3D-FBK pixel sensors with CMS readout: first tests results

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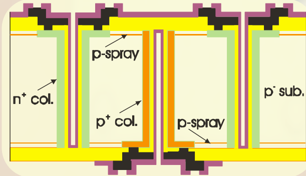
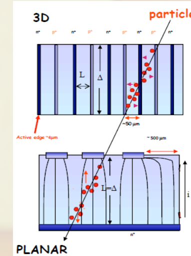
3D sensors consist of an array of columnar electrodes (radius ~ 5μm) of both doping types which penetrate entirely in the silicon substrate, perpendicularly to the surface.



This structure decouples the electrode distance from the sensor substrate thickness. The close electrode spacing provides several advantages compared to the planar sensor design:

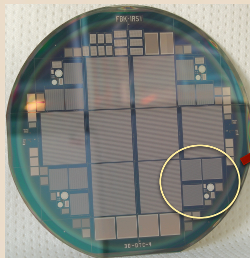
- low full depletion voltage (about -10 V),
- fast charge collection time,
- reduced charge trapping probability and therefore high radiation hardness.



3D pixel sensors compatible with the CMS PSI46 readout chip were first fabricated at SINTEF (Oslo, Norway), and more recently at FBK (Trento, Italy) and CNM (Barcelona, Spain). Several sensors with different electrode configurations (single n-type electrode (1E), two n-type electrodes (2E), and four n-type electrodes (4E) per pixel cell), all bump-bonded with the CMS pixel PSI46 readout chip, were characterized in laboratory and tested at Fermilab with a proton beam of 120 GeV/c, before and after irradiation. New productions of 3D sensors with different characteristics are foreseen in view of the CMS tracker upgrade.

Results presented in this poster concentrate on one un-irradiated FBK 3D sensor tested in April 2012.

FBK WAFER



3 1E CMS sensors with:

- 80 x 52 pixels of size 100 μm x 150 μm
- passing through columns (full 3D)
- 200 μm thickness
- slim edges (200 μm on two sides)

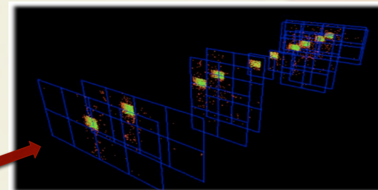
bump bonded at Selex (Rome) and tested at Fermilab in April 2012

Fermilab testbeam

- Telescope with eight pixel planes of CMS Forward Pixel Detector.
- Pixel size is 100 μm x 150 μm, but enhanced resolution is derived from charge sharing by tilting the telescope planes at 25°.
- Telescope resolution on the DUT (Detector Under Test) ~ 6 μm.
- Rotation and cooling of DUTs possible
- Alignment done using a software developed at the University of Milano Bicocca.

No B field

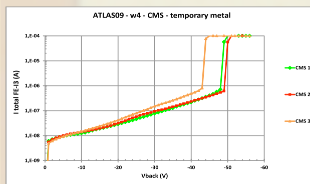
120 GeV/c protons



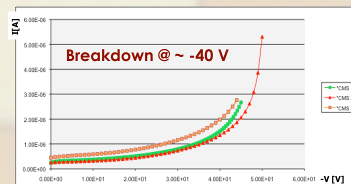
More details in "*Test-beam studies of diamond sensors for SLHC*" L. Uplegger

Laboratory measurements

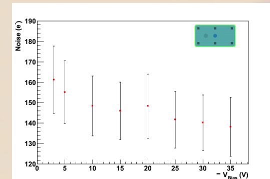
On wafer electrical test performed at FBK

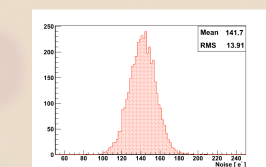


I-V curve measured after bump bonding



Noise measurement



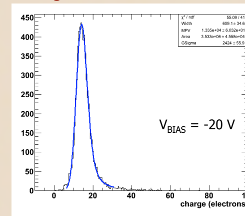


Noise measurement from S-curve

Noise vs V_{BIAS} behaviour as expected from CV measurements

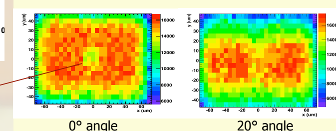
Preliminary test beam results

Charge distribution

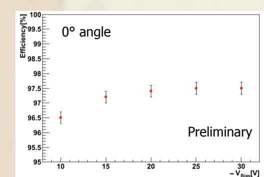


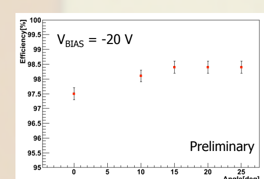
Total collected cluster charge is ~13.3 ke⁻.

The plots below show that the collected charge is what expected in 200 μm thick silicon (~16 ke⁻) only if the track hits the central part of the pixel. Elsewhere it is reduced by the combined effect of charge sharing and readout chip threshold (~2500-3000 e⁻).



Efficiency measurement

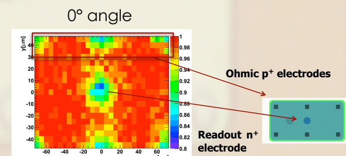


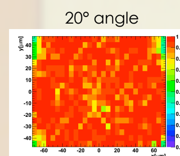


Detector efficiency versus bias voltage at 0° angle:

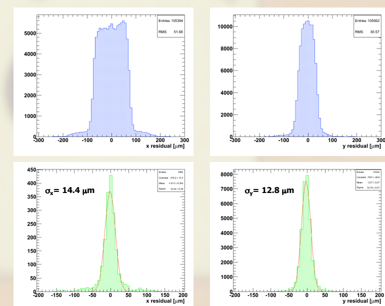
- it saturates at 20 V, where the sensor is completely depleted
- absolute value related to the geometrical acceptance of the sensor which at 0° is limited by the vertical electrodes (inactive volumes)

Efficiency increases by rotating the DUT with respect to the beam. Further improvement expected by a better treatment of charge sharing.





Spatial resolution (20° angle)



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