Test-beam studies of diamond sensors for SLHC

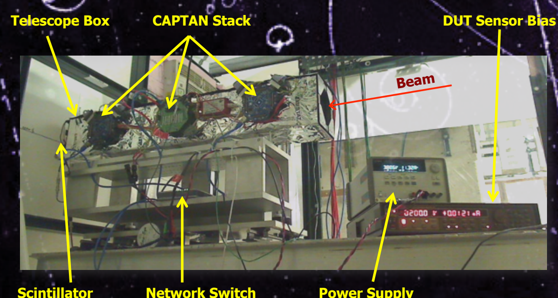
L. Uplegger, J. Ngadiuba, E. Alagoz, J. Andresen, K. Arndt, G. Bolla, D. Bortoletto, J.M. Brom, R. Brosius, M. Bubna, J. Chramowicz, J. Cumalat, F. Jensen, A. Krzywda, A. Kumar, S. Kwan, CM Lei, D. Menasce, L. Moroni, M. Obertino, I. Osipenkov, L. Perera, A. Prosser, R. Rivera, A. Solano, P. Tan, S. Terzo, N. Tran, S. Wagner

Abstract – Diamond sensors are studied as an alternative to silicon sensors to withstand the high radiation doses that are expected in future upgrades of the pixel detectors for the SLHC. Diamond pixel sensors are intrinsically radiation hard and are considered as a possible solution for the innermost tracker layers close to the interaction point where current silicon sensors cannot cope with the harsh radiation environment.

An effort to study possible candidates for the upgrades is undergoing using the Fermilab test-beam facility, FTBF, where diamonds and 3D silicon sensors have been studied. Using a CMS pixel-based telescope built and installed at the FTBF we are studying charge collection efficiencies for unirradiated and irradiated devices bump-bonded to the CMS PSI46 pixel readout chip. A description of the test-beam effort and preliminary results on diamond sensors will be presented.

Pixel Telescope Overview

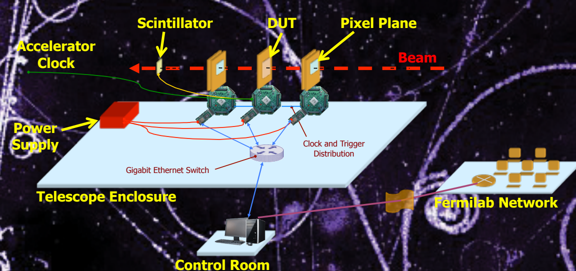
- The pixel telescope consists of eight pixel planes leftover from the CMS Forward Pixel Detector production.
- The pixel size is 150 µm x 100 µm, but enhanced resolution is derived from charge sharing by tilting the telescope planes at 25°.
- The telescope resolution on the DUT (Detector Under Test) is as small as 6 µm both in X (150 µm) and Y (100 µm).



Above the pixel telescope hardware is shown in the beam line at the Fermilab Test Beam Facility. Two CAPTAN stacks are connected to the upstream and downstream telescope planes while the central CAPTAN stack is connected to two DUTs. Trigger and clock are connected to the central CAPTAN which then distributes them to the other two stacks.

DAQ Overview

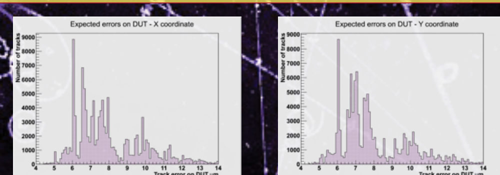
- The hardware is based on the CAPTAN system, developed at Fermilab, which uses a gigabit Ethernet link to transfer the data.
- The software, also developed at Fermilab, runs on Windows PC and is a suite of multithreaded applications.
- A Data Quality Monitor runs live while data is acquired to provide immediate feedback on the data quality.



Above is the complete system overview. The raw telescope data is pushed in real-time through a gigabit Ethernet network to a Windows PC where it is stored to disk. The gigabit link is capable of sustaining a rate up to few hundred thousands particle each spill which, at the FTBF, is delivered every minute for four seconds.

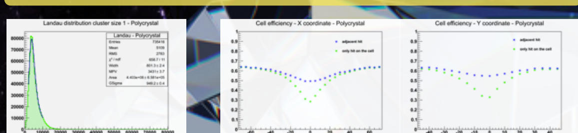
Offline Analysis

- The alignment is done using software developed at the University of Milan Bicocca, which achieves a track resolution on the DUT as small as 6 µm.
- Tracks are saved in ROOT format to be later analyzed by another program - the results are shown here.

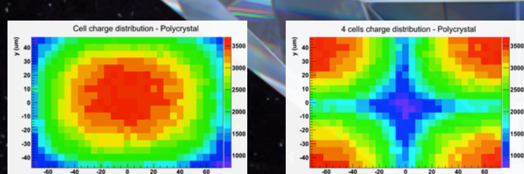


Above is the track resolution on the DUT along the X and Y coordinate.

Polycrystal Diamond Detector Results

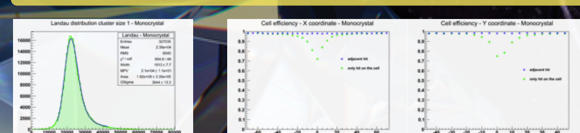


Above, on the left, is the charge for individual pixel hits. The total charge collected in this 500 µm thick polycrystal with a charge collection distance of ~172 µm is only around 3400 e⁻. Above, on the right, is the measured efficiency along the X and Y coordinate of a pixel cell. The efficiency reaches only a maximum of 65% because the Readout Chip threshold was set around 2400e⁻.

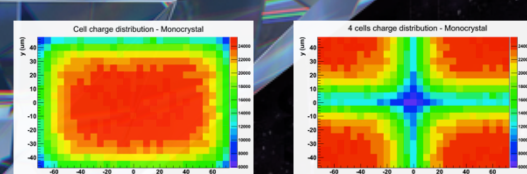


Above, on the left, is the charge distribution in the 100 um x 150 um pixel cell of the polycrystal diamond detector. Above, on the right, is the charge distribution centered at the corner between four pixel cells.

Monocrystal Diamond Detector Results



Above, on the left, is the charge for individual pixel hits. The total charge collected in this 500 µm thick monocrystal with a charge collection distance >500 µm is around 24000 e⁻. Above, on the right, is the measured efficiency along the X and Y coordinate of a pixel cell. The efficiency is 99.8% for this crystal.



Above, on the left, is the charge distribution in the 100 um x 150 um pixel cell of the monocrystal diamond detector. Above, on the right, is the charge distribution centered at the corner between four pixel cells.