Study of the MUSIC ASIC for possible SST-1M upgrade

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Outline

→ Introduction: sensor upgrade on SST-1M camera

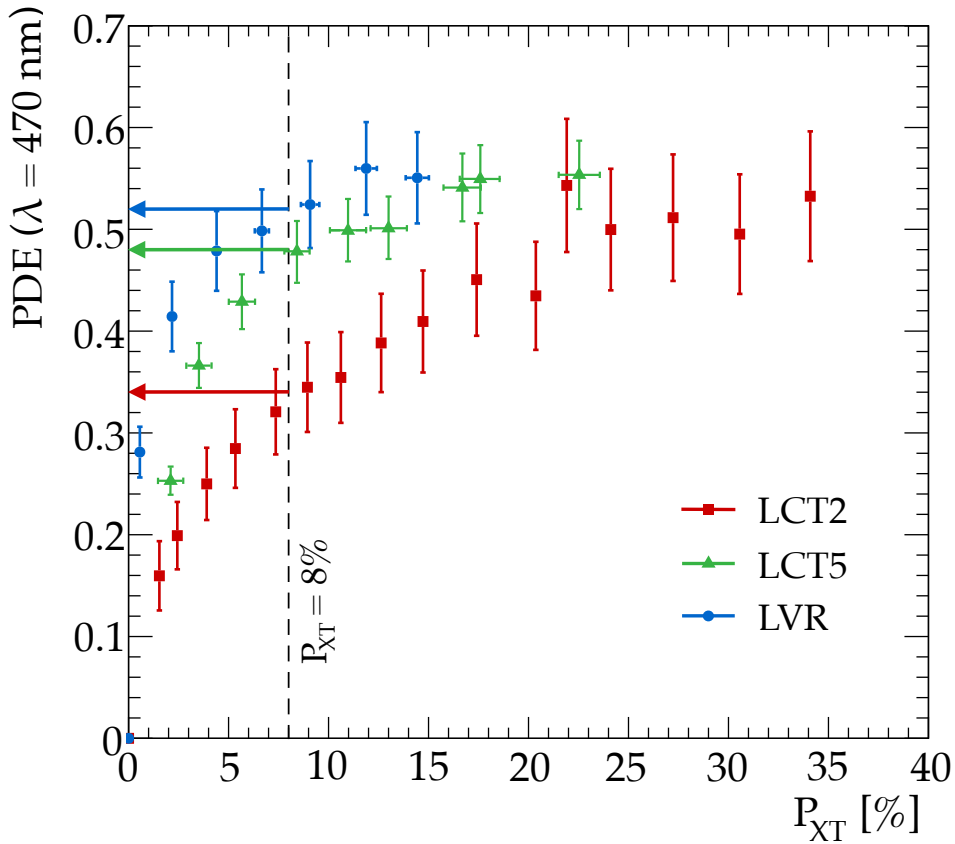
→ The MUSIC readout ASIC

→ Characterisation of the MUSIC ASIC
- ↪ Measurement setup
- ↪ Applying Pole Zero Cancellation to LVR3 pulse
- ↪ Applying Pole Zero Cancellation to LCT5 pulse
- ↪ MUSIC behavior in saturation with LCT5 sensor

→ Simulation of MUSIC
- ↪ Simulation of pulse shapes with Pole Zero Cancellation
- ↪ Simulation of the behavior in saturation

Sensor upgrade on SST-1M

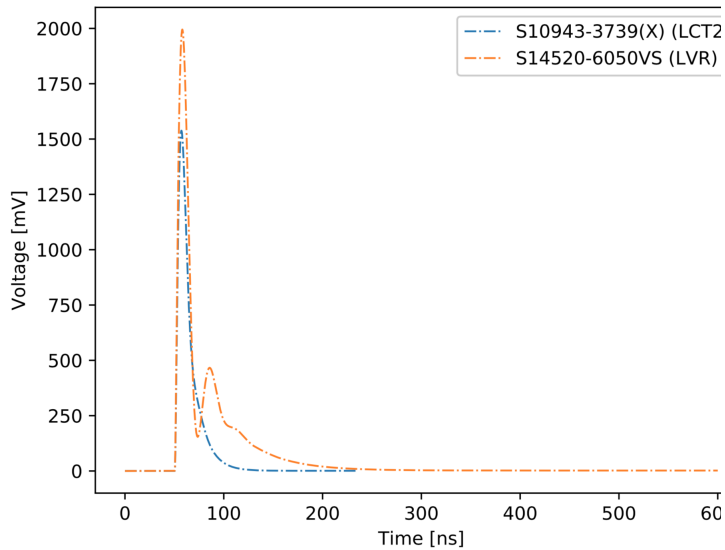
- SST-1M camera currently working with LCT2 sensor operated at 8% cross talk probability $\Longrightarrow$ PDE=34%
- Photo-detection efficiency can be improved by changing the sensor:
  - LCT5: PDE(P_{XT}=8%)=48%
  - LVR3: PDE(P_{XT}=8%)=52%

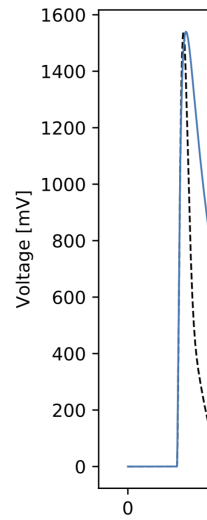


Measurements from A. Nagai

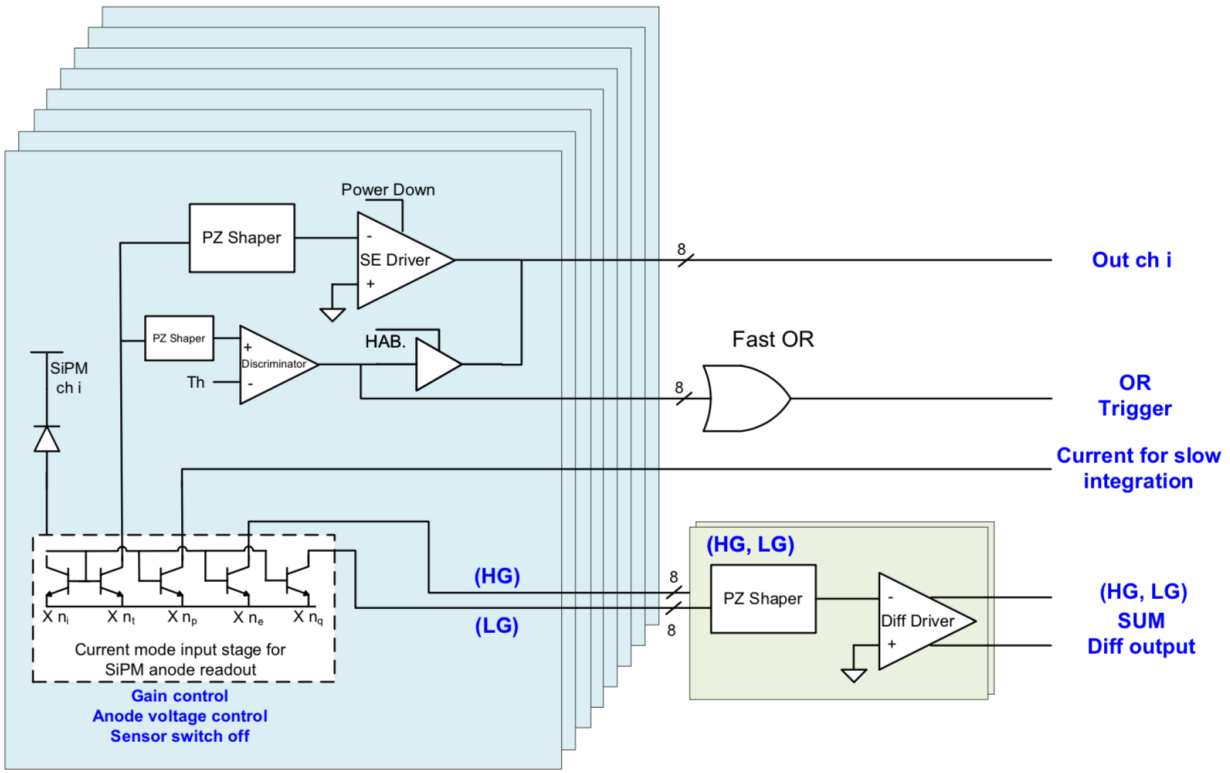
Simulation of front-end electronics
LCT2 vs. LVR3 pulse shapes

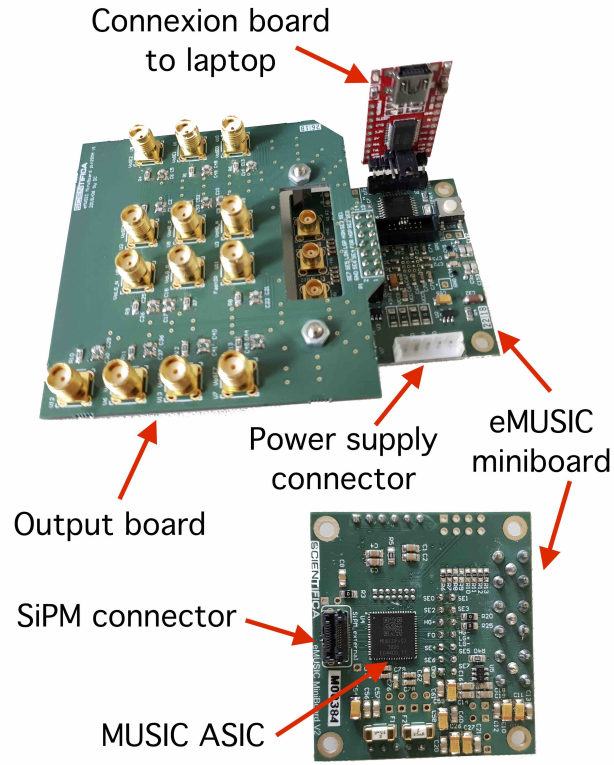
- Simulation of front-end electronics with PSpice
- SiPM : Corsi model
- By changing only Corsi parameters for LVR3: strange pulse shape with secondary bump
- Shortest pulse shape achievable: 177ns (1-1%)
  (R_G=10Ω, R_{IN}=2Ω, R_F=1000Ω)





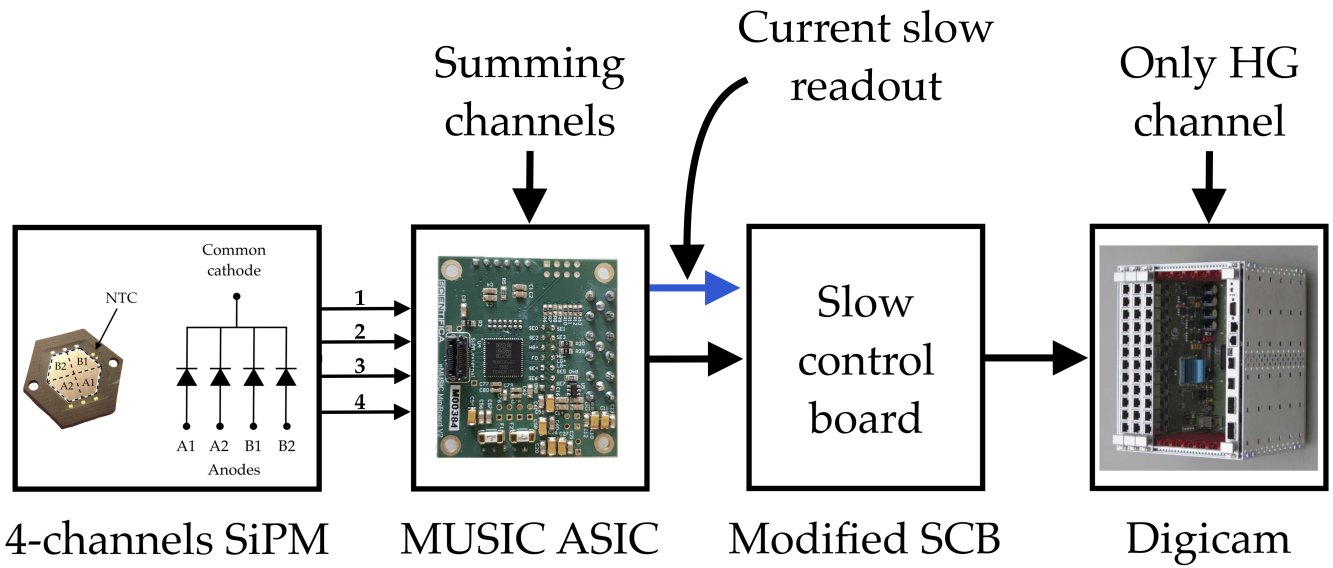
The MUSIC readout ASIC





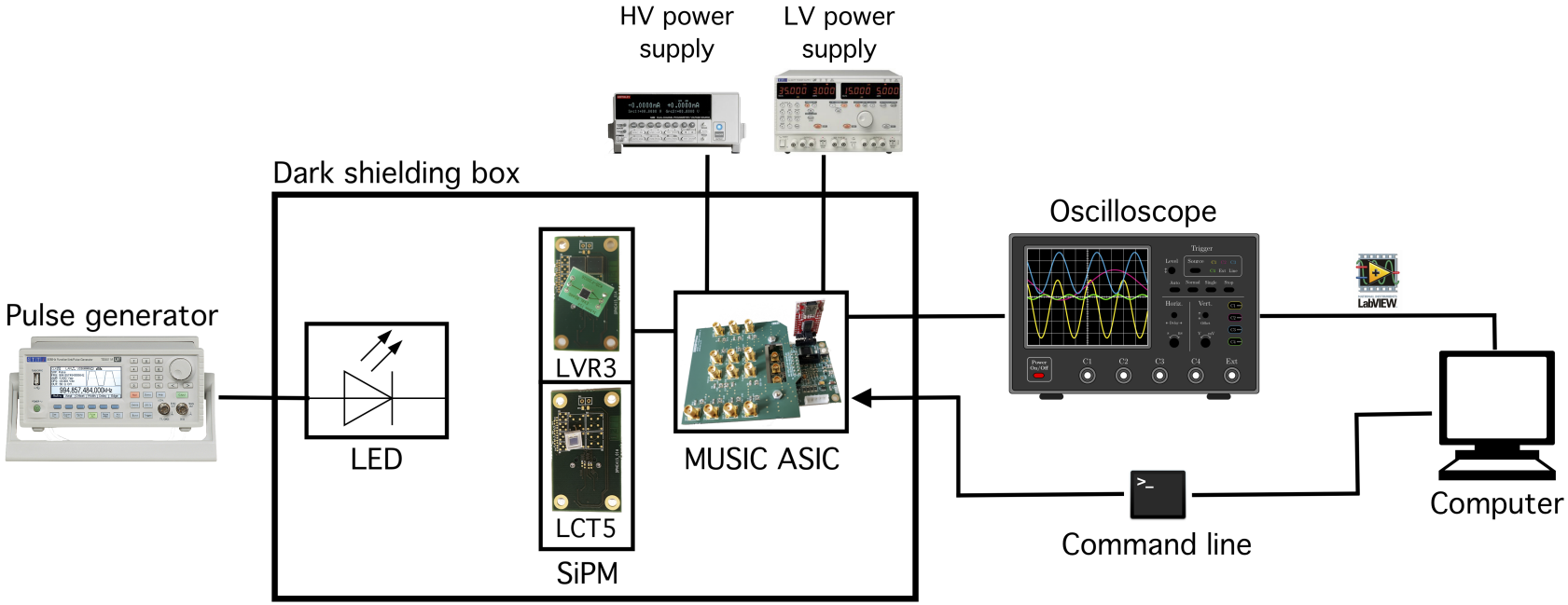
Gómez, Sergio, et al. "MUSIC: An 8 channel readout ASIC for SiPM arrays." Optical Sensing and Detection IV. Vol. 9899. International Society for Optics and Photonics, 2016.

Integrating MUSIC in the camera

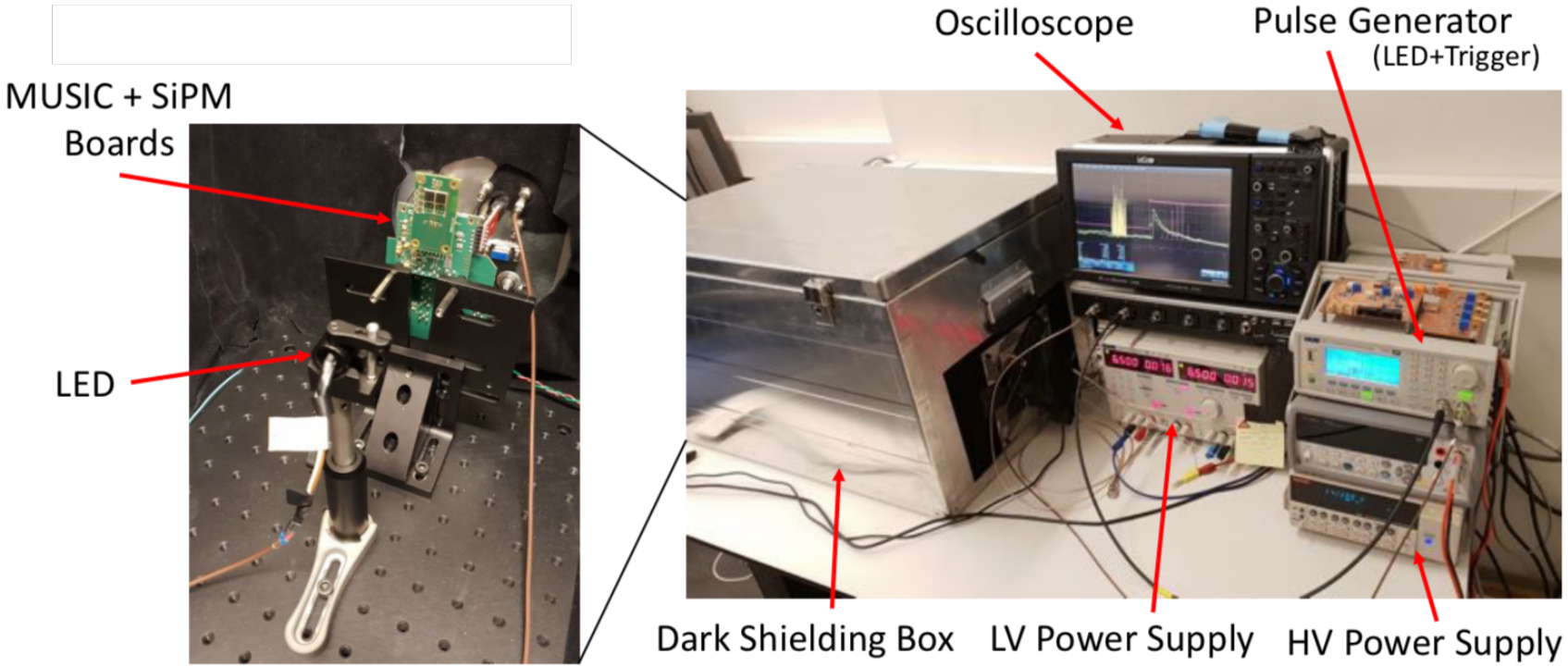


- 1 output channel per pixel $\Longrightarrow$ 1 MUSIC to sum the 4 anodes of a single pixel $\Longrightarrow$ 1 MUSIC per pixel $\Longrightarrow$ expensive, power consuming
- Currently DC coupled $\rightarrow$ MUSIC is AC coupled $\Longrightarrow$ we have to use the slow readout current to monitor baseline shifts
- SCB needs to be modified to readout slow integration output

MUSIC measurement setup



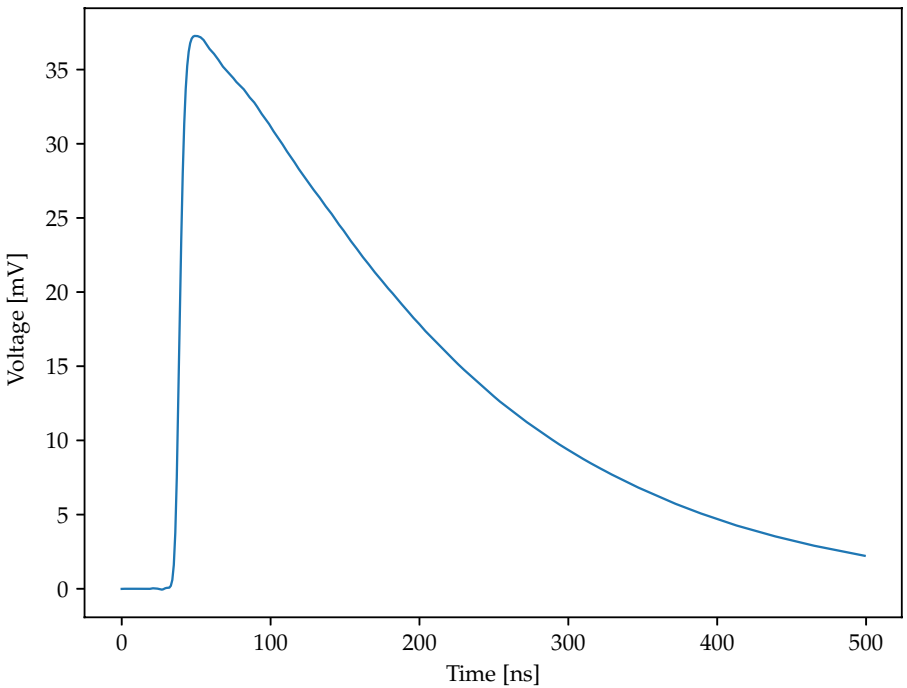
MUSIC measurement setup



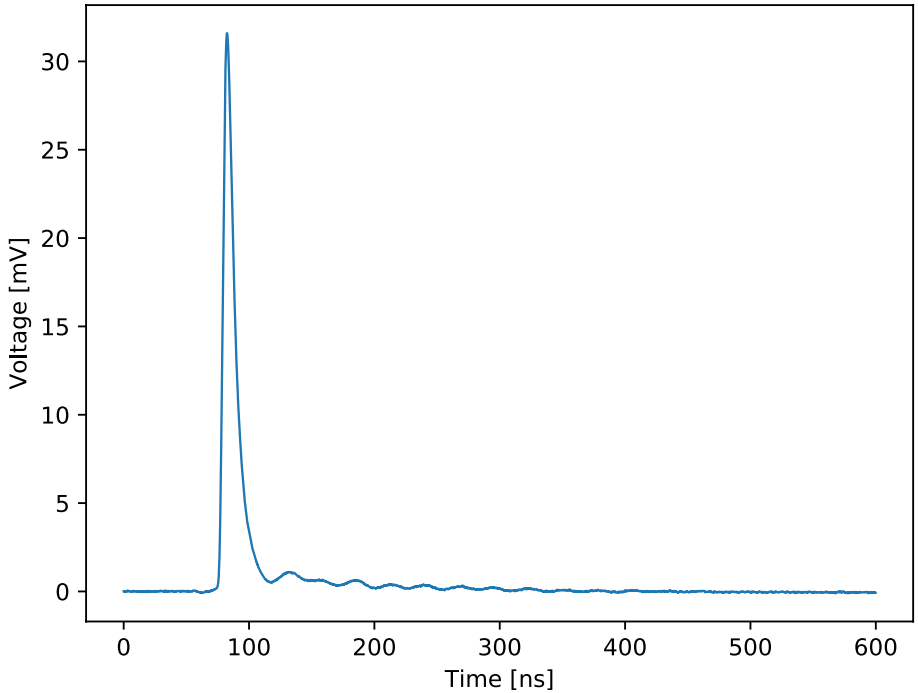
PZ cancellation with LVR3 sensor

Pulse shape before vs. after PZ

No PZ cancellation



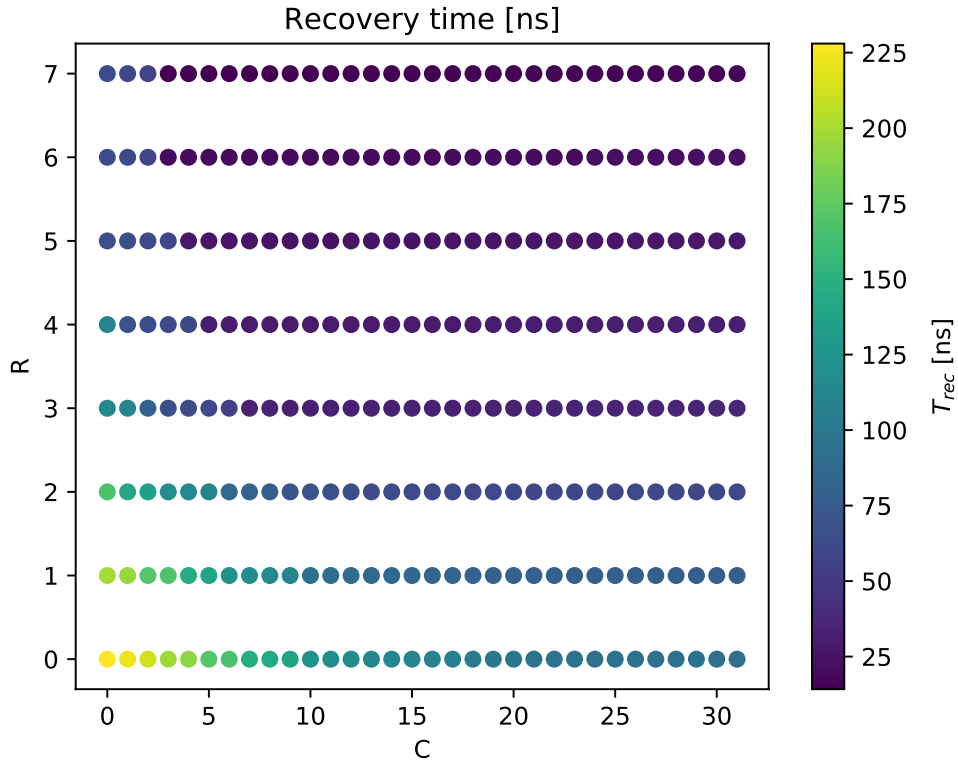
PZ cancellation R=4, C=9



PZ cancellation with LVR3 sensor

Recovery time

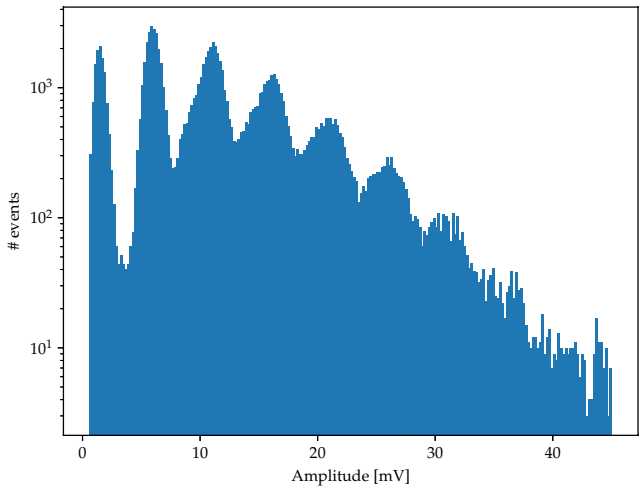
- Integration window 80 ns (CTA requirement)
- Without PZC, LVR3 6x6 pulse recovery time (1 to 1 %) is 400 ns



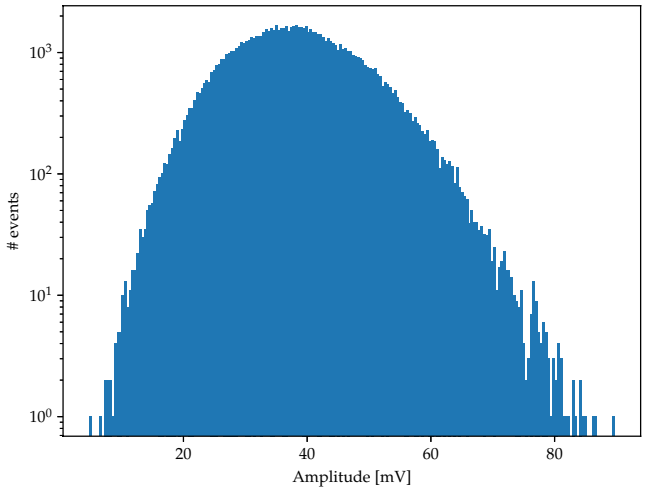
PZ cancellation with LVR3 sensor

Sensitivity to single photon

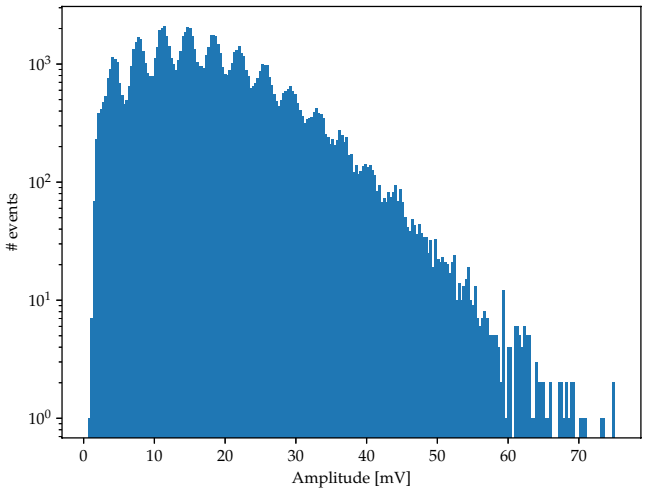
LVR3 3x3
$(\Delta V = 4.4V)$



LVR3 6x6
$(\Delta V = 4.4V)$



LVR3 6x6
$(\Delta V = 7V)$

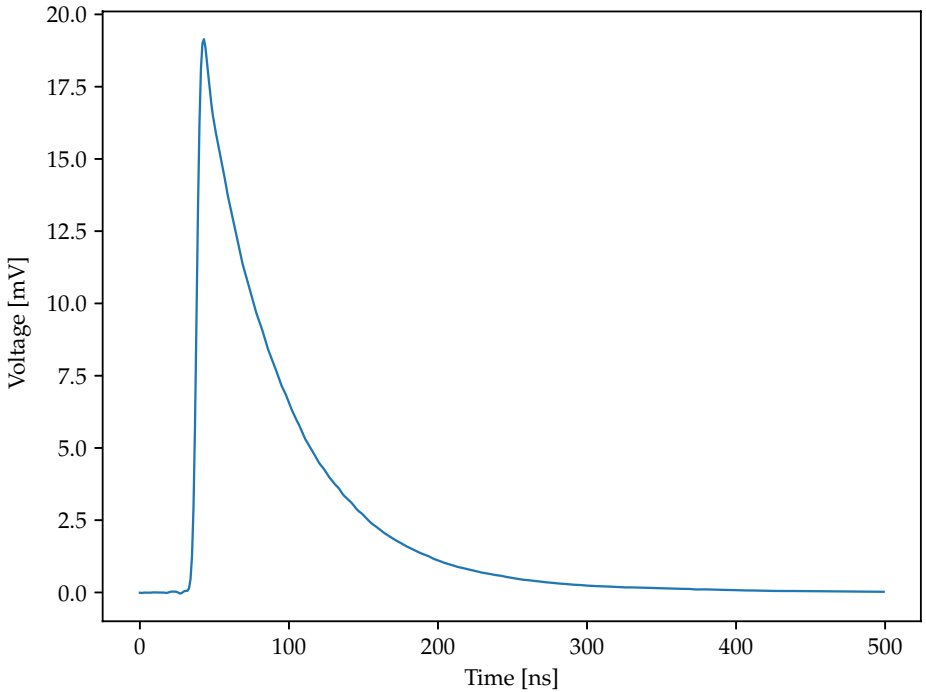


Having a reasonable photon sensitivity would require to work with an over-voltage of at least 7 V and then increase the cross talk probability from 8% to 15%

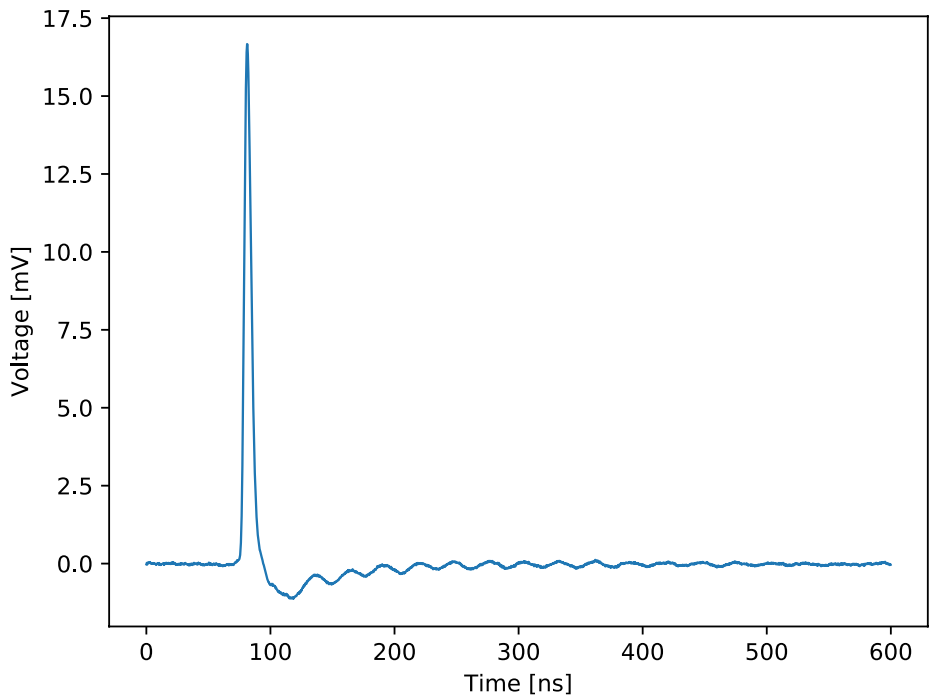
PZ cancellation with LCT5 sensor

Pulse shape before vs. after PZ

No PZ cancellation



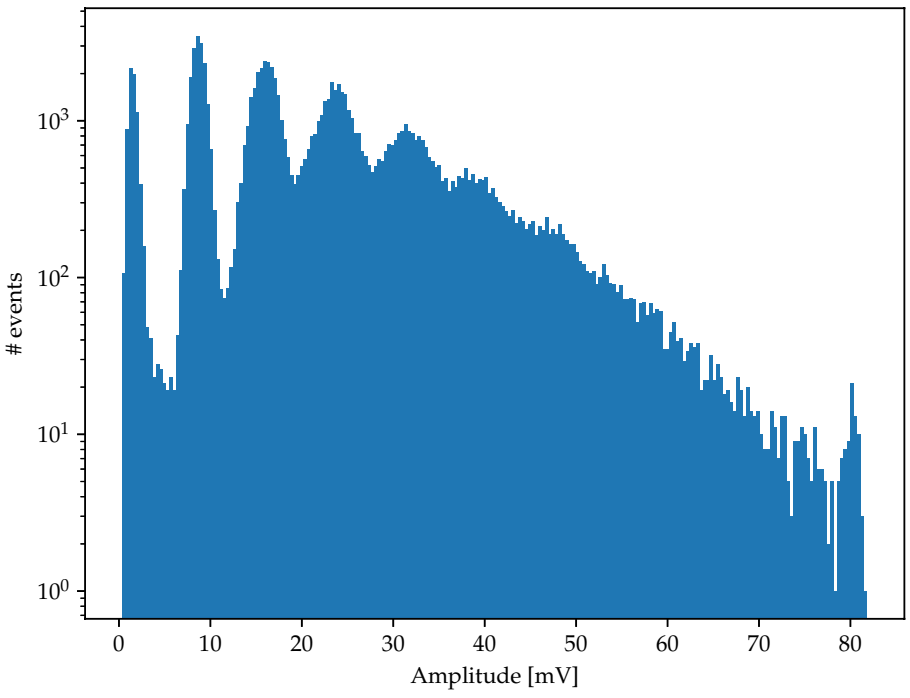
PZ cancellation R=4, C=9



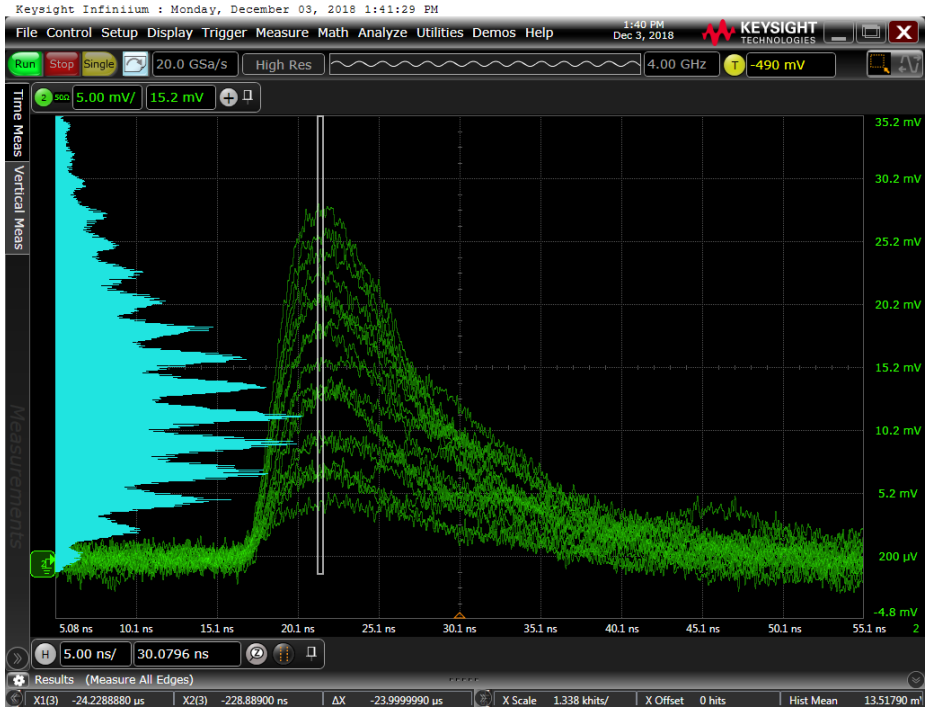
PZ cancellation with LCT5 sensor

Sensitivity to single photon

LCT5 3x3



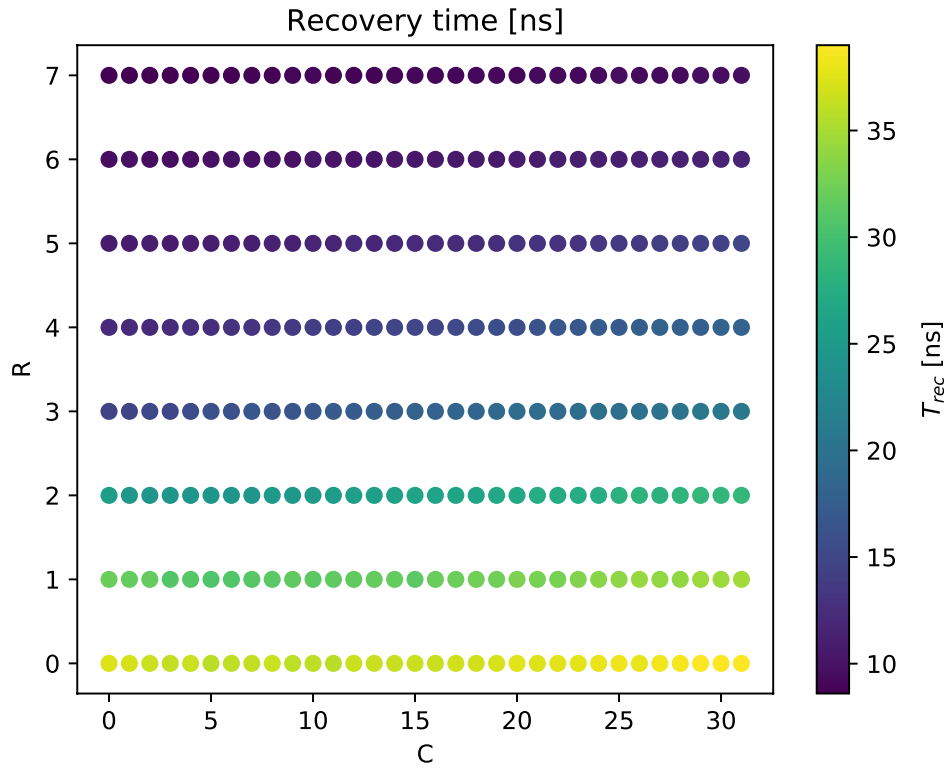
LCT5 6x6



PZ cancellation with LCT5 sensor

Recovery time

- Integration window 80 ns (CTA requirement)
- Without PZC, LCT5 3x3 pulse recovery time (1 to 1 %) is 120 ns

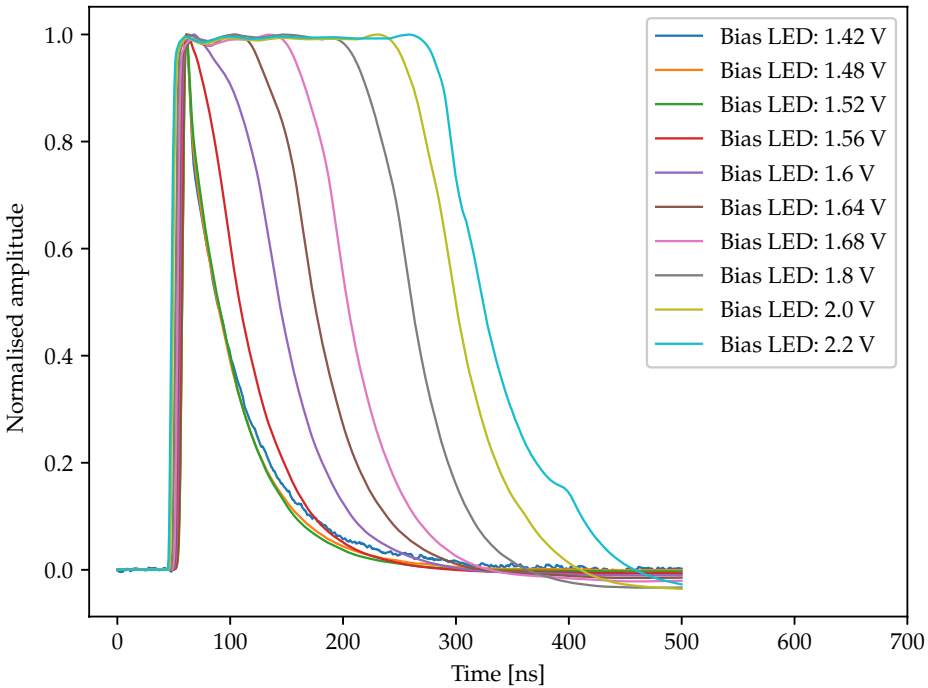


Saturation behavior with LCT5

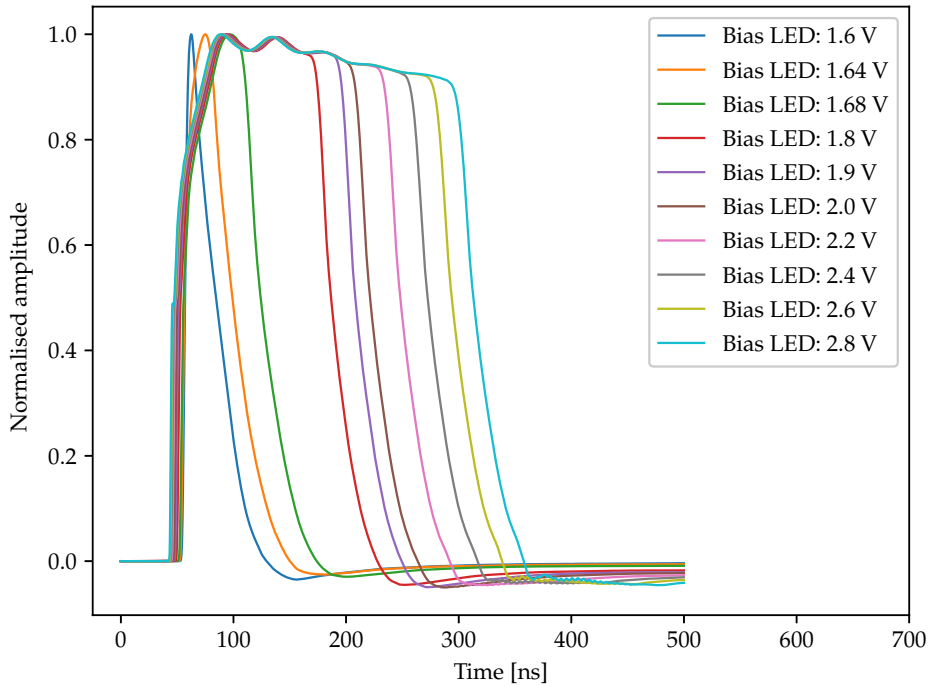
Pulse shapes for increasing light level

Using differential outputs:

High Gain

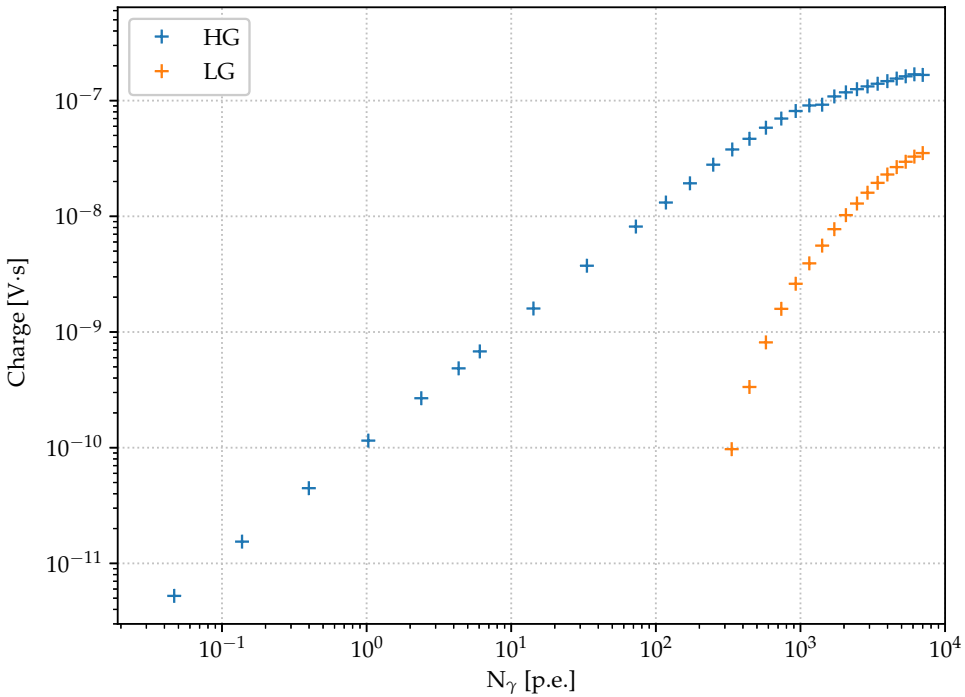


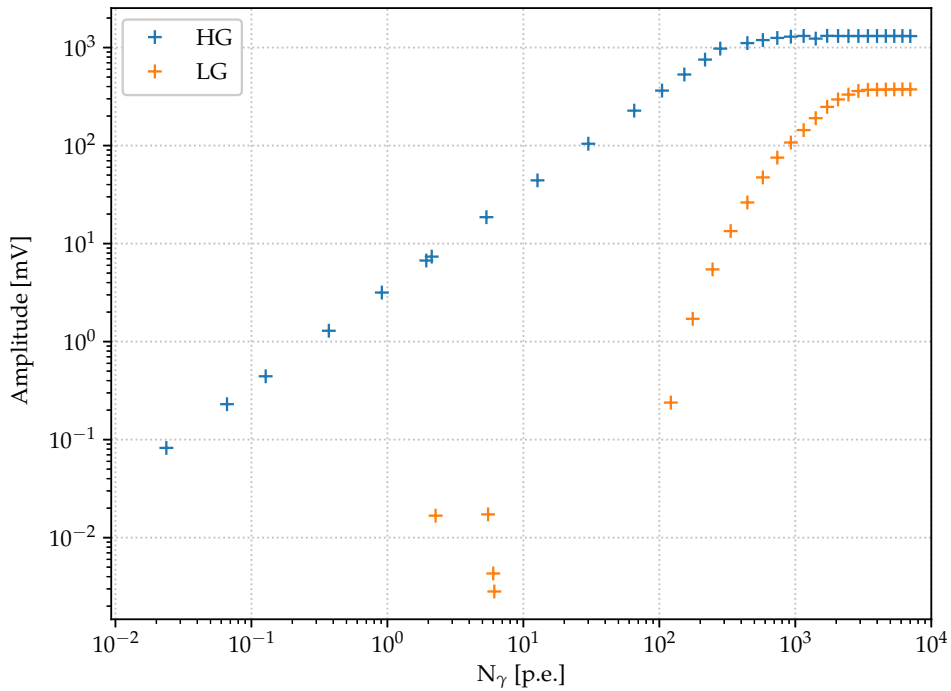
Low Gain



Saturation behavior with LCT5

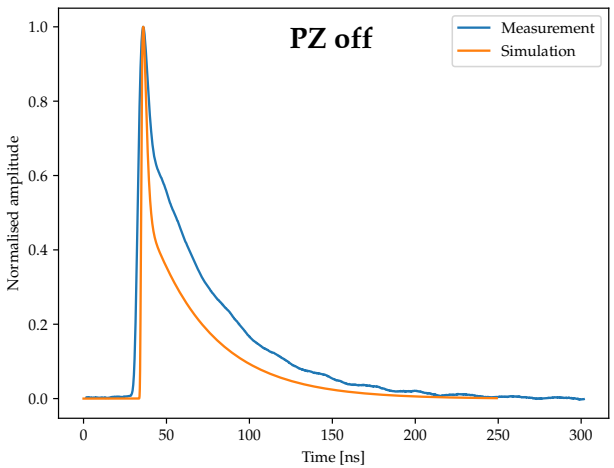
Light level scan

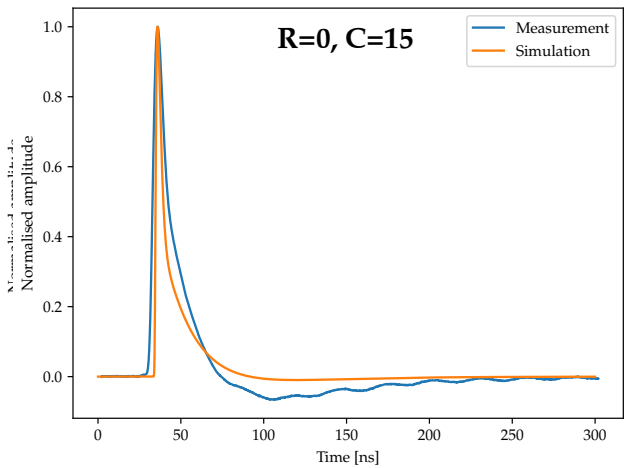


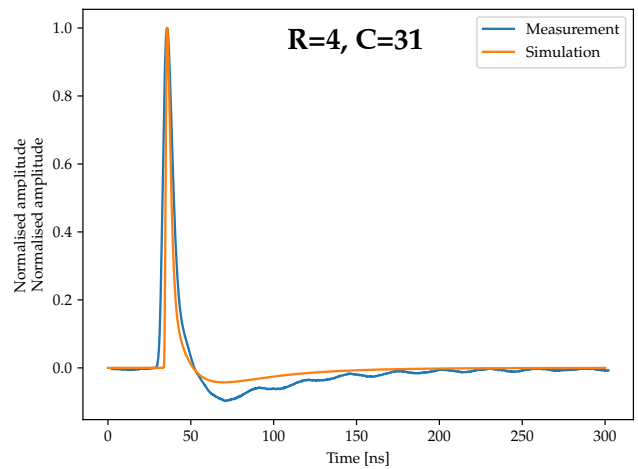


Simulation of the MUSIC ASIC

LCT5 pulse shapes

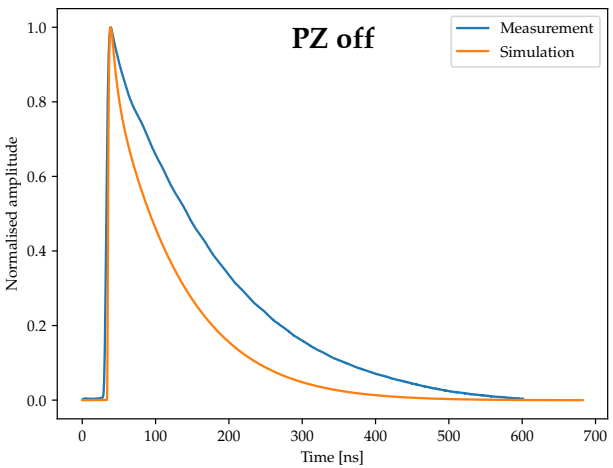


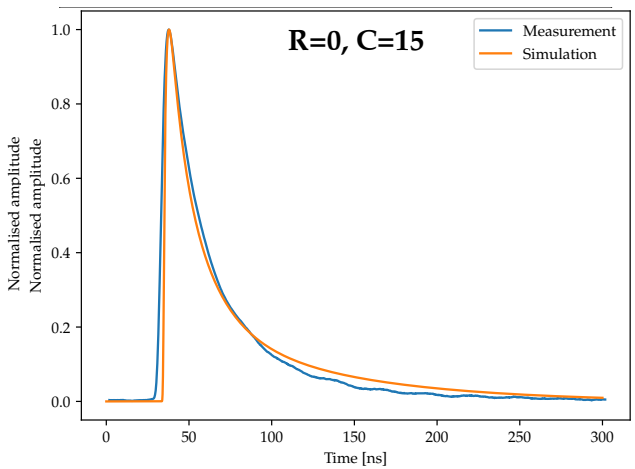


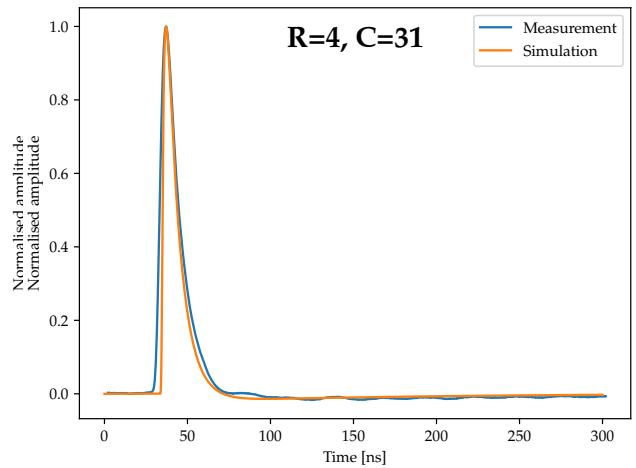


Simulation of the MUSIC ASIC

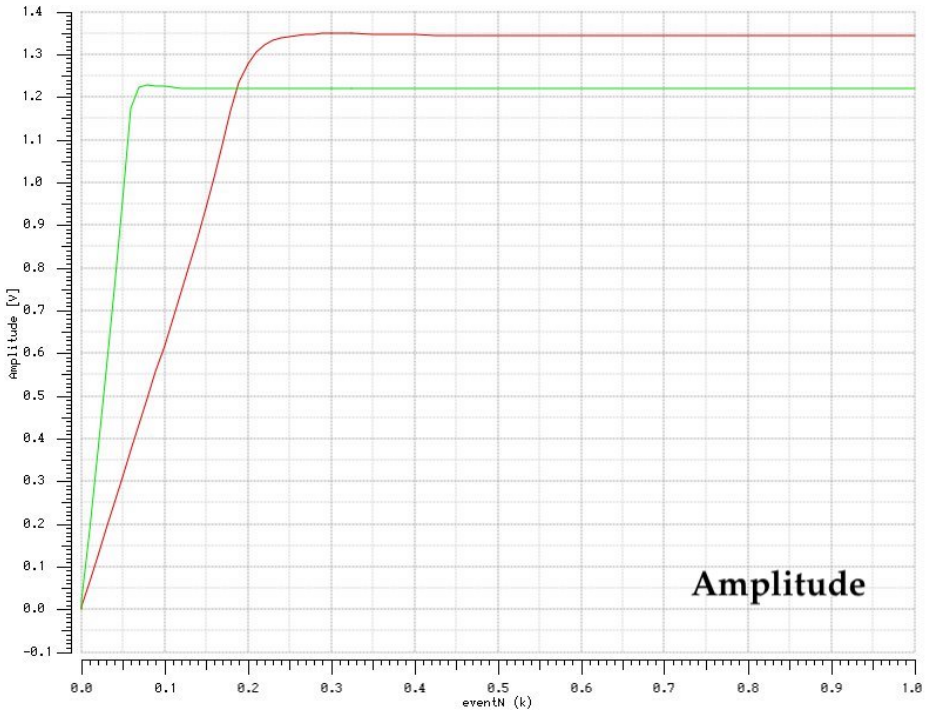
LVR3 pulse shapes

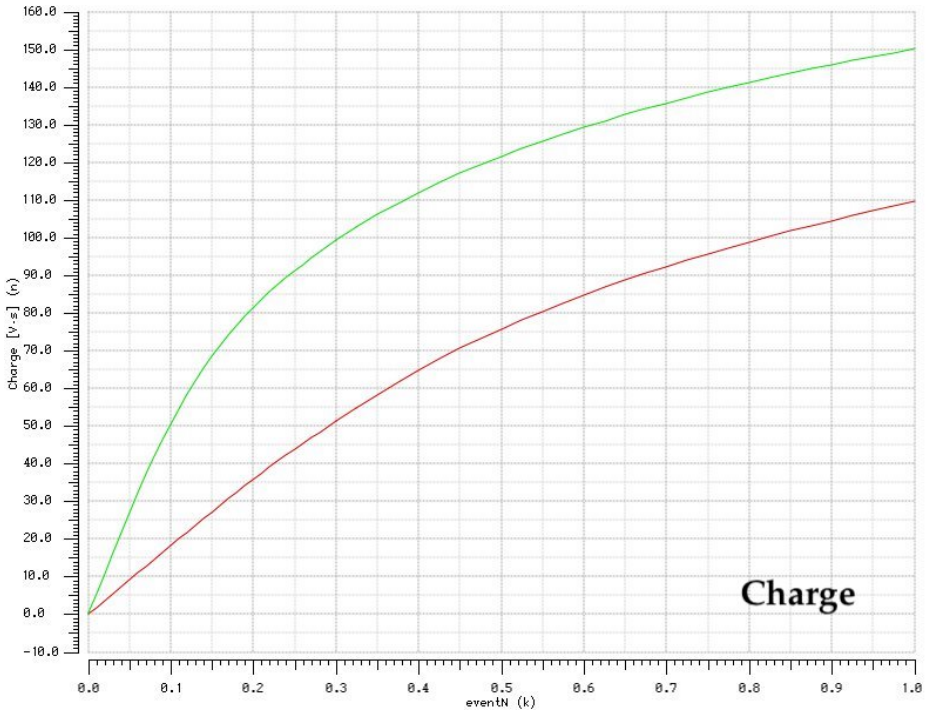






Simulation of the MUSIC ASIC
Saturation behavior





Conclusions

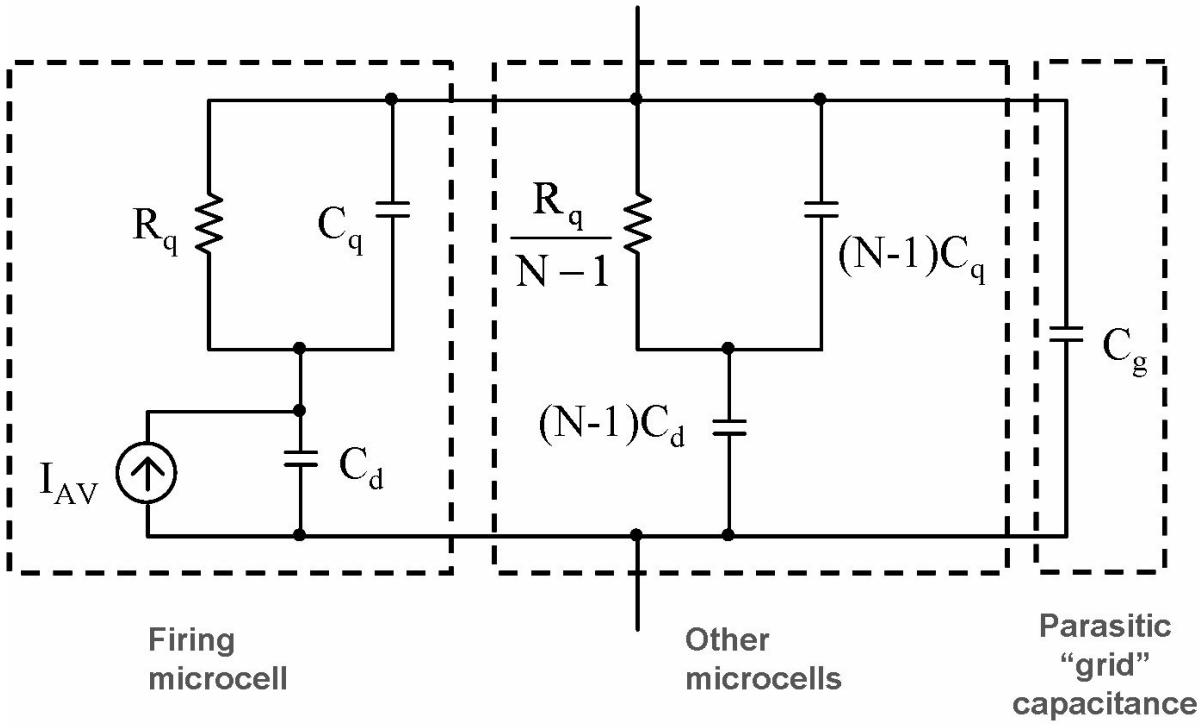
- LVR3 not suitable for our application $\rightarrow$ even if PZC allow short pulses, not able to see single photons
- LCT5+MUSIC could be a good solution for SST-1M
  - PDE from 34% to 48% by replacing LCT2 by LCT5
  - Applying PZC allow very short pulses (less than 30ns)
  - Able to see single photons
  - Good behavior in saturation
  - Very good agreement for the pulse shape between measurements and simulations
- But we would need one MUSIC per pixel, which could be quite expensive and power consuming

  (it would be nice if MUSIC allowed sub-summations)

cherenkov telescope array

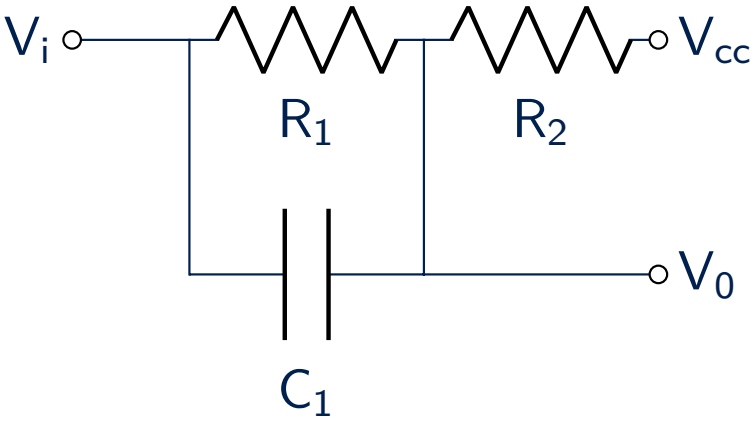
Questions ?

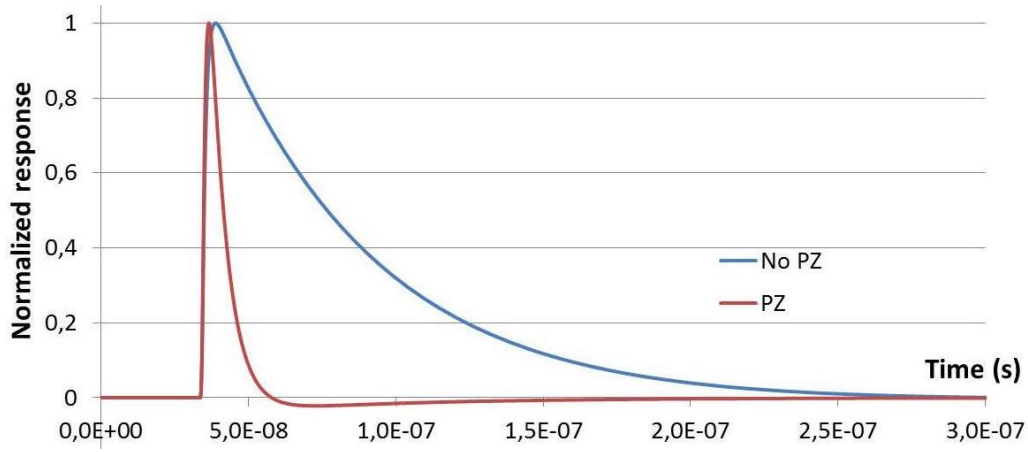
Backup slides
The Corsi model



Corsi, F., et al. "Electrical characterization of silicon photo-multiplier detectors for optimal front-end design." 2006 IEEE Nuclear Science Symposium Conference Record. Vol. 2. IEEE, 2006.

Backup slides
Pole Zero Cancellation





- Resistance ladder R1/R2 take values listed in the table
- 5bit capacitance ladder (C1) follows a linear distribution starting at 1.2pF with steps of 0.1pF

R_{lad}	R_1 (low atten OFF) [kΩ]	R_1 (low atten ON) [kΩ]	R_2 [Ω]
0	46.50	18.60	7650
1	48.30	20.40	5850
2	50.10	22.20	4050
3	51.90	24.00	2250
4	52.35	24.45	1800
5	52.80	24.90	1350
6	53.25	25.35	900
7	53.70	25.80	450