FUTURE OPPORTUNITIES WITH CEBAF UPGRADES

- **Bob McKeown**
- Light Cone 2021
- Dec. 4, 2021

OUTLINE

- Current Program

- Future Opportunities
  - Higher Luminosity/Acceptance
  - Positron Beams
  - Higher Energy

- Accelerator Upgrade Options
- Summary

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PAC Approved experiments (September 10, 2021)

Topic	Hall A	Hall B	Hall C	Hall D	Total
Hadron spectra as probes of QCD	0	2	1	4	**7**
Transverse structure of the hadrons	7	4	3	1	**15**
longitudinal structure of the hadrons	1	3	7	1	**12**
3D structure of the hadrons	6.5	9	6.5	0	**22**
Hadrons and cold nuclear matter	10	6	8	1	**25**
Low-energy tests of the Standard Model and Fundamental Symmetries	3	1	0	1	**5**
Total	**27.5**	**25**	**25.5**	**8**	**86**
Total Experiments Completed	**10**	**10**	**8.0**	**1.0**	**29**
Total Experiments Remaining	**18**	**15**	**17.5**	**7**	**57.5**

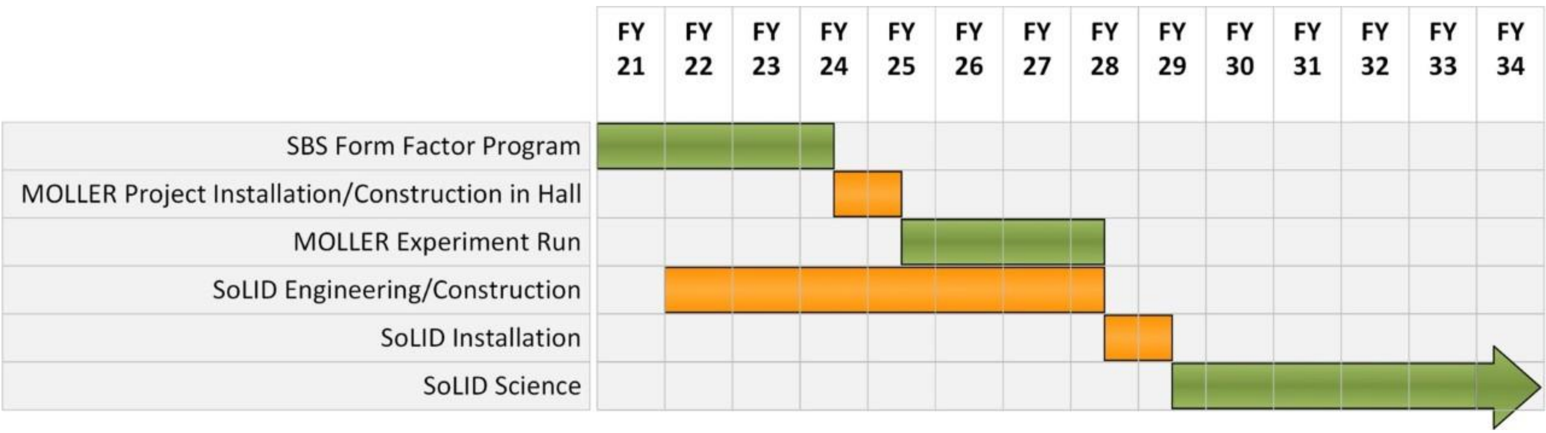
12 GeV Experiments by PAC Days (September 10, 2021)

Topic 9/10	Hall A	Hall B	Hall C	Hall D	Total
Hadron spectra as probes of QCD	0	219	11	740	**970**
Transverse structure of the hadrons	152.5	125	146	25	**448.5**
Longitudinal structure of the hadrons	42	170	211	33	**456**
3D structure of the hadrons	371	872	225	0	**1468**
Hadrons and cold nuclear matter	254.5	305	205	15	**779.5**
Low-energy tests of the Standard Model and Fundamental Symmetries	547	180	0	79	**806**
Total Days	**1367.0**	**1871.0**	**798.0**	**892**	**4928.0**
Total Days - (includes MOLLER)	**893.0**	**1871**	**798**	**892**	**4454**
Total Approved Run Group Days (includes MIE)	**1319.5**	**1066**	**755**	**692**	**3832.5**
Total Approved Run Group Days (includes MOLLER)	**893**	**1066**	**755**	**692**	**3406**
Total Days Completed	**256.5**	**323**	**173.0**	**206**	**958.5**
Total Days Remaining	**610.5**	**743**	**561.0**	**486**	**2400.5**

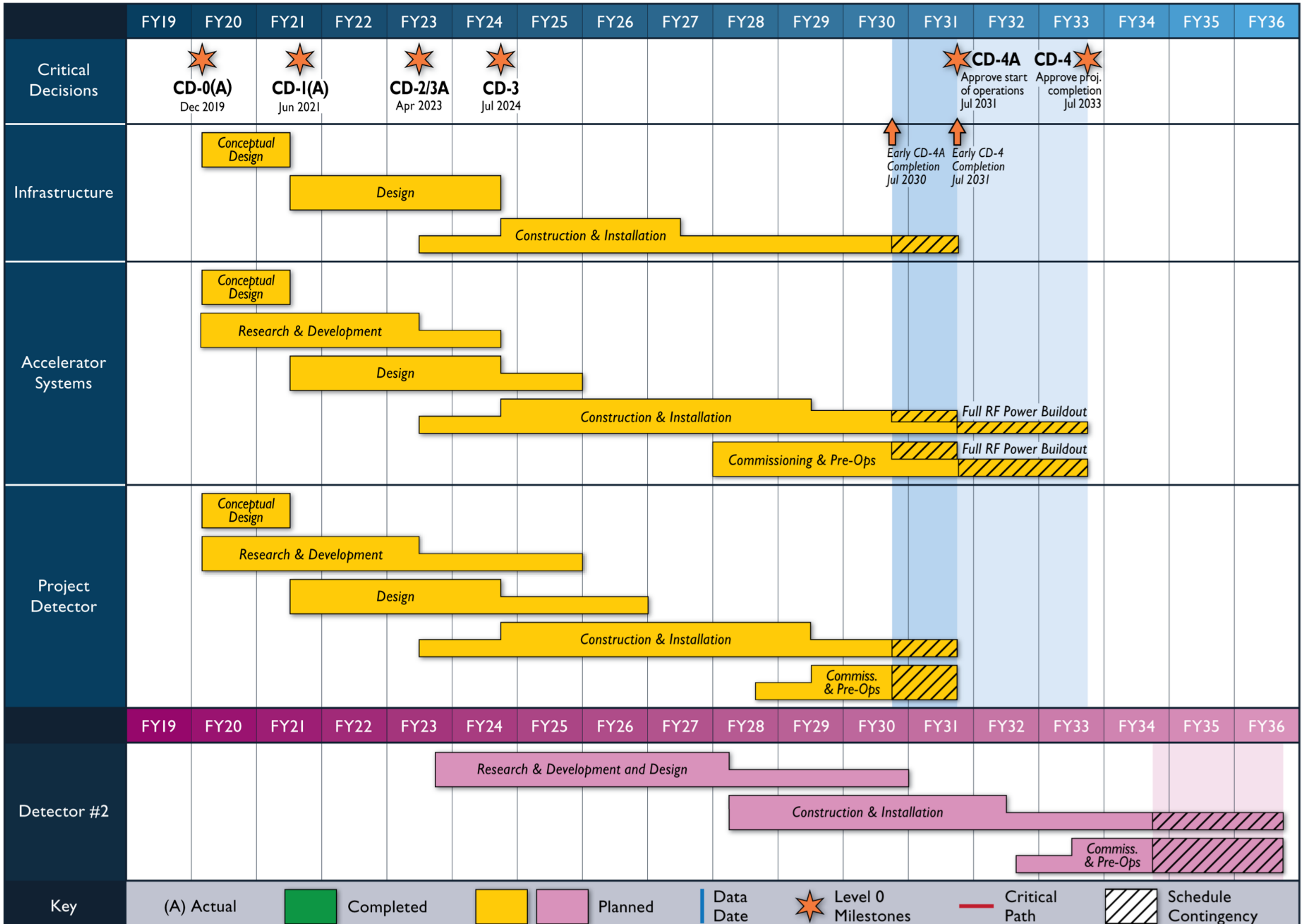
JEFFERSON LAB 12 GEV VISION:
LUMINOSITY FRONTIER

- CEBAF has a long program ahead that is complementary to the envisioned EIC program
- CEBAF will remain the prime facility for fixed target electron scattering at the luminosity frontier

Approved Hall A Program – projected schedule:



PROJECTED EIC SCHEDULE



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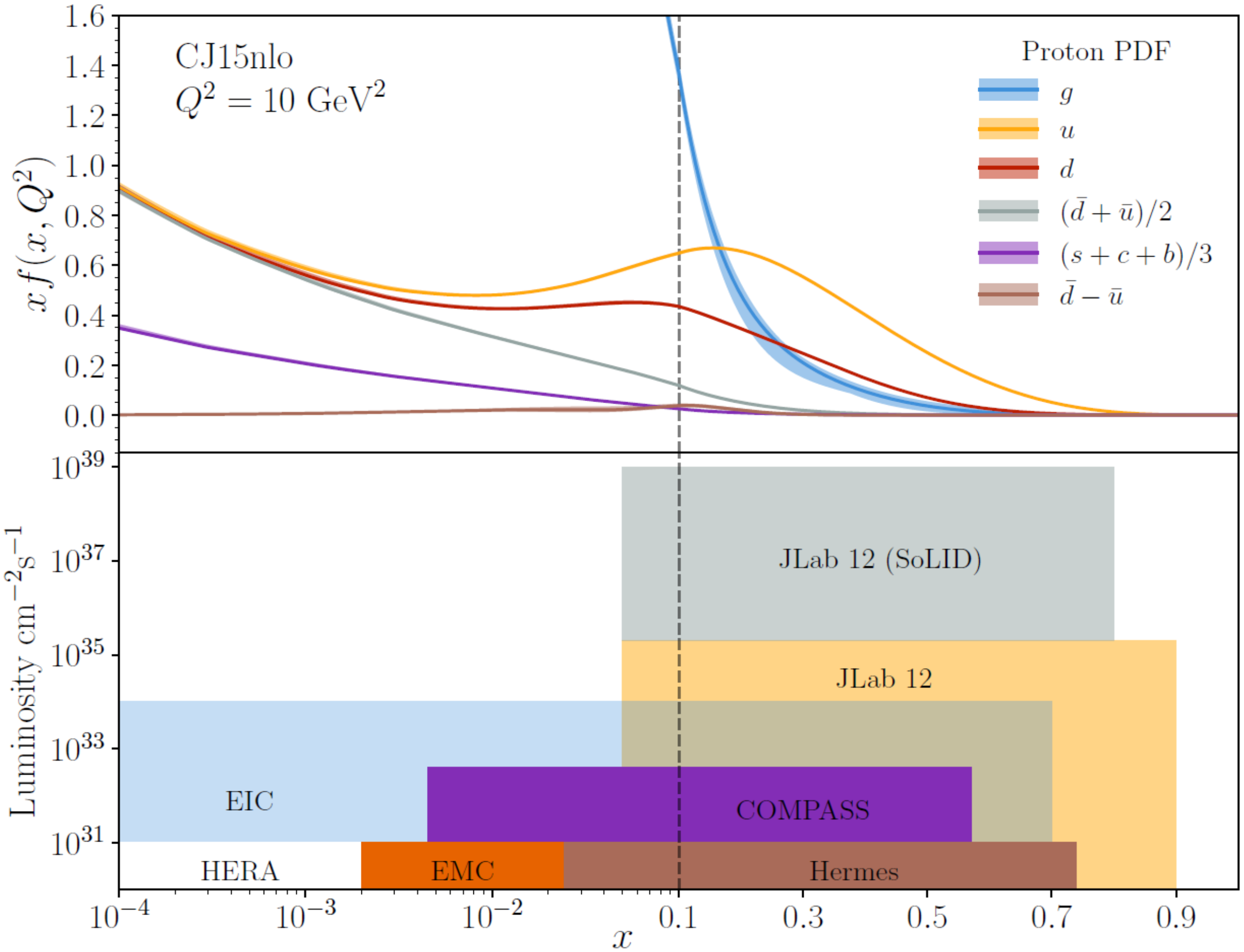
JLAB IS UNIQUE AND COMPLEMENTARY



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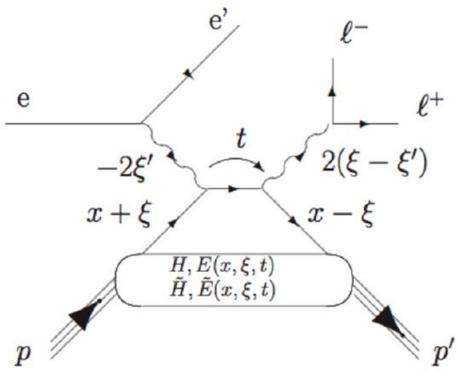
Double Deeply Virtual Compton Scattering (DDVCS)



$$ep \rightarrow e'p'\mu^+\mu^-$$

- Access GPD's away from x=± ξ
- Cross section 100x smaller than DVCS
- Requires large acceptance, high luminosity detector with superb muon detection
- Two Letters of Intent submitted to PAC

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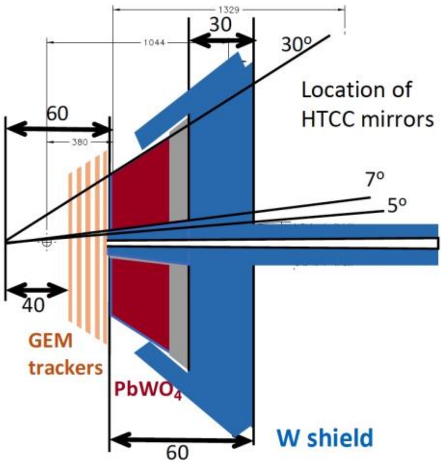
TWO OPTIONS FOR DDVCS

CLAS12 Upgrade ⇒ μ-CLAS12

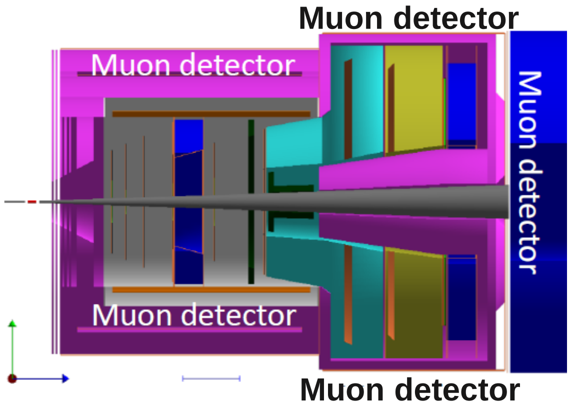
Will handle few $\times 10^{37} cm^{-2} s^{-1}$ luminosities



Calorimeter is for electron detection. The shielding in front of the CLAS12 forward detector converts it into a muon detector.

SoLID with Muon detectors

Can run at luminosities $> 10^{37} cm^{-2} s^{-1}$



With target inside the solenoid and added shielding luminosity of $10^{38} cm^{-2} s^{-1}$ can be reach

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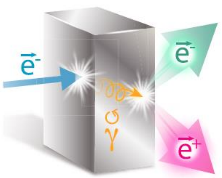
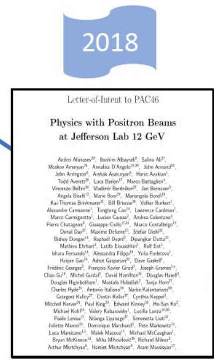
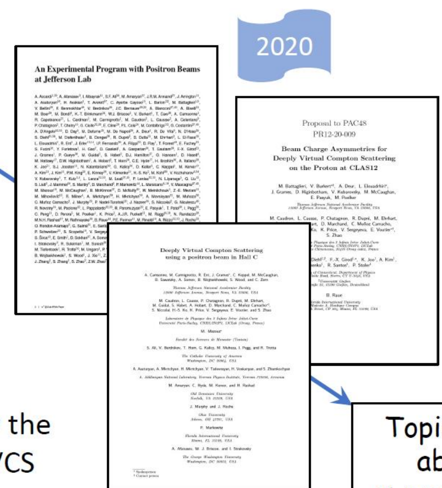
JLAB POSITRON WORKING GROUP



The PWG was created in 2017 after JPos17 (International Workshop on Physics with Positrons at Jefferson Lab) to promote the physics case of positron beams at JLab. It now gathers about 250 physicists from 70 institutions supporting an ambitious experimental program.





2021...

Topical EPJ A Issue
about e^+@JLab
e^+ proposals to PAC49

(E. Voutier)

The Letter-of-Intent to PAC46 was followed in FY20 by the e^+@JLab White Paper (arXiv:2007.15081), and two DVCS proposals to PAC48 (*conditionally approved - C2*).

More proposals to come…

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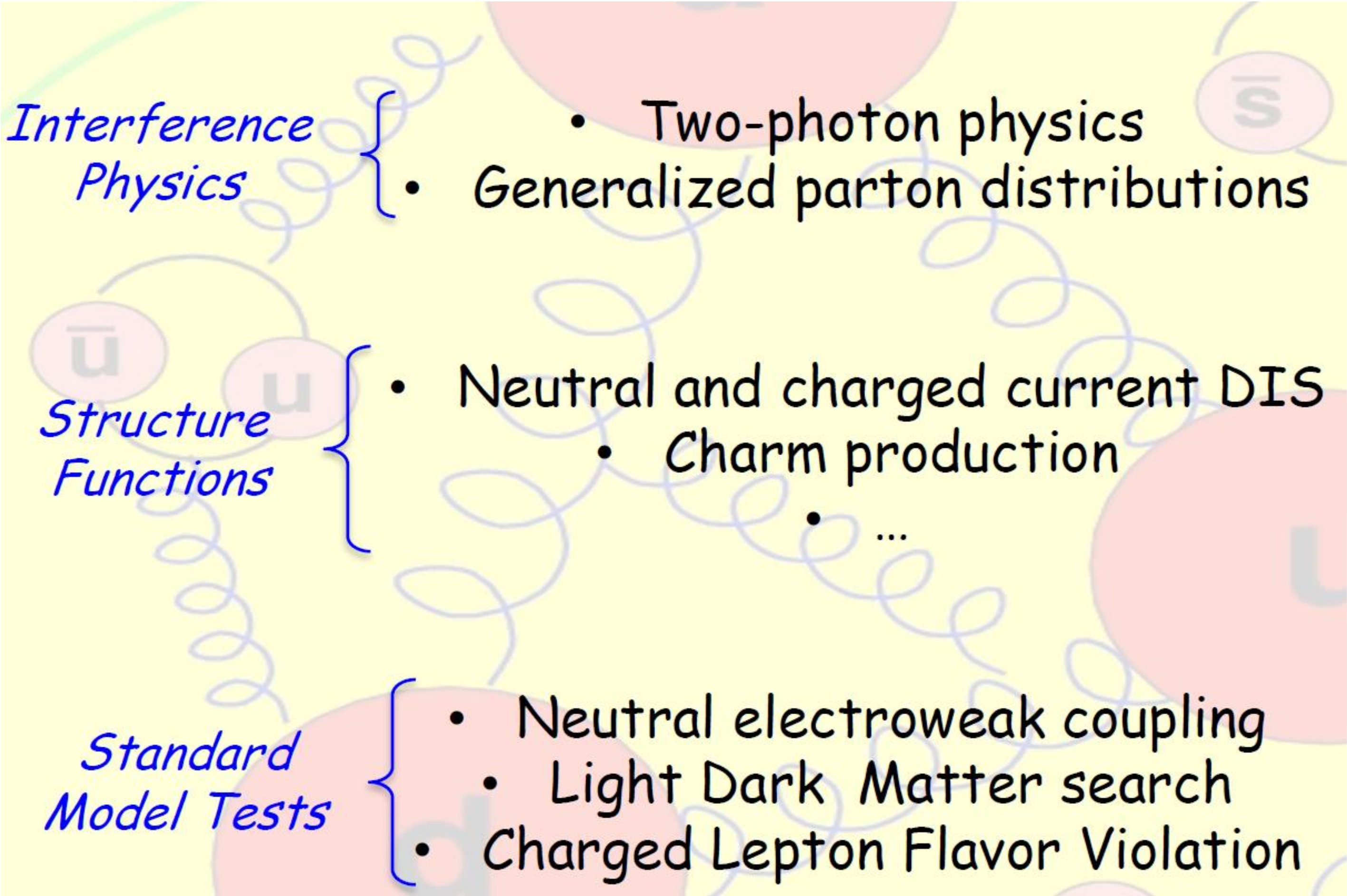
PHYSICS WITH POSITRON BEAMS



(E. Voutier)

CLAS12 PROPOSAL

Pr12-20-009

V. Burkert, L. Elouadrhiri, F.-X. Girod, S. Niccolai, E. Voutier et al.

V. Burkert et al. EPJ A 57 (2021) 186

Beam Charge Asymmetries are proposed to be measured at CLAS12:

- 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 neutral beam spin asymmetry A^0_{LU}, which is sensitive to **higher twist effects**

New GPD Observables @ JLab

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

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

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

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

(E. Voutier)

HALL C PROPOSAL

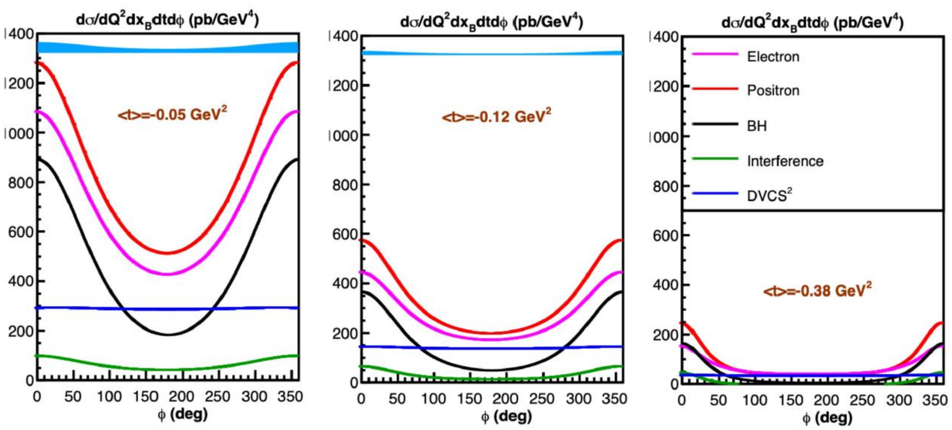
Pr12-20-012

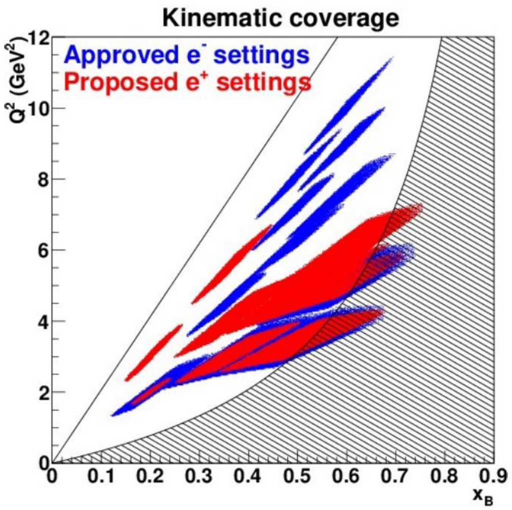
J. Grames, M. Mazouz, C. Muñoz Camacho et al.

A. Afanasev et al. arXiv:2105.06540 (2021)

- Combining the **HMS** and the **NPS** spectrometers, precise cross section measurements with **unpolarized positron** beam will be performed at selected kinematics where **electron beam** data will soon be accumulated.

$x_B = 0.5 \quad Q^2 = 3.4\ GeV^2$

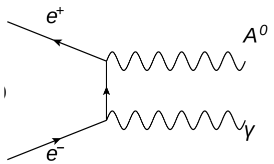


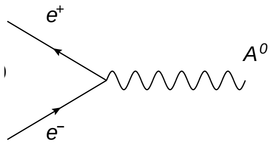


(E. Voutier)

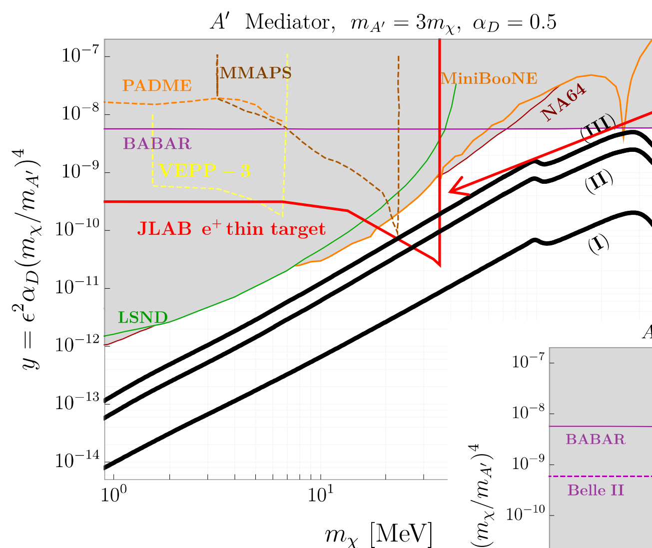
Positron Beam → New Dark Sector Opportunities

- Key Idea: positron annihilation off atomic electrons opens new dark sector production channels
  - Enhanced yield
  - Unique kinematics permits inference of A' mass & model-independent searches

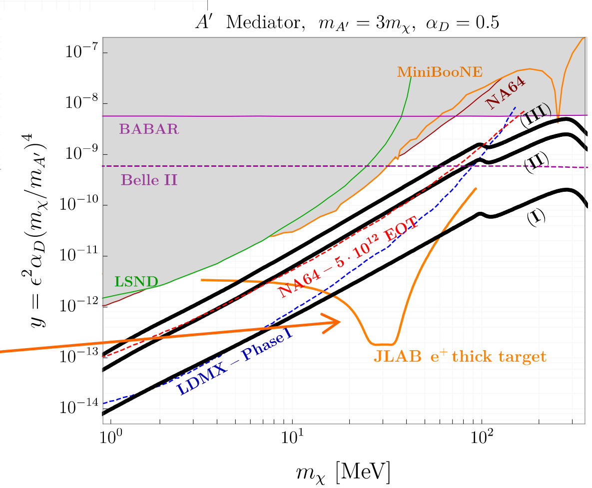




- Two proposed experimental configurations with thin and thick targets yield complementary sensitivity



Thin target: Model-independent search for new forces

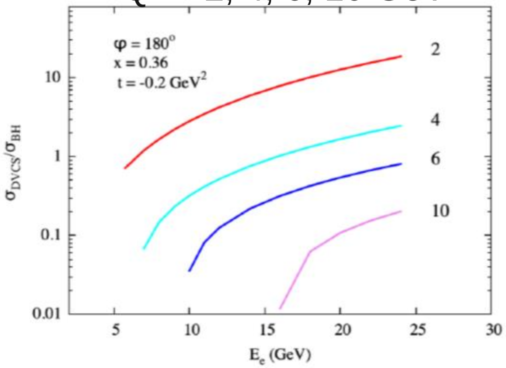


Thick target/active dump: Powerful probe of dark matter production

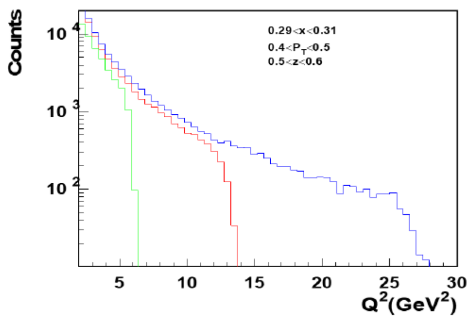
Figure credits: Battaglieri et al. 2105.04540

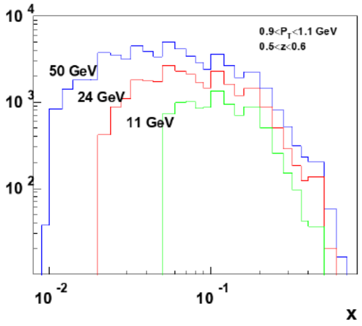
FEMTOGRAPHY AT 24 GEV BEAM ENERGY

Q^2 = 2, 4, 6, 10 GeV^2



DVCS cross section grows with electron energy relative to BH contribution





Higher Q^2 , lower x for SIDIS

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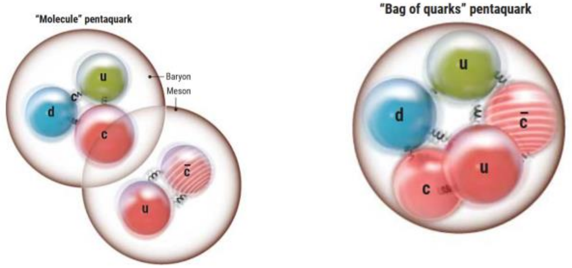
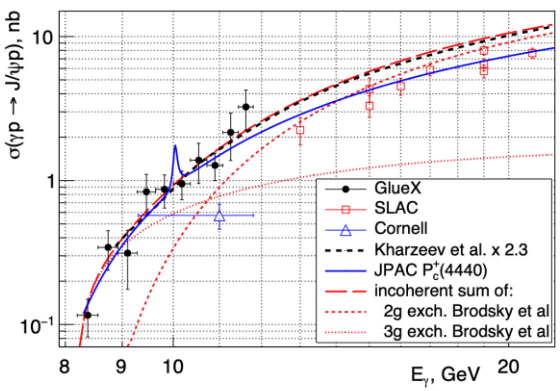
THRESHOLD CHARMONIUM PRODUCTION

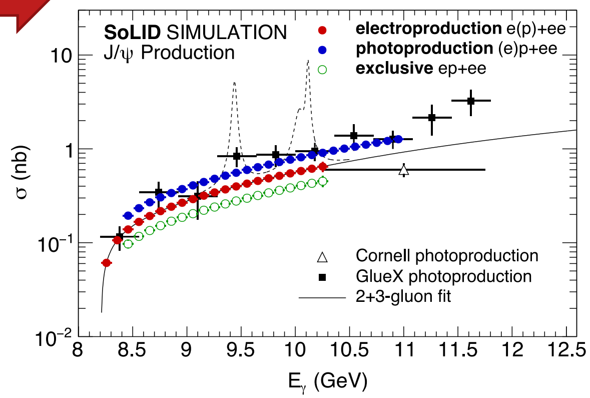
- Proton mass decomposition… mass radius?
- Connection to pentaquarks at LHCb
- Connection between GlueX -> SOLID -> CEBAF energy upgrade…



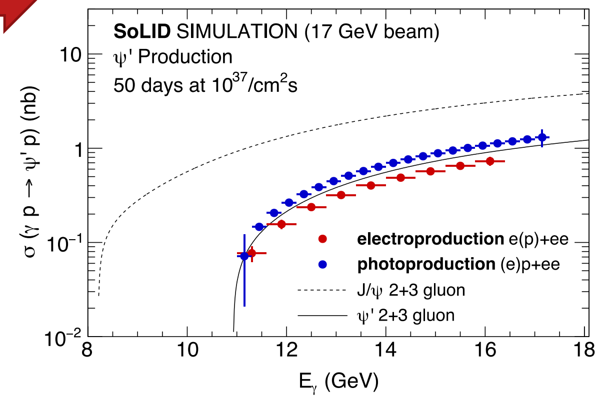
GlueX (current): PRL…



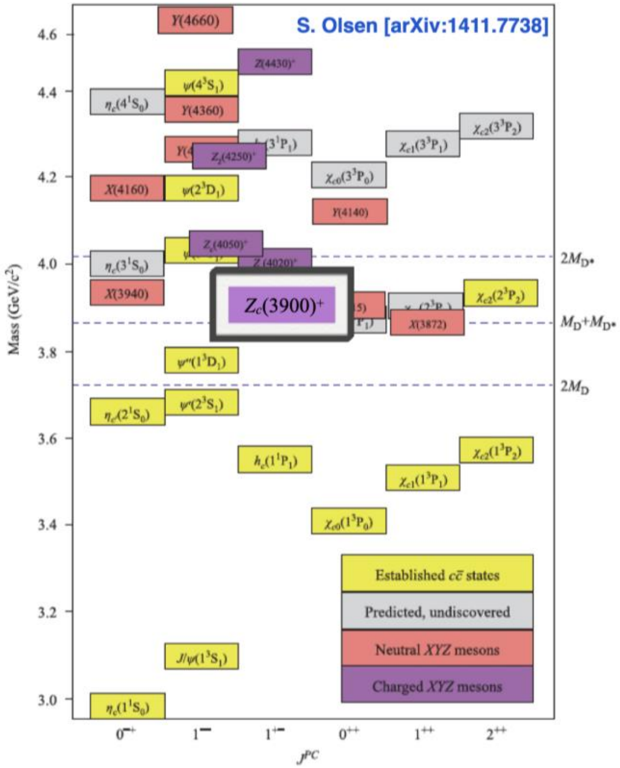
SoLID 12 GeV (2029+)



CEBAF Energy Upgrade

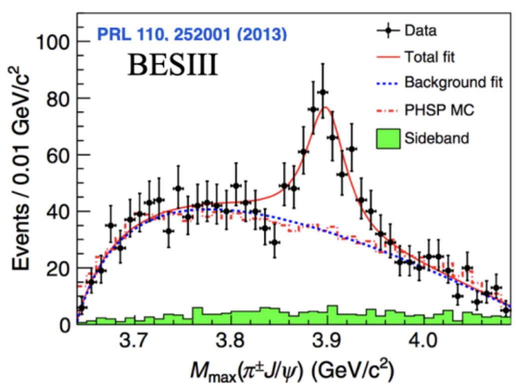


EXCLUSIVE XYZ PRODUCTION

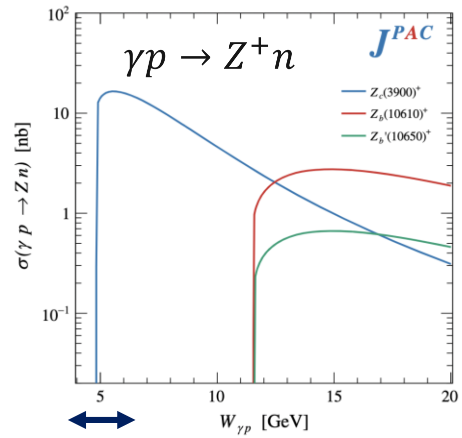


- Unexpected *XYZ* structures observed in charmonium, with many models for interpretation: resonant states, meson molecules, re-scattering, etc.
- Novel photoproduction mechanism, with models suggesting enhanced production ***near threshold for X and Z states***
- Unique access with high luminosity, CEBAF energy upgrade

$$e^+e^- \to \pi^+\pi^- J/\psi \ (4260 \text{ MeV})$$



$$\gamma p \to Z^+ n$$



CEBAF 24 GeV

EIC?

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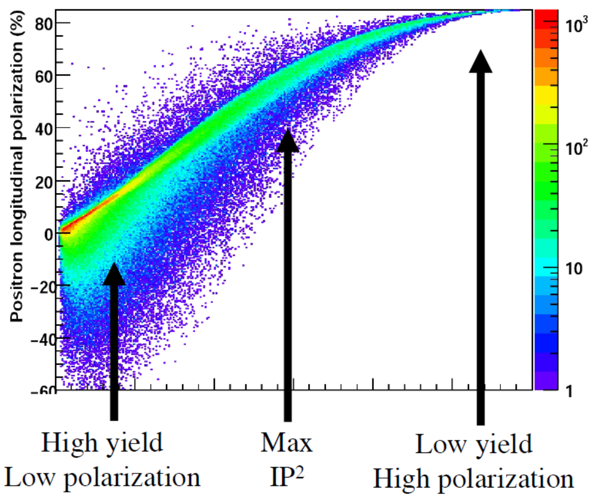
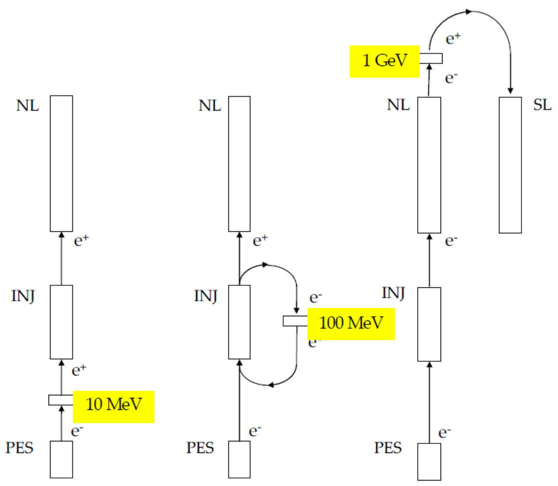
REALIZATION OF POLARIZED POSITRONS AT CEBAF

Positron Source & Beam

- It is the goal of the **current R&D** to identify the most appropriate implementation of **PEPPo at CEBAF**, taking into account the many constraints and technological challenges (**target heating**, **collection system**, **emittance filter**, **injection into CEBAF**, **radiation environment**, **civil construction**, **cost**…) towards the development of a **prototype** and a **CDR**.



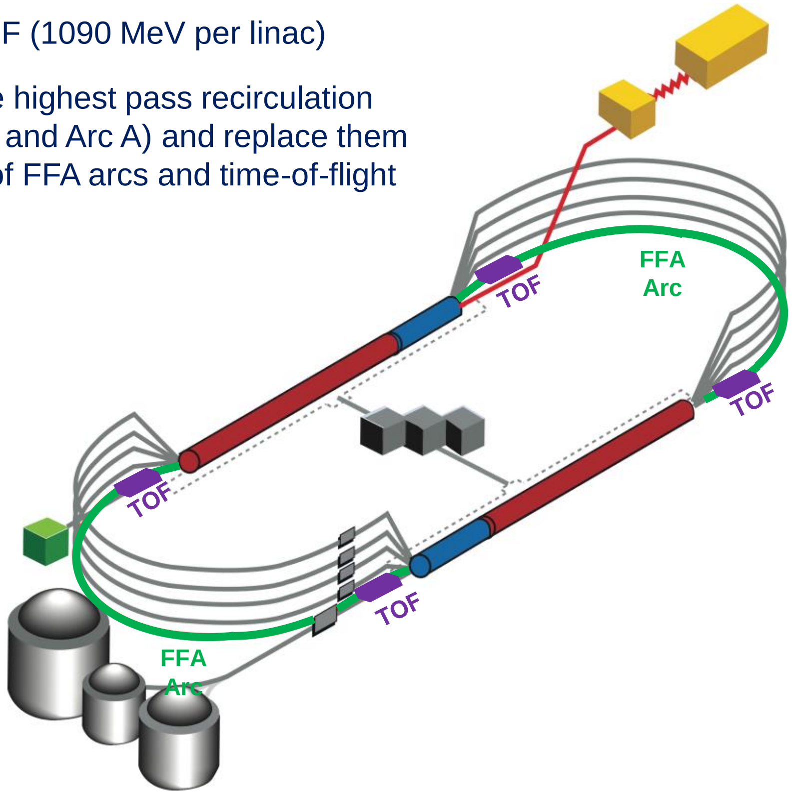


Towards a Conceptual Design Report for end of 2022…

(E. Voutier)

CEBAF FFA UPGRADE CONCEPT

- Starting with 12 GeV CEBAF as a baseline
- NO new SRF (1090 MeV per linac)
- Remove the highest pass recirculation arcs (Arc 9 and Arc A) and replace them with a pair of FFA arcs and time-of-flight chicanes



- Recirculate as many times as feasible to get to 24 GeV:
  - 4 passes with the current CEBAF (Arcs 1-8)
  - 7 passes through non-scaling FFA arcs
  - Permanent magnets used for power and cost savings

(A. Bogacz)

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White Paper

Physics with CEBAF at 12 GeV and Future Opportunities

J. Arrington[1], M. Battaglieri[2,15], A. Boehnlein[2], S.A. Bogacz[2], W.K. Brooks[10], E. Chudakov[2], I. Cloët[3], R. Ent[2], H. Gao[4], J. Grames[2], L. Harwood[2], X. Ji[5,6], C. Keppel[2], G. Krafft[2], R. D. McKeown[2,8,*], J. Napolitano[7], J.W. Qiu[2,8], P. Rossi[2,14], M. Schram[2], S. Stepanyan[2], J. Stevens[8], A.P. Szczepaniak[12,13,2], N. Toro[9], X. Zheng[11]

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arXiv:2112.00060

To be published in Progress in Particle and Nuclear Physics, 2022

White Paper Contents

Physics with CEBAF at 12 GeV and Future Opportunities

- Overview
- Electromagnetic Form Factors and Parton Distributions
- Nuclear Femtography
- Hadron Spectroscopy
- QCD and Nuclei
- Standard Model and Beyond
- Experimental Equipment
- Positron Beams at CEBAF
- CEBAF Energy Upgrade
- Computation for NP

SUMMARY

- CEBAF has a long program ahead that is complementary to the envisioned EIC program
- Upgrades for higher luminosity, polarized and unpolarized positron beams, and higher energies up to 24 GeV are envisioned
- CEBAF will remain the prime facility for fixed target electron scattering at the luminosity frontier