Design of the Active Ganging boards

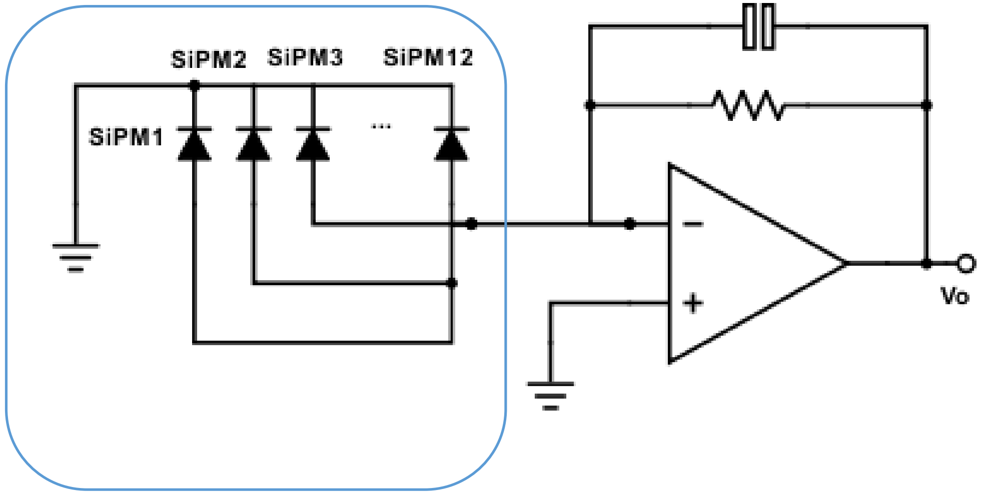
Esteban Cristaldo, Jorge Molina
Carlos Montiel, Diego Aranda

DUNE-SP Photon Detection System
Conceptual Design Review

November 12th, 2018

CASE OF STUDY

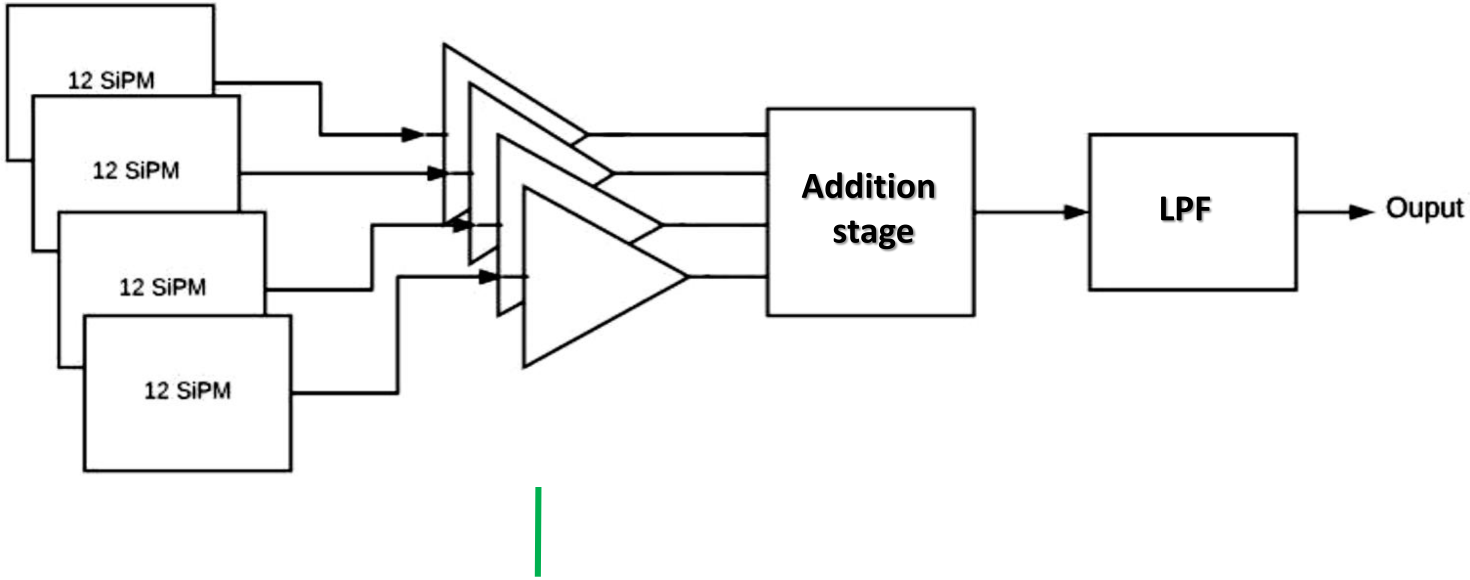
We want to know if we can amplify **12** SiPM in paralell (active *ganging*) with just one output channel.



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

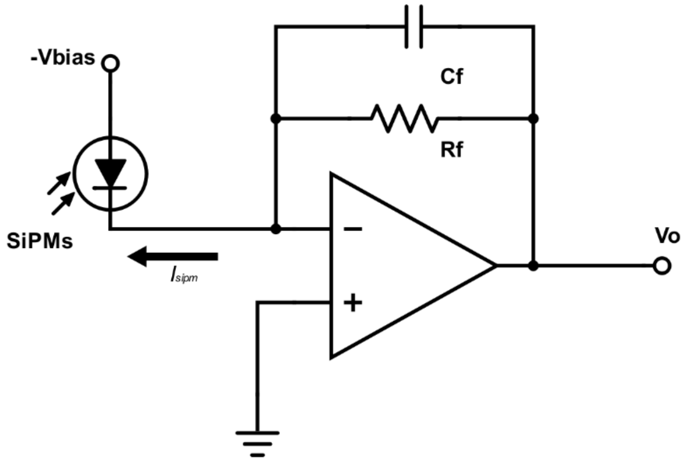
Design scheme

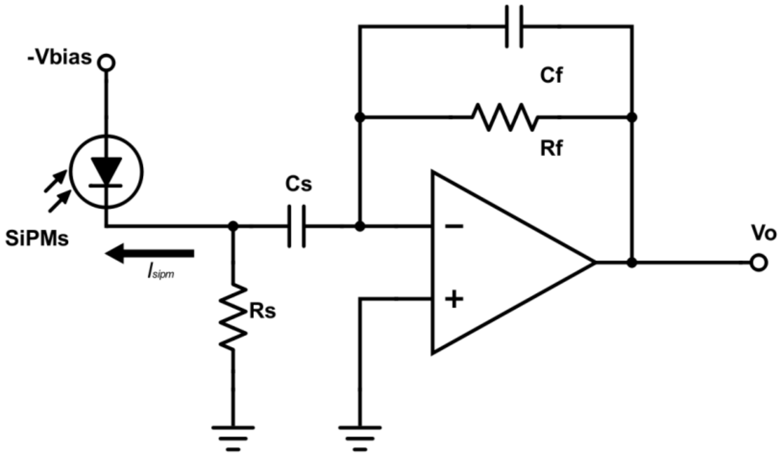
Three stages of the circuit for 48 SiPM:



Charge integrators or transimpedance

Two preamps models studied





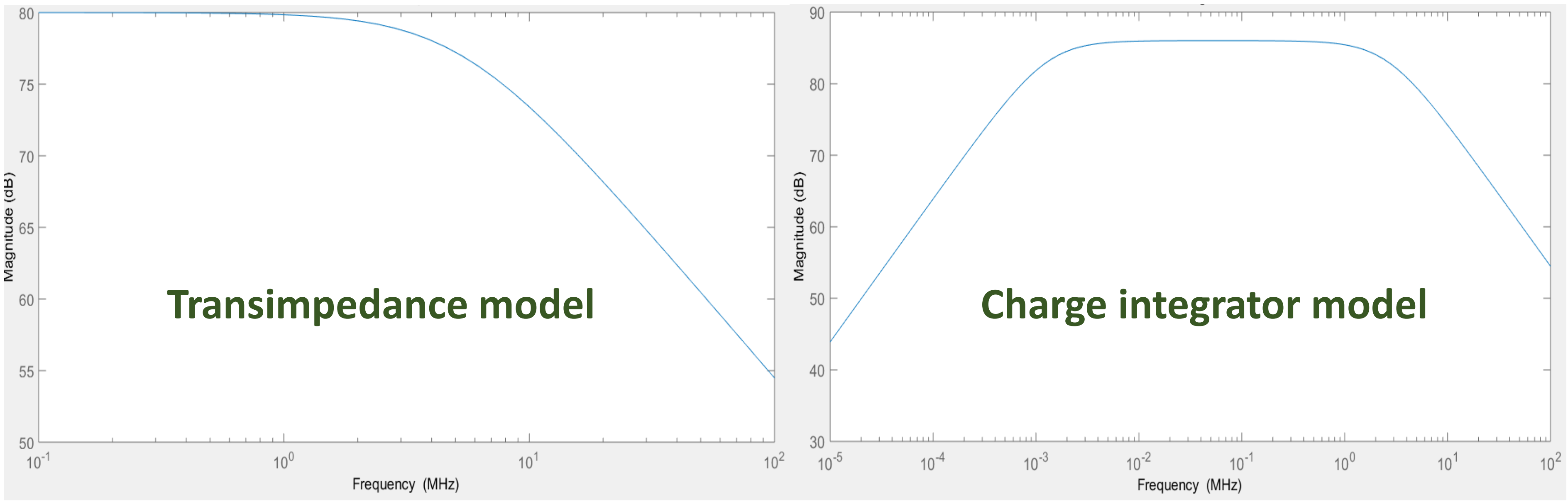
Transimpedance model

- This is a first order low pass filter
- Rf and Cf establish the bandwith and frequency cut point
- Eliminates high frequency noise

Charge integrator model

- This is a second order band pass filter
- Cf and Cs establish the bandwith and frequency cut point
- Eliminates low and high frequency noise

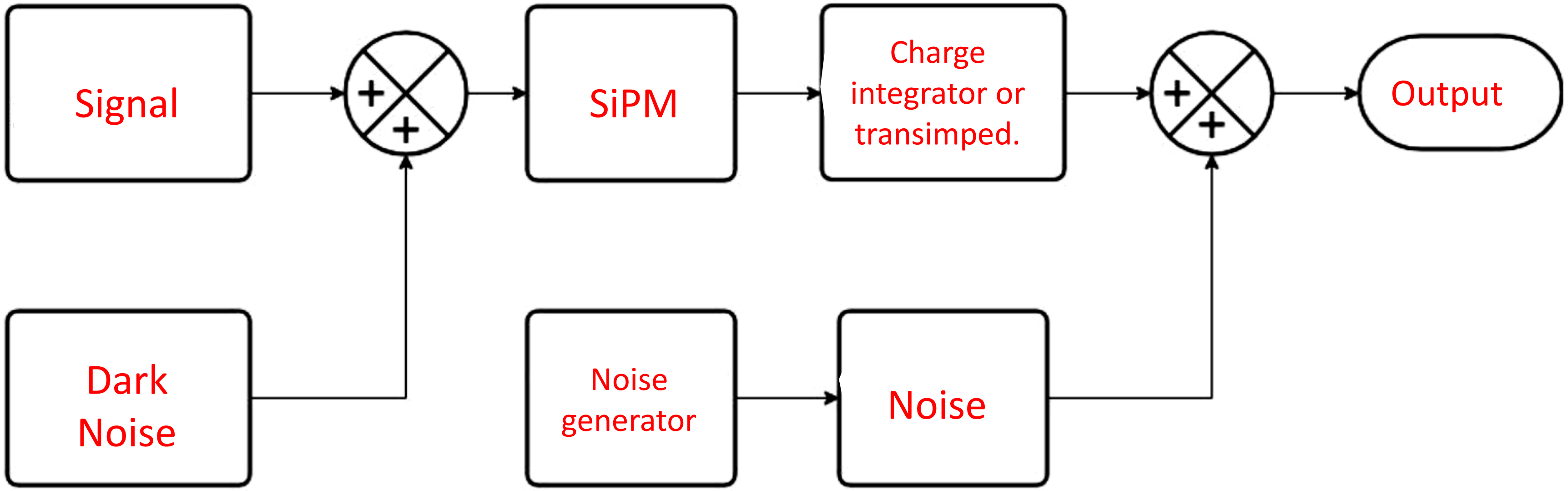
Comparison between Transimpedance and Charge Integrator



- **Cut of 20 dB per decade.**
- **Range of frequency form zero to first pole (with low frequency noise)**
- **Direct coupling from the SiPM to the filter.**

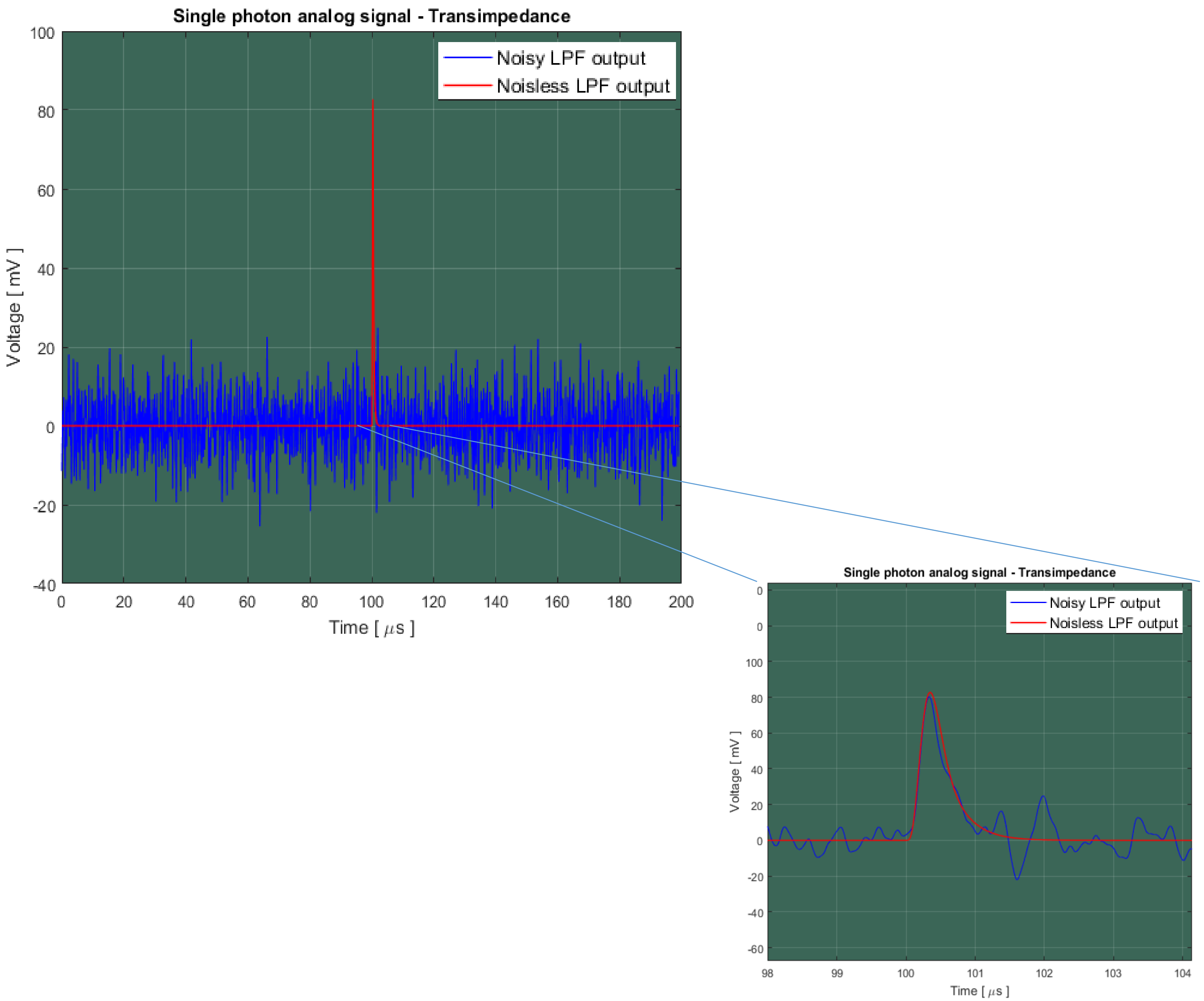
- **Cut of 40dB per decade**
- **Range of frecuency from the first to second pole.**
- **The SiPM is connected to the decoupling capacitor.**

Simulation outline

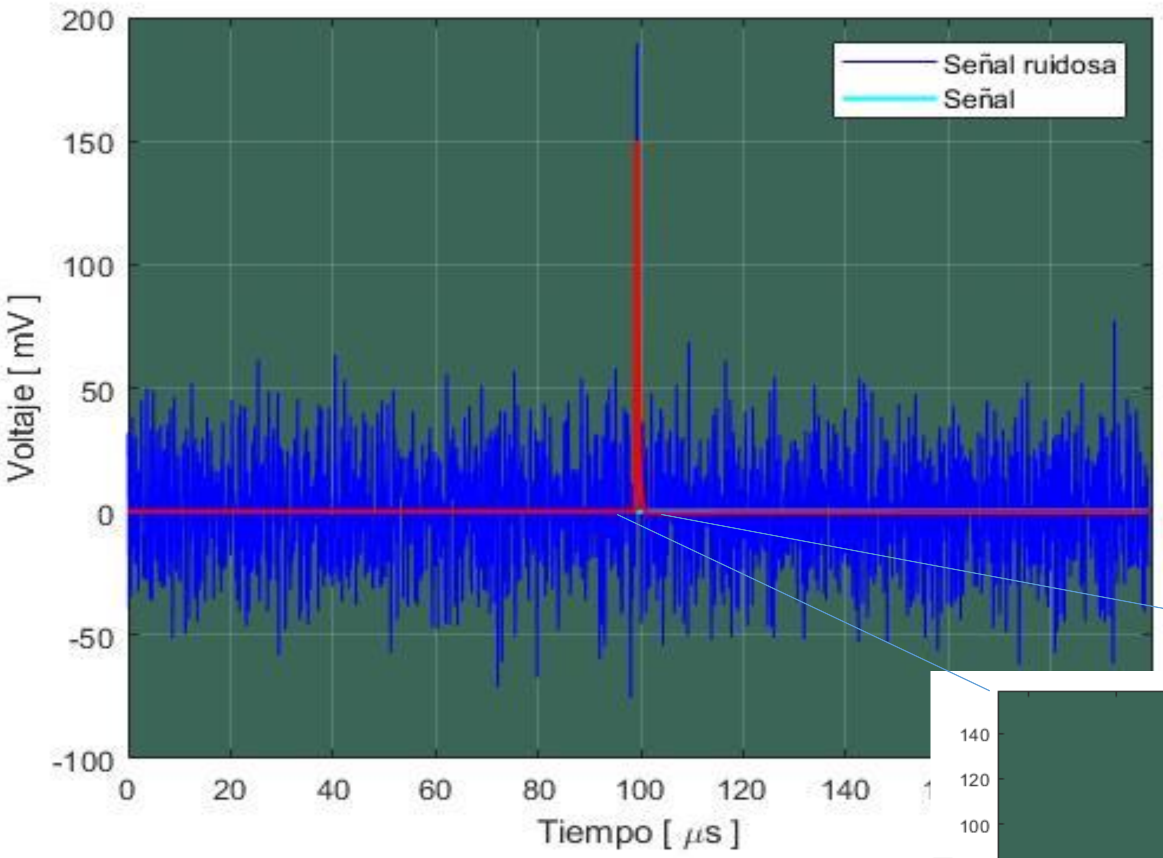


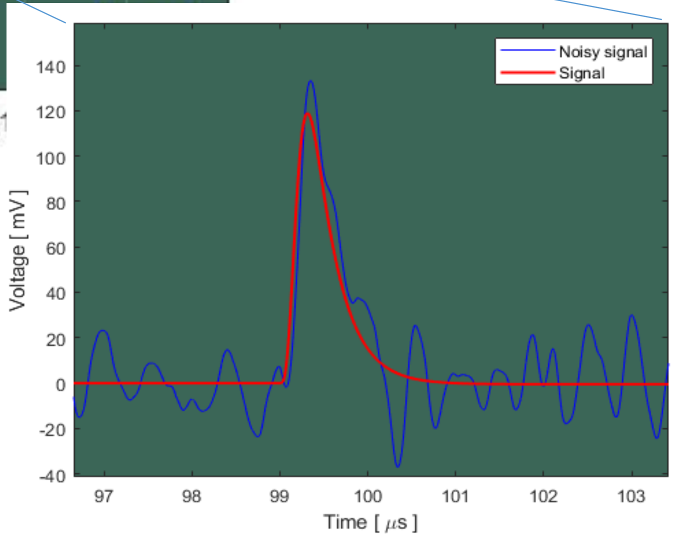
Both models are running using Hamamatsu's parameters for single photon analysis (thanks to Vishnu for sending the detector parameters!)

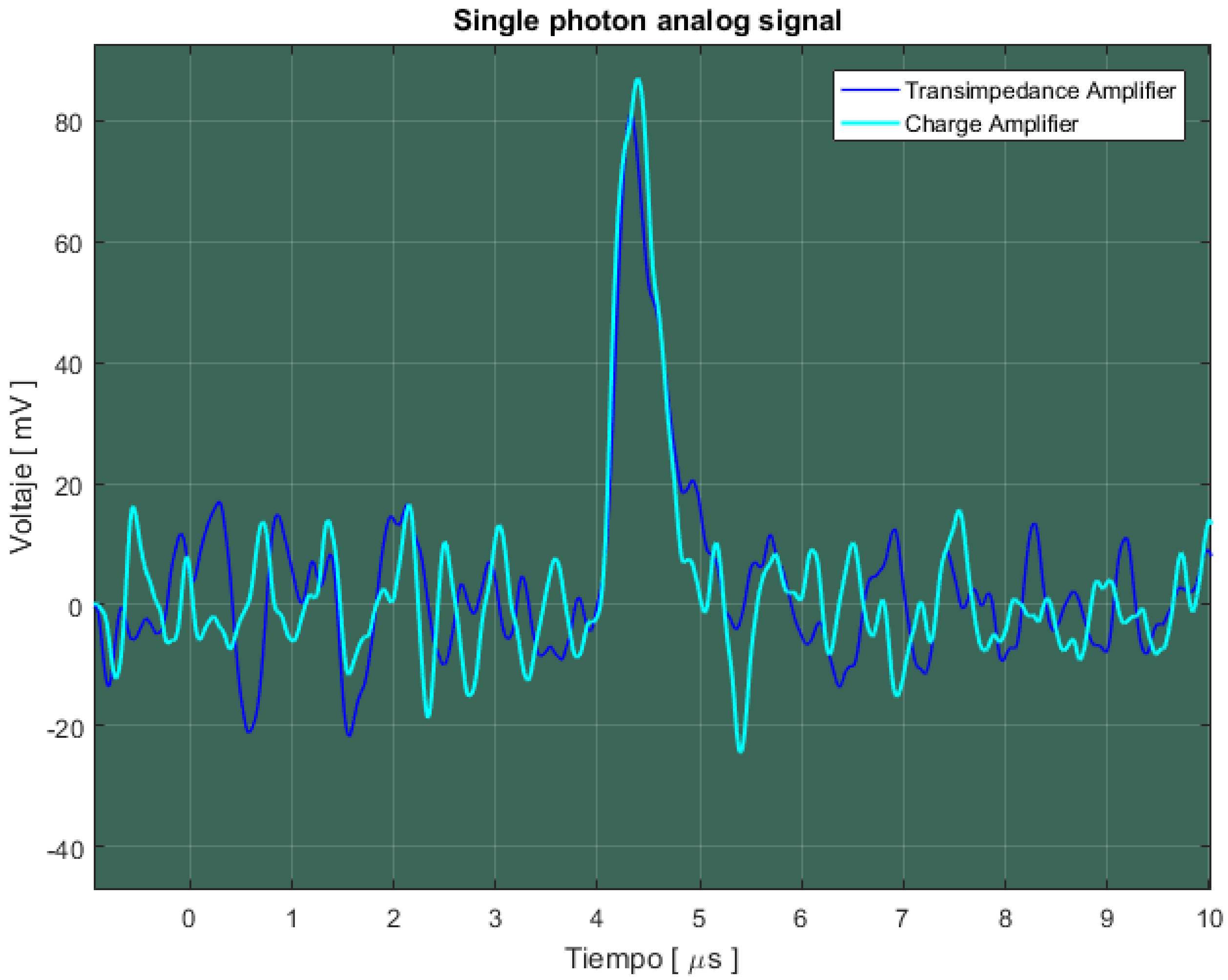
Results for the transimpedance



Results for charge integrator

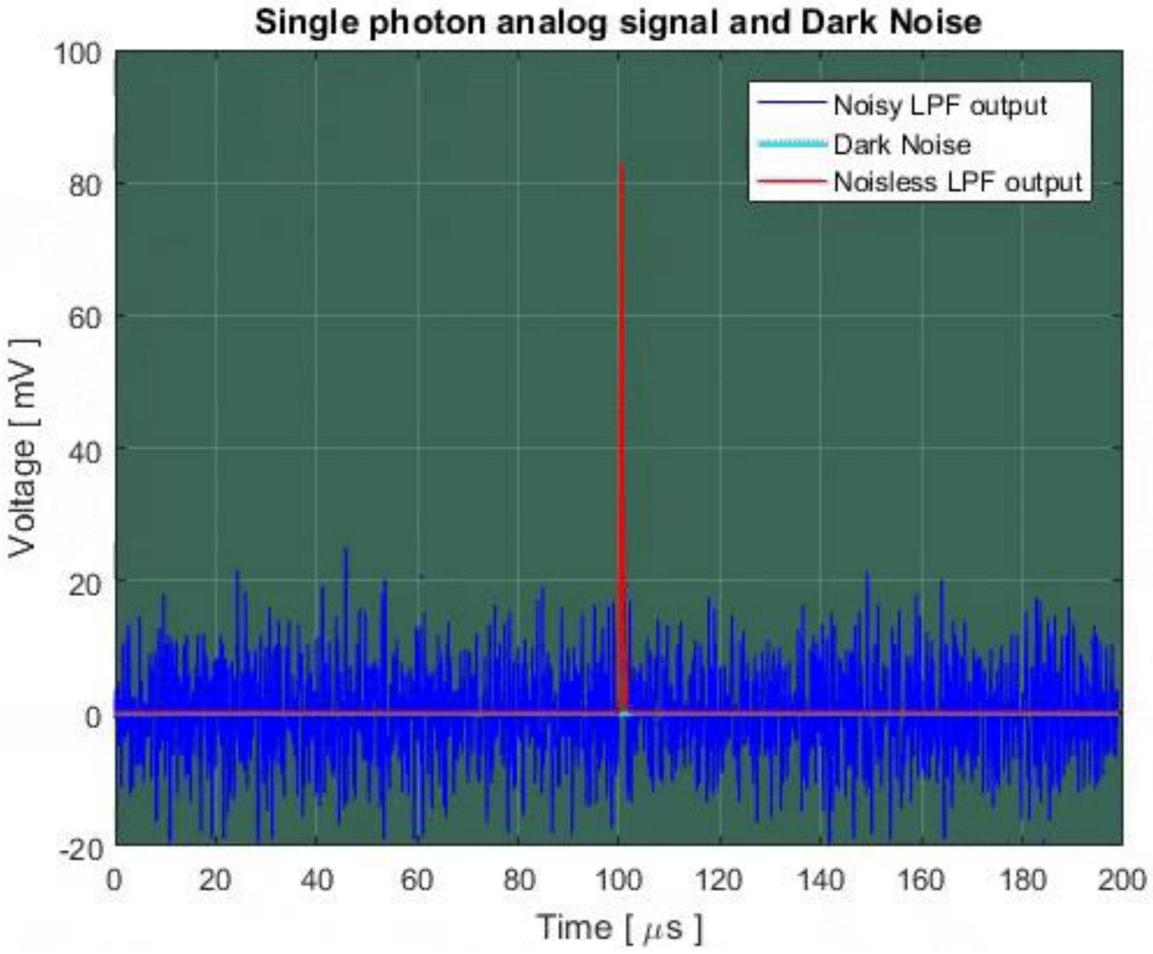


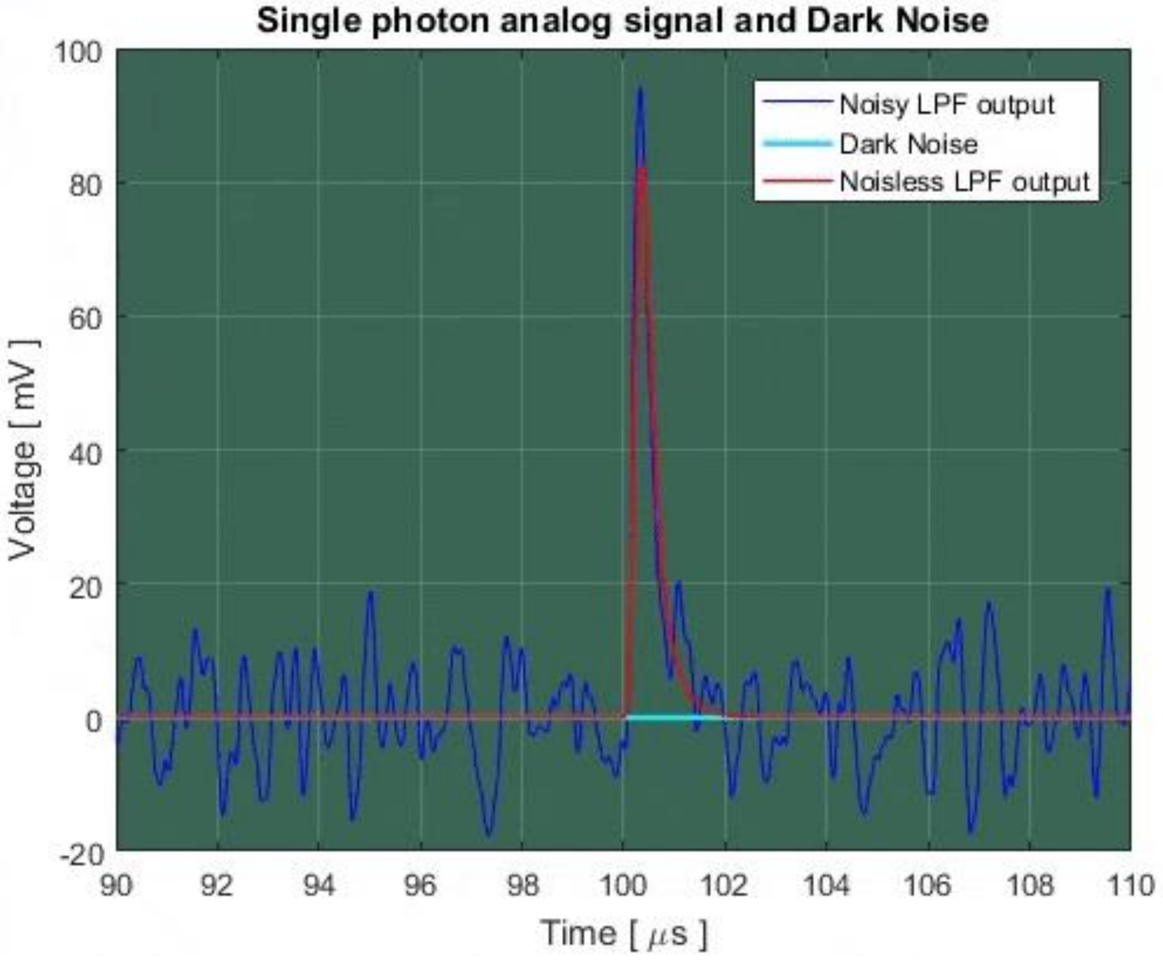




We cannot see a big diference between them in the response. The best values of SNR the we obtained are about 8 dB and a 1 us of settling time in both topologies.

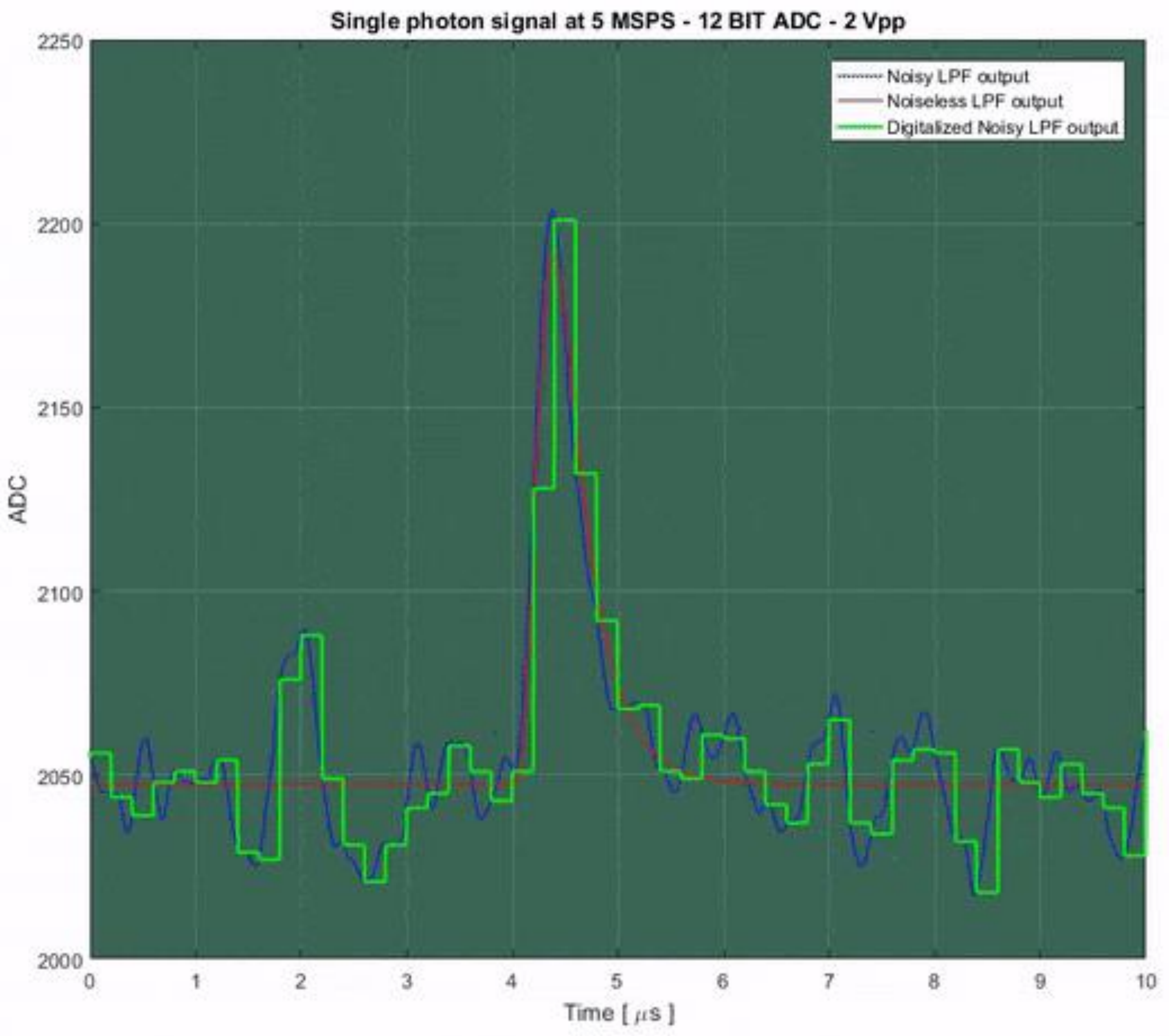
Dark noise for 48 SiPM

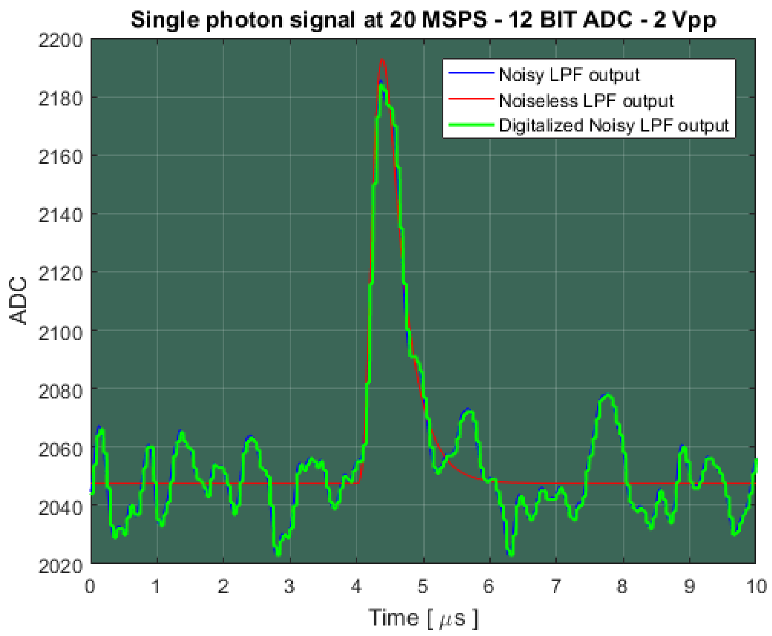




We see that we should no worried about the dark noise

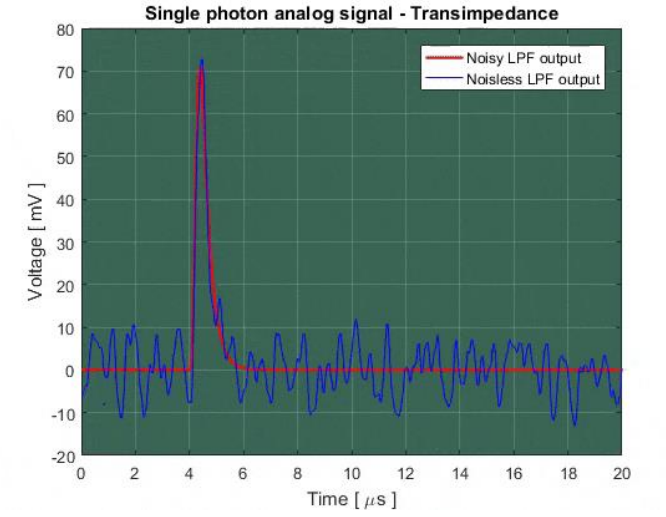
How many samples per second?

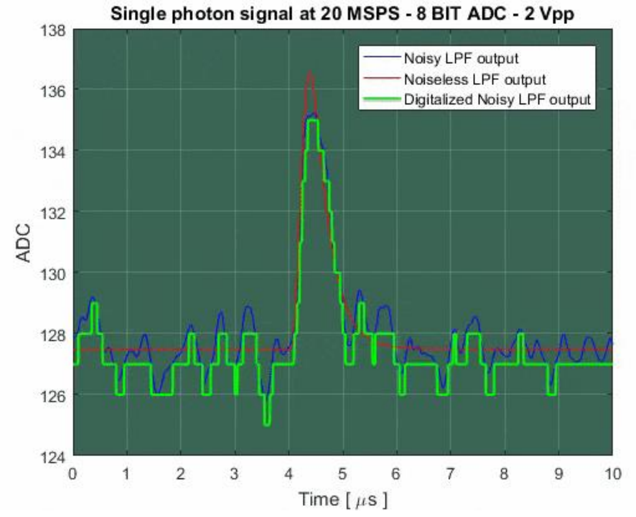


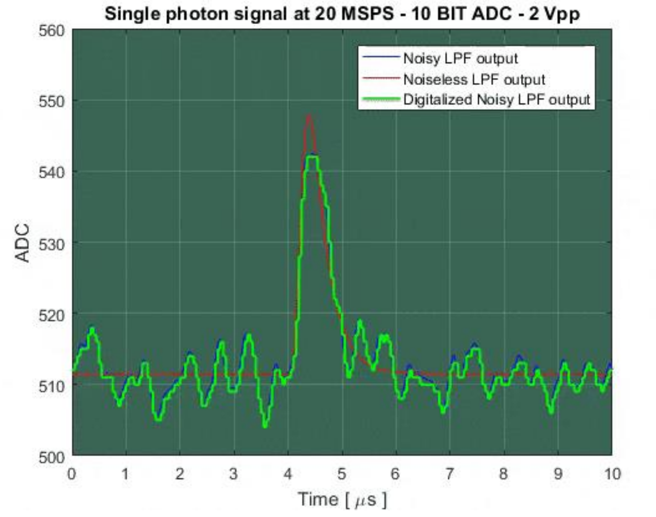


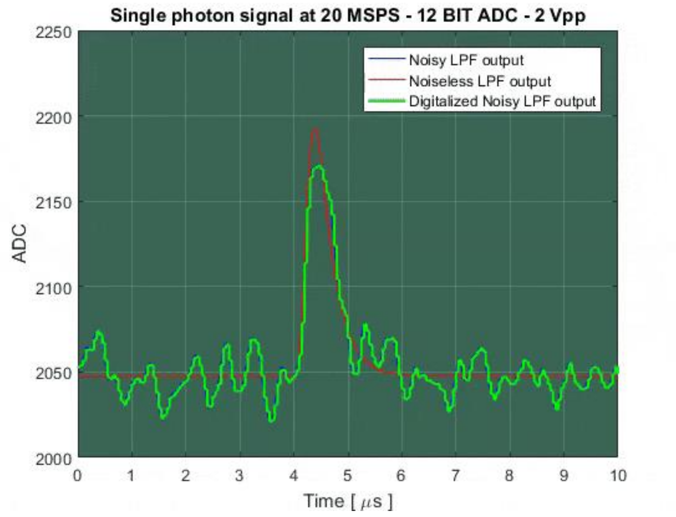
We think that we can do well with a 20 MSPS

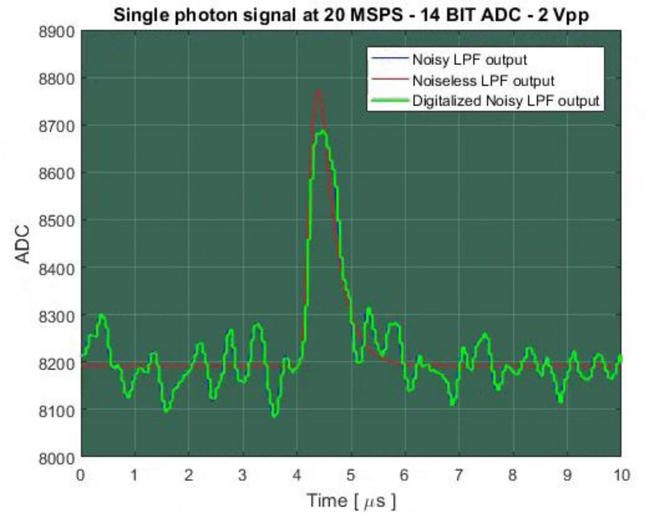
How many bits for dynamic range?

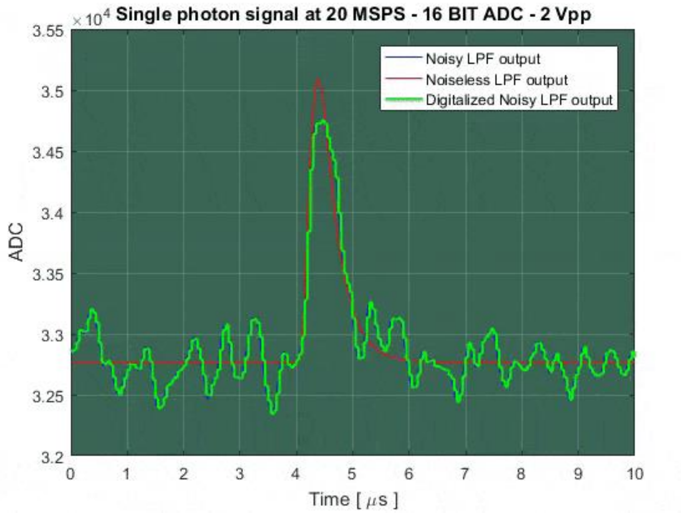












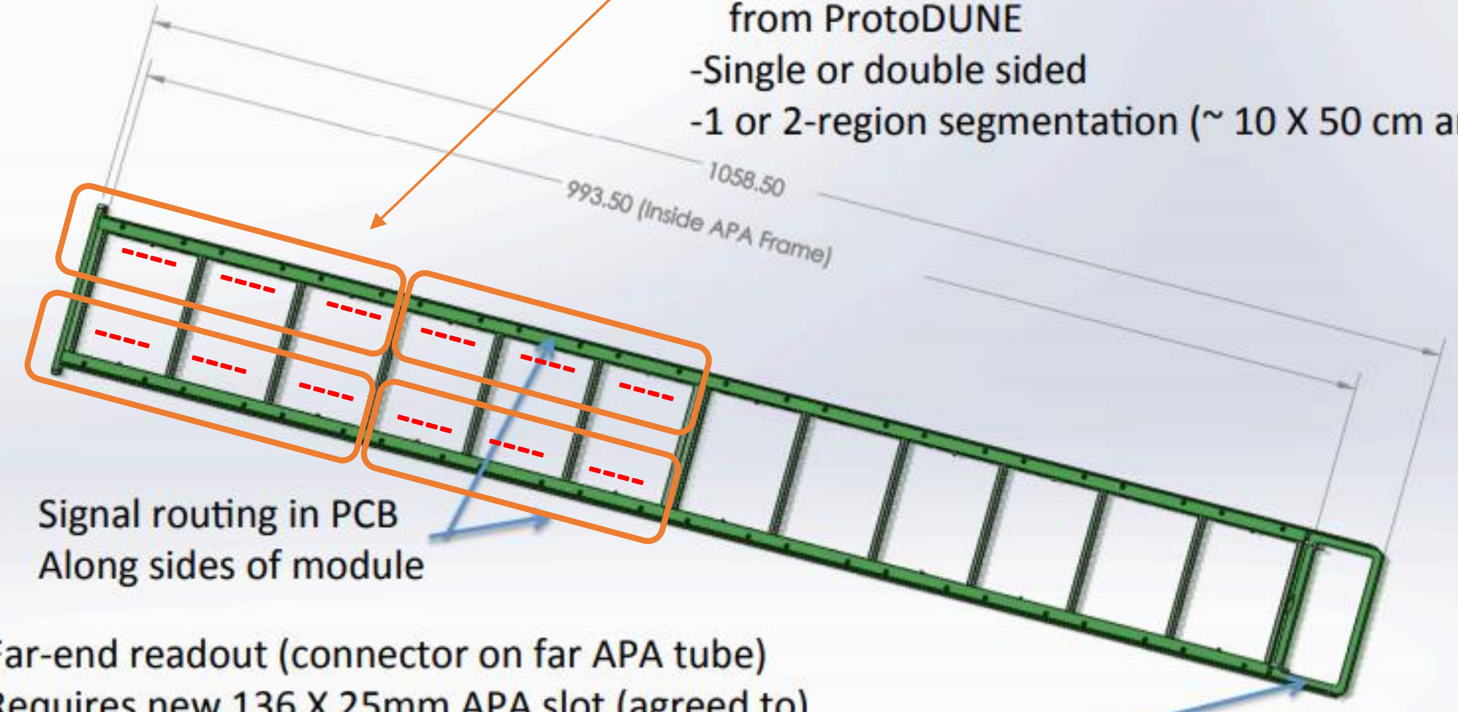
Results for transimpedance preamp

Two-Supercell ARAPUCA PD Concept

- -1 or 2 Supercells/module
- -48 MPPCs/Supercell

4 boards with 12 actively ganged hammamatsu SiPM

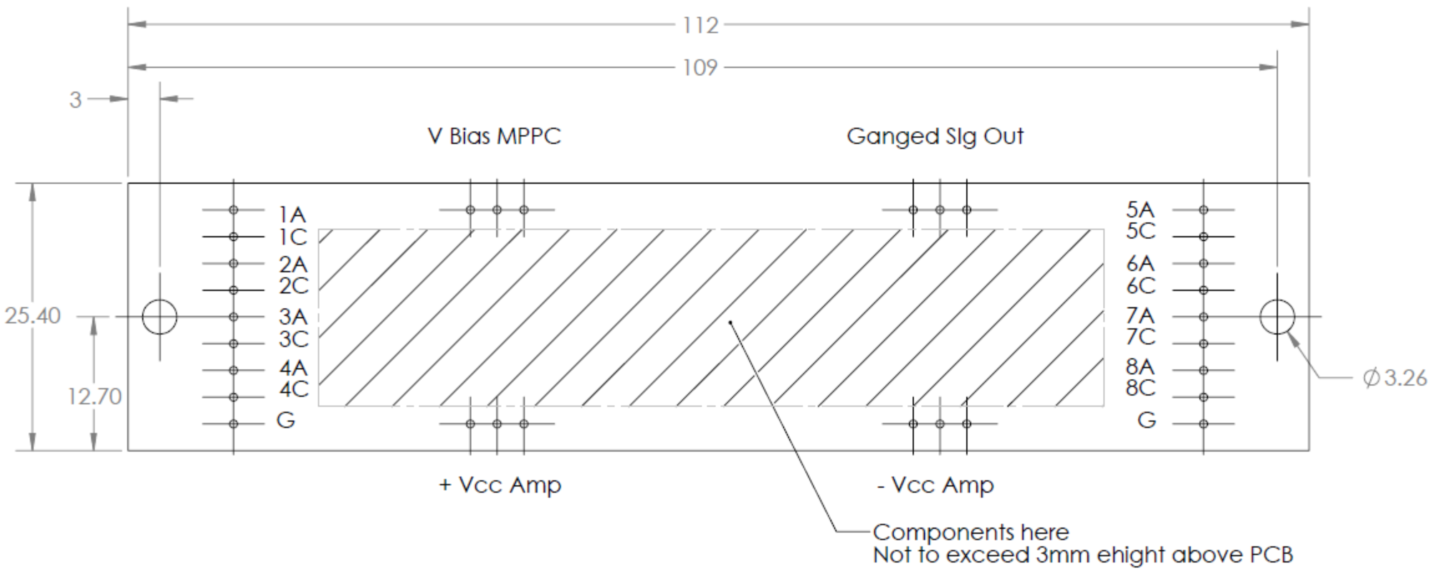
- -Nearly 50% more collection area (per Supercell) from ProtoDUNE
- -Single or double sided
- -1 or 2-region segmentation (~ 10 X 50 cm area)



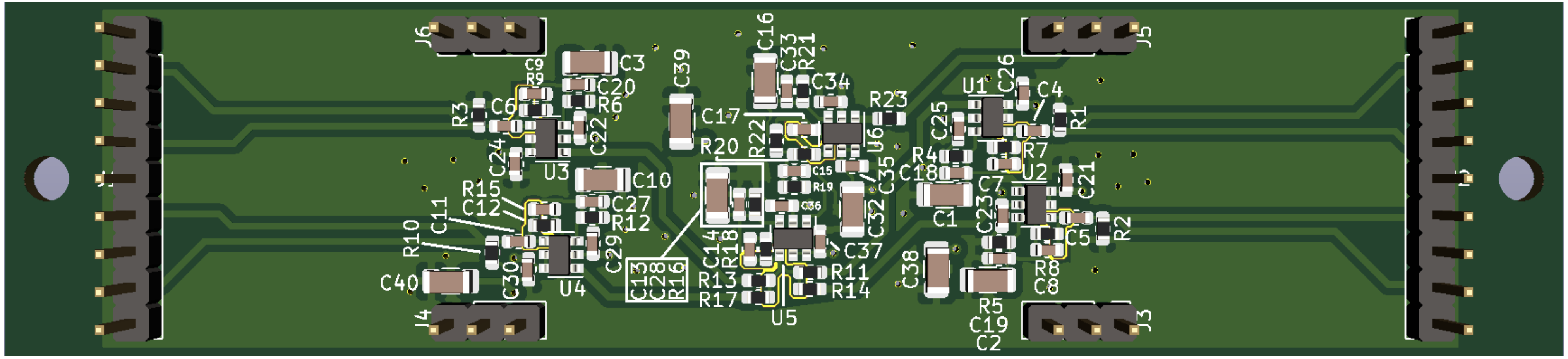
Signal routing in PCB
Along sides of module

- -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

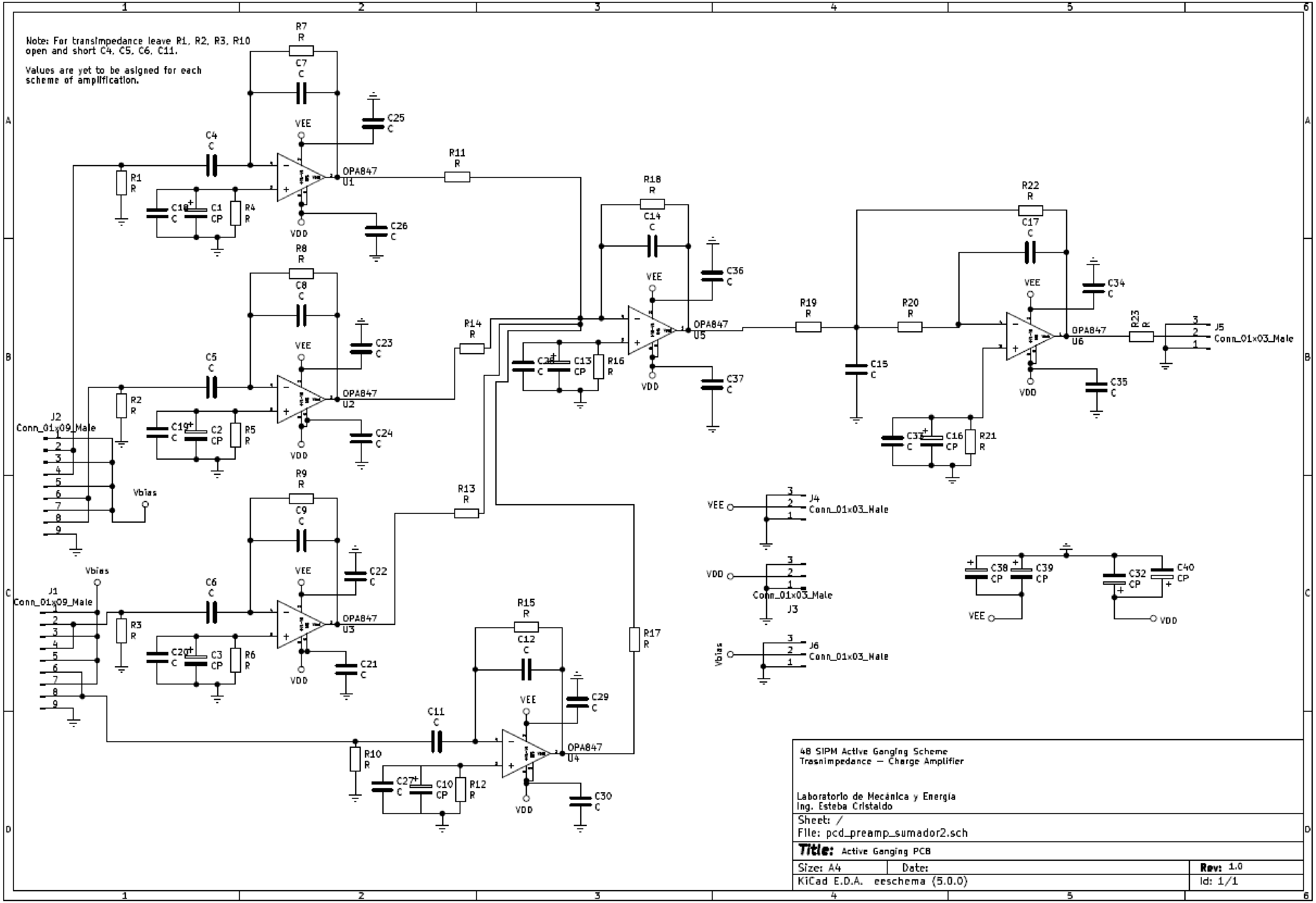
Active Ganging PCB
Inside far APA tube



Single-Channel Active Ganging Board



For transimpedance R1, R2, R3 & R10left 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 asigned for each
scheme of amplification.
OPA847
U1
U2
U3
U4
U5
U6
VEE
VDD
Vbias
J1
Conn_01x09_Male
J2
Conn_01x09_Male
J3
J4
J5
J6
Conn_01x03_Male
48 SIPM Active Ganging Scheme
Trasnimpedance — Charge Amplifier
Laboratorio de Mecánica y Energía
Ing. Esteba Cristaldo
Sheet: /
File: pcd_preamp_sumador2.sch
Title: Active Ganging PCB
Size: A4
Date:
Rev: 1.0
KiCad E.D.A. eeschema (5.0.0)
Id: 1/1

Current scientific requierements

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 occuring 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 µs	< 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 µs 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 show that we have 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 μs 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.**

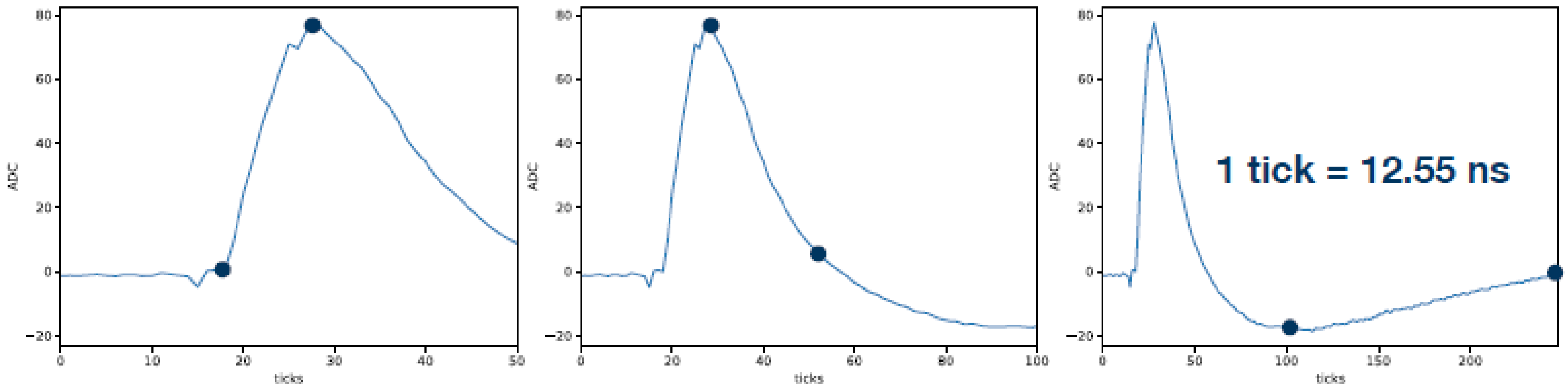
4. **The S/N ratio obtained is about 8 dB, with all noise effects included (thermal, DN).**

5. **The optimal sampling rate obtained is >≈ 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

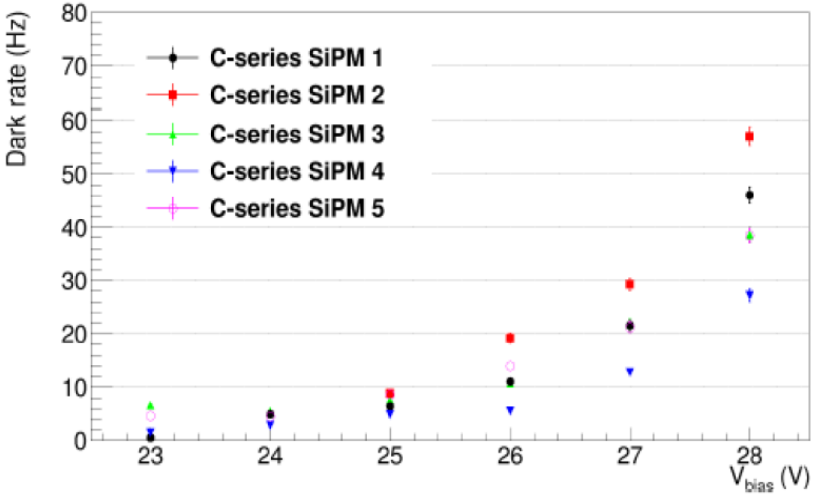
mean signal



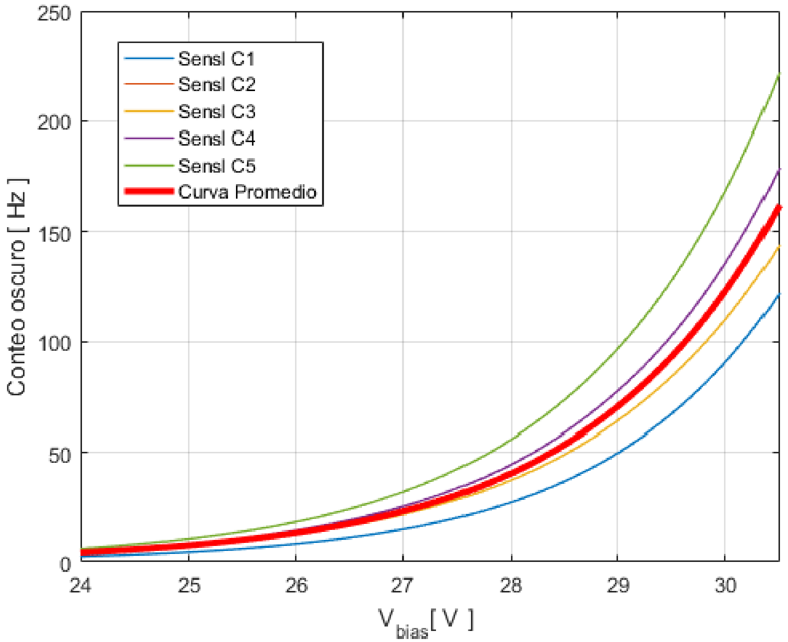
- Rise time: 125 ns
- Fall time: 350 ns
- Recovery time: O(2us) — what's shown on the right is as wide a window as the FEB allows

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				cry02			
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

Table from Kurt Francis taken from Photosensor WG Meeting 10/23/2018 slide 22

DARK NOISE FOR 48 SiPMs