- Physics Motivation
- Experimental Design
- Recent Progress
- Outlook

SLAC EPAC Meeting, November 9 2000
SLAC E158 in End Station A

Left-Right Asymmetry in Fixed Target Moller Scattering

Goal: Most precise $\sin^2 \theta_W$ away from the Z pole

\[ A_{\text{LR}} = \frac{\sigma^- - \sigma^+}{\sigma^- + \sigma^+} = \frac{A_Z}{A_\gamma} = 0.32 \text{ ppm} \]

\[ \delta(A_{\text{LR}}) = +/- 7\% \quad +/- 3\% \]

12 $\mu$A

48 GeV

liquid hydrogen

4 GHz

integrating flux counter
Beyond the Standard Model

Complementary Approaches to Energy Frontier

Symmetry Violations
Rare/Forbidden Processes
Precision Electroweak Measurements

\[ Q^2 \sim M_Z^2 \]

on resonance: \( A_Z \) imaginary

\[ A_X \alpha \frac{1}{Q^2 - M_X^2} \sim \frac{4\pi}{\Lambda^2} \]

Contact interaction

no interference!

\[ A_Z^2 \left[ 1 + \frac{A_X^2}{A_Z^2} \right] \]
LOW $Q^2$ Z PHYSICS

$$\frac{\delta A_Z}{A_Z} \propto \frac{\pi/\Lambda^2}{gG_F} \implies \delta(\frac{g}{g}) \sim 0.1$$
$$\Lambda \sim 10 \text{ TeV}$$

$$\frac{\delta (\sin^2 \theta_W)}{\sin^2 \theta_W} \lesssim 0.01$$

lepton-quark interactions probed to 10 TeV

**NuTeV**
$$\delta M_W = 110 \text{ MeV}$$

**Atomic Cs**
$$\delta (\sin^2 \theta_W) = 0.6 \%$$
Electron-Electron (Moller) Scattering

- Unique Low Energy Leptonic Reaction
- \( A_{LR} \propto (1 - 4 \sin^2 \theta_W) \) : Added Sensitivity

**new theoretical correction "discovered"**

Czarnecki and Marciano '00

unique sensitivity to specific TeV physics
New Physics Sensitivity

- LEP II
- $e_+ e_+$
- $e^- e^-$
- 15 TeV

- Fermilab
- $q Z' e$
- $0.5-1.0$ TeV

- $\frac{g^2}{2M_\Delta^2} < 0.01 G_F$
- doubly charged scalar exchange

- E158
- compositeness
- new forces
- lepton flavor violation

Recent Review: Ramsey-Musolf, hep-ph 9903264
E158 Collaboration

Institutions
Caltech                      Syracuse University
Kent State University       Smith College
Princeton University        Jefferson Lab
SLAC                        UMass Amherst
Saclay                      University of Virginia

49 physicists

E158 Graduate Students
Klejda Bega                Peter Mastromarino
Brian Humensky             David Relyea
Mark Jones                 Baris Tonguc
Lisa Kaufman               Imran Yousef
$A_{LR}$ via Optical Pumping

- Polarized Source
- GaAs
- 100 kV
- Acceptor
- HV Pulse
- Polarized Electrons
- $P_e = 80\%$

**SLAC E122**
- Rapid Helicity Flips
- Flux Integration
- Beam Monitoring

**HV Polarity**
- Laser Handedness
- Electron Chirality

**Pseudo-Random Helicity Flips**

- Pulse Pair
- 30 Hz Quadruplet
Flux Counting

Measure flux $F$ for each window

$$A_{\text{pulse pair}} = \frac{F_R - F_L}{F_R + F_L}$$

$$A_{\text{raw}} = 0.1 \text{ ppm}$$

Rate = 40 Million/pulse

$$\sigma(A) = 1.7 \times 10^{-4}$$

$$\delta(A_{\text{raw}}) = 7 \text{ ppb}$$

Signal Average N Windows Pairs

$$A = A_{\text{raw}} + \sigma(A) \sqrt{N_{\text{pairs}}}$$

ADCs

* True 16 Bit
* Nonlinearity $< 10^{-3}$

$$N_{\text{pairs}} = 500 \text{ Million}$$
Hydrogen Target

Caltech & SLAC

Refrigeration Capacity 700 W
Operating Temperature 20 K
Length 1.5 m
Flow Rate 10 m/s

- assembly in Aug 00
- cold test in Sep 00
- transported to ESA in Oct 00
- hydrogen test in late Nov 00
* houses target and limits migration of Liquid Hydrogen
* has the ability to raise the target up 6" with liquid
Quadrupole Quadruplet

- primary, beam, signal and background are symmetric about quadrupole axes
- Mollers focused, Motts defocused
- full range of the azimuth

upstream of quads

30 m after quads
Kinematics

\[ e^- \theta e^- \]

\[ e^- \theta_{lab} e^- \]

Graphs showing the relationship between \( |\cos \theta| \) and the scattering angle. The graph on the left represents the differential cross section \( d\sigma/d(\cos \theta) \) normalized to 1 barn, with a peak at 12 \( \mu \)Barns. The graph on the right shows \( \theta_{lab} \) in mrad as a function of \( \cos \theta \).
Dipole "Chicane"

target: 18% X

low energy photons
high energy photons
high energy pions
Mott (e-p) electrons
Collimation and Masking

* fabrication of final collimators in progress
* installed by mid-December

* spectrometer commissioning at low power
* counting detectors
* map out acceptance and backgrounds
Spectrometer Status

* Final buttoning up and alignment Dec 00
* checkout Jan 00 at low power
* concrete bunker and consequent earthquake bracing just before high power run
Detector Layout

* 4 integrating detectors
* profile detectors for calibration
Moller Calorimeter
Syracuse University

* total absorption calorimeter
* copper quartz sandwich
* radiation dose comparable forward angle calorimeter at LHC
Radial Profile Detectors
UMass & Smith College

- single particle tracking
- pion background
- spectrometer optics
- Moller Coincidences

- integrated response
- radiative corrections
- spectrometer stability
- Polarimetry
E158 PROJECTED ERRORS

Statistics for 20 week production run:

| Parameter             | 48.3   | 45.0   |
|-----------------------|--------|--------|
| E beam (GeV)          |        |        |
| e⁻ /pulse             | 3.5x10^{11} | 6x10^{11} |
| Mollers/pulse         | 2.5x10^7   | 4.5x10^7   |
| d(A)/pulse            | 2.14x10^{-4} | 1.65x10^{-4} |
| d(A)                  | 1.13x10^{-8} | 1.13x10^{-8} |
| d(sin²q_w)            | 0.00103  | 0.00110  |

120 pulses/sec
50% X 90%
Pbeam: 0.75

Systematics on the raw asymmetry (parts per billion):

- Statistics: 7.5
- Beam helicity correlations: < 3
- Cross-talk: < 1
- Transverse polarization: < 1
- Magnetized iron: < 1

Impact of Normalization Errors on d(sin²q_w):

- Beam Polarization: 0.0003
- Radiative corrections: <0.0001
- Backgrounds: <0.0001
- Theory: <0.0002
Pulse to Pulse Beam Fluctuations

\[ 4.5 \times 10^{-7} \text{ Mollers/pulse} \]

1% Intensity Fluctuations

\[ \sigma (A) = 1.1 \times 10^{-4} \]

\[ \sigma \left( \frac{\Delta D}{2D} \right) = 7 \times 10^{-3} \]

\[ A_{\text{pulse pair}} \approx \frac{\Delta D}{2D} - \frac{\Delta I}{2I} + \frac{\Delta E}{2E} + \alpha_i \Delta X_i \]

Jitter (ppm) | 150 | 10,000 | 4000 | 6700
Accuracy (ppm) | 30 | 15 | 35 | 50
Demonstrate adequate resolution for measurement of electron beam intensity, position and angle.
Cumulative Corrections

\[ \sigma(A) = \frac{11 \text{ ppb}}{\sqrt{N}} \]

(45 GeV) (48 GeV) (about 0.6 Billion pulses)

\[ A \approx \frac{\Delta D}{2D} - \frac{\Delta I}{2I} + \frac{\Delta F}{2E} + \alpha_i \Delta X_i \]

ppb

110

+/-7

200

+/-1

20

+/-1

10

+/-1

measure \ X \ vs \ C, \ F \ vs \ C, \ extract \ F \ vs \ X