https://indico.bnl.gov/event/8110/timetable/

Center for Frontiers in Nuclear Science

Electroweak and BSM physics at the EIC

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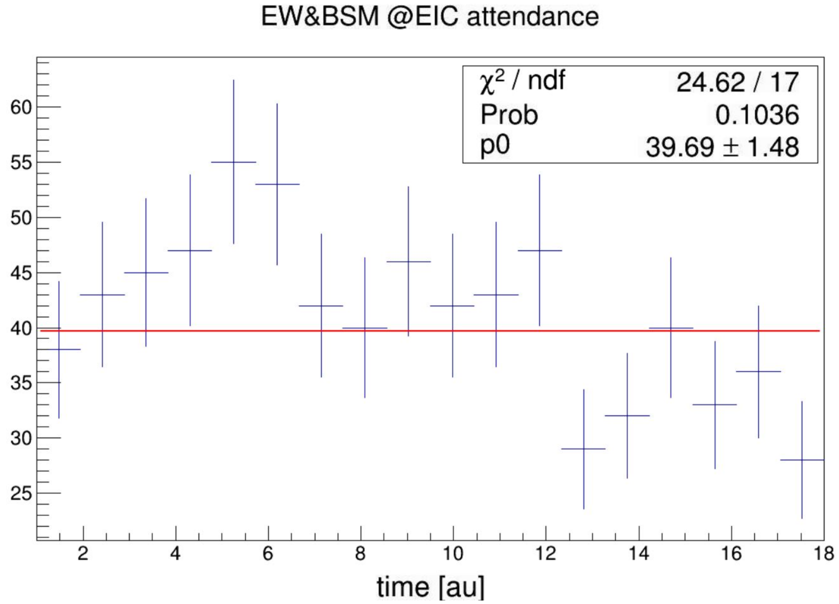
Aim of this exercise :

Without changing the central goals of the US electron ion collider, what physics could be done of interest to the community of scientists outside of NP? (⇒ HEP)

This is NOT an attempt to influence the central thrusts of the EIC science case, and its core planning but rather to augment them with things we may not yet have been explored.



If there are investigations of high interest outside of core NP, then this is an attempt to identify, and understand what modifications if any may be needed to the EIC project & planning.

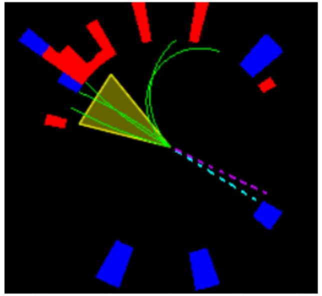
Outline and disclaimer

- Overview of salient outcomes of dedicated EIC workshop on EW and BSM physics
  - Highlight of some physics that may not have gotten regular updates within the YR effort
- Outline
  - Impact on large x PDFs
  - Physics with positron beams
  - NC parity violating asymmetries
  - Charge symmetry violation
  - Charge lepton flavor violation
  - Beyond the Standard Model sensitivities
  - Possible future studies

Jets in CC DIS
for 3D imaging

Miguel Arratia

UC RIVERSIDE
UNIVERSITY OF CALIFORNIA



T Violation Search at the EIC?

IUCSS

Mike Snow

Indiana University/CEEM

IU Center for Spacetime Symmetries

INDIANA UNIVERSITY

The scientific motivation

Impact on HEP extractions

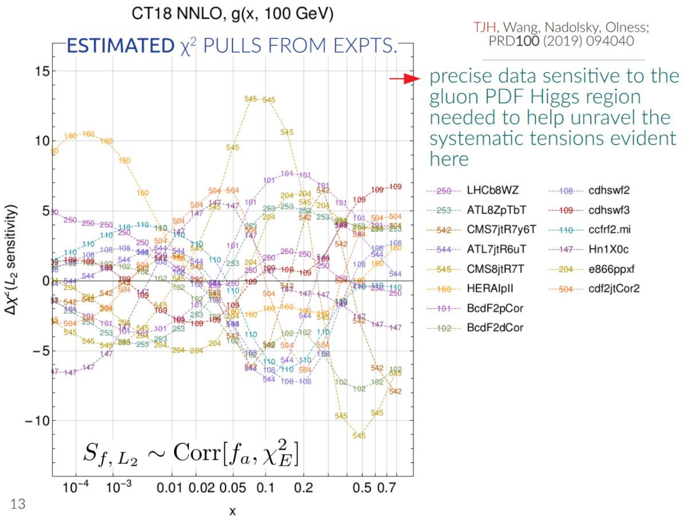
Tim Hobbs

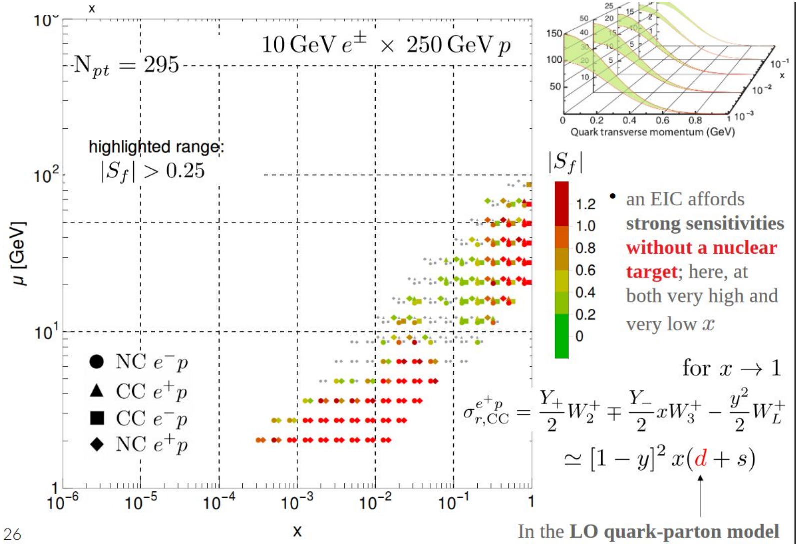
EIC and LHC workshop

ATLAS, 1701.07240 — for example:

Channel	$m_{W^+} - m_{W^-}$ [MeV]	Stat. Unc.	Muon Unc.	Elec. Unc.	Recoil Unc.	Bckg. Unc.	QCD Unc.	EW Unc.	PDF Unc.	Total Unc.
$W \to e\nu$	−29.7	17.5	0.0	4.9	0.9	5.4	0.5	0.0	24.1	30.7
$W \to \mu\nu$	−28.6	16.3	11.7	0.0	1.1	5.0	0.4	0.0	26.0	33.2
Combined	−29.2	12.8	3.3	4.1	1.0	4.5	0.4	0.0	23.9	28.0

- The limitations on HEP extractions are mostly coming from PDF uncertainties
- We have reached a limit on extractions using the current data as they pull in different directions
  - The EIC would play the vital role as a arbiter (particularly with high precision dataset)
- Measuring both NC and CC for electron and positron beams allows for a simple deconvolution without nuclear effects





Positron beams

Interference Physics
- Two-photon physics
- Generalized parton distributions

Structure Functions
- Neutral and charged currents DIS
- Charm production
- Pion and kaon structure

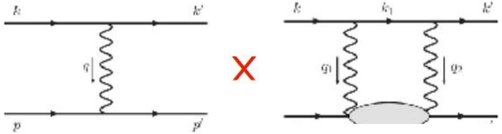
Standard Model Tests
- Charge conjugation violation
- Right-handed W-bosons
- Dark photon search
- Leptoquarks, leptogluons

Charged current measurements in $e^{\pm}p$ DIS are potentially capable of improving our knowledge of PDFs by providing:

- Better constraints on d/u in the large x region
- Additional constraints on $\bar{d}/\bar{u}$ to complement information from lepton pair production
- Constraints on $\frac{s+\bar{s}}{\bar{u}+\bar{d}}$ without the need for nuclear corrections

Two photon exchange contribution changes sign for e+ and e-

$\mathcal{M}_0$ X $\mathcal{M}_{\gamma\gamma}$



$$R_{2\gamma} = \frac{\sigma^{e^+}}{\sigma^{e^-}} \approx 1 - 2\delta_{\gamma\gamma} \qquad \delta^{(2\gamma)} = \frac{2\mathcal{R}e\left\{\mathcal{M}_0^\dagger\, \mathcal{M}_{\gamma\gamma}\right\}}{|\mathcal{M}_0|^2}$$

Exclusive photon production

Eric Voutier — IJCLab Irène Joliot-Curie

Beam Charge Asymmetries

Using polarized electron and positron beams, we are proposing to measure

- The unpolarized beam charge asymmetry A^C_{UU}, which is sensitive to the **CFF real part**
- The polarized beam charge asymmetry A^C_{LU}, which is sensitive to the **CFF imaginary part**
- The charge averaged beam spin asymmetry A^0_{LU}, which is sensitive to **higher twist effects**

New GPD Observables

$$A^C_{UU} = \frac{(Y^+_+ + Y^+_-) - (Y^-_+ + Y^-_-)}{Y^+_+ + Y^+_- + Y^-_+ + Y^-_-} = \frac{\sigma_{INT}}{\sigma_{BH} + \sigma_{DVCS}}$$

$$A^C_{LU} = \frac{(Y^+_+ - Y^+_-) - (Y^-_+ - Y^-_-)}{Y^+_+ + Y^+_- + Y^-_+ + Y^-_-} = \frac{\tilde{\sigma}_{INT}}{\sigma_{BH} + \sigma_{DVCS}}$$

$$A^0_{LU} = \frac{(Y^+_+ + Y^-_+) - (Y^+_- + Y^-_-)}{Y^+_+ + Y^+_- + Y^-_+ + Y^-_-} = \frac{\tilde{\sigma}_{DVCS}}{\sigma_{BH} + \sigma_{DVCS}}$$

NC extractions

Yuxiang Zhao

Eur. Phys. J. A, 53 3 (2017) 55

With parity violation and $Q^2 << Z^2$

Inclusive electron measurements

pol. electron & unpol. nucleon:

$$A_{beam} = \frac{G_F Q^2}{2\sqrt{2}\pi\alpha}\left[g_A^e \frac{F_1^{\gamma Z}}{F_1^{\gamma}} + g_V^e \frac{Y_-}{2Y_+}\frac{F_3^{\gamma Z}}{F_1^{\gamma}}\right]$$

$$F_1^{\gamma Z} = \sum_f e_{q_f}(g_V)_{q_f}(q_f + \bar{q}_f)$$

$$F_3^{\gamma Z} = 2\sum_f e_{q_f}(g_A)_{q_f}(q_f - \bar{q}_f)$$

unpol. electron & pol. nucleon:

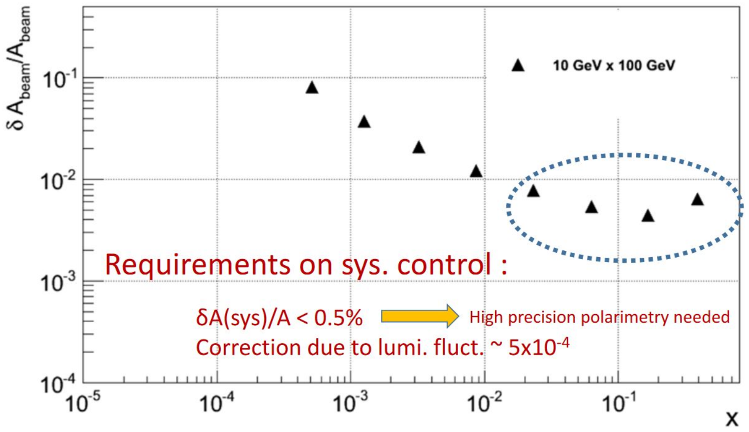
$$A_L = \frac{G_F Q^2}{2\sqrt{2}\pi\alpha}\left[g_V^e \frac{g_5^{\gamma Z}}{F_1^{\gamma}} + g_A^e \frac{Y_-}{Y_+}\frac{g_1^{\gamma Z}}{F_1^{\gamma}}\right]$$

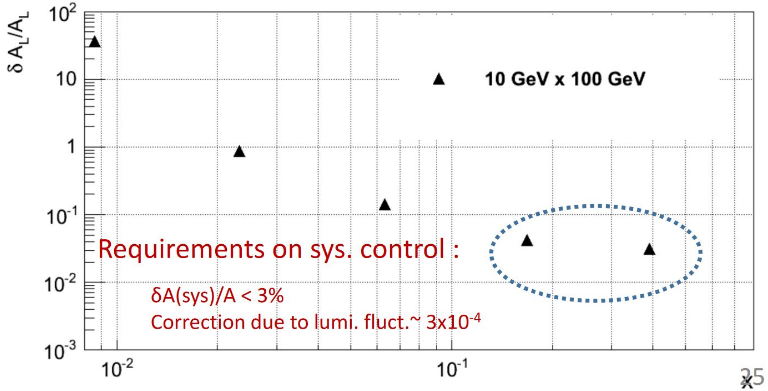
$$g_1^{\gamma Z} = \sum_f e_{q_f}(g_V)_{q_f}(\Delta q_f + \Delta\bar{q}_f)$$

$$g_5^{\gamma Z} = \sum_f e_{q_f}(g_A)_{q_f}(\Delta q_f - \Delta\bar{q}_f)$$

e-p collisions	10x100, 10x250, 15x100, 15x250
Integrated luminosity	500 fb^{-1}
Proton (electron) beam polarization	70% (80%)

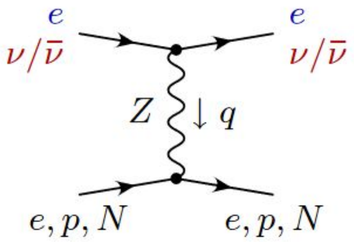
		Barrel ($-1.1 < \eta < 1.1$)	electron going direction
Tracking	θ (mrad)	10	1
	ϕ (mrad)	0.3	0.3
	$\frac{dp_T}{p_T}$	0.65% (+) 0.09% * p_T	0.65% (+) 1% * p_T
EMCal:	$\frac{dE}{E}$	3% (+) 11.7%/ $\sqrt{E}$	1% (+) 2.5%/ $\sqrt{E}$





Weak mixing angle extractions

Ayres Freitas



$$A_{LR}^{ep} \approx \frac{\sigma_L - \sigma_R}{\sigma_L + \sigma_R} = \frac{G_\mu(-q^2)}{4\sqrt{2}\pi\alpha} Q_W(p)$$

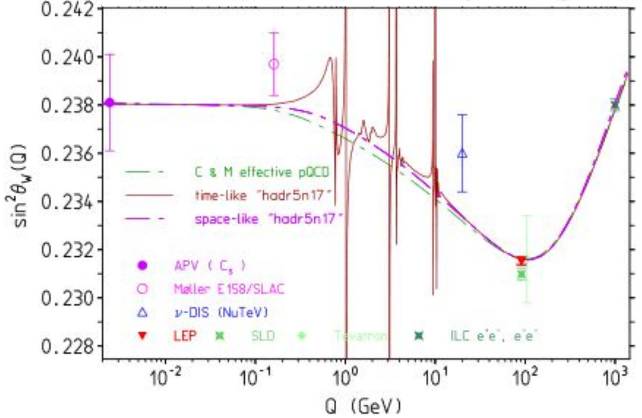
$$y \approx \tfrac{1}{2}(1 - \cos\theta_{CM})$$

$$Q_W(e) = Q_W(p) = 1 - 4\sin^2\theta_W$$

- Radiative corrections must be included:

$$1 - 4\sin^2\theta_W \quad \rightarrow \quad [1 - 4\kappa(\mu)\sin^2\bar{\theta}(\mu)] + \Delta Q(\mu)$$

$$\Delta_{\gamma Z} = \sum_f (I_{3f}Q_f - 2s^2Q_f^2)\ln m_f^2/M_Z^2$$



At the EIC

$$A_{LR}^{ep} \approx \frac{\sigma_L - \sigma_R}{\sigma_L + \sigma_R} = \frac{G_\mu(-q^2)}{4\sqrt{2}\pi\alpha}\left[\frac{F_1^{\gamma Z}}{F_1^\gamma} + (1 - 4\sin^2\theta_W)\frac{y(1-y)}{1+(1-y)^2}\frac{F_3^{\gamma Z}}{F_1^\gamma}\right]$$

$$y = 1 - E'_e/E_e$$

Need precise knowledge of PDFs for 100 GeV^2 < Q2 < 5000 GeV^2

$$F_1^\gamma = \sum_q q_q(f_q + f_{\bar{q}})$$

$$F_1^{\gamma Z} = \sum_q q_q\, g_V^q(f_q + f_{\bar{q}})$$

$$F_1^{\gamma Z} = 2\sum_q q_q\, g_A^q(f_q + f_{\bar{q}})$$

- Polarized e^- on d for $Q^2 \gg \Lambda_{QCD}$
- d is iso-singlet $\rightarrow$ PDF dependence approximately cancels in LR asymmetry:
- Assuming valence quark dominance and charge symmetry:

$$f_u \approx f_d,$$
$$f_{\bar{u}} \approx f_{\bar{d}} \approx f_{s,c,b} \approx f_{\bar{s},\bar{c},\bar{b}} \approx 0$$

$$A_{LR}^{ep} \approx \frac{G_\mu(-q^2)}{4\sqrt{2}\pi\alpha}\left[\frac{9}{5} - \sin^2\theta_W + \frac{9}{5}(1 - 4\sin^2\theta_W)\frac{y(1-y)}{1+(1-y)^2}\right]$$

- Extractions from different ion will need a more complicated analysis

NC extractions

Yuxiang Zhao

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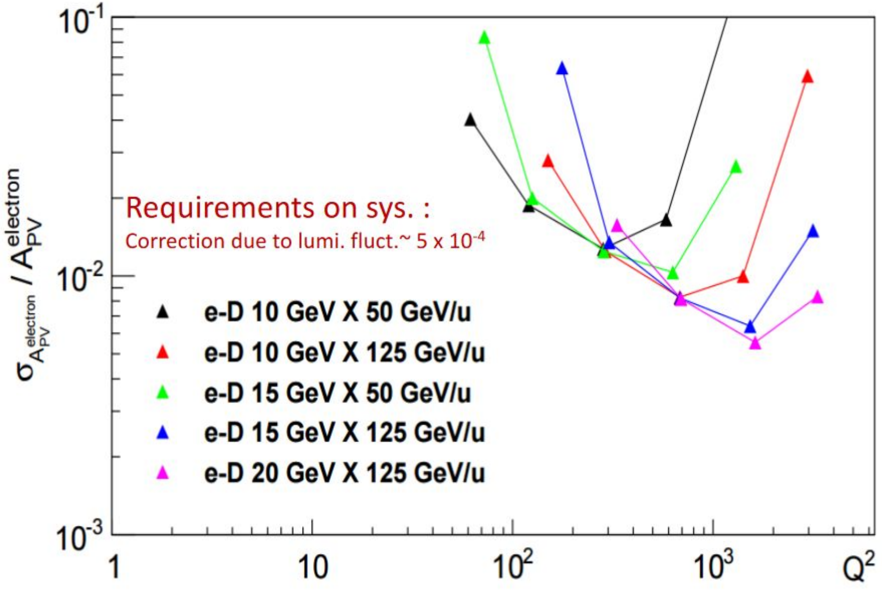

e-D collisions	10x50,10x125,15x50,15x125,20x125 GeV/u
Integrated luminosity	267 fb^{-1}
Electron beam polarization	80%

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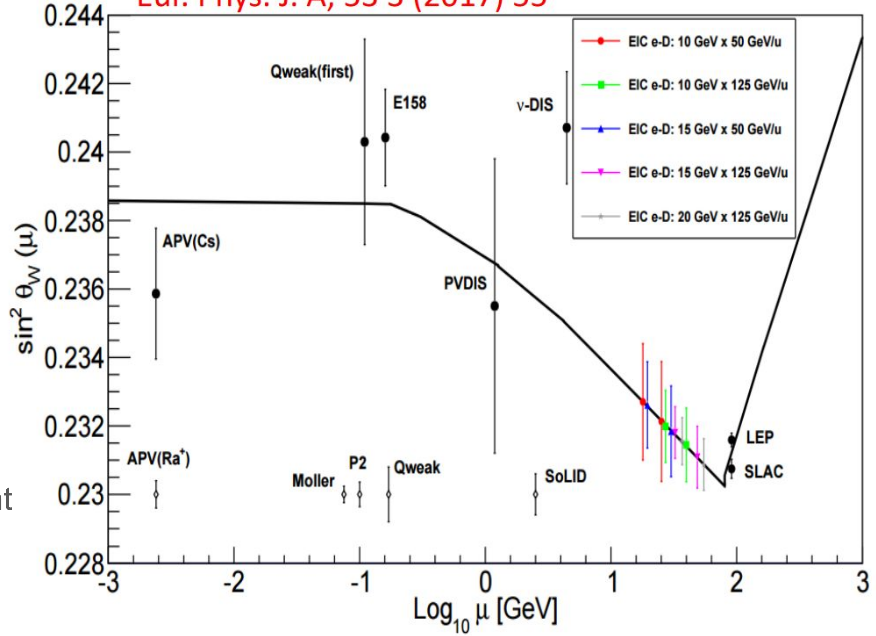


- The weak mixing angle extractions are in a region that has not been probed before and overall reach similar precisions as SoLID
- Beyond the weak mixing angle extractions Yuxiang made the point that together with the CC current measurements on deuteron we can obtain similar if not better precision than with positron beams

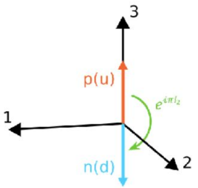
Charge symmetry violation

Phiala Shanahan

Charge symmetry

180° rotation about the '2' axis in isospin space

$$P_{CS} = e^{i\pi T_2}$$



Partonic charge symmetry relations

$$\begin{aligned} u^p(x,Q^2) &= d^n(x,Q^2) \\ d^p(x,Q^2) &= u^n(x,Q^2) \\ s^p(x,Q^2) &= s^n(x,Q^2) \\ c^p(x,Q^2) &= c^n(x,Q^2) \end{aligned}$$

Analogous for antiquark PDFs

Constrain $\sin^2\theta_W$ using parity-violating e-D scattering

$$A_{PV}^{eD}(x,y) = \frac{-G_F Q^2}{4\sqrt{2}\pi\alpha}\left[a_1^d + f(y)a_3^d\right]$$

CSV terms contribute to both couplings

$$a_1^d \to a_1^{d(0)} + \delta^{(CSV)}a_1^d \qquad a_3^d \to a_3^{d(0)} + \delta^{(CSV)}a_3^d$$

$$\frac{\delta^{(CSV)}a_1^d}{a_1^{d(0)}} = \left[-\frac{3}{10} + \frac{2g_V^u + g_V^d}{2(2g_V^u - g_V^d)}\right]\frac{\delta u(x) - \delta d(x)}{u(x)+d(x)}$$

$$\frac{\delta^{(CSV)}a_3^d}{a_3^{d(0)}} = \left[-\frac{3}{10} + \frac{2g_A^u + g_A^d}{2(2g_A^u - g_A^d)}\right]\frac{\delta u(x) - \delta d(x)}{u(x)+d(x)}$$

CSV contribution to parity-violating asymmetry is at the **sub-percent level**

Semi-inclusive pion production

Lepton DIS on isoscalar nuclear targets

$$\frac{1}{\sigma_N(x)}\frac{d\sigma_N^h(x,z)}{dz} = \frac{N^{Nh}(x,z)}{\sum_i e_i^2 q_i^N(x)}$$

Yield of hadron h per scattering from nucleon N

$$R^\Delta(x,z) \equiv \frac{8\left(\frac{N^{D\pi^-}(x,z)}{1+4\Delta(z)} - \frac{N^{D\pi^+}(x,z)}{4+\Delta(z)}\right)}{N^{D\pi^+}(x,z) - N^{D\pi^-}(x,z)}$$

$$= C^\Delta(z)\left[R_{CS}(x) + R_{SV}(x,z)\right]$$

CSV

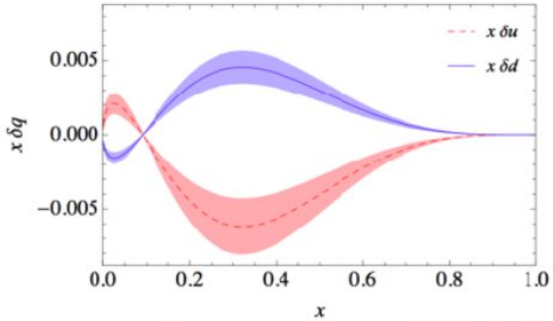
Sea-valence interference term, less important at large x

$$R_{CS}(x) = \frac{4(\delta d_v(x) - \delta u_v(x))}{3(u_v(x)+d_v(x))}$$

- CSV terms substantial for x>0.4
- Determine CSV via measurement of x-dep of R for fixed z

- Requires that factorisation be valid to a few percent

- Theory and lattice QCD calculations suggest ~1% level in valence PDFs



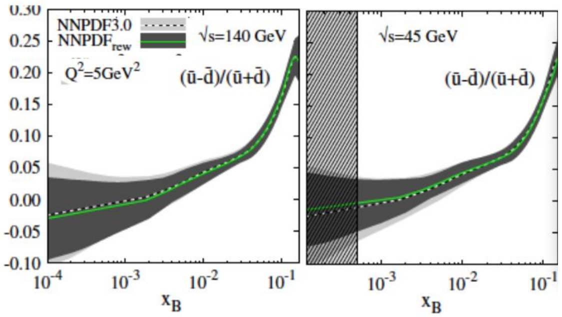
Young, PES, Thomas [arXiv:1312.4990]

Charge symmetry violation

Dipangkar Dutta

EIC data will have little impact on the uncertainty for the PDF combinations that are sensitive to CSV and ISV
(as indicated by the reweighing of the NNPDF3.0 with EIC pseudodata)

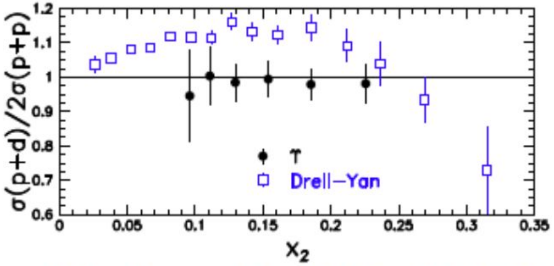
E. C. Aschenauer et al., PRD 99, 094004 (2019)



Upsilon production ratio of D and H is sensitive to gluon CSV

$$\frac{\sigma(p+D\to\Upsilon)}{2\sigma(p+p\to\Upsilon)}\to\left[1-\frac{\delta g(x_t)}{2g(x_t)}\right]$$

E866/NuSea results put a 10% upper limit on gluon CSV.



J. T. Londergan et al., Rev. Mod. Phys. 82, 2009 (2010).

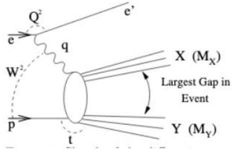
- CSV measurements are necessary to have a complete understanding of the nuclear force
- While the EIC data will not improve on the PDF combination sensitive to CSV it could potentially access some CSV observables directly
- More detailed studies will be needed

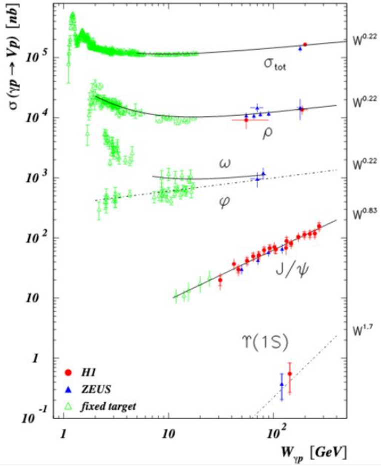
Needs high precision (% level) measurement of the pi+/pi- production ratio in e-D collisions for SIDIS kinematics.

Desirable to have the acceptance for pi+ and pi- as similar as possible.

A major source of background are the pions from diffractive rho production. Need ability to distinguish these pions from the SIDIS events.

For example: @ HERA it was found that ~10% of the DIS events were from diffractive events (characterized by large rapidity gap)

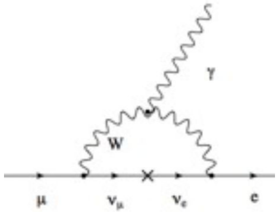




Charged Lepton Flavor Violation

Sonny Mantry

- LFV in the neutrinos also implies Charged Lepton Flavor Violation (CLFV):



$$\mathrm{BR}(\mu \to e\gamma) < 10^{-54}$$

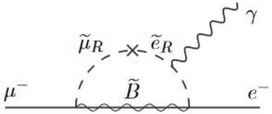
However, SM rate for CLFV is tiny due to small neutrino masses

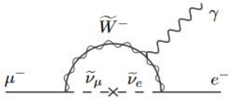
- No hope of detecting such small rates for CLFV at any present or future planned experiments!

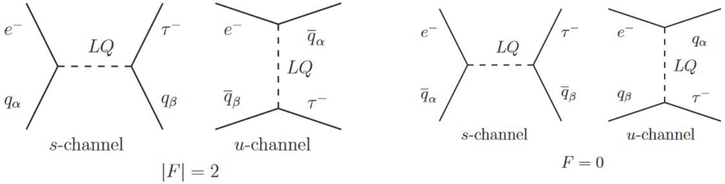
LFV transitions	LFV Present Bounds (90%CL)	Future Sensitivities
$\mathrm{BR}(\mu \to e\gamma)$	4.2×10^{-13} (MEG 2016)	4×10^{-14} (MEG-II)
$\mathrm{BR}(\tau \to e\gamma)$	3.3×10^{-8} (BABAR 2010)	10^{-9} (BELLE-II)
$\mathrm{BR}(\tau \to \mu\gamma)$	4.4×10^{-8} (BABAR 2010)	10^{-9} (BELLE-II)
$\mathrm{BR}(\mu \to eee)$	1.0×10^{-12} (SINDRUM 1988)	10^{-16} Mu3E (PSI)
$\mathrm{BR}(\tau \to eee)$	2.7×10^{-8} (BELLE 2010)	$10^{-9,-10}$ (BELLE-II)
$\mathrm{BR}(\tau \to \mu\mu\mu)$	2.1×10^{-8} (BELLE 2010)	$10^{-9,-10}$ (BELLE-II)
$\mathrm{BR}(\tau \to \mu\eta)$	2.3×10^{-8} (BELLE 2010)	$10^{-9,-10}$ (BELLE-II)
$\mathrm{CR}(\mu - e, \mathrm{Au})$	7.0×10^{-13} (SINDRUM II 2006)	
$\mathrm{CR}(\mu - e, \mathrm{Ti})$	4.3×10^{-12} (SINDRUM II 2004)	10^{-18} PRISM (J-PARC)
$\mathrm{CR}(\mu - e, \mathrm{Al})$		3.1×10^{-15} COMET-I (J-PARC)

[taken from a talk by Y. Furletova]

- However, many BSM scenarios predict enhanced CLFV rates:
  - SUSY (RPV)
  - SU(5), SO(10) GUTS
  - Left-Right symmetric models
  - Randall-Sundrum Models
  - LeptoQuarks
  - ...







F= 3B+L

- With electron beams, LQs couple to:

|F|= 2:
-quarks in s-channel
-antiquarks in u-channel

F= 0:
-antiquarks in s-channel
-quarks in the u-channel

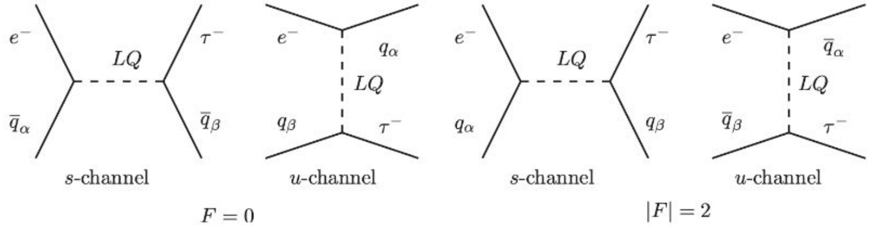
- With positron beams, LQs couple to:

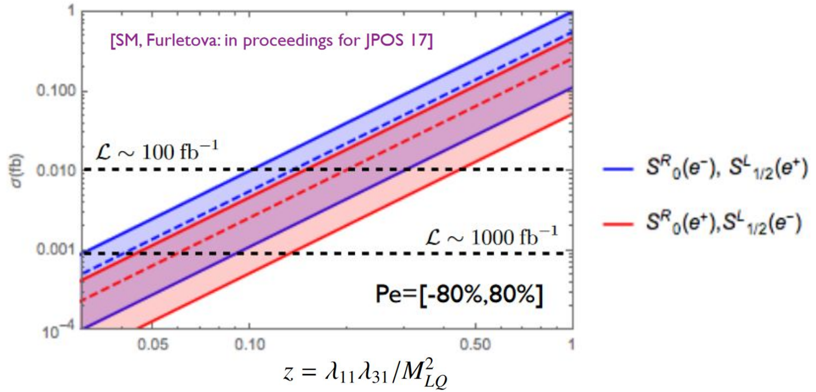
|F|= 2:
-antiquarks in s-channel
-quarks in u-channel

F= 0:
-quarks in s-channel
-antiquarks in the u-channel

CLFV: e to tau (lepto-quarks)

Jinlong Zhang

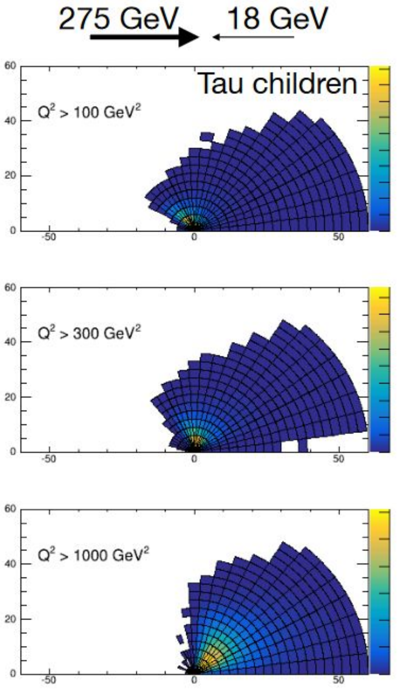




- Sensitivities to the CLFV(1,3) would be enhanced with positron beams (can search for specific LQ)
- Current limits set by HERA sitting at sensitivities of a few fb
  - The high luminosity of the EIC will gain us 2 orders of magnitude

Tau decay mode and branching ratio

- **3-prong** **15.21 (0.06)%**
  - $\pi^-\pi^+\pi^-\nu_\tau$ 9.31 (0.05)%
  - $\pi^-\pi^+\pi^-\pi^0\nu_\tau$ 4.62 (0.05)%
  - others (kaon, etc) 1.28%
- **1-prong** **84.58 (0.06)%**
  - $\mu^-\bar{\nu}_\mu\nu_\tau$ 17.39 (0.04)%
  - $e^-\bar{\nu}_e\nu_\tau$ 17.82 (0.04)%
  - $\pi^-\nu_\tau$ 10.82 (0.05)%
  - $\pi^-\pi^0\nu_\tau$ 25.49 (0.09)%
  - $\pi^-2\pi^0\nu_\tau$ 9.26 (0.10)%
  - $\pi^-3\pi^0\nu_\tau$ 1.04 (0.07)%
  - others (kaon, etc) 3.24%
- others 0.21%
- **Tau vertex displaced at cm level**
  - 3-prong tau jet; decay topology important for τ jet ID
  - 1-prong: recovering higher branching ratios; but background control is much more demanding

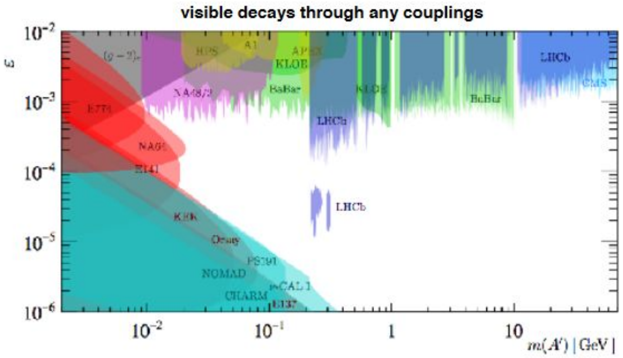


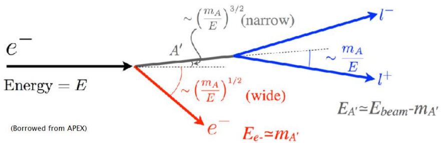
Angle for theta, radius for momentum

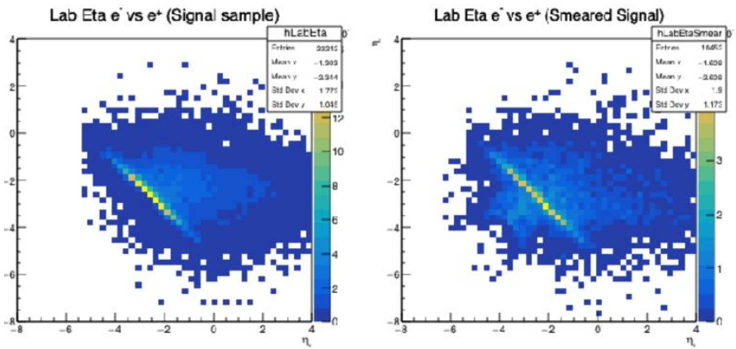
- Assumes hadron calorimetry in the central barrel
- Needs 1-prong analysis to reach full potential

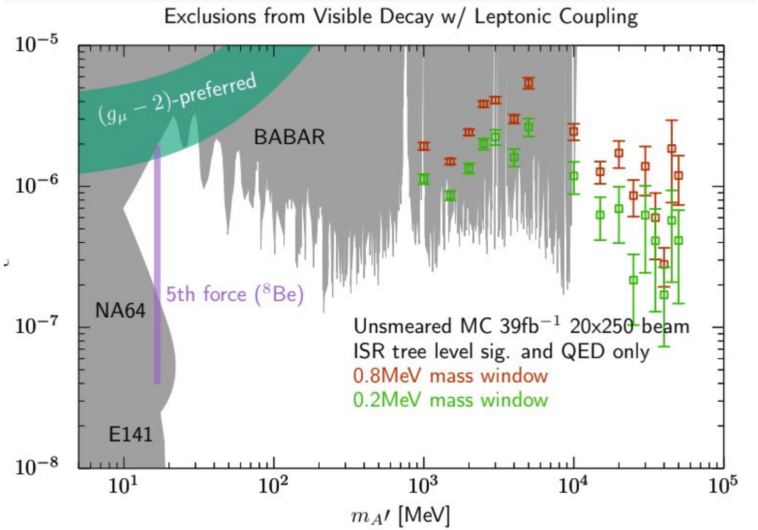
Dark photons

Ross Corliss









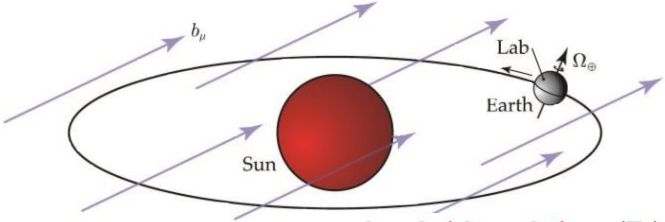
$$\alpha_D = S \frac{\alpha_{D0}}{\sqrt{L}} \frac{\sqrt{\sigma_{QED}}}{\sigma_{A0}}$$

- First analysis looks at e+e- decay, but hadronic final states could be investigated as well
- The boosted kinematics significantly opens up the angle between the decay leptons creating a specific topology
- Only consider QED background for now
- With 6 months of running 25 on 250 (~39 fb^{-1}) we could reach similar sensitivities than BABAR but in a wider mass range
  - Handbook detector used for initial smearing studies
- Measurement would benefit from improved charge sign reconstruction (PID)
- Higher eta coverage would lead to access to lower mass dark photons
- There is still the possibility that the muon g-2 anomaly could be explained by a dark photon with a purely leptonic coupling

Lorentz violating effects

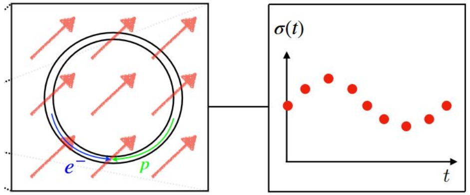
Based on:
A. Kostelecky, E.L. and A. Vieira [1610.09318]
E.L. and N. Sherrill [1805.11684]
A. Kostelecky, E.L., N. Sherrill and A. Vieira [1911.04002]

Enrico Lunghi



- **local sidereal time** ($T_\oplus$)

$$\sigma(T_\oplus) \sim \sigma_{SM}\,(1 + c_0 + c_1 \cos(\omega_\oplus T_\oplus) + c_2 \cos(2\omega_\oplus T_\oplus) + \cdots)$$



- Construct an extension to the SM where the vacuum expectation of a constant background field is not Lorentz invariant
  - For example: the lifetime of a boosted muon and the lifetime of a muon at rest but measured in a boosted frame would differ
- This would lead measurements varying with sidereal time

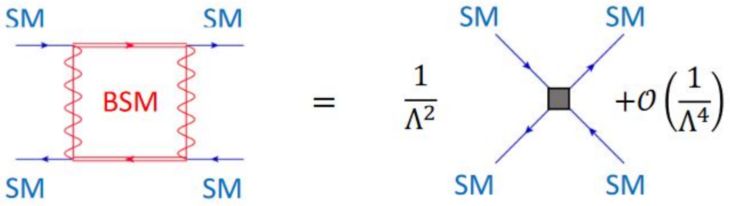
- Expected bounds in units of 10^{-5}

	HERA	JLEIC	eRHIC	JLEIC	eRHIC
		one year		ten years	
$\lvert c_u^{TX}\rvert$	6.4 [6.7]	1.1 [11.]	0.26 [11.]	0.072 [9.3]	0.084 [11.]
$\lvert c_u^{TY}\rvert$	6.4 [6.7]	1.1 [11.]	0.27 [11.]	0.069 [9.4]	0.085 [11.]
$\lvert c_u^{XZ}\rvert$	32. [33.]	1.9 [16.]	0.36 [15.]	0.12 [16.]	0.11 [15.]
$\lvert c_u^{YZ}\rvert$	32. [33.]	1.8 [16.]	0.37 [15.]	0.12 [16.]	0.12 [15.]
$\lvert c_u^{XY}\rvert$	16. [16.]	7.0 [60.]	0.96 [40.]	0.44 [58.]	0.31 [40.]
$\lvert c_u^{XX} - c_u^{YY}\rvert$	50. [50.]	6.0 [51.]	2.8 [120.]	0.37 [50.]	0.89 [120.]

- Coefficients in the photon, electron, muon, proton and neutron sectors are strongly constrained.
- The quark sector is much harder to constraint because of the nature of QCD
- We focused on electron-proton Deep Inelastic Scattering and Drell-Yan for which high statistics measurements exist (and are possible in the future) and found that bounds in the $10^{-5,6}$ range are attainable using existing HERA/LHC and future EIC data.
- Analysis of a subset of Zeus data is undergoing
- Future studies include
  - Impact on PDFs (standard and polarization dependent)
  - Inclusion of weak effects (Z-pole observables, …)

SMEFT

Daniel Wiegand



Non-SM operators **suppressed by powers of** $\frac{1}{\Lambda}$**:**

- Higher dimensional operators built from SM fields
- Modification of SM couplings/EWSB/…

Quantify deviation from SM through comparison with data

- **Model independent constraints** on new physics
- Maximal gain from data
- Part of the **LHC legacy**

Boughezal/Petriello/DW - (arXiv: 2004.00748)

$1: X^3$		$2: H^6$		$3: H^4D^2$		$5: \psi^2H^3 + \text{h.c.}$	
Q_G	$f^{ABC}G_\mu^{A\nu}G_\nu^{B\rho}G_\rho^{C\mu}$	Q_H	$(H^\dagger H)^3$	$Q_{H\Box}$	$(H^\dagger H)\Box(H^\dagger H)$	Q_{eH}	$(H^\dagger H)(\bar{l}_p e_r H)$
$Q_{\widetilde{G}}$	$f^{ABC}\widetilde{G}_\mu^{A\nu}G_\nu^{B\rho}G_\rho^{C\mu}$			Q_{HD}	$(H^\dagger D_\mu H)^*(H^\dagger D_\mu H)$	Q_{uH}	$(H^\dagger H)(\bar{q}_p u_r \widetilde{H})$
Q_W	$\epsilon^{IJK}W_\mu^{I\nu}W_\nu^{J\rho}W_\rho^{K\mu}$					Q_{dH}	$(H^\dagger H)(\bar{q}_p d_r H)$
$Q_{\widetilde{W}}$	$\epsilon^{IJK}\widetilde{W}_\mu^{I\nu}W_\nu^{J\rho}W_\rho^{K\mu}$						

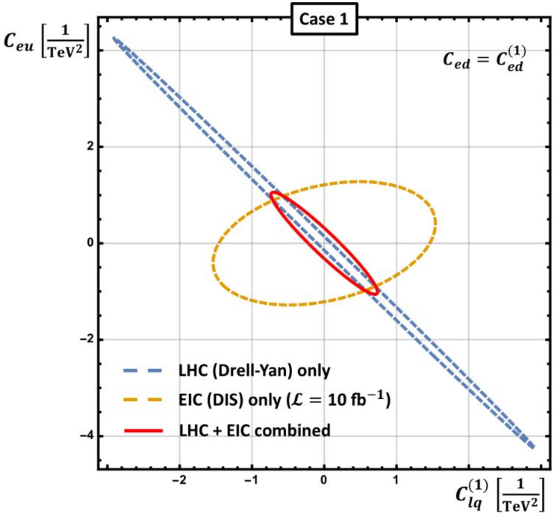
$4: X^2H^2$		$6: \psi^2XH + \text{h.c.}$		$7: \psi^2H^2D$	
Q_{HG}	$H^\dagger H\, G_{\mu\nu}^A G^{A\mu\nu}$	Q_{eW}	$(\bar{l}_p\sigma^{\mu\nu}e_r)\tau^I H W_{\mu\nu}^I$	$Q_{Hl}^{(1)}$	$(H^\dagger i\overleftrightarrow{D}_\mu H)(\bar{l}_p\gamma^\mu l_r)$
$Q_{H\widetilde{G}}$	$H^\dagger H\, \widetilde{G}_{\mu\nu}^A G^{A\mu\nu}$	Q_{eB}	$(\bar{l}_p\sigma^{\mu\nu}e_r)H B_{\mu\nu}$	$Q_{Hl}^{(3)}$	$(H^\dagger i\overleftrightarrow{D}_\mu^I H)(\bar{l}_p\tau^I\gamma^\mu l_r)$
Q_{HW}	$H^\dagger H\, W_{\mu\nu}^I W^{I\mu\nu}$	Q_{uG}	$(\bar{q}_p\sigma^{\mu\nu}T^A u_r)\widetilde{H}\, G_{\mu\nu}^A$	Q_{He}	$(H^\dagger i\overleftrightarrow{D}_\mu H)(\bar{e}_p\gamma^\mu e_r)$
$Q_{H\widetilde{W}}$	$H^\dagger H\, \widetilde{W}_{\mu\nu}^I W^{I\mu\nu}$	Q_{uW}	$(\bar{q}_p\sigma^{\mu\nu}u_r)\tau^I\widetilde{H}\, W_{\mu\nu}^I$	$Q_{Hq}^{(1)}$	$(H^\dagger i\overleftrightarrow{D}_\mu H)(\bar{q}_p\gamma^\mu q_r)$
Q_{HB}	$H^\dagger H\, B_{\mu\nu}B^{\mu\nu}$	Q_{uB}	$(\bar{q}_p\sigma^{\mu\nu}u_r)\widetilde{H}\, B_{\mu\nu}$	$Q_{Hq}^{(3)}$	$(H^\dagger i\overleftrightarrow{D}_\mu^I H)(\bar{q}_p\tau^I\gamma^\mu q_r)$
$Q_{H\widetilde{B}}$	$H^\dagger H\, \widetilde{B}_{\mu\nu}B^{\mu\nu}$	Q_{dG}	$(\bar{q}_p\sigma^{\mu\nu}T^A d_r)H\, G_{\mu\nu}^A$	Q_{Hu}	$(H^\dagger i\overleftrightarrow{D}_\mu H)(\bar{u}_p\gamma^\mu u_r)$
Q_{HWB}	$H^\dagger\tau^I H\, W_{\mu\nu}^I B^{\mu\nu}$	Q_{dW}	$(\bar{q}_p\sigma^{\mu\nu}d_r)\tau^I H\, W_{\mu\nu}^I$	Q_{Hd}	$(H^\dagger i\overleftrightarrow{D}_\mu H)(\bar{d}_p\gamma^\mu d_r)$
$Q_{H\widetilde{W}B}$	$H^\dagger\tau^I H\, \widetilde{W}_{\mu\nu}^I B^{\mu\nu}$	Q_{dB}	$(\bar{q}_p\sigma^{\mu\nu}d_r)H\, B_{\mu\nu}$	Q_{Hud} + h.c.	$i(\widetilde{H}^\dagger D_\mu H)(\bar{u}_p\gamma^\mu d_r)$

$8: (\bar{L}L)(\bar{L}L)$		$8: (\bar{R}R)(\bar{R}R)$		$8: (\bar{L}L)(\bar{R}R)$	
Q_{ll}	$(\bar{l}_p\gamma_\mu l_r)(\bar{l}_s\gamma^\mu l_t)$	Q_{ee}	$(\bar{e}_p\gamma_\mu e_r)(\bar{e}_s\gamma^\mu e_t)$	Q_{le}	$(\bar{l}_p\gamma_\mu l_r)(\bar{e}_s\gamma^\mu e_t)$
$Q_{qq}^{(1)}$	$(\bar{q}_p\gamma_\mu q_r)(\bar{q}_s\gamma^\mu q_t)$	Q_{uu}	$(\bar{u}_p\gamma_\mu u_r)(\bar{u}_s\gamma^\mu u_t)$	Q_{lu}	$(\bar{l}_p\gamma_\mu l_r)(\bar{u}_s\gamma^\mu u_t)$
$Q_{qq}^{(3)}$	$(\bar{q}_p\gamma_\mu\tau^I q_r)(\bar{q}_s\gamma^\mu\tau^I q_t)$	Q_{dd}	$(\bar{d}_p\gamma_\mu d_r)(\bar{d}_s\gamma^\mu d_t)$	Q_{ld}	$(\bar{l}_p\gamma_\mu l_r)(\bar{d}_s\gamma^\mu d_t)$
$Q_{lq}^{(1)}$	$(\bar{l}_p\gamma_\mu l_r)(\bar{q}_s\gamma^\mu q_t)$	Q_{eu}	$(\bar{e}_p\gamma_\mu e_r)(\bar{u}_s\gamma^\mu u_t)$	Q_{qe}	$(\bar{q}_p\gamma_\mu q_r)(\bar{e}_s\gamma^\mu e_t)$
$Q_{lq}^{(3)}$	$(\bar{l}_p\gamma_\mu\tau^I l_r)(\bar{q}_s\gamma^\mu\tau^I q_t)$	Q_{ed}	$(\bar{e}_p\gamma_\mu e_r)(\bar{d}_s\gamma^\mu d_t)$	$Q_{qu}^{(1)}$	$(\bar{q}_p\gamma_\mu q_r)(\bar{u}_s\gamma^\mu u_t)$
		$Q_{ud}^{(1)}$	$(\bar{u}_p\gamma_\mu u_r)(\bar{d}_s\gamma^\mu d_t)$	$Q_{qu}^{(8)}$	$(\bar{q}_p\gamma_\mu T^A q_r)(\bar{u}_s\gamma^\mu T^A u_t)$
		$Q_{ud}^{(8)}$	$(\bar{u}_p\gamma_\mu T^A u_r)(\bar{d}_s\gamma^\mu T^A d_t)$	$Q_{qd}^{(1)}$	$(\bar{q}_p\gamma_\mu q_r)(\bar{d}_s\gamma^\mu d_t)$
				$Q_{qd}^{(8)}$	$(\bar{q}_p\gamma_\mu T^A q_r)(\bar{d}_s\gamma^\mu T^A d_t)$

$8: (\bar{L}R)(\bar{R}L) + \text{h.c.}$		$8: (\bar{L}R)(\bar{L}R) + \text{h.c.}$	
Q_{ledq}	$(\bar{l}_p^j e_r)(\bar{d}_s q_{tj})$	$Q_{quqd}^{(1)}$	$(\bar{q}_p^j u_r)\epsilon_{jk}(\bar{q}_s^k d_t)$
		$Q_{quqd}^{(8)}$	$(\bar{q}_p^j T^A u_r)\epsilon_{jk}(\bar{q}_s^k T^A d_t)$
		$Q_{lequ}^{(1)}$	$(\bar{l}_p^j e_r)\epsilon_{jk}(\bar{q}_s^k u_t)$
		$Q_{lequ}^{(3)}$	$(\bar{l}_p^j\sigma_{\mu\nu}e_r)\epsilon_{jk}(\bar{q}_s^k\sigma^{\mu\nu}u_t)$

Warsaw Basis: 59 Operators $(\delta B = 0, \delta L = 0)$

Grzadkowski/Iskrzynski/Misiak/Rosiek (1008.4884)



SMEFT suffers from a large number of flat directions

→ We presented a strategy to lift 4-Fermi **flat directions**

The future **EIC** will complement LHC data

→ Combine EIC observables with **different polarizations** additionally to LHC measurements

→ Interplay of different measurements improve bounds significantly

Studies that should be integrated in the YR effort

- Combined fits of neutral and charge current can help constrain flavour separation and polarized PDFs:
  - Eur. Phys. J. A (2017) 53 contains most of the information in the tables, but help from theorists is needed to implement this in something like ePump for assessment of impact on PDFs (Phys. Rev. D 99, 054004 (2019))
- Positrons and deuteron running present two ways of expanding beyond ep scattering.
  - The community should combine sufficient information about the tradeoffs between positron or deuteron running to allow for better planning.
  - Additional work on polarized charged current cross-sections could further bolster the case for positron beams (see https://doi.org/10.1063/1.5040210 for details)
- Lepton flavour violation using the e- to tau- presents opportunities at integrated luminosities of 100 fb^{-1} or more
  - The one prong decay analysis chain must be developed for more detailed assessments. Such an analysis could allow for a study of lepton number violation in the e- to tau+ channel
- Searches for dark photons at the EIC are in a kinematic region that will not be covered by other experimental results in the foreseeable future. The community believes that it will be worth the effort to pursue this further.

Potential new studies

- Full list in open session summary on workshop indico page
- If heavy ion statistics is sufficient for weak neutral current extractions studies of nuclear effects, EMC-life effects, or extractions of the weak mixing angle could be pursued
- While measurements of the V_{ud} CKM element is certainly not profitable for the EIC, the V_{us} or V_{uc} could provide sensitivities beyond what is going to be measured in the next decade
- Charged current diffractive PDFs (see https://arxiv.org/pdf/hep-ph/9803423.pdf for details)
- It is well known that in the s-channel e- e+ polarized collisions the polarizations of the two beams add up to provide a higher sensitivity for a double spin asymmetry
  - It would be worth investigating which kind of observables would benefit from this type of addition in e-p collisions