



Laidlaw Scholars

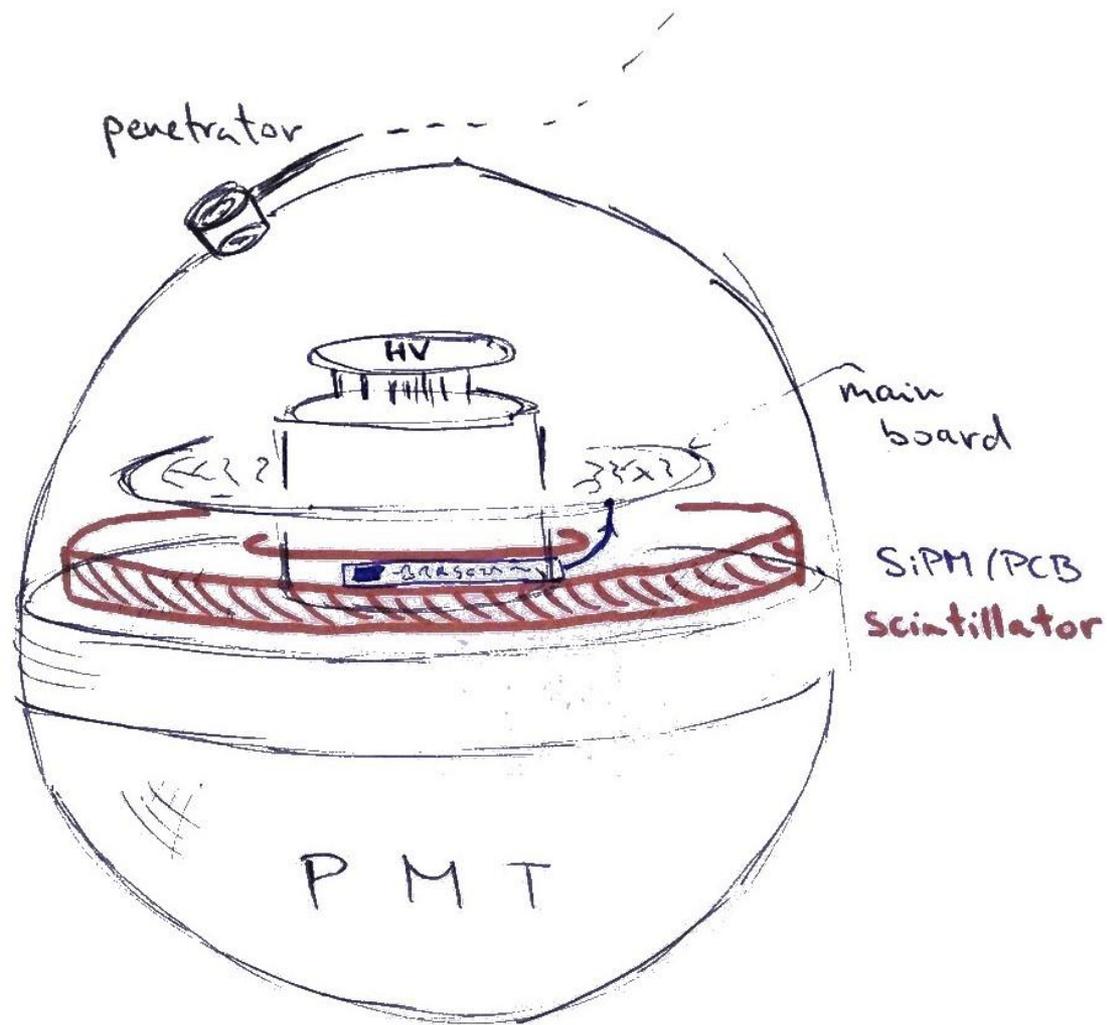
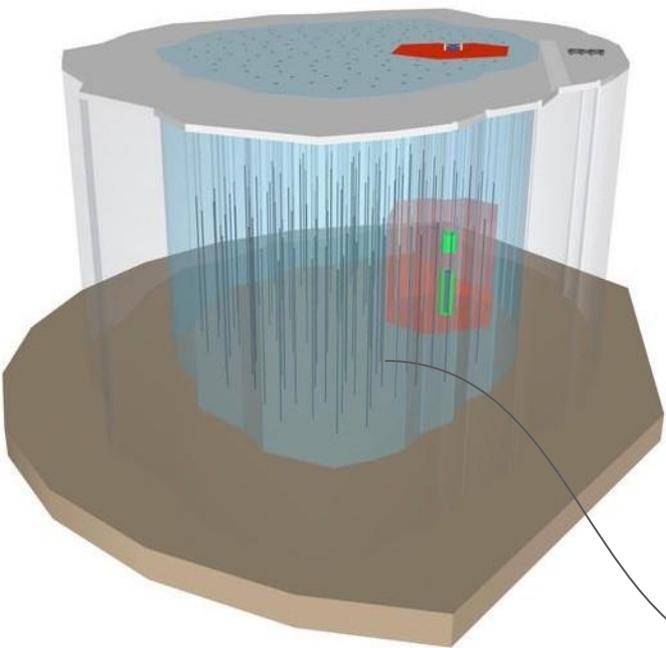
Undergraduate Research and Leadership Programme



NEW COLLEGE
UNIVERSITY OF OXFORD

Project mTOM

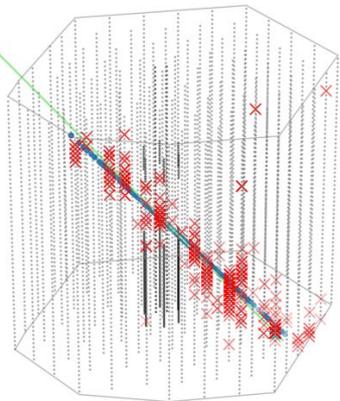
Petr Jakubčík



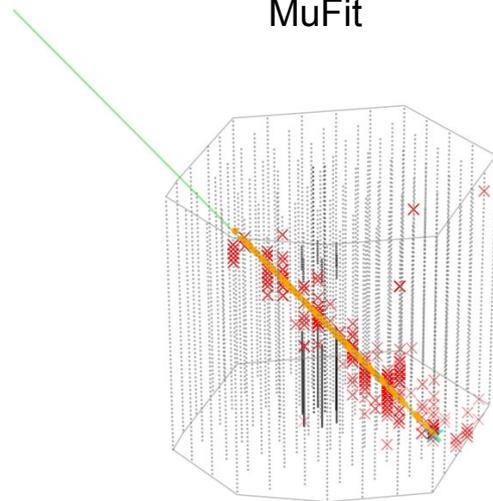
- calibration
- 'golden' events for reconstruction
- ML training sets
- other cosmic ray surveys

Motivation

LineFit



MuFit



← 2.25° off vs 0.37° off →

$$\chi^2 = \sum_j (x_{i,j} - m_i t_j - b_i)^2$$

$$m_i = \frac{\langle x_i \rangle \langle t \rangle - \langle x_i t \rangle}{\langle t \rangle^2 - \langle t^2 \rangle}$$

$$b_i = \langle x_i \rangle - m_i \langle t \rangle$$

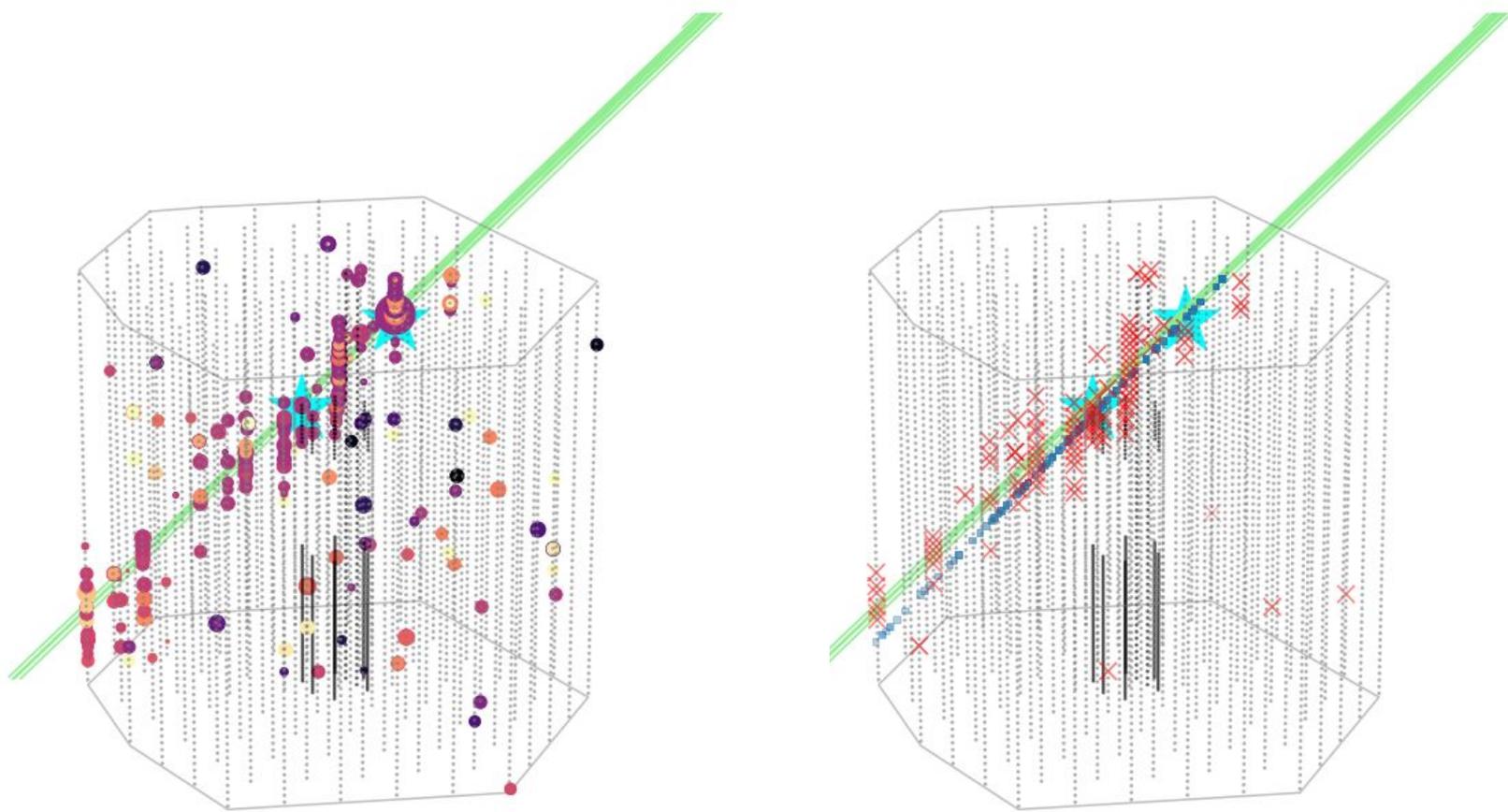
minimize

solve given x, t

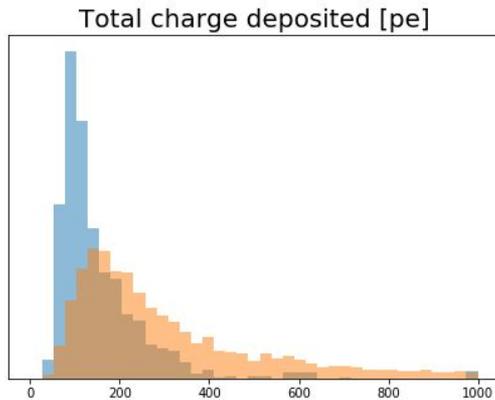
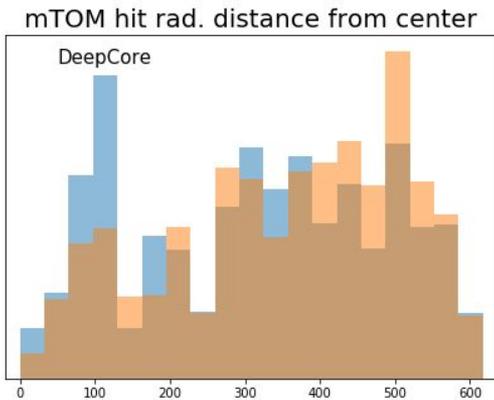
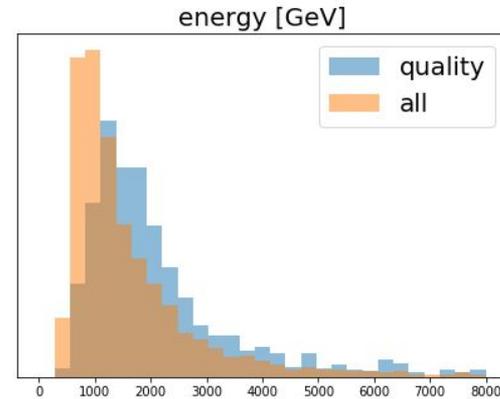
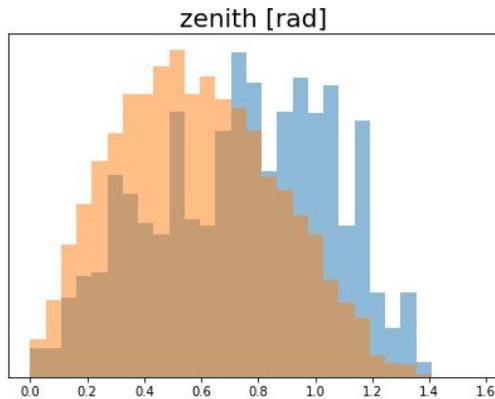
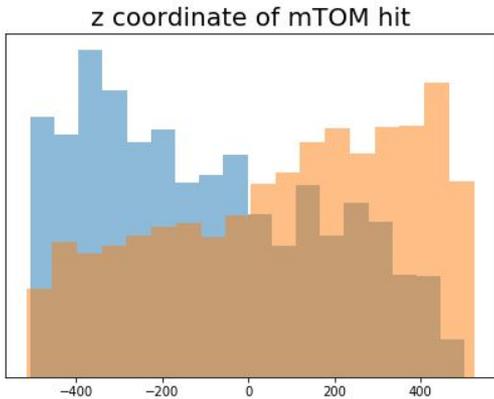
$$\chi^2 = \sum_j ((x_{i,0} - x_{i,j}) - m_i(t_0 - t_j))^2$$

$$m_i = \frac{\langle (x_{i,0} - x_{i,j})(t_0 - t_j) \rangle}{\langle (t_0 - t_j)^2 \rangle}$$

$$b_i = x_{i,0} - m_i t_0$$



3.06° would be reduced to ~0.1°



Significant difference in both observed and naively reconstructable quantities

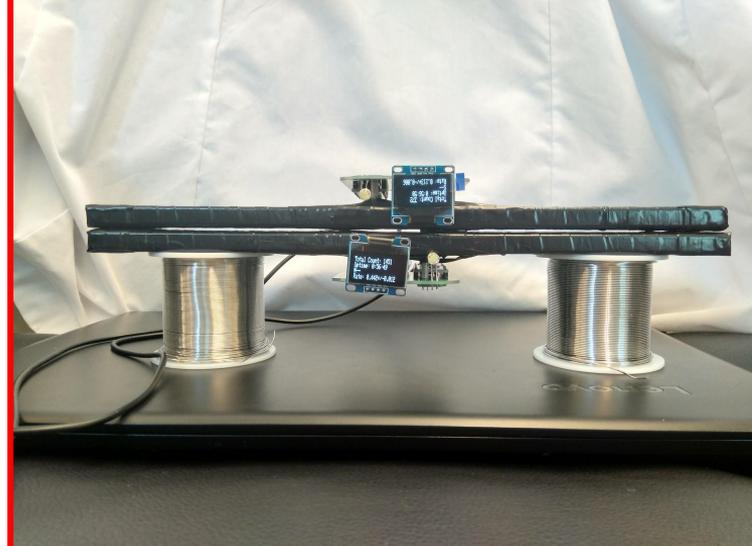


Rel. simple selection of 'golden' events

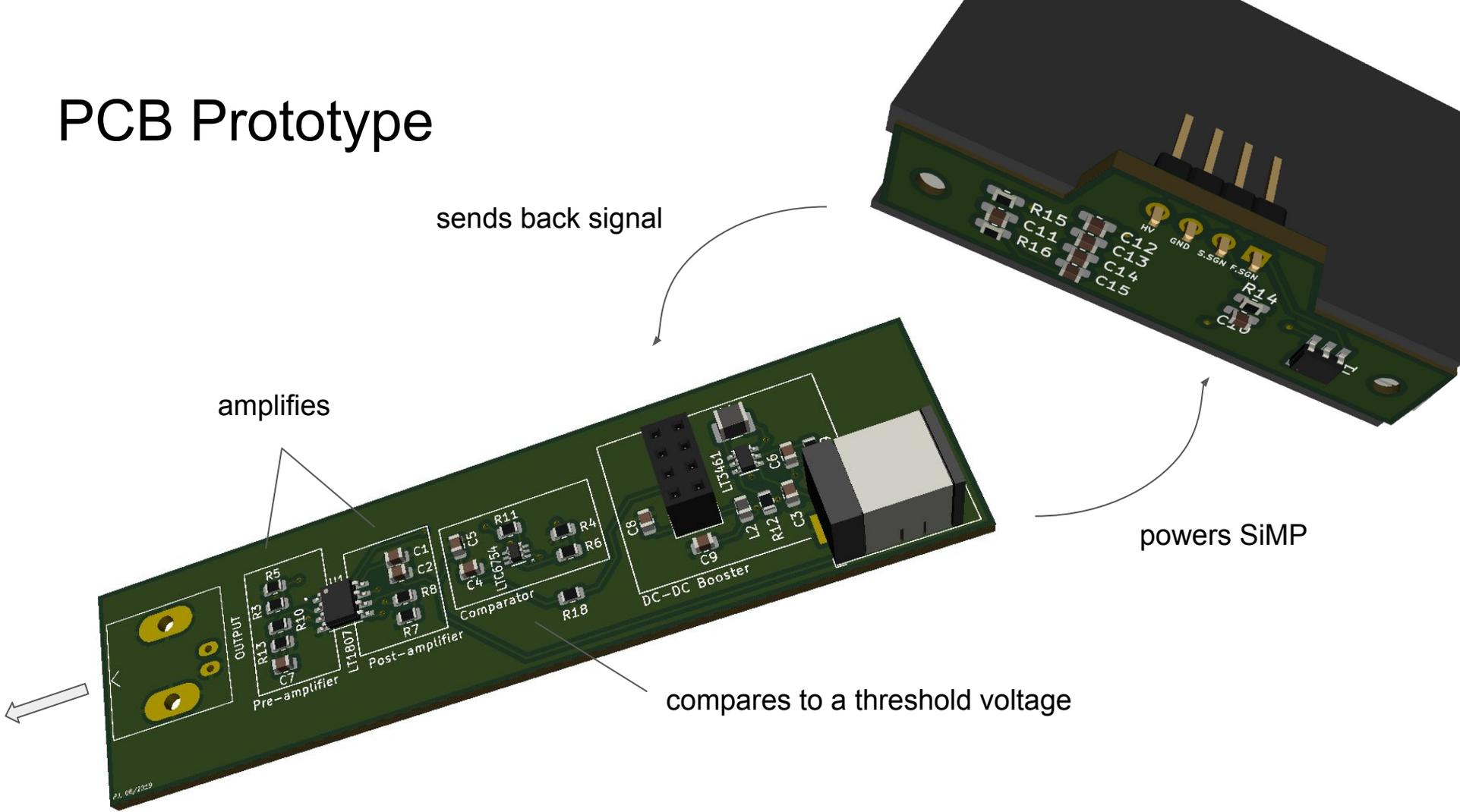
Current state

Scintillator geometry

- ideal length is ~15 cm
 - active area vs attenuation
 - 120° arc
- SiPM mounted **from the sides** significantly more efficient than **from above**
 - cosmic ray incidence rate 3 times higher
- reflective surface and light-tight
 - possibility of TiO_2 coating (no major difference)

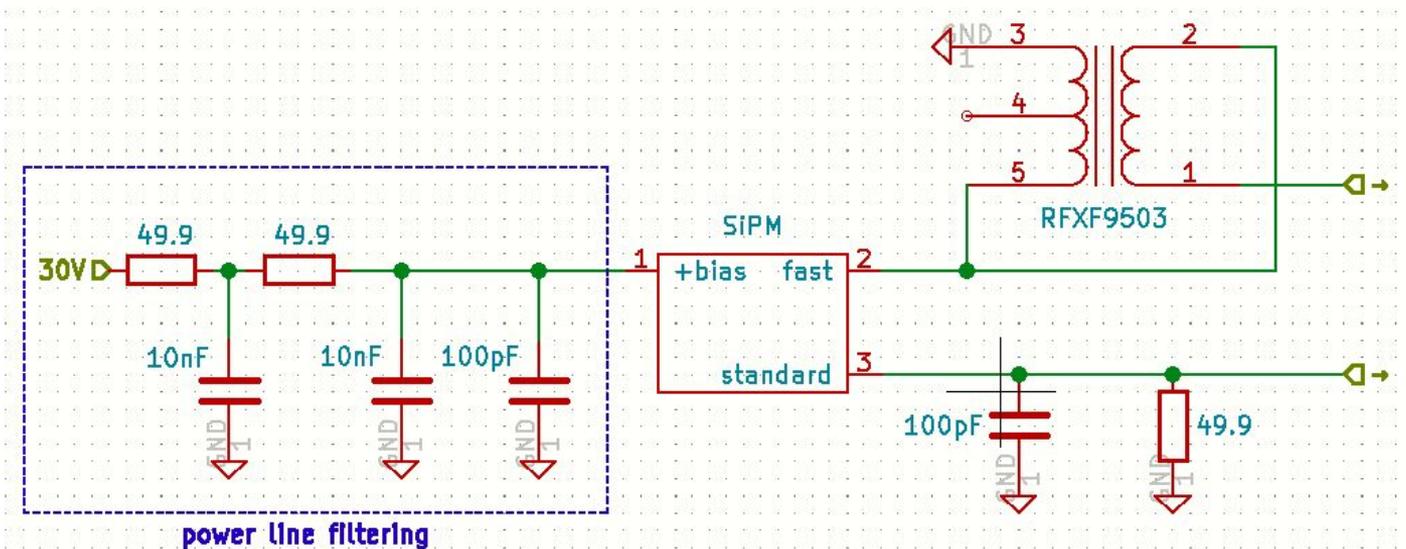
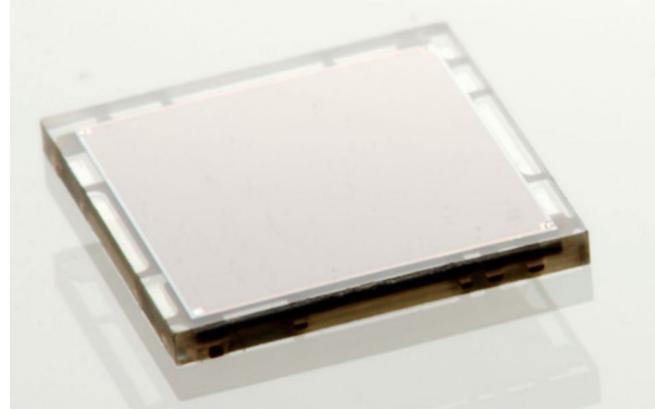


PCB Prototype



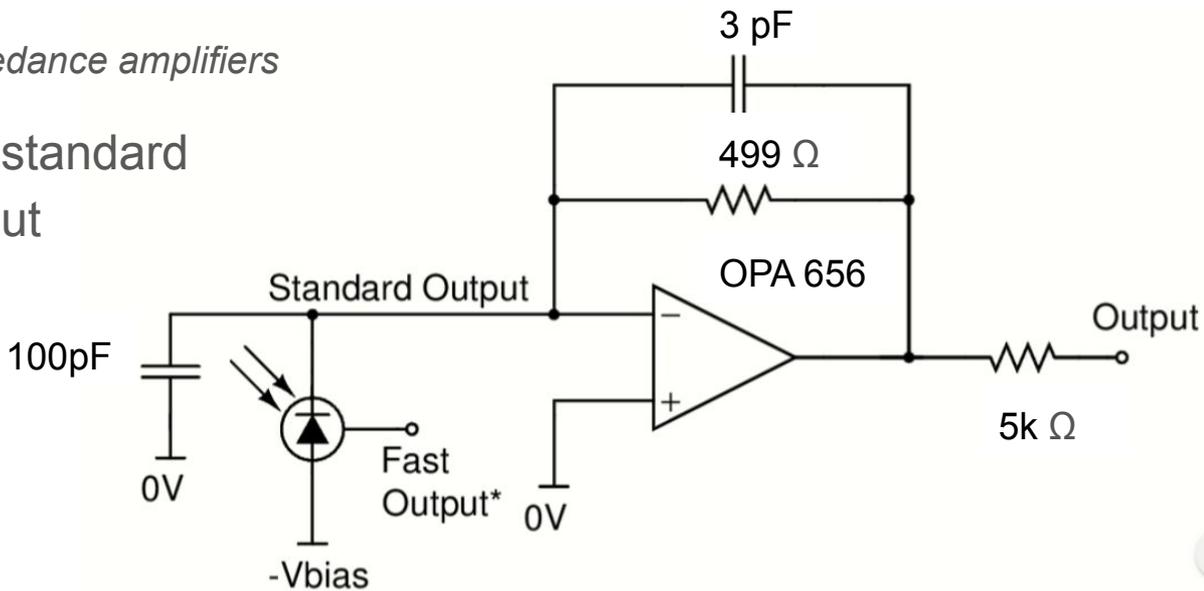
SiPM read-out

- uses 6x6mm SenSL SMT photomultipliers
- is powered from a 5V powering line boosted to 30V (neg. bias recommended)
- outputs a “standard” (100s of ns) and “fast” (2-5 ns) signal



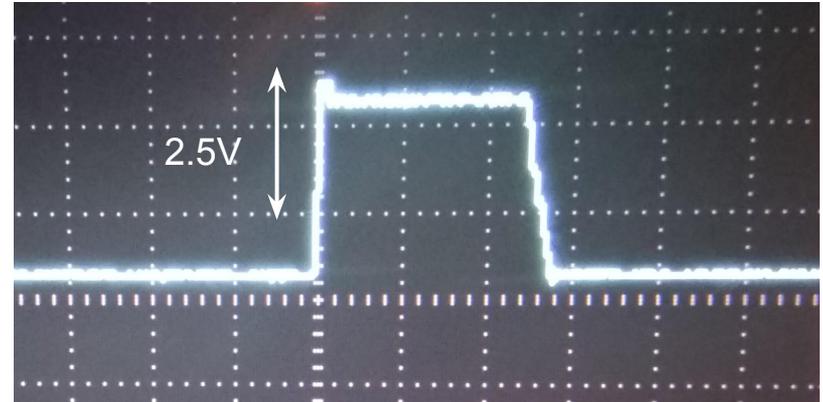
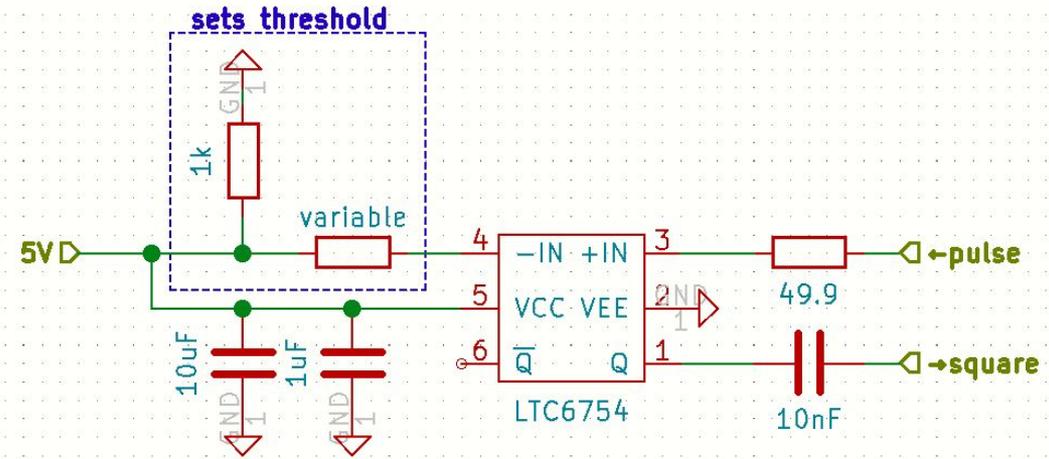
Pre-amplification

- ideally right after SiPM output (robust signal before any bends/wires)
- LT1807 *↖ dual, user-friendly, lower unity-gain bandwidth*
- OPA656 *↖ built for transimpedance amplifiers*
- currently working well for standard but distortion for fast output



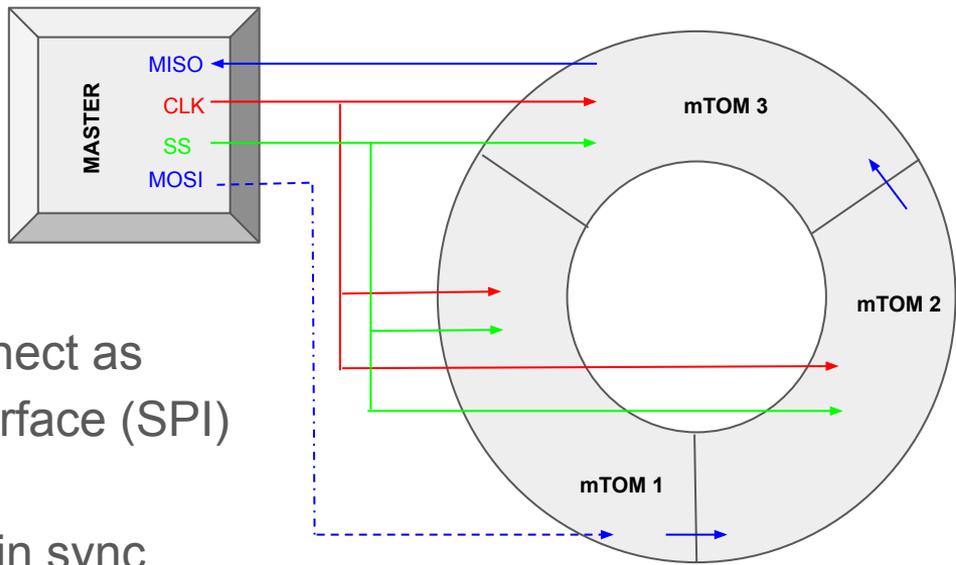
Comparator

- LTC 6754 - 1.8ns propagation delay, 13mA quiescent current
- voltage threshold currently from a voltage divider (eventually from DAC)



Goals

Communication



- each mTOM in a DOM can connect as a Slave in Serial Peripheral Interface (SPI) through CLK, MISO, (SS) lines
→ ensures DOM/mTOM time in sync
- LTC6754 (which draws the most current) allows a shutdown mode - can be handled through the Slave-Select line
- 3 mTOMs in a DOM can be daisy-changed, then master can sample each comparator output at clock frequency (lower angular resolution)
- microcontrollers on mTOMs programmed to send a unique sequence when comparator output high (timing issues)

Power, noise, temperature management

- currently using a DC-DC booster to achieve 30V (includes an inductor)
- bypass transformer recommended by manufacturer
- comparator draws 13.5 mA at 5V
(1mA when shut down)
→ total power consumed < 0.1 mW
- digital/analog separation, sizable ground plane, no loops etc.
- temperature calibration curve will need to be measured

