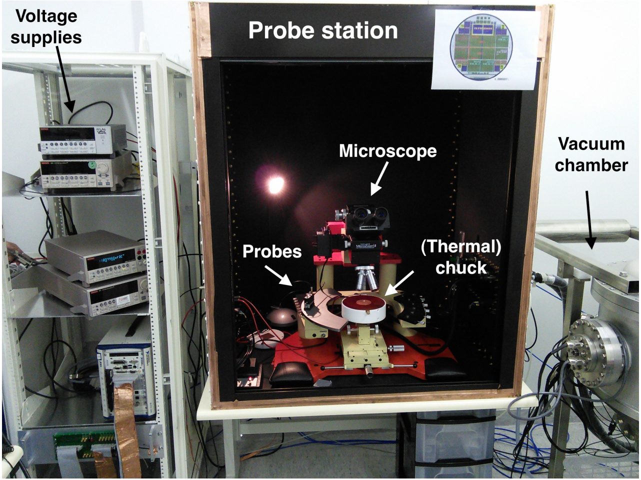




Who are we? (ATLAS LAL pixel group)

- **Abdenour Lounis**, Université Paris Sud (ATLAS LAL Pixel Group Leader)
- Nicoleta Dinu, Research Engineer
- Clara Nellist, Post-Doc
- Vagelis Gkougkousis, PhD Student
- Ahmed Bassalat, PhD Student (IBL at CERN)
- Aboud Falou, Research Engineer (IBL at CERN)

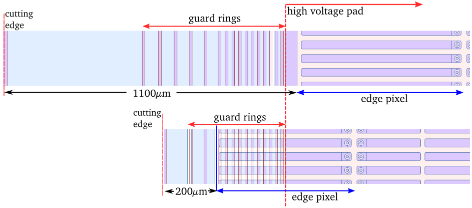
The clean room (salle blanche)



- Probe station works well.
- See IV results in Vagelis's talk.

Guard ring test structures

- Guard rings provide a controlled potential drop from the high voltage used for biasing the electrodes and the cutting edge of the device.
  - Usually this area is then inactive.
- Increasing the active area of pixel devices for future upgrades of ATLAS is important to minimise the material budget (therefore reduce scattering before the calorimeters).
  - For the IBL the dead area was reduced from $\sim$1100 μm $\rightarrow$ 200 μm by moving the edge pixels to partially underneath the guard rings.
  - Diodes with different numbers of guard rings were included in the wafer production for 2011.



Diodes with varying numbers of guard rings. From 1-4.

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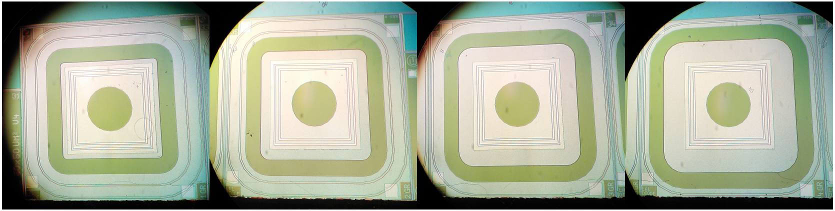
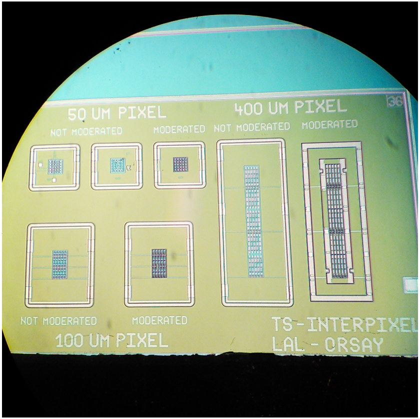


Diodes with varying numbers of guard rings. From 1-4.

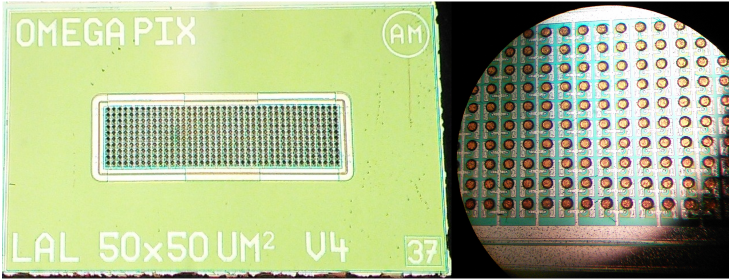
Inter-pixel test structures

- Structures of various pixel size (50 μm, 100 μm and 400 μm).
  - Each structure contains a central pixel, 8 surrounding pixels (connected together) and 16 outer pixels (also connected together).
- Can study the inter-pixel capacitance of various designs.



Omegapix

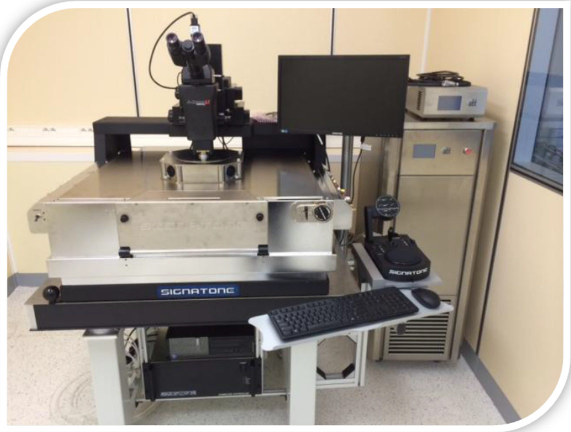
- Smaller pixel size of 50 x 50 μm.
- Study of new, 3D read-out chips.
  - "an emerging, system level integration architecture wherein multiple strata (layers) of planar devices are stacked and interconnected using silicon (or other semiconductor material) vias (TSV) in the Z direction"[1]



[1]: Handbook of 3D Integration, edited by Philip Garrou, Christopher Bower and Peter Ramm.

The clean room (salle blanche)

New probe station:



New clean 100 m^2 room construction combined with acquisition of semi-automatic testing system and wire bonding machine (CAPTINoV platform)

SIMS

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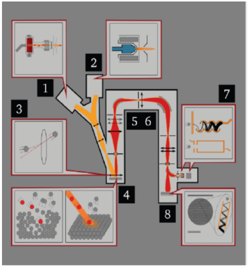
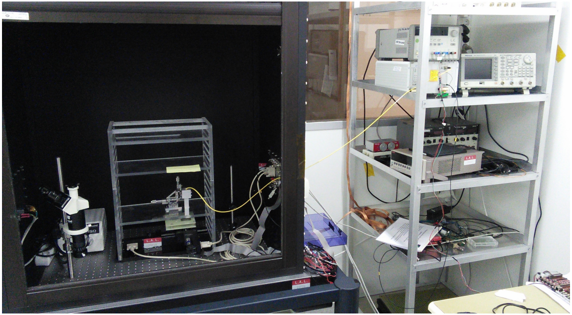
SIMS system at Versailles (Cameca IMS 7F):



- Primary energetic ion beam (0.5-20 keV
- Depth resolution of 1 to 5 nm
- **Destructive method**

- Already discussed by Vagelis. G in his talk yesterday: `https://indico.cern.ch/event/307015/session/7/contribution/30/material/slides/0.pdf`

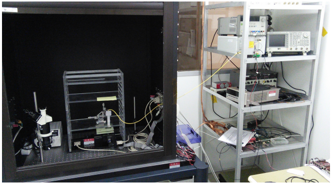
The Clean Room - test bench

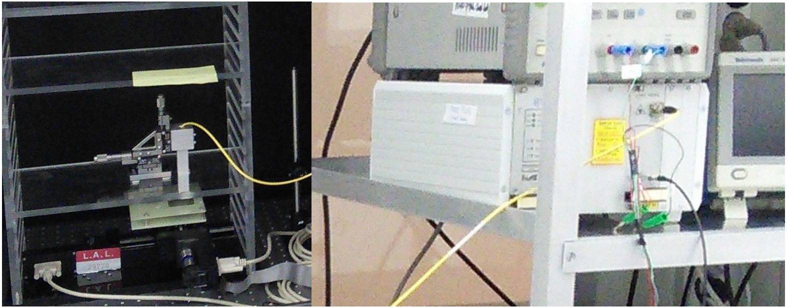


- Setup the USBPix test bench.
  - Test devices with the laser and strontium-90 source (a β-source) with external triggering.
  - Requires scintillators with photomultiplier tubes - these have arrived from CERN (see next photo).
  - NOTE: photo above is from before the setup was completed (looks tidier now!)

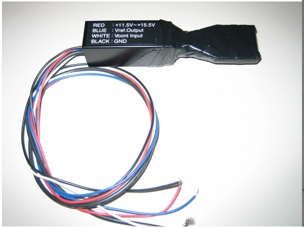
Laser System

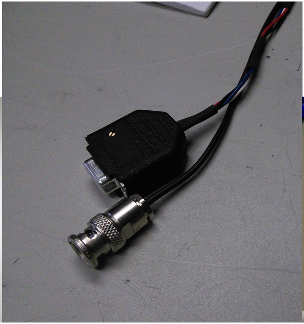
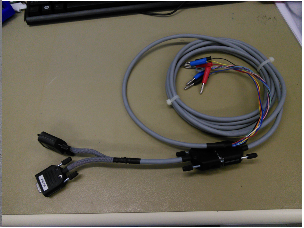
- Pulse generator Agilent 81104A
- Built at CERN by Maurice Glaser
- Wavelength: 1068nm (close infra-red)
- Power output at 1.72 V = 0.592 mW
- New lens required.





Trigger



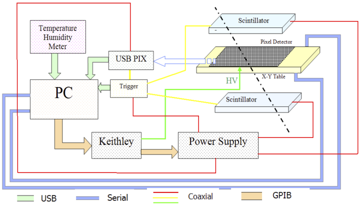



- The scintillators and photomultiplier tubes are from CERN.
- The final cabling has been performed at LAL.
- Two scintillators required. Three purchased / assembled to allow for redundancy in case of issues.

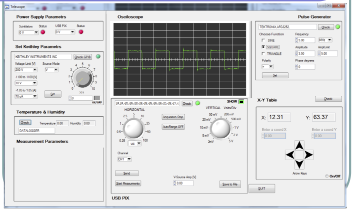
Trigger - cosmics

- We had a master's student (D. Hohov) at LAL who wrote LabView code to automate the test bench setup.

Flowchart for Telescope (cosmics)



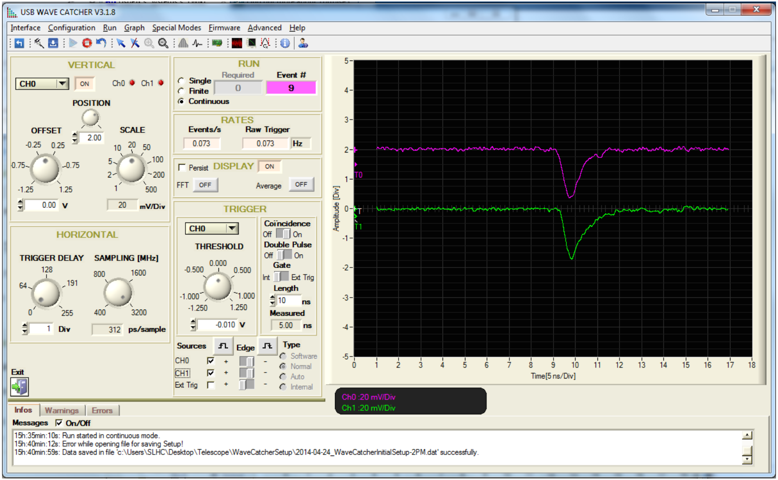
Screenshot of under development LabWindows programm



Diagrams by D. Hohov.

Trigger - wavecatcher

- Input is an analogue signal from the scintillators.
- Output as a digital trigger pulse.



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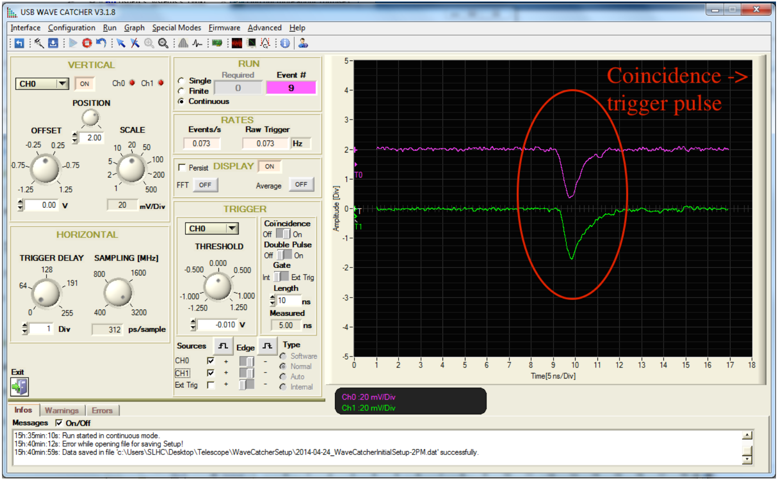
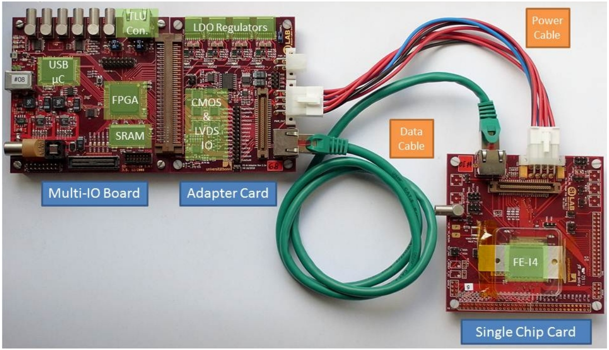


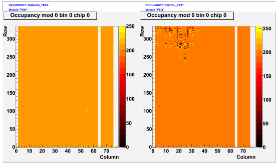
Laboratory Characterisation



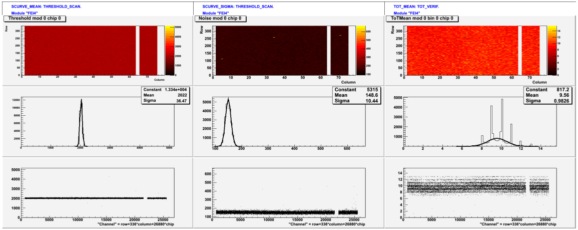
- USBPix is used to characterise the sensors.
  - Few hardware components, modular and portable.
- Data analysis using STcontrol software.

Laboratory Characterisation

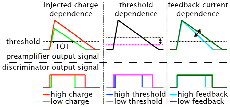
Analogue and digital:



Threshold, noise and Time Over Threshold (TOT):



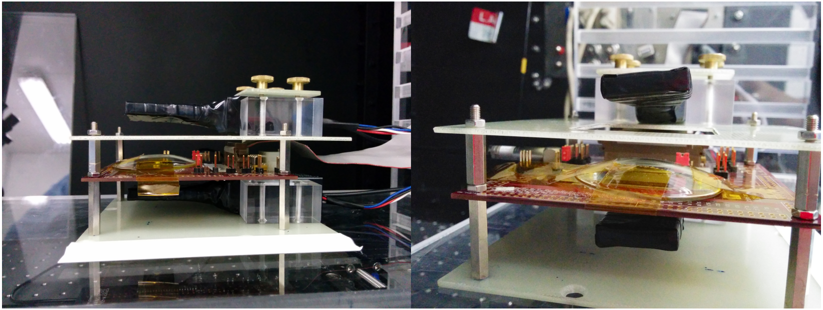
- The Analogue scan looks very good, but there is an issue in the top left of the Digital scan.
- This is understood and requires changing the Efuse_Cref parameter during the tuning.



How TOT and Threshold tuning effects the results.

TOT tuning could be better, but since this is just for proof of principle, it is fine for now.

Source scans - setup



- One scintillator above and one below.
- Top scintillator can be removed to place the source as close to the sensor as possible.
- Collimator plates are under production to focus the source beam to a small number of pixels.

Source scans

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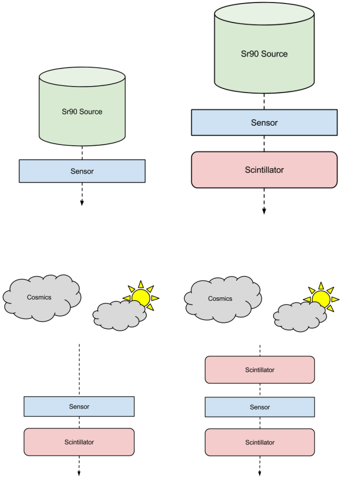
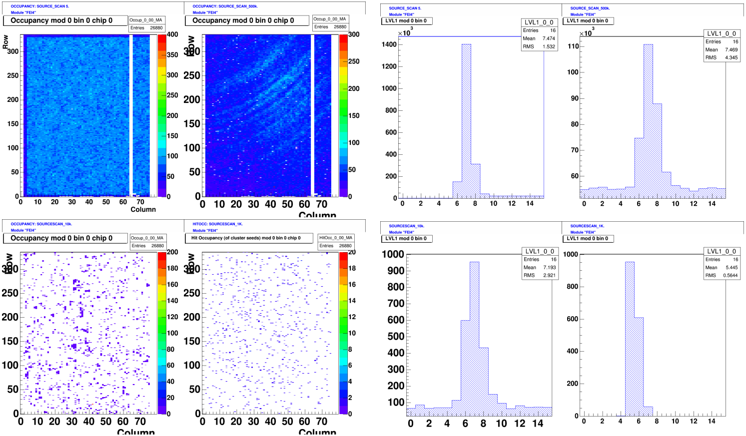
Performed scans with six different setups:
First four at perpendicular angles:

1. Source scan with Strontium 90
   - Self triggered
   - 500k triggers
2. Source scan with Strontium 90
   - One trigger
   - 500k triggers
3. Source scan with cosmics
   - One trigger
   - 10k triggers
4. Source scan with cosmics
   - Two triggers
   - 1k triggers



Source scan results

- Hit occupancy maps
- LVL1
- TOT



Clockwise:

Source scan with Strontium 90

- Self triggered
- 500k triggers

Source scan with Strontium 90

- One trigger
- 500k triggers

Source scan with cosmics

- One trigger
- 10k triggers

Source scan with cosmics

- Two triggers
- 1k triggers

Source scan results

- Hit occupancy maps
- LVL1
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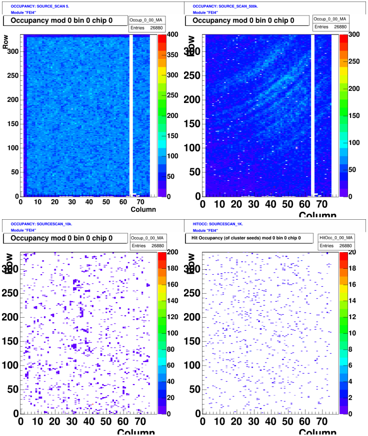

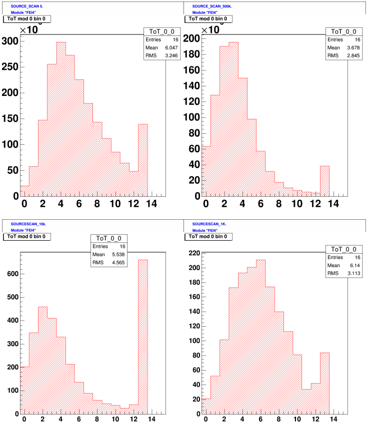

Clockwise:

Source scan with Strontium 90

- Self triggered
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Source scan with Strontium 90

- One trigger
- 500k triggers

Source scan with cosmics

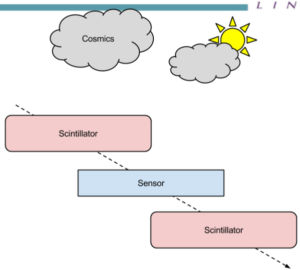
- One trigger
- 10k triggers

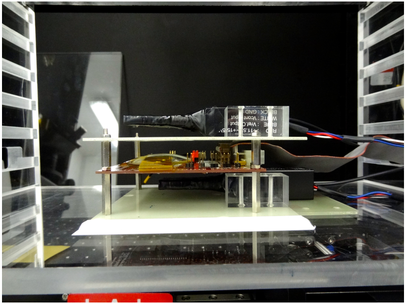
Source scan with cosmics

- Two triggers
- 1k triggers

Source scans

1. Source scan with cosmics
   - Two triggers
   - 500 triggers
   - Each scintillator overlaps half of the sensor
   - Data taking time = $\sim$ 1 day
2. Source scan with cosmics
   - Two triggers
   - 500 triggers
   - Neither scintillator overlaps the sensor
   - Data taking time = $\sim$ 2 days





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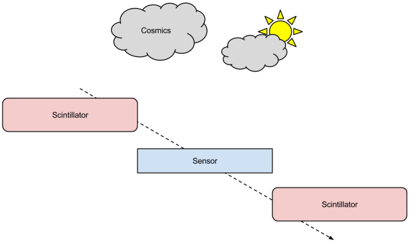
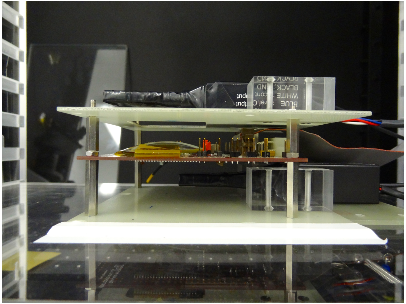
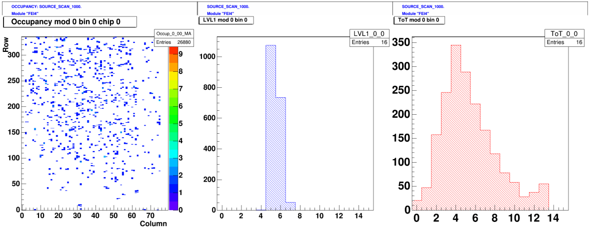




Source scan results



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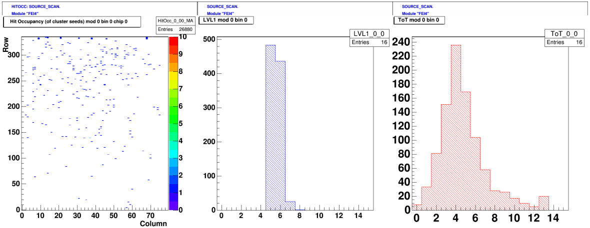
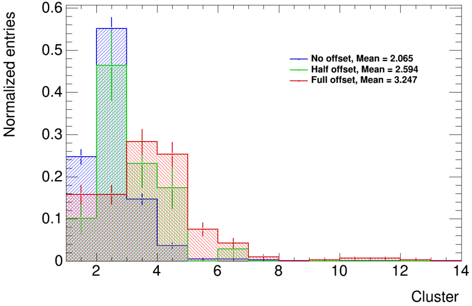


- Source scan with cosmics
  - Two triggers
  - 500 triggers
  - Neither scintillator overlaps the sensor

Source scan results

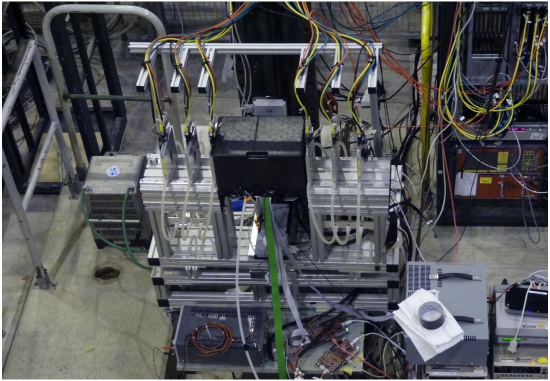
Cluster Size as function of scintillator offset:



- Increase of cluster size as scintillator gap is increased (as expected).
- With thanks to Marco B. for sharing his adaption of Christian G.'s clustering programme. Now work offline & offsite, which is great for us Windows-challenged (Mac) people.
- More people want to do these studies, please contact me to discuss.

Future Plans

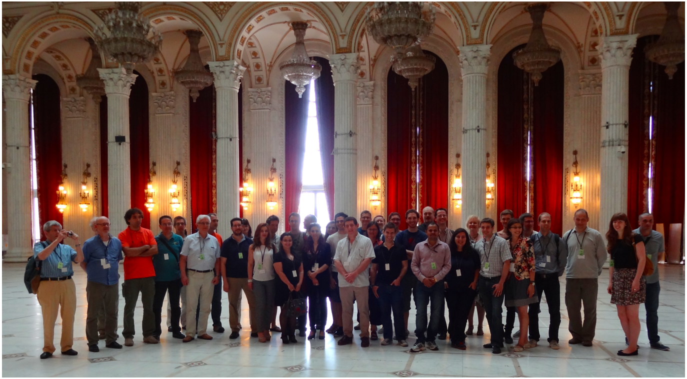
- Test beam measurements with CiS modules with alternative bias rail layouts and with the new production when it arrives (hello Marco - I will send you an email!).
- Afterwards, irradiate modules and retest.



Summary

- The setup is working well and taking sensible data.
- The triggering system is good and the data rate is as expected.
- Can take cosmic scans at angles.
  - Limited by time. Since the greater the offset of the scintillators, the lower the data taking rate.
  - Intend to implement a tilt to the xy-table to achieve same results with increased rate, but this increases the distance of the scintillators from the device.
- There are a few issues with data loss from power cuts and computer issues
  - since the data taking period can be very long, using the source instead of replying on cosmics is a faster solution.
- The next stage is to finalise the setup with the laser system (new fibre optic cable required) and develop a TCT system.
- Then the setup can be used with other FE-I4 devices and especially **irradiated** devices.

Thank you for your attention



Any questions?

Backup