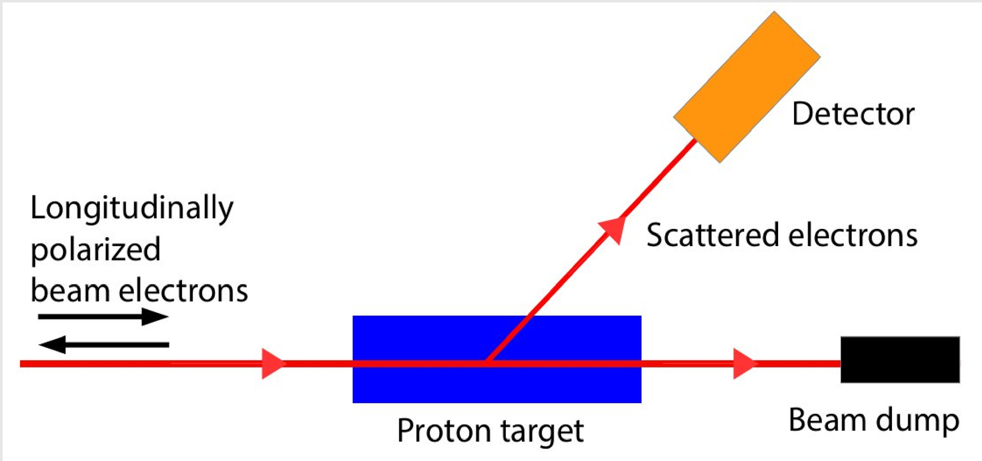
Design of the Target cell for the P2 Experiment at MESA

EINN 2025

Goal of the experiment

- Aims for a high precision determination of the weak mixing angle $\sin^2\theta_w$
- To a precision of 0.16% ($\Delta\sin^2\theta_w / \sin^2\theta_w$)
- The expected parity-violating asymmetry $\langle A^{raw}\rangle_{sig}$ = - 39.94 ppb
- Measurement time of 10000 hour
- A liquid hydrogen high-power target needs to be designed and constructed
- The target must support luminosity of $\mathscr{L} = 2.38 \times 10^{39}$ $cm^{-2}s^{-1}$



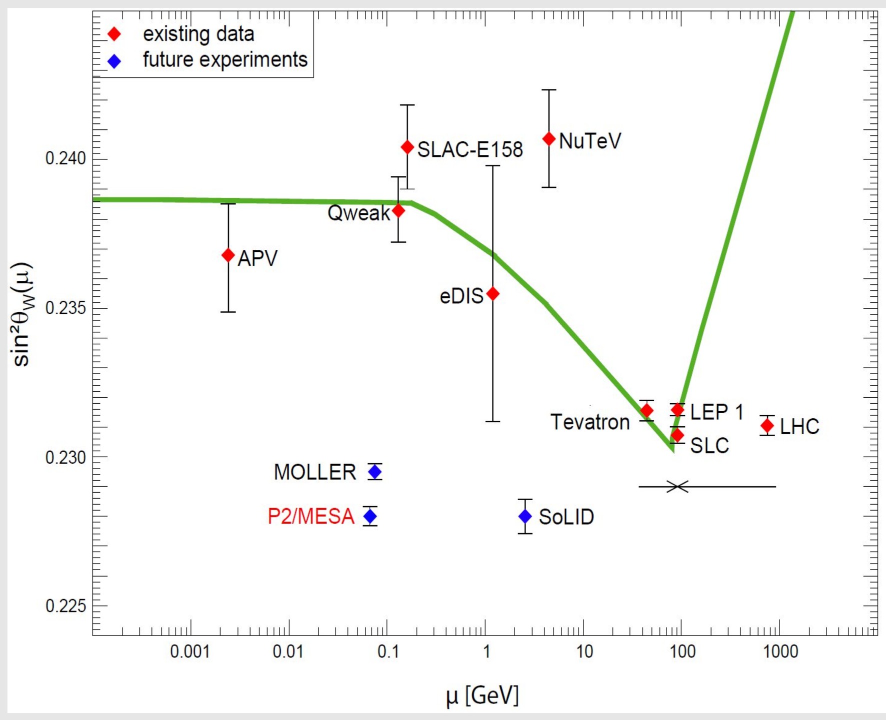
Experimental Method

- Determine the weak mixing angle $\sin^2\theta_w$ by measuring A^{PV}
- It is an asymmetry in the cross section which is defined by:

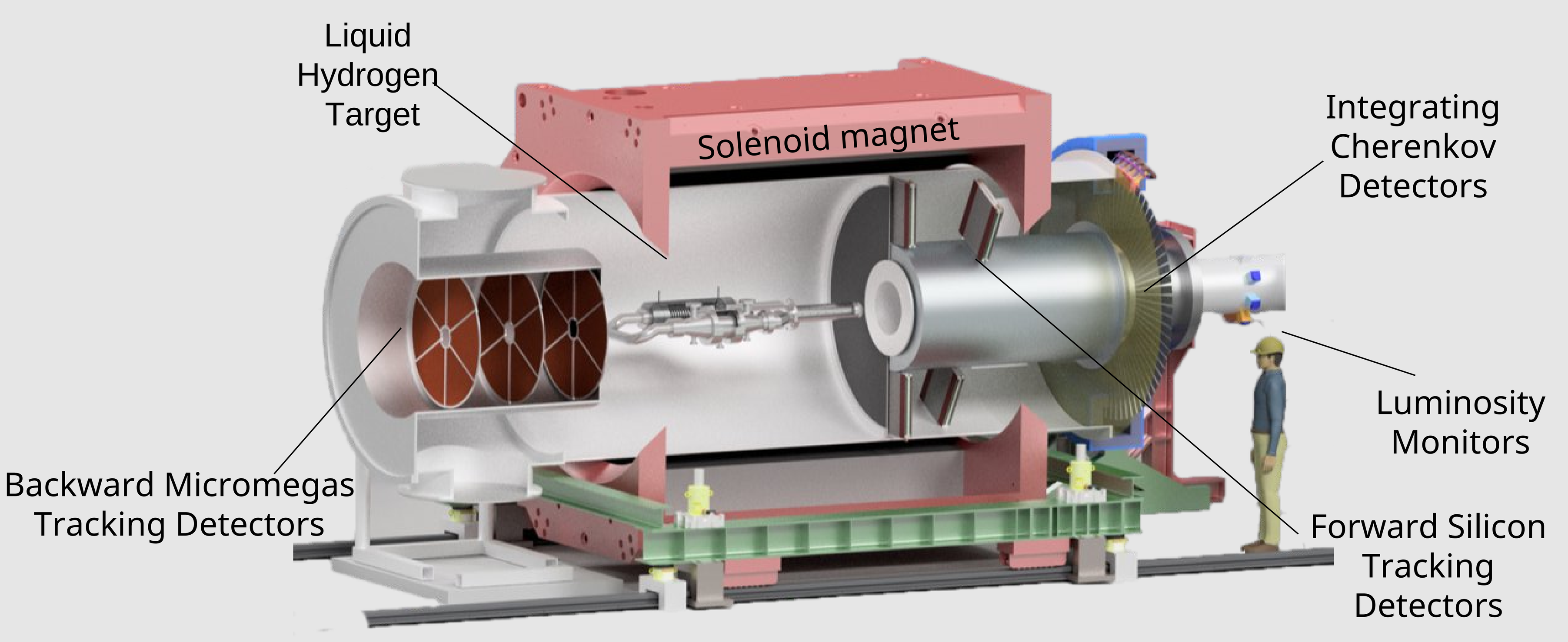
$$A^{PV} = \frac{d\sigma^{+}_{ep} - d\sigma^{-}_{ep}}{d\sigma^{+}_{ep} + d\sigma^{-}_{ep}}$$

- The measured asymmetry is $\langle A^{raw}\rangle_{sig} = \frac{N^{+}-N^{-}}{N^{+}+N^{-}}$ = P. $\langle A^{PV}\rangle_{sig} + A^{false}$

- Beam Energy E_{beam} = 155 MeV
- Beam Current I_{beam} = 150 µA



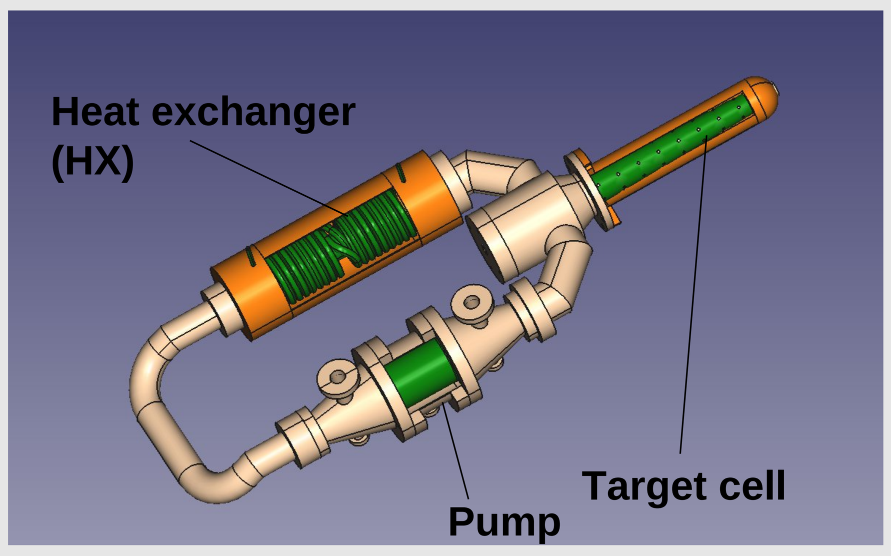
Experimental setup at MESA



Target Loop

Main components of the target loop :

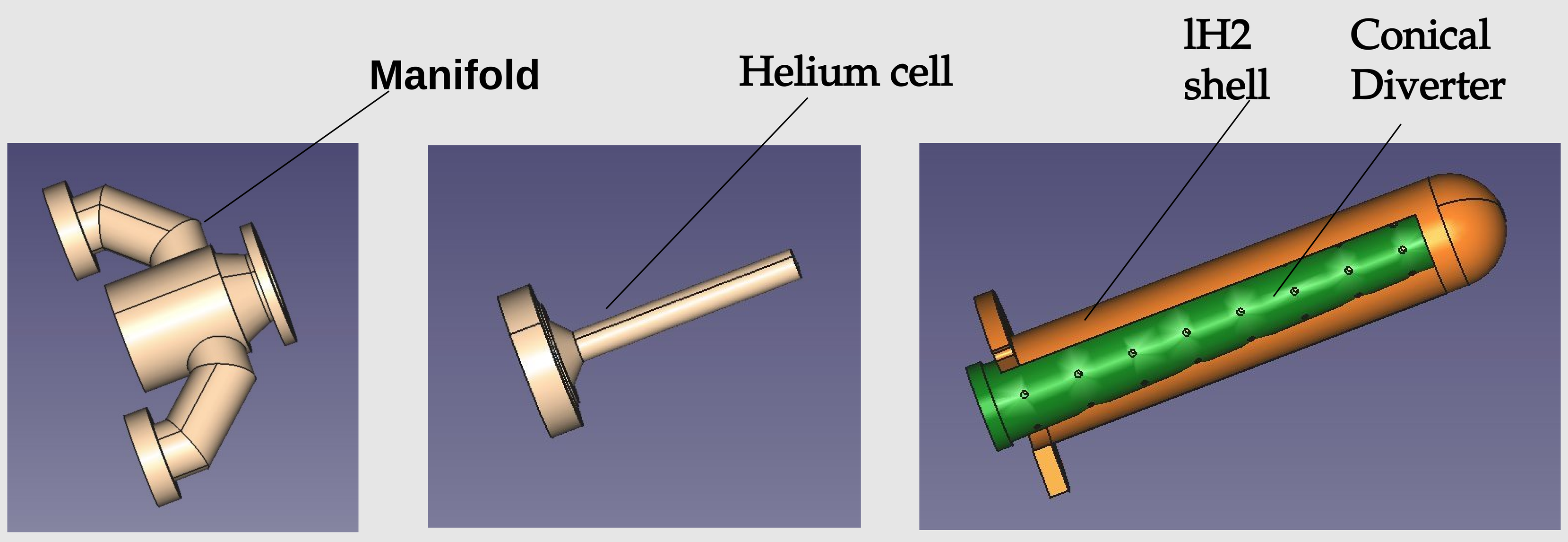
- $\ell H2$ centrifugal pump : drive the $\ell H2$ flow
- Heat Exchanger (HX) : liquefy the hydrogen gas and provides the necessary cooling power to remove the total heatload
- High Power Heater (HPH) : regulate the loop temperature
- Target cell : The cell contains the liquid hydrogen where the electron beam interacts



The Target Cell

- The Target cell is based on the G0 experiment target design.
- Material and Length: 60 cm long unpolarized liquid hydrogen
- Cell Diameter : 75 mm
- Cell wall thickness : 0.25 mm
- Upstream window (Beam entrance) :
  Radius = 19.05 mm
  Thickness = 0.25 mm which is divided
  1. Between vacuum and helium cell 0.125 mm thickness (not curved)
  2. Between helium cell and lH2 0.125 mm (curved with radius of 75 mm)
- Downstream window (Beam exit) :
  Radius = hemispherical window with radius 75 mm
  Thickness = 0.25 mm thick
- The incident 150 µA electron beam deposits approximately 3135 W in the lH2 target cell materials.

- The total 4 kW heat load requires equal cooling power from the MESA refrigerator.
- The overall reduction in density caused by beam heating must be less than 2%.
- Time-dependent fluctuations (boiling noise) over the time period of electron helicity reversal (~1 kHz) must be less than 10 ppm.



Simulation Results

Conical flow diverter

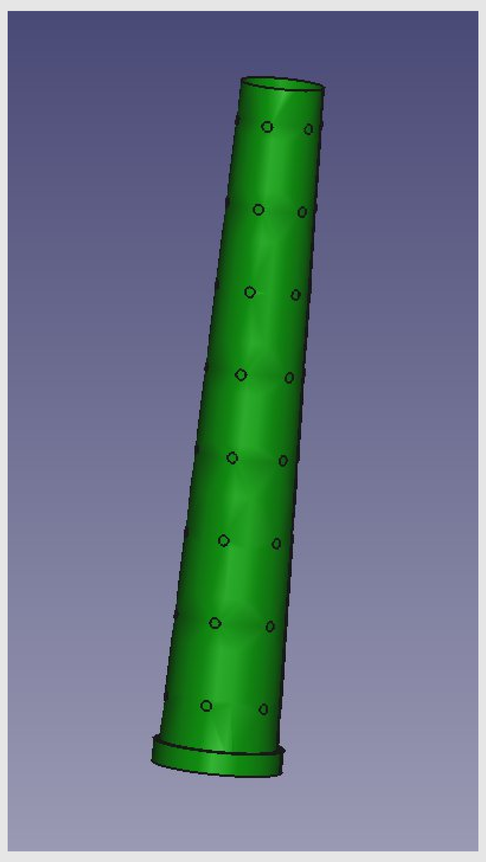
Internal flow diverter : Conical, 0.20 mm thick aluminum foil. upstream radius : 54 mm and downstream radius 37.50 mm

Reasons for incorporating a conical flow diverter include:

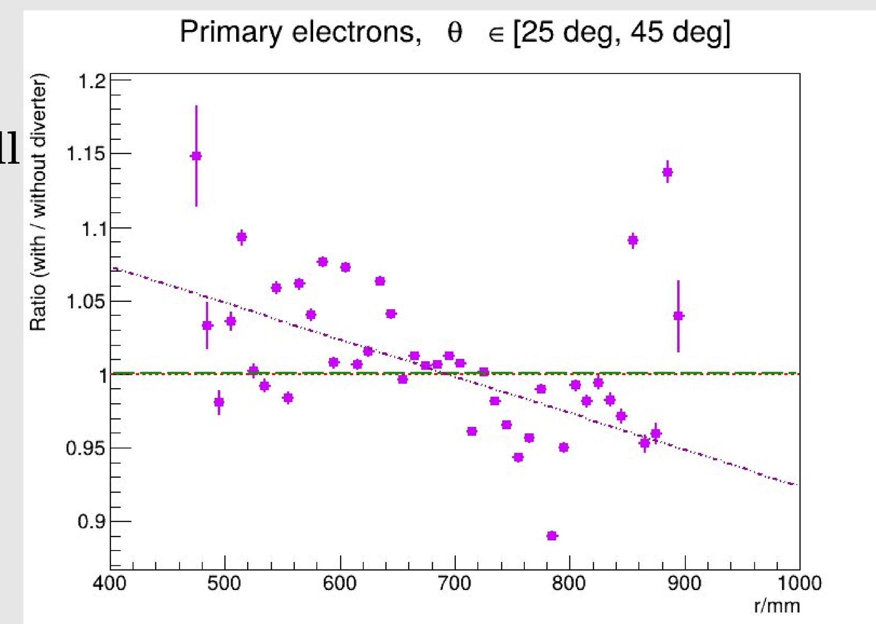
- Increasing Fluid Speed and Velocity : Reducing Interaction Time, Enhancing Turbulence and Mixing

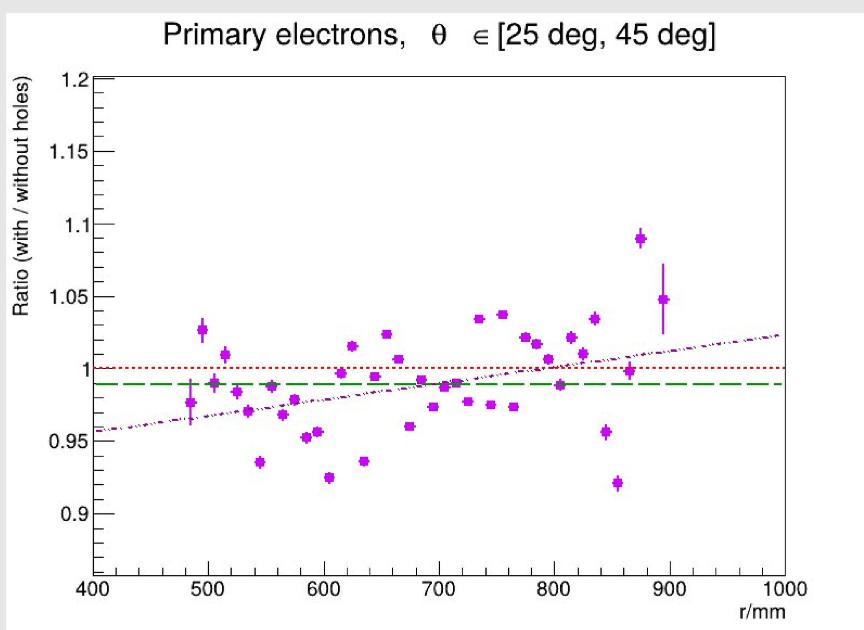
The reasons for having these holes on the wall include:

- Rapid Removal of Heated Fluid: Introduce transverse flow,
- Mechanical Stability: Relieving the static pressure,
- Non-interference with Experimental Data :



- Possible reason for the shift : energy loss of scattered electrons due to the presence of diverter but not enough to fall outside of the detector.

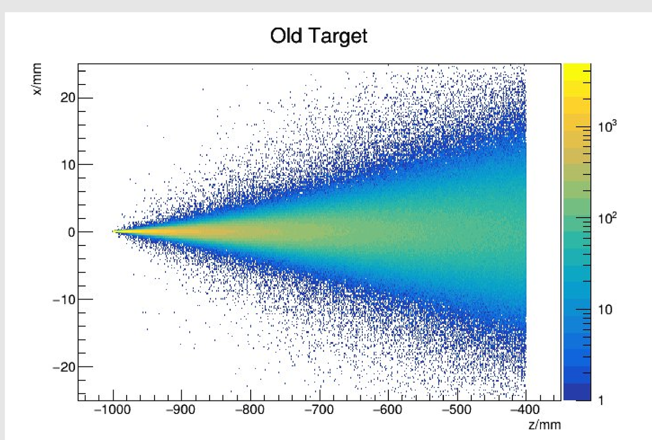




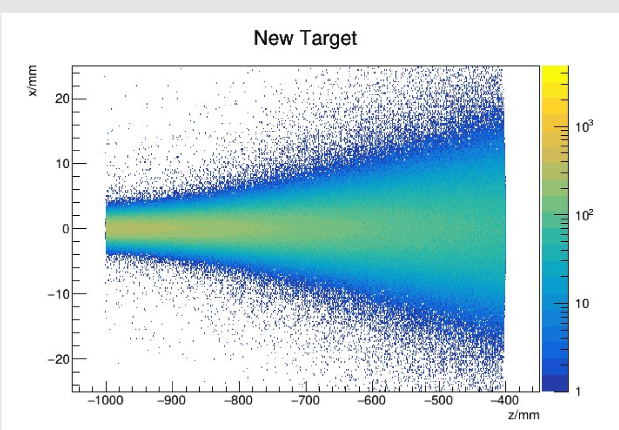
- By having holes on the wall of conical diverter does not make that much difference on hit rate.

Helium cell

- The primary reason for having the helium cell was balancing the pressure across the thin windows
- The cylindrical helium cell has about 483 mm length and radius 19.05 mm



Old target : with 0.25 mm thick aluminum window at the upward stream and no helium cell



New target : Helium cell in between two 0.125 mm thick aluminum windows

Further work

- Analysis on affect of holes on the wall of diverter as well as the width of the diverter.
- Analysis on helium cell as well as upstream and downstream windows thickness.
- CFD simulation to understand the target design better.

Jayanta Kumar Naik | P2 collaboration | Johannes-Gutenberg University Mainz