Evaluation of novel pixel sensor for future tracking detector

A. La Rosa and H. Pernegger

CERN PH

14th RD50 Workshop - Freiburg, June 3-5, 2009

Pixel Sensors RD at Cern

Studies of different detector materials for (very) high radiation

Close collaboration between CERN group on ATLAS upgrade, sensors RD groups (RD50, RD42) and CERN PH-DT (SLHC-PP / WP4 – Rad. Hard Detector).

Interests in the following specific areas:

1. Performance evaluation of different sensor types with the sLHC front-end electronics (*The interface sensors to electronics*)
2. Characterization of sensor before & after irradiation in Lab with sLHC front-end electronics (using currently the ATLAS FE-I3 pixel chip)
3. Test beams with different sensor types.

Collaboration:

ATLAS RD on 3D-Si Detectors (since Sept. 08)

Currently measure ATLAS layout 3D Stanford and 3D FBK/irst detectors

ATLAS RD on Planar sensors (since Feb.09)

Measurements on "standard" N-in-N detectors, N-in-P /thin next

ATLAS RD on CVD Diamond pixel detector (since Feb. 08)

Measurements on single-crystal single-chip module.

CERN Participants:

B. Di Girolamo, D. Dobos, A. La Rosa, H. Pernegger, S. Roe

Detectors Under Test

3D-Si

FBK/irst: Double side Double Type Columns (DDTC)
Stanford: Full 3D sensors

Diamond Pixel Sensors

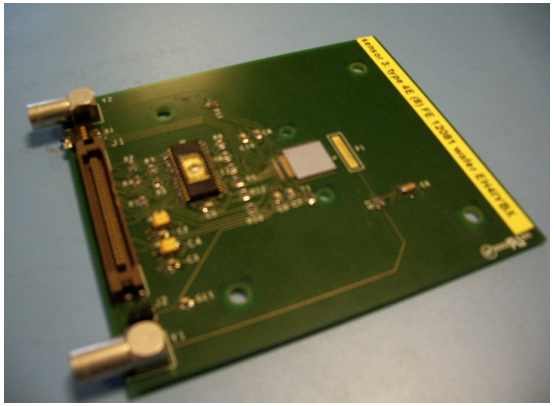
pCVD(full module) and scCVD (single chip module)

Looking forward to testing ***N-in-P/ thin Planar*** *Pixel Sensors*

As reference: **ATLAS N-in-N Planar sensors**

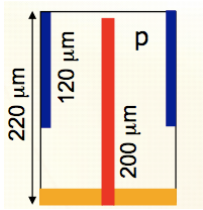
On bench measurements:

- Started to do measurements on different detectors:
  - Leakage currents
  - Threshold scan (threshold and noise measurements)
  - Noise vs bias voltage
  - Source test with Am-241, Cd-109 and Sr90



FBK 3D Silicon sensors

Double side Double Type Columns

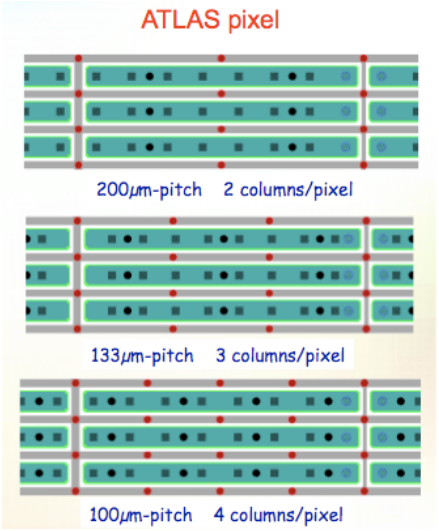


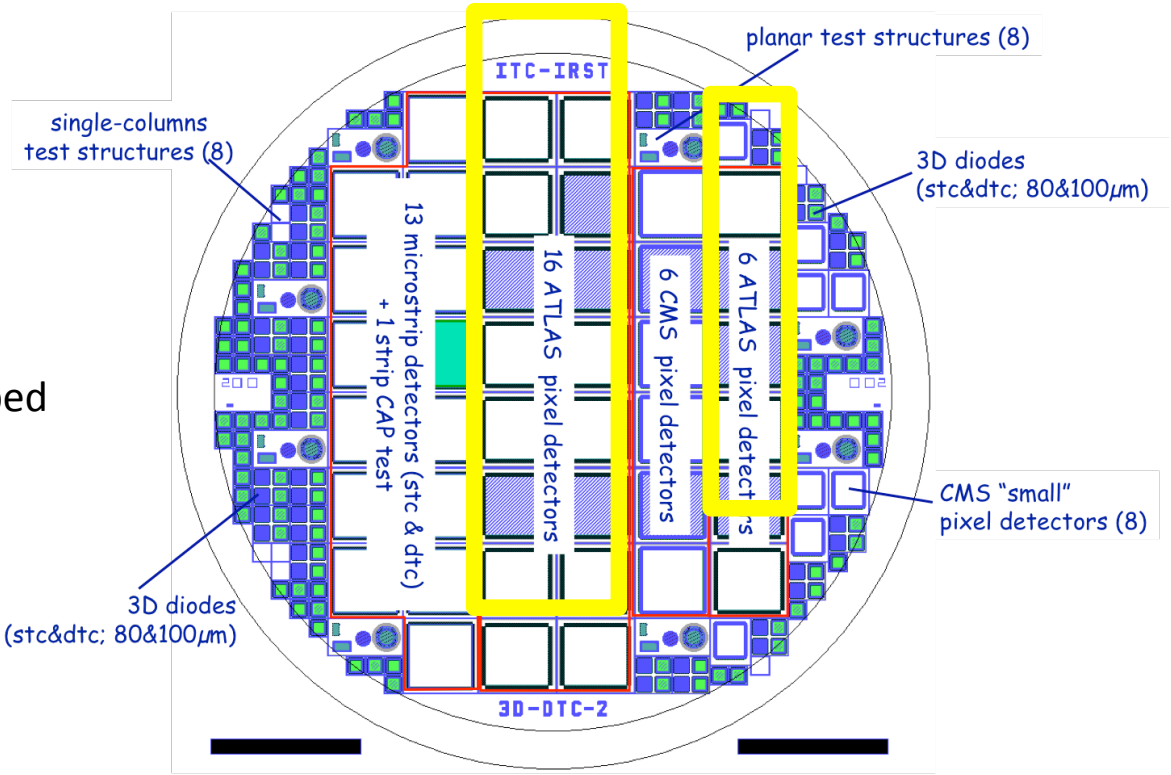
Structure with 2,3 and 4 elect. per pad
Thickness 220um
Column overlap ~ 100 um
Depletion voltage ~ 11V

•Bump-bonding → SELEX S.I. (Indium).

•22 devices have been bump-bonded.

•9 of 22 3D sensors have been flip-chipped on ATLAS FE-I3.



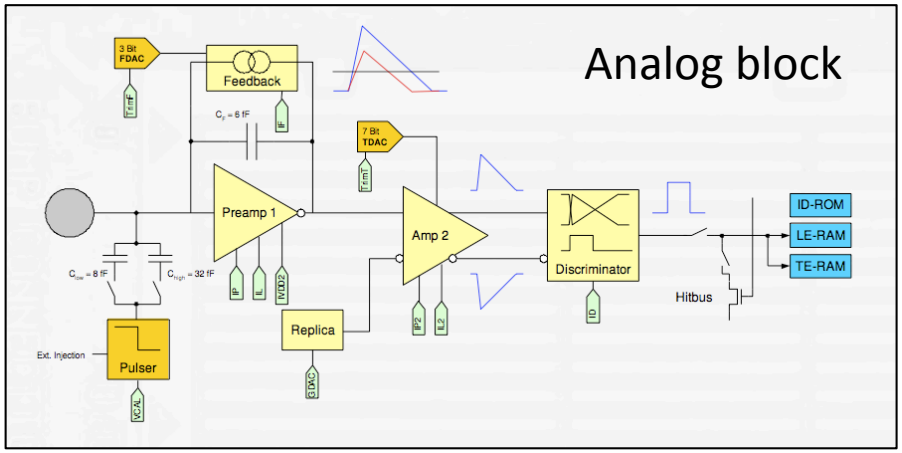


M. Boscardin, C. Piemonte (FBK-irst),
G.F. Dalla Betta (UniTN & INFN-TN),
G. Darbo (INFN-GE).

The Atlas Pixel chip: FEI3

Overall chip architecture:

-Standard 0.25um CMOS technology
-2880 readout cells of 50um x 400um
-18x160 matrix
-Radiation tolerance up to a total dose of 50Mrad

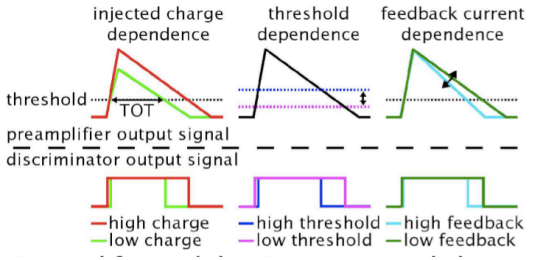


Each readout cell:

Analog block where the sensor charge is amplified and compared to a programmable threshold by a discriminator;

Digital readout part transfers the hit pixel address, a hit time stamp and a digitized amplitude information, the ToT to buffers at the chip periphery.

Preamplifier and discriminator shape:

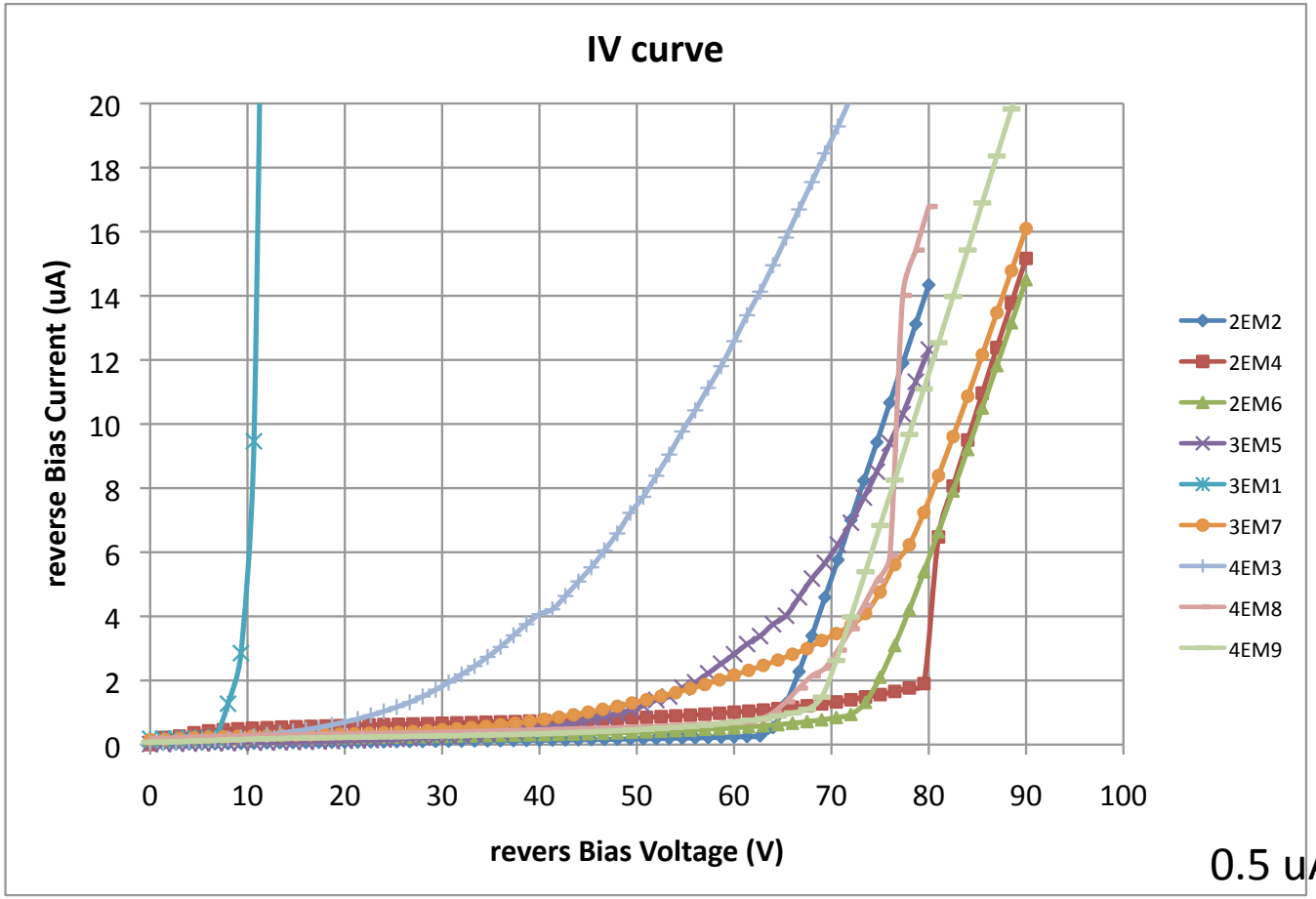


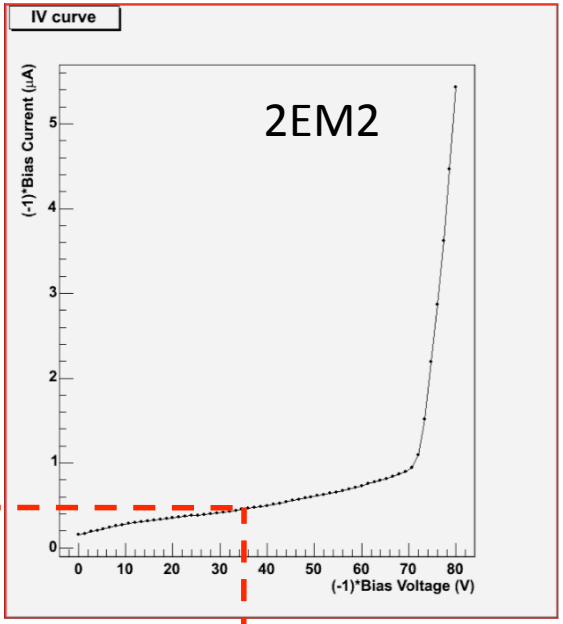
Time over Threshold (length of discriminator signal) depends on:

- deposited charge
- discriminator threshold
- feedback current

Information of the ToT (in unit of 25 ns) is read out together with the hit information

Leakage currents

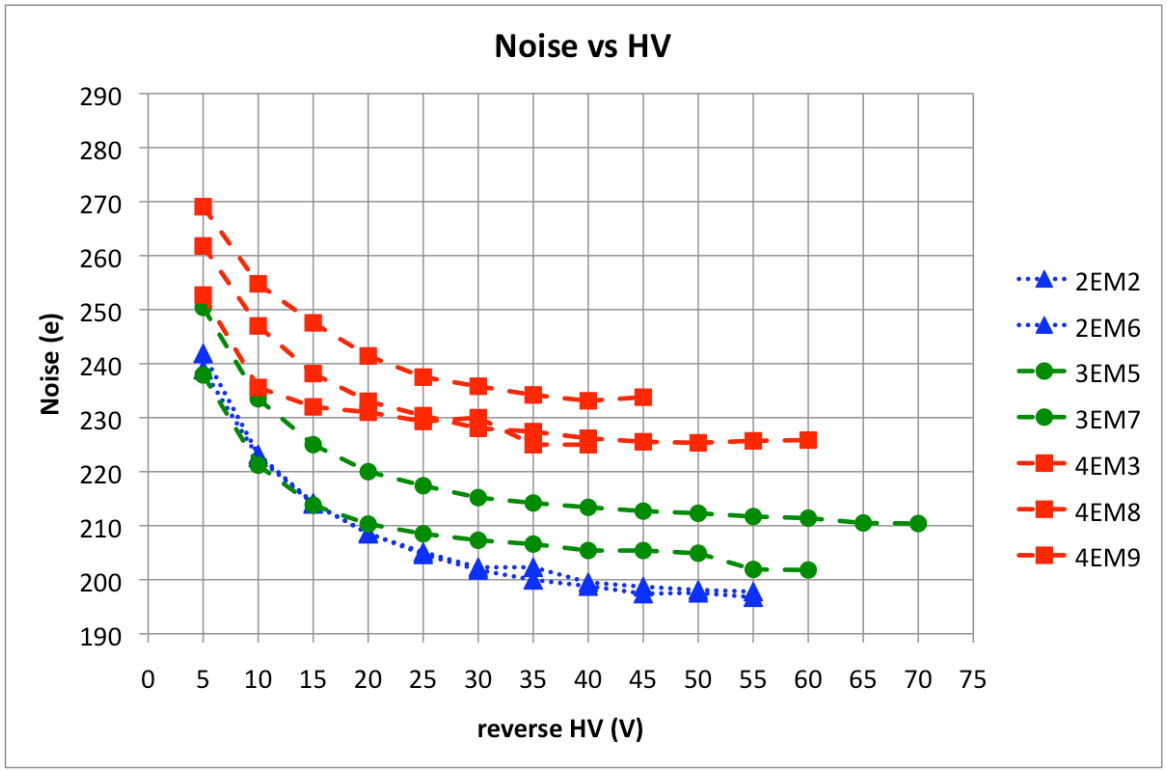




0.5 uA

35 V

Noise vs bias voltage



2 electrodes per pixel

3 electrodes per pixel

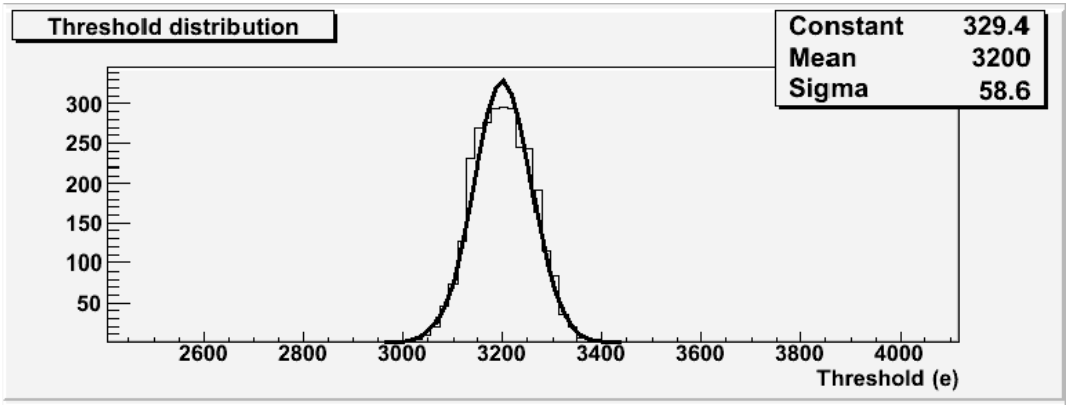
4 electrodes per pixel

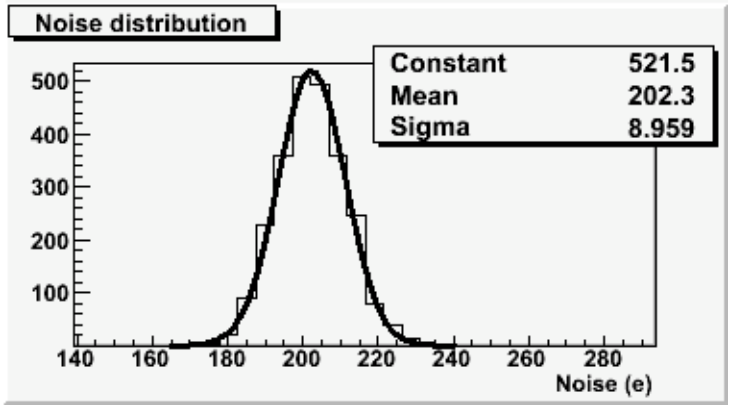
Measurements at CERN setup (climate chamber) 20 °C and relative humidity of 12%.

Threshold and noise measurements

FE Tuned with Th=3k2e- and 60 ToT @ 20ke-

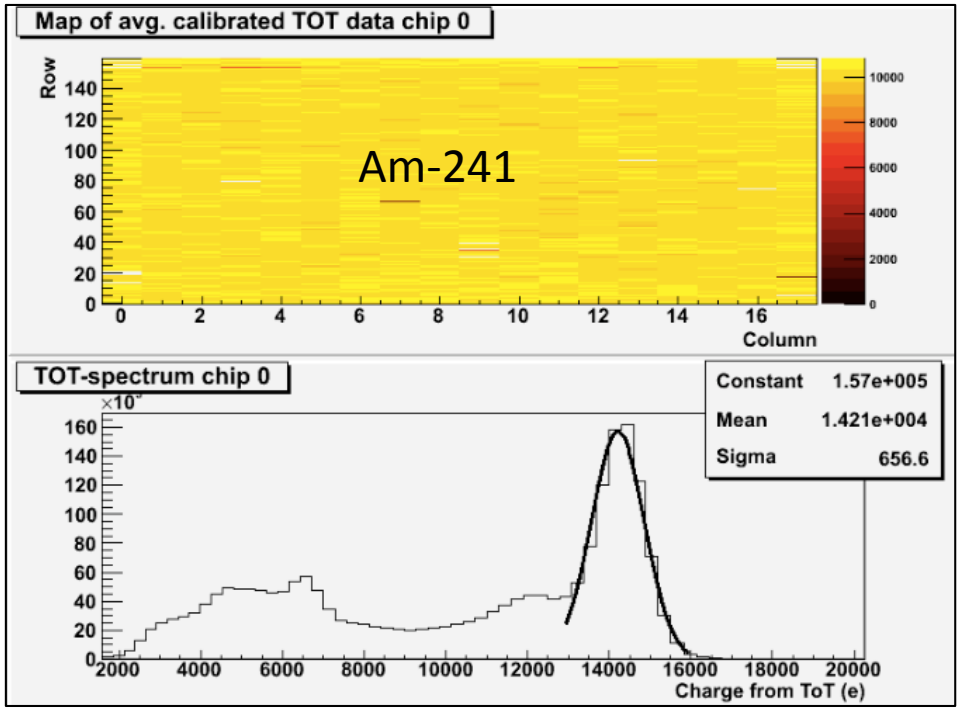
sensor	<Th>	σ(th)	<Noise>	σ(noise)	HV
FBK-2E	3200	58.6	202.3	8.96	-35
FBK-3E	3318	42.02	206.6	8.29	-35
FBK-4E	3284	41.27	229.8	9.87	-35
N-in-N	3259	42.96	181.1	9.367	-150

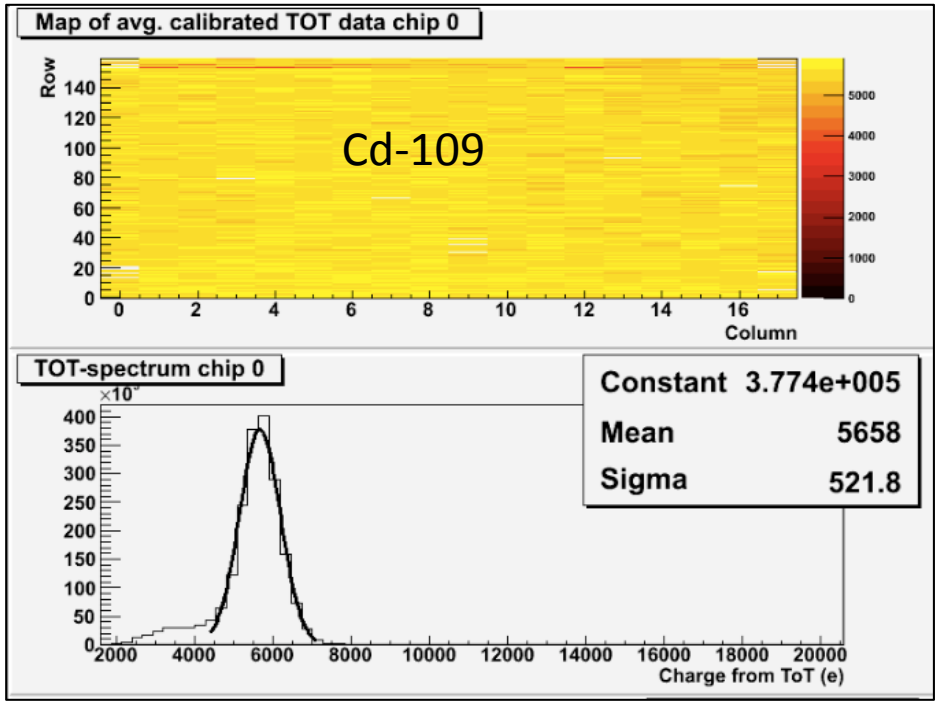




Source tests

Preliminary measurement with Am-241 and Cd-109



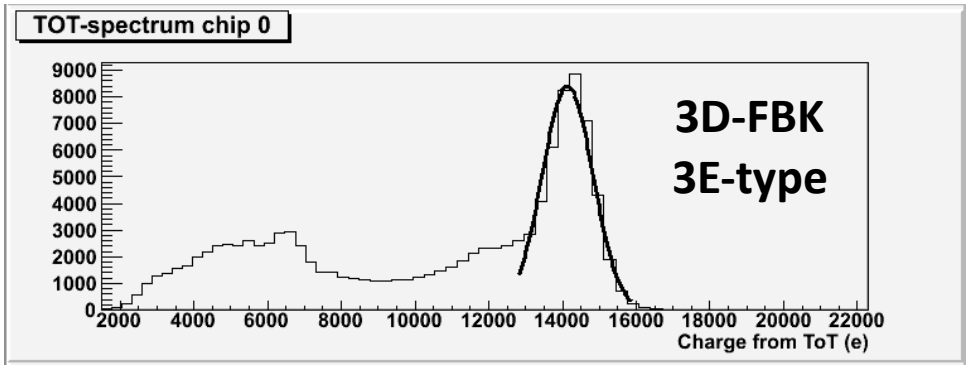


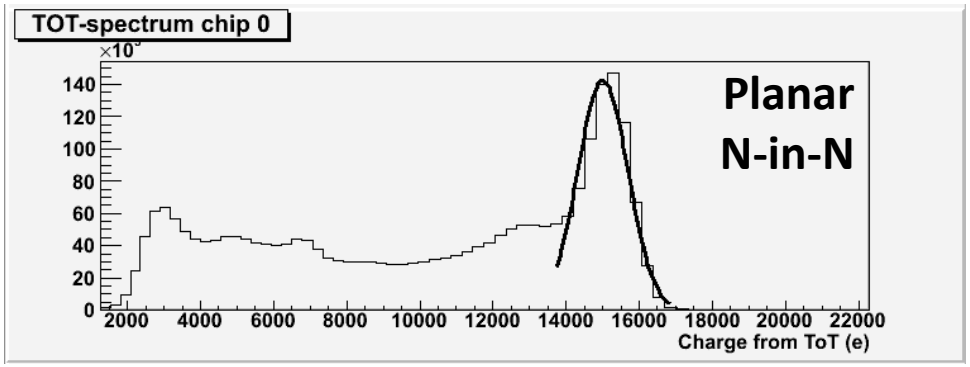
See the expected 60 keV (Am241) and 22 keV (Cd109) peaks

Source test (Am-241)

Preliminary measurement with Am-241 source in comparison with ATLAS N-in-N Planar sensor single-chip module

Spectrum as a sum over all pixel without any clustering





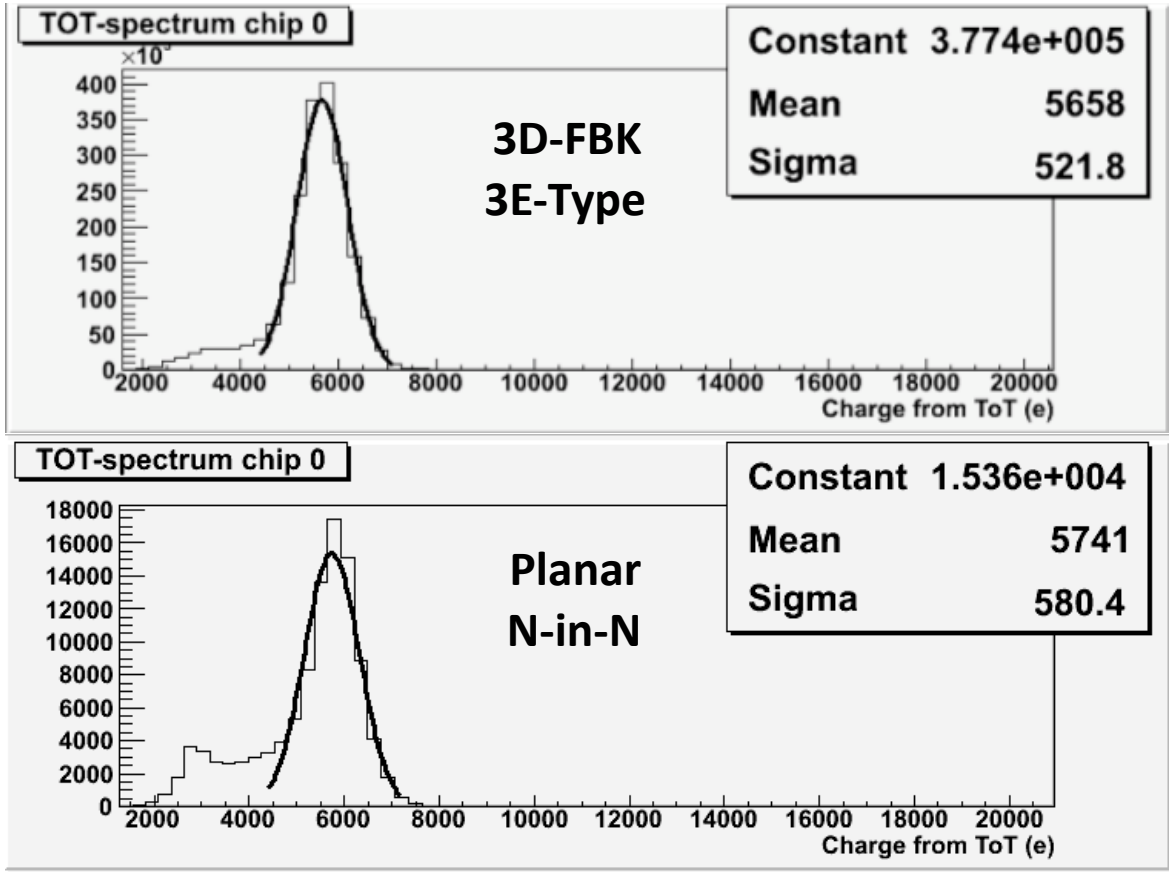
Detector	Peak (10^4 e)	Sigma (e)
3D-2EM2	1.411	695.3
3D-2EM6	1.401	673.6
3D-3EM5	1.414	686.2
3D-3EM7	1.537	778.4
3D-4EM3	1.406	759.0
3D-4EM8	1.383	775.2
3D-4EM9	1.415	760.0
Planar (N-in-N)	1.501	688.4

See the expected 60keV peak

Source test (Cd-109)

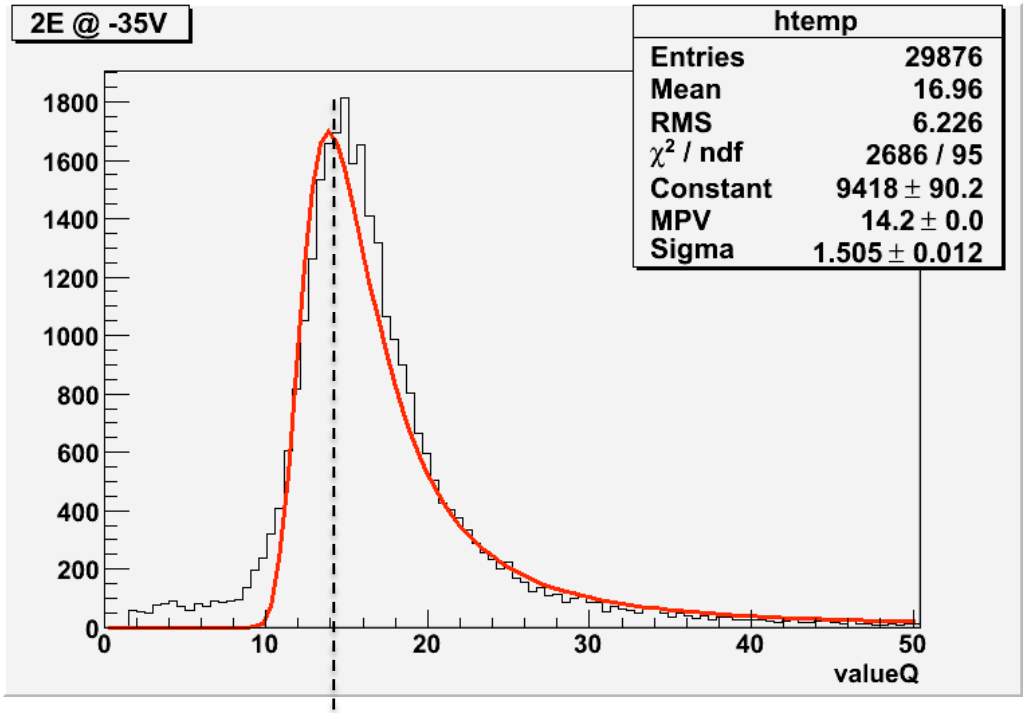
Preliminary measurement with Cd-109 source in comparison with ATLAS N-in-N Planar sensor single-module

Spectrum as a sum over all pixel without any clustering



See the expected 22keV peak

Source test (Sr90)

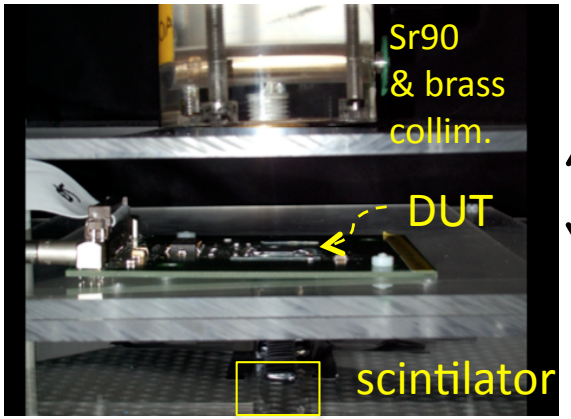


MPV ~ 14,200e

Thick. ~ 220um

Measurements at CERN setup (climate chamber) 20 °C and relative humidity of 18%.

Contribution to measurements: J.W. Tsung/Bonn



During test
6 mm

Sr90 independently triggered

To check if the charge collected changes with the electric field three different bias voltages have been chosen (-15V, -35V and -55V).

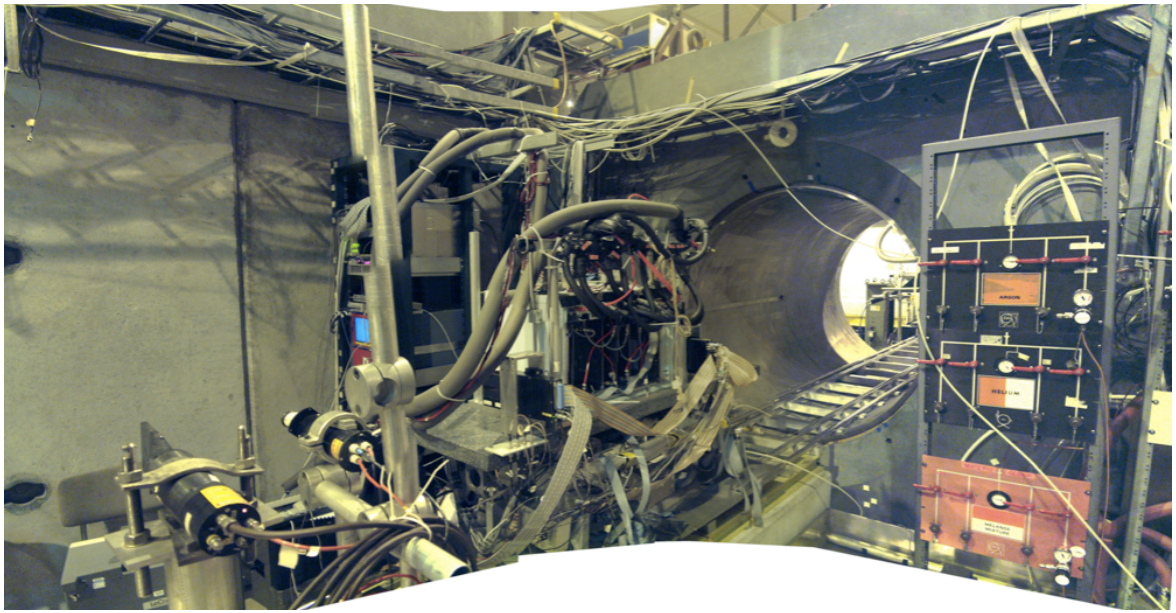
Bias Voltage [V]	MPV [Ke]	Sigma [Ke]
-15	13.66	1.522
-35	14.21	1.505
-55	14.11	1.495

Depletion voltage @ ~-11V

Test-beam overview

In the framework of **ATLAS 3D Collaboration** **two FBK/irst sensors** have been tested:

- **DDTC-1**: *N-in-P, 220 um thick substrate, Non- passing-through columns (100um) No active edge.*
- **DDTC-2** *: N-in-P, 200 um thick substrate, Non- passing-through columns (180um) No active edge.*



CERN SPS – H8

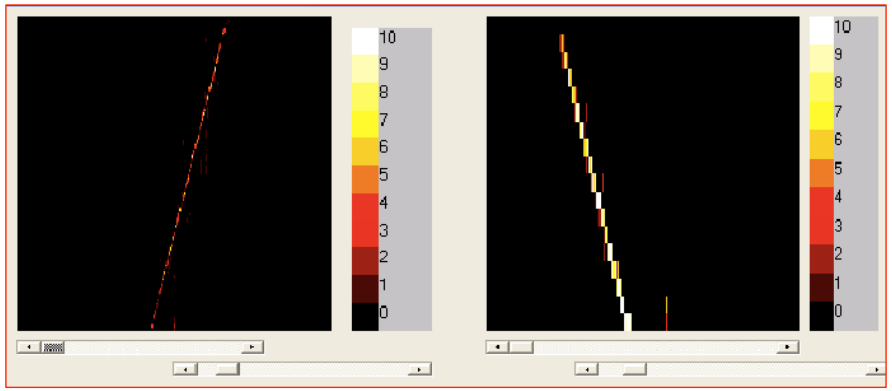
DUTs : - Traditional PPS
- STA-3E (full 3D)
- FBK-3E (100um overlap)
- FBK-3E (180um overlap)

Angle scan (0 and 15) w/ &without magnetic field (~2T)

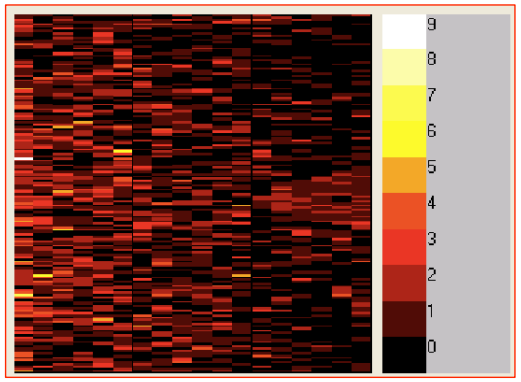
Test-beam overview

In the framework of **ATLAS 3D Collaboration:** FBK/irst (*DDTC-1*) 3E-type sensor

JUST FEW PICS from DQM during data taking !!!



Correlation: BAT vs FBK/irst

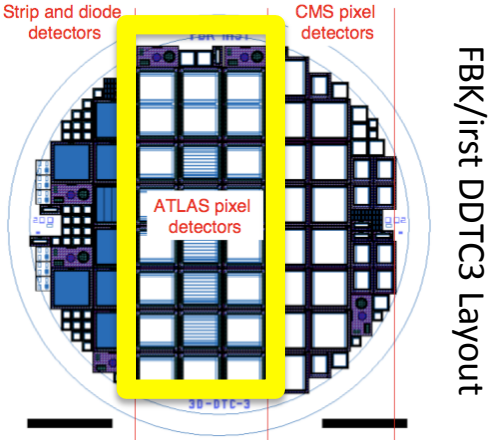


Hit Map

Data analysis on all sensors tested is on-going !!!!

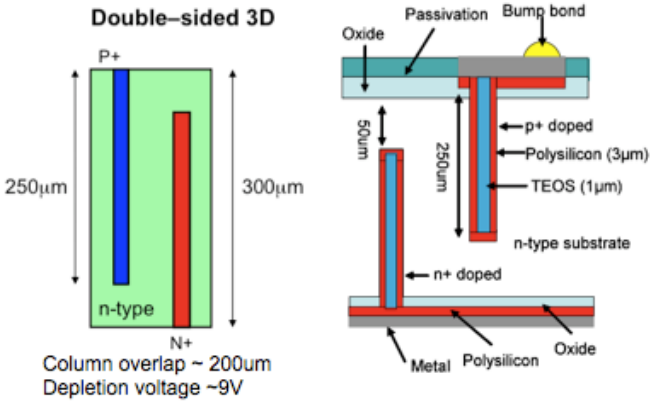
3D-Si: next step

FBK-DDTC3:
N-in-P, 250 um thick substrate,
FULL 3D sensors (passing-through) columns
No active edge



FBK/irst DDTC3 Layout

CNM (G. Pellegrini et al.):
Double side 3D detector,
300 um thick substrate and 200um column overlap



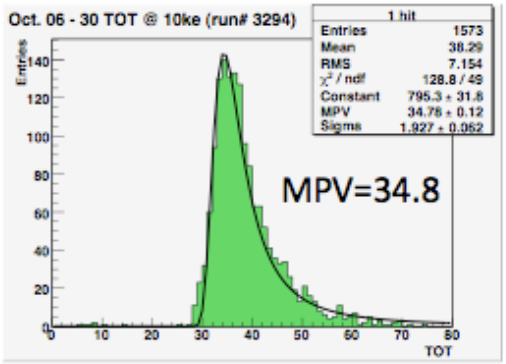
✓Lab Characterization
✓Test Beam (October 2009)
✓Sensor Irradiation (Aug-Sept)
- Proton: CERN IRRAD3 ($4x10^{15}$ p/cm^2)
[*FBK, Planar N-in-N*
Other sensors are welcome]

sc-CVD Diamond

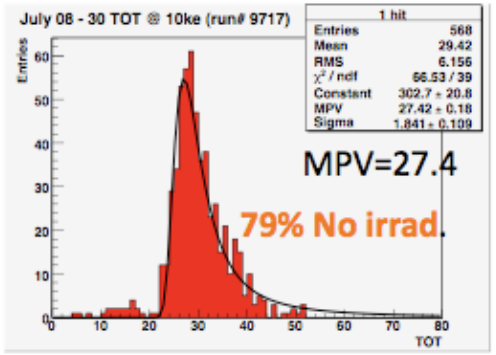
RD42 and
ATLAS RD on CVD Diamond pixel detector

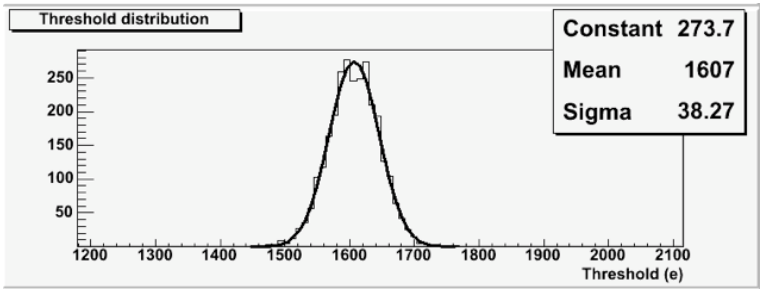
- scCVD diamond: CD181
  - Thickness: 395 um
  - Dimension: ~ (10x10) mm^2
  - Pixel size: (50x400) um^2
  - Pixels: 2880, arranged in 18x160

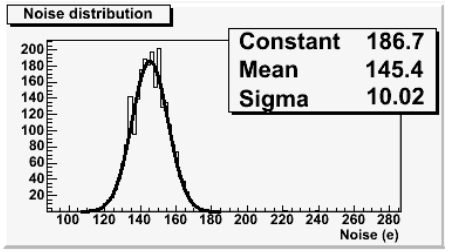
BEFORE irradiation



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





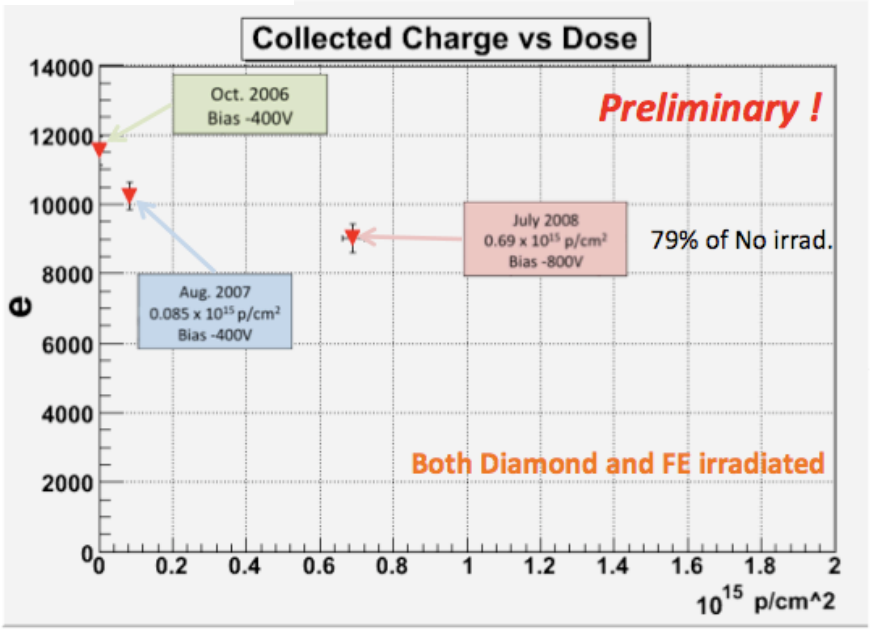


After 0.7 x 10^{15} p/cm^2

Th@ 1k6e-

Noise ~ 145e-

@ room temperature



Lower capacitance → Lower Th (factor 2) & Noise

But 50% Silicon signal !!!!!

This analysis is very sensitive to calibration !!

Outlook

- The performance of the 3D-Si (FBK/irst DDTC-1) have been studied
  - 9 detectors have been tested: one of them (3EM1) has showed problem in IV scan (breakdown ~ -10V), while one (2EM4) has presented problems in the FE calibration.
  - Many thanks to M. Boscardin, G.F. Dalla Betta, C. Piemonte and G. Darbo for their kind cooperation in the detector understanding and measurements.

- Study of detector behavior in terms of noise and threshold
  - Using the same setups
  - Before and after irradiation
  - Warm and cold measurements

- Started on 3D Silicon and scCVD Diamonds detectors in ATLAS pixel pad geometry
  - Lab measurement with source (Am-241, Cd-109 and Sr-90)
  - Test-beams

- Plan to expand measurements to planar sensors (different bulk material, also thin sensors)