



UNIVERSIDAD NACIONAL
DE ASUNCIÓN
FACULTAD DE
INGENIERÍA

Design of the Active Ganging boards

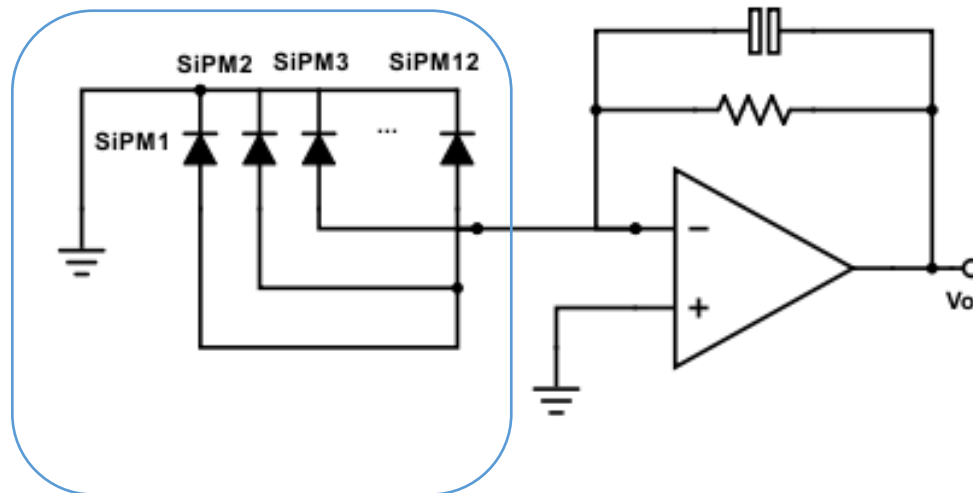
**Esteban Cristaldo, Jorge Molina
Carlos Montiel, Diego Aranda**

**DUNE-SP Photon Detection System
Conceptual Design Review**

November 12th, 2018

CASE OF STUDY

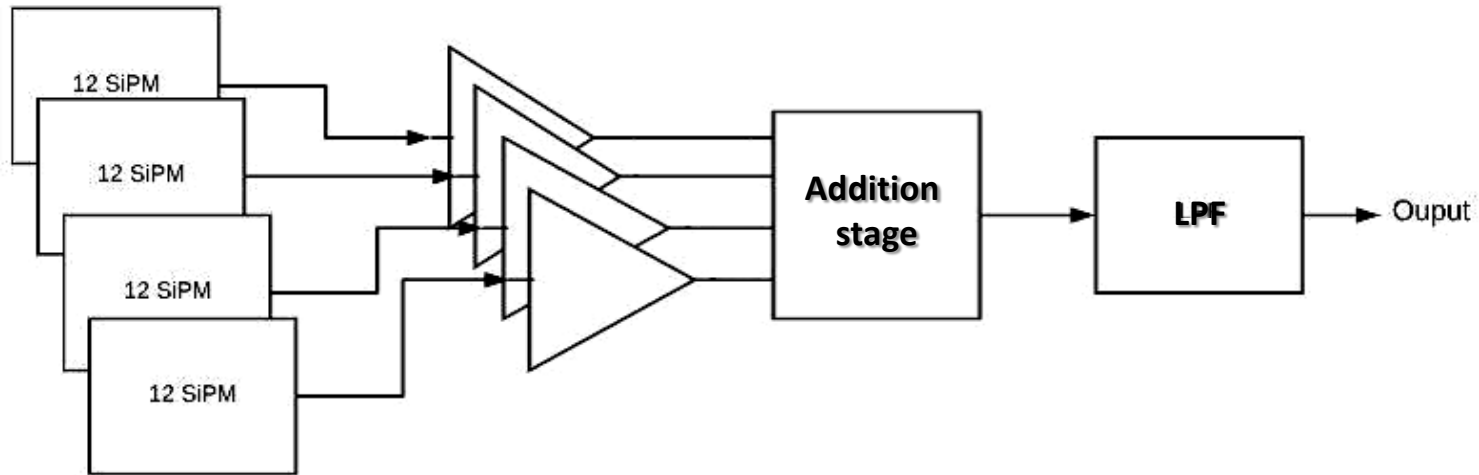
We want to know if we can amplify **12** SiPM in parallel (active *ganging*) with one output channel.



We simulate a Charge amplifier transimpedance model and a Charge integrator model

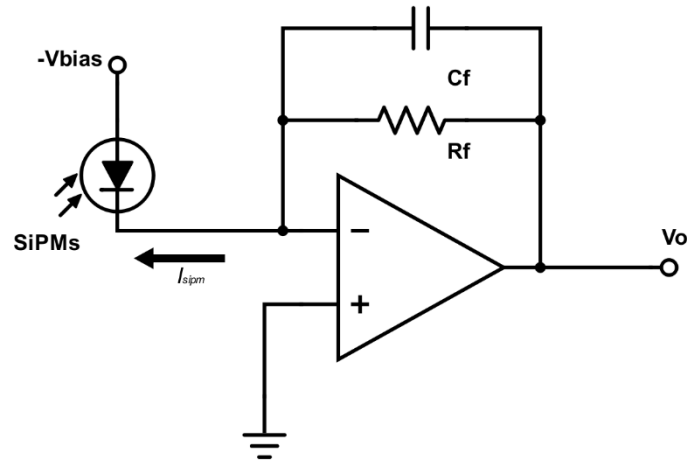
Design scheme

Three stages of the circuit for 48 SiPM:



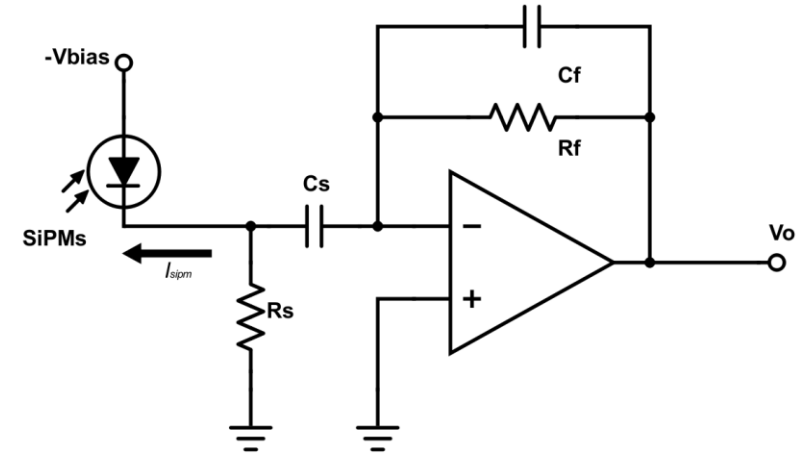
Charge integrators
or transimpedance

Two preamps models studied



Transimpedance model

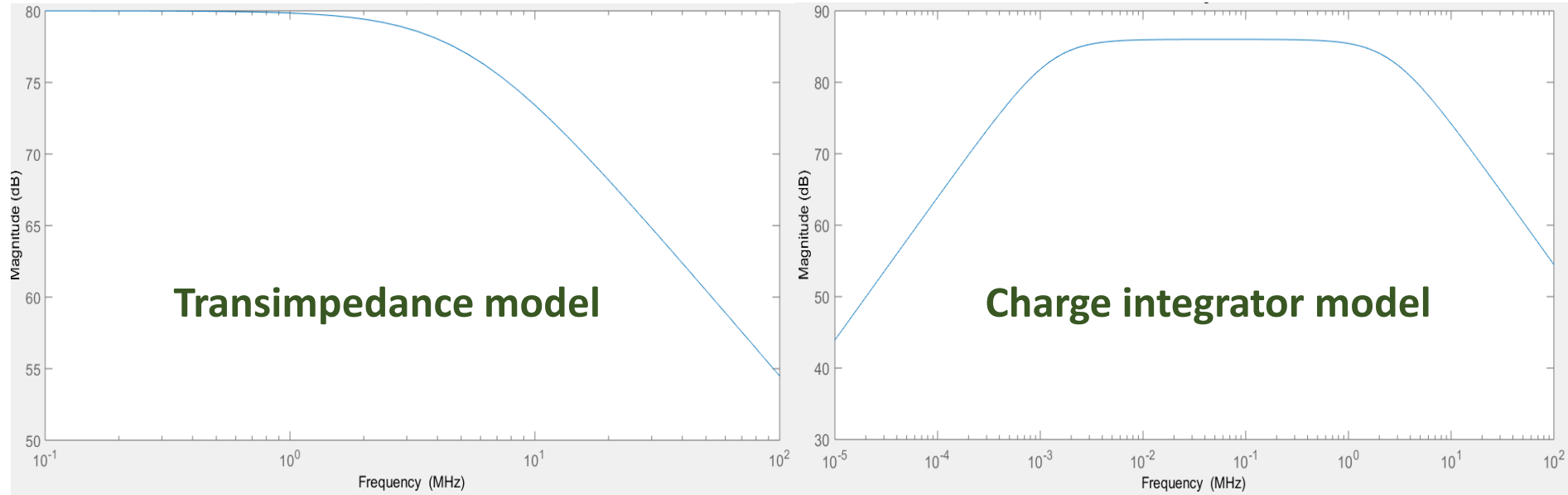
- This is a first order low pass filter
- R_f and C_f establish the bandwidth and frequency cut point
- Eliminates high frequency noise



Charge integrator model

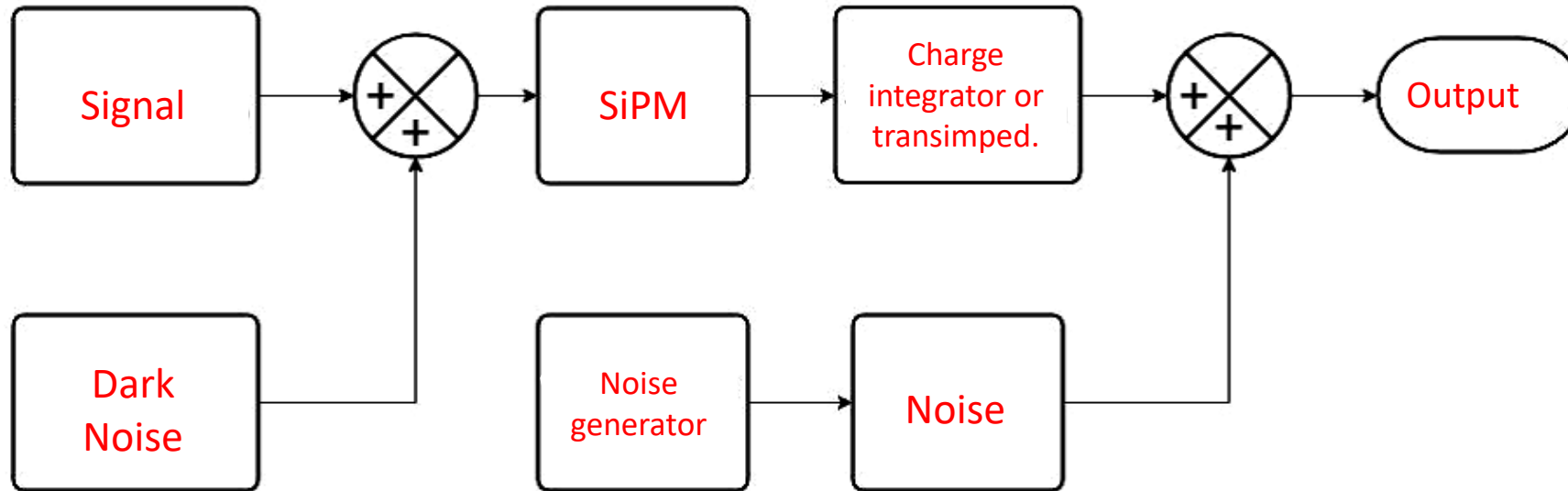
- This is a second order band pass filter
- C_f and C_s establish the bandwidth and frequency cut point
- Eliminates low and high frequency noise

Comparison between Transimpedance and Charge Integrator



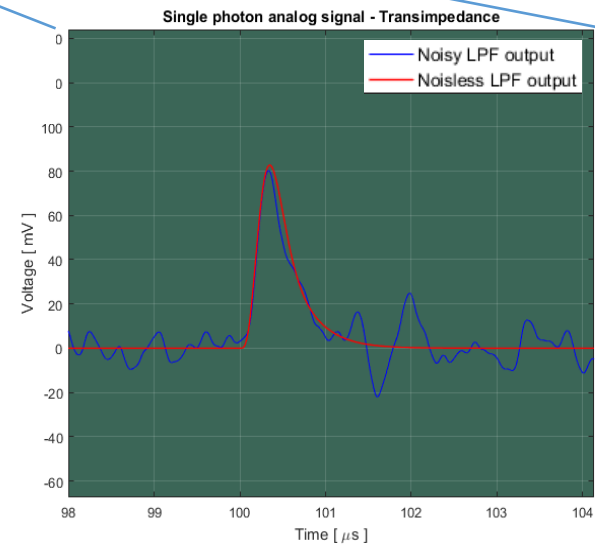
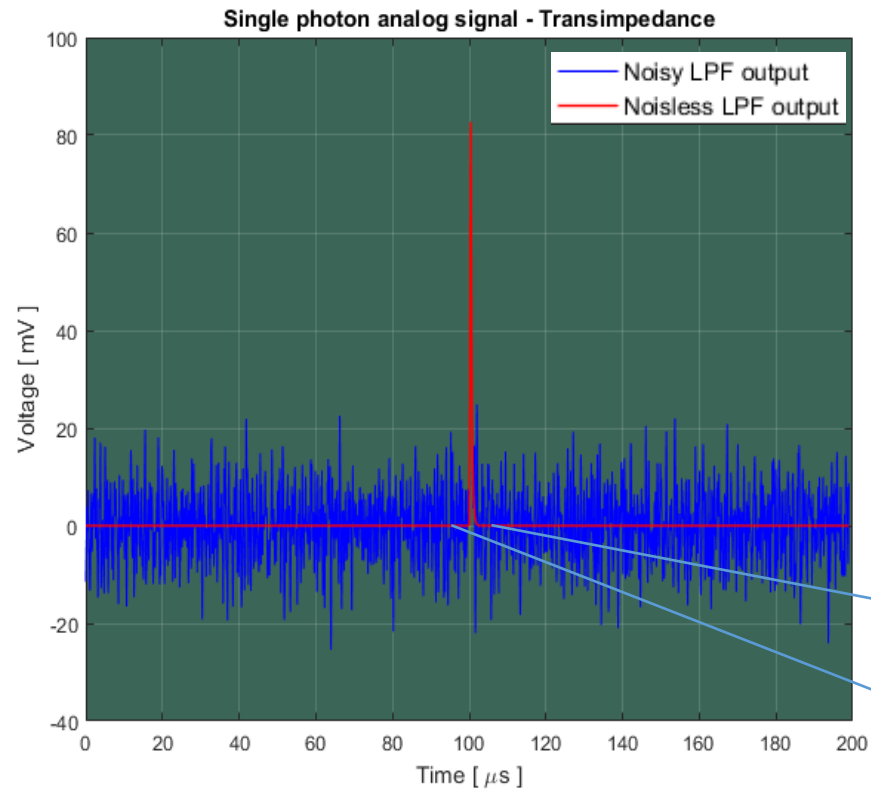
- **Cut of 20 dB per decade.**
- **Range of frequency from zero to first pole (with low frequency noise)**
- **Direct coupling from the SiPM to the filter.**
- **Cut of 40dB per decade**
- **Range of frequency from the first to second pole.**
- **The SiPM is connected to the decoupling capacitor.**

Simulation outline

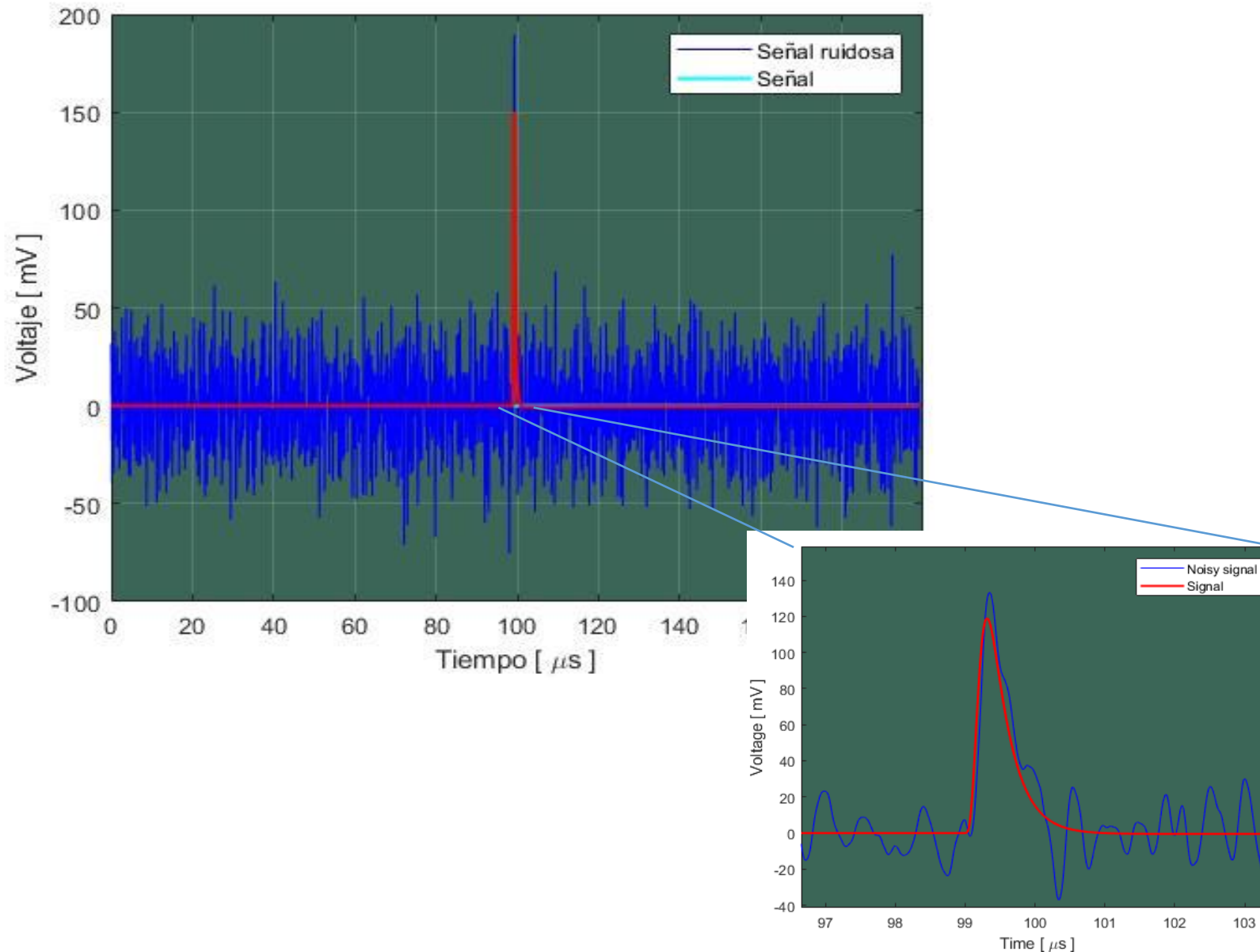


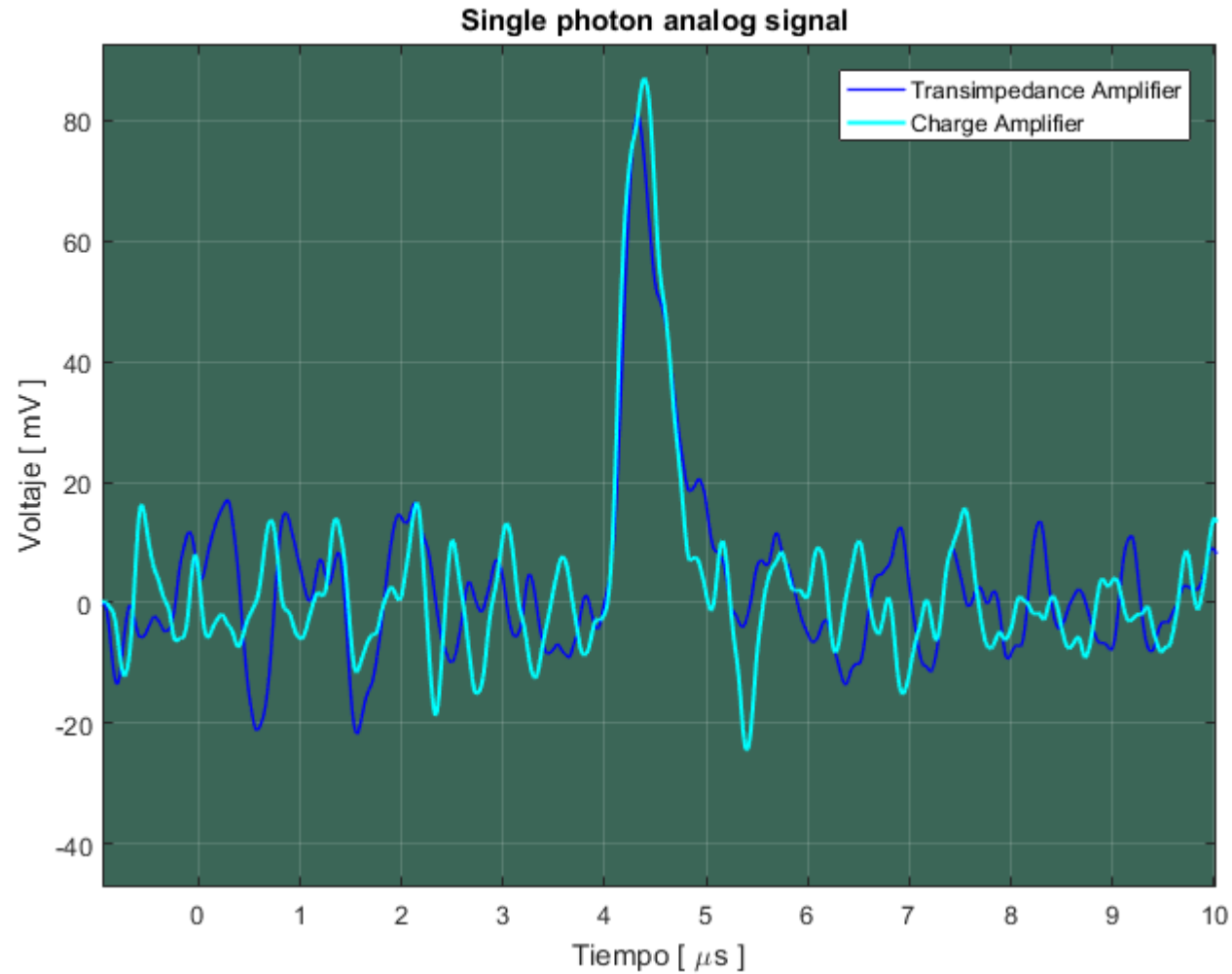
Both models are running using Hamamatsu's parameters for single photon analysis at LAr temperatures (thanks to Vishnu for sending the detector parameters!)

Results for the transimpedance



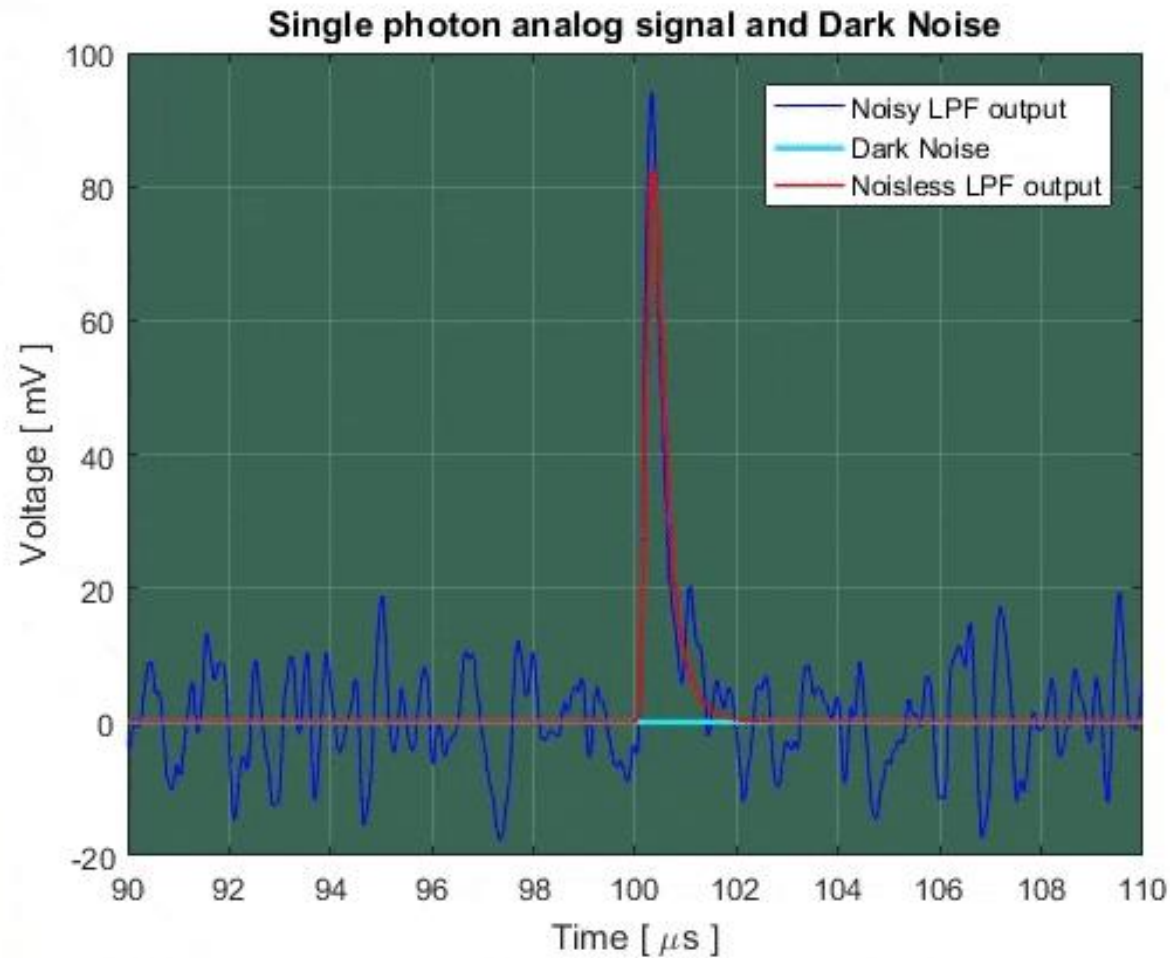
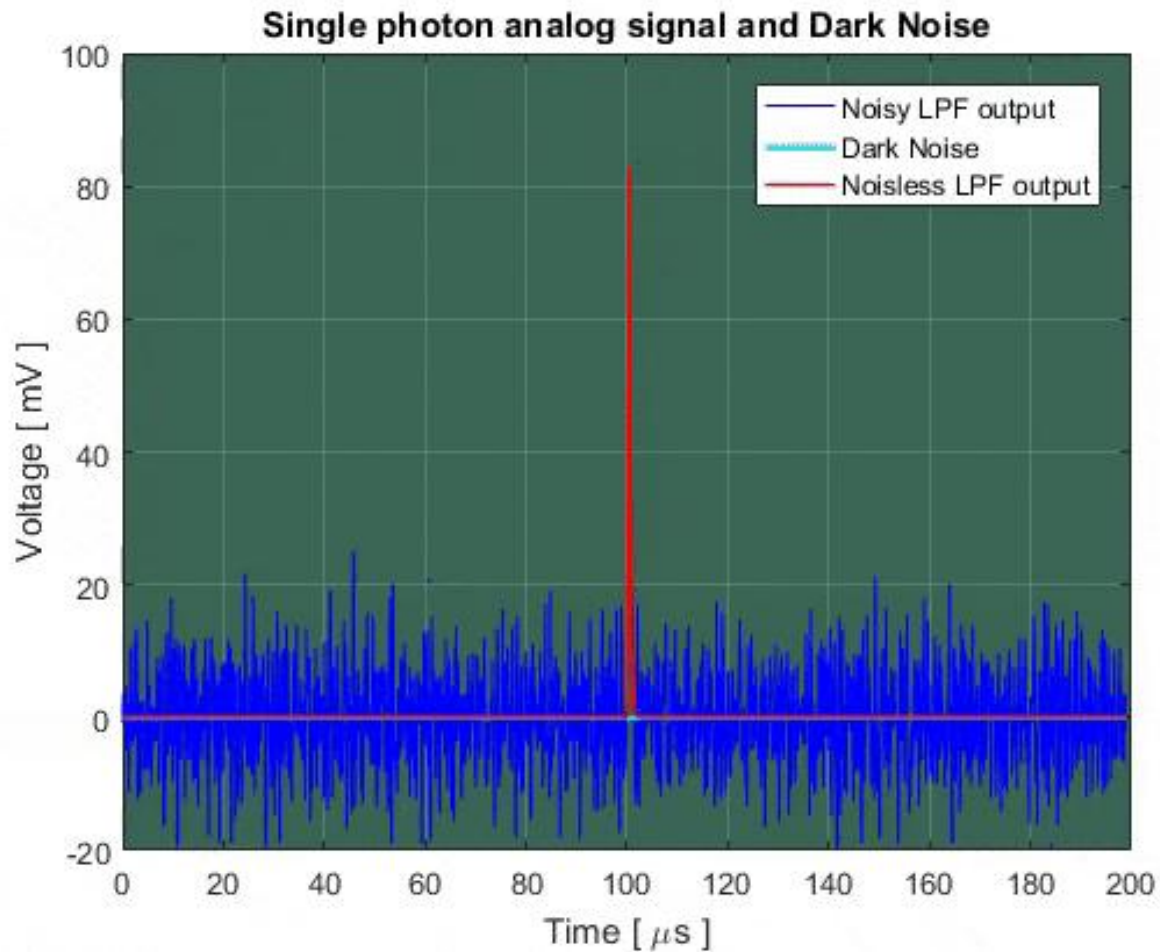
Results for charge integrator





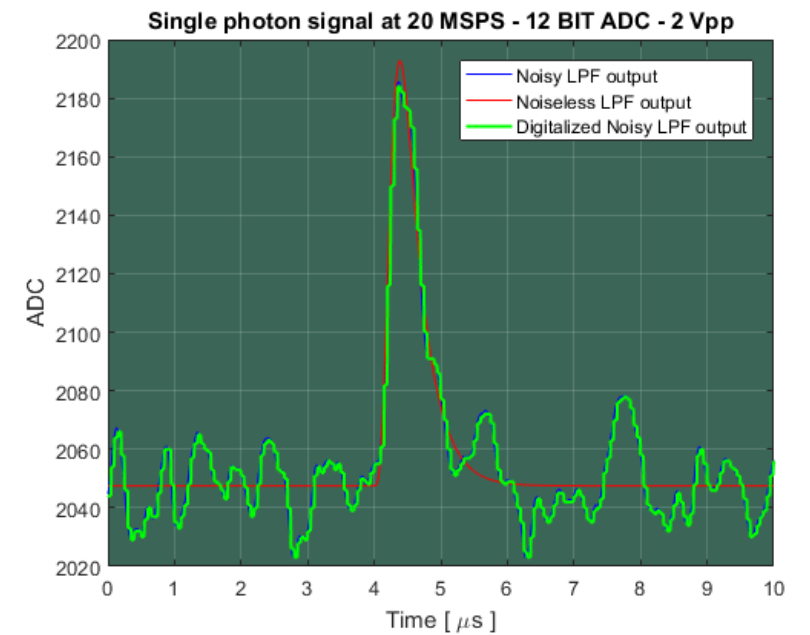
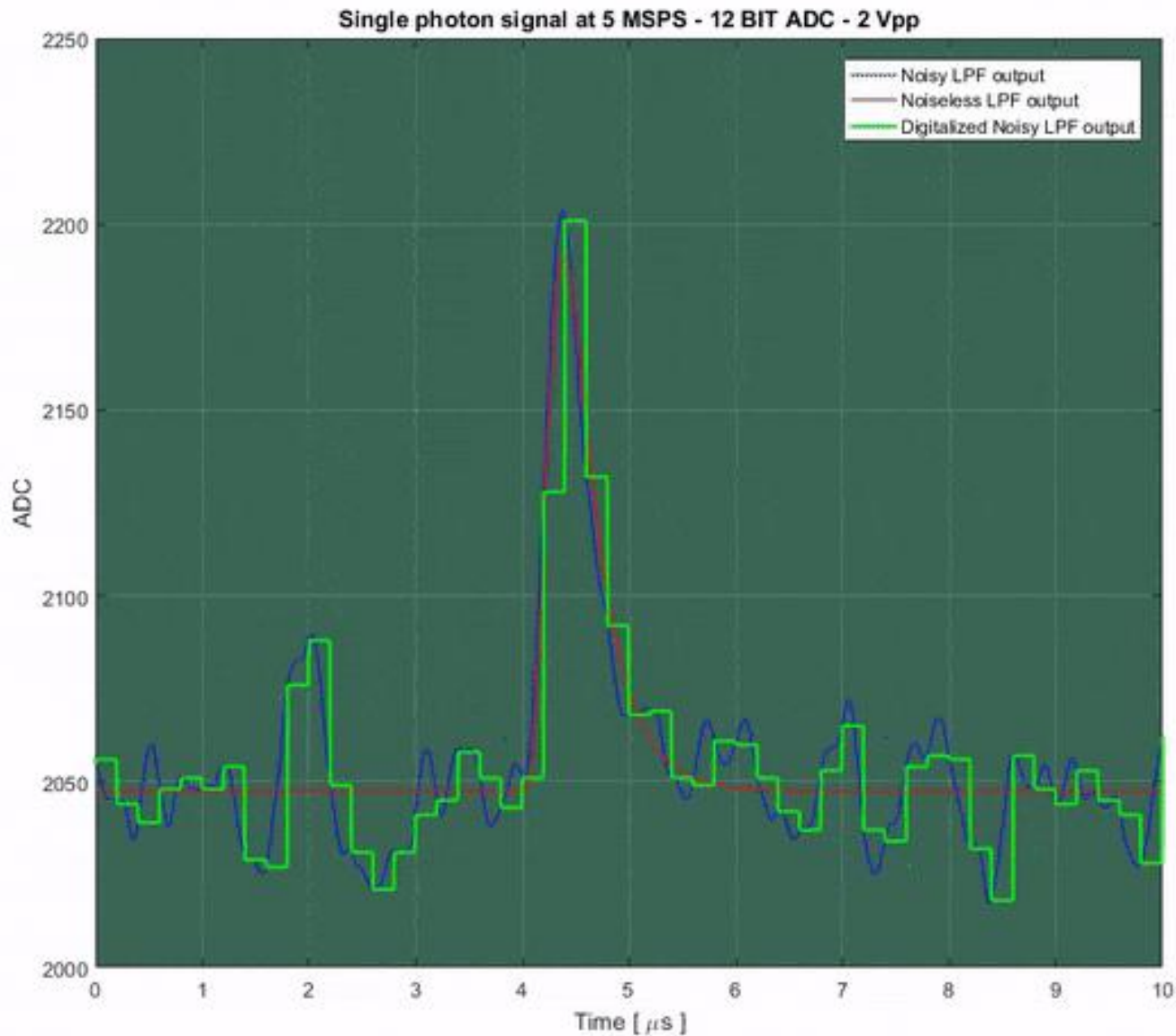
We cannot see a big difference between them in the response. The best values of SNR the we obtained are about 8 dB and a 1 μs of settling time in both topologies.

Dark noise for 48 SiPM



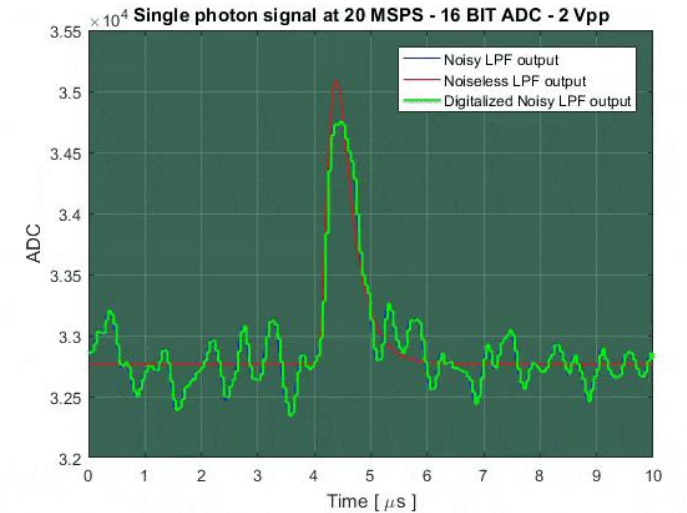
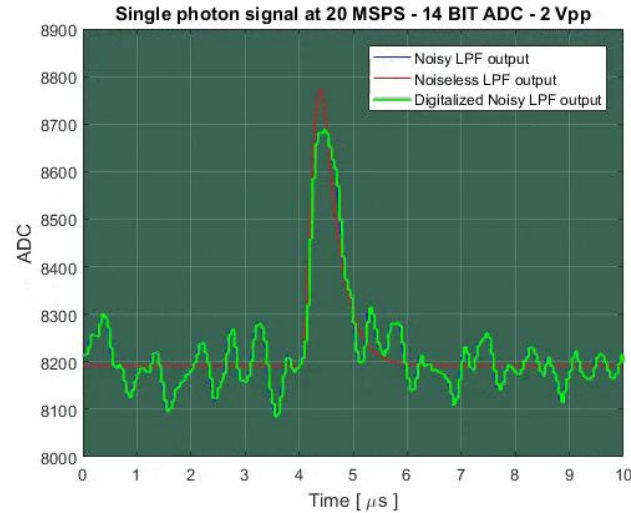
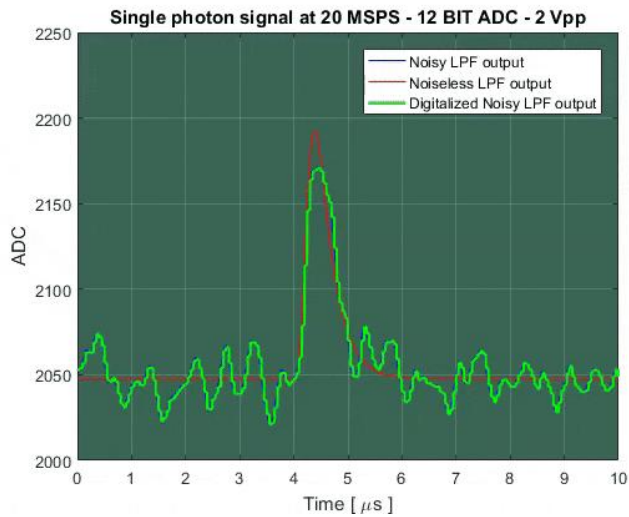
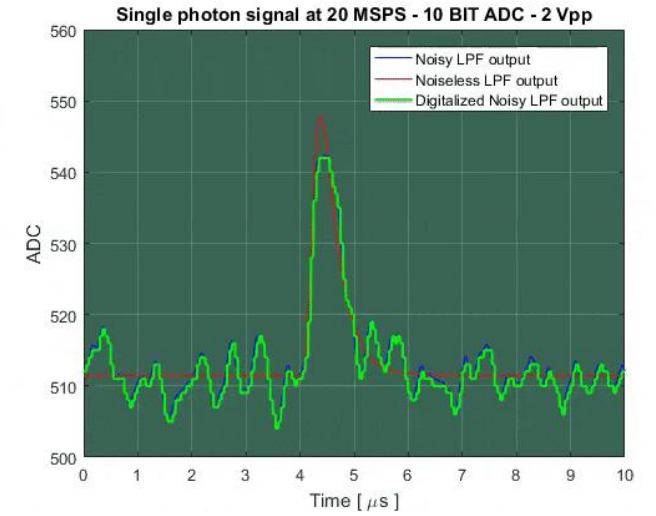
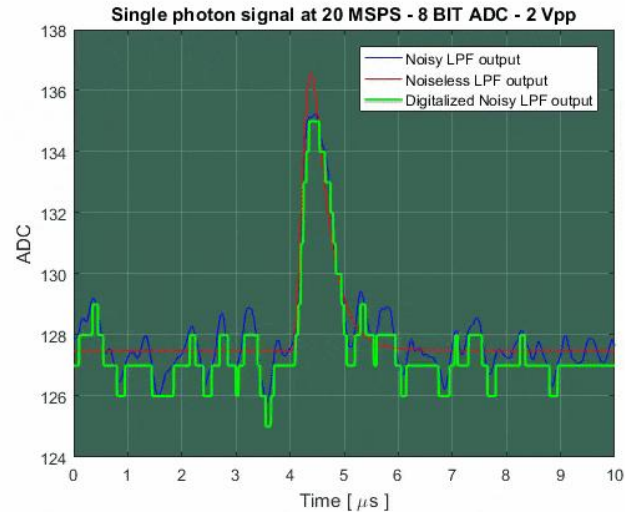
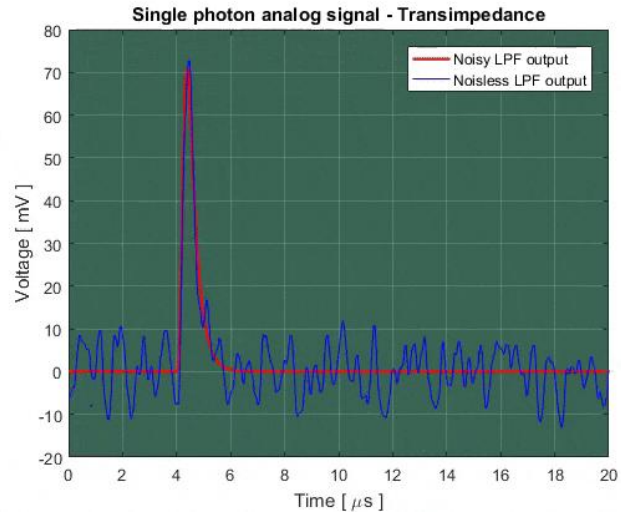
We see that we should no worried about the dark noise

How many samples per second?



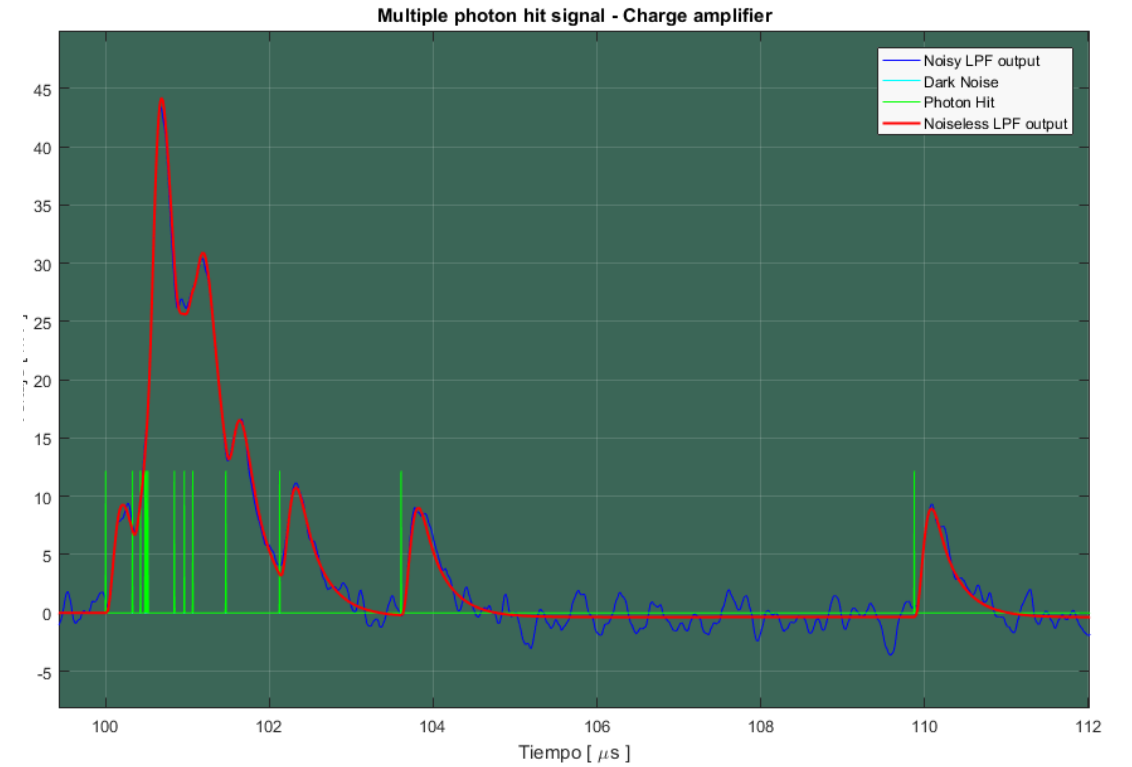
We think that we can do well with a 20 MSPS

How many bits for dynamic range?



Results for transimpedance preamp

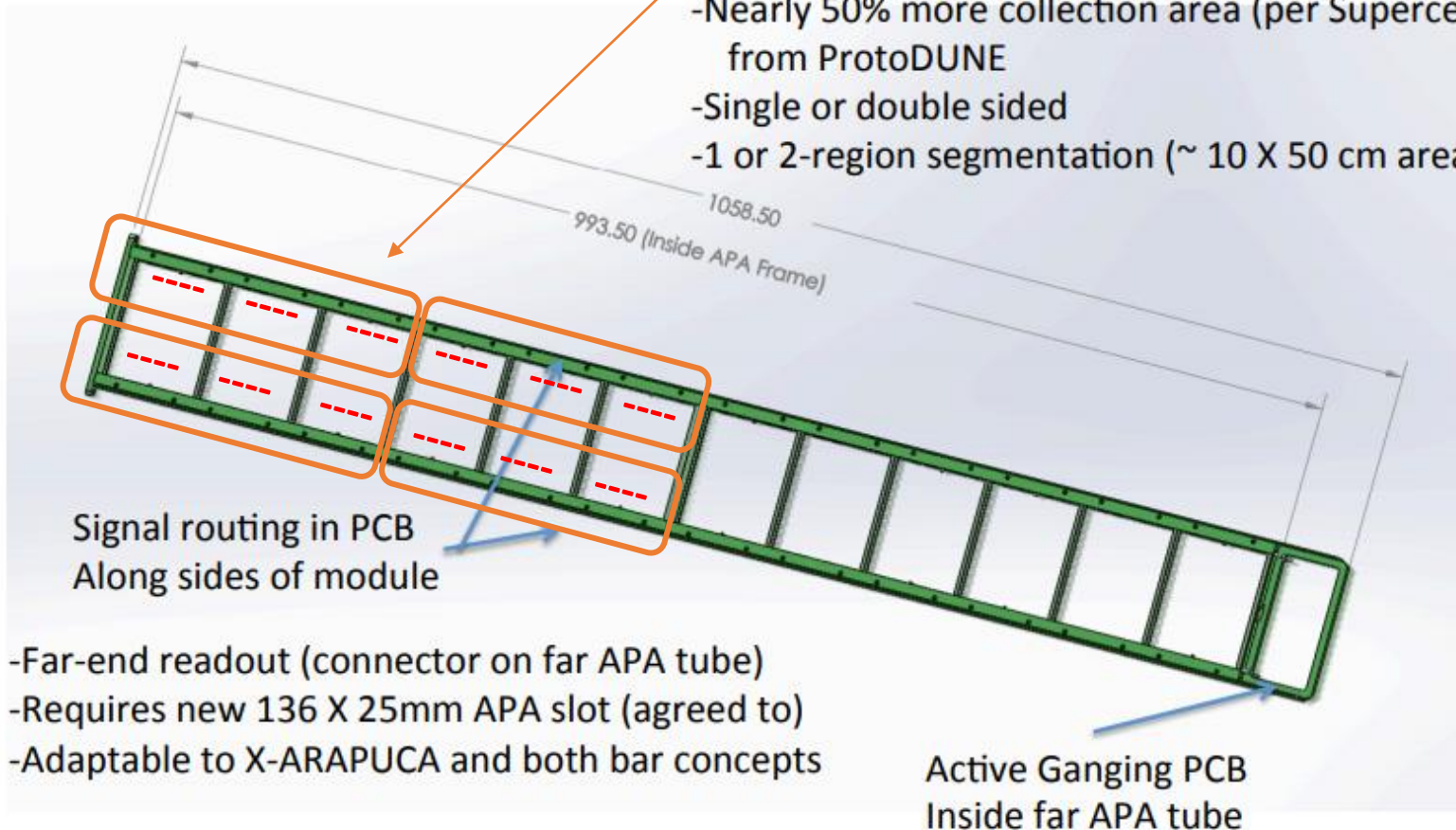
Random generation of 10 photons striking the detectors in one channel



COLD ELECTRONICS TESTS

Two-Supercell ARAPUCA PD Concept

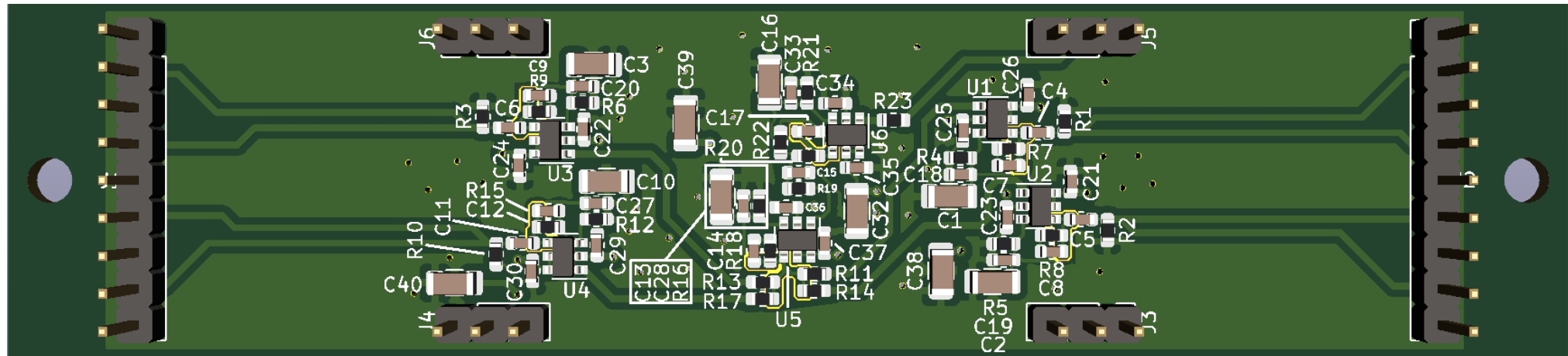
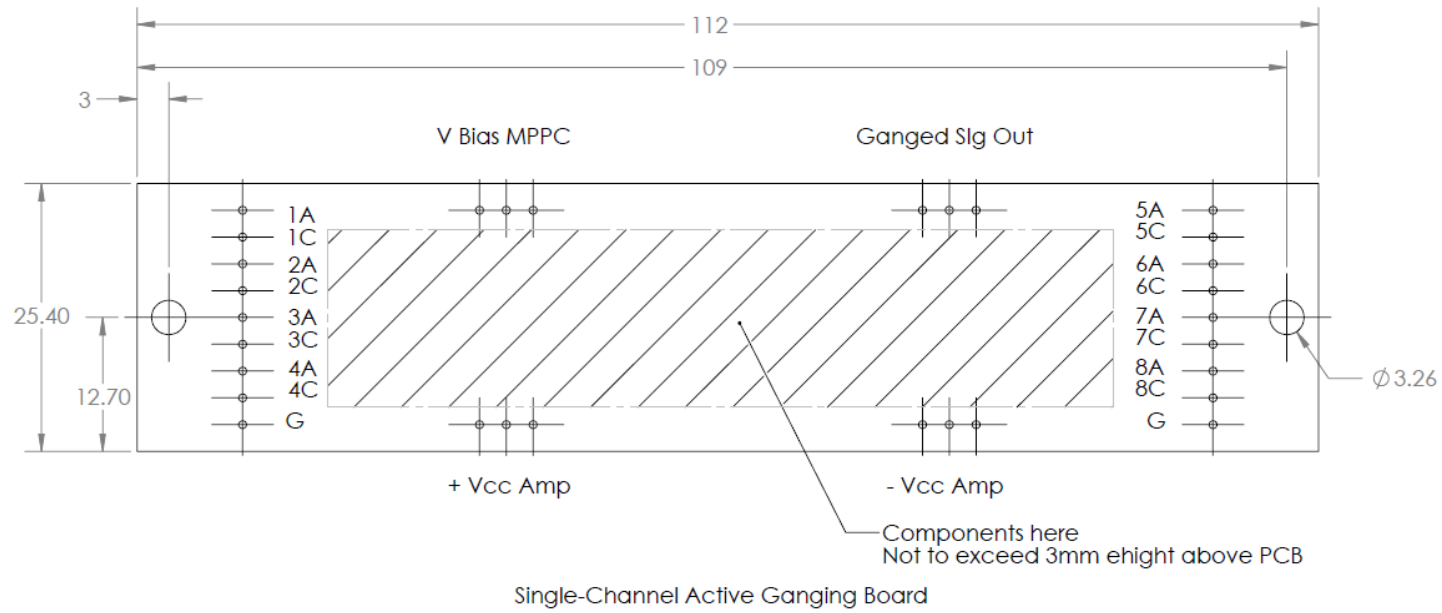
- 1 or 2 Supercells/module
- 48 MPPCs/Supercell
- **4 boards with 12 actively ganged hammamatsu SiPM**
- Nearly 50% more collection area (per Supercell) from ProtoDUNE
- Single or double sided
- 1 or 2-region segmentation (~ 10 X 50 cm area)



Signal routing in PCB
Along sides of module

- Far-end readout (connector on far APA tube)
- Requires new 136 X 25mm APA slot (agreed to)
- Adaptable to X-ARAPUCA and both bar concepts

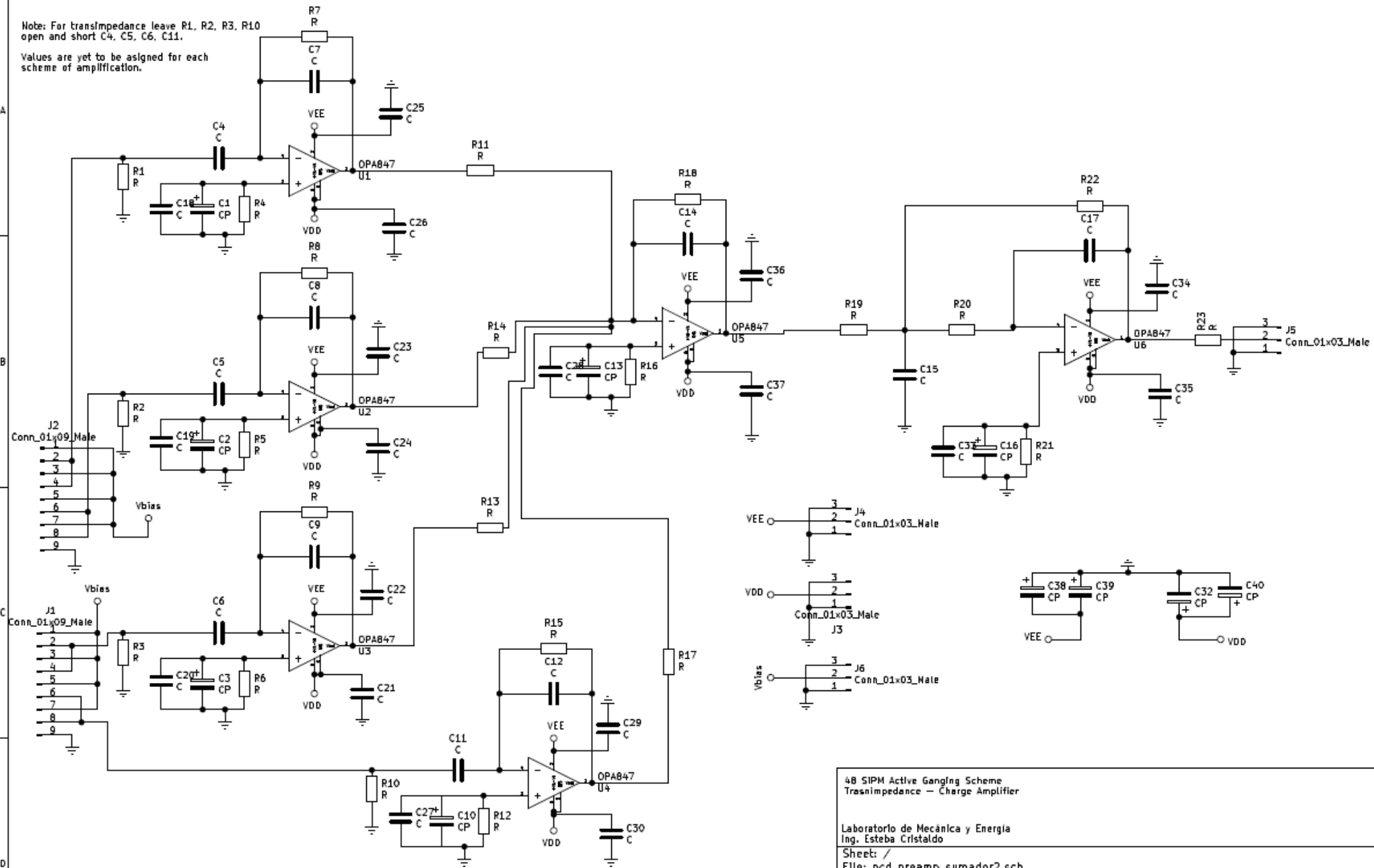
Active Ganging PCB
Inside far APA tube



For transimpedance R1, R2, R3 & R10 left open; and C4, C5, C6 & C11 are shorted

Note: For transimpedance leave R1, R2, R3, R10 open and short C4, C5, C6, C11.

Values are yet to be assigned for each scheme of amplification.



48 SIPM Active Ganging Scheme
Transimpedance - Charge Amplifier

Laboratorio de Mecánica y Energía
Ing. Esteba Cristaldo

Sheet: /
File: pcd_preamp_sumador2.sch

Title: Active Ganging PCB

Size: A4 Date:

KiCad E.D.A. eeschema (5.0.0)

Rev: 1.0

Id: 1/1

Current scientific requirements

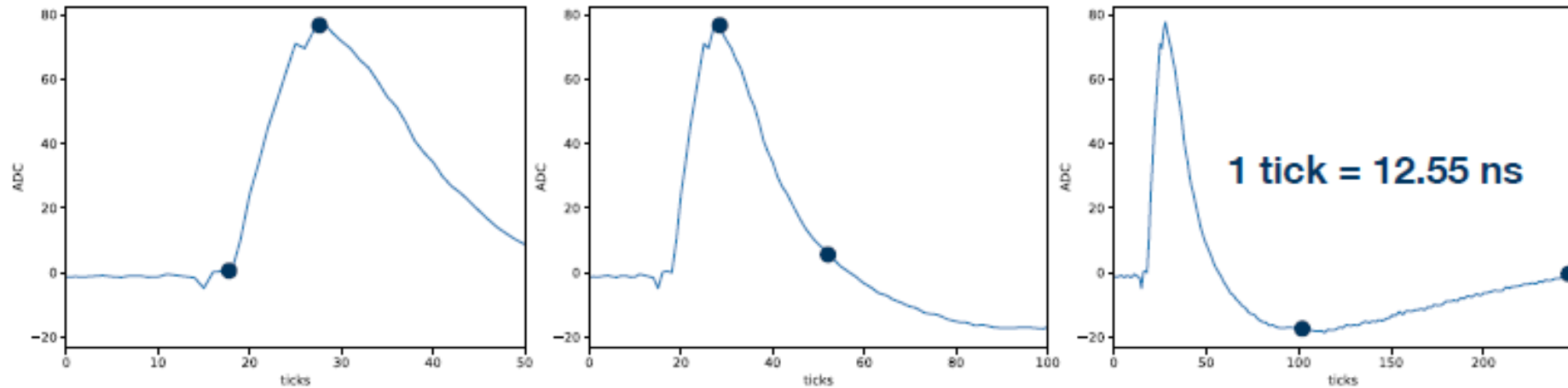
Item	Type	System	Quantity/Parameter	Requirement	Goal	Explanation	Comments	Notes
1	Scientific	SP-PD	light-yield	> 0.5 pe/MeV	> 5 pe/MeV	Minimal requirement is for light-yield to be sufficient for measuring event time (and total intensity) of events with visible energy above 200 MeV. Goal is to make possible a 10% energy measurement for events with a visible energy of 10 MeV.	Minimal requirement is based on events occurring near the cathode, for which the produced photons need to travel furthest to reach the photon detectors.	The minimum requirements are based on determining T0 for nucleon decay events, and the goals are based on a high-level estimate of the needs for supernova physics. We are currently in the process of determining the detector specifications needed for a set of supernova physics goals, some of which may lead to new requirements for the TDR, depending on the outcome of the simulation studies and the measurements at protoDUNE and ICEBERG.
2	Scientific	SP-PD	time resolution	< 1 μ s	< 100 ns	Based on the minimal energy deposition (10 MeV), spatial separation (1 m), and temporal separation (1 ms) for which one wants to assign a unique event time.	Time resolution of 1 μ s is required to have position resolution along the drift direction of about 1 mm. This is to match the resolution due to the wire spacing.	Goal value is readily obtainable from a technological perspective.

Conclusions

- 1. We presented a very powerful tool that can be used in the design of the electronics needed.**
- 2. We showed that is possible to gang 48 SiPM and distinguish single photon signals with less than 1 μ s width (recovery time included).**
- 3. For single photons there is no significant difference between both models in duration of the pulse and S/N ratio. Preliminary simulations indicates that for 10 photons we don't see any difference either.**
- 4. The S/N ratio obtained is about 8 dB, with all noise effects included (thermal, DN).**
- 5. The optimal sampling rate obtained is $>\approx$ 20 MSPS.**
- 6. The design of the board for the ICEBERG test stand is ready and in process of fabrication. It includes both designs in the same board, that can be easily exchanged.**

Backup slides

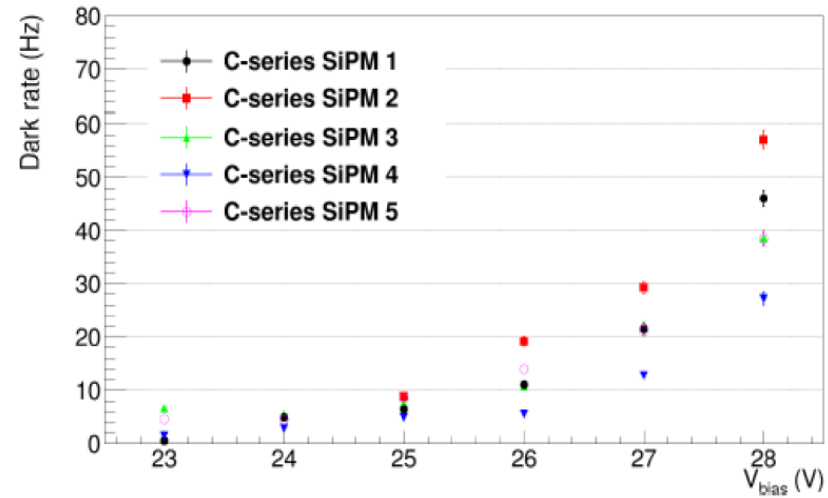
mean signal



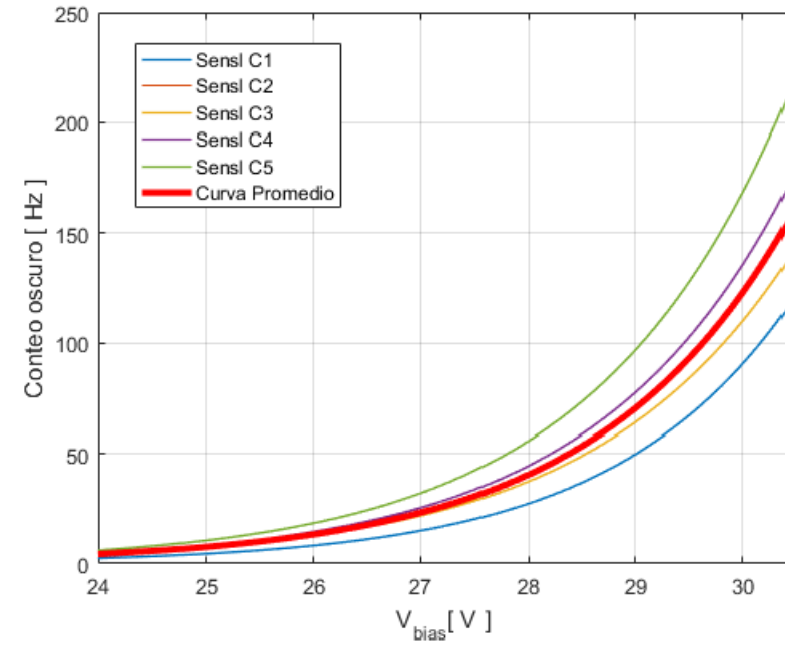
- Rise time: 125 ns
- Fall time: 350 ns
- Recovery time: $O(2\mu s)$ – what's shown on the right is as wide a window as the FEB allows

DARK NOISE

DCR a T = 80 K



*Yujing Sun, Jelena Maricic, Marc Rosen
University of Hawaii at Manoa*



$$\lambda = ae^{bx}$$

$$x = \frac{V_{bias} - \mu}{\sigma}$$

Dark Count Rate

SSP				hwb1	hwb2		
setting	Vop	Vbr	Vovr	dcr(Hz)	dcr(Hz)		PDE
165	33	31.5	1.5	1	1		
170	34	31.5	2.5	12.9	9.2		45%
175	35	31.5	3.5	18.2	15.1		
180	36	31.5	4.5	47.9	34.5		
SSP				tsv1	tsv2	cryo1	
setting	Vop	Vbr	Vovr	dcr(Hz)	dcr(Hz)	dcr(Hz)	PDE
220	44	42	2	3	1.2	3	
225	45	42	3	7.3	8.9	4.7	
230	46	42	4	19.5	9.5	6.5	46%
235	47	42	5	16.5	10.4	6.7	
240	48	42	6	20.3	13.2	9	
SSP				cryo2			
setting	Vop	Vbr	Vovr	dcr(Hz)			
220	44	42.8	1.2	0.1			
225	45	42.8	2.2	2.3			
230	46	42.8	3.2	6.4			43%
235	47	42.8	4.2	7.1			
240	48	42.8	5.2	9.2			

For Hammamatsu SiPM

Overvoltage value used in our simulations

DARK NOISE FOR 48 SiPMs

