Testing a Silicon Photomultiplier (SiPM) Time-of-Flight (TOF) System in Fermilab's Test Beam Facility.

Goal is to develop affordable time of flight measurement for single particles to better than 10 psec

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Why SiPMs for TOF?

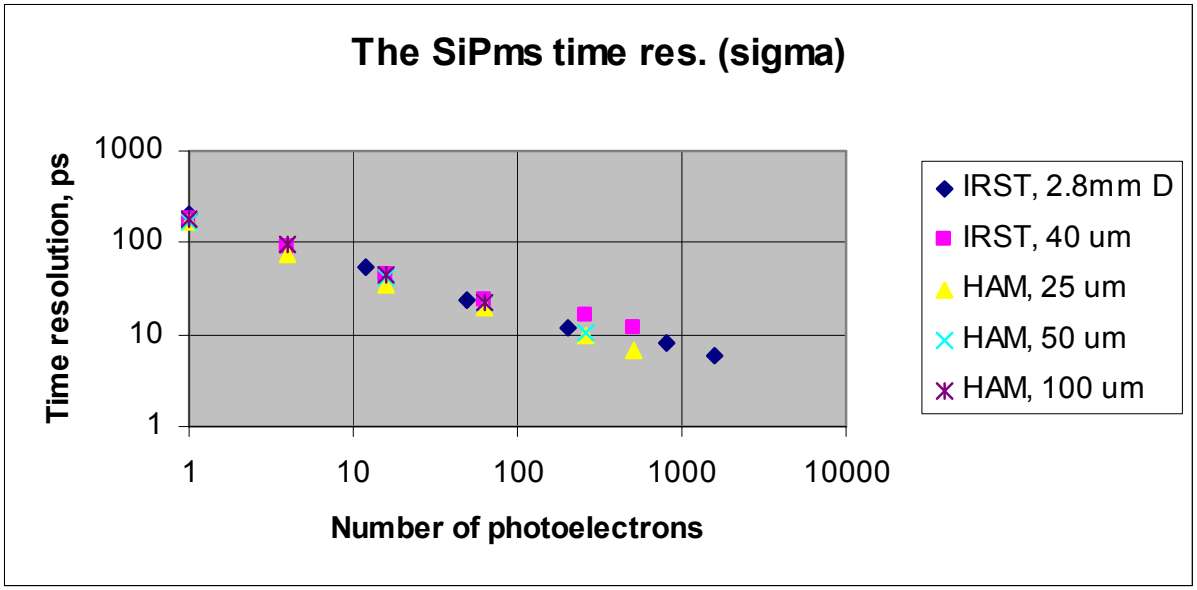
SiPms have:

- Good single photoelectron time (SPT) resolution. (~100 ps).
- High quantum efficiency (QE). (~60% for blue light).
- Self calibration because of excellent few photoelectron's separation in pulse height spectrum.
- Voltage supply is of the order of a few tens of Volts, so even a battery can be used as the SiPMs power supply.
- Non sensitivity to magnetic field.

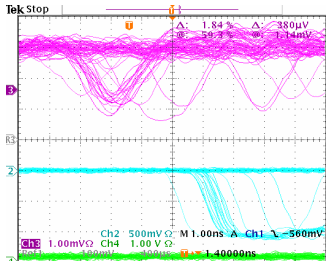
But:

- Small size of the sensitive area (currently up to 3x3 mm^2 for shallow junction, fast, blue sensitive SiPMs).
- Pulse width is a few nanosecond (3-7 ns) with pulse clamping.
- Higher than PMT temperature sensitivity.

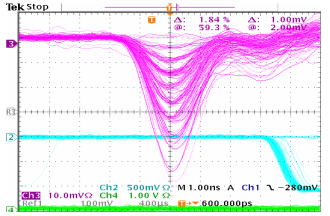
Dependence of the SiPMs time resolution on the number of photoelectrons, PiLas laser, the red head (635 nm). SiDet, Fermilab.



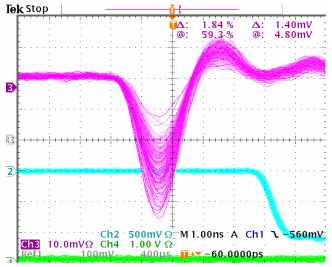
N phes	IRST 2.8 diam	IRST1mm2	HAM-025U-10	HAM-050U-9	HAM-100U-10
	50mk, 2500 pixs	40mk, 625 pixs	25mk, 1600 pixs	50mk, 400 pixs	100mk, 100 pixs
1	210	178	164.6	171.4	182.2
3					
4		89	72.3		93.3
12	53.7				
16		44.6	35.1	42.5	45.8
50	24.2				
64		23.6	19.5	22	22.7
200	12				
256		16.1	9.9	10.2	
512		11.9	6.8		
800	7.9				
1600	5.9				



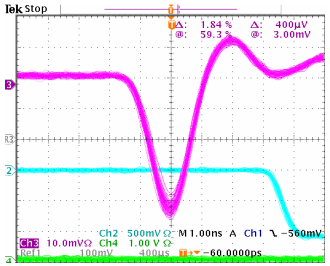
1 phe



4 phes



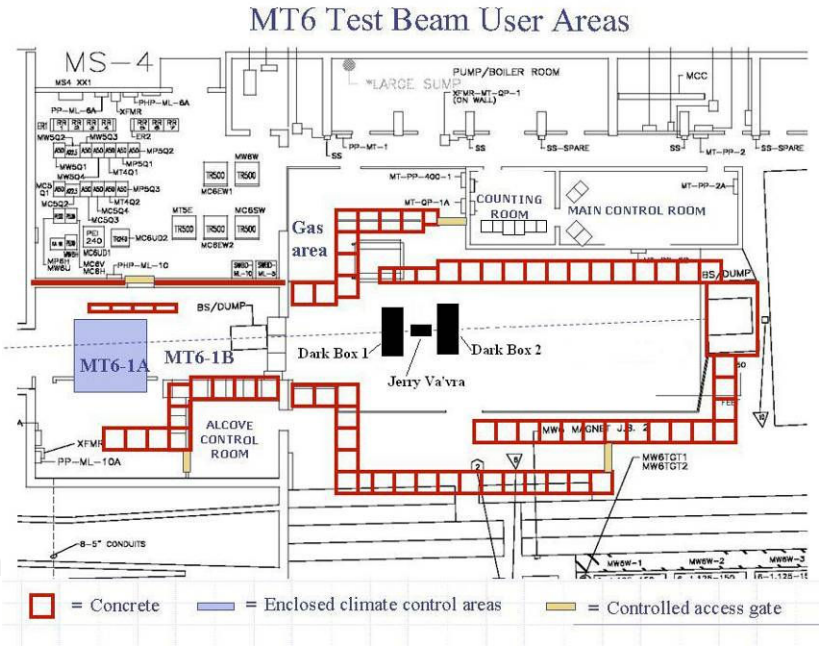
32 phes

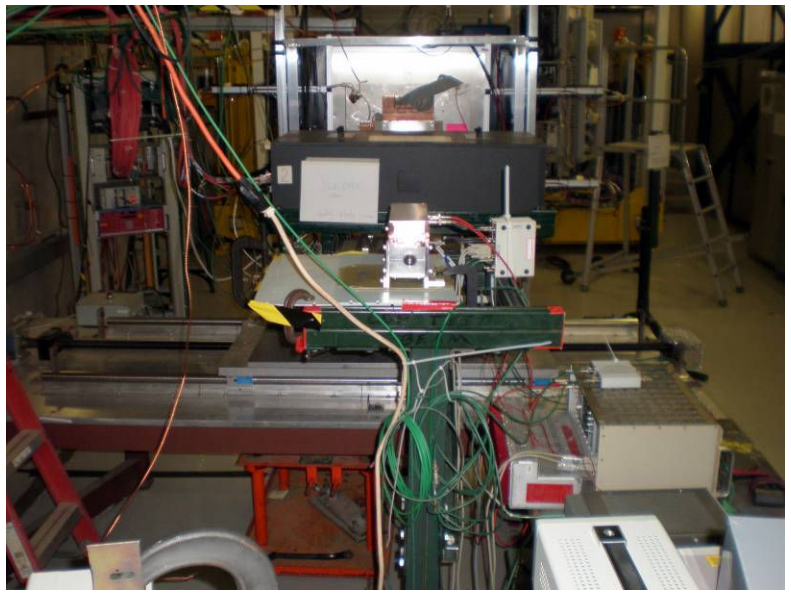


256 phes

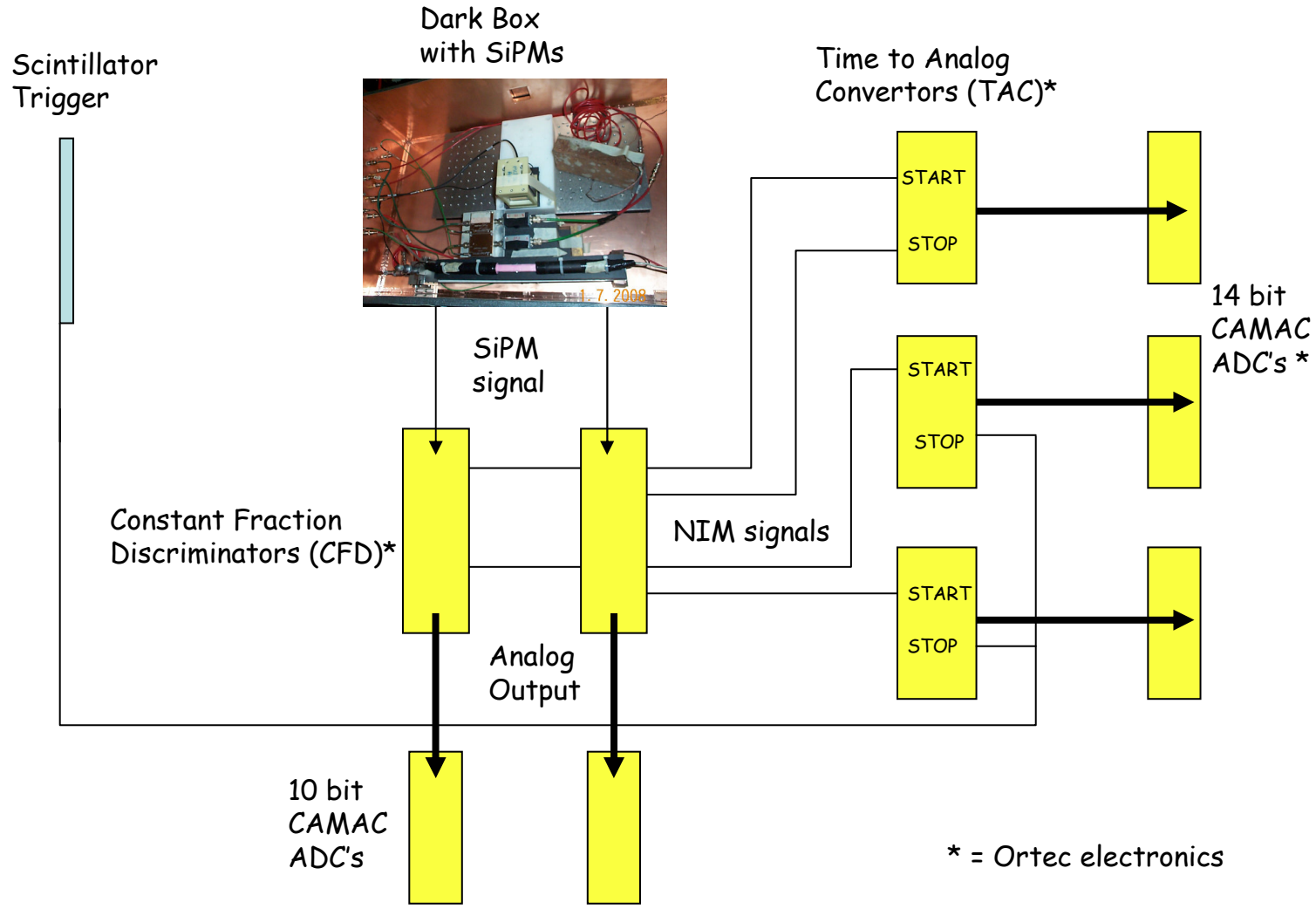
Fermilab Test Beam Setup

- Three dark boxes
  - 2mm x 2mm trigger scintillator
  - 2 PMTs for coincidence triggering in each box.
  - 2 MCPs or SiPMs in each box
- 3 DAQ systems
  - DAQ-1
    - uses FERA readout for fast data collection
  - DAQ-2
    - CAMAC
    - Allows other users to quickly connect to our system
  - Tektronix TDS6154C oscilloscope
    - 40 Gsample/sec (total of channels)
- 120 GeV proton beam used



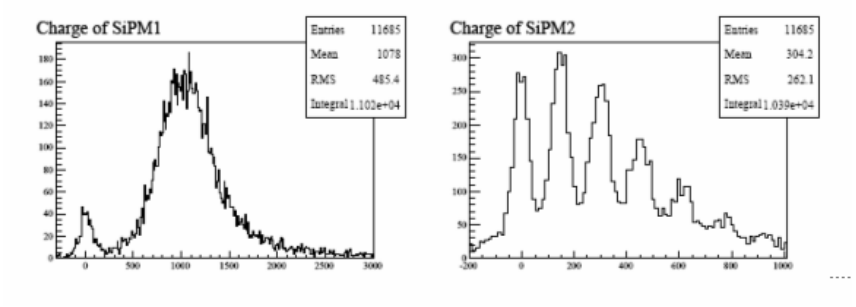


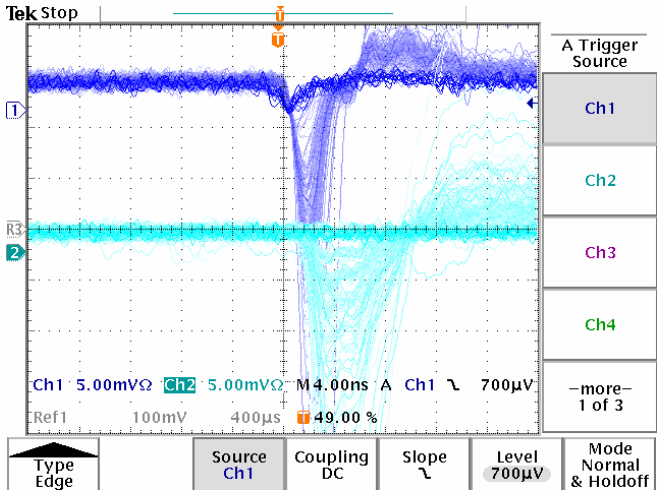
Electronic Measurement



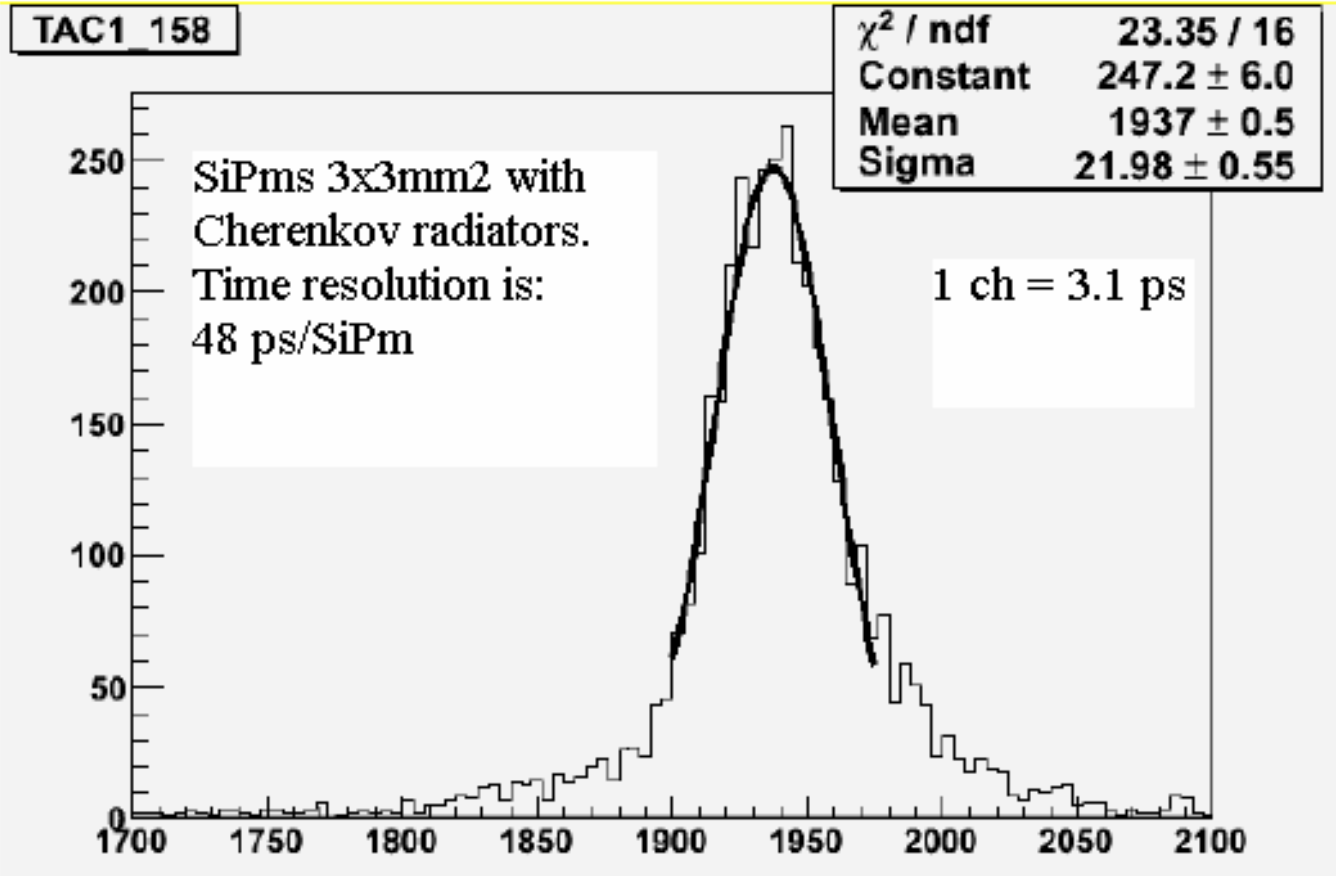
Testing several SiPM's

- All SiPM timing data measured in the laboratory (Silicon Detector Facility, Fermilab) with Pilas laser presented above.
- Then tested the SiPMs on a beam. Trigger counter used was 2x2 mm^2 in transverse size. 3x3mm^2 devices were tested with 3x3mm^2 of the transverse size of the Cherenkov radiator made of plastic. The length of the radiator was 16 mm, but working "effective length" was at the level of 1.5mm by estimation.
- The 1x1mm^2 SiPMs were tested with a fiber optic faceplate of 5 mm length. The measured time resolution obtained is about 150 psec per SiPM. In this case only a few photoelectrons (1-2) were detected.
- We found Hamamatsu MPPC (SiPM), blue sensitive, 3x3 mm^2 to have the best time resolution on the beam.





Test beam SiPM time resolution, 48 ps per device



Conclusion

- The obtained time resolution, 48 picoseconds/device, of the TOF system based on SiPMs looks promising. It is clear now it could be improved with better light collection.

- The possible TOF counter design is a plain matrix of SiPMs with Cherenkov radiator made of quartz optically attached to the SiPMs. The considered design is for normal particle's incidence.

- Such a system is not sensitive to magnetic fields, which should be crucial for some applications.