front-end electronics for the mini Beam-Beam detector.

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MEX

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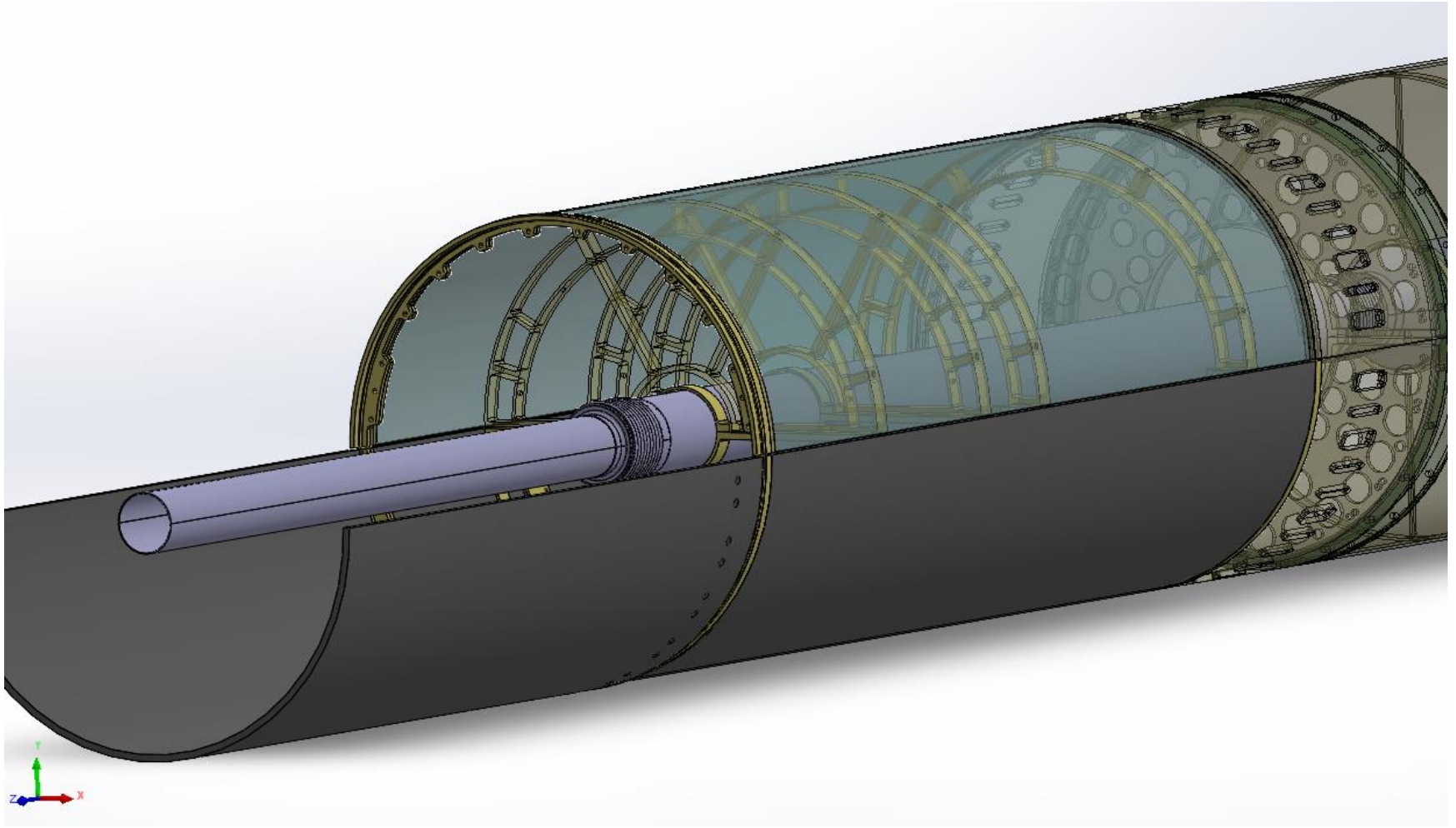
Background

Proposed as a detector to provide a wake-up trigger signal for events ranging from low to high multiplicities, for the TOF of the MPD-NICA.

- Presented during NICA Days 2019:
  - “Mini Beam-Beam monitoring: a wake-up trigger detector for the TOF of MPD”.
- Detector Advisory Committee Meeting (*October 19, 2020*):
  - “MiniBeBe Conceptual Design” (CDR).
- “The conceptual design of miniBeBe detector proposed for NICA-MPD”, R. Acevedo Kado et al **2021**, JINST 16 P02002. *https://doi.org/10.1088/1748-0221/16/02/P02002*

MiniBeBe location with respect to beam pipe



Characteristics

- Original design
- Required time resolution of 30 ps
- Stripe of sensors
- 16 sensor stripes
- 20 cells per stripe, made of:
  - BC404 Scintillator of 20x20x3 mm^3
  - 4- 6x6 mm^2 SiPMs

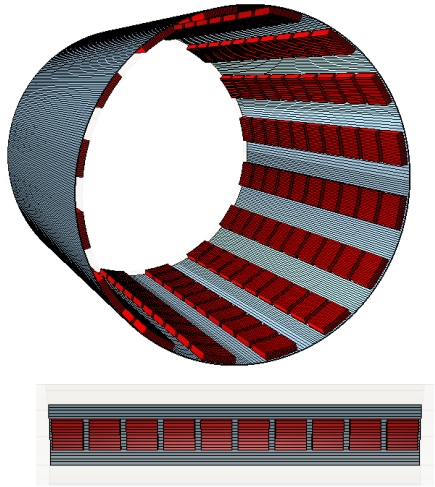


Figure1: Schematics of MBB detector

$$\sigma_{total} = \sqrt{\sigma^2_{miniBeBe} + \sigma^2_{TOF}} \leq 100\ ps$$

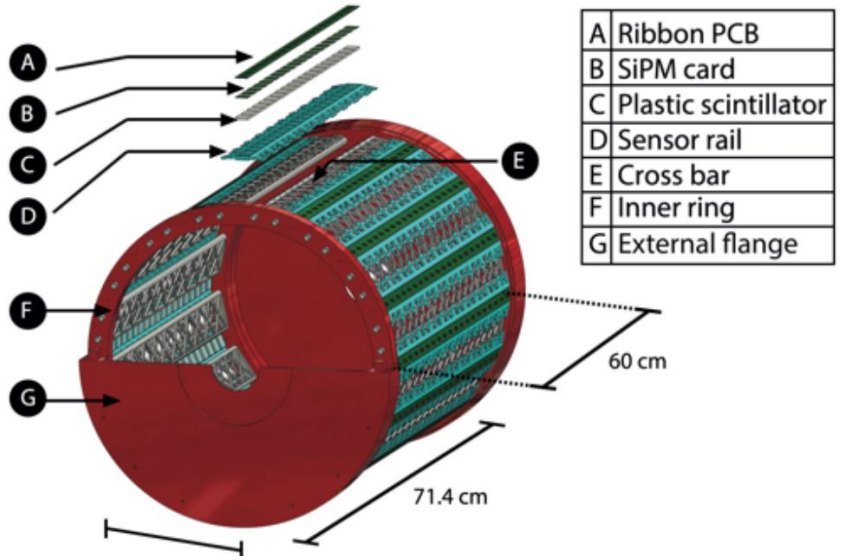
$$\sigma_{miniBeBe} \leq 30\ ps$$

Conceptual design

- Baseline design

(*JINST 16 (2021) P02002*)

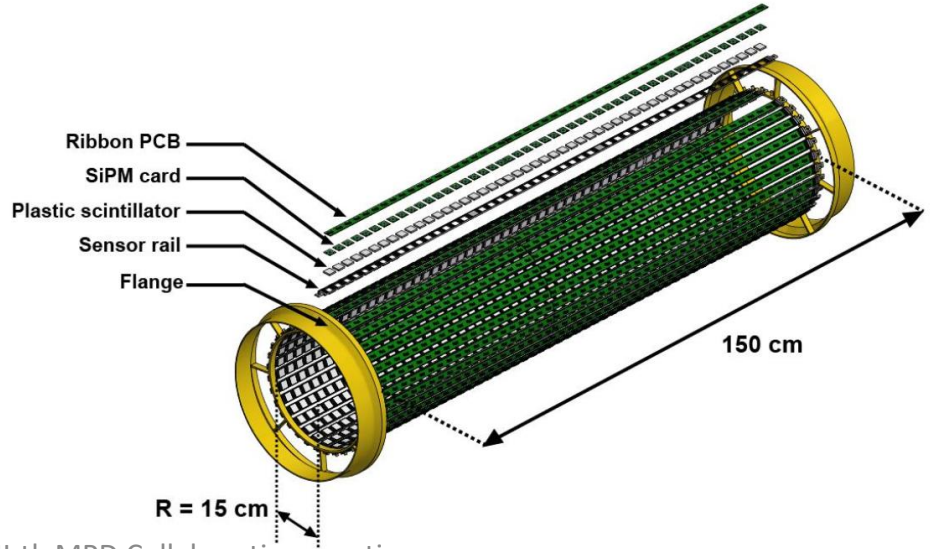
  - 60 cm – Length
  - 26 cm – Radius
  - 20 cells per strip
  - 320 Cells



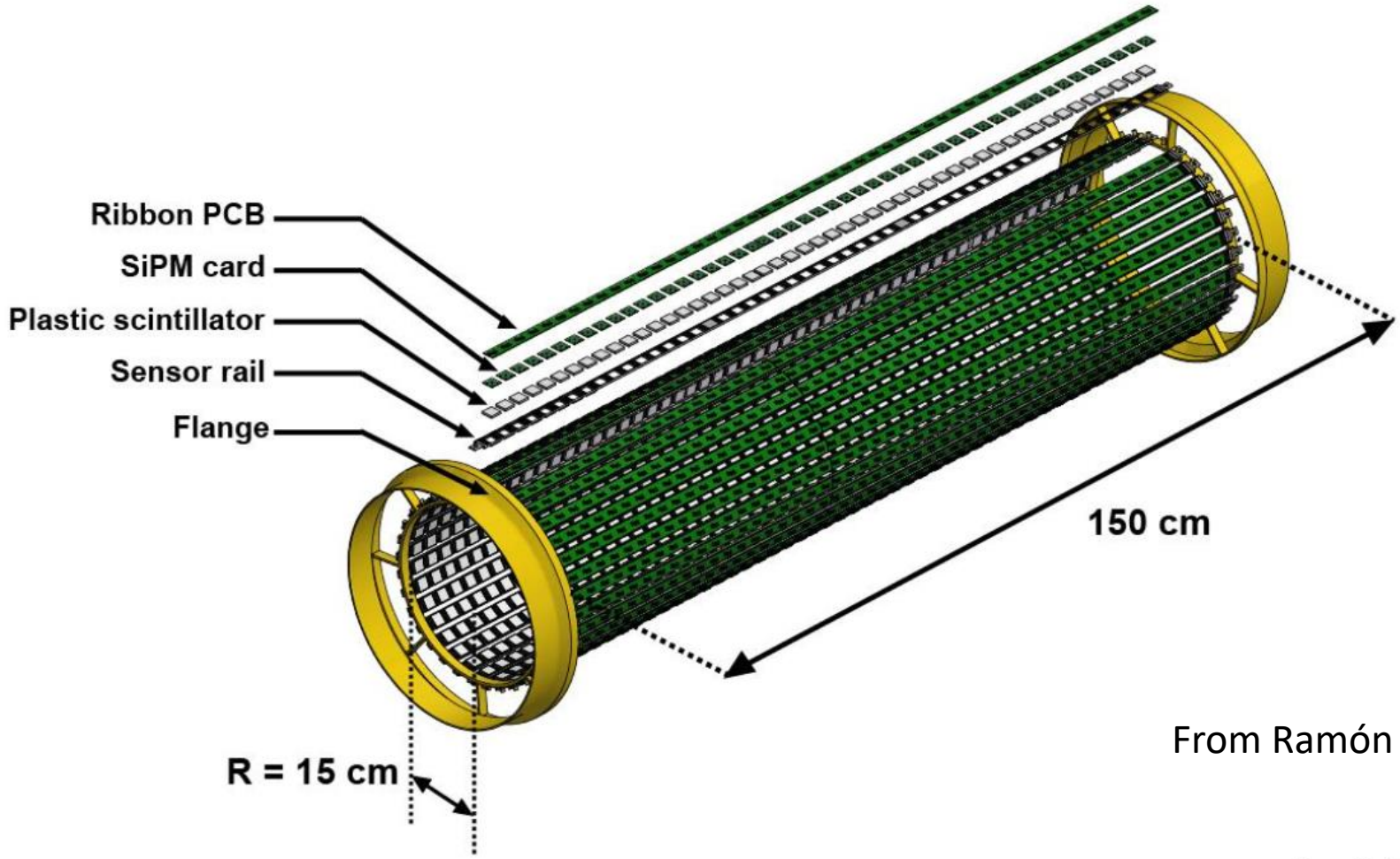
A	Ribbon PCB
B	SiPM card
C	Plastic scintillator
D	Sensor rail
E	Cross bar
F	Inner ring
G	External flange

- Improved design

  - 150 cm – Length
  - 15 cm – Radius
  - 48 Cells per strip
  - 1536 Cells



MiniBeBe initial design

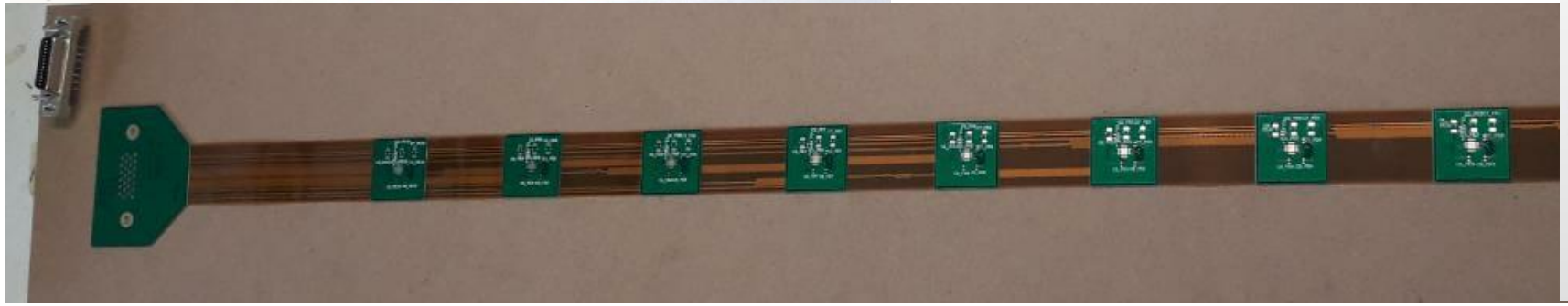


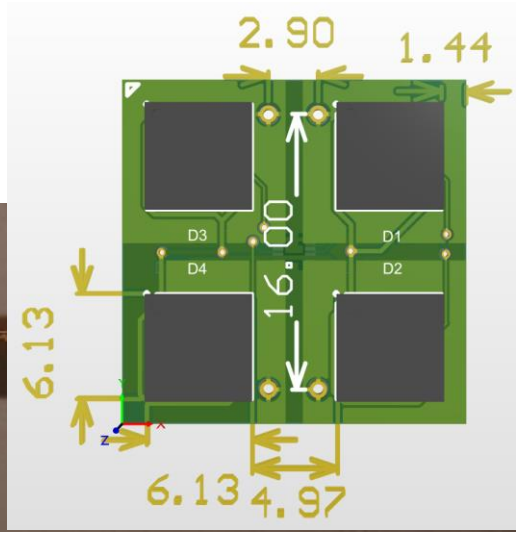
- 32 strips
- 48 cells/strip

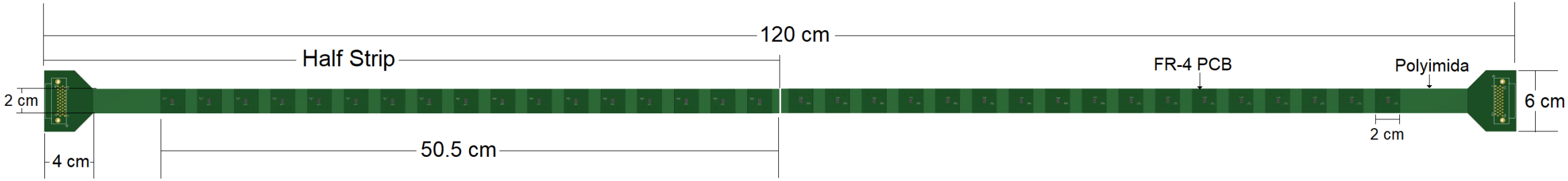
From Ramón Acevedo's presentation

L=150 cm , R=15 cm

MiniBeBe baseline



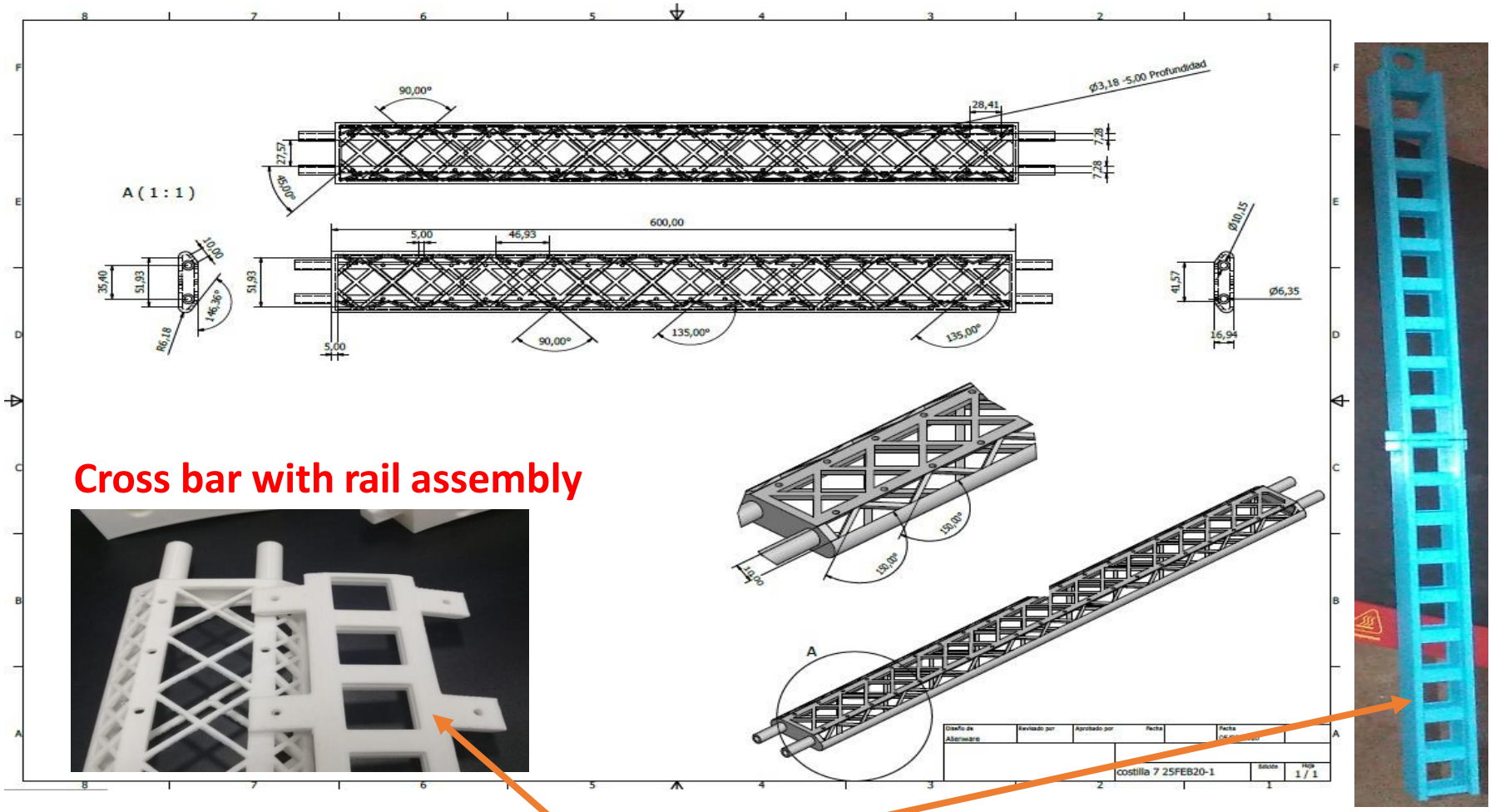




Cross Bar

Characteristics:

1. Transverse stiffness for the assembly of rails, rings and flanges.
2. Lightweight structure.
3. In finite element analysis does not show deformation along the 60cm.

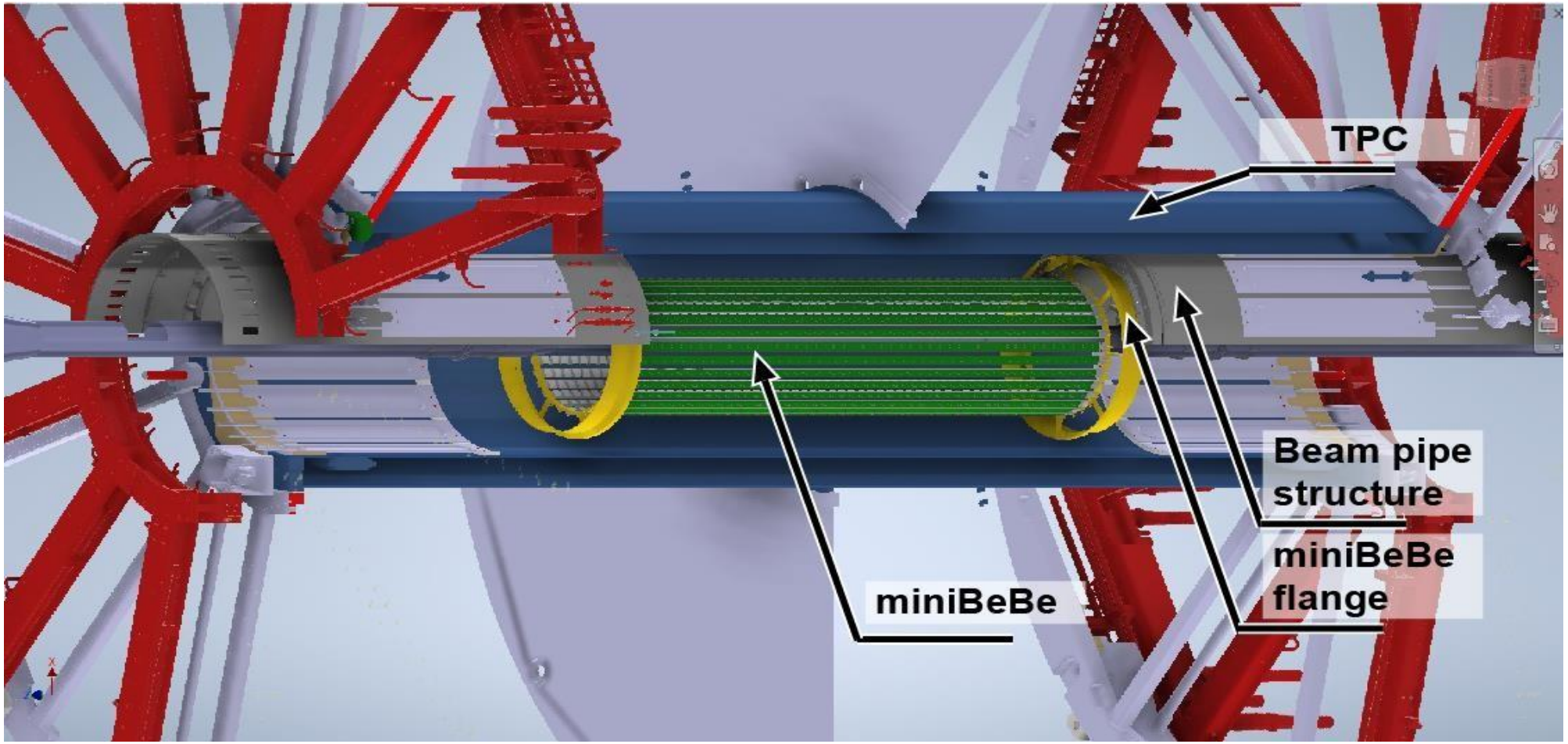


Cross bar with rail assembly

3D print

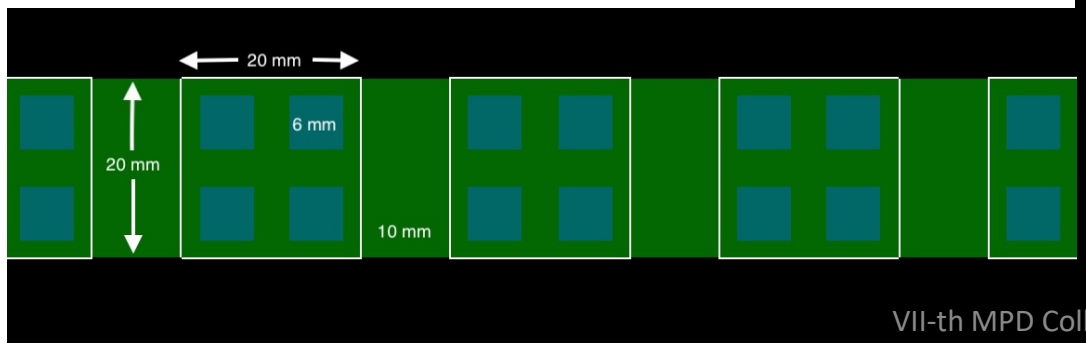
Sensor rail

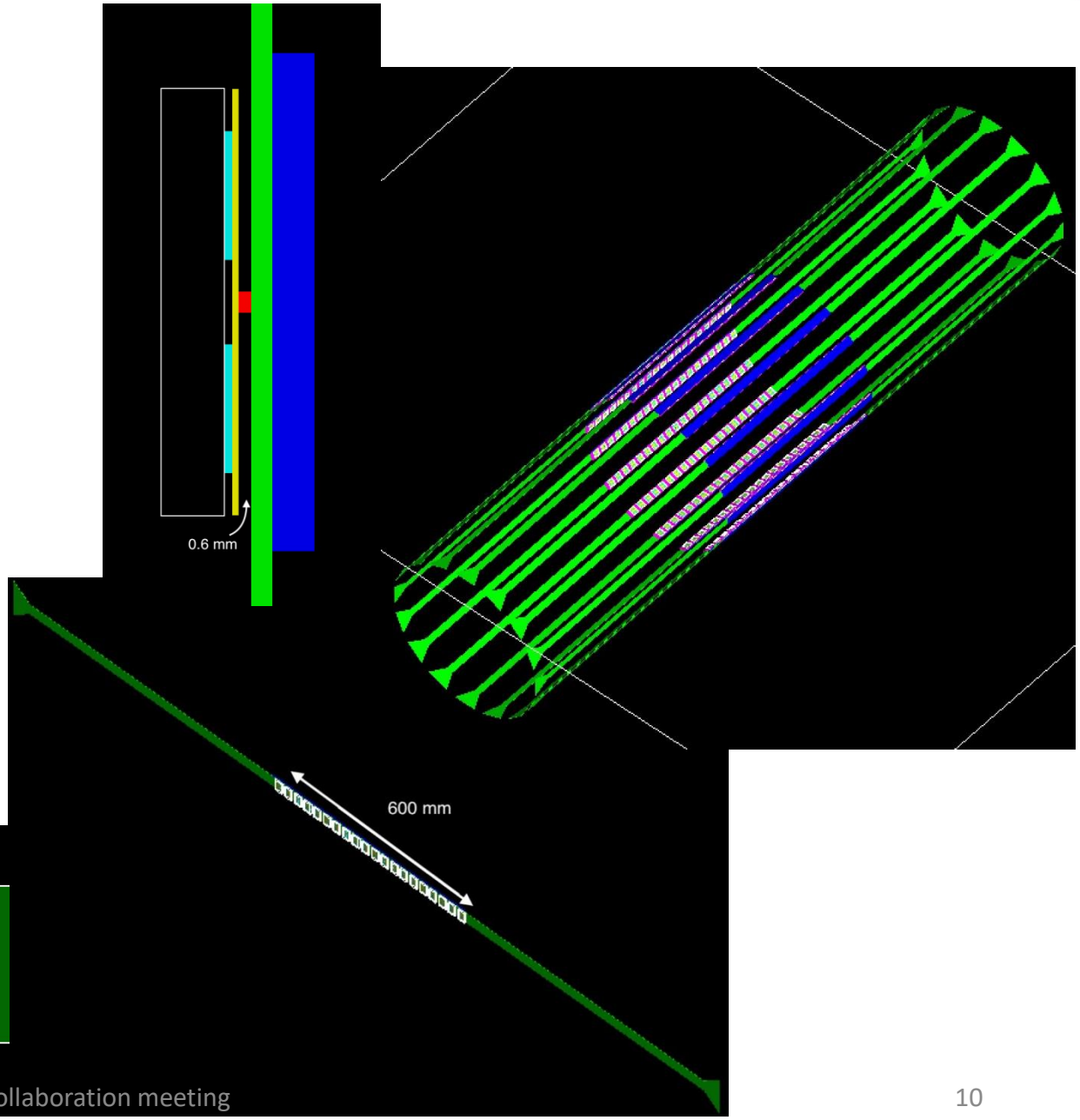
MiniBeBe @MPD



Geant4 simulations

- Baseline MiniBeBe.
  - MBB-60-25 16 strips.
  - 20 Cell per Strip
  - 320 total Cells.
  - Material: PLA
- Modelling of real mechanics and electronics.



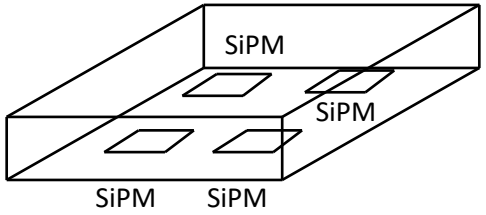


Time resolution

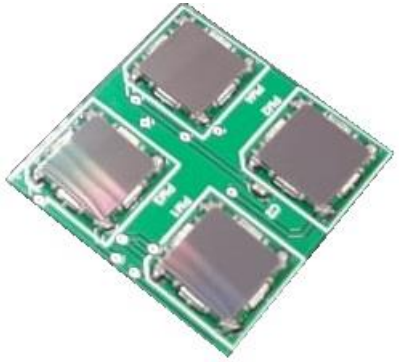
- **Result:**
- Time resolution ≈ 200 ps with *Standard signal.*
- 300 ps with *fast signal.*
- With CAEN digitizer (poor time resolution).
- Also with oscilloscope of 40 GSps (better time resolution)

Change in cell design

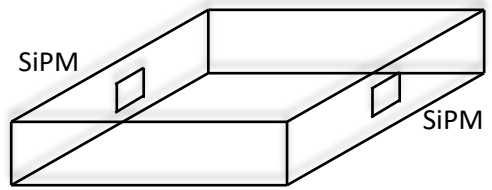
EJ232 Plastic scintillator



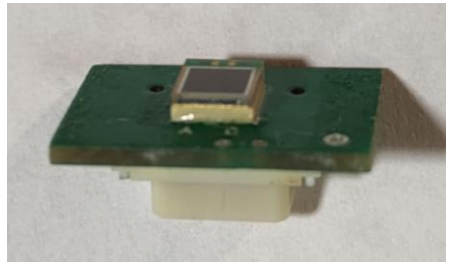
6x6 mm^2 SiPM



First design



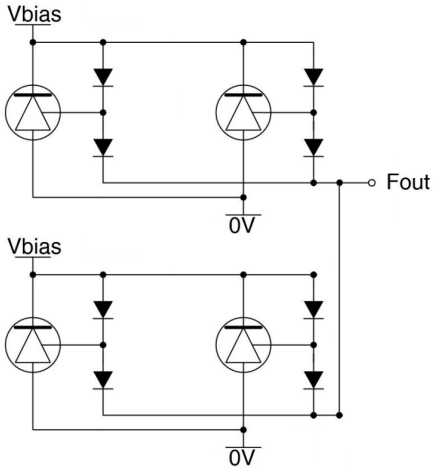
3x3 mm^2 SiPM

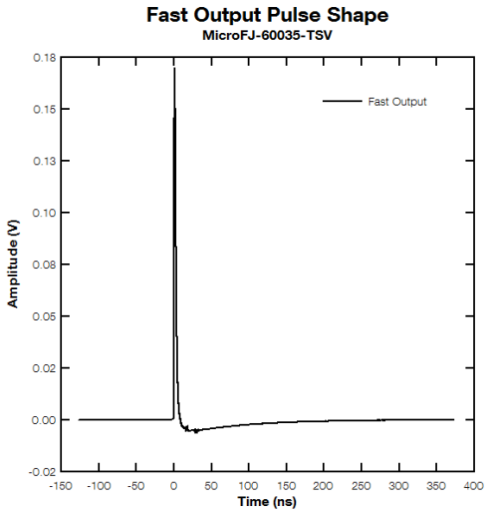


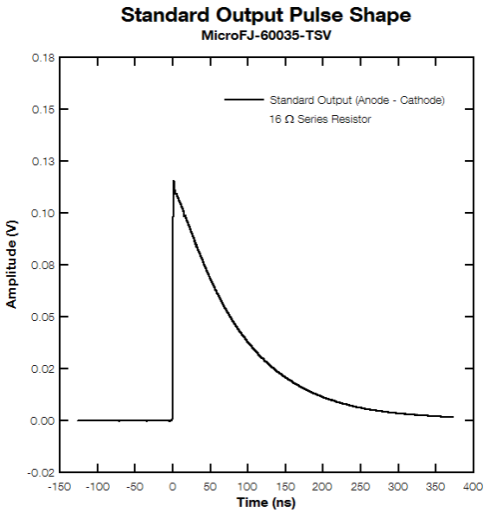
Current design

SiPM selection

- SensL SiPMs:
  - MicrofC – 6x6 mm^2
  - MicrofJ – 6x6 mm^2
  - MicrofJ – 3x3 mm^2





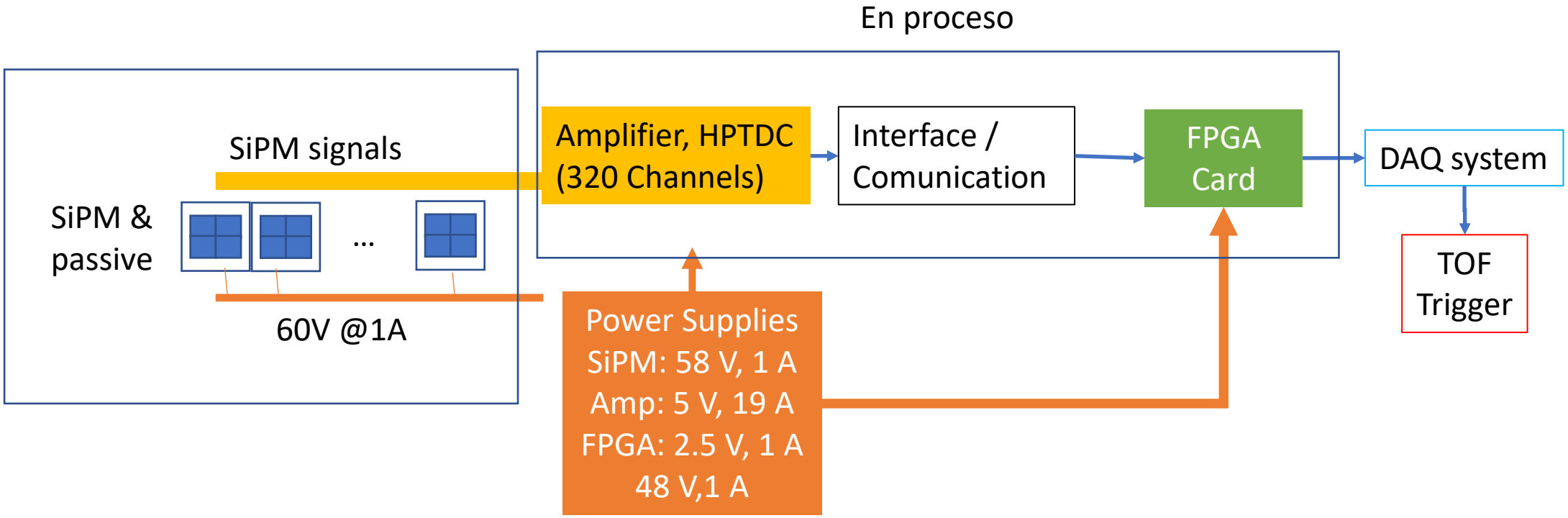


- Hamamatsu:
  - S13360-6075PE - 6x6 mm^2
  - S13360-3075PE – 3x3 mm^2

Cell geometry update

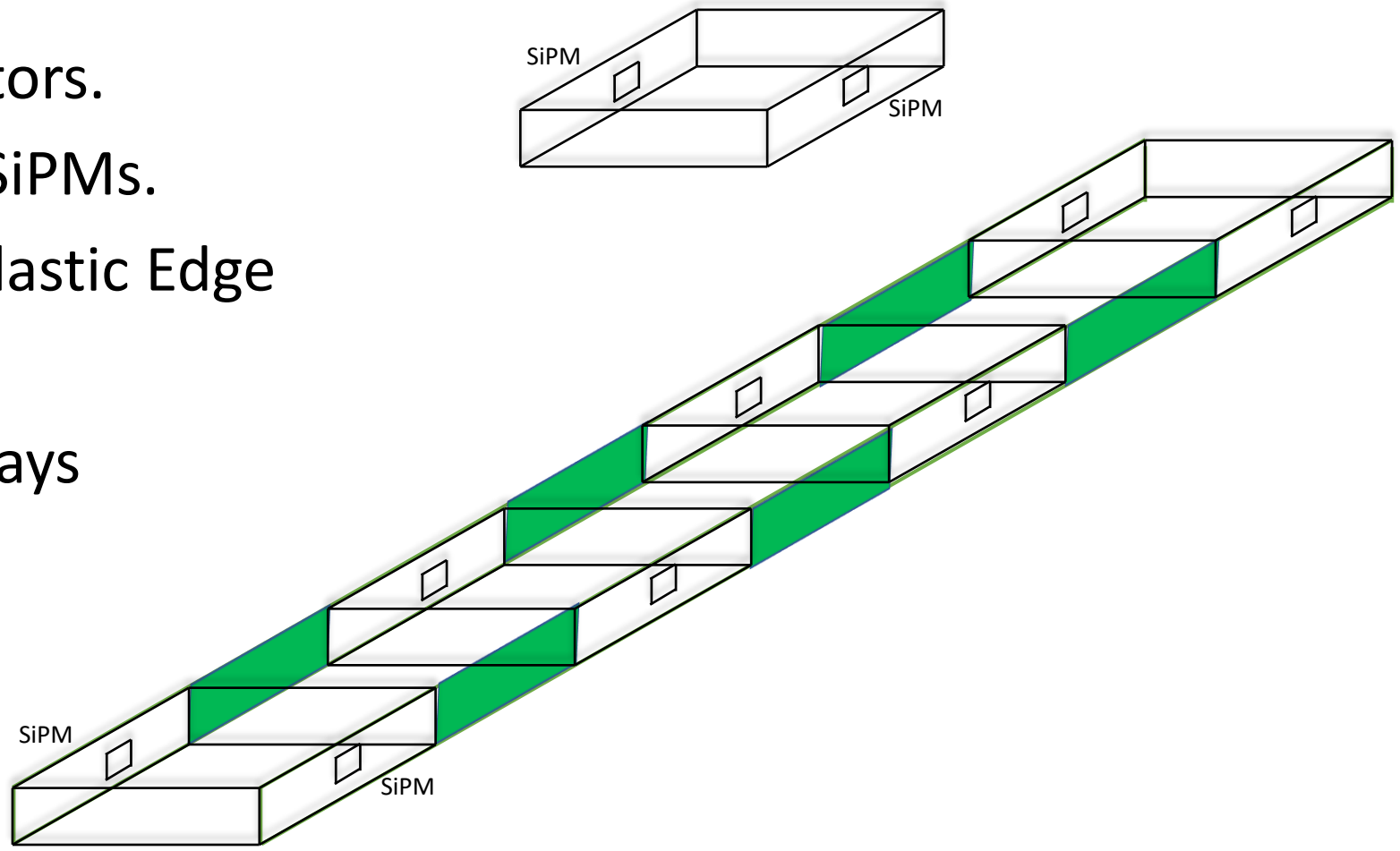
Geometry (by cell)	Plastic scintillator	Scintillator size (mm^3)	SiPM vendor and model	Amplifier	Array	Instrument for measurement	Time resolution
Original	BC404	20x20x3	SensL 6x6 mm^2 (C series)	Differential	4 SiPM Serie - parallel		
Dubna (2021)	BC404	20x20x3	SensL 6x6 mm^2 (J series)	Differential	4 SiPM Serie - parallel	Digitizer /Scope	200 ps
Begining 2023	EJ232 (BC422)	20x20x5	SensL 3x3 mm^2 (J series)	None	2 SiPM On the edges	CAEN TDC+CFD	127 ps
Current design	EJ232 (BC422)	20x20x5	**Hamamatsu** 3x3 mm^2	Transimpedance (OPA 858)	2 SiPM On the edges	CAEN TDC+CFD	44 ps

General Front-end



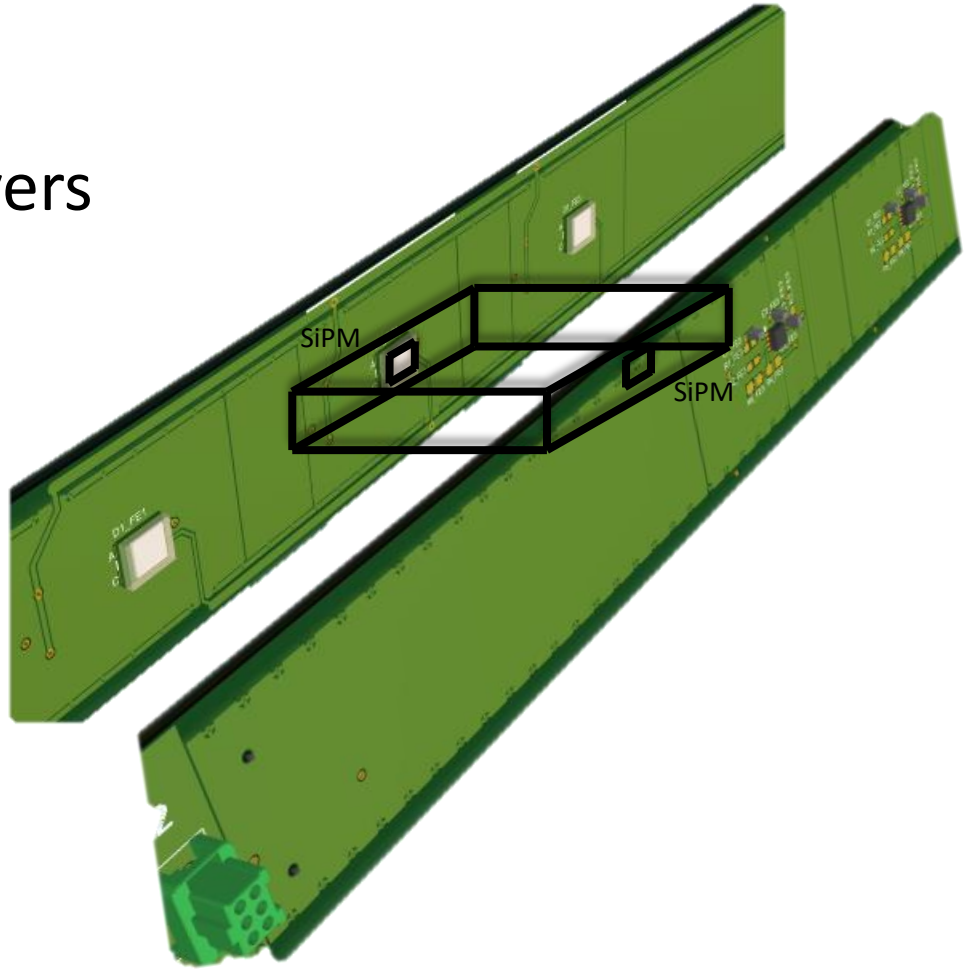
Begining 2023

- EJ232 plastic scintillators.
- SensL J-Series 3 mm SiPMs.
- Two SiPMs on each plastic Edge
- No amplification
- Muons from cosmic rays



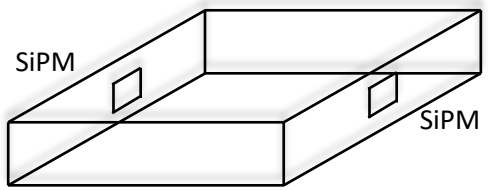
Schematics of plastic and electronics

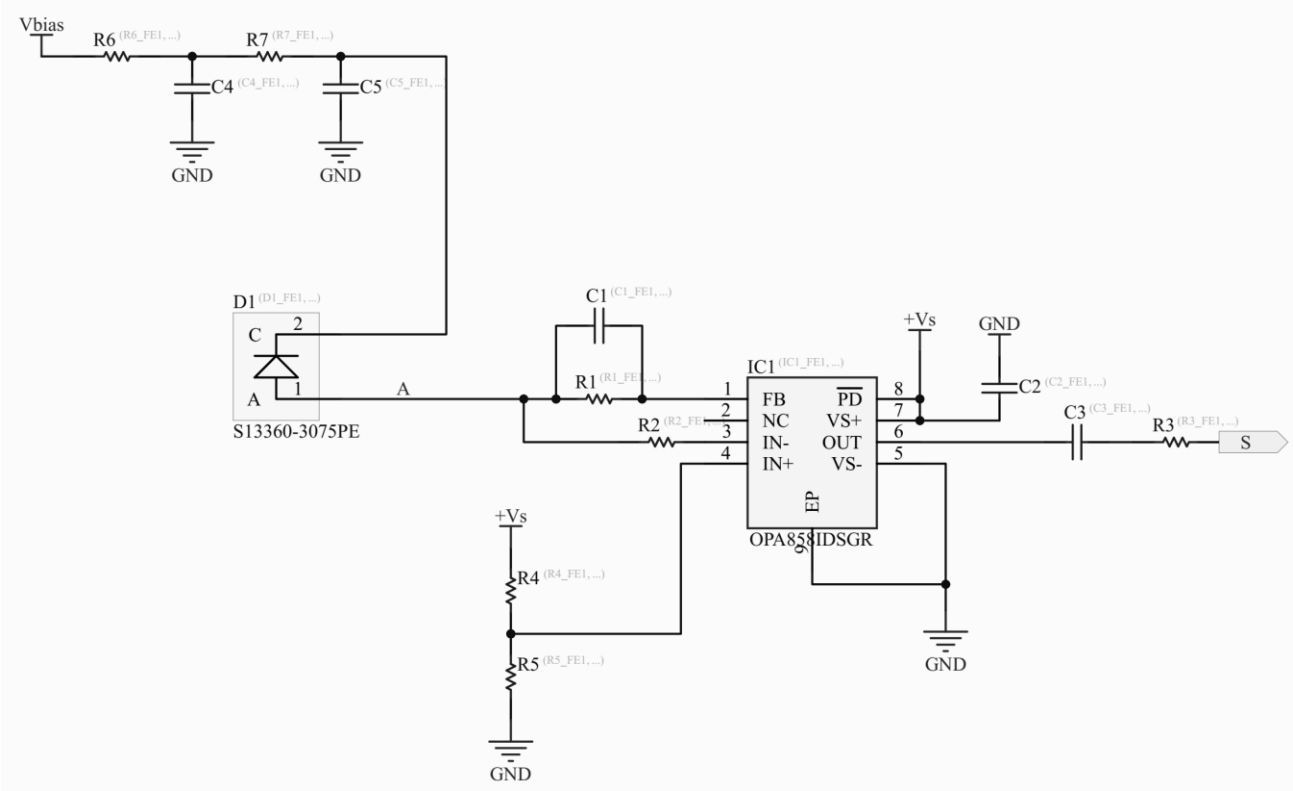
- Four layers PCB
- Ground plane on Top and Bottom layers
- Through holes for isolation
- Separated signal ground
- 50 Ohms impedance control
- Signal connector + Power connector
- 15 x 2.5 cm^2



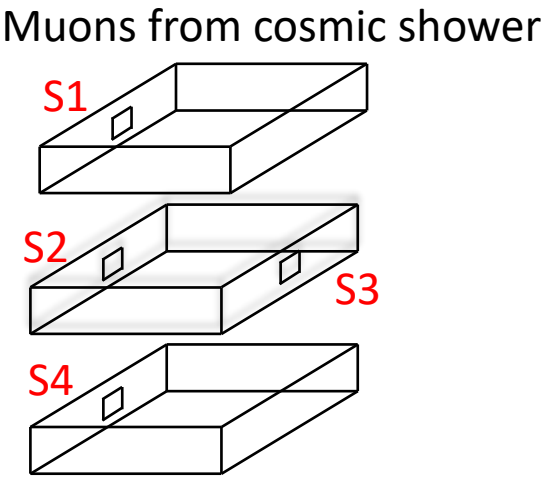
Currently

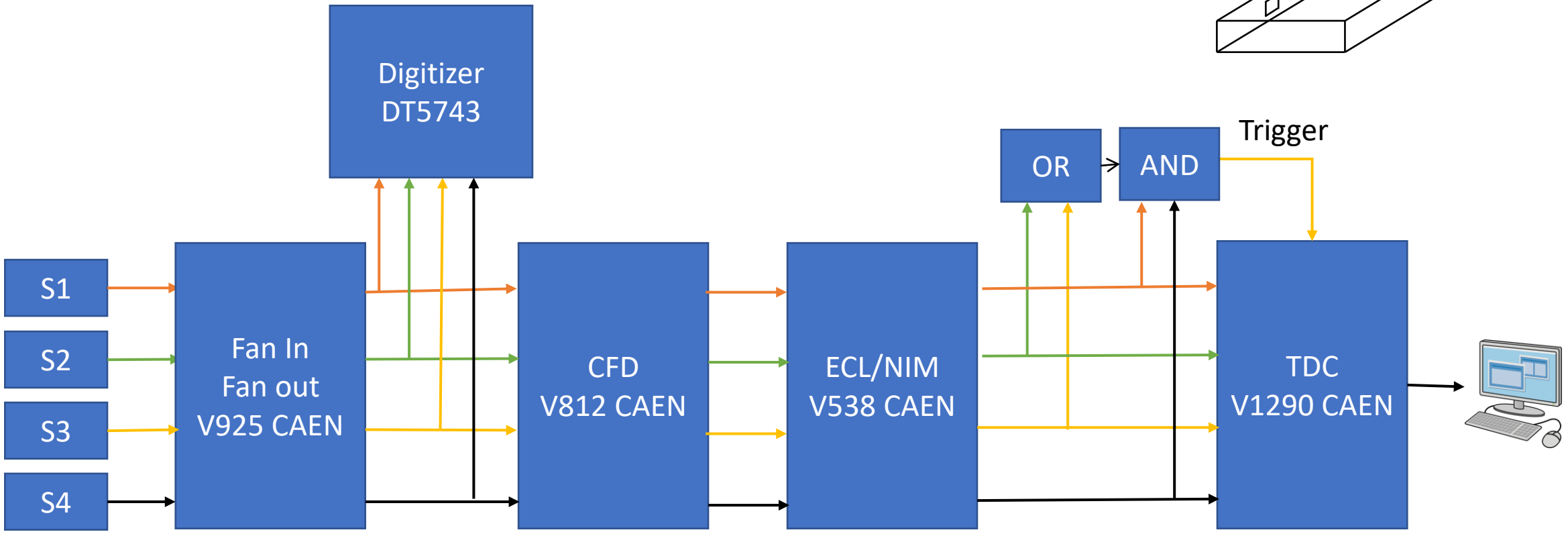
- EJ232 plastic scintillators.
- Hamamatsu 3 mm SiPMs.
- Two SiPMs on each plastic Edge
- Transimpedance amplifier
- Gamma from ^{22}Na (511 KeV)

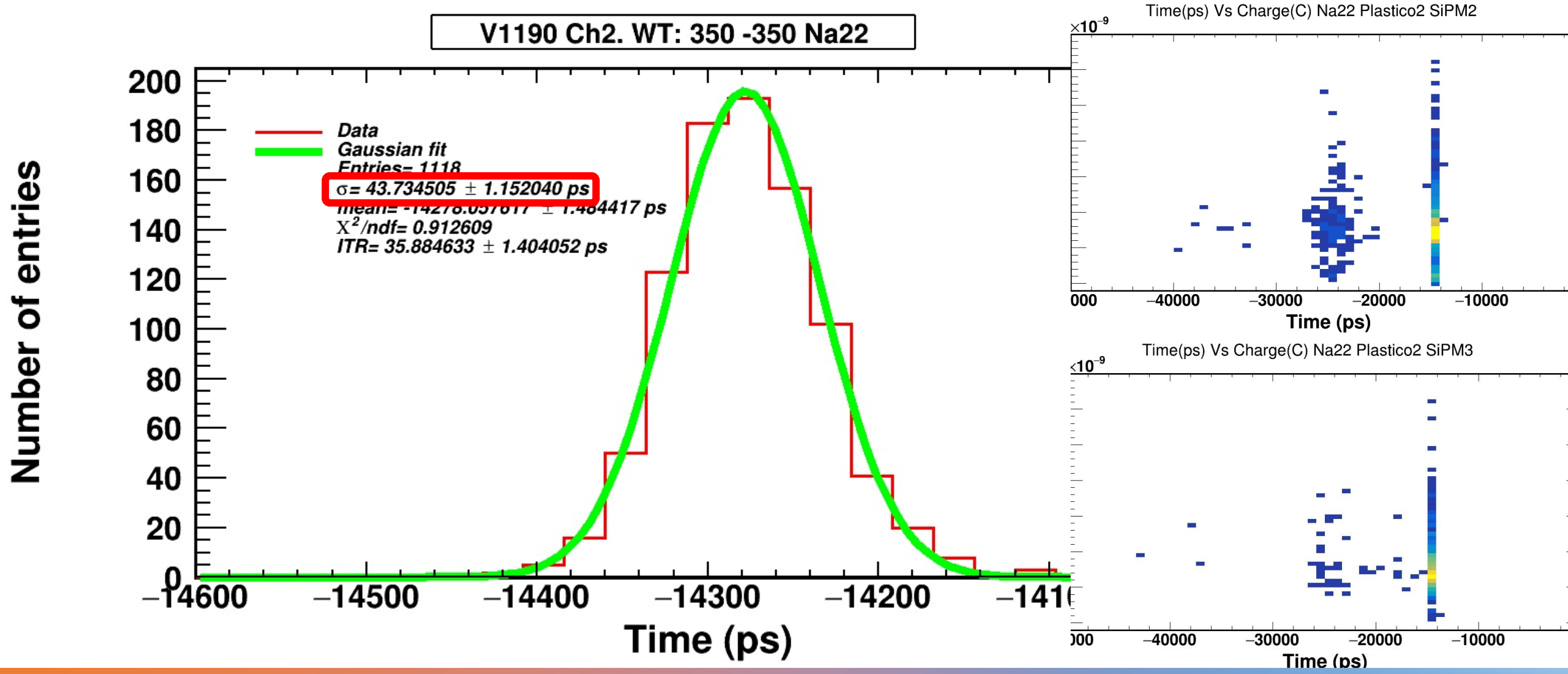




Instrumentation used

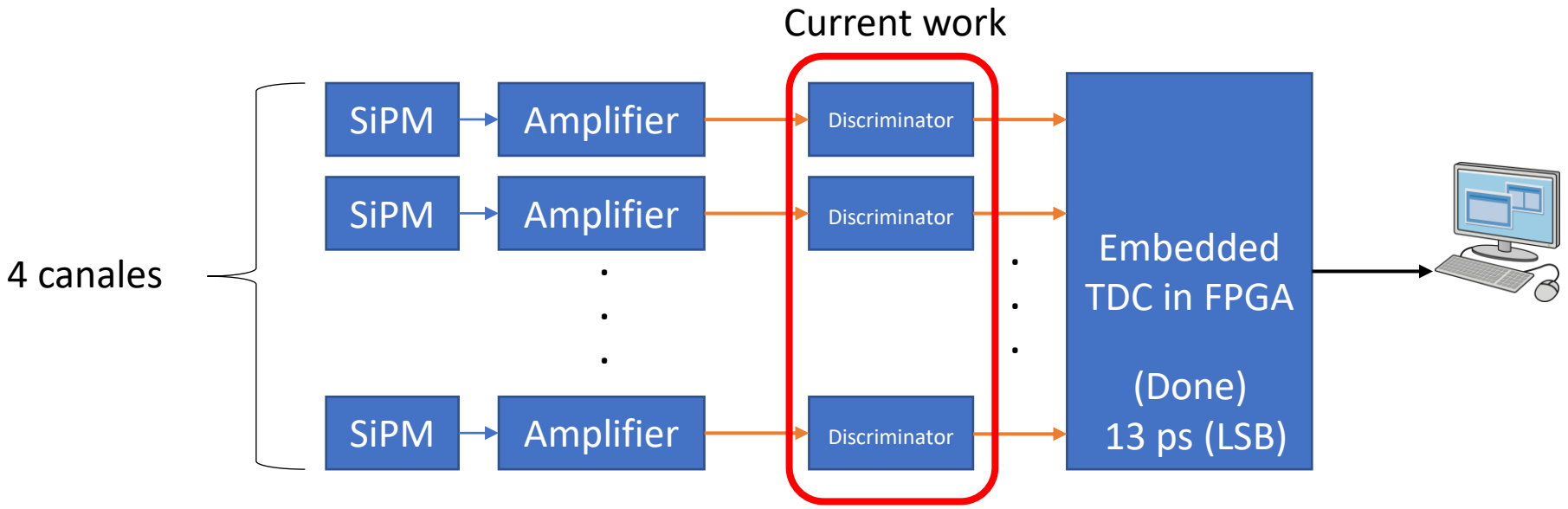






Resulting time resolution: ***44 ps***

FPGA implementation of TDC



GRACIAS

BACKUP SLIDES

BC422Q

	Weight % Benzophenone					
	None*	**0.5**	**1.0**	**2.0**	**3.0**	**5.0**
Scintillation Properties						
Light Output, %Anthracene	55	19	11	5	4	3
Rise Time, ps	350	110	105	100	100	100
Decay Time (ns)	1.6	0.7	0.7	0.7	0.7	0.7
Pulse Width, FWHM, ps	1300	360	290	260	240	220
*BC-422						

BC404

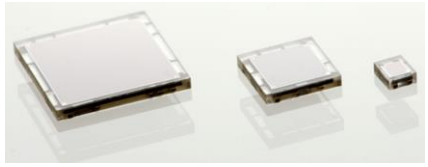
	BC-400	BC-404	BC-408	BC-412	BC-416
Radiation Detected					
<100keV X-rays			X		
100keV to 5MeV gamma rays				X	
>5MeV gamma rays	X				
Fast neutrons				X	X
Alphas, betas	X	X	X		
Charged particles,cosmic rays, muons, protons, etc.			X	X	X
Principal Uses/Applications	general purpose	fast counting	TOF large area	large area	large area economy
Scintillation Properties					
Light Output, %Anthracene	65	68	64	60	38
Rise Time, ns	0.9	0.7	0.9	1.0	–
Decay Time (ns)	2.4	1.8	2.1	3.3	4.0
Pulse Width, FWHM, ns	2.7	2.2	~2.5	4.2	5.3
Wavelength of Max. Emission, nm	423	408	425	434	434
Light Attenuation Length, cm*	160	140	210	210	210
Bulk Light Attenuation Length, cm	250	160	380	400	400

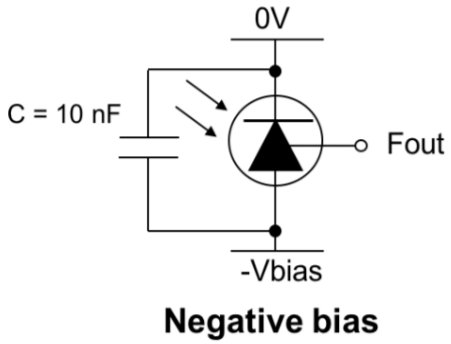
EJ232

PROPERTIES	EJ-232	EJ-232Q (% BENZOPHENONE)				
		0.5	1.0	2.0	3.0	5.0
Light Output (% Anthracene)	55	19	11	5	4	3
Scintillation Efficiency (photons/1 MeV e^-)	8,400	2,900	1,700	770	610	460
Wavelength of Maximum Emission (nm)	370	370	370	370	370	370
Rise Time (ps)	350	110	105	100	100	100
Decay Time (ps)	1,600	700	700	700	700	700
Pulse Width, FWHM (ps)	1,300	360	290	260	240	220
H Atoms per cm³ ($\times 10^{22}$)	5.13	5.12	5.12	5.12	5.12	5.12
C Atoms per cm³ ($\times 10^{22}$)	4.66	4.66	4.66	4.66	4.66	4.66
Electrons per cm³ ($\times 10^{23}$)	3.30	3.38	3.38	3.38	3.38	3.38
Density (g/cm^3)	1.023	1.023	1.023	1.023	1.023	1.023

Proposed SiPM

- **SensL MicroFJ-30035**
- Rise Time = 90ps
  - (2.5 V Over-voltage)
- FWHM = 1.5ns

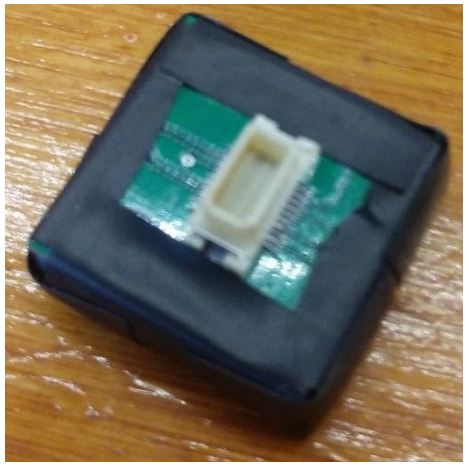


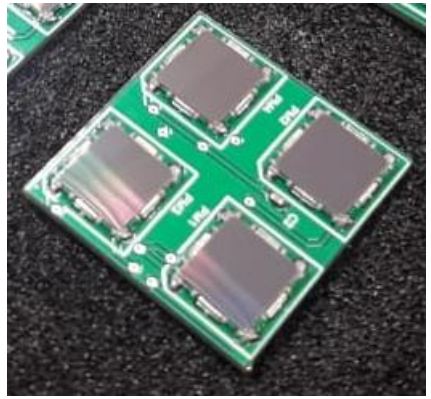


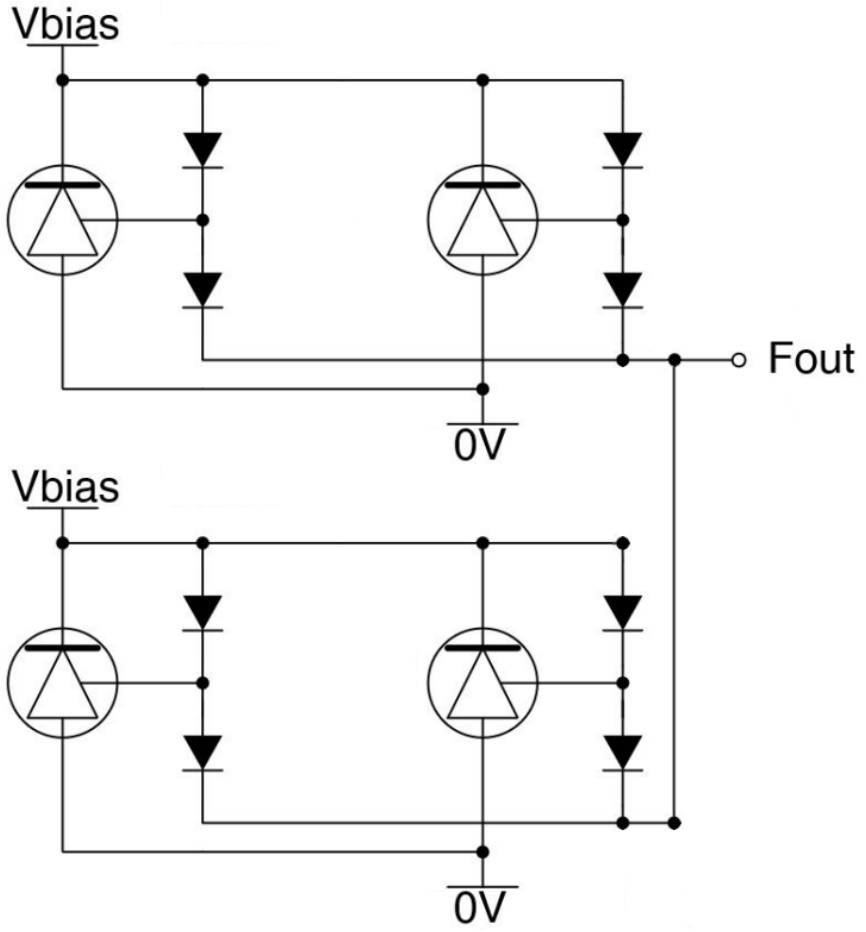
- SensL MicroFJ-30035 (3x3 mm^2)
- Breakdown voltage max (Vbr): 24.7V
- Photon Detection Efficiency (PDE):
  - 38% Vbr+2.5 V
  - 50% Vbr+6.0 V
- Gain: 6.3×10^{16}
- Crosstalk: 8%

SiPM parallel interconnection

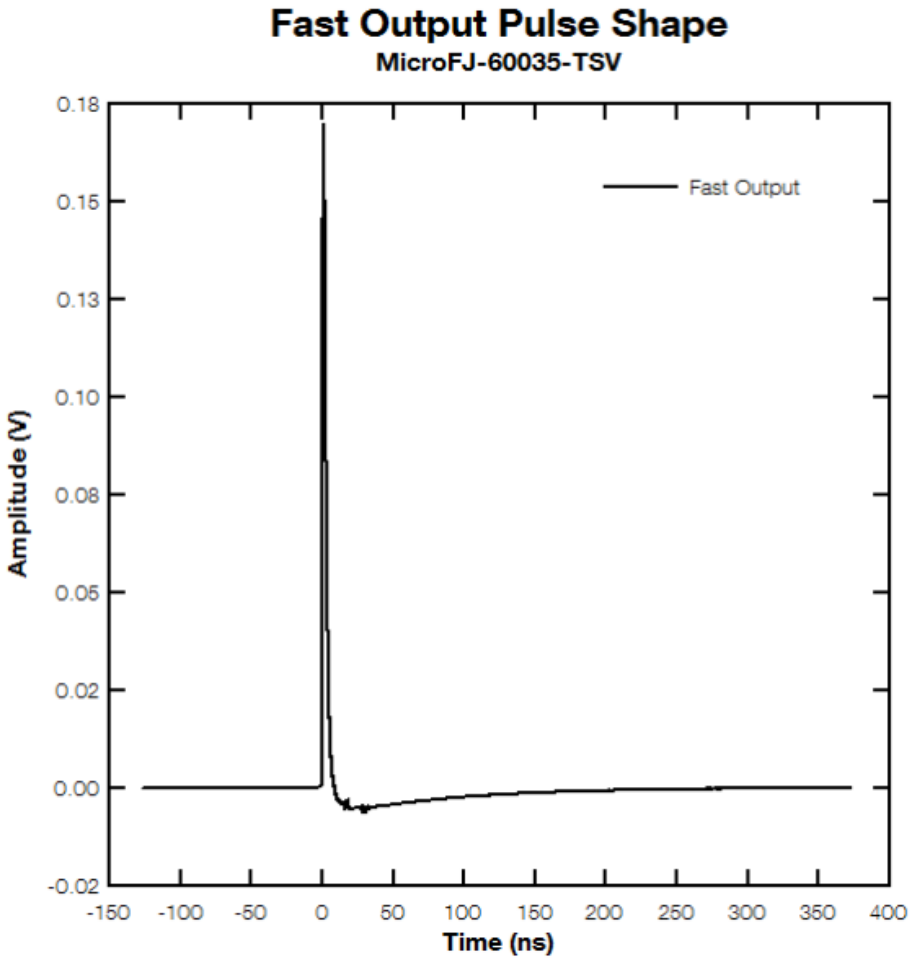
- Only fast output signals
- Capacitance effects if direct parallel
- Schottky diodes for interconnection
- Lower capacitance effect
- Affects the pulse width and rise time

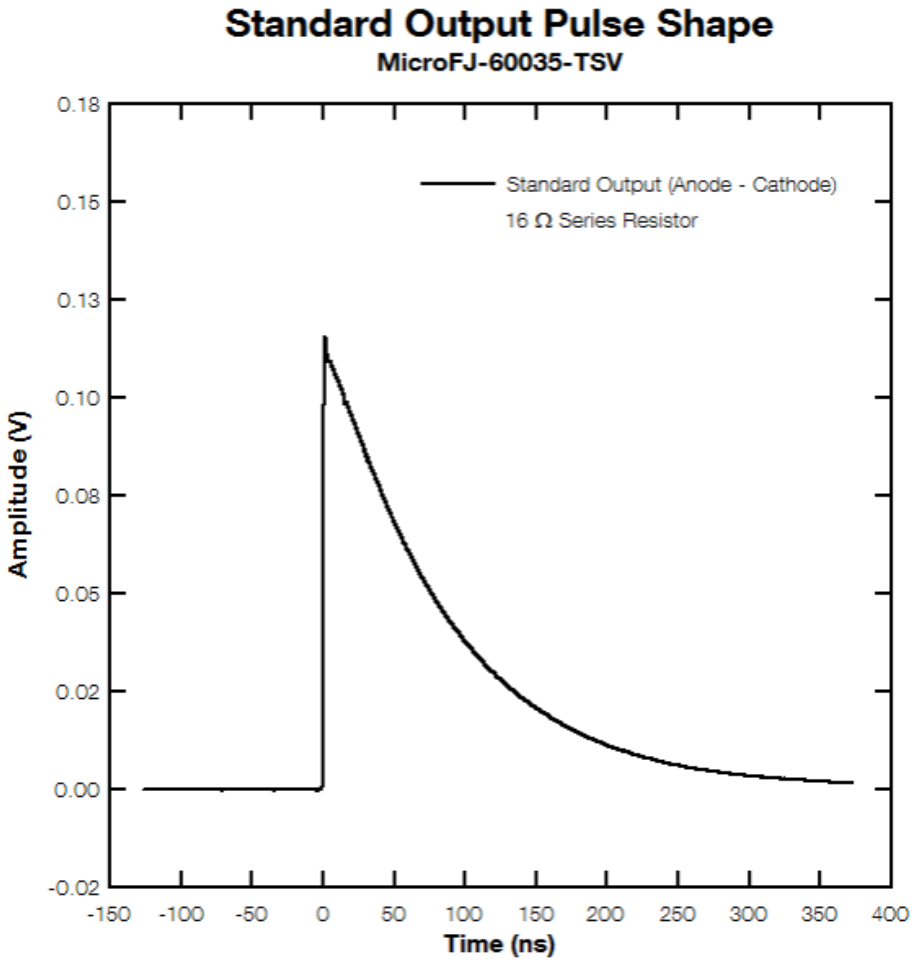






SensL signals





Dynamic range

- Given a 0.5 GeV pion:
  - For BC-404 – 551 photons are expected on each SiPM
  - For BC-422Q – 509 photons are expected on each SiPM
- Deposited charge expected depends on:

Source	Over voltage (5V)	Over voltage (2.5 V)
PDE	41%	31%
Total number of cells	18,980	-
Gain	$3x10^6$	-
Number of photons	551	-

Dynamic Range SensL C-Series SiPM