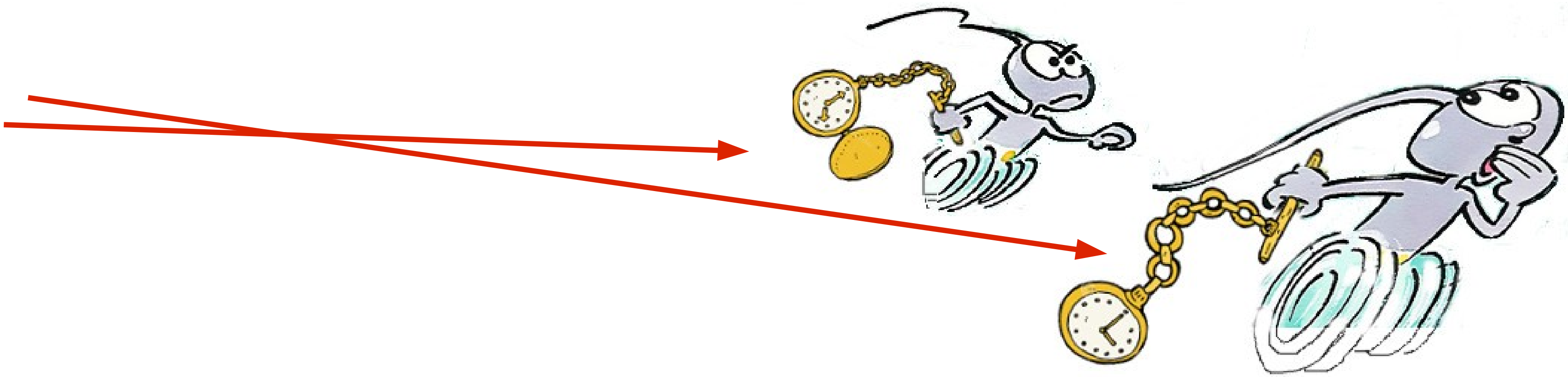

Spectrometer Timing Detector – plastic scintillator option

SHiP Collaboration Meeting
London, 14 June 2016

A. Korzenev, P. Mermod, E. Noah (U. Geneva)
C. Betancourt, N. Serra, B. Storaci (U. Zurich)
J. Chauveau (CNRS), D. Breton, J. Maalmi (LAL)

SHiP
Search for Hidden Particles

Random crossing background

Huge muon rate coming from target. Possible handles :

- Deflexion
  - Muon shield
  - Cavern geometry
- Tagging
  - Upstream veto
  - Surround veto
- Tracking resolution
  - Vertex doca
  - Reconstructed parent origin
- Time resolution
  - Muon detector
  - Spectrometer timing detector

All these need to be optimised in a unified way.

Random crossing background

Huge muon rate coming from target. Possible handles :

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- Tagging
  - Upstream veto
  - Surround veto
- Tracking resolution
  - Vertex dca
  - Reconstructed parent origin
- Time resolution
  - Muon detector
  - Spectrometer timing detector →

Specifications :

6 x 12 m^2 coverage

< 100 ps time resolution

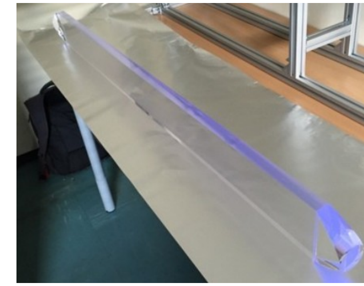
~20 cm space resolution

Robust, low budget

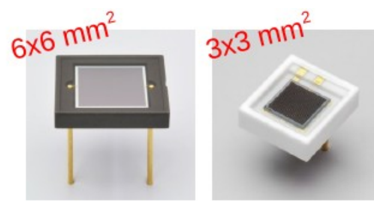
All these need to be optimised in a unified way.

Plastic scintillator option – study areas

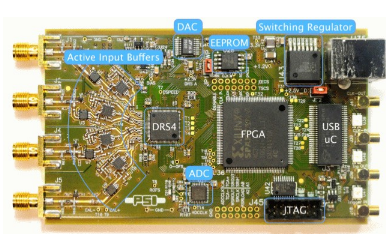
- Plastic
  - Type (rise time constant, attenuation length)
  - Bar geometry (length, thickness, lightguides)
  - Reflector

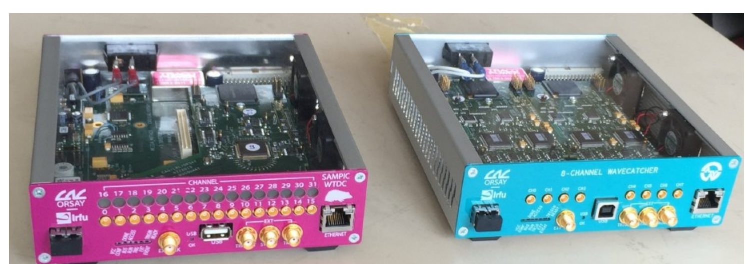


- Photodetectors
  - PMTs
  - Large-area SiPM arrays



- Electronics
  - Waveform digitisers – DRS4, Wavecatcher, SAMPIC

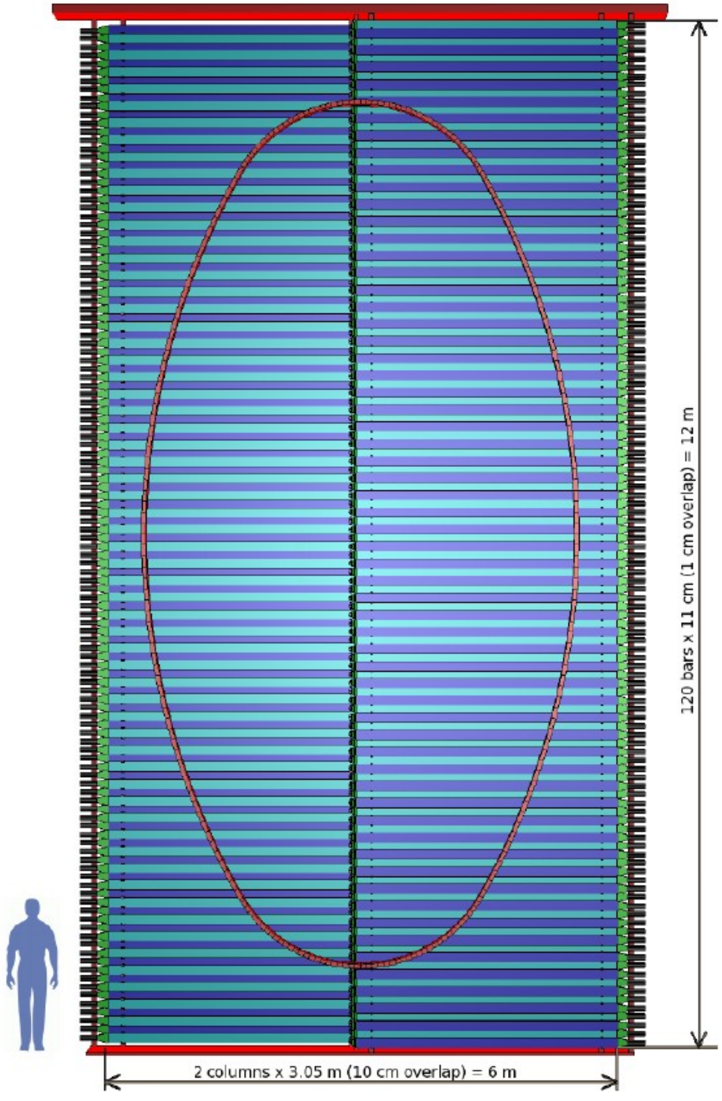




Layout

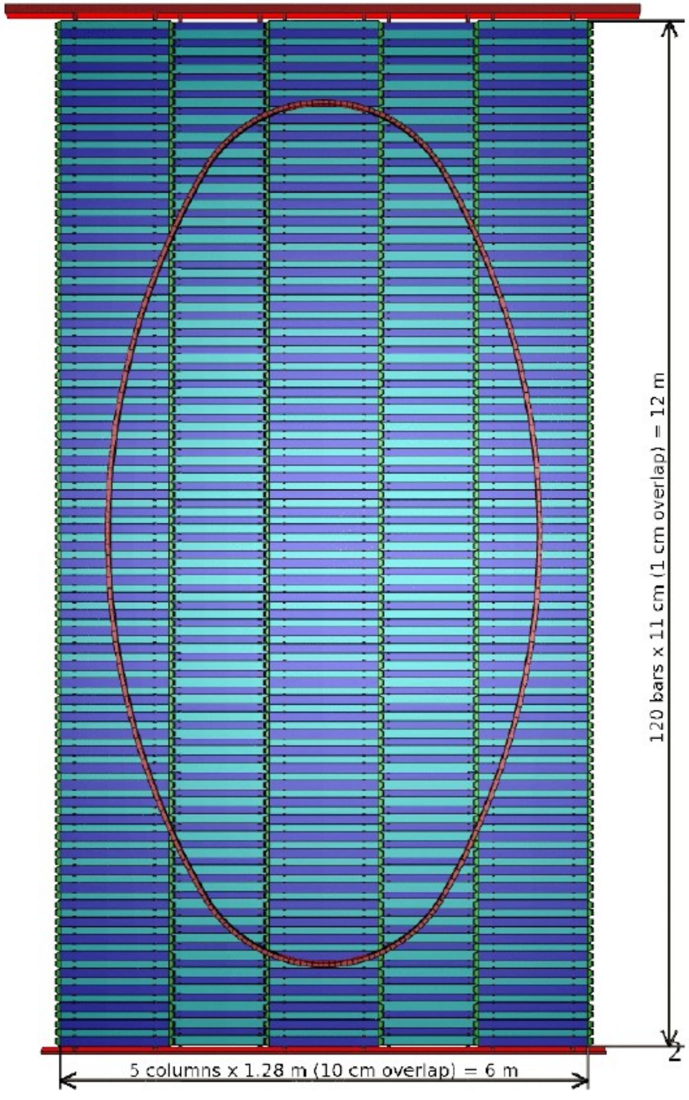
TP baseline

(two columns, PMTs, ~100 ps)



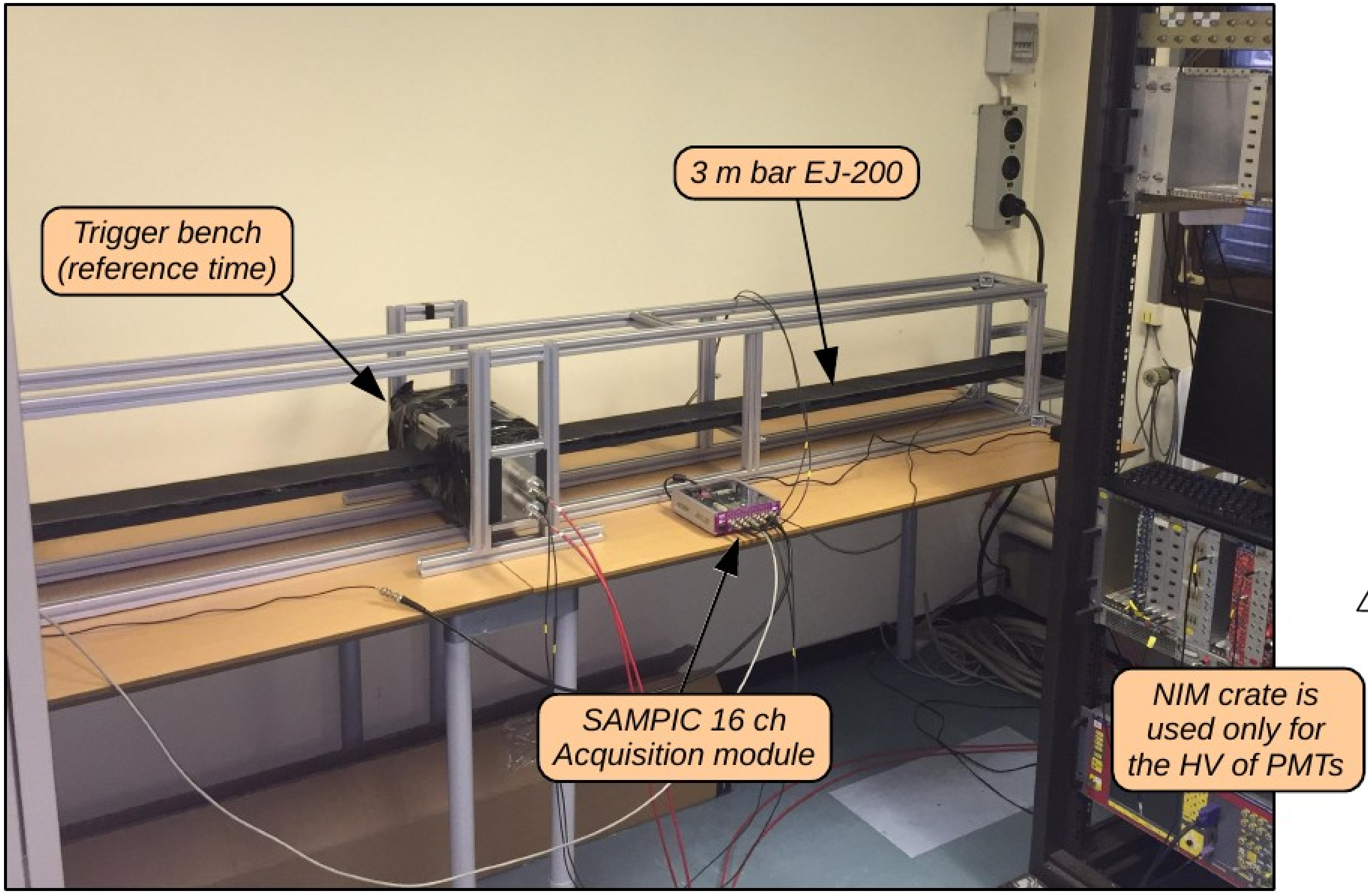
Goal after 1 year R&D

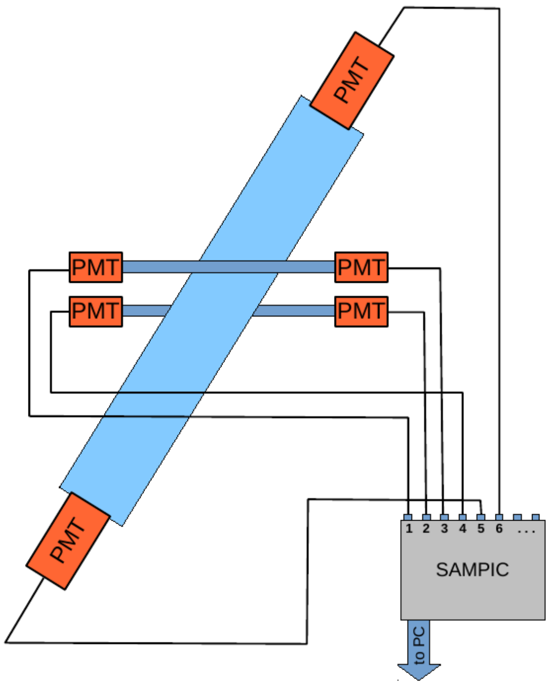
(5+ columns, SiPMs, ~60 ps)



Measurements with cosmics

Test bench in UniGe's lab (CERN 595 R-005)

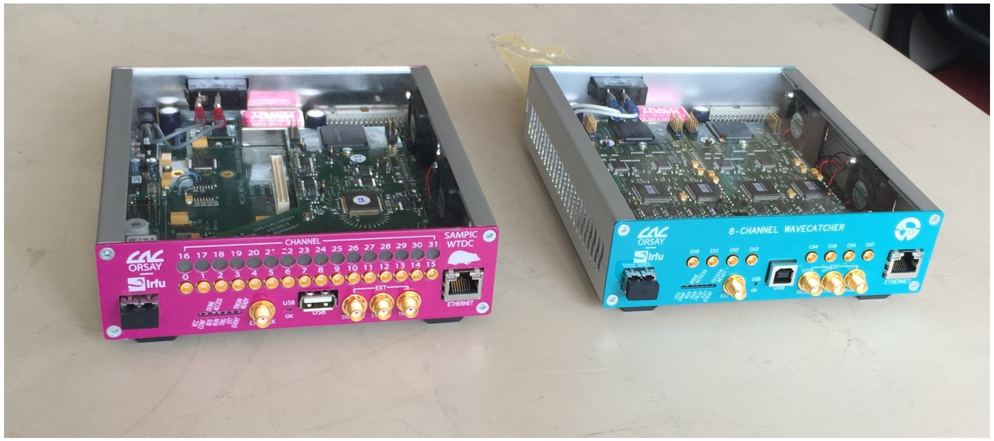




Test bar: 3 m long, 11 cm broad, 2.5 cm thick, EJ-200 plastic, Al wrapping, fish-tail lightguides, R13089-10 PMTs

Electronics

Two acquisition modules kindly lent to us by LAL group



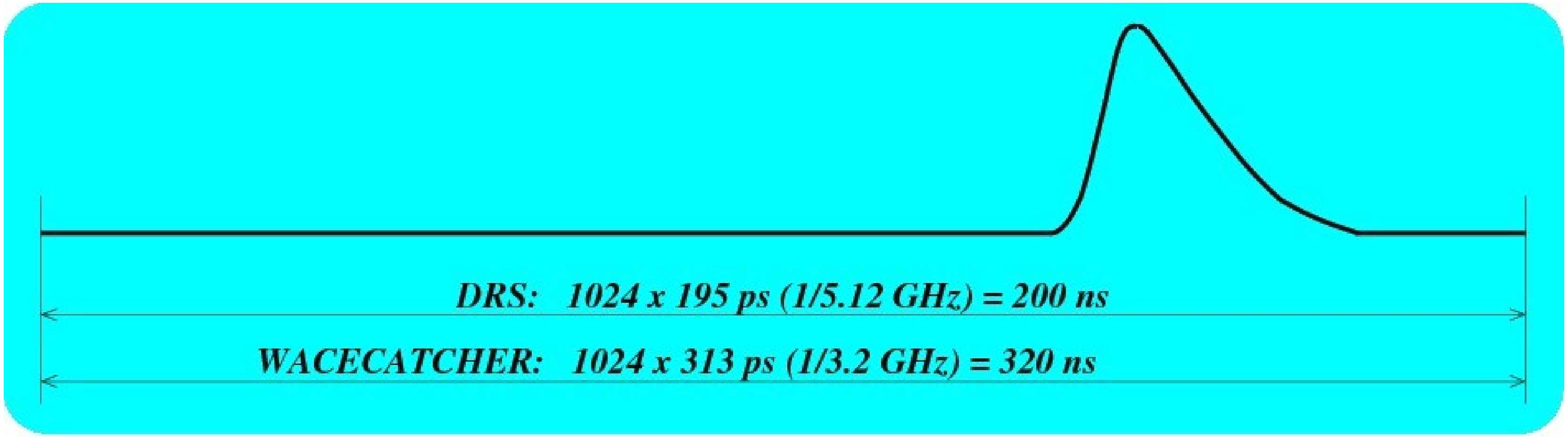
SAMPIC

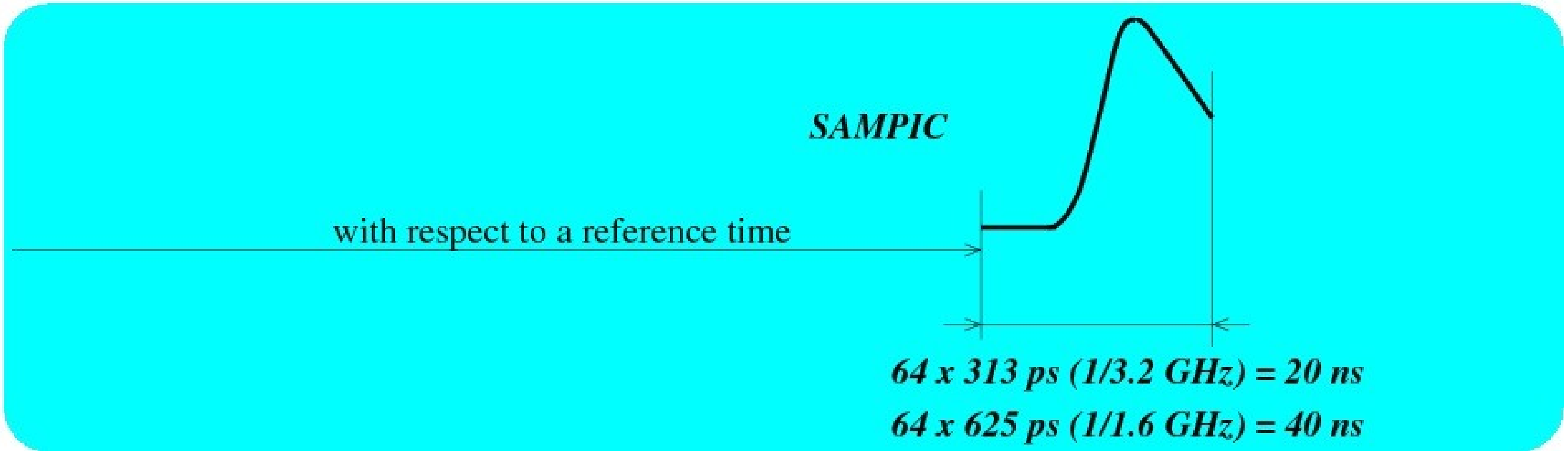
- 16 channels, each self-triggering – more suited to triggerless readout foreseen in SHiP, but will need online filter to reduce data size
- 64 samplings over 20 ns – cannot record full pulse shape
- Up to 150 kHz signal rate
- Dynamic range 1 V

WAVECATCHER

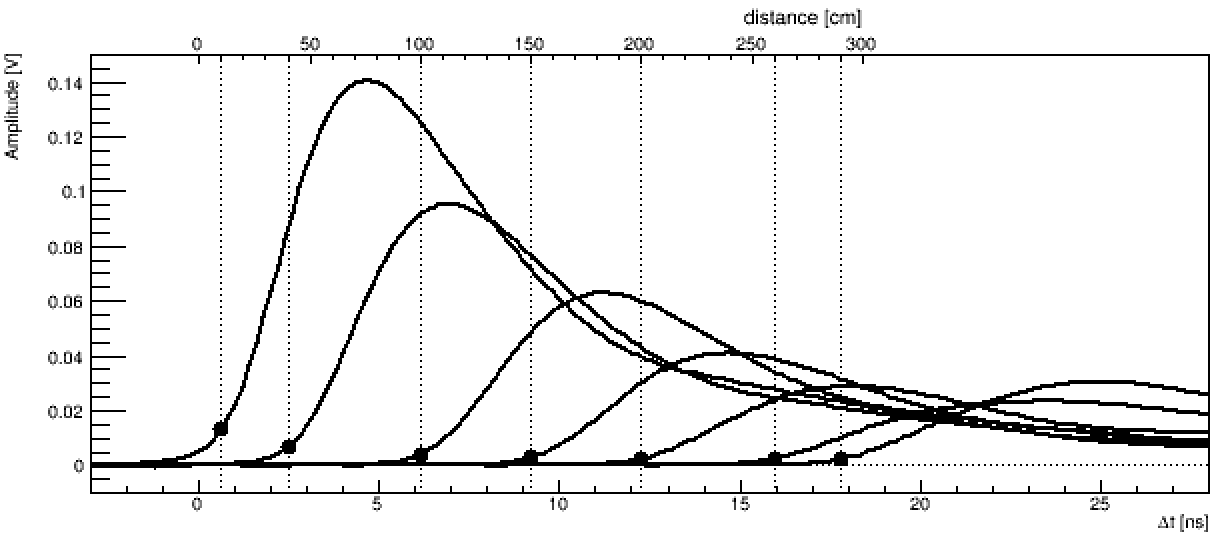
- 8 channels, all read out using common trigger (similar to DRS4)
- 1024 samplings over 320 ns
- Few kHz signal rate
- Dynamic range 2.5 V

Sampling

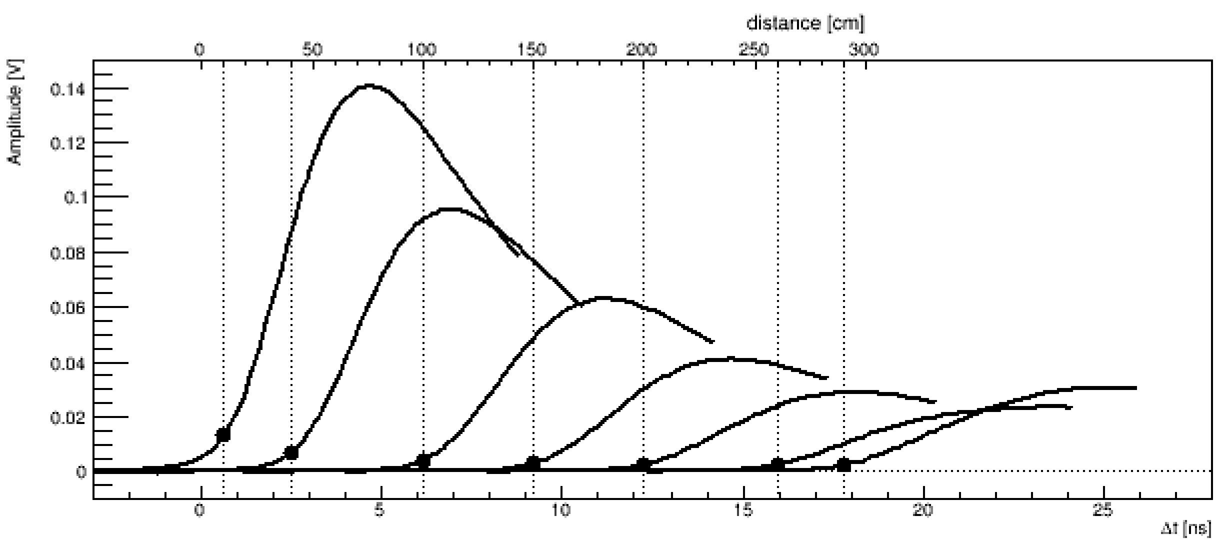

DRS: 1024 x 195 ps (1/5.12 GHz) = 200 ns
WACECATCHER: 1024 x 313 ps (1/3.2 GHz) = 320 ns


SAMPIC
with respect to a reference time
64 x 313 ps (1/3.2 GHz) = 20 ns
64 x 625 ps (1/1.6 GHz) = 40 ns

Measured pulse shapes vs distance



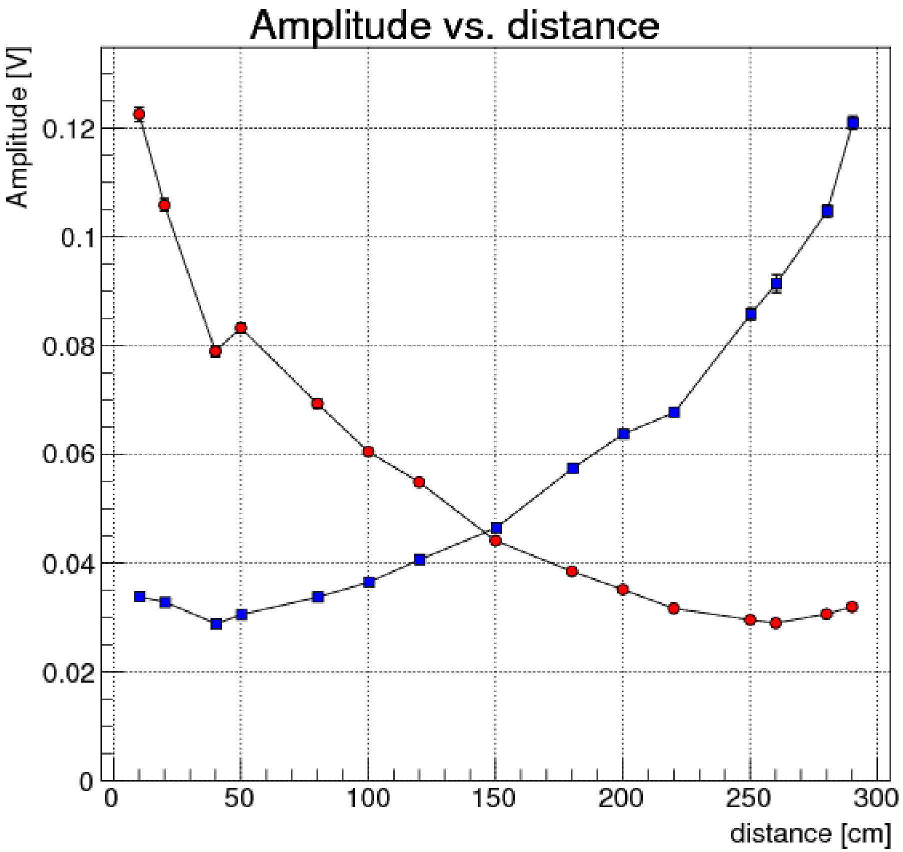
WAVECATCHER

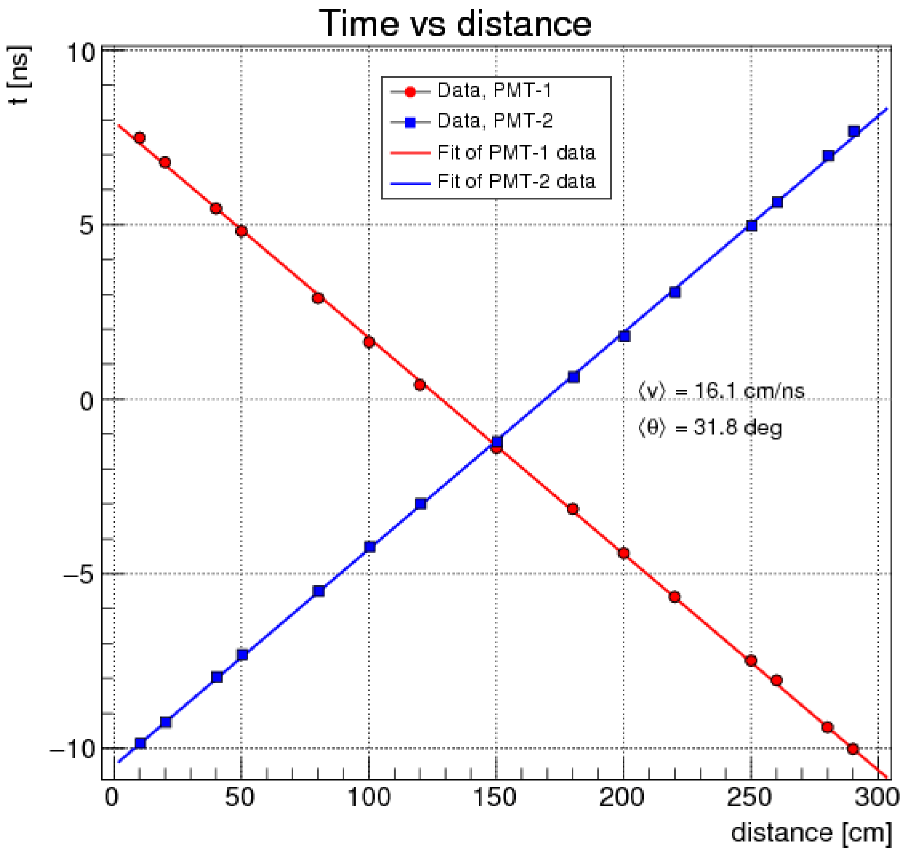


SAMPIC

- Pulse maximum not registered beyond ~3 m

Measurements with SAMPIC



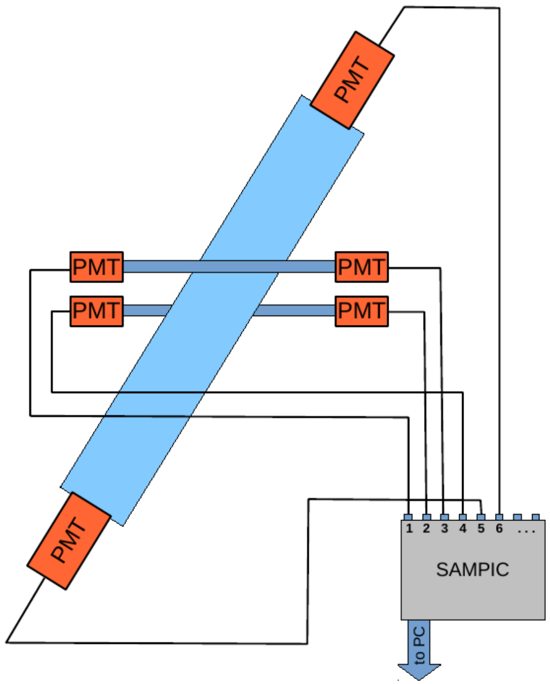


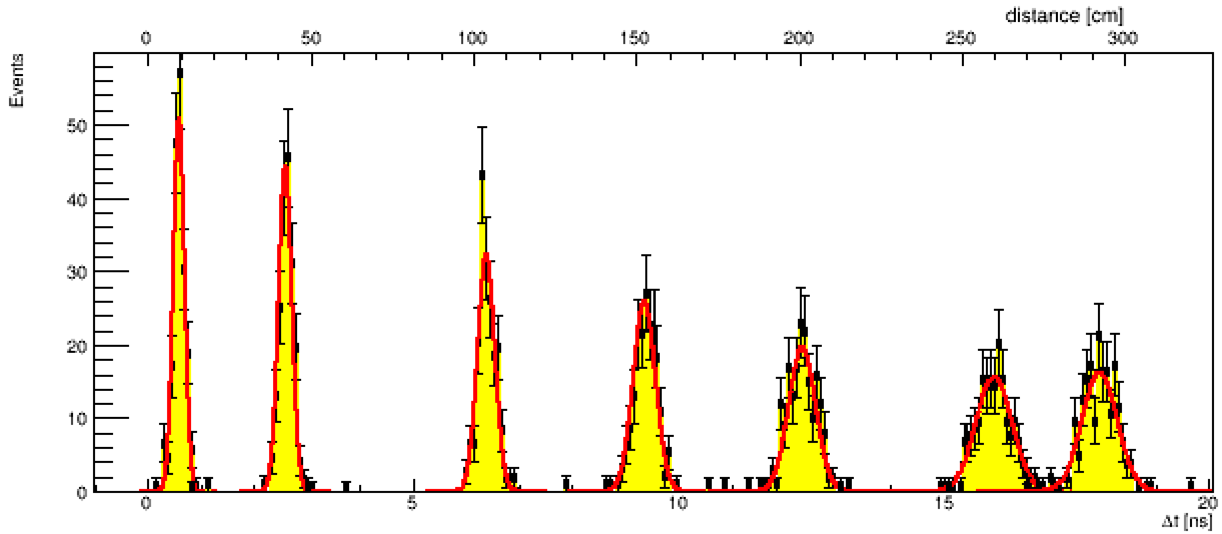
Results consistent with those obtained with DRS4 and WAVECATCHER

Time measurements wrt reference counter

- Digital constant fraction discriminator technique
- Reference counter time resolution σ_{trig} = 60 ps
- Measured time:

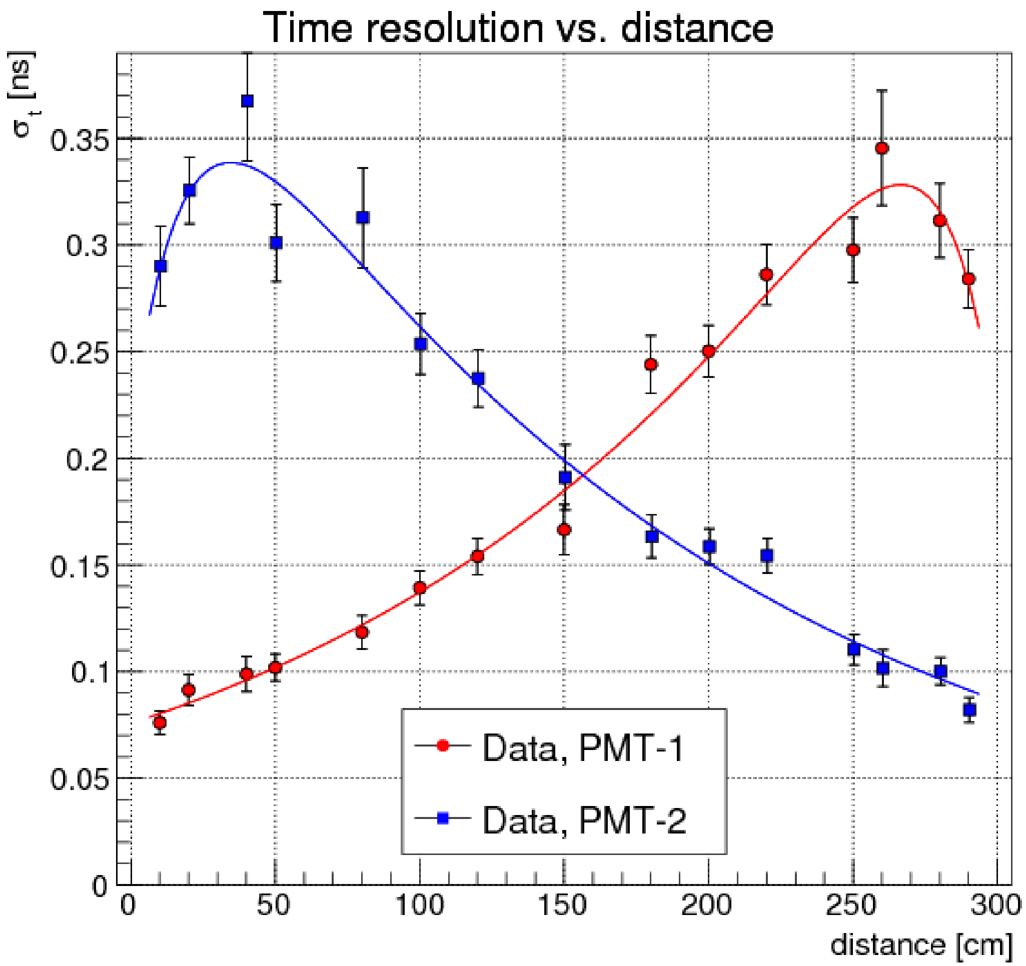
$$\Delta t = \frac{t_1+t_2+t_3+t_4}{4} - t_{5,6}$$





- Time resolution: σ_t = width of Δt distribution with σ_{trig} subtracted (in quadrature)

Time resolution vs distance (with SAMPIC)



- Reference time

$$t_{trig} = \frac{t_1 + t_2 + t_3 + t_4}{4}$$

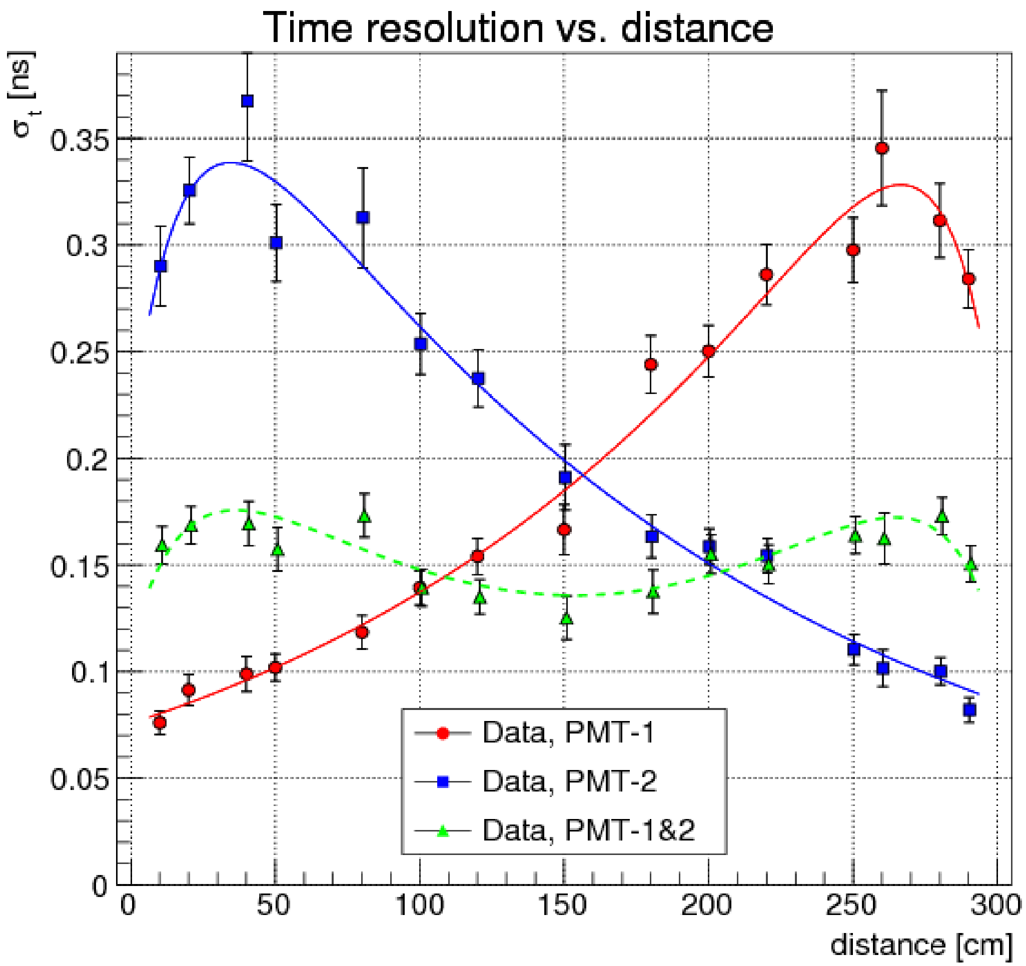
- PMT-1 time

$$\Delta t = t_{trig} - t_5$$

- PMT-2 time

$$\Delta t = t_{trig} - t_6$$

Time resolution vs distance (with SAMPIC)



- Reference time

$$t_{trig} = \frac{t_1+t_2+t_3+t_4}{4}$$

- PMT-1 time

$$\Delta t = t_{trig} - t_5$$

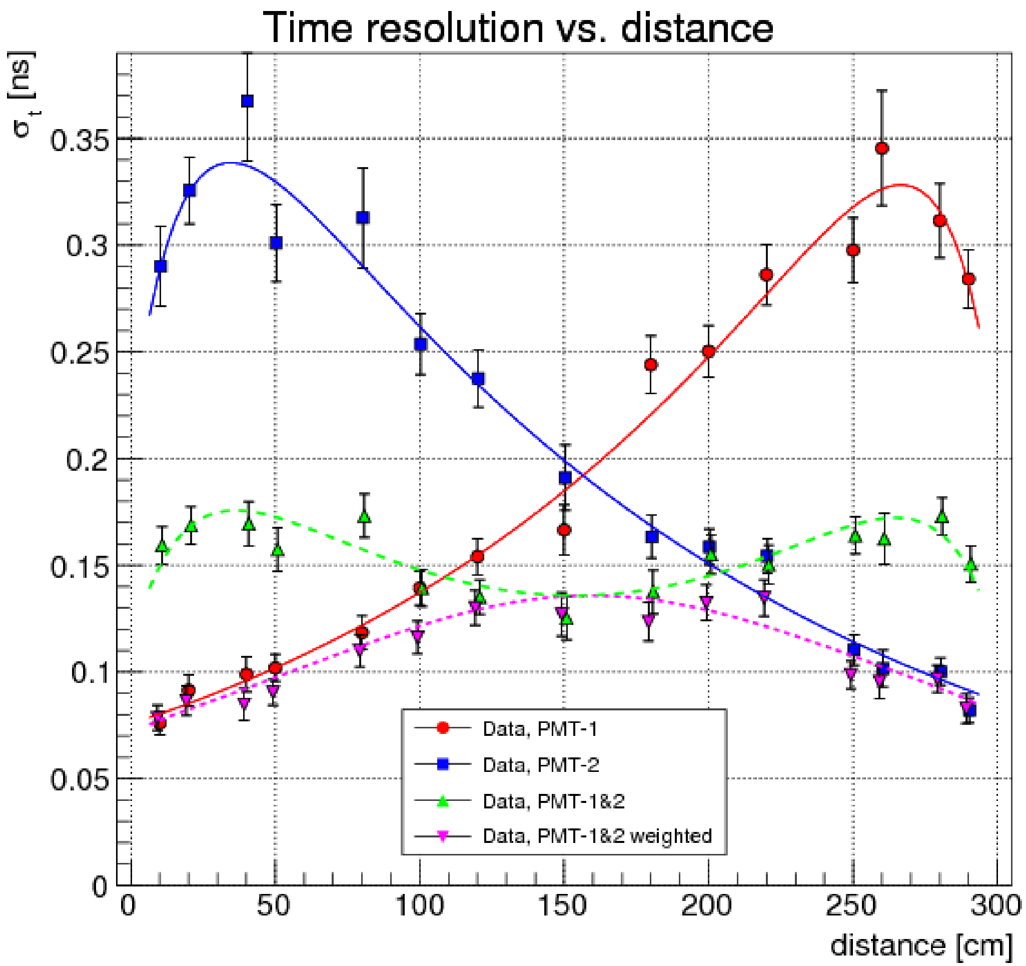
- PMT-2 time

$$\Delta t = t_{trig} - t_6$$

- Combined without space info

$$\Delta t = t_{trig} - \frac{t_5+t_6}{2}$$

Time resolution vs distance (with SAMPIC)



- Reference time

$$t_{trig} = \frac{t_1 + t_2 + t_3 + t_4}{4}$$

- PMT-1 time

$$\Delta t = t_{trig} - t_5$$

- PMT-2 time

$$\Delta t = t_{trig} - t_6$$

- Combined without space info

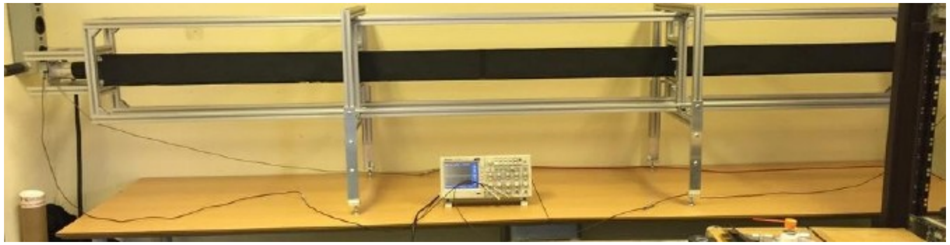
$$\Delta t = t_{trig} - \frac{t_5 + t_6}{2}$$

- Combined with space info

$$\Delta t = t_{trig} - \frac{t_5 / \sigma_5^2 + t_6 / \sigma_6^2}{1/\sigma_5^2 + 1/\sigma_6^2}$$

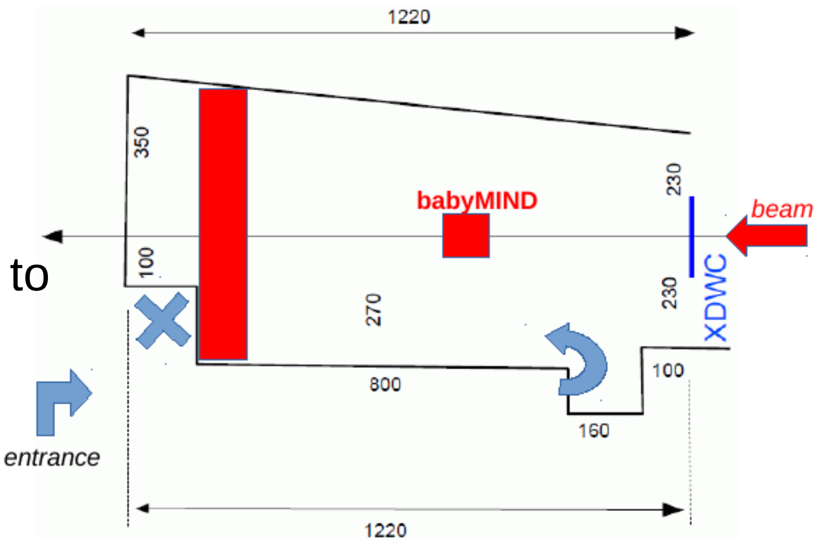
Test beam

Bar holder



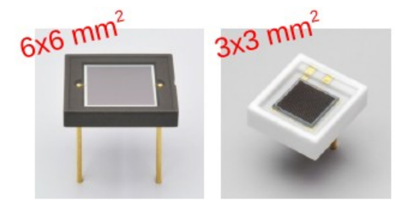
Trigger counters
(2x2 cm^2 active area)

- Muon beam next week (22-29 Jun)
- T9 (east area) to be shared with BabyMIND
- Another slot in July (20-28) if needed
- Goals:
  - High statistics in various positions along 3 m bar
  - Also different transverse positions
  - Also different angles of incidence
  - Mostly SAMPIC, WAVECATCHER to cross-check
  - Aim at NIM paper

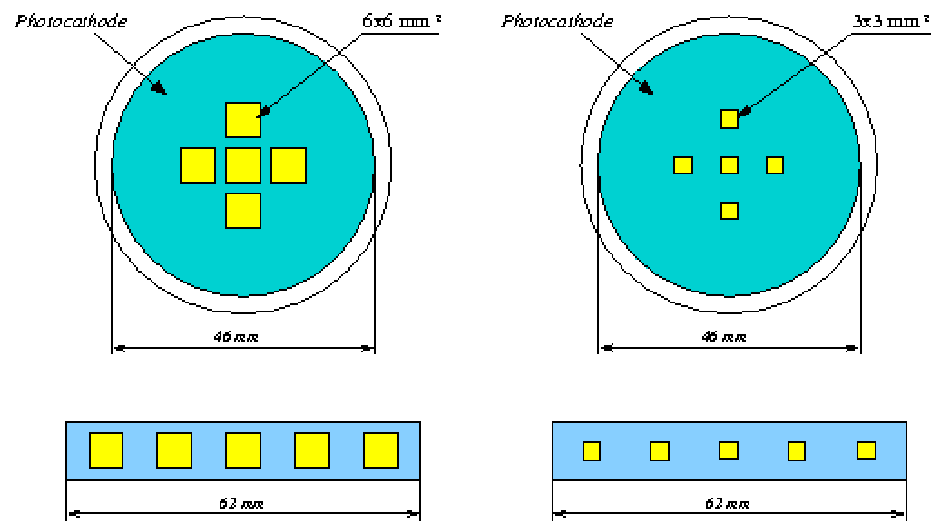


R&D with large-area SiPM arrays

- Sensors from Hamamatsu and SensL, 6x6 mm^2 and 3x3 mm^2



- Starting tests in both Geneva and Zurich labs
  - Sensor manufacturer
  - Sensor area
  - Array configuration, surface coverage
  - Preamplifier vs no preamplifier
  - Series vs parallel readout
  - Lightguides vs direct application on bar surface
  - …



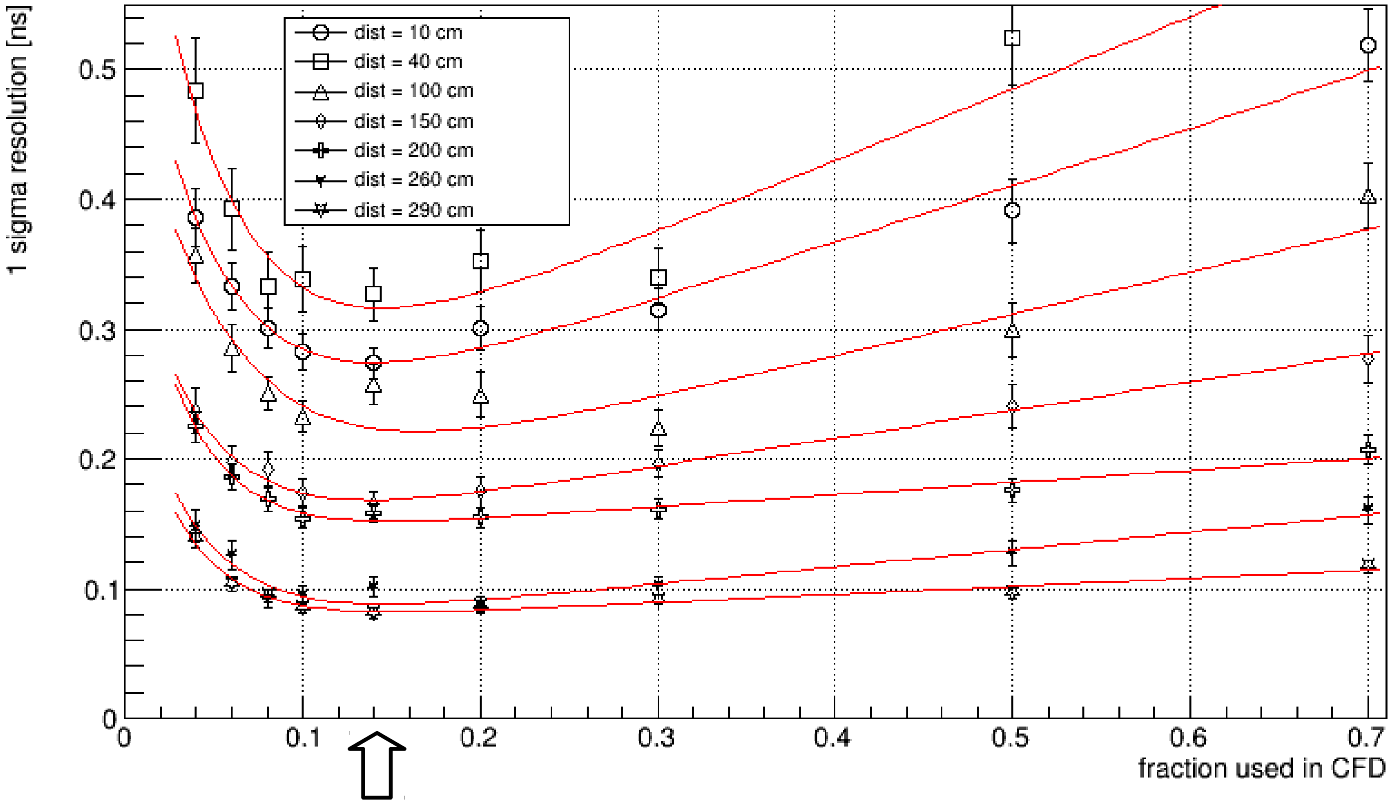
- Participating in EU COST action on Fast Scintillator Timing (FAST)

Summary

- Tested 3 m bar with cosmic muons
  - PMTs on both ends
  - SAMPIC digitiser
  - Time resolution around 100 ps
- Test beam next week
  - Time resolution as a function of position, angle, acquisition and analysis procedures...
- R&D with large-area SiPM array readout ramping up
  - Promising prospects – shorter bars, better timing, low cost...

Extras

Optimization of the threshold of d-CFD (SAMPIC)



- Threshold (fraction) of d-CFD is a subject of optimization
- Can be calculated on firmware and software levels
- 14% fraction was used in the analysis