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

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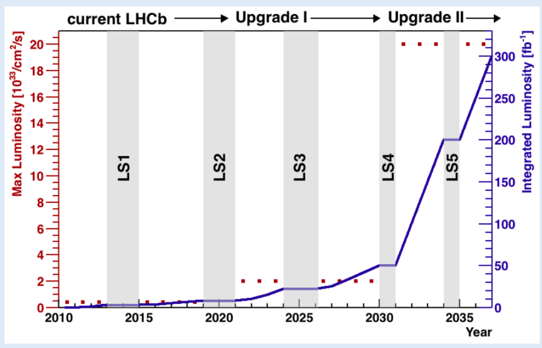
Future Colliders



- Huge number of vertices and tracks
- $\sim 10^{17}$ 1 MeV n_{eq}/cm^2 radiation levels

New detectors:

- Resolution: 30 ps & 10 μm to disentangle collisions
- Rad-hard

The TimeSPOT project[1]

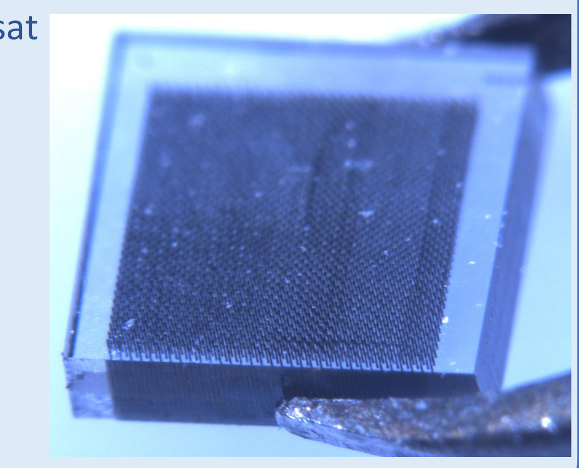
Rad-hard pixel detector with 4D tracking

- 3D sensors: silicon and **diamond**
- Rad-hard 28nm read-out chip
- FPGA-based DAQ for extreme throughput

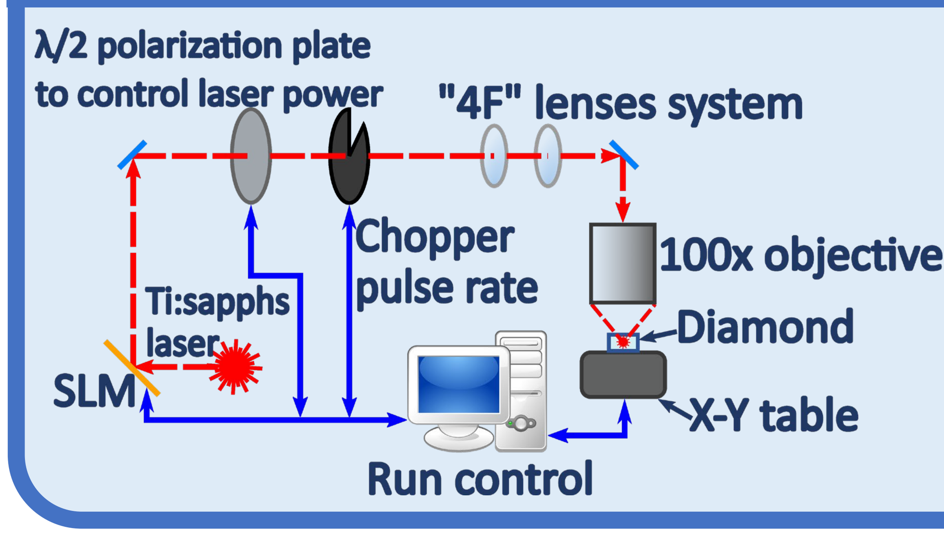
3D diamond sensors

- High mobility and v_{sat}
- Short drift length and collection time

Very rad-hard
+
Timing!

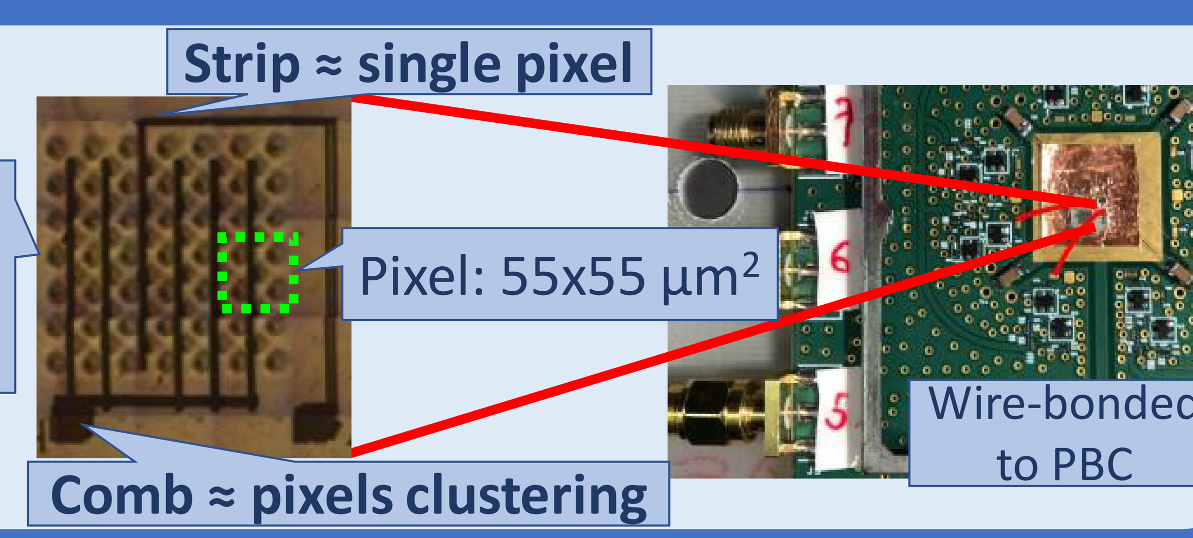


Fabrication of All Carbon Sensors



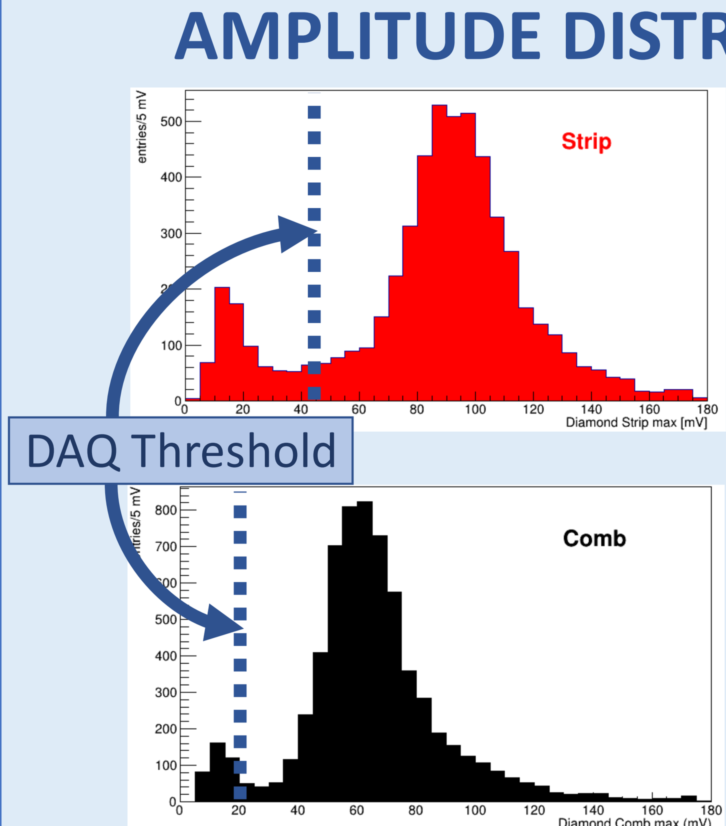
- Pulsed laser graphitization of bulk
- Short pulses (~ fs) + real-time aberrations corrections with SLM
- Fully automatized process

Graphitic Electrodes: R~30 kΩ



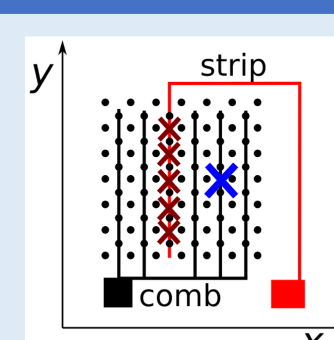
Test @ CERN SPS H8 – Late 2021[2]

AMPLITUDE DISTRIBUTION:

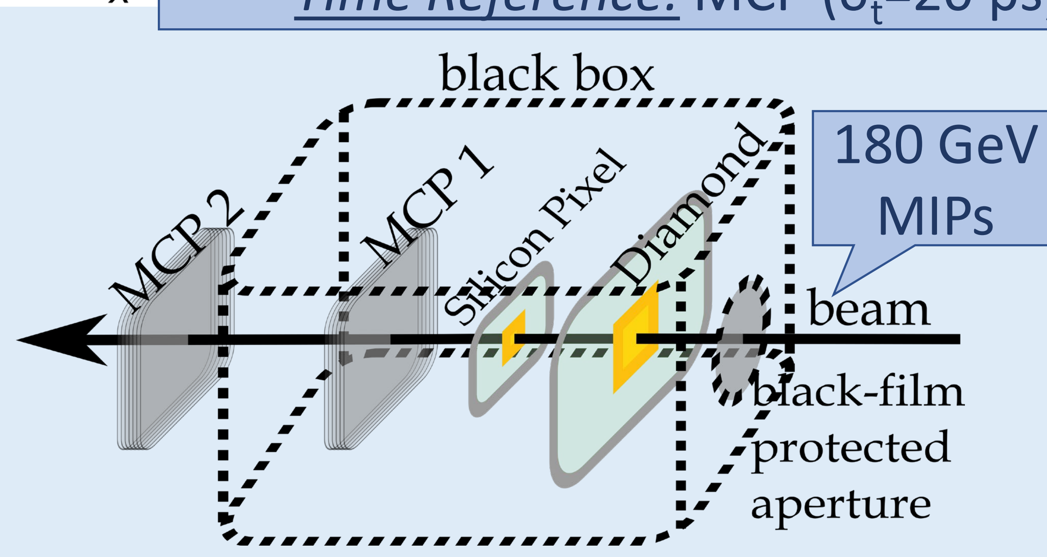


Strip:
Landau peak at 90mV
S/N = 18

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



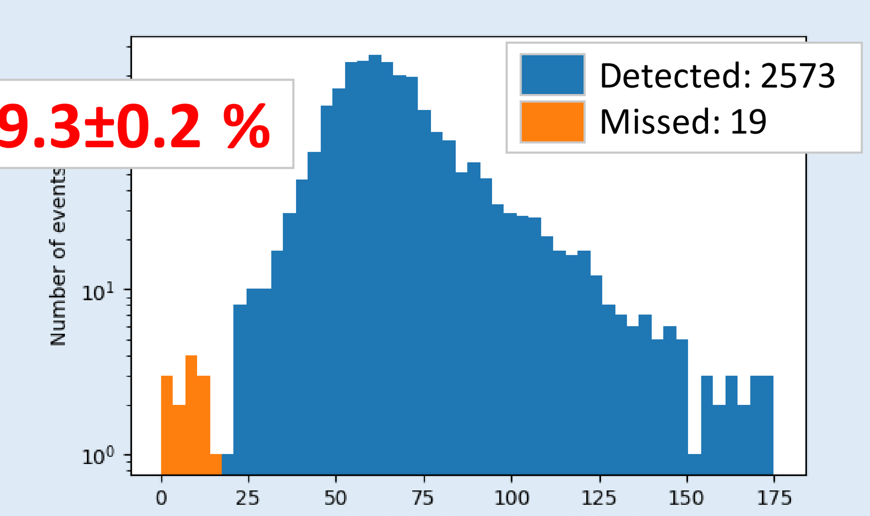
DAQ oscilloscope @ 20 Gsps
Alignment: use Si pixel to intercept a very small region on the diamond ($\sigma_x \sim$ μm)
Trigger: Si pixel (TimeSPOT CA) + MCP
Time Reference: MCP (σ_t=20 ps)



EFFICIENCY:

- Si pixel and MCP amplitude compatible with MIPs
- No charge sharing from Strip

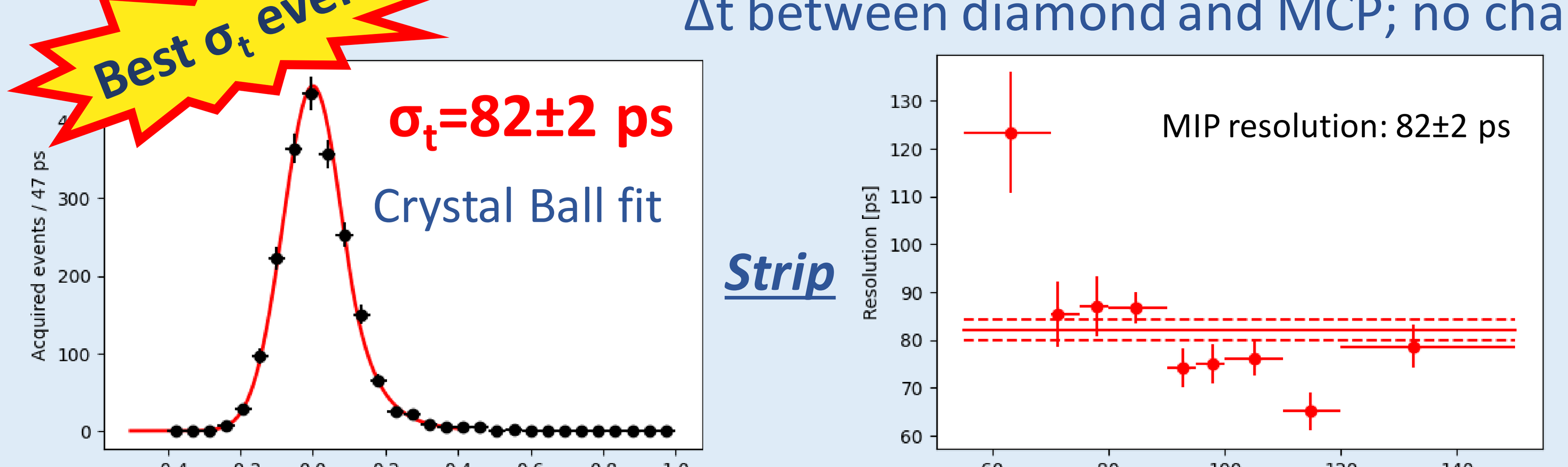
ε=99.3±0.2 %



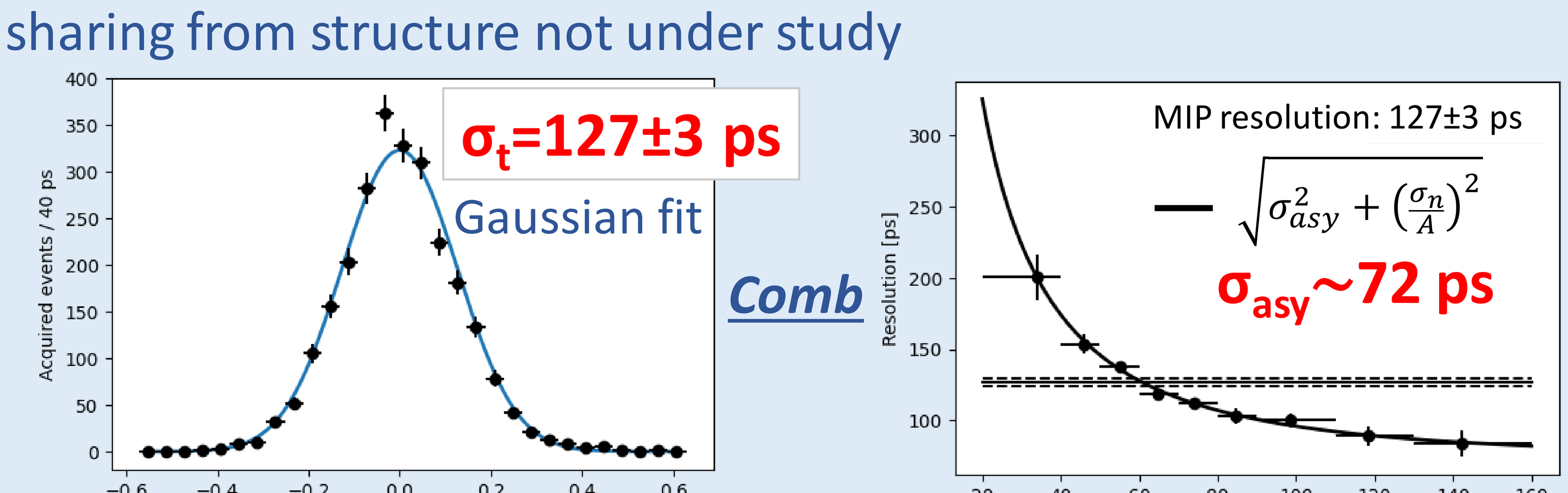
TIME RESOLUTION:

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

Best σ_t ever!



Strip

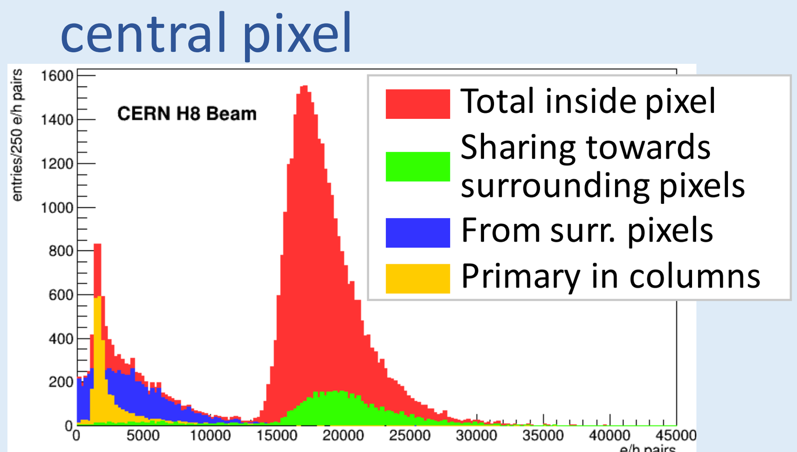


Comb

Simulation[3]

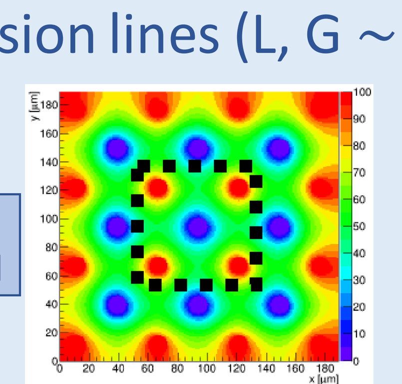
CHARGE GENERATION: GEANT4

- 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 ~ 0)

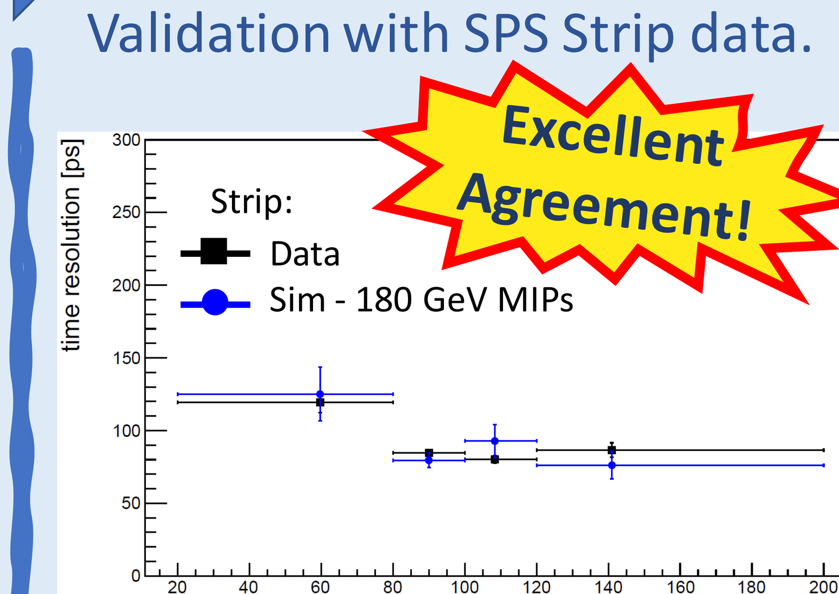


ELECTRONIC READ-OUT:

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

RESULTS:

Validation with SPS Strip data.



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.

References

[1] L. Anderlini et al., "Intrinsic time resolution of 3D-trench silicon pixels for charged particle detection", JINST 15 (2020), P09029

[2] L. Anderlini et al., "A 4D diamond detector for HL-LHC and beyond", submitted to NIMA proceedings

[3] L. Anderlini et al., "Fabrication and First Full Characterisation of Timing Properties of 3D Diamond Detectors", Instruments 5(4) (2021) 39