The EIC and Future US Collider Physics

William J. Marciano May 14, 2010

General Remarks
 Electroweak Physics at the EIC



Current US On Shore Collider Programs

1) <u>SLAC</u> $e^+e^- \rightarrow b\overline{b}$ factory (Ended!)

Possible Super b in Italy (Why not JLAB?)

2) *Fermilab* 2TeV pp Collider

Still Higgs Hunting (1-3 More Years) Future $\mu^+\mu^-$ Collider? Needs lots of R&D (20yrs) Meanwhile high intensity v and μ physics

 3) <u>BNL</u> RHIC & Polarized pp for Nuclear Physics Luminosity and Detector Upgrades (~10 yr program)
 <u>Last Collider Standing!</u> Future polarized ep/elon collider? 4) <u>JLAB</u> Fixed Target polarized ep, eN scattering $E_e = 6 \text{GeV} \rightarrow \underline{12 \text{GeV}} \rightarrow 2 \text{ L} \sim 10^{38} \text{cm}^2 \text{s}^{-1}!$ Mainly QCD/Nuclear Physics But Flagship A_{LR} ep, ee, eD Experiments Precision $\sin^2\theta_W$ and "New Physics" Effects **Future** Polarized ep, eD, e³He, elon Collider

Goal L~1035cm-2s-1

US has room for (at most) one EIC

Cost \$500-1000M Affordable if the Physics Case is strong

(In my view, EIC has a good chance to happen)

The US Needs a Collider!

Physics Case

Must be primarily a Nuclear/QCD Facility

Structure functions (polarized), small x gluons... properties of quarks in nuclei (EMC effects)... sum rules (Bj), $\alpha(Q^2)_{QCD}$... HERA(ep): L~10³¹cm⁻²s⁻¹ \rightarrow 10^{33,34,35}cm⁻²s⁻¹ polarized e,p,D,³He; Heavy lons <u>What about Electroweak Physics?</u>

Second Detector? Complementary Program!

LDRD Proposal 2009

Electroweak Physics with an Electron-Ion Collider Deshpande, Kumar, Marciano, Vogelsang

- DIS & Nuclear Structure Functions (γ,Z,W) (Beyond HERA)
- A_{RL}, sin²θ_W(Q²), Radiative Corrections, "New Physics"
- Lepton Flavor Violation: eg ep→τX (inverse attobarn=1000fb⁻¹!)

What are the Machine and Detector Requirements?

Inclusion of Electroweak Radiative Corrections (Important?) High Precision & Polarization(±0.5%?, ±0.25%?)

Nucleon vs Nuclear Asymmetries (EMC Effect, CSV?)

Proton Polarization (Spin Content-Other?)

Various Issues Under Study

Running sin²0



Goals of Future Experiments

- High Precision: $\Delta sin^2 \theta_W \sim 0.00025$ or better
- Low Q² Sensitivity to "New Physics"
 m_{Z'} >1TeV, |S|<0.1-0.2, SUSY Loops, Extra Dim., Compositeness....

• $H_{PV} = G_{\mu} / \sqrt{2} [(C_{1u} \overline{u} \gamma^{\nu} u + C_{1d} \overline{d} \gamma^{\nu} d) \overline{e} \gamma_{\nu} \gamma_{5} e + (C_{2u} \overline{u} \gamma^{\nu} \gamma_{5} u + C_{2d} \overline{d} \gamma^{\nu} \gamma_{5} d) \overline{e} \gamma_{\nu} e + ...]$

What About C_{2u} and C_{2d} ?

 Renormalized at low Q² by Strong Interactions <u>Measure in Deep-Inelastic Scattering (DIS), eD & ep</u> A_{RL}(eD→eX)∝2x10⁻⁴GeV⁻²Q²[(C_{1u}-C_{1d}/2)+f(y)(C_{2u}-C_{2d}/2)]

Standard Model:
$$C_{1u} = (1-8sin^2\theta_W/3)/2 \approx 0.20$$

 $C_{1d} = -(1-4/sin^2\theta_W/3)/2 \approx -0.32$

 C_{2u} = (1-4sin²θ_W)/2 ≈0.04 C_{2d} =-(1-4sin²θ_W)/2≈-0.04

 C_{2q} sensitive to RC & "New Physics" eg Z χ (SO(10)) Measure A_{RL} to ±1/2%? Measure C_{2q} to ±1-2%? Theory (loops)?

JLAB 6 GeV DIS $eD \rightarrow eX$ On the books JLAB 12 GeV DIS eD Proposed (Likely) <u>Goals</u>: Measure C_{2a}s, "New Physics", Charge Sym. Violation ... Effective Luminosity (Fixed Target) 10³⁸cm⁻²sec⁻¹! What can ep and ed at e-lon contribute? Asymmetry F.O,M,~ A^2N , $A \propto Q^2$, $N \propto 1/Q^2$ (acceptance?) High Q² Better (but Collider Luminosity?) 100fb⁻¹ Needed **Program can be started with lower luminosity** Do DIS ep, eD, eN at factor of 10 lower

Single and Double Polarization Asymmetries

<u>Polarized e</u>: $A^{e}_{RL} = (\sigma_{RR} + \sigma_{RL} - \sigma_{LL} - \sigma_{LR})/(\sigma_{RR} + \sigma_{RL} + \sigma_{LL} + \sigma_{LR}) \propto P_{e}$ <u>Polarized p</u>: $A^{p}_{RL} = (\sigma_{RR} + \sigma_{LR} - \sigma_{RL} - \sigma_{LL})/(\sigma_{RR} + \sigma_{LR} + \sigma_{RL} + \sigma_{LL}) \propto P_{p}$

Polarized e&p $A^{ep}_{RRLL} = (\sigma_{RR} - \sigma_{LL})/(\sigma_{RR} + \sigma_{LL}) \propto P_{eff}$ $P_{eff} = (P_e - P_p)/(1 - P_e P_p)$ opposite signs like relativistic velocities addition≤1 eg $P_e = 0.8 \pm 0.008$, $P_p = -0.7 \pm 0.03 \rightarrow P_{eff} = 0.956 \pm 0.005$ small uncertainty

How to best utilize P_{eff}?

LDRD A_{RL} GOALS

Examine Machine and Detector Requirements For ±1% A_{LR}

Include EW Radiative Corrections to DIS

Is 100fb⁻¹ Sufficient?

Utility of Proton Polarization?

Stage 1 e-lon aim for ±4%

Study Nuclear Effects (EMC, CSV, polarization effects)

Important Secondary e-Ion Goal? Improve Proposal?

There Must Be A US Collider