

Charmonium Working Group Overview

Workshop on the Physics Program with High Luminosity
Facilities

P. Chatagnon, Y. Guo, S. Joosten

Charmonium Session Overview

	CEBAF CENTER F113, Jefferson Lab	15:30 - 16:00
16:00	Holographic QCD Observables	ismail zahed
	CEBAF CENTER F113, Jefferson Lab	16:00 - 16:30
	Observables through J/psi and phi production (remote)	Yoshitaka Hatta
	CEBAF CENTER F113, Jefferson Lab	16:30 - 17:00
17:00	Open charm, pentaquarks, u-channel (remote speaker)	Daniel Winney
	CEBAF CENTER F113, Jefferson Lab	17:00 - 17:30
	Coffee	
	CEBAF CENTER F113, Jefferson Lab	08:30 - 09:00
09:00	Charmonium in Hall A + Hall C	Sylvester Joosten
	CEBAF CENTER F113, Jefferson Lab	09:00 - 09:30
	Charmonium in Hall B	Pierre Chatagnon
	CEBAF CENTER F113, Jefferson Lab	09:30 - 10:00
10:00	Charmonium in Hall D	Lubomir Pentchev
	CEBAF CENTER F113, Jefferson Lab	10:00 - 10:30
	Coffee and Cookies	
	CEBAF CENTER F113, Jefferson Lab	10:30 - 11:00
11:00	SI Charmonium at the EIC and LHC (remote)	Charlotte Van Hulse
	CEBAF CENTER F113, Jefferson Lab	09:50 - 10:20
	Phi production at high luminosities	Henry Klest
	CEBAF CENTER F113, Jefferson Lab	11:30 - 12:00
12:00	Discussion and White Paper Planning	Conveners
	CEBAF CENTER F113, Jefferson Lab	12:00 - 12:30
	Lunch	

Theory

JLab
measurements

Complementary
measurements

Work:

Working Group

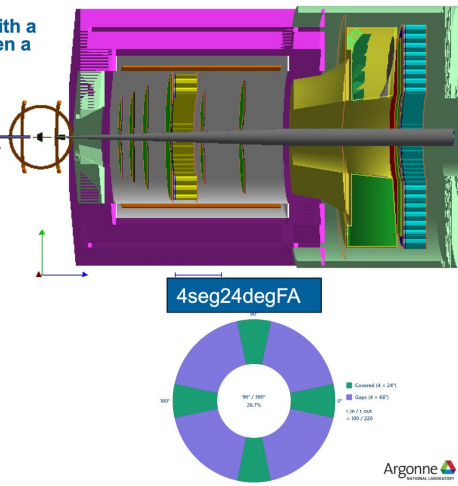
New Detectors for High-Luminosity Charmonium

A “SoLID-lite” detector built around the CLEO magnet is a promising avenue for high-precision J/ψ photoproduction

SOLID-LITE

An option that delivers on the science program with a first focus on near-threshold J/ψ production & then a modest enhancement for SIDIS

- SoLID light option (“4seg24degFA”)
 - Works for both J/ψ and polarized ^3He SIDIS
 - Reduce Forward Angle into 4 segments of 24 deg each while keeping Large Angle full
 - Solenoid magnet using CLEO iron (purple) without modification for J/ψ , then add front piece and endcap (green) for SIDIS, no magnet endcap nose
 - One Cherenkov with CO_2 , with the reuse of the sPHENIX ECAL to populate the Large Angle and 4 sections of the Forward Angle



CLAS12 has a phased upgrade strategy that enables further high-precision J/ψ observables with each step

Upgrade path: Stage II

Stage I

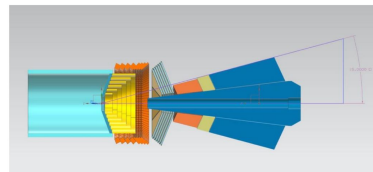
7° Møller cone, no Forward Tagger
up to $5 \times 10^{26} \text{ cm}^{-2}\text{s}^{-1}$

Stage II

wECal + Pb shield, 7°–15°, no HTCC
up to $10^{26} \text{ cm}^{-2}\text{s}^{-1}$

Stage III = μCLAS12

full FD shield and wCal
 $10^{27} \text{ cm}^{-2}\text{s}^{-1}$



Stage II layout: wECal and Pb shield from 7° to 15°

Configuration

- wECal + Pb shield from the 7° Møller cone to 15°
- HTCC removed

Physics

- CLAS12 program, limited to high-rate kinematics
- J/ψ quasi-real photoproduction tagging the recoil nucleon
- Deuteron target: separate bound neutron and proton
- Possible first DDVCS measurements

Operations

- Experience running with μA beam currents

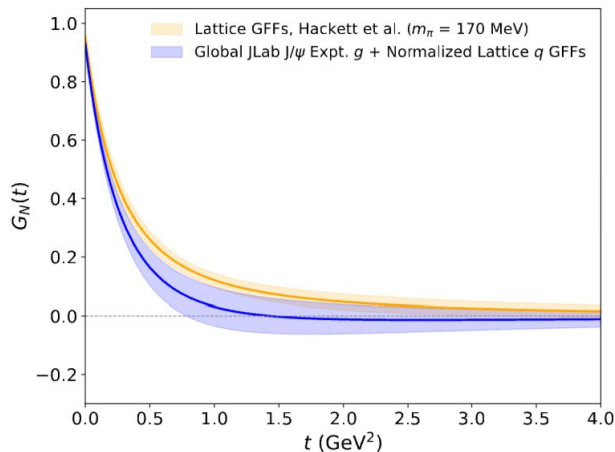
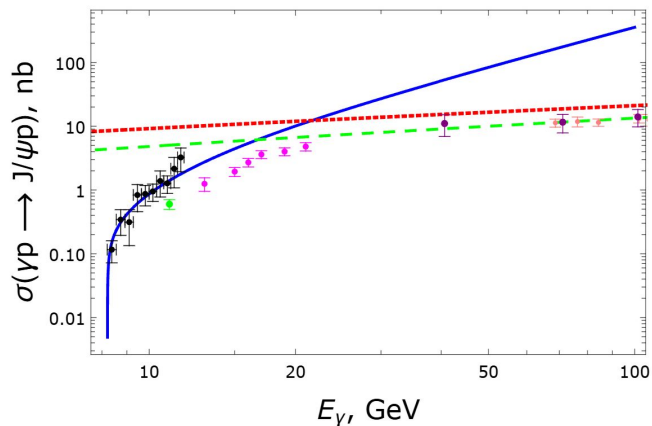
Simulation studies

- Luminosity up to $10^{26} \text{ cm}^{-2}\text{s}^{-1}$, based on estimated background levels
- First estimates for J/ψ production on neutron

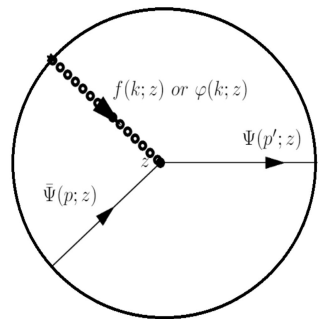
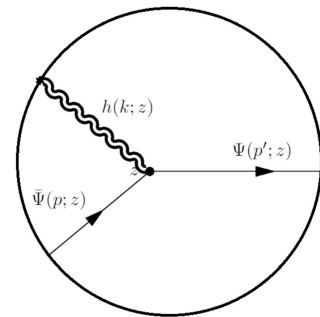
Holographic QCD Observables - I. Zahed

Scalar and tensor exchanges correspond to the A and C GFFs that can be probed in exclusive J/ψ production.

Predictions extend to general observables including GPDs and generalized form factors, showing agreements with lattice and exp.

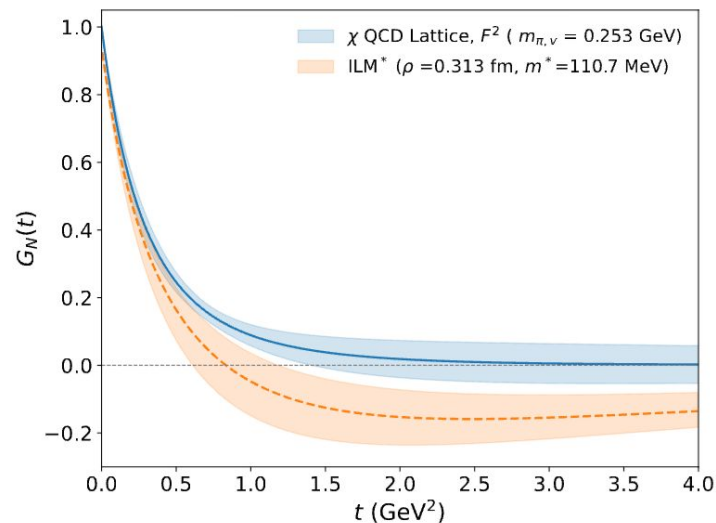
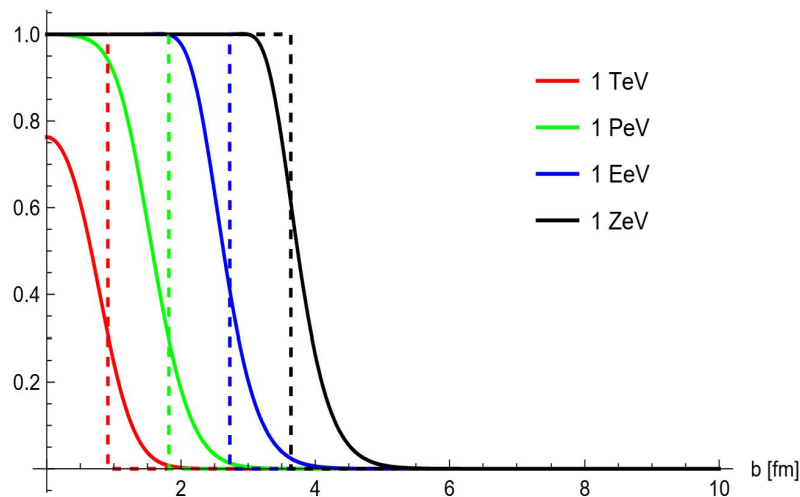


Nucleon GFFs
in holographic QCD



Holographic QCD Observables 2 - I. Zahed

The QCD vacuum is effectively described with strings. This allows predictions of the saturation physics (above 1 PeV in pp). The vacuum physics can be described well by the instanton liquid model (ILM) as well, showing agreement with the lattice.



Observables through J/ψ and φ production - Y. Hatta

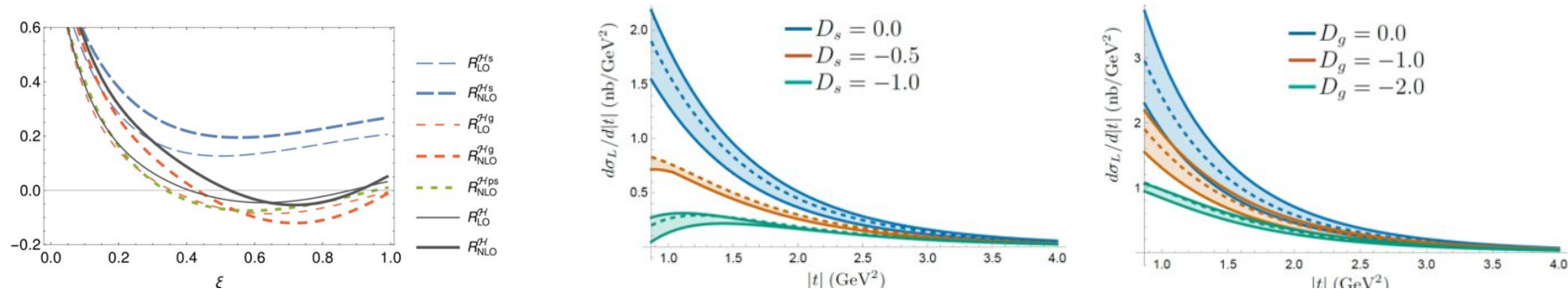
Exclusive productions are well established in the GPD framework within QCD factorization. Applications include but are not limited to DVCS, exclusive heavy and light meson productions, the Sullivan process, etc.

Threshold expansion connects scattering amplitude with the nucleon GFFs.

what is measurable

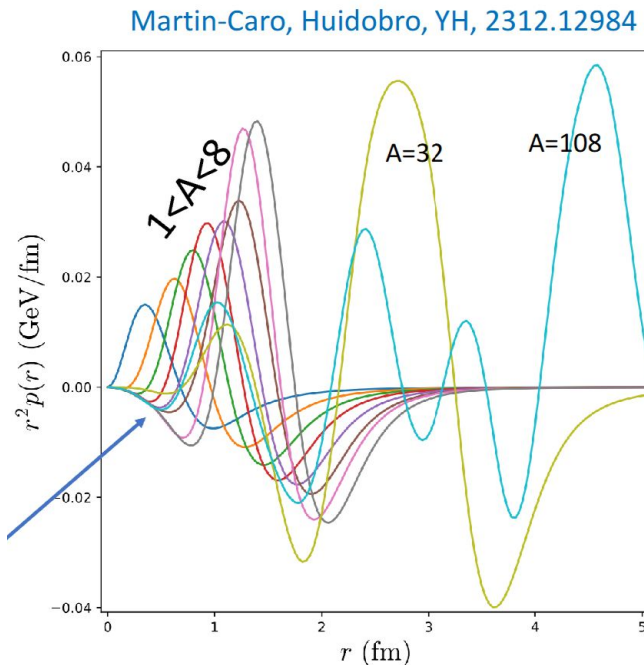
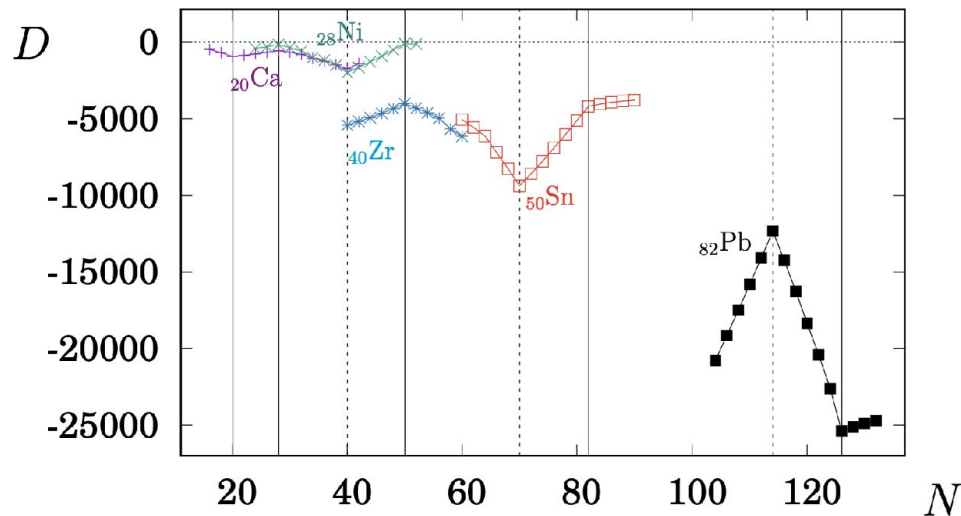
what we want

$$\int_{-1}^1 dx \frac{1}{\xi - x - i\epsilon} \left\{ \frac{1}{2} H^{q(+)}(x, \xi, t, \mu^2), \frac{1}{x} H^g(x, \xi, t, \mu^2) \right\} \approx \frac{2}{\xi^2} \frac{5}{4} (A^a(t, \mu^2) + \xi^2 D^a(t, \mu^2))$$



Observables through J/ψ and ϕ production 2 - Y. Hatta

Additionally, the GFFs of nuclei appear to involve even richer physics and motivate further investigations.

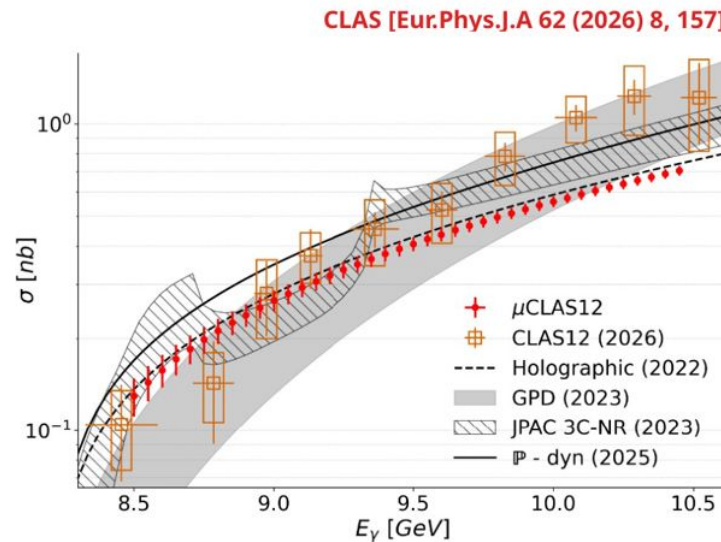
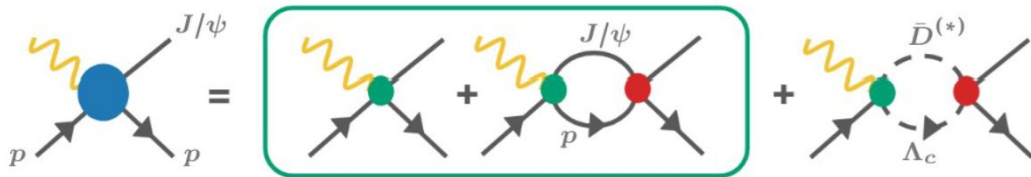


Open charm, pentaquarks, u-channel - D. Winney

The production mechanism merits further examination:

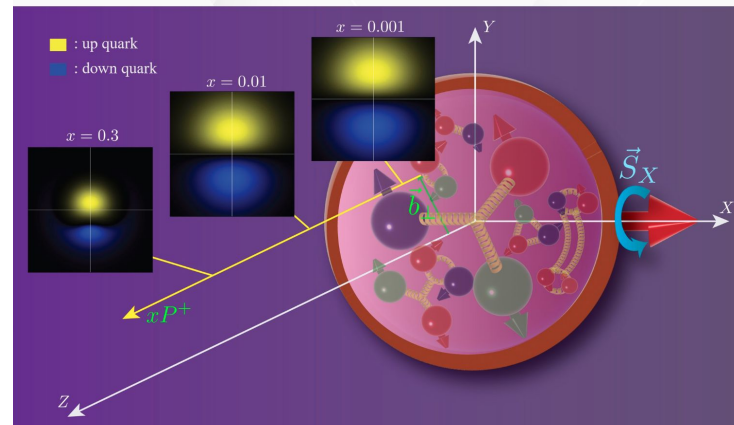
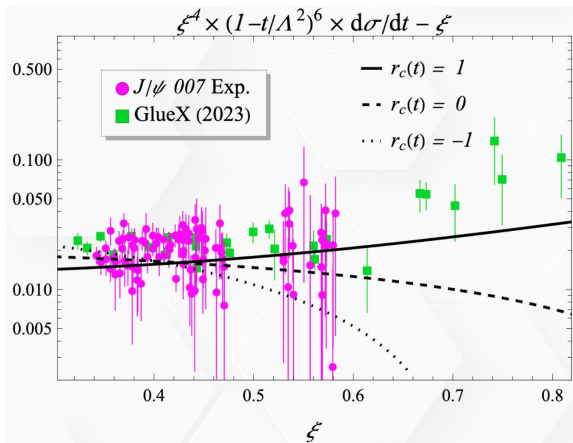
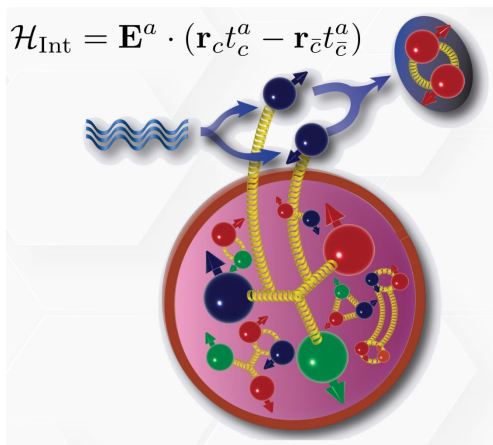
Need to identify observables and experimental measurements to test models (feasibility of polarization observables?)

$$\text{Im} \langle \lambda_\psi \lambda_f | F_J | \lambda_\gamma \lambda_i \rangle = \sum_{\lambda'_\psi \lambda'_f} \rho \langle \lambda_\psi \lambda_f | T_J^\dagger | \lambda'_\psi \lambda'_f \rangle \langle \lambda'_\psi \lambda'_f | F_J | \lambda_\gamma \lambda_i \rangle$$



GPDs and Gravitational form factors- Y. Guo

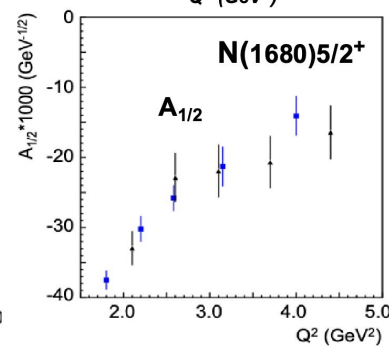
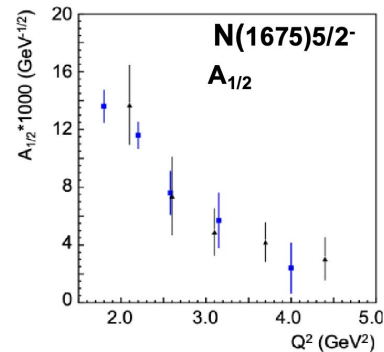
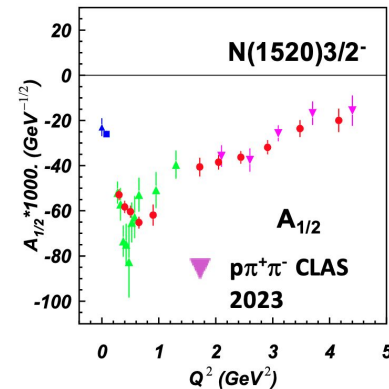
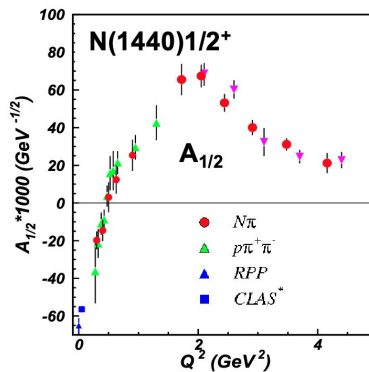
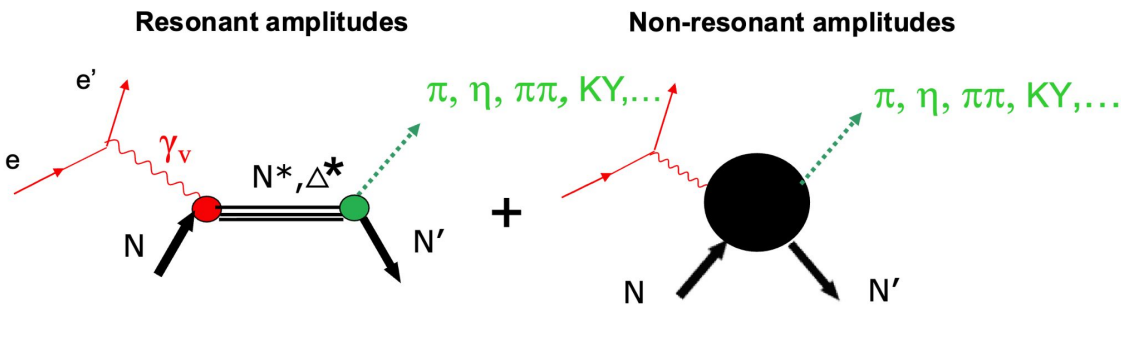
Determining GPDs and their associated gravitational form factors is a major objective at the luminosity frontier. Their extraction benefits significantly from broad kinematic coverage, complementary reaction channels and polarization configurations, and high-precision data. Ongoing theoretical efforts aim to assess perturbative convergence, test GPD universality, and quantify kinematic and other corrections.



High Q^2 Nucleon Resonance Study - V. Mokeev

N^* electroexcitation amplitudes provide a window into strong interaction dynamics in the non-perturbative regime.

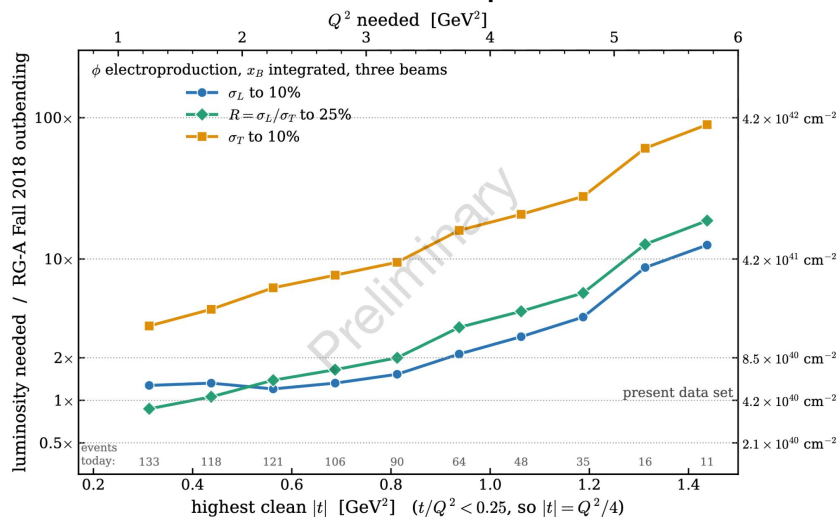
Higher luminosity operations with the large acceptance CLAS12 detector enable significant gains in extracting the N^* electroexcitation amplitudes.



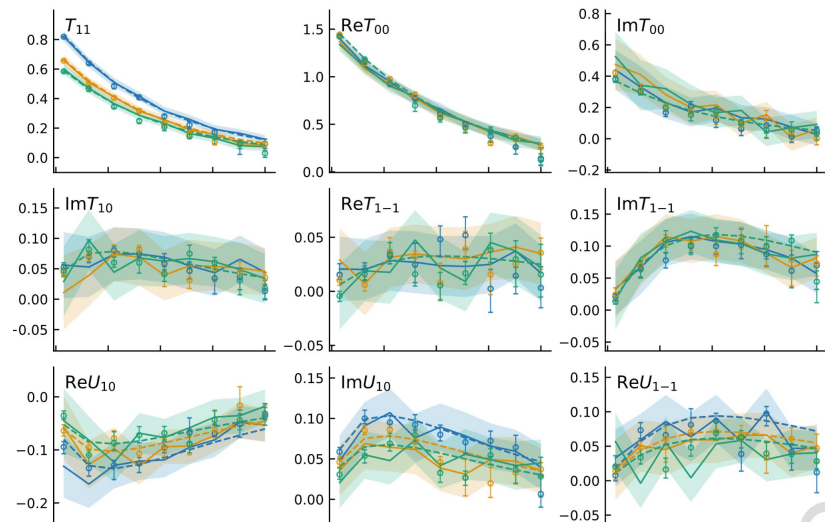
Vector meson helicity amplitudes - B. Singh

Helicity amplitudes provide a complete description of the reaction at general kinematics. A new Bayesian approach applied to extract the helicity amplitudes with calibrated uncertainties and kinematics dependencies.

Partial examples of extracted helicity amplitude for the phi meson

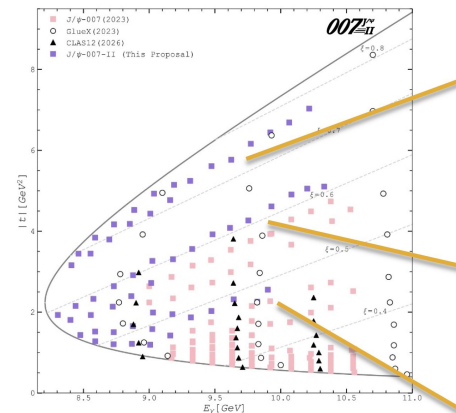
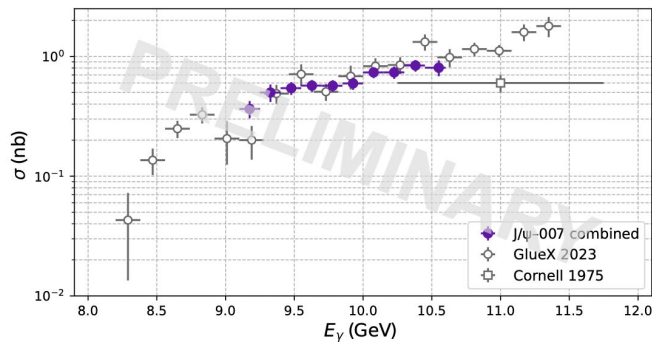
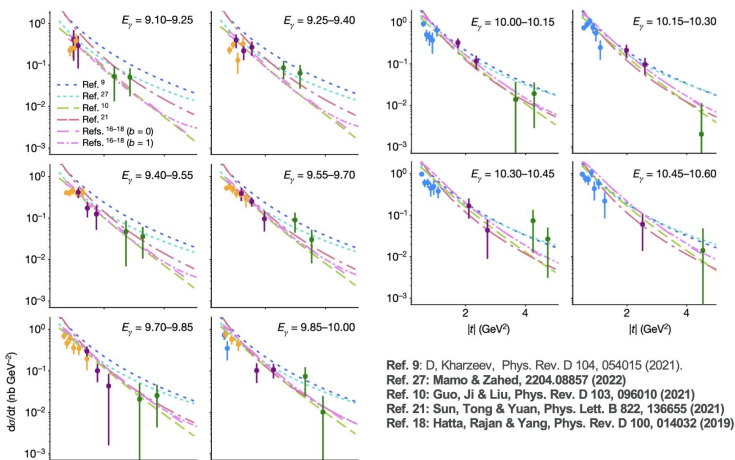


The impact of high luminosity

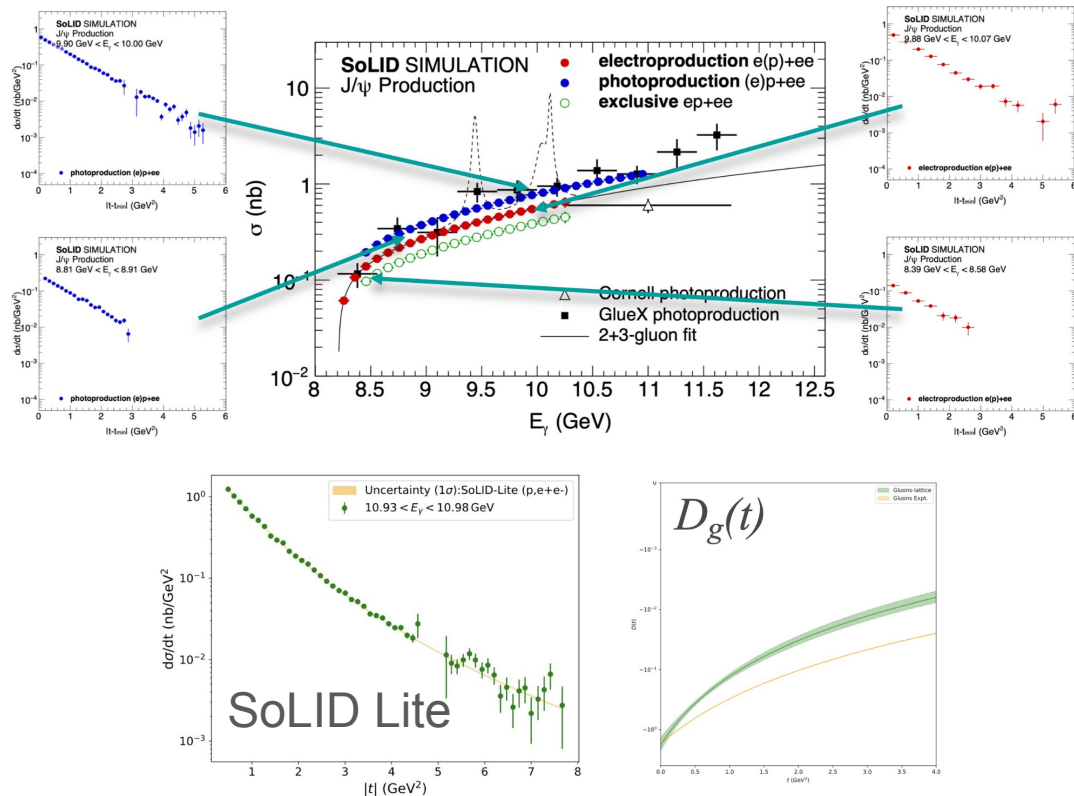


Charmonium in Hall A + Hall C - S. Joosten

- First extraction of the gluonic GFFs of the proton. Holographic and GPD model fits agree well with Lattice results.
- New results using muon final state, including total cross section
- Experiment approved by PAC in 2026 to extend the measurement to large t

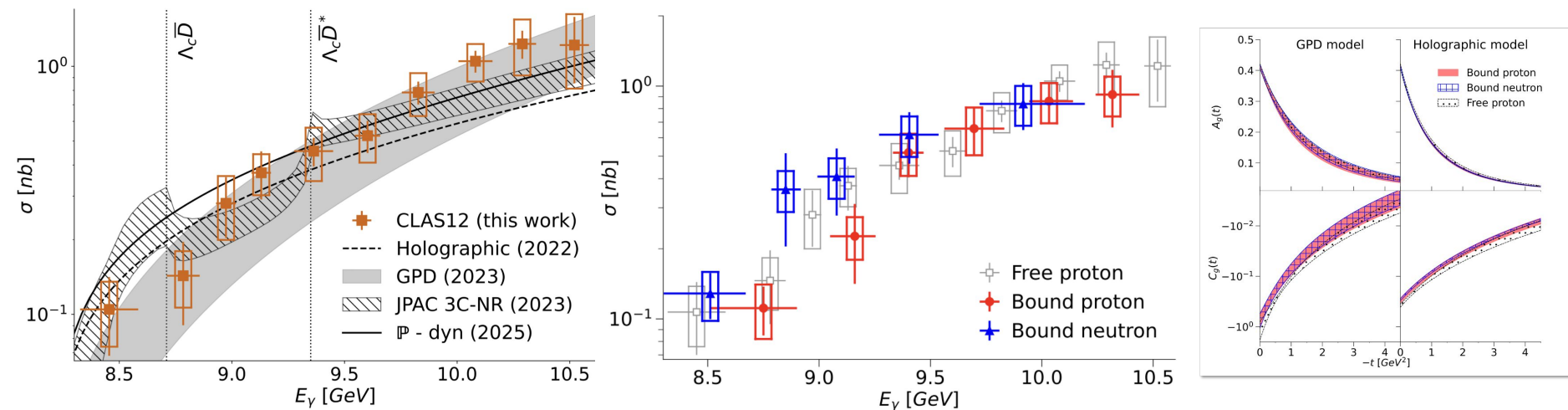


- Projections for SoLID for the total and differential cross section in the three possible final state topology
- SoLID-lite would also achieve high precision on the gluon GFFs
- At the start of a new field: should develop new observables to fully leverage high-luminosity experiments



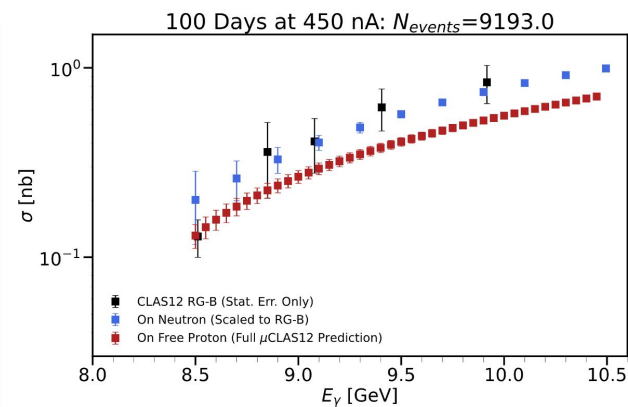
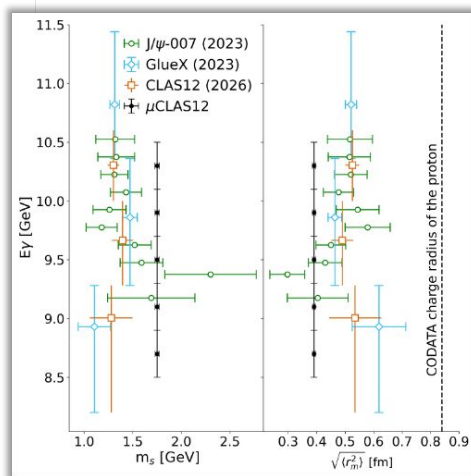
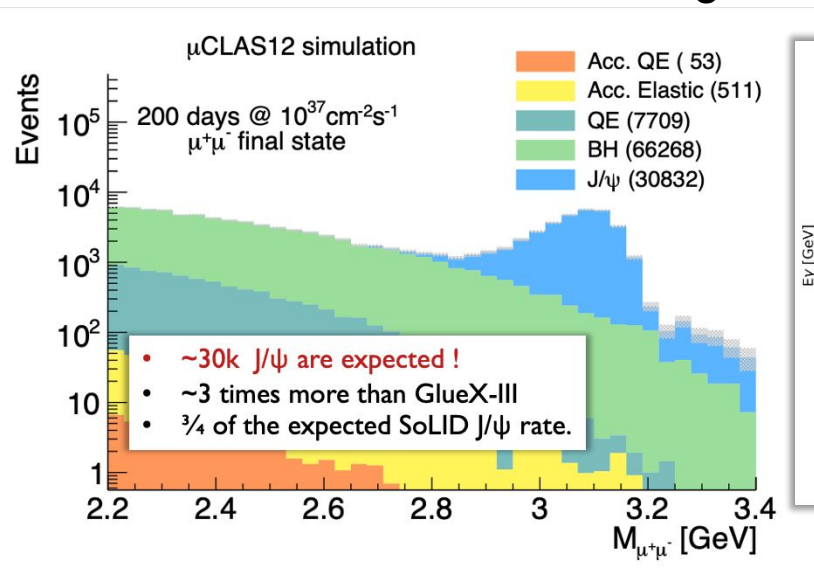
Charmonium in Hall B - P. Chatagnon - 1

- Total and differential cross section on proton published this year, smooth behaviour as a function of the photon energy
- New results on neutron and proton in deuterium being peer-reviewed
- Rich charmonium program on other targets: polarized proton, nuclear targets



Charmonium in Hall B - P. Chatagnon - 2

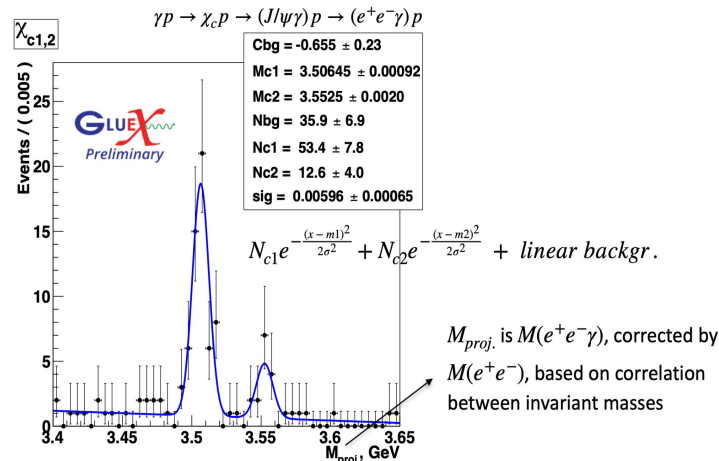
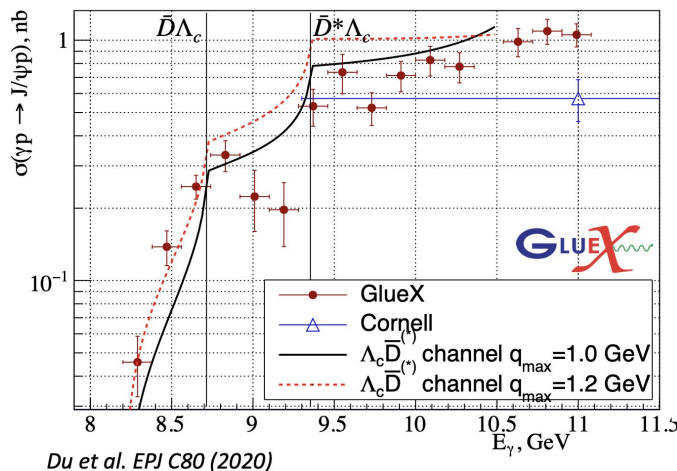
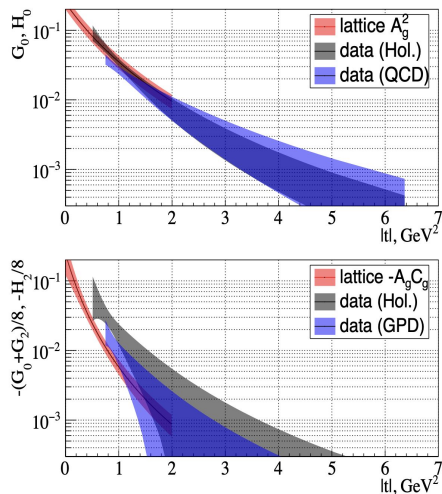
- muCLAS12 would provide enough data to test the J/ψ production mechanism
- Yield comparable to SoLID, reaching precision era for GFF extraction
- *mini*-muCLAS12 would allow to perform high-luminosity measurement on deuterium and nuclear targets



Deuterium target in
mini-muCLAS12

Charmonium in Hall D - L. Pentchev - 1

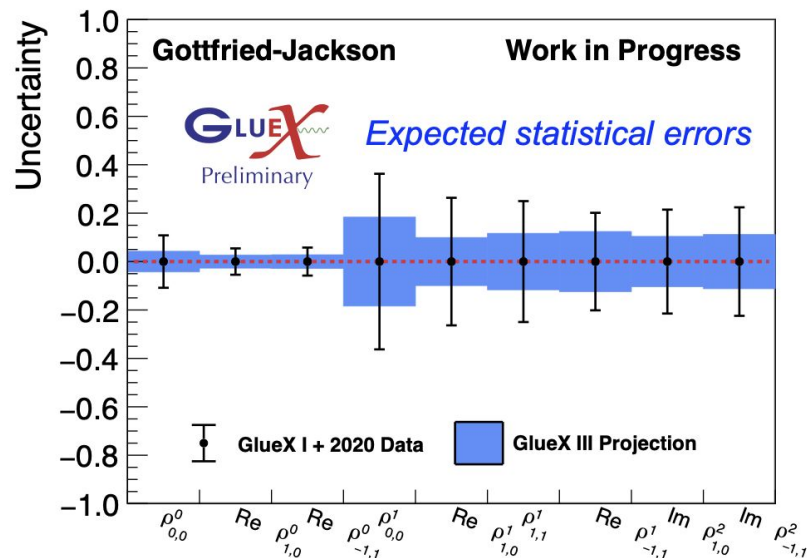
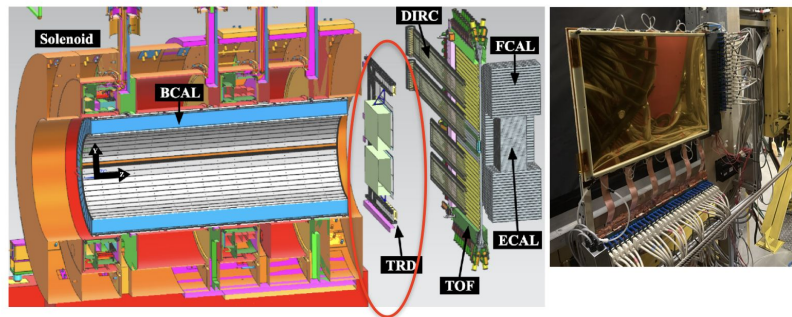
- Rosenbluth-like GFF extraction
- Cusp-structure visible in the data, require more data to confirm this behaviour
- Chi_c1 and Chi_c2 accessible, C-odd gluon exchange



Charmonium in Hall D - L. Pentchev - 2

- GlueX-Phase III will largest J/ψ sample near threshold
- Allow to extract SDMEs
- Importance of polarization observables to confirm the production mechanism

Run Period	PAC Days	J/ψ Yield	In coh. peak	χ_{c1} Yield	$\psi(2S)$ Yield
All Phase I	120	2,180	326	↓	↓
2020 Phase II	67.5	1,780	162	52	12
2023 Phase II	28.1	741	67	↓	↓
2024-2026 Phase II	109	2,874	262	48	11
2027-2028 Phase III	200	11,271	1,795	364	178
Projected Total		18,846	2612	464	201



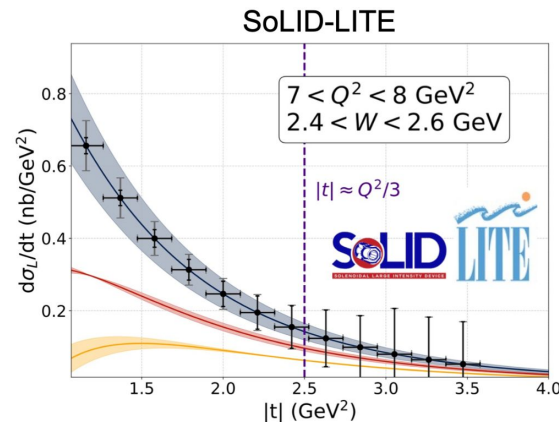
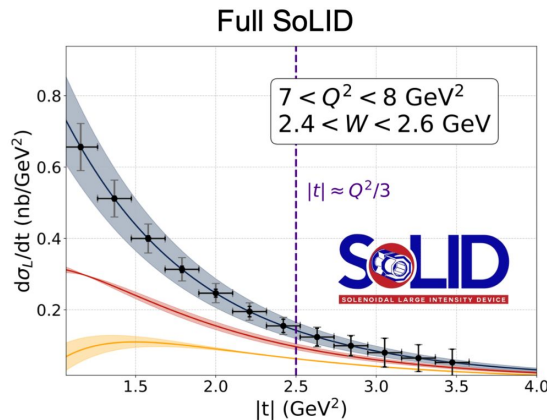
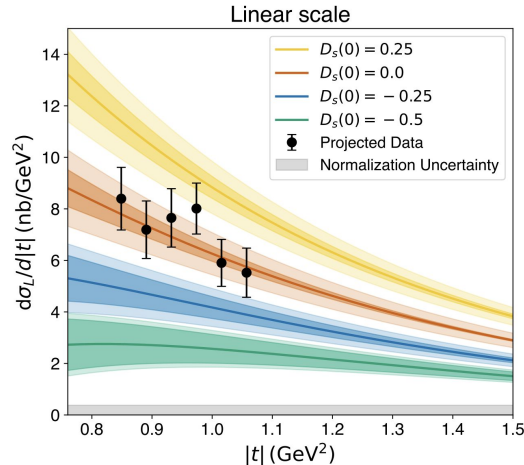
Phi electroproduction - H. Klest

- Phi production is both sensitive to strange quarks and gluons
- SoLID and SoLID-lite ideal setup to reach precision

$$\mathcal{H}(\xi, t) \approx \frac{2\kappa}{\xi^2} \frac{15}{2} \left[\left\{ \alpha_s(\mu) + \frac{\alpha_s^2(\mu)}{2\pi} \left(25.7309 - 2n_f + \left(-\frac{131}{18} + \frac{n_f}{3} \right) \ln \frac{Q^2}{\mu^2} \right) \right\} (A_s(t, \mu) + \xi^2 D_s(t, \mu)) \right. \\ \left. + \frac{3}{8} \left\{ \alpha_s + \frac{\alpha_s^2}{2\pi} \left(13.8682 - \frac{83}{18} \ln \frac{Q^2}{\mu^2} \right) \right\} (A_g + \xi^2 D_g) \right]$$

Large cancellation for D_g !
 $A_g \approx 0.4, D_g \approx -2$

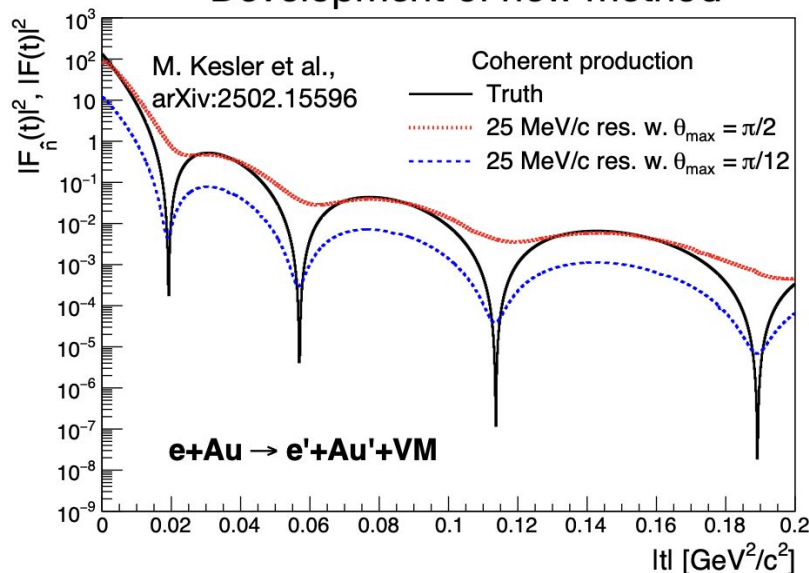
While D_s contributes directly!
 $A_s \approx 0.03, D_s \approx ?$



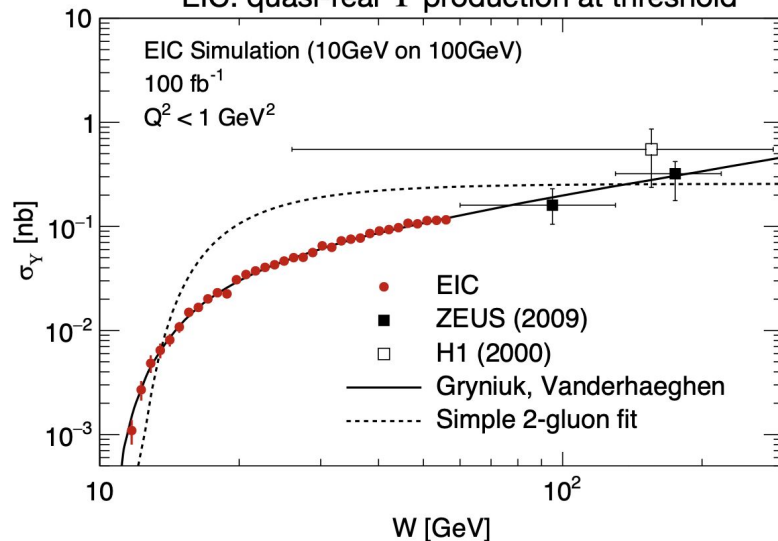
Charmonium at the EIC and LHC - C. Van Hulse

- EIC will be ideal for coherent VM production on nuclear targets, can high-luminosity at JLab provide complementary measurements ?
- Upsilon production, very complementary to high-luminosity experiment at JLab

Development of new method



EIC: quasi-real Υ production at threshold



White Paper Planning Discussion - Global Planning

1. **White paper purpose:** feed JLab long-range planning (CEBAF 2037) assuming a flat budget
2. **WG sections:** up to 5 pages/WG; the full paper should be 20-30 pages
3. **Authorship:** organizers write the intro; WG conveners write a coherent section based on speaker input
4. **Figures:** Focus on global impact plots and avoid “one plot per experiment”
5. **Scope:** physics case for future high-lumi upgrades across all four halls, without picking specific options

White Paper Planning Discussion - Charmonium Section

1. **Physics case:** J/ψ near threshold at JLab is a unique handle for gluonic structure
2. **Headline is "precision":** Precision through luminosity and large acceptance
3. **Multi-Hall program:** Complementary measurements and systematics
4. **Experiment-theory interplay:** J/ψ near threshold experiments opened up a new field in “EIC Physics before EIC” that requires precision data
5. **For the next generation:** A decade-long program before EIC, giving early-career researchers a path to get established