Characterisation of Cherenkov detectors for the MOLLER experiment

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Introduction & overview

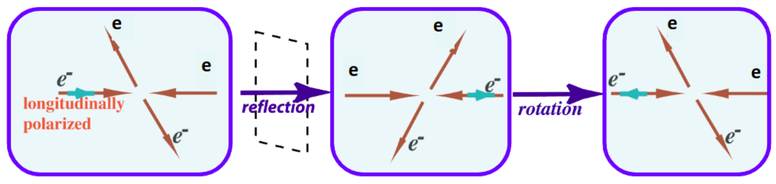
- **Measurement Of a Lepton Lepton Electroweak Reaction (MOLLER) is a future experiment at Jefferson Lab, Virginia, USA to measure the weak mixing angle with unprecedented precession.**
- **The weak mixing angle can be expressed in terms of the A_{PV} as;**

  $A_{PV} \propto Q_W^e = 1 - 4\sin^2\theta_w$ (at tree level), θ_w is the weak mixing angle
- **MOLLER projection with electron beam of 11 GeV:**

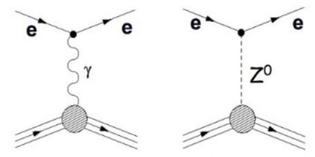
  A_{PV} ~ 35 × 10^{-9} or 35 ppb (parts per billion)

  δA_{PV} ~ ± 0.7 ppb (2.4% precision)

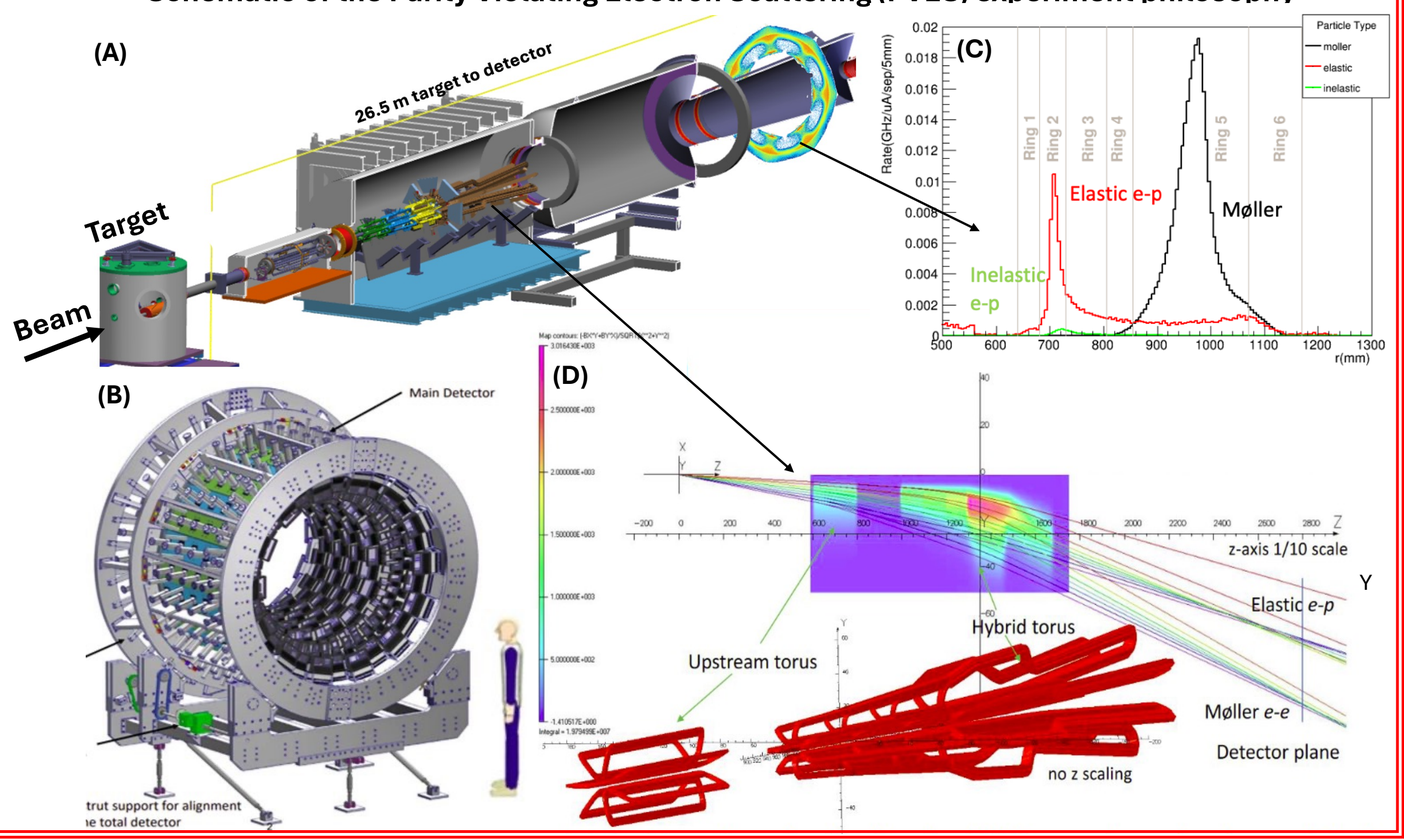
  2.4% precession on $Q_W^e \Rightarrow$ 0.1 % on $\sin^2\theta_w$
- **Radiation hard thin quartz Cherenkov radiators will be used as the main detector to intercept the scattered electrons**
  - ➢ Fused silica (quartz) is chosen as the Cherenkov radiator
    - ➢ Negligible scintillation & Radiation hard
    - ➢ highly linear and relatively large active area
  - ➢ Standard Photo Multiplier Tubes (PMT) will be used to readout the signal



$$A_{pv} = \frac{\sigma_R - \sigma_L}{\sigma_R + \sigma_L}$$



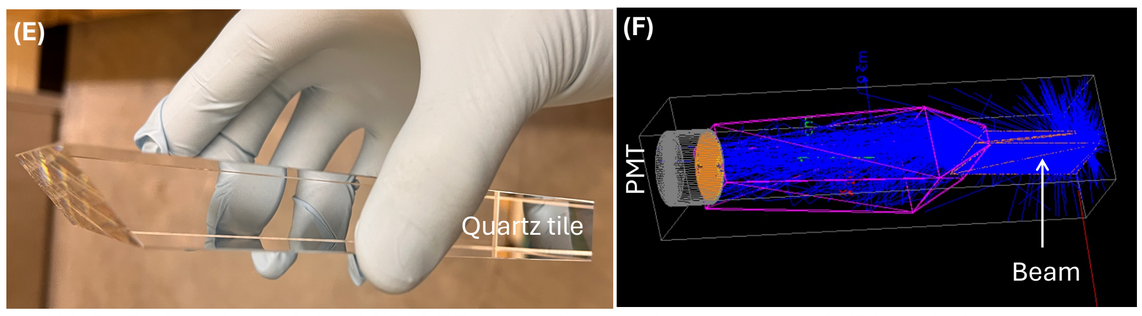
Schematic of the Parity Violating Electron Scattering (PVES) experiment philosophy



R&D of Main Integrating Detector

Design

- 224 thin detector modules & 6 radial rings
- Foreseen average electron rate is ~ 50 kHz/mm^2 but it can for the peak Møller events reach up to ~ 1 MHz/mm^2
  - ✓ 28 azimuthal channels per radial ring (84 azimuthal channels in Møller Ring 5)
- The anticipated peak dose over the experimental lifetime is 120 Mrad/5x5 mm^2 for Ring 2 and 45 Mrad/5x5 mm^2 for Ring 5



(A) CAD drawing of the MOLLER experimental apparatus & (B) Main integrating detector rings (C & D) Spectrometer principle & scattered particle profile at the main detector (E) Quartz tile (Ring 5) (F) Monte Carlo simulation of the ring

R&D stages

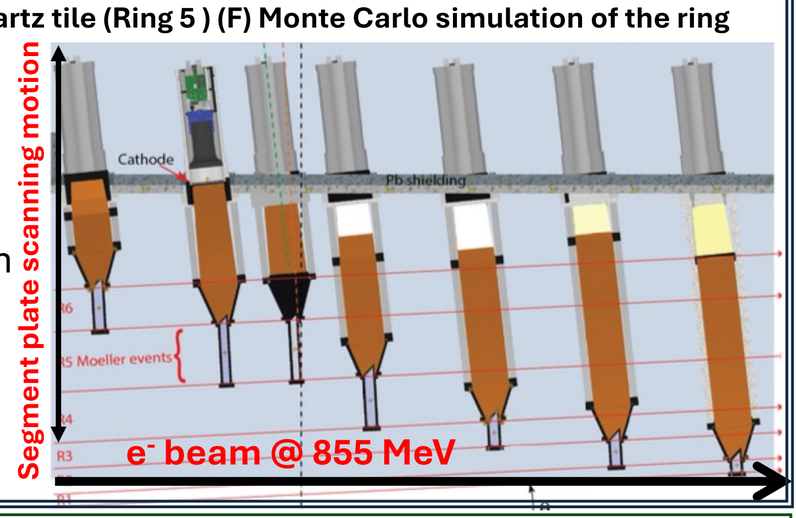
- Beam test with e$^-$ beam of 855 MeV of the Cherenkov detector prototypes at MAMI, Germany
  - Testing of different quartz tile & light-guide materials
- Irradiation test of the detector components (e.g. 3D printed parts, electronics, light tight materials etc.)
- Testing of the detector prototypes with cosmic muons to benchmark the performance with the electron beam : **Final QA test before commissioning**

Dimensions (length x breadth x height):

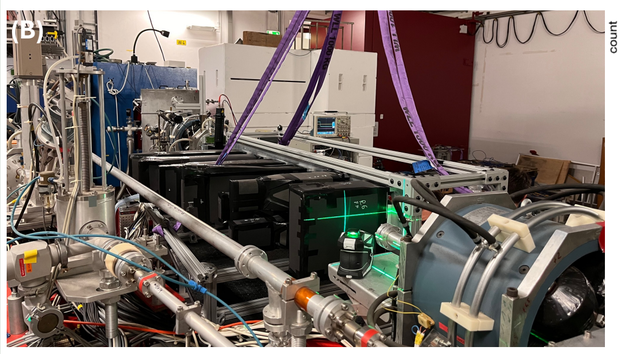
Ring1 : 169 mm x 30 mm x 20 mm

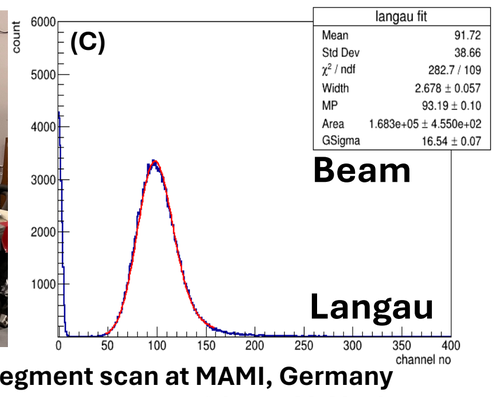
Ring5 : 80 mm x 140 mm x 17 mm

Ring6 : 260 mm x 100 mm x 20 mm

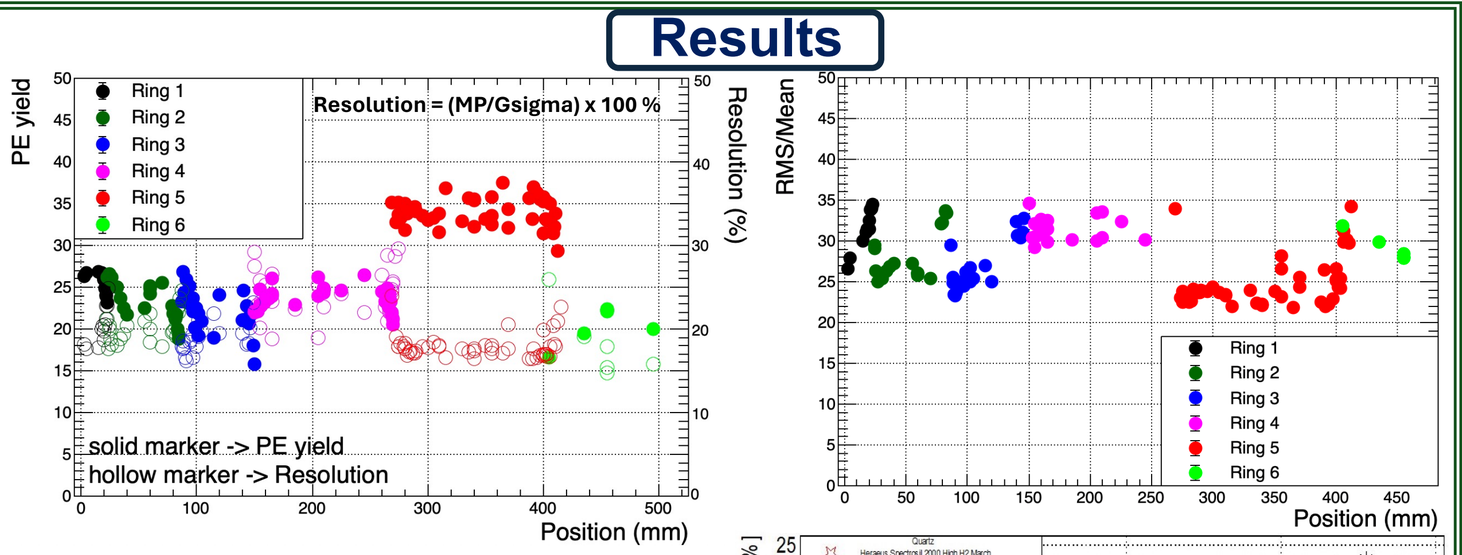


Results





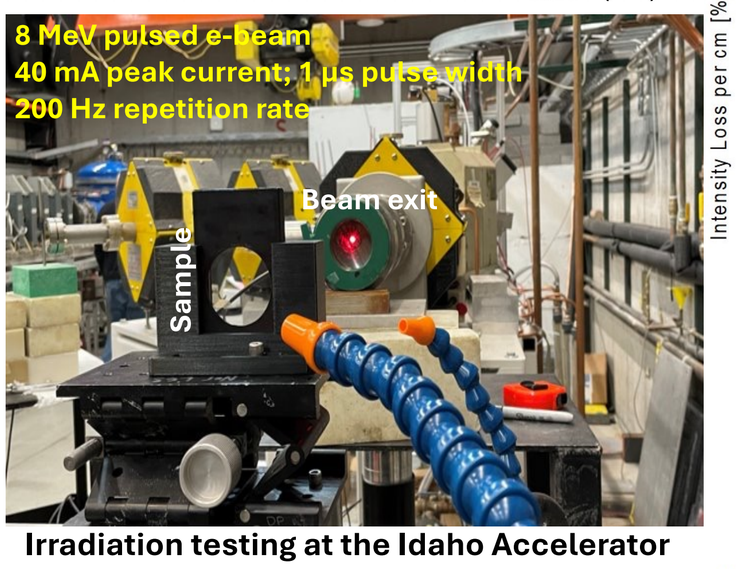
(A) Ring 1, 5 & 6 detector prototypes (B) Segment scan at MAMI, Germany
(C) Typical pulse height distribution from the ring 5 prototype with 855 MeV e-beam



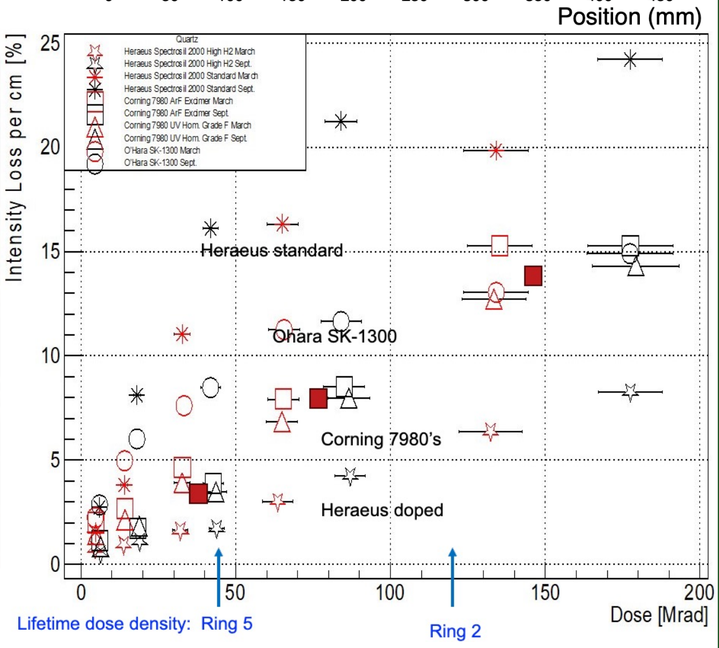
Summary & Acknowledgement

- ✓ **All the prototypes behave as expected in terms of the PE yields and RMS/MEAN values at the 855 MeV e$^-$ beam test**
- ✓ **MC simulation agrees relatively well (~10%) with the beam data**
- ✓ **Radiation tests have been carried out to study the tolerances**
- ✓ **Design & critical detector prototyping for the main integrating detector in counting and integrating mode is complete**

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)		~ 25 % (UVS)	
6	20.7 + 0.2	21.5 ± 0.1	~ 32 %	23 %



Irradiation testing at the Idaho Accelerator Center at Idaho State University campus



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References: (1) MOLLER Technical Design Report (2) The MOLLER Experiment (arXiv: 1411.4088)