Advances in the MiniBeBe Front-End

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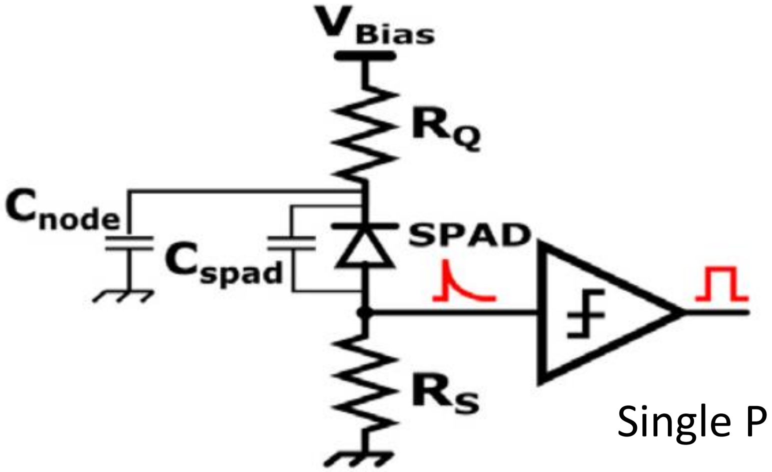
December 16th. 2020

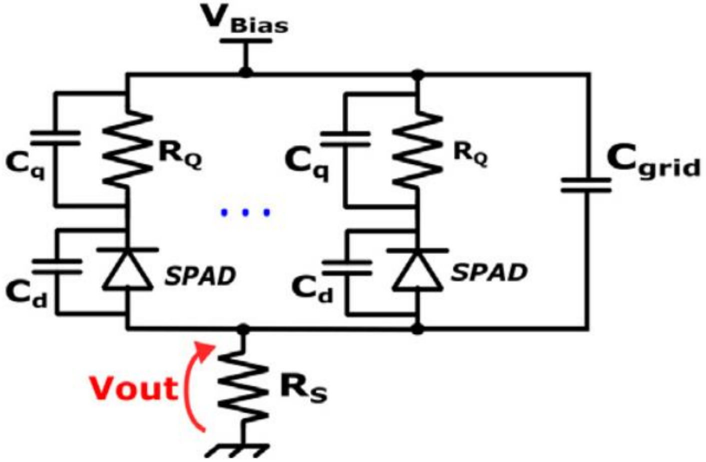
Preliminar design work

SiPM bases and Dynamic range

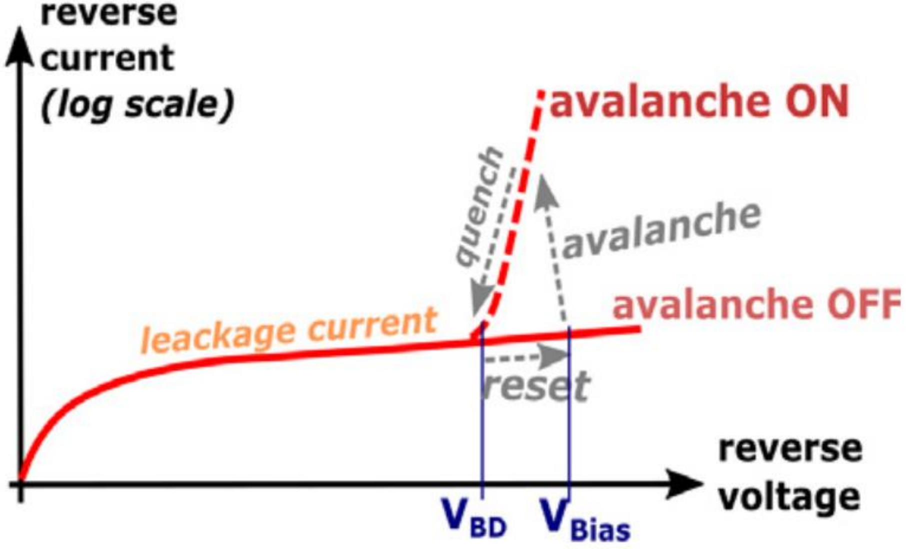
SPAD ELECTRICAL MODEL

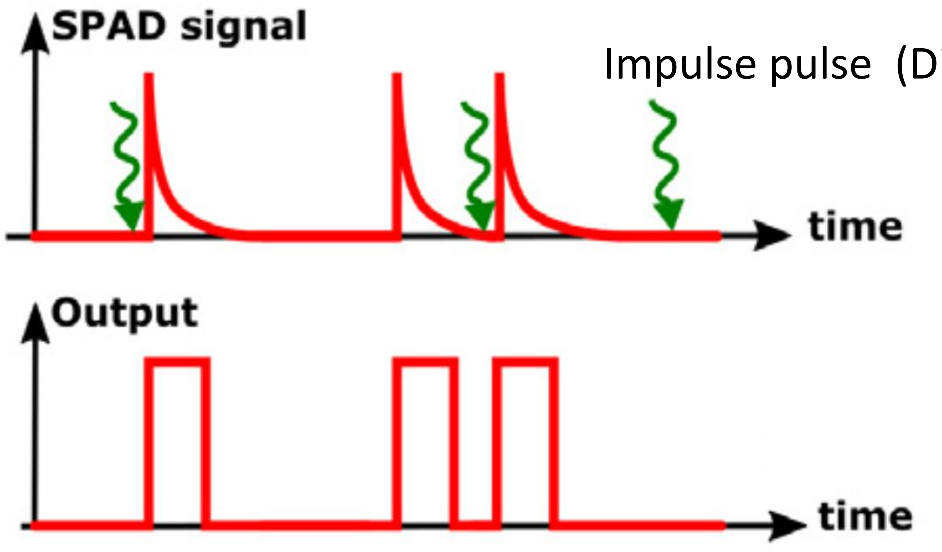


$$V_{Bias} = I_d R_q + V_d$$



Single Photon Avalanche Detector (SPAD)

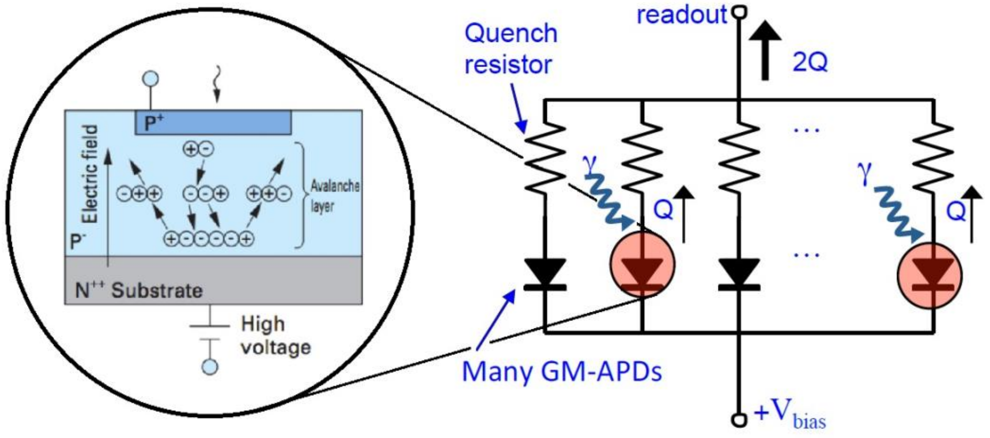


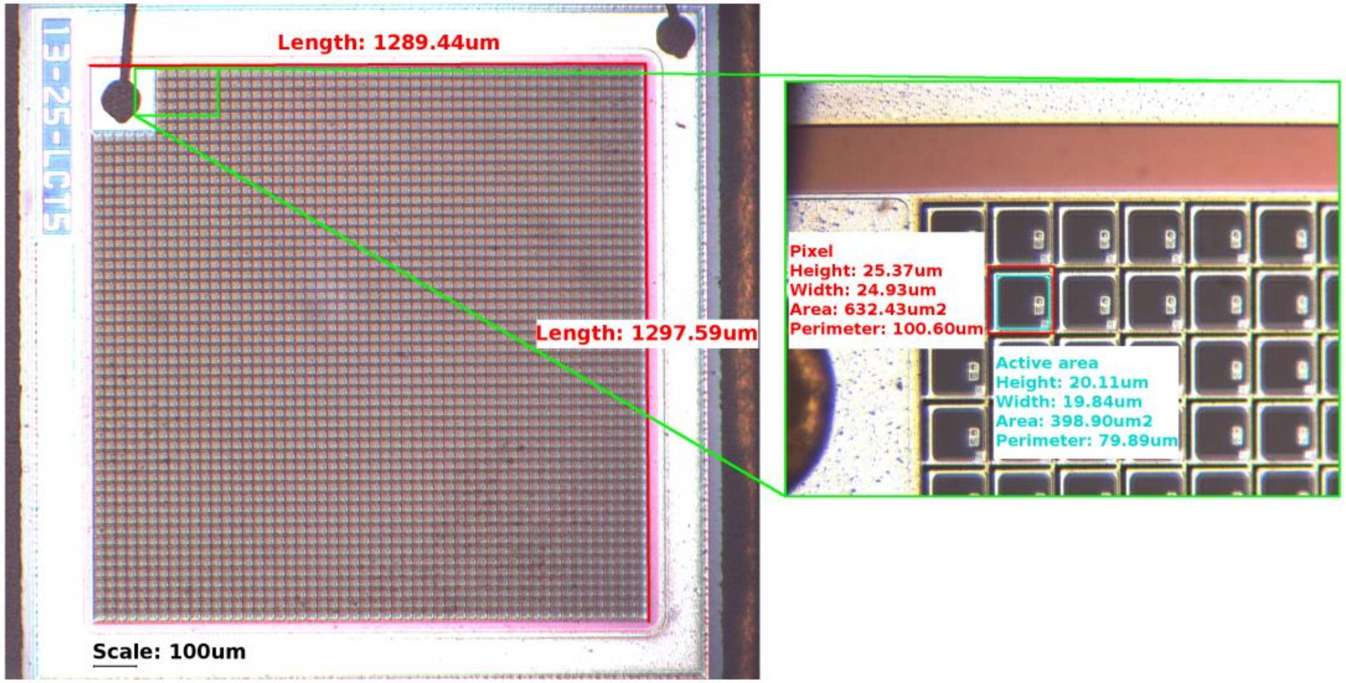


Impulse pulse (Digital)

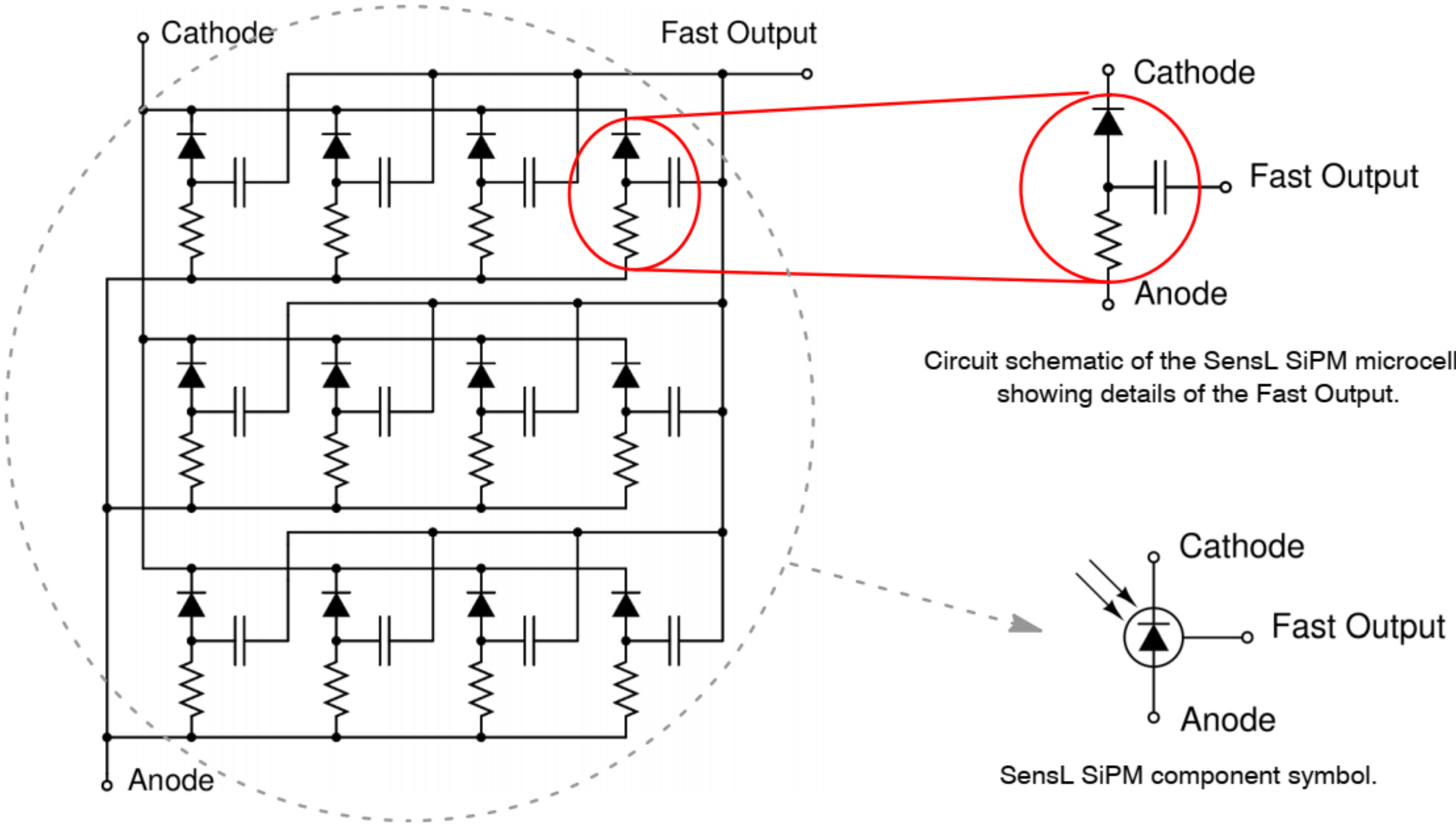
The Silicon PhotoMultiplier (SiPM)

- Several SPADs in parallel
- Analog device





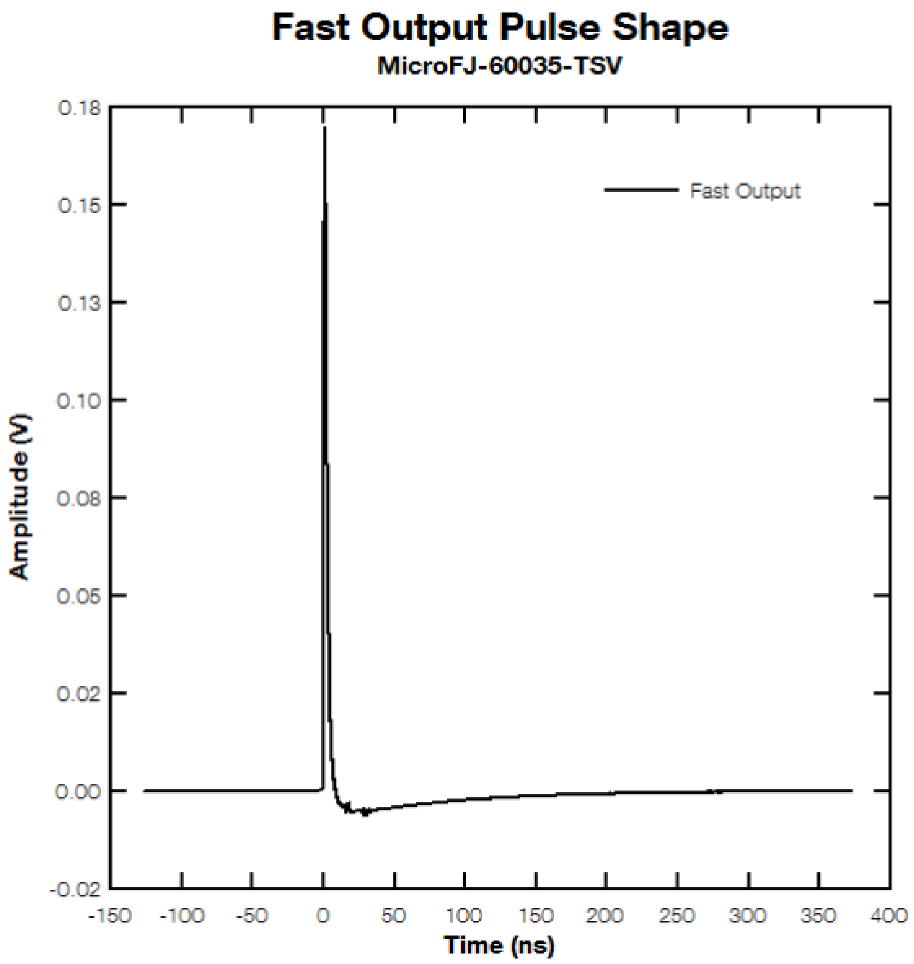
SensL SiPM characteristics

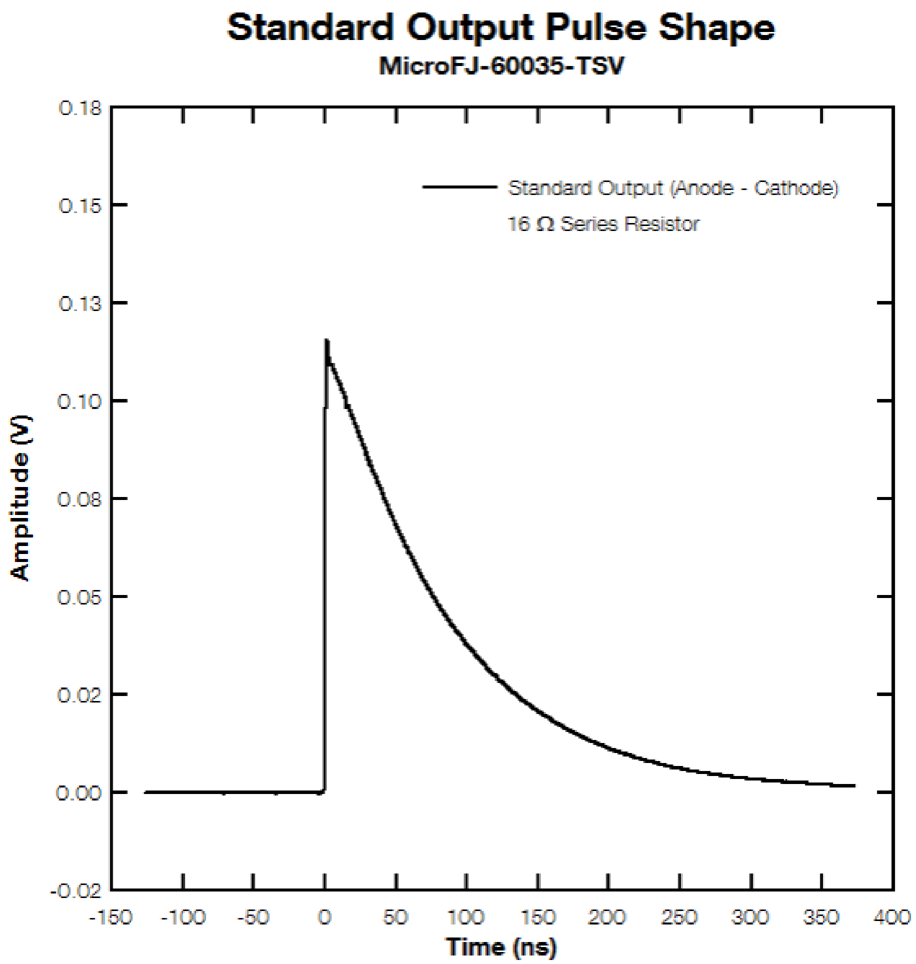


Circuit schematic of the SensL SiPM microcell, showing details of the Fast Output.

SensL SiPM component symbol.

SensL signals



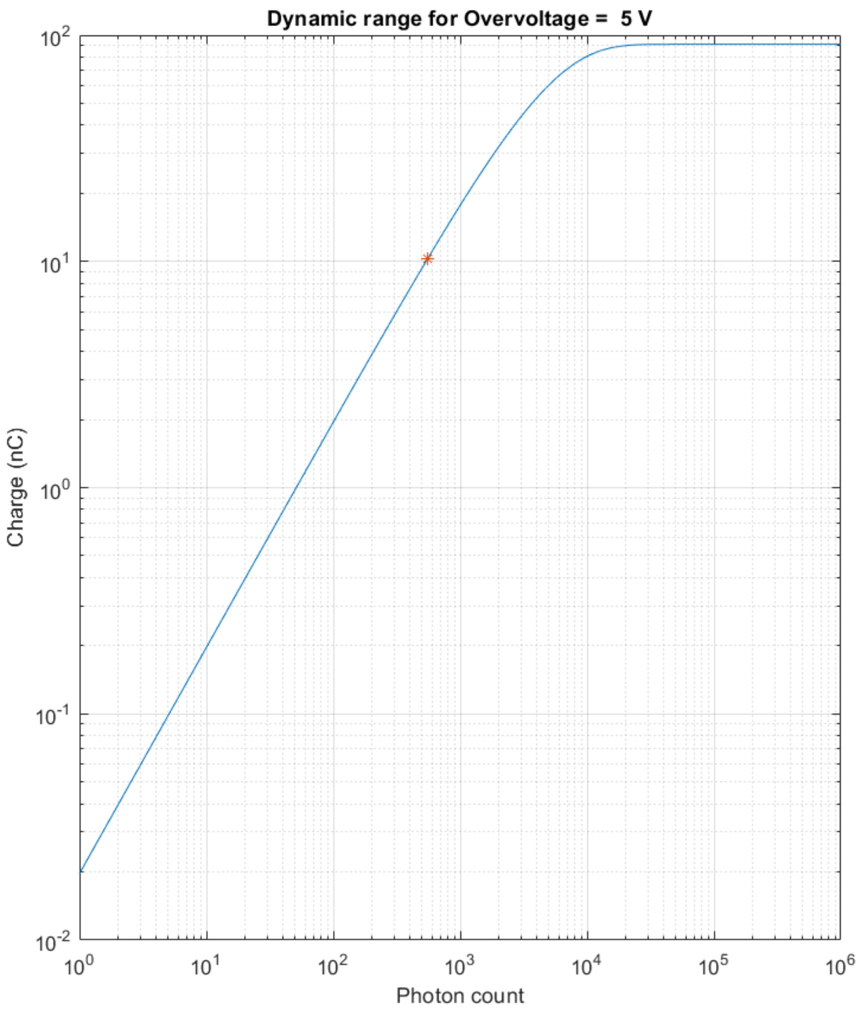


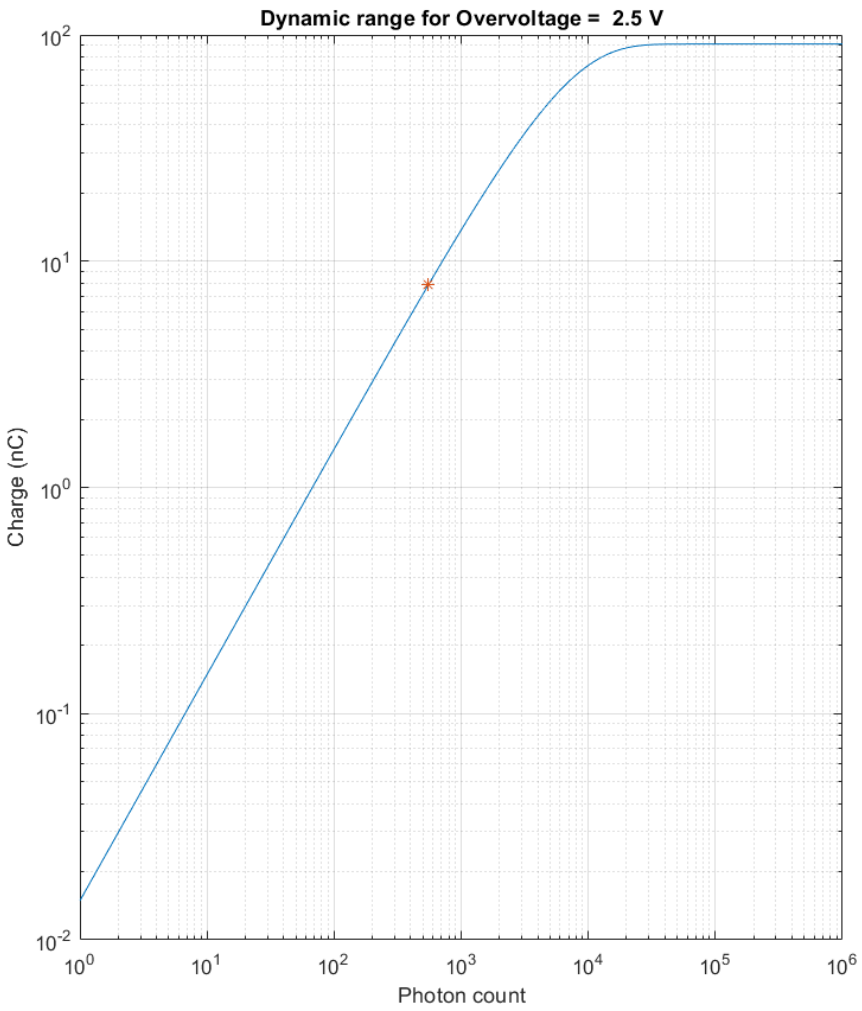
Dynamic range

- 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



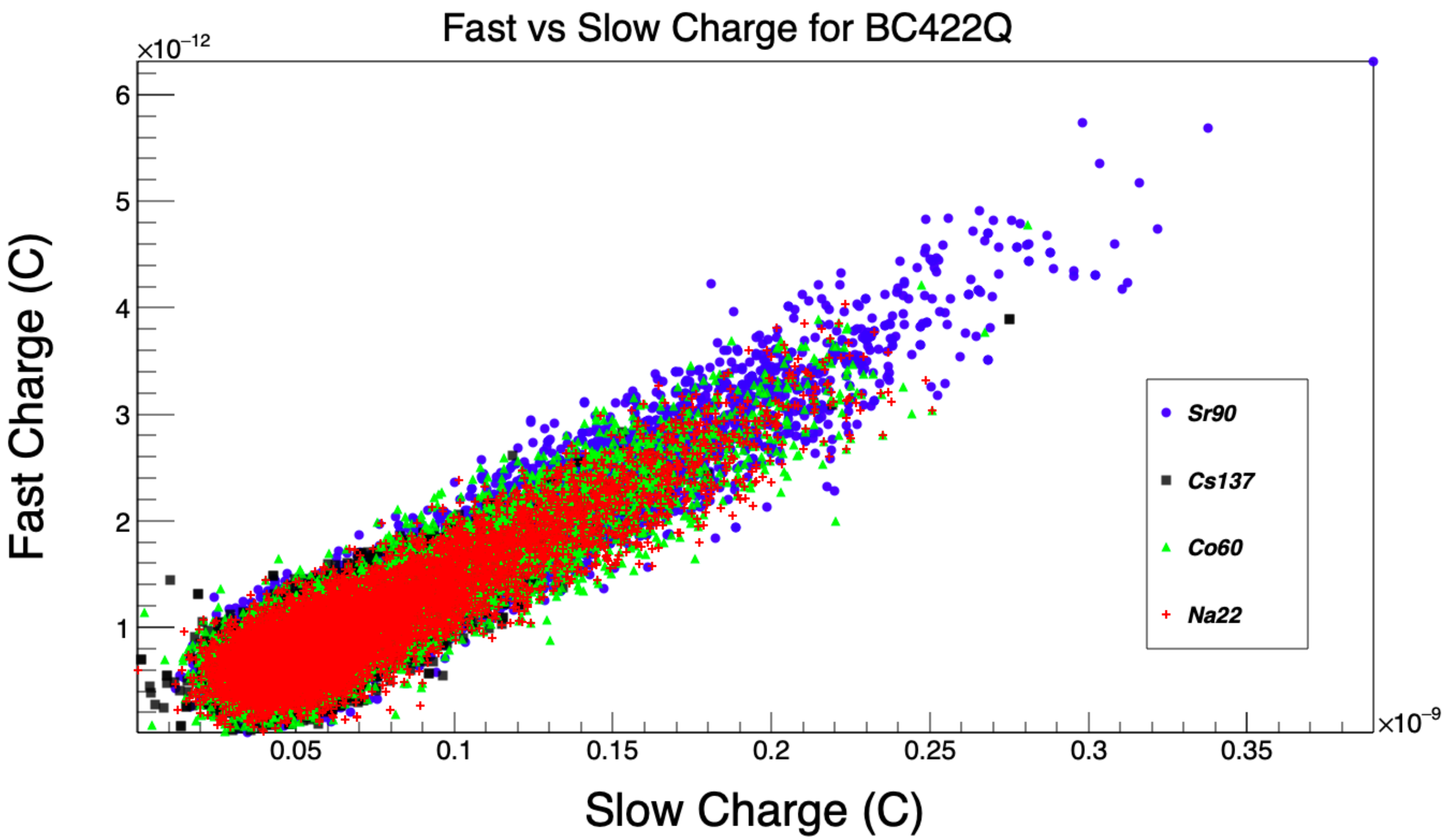


Charge estimation

From fast output

Standard vs Fast output on SensL SiPMs

- Standard output signal
  - Pulse width of 100 ps.
  - Capacitance: 3400 pF
- Fast output signal
  - Pulse width: 3.4 ns
  - Capacitance: 48 pF



Charge estimation from fast output

- Fast output is the derivative of standard signal
- Correlated signals
- Linear regression relationship

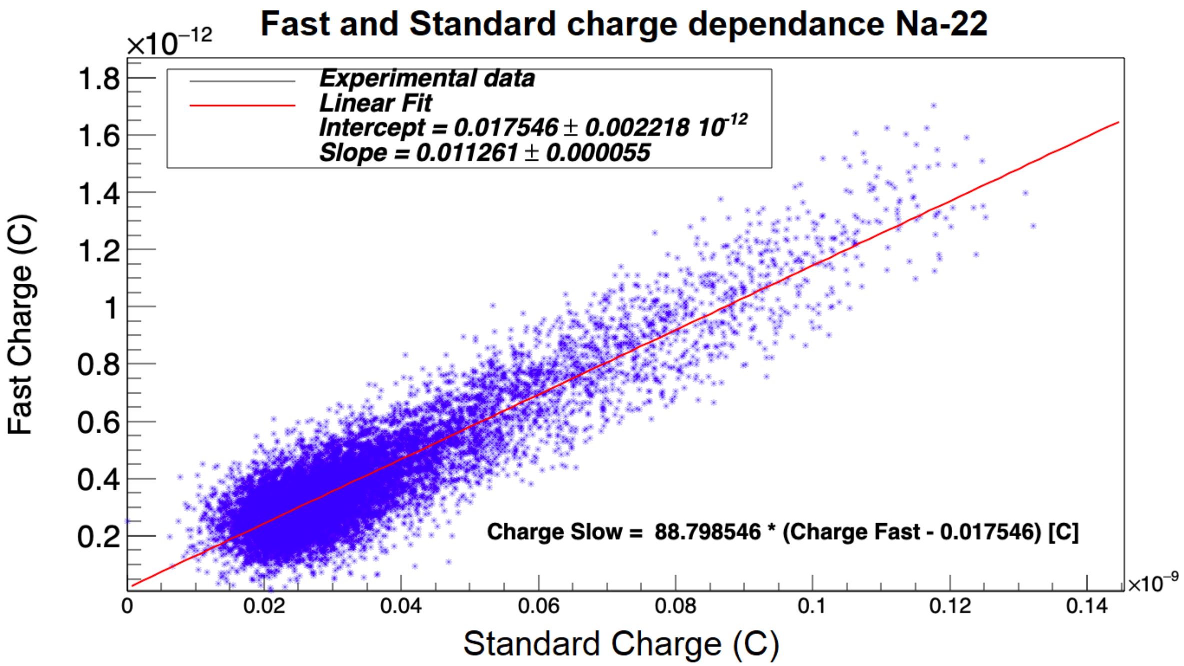
$$Q_s = R_{f,s}(Q_f - \overline{Q_f}) + \overline{Q_s}$$

$$a = \frac{\sigma_f}{\sigma_s} R_{f,s}\ ; \quad b = \overline{Q_s} - \mathrm{a}\overline{Q_f}$$

$$\Rightarrow Q_s = aQ_f + b$$

$$Q_s = \int_{t_i}^{t_f} i_s(t)dt = \frac{1}{50}\int_{t_i}^{t_f} V_s(t)dt$$

$$Q_F = \int_{t_{i'}}^{t_{f'}} i_f(t)dt = \frac{1}{50}\int_{t_{i'}}^{t_{f'}} V_f(t)dt$$



Linear regression results

BC404

Source -	$\bar{Q_f}$ $[10^{-12}C]$	σ_f $[10^{-12}C]$	$\bar{Q_s}$ $[10^{-10}C]$	σ_s $[10^{-10}C]$
$Na22_{peak_1}$	2.910	0.338	2.784	0.374
$Na22_{peak_2}$	3.431	0.482	3.194	0.594
Sr90	5.492	0.314	5.127	0.373
Cs137	2.450	0.345	2.297	0.355
Co60	3.648	0.259	3.464	0.433

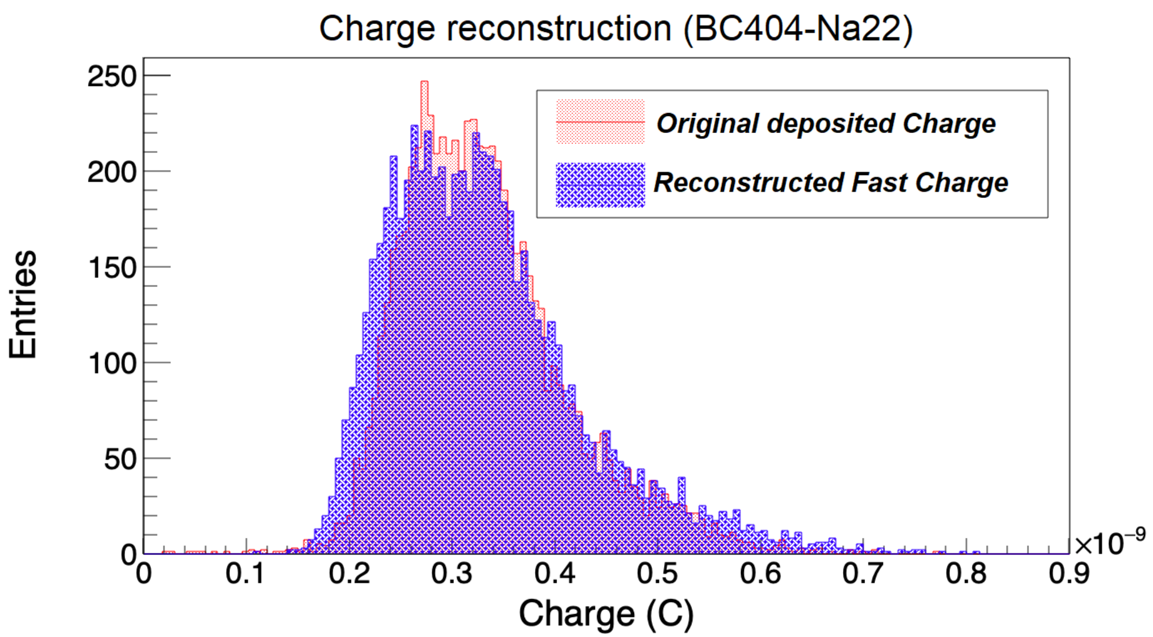
BC422Q

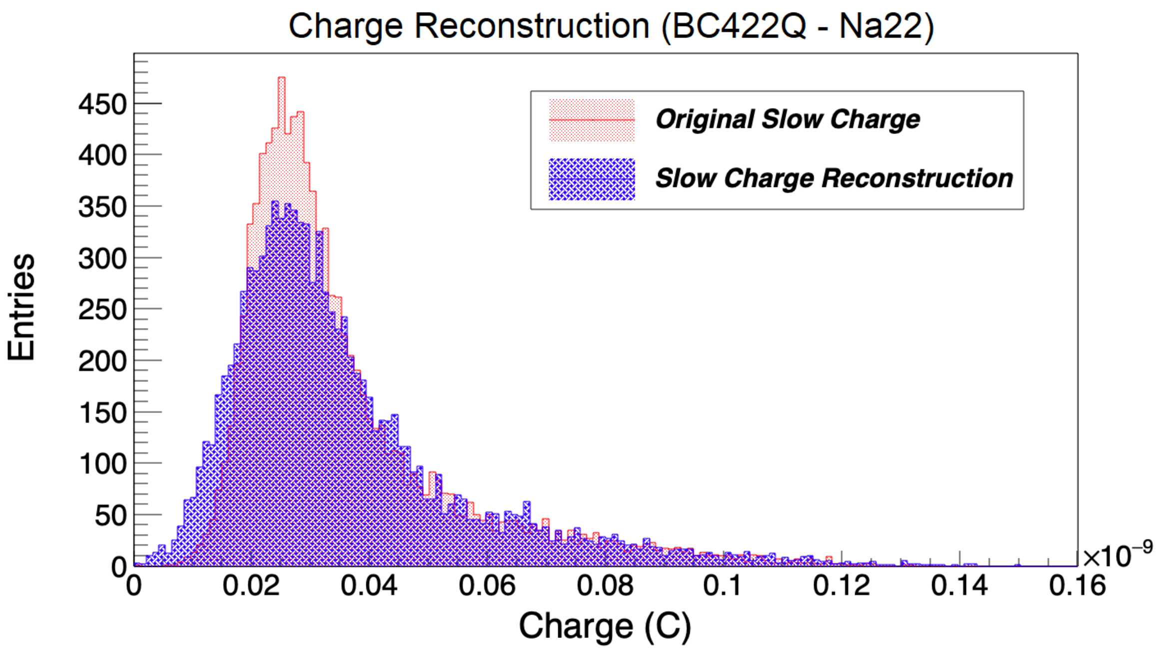
Source -	$\bar{Q_f}$ $[10^{-12}C]$	σ_f $[10^{-12}C]$	$\bar{Q_s}$ $[10^{-10}C]$	σ_s $[10^{-10}C]$
Na22	0.311	0.099	0.258	0.068
Sr90	0.323	0.116	0.262	0.074
Cs137	0.333	0.131	0.269	0.082
Co60	0.323	0.120	0.263	0.080

Source -	a $[10^{-3}]$	a (error) $[10^{-5}]$	b $[10^{-12}$C]	b (error) $[10^{-12}$C]
Co60	7.75	6.3	1.14	0.03
Cs137	6.18	9.9	1.06	0.22
Na22	8.43	9.3	0.69	0.02
Sr90	9.06	5.5	0.95	0.03

Source -	a $[10^{-2}]$	a (error) $[10^{-5}]$	b (10^{-12})C	b (error) (10^{-15})C
Co60	1.16	5.3	0.014	2.30
Cs137	1.01	9.4	0.052	3.10
Na22	1.13	5.5	0.017	2.22
Sr90	1.17	4.3	0.004	2.11

Charge estimation results



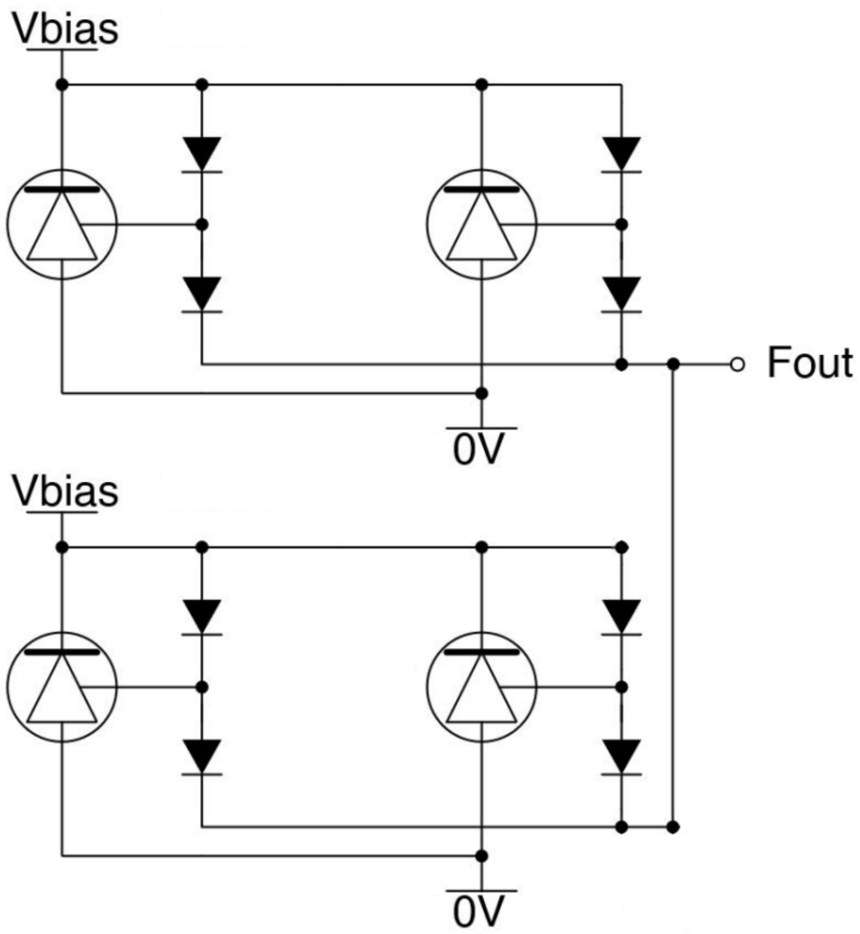


SiPM array

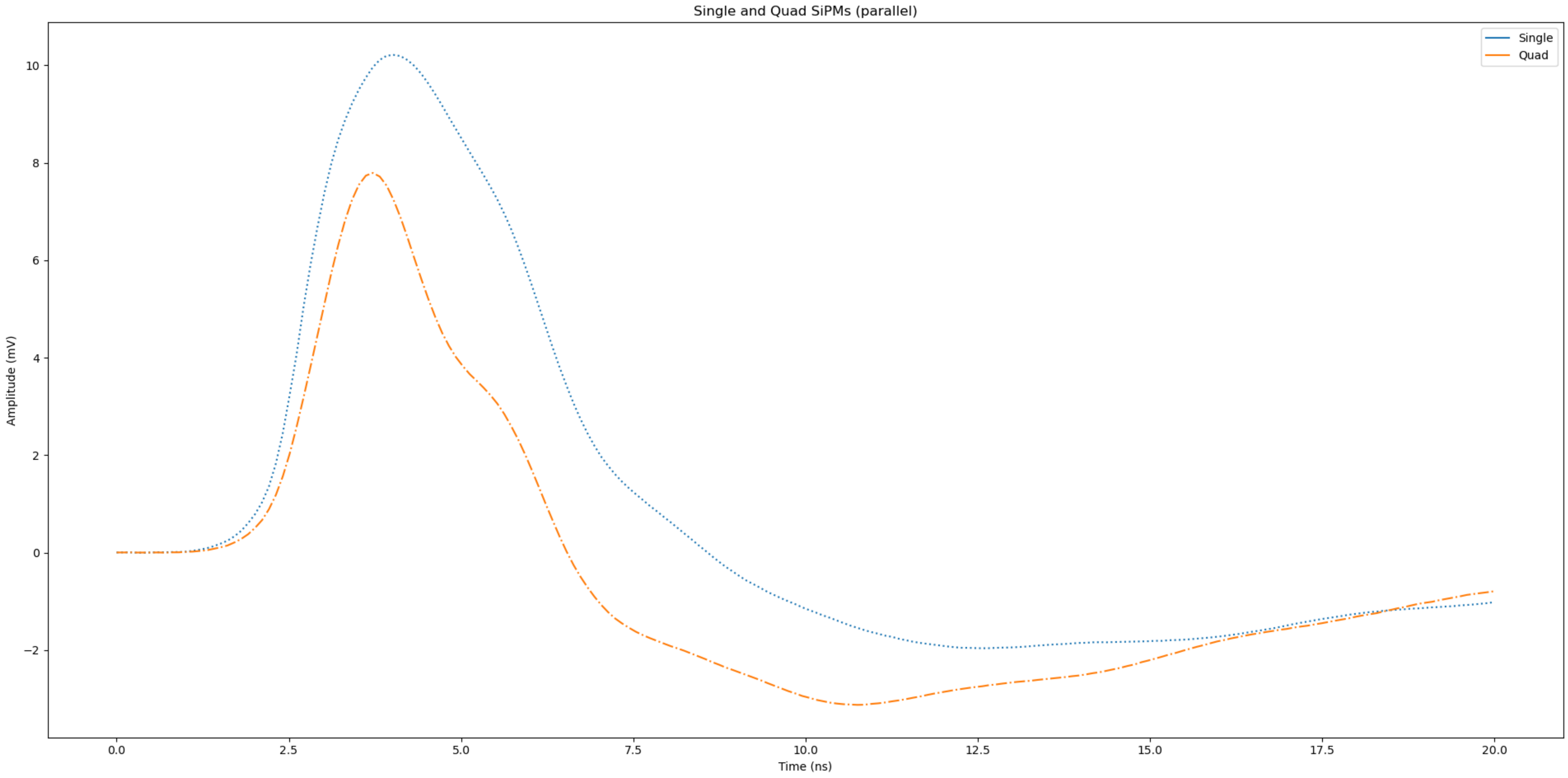
Parallel SiPM interconnection

SiPM parallel interconnection

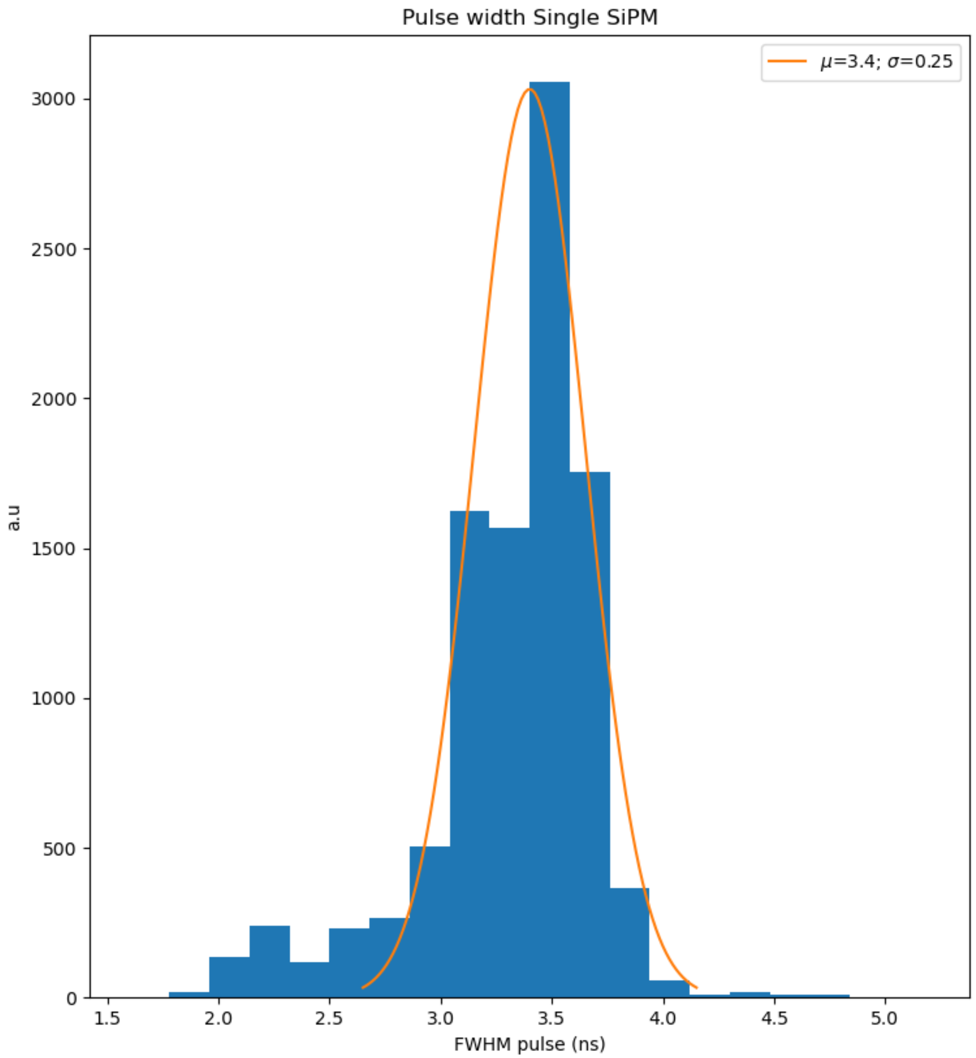
- Only Fast output signals
- Capacitance effects if direct parallel
- Schottky diodes for interconnection
- Lower capacitance effect
- Affects the Pulse width and rise time

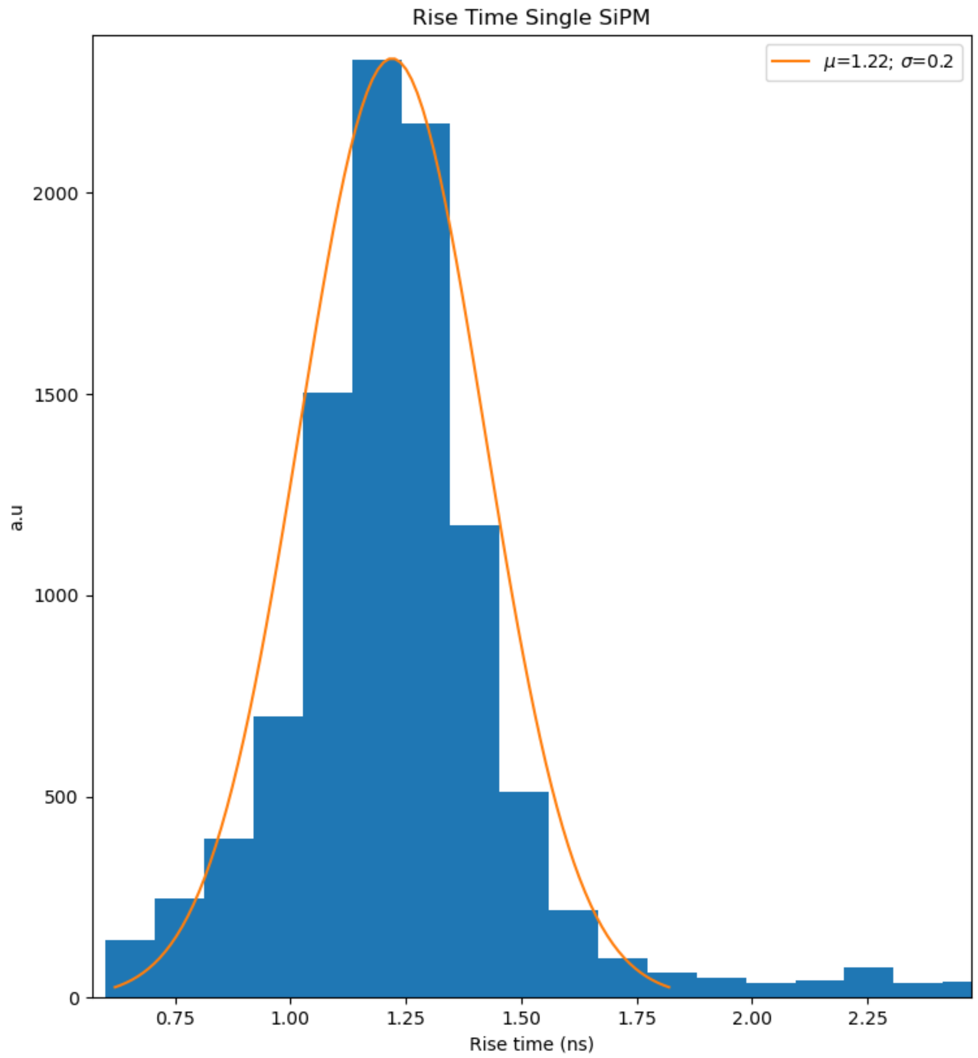


Parallel interconnection effects (Fast signal)



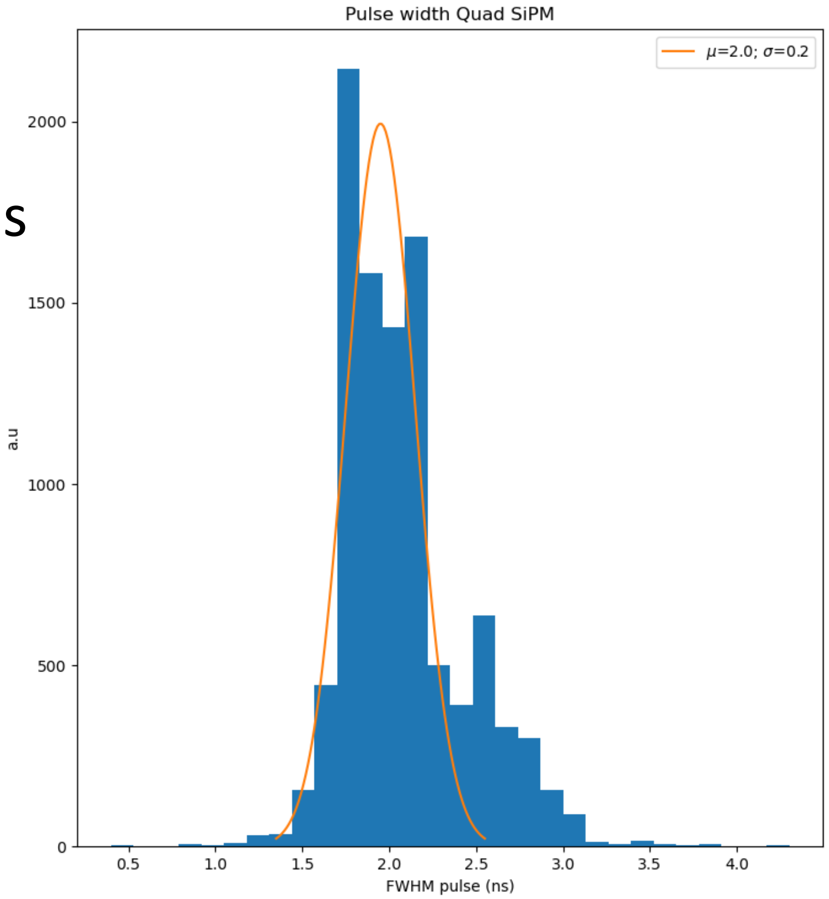
FWHM and Rise time for single SiPM

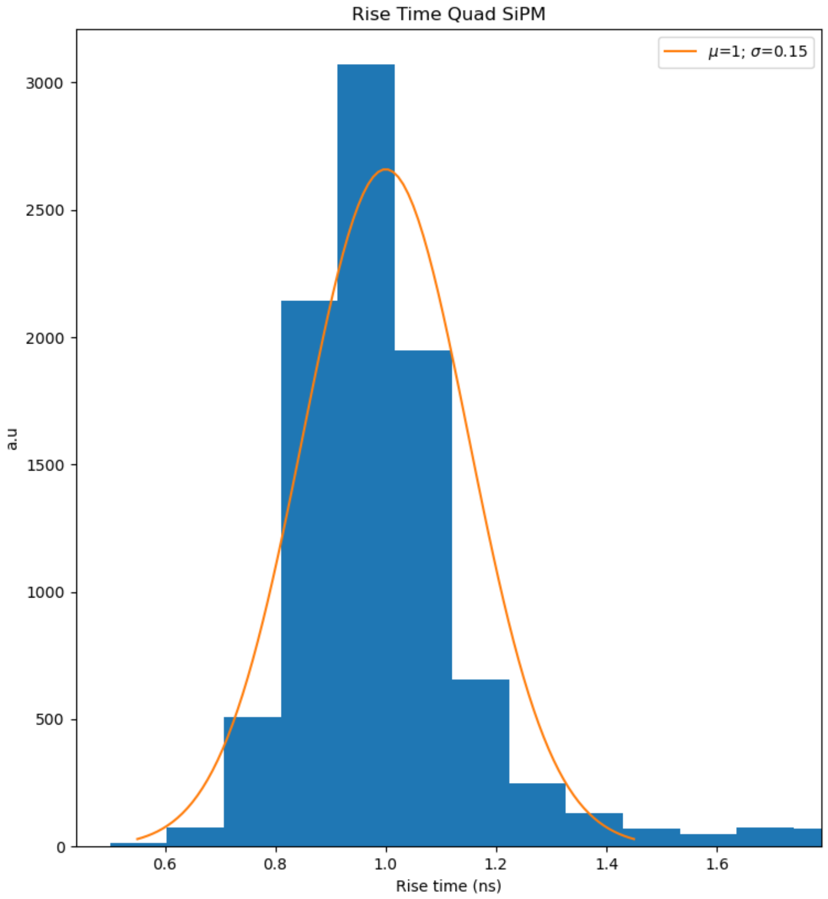




FWHM and Rise time for Quad SiPMs

- Single FWHM = 3.4 ns
- Single Rise time = 1.22 ns
- Quad FWHM = 2.0 ns
- Quad Rise time = 1.0 ns

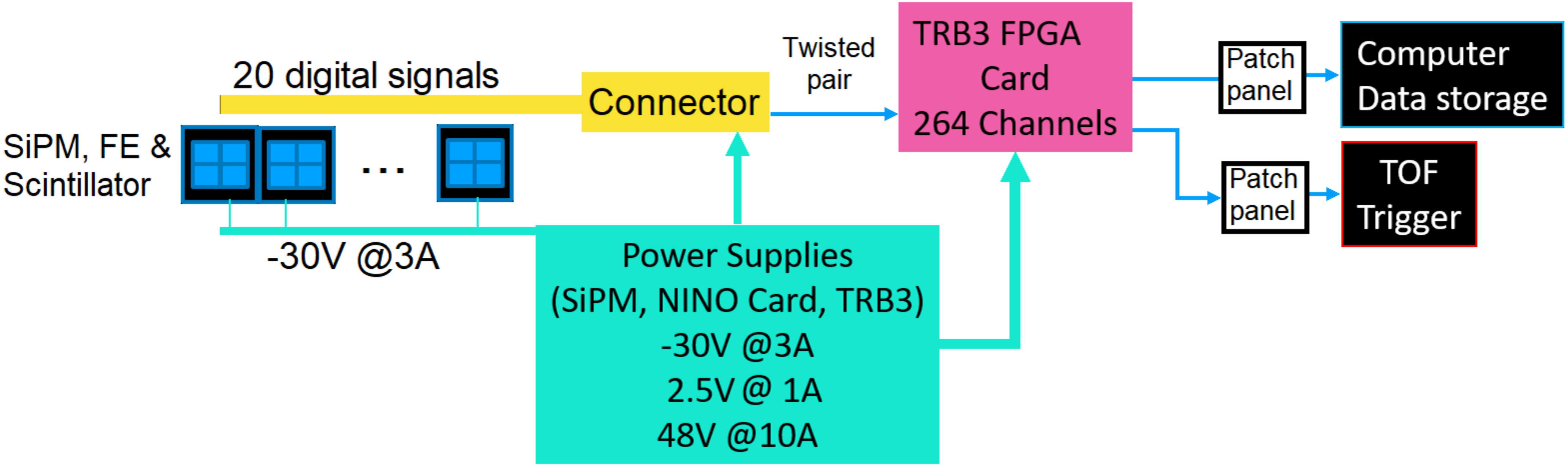




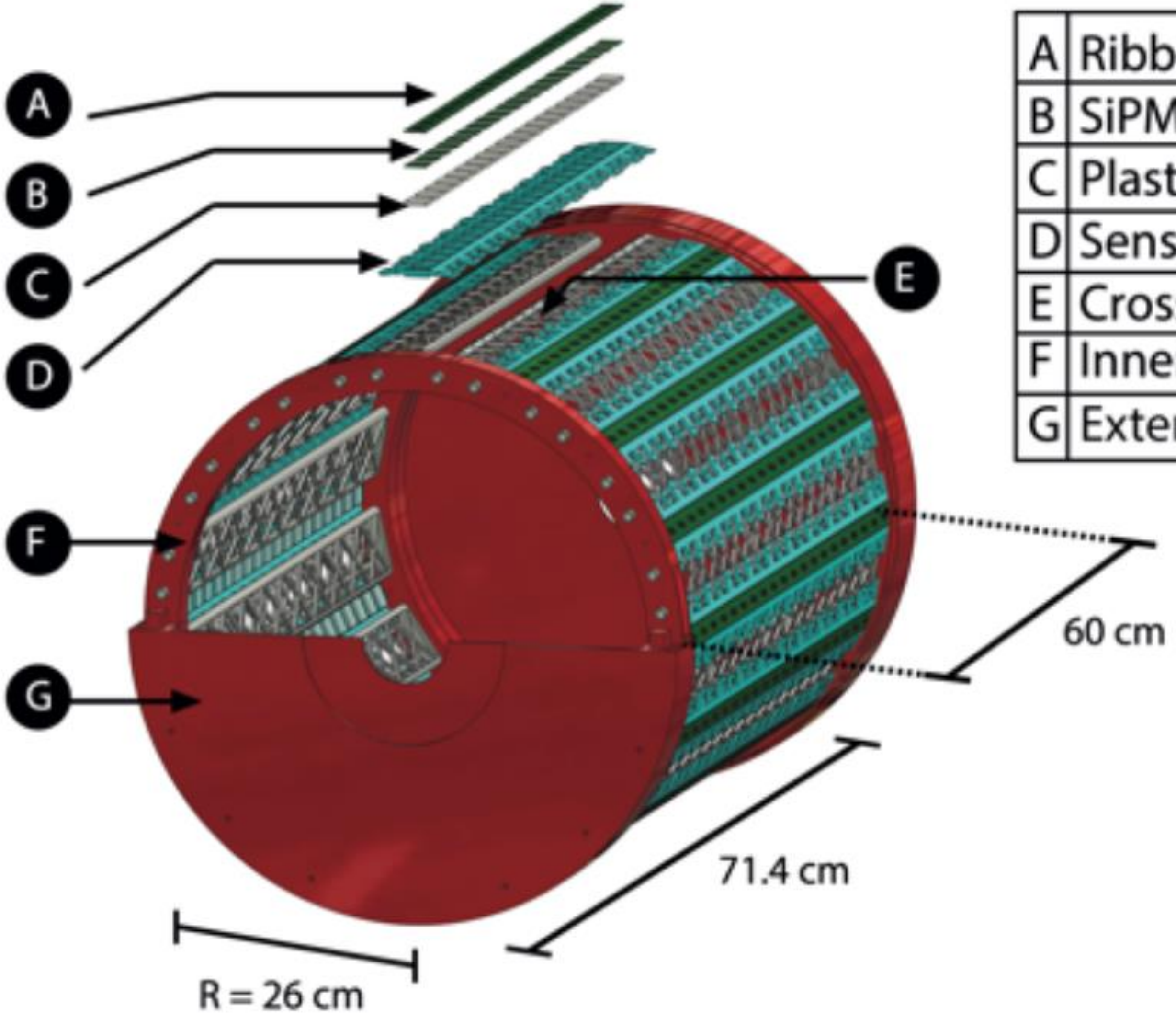
MiniBeBe design

Baseline design and future design

General scheme MiniBeBe

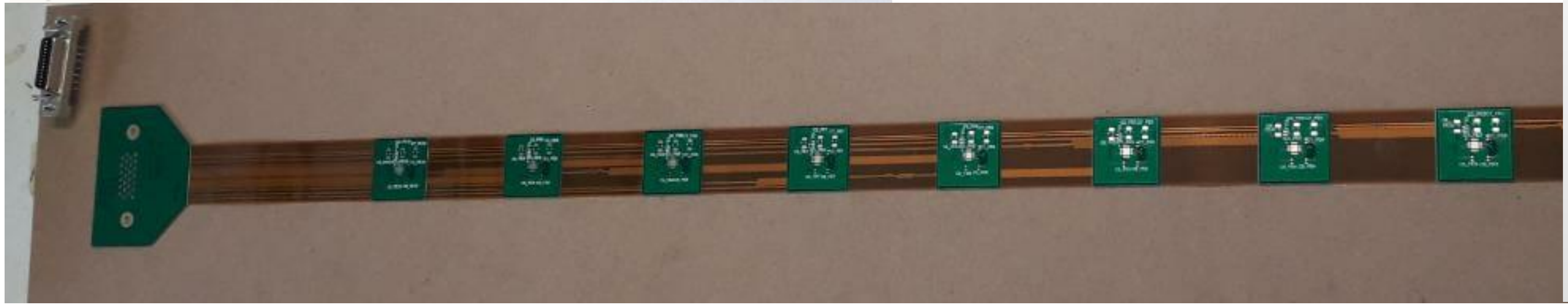


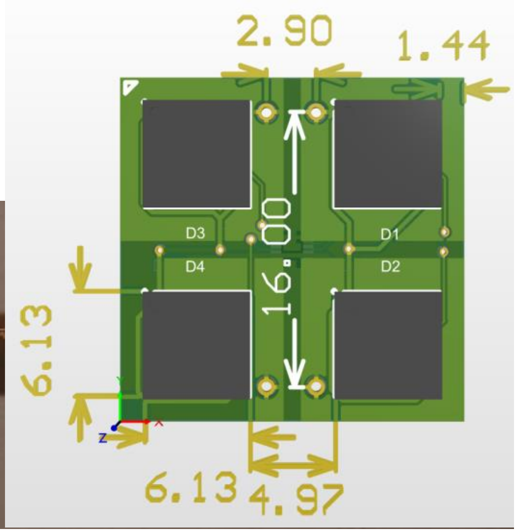
MiniBeBe baseline design

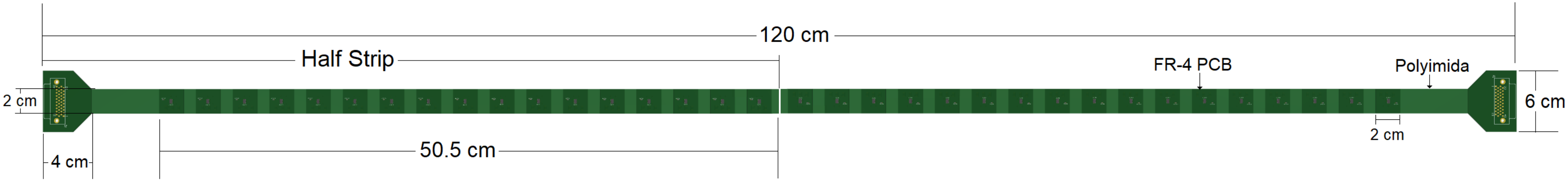


A	Ribbon PCB
B	SiPM card
C	Plastic scintillator
D	Sensor rail
E	Cross bar
F	Inner ring
G	External flange

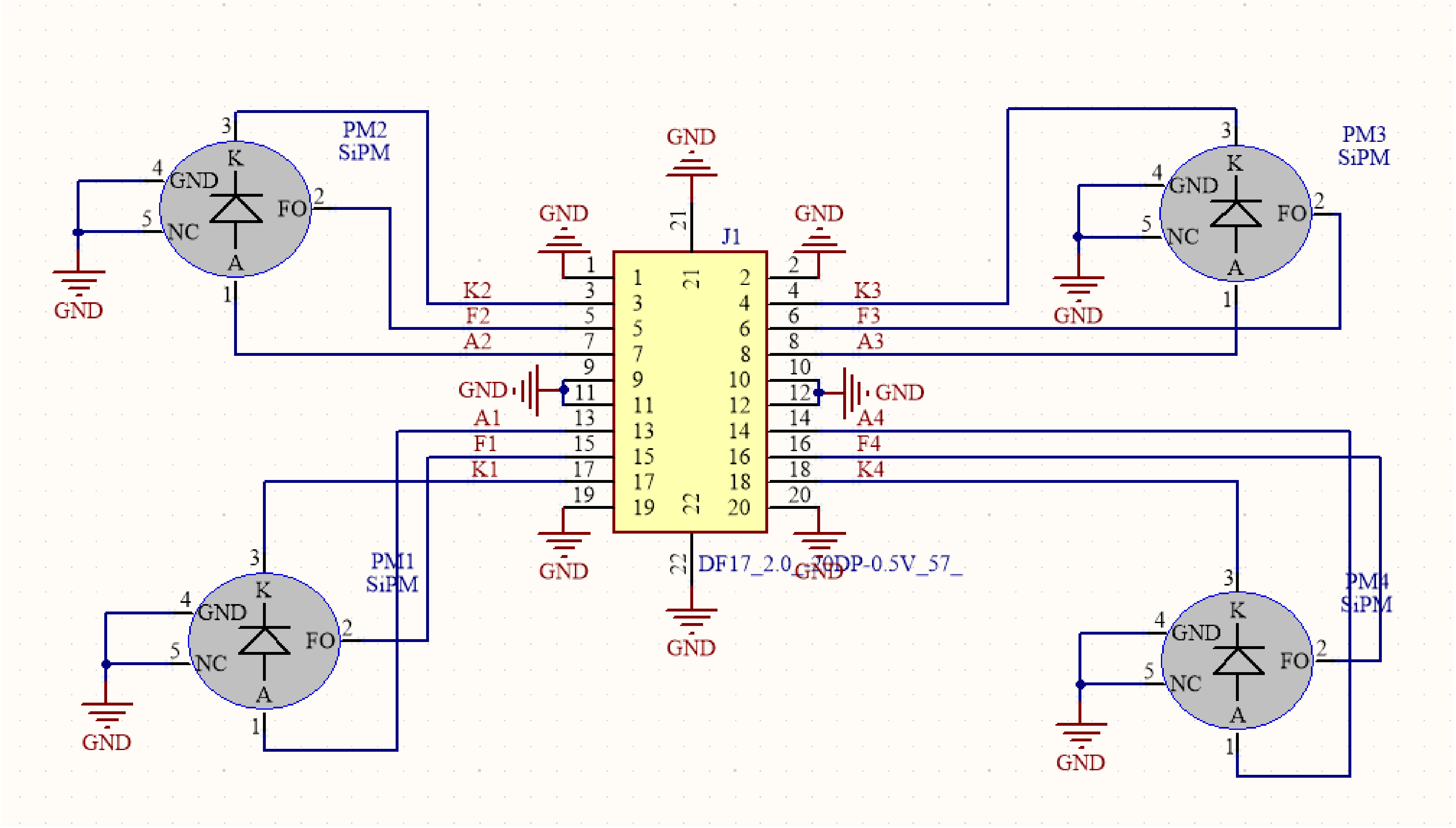
MiniBeBe baseline

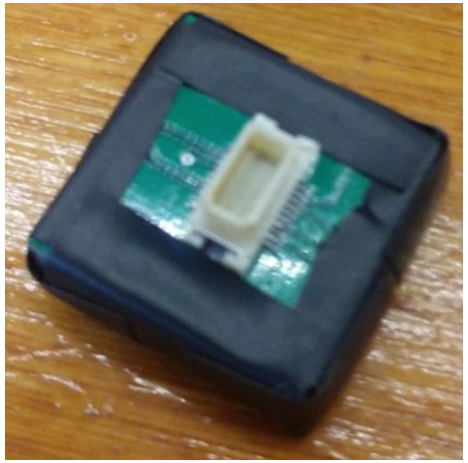


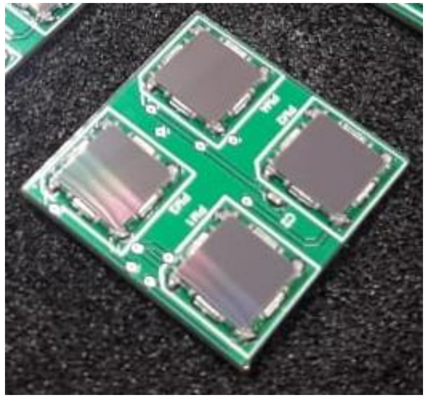




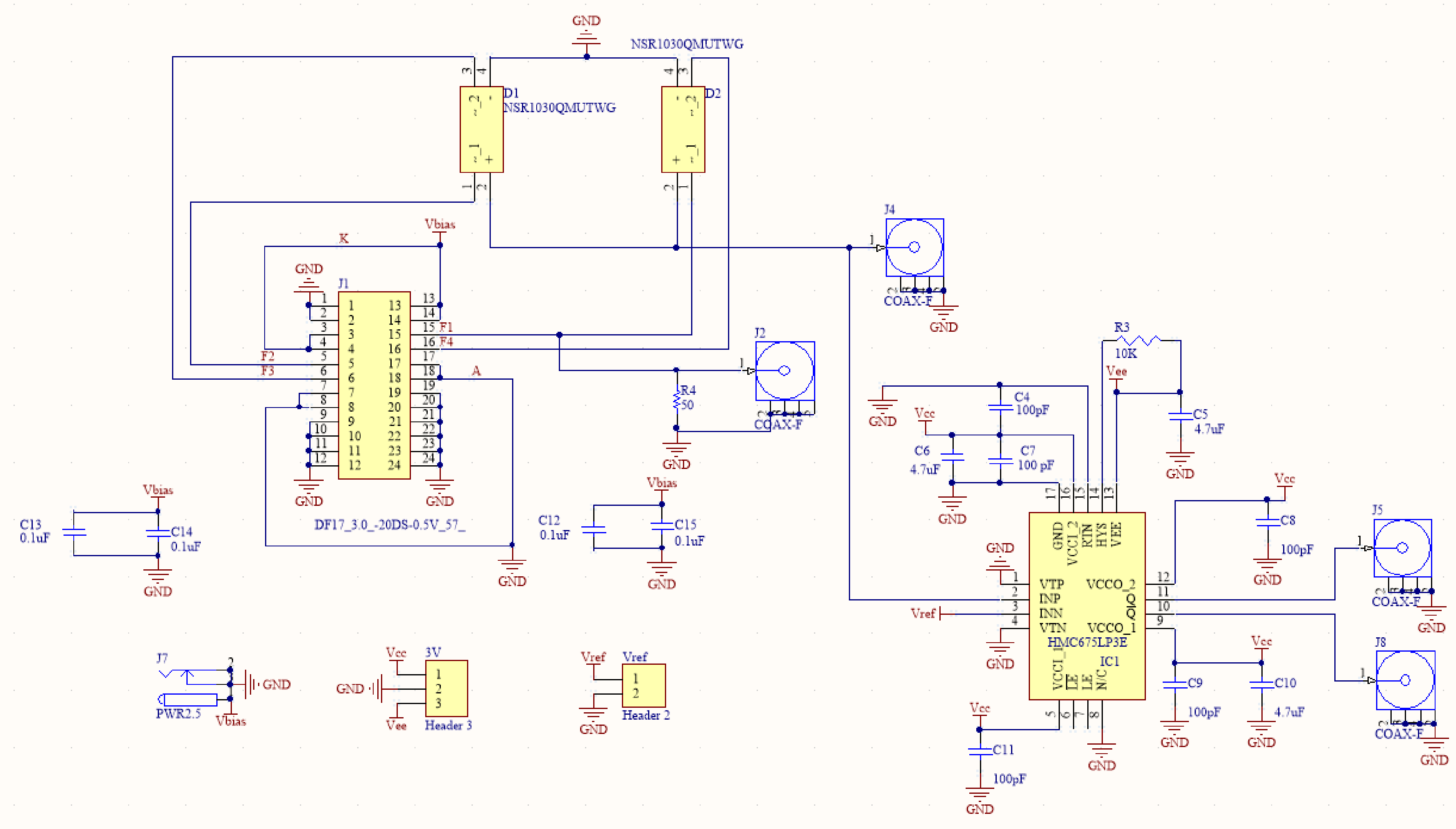
SFED Card

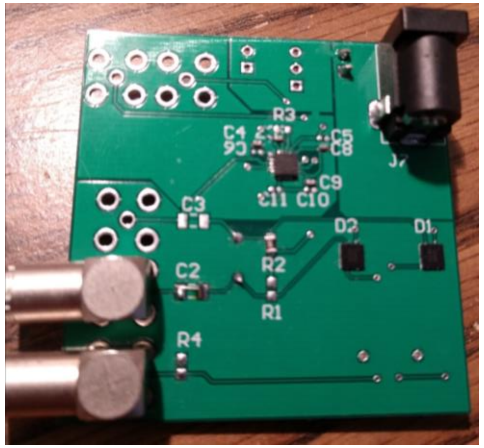

PM1
SiPM
PM2
SiPM
PM3
SiPM
PM4
SiPM
J1
DF17_2.0_20DP-0.5V_57_
K1
F1
A1
K2
F2
A2
K3
F3
A3
K4
F4
A4
GND
K
A
FO
NC

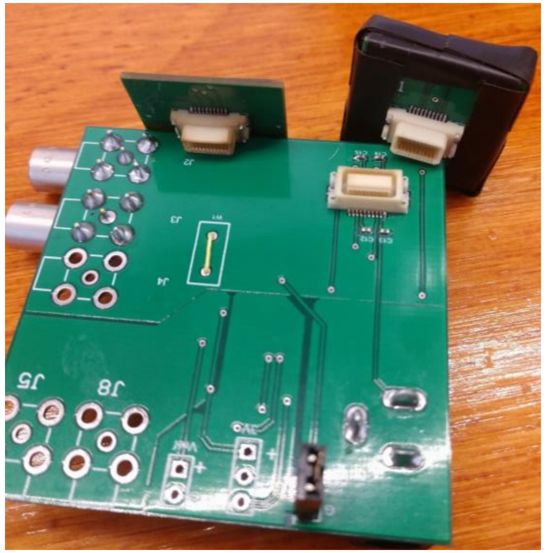




Single channel detector



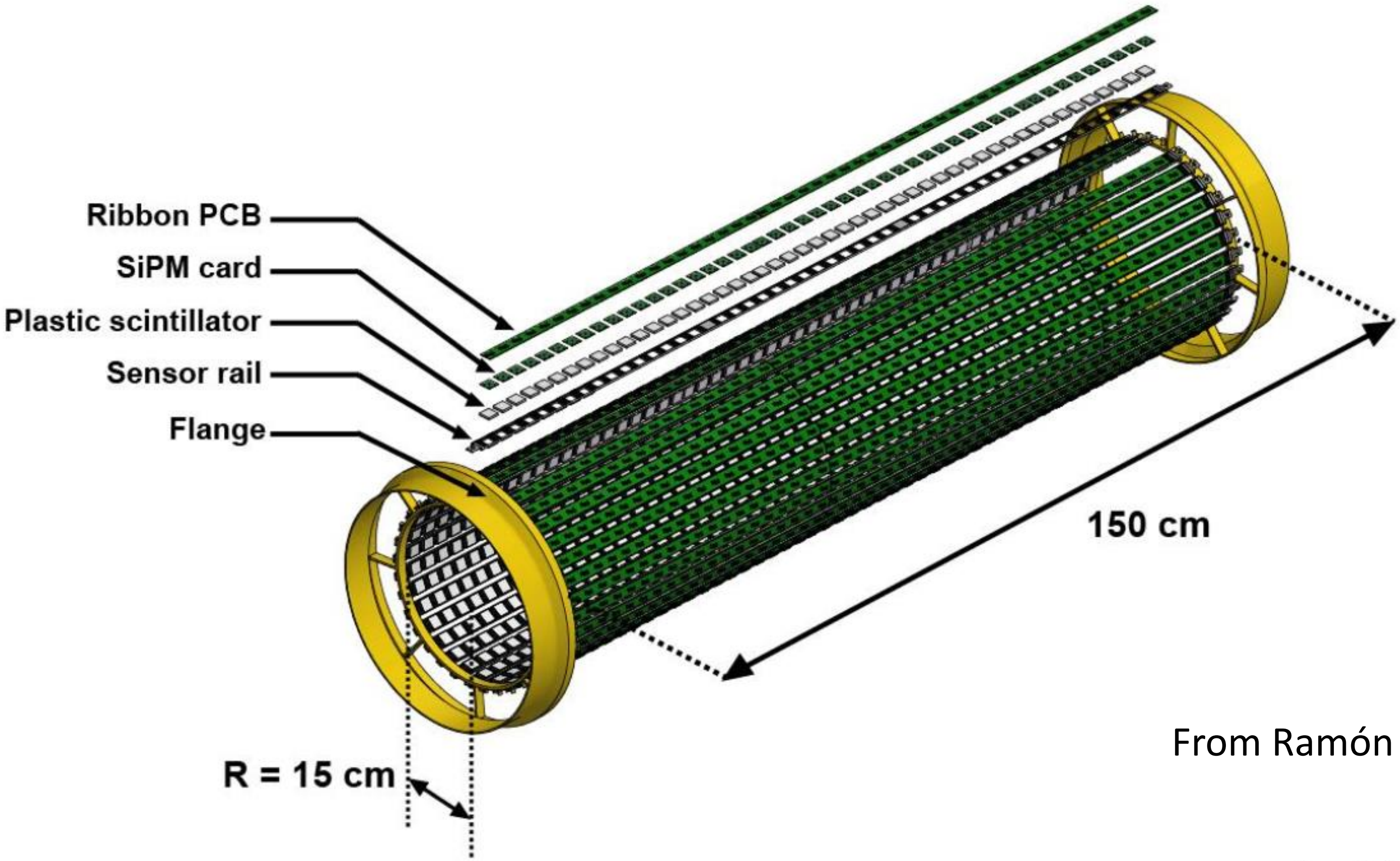




Triggering circuit

- HMC674 ultra fast comparator.
- Equivalent input bandwidth: 9.3 GHz typical
- Propagation delay: 85 ps typical
- Overdrive and slew rate dispersion: 10 ps typical
- Input signal minimum pulse width: 60 ps typical
- Resistor programmable hysteresis
- Differential latch control
- Power dissipation: 140 mW typical
- Reduced Swing Positive Emitter-Coupled logic (RSPECL) output

New MiniBeBe design



- 32 strips
- 48 cells/strip

From Ramón Acevedo's presentation

L=150 cm , R=15 cm

Conclusions

- Using the fast output signal from SiPM we can estimate the deposited charge.
- Parallel interconnection of four SiPM is posible with some timing benefits.
- The MiniBeBe baseline was the first step for a complete design.
- The new MiniBeBe design is under test for soon fabrication.
- The new design will include heat dissipation.

Thank you!