Precision Timing with Silicon Sensors for Use in Calorimetry

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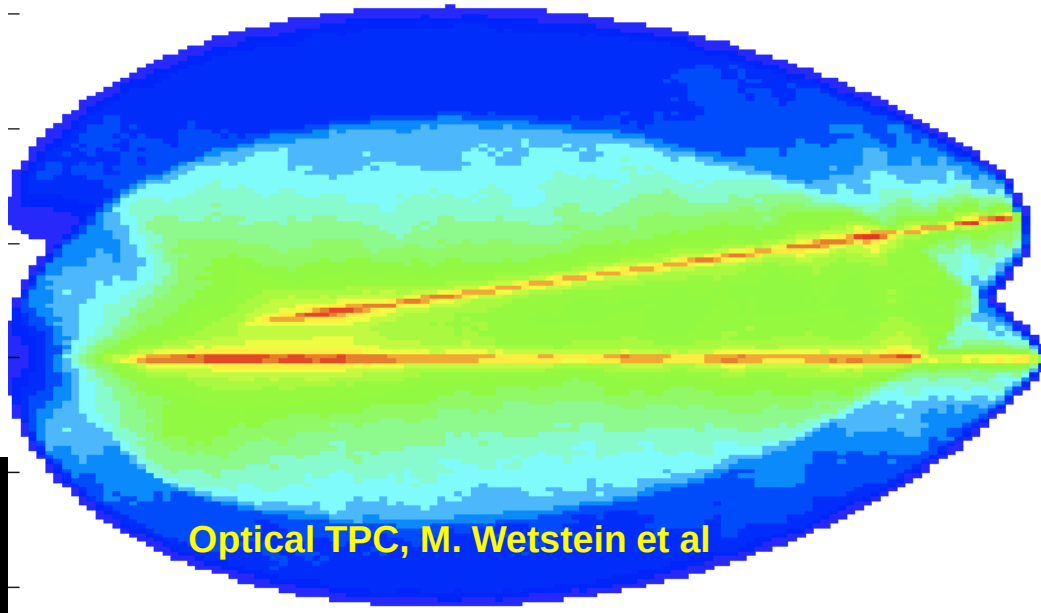
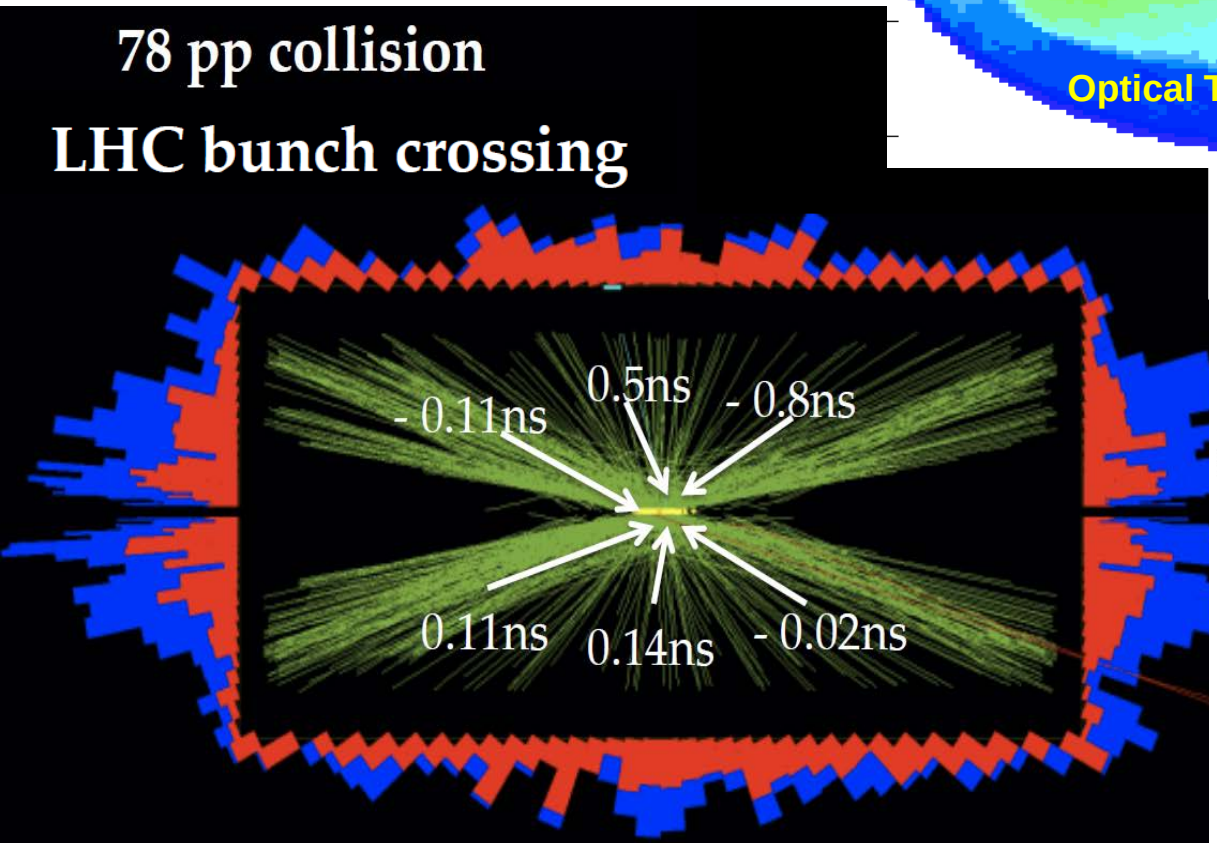
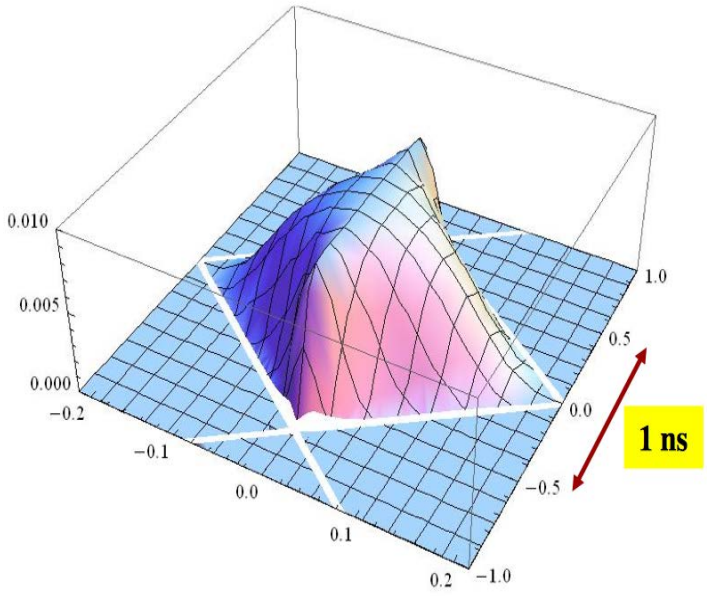
Precision Timing in HEP

5D event reconstruction opens new territory in difficult experimental environments.



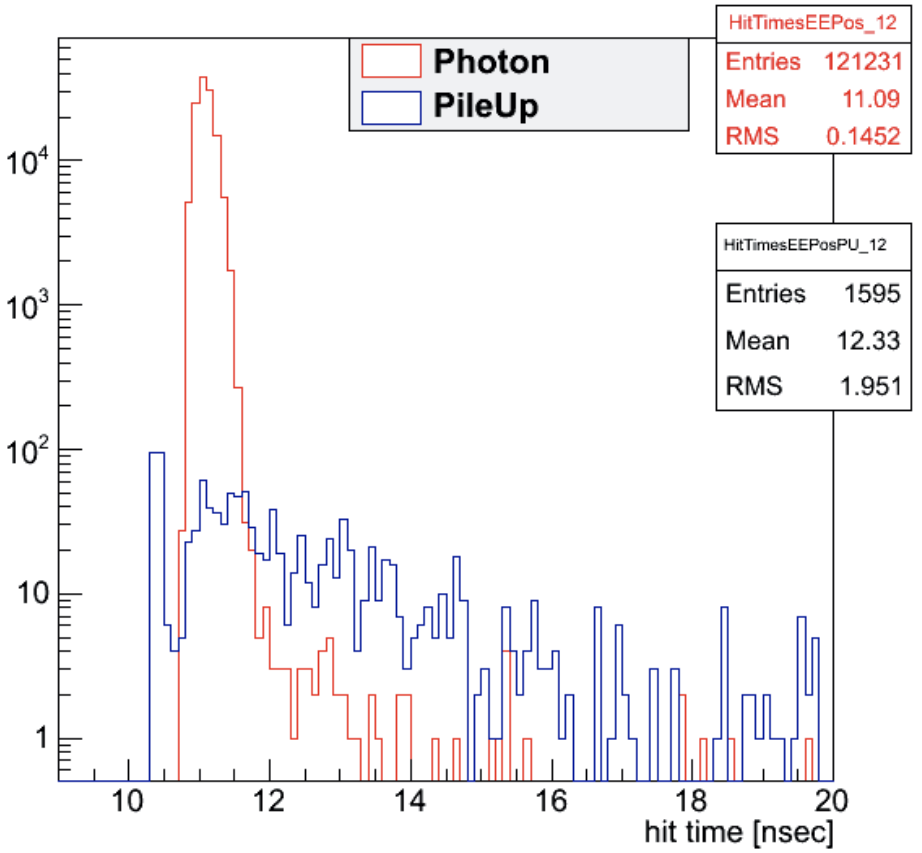


HL-LHC Beam Spot, S. Fartouk et al



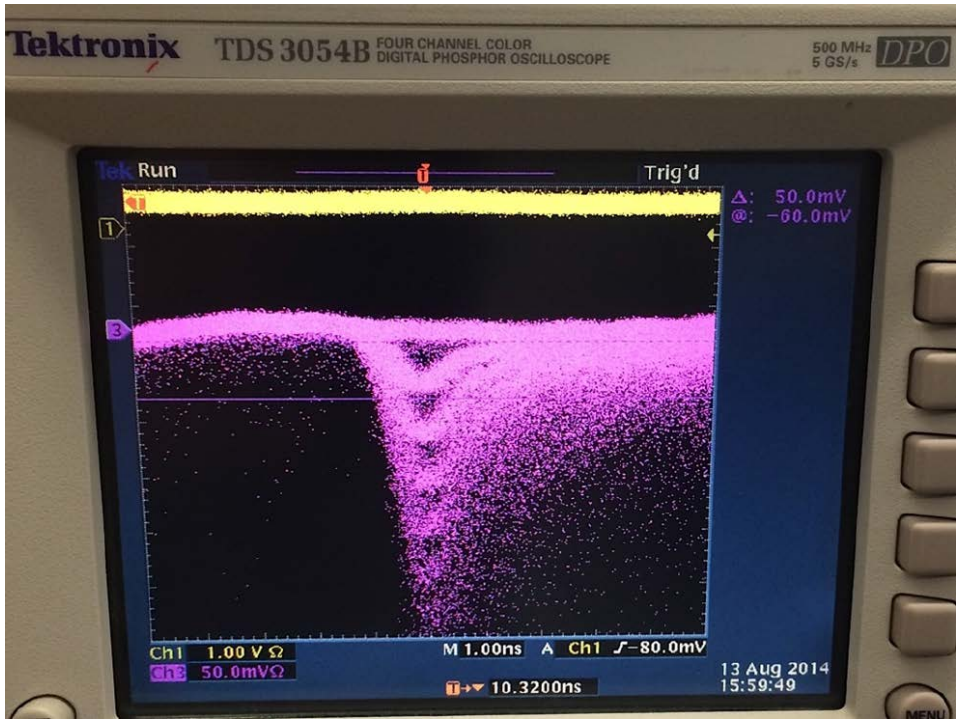
Calorimeter Precision Timing

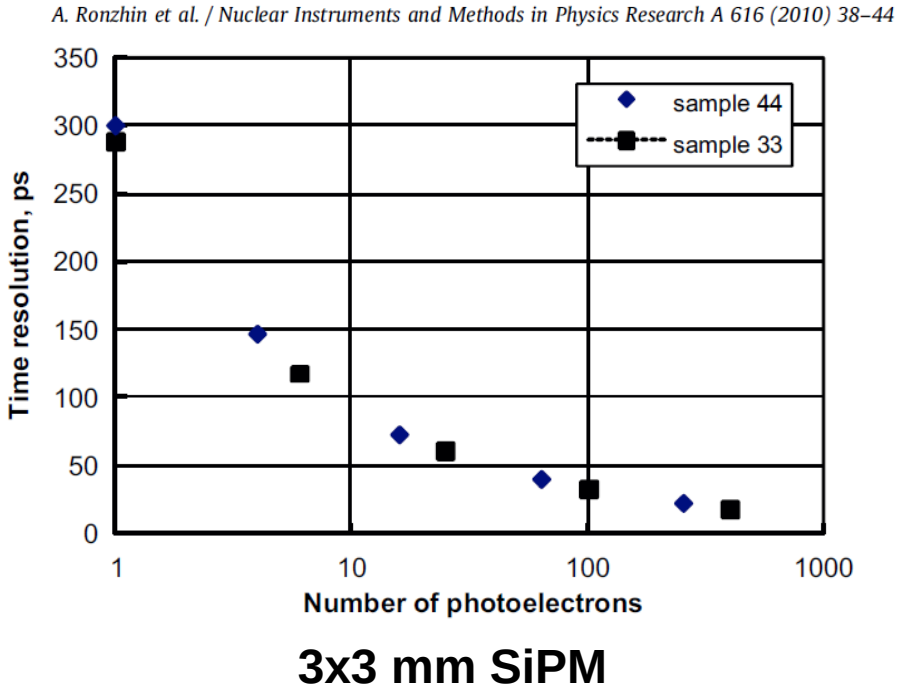
- EM showering process provides a coherent amplification process.
- Pile-up in the range of 200 will be major challenge at HL-LHC.
- Hadronic activity is ~1/3 photons (π_0).
- In high energy, high pile-up and high magnetic field of LHC experiments, time spectrum of particle flux is complex.
- CMS choice for forward calorimeter upgrade is a Si sampling calorimeter.



Timing vs raw signal size

- **Timing resolution of SiPMs scales with signal amplitude**

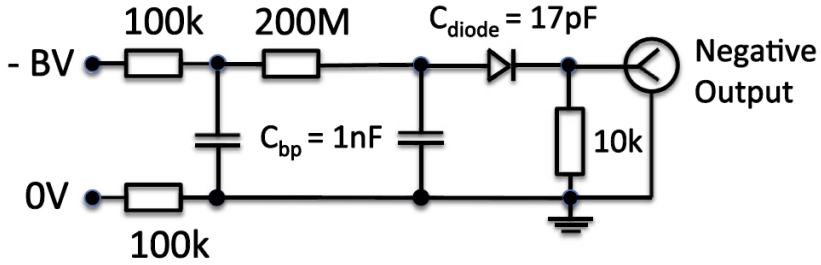




3x3 mm SiPM

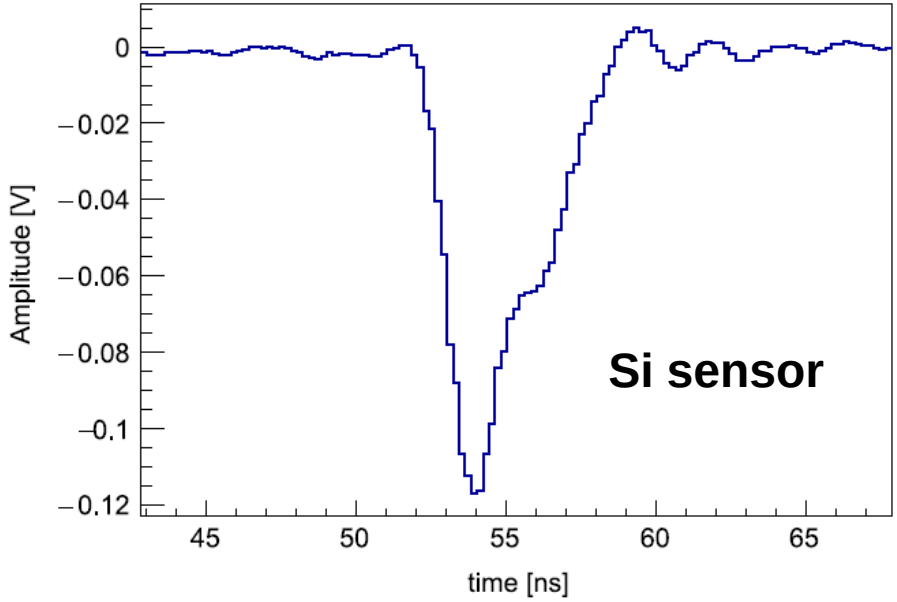
Si Pad

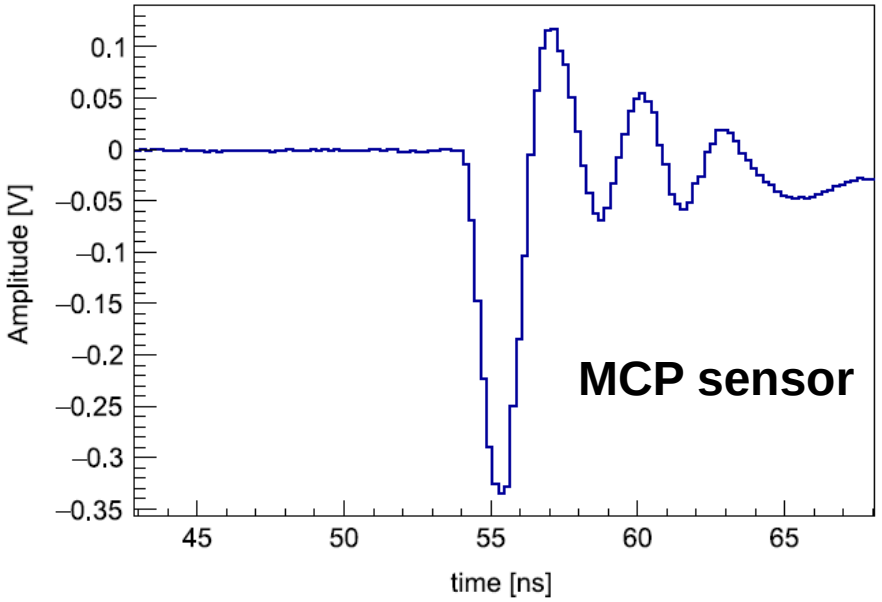
- **Si pad : Hamamatsu, 6x6 mm, 325 μm, no gain.**
- **0.2 mm steel box, 1.5 cm “thick”**
- **ORTEC VT120C pre-amplifier**
- **Hamamatsu C5594 amplifier**



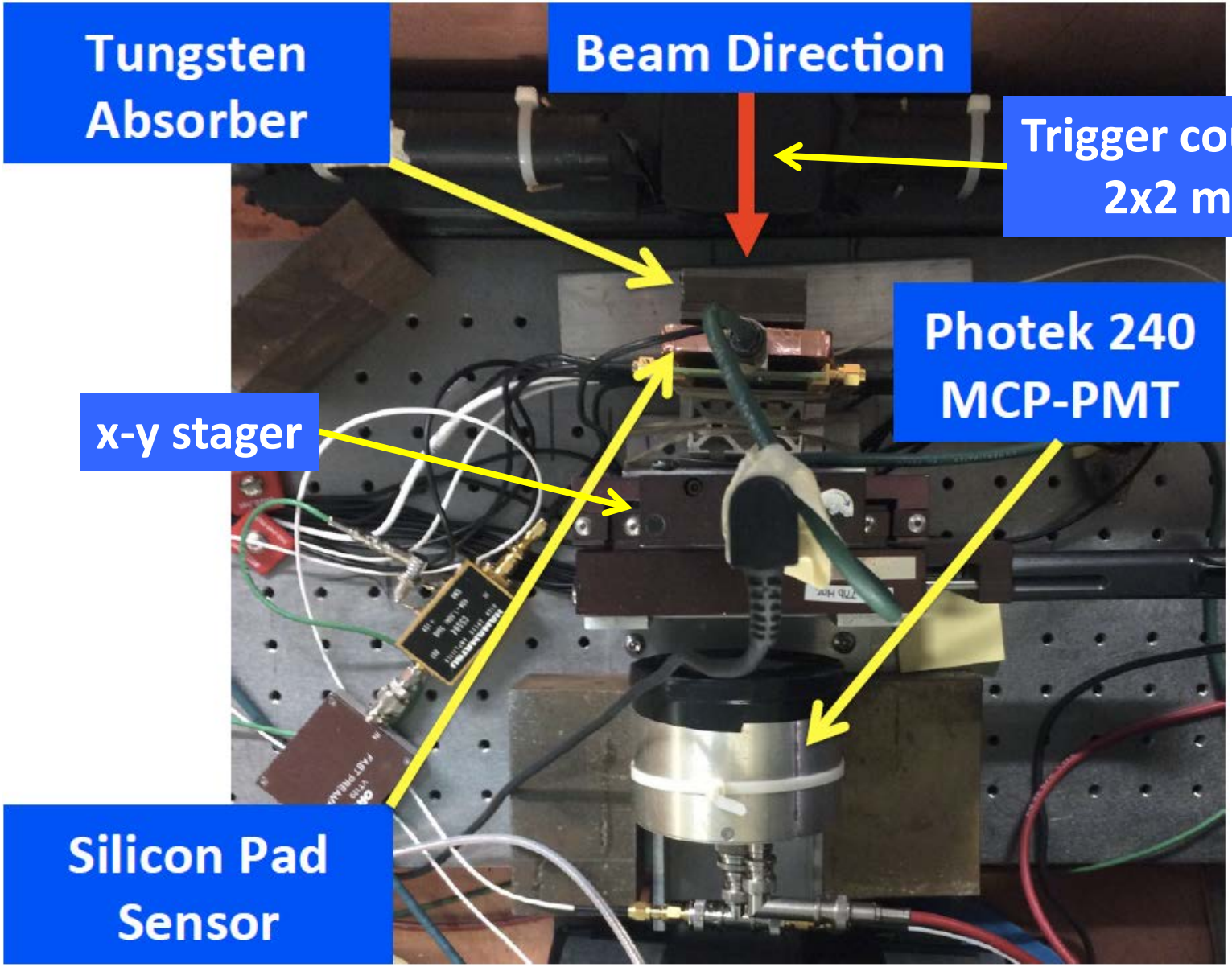
Pulse Shapes

- **Si pad rise time ~2 ns, MCP rise time ~1 ns.**
- **Pulse reconstruction :**
  - **Leading edge fit for Si pulses**
  - **Fit to first peak**



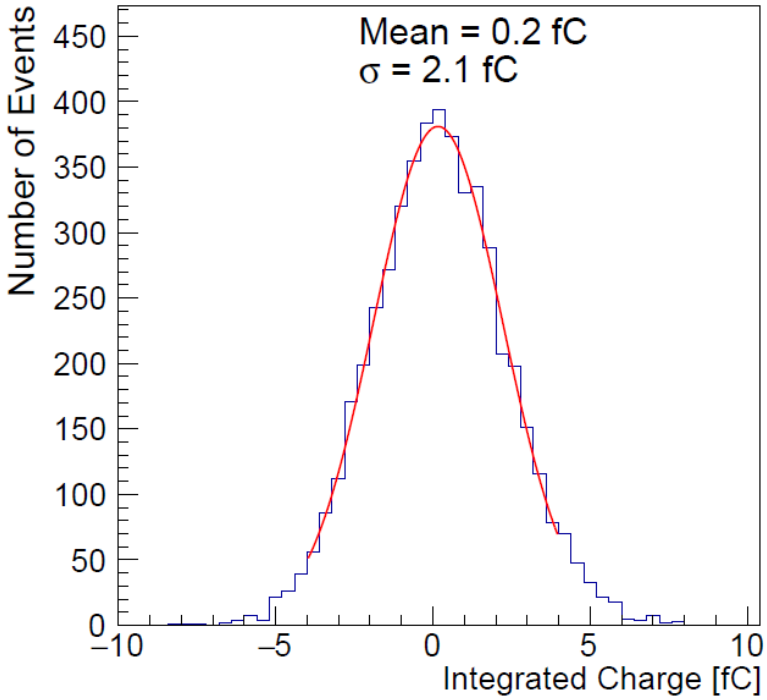


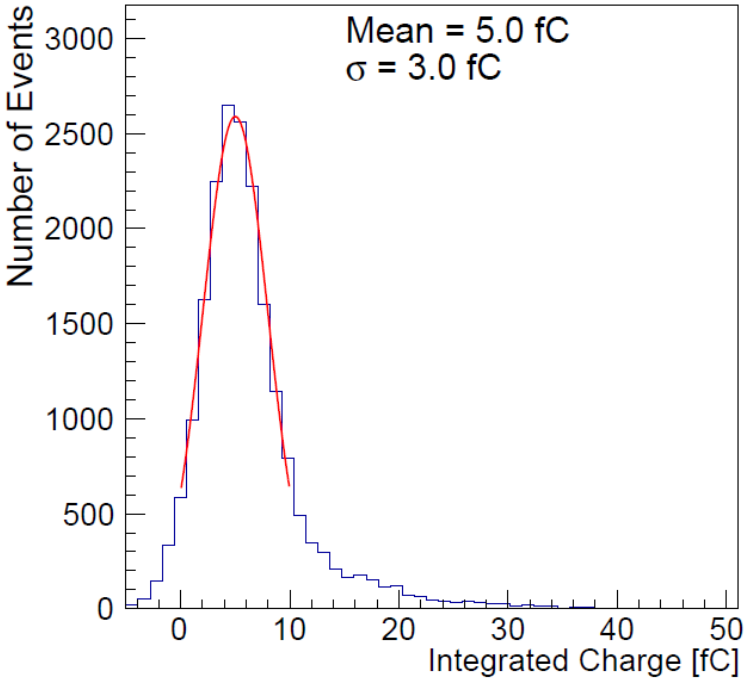
Experimental Setup



Noise & MIP Response

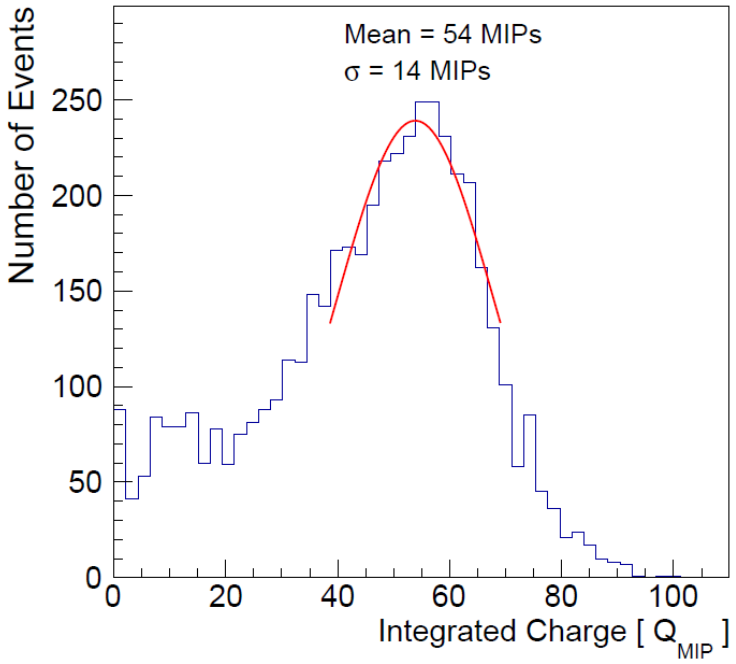
- **Noise, measured with external trigger, no beam : 2.1 fC**
- **“MIP” signal ~5 fC for a 8 GeV electron (no absorber).**

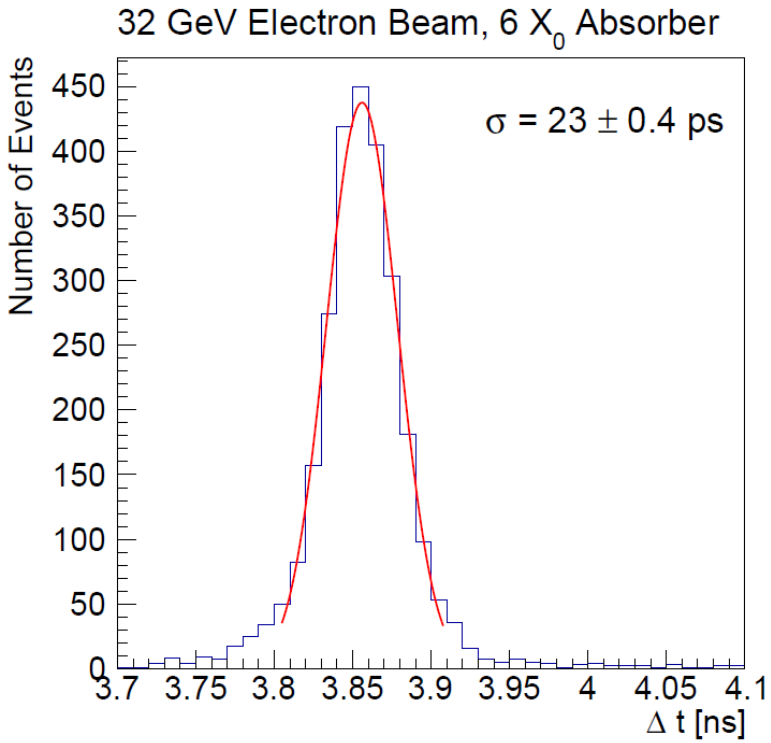




Showering Electrons

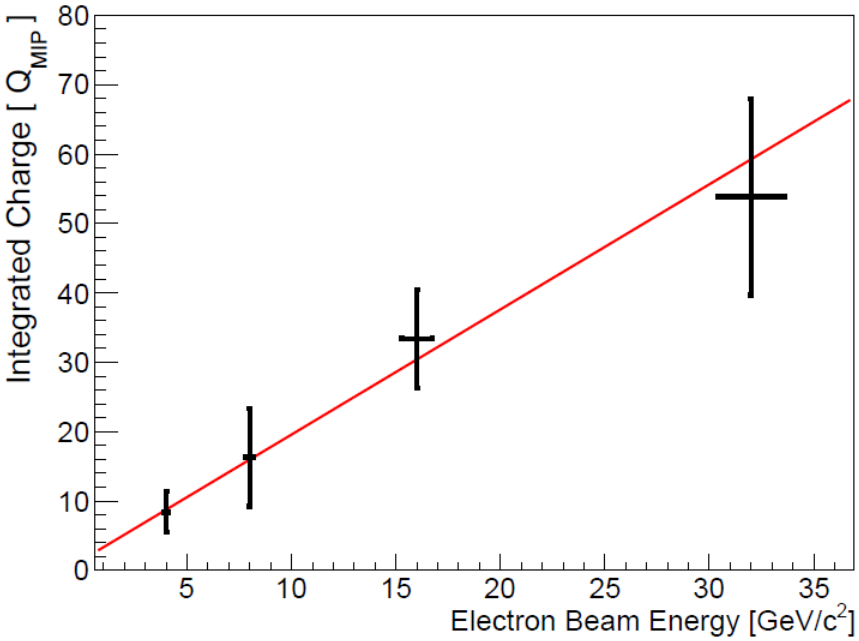
- **Measure signal amplitude and timing resolution at different energies and absorber thickness.**
- **Electron beam purity at 32 GeV @FNAL 10%, simple electron ID applied.**
- **Timing extracted from the bulk of the events.**

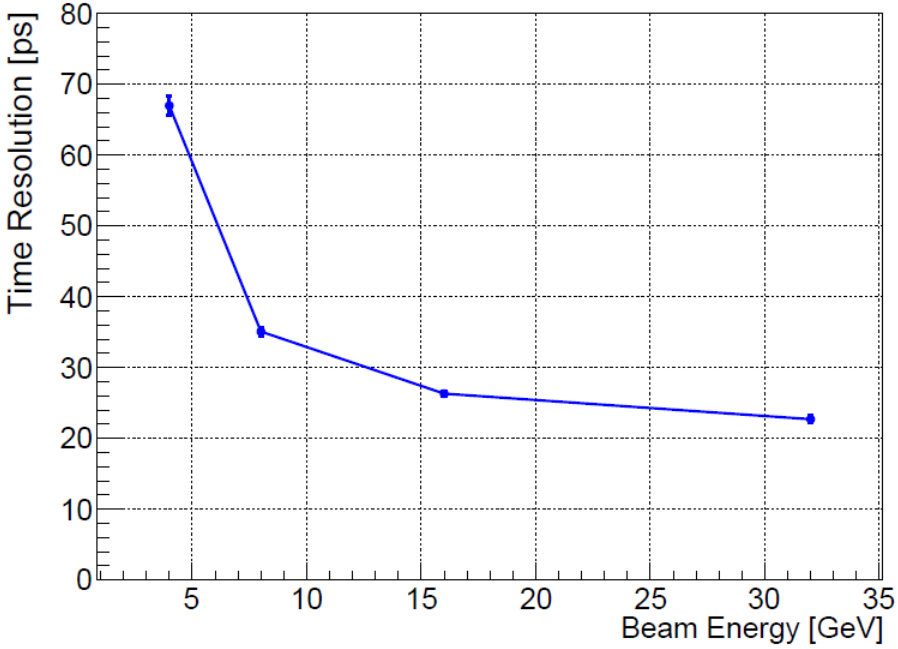




Energy and Timing Measurements

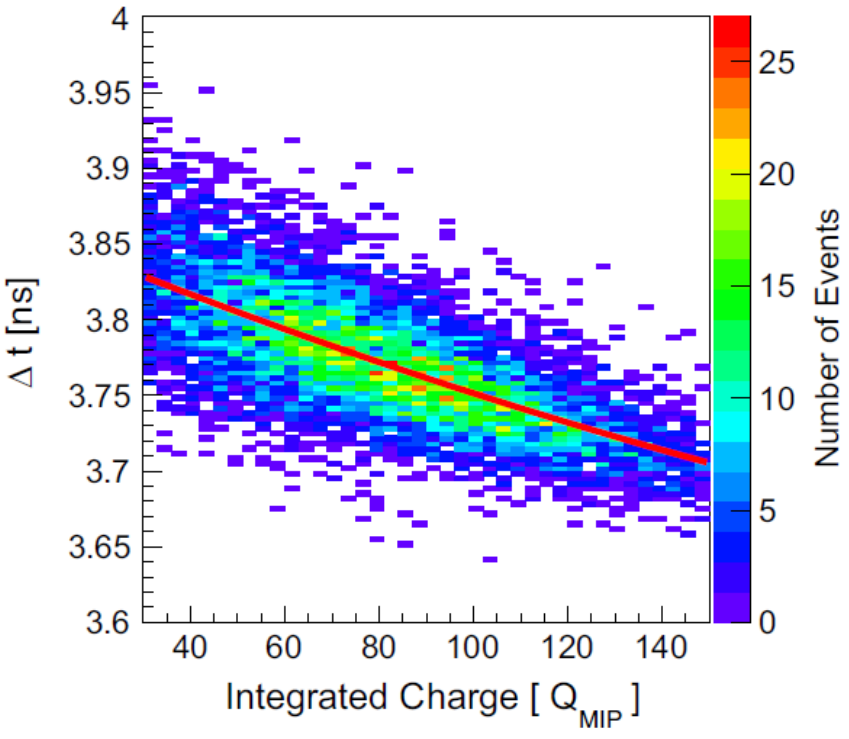
- **Correlation between beam energy and signal amplitude (recall, only one 6x6 mm pad).**
- **Timing resolution improves with signal amplitude.**

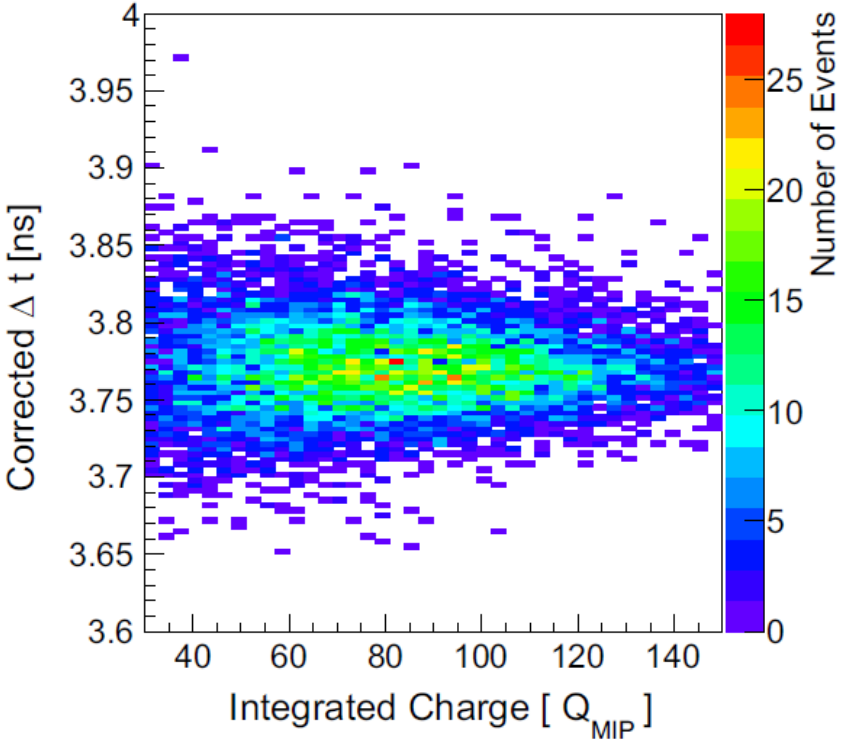




Amplifier linearity

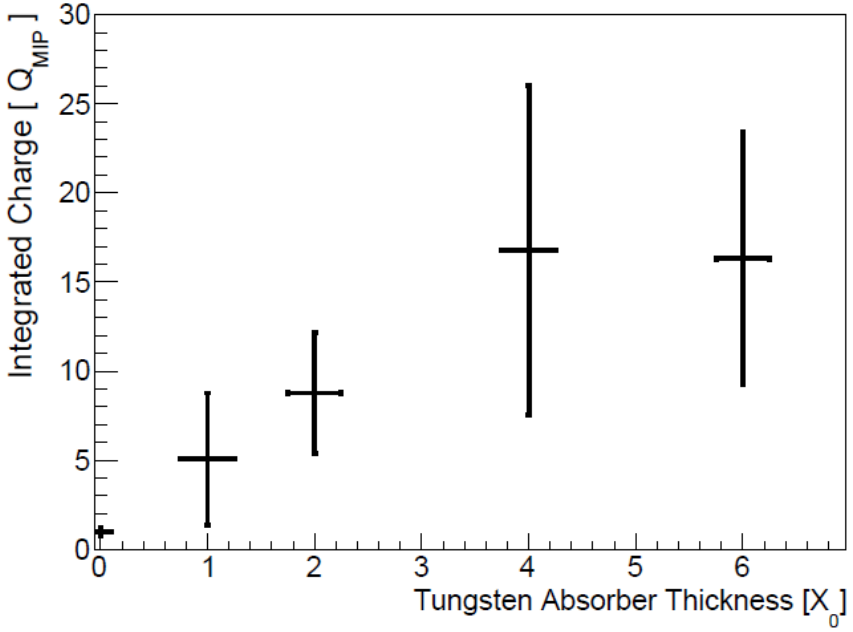
- **Mean timing of silicon pad signal depends on amplitude.**
- **Traced to the amplifiers with test pulse measurement.**

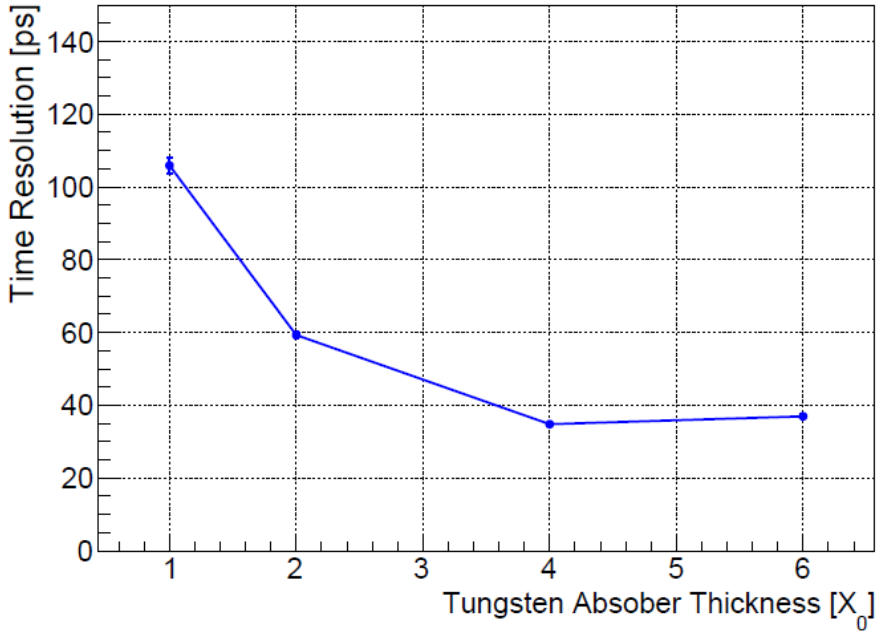




Time Resolution vs Absorber Thickness

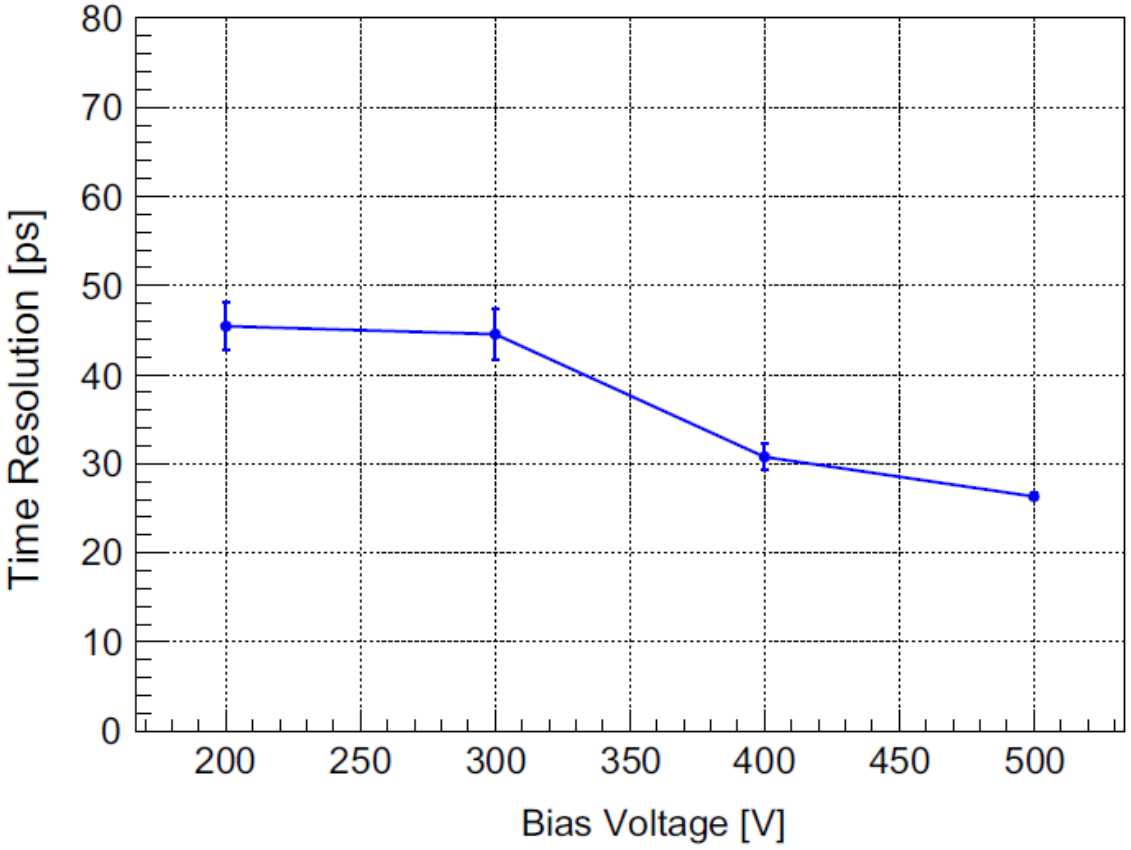
- **Signal amplitude maps shower depth profile.**
- **Timing resolution improves with signal amplitude as before.**
- **Here : 8 GeV electrons.**





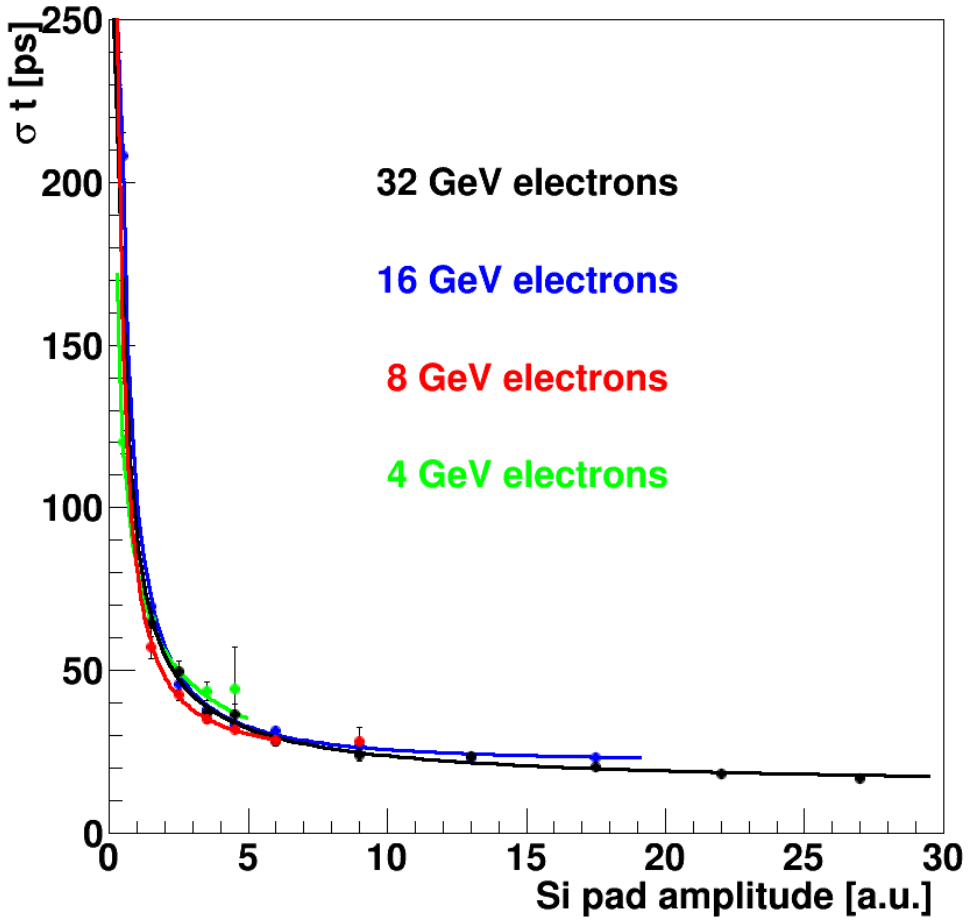
Impact of Bias Voltage

- **Timing resolution varies with bias voltage. Large voltage implies slightly large signals.**



Amplitude Dependence

- **Signal amplitude spread varies due to limited containment on single Si sensor. Use to look at timing resolution vs amplitude.**
- **Timing resolution strictly scales with the signal amplitude.**



Summary

- **We demonstrate that a timing precision of better than 20 ps can be achieved with a Si diode in an EM shower.**
- **The timing precision scales with the signal size in the Si diode.**
- **Our studies with pixelated MCPs and LYSO calorimeters suggest that sampling the same EM shower will allow to extend this performance to lower energies.**