Update on PS analysis

PSD detector with CITIROC readout

Beam Test @CERN 2022

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On behalf of the Lecce and Bari Groups

PSD International Meeting 10/03/2023

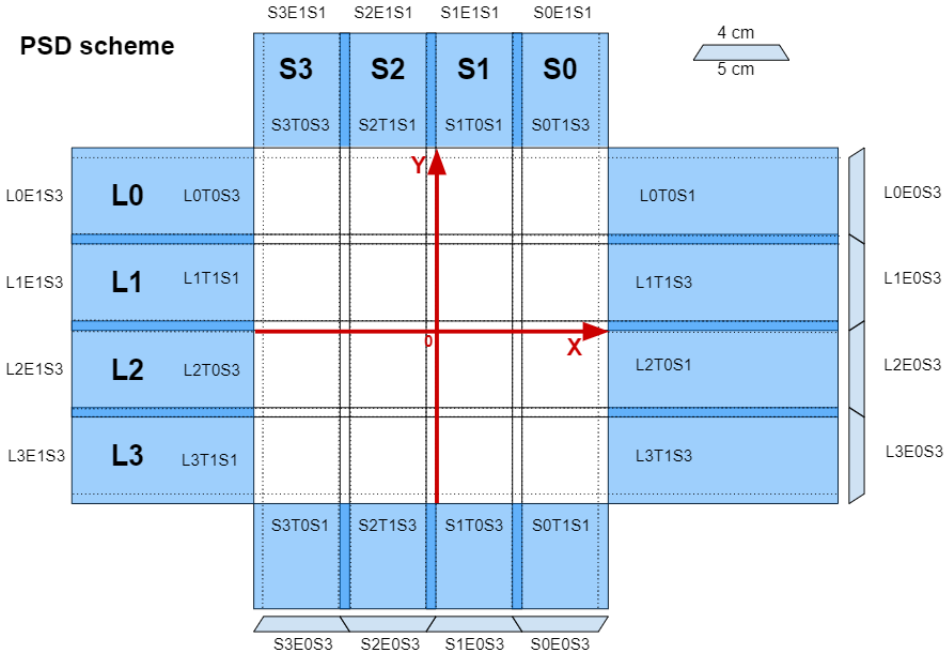
Outline

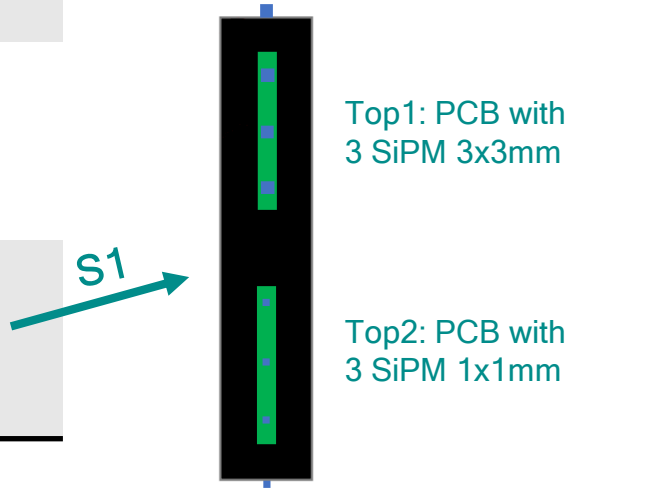
- **PSD bars configuration (with CITIROC readout)**
- **CITIROC data analysis:**
  - **Pedestal peak evaluation**
  - **MIPs peak evaluation**
  - **Attenuation coefficients**
  - **HG-LG calibration**
  - **Gain scan**
- **Conclusions**

PSD bars configuration

3 bars with CITIROC ASIC readout are taken into account for this analysis: **L1**, **L3** and **S1**.

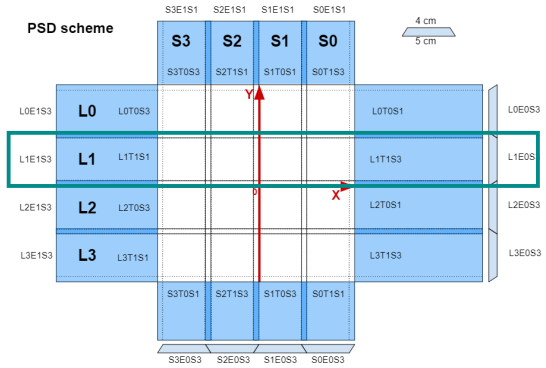
Bar	Channels	Type	SiPM size [mm²]
L1 (BC-404)	L1E0S3	EndCap1	3x3
	L1T1S3	Top 1	3x3
	L1T1S1	Top 2	1x1
	L1E1S3	EndCap2	3x3
L3 (BC-408)	L3E0S3	EndCap1	3x3
	L3T1S1	Top 1	1x1
	L3T1S3	Top 2	3x3
	L3E1S3	Endcap2	3x3
S1 (BC-408)	S1E0S3	EndCap1	3x3
	S1T1S3	Top 1	3x3
	S1T1S1	Top 2	1x1
	S1E1S1	EndCap2	1x1





Hamamatsu SiPMs S14160-3015 (3x3 mm²) & S14160-1315 (1.3x1.3 mm²)

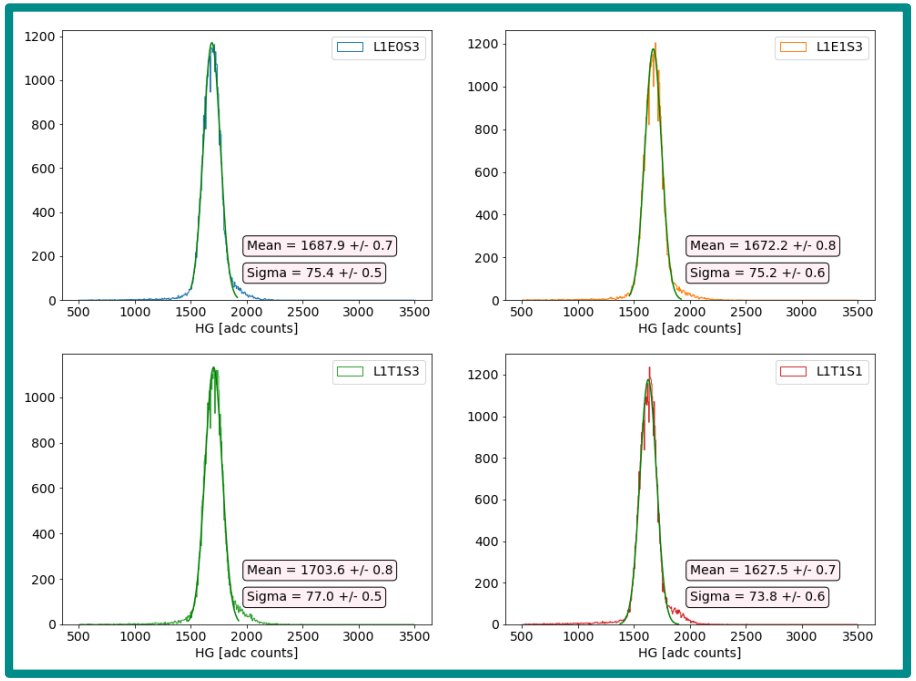
Pedestal peak evaluation



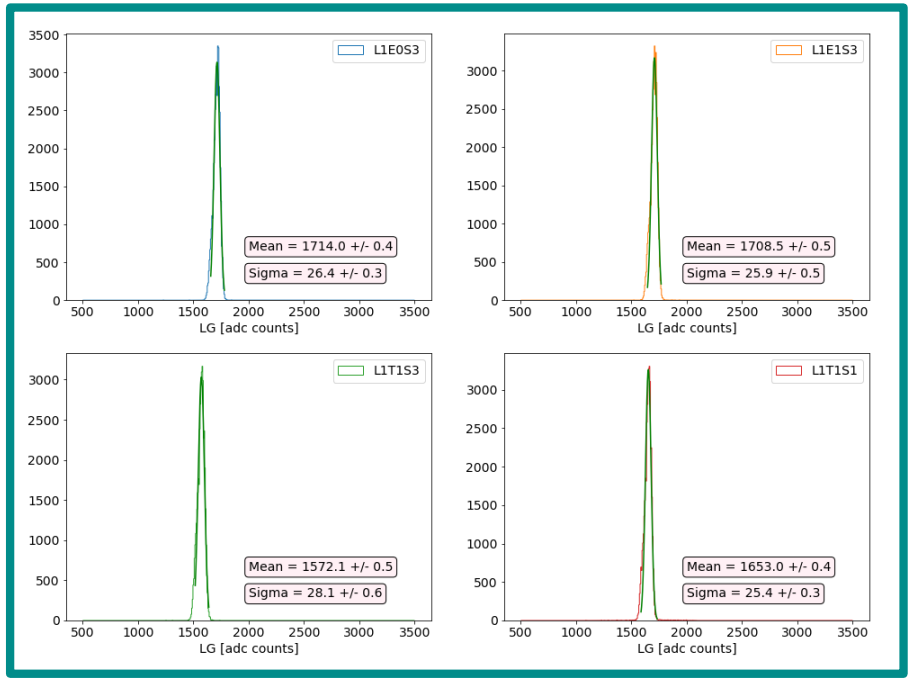
No beam.

The pedestal peak and width in ADC counts are taken as the mean and sigma of a **Gaussian fit** to the data (considering a run without beam).

L1 - High Gain (HG)



L1 - Low Gain (LG)



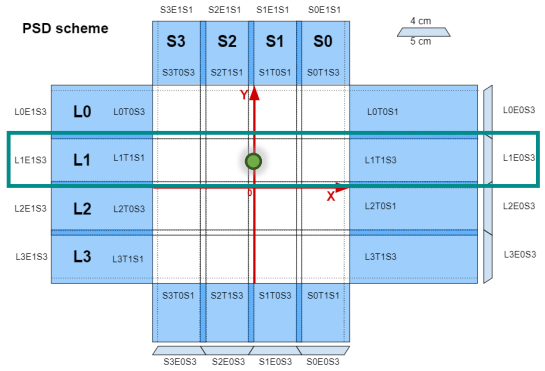
Similar distributions have been obtained for L3 and S1 bars.

Pedestal peak evaluation

The pedestal peak and width obtained with the Gaussian fit are summarized in the table below.

Channels	Mean [ADC] HG	Sigma [ADC] HG	Mean [ADC] LG	Sigma [ADC] LG
L1E0S3	1687.9 ± 0.7	75.4 ± 0.5	1714.0 ± 0.4	26.4 ± 0.3
L1T1S3	1703.6 ± 0.8	77.0 ± 0.5	1572.1 ± 0.5	28.1 ± 0.6
L1T1S1	1627.5 ± 0.7	73.8 ± 0.6	1653.0 ± 0.4	25.4 ± 0.3
L1E1S3	1672.2 ± 0.8	75.2 ± 0.6	1708.5 ± 0.5	25.9 ± 0.5
L3E0S3	1684.7 ± 0.7	79.6 ± 0.6	1677.2 ± 0.6	26.1 ± 0.4
L3T1S1	1688.6 ± 0.8	76.9 ± 0.6	1649.4 ± 0.4	26.0 ± 0.4
L3T1S3	1562.8 ± 0.8	82.3 ± 0.7	1641.4 ± 0.6	26.3 ± 0.6
L3E1S3	1574.4 ± 0.8	77.6 ± 0.6	1678.9 ± 0.5	24.4 ± 0.3
S1E0S3	1555.1 ± 0.7	78.0 ± 0.6	1637.9 ± 0.4	24.2 ± 0.3
S1T1S3	1709.8 ± 0.7	77.6 ± 0.6	1736.9 ± 0.5	24.4 ± 0.3
S1T1S1	1624.4 ± 0.7	74.6 ± 0.5	1719.9 ± 0.4	24.5 ± 0.4
S1E1S1	1709.9 ± 0.7	71.0 ± 0.5	1725.1 ± 0.5	22.8 ± 0.4

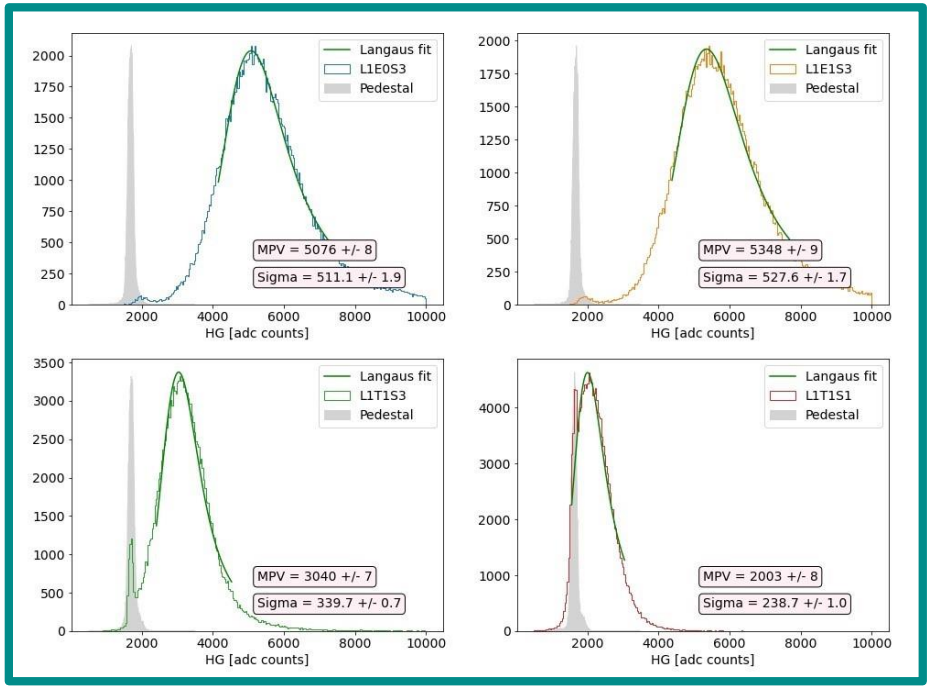
MIPs evaluation



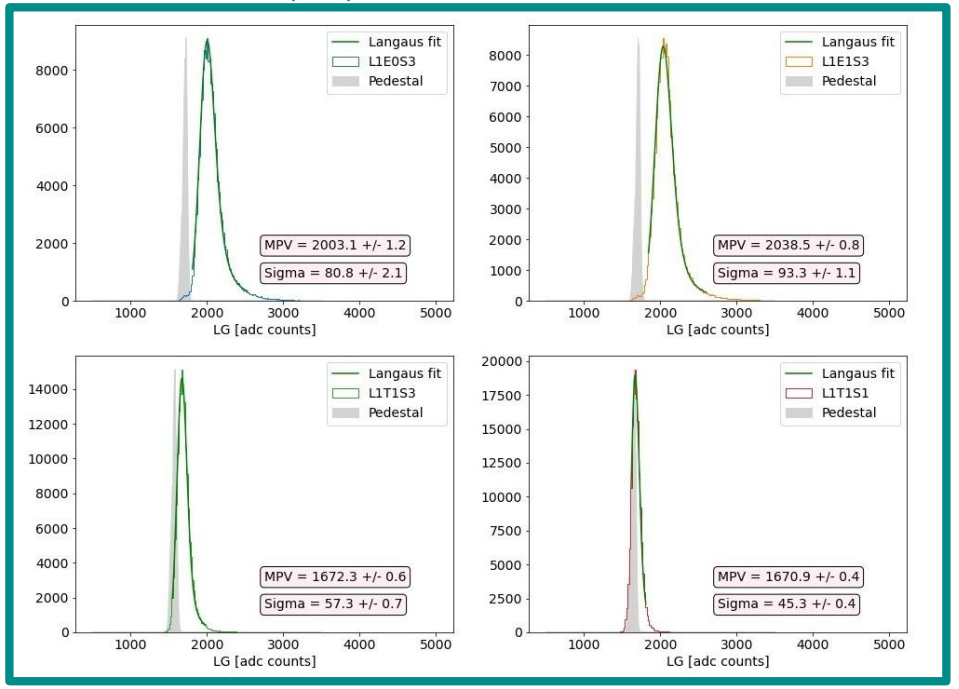
π^- beam (15 GeV)

The MIP value in ADC counts can be estimated as the MPV of the **Langaus fit** (convolution between a Landau function and Gaussian distribution).

L1 - High Gain (HG)

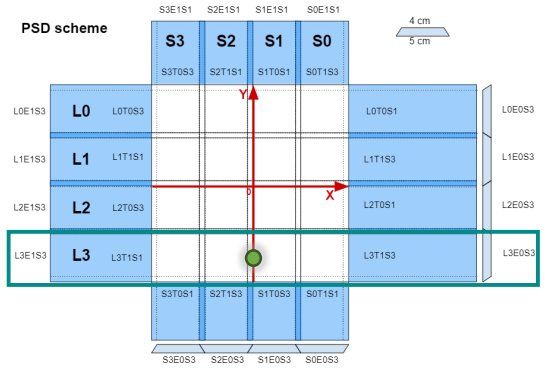


L1 - Low Gain (LG)



Note: to make the fit converge, it is necessary to narrow the fit range around the peak value

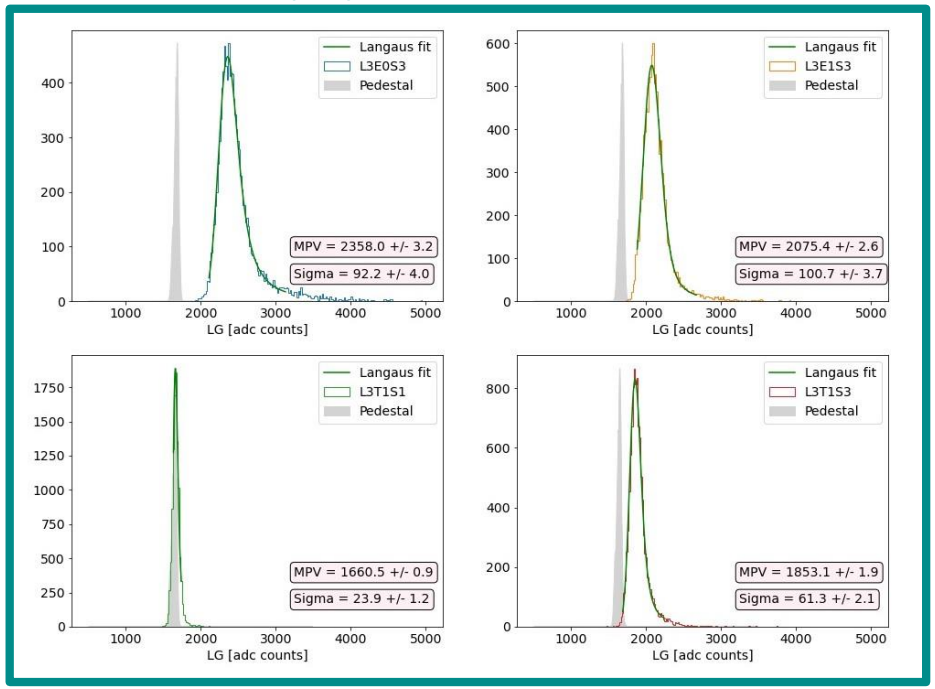
MIPs evaluation



π^- beam (15 GeV)

The MIP value in ADC counts can be estimated as the MPV of the **Langaus fit** (convolution between a Landau function and Gaussian distribution).

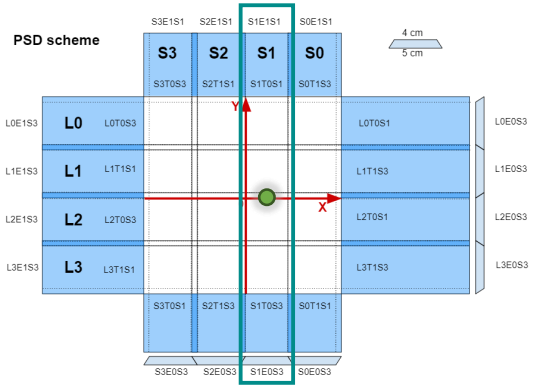
L3 - Low Gain (LG)



For L3 bar only the LG distributions are taken into account, because the HG was significantly saturated.

Note: to make the fit converge, it is necessary to narrow the fit range around the peak value

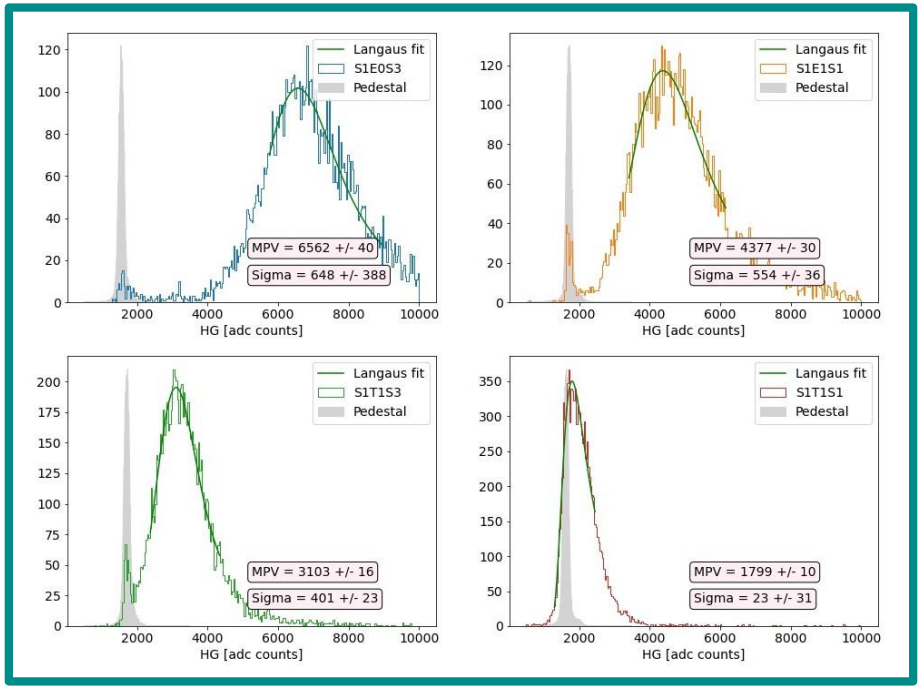
MIPs evaluation



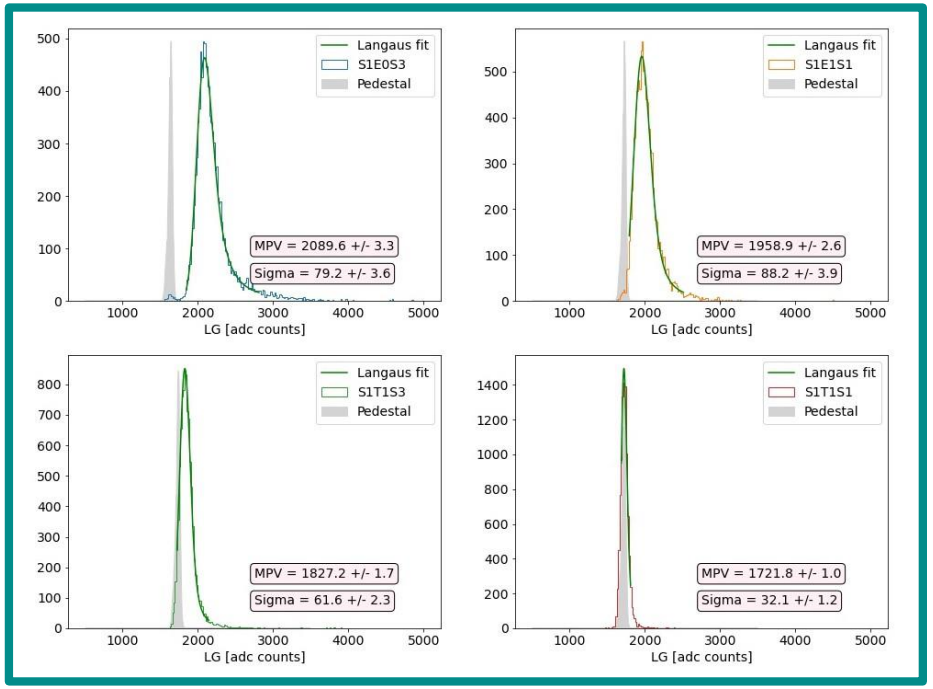
e^- beam (1 GeV)

The MIP value in ADC counts can be estimated as the MPV of the **Langaus fit** (convolution between a Landau function and Gaussian distribution).

S1 - High Gain (HG)



S1 - Low Gain (LG)



Note: to make the fit converge, it is necessary to narrow the fit range around the peak value

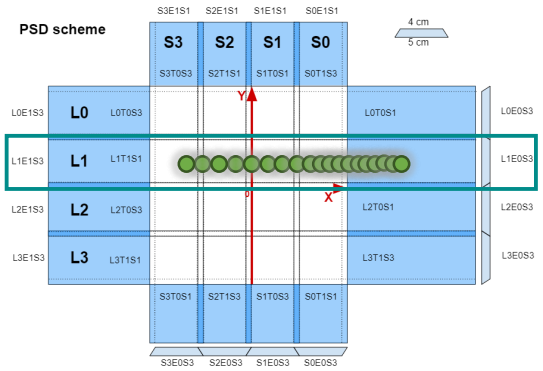
MIPs evaluation

The MIP values obtained with the Langaus fit to the data for the 3 different bars are summarized in the table below.

Channels	MPVs HG [ADC]	MPVs LG [ADC]	Beam
L1E0S3	5076 ± 8	2003.1 ± 1.2	π^- (15 GeV)
L1T1S3	3040 ± 7	1672.3 ± 0.6	
L1T1S1	2003 ± 8	1670.9 ± 0.4	
L1E1S3	5348 ± 9	2038.5 ± 0.8	
L3E0S3	-	2358.0 ± 3.2	π^- (15 GeV)
L3T1S1	-	1660.5 ± 0.9	
L3T1S3	-	1853.1 ± 1.9	
L3E1S3	-	2075.4 ± 2.6	
S1E0S3	6562 ± 40	2089.6 ± 3.3	e^- (1 GeV)
S1T1S3	3103 ± 16	1827.2 ± 1.7	
S1T1S1	1799 ± 10	1721.8 ± 1.0	
S1E1S1	4377 ± 30	1958.9 ± 2.6	

From a comparison between pedestals (slide 5) and MIPs positions, it is clear that in some cases (for the TOP SiPMs with 1mm^2 size) it is very difficult to distinguish the signal from the pedestal.

Attenuation coefficients

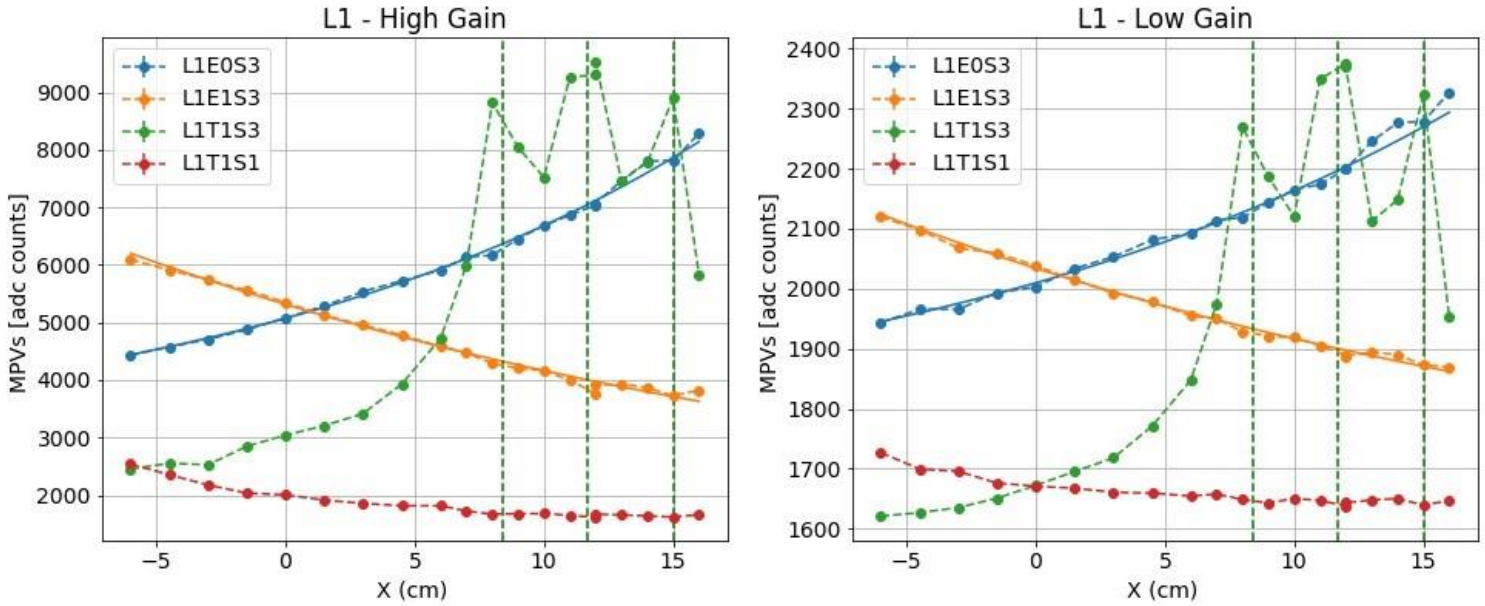


π^- beam (15 GeV)

The MPVs taken from the Langaus fit to the data are plotted as a function of the x coordinate, and fitted with an exponential function (for the EndCap SiPMs):

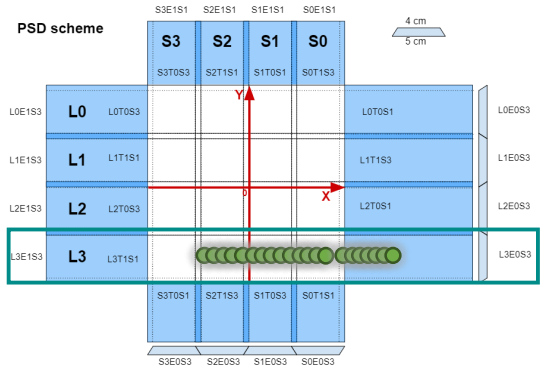
$$f(x) = Ae^{x/\lambda} + C$$

where λ represents the attenuation coefficient of the signal inside the bar. Here the plots for the **bar L1**.



Note that the TOP channels present some “sharp” peaks in coincidence with the presence of the SiPMs (their positions are represented by the vertical dashed lines).

Attenuation coefficients

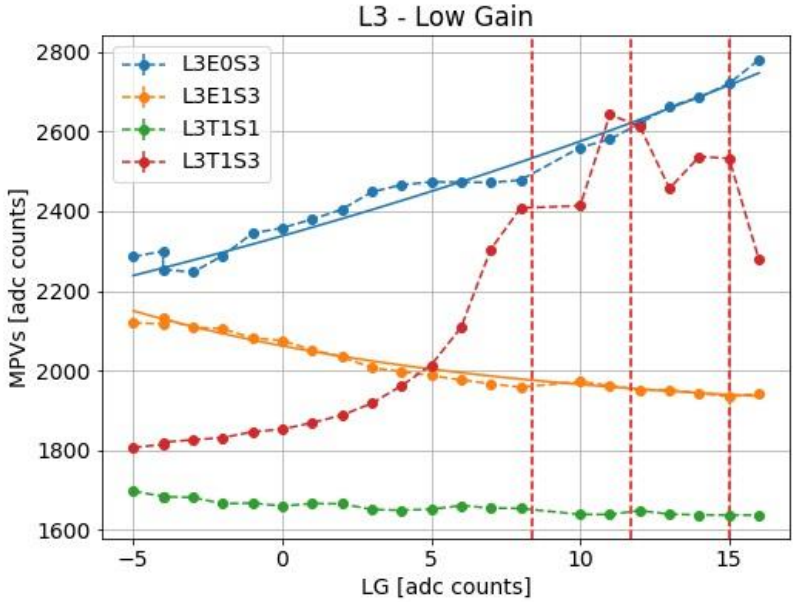


π^- beam (15 GeV)

The MPVs taken from the Langaus fit to the data are plotted as a function of the x coordinate, and fitted with an exponential function (for the EndCap SiPMs):

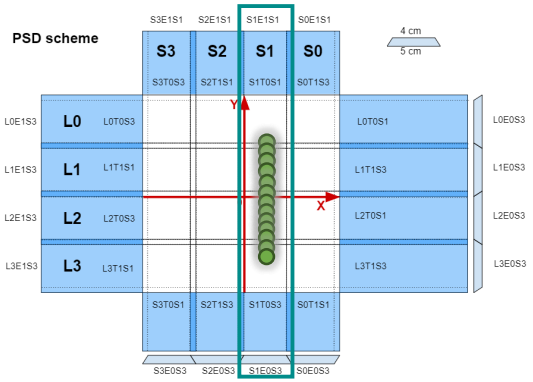
$$f(x) = Ae^{x/\lambda} + C$$

where λ represents the attenuation coefficient of the signal inside the bar. Here the plots for the **bar L3**.



Note that the TOP channels present some “sharp” peaks in coincidence with the presence of the SiPMs (their positions are represented by the vertical dashed lines).

Attenuation coefficients

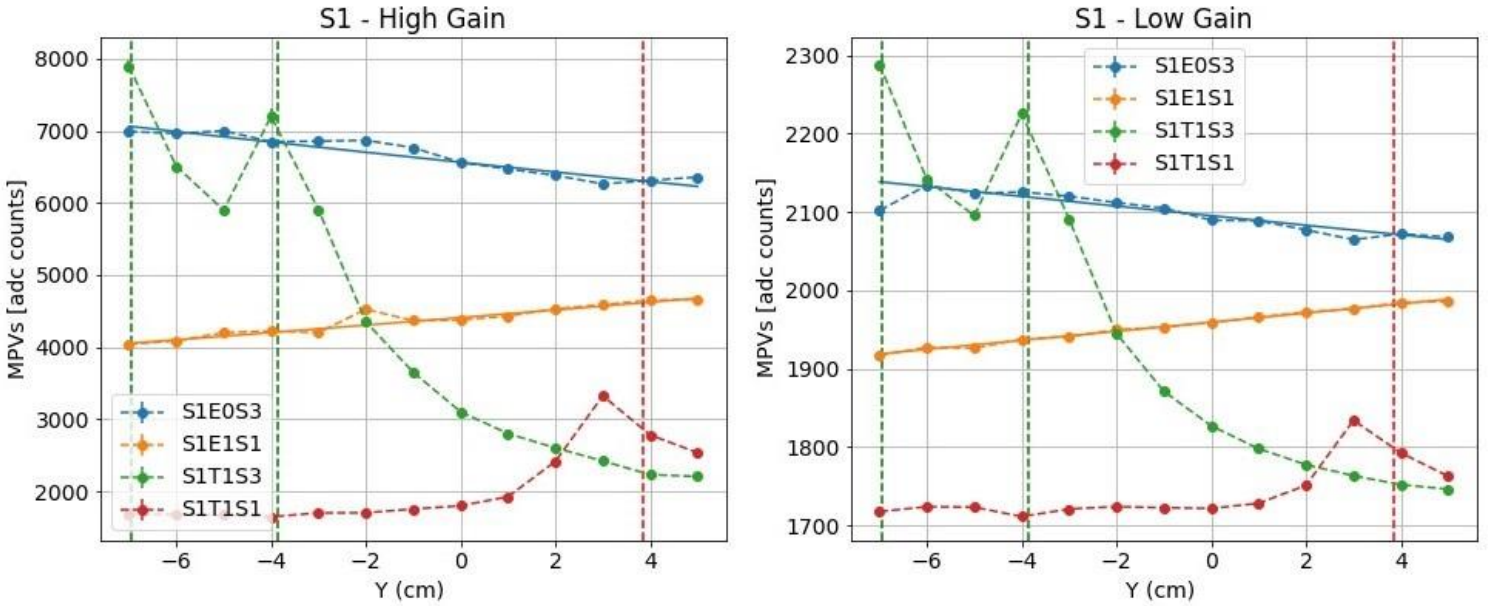


e^- beam (1 GeV)

The MPVs taken from the Langaus fit to the data are plotted as a function of the y coordinate, and fitted with an exponential function (for the EndCap SiPMs):

$$f(y) = Ae^{y/\lambda} + C$$

where λ represents the attenuation coefficient of the signal inside the bar. Here the plots for the **bar S1**.



Note that the TOP channels present some “sharp” peaks in coincidence with the presence of the SiPMs (their positions are represented by the vertical dashed lines).

Attenuation coefficients

The results provided by the application of the exponential fit to the EndCap channels are summarized in the table below.

Channels	Material	Beam	Attenuation coefficients [cm] HG	LG
L1E0S3 L1E1S3	BC-404	π^- (15 GeV)	19.2 ± 1.8 31.5 ± 1.1	22.7 ± 1.4 32.1 ± 1.2
L3E0S3 L3E1S3	BC-408	π^- (15 GeV)	- -	43 ± 3 12.1 ± 0.9
S1E0S3 S1E1S1	BC-408	e^- (1 GeV)	90 ± 10 106 ± 8	334 ± 22 339 ± 18

- There is a good consistency between HG and LG for the L1 channels, while for S1 the results are very different.
- The results between the two EndCaps are consistent within the statistical error of the fit only for the S1 bar.

Expected light attenuation length*: 140 cm (BC-404), 210 cm (BC-408)

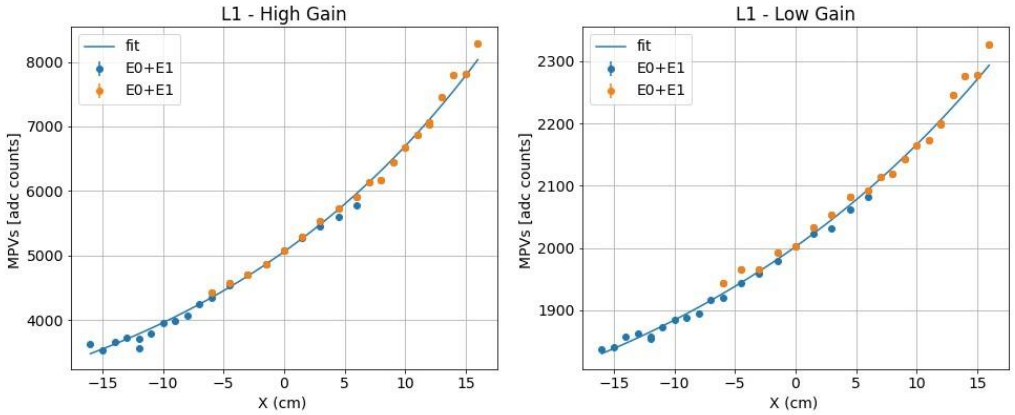
*The typical 1/e attenuation length of a 1x20x200cm cast sheet with edges polished as measured with a bialkali photomultiplier tube coupled to one end.

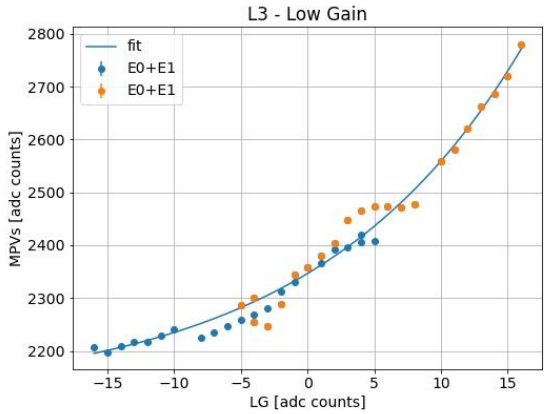
Attenuation coefficients

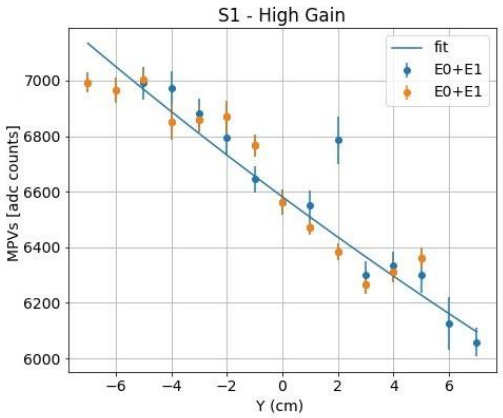
It is possible to evaluate the attenuation coefficients given by the combination of the two EndCaps for each bar (scaling the END-1 SiPM with respect to the END-0 one in x/y = 0).

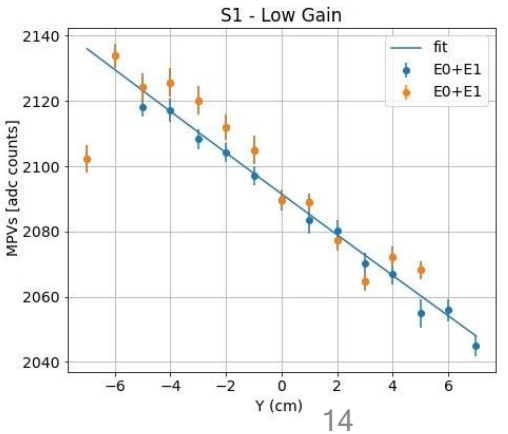
Again, an exponential fit is applied to evaluate the attenuation coefficients (which are summarized in the table).

Channels	Material	Beam	Attenuation coefficients [cm] HG	LG
L1E0S3 & L1E1S3	BC-404	π^- (15 GeV)	25.3 ± 1.0	30.2 ± 0.8
L3E0S3 & L3E1S3	BC-408	π^- (15 GeV)	-	15.5 ± 0.4
S1E0S3 & S1E1S1	BC-408	e^- (1 GeV)	55 ± 15	325 ± 5









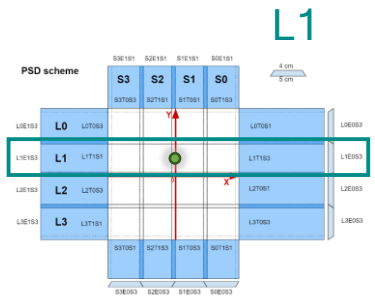
HG-LG gain calibration

The scatterplots between the HG and LG distributions are obtained after the pedestal subtraction. Then a linear fit is applied, using the sigma of the HG pedestal as y-error.

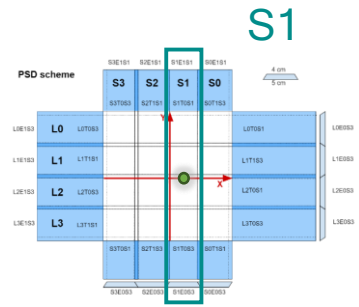
The results for the EndCaps SiPMs are summarized in the table.

L1 Channels	Calibration slope	S1 Channels	Calibration slope
L1E0S3	8.5784 ± 0.0012	S1E0S3	8.226 ± 0.004
L1E1S3	8.8175± 0.0011	S1E1S1	8.306 ± 0.004

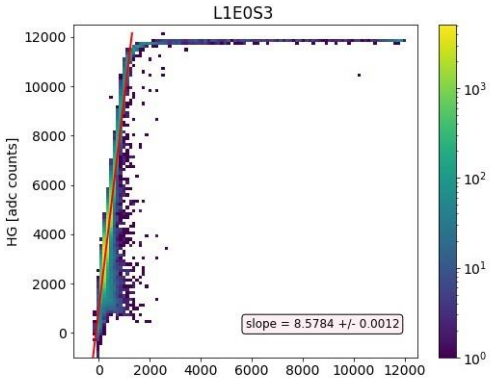
* The HG has a tabulated amplification factor **10** time greater than LG.

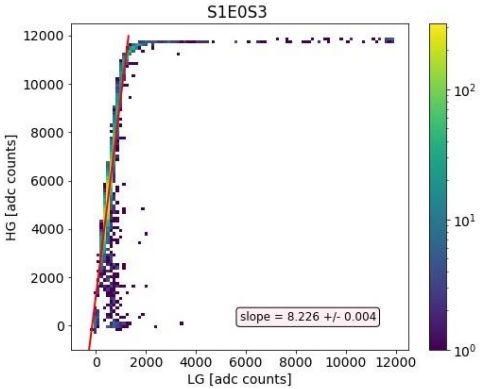


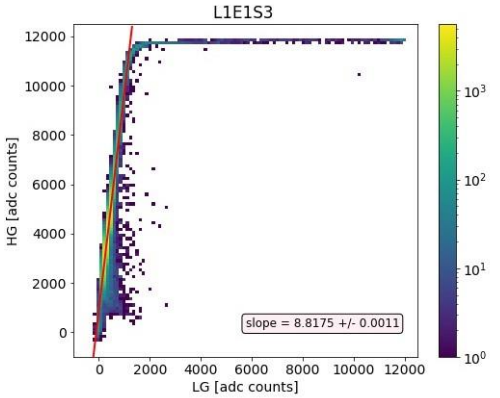
π^- beam (15 GeV)

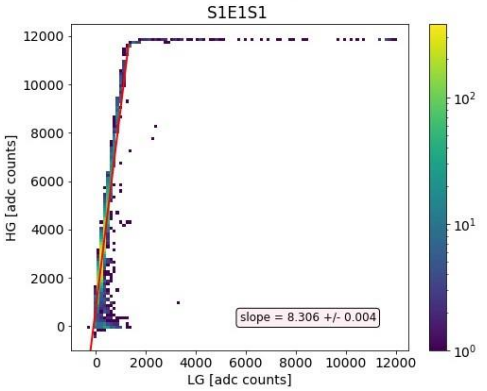


e^- beam (1 GeV)

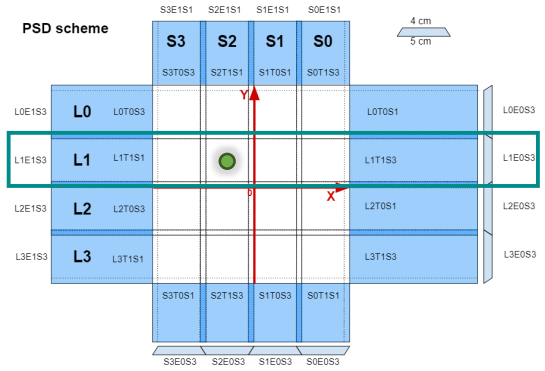








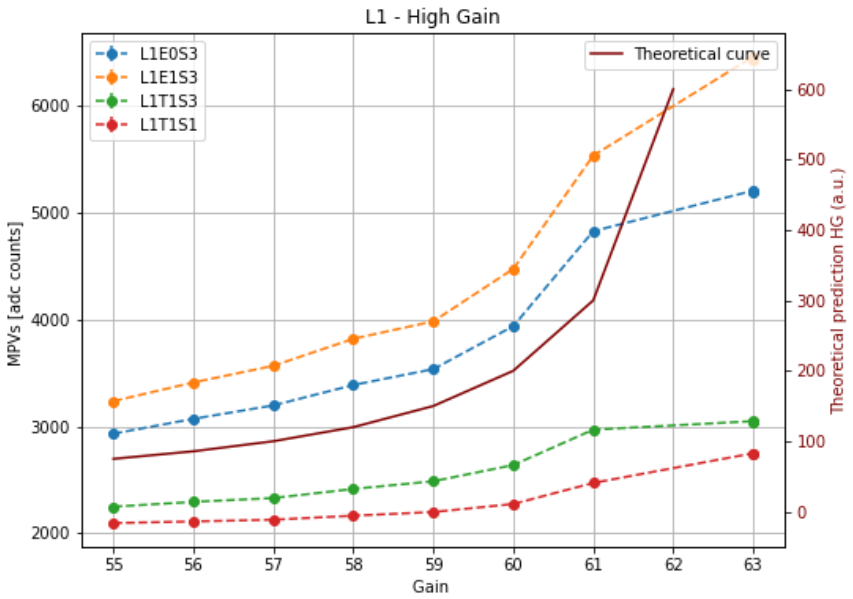
Gain scan

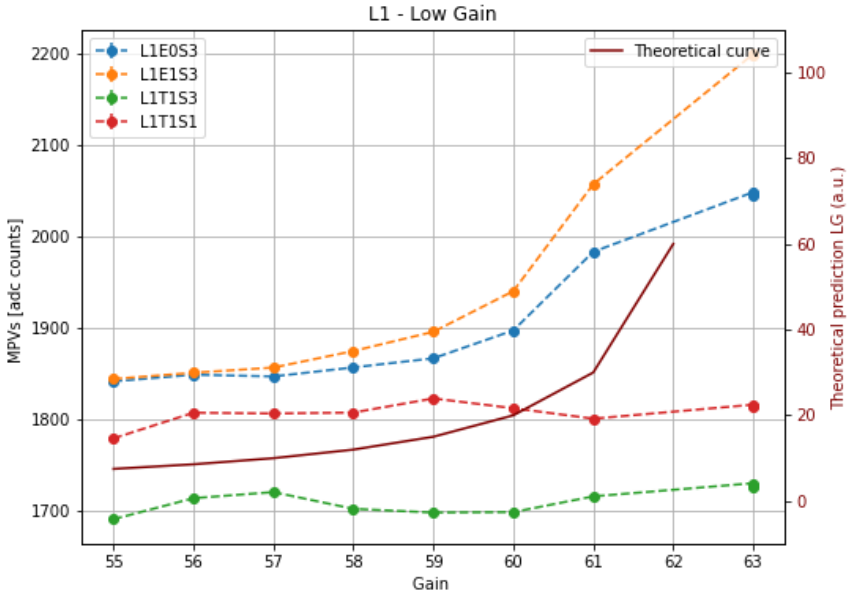


π^- beam (15 GeV)

A gain scan was performed fixing the position of the beam in (x,y)=(-2,2).
The MPVs taken from the Langaus fit are plotted as a function of the gain.
From the CITIROC datasheet, the expected HG and LG amplification gain is calculated up to gain 62 and reported in the plot.

It can be noted that the experimental data reproduce quite well the trend of the theoretical curve (up to gain 61).





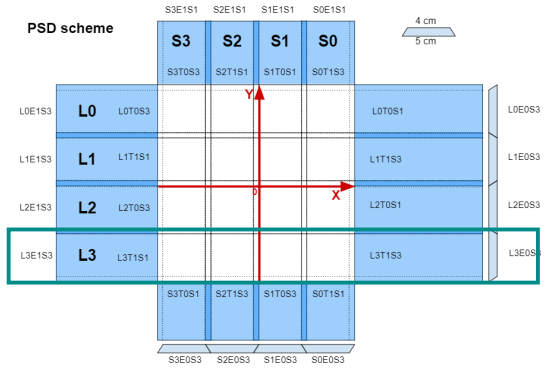
Note:
All the results presented in the previous slides have been acquired with **gain 63**.

Conclusions

- For the Top 1x1 mm^2 SiPMs it's quite impossible to distinguish between the signal and the pedestal (especially for the LG).
- The attenuation coefficients obtained from the exponential fit to the EndCap SiPMs show a good consistency between HG and LG for L1 channels, while for S1 they are very different. However, the results between the two EndCaps are consistent within the statistical error of the fit only for the S1 bar. These discrepancies should be better understood.
- Looking at the calibration curves (scatterplots HG vs LG) it seems that the HG has an amplification factor more than 8 times greater than that of LG.
- The gain scan shows that the experimental data reproduce quite well the trend of the theoretical curve up to gain 61, although most of the PS data were acquired with **gain 63** (which turns out to be over the limit of the reported maximum gain).

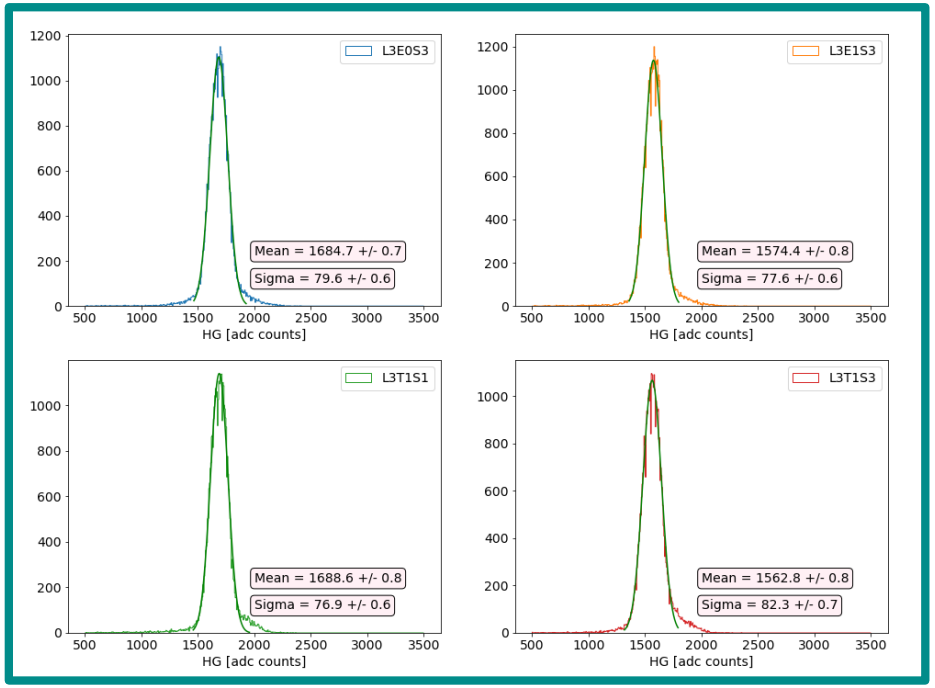
BACKUP

Pedestal peak evaluation

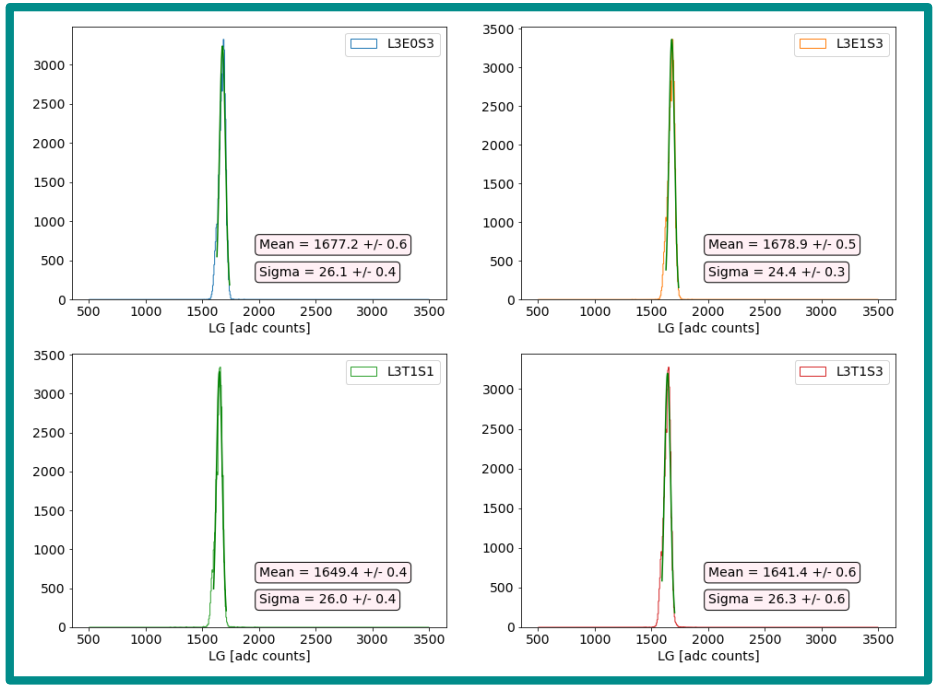


The pedestal peak and width in ADC counts are taken as the mean and sigma of a **Gaussian fit** to the data (considering a run without beam).

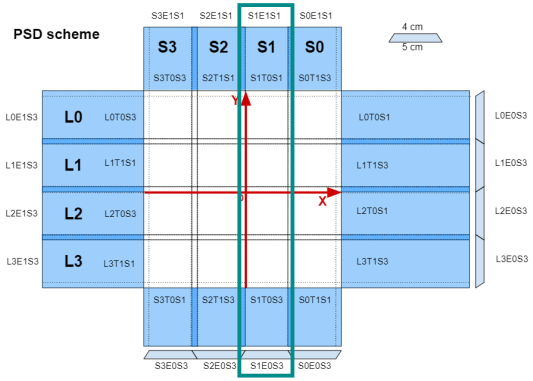
L3 - High Gain (HG)



L3 - Low Gain (LG)

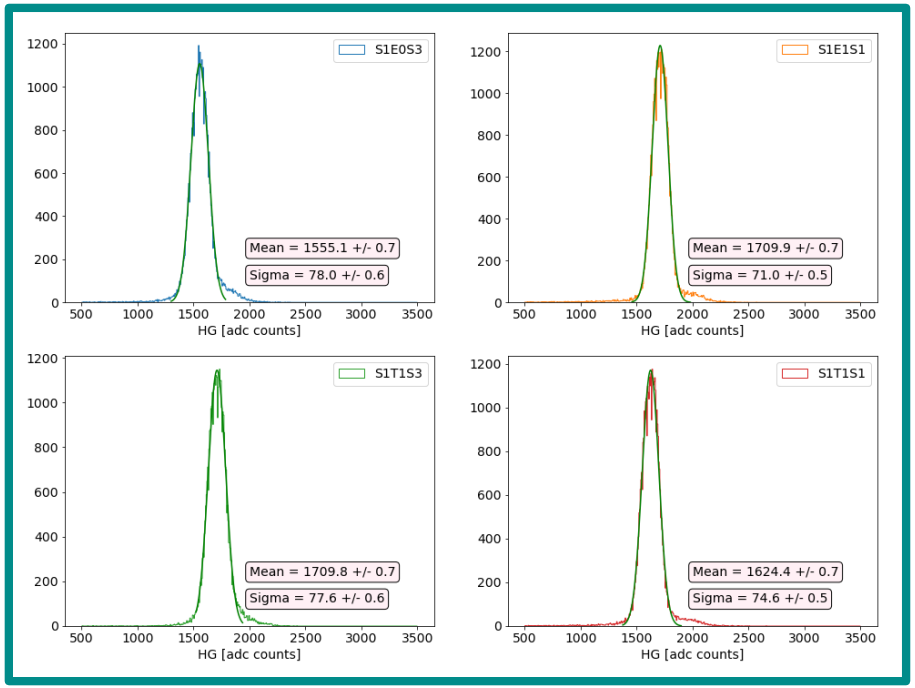


Pedestal peak evaluation

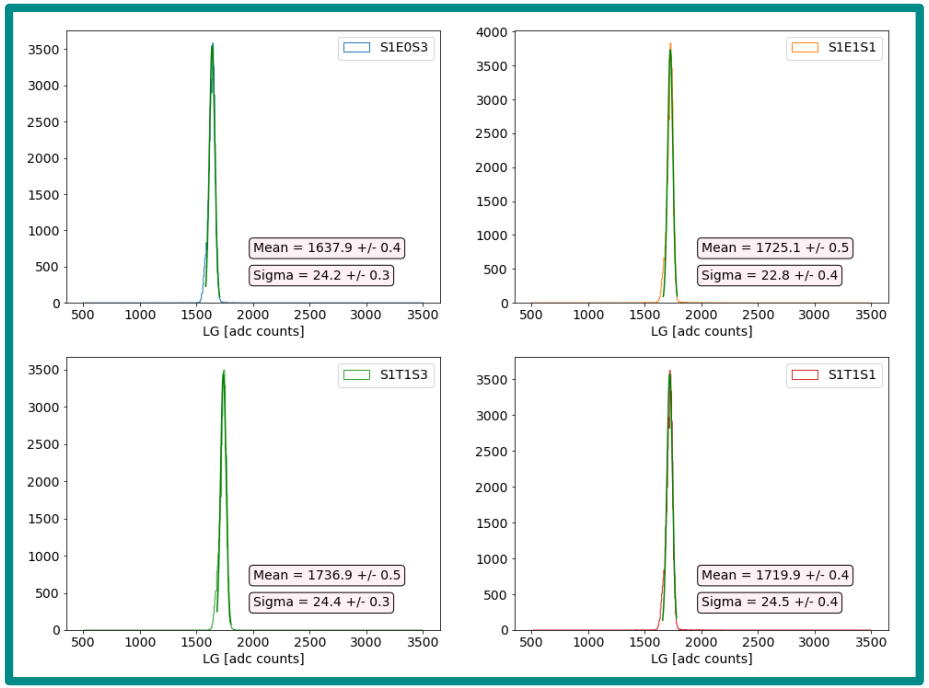


The pedestal peak and width in ADC counts are taken as the mean and sigma of a **Gaussian fit** to the data (considering a run without beam).

S1 - High Gain (HG)



S1 - Low Gain (LG)



HG-LG gain calibration

The pedestals are removed from both the HG and LG distributions, by applying the following cut:

$$ADC > \mu + 2\sigma$$

where μ and σ are the mean value and sigma given by the Gaussian pedestals fit.

A linear fit is applied to the calibration curves, by applying as error on y axis equals to the width of the HG pedestal.

L1 Channels	Calibration slope	S1 Channels	Calibration slope
L1E0S3	8.2505 ± 0.0011	S1E0S3	7.917 ± 0.004
L1T1S3	8.0748 ± 0.0022	S1T1S3	8.262 ± 0.008
L1T1S1	8.694 ± 0.004	S1T1S1	8.739 ± 0.0013
L1E1S3	8.4477 ± 0.0011	S1E1S1	8.664 ± 0.004

* The HG has an amplification factor **10** time greater than LG