

Discussion: Spin-related observables

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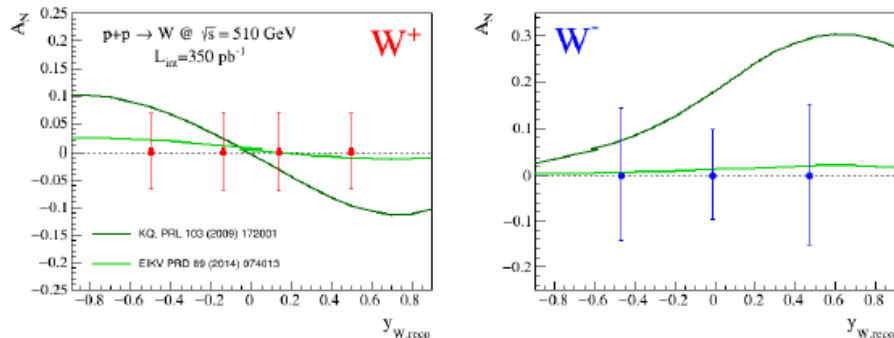
CNFS Workshop: RHIC Science Programs Informative Toward EIC

May 26, 2021

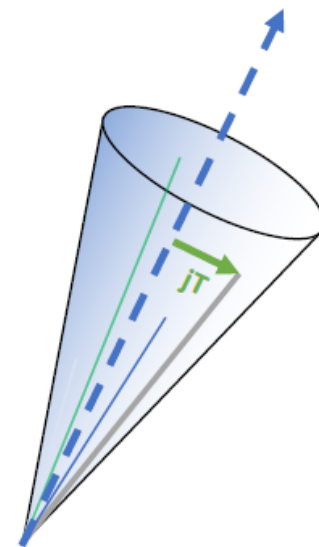
From Renee Fatemi

High Priority 22-24 for RHIC Spin

Sivers Sign Change (TMD/twist-3)
using $W^{+/-}$, DY and direct photon.

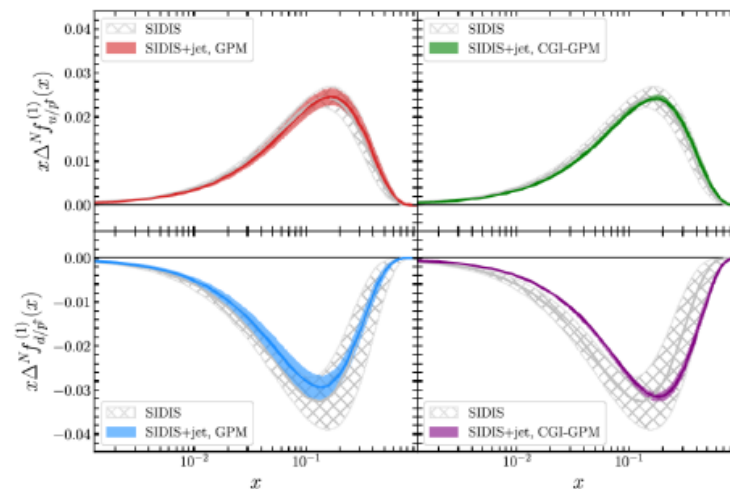
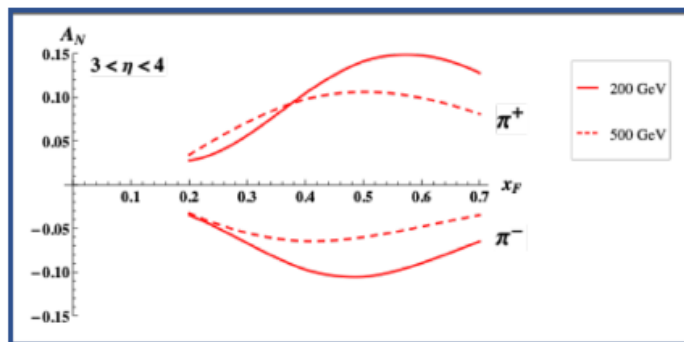


Precision spin and unpolarized
TMDFF at mid-rapidity using
hadrons in jets – both in pp and pA.



High x Sivers and Transversity using
forward gamma, jet and IFF channels.
? How does h^+h^- restrict us?

Definitely test role
of twist-3 FF with
forward π^+/π^- TSSA

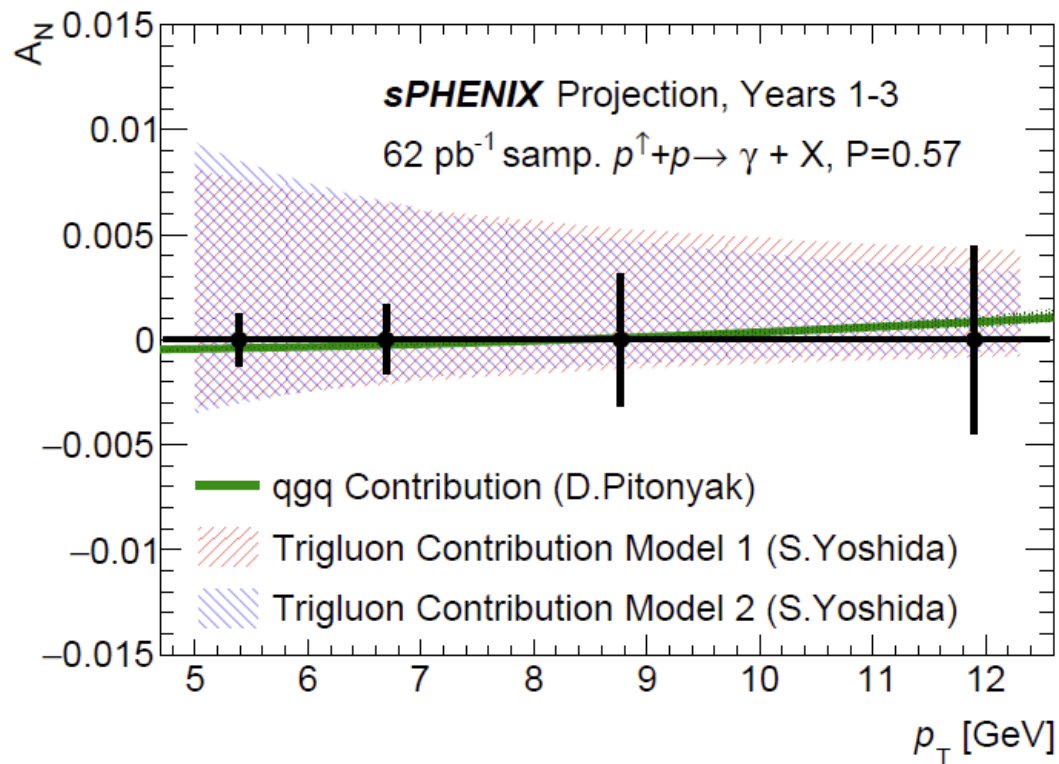


From John Lajoie

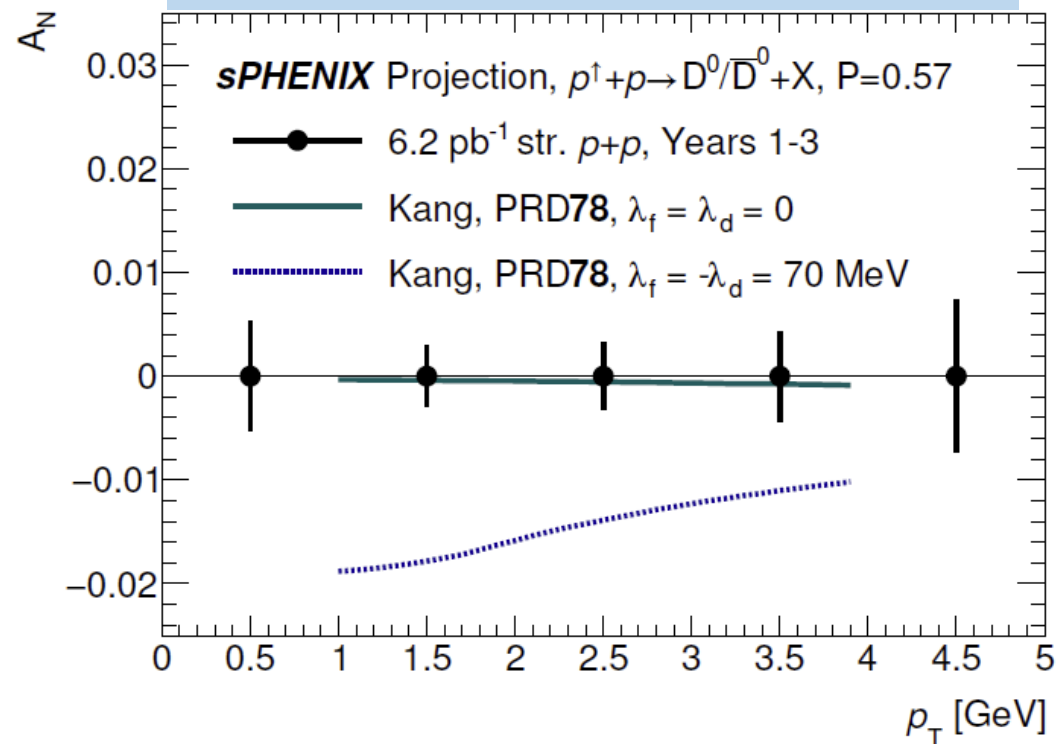
TSSA's sPHENIX - γ and HF

Prompt photons and HF
probe gluon correlations
in the nucleon

Prompt photons collected with EMCal-based trigger



D meson A_N also highlighted by Xin Dong



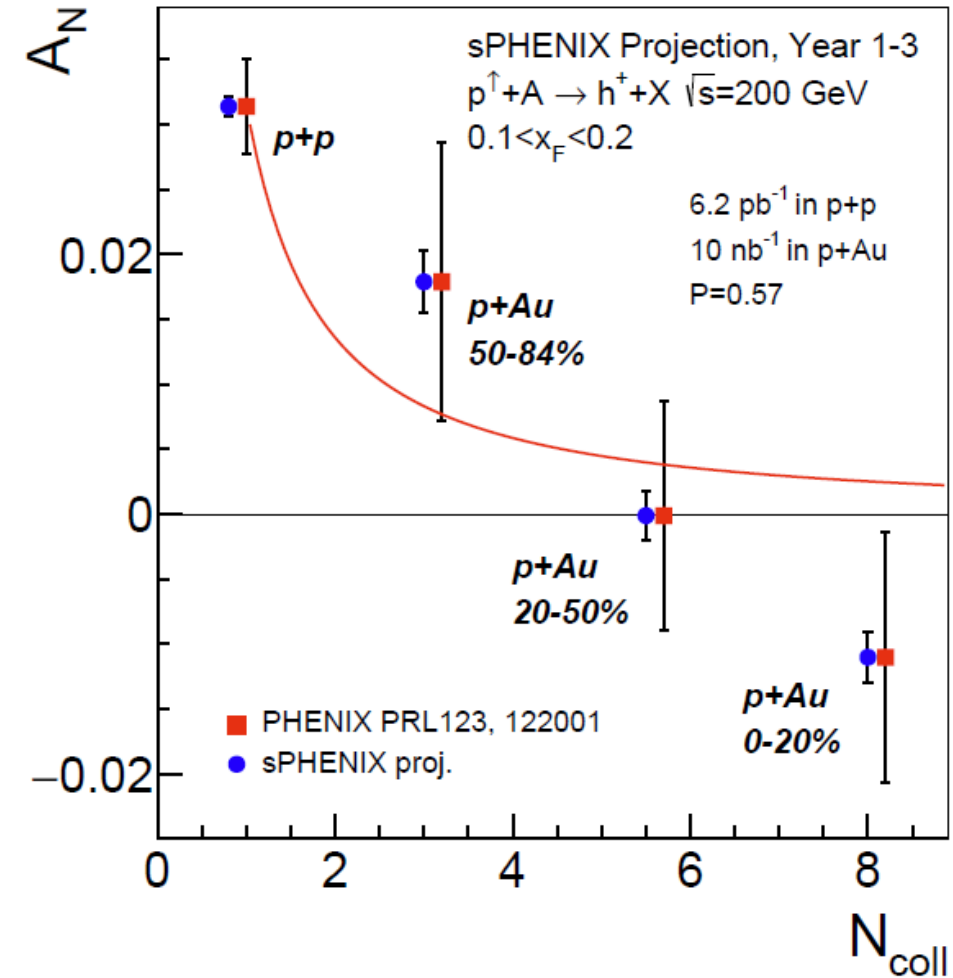
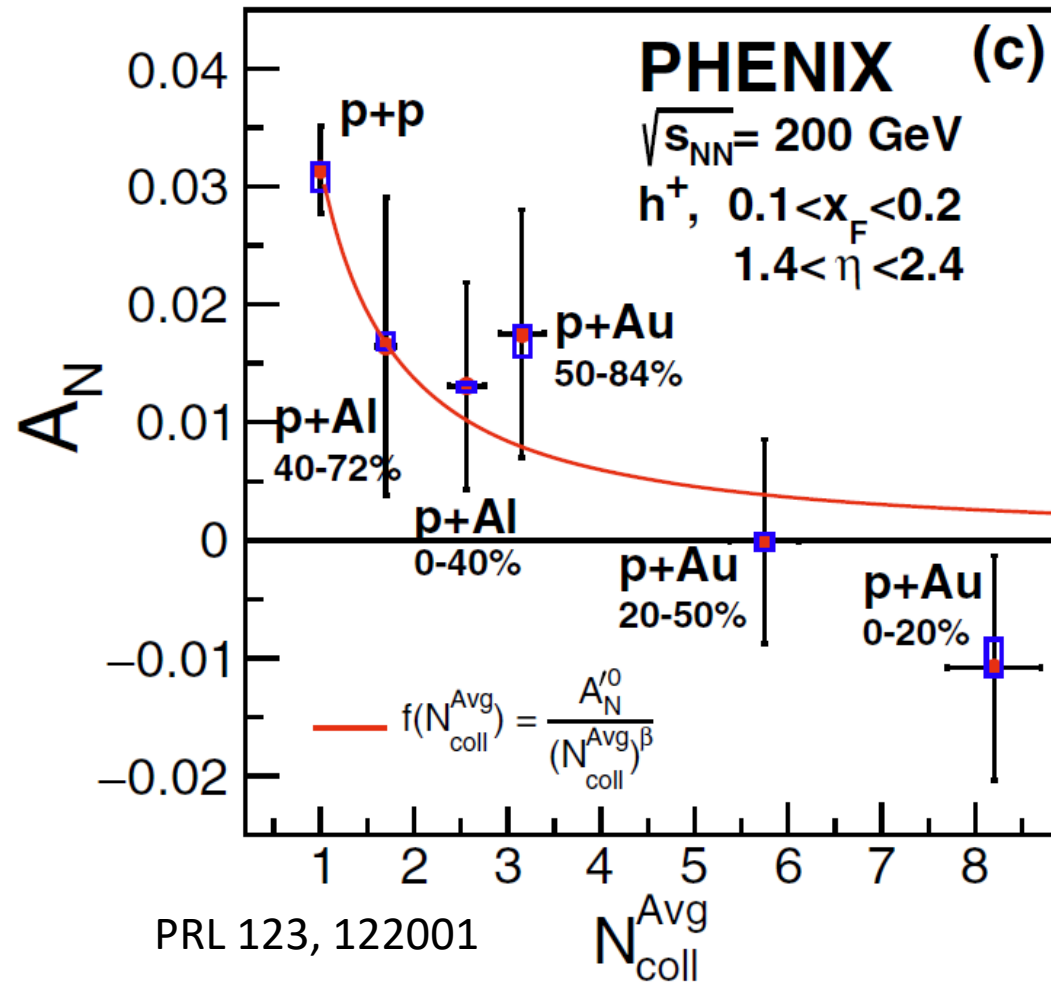
D^0 meson TSSA enabled by sPHENIX hybrid streaming DAQ

Direct access to the tri-gluon correlator
unique to hadron collision data!

Recent PHENIX measurement of prompt photon A_N - arXiv:2102.13585

Hadron A_N in sPHENIX

Hadron A_N combines a variety of effects – but the *nuclear dependence* is a tool to separate them!

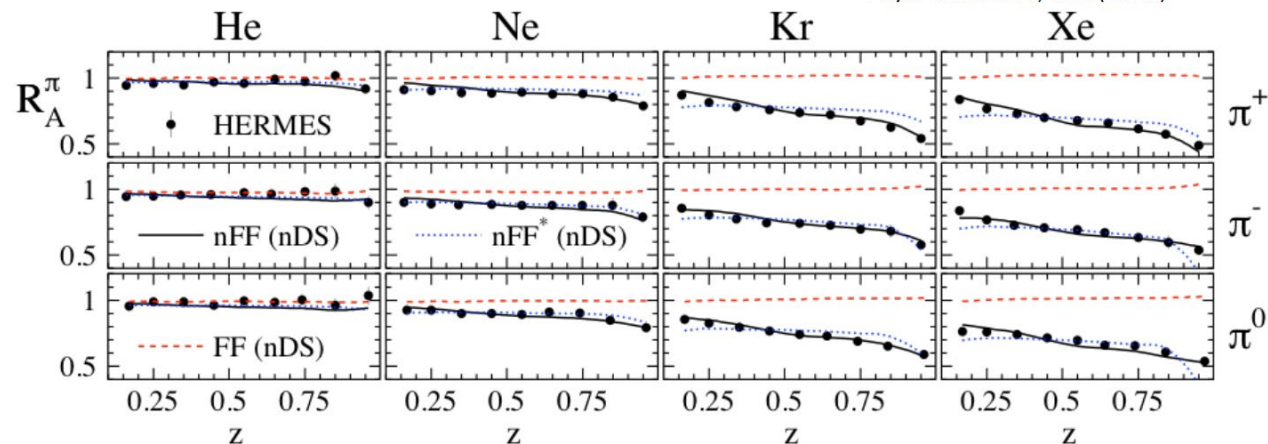


Interesting spin measurements

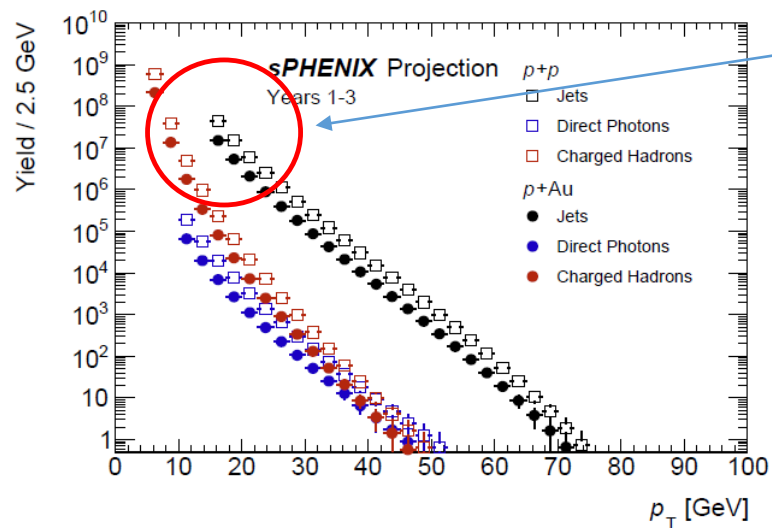
- Single transverse spin asymmetry of W/Z boson
 - TMD evolution
 - Sivers + g_{1T}
- Spin asymmetry for single jet production
 - Exploring flavor separation in forward rapidity
- Sivers asymmetry in dijet
 - Jet charge for flavor separation
 - Sivers function + TMD factorization breaking
- Photon+jet production
 - Both unpolarized cross section and spin asymmetry
- Photon+hadron and dihadron measurement
 - Further improve and reduce the experimental uncertainty
 - To test possible TMD factorization breaking
- Jet substructure for TMD FFs
 - Unpolarized hadron TMD distribution inside the jet
 - Collins asymmetry for hadron in jet
 - Lambda polarization in either unpolarized pp, or Lambda transverse spin transfer in polarized pp
 - Possible measurement in p+A collisions to study nuclear modification of TMD FFs

Hadronization in a Nuclear Environment

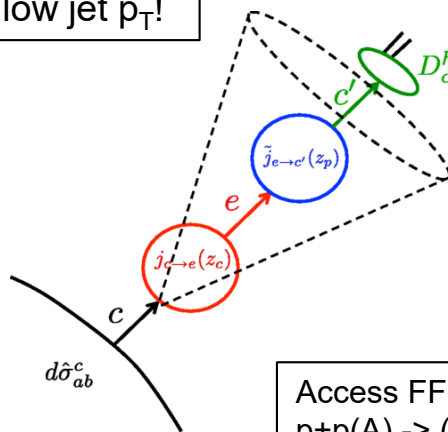
Phys. Lett. B577, 37 (2003)
Phys. Lett. B684, 114 (2010)



Hadron production in e+A suppressed compared to e+p – must be a fragmentation effect, but at low- Q^2

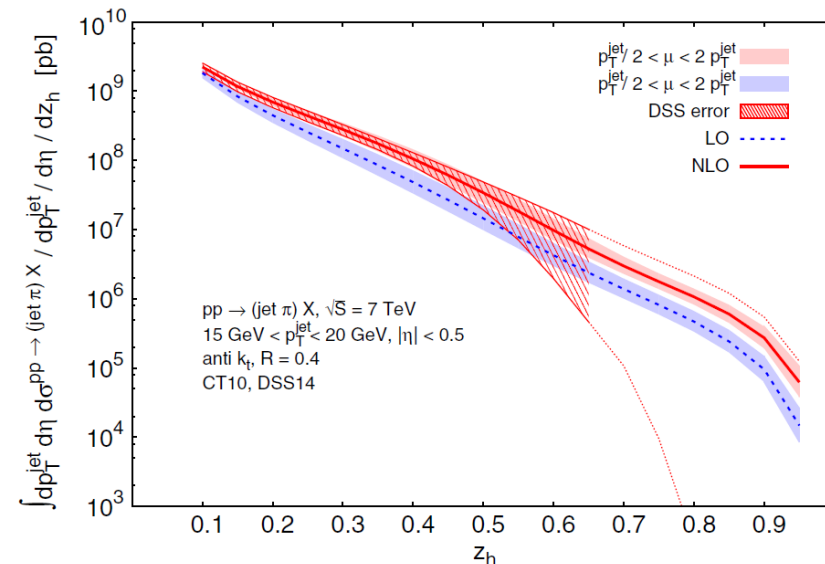


Enormous statistics available at low jet p_T !



Access FF's through
 $p+p(A) \rightarrow (\text{jet } h) X$

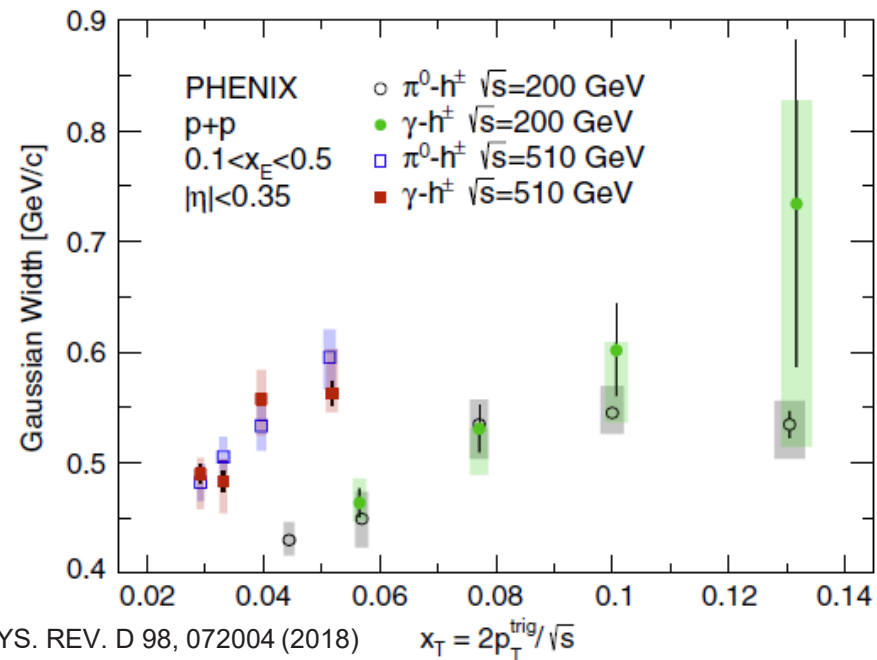
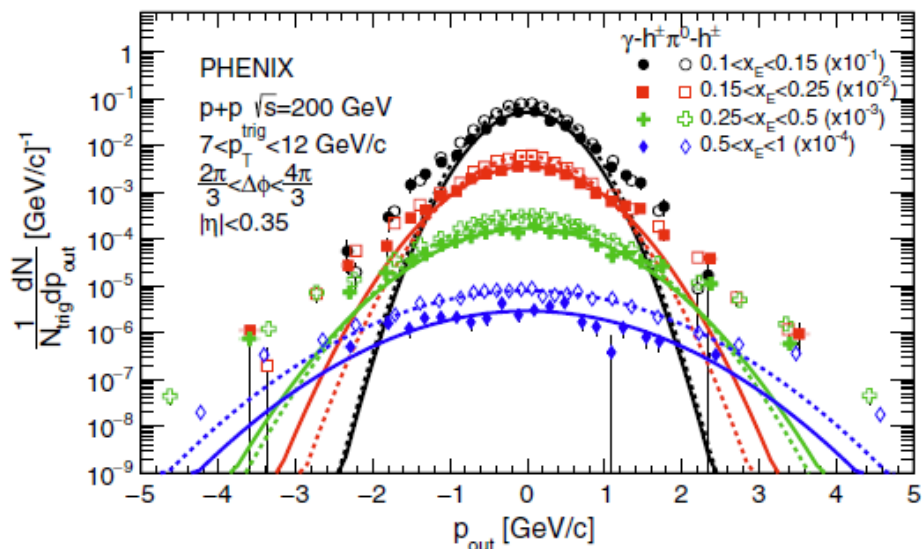
Kaufmann, Mukherjee and Vogelsang Phys.Rev.D 92 5, 054015



Hadronization—connections to spin-dependent and unpolarized observables

From John Lajoie

TMD Factorization Breaking



Relates also to interpretation of various spin observables. Connections to entanglement as well.

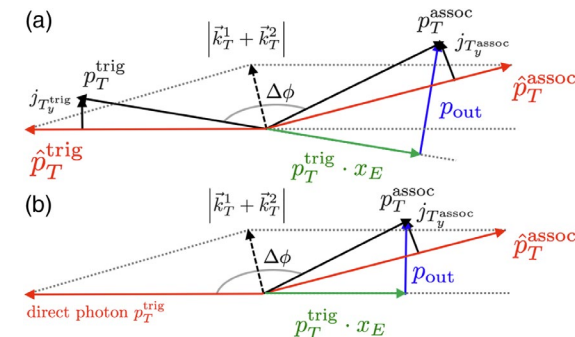
Di-hadron and photon-hadron correlations studied in PHENIX. Predicted to violate TMD factorization due to quantum-correlated partons between colliding hadrons due to color flow.

sPHENIX:

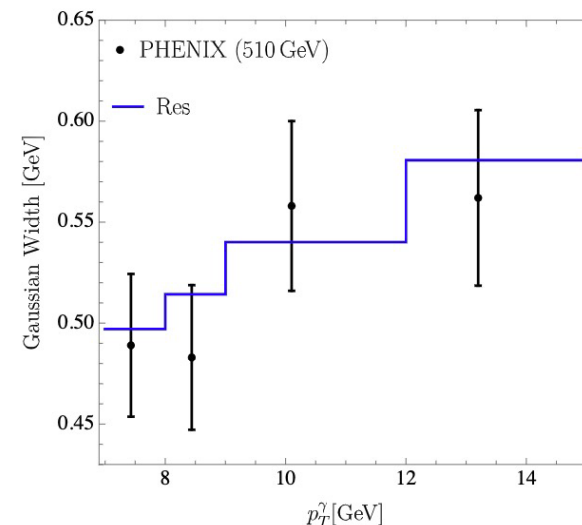
- Full jet reconstruction – access to better proxies for parton kinematics

Availability of theory calculations that *assume* factorization is key!

New data will be much more sensitive to even *subtle* effects of factorization breaking!

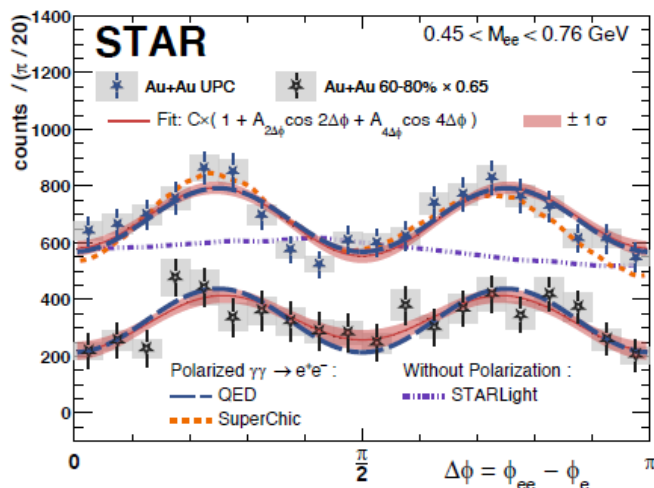


See talk by Zhongbo Kang

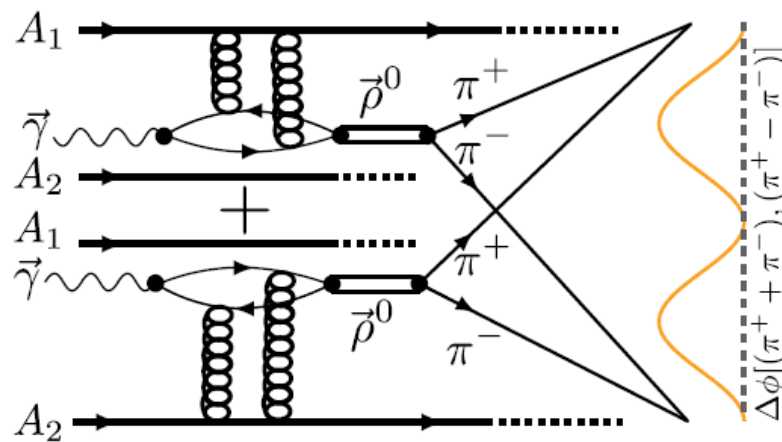


Highlights I : Polarized Photon-Gluon Collisions

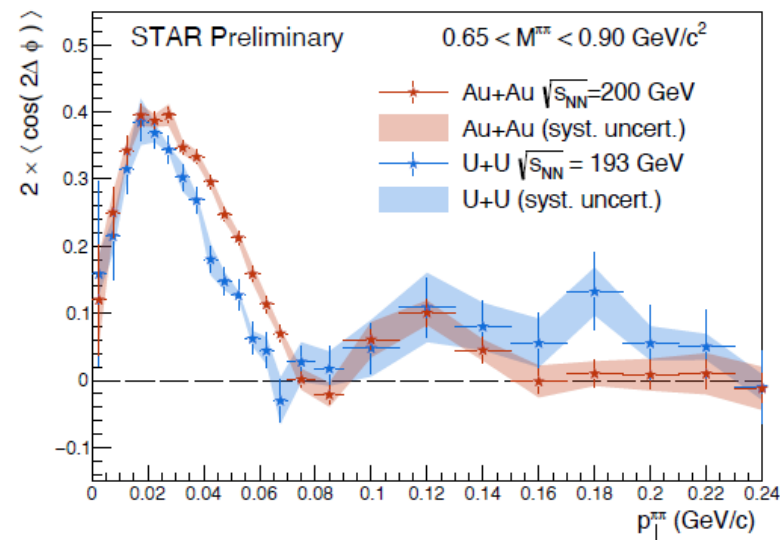
Significant $\cos 4\Delta\phi$ modulation in $\gamma\gamma \rightarrow e^+e^-$ process: Experimental demonstration of linear polarization of quasi-real photons



Two source interference in VM production → $\cos 2\Delta\phi$ modulation in $\rho^0 \rightarrow \pi^+\pi^-$



Interference shows rich structure vs. P_T

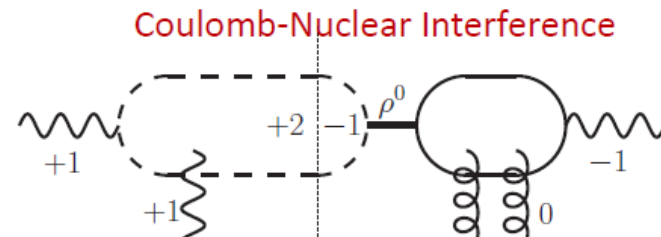


New Interference pattern observed in diffractive photo-nuclear interactions

- Experimental demonstration of sensitivity to gluon distribution and that incoherent does not contribute to interference pattern
- New measurement possibilities:
 - J/ψ , which provides hard scale for theoretical calculations,
 - Measurements in non-UPC, comparison of $\rho^0 \rightarrow \pi^+\pi^-$ vs. $J/\psi \rightarrow l^+l^-$ to see if interference exists in both
 - Differential measurements w.r.t. mass, rapidity to test interference characteristics
 - Observation of Coulomb-Nuclear Interference

May 25, 2021

Daniel Brandenburg
Christine Aidala, UMich



Should we be exploring even more spin-dependent QED-QCD connections? The two known QFTs in nature that admit bound states.

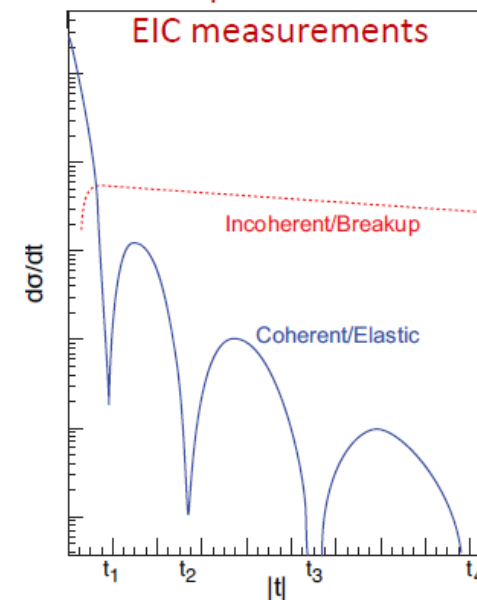
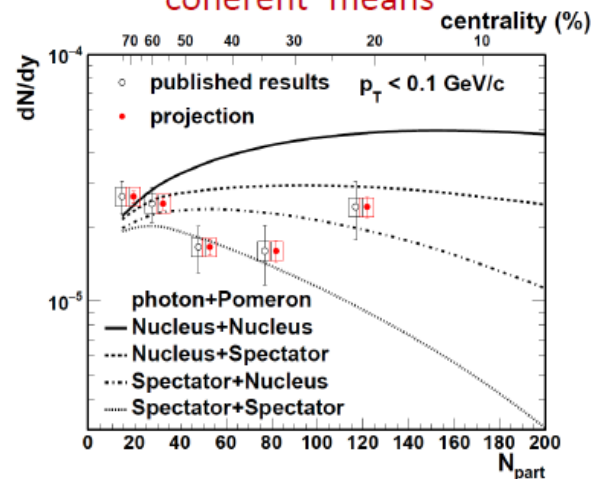
Highlights II : Theory Questions and EIC

Separation of coherent vs. incoherent is the essential experimental challenge for

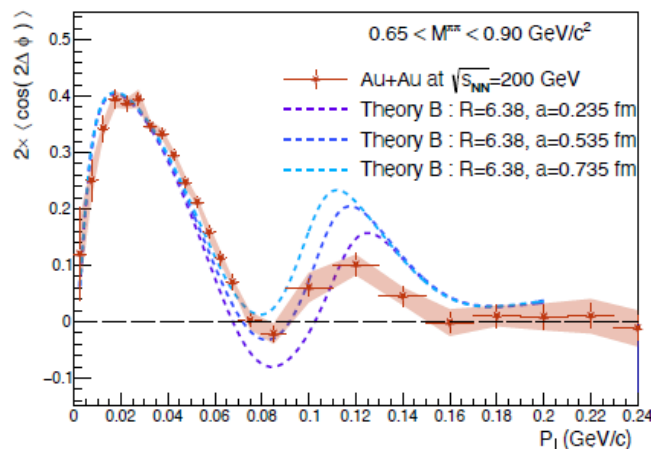
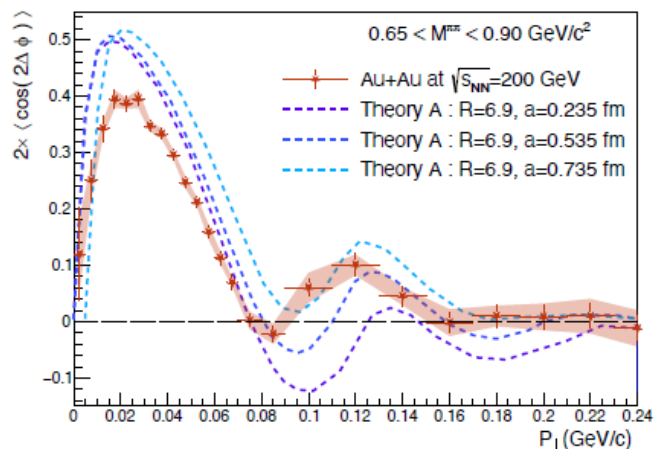
Theory Wish List:

- Full calculations for J/ψ etc.
- Predictions for U+U considering deformation
- Rapidity and mass dependence
- Pursue calculations for EIC case – do correlations exist and if so, what can we learn?
- Quantify effects of saturation/ modified gluon distribution?

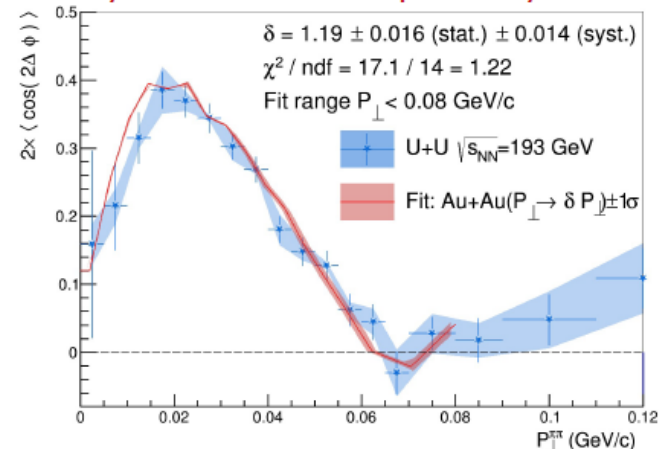
Gain a deeper understanding of what 'coherent' means



- Continue to pursue theory – gain quantitative agreement



Why are we sensitive primarily to the 'long'-axis

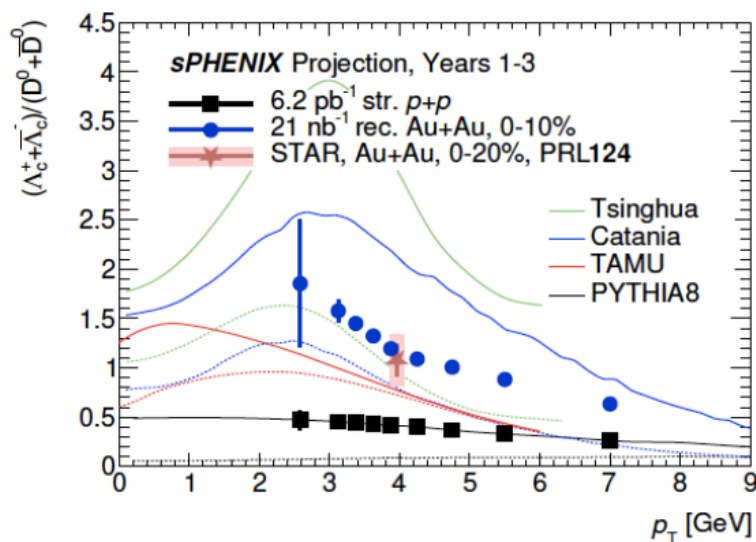


Further thoughts – Data analysis preservation

- Highlighted in Joe Osborn's talk
- RHIC data sets are unique worldwide (polarization, collision species, energies) and will remain so into the indefinite future—data preservation is critical!! Should initiate a more formal RHIC-wide effort, joint/coordinated among collaborations.
 - Seek dedicated funding for a collaborative effort?
 - Take advantage of DOE Computational Science Graduate Fellowships?
 - Data preservation is linked to open data. Other resources potentially available for open data?
 - Elevate formal data preservation service roles within the collaborations, so that individuals get due credit/visibility?

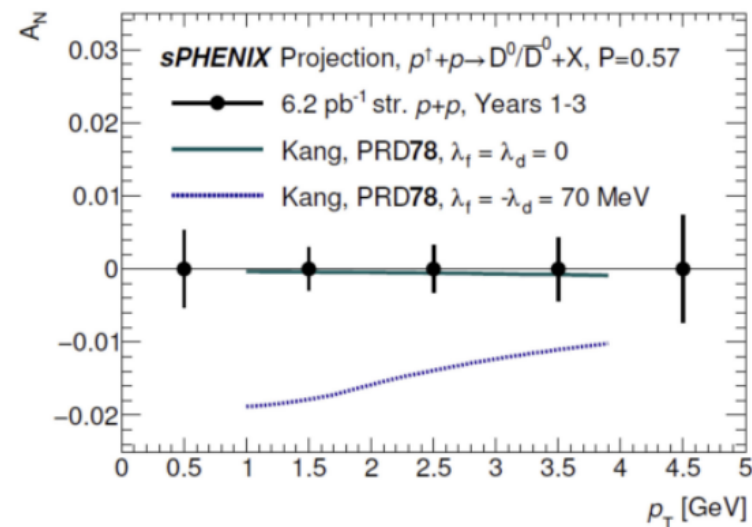
Backup

Charm/Bottom Hadrochemistry



- Precise measurement of various charm hadrons (Λ_c^+, D_s^+)
- Enable access to open bottom hadrons (Λ_b, B_s etc)
- Detail investigation of charm baryon spectroscopy in p+p collisions

D-meson A_N - Gluon Sivers Function



- D/Dbar A_N measurements allow access to tri-gluon correlator \rightarrow gluon Sivers function
- Opportunity with STAR forward upgrade to look for forward D/Dbar mesons
- pp/pA allows to constrain the gluon nPDFs