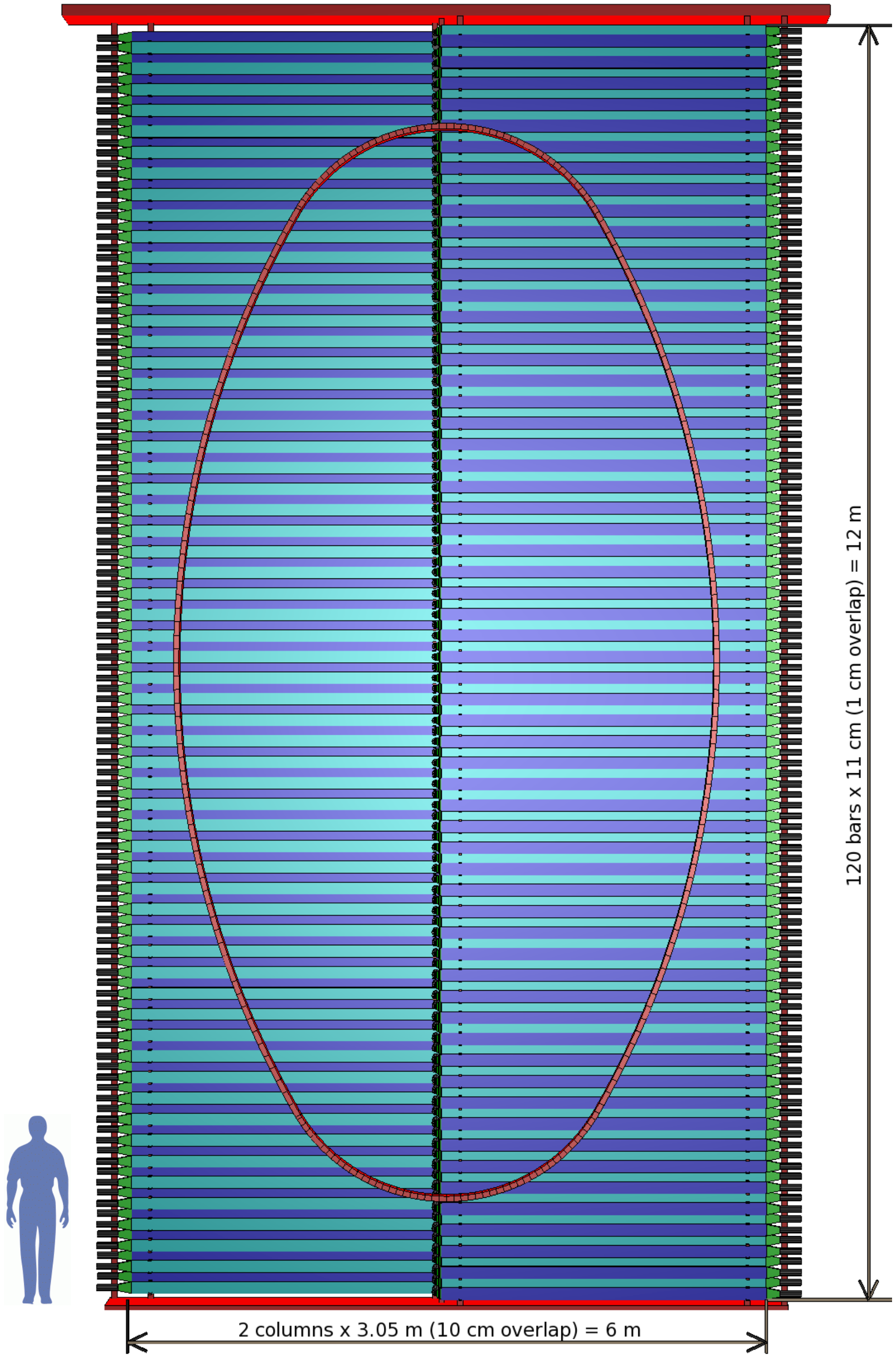
Timing detector (plastic option).
Status of the test bench measurements

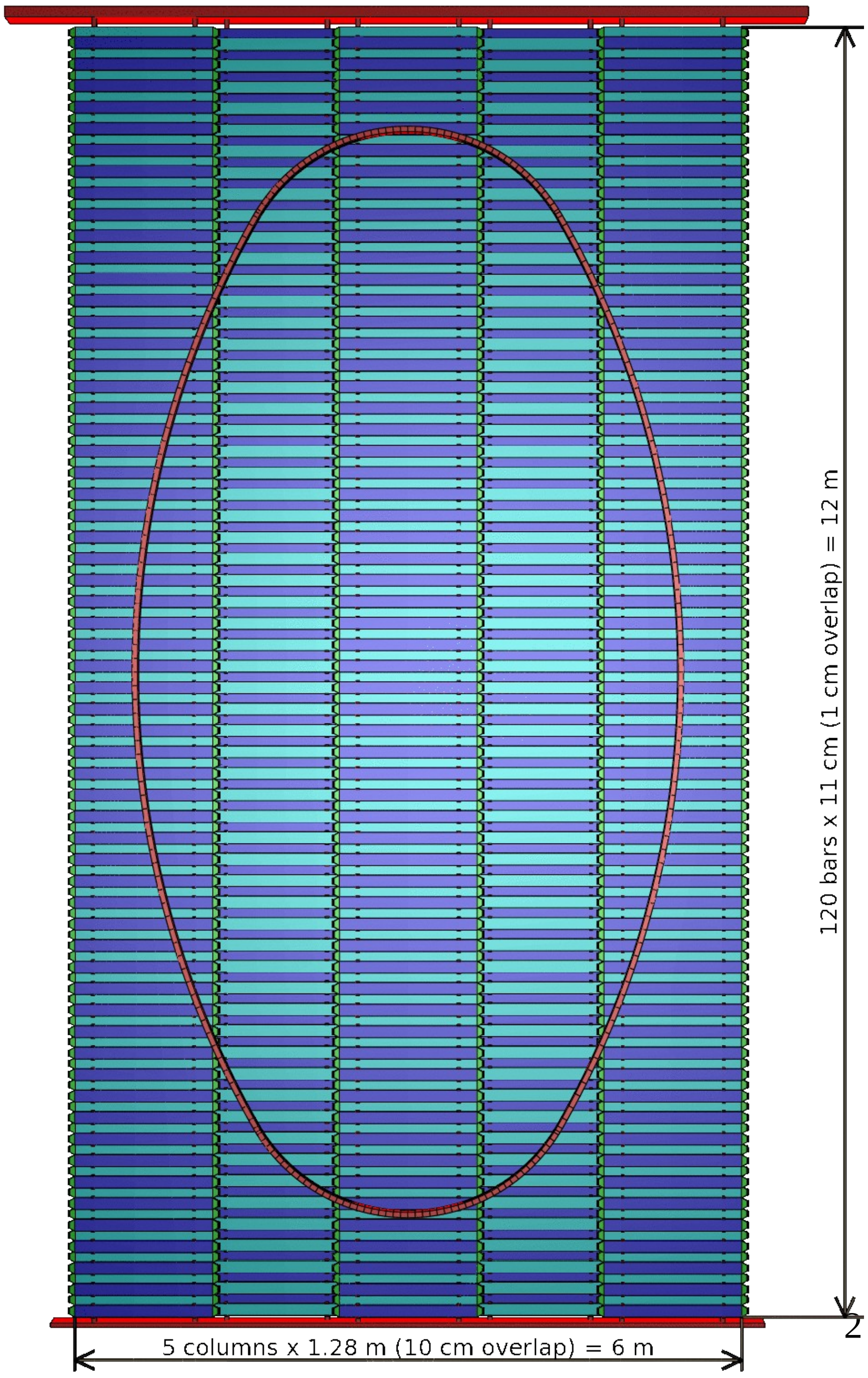
Alexander Korzenev, University of Geneva
on behalf of the Geneva-Zurich group

Collaboration meeting in CERN
Feb 11, 2016

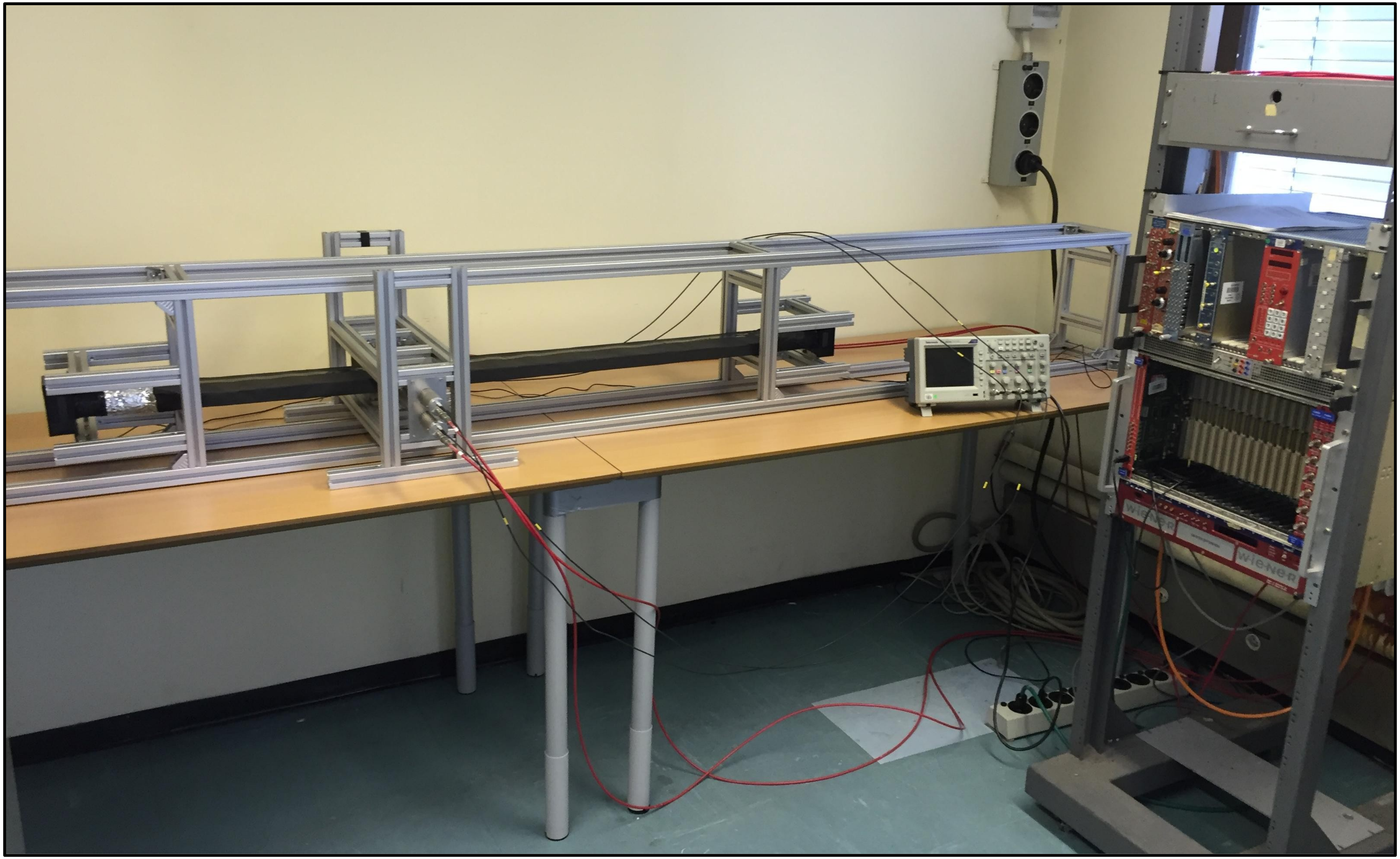
Timing Detector: PMT option



Timing Detector: Array-SiPM option



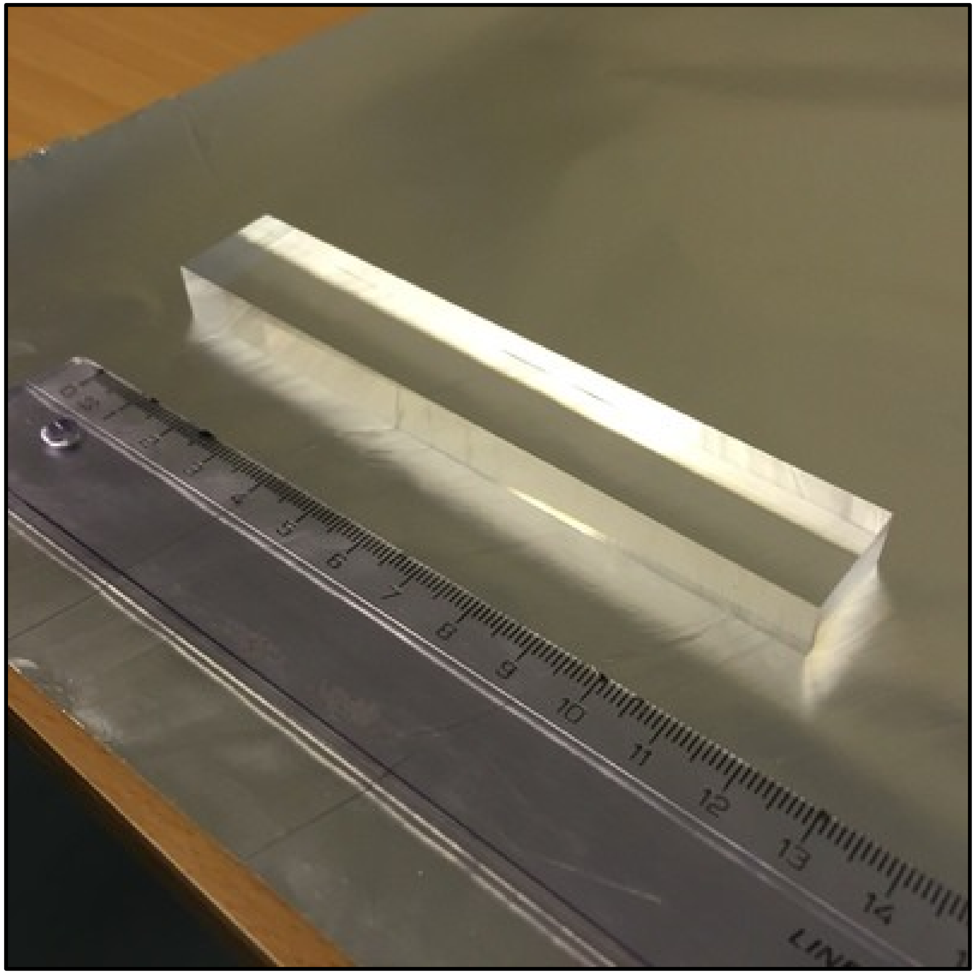
Test bench in UniGe's lab in CERN 595 R-005



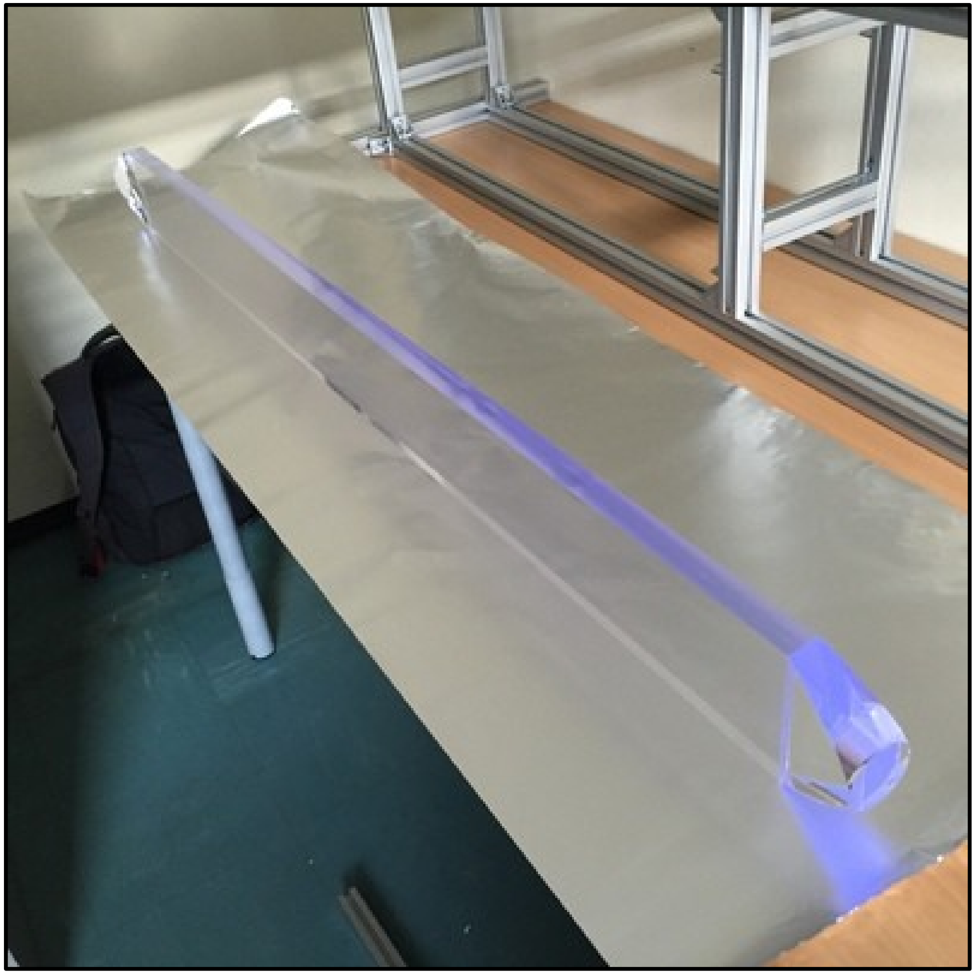
Bars 1.2 m and 3 m long have been delivered to CERN ~2 weeks ago.
+ two 12 cm long sticks for the cosmic trigger

Bars which are used presently for tests

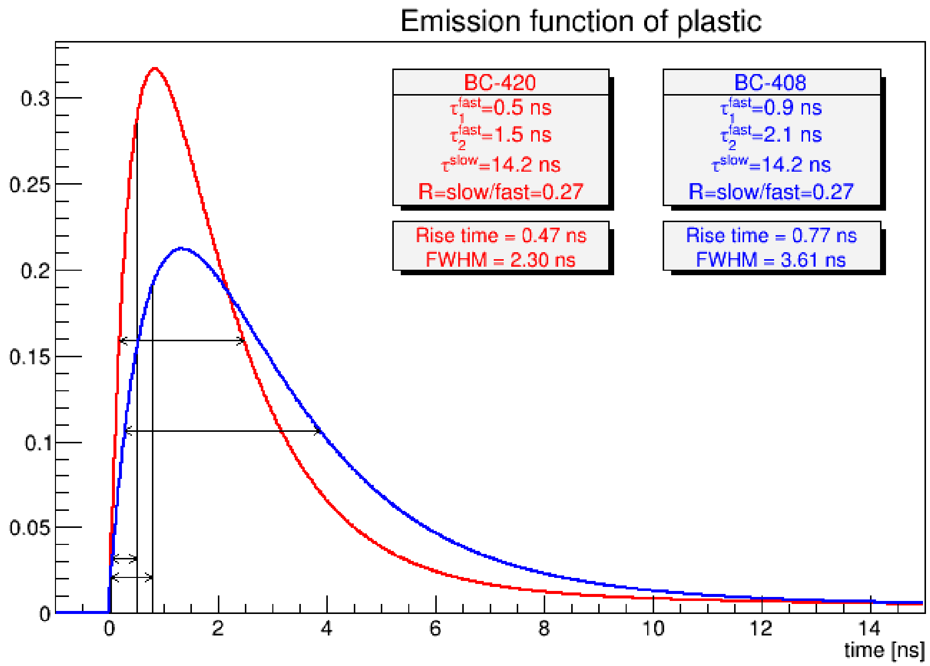
Trigger bars: EJ-230, size 12 x 2 x 1 cm^3



Detector bar: EJ-200, size 120 x 11 x 2.5 cm^3



Emission time distribution in plastic



$$E(t) = \frac{1}{1+R}\left[\frac{e^{-t/\tau_2} - e^{-t/\tau_1}}{\tau_2 - \tau_1} + R\frac{e^{-t/\tau_3}}{\tau_3}\right]$$

- τ_1 and τ_2 are decay constants of the fast two step scintillation cascade
- τ_3 is the decay time of the slow component
- *R* is the ratio of the light slow to fast components

SAINT-GOBAIN CRYSTALS	ELJEN Technology	Light output	Wavelength	Rise time	Decay time	Att. length
BC-408	EJ-200	64 %	425 nm	0.9 ns	2.1 ns	~3.8 m
BC-420	EJ-230	64%	391 nm	0.5 ns	1.5 ns	~1.0 m

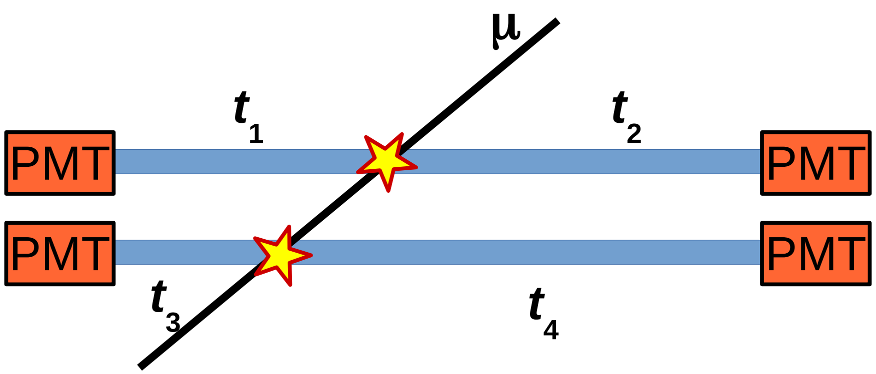
Detector's bars 1.2 and 3 m

Trigger bars 12 cm

Measurements with the PMT readout

- Cosmic trigger bench (reference counter, 12 cm)
  - Fast plastic EJ-230
  - 4 PMTs Philips XP2972
- Main bench (bar 1.2 m long)
  - Plastic with long attenuation length EJ-200
  - 2 PMTs Hamamatsu R13089-10

Time resolution of the reference counter



- To be determined before the main measurements and to be subtracted later
- Time resolution of the reference counter should be much better the the one of the main bar

- The time of the interaction t_0 for a single bar could be calculated as

$$\left.\begin{aligned} l_1 &= v(t_1+t_0) \\ l_2 &= v(t_2+t_0) \end{aligned}\right\} \Rightarrow \quad t_0 = \frac{l_1+l_2}{2v} - \frac{t_1+t_2}{2}$$

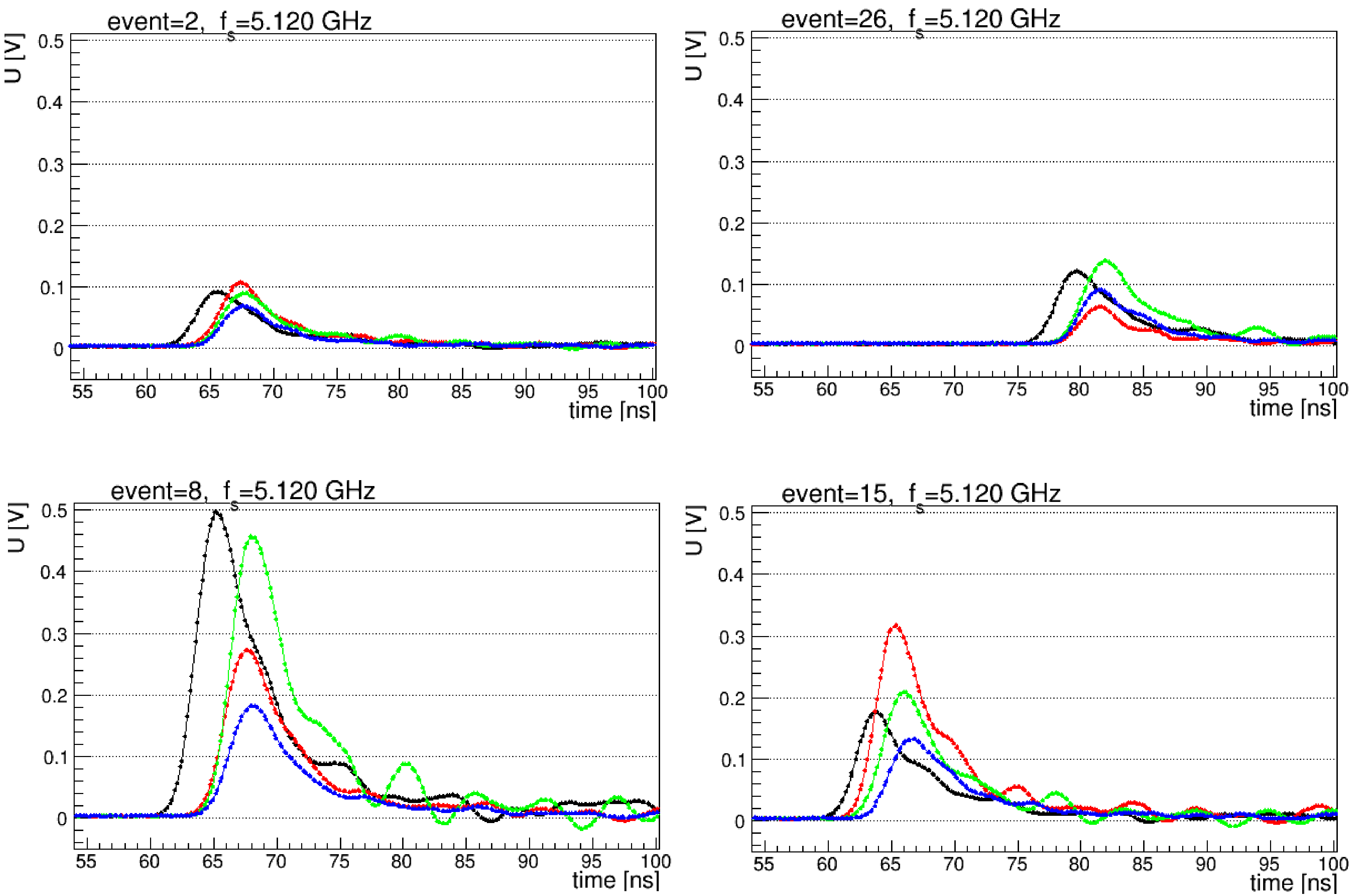
- Time measured by the main bar is average of the top and bottom measur.

$$t_0^{main} = \frac{t_0^{top}+t_0^{bot}}{2} = \frac{l}{2v} - \frac{1}{2}\left(\frac{t_1+t_2}{2} + \frac{t_3+t_4}{2}\right)$$

- For the determination of the resolution is more convenient to use

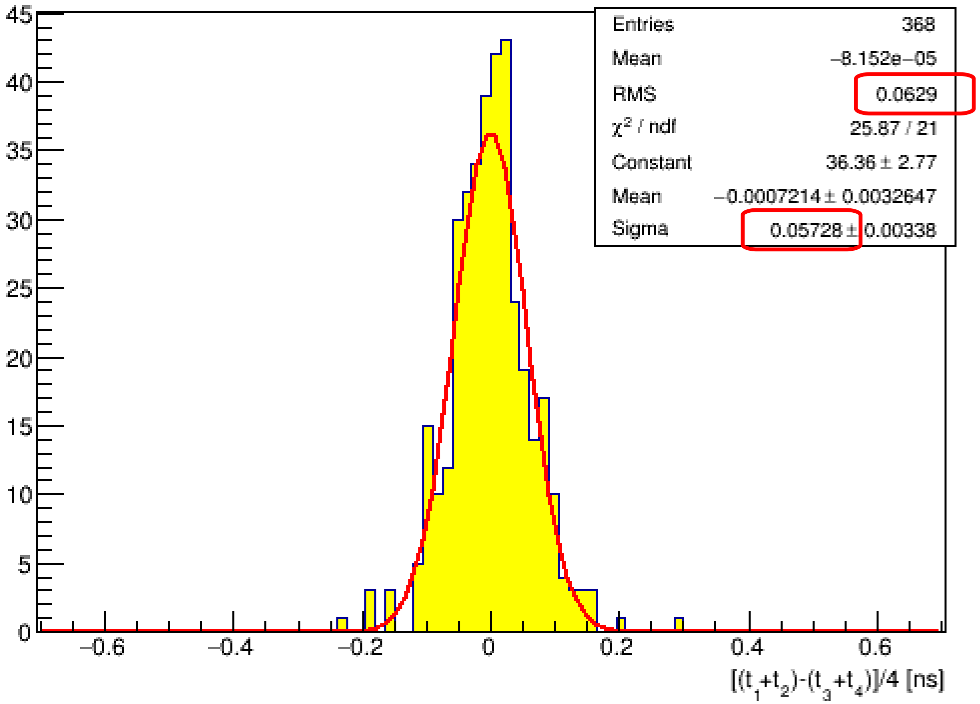
$$\Delta t = \frac{(t_1+t_2)-(t_3+t_4)}{4}$$

Examples of typical cosmic-trigger signals (readout by DRS4/PSI)

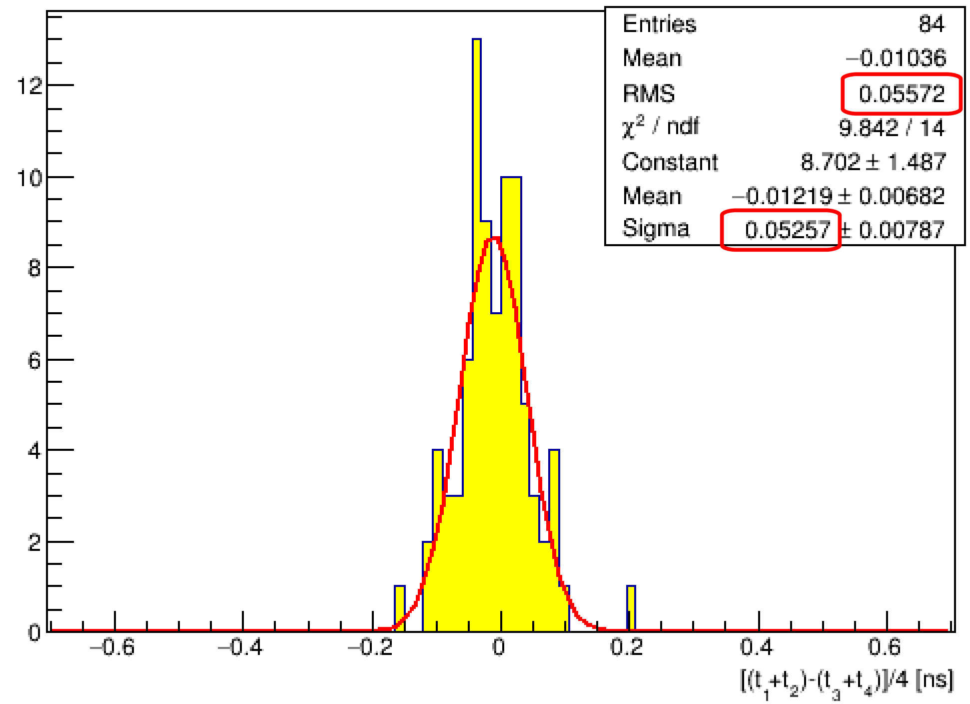


Time resolution of the reference counter system

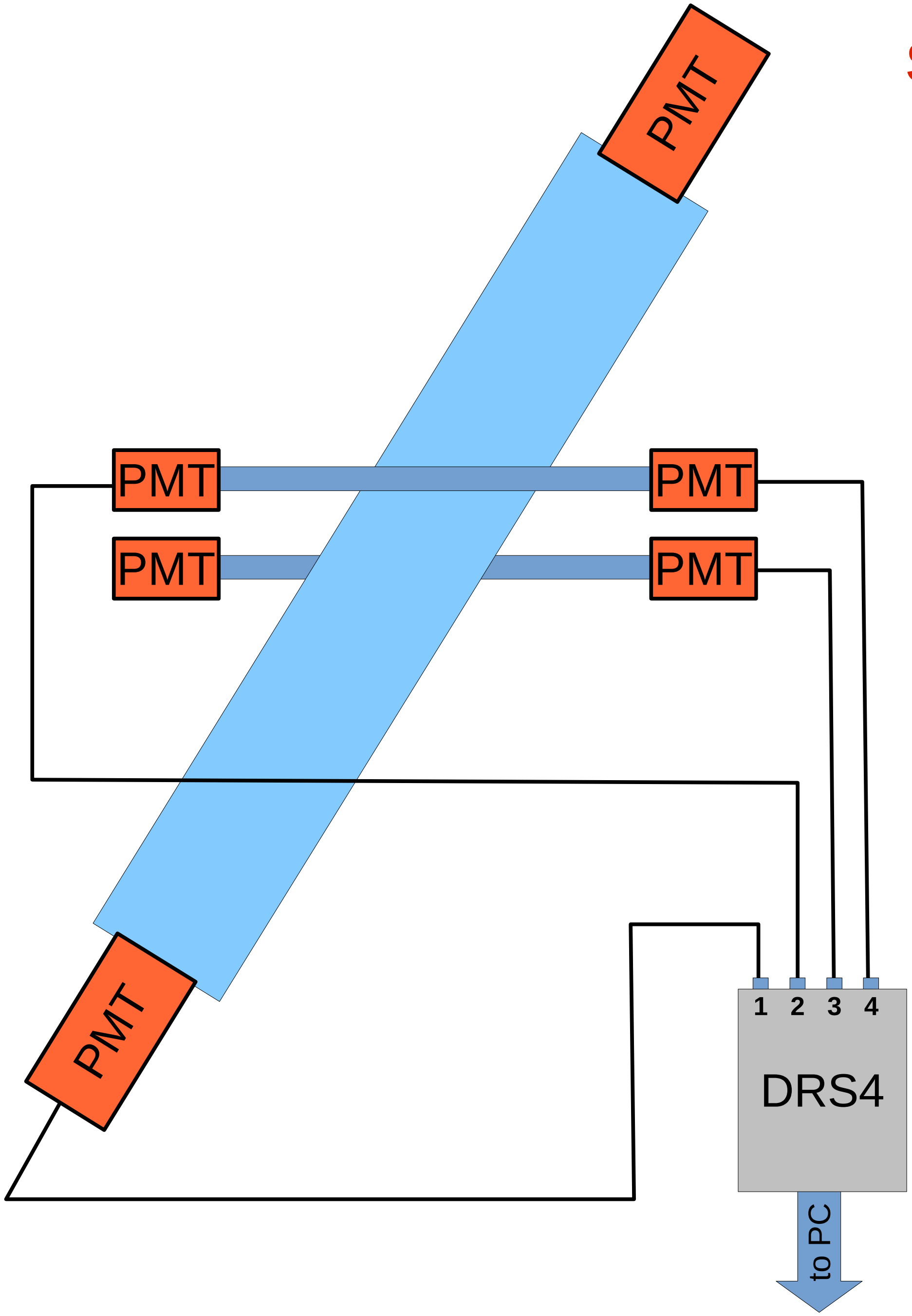
Minimum energy deposition: Integr > 0.3



Minimum energy deposition: Integr > 0.6



- The time resolution of the cosmic counter system is ~60 ps
- Should be improved in future
  - Better PMT: rise time 2 → 0.7 ns, TTS 500 → 150 ps
  - Thicker trigger counter: 1 → 2.5 cm



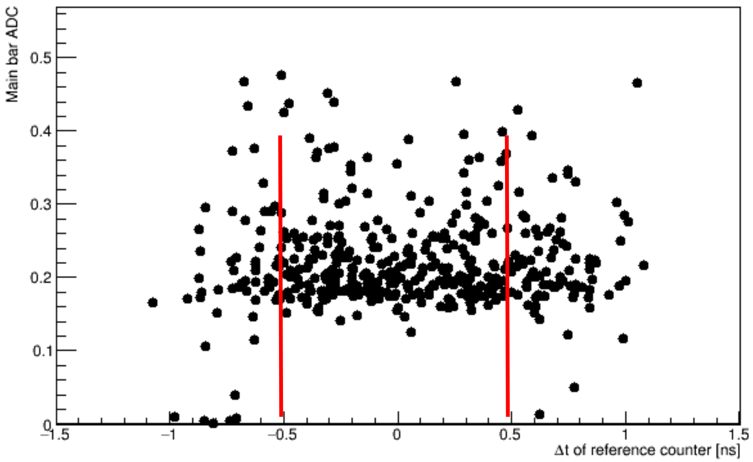
Study of Attenuation Length

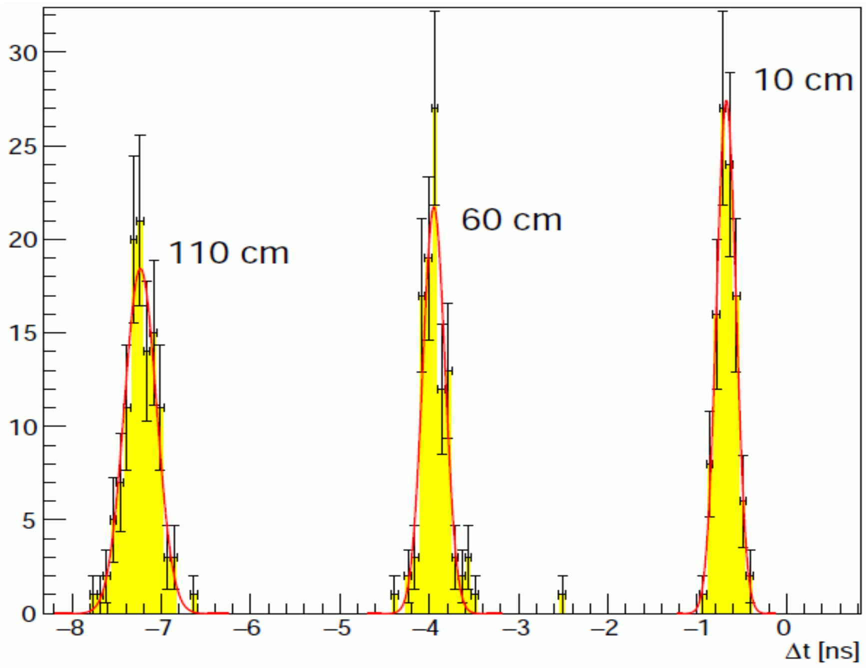
- Only 4 DRS4/PSI channels available for the readout
  1. PMT under study
  2. Trigger + time measurements
  3. Trigger
  4. Trigger + time measurements
- Time resolution of the reference (cosmic) counters degrades $\sigma_t = 60\ \text{ps} \times \sqrt{2} = 85\ \text{ps}$
- The sigma of the following distribution is measured:

$$\Delta t = \frac{t_2 + t_4}{2} - t_1$$

Time response of the 1.2 m bar w.r.t. the reference counter

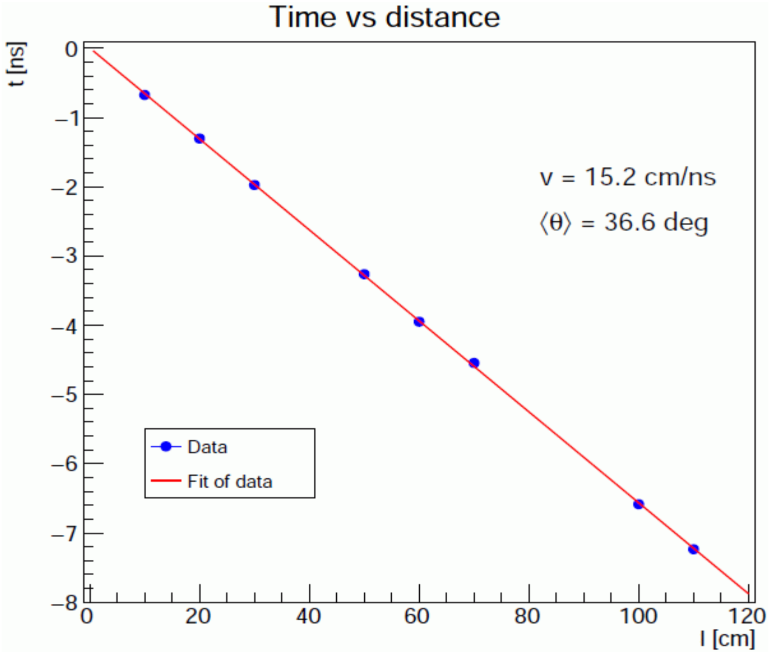
- Additional cut was applied to account for inefficiency (spacial mismatch)
  - Width of the main bar is 11 cm but length of the trigger counter is 12 cm
  - Time cut: $|t_1^{ref} – t_2^{ref}| < 0.5$ ns
- Can be a bit dangerous since the resolution changes in transverse direction





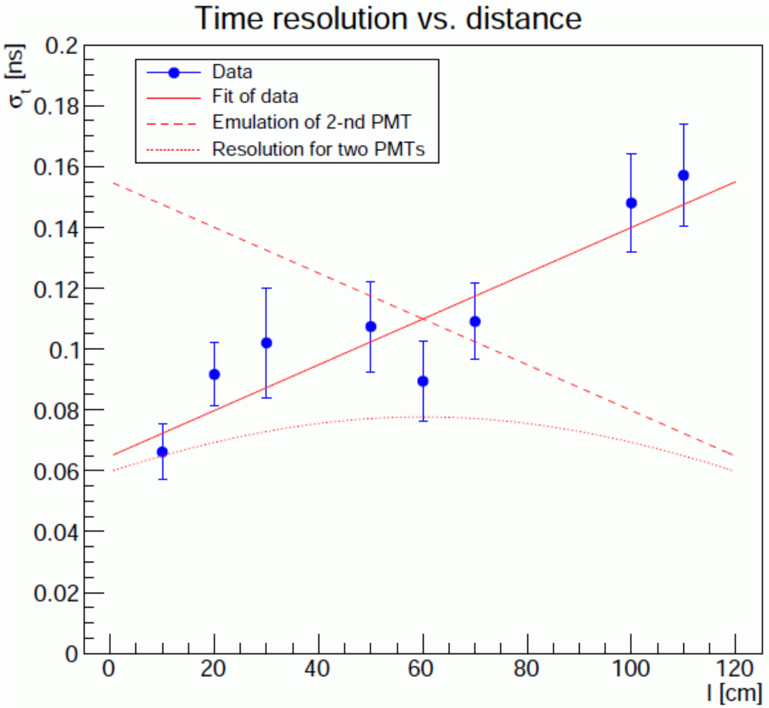
- Example of the time measured by the main bar with respect to the reference counter
- The further from the PMT the worse resolution

Time resolution as a function of distance



- Mean value of the fit as a function of distance gives the velocity of the light signal in the bar
- The average angle of the light with respect to the bar axis is:
  $\theta = \mathrm{acos}(n \times v / c) \approx 36$ deg

- Sigma of the Gaussian as a function of distance give the relative resolution
- The time resolution of the reference counter (85 ps) is subtracted
- Spread due to the finite size of the counter along the main bar axis (2 cm) is also subtracted (30 ps)



SiPM study

- Two evaluation boards from SensL: 6x6 mm^2, without amplification
- SiPMs from Hamamatsu: 3x3 cm^2 and 6x6 mm^2. To be used with our own preamplifier

MicroFC-SMA-60035 (6x6 mm^2 sensL)

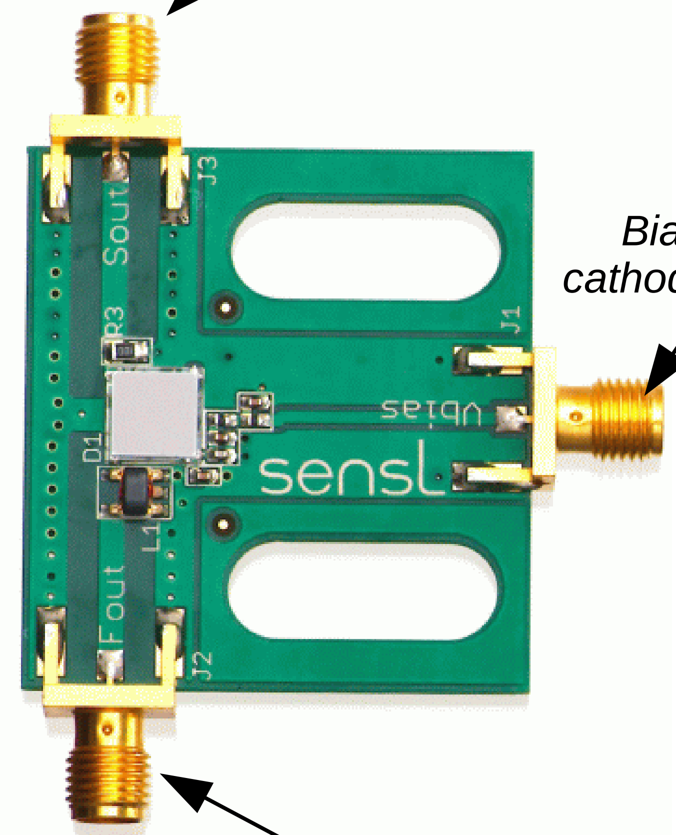
EVALUATION BOARD OPTIONS

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.

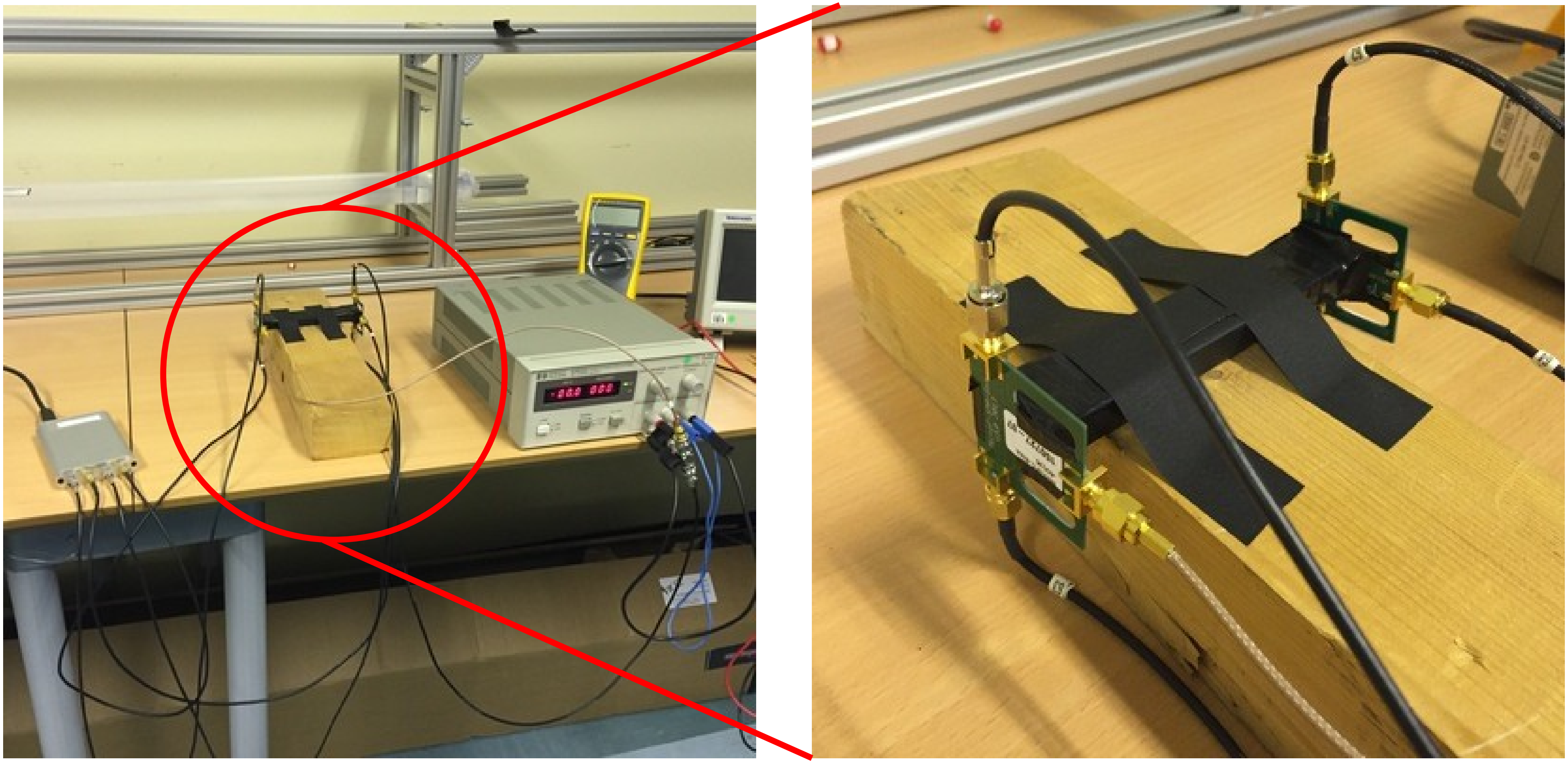
The MicroFC-SMA is recommended for users who require a plug-and-play set-up to quickly evaluate FC-Series SMT sensors with optimum timing performance. The board also allows the standard output from the anode to be observed at the same time as the fast output. The outputs can be connected directly to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

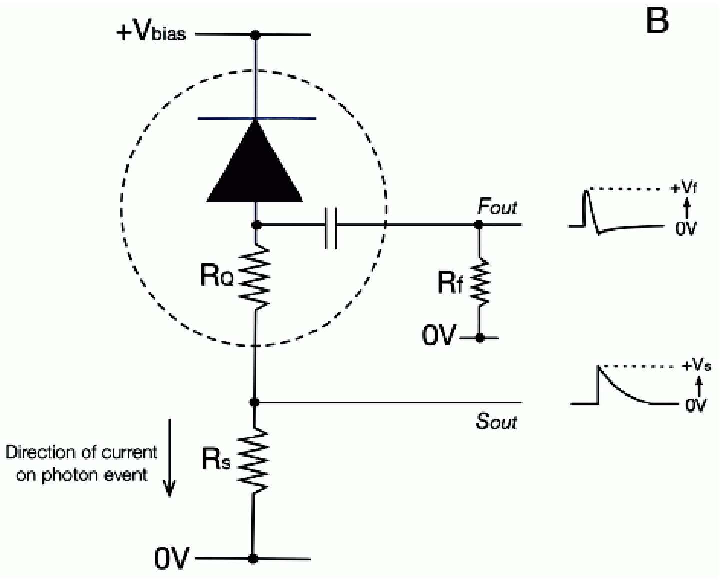


MicroFC-SMA-60035: eval board, 6 x 6 mm^2, C series, 35 µm cell
2 EB purchased. Light readout of a trigger bar from two sides

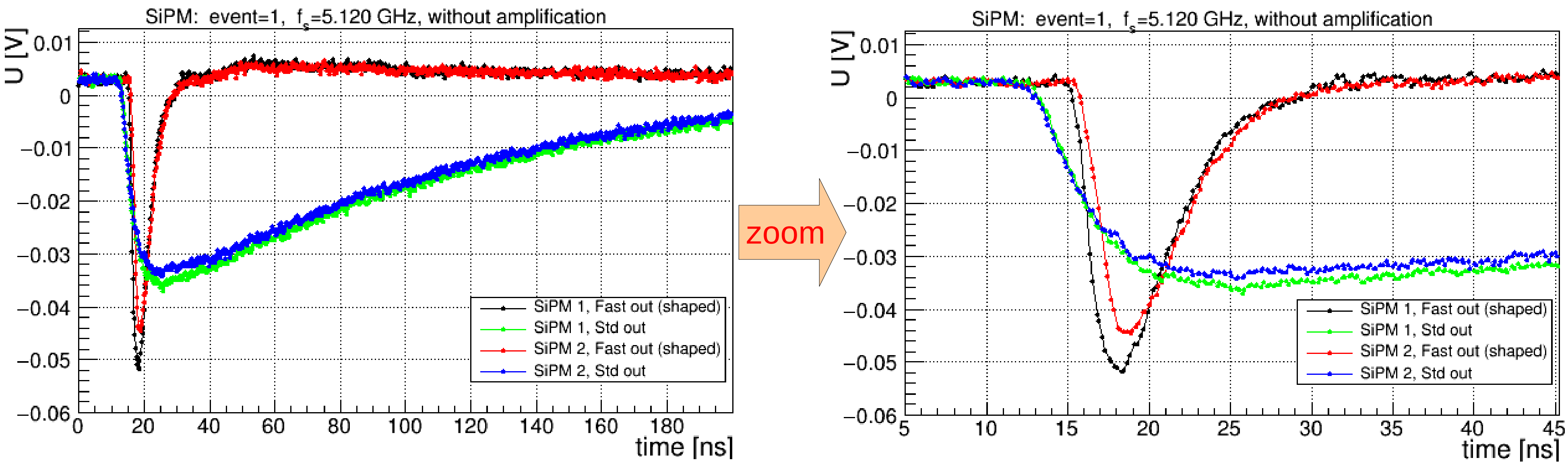
Setup for the test



Fast output in the sensL SiPM

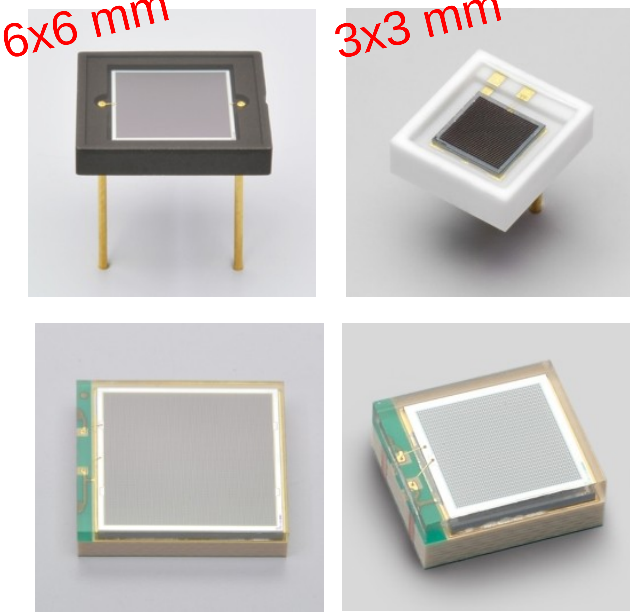


- For applications requiring simultaneous measurements of intensity and timing of light pulses
- About 2% of the SiPM charge is injected to the Fast Output
  - Pulse duration is 100 shorter ⇒ amplitude 0.02x100=2 times higher
- Rise time of Fast Output is ~2 ns, Standard Output is ~7 ns

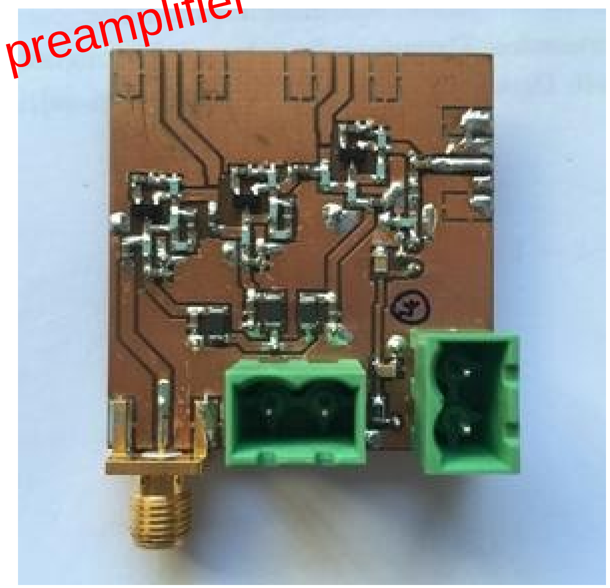


Amplification by a factor of x10 is required !

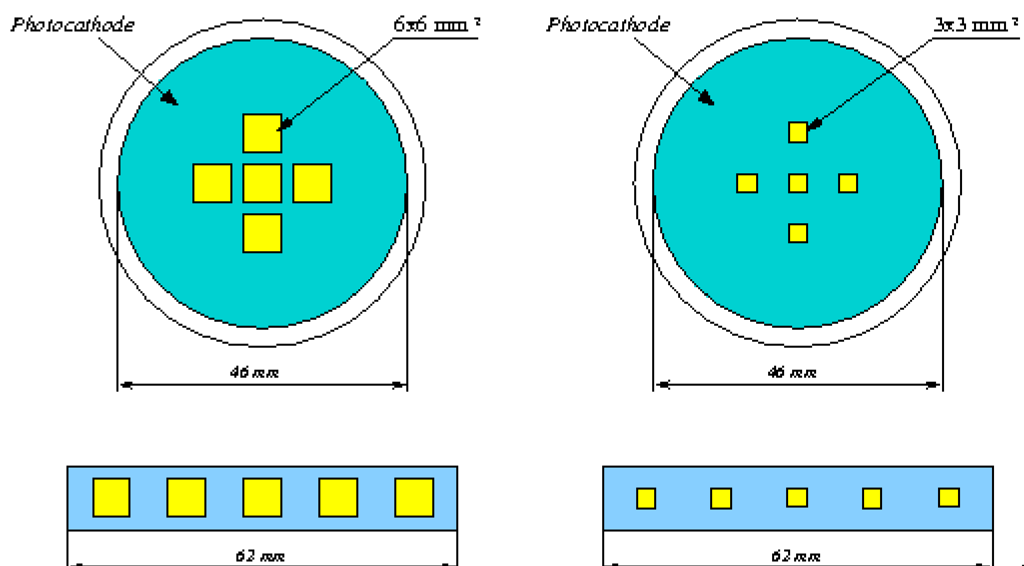
SiPM from Hamamatsu



- Recently delivered (UniGe)
- MPPC 50 um pixel, low crosstalk and afterpulse
  - 6x6mm2, STM and ceramic package (10+2)
  - 3x3mm2, STM and ceramic package (10+2)
- To be used with our own preamplifier



- Possible layout of MPPCs to be discussed
- Parallel or connection in series - to be found out
- Tests for a single SiPM will be done with the existing preamplifier. Any other modification will require R&D



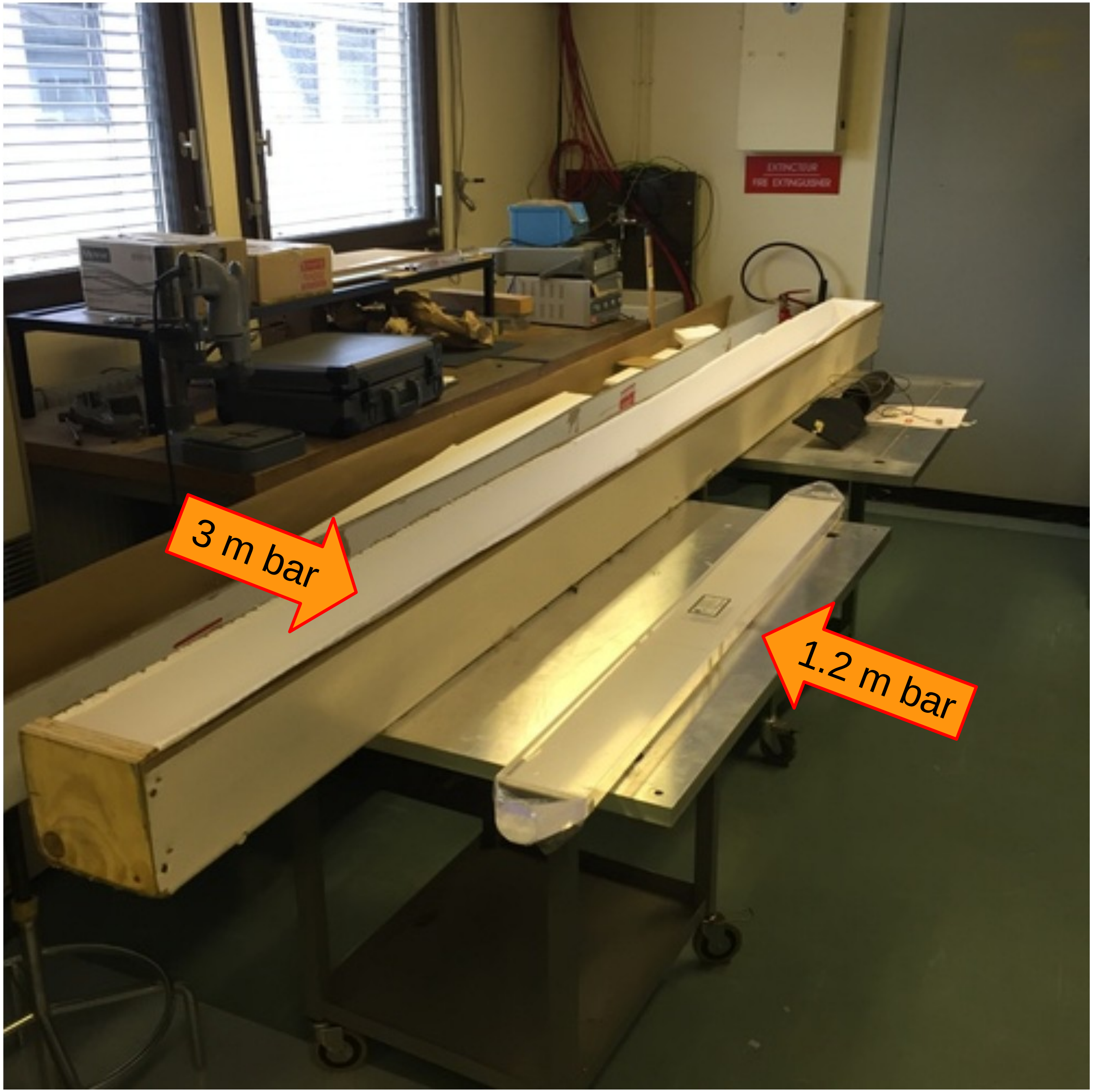
Conclusions

- Materials which have been received and used presently for the test bench
  - 3 and 1.2 m bars EJ-200 delivered 2 weeks ago!
  - PMT readout tested so far
  - DRS4 evaluation board from PSI (4 channels)
    - SAMPIC to borrow from the CNRS group: 16 ch/board
  - For 1.2 m bar with 2 side readout the resolution σ_t<100 ps
  - Results for the 3 m bar will come soon
  - Upgrade of the reference system is needed (presently $\sigma_t \approx 60$ ps)
- Study of the readout with an Array of SiPMs
  - 2 evaluation boards from sensL
  - SiPMs from Hamamatsu + custom amplifier
- Test beam in July/August/October would be fine

backup

Measurements with the PMT readout

- Cosmic trigger bench (reference counter, 12 cm)
  - Fast plastic EJ-230
  - 4 PMTs Philips XP2972: ∅=29 mm, rise time = 1.9 ns, TTS≈450 ps, gain $=3x10^{6}$
- Main bench (bar 1.2 m long)
  - Plastic with long atten length EJ-200
  - 2 PMTs Hamamatsu R13089-10: ∅=52 mm, rise time = 2 ns, TTS=270 ps, gain$=3.2x10^{5}$



Bars finally arrived on Jan 18 !

<u>To keep in mind:</u>
3 months between having the order accepted and the delivery

Technical attenuation length

- The effective or technical attenuation length (TAL) can be measured with the test bench: light yield (N) vs distance (x)

$$N = N_0 e^{-x/\lambda_{TAL}}$$

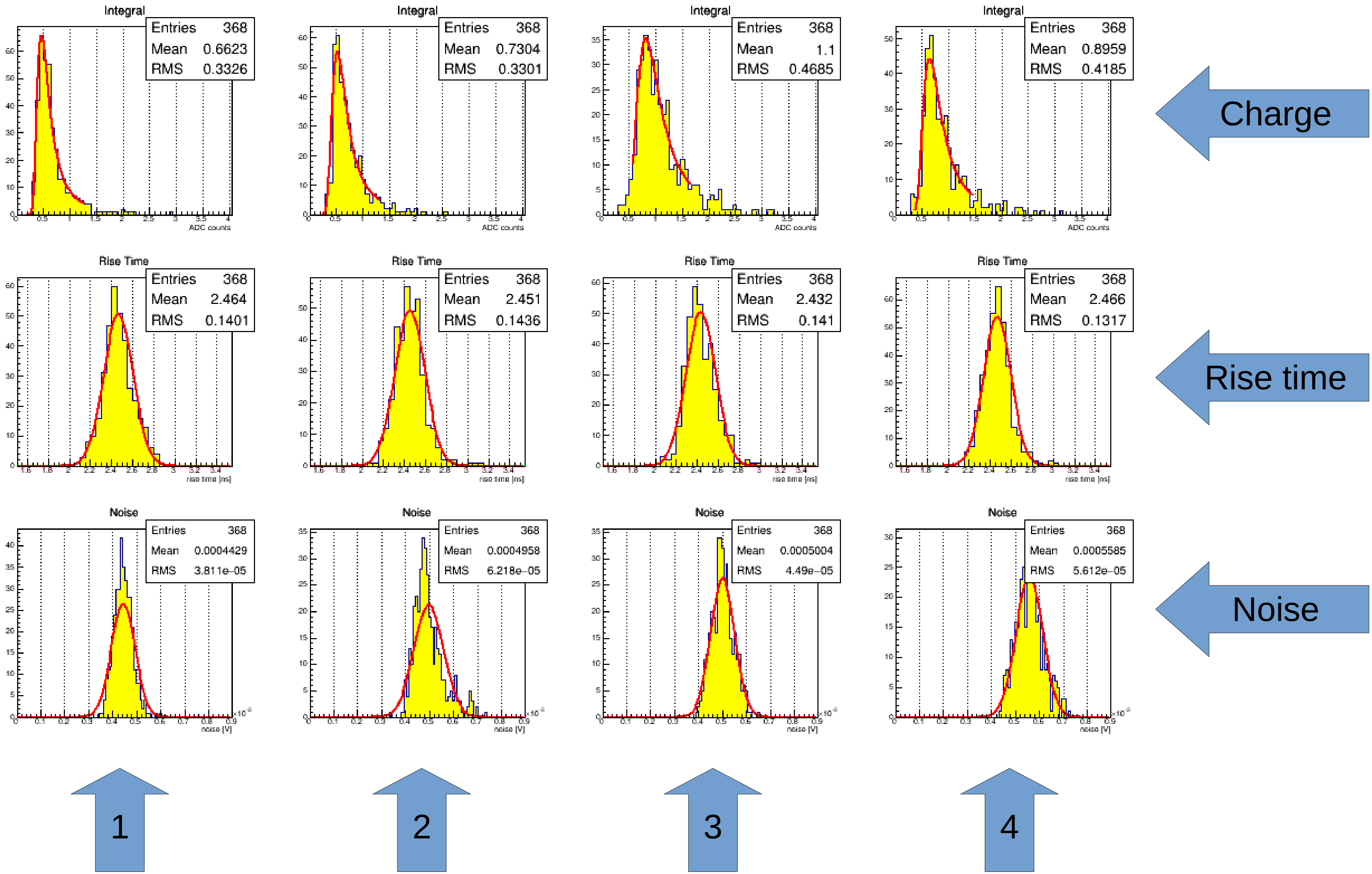
- The bulk attenuation length (λ_{bulk}≈4m) relates to the average path of photons (d), number of reflections (n) and the reflection efficiency (R)

$$N = N_0 e^{-d/\lambda_{bulk}} R^n$$

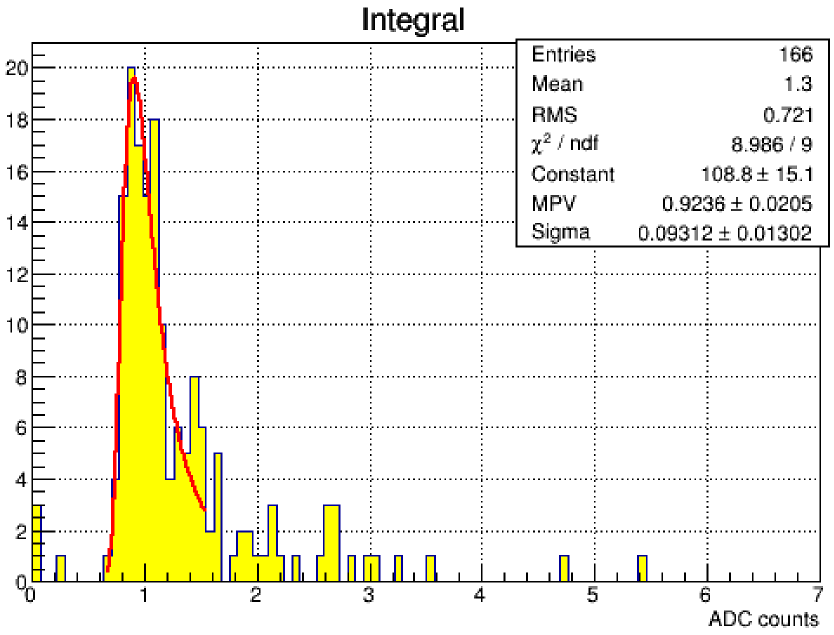
- Thus, TAL is a function of θ (average angle, $d \cdot \cos\theta = x$) and cross-sectional dimension of the bar r ($d \cdot \sin\theta = nr$)

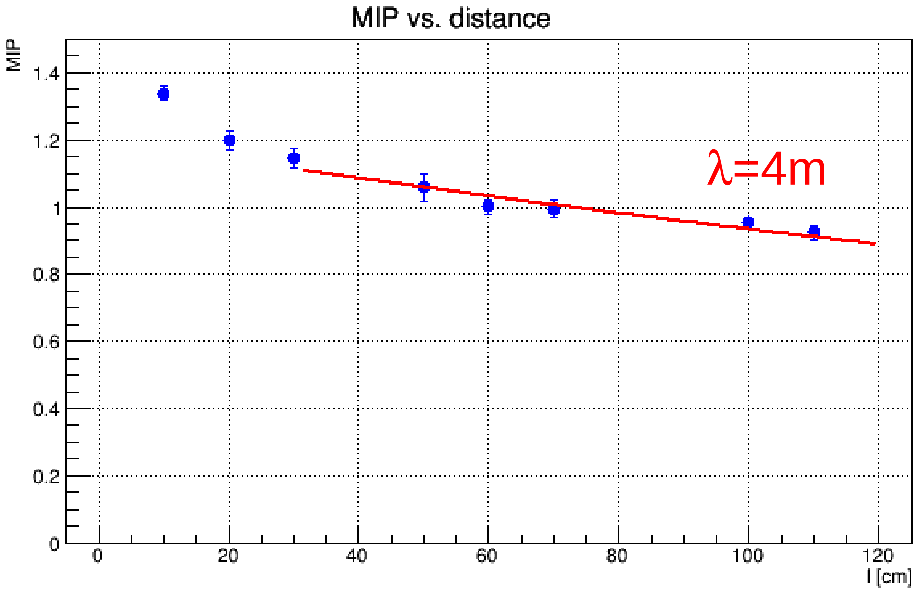
$$\frac{1}{\lambda_{TAL}} = \frac{1}{\lambda_{bulk}\cos\theta} + \frac{\ln(1/R)\tan\theta}{r}$$

Measurements for the reference counter



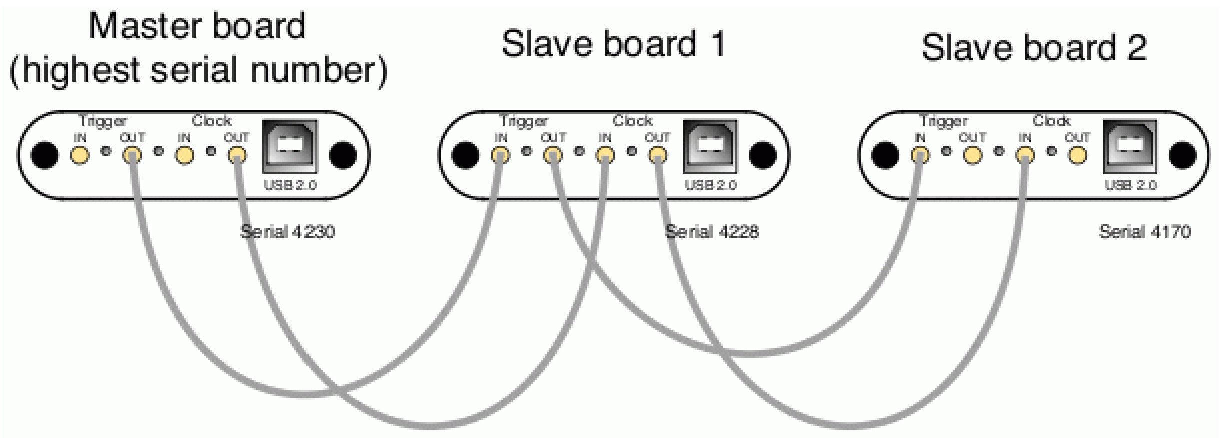
Time resolution as a function of distance





- Position of the MPV is proportional to the number of photons reaching PMT
- Measured as a function of distance. No way to fit with an exponent. Measurement with the 3 m bar would clarify the issue
- Also can be done with the β-source, ^{90}St, measurements E_e<2.28 MeV

Multi-board configuration for DRS4



- Trigger and master clock are passed in a daisy-chain mode from the master board to slave boards
  - Trigger only at channels in the master board
  - Trigger rate drops proportional to the number of boards
  - Time resolution degrade by 60 ps (manual)
- SAMPIC to borrow from the CNRS group (16 channels)