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CLAS12 Collaboration Meeting, March 6, 2025

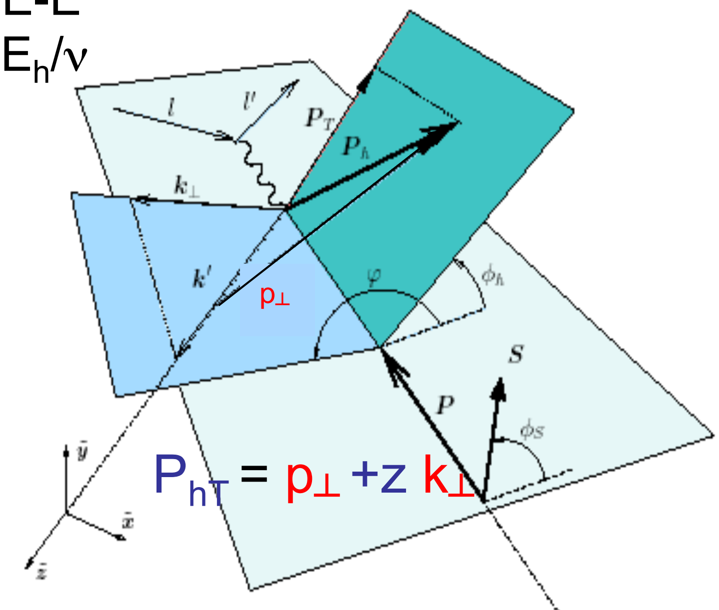
- Why measurements of exclusive VMs are critical?
  - •Access to OAM and GPD E
  - •Understanding of the impact of diffractive VMs on studies of the 3D structure and PDF, Sivers in particular
- Challenges in interpretation of exclusive rhos
  - •separation of exclusive rhos from semi-exclusive rhos
  - •separation of transverse rho from longitudinal rhos
  - •separation of transverse photon contributions from longitudinal
- Proposal to measure exclusive diffractive VMs with transversely polarized target
- Summary

*) RGH run group addition

SIDIS kinematical coverage and observables

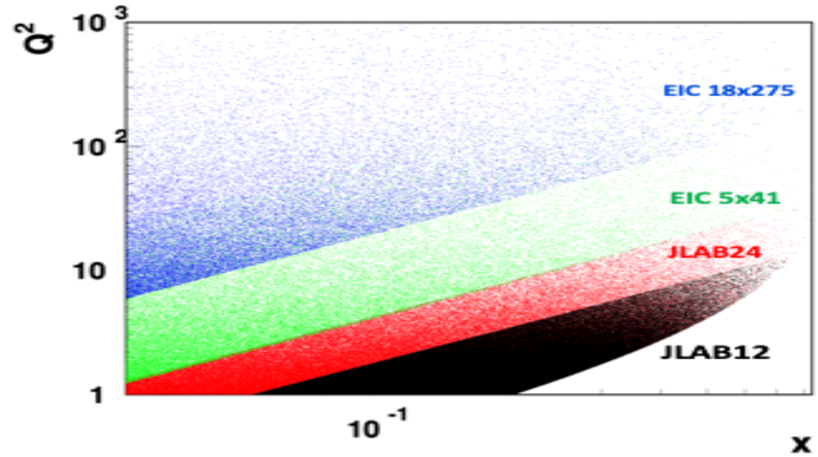
ν=E-E'

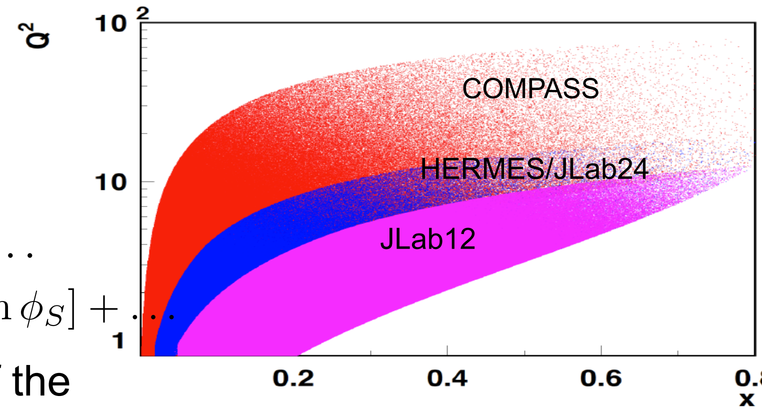
$z=E_h/\nu$

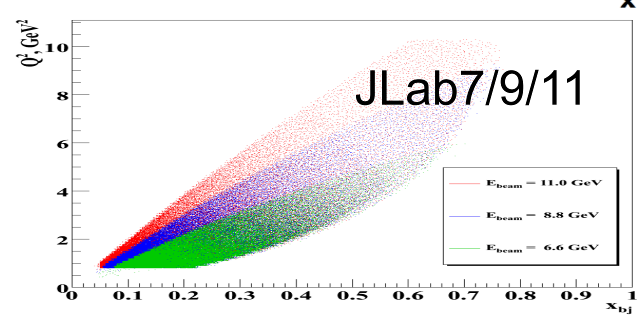


EIC

$$\sigma \propto F_{UU} + P_b\sqrt{2\epsilon(1-\epsilon)}F_{LU}^{\sin\phi}\sin\phi + P_t\epsilon F_{UL}^{\sin 2\phi}\sin 2\phi + \ldots$$
$$+\epsilon F_{UU,L} + |S_\perp|[F_{UT}^{\sin\phi-\phi_S}\sin(\phi-\phi_S) + \sqrt{2\epsilon(1+\epsilon)}F_{UT}^{\sin\phi_S}\sin\phi_S] + \ldots$$







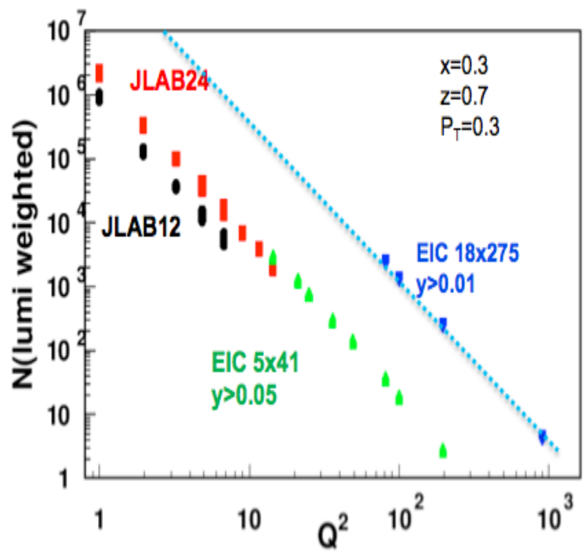
- Experiments measures the full azimuthal dependence of the cross section (x,y,z,P_T,ϕ,ϕ_S) and tries to separate different modulations
- Some model dependent systematics introduced in modeling of acceptance and account of radiative corrections
- Large acceptance and multiparticle detection capabilities allow tests of all kind of assumptions used by theory

Structure functions and depolarization factors

- **At large x fixed target experiments are sensitive to ALL Structure Functions**
- **At higher energies (EIC), observables surviving the $\varepsilon \rightarrow 1$ limit (F_{UU}, F_{UL}, Transversely pol. F_{UT})**

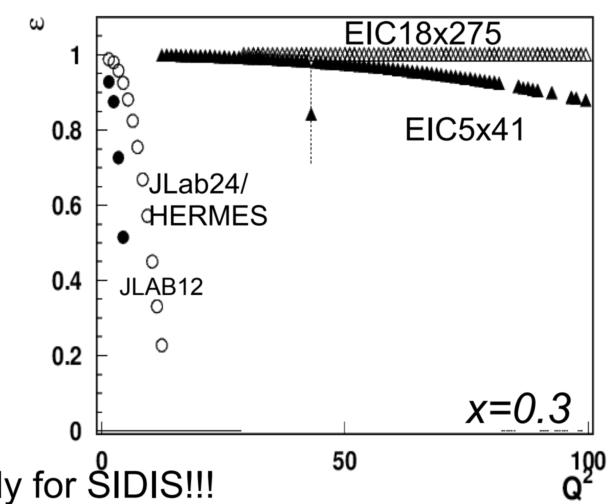
x-section for eN→e'hX

$$\frac{d\sigma}{dx\,dy\,d\phi_S\,dz\,d\phi_h\,dP_{h\perp}^2} = \frac{\alpha^2}{x\,y\,Q^2}\frac{y^2}{2(1-\varepsilon)}\Bigg\{F_{UU,T}+\varepsilon F_{UU,L}+\sqrt{2\varepsilon(1+\varepsilon)}\cos\phi_h\,F_{UU}^{\cos\phi_h}+\varepsilon\cos(2\phi_h)\,F_{UU}^{\cos 2\phi_h}$$
$$+\lambda_e\sqrt{2\varepsilon(1-\varepsilon)}\sin\phi_h\,F_{LU}^{\sin\phi_h}+S_L\Big[\sqrt{2\varepsilon(1+\varepsilon)}\sin\phi_h\,F_{UL}^{\sin\phi_h}+\varepsilon\sin(2\phi_h)\,F_{UL}^{\sin 2\phi_h}\Big]$$
$$+S_L\lambda_e\Big[\sqrt{1-\varepsilon^2}\,F_{LL}+\sqrt{2\varepsilon(1-\varepsilon)}\cos\phi_h\,F_{LL}^{\cos\phi_h}\Big]$$
$$+S_T\Big[\sin(\phi_h-\phi_S)\Big(F_{UT,T}^{\sin(\phi_h-\phi_S)}+\varepsilon F_{UT,L}^{\sin(\phi_h-\phi_S)}\Big)+\varepsilon\sin(\phi_h+\phi_S)\,F_{UT}^{\sin(\phi_h+\phi_S)}$$
$$+\varepsilon\sin(3\phi_h-\phi_S)\,F_{UT}^{\sin(3\phi_h-\phi_S)}+\sqrt{2\varepsilon(1+\varepsilon)}\sin\phi_S\,F_{UT}^{\sin\phi_S}$$
$$+\sqrt{2\varepsilon(1+\varepsilon)}\sin(2\phi_h-\phi_S)\,F_{UT}^{\sin(2\phi_h-\phi_S)}\Big]+S_T\lambda_e\Big[\sqrt{1-\varepsilon^2}\cos(\phi_h-\phi_S)\,F_{LT}^{\cos(\phi_h-\phi_S)}$$
$$+\sqrt{2\varepsilon(1-\varepsilon)}\cos\phi_S\,F_{LT}^{\cos\phi_S}+\sqrt{2\varepsilon(1-\varepsilon)}\cos(2\phi_h-\phi_S)\,F_{LT}^{\cos(2\phi_h-\phi_S)}\Big]\Bigg\}$$



x-section from Bacchetta et al, 1703.10157

Measurements of correlations of spin and transverse momenta provides direct access to details of QCD dynamics

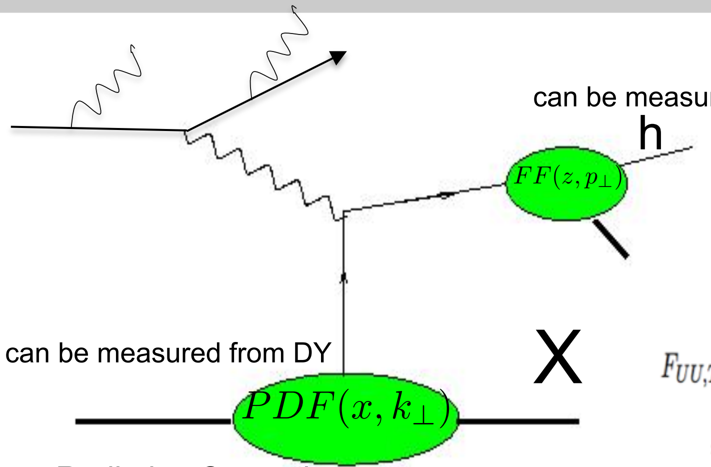


Combination of statistics and depolarization factors defines measurable SFs

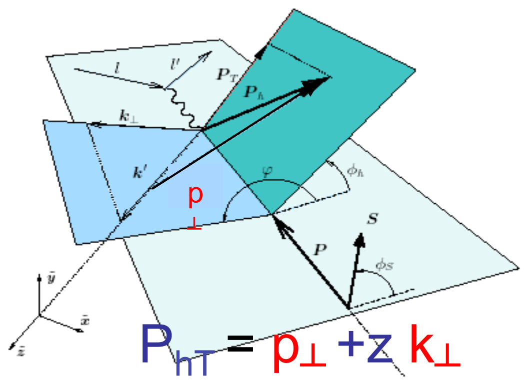
Measurements of $F_{UU,T}$ and Sivers requires *separation*, evaluation of longitudinal photon (JLab)

Full decomposition of SFs to underlying 3D PDFs up to twist 3 level exist only for SIDIS!!!

SIDIS as THE theory describes it



+Radiative Corrections



Probability to produce 1 or 2 hadrons in single photon exchange

$$eN \to e'hX$$

$$\frac{d\sigma}{dx\, dy\, d\phi_S\, dz\, d\phi_h\, dP^2_{h\perp}}$$

TMD Parton Distribution Functions — TMD Parton Fragmentation Functions

$$F_{UU,T}(x,z,P^2_{hT},Q^2) = x\sum_q \mathcal{H}^q_{UU,T}(Q^2,\mu^2)\int d^2\boldsymbol{k}_\perp\, d^2\boldsymbol{P}_\perp\, f_1^a(x,\boldsymbol{k}^2_\perp;\mu^2)\, D_1^{a\to h}(z,\boldsymbol{P}^2_\perp;\mu^2)\,\delta(z\boldsymbol{k}_\perp-\boldsymbol{P}_{hT}+\boldsymbol{P}_\perp)$$
$$+Y_{UU,T}(Q^2,\boldsymbol{P}^2_{hT})+\mathcal{O}(M^2/Q^2)$$

hard part

Factorization allowing description using distribution functions (TMD-PDF) and fragmentation functions (TMD FF)
X→ multiplicity of unobserved hadrons LARGE, and x-section doesn't depend on X (independent fragmentation)
Leading twist dominates, $Q^2 >> 1$
$k_\perp/Q << 1$

"much bigger/smaller" defined in comparison with experiment

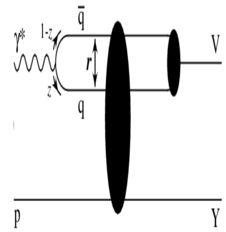
Conclusions in case of apparent disagreement:

1)factorization is broken?
2)<u>unaccounted terms may contribute (assumptions are not good in certain kinematics,…)</u>

Data has it all!!! Dealing with unaccounted terms:
- Theory accounts for them (ex. VMs)
- Experiment measures and excludes them!!! (ex.VMs)

Theory predictions for transverse SSAs for rho

Goeke et al: hep-ph/0106012



$$A_{\rho^0_L\,p} = \int_{-1}^{1} dx\, \frac{1}{\sqrt{2}} \left(e_u\, H^u - e_d\, H^d\right) \left\{ \frac{1}{x-\xi+i\epsilon} + \frac{1}{x+\xi-i\epsilon} \right\}$$

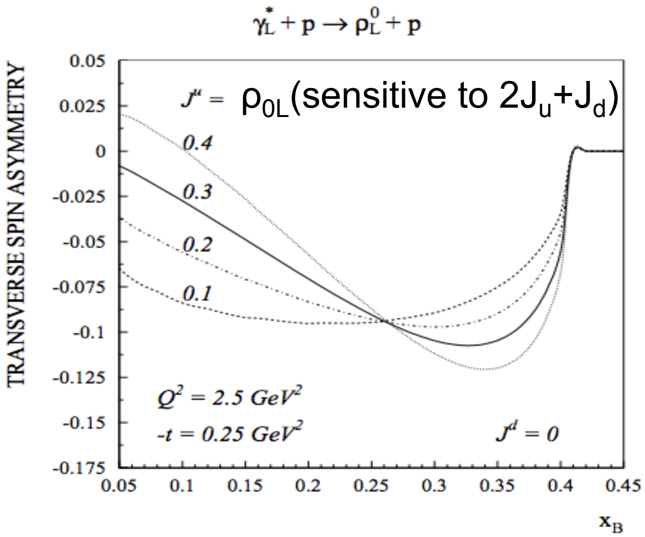
$$B_{\rho^0_L\,p} = \int_{-1}^{1} dx\, \frac{1}{\sqrt{2}} \left(e_u\, E^u - e_d\, E^d\right) \left\{ \frac{1}{x-\xi+i\epsilon} + \frac{1}{x+\xi-i\epsilon} \right\}$$

$$A_{\rho^+_L\,n} = -\int_{-1}^{1} dx\, \left(H^u - H^d\right) \left\{ \frac{e_u}{x-\xi+i\epsilon} + \frac{e_d}{x+\xi-i\epsilon} \right\}$$

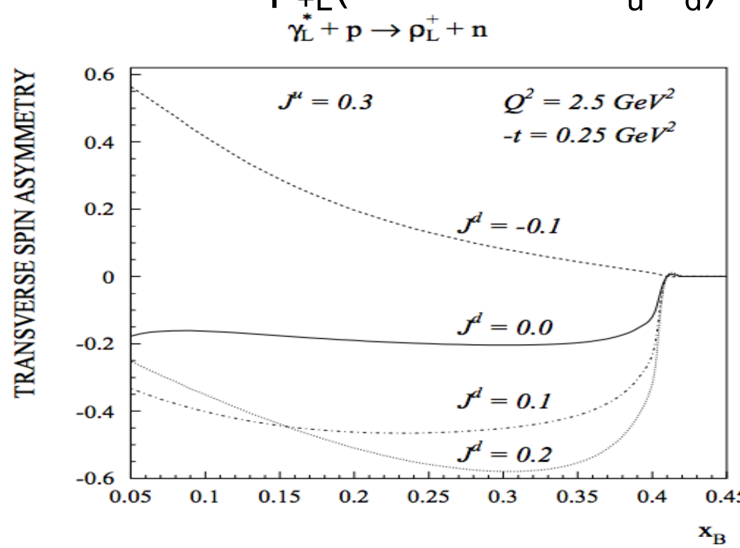
$$B_{\rho^+_L\,n} = -\int_{-1}^{1} dx\, \left(E^u - E^d\right) \left\{ \frac{e_u}{x-\xi+i\epsilon} + \frac{e_d}{x+\xi-i\epsilon} \right\}.$$

$$\frac{d\sigma_L}{dt} = \frac{1}{16\pi\,(s-m_N^2)\,\Lambda(s,-Q^2,m_N^2)}\,\frac{1}{2}\sum_{h_N}\sum_{h'_N} |\mathcal{M}^L(\lambda_M = 0, h'_N; h_N)|^2$$

$$\mathcal{A}_{V_L N} = -\frac{2\,|\Delta_\perp|}{\pi}\,\frac{\mathrm{Im}(AB^*)/m_N}{|A|^2\,(1-\xi^2) - |B|^2\,(\xi^2 + t/(4m_N^2)) - \mathrm{Re}(AB^*)\,2\,\xi^2}$$



ρ_{+L}(sensitive to J_u-J_d)



Significant SSAs predicted, sensitive to OAM contributions

Theory predictions for transverse SSAs for rho

Goloskokov&Kroll 0809.4126

$$t_{\min} = -\frac{2\xi}{1-\xi^2}\left[(1+\xi)M^2-(1-\xi)m^2\right]$$

$$\frac{d\sigma_{L(T)}}{dt} = \frac{1}{16\pi(W^2-m^2)\sqrt{\Lambda(W^2,-Q^2,m^2)}}\sum_{\nu'}\left|\mathcal{M}_{0(+)\nu',0(+)+}\right|^2$$

$$\xi \simeq \frac{x_{\rm Bj}}{2-x_{\rm Bj}}\left[1+m_V^2/Q^2\right]$$

$$\Lambda(s,-Q^2,m_N^2) = 2m_N|\vec{q}_L|$$

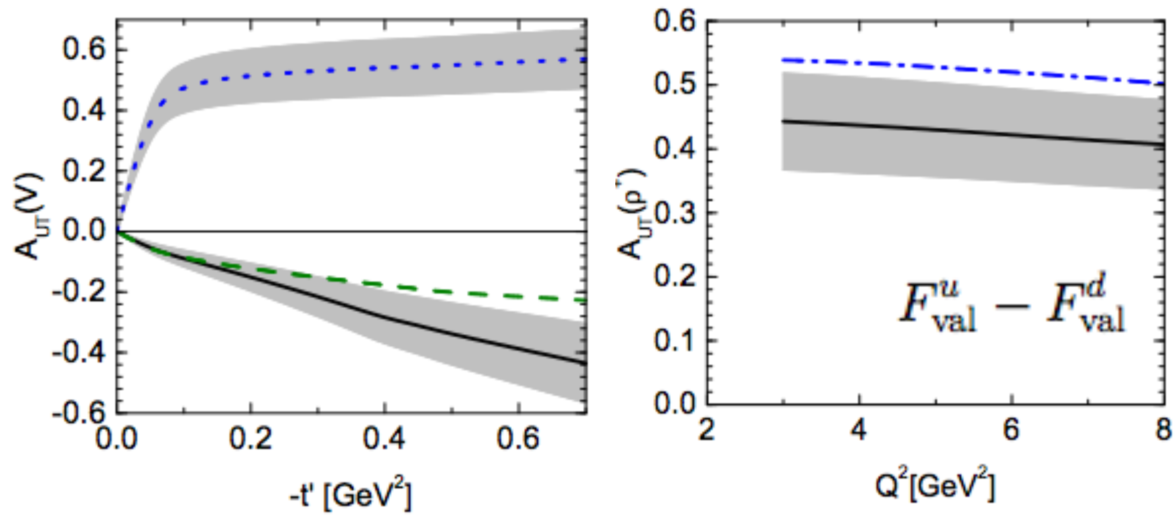
$$A_{UT} = -2\,\frac{\mathrm{Im}[\mathcal{M}^*_{+-,++}\,\mathcal{M}_{++,++}] + \varepsilon\,\mathrm{Im}[\mathcal{M}^*_{0-,0+}\,\mathcal{M}_{0+,0+}]}{\sum_{\nu'}\left[\,|\,\mathcal{M}_{+\nu',++}\,|^2 + \varepsilon\,|\,\mathcal{M}_{0\nu',0+}\,|^2\,\right]}$$

$$\mathcal{M}_{\mu-,\mu+}(\rho^0) \sim \langle e_u E^u_{\rm val} - e_d E^d_{\rm val}\rangle$$

Opposite signs from HERMES!!

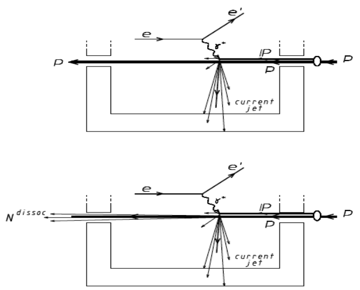
$$A_{UT}(\rho^0_L) = 0.04 \pm 0.12$$

$$A_{UT}(\rho^0_T) = -0.08 \pm 0.10$$

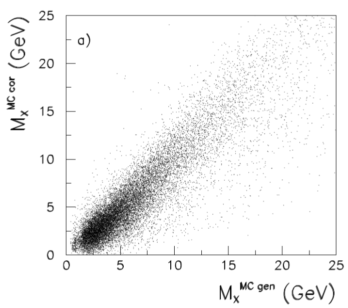


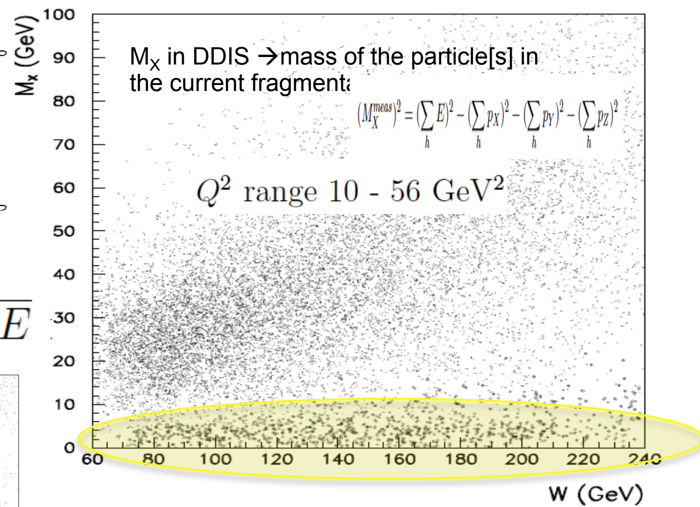
Significant SSAs for VMs

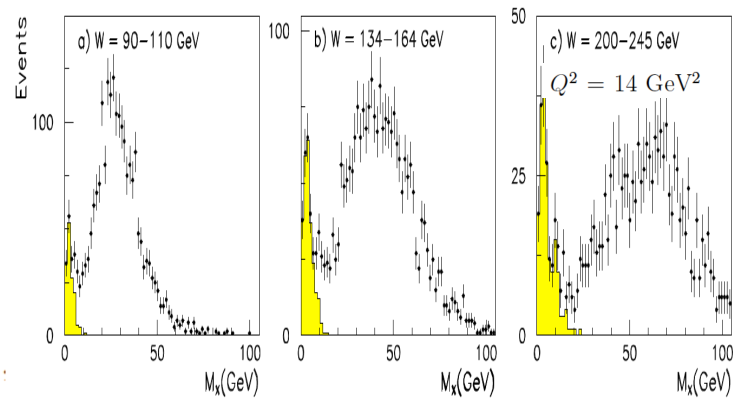
Measured x-section: DDIS vs DIS



$\sigma_E/E = 18\%/\sqrt{E}$







~1/Q²?

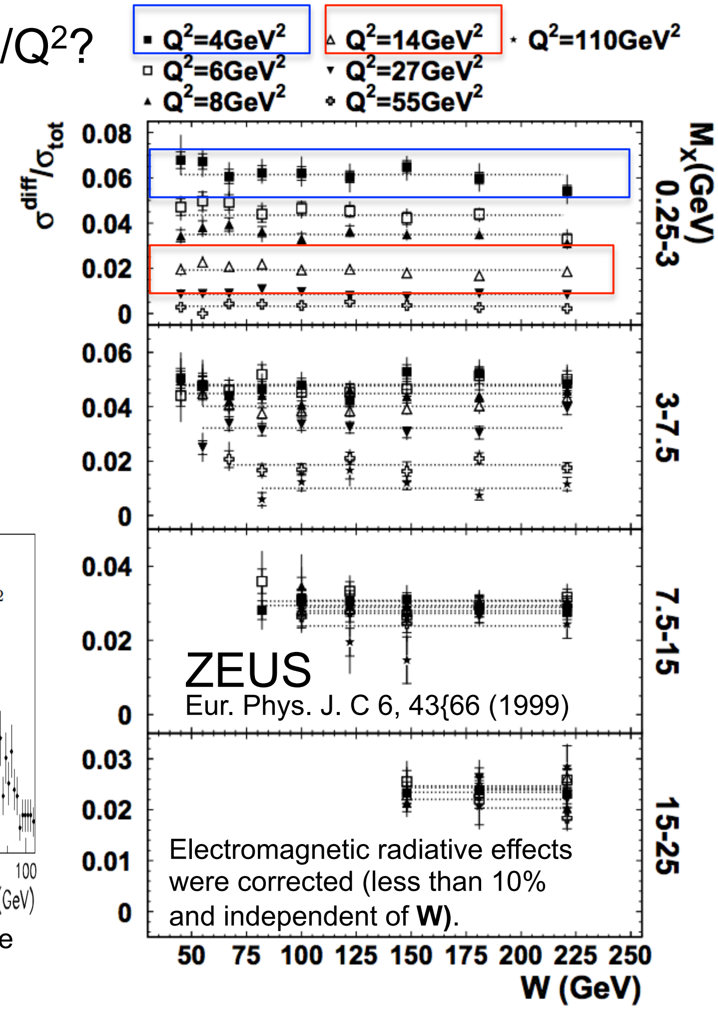


Figure 11.6: The ratio of the diffractive cross section σ^{diff}, integrated over the bin width $M_a < M_X < M_b$, and the total $\gamma^* p$ cross section σ^{tot} is shown as a function of W for different bins of M_X and Q^2. The dotted lines indicate the average values of $\sigma^{diff}/\sigma^{tot}$ in the measured W region for each bin in Q^2 and M_X.

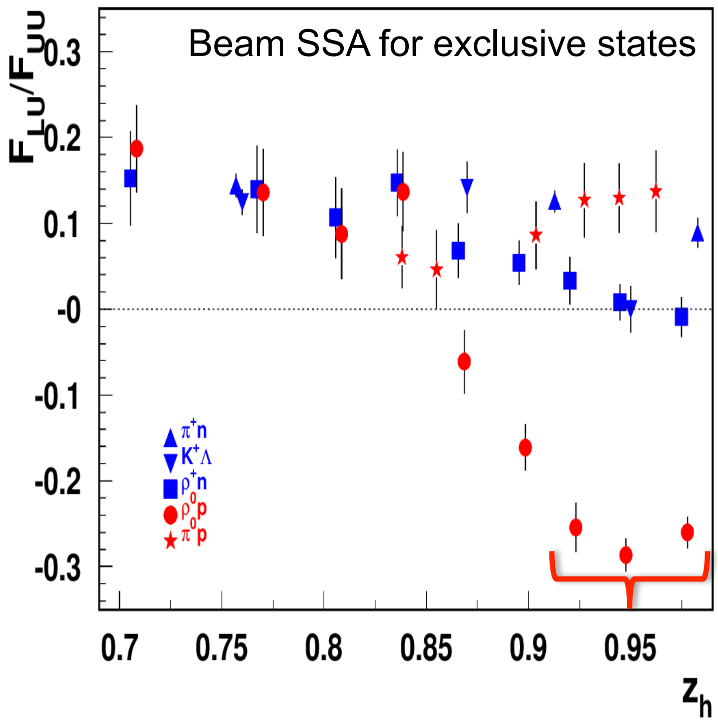
Week increase with W in photoproduction
Strong increase in electroproduction (longitudinal rho?)

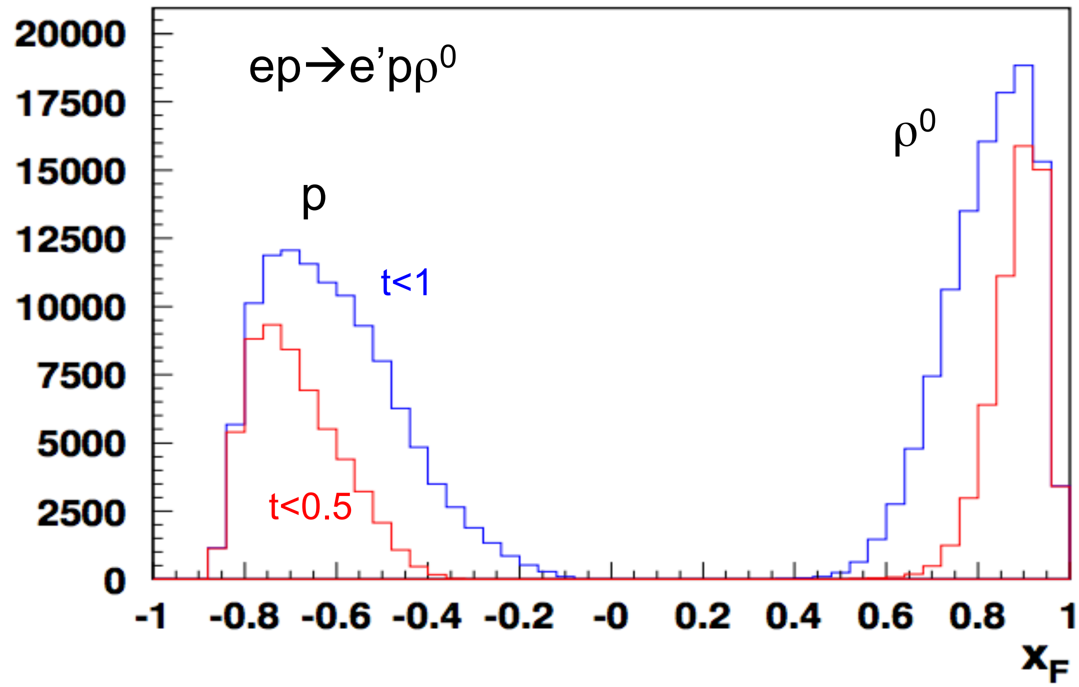
η is defined as $-\ln(\tan\frac{\theta}{2})$.

For $\eta_{max} < 1.5$ the contribution from nondiffractive scattering is expected to be negligible

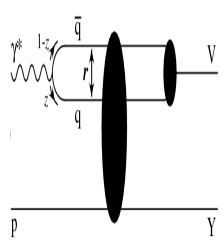
No dependence of DDIS/DIS on W, decrease with Q^2 indicating the VMs can be the main contributor
At lowest M_X seem to be ~1/Q^2, at higher M_X there seem to be no Q^2-dependence

“diffractive” VMs: rapidity gap





Diffractive VMs (ρ^0)



Significant rapidity gap between protons (backward) and rho (forward)

What is the fraction of VMs in DDIS?

What is the relative fraction of VMs as a function of W and Q^2?

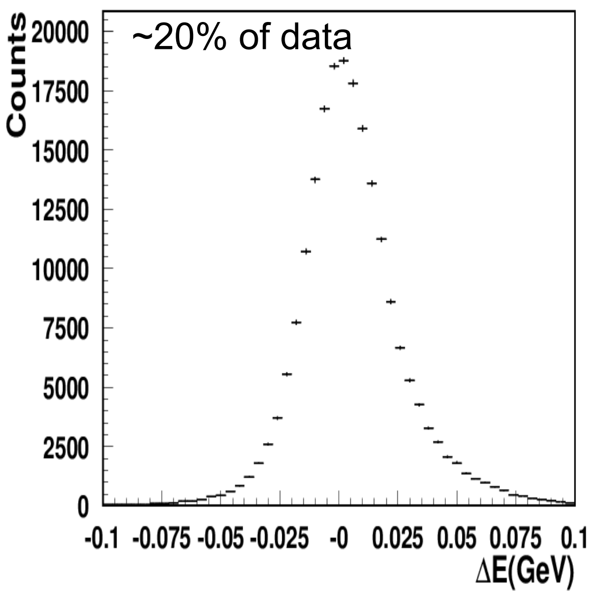
Identify kinematics of “diffractive” ρ^0 by comparison with ρ^+

CLAS12 Experiments involved: Exclusive rhos

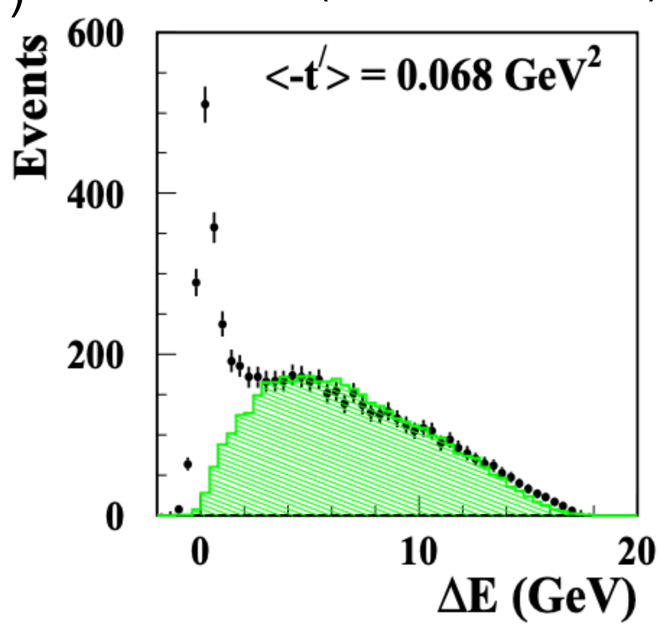
Exclusivity condition defined by the missing Energy:

$$M_X^2 = (p + q - p_{\pi^+} - p_{\pi^-})^2 \qquad E_{\mathrm{miss}} = \frac{M_X^2 - M^2}{2M}$$

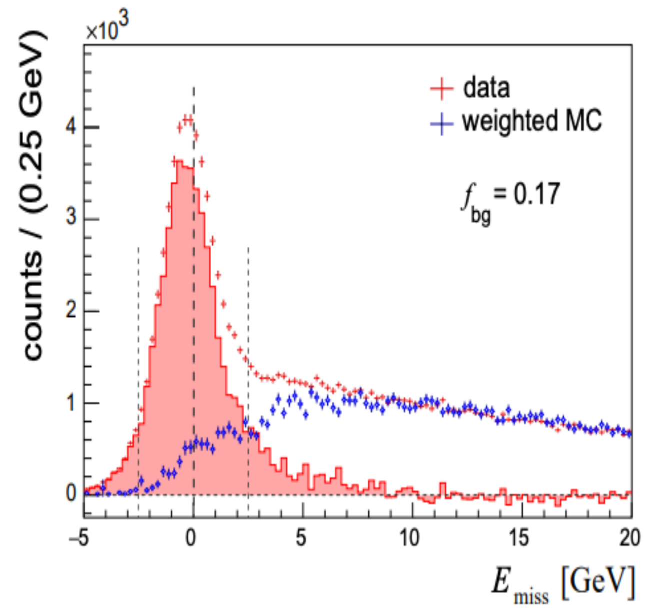
CLAS12 (width <0.1GeV)



HERMES(width ~0.6GeV)

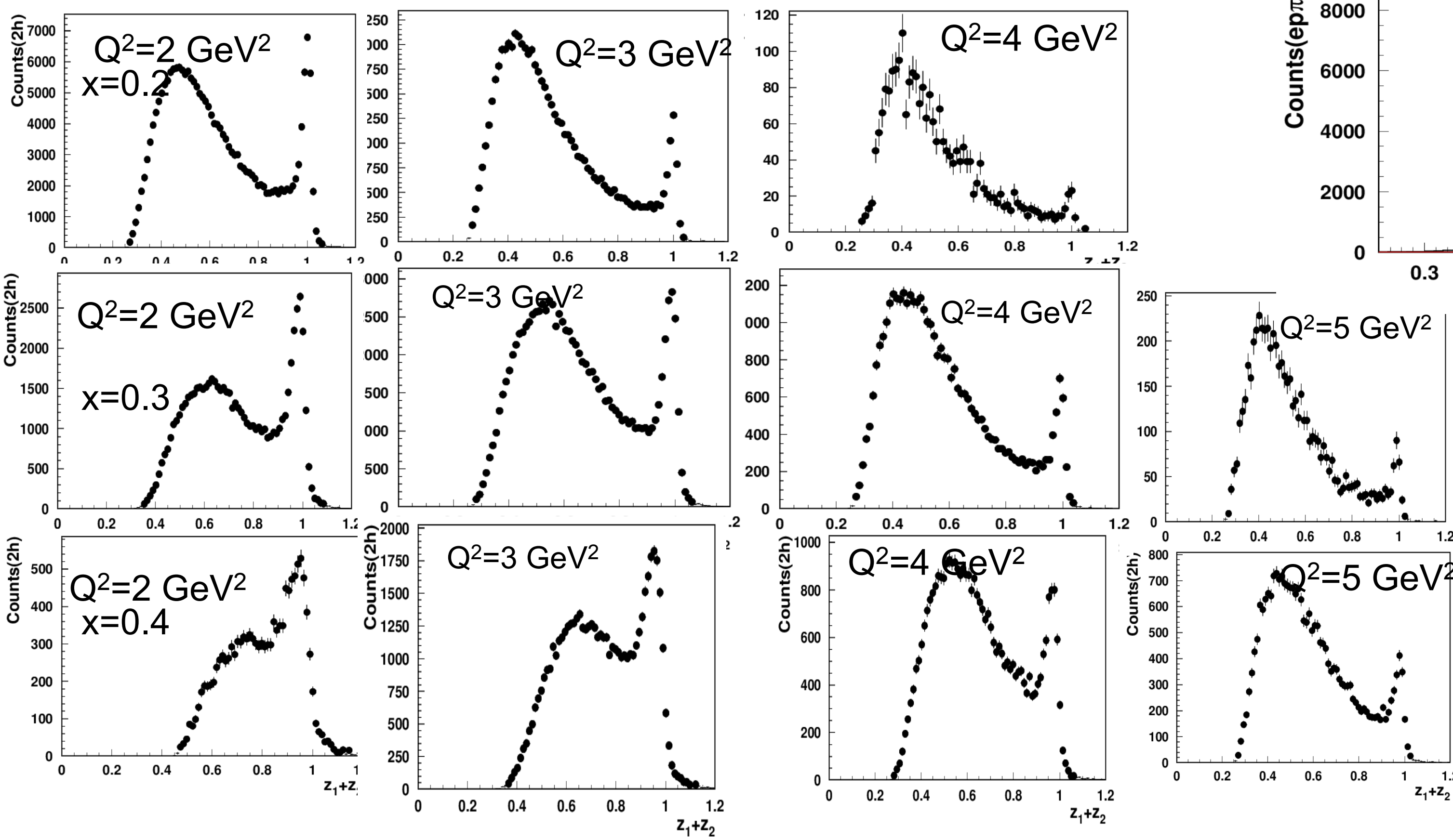


COMPASS(width ~2GeV)

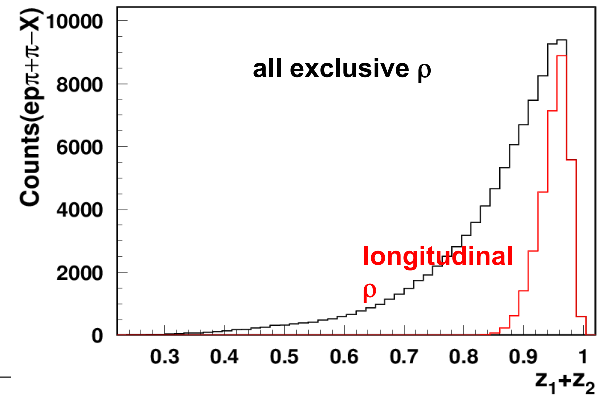


- Guarantying the “exclusivity” requires good resolutions (get worse at higher energies)
- Subtraction procedure relays on normalization, based on exclusive limit of LUND-MC
- All distributions have tails, indicating the RC may not be negligible
- Extraction of SDMEs, will require validation in the multi-D space (significant samples)

Exclusive dihadrons from CLAS12



$t_{min} \approx -M^2x^2/(1-x)$



$$\gamma_L^* \to \rho_L \propto 1$$
$$\gamma_T^* \to \rho_L \propto \sqrt{(1-z)/x}$$
$$\gamma_L^* \to \rho_T \propto \sqrt{< k_\perp^2 > (1-z)/x}$$

at lower x
need higher z

The exclusive rho contributions in SIDIS drop with Q^2 ($\sim 1/Q^2$)
At large $z=z_1+z_2$ the transverse photon contributions to ρ_L suppressed

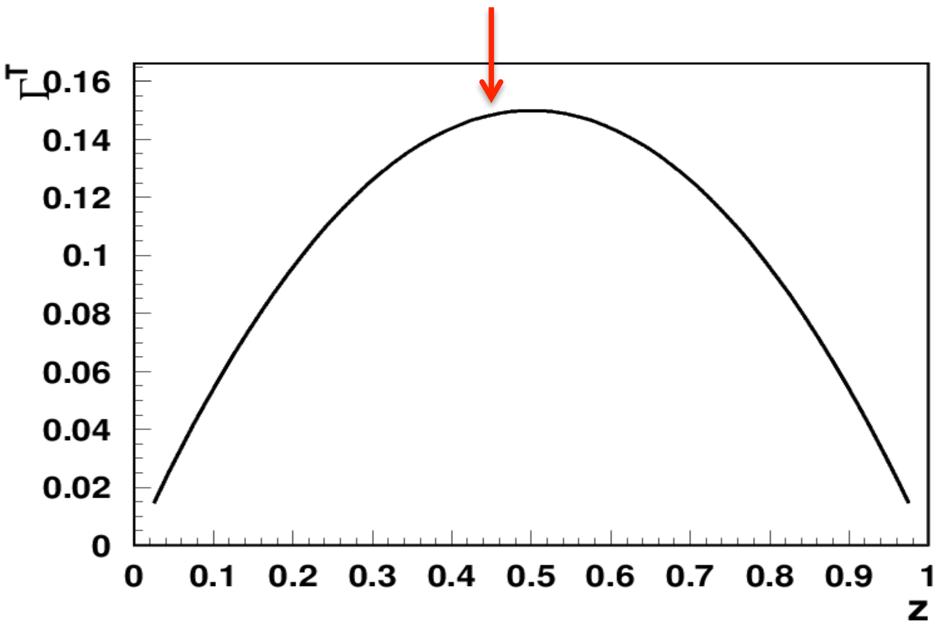
VM contributions $\rho^0 \to \pi^+\pi^-$

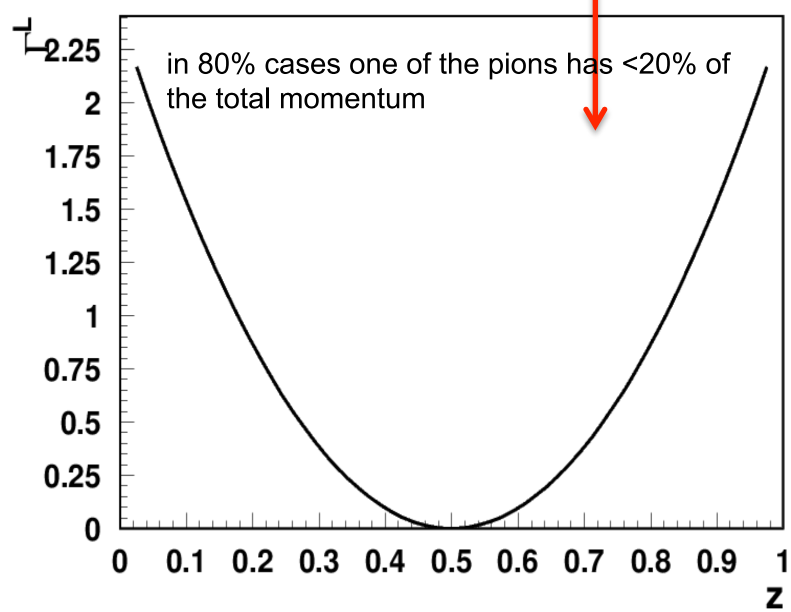
Yuri Kovchegov

$$k_T^2 = z(1-z)\, M_\rho^2 - m_\pi^2.$$

$$\Gamma^L_{\rho^0\to\pi^+\pi^-} \sim |M^L_{\rho^0\to\pi^+\pi^-}|^2 \sim \left| \frac{k_\perp^2 + m_\pi^2}{M_\rho} \left(\frac{1}{z} - \frac{1}{1-z} \right) + M_\rho\,(1-2z) \right|^2 = 4\, M_\rho^2\,(1-2z)^2.$$

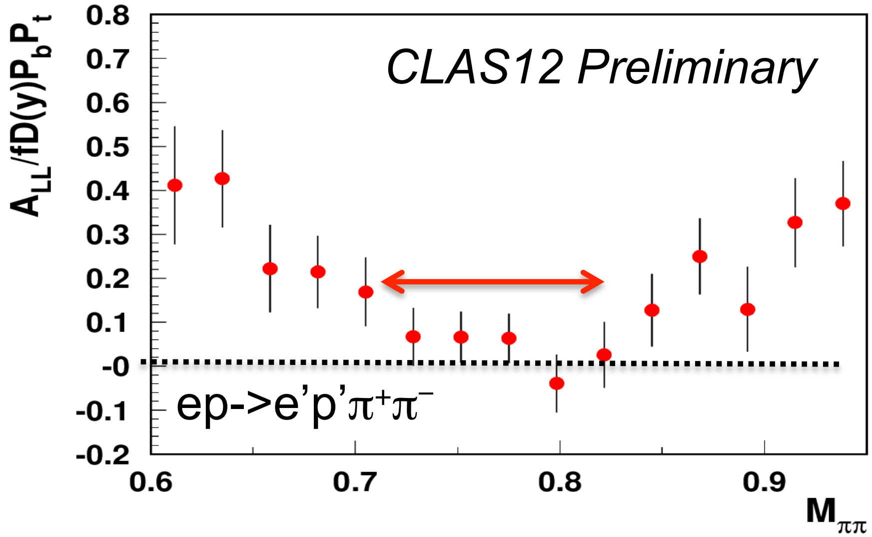
$$\Gamma^T_{\rho^0\to\pi^+\pi^-} \sim k_T^2 \sim z(1-z)\, M_\rho^2 - m_\pi^2$$

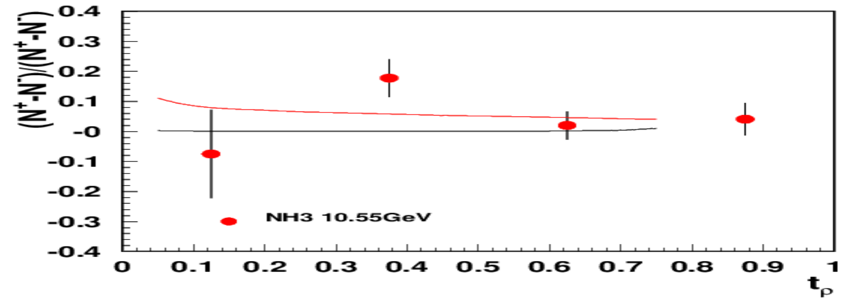


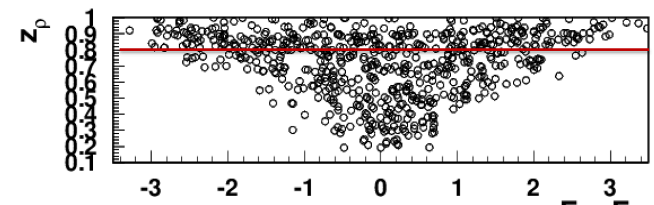


Asymmetric decays of longitudinall rho lead to much smaller acceptance
Similar but inverted distributions for e+e- decays

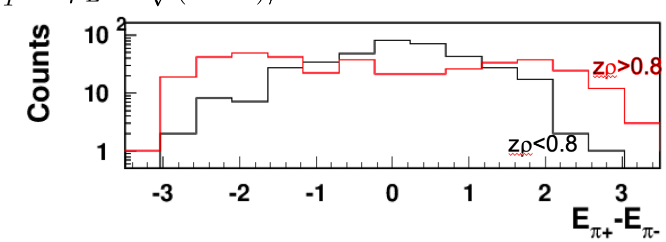
Studies of ρ^0 impact with longitudinally polarized NH_3 target







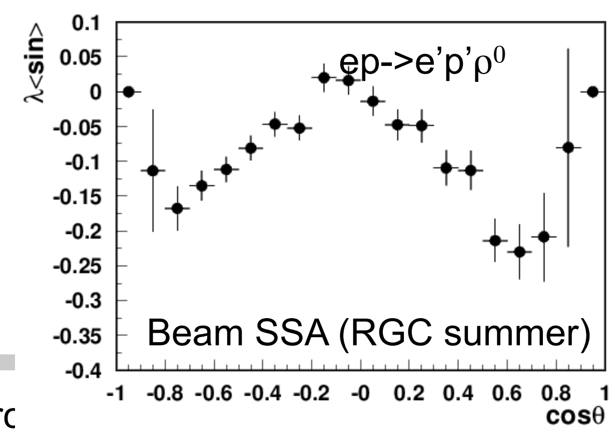
$\gamma^*_T \rightarrow \rho_L \propto \sqrt{(1-z)/x}$



Need clear separation of hydrogen from NH_3
and diffractive exclusive ρ0s from exclusive π+π−

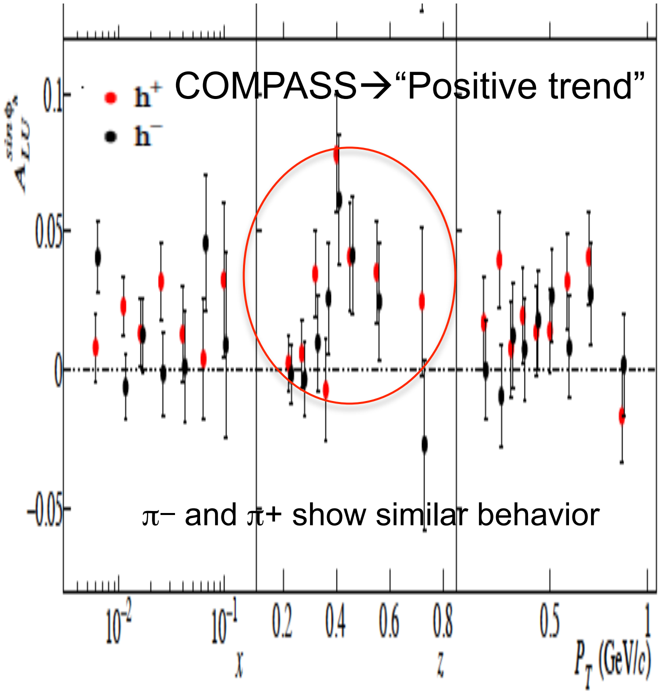
- DSA is P-even, SSA is P-odd
- longitudinal photon cross section is P-odd

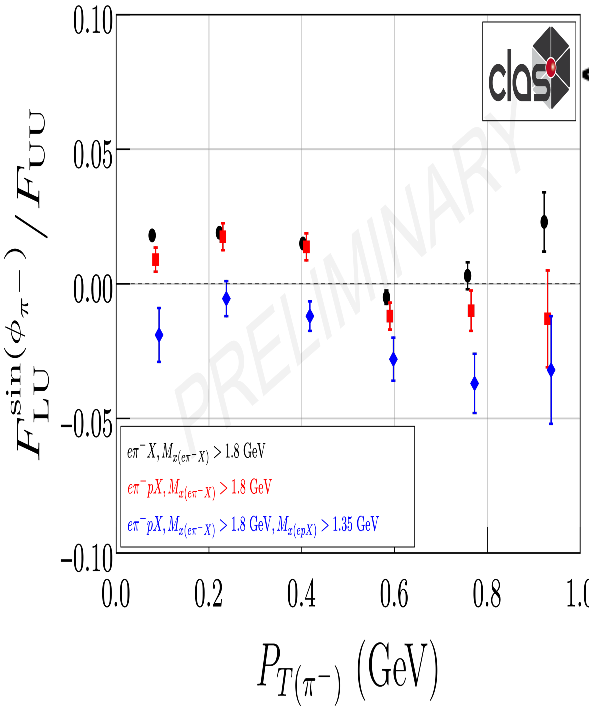
→ contribution appears only in the SSA, a P-odd observable, and does not appear in DSA

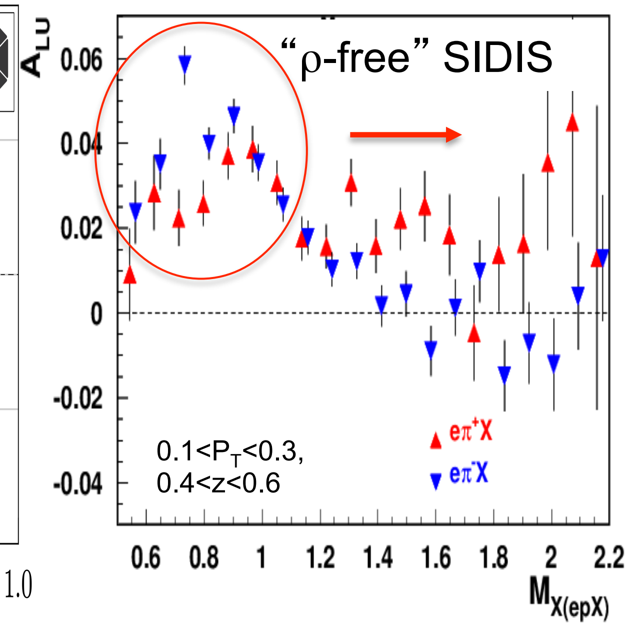


With x10 less statistics than RGC, RGH can provide a significant measurement of ρ0 SSAs

Exclusive ρ contributions to π: P_T-dependence







COMPASS→"Positive trend" also reproduced
when additional proton in TFR detected (red)

- The same sign and size of π+ and π- SSA indicates the rho0 may not be properly subtracted(require detailed MC studies, which require proper SDMEs)
- While VM contributions are ~20% in multiplicities in SSA they can be >100%
- Detection of the target proton introduces much smaller bias on the inclusive charged pion SSA, than the exclusive rho contributions

SUMMARY

Measurements of diffractive exclusive ρ with transversely polarized target will be crucial for completeness of the measurements of 3D structure, including GPDs and TMDs

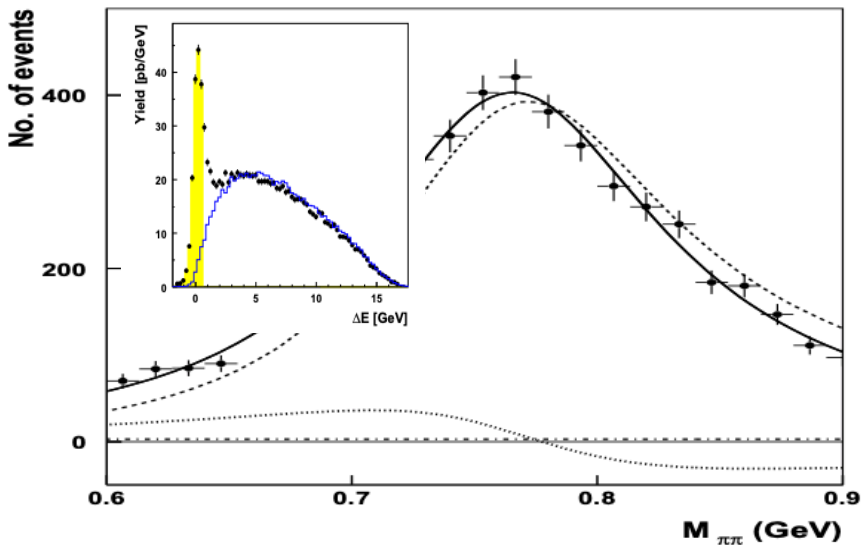
- Significant transverse single-spin asymmetries were predicted for exclusive rho0 and rho+
- CLAS12 has significant advantage compared to higher energy experiments in resolution and statistics, required for proper separation of exclusive VMs from semi-exclusive VMs, and separation of transverse rhos from longitudinal
- Target and beam SSAs and DSA can help to separate diffractive rho from other exclusive and semi-exclusive processes
- The diffractive VM contributions, violate the factorized picture of SIDIS based on the dominance of the leading twist contributions, and detailed understanding of exclusive rho contributions in the multi-D space will be critical to address the challenges of phenomenology (“rho-subtracted SIDIS”)

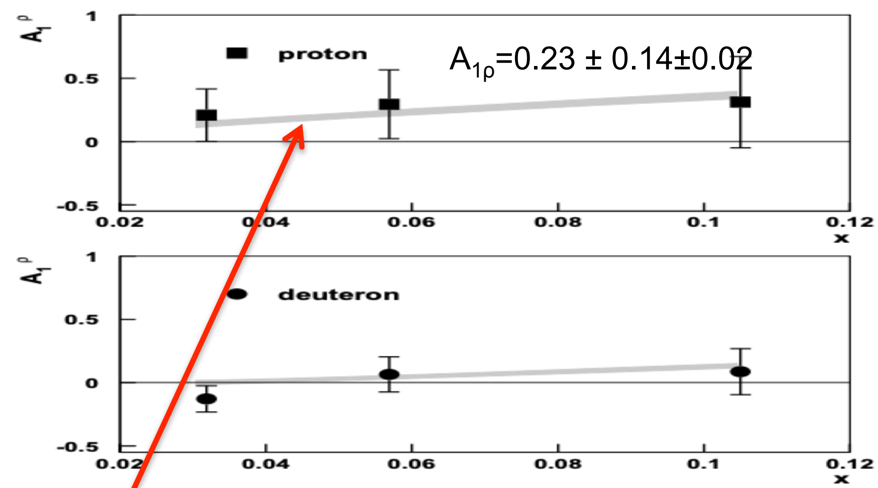
Submit a proposal to study SSAs for exclusive VMs with tranversely polarized target
→run group extension to RGH (involved Duke, MSU, Argonne, Duquesne)

Combine efforts of CLAS+COMPASS communities (ex. generator development) in understanding the diffractive ρ and sort out the impact on OAM, TMD-PDFs, including the helicity and Sivers

- support slides

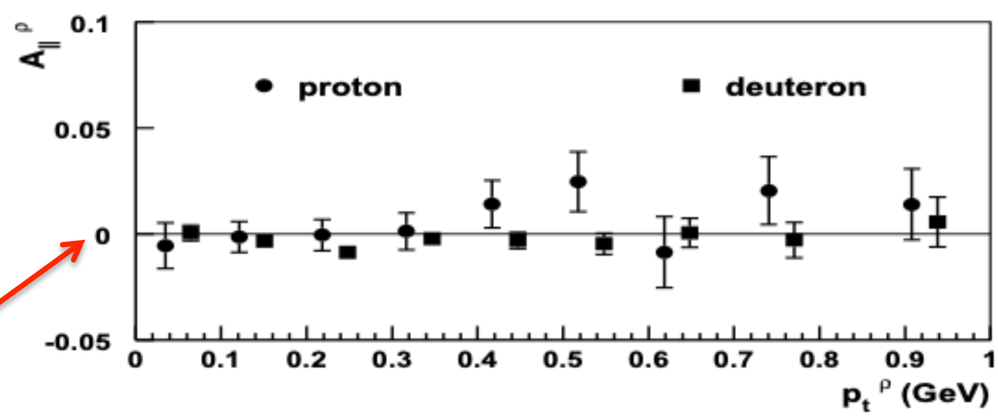
A_{LL} studies of exclusive ρ^0 : HERMES





1D plots can be really misleading need multi-D

For a proper extraction of multiplicities and spin-azimuthal modulations of exclusive ρs, clean separation is needed for ρ^0, and longitudinally polarized ρ^0 signal, in particular



At low P_T, where the background is smaller, the asymmetry indeed tend to be negative

Accounting of ρ^0 will change the phenomenology of helicity distributions

Excluding the "diffractive" rho from SIDIS

Depending on how we exclude the exclusive rho we can have several versions of experimental samples of inclusive hadrons, each with their own bias:

1) Standard SIDIS (eN→ehX, h=π,K,..) within the full accessible kinematics, corrected for acceptance and RC, measured in the multidimensional space

→eπX biased with respect to theory by presence of contributions from diffractive rho, contributing to ~20% of counts, in low P_T, with contributions to SSA ~10 times higher

2) Standard SIDIS (eN→eπX) within the full accessible kinematics, corrected for acceptance and RC, measured in the multidimensional space, with subtracted in multi-D bins for rho0 contributions ("rho-subtracted SIDIS")

→requires measurements of pions from diffractive rho in multidimensional space, means detailed studies of SDMEs of rhos, requiring good precisions and huge statistics, develop MC (ex. HEPGEN) also for all polarization observables, extensive validation needed, little known RC

3) SIDIS subsamples (eN→epπX, eN→e$\pi\pi$X) within the full accessible kinematics, allowing clear eliminiation of rho0 contributions using cuts on missing masses of epX or e$\pi\pi$X ("rho-free SIDIS")

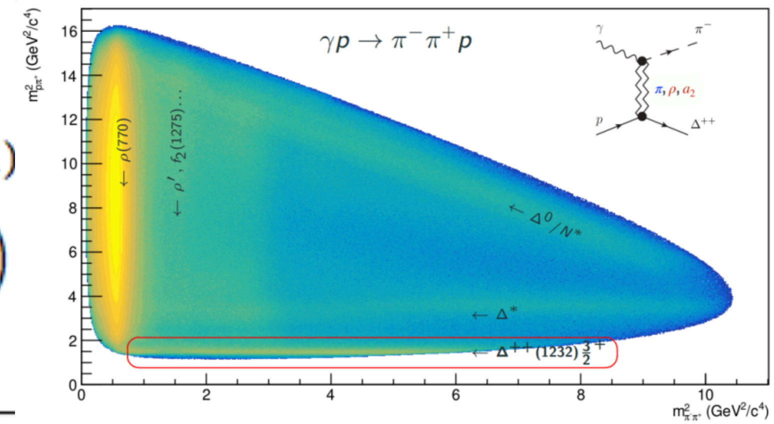
→biased by the presence of additional hadron in TFR (epX) or CFR (eppX), may need a new phenomenology

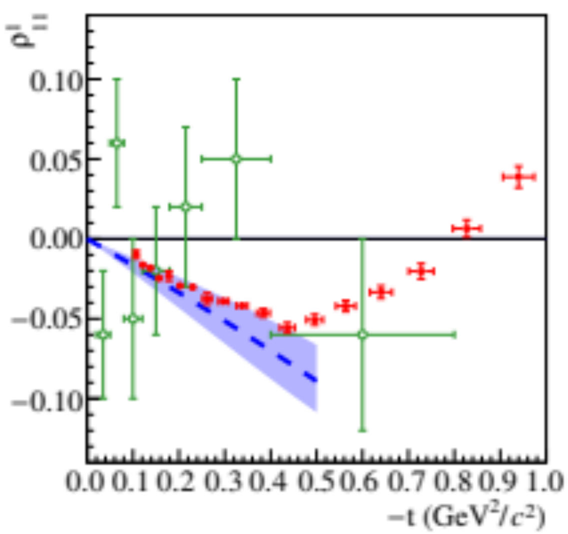
requires measurements of dependence on M_X to understand the bias,
Theory should be able to evaluate the bias from the presence of an additional hadron

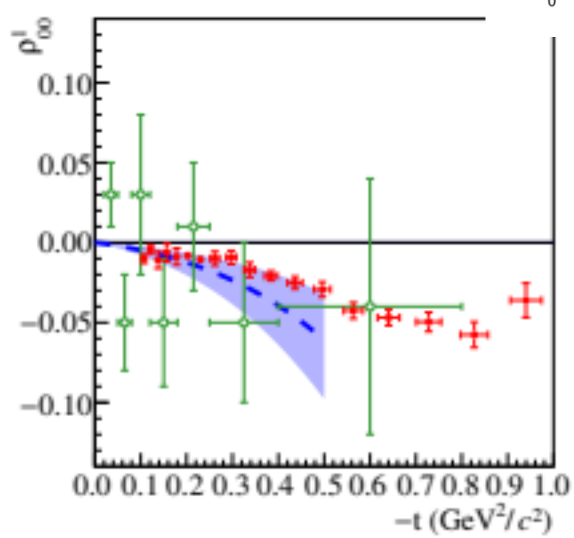
SDMEs from photoproduction

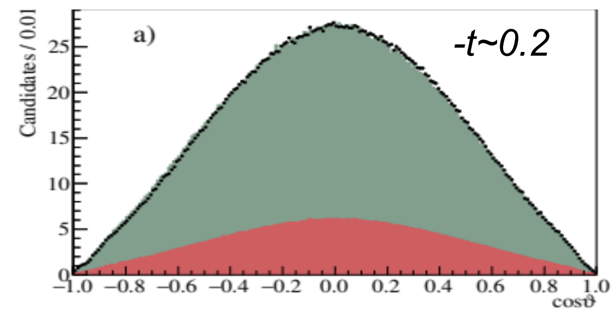
JLab/GlueX, S. Adhikari et al, Phys.Rev.C 108 (2023), 055204: ArXiv:2305.09047

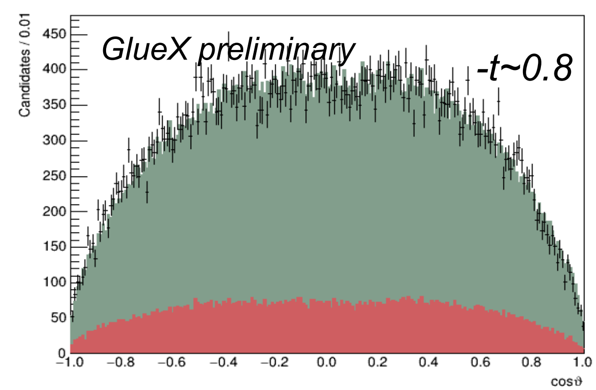
$$W^1(\cos\vartheta,\varphi) = \frac{3}{4\pi}\Big(\rho^1_{11}\sin^2\vartheta + \rho^1_{00}\cos^2\vartheta - \sqrt{2}\mathrm{Re}\rho^1_{10}\sin 2\vartheta\cos\varphi - \rho^1_{1-1}\sin^2\vartheta\cos 2\varphi\Big) \quad (11)$$







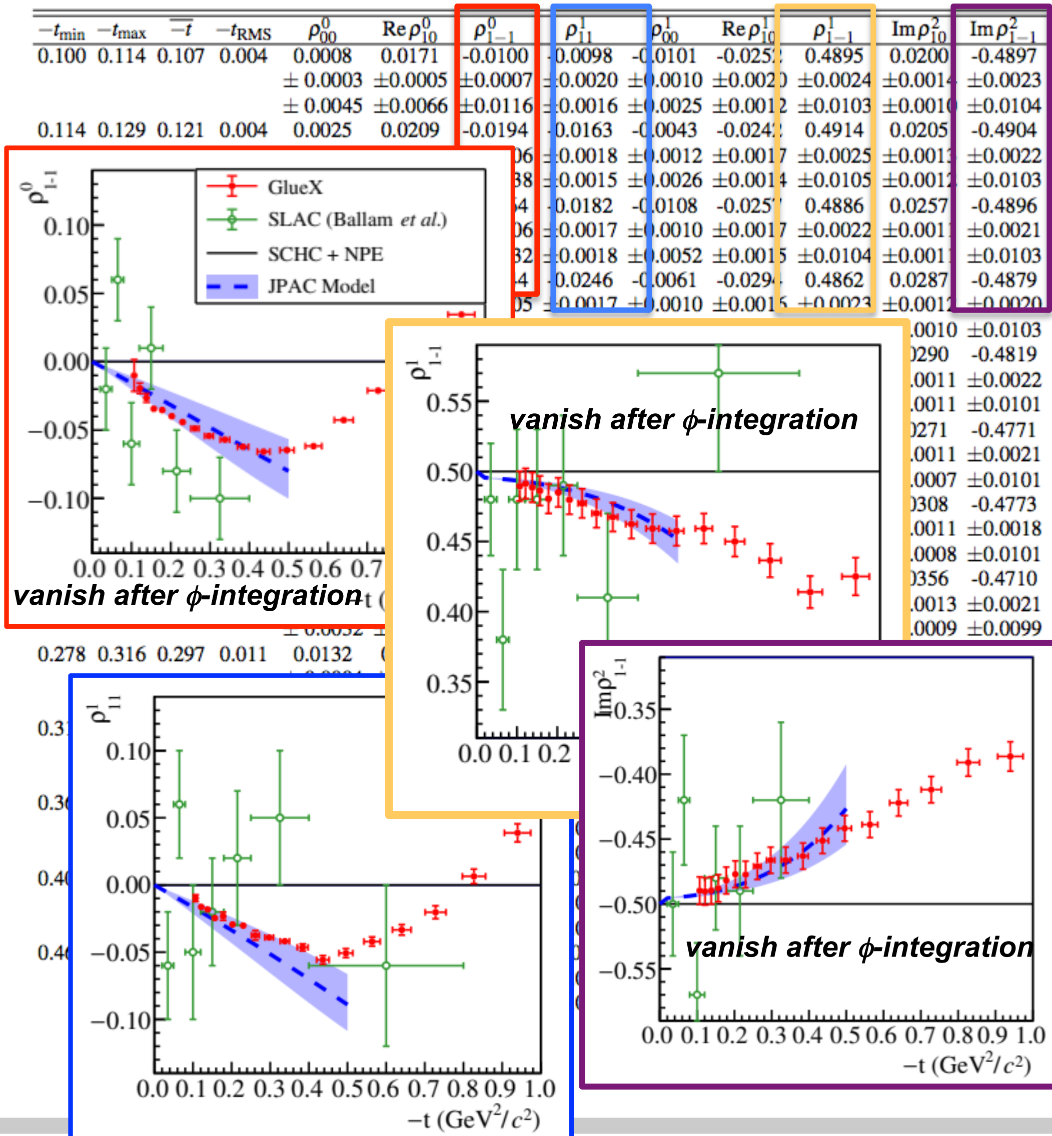


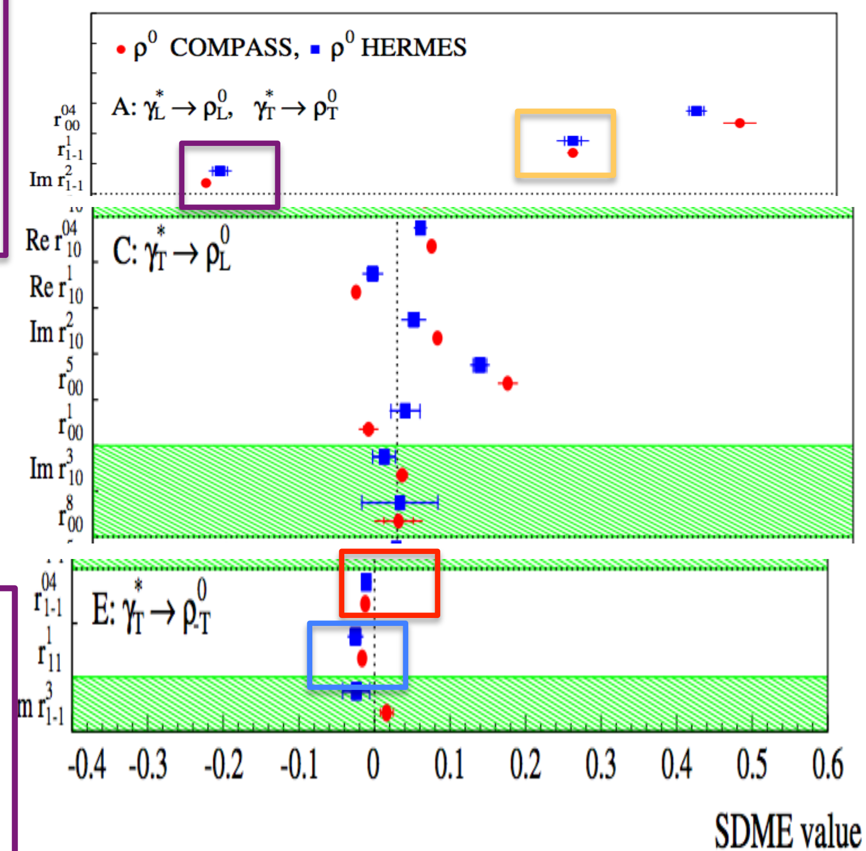


While at small t (dominant part of the statistics) the transverse rhos dominate, at large t the contribution from transverse photons going to longitudinal rho becomes more significant

SDMEs from photoproduction

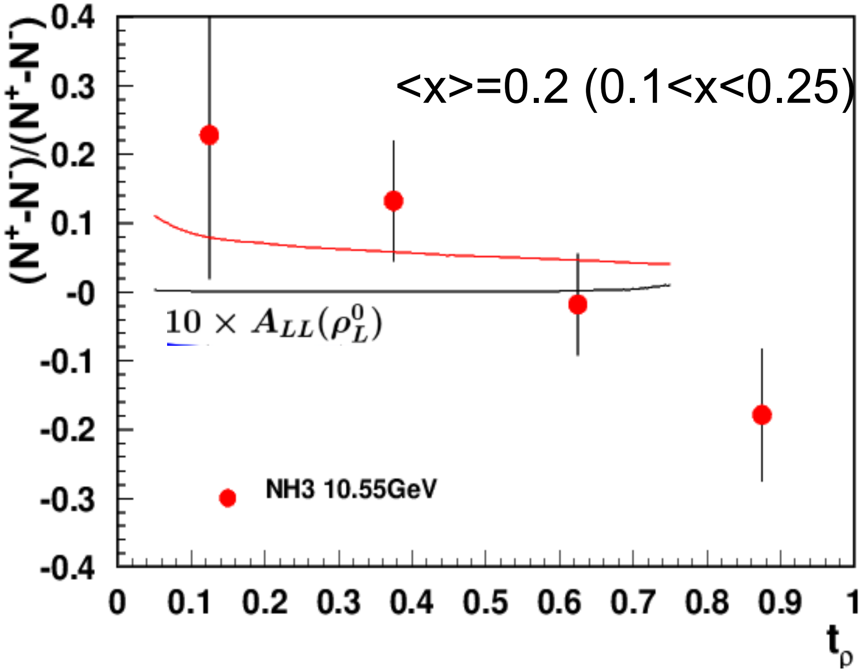
JLab/GlueX. S. Adhikari et al: https://arxiv.org/pdf/2305.09047

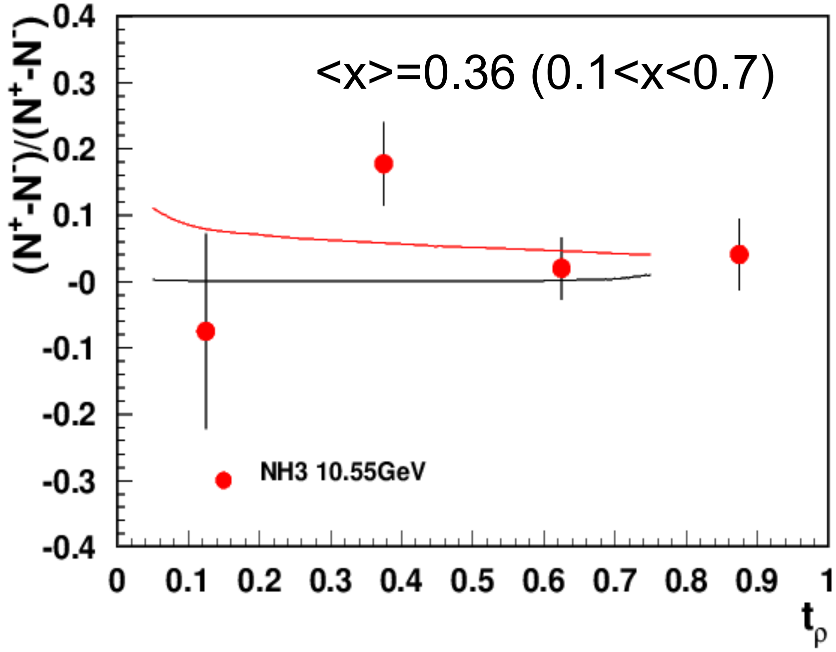




The SDMEs for transverse photons with $\sin^2\theta$ (to transverse rho?) at $Q^2>0$ seem to be smaller (detailed comparison vs Q^2).

What is the gluon polarization at large x?



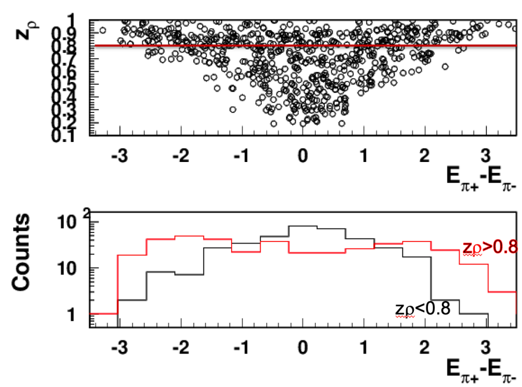


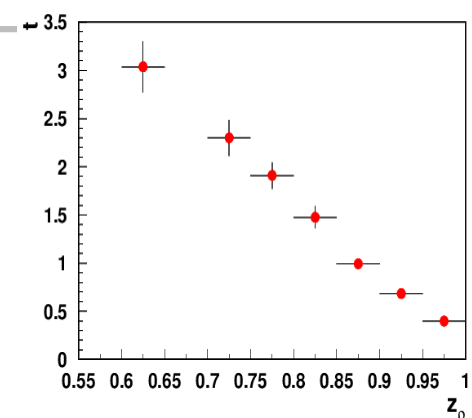
Curves calculated by Kroll&Goloskokov (x=0.12)

The full sample would allow fine binning in

and separation of longitudinal/transverse ρ

Polarization of rho

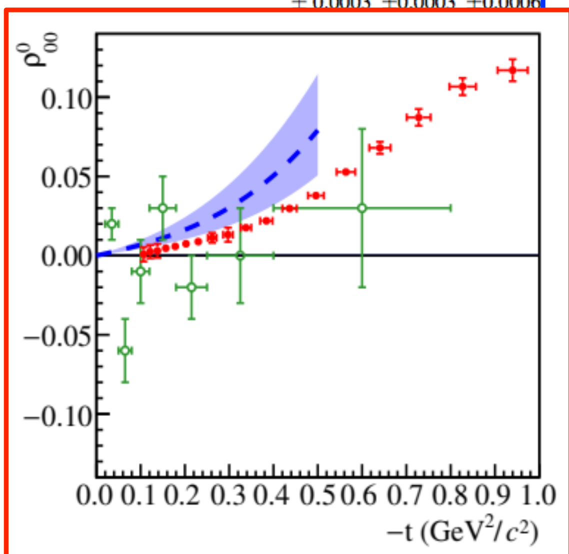


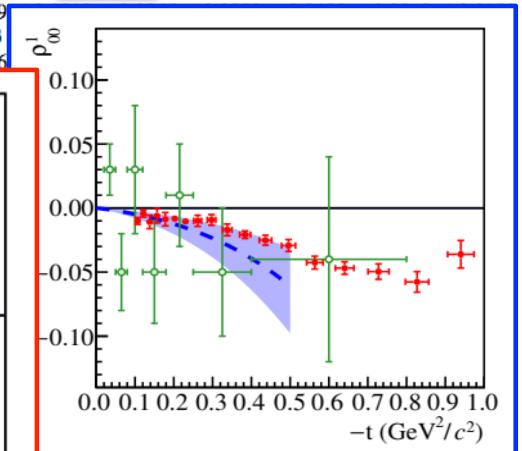


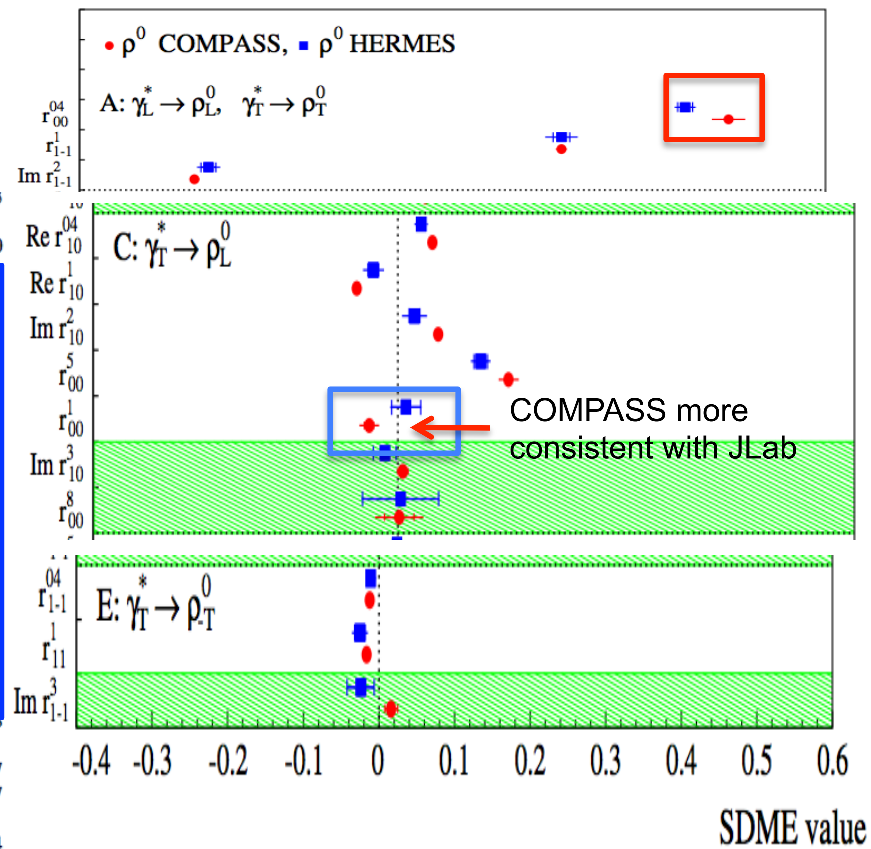
SDMEs from photoproduction

JLab/GlueX. S. Adhikari et al: https://arxiv.org/pdf/2305.09047

$-t_{min}$	$-t_{max}$	$-\overline{t}$	$-t_{RMS}$	ρ^0_{00}	$\mathrm{Re}\,\rho^0_{10}$	ρ^0_{1-1}	ρ^1_{11}	ρ^1_{00}	$\mathrm{Re}\,\rho^1_{10}$	ρ^1_{1-1}	$\mathrm{Im}\,\rho^2_{10}$	$\mathrm{Im}\,\rho^2_{1-1}$
0.100	0.114	0.107	0.004	0.0008	0.0171	-0.0100	-0.0098	-0.0101	-0.0252	0.4895	0.0200	-0.4897
				± 0.0003	±0.0005	±0.0007	±0.0020	±0.0010	±0.0020	±0.0024	±0.0014	±0.002
				± 0.0045	±0.0066	±0.0116	±0.0016	±0.0025	±0.0012	±0.0103	±0.0010	±0.010
0.114	0.129	0.121	0.004	0.0025	0.0209	-0.0194	-0.0163	-0.0043	-0.0242	0.4914	0.0205	-0.4904
				± 0.0003	±0.0004	±0.0006	±0.0018	±0.0012	±0.0017	±0.0025	±0.0013	±0.002
				± 0.0042	±0.0030	±0.0038	±0.0015	±0.0026	±0.0014	±0.0105	±0.0012	±0.010
0.129	0.147	0.138	0.005	0.0030	0.0244	-0.0264	-0.0182	-0.0108	-0.0257	0.4886	0.0257	-0.4896
				± 0.0003	±0.0004	±0.0006	±0.0017	±0.0010	±0.0017	±0.0022	±0.0011	±0.002
				± 0.0044	±0.0023	±0.0032	±0.0018	±0.0052	±0.0015	±0.0104	±0.0011	±0.0103
0.147	0.167	0.157	0.006	0.0047	0.0283	-0.0344	-0.0246	-0.0061	-0.0294	0.4862	0.0287	-0.4879
				± 0.0002	±0.0004	±0.0005	±0.0017	±0.0010	±0.0016	±0.0023	±0.0012	±0.0020
				± 0.0022	±0.0011	±0.0009						
0.167	0.190	0.178	0.007	0.0058	0.0295	-0.0353						
				± 0.0003	±0.0003	±0.0006						
							.0464	-0.0208	-0.0449	0.4624	0.0378	-0.4631
							.0022	±0.0017	±0.0017	±0.0031	±0.0014	±0.0027
							.0014	±0.0025	±0.0010	±0.0097	±0.0011	±0.0097
							.0557	-0.0251	-0.0507	0.4592	0.0366	-0.4513
							.0026	±0.0020	±0.0020	±0.0036	±0.0017	±0.0024
							.0018	±0.0033	±0.0016	±0.0098	±0.0012	±0.0095
0.464	0.527	0.496	0.018	0.0379	0.0480	-0.0647	-0.0507	-0.0293	-0.0519	0.4575	0.0356	-0.4417
				± 0.0006	±0.0005	±0.0008	±0.0029	±0.0029	±0.0020	±0.0042	±0.0019	±0.0033
				± 0.0022	±0.0019	±0.0013	±0.0017	±0.0037	±0.0015	±0.0097	±0.0014	±0.0093







The SDMEs for transverse photons with $\cos^2\theta$ (to longitudinal rho?) at $Q^2>0$ different, in particular r_{00}^1 (relevant for BM).

Understanding exclusive rhos and SDME validations

$$\mathcal{W}^U(\Phi,\phi,\cos\Theta)$$

$$+\quad \sqrt{2\epsilon(1+\epsilon)}\cos\Phi\left(r^5_{11}\sin^2\Theta + r^5_{00}\cos^2\Theta\right.$$

corr. with r_{1-1}^5 , r_{1-1}^6 ,r_{00}^5 (Hermes, COMPASS)

$$\mathcal{W}^L(\Phi,\phi,\cos\Theta)$$

$$+\quad \sqrt{2\epsilon(1-\epsilon)}\sin\Phi\left(r^8_{11}\sin^2\Theta + r^8_{00}\cos^2\Theta\right.$$

$$\left. -\sqrt{2}\mathrm{Re}\{r^8_{10}\}\sin 2\Theta\cos\phi - r^8_{1-1}\sin^2\Theta\cos 2\phi\right)\Bigg].$$

corr. with r_{1-1}^8 ,r_{00}^8 (Hermes, COMPASS)

$$\gamma^*_L \to \rho^0_T,\quad \tau_{10} \approx \frac{\sqrt{(r^5_{11}+\mathrm{Im}\{r^6_{1-1}\})^2 + (\mathrm{Im}\{r^7_{1-1}\} - r^8_{11})^2}}{\sqrt{2(r^1_{1-1} - \mathrm{Im}\{r^2_{1-1}\})}}$$

Since the decay angle is correlated with the polarization of the rho, then r_{11}^8 and r_{11}^5 will be responsible for transverse rho (no Cahn?)

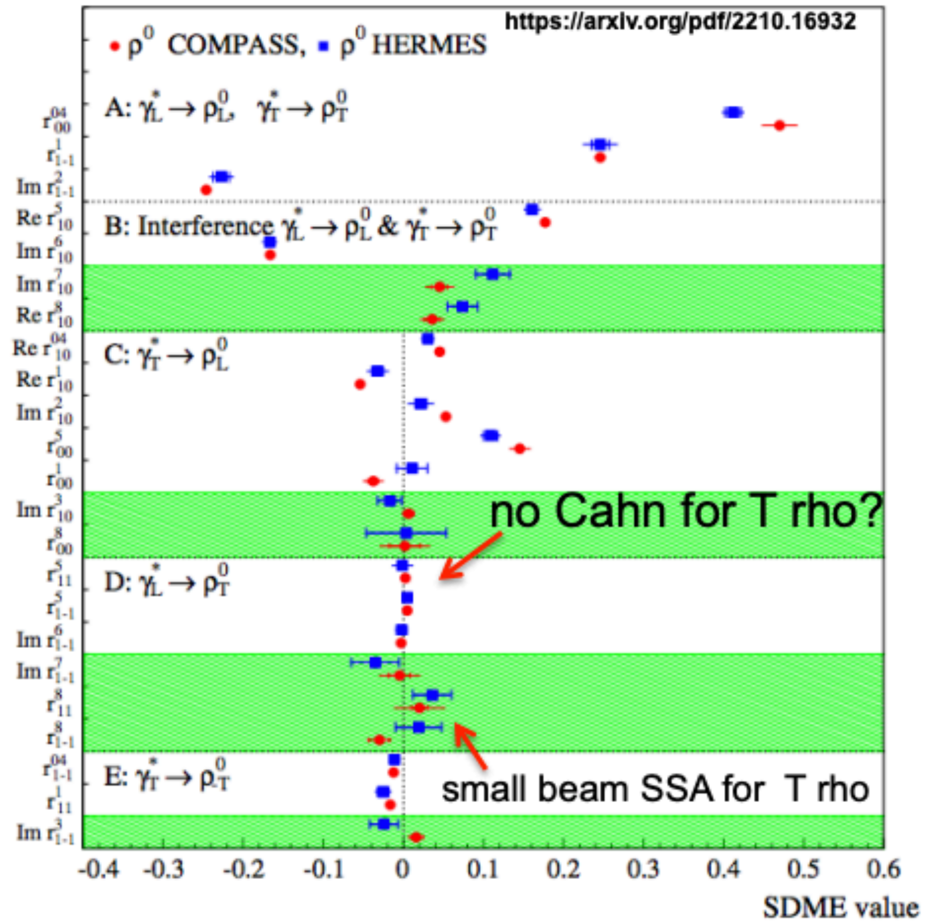


Fig. 12: Comparison of the 23 SDMEs for exclusive ρ^0 leptoproduction on the proton extracted in the entire kinematic regions of the HERMES and COMPASS experiments. For HERMES the average kinematic values are $\langle Q^2\rangle = 1.96$ (GeV/c)^2, $\langle W\rangle = 4.8$ GeV/c^2, $\langle |t'|\rangle = 0.13$, while those for COMPASS are $\langle Q^2\rangle = 2.40$ (GeV/c)^2, $\langle W\rangle = 9.9$ GeV/c^2, $\langle p_T^2\rangle = 0.18$ (GeV/c)^2. Inner error bars represent statistical uncertainties and outer ones statistical and systematic uncertainties added in quadrature. Unpolarised (polarised) SDMEs are displayed in unshaded (shaded) areas.

Understanding exclusive rhos and SDME validations

$$\mathcal{W}^U(\Phi,\phi,\cos\Theta)$$

$$+\ \sqrt{2\epsilon(1+\epsilon)}\cos\Phi\left(r^5_{11}\sin^2\Theta + r^5_{00}\cos^2\Theta\right)$$

corr. with r_{10}^5 (Hermes) no corr (COMPASS)

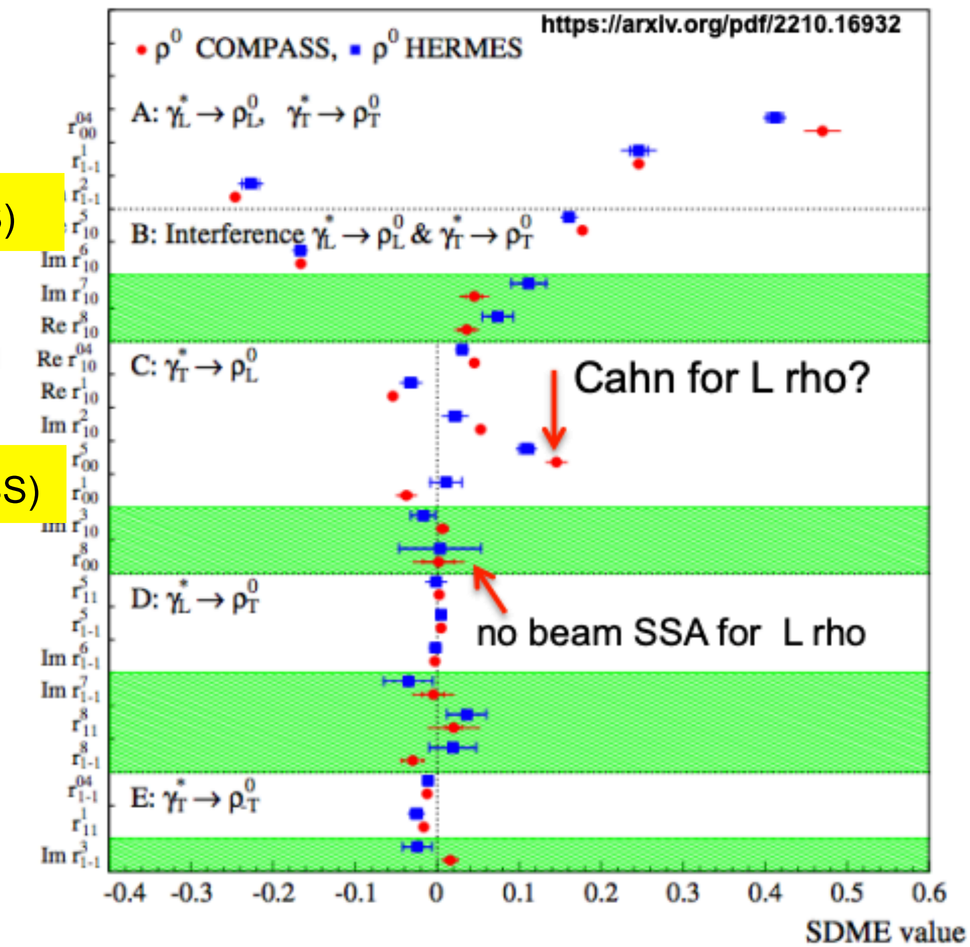
$$\mathcal{W}^L(\Phi,\phi,\cos\Theta)$$

$$+\ \sqrt{2\epsilon(1-\epsilon)}\sin\Phi\left(r^8_{11}\sin^2\Theta + r^8_{00}\cos^2\Theta\right)$$

corr. with r_{1-1}^8 (Hermes) no corr (COMPASS)

$$\gamma^*_T \to \rho^0_L \qquad \tau_{01} \approx \sqrt{\epsilon}\,\frac{\sqrt{(r^5_{00})^2+(r^8_{00})^2}}{\sqrt{2r^{04}_{00}}}$$

Since the decay angle is correlated with the polarization of the rho, then r_{00}^8 and r_{00}^5 will be responsible for longitudinal rho, so tiny beam SSA expected for longitudinal rho



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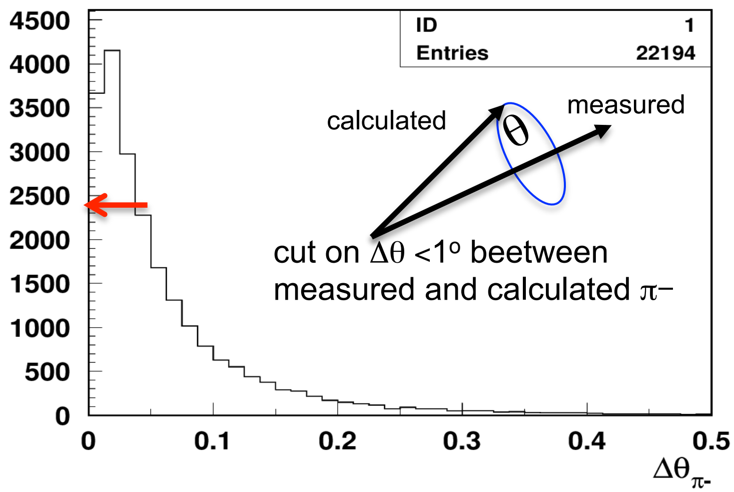
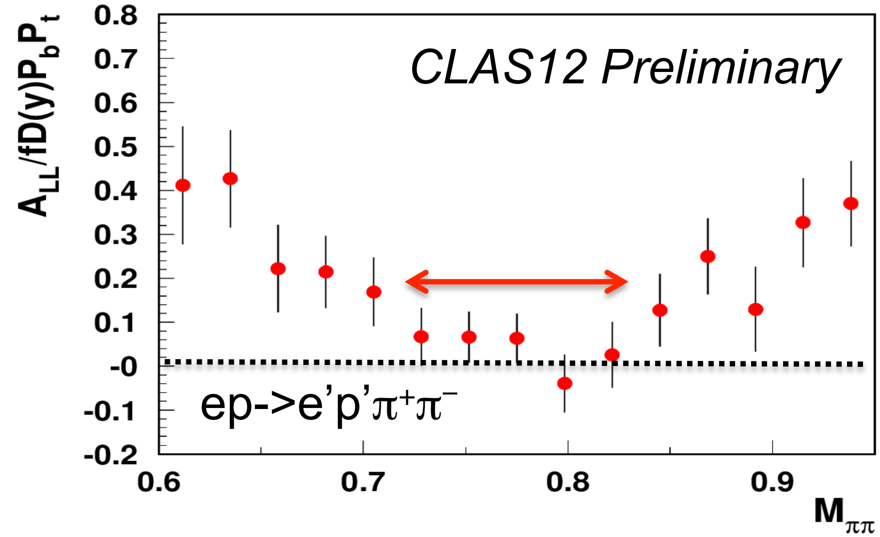
Studies of ρ^0 impact with longitudinally polarized NH_3 target

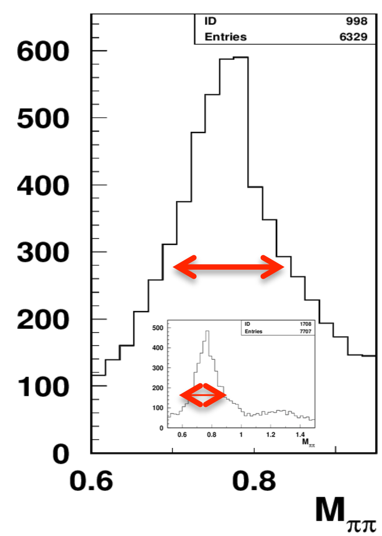
Separating exclusive dihadrons

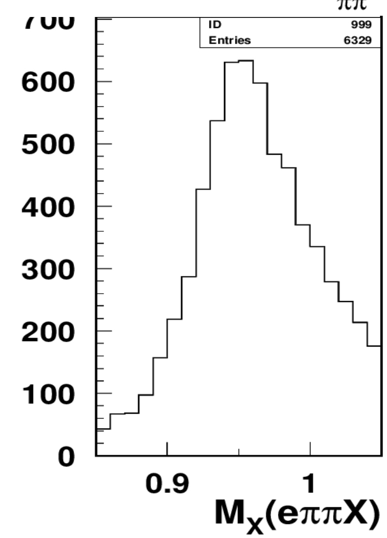


- Require the angle of negative pions is within a degree from calculated from e’,p,π+ assuming exclusive e’,p,π+π- event.
- Measurements of A_{LL} for ρ^0 indicate very small values (with ~10-20% bck, likely negative ~ -2-10%), and can be one of the reasons for higher A_{LL} with protons with a M_X cuts above 1.35 GeV (excluding exclusive ρ^0)

Request to theory→ evaluate the impact on $g_1(x,k_T)$ with all A_{LL}s increasing 10-20%





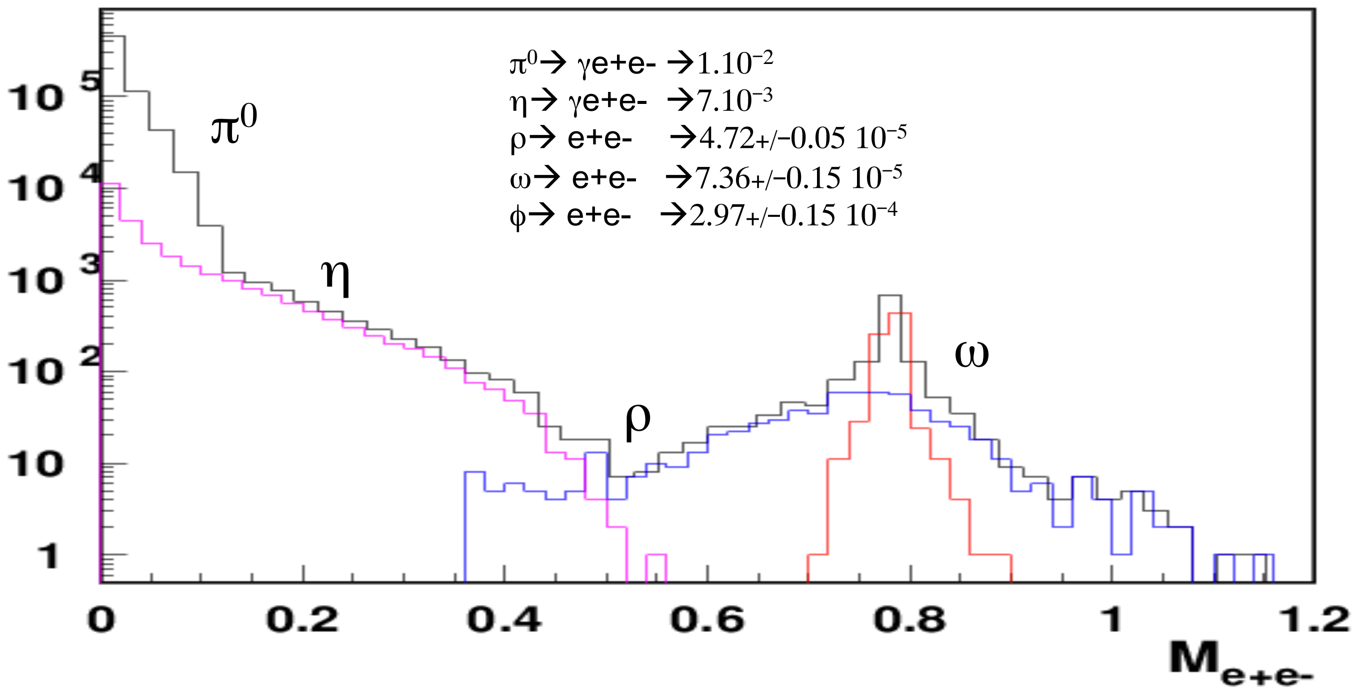


Need clear separation of hydrogen from NH_3 and diffractive exclusive ρ0s from exclusive π+π−

Using e+e- to estimate vector mesons

The invariant mass of dihadrons is contaminated by other vector mesons, with shape not changing significantly with hadronization fraction to spin-1 vs spin-0 mesons

decays of π and η are kinematically sepaeated from ω and ρ^0



Vector meson per electron can be independently estimated from ep→e'e+e-X
Significant fraction of VM may affect DY studies.