Timing Performance of new Hamamatsu Silicon Photomultipliers

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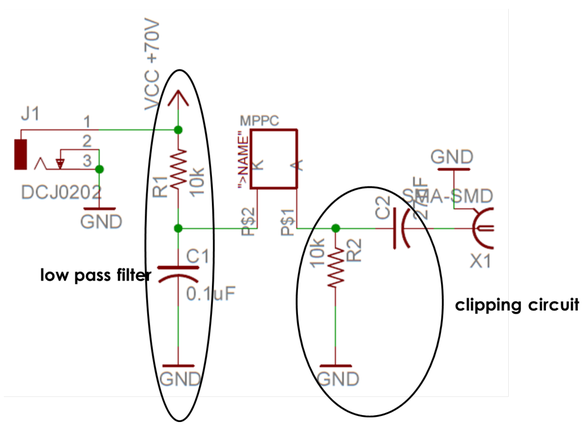
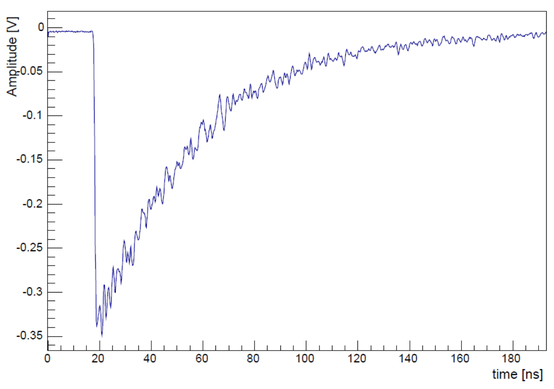
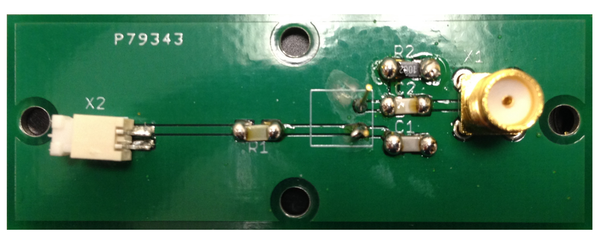
Introduction

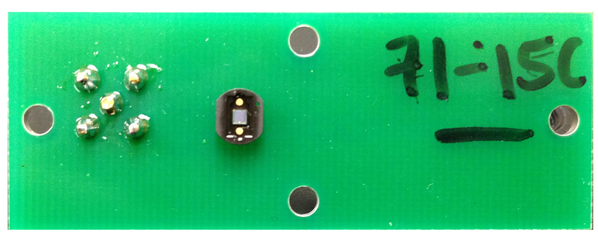
- photodetectors capable of high-resolution timing measurements have the potential to significantly improve the detection capabilities in high-energy physics experiments and positron emission tomography (PET)
- Silicon Photomultipliers offer several advantages:
  - low transit time spread (TTS)
  - high photodetection efficiency and gain
  - **low cost and insensitivity to magnetic field**
  - high radiation tolerance
- a calorimeter at the LHC with time resolution ~O(30ps) will help mitigate pile-up events
- **GOAL: study the timing properties of Silicon Photomultipliers with the aim to achieve ~O(100ps) time resolution**

SiPM Clipping Circuit







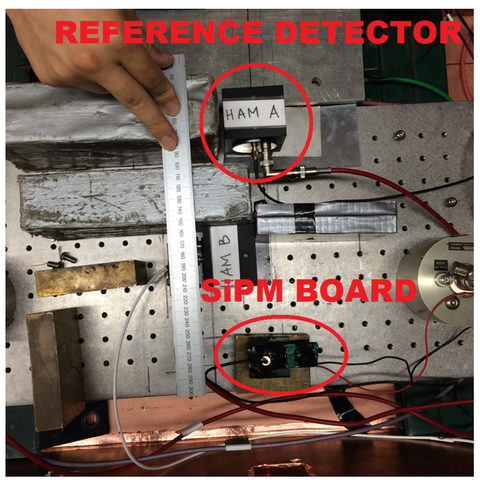


- primarily used the Hamamatsu 1x1mm^2 S12571-015C [1] SiPM with pixel size 15 microns
- top right shows a sample pulse digitized by the DRS4 board [2] from the reference Hamamatsu R3809 MCP-PMT [3] optically coupled to a (1.7cm)^3 LYSO crystal recorded during an 8 GeV electron run
- achieve better signal to noise ratio by clipping output signal to adjust signal to noise ratio and shorten SiPM's pulses [4]

LYSO-based Sampling Calorimeter Studies

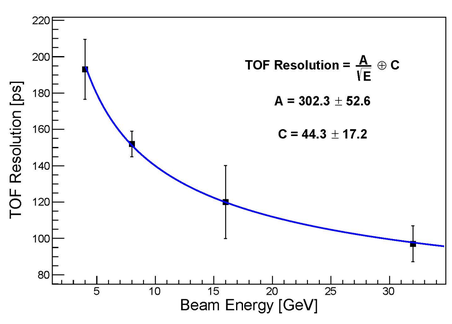
experimental setup:

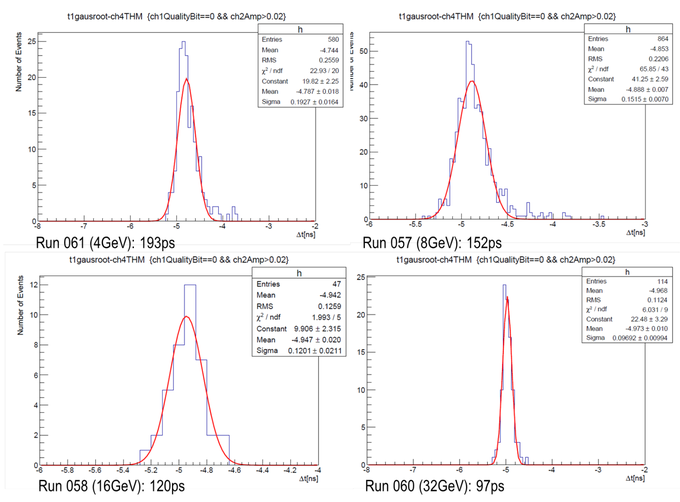
- performed at Fermilab Test Beam Facility (FTBF) which provides electron (4-32 GeV) and proton beams (120 GeV) from Fermilab Main Injector accelerator
- version 4 DRS4 waveform digitizer evaluation board connected to laptop via USB device used as primary DAQ system
- reference MCP-PMT photodetector used was Hamamatsu R3809-52 [3]
- studied effect of clipping capacitances (10pF, 50pF, 100pF, 27nF) on SiPM



measurements:

- better time resolution with increasing electron energy (as shown on right); TOF resolution has $\frac{1}{\sqrt{E}}$ dependence

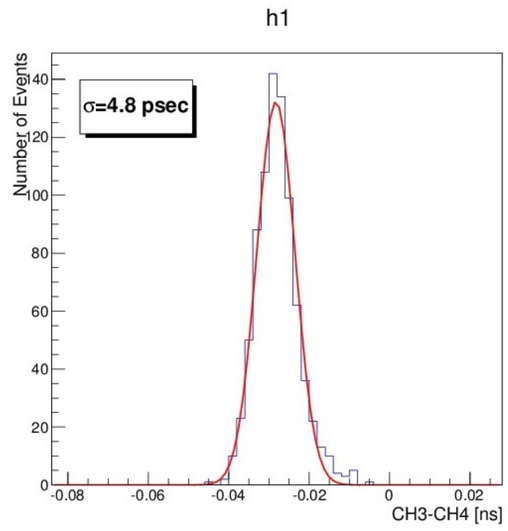




Single Photoelectron Time Resolution (SPTR) Studies

experimental setup:

- PiLas laser red light (635nm)
- version 4 DRS4 waveform digitizer evaluation board connected to laptop via USB devie used as primary DAQ system
- trigger provided by PiLas laser system

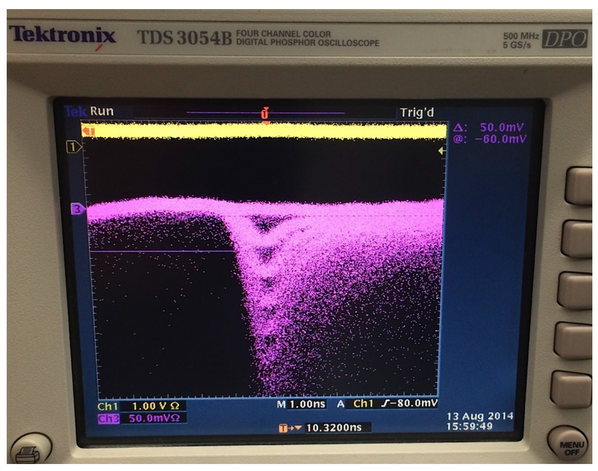


measurements:

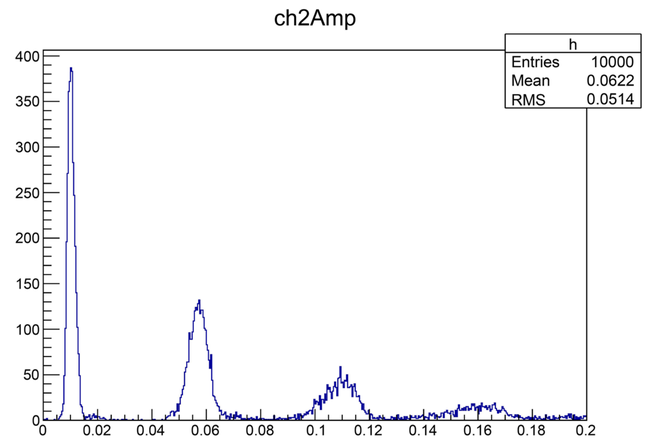
- signal from detector split into 2 equal parts and connected to adjacent channels on same DRS4 unit
- measured electronic time resolution of the DRS4 unit measured to be ~5ps (σ, Gaussian fit)

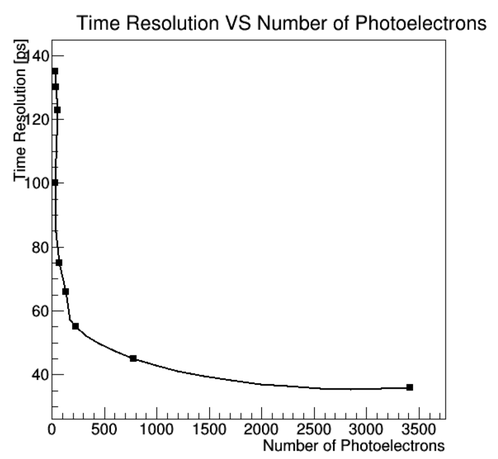
preliminary results:

- can see 1, 2, 3, 4, and 5 photoelectron peaks
- efficienty of single photon's registration <10% with chosen PiLas light intensity
- number of events with only 1 photoelectron used in timing distribution



- SPTR at level <200ps obtained generally for SiPM illuminated by a 40ps light pulse with 635nm wavelength, 1V overvoltage
- SPTR <140ps generally obtained for overvoltage >1V
- preliminary results give the exponential-seeming relationship between time resolution and number of photoelectrons





Conclusions

- SPTR from new Hamamatsu SiPMs looks promising with good time resolution
- future studies will focus on:
  - temperature dependence
  - varying dimension (3mmx3mm, 1mmx1mm) with varying pixel size (10um, 15um, 25um)
  - further investigation into role and optimization of clipping circuit and input filter
- plan to perform more test beam measurements with SiPMs coupled to LYSO crystal

References

[1] http://www.hamamatsu.com/resources/pdf/ssd/s12571-010_etc_kapd1044e03.pdf

[2] S. Ritt, R. Dinapoli, and U. Hartmann, "Application of the DRS chip for fast waveform digitizing," *NIM* **A** *623 (2010) 486-488*

[3] http://www.hamamatsu.com/resources/pdf/etd/R3809U-50_TPMH1067E09.pdf

[4] A. Ronzhin, M. Albrow, S. Los, *et al.*, "A SiPM-based TOF-PET detector with high speed digital DRS4 readout," *NIM* **A** *703 (2013) 109-113*

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