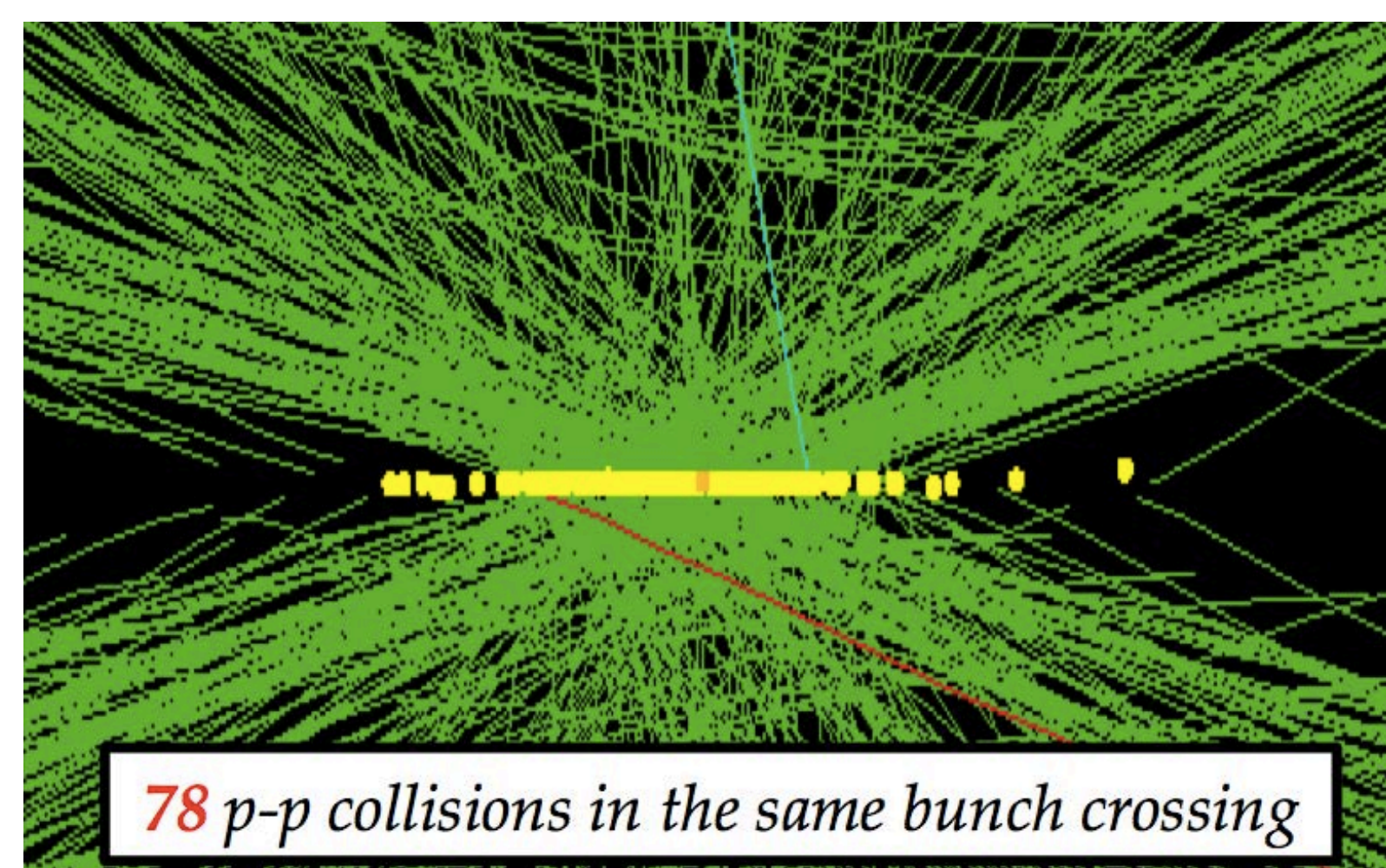




Motivation: Precision Timing at the LHC

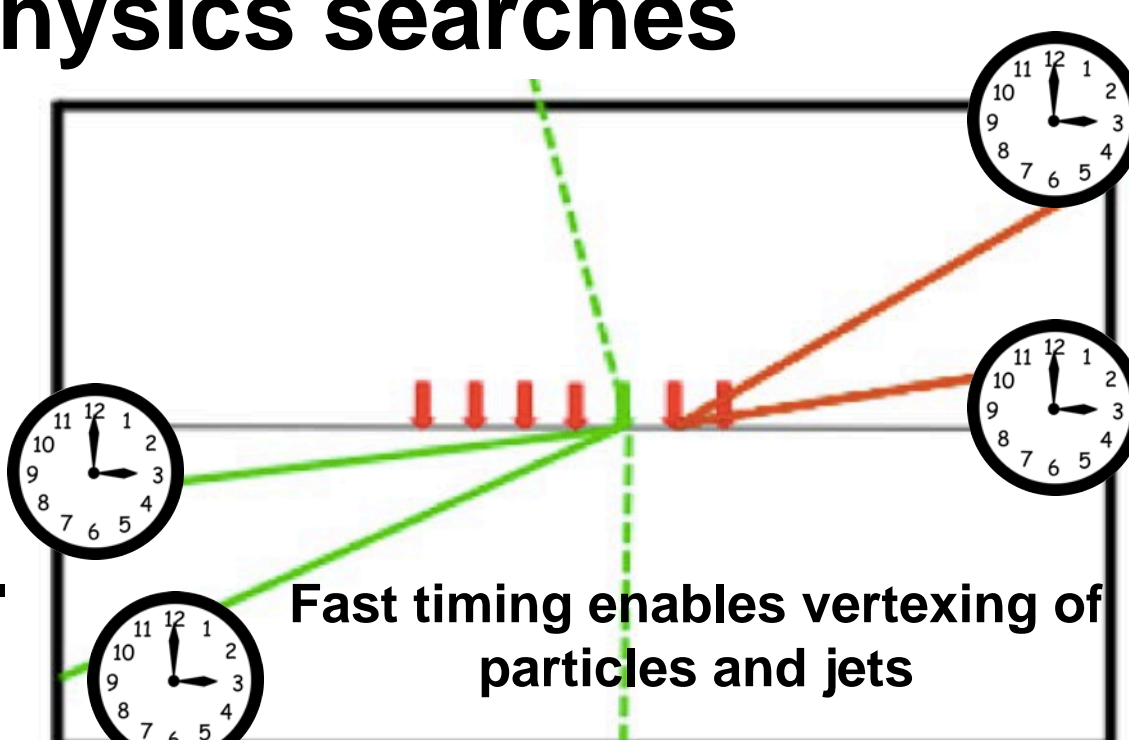
- The pileup environment at the High-Luminosity Large Hadron Collider (HL-LHC) will present a significant challenge for physicists:
- Up to 140 proton-proton collisions per bunch crossing
- Standard particle identification algorithms may not work



- Fast detector timing can provide a way forward:
 - Jet vertexing for pileup mitigation
 - Photon vertexing for precision Higgs boson measurements
 - Accurate missing energy measurements for new physics searches

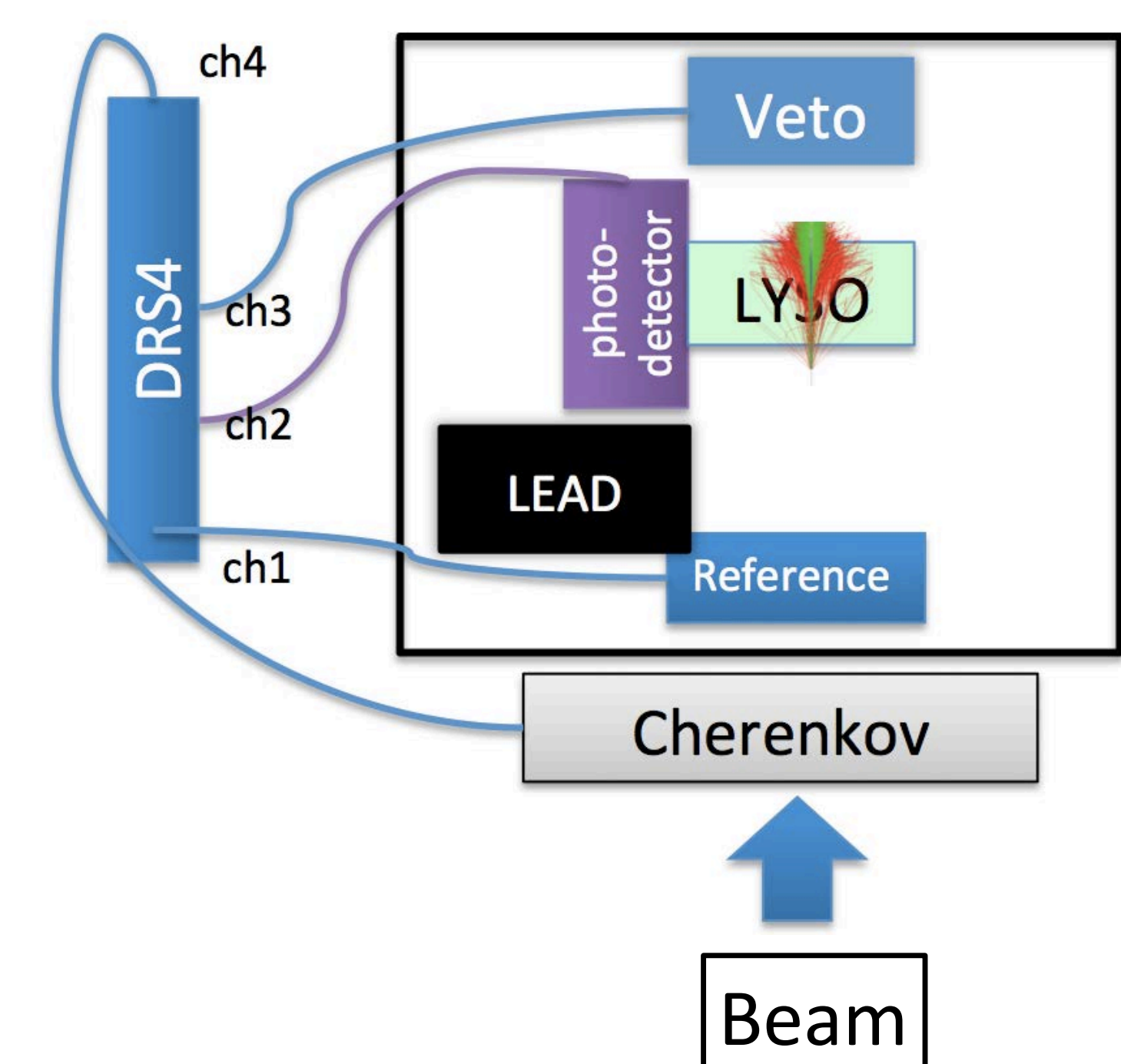
- Target time resolution: O(20-30) ps

- We investigate crystal-based timing using LYSO crystals read out by MCP-PMTs (MCPs)



The Experimental Setup

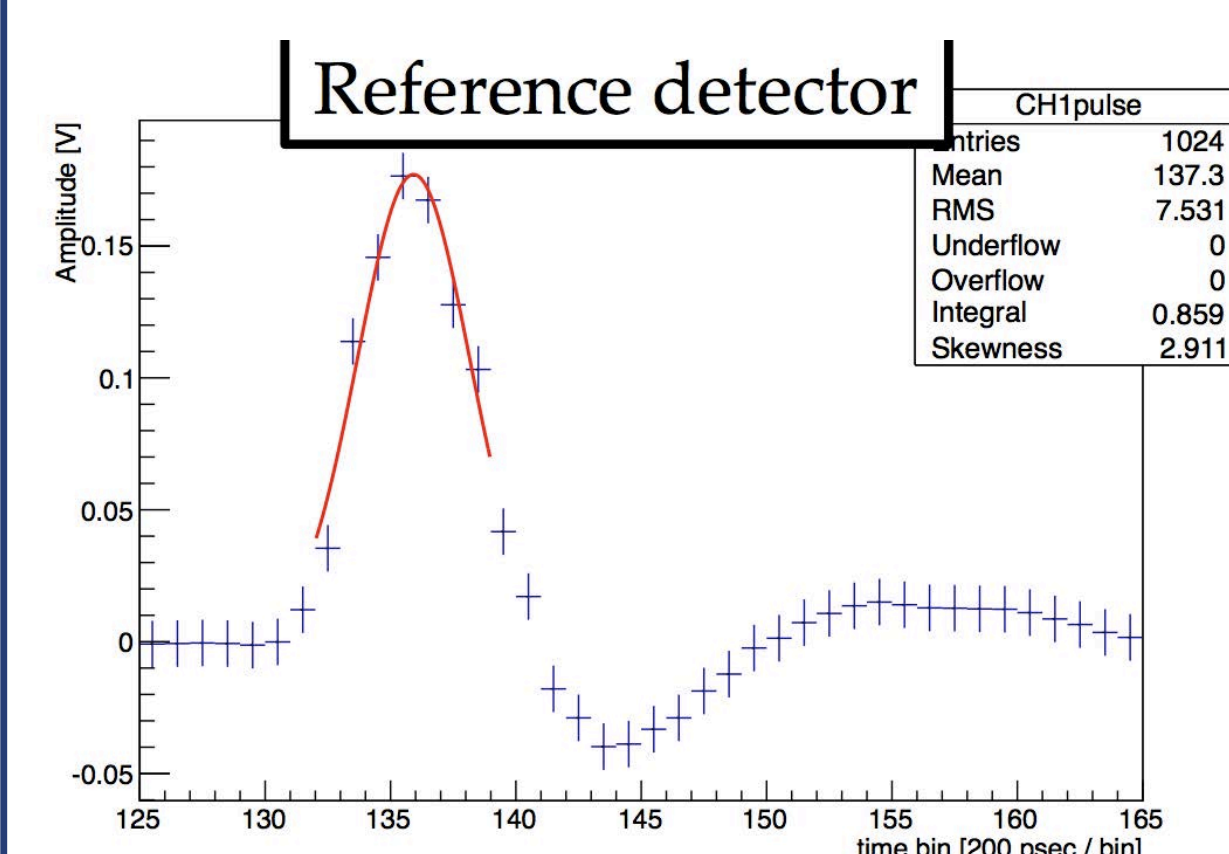
- Measurements made at Caltech and at Fermilab test beam facility
- MCPs: Photek 240, Hamamatsu R3809U
- Readout: DRS4 digitizer units (~5ps time resolution)
- Crystals: LYSO (1.7cm cube, 2.5x2.5x20cm³ crystal)
- Electron beams: 4, 8, 16, 32 GeV
- Cherenkov counter used to tag electron events
- Lead bricks placed in front of MCPs to prevent direct hits



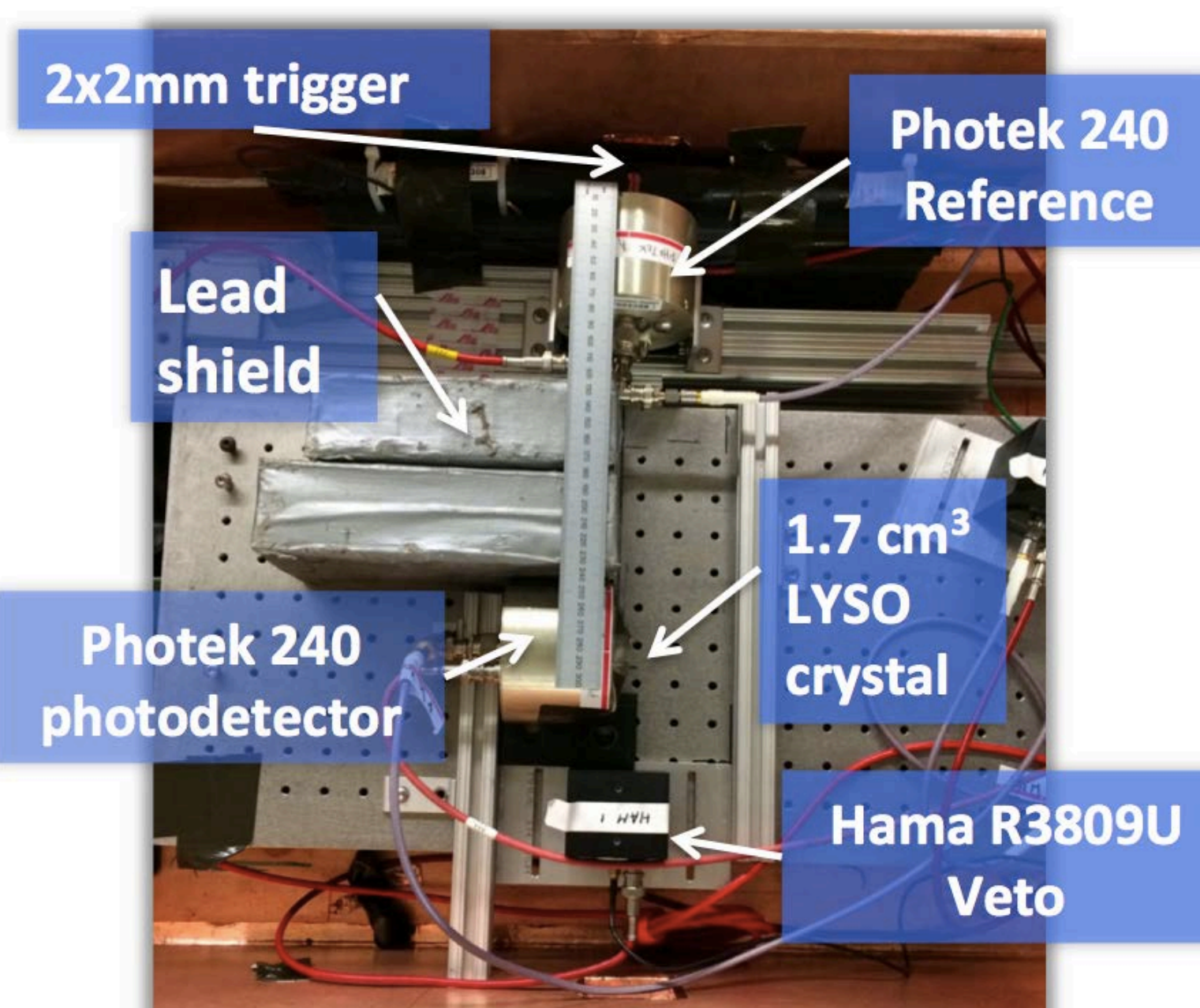
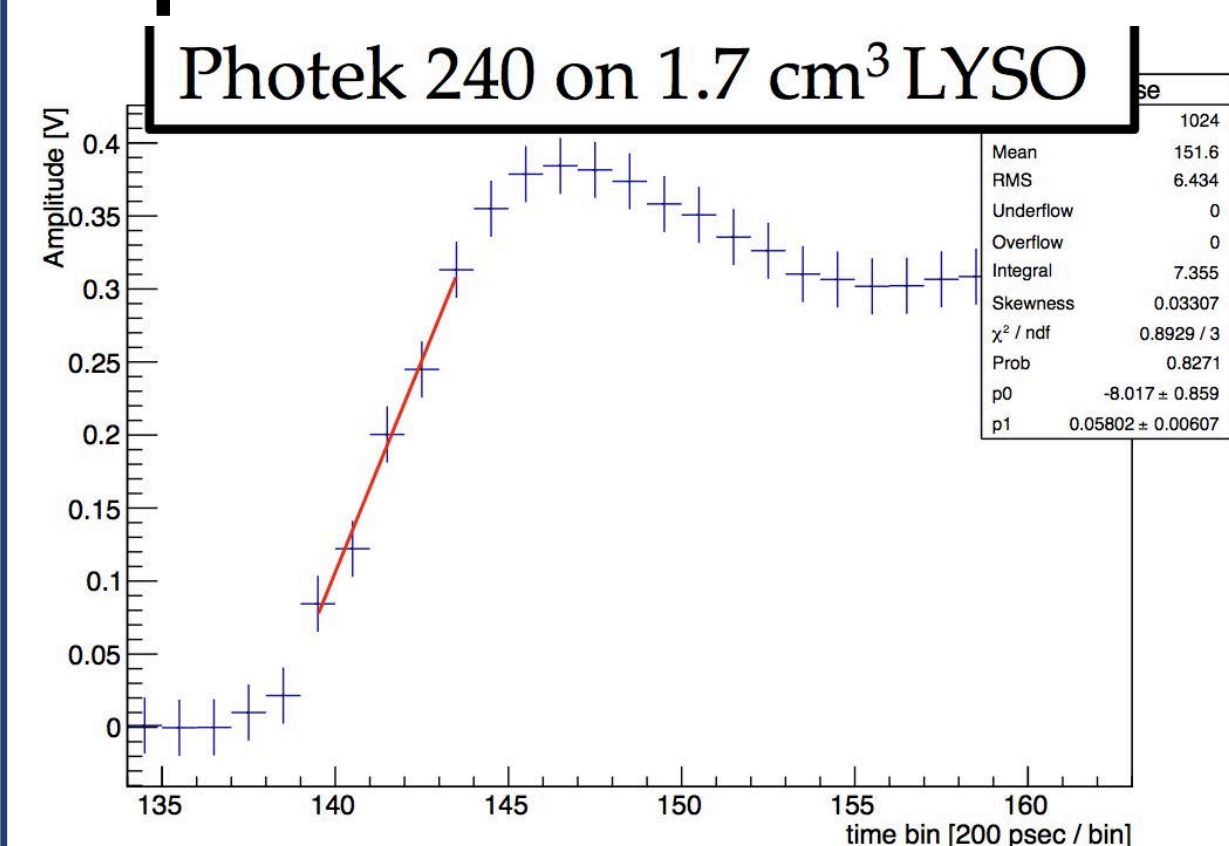
- Intrinsic time resolution (with no crystal attached) between two Photek/Hamamatsu MCPs: ~20ps

Time Measurement

- Gaussian fit to extract time stamp from reference MCP:

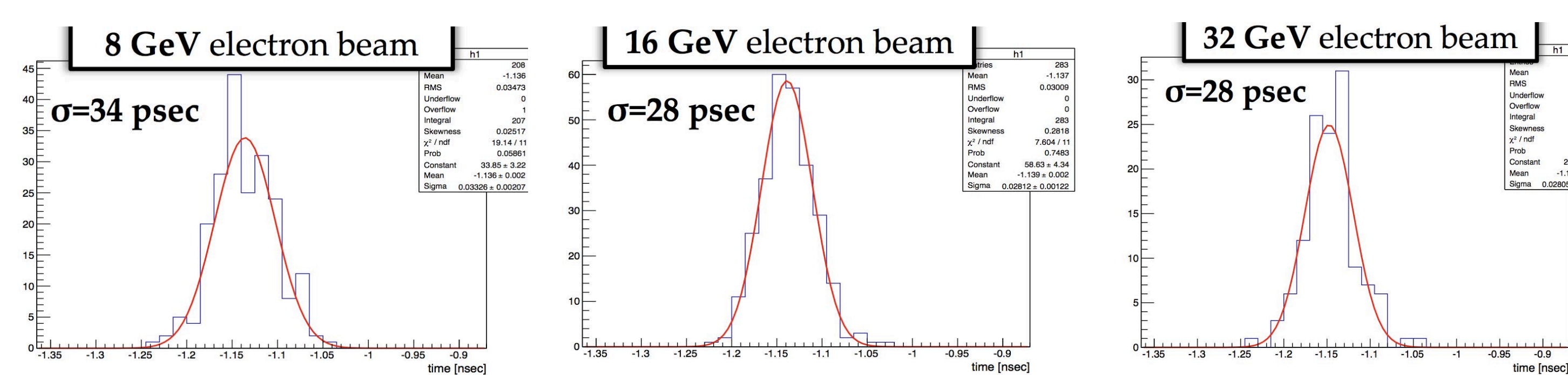


- Constant-fraction fit to extract time from rising edge of scintillation pulse:



Results

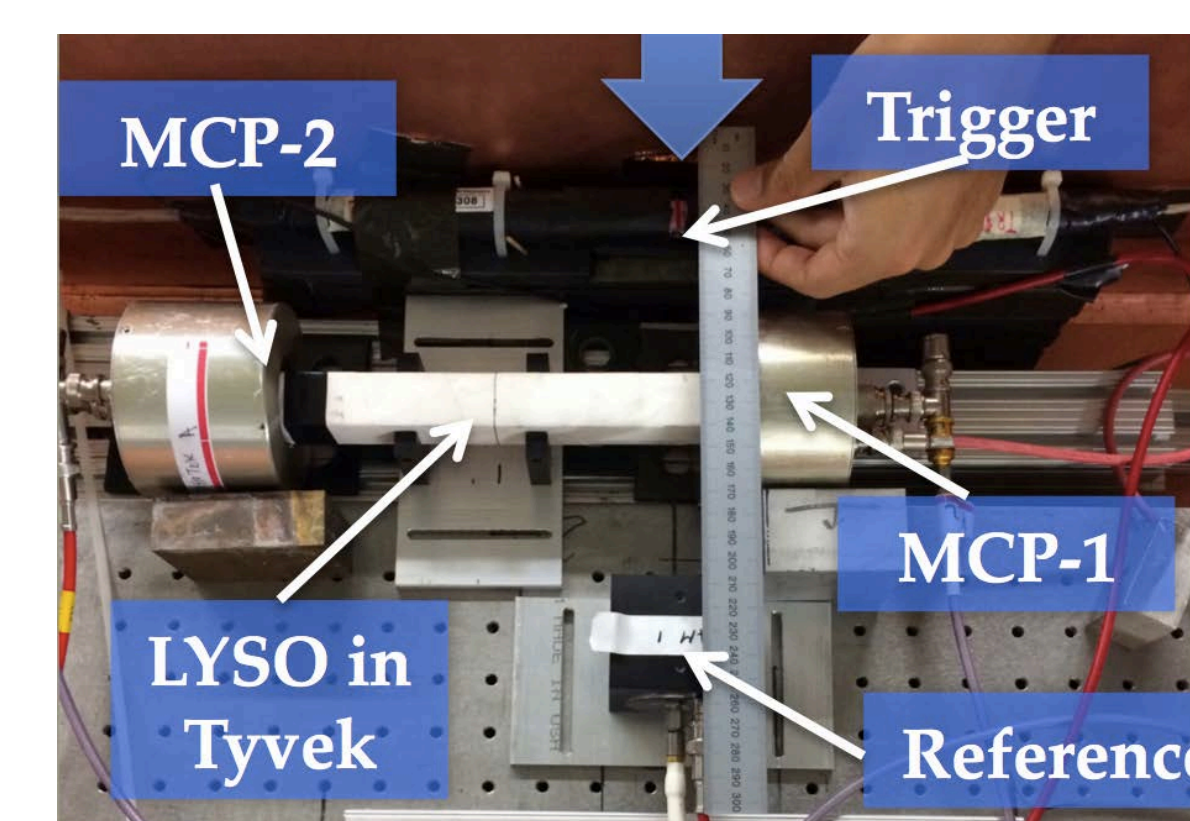
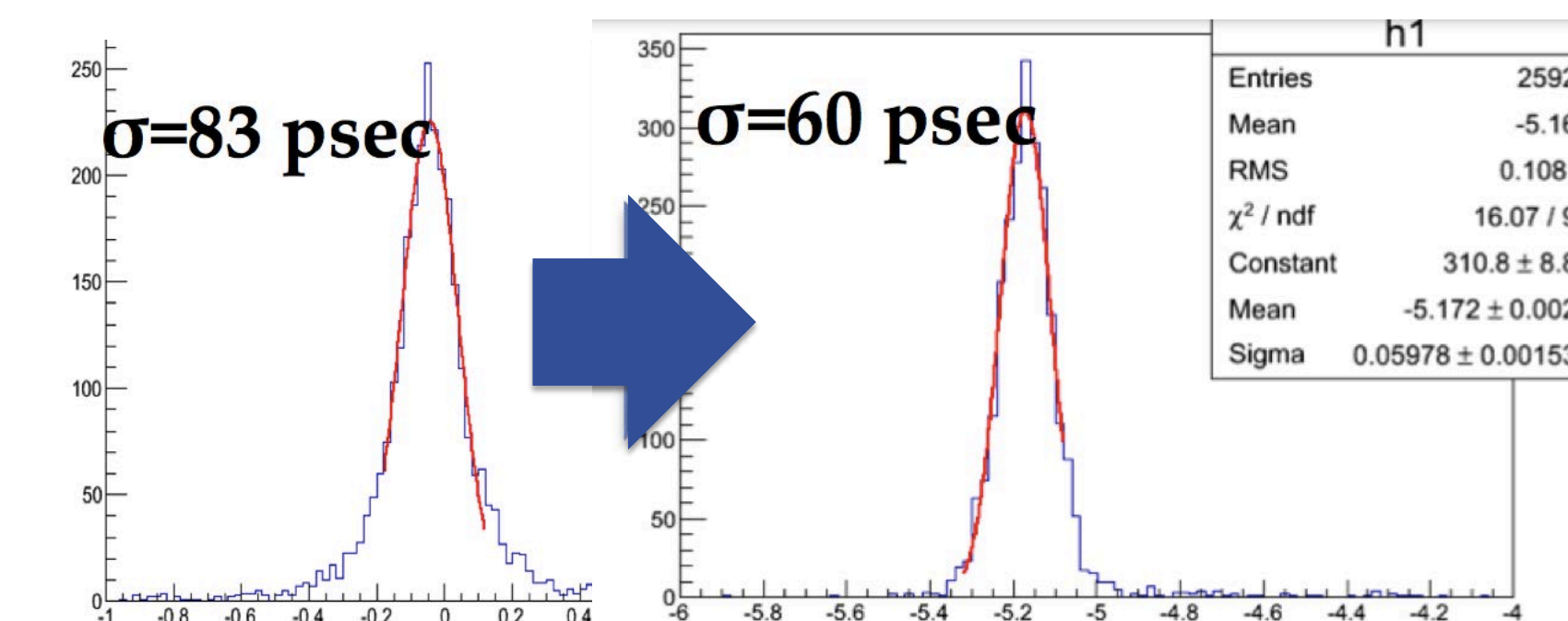
1.7cm LYSO cube:



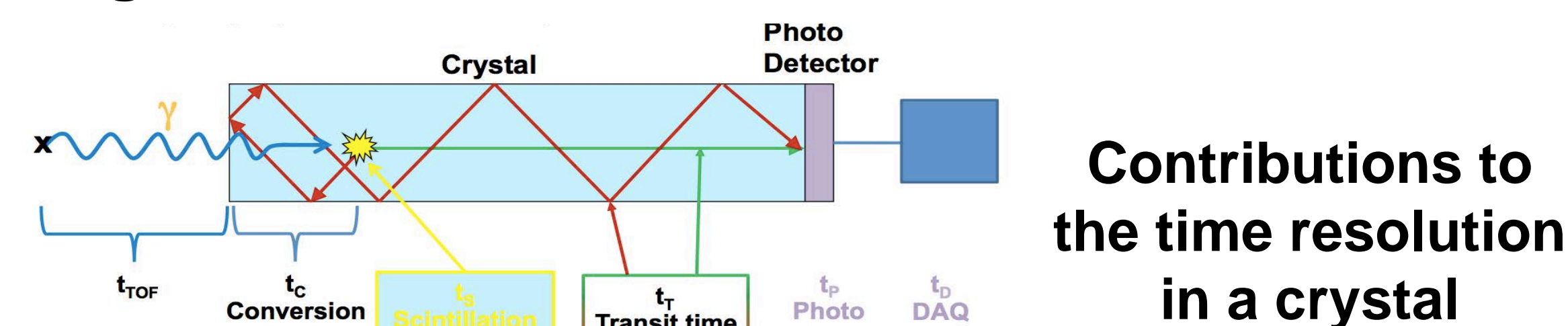
- Pulses are dominated by scintillation light
- Obtain ~30ps resolution for a variety of electron beam energies

20 cm LYSO crystal:

- Crystal ⊥ to beam, with readout MCPs on both ends
- Measurement at both ends of the crystal reduces the uncertainty due to position of electron hits

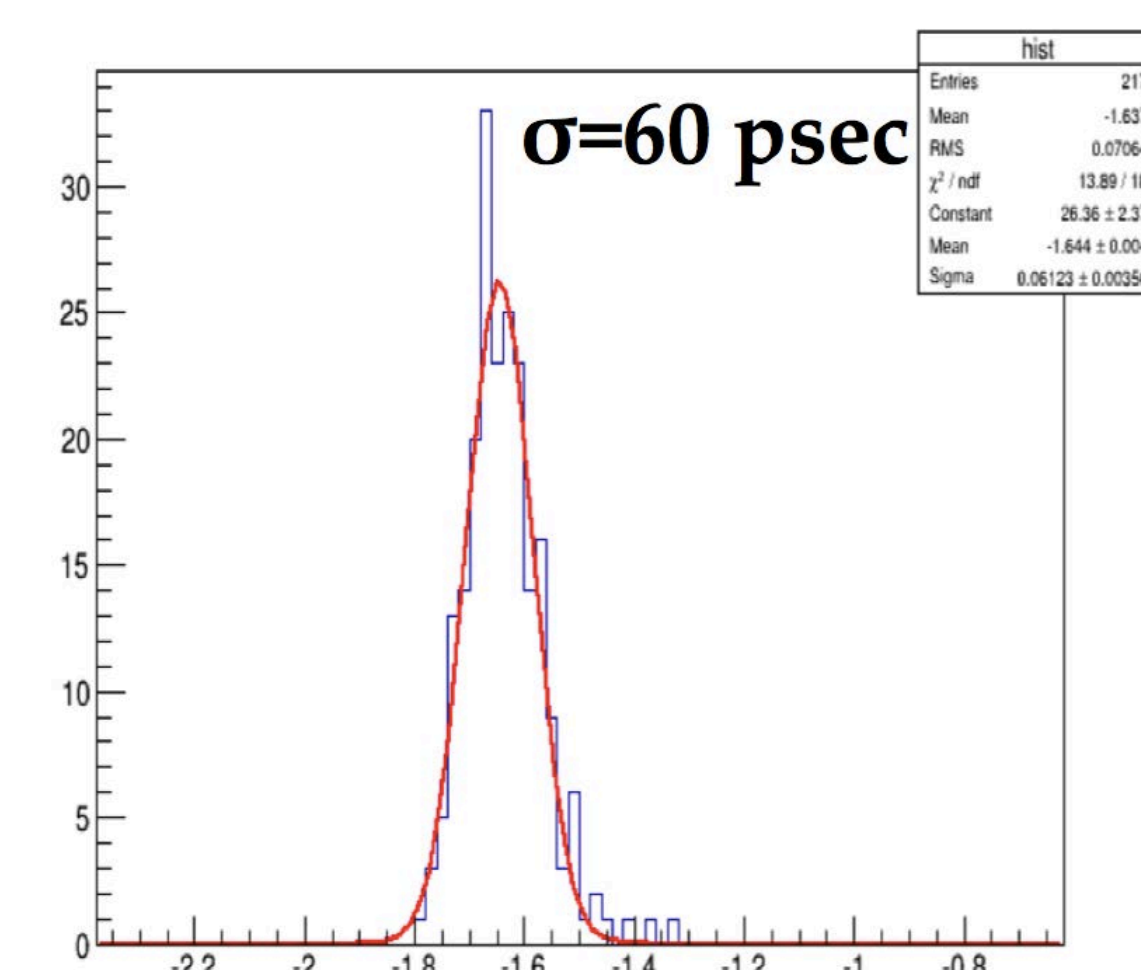
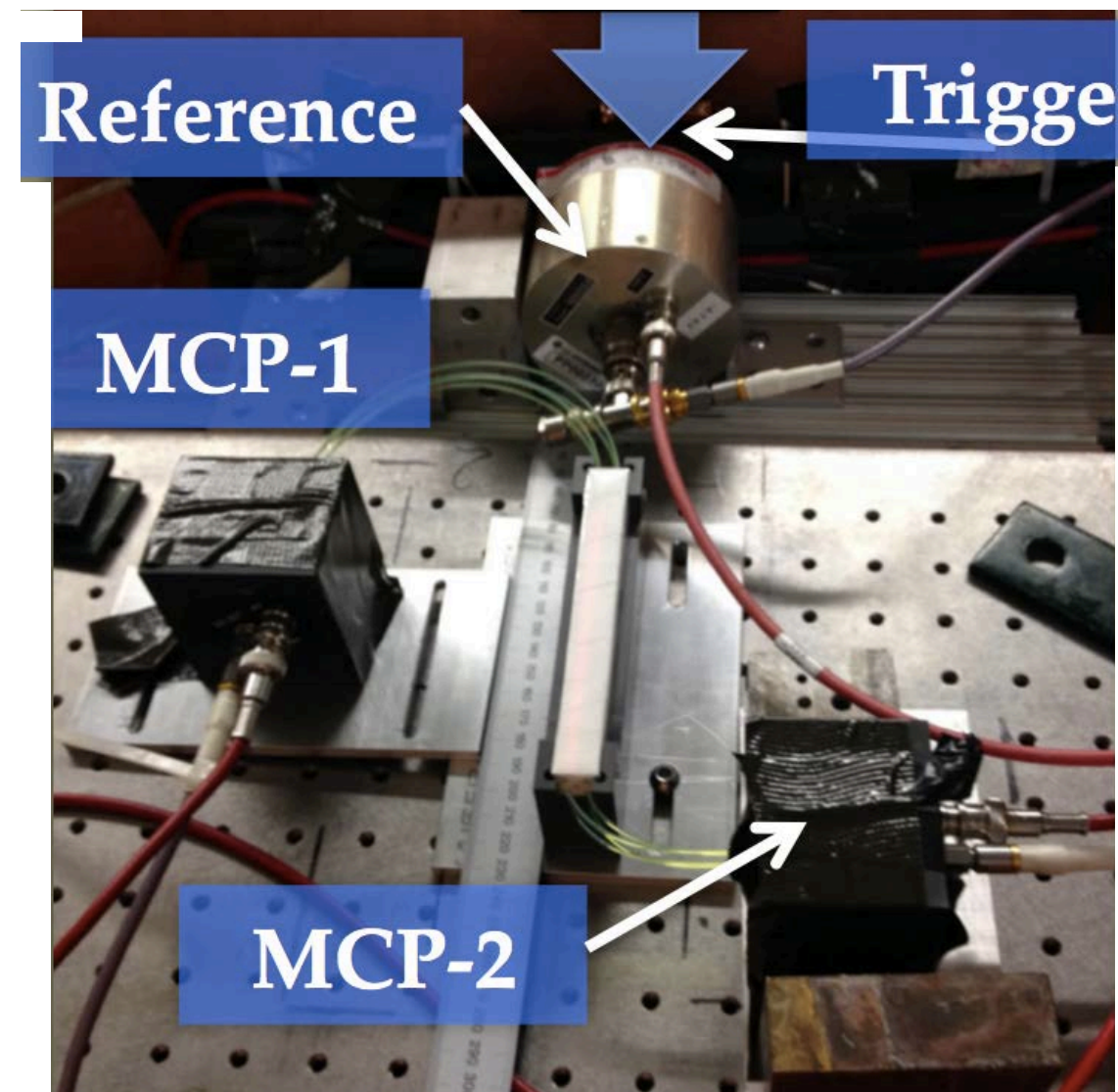
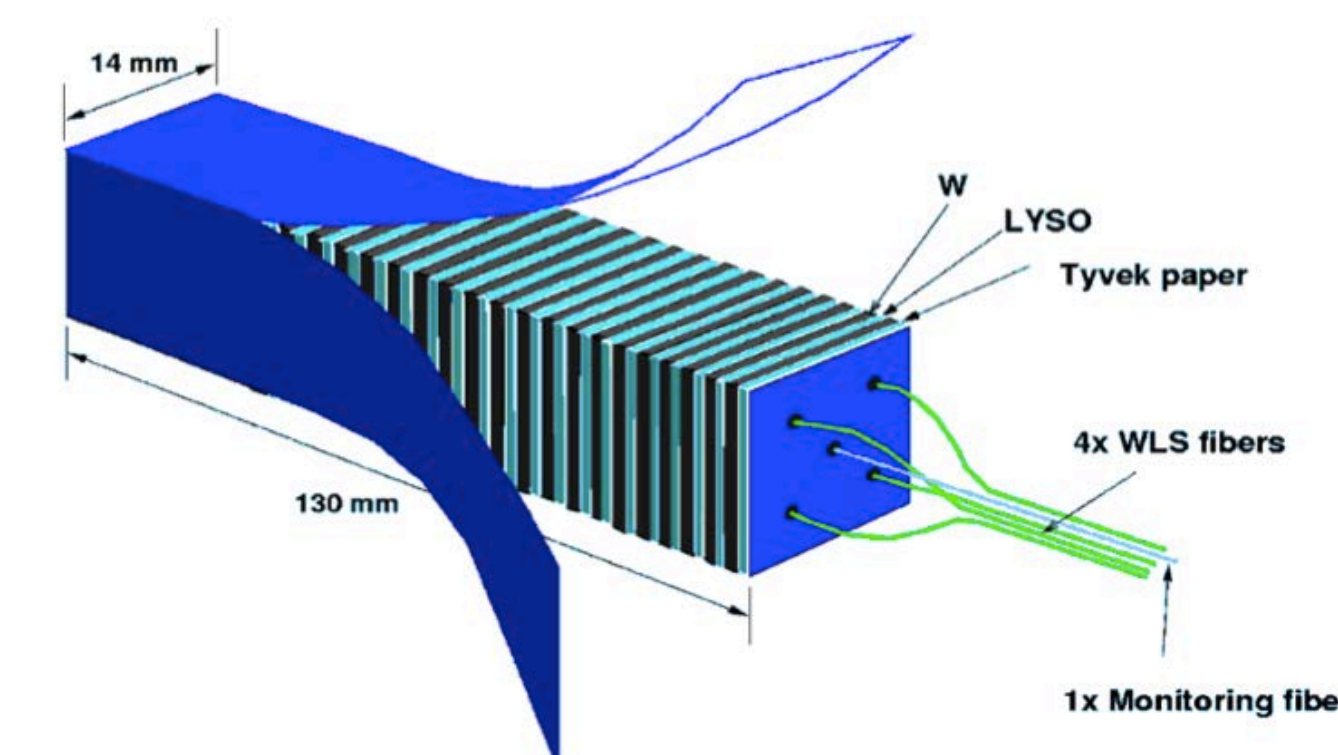


- We obtain ~60ps resolution between reference MCP and scintillation light times



Timing with Shashlik Calorimeter Cell

- Prototype calorimeter cell made of alternating LYSO and tungsten plates
- Read out the ends using WLS fibers, for energy measurement
- Read out a single tile using MCPs on the sides, for time measurement



- We obtain ~60ps time resolution

Outlook

- For a 1.7cm LYSO cube, we obtain 30ps time resolution.
- First-pass measurement using Shashlik cell with single tile readout yields 60ps time resolution – further optimization will be possible.
- Measurements were made using GeV electrons – will follow up with photon measurements as opportunities permit.
- Will move from MCP-PMTs to other readout options for application to HL-LHC: future possibilities include embedded APDs, large area photodetectors, ...

