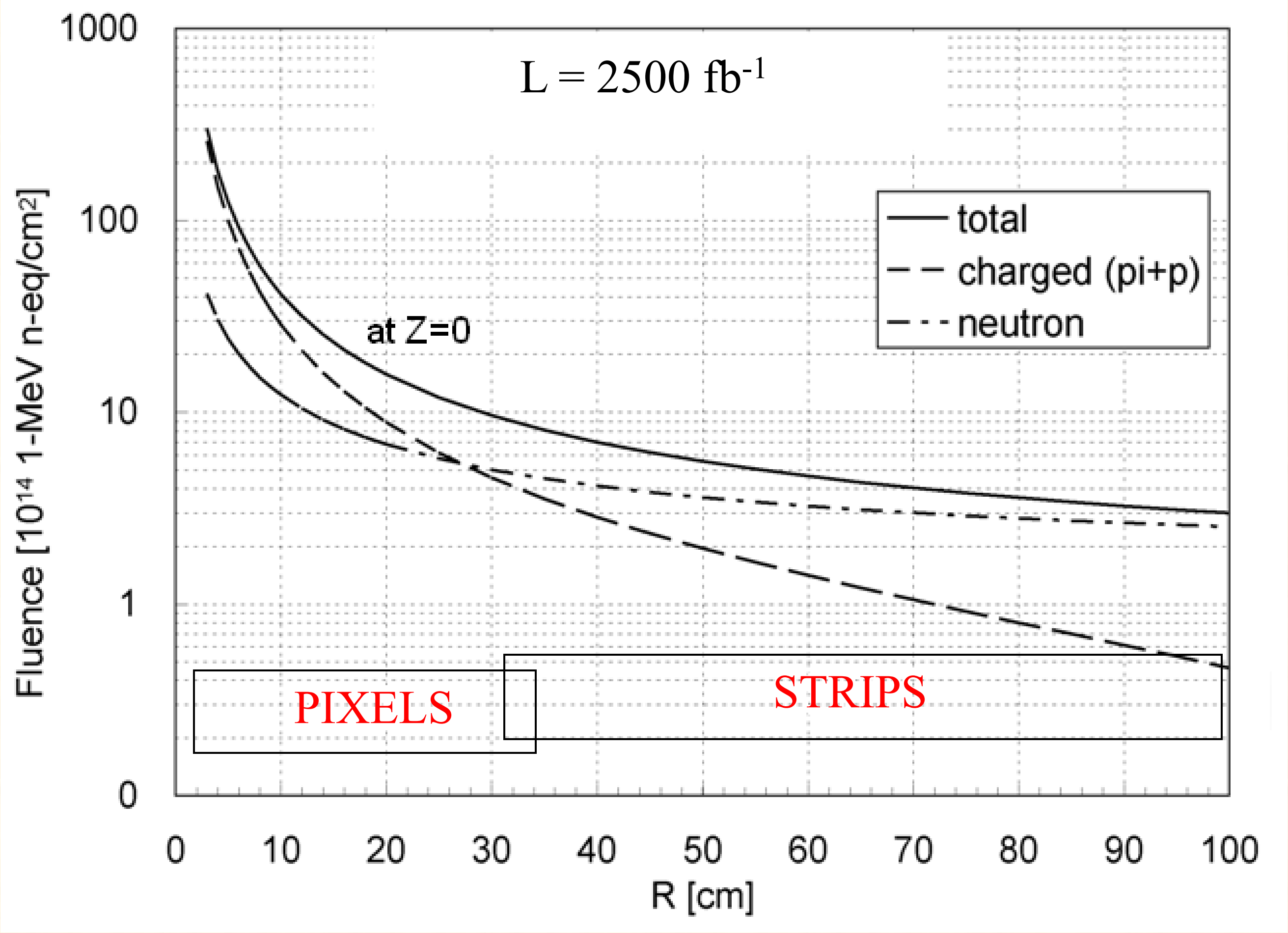
Sensor Studies for SLHC Using CMS Pixel-Based Telescope

Lorenzo Uplegger

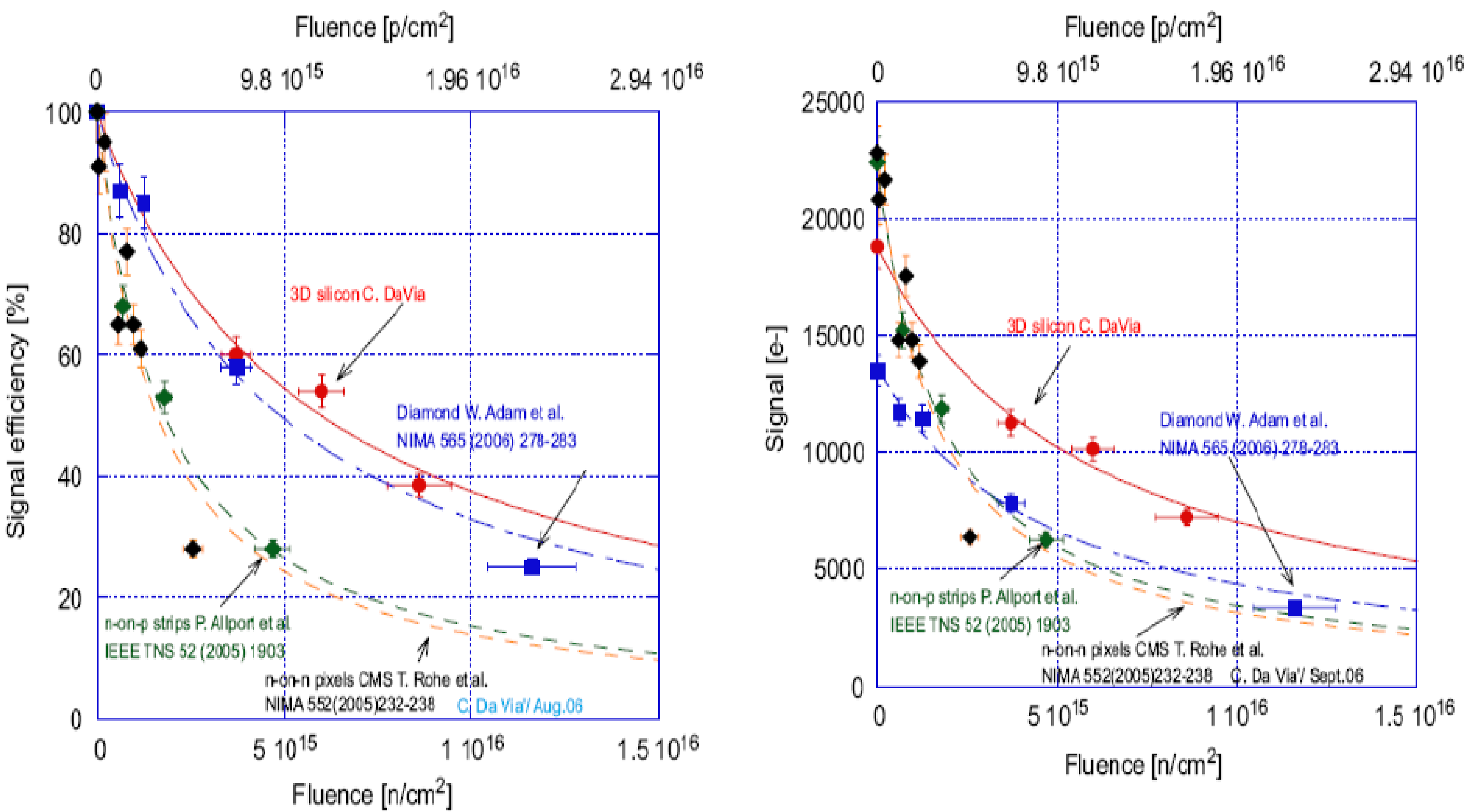
On behalf of the T992 test-beam experiment at Fermilab

Particle fluence at SLHC



At R=5cm the radiation fluence will be around 10^{16} n-eq/cm^2!!

Radiation Hardness of Sensors



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Test-beam Goals

• Our goal is to test the candidates for the SLHC upgrade before and after irradiation to compare the performances and understand if we have a technology capable of withstanding the enormous fluences. We are mainly focusing our efforts on three different sensor types:

- Diamond sensors
- 3D sensors
- MCZ Planar silicon sensors

• Big global effort on Sensor R&D for the SLHC

- RD42 (diamond)
- 3D consortium (3D sensors)
- ATLAS, CMS and LHCb

• We are testing all the different sensors using the same Read Out Chip (ROC) in order to have a fair comparison between all candidates

• Our effort is open to all, independent of their experimental affiliation or interest in any particular technology

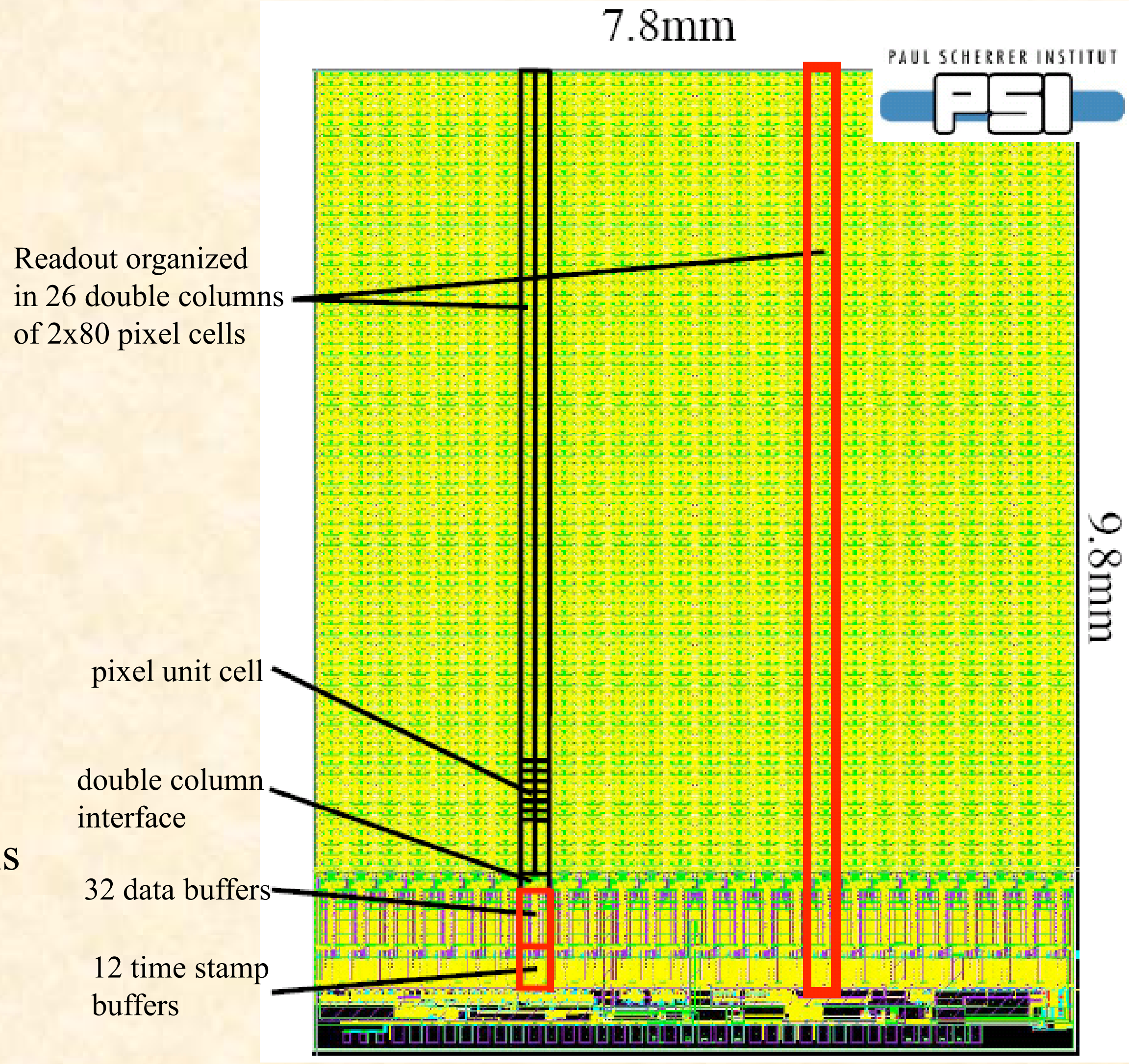
Collaboration

- Many different institutions and collaborators for the CMS pixel upgrade
  - Fermilab
    - S. Kwan, A. Prosser, L. Uplegger, R. Rivera, J. Andresen, J. Chramowicz, P. Tan, C. Lei,
  - Purdue
    - E. Alagoz, O. Koybasi, G. Bolla, D. Bortoletto
  - Colorado
    - M. Dinardo, S. Wagner, J. Cumalat
  - Texas A&M
    - I. Osipenkov
  - Milano
    - L. Moroni, D. Menasce, S. Terzo
  - Torino
    - M. Obertino, A. Solano
  - Tata Institute
    - S. Bose
  - Buffalo
    - A. Kumar, R. Brosius
  - IHPC Strasbourg
    - J. M. Brom
  - Florida State University
    - S.Tentindo

- Non-CMS T992 participants:
  - Syracuse
    - J. Wang, M. Artuso

Read-Out Chip

- 0.25µm IBM CMOS rad hard technology
- 100x150 µm pixel cell size which provide a spatial resolution of ~10µm in rφ and ~20µm in z
- 52x80 cells organized in double columns
- 32 data and 12 time stamp buffers
- Data are encoded on 6 analog levels

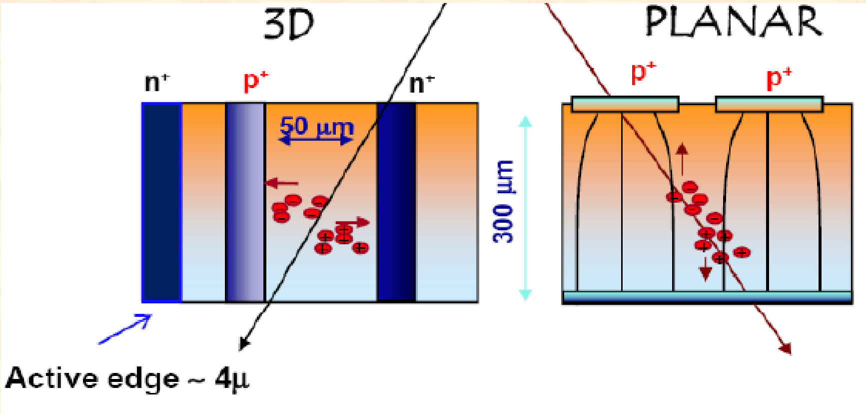


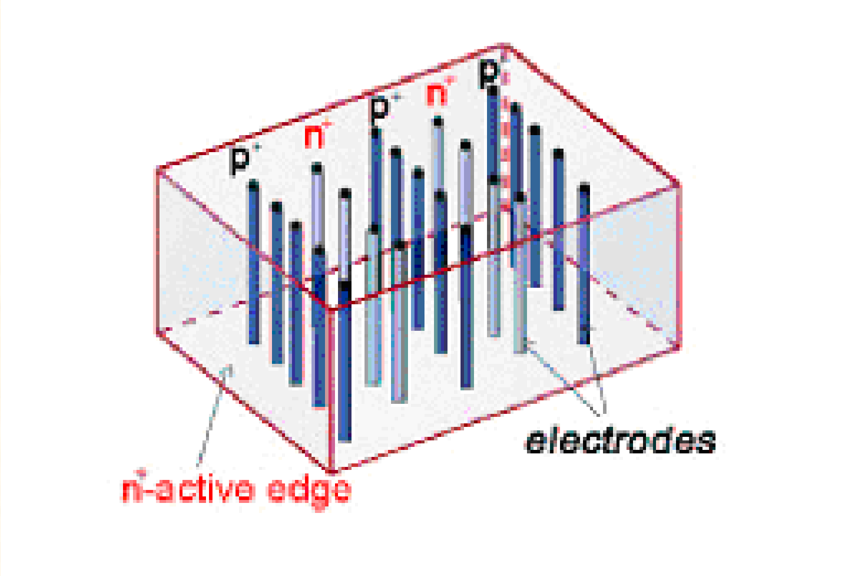
3D Sensors

First proposed by Sherwood Parker in the mid-90s:

- "3D" electrodes -> narrow columns along the detector thickness
  - ➢ diameter: 10 µm, distance: 50-100 µm

- **Lateral depletion: great for rad-hard**
  - ➢ Lower depletion voltage
  - ➢ Fast signal

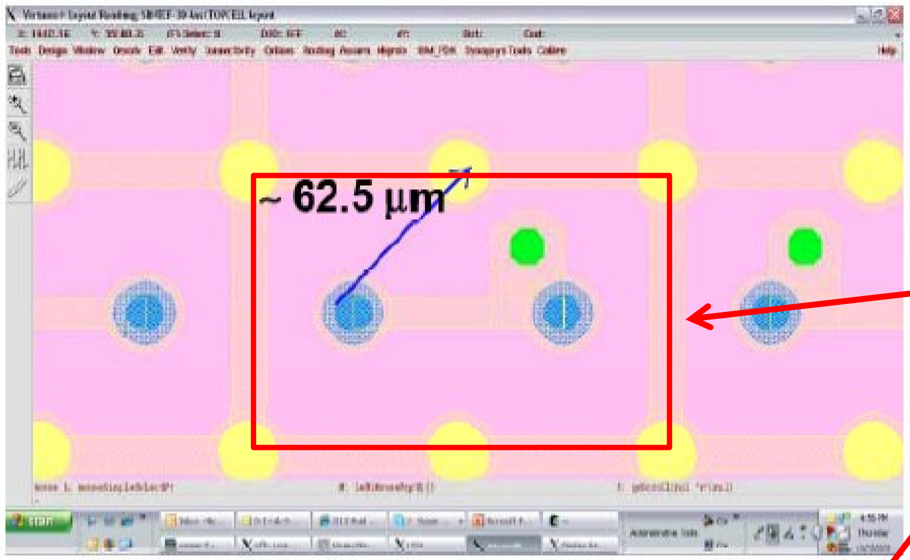


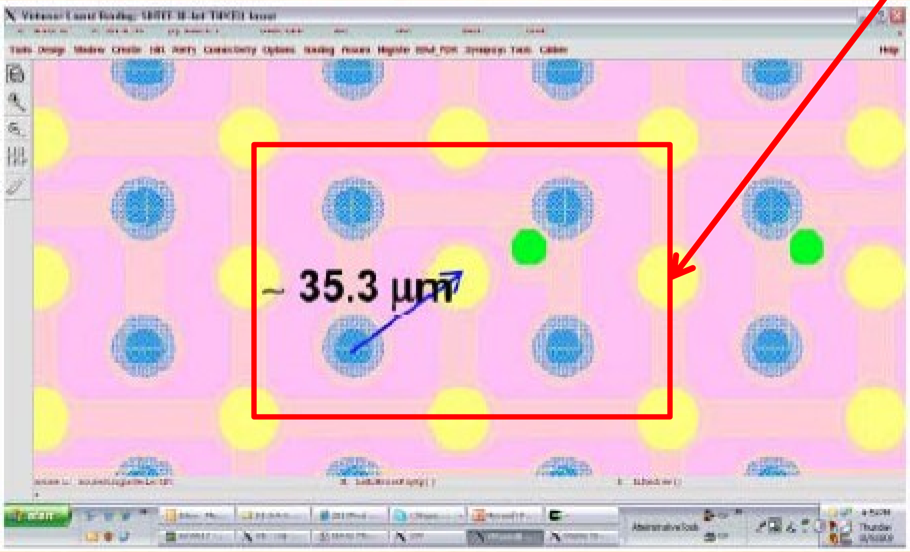


- 3D detectors also allow the implementation of the "Active Edge" concept
- Interest in the Forward physics community
- Active Edge concept can lead to improved layout geometries

CMS 3D Sensors

• 3D sensors from SINTEF and FBK

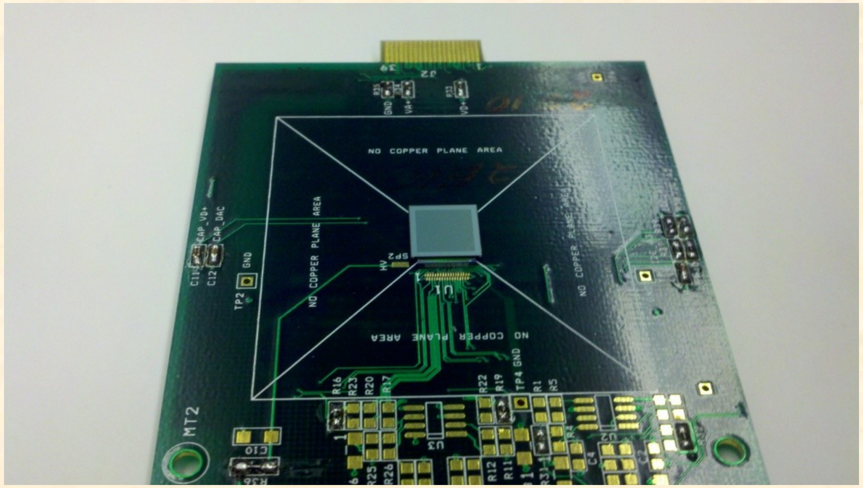




• CMS pixel size is 100 µm x 150 µm

• Different designs:
- ➢1 column pixel
- ➢2 columns pixel
- ➢4 columns pixel

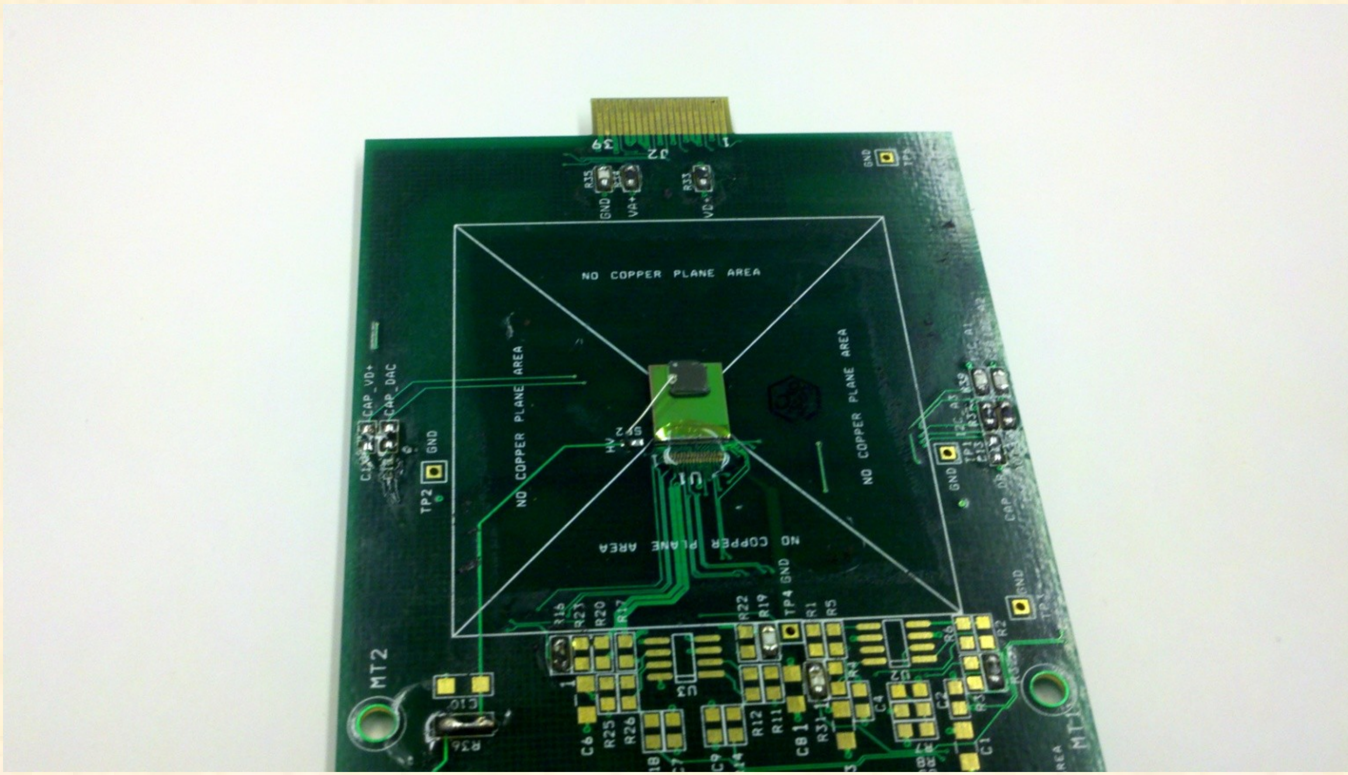
3D sensor produced at SINTEF



Diamond sensor

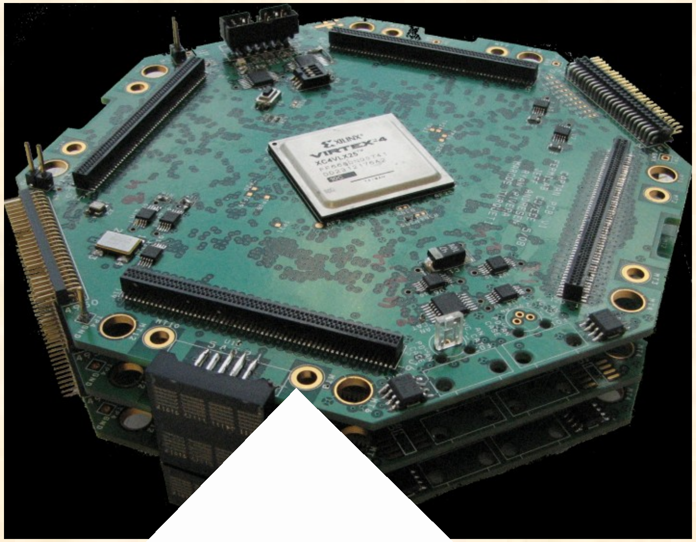
- Diamond sensor LC500 bump-bonded to the CMS pixel ROC

- We have available for testing both single and poly crystals diamonds



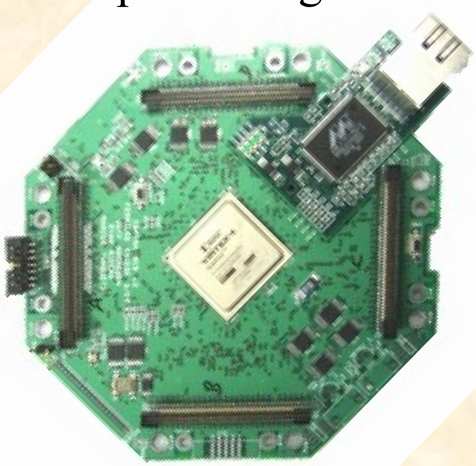
Setup

• The setup is the CAPTAN (**C**ompact **A**nd **P**rogrammable da**T**a **A**cquisition **N**ode) based pixel DAQ



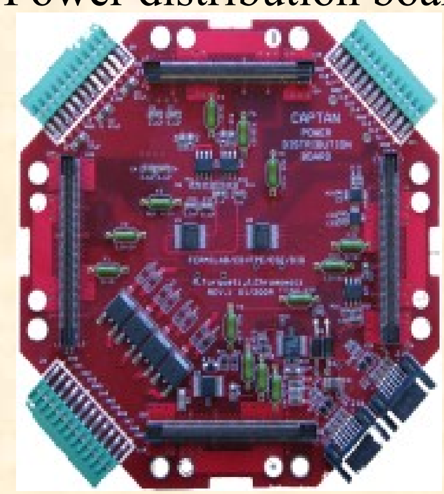
The CAPTAN system is based on a set of core boards that are communicating through a vertical bus

Node processing board



Data conversion board

Power distribution board

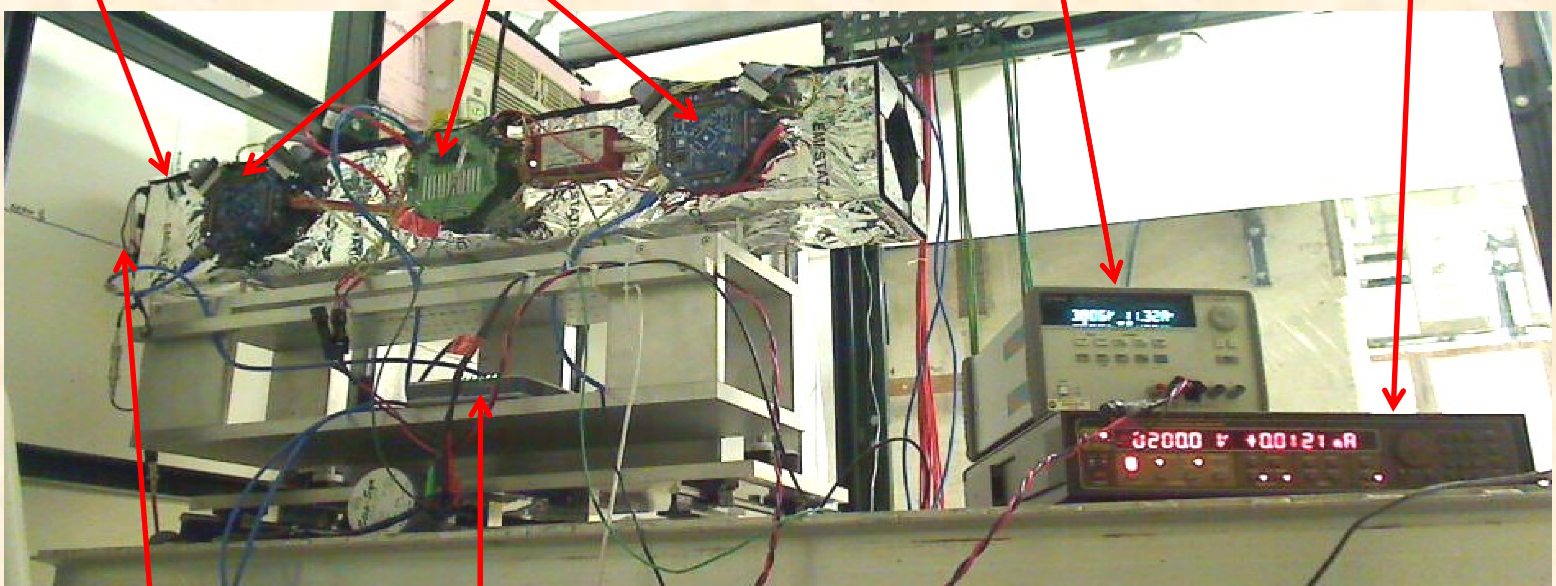


Setup

• The setup is part of the Meson Test-beam facility (MTEST) at Fermilab.

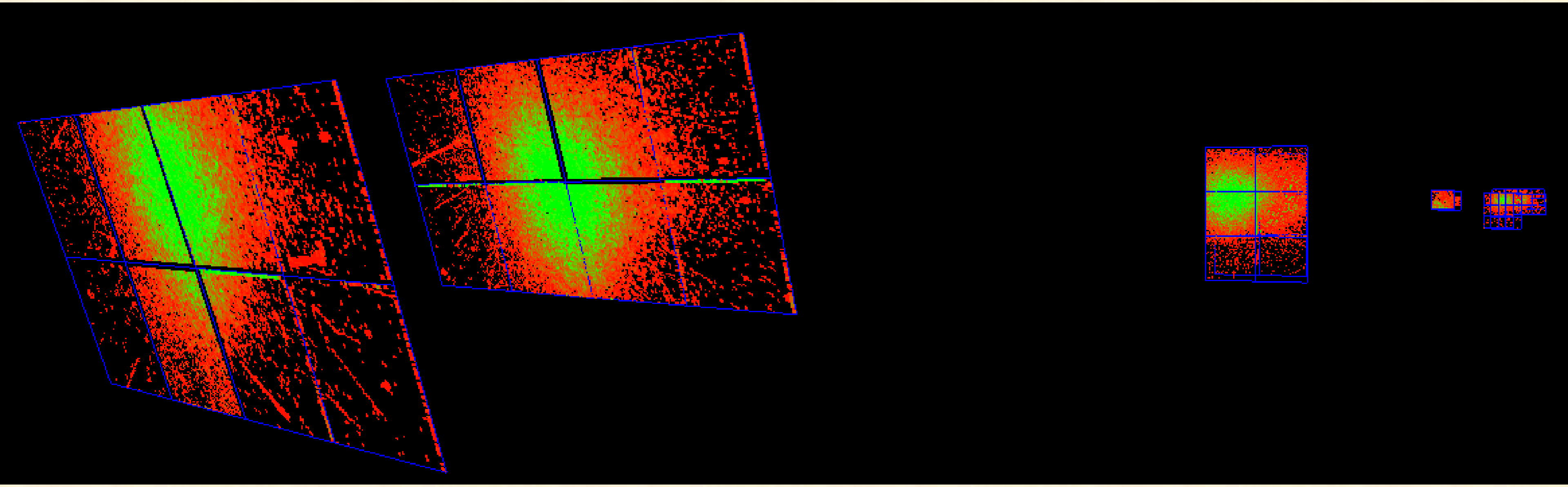
• We have an entire pixel telescope with 8 silicon planes, 4 upstream and 4 downstream, and we can place 2 Detectors Under Test (DUTs) in the middle.

• 4 planes have the narrow pixel size (100µm) measuring the X coordinate while the other 4 are measuring the Y coordinate. All planes are bent at an angle of 24° to maximize charge sharing and improve the resolution



Online quick check

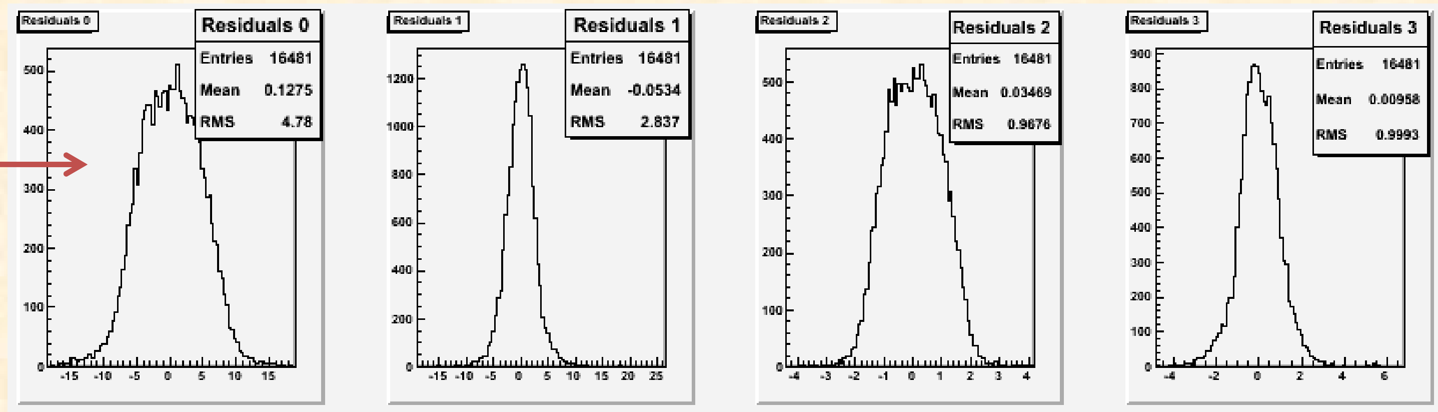
Our software allows us to verify online that we don't have particular problems…



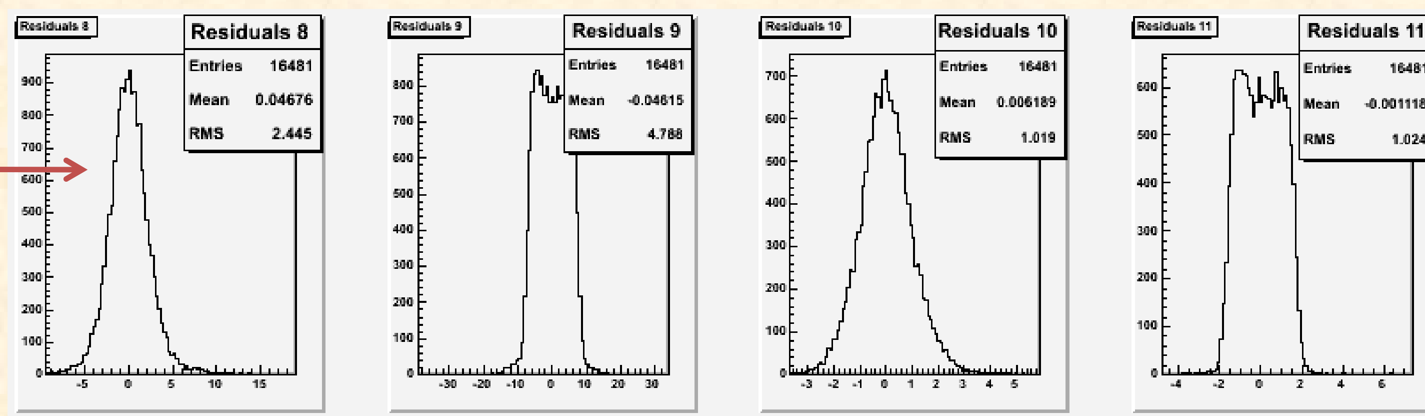
Telescope Alignment

• The alignment software is already capable of reaching a good precision (residuals ~20μm) but we are still working on it to improve its capabilities.

Y measuring telescope plane



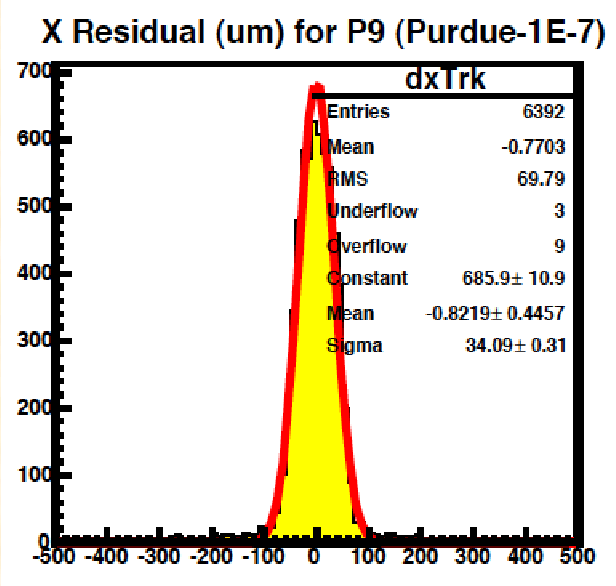
X measuring telescope plane

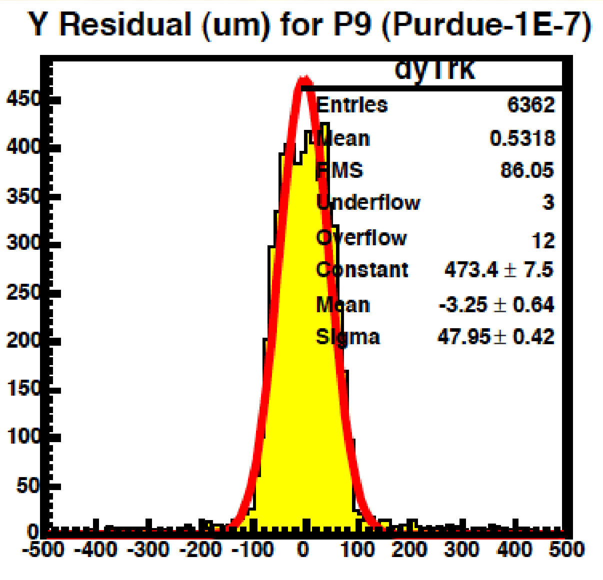


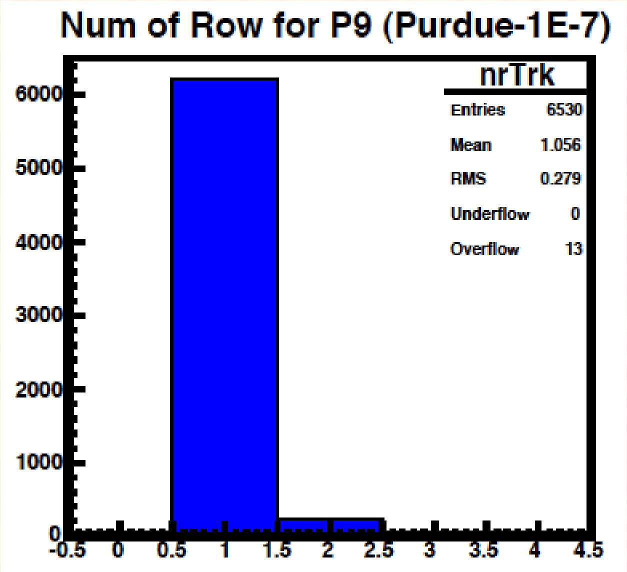
Preliminary results 3D

• The analysis is ongoing and we only have few results.
• Everything looks as expected and we are getting the resolution expected for a single hit resolution when the DUT is facing the beam at 0°

3D 1E detector residuals







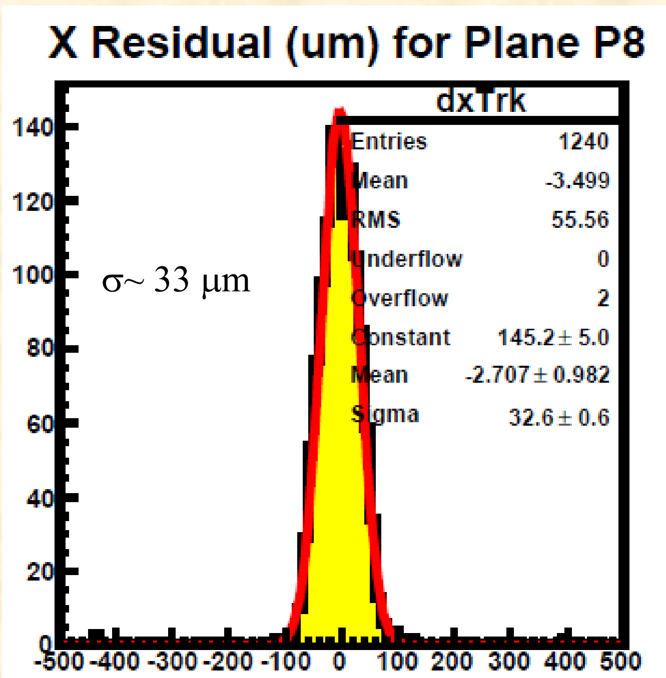
$X_{trk} - X_{hit}$ (μm) $Y_{trk} - Y_{hit}$ (μm)

• While both 1E and 2E configurations are working fine, none of the 4E design have been working correctly!

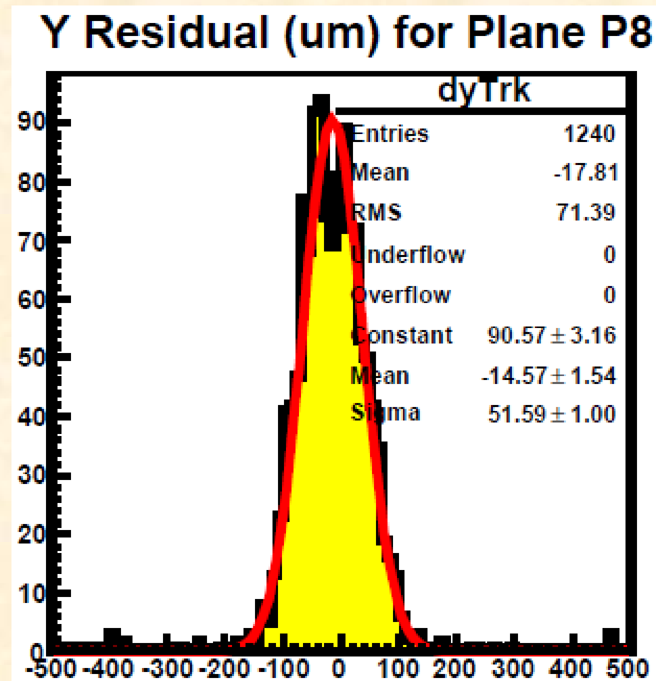
Preliminary results Diamond

• Residuals are in agreement with the single hit resolution expected when the detector is facing the beam at 0°

Diamond detector residuals



$X_{trk} - X_{hit}$ (μm)



$Y_{trk} - Y_{hit}$ (μm)

Conclusions and plans

• None of the two 3D detectors with 4E electrodes configuration worked reliably, but we tested seven other 3D sensors with 1E and 2E electrodes configuration and also 1 diamond sensor.

• We will irradiate these detectors at LANL at the beginning of August with a 800 MeV proton beam

• Since we have many detector in hand we'll irradiate them at different doses

• In October we'll be back in the test-beam to test these irradiated devices and to characterize new prototypes

• Finally, after we finalize our offline analysis programs, we'll be able to characterize in detail the detectors before and after irradiation!