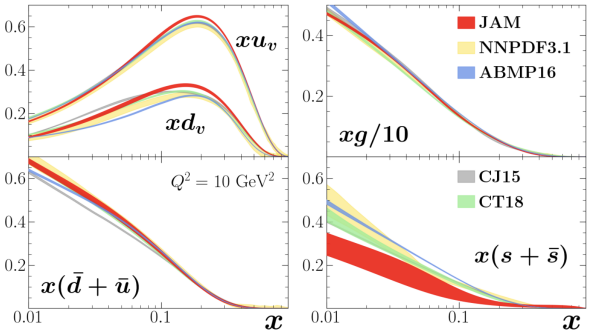
Impact of parity-violating DIS on the nucleon strangeness and weak mixing angle

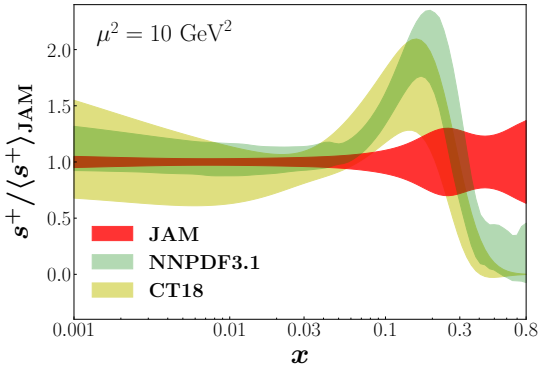
Richard Whitehill

Collaborators: M. M. Dalton, T. Liu, W. Melnitchouk, J. Qiu, and N. Sato

Current Status – PDFs

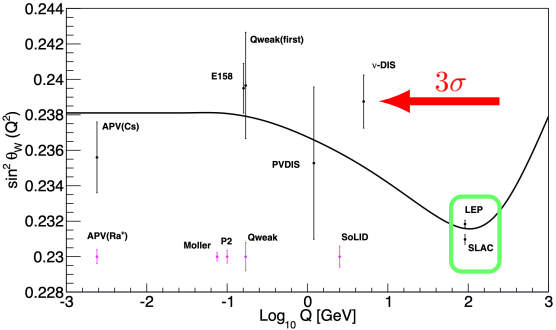


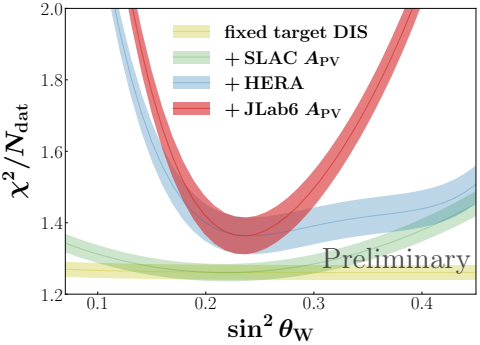
C. Cocuzza, W. Melnitchouk, A. Metz, N. Sato
Phys.Rev.D 104 (2021)



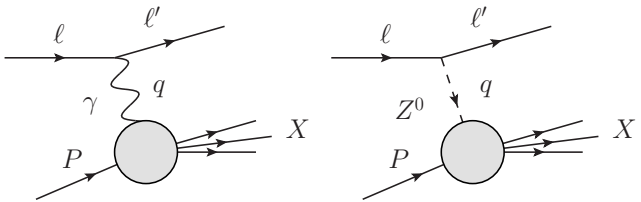
T. Anderson, et al. In preparation (2024)

Current Status – $\sin^2\theta_{\mathrm{W}}$

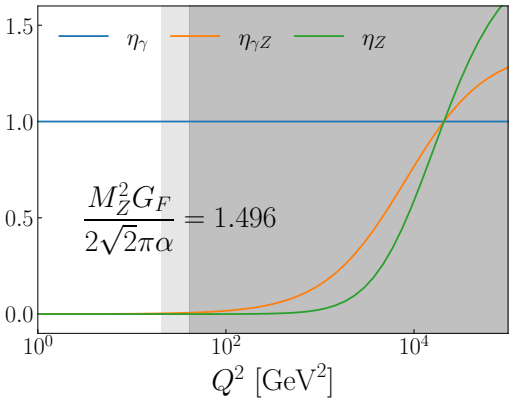




Parity-Violating Deep-Inelastic Scattering (PVDIS)



$$\frac{\mathrm{d}\sigma_{\lambda_\ell}}{\mathrm{d}x_\mathrm{B}\,\mathrm{d}y} = \frac{2\pi\alpha^2 y}{Q^4}\sum_i \eta_i C_i L^\gamma_{\mu\nu} W^{\mu\nu}_{i,U}$$



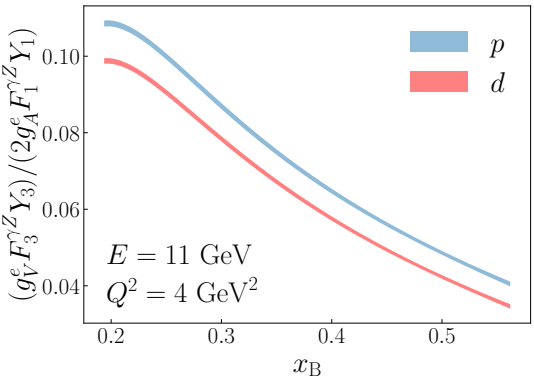
Parity-Violating Asymmetry

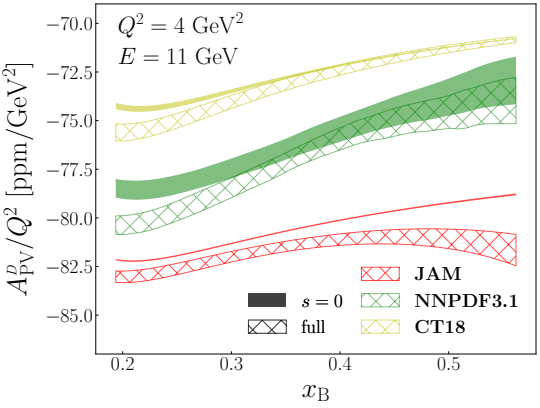
$$A_{\mathrm{PV}} = \frac{\mathrm{d}\sigma_+ - \mathrm{d}\sigma_-}{\mathrm{d}\sigma_+ + \mathrm{d}\sigma_-} \approx \frac{G_F Q^2}{4\sqrt{2}\pi\alpha}\left[2g_A^e \frac{F_1^{\gamma Z}}{F_1^\gamma} Y_1 + g_V^e \frac{F_3^{\gamma Z}}{F_1^\gamma} Y_3\right]$$

$$Y_1 = \left(\frac{1+R^{\gamma Z}}{1+R^\gamma}\right)\frac{1+(1-y)^2 - \frac{y^2}{2}\left[1+r^2 - \frac{2r^2}{1+R^{\gamma Z}}\right]}{1+(1-y)^2 - \frac{y^2}{2}\left[1+r^2 - \frac{2r^2}{1+R^{\gamma}}\right]}, \quad r^2 = 1 + 4M^2 x_{\mathrm{B}}^2/Q^2$$

$$Y_3 = \left(\frac{1+R^{\gamma Z}}{1+R^\gamma}\right)\frac{1-(1-y)^2}{1+(1-y)^2 - \frac{y^2}{2}\left[1+r^2 - \frac{2r^2}{1+R^{\gamma}}\right]}, \quad R^i = \frac{F_2^i}{2x_{\mathrm{B}}F_1^i}r^2 - 1$$

A_{PV} on a deuterium target

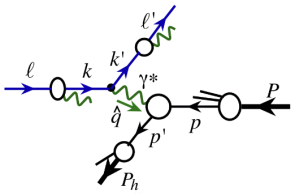




$$A_{\mathrm{PV}}^D \approx -\frac{G_F Q^2}{4\sqrt{2}\pi\alpha}\left[\left(\frac{9}{5} - 4\sin^2\theta_{\mathrm{W}}\right) + \frac{2}{25}\frac{s^+}{u^+ + d^+}\right]$$

QED radiative effects

$$\frac{\mathrm{d}\sigma}{\mathrm{d}x_\mathrm{B}\,\mathrm{d}y} = \int_{\zeta_\mathrm{min}}^1 \frac{\mathrm{d}\zeta}{\zeta^2} \underbrace{D_{e/e}(\zeta,\mu^2)}_{\mathrm{LFF}} \int_{\xi_\mathrm{min}}^1 \mathrm{d}\xi\, \underbrace{f_{e/e}(\xi,\mu^2)}_{\mathrm{LDF}} \left[\frac{Q^2}{x_\mathrm{B}}\frac{\hat{x}_\mathrm{B}}{\hat{Q}^2}\right] \frac{\mathrm{d}\hat{\sigma}}{\mathrm{d}\hat{x}_\mathrm{B}\,\mathrm{d}\hat{y}}$$



T. Liu et al.
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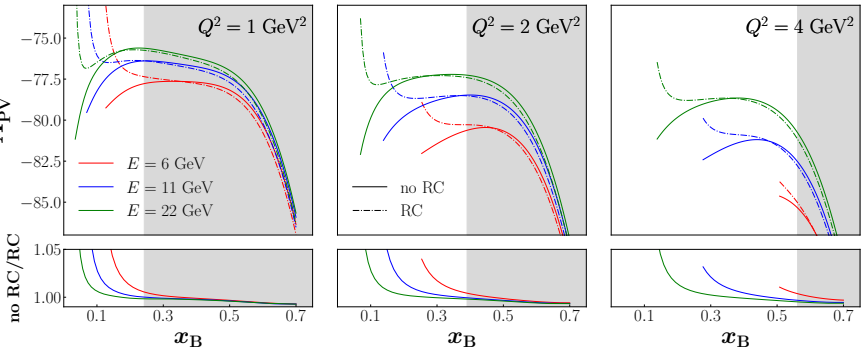


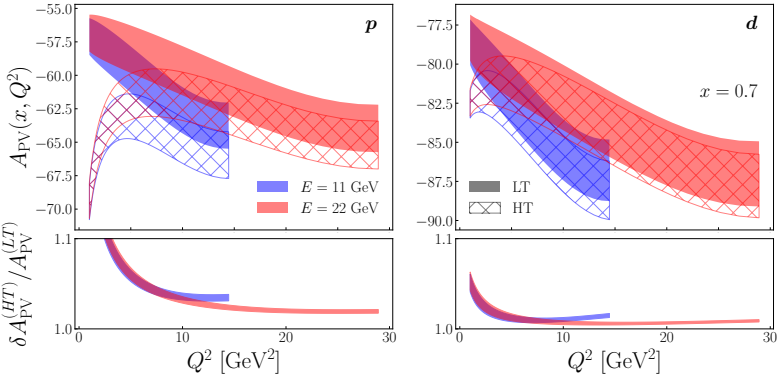
Higher Twist Corrections

$$F_i^\gamma = F_{i,LT}^\gamma \left(1 + \frac{H_i^\gamma}{Q^2}\right)$$

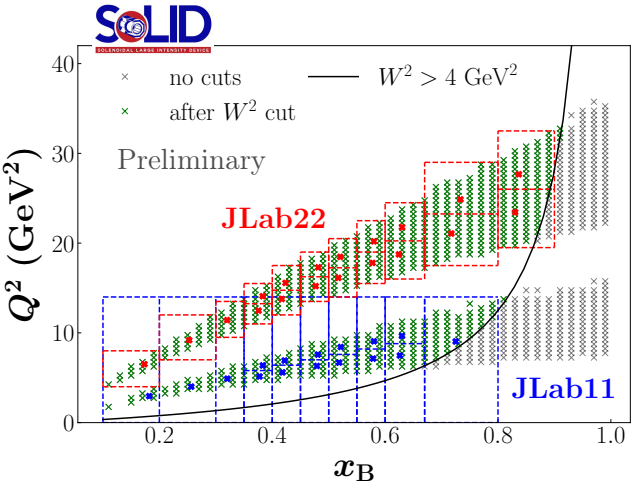
$$F_i^{\gamma Z} = F_{i,LT}^{\gamma Z} \left(1 + \frac{H_i^{\gamma Z}}{Q^2}\right)$$

Model:

$$\rightarrow F_{i,LT}^{\gamma Z} H_i^{\gamma Z} = R\, F_{2,LT}^{\gamma} H_i^{\gamma}$$



Simulating pseudo-data



Scenarios:

1. statistical uncertainties + experimental systematics
2. (1) + QED effects
3. (2) + HT effects

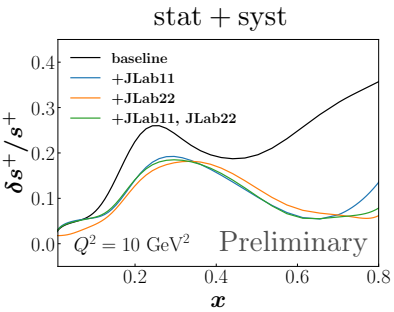
Note:

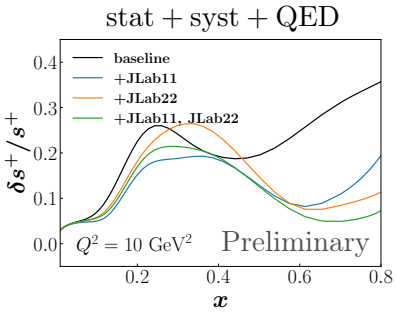
$\rightarrow P = 85\%$

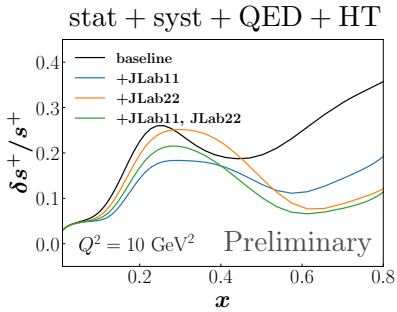
$\rightarrow \mathrm{d}\mathcal{L}/\mathrm{d}t = 4.85 \times 10^{38}$ cm^{-2} s^{-1}

$\rightarrow$ run time: 50 days/target

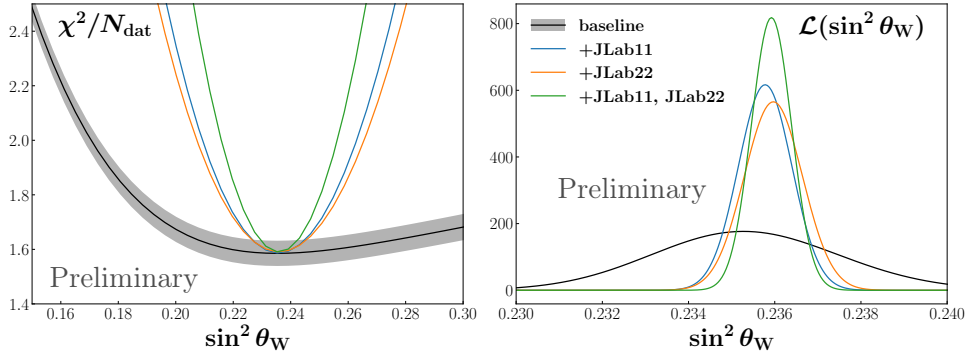
Impact on s^+


stat + syst
baseline
+JLab11
+JLab22
+JLab11, JLab22
$\delta s^+/s^+$
$Q^2 = 10$ GeV^2
Preliminary
x

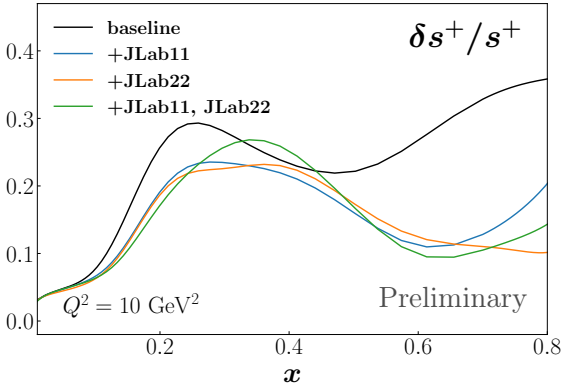

stat + syst + QED
baseline
+JLab11
+JLab22
+JLab11, JLab22
$\delta s^+/s^+$
$Q^2 = 10$ GeV^2
Preliminary
x

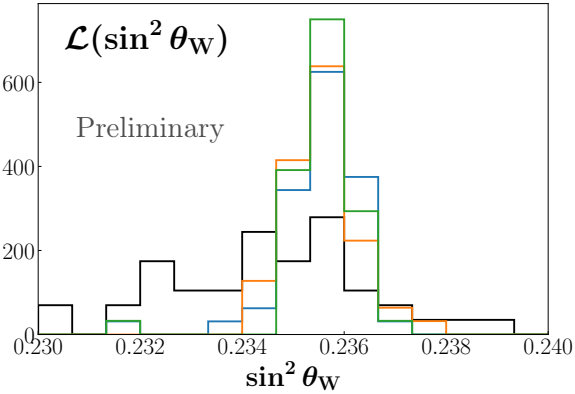

stat + syst + QED + HT
baseline
+JLab11
+JLab22
+JLab11, JLab22
$\delta s^+/s^+$
$Q^2 = 10$ GeV^2
Preliminary
x

Impact on $\sin^2\theta_{\mathrm{W}}$



Combined impact on $\sin^2\theta_{\mathrm{W}}$ and s^+





Summary and Outlook

- A_{PV} is a unique and clean observable that can be used in future global analyses to make progress toward

$\rightarrow$ constraint of nucleon strangeness for better understanding of nucleon structure

$\rightarrow$ tests of BSM physics through the determination of the weak mixing angle

- Future work:

$\rightarrow$ electron/positron PVDIS for constraint of sea quark asymmetries

$\rightarrow$ Charge symmetry violation

$\rightarrow$ Polarized A_{PV}?