Status of 3D detector fabrications at CNM

G. Pellegrini

D. Bassignana, JP Balbuena, C. Fleta, C.Guardiola, M. Lozano, D. Quirion, M.Ullan

Activity on 3D detectors

- 3d ultra-thin for diagnostics of plasma and ions tracking

HELSINKI INSTITUTE OF PHYSICS

- 3D for medipix3 for synchrotron applications

University of Glasgow

diamond

- Stripixels for high energy physics and space applications

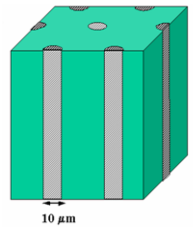
BNL

- FE-I4 Atlas pixels for IBL and atlas upgrade

IFAE

Fabrication of 3D detectors at CNM-IMB clean room facilities

Technology:



First proposed by Parker et al.
Nucl. Instr. Meth. A, 395 (1997) 328

- 4” silicon wafer
- 285um FZ high resistivity wafers (n and p- types)
- All fabrication done in-house
  - ICP etching of the holes: Bosch process, ALCATEL 601-E
  - Holes partially filled with 3 µm LPCVD poly doped with P or B
  - Holes passivated with 2 µm TEOS SiO2
- Double side process proposed by CNM in 2006

G. Pellegrini at the Second Trento Workshop on Advanced Silicon Radiation Detectors, Trento,Italy, 2006.

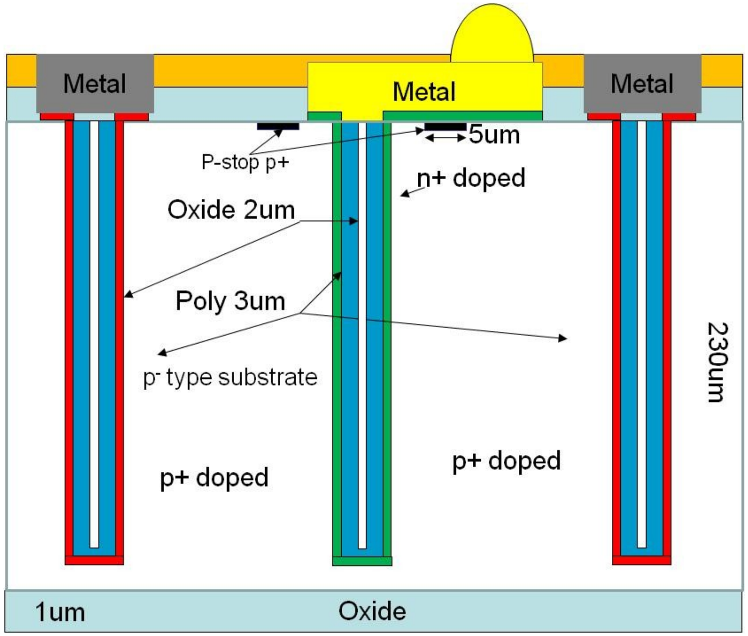
- First fabrication of 3D double sided in 2007.
- Since 2007 runs ongoing continuously.
- First fabrication of 3D single side in 2008.
- In 2010 CNM started the fabrication 235um thick wafers.
- Devices tested under extreme radiation fluences.
- Different test beam successfully carried out on device before and after irradiation at SHLC fluences (2*10^{16} cm^2 1 MeV neutr. Equiv.).
- Test beam at Diamond synchrotron.

Technologies

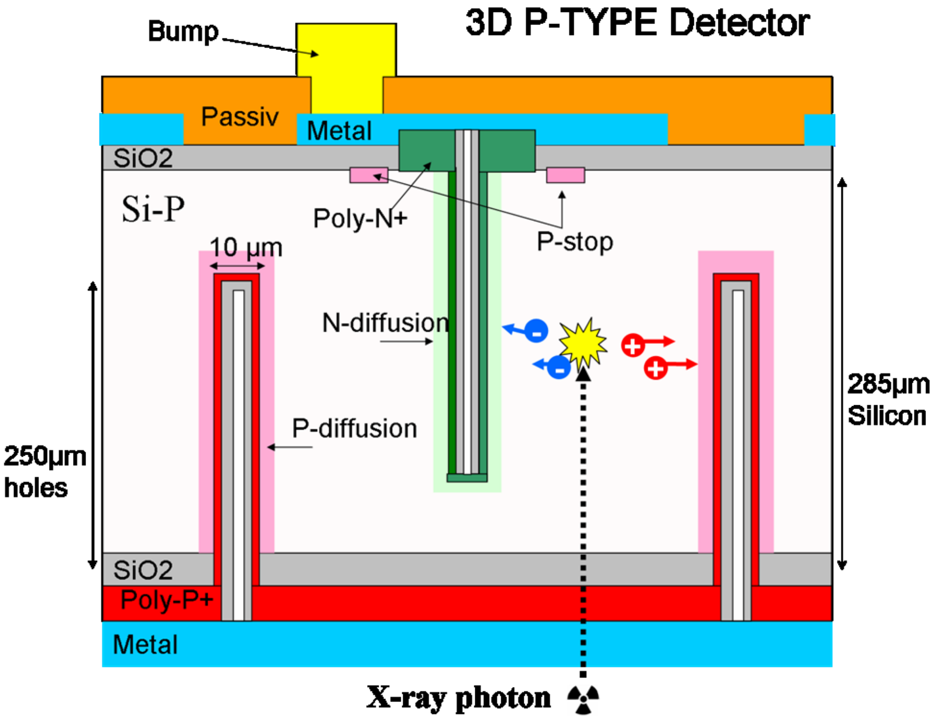
Array of electrode columns passing through substrate
Electrode spacing << wafer thickness (e.g. 10μm:300μm)

CNM has developed both technologies

Single sided

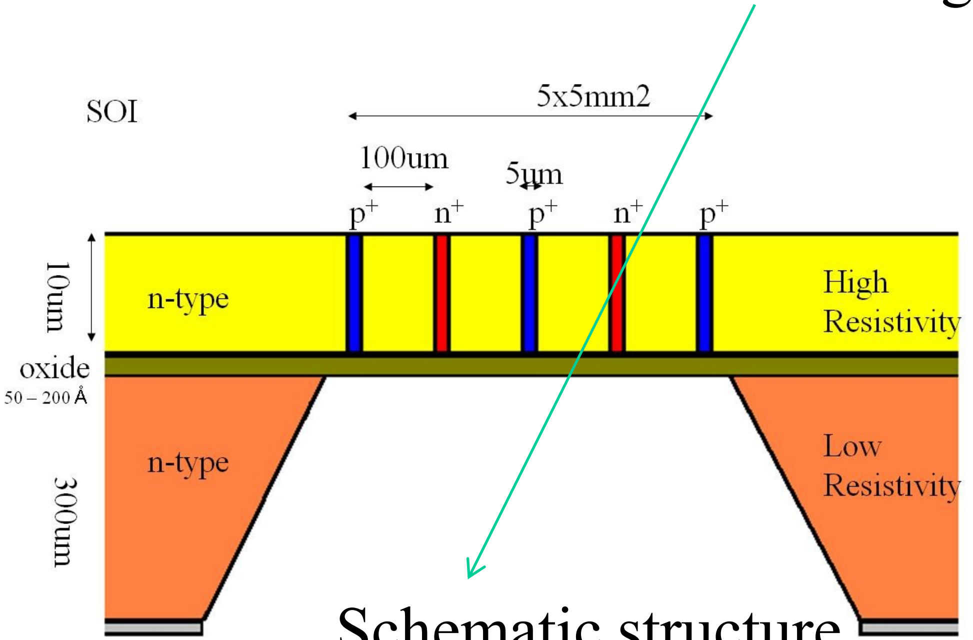


Double sided 3D

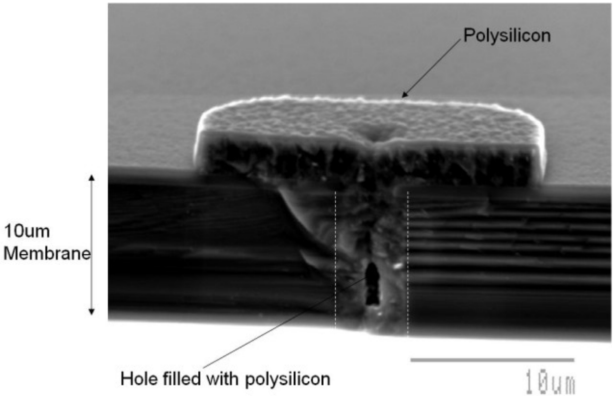


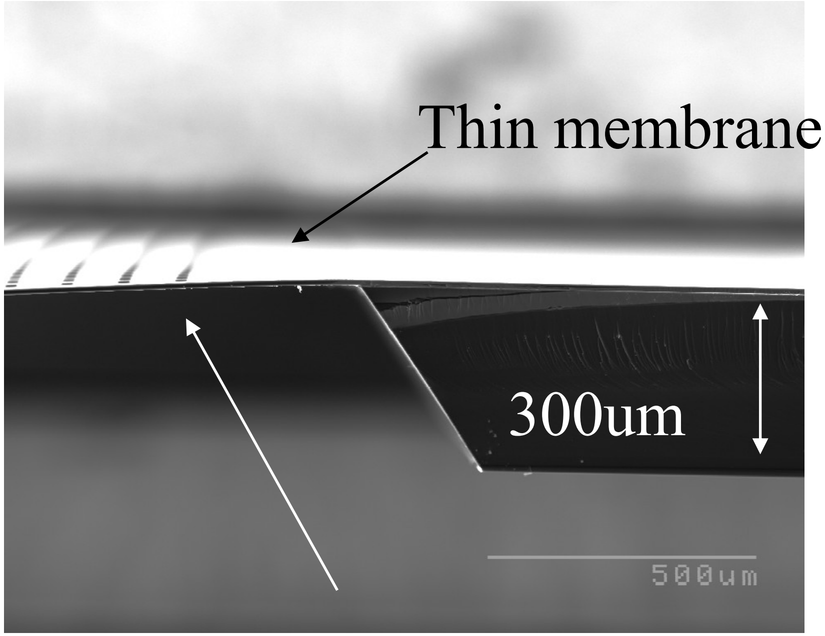
Thin 3D detectors

Tracking of ions is possible



Schematic structure

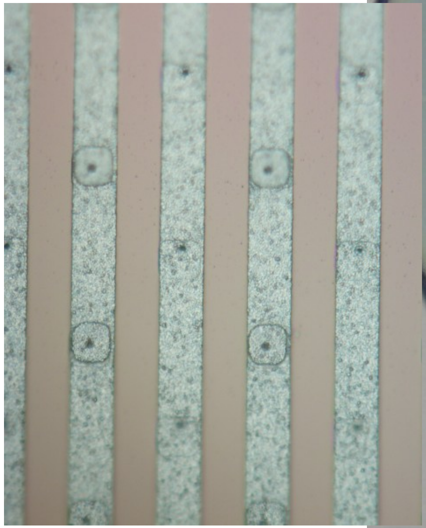


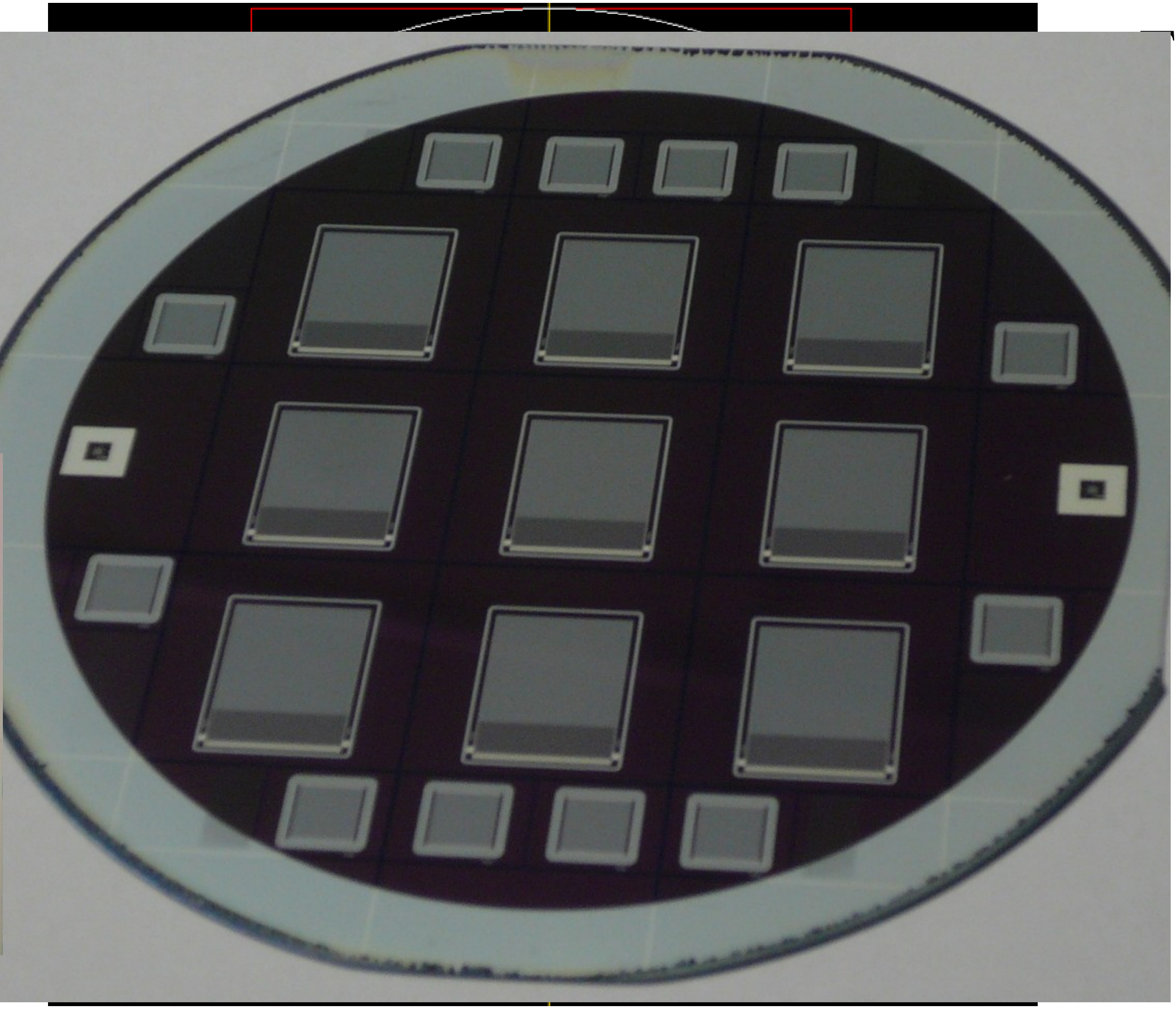


Etched backside

Thick pa

Thin stri

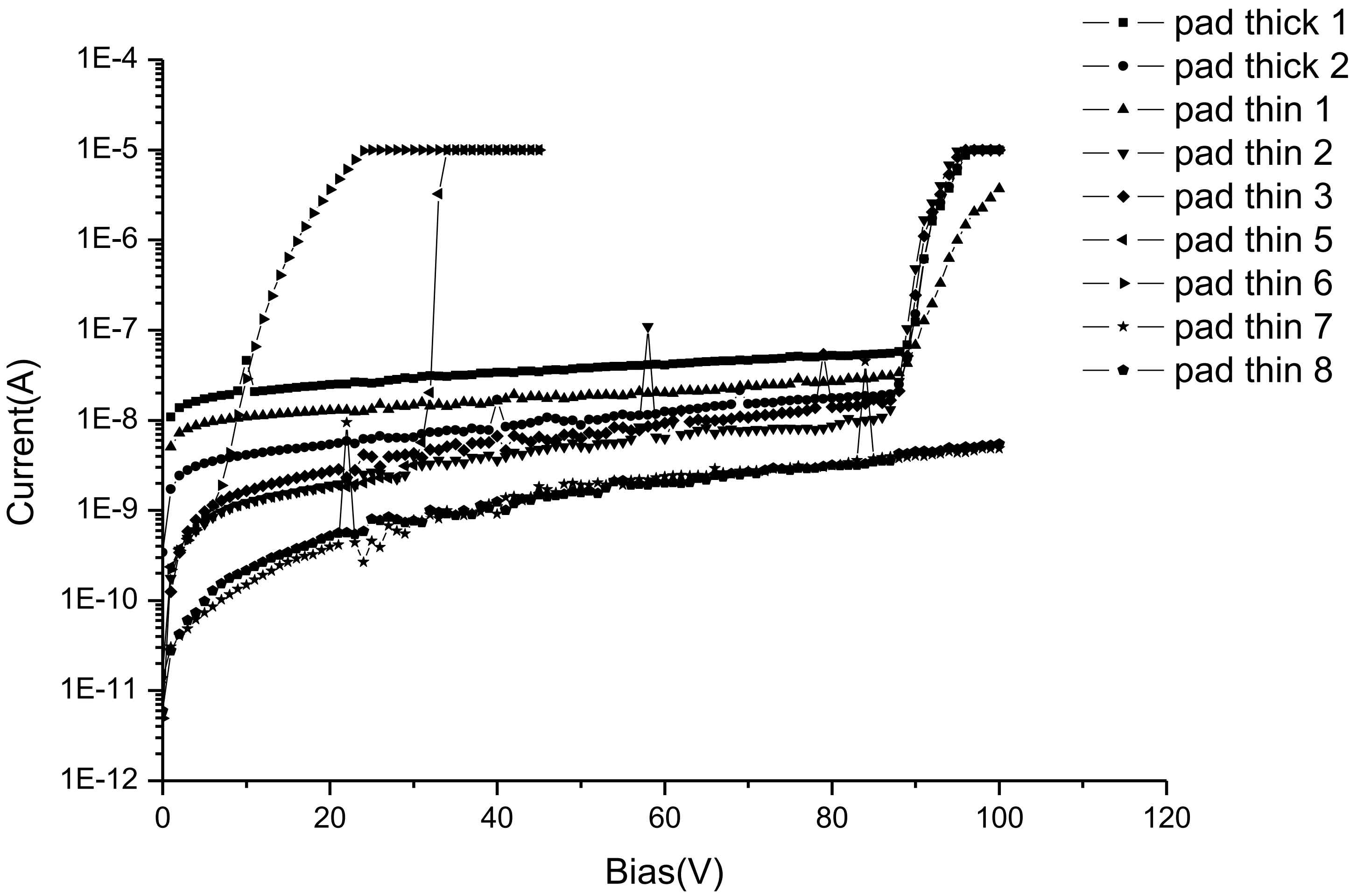




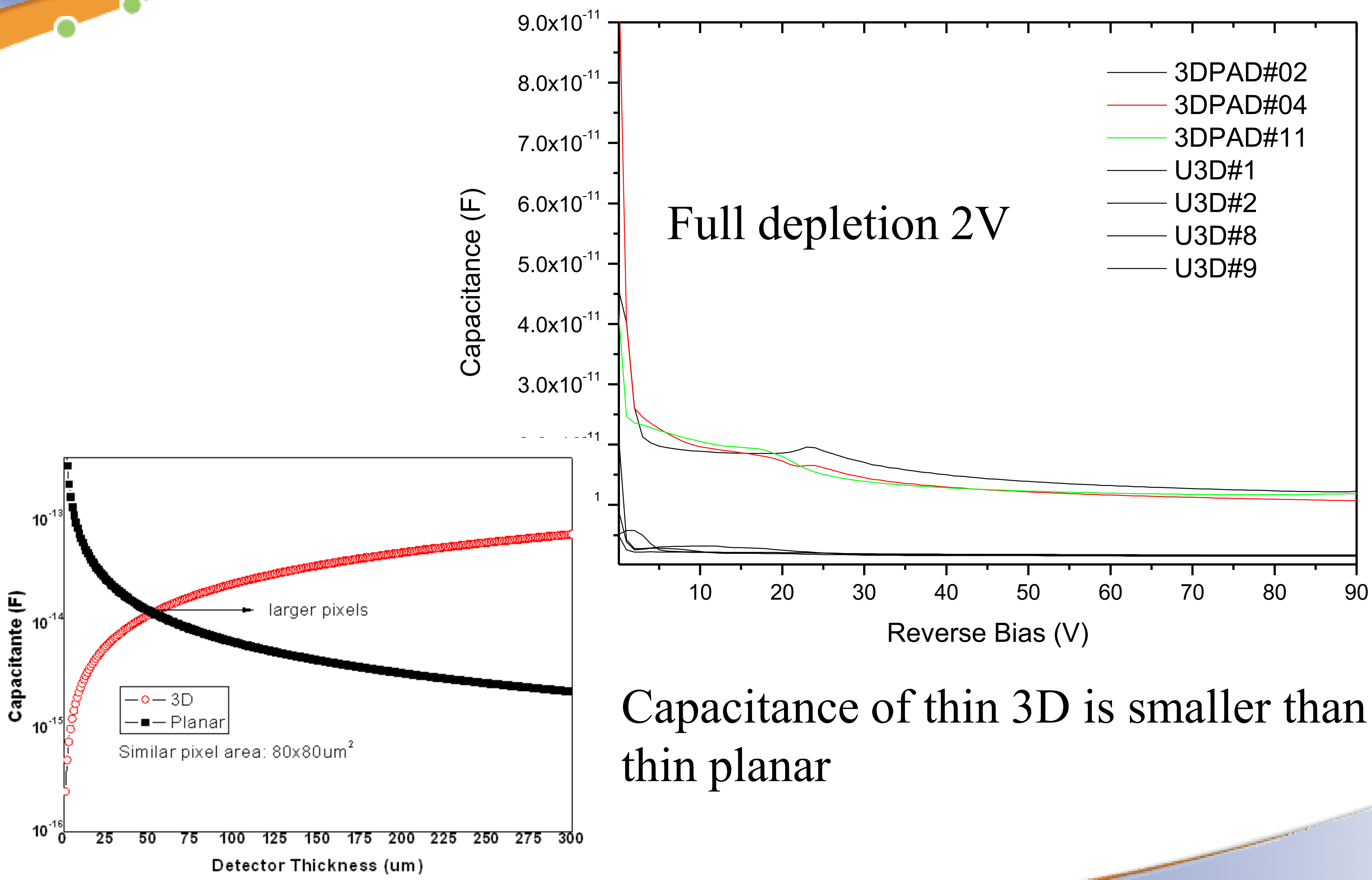
Thin pads

4 wafers fabricated and all working

I-V characterization



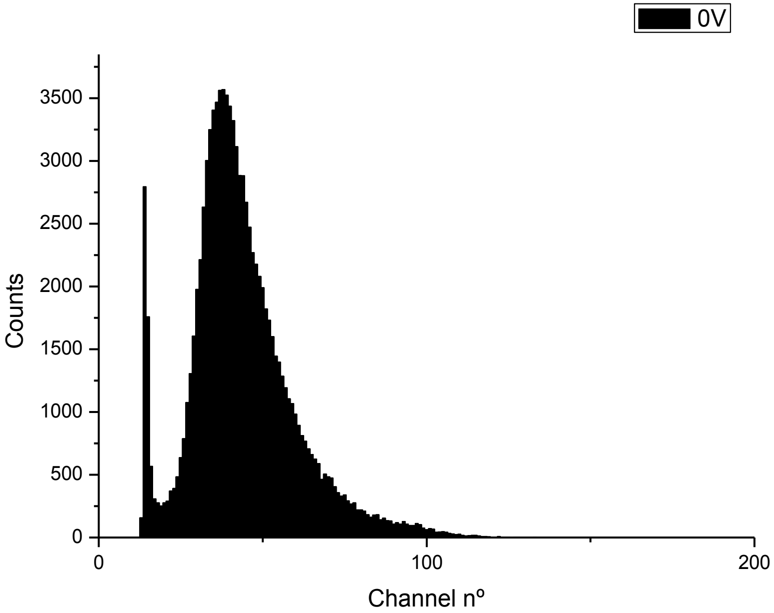
CV mesurements

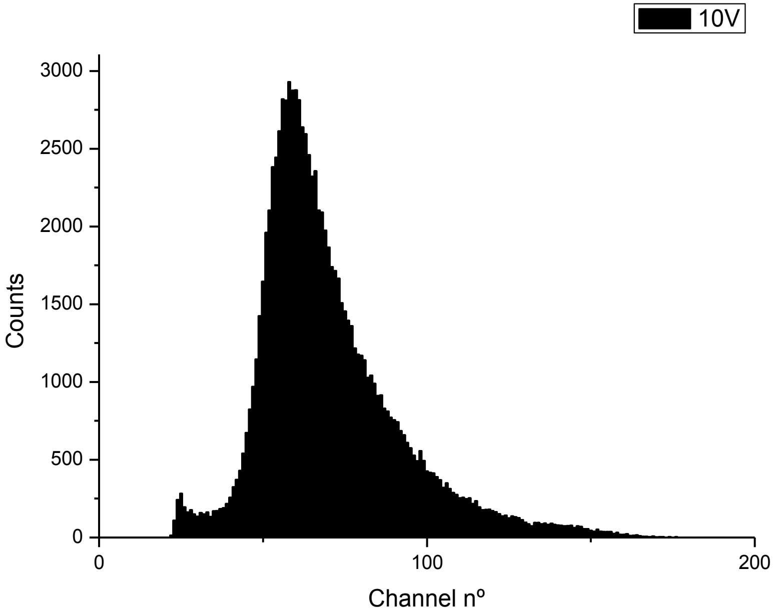


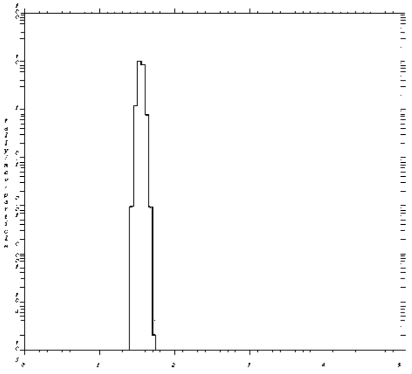
Capacitance of thin 3D is smaller than thin planar

Alpha particles

Alpha particles measured from an Am source.
Particles do not stop but deposit 1,5MeV in 10um Si



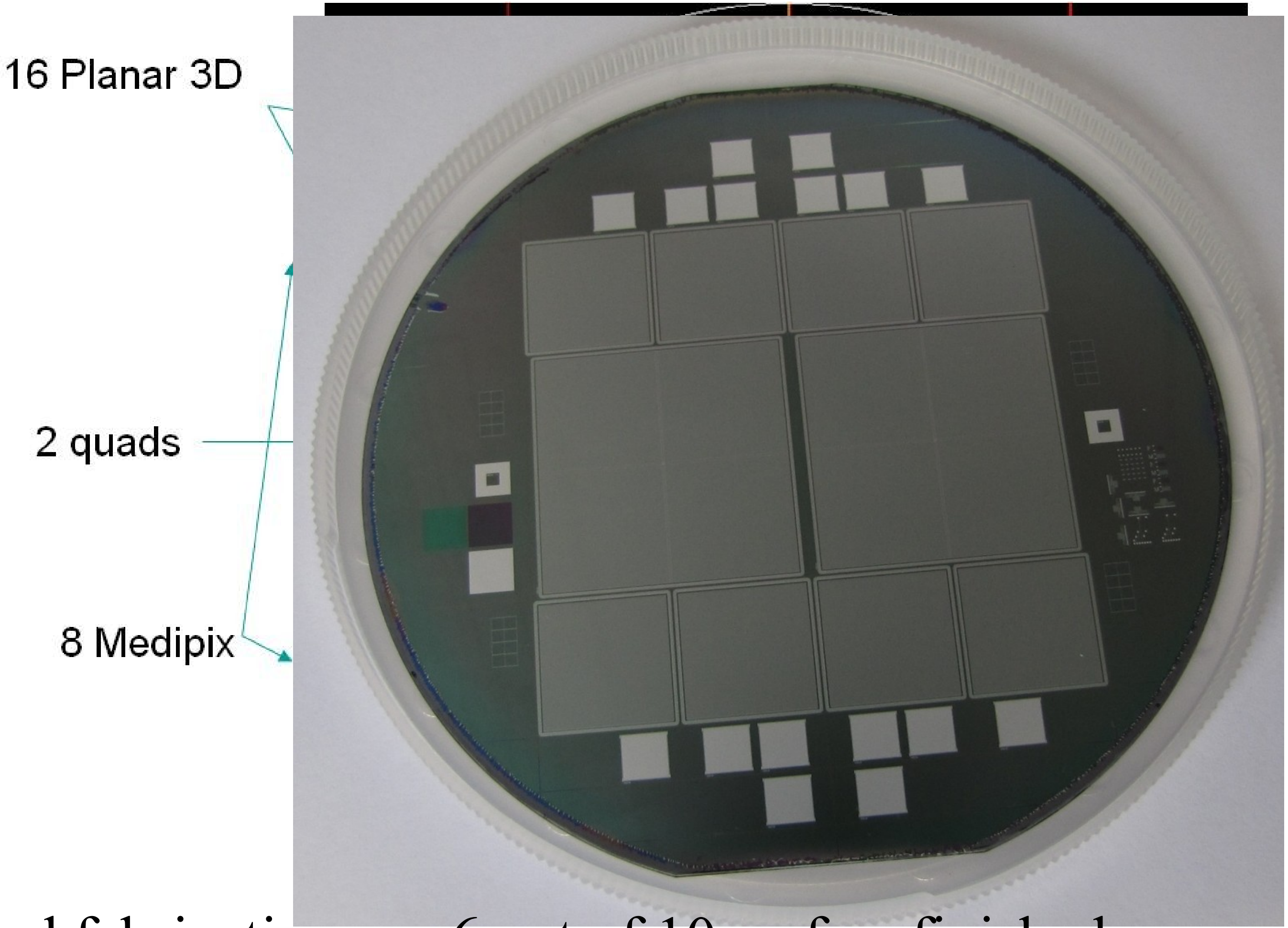




Preliminary simulation

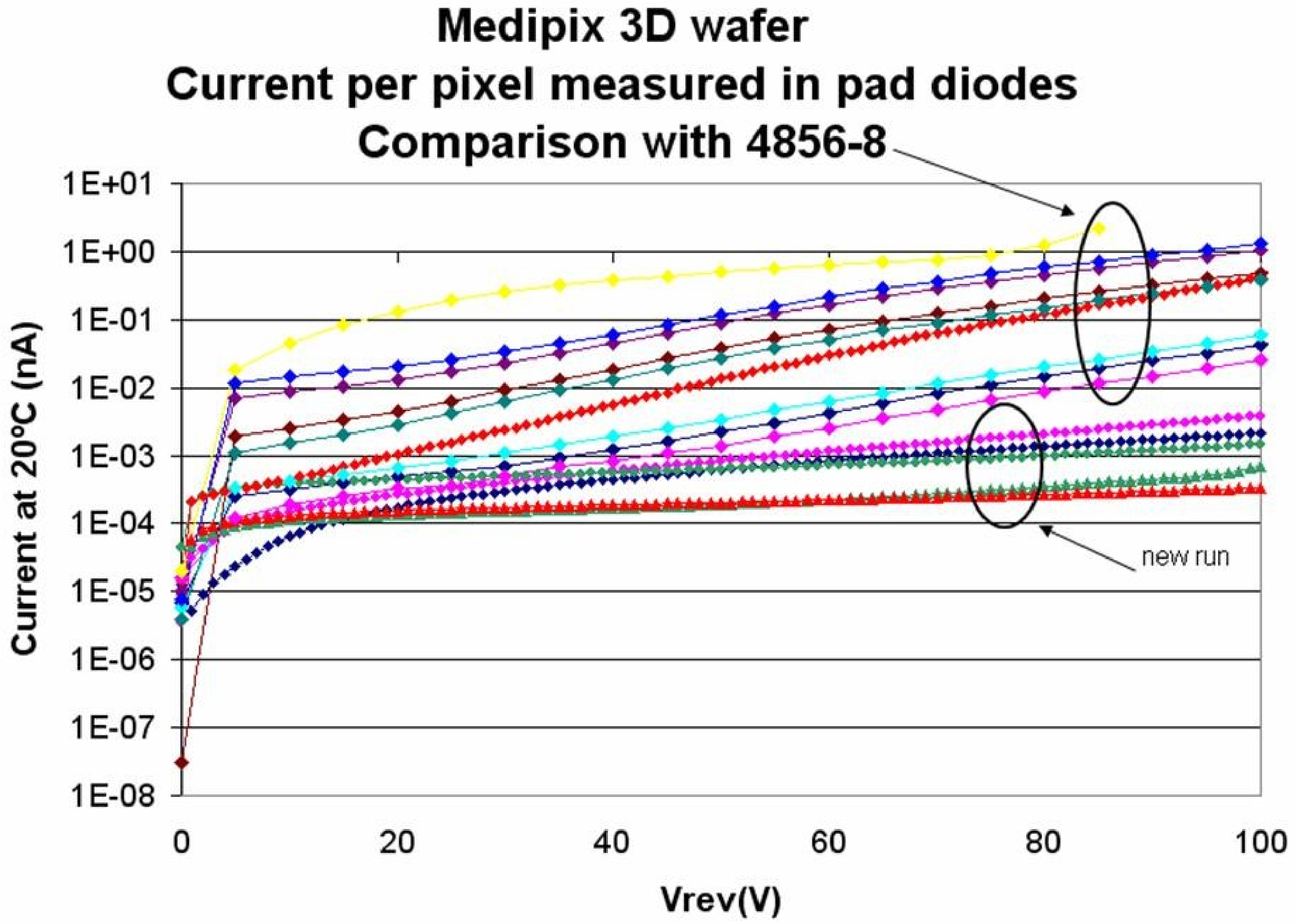
MCNPX, 10e6 alphas (5MeV), threshold 100KeV

3D pixel detectors for Medipix3 chip



Second fabrication run 6 out of 10 wafers finished.
Double sided 3D detectors 285um thick.

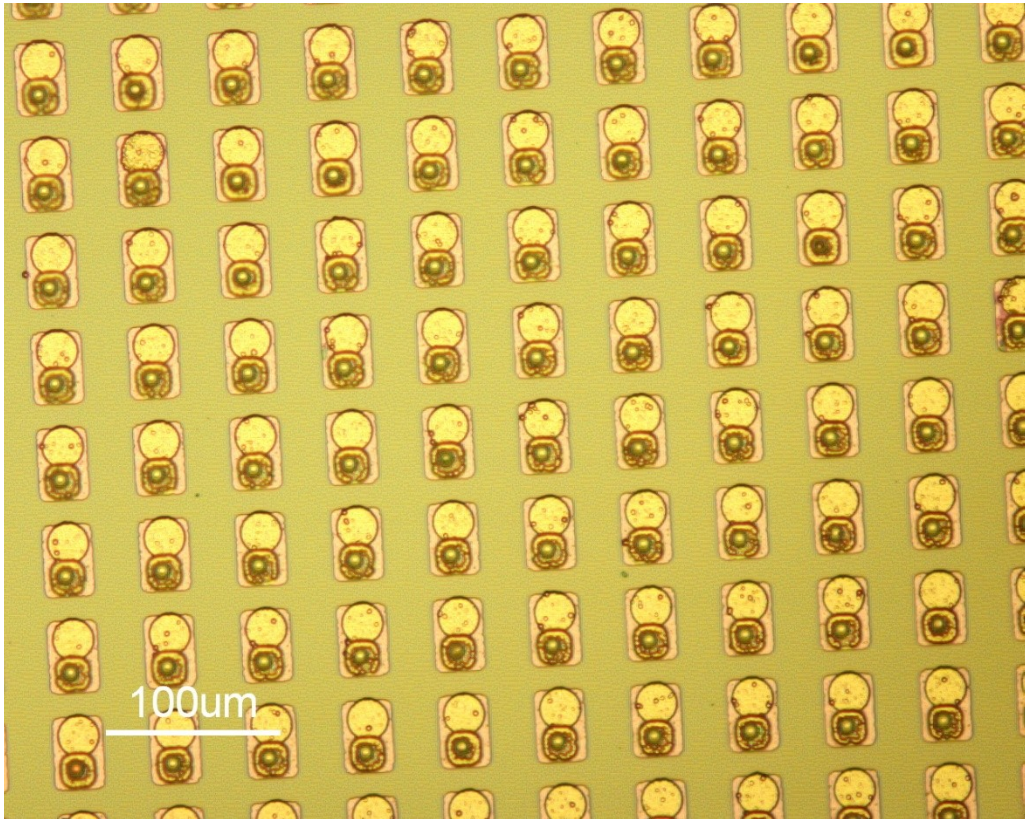
Characterizations



90x90 pixels

Mdp3 detector

UBM electroplated on pixels



Detectors diced and ready for bump bonding at CNM, waiting for Mdp3 chips

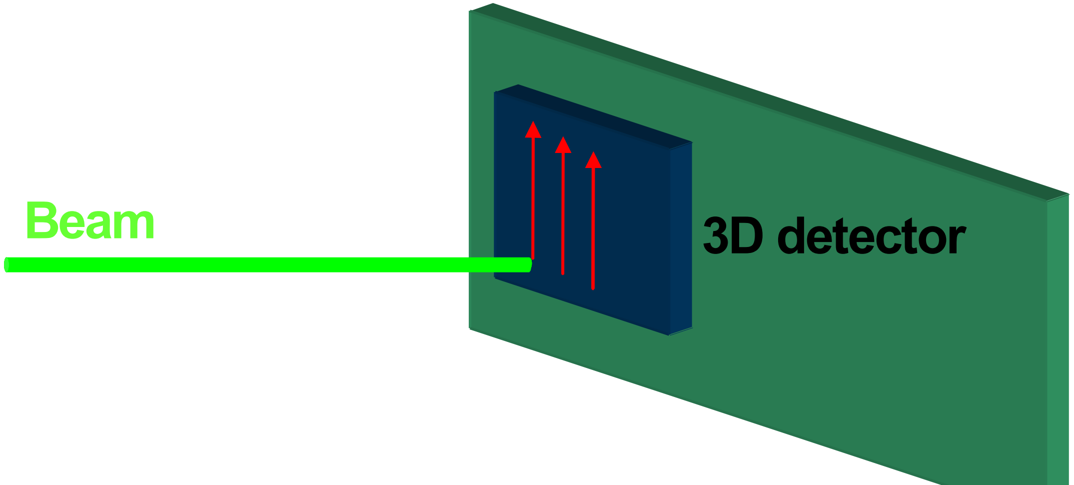
Work done on 3D MPX2

B16 Test beamline at the Diamond

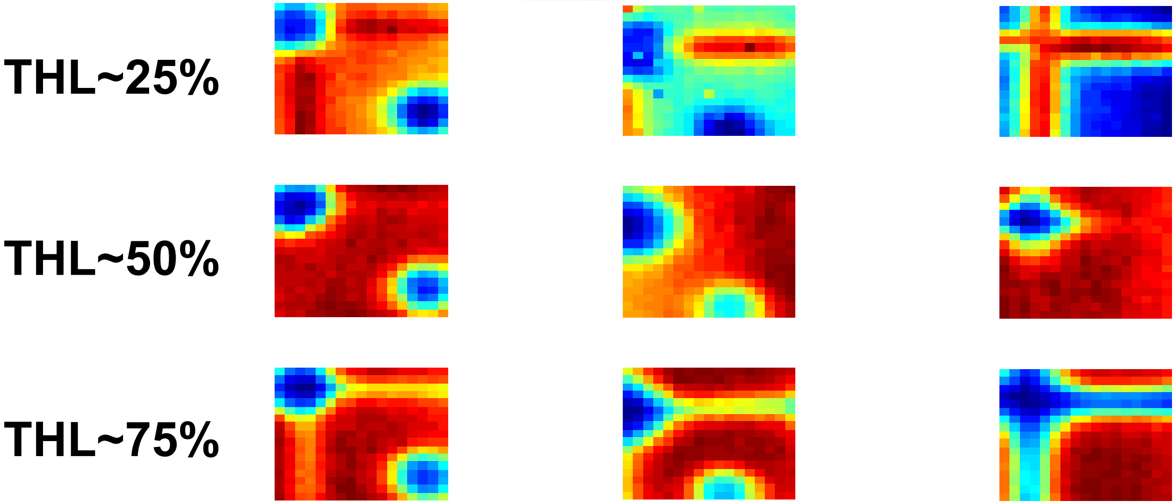
Monochromatic X-ray beam of 14.5keV

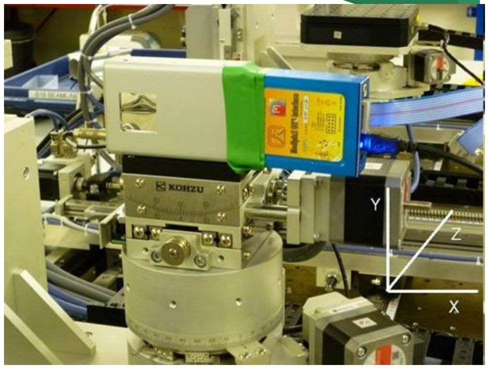
Beam size FWHM were measured as

- **4.5±0.3 μm in x**
- **6.7±0.3 μm in y**



Inefficiencies	Centre	Corners*
Planar	0%	7%
3D N –Type	3%	7%
3D P –Type	4%	7%

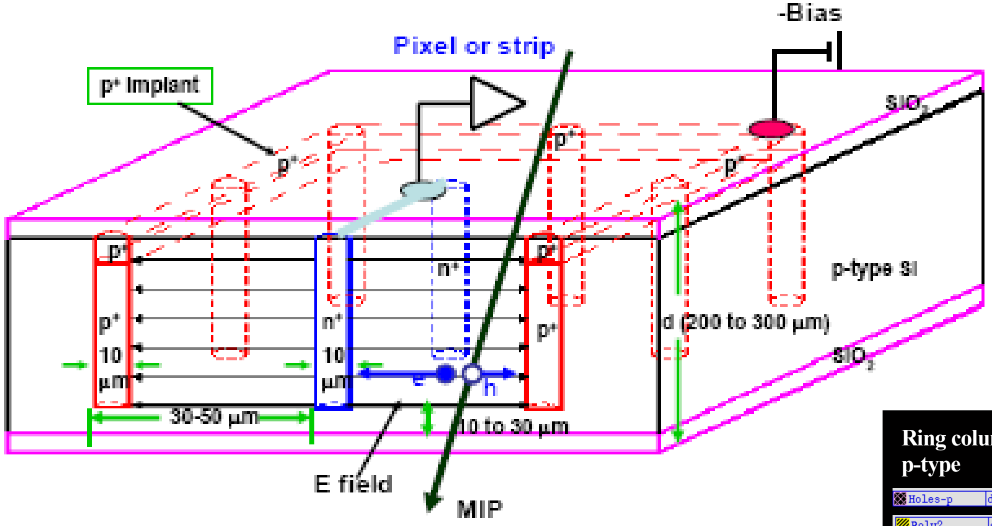




Reduced level of over counting and under counting in 3D

Work done with Diamond light source and Glasgow Uni.

Stripixels

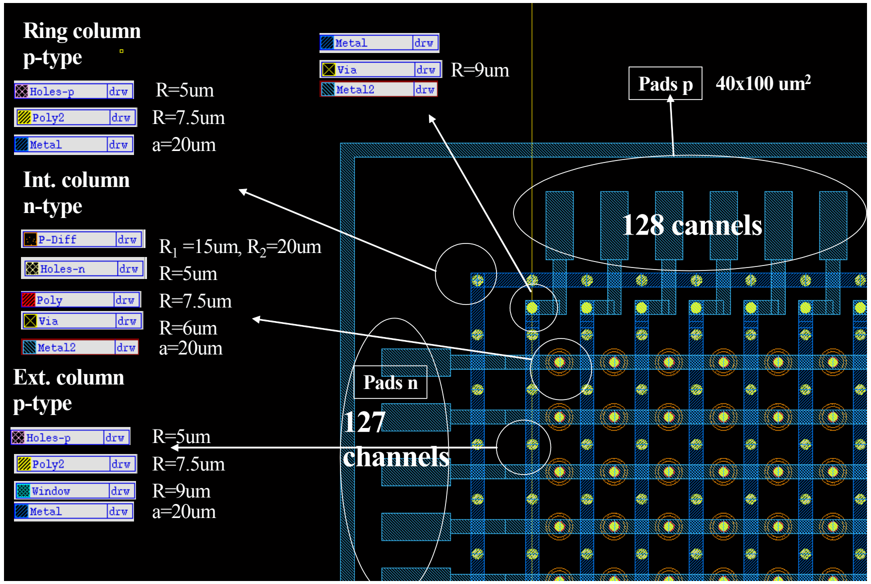


3D strip detectors with 2D positioning on one side.

Double metal process.

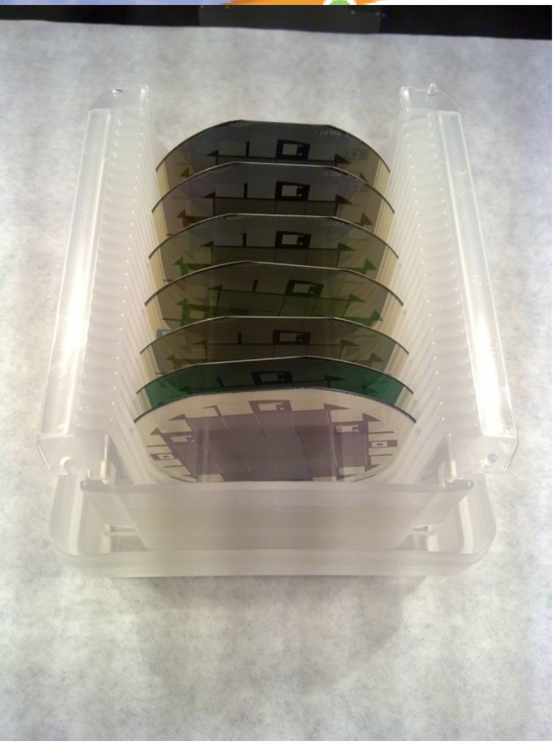
3D single sided process

N-type FZ thick wafers



Work done with Brookhaven National Laboratory .

Stripixel Detectors (CNM-BNL)



8 wafers
(4 inches)

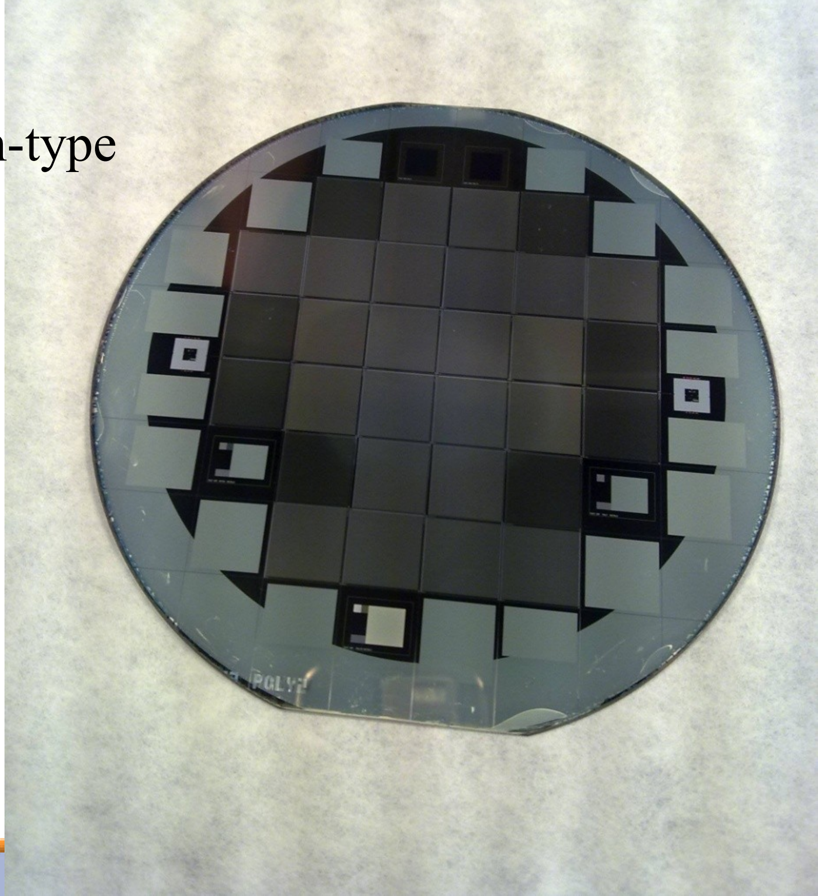
- 1-6 high resistivity wafers 300µm thick
- 7-8 SOI wafers 20 µm thick
  - Wafer 8 broken during Thinning process

- 2D position-sensitive detectors
- 3D technology
- Single-side process
- Crossed p-type and n-type strips

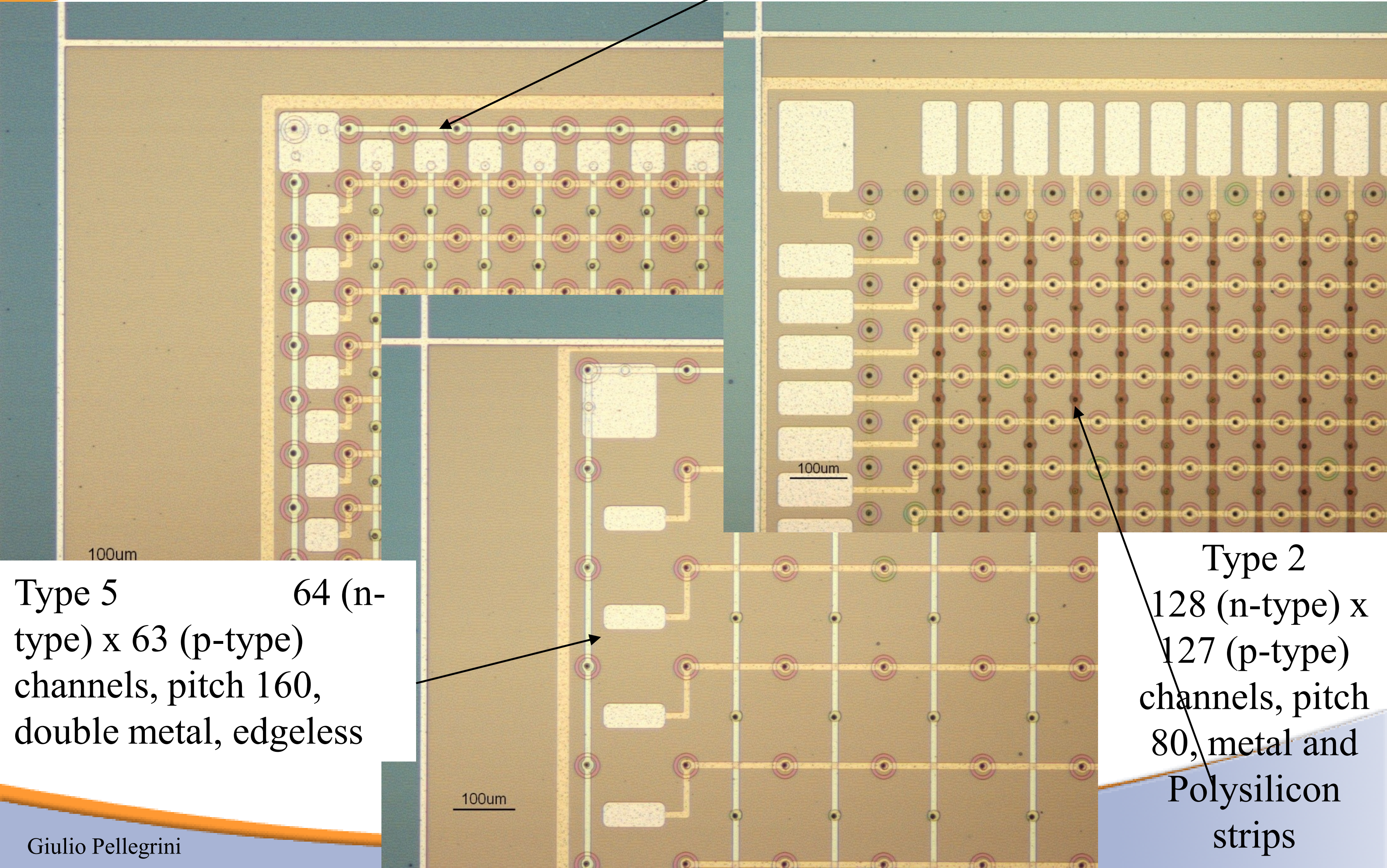
5 different type of baby sensor for each wafer:

1. Pitch 80 µm double metal
2. Pitch 80 µm polysilicon and metal
3. Pitch 160 µm double metal
4. Pitch 80 µm double metal edgeless
5. Pitch 160 µm double metal edgeless

More 1D position-sensitive test structures



Different type of detectors



Type 4 128 (n-type) x 127 (p-type) channels, pitch 80, double metal, edgeless

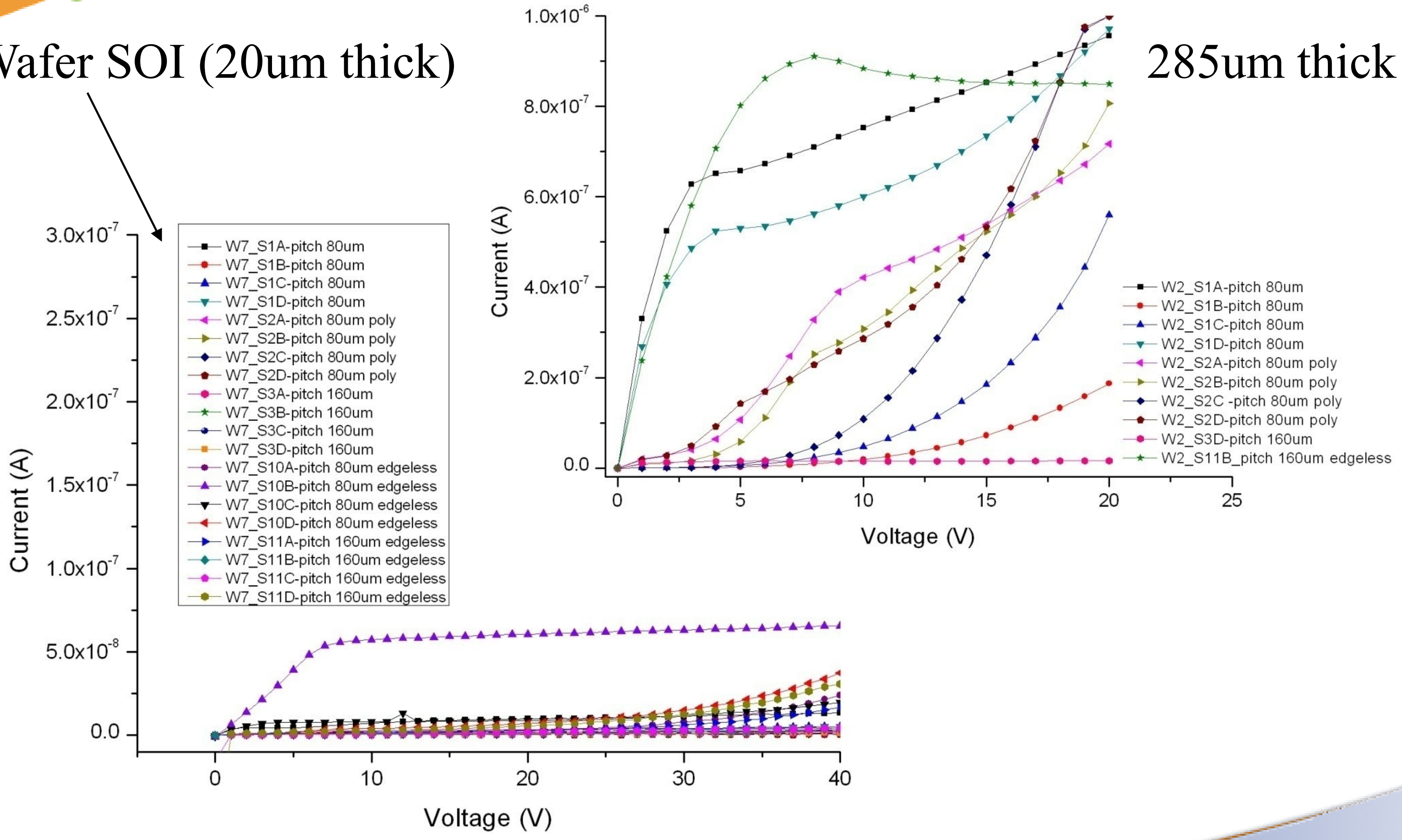
Type 5 64 (n-type) x 63 (p-type) channels, pitch 160, double metal, edgeless

Type 2
128 (n-type) x 127 (p-type) channels, pitch 80, metal and Polysilicon strips

IV Characteristic (detectors)

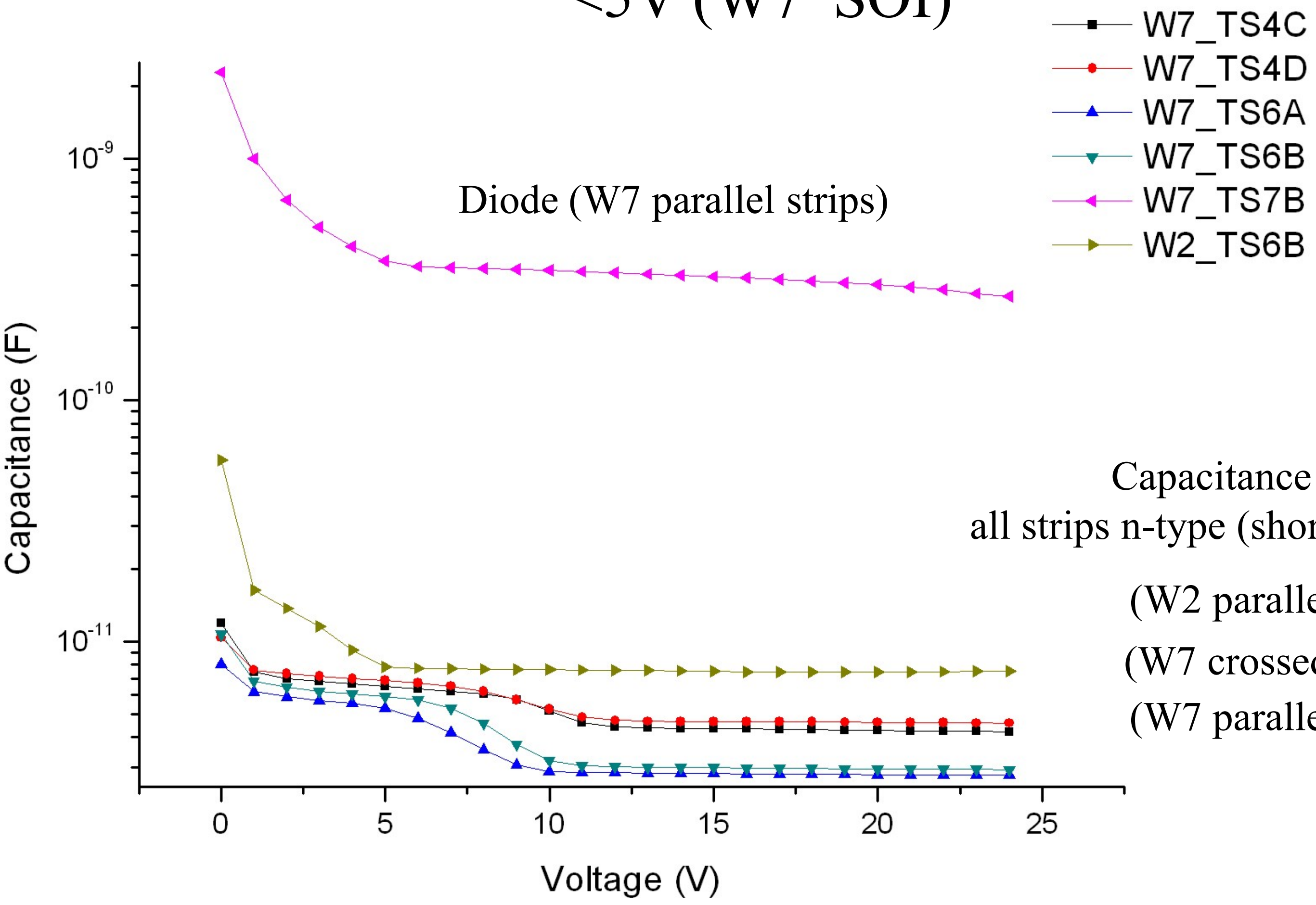
Wafer SOI (20um thick)

285um thick



CV Characteristic (test structures)

Deplation Voltage ~2V (W2 300 um thick)
<5V (W7 SOI)



Diode (W7 parallel strips)

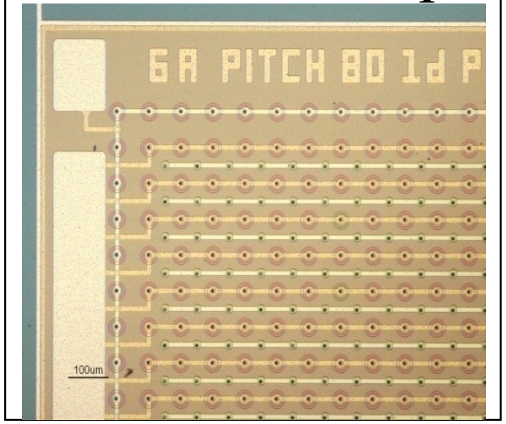
Capacitance between
all strips n-type (shorted) and 1 p-type

(W2 parallel strips)

(W7 crossed strips)

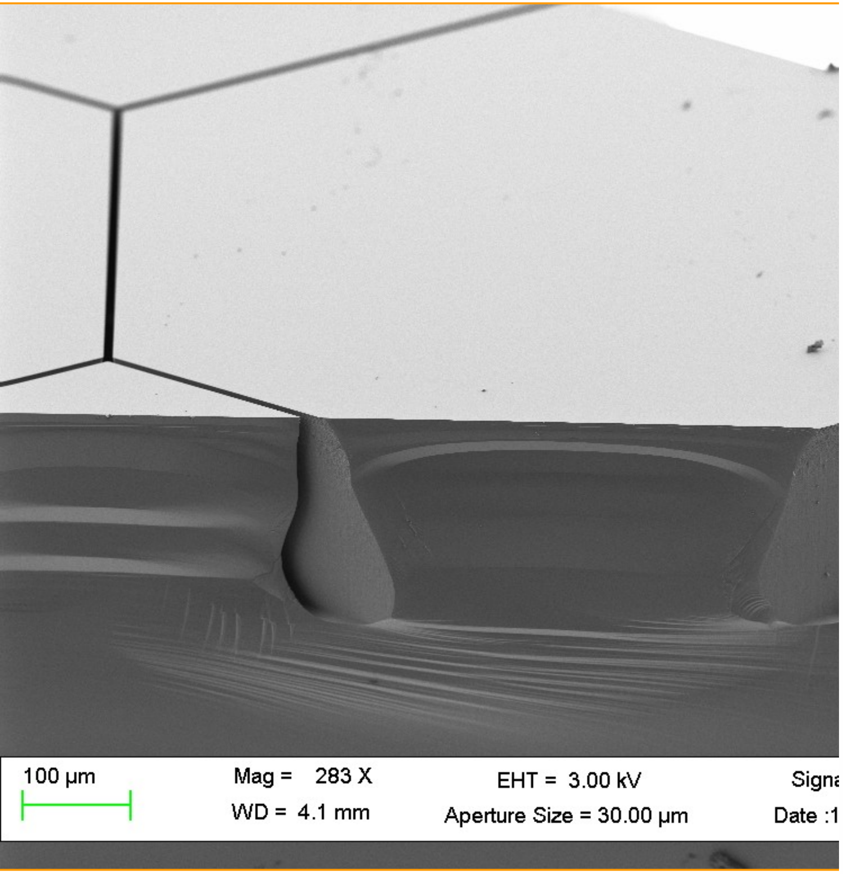
(W7 parallel strips)

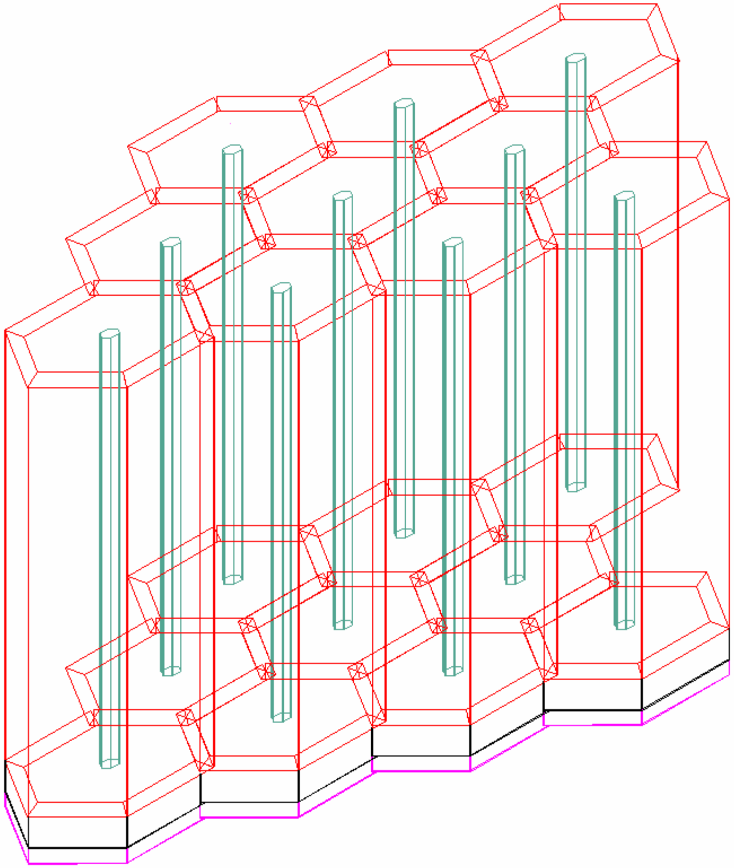
Ex. Parallel strips



Trenched 3D

Concept of the new Independent Coaxial Detector Array (ICDA), proposed by Zheng Li (BNL)





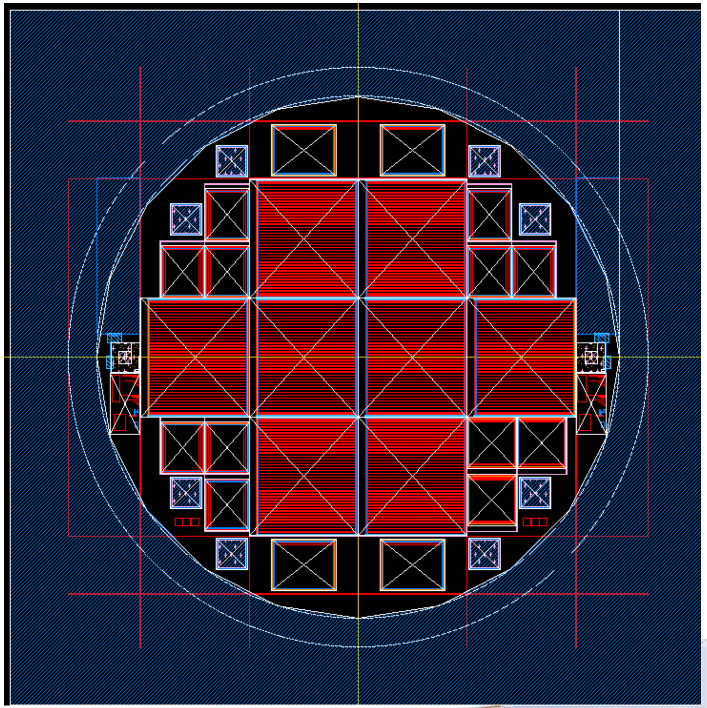
Test runs already done

Fabrication run will start by the end of March

3D Atlas pixels for IBL

Atlas pixels, FE-I3 and new FE-I4 fabrication and irradiation for Insertable B-Layer and testbeam. In the framework of the Atlas 3D collaboration (http://test-3dsensor.web.cern.ch/test-3dsensor/).

Common layout in the Atlas 3D collaboration (CNM,FBK,SINTEF, Stanford).
New FE-I4 design (2x2 cm^2).
A module should be fabricated with 3D detectors.

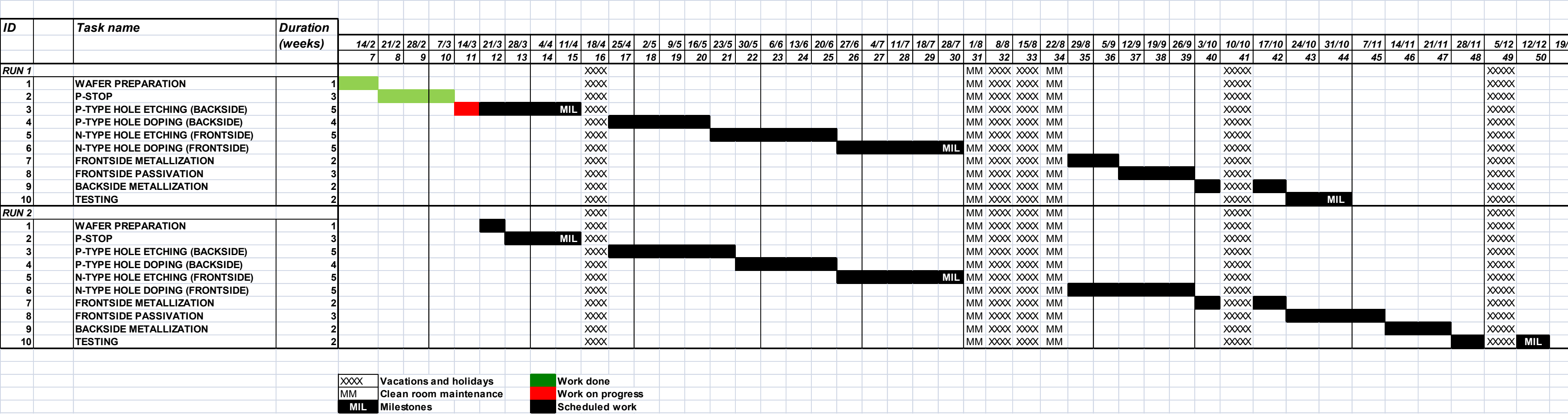


Qualification run almost finished, due by end of March

First full fabrication run already started, 24 wafers.
Second run will start in two weeks.

Work done with IFAE and Glasgow Uni.

Status of production run



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			7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	
RUN 1												XXXX															MM	XXXX	XXXX	MM							XXXXX								XXXXX		
1	WAFER PREPARATION	1	🟩									XXXX															MM	XXXX	XXXX	MM							XXXXX								XXXXX		
2	P-STOP	3		🟩	🟩	🟩						XXXX															MM	XXXX	XXXX	MM							XXXXX								XXXXX		
3	P-TYPE HOLE ETCHING (BACKSIDE)	5					🟥	⬛	⬛	⬛	MIL	XXXX															MM	XXXX	XXXX	MM							XXXXX								XXXXX		
4	P-TYPE HOLE DOPING (BACKSIDE)	4										XXXX	⬛	⬛	⬛	⬛											MM	XXXX	XXXX	MM							XXXXX								XXXXX		
5	N-TYPE HOLE ETCHING (FRONTSIDE)	5										XXXX					⬛	⬛	⬛	⬛	⬛						MM	XXXX	XXXX	MM							XXXXX								XXXXX		
6	N-TYPE HOLE DOPING (FRONTSIDE)	5										XXXX										⬛	⬛	⬛	⬛	MIL	MM	XXXX	XXXX	MM							XXXXX								XXXXX		
7	FRONTSIDE METALLIZATION	2										XXXX															MM	XXXX	XXXX	MM	⬛	⬛					XXXXX								XXXXX		
8	FRONTSIDE PASSIVATION	3										XXXX															MM	XXXX	XXXX	MM			⬛	⬛	⬛		XXXXX								XXXXX		
9	BACKSIDE METALLIZATION	2										XXXX															MM	XXXX	XXXX	MM						⬛	XXXXX	⬛							XXXXX		
10	TESTING	2										XXXX															MM	XXXX	XXXX	MM							XXXXX		⬛	MIL					XXXXX		
RUN 2												XXXX															MM	XXXX	XXXX	MM							XXXXX								XXXXX		
1	WAFER PREPARATION	1						⬛				XXXX															MM	XXXX	XXXX	MM							XXXXX								XXXXX		
2	P-STOP	3							⬛	⬛	MIL	XXXX															MM	XXXX	XXXX	MM							XXXXX								XXXXX		
3	P-TYPE HOLE ETCHING (BACKSIDE)	5										XXXX	⬛	⬛	⬛	⬛	⬛										MM	XXXX	XXXX	MM							XXXXX								XXXXX		
4	P-TYPE HOLE DOPING (BACKSIDE)	4										XXXX						⬛	⬛	⬛	⬛						MM	XXXX	XXXX	MM							XXXXX								XXXXX		
5	N-TYPE HOLE ETCHING (FRONTSIDE)	5										XXXX										⬛	⬛	⬛	⬛	MIL	MM	XXXX	XXXX	MM							XXXXX								XXXXX		
6	N-TYPE HOLE DOPING (FRONTSIDE)	5										XXXX															MM	XXXX	XXXX	MM	⬛	⬛	⬛	⬛	⬛		XXXXX								XXXXX		
7	FRONTSIDE METALLIZATION	2										XXXX															MM	XXXX	XXXX	MM						⬛	XXXXX	⬛							XXXXX		
8	FRONTSIDE PASSIVATION	3										XXXX															MM	XXXX	XXXX	MM							XXXXX		⬛	⬛	⬛				XXXXX		
9	BACKSIDE METALLIZATION	2										XXXX															MM	XXXX	XXXX	MM							XXXXX					⬛	⬛		XXXXX		
10	TESTING	2										XXXX															MM	XXXX	XXXX	MM							XXXXX							⬛	XXXXX	MIL	

XXXX	Vacations and holidays	🟩	Work done
MM	Clean room maintenance	🟥	Work on progress
MIL	Milestones	⬛	Scheduled work

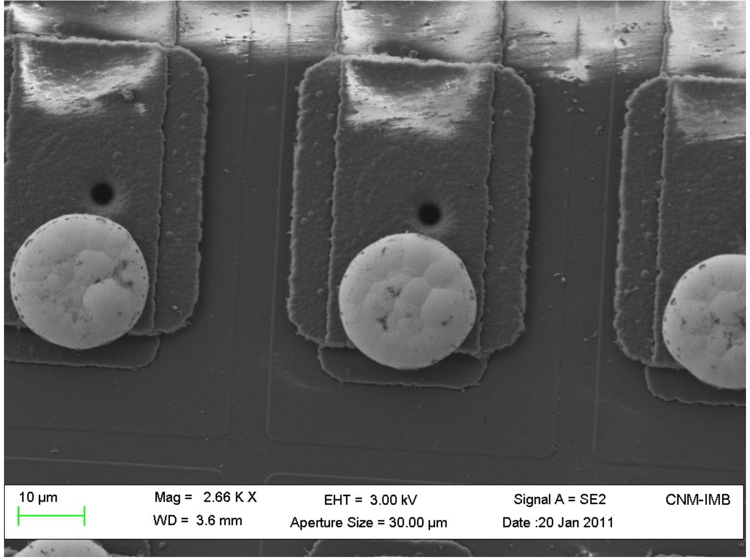
First production started

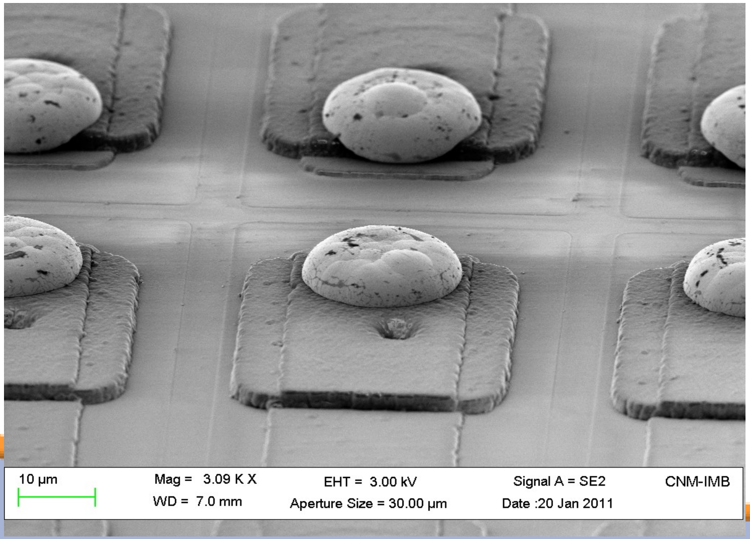
Second production will start soon

Third production to be agreed.

FE-I3 status

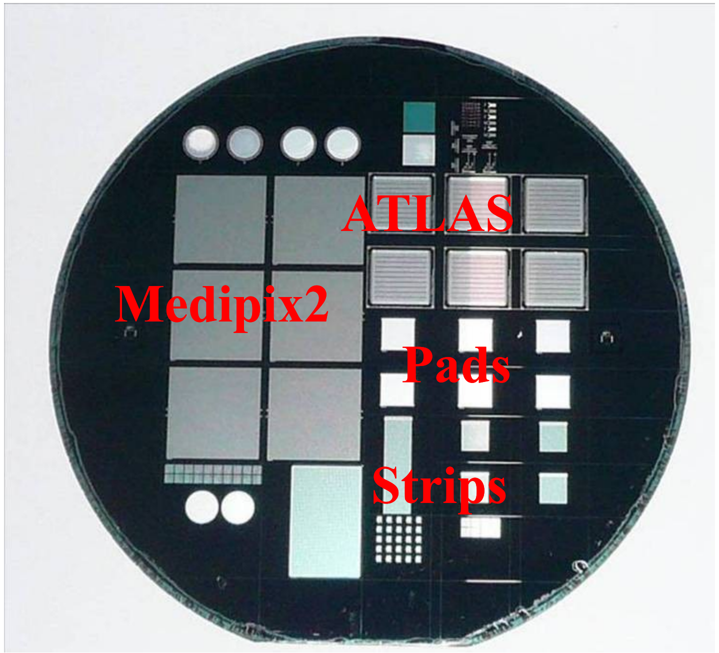
- UBM deposited at CMN on one wafer and flip chipped to FE-I3





Devices designed at Glasgow & CNM
Fabricated at CNM

CNM 3D-wafer

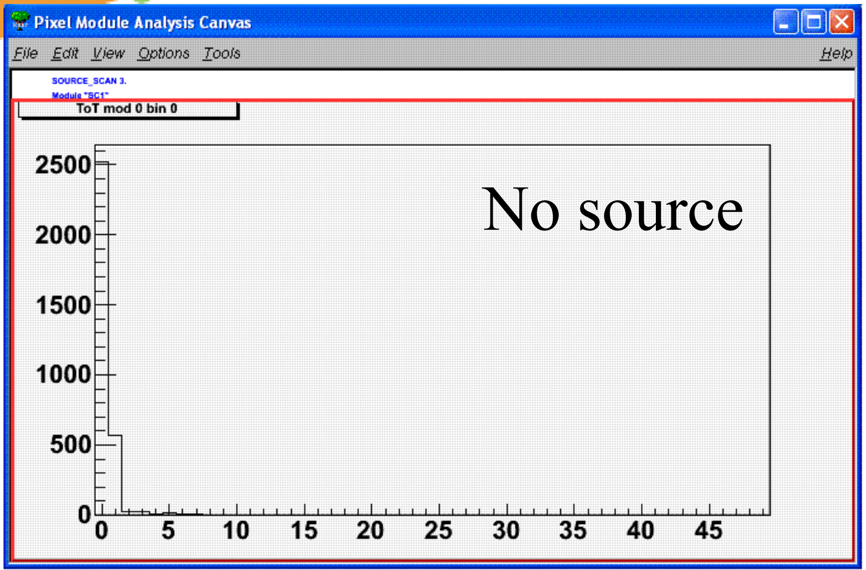


4 inch wafer

Another wafers is at IZM waiting for UBM and flip chip

Source Scan with BCN_CNM_3D_11

- FE-I3 Run 5051
- Cd-109 source
- HV=-33V
- Preliminar calibration
  (30ToT at20ke)
- With USBpix system (at IFAE)



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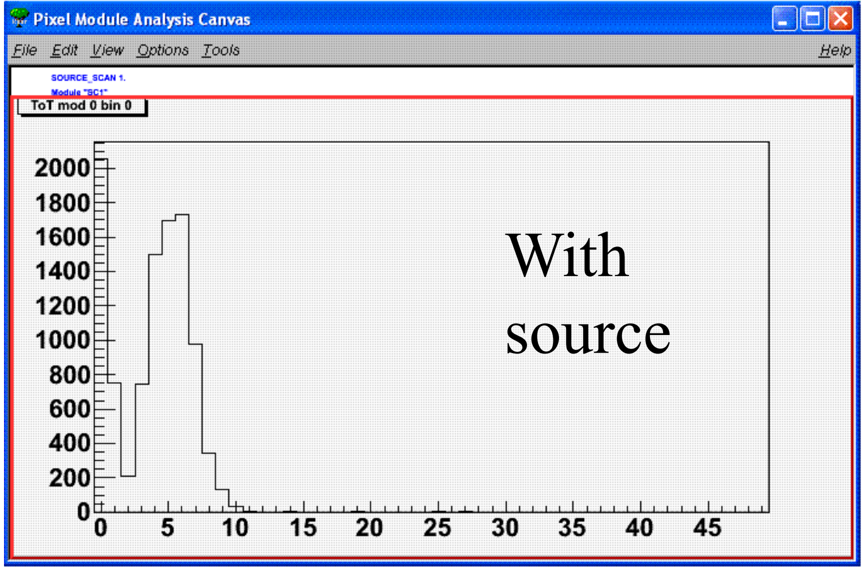
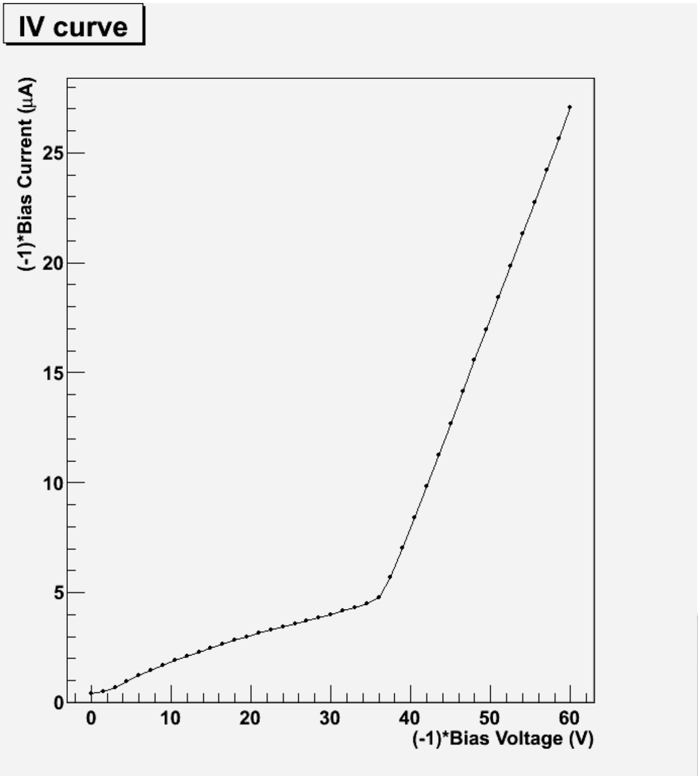
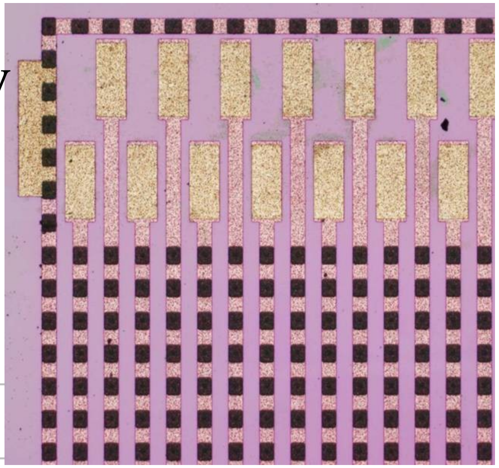


With source

ToT Counts

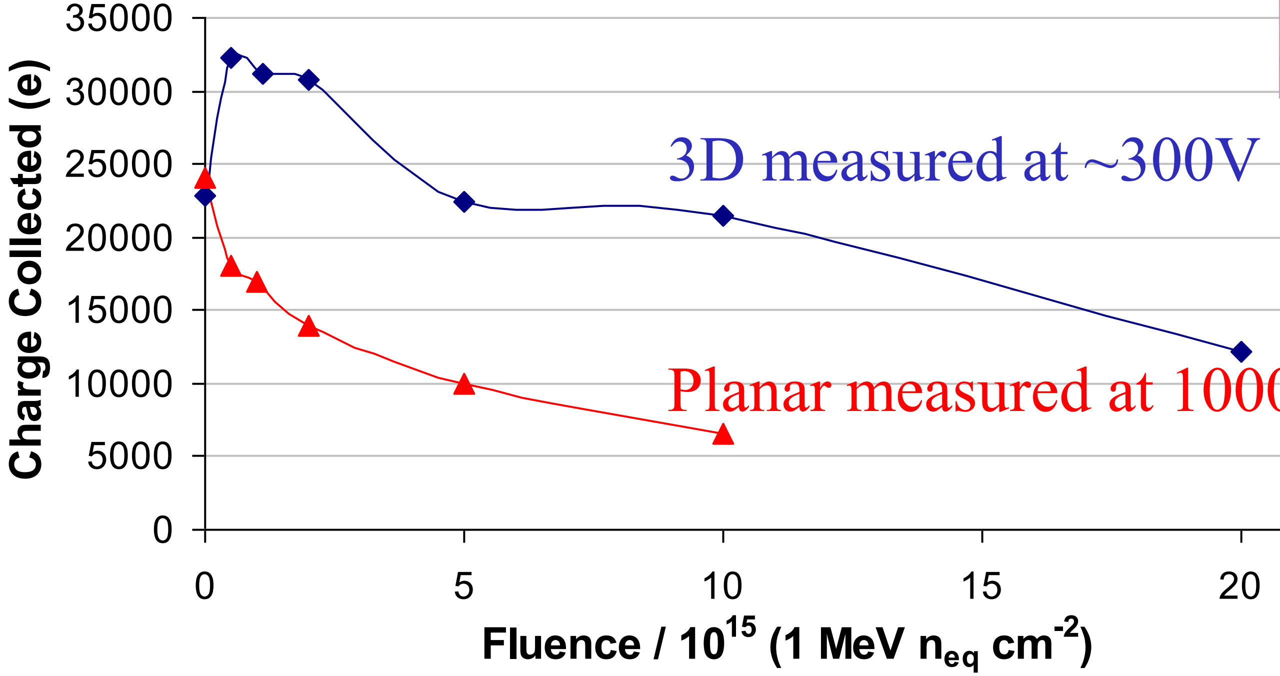


Radiation hard measurments



Measured with Alibava System at Glasgow University

LHCb speed bi-polar amplifier (25ns peaking time)



Sr90 source

See also Michael Koehler´s talk, tomorrow

References of CNM 3D detectors

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13. Simulation and test of 3D silicon radiation detectors: NIM A Volume 579, Issue 2, 1 September 2007, Pages 642-647.

The work on 3D detectors has been done in collaboration with different high energies institutes expert in device characterization: Glasgow University, Diamond light source, Freiburg University, Brookhaven National Lab, IFIC Valencia, IFAE Barcelona.

Thanks for your attention