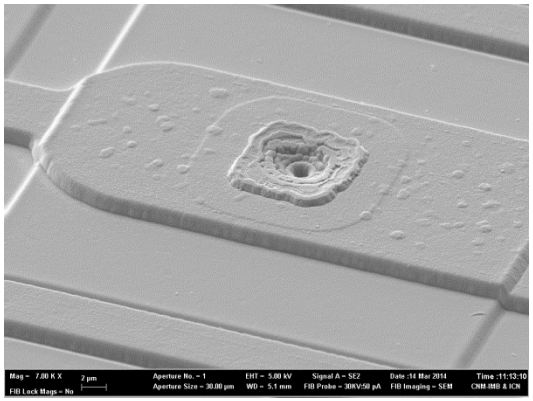
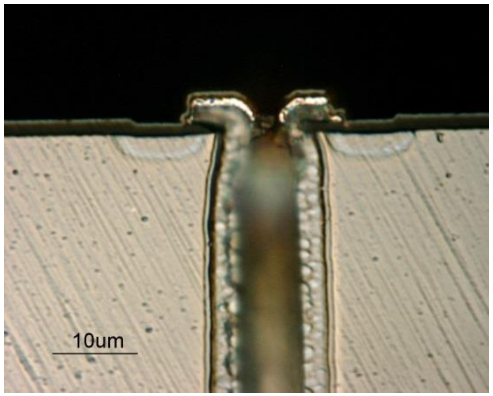
Status of 3D detector activities at CNM-CSIC

G. Pellegrini

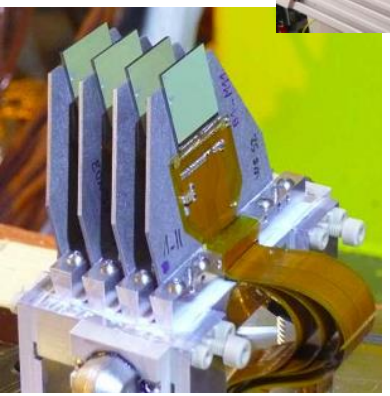


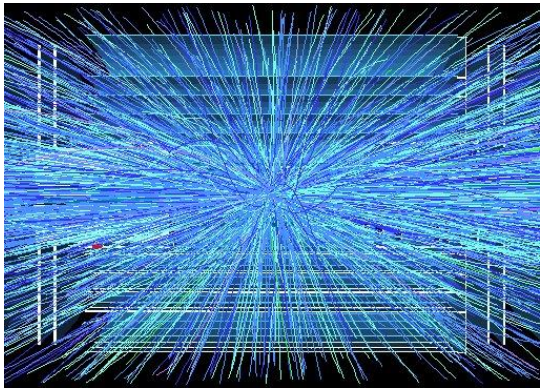


Outline

- Last production of 3D detectors for AFP.
- Processes under fabrication (small pixels)
- New process to get thin 3D detectors with biasing on the back surface.
- Future fabrication
- LGAD activity will be presented by I. Vila.

Applications of 3D Pixel Detectors





- **ATLAS IBL**
  - **25% 3D FEI4 detectors**
  - **Installed during LS1 2014/15 and running since June 2015**

- **ATLAS Forward Proton (AFP)**
  - **Successful 3D FEI4 module production Dec 2015- Feb 2016**
  - **Installed in Feb 2016 and running in LHC since March 2016**

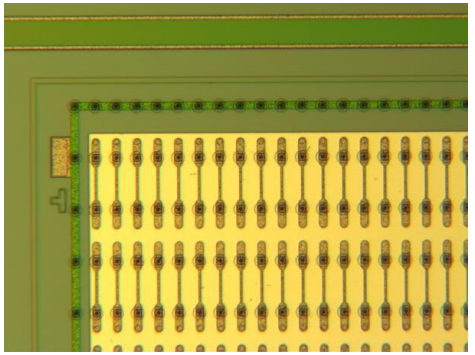
- **CMS-TOTEM PPS**
  - **Sensors produced, installation planned this year**

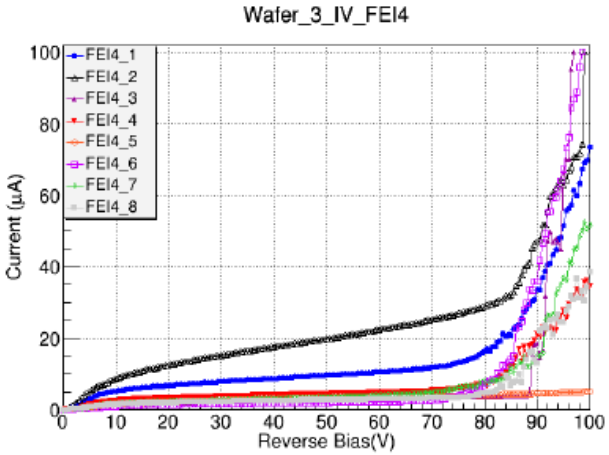
- **HL-LHC pixel detectors**
  - **Possible installation 2024, sensor qualification for Pixel TDRs 2017**
  - **Radiation hardness studies with IBL/AFP 3D FEI4 generation on-going**
  - **First dedicated 3D sensors with small pixel size and inter-electrode distance produced and characterised**

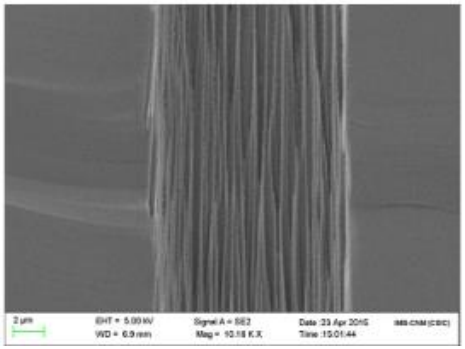
AFP Sensor Production
ATLAS Forward Proton Detector

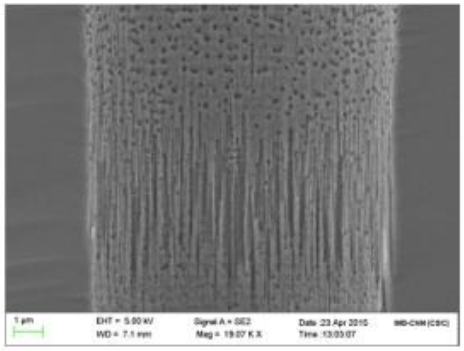
Investigation and improvement of CNM process (2015)

- DRIE optimization → less 3D side wall defects
- Wafer edge protection → less broken wafers
- IV measured with Temporary metal
- UBM at IZM (to be shipped this week)
- Bump-bonding and assembly performed at IFAE
- Installation in EYETS 2016/17 (16 modules)





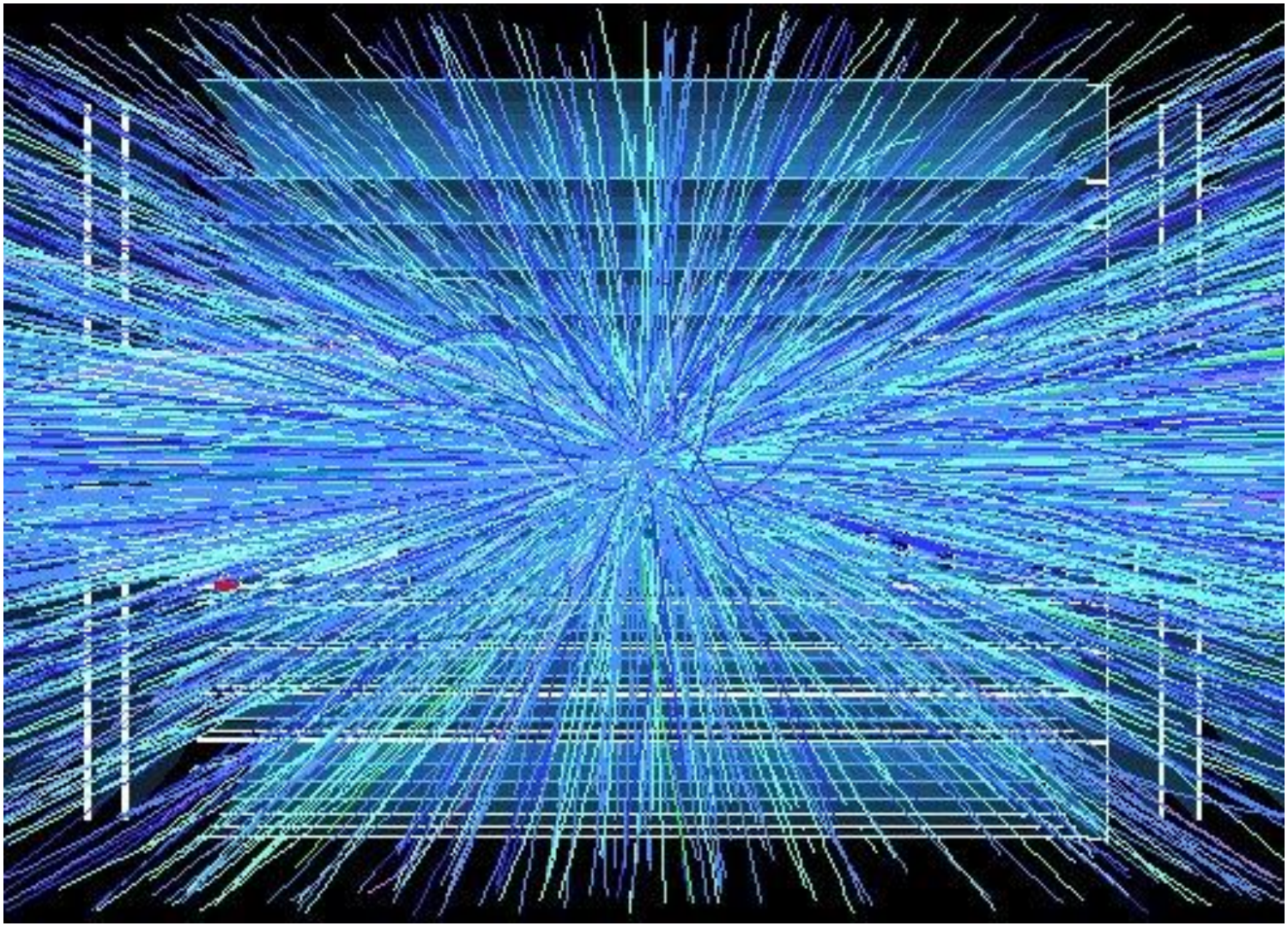




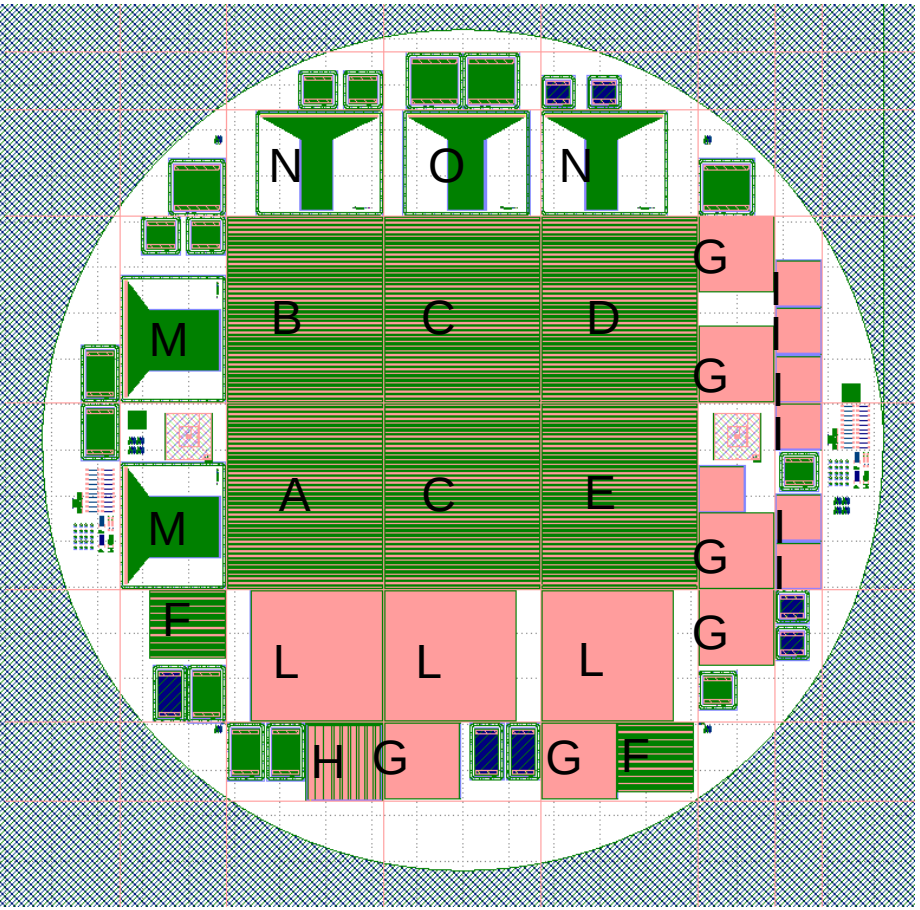
Working detectors		Yield
73	Vbd>20V	91,3%
63	Vbd>50V	78,8%
43	Vbd>100V	53,8%

Presentations at various RD50 Workshops
- *S. Grinstein et al., NIM A730 (2013) 28*
- *J. Lange et al., JINST 10 (2015) C03031*

Development of HL-LHC 3D Pixel Detectors



Standard double sided 3D-
Joint 3D MPW pixel run (Atlas, CMS, LHCb)



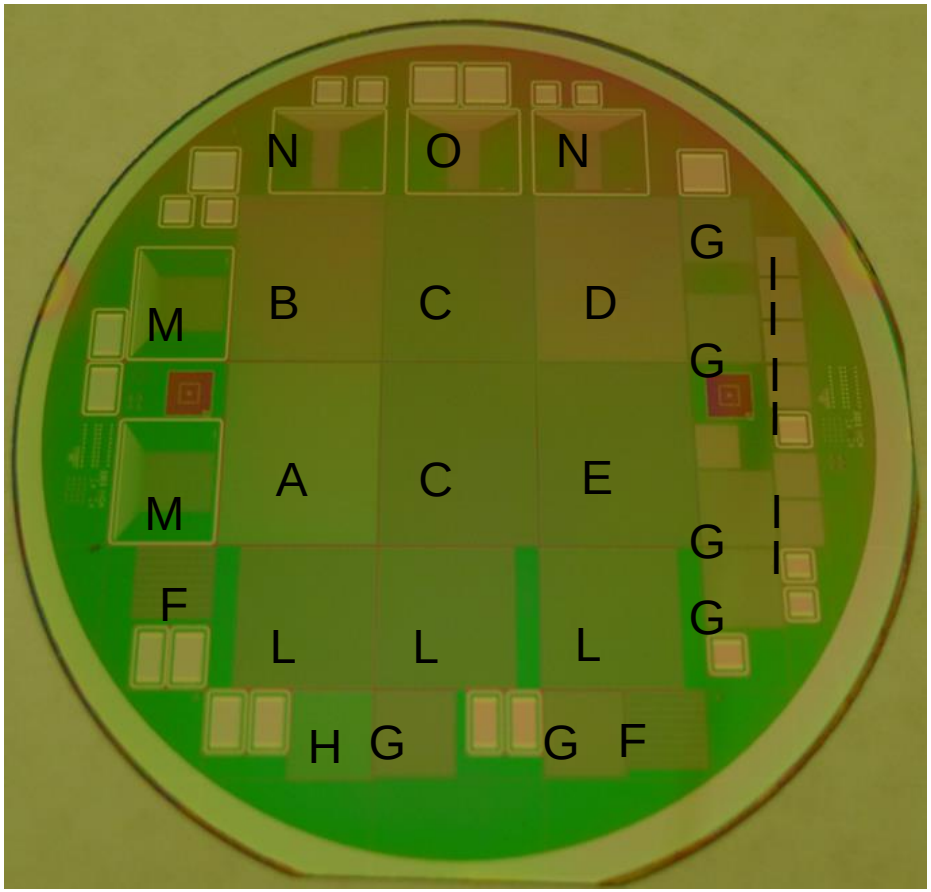
- A: standard Fe-I4
- B:25x100um2 ("25x500" 1E, with 3DGR - a la GP).
- C:50x50um2 with the rest connected to GND with 3DGR
- D:25x100um2 (2E - version 4x100+grid to GND - a la GF)
- E:50x50um2 with the rest connected to GND without 3DGR
- F:FEI3 device: x 50x50um2 with rest to GND with 3D GR
- G: ROC4sens 50x50um2
- H: PSI46dig
- I FERMILAB RD ROC 30x100um2
- L: Velopix 55x55um2
- M: Strip 50x50um2
- M Strip 25x100um2
- O Strip 30x100um2f

- Started in December, 2014 (To be finish in end of 2015)
- 8um holes, 200um thick wafers. Aspect ratio 25:1.
- Radiation hardness of strips with different geometries.
- 4 sides slim edges, 100um and 200um.

Status= fabrication process done.
5 wafers.

RD50 collaboration project

Standard double sided 3D-
Joint 3D MPW pixel run (Atlas, CMS, LHCb)



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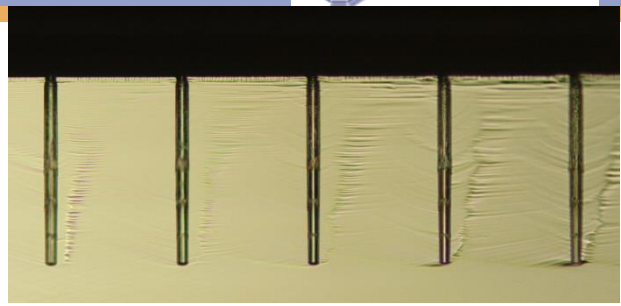
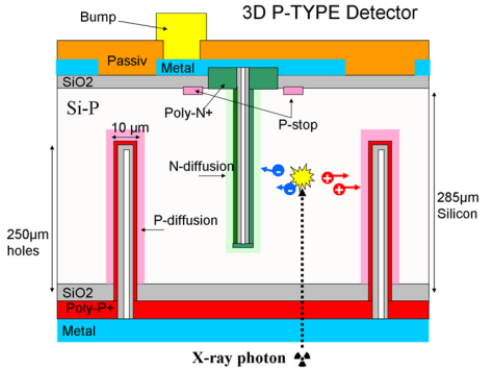
RD50 collaboration project

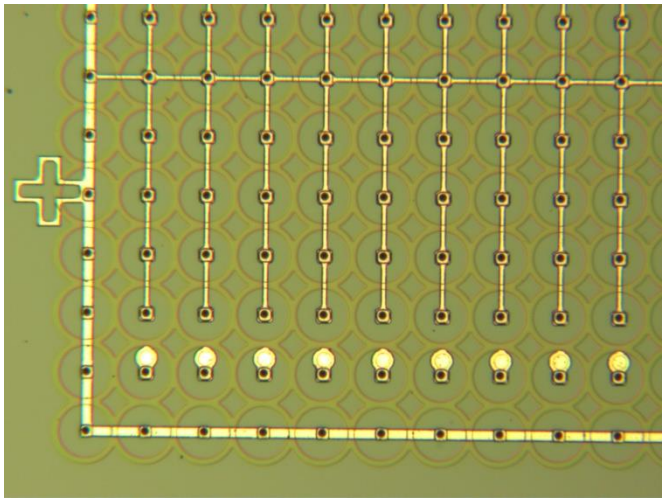
Technology tests



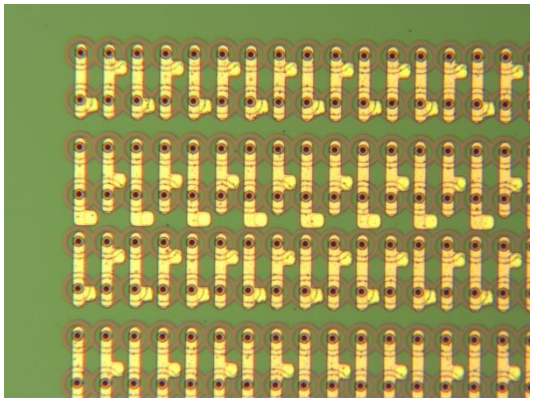
- Increase aspect ratio, 25:1
- Reducing sidewall damage in deep holes.
- Reducing wafer breaking during process. New fabrications.
- Temporary metal for IV tests
- Bumps for UBM growth at CNM (for testing).



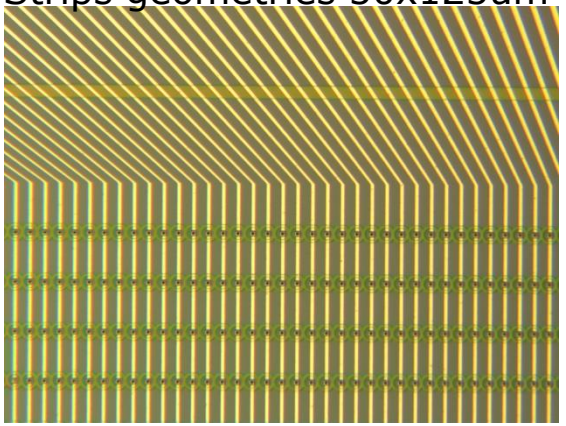
50x50um^2 with the rest connected to GND.



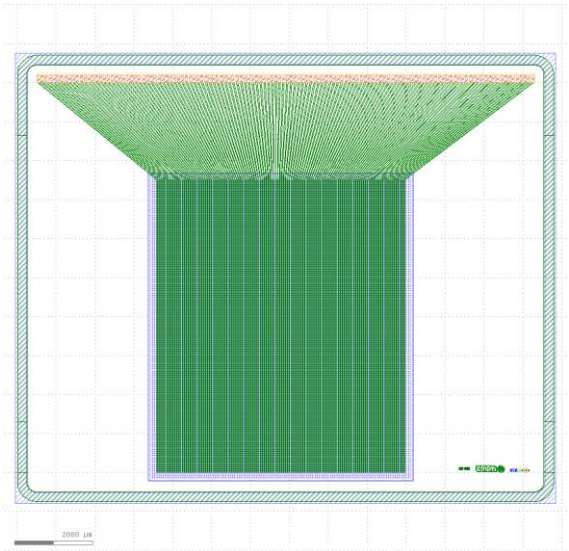
FERMILAB FCP130 2E 30x50um2



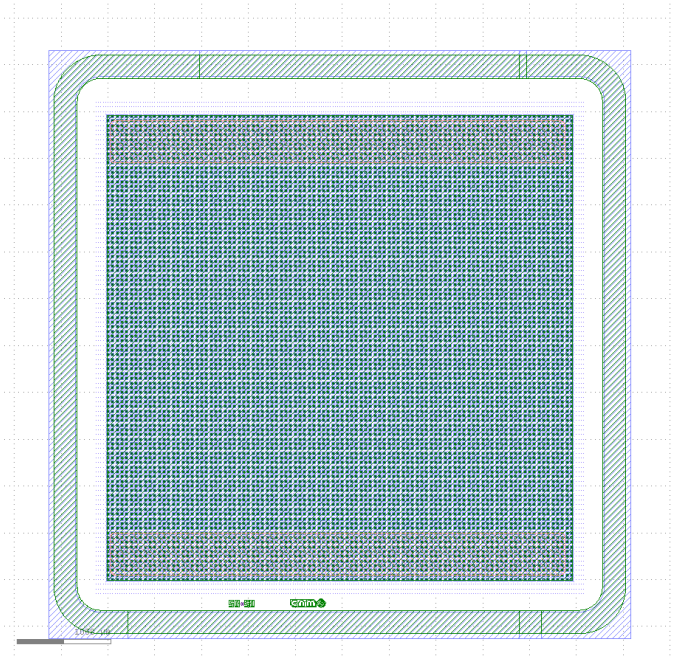
Strips geometries 50x125um^2



Diodes and strips



Strips geometries: 50x50, 25x100, 30x120um^2



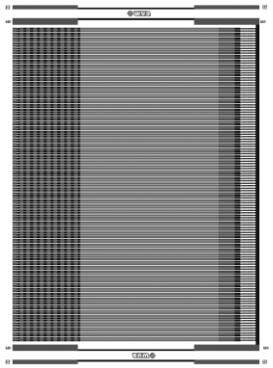
Pad geometries: 25x25, 25x50, 30x30, 30x50, 50x50um^2

Already irradiated with neutrons and under test at IFAE

No guard ring.
Useful to study radiation hardness.
Test current density vs holes density
Metal routing to fit 80um pitch electronics (**Alibava Systems**).
May be connected trough our AC fan ins.

Characterization Plans for 3D strips

Strips: 3x**M** (50x50 μm^2) and 3x**N** (25x100 μm^2)



Unirradiated:

- IV/CV measurements all strips polarized using FAN AC
- TCT measurements of 3 neighbor strips (all strips polarized)

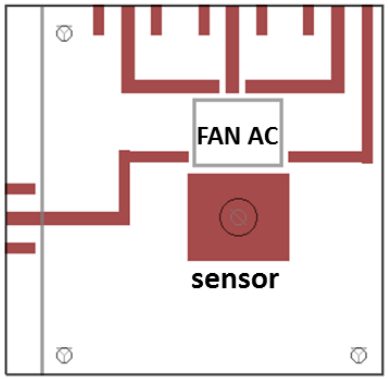
Irradiate 2xM and 2xN with protons at SPS to fluence 10^{16} n_{eq}/cm^2

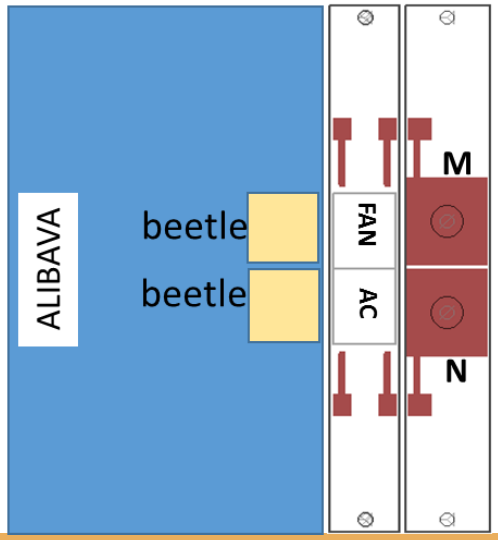
- Repeat IV/CV/TCT characterization for irradiated devices

Test Beam @ CERN (end of July)

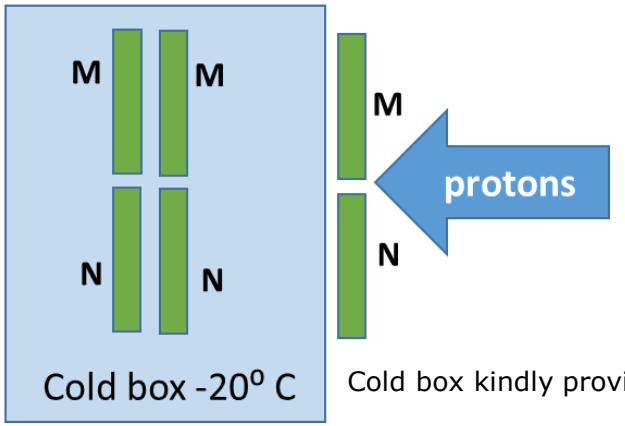
- Test 4 irradiated sensors (10^{16}) and 2 unirradiated sensors

PCB for IV/CV/TCT



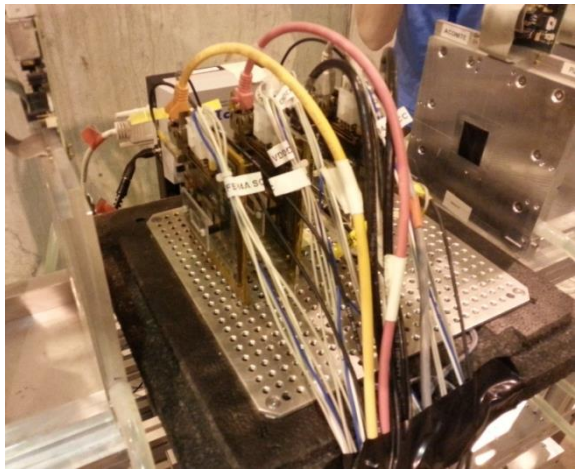


setup for TB



Cold box kindly provided by ATLAS

Beam Tests and Irradiations

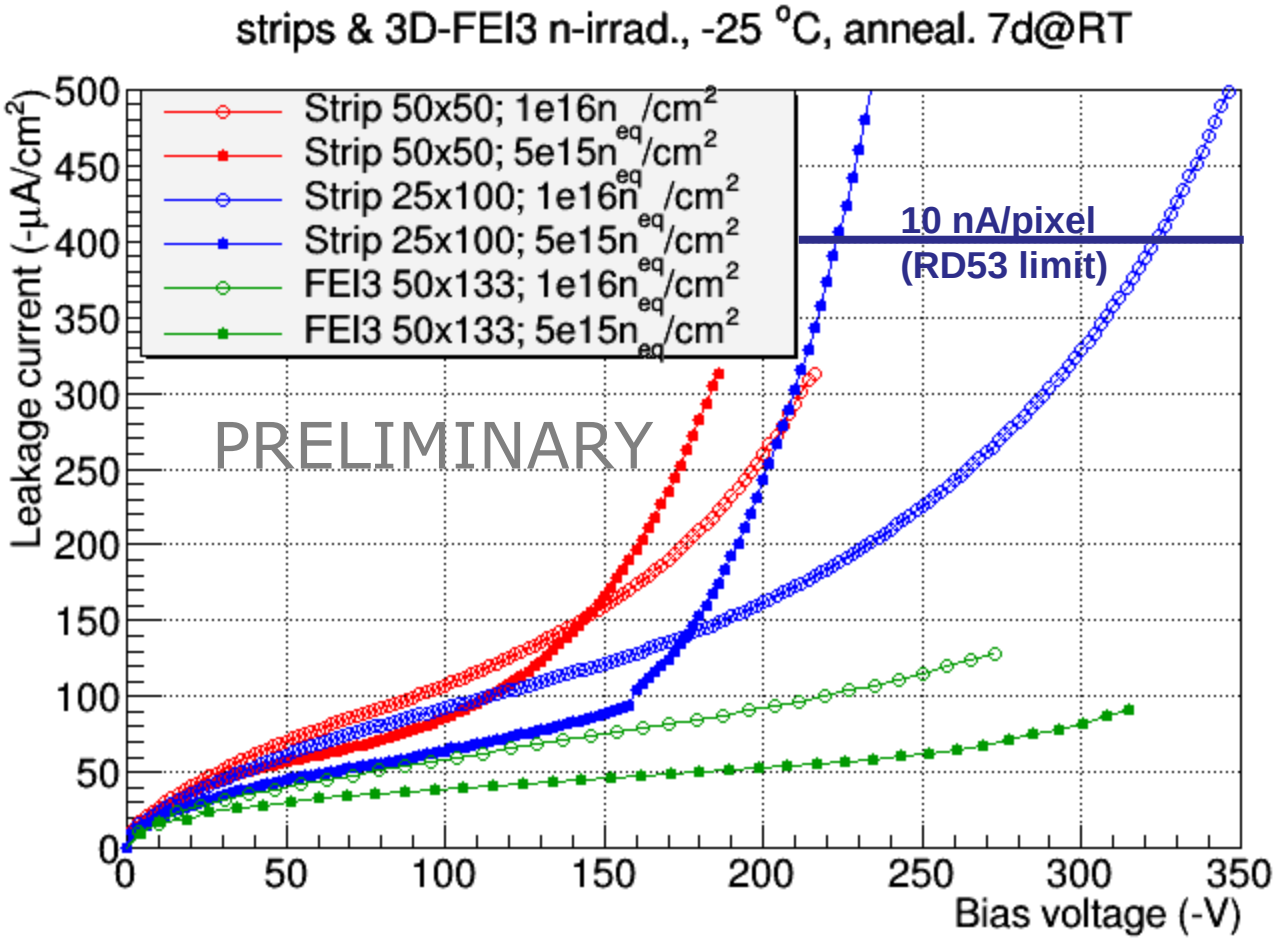


- **4 FEI4 devices measured in beam tests in May+June 2016 (4 C/E 50x50, 1 D 25x100)**
  - **Both in AIDA-type telescope and FEI4 telescope**
  - **Data reconstruction and analysis on-going**

- **3 FEI4 Devices being irradiated at PS IRRAD**
  - **Same devices as in beam test (2 C 50x50, 1 D 25x100)**
  - **Target fluence: 1e16 n_{eq}/cm^2 over 20x20 mm^2 → peak of 1.4e16 n_{eq}/cm^2**
  - **Plan to measure in Summer/Fall beam tests**

– **Irradiation at JSI Ljubljana**
  - **Strips already irradiated to 5e15+1e16 n_{eq}/cm^2**
  - **Up to 2e16 n_{eq}/cm^2 for strips, pads +FEI3 soon**

IV after Irradiation for Different 3D Geometries



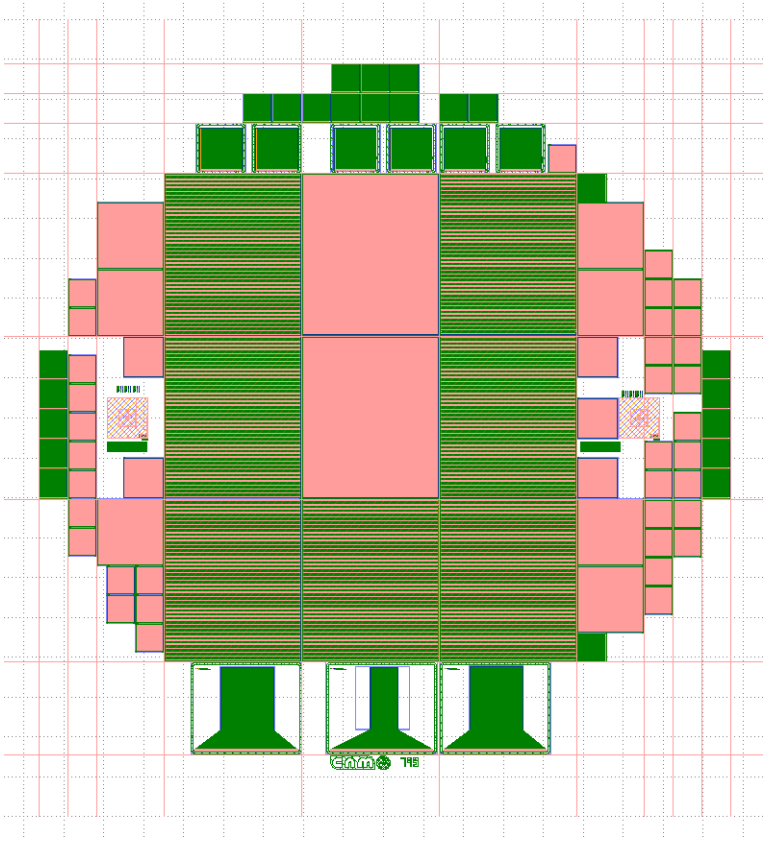
- **Higher I_{leak} and lower V_{BD} for smaller 3D cell sizes**
- **Still under investigation**
  - **Artifact of this run? (before CNM process optimis.)**
  - **Or real trend for smaller 3D cell sizes due to higher el. field and multiplication?**
- **Still much lower than RD53 limit of 10 nA/pixel**
- **In any case V_{op} will be lower for smaller 3D cell sizes → compensating effect for power**

Presentations at the Torino RD50 Workshops in 2016

- *J. Lange et al.*

Mask set (single side, thin 3D). Joint 3D MPW pixel run (Atlas, CMS)

<u>Objective</u>: fabricate thin 3D detectors using single side process (very well established at CNM since many years) but with biasing on the back surface.

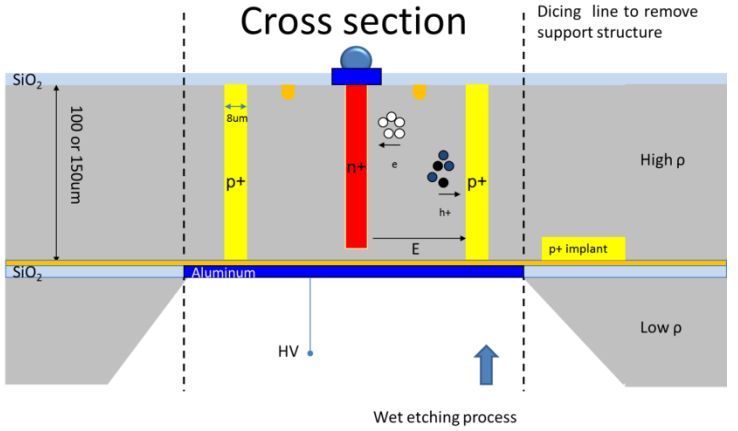


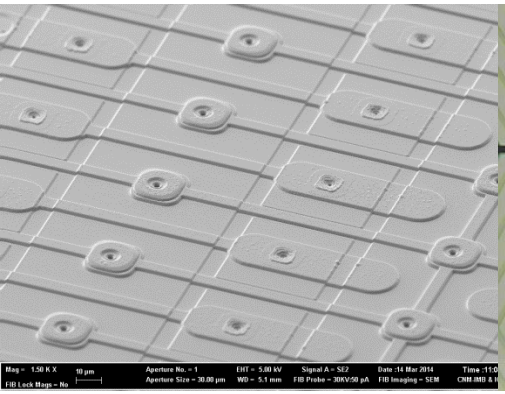
- 3 FE-I4 standard (50x125um^2)
- 2 FE-I4 50x50um^2
- 2 FE-I4 50x50um^2 part of the pixel shorted.
- 2 FE-I4 25x50um^2 part of the pixel shorted
- 7 CMS PSI 50x50um^2
- 4 Fermilab chip 30x50um^2
- 14 RD53 chip 50x50um^2, 1E (64x64)
- 13 RD53 chip 50x50um^2, 2E (64x64)
- Diodes 50x50, 25x50, 50x125um^2
- 3 strips 50x50, 25x50, 50x125um^2

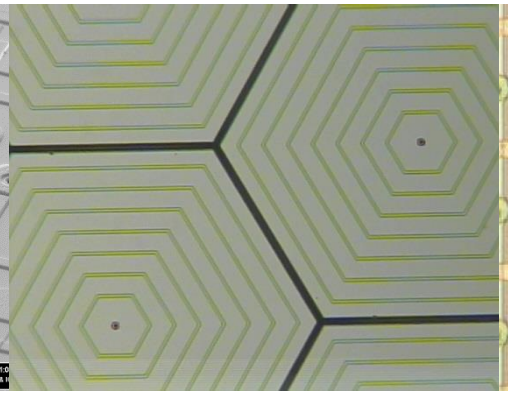
Fabrication started in January 2016. 50% done.

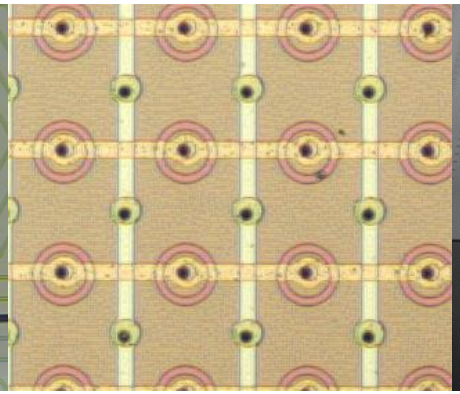
3d Single side technology

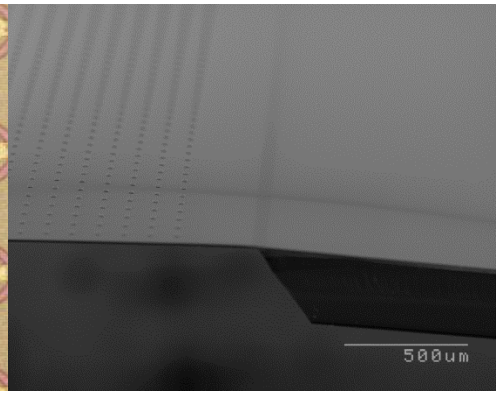
- Proposed for the Atlas pixel layer at large η
- CNM developed this technology in 2008*.
- We used it to fabricate different detectors for various applications and geometries.
- Our experience is that single side 3D detectors are more complicate to be fabricated and the technology is more difficult to be tuned. Anyway, the yield is higher and the breaking of the wafer is negligible.





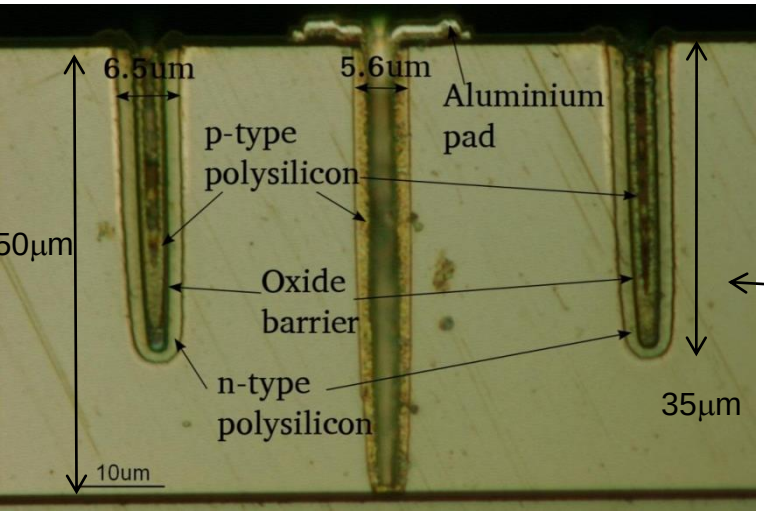






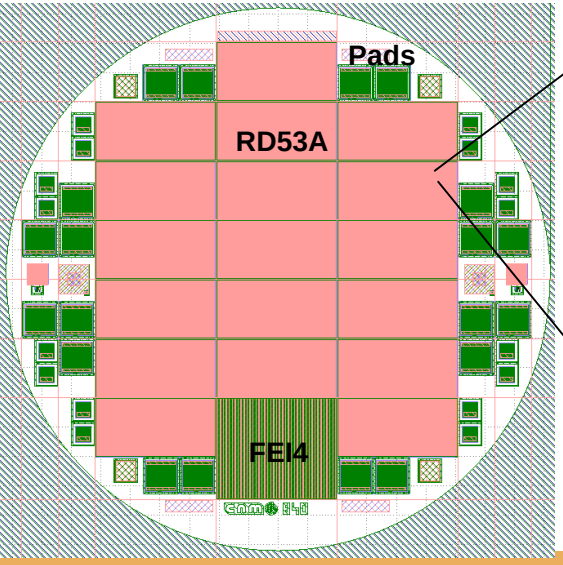
* *As proposed by C. Kenney and S. Parker*

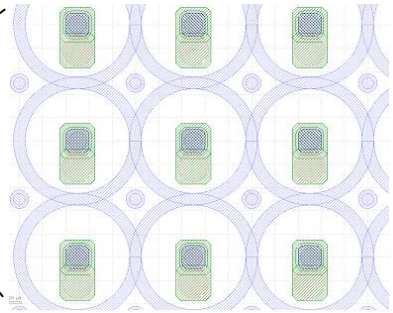
Up-coming 3D Runs at CNM



- **New run as copy of 7781 with improved process**
  - **Expect better yield and IVs (shown by AFP+CT-PPS runs)**
  - **Production started → expected for end of year**
- **Thin 3D runs (100-150 µm on SOI)**
  - **Same mask as recent 3D run 7781**
  - **Production started → expected for end of year**
- **Runs with RD53A pixel devices**
  - **Single-sided 72, 100+150 µm: masks ordered → ~1 year**
  - **Double-sided 200 µm planned later**

  Devices
  - **14 RD53A 50x50µm² 1E**
  - **2 RD53A 25x100µm² 1E**
  - **2 RD53A 25x100µm² 2E**
  - **1 FEI4 50x50µm² 1E (equivalent to 7781 C)**
  - **Pad diodes of 50x50µm² and 25x100µm² (big and small)**





Thank you for your attention !!!!

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 654168