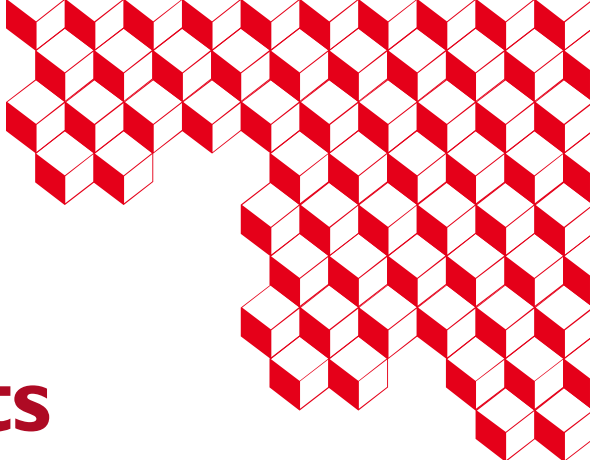




Studying the in-medium nuclear effects on the nucleon gluon distribution with vector meson production

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November 2025 CLAS Collaboration meeting
19th of November 2025

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Vector Meson Production

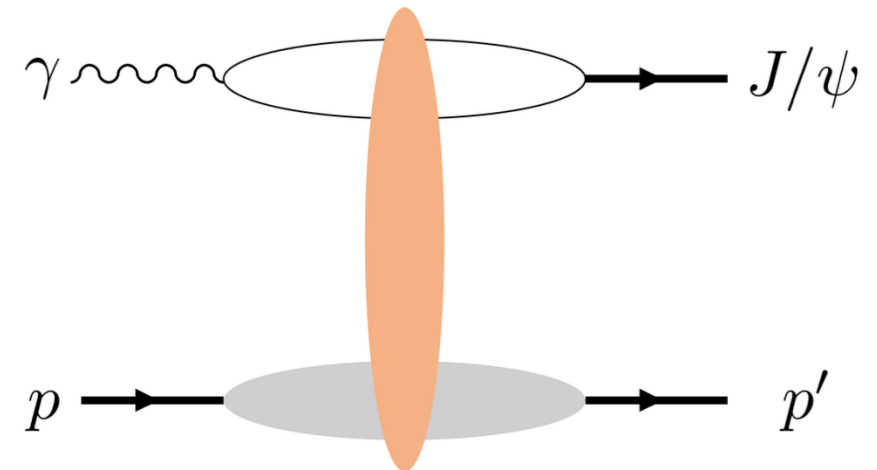
Exclusive Vector meson production gives access to the gluon content of the nucleon.

⇒ Estimations of the **gluonic mechanical properties** of the nucleon

Extensive program on proton target.

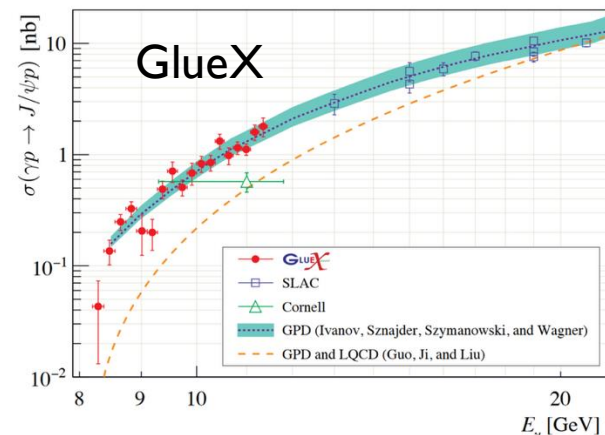
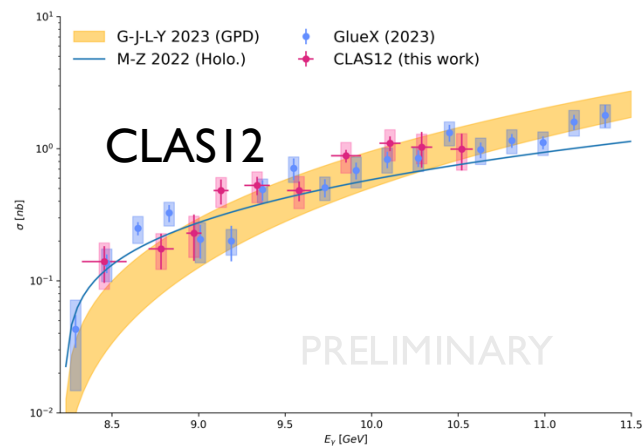
Very few measurements for bound nucleon in nuclear targets available:

- First exclusive J/ψ photoproduction results on bound proton from D, C and He from Hall D this year.
- J/ψ photoproduction on bound proton in D from RGB in collaboration review

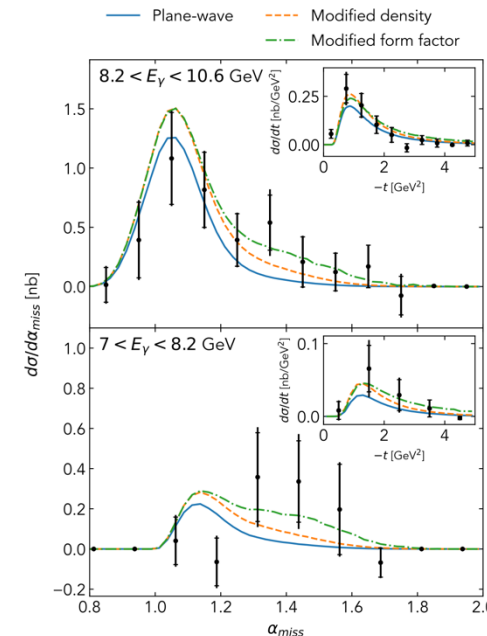
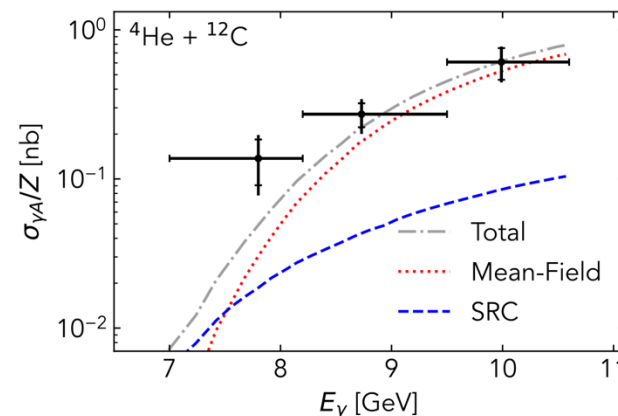


Previous Results and Ongoing Analyses

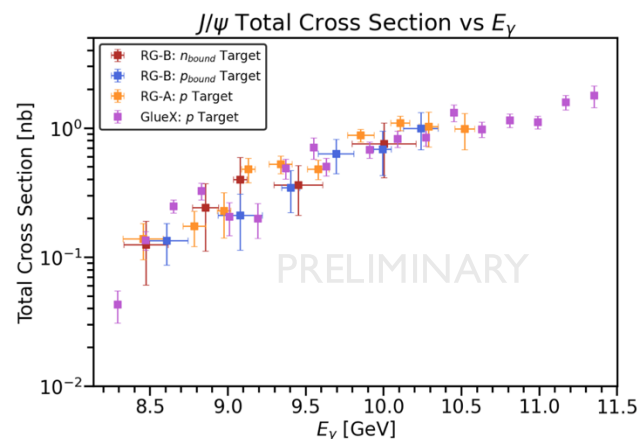
J/ψ photoproduction on free proton @Hall C @GlueX @CLAS12



J/ψ photoproduction on bound proton in D, C and He @GlueX



J/ψ photoproduction on bound proton/neutron in LD2 @CLAS12



ϕ electro and photoproduction:

- Ongoing analyses on RG-A data
- Preliminary analysis on neutron in RG-B
- Approved proposal for Hall C

Motivation

Measurements of ϕ and J/ψ on the bound proton in nuclear target could give access to the **nuclear medium effects on the gluon distribution** of bound nucleons.

Aim to measure:

- t-differential cross sections (to extract gluonic properties of the bound nucleon),
- ratios of the cross sections measured in deuterium targets to heavier nuclear targets.

The correlation between SRC prevalence and the EMC effect suggest that these effects would be enhanced at large x and when only considering kinematics with SRC candidates.

ϕ and J/ψ Final State Interaction contributions to the cross section are expected to be small. However, certain kinematics (eg high spectator momenta) may see an enhancement:
⇒ possibility to extract model dependent ϕ N and NN FSI contributions.

Reactions of Interest

- Untagged J/ψ photo-production on bound nucleon:
 - $eN \rightarrow (e')\gamma N \rightarrow (e')J/\psi N' \rightarrow (e')e^+e^- N'$
- ϕ electro-production on bound nucleon:
 - $eN \rightarrow e'\phi N' \rightarrow e'K^+K^- N'$
- Untagged ϕ photo-production on bound nucleon:
 - $eN \rightarrow (e')\gamma N \rightarrow (e')\phi N' \rightarrow (e')e^+e^- N'$

Run group	Target	$J/\psi \rightarrow e^+e^-$	$\phi \rightarrow e^+e^-$	$\phi \rightarrow K^+K^-$
RG-D	LD2	✓		✓
	C			
	Cu			
	Sn			
RG-E	LD2	✓	✓	✓
	Sn			
	Al			
	Pb			

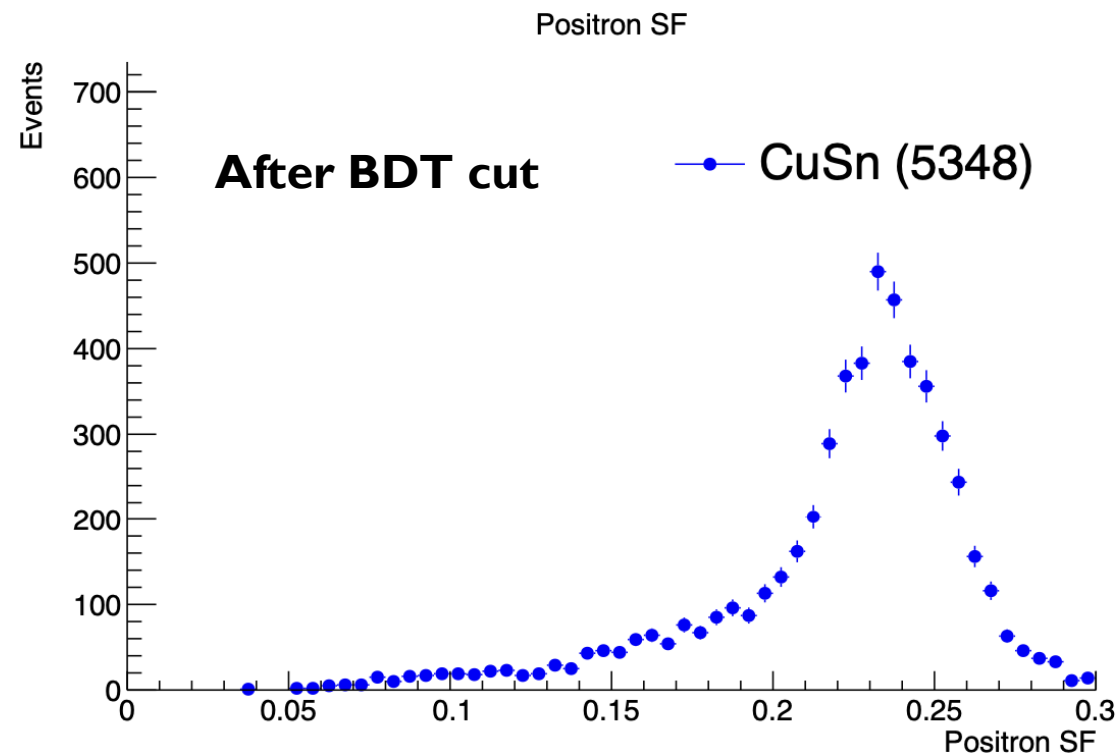
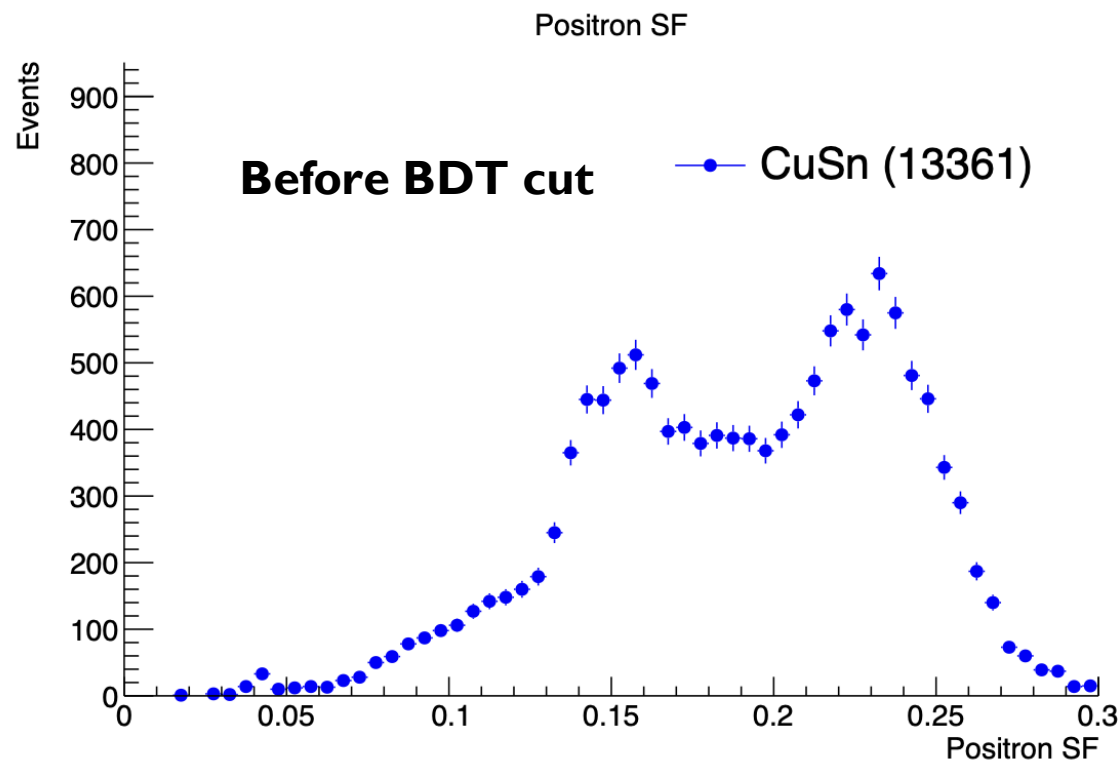
J/ψ Photoproduction

$$ep \rightarrow (e')\gamma p \rightarrow (e')J/\psi p' \rightarrow (e')e^+e^-p'$$

- Untagged photoproduction channel $\Rightarrow$ lose access to spectator neutron
- Leptons & Proton in the FD.
- ϕ photoproduction in its electron/positron decay is possible in the inbending configuration (RG-E).

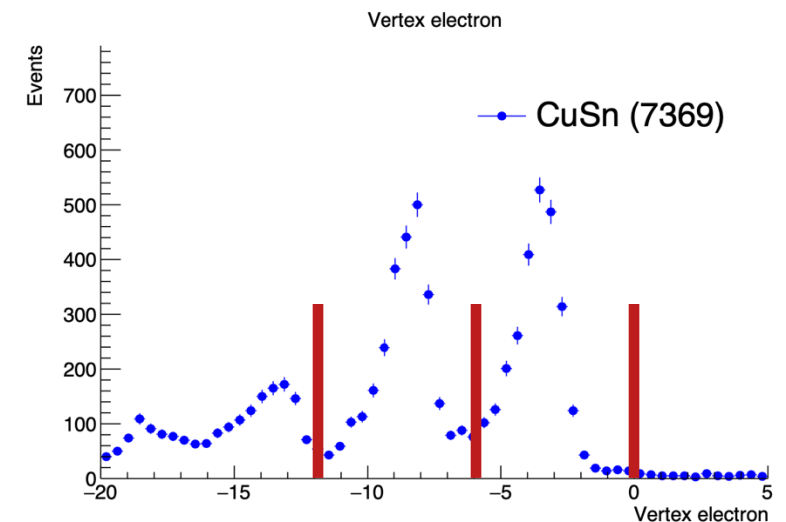
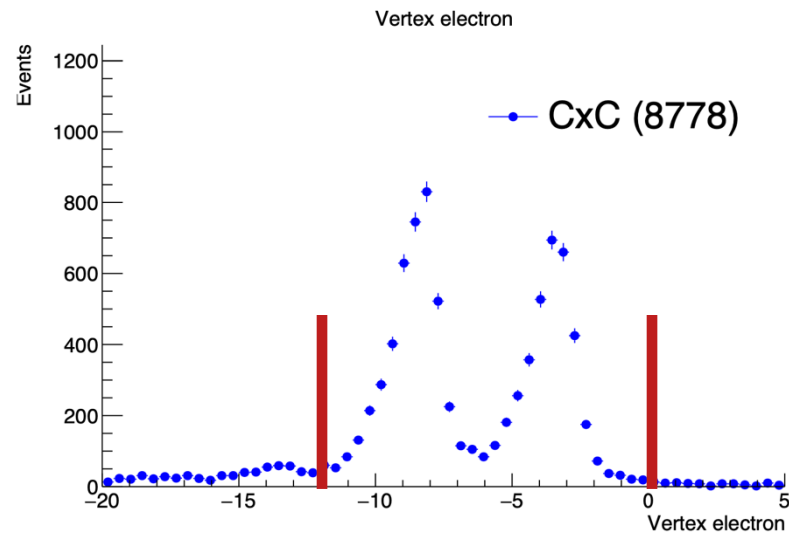
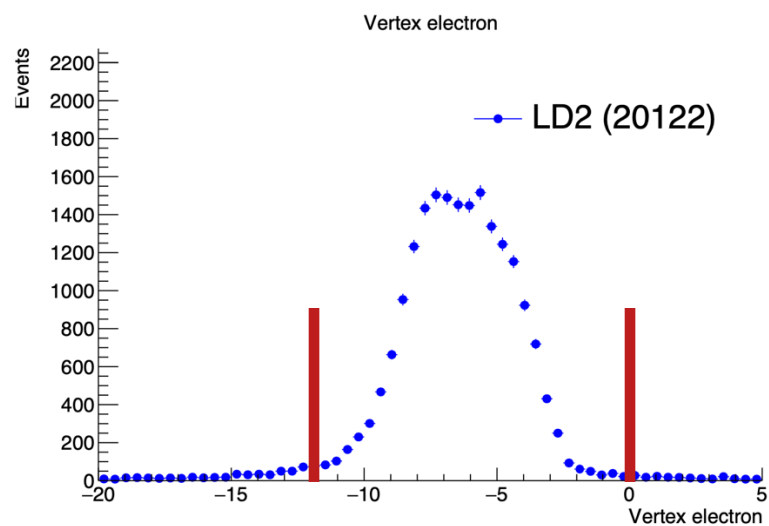
Particle Identification

- RG-A and RG-B J/ψ measurements highly affected by pion contamination in the positron PID.
 - Also seen in RG-D.
- ⇒ use AI-Lepton PID from outbending RG-A, provides a good starting point for positron PID.



Vertex Cuts

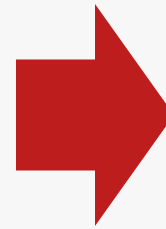
- Lepton vertex cut to remove target windows
- So far, Cu/Sn cut only in the case of the ϕ analysis



Exclusivity Cuts

- Exclusivity is ensured by requesting a small invariant mass and small reconstructed photon virtuality

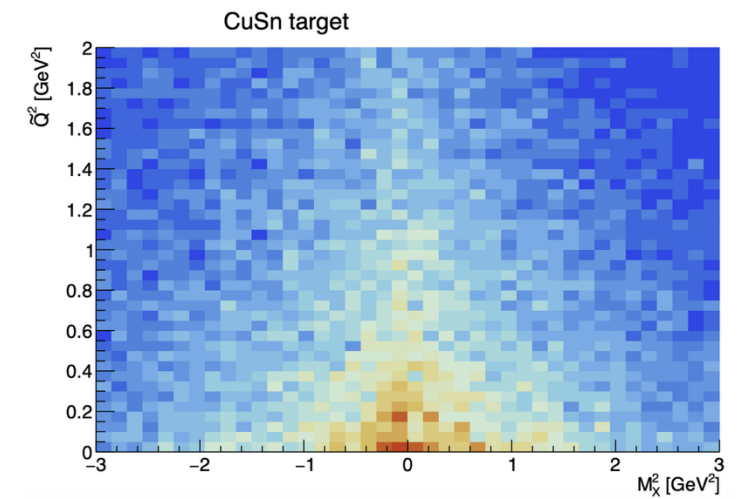
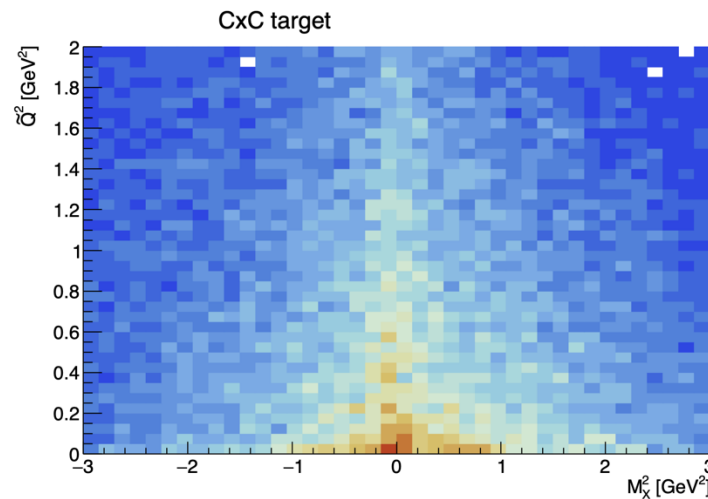
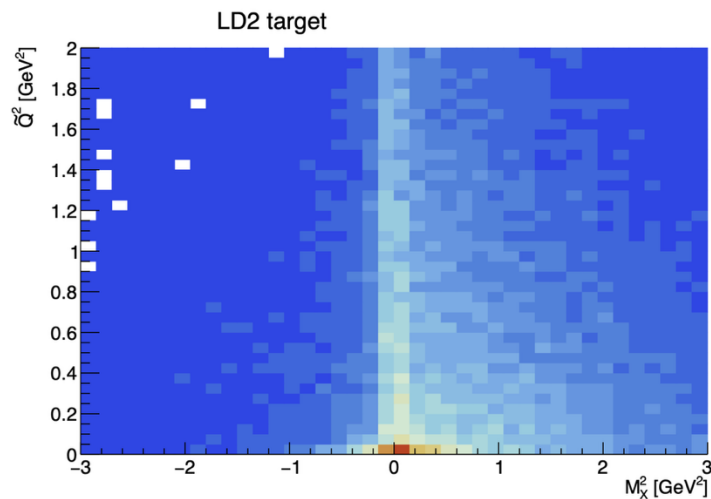
$$\tilde{Q}^2 = 2 \cdot E_{beam} \cdot E_X (1 - \cos \theta_X)$$



$$0 \text{ GeV}^2 < \tilde{Q}^2 < 1 \text{ GeV}^2$$

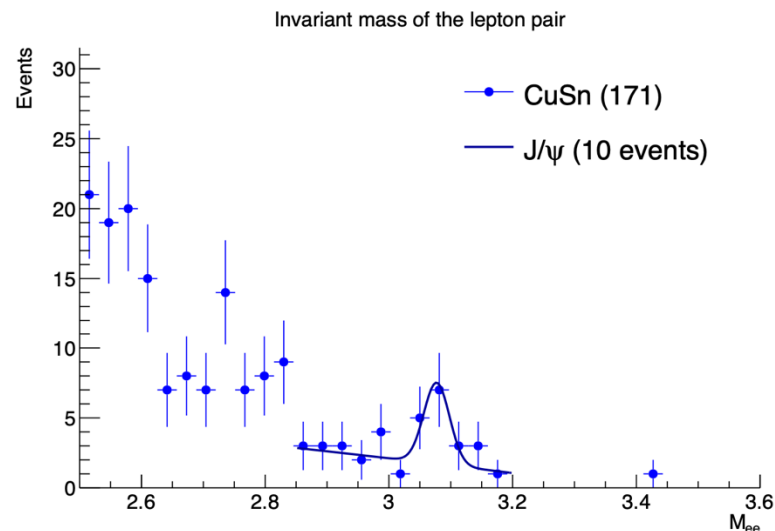
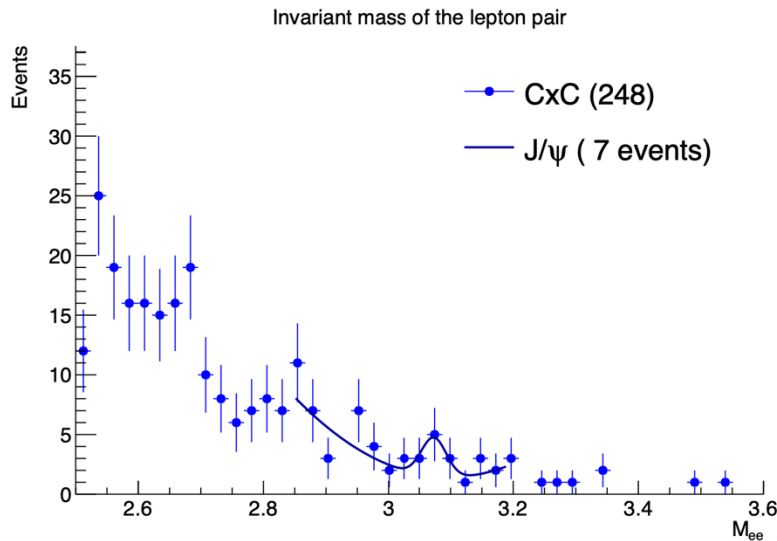
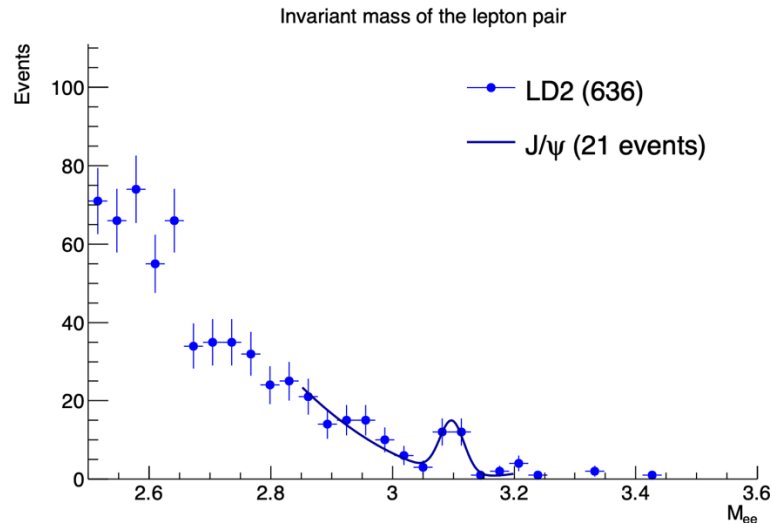
$$M_X^2 = (p_{beam}^\mu - (p_p^\mu + p_{e^+}^\mu + p_{e^-}^\mu - p_{target}^\mu))^2$$

$$|M_X^2| < 3 \text{ GeV}^2$$



J/ψ Yield Estimation

Di-lepton invariant mass spectra



Expected final yields on full RG-D dataset

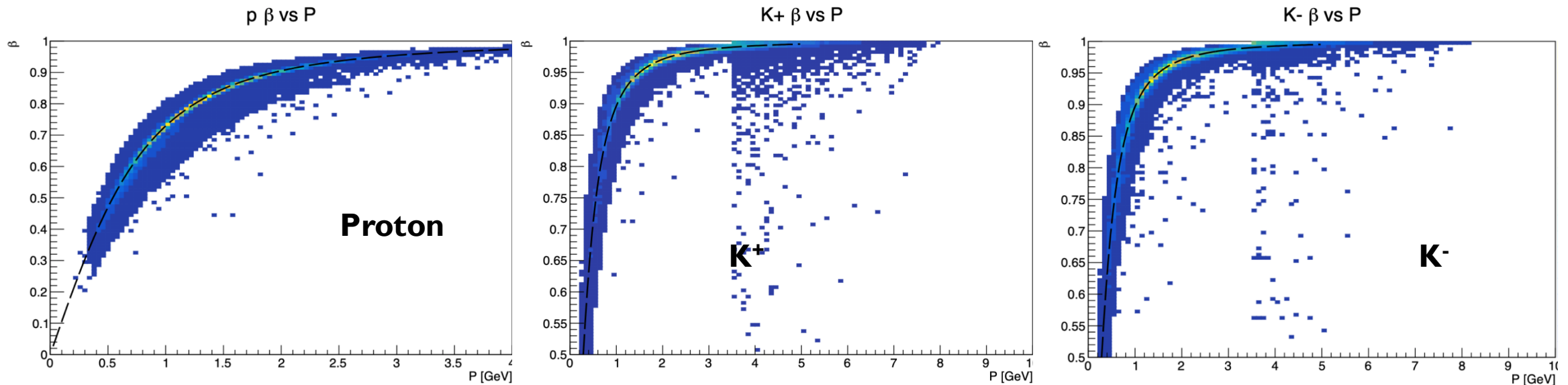
- LD2: ~210
- CxC: ~70
- Cu/Sn: ~100

- Similar/slightly better yields expected for RG-E (inbending torus).
- GlueX published measurement:
 - ~50 J/ψ on C
 - ~45 J/ψ on He
 - ~25 J/ψ on D

ϕ Electroproduction

$$ep \rightarrow e' \phi p' \rightarrow e' K^+ K^- p'$$

- Fully exclusive final state
- Electron in the FD, EB PID cut only.
- Proton in FD and CD, EB PID cuts only.
- Kaon with momenta below 3.5 GeV from EB, above 3.5 GeV only from charge.
- Vertex time cut difference to remove out-of-time particles.



Event Selection and Kinematic Coverage

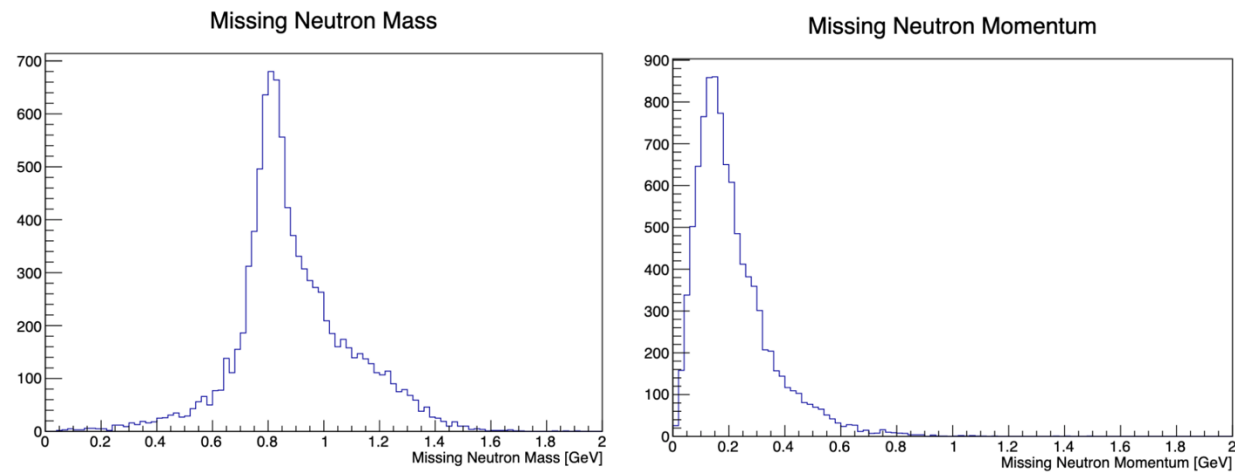
- Total missing mass squared below 0.1 GeV²

$$ep \rightarrow e' \phi p \rightarrow e' K^+ K^- p X$$

- Proton missing mass between 0.6 and 1.2 GeV

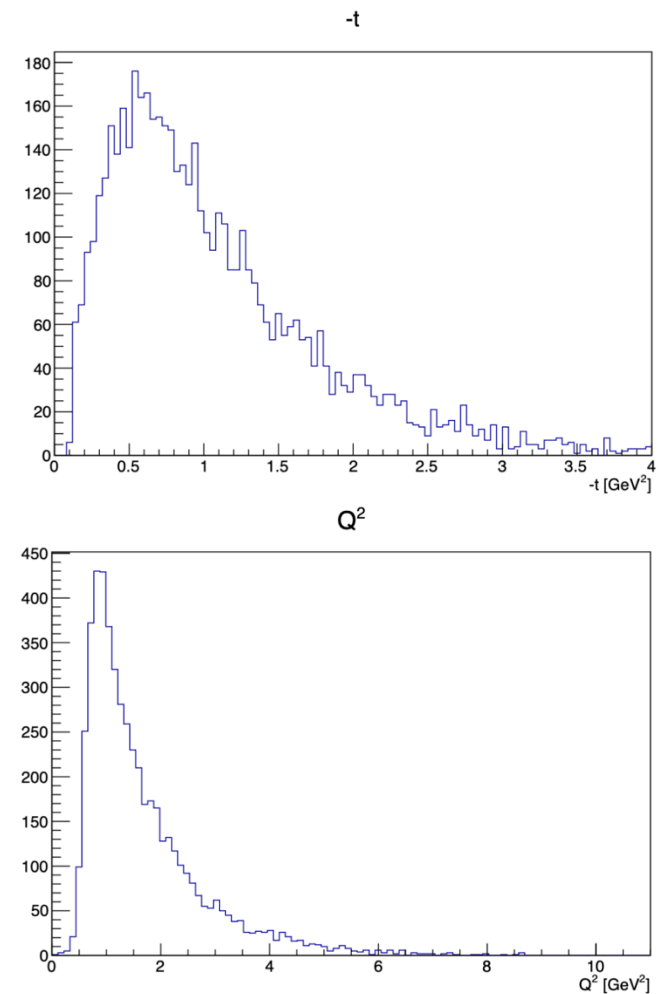
$$ep \rightarrow e' \phi p \rightarrow e' K^+ K^- (p)$$

Exclusivity checks on LD2 target



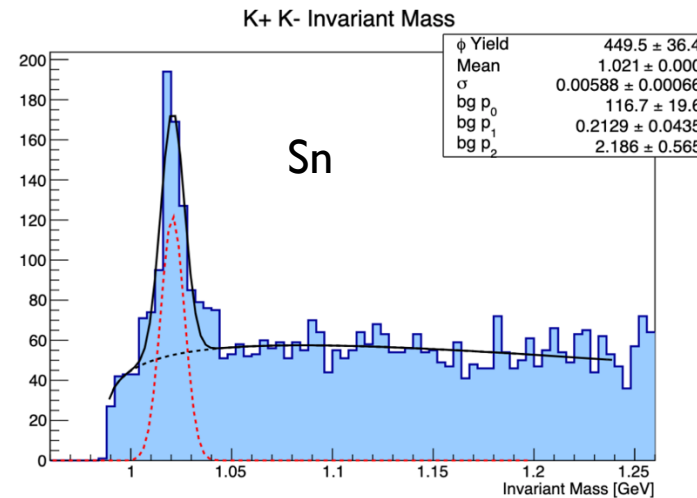
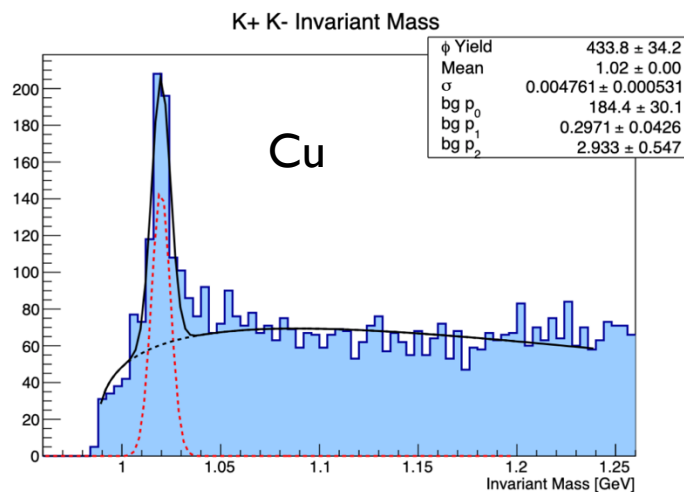
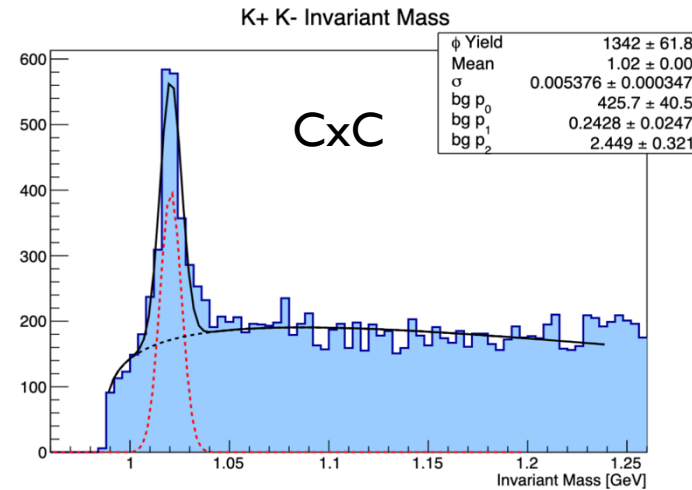
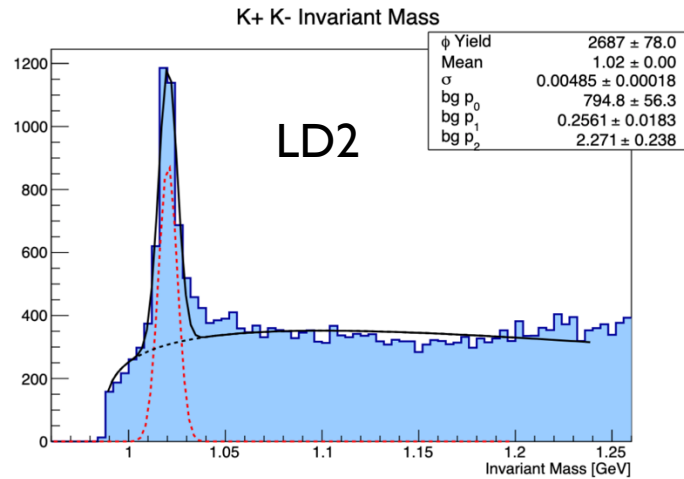
$$ed \rightarrow e' K^+ K^- p(n_s)$$

Kinematic coverage



ϕ Yield Estimation

Di-kaon invariant mass spectra



Expected final yields on full RG-D dataset

- LD2: ~25000
- CxC: ~13000
- Cu: ~4500
- Sn: ~4500

Similar yields expected from RG-E.

Observables

- Cross-section
 - as a function of t , Q^2 for the ϕ
 - as a function of t , E_x for the J/ψ and ϕ photo-production
- Cross-section ratios

Main remaining steps:

- Development of a realistic event generator including radiative corrections,
- Understanding of the Fermi motion effect.
- Efficiency correction,
- Cross section normalisation,
- Multi-dimensional binning (Q^2 and t for electroproduction, E_γ and t for photoproduction),
- Cross section calculation.

Including modeling of FSI contribution

Based on current J/ψ analysis on RG-A and RG-B datasets

CAA

- All the material in these slides has been compiled in a CAA submitted for review to the NPWG.
- We are asking for approval by vote at this collaboration meeting
- We're happy to include anyone else who wants to sign.
- <https://www.overleaf.com/read/rbhbdcbtwbgd#ca4501>

CAA: Studying the in-medium nuclear effects on the nucleon gluon distribution with vector meson production.

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November 13, 2025

Abstract

We are proposing to measure the production of vector meson on bound nucleon from nuclear targets. These measurements are expected to be sensitive to the gluon content of the nucleon in nuclear medium. In particular, the ratio of the cross section on the bound nucleon in nuclear targets to that in the deuteron will provide insight into the modification of the gluon content of bound nucleons. The J/ψ Nucleon and ϕ Nucleon cross sections are also poorly constrained at low energy, and model-dependent extraction of Final-State Interaction contributions to the J/ψ and ϕ cross sections may provide further insight into the interaction of J/ψ and ϕ with nuclei. The reactions planned to be investigated include the photoproduction of both J/ψ and ϕ meson on the bound nucleon, as well as the hard electroproduction of ϕ on the bound nucleon, using the full RG-D and RG-E datasets.

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