T-992 Diamond and 3-D Detector tests at FTBF

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ALL-EXPERIMENTERS’ MEETING

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**Particle Fluence at SLHC**

**SLHC Upgrade @ \( \mathcal{L} = 10^{35} \text{cm}^{-2} \text{s}^{-1} \)**

\[ \rightarrow L = 2500 \text{ fb}^{-1} \text{ after 5 years} \]

At \( R = 5 \text{ cm} \) the radiation fluence will be around \( 10^{16} \text{n-eq/cm}^2 \)!!

Being so close to the IP, the Pixel Detector requires an excellent radiation hardness.

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Test Beam Goal

- our goal is to test the candidates for the SLHC upgrade before and after irradiation to compare the performances and understand if we have a technology capable of withstanding the enormous fluences.

- efforts has been focused on two different sensor types:
  - 3D Silicon sensors
  - Diamond sensors

- all the different sensors have been tested using the same Read Out Chip (ROC) in order to have a fair comparison between all candidates.
3D Silicon & Diamond Sensors

**3D Sensors**

- first proposed by Sherwood Parker of the University of Hawaii and colleagues in 1995
- $p^+$ and $n^+$ electrodes are arrays of columns that penetrate through the silicon bulk

**lateral depletion: good for rad-hard**

- shorter collection path
- lower full-depletion voltage
- less carrier trapping
- faster charge collection

**Diamond sensor - intrinsically rad-hard**

- high bandgap and high displacement energy
- fast charge collection
- absence of thermally generated leakage current
Setup

- Telescope with 8 silicon planar pixel sensors (4 upstream and 4 downstream) with 2 Detectors Under Test (DUTs) in the middle
- Data acquisition with CAPTAN system

- Our software allowed us to check almost real time the data quality
Collaboration

- Many different institutions and collaborators for the CMS pixel upgrade
  - Fermilab
    - S. Kwan, A. Prosser, L. Uplegger, R. Rivera, J. Andresen, J. Chramowicz, P. Tan, C. Lei, F. Yang
  - Purdue
    - E. Alagoz, O. Koybasi, G. Bolla, D. Bortoletto, M. Bubna, A. Krzywda, K. Arndt
  - Colorado
    - M. Dinardo, S. Wagner, J. Cumalat, F. Jensen
  - Texas A&M
    - I. Osipenkov
  - Milano
    - L. Moroni, D. Menasce, S. Terzo, J. Ngadiuba
  - Torino
    - M. Obertino, A. Solano
  - Buffalo
    - A. Kumar, R. Brosius
  - IHPC Strasbourg
    - J. M. Brom
Test beam preliminary results

- A large number of detectors has been tested on beam and for each of them several scans has been made
  - threshold scan
  - bias scan
  - angle scan
- Preliminary studies has been made just on few runs
  - Resolution
  - Efficiency
  - Charge

These are just preliminary studies

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Work in progress!!
3D sensor resolution - Preliminary

X Residuals Cluster Size 1
\(\sigma = 33.36 \, \mu m\)

Y Residuals Cluster Size 1
\(\sigma = 46.2 \, \mu m\)

X Residuals Cluster Size 2
\(\sigma = 26.83 \, \mu m\)

Y Residuals Cluster Size 2
\(\sigma = 19.81 \, \mu m\)

Residuals are not yet optimized but already in good agreement with expectations
3D sensor efficiency - Preliminary

**CNM sensor**
produced at Centro National de Microelectronica (Barcelona, Spain)

**Efficiency = 97.3%**

**FBK sensor**
produced at Fondazione Bruno Kessler (Trento, Italy)

**Efficiency = 97.6%**
most of the inefficiency is due to particles passing through the $p^+$ and $n^+$ electrodes

but part of this effect is also due to the fact that both FBK and CNM are double-sided with about 30\(\mu\)m from the edge for each electrode and so there’s a slight distortion of the field near the edge
$10^{14}$ n-eq/cm$^2$ Irradiated FBK resolution - Preliminary

X Residuals Cluster Size 1

$\sigma = 31.28 \mu m$

Y Residuals Cluster Size 1

$\sigma = 48.93 \mu m$

X Residuals Cluster Size 2

$\sigma = 23.26 \mu m$

Y Residuals Cluster Size 2

$\sigma = 30.01 \mu m$

Also for the irradiated we don’t see a particular degradation of the resolution
10^{14}\text{n-eq/cm}^2\text{ Irradiated FBK efficiency - Preliminary}

Efficiency = 77.8%

- inefficiency due to particles passing through the electrodes
- but clear effects caused also by a too low field applied (bias = 15V)
  → need to increase the bias voltage to obtain better efficiency results
Diamond efficiency - Preliminary

- cause of the higher bandgap the charge released by particles is about less than half of what we get with our silicon detectors
- since we’re using the same CMS ROC optimized for silicon planar design it is important to optimize correctly its registers to match the diamond requirements
- we believe we operated the detector with a threshold too high

\[ \text{Efficiency} = 43.4\% \]

for these reasons we’ll have another test beam run in January exclusively dedicated to diamond sensors
Conclusions and future plans

- we successfully tested many 3D and diamond detectors
- these preliminary results help us to understand their operational parameters which need to be optimized well to make them work correctly
- for these reasons we’ll come back to the test beam in January with few selected detectors
- at the last test beam we were not able to test the irradiated devices because after the irradiation none of them worked so this time we irradiated them only up to $10^{14}\text{n-eq/cm}^2$
  - we will irradiate them much more in December and then come back to test them in March
- we have all the tools ready to do the analysis although they still need some improvements