Timing and Upstream-Veto Detectors (plastic option)

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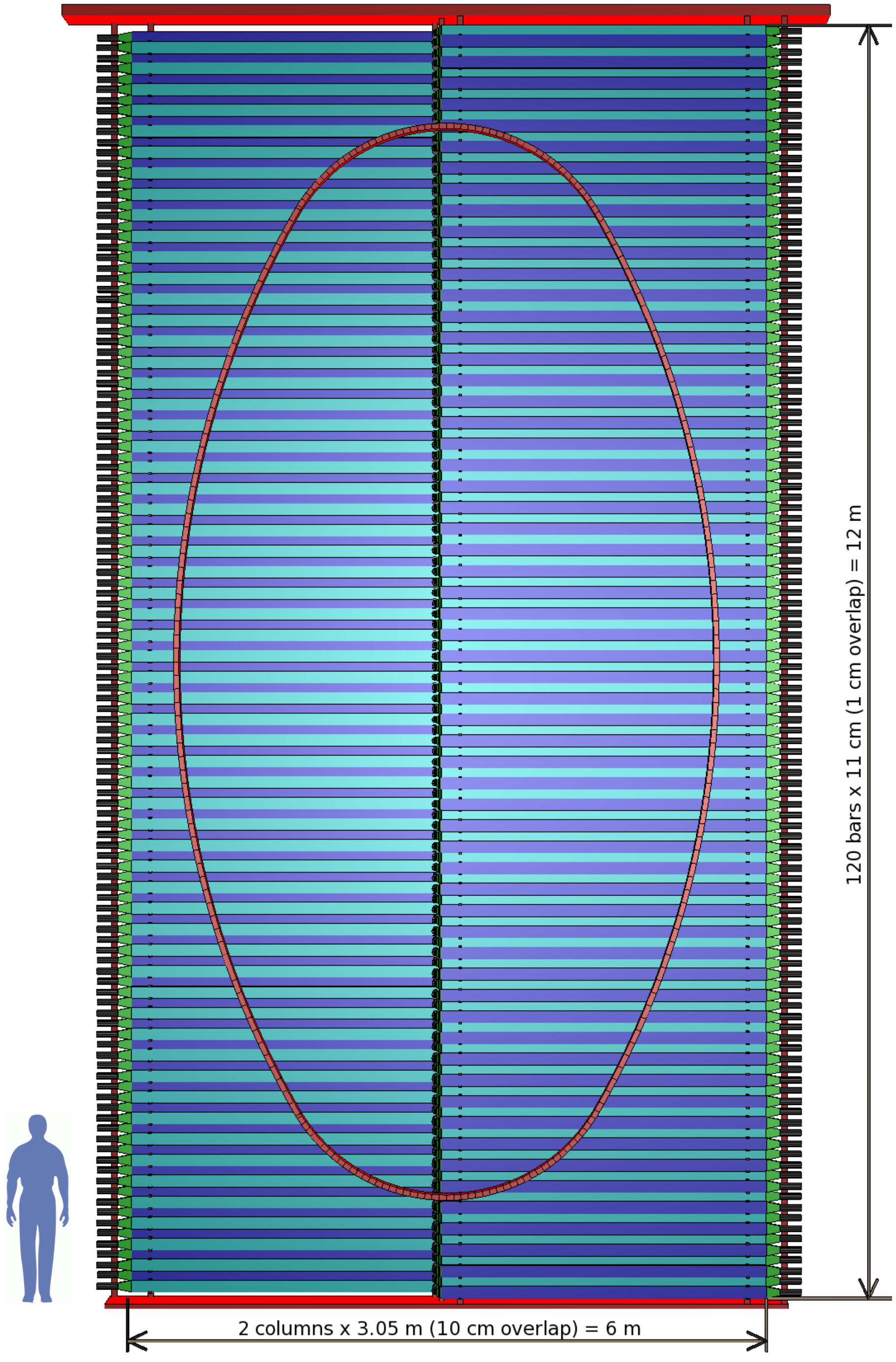
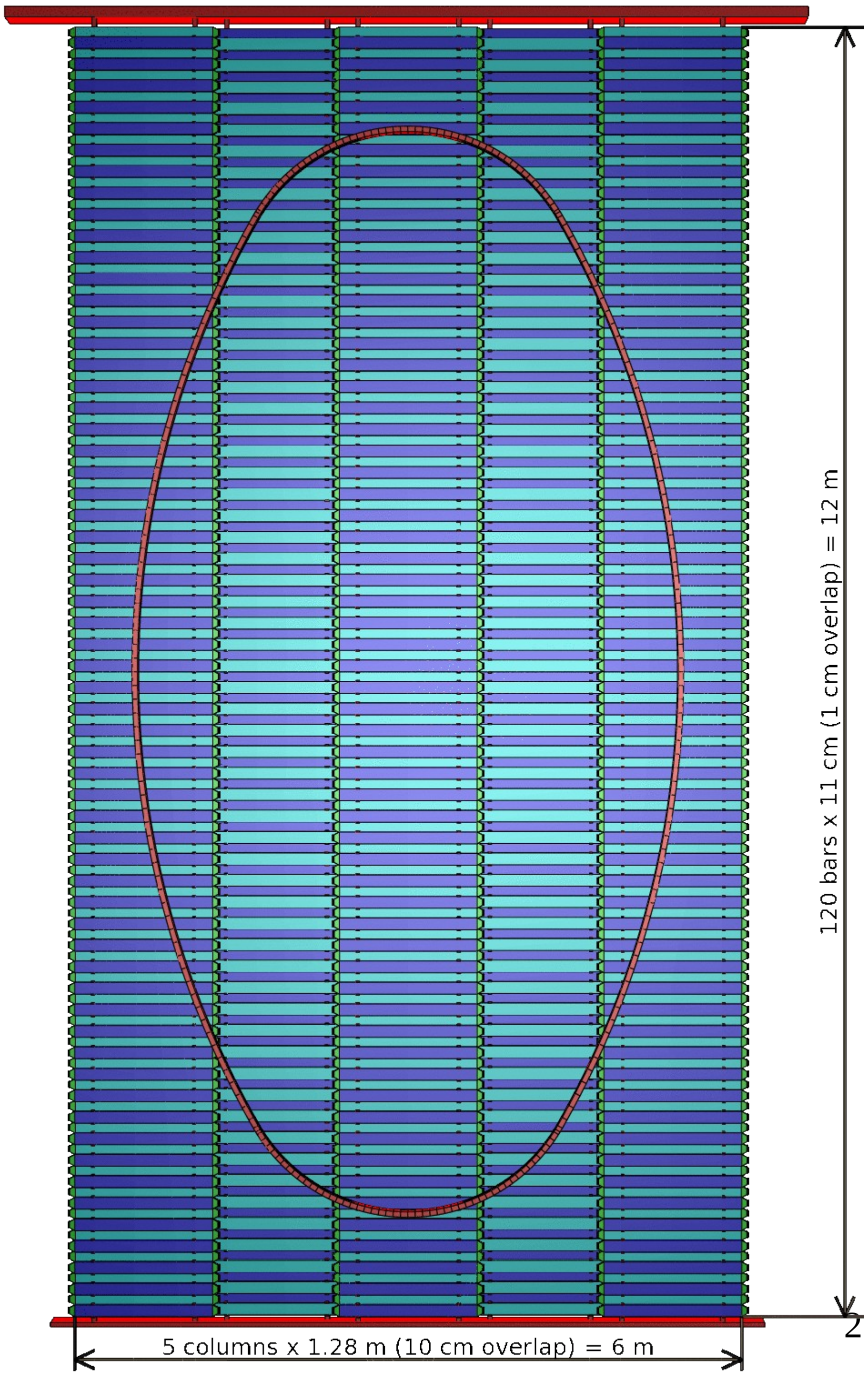
SHIP workshop in CERN
Oct 7, 2015

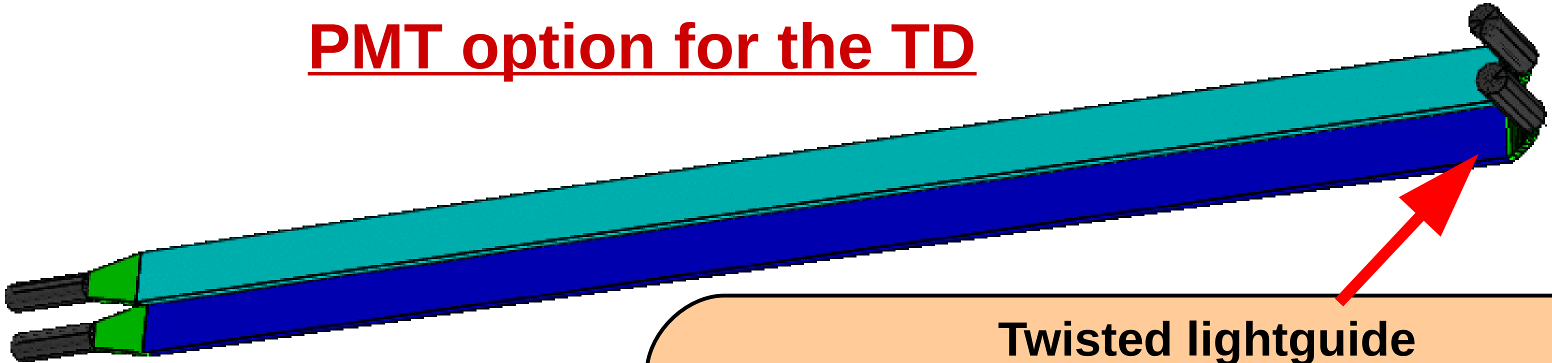
Timing Detector: PMT option



Timing Detector: Array-SiPM option

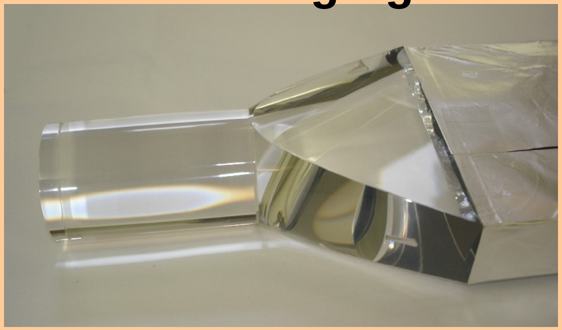


PMT option for the TD



Twisted lightguide

Fish-tail lightguide



PMT /R13089-10 during the test

Time resolution of a scintillator counter σ_t

$$\sigma_t \sim \sqrt{\frac{\tau^2_{scint} + \left(\frac{1}{2}\frac{n(n-1)}{c}\cdot L\right)^2 + \tau^2_{PMT}}{N_e} + \sigma^2_{elect}}$$

- τ_{scint} is a decay time of the scintillator
- 2-nd term is a time spread of the light transmission
- τ_{PMT} is a time jitter of the PMT
- σ_{elect} is an uncertainty due to electronics
- N_e is the number of p.e. $N_e = N_0 e^{-L/\lambda}$

Choice of scintillator

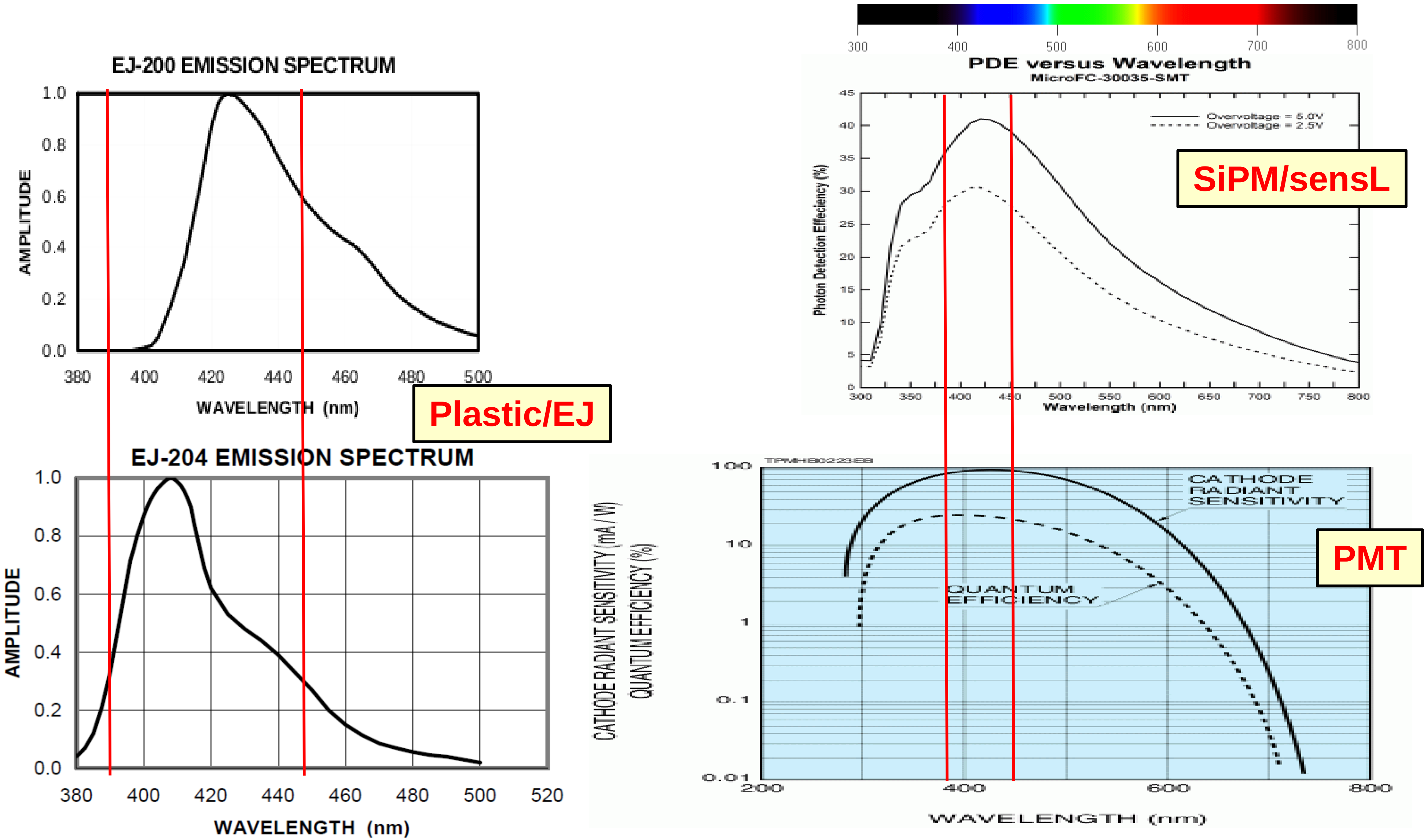
SAINT-GOBAIN CRYSTALS	ELJEN Technology	Light output	Wavelength	Decay const	Att. length
BC-404	EJ-204	68 %	408 nm	1.8 ns	1.6 m
BC-408	EJ-200	64 %	425 nm	2.1 ns	~3.8 m

- Energy loss in plastic: dE/dx_{min} = 2 MeV/cm, light yield: 10000 photons/MeV
- For long bar mainly those γ which have total internal reflection (θ >39°) are detected

- Effective attenuation length depends on a thickness of a bar (SGC brochure for BC408)
  - For 0.5 cm thick, TAL = 1.9 m
  - For 1 cm thick, TAL = 2.1 m
  - For 2 cm thick, TAL = 2.75 m

Sensitivity match for plastic and sensors

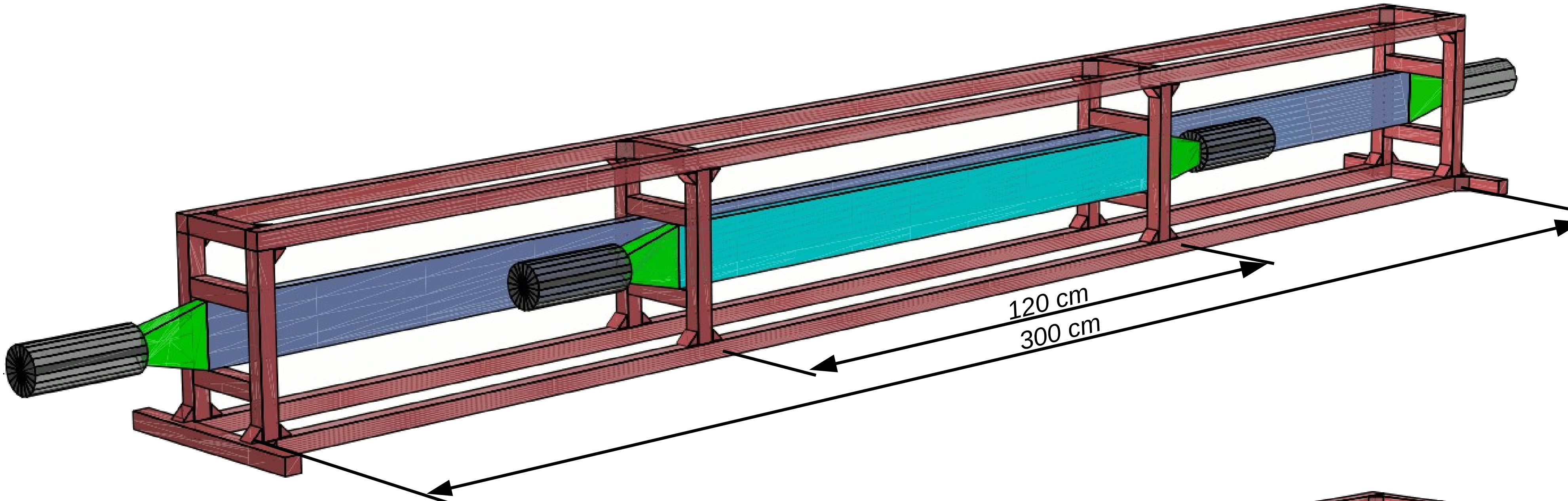
- Sensitivity of PMT and SiPM around the emission peak of EJ plastic is relatively flat
- PDE of SiPM is larger than QE of PMT: 40% vs. 25%

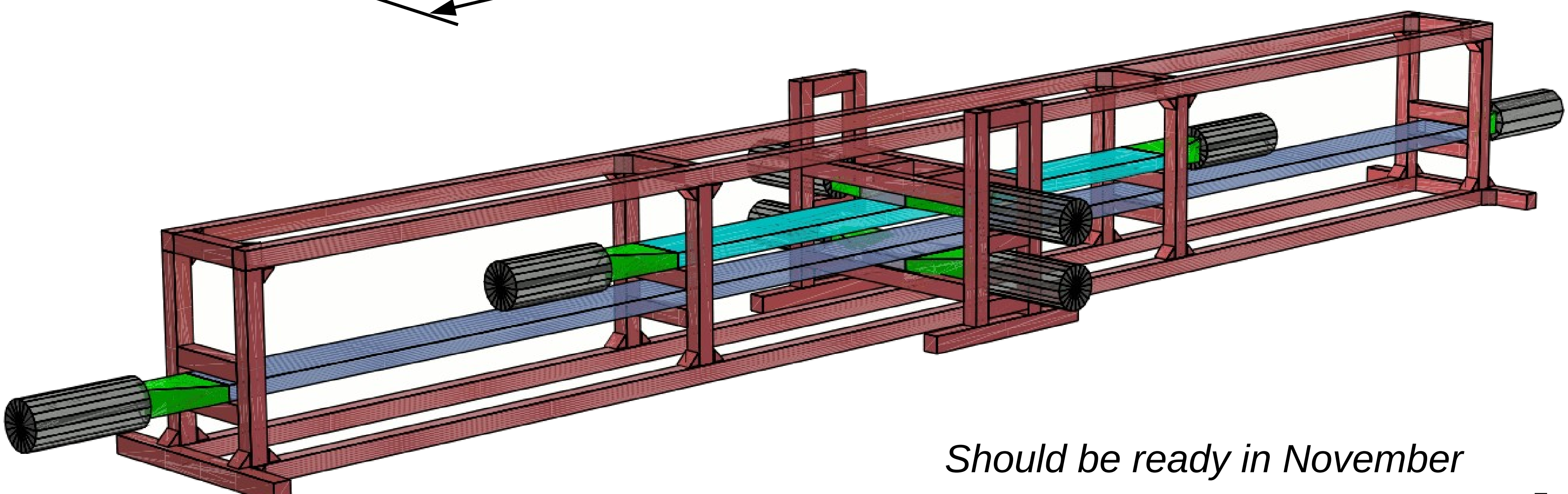


Status of the test bench construction

- Materials which have been ordered so far
  - 3 and 1.2 m bars EJ-200, fishtail lightguide
  - Wrapping material: Al foil, black stretchable film
  - Aluminum support structure
  - Two PMTs
  - DRS4 evaluation board from PSI (4 channels)
- Should be ready in November
- Test property of bars and PMTs: attenuation length, time resolution, gain ...

Test bench construction

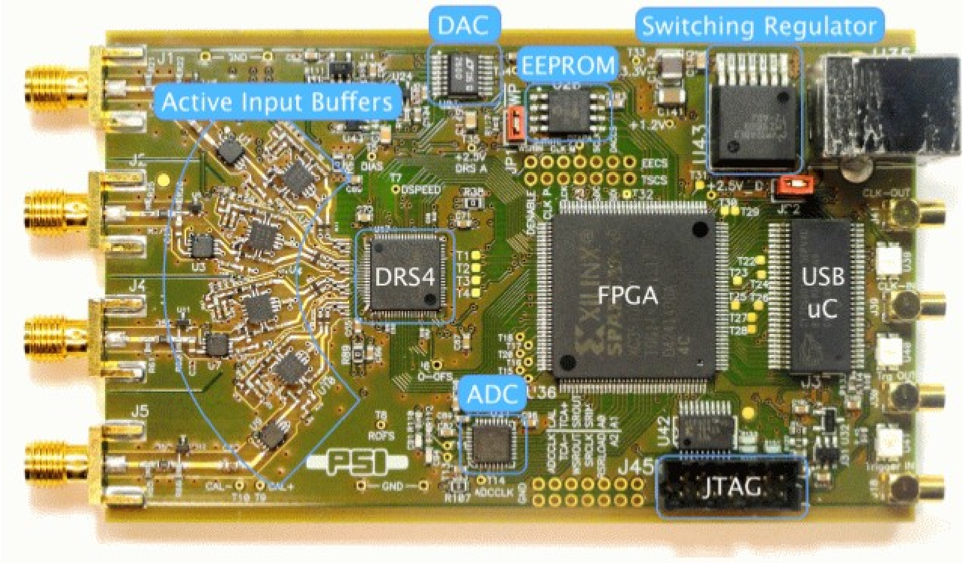


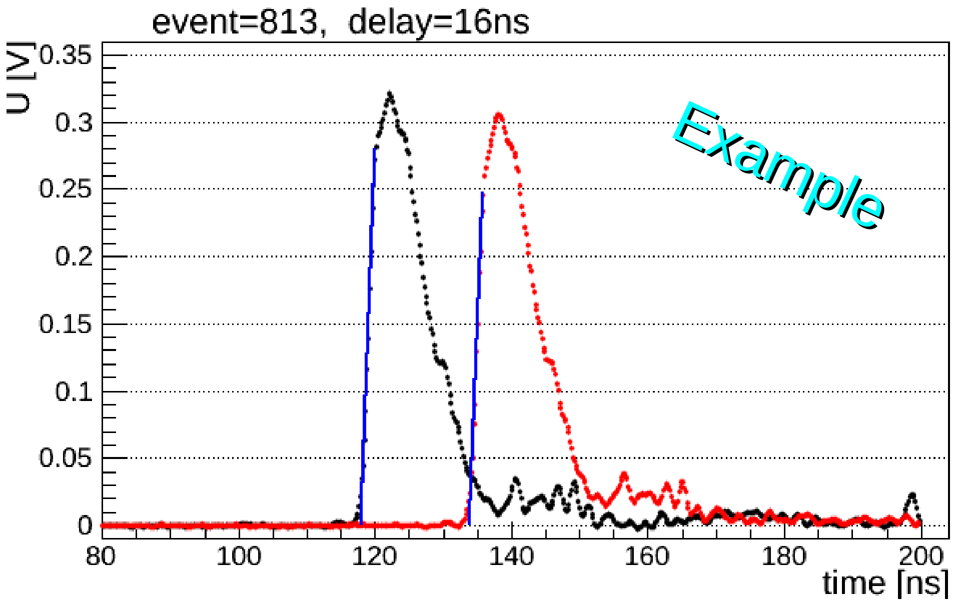


Should be ready in November

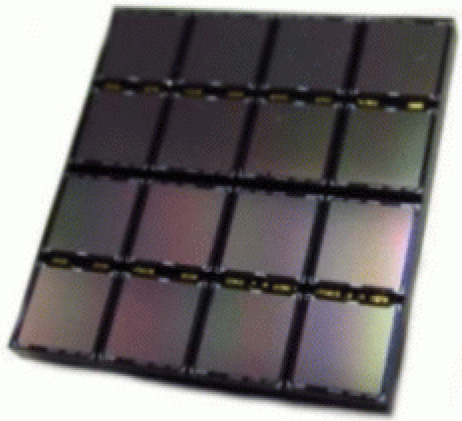
Readout with DRS4

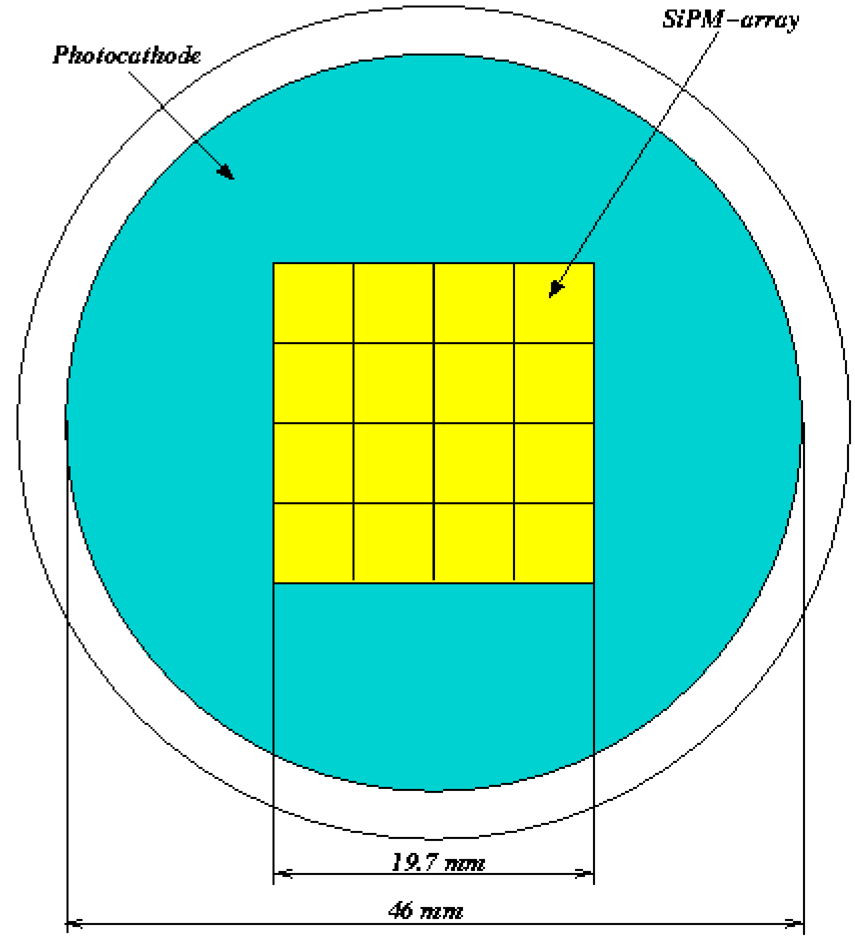
- DRS (domino ring sampler)
- Board is developed in PSI
- Switched Capacitor Array (SCR)
- Sampling speed 5 GSPS
- 1024 sampling points
- Readout time 30 us
- 4 channels
- Noise 0.35 mV after calibration
- Development of our own board is ongoing in UniGe for NA61 (8x4=32 channels/board)





Plans for the next year: readout with array of SiPMs





Features

- Detection of extremely faint light
- Very high gain (10^6)
- Extremely good timing performance
- Insensitive to magnetic fields
- Not damaged by ambient light
- Small and compact
- CSP Nickel free

NUV-SiPMs Features

- Near Ultra Violet light detection
- Superior breakdown voltage uniformity
- Excellent temperature stability

ASD-NUV4S-P-4x4T

4x4 = 16 channels, active aria of SiPM 4x4 mm^2

Evaluation board from sensL : 6x6 mm^2 sensor

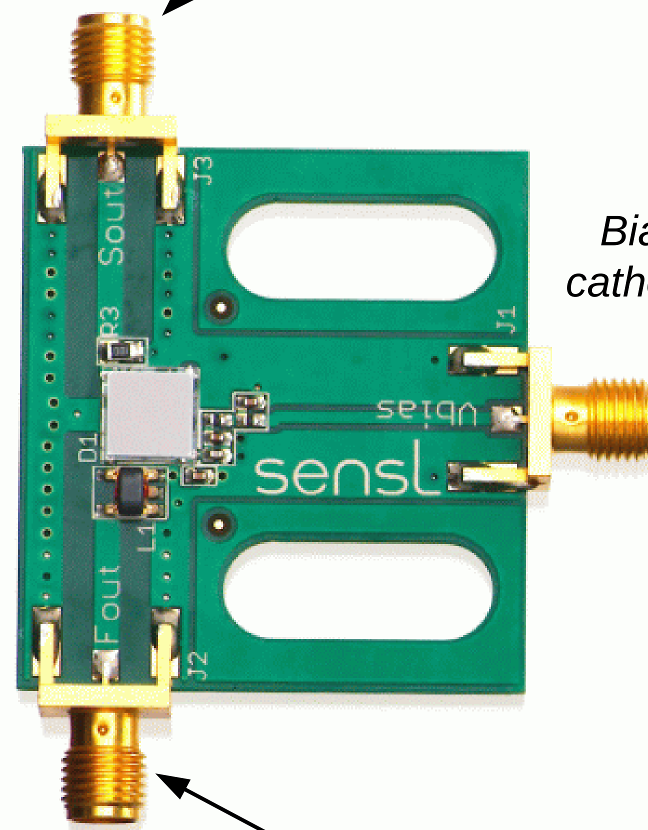
EVALUATION BOARD OPTIONS

SMA BIASING BOARD (MicroFC-SMA-XXXXX)

The MicroFC-SMA is a simple board designed to allow evaluation of the MicroFC SMT range of SiPM sensors. The board has three female SMA connectors for connecting the bias voltage, standard output from the anode and the fast output signal. The biasing and output line is laid out in such a way as to preserve the fast timing characteristics of the sensor.

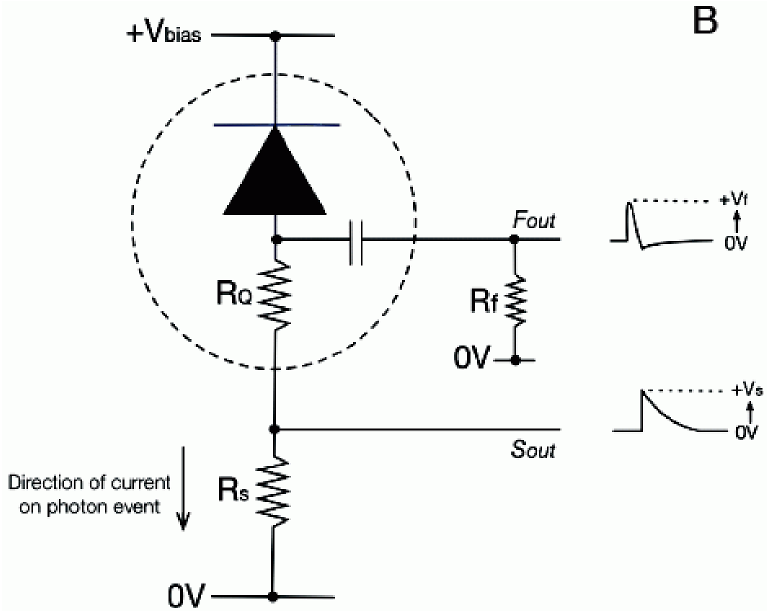
The MicroFC-SMA is recommended for users who require a plug-and-play set-up to quickly evaluate FC-Series SMT sensors with optimum timing performance. The board also allows the standard output from the anode to be observed at the same time as the fast output. The outputs can be connected directly to the oscilloscope or measurement device. The table below lists the SMA board connections.

Output	Function
Vbias	positive bias input (cathode)
Fout	fast output
Sout	standard output (anode)

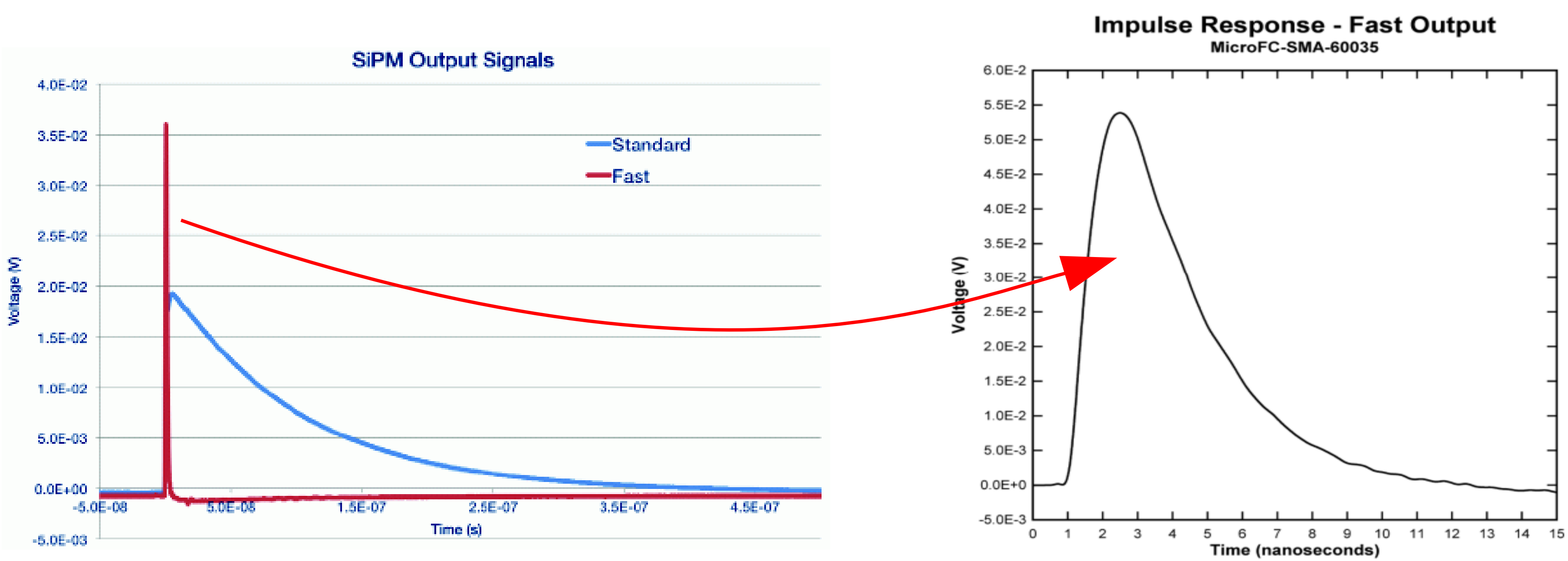


MicroFC-SMA-60035: eval board, 6 x 6 mm2, C series, 35 um
We need 2 EB. They can be used to readout light of the trigger bar

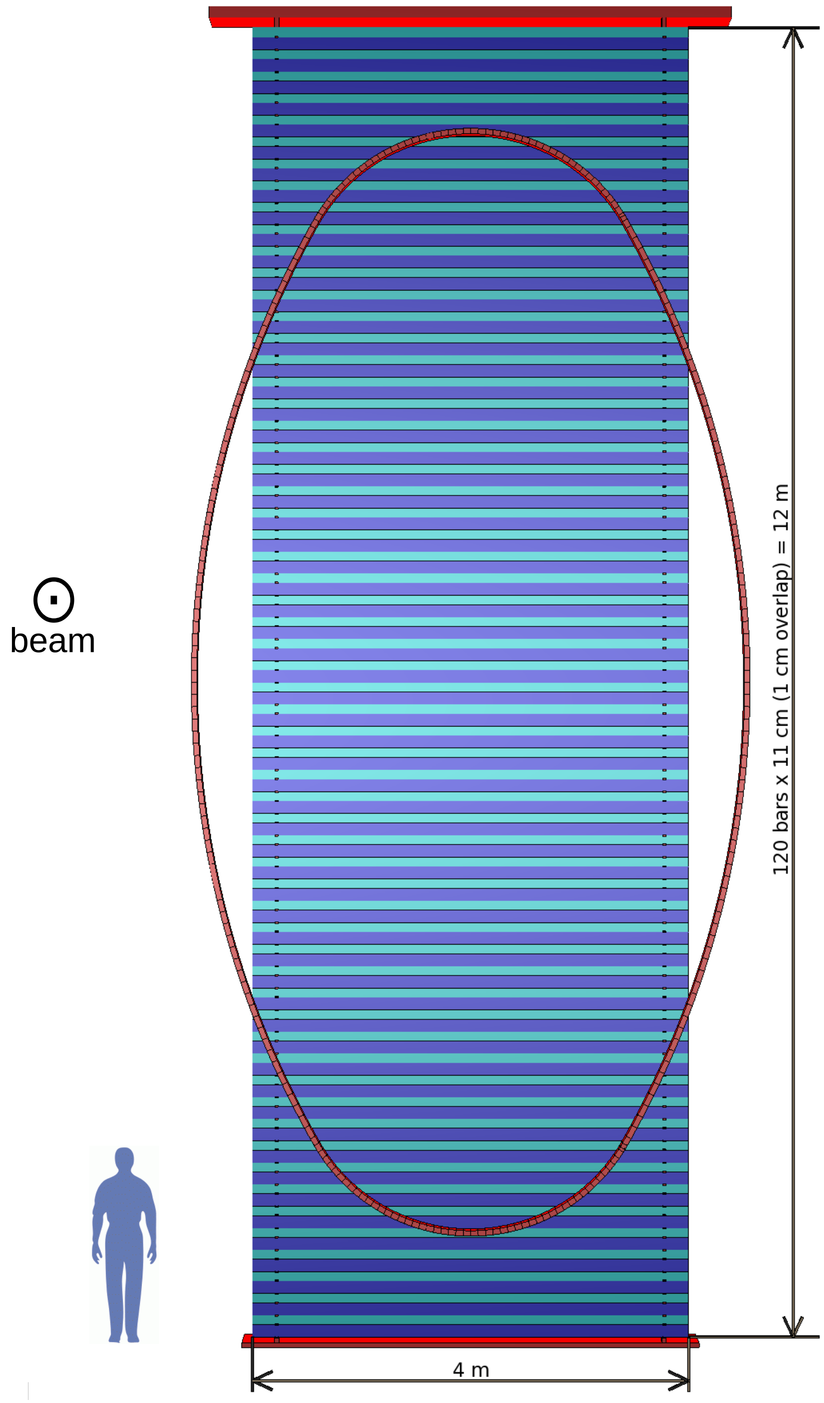
Fast output in sensL SiPM



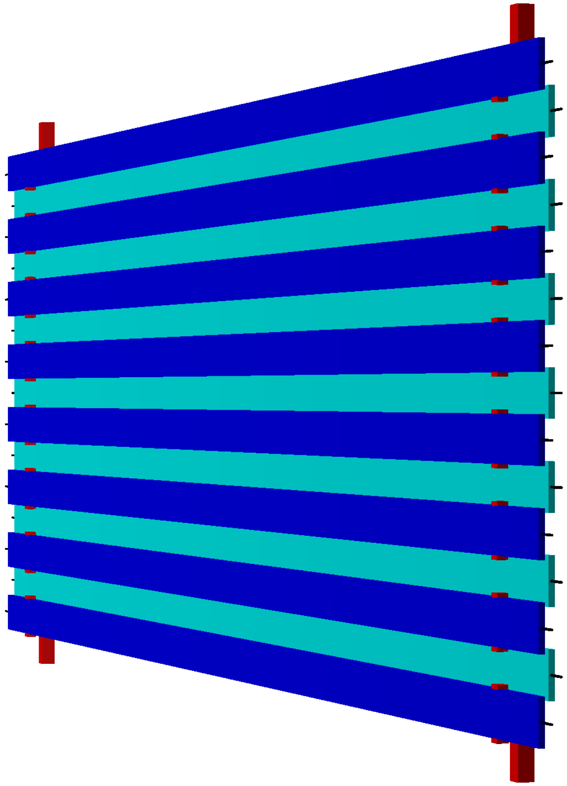
- For applications requiring simultaneous measurements of intensity and timing of light pulses
- About 2% of the SiPM charge is injected to the Fast Output
  - Pulse duration is 100 shorter ⇒ amplitude 0.02x100=2 times higher
- Rise time is ~1ns



Upstream Veto detector

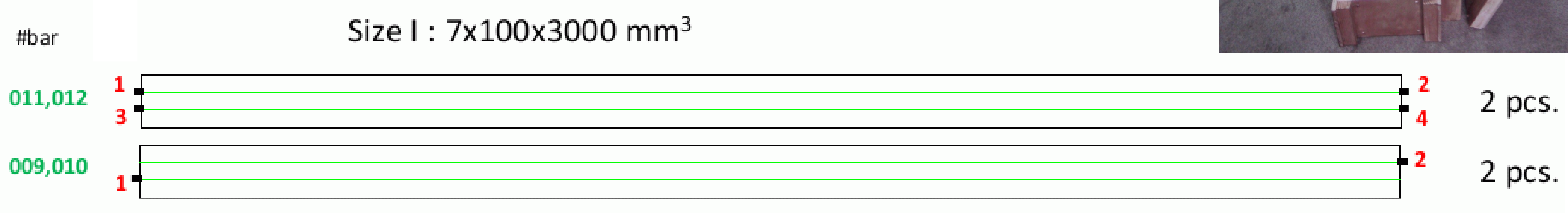


- Scintillator bars with WLS fibers and opto-electronic readout is well established technology for massive detectors
- Single column of bars 400x11x1 cm^3 which are readout from both sides by SiPM
- Extruded (cheap) plastic can be used
  - Length, width of bar can be modified
- Decay time of WLC fiber (Y11 Kuraray) is ~12 ns => Time resolution would be ~1 ns
- Support structure should be set upstream of a sensitive plane



INR bars for the prototype of the μ detector

- 6 types of scintillator bars (12 pcs) has been delivered to CERN (bld 595)
- Produced in Vladimir (group of Yu.Kudenko)
- To be used in the test beam in October
- Those which are 10 cm wide can be used for the Upstream Veto detector



Light yields in p.e. / MIP for 3 positions

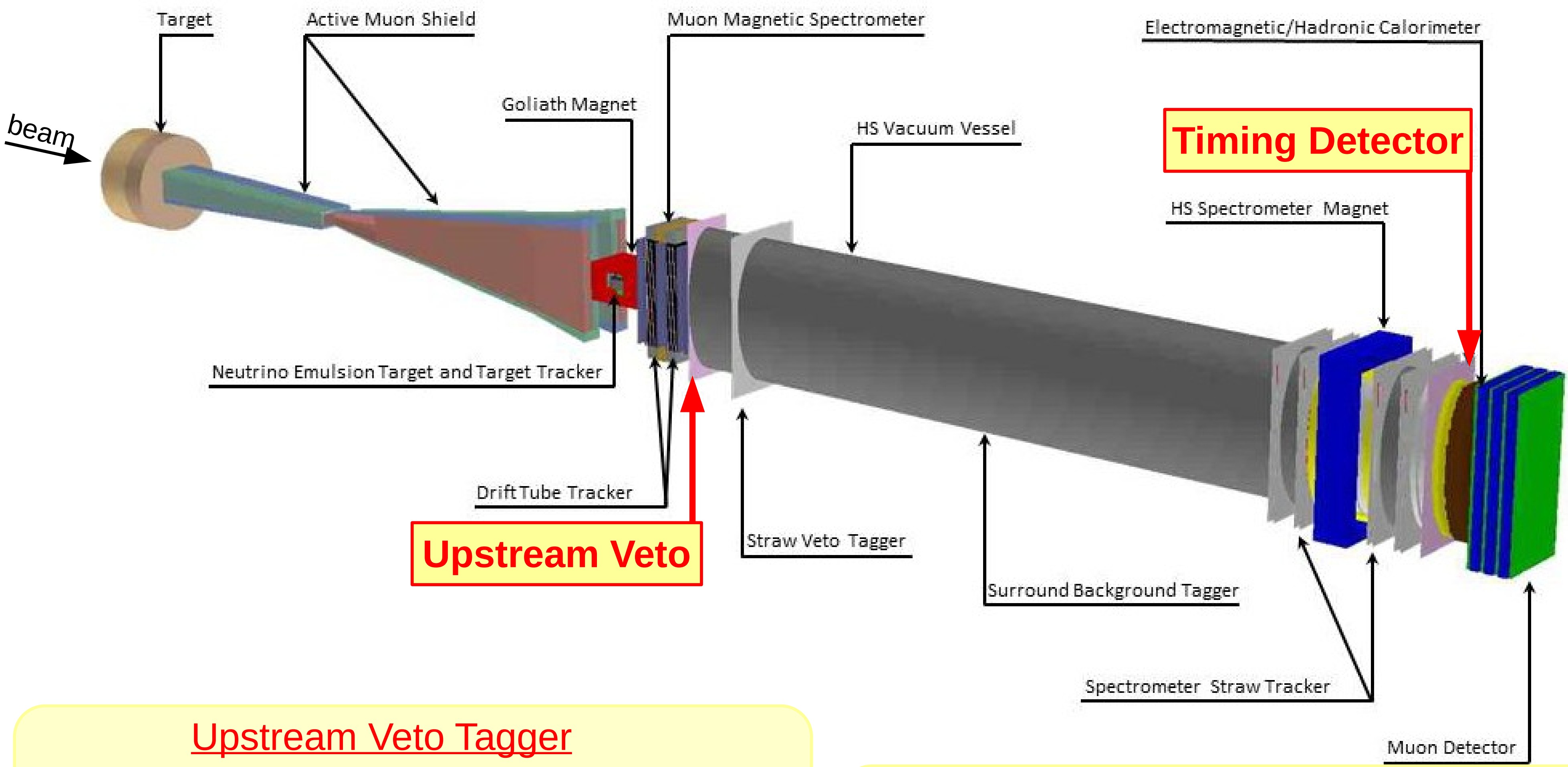
#bar			L1=2.6 m	L2=1.5 m	L3=0.4 m
009	Readout 1	Width 10 cm	10	14.1	21.6
010	Readout 1		11.6	19.7	29.3
011	Readout 1		12.5	16.3	23.3
	Readout 3		14.0	18.1	26.7
012	Readout 1		7.6	10.2	13.7
	Readout 3		8.6	11.4	16.9

courtesy of A.Khotyantsev

Conclusions

- Timing Detector
  - Materials have been ordered for the test bench (PMT readout)
    - Should be ready in November
  - Study of the readout with Array of SiPM for next year
- Upstream Veto Detector:
  - Plastic bar + WLS fiber + SiPM readout
  - Bars from INR considered as prototype

Backup



Upstream Veto Tagger

- Aim is to suppress the background source from neutral K/Λ produced by neutrino and muon interactions upstream the vacuum vessel. Also to tag muons
- Resolution should be ≲1 ns
- Extruded scintillator slabs with light collection by WLS fibers coupled to photodiods from both ends

Timing Detector

- Aim is to reduce a combinatorial background by tagging tracks belonging to a single event. Also to tag muons.
- Can be used for PID of few GeV's particles
- Resolution should be ≲100 ps
- Cast plastic slabs with light collection by PMTs or array of SiPMs from both ends

Example of a time resolution for <u>long bars</u>, GlueX/JLAB

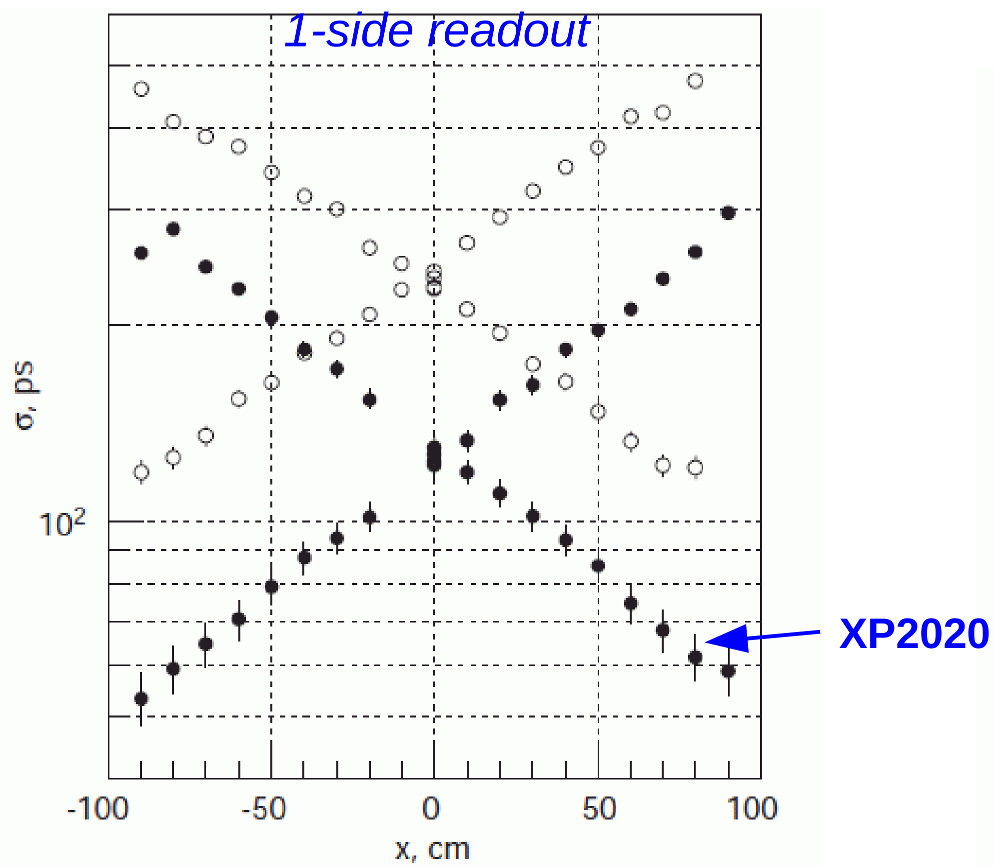


Fig. 3. The x-dependence of the time resolution of XP2020 (•) and FEU-115M (◦) PMTs for the 2.5 cm square bar.

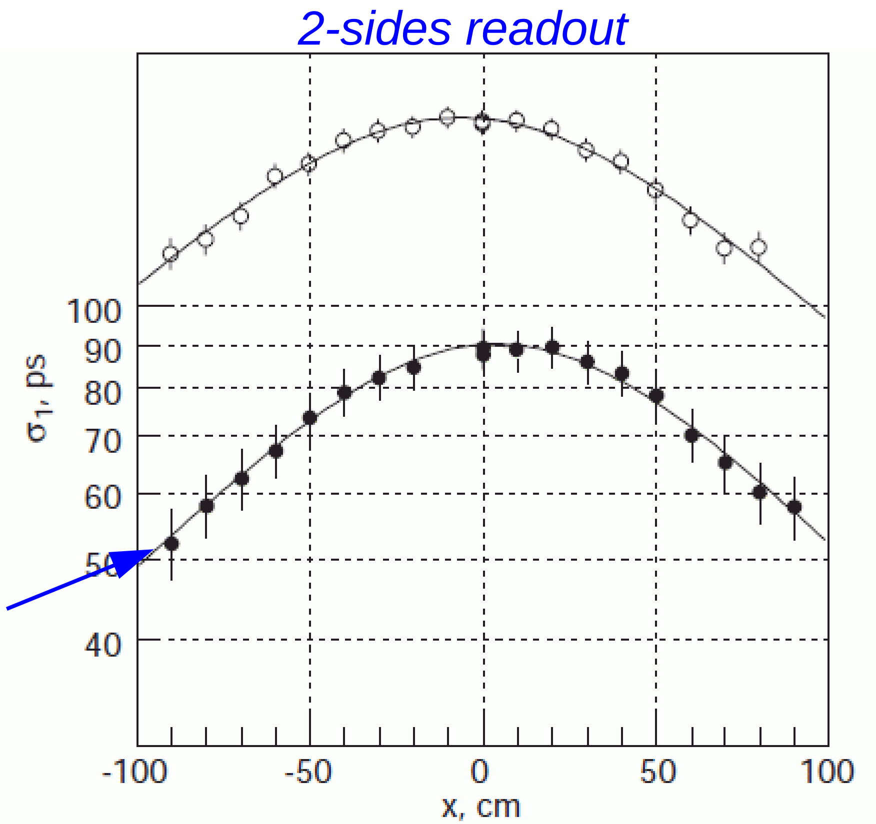
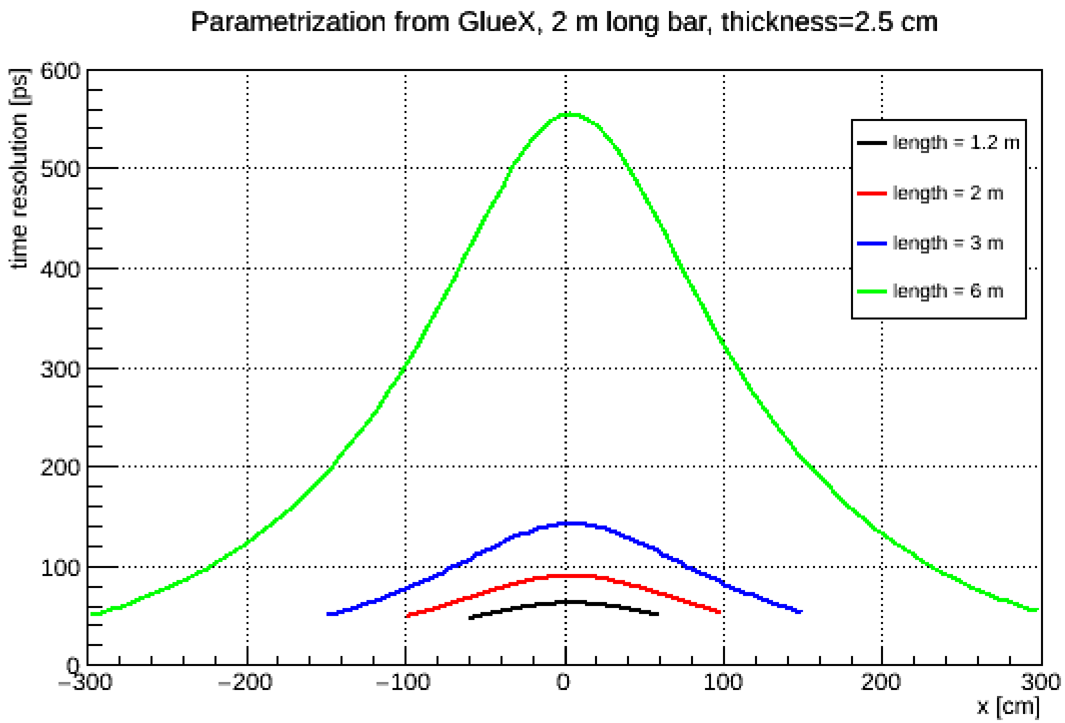


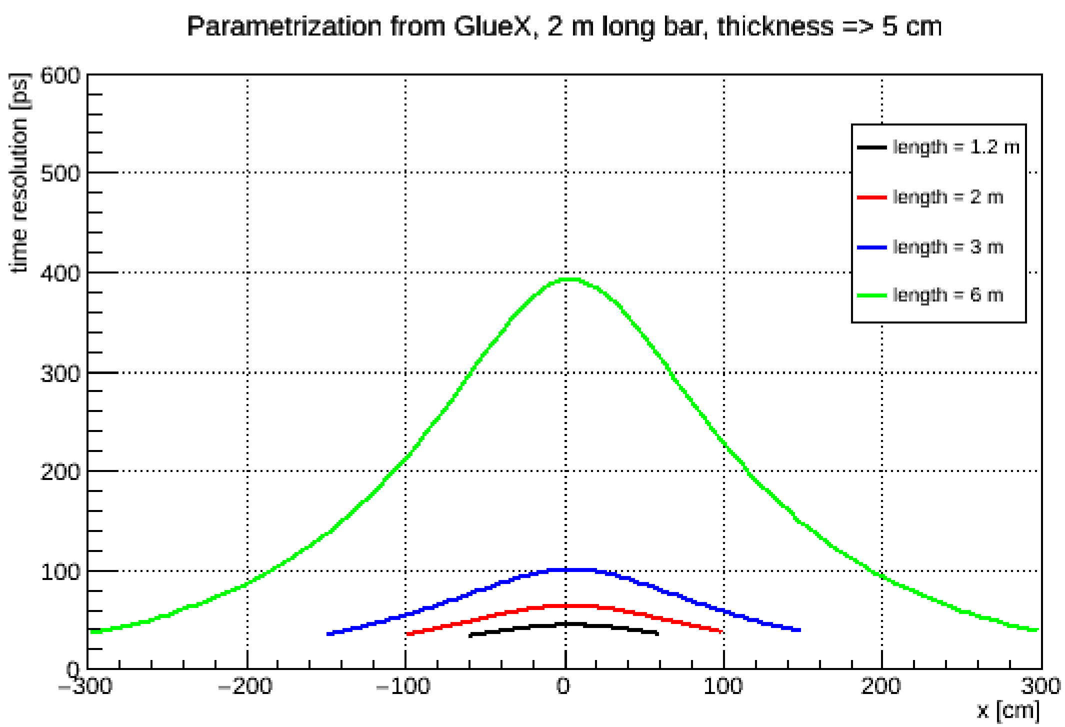
Fig. 5. The time resolution of the 2.5 cm square bar viewed by XP2020 (•) and FEU115 (◦) PMTs.

- "Systematic study of timing characteristics for 2 m long scintillation counters", S.Denisov et al., NIMA525 (2004)183
- Resolution is the best at edges (50 ps) and worse in the center (90 ps) of a bar

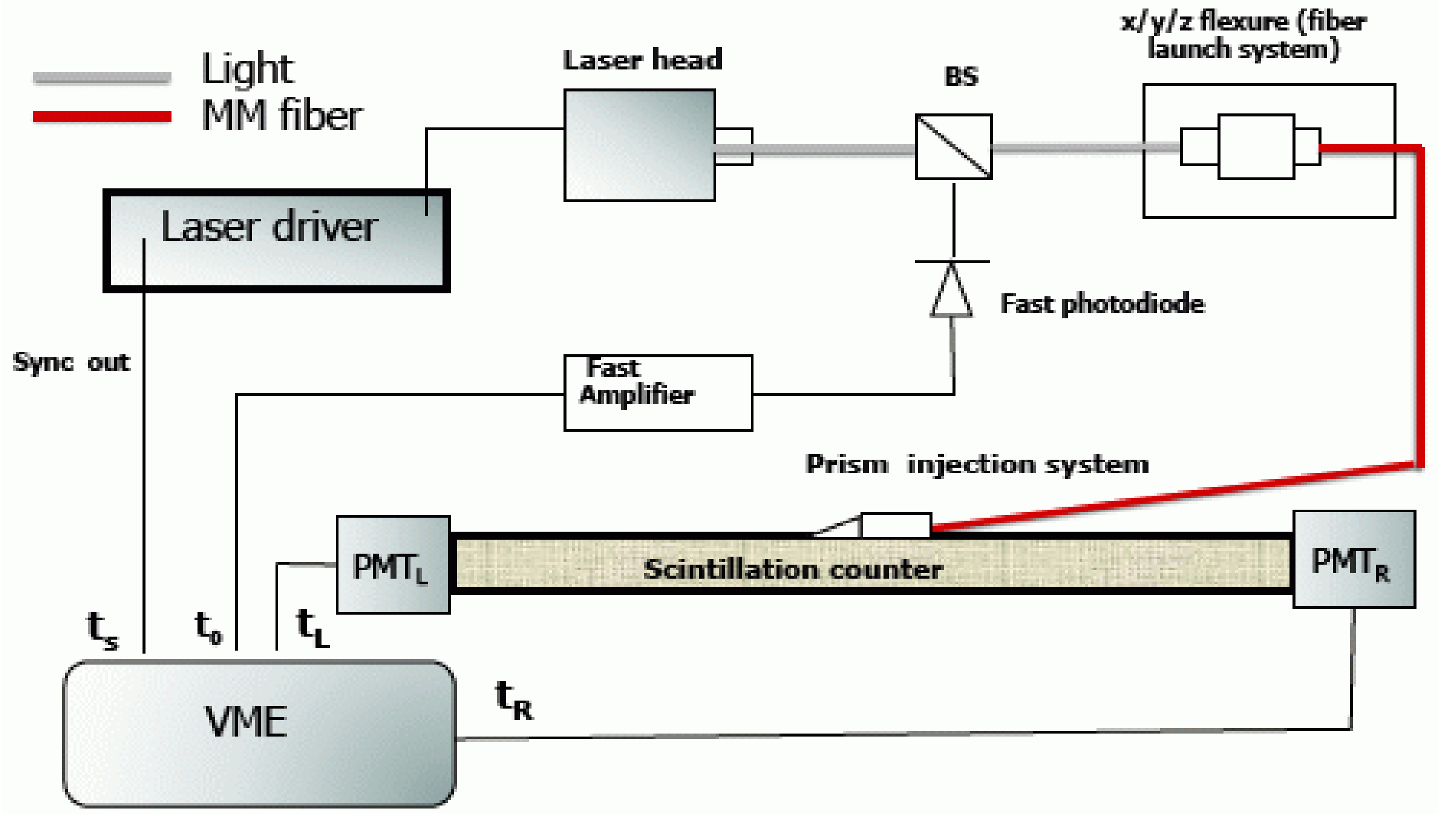


- Parametrization of GlueX for the bar of 2.5 cm thick
- Measurements for the bar up to 4 m long
- Extrapolation for 6 m bar

- If the thickness increases to 5 cm => naively the number of photons at PMT increase by a factor of 2 => precision improves by sqrt(2) = 1.4
- There is a chance for the 3 m bar to be within 100 ps resolution



Example of a test bench



- *M.Bonesini et al, Performance of SiPM array readout for fast time-of-flight detectors, 2014 JINST 9 C03044*
- Light pulser can be replaced by a small scintillator plate for the cosmics (2 more PMTs?) or we can use a radioactive source
- DRS4v5 evaluation board from PSI instead of VME electronics

SiPM option

- M.Bonesini et al, Performance of SiPM array readout for fast time-of-flight detectors, 2014 JINST 9 C03044

Table 1. Main characteristics of used SiPMT arrays.

	$V_{brk}(V)$	Bias range (over V_{brk})	$\lambda_{\max}(nm)$	PDE (at $\lambda_{\max}$)
Hamamatsu S11828-3344	65 ± 10	1-4	440	$\sim 35\%$
SenSLArray SM-4-3035-CER	27.5 ± 0.5	1-5	500	$\sim 20\%$
Advansid ASD-SiPM3S-4x4A	35 ± 7	2-7	480	$\sim 22\%$

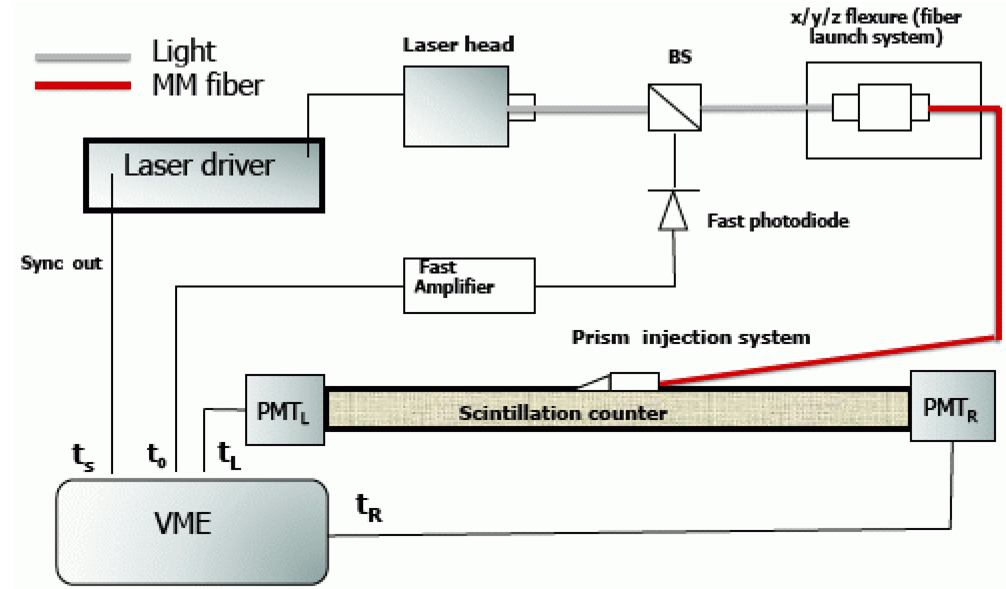
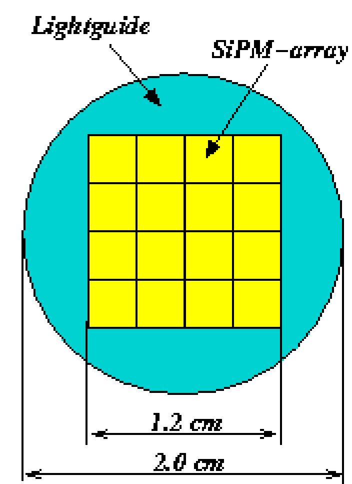


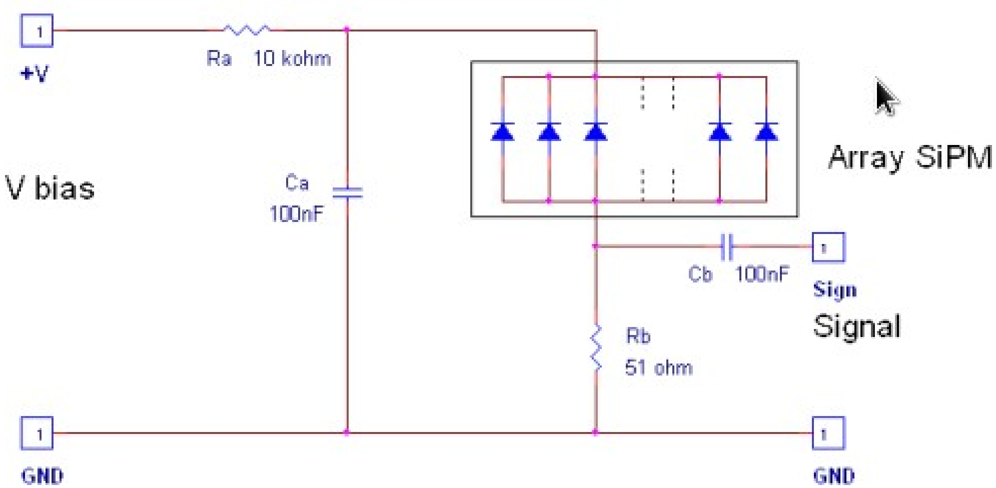
Table 2. $10-90\%$ risetime and falltime measured for the SiPMT arrays under test, with V_{op} in an extended range around V_{brk}. The leading edge tr_R is negative (Fall) with the inverting amplifier and positive without it (Rise). The reverse for the trailing edge tr_F.

		no amplifier		amplifier	
	$V_{op}(V)$	tr_R (ns)	tr_F (ns)	tr_R (ns)	tr_F (ns)
Hamamatsu S11828-3344 (cosmics)	72.5 - 74	10-20	160-280	~ 4	15-20
Hamamatsu S11828-3344 (laser)	72.5-74	8-15	≥ 270	~ 3	14-20
Advansid ASD-SiPM3S-4x4A (cosmics)	29.5 - 31.5	12 -15	≥ 400	3-4	13-20
Advansid ASD-SiPM3S-4x4A (laser)	29.5 - 31.5	7-14	≥ 400	2-3	10-27
SenSL SM-4-30035-CER (cosmics)	29.0 - 32.0	20-32	120-170	8-14	34-40

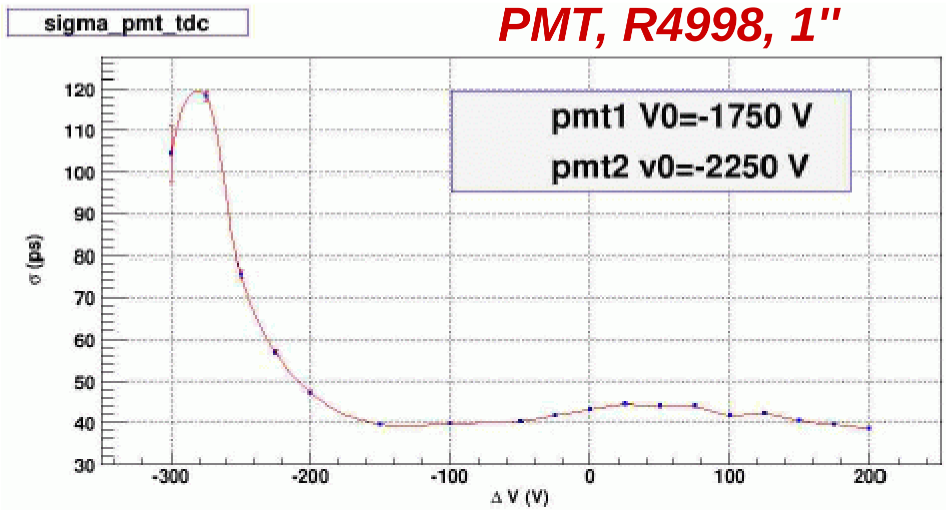


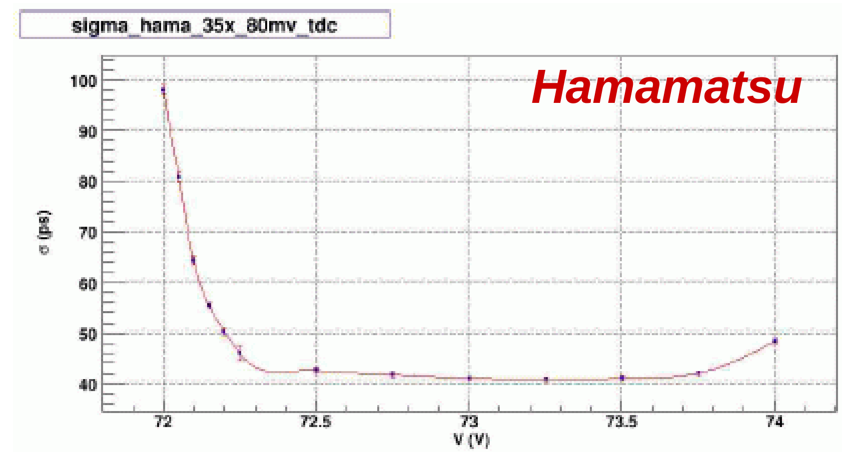
Readout chain for SiPMT arrays

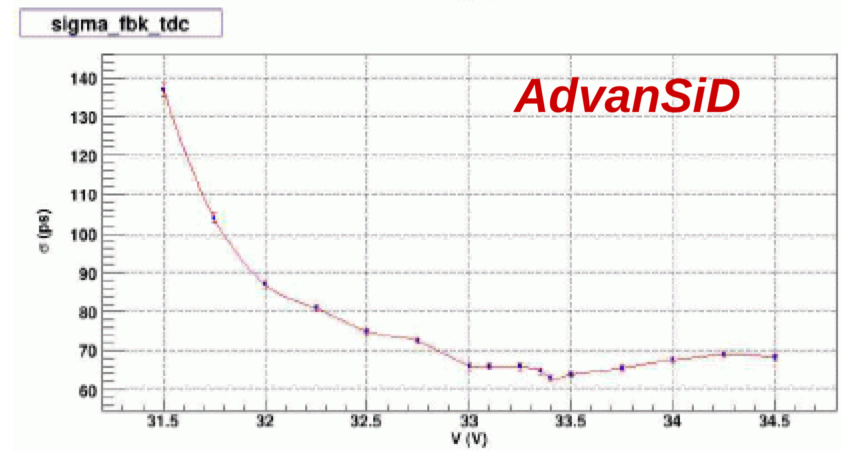
- SiPMT array custom mount
- 16 macrocells signals are summed up in the basette and then amplified



Results on the time resolution







- Conclusion: SiPM-array provides a similar time resolution as PMT:
  - 40 ps for 60 cm long bar of BC404

Present situation

- Arrays of SiPM from all companies are provided without preamplifies (unless preamplifier is not needed)
- Both engineers in UniGe are presently busy
- Now we can order 2 evaluation boards from sensL to learn how to work with the fast output. They can be used for trigger
- We can propose the collaboration to Bonesini
- In general the strategy should be similar to the one described in the Bonesini's paper
  - Working setup with PMT for reference
  - SiPM-arrays of smaller sizes from Hamamatsu, sensL and AdvanSiD
  - Large size arrays of SiPMs

To do

- Order materials
  - 3 and 1.2 m bars EJ-200, fishtail lightguide, 2 eval boards of 6x6 mm2 from SensL ≈ 6 kCHF
- Test property of bars and PMTs (attenuation length, time resolution, gain)
- Learn how to work with a large size SiPM
- Order arrays of SiPMs: Hamamatsu, SensL, AdvanSiD