Summary ?

Jianwei Qiu

Goal of this workshop:

To probe the science that would be opened up by a higher energy electron beam (~20-24 GeV) at Jefferson Lab

- **Identify the flagship measurements that can be done only with 20+ GeV**
- **Identify the flagship measurements with 20+ GeV that can extend and improve the 11 GeV measurements, helping the physics interpretation through multidimensional bins in extended kinematics.**
- **Identify the measurements with 20+ GeV that can set the bridge between JLab12 and EIC (complementarity)**

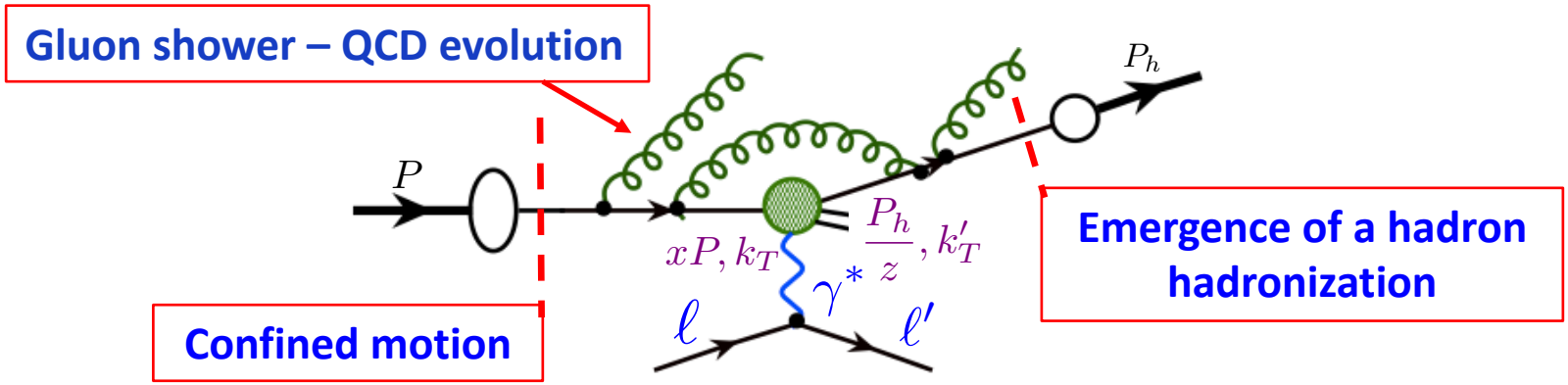
KT measured =\= KT of confined motion in proton

TMD-theory, see Bacchetta

- If the proton is broken, …

Liberation of confined states → *gluon shower* → *new particles produced*

+ QED shower !



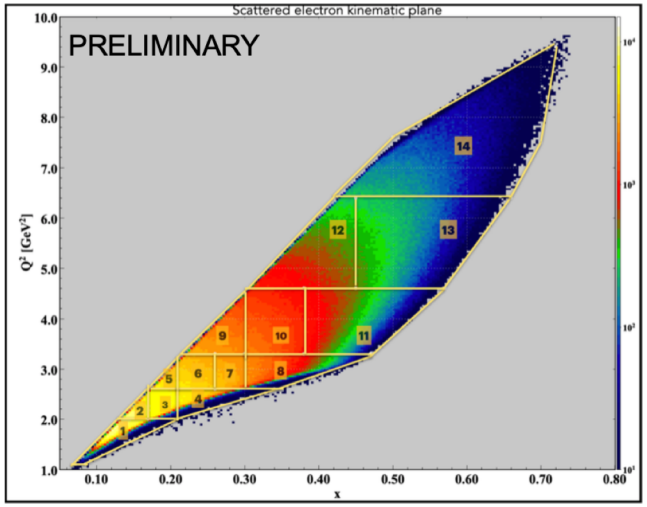
- *Measured k_T is NOT the same as k_T of the confined motion!*
- *Structure information vs. collision effects*

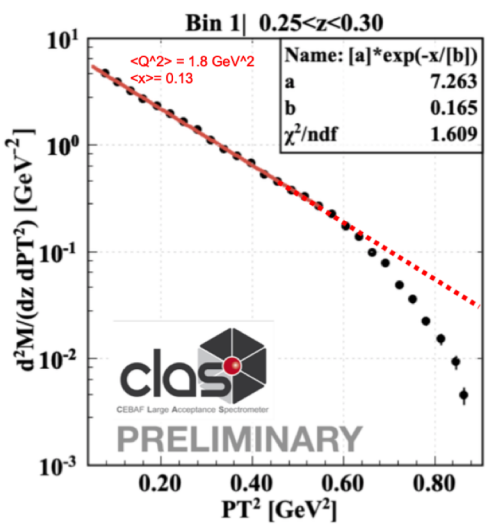
Hybrid factorization for lepton-hadron scattering & SIDIS

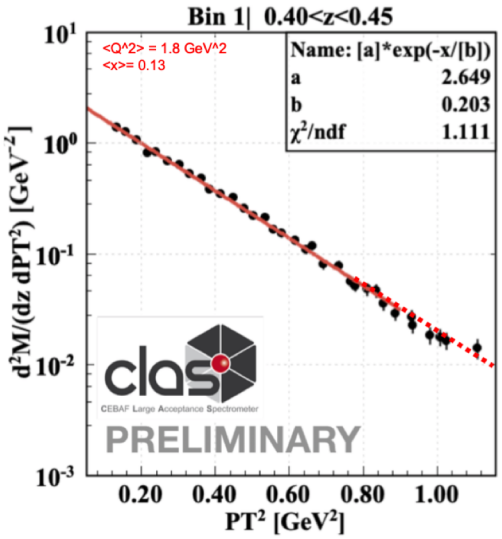
Library of Lepton Distribution and Fragmentation Functions!

Phase space for TMD physics – CLAS12

CLAS12 Multiplicities: high P_T & phase space

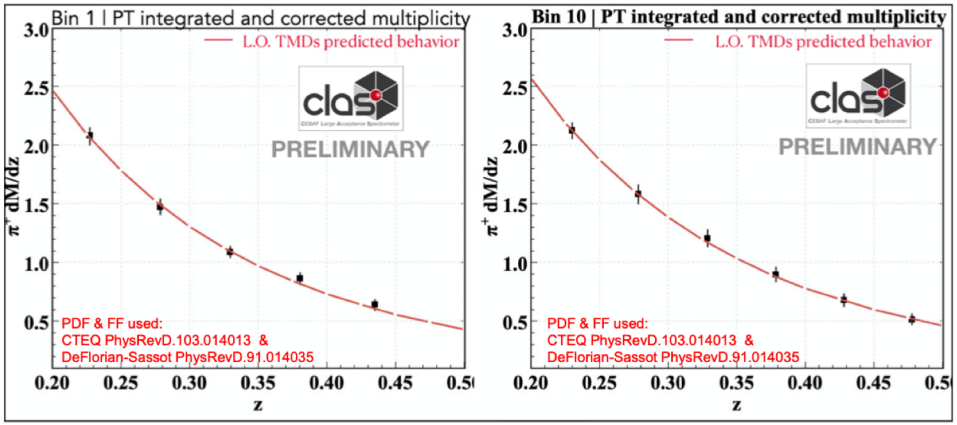






For some kinematic regions,
at low z, the high P_T distribution appear suppressed: there is no enough energy in the system to produce hadron with high transverse momentum (phase space effect).

<u>If the effect is accounted, the CLAS data follows global fits.</u>

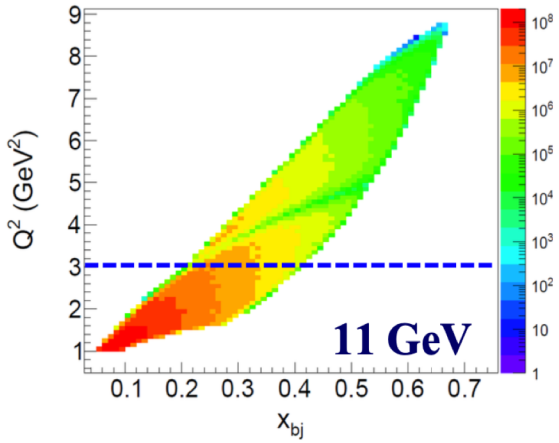


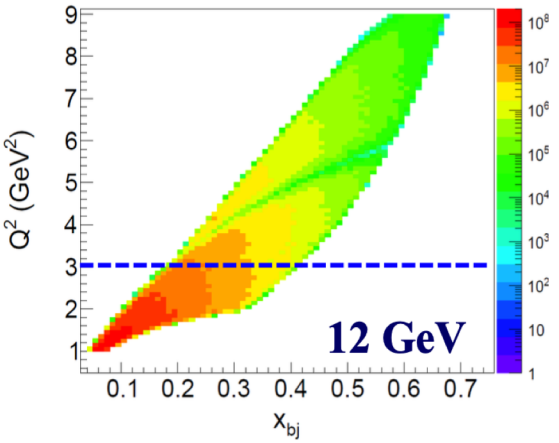
Avakian's talk

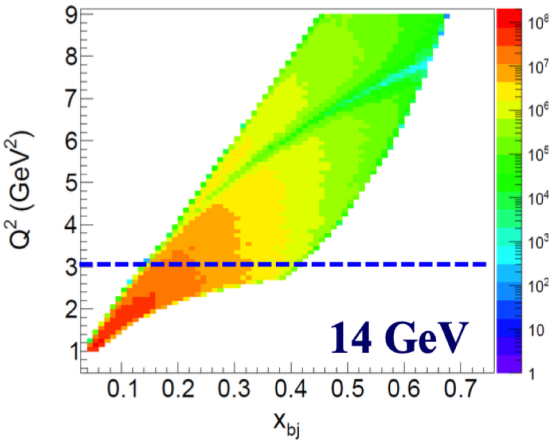
Jefferson Lab

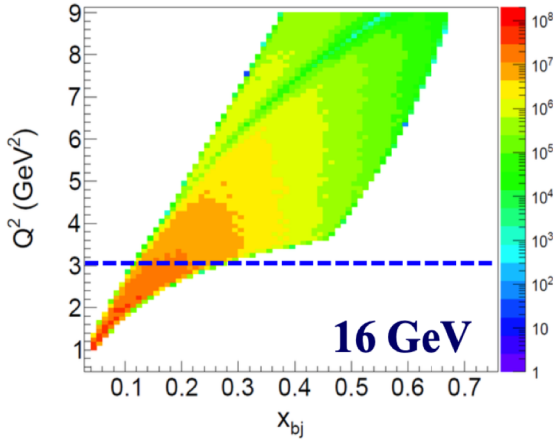
Phase space for TMD physics - SoLID

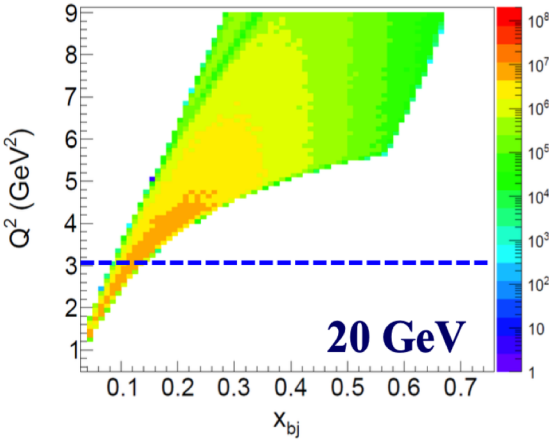
Phase - space examples obtained with the ^{3}He target at various beam energies: Q^2 vs. x_{bj}

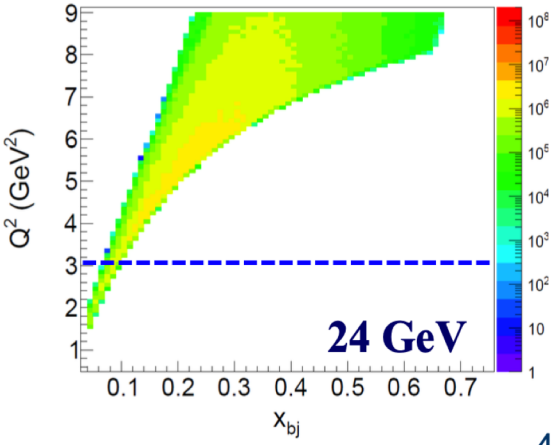












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Reduction from QED radiation ?

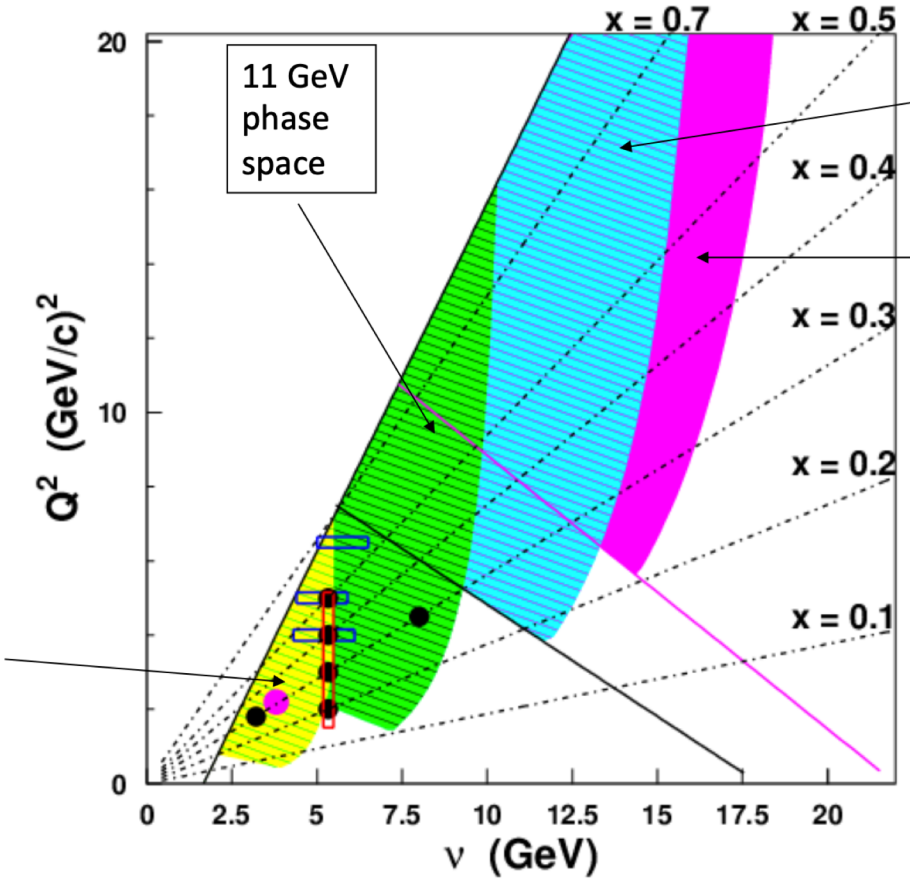
Khachatryan's talk

Jefferson Lab

Phase space for TMD physics – Hall C

22 GeV Hall C SIDIS Phase Space – HMS+SHMS

Assumptions: HMS + SHMS minimum angle constraints unchanged
→ Increase in HMS maximum momentum (higher field magnets)
→ Smaller HMS angle may be possible, but would require special bender like SHMS

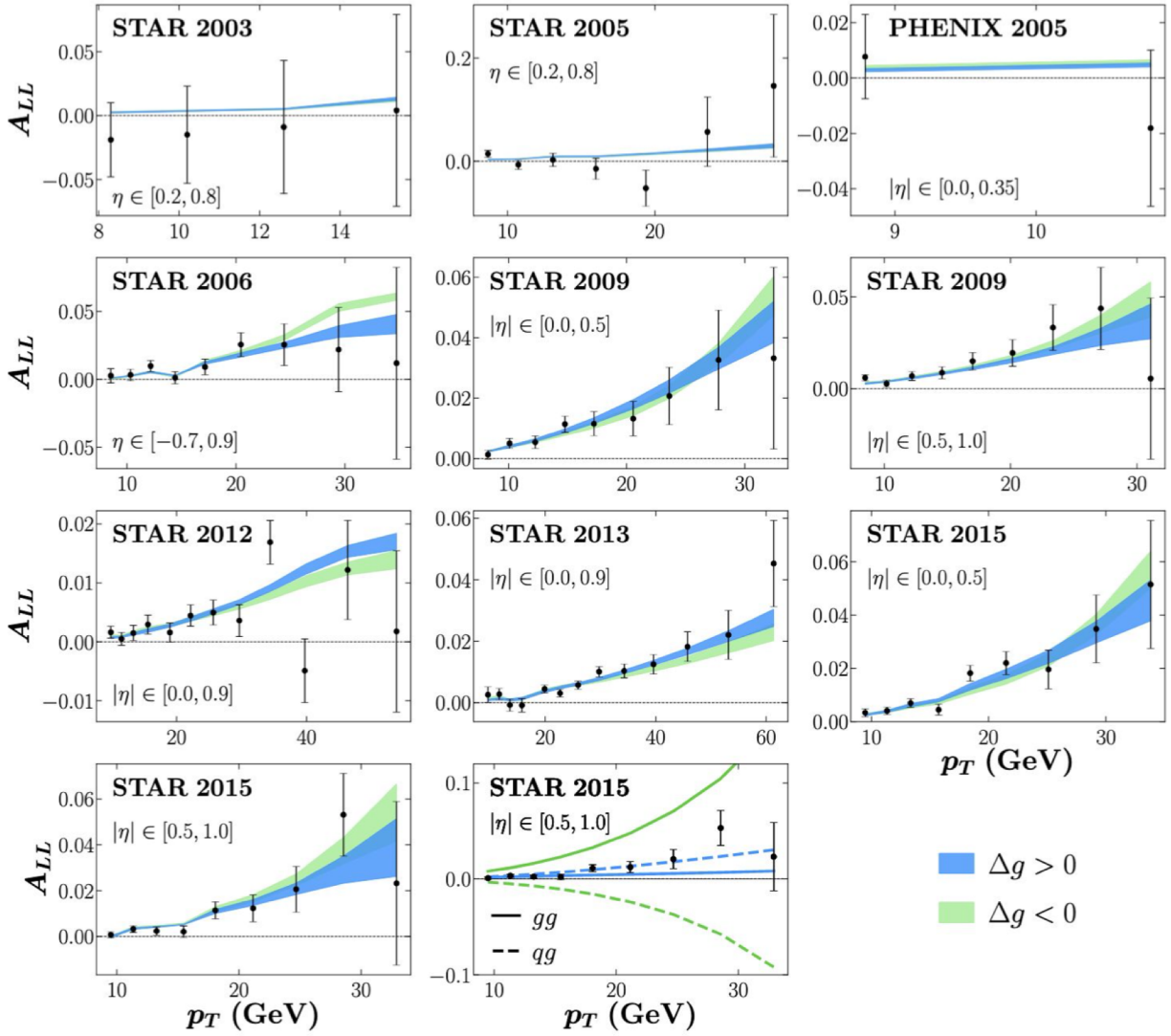


Possible Measurements
→ Additional L-T separations: expanded x/Q^2
→ Large P_T, cross sections and ratios in particular phase space
→ Measurements of cross sections and ratios at largest Q^2 and x

Gaskell's talk

Flagship measurements only at 20+ GeV

- SIDIS with large pT can have direct access to gluon polarizations



New measurements:

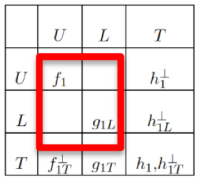
Polarized single hadron production vs PT ?

No 2nd scale Q^2 !

Sato's talk

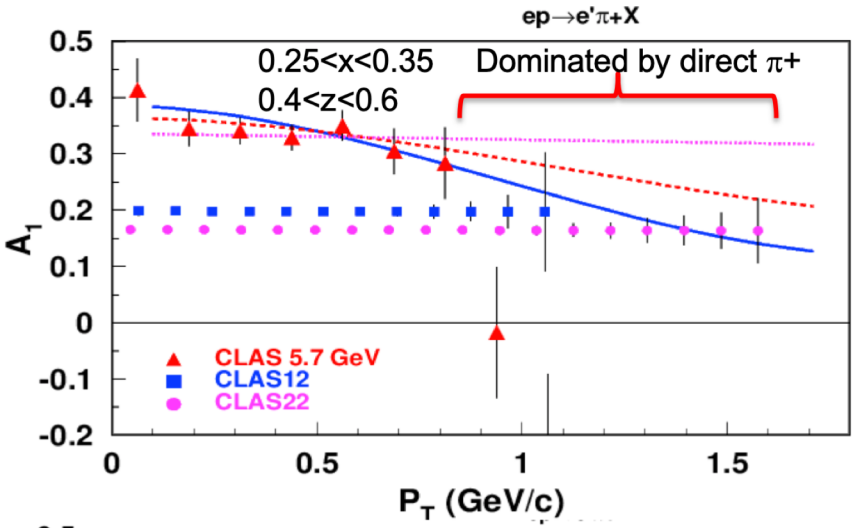
Jefferson Lab

Flagship measurements improved from 11 GeV

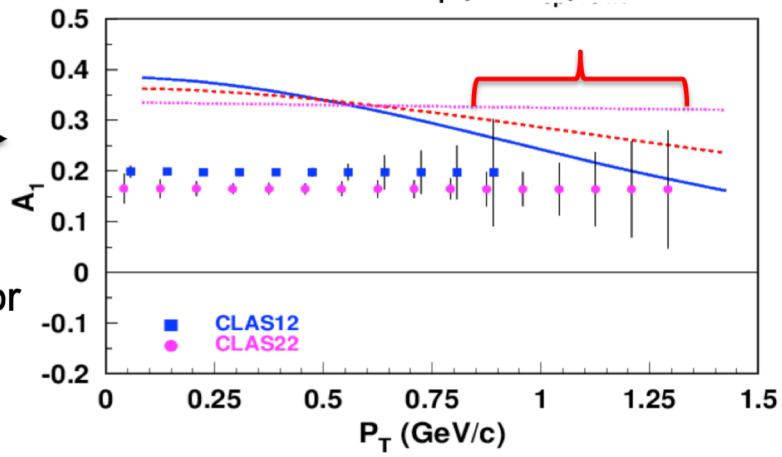


Impact of limitations from theory

- Gain with 22 GeV will be more critical with additional kinematical cuts imposed by theory



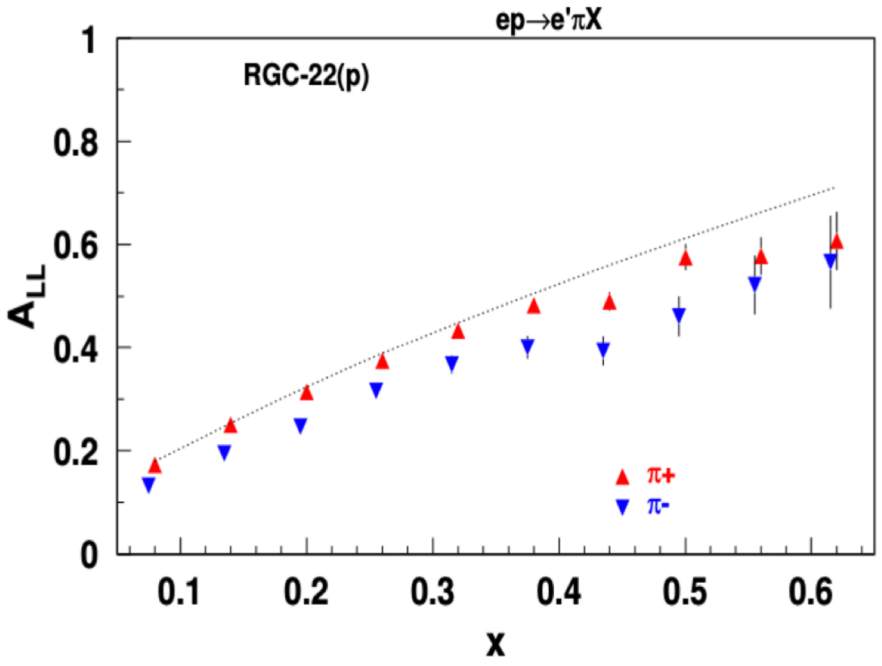
$P_T/z/Q<0.5$ →

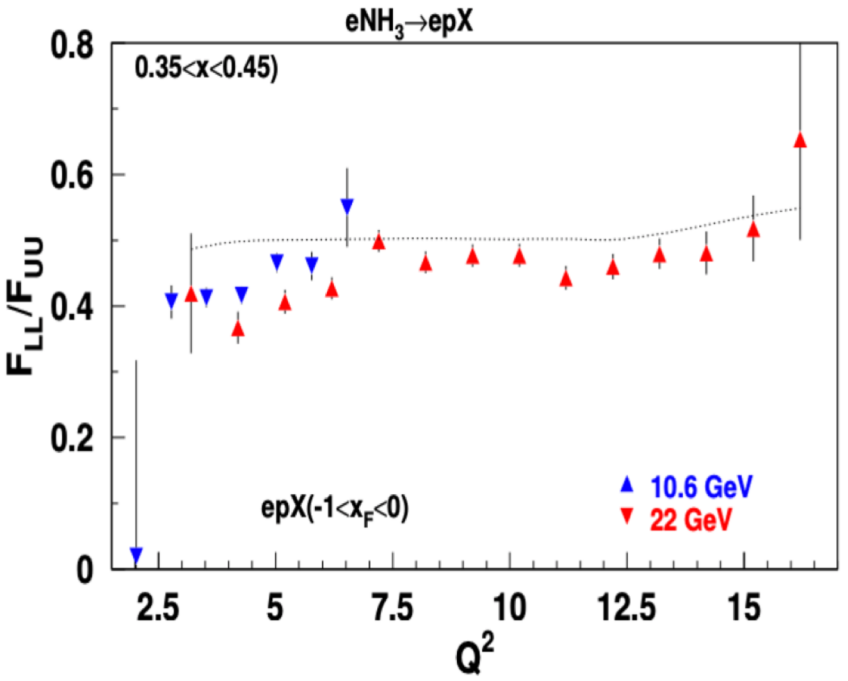


More theory limitation, may convert the observable from major improvement (type 2) to only possible with 20+ GeV (type 1)

Gaskell's talk

Flagship measurements improved from 11 GeV

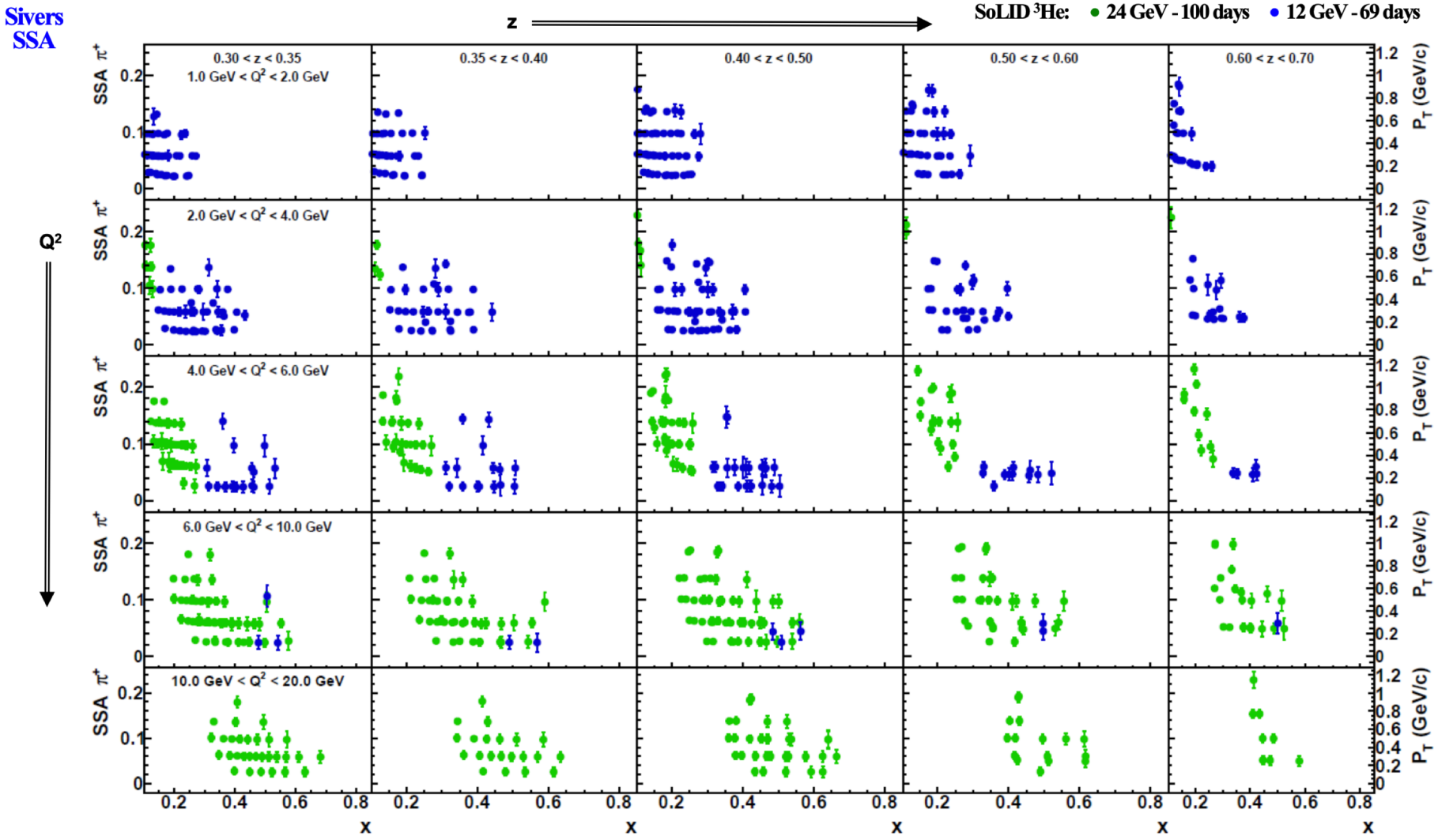




- Studies of evolution of observed double spin asymmetries will be a critical task in validating the QCD predictions $g_1(x,k_T)$-studies CLAS12
- Asymmetries measured with input polarized and unpolarized PDFs, can be used to test the flavor decomposition capabilities
- Kinematical correlations, even for small bins relevant (multidimensional bins critical)

Gaskell's talk

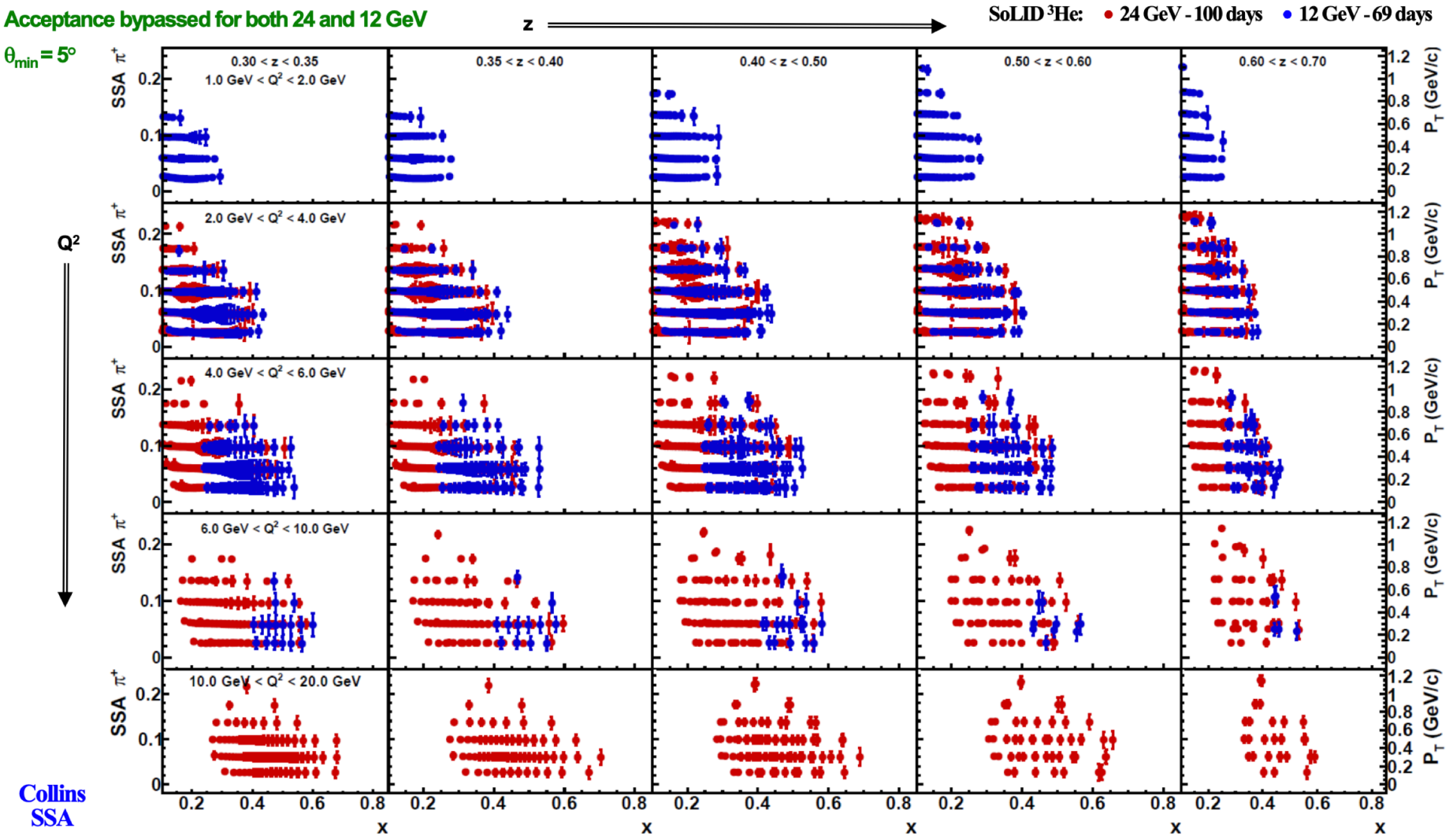
Flagship measurements improved from 11 GeV



Khachatryan's talk

Jefferson Lab

Flagship measurements improved from 11 GeV



Khachatryan's talk

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Flagship measurements improved from 11 GeV

Hall C Program at Higher Energy

- Higher energy capabilities similar to 12 GeV program
  - Precision cross sections
  - L/T separations
  - Low rate processes → large P_T
  - Precision ratios (π+/π-, and more)
  - Excellent π/K/p separation
  - Neutral particle capabilities w/calorimeter (NPS)
- Upgraded equipment
  - Higher momentum capability for electron arm (HMS) would be beneficial
  - Smaller angle capability?

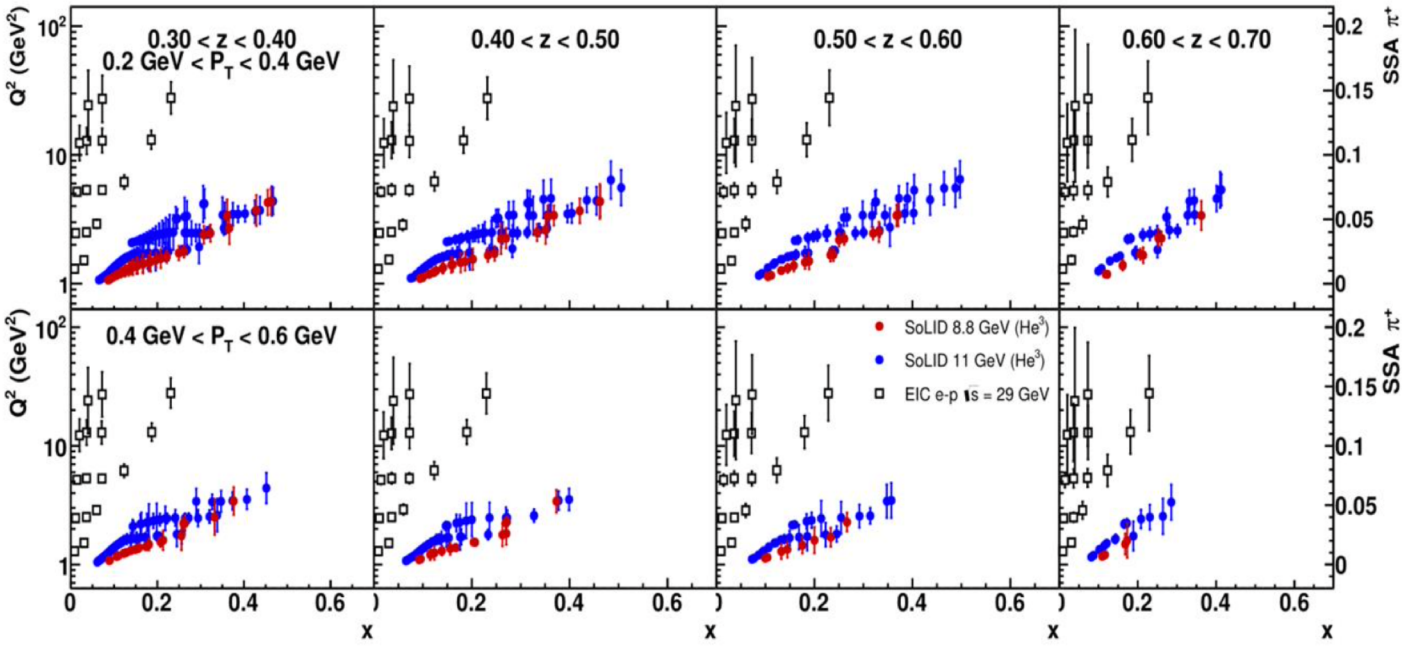
Gaskell's talk

Measurements can set the bridge between JLab12 & EIC

Just an example of the SOLID 12 GeV pseudo-data compared to that at EIC kinematics

- SoLID SIDIS projections of A_{UT} in various 4-D bins at 11 / 8.8 GeV beam energies from trans. pol ^{3}He target
- Projections at EIC kinematics for the same observable at 29 GeV center-of-mass energy
- SSA scale and uncertainties shown on the right-side axis of the figures
- SoLID and EIC projections synergistic towards each other, by covering different x and Q^2 ranges

A_{UT} non-separated asymmetry of π^+ particles



Reach of x and Q – bridged between JLab12 and EIC

Khachatryan's talk

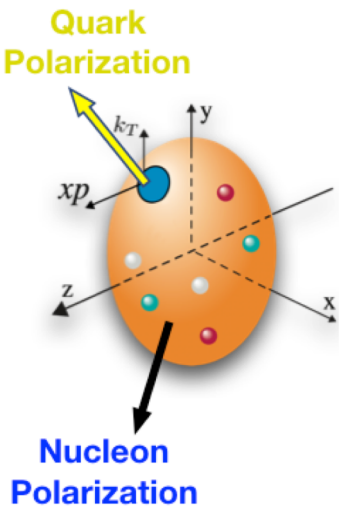
Jefferson Lab

Backup slides

Transverse momentum dependent PDFs (TMDs)

❑ Quark TMDs with polarization:

Nucleon Polarization	Quark Polarization: Unpolarized (U)	Quark Polarization: Longitudinally Polarized (L)	Quark Polarization: Transversely Polarized (T)
U	$f_1(x,k_T^2)$		$h_1^\perp(x,k_T^2)$ Boer-Mulders
L		$g_1(x,k_T^2)$ Helicity	$h_{1L}^\perp(x,k_T^2)$ Long-Transversity
T	$f_1^\perp(x,k_T^2)$ Sivers	$g_{1T}(x,k_T^2)$ Trans-Helicity	$h_1(x,k_T^2)$ Transversity; $h_{1T}^\perp(x,k_T^2)$ Pretzelosity



Analogous tables for:

- Gluons $f_1 \to f_1^g$ etc
- Fragmentation functions
- Nuclear targets $S \neq \frac{1}{2}$

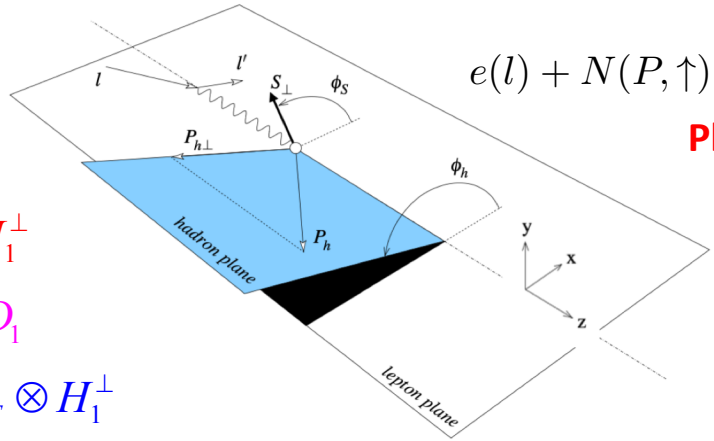
❑ Semi-Inclusive DIS (SIDIS):

$$A_{UT} = \frac{1}{P}\frac{\sigma_{lN(\uparrow)} - \sigma_{lN(\downarrow)}}{\sigma_{lN(\uparrow)} + \sigma_{lN(\downarrow)}}$$

$$A_{UT}^{Collins} \propto \left\langle \sin(\phi_h + \phi_S) \right\rangle_{UT} \propto h_1 \otimes H_1^\perp$$

$$A_{UT}^{Sivers} \propto \left\langle \sin(\phi_h - \phi_S) \right\rangle_{UT} \propto f_{1T}^\perp \otimes D_1$$

$$A_{UT}^{Pretzelosity} \propto \left\langle \sin(3\phi_h - \phi_S) \right\rangle_{UT} \propto h_{1T}^\perp \otimes H_1^\perp$$



$$e(l) + N(P,\uparrow) \to e(l') + h(P_h) + X$$

Photon-hadron frame

Two planes
Leptonic plane
Hadronic plane

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