Scintillator readout for the SHiP timing detector

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C. Betancourt[1], I. Bezshyiko[1], A.Blondel[2], D. Breton[3], R. Brundler[1], A. Dubreuil[2], A. Khotyntsev[4], A. Korzenev[2], J. Maalmi[3], A. Mefodev[4], P. Mermod[2], E. Noah[2], N. Serra[1], B. Storaci[1]

[1]Universität Zürich
[2]Université de Genève
[3]CNRS/IN2P3, Centre scientifique d'Orsay
[4]Russian Academy of Sciences, Moscow

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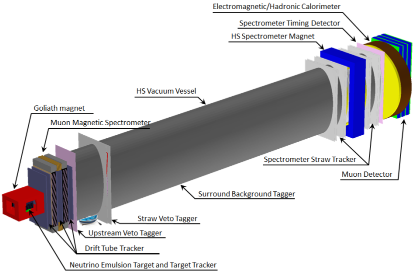
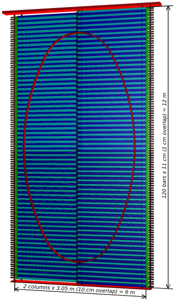
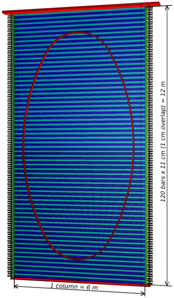
The SHiP timing detector

- A dedicated timing detector can be used to reduce random crossing in the detector
- Combinatorial di-muon background can be reduced to an acceptable level by requiring a timing resolution of 100 ps or less
- Two options have been proposed for the timing detector plastic scintillators
    1. plastic scintillators read-out by PMTs or SiPMs
    2. multigap resistive plate chambers
- This study focuses on the plastic scintillator option read-out by PMTs or SiPMs

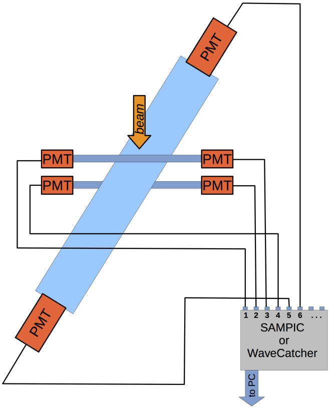






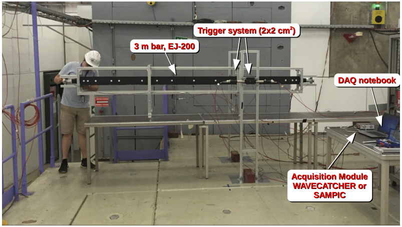
PMT option

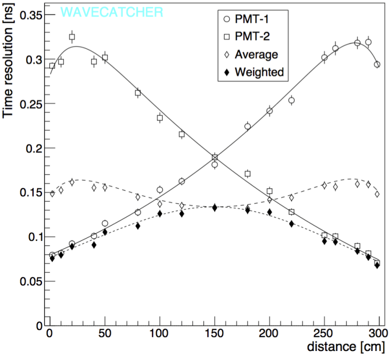
Set-up

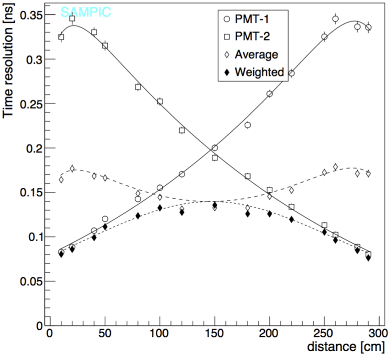


[arXiv:1610.05667]

- 10 GeV/c muon beam produced from the CERN PS (T9 beamline)
- 3 m long bar (EJ-200) readout by PMTs
- 2 reference counters used for trigger $\rightarrow$ 40 ps resolution
- Two DAQ systems are studied
  1. WAVECATCHER: 8 channel, hardware trigger $\sim$ few kHz
  2. SAMPIC: 16 channel, self triggering $\sim$ 150 kHz
- Time resolution of entire system is taken as Gaussian width of the following
  $\Delta t = \frac{t_1+t_2+t_3+t_4}{4} - t_{5,6}$

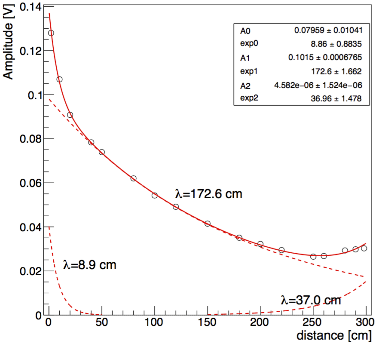


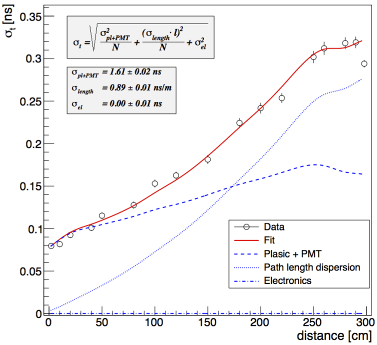




- Very little difference between WAVECATCHER (135 ps in center) and SAMPIC (140 ps in center) using weighted average
- Degradation of time resolution is worse for SAMPIC at the far end $\rightarrow$ too small of an interval to fit baseline

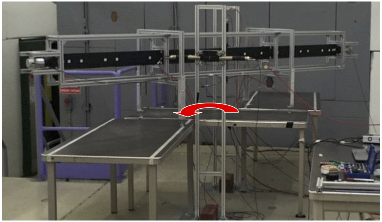
Phenomenological fit

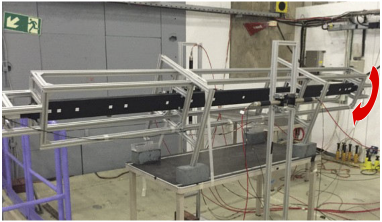




- About 130 p.e./PMT when interaction is at middle of the bar
- Path length dispersion in the bar dominates time resolution at large distances
  $\rightarrow$ Main limiting factor for long bars
  $\rightarrow$ Faster electronics won't help

Angular scans



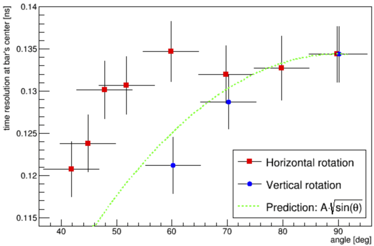


Horizontal rotation

- 42°, 45°, 48°, 52°, 60°, 70°, 80°, 90°
- Track length increases, effective bar length decreases
  → time resolution improves

Vertical rotation

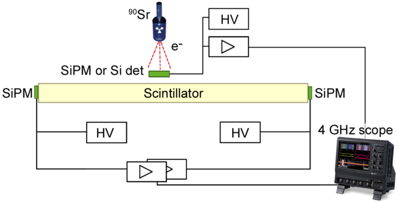
- 60°, 70°, 90°
- Track length increases
  → time resolution improves

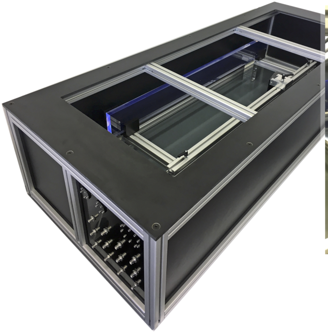


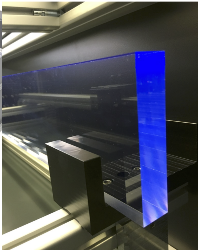
SiPM option

Set-up

- Signal generated by ^{90}Sr source
- Scintillating plastic bars (EJ-200, $120 \times 11 \times 2.5$ cm) read out on both ends by SiPMs / SiPM Arrays
- Reference counter used for triggering consists of a small SiPM or Si diode (UFSD?)
- Signal sent to amplifier and readout out by 4 GHz oscilloscope







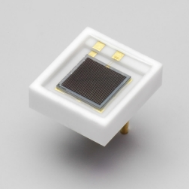
SiPM characterization

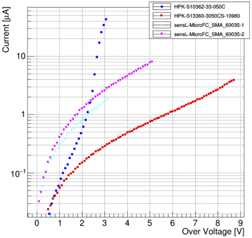
- SiPMs from two manufacturers:

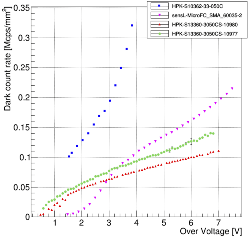
  Hamamatsu Photonics
  SensL

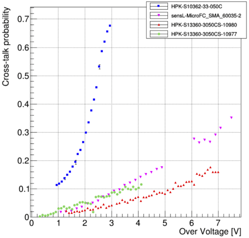
- SiPM characterized by:

  Current-Voltage behavior
  Dark count rate
  Cross-talk probability
  Single photon time resolution



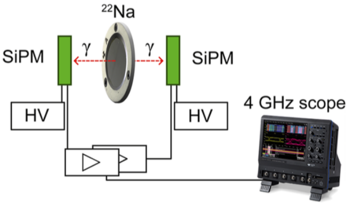


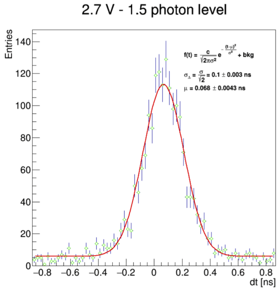


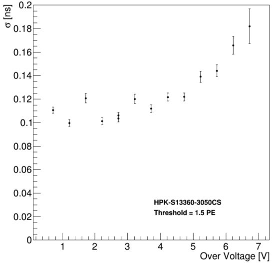


SiPM single photon time resolution

- Back-to-back γs from pair-annihilation in ^{22}Na is used as a source
- Single photon time resolution is taken as the Gaussian width in the time difference spectrum from coincidence signals
- Very good resolution $\sim$ 100 ps is observed in 3×3 mm HPK SiPM

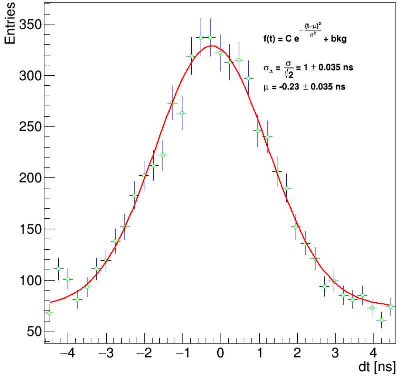


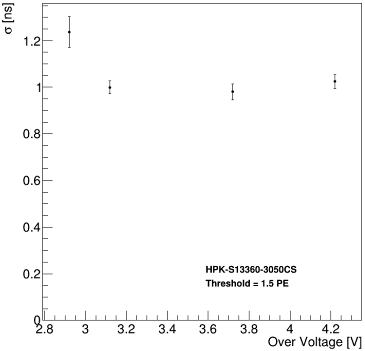




Time resolution: SiPM+bar

- ^{90}Sr pointed at bar center (60 cm)
- 3×3 mm SiPM on either end of bar
- Initial measurements indicate time resolution of 1 ns
- Assuming $\sigma \propto 1/\sqrt{N_{p.e.}}$
  $\sim$ 100 ps for 33% sensor coverage
  $\sim$ 60 ps for full sensor coverage
- Optimization studies ongoing (CFD threshold)





MUSIC: Multiple Use SiPM Integrated Circuit

Operational Modes

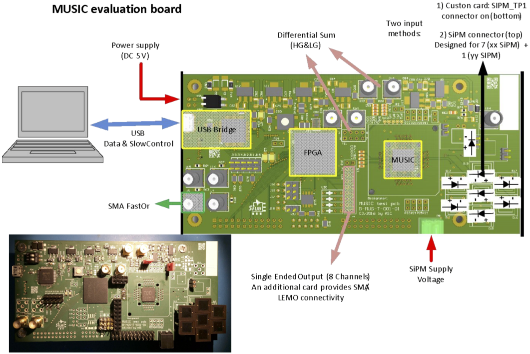
- Single channel: analog or discriminated
- Up to 8 ch summation
- Trigger output

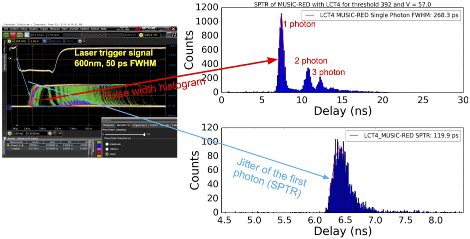
Performance

- Low noise
- High speed: $>$ 500 MHz without filtering
- Tuneable PZ cancellation
- SPTR 100 ps
- Dynamic range: from $< 1/5$ to $>$2000 p.e.

Applications

- Cherenkov Telescopes
- High Energy Physics and nuclear detectors
- Lab test benches for SiPM characterization: flexibility





Summary & Outlook

- Exploring scintillator based option for SHiP timing detector
- Readout by PMTs

  3 m long bars
  135 ps in bar center
  time resolution limited by bar length
  two DAQ systems investigated
  [arXiv:1610.05667]
- Readout by SiPMs

  1.2 m long bar
  1 ns in bar center for 3×3 mm sensors
  $\rightarrow$ 100 ps for 33% coverage, 60 ps for full coverage
  Custom DAQ based on MUSIC board being investigated
- Plan for testbeam in Summer 2017
- Plan to finalize design by end of 2017
- Much more work to do, stay tuned!