SLAC E158 Status Report

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- Physics Motivation
- Experimental Design
- Recent Progress
- Outlook

SLAC EPAC Meeting, November 9 2000
Goal: Most precise $\sin^2\theta_W$ away from the Z pole

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

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

12 $\mu$A, 48 GeV, 4 GHz, liquid hydrogen, integrating flux counter
Beyond the Standard Model

Complementary Approaches to

Energy Frontier

Precision Electroweak Measurements

Symmetry Violations

Rare/Forbidden Processes

Contact interaction

\[ X \]

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

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

on resonance: \( A_z \) imaginary

\[ A_Z^2 \left[ 1 + \frac{A_X^2}{A_Z^2} \right] \] no interference!
LOW $Q^2 Z$ PHYSICS

\[ \frac{\delta A_Z}{A_Z} \propto \frac{\pi/\Lambda^2}{g G_F} \rightarrow \delta(g)/g \sim 0.1 \]
\[ \Lambda \sim 10 \text{ TeV} \]
\[ \frac{\delta(\sin^2 \theta_W)}{\sin^2 \theta_W} \lesssim 0.01 \]

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

![Graph](image)

- **Czarnecki and Marciano '00**
- **New theoretical correction "discovered"**
- **Unique sensitivity to specific TeV physics**
New Physics Sensitivity

LEP II

\[ e R \times e R + e L \times e L \]

15 TeV

15 TeV

LEP II

Fermilab

q \[ Z' \] q

0.5-1.0 TeV

\[ g^2 \left< \frac{2M_\Delta}{2} \right> < 0.01 \, G_F \]

doubly charged scalar exchange

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

SLAC E122
* rapid helicity flips
* flux integration
* beam monitoring

HV Polarity
laser handedness
electron chirality

$P_e = 80\%$

HV pulse
30 Hz quadruplet

Pseudo-Random Helicity Flips
Flux Counting

Measure flux $F$ for each window

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

$p = 0.1 \text{ ppm}$

Rate $= 40 \text{ Million/pulse}$

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

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

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

Signal Average
$N$ Windows Pairs

$$A +/-(\sigma(A)) = \frac{\sum A}{\sqrt{N_{\text{pairs}}}}$$

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

* 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
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

- pion background
- spectrometer optics
- Moller Coincidences

- radiative corrections
- spectrometer stability
- Polarimetry
E158 PROJECTED ERRORS

Statistics for 20 week production run:

<table>
<thead>
<tr>
<th>E beam (GeV)</th>
<th>48.3</th>
<th>45.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>e⁻ /pulse</td>
<td>3.5x10¹¹</td>
<td>6x10¹¹</td>
</tr>
<tr>
<td>Mollers/pulse</td>
<td>2.5x10⁷</td>
<td>4.5x10⁷</td>
</tr>
<tr>
<td>d(A)/pulse</td>
<td>2.14x10⁻⁴</td>
<td>1.65x10⁻⁴</td>
</tr>
<tr>
<td>d(A)</td>
<td>1.13x10⁻⁸</td>
<td>1.13x10⁻⁸</td>
</tr>
<tr>
<td>d(sin²qₘₚ)</td>
<td>0.00103</td>
<td>0.00110</td>
</tr>
</tbody>
</table>

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(sin²qₘₚ)

- 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} \quad \rightarrow \quad \sigma (A) = 1.1 \times 10^{-4}

1\% \text{ Intensity Fluctuations} \quad \rightarrow \quad \sigma \left( \frac{\Delta D}{2D} \right) = 7 \times 10^{-3}

\left| \frac{\Delta I}{2I} \right|
\left| \frac{\Delta D}{2D} \right|

\left| \frac{\Delta E}{2E} \right|
\left| \frac{\Delta D}{2D} - \frac{\Delta I}{2I} \right|

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

\begin{array}{cccc}
\text{jitter (ppm)} & 150 & 10,000 & 4000 & 6700 \\
\text{accuracy (ppm)} & 30 & 15 & 35 & \rightarrow \ 50
\end{array}
1 GeV Test

Jan 4 - Jan 14, 1999

Demonstrate adequate resolution for measurement of electron beam intensity, position and angle

![Diagram showing BPMs and toroids with 1 GeV electrons passing through them, along with jitter correlation and position resolution graphs.](image-url)
Cumulative Corrections

\[ \sigma(A) = 11 \text{ ppb} \quad 11 \text{ ppb} \quad (\text{about 0.6 Billion pulses}) \]

\[ \frac{1}{\sqrt{N}} \quad (45 \text{ GeV}) \quad (48 \text{ GeV}) \]

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

ppb

\begin{array}{cccc}
110 & 200 & 20 & 10 \\
+/-7 & +/-1 & +/-1 & +/-1 \\
\end{array}

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