Initial characterization of 3D-DDTC detectors with ATLAS Pixel readout chip

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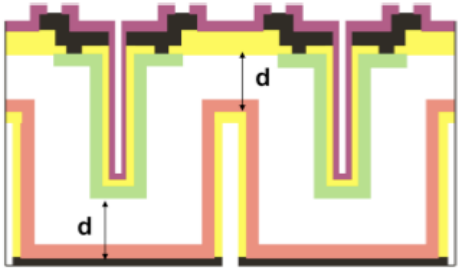
3D ATLAS General Meeting – CERN Jan. 9, 2009.

On bench measurement

- Recently started to do measurements on 3D-DDTC Silicon Sensor:
  - Leakage currents
  - Threshold scan (threshold and noise measurements)
  - Noise vs bias voltage
  - Calibration and first source test with 241Am source



M. Boscardin (FBK-irst)
G.F. Dalla Betta (UniTN&INFN-TN)

DDTC on p-type substrate

Structure with 2,3 and 4 electrodes per pad

Sensor type	Distance (μm)
2E	103
3E	71
4E	56

Thickness 220um
Column overlap ~ 100 um
Depletion voltage ~ 11V

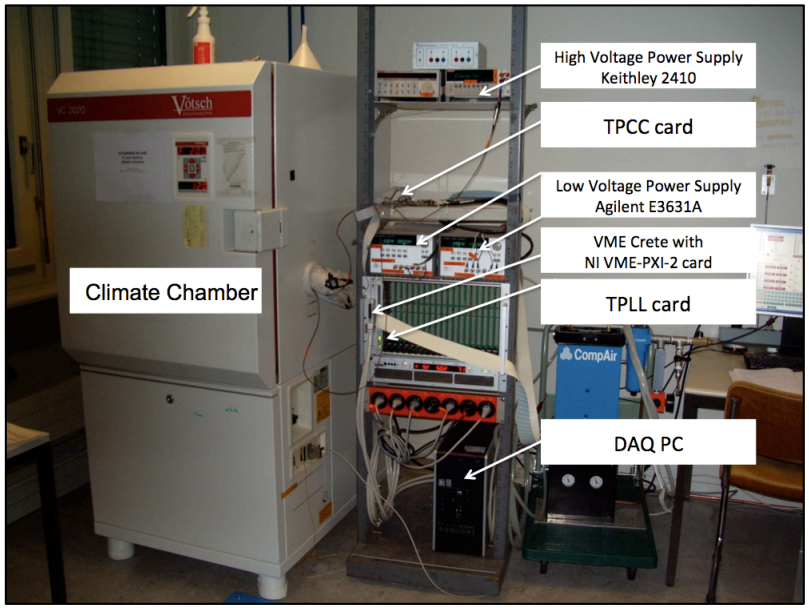
Detector	Measurements
2EM2	$I_{Leakage}$, Threshold scan; Noise vs HV; source
2EM4	$I_{Leakage}$
2EM6	$I_{Leakage}$; Threshold scan; Noise vs HV; source
3EM1	$I_{Leakage}$
3EM5	$I_{Leakage}$; Threshold scan; Noise vs HV; source
3EM7	$I_{Leakage}$; Threshold scan; Noise vs HV; source
4EM3	$I_{Leakage}$; Threshold scan; Noise vs HV; source
4EM8	$I_{Leakage}$; Threshold scan; Noise vs HV; source
4EM9	$I_{Leakage}$; Threshold scan; Noise vs HV; source

Contribution to measurements: N. Darbo, G. Gariano, A. Rovani, E. Riuscino / INFN-Genova

Pixel Lab at Bat. 161

The Lab is operated as semi-clean room with safety precaution for cleanliness and radiation zone

PIXEL TEST STATION (based on Turbo DAQ system)

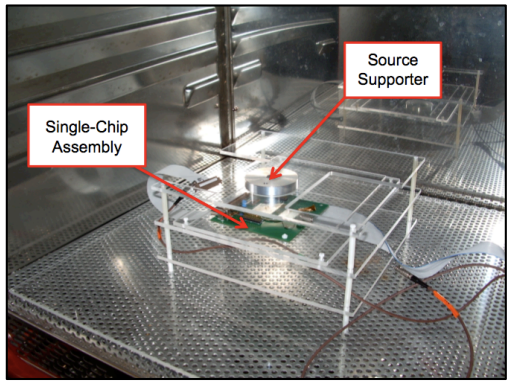


✓with SOURCE:

- Climate chamber (-25÷100 °C) + Liquid cooling
- Source : a) Am 60KeV self triggered for calibration
  b) Sr90 trigger independently triggered by scintillator (working in progress)

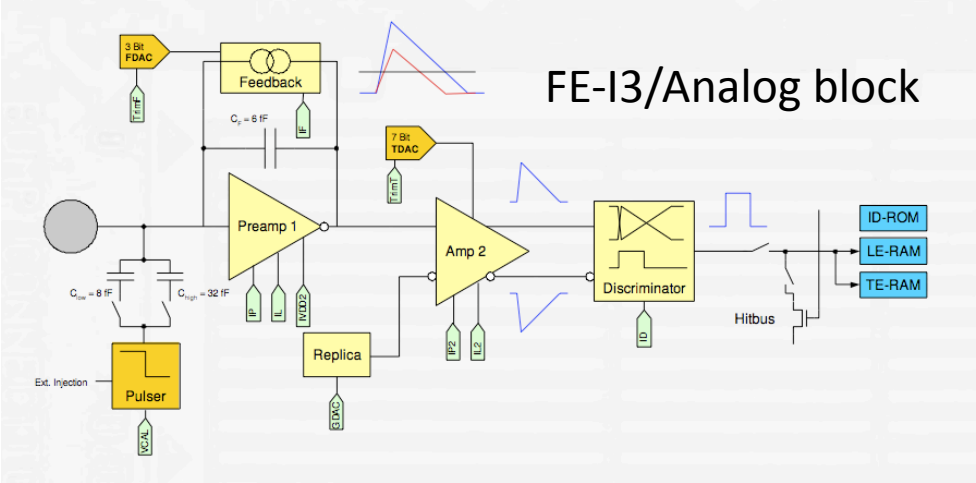
✓for calibration and front-end electronic test

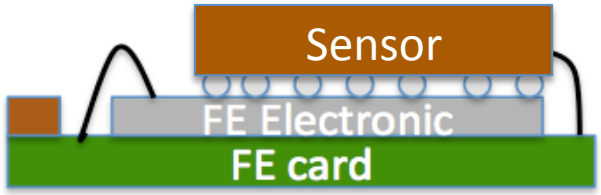
- mobile system, on-loan from INFN/Genova



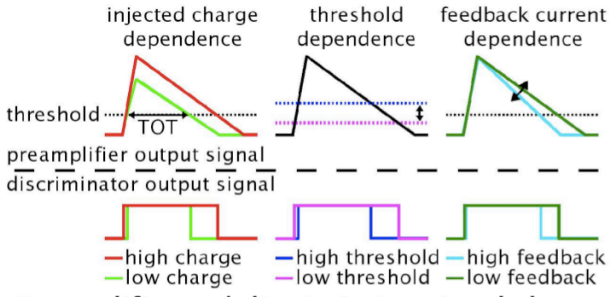
Single-chip assembly

3D-DDTC sensors are bump bonded on ATLAS FE-I3 readout chip.





Preamplifier and discriminator shape



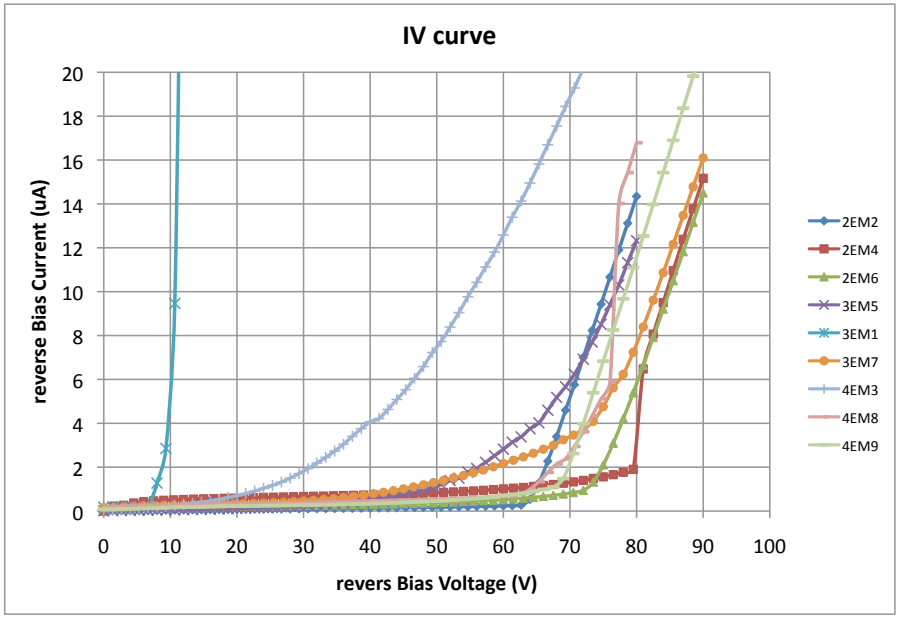
Overall chip architecture:
-Standard 0.25um CMOS technology
-2880 readout cells of 50um x 400um
-18x160 matrix

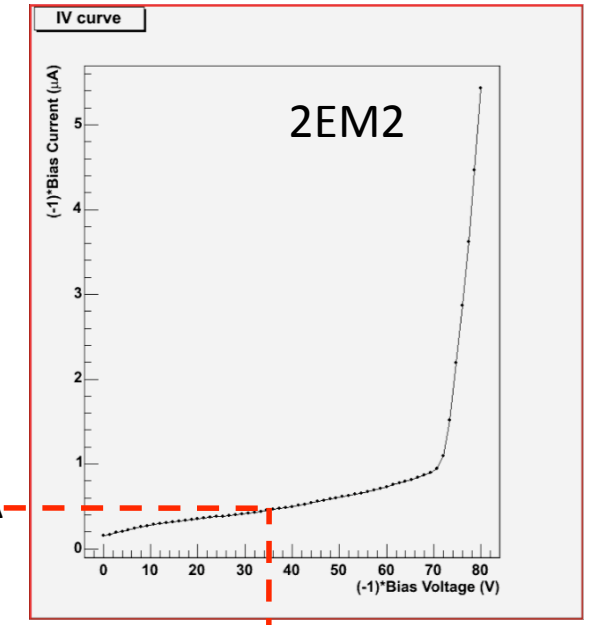
Each readout cell:
Analog block where the sensor charge is amplified and compared to a programmable threshold by a discriminator;
Digital readout part transfers the hit pixel address, a hit time stamp and a digitized amplitude information, the ToT to buffers at the chip periphery.

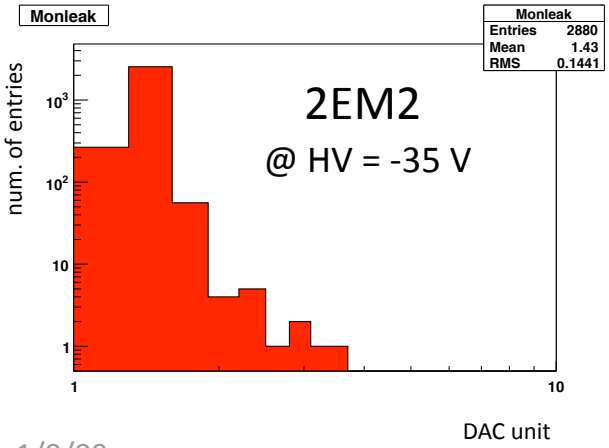
Time over Threshold (length of discriminator signal) depends on:
- deposited charge
- discriminator threshold
- feedback current

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

Leakage currents







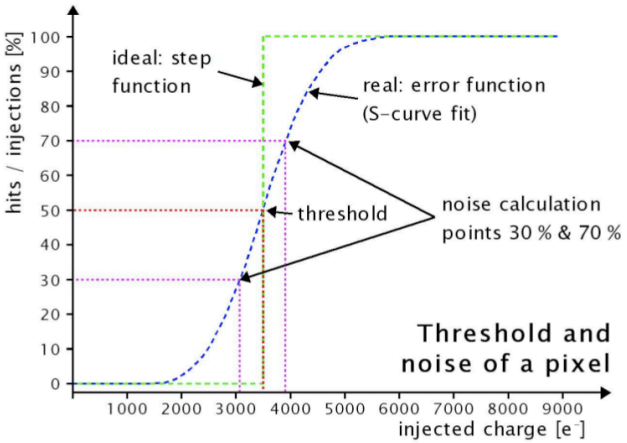
Monleak → leakage current for each pixel in DAC unit (1 DAC = 125pA)

$\langle I_{leak} \rangle$ = 1.43 DAC unit → $\langle I_{leak} \rangle$ ~ 179 pA

Per chip → 179pA x 2880 = 0.52 uA

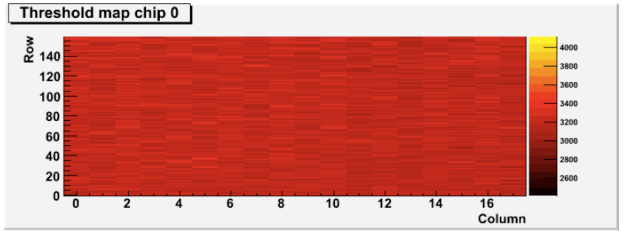
Threshold scan

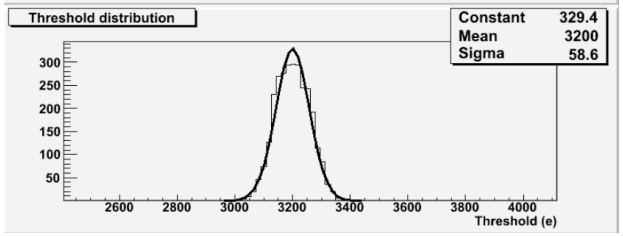
Performed to measure the threshold and noise of each pixel



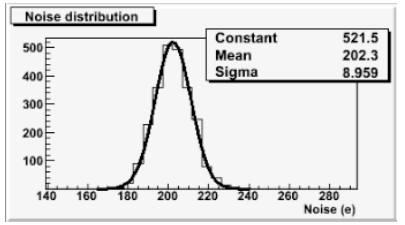
- **A** voltage pulse is injected into the injection capacitor (eg Clow).
- **T**he input amplifier see a signal of Vpulse x Clow.
- **1**00 digital injection are performed for each pxl and each injected charge value between 0e- and 9000e- in several steps.
- **T**he num. of collected hits for each pxl and each injected charge is recorded.
  → **Measure reesponse (hit/injection).**
- **R**esponse fuction: convolution of ideal step function and Gaussian pxl noise distribution → error fuction.
- **F**it gives **threshold** and **noise** value.

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





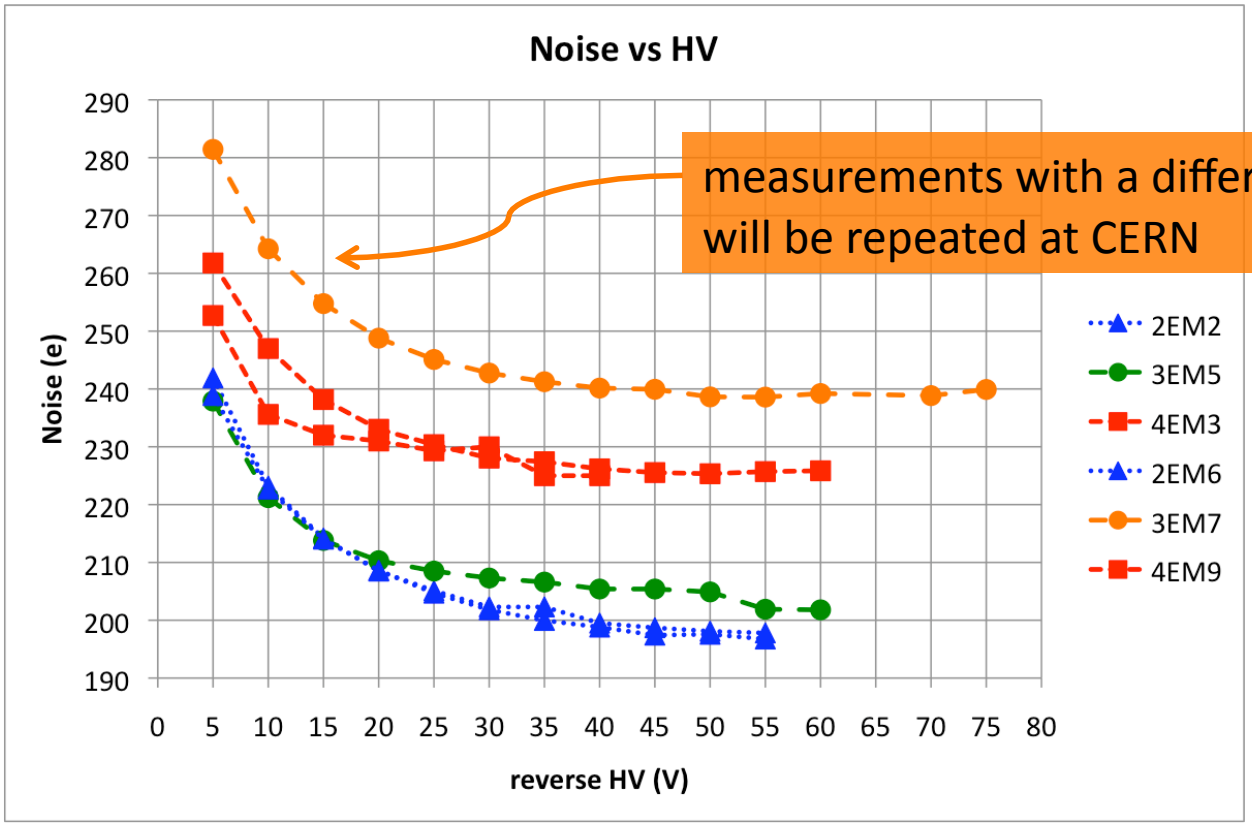
3D-DDTC
2EM2



Detector	<Th> (e)	σ(Th) (e)	<N> (e)	σ(N) (e)	HV (V)
3D-2EM2	3200	58.6	202.3	8.96	-35
3D-2EM6	3281	49.57	199.4	9.55	-35
3D-3EM5	3318	42.02	206.6	8.29	-35
3D-3EM7	3302	53.37	244.9	9.80	-35
3D-4EM3	3284	41.27	229.8	9.87	-25
3D-4EM8	3314	70.11	232.7	12.32	-35
3D-4EM9	3294	56.08	225.9	10.65	-35
3D-3EG	3241	64.48	291.7	13.03	-35
ATLASnn	3259	42.96	125.9	16.23	-150

SAME SETUP

Noise vs bias voltage



measurements with a different setup (Genova) will be repeated at CERN

▲ 2 electrodes per pixel

● 3 electrodes per pixel

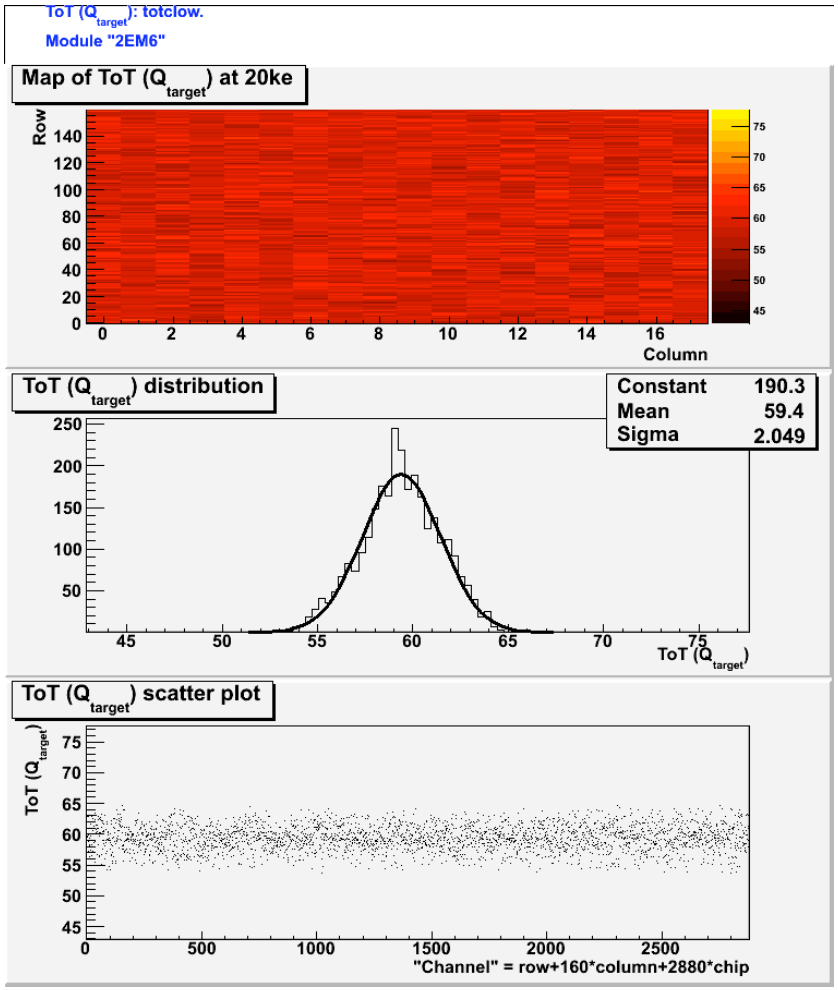
■ 4 electrodes per pixel

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

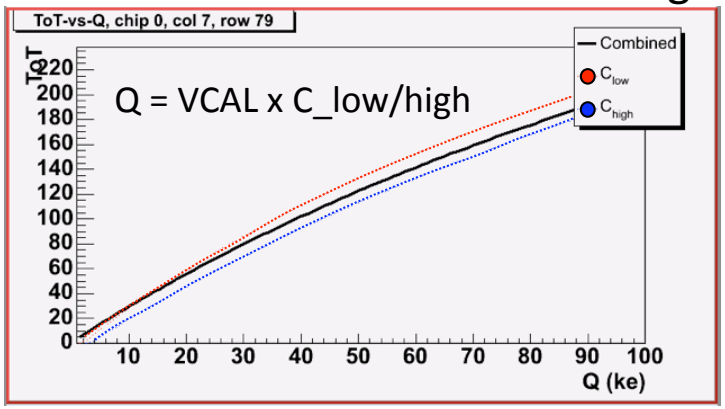
Self-ToT calibration

Performed to determine the charge dependence of the ToT values for each pixel

Procedure and algorithms described in ATLAS Project Document No: ATL-IP-QP-0144



It injects a different charges above the threshold and measures the average ToT



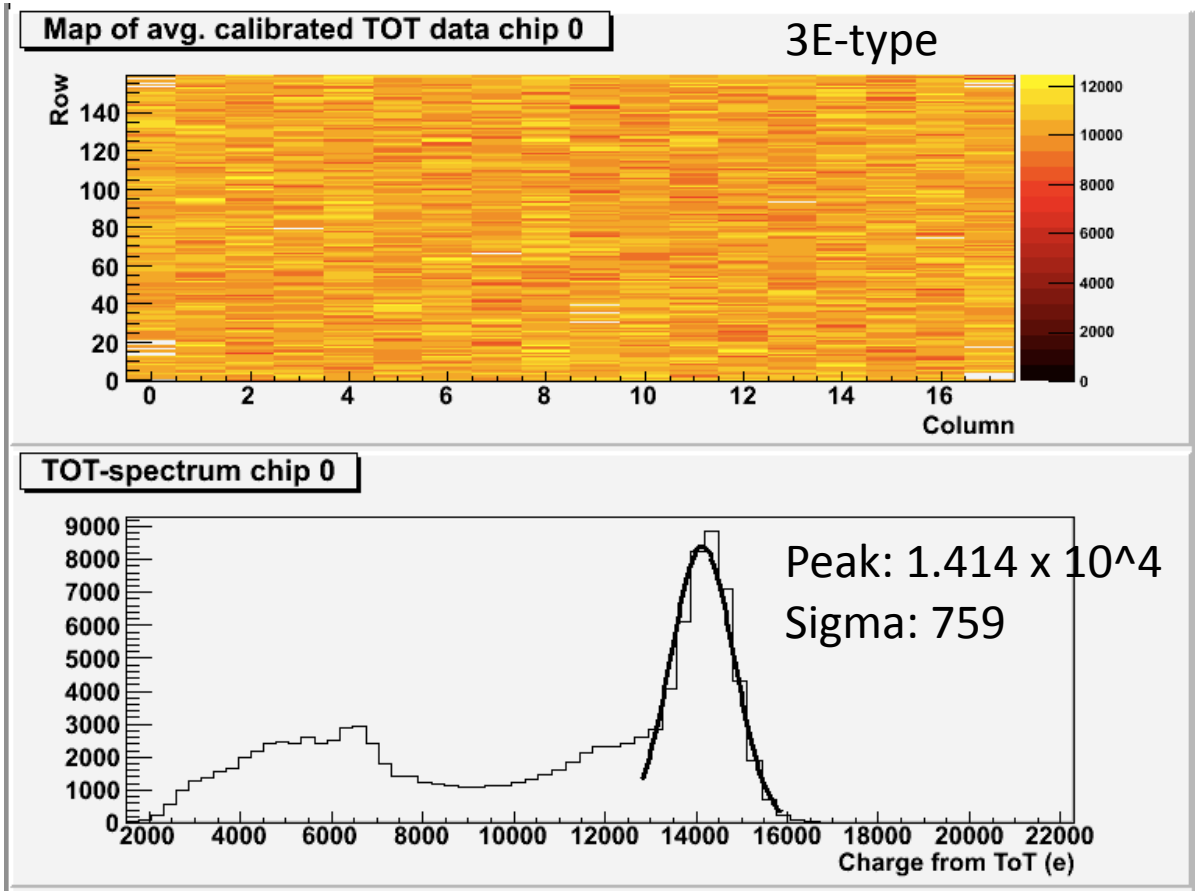
ToT tuned with 60 ToT @ 20ke-

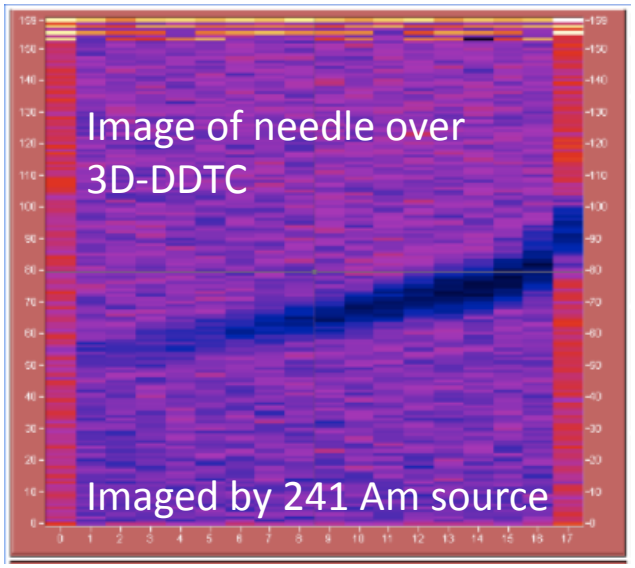
Detector	<ToT>	σ(ToT)	HV (V)
3D-2EM2	61.99	1.564	-35
3D-2EM6	59.4	2.049	-35
3D-3EM5	61.9	1.833	-35
3D-3EM7	59.07	1.946	-35
3D-4EM3	61.8	1.777	-25
3D-4EM8	59	2.177	-35
3D-4EM9	59.4	2.049	-35
3D-3EG	60.74	2.703	-35

SAME SETUP

Source test

Preliminary measurement with 241 Am

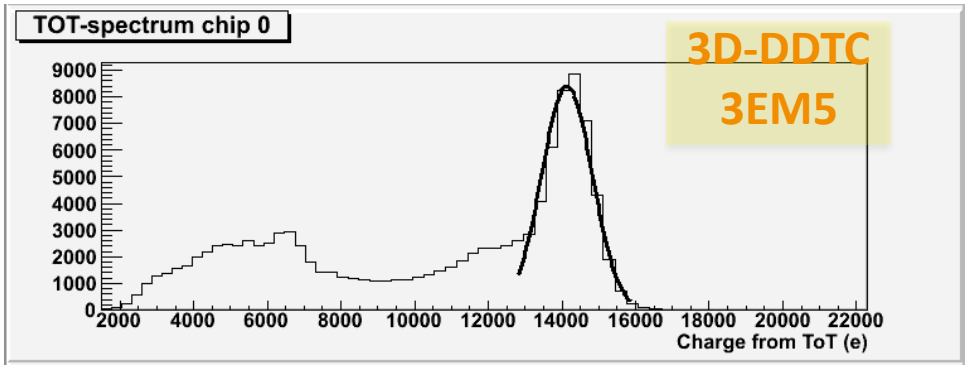


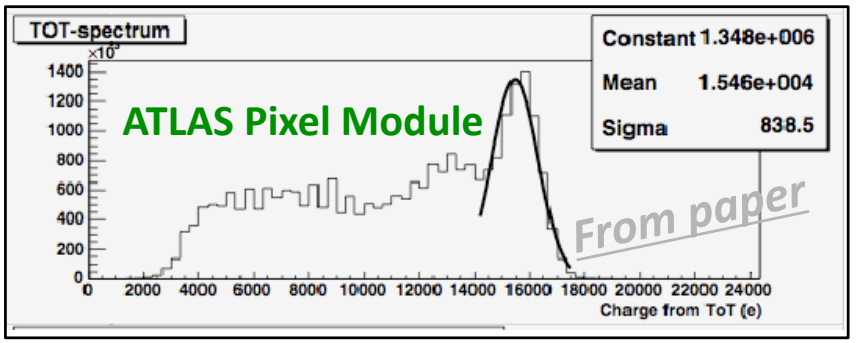


Source test

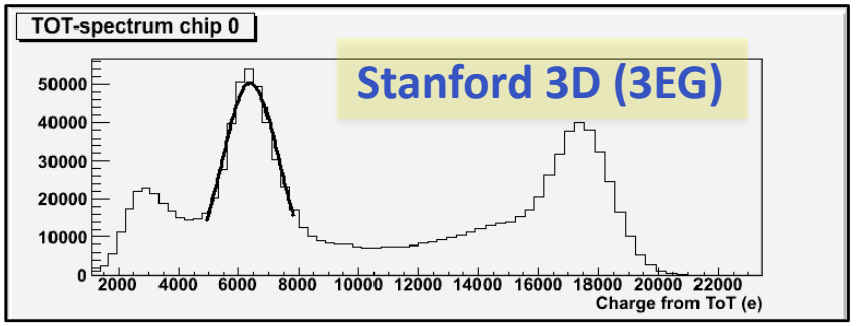
Preliminary measurement with 241Am source in comparison with **ATLAS Pixel full module** and **Stanford 3D** sensor

Spectrum as a sum over all pixel without any clustering





Detector	<Peak> (10^4e)	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
3D-4EM8	1.383	775.2
3D-4EM9	1.415	760.0



SAME SETUP

Not 26.3 keV (7.3 Ke-) and 13.9 keV (3.8ke-) …. ***(?)***

To be investigated !!!!!!

Outlook

- We've just started to look at 3D-DDTC sensors …….. too early for a summary !

- Part of the activities has been already presented in several conference and workshops: RESMDD08; IEEE; ATUW-Nikhef; RD50 Workshop; INFN Meeting: Atlas and CMS Upgrade for S-LHC.

- The performance of the 3D-DDTC have been studied by measuring:
  - Leakage currents
  - Threshold scan (threshold and noise measurements)
  - Noise versus bias voltage
  - Calibration and first source test with 241Am source ★★★★★

  (A note on this study is going to be prepared)

- 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 (FBK-irst), G.F. Dalla Betta (UniTN&INFN-Trento) and N. Darbo, G. Gariano, A. Rovani, E.Ruscino (INFN- Genova) for their kind cooperation in the detector understanding and measurements.

Outlook

- Present/Future interest:
  - Study of detector behavior in terms of noise and threshold:
    - Using the same setups
    - Before and after irradiation
    - Warm and cold measurements
  - Strongly support testbeam activity:
    - Device preparation and characterization before testbeam
    - Data taking
    - Data analysis