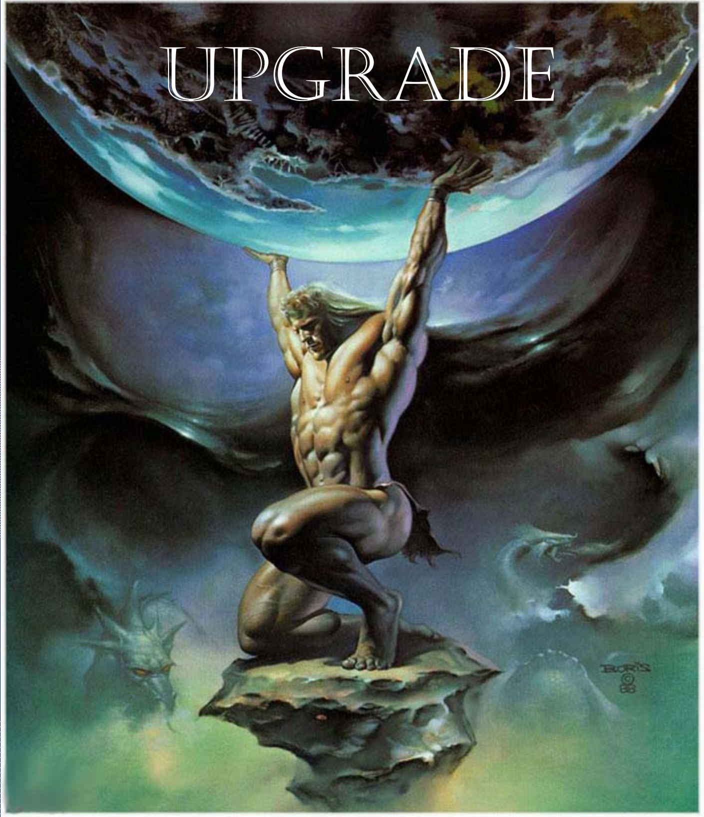


Recent results from the 3D ATLAS R&D Collaboration

Giulio Pellegrini CNM-IMB

on behalf of The 3D ATLAS R&D Collaboration

ATLAS 3D Silicon Sensors R&D Collaboration

VTT

B. Stugu, H. Sandaker, K. Helle, (Bergen University), M. Barbero, F. Hügging, M. Karagounis, V. Kostyukhin, H. Krüger, J-W Tsung, N. Wermes (Bonn University), M. Capua; S. Fazio, A. Mastroberardino; G. Susinno (Calabria University), C. Gallrapp, B. Di Girolamo; D. Dobos, A. La Rosa, H. Pernegger, S. Roe (CERN), T. Slavicek, S. Pospisil (Czech Technical University), K. Jakobs, M. Köhler, U. Parzefall (Freiburg University), N. Darbo, G. Gariano, C. Gemme, A. Rovani, E. Ruscino (University and INFN of Genova), C. Butter, R. Bates, V. Oshea (Glasgow University), S. Parker (The University of Hawaii), M. Cavalli-Sforza, S. Grinstein, I. Korokolov, C. Padilla (IFAE Barcelona), K. Einsweiler, M. Garcia-Sciveres (Lawrence Berkeley National Laboratory), M. Borri, C. Da Vià, J. Freestone, S. Kolya, C. Li, C. Nellist, J. Pater, R. Thompson, S.J. Watts (The University of Manchester), M. Hoeferkamp, S. Seidel (The University of New Mexico), E. Bolle, H. Gjersdal, K-N Sjoebaek, S. Stapnes, O. Rohne, (Oslo University) D. Su, C. Young, P. Hansson, P. Grenier, J. Hasi, C. Kenney, M. Kocian, P. Jackson, D. Silverstein (SLAC), H. Davetak, B. DeWilde, D. Tsybychev (Stony Brook University). G-F Dalla Betta, P. Gabos, M. Povoli (University and INFN of Trento) , M. Cobal, M-P Giordani, Luca Selmi, Andrea Cristofoli, David Esseni, Andrea Micelli, Pierpaolo Palestri (University of Udine)

Processing Facilities: C. Fleta, M. Lozano G. Pellegrini, (CNM Barcelona, Spain); (M. Boscardin, A. Bagolini, G. Giacomini, C. Piemonte, S. Ronchin, E. Vianello, N. Zorzi (FBK-Trento, Italy) , T-E. Hansen, T. Hansen, A. Kok, N. Lietaer (SINTEF Norway), J. Hasi, C. Kenney (Stanford). J. Kalliopuska, A. Oja (VTT , Finland)*

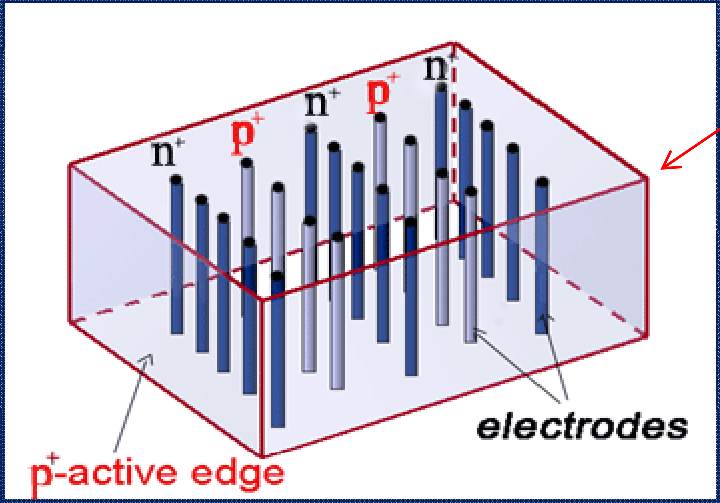
18 institutions and 5 processing facilities

3D designs

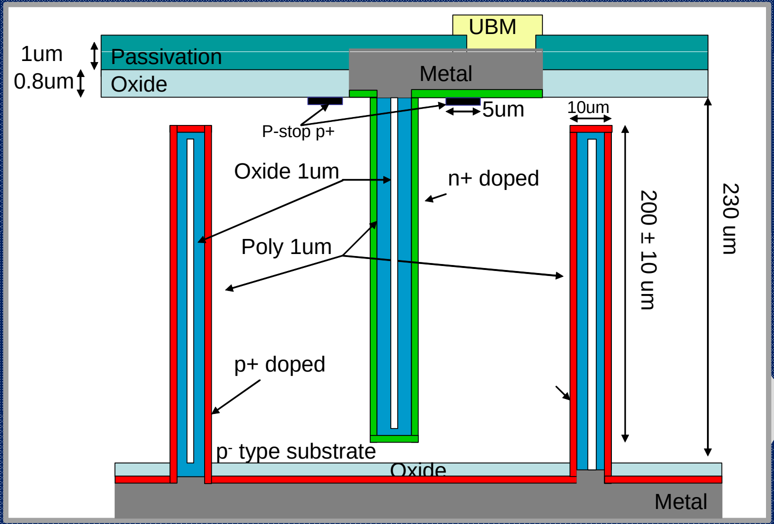
This for IBL because
More compatible with planar
For loading and HV supply

3D Consortium

Full 3D with active edges



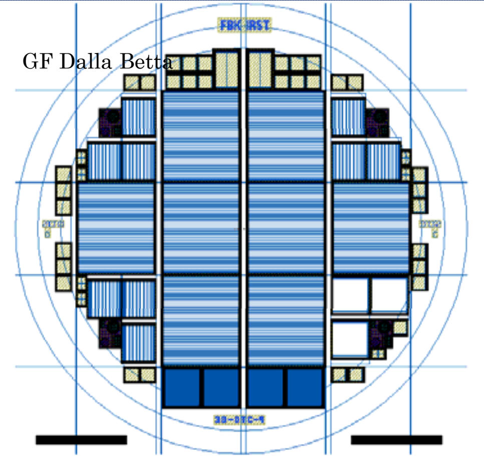
Double Column Design



3D silicon for Fast-Track IBL

➢Technical specifications for FT-IBL:

Common floor plan – same bump-bonding masks



Material		:	HPS WAFER
Type/Atom		:	P B
Ingot orientation		:	(1-0-0) +/- 1,00 Deg
Resistivity	Ohm cm	:	10.000,00 - 30.000,00
Lifetime	min µsec	:	1.000,00
Carbon content	Max Atoms/cm3	:	2.0X10E16
Oxygen content	Max Atoms/cm3	:	2.0X10E16
Diameter	mm	:	99,50 - 100,50
Wafer front side		:	Polished
Wafer back side		:	Polished
Primary Flat	mm	:	30,00 - 35,00 (1-10) +/- 1 Deg.
Secondary Flat	mm	:	16,00 - 20,00 90 +/ - 5 Deg.
Thickness	µm	:	230 +/- 10,00
TTV	µm	:	≤ 5,00
Bow	µm	:	≤ 40,00
Edge rounding		:	YES - Standard

•**Tile type**	**single**
•**Number of columns per 250 micron pixel**	**2**
•**Sensor thickness**	**230±20 um**
•**Columns overlap**	**≥ 200 um**
•**Sensor active area**	**18860 X 20560 (+scribe line)**
•**Dead region in Z**	**200um guard fence +~25um cut**
•**Wafer bow after processing**	**<60 microns**
•**Front back alignment**	**< 5 microns**
•**Alignment marks**	**as specified for stave loading**
•**Bias Voltage Pads**	**as specified**

Both *p-spray* and *p-stop* techniques with concentrations of **$2.0 \pm 0.5 \times 10^{12}$ cm^{-2}** and **$4.0 \pm 0.5 \times 10^{12}$cm^{-2}** respectively will be allowed provided they ensure surface isolation and the electrical specifications described in the next paragraph to be met.

Each manufacturer shall provide undiced wafers with the above specifications to allow photolithography for under-bump metallization deposition.

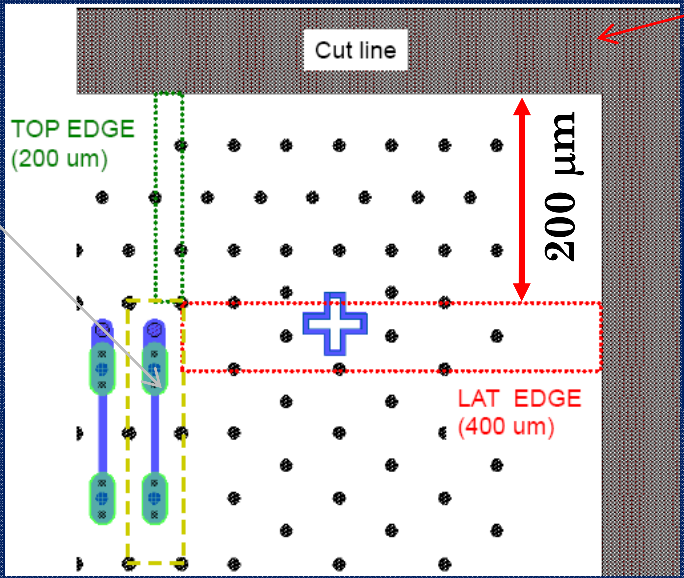
200 um guard fences

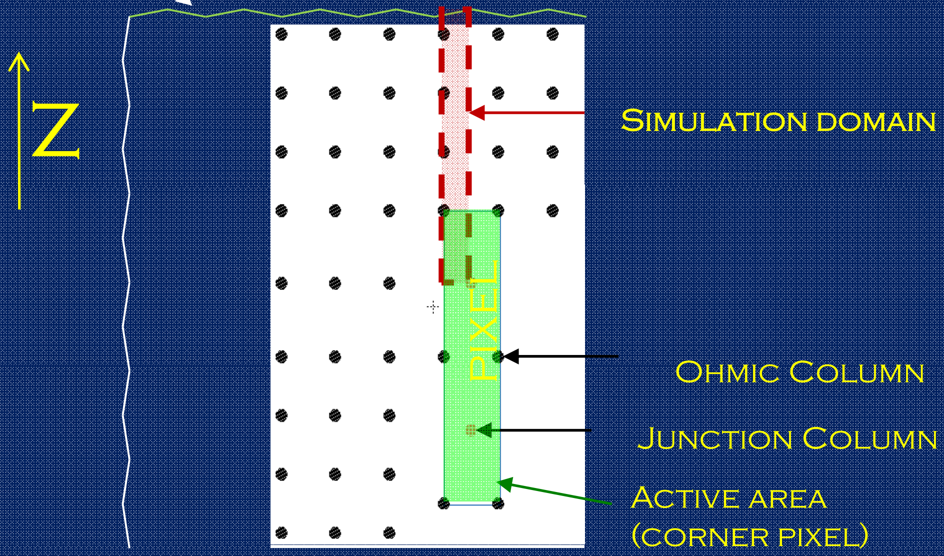
recent tests have shown 100 um safe

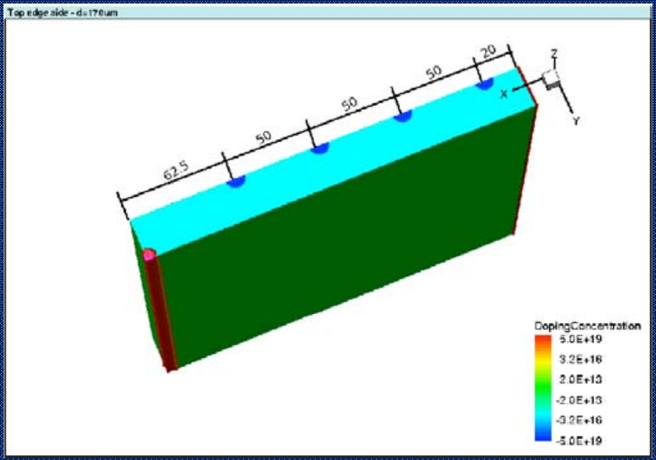
G.Giacomini, et al, 6th Trento Workshop, 2-4 March 2011 (http://tredi.fbk.eu)

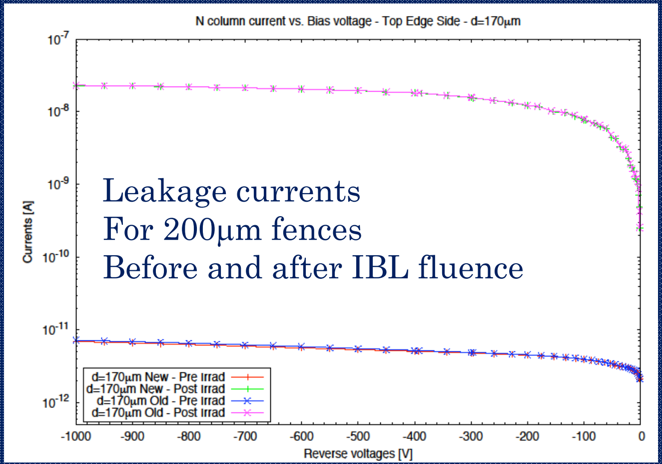
Design and simulation
GF Dalla Betta and
Marco Povoli, Trento

Cut line – precision 20 um







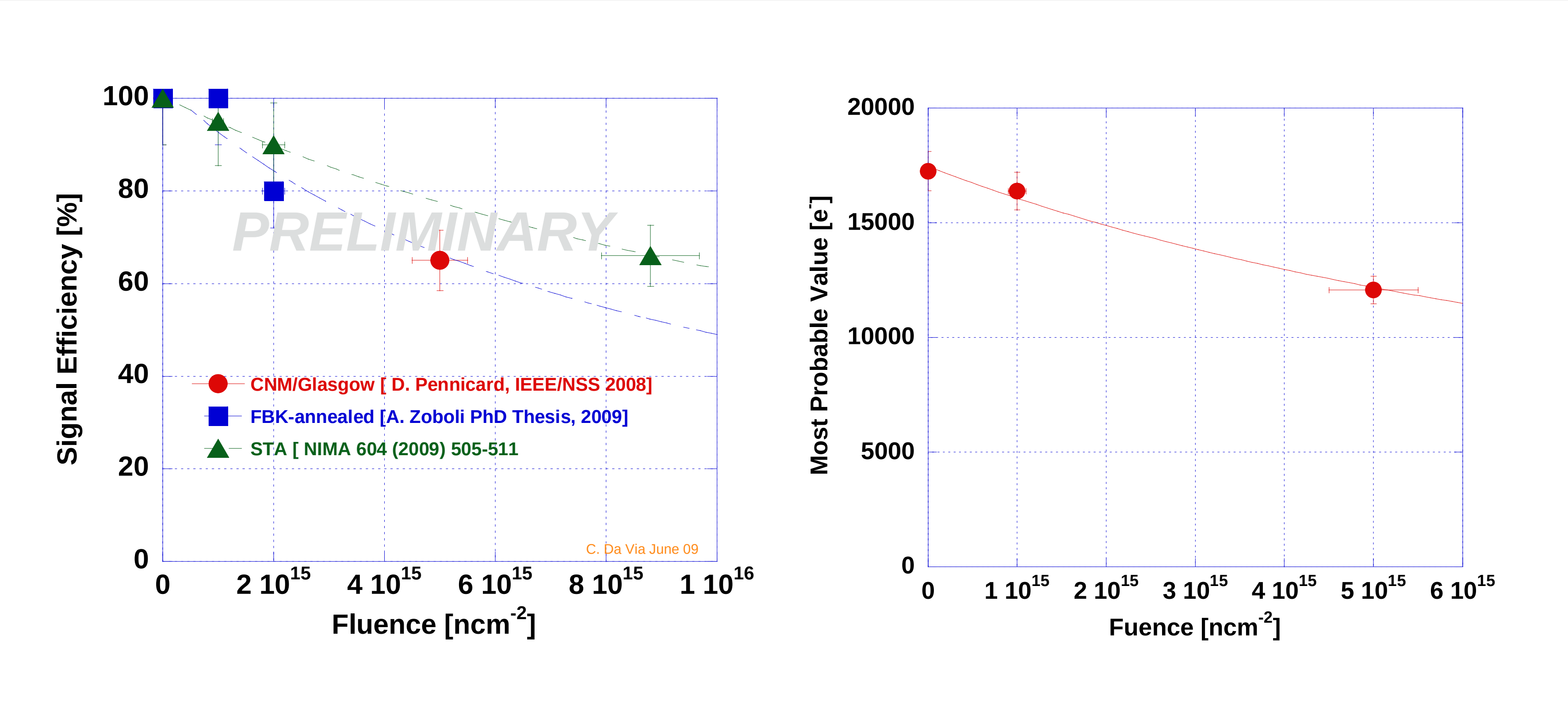


Signal after IBL fluence

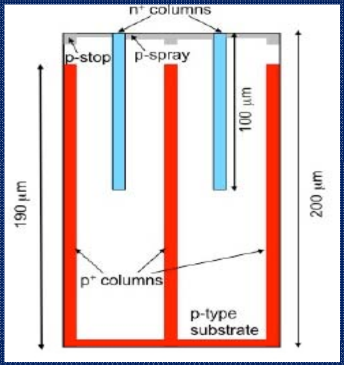
Compilation of Stanford, CNM,FBK

Fluence [ncm^{-2}]	MPS [e^{-}]
0	17250
1×10^{15}	16380
5×10^{15}	12075

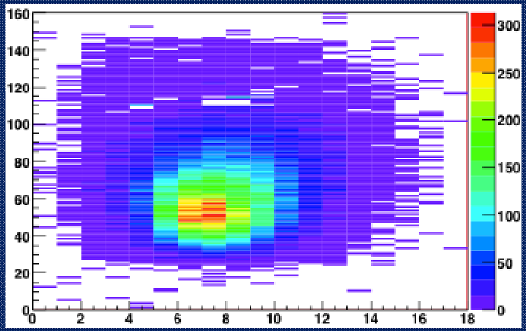
MPS=230μm x 75e^{-} = 17 250



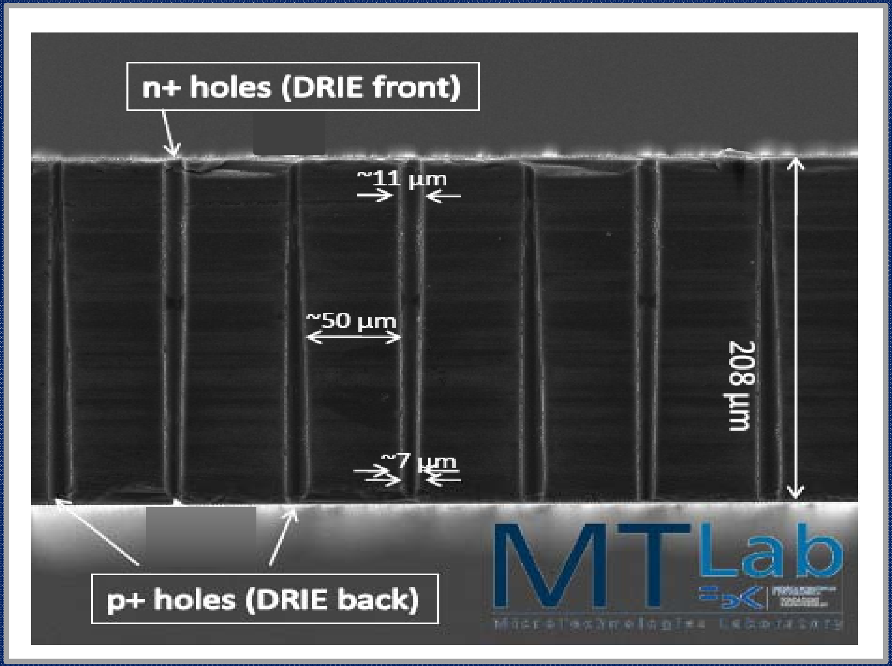
Irradiated FBK double side with non optimal column overlap up to $5 \times 10^{15} n cm^{-2}$

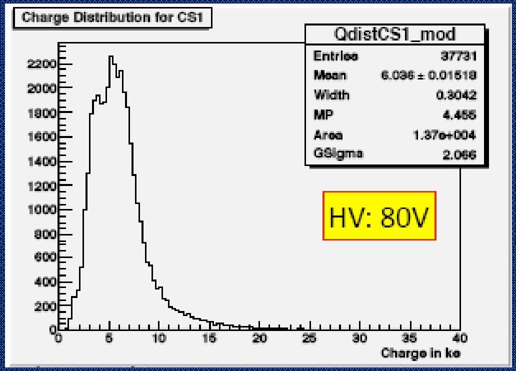


Signal efficiency
Depends on column
overlap



Current productions
Layout:





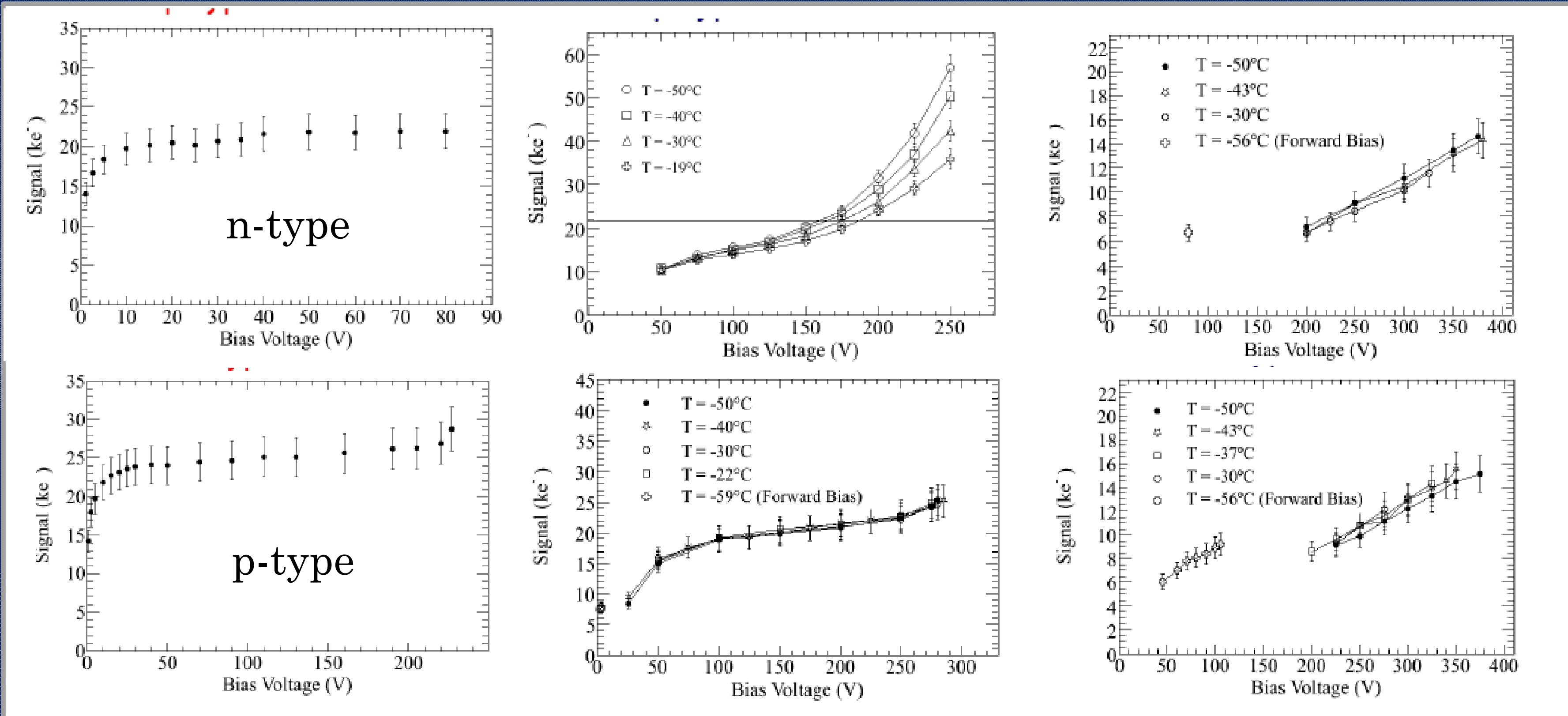
^{90}Sr source
HV= 80V!
T= -20°C
Environmental chamber

Data A. La Rosa

Despite non optimal layout
Signal still visible at 80V

Double Side 3D from CNM irradiated Uni-Freibugh with Alibava system (Thanks to M. Kohler, Freiburg)

Before irradiation total charge 22000e	$2x10^{15}ncm^{-2}$ 22000e$^-$ at 180V	$2x10^{16}ncm^{-2}$ 15000e$^-$ at 380V

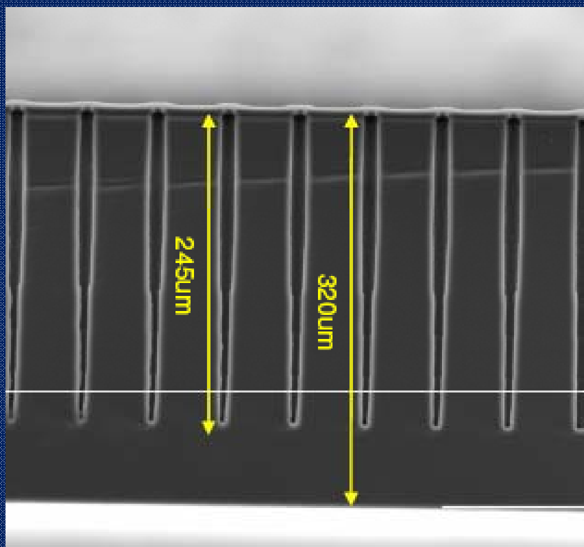


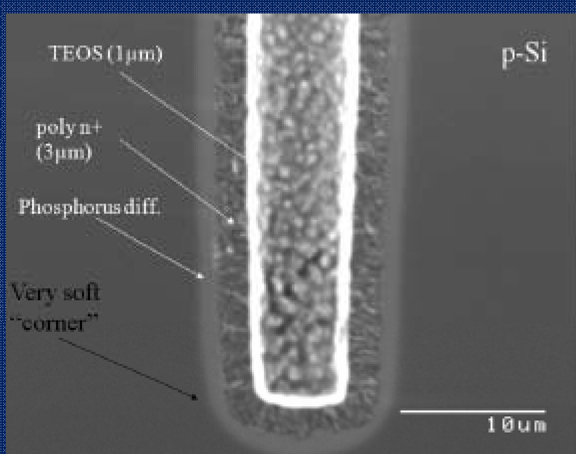
250 um column overlap, IES= 56 microns
Detectors irradiated at the proton cyclotron Karlsruhe with 25 MeV protons
Annealing state: ~ 5 days at RT (only p-type detector, $2x10^{16}$ neq/cm2: ~30 days)
Noise at $2x10^{16}$is 1000e- at -45 °C -50 °C

Irradiation results from CNM 3D sensors

Measured in Glasgow using the ALIBAVA system +**MIPs**

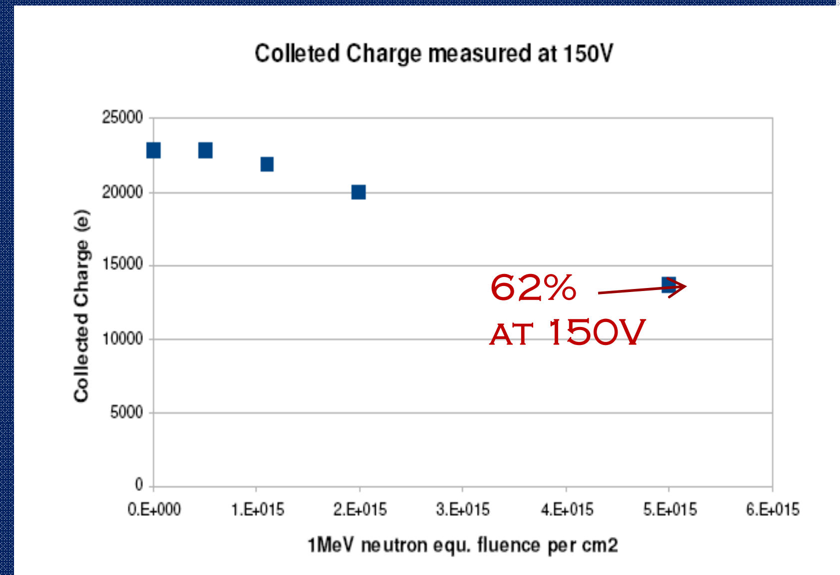
Evidence for charge multiplication

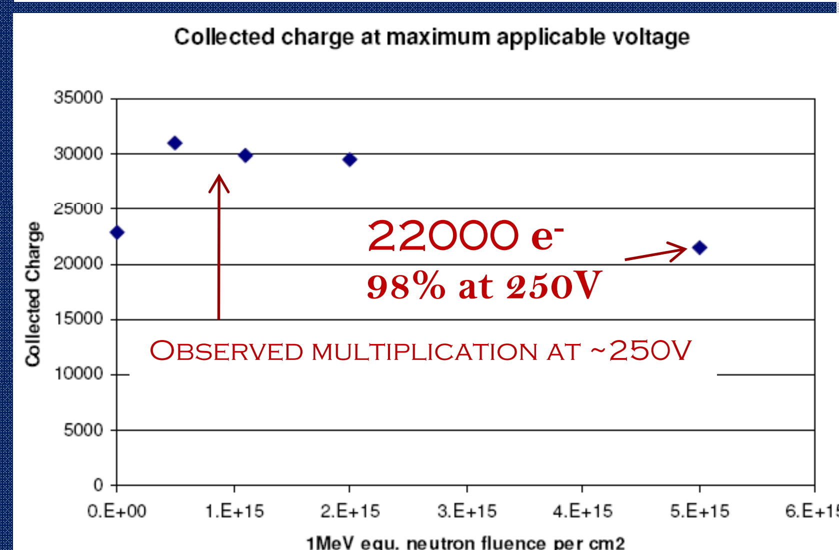




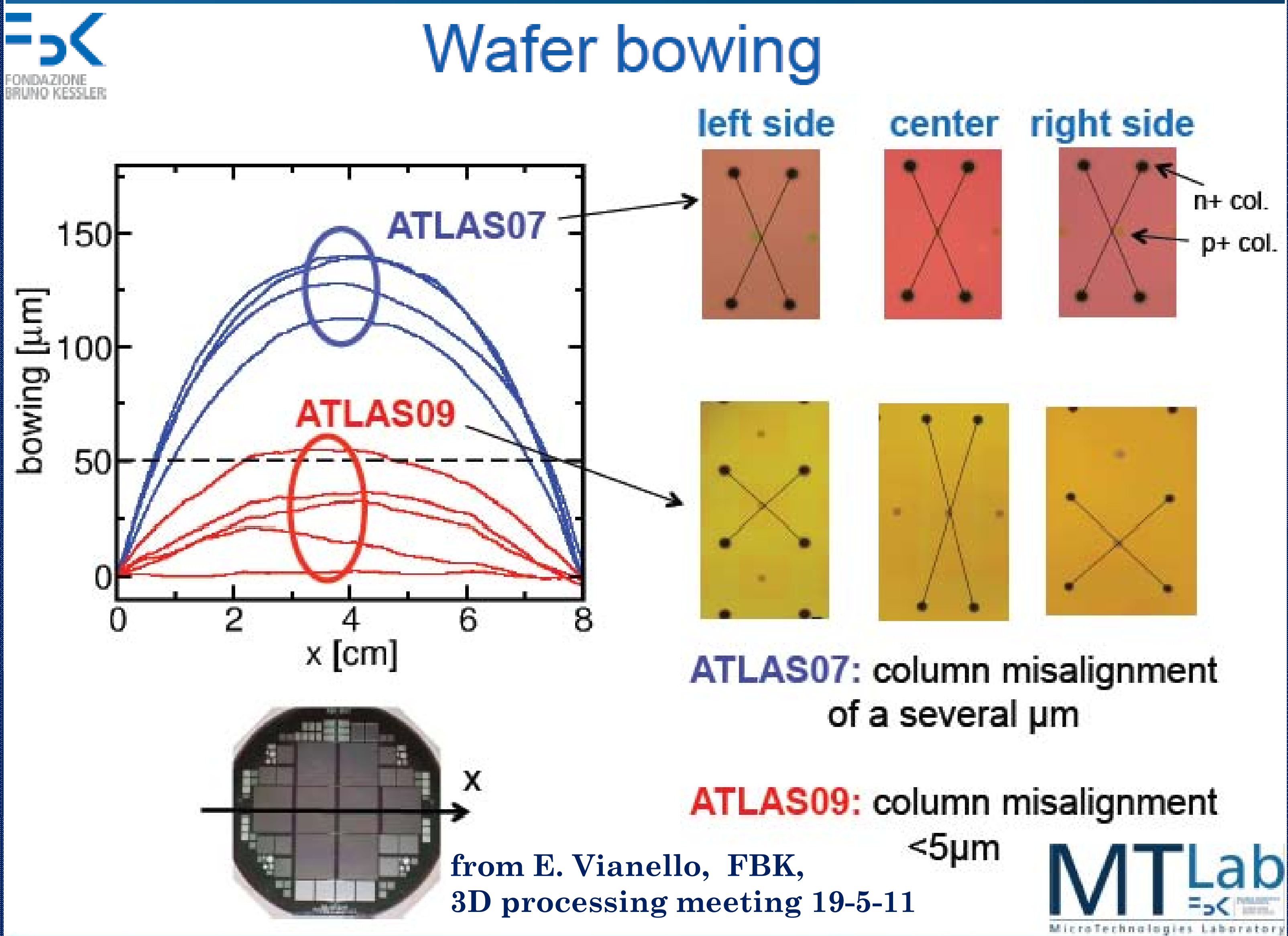
Aspect ratio 25:1

10 µm electrode diameter





QA for wafer bowing is < 60 microns with an alignment <5 microns
This is valid for both FBK (this slide) and CNM ()



from E. Vianello, FBK,
3D processing meeting 19-5-11

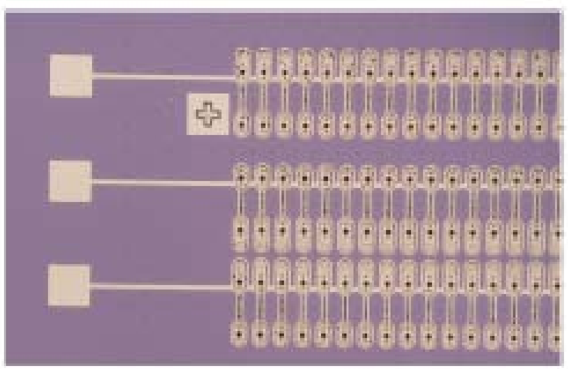
Sensor selection criteria FBK

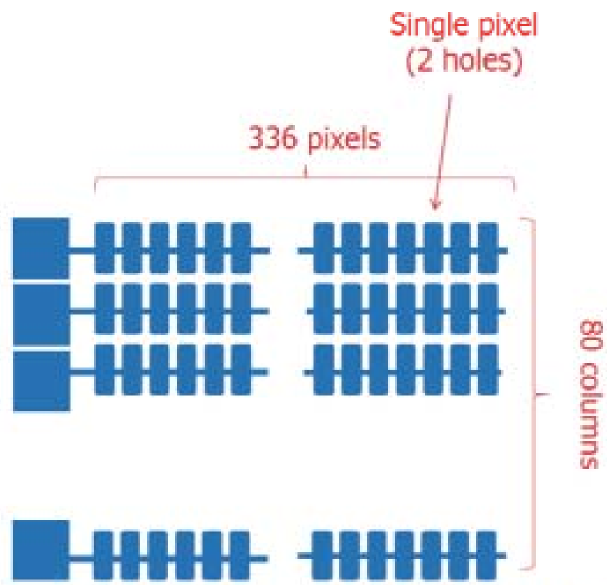
from E. Vianello, FBK,
3D processing meeting 19-5-11

Temporary metal

Test after BB
Will be performed
On dedicated
wafers.

- Allows to perform electrical tests on the FE-I4 pixel sensors before bump-bonding
- The temporary metal shorts 336 pixels together in a strip
- The IV characteristics of 80 strips form a FE-I4 pixel sensor
- Implemented on ATLAS09 batch



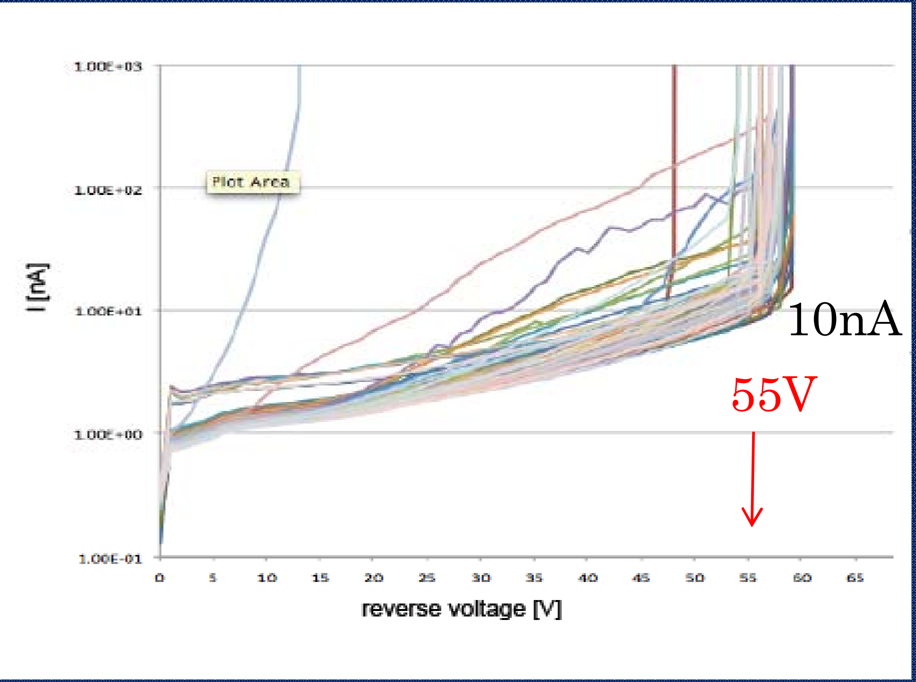


MTLab
MicroTechnologies Laboratory

from E. Vianello, FBK,
3D processing meeting 19-5-11

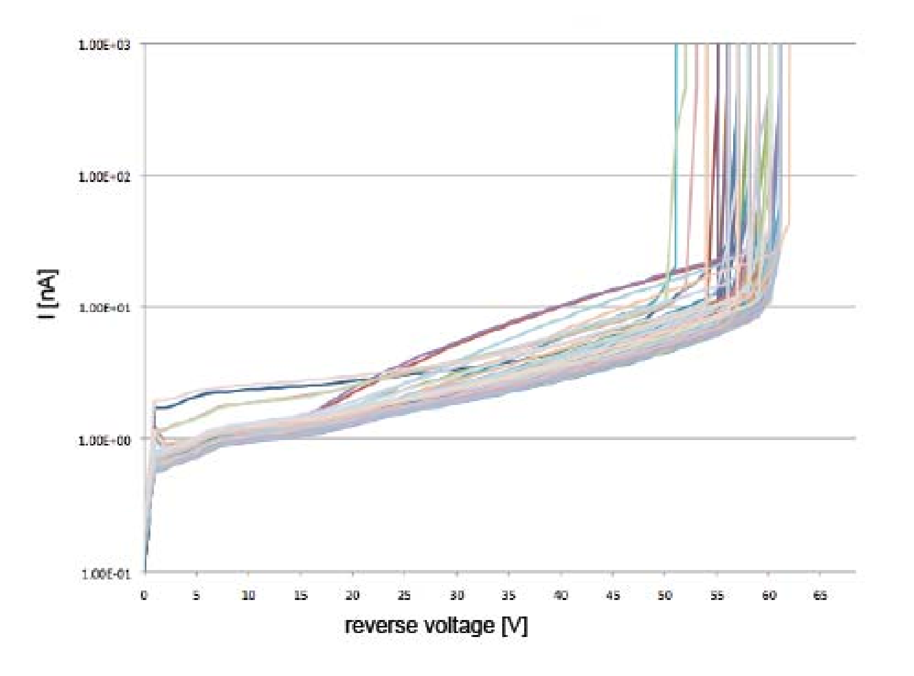
Selection criteria definition

BAD sensor



1 column / 80 pulling current
Remind 1 column=336 pixels

GOOD sensor



All pixels/columns working fine . I_{pixel}= 5pA

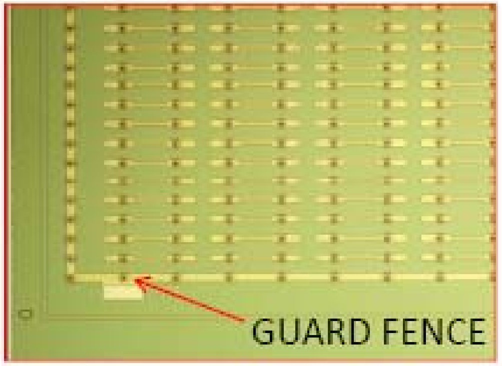
V_{bd}>25V

I_{vop}< 2uA

Sensor selection criteria CNM

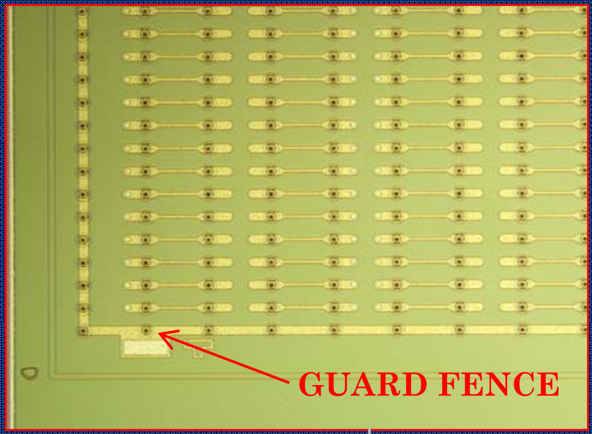
from C. Fleta, G. Pellegrini CNM, 3D processing meeting 19-5-11

QA selection before bump-bonding: IV current from guard-fence

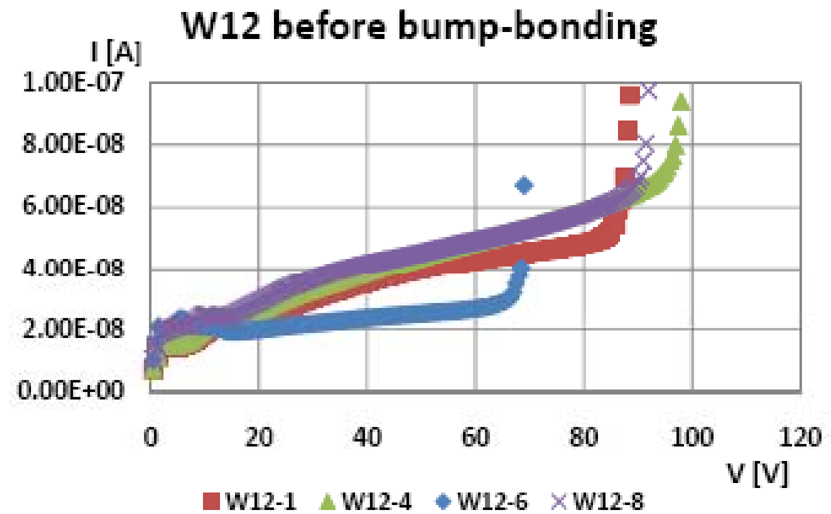


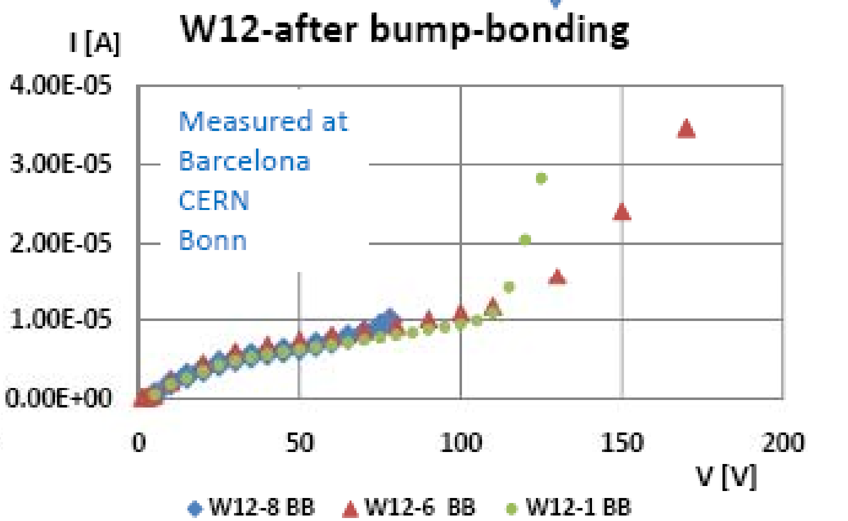
- Measured at 20ºC in Cascade probe station with thermal chuck (-70º to 200ºC)
- Tests on full wafers without UBM
- This is not the total current of the sensor but gives a good indication of the presence of defects
- Good sensors: VBD > 25V

QA selection criteria before BB



- After BB: higher current (full sensor vs. guard ring only), higher breakdown voltage (stress release after dicing)
- Guard fence IV so far a good criterion for sensor selection

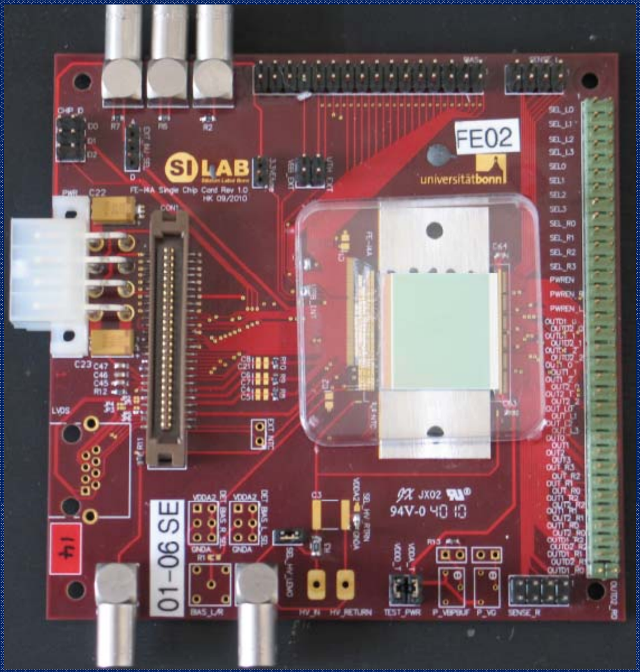


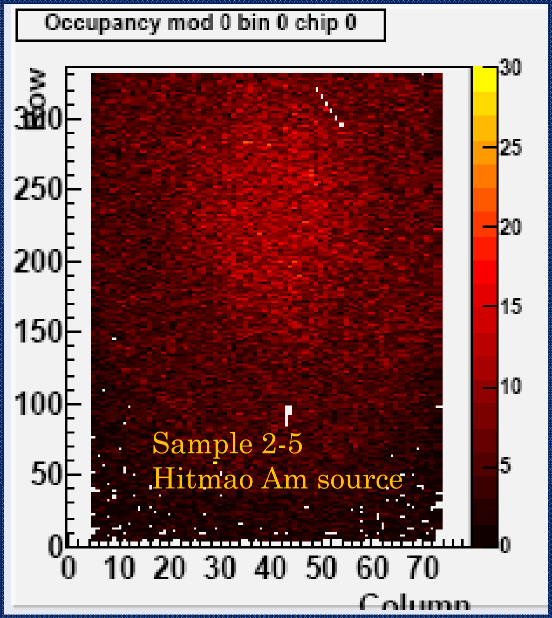


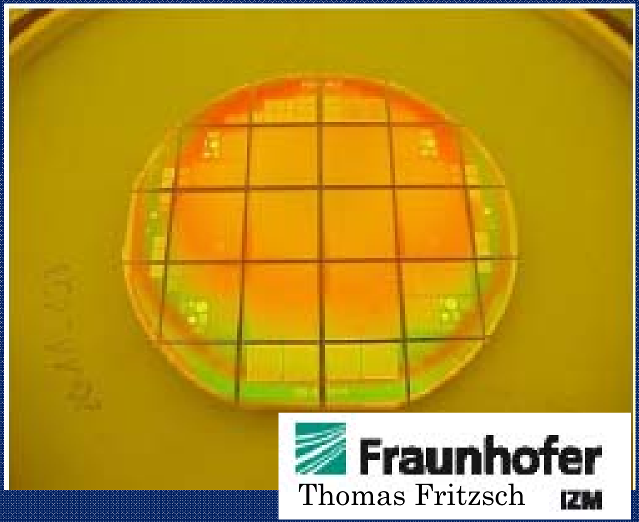
C. Da Via IBL Module WG 19-05-11

3D FE-I4 FBK assemblies

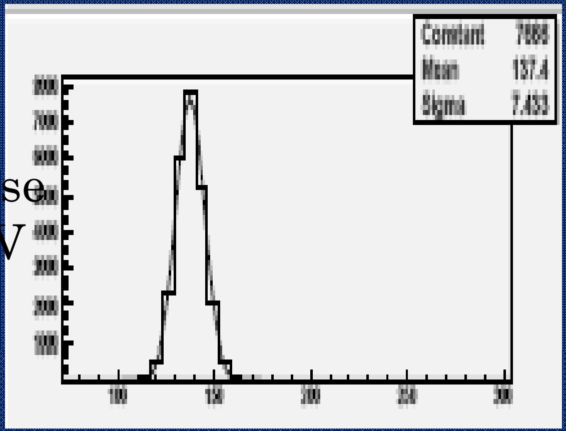
Paparazzi and measurements = Christian Gallrapp, Sebasdtian Grinstein





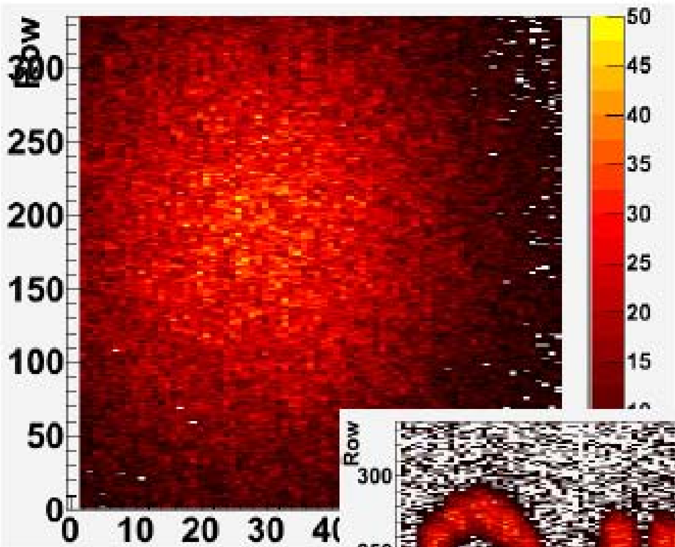


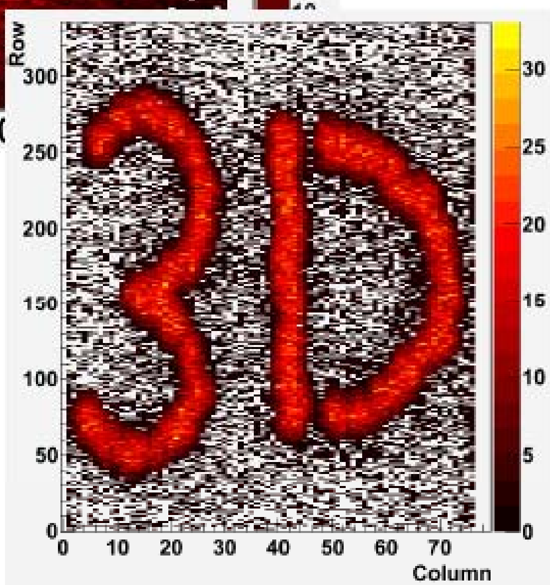
Noise
-15V



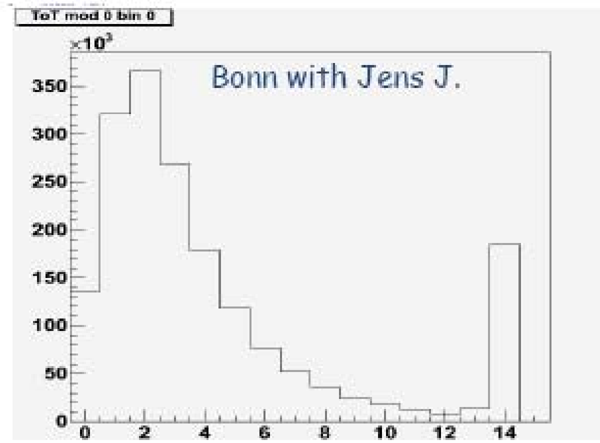
3D FE-I4 CNM assemblies

Measurements fron S. Grinstein IFAE, 3D meeting 19-5-11

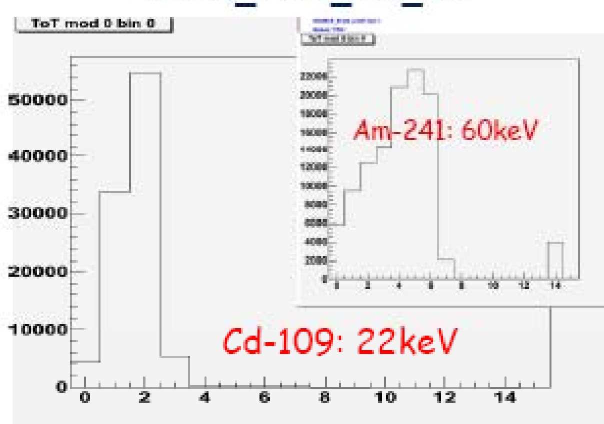




bon_cn4_3d_36 Sr 90



BON_CN4_3D_34



S. Grinstein (IFAE) - 3D Meeting

Both devices Irradiated at KiT, now/soon at Bonn.

3D Qualification pre-production and production plan

❖The numbers in the table correspond to the total number of sensors (#w x 8)
❖In red, qualifications wafers, in black pre-production wafers,, in green and in violet production wafers (green wafers started in May 2011, violet wafers dates and # to be confirmed)

Pre-prods =736 sensors by Beginning of December 11 (**176** by September11)

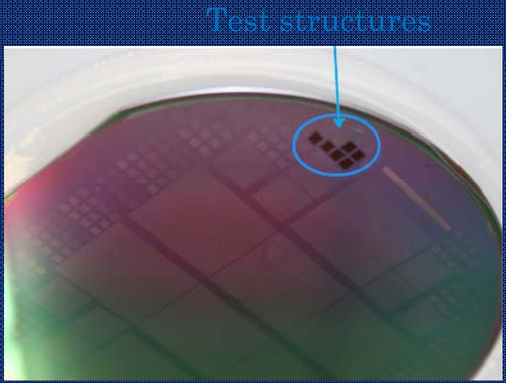
50%yield= 178+**192=368** Dec.11
Third run = 400/2= **200** Jan. 2012

568 + **200** (March/April) = **768** + 200 (spares)=968

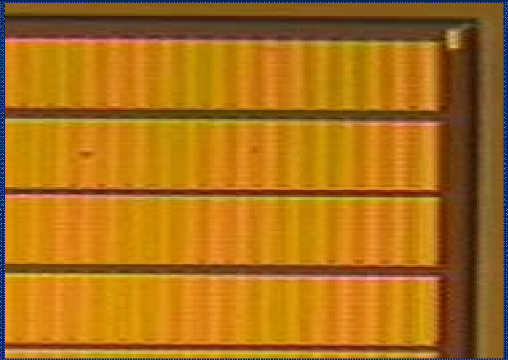
2011/12	March	April	May	June	July	august	Sept	Octob er	Nov	Dec	Janua ry	March /April	Sune /Sept
FBK A07-A09		64											
FBK A10					176								
FBK A11						176							
FBK A12											200		
FBK A13												200	
FBK A14													200
CNM Q1	24												
CNM P1								192					
CNM P2										192			
CNM P3											200		
CNM P4												200	
CNM P5													200

Full3D with active edge from SINTEF/Stanford

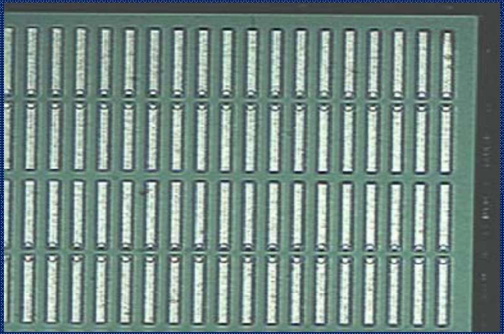
... moreover, qualification run completed - even if not for the FT-IBL – with the same floor-plan



Picture of one of the FE-I4 wafers



Temporary metal to test rows of pixels on wafer



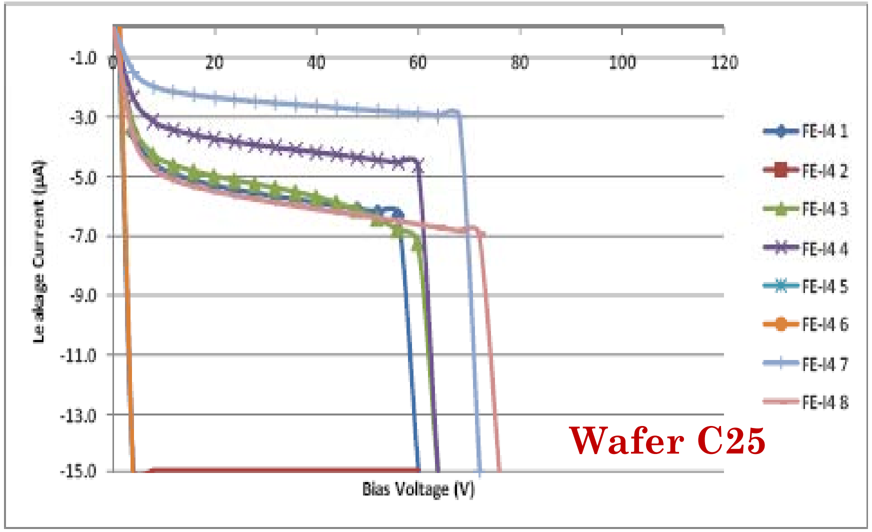
Same region of above after final metal deposition

❖16 wafers 230 um thick with support wafer completed

❖STANFORD started an independent run which will end in May 2011

❖IV curves measured using temporary metal strips look very encouraging!

❖This method is used to select good samples before bump-bonding



A. Kok, T-E Hansen, J. Hasi, C. Kenney

Summary

The 3D collaboration is testing 3D sensors with FE-I4 for the FT-IBL Several wafers have been completed and sensors bump-bonded. Pre-productions (~100 wafers) ongoing

QA test results show that the processing recipes successful so far!!!

3D offers :

- **Large signal after IBL irradiation.**
- **Low operational voltage and low power dissipation after irradiation.**
- **Operational temperature at -15 ^{o}C after IBL irradiation.**
- **200 microns dead border in a conservative design.**

Yield on the qualification FE-I4 batches looks promising. IV before and after BB being measured and confirm QA tests. We will have tests on several wafers by the review time (July 4-5 2011) to get a prediction on sensors yield and bb yield (for the last one, limited statistical sample alas)

The entire 3D production programme for FT-IBL can be fulfilled with 50% yield.