Target Design Analysis

Jayanta Kumar Naik

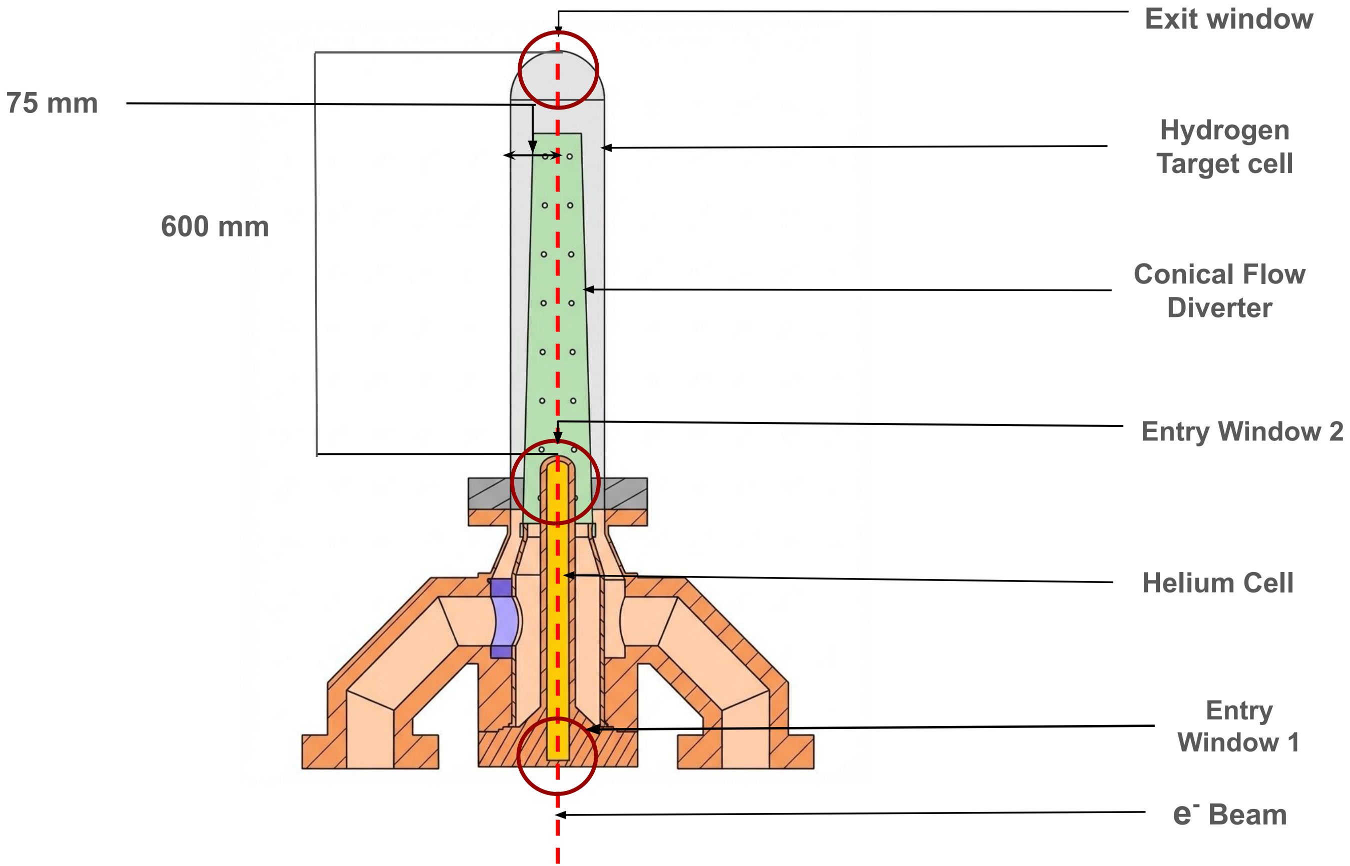
Institute of Nuclear Physics
Johannes Gutenberg University Mainz

JG|U

HIM
Helmholtz-Institut Mainz

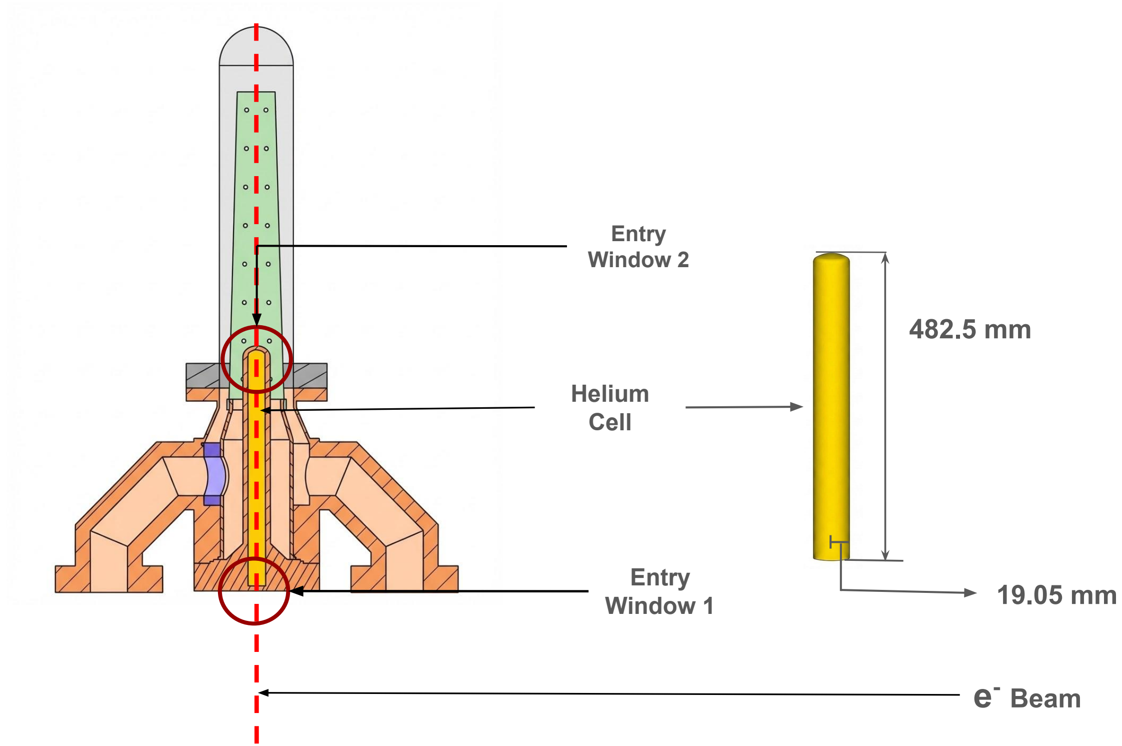
Content

1. Target design overview



Picture credit: Siddharth Thakker

2.1 Helium Cell



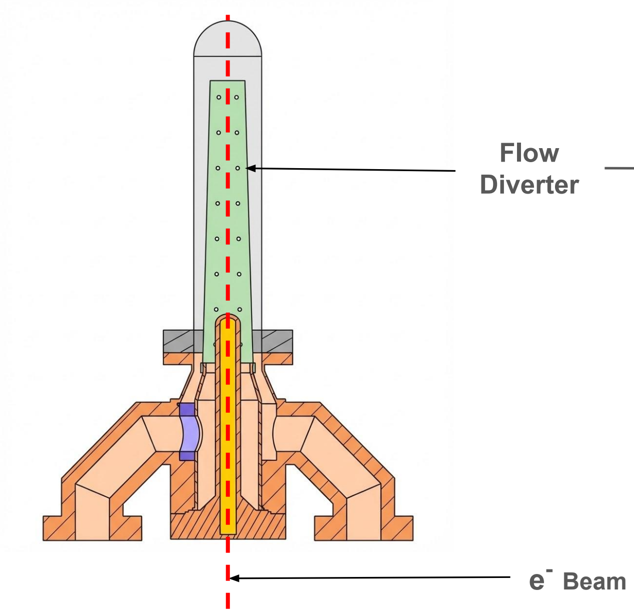
Arguments for:

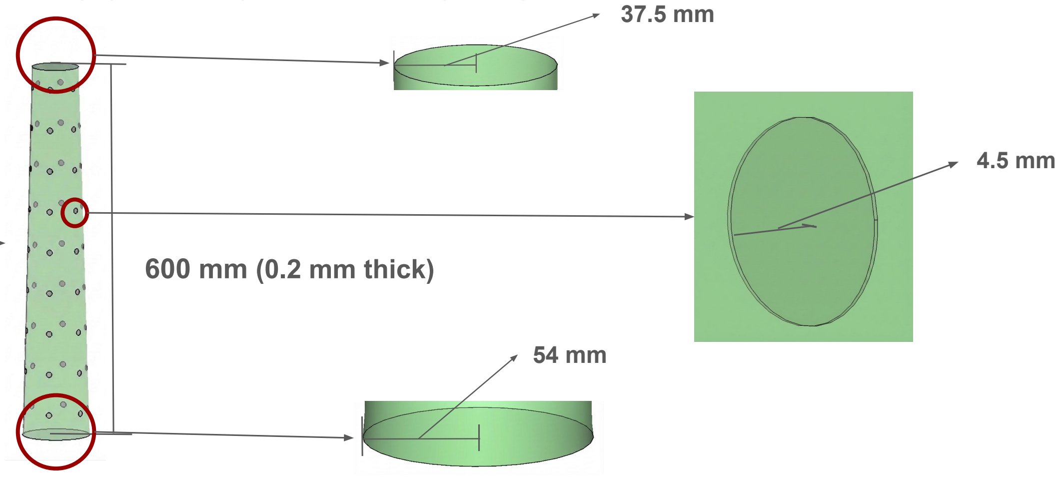
- pressure regulation on either side of the Entry Window 2

Arguments against:

- Introduces integration complexities

2.2 Conical Flow Diverter





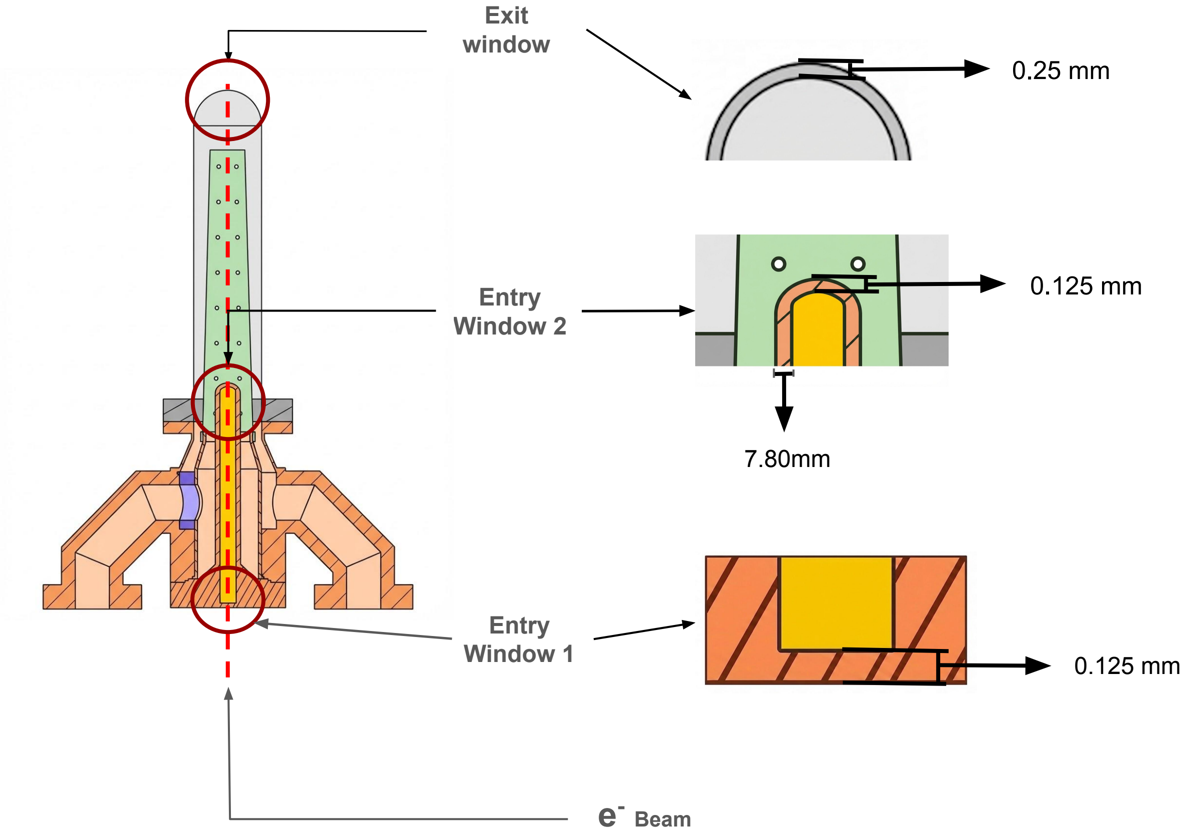
Reasons for incorporating a conical flow diverter:

- Increasing Fluid Speed

The reasons for having these holes on the diverter:

- Introduce transverse flow
- Relieving the static pressure

2.3 Target Windows



Effect of Target windows on experiment :

$$A_{exp} = P \cdot \left[(1 - f_{Al}) \cdot A_H^{total} + f_{Al} \cdot A_{Al} \right] + A_{app}$$

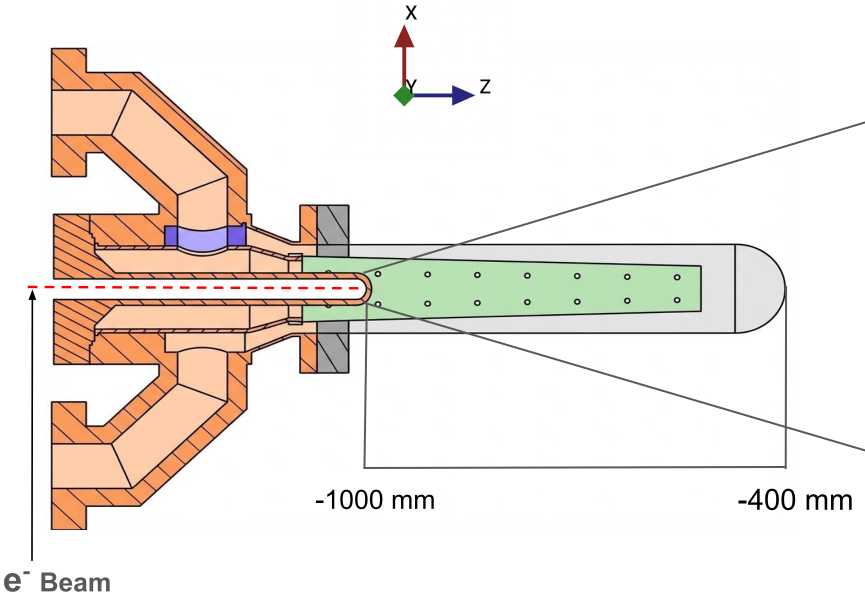
Dilution factor

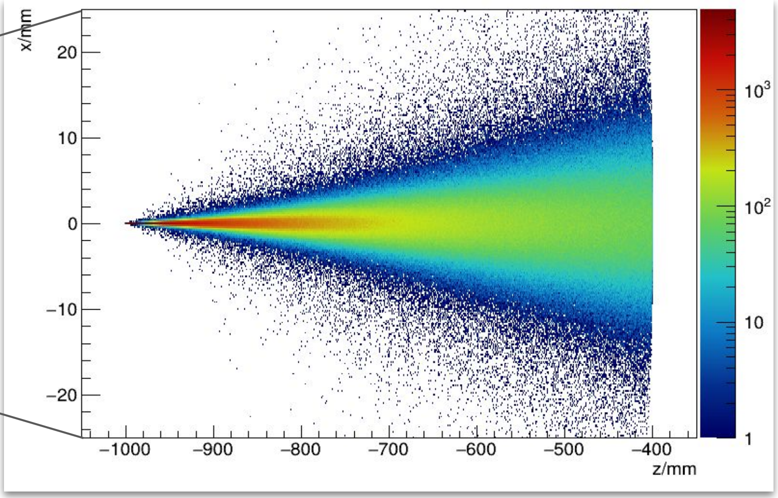
Asymmetry

3.1.1 Vertex distribution

without Helium cell

In Geant4 simulations, vertices represent randomly sampled interaction points along the continuous trajectories of the beam electrons.

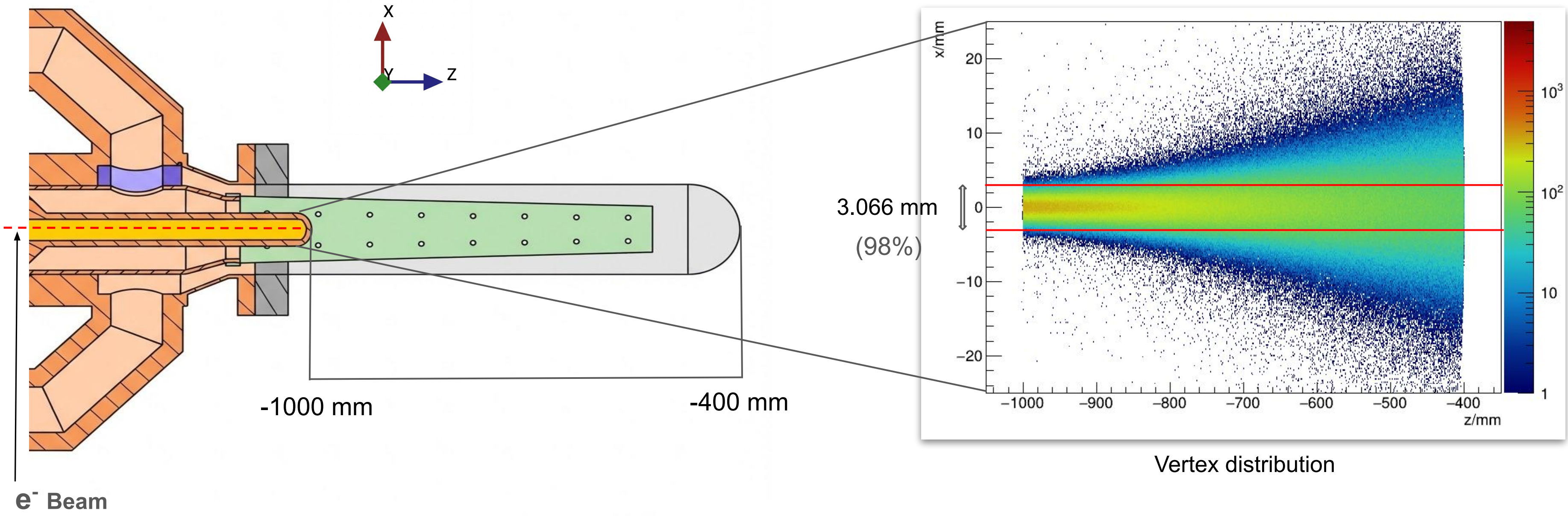




Vertex distribution

3.1.2 Vertex distribution

with Helium cell



Vertex distribution

- **Reason :** Multiple Coulomb scattering while passing through different media of varying lengths.

3.2.1 Multiple Coulomb Scattering

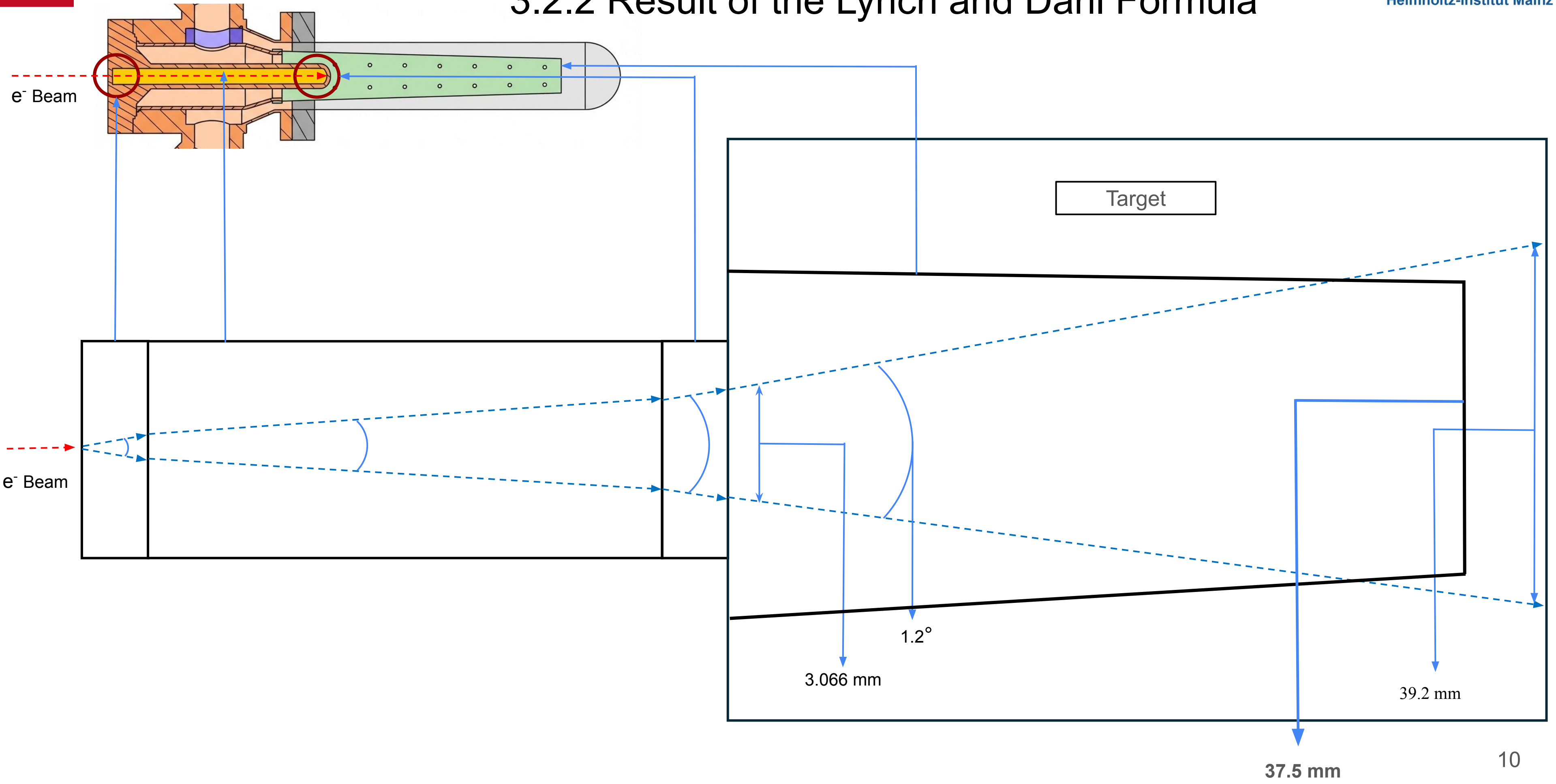
(Lynch and Dahl formula)

- Small-angle scatters are generally Gaussian.
- Less frequent "hard" scatters contribute non-Gaussian tails to the distribution.
- For the Gaussian distribution the **Lynch and Dahl formula** is used to understand the vertex distribution.

$$\theta_0 = \frac{13.6\ \text{MeV}}{\beta c p}\, z \sqrt{\frac{x}{X_0}} \left[1 + 0.088 \log_{10}\left(\frac{x\, z^2}{X_0 \beta^2}\right)\right]$$

x : The thickness of the scattering material
X_0 : The radiation length of the scattering material
Z : Charge number of the incident particle
p : Momentum of the incident particle

3.2.2 Result of the Lynch and Dahl Formula

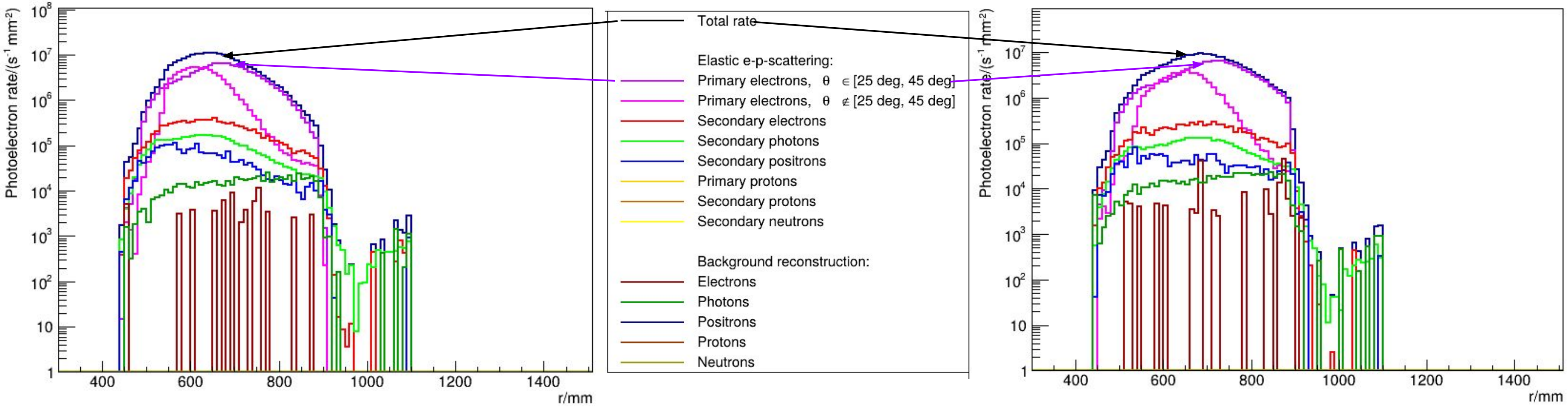


3.3.1 Photoelectron rate distribution

Helium Cell

Without Helium cell

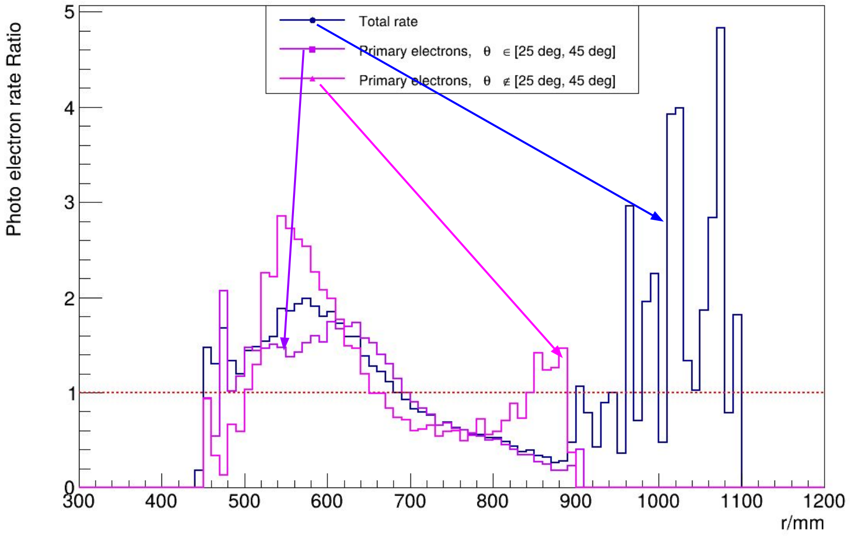
With Helium cell



- Slight shifting of photoelectron rate

3.3.2 Photoelectron rate comparison

Ratio(Without Helium cell / With Helium cell)



Contribution	Rate (without He) [s-1]	Rate (with He) [s-1]	% Change (Rate)
Total	8.52E+12	8.16E+12	-4.29%
Elastic Primary Electrons (25-45 deg)	5.17E+12	4.98E+12	-3.55%
Elastic Primary Electrons (Other)	2.70E+12	2.53E+12	-6.15%
Target Background Electrons	2.77E+09	9.85E+09	+255.9%
Target Background Photons	2.84E+10	3.06E+10	+7.63%
Target Background Positrons	0.00E+00	1.68E+08	New

Without Helium Cell

$\mathbf{A}_{\mathbf{exp}}$ = -23.90 +/- 0.61 ppb (2.57 %) (Total unc.)

{statistical Unc. contribution = 0.52 ppb (2.19 %) }

With Helium Cell

$\mathbf{A}_{\mathbf{exp}}$ = -23.87 +/- 0.62 ppb (2.58 %) (Total unc.)

{statistical Unc. contribution = 0.53 (2.22 %) }

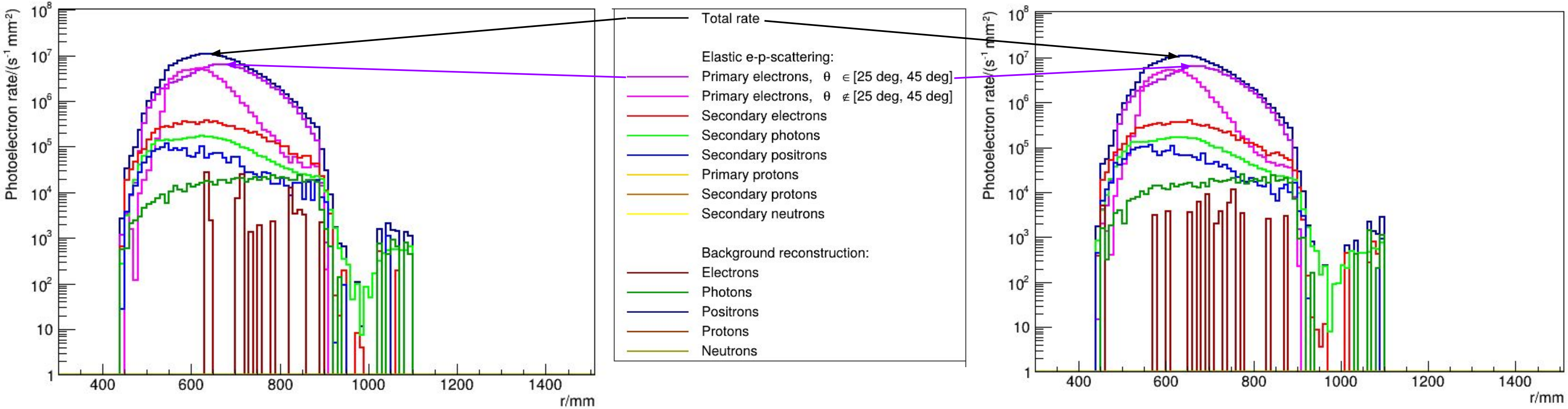
Polarization (P) = 85 %
Beam Hours = 10,000 hrs
central scattering angle = 35°
detector acceptance = 20° (25° - 45°)
Total Luminosity = 1.97×10^{40} cm^{-2} s^{-1}

3.3.3 Photoelectron rate distribution

Conical Flow Diverter

Without flow diverter
Without Helium cell

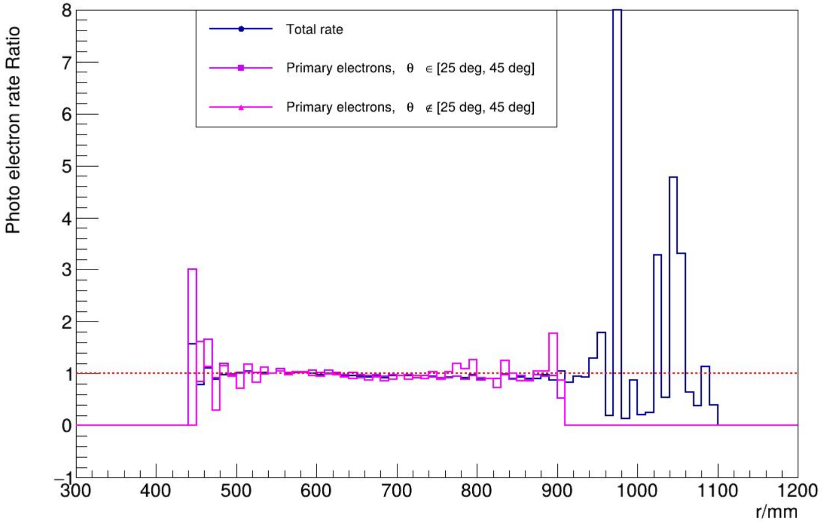
With flow diverter
Without Helium cell



- No Shifting of photoelectron distribution

3.3.4 Photoelectron rate distribution

Ratio(Without Diverter / With Diverter)



Contribution	Rate (Without Diverter) [s-1]	Rate (With Diverter) [s-1]	% Change (Rate)
Total	8.26E+12	8.52E+12	+3.15%
Elastic Primary Electrons (25-45 deg)	5.04E+12	5.17E+12	+2.58%
Elastic Primary Electrons (Other)	2.59E+12	2.70E+12	+4.25%
Target Background Electrons	4.31E+09	2.77E+09	-35.73%
Target Background Photons	3.01E+10	2.84E+10	-5.65%
Target Background Positrons	0.00E+00	0.00E+00	0%

Without diverter

A_{exp} = -23.87 +/- 0.61 ppb (2.57 %) (Total unc.)

{statistical Unc. contribution = 0.53 ppb (2.21%) }

With diverter

A_{exp} = -23.90 +/- 0.61 ppb (2.57 %) (Total unc.)

{statistical Unc. contribution = 0.52 (2.19 %)}

To be analysed : Effect of conical flow diverter (0.2 mm thick) on e-Al parity violating interaction

4. Ongoing modification to simulation

- Included the windows as a part of event generation process
- Adding a different Event Generator for Aluminium Windows
- Modified analysis to separate the particles according to their origins (i.e. from windows or from target cell)
- Asymmetry calculation for aluminium

5. Summary

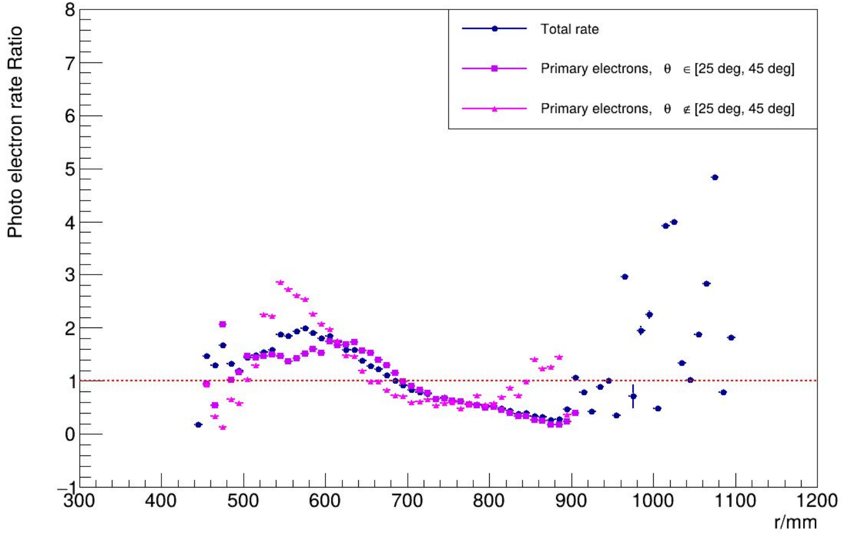
- **Effect of Helium cell :** Shifting of photoelectron rates
- **Conical diverter :** Less interference with the scattered particle
- **Target windows :** Modifying Simulation to include the e-Al interaction

Thank You

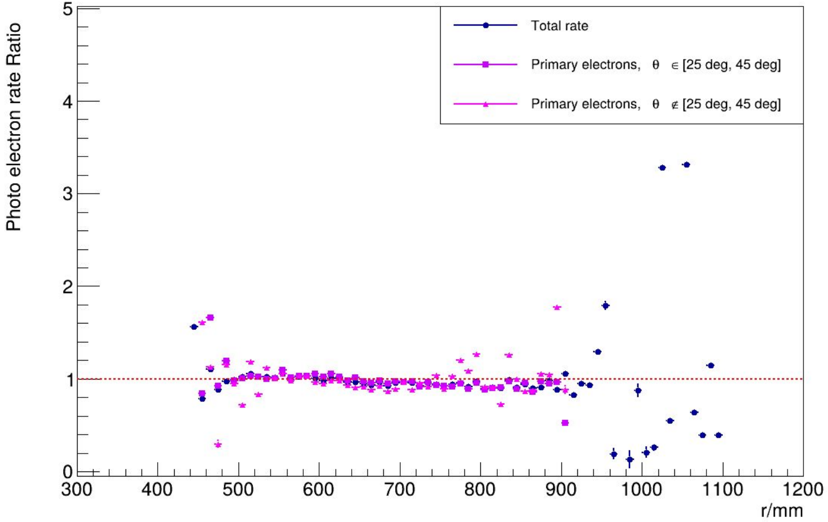
Extra Slides

Primary Particles

Helium Cell

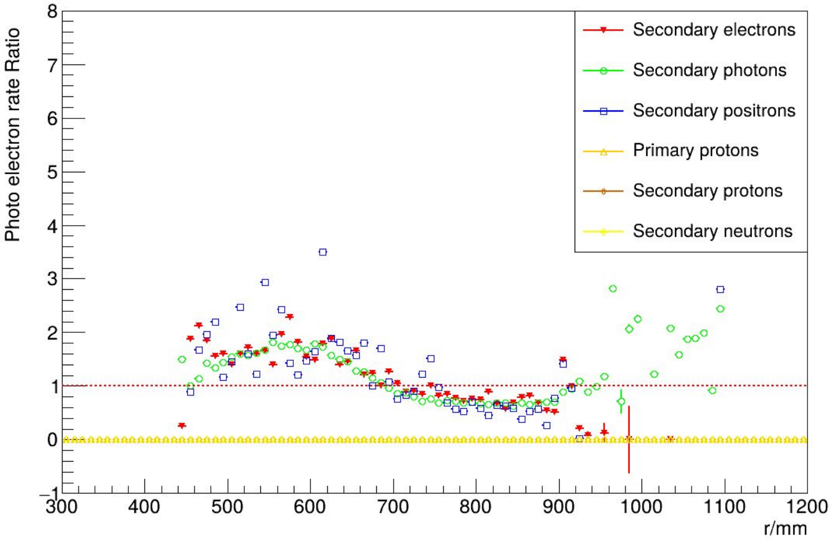


Conical Flow Diverter

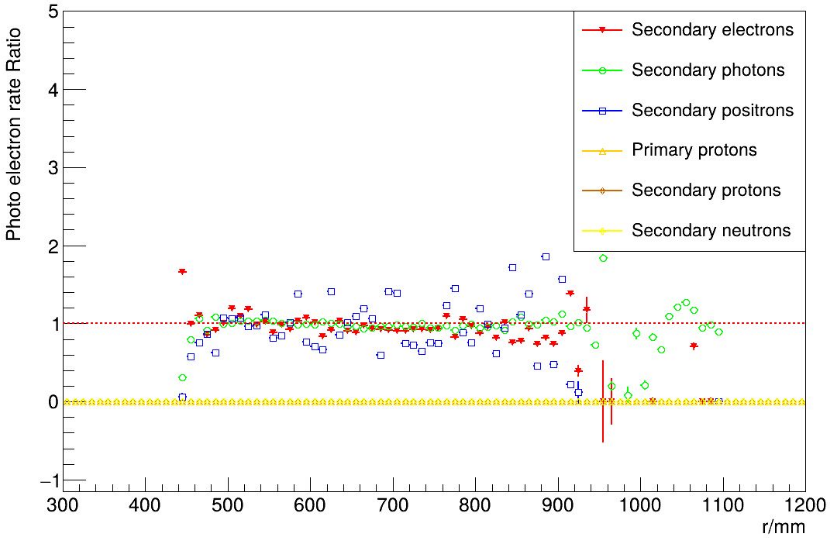


Secondary Particles

Helium Cell

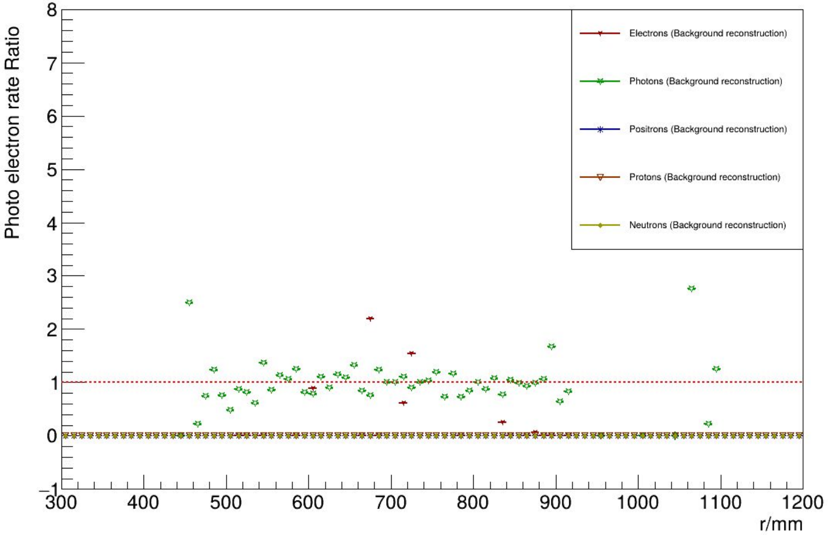


Conical Flow Diverter

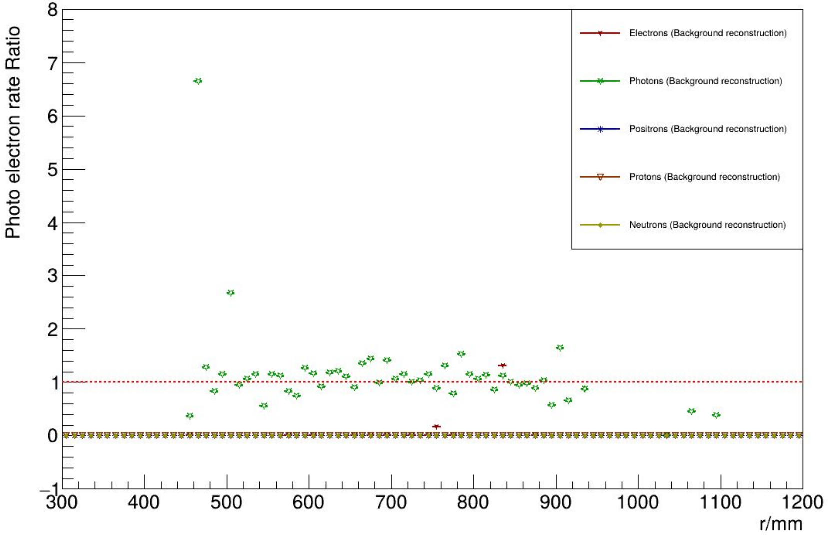


Background Particles

Helium Cell



Conical Flow Diverter



Input variables used

$$A_{exp} = P \cdot \left[(1 - f_{Al}) \cdot A_H^{total} + f_{Al} \cdot A_{Al}\right] + A_{app}$$

$\mathbf{P}$ = 85 % +/- 0.5%

$\mathbf{f_{Al}}$ = 0.01 (or 1%) +/- 0.0005

$\mathbf{A_H^{total}}$ = $\mathbf{A_{PV}^{ep}}$ + $\mathbf{A_{H2}^{bg}}$

$\mathbf{A_{H2}^{bg}}$ = 0.086 +/- 0.01 ppb

$\mathbf{A_{Al}}$ = 400 +/- 6 ppb

$\mathbf{A_{app}}$ = 0 +/- 0.1 ppb

Without Helium Cell

$\mathbf{A_{exp}}$ = -23.90 +/- 0.61 ppb (2.57 %)

{stats = 0.52 (2.19 %) , Pol = 0.12 (0.5%) ,

Apparatus = 0.10 (0.42%) , T.p. = 0.008 (0.035 %),

T.W = 0.05 (0.2%}

$\mathbf{Sin^2\theta_W}$ = 0.2311528 +/- 0.000382 (0.165 %)

With Helium Cell

$\mathbf{A_{exp}}$ = -23.87 +/- 0.62 ppb (2.58 %)

{stats = 0.53 (2.22 %) , Pol = 0.12 (0.5%) ,

Apparatus = 0.10 (0.42%) }, T.p. = 0.008 (0.035 %),

T.W = 0.05 (0.2%)

$\mathbf{Sin^2\theta_W}$ = 0.2311518 +/- 0.000384 (0.166%)

Without diverter

$\mathbf{A_{exp}}$ = -23.87 +/- 0.61 ppb (2.57 %)

{stats = 0.53 (2.21%) , Pol = 0.12 (0.5%) ,

Apparatus = 0.10 (0.42%) , T.p. = 0.008 (0.035 %),

T.W = 0.05 (0.2%)}

$\mathbf{Sin^2\theta_W}$ = 0.2311600 +/- 0.00038 (0.165 %)

With diverter

$\mathbf{A_{exp}}$ = -23.90 +/- 0.61 ppb (2.57 %)

{stats = 0.52 (2.19 %) , Pol = 0.12 (0.5%) ,

Apparatus = 0.10 (0.42%) , T.p. = 0.008 (0.035 %),

T.W = 0.05 (0.2%}

$\mathbf{Sin^2\theta_W}$ = 0.2311528 +/- 0.00038 (0.165 %)

Result of the Lynch and Dahl Formula