Studies Towards a Precision Timing Calorimeter for High Energy

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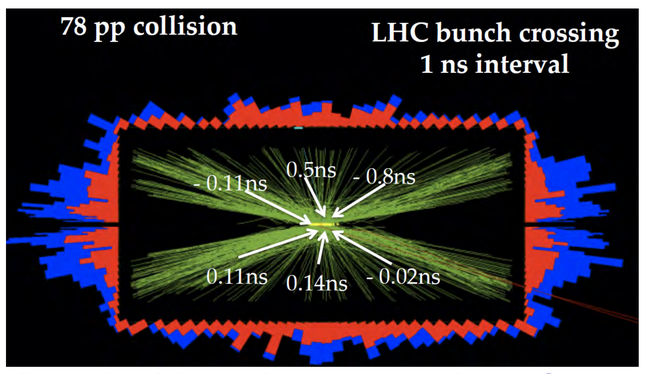
Introduction

- The High-Luminosity Large Hadron Collider (HL-LHC) will collect approximately 3 $\mathbf{ab^{-1}}$ of data at a higher average primary interaction per bunch crossing (pileup)
- The HL-LHC program will perform precise measurements of Higgs properties :
  - Higgs coupling, tensor structure, rare decays
- The HL-LHC program will further explore signal for new physics :
  - Supersymmetry, dark matter direct production
  - Many analyses require jets and MET
- The higher luminosity environment will pose the following challenges

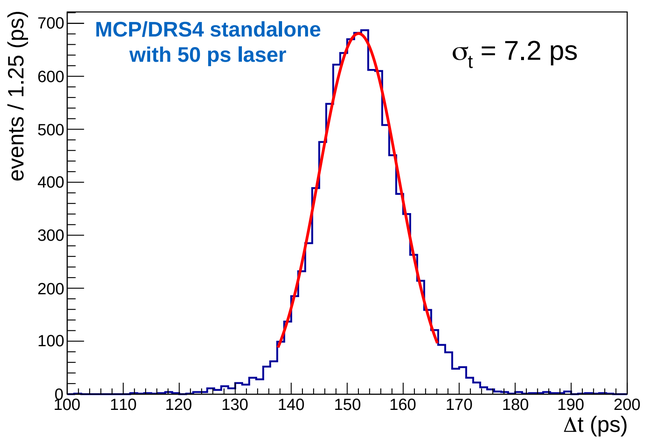
- Pileup interactions will increase up to 140
- Degradation of physic objects performance due to PU energy
- Key physics measurements will be affected by this harsh environment



- **Mitigation: calorimeter equipped with a time resolution of the $\mathcal{O}$(20-30 ps) time resolution**

Precision Timing Experimental Context

- Test photodetector time resolution by impinging ∼50 ps light pulse
- Number of photons is very large
- DRS4 readout (electronic noise ∼5 ps)
- MCP-PMT has a vert fast time response (rise time ∼100 ps) and low transit time spread (∼ 100 ps)
- MCP-PMT differential time resolution ∼ **7 ps**



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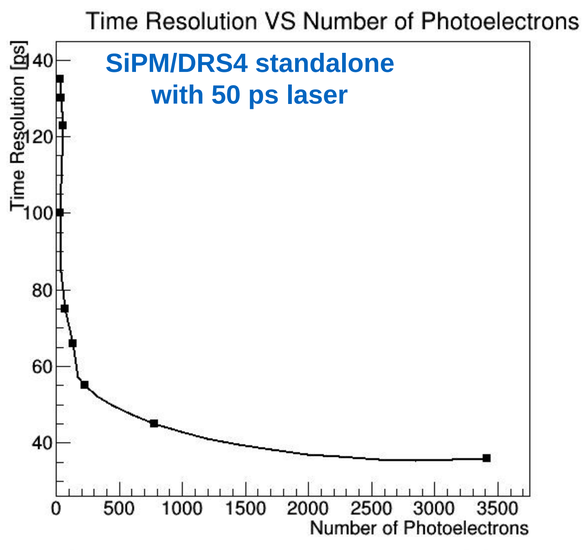
A.Bornheim, 13 PisaMeeting, to appear in NIM Proceedings

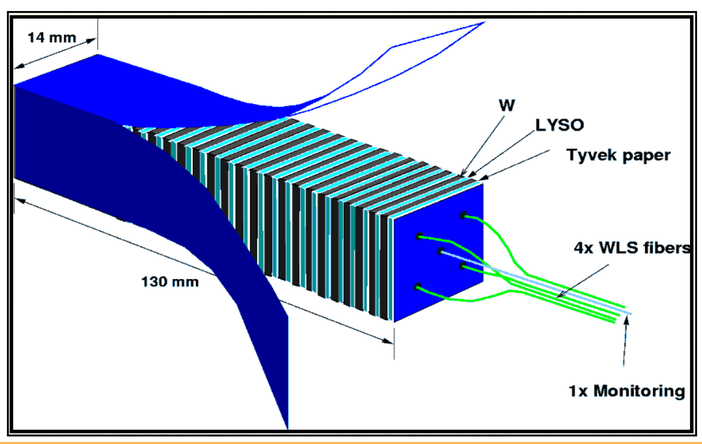
- Test photodetector time resolution by impinging ∼50 ps light pulse
- Hamamatsu SiPMs have a fast time response (rise time ∼1 ns) and good SPTM (∼ 300 ps)
- Measaure time resolution as function of photoelectrons
- SiPM time resolution saturates at ∼ **40 ps**



Timing Performance of new Hamamatsu Silicon Photomultipliers, NSS-MIC conference, Seattle 2014. A. Mangu et. al.

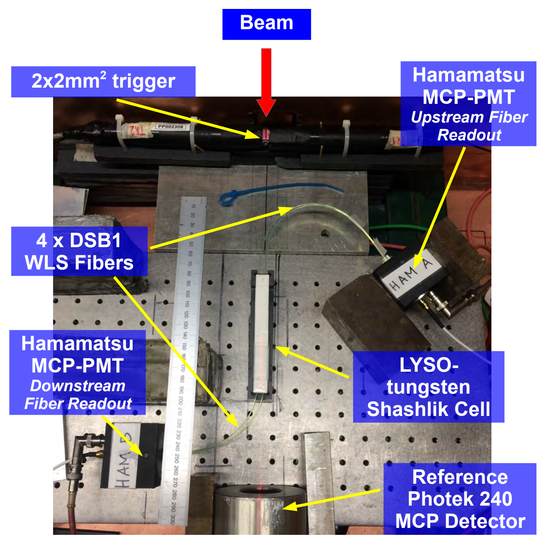
Shashlik Calorimeter Techonology

- Each shashlik cell: 26 layer of LYSO and tungsten (absorber)
- Light readout provided by 4 wavelength shifting fibers
- Radiation hard in HL-LHC conditions up to 3 $\mathbf{ab^{-1}}$
- Energy resolution of $\mathbf{10\%/\sqrt{E(GeV)} \oplus 1\%}$
- Single shashlik cell is tested with different photodetectors to obtain timing resolution

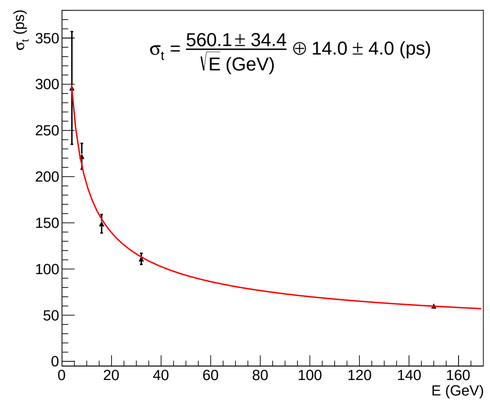


Beam test results: MCP-PMT readout

- 4-150 GeV electron beam (Fermilab + CERN)
- 4 DSB1 WLS fibers (2.4 ns decay time)
- Dual readout into Hamamatsu R3809 MCP-PMT (rise time ∼150 ps and TTS ∼ **25ps**)
- Photek 240 MCP-PMT as reference time detector (rise time ∼115 ps and TTS ∼ **170ps**)
- DRS4 based readout (5 GSPS, 700 MHz analog bandwidth)



- Time resolution follows $1/\sqrt{E}$ dependence
- Time resolution for 150 GeV electrons is ∼ **70ps**
- Ultimate time resolution possible limited by MCP-PMT response



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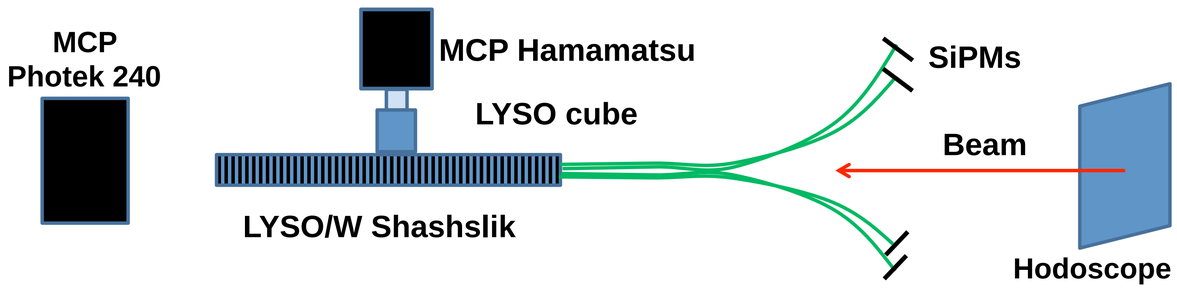
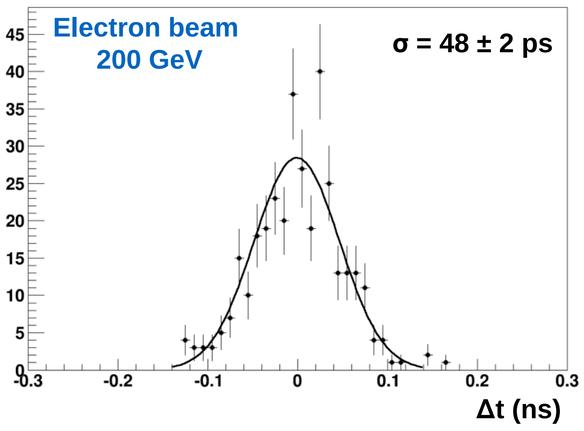
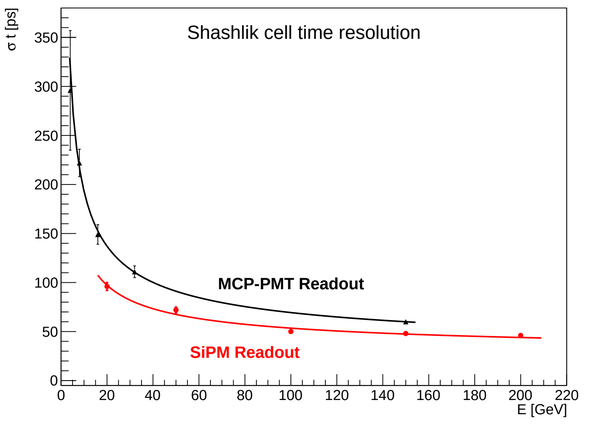
New beam test results: SiPM readout

- 20-200 GeV electron beam (CERN)
- 4 DSB1 WLS fibers. Capillaries were also used (results will appear soon). See presentation by Barry Baumbaugh at this conference.
- Each fiber is read out independently using 4 Hamamatsu SiPMs (1x1, 3x3 mm, 10,000 pixels)
- DSB WLS fibers coupled through optical connector and clear fibers to SiPM
- Photek 240 MCP-PMT as reference time detector



- Time resolution obtained by combining the 4 fibers readout
- Preliminary results show an improvement in time resolution wrt. the results using MCP-PMTs
- Time resolution follows $1/\sqrt{E}$ dependence
- Time resolution for 200 GeV electrons is about **50 ps**





Conclusions

- Obtain better than **50 ps** time resolution using a single LYSO/tungsten shashlik cell for 200 GeV electrons
- Preliminary SiPM readout results improves previous time resolution measurements using MCP-PMTs
- Limiting factors in MCP readout still under investigation

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