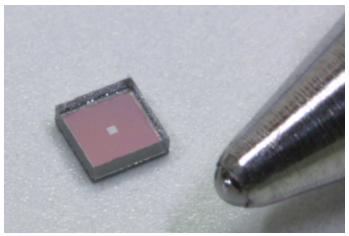
SiPM readout

R. Santoro

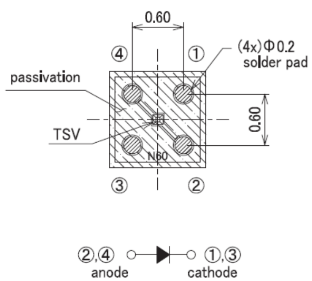
Università degli Studi dell'Insubria (COMO) and INFN (Milano)

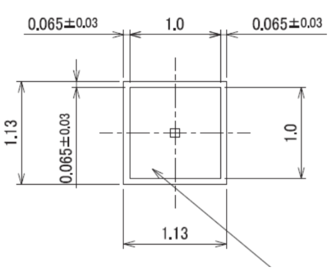
The SiPM used in the previous test beams

The sensors used were 25 μm cell pitch (S13615-1025)



Parameters	S13615		Unit
	-1025	-1050	
Effective photosensitive area	1.0x1.0		mm^2
Pixel pitch	25	50	μm
Number of pixels / channel	1584	396	-
Geometrical fill factor	47	74	%

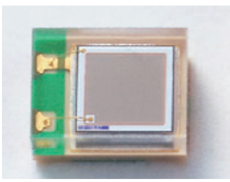




Parameters		Symbol	S13615		Unit
			-1025	-1050	
Spectral response range		λ	320 to 900		nm
Peak sensitivity wavelength		λp	450		nm
Photon detection efficiency at λp*3		PDE	25	40	%
Breakdown voltage		V_{BR}	53 ±5		V
Recommended operating voltage*4		V_{op}	V_{BR} + 5	V_{BR} + 3	V
Dark Count	Typ.	-	50		kcps
	Max.		150		
Crosstalk probability	Typ.	-	1	3	%
Terminal capacitance		Ct	40		pF
Gain*5		M	7.0×10^5	1.7×10^6	-

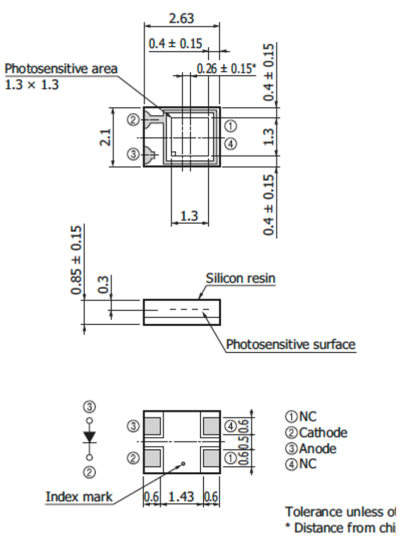
New SiPMs under test

- Unfortunately Hamamtsu confirmed that this sensor is not available with a compact package. The actual doesn't fit the available space.
- Massimo already started to contact and to discuss this with other producers (i.e. ketek)



New sensors: S14160-1310PS / S14160-1315PS

Parameter	Symbol	S14160 -1310PS	S14160 -3010PS	S14160 -1315PS	S14160 -3015PS	Unit
Effective photosensitive area	-	1.3 × 1.3	3 × 3	1.3 × 1.3	3 × 3	mm
Pixel pitch	-	10		15		μm
Number of pixels	-	16675	90000	7296	40000	-
Geometrical fill factor	-	31		49		%
Package	-	Surface mount type				-
Window	-	Silicone resin				-
Window refractive index	-	1.57				-

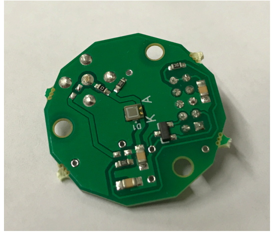


Parameter		Symbol	S14160 -1310PS	S14160 -3010PS	S14160 -1315PS	S14160 -3015PS	Unit
Spectral response range		λ	290 to 900				nm
Peak sensitivity wavelength		λp	460				nm
Photon detection efficiency at λp*2		PDE	18		32		%
Breakdown voltage*3		VBR	38±3				V
Recommended operating voltage*3		Vop	Vbr + 5		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	1.8×10^5		3.6×10^5		-
Temperature coefficient of Vop		ΔTVop	34				mV/°C

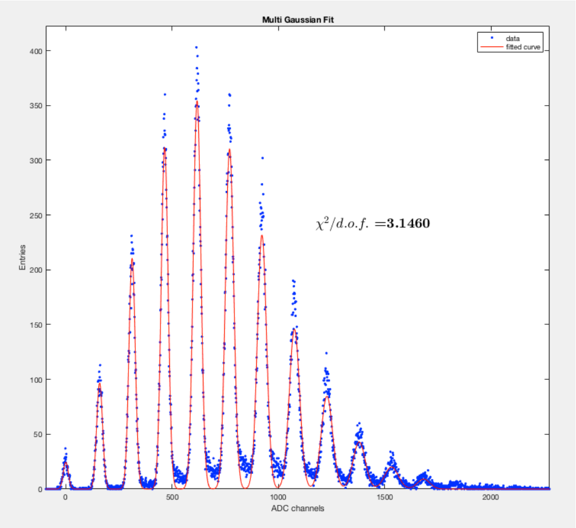
*2: Photon detection efficiency does not include crosstalk and afterpulses.
*3: Refer to the data attached for each product.
*4: Threshold=0.5 p.e.

A first look at the SiPMs

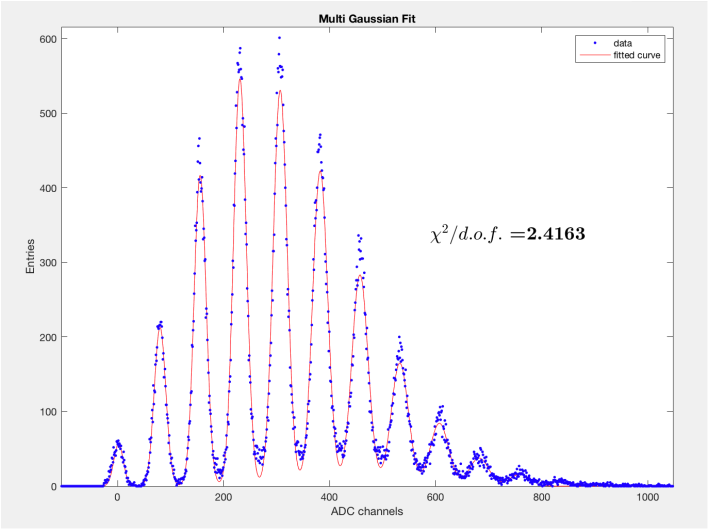
We tested the new SiPMs using our standard equipment (SP5600 and DT5720A from Caen) together with an automatic software tool developed to characterize SiPMs (JINST 10, C08008)



Sensor: S14160-1315PS
Cell size $=15\mu m$
Vbias = 42 (≈ 4 V over breakdown)
Signal amplification: 40dB
Measured Xtalk = 2%



Sensor: S14160-1310PS
Cell size $=10\mu m$
Vbias = 42.5 (≈ 4.5 V over breakdown)
Signal amplification: 40dB
Measured Xtalk = 1.8%



The evaluation boards

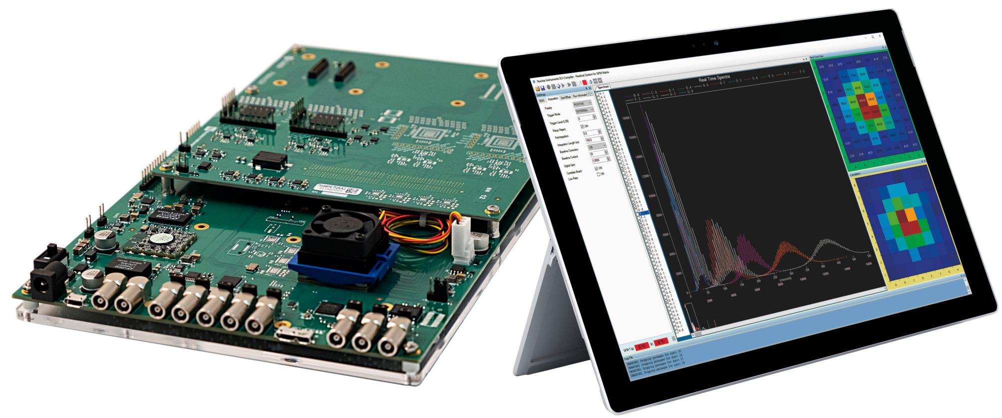
The qualification:

- Check the multiphoton with available SiPMs to assess the single photon capability (smaller pitch means larger dynRange but also smaller signal for ph-e)
- Measure the full dynamic range using both amplification branches
- Measure the front-end linearity

CAEN
Tools for Discovery

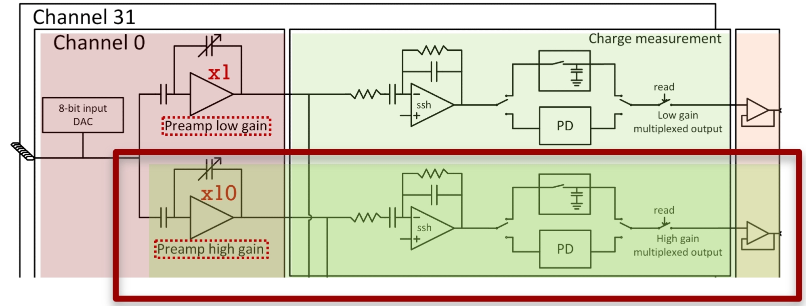
A1702 / DT5702

DT5550W

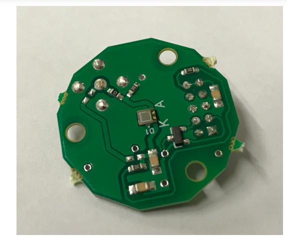


DT5702

- Even if with temporary connections, we can assess the multi-photon also with a15mu pitch sensor
- The reason why we don't see the multiphoton using the 10mu pitch is under investigation (i.e. connections, gain, bit granularity …)

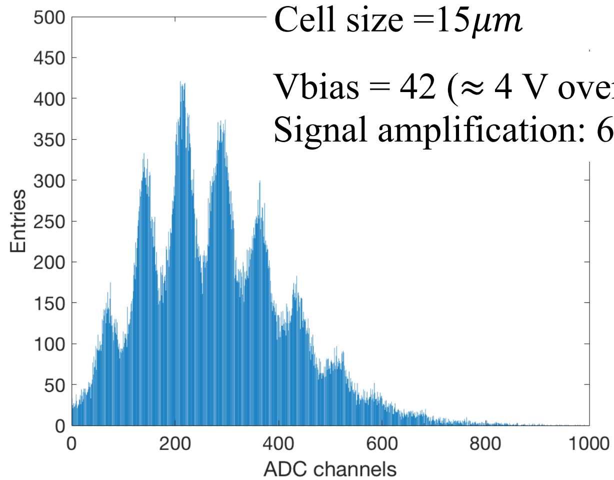


High Gain branch
Track and hold



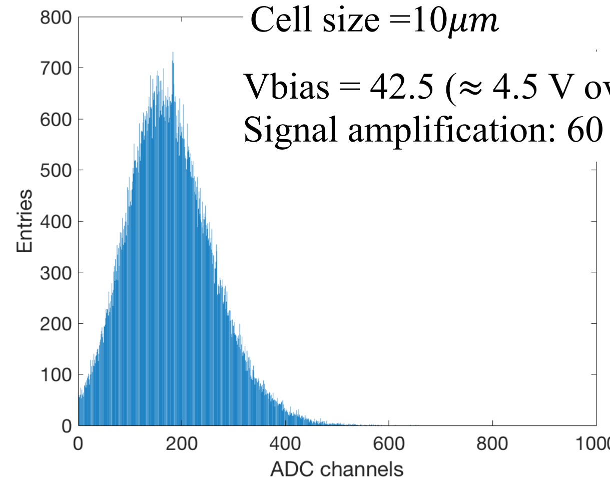
Sensor: S14160-1315PS
Cell size $=15\mu m$

Vbias = 42 (≈ 4 V over breakdown)
Signal amplification: 60 a.u.



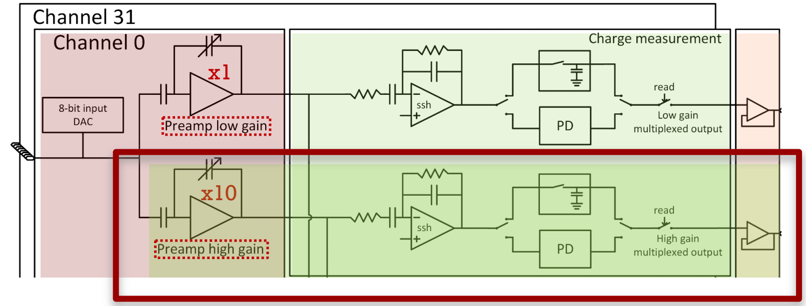
Sensor: S14160-1310PS
Cell size $=10\mu m$

Vbias = 42.5 (≈ 4.5 V over breakdown)
Signal amplification: 60 a.u.

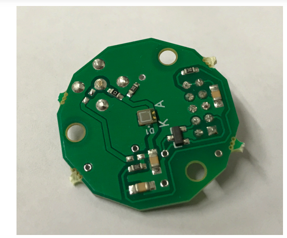


DT5550W

- Using the Peak finder technique we clearly have better results and we start having the multiphoton also with the 10 μm pitch
- The reason why we had to change the evaluation board is because none of them have properly implemented both techniques to measure the charge

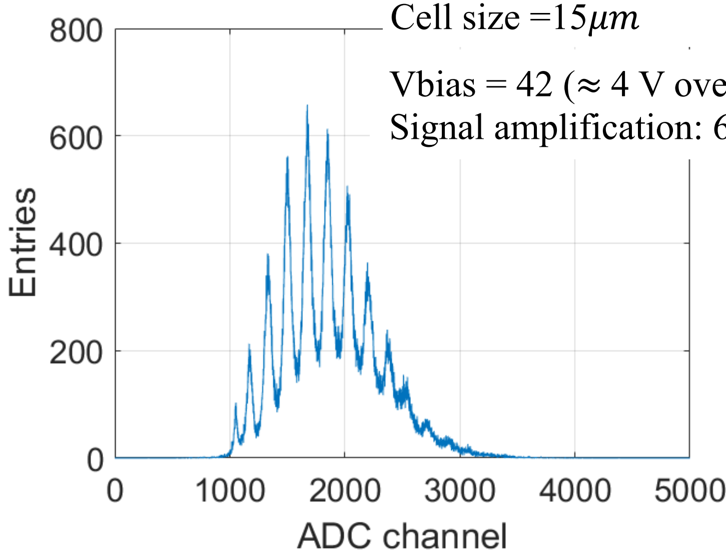


High Gain branch
Peak detector



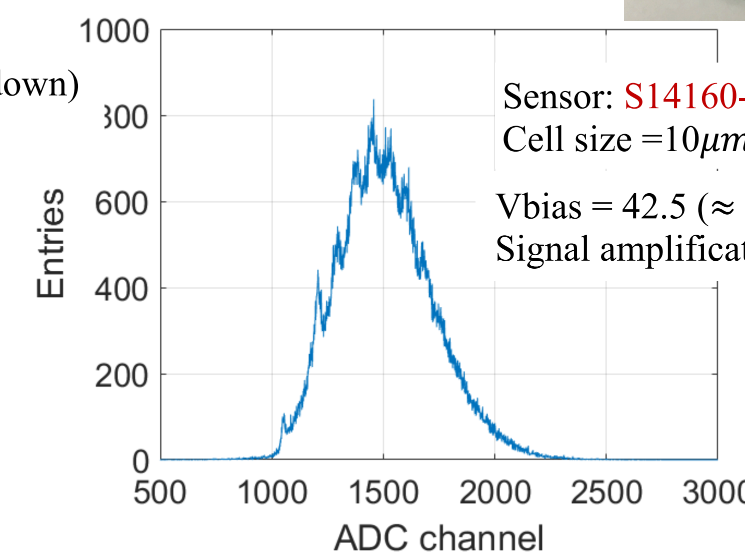
Sensor: S14160-1315PS
Cell size =15μm

Vbias = 42 (≈ 4 V over breakdown)
Signal amplification: 60 a.u.

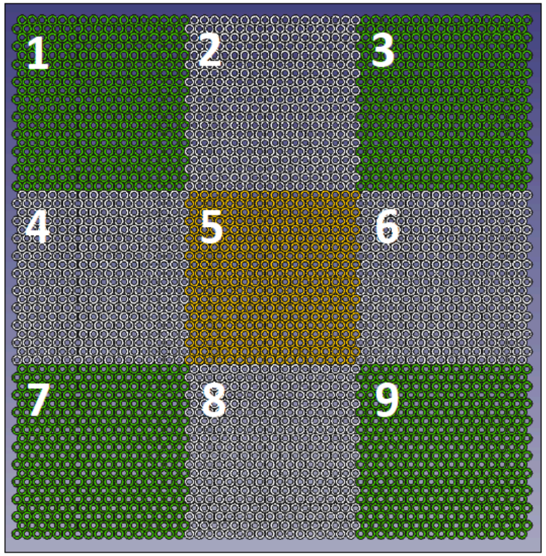


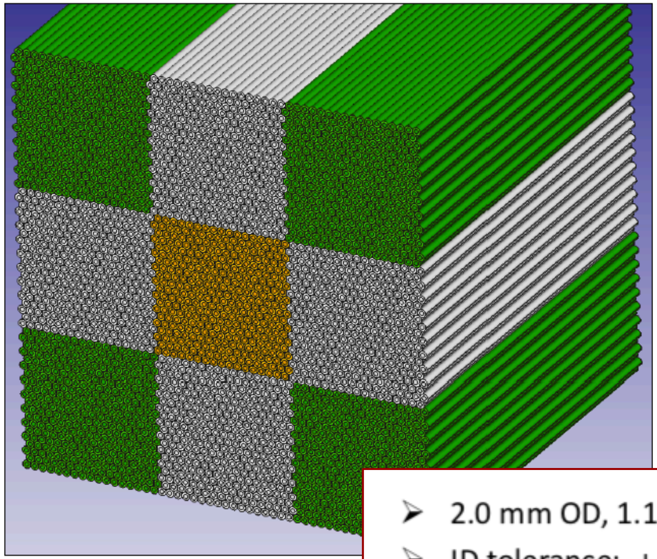
Sensor: S14160-1310PS
Cell size =10μm

Vbias = 42.5 (≈ 4.5 V over-V)
Signal amplification: 60 a.u.



Test beam 2020



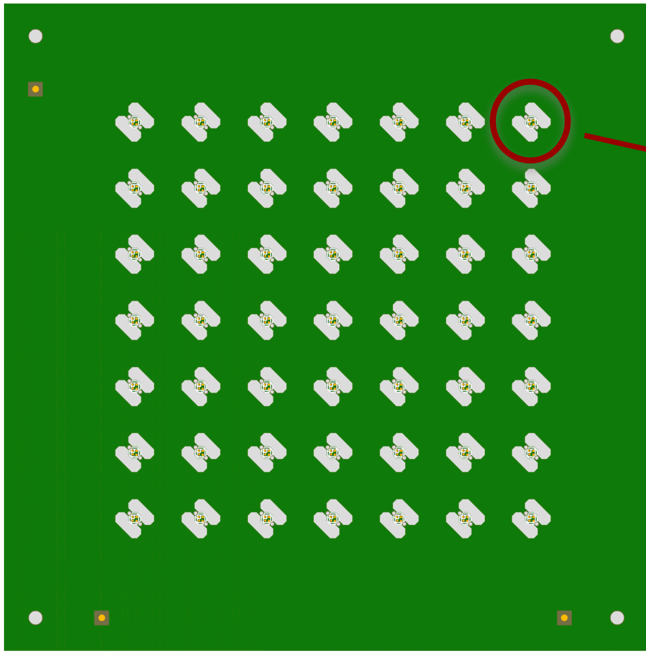


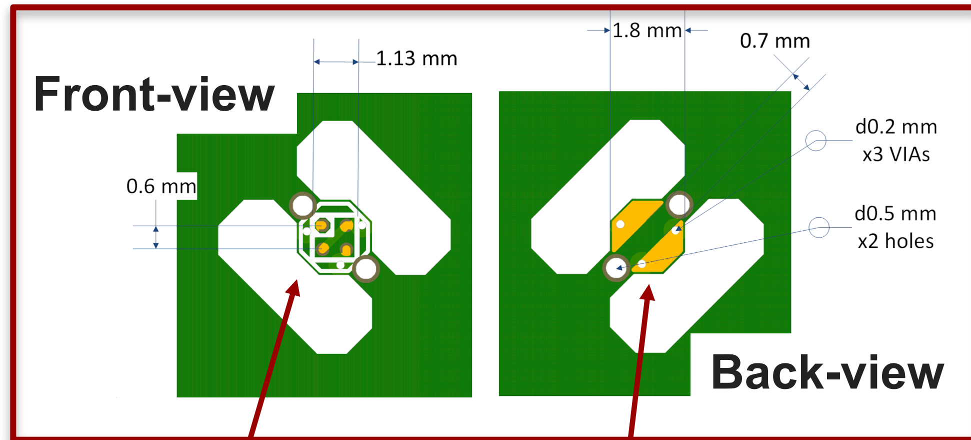
- 2.0 mm OD, 1.1 mm ID and 1000 mm Length
- ID tolerance: + 0.1 mm and - 0.0 mm
- Material: CuZn37, 170 VPN Hardness

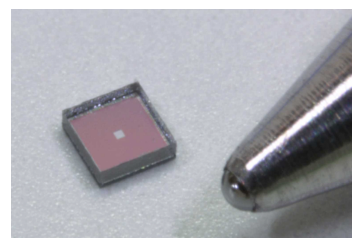
The prototype for the test beam

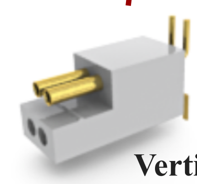
- 9 modules 16 x 20 tubes (2mm outer diameter) = 320 tubes
- 8 modules readout with PMTS
- The central module equipped with SiPMs
  - 320 SiPMs to be readout
  - 5 FERS board + 1 Data collector

A possible strategy for the assembly





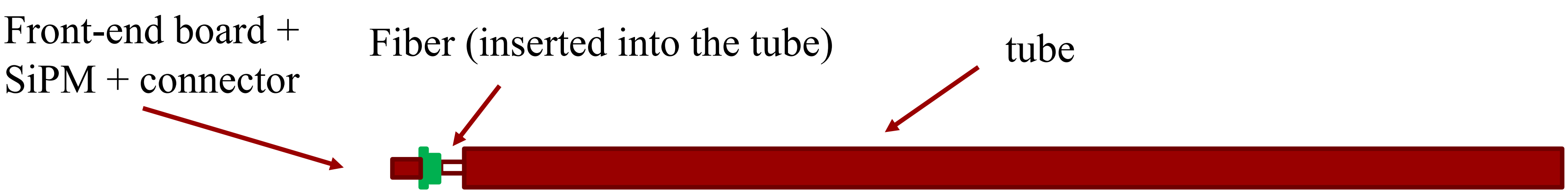




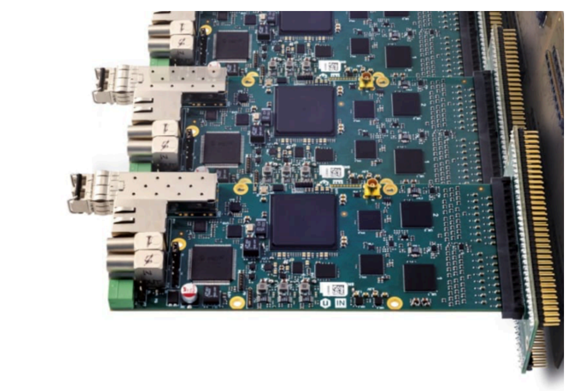
Vertical SMD connector
A79602-001 PZN-04-VV

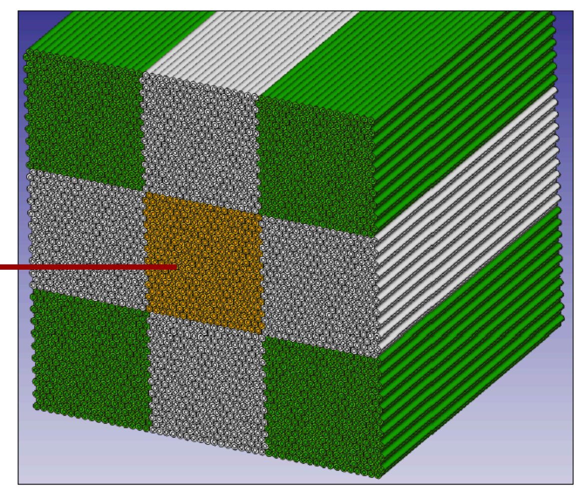
- We start with an array of small front-end boards (1.8 x 1.8 mm^2 each) designed to host 1 SiPM and a connector on the back side
- The array is firstly populated with all the components and then each front-end board will be removed from the array and it will be qualified before the next step of the assembly

A possible strategy for the assembly



- The front-end board + SiPM will be glued to the tip of the fiber
- Both the functionality and optical coupling for the basic unit will be qualified
- Once all tubes, equipped with the SiPMs, will be qualified the module assembly starts





A possible strategy for the assembly

At this stage it is just an idea, it is very preliminary and all the details has to be carefully verified but, if feasible, it has a lot of advantages

- The design of the front-end board is easy and cheap: it doesn't require any complex routing in the pcb board
- The individual SiPM can be qualified at each step of the assembly procedure
- We can guarantee a good contact between SiPMs and fibers: each individual tube can be qualified before the final assembly
- The tube assembly can be easily distribute among institutes (a must if we really want to go for larger and larger prototypes)
- In principle, the tubes are immune from cross-talk: we can also imagine glob top encapsulation on the back
- Once the tubes are qualified, they will be collected into specialized centers for the final assembly and qualification
  - the prototype module will have on the back a series of connectors and wires to be plugged into the FERS