Construction and characterization of high time resolution 3D diamond pixel detectors

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Future Colliders

- Huge number of vertices and tracks
- $10^{17}$ 1 MeV neq/cm² radiation levels
- Resolution: 30 ps & 10 μm to disentangle collisions
- Rad-hard

The TimeSPOT project[1]

Rad-hard pixel detector with 4D tracking
- 3D sensors: silicon and diamond
- Rad-hard 28nm read-out chip
- FPGA-based DAQ for extreme throughput

3D diamond sensors

- High mobility and $v_{sat}$
- Short drift length and collection time
- Very rad-hard + Timing!

Fabrication of All Carbon Sensors

- Pulsed laser graphitization of bulk
- Short pulses (~ fs) + real-time aberrations corrections with SLM
- Fully automated process

Test @ CERN SPS H8 – Late 2021[2]

AMPLITUDE DISTRIBUTION:

Strip: Landau peak at 90mV
S/N = 18

Comb: Landau peak at 60mV
S/N = 12

TIME RESOLUTION:

Δt between diamond and MCP; no charge sharing from structure not under study

$\sigma_t = 82\pm 2$ ps
Crystal Ball fit

Strip

$\sigma_t = 127\pm 3$ ps
Gaussian fit

Comb

$\sigma_{39y} \sim 72$ ps

Simulation[3]

CHARGE GENERATION: GEANT4
- 3x3 matrix of pixels
- Charge produced inside the central pixel

DRIFT OF CHARGE CARRIERS: KDetSim
- Calculation of E, W fields and induced currents
- Resistive electrode as transmission lines ($L$, $G \sim 0$)

ELECTRONIC READ-OUT:
- Transfer function of the amplifier
- Acquired noise superimposed
- Waveforms processed with the same algorithms used for real data

RESULTS:

Validation with SPS Strip data.

References


Future

Optimization:
Dominant effect on time resolution: electrode resistance.
Work in progress to further reduce R!

Demonstrator:
32x32 pixels sensors bump-bonded on 28nm TimeSPOT ASIC.

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