

Physics with High-Luminosity Facilities

BSM summary · High Luminosity workshop, Oct 5–9, 2026

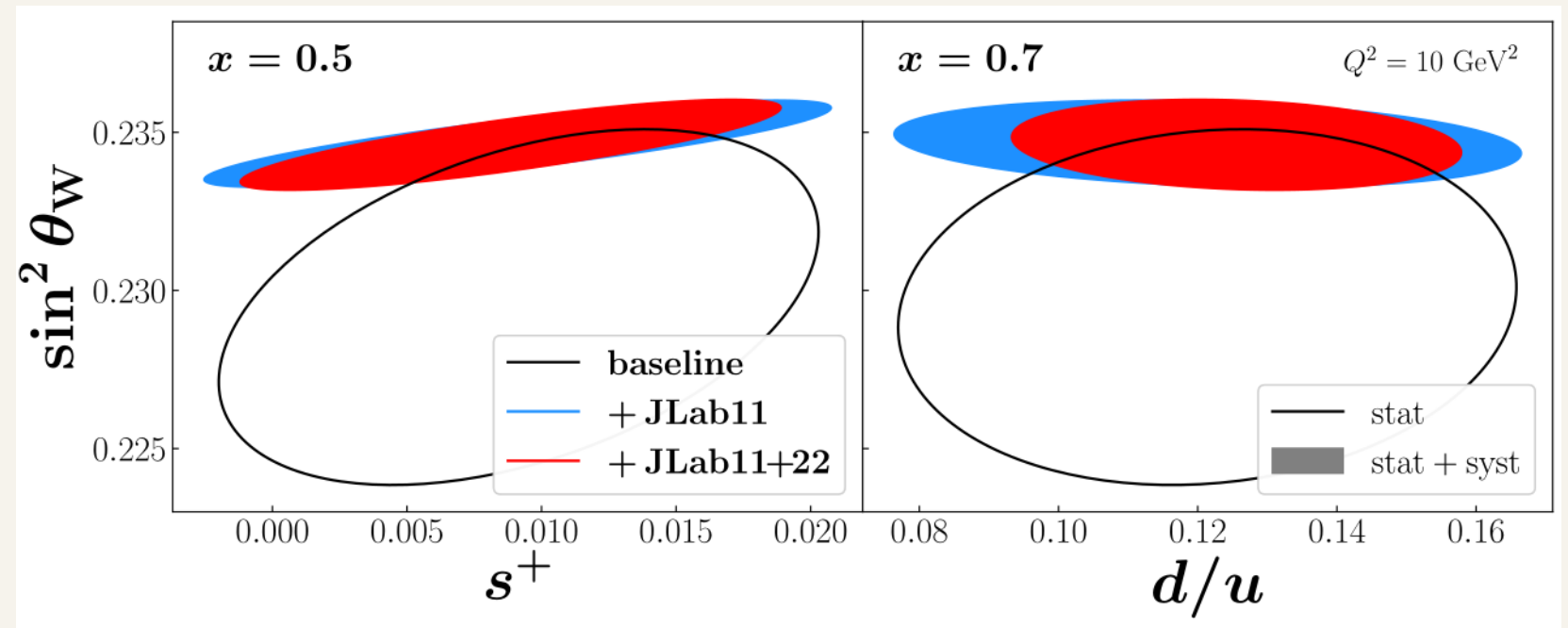
Talks by: Mantry · Zheng · Gaskell · Graham · Furletova · Cappuzzello

Conveners: Ciprian Gal, Rafayel Paremuzyan, Xiaochao Zheng

Slides generated by Claude AI

PVDIS probes new physics

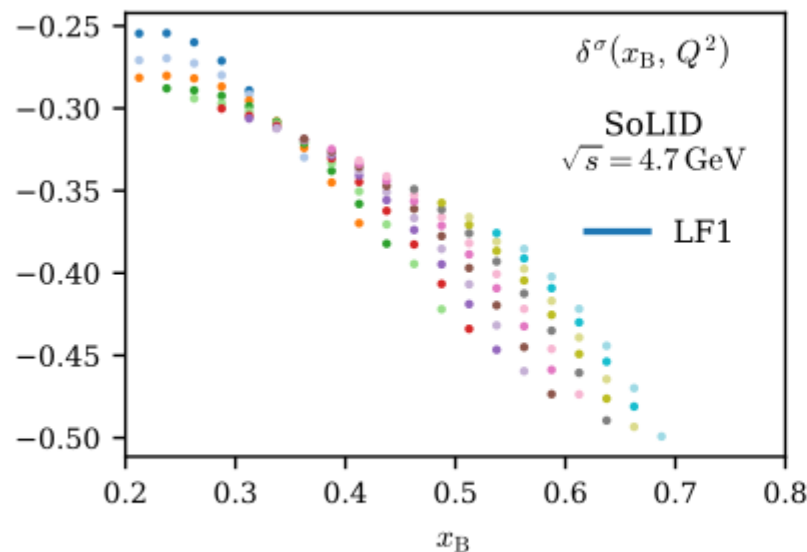
- Parity-violating DIS on a deuteron target measures the electron-quark couplings C_{1q} and C_{2q}
- 11 GeV polarized beam, 40 cm LD2, 120 days: sub-percent asymmetries over a wide x , Q^2 range
- BSM reach of roughly 10–20 TeV for contact interactions (Z' , leptoquarks, RPV SUSY)
- Constrains leptophobic Z' , dark photons and a light dark Z through shifts in the C_{1q}
- In global SMEFT fits, SoLID lifts flat directions that LHC Drell-Yan, Qweak, P2 and APV
- Simultaneous fit of PDF and SM parameters possible



Radiative Corrections

- Hadronic and QED radiative effects must be under control

- Impact on cross sections and PVDIS asymmetry:



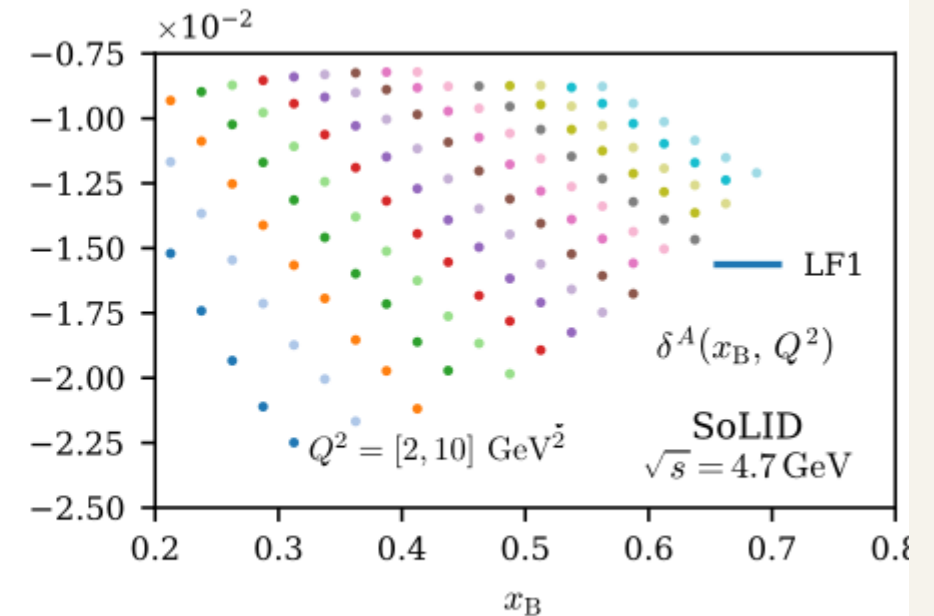
[SM, Qiu, Zhang]

$$d\sigma_0 = d\sigma_0^{\text{NR}} (1 + \delta^\sigma)$$

$$A_e = A_e^{\text{NR}} (1 + \delta^A)$$

$$Q^2 = [2, 10] \text{ GeV}^2$$

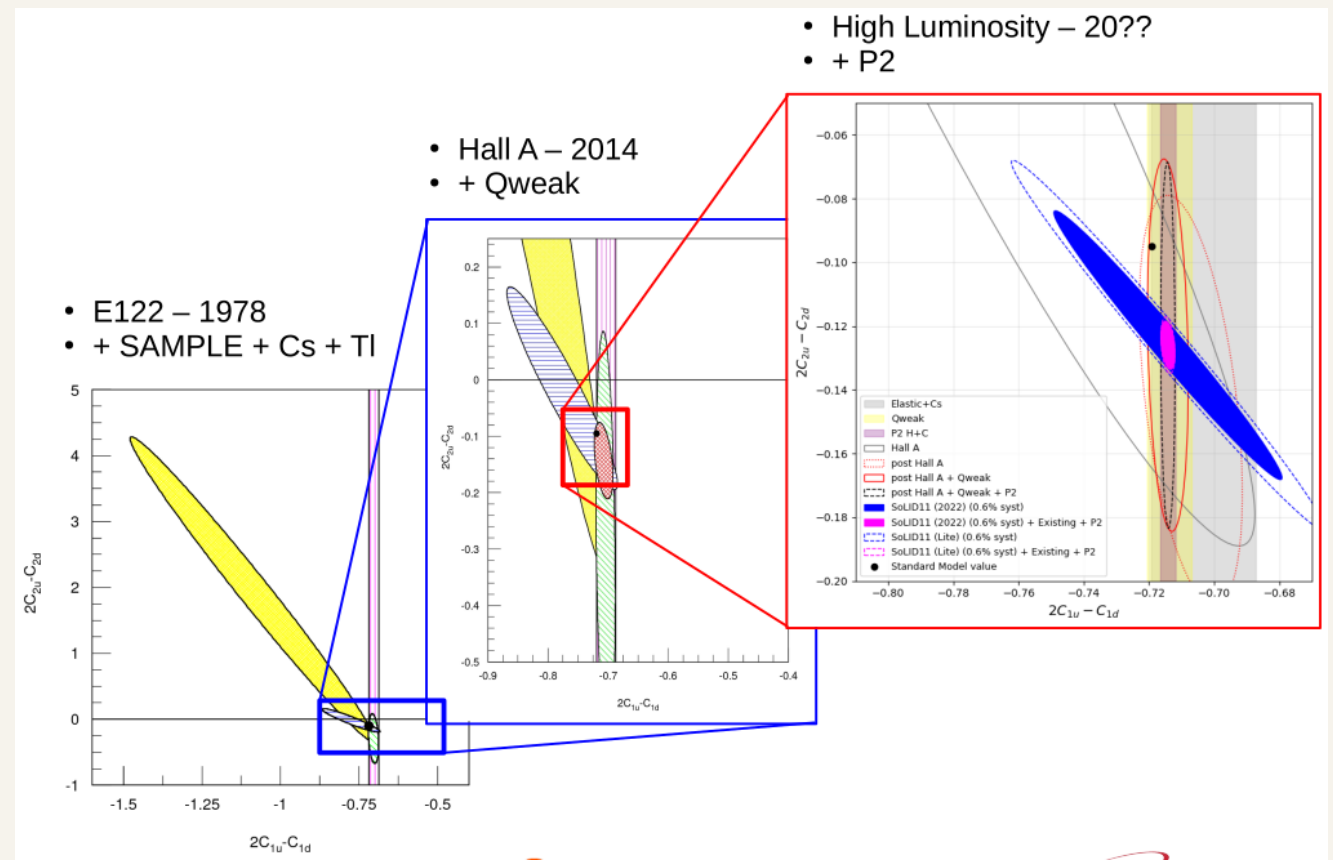
$$\Delta Q^2 = 0.5 \text{ GeV}^2$$



- Asymmetries are relatively more robust to the effects of QED radiation.

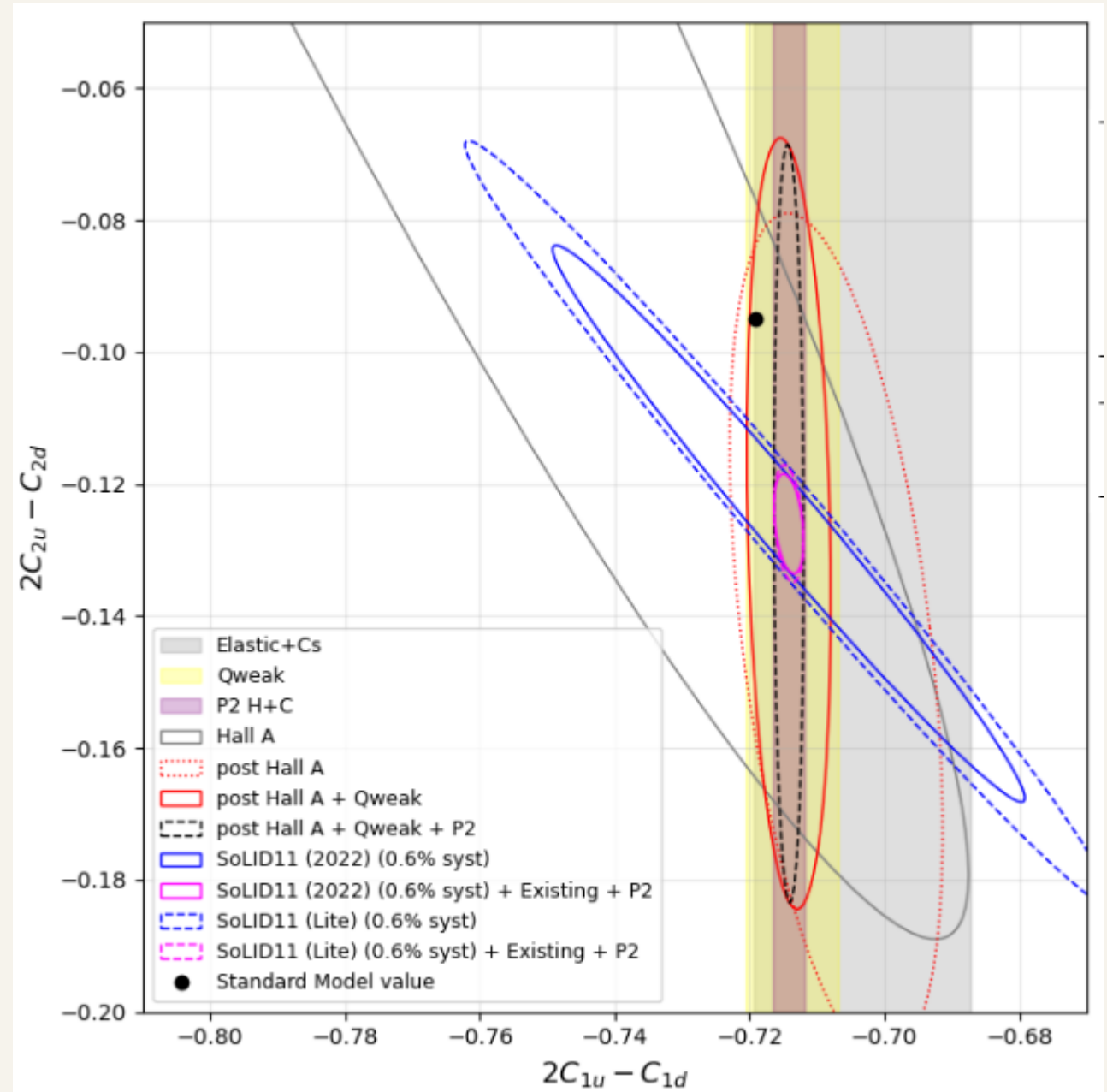
PVDIS with the next-generation spectrometer

- Hall A 6 GeV PVDIS made the first non-zero determination of $2C_{2u} - C_{2d}$
- With SoLID: Luminosity of $10^{37} - 10^{39} \text{ cm}^{-2}\text{s}^{-1} \rightarrow$ wide coverage allows simultaneous fits of the two hadronic effects, higher twist and charge-symmetry violation
- Strong-interaction parity violation: baseline $\alpha = (-1.01 \pm 0.66) \times 10^{-4}$, improving to ± 0.21 (d) and ± 0.15 (p) with SoLID
- Program arc: E122 (1978), Hall A (2014), high-luminosity precision (with P2) (20??)



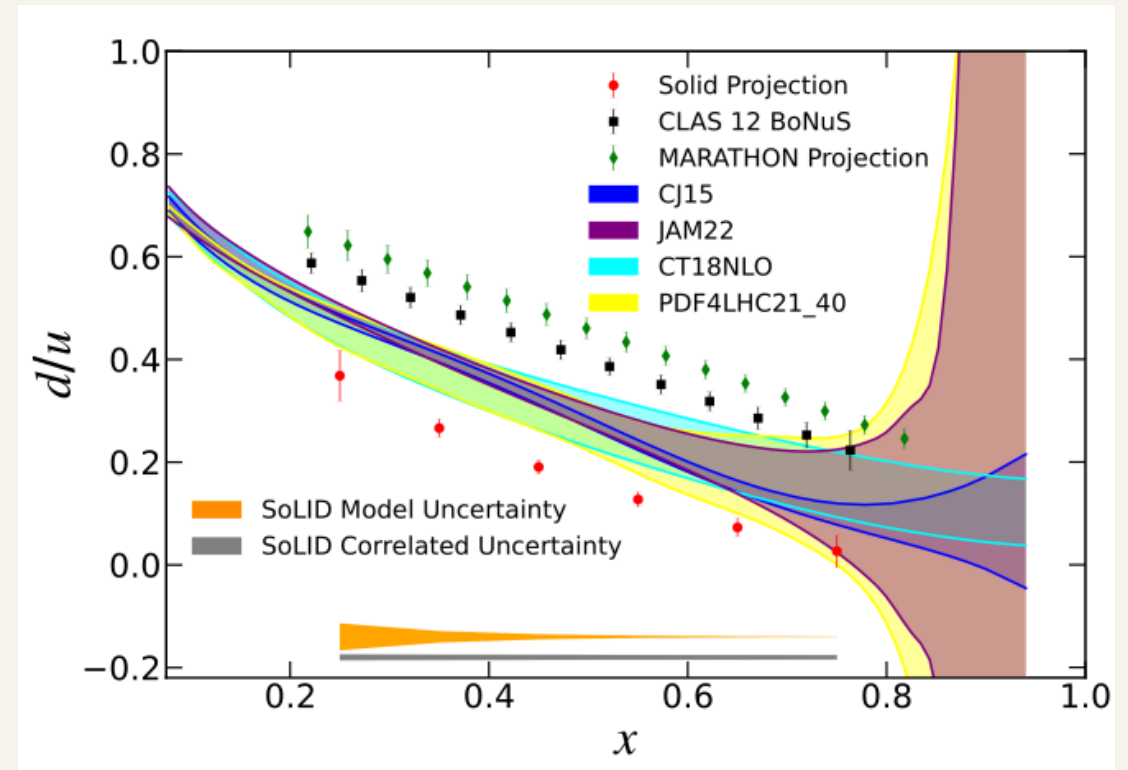
PVDIS-Lite

- SoLID-Lite: with $\frac{1}{2}$ of statistics, the C_1 , C_2 SoLID ellipse grows 40%, but the +P2 combined C_2 uncertainty grows only 20%



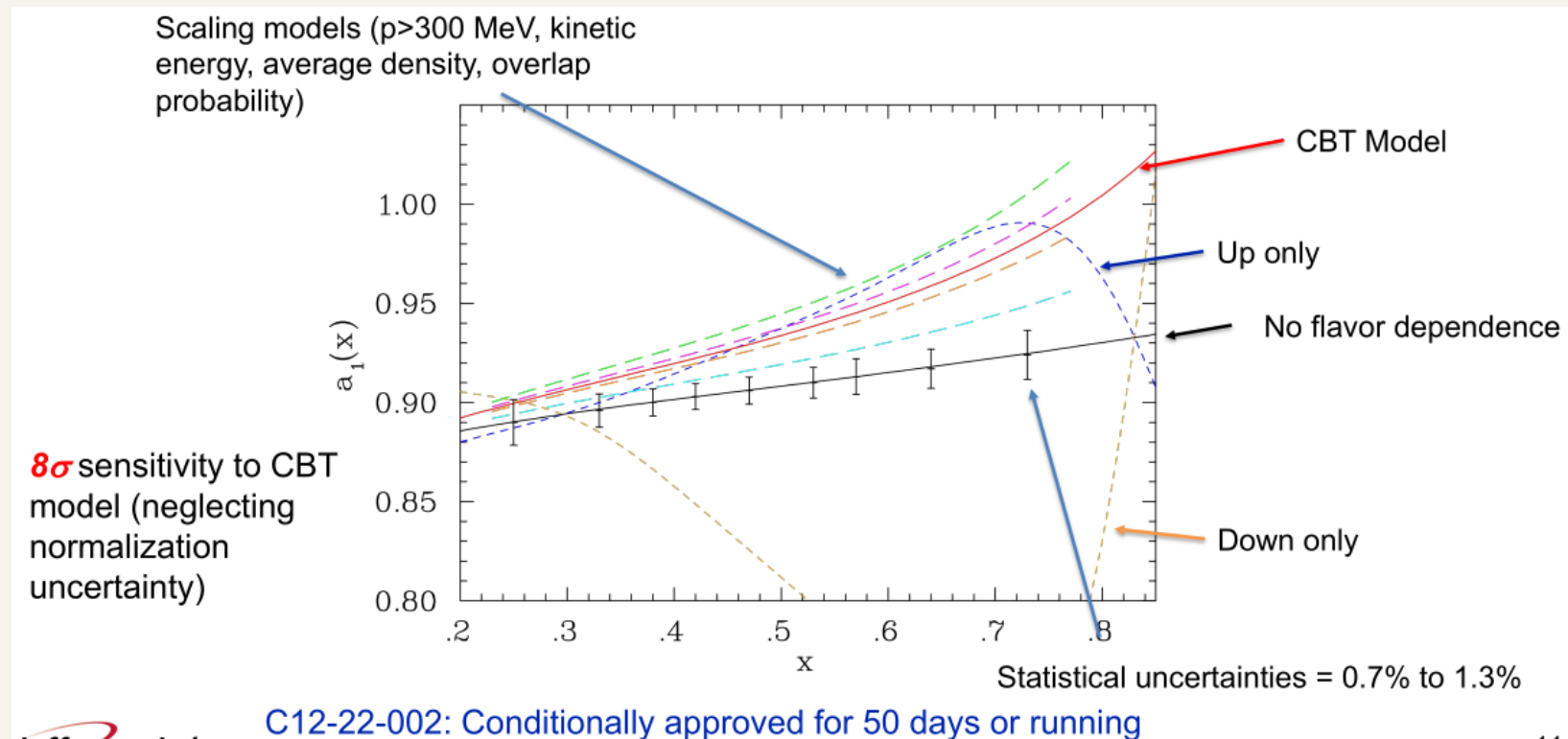
SoLID PVDIS and the d/u ratio at large x

- d/u extractions from H and D are complicated by nuclear effects at large x
- MARATHON ($^3\text{He}/^3\text{H}$) and BONuS12 (spectator tagging) have run; global fits suggest MARATHON speaks more to an isovector EMC effect
- A PVDIS proton target gives d/u with no nuclear effects, a different systematic path



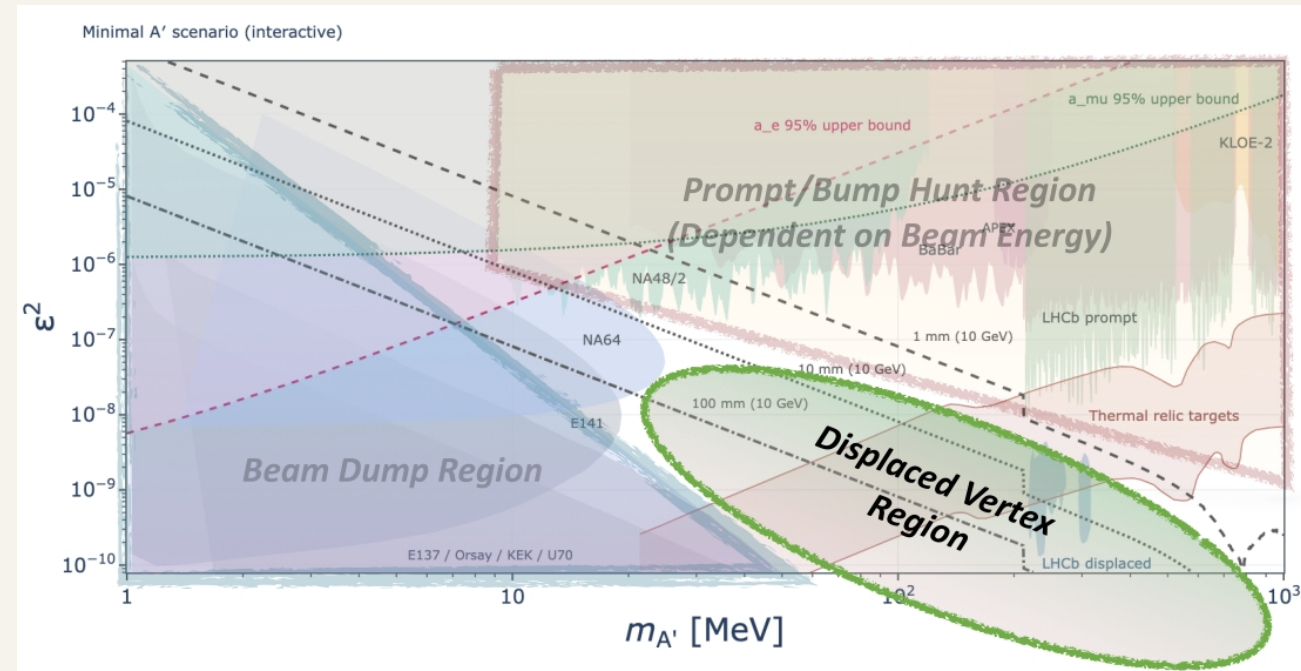
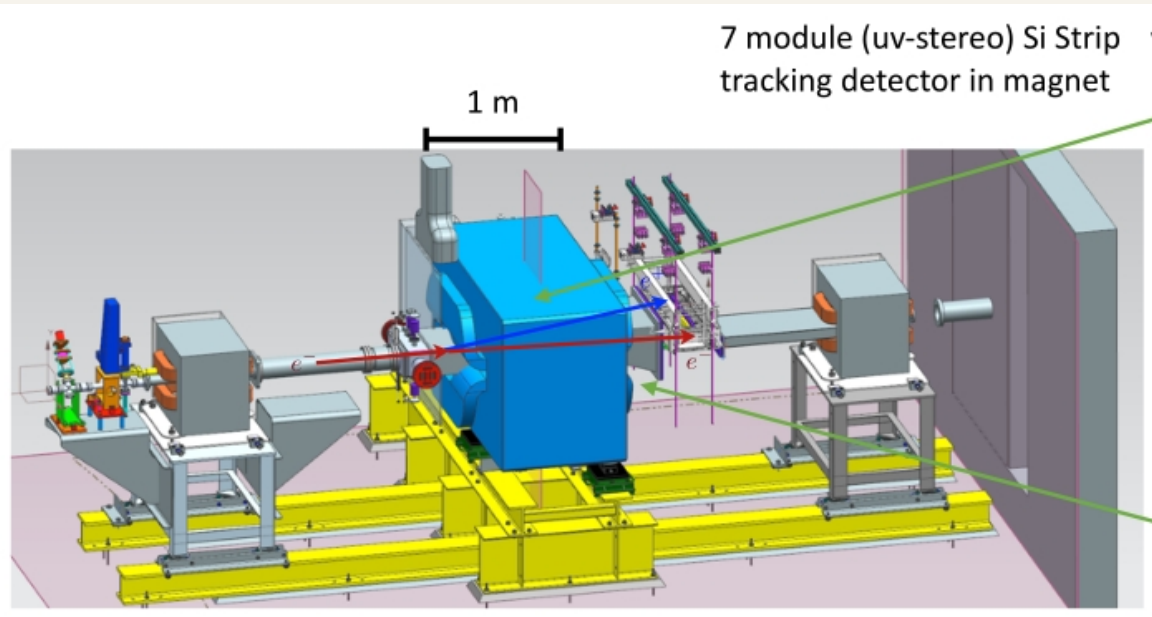
Flavor-dependent EMC, two-photon exchange and SoLID-Lite

- PVDIS on ^{48}Ca is directly sensitive to up versus down quark differences in nuclei
- 8σ sensitivity to the CBT model (C12-22-002, conditionally approved, 50 days)
- BNSSA (E12-22-004, 38 days) accesses the imaginary part of two-photon exchange
- SoLID-Lite: half the calorimeter acceptance; d/u and PVEMC tolerable, BNSSA harder



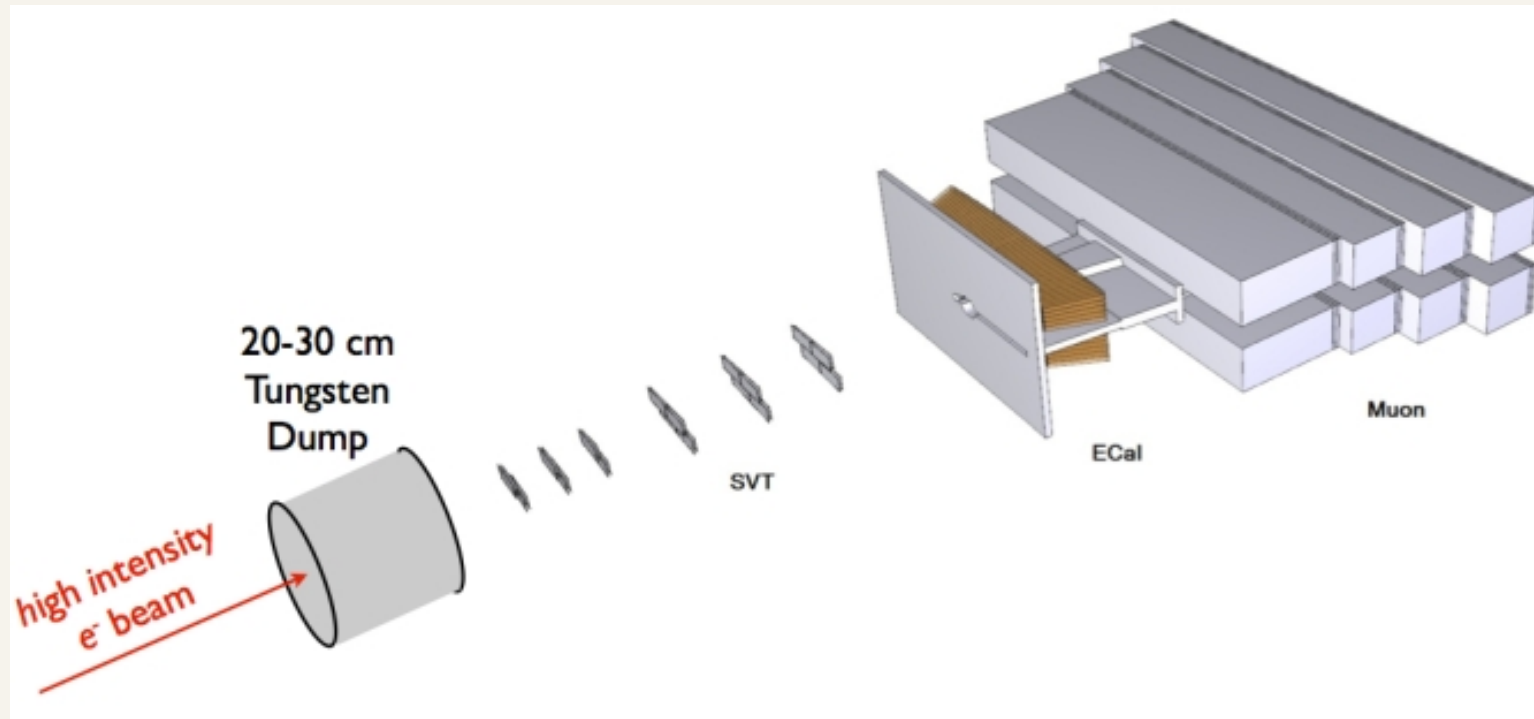
Dark photon searches at fixed-target electron beams

- Dark photons A' are well motivated as a mediator between dark matter particles, can mix with photons
- Try producing dark photons and measure decay product $\rightarrow$ set limit on mass ($m_{A'}$) and coupling (ϵ)
- Three regions: prompt bump hunt, displaced vertex, beam dump
- HPS (heavy photon search) already taking data, but bump hunts are limited by silicon occupancy near the beam; reach improves only as $\sqrt{\mathcal{L}}$



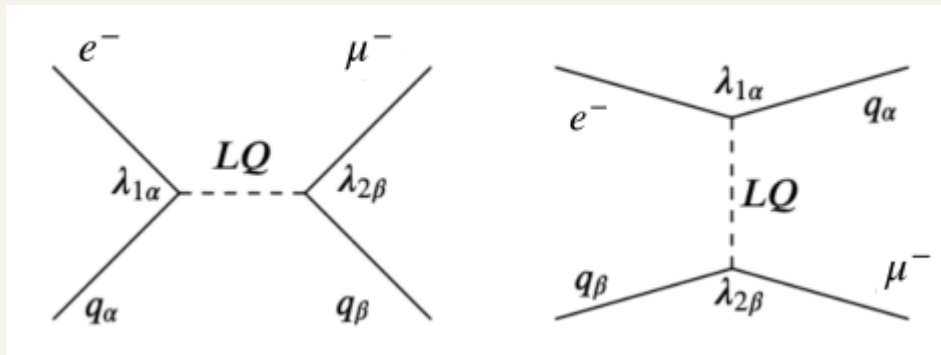
New concepts: two-armed HPS and dump HPS

- Two-armed HPS moves detectors off the beam; 30 days at 4 GeV could reach new low-mass parameter space
- Dump HPS uses a 20–30 cm tungsten dump with a detector behind it; it needs only about $1\ \mu\text{A}$
- Challenges: dump cooling and fast neutrons; the crowded field includes NA64, FASER and SHIP
- High-luminosity CLAS: forward kinematics limit it, though SIMP and iDM models may suit it



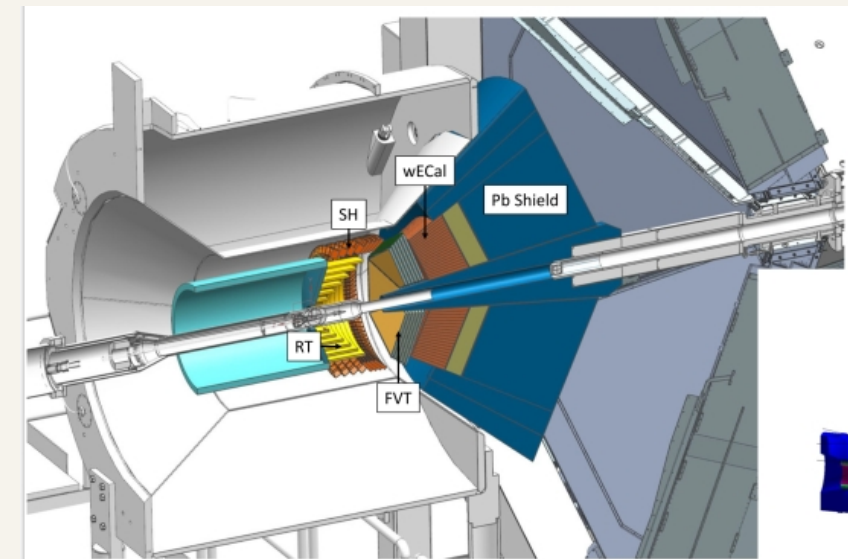
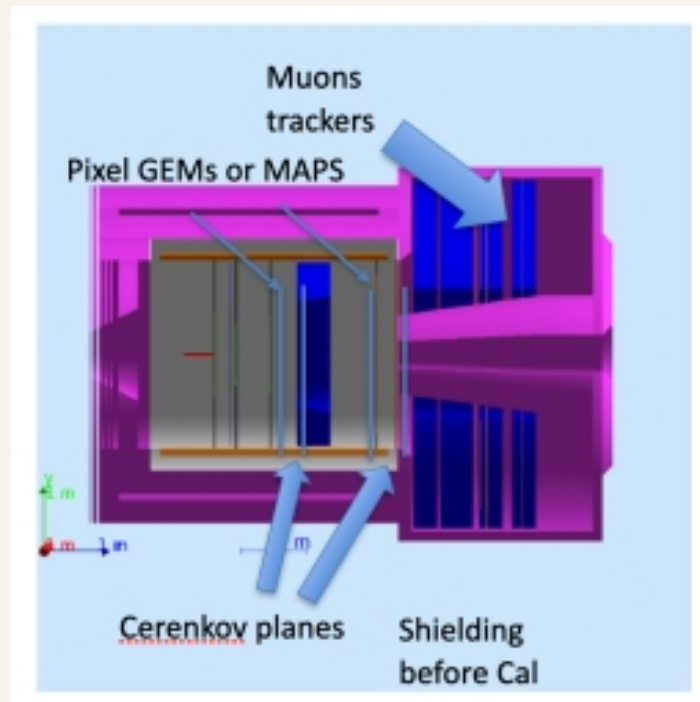
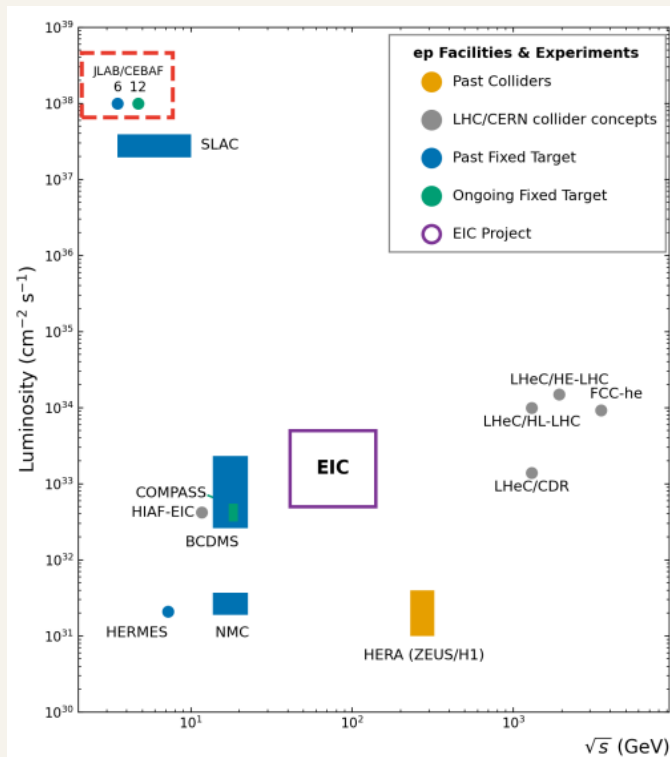
Charged lepton flavor violation: why look

- Flavor is not a conserved quantity in weak interactions
- Neutrinos mix, quarks mix, but charged-lepton mixing is unobserved and tiny in the SM (below 10^{-54})
- Best limit: MEG II $\mu \rightarrow e\gamma$ below 1.5×10^{-13} ; Mu3e, Mu2e and COMET ($\mu N \rightarrow e N$) push further; τ channels also being studied at Belle II
- Complementary route: $e N \rightarrow \mu N$ in lepton-hadron scattering, current limit $< 10^{-8}$ fb, probing lepton-quark couplings at high momentum transfer
- Leptoquarks give a direct mechanism; HERA already showed the approach works
- EIC: $e \rightarrow \tau$ channel ($ep \rightarrow \tau X$) studied



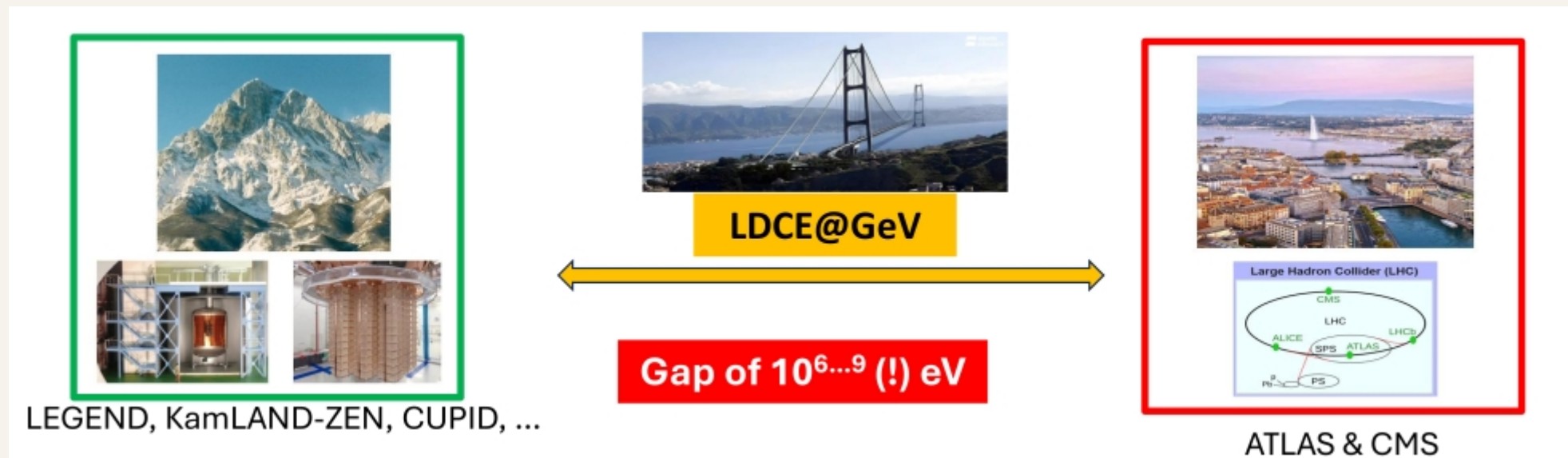
$eN \rightarrow \mu N$ at high luminosity

- Signature: one isolated high-pT muon plus hadrons and no scattered electron
- JLab/CEBAF luminosity is 10^7 – 10^8 above HERA, against 10^2 – 10^3 for the EIC
- At $5 \times 10^6 \text{ fb}^{-1}$, cross sections near 0.2 zb become reachable: a factor of 100 beyond HERA
- Positron beams would sharpen sensitivity to specific leptoquarks ($|F|=2$ vs. $|F|=0$, with $F=3B+L$)



Lepton double charge exchange as an LNV probe

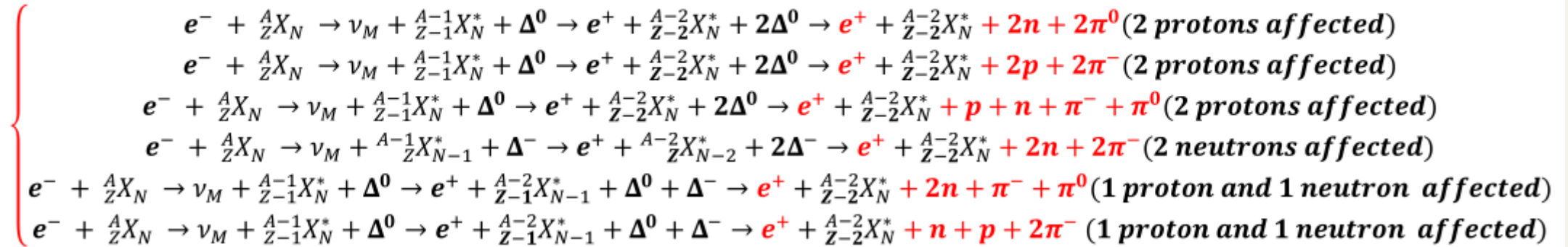
- Lepton number violation could explain the matter-antimatter asymmetry via leptogenesis
- The GeV-scale reaction $A(e^-, e^+)X$ bridges $0\nu\beta\beta$ (MeV) and collider $\ell\ell jj$ (TeV), a gap of $10^6\text{--}10^9$ eV
- The Black Box Theorem: observing any of them shows neutrinos are Majorana fermions
- Cross sections are lower limits; JLab has little competition for years



LDCE signatures, backgrounds and roadmap

- Signature: a forward positron near the full beam energy plus nucleons and pions with the right momenta
- Electromagnetic backgrounds dominate inclusive e^+ spectra and are hard to simulate
- Existing CLAS12 data (RG-D) are key for background studies; a dedicated trigger is desirable
- Roadmap: CLAS12 first, (e^-, μ^+) channel, polarization observables, Hall A/C, EIC

✓ *For example, in a double resonant process RES-RES we can have the following reaction routes:*



Summary

- Luminosity is the shared lever: rare processes and small asymmetries require luminosity 10^{36} – 10^{39}
- Four BSM routes: contact interactions, dark sectors, CLFV and LNV
- Controlling backgrounds and hadronic effects decide what can be claimed
- SoLID-Lite, muCLAS12, and many other ideas/possibilities

White Paper Planning

- Each speaker provides a 1-1.5 page contribution, with figures
- conveners put the contributions in a coherent picture.
- describe both “PAC-vetted” experiments and “just ideas”.