Studies of the 3D Structure of the Nucleon

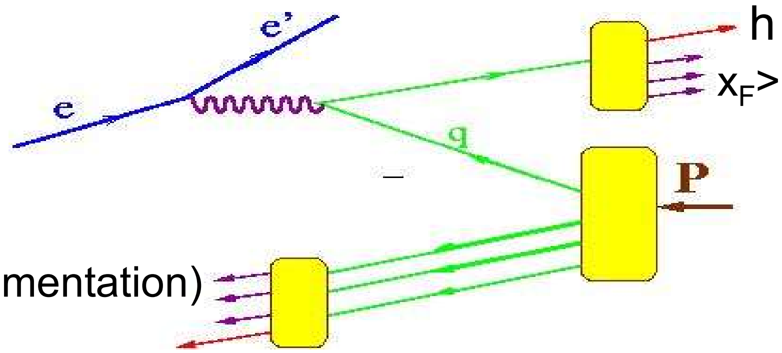
Harut Avakian (JLab)

The XV Hadron Physics, 13-17 Sep 2021

- Studies of 3D structure of nucleon at JLab
- Studies of DVCS
- Studies of transverse momentum of hadrons
  - multiplicities
  - azimuthal modulations
- Interpretations & challenges
- Future measurements and complementarity
- Summary

Electroproduction: extending 1D PDFs

x_F – fractional momentum in the CM frame

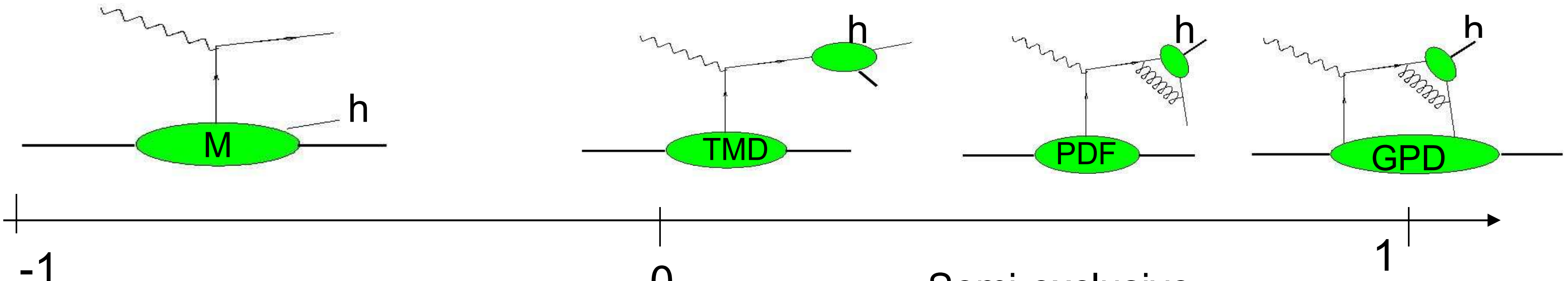


$x_F>0$ (current fragmentation)

$x_F<0$ (target fragmentation)

Target fragmentation

Current fragmentation



Fracture Functions

k_T-dependent PDFs

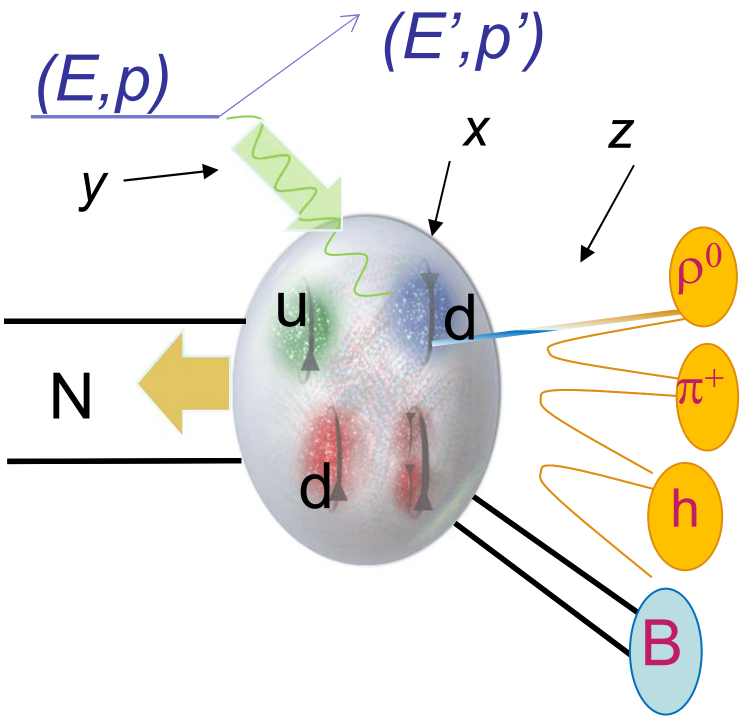
Semi-exclusive production

x_F

Generalized PDFs

Wide kinematic coverage of large acceptance detectors allows studies of semi-inclusive and exclusive processes simultaneously

SIDIS kinematical coverage and observables



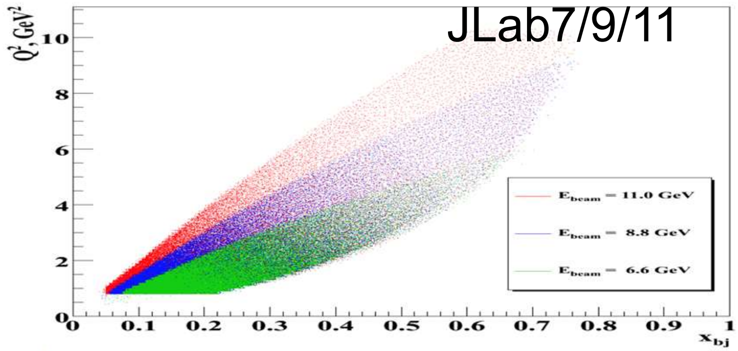
hermes

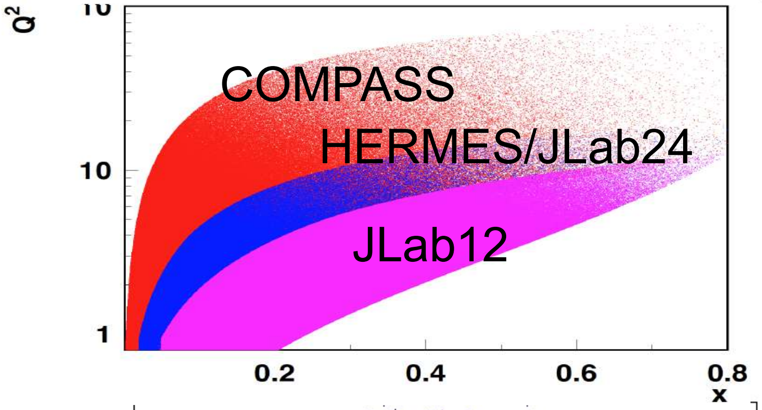
COMPASS

Jefferson Lab

EIC²
EIC Center at Jefferson Lab

EIC





$$\sigma = F_{UU} + P_t F_{UL}^{\sin\phi} \sin 2\phi + P_b F_{LU}^{\sin\phi} \sin\phi \ldots$$

$$\int d^2\vec{k}_T d^2\vec{p}_T \delta^{(2)}(z\vec{k}_T + \vec{p}_T - \vec{P}_T)$$

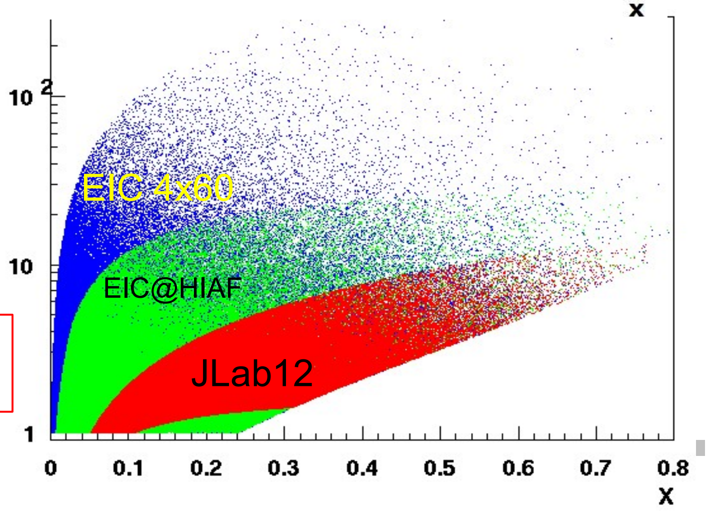
$$F^h_{XY}(x,z,P_T,Q^2) \propto \sum H^q \times f^q(x,k_T,..) \otimes D^{q\to h}(z,p_T,..) + Y(Q^2,P_T) + \mathcal{O}(M/Q)$$

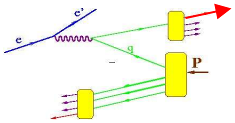
beam polarization

target polarization

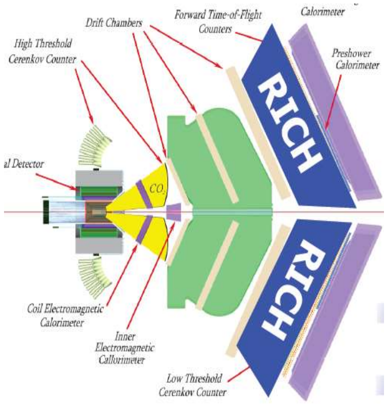
corrections for the region of large kT~Q

$$\boxed{q_T = P_T/z}$$





SIDIS at JLab12



CLAS12

E12-06-112: π^+,π^-,π^0
E12-09-008: K^+, K^-,K^0

E12-07-107: π^+,π^-,π^0
E12-09-009: K^+,K^-,K^0

C12-11-111: π^+,π^-,π^0 K^+, K^-

H_2, NH_3, HD

Proton

Quark spin polarization

Nucleon polarization

N q	U	L	T
U	f_1		$h_1^\perp$
L		g_1	$h_{1L}^\perp$
T	$f_{1T}^\perp$	g_{1T}	h_1 $h_{1T}^\perp$

Hall C | Hall A

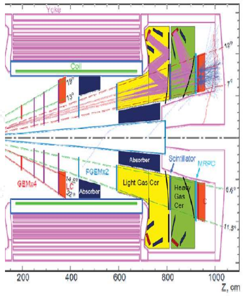
E12-09-017: π^+,π^-, K^+,K^-
C12-11-102: π^0

HMS
SHMS

C12-11-108: π^+,π^-

Solid

H_2 | NH_3



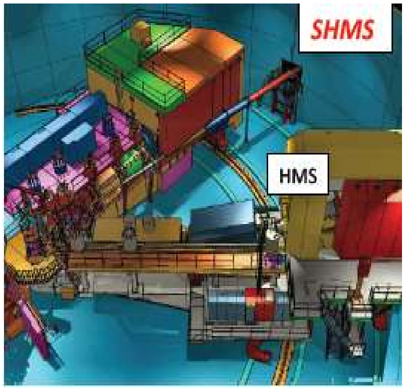
CLAS12

E09-008: π^+,π^-,π^0 K^+, K^-,K^0

E07-107: π^+,π^-,π^0
E09-009: K^+,K^-,K^0

D_2, ND_3

C12-20-002
$\pi^+,\pi^-.\pi^0$,K+



D_2

Quark spin polarization

Nucleon polarization

N q	U	L	T
U	f_1		$h_1^\perp$
L		g_1	$h_{1L}^\perp$
T	$f_{1T}^\perp$	g_{1T}	h_1 $h_{1T}^\perp$

Hall C

E12-09-017: π^+,π^-, K^+,K^-
C12-11-102: π^0

HMS
SHMS

D_2

^3He

Quark spin polarization

Nucleon polarization

N q	U	L	T
U	f_1		$h_1^\perp$
L		g_1	$h_{1L}^\perp$
T	$f_{1T}^\perp$	g_{1T}	h_1 $h_{1T}^\perp$

Hall A

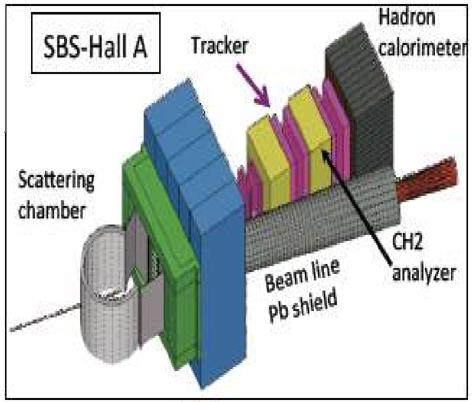
E12-07-007: π^+,π^-

Solid

E10-006: π^+,π^-
E12-09-018: π^+,π^-, K^+,K^-

Solid
SBS

^3He



12 GeV Approved Experiments by Physics Topics

Topic (status: May 2021)	**Hall A**	**Hall B**	**Hall C**	**Hall D**	**Other**	**Total**
Hadron spectra as probes of QCD	0	2	1	4	0	**7**
Transverse structure of the hadrons	7	4	3	1	0	**15**
longitudinal structure of the hadrons	1	3	7	1	0	**12**
3D structure of the hadrons	5.5	9	6.5	0	0	**21**
Hadrons and cold nuclear matter	9	6	7	1	0	**23**
Low-energy tests of the Standard Model and Fundamental Symmetries	3	1	0	1	1	**6**
Total	**25.5**	**25**	**24.5**	**8**	**1**	**84**
Total Experiments Completed	**9.0**	**9.7**	**7.3**	**1.5**	**0**	**27.5**
Total Experiments Remaining	**16.5**	**15.3**	**17.2**	**6.5**	**1.0**	**56.5**

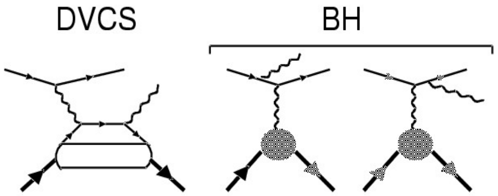
~10 years

JLab 2015 Science & Technology review closeout bullets:

•develop an integrated picture of what measurements are necessary and will be conducted in determining the GPDs and TMDs

•develop milestones for extraction of GPDs and TMDs from experiment

Deeply Virtual Compton Scattering ep→e’p’γ



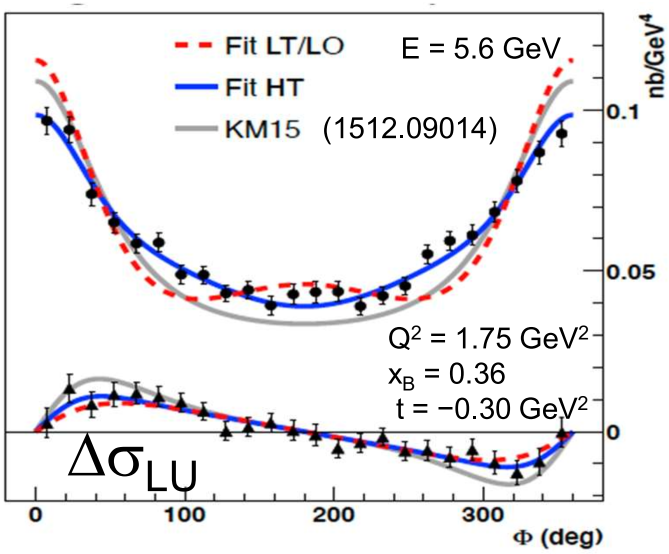
$$|\mathcal{T}_{\rm BH}|^2 = \frac{e^6}{x_{\rm B}^2 y^2 (1+\epsilon^2)^2 \boxed{\Delta^2 \mathcal{P}_1(\phi)\mathcal{P}_2(\phi)}} \left\{ c_0^{\rm BH} + \sum_{n=1}^{2} c_n^{\rm BH} \cos(n\phi) + s_1^{\rm BH} \sin(\phi) \right\}$$

$$\mathcal{I} = \frac{\pm e^6}{x_{\rm B} y^3 \boxed{\Delta^2 \mathcal{P}_1(\phi)\mathcal{P}_2(\phi)}} \left\{ c_0^{\mathcal{I}} + \sum_{n=1}^{3} \left[c_n^{\mathcal{I}} \cos(n\phi) + s_n^{\mathcal{I}} \sin(n\phi) \right] \right\},$$

$$|\mathcal{T}_{\rm DVCS}|^2 = \frac{e^6}{y^2 Q^2} \left\{ c_0^{\rm DVCS} + \sum_{n=1}^{2} \left[c_n^{\rm DVCS} \cos(n\phi) + s_n^{\rm DVCS} \sin(n\phi) \right] \right\}$$

$$\Delta\sigma_{LU} \sim \sin\phi\{F_1 \overbrace{H(\xi,\xi,t) + \xi(F_1+F_2)\tilde{H} + kF_2 E}^{s_2^I}\}$$

$$\Delta\sigma_{UL} \sim \sin\phi\{F_1\tilde{H} + \xi(F_1+F_2)(H + .. \}$$



Hall-A: 1504.05453 (LU)
Hall-B: 1501.07052 (UL)

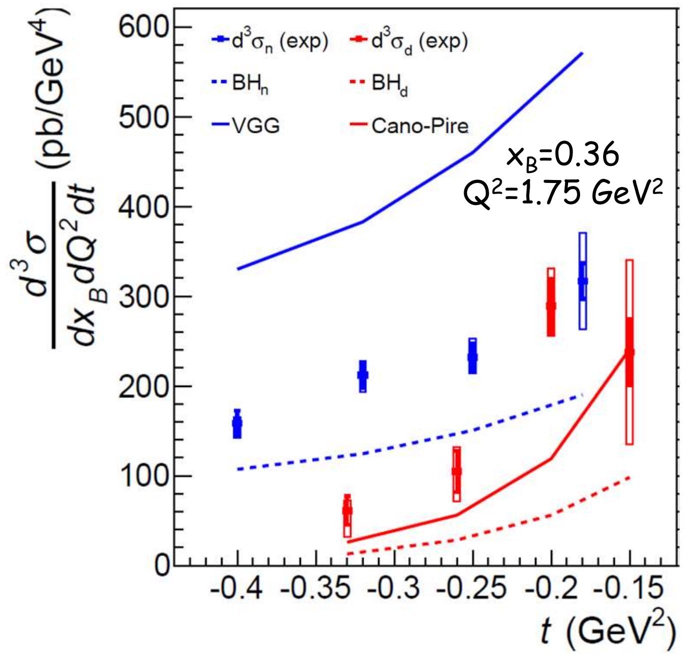
- Interference responsible for SSA, contain the same lepton propagator $P_1(\phi)$ as BH
- Different contributions have different kinematical dependences
- Higher twist contributions may be important in separation of DVCS

Hall-A:DVCS off the neutron (en→enγ)

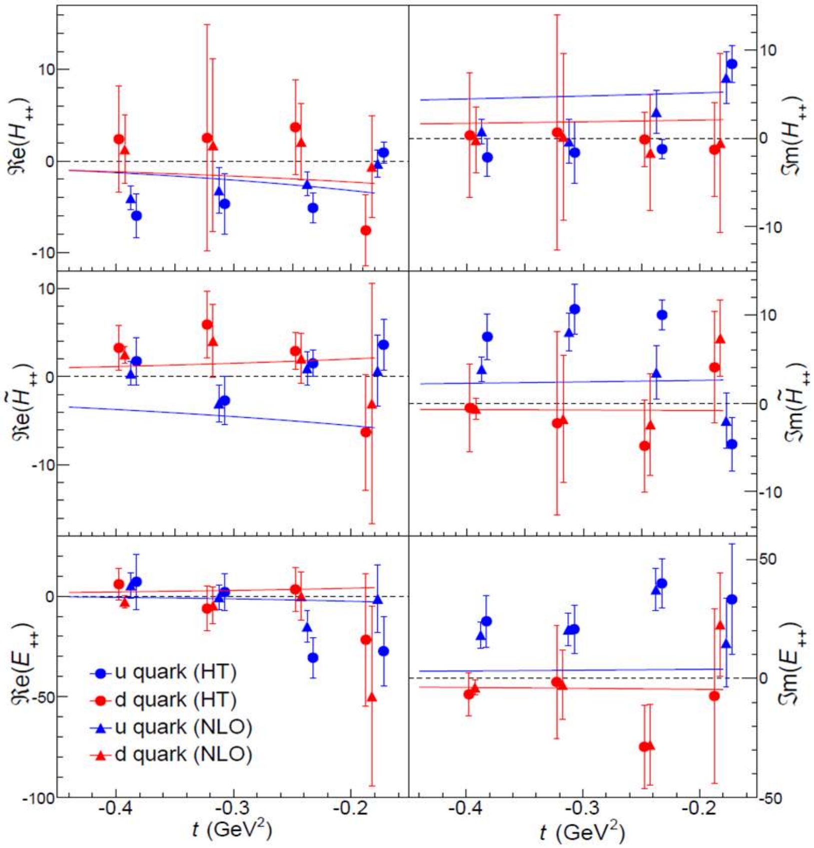
C.M. Camacho

$$D(e,e\,\gamma)X - p(e,e\,\gamma)p = n(e,e\,\gamma)n + d(e,e\,\gamma)d$$

- JLab Hall A experiment E08-025: DVCS off an LD2 target
- Quasi-free *p* events subtracted using normalized LH2 data
- Coherent DVCS off *d* separated using $ed \to e\gamma X$ missing mass



- ➢ 1st observation of DVCS off the neutron
- ➢ Sizeable cross section (significantly larger than BH)



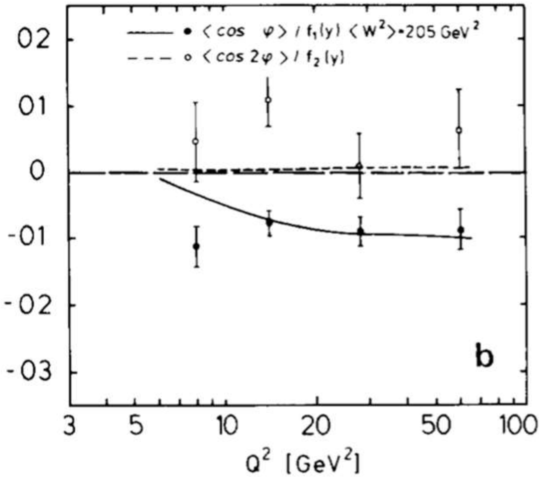
- ➢ Flavor separation of Compton Form Factors by combining proton and neutron DVCS data
- ➢ Uncertainties dominated by correlations originating from the (partial) separation of the coherent *d*-DVCS channel

Nature Physics 16, 191 (2020)

Azimuthal distributions in SIDIS (unpolarized)

$$\frac{d\sigma}{dx_B\, dy\, d\psi\, dz\, d\phi_h\, dP_{h\perp}^2} = \frac{\alpha^2}{x_B y Q^2} \frac{y^2}{2\,(1-\varepsilon)} \left(1+\frac{\gamma^2}{2x_B}\right) \Bigg\{ F_{UU,T} + \varepsilon \overset{\text{H.T.}\downarrow}{F_{UU,L}} + \sqrt{2\,\varepsilon(1+\varepsilon)}\, \cos\phi_h\, \overset{\text{H.T.}\downarrow}{F_{UU}^{\cos\phi_h}} + \varepsilon \cos(2\phi_h)\, F_{UU}^{\cos 2\phi_h} + \lambda_e \sqrt{2\,\varepsilon(1-\varepsilon)}\, \sin\phi_h\, F_{LU}^{\sin\phi_h} \overset{\leftarrow\text{H.T.}}{\Bigg\}},$$

EMC-1983 (PL,v130,118)



Observables: - Azimuthal Moments - Multiplicity

$$\frac{d^4 M^{\pi^\pm}(x,Q^2,z,P_T^2)}{dx\,dQ^2\,dz\,dP_T^2} = \left(\frac{d^4\sigma^{\pi^\pm}}{dx\,dQ^2\,dz\,dP_T^2}\right) / \left(\frac{d^2\sigma^{DIS}}{dx\,dQ^2}\right)$$

$$m^h(x,z,P_T^2,Q^2) = \frac{\pi F_{UU,T}(x,z,P_T^2,Q^2) + \pi\epsilon F_{UU,L}(x,z,P_T^2,Q^2)}{F_T(x,Q^2) + \epsilon F_L(x,Q^2)}$$

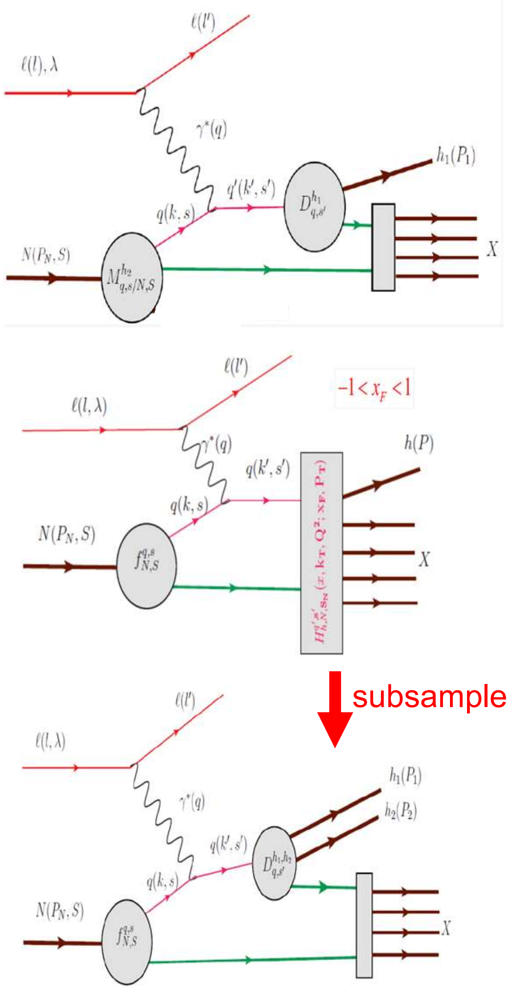
- Quark-gluon correlations are significant in electro production experiments (even if at high energy).
- Large cosϕ modulations observed in electroproduction (EMC, COMPASS, HERMES) may be a key in understanding of the QCD dynamics.

MC simulations: Why LUND works?

- A single-hadron MC with the SIDIS cross-section where widths of k_T-distributions of pions are extracted from the data is not reproducing well the data.
- LUND fragmentation based MCs were successfully used worldwide from JLab to LHC, showing good agreement with data.

So why the LUND-MCs are so successful in description of hard scattering processes, and SIDIS in the first place?

- The hadronization into different hadrons, in particular Vector Mesons is accounted (full kinematics)
- Accessible phase space properly accounted
- The correlations between hadrons, as well a as target and current fragments accounted
- ….



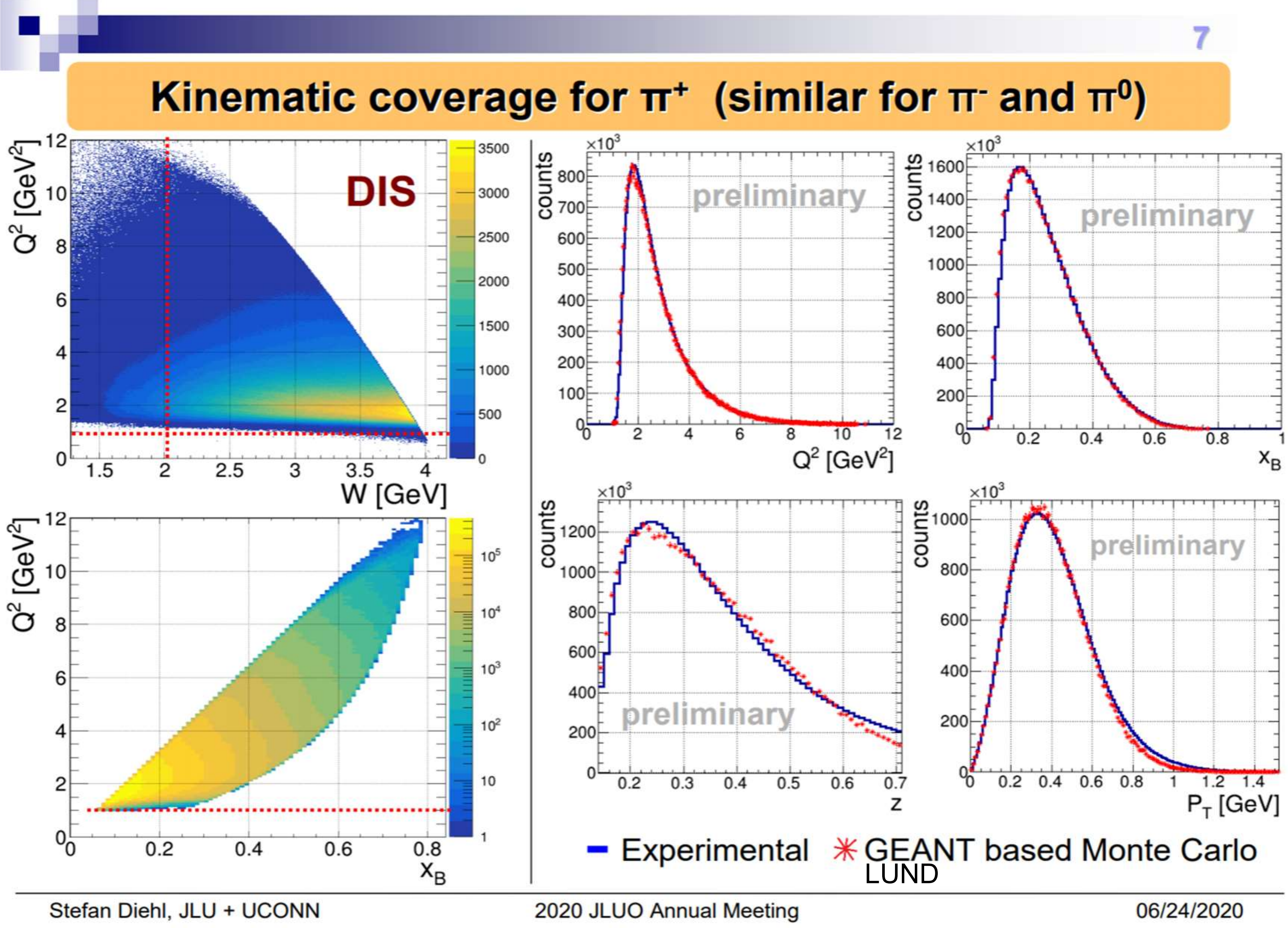
subsample

To understand the measurements we should be able to simulate, at least the basic features we are trying to study (P_T and Q^2,-dependences in particular)

The studies of correlated hadron pairs in SIDIS may be a key for proper interpretation !!!

SIDIS ehX: CLAS12 data

CLAS12 single hadron distributions ep→e'π^+X



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Kinematic coverage for π^+ (similar for π^- and π^0)

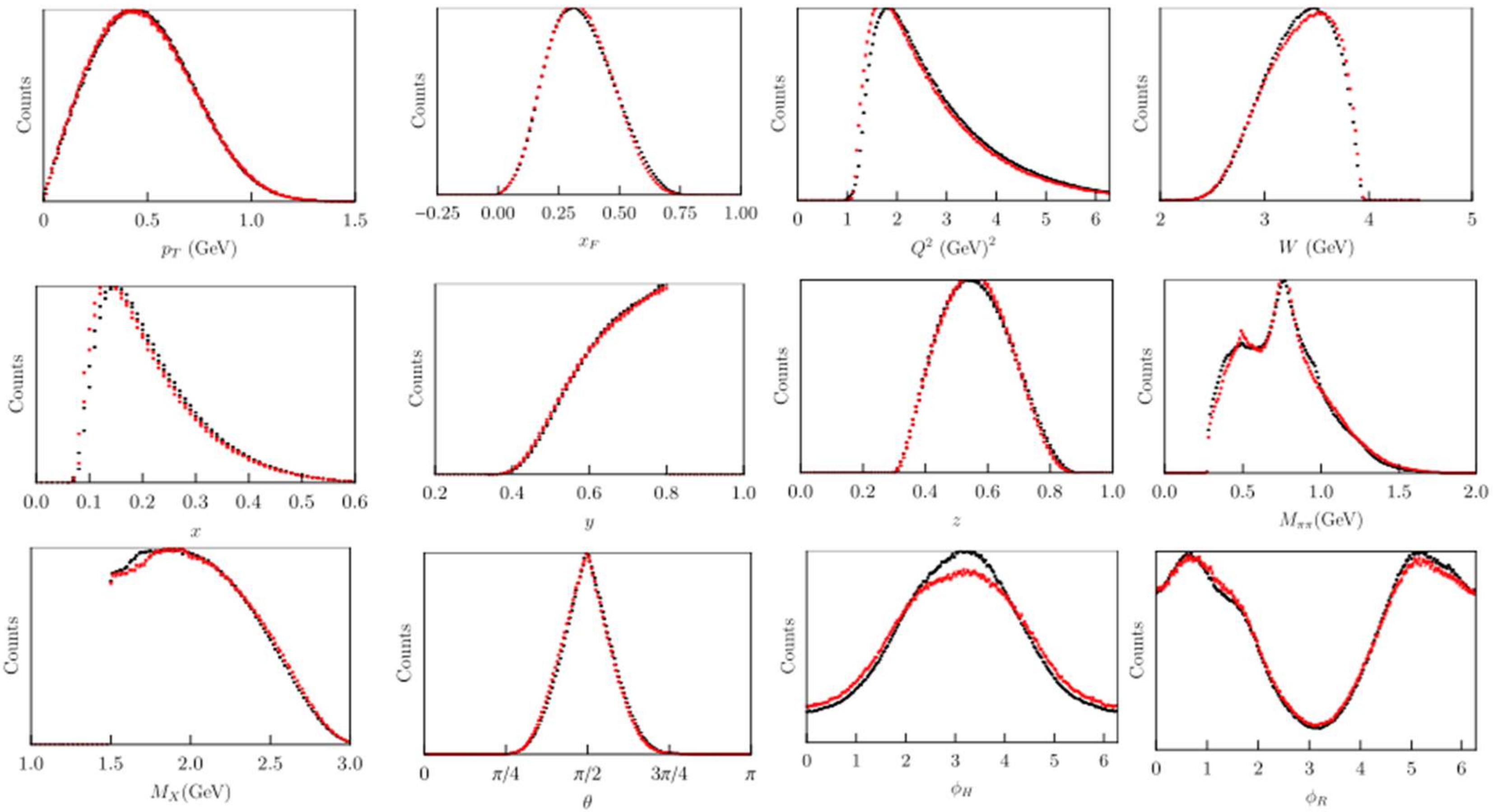
- Experimental ✳ GEANT based Monte Carlo

LUND

Stefan Diehl, JLU + UCONN 2020 JLUO Annual Meeting 06/24/2020

SIDIS ehhX: CLAS12 data vs MC

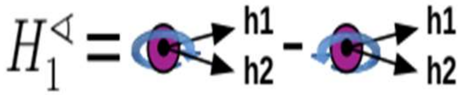
CLAS12 dihadron production ep→ehhX



CLAS12 MC, based on the PEPSI(LEPTO) simulation with most parameters ”default” is in a good agreement with CLAS12 measurements for all relevant distributions

Observation of SSAs in ep→e'$\pi^+\pi^-$X

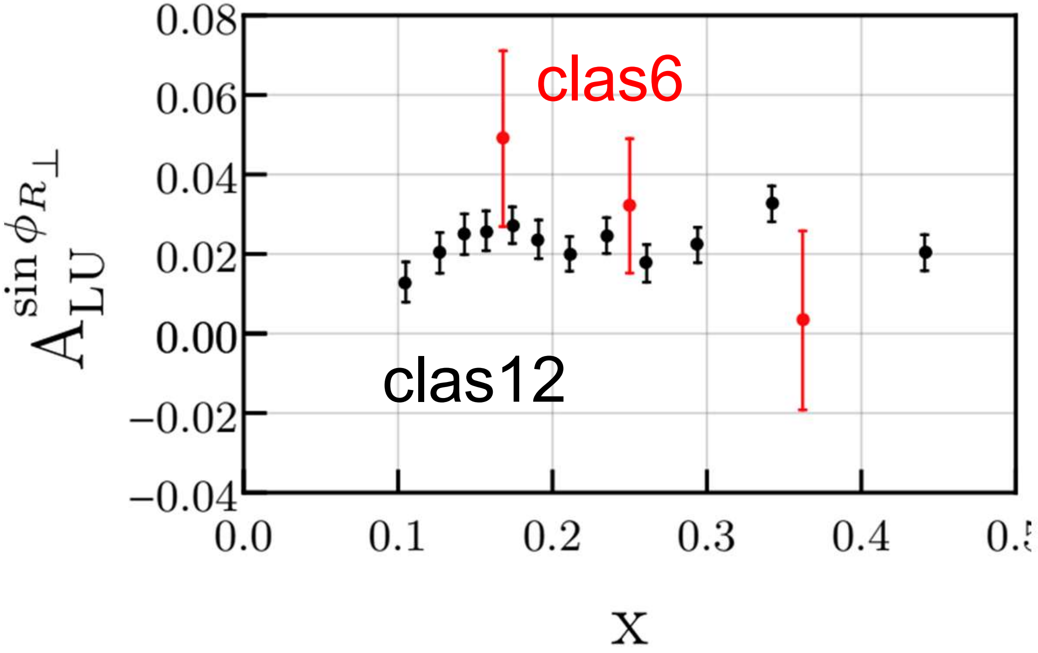
T. Hayward et al. Phys. Rev. Lett. 126, 152501 (2021)

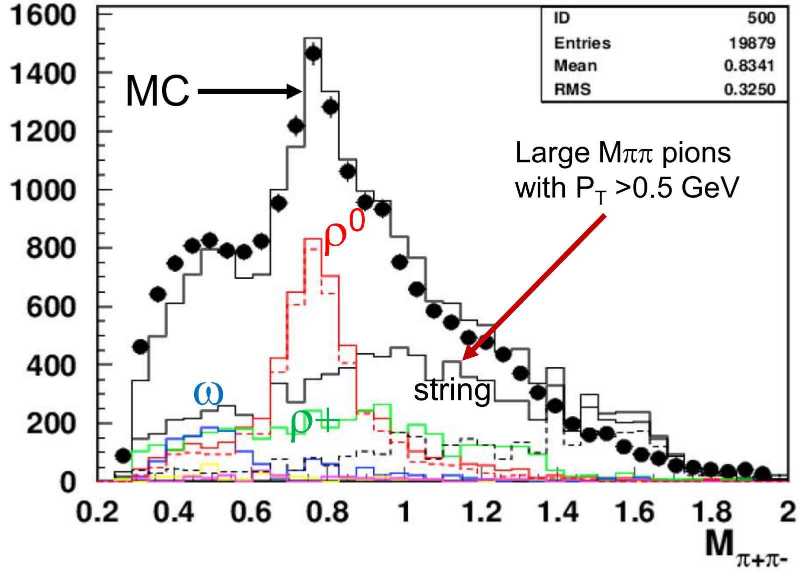


$$d\sigma_{LU} \propto \lambda_e \sin(\phi_{R_\perp})\left(xe(x)H_1^{\sphericalangle}(z,M_h)+\frac{1}{z}f_1(x)\tilde{G}^{\sphericalangle}(z,M_h)\right)$$

Bacchetta&Radici: arXiv:hep-ph/0311173

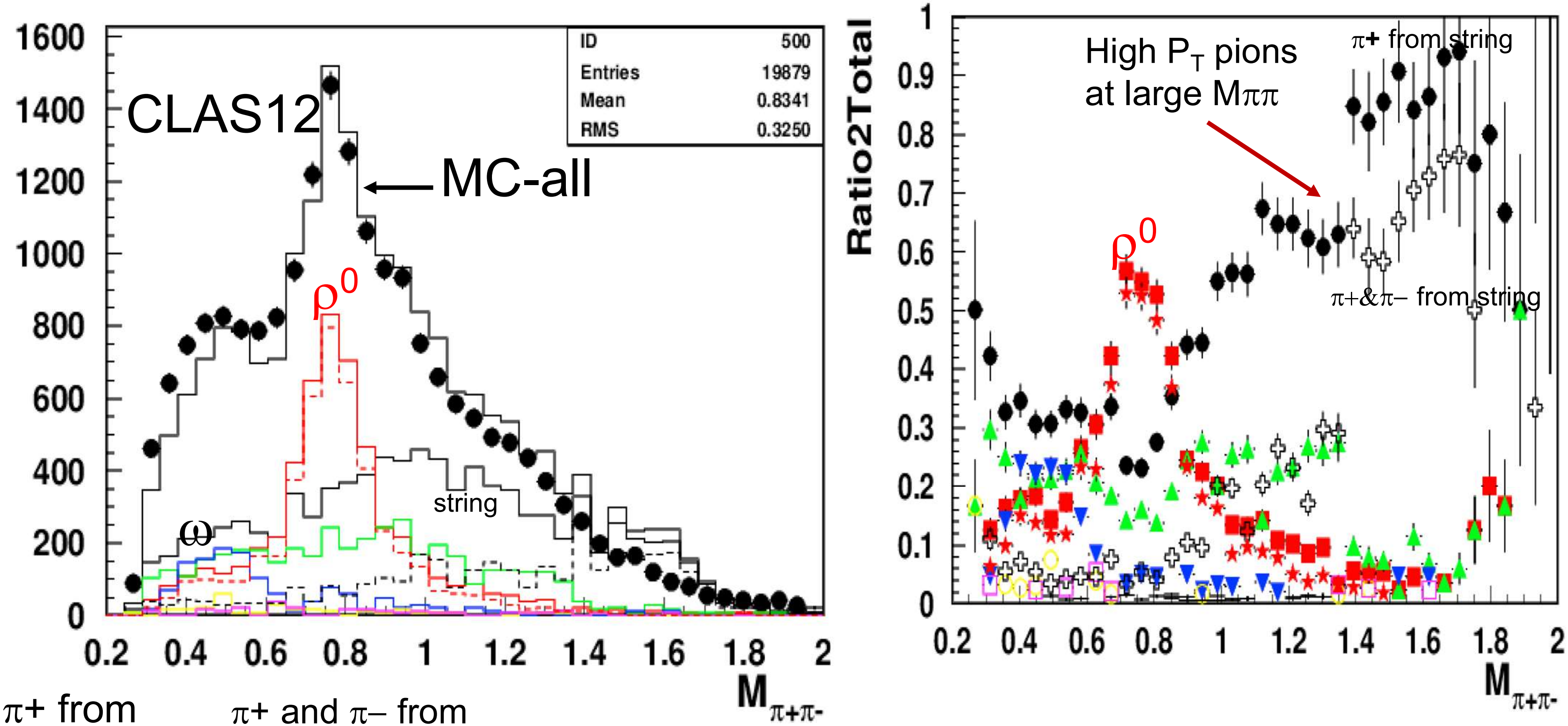
PDF e describes the force on the transversely polarized quark after scattering





- Spin-azimuthal correlations in hadron pair production are very significant
- Hadron pairs in SIDIS (true from JLab to LHC) are dominated by VM decays (therefore single hadron channel too)

Sources of inclusive pions: CLAS12 vs MC



	π+ from	π+ and π– from
ρ0	🟥	----
string	▬	----
ρ+	🟩	
ω	🟦	

- Dominant fraction of inclusive pions come from VM decays
- Relative fraction by default in JETSET ~50%

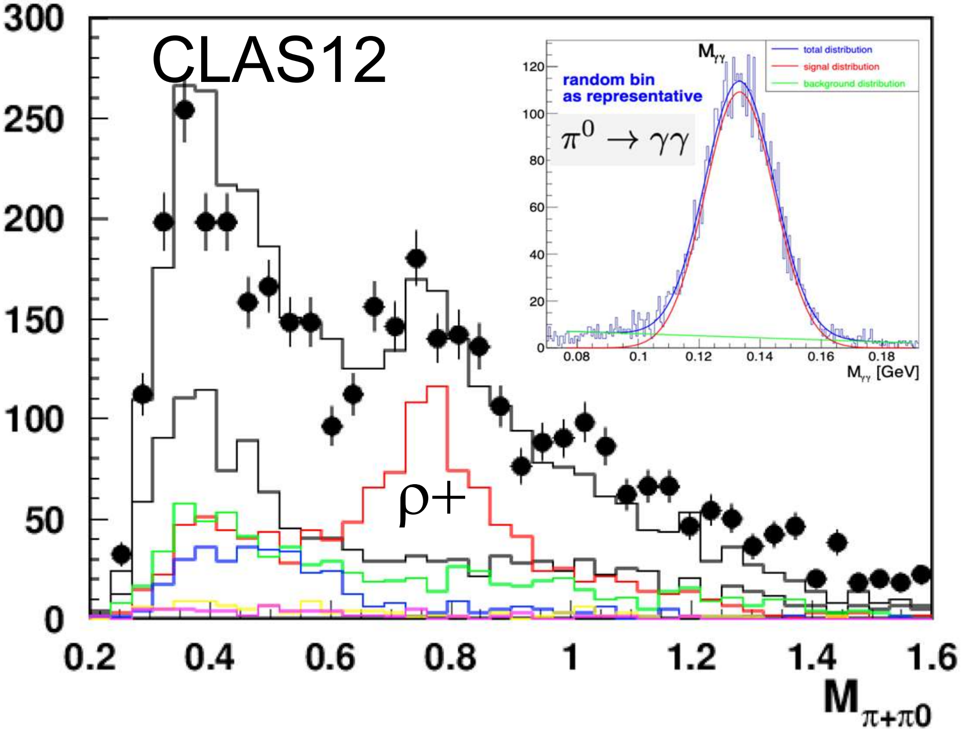
Very important to have multidimensional TMD Fragmentation Functions!

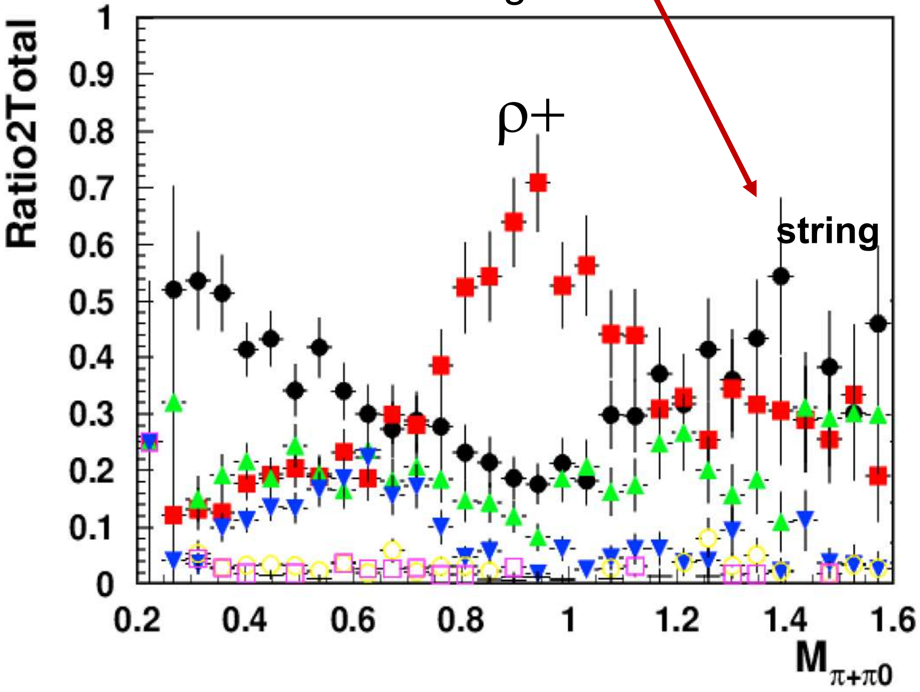
Sources of inclusive pions: CLAS12 vs MC

$\rho^{\pm} \rightarrow \pi^0 + \pi^{\pm}$

Detection of π^0s allows studies of $\rho^{\pm}$

High P_T pions at large $M\pi\pi$





🟥 ρ+
⬛ string
🟩 ρ0
🟦 ω

Dominant fraction of inclusive pions come from VM decays

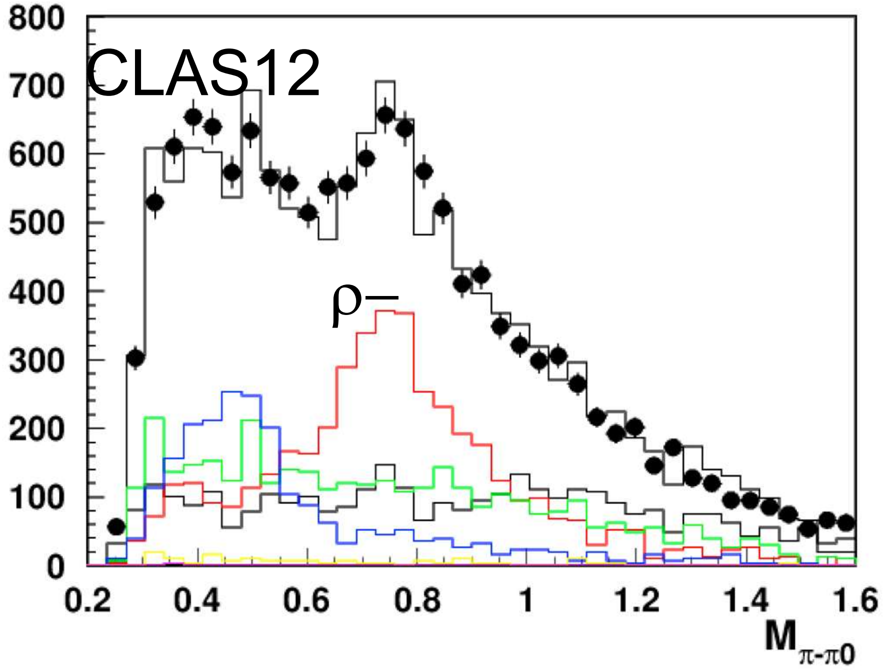
CLAS12 due to unique capability for precision measurements of neutral pions, will provide measurements of multiplicities of variety of semi-inclusive and exclusive hadron pairs (could be also VMs).

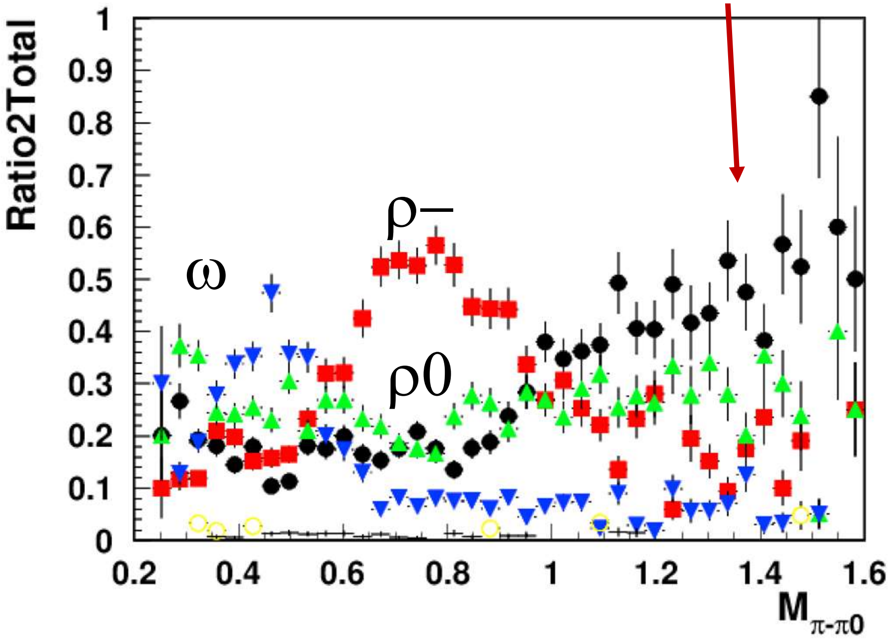
Sources of inclusive pions: CLAS12 vs MC

$\rho^{\pm} \to \pi^{0} + \pi^{\pm}$

Detection of π^0s allows studies of $\rho^{\pm}$

High P_T pions at large $M\pi\pi$





π– from:

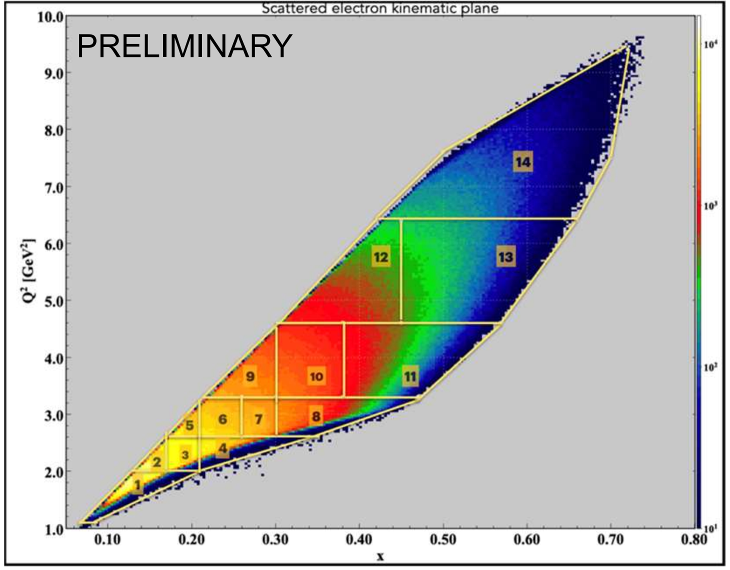
- 🟥 ρ–
- ⬛ string
- 🟩 ρ0
- 🟦 ω

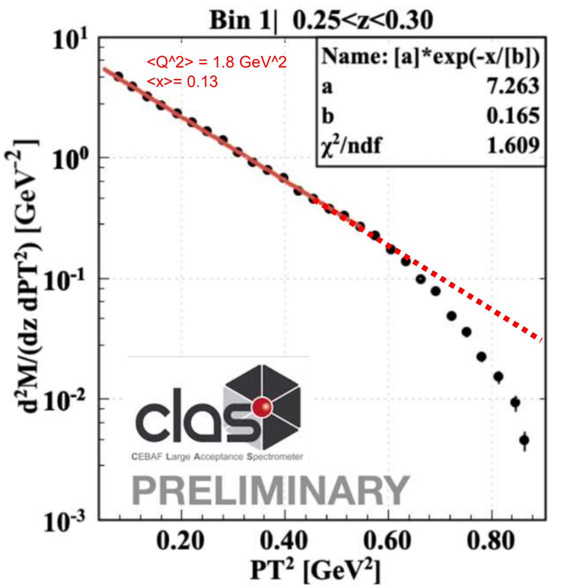
Dominant fraction of inclusive pions come from VM decays

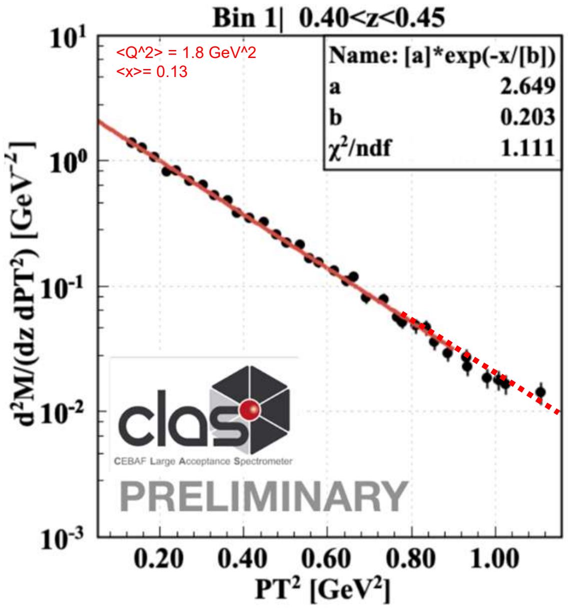
Precision measurements of all combination of pion pairs is crucial for separation of multiplicities of different vector mesons

CLAS12 1h Multiplicities: high P_T & phase space

G.Angelini (Sardinia 2021)

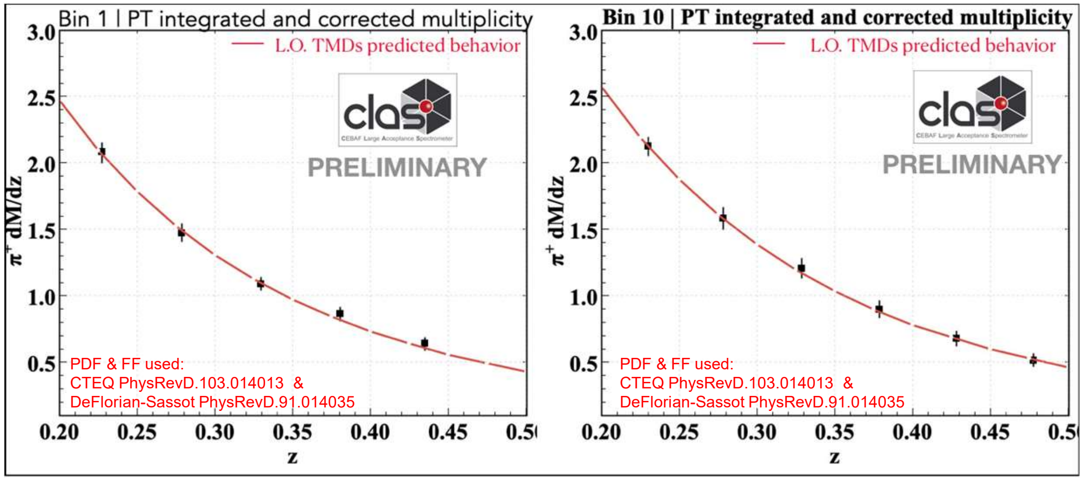






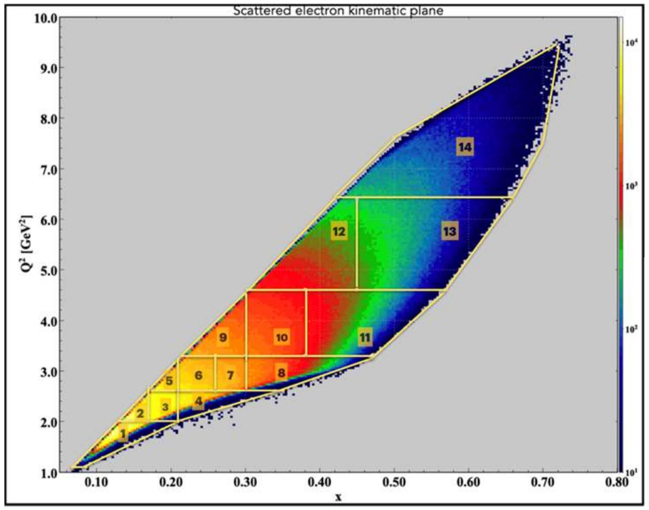
For some kinematic regions, at low z, the high P_T distribution appear suppressed: there is no enough energy in the system to produce hadron with high transverse momentum (phase space effect).

If the effect is accounted, the CLAS data follows global fits.

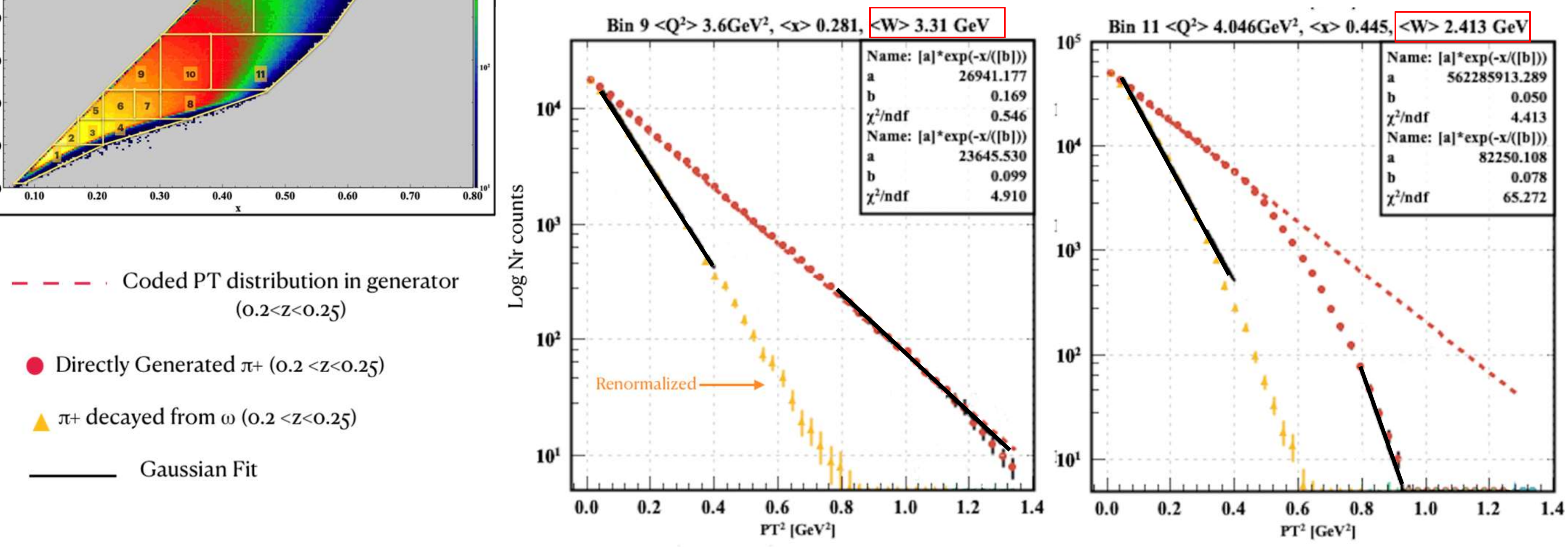


CLAS12 1h Multiplicities: high P_T & phase space

G.Angelini (Sardinia 2021)



We binned the MC Phase space as for the CLAS12 multiplicity analysis, we used a single hadron generator with PDFs, FFs, and Gaussian Ansatz for transverse momentum and looked at the produced distribution.



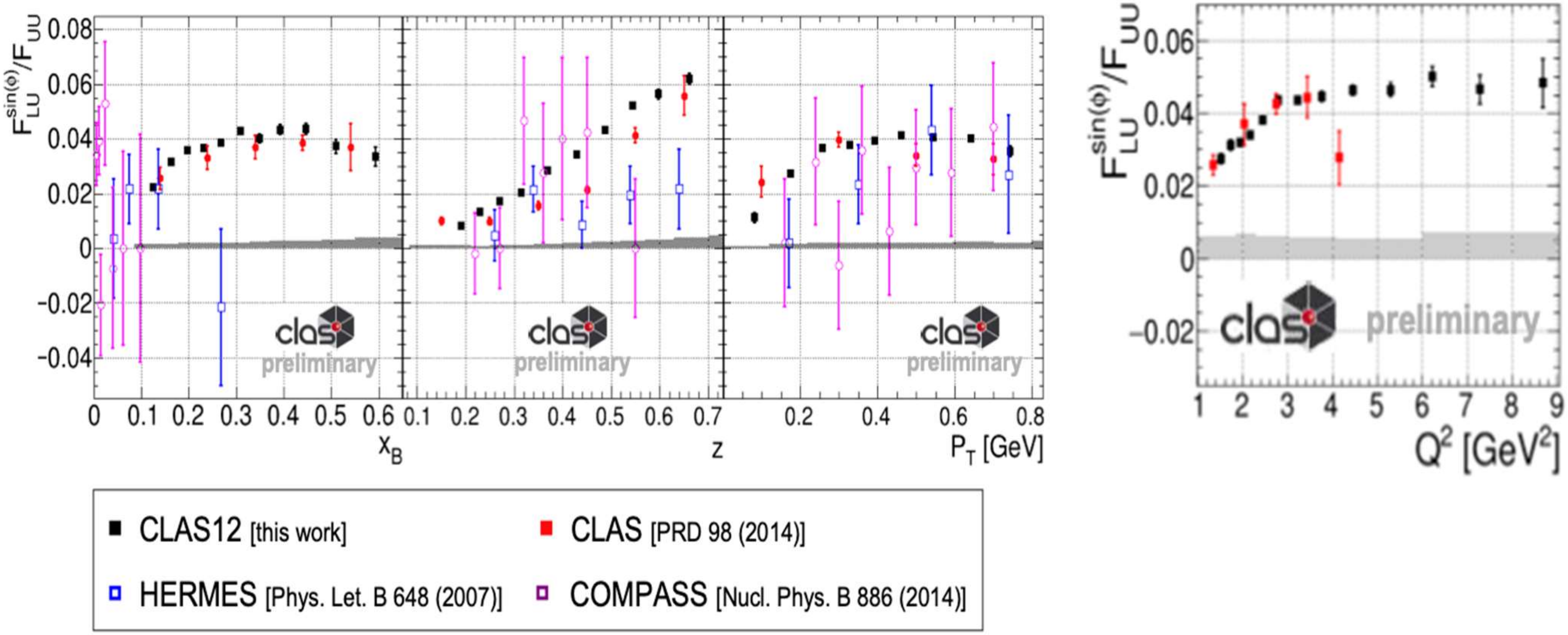
- Phase space limitations for direct pion production more significant at low W, and low z
- Decayed pions have a much steeper P_T distribution at the same z

SSA from CLAS12

S. Diehl et al (in publication) arXiv:2101.03544

$$BSA_i = \frac{1}{P_e} \cdot \frac{N_i^+ - N_i^-}{N_i^+ + N_i^-}$$

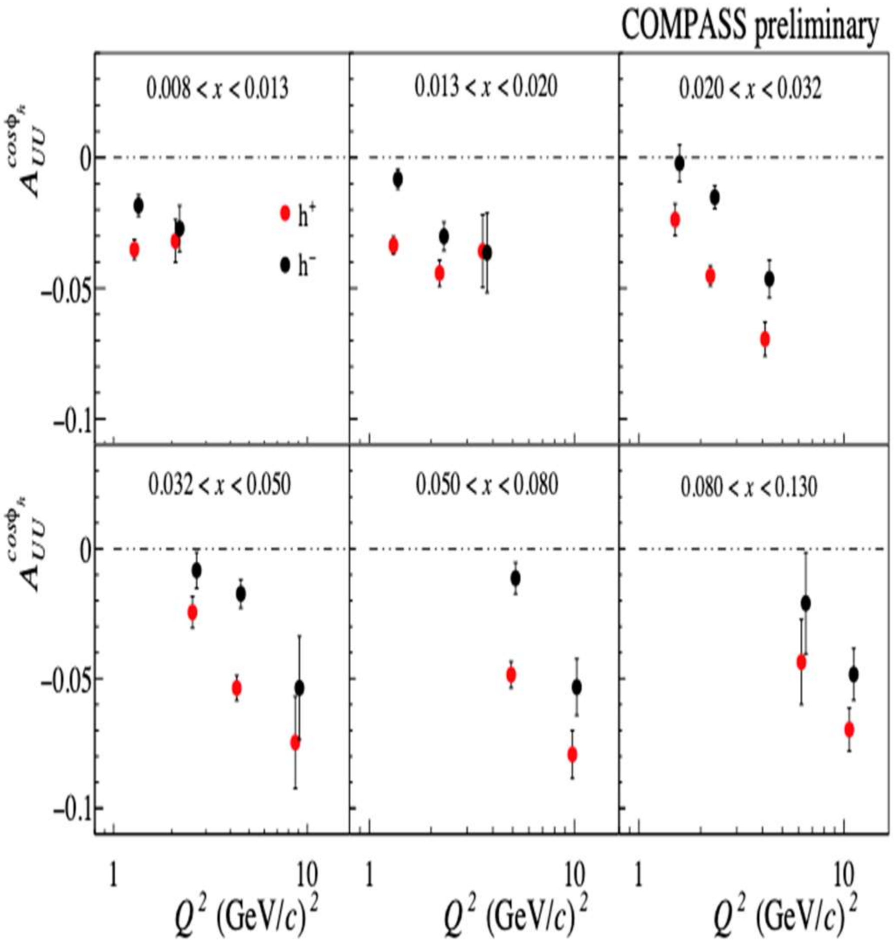
$$\langle \sin\phi \rangle \propto F_{LU}^{\sin\phi} / F_{UU} \propto 1/Q$$



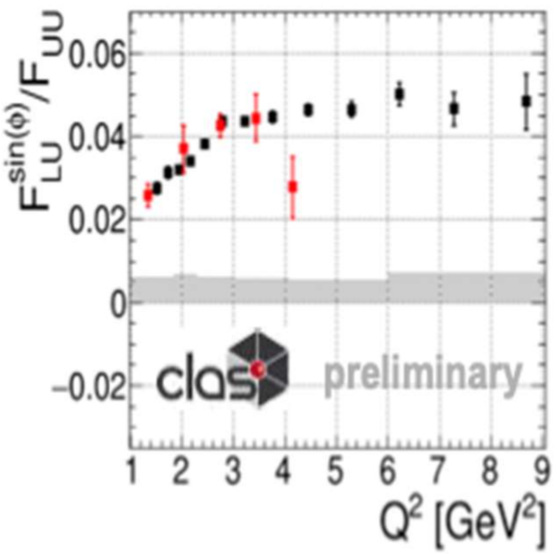
- Superior statistics in large x-region most relevant for spin-orbit correlation studies
- Unexpected Q^2-dependence is under study in fine multidimensional bins x,z,P_T

Large HT azimuthal moments from COMPASS and CLAS

A. Moretti: https://arxiv.org/pdf/2107.10740.pdf



CLAS12

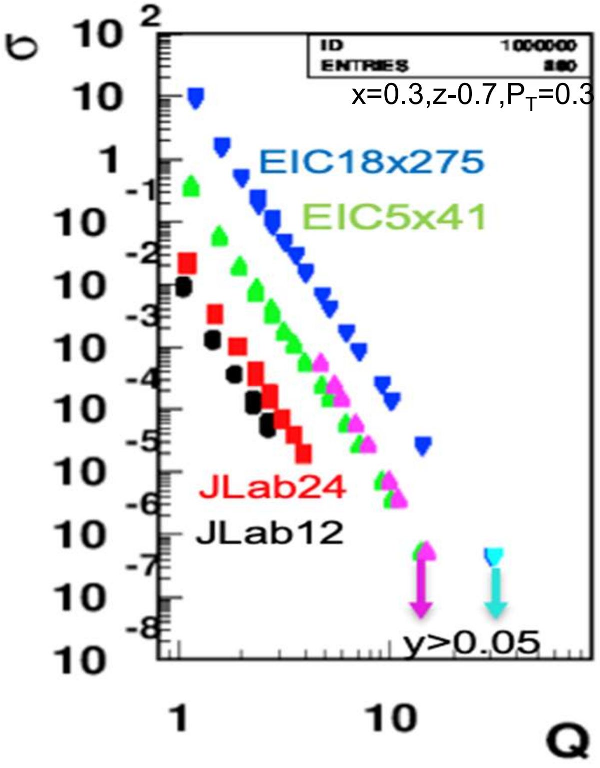


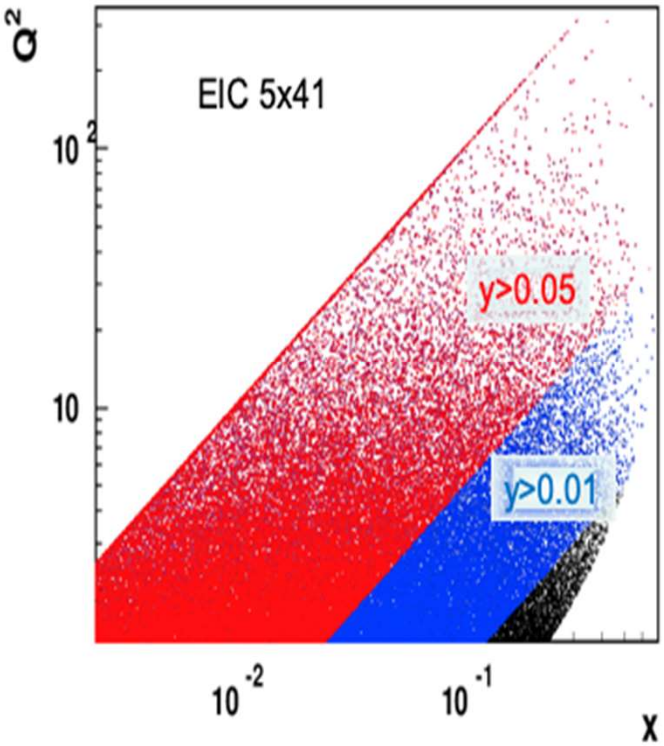
J. Aubert *et al.*, "Measurement of Hadronic Azimuthal Distributions in Deep Inelastic Muon Proton Scattering," *Phys. Lett. B*, vol. 130, pp. 118–122, 1983.

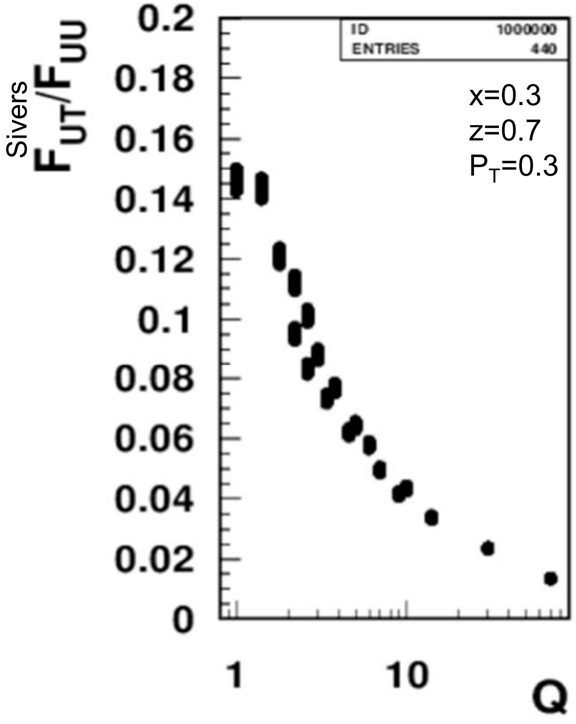
A. Konig and P. Kroll, "A Realistic Calculation of the Azimuthal Asymmetry in Semi-inclusive Deep Inelastic Scattering," *Z. Phys. C*, vol. 16, p. 89, 1982.

Higher twist moments do not really follow the expected Q^2-behavoir

From JLab to EIC: complementarity





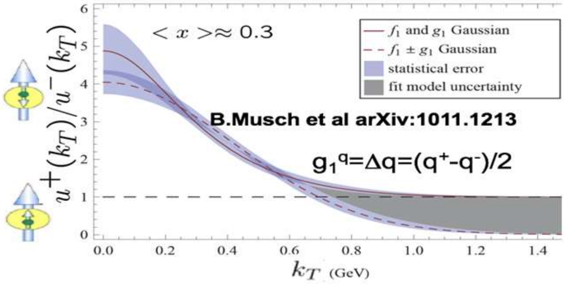


- Understanding of Q^2-dependence of multiplicities crucial for interpretation
- Proper evaluation of systematics, will require definition of fiducial kinematics
- JLab at 24 GeV will provide critical input in evolution studies of TMDs
- Higher Q^2-coverage of “Low s” EIC running will provide validation of evolution studies at JLab at large x

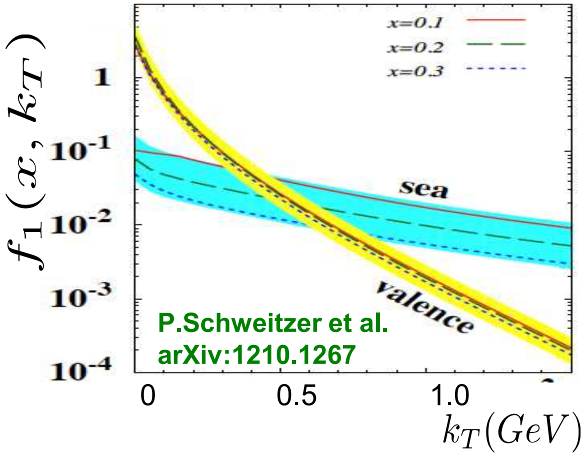
Extending to small x, large Q2 and large P_T

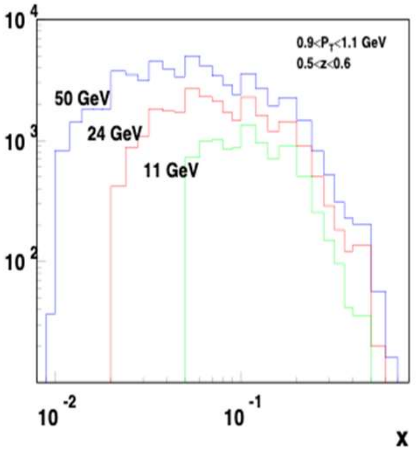
Non-perturbative sea (“tornado”) in nucleon is a key to understand the nucleon structure

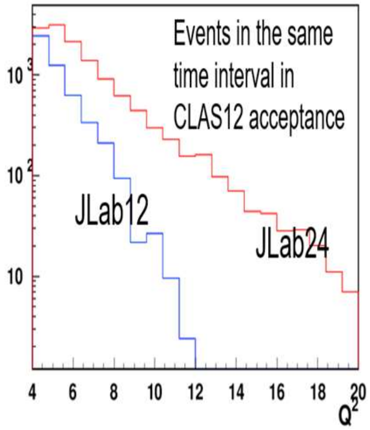
$\bar{d} > \bar{u}$

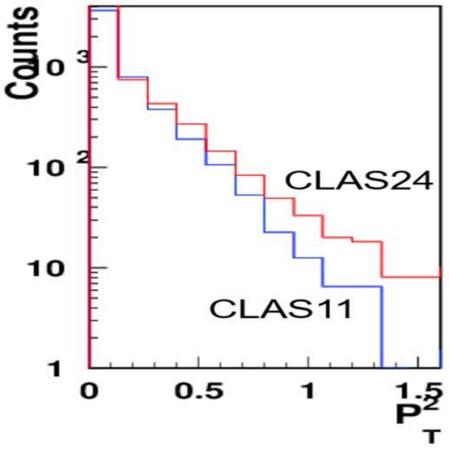


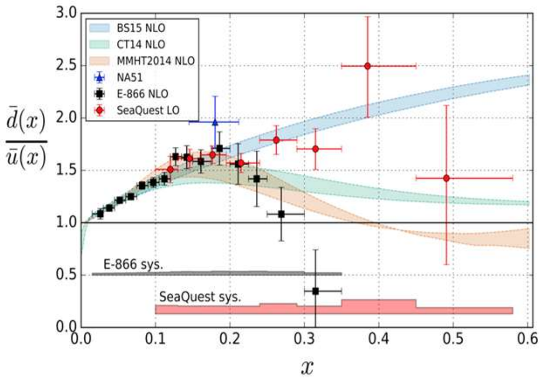
- Spin and momentum of struck quarks are correlated with remnant
- Correlations of spins of q-q-bar with valence quark spin and transverse momentum will lead to observable effects
- Spin-Orbit correlations so far were shown (measurements and model calculations) to be significant in the region where non-perturbative effects dominate











Upgrade to 24 GeV will qualitatively increase the JLab phase space, opening access to large P_T, high Q^2 and low x (sea) region

Summary

Measurements of dihadron multiplicities and asymmetries provide qualitatively new possibilities for understanding the structure of the nucleon and the process of hadronization, allowing experimental studies of the fractions and distributions of pions coming from vector meson decays. CLAS12 provides high statistical multidimensional measurements.

Extraction of multiplicities and spin-azimuthal asymmetries in multidimensional space is critical for interpretation of results and understanding of the systematics of GPD and TMD extractions

The extraction of universal 3D PDFs requires a clear understanding of the Q^2-dependence of observables, and separation of higher twists

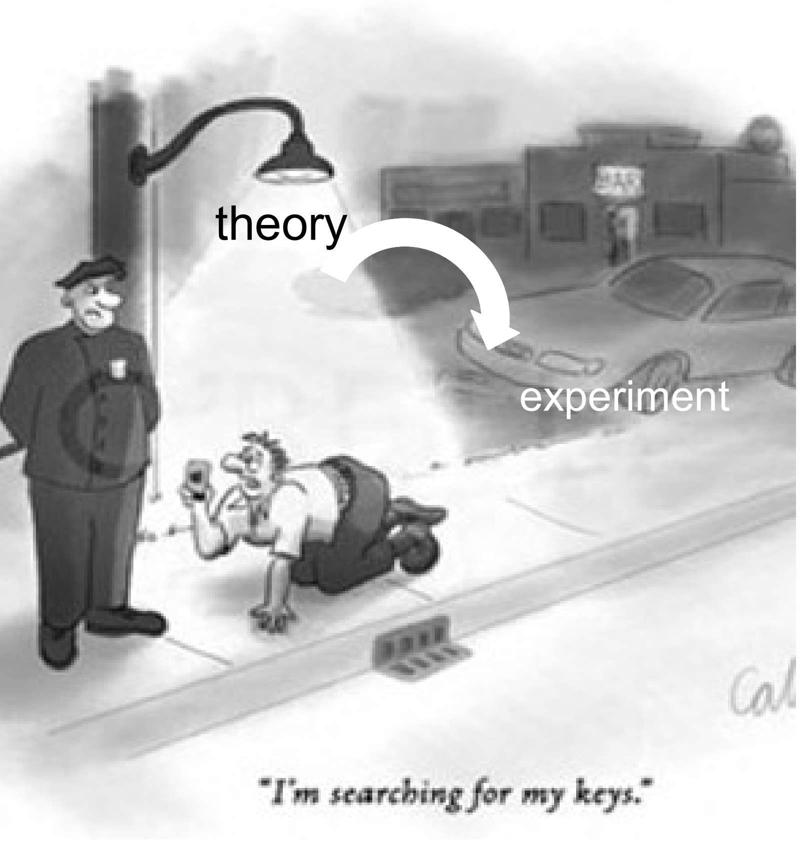
Understanding contributions from VM (with stronger phase space dependence) will be important to understand the systematics of TMD extraction and maybe provide a possible explanation for the single hadron P_T distribution.

Upgrade to 24 GeV will qualitatively increase the JLab phase space, opening access to large P_T, high Q^2 and low x (sea) region

Support slides

Nucleon structure, TMDs and SSAs

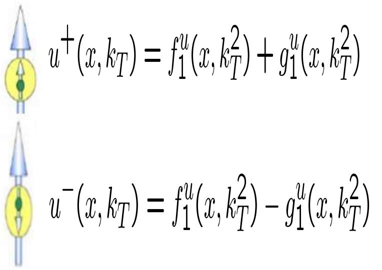
- Large effects observed at relatively large x, relatively large P_T and relatively low Q^2
- Theoretical framework works better, and is “trustworthy” at higher Q^2 and lower P_T
- TMD Fragmentation functions poorly known and understood, systematics not controlled well
- Higher twist SSAs are significant, indicating strong quark-gluon correlations, issues theory has, may become a key to resolve the problems
- Real experiments have “phase space limitations” due to finite energies, introducing correlations between kinematical variables
- Impact of radiative corrections with full account of azimuthal moments in the polarized x-sections still in development



The main goal of SIDIS measurements is the study of non-perturbative QCD (or find a corner of kinematics where the current “TMD theory” works?) , through spin-orbit correlations, where they are significant enough to be measurable

Understanding of the limitations of the current TMD framework with all its assumptions and approximations, is important for predictions, and projections for future experiments

Unknown “known” f_1,g_1 TMDs

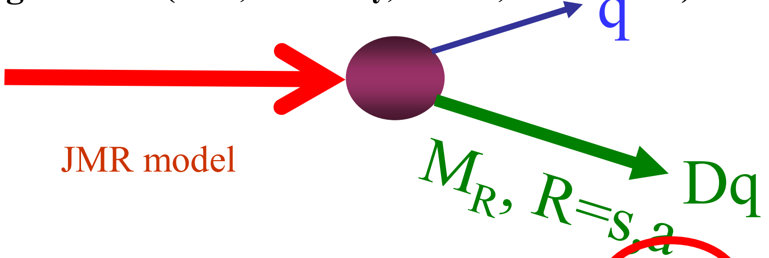


$u^+(x,k_T) = f_1^u(x,k_T^2) + g_1^u(x,k_T^2)$

$u^-(x,k_T) = f_1^u(x,k_T^2) - g_1^u(x,k_T^2)$

	U	L	T
U	f_1		$h_1^\perp$
L		g_{1L}	$h_{1L}^\perp$
T	$f_{1T}^\perp$	g_{1T}	$h_1, h_{1T}^\perp$

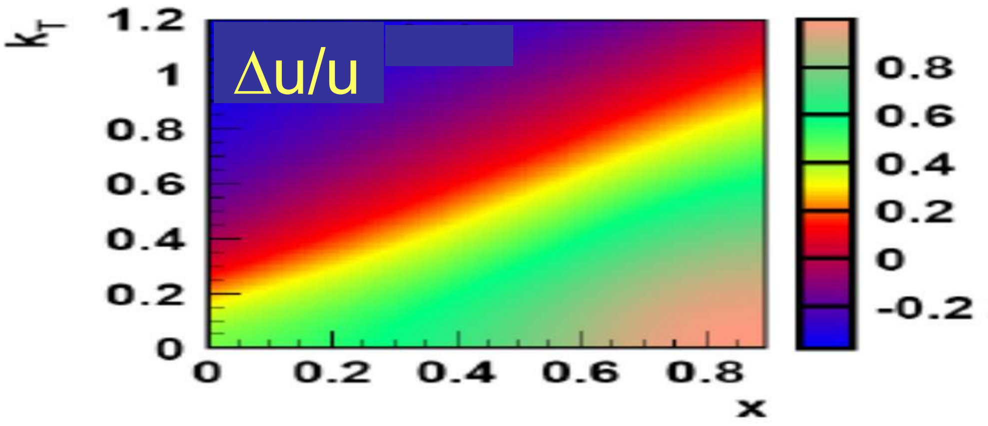
Effect of the orbital motion on the q- may be significant (H.A.,S.Brodsky, A.Deur, F.Yuan 2007)

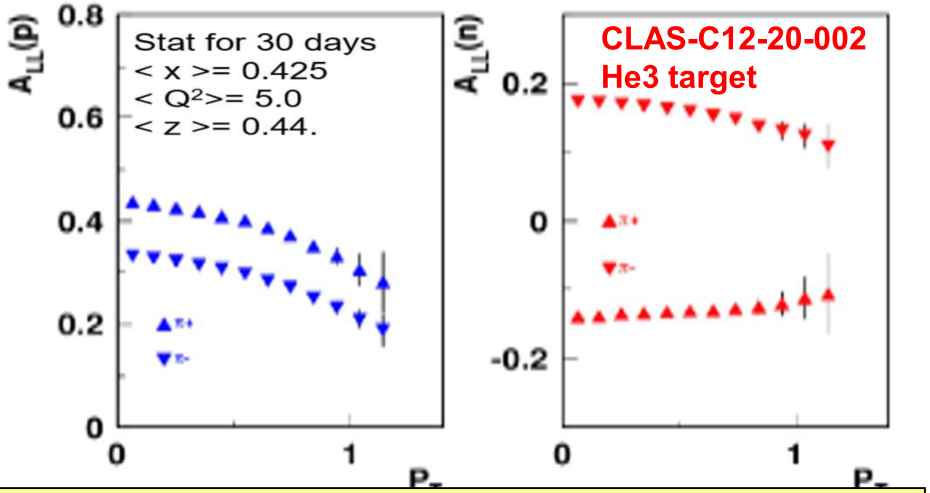


$$f_1(x,\mathbf{k}_T^2) = A\frac{(xM+m)^2\boxed{+\mathbf{k}_T^2}}{(\mathbf{k}_T^2+\lambda_R^2)^{2\alpha}},$$

$$g_1(x,\mathbf{k}_T^2) = A\frac{(xM+m)^2\boxed{-\mathbf{k}_T^2}}{(\mathbf{k}_T^2+\lambda_R^2)^{2\alpha}},$$

(dipole formfactor), J.Ellis, D-S.Hwang, A.Kotzinian





Stat for 30 days
< x >= 0.425
< Q²>= 5.0
< z >= 0.44.

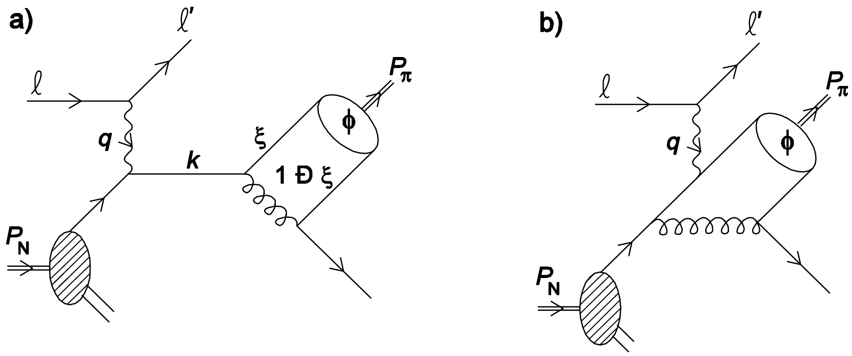
CLAS-C12-20-002
He3 target

Models and lattice predict very significant spin and flavor dependence for TMDs
Large transverse momenta are crucial to access the large k_T of quarks
A dedicated to g1(x,k_T)-studies CLAS12 proposal with He3 target approved by PAC

Azimuthal Asymmetries in semi-exclusive limit

•*Phys.Lett.B* 347 (1995) 413-418

- Higher twists (Berger 1980, Brandenburg et al 1995) z→1 dominant contribution u+e- →e- π+ d



$$H_1 \;=\; \mathcal{N}\,\frac{1}{2x_B}\left([I_2(z,p_T/Q)]^2 \;+\; \frac{p_T^4}{Q^4}[I_1(z,p_T/Q)]^2\right),$$

$$H_2 \;=\; \mathcal{N}\left([I_2(z,p_T/Q)]^2 \;+\; 4\frac{p_T^2}{Q^2}z^2[I_1(z,p_T/Q)]^2 \;+\; \frac{p_T^4}{Q^4}[I_1(z,p_T/Q)]^2\right)$$

$$I_1(z,p_T/Q) \;=\; z\int_0^1 d\xi\,\frac{\phi(\xi)}{z \;-\; \xi(z^2-p_T^2/Q^2)};$$

$$I_2(z,p_T/Q) \;=\; \int_0^1 d\xi\,\frac{\phi(\xi)}{1-\xi} \;-\; z^2 I_1(z,p_T/Q)$$

$$\frac{Q^2\,d\sigma}{dx_B dy dz dp_T^2 d\varphi} \;=\; \frac{4\pi\alpha^2 ME}{Q^2}\Bigg(x_B y^2\;H_1 \;+\; (1-y)\;H_2$$

$$+\;\frac{p_T}{Q}(2-y)\sqrt{1-y}\;H_3\;\cos\varphi \;+\; \frac{p_T^2}{Q^2}(1-y)\;H_4\;\cos 2\varphi\Bigg)$$

Significant contributions at large z and P_T also for H_1/F_{UU}

$$F_{UU,T} = 2xH_1$$

Multiplicities of hadrons in SIDIS

Gaussian Ansatz $\boxed{f_1^q} \otimes \boxed{D_1^{q\to h}} = x f_1^q(x)\, D_1^{q\to h}(z) \frac{e^{-P_{hT}^2/<P_{hT}^2>}}{\pi < P_{hT}^2 >}$

TMDs universal, so what is the origin of the differences observed ?

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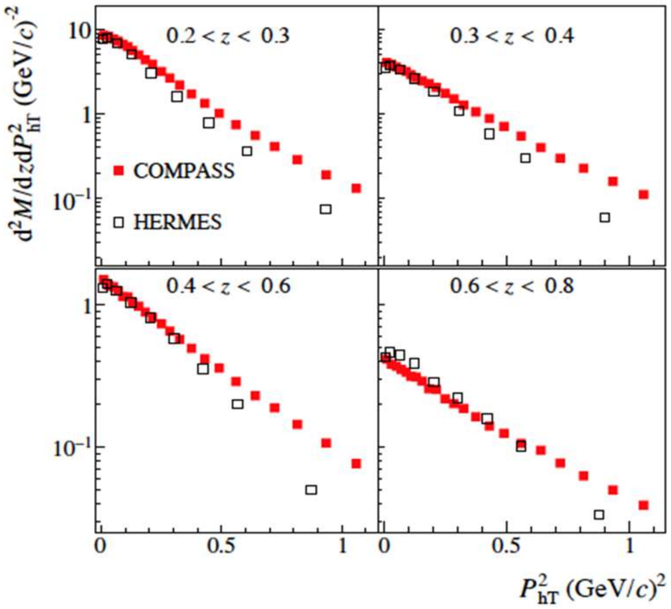
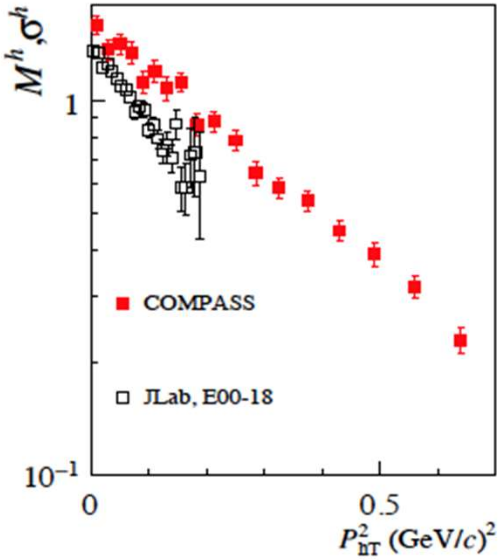
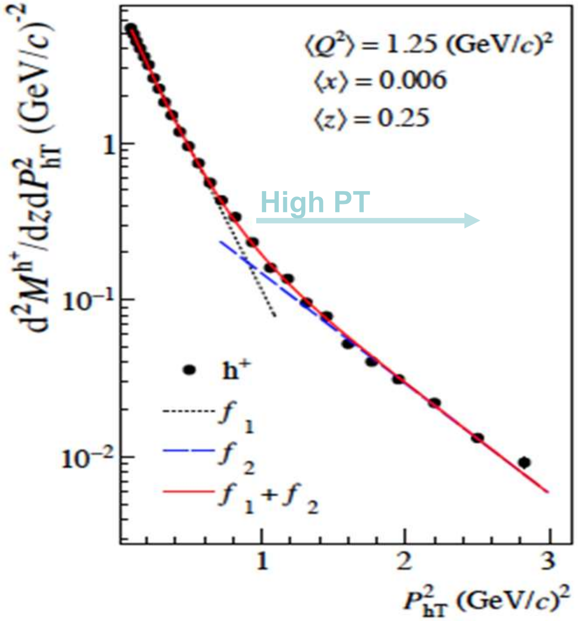






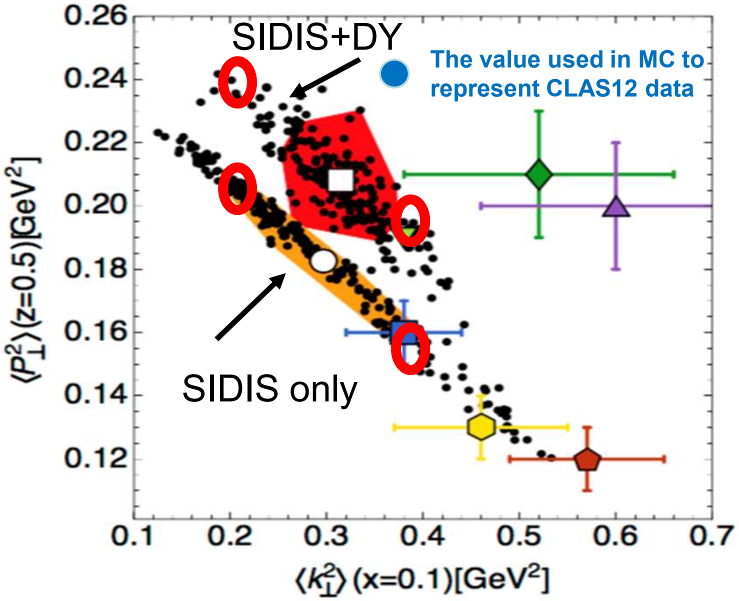
- TMDs evolution makes distribution wider
- Lower the beam energy, less phase space for high P_T

- What is the origin of the “high” PT tail?
  1) Perturbative contributions?
  2) Non perturbative contributions? (TMDs dependence not 1 Gaussian)

Extracting the average transverse momenta

Andrea Signori,[1,*] Alessandro Bacchetta,[2,3,†] Marco Radici,[3,‡] and Gunar Schnell[4,5,§] 10.1007/JHEP11(2013)194

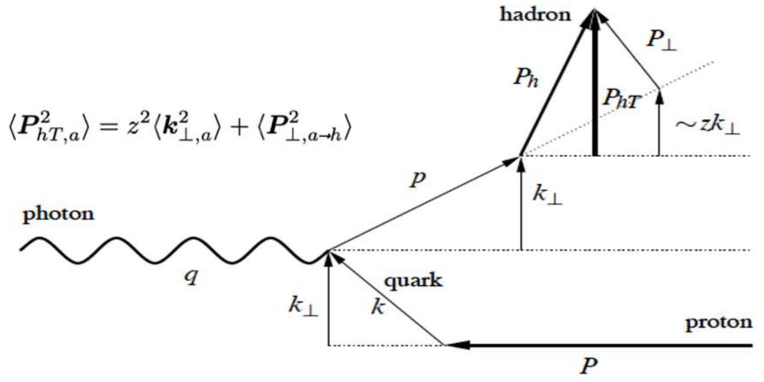
$$F^{h}_{UU,T}(x,z,P_{hT}^2,Q^2) = \sum_a \mathcal{H}^a_{UU,T}(Q^2;\mu^2) \int dk_\perp\, dP_\perp\, f_1^a(x,k_\perp^2;\mu^2)\, D_1^{a\to h}(z,P_\perp^2;\mu^2)\, \delta(zk_\perp - P_{hT} + P_\perp)$$
$$+ Y_{UU,T}(Q^2,P_{hT}^2) + \mathcal{O}(M/Q)\,.$$



SIDIS+DY

● The value used in MC to represent CLAS12 data

SIDIS only



$$\langle \boldsymbol{P}_{hT,a}^2\rangle = z^2\langle \boldsymbol{k}_{\perp,a}^2\rangle + \langle \boldsymbol{P}_{\perp,a\to h}^2\rangle$$

- Extraction very sensitive to input (replicas)
- Most sensitive to parameters is the large P_T
- Why DY gives higher values
- Why the large P_T are not described
- How to reconcile data with 1pion MC?

$$m_N^h(x,z,\boldsymbol{P}_{hT}^2) = \frac{\pi}{\sum_a e_a^2\, f_1^a(x)}$$
$$\times \sum_a e_a^2\, f_1^a(x)\, D_1^{a\to h}(z)\, \frac{e^{-\boldsymbol{P}_{hT}^2/\left(z^2\langle \boldsymbol{k}_{\perp,a}^2\rangle + \langle \boldsymbol{P}_{\perp,a\to h}^2\rangle\right)}}{\pi\left(z^2\langle \boldsymbol{k}_{\perp,a}^2\rangle + \langle \boldsymbol{P}_{\perp,a\to h}^2\rangle\right)}$$

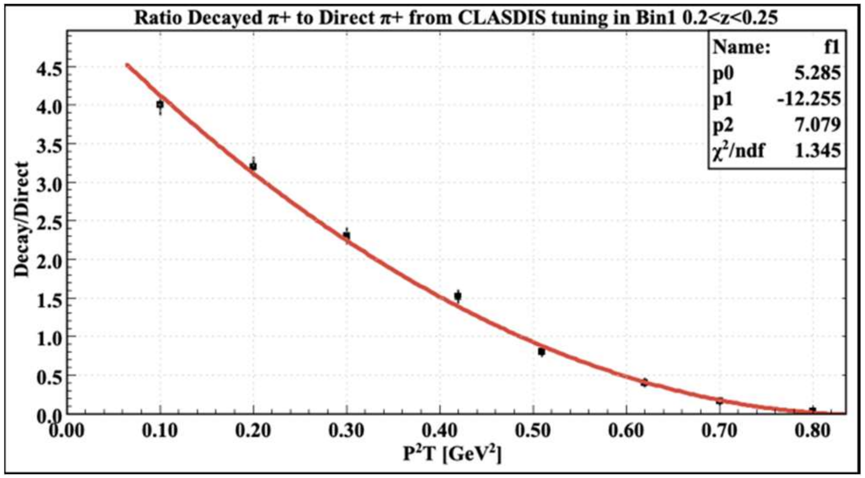
Sea is not divided to perturbative and non-perturbative

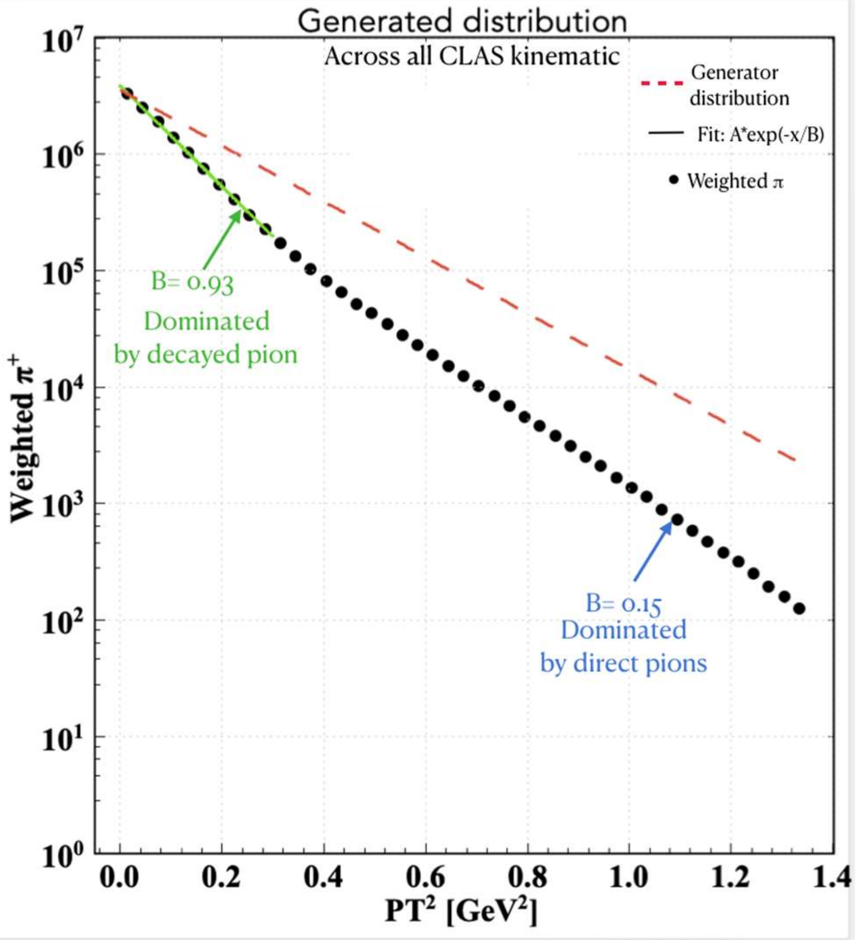
- Theory: FFs include all possible sources of a given hadron, including fragmentation and diffractive VMs!
- How do we get the TMD FFs and what are their $P^\perp$ and Q^2 dependence?

CLAS12 high P_T : impact of vector mesons

G.Angelini (Sardinia 2021)

We consider the ratio of Decayed to Direct pions from the LEPTO MC (that well describes our data) and reweighted the distribution of pions accordingly.





By combining the directly produced pions and the decayed pions, two Gaussian slopes are effectively generated even if we started with one single gaussian