A luminosity monitor for a high precision measurement of the weak mixing angle at low energies

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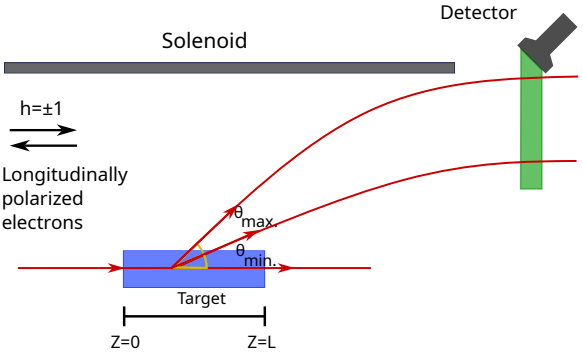
Parity-violating electron scattering and measurement of the weak mixing angle

- Precise determination of the electroweak mixing angle $\sin^2\Theta_w$ in the parity-violating elastic electron-proton scattering A^{PV}
- By measuring the weak charge of the proton Q_W^p at a low negative square of the four-momentum transfer Q^2



$$A^{PV} = \frac{d\sigma_{ep}^{+} - d\sigma_{ep}^{-}}{d\sigma_{ep}^{+} + d\sigma_{ep}^{-}} = \frac{-G_F Q^2}{4\pi\sqrt{2}\alpha}\left(Q_W^p - F(Q^2)\right)$$

$$A^{PV} \approx \mathcal{O}(10^{-8}) \quad \Delta A^{PV} \approx \mathcal{O}(10^{-10})$$

$$Q_W^p = 1 - 4 \cdot \sin^2\Theta_w$$

- For a measurement time of 10^4 h $\rightarrow \frac{\Delta \sin^2\Theta_w}{\sin^2\Theta_w} = 0.16\%$

Determination of parity-violating asymmetry and the influence of the luminosity

- Parity-violating asymmetry measured in experiment A_{exp}, determined from the number of elastically scattered electrons $N^{\pm}$ with beam polarization P:

$$A_{exp} = \frac{N^+ - N^-}{N^+ + N^-} = P \cdot A^{PV} + A_{false} \approx \mathcal{O}(10^{-8})$$

- Luminosity $\mathcal{L}$:

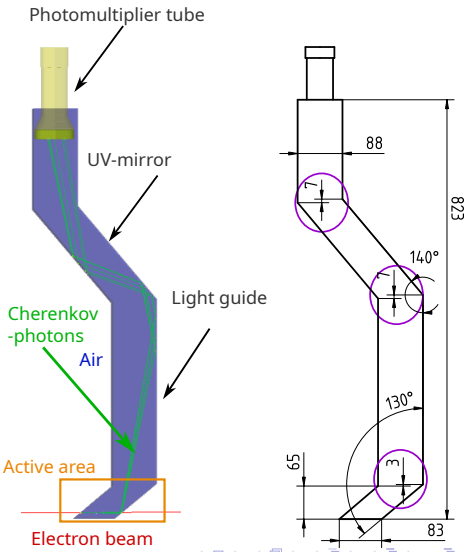
$$\mathcal{L} = \frac{N}{\sigma} \qquad \mathcal{L} = I_{beam}/e \cdot \rho \cdot L$$

$$A^{PV} = \frac{\sigma^+ - \sigma^-}{\sigma^+ + \sigma^-} = \frac{N^+/\mathcal{L} - N^-/\mathcal{L}}{N^+/\mathcal{L} + N^-/\mathcal{L}} = \frac{N^+ - N^-}{N^+ + N^-}$$

- $A_{false} \rightarrow$ helicity-correlated fluctuations in beam parameters such as current I_{beam}, energy, beam position, and beam angle, as well as fluctuations in the target density ρ
- To achieve an accuracy of $\frac{\Delta \sin^2 \Theta_w}{\sin^2 \Theta_w} = 0.16\%$, it is necessary to monitor A_{false}

Detector design of luminosity monitor

- Particle rates $\mathcal{O}(10^{14} s^{-1})$
- Analog integrating Cherenkov (Air) detector
- Light yield air sufficiently low $\rightarrow$ suitable for operation at high rates
- Design: Active detector region, light guide for Cherenkov photons to photomuliplier
- Readout electronis outside high-radiation region



Poster outlook

- Systematic limits for luminosity monitor
- Simulation results on detector response in the P2 experiment
- Experimental verification of the detector design using an electron beam at MAMI accelerator