Measurements with SiPM-based Front-End Electronics FERS-5200

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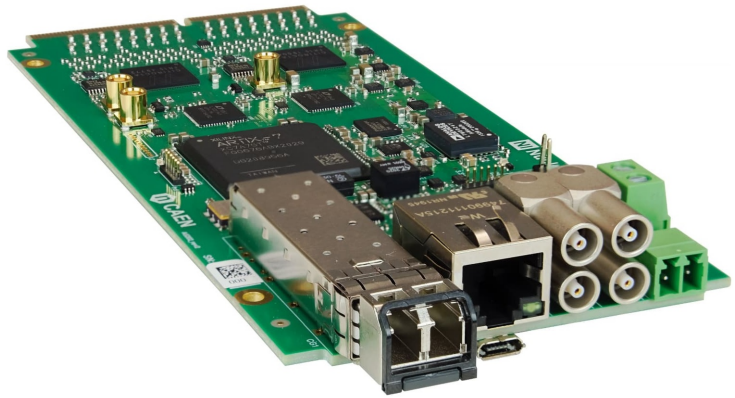
- **Comparison of the results** with a complementary system based on charge integration acquisition.

Front-End Structure

A5202 board

The A5202 [1] is an **all-in-one** front-end board optimized to work with **SiPM**.

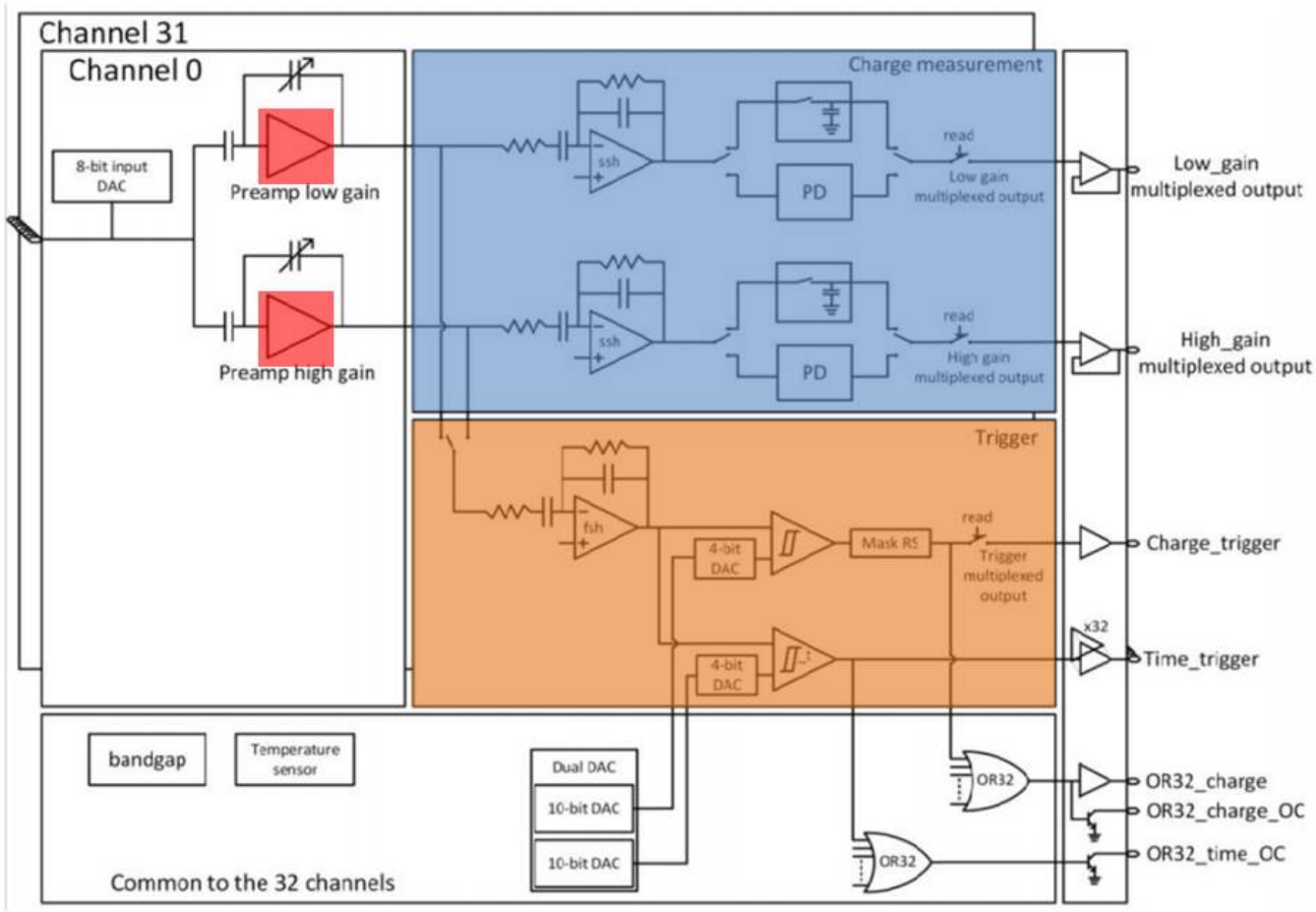
- bias voltage provided by power supply embedded in the board
- event acquisition handled with ASIC Citiroc-1A [2]
- multiple trigger logic options onboard
- 64-ch on a single board, easily scalable up to 8 boards



[1] https://www.caen.it/products/a5202/
[2] https://www.weeroc.com/my-weeroc/download-center/citiroc-1a/16-citiroc1a-datasheet-v2-5/file

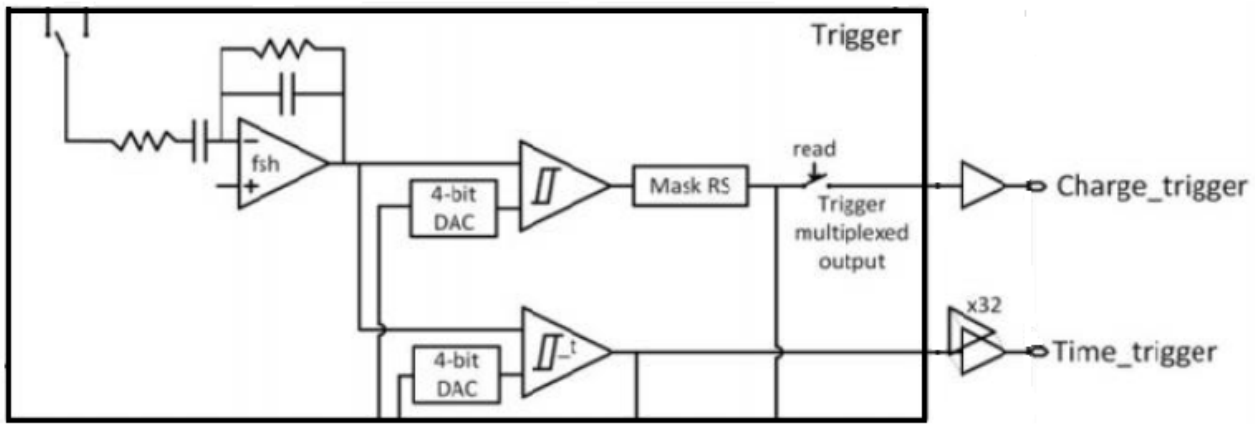
Front-End Structure

two preamplifiers connected to: charge measurement and trigger sections



Front-End Structure: Trigger section

- **Fast shaper** amplifier: 15 ns peaking time, followed by:
  - **Timing discriminator**: its output is used for logical combination of the channels by the FPGA
  - **Charge discriminator**: output used for the charge circuit

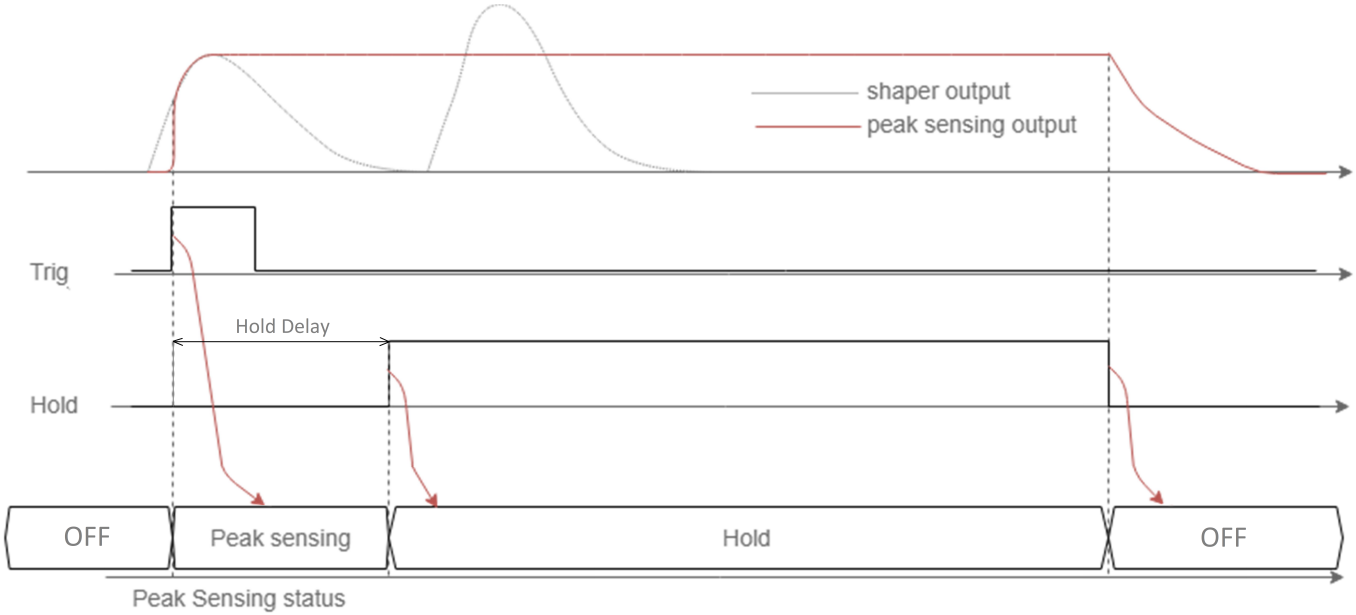


Front-End Structure: Charge section

- Two preamplication stages: high and low gain
- Slow shaper amplifier: shaping time range between 12.5 ns and 87.5 ns

Peak Detector Working Principle

Three sequentially phases:

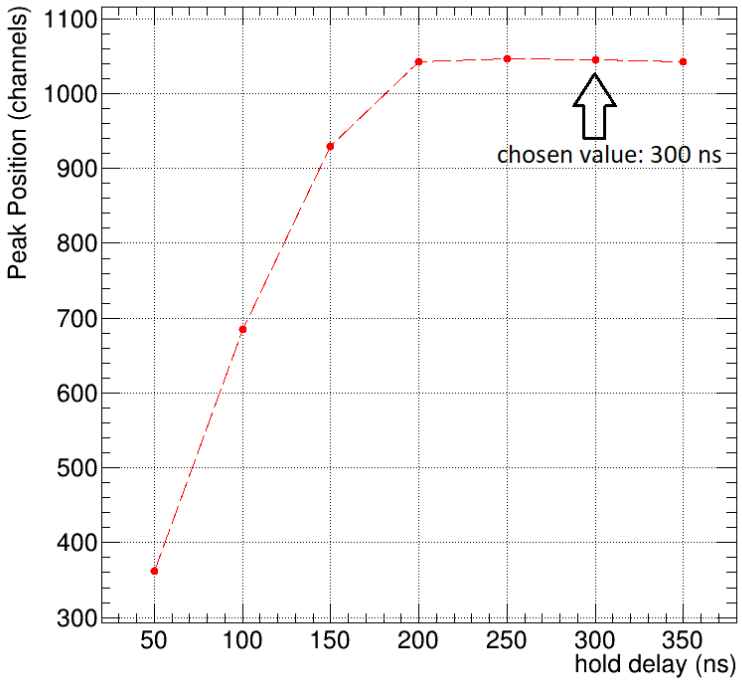


Event Selection

Hold delay:

Time difference between the bunch trigger and the arrival of the hold signal.

Crystal: LYSO



- Small values of hold delay lead to incorrect energy values.
- Correct values are in the plot flat region. **We selected 300 ns**.

Set-up

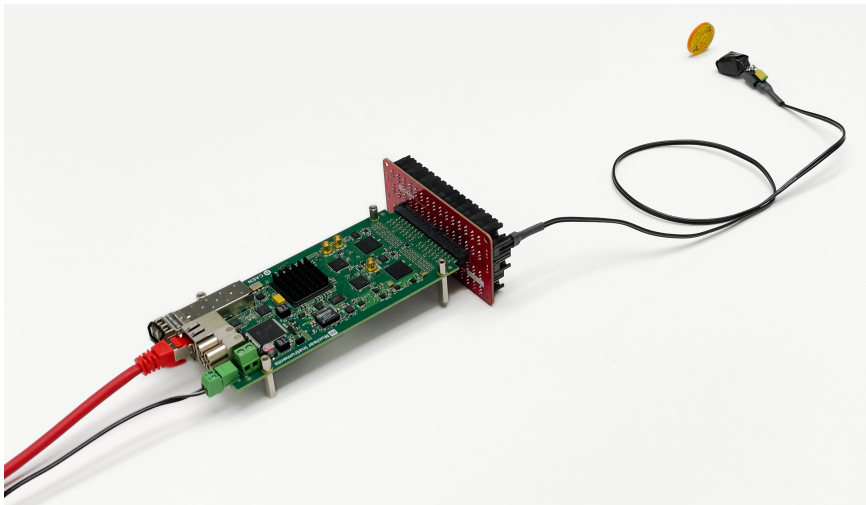
Measurements have been taken with two types of SiPM:

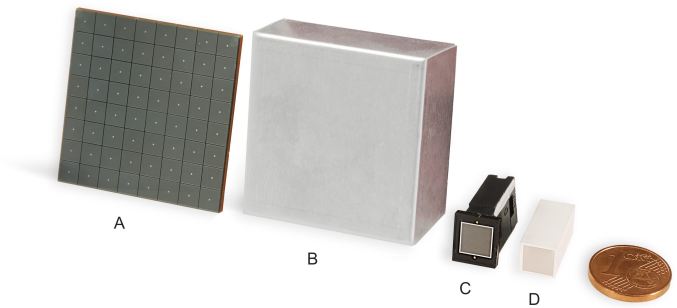
A. 64 channels Hamamatsu SiPM matrix S13361-3050AE-08 (single cell dimensions: 3x3 mm^2)

B. LYSO matrix

C. Hamamatsu SiPM MPPC S13360-6050CS (6x6 mm^2)

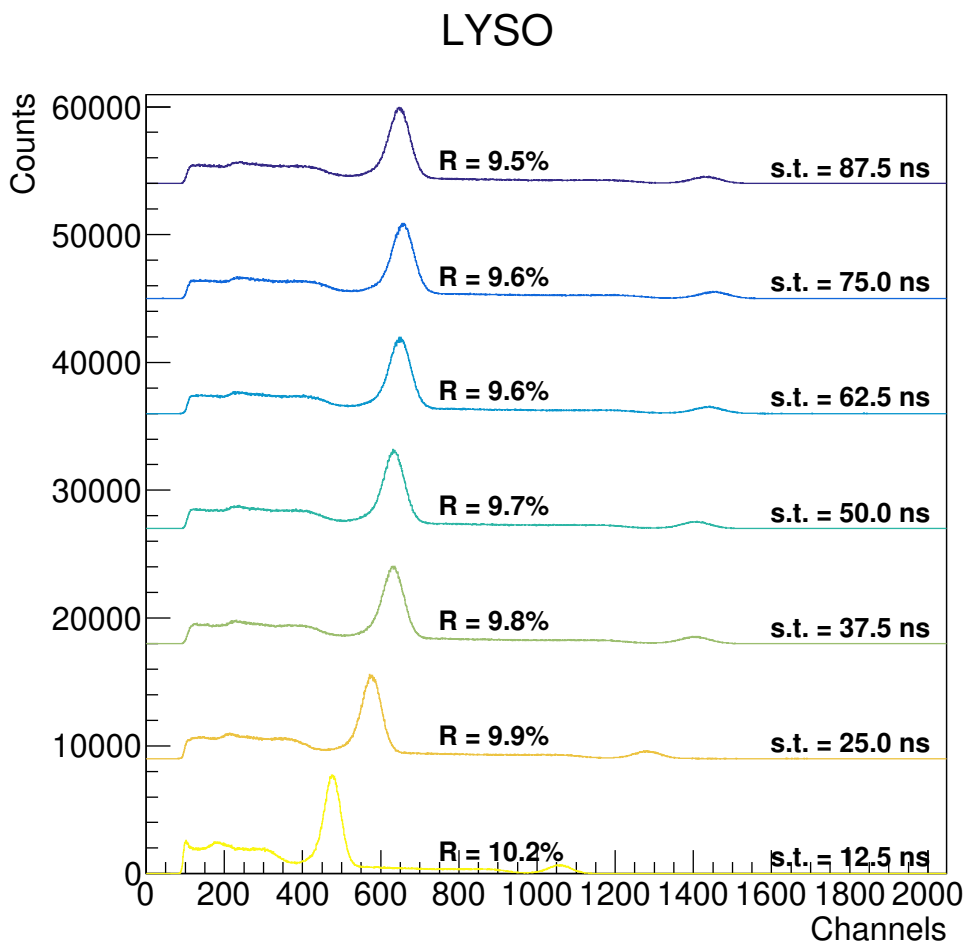
D. LYSO crystal (6x6x15 mm^3)





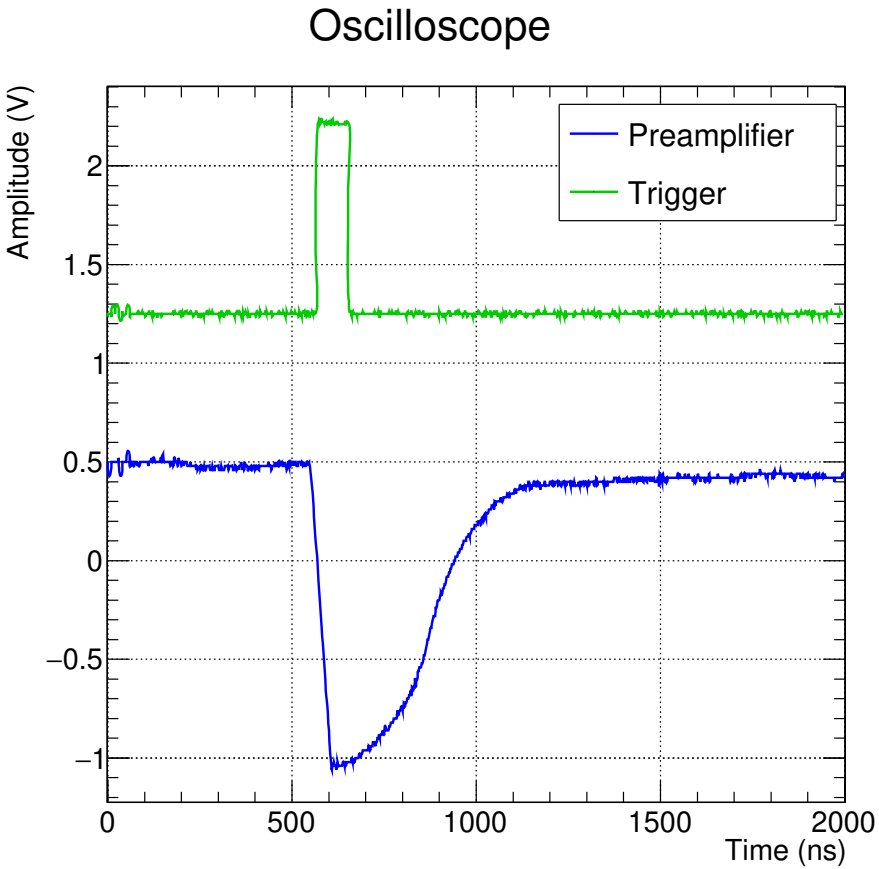
Event Selection: Shaping Time

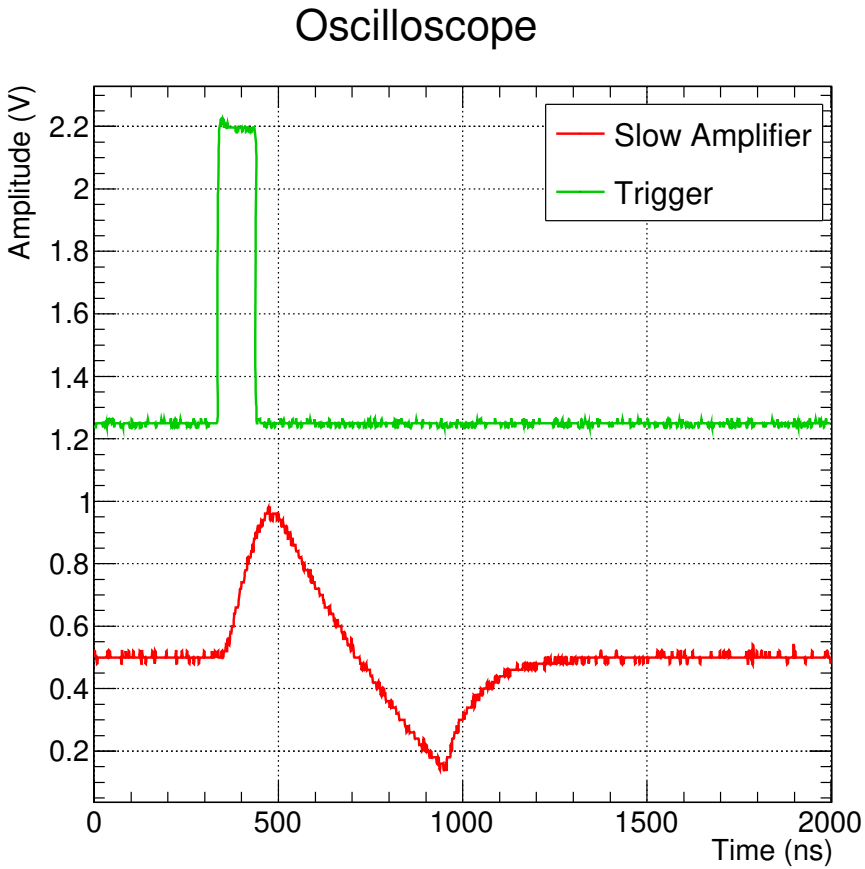
- ^{22}**Na** energy spectra for all the possible A5202 shaping times acquired with **LYSO** (SiPM 6x6 mm^2).



Event Selection: Oscilloscope

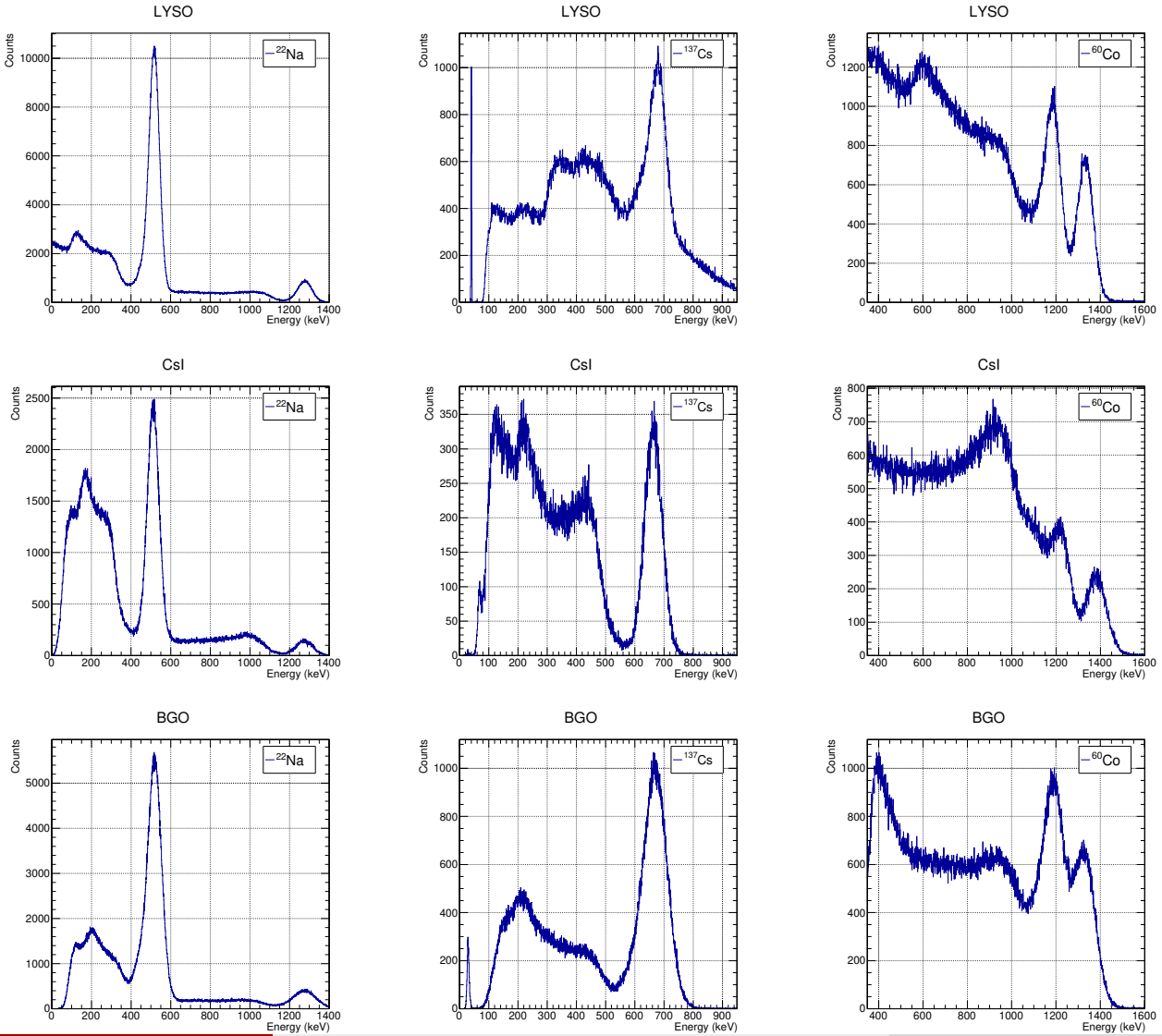
Analog and digital probes are available on the A5202 board to check that the event selection is correctly done.





Results

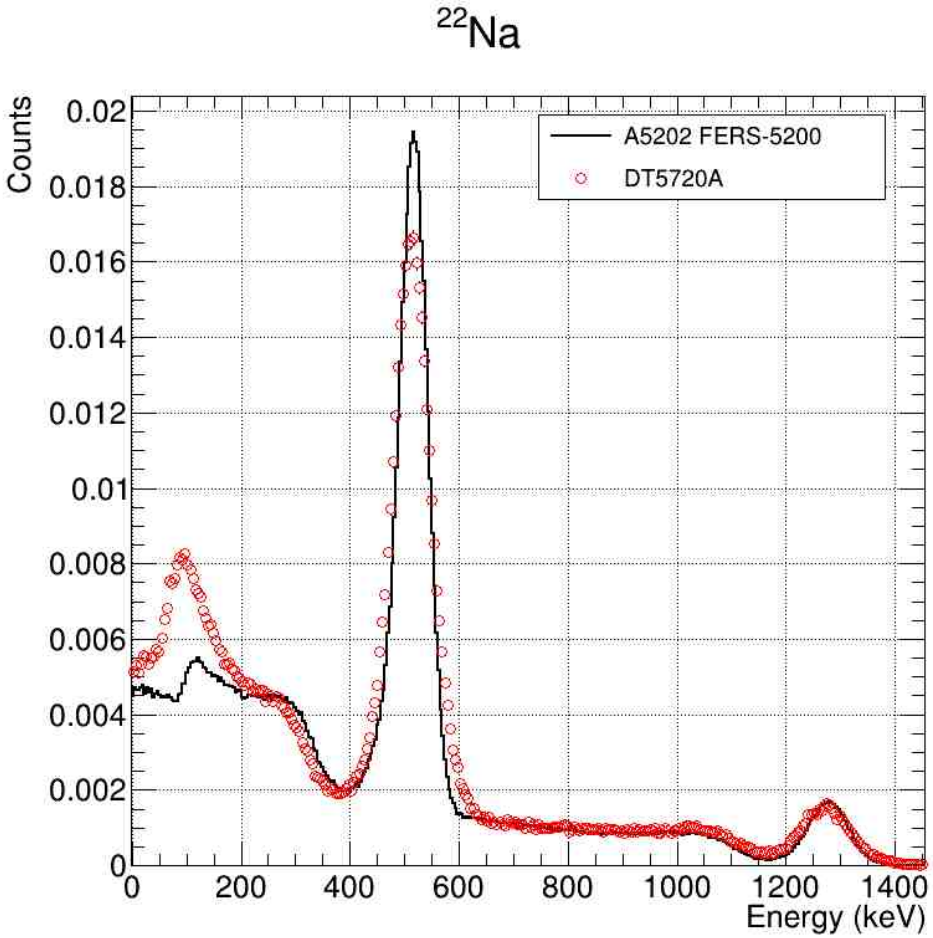
SiPM: 6x6 mm^2. **Crystals**: LYSO, CsI, BGO. **Sources**: ^{22}Na, ^{137}Cs, ^{60}Co



Control System

We took the same measurements with the DT5720A digitizer and with the same scintillators.

- digitizer method: charge integration



Results

Resolutions obtained so far

sources:

- ^{22}Na
- ^{137}Cs
- ^{60}Co

crystals:

- LYSO
- CsI
- BGO

	^{22}Na (511 KeV)	^{137}Cs (662 KeV)	^{60}Co (1172 KeV)	^{60}Co (1332 KeV)
A5202+LYSO	$(9.5 \pm 0.1)\%$	$(9.3 \pm 0.1)\%$	$(5.8 \pm 0.1)\%$	$(5.0 \pm 0.1)\%$
DT5720A+LYSO	$(12.3 \pm 0.1)\%$	$(10.3 \pm 0.1)\%$	$(6.3 \pm 0.4)\%$	$(5.4 \pm 0.2)\%$
A5202+CsI(Tl)	$(11.9 \pm 0.1)\%$	$(10.9 \pm 0.1)\%$	$(5.8 \pm 0.2)\%$	$(5.6 \pm 0.1)\%$
DT5720A+CsI(Tl)	$(9.6 \pm 0.1)\%$	$(8.9 \pm 0.1)\ \%$	$(5.6 \pm 0.2)\%$	$(5.4 \pm 0.1)\%$
A5202+BGO	$(14.4 \pm 0.1)\%$	$(13.5 \pm 0.1)\%$	$(8.7 \pm 0.1)\%$	$(7.1 \pm 0.1)\%$
DT5720A+BGO	$(12.0 \pm 0.1)\%$	$(11.0 \pm 0.1)\%$	$(7.7 \pm 0.3)\%$	$(6.8 \pm 0.4)\%$

Conclusion and Future Work

- We were able to obtain **reliable energy spectra** with the ASIC based Citiroc-1A, even with a shaping time as small as **87.5 ns**

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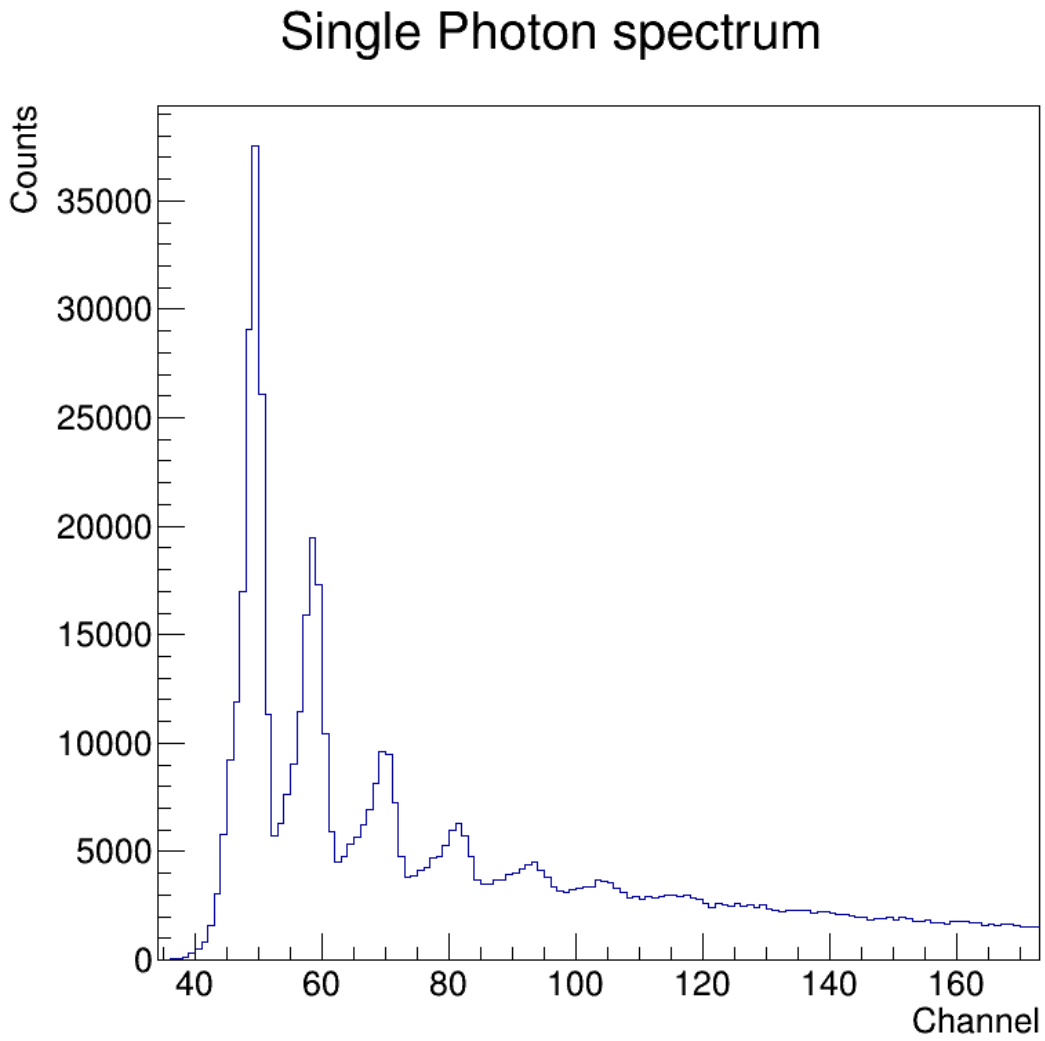
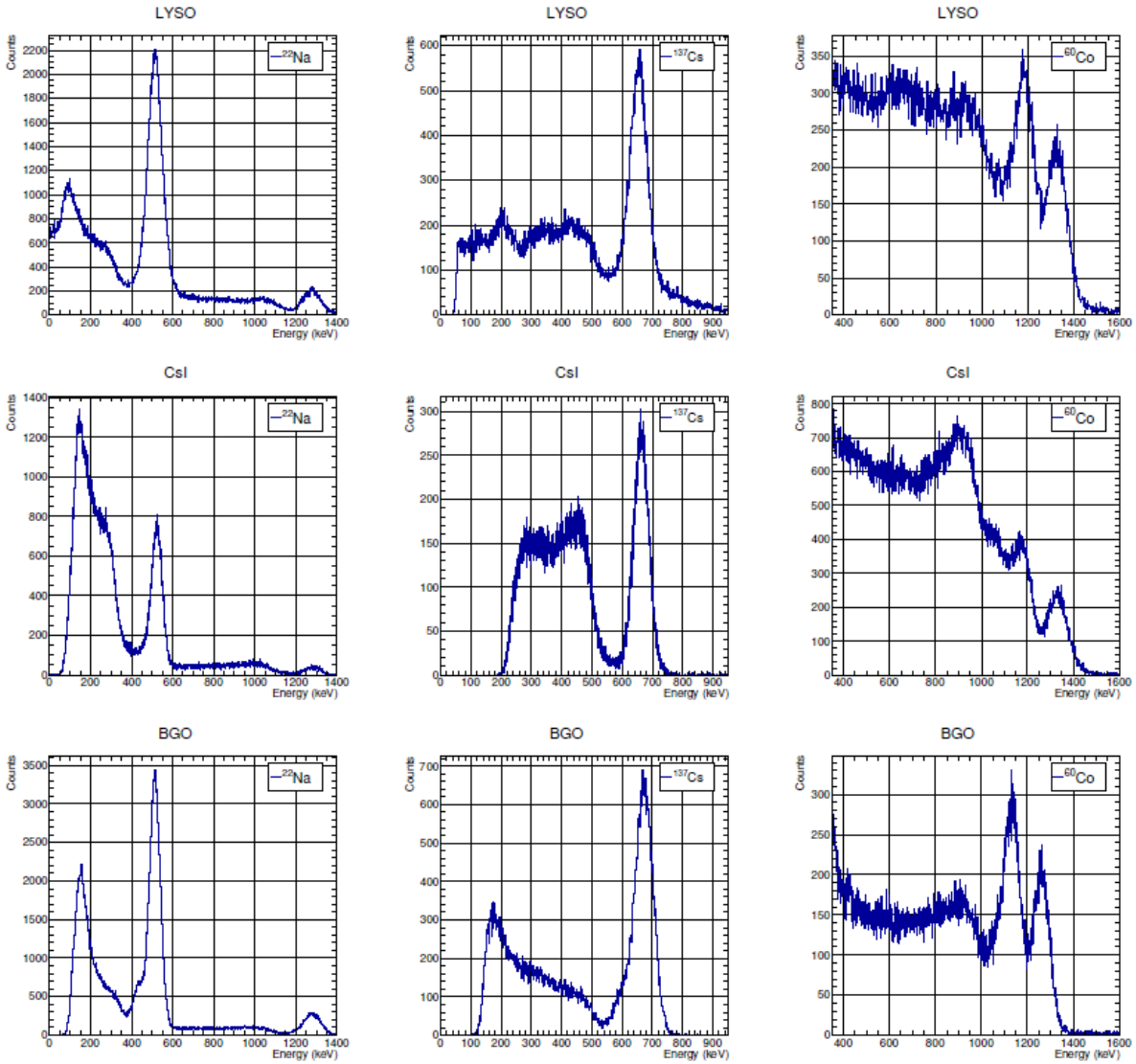
- The results obtained with the A5202 are all **comparable** with the ones obtained with the DT5720A. Furthermore, in the case of LYSO the resolution are considerably better with the A5202.
- We have found that the **dimensions** of the SiPM active area directly determines whether the system is able or not to perform **energy resolution measurements** and to build the energy spectra
- We plan on taking measurements even with **faster scintillators** like Lathanum Bromine and to perform **timing resolution measurements**.

Back-Up


Single Photon spectrum
Counts
35000
30000
25000
20000
15000
10000
5000
0
40
60
80
100
120
140
160
Channel

Back-Up- DT5720A spectra



Back-up: SiPM Matrix

Structure

Parameter	Symbol	S13361-3050NE-04	S13361-3050AE-04	S13361-3050NE-08	S13361-3050AE-08	Unit
Number of channels	-	16 (4 × 4)		64 (8 × 8)		-
Effective photosensitive area/channel	-	3 × 3				mm
Pixel pitch	-	50				μm
Number of pixels/channel	-	3584				-
Fill factor	-	74				%
Package type	-	Surface mount	With connector*1	Surface mount	With connector*1	-
Window	-	Epoxy resin				-
Refractive index of window material	-	1.55				-

Parameter		Symbol	Value	Unit
Spectral response range		λ	320 to 900	nm
Peak sensitivity wavelength		λp	450	nm
Photon detection efficiency (λ=λp)*4		PDE	40	%
Dark count*5	Typ.	CD	0.5	Mcps
	Max.		1.5	
Terminal capacitance		Ct	320	pF
Gain		M	1.7×10^6	-
Breakdown voltage		VBR	53 ± 5	V
Recommended operating voltage		Vop	VBR + 3	V
Vop variation between channels in one product	Typ.	-	0.1	V
	Max.		0.3	
Temperature coefficient of recommended operating voltage		ΔTVop	54	mV/°C

Back-up: Single SiPM

Selection guide

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

Back-up: Single SiPM

Electrical and optical characteristics (Typ. Ta=25 °C, unless otherwise noted)

Type no.	Measure-ment conditions	Spectral response range λ (nm)	Peak sensitivity wavelength λp (nm)	Photon detection efficiency PDE*4 λ=λp (%)	Dark count*5 Typ. (kcps)	Dark count*5 Max. (kcps)	Terminal capaci-tance Ct (pF)	Gain M	Break-down voltage VBR (V)	Crosstalk probability (%)	Recom-mended operating voltage Vop (V)	Tem-perature coefficient at recom-mended operating voltage ΔTVop (mV/°C)
S13360-1325CS	Vover =5 V	270 to 900	450	25	70	210	60	7.0 × 10^5	53 ± 5	1	VBR + 5	54
S13360-1325PE		320 to 900										
S13360-3025CS		270 to 900			400	1200	320					
S13360-3025PE		320 to 900										
S13360-6025CS		270 to 900			1600	5000	1280					
S13360-6025PE		320 to 900										
S13360-1350CS	Vover =3 V	270 to 900		40	90	270	60	1.7 × 10^6		3	VBR + 3	
S13360-1350PE		320 to 900										
S13360-3050CS		270 to 900			500	1500	320					
S13360-3050PE		320 to 900										
S13360-6050CS		270 to 900			2000	6000	1280					
S13360-6050PE		320 to 900										
S13360-1375CS	Vover =3 V	270 to 900		50	90	270	60	4.0 × 10^6		7	VBR + 3	
S13360-1375PE		320 to 900										
S13360-3075CS		270 to 900			500	1500	320					
S13360-3075PE		320 to 900										
S13360-6075CS		270 to 900			2000	6000	1280					
S13360-6075PE		320 to 900										

*4: Photon detection efficiency does not include crosstalk or afterpulses.
*5: Threshold=0.5 p.e.
Note: The above characteristics were measured at the operating voltage that yields the listed gain. (See the data attached to each product.)