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

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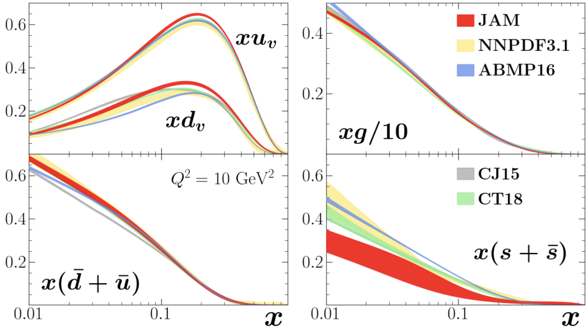
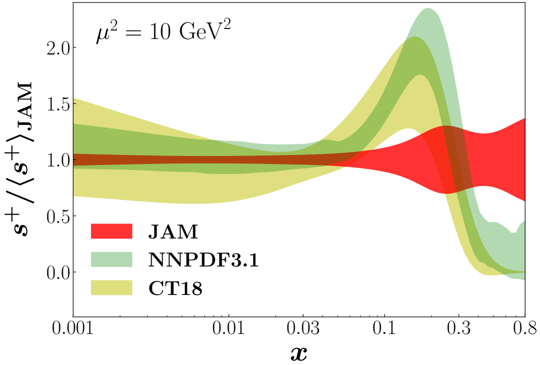
Current Status – PDFs





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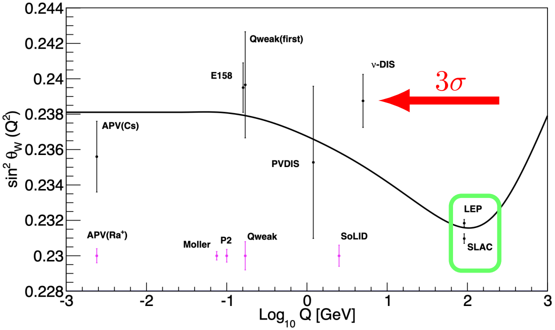
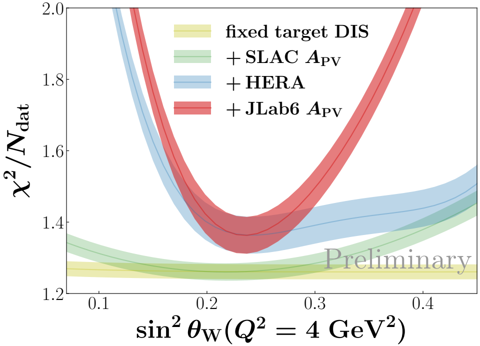
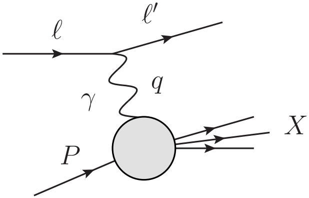
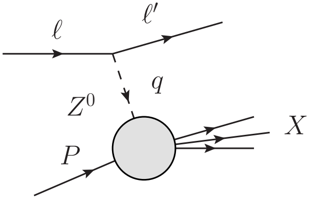
Current Status – $\sin^2\theta_W$

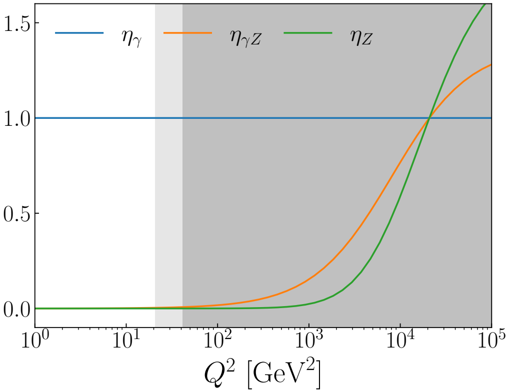




Parity-Violating Deep-Inelastic Scattering (PVDIS)







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

Parity-Violating Asymmetry

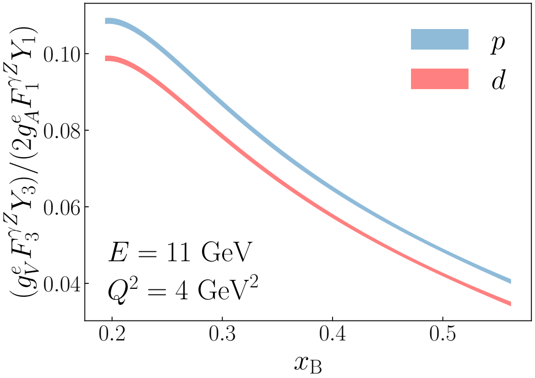
$$A_{\mathrm{PV}} = \frac{\mathrm{d}\sigma_+ - \mathrm{d}\sigma_-}{\mathrm{d}\sigma_+ + \mathrm{d}\sigma_-} \approx \frac{G_F Q^2}{4\sqrt{2}\pi\alpha}\left[2g_A^e \frac{F_1^{\gamma Z}}{F_1^{\gamma}} Y_1 + g_V^e \frac{F_3^{\gamma Z}}{F_1^{\gamma}} Y_3\right]$$

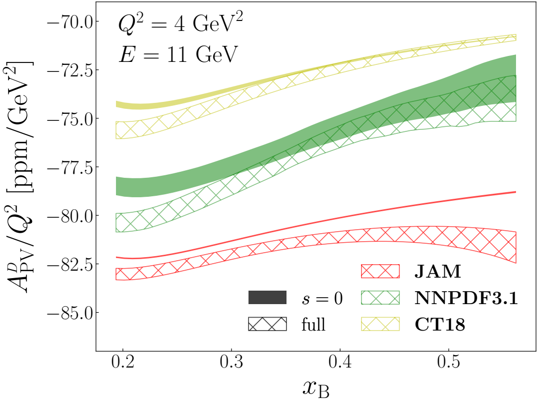
$$g_A^e = -1/2, \quad g_V^e = -1/2 + 2\sin^2\theta_{\mathrm{W}}$$

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

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

A_{PV} on a deuterium target

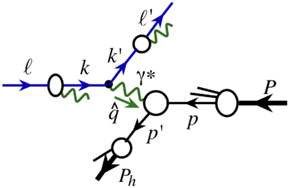




$$A_{\mathrm{PV}}^D \approx -\frac{G_F Q^2}{4\sqrt{2}\pi\alpha}\left[\left(\frac{9}{5} - 4\sin^2\theta_\mathrm{W}\right) + \frac{2}{25}\frac{s^+}{u^+ + d^+}\right]$$

QED radiative effects

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



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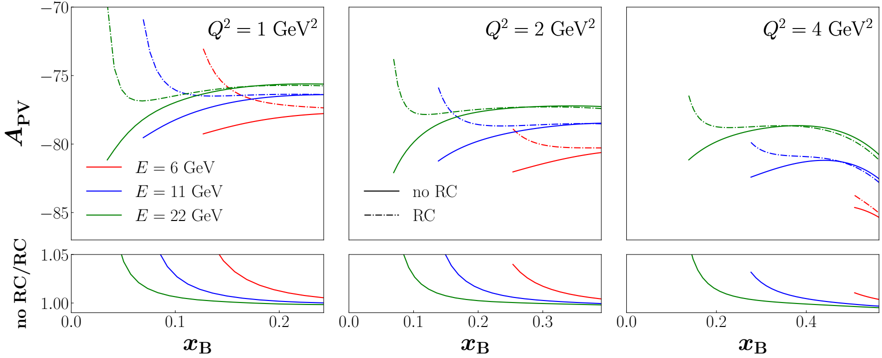


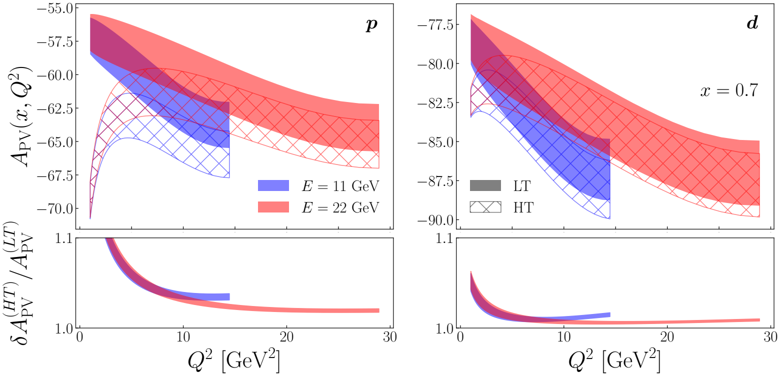
Higher Twist Corrections

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

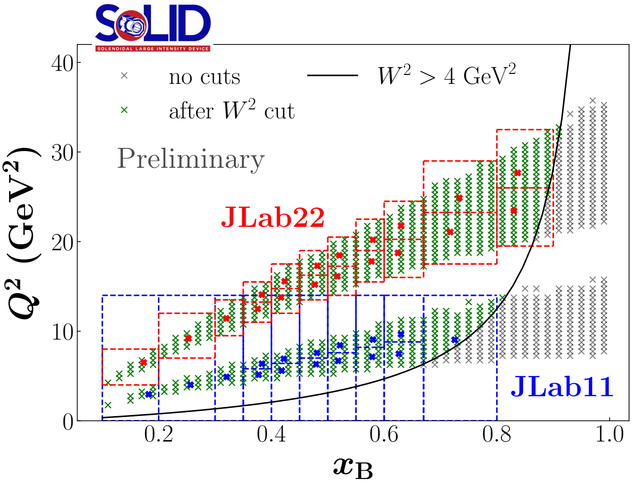
$$F_i^{\gamma Z} = F_{i,LT}^{\gamma Z}\left(1 + \frac{H_i^{\gamma Z}}{Q^2}\right)$$

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:

$\rightarrow P = 85\%$

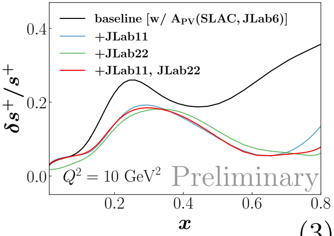
$\rightarrow \mathrm{d}\mathcal{L}/\mathrm{d}t = 4.85 \times 10^{38}\ \mathrm{cm}^{-2}\ \mathrm{s}^{-1}$

$\rightarrow$ run time: 50 days/target

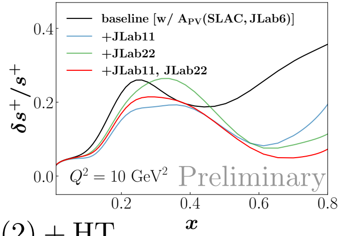
$\rightarrow \delta^{\rm syst} A_{\rm PV} = 0.5\%$

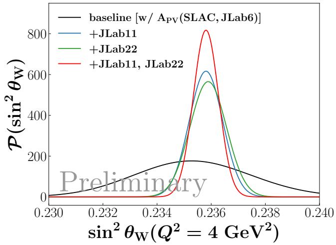
Separate impact on PDFs and $\sin^2\theta_W$

(1): stat + exp

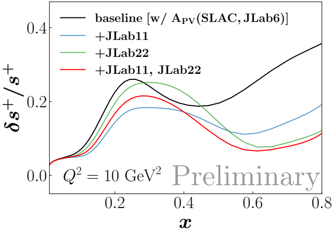


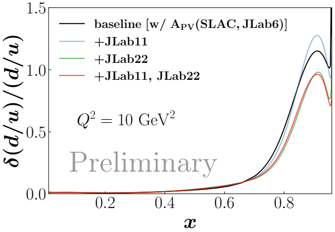
(2): (1) + QED



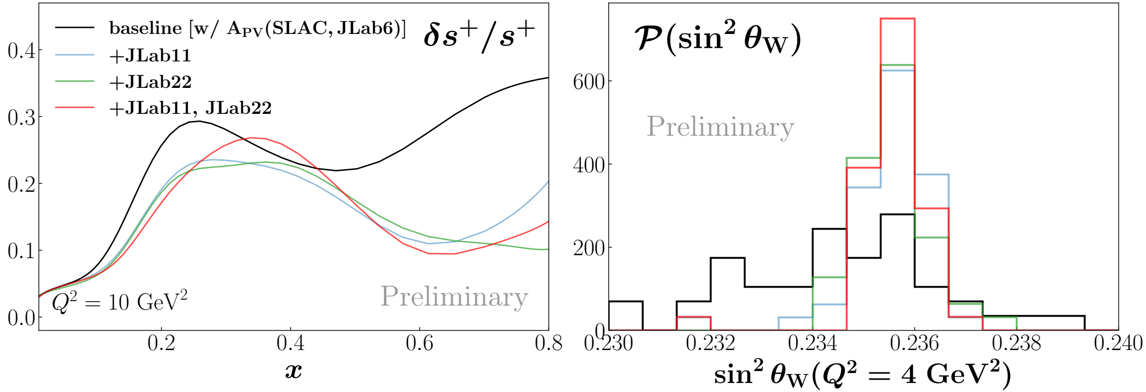


(3): (2) + HT





Combined impact on PDFs and $\sin^2\theta_W$



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:

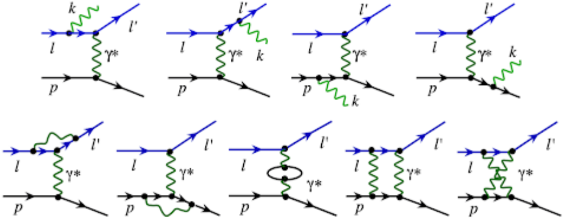
$\rightarrow$ electron/positron PVDIS for constraint of sea quark asymmetries

$\rightarrow$ Charge symmetry violation

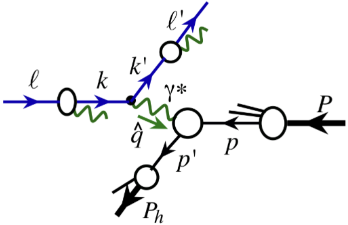
$\rightarrow$ Polarized A_{PV}?

Backup Slides

Hybrid QED+QCD factorization



QED
resummation



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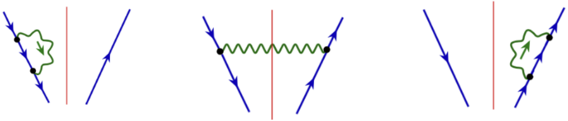
$$f_{i/e}(\xi) = \int \frac{\mathrm{d}z^-}{4\pi} e^{i\xi\ell^+z^-} \langle e|\overline{\psi}_i(0)\gamma^+\Phi_{[0,z^-]}\psi_i(z^-)|e\rangle$$

$$D_{e/j}(\zeta) = \frac{\zeta}{2}\sum_X \int \frac{\mathrm{d}z^-}{4\pi} e^{i\ell^+z^-/\zeta}\mathrm{Tr}\Big[\gamma^+ \langle 0|\overline{\psi}_j(0)\Phi_{[0,\infty]}|e,X\rangle\ \langle e,X|\psi_j(z^-)\Phi_{[z^-,\infty]}|0\rangle\Big]$$

LDF and LFF RGE



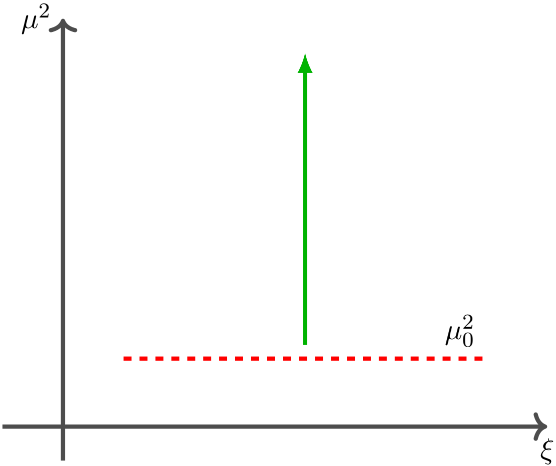
$$f^{(0)}_{e/e}(\xi,\mu_0^2) = \delta(\xi - 1)$$

$$f^{(1)}_{e/e}(\xi,\mu_0^2) = \frac{\alpha}{2\pi}\left[\frac{1+\xi^2}{1-\xi}\ln\frac{\mu_0^2}{(1-\xi)^2 m_e^2}\right]_+$$

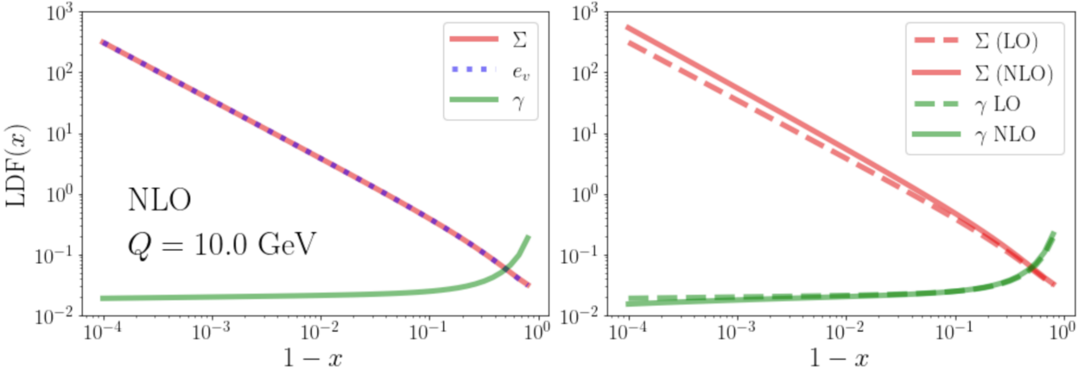
$$D^{(0)}_{e/e}(\zeta,\mu_0^2) = \delta(\zeta - 1)$$

$$D^{(1)}_{e/e}(\zeta,\mu_0^2) = \frac{\alpha}{2\pi}\left[\frac{1+\zeta^2}{1-\zeta}\ln\frac{\mu_0^2}{(1-\zeta)^2 m_e^2}\right]_+$$

$$\frac{\partial f_{i/\ell}(\xi,\mu^2)}{\partial \ln \mu^2} = \sum_j \int_\xi^1 \frac{\mathrm{d}z}{z} P_{ij}(z) f_{j/\ell}\left(\frac{z}{\xi},\mu^2\right)$$



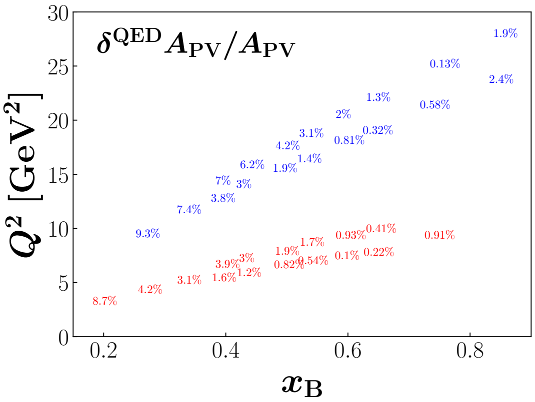
LDFs and LFFs

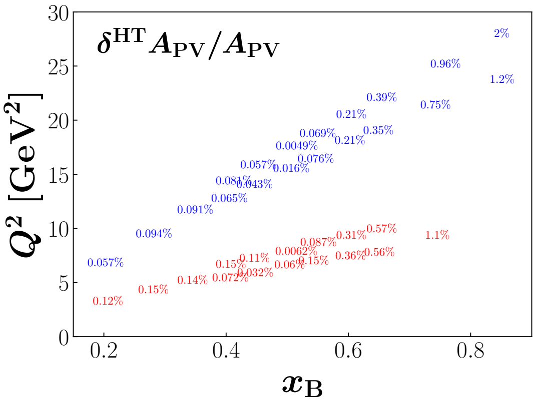


Subtraction "trick":

$$\to \int_{\xi_{\min}}^{1} \mathrm{d}\xi\, \mathcal{H}(\xi) f(\xi) = \int_{\xi_{\min}}^{1} \mathrm{d}\xi\, [\mathcal{H}(\xi) - \mathcal{H}(1)] f(\xi) + \mathcal{H}(1) \frac{\xi_{\min}}{2\pi i} \int \mathrm{d}N\, \xi_{\min}^{-N} \frac{F_N}{N-1}$$

Size of QED and HT systematics





Impact on s^+ with proton data

$$\mathcal{F} = 5F_{2,p}^{\gamma Z} - 4F_{2,D}^{\gamma} \sim xs^+$$