Thin Detector Design
and
Beam Test Results

MOLLER Collaboration Meeting

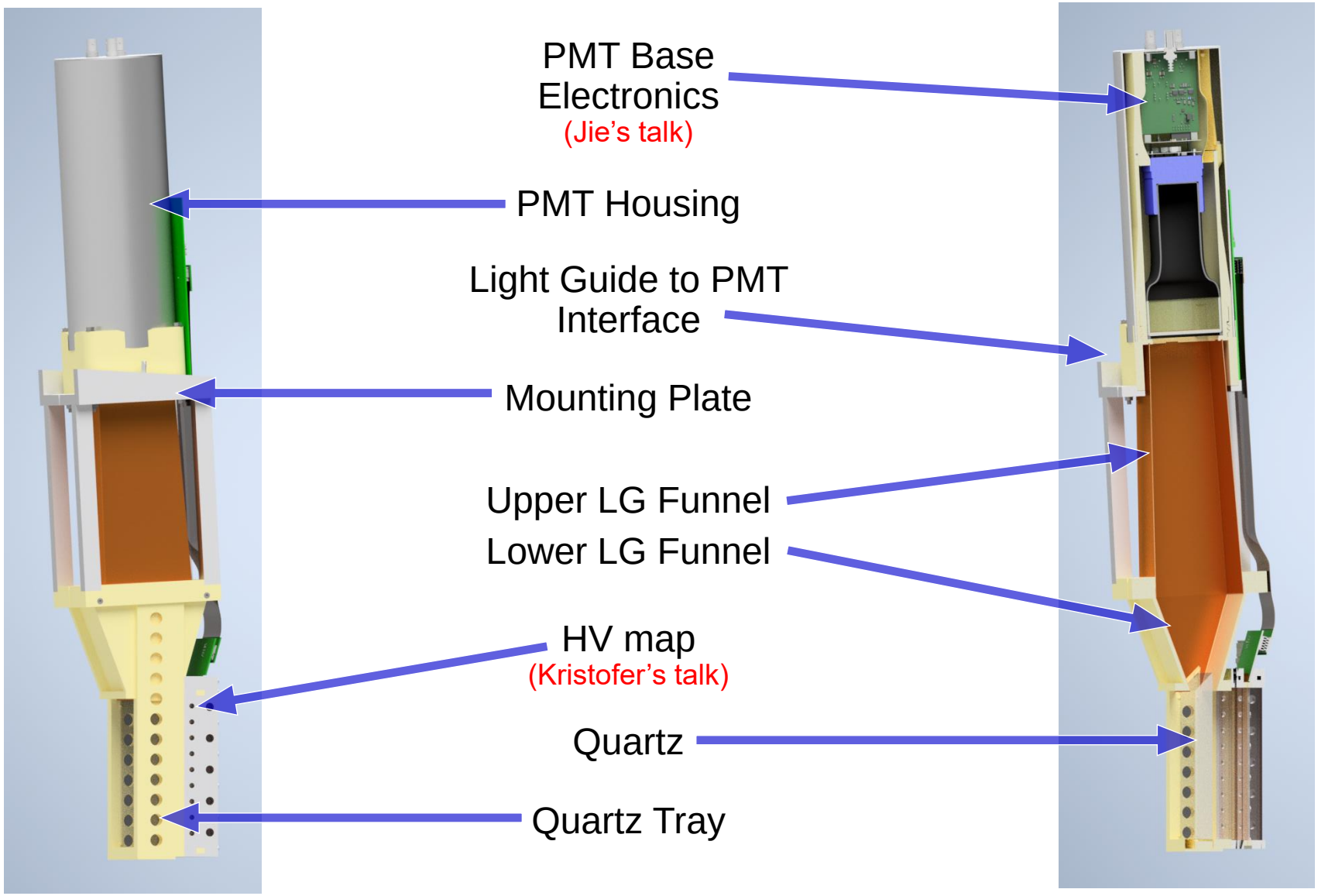
6 May 2023

Brynne Blaikie

Outline

- Thin quartz module design
  - Ring 5 overview
  - Quartz tray
  - PMT housing
- Event mode data
  - Average photoelectrons for Rings 1,2,5
  - Light guide and quartz types
- Integration mode data
  - Data collection method: firmware and software
  - Electronic noise levels

Ring 5 Module



3D Printed Quartz Trays

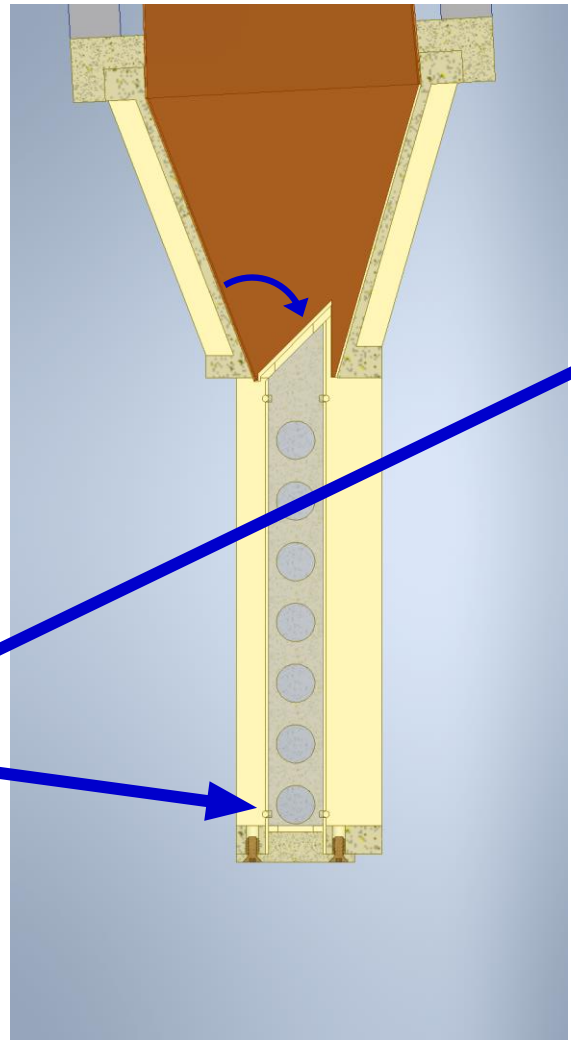
Design Components:

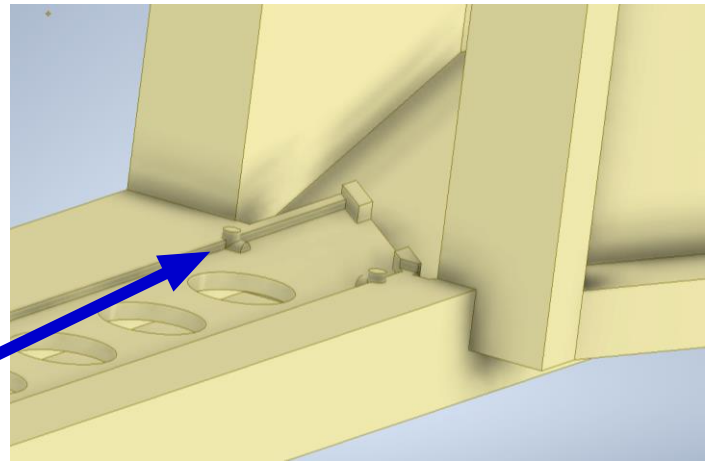
Monolithic tray combines quartz holder and lower LG funnel structure

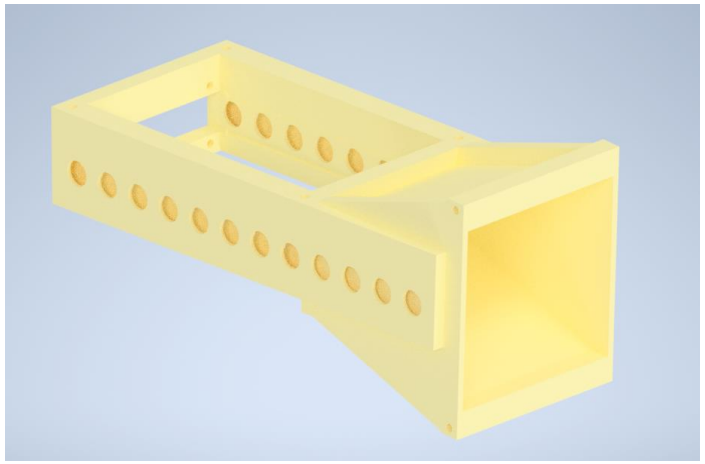
- Fixes the angle between quartz and primary mirror

Removable end cap to insert and secure quartz tiles

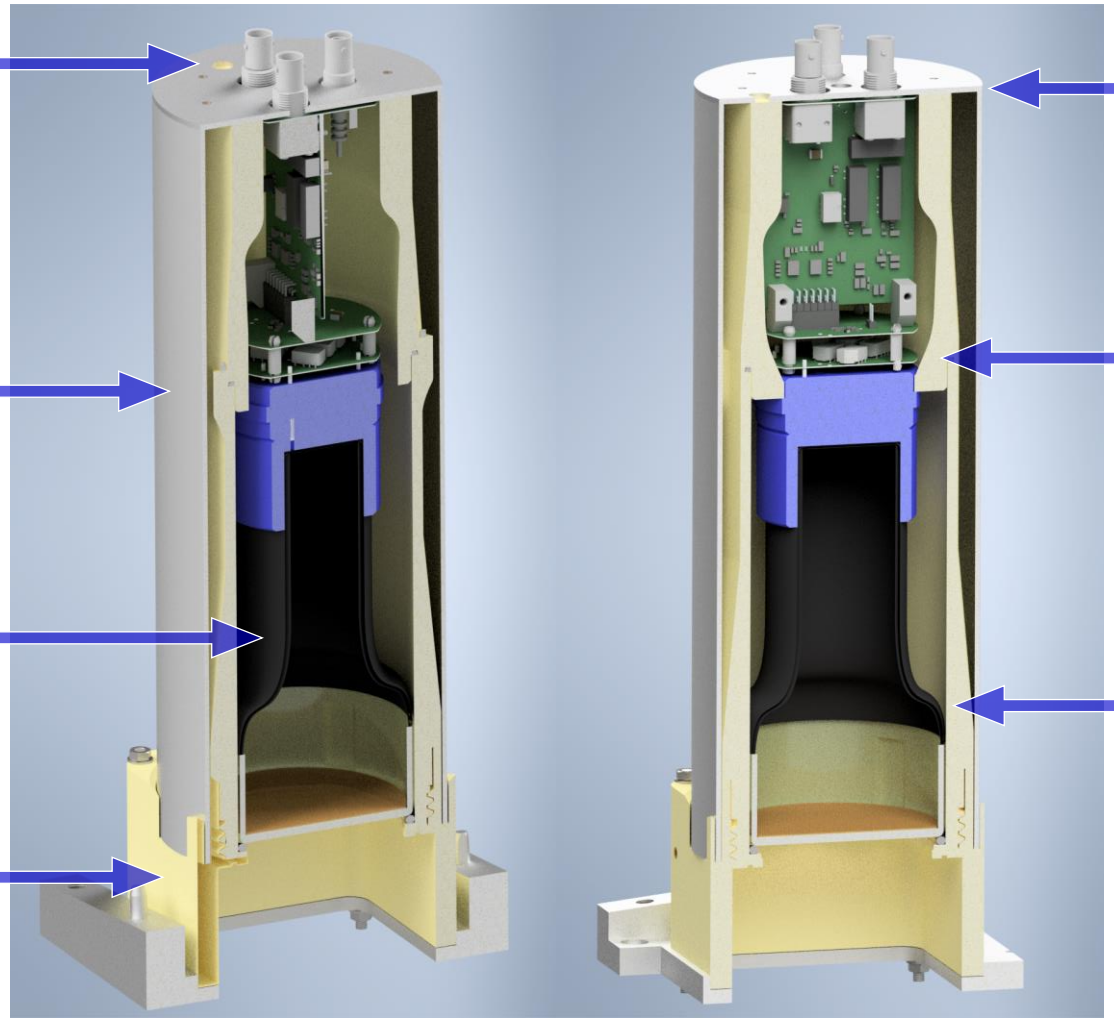
Minimal contact points to guide and secure quartz







PMT Housing and Interface Design



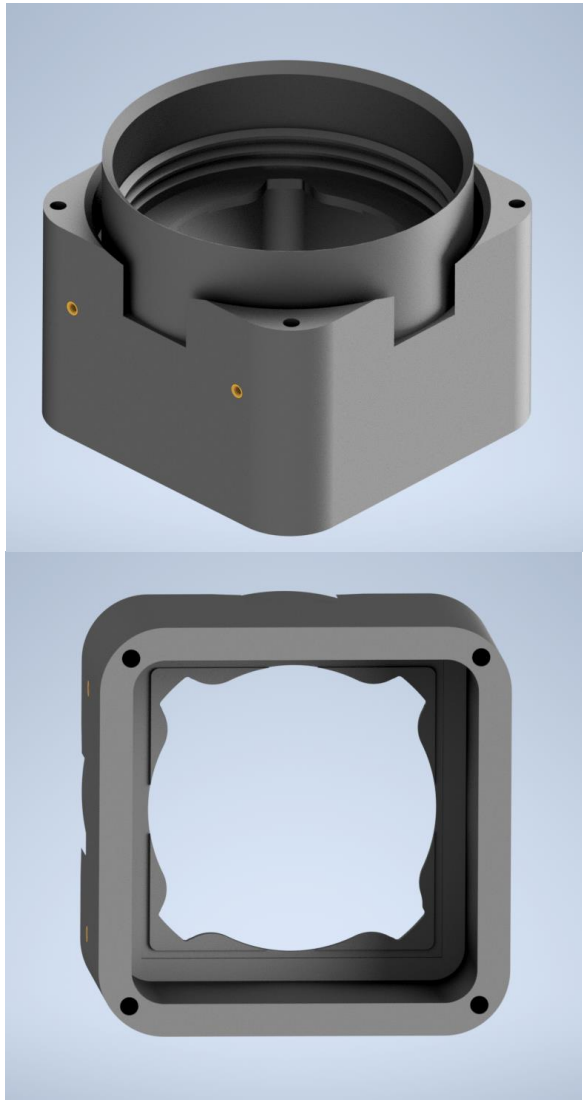
Threaded PMT Housing Interface

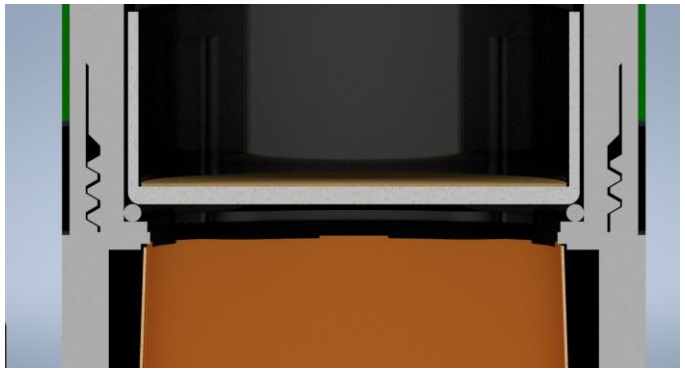
Design Components:

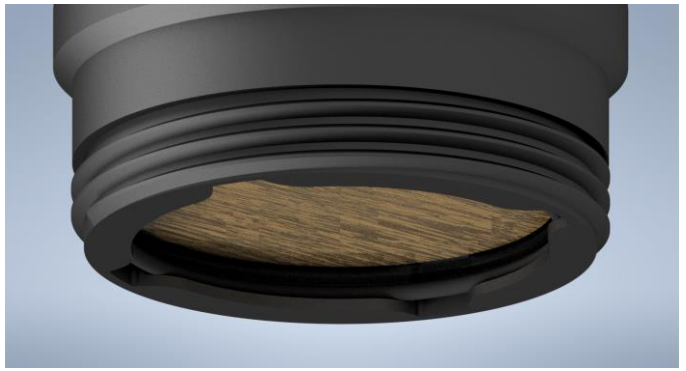
Threaded LG – PMT housing interface introduces ease of removal

O-ring to protect front glass of PMT from 3D printed material

Air channels from bottom tube section through interface
- Allows air flushing for electronics & light guides
- 3D printed threads ensure proper alignment







Multi Tube Interface

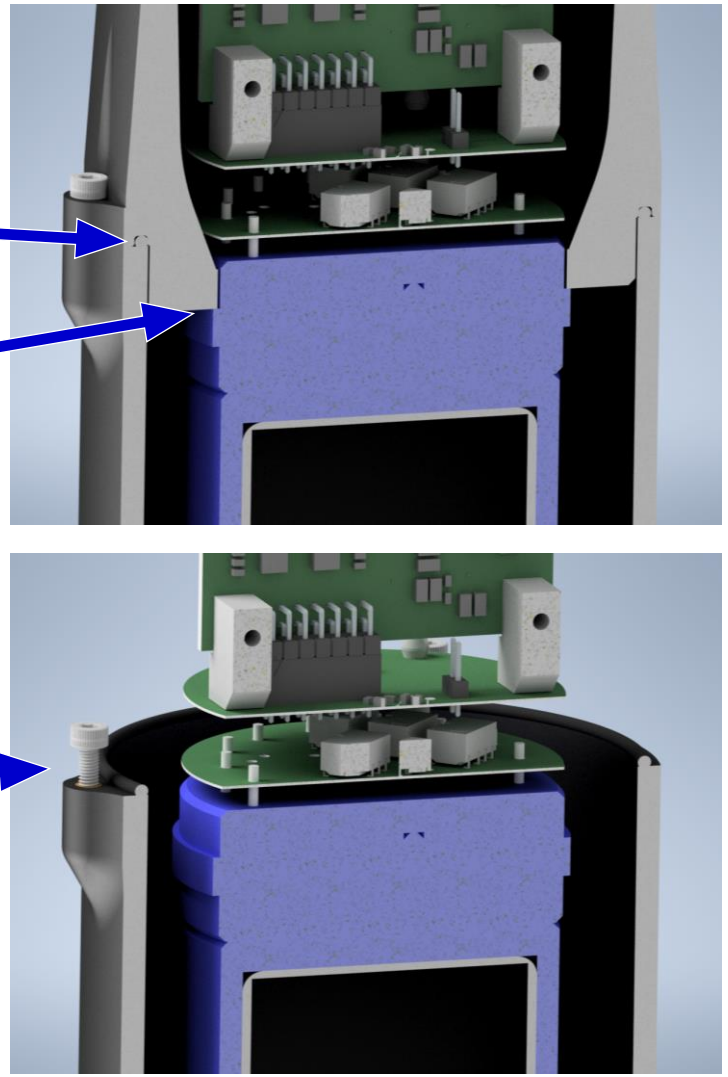
Design Components:

O-ring for light tightness between two parts

Top tube sits snug against lip of PMT base socket

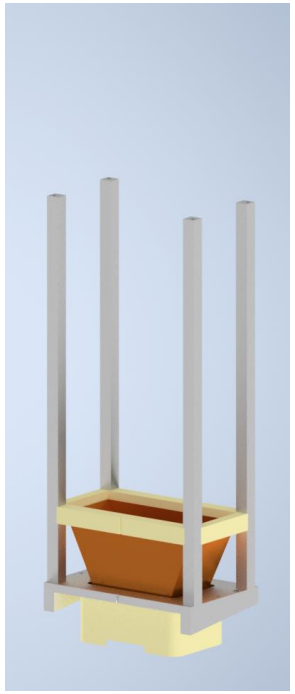
- Secures the PMT from moving inside tube
- Allows lid removal in detector array while still securing the PMT & electronics

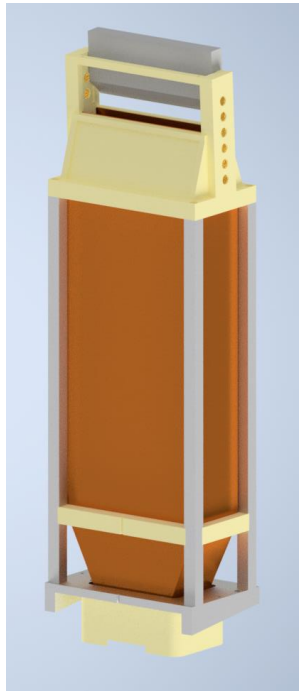
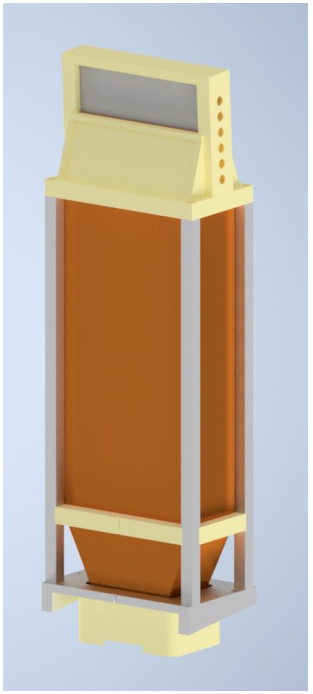
Secured with screws through flanges in the top tube into brass inserts in flanges around the bottom tube



Steps for Assembly

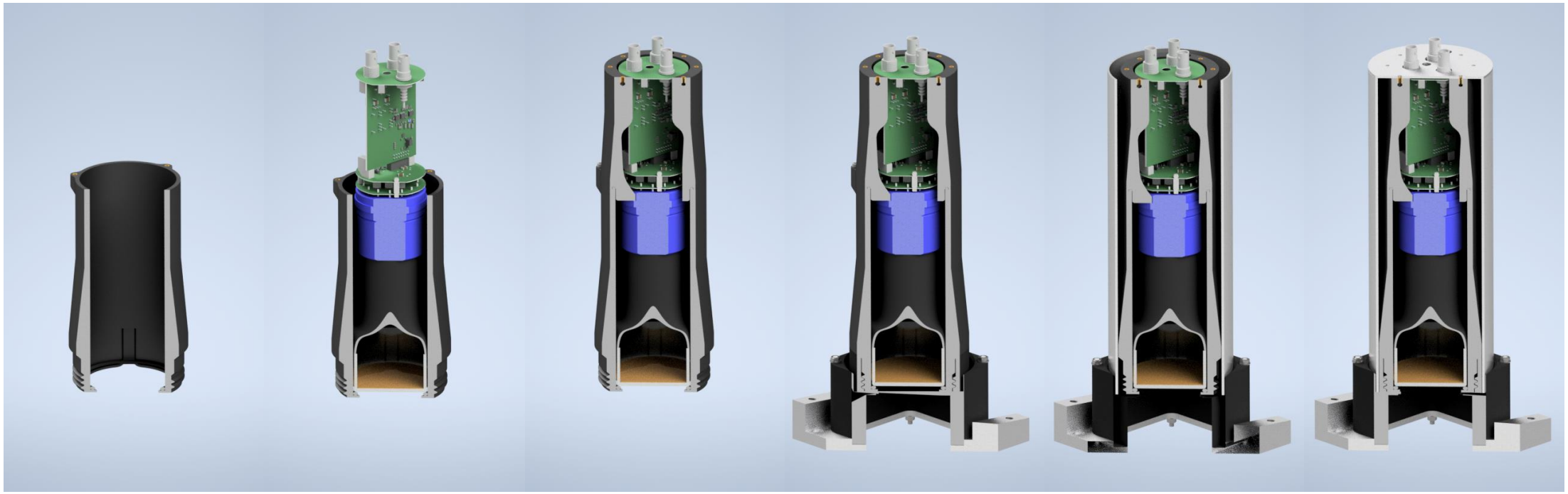
1. Fasten PMT LG interface to mounting plate
2. Fasten support bars to mounting plate
3. Insert upper LG funnel through brace
4. Insert middle LG straight section into brace
5. Insert lower LG funnel into quartz tray
6. Align quartz tray onto support bars + fasten
7. Insert quartz tile through guide points
8. Fasten quartz tile stop

Steps for Assembly – PMT Housing

1. Tube bottom w o-ring
2. Insert PMT + base
3. Insert tube top while aligning screw flanges + fasten w screws
4. Screw tube into PMT LG interface
5. Insert aluminium tube shielding + fasten lid w screws



Mainz Beam Tests

May 2022

- Ring 5
  - UVS light guide
  - Miro-Silver light guide
  - Heraeus Quartz 157x80x15 mm
    (radial x azimuthal x thickness)
- Ring 6
  - Aluminized Mylar
  - Heraeus Quartz 105x245x10 mm

November 2022

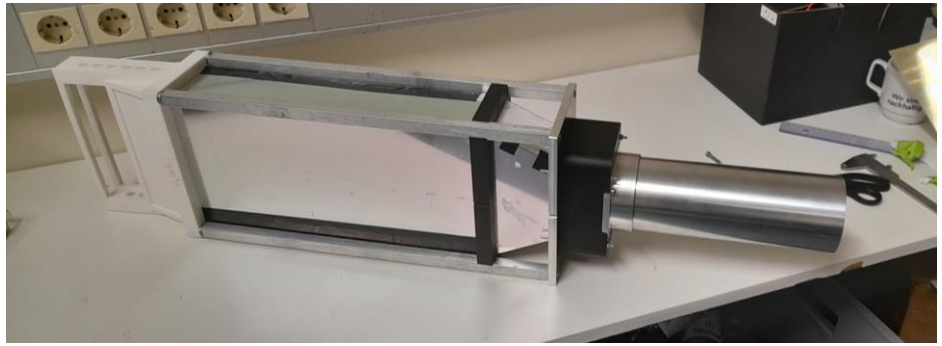
- Ring 1
  - Tosoh quartz 50x166x20 mm
- Ring 2
  - Tosoh quartz 80x177x20 mm
- Ring 5
  - Tosoh quartz 157x80x17 mm
- Ring 6 (Sayak's talk)
  - Tosoh quartz 120x260x20 mm
  - Heraeus quartz 105x245x10 mm

- All Miro-Silver light guides

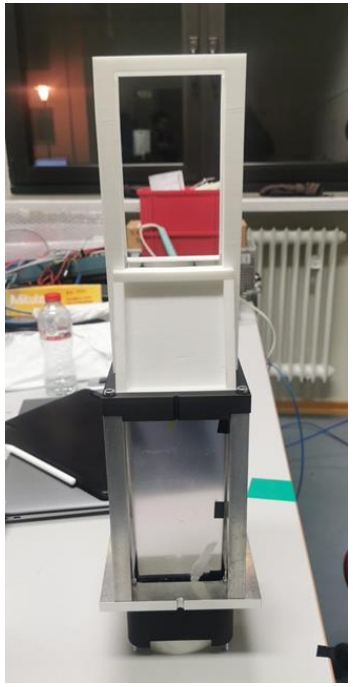
Modules at November 2022 Beam Test

Ring 1

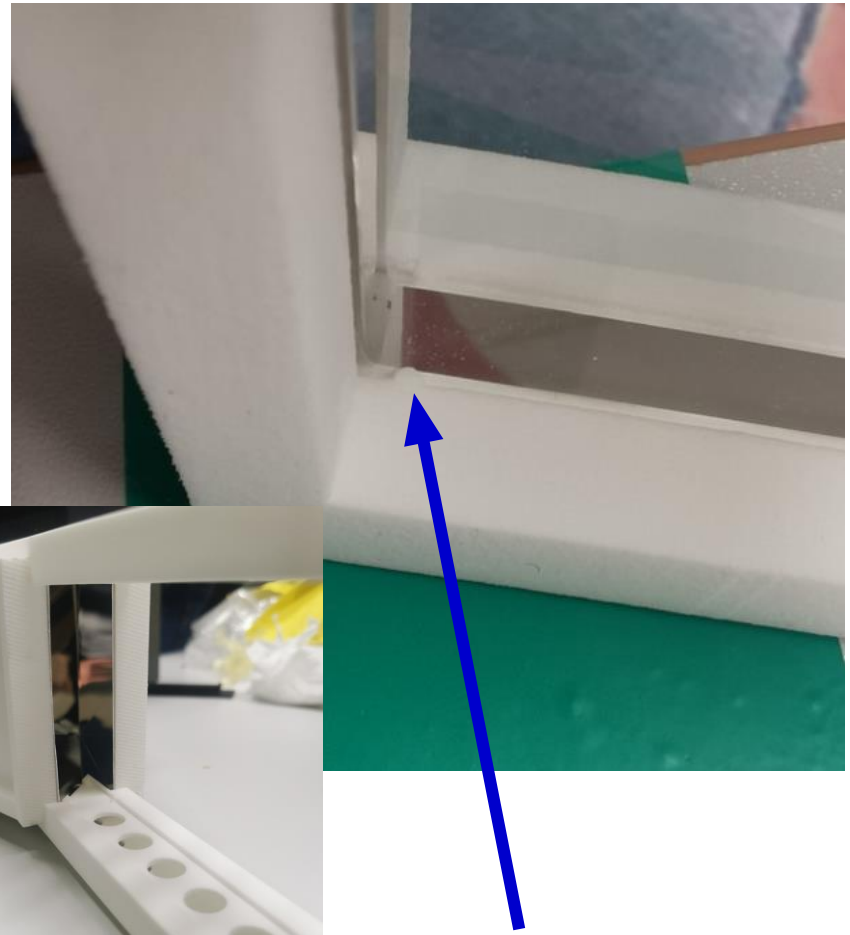
Ring 2



Ring 5



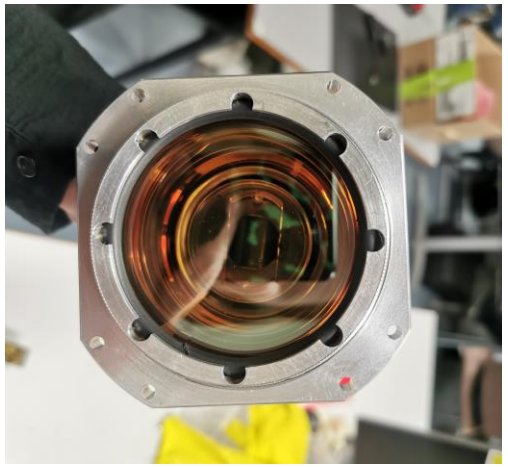
Ring 6



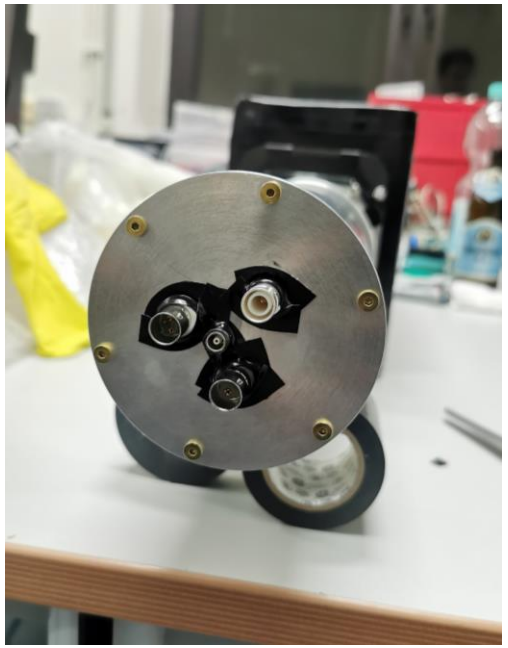
tile side stops

PMT Housing November 2022 Beam Test

New PMT base: voltage divider
event mode amplifier
integration mode amplifier



Previous PMT housing design containing many similar ideas



Event Mode Data Analysis

- Identify pedestal and event peaks using the ROOT TSpectrum class
- Event peak fitted with a Landau-Gauss convolution
- The “most probable value” (MP) and the fit sigma (GSigma) were extracted to record the mean photo-electron yield

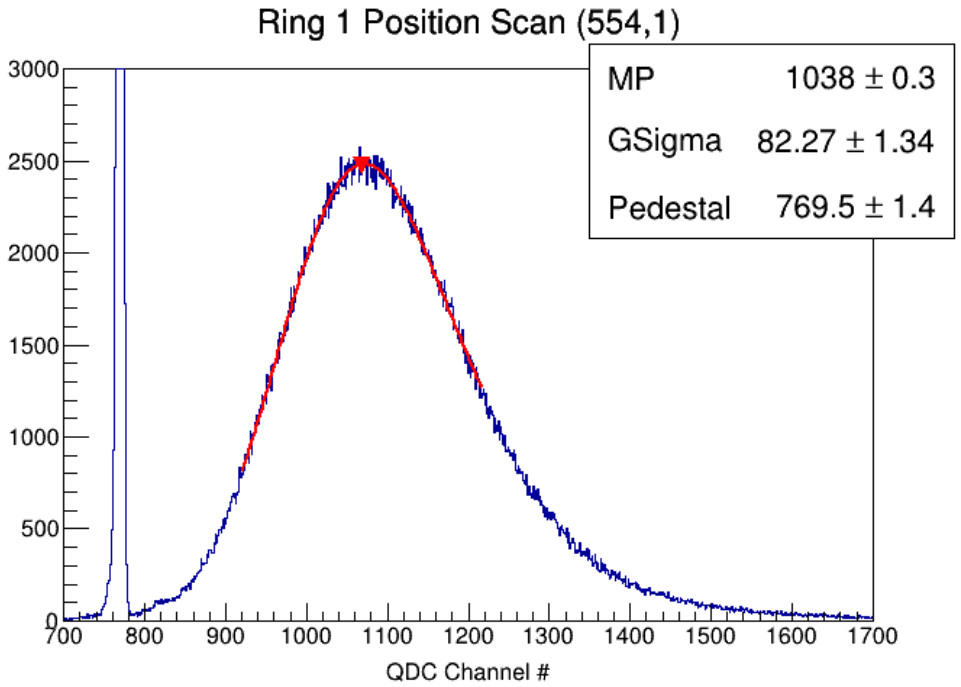
$$n_{pe} = \frac{(\mathrm{MP} - \mathrm{Ped})^2}{\sigma^2}$$

November 2022 photoelectron yields:

Ring 1 $n_{pe} \approx 9$

Ring 2 $n_{pe} \approx 15$

Ring 5 $n_{pe} \approx 21$



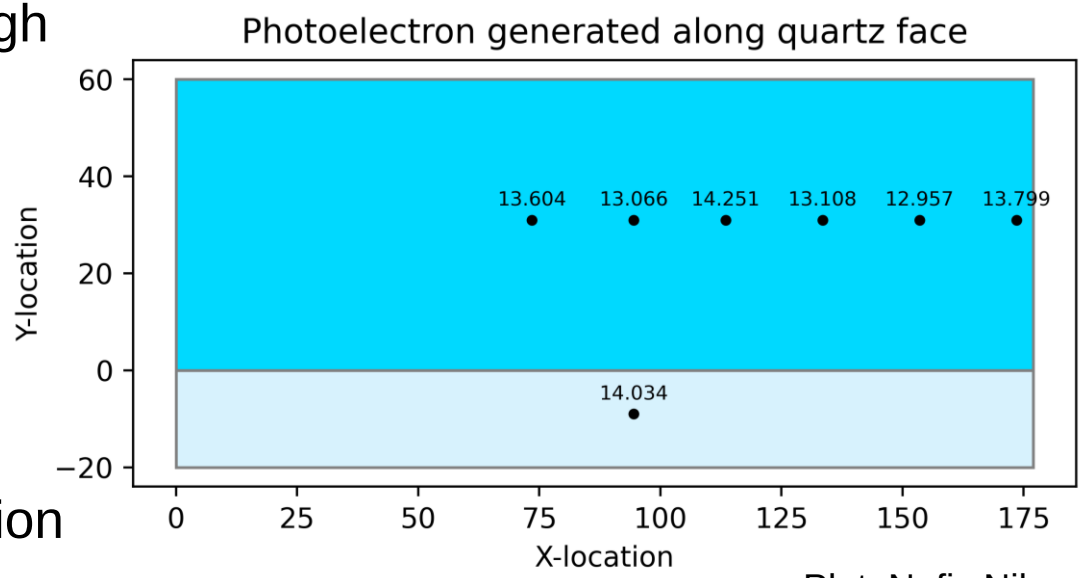
Ring 2 Position Scan

Tests for uniformity in photoelectron generation through the quartz tile

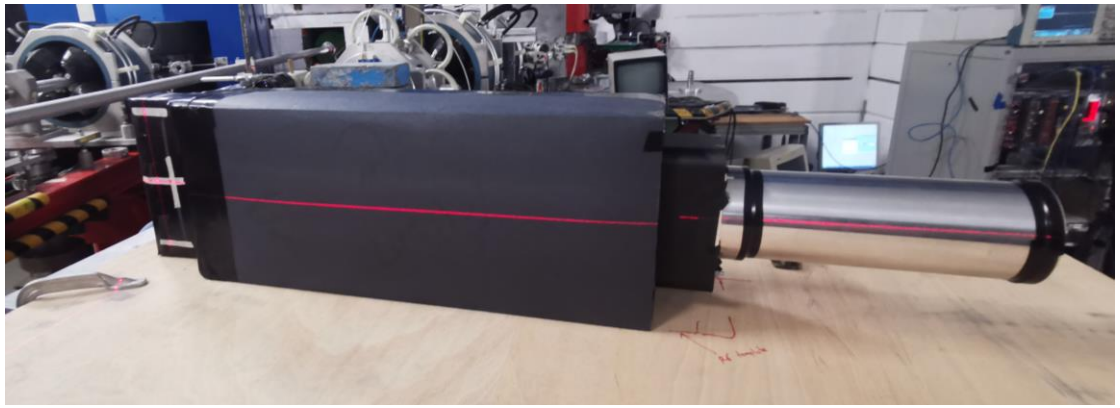
- Non-uniformity in PE generation across quartz surface will lead to a bias in the measured asymmetry

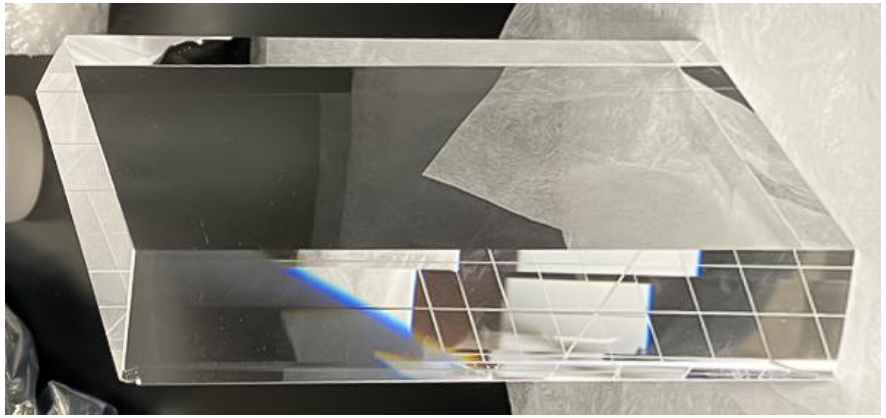
Raised table to change azimuthal position

Moved table in/out of beamline to change radial position



Plot: Nafis Niloy



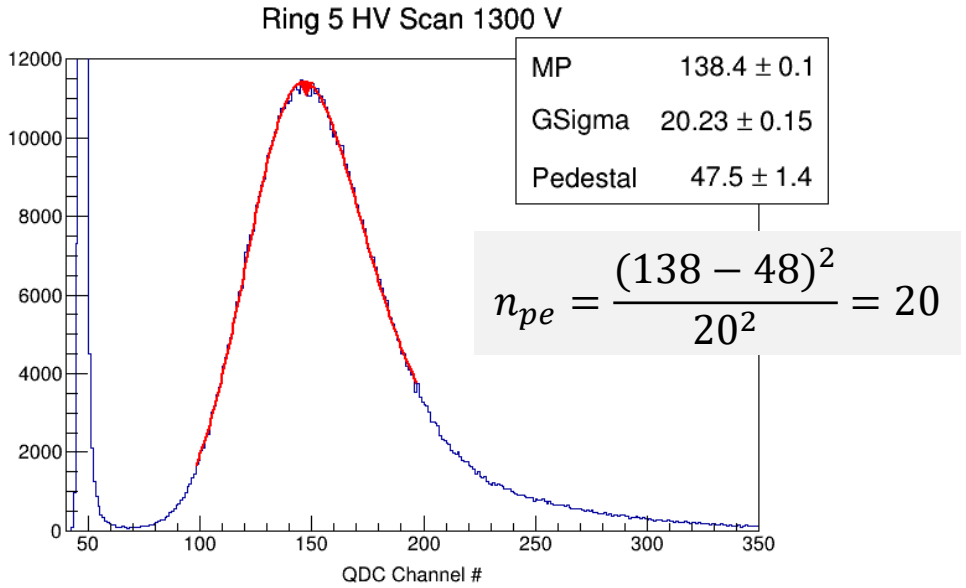


Heraeus and Tosoh PE Yield

May 2022: Heraeus Quartz 15 mm

Miro-Silver, no amplifier

Average: $n_{pe} \approx 20$

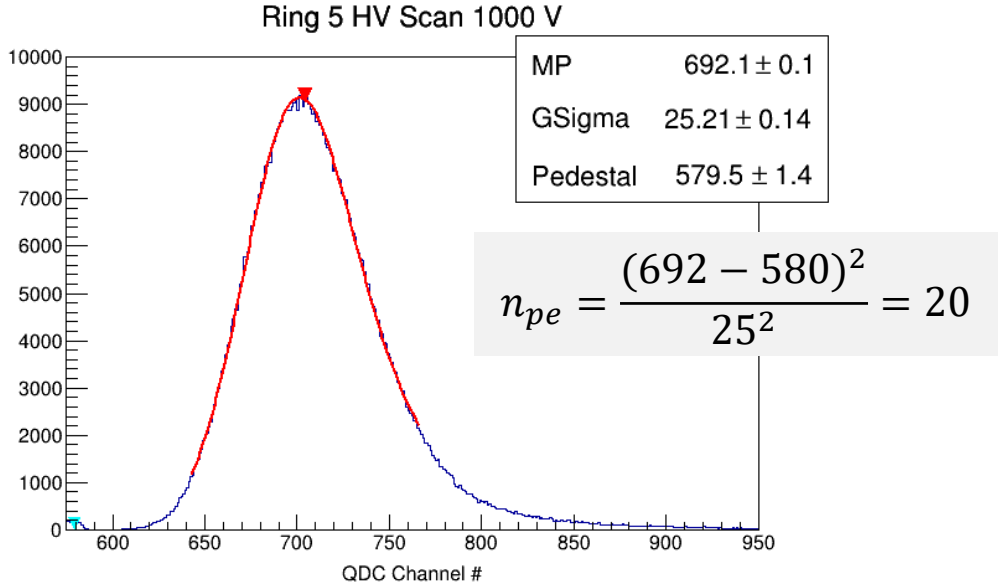


$$n_{pe} = \frac{(138 - 48)^2}{20^2} = 20$$

Nov 2022: Tosoh Quartz 17 mm

Miro-Silver, with MOLLER amplifier

Average: $n_{pe} \approx 20$



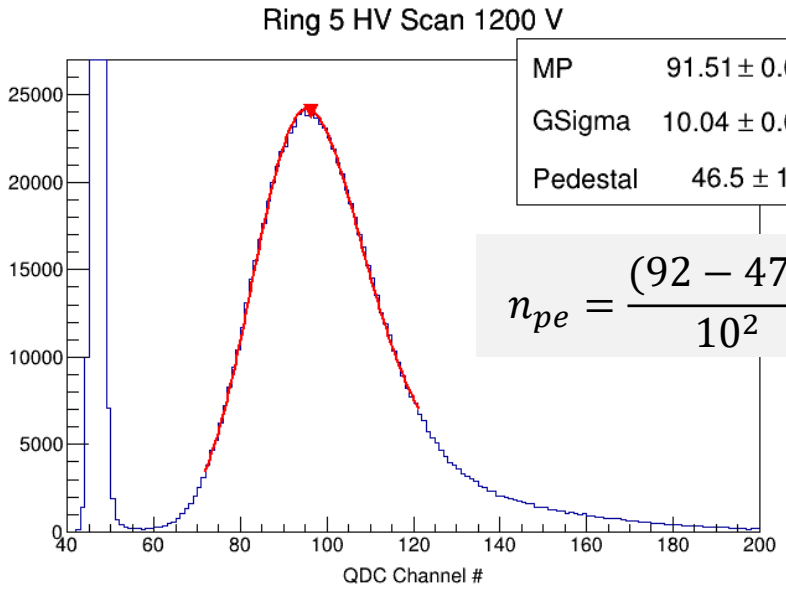
$$n_{pe} = \frac{(692 - 580)^2}{25^2} = 20$$

UVS and Miro-Silver PE Yield

May 2022: Miro-Silver

No amplifier

Average: $n_{pe} \approx 20$

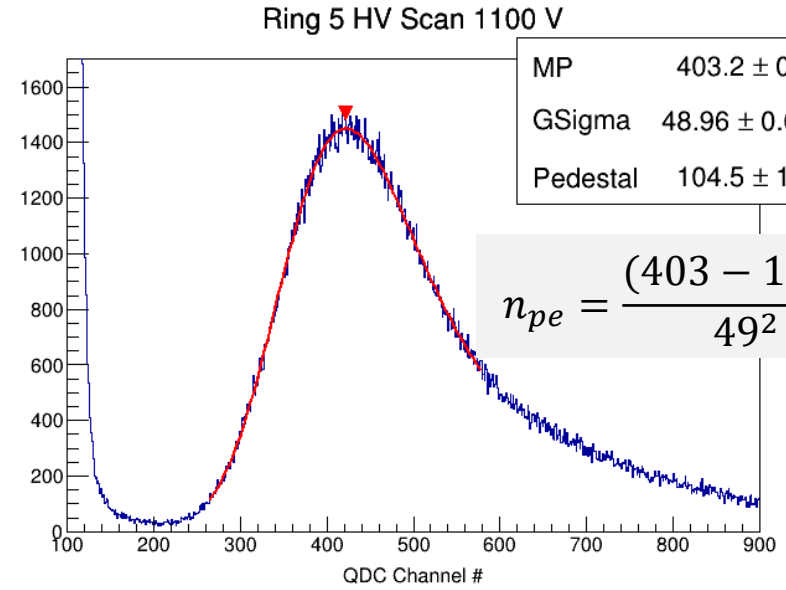


$$n_{pe} = \frac{(92-47)^2}{10^2} = 20$$

May 2022: UVS

With P2 amplifier

Average: $n_{pe} \approx 37$



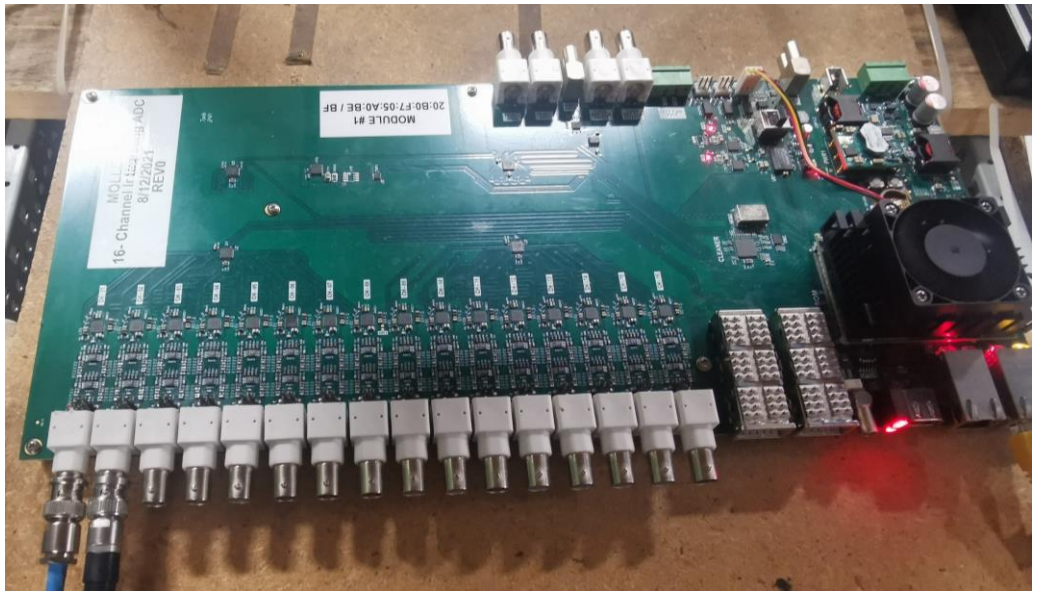
$$n_{pe} = \frac{(403-105)^2}{49^2} = 37$$

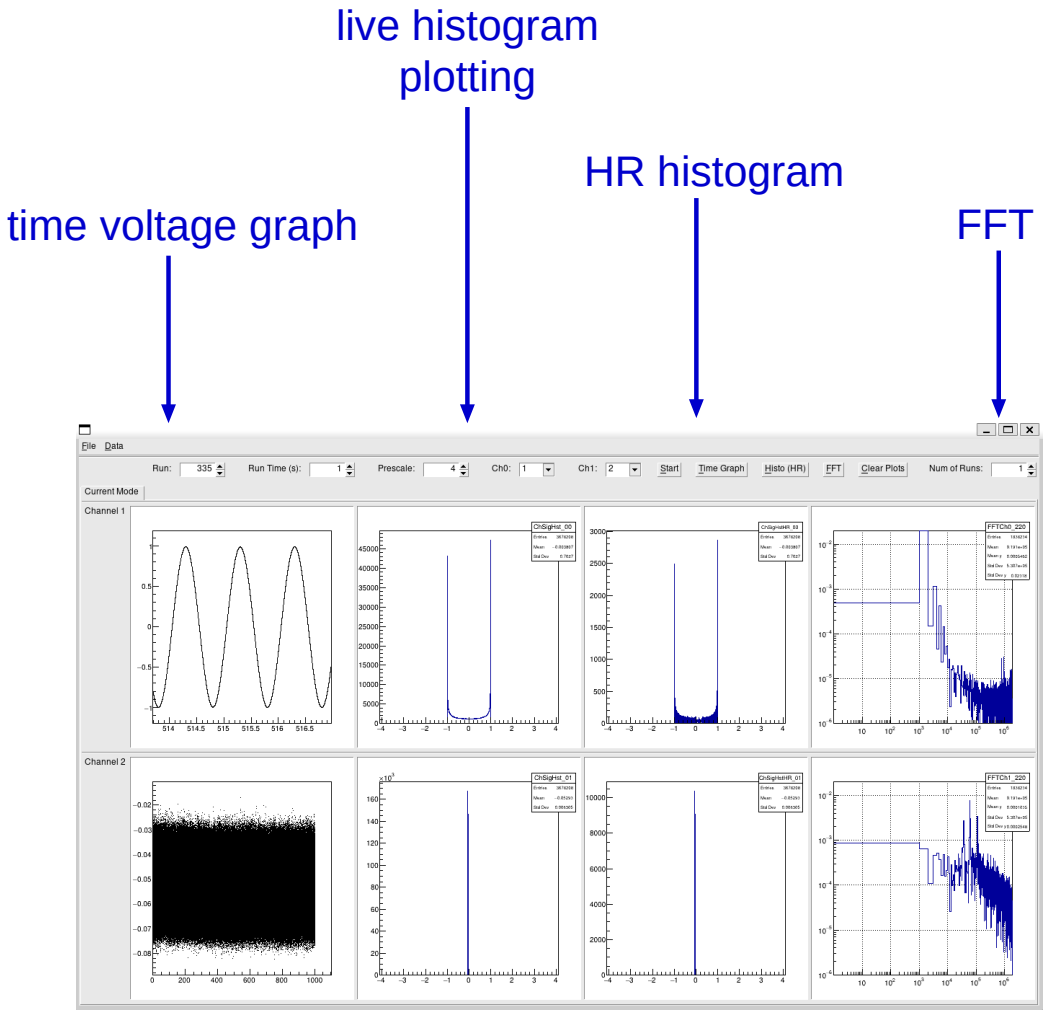
Integration Mode Data Collection

16 channel ADC board

Firmware and software set up to adjust:

- run time
- prescale
- ADC readout channels
- number of runs





Integration Mode Data Analysis

Overall experimental error grows with the excess noise factor

Need to keep detector resolution or excess noise limited to:

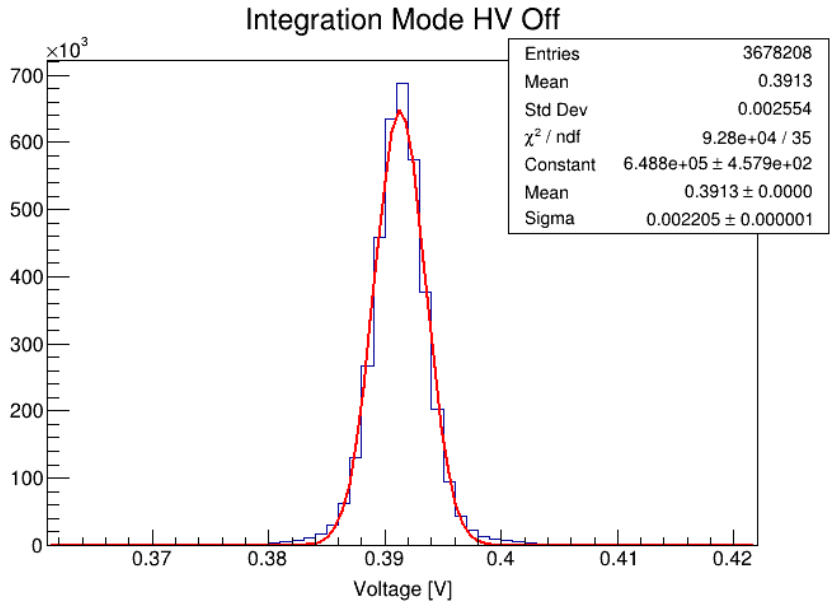
$$\frac{1}{\sqrt{N}}\left(\sqrt{1+\alpha_{exc}^2}-1\right)=\frac{1}{\sqrt{N}}\left(\sqrt{1+\delta_{Det}^2+\delta_{PMT}^2+\delta_{Elect}^2}-1\right)\leq 4\%$$

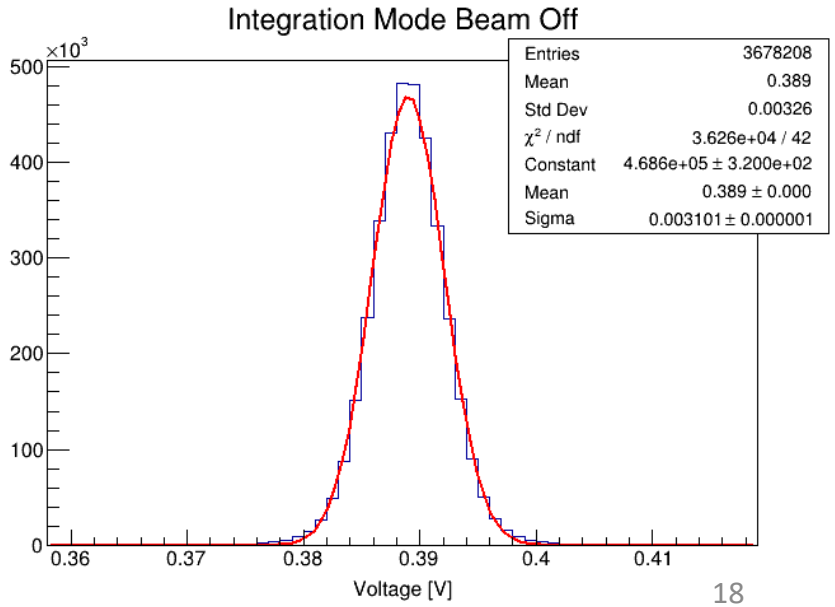
$$\delta \equiv \frac{\sigma}{\sigma_V}$$

Corresponds to 1% limit goal $\sigma_{PMT}=\sigma_{elec}<4.8\ \mathrm{mV}$ for $n_{pe}=30$

Preamp noise signal: $\sigma_{amp}\simeq 2.21$ mV

Preamp + PMT noise signal: $\sigma_{total\ elec}\simeq 3.10$ mV





Summary

- Thin detector housing design at the final stages

- Mainz beam tests of Rings 1,2,5,6
  - Tested UVS in Ring 5 and Miro-Silver in Rings 1,2,5
  - Tested Heraeus and Tosoh quartz
  - Current mode preamplifier producing reduced noise

- Next beam tests
  - Testing UVS & Miro-Silver with Heraeus & Tosoh (June 2023)
  - Full set of 6 detectors (Fall 2023)
  - Final PMT housing design