Pixel Detector Measurements at Cern

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Measurement interests

- Studies of different detector materials for (very) high radiation
  - Close collaboration between CERN group on ATLAS upgrade, sensor RD groups (RD50,RD42) and CERN PH-DT2
- Interests in the following specific areas

1. Performance evaluation of different sensor types with sLHC front-end electronics ("the interface sensors to electronic")
2. Characterisation of sensors before & after irradiation in lab tests with sLHC front-end electronics (using currently the ATLAS FE-I3 pixel chip)
   1. Comparative before/after irrad under identical conditions
   2. Warm and cold tests in lab measurements
3. Test beams with different sensor types
   1. CERN team strongly supports testbeam activities of all detector types already
   2. Several different upgrade RD projects (planar, 3D, diamond) benefit from each other using same test setups and common running (e.g. shared use of telescope, device preparation and characterization before testbeam, …)

Detectors and collaboration

- **ATLAS 3D sensor** → C. Da Via, O. Rohne, G. Darbo, G.F. Dalla Betta et al.

  Measurements on ATLAS layout 3D Stanford and 3D IRST/Trento detectors

- **Planar pixel sensor** → N. Wermes/ Bonn, C. Goessling/Dortmund

  Sofar on “standard” n-in-n detectors, n-in-p / thin next

- **CVD Diamond pixel** → H. Kagan, M. Mikuz, W. Trischuk, J. Moss /RD42 & Bonn.

  Full-size pixel module poly-crystalline CVD and single-crystal singe-chip module

Pixel Lab Setup

ATLAS 3D sensors

sc Diamond pixel

n-in-n pixel sensor

Thanks to ATLAS Pixel collaboration for their strong support !

- **2 Pixel test station (based on TurboDAQ system) with Source:**
  - Climate chamber + Liquid cooling
  - Source: a) Sr90 trigger independently triggered by scintillator
    b) Am 60KeV self triggered for calibration

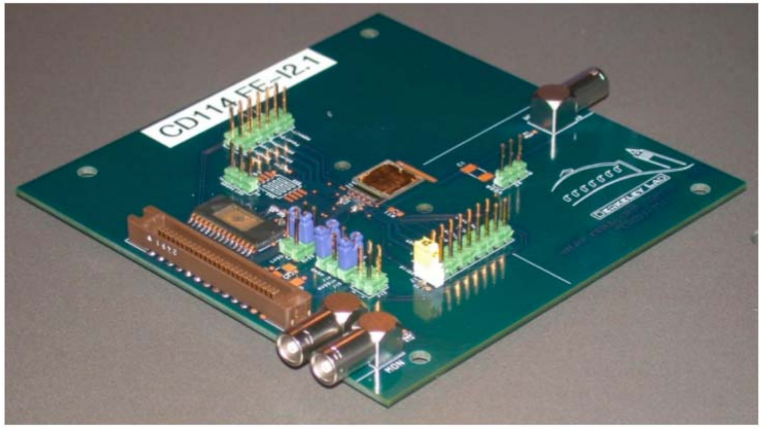
  for calibration and electronic tests
  - mobile system, on-loan from Genova

Single-chip assemblies

- Mostly use single-chip assemblies at the moment under identical test conditions

3D IRST & Stanford sensor	planar pixel sensor	sc Diamond pixel

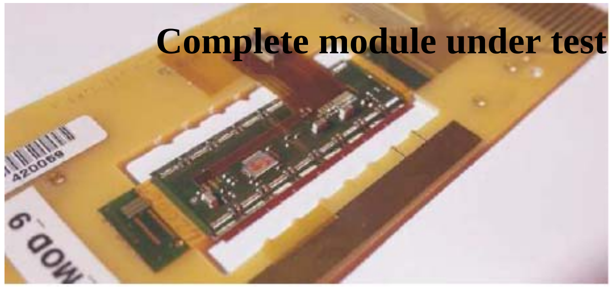
Pixel size: (50x400) um^2
Pixel 2880, arranged in 18x160

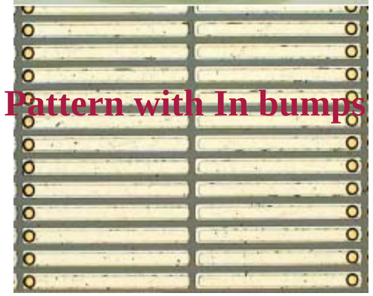


3D and diamond sensors are bump bonded on ATLAS FE-I3
n-in-n pixel sensor is bump bonded on ATLAS FE-I2.1

Full Size Diamond Pixel Modules

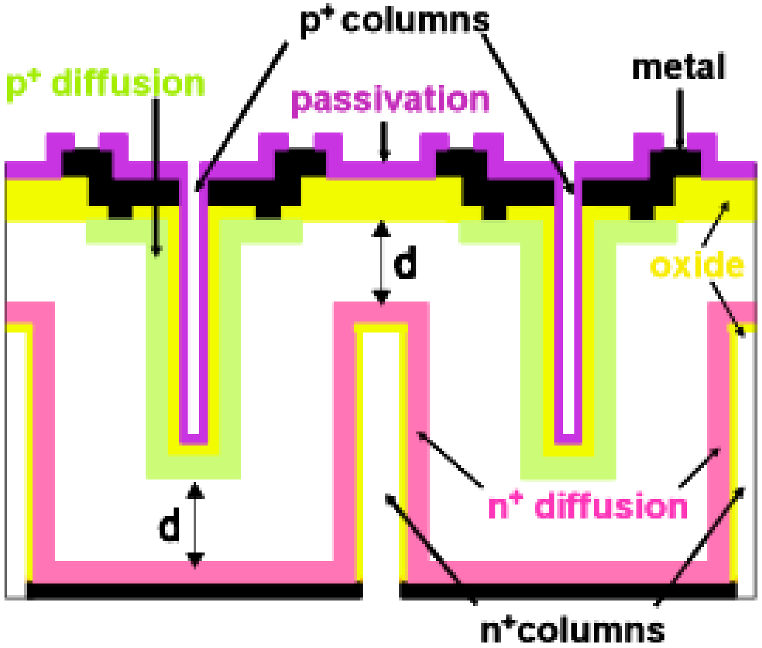
- 3 modules built with ATLAS pixel chips @ OSU, IZM and Bonn
  - 1 full (16 chip) pCVD module
    - Test beam at DESY and CERN
    - Irradiated to 5×10^{14} p/cm^2
  - 1 single-chip scCVD module
    - CERN SPS test beam
    - Irradiated to 5×10^{14} p/cm^2
    - SPS test beam 3 weeks ago
  - 1 single-chip pCVD module
    - Irradiated to 2×10^{15} p/cm^2
    - ✯ Electronics heavily damaged





Results on bench measurements

- Recently started to do first measurements on FBK-IRST 3D sensors
  - Leakage currents
  - Noise versus bias voltage
  - Calibration and first source tests with 241 Am source



- DDTC on p-type substrate
- structures with 2, 3 and 4 electrodes per pad
- thickness 220um
- column overlap ~ 100um

- bump-bonded to ATLAS FE-I3 readout chip

See "**Developments on 3D detectors at FBK-IRST**"
M. Boscardin, L. Bosisio, G-F. Dalla Betta, C. Piemonte, S. Ronchin, A. Zoboli, N. Zorzi
FBK-IRST, Trento
INFN and University of Trento
INFN and University of Trieste

IRST 3D sensor with 241Am

4E response to Am^{241}

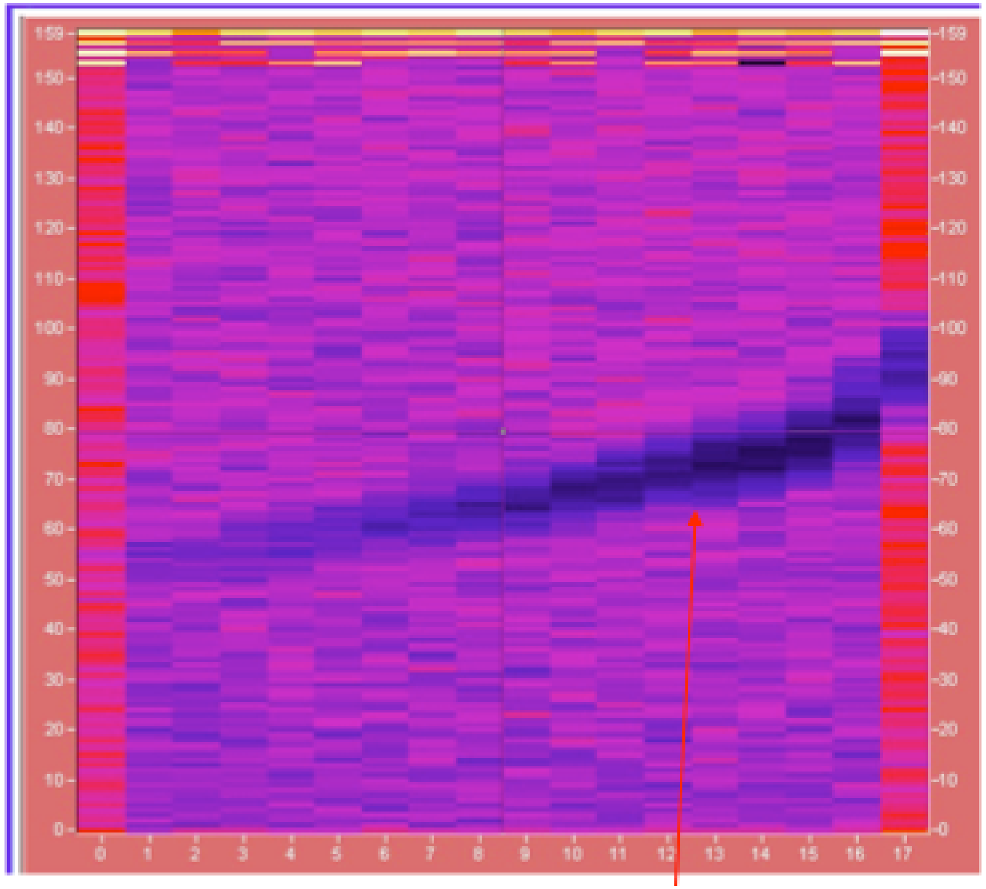


Image of needle over IRST 3D detector imaged by 241Am source

Depletion voltage ~11V

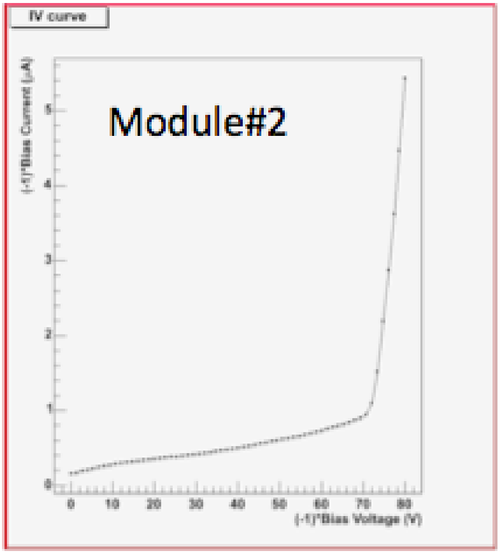
Type	Module	Test
2E	2	IV, noise vs HV, Am241 source scan
2E	4	IV and noise vs HV
2E	6	IV, noise vs HV, Am241 source scan
3E	1	IV
3E	5	IV, noise vs HV
3E	7	IV, noise vs HV, Am241 source scan
4E	3	IV and noise vs HV
4E	8	IV, noise vs HV, Am241 source scan
4E	9	IV, noise vs HV, Am241 source scan

IV characteristics

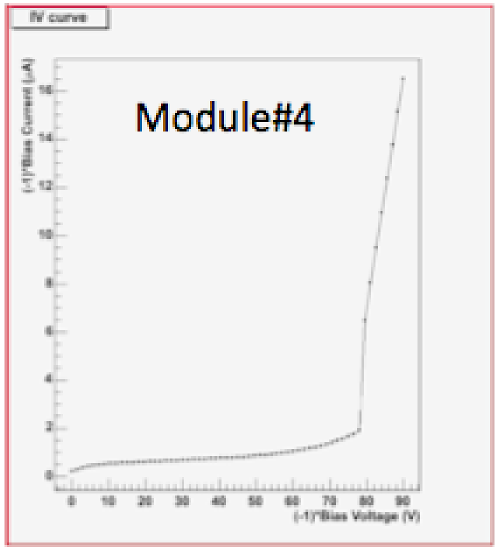
2E-type: I-V scan

Breakdown: ~ 70 ÷ 80 V

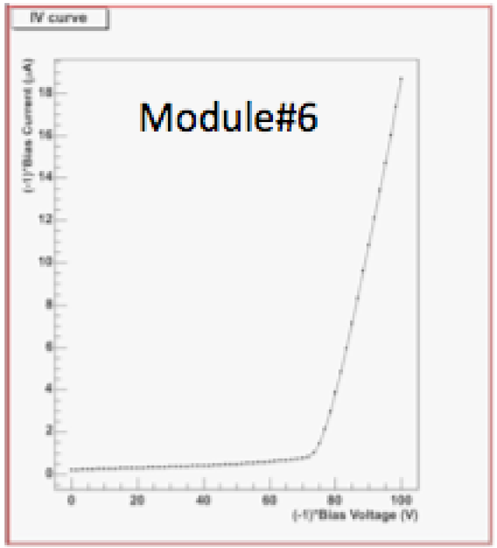
Module #	Sensor ID	Type	FE	Wafer	R HV	Place	Note
2	S2	2E	2111	EH4IYBX	1M	Cern	
4	S4	2E	11081	EH4IYBX	1M	Genova	
6	S1	2E	8101	EH4IYBX	1M	Genova	for irradiation



Module #2 has been tested, source test included

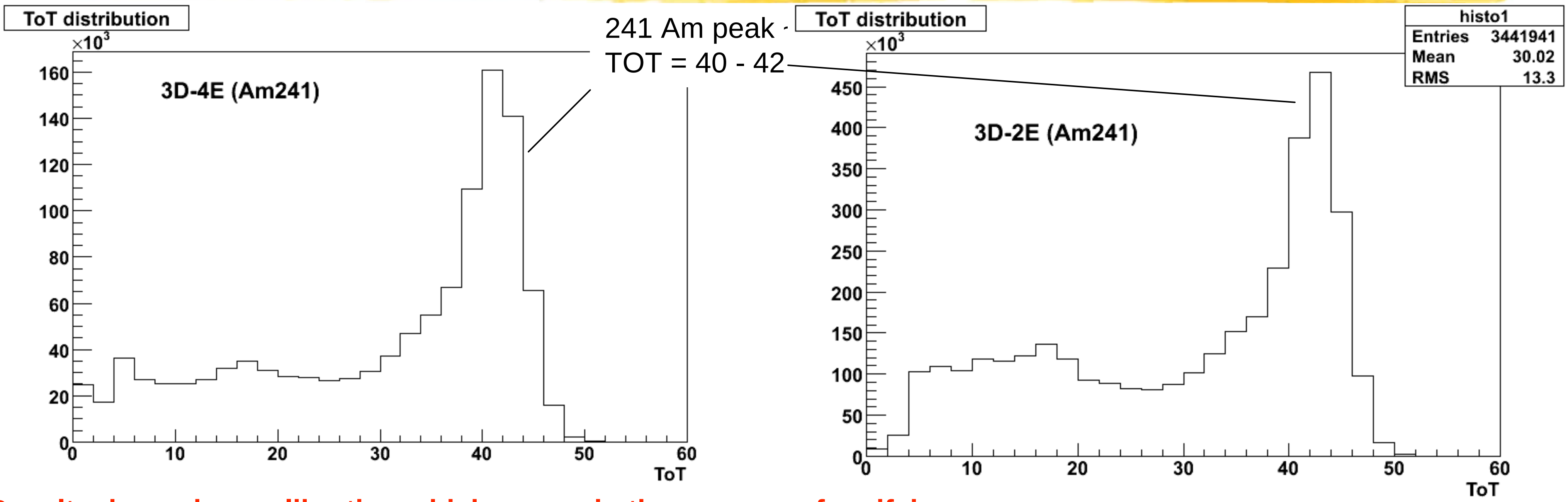


Module #4 only IV scan has been done (problems with FE → to be investigated)



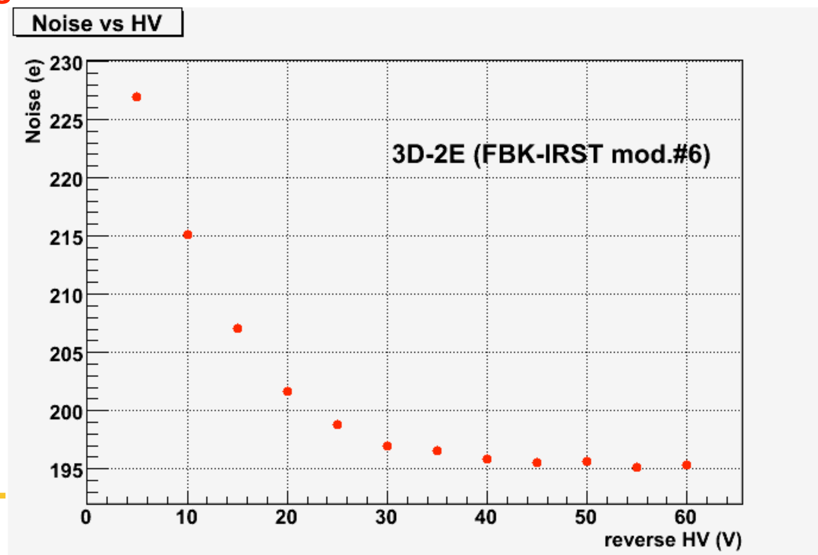
Module #6 has been tested, source test included

Very Preliminary TOT measurements with 241Am



Results depend on calibration which we are in the process of verifying

Type	Module	Test
2E	6	IV, noise vs HV, Am241 source scan



2E @ room temperature FE tuned at 60ToT/20ke-

<Th> = (3299 ± 41)e-

<Noise> = (197 ± 10) e-

Noise of different structures

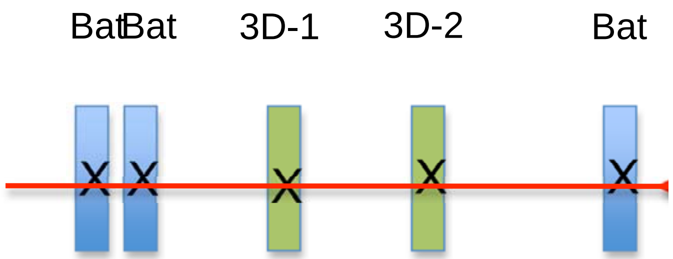
VERY PRELIMINARY!

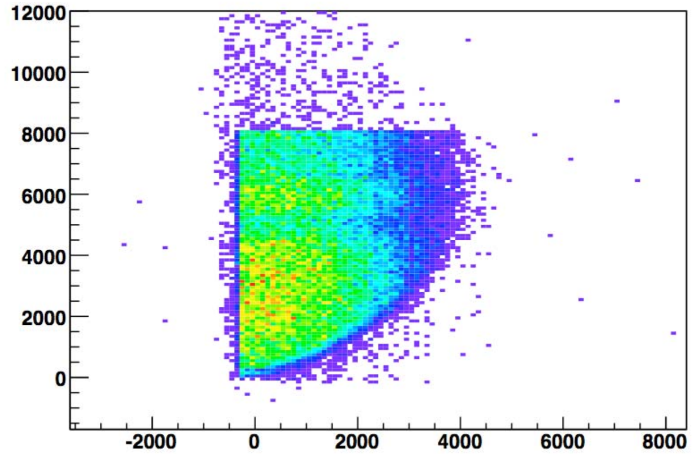
Type	Module	Threshold	Noise	Measurements
2E	2	3183 ± 68	157 ± 8	IV, noise vs HV, Am241 source scan
2E	4	---	---	IV and noise vs HV
2E	6	3299 ± 41	197 ± 10	IV, noise vs HV, Am241 source scan
3E	1	---	---	IV
3E	5	3287 ± 40	207 ± 8	IV and noise vs HV
3E	7	3307 ± 48	238 ± 10	IV, noise vs HV, Am241 source scan
4E	3	---	---	IV and noise vs HV
4E	8	3111 ± 70	232 ± 12	IV, noise vs HV, Am241 source scan
4E	9	3310 ± 62	225 ±11	IV, noise vs HV, Am241 source scan

Test beam studies on 3D in ATLAS 3D collab.

- Participated in beam tests and analysis of different pixel sensors

ATLAS 3D Stanford sensor





Beam

- CERN SPS North-area H6 test beam
- Minimum ionizing particles (MIP): 180 GeV/c $\pi^{\pm}$
- Beam period: June 2008

Trigger and timing

- Overlap coincidence
- Veto counter for shower suppression
- Trigger phase measurement (TDC)

Bonn ATLAS Telescope (BAT)

- Developed for ATLAS Pixel test beams
- Two-sided Si micro-strip
- Strip pitch: 50 μm, analog read-out
- Point resolution: 5 μm (estimated)

Sensors: 3E-C, 3E-G and 3E-S (irradiated)
- Edge effects
- Testing irradiated chip
- Bias scans

→ H. Gjersdal and O.Rohne : Test beam data reconstruction & analysis.

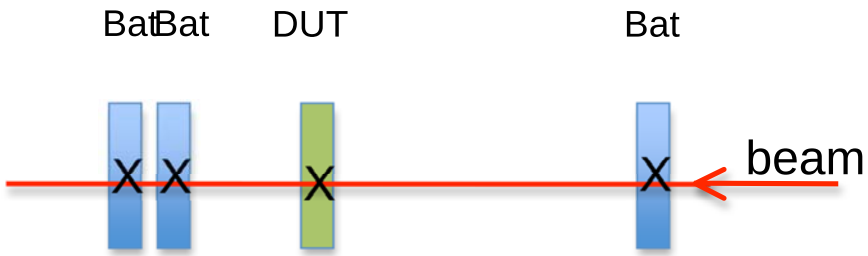
Ian McGill

Beniamino Di Girolamo

Bonn University with IZM

E. Bolle, B. Buttler, C. Da Via, O. Dorholt, S. Fazio, H. Gjersdal, J. Hasi, A. La Rosa, C. Kenney, D. Miller, C. Young, V. Linhart, H. Pernegger, T. Slavicec, K. Sjobak, M. Tomasek, S. Watts

Test beam studies on planar sensors and CVD diamond in coll. with RD42 and Bonn/Genova



sc Diamond pixel

~ 370 runs (mainly short runs ~ 5K triggers)

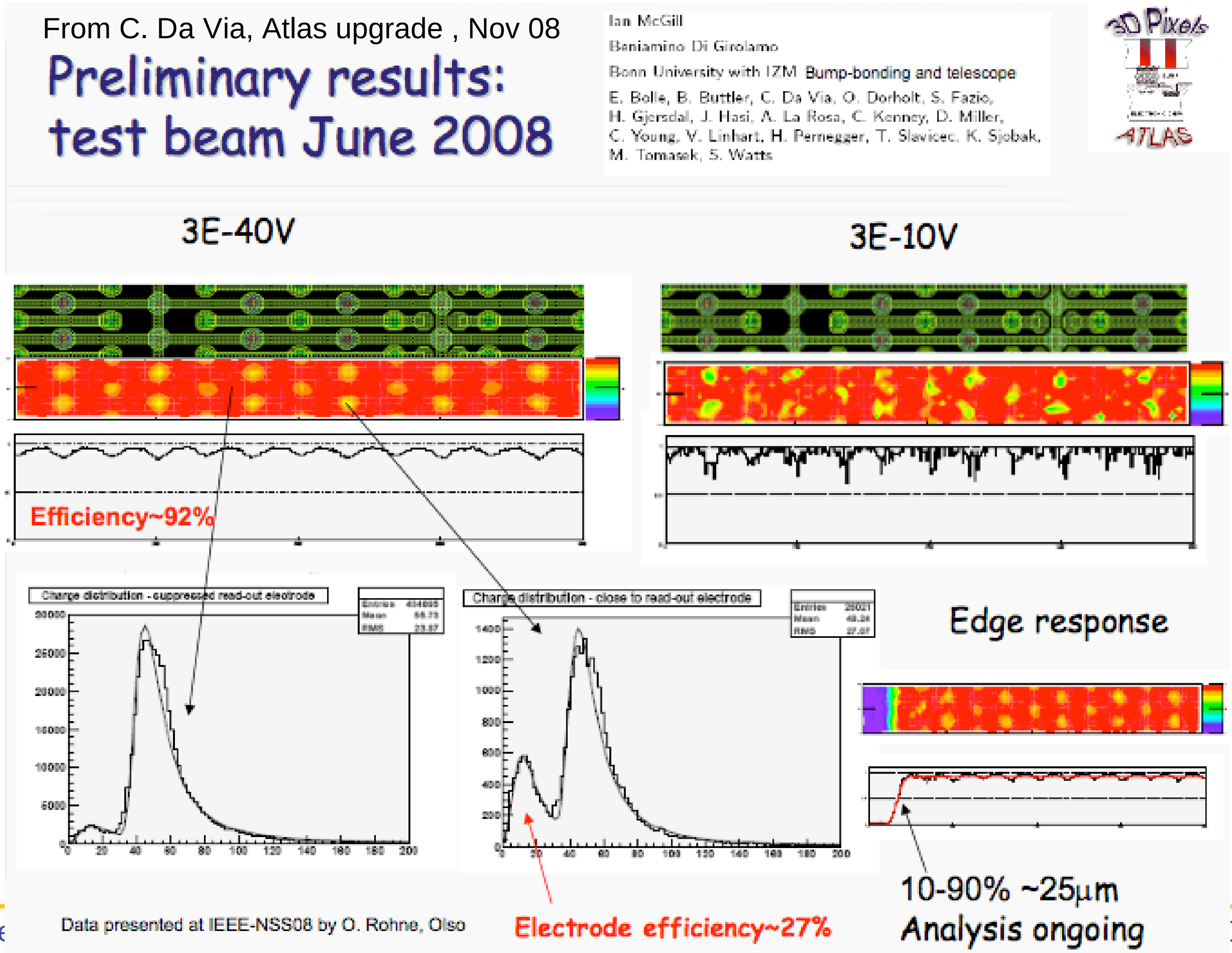
Goals:
- Run cold (~ 10°)
-Angle scan at 0°, 10°, 15°

n-in-n pixel sensor

~ 120 runs (mainly short runs ~ 5K triggers)

Goals:
- Angle tilt at 0°
- Used as reference sensor

ATLAS 3D Stanford detector in TB

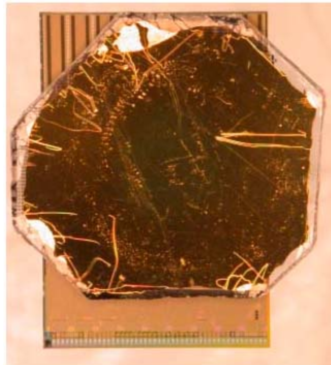


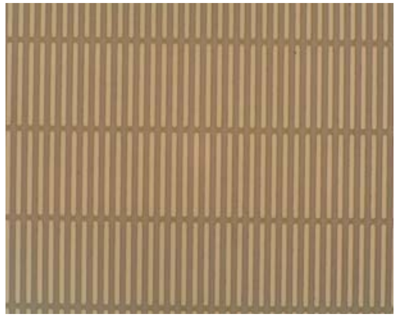
Single-crystal CVD diamond Pixel detector

- scCVD diamond bonded to FE-I3 (IZM)

Testbeams	Irradiation
October 2006	June 2007 (6 hours) Requested: $1x10^{14}$ p/cm^2 Received : 8.5 x 10^{13} p/cm^2
August 2007 f_T= 8.5 x 10^{13} p/cm^2	Sept 2007 (3 days) Requested: $5x10^{14}$ p/cm^2 Received : 6.0 x 10^{14} p/cm^2
October 2007 f_T= 0.7 x 10^{15} p/cm^2	
July 2008 f_T= 0.7 x 10^{15} p/cm^2	

Irradiated twice in 2007 followed testbeams

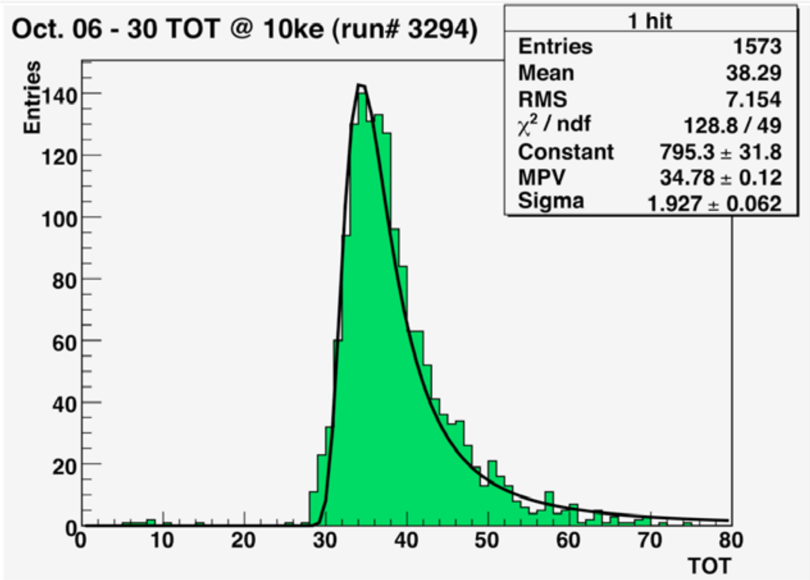




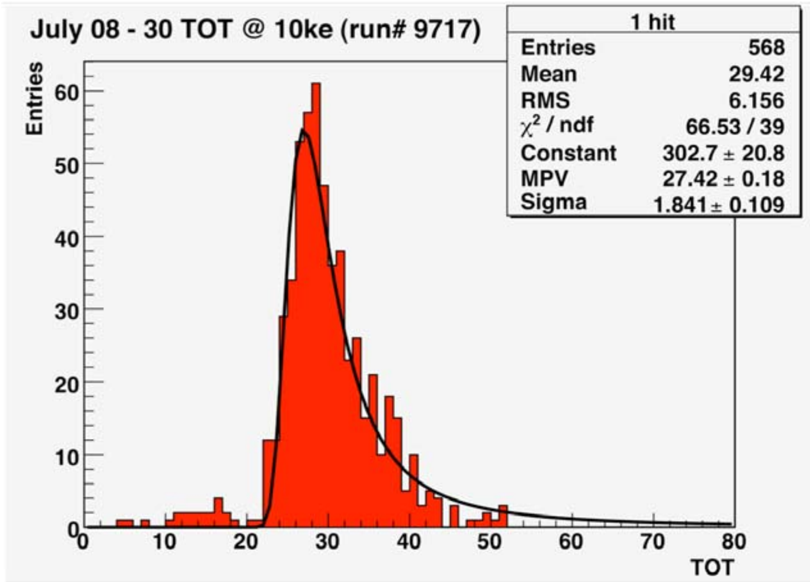
scCVD diamond: CD181
- Thickness: 395 um
- Dimension: ~ 10x10 mm^2
- Pixel size: (50x400) um^2
- Pixels: 2880, arranged in 18x160

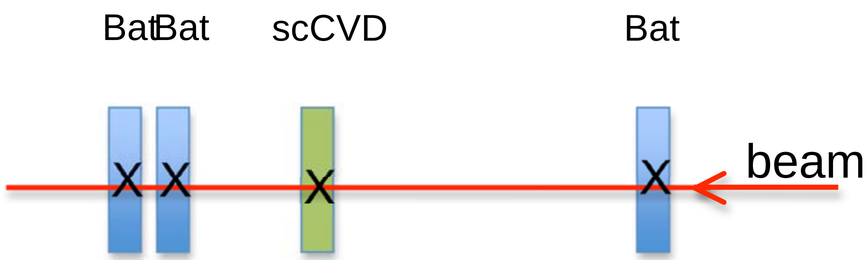
Signals before and after irradiation (scCVD)

BEFORE irradiation



AFTER irradiation (f_T= 0.7 x 10^{15} p/cm^2)

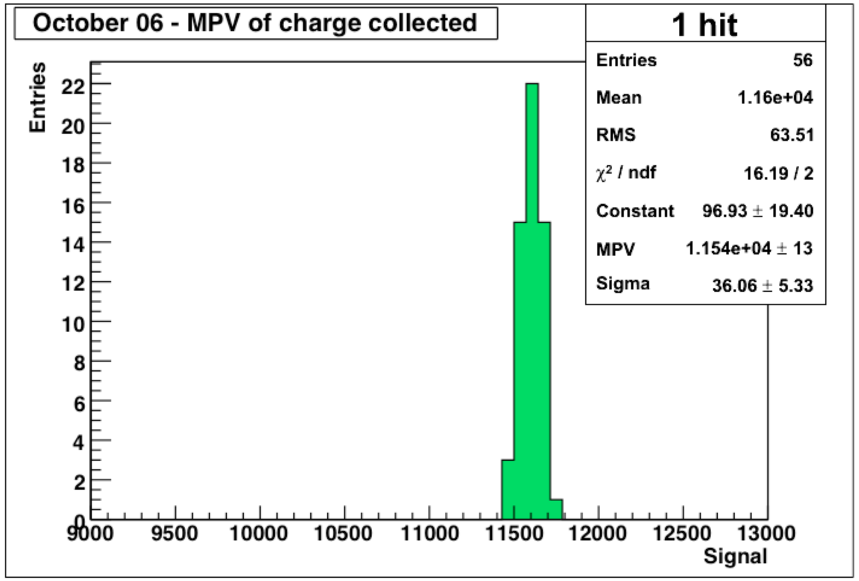




Only data from events with a single hit in each of the telescope planes are selected.

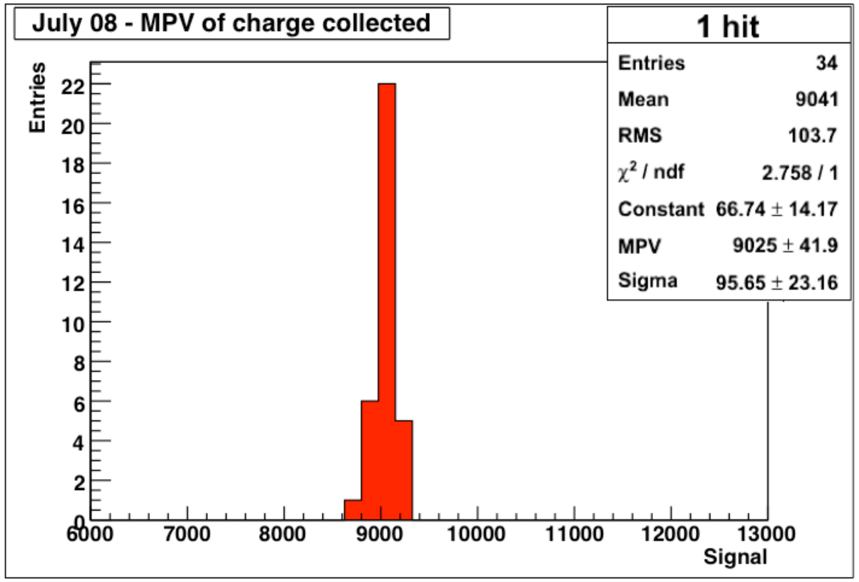
Distribution of most probable signal (scCVD)

BEFORE irradiation



MPV of Charge Collected: ≈ 11540e
MPV of TOT : ≈34.6
Bias – 400 V
Th= ~1700e Noise = ~130e

AFTER irradiation (f_T= 0.7 x 10^{15} p/cm^2)



MPV of Charge Collected: ≈ 9025e
MPV of TOT : ≈27.6
Bias – 800V
Th= ~1470e Noise= ~180e (~10°C)

Only data from events with a single hit in each of the telescope planes are selected.

Outlook

- … because it's way to early for a summary

- Have started to look at different sensor materials using the same FE pixel electronics
- With the goal measure and understand the different signal response, noise and threshold obtainable for different detectors
  - Using the same setups
  - Before and after irradiation, warm and cold
- Sofar started on 3D silicon detectors and scCVD diamonds in ATLAS pixel pad geometry
  - Lab measurements with source
  - testbeam
- Plan to expand measurements now to planar sensors now (different bulk material, also thin sensors)