NPS Physics Overview

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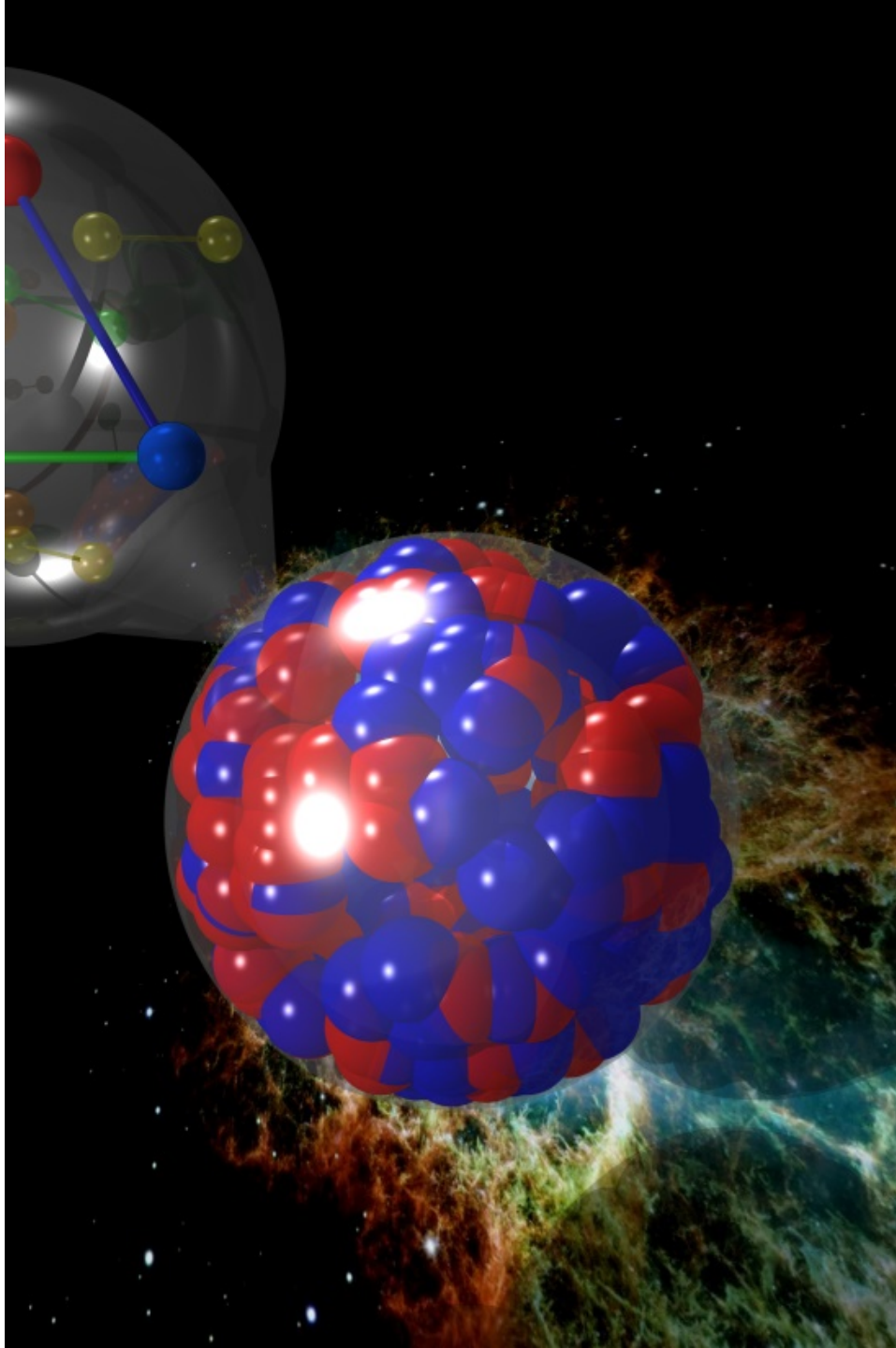
(on behalf of the NPS collaboration)

Hall C Collaboration Meeting
18th February 2022



NPS collaboration

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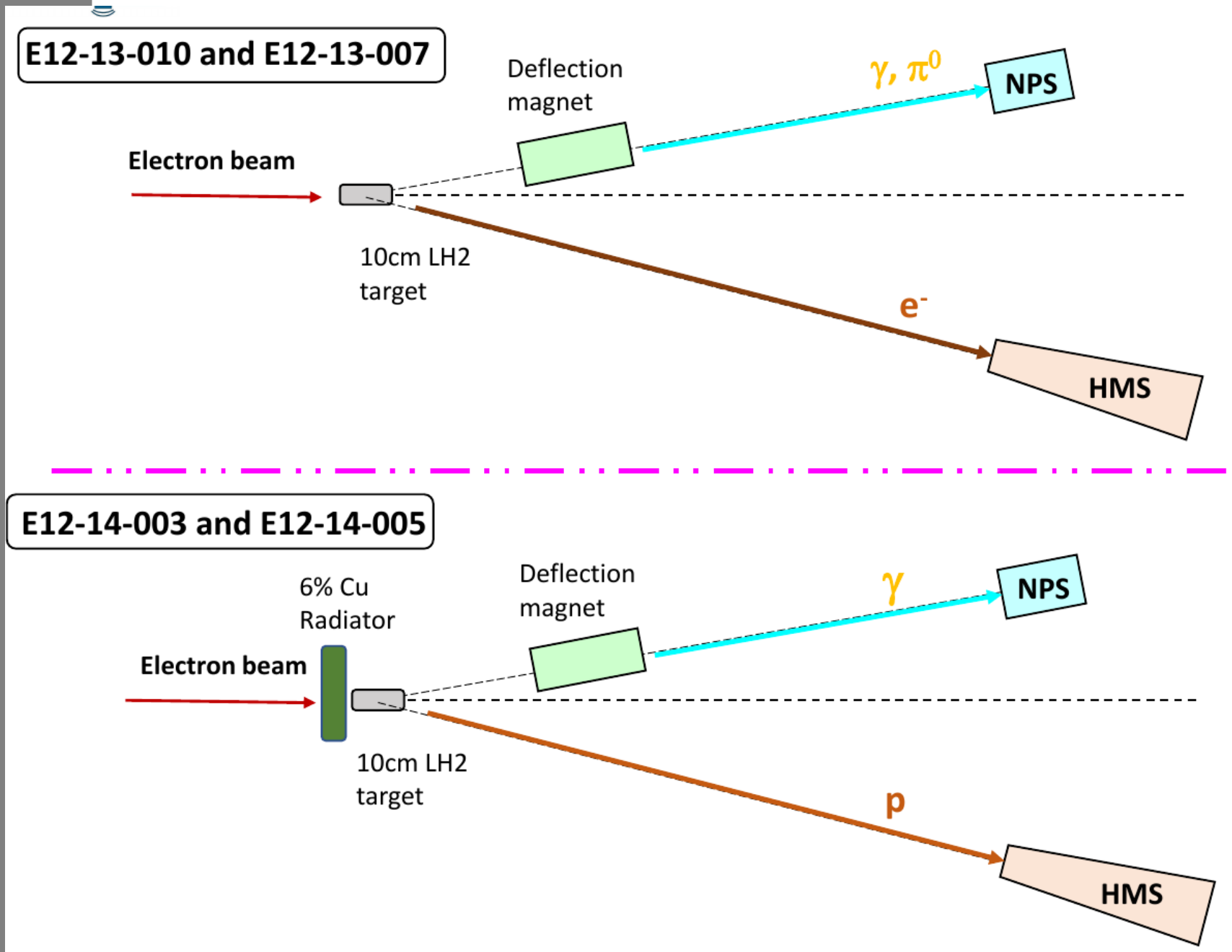
More info in the NPS Wiki: https://wiki.jlab.org/cuawiki/index.php/Main_Page

Overview of NPS experiments

Table from Tanja Horn (2022 NPS collab meeting)

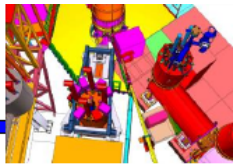
Experiment	Exp #	Beam	Target	PAC Days	Rating
π^0 SIDIS	E12-13-007	$\vec{e}^-$	L H_2	(26)	A$^-$
DVCS and Exclusive π^0	E12-13-010	$\vec{e}^-$	L H_2	53	A
Wide Angle Compton Scattering (WACS)	E12-14-003	e^-, γ	L H_2	18	A$^-$
Wide Angle Exclusive π^0 photoproduction	E12-14-005	e^-, γ	L H_2	(18)	B
DVCS – days moved from Hall A	E12-06-114	$\vec{e}^-$	L H_2	35	A
A_{LL} & A_{LS} Polarization Observables in WACS at large s, t, and u	E12-17-008	CPS: $\vec{\gamma}$	$N\vec{H}_3$	46	A$^-$
Timelike Compton Scattering (TCS) off a Transversely Polarized Proton	C12-18-005	CPS: $\vec{\gamma}$	$[N\vec{H}_3]_T$	35	C2

- Successful ERR in 2019 for first 4 experiments in the table (E12-17-008 fully approved in 2018).
- Scheduling request submitted for E12-13-007 and E12-13-010.



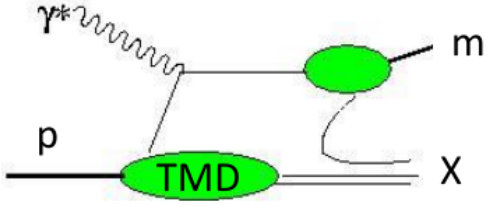
Figures from Tanja Horn (2019 ERR meeting)

E12-13-007 – SIDIS basic (e,e'π) cross sections



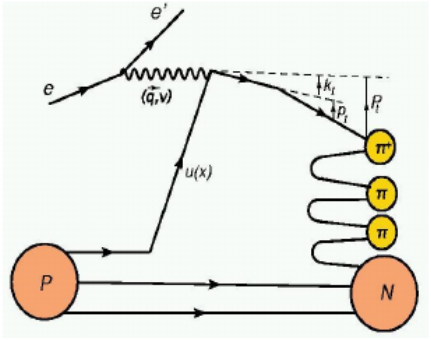
Linked to framework of *Transverse Momentum Dependent Parton Distributions*

- Validation of factorization theorem needed for most future SIDIS experiments and their interpretation
- Need to constrain TMD evolution w. precision data
- Questions on target-mass corrections and ln(1-z) re-summations require precision large-z data



$TMD^q(x,k_T)$

Transverse momentum widths of quarks with **different flavor (and polarization)** can be different



$P_T = p_t + z\,k_t + O(k_t^2/Q^2)$

E12-13-007 goal: Measure the basic SIDIS cross sections of π^o production off the proton, including a map of the P_T dependence ($P_T \sim \Lambda < 0.5$ GeV), to validate(*) flavor decomposition and the k_T dependence of (unpolarized) up and down quarks

(*) Can only be done using spectrometer setup capable of %-type measurements (an essential ingredient of the global SIDIS program!)

Requires new ~25 msr Neutral-Particle Spectrometer

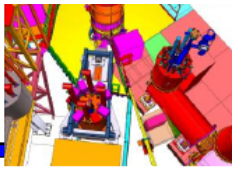
Advantages of (e,e'π^o) beyond (e,e'$\pi^{+/-}$)

- Many experimental and theoretical advantages to validate understanding of SIDIS with neutral pions
- Can verify: $\sigma^{\pi^o}(x,z) = \frac{1}{2}(\sigma^{\pi^+}(x,z) + \sigma^{\pi^-}(x,z))$
- Confirms understanding of flavor decomposition/k_T dependence

PAC: "the **cross sections** are **such basic tests of the understanding of SIDIS** at 11 GeV kinematics that they will play a **critical role** in establishing the entire SIDIS program of studying the partonic structure of the nucleon."

Figures from Tanja Horn (2018 Hall C collab meeting)

E12-13-010: precision DVCS cross sections



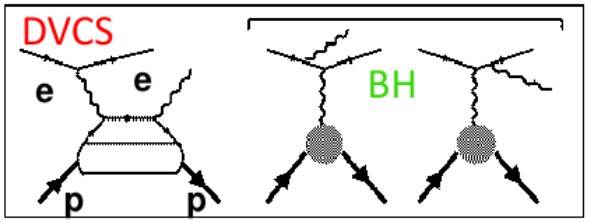
Simplest process: **e + p → e' + p + γ (DVCS)**

E12-13-010 DVCS measurements follow up on measurements in Hall A:

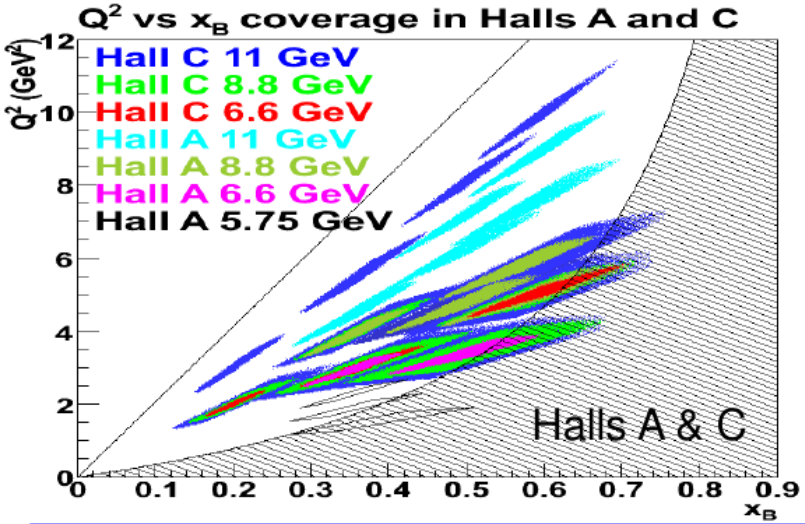
- Scaling of the Compton Form Factor
- Rosenbluth-like separation of DVCS:

$$\sigma = |BH|^2 + \underbrace{\mathrm{Re}\left[DVCS^{\perp}\ BH\right]}_{\sim E_{beam}^{2}} + \underbrace{|DVCS|^2}_{\sim E_{beam}^{3}}$$

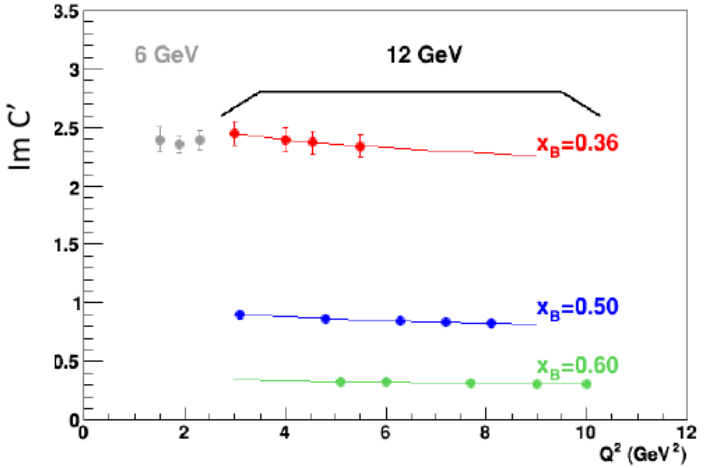
- L/T separation of π^0 production



Hall A data for Compton form factor (over *limited* Q^2 range) agree with hard-scattering



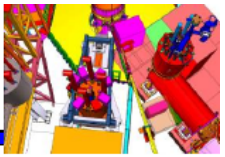
12 GeV projections: confirm formalism

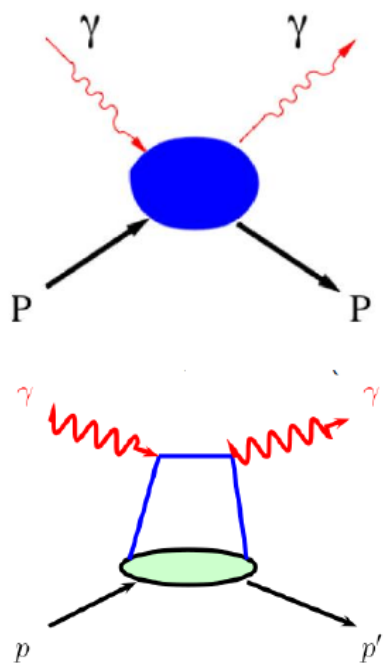


Extracting the real part of CFFs from DVCS requires measuring the cross section at multiple beam energies ($DVCS^2$–Interference separation)

Figures from Tanja Horn (2018 Hall C collab meeting)

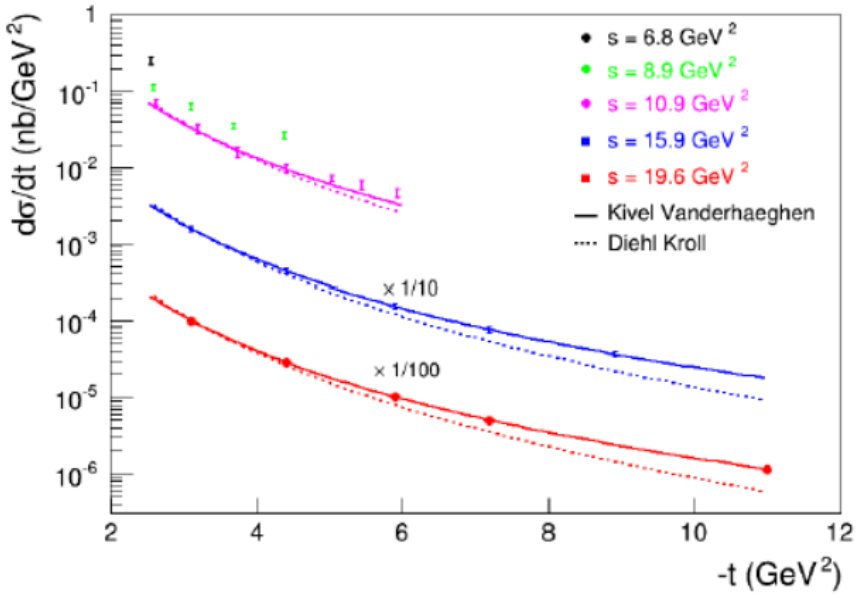
E12-14-003: Wide Angle Compton Scattering





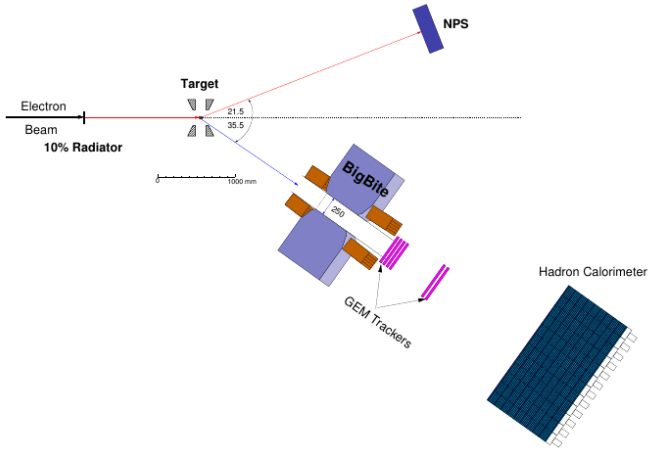
- Arguably the least understood of the fundamental reactions in the several-GeV regime
- Wide-Angle Compton Scattering cross section behavior was a foundation leading to the GPD formalism
- Reaction mechanism intrinsically intertwined with basics of hard scattering process (handbag diagram), yet also sensitivity to transverse structure like high-Q^2 form factors

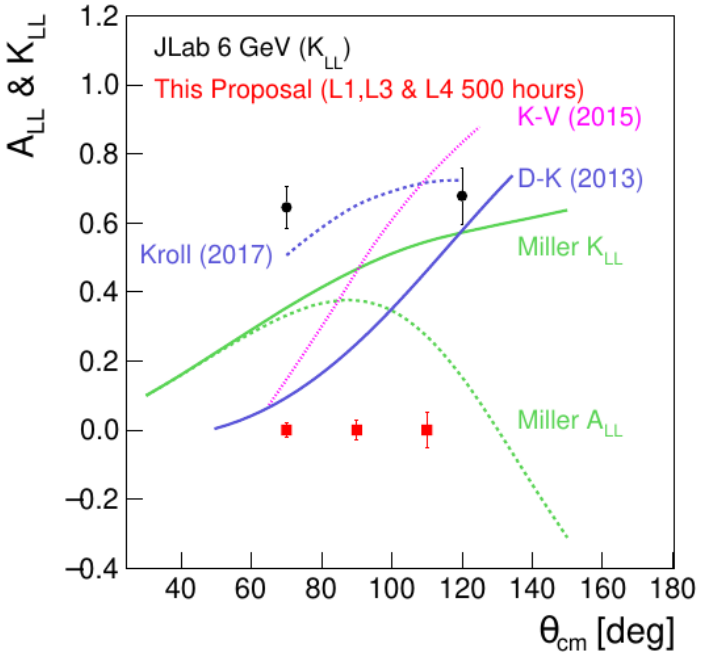
- Perhaps (6-GeV data) factorization valid for *s, -t, -u > 2.5 GeV²*
- 12-GeV data for *–u > 2.5* and *–t* up to *~ 10, s* up to *~ 20* GeV²



Figures from Tanja Horn (2018 Hall C collab meeting)

E12-17-008: Polarized Wide-angle Compton Scattering



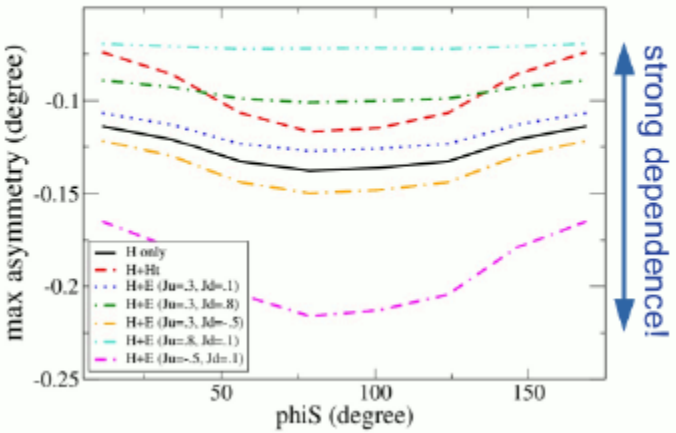


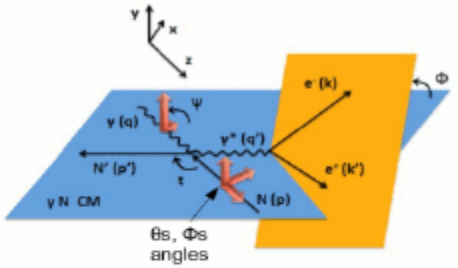
The use of the CPS and BigBite results in a significantly improved figure-of-merit over all previous experiments and opens up a new range of polarized physics opportunities at JLab.

- Make an explicit, model-independent test of factorization by measuring the s-dependence of the polarization observables at fixed θ_p^{cm}, and verify that target mass corrections and higher twist effects are small.
- Constraining the GPDs $\tilde{H}$ and E at high $-t$ and comparing with the Axial and Pauli form factors will have a significant and broad impact in the fields of electron and neutrino scattering.

C12-18-005: Time-like Compton Scattering

Sin(φ) moment of transverse spin asymmetry vs φ_S,
Dependence in GPD E and $J^{u,d}$ (VGG model)

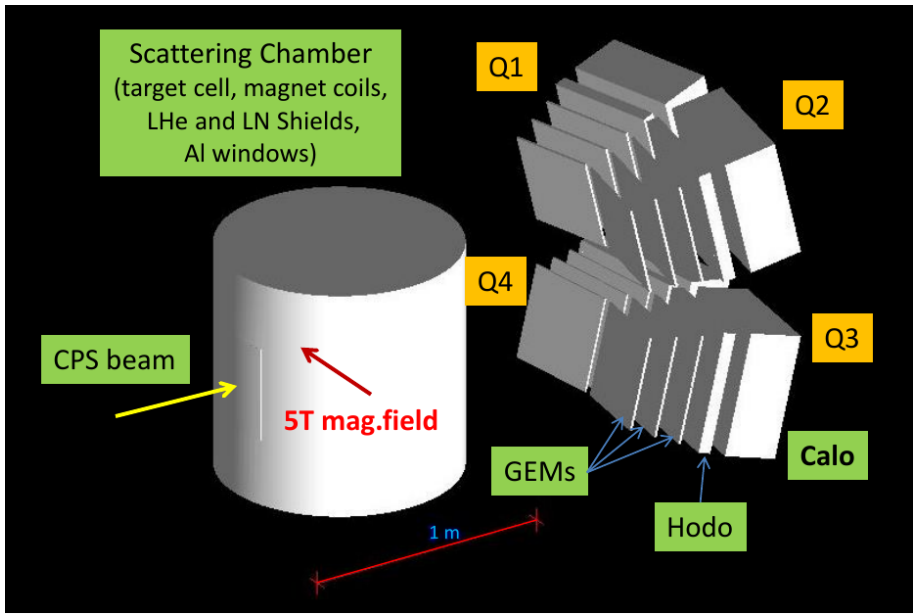




TSA as a function of φ and φ_s

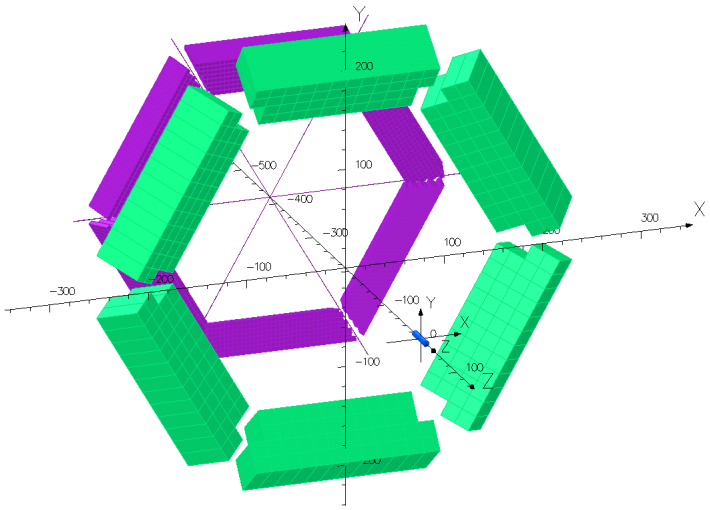
- Sensitive to Im(interference), BH cancels
- Strong dependence in angular momenta,

Sensitivity to GPD E (also to H, Ht)

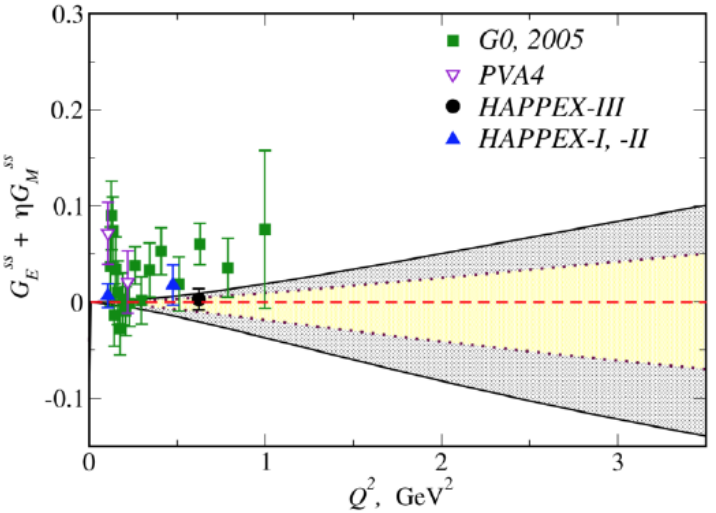


Figures from Vardan Tadevosyan (2022 NPS collab meeting)

New physics with NPS: G_s at 3 GeV^2

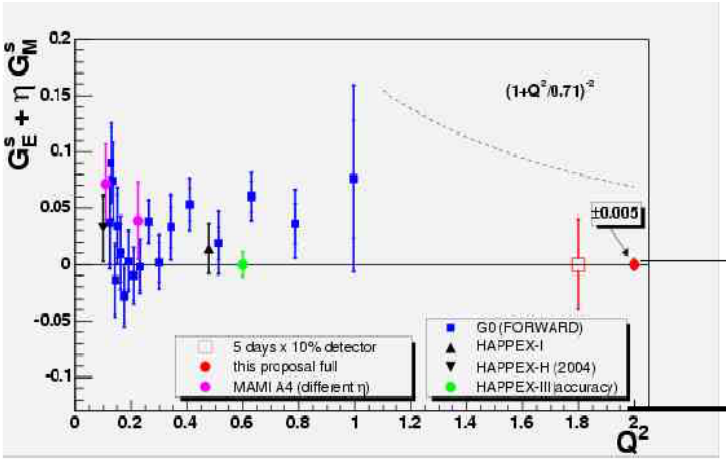


T.Hobbs & J.Miller, 2018



projected precision
at Q^2 = 3 GeV^2

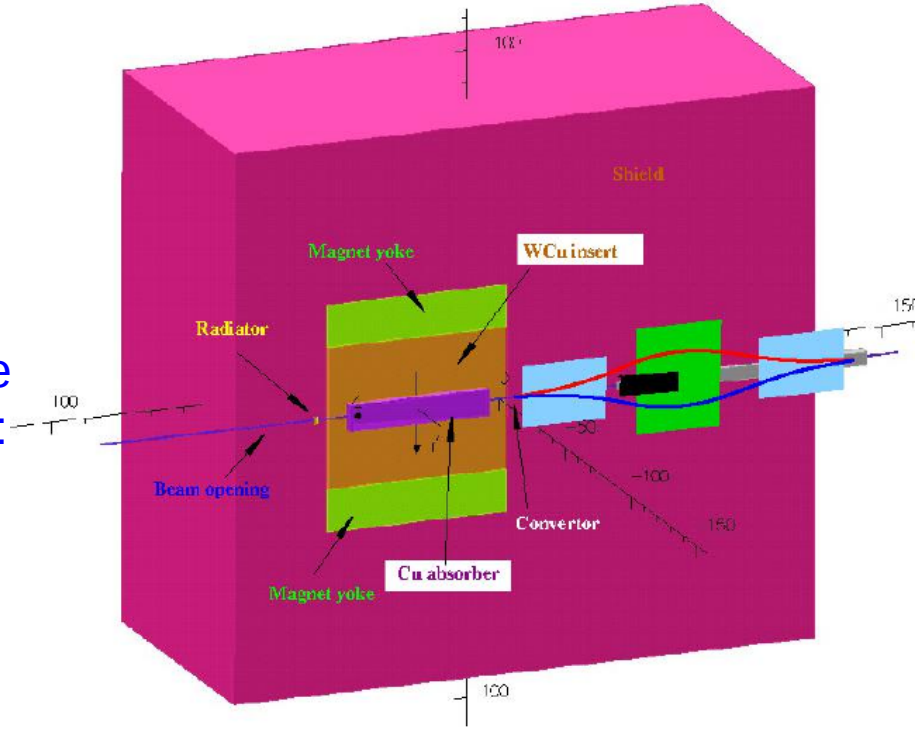
$\Delta G^s/G_D = 0.05$



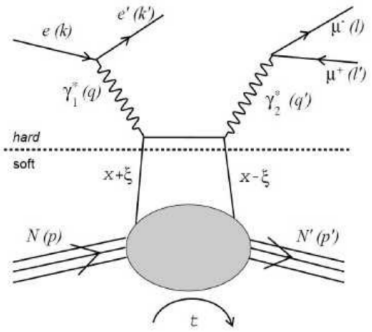
Figures from Bogdan Wojtsekhowski (2022 NPS collab meeting)

Other new physics ideas with NPS

- CPS as a positron source (Bogdan Wojtsekhowski):
  - TPE effects
  - Dark photon search



- Beyond DVCS and TCS (Marie Boer):
  - DDVCS (access to ERBL region)
  - J/Psi on transversely polarized target



DDVCS
Access GPDs
Q'² != Q² & greater than 1 GeV²
Depends on x, xi, t + evolution

Figures from Bogdan Wojtsekhowski (Hall C Futures Whitepaper)

and

Marie Boer (NPS collab meeting 2022)

Summary & Outlook

- NPS physics programme consists of six approved experiments.
- Common feature is high-precision studies of cross sections and polarization observables involving neutral final states in order to:
  - systematically study reaction mechanism and factorization;
  - map out nucleon structure in new kinematic regimes.
- Some exciting new physics ideas under development.
- Calorimeter construction planned this summer.
- More details at: https://wiki.jlab.org/cuawiki/index.php/Main_Page

Thank you for your attention