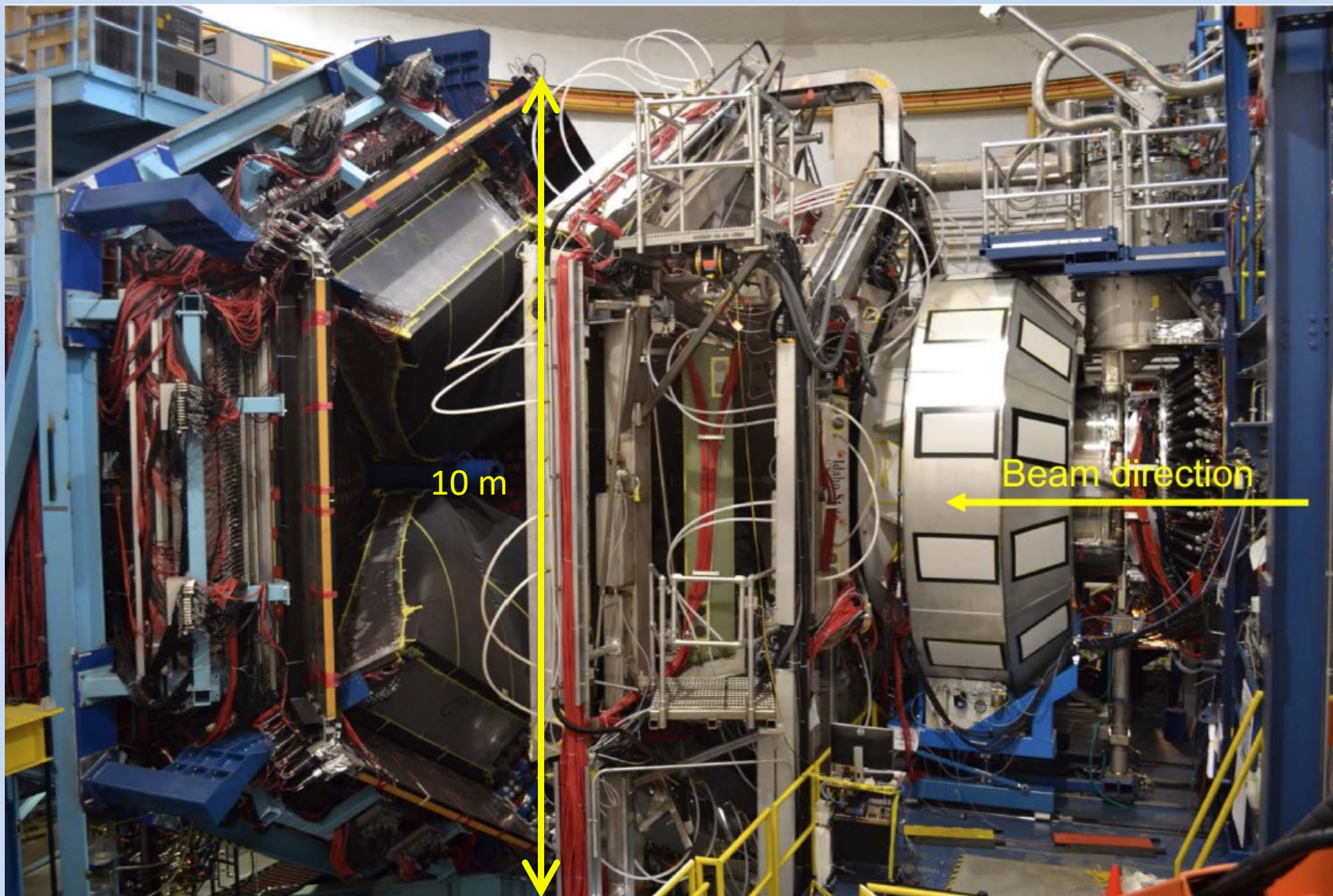


TMD Studies at CLAS12

Marco Contalbrigo – INFN Ferrara

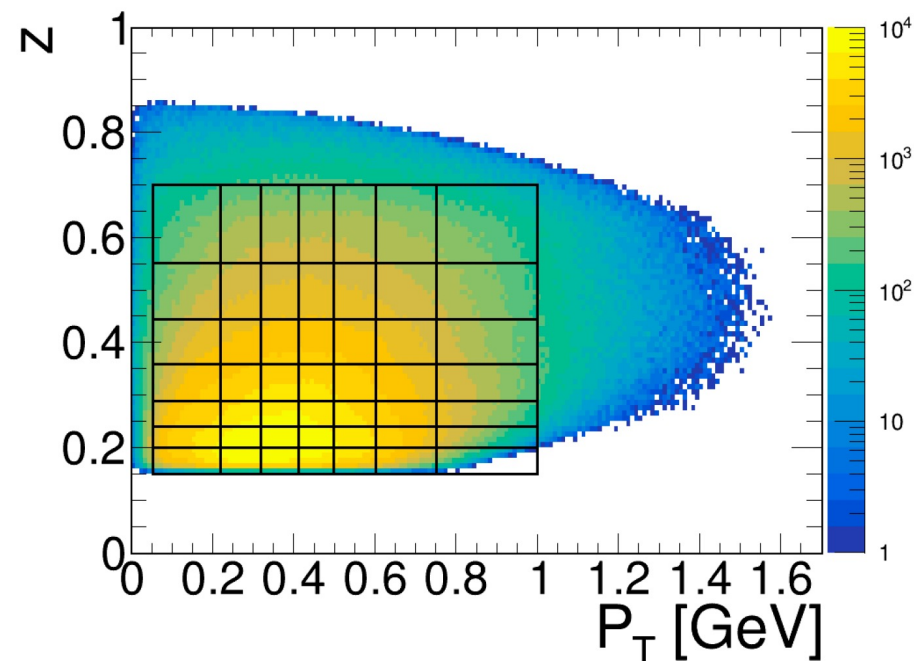
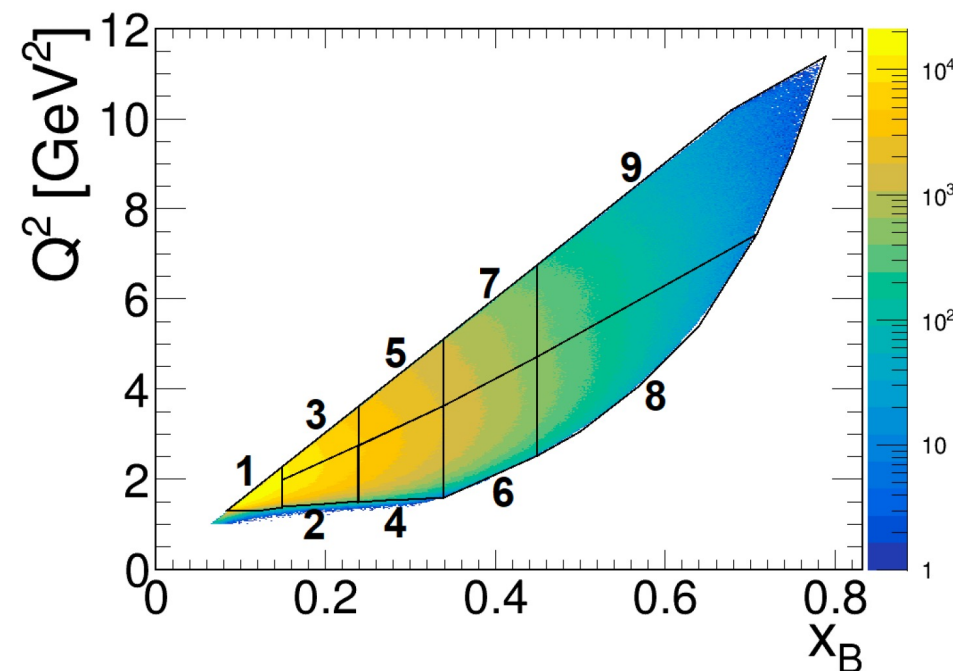
TMDs Studies: from JLab to EIC - 6-7 May 2021

Large acceptance spectrometer. Operative since 02/18
Luminosity up to $10^{35} \text{ cm}^{-2} \text{ s}^{-1}$; Wide rapidity coverage



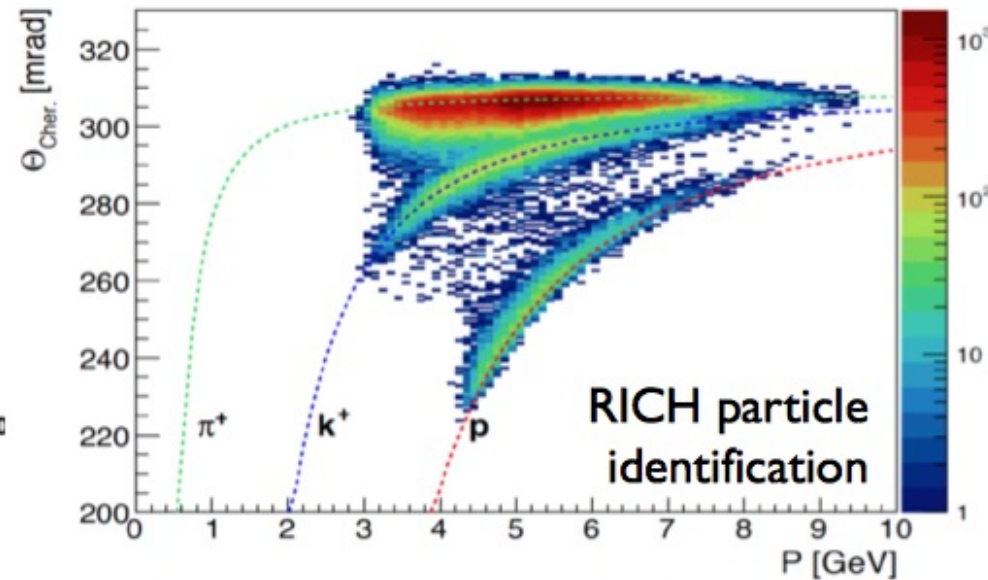
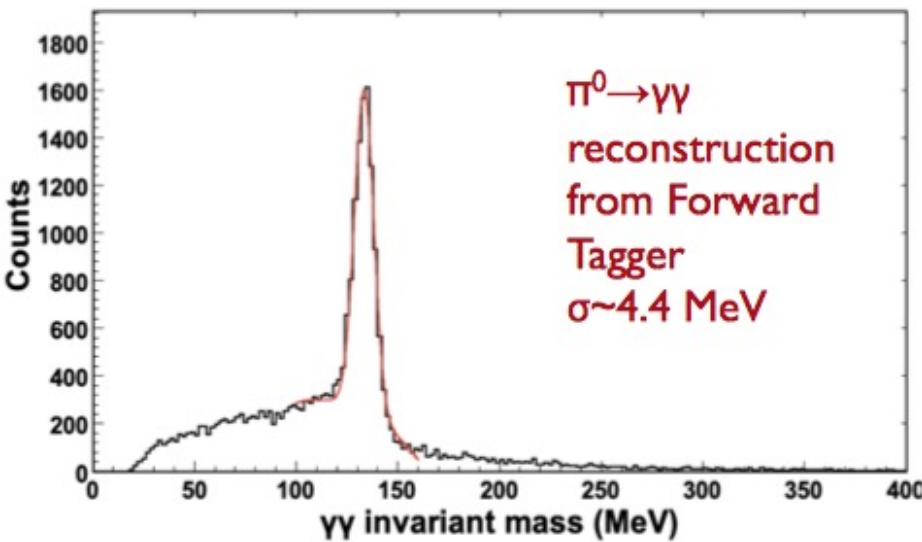
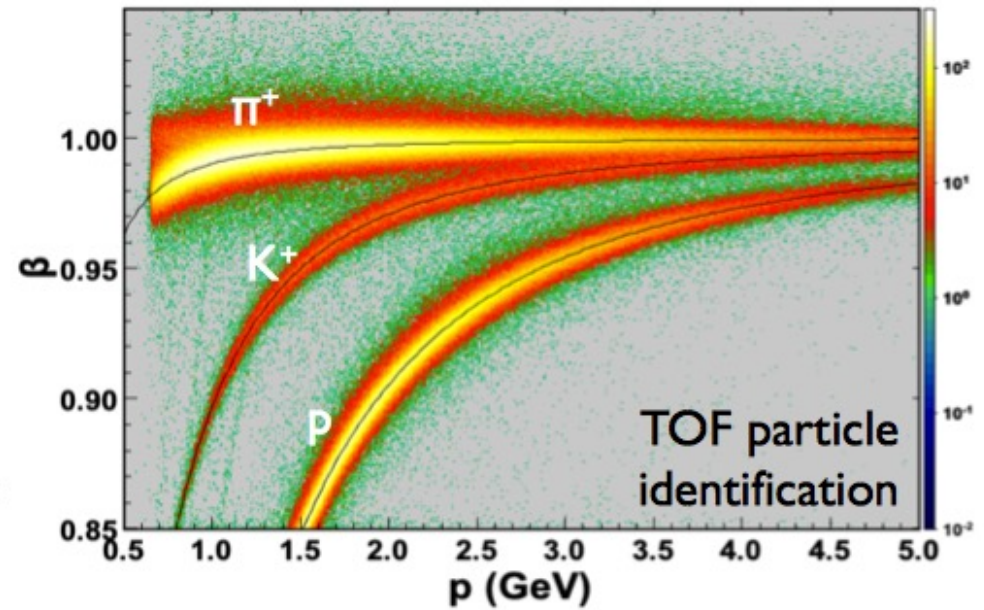
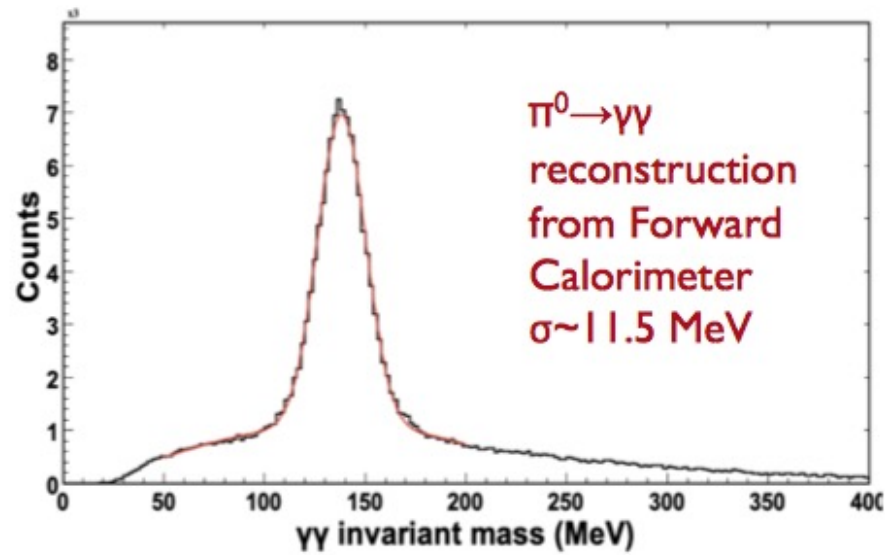
Valence region
Several Q^2

Extended p_T range
Weak correlation with z



Goal: explore quark dynamic effects in a extended phase-space
matching various compelling regimes

Leverage in	Q^2 leverage:	higher-twists	} TMD study prescription
	p_T leverage:	perturbative vs non-perturbative	
	η leverage:	target fragmentation	



Year	Period	Run	Target	Polarization	Beam
2018	Spring-Fall	RGA	Proton	-	10.6 GeV
	Fall	RGK	Proton	-	6.5-7.5 GeV
2019	Spring	RGA	Proton	-	10.6 GeV
2019	Spring-Fall	RGB	Deuteron	-	10.6 GeV
2020	Spring-Fall	RGF	Deuteron	-	10.6 GeV
2021	Fall	RGM	Nuclear	-	Several GeV
2022	Spring-Fall	RGC	NH ₃ -ND ₃	Longitudinal	10.6 GeV
> 2022		RGH	HDice, NH ₃ -ND ₃	Transverse	10.6 GeV
> 2022			³ He	Longitudinal	10.6 GeV
> 2022		RGG	⁷ LiD, ⁶ LiH	Longitudinal	10.6 GeV

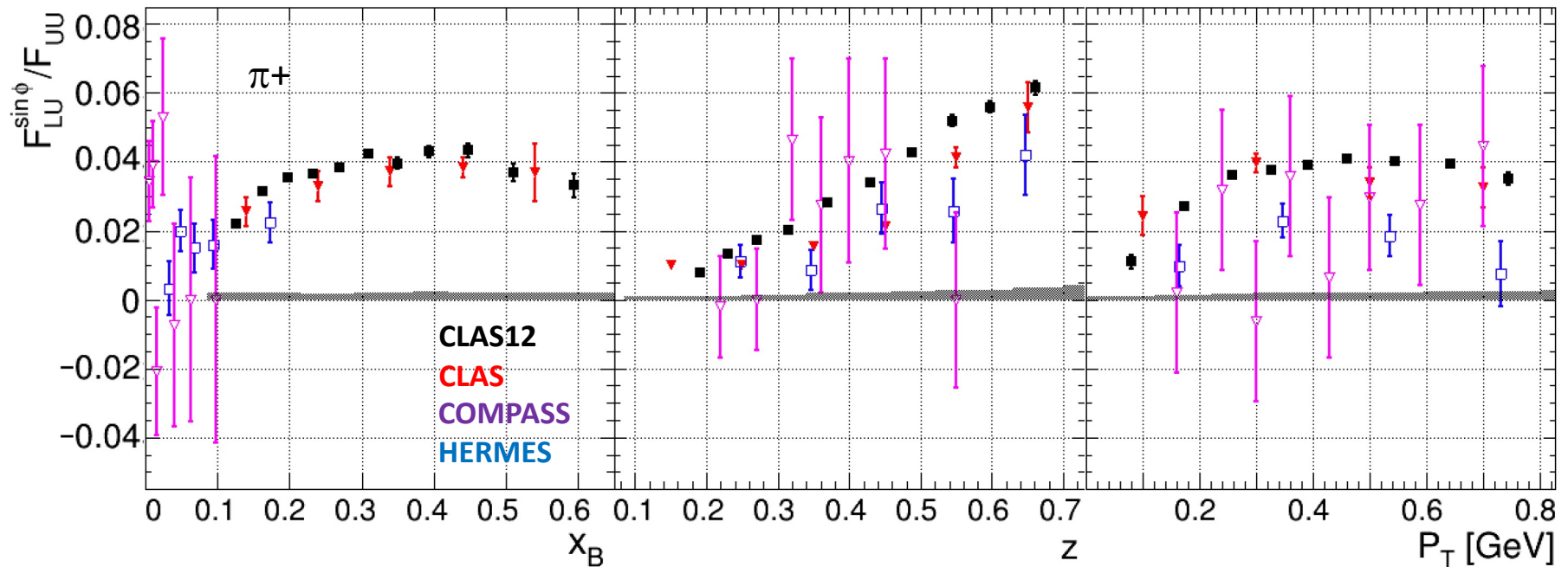
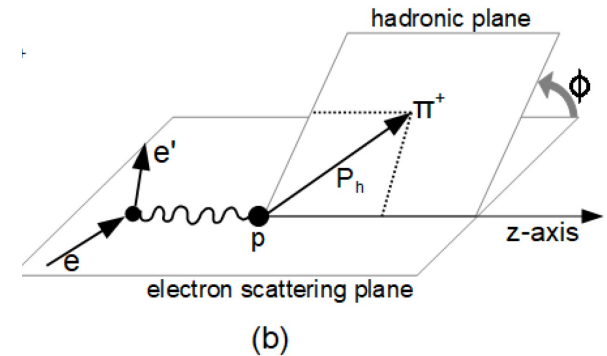
++ Increased luminosity, extended energy range, additional targets

CLAS12 proton data (RGA)

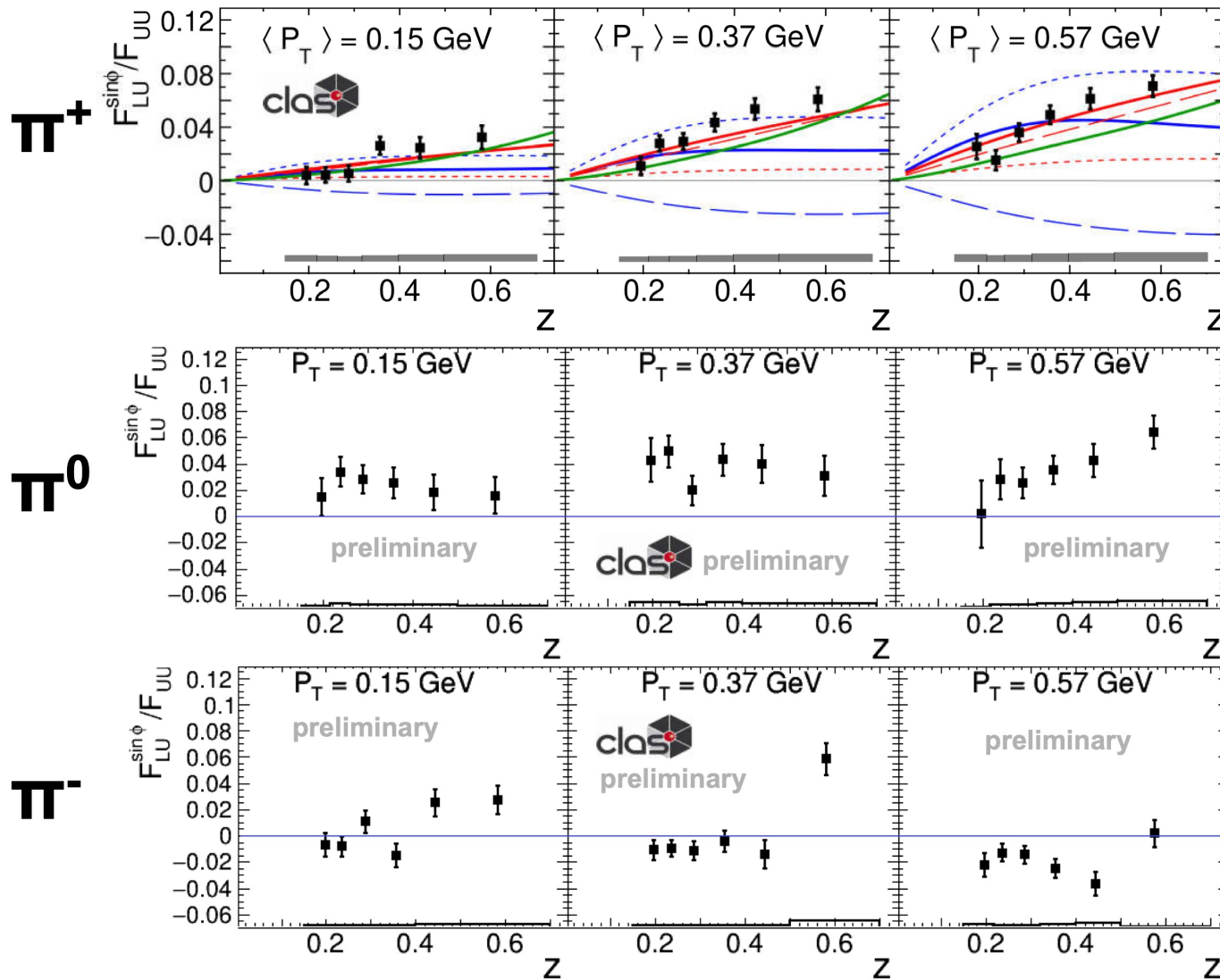
S. Diehl et al., e-Print: 2101.03544

$$F_{LU}^{\sin\phi} = \frac{2M}{Q} c \left[-\frac{\hat{h} \cdot k_T}{M_h} \left(x_B e H_1^\perp + \frac{M_h}{M} f_1 \frac{\tilde{G}^\perp}{z} \right) + \frac{\hat{h} \cdot P_T}{M} \left(x_B g^\perp D_1 + \frac{M_h}{M} h_1^\perp \frac{\tilde{E}}{z} \right) \right]$$

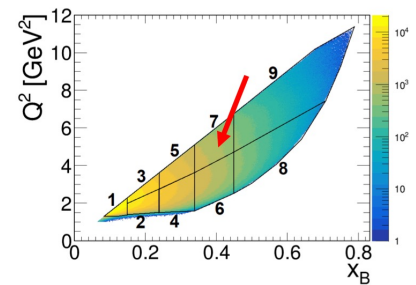
86.9 ± 2.6 %



Opening the multi-state & multi-dimensional study



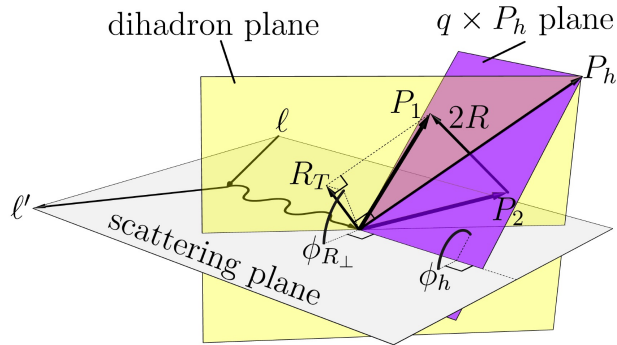
bin 7:
 $Q^2 = 4.8 \text{ GeV}^2$
 $x_B = 0.39$



- model 1 eH_1^\perp
- model 1 $g^\perp D_1$
- model 1 sum
- model 2 eH_1^\perp
- model 2 $g^\perp D_1$
- model 2 sum
- model 3 eH_1^\perp

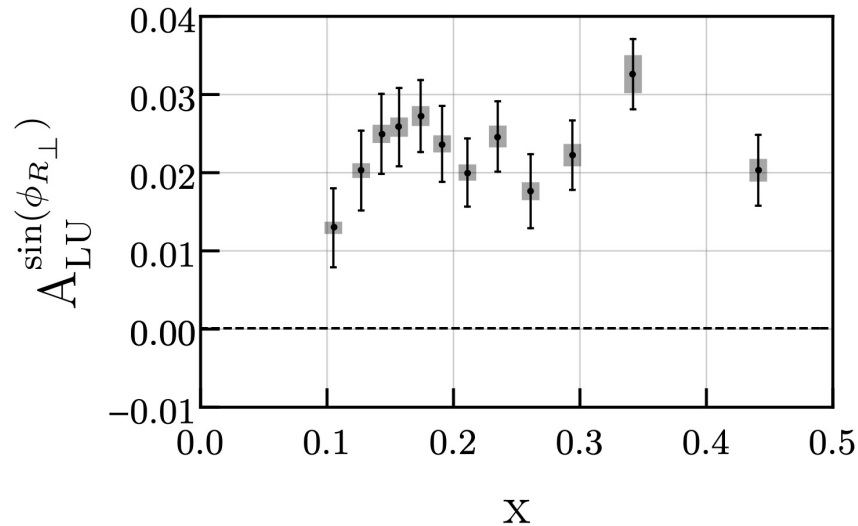
CLAS12 proton data (RGA)

T.B. Hayward et al., PRL 126 (2021) 152501

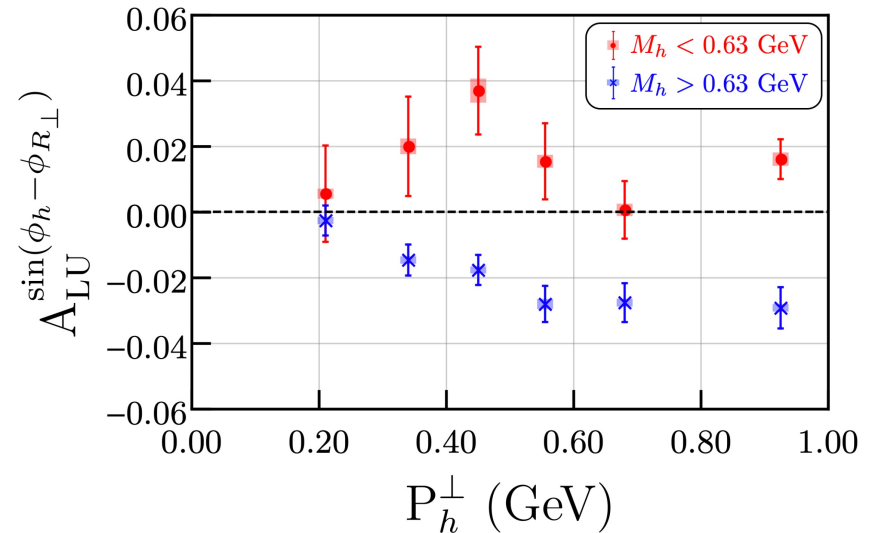
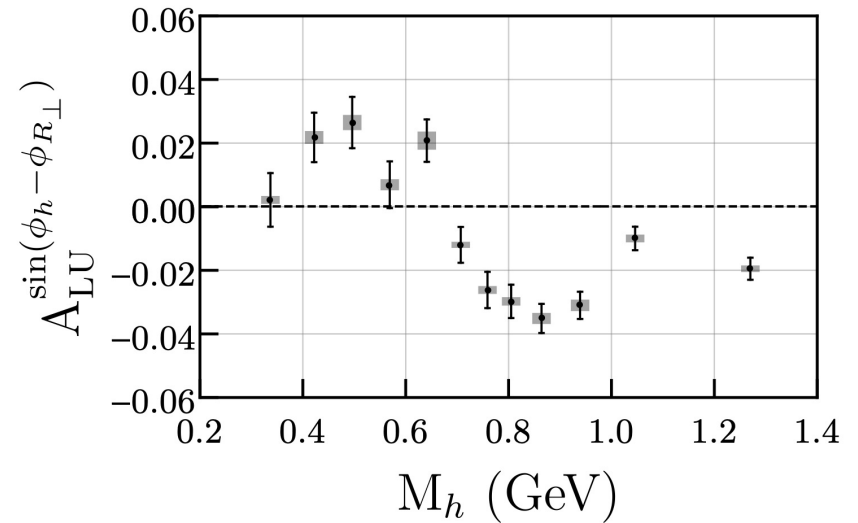


$$d\sigma_{LU} \propto$$

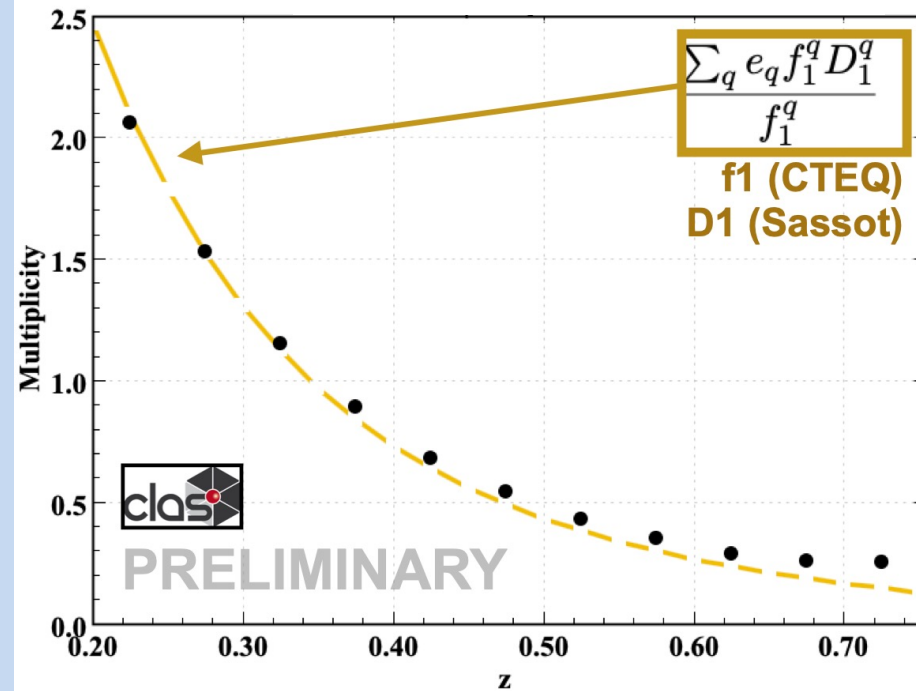
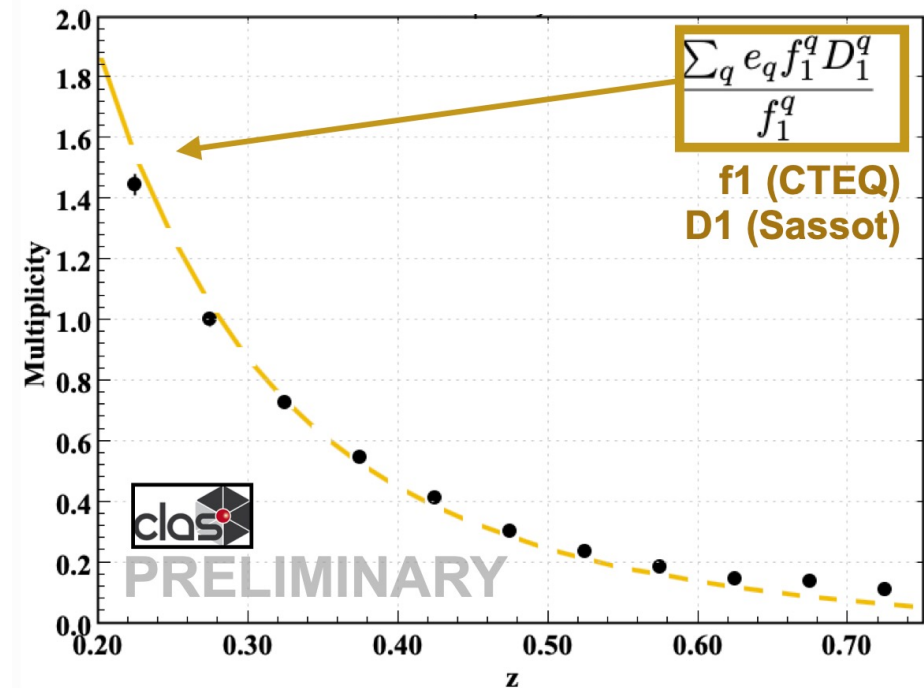
$$W\lambda_e \sin(\phi_{R_\perp}) \left(xe(x)H_1^\triangleleft(z, M_h) + \frac{1}{z}f_1(x)\tilde{G}^\triangleleft(z, M_h) \right)$$



$$d\sigma_{LU} \propto C\lambda_e \sin(\phi_h - \phi_{R_\perp})\mathcal{I} [f_1 G_1^\perp]$$



Collinear study

 $e p \rightarrow e \pi^+ X$  $e p \rightarrow e \pi^- X$ 

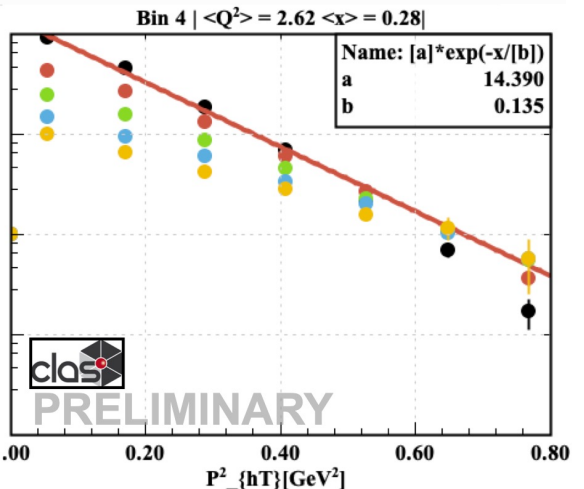
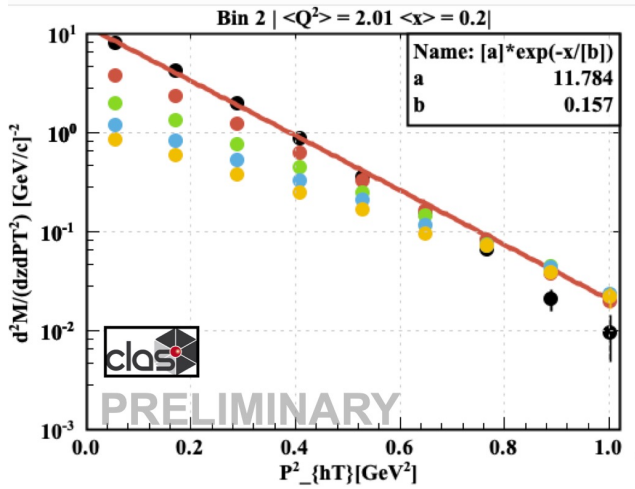
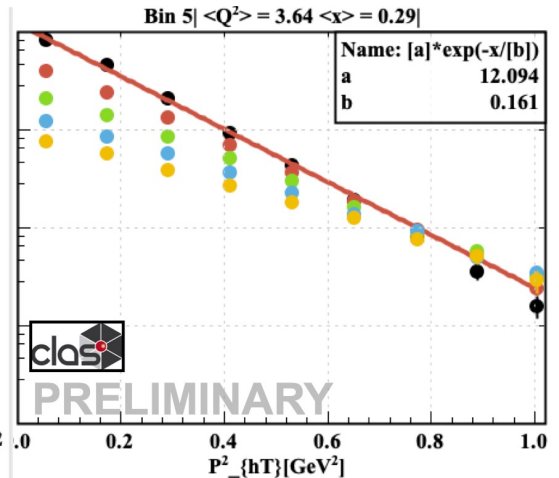
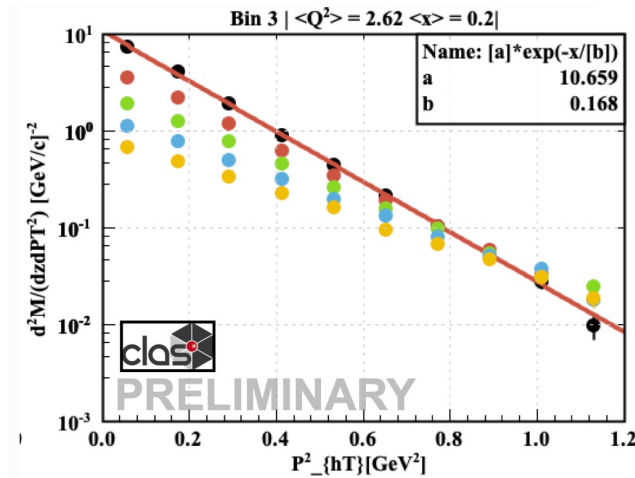
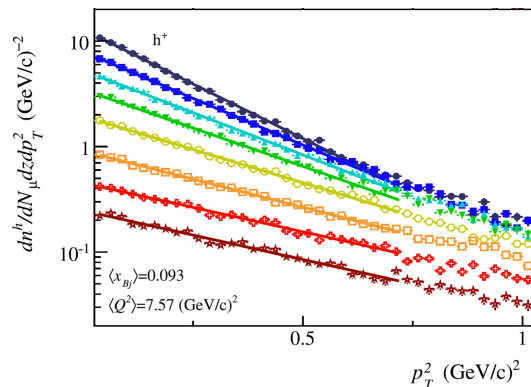
Transverse momentum dependence and phase space

 $e p \rightarrow e \pi^+ X$

Color legend

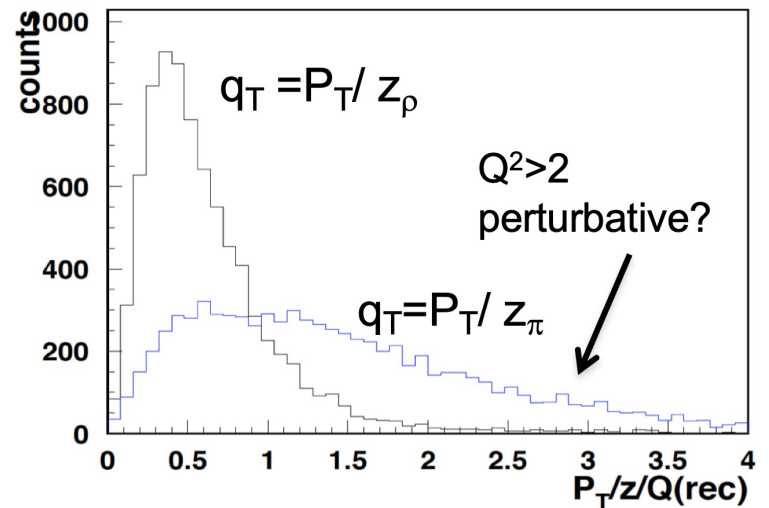
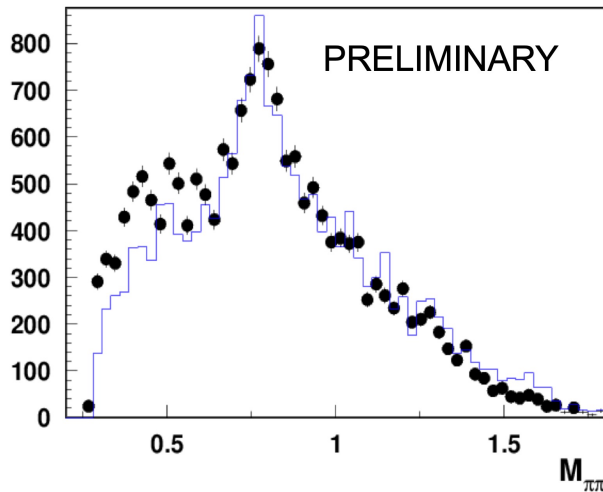
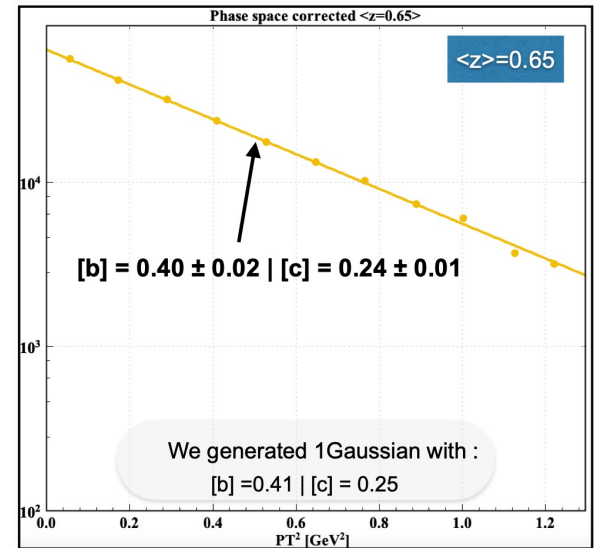
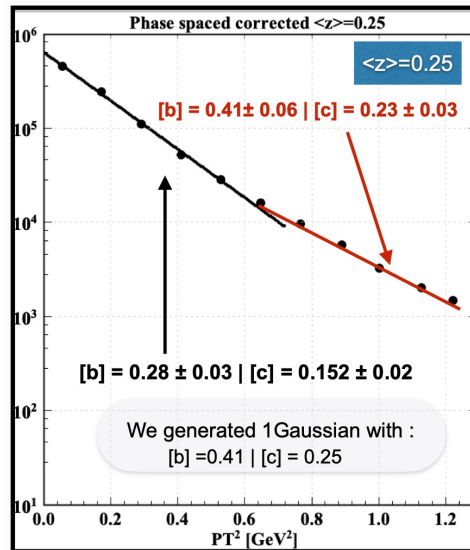
- $0.2 < z < 0.3$
- $0.3 < z < 0.4$
- $0.4 < z < 0.5$
- $0.5 < z < 0.6$
- $0.6 < z < 0.7$

COMPASS, EPJC 73 (2013) 8, 2531

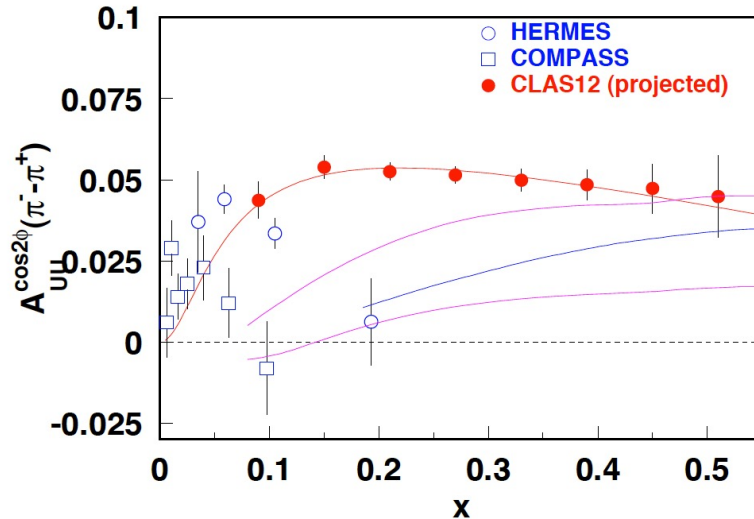
 $\langle x \rangle = 0.2$ $\langle x \rangle = 0.29$

Transverse momentum dependence and role vector meson decays & phase space

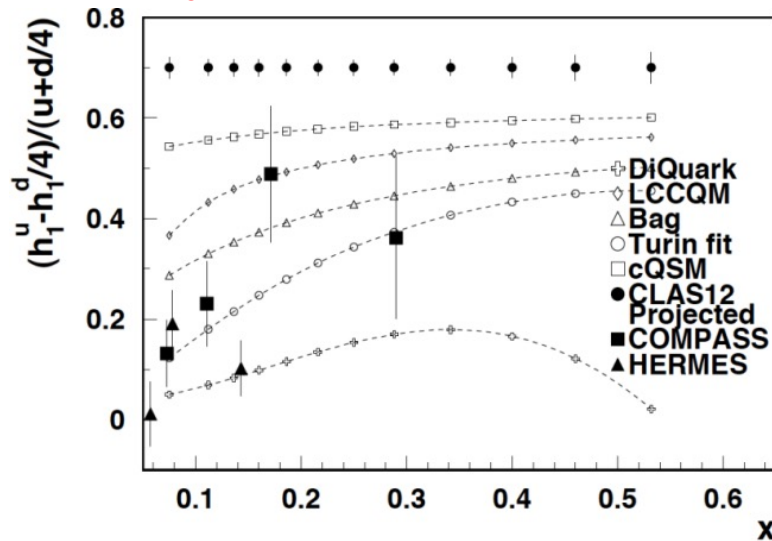
Example of
precision & validation
Monte Carlo study



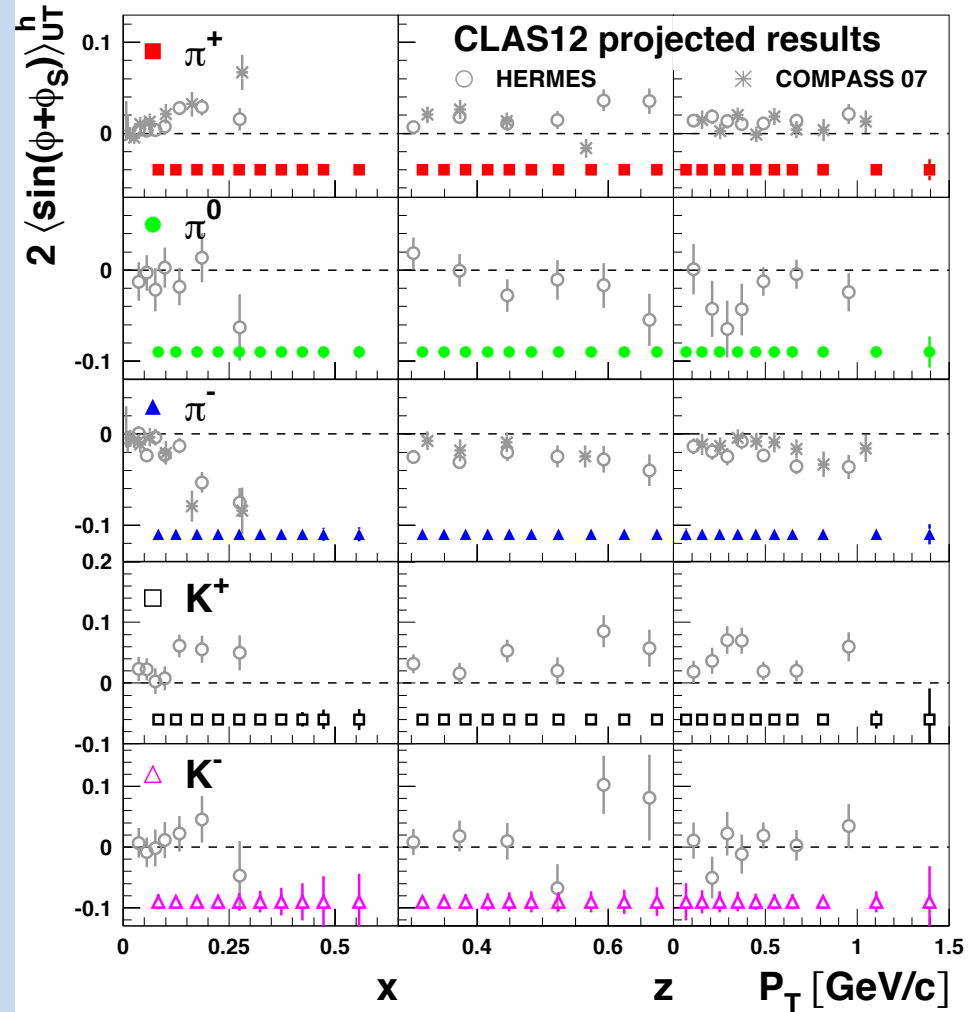
A_{UU} Pion channel:



A_{UT} Di-hadron channel:



A_{UT} Single-hadron channel:



CLAS12 is entering the 12 GeV production era

First beam-spin asymmetry published

Comprehensive program with

- polarized beam and targets
- nuclear targets

Large luminosity, wide acceptance, excellent PID

Important synergy & complementarity with EIC

Working for precision and new approaches

to exploit existing infrastructure

to boost the physics program

