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SLAC E158: An Experiment to Measure Parity Violation in Moller Scattering

M. Woods* (Representing the E158 Collaboration)

Stanford Linear Accelerator Center
Stanford University, Stanford, CA 94309, USA

Abstract. The E158 experiment at SLAC will make the first measurement of parity violation in Moller scattering. The left-right cross-section asymmetry (A_{LR}) in the elastic scattering of a 45-GeV polarized electron beam with unpolarized electrons in a liquid hydrogen target will be measured. This will give a precise measurement of the weak mixing angle, with $\delta(\sin^2\theta_W^{eff}) \approx 0.0008$ (at $Q^2 = 0.03 GeV^2$).

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INTRODUCTION

The weak mixing angle has been precisely measured at the Z-pole by experiments at CERN's LEP and SLAC's SLC machines. But precise measurements away from the Z-pole are needed to probe for certain classes of new physics, and to test the Standard Model predictions for the running of $\sin^2\theta_W^{eff}$ with Q^2. [1] E158 will measure A_{LR} for small angle Moller scattering with very high statistics. [2] The expected asymmetry at tree level is approximately $3 \cdot 10^{-7}$. Radiative corrections reduce this asymmetry by about 40%. E158 will measure A_{LR} with a relative accuracy of 7%. This will give the best measurement of $\sin^2\theta_W^{eff}$ away from the Z-pole, and will be sensitive (at 95% confidence level) to additional Z' bosons in the range 600-900 GeV and to compositeness scales to ≈ 10 TeV.

POLARIZED ELECTRON BEAM

The electron beam is produced by photoemission, using a circularly polarized laser beam and a strained GaAs photocathode. The expected electron polarization is 75%. The beam is accelerated to high energy in the two-mile SLAC Linac and then transported through a 24.5° bend angle in the A-line to a liquid hydrogen (LH_2)target in End Station A (ESA). The electron beam spin is longitudinal at the source and remains longitudinal in the Linac. In the A-line bend magnets, the spin precesses and becomes longitudinal at the target for a beam energy of 45 GeV. The beam is pulsed at 120 Hz with an intensity of $4 \cdot 10^{11}$ electrons in a 300ns pulse.

The E158 Data Acquisition (DAQ) will control three Pockels cells and a piezo mirror in the polarized laser source. Two of these Pockels cells are used to polarize the laser beam (similar to SLAC's Compton polarimeter laser system). [3] A third Pockels cell is used in a feedback to achieve equal intensities for the left and right beams, and a piezo mirror is used in a feedback to achieve equal steering for the left and right beams. Careful attention is also paid to the laser's residual linear polarization, since photoemission from strained GaAs can have a significant dependence on this. [4]

TARGET, SPECTROMETER AND DETECTORS

The LH_2 target is 1.5 meters long (0.18 radiation lengths), with a volume of 47 liters and a flow rate of 10 meters/s. Eight wire-mesh annular disks in the target cell region introduce turbulence at the 2mm scale (comparable to the beam size) and also induce a transverse velocity component to ensure mixing of the liquid between beam pulses.

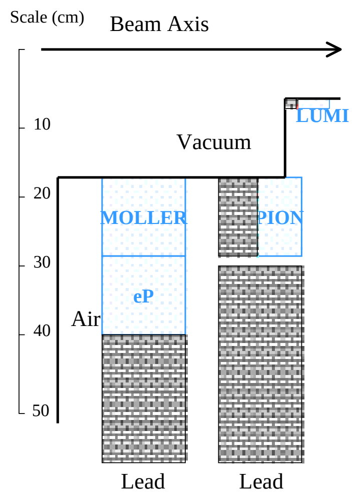

FIGURE 1. Detector Layout for E158 in one azymuthal section.

A spectrometer consisting of a 3-dipole chicane and 4 quadrupoles is used to spatially separate the Moller-scattered electrons from the Mott (electron-proton scattering) background at the detector plane 60 meters downstream of the LH_2 target. The detector layout is shown in Fig. 1. There are 4 principle detectors: MOLLER to look at the Moller signal, MOTT to look at the Mott background, PION to look at the pion background and LUMI to look at the very forward Mott and Moller electrons with small asymmetry. The MOLLER and MOTT detectors will be quartz fiber calorimeters; the PION detector will be a quartz bar radiator; and LUMI will be a threshold gas Cherenkov detector.

EXPERIMENTAL FEATURES

To perform an accurate measurement of the small Moller physics asymmetry, left-right beam asymmetries must be minimized and accurately measured. First, the beam helicity is chosen in a pseudo-random sequence of pulse quadruplets, $R_1R_2\overline{R_1R_2}, R_3R_4\overline{R_3R_4}$... The helicity of the first two pulses are chosen pseudo-randomly, while the next two states are complements of the first two. Then two more pseudo-random helicity states are chosen and so on. The experimental analysis will compute the asymmetry from each pulse quadruplet and then average all the quadruplet asymmetry results. Second, the physics asymmetry can be reversed either by inserting a halfwave plate in the polarized light source or by changing the beam energy 3.2 GeV. Third, the LUMI detector should measure an asymmetry a factor 10 smaller than the MOLLER detector. Lastly, we are planning to implement laser and beam optics to allow reversing of some false asymmetries, while leaving the physics asymmetries unchanged. This can be achieved by alternately running with "+I" and "-I" optics configurations. An "I" transformation maps $x \to +x$ and $x' \to +x'$, while an "-I" transformation maps $x \to -x$ and $x' \to -x'$.

RUN SCHEDULE

E158 will perform a series of beam tests in preparation for a first physics run in 2001. The polarized source will be commissioned in a week-long test with full current beam to a diagnostic station at 1.2 GeV, with 3 cavity BPMs and 2 toroids read out by the E158 DAQ. In January 2001, compatible running of ESA beam with PEP-II beam will be studied, and beam will be brought to ESA for spectrometer checkout and background measurements. Beam dithering will be commissioned for mapping detector and BPM sensitivities to energy, position and angle effects. The pulse-to-pulse fluctuations of beam and detector signals will be analyzed. It will be challenging to achieve the goal of $< 2 \cdot 10^{-4}$ ($< 1 \cdot 10^{-4}$) fluctuations in the normalized MOLLER (LUMI) signals.

E158 plans to have a 2-month physics run in Spring 2001. Goals for this run are to make the first observation of parity violation in Moller scattering and a modest measurement of the weak mixing angle, with an uncertainty $\delta(sin^2\theta_W)$ of 0.0025. The main physics run is expected to occur one year later in Spring 2002. In this run, E158 hopes to make the best measurement of the weak mixing angle away from the Z-pole with an uncertainty of $\delta(sin^2\theta_W) = 0.0008$.

REFERENCES

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