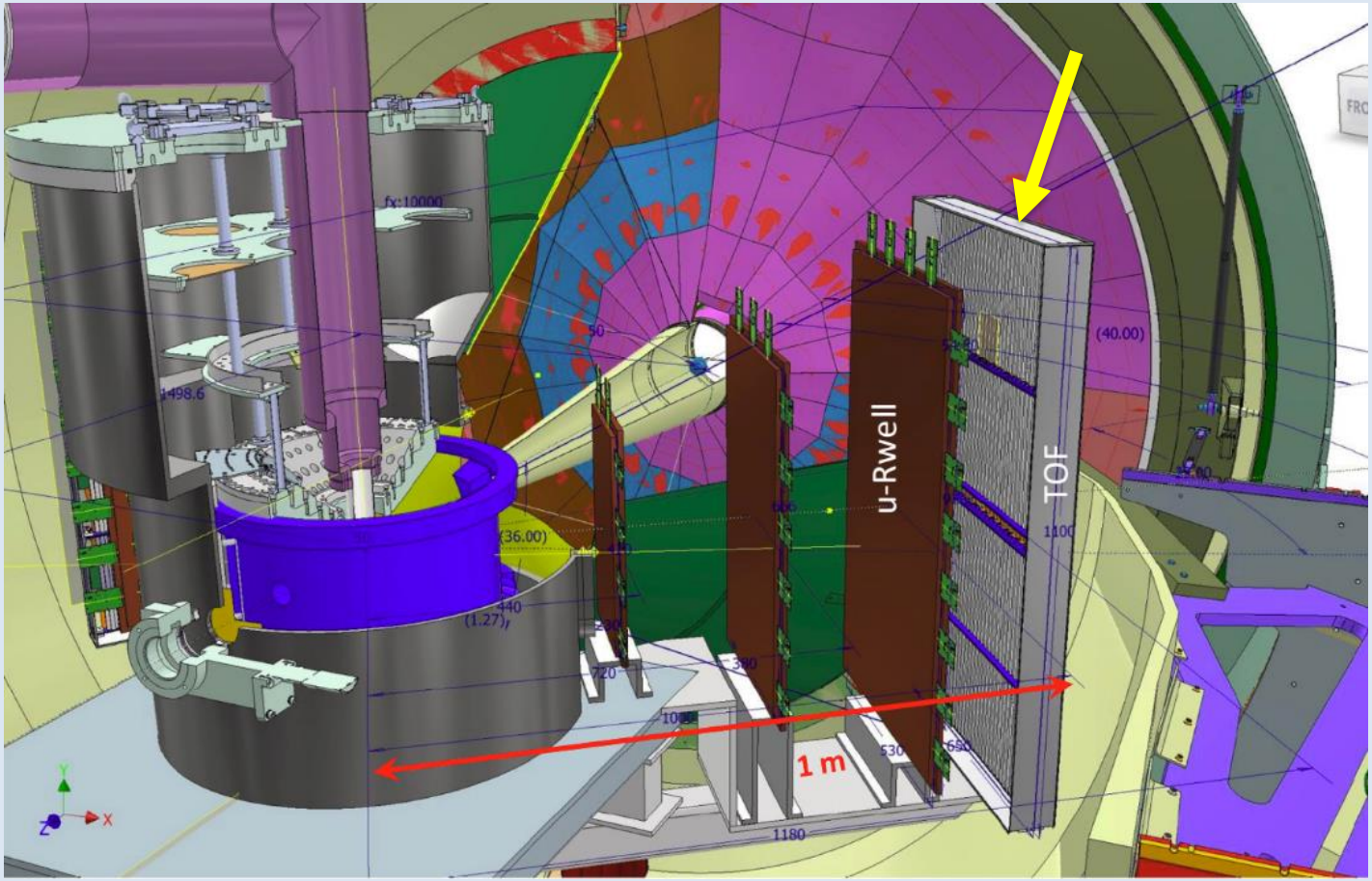
CLAS12 Run Group H Workshop

TOF Scintillation+SiPM Prototype

L. L. Pappalardo
(pappalardo@fe.infn.it)

JLab – November 13-14, 2026

RGH Recoil Timimg Detector



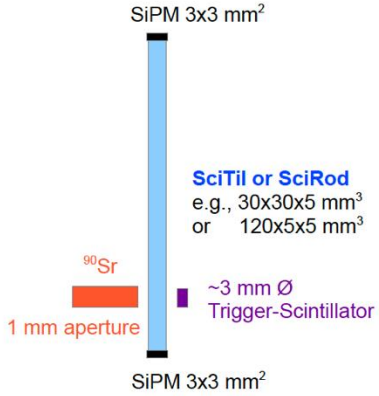
Main requirements:

- compact layout to fit into the HTCC envelope while maximizing acceptance
- O(100 ps) time resolution
- flexible tessellation to reduce pileup and provide temporal seed to the tracking detector (μRwell $\sigma_T \sim$ 10 ns) to suppress background from out-of-time tracks
- use of well-established technology (no need for R&D)

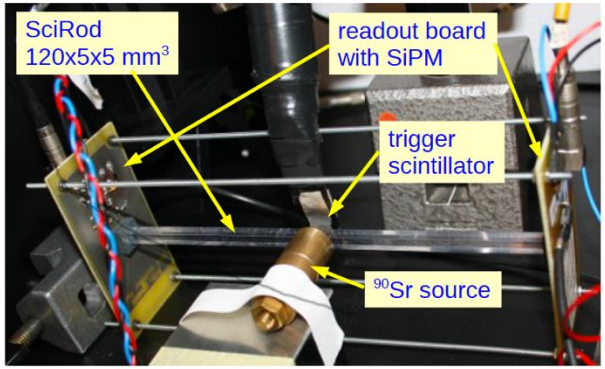
Current choice: plane of **scintillating bars** readout on both ends by SiPM
dimensions: 6 mm thickness, 12 mm width, 5-30 cm length

Time resolutions < 100 ps achieved with similar layouts by PANDA and MUSE Collaborations

M. Bohm et al., JINST 11 (2016) C05018 – **PANDA TOF**



(a) schematic



(b) photograph

T. Rostomyan, Nucl. Instrum. Meth. A 986 (2021) 164801 – **MUSE experiment**

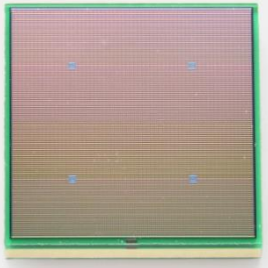
Table A.2: Time resolutions and efficiencies for 3 mm thick, 300 mm long and 12 mm wide BC-404 BM paddles. All results are better than the experimental requirements.

Scintillator	SiPM	σ_T (ps)	ϵ (%)
BC-404	S13360-3075PE	59	$\geq$ 99.9
BC-404	S13360-3050PE	60	$\geq$ 99.7
BC-404	ASD-NUV3S-P-40	65	$\geq$ 99.0

scintillator size	MPPC	BC408	BC420
$170 \times 5 \times 5$ mm^3	S10362-050P	97 ± 19	
$120 \times 5 \times 5$ mm^3	S12652-050C	81 ± 12	68 ± 10
$50 \times 5 \times 5$ mm^3		83 ± 6	62 ± 5
$120 \times 10 \times 5$ mm^3	S10362-100P	105 ± 18	93 ± 25
$50 \times 10 \times 5$ mm^3	S12572-050P	109 ± 16	

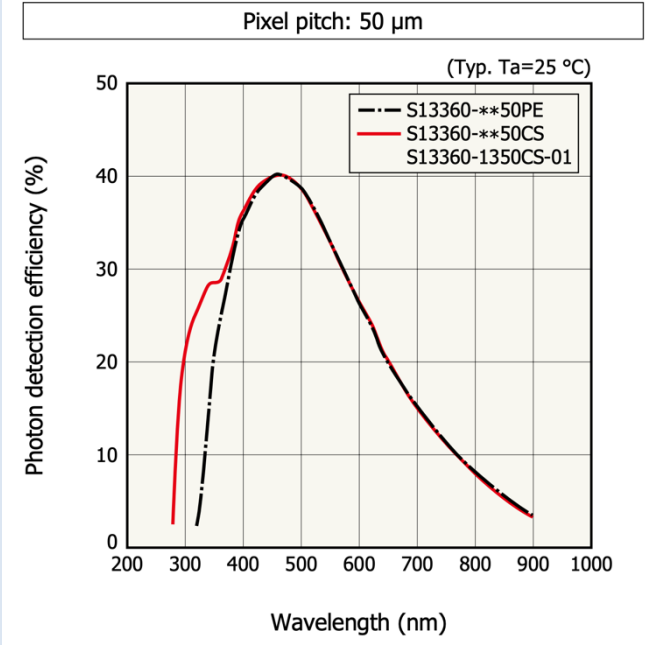
Hamamatsu S13360-6050VS

6x6 mm^2 area
50 pixel pitch
320-680 nm wavelength range picking at 380 - 580 nm



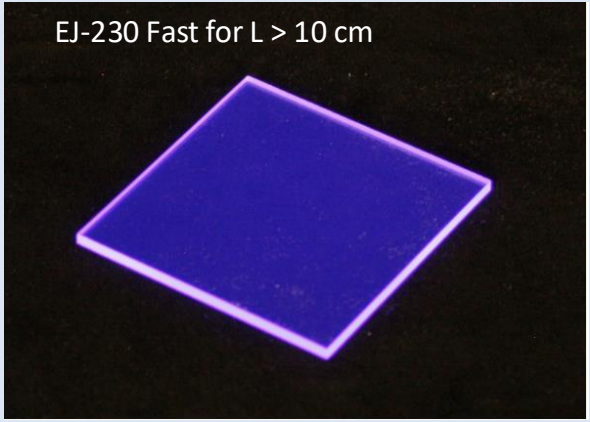
Selection guide

Type no.	Pixel pitch (μm)	Effective photosensitive area (mm)	Number of pixels	Package	Fill factor (%)
S13360-1325CS-01 NEW	25	1.3 × 1.3	2668	Ceramic	47
S13360-1325PE				Glass epoxy	
S13360-3025CS		3.0 × 3.0	14400	Ceramic	
S13360-3025PE				Glass epoxy	
S13360-6025CS		6.0 × 6.0	57600	Ceramic	
S13360-6025PE				Glass epoxy	
S13360-1350CS-01 NEW	50	1.3 × 1.3	667	Ceramic	74
S13360-1350PE				Glass epoxy	
S13360-3050CS		3.0 × 3.0	3600	Ceramic	
S13360-3050PE				Glass epoxy	
S13360-6050CS		6.0 × 6.0	14400	Ceramic	
S13360-6050PE				Glass epoxy	
S13360-1375CS-01 NEW	75	1.3 × 1.3	285	Ceramic	82
S13360-1375PE				Glass epoxy	
S13360-3075CS		3.0 × 3.0	1600	Ceramic	
S13360-3075PE				Glass epoxy	
S13360-6075CS		6.0 × 6.0	6400	Ceramic	
S13360-6075PE				Glass epoxy	



Scintillating Materials



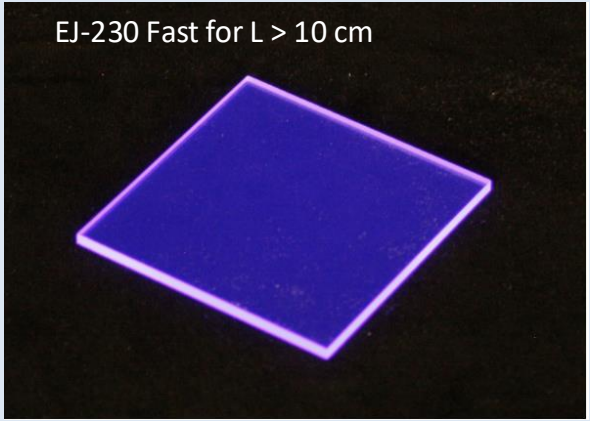




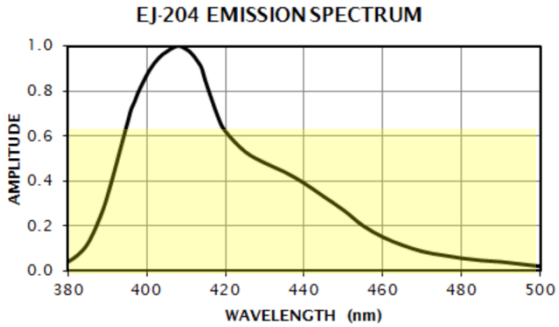
PROPERTIES	EJ-200	EJ-204	EJ-228	EJ-230		EJ-232	EJ-232Q (% Benzophenone)				
							0.5	1.0	2.0	3.0	5.0
Light Output (% Anthracene)	64	68	67	64		55	19	11	5	4	3
Scintillation Efficiency (photons/1 MeV e⁻)	10,000	10,400	10,200	9,700		8,400	2,900	1,700	770	610	460
Wavelength of Maximum Emission (nm)	425	408	391	391		370	370	370	370	370	370
Light Attenuation Length (cm)	380	160	–	120		350	110	105	100	100	100
Rise Time (ns)	0.9	0.7	0.5	0.5	ps	1600	700	700	700	700	700
Decay Time (ns)	2.1	1.8	1.4	1.5	ps	1300	360	290	260	240	220
Pulse Width, FWHM (ns)	2.5	2.2	1.2	1.3		5.13	5.12	5.12	5.12	5.12	5.12
No. of H Atoms per cm^3 ($x10^{22}$)	5.17	5.15	5.15	5.15		4.66	4.66	4.66	4.66	4.66	4.66
No. of C Atoms per cm^3 ($x10^{22}$)	4.69	4.68	4.69	4.69		3.30	3.38	3.38	3.38	3.38	3.38
No. of Electrons per cm^3 ($x10^{23}$)	3.33	3.33	3.33	3.33		1.023	1.023	1.023	1.023	1.023	1.023
Density (g/cm^3)	1.023	1.023	1.023	1.023							

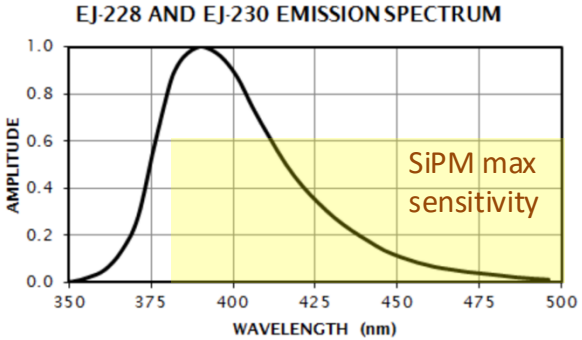
Scintillating Materials

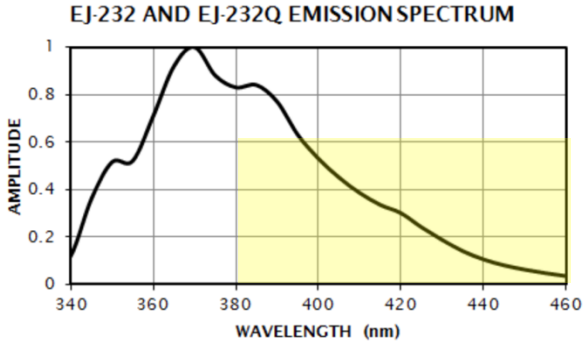




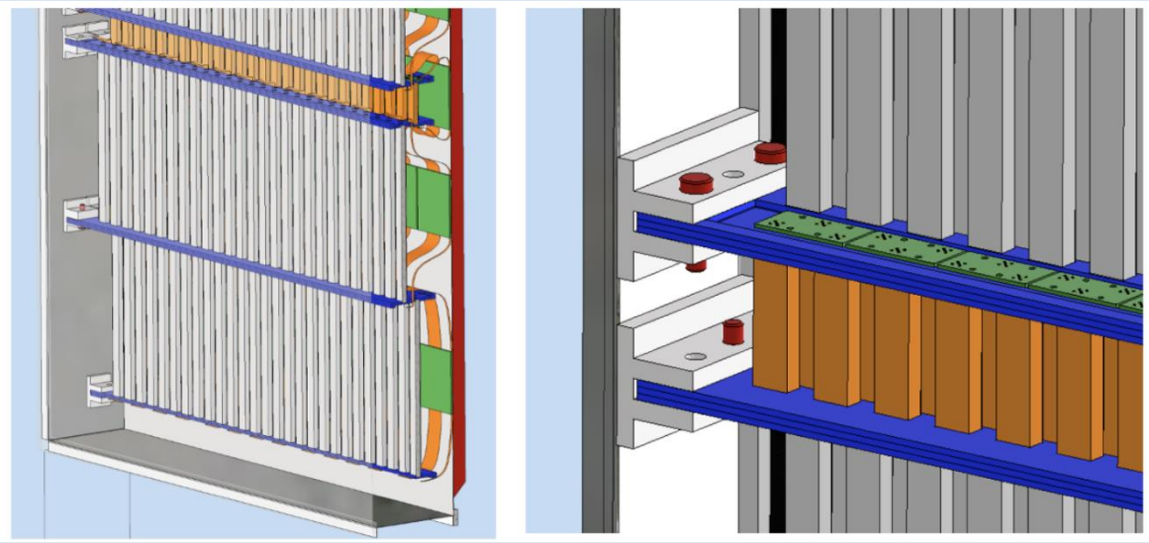


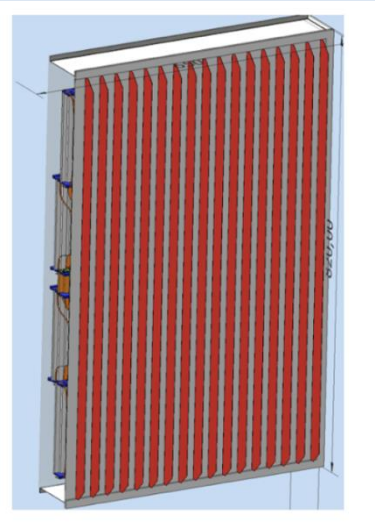






Final layout: The timing wall will be composed by arrays of vertical scintillating bars readout by SiPMs with the front-end electronics mounted on the downstream support structure



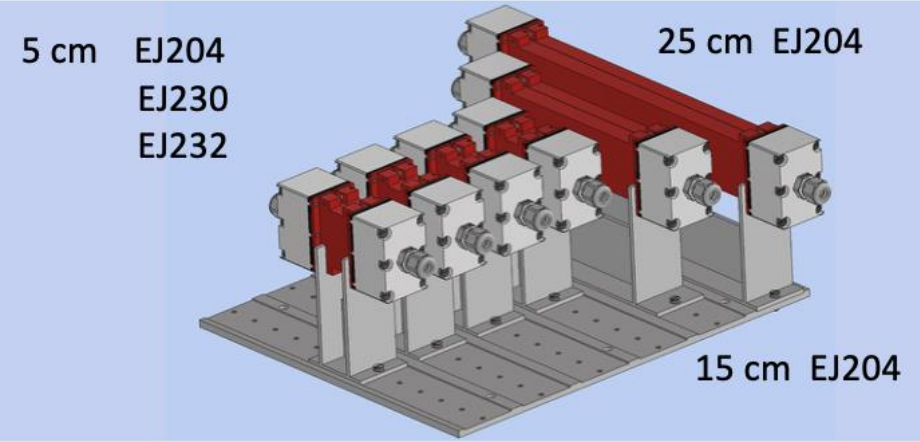


To limit accidental rate < 200 kHz, bars with 2 different lengths are foreseen:

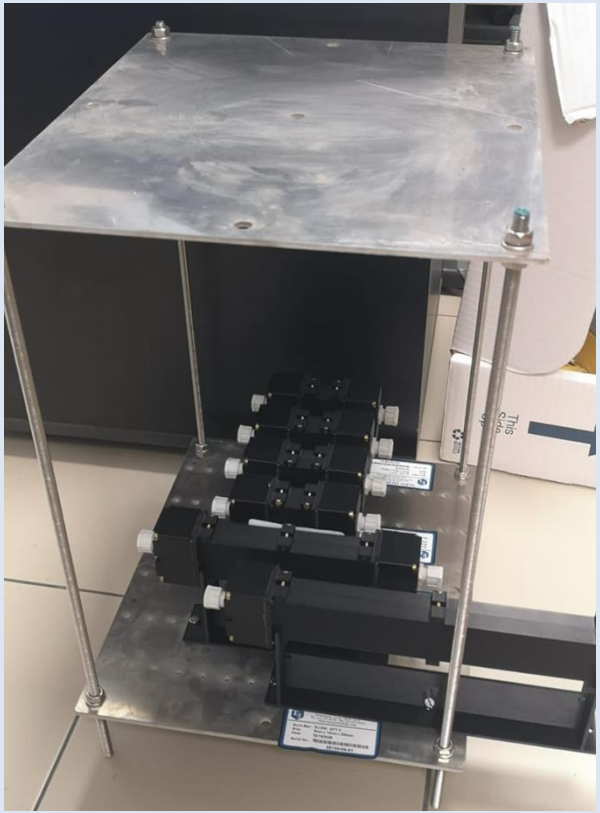
- 40 mm across the bending plane where background concentrates
- 250 mm outside the bending plane

The support structure provides cooling and services

2026 (&'25): INFN funded a demonstrator made by small modules of various scintillating bars + SiPM

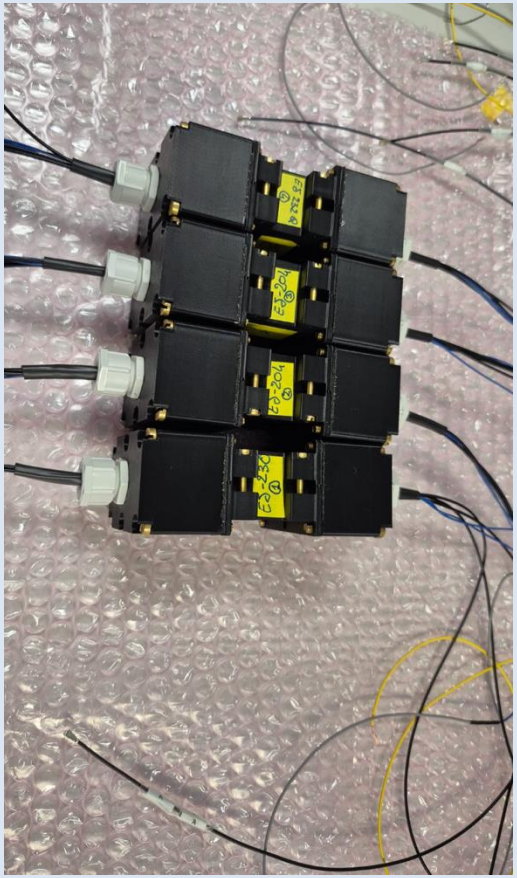


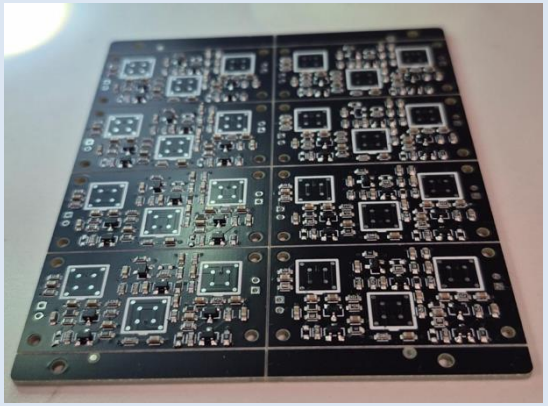




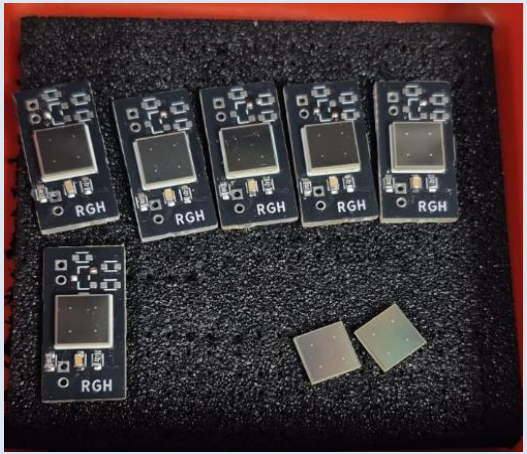
TOF Demonstrator Assembling

TOF Demonstrators

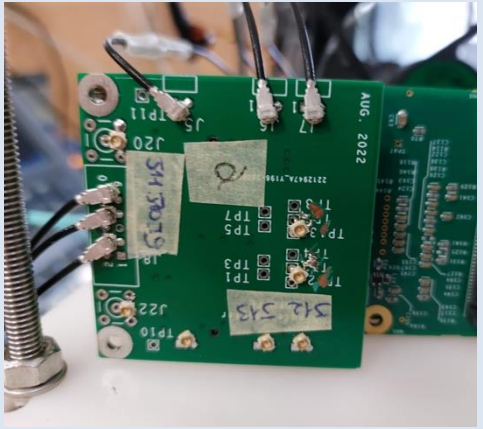




Hamamatsu 13360 6x6 mm^2



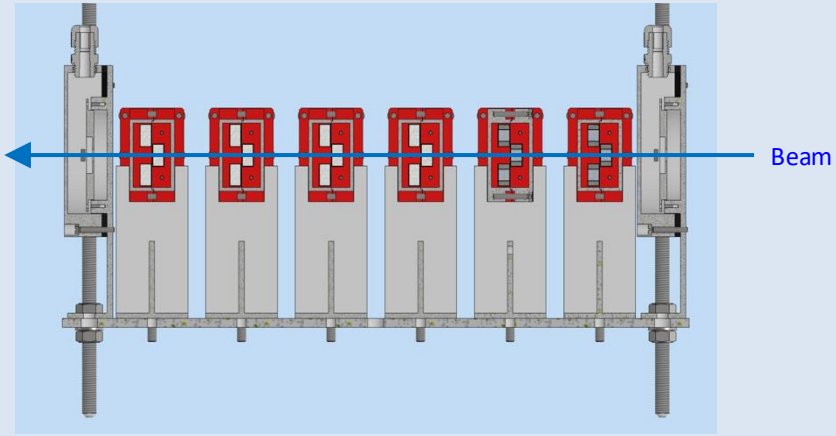
Adapter board

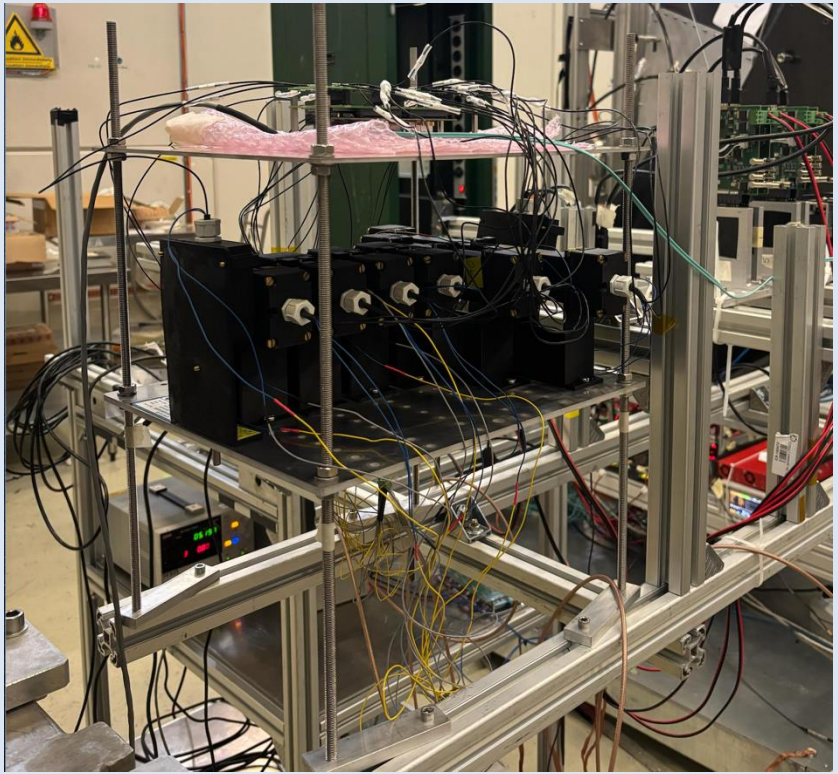


MAROC3 electronics



Prototype completed, complemented with two trigger/timing stations and deployed at CERN at the end of June, during ePIC test-beam at SPS



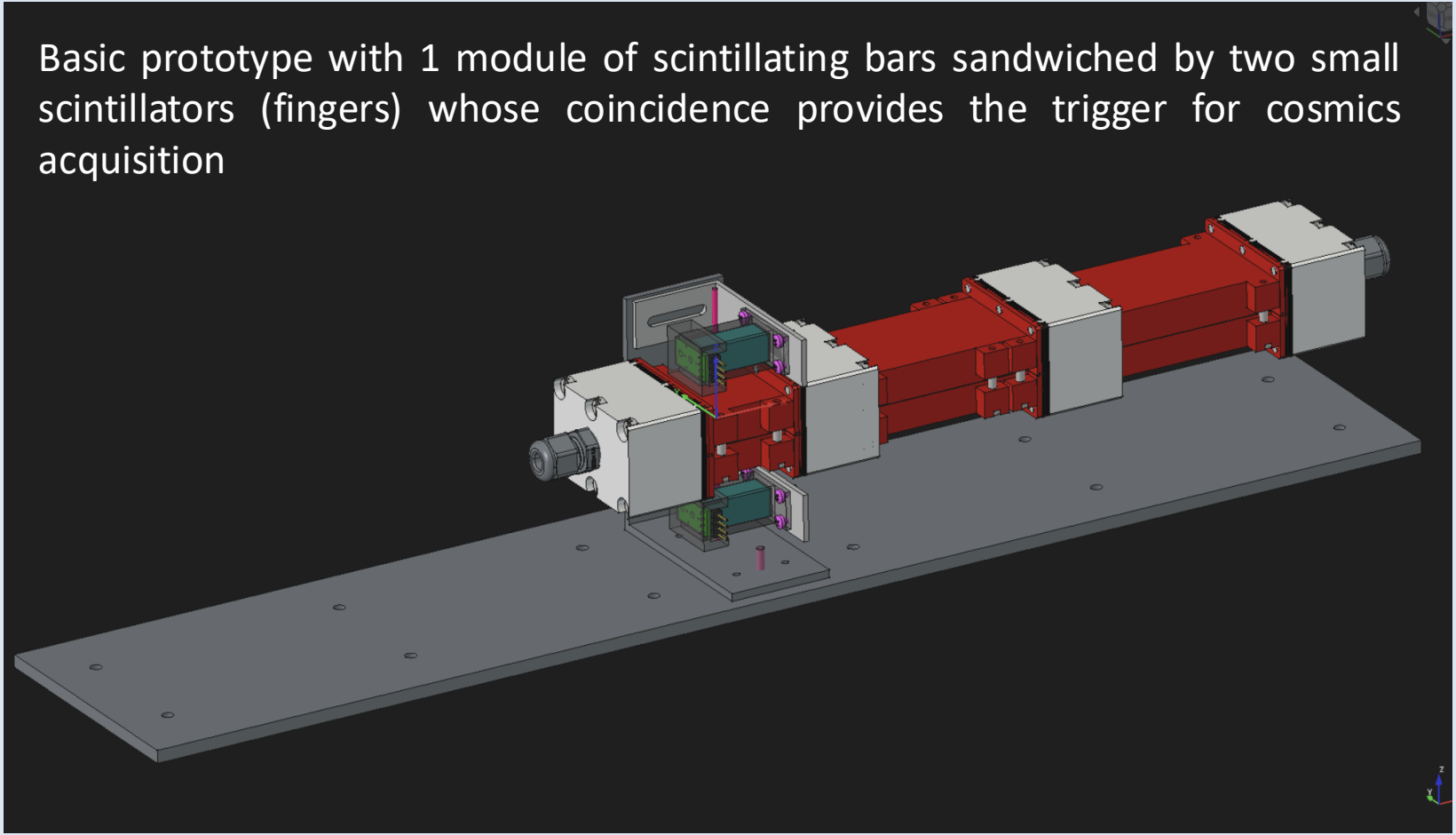


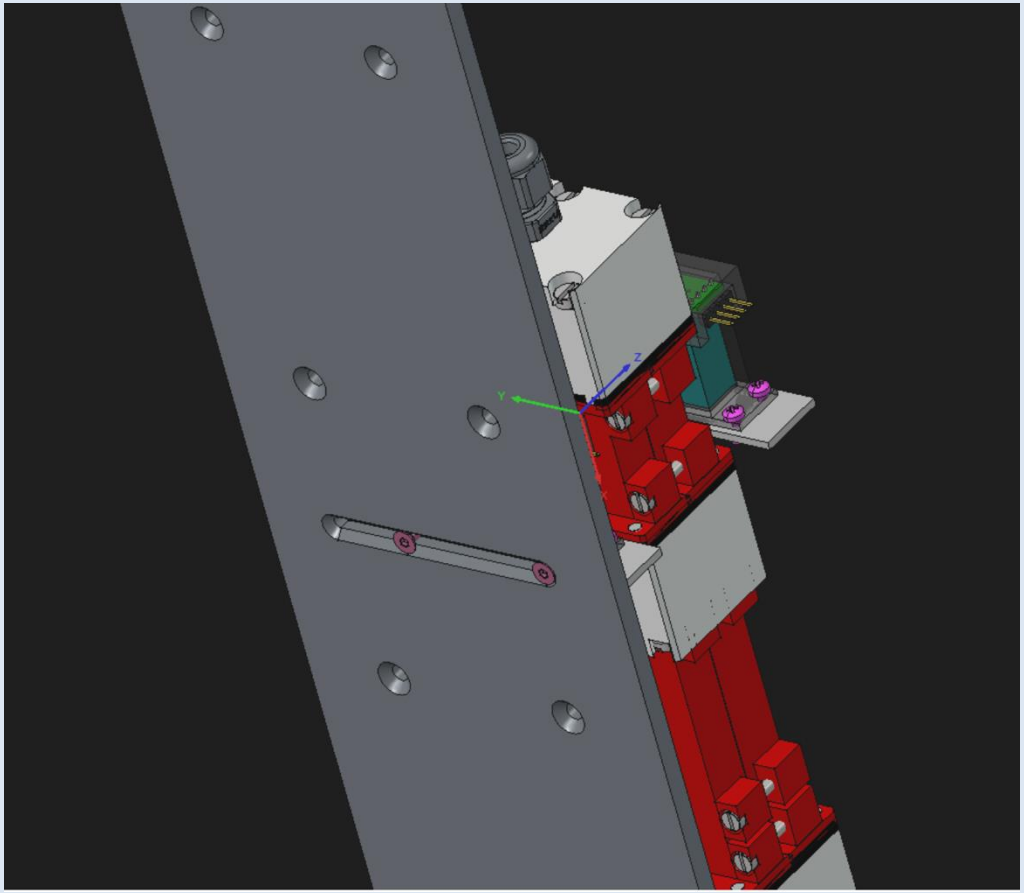
Ben Raydo prepared
new firmware (front-end FPGA) and
new software (backend SSP)

Issue found with upgraded firmware (no external trigger accepted)

→ Back to Ferrara for tests with cosmics or sources

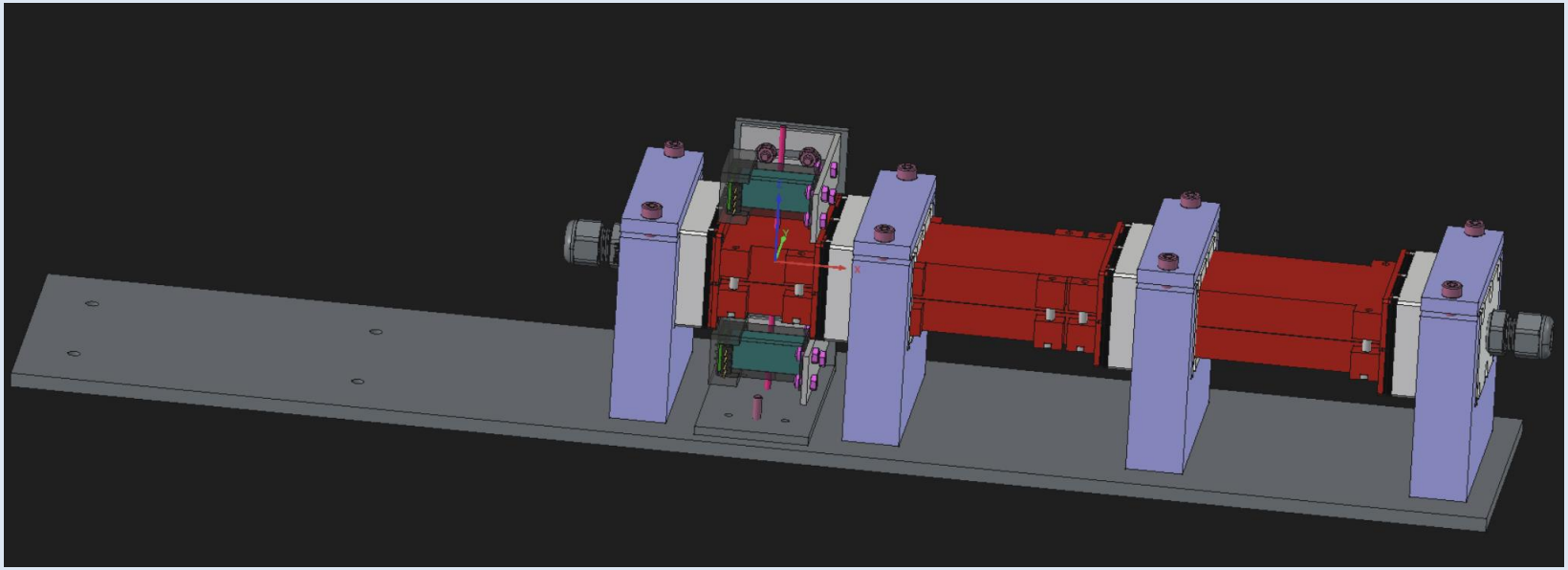
Basic prototype with 1 module of scintillating bars sandwiched by two small scintillators (fingers) whose coincidence provides the trigger for cosmics acquisition





Beneath the platform is a guide along which the supports for the two fingers can slide, allowing them to be centred over each of the three scintillating bars.

Side view of full prototype with the suports



The support allows to mount short and long bars, and to shift them to change the illuminated area

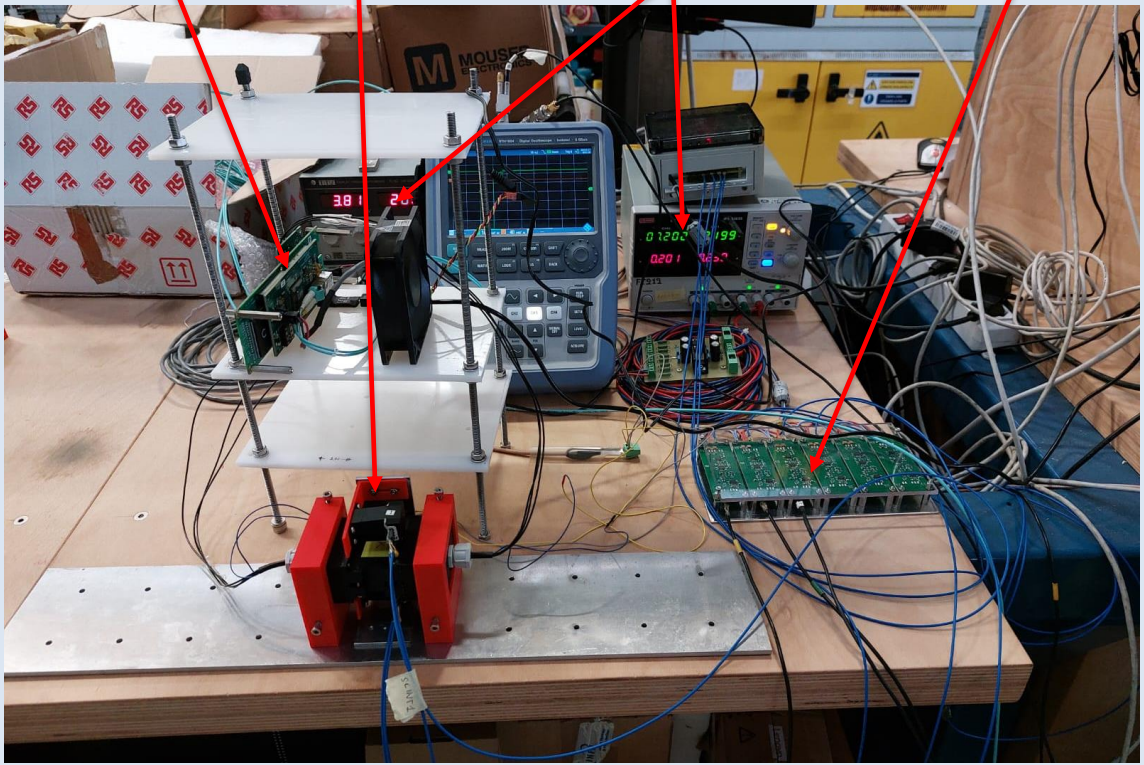
Prototype testbench in Ferrara

MAROC board

small-scale prototype

power suppliers

amplifiers

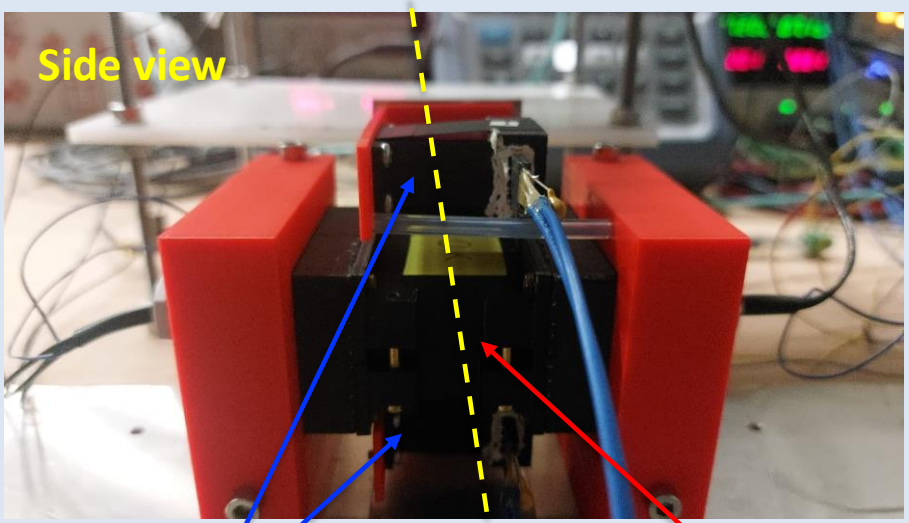


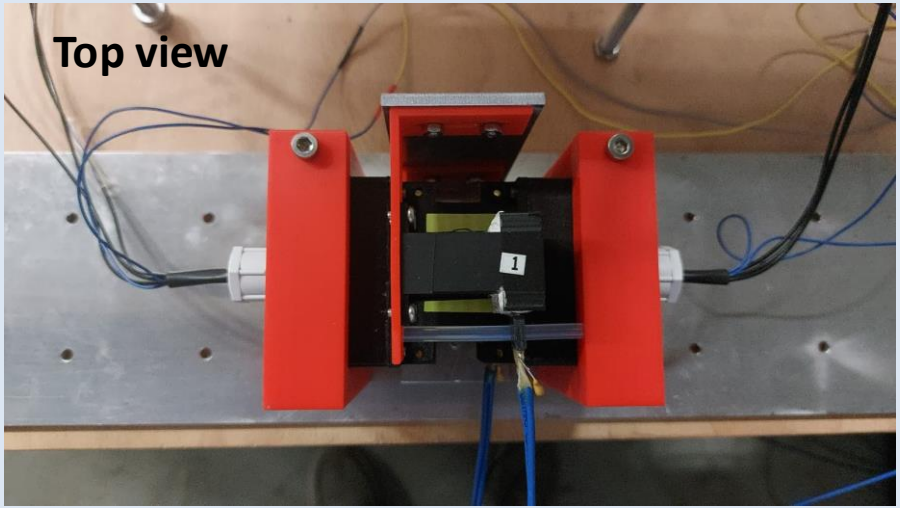
coincidence unit



Prototype testbench in Ferrara

cosmics



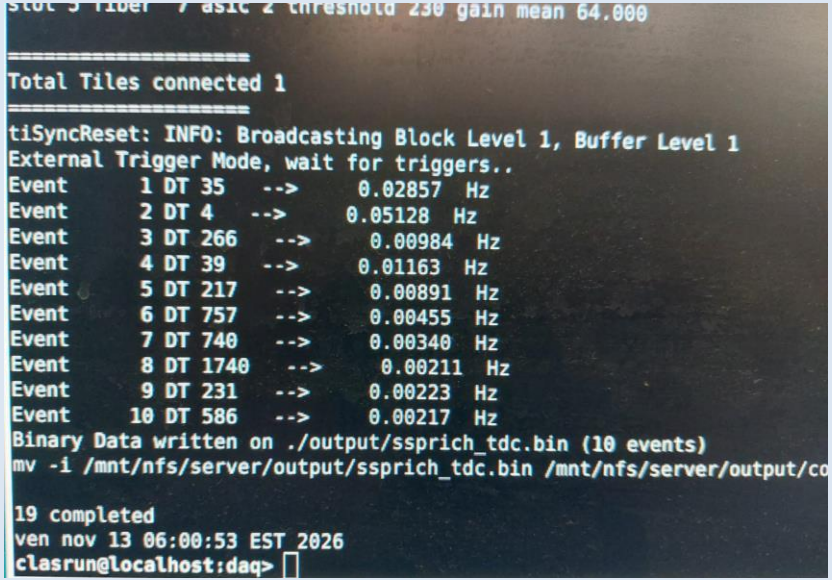


2 scintillating fingers (top-bottom) provide the trigger

1 module with three 5cm long scintillating bars

Prototype testbench in Ferrara

Ben Raydo has recently deployed a new firmware for the front-end FPGA, which now allows to accept the external trigger.



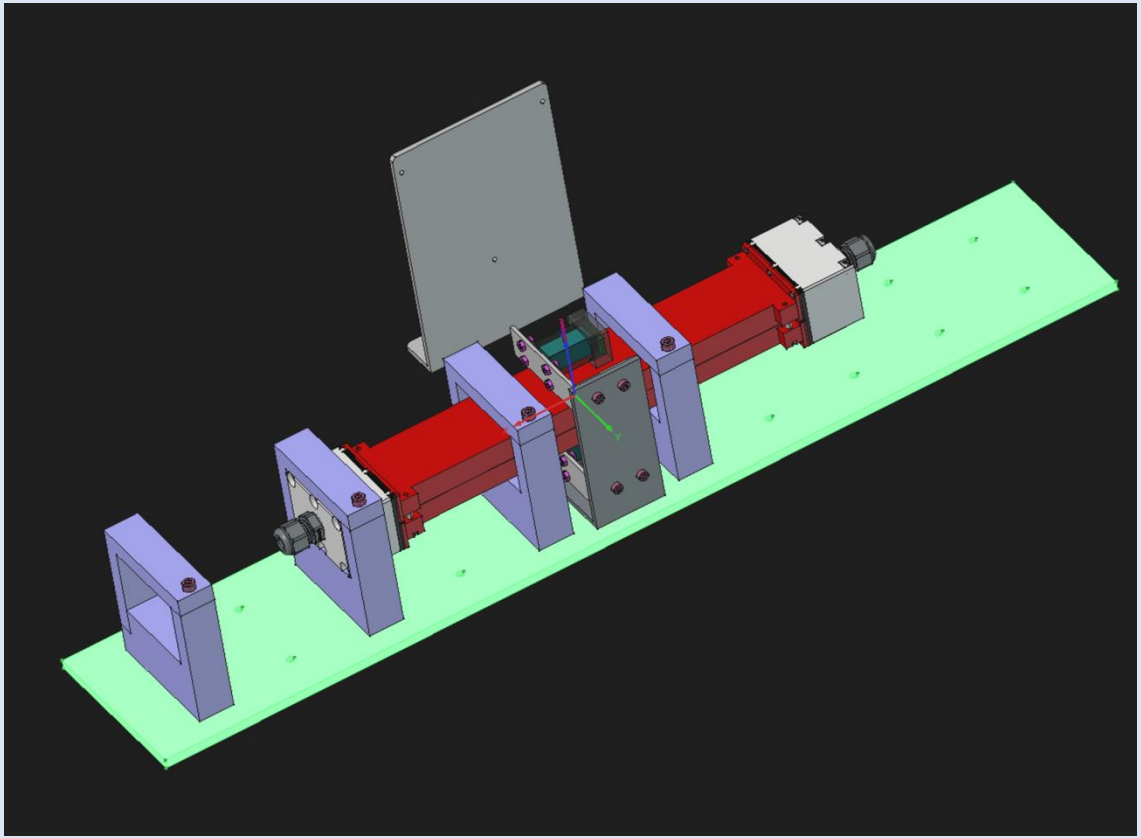
Example of acquisition of coincidence events

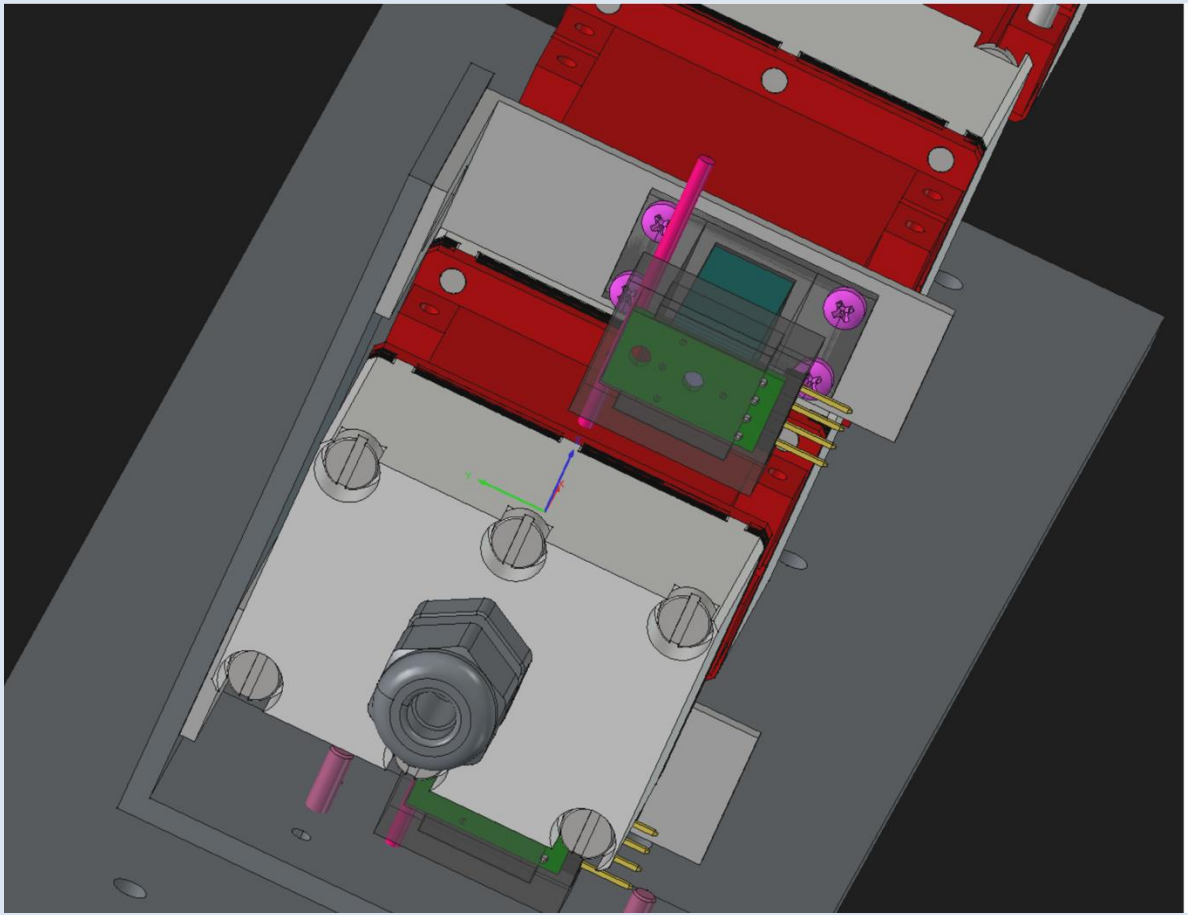
Coincidence frequency expected to be low due to small (overlapping) areas of the two fingers

Conclusions

- The **scintillating bars + SiPM** combination represents a suitable technology for the **RGH Recoil Timing Detector** in terms of time resolution, layout flexibility and overall reliability
- Time resolution O(100 ps) or better is at reach
- Flexible tessellation provides matching with μRwell tracks and allows to control the accidentals bkg
- A dedicated testbench is being developed in Ferrara for testing a small prototype with cosmics
- 3 different scintillators are being tested which match with different decay time and match to the SiPM efficiency peak (380 - 580 nm)
- A test-beam of the full prototype (funded by INFN) is foreseen in future

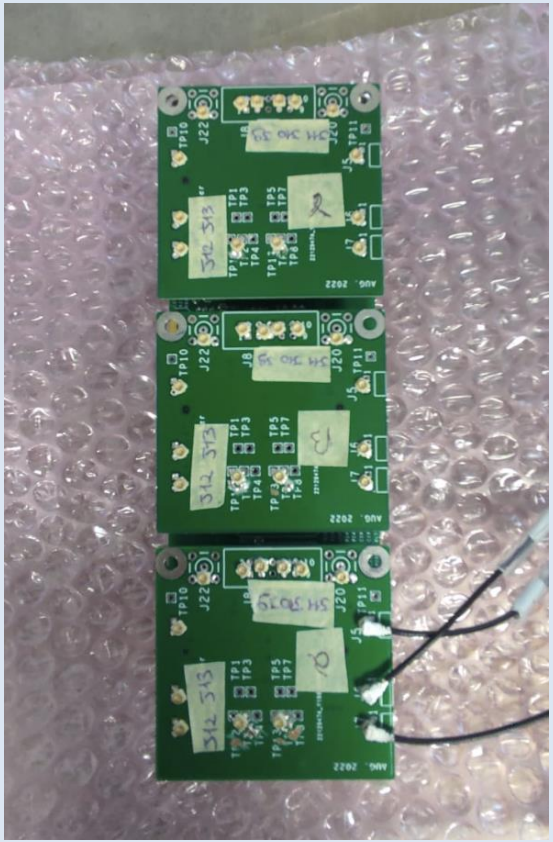
BACK-UP

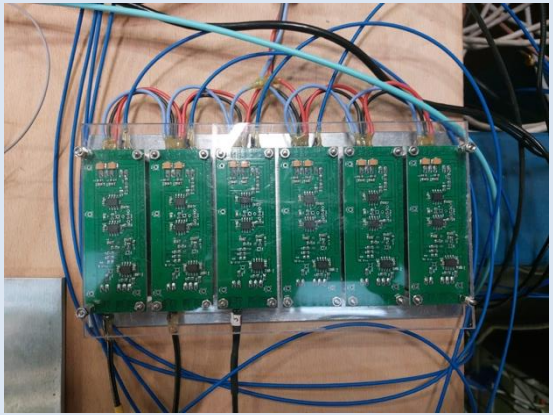


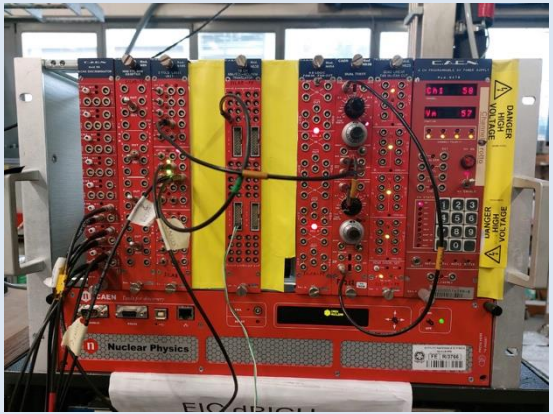


Prototype testbench in Ferrara

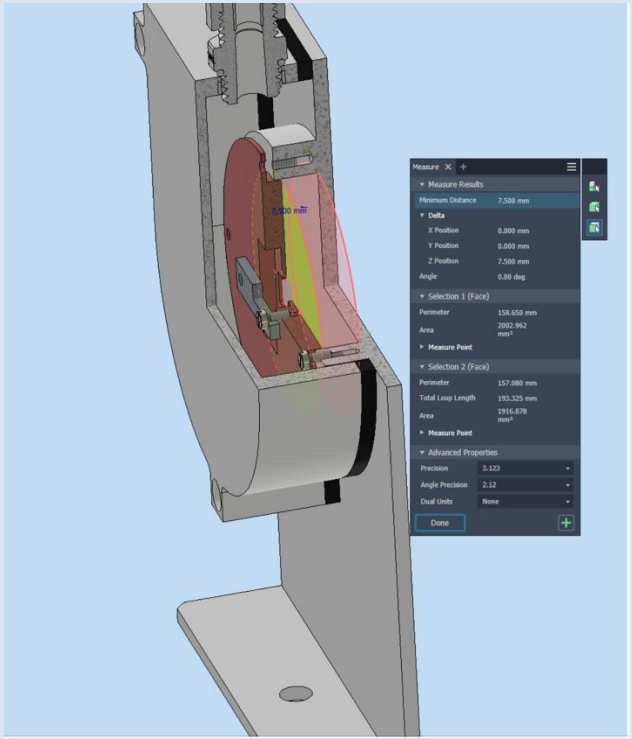
The 6 SiPM signals on the front board connected to the MAROC board

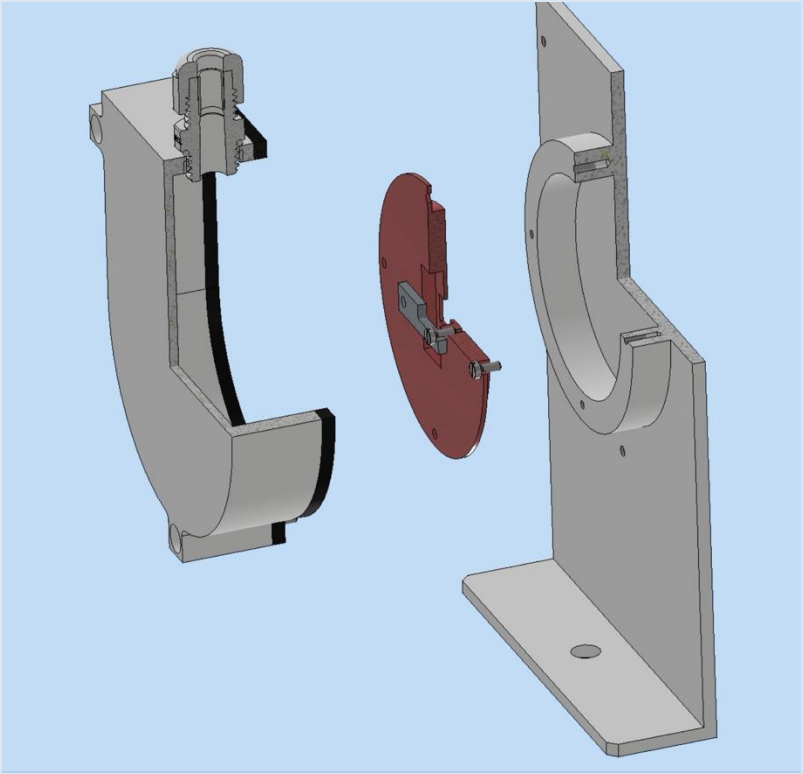






Quartz window + SiPM to get Cherenkov cone and prompt reference signal (<100 ps)





https://eljentechnology.com/products/plastic-scintillators/ej-200-ej-204-ej-208-ej-212

https://eljentechnology.com/products/plastic-scintillators/ej-228-ej-230

https://eljentechnology.com/products/plastic-scintillators/ej-232-ej-232q versione 0.5

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