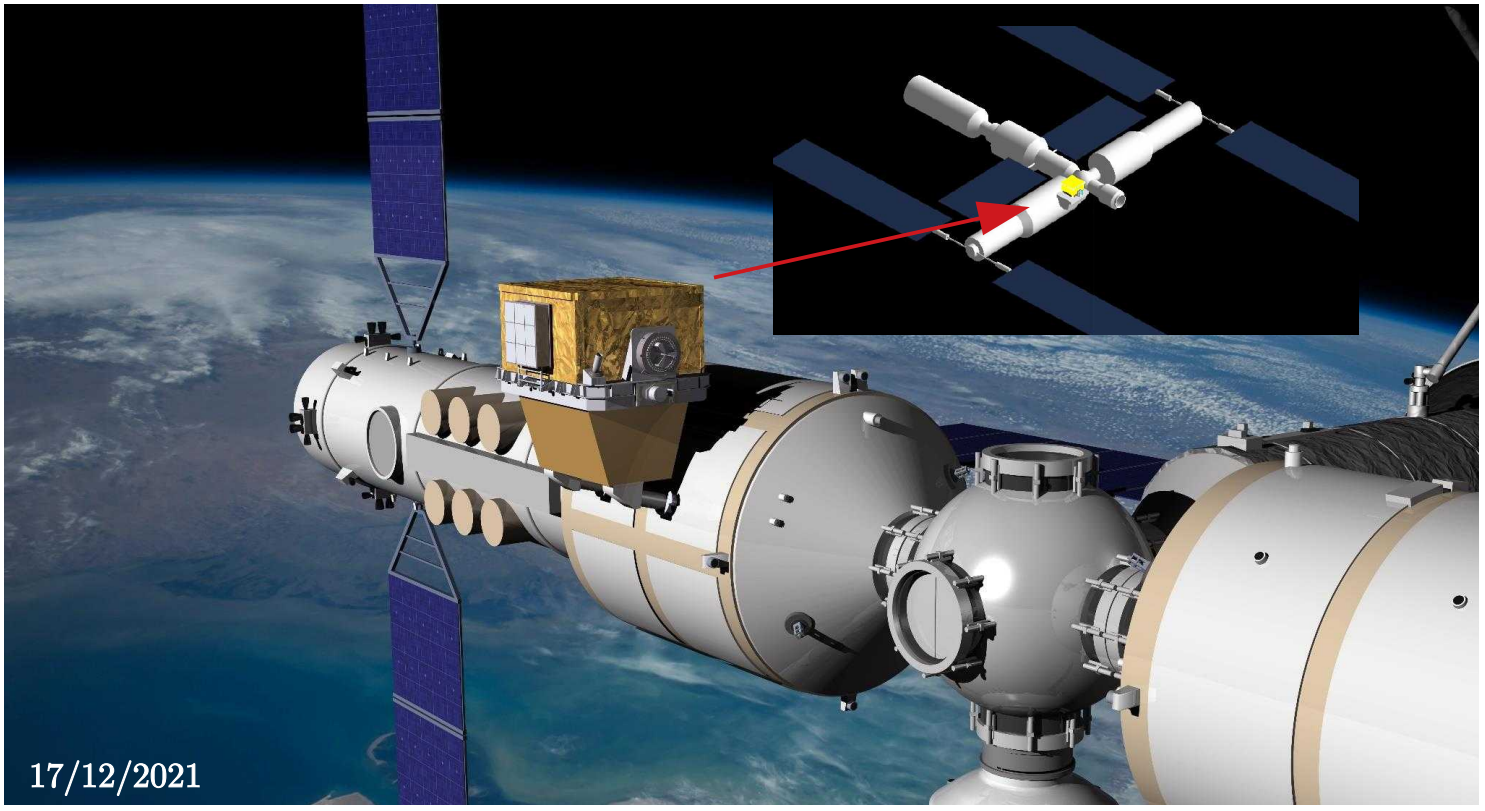
The HERD space mission



Attenuation Length Updates from Lab & MC activities

D. Kyratzis, A. Parenti, F. Alemanno, F. Barbato, I. De Mitri, A. Di Giovanni, L. Silveri, L. Wu

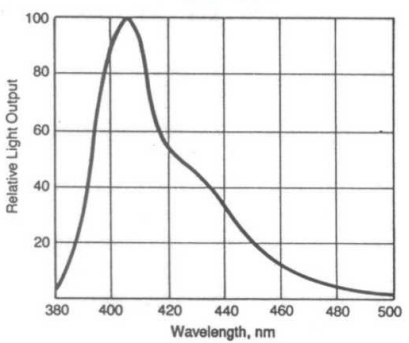
for the GSSI group

Gran Sasso Science Institute (GSSI) & INFN-LNGS

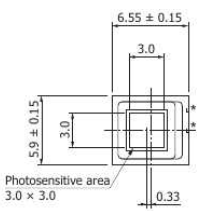
Configuration Characteristics

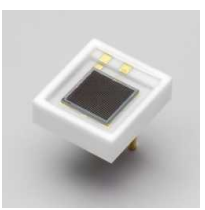
	BC-404
Radiation Detected	
<100keV X-rays	
100keV to 5MeV gamma rays	
>5MeV gamma rays	
Fast neutrons	
Alphas, betas	X
Charged particles,cosmic rays, muons, protons, etc.	
Principal Uses/Applications	fast counting
Scintillation Properties	
Light Output, %Anthracene	68
Rise Time, ns	0.7
Decay Time (ns)	1.8
Pulse Width, FWHM, ns	2.2
Wavelength of Max. Emission, nm	408
Light Attenuation Length, cm*	140
Bulk Light Attenuation Length, cm	160

BC-404

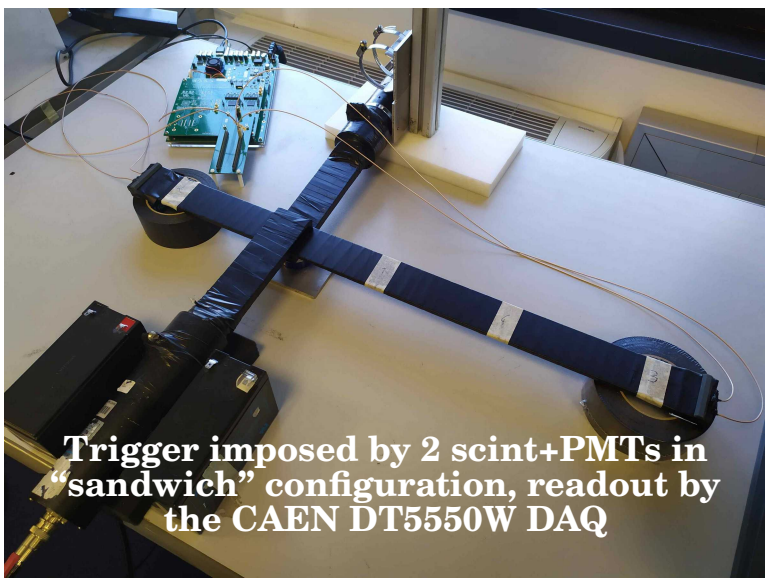


SiPM model	S13360 – 3025CS
Effective area (mm)	3 x 3
Cell count	14400
Cell size (μm)	25
Cell fill factor (%)	47
Response range (nm)	270 – 900
Peak sensitivity (nm)	450
PDE (%)	25
Breakdown voltage (V)	65 ± 10
Overvoltage (V)	5.0
Dark count rate	400 – 1200 (kcps)
Gain	7×10^5





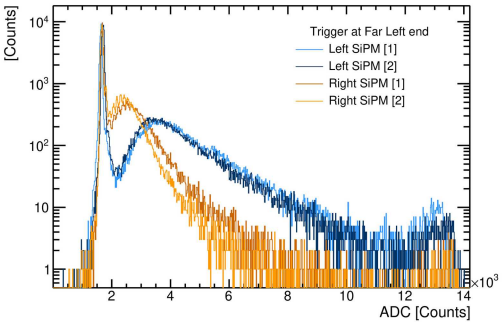
Saint-Gobain (BC-404) [75 x 5 x 0.5 cm^3] scintillator bar coupled with 2 SiPM/side [Hamamatsu S13360 – 3025CS]

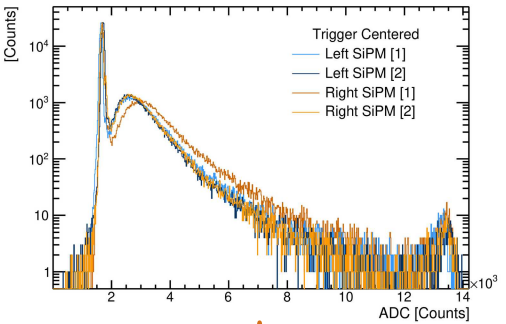


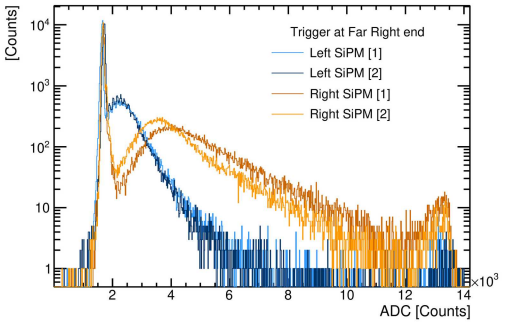
Summary of Muon Spectral Measurements

"Sandwich" trigger placed in various positions along the bar

Left & Right SiPMs

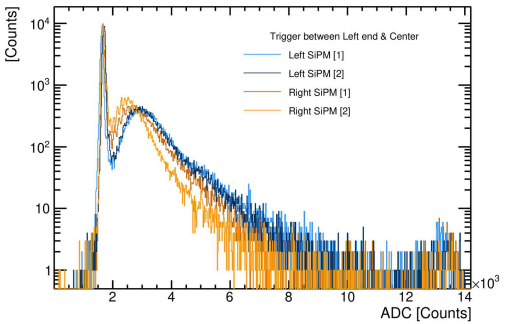




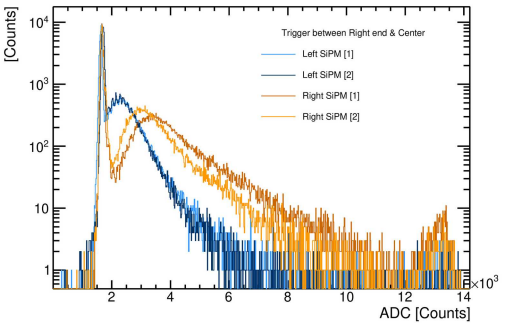


Left

Right



Characteristics:
HV- 57.5 V, HG Gain – 60
Shaping time: 50 ns

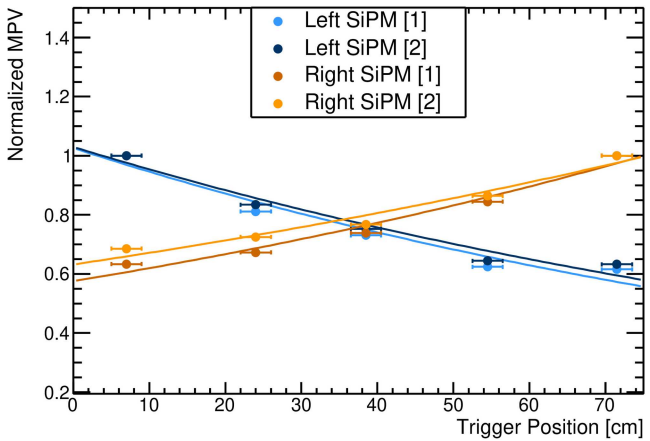


The full 75 cm bar is graphically illustrated with its trigger positions (in cm)

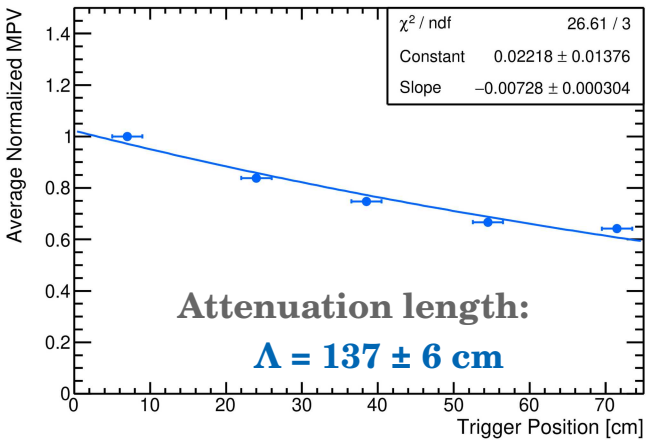
Results

Fitting all SiPM charge distributions w/ LanGaus functions

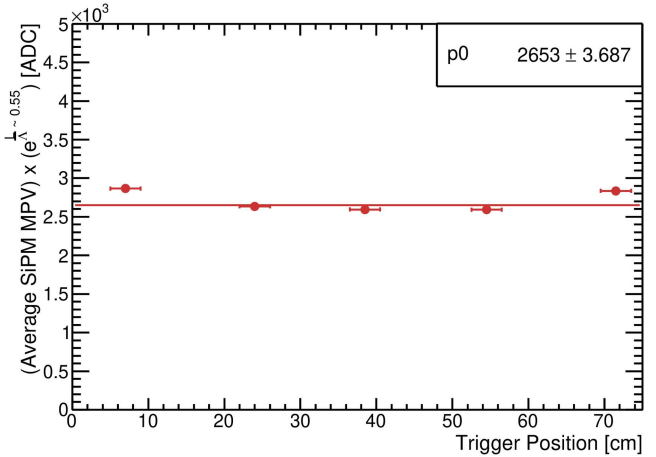
BC – 404 w/ Hamamatsu S13360-3025CS SiPMs



Individual behaviour of both sides derived from all MPVs

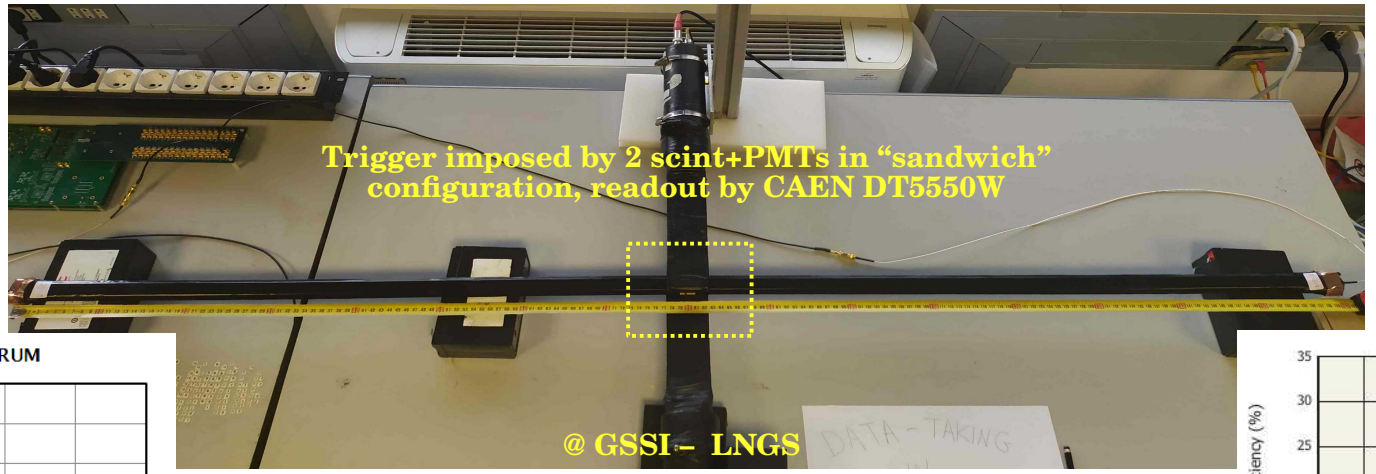


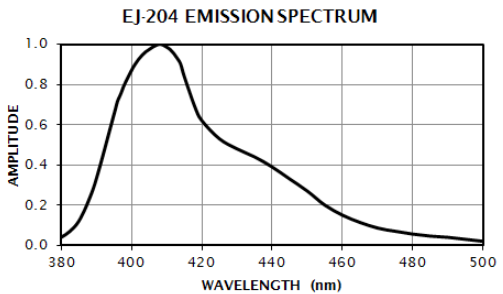
Average Normalized MPV leading to attenuation length measurement regarding the bar under test



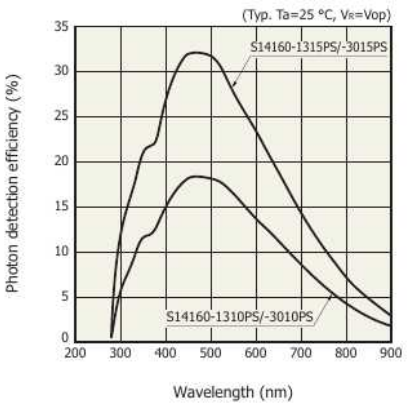
Average MPV count in all trigger positions

Configuration characteristics



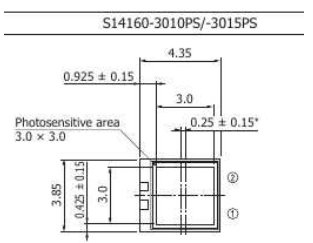


EJ-204 [160 x 3 x 0.5 cm] + 2 SiPMs/side [S14160-3015PS]



PROPERTIES	EJ-200	EJ-204
Light Output (% Anthracene)	64	68
Scintillation Efficiency (photons/1 MeV e⁻)	10,000	10,400
Wavelength of Maximum Emission (nm)	425	408
Light Attenuation Length (cm)	380	160
Rise Time (ns)	0.9	0.7
Decay Time (ns)	2.1	1.8
Pulse Width, FWHM (ns)	2.5	2.2
H Atoms per cm³ (×10²²)	5.17	5.15
C Atoms per cm³ (×10²²)	4.69	4.68
Electrons per cm³ (×10²³)	3.33	3.33
Density (g/cm³)	1.023	1.023

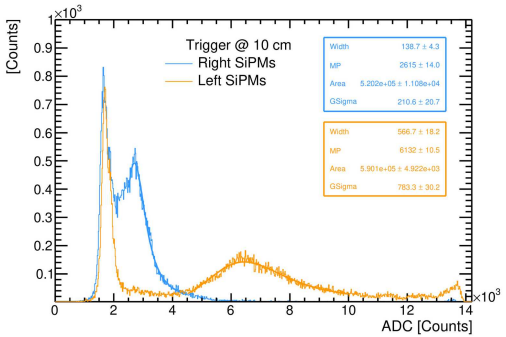
Parameter		Symbol	S14160				Unit
			-1310PS	-3010PS	-1315PS	-3015PS	
Spectral response range		λ	290 to 900				nm
Peak sensitivity wavelength		λp	460				nm
Photon detection efficiency at λp*2		PDE	18		32		%
Breakdown voltage*3		VBR	38±3				V
Recommended operating voltage*3		Vop	Vbr + 5		Vbr + 4		V
Vop variation within a reel		-	±0.1				V
Dark count rate*4	typ.	DCR	120	700	120	700	kcps
	max.		360	2100	360	2100	
Direct crosstalk probability		Pct	< 1				%
Terminal capacitance at Vop		Ct	100	530	100	530	pF
Gain		M	1.8 × 10⁵		3.6 × 10⁵		-
Temperature coefficient of Vop		ΔTVop	34				mV/°C

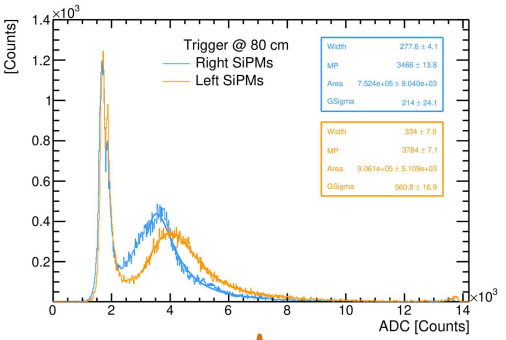


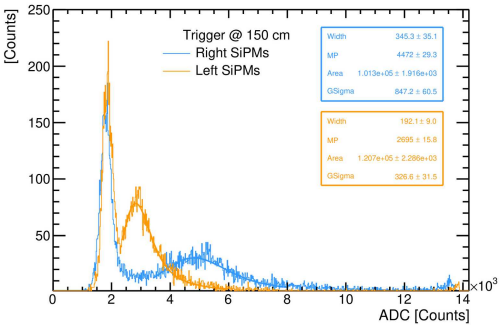
Summary of CR Muon spectral measurements

"Sandwich" trigger placed in various positions along the bar

Right & Left SiPMs

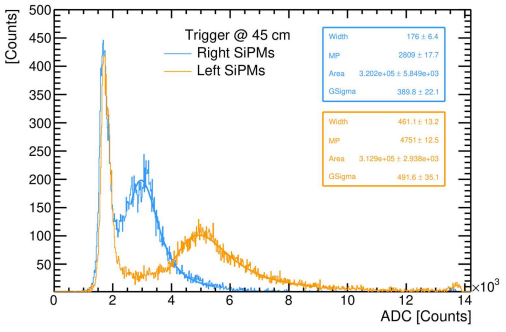


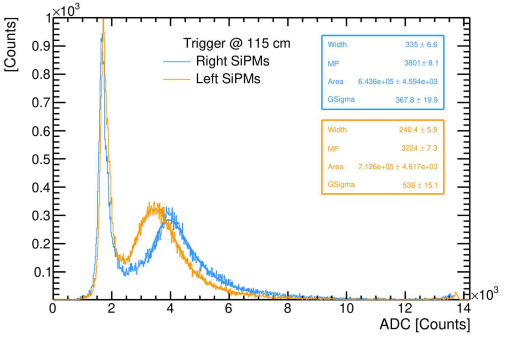




Left

Right



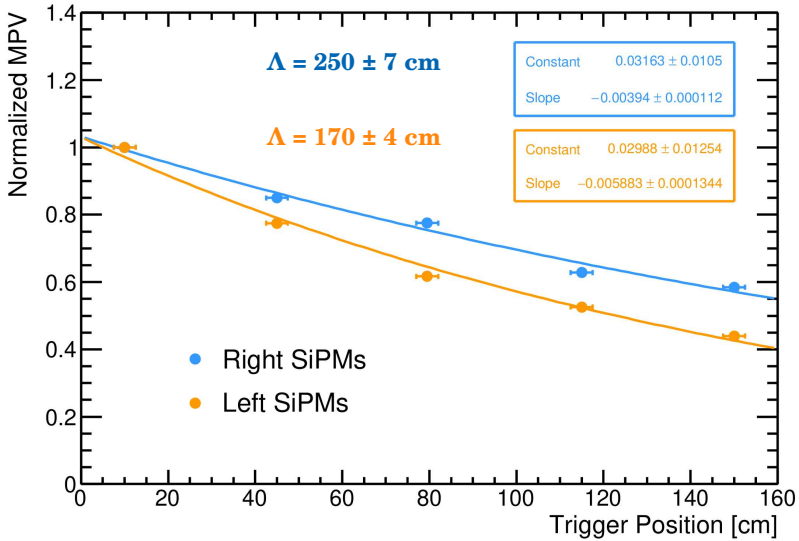


The full 160 cm bar is graphically illustrated with its trigger positions (in cm)

Preliminary Results

Fitting all SiPM charge distributions w/ LanGaus functions

EJ-204 w/ Hamamatsu S14160-3015PS SiPMs



Individual behaviour of both sides derived from all MPVs

Additional measurements in the first 50 cm of the 160 cm bar to evaluate hypotheses of additional components contributing in the light attenuation curve

Summary [Lab activities]

BC – 404 [75 cm] rectangular bar

- Construction, calibration and test of 75 cm bar w/ Hamamatsu SiPMs
- CR muons detected in 5 trigger positions along the 75 cm bar
- Light attenuation measurement: $\Lambda = 137 \pm 6$ cm

EJ – 204 [160 cm] trapezoidal bar

- Instrumentation of novel 1.6 m trapezoidal bar, validating performance aspects in larger scales
- CR muons detected in 5 trigger positions along the 1.6 m bar
- Preliminary light attenuation measurement: $\Lambda > 170 \pm 4$ cm

Additional measurements in the first 50 cm (of each side) of the 160 cm bar to evaluate hypotheses of additional components in the light attenuation curve

TAL estimation from simulation

Simulation setup

Beam:

Monoenergetic muons: 1 GeV

Different positions along the bar: 0, 40, 67, 72.5 cm from the center

500 events for each position

Rectangular geometries (two 3x3mm^2 SiPMs per side):

- 200 x 3 x 0.5 cm^3
- 200 x 3 x 1 cm^3
- 200 x 5 x 1 cm^3
- 200 x 12 x 0.5 cm^3
- 200 x 12 x 1 cm^3
- 200 x 12 x 2 cm^3

Trapezoidal geometries (one 3x3mm^2 SiPMs per side):

- 200 cm long
  - 1 cm height, 4 cm and 2 cm sides at 45° angle
  - 0.5 cm height, 3 cm and 2 cm sides at 45° angle

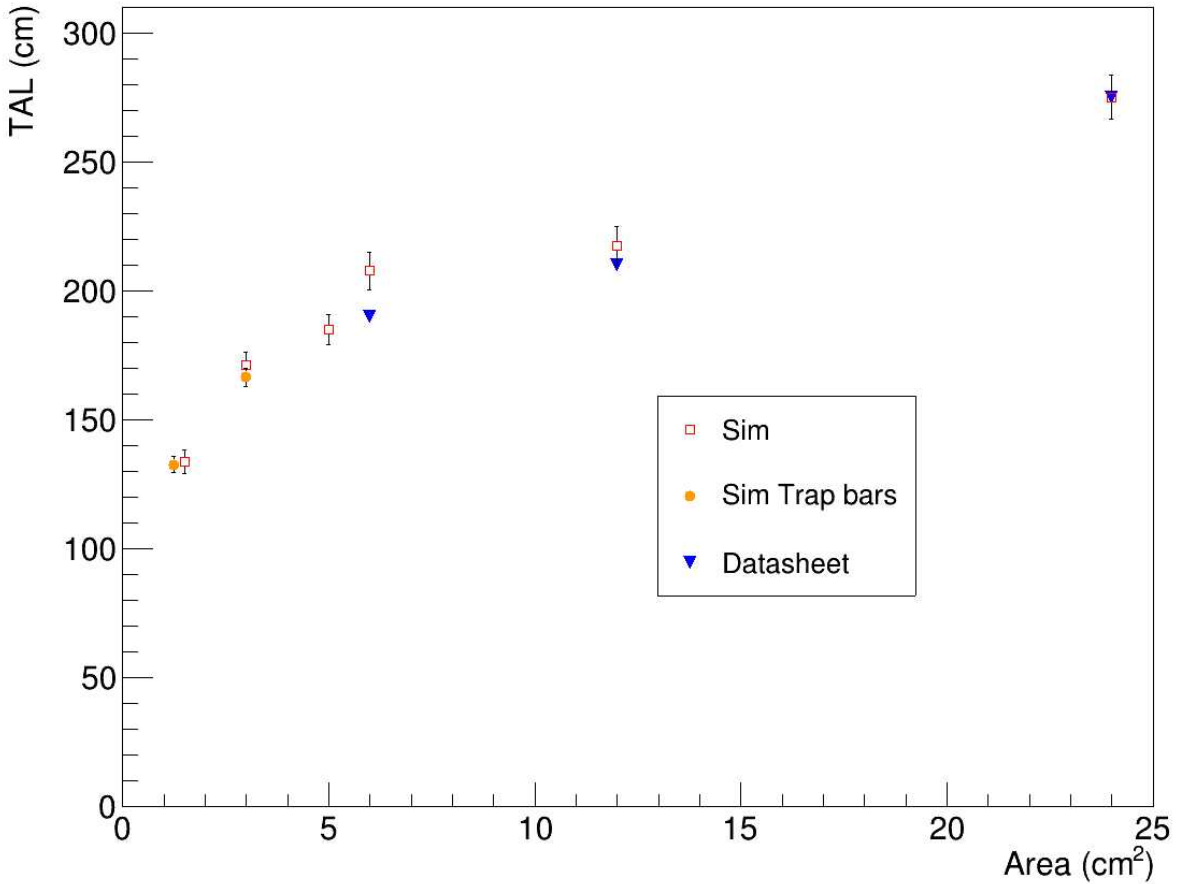
Parameters :

- MC Attenuation Length = 200 cm (to be normalized)
- BC-404 emission spectrum and light yield
- Wrapping thickness: 0.5 mm
- 100% or 97% wrapping reflectivity

TAL estimation: for each geometry, fit average number of photons collected by a SiPM as a function of the beam position with an exponential.

TAL as a function of the bar cross section area

Simulation results



From Saint-Gobain datasheet (link): study on BC-408 bars

Try reproducing values from manual (BC-408) with simulation.

TAL plotted normalizing highest simulation value with highest value from the manual, referring to the same geometry.

Good agreement between simulation and manual values.

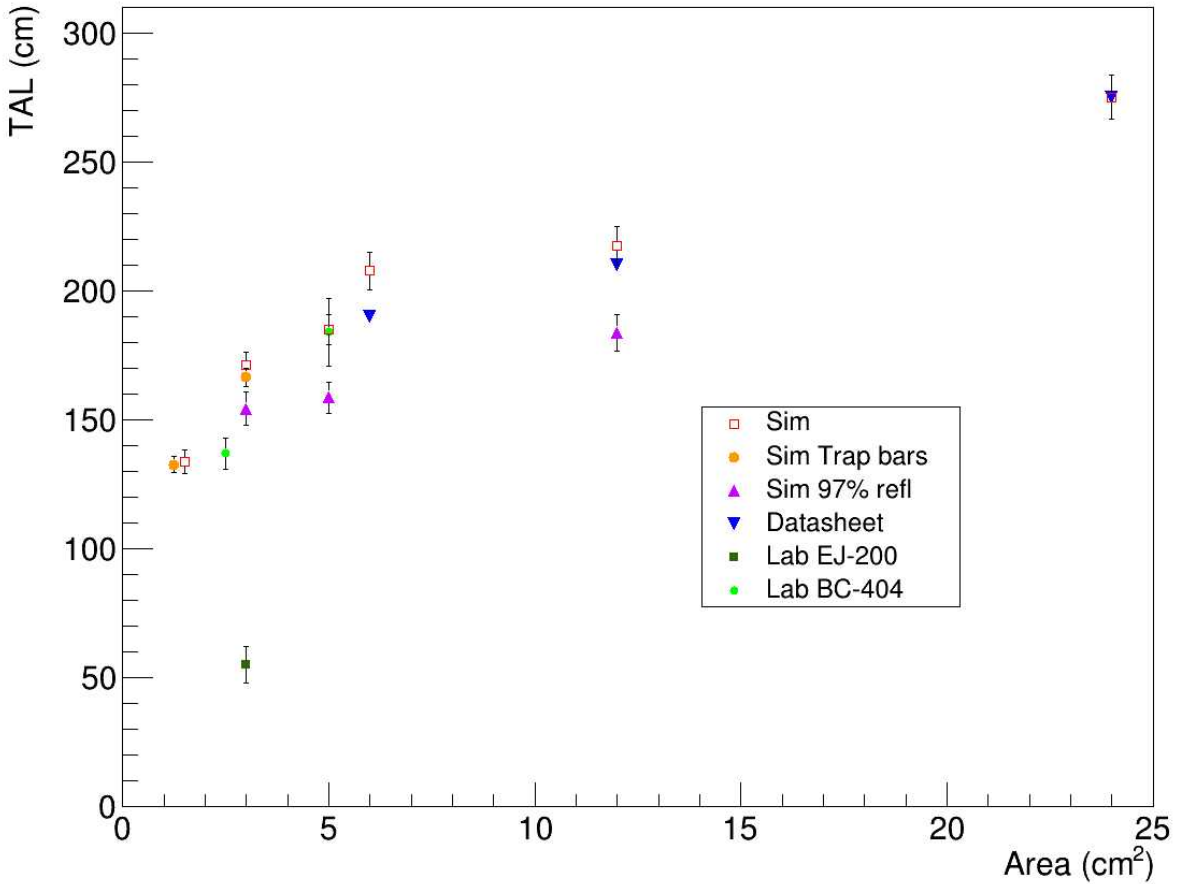
Trapezoidal bars seem to follow same behaviour as rectangular ones.

Simulation wrapping has 100% reflectivity.

Simulation emission spectrum: BC-404

TAL as a function of the bar cross section area

Simulation results



Increasing trend of the estimated TAL with the bar cross section area.

Lab points refer to different scintillators: EJ-200 and BC-404.

From datasheets:

EJ-200:

TAL = 380 cm for 300 x 20 x 2 cm^3

BC-404:

BAL = 160 cm

TAL = 140 cm for 200 x 20 x 1 cm^3

Summary [MC activities]

Aim of the simulation:
study TAL dependency on cross section area and wrapping reflectivity.

8 geometries were simulated: 200 cm long rectangular and trapezoidal bars with different cross section.
Wrapping reflectivity set to 100 % or 97%

Beam: 1 GeV muons in different positions along the bar

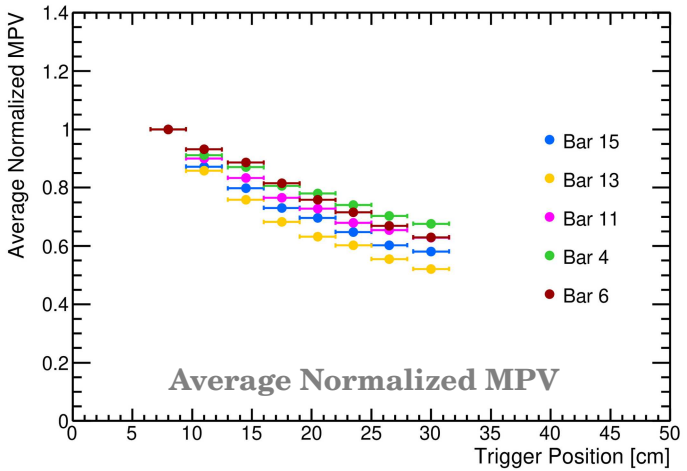
Estimation of TAL for different set-ups

Results:
TAL increases with bar cross section area
Trapezoidal and rectangular bars have same behaviour

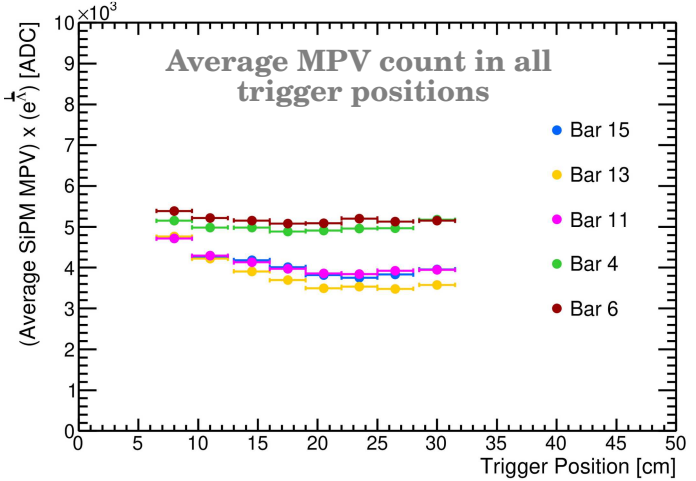
Additional Info

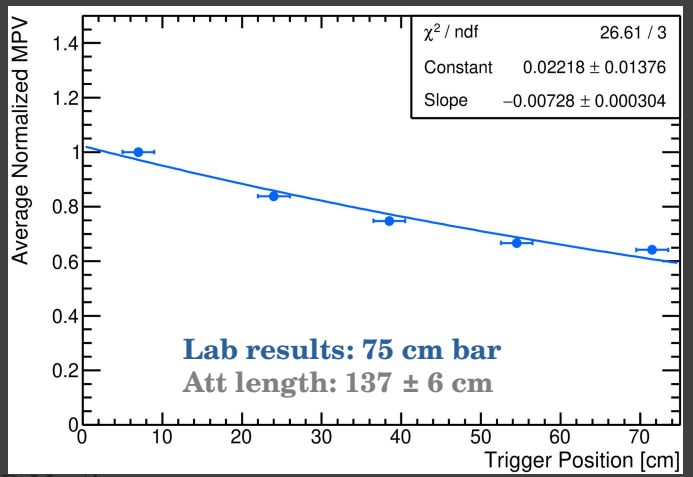
Horizontal bar results

Fitting all SiPM charge distributions w/ LanGaus functions

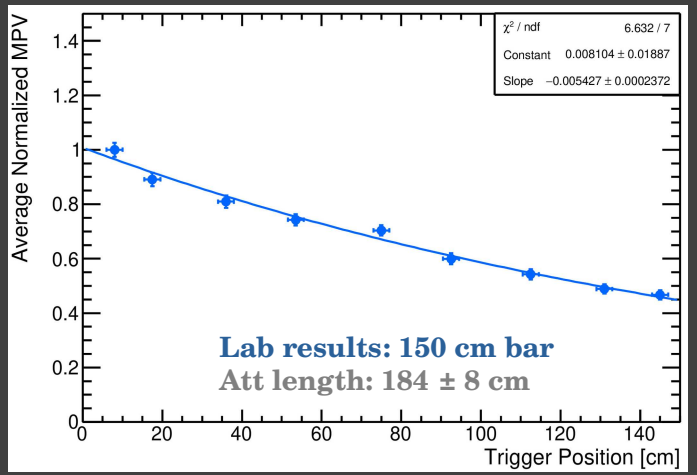


More results ongoing...



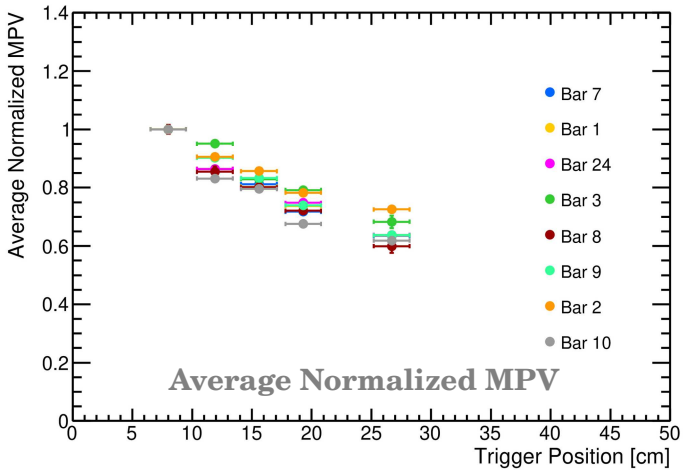


Previously tested bars @ LNGS

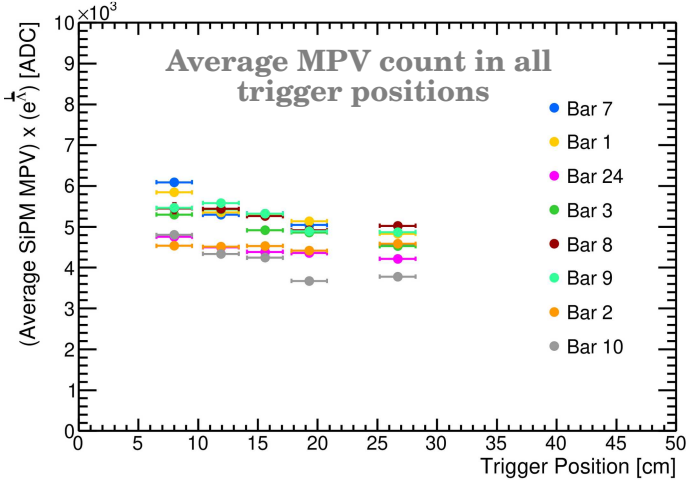


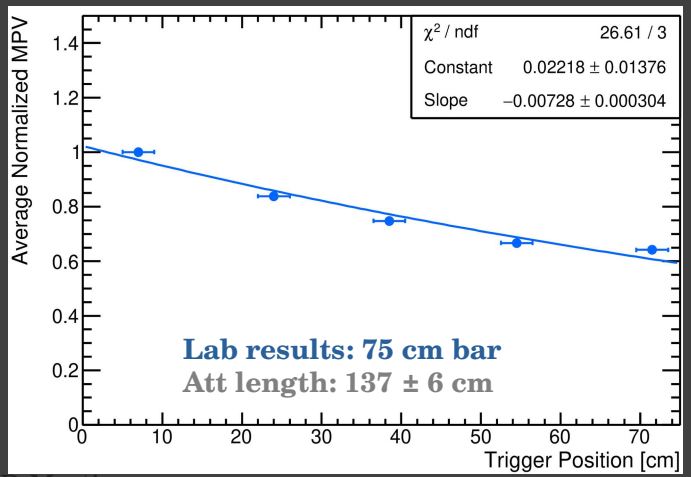
Vertical bar results

Fitting all SiPM charge distributions w/ LanGaus functions



More results ongoing...





Previously tested bars @ LNGS