Topics from RD50

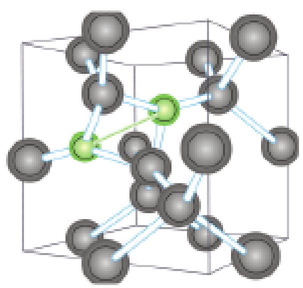
I have shown here topics which I got an impression

Special Topic , 03/30/2018

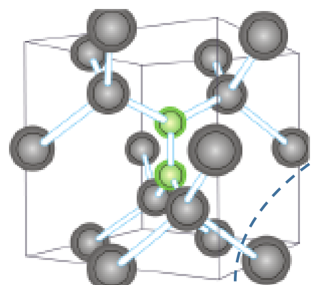
Nitrogen-enriched Wafer (Silicon) - I

Motivation

- As shown in previous RD50 Workshops Nitrogen enriched wafers show promising behaviour after irradiation:
  - The concentrations of defect centers with the activation energies of 30 meV, 310 meV, 360 meV, 380 meV, and 460 meV are found to be significantly lower in the material with a higher nitrogen concentration

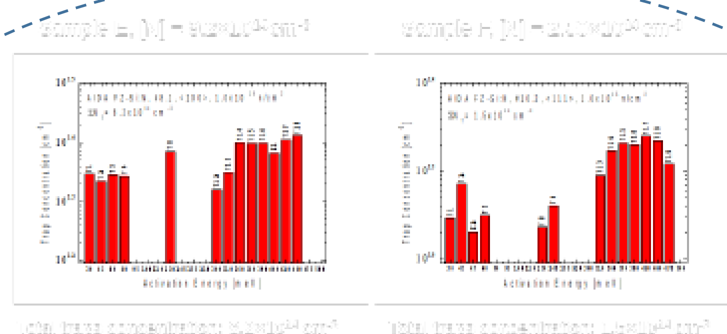


N_iN_i dimer
two split-interstitials



N_iN_s pair
N_s + split-interstitial

• R. Jones *et all.* Solid State Phenomena 93, (2004) 95-96

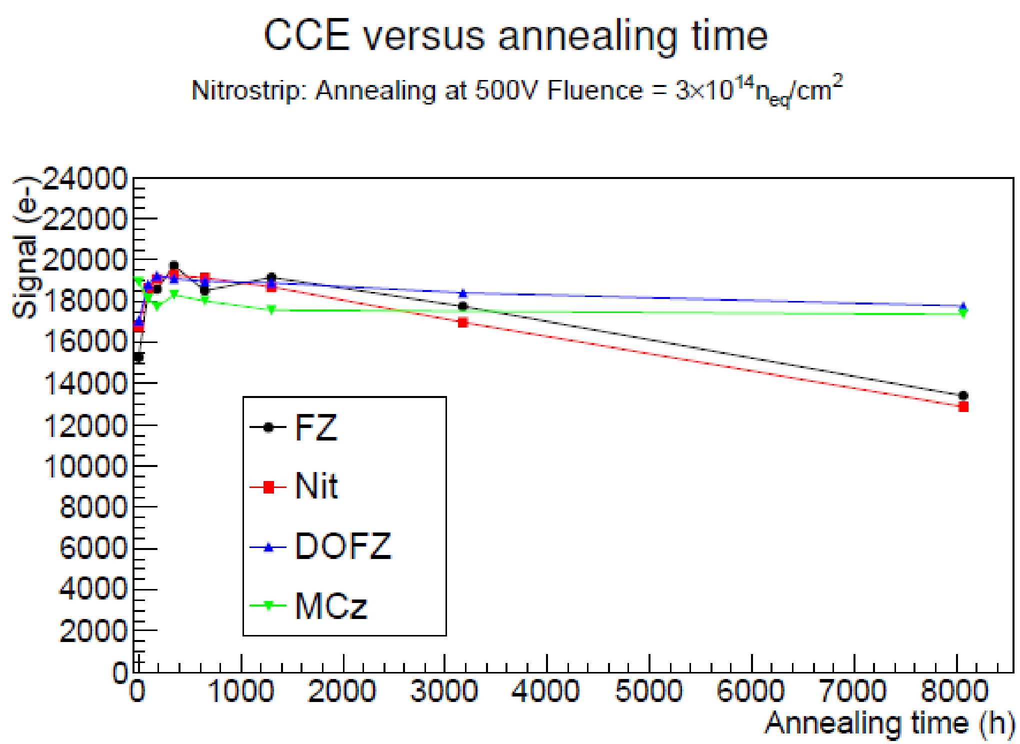


[Kaminski, RD50 Workshop, November 2014]

- Fluence $1 \times 10^{15}\, n_{eq}/cm^2$

Nitrogen-enriched Wafer (Silicon) - II

Irradiated strips with 23 MeV **protons**



More degradation after annealing for the FZ and Nit wafers.

Nitrogen enriched wafers do not show improvement for CCE .....

SiC (Silicon Carbide detectors) or Si-GaN

Generally, it is well known that SiC > Si for the radiation tolerance. It is already used in industry level, for example, robots for places where the radiation level is high.

→ SiC is one of candidate which could show high radiation tolerance. . .

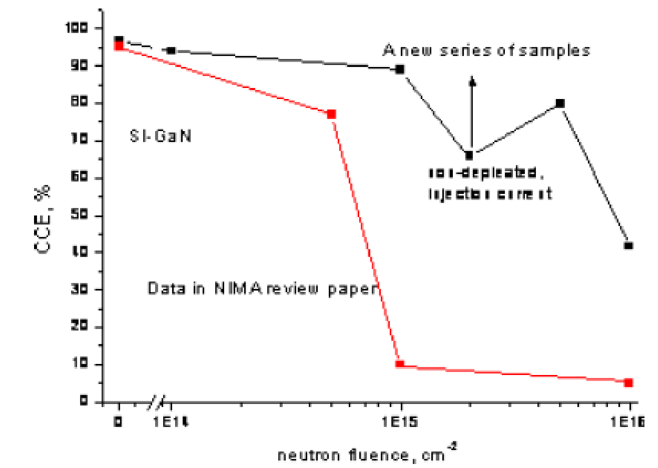


Fig. 6-15. A summary of the best CCE data in SI-GaN for 2004-2006 years

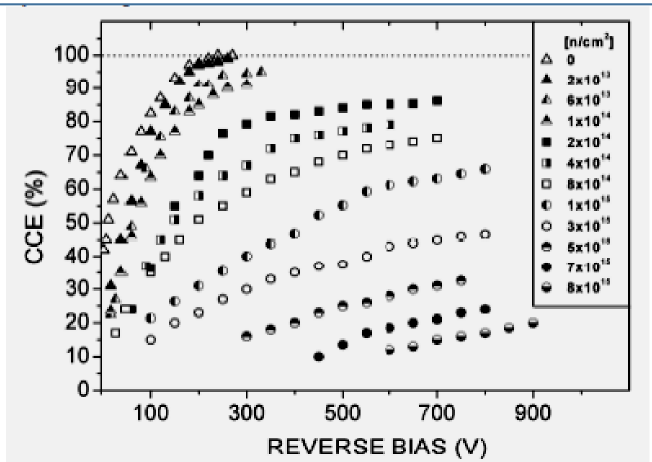


Fig. 6-2. Charge collection efficiency vs. applied voltage bias at different fluences.

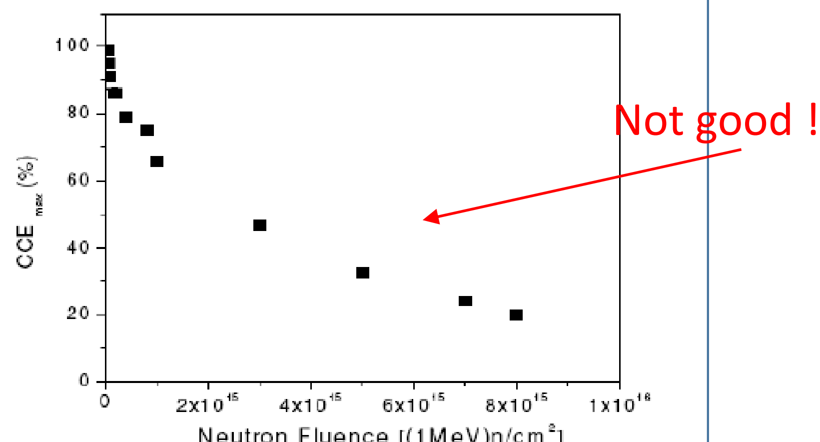
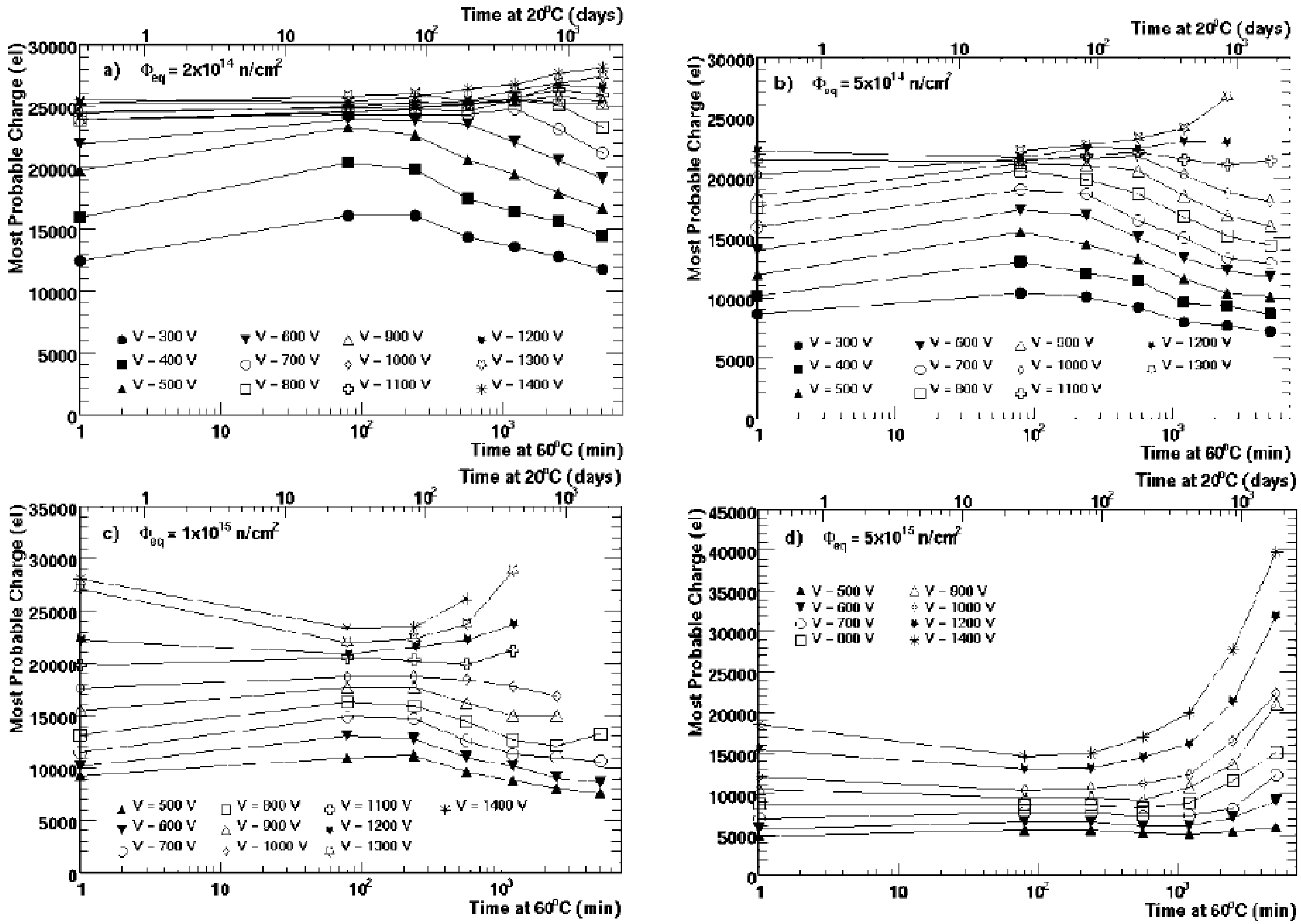


Fig. 6-3. CCE values at the highest applied voltages (CCE_{max}), as a function of the neutron fluence.

Annealing

By annealing procedure (heating), the defect will be smoothed (or diffused out) and the sensor performance could recover.



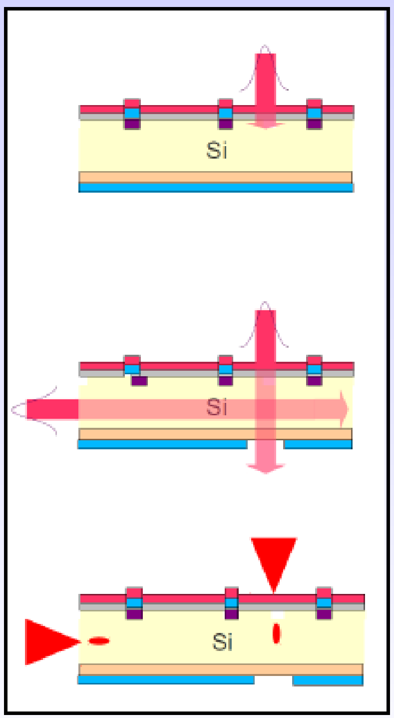
So far, no promising data are obtained . . .

Two Photon Absorption TCT

TCT – Transient Current Technique

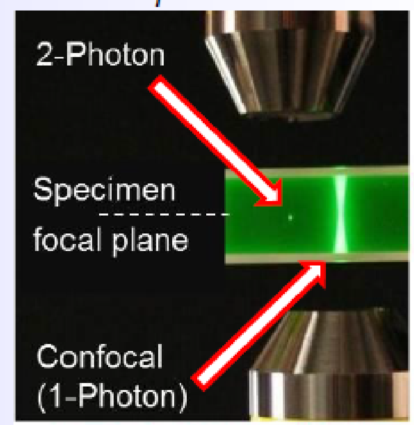
- **TCT: Pulsed laser induced generation of charge carriers in the detector**
  - Study of: electric field in sensor, charge collection efficiency, homogeneity,..
  - Benchmarking of simulation tools, measure physics parameters from mobility to impact ionization

- **New TCT technology: TPA-TCT – Two Photon Absorption TCT**



- **TCT (red)**
  - **short penetration length (650nm = 1.9eV)**
  - **carriers deposited in a few µm from surface**
  - **front and back TCT**
  - **study electron and hole drift separately**
  - **2D spatial resolution (5-10µm)**
- **TCT (infrared)**
  - **long penetration (1064nm = 1.17 eV)**
  - **similar to MIPs (though different dE/dx)**
  - **top and edge-TCT**
  - **2D spatial resolution (5-10µm)**
- **TPA-TCT (far infrared)**
  - **No single photon absorption in silicon**
  - **2 photons produce one electron-hole pair**
  - **Point-like energy deposition in focal point**
  - **3D spatial resolution (1 x 1 x 10 µm³)**

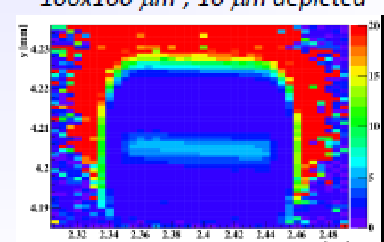
Concept: TPA TCT



Photography: Ciceron Yanez, University of Central Florida

Example: HV-CMOS

100x100 µm², 10 µm depleted

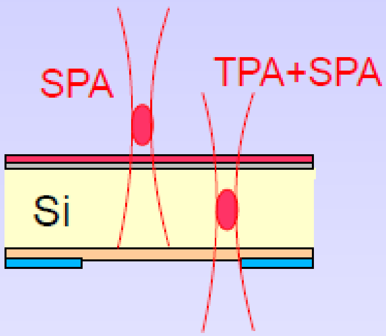


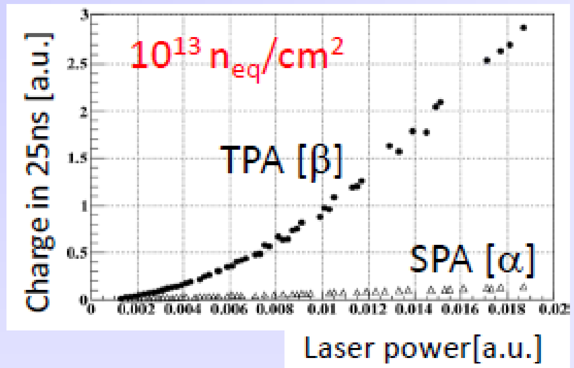
[M.Fernandez, TCT Workshop, Ljubljana, 10/2016]

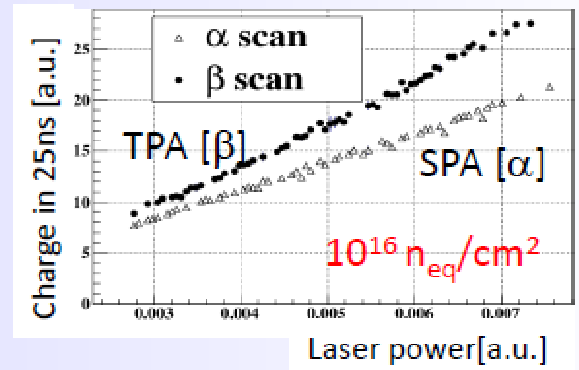
TPA – TCT on Irradiated Sensors

- **Problem:** Radiation creates defects absorbing far-infrared light!
- **Worry:** TPA method compromised by radiation damage?
- **Solution:** Measure both SPA and TPA and correct data

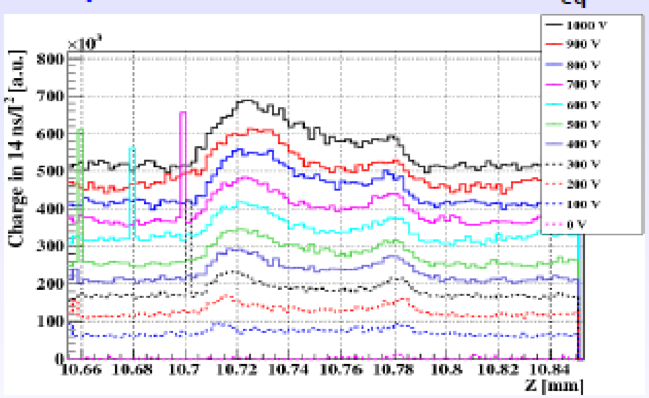
$$\frac{d}{dt}N(r,z) = \alpha\frac{I(r,z)}{\hbar\omega} + \beta\frac{I^2(r,z)}{2\hbar\omega}$$



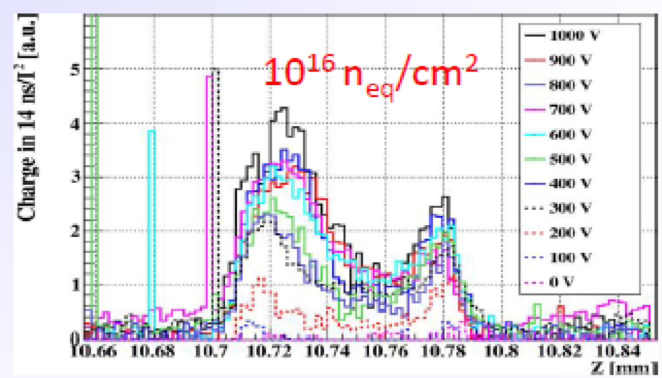




- **Example:** **Diode irradiated to 10^{16} n_{eq}/cm^2**



SPA correction

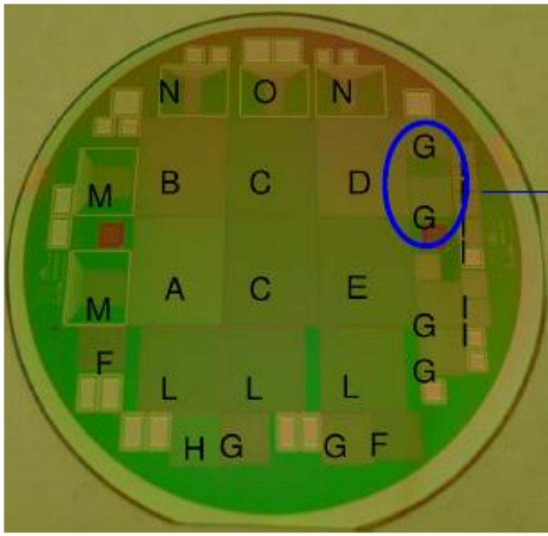


- **Conclusion: TPA-TCT can be applied to highly irradiated silicon sensors!**

[M.Fernandez, Seminar, Geneva Uni, Nov.2016]

3D sensor (I)

CNM small pitch double sided 3D run (7781)



This study focuses on **unirradiated** 3D pixel (G) readout using ROC4sens chip:

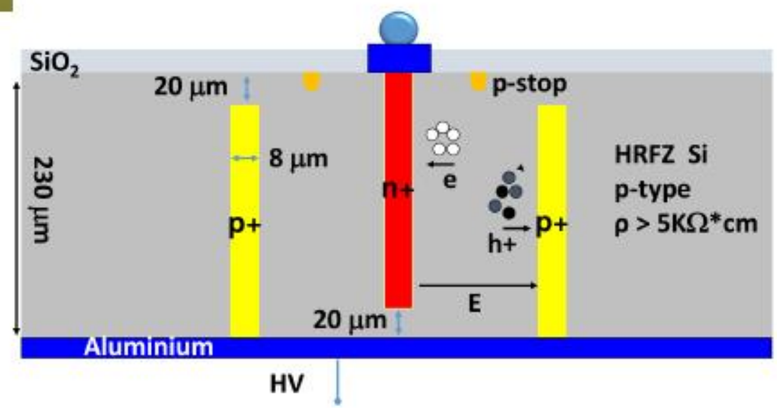
G: pixel 50x50x230 μm^3 (1E).

Produced in 2016 within the RD50 collaboration.

RD50

CNM double sided 3D process:

Cross section.



5

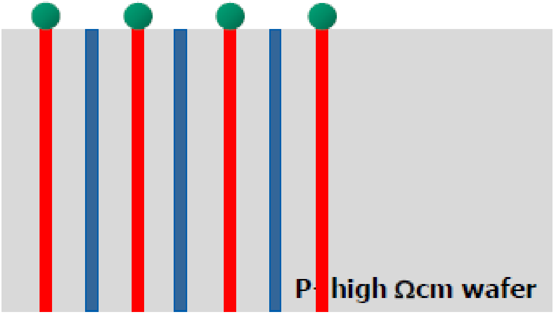
Comment: Owing to the “short” distance, it is already proven that 3D or generally thin sensors have radiation tolerance.

3D sensor (II)

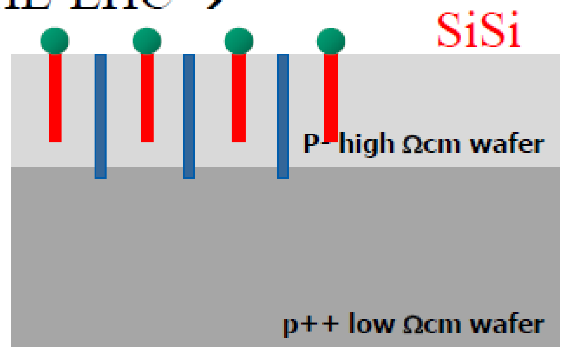
FONDAZIONE BRUNO KESSLER

Si3D technology at FBK:

- Double-side 3D, produced by FBK for IBL →
  - 4 inch Fz wafers
  - 230 un thick
  - "large" electrodes (12 µm)



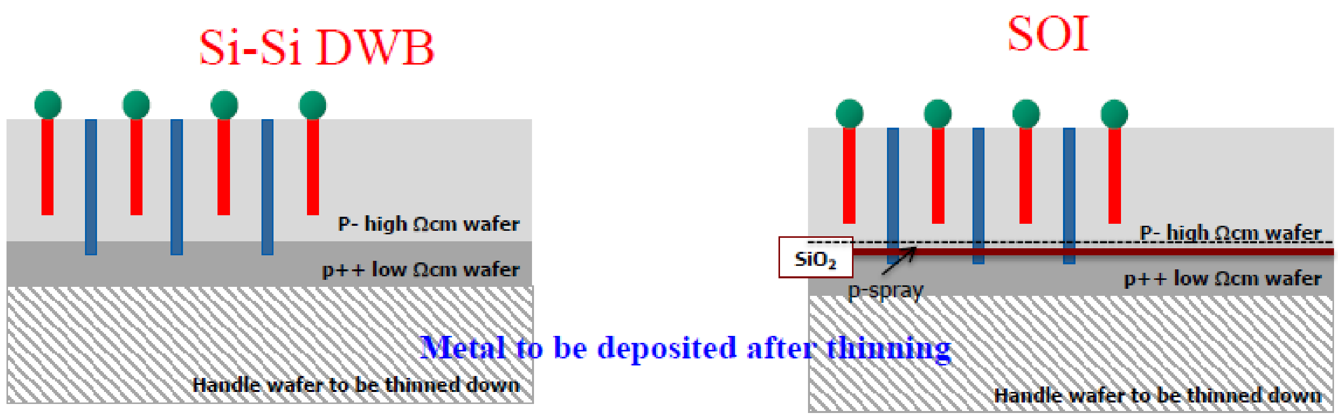
- New single-side 3D technology/design for HL-LHC →
  - 6 inch Si-Si and SOI wafers
  - thinner sensors (100-150 µm)
  - narrower electrodes (5 µm)
  - reduced inter-electrode spacing (~30 µm)



SOI (Silicon on Insulator) or Si-Si bonding techniques is used for 3D sensor !

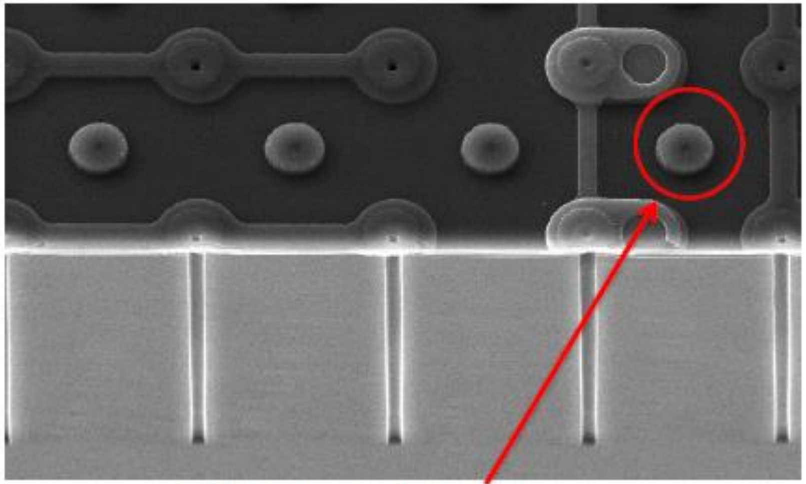
FONDAZIONE BRUNO KESSLER

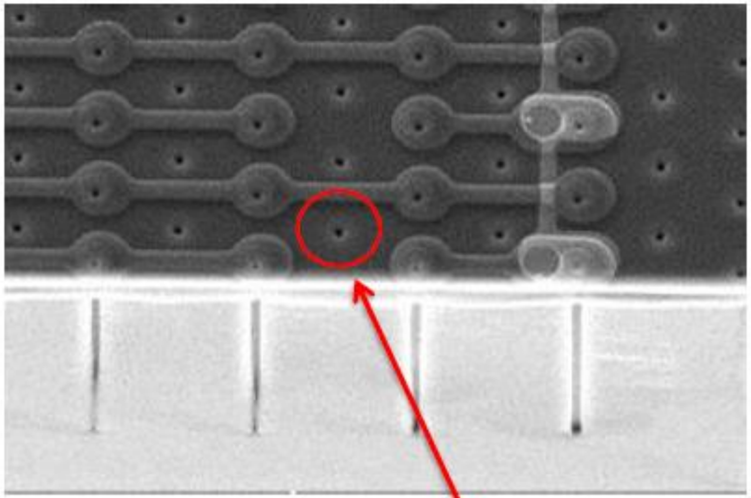
New single-side approach to 3D pixels



- Thin sensors on support wafer: SOI and Si-Si
- Target active layer thickness: 130-150 um
- Ohmic columns depth > active layer depth (for back side bias)
- Junction columns depth < active layer depth (for high V_{bd})
- Hole diameters 5 um
- Holes (partially) filled with poly-Si

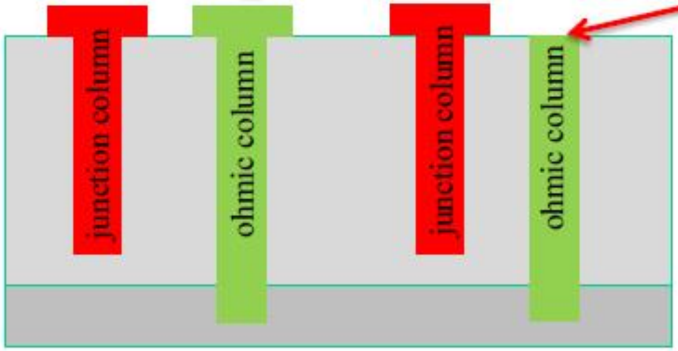
Poly cap splitting – SEM images





Ohmic column with poly cap

Ohmic column without poly cap

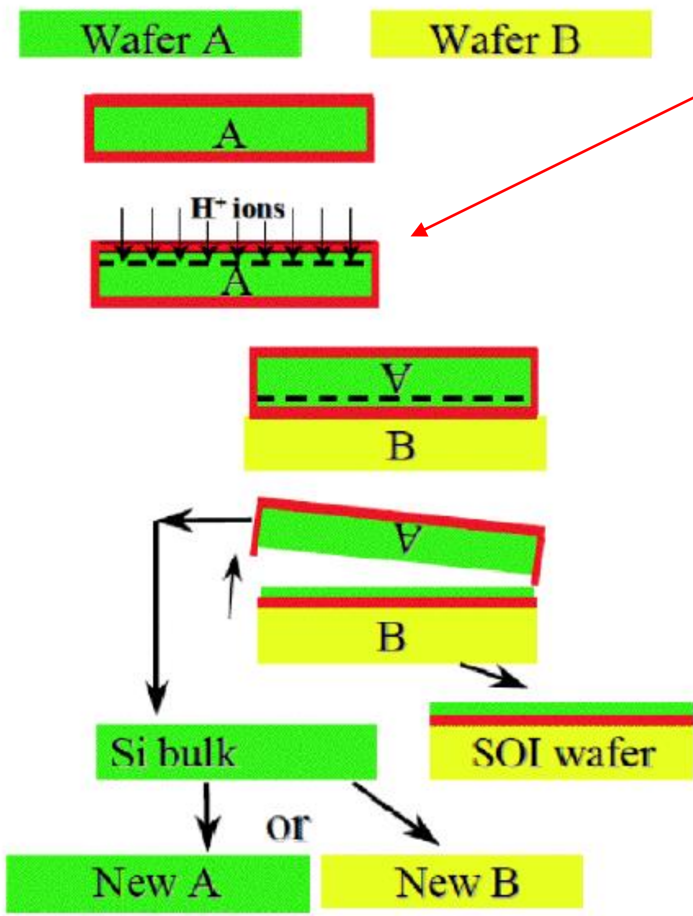


⇨ Reduction of one mask

⇨ Increase the effective «distance» between poly and metal

Reference : SOI

"Smart Cut" technique



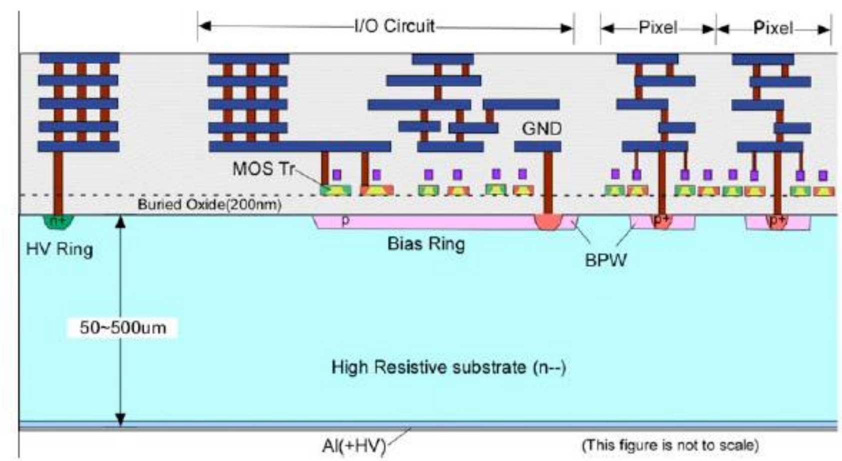


Fig. 3. Cross sectional view of a typical SOI pixel detector.