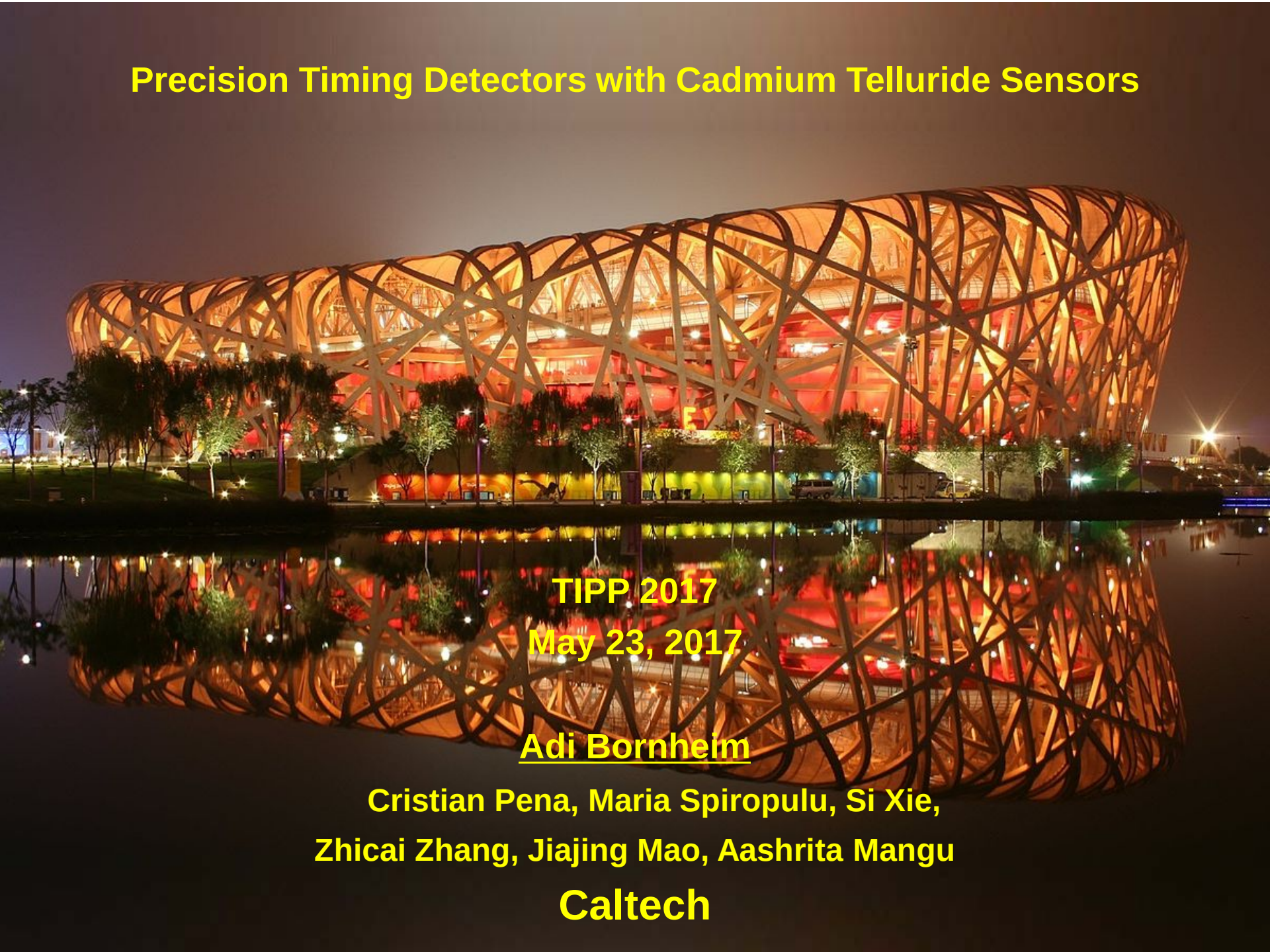
Precision Timing Detectors with Cadmium Telluride Sensors



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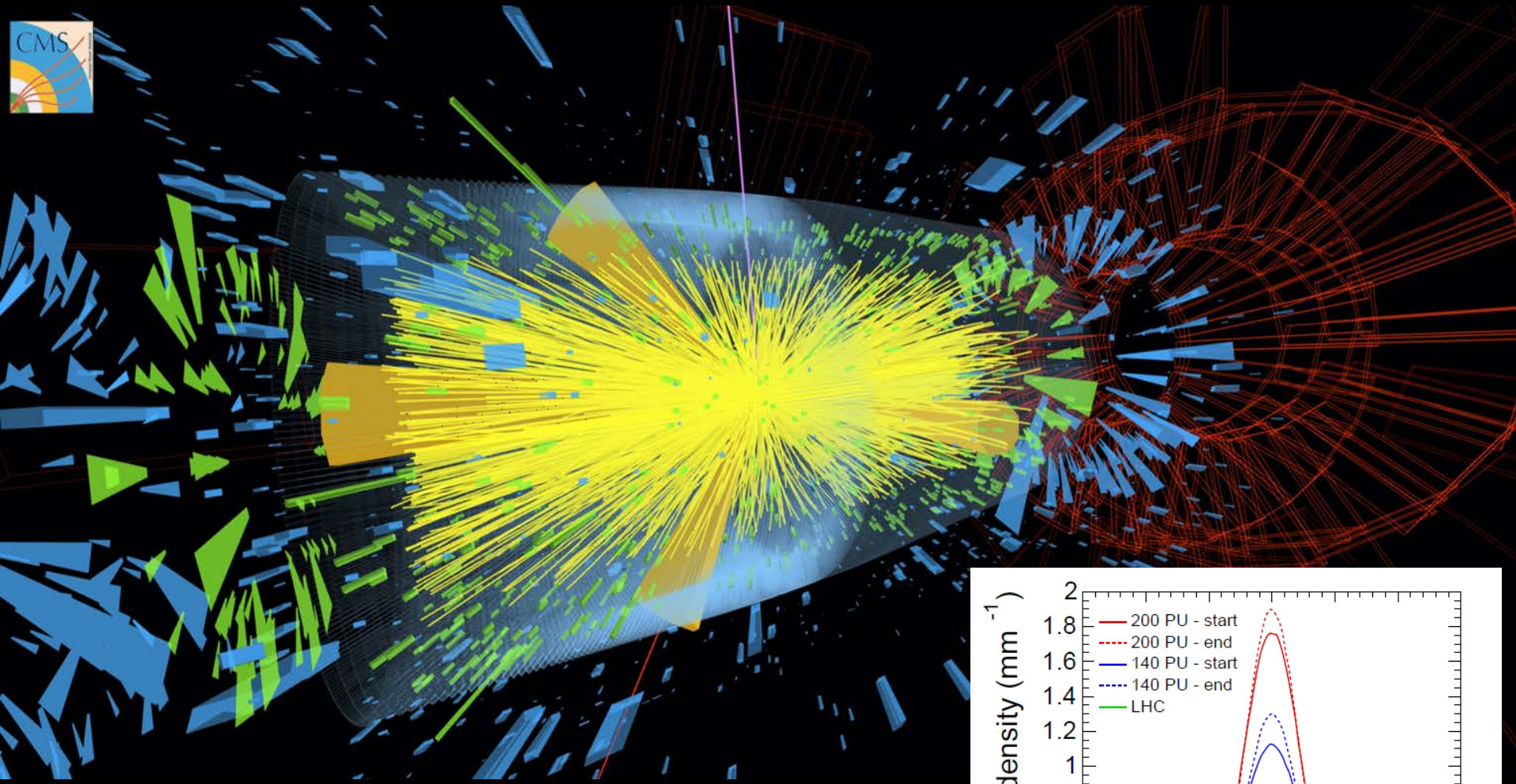
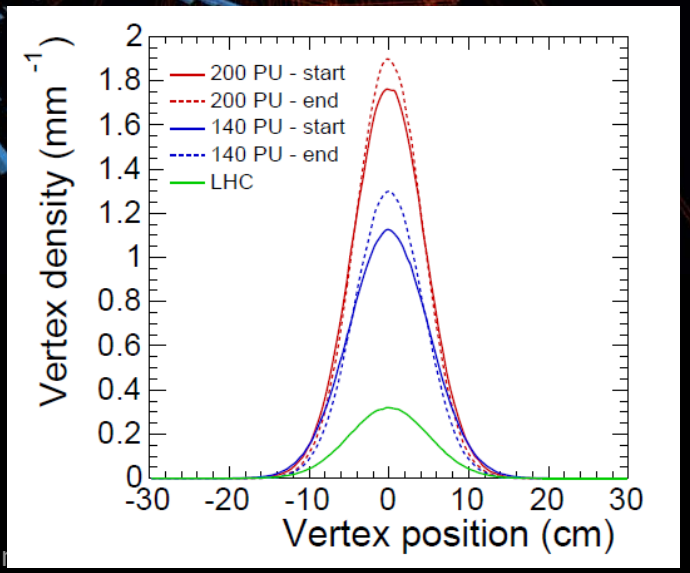
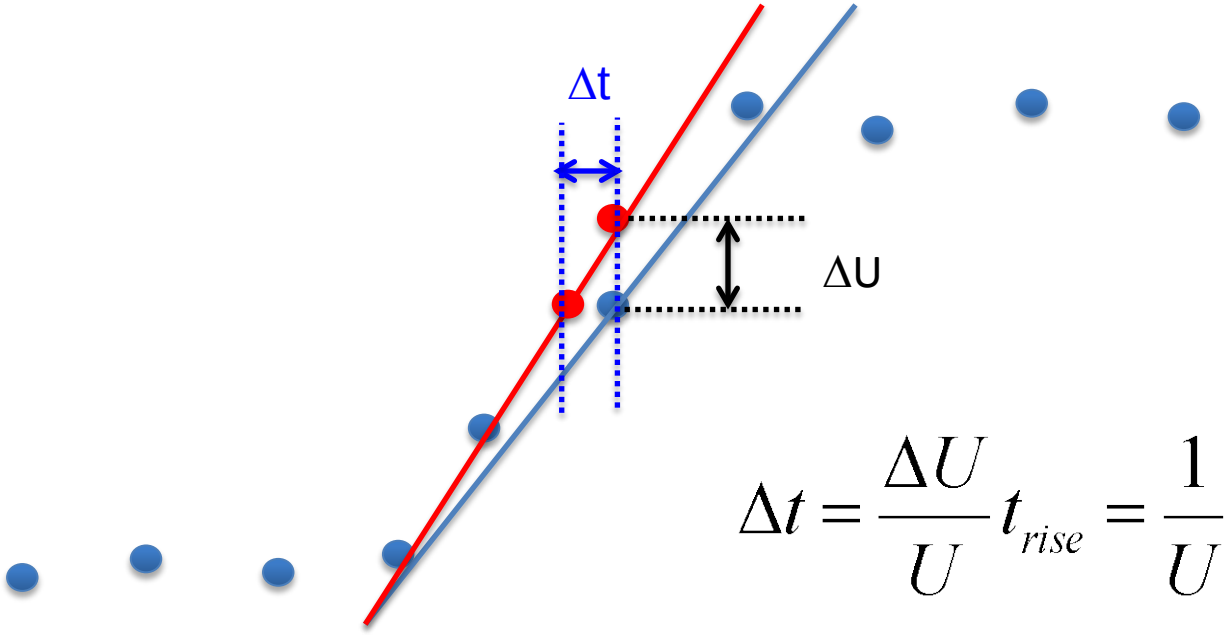
Caltech

Physics at HL-LHC





Fast Timing Fundamentals



$$\Delta t = \frac{\Delta U}{U} t_{rise} = \frac{1}{U} \frac{\Delta U_i}{\sqrt{n_{samples}}} t_{rise}$$

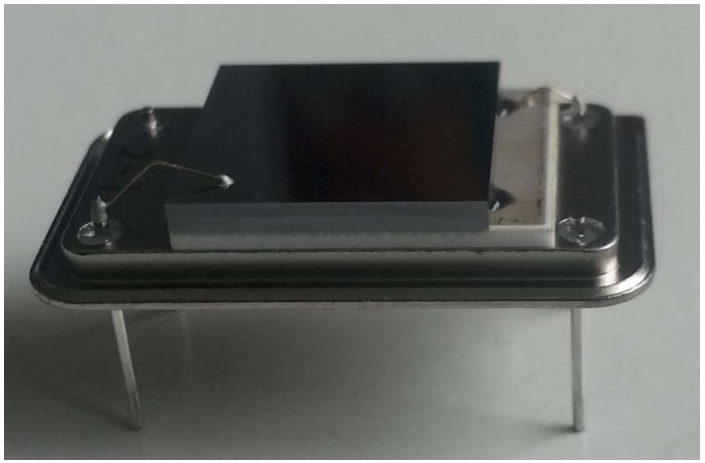
For good time resolution, need:

1. **fast rise time (t_{rise}) ⇒ primary signal rise time (scintillation : LYSO ~30 ps, Si sensors ~1ns)**
2. **low Signal-to-Noise (ΔU/U) ⇒ primary signal amplitude : LYSO 30k photons/MeV (1.07 MeV/mm MIP) , Si sensors ~30k e/h pairs in 300 μm for a MIP**
3. **more time samples ($n_{samples}$)**

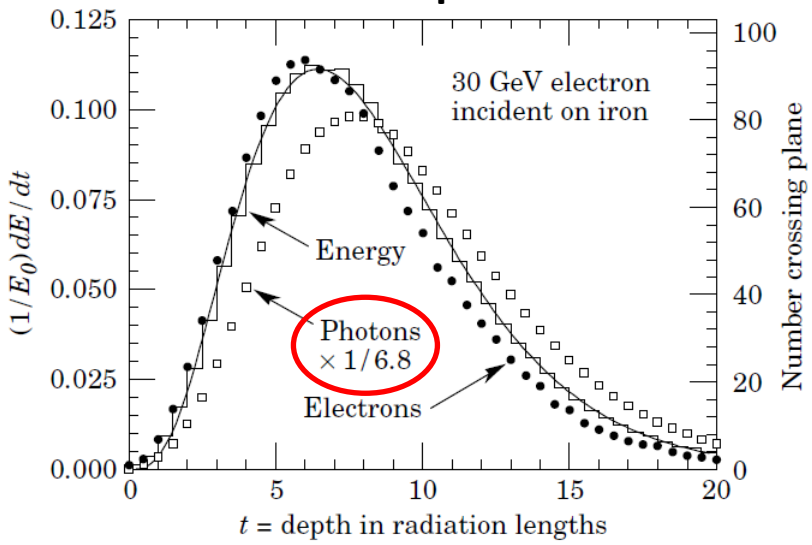
Calorimeter showers provide large, temporally coherent primary signals.

Timing Calorimeter with CdTe

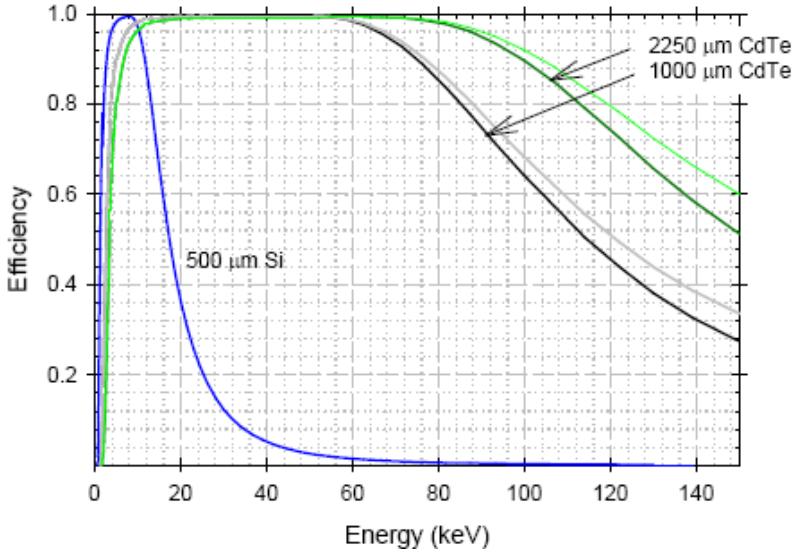
- MIP signal 50k electrons in 300 μm.
- CdTe density ~5.8 g/cm^3
- Sensor available in large thickness (here : 1 mm).
- CdTe more suitable for calorimetric application.



EM Showers are photon rich

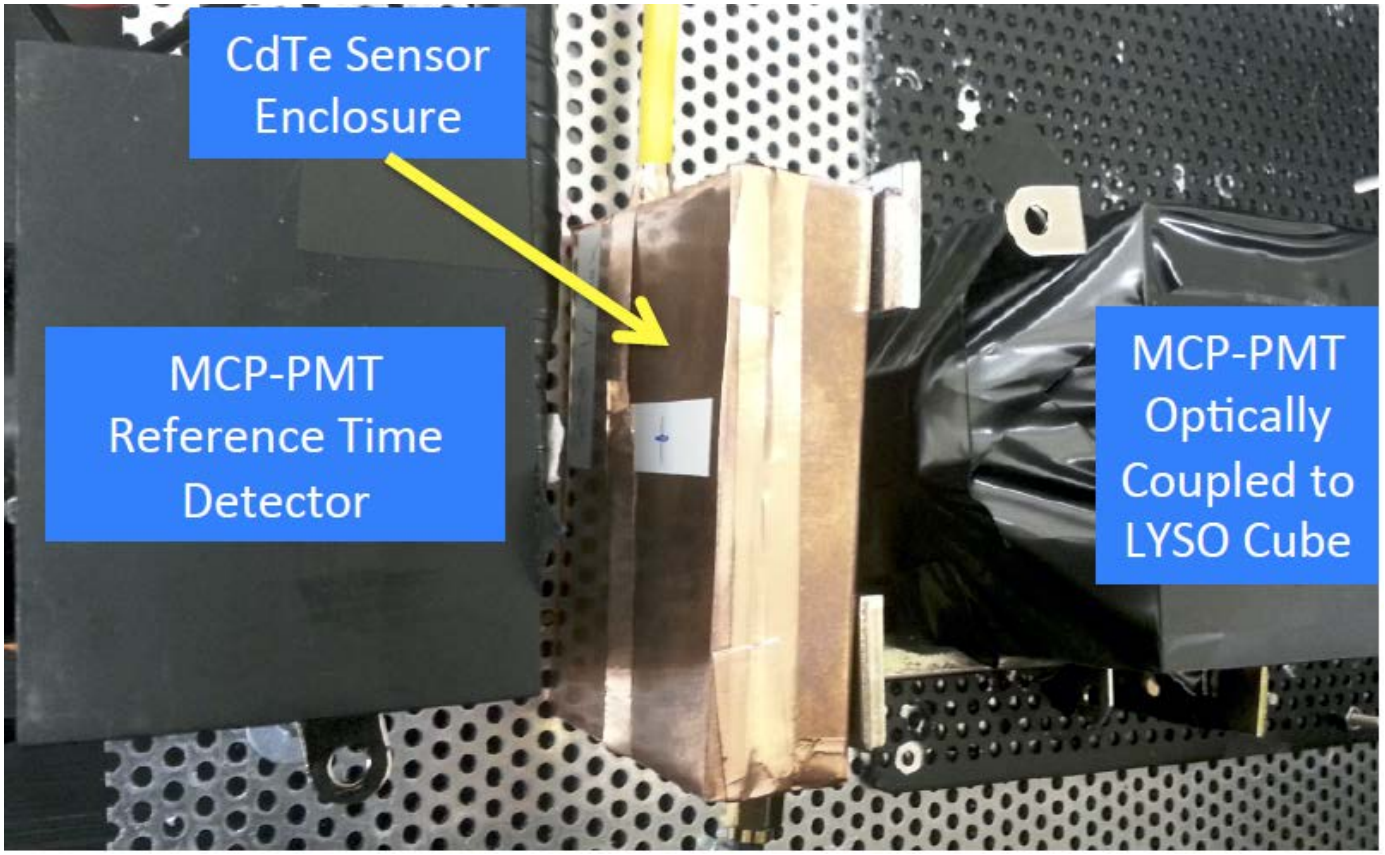


CdTe has high sensitivity for low energy photons



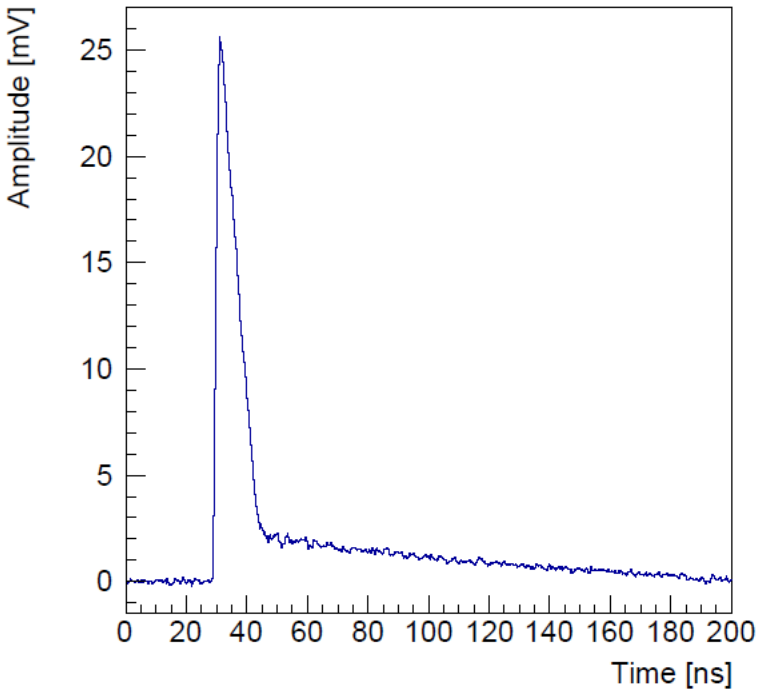
Test Beam Setup

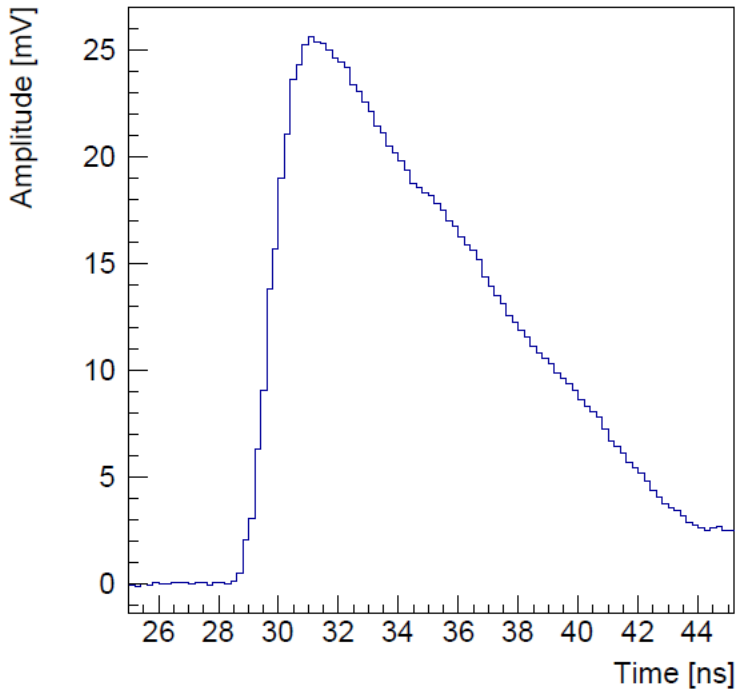
- **Tests performed at CERN test beam facilities T9 (up to 7 GeV) and H2 (up to 200 GeV)**
- **DRS based fast digitizer as readout with MCP as timing reference (<10 ps precision).**



Pulse Shapes

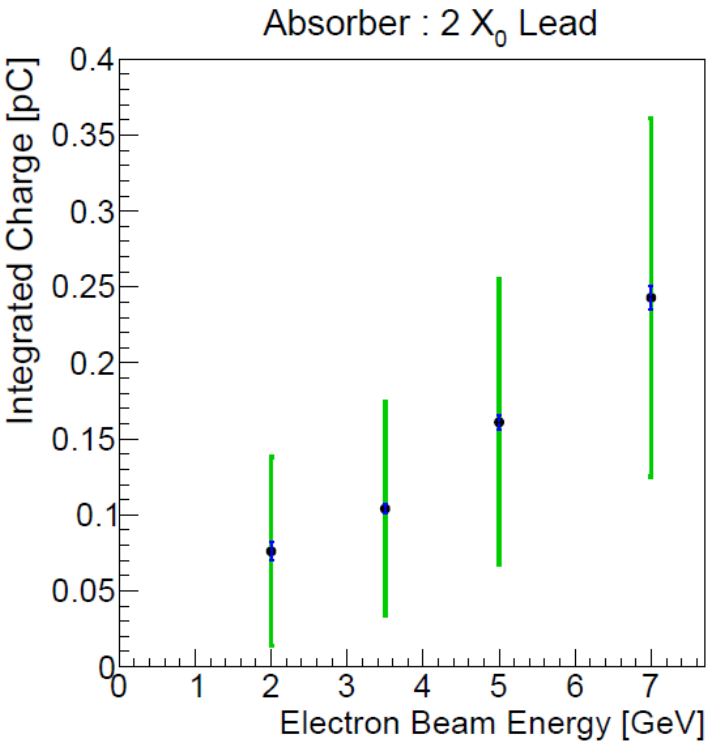
- Example pulse shapes from 100 GeV electron beam
- Pulse shape have fast rise time : ~1 ns.
- Excellent signal/noise due to high ionization density in the shower.
- Two time constants : electron- and hole-induced pulse.

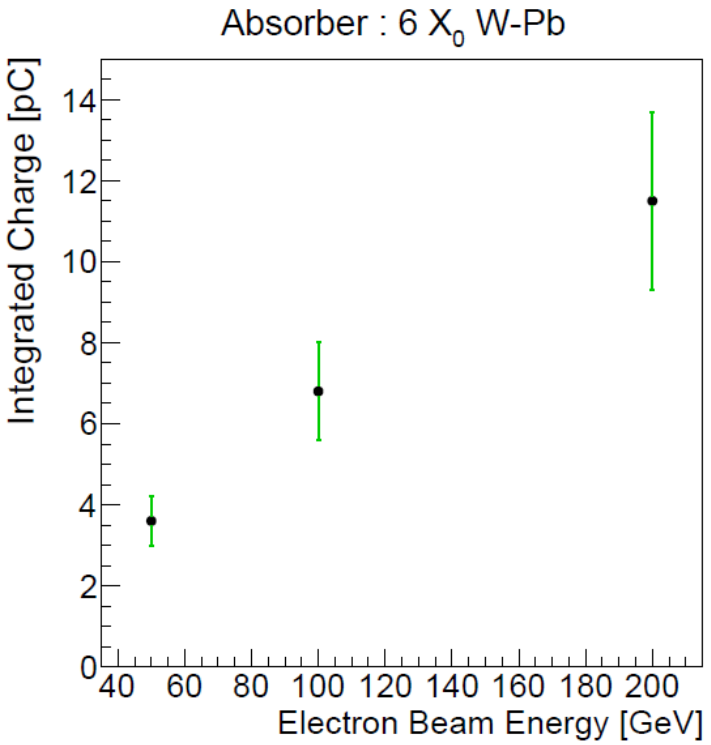




Energy Response

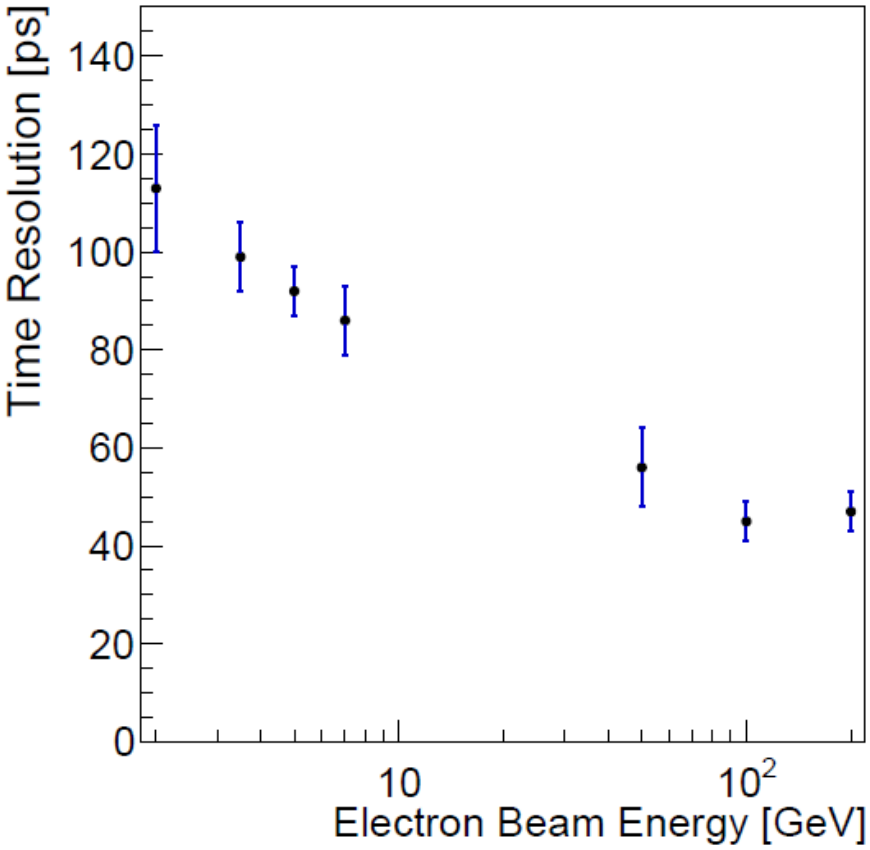
- **Energy response scales well with beam energy.**
- **Single sensor test (1x1 cm^2) does not allow detailed performance study.**
- **High density of CdTe allows rather homogeneous sandwich calorimeter.**





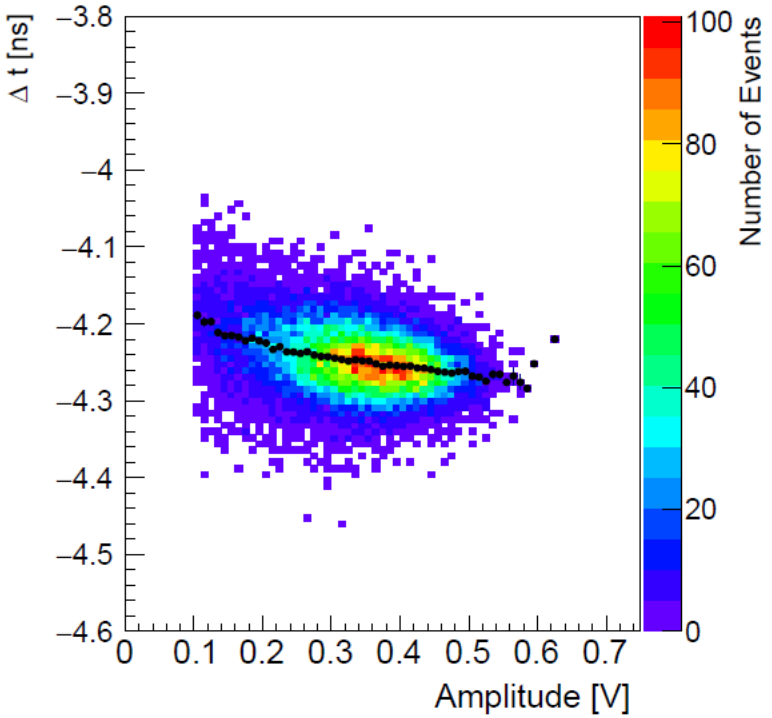
Time walk Correction

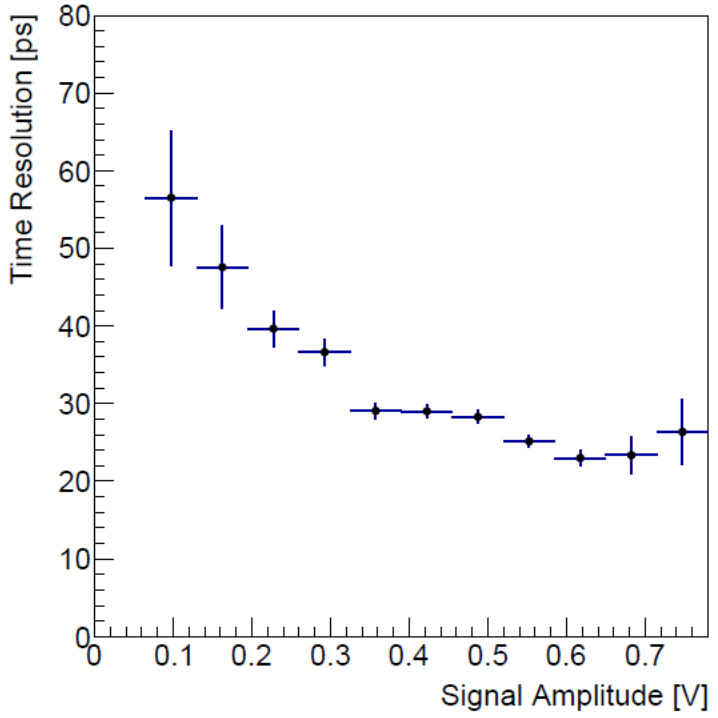
- **Time response depends on amplitude : change in S/N, electronic chain typically not perfectly linear.**
- **Still observe very good time resolution of ~110 ps at the lowest energy shower (2 GeV, 2 X_0)**



Time Walk Correction

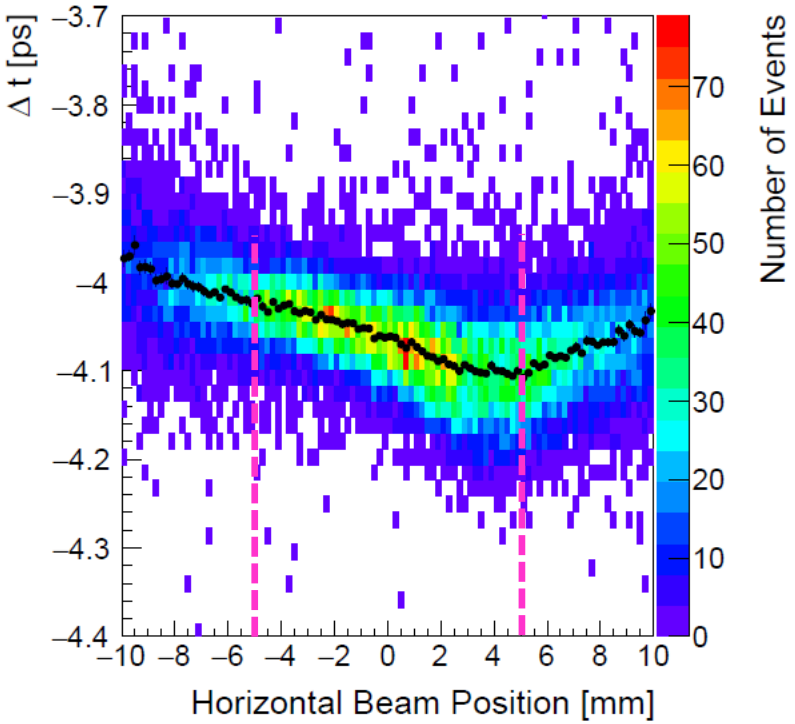
- **Only partial containment with a 1x1 cm² sensor.**
- **Large spread in contained energy also results in sizeable effect of the time walk correction for fixed energy.**

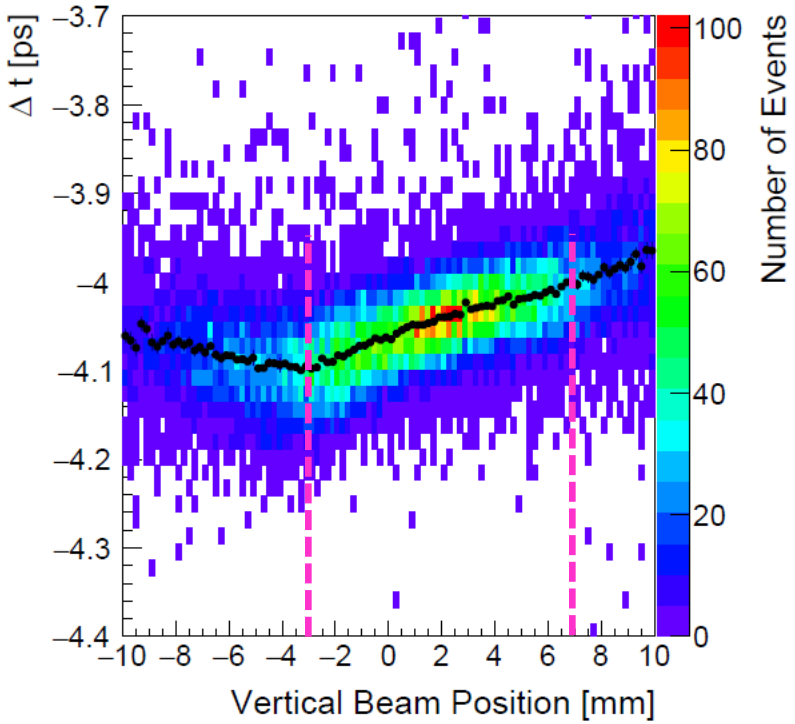




Timing Response Uniformity

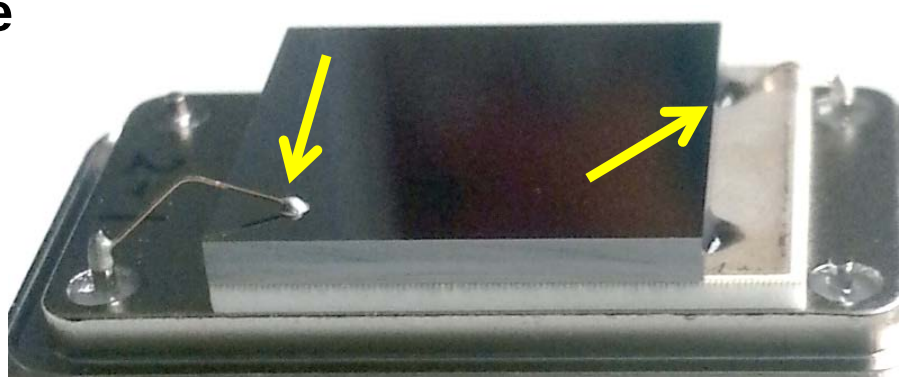
- **Timing response of the sensors shows a strong dependence on impact point.**
- **Note : Sensor exposed to a shower after 6 X_0 tungsten.**

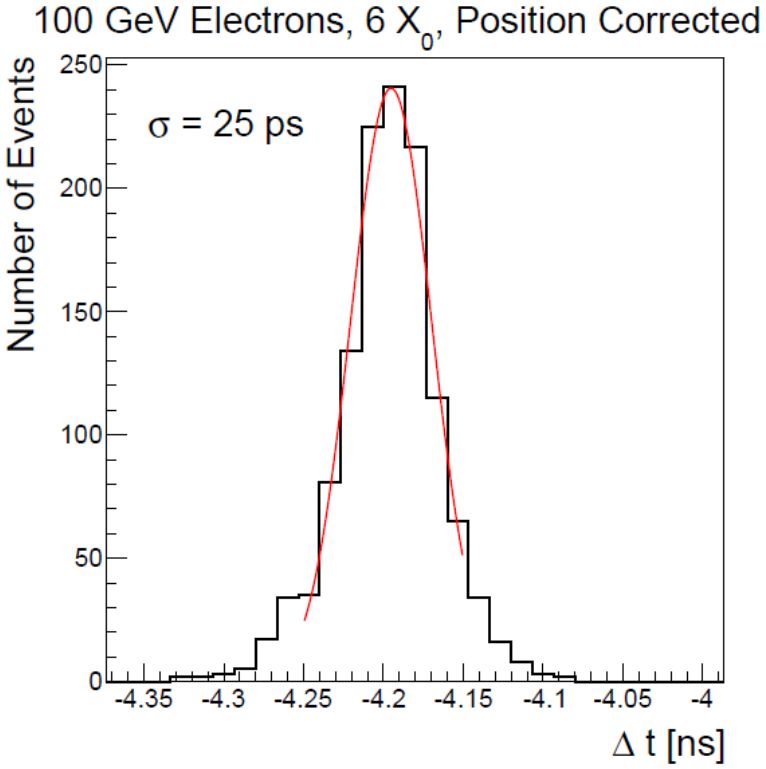


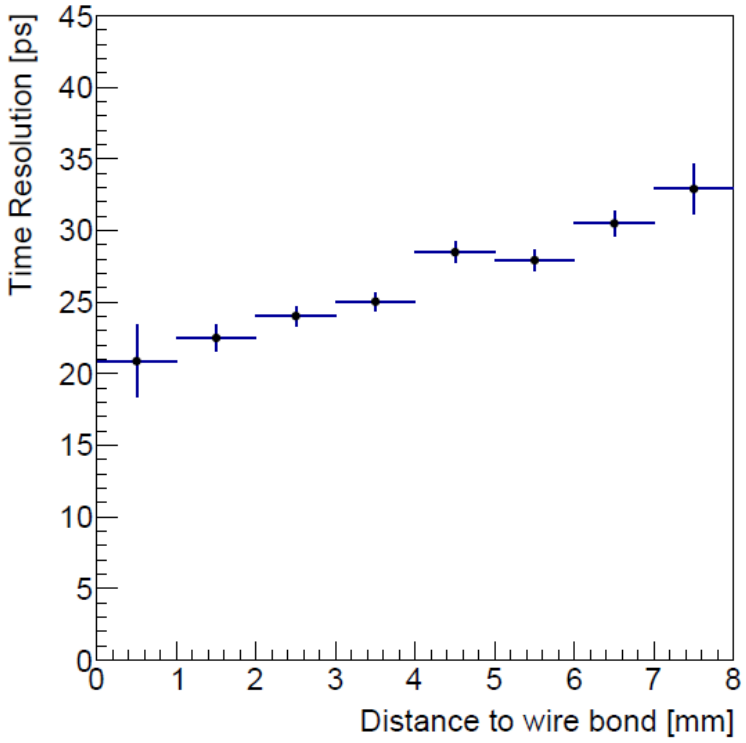


Corrected Timing

- **Timing resolution depends on the impact point relative to the diode contacts.**
- **Corrected resolution across sensor : 25 ps.**
- **Best resolution : 20 ps.**

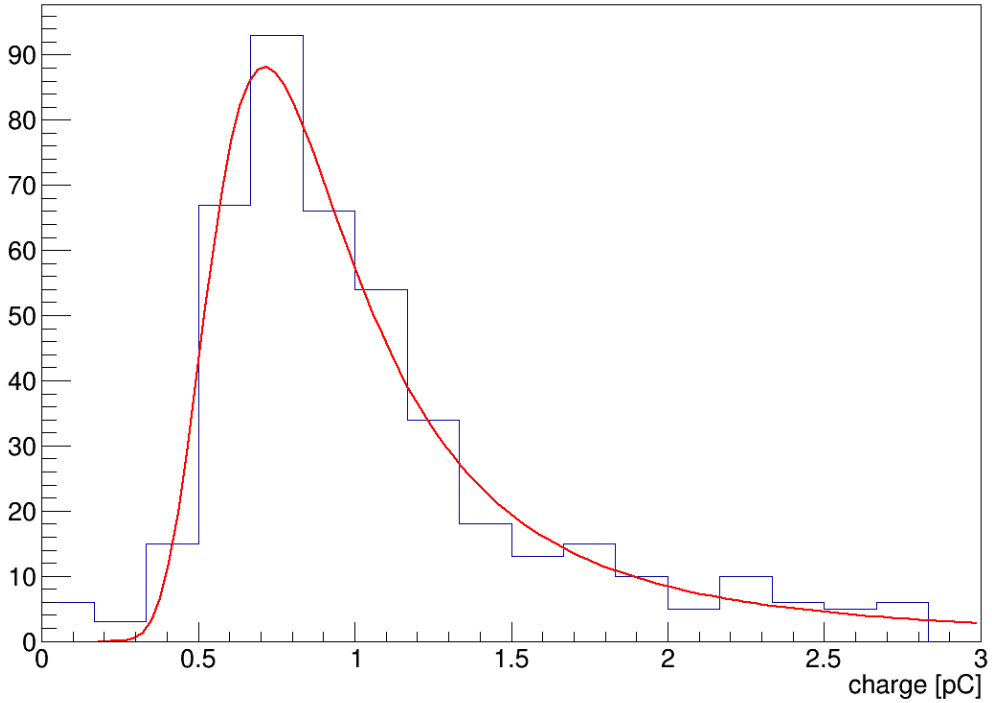






Single Mip Timing

- **Ongoing test beam at FNAL.**
- **New boards and housing to reduce noise will allow access to smaller signal, eventually single MIP timing.**



Summary

- **Shower timing measurements with a precision down to 20 ps achieved with CdTe sensor.**

- **Various properties of CdTe sensors make them very interesting for calorimetric applications.**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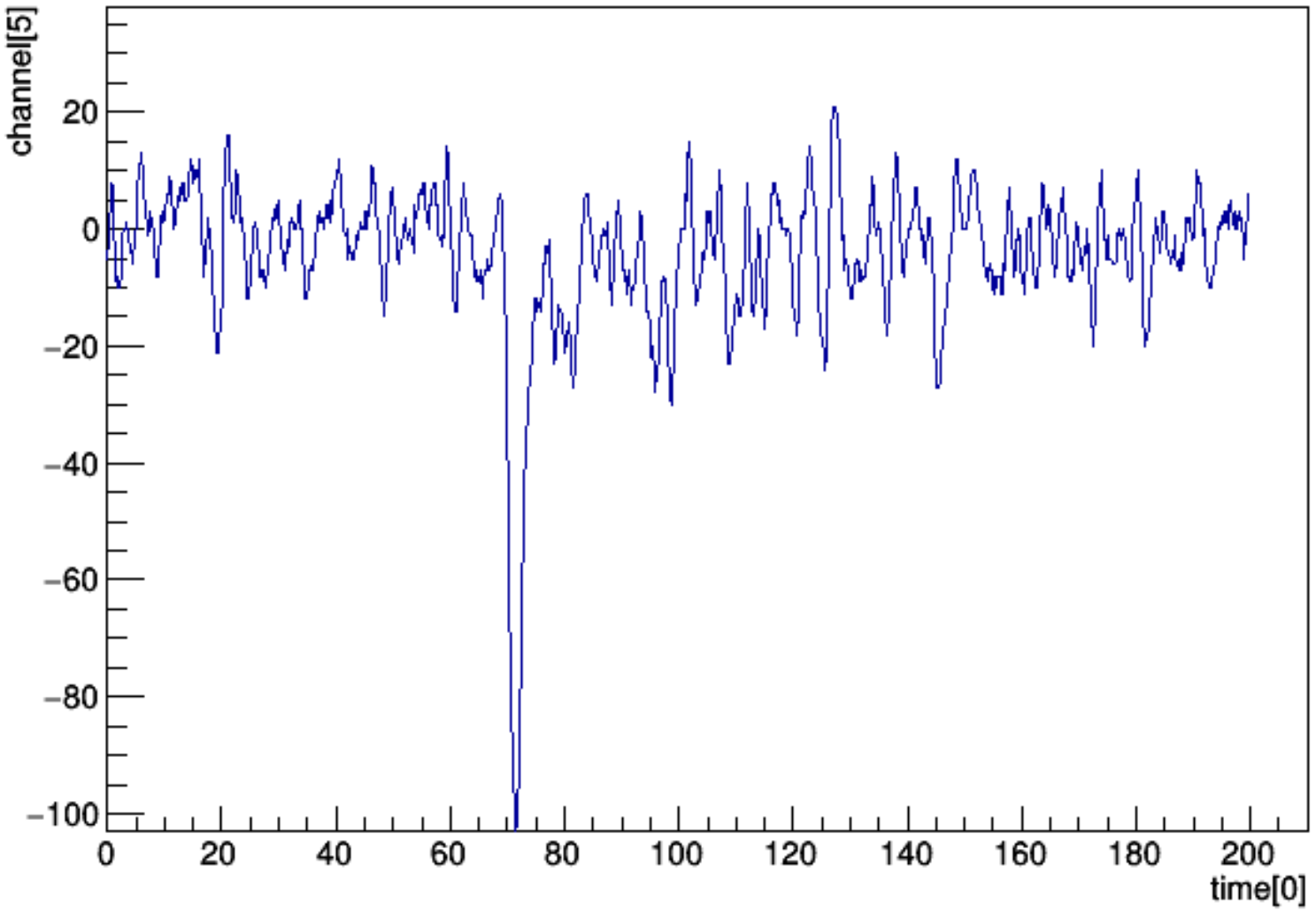
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