New limits on physics beyond the Standard Model in parity-violating electron scattering

Ross Young
R. Carlini, J. Roche, A. Thomas
Outline

• Status of PV electron-quark interactions
• Hadronic structure in PVES SM tests
  – Strangeness content of the nucleon
• New experimental limits on low-energy PV electron(A)-quark(V) interactions
• Qweak Experiment
PV Electron-Quark Couplings

Couplings precisely determined by high-energy measurements and SM scale evolution

Precise low-energy measurements can reveal new beyond the Standard Model physics
PV Electron-Quark Couplings

Precise low-energy measurements can reveal new beyond the Standard Model physics.
$C_{1q}$ Couplings

![Diagram showing the coupling constants $C_{1u}$ and $C_{1d}$ with regions from SLAC: D DIS, Mainz: Be, APV Tl, and APV Cs. The 95% CL confidence level is indicated.]
$C_{2q}$ Couplings

$C_{2u} + C_{2d}$ vs. $C_{2u} - C_{2d}$

Mainz: Be
CERN: $\mu$–C DIS
SLAC: D DIS
SAMPLE: D

95% CL
Qweak Experiment

• Precise measurement of the proton’s weak charge in PVES
  \[ Q_p^{\text{weak}} = -2(2C_{1u} + C_{1d}) \]
  \[ Q^2 = 0.03 \text{GeV}^2, \ \theta = 8^\circ \]

• At low energy and small scattering angle:

\[ A_{LR} = - \frac{G_{\mu} Q^2}{4\pi\alpha \sqrt{2}} \left[ Q_{\text{weak}} + \beta_A \tilde{G}_A^p \sqrt{Q^2} + \beta_V Q^2 + \ldots \right] \]

\[ \beta_A \propto \theta + O(\theta^3) \]

Anapole uncertainty

Strangeness uncertainty
Strangeness Measurements

- Dedicated measurements to determine strangeness content of nucleon: SAMPLE, A4-Mainz, HAPPEX, G0
- Constrain hadronic background for Qweak!

Global fits to all data $Q^2 < 0.3 \text{ GeV}^2$

\[
G_E^s = \rho_s Q^2 + \rho'_s Q^4 + \ldots
\]

\[
G_M^s = \mu_s + \mu'_s Q^2 + \ldots
\]

\[
\tilde{G}_A = \tilde{g}_A^N \left( \frac{1}{1 + Q^2 / M_A^2} \right)^2
\]

\[
\tilde{g}_A^N = \left( \xi_{A}^{T=1} g_A \tau_3 + \xi_{A}^{T=0} a_8 + \xi_{A}^0 a_s \right) + \left( A_{\text{ana}}^{T=1} \tau_3 + A_{\text{ana}}^{T=0} \right)
\]
Strangeness @ $Q^2=0.1 \text{ GeV}^2$

- RDY et al., PRL(2006)
  - SAMPLE, PVA4, HAPPEX, G0

- New precision
  - HAPPEX nucl-ex/0609002

- Leinweber, RDY et al., PRL(2005,2006)

95% CL
Electroweak Couplings in PVES

- Without Qweak experiment, what are the present limits on $C_{1q}$?
- Repeat global fits with weak charges free – and free hadronic structure
Proton Weak Charge Extrapolation

![Graph showing the extrapolation of proton weak charge with data points from SAMPLE, HAPPEX, G0, and PVA4. The graph plots $A_{LR}^p$ vs. $Q^2$ (GeV$^2$).]
$C_{1q}$ Couplings with PVES
$C_{2q}$ Couplings with PVES

- Mainz: Be
- CERN: $\mu$–C DIS
- SLAC: D DIS

95% CL
Remarks

• New precision PVES providing critical test of hadronic theory

• Experimental knowledge of electroweak couplings improved by factor $\sim 5$

• Can now provide model-independent limits on new physics in general isospin parameter space
The Qweak Measurement!