Novel Spin Structure Functions

\[ A_{TPV} = \frac{G_F Q^2}{2\sqrt{2} \pi \alpha} \left[ g^\gamma_Z \frac{g_5}{F_1} + g_A f(y) \frac{g_1^\gamma_Z}{F_1} \right] \]

- unpolarized electron, polarized hadron
- new frontiers in precision QCD tests in inclusive DIS:
  - new sum rules: is there new dynamics to be tested or is it a trivial isospin rotation of original Bjorken sum rule?
  - More comprehensive exploration of twist-3 terms (Bluemlein)
  - \( Q^2 \) evolution carries new dynamics?

\[ \begin{align*}
1^H & : \quad \frac{2\Delta u^- + \Delta d^- + \Delta s^-}{4u^+ + d^+ + s^+} \\
2^H & : \quad \frac{3\Delta u^- + 3\Delta d^- + 2\Delta s^-}{u^+ + d^+ + 2s^+} \\
3^H & : \quad \frac{\Delta u^+ + \Delta d^+ + \Delta s^+}{4u^+ + d^+ + s^+}
\end{align*} \]

- EW amplitudes measure a different linear combination of quark polarizations, allowing a determination of \( \Delta s \) without \( SU(3)_f \)
- initial indications: very competitive with semi-inclusive, phase 1 designs can make impact

★ Enough y range to separate vector and axial-vector pieces
★ \( ^1H, ^2H \) and \( ^3He \) measurements
★ Precise measurements to \( x \approx 0.01 \) at low \( s \) and \( x \approx 0.001 \) at high \( s \)
Spin Structure Functions

Start with focus on spin-dependent PDFs
- Check $A_{PV}$ form and QPM sensitivities
- Role of new structure function in global PDF fit
- Rates / sensitivities vs. machine energy/luminosity
- Detector & acceptance resolution issues: $x$ range

- **In the long term**, there are 15 different combinations that can be measured (EM, $\gamma Z$, W)
- W production needs to be fully explored:
  - two structure functions $g_1$ and $g_5$
  - $^1H + ^2H$ with $e^-$ equivalent to $^1H$ with $e^-$ & $e^+$
- Sum rules, $Q^2$ evolution, other implications
Charged Lepton Flavor Violation

\[ e^- + p \rightarrow \tau^- + X \]

Topology: neutral current DIS event; except that the electron replaced by tau lepton

- If mixed in with hadron remnants, the tau would be boosted
- If forward in the incident electron direction, the tau would be isolated
- Potential for clean identification with high efficiency:
  - look for single pion, three pions in a narrow cone, single muon: should be able to devise several good triggers
  - tau vertex displaced 200 to 3000 microns: would greatly help background rejection and maintain high efficiency if vertex detector is included in EIC detector design

Must also investigate the sensitivity and motivation for

*Lepton Number Violation* \[ e^- + p \rightarrow \mu^+ + X \quad e^- + p \rightarrow \tau^+ + X \]

- theoretical homework suggests better than 0.1 fb sensitivity may be valuable
- Experimental signature and detection issues
- Monte Carlo study to design cuts
- efficiency and background rejection

\[ e^- + p \rightarrow \pi^- + X \]
High x Structure Functions

\[ A_{PV} = \frac{G_F Q^2}{2 \sqrt{2} \pi \alpha} \left[ g_A \frac{F_1^{\gamma Z}}{F_1^\gamma} + g_V \frac{f(y) F_3^{\gamma Z}}{2 F_1^\gamma} \right] \]

*APV in Electron-Nucleon DIS:*

- polarized electron, unpolarized hadron

Program to map this out at high x (x~0.3-0.7) with high precision (SOLID at JLab-12GeV)
- \( C_{2q} \)'s and \( \sin^2 \theta_w \)
- CSV
- higher twist

For \(^2\text{H},\) assuming charge symmetry, structure functions largely cancel in the ratio:

\[
\begin{align*}
A_{PV} &= \frac{G_F Q^2}{\sqrt{2} \pi \alpha} \left[ a(x) + f(y) b(x) \right] \\
 a(x) &= \frac{3}{10} \left[ (2C_{1u} - C_{1d}) \right] + \cdots \\
 b(x) &= \frac{3}{10} \left[ (2C_{2u} - C_{2d}) \frac{u_v(x) + d_v(x)}{u(x) + d(x)} \right] + \cdots
\end{align*}
\]

It is hard to beat fixed-target luminosity

- SOLID aims for many bins at measuring APV at 0.5%. At an EIC, this would seem to require \( 10^{35} \text{ cm}^{-2} \) at very high s.

- Mapping out potential DIS measurements should still be done
  - independent constraint on \( C_{2q} \)'s
  - determine relevant ranges of electron angle and \( E' \)
Higher Twist

- Collider advantage: Larger $Q^2$ range - higher twist is accessible

Small $y$ variation for large $Q^2$ variation, focus on higher twist is $a(x)$ term
Higher Twist

- Collider advantage: Larger $Q^2$ range - higher twist is accessible

Small $y$ variation for large $Q^2$ variation, focus on higher twist is $a(x)$ term
Jet Kinematics
x Resolution requires measurement of jet

Jacquet-Blondel reconstruction

Constant $F_{JB}$ contours

\[
\cos \gamma_h = \frac{P_{T,h}^2 - (E_h - P_{z,h})^2}{P_{T,h}^2 + (E_h - P_{z,h})^2}
\]
\[
F_h = \frac{P_{T,h}^2 + (E_h - P_{z,h})^2}{2(E_h - P_{z,h})}
\]

Jacquet-Blondel reconstruction
Plan for high x structure functions

Best prospect: higher twist
potentially large effects (?) and relatively low $Q^2$
• Rates / sensitivities vs. machine energy/luminosity
• Detector acceptance & resolution issues (including jet measurements)

map high-x $C_{iq}$ impact
difficult to improve significantly on SOLID
• Rates / sensitivities vs. machine energy/luminosity
• Detector issues (jet reconstruction, e-/Jet hybrid)
• separation of $C_{2q}$ term from $C_{1q}$

Additional high x structure functions
CSV (eD), d/u (ep) at high-x
Nuclear Structure Functions

- They propose that a neutron or proton excess in nuclei leads to an isovector–vector mean field dominated by $\rho$ exchange
- shifts quark distributions: “apparent” CSV violation
- Isovector EMC effect: explain 1/2 of NuTeV anomaly

Would be a smoking gun demonstration of medium modification

It is hard to beat fixed-target luminosity

More generally, $F_2(\gamma Z)$ and $F_3(\gamma Z)$ for nuclear DIS interesting and new

EMC effect with nuclei
- polarized e- with A?
- inclusive rates for eA at low x, with y separation
- nuclear $F_3\gamma Z$
- x range
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