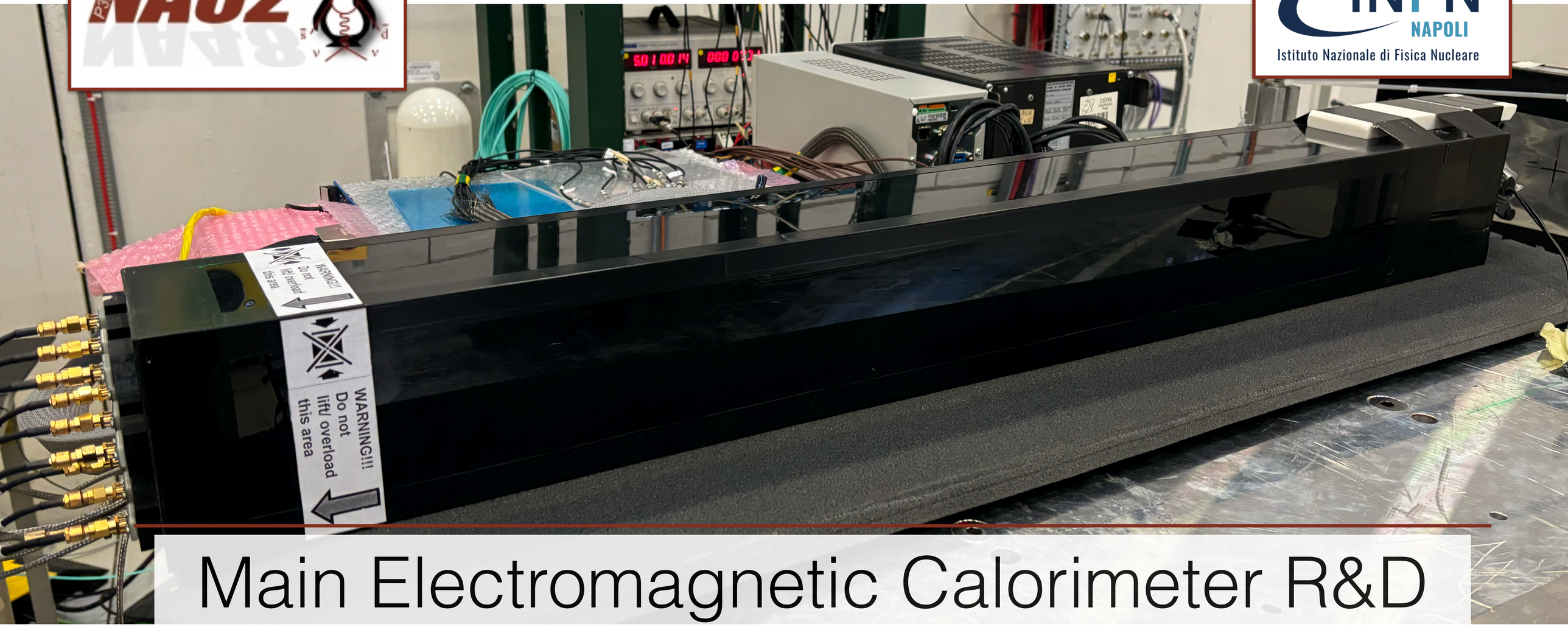
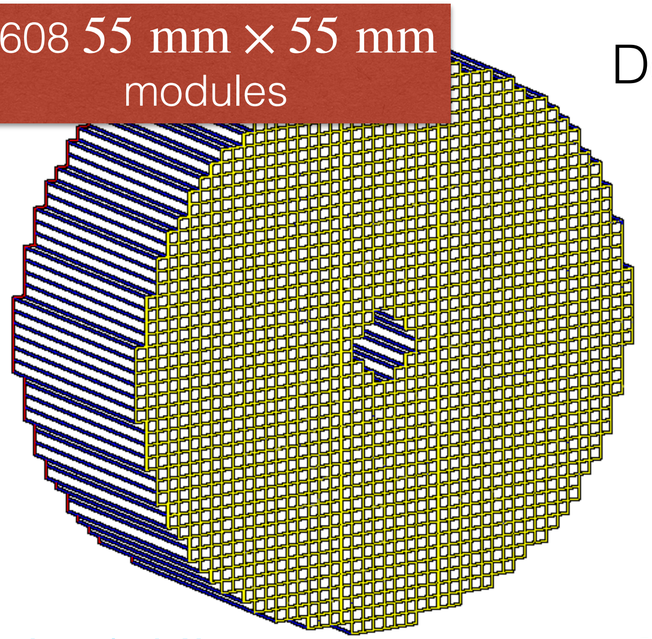


Main Electromagnetic Calorimeter R&D

Marco Francesconi for the (HIKE) MEC team

NA62 Italia meeting, 8th Nov 2024

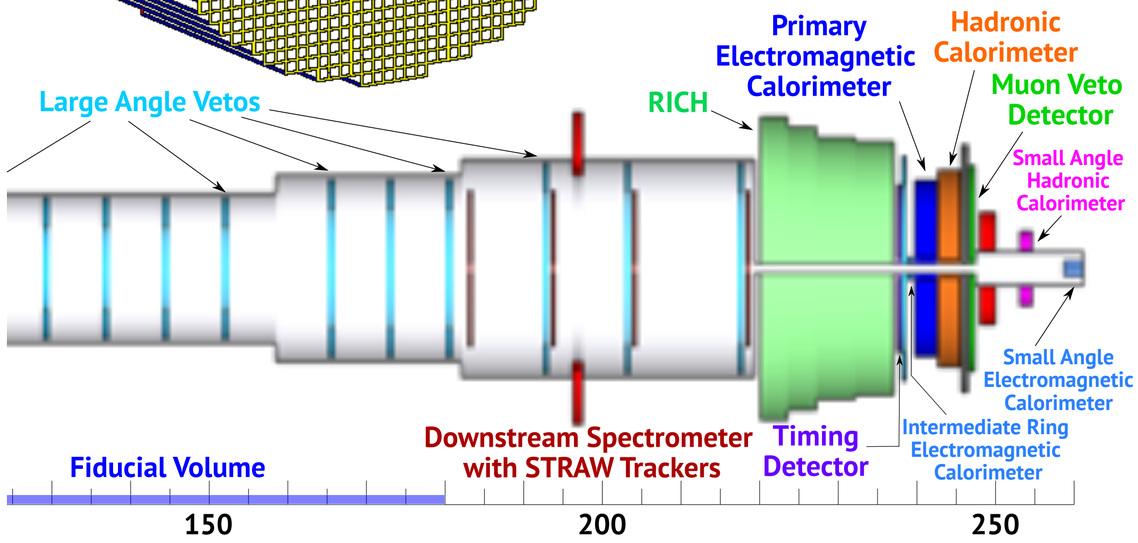
HIKE Baseline Calorimeter



Designed as Main Electromagnetic Calorimeter for the HIKE experiment

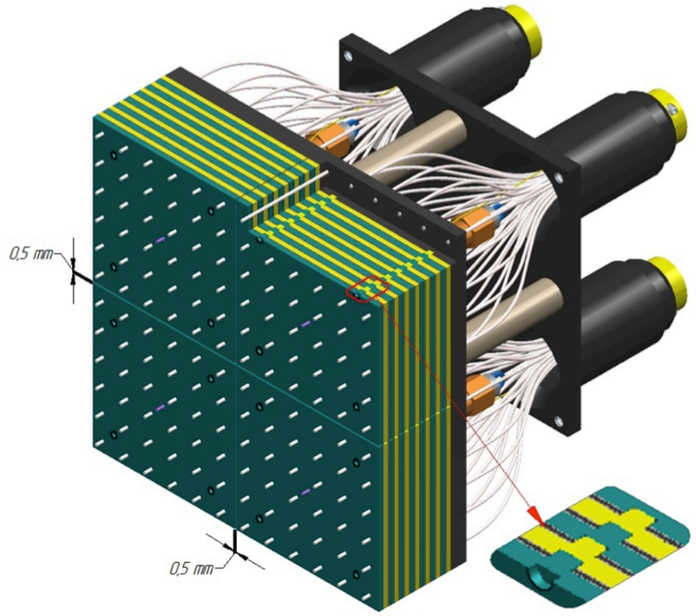
Covers the radii between 12 cm and 125 cm at current LKr position with similar σ_E/E and improved σ_T

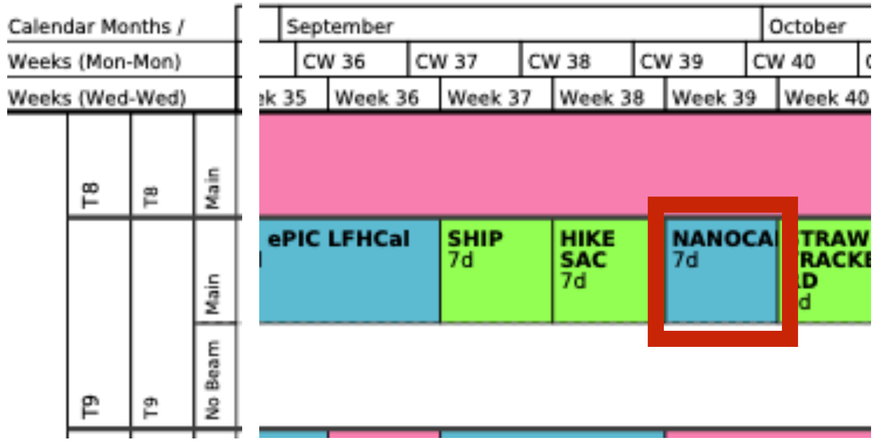
Baseline technology: fine-sampling shashlik calorimeter based on PANDA/KOPIO design (extended from $20\ X_0$ to $25\ X_0$)



Calorimeter	Pb/Scint [mm]	Energy resol.	Sampling frac.
ALICE EMCal	1.44/1.76	$10\%/\sqrt{E} \oplus 5\%$	16%
LHCb ECAL	2.0/4.0	$8\%/\sqrt{E} \oplus 1\%$	24%
PANDA/KOPIO	0.275/1.5	$2.8\%/\sqrt{E} \oplus 1.3\%$	47%
NA62 LKr		$3.2\%/\sqrt{E} \oplus 0.4\%$	

HIKE MEC after ECN3 selection





R&D funds PRIN by M.Mirra in Naples,
to test a full-length 3×3 cell prototype

Short term goals: Evaluate energy and time resolutions with both SiPM and PMT readout options
Long term plans: prototype platform for modifications (faster WLS, newer photodetectors, …)

Using "standard" technologies:
PVT/POPOP ("Protvino") scintillators + commercial WLS fibres
Without spy tiles

Decoupled R&D on new scintillators by NanoCal, see Mattia presentation

1 week beam-time allocation at T9
under the NanoCal project
(positrons $1 - 6$ GeV)

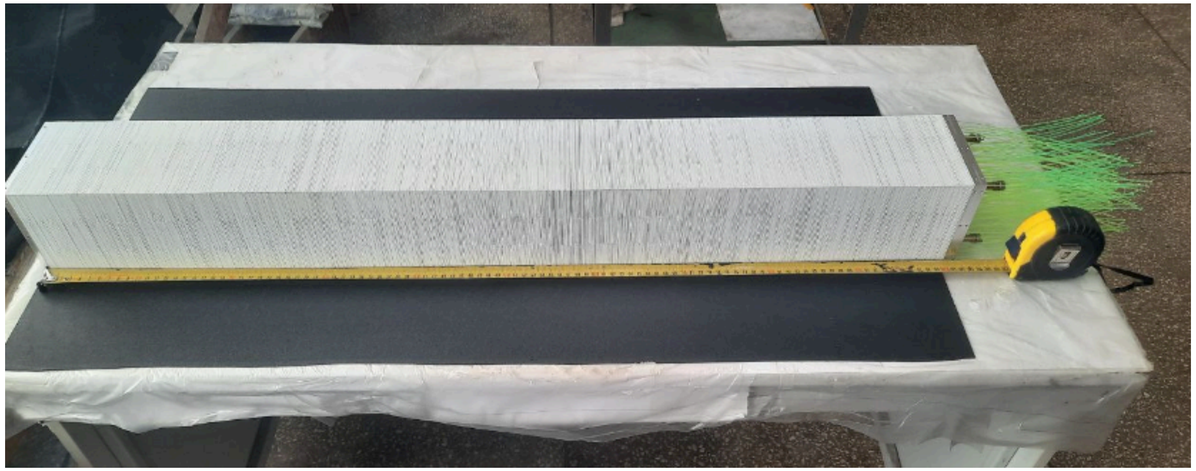
First big prototype

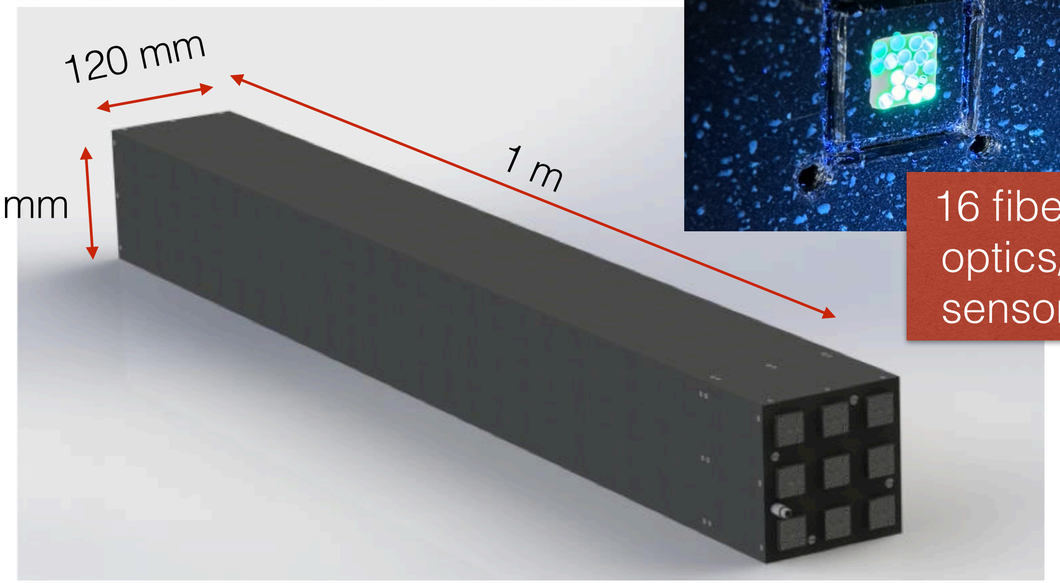
3×3 detector module assembled by DETEC in Kharkiv (arrived just in time!)

$40\ \text{mm} \times 40\ \text{mm}$ towers of 500 layers ($27\ X_0$)

each with 16 BCF-92XL 1.2mm WLS fibres mirrored on opposite side

0.3 mm Lead + 1.6 mm TiO_2-painted plastic scintillator





16 fiber optics/ sensor

Photosensor options

Two options considered:

SiPMs

Hamamatsu S13360-6025CS

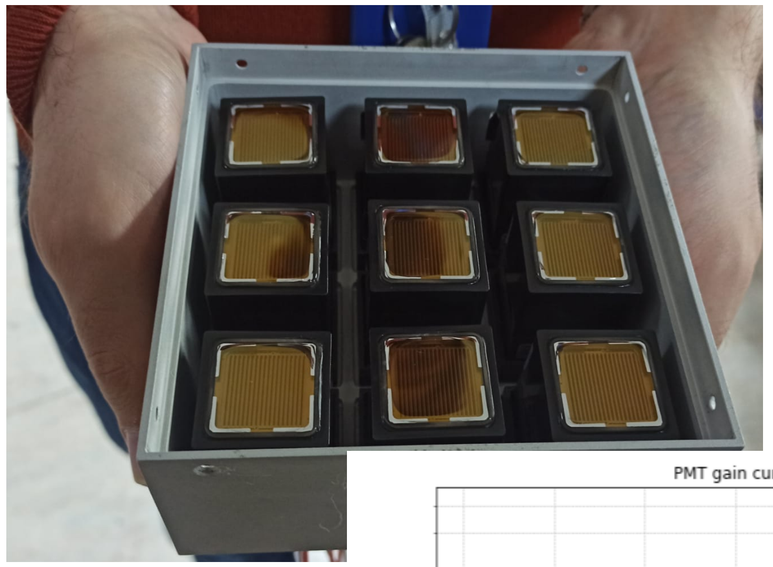
25um SPADs, smallest available for S13360-series

NA62 CHANTI board for HV and preamp

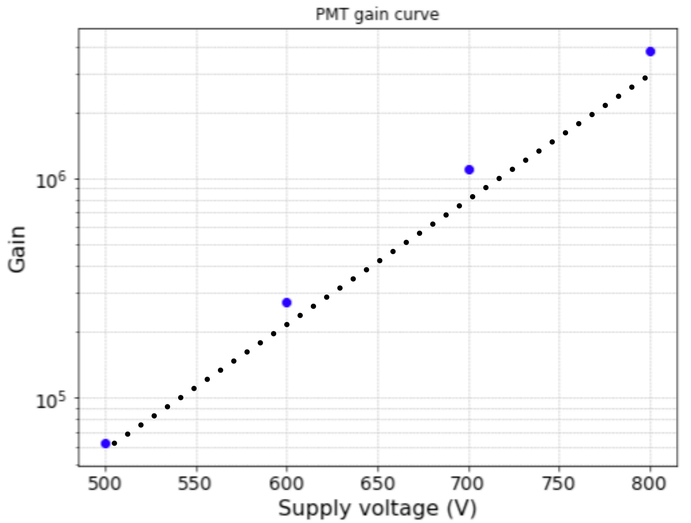
Cannot use 10um from S14160-series because $V_{BR} = 42 \pm 3$ V and minimum HV from CHANTI board is ~42 V

PMTs

Hamamtsu R7600U-300 extended green



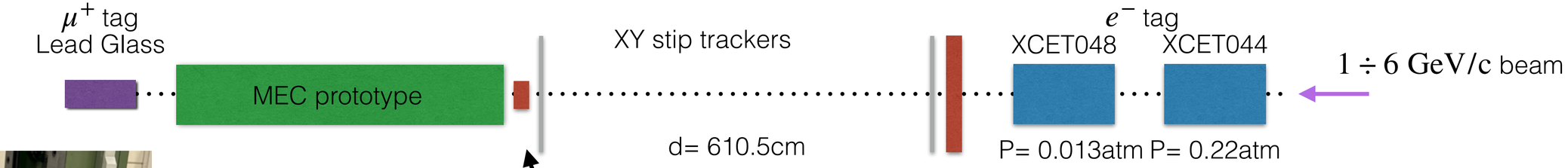
Preliminary checks by F.Milano for his bachelor in Naples

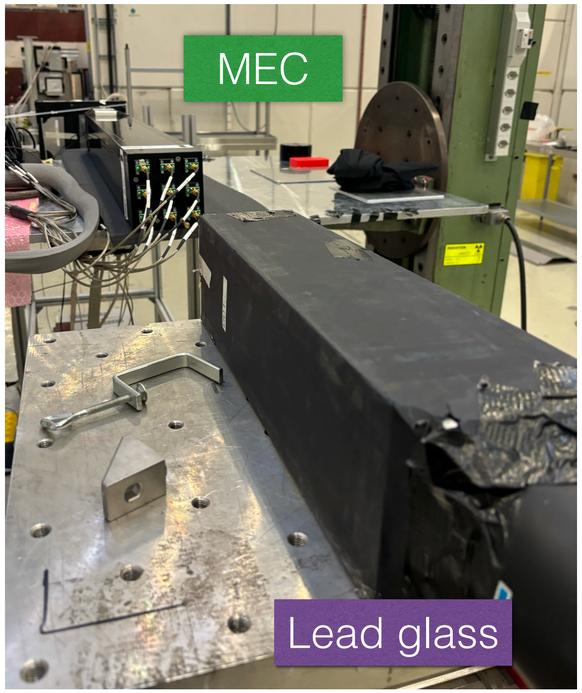


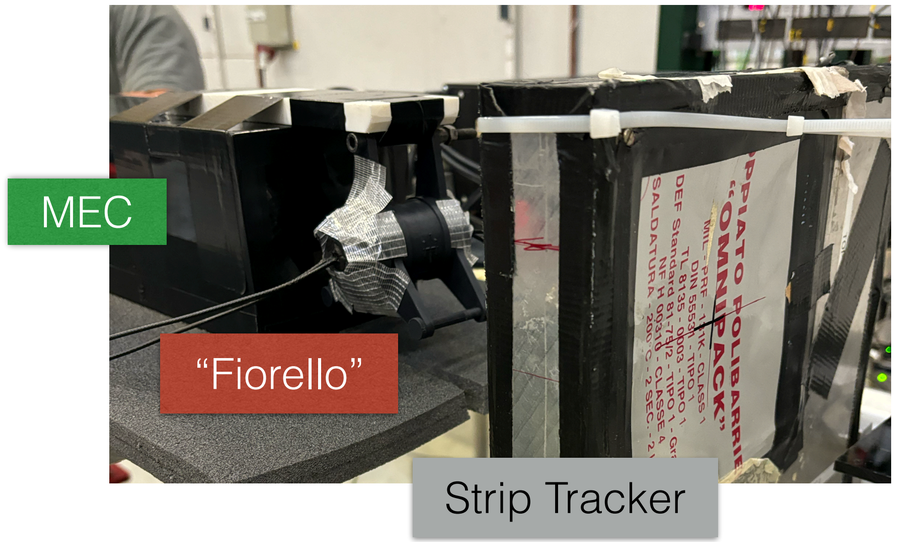
Testbeam time in T9

Profited to be back-to-back with CRILIN/OREO beamtime

Shares the same upstream structure:
beamline Cherenkov, plastic scintillators, and uninsubria strip detectors



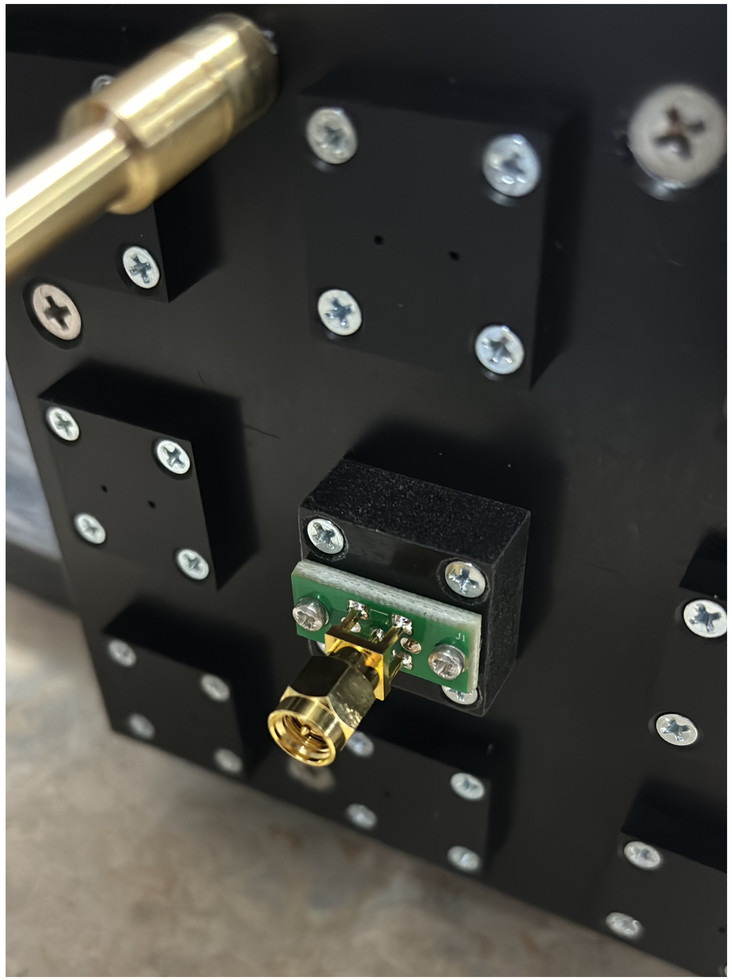




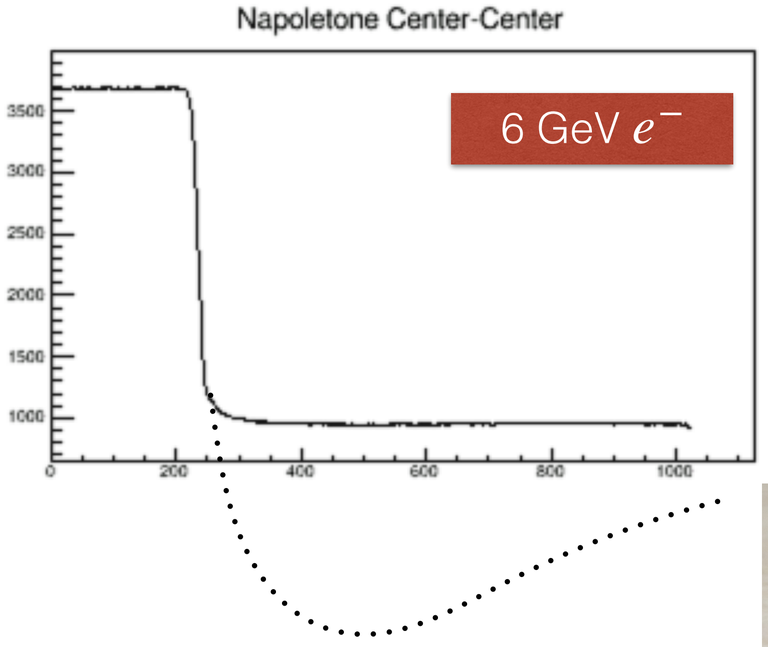
Ultra-fast plastic scintillator "Fiorello" to trigger on particles hitting center of the MEC, timing reference for σ_T

Large upstream plastic scintillator for wide illumination

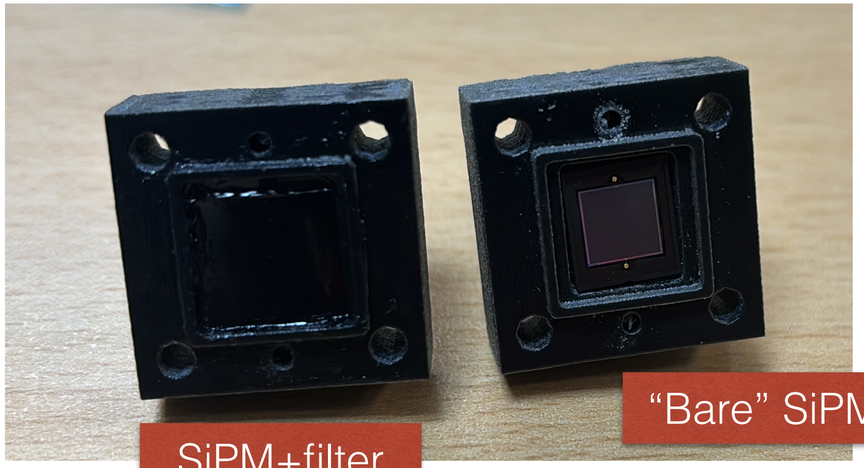
SiPM signal check



Waiting for PMT and SiPM delivery, tested single central module with SiPM to look for saturations (+3V OV)

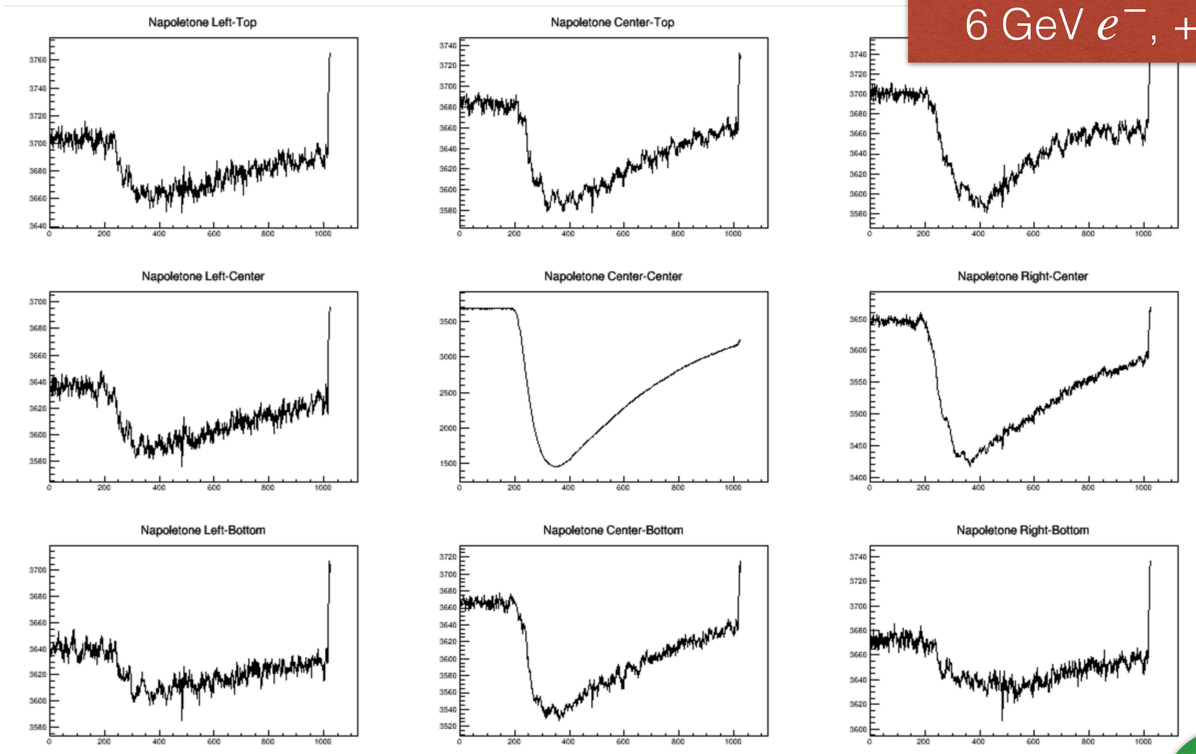


No hope with 6 GeV because of CHANTI board $\times 25$ internal gain… added OD1 ($\times 1/10$) optical filter



SiPM signals with OD1 filter

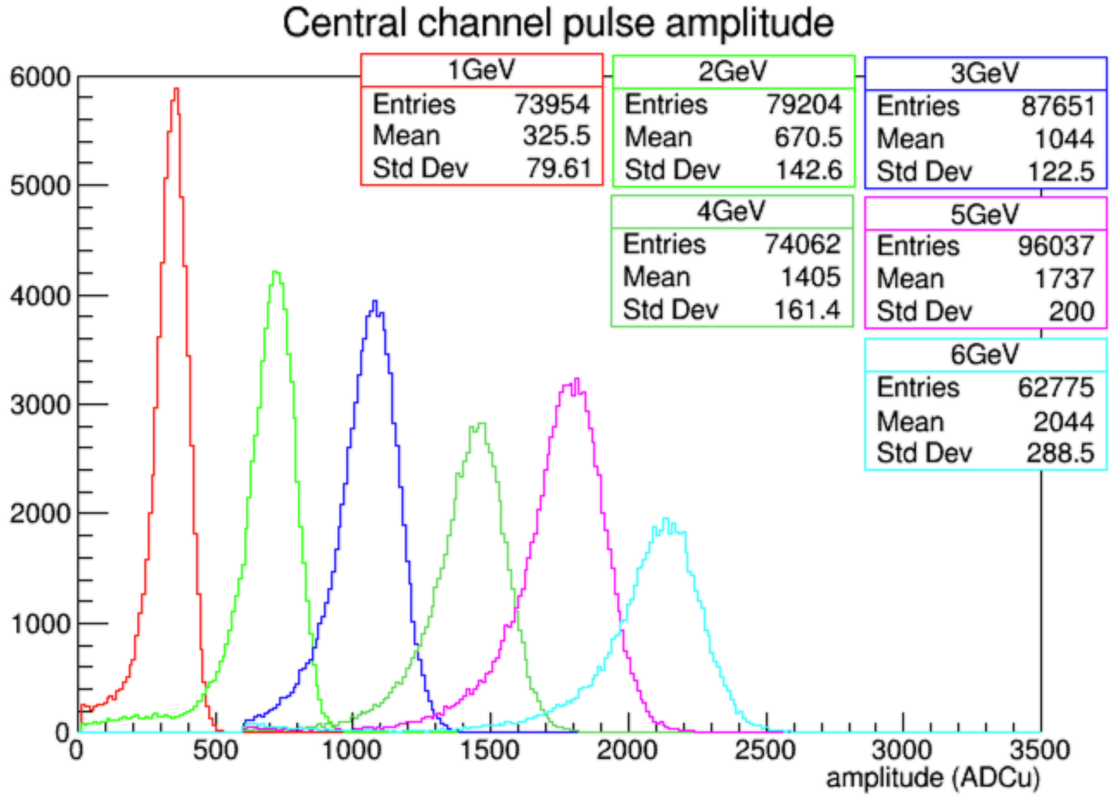
6 GeV e^-, + 3.2V OV

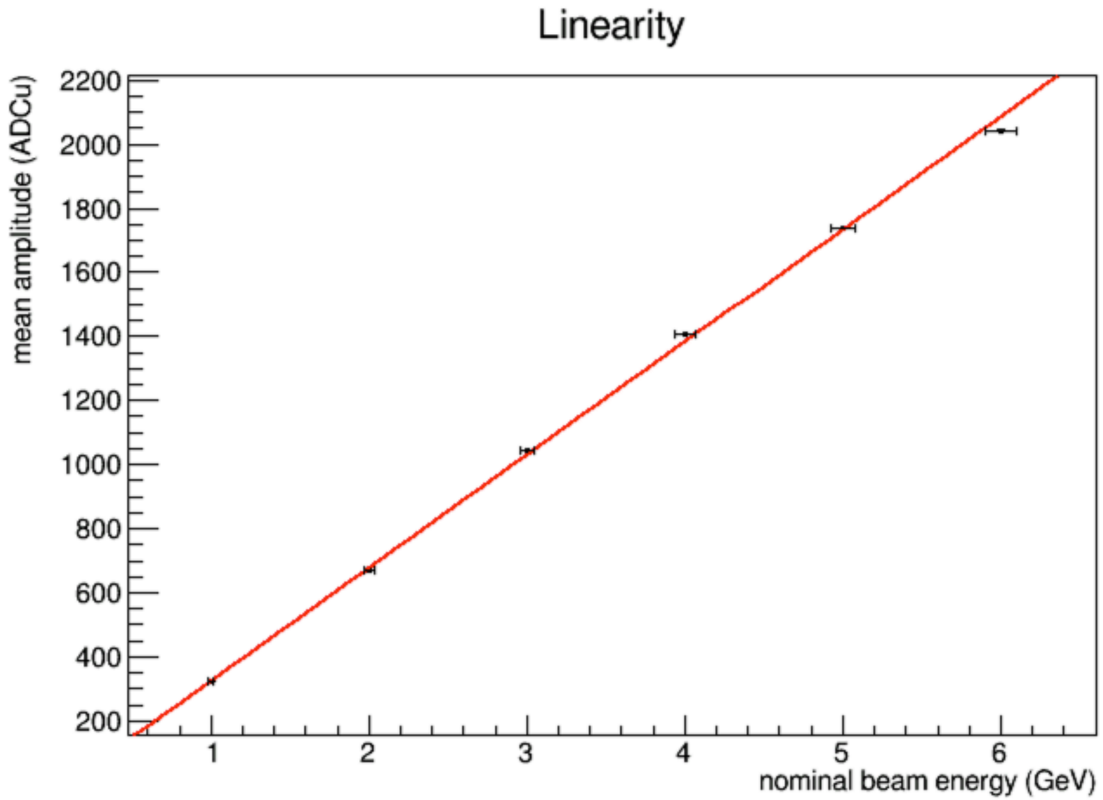


Minor OV tuning to maximise the dynamic range

Collected statistics with SiPMs

Good statistic collected, approximately 50 evts/spill





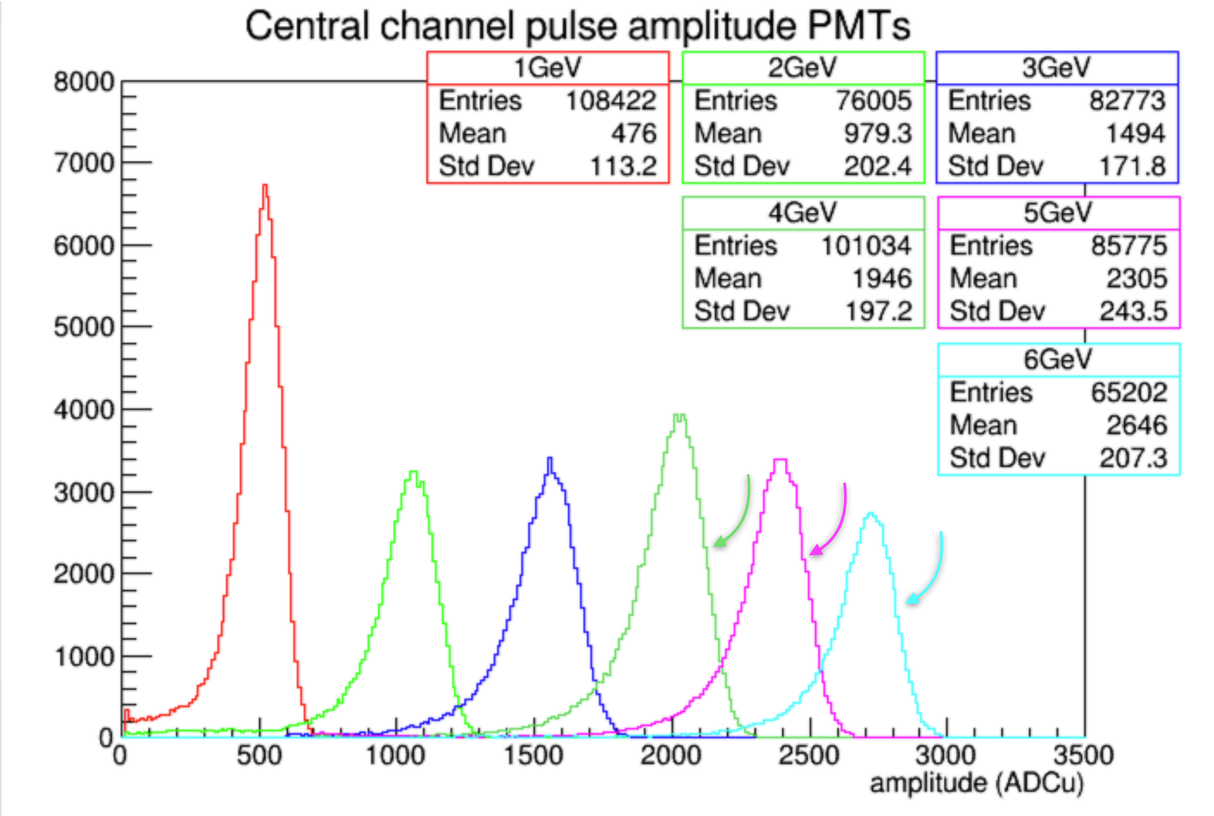
e^- cuts applied: hit in one of Cherenkov, no hit in Lead Glass and single hit in strip sensors

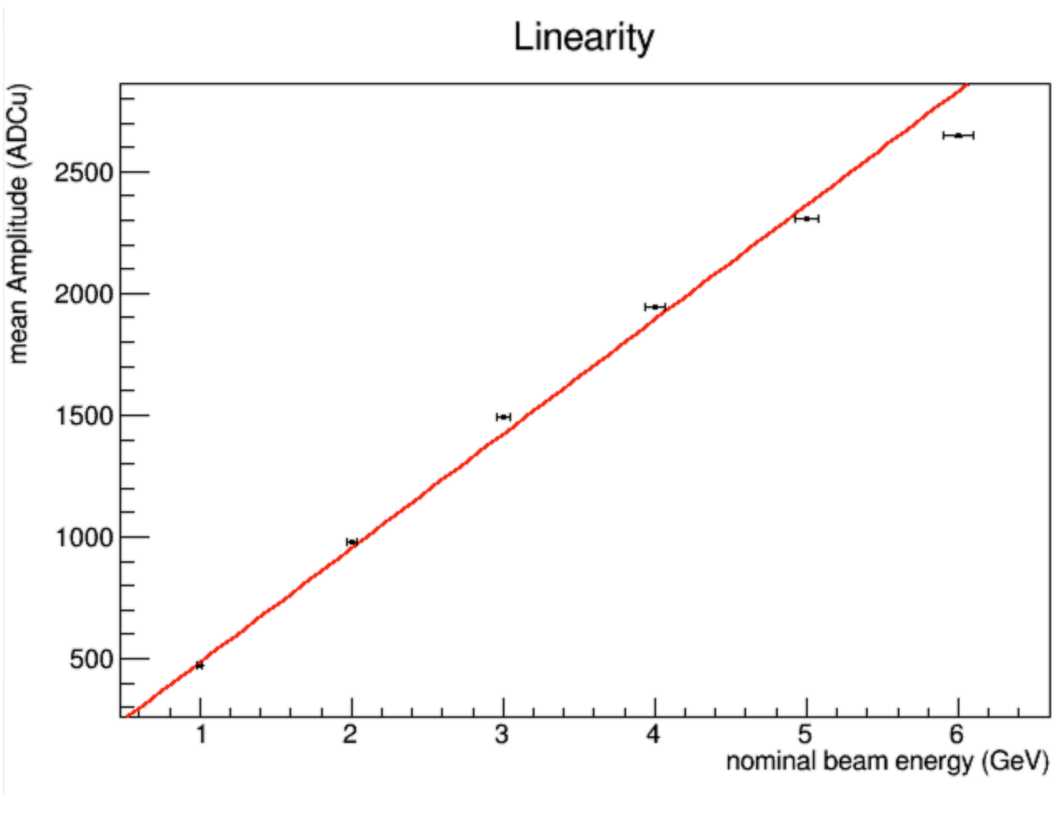
1.6% uncertainty on beam energy

Additional non-linearity due to leakage from central cell

Spectra with PMTs

Large variation of PMT gains, HV tuning required to uniform response

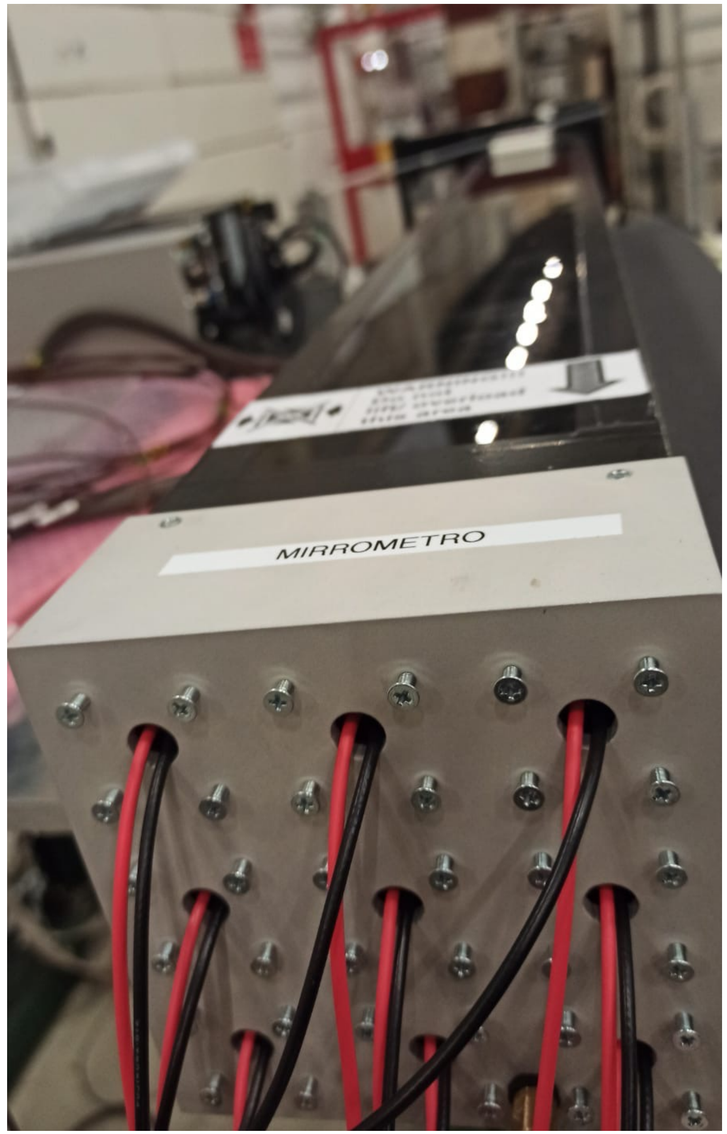




Better right tail of the energy deposits

Larger non-linearity effect, probably from asymmetric tails

Conclusions and further steps



First tests of a full-length prototype of HIKE MEC calorimeter

Large dataset collected at T9 with e^-
being analysed right now

Next steps:

Channel inter-calibration and time resolution extraction, ongoing

Full geant4 simulation ongoing, reported by Ilaria in the next presentation

Longer term:

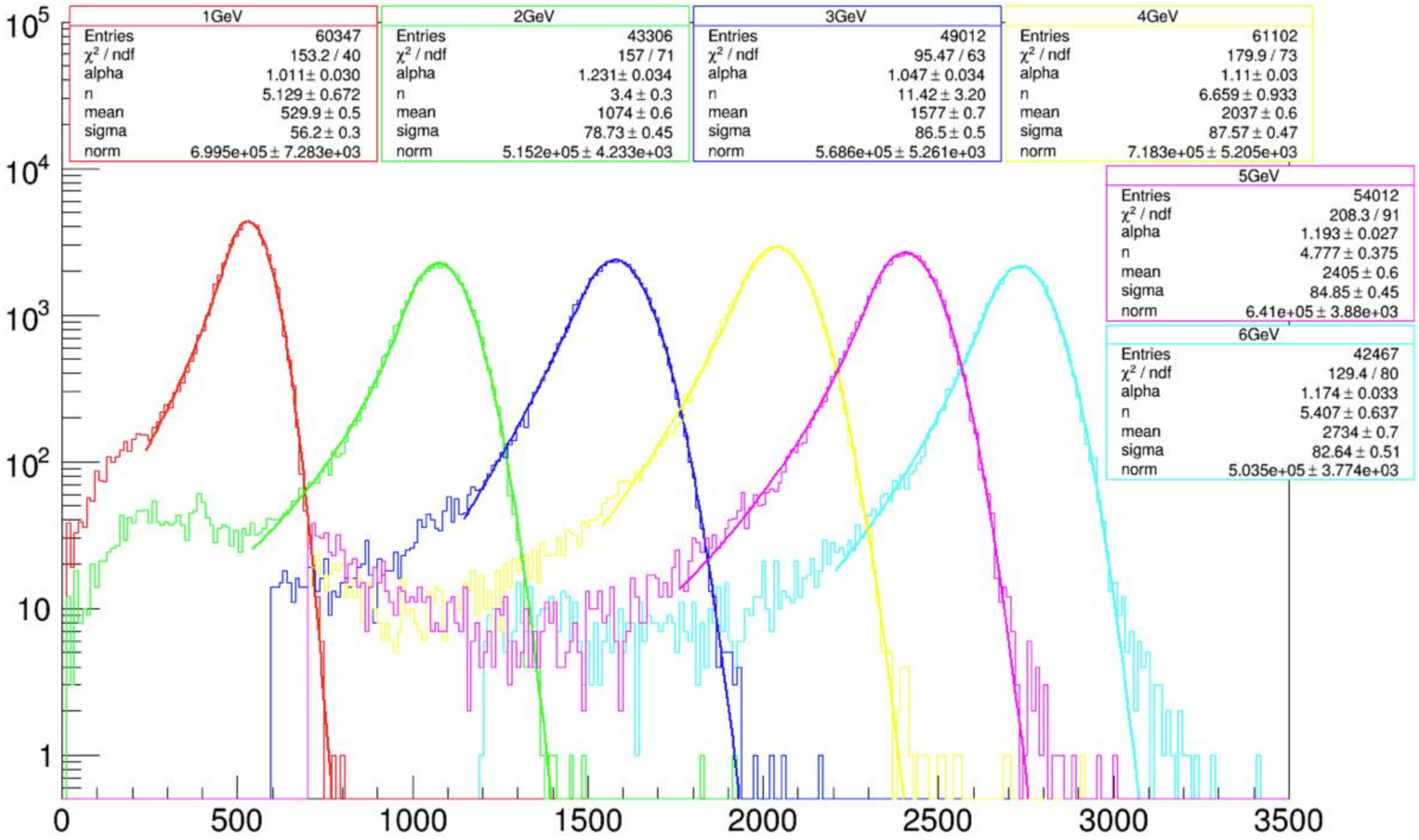
Another 1-week testbeam request for T9 submitted for next year

Test modified setups: Kuraray YS4 WLS, 10um SiPM, different PMTs…

Include custom ADC readout

Extra slides

Crystalbox fit of central module



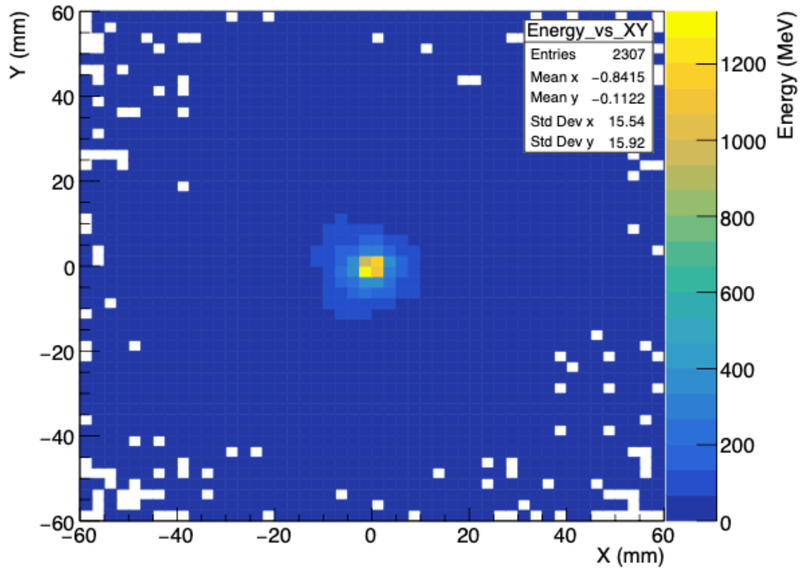
Cut part of events on nearby channel

Fit in $-2.8\sigma \div 3\sigma$

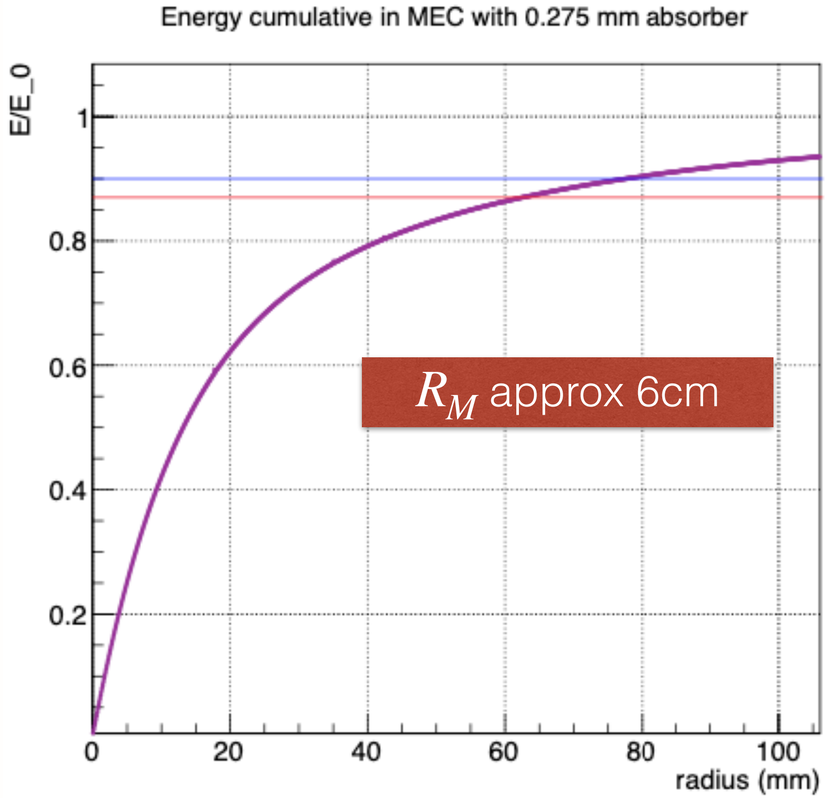
Molière radius

Geant4 implementation

- XY module segmentation
- Numerical integration (cumulative curves)
- Shower profile in homogeneous media and MEC
- Optimisation of the transverse module dimensions

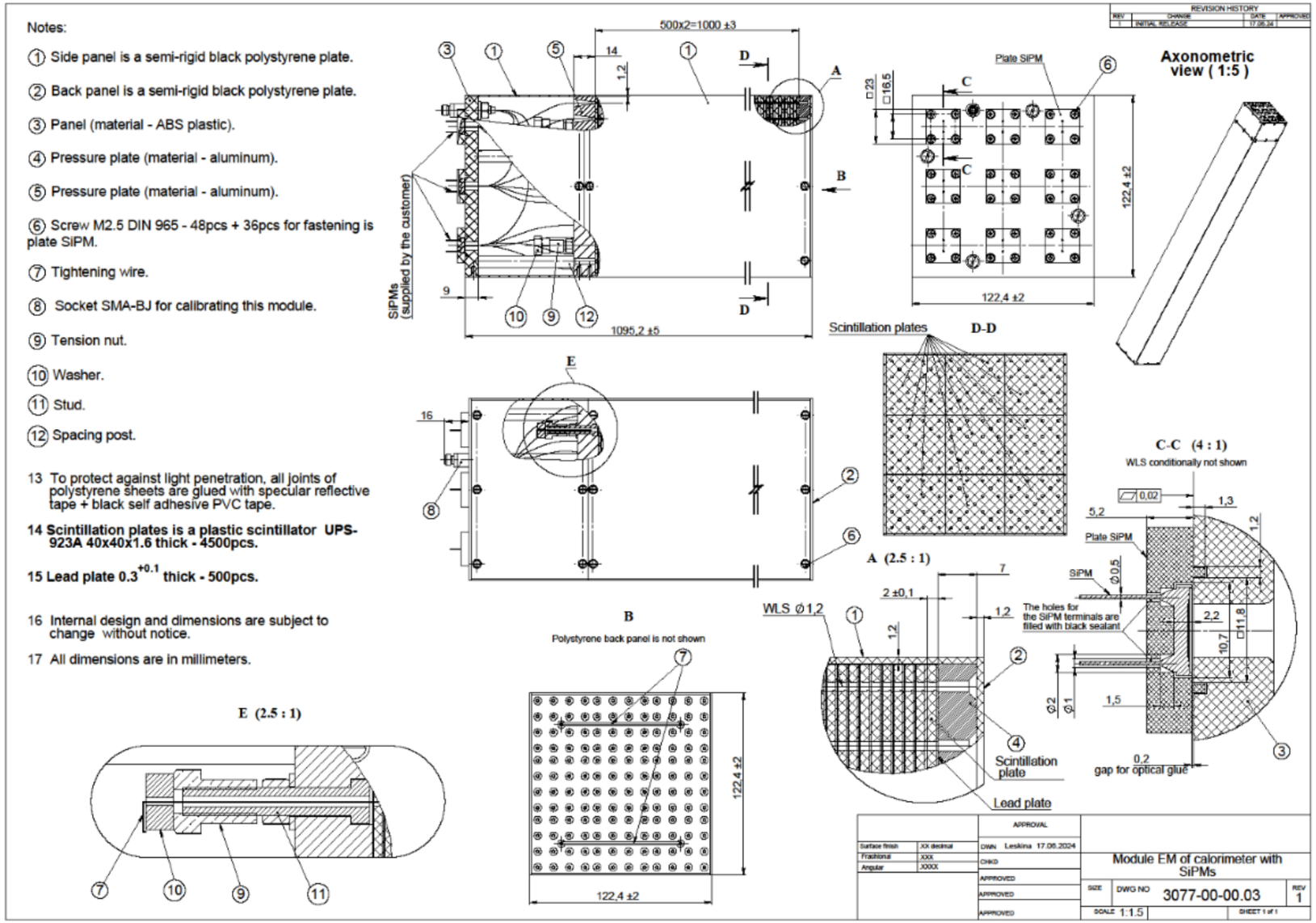


E_{e^-} = 30 GeV, 12x12 cm² module (~27 X_0)

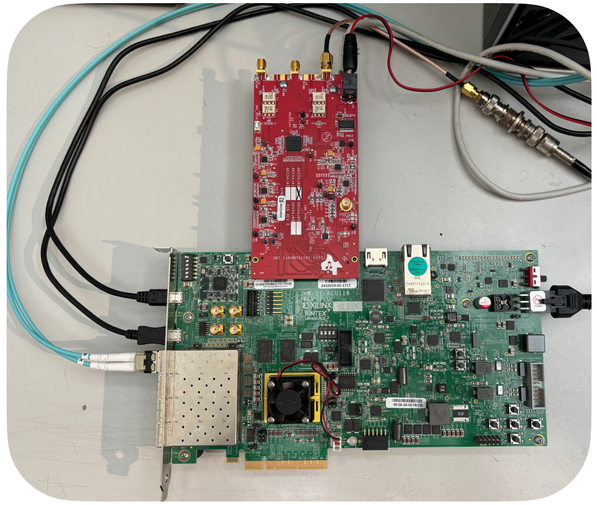


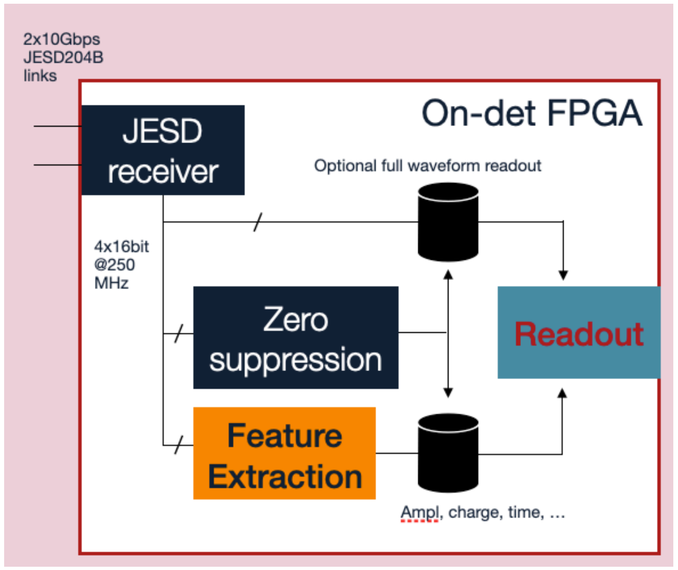
More details in Ilaria's presentation al JPARC

Technical drawing



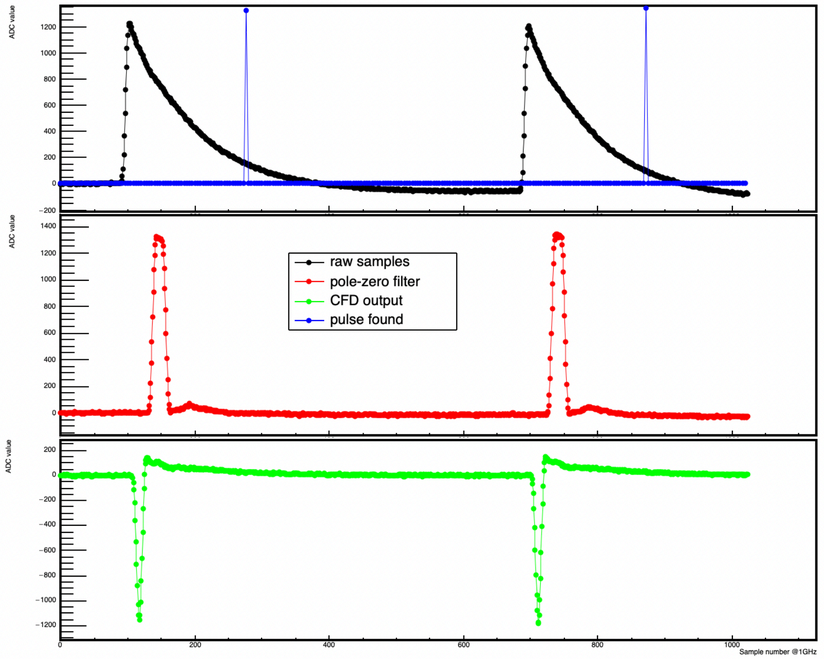
ADC readout status

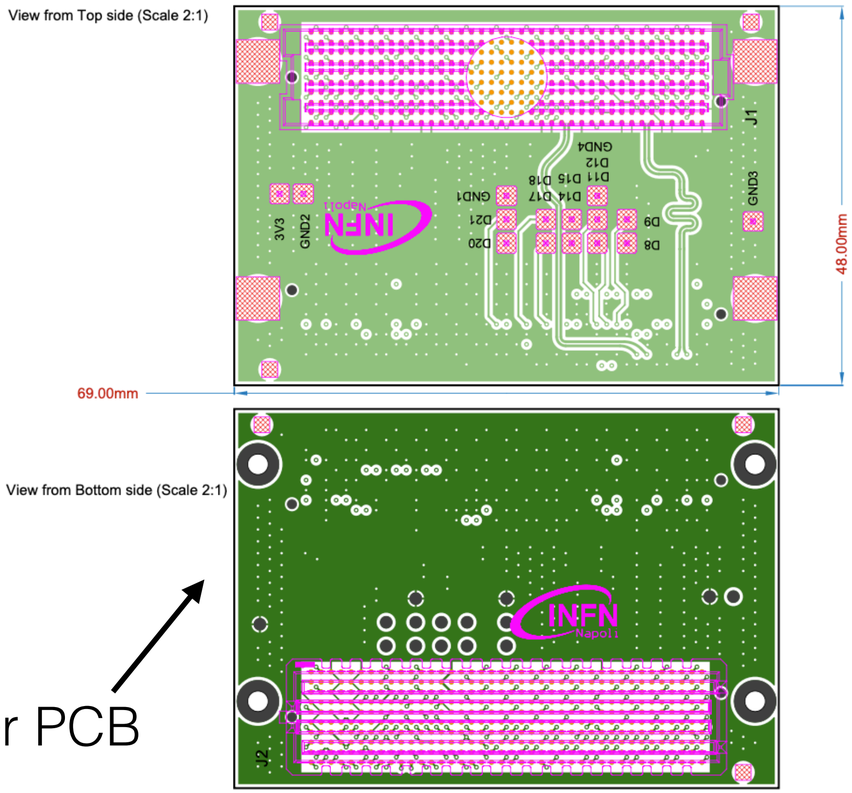




1 Channel prototype of tested with external pulser

MEC delivery to Naples will allow performance validation with real-world signals





Second channel requires an adapter PCB

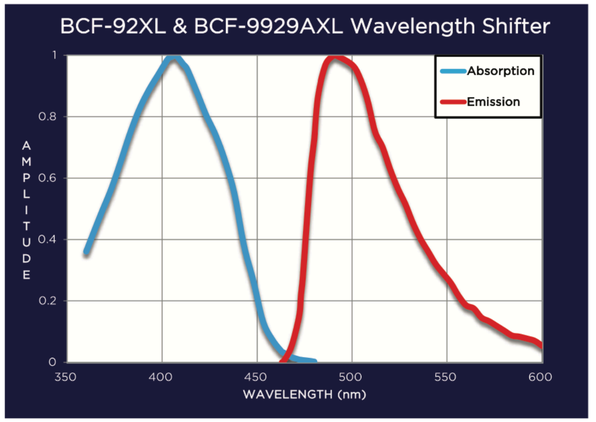
Interface to external DAQ to be developed

New fiber options

Luxium (Saint Gobain)

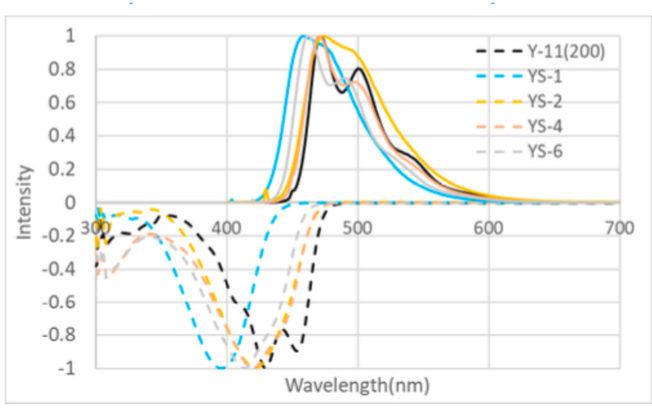
Specific Properties of BCF-XL Series Formulations

Fiber	Emission Color	Emission Peak, nm	Decay Time, ns	# of Photons per MeV*	Attenuation Length (m)**	Characteristics / Applications
BCF-91AXL	green	494	12	n/a	>4	Shifts blue to green
BCF-92XL	green	492	2.7	n/a	>4	Fast blue to green shifter
BCF-9929AXL	green	492	2.7	n/a	>4	Blue to green shifter. Pairs well when exciting wavelengths are >425nm (e.g. injection-molded and extruded scintillators)
BCF-9995XL	blue	450	n/a	n/a	>4	UV to blue shifter
BCF-98XL	n/a	n/a	n/a	n/a	Not available	Clear Waveguide

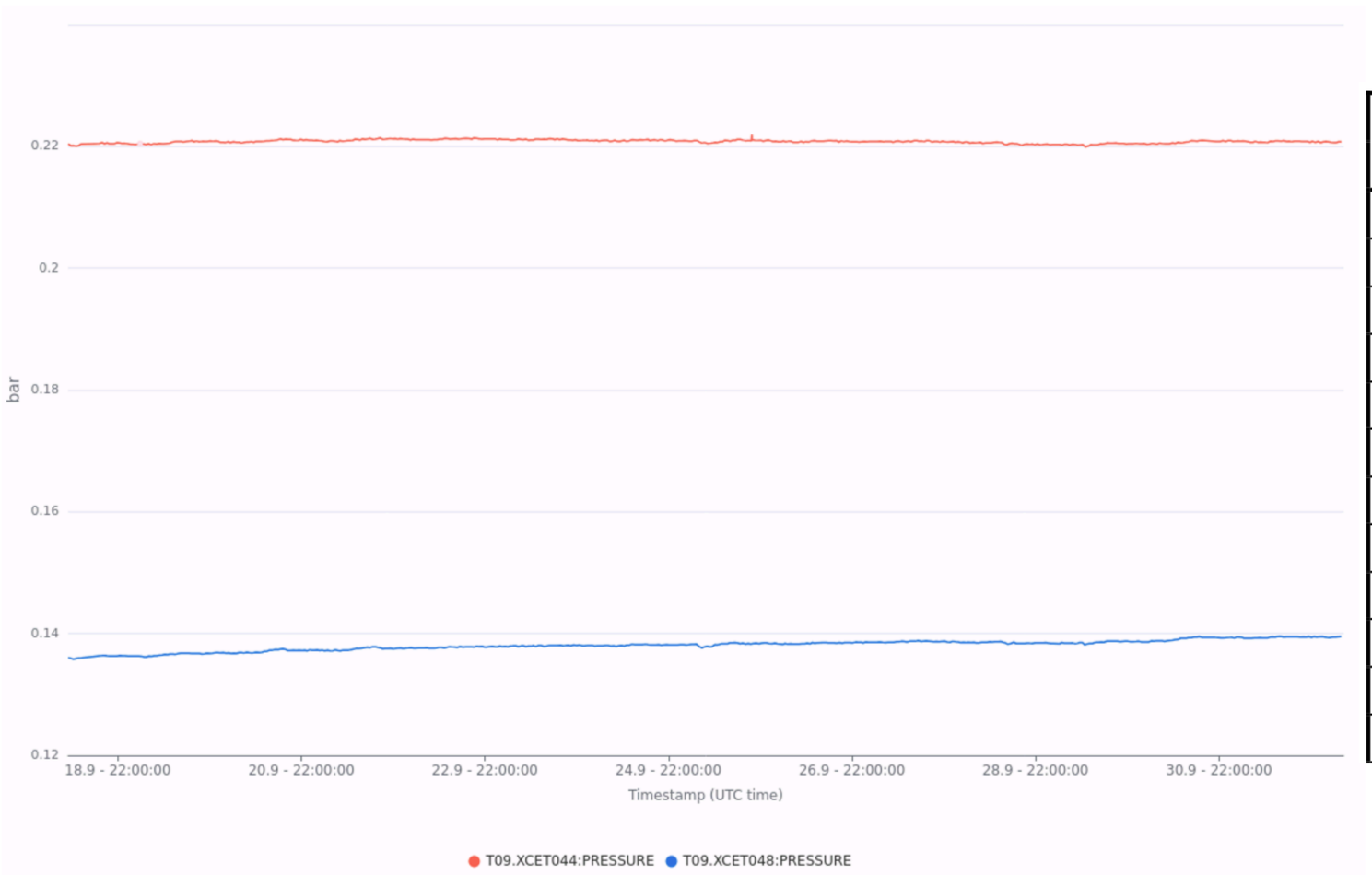


Kuraray

	Y-11 Standard Grade	YS-1	YS-2	YS-4	YS-6
Absorption peak(nm)*1	430	395	422	420	414
Emission peak(nm)*1	476	454	474	470	462
Decay time(ns)*2	6.9	2.7	3.2	1.4	1.3
Attenuation length(m)*3	>3.5	>3.5	>3.5	>3.0	>3.0



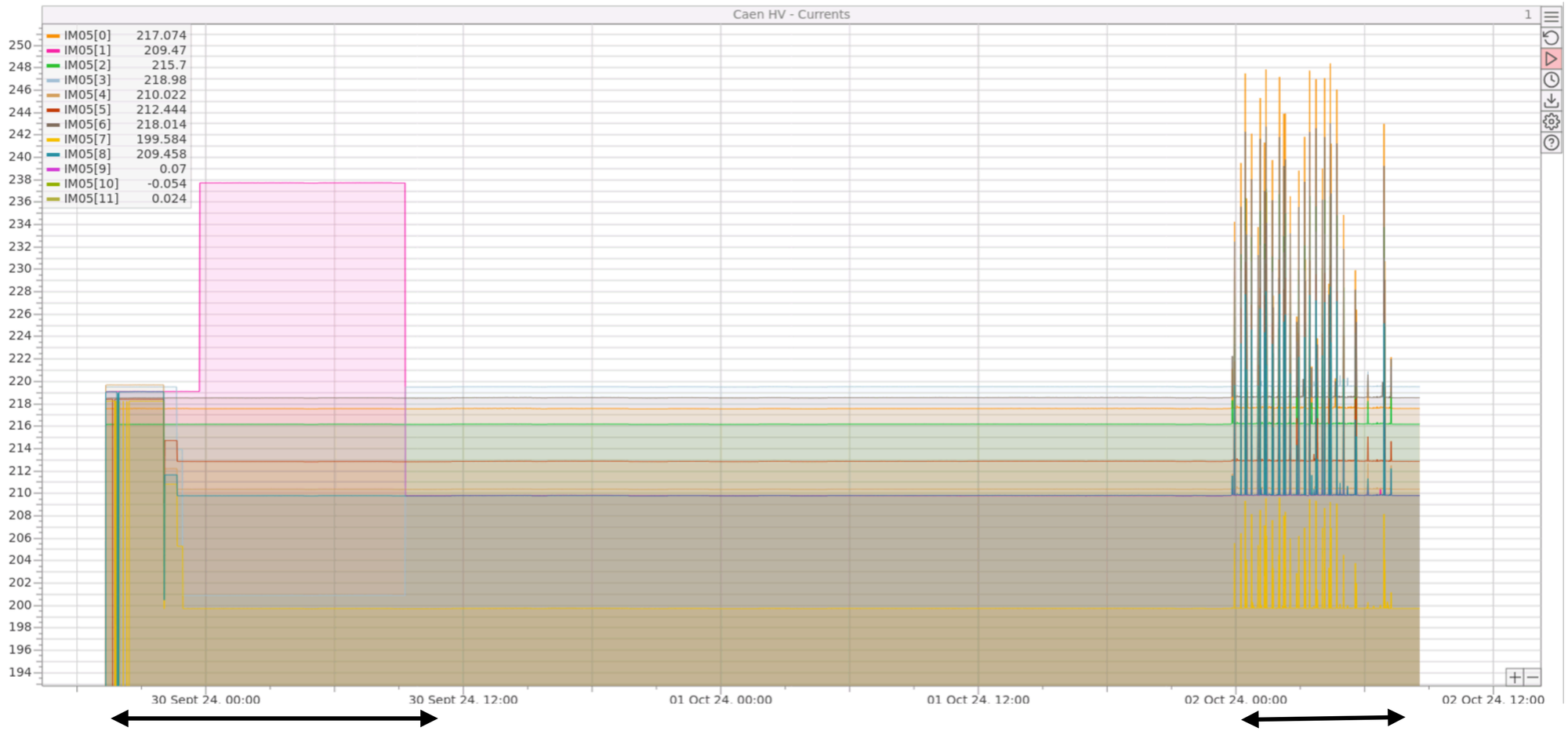
XCET044 and XEC048 pressure



p GeV/c	CO2			
	e	μ	π	p
0.500	0.00	52.92	91.06	2680.67
1.000	0.00	13.34	23.09	883.51
1.500	0.00	5.94	10.29	427.20
2.000	0.00	3.34	5.79	248.85
2.500	0.00	2.14	3.71	162.07
3.000	0.00	1.49	2.58	113.67
3.500	0.00	1.09	1.89	84.02
4.000	0.00	0.84	1.45	64.59
4.500	0.00	0.66	1.15	51.18
5.000	0.00	0.53	0.93	41.54
5.500	0.00	0.44	0.77	34.38
6.000	0.00	0.37	0.64	28.92

PMT HV Current

Channel	Voltage (V)
CC	600
TR	575
TC	600
TL	600
CL	575
BL	585
BC	600
BR	550
CR	575

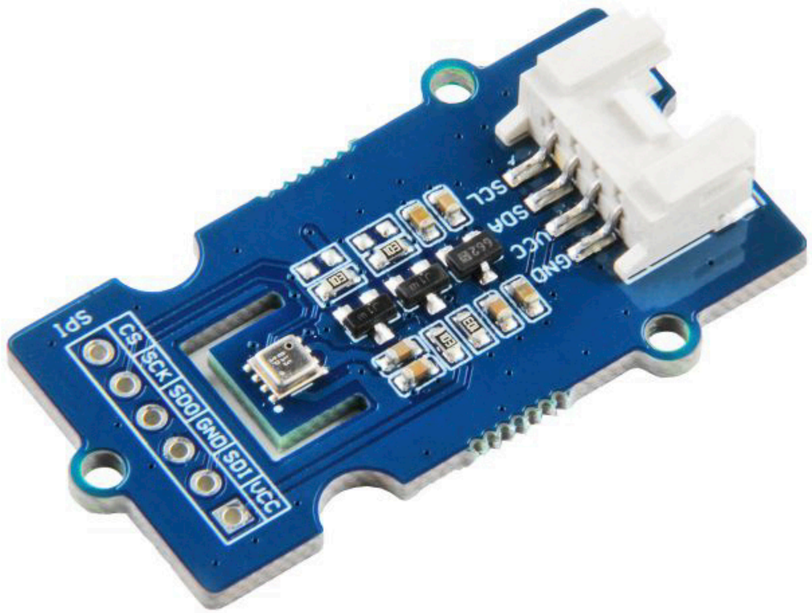


HV tuning

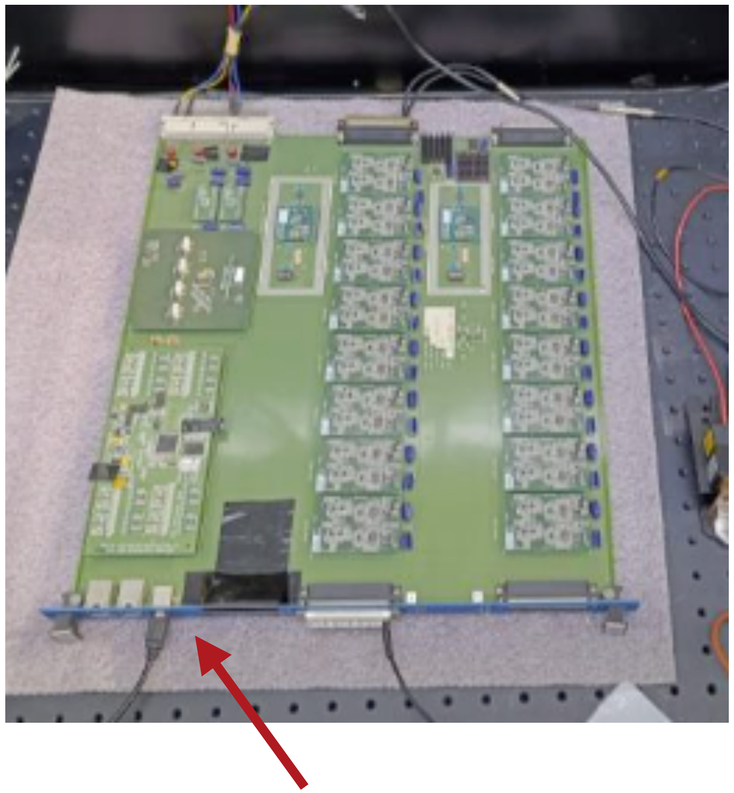
Loaded wrong beam file

Other monitoring tools

Temperature monitoring (including humidity and atm. pressure) through the data acquisition using an arduino + a BME680 sensor



Also CHANTI current (Imon) and voltages (Vmon) recorded when sipm in use using console port



Data in uninsubria DAQ pc, to be retrieved