Cherenkov Threshold Detector Prototype Beam Test in H8 North Area

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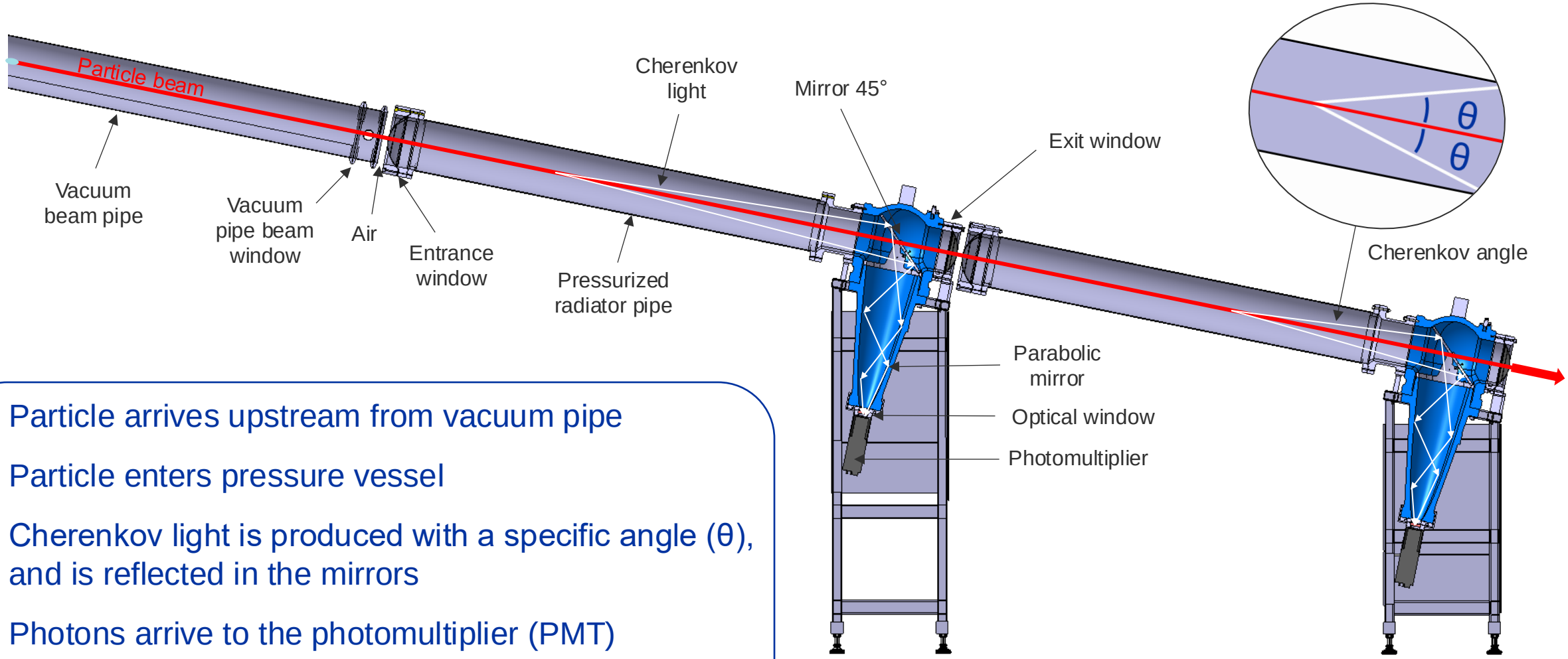
26th November 2024

Cherenkov Threshold Detector Layout



- Particle arrives upstream from vacuum pipe
- Particle enters pressure vessel
- Cherenkov light is produced with a specific angle (θ), and is reflected in the mirrors
- Photons arrive to the photomultiplier (PMT)
- Particle is detected

Motivation For New Design

XCET detectors were built in 1970s

Current mechanical design not compliant with unfired pressure vessel safety regulations

- no personnel access when P > 3.5 bar (g), maximum pressure of 15 bar (g)

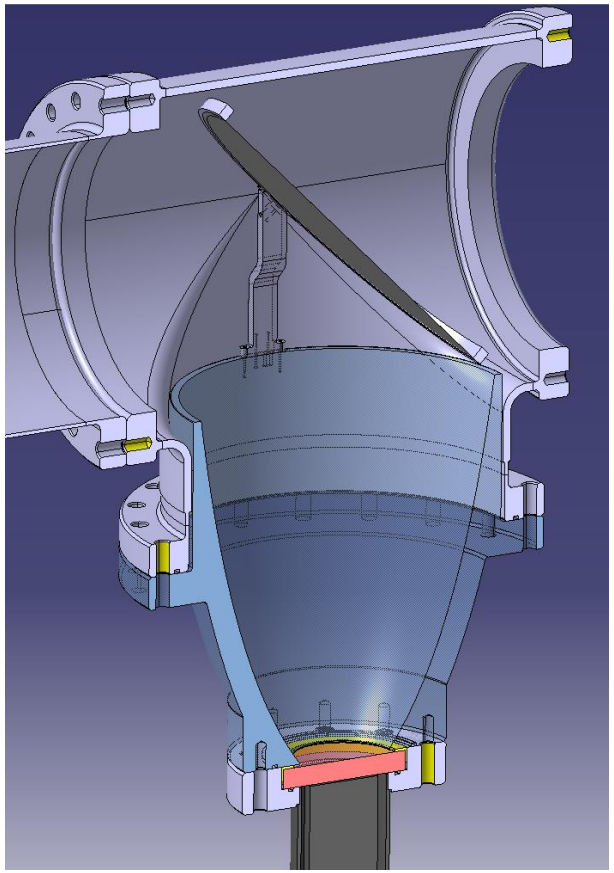
Mirror optics have degraded over time, decreasing detector's efficiency.

With a new mechanical design, opportunity to bring an improved design of the optics

Assembly of prototype in PPE158

New Mechanical Design

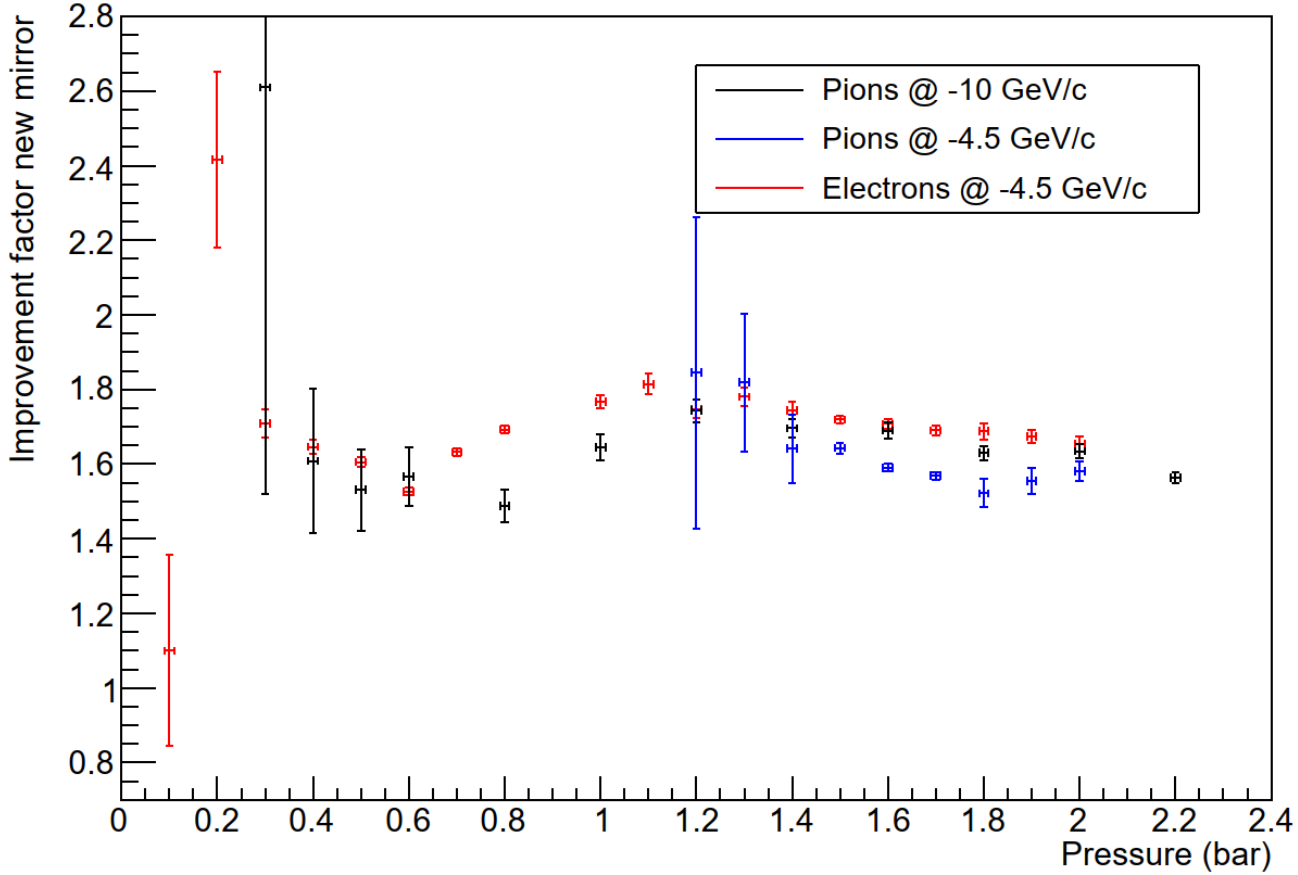
- The new XCET detector prototype has been designed, manufactured, inspected and tested according to the European standard EN-13445 (unfired pressure vessels)
- HSE has issued an SRF lifting access restrictions with new prototype
- Head was manufactured in EN-MME main workshop
- Parabolic mirror manufactured by Wielandts UPMT
- 45-degree mirror manufactured by BE-EA and EP-DT
- Other machined components by SY-STI main workshop

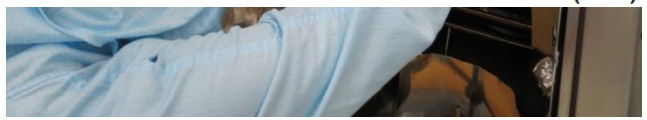


3D cross-section of XCET prototype

New 45-degree Mirror First Tested in East Area (2023)

- New 45-degree mirror tested in T10 beamline low pressure XCET in April 2023
- Mirror coated with enhanced UV reflective coating (Al+MgF2)
- Compare the new to the old mirror by taking the ratio of the charge observed before and after
  - **We consistently found 50-80% more light for the new mirror!**
- Same mirrors were used during the beam test of the October 2024 in H8 North Area

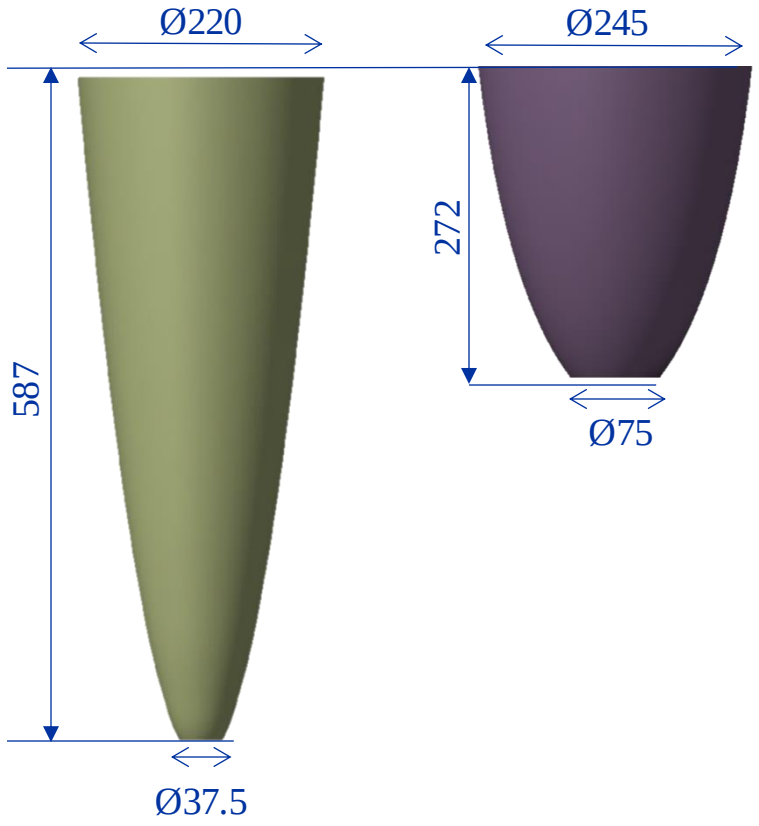




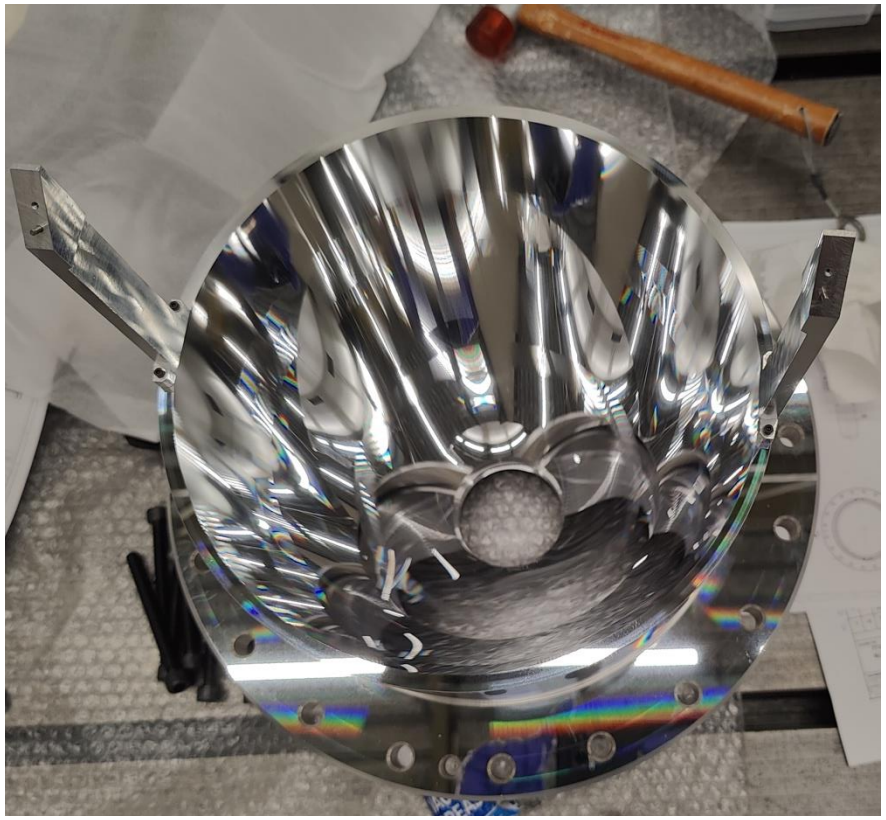
Beam Test to Assess New Parabolic Mirror Design

Original parabolic mirror

Parabolic mirror prototype



- New optical design to enhance the photon collection performance using a Compound Parabolic Concentrator (CPC) while minimizing dimensions to reduce cost and allow machinability.



Beam Test Program

Beam momenta: 180 GeV/c
Beam composition: 70% protons – 30% pions

- Main users in PPE158 in H8 beamline in North Area during week 41 (October 2024)
- Tested with CO2 and Helium from 0.05 bar to 15 bar

1. Tested as-built XCET version from NP02 with new 45-degree mirror
2. Tested prototype parabolic mirror and body with new 45-degree mirror
3. Tested prototype parabolic mirror and body with UV-enhanced 45-degree mirror

As-built XCET detector

Prototype XCET detector

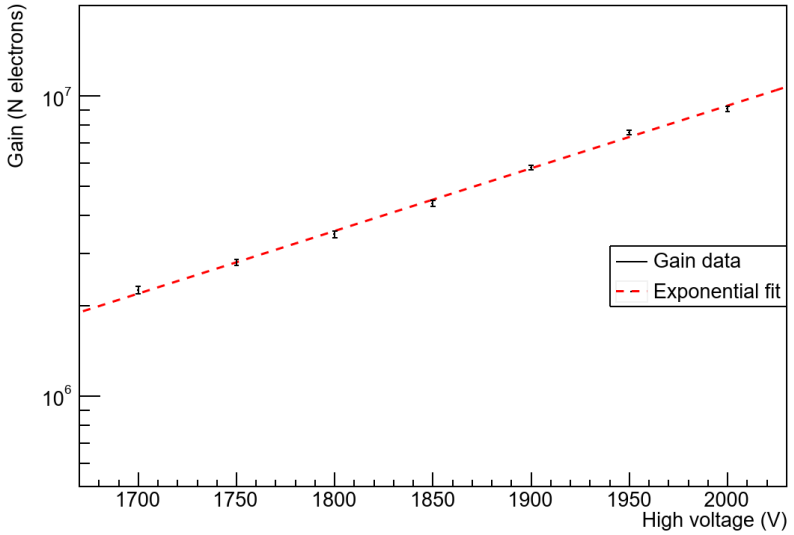
Data Acquisition

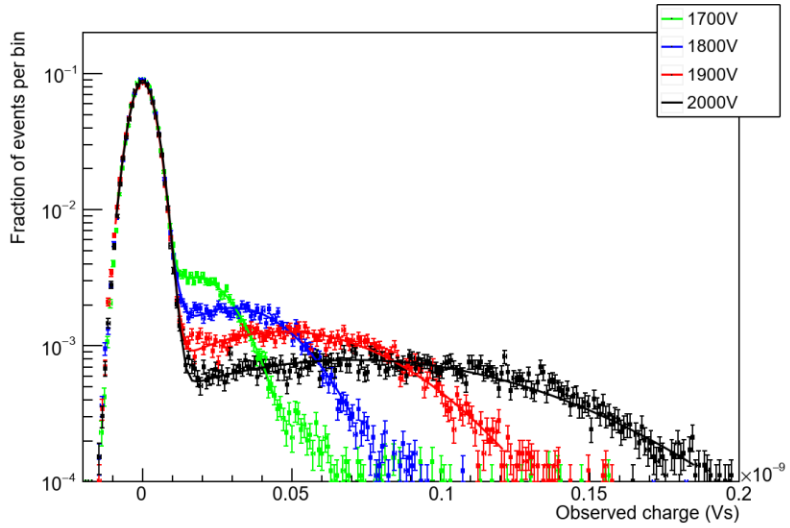
- Basic plan for testing: take baseline measurement with old parabolic mirror, replace, repeat
  - We measure the amount of light collected by the mirrors
  - Use for this the amount of charge collected by the PMT

- Main tool: Oscilloscope
  - Use signal from scintillators as trigger to verify particle goes all the way through (yellow)
  - Check PMT signal on scope (pink)
  - Integrate under the curve using scope (between lines)
  - Save resulting histogram, analyze offline

Crosschecks on PMT – Gain and Linearity

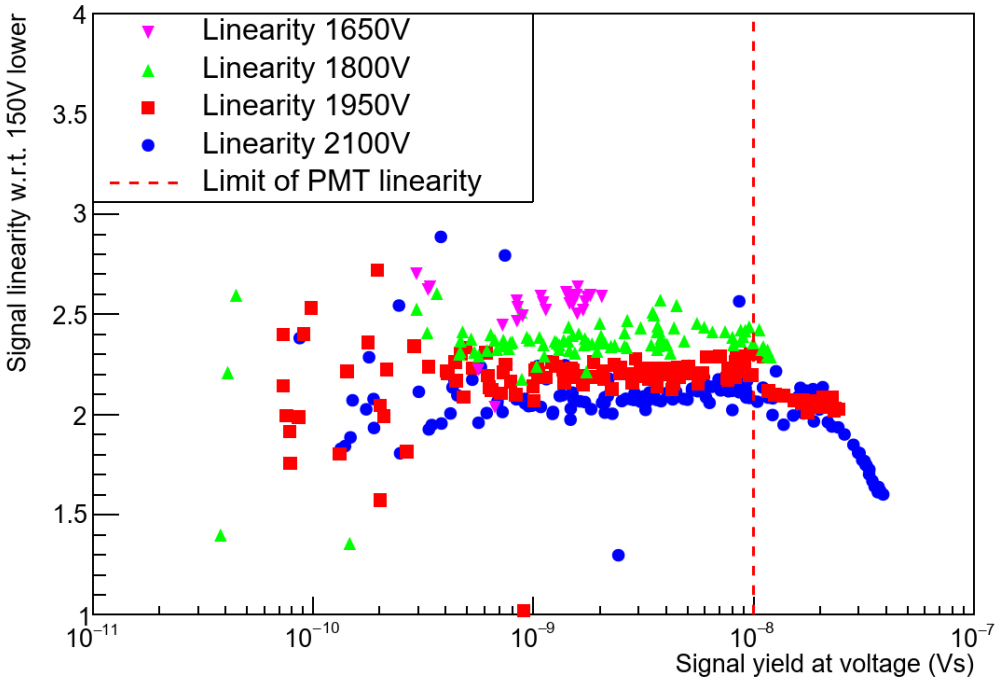
- PMT gain needed to calculate number of observed photons from signal
  - Measurements done by **M. Kirschbaum** – THANKS!
  - Measure PMT gain in lab using LED with around 9% single photons (derived from fits)
  - Observed signal for single photons at given HV unfolded to gain
  - Use as key input for analysis





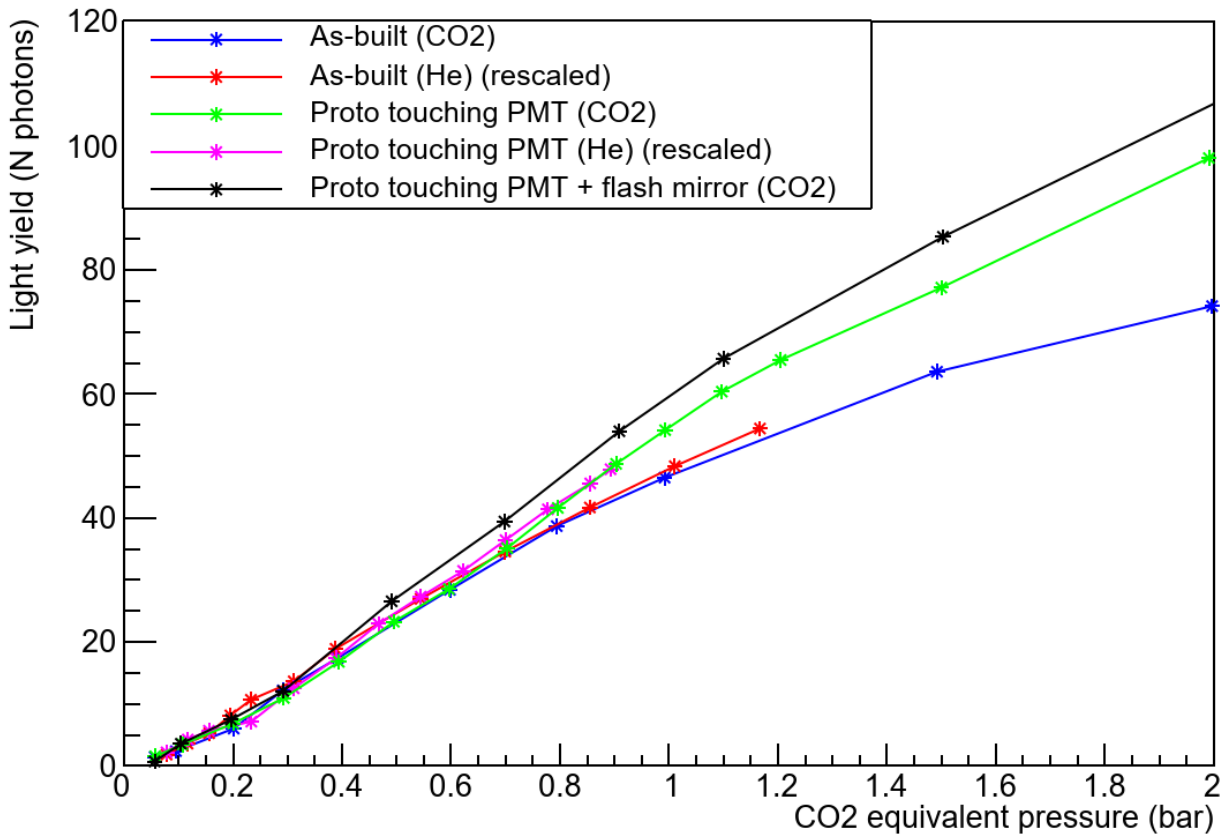
Crosschecks on PMT – Gain and Linearity

- Key requirement for signal: use regime where PMT is linear
  - Can cross-check using data from beamtest: compare different HV in same conditions
  - So, for example, take for identical pressure the signal at 2100V and 1950V, then make a scatter plot of all these for the high voltage, against the size of the signal
  - This number should be independent of the signal size for as long as the PMT is linear
  - Where it starts dropping off (approximately, red dotted line) is onset of non-linearity
  - Discard in signal analysis the points where the signal is >10nVs (~1.2 10^9 electrons)



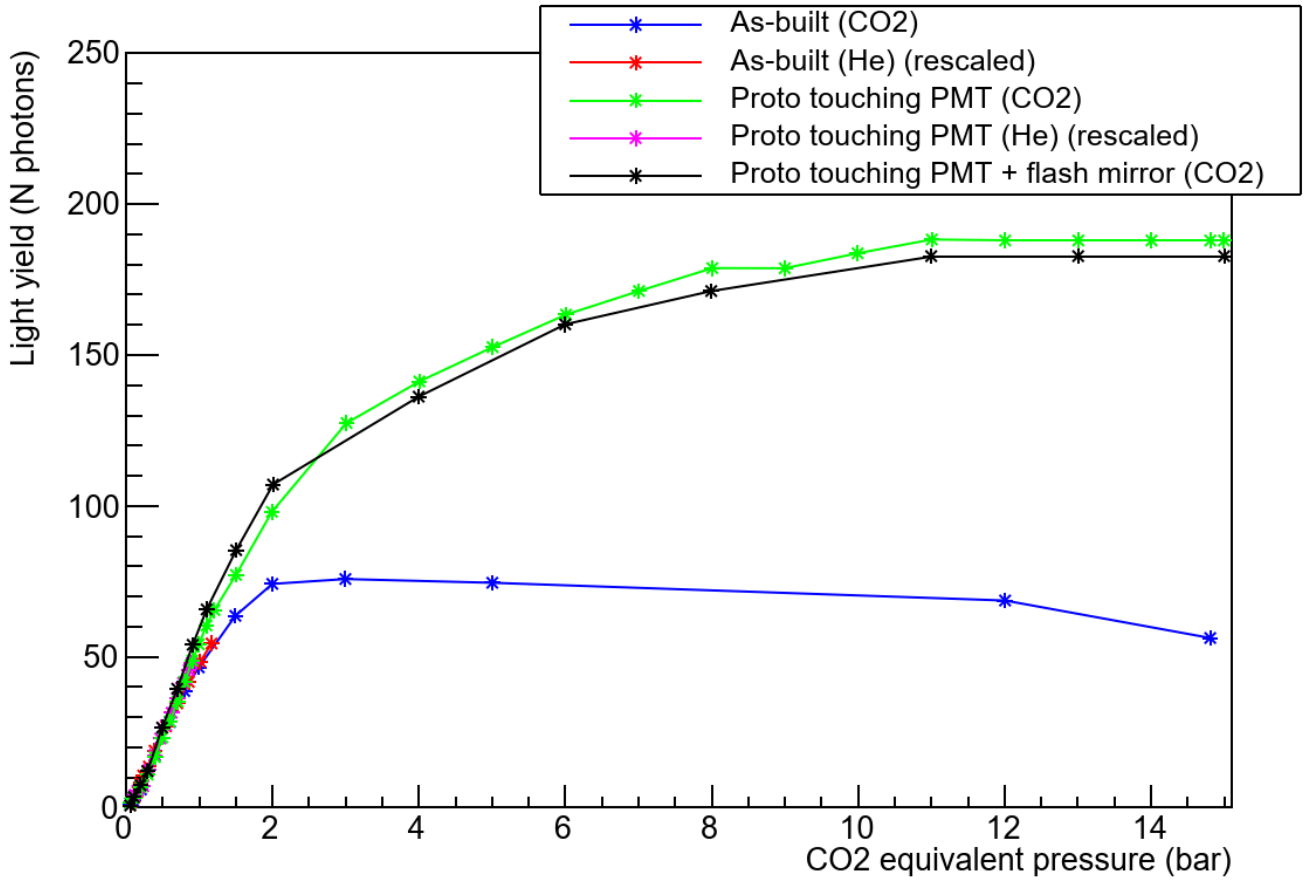
New Parabolic Mirror Improves Detector Efficiency at all Pressures

- Parabolic mirror prototype performed better than the original parabolic mirror for all pressure points.
- For the same 45-degree mirror, **parabolic mirror prototype increased photon collection from 20%- 50%** < 2 bar
- With UV-enhanced 45-degree mirror (flash mirror) light collection improved by another 10%-15%



New Parabolic Mirror Improves Detector Efficiency at all Pressures

- For the same 45-degree mirror, **parabolic mirror prototype increased photon collection an extra 50%** at 2 bar **to 320%** at 15 bar
- With large Cherenkov angles, light starts touching stainless steel radiator tube, low UV reflectivity, light is absorbed (kink in curve).
- Old parabolic mirror has maximum light collection at 2 bar, old design was not intended to capture large Cherenkov angles

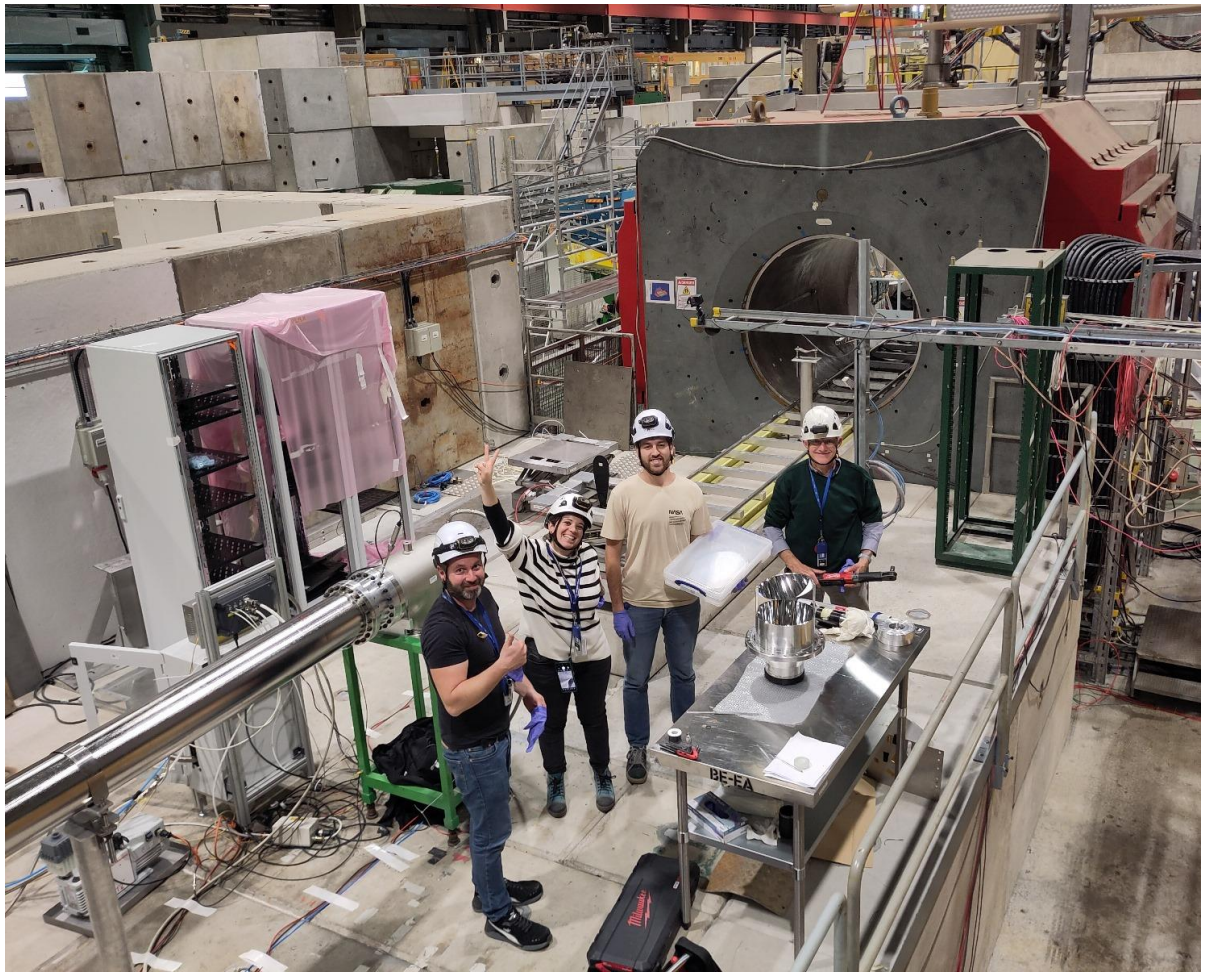


Conclusions

- Extremely successful beam test program performing all tests desired.
- With the **new 45-degree mirror**, **XCET efficiency increases by 50%-80%** wrt to as-buil/old mirrors.
- Adding the **new parabolic mirror**, **photon collection increases an extra 20-50%** below 2 bar **and up to 320%** at maximum pressure of 15 bar.
- Using the UV-enhanced 45-degree mirror **(flash coating) adds a 10%-15%** photon collection wrt to the EB-PVD mirror below 2 bar.
- Significant insights of the XCET operations were discovered leading to potential improvement for a prototype v2 if needed.
- Expertise in the design and manufacturing of each component has been successfully developed.
- Full debriefing of beam test coming tomorrow. Potential publication to be sent by end of the year.

Thank you!

- All people attending the talk today!
- The teams that have helped us make this happen
  - To all BE-EA teams involved! ☺
  - SY-BI S. Deschamps, W. Devauchelle, I. Ortega Ruiz, J. Tan, M. Kirschbaum
  - EP-DT T. Schneider, M. van Stenis
  - EN-MME E. Rigutto team
  - SY-STI P. Broussart team



THANK YOU!!!