CITIROC BASED SIPM READOUT FOR HELIX RICH DETECTOR

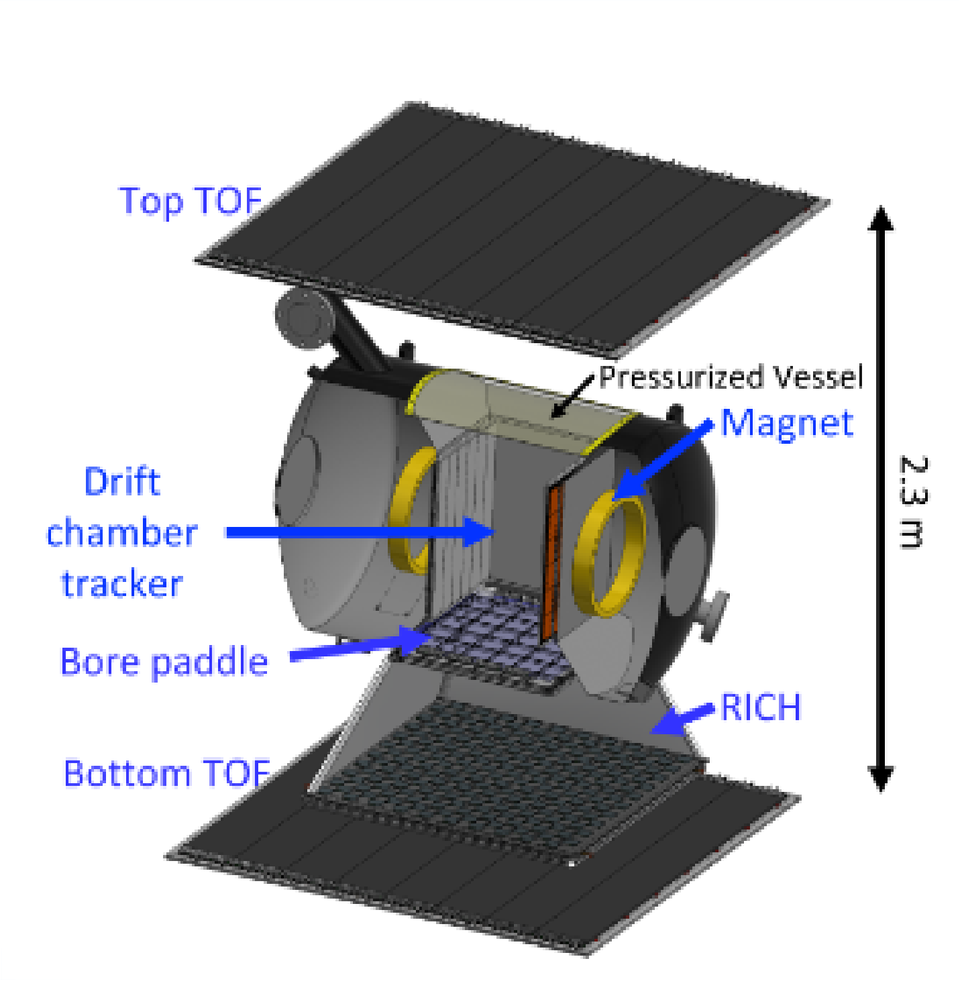
Lily Moss
Queen’s University
Supervised by Dr. Nahee Park

Project Background

High Energy Light Isotope eXperiment (HELIX)

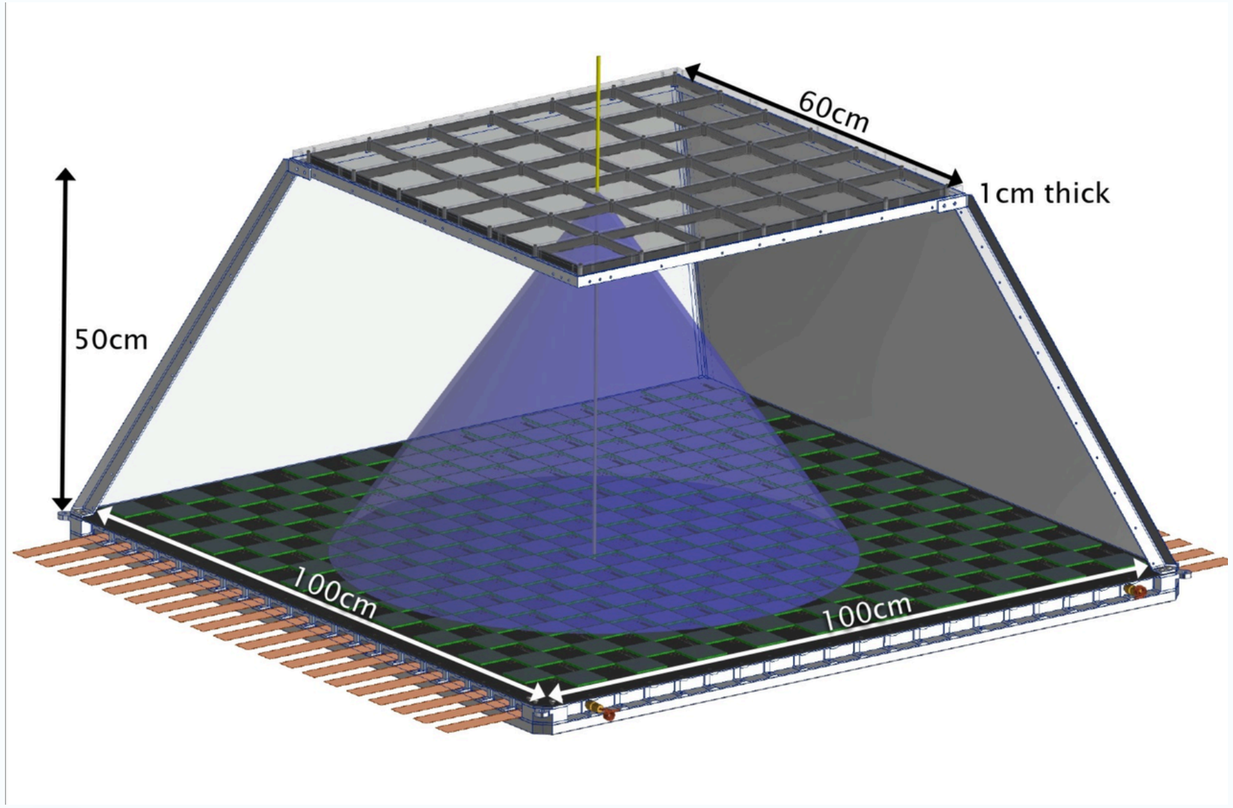
- Cosmic ray balloon experiment
- Studying propagation of cosmic rays
- Optimized to measure 9-Be and 10-Be isotopes
- Clock isotopes provide insight into propagation times
- First flight in May 2024, studied 0.2 - 3 GeV / n
- Further flights up to 10 GeV / n

HELIX Instrument



- TOF: scintillating paddles, measures timing, velocity and charge
- DCT: multi-wire gas detector, tracks position to measure rigidity
  - Housed within 1 T superconducting magnet
- RICH: Ring Imaging CHerenkov detector
  - Radiator plane: aerogel tiles produce Cherenkov light
  - Focal plane: array of 12800 Silicon Photomultipliers (SiPMs)
  - Measures velocity of higher energies

The RICH



Radiator Plane:

- Aerogel properties:
  - Tuneable refractive index
  - Low density
- NaF: for cross calibration measurements with TOF

Focal Plane:

- 1 square meter
- 12800 SiPMs each 6mm x 6mm

Requirements

- Low power consumption
- Trigger 12800 SiPMs at 1 PE (Photoelectron)

The CITIROC

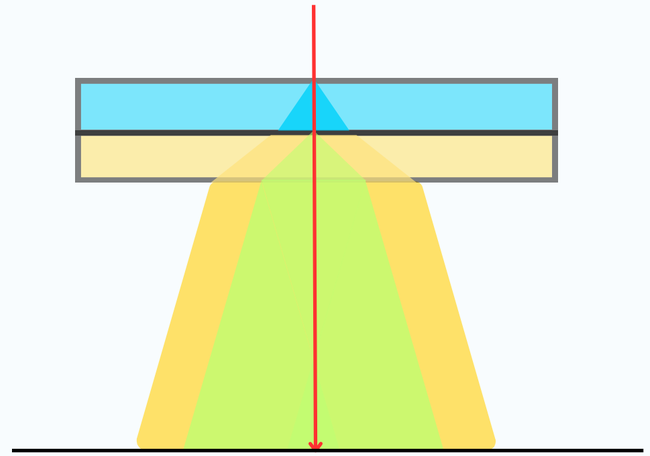
Cherenkov Imaging Telescope Integrated Read Out Chip (CITIROC)

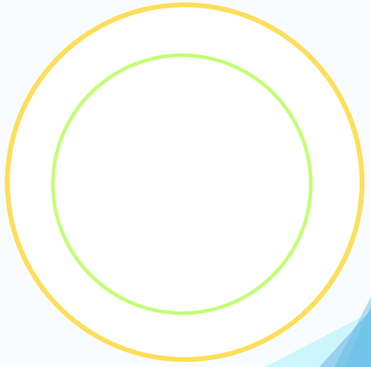
- 32 channel ASIC (Application-Specific Integrated Circuit)
- Triggers on > ⅓ PE
- Charge measurements through positive signal integration
- Power consumption 225 mW (low)

Upgrade to the RICH

Dual-Layered Aerogel

- Aerogel tiles with two different refractive indices
- Benefits:
  - Multiple cherenkov cones
  - **Improved energy threshold (maintaining mass resolution)**
- Upcoming beam test to quantify how much this will improve our resolution
- Beam test will involve a model set-up with CITIROCs and SiPMs
- My work: characterize SiPMs and CITIROC DT5202 to be used in beam test

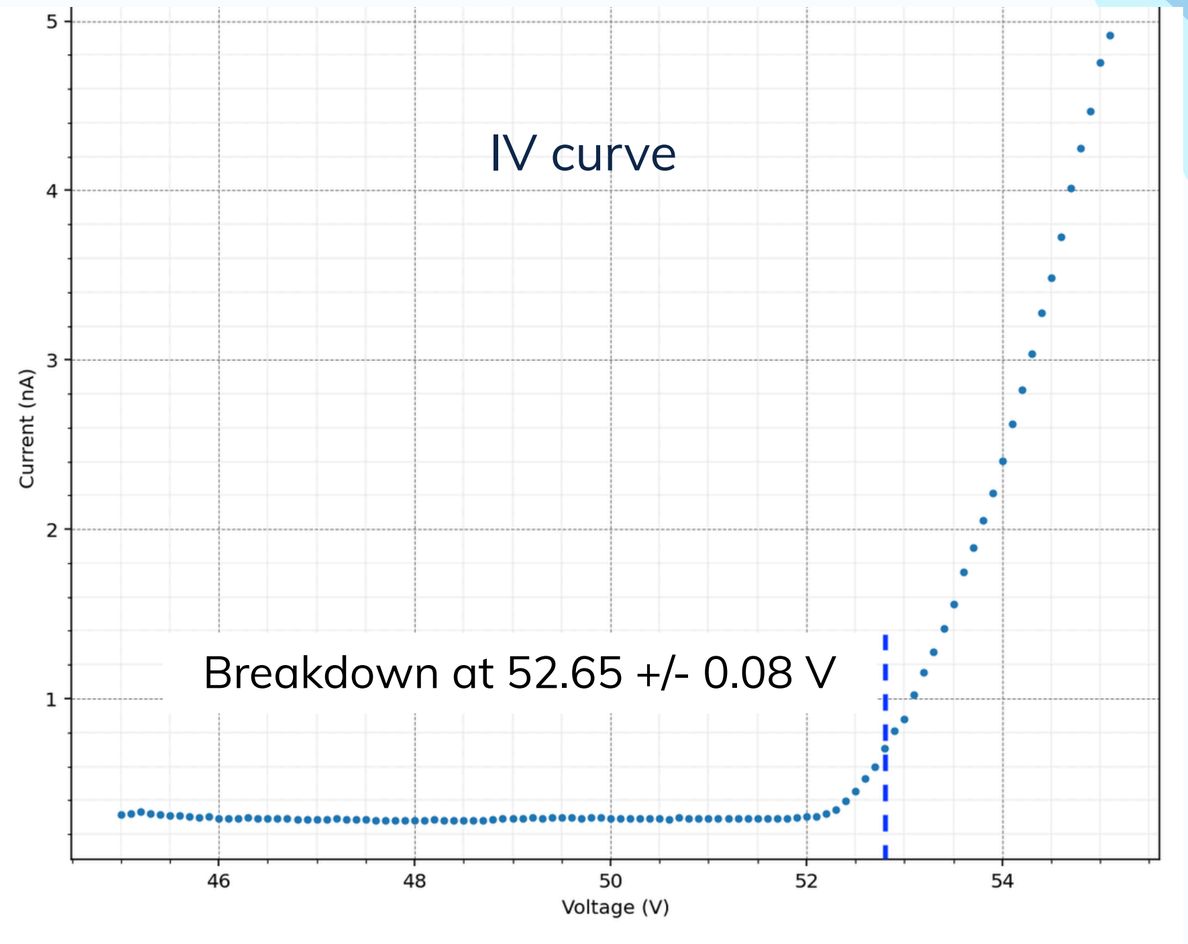




Characterizing SiPM

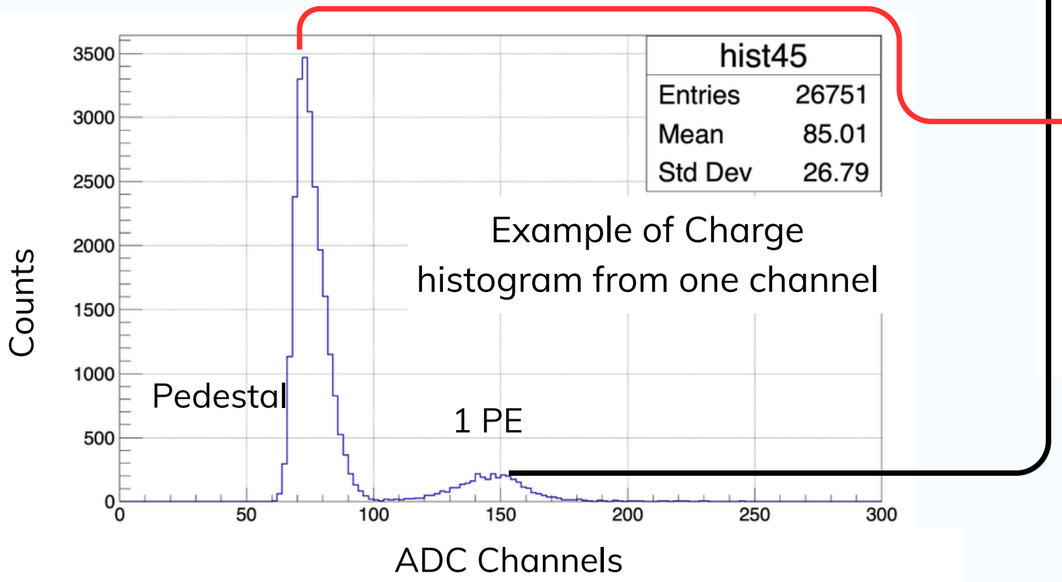
Current vs Voltage (IV) curves:

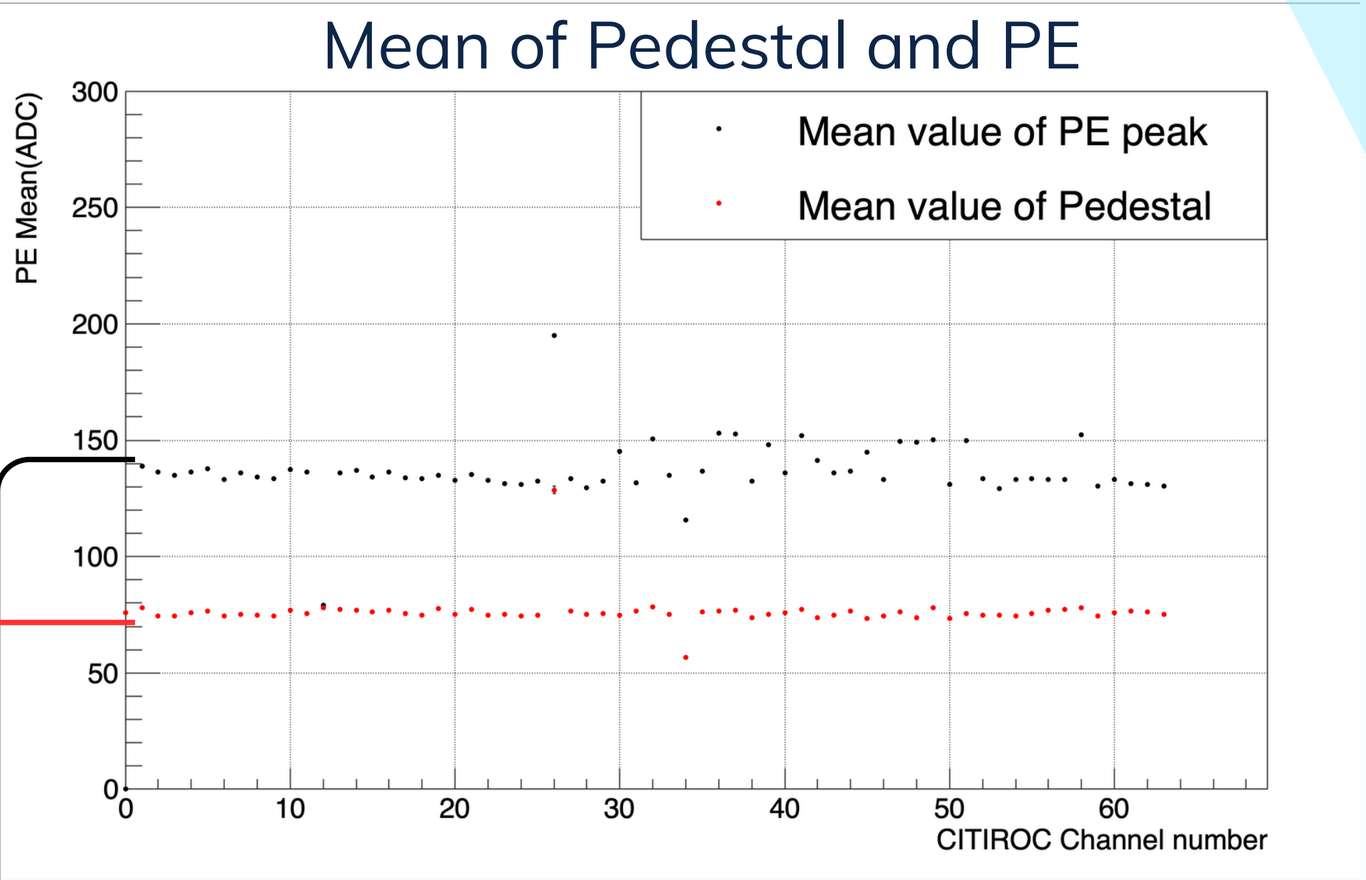
- Goal: measure breakdown voltage for gain calculation
- Breakdown voltage is a property of the SiPM
  - It’s the point when the SiPM starts being conductive and able to measure light
- It is calculated using an approximation of the local second derivative
- Measured breakdown at 52.65 +/- 0.08 V
- Manufacturer breakdown at 52.2 V



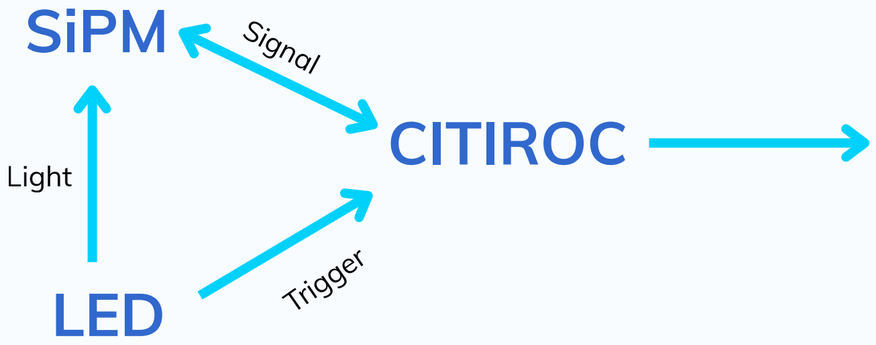
CITIROC DT5202

- CITIROC DT5202 is the model planned for use during RICH upgrade beam test
- Goal: check uniformity of all 64 channels
  - Pedestals: 3.5% variation
  - Photoelectron (PE) peaks: 7.4% variation

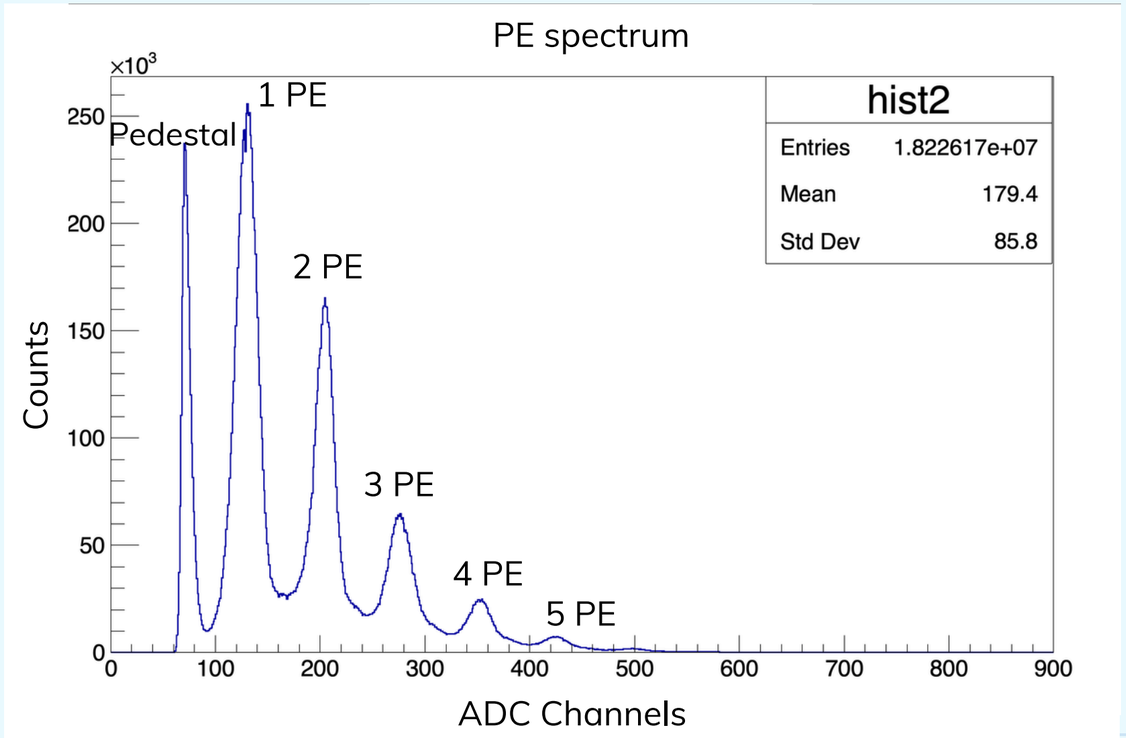




PE spectrum



- Testing with LED driver
- Results
  - CITIROC parameters have been optimized
  - CITIROC board output has linearity

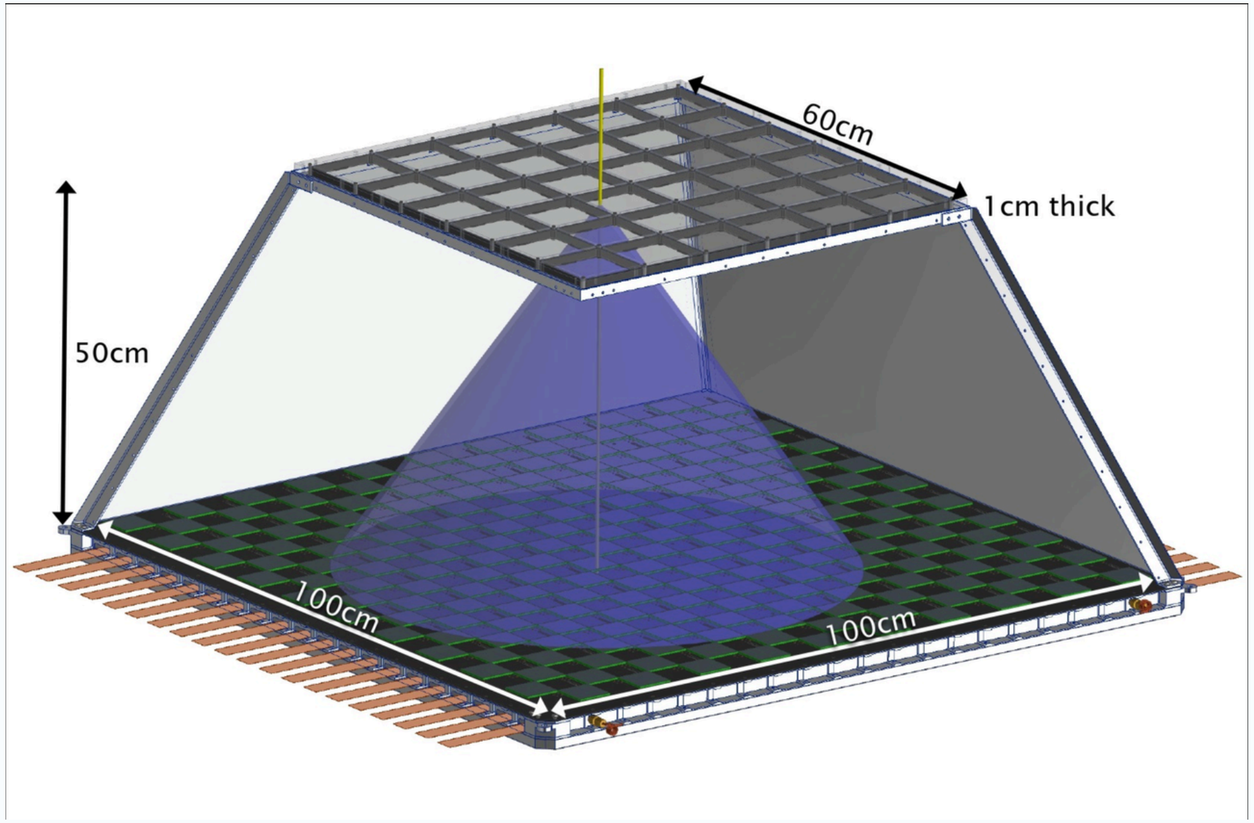


Summary

- Dual-refractive index aerogel upgrade to RICH, needs to be tested to make sure performance will improve
- CITIROCs for SiPM readout in the RICH
- SiPM characterized by the breakdown voltage
- CITIROC channel validation
- Tested CITIROC paramters and linearity

THANK YOU

RICH Specs



- 32 hydrophobic aerogel tiles (n=1.16)
- 4 tiles of NaF (n=1.33), one in each corner
- All tiles are 10 cm x 10 cm x 1 cm
- Focal plane has 200 SiPM arrays
  - Each has 64 SiPMs
- β resolution of 0.1% for Z>3
- Hamatsu SiPMs with 75 um pitch
- Checkered pattern to maximize area and reduced cost

The CITIROC (cont’d)

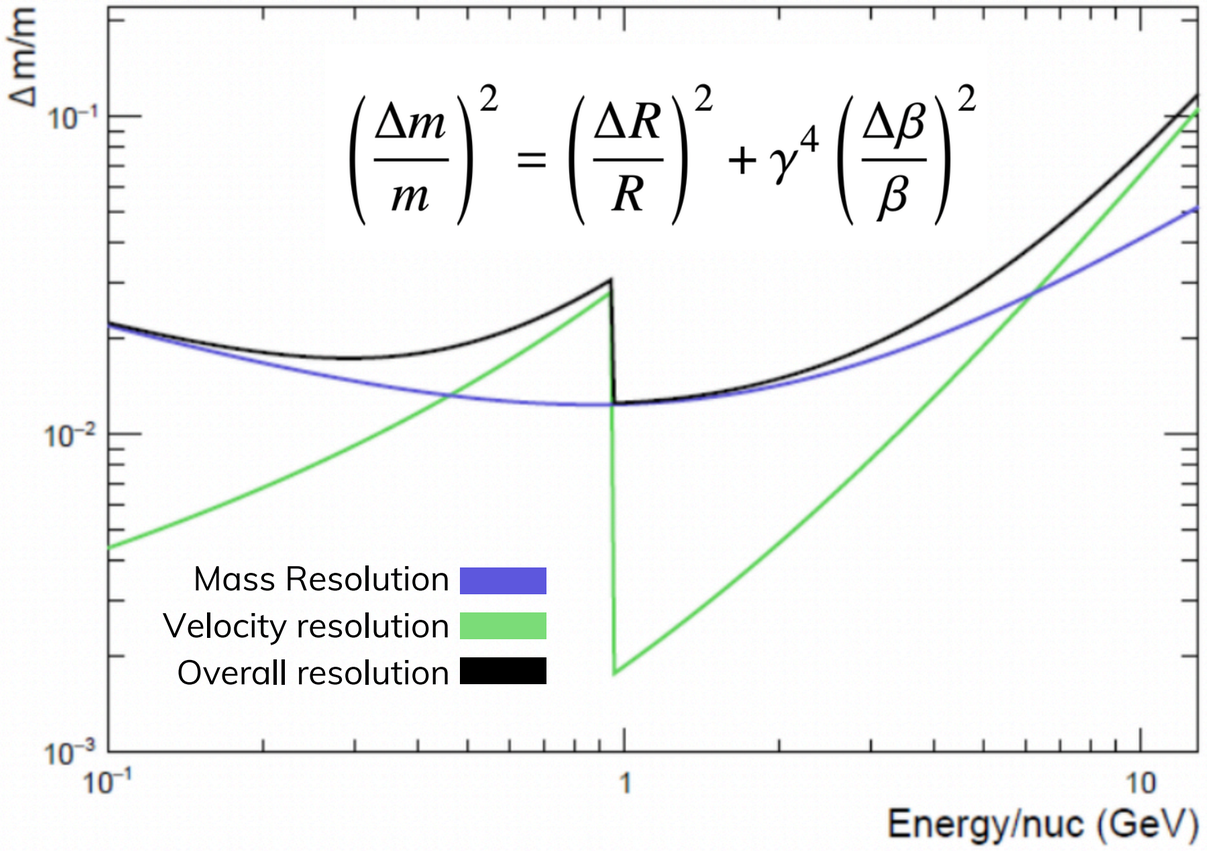
CITIROC specs

- Power consumption of 225 mW
- Supply voltage 3.3 V
- Positive Signal Polarity
- Timing resolution better than 100 ps (RMS of one PE)
- Dynamic range 0-400 pC (or 2500 PE with SiPM gain of 10e6)

HELIX Resolution

- HELIX measures rigidity, velocity and charge
- Calculates mass to determine which isotope of Beryllium
- Requires high mass resolution to distinguish between isotopes (designed for 3%)

$$R = \frac{\beta m c^2}{Ze\sqrt{1-\beta^2}}$$



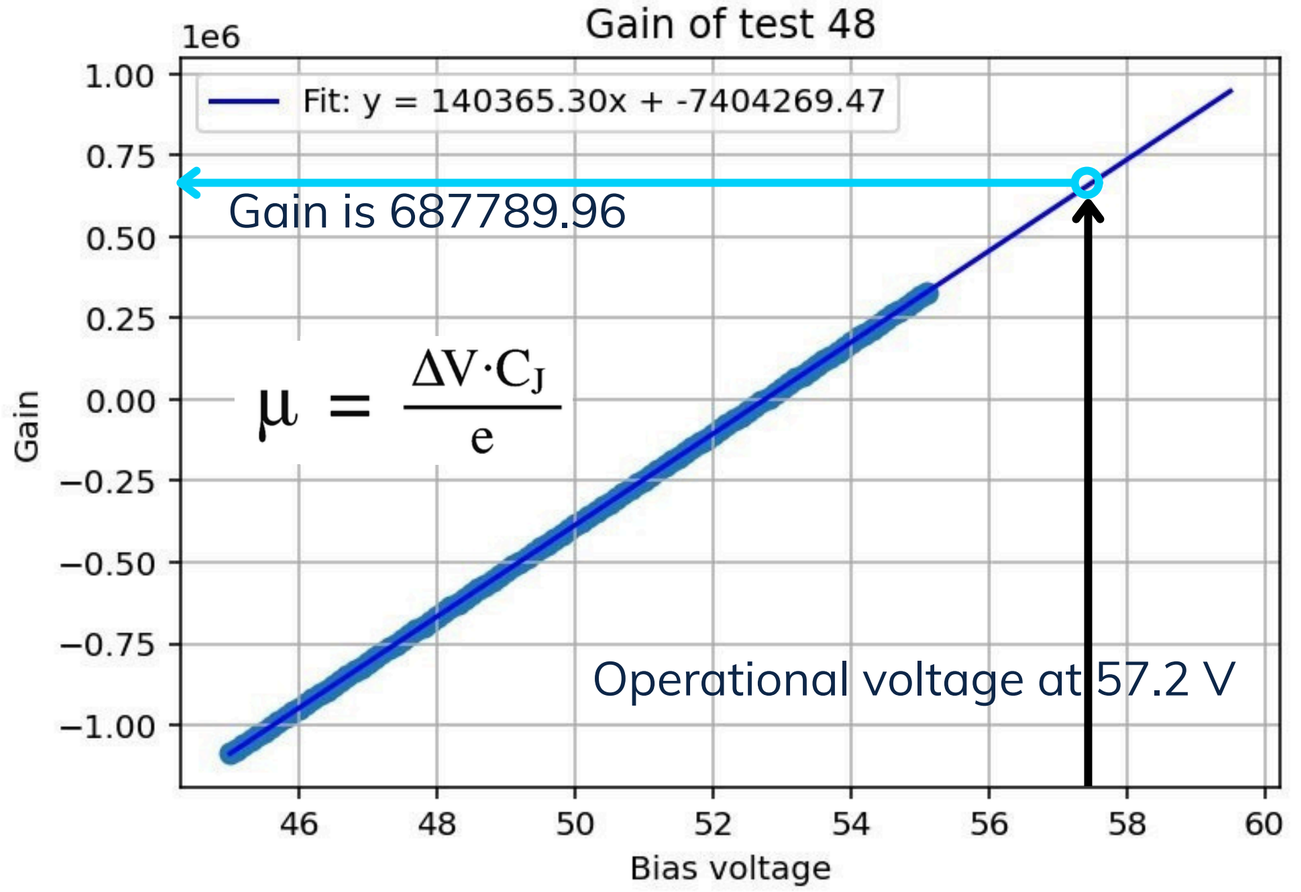
The High Energy Light Isotope eXperiment program of direct cosmic-ray studies (2024)
Cosmic-ray isotope measurements with HELIX (2019)

Characterizing SiPM

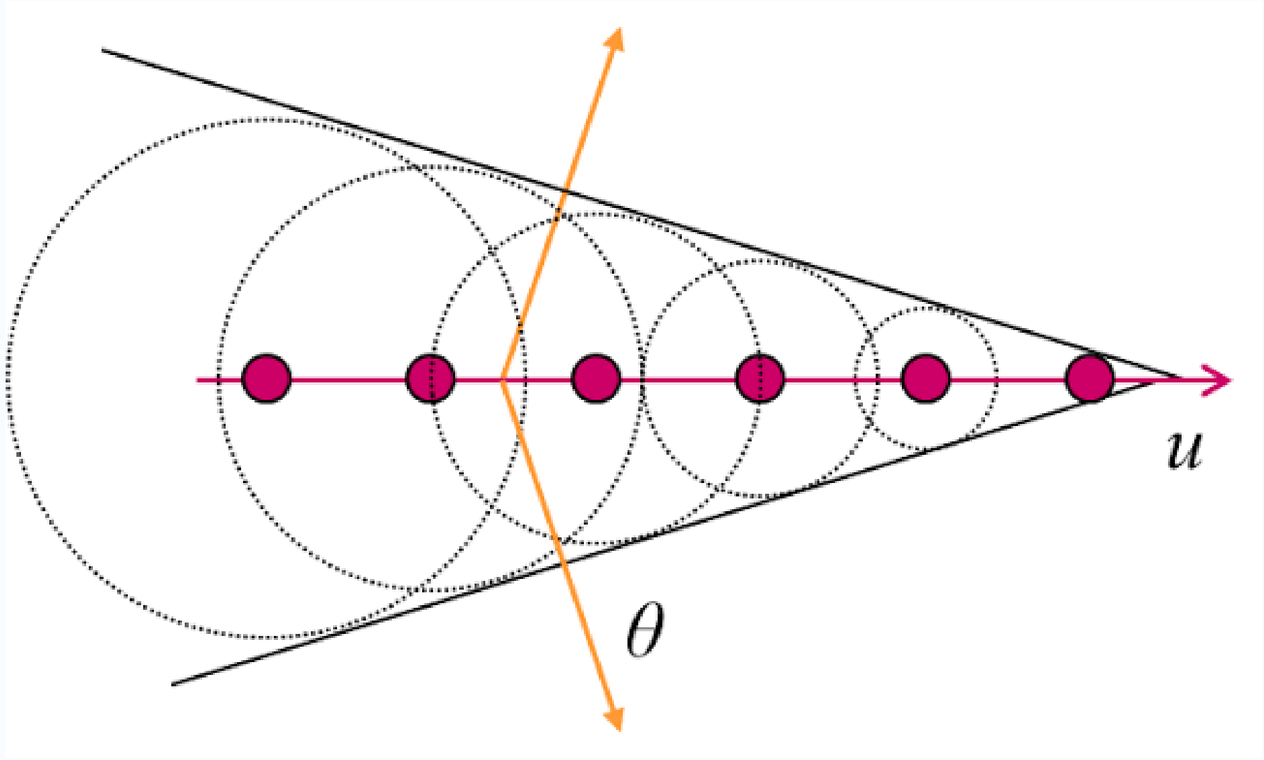
02.

Gain from IV curve:

- Goal: calculate gain using breakdown voltage
- Results: gain = 687789.96 (at 22.6°C)
- Matches expectations of 7e5 at 25°C
- So this SiPM is functional and we can use it with the CITIROC!



The RICH



Cherenkov Light

- A particle travels faster than light in a medium
- Medium is excited, and as it returns to ground state, emits photons
- Wave fronts interefere constructively, creating a cone shape