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R&D on cold electronics and summing board for PD

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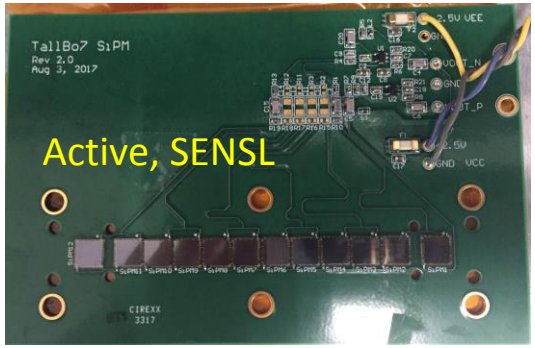
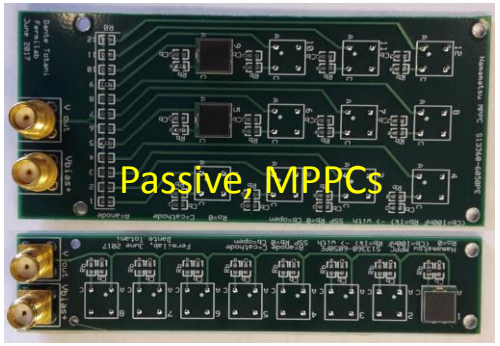
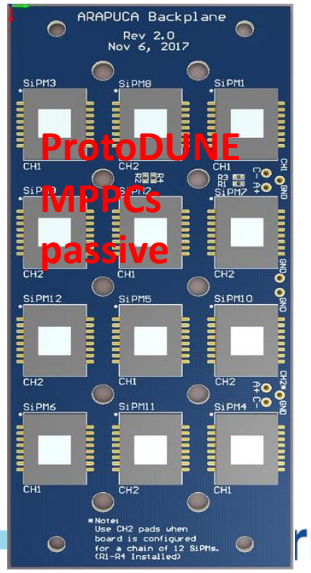
1st March 2018

What have we done regarding passive and active ganging of SiPMs?

- We designed a summing board for the SENSL 4x4 array.
- We designed a 12 SENSL (6x6 mm C series) summing board that was used by the IU group in their light bars during the TallBo run of Oct-Nov 2017.
- We have tested Hamamatsu MPPCs (S13360-6050PE) at 25C, -70C and 77K.
- We have designed and used a passive gang of 4 SENSL (6x6 mm C series) for ARAPUCAs during the TallBo run of Oct-Nov 2017.
- We have designed and tested the ARAPUCA back plane with passive gangs of 6 and 12 MPPCs
- We are designing a new active ganging board with a lower noise OP Amp.







So, what have we learned?

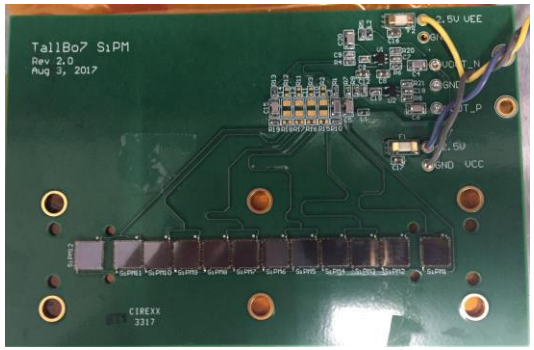
Focusing on most interesting results:

- Active ganging: summing board for the SENSL 4x4 array tested at TallBo in March 2017

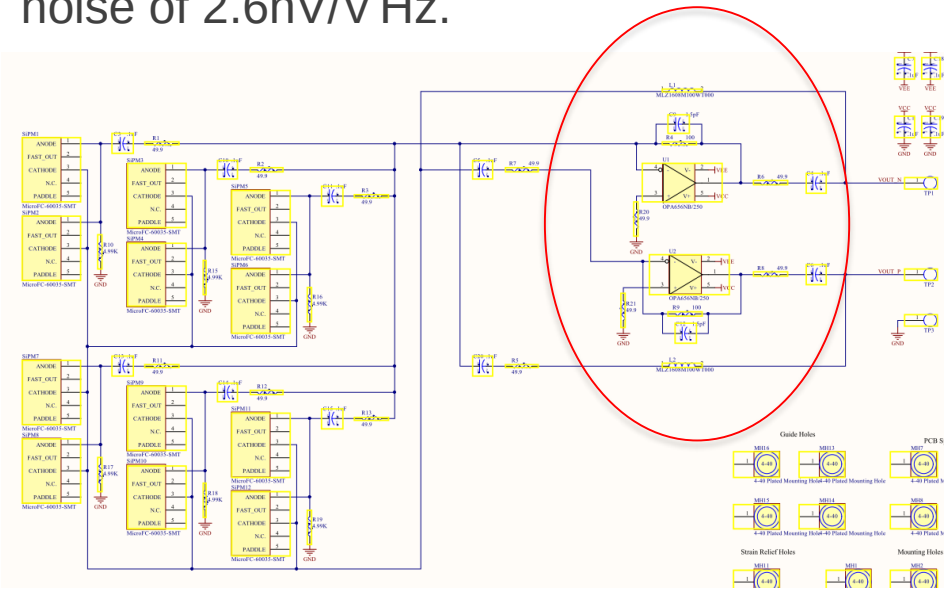
Ch N	Position	Acceptance	Ph	Eff % ? (151KPh)
Ch0	7600	5 e-3	2.95	(0.40)
Ch1	6600	6.7e-3	4.1	(0.41)
Ch3	5800	2.5e-2	11.2	(0.30)
Ch4	4800	2.5e-2	10.1	(0.27)
Ch5	7600	6.9e-3	4.9	(0.5)
Ch6	6600	6.7e-3	4.6	(0.45)
SiPM array	7000	2e-3	21	(7.0)

SiPM array coated with TPB, no filter, no light bounces
Efficiency > 7%.
Probably higher. We did not have a good characterization of the radioactive source spectrum.

Active ganging of 12 SENSL (6x6 mm C series) summing board for IU light bars, used in the TallBo run of Oct-Nov 2017



- The design used 2 single ended OP Amps (OPA842) with noise of 2.6nV/√Hz.

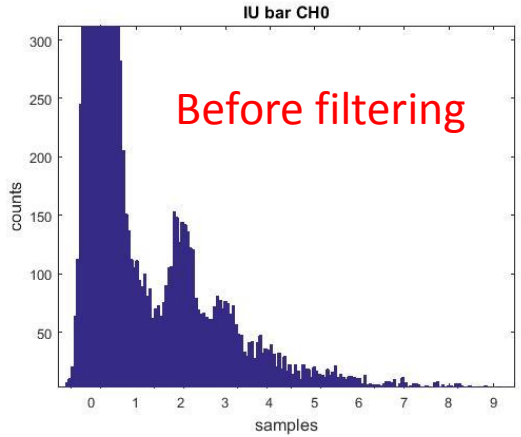


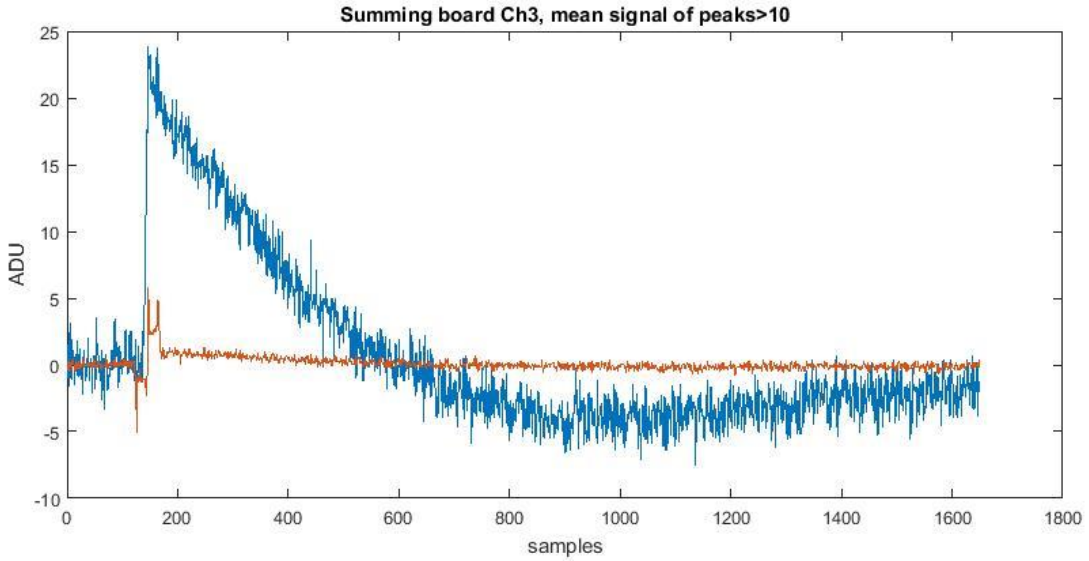
We also learned that our 1st pick (a differential Op Amp) had a latch up problem. The OPA842 did not have that problem but we needed two and payed some more noise penalty.
Some OpAmps have a protection circuit for overheating that latch up when the devices are operated very cold (like 85K). This is NOT a failure of the device, it's a protection circuit but makes it unusable for cryogenics.

Solution: Pick an Op Amp that does not have such a protection circuit.

Active ganging of 12 SENSL (6x6 mm C series) summing board for IU light bars, used in the TallBo run of Oct-Nov 2017

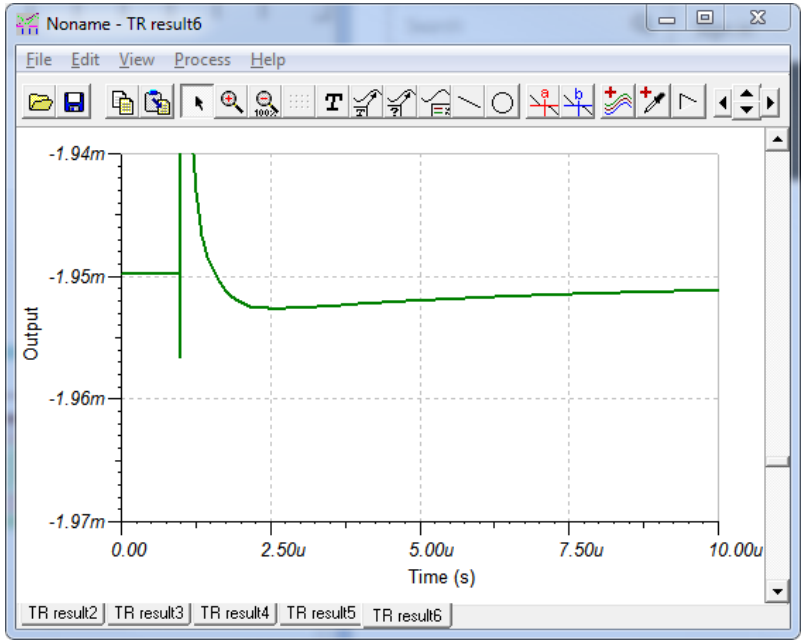
- The Op Amp adds noise to the signal.
- It was hard to see single PEs without filtering the data.
- A digital filter (such as a Matched filter) worked well and a good calibration was achieved.

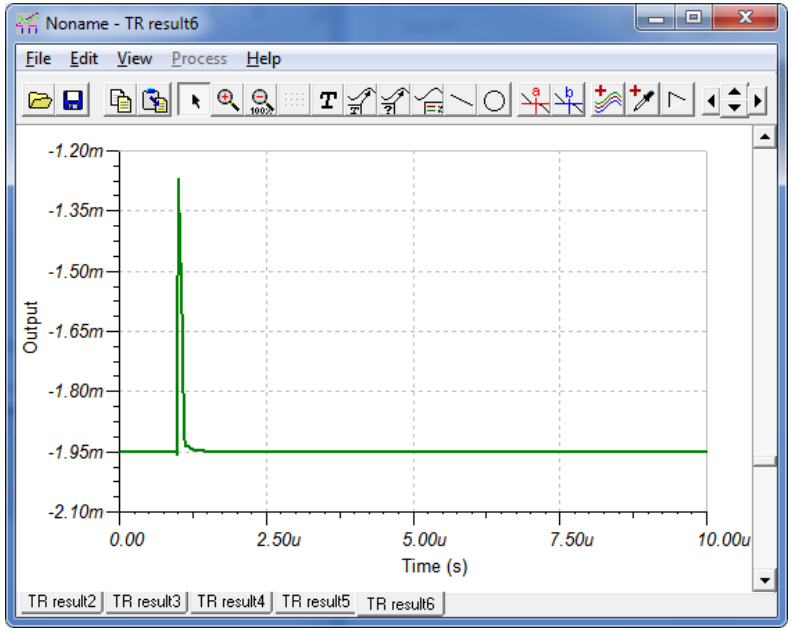




There was also an undershoot in the signal. This is due to AC coupling time constants, not to the summing Op Amp. And it can be fixed by increasing capacitor values.
There was also a “glitch” feature. We believe that is related to the SSP trigger but we are not sure.

How to move forward with passive & active ganging? (proposal)



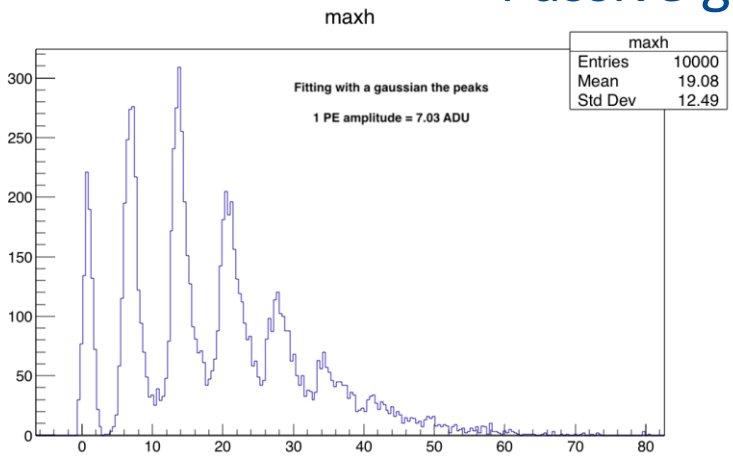


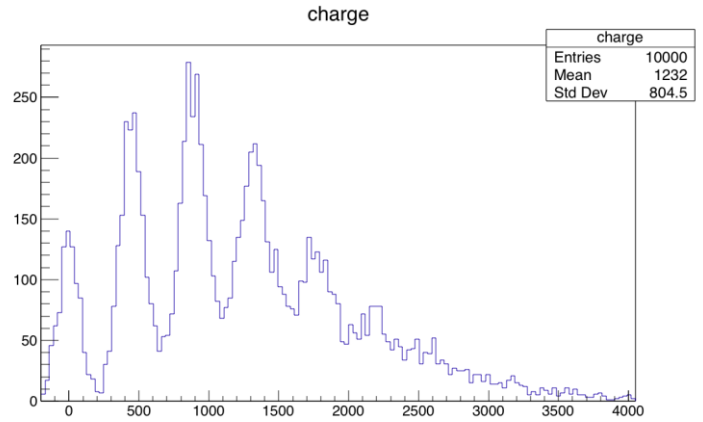
- Simulation of undershoot generated by AC coupling.
- Can be minimized to <0.3% of signal size by adjusting the input pole of the electronics.

Passive ganging of MPPCs

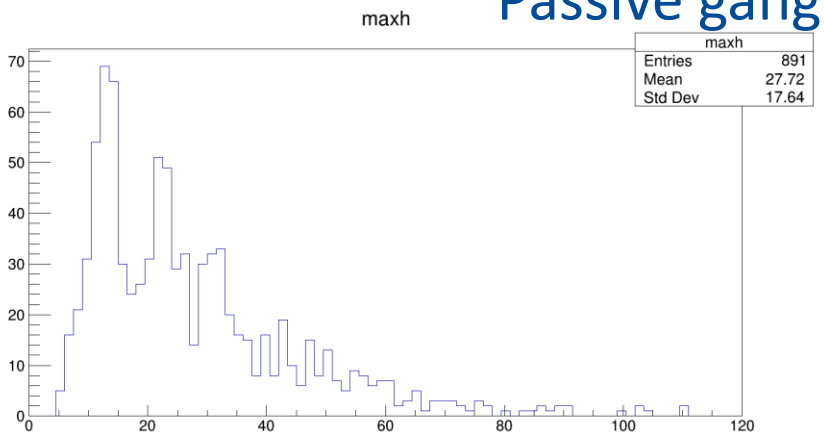
- Dante Totani, Adam Para, Kurt Francis (NIU) and maybe others have tested Hamamatsu MPPCs (S13360-6050PE) at 25C, -70C and 77K.

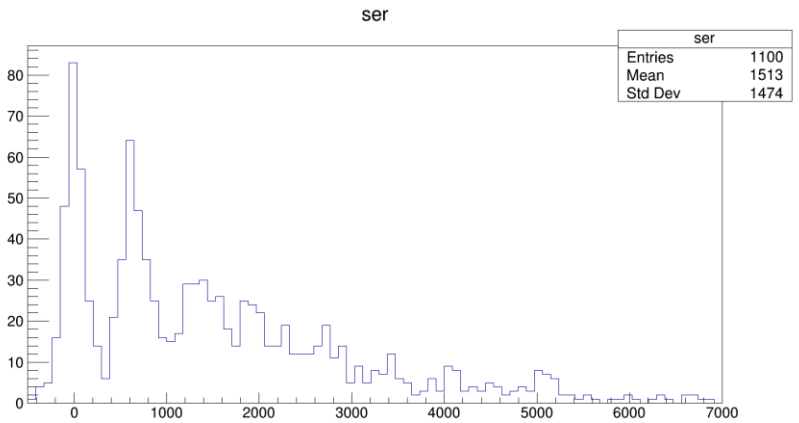
Passive gang of 4 in LAr





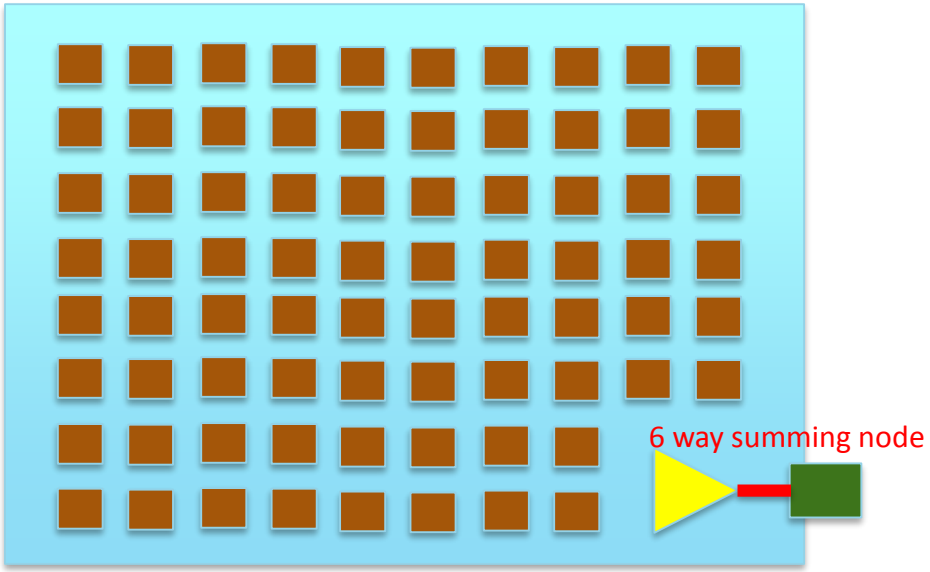
Passive gang of 12 @-70C





How to move forward with passive & active ganging? (proposal)

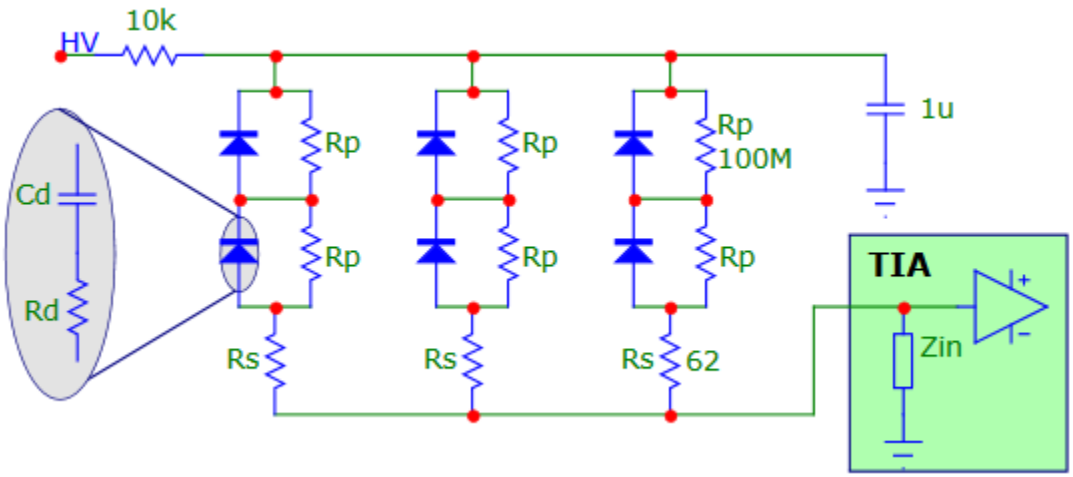
- Active ganging: 6 groups of 12 SiPMs summed in the operational amplifier
- Total of 72 MPPCs in 8cm by 10 cm



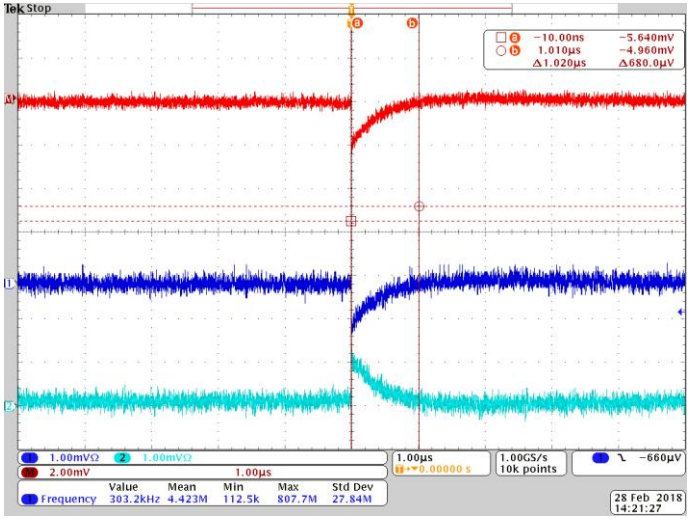
Each group has 12 SiPMs passively ganged.
Each group has 6 pairs of 2 SiPMs connected in series.
The effective capacitance of each group of 12 MPPCs is 3.4 nF (equivalent to the capacitance of a single SENSL C).
Active ganging of 6 groups has been tested.
Only new thing (drawback) is the ~130V needed for the series of 2.

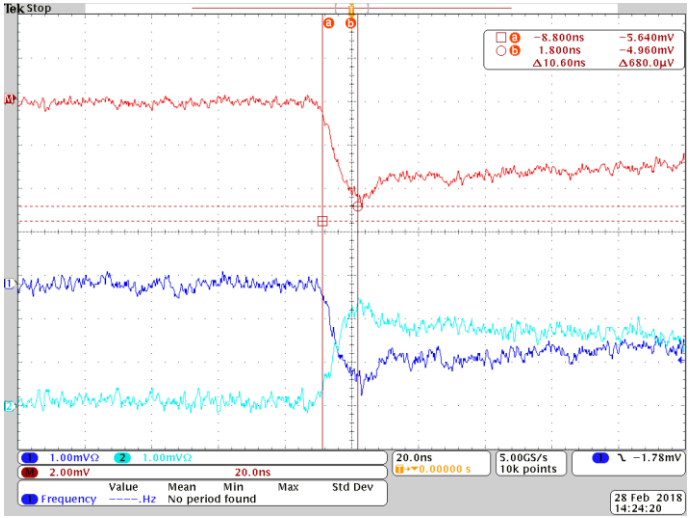
60% area coverage (of the 8cm x 10cm) should give us a 10 to 15% photon collection efficiency.
The layout can be done with bypasses to partially stuff it with less MPPCs.
No filters needed only TPB on MPPCs,
Cost effective, easy to double side. 8cm x 10 cm areas can be summed again into a single channel.

How to move forward with passive & active ganging? (proposal)



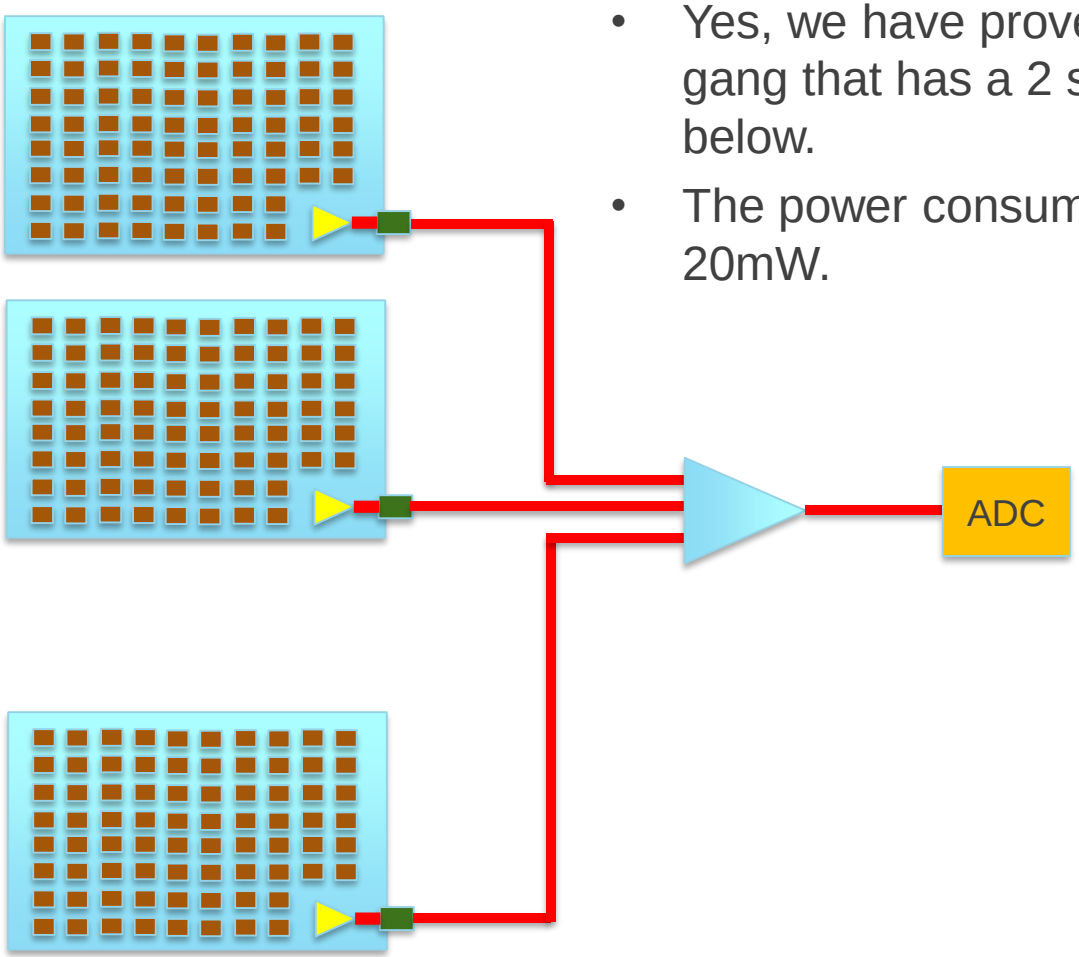
- We tested the THS4131 and are in the process of testing the LMH6629
- Scope traces with 2 SENSL SiPMs (6.8nF capacitance) and LED pulser.
- < 10ns rise time.





How to move forward with passive & active ganging? (proposal)

- Can actively ganged ARAPUCAs be combined in a single readout channel?
- Yes, we have proved is in the SENSL array active gang that has a 2 stage amplifier like in the figure below.
- The power consumption of the Op Amp is below 20mW.



Conclusions

- We have already demonstrated that the combination of passive and active ganging works and will increase the photon collection efficiency of a PD.
- Noise and undershoot problems can be minimized based on what we have learned with previous experience.
- The 2nd generation proposed can be achieved in a short time (1 month) with a modest investment.
- Resources needed from project: SiPMs., labor to layout and test the board, dewar expenses covered to do a LAr test with a radioactive source at PAB.

- The passive+active ganging is totally compatible with ARAPUCA.
- It allows to pick the best area coverage for optimum photon detection.