Scintillator + SiPM tests

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and many others

INFN Bari

HERD F2F meeting

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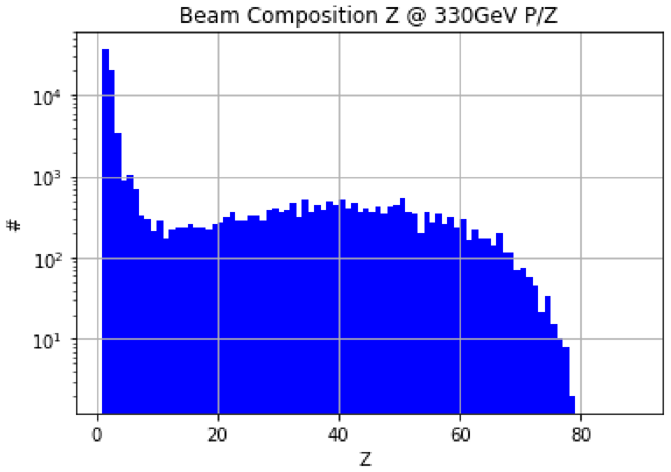
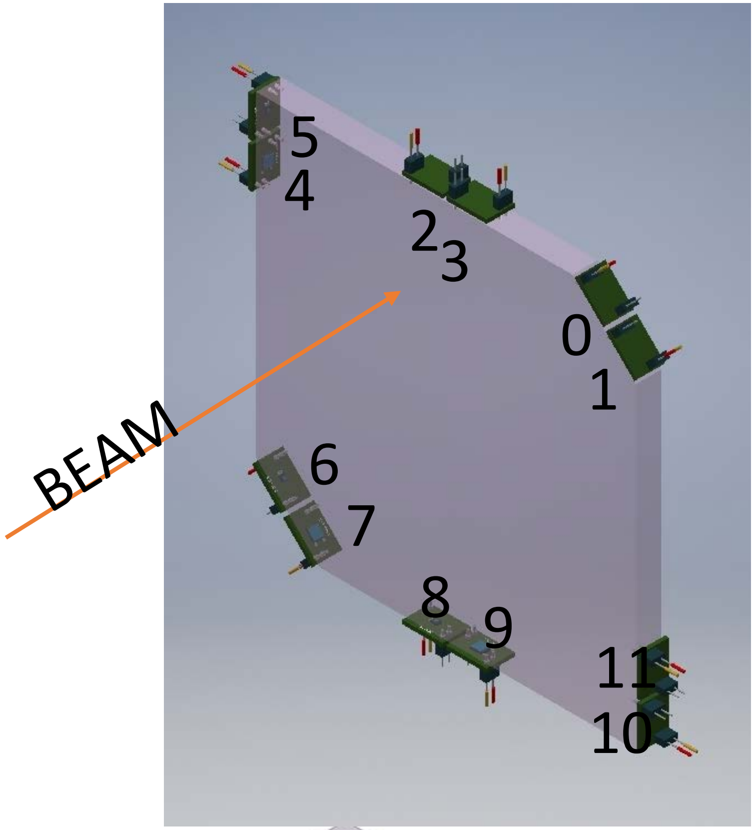
Outline

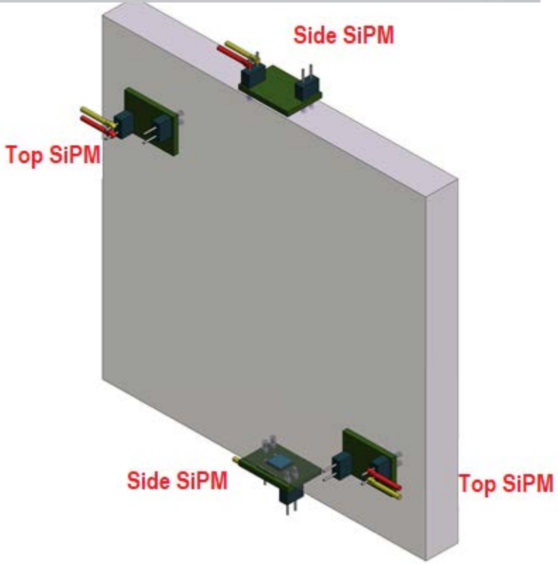
- Two scintillator tiles assembled in 2018
  - BC-404 scintillator coupled to AdvanSiD NUV SiPM
  - Wrapping with white cardboard
- Beam tests at CERN PS and SPS
  - Response with beam in different positions with pion beam
  - Response to ion beam of 330 GeV/Z coming from a primary beam of lead, with energy 150 GeV/A, impinging onto a Beryllium target
- Cosmic ray measurements



Tile assembly

- Plastic scintillator BC-404 , 1 cm thickness
- NUV SiPMs by AdvanSiD readout
  - 40μm cell pitch
  - Peak PDE @ 400nm: 43%
  - Transimpedance amplifier with RC filter
- Signals integrated with a Caen V792 QDC
- Tile 1:
  - 15 cm x 15 cm with two cutted angles
  - 1x1mm^2 and 4x4mm^2 area (12 SiPMs in total)
- Tile 2:
  - 10 cm x 10 cm
  - 4x4mm^2 area placed on side and top of the tile (4 SiPMs in total)
  - 2 amplification gains for each SiPM (HG = 5*LG)





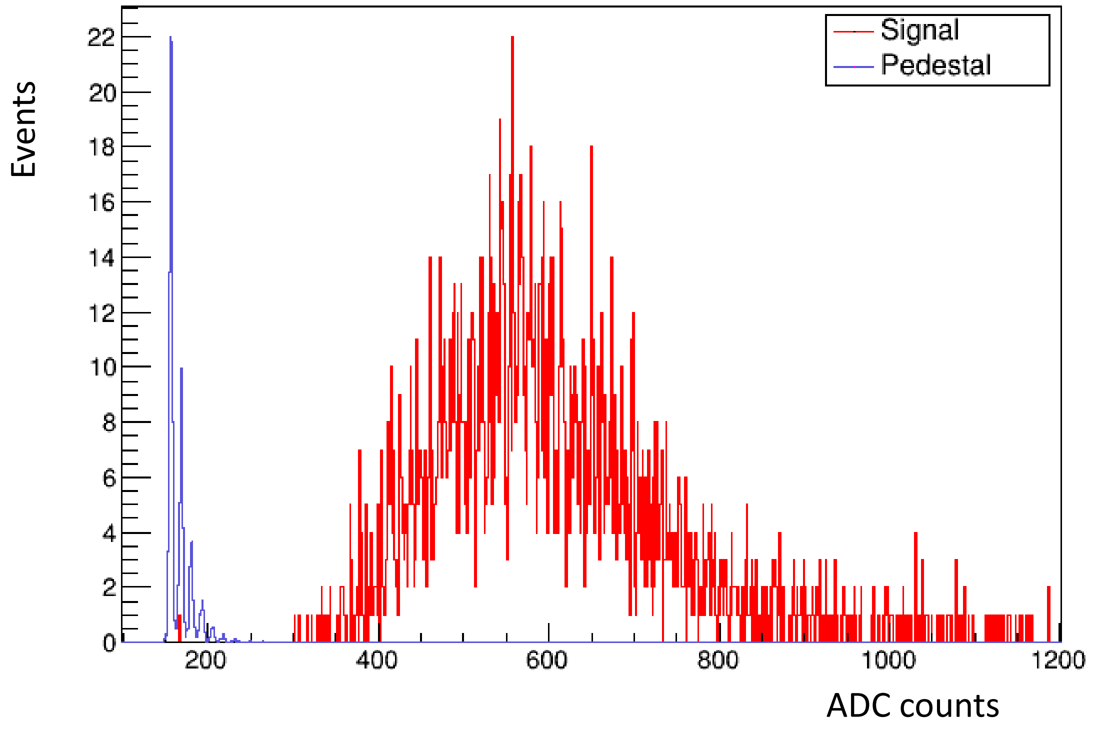
Beam test at CERN PS and SPS

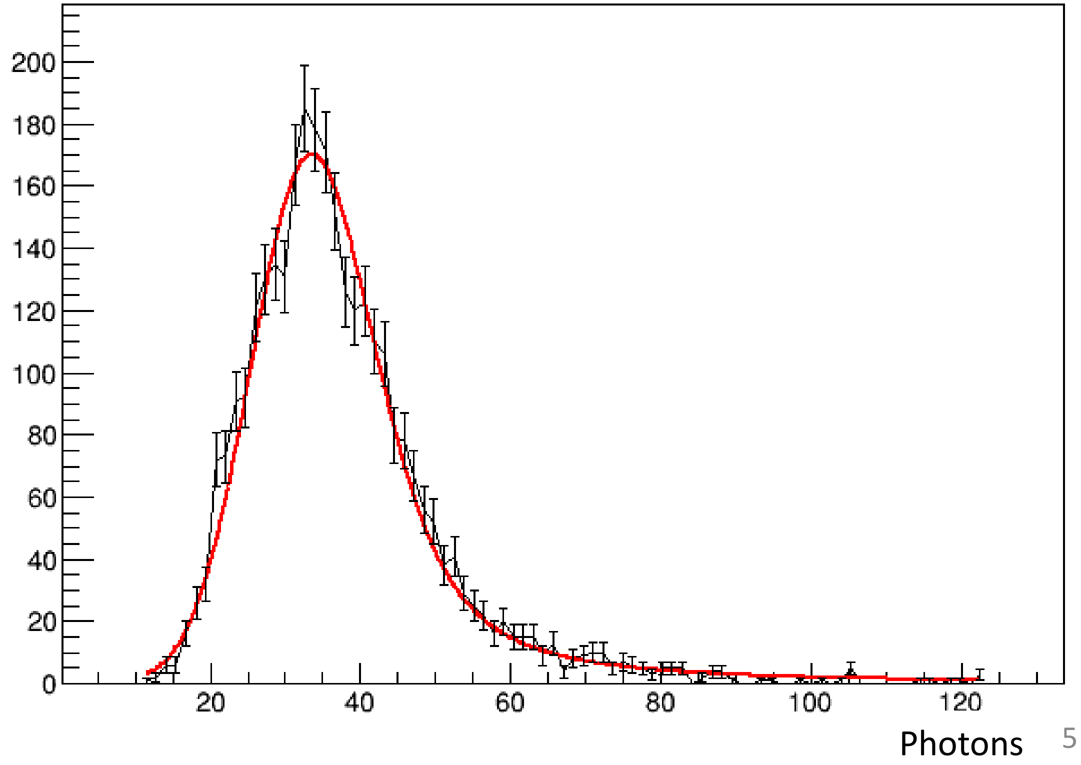
- Tile 1 tested @ CERN PS - T10: 5 GeV particles (e/pi)
  - Scintillator irradiated in different positions with a beam spot of 3cm diameter
- Tile 1 tested @ CERN SPS – H8: 20 GeV particles (e/pi)
  - Scintillator irradiated only in the central position

- Tile 2 tested @ CERN SPS – H4:
  - Scintillator irradiated only in the central position
  - 2 amplification gains used

Analysis method

- Fingerplots fitted from pedestal runs to obtain pedestal position and gain
- Signal fitted with a Landau+gaussian distribution and converted in p.e. from pedestal information

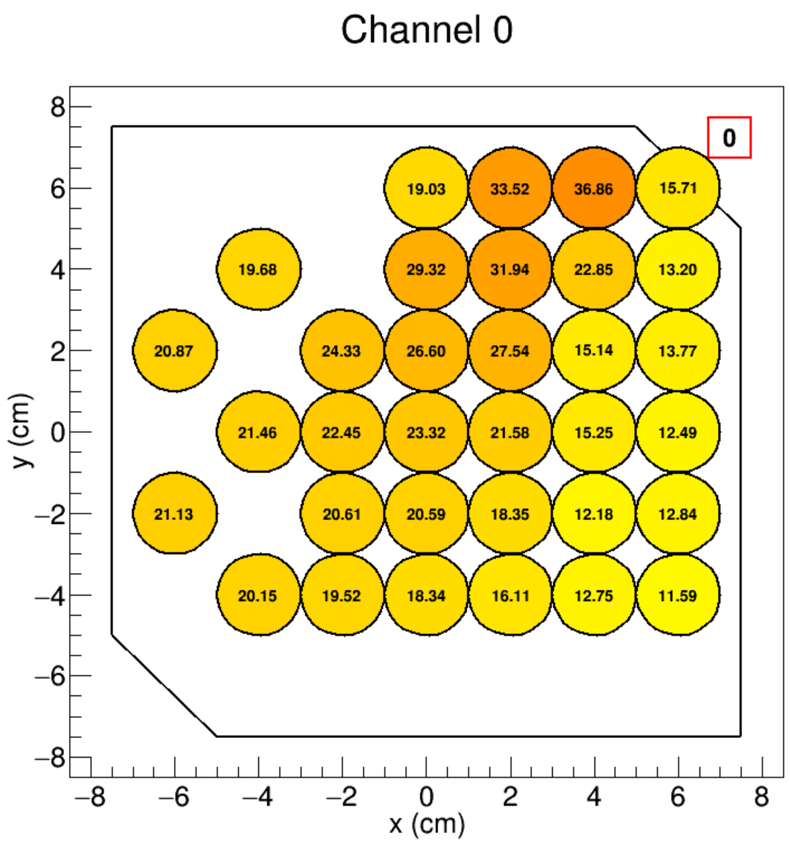




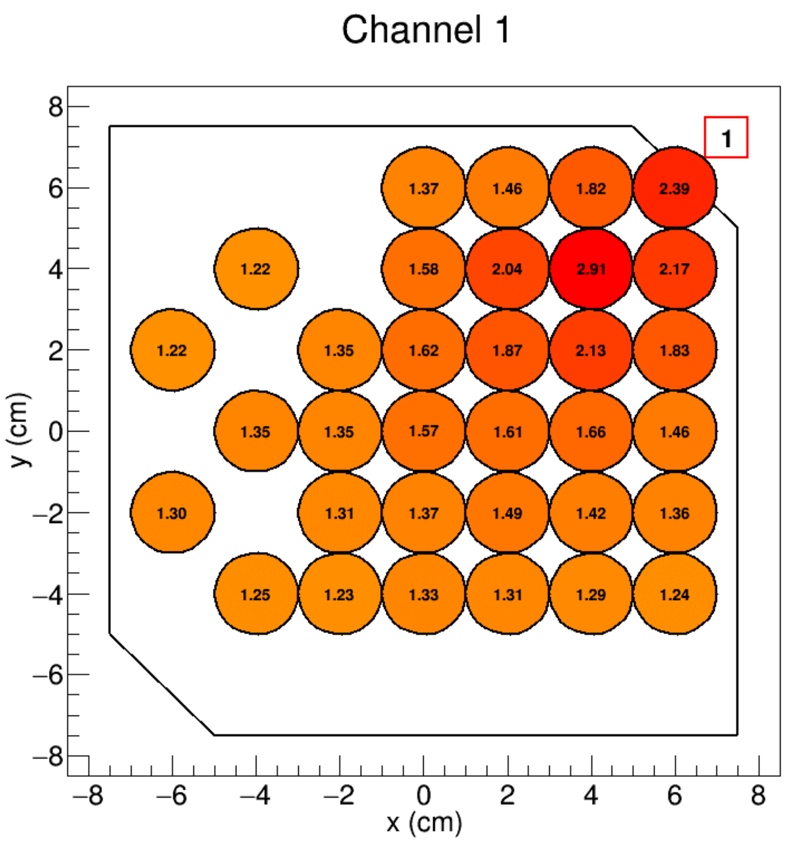
Tile 1 - yield for each SiPM

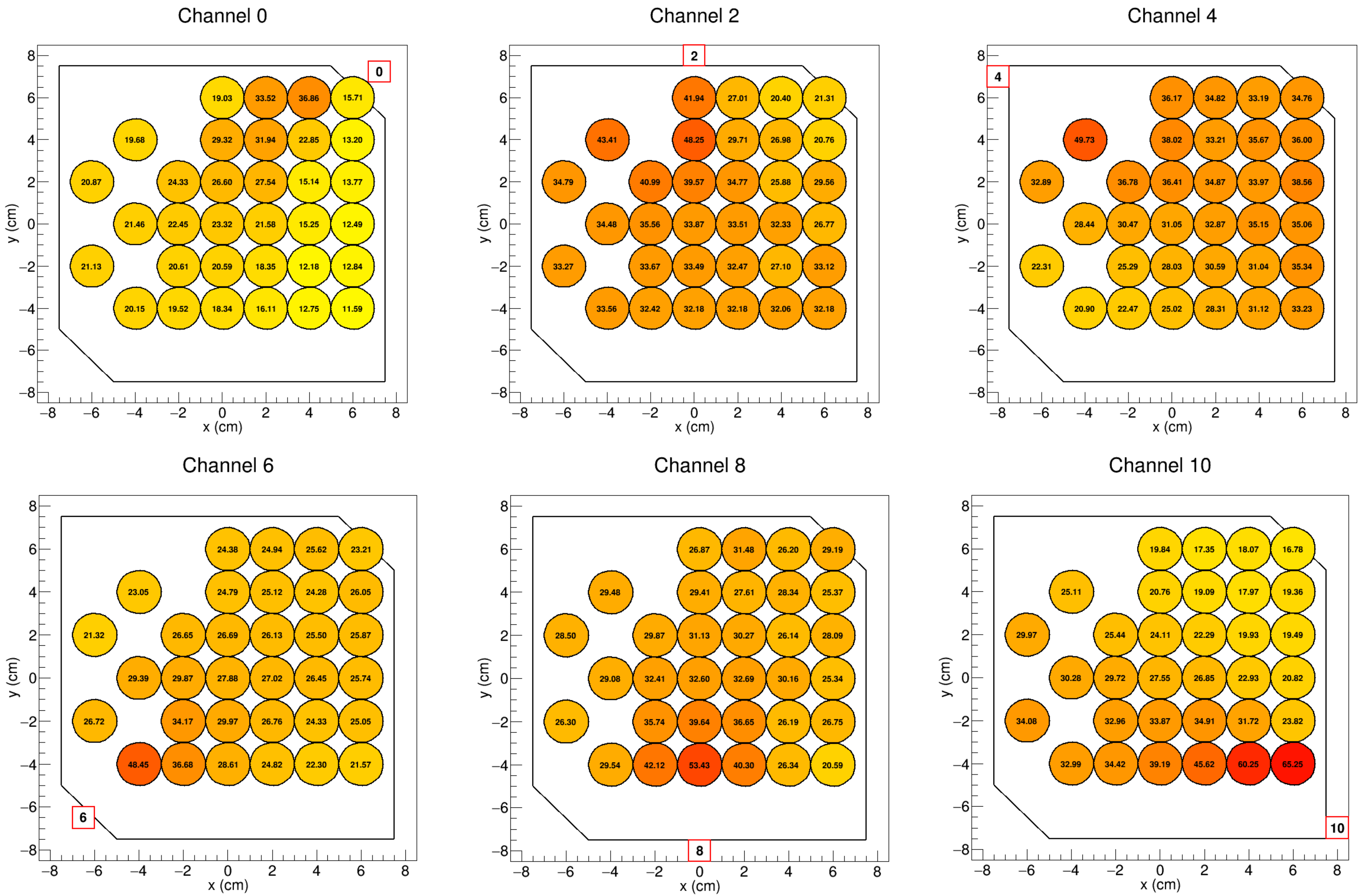
- Values represent the detected photons by the selected SiPM in all positions tested

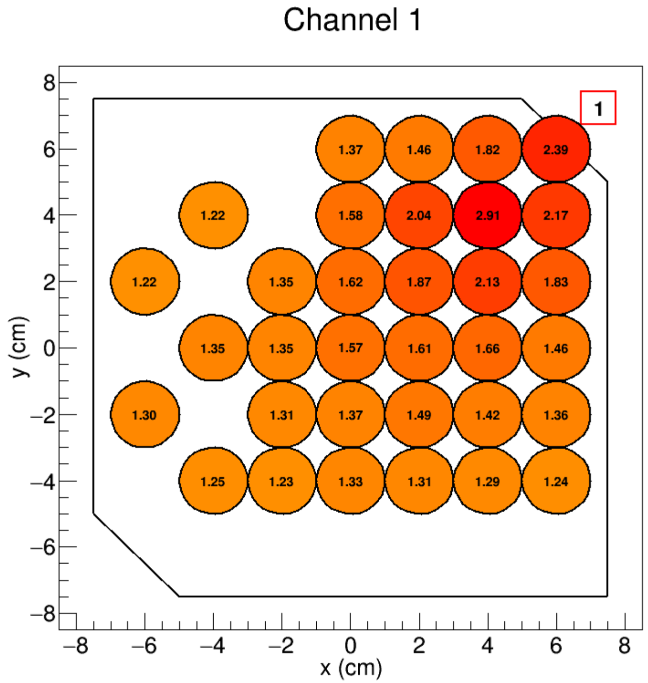
Large SiPMs

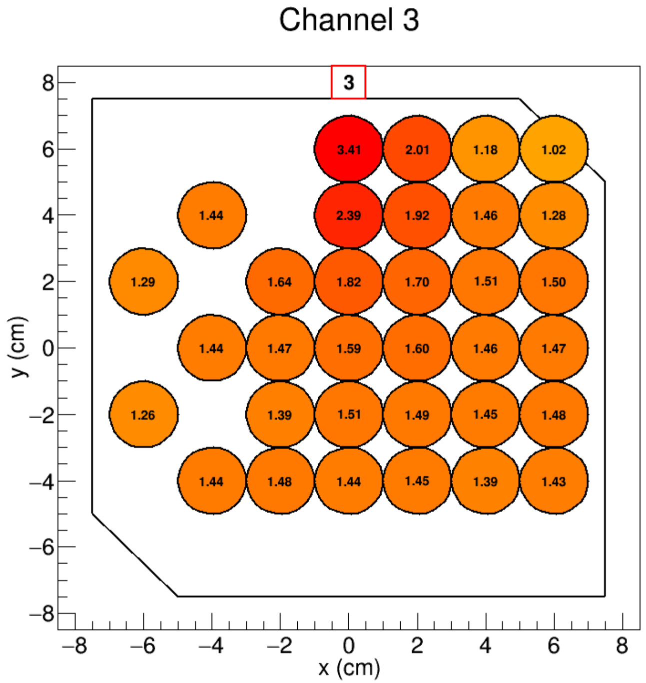


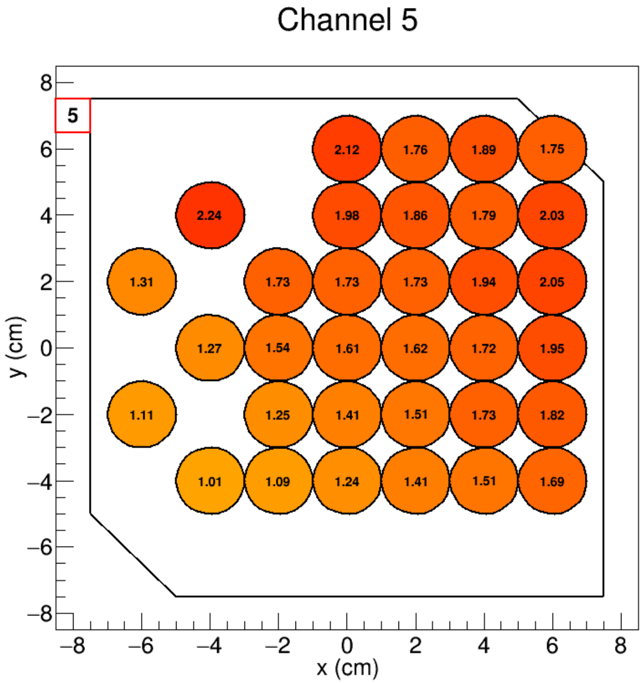
Small SiPMs

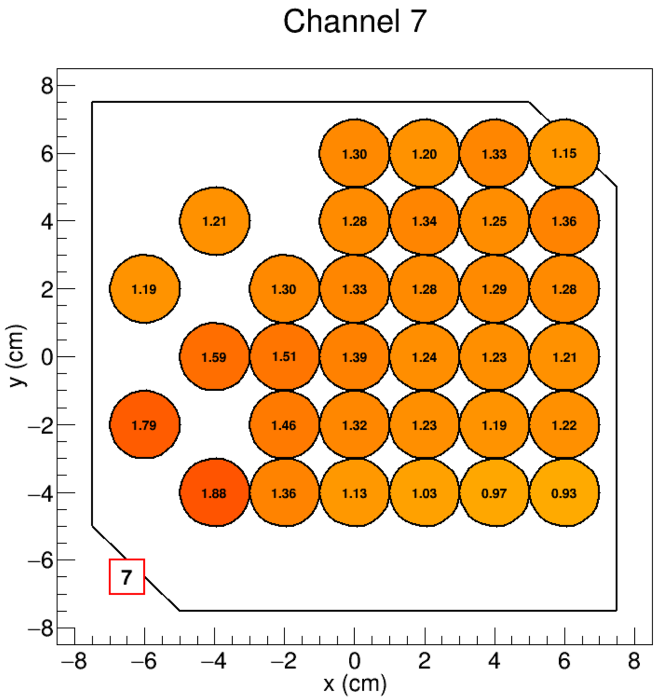


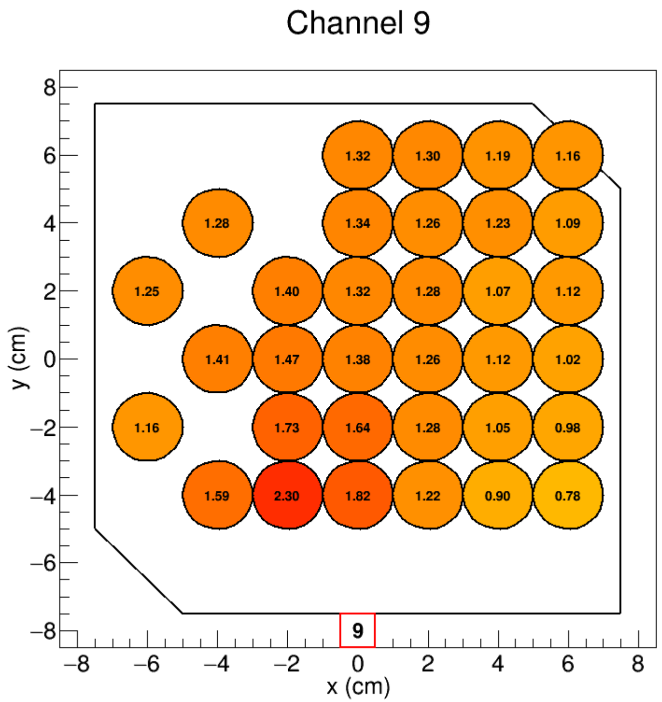

Channel 0
0
19.03 33.52 36.86 15.71
19.68 29.32 31.94 22.85 13.20
20.87 24.33 26.60 27.54 15.14 13.77
21.46 22.45 23.32 21.58 15.25 12.49
21.13 20.61 20.59 18.35 12.18 12.84
20.15 19.52 18.34 16.11 12.75 11.59
Channel 2
2
41.94 27.01 20.40 21.31
43.41 48.25 29.71 26.98 20.76
34.79 40.99 39.57 34.77 25.88 29.56
34.48 35.56 33.87 33.51 32.33 26.77
33.27 33.67 33.49 32.47 27.10 33.12
33.56 32.42 32.18 32.18 32.06 32.18
Channel 4
4
36.17 34.82 33.19 34.76
49.73 38.02 33.21 35.67 36.00
32.89 36.78 36.41 34.87 33.97 38.56
28.44 30.47 31.05 32.87 35.15 35.06
22.31 25.29 28.03 30.59 31.04 35.34
20.90 22.47 25.02 28.31 31.12 33.23
Channel 6
6
24.38 24.94 25.62 23.21
23.05 24.79 25.12 24.28 26.05
21.32 26.65 26.69 26.13 25.50 25.87
29.39 29.87 27.88 27.02 26.45 25.74
26.72 34.17 29.97 26.76 24.33 25.05
48.45 36.68 28.61 24.82 22.30 21.57
Channel 8
8
26.87 31.48 26.20 29.19
29.48 29.41 27.61 28.34 25.37
28.50 29.87 31.13 30.27 26.14 28.09
29.08 32.41 32.60 32.69 30.16 25.34
26.30 35.74 39.64 36.65 26.19 26.75
29.54 42.12 53.43 40.30 26.34 20.59
Channel 10
10
19.84 17.35 18.07 16.78
25.11 20.76 19.09 17.97 19.36
29.97 25.44 24.11 22.29 19.93 19.49
30.28 29.72 27.55 26.85 22.93 20.82
34.08 32.96 33.87 34.91 31.72 23.82
32.99 34.42 39.19 45.62 60.25 65.25
x (cm)
y (cm)

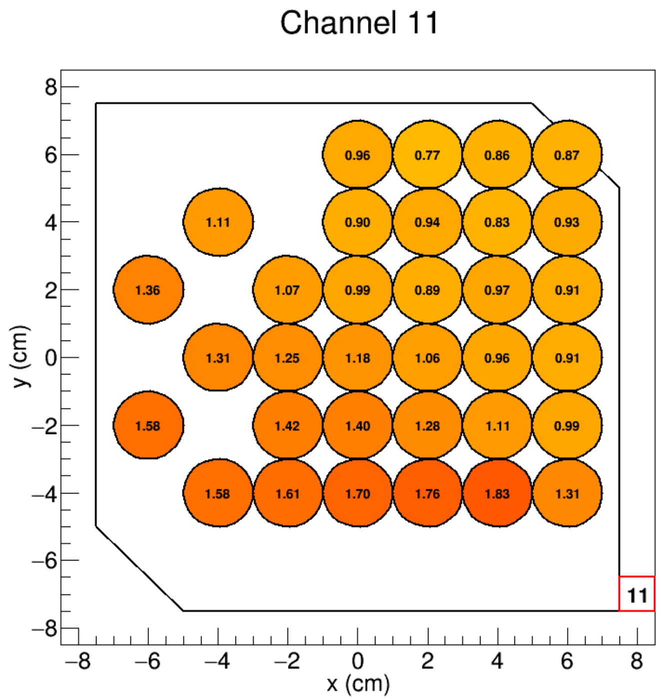

Channel 1
1
1.37 1.46 1.82 2.39
1.22 1.58 2.04 2.91 2.17
1.22 1.35 1.62 1.87 2.13 1.83
1.35 1.35 1.57 1.61 1.66 1.46
1.30 1.31 1.37 1.49 1.42 1.36
1.25 1.23 1.33 1.31 1.29 1.24
y (cm)
x (cm)


Channel 3
3
3.41 2.01 1.18 1.02
1.44 2.39 1.92 1.46 1.28
1.29 1.64 1.82 1.70 1.51 1.50
1.44 1.47 1.59 1.60 1.46 1.47
1.26 1.39 1.51 1.49 1.45 1.48
1.44 1.48 1.44 1.45 1.39 1.43
y (cm)
x (cm)


Channel 5
5
2.12 1.76 1.89 1.75
2.24 1.98 1.86 1.79 2.03
1.31 1.73 1.73 1.73 1.94 2.05
1.27 1.54 1.61 1.62 1.72 1.95
1.11 1.25 1.41 1.51 1.73 1.82
1.01 1.09 1.24 1.41 1.51 1.69
y (cm)
x (cm)

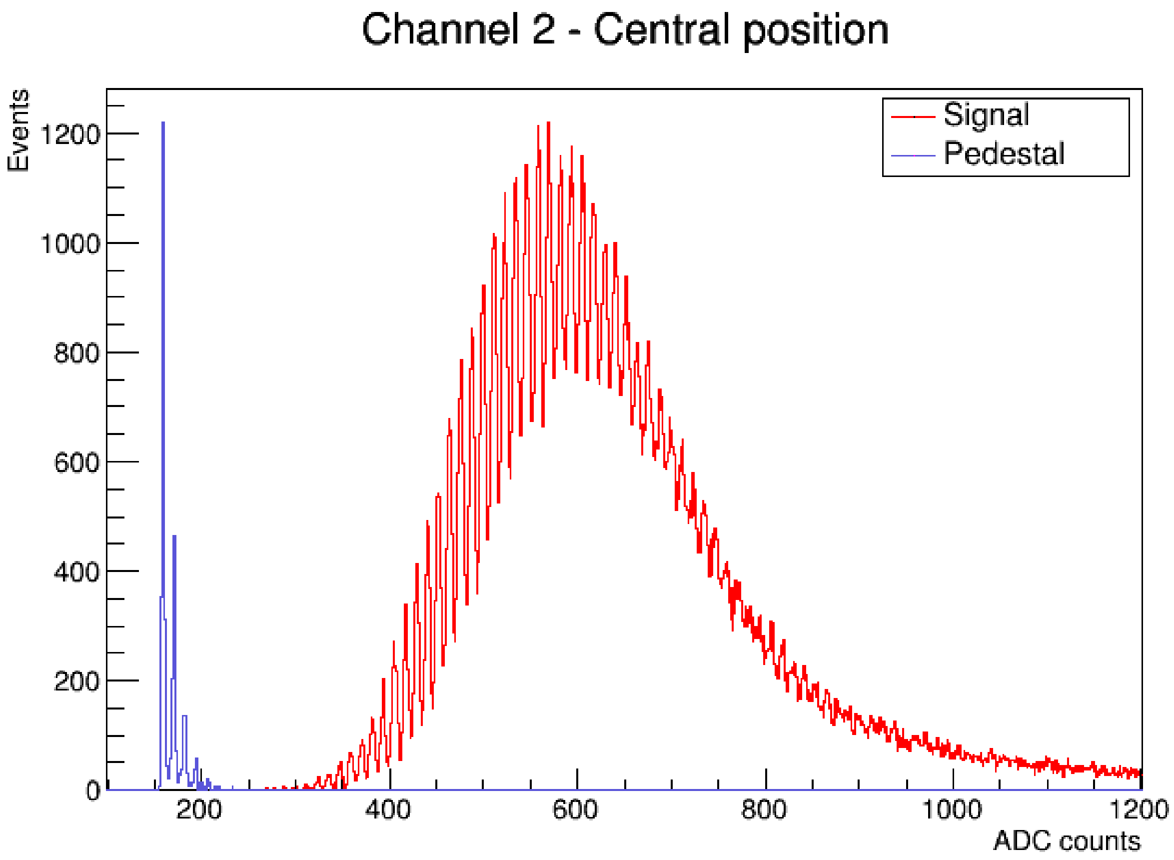

Channel 7
1.30 1.20 1.33 1.15
1.21 1.28 1.34 1.25 1.36
1.19 1.30 1.33 1.28 1.29 1.28
1.59 1.51 1.39 1.24 1.23 1.21
1.79 1.46 1.32 1.23 1.19 1.22
1.88 1.36 1.13 1.03 0.97 0.93
7
y (cm)
x (cm)


Channel 9
1.32 1.30 1.19 1.16
1.28 1.34 1.26 1.23 1.09
1.25 1.40 1.32 1.28 1.07 1.12
1.41 1.47 1.38 1.26 1.12 1.02
1.16 1.73 1.64 1.28 1.05 0.98
1.59 2.30 1.82 1.22 0.90 0.78
9
y (cm)
x (cm)


Channel 11
0.96 0.77 0.86 0.87
1.11 0.90 0.94 0.83 0.93
1.36 1.07 0.99 0.89 0.97 0.91
1.31 1.25 1.18 1.06 0.96 0.91
1.58 1.42 1.40 1.28 1.11 0.99
1.58 1.61 1.70 1.76 1.83 1.31
11
y (cm)
x (cm)

SPS data

- Scintillator irradiated in the central position with 20 GeV particles



- Good separation of signal and pedestal
- Individual peaks visible up to 40-50 photons

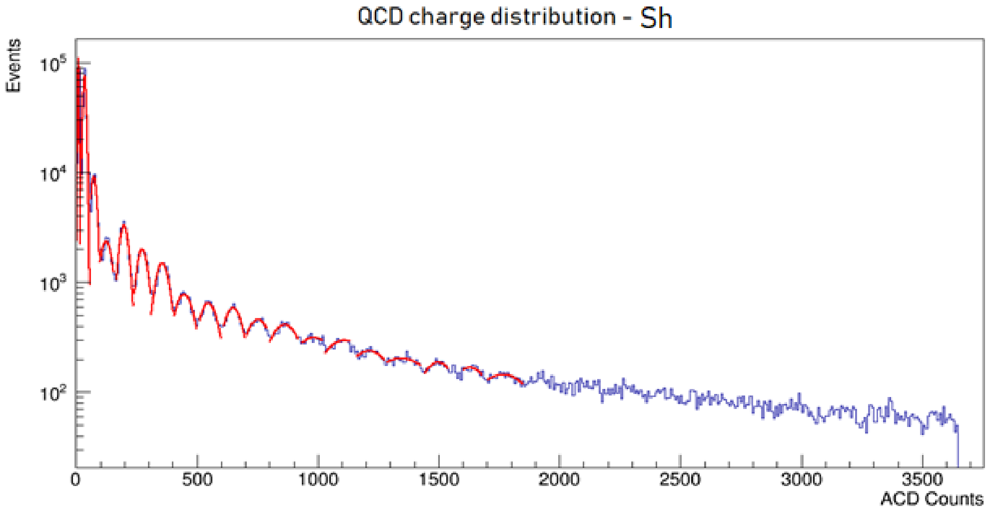
Conclusions

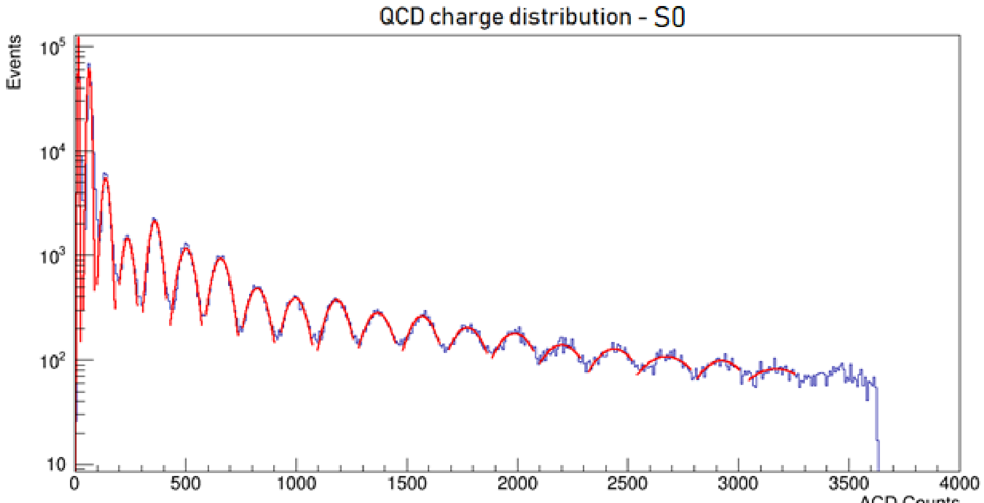
- Small SiPMs detect too few photons
- Response is almost uniform in the tile, with peaks in the points closer to the SiPMs
- Efficiency reached with this configuration is close to the requirements of ACD detectors for satellites
  - Improvements can be obtained by summing or implementing coincidence of multiple SiPMs

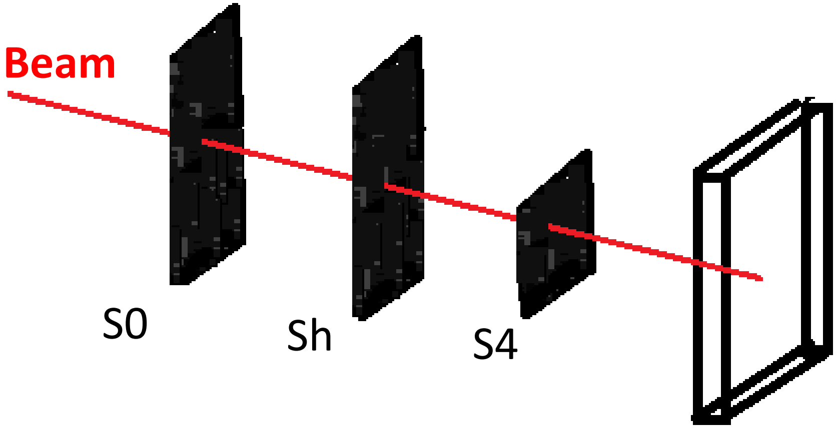
- Future plans:
  - Repeat tests with a new scintillator and SiPMs
  - Test with cosmic rays or a radioactive source in lab or new beam test in near future

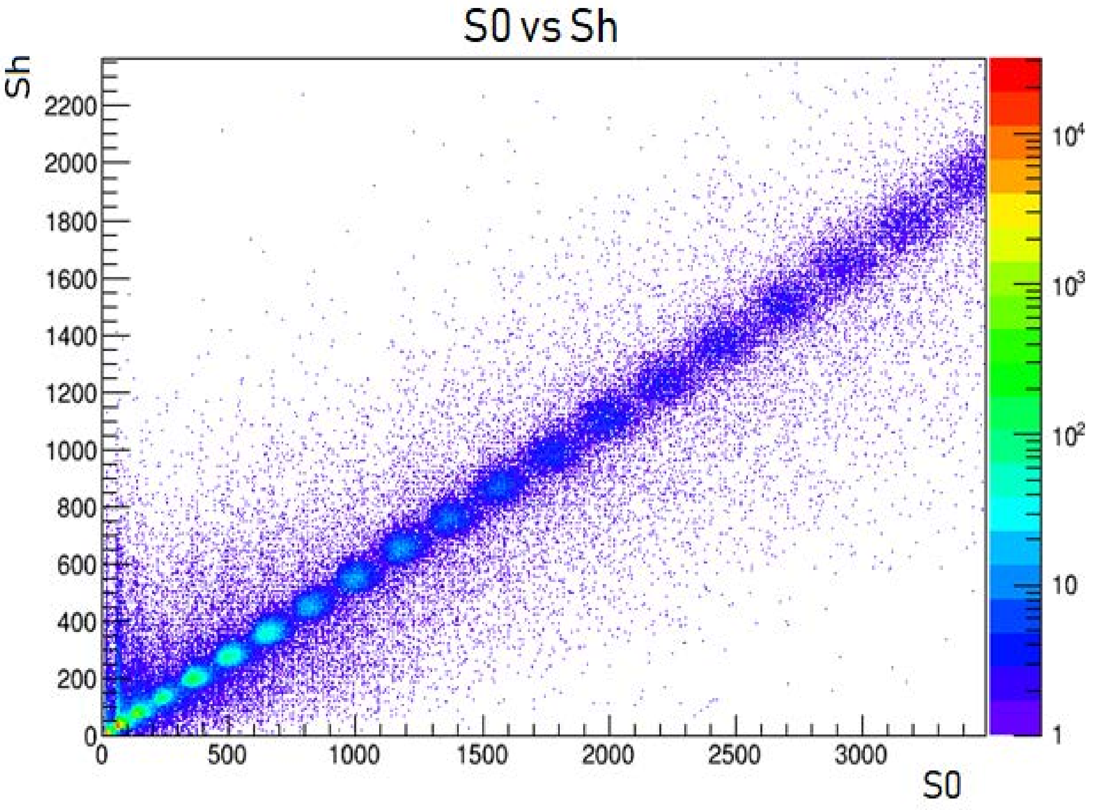
Response to ions

- Spectra on trigger scintillators



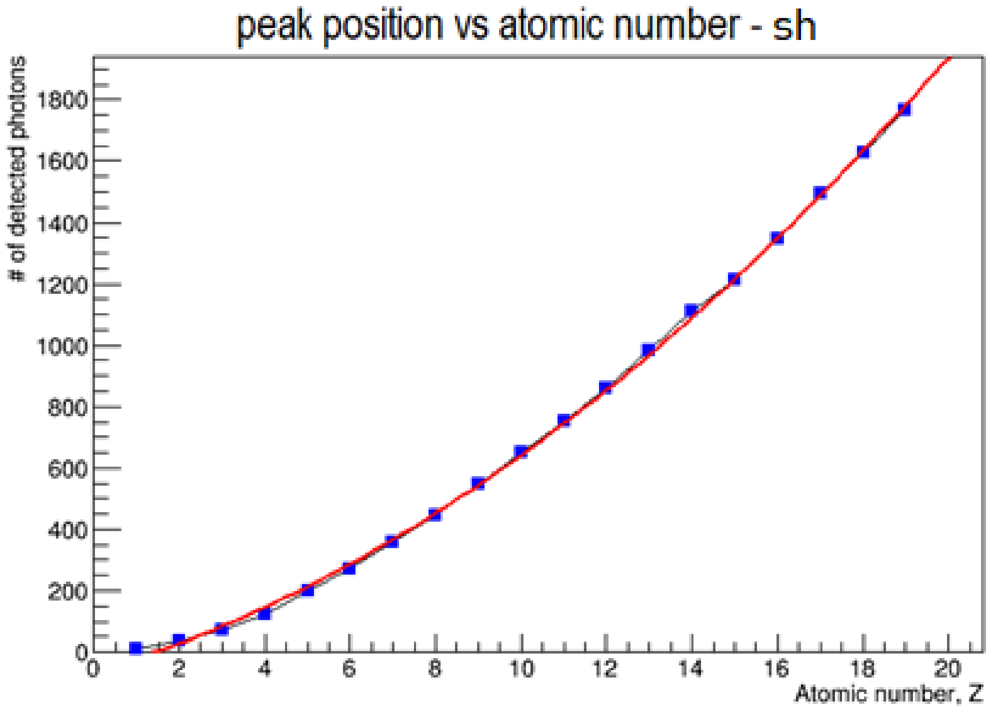


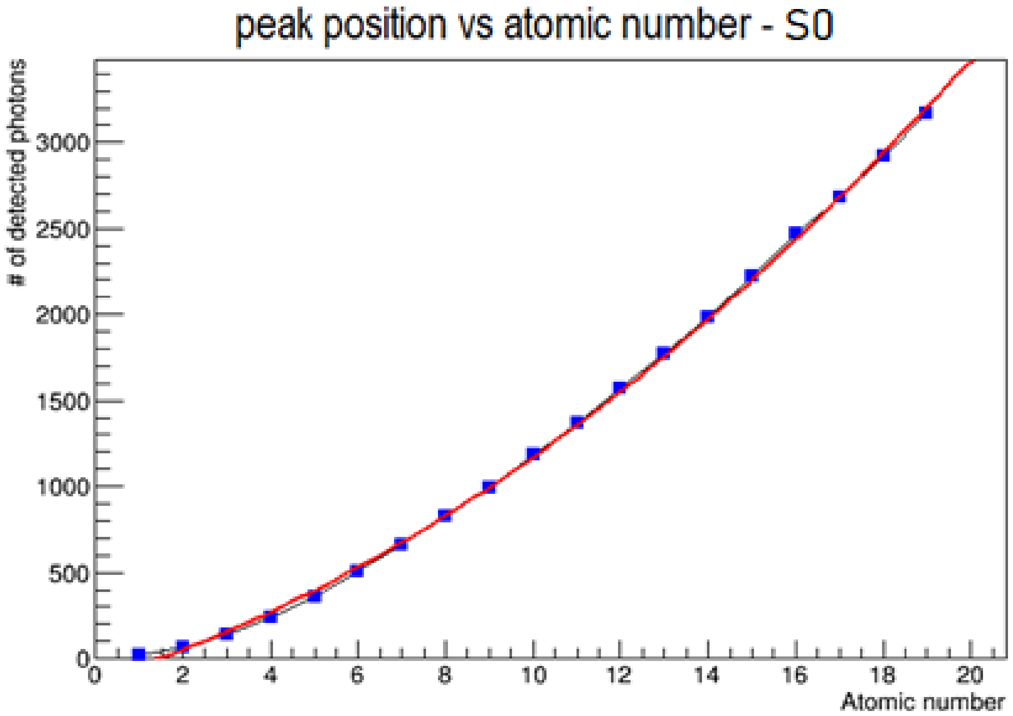




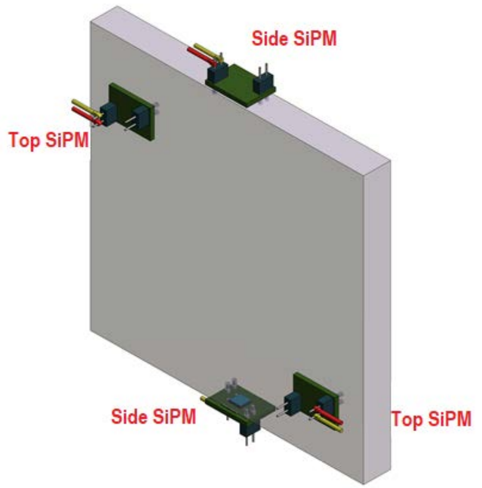
Response to ions

- The peak positions are very well described with a quadratic function as expected.
- The first peak (Z=1) seem to be slightly over the best-fit. This is probably an effect of the threshold used in the trigger logic that reject the Deuterium nuclei that release less charge in the scintillators.

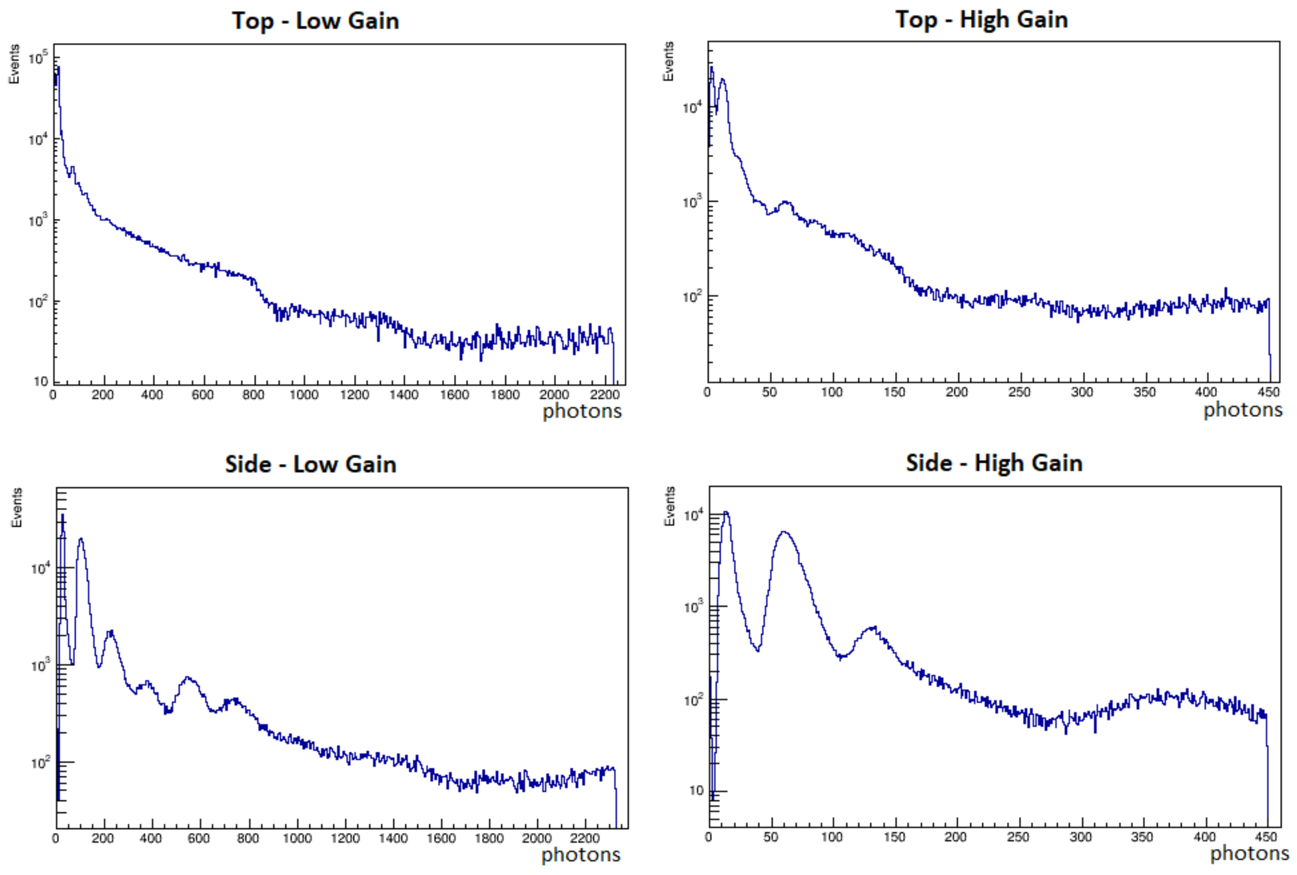




Tile 2 – individual SiPM

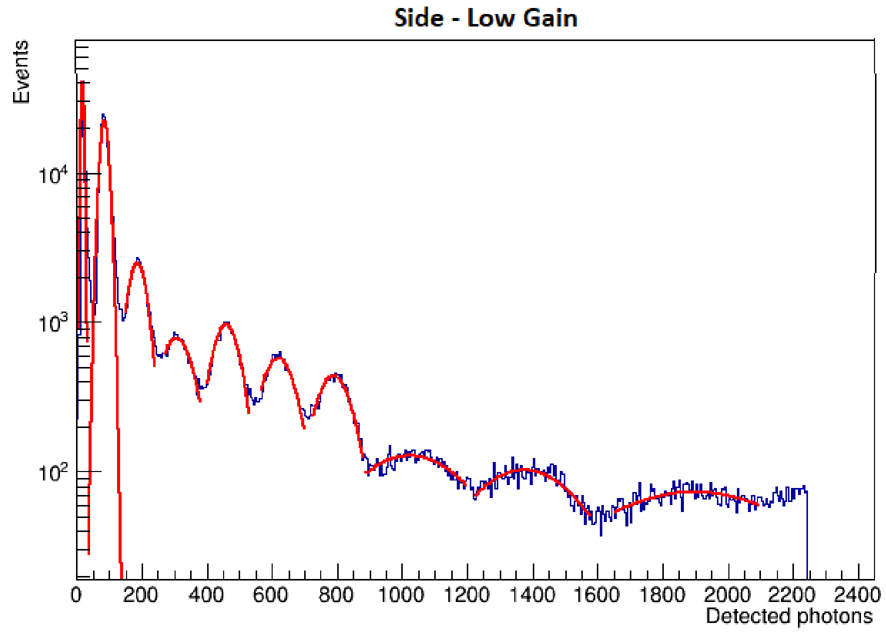


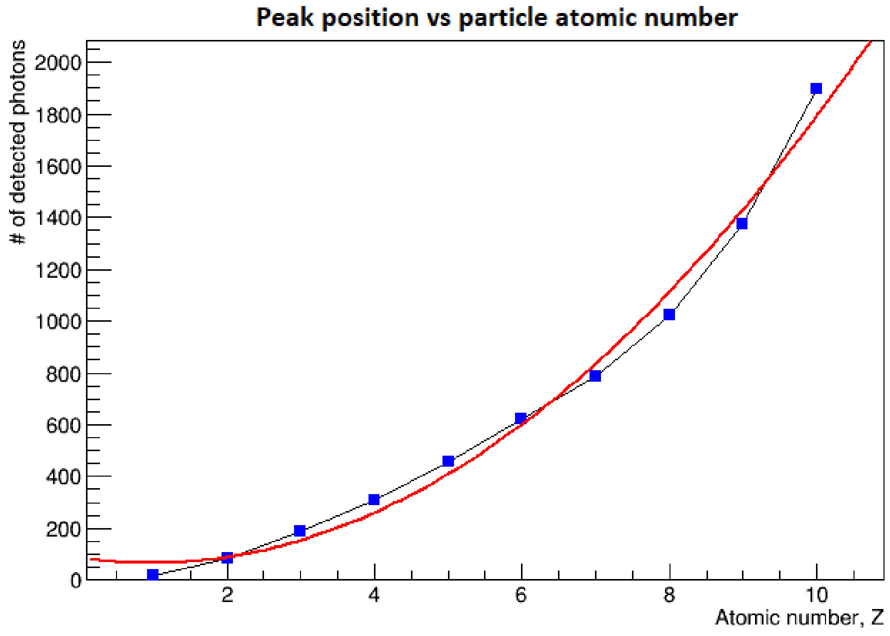
- “Side” SiPMs show better resolution with respect to the “Top” ones since they collect more photons per unit area.
- In “Side” SiPMs, the high gain amplification starts saturating for Z=2
- “Top” SiPMs show an opposite behaviour: HG resolve more peaks than LG



Tile 2 – individual SiPM

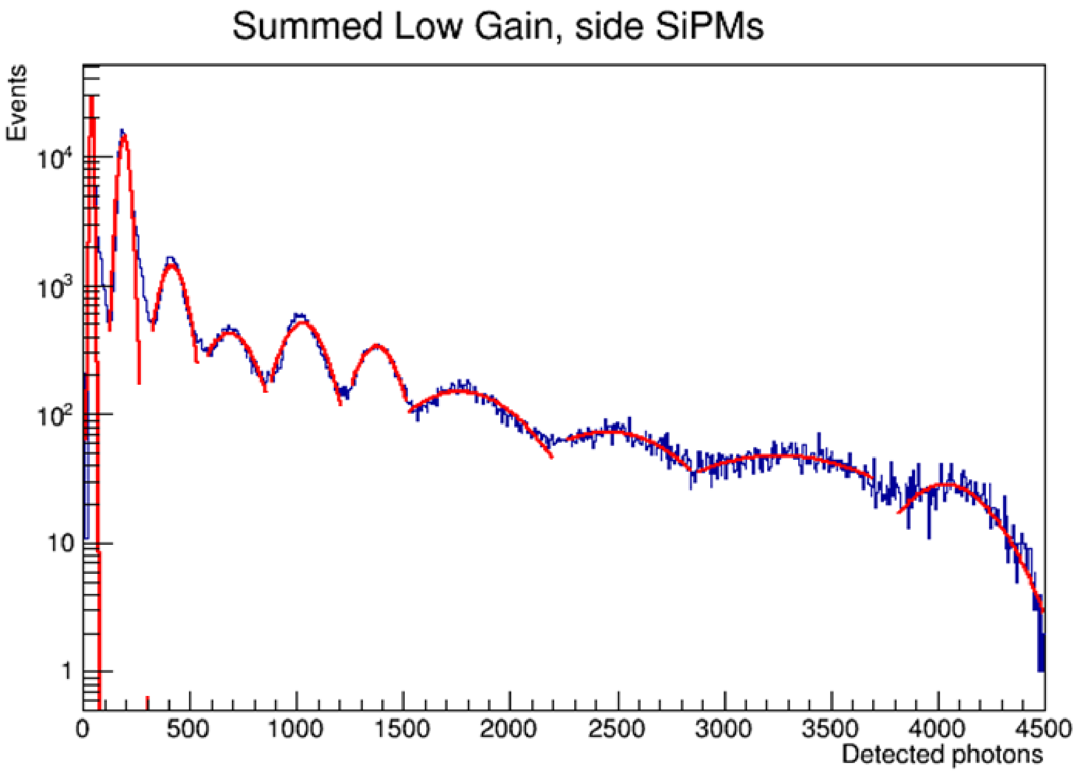
- Example fit for a side SiPM – LG
  - Peaks fitted with Gaussian functions
- Peak positions agree with a quadratic relation
- Resolved with good resolution up to Z=7

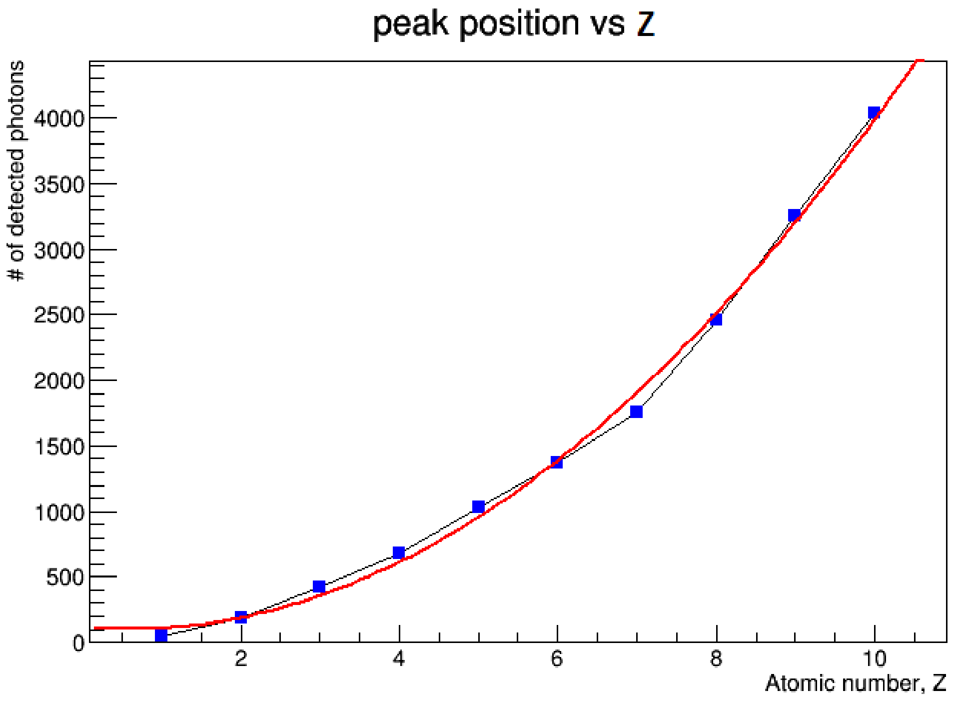




Tile 2 – summed channels – side LG

- We sum channels of the same type (side/top, HG/LG) event by event after calibration

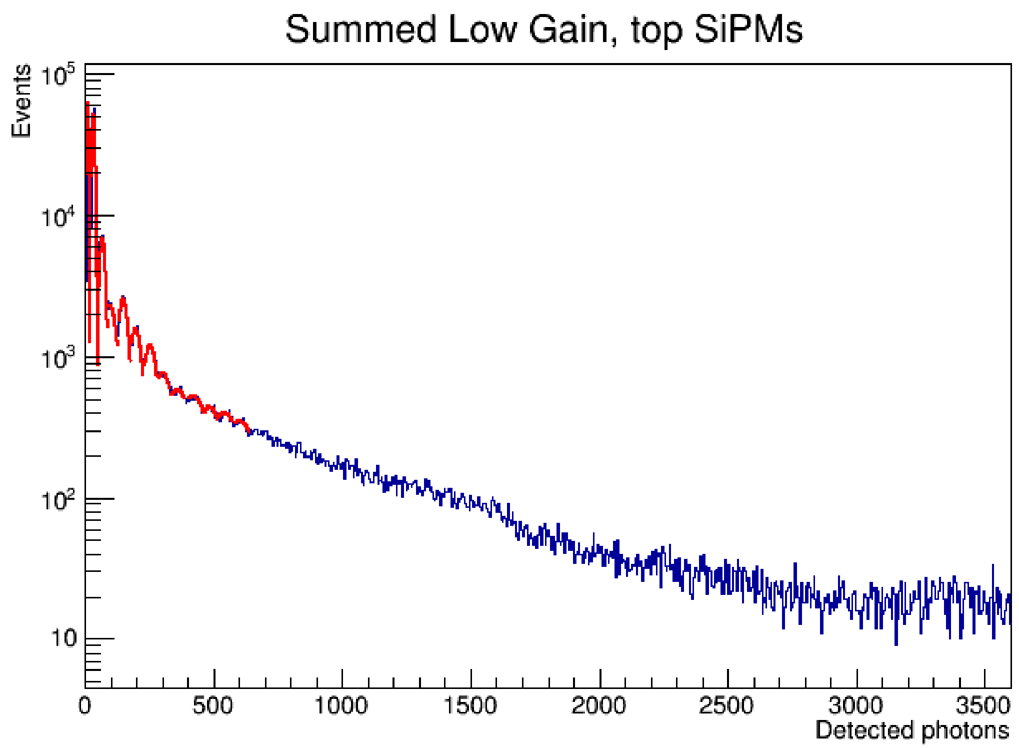


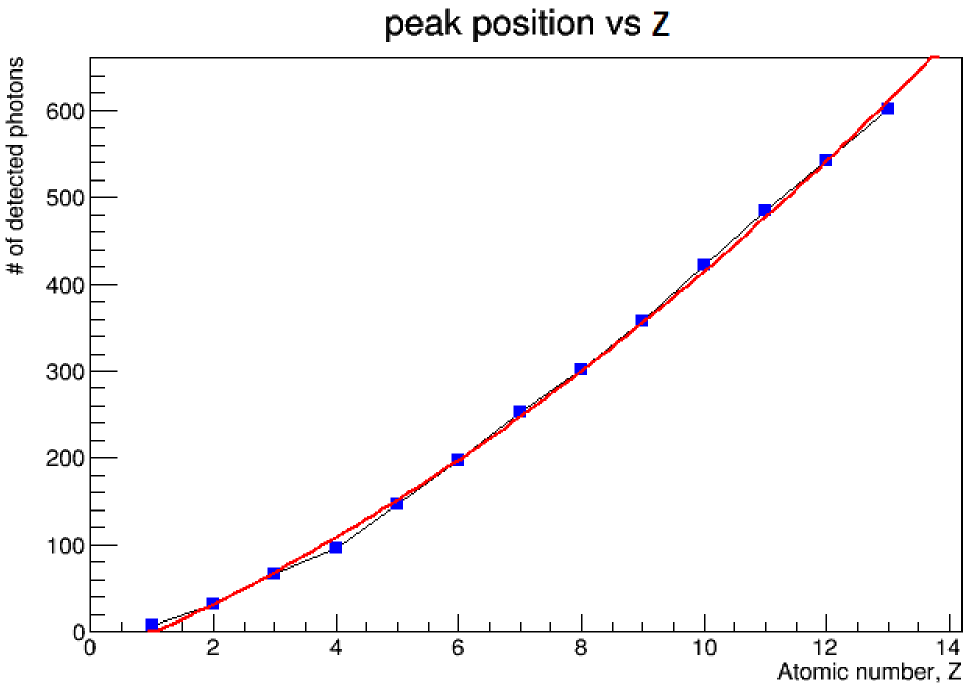


Z	Resolution
1	0.181 ± 0.001
2	0.1291 ± 0.0004
3	0.150 ± 0.001
4	0.171 ± 0.003
5	0.101 ± 0.001
6	0.073 ± 0.001
7	0.161 ± 0.003
8	0.136 ± 0.006
9	0.152 ± 0.005
10	0.053 ± 0.02

Reaching Z = 10 (equivalent to Neon)
With good resolution up to Z = 7 (Nitrogen)

Tile 2 – summed channels – top LG

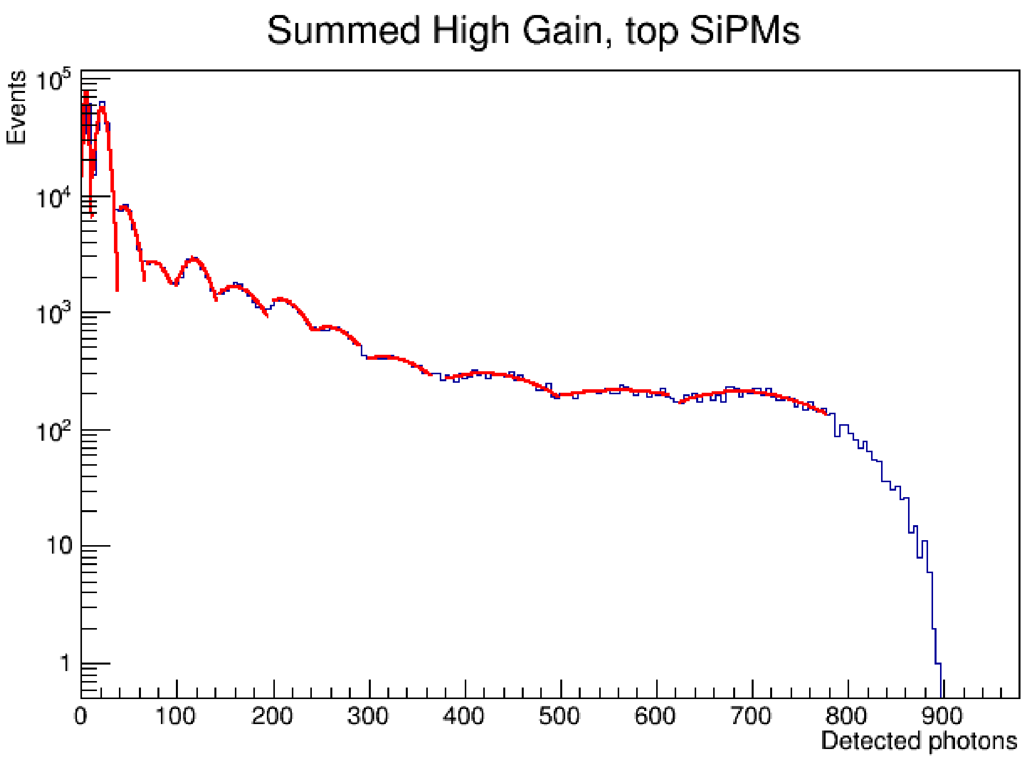


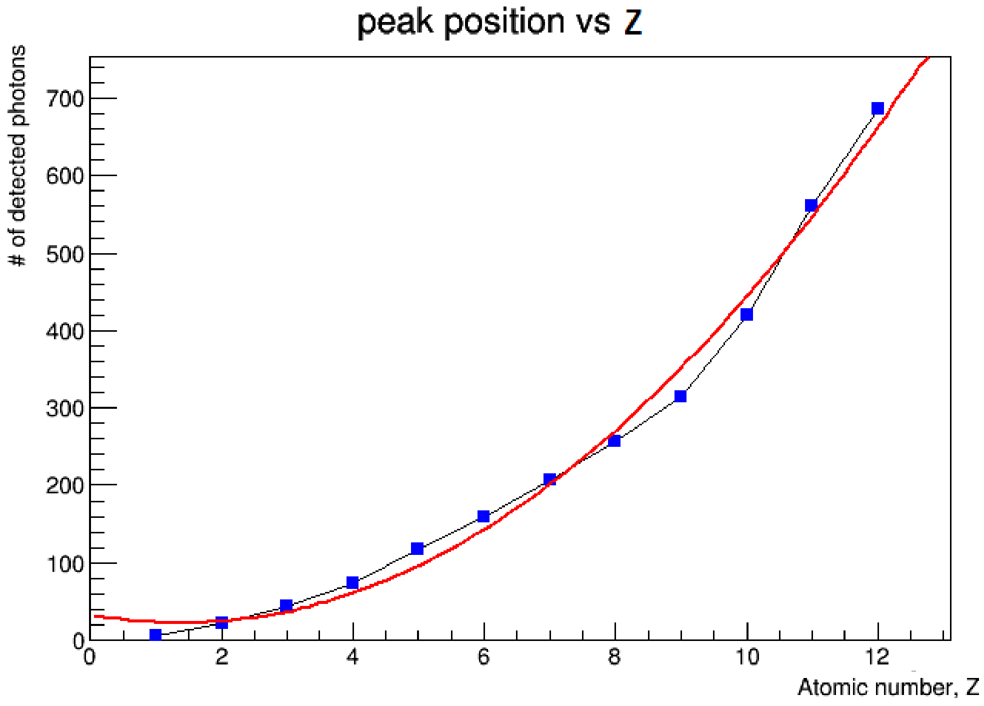


Z	Resolution
1	0.661 ± 0.009
2	0.204 ± 0.001
3	0.166 ± 0.001
4	0.275 ± 0.001
5	0.135 ± 0.002
6	0.116 ± 0.002
7	0.105 ± 0.002
8	0.127 ± 0.006
9	0.15 ± 0.009
10	0.132 ± 0.01
11	0.085 ± 0.005
12	0.110 ± 0.006
13	0.099 ± 0.008

Reaching Z = 13 (equivalent to Aluminium)
With good resolution up to Z = 9 (Fluorine)

Tile 2 – summed channels – top HG





Z	Resolution
1	0.43 ± 0.016
2	0.281 ± 0.001
3	0.303 ± 0.001
4	0.293 ± 0.002
5	0.161 ± 0.002
6	0.203 ± 0.007
7	0.154 ± 0.015
8	0.145 ± 0.01
9	0.186 ± 0.017
10	0.198 ± 0.01
11	0.225 ± 0.018
12	0.141 ± 0.005

Reaching Z = 12 (equivalent to Magnesium)
With good resolution up to Z = 9 (Fluorine)

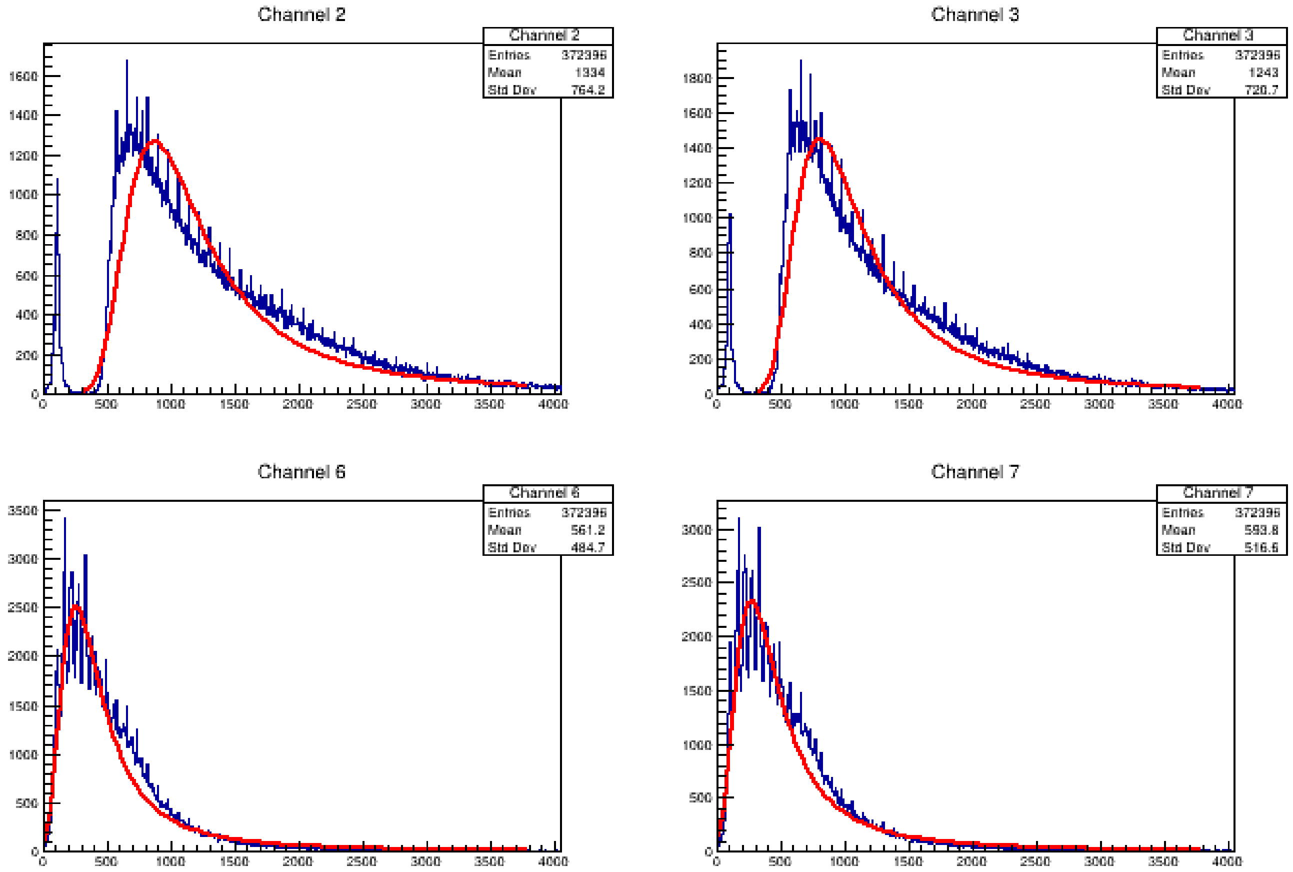
Conclusions

- The performed measurements show that SiPMs can be coupled to scintillators in order to detect nuclei and to identify their charge.
- The spectra show that we can easily resolve up to an atomic number of ten using the single channels, having a better resolution for those SiPMs located at the edges of the tile compared to those on the frontal part of the tile.
- Summing up the equivalent channels, a clear improvement in the signal of the Top SiPMs is observed, while the Side SiPMs do not show significant changes. It was possible, using these associations, to reach Z=13 , equivalent to Aluminium.
- However, the readout used in these tests limited the dynamics that we could test and must be improved.
- In conclusion, this study is showing that SiPM technology can be used instead of the classical PMTs to identify ions and that the resolution is improved if multiple SiPMs are combined.

Cosmic ray data

- Tile 2 tested with CRs
- SiPMs connected to Caen A1702
  - SiPMs on side : channels 2-3
  - SiPMs on top : channels 6-7
- Gain setup:
  - ch2, ch3 : DAC=40 (gain 26V/V)
  - ch6, ch7 : DAC = 51 (gain 46 V/V) → because we expect fewer photons
  - From measurements on ch1 we know that:
    - pedestal is around 100 ADC channel
    - Gain for DAC=40 is 47 ADC/p.e.
    - Gain for DAC=50 is 79 ADC/p.e.
- Trigger: ch2 && ch3 with different thresholds

Individual channel distributions



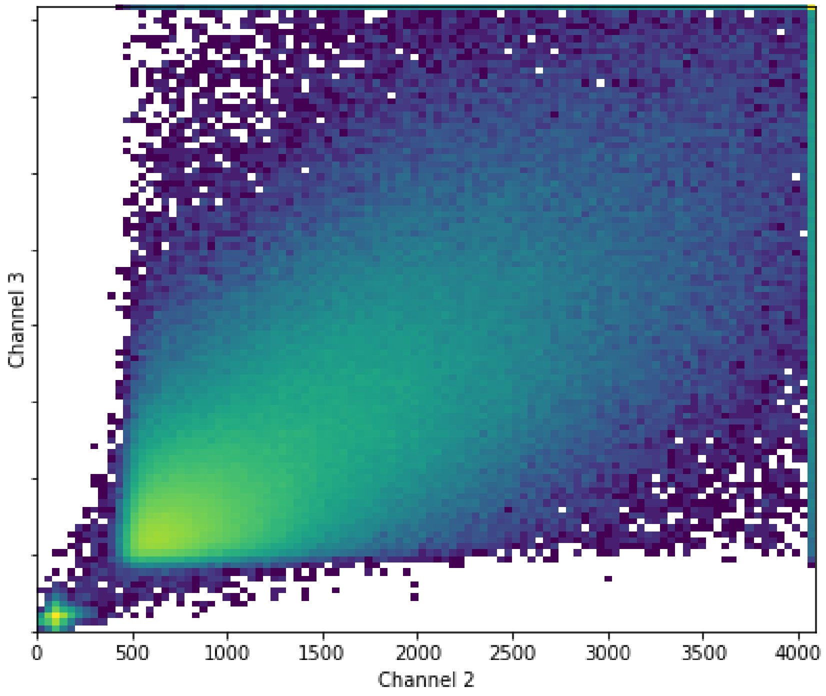
- Ch2 and ch3 do not show a Landau distribution, probably due tot he threshold effect
- They show strange events below threshold

- Ch6 and ch7 are well fitted by a landau, but some positive residuals are found between 500 and 1000 ADC counts (‘bump’)

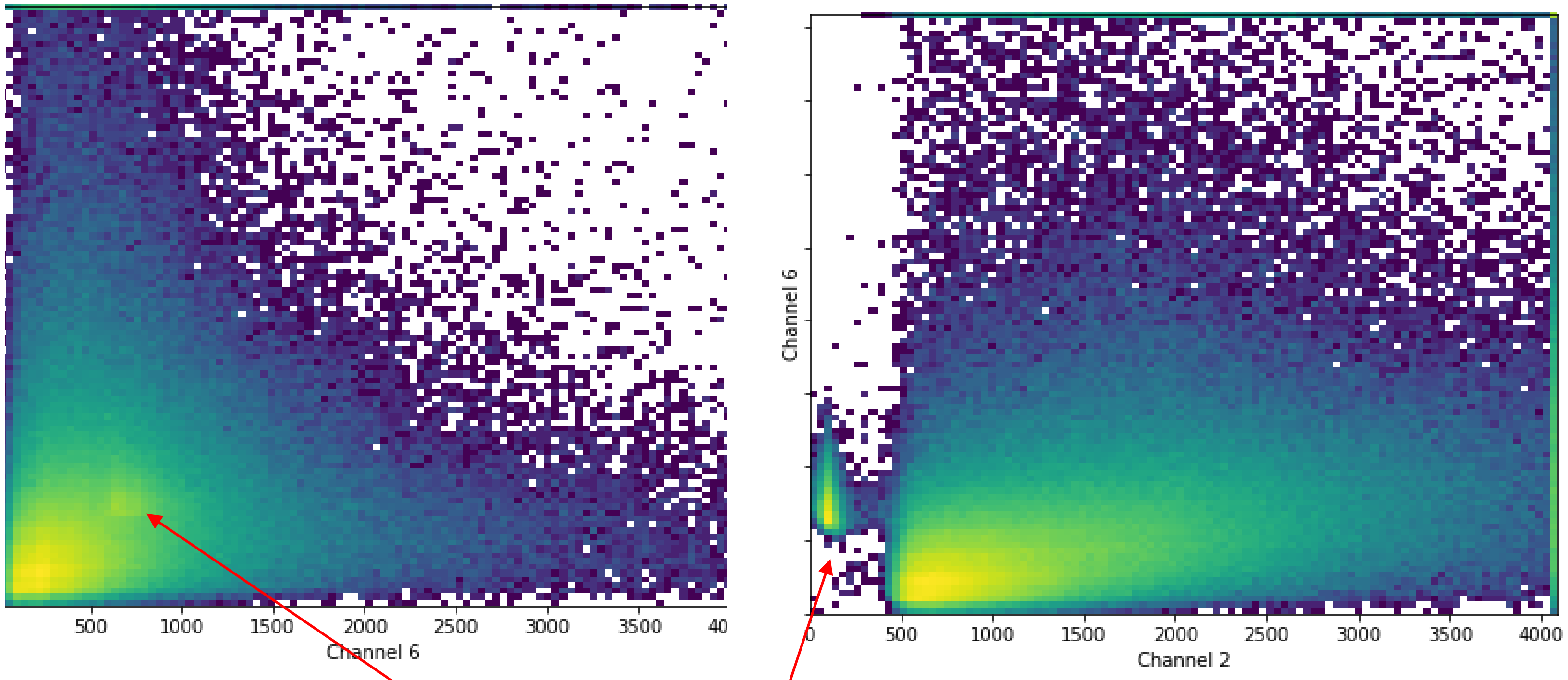
- Gain estimates:
  - ch2 & ch3: peak @700 ADC, ped @100 ADC → peak is @ 13 p.e.
  - ch6 & ch7: assuming first peak is pedestal (should be since it is around 100 ADC), the peak is around 2-3 p.e

Correlation plots : top SiPMs

Side SiPMs

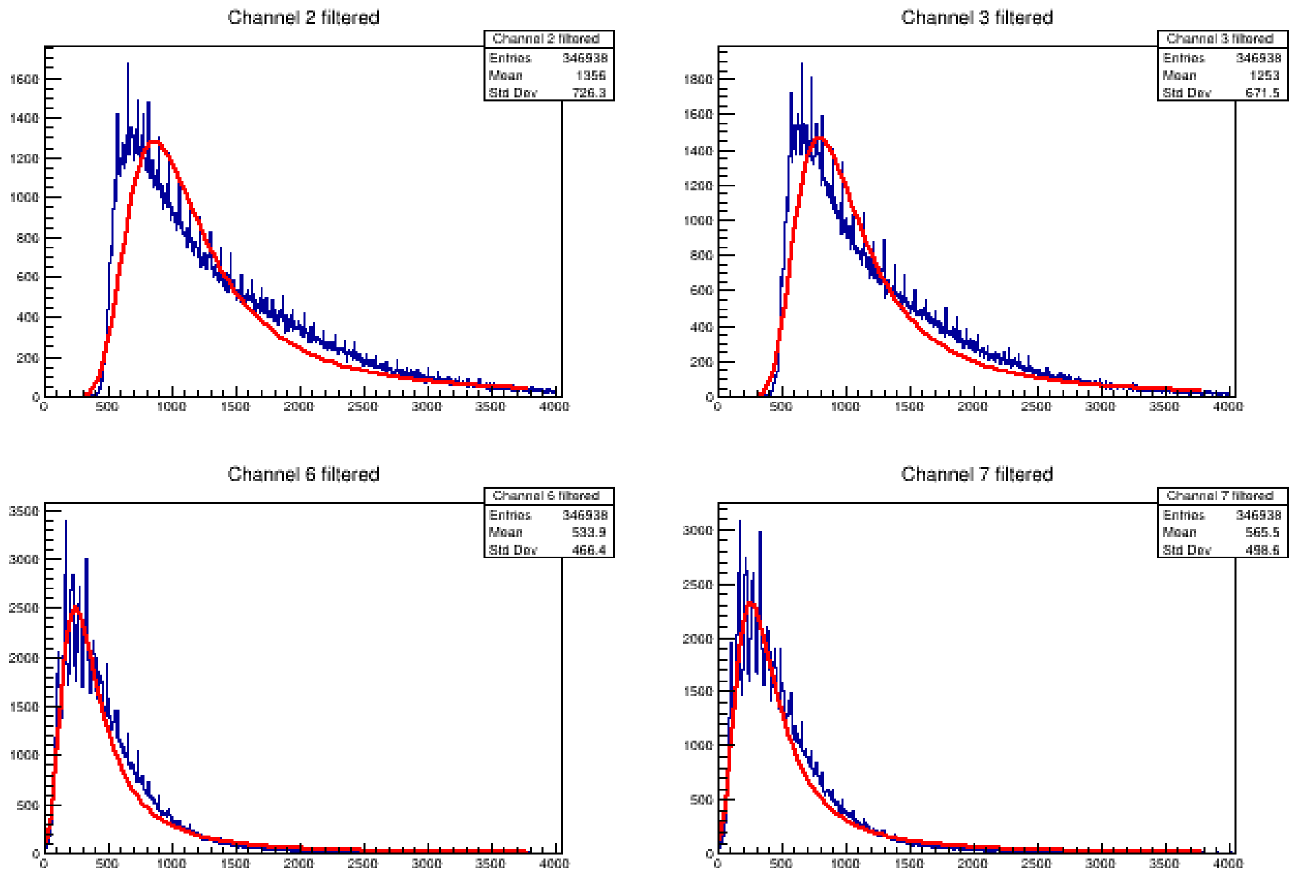


Top SiPMs



Correlation is visible. Also events below the threshold al correlated
A double peak is visible in the right plot, corresponding to the events in the 'bump'

Individual channel distributions - filtered



- Filtered events to get rid of the strange events: ch2 >=300 & ch3>=300
- Cutted events: 7%

- The ‘bump’ in ch6 and ch7 is reduced but does not disappear

Correlation plots : side SiPMs - filtered

Side SiPMs

Top SiPMs