MAINZ test beam: September 2023

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Outline

- **Overview of the MAINZ beam test setup (September 2023)**
- **Results from the MAINZ test beam campaign**
  - In-situ measurement of the PMT gain
  - Horizontal & vertical scans with different quartz (Heraeus & Corning) tiles
  - Effect of back reflector panels on the PE yield
- **Cosmic test setup at UMass**
  - Ongoing activities and future plans

Test beam team

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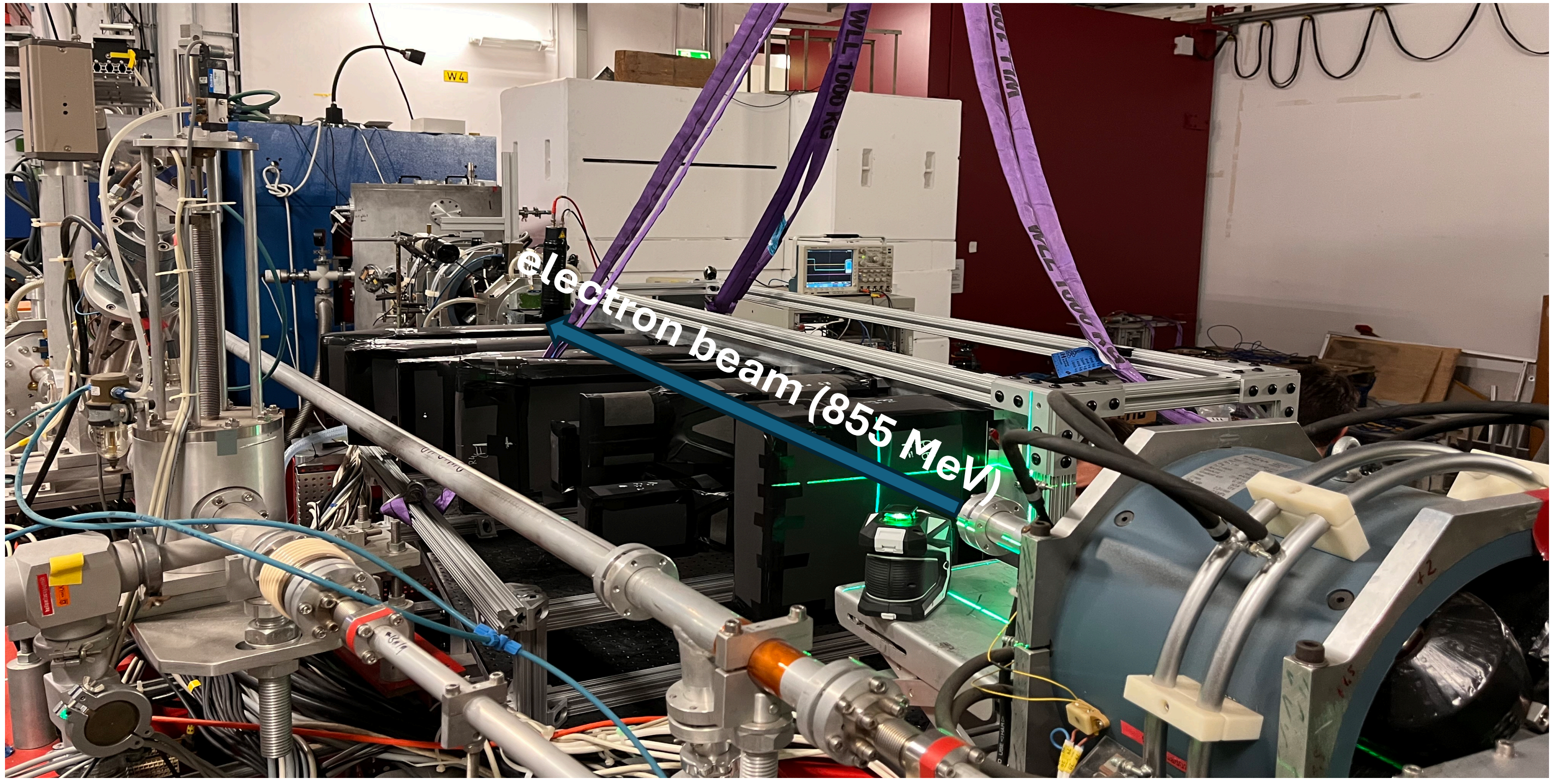
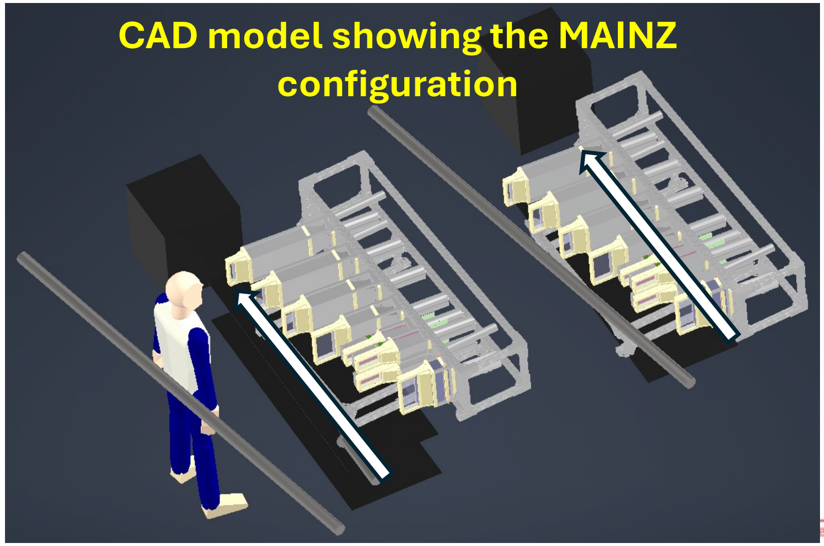
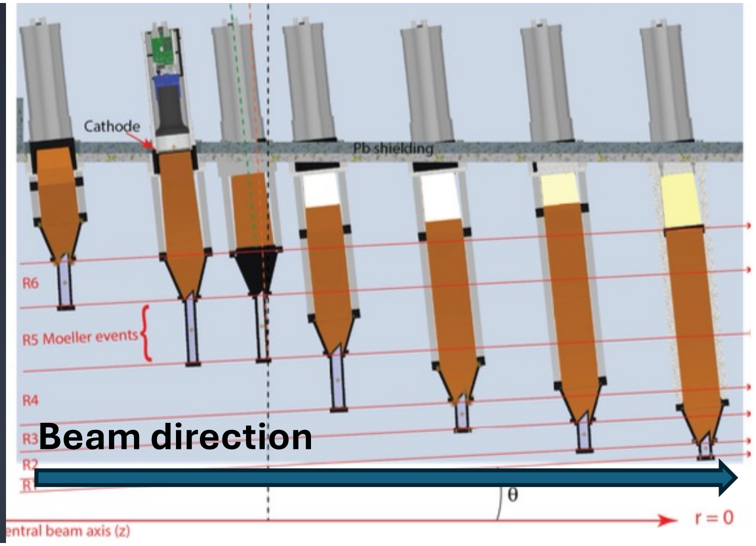
MAINZ test beam campaign (September 2023)





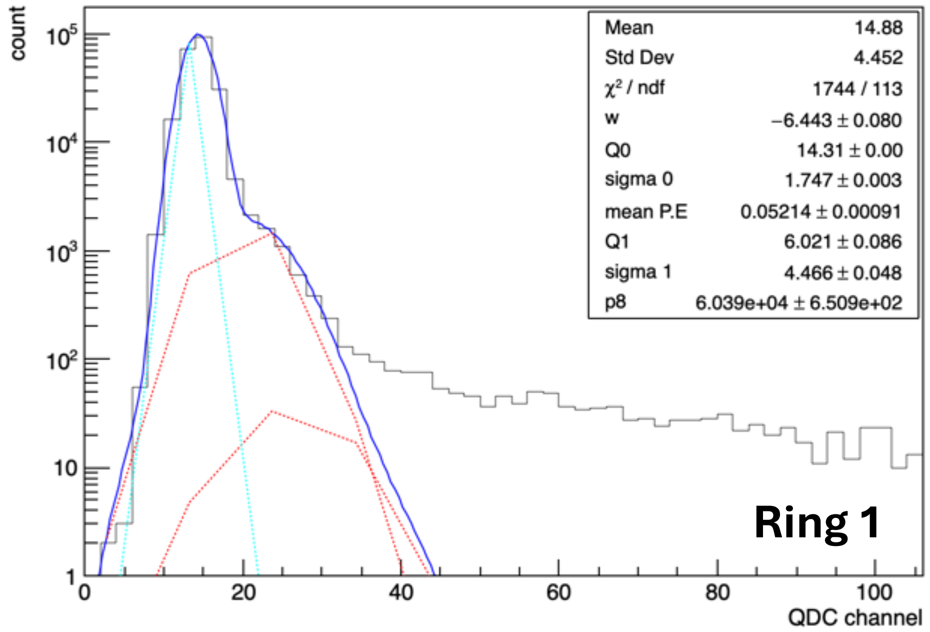


- Entire front flush segment is scanned with electron beam of energy 855 MeV
- Performance with different quartz tiles and reflective light guide materials are investigated
  - Quartz tiles: Corning & Heraeus
  - Light guide: UVC & UVS
- Detectors are tested in event mode as well as in the integration mode

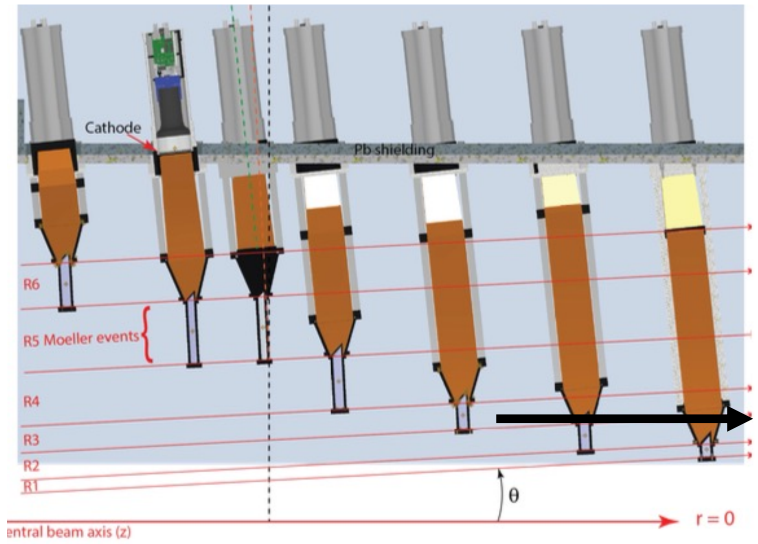
Performance of the individual Rings with electron beam of 855 MeV

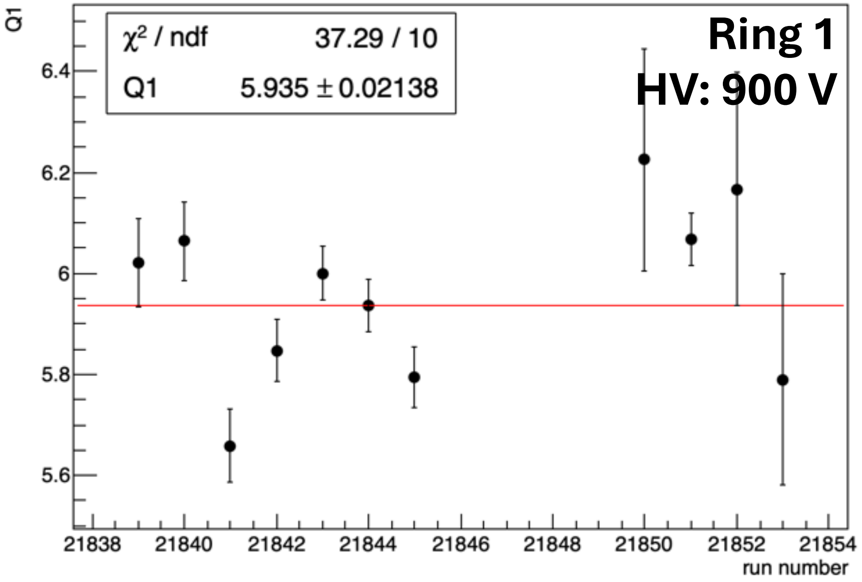
(Spectra are fitted with Langau distribution)

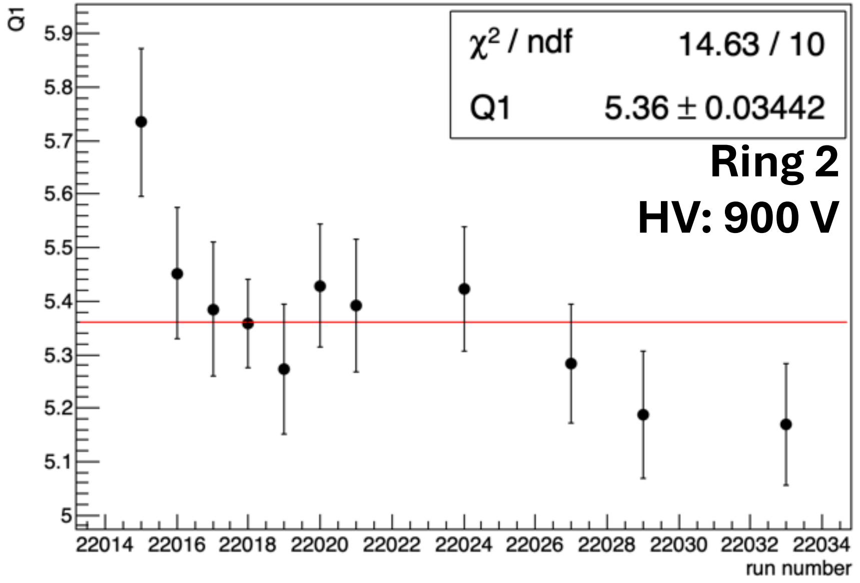
In-situ PMT gain calibration



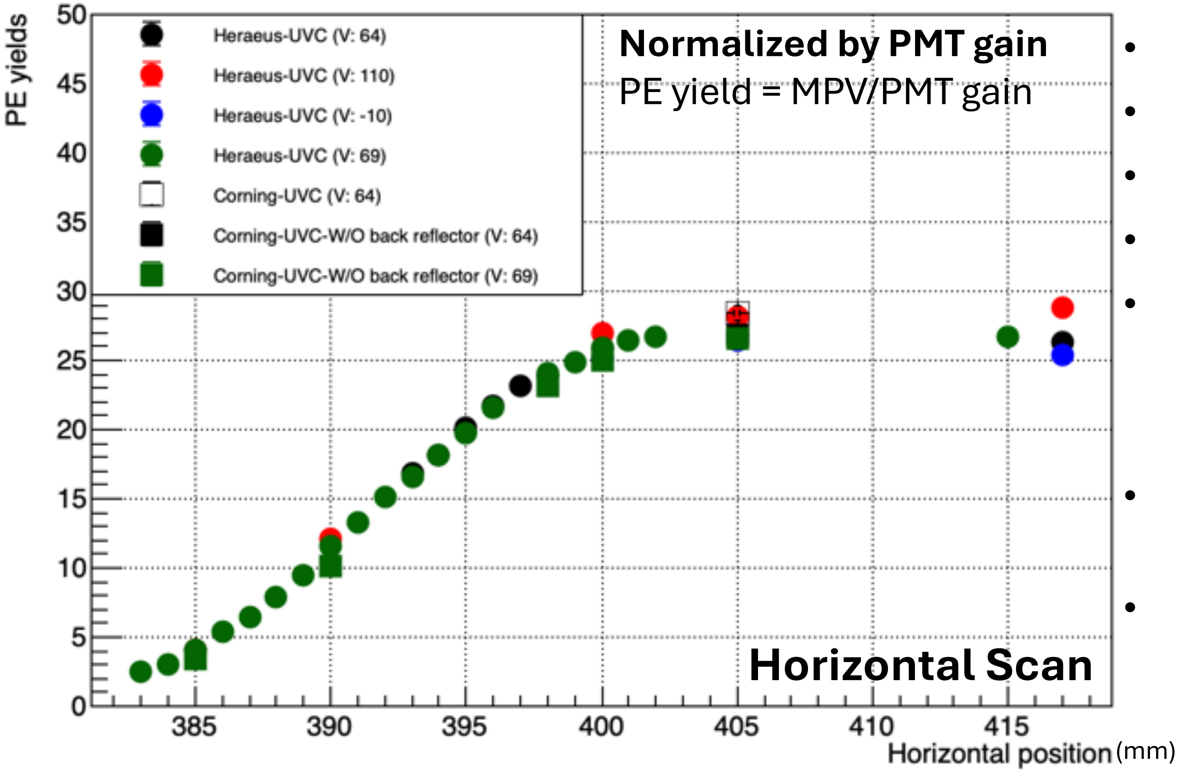
- Data is taken when the is beam is hitting at the light guide region
- The spectrum is fitted with the PMT gain calibration script that is being used to analyze the single PE measurements in the lab (Ref: NIMA 339 (1994) 468)
- Average is taken over different runs
- The Q1 value corresponds to single PE and it is then used to calculate the PE yields from the Cherenkov detectors







Ring 1: PE yield



- Ring 1 was operated at 900 V
- PMT used: Jlab, 616
- Q1 (@ 900 V) = 5.98 (±0.10) , 5.42 (±0.11)
- Gain (x 10^6): 7.5 (±0.12), 6.8 (±0.14)
- Average PE yield is (400–420 mm);

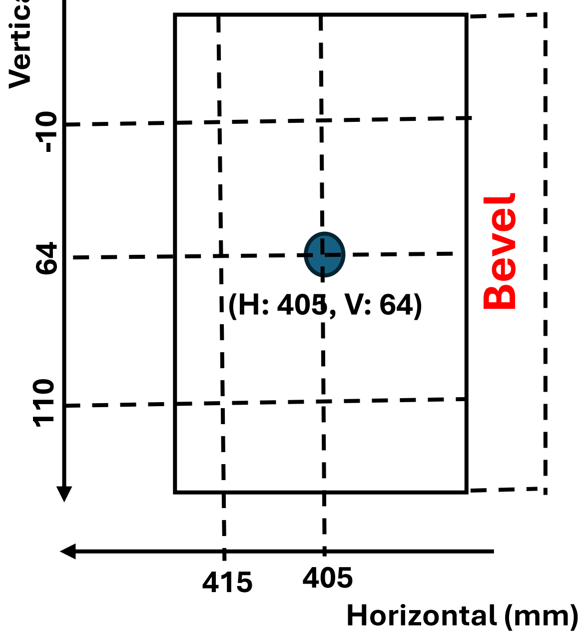
  26.56 ± 0.12 (gain norm.)

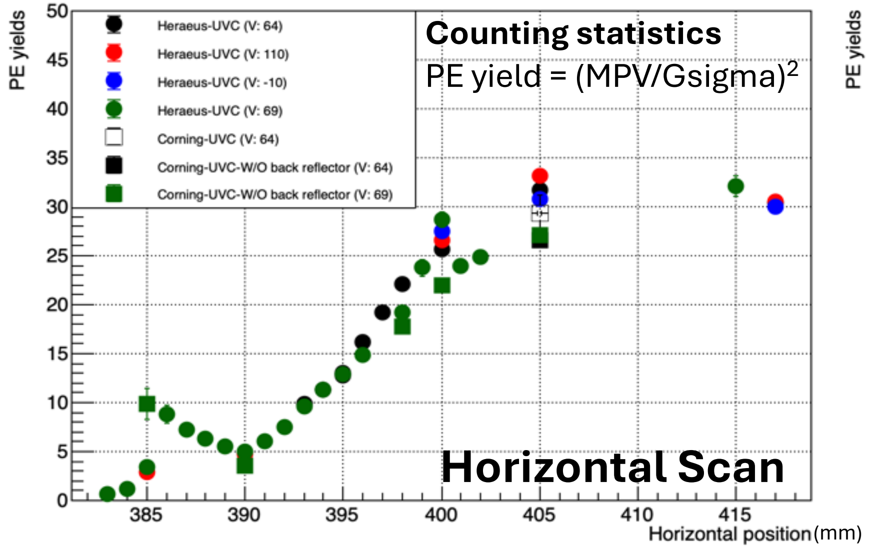
  27.62 ± 0.07 (counting stat.)
- Both the Heraeus and Corning quartz tile behave similarly
- With out the back reflectors no significant change in the PE yield is observed

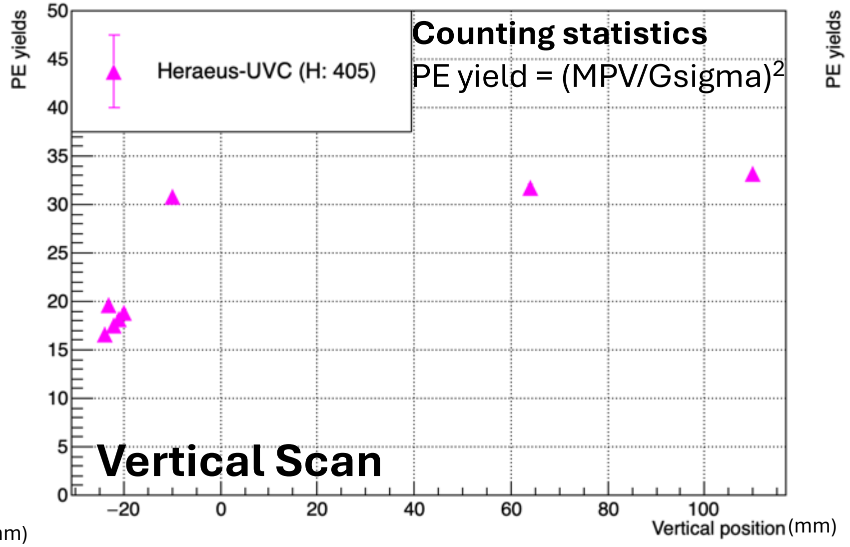
Ring 1 dimensions:

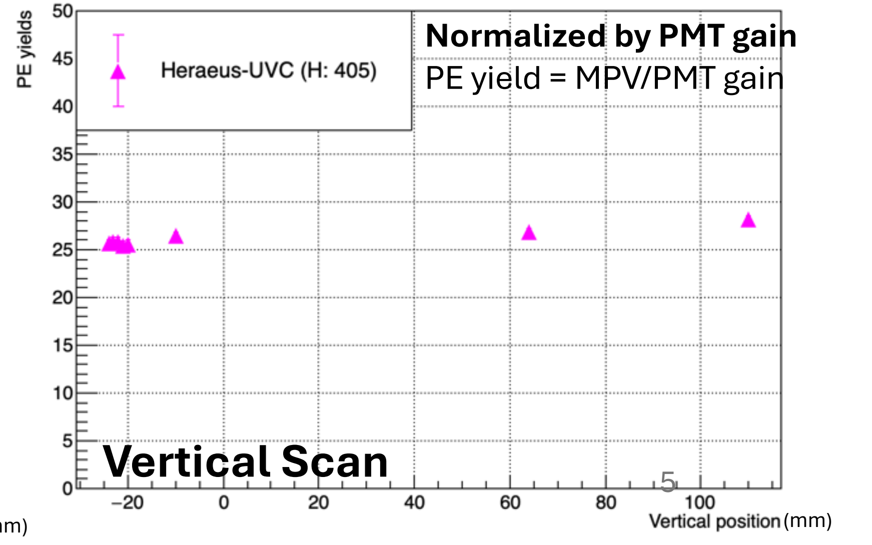
Horizontal : **30 mm**
(W/O bevel)

Vertical : **169 mm**

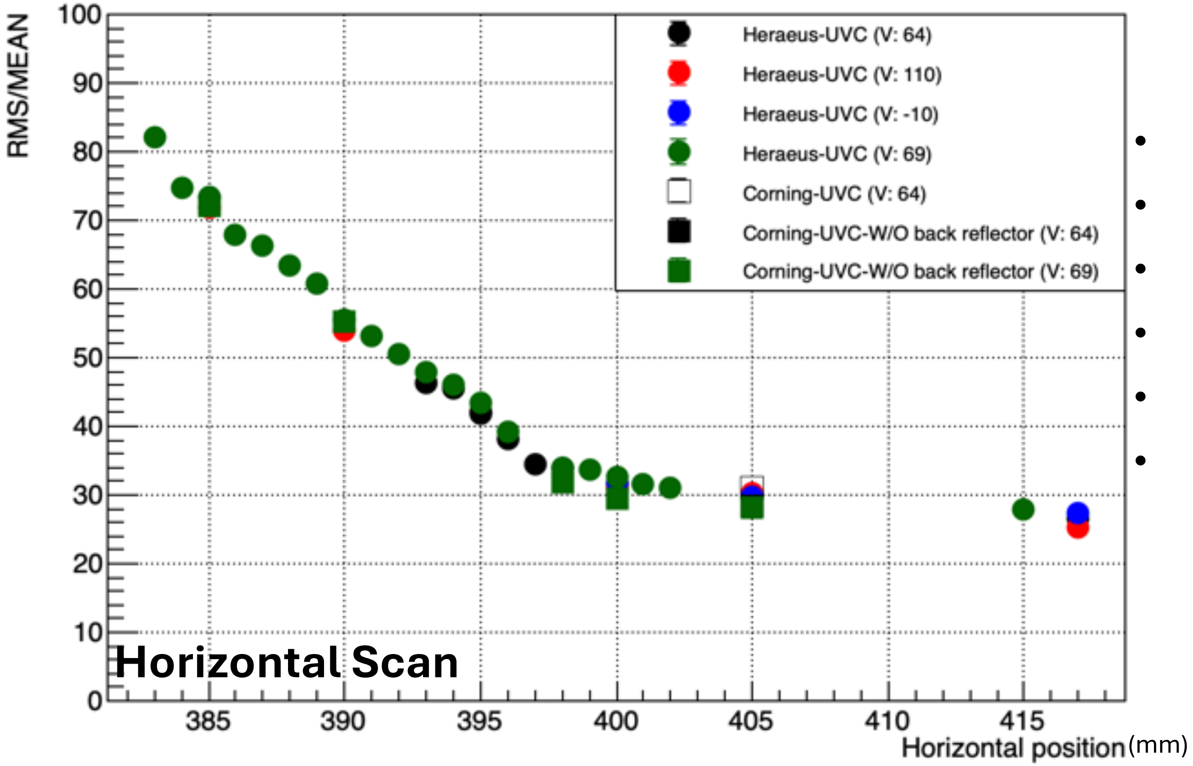








Ring 1: RMS/MEAN & Resolution

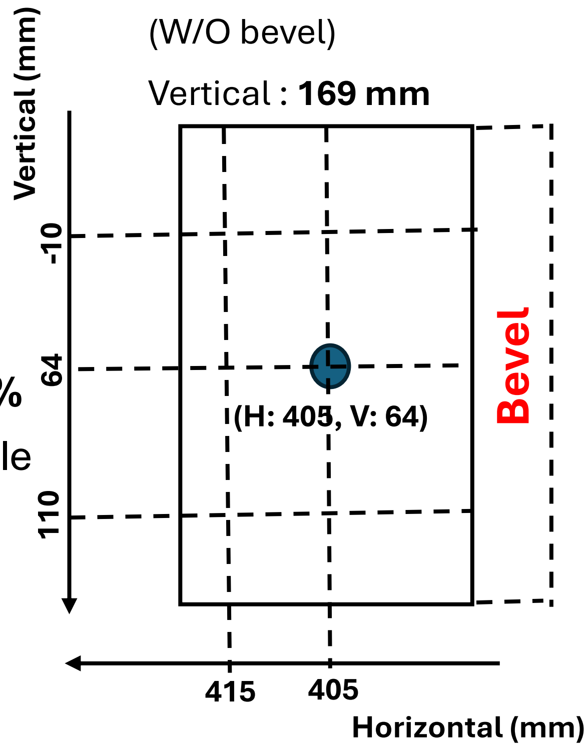


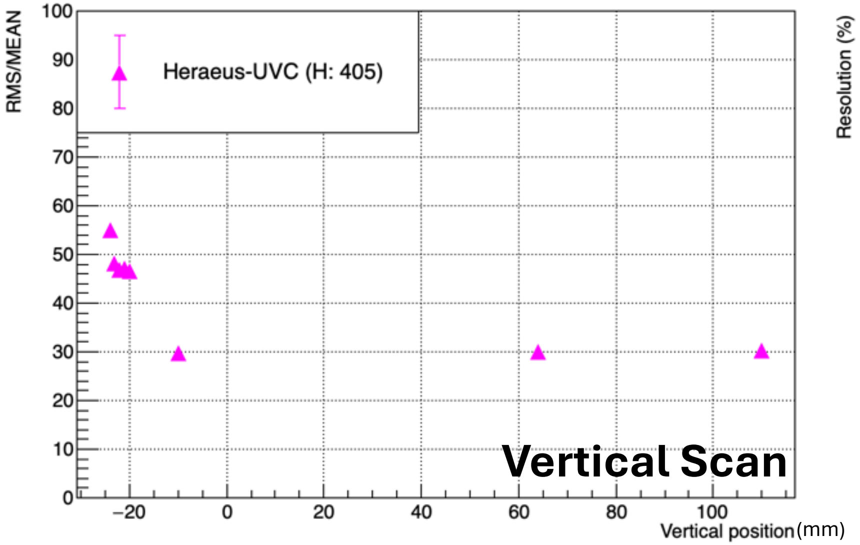
- Ring 1 was operated at 900 V
- PMT used: Jlab, 616
- Q1 (@ 900 V) = 5.98 (±0.10) , 5.42 (±0.11)
- Gain (x 10^6): 7.5 (±0.12), 6.8 (±0.14)
- **Average RMS/MEAN (400–420 mm) ~ 30%**
- Both the Heraeus and Corning quartz tile behave similarly

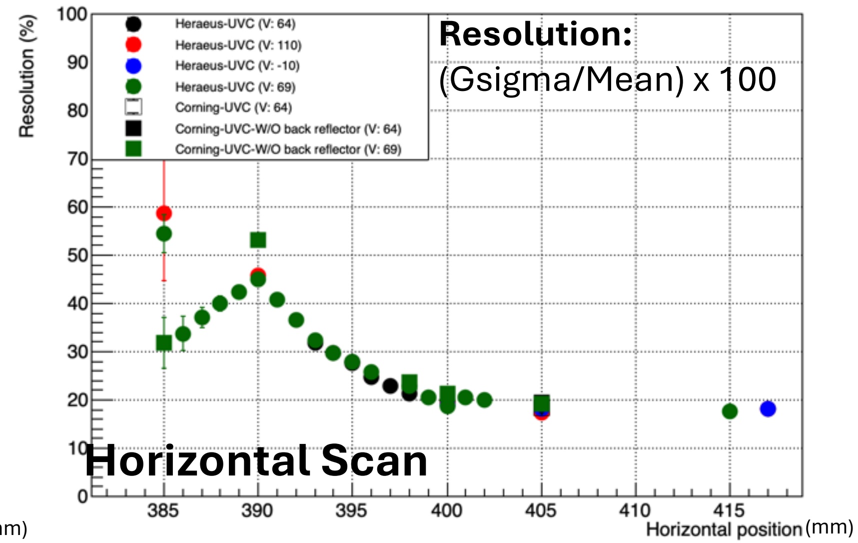
Ring 1 dimensions:

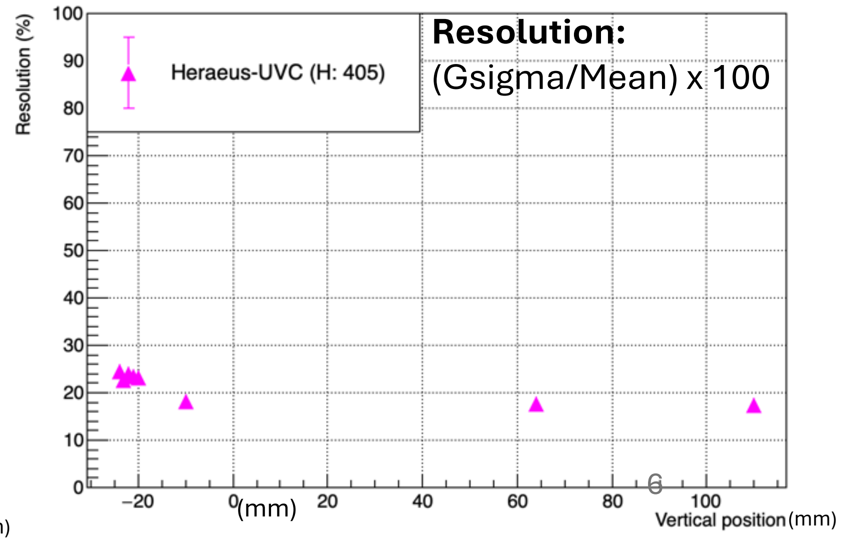
Horizontal : **30 mm** (W/O bevel)

Vertical : **169 mm**

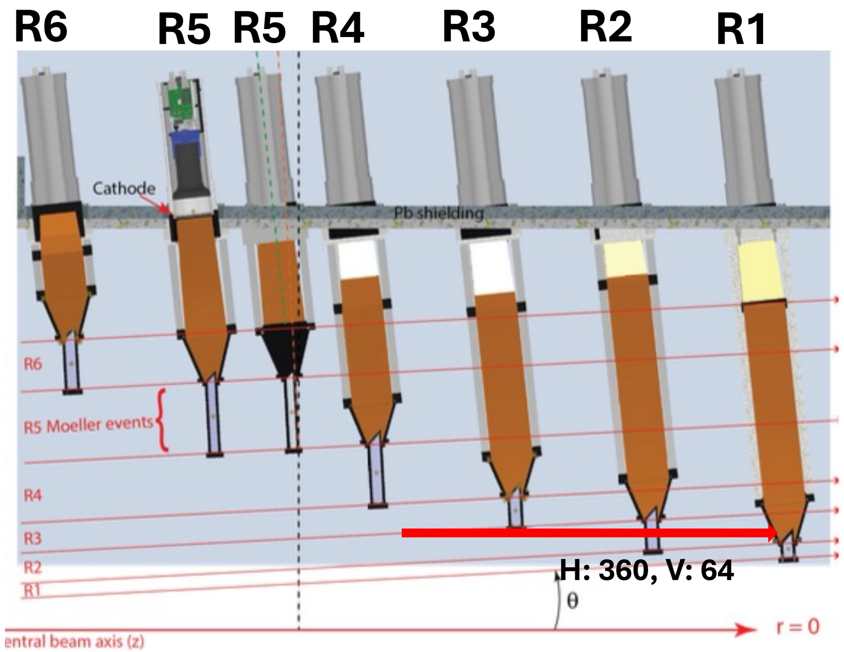


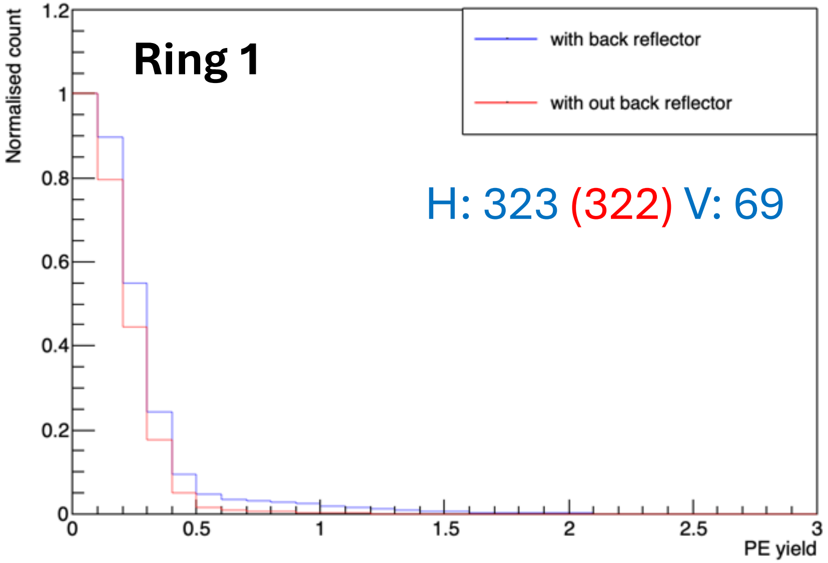


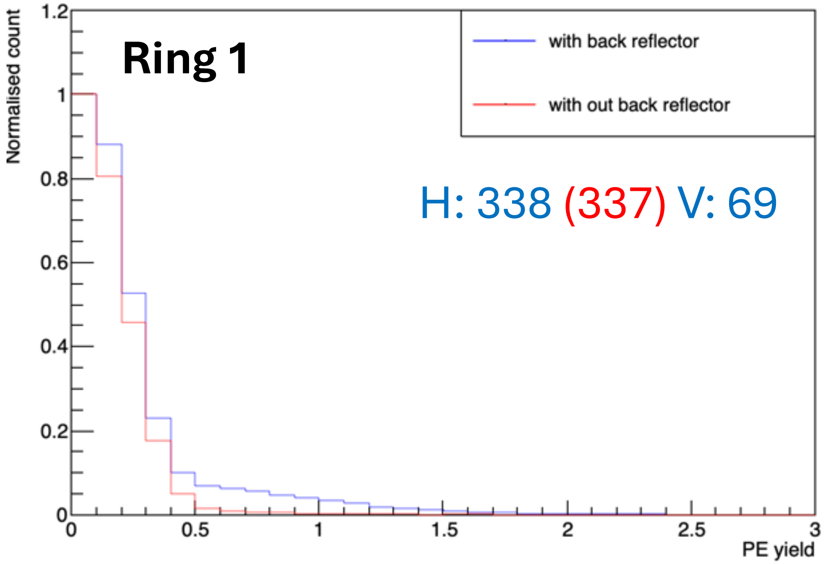


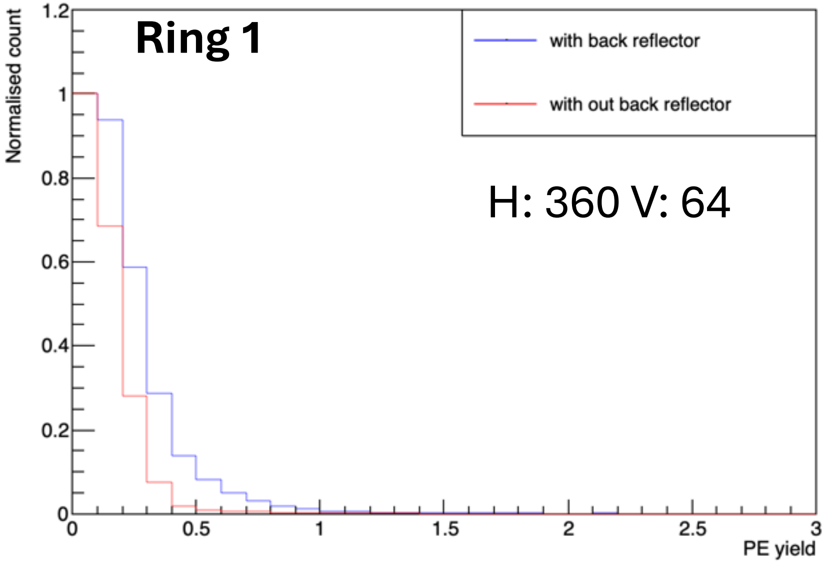


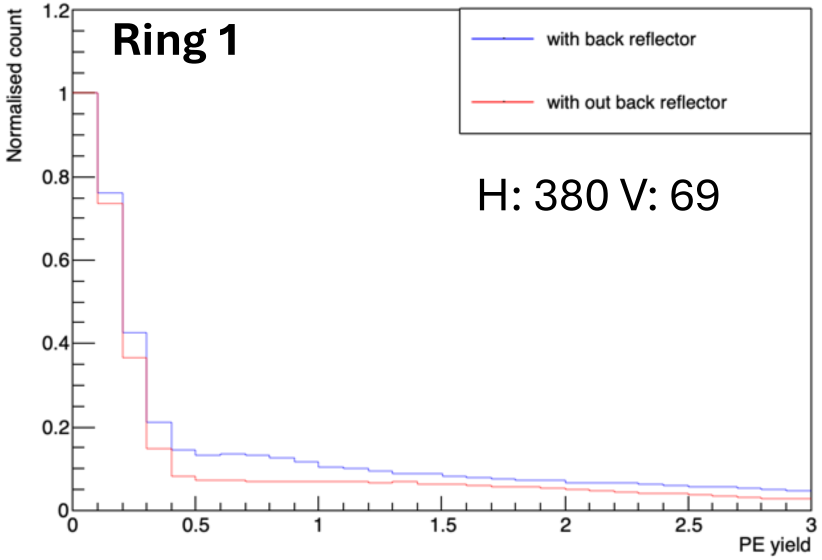
Ring 1: Effect of back reflector panels









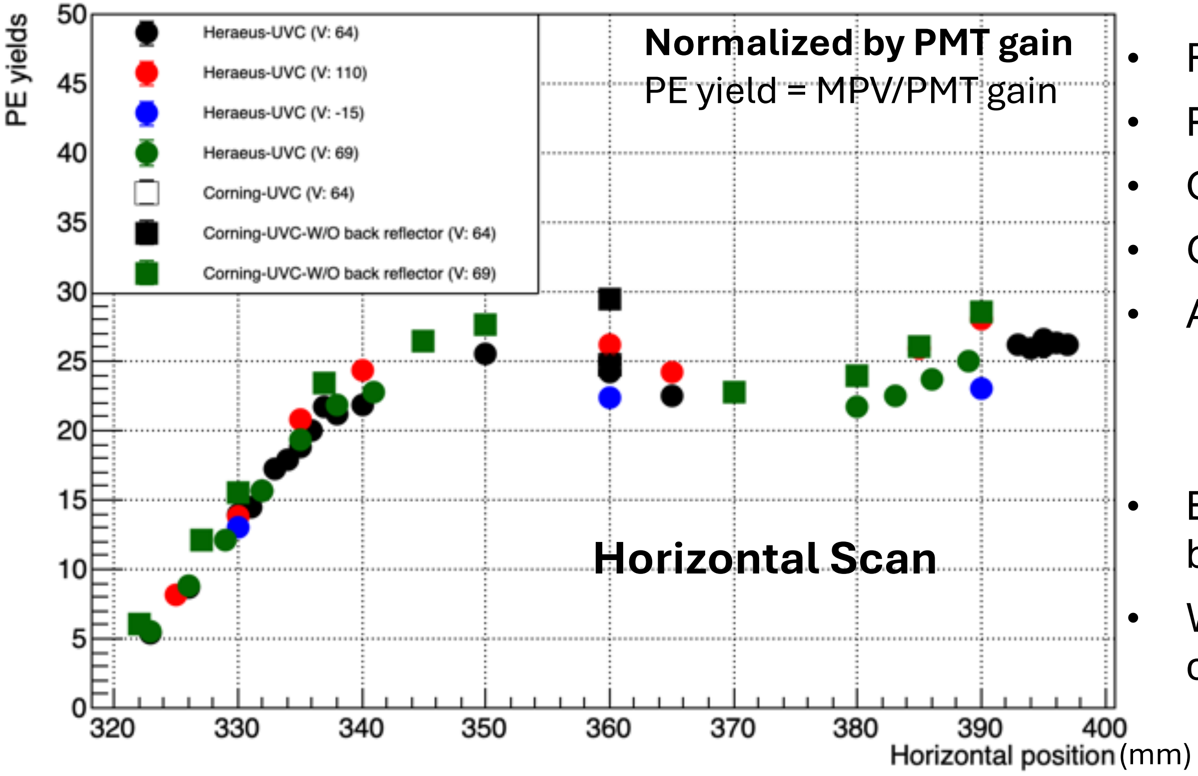


- **Beam hitting at Ring 2**
  - Ring 2 center ~ H: 360 V: 64
- **Signal from R1 is studied with and without the back reflector panels**

✓ **Performance without the back reflector panels seems better**

✓ **No change in the PE yield is observed due to the removable of the back reflector panels**

Ring 2: PE yield



- Ring 2 was operated at 900 V
- PMT used: 616, Jlab
- Q1 (@ 900 V) = 5.42 (±0.11), 5.98 (±0.10)
- Gain (x 10^6): 6.8 (±0.14), 7.5 (±0.12)
- Average PE yield is (350–400 mm);

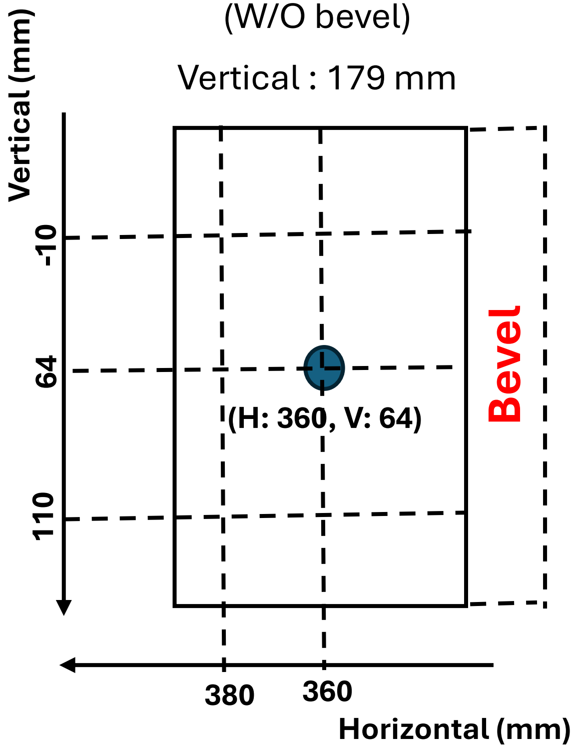
  25.0 ± 0.10 (gain norm.)

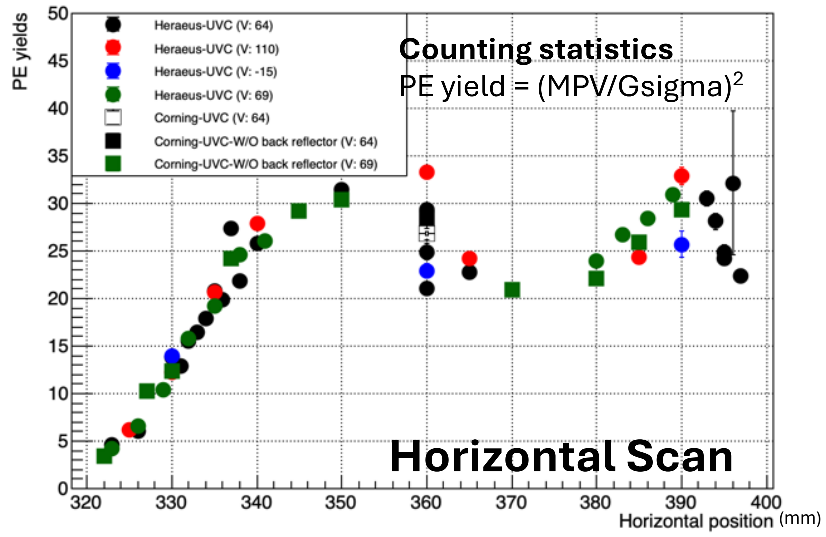
  24.89 ± 0.07 (counting stat.)
- Both the Heraeus and Corning quartz tile behave similarly
- With out the back reflectors no significant change in the PE yield is observed

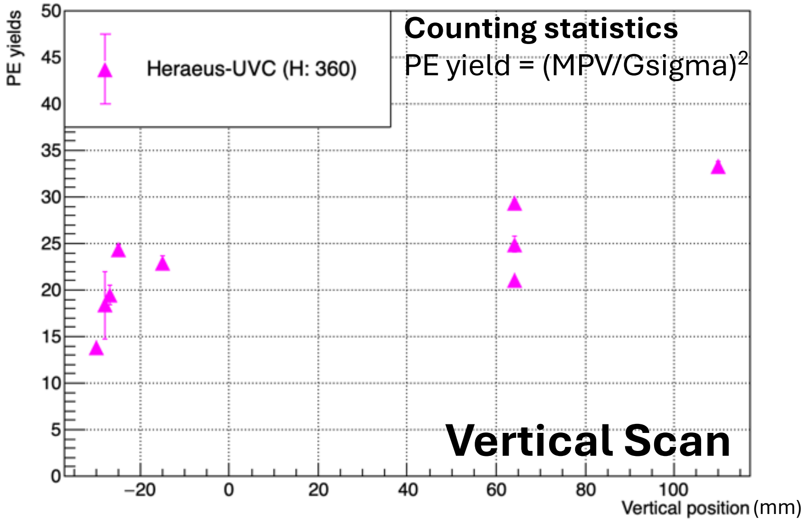
Ring 2 dimensions:

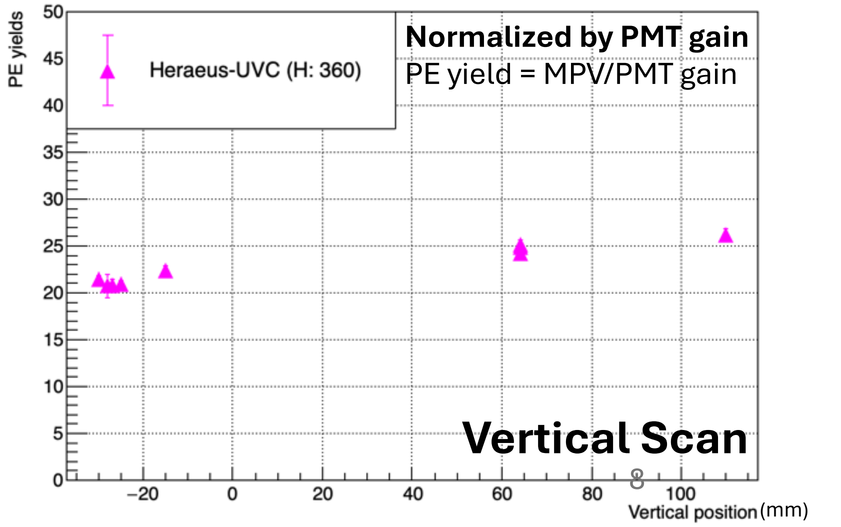
Horizontal : 60 mm (W/O bevel)

Vertical : 179 mm

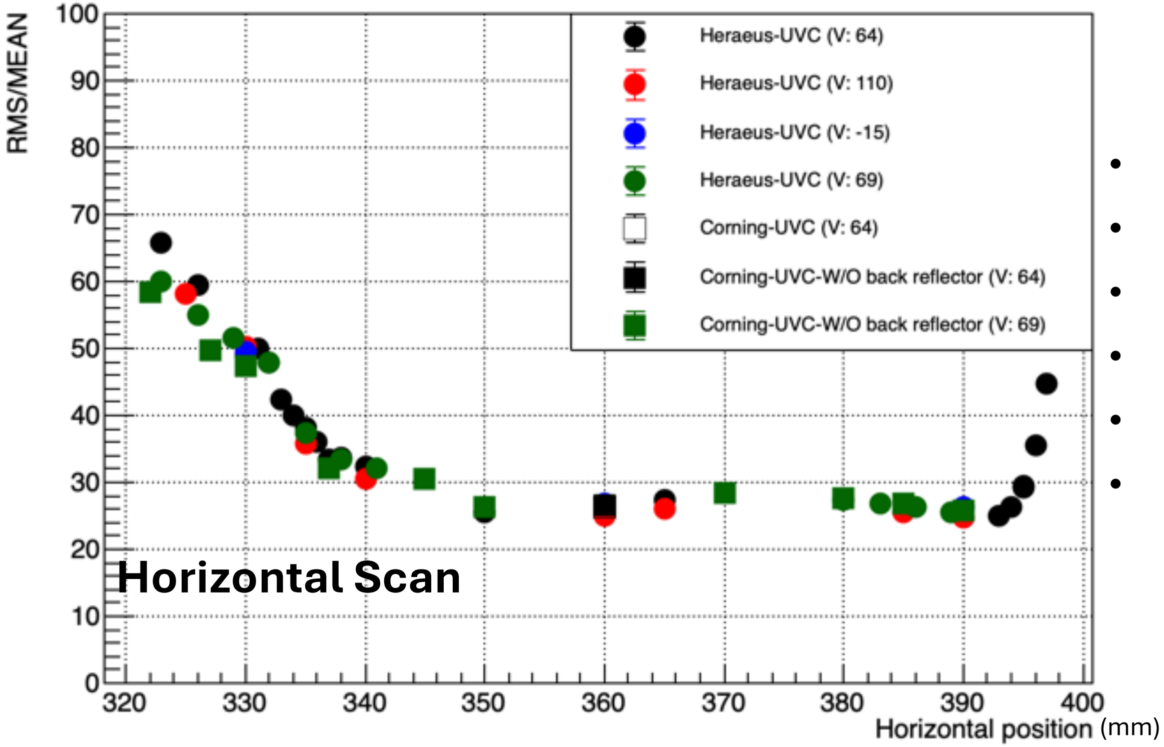








Ring 2: Resolution & RMS/MEAN

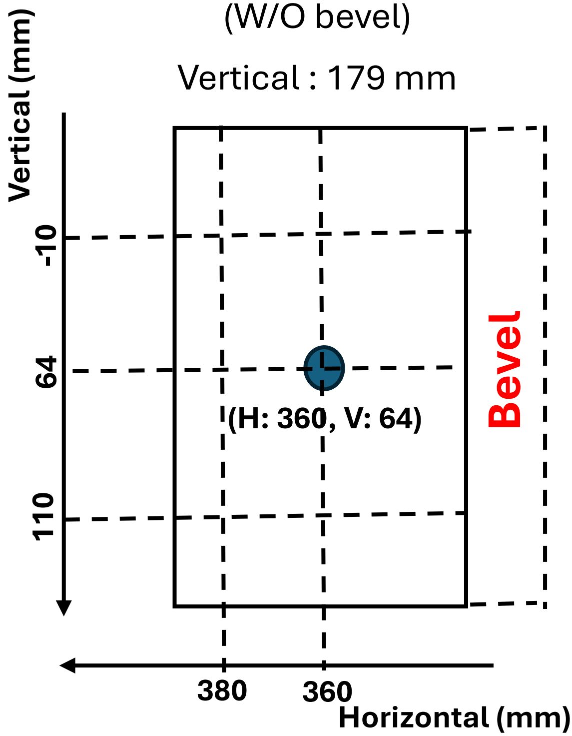


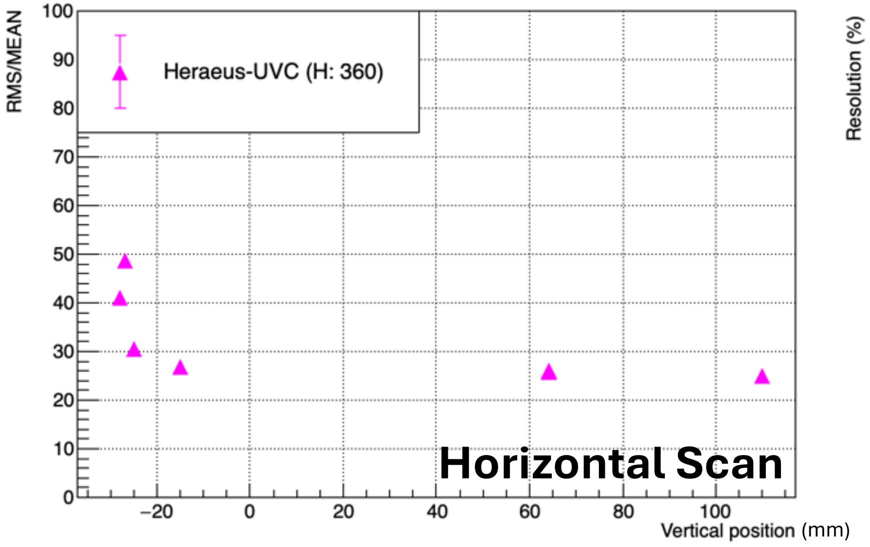
- Ring 2 was operated at 900 V
- PMT used: 616, Jlab
- Q1 (@ 900 V) = 5.42 (±0.11), 5.98 (±0.10)
- Gain (x 10^6): 6.8 (±0.14), 7.5 (±0.12)
- **Average RMS/MEAN (400–420 mm) ~ 28%**
- Both the Heraeus and Corning quartz tile behave similarly

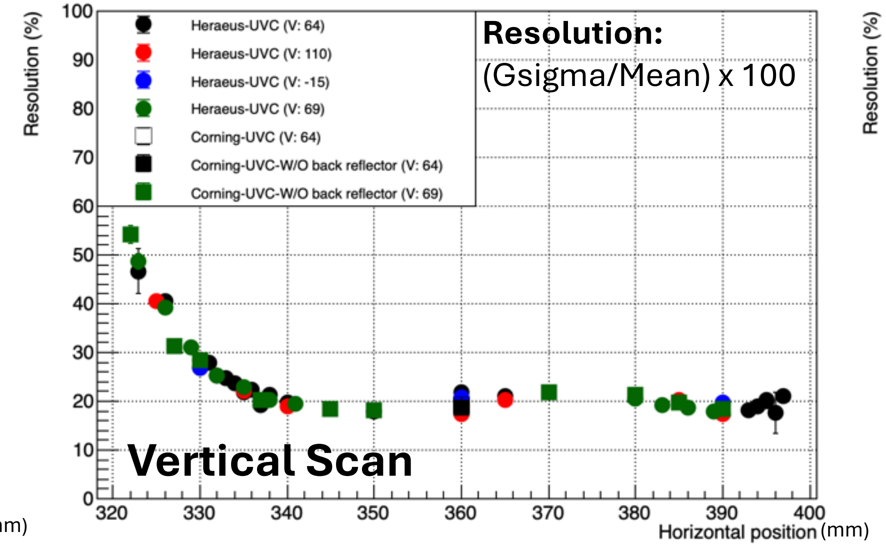
Ring 2 dimensions:

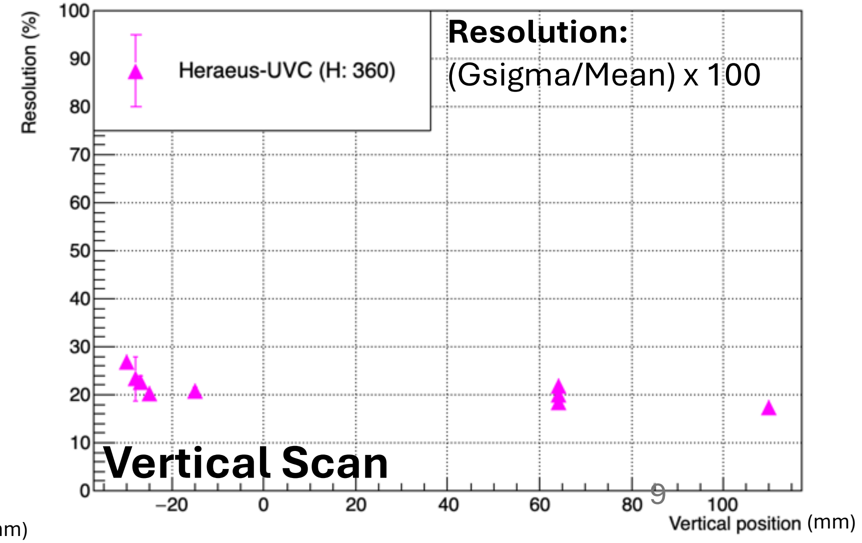
Horizontal : 60 mm
(W/O bevel)

Vertical : 179 mm

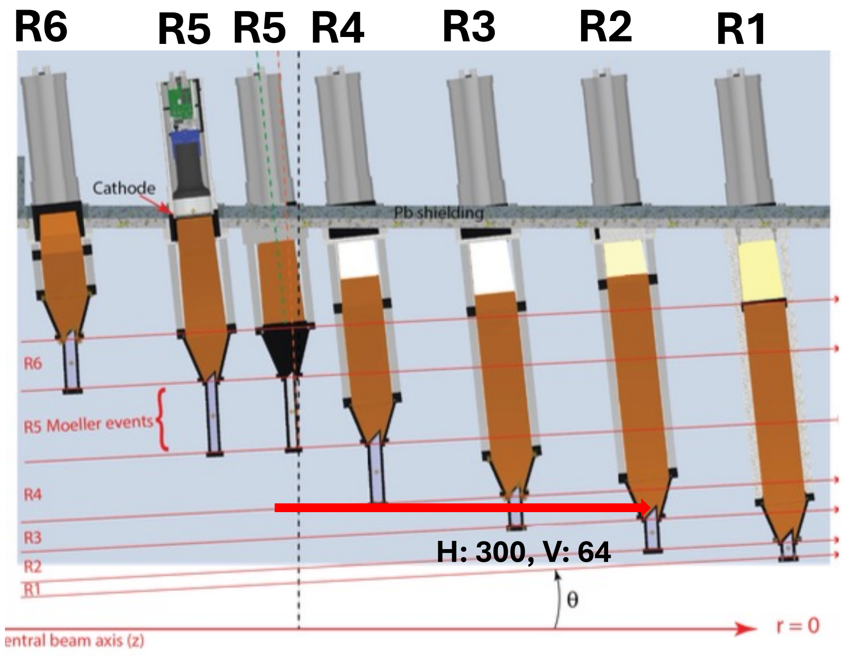


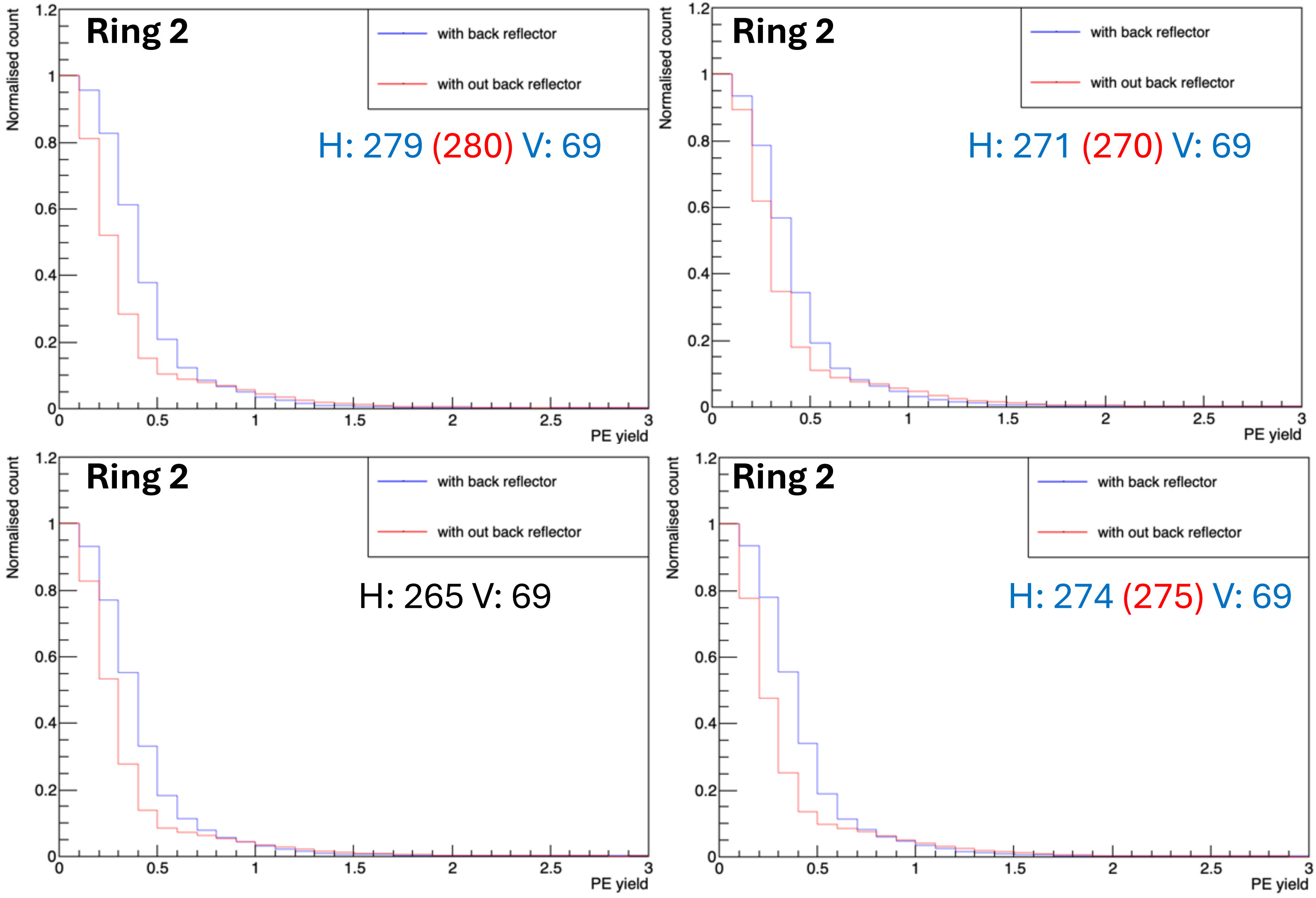






Ring 2: Effect of back reflector panels



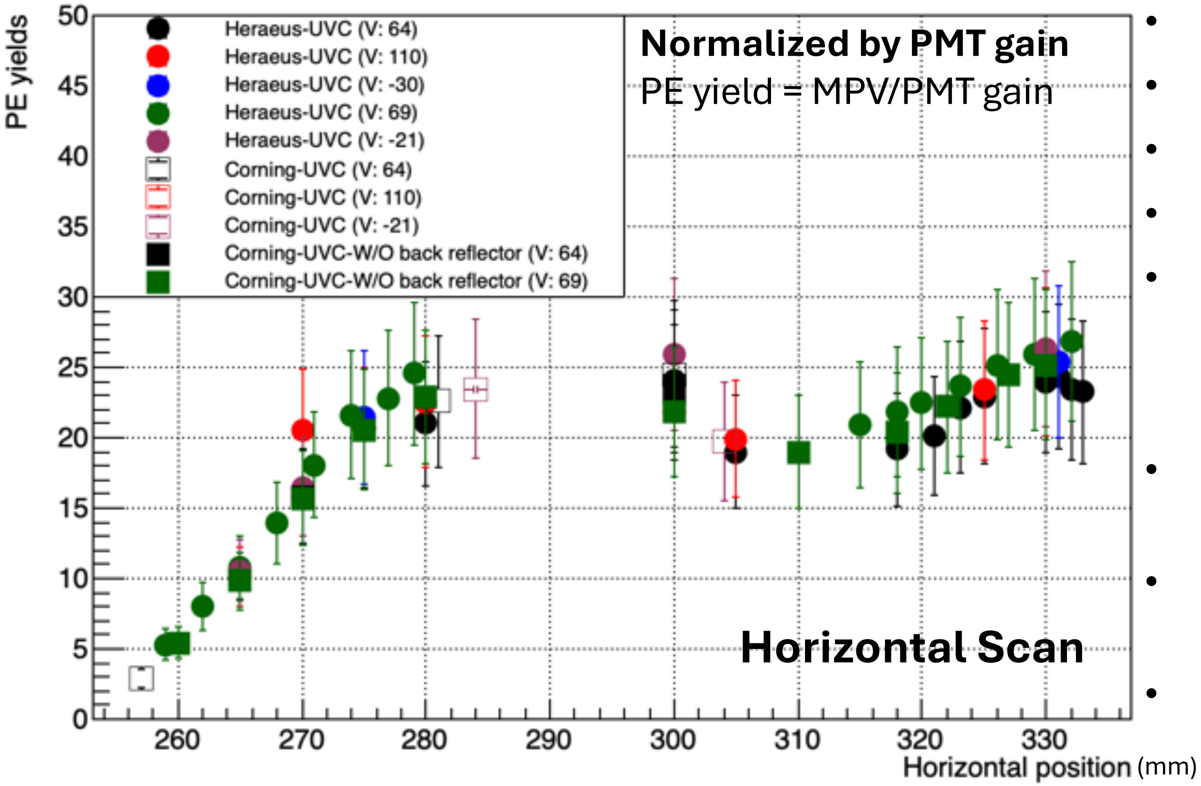


- **Beam hitting at Ring 3**
  - Ring 3 center ~ H: 300 V: 64
- **Signal from R2 is studied with and without the back reflector panels**

✓ **Performance without the back reflector panels seems better**

✓ **No change in the PE yield is observed due to the removable of the back reflector panels**

Ring 3: PE yield



- Ring 3 was operated at 850 V
- PMT used: 542
- Q1 (@ 850 V) = 4.86 (±1.01)
- Gain (x 10^6): 6.1 (±1.3)
- Average PE yield is (280–340 mm);

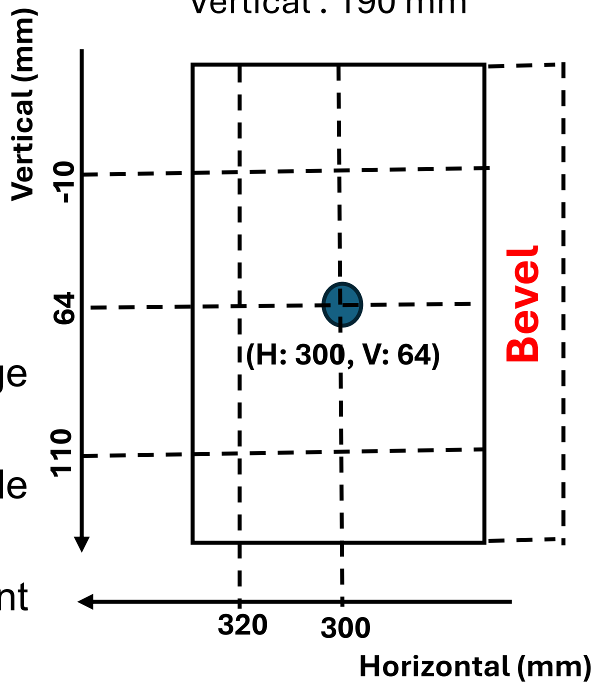
  22.51 ± 0.77 (gain norm.)

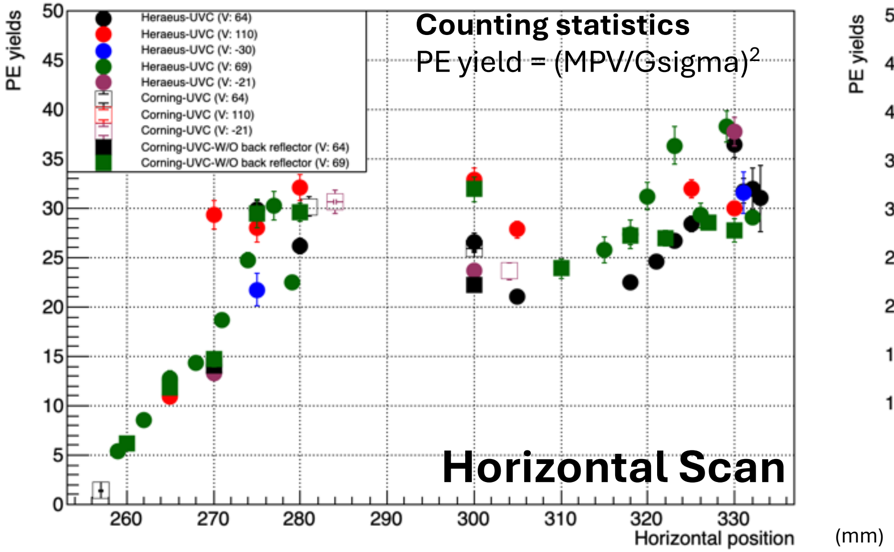
  24.94 ± 0.09 (counting stat.)
- The higher error bar is due to the large error in Q1
- Both the Heraeus and Corning quartz tile behave similarly
- With out the back reflectors no significant change in the PE yield is observed

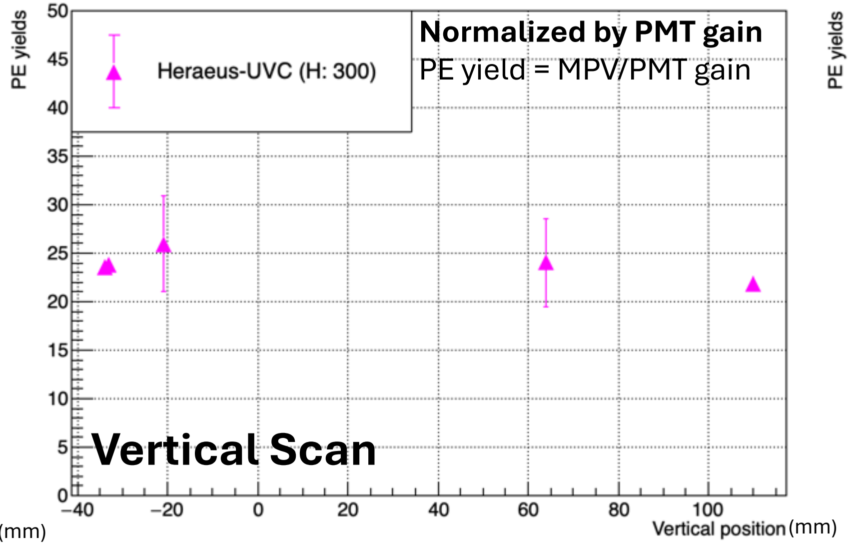
Ring 3 dimensions:

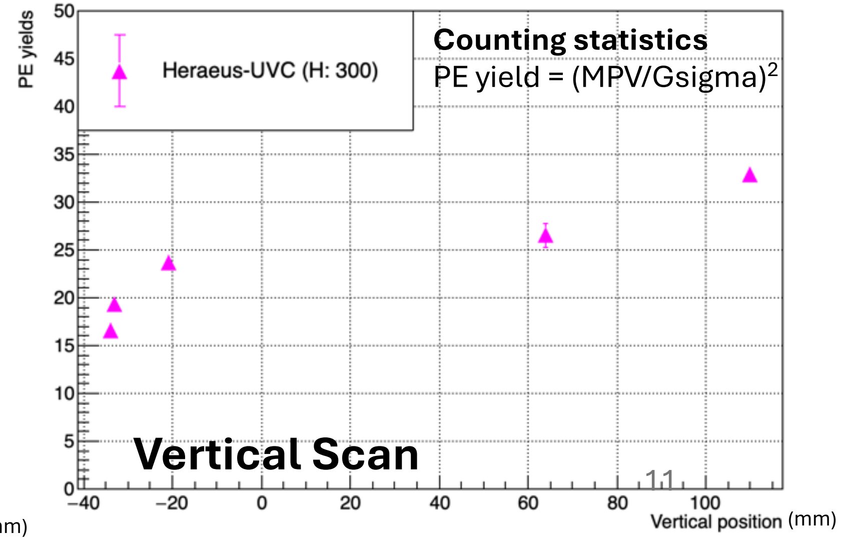
Horizontal : 60 mm (W/O bevel)

Vertical : 190 mm

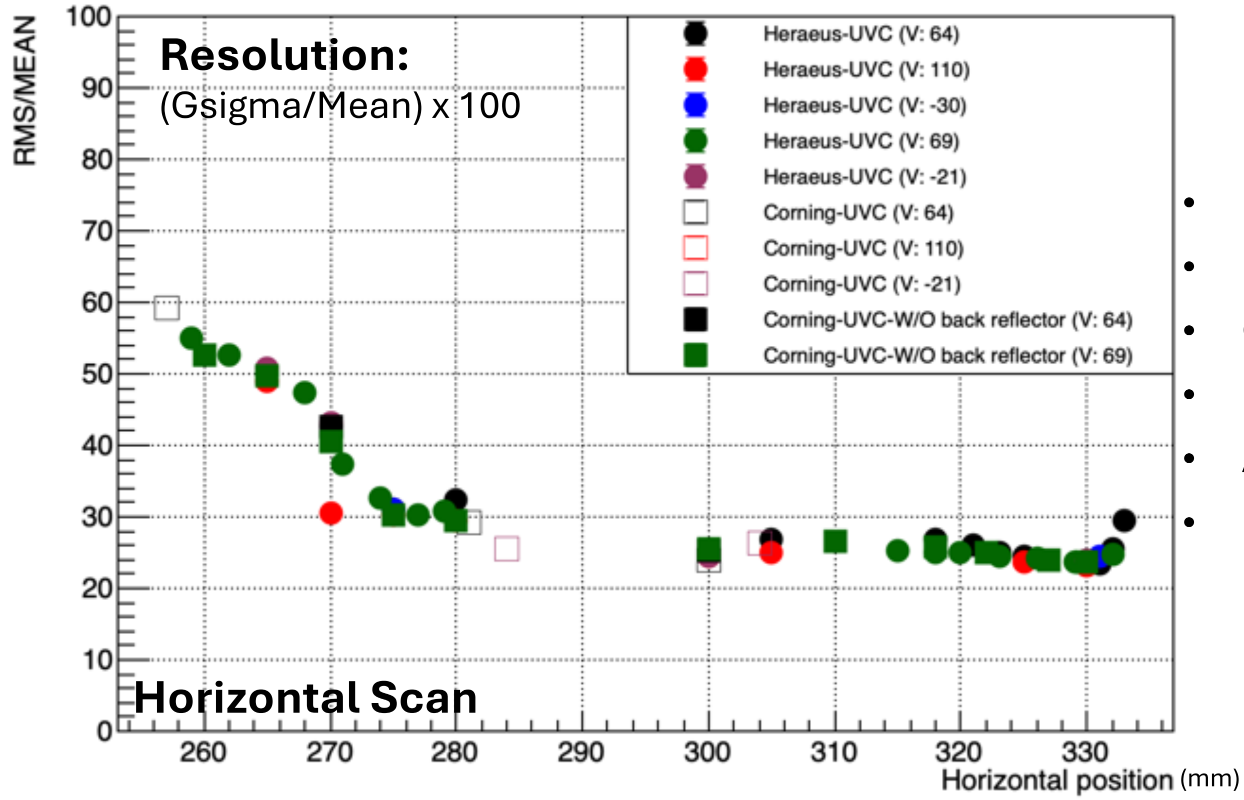








Ring 3: Resolution & RMS/MEAN

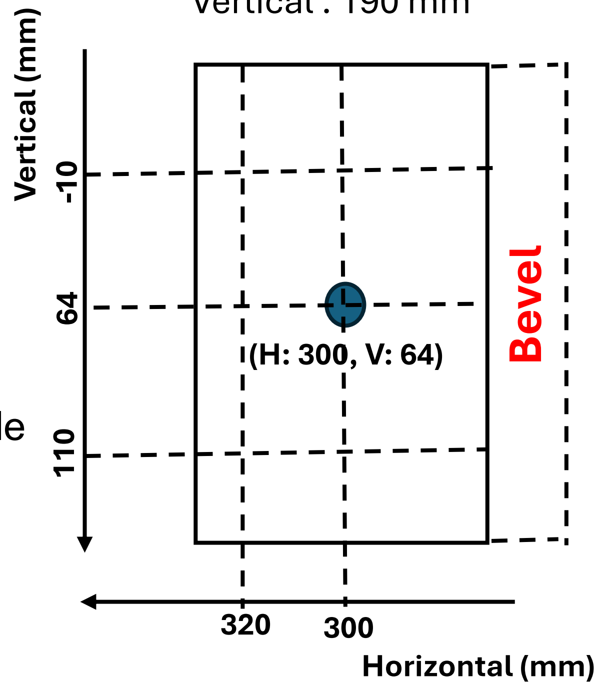


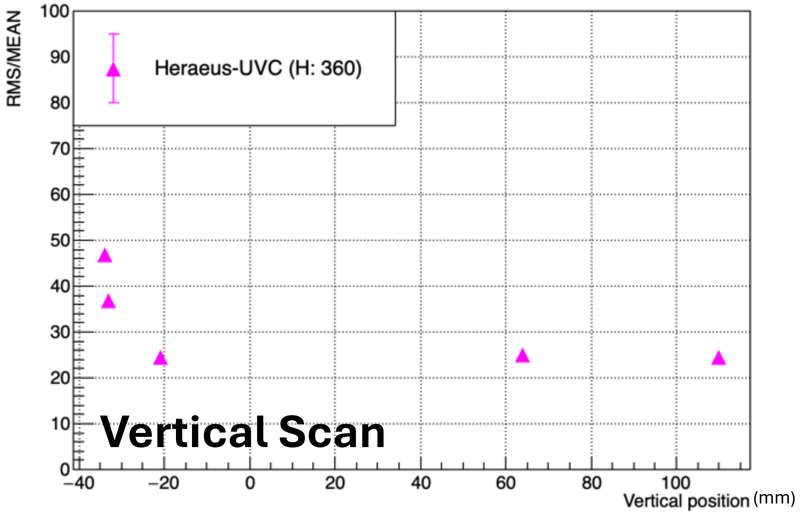
- Ring 3 was operated at 850 V
- PMT used: 542
- Q1 (@ 850 V) = 4.86 (±1.01)
- Gain (x 10^6): 6.1 (±1.3)
- Average **RMS/MEAN (280-340) ~ 28%**
- Both the Heraeus and Corning quartz tile behave similarly

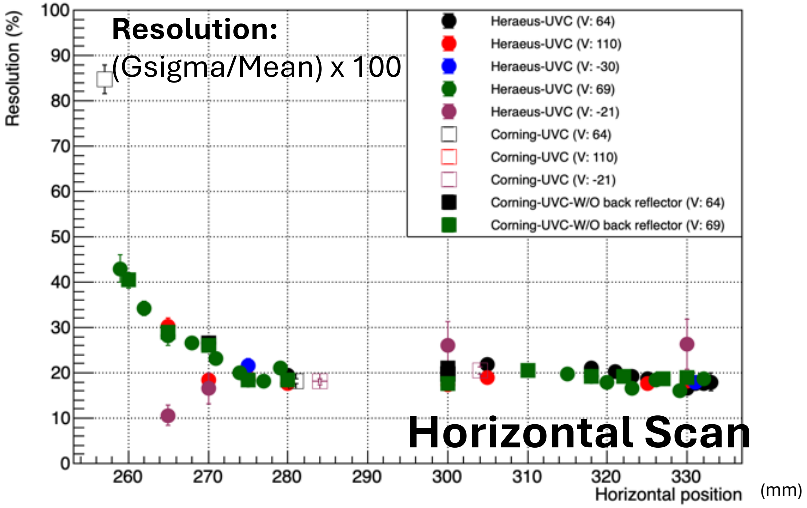
Ring 3 dimensions:

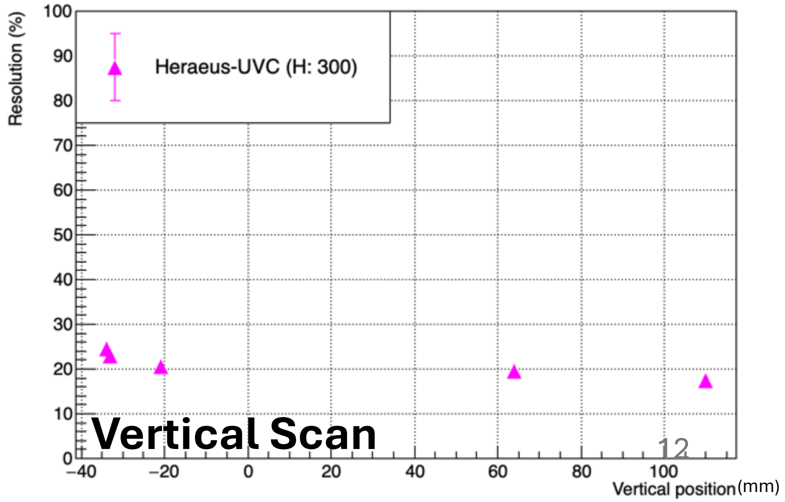
Horizontal : 60 mm (W/O bevel)

Vertical : 190 mm

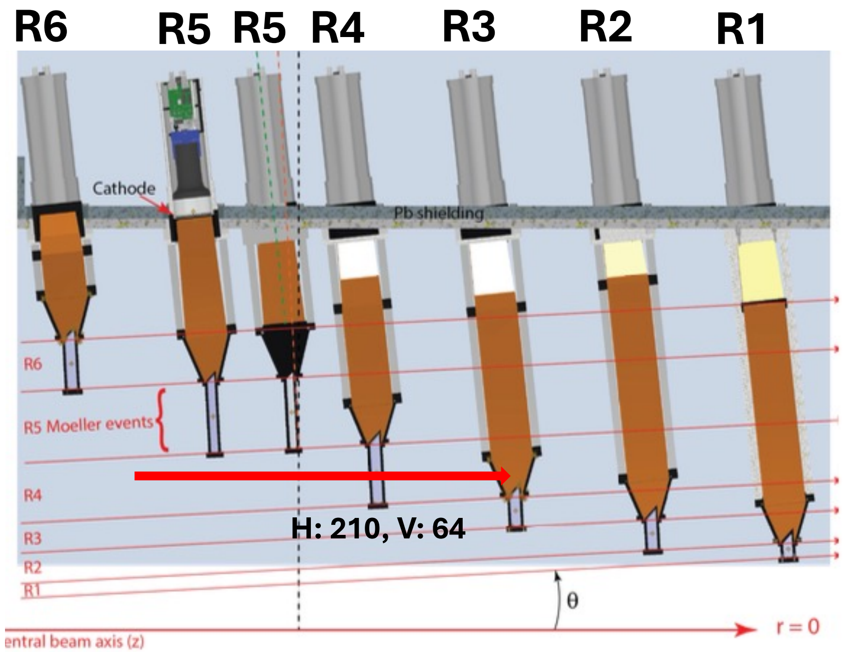




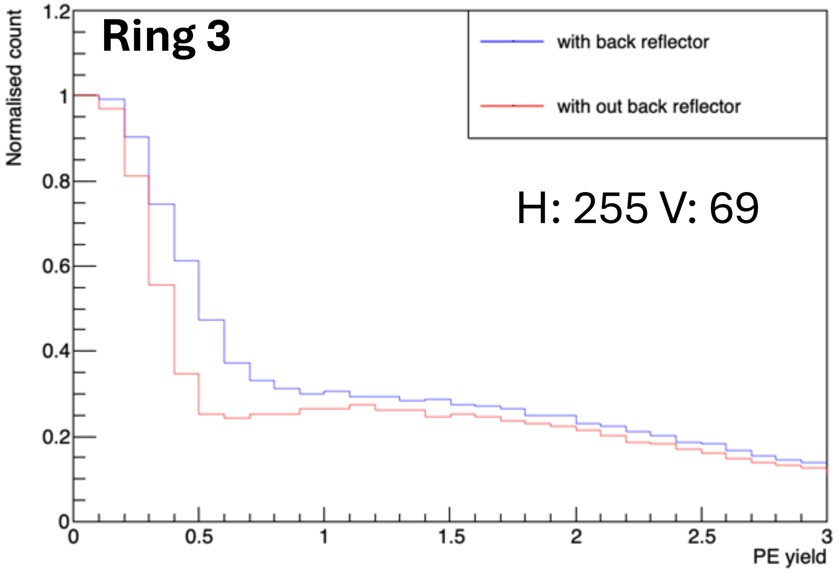


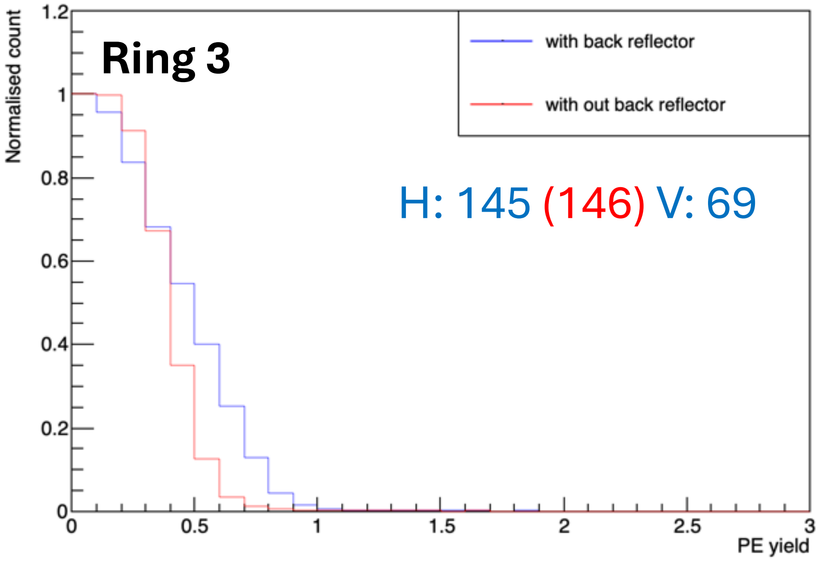


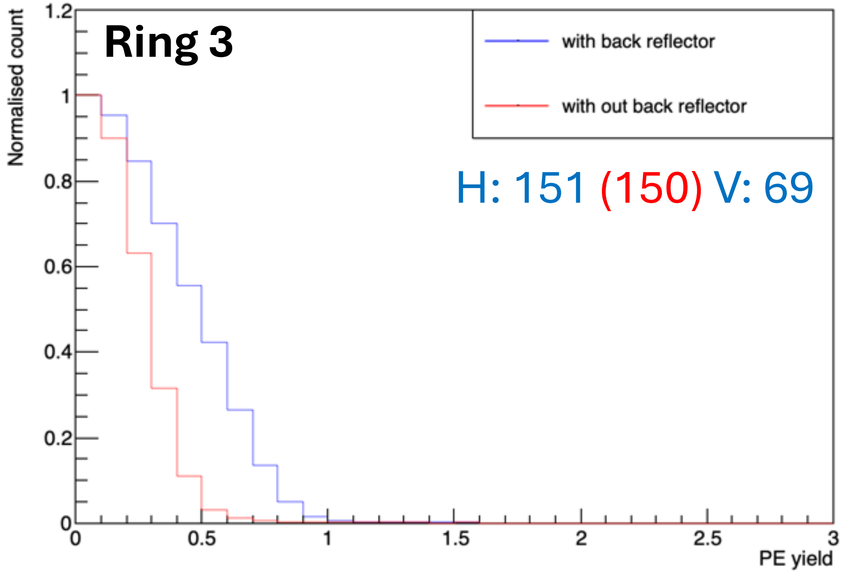
Ring 3: Effect of back reflector panels

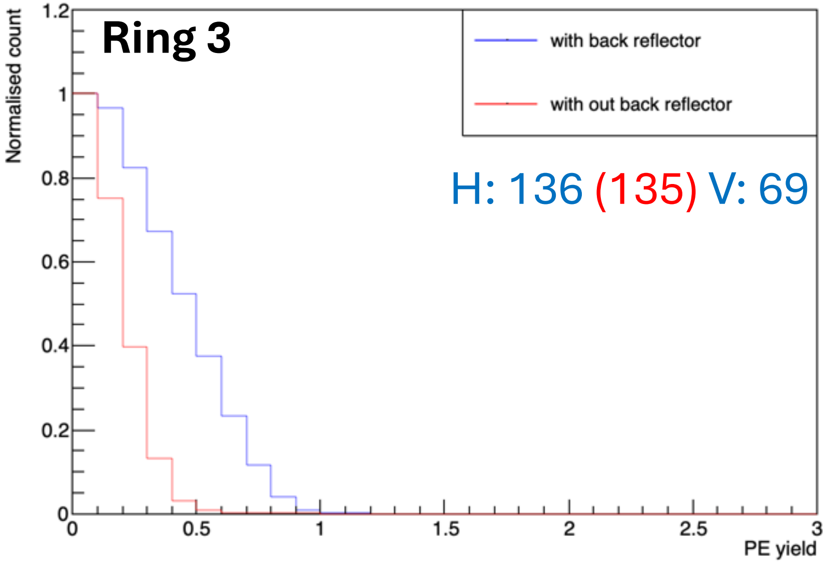


- **Beam hitting at Ring 4**
  - Ring 4 center ~ H: 210 V: 64
- **Signal from R3 is studied with and without the back reflector panels**





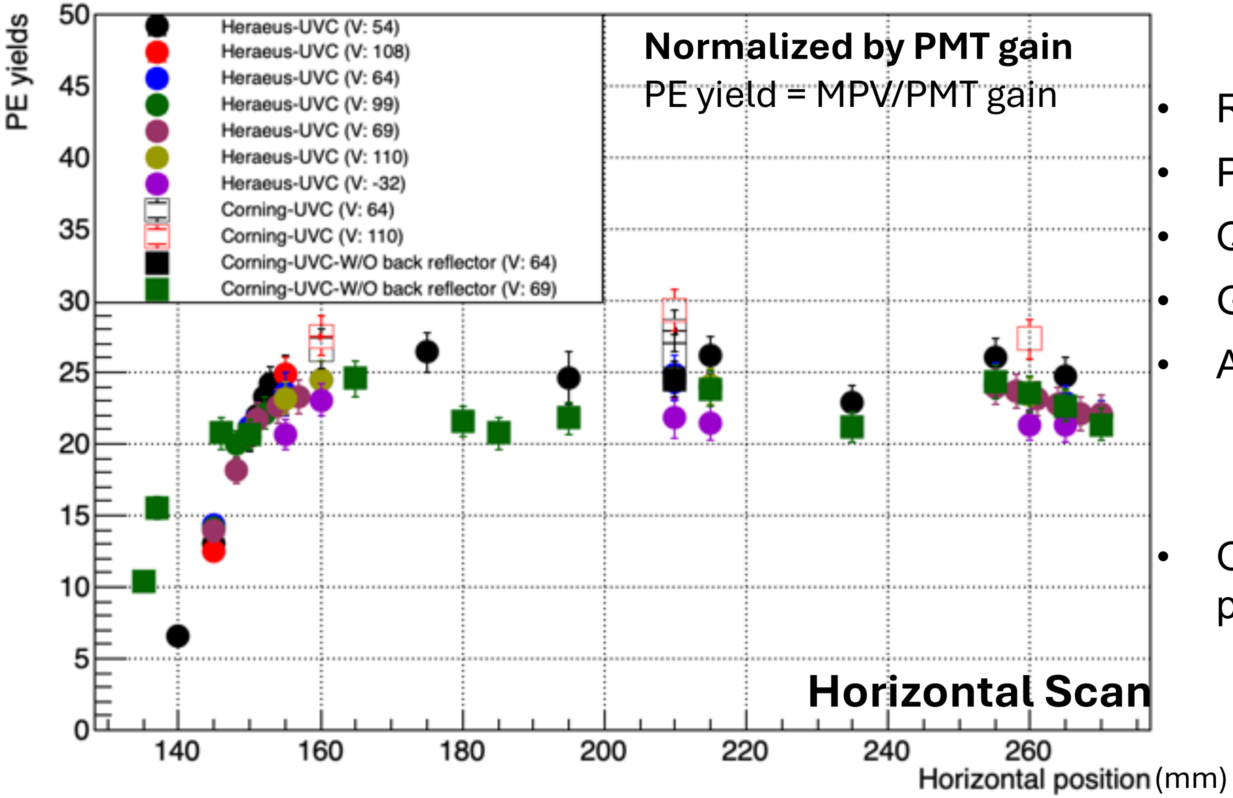




✓ **Performance without the back reflector panels seems better**

✓ **No change in the PE yield is observed due to the removable of the back reflector panels**

Ring 4: PE yield



- Ring 4 was operated at 975 V
- PMT used: 539
- Q1 (@ 850 V) = 5.21 (±0.26)
- Gain (x 10^6): 6.5 (±0.3)
- Average PE yield is (160–280 mm);

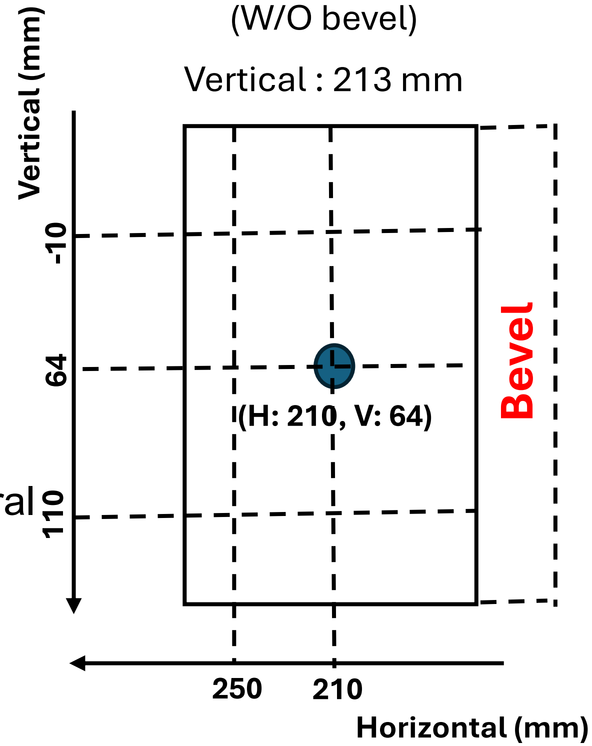
  23.58 ± 0.18 (gain norm.)

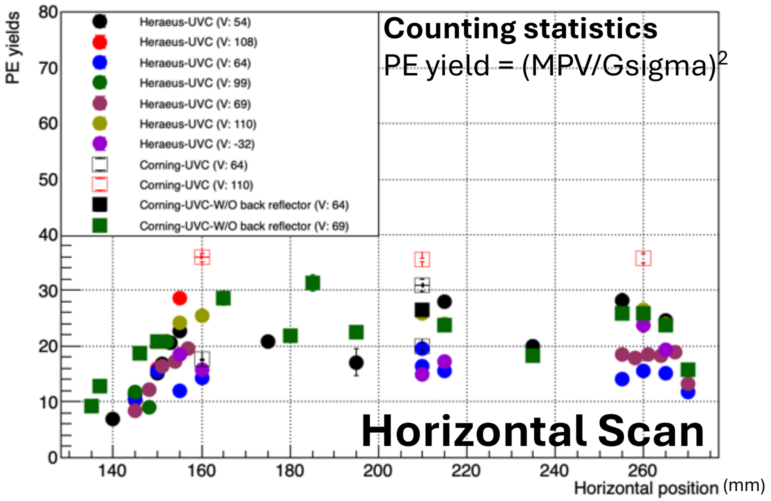
  18.02 ± 0.04 (counting stat.)
- Observed larger variation at the central position of the quartz tile

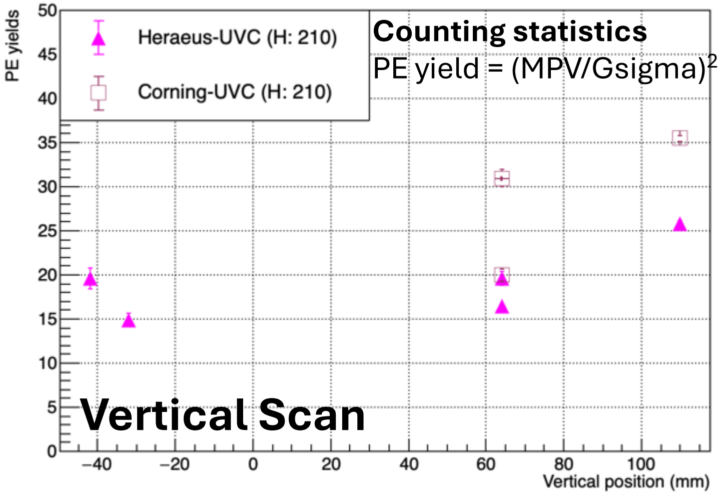
Ring 4 dimensions:

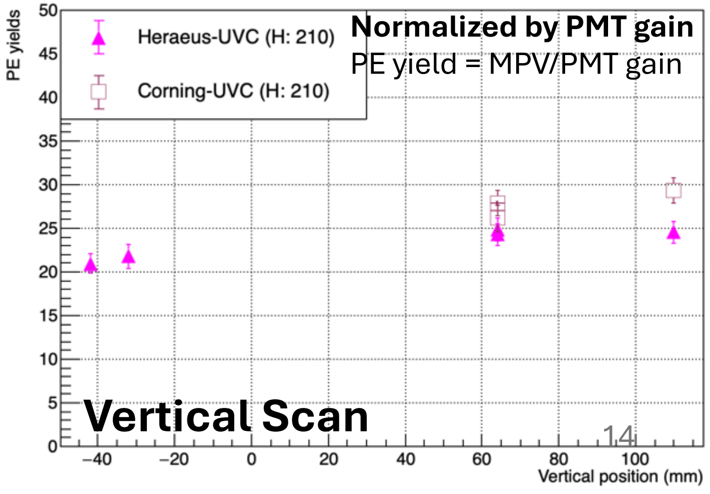
Horizontal : 120 mm (W/O bevel)

Vertical : 213 mm

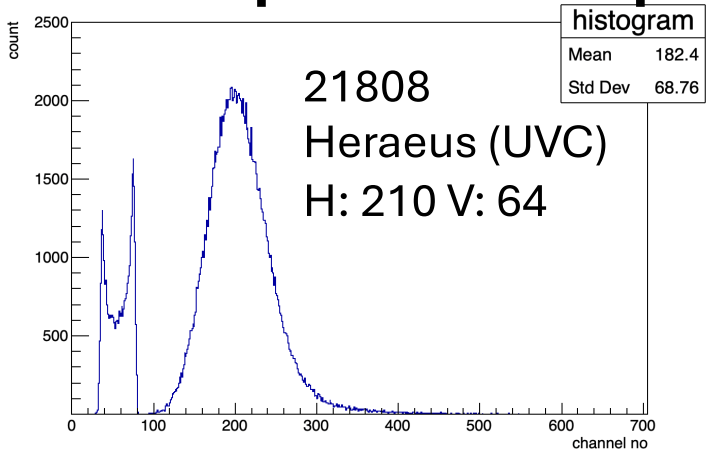


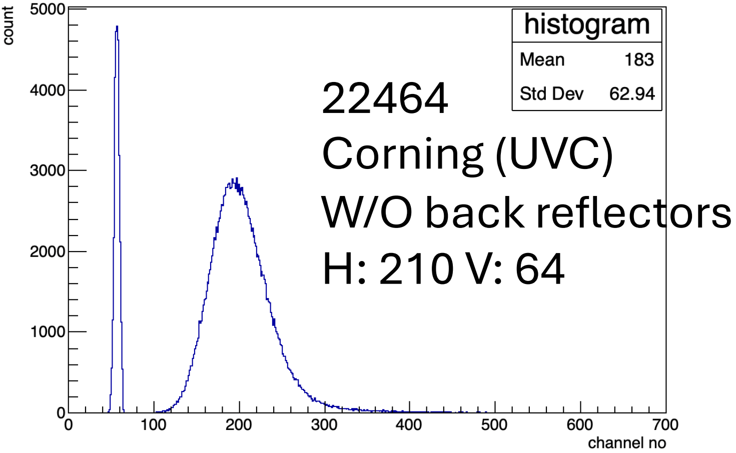


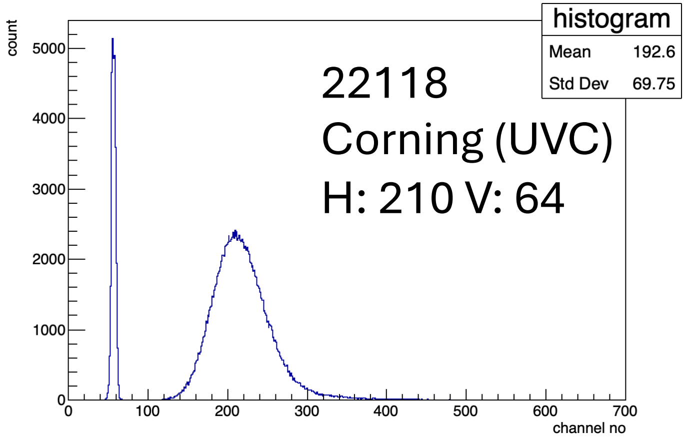


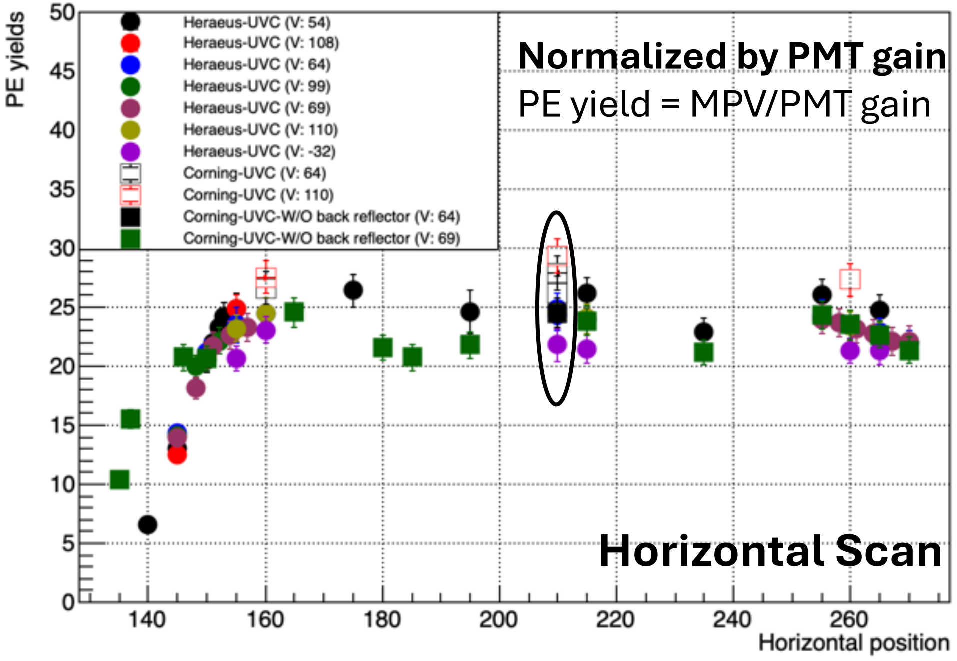


Double peaks in the pedestal





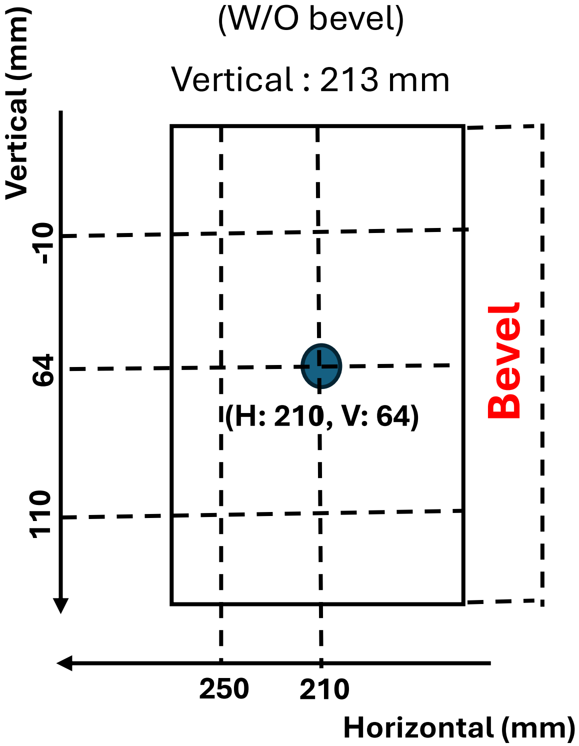




Ring 4 dimensions:

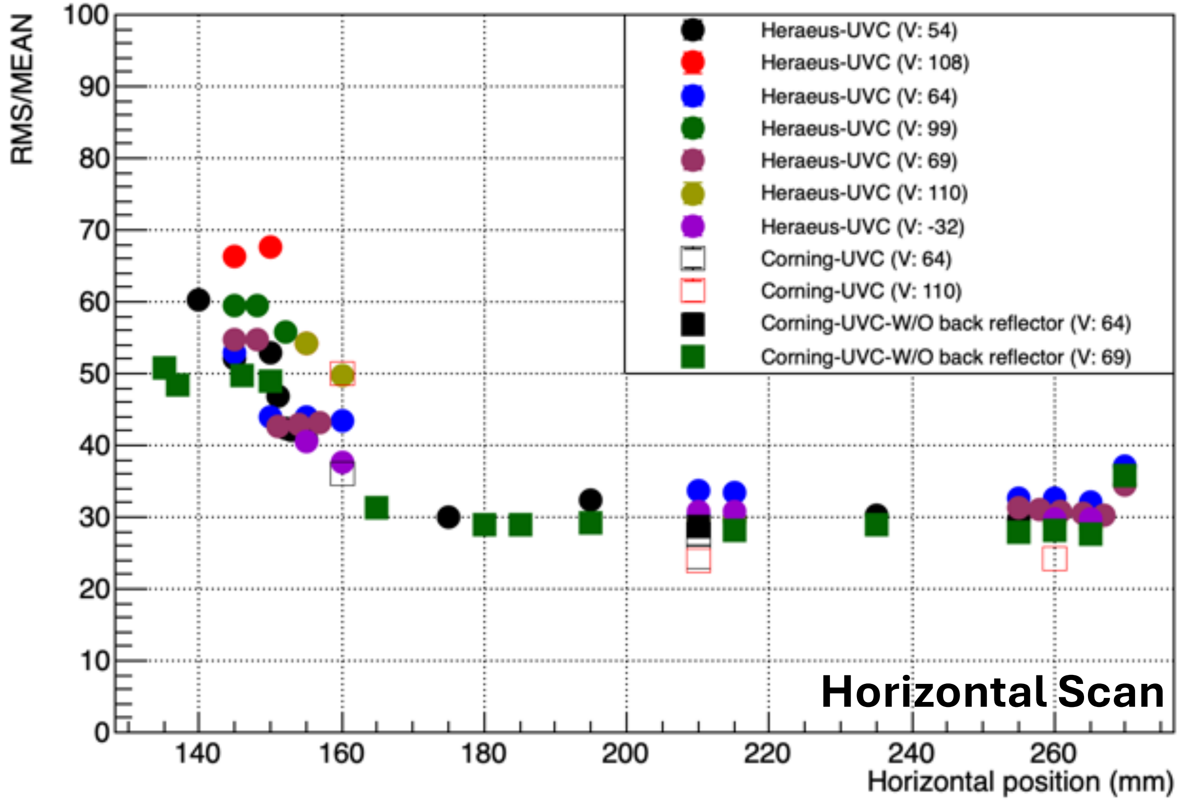
Horizontal : 120 mm (W/O bevel)

Vertical : 213 mm



- **Couple of runs show multiple peaks in the pedestal**
- **Due to that some changes in the PE yield is observed**
- **The reason behind observing the multiple pedestal could be due to the bad cable connection or fluctuation in the LV power supply**

Ring 4: Resolution & RMS/MEAN

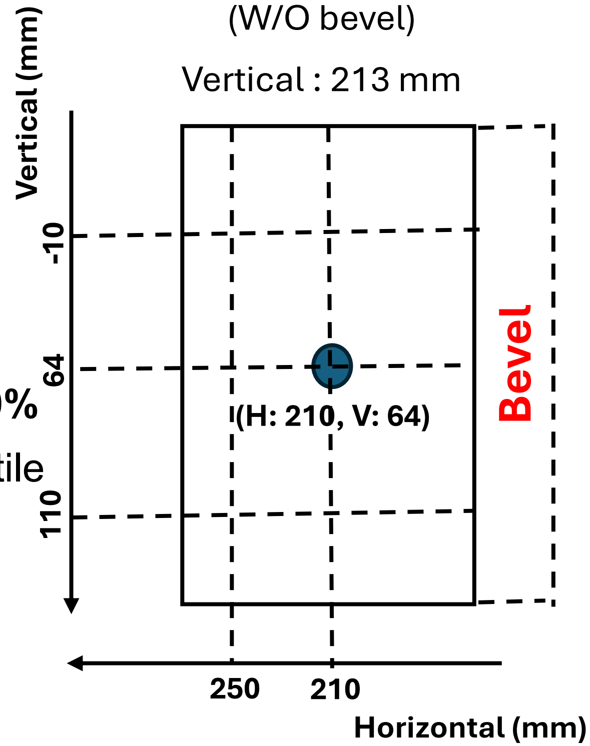


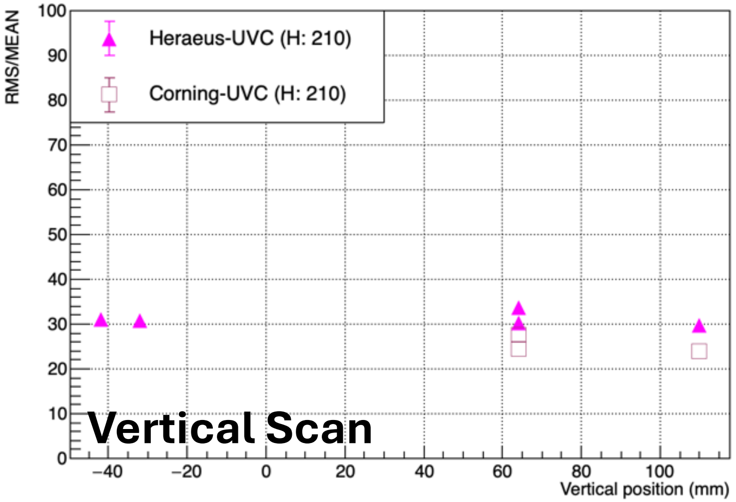
- Ring 4 was operated at 975 V
- PMT used: 539
- Q1 (@ 850 V) = 5.21 (±0.26)
- Gain (x 10^6): 6.5 (±0.3)
- Average **RMS/MEAN (160-280 mm) ~ 30%**
- Both the Heraeus and Corning quartz tile behave similarly

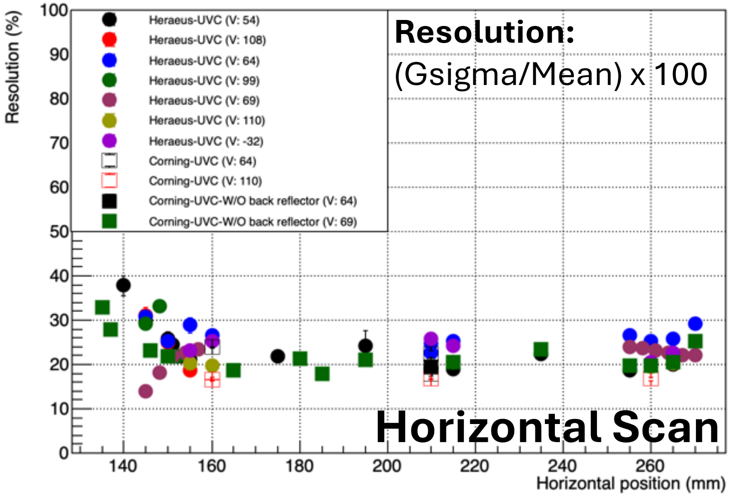
Ring 4 dimensions:

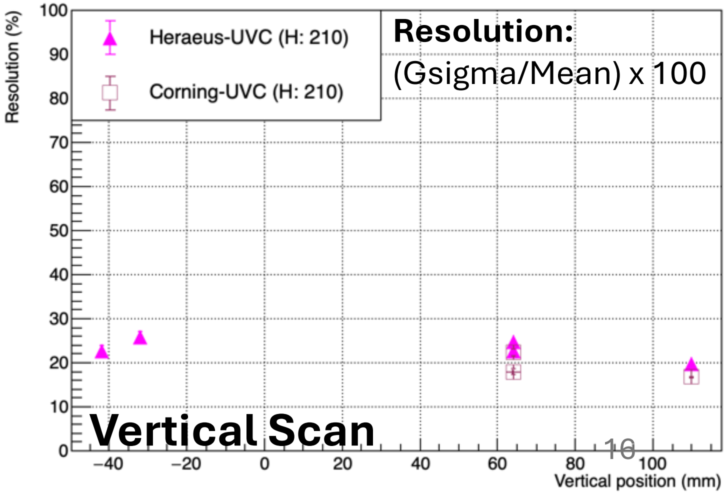
Horizontal : 120 mm
(W/O bevel)

Vertical : 213 mm

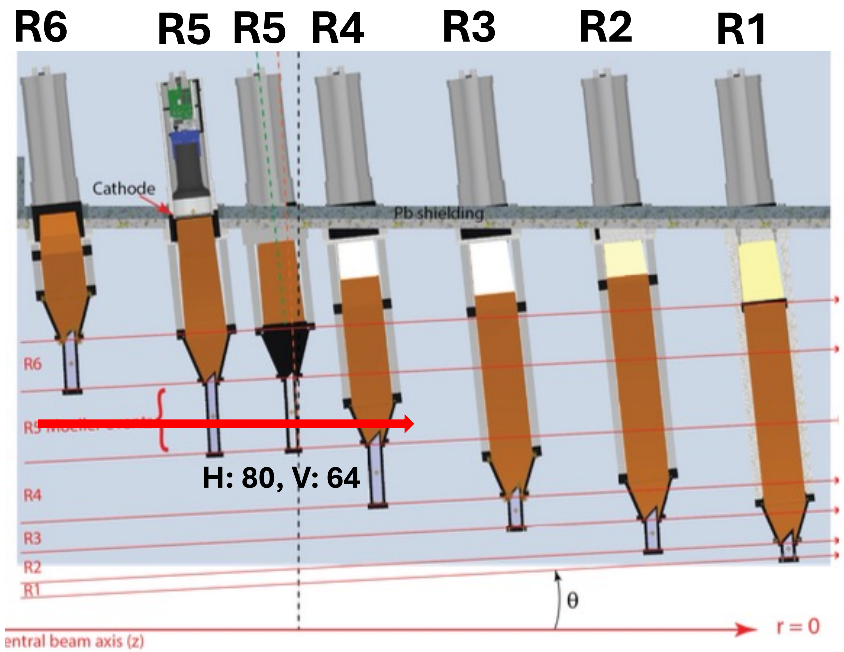




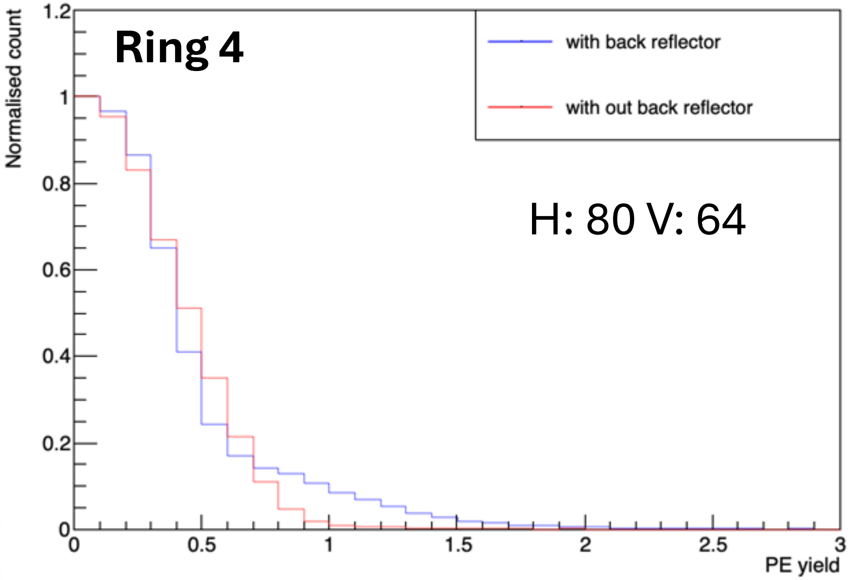


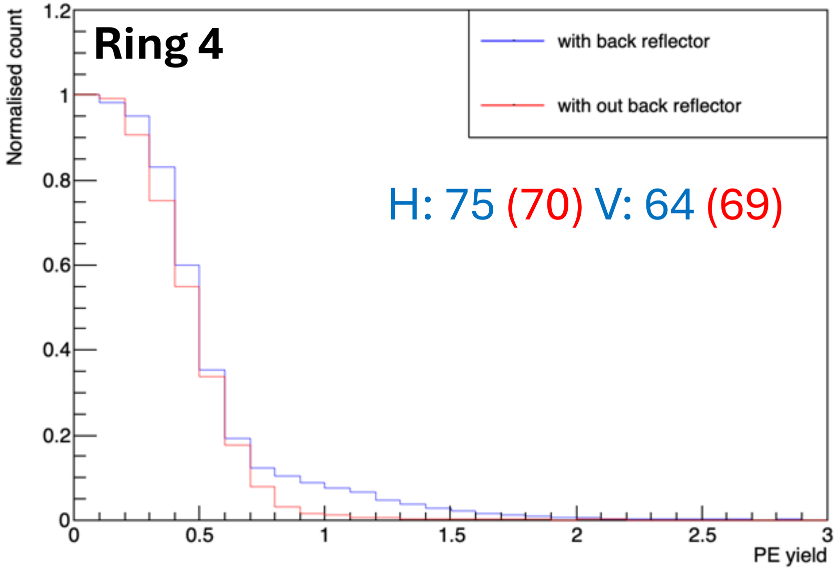


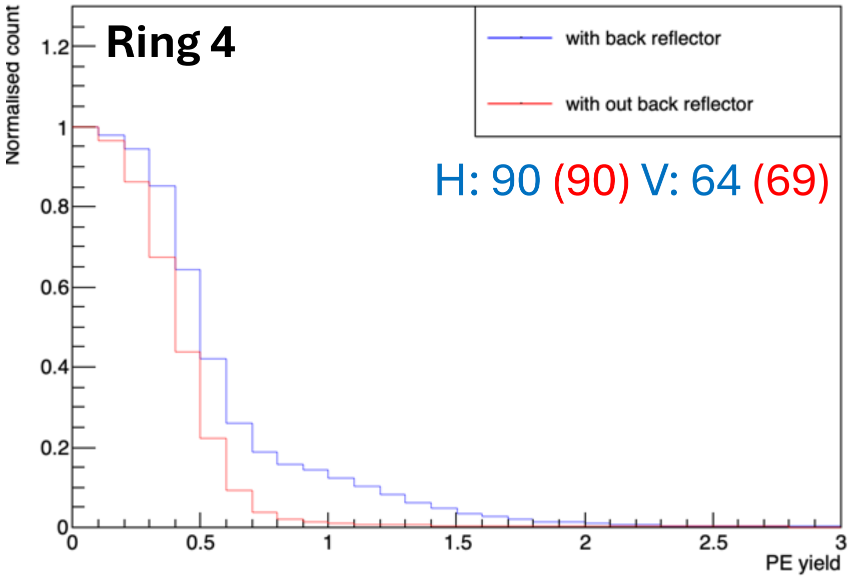
Ring 4: Effect of back reflector panels

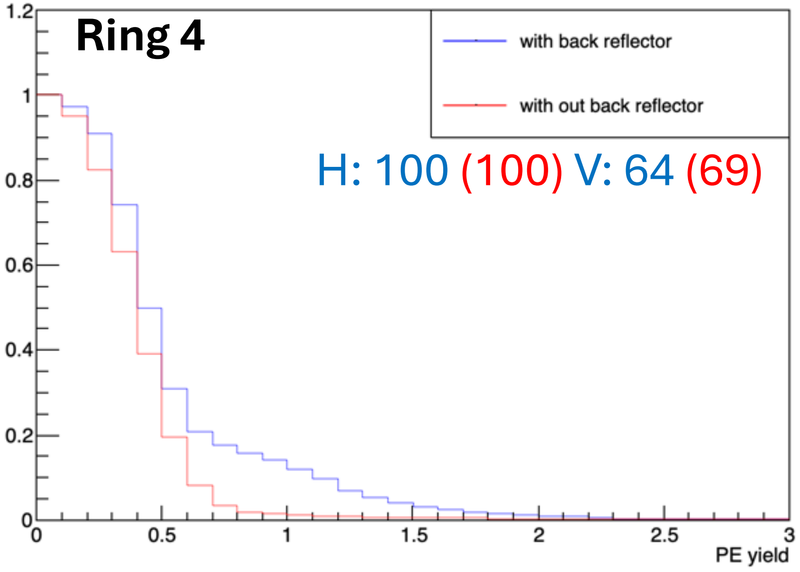


- **Beam hitting at Ring 5 BF**
  - Ring 5 BF center ~ H: 80 V: 64
- **Signal from R4 is studied with and without the back reflector panels**





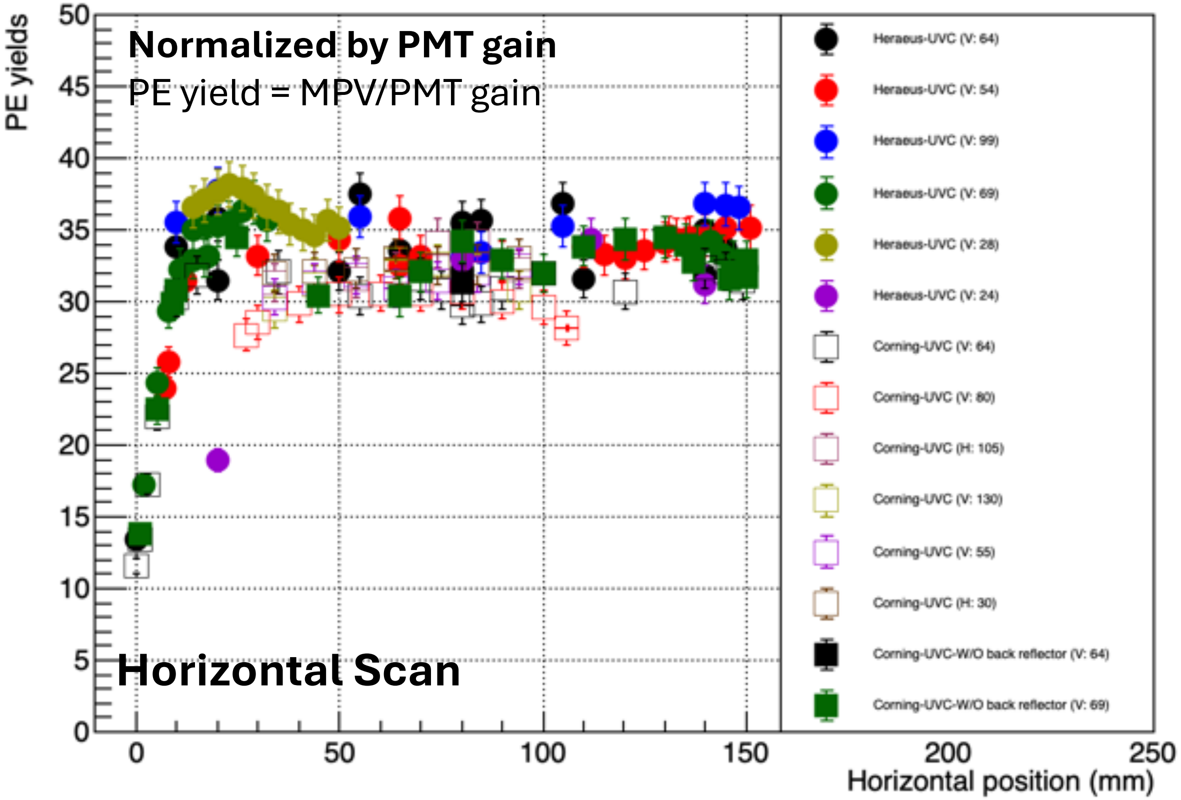




✓ **Performance without the back reflector panels seems better**

✓ **No change in the PE yield is observed due to the removable of the back reflector panels**

Ring 5 BF: PE yield



- Ring 5 BF was operated at 950 V
- PMT used: 539
- Q1 (@ 850 V) = 2.83 (±0.11)
- Gain (x 10^6): 3.5 (±0.1)
- Average PE yield is (70–150 mm);

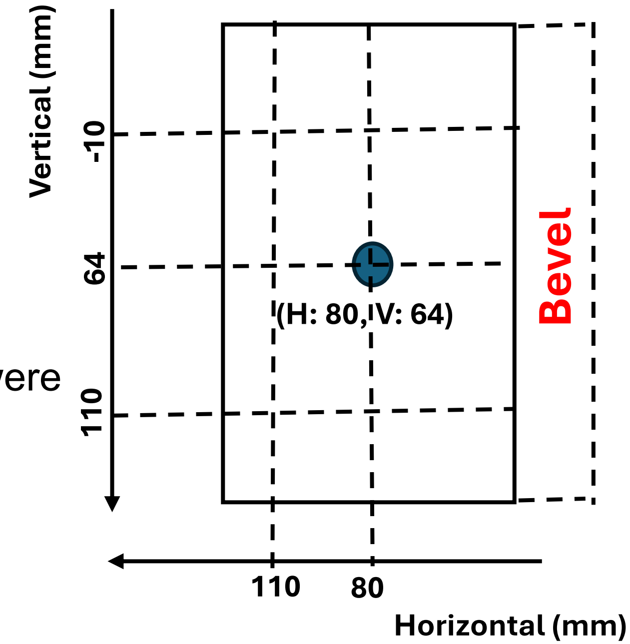
  32.8 ± 0.16 (gain norm.)

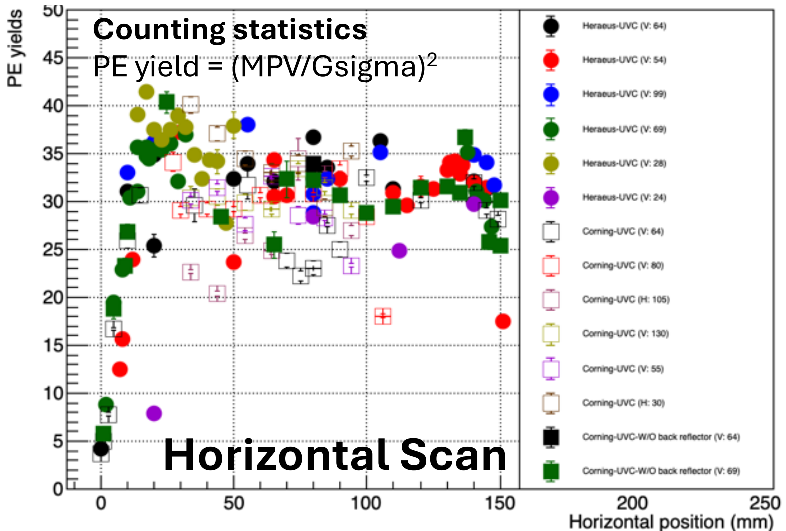
  29.84 ± 0.04 (counting stat.)
- The Ring5 BF Corning quartz tiles were polished from China

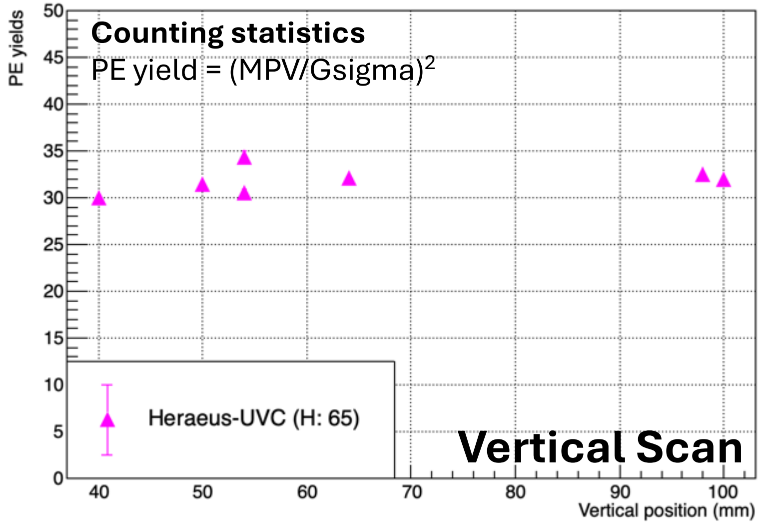
Ring 5 BF dimensions:

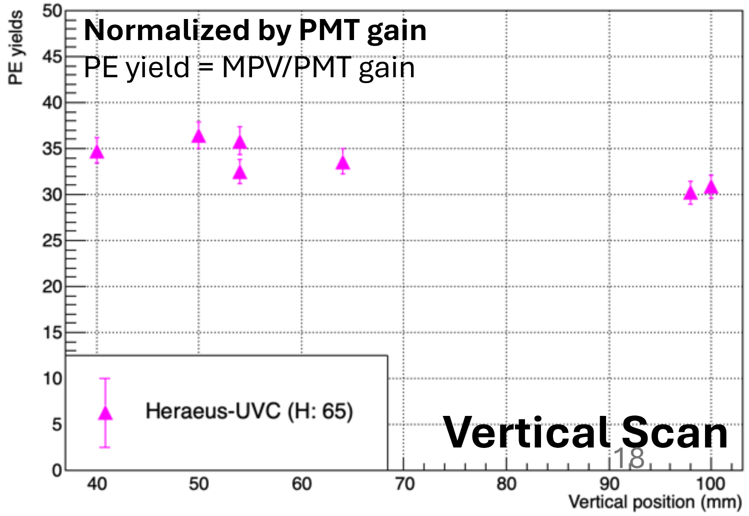
Horizontal : 80 mm
(W/O bevel)

Vertical : 140 mm

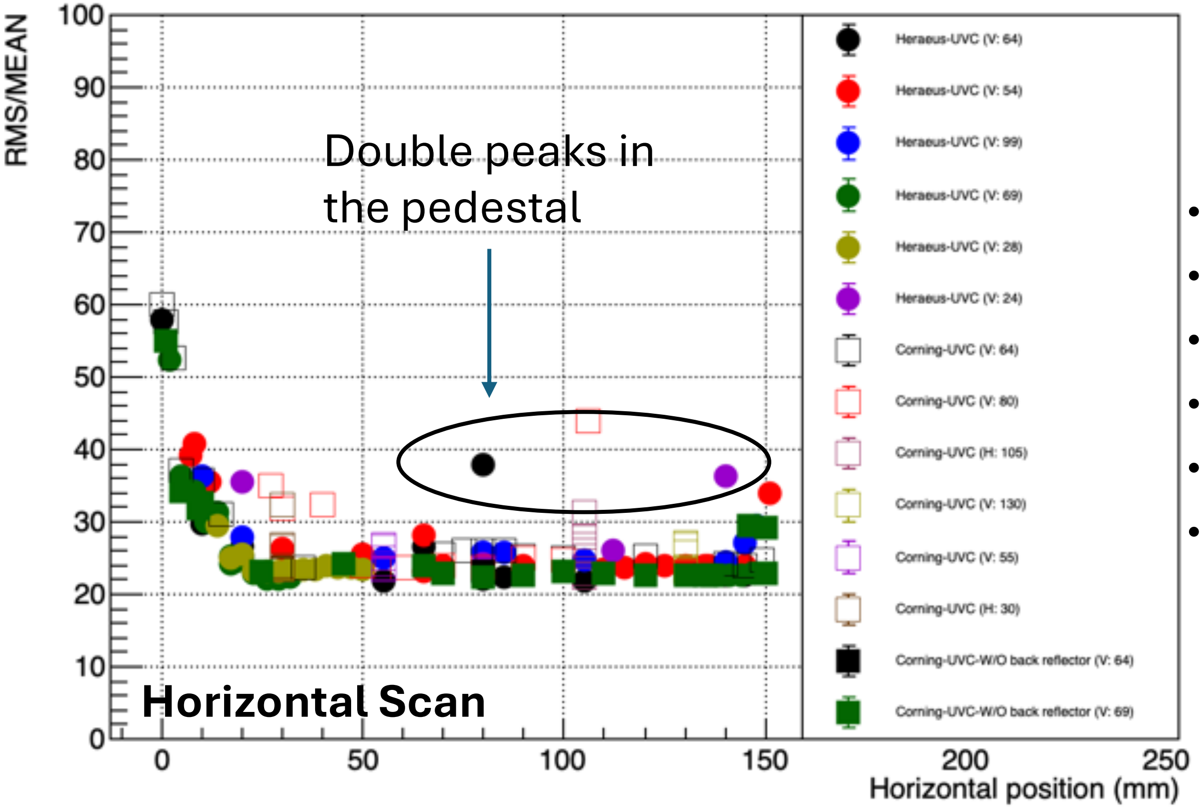








Ring 5 BF: Resolution & RMS/MEAN

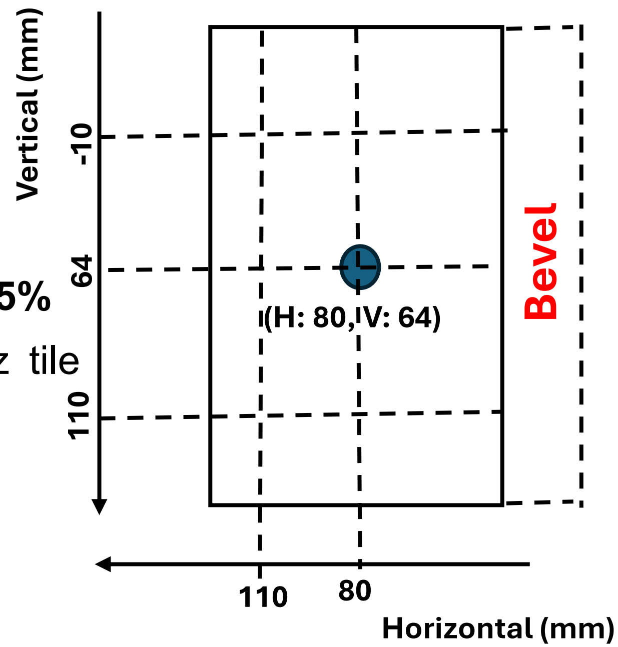


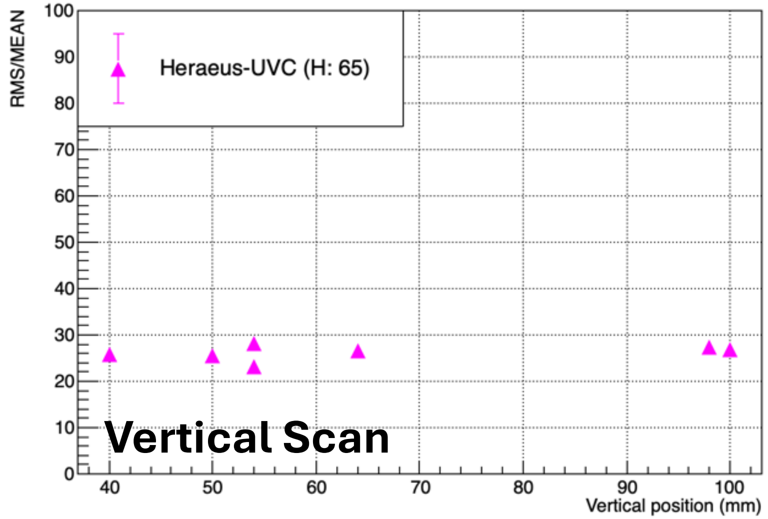
- Ring 5 BF was operated at 950 V
- PMT used: 539
- Q1 (@ 850 V) = 2.83 ($\pm$0.11)
- Gain (x 10^6): 3.5 ($\pm$0.1)
- Average **RMS/MEAN (70-150 mm) ~ 25%**
- Both the Heraeus and Corning quartz tile behave similarly

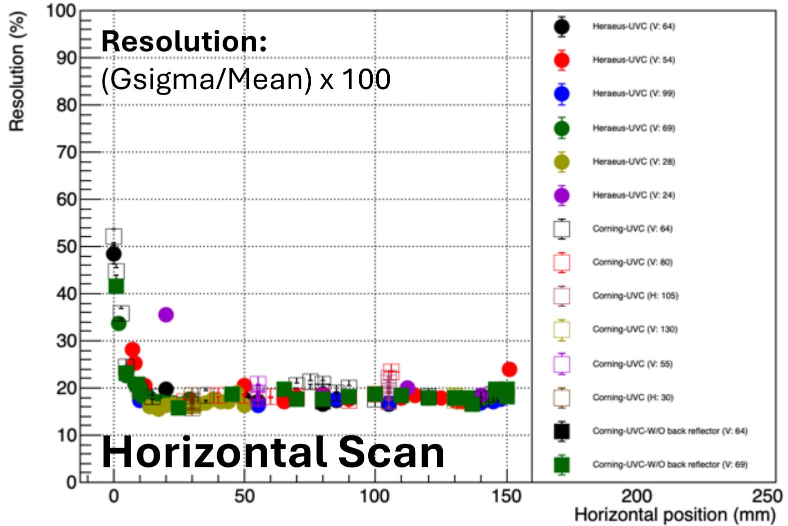
Ring 5 BF dimensions:

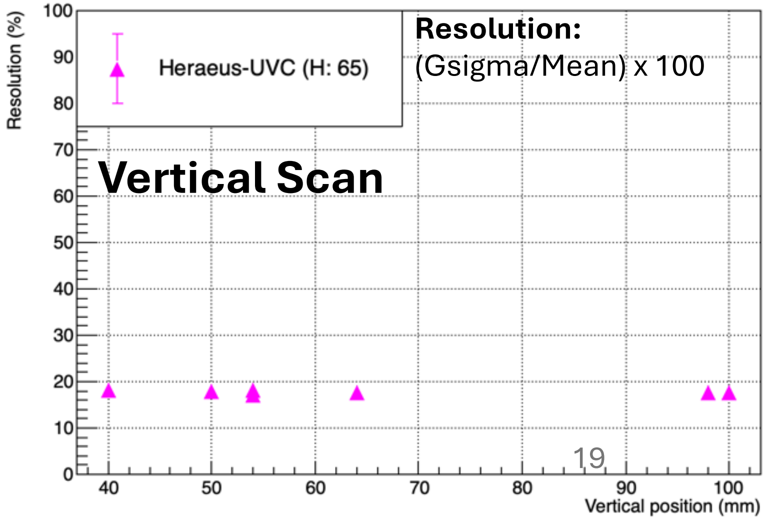
Horizontal : 80 mm
(W/O bevel)

Vertical : 140 mm

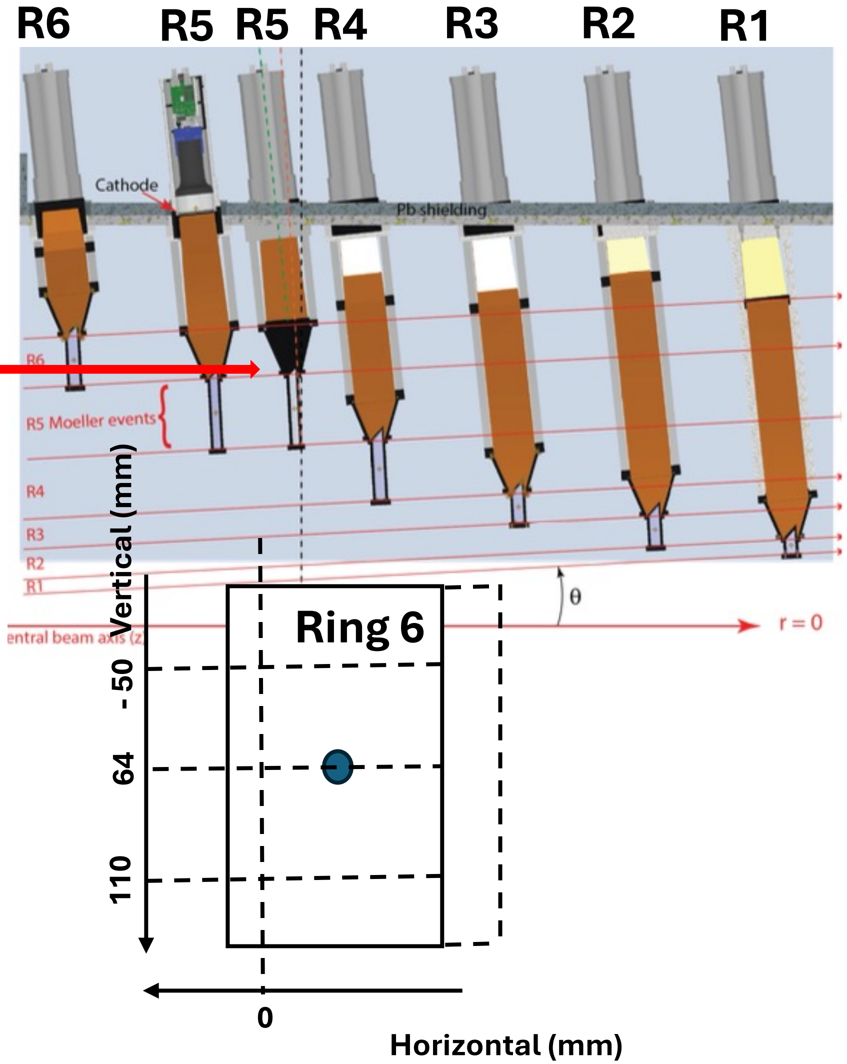


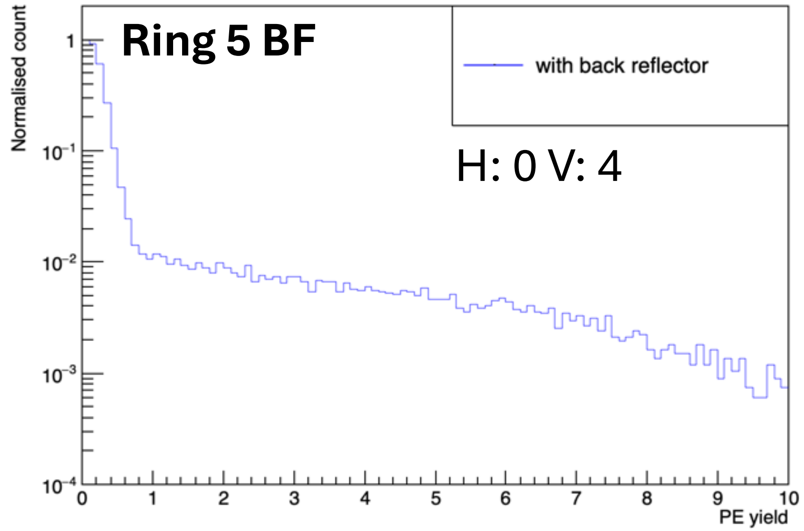


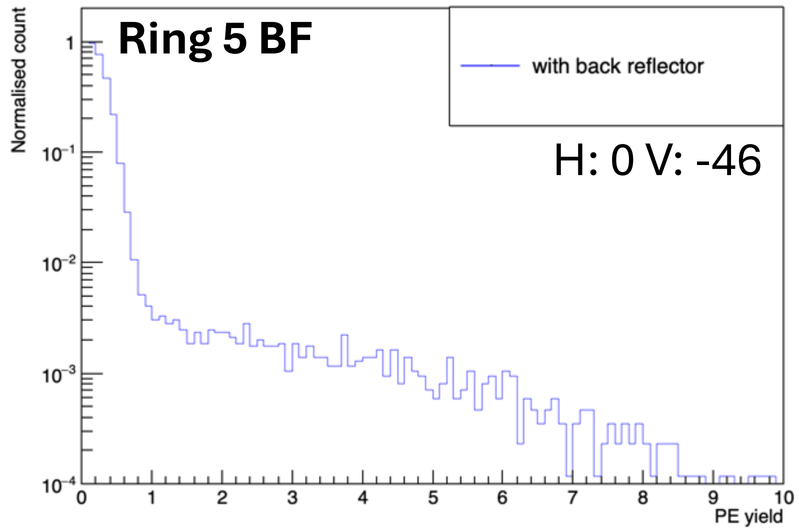


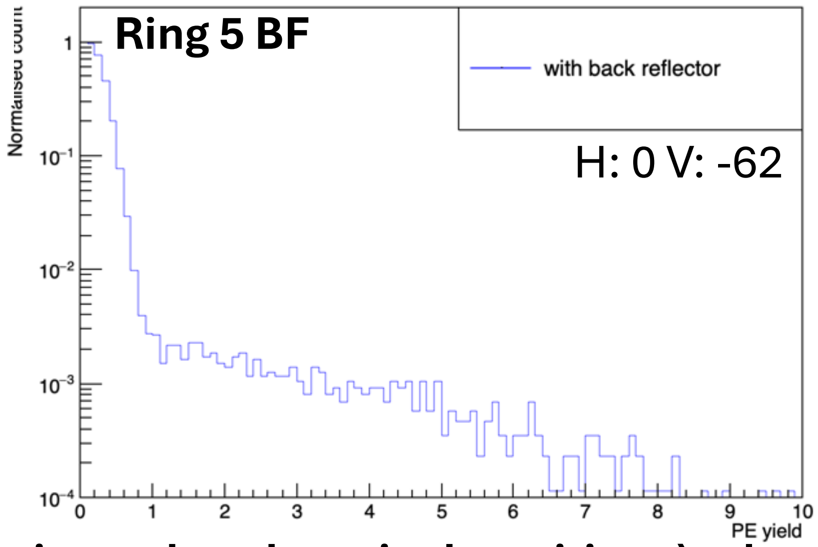


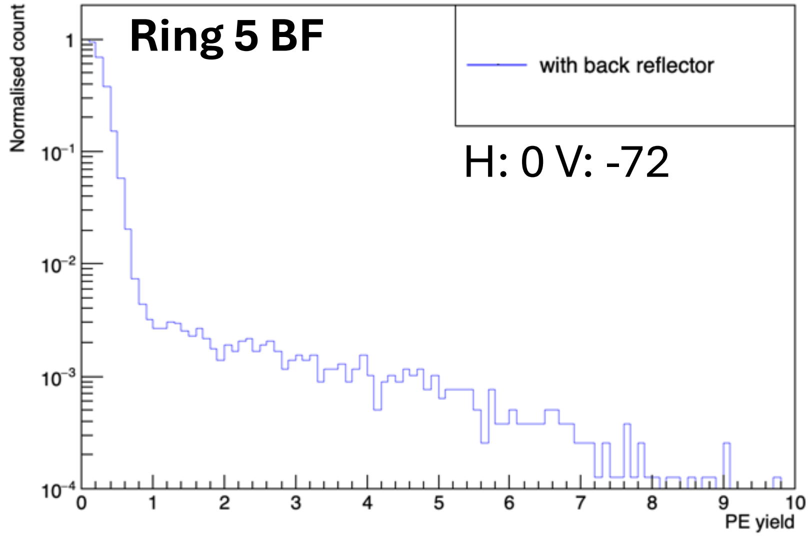
Ring 5 BF: Effect of back reflector panels





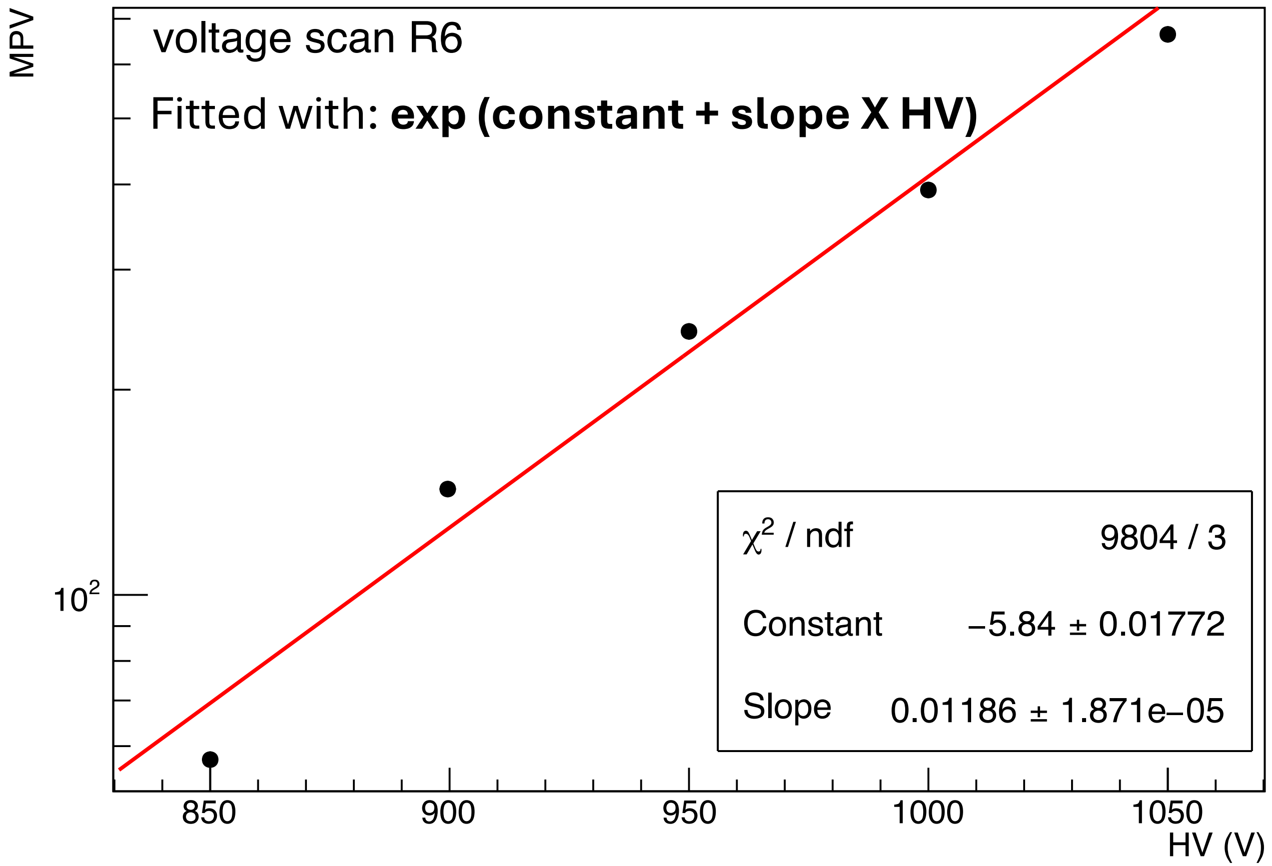






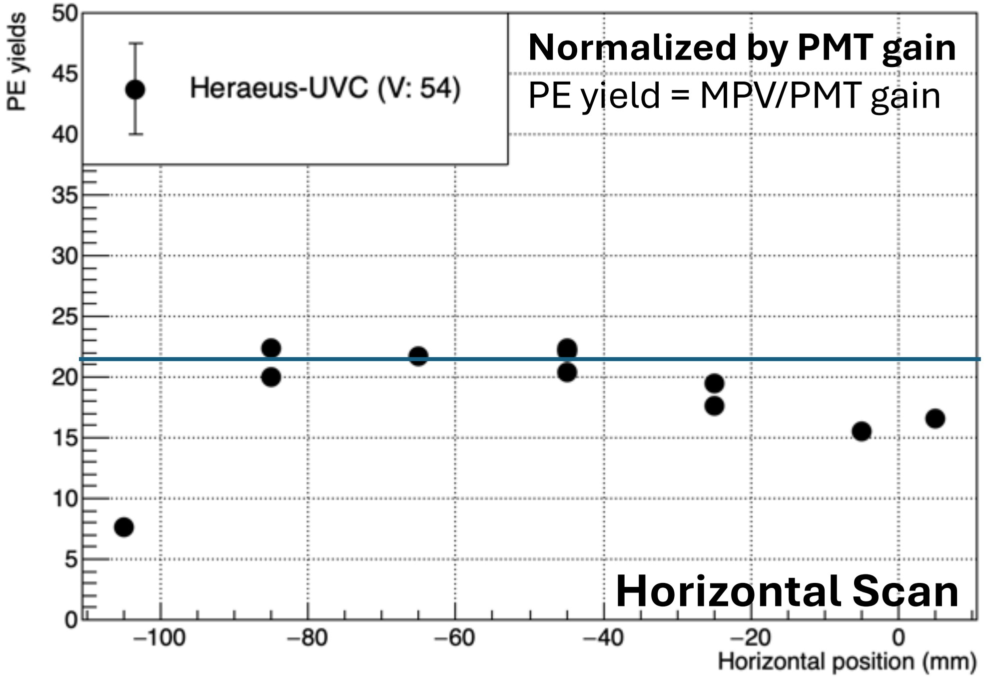
- **No consistent data (in terms of Horizontal and vertical positions) where beam is hitting R6 edge and going through the R5 BF lower light guide region after removing the back panels**
- **However, no exception is expected for Ring 5 as for all the other rings we do observe a low background level with out the back reflector panels**

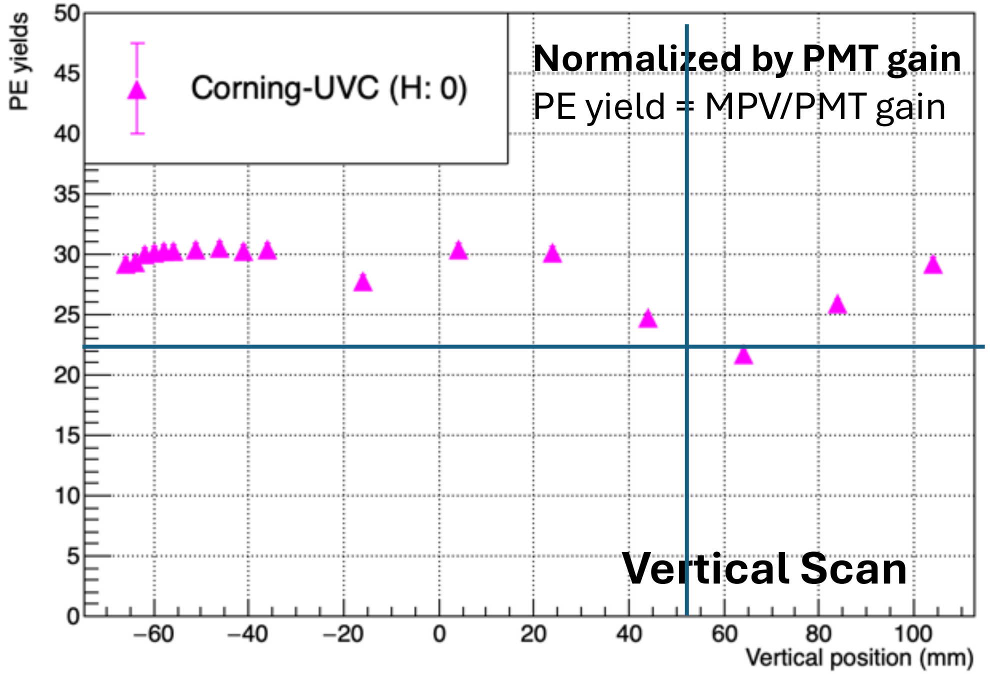
Ring 6: Scaling of the MPV due to change in HV

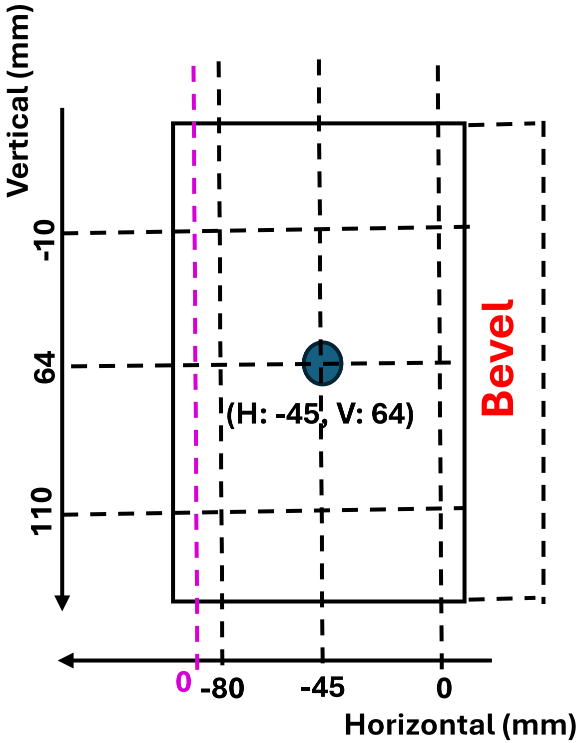


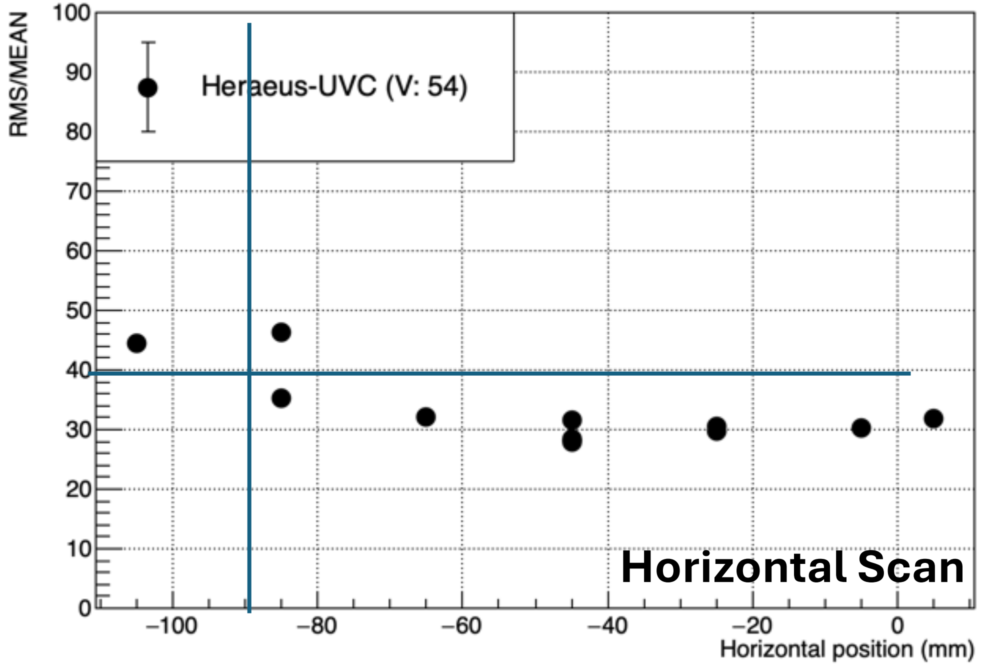
- **Ring 6 segment scan was performed with three different voltage settings (900 V, 950 V & 1000 V)**
- **The data for in-situ PMT calibration is available only for 900 V**
- **The MPV of the spectrum is scaled down to HV 900 V using the exponential parameterization**

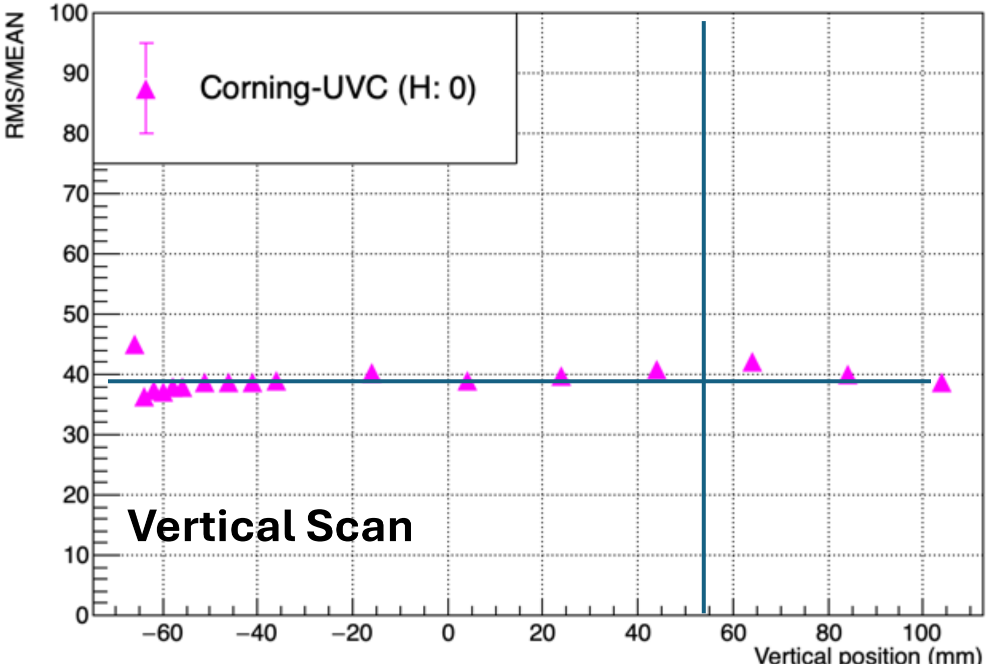
Ring 6: PE yield











Ring 6 dimensions:

Horizontal : 100 mm
(W/O bevel)

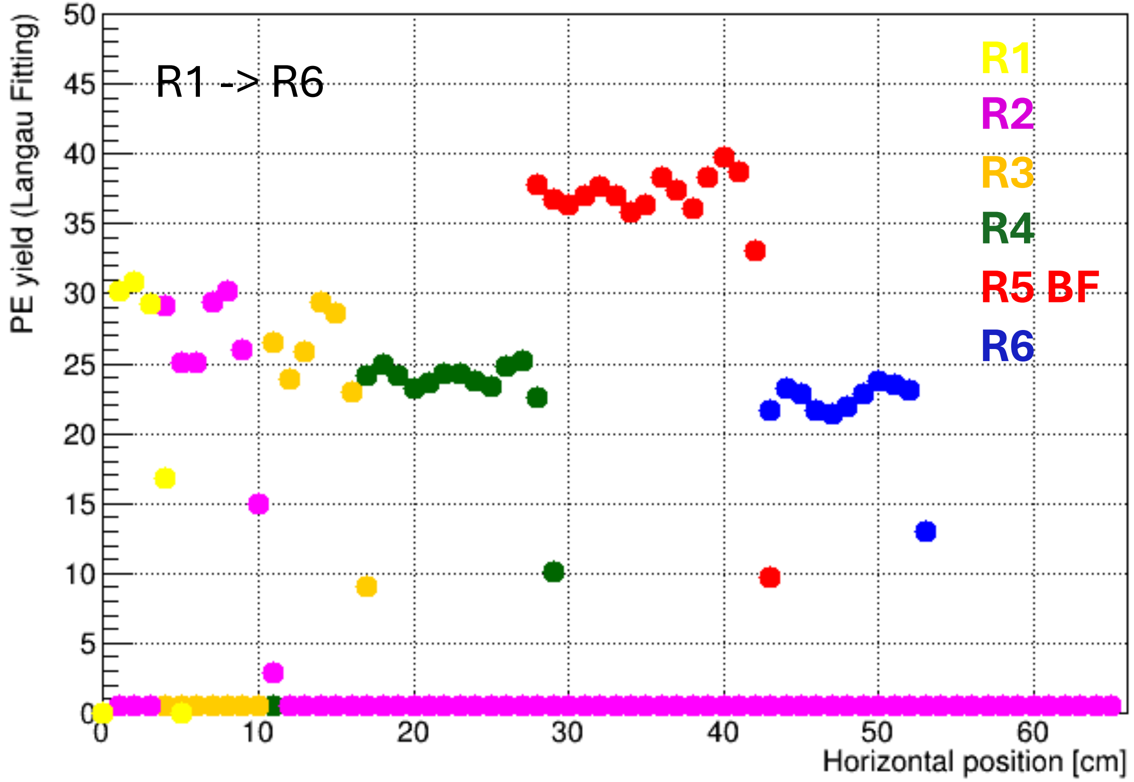
Vertical : 260 mm

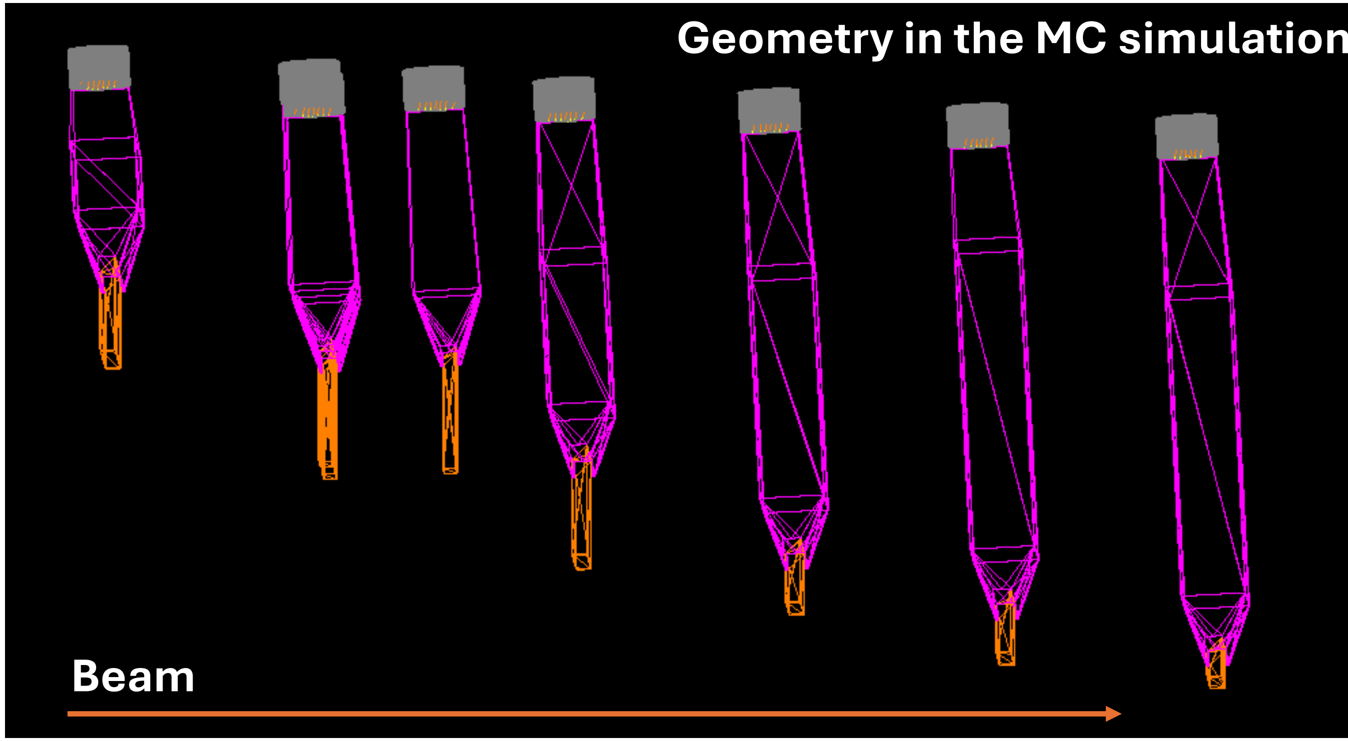
Average PE yield is
(20–100 mm);

20.74 ± 0.18 (gain norm.)

Average RMS/MEAN is
(20–100 mm) **~ 32%**

Monte Carlo simulation & comparison with the beam data



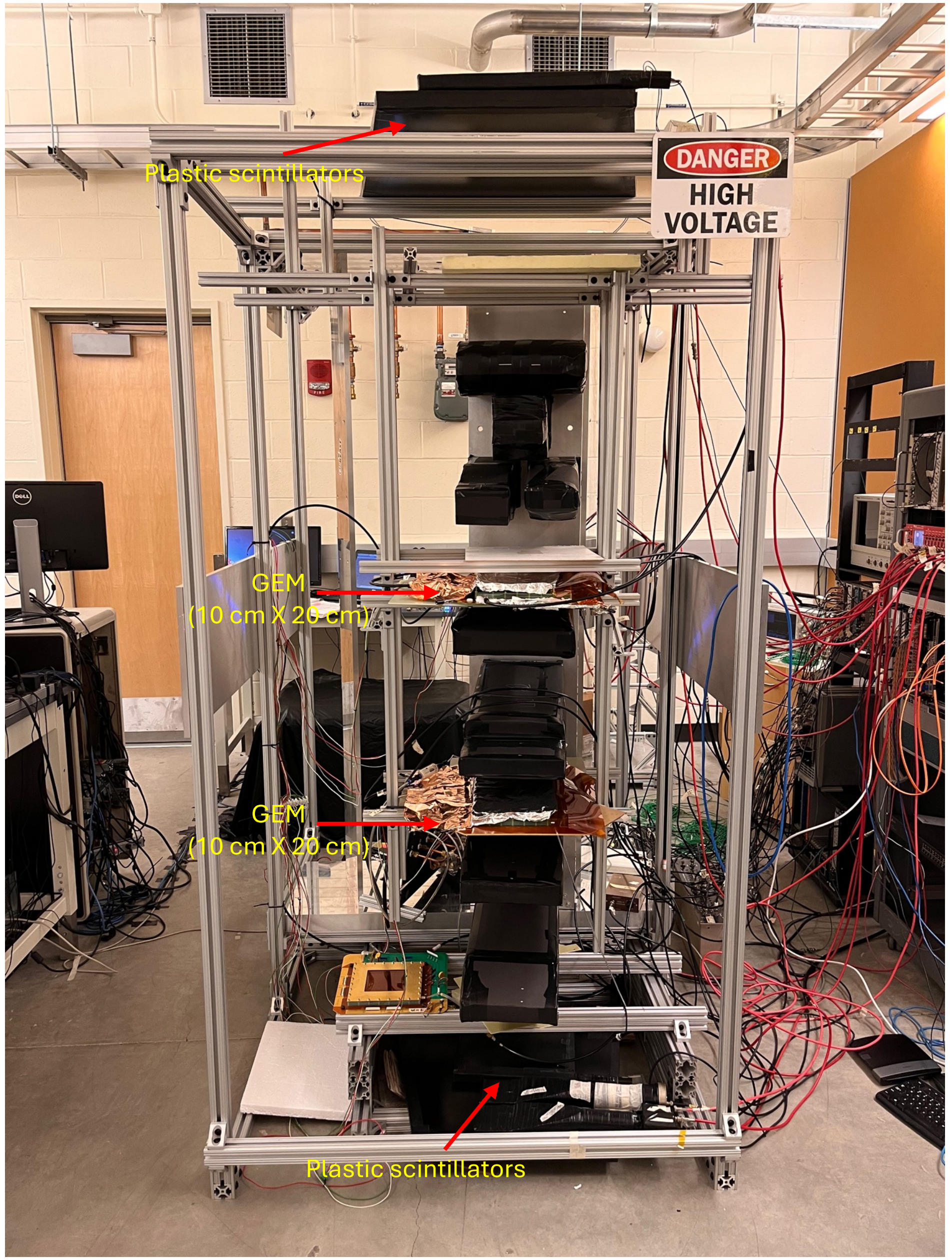


Rings	PE yield (beam data)	PE yield (MC sims)	RMS/MEAN (beam data)	RMS/MEAN (MC sims)
1	26.6 + 0.1	30.2 ± 0.1	~ 30 %	30 %
2	25.0 + 0.1	26.1 ± 0.1	~ 28 %	28 %
3	22.5 + 0.8	25.5 ± 0.1	~ 28 %	28 %
4	23.6 + 0.2	24.3 ± 0.1	~ 30 %	28 %
5 BF	32.8 + 0.2 (UVS)	37.0 ± 0.1 (UVC)	~ 25 % (UVS)	23 % (UVC)
6	20.7 + 0.2	21.5 ± 0.1	~ 32 %	23 %

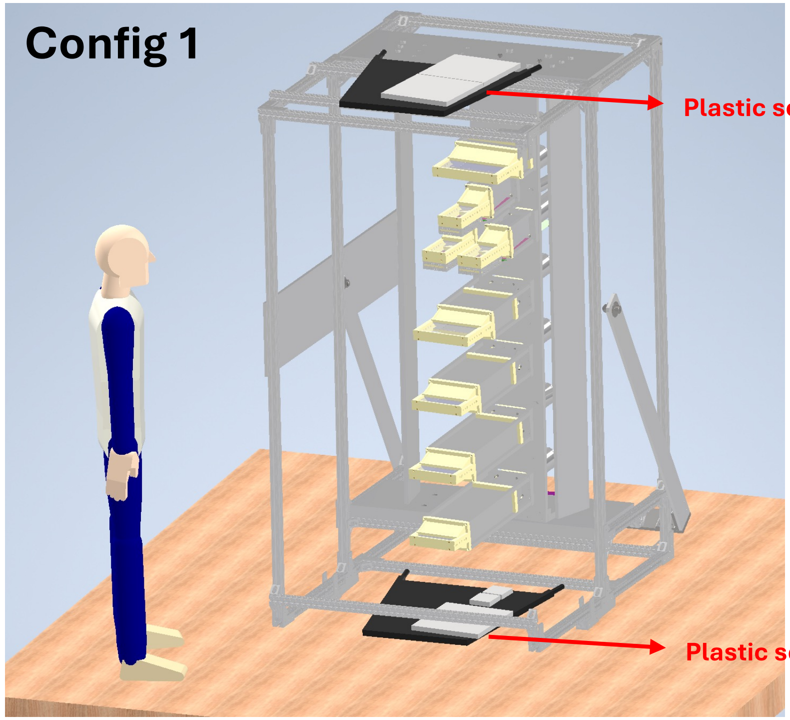
- **Good agreement between the MAINZ test beam data and the Monte-Carlo (~ 10 %)**
- **Work is ongoing to simulate the cosmic stand setup at UMass**

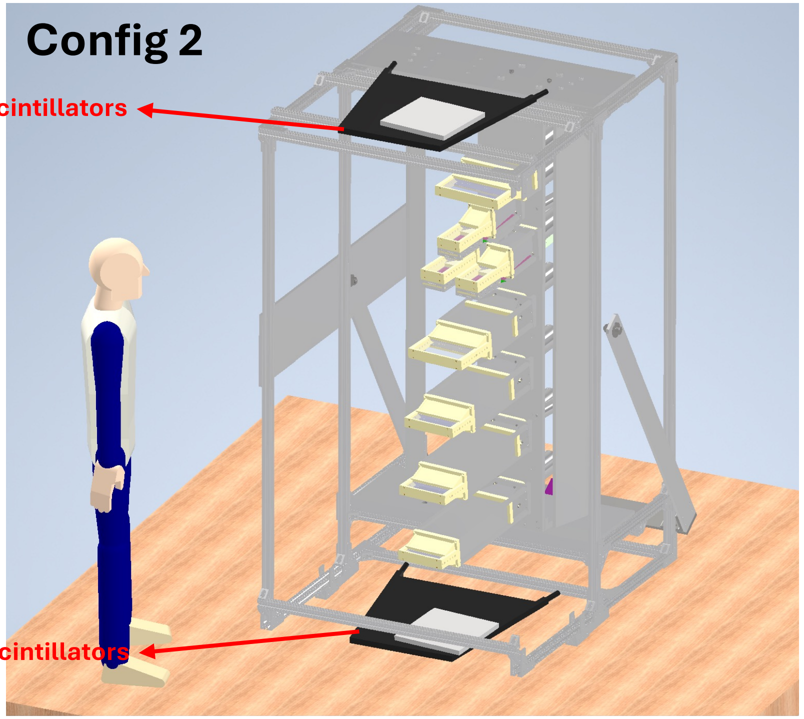
Work done by Jonathon Mott

Cosmic test stand at UMass



- **Different trigger scintillator configurations are being tested in the lab**
- **Data taking in ongoing using a CAEN QDC module**
- **The FADC based readout system will be used to compare the data taken using the QDC**
- **Benchmarking the performance of the individual detector rings with cosmic and its comparison with beam data and monte carlo**





Work done by Joelle Beck

Summary

- Both the quartz tiles Corning and Heraeus give us comparable PE yields for all the rings
- For all the detectors (R1 through R4 and R6) the RMS/MEAN value is found to be ~ 30 % & for R5 BF it is observed to be ~ 25 %
- The UVC light guide material gives us the desired performance for the modules Ring 1 through Ring 4 and Ring 6
- For the Ring 5 BF, the UVS light guide material gives us the required PE yield
- The removable of the back reflector panels help to reduce the background with out affecting the PE yields
- The MC simulation shows very good agreement (~ 10%) with the MAINZ test beam data
- Data taking is ongoing with the UMass cosmic stand with different trigger scintillator configurations

Thank you for your attention...

PMT gain calibrations