Summary:

(A Few) Highlights of Our Discussions

Collinear PDFs / FFs and Applications:

- What are the limiting factors in PDF uncertainties which are relevant for BSM searches?
  - Large-x gluons esp. from charm
  - What kind of improvement in precision would be necessary to make those uncertainties competitive?
  - Do we have the “technology” necessary to achieve N3LO precision?

- Do simultaneous PDF / FF extractions fully resolve the Kaon fragmentation puzzle?
  - Data limitations? What can be done at RHIC or LHC to help this befor the EIC? Forward W + charm to improve on strangeness?
  - BELLE II? Could we collaborate or contribute a student for a dedicated analysis?

Collinear PDFs / FFs and Applications:

- What consistency checks / reliability measures do we need (e.g. in PDF / FF reweighting) to be confident that we can trust the extractions and be confident that we haven't hidden new physics in the PDFs / FFs

- Do we see any hints of factorization breaking within the leading-twist, collinear picture?
  - What might such breaking or violations look like?
  - What would it take (theory + expt) to search for this?

Status and Prospects for TMDs:

•If we believe we have turned the corner on A_N for p p → pi X, what more do we need to "seal the deal"?

- •More phenomenological studies?
- •More data required?
- •Is this already in progress, or is there a need for a more concerted effort?

•If (transversity) x (Collins) fragmentation is the dominant mechanism in A_N for p p → pi X and these provide transversity constraints which are competitive with, e.g. dihadrons, is anything needed to take maximum advantage of this? Is it already in progress?

- Manpower limited at RHIC
- Forward upgrades would be essential if we need charged hadron discrimination

Status and Prospects for TMDs:

- What is the status of A_N for p A → h X?
  - Do we now have a complete calculation in the hybrid approach? (Hatta, Xiao, Yoshida, Yuan?)
  - What about the collinear twist-3 approach?
  - Jets vs identified hadrons?

- Is there potentially a problem within Pythia for HERMES / COMPASS kinematics in SIDIS?
  - If there is really a problem here, we're in deep trouble with knowledge of TMDs!
  - Could this be related to nonperturbative, factorization-breaking "string effects"?
  - Or just an insufficiently tuned DIRE module…?

- Are we lacking a solid factorization proof for e p → e' Q Qbar?

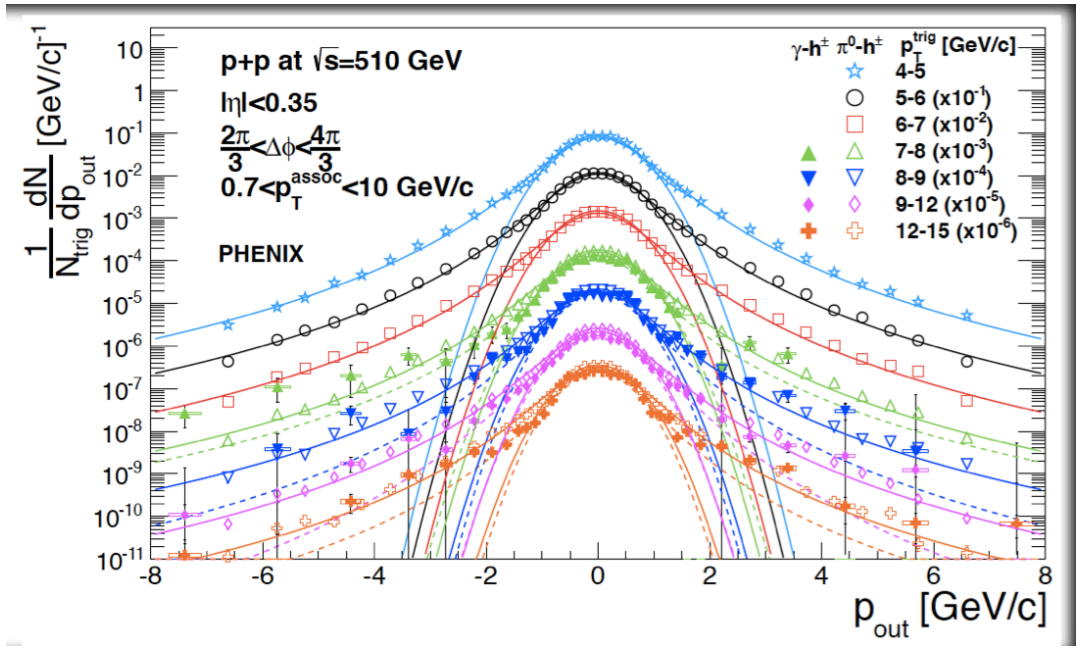
Factorization and Factorization Breaking:

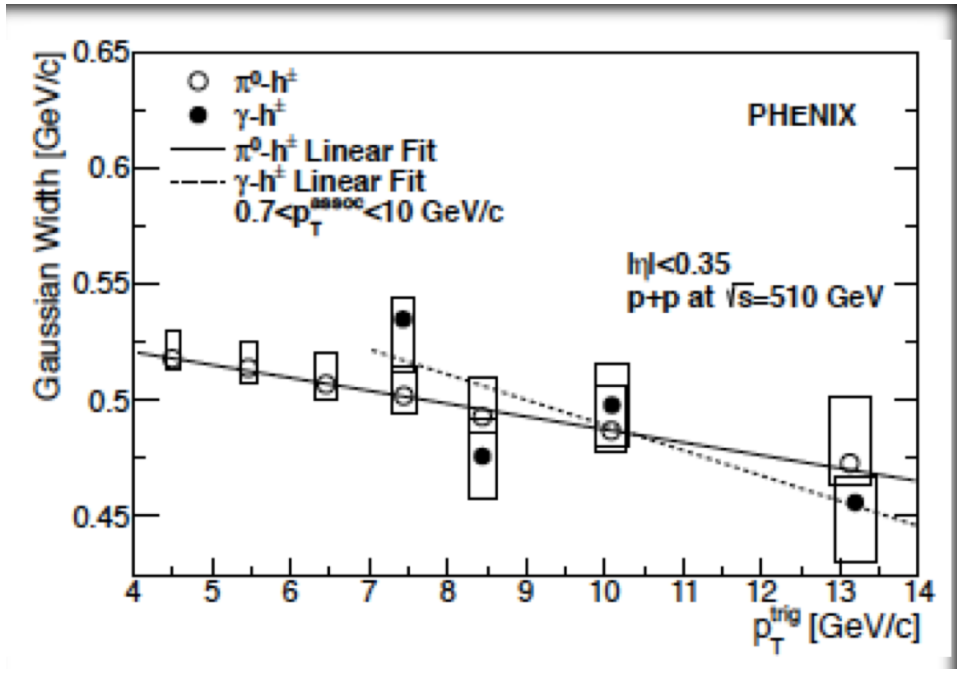
- How solidly tested is diffractive factorization? How could we improve or invalidate it?

- What is the nature / magnitude of factorization breaking in diffractive UPCs?
  - Is any relationship / universality between factorization breaking in pp or AA UPCs and the factorization breaking in pp → jet X?

- If "factorization breaking" is synonymous to multi-parton interactions, in which processes do we expect them to matter? What does this intuition add?
  - Are these "collective effects" of MPI in any way analogous / related to collectivity in heavy-ion collisions or high-multiplicity small systems?
  - Is it ludicrous to imagine a single "lensing function" or "gap survival probability" or other effective description applied between processes?
  - What does this mean for (approximate) universality?

Factorization and Factorization Breaking:





- How should we interpret PHENIX data on "nonperturbative factorization-breaking effects"?
  - Could this measurement in principle be really sensitive to factorization breaking?
  - Are they really reflected in the widths of the Gaussians?
  - Can the observable be improved (e.g. with jets instead of identified hadrons)?
  - Can it be replicated or extended at STAR or the LHC?
  - Is it appropriate to compare against simulations in Pythia, and which ones?

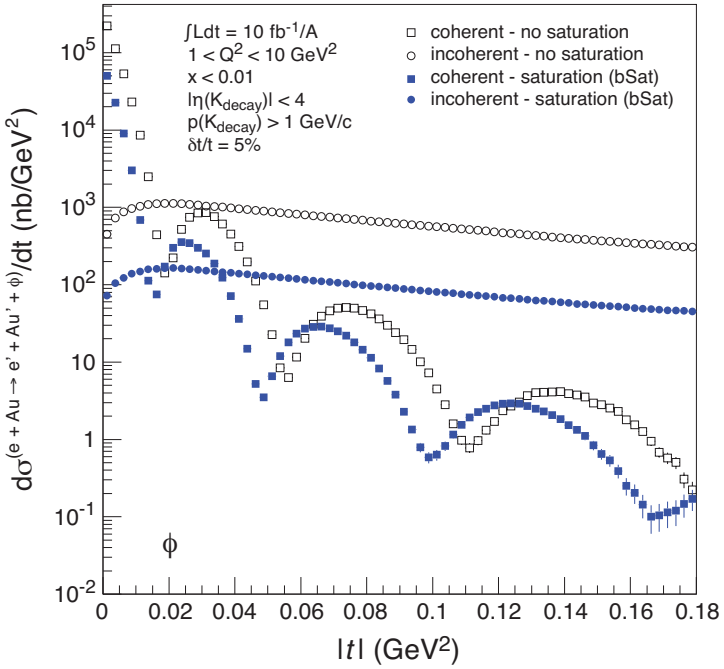
Diffraction:

- What is the meaning (or is there one?) or validity of the effective “Ingelman-Schlein model” which factorizes the “pomeron flux” from diffractive PDFs?

- What is the effect of skewedness on diffractive PDFs? Is this under any kind of control?

- What are the prospects at current RHIC (and post forward upgrades) for discerning between saturated and unsaturated states using diffraction?

    - Can / has a diffractive study for RHIC be / been done to see how big the possible separation is between leading-twist shadowing vs saturation?



Some Important Observables

(Suggestions Welcome!)

- Fragmentation channels in A_N for p p → h X in the forward direction
  - What about p A → h X A_N? What does it tell us different than p p?

- Odderon-mediated asymmetries in A_N for p p → h X in the backward direction
  - Look for C-odd asymmetry effects (h^+ , h^- splitting?)
  - Subleading sources of C-even observables?

- Diffraction and diffractive particle production - heavy quarks, inclusive jets, dijets, etc.
  - Sub-nucleonic fluctuations can make a difference in diffractive vector meson production in pA collisions → enhancement of the |t|-slope

- Diffractive dijet production in ep / eA collisions
  - Single longitudinal spin asymmetry → Jaffe-Manohar OAM

- Charge imbalance Q_T → proxy for N_{part} and hence collision geometry

- p p (or p A) → jet1 jet2 X to measure factorization-breaking effects.
  - What would these look like? How can we be sure we're measuring them?

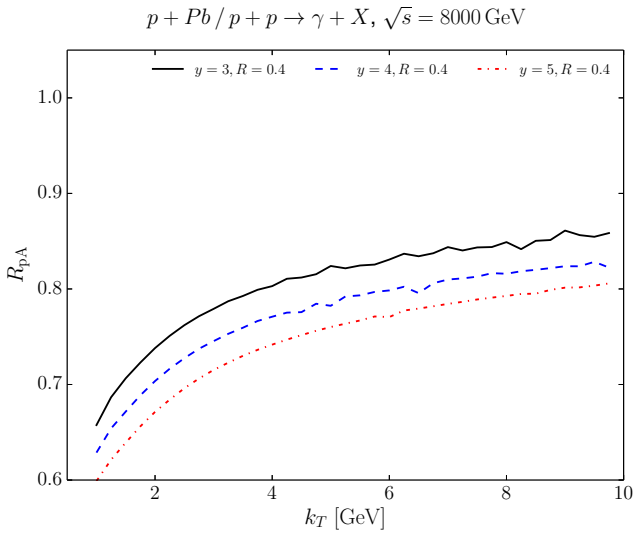
- Various TMD asymmetries: Sivers-type or Boer-Mulders-type
  - p p (or p A) → γ^* X (DY)
  - p p (or p A) → W X (DY-like)
  - p p (or p A) → h X at backward rapidities
  - p p (or p A) → $\gamma\ \gamma$ X
  - p p (or p A) → $\gamma(*)$ jet X
  - p p (or p A) → jet1 jet2 X
- Which of these are experimentally feasible at RHIC / sPHENIX / LHC?

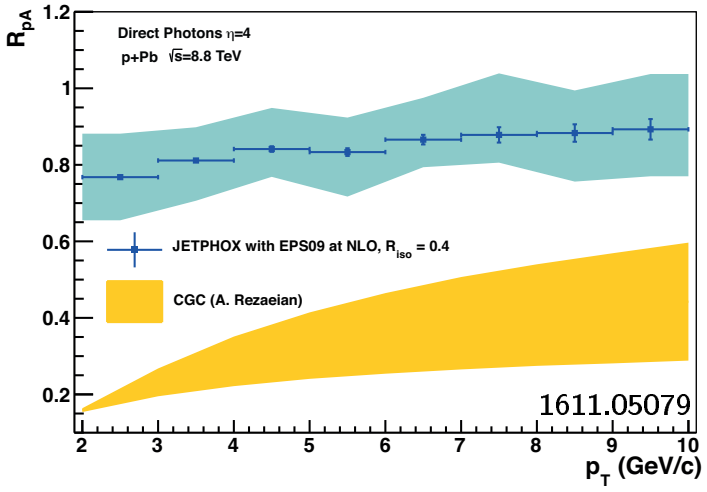
- Forthcoming data on W boson A_N from STAR with 14x as much data as the preliminary study.

- Forward jets / dijets and/or higher energies in A_{LL} will constrain the x-dependence of ΔG

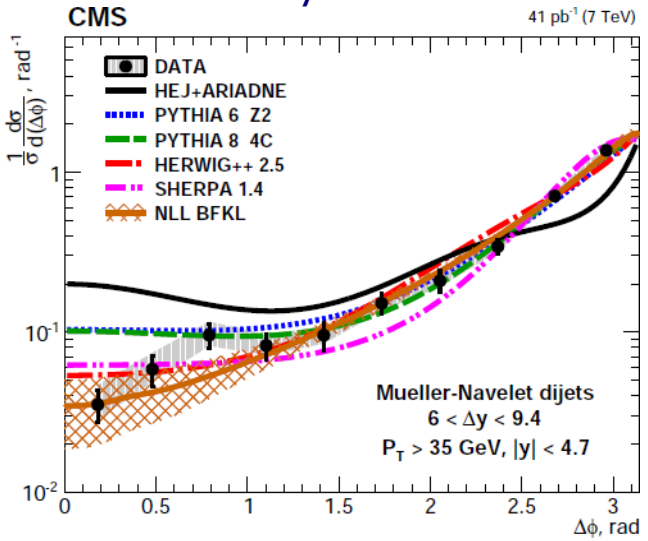
- Direct photon A_N → direct probe of twist-3 formalism (what do we know…???)

- Very forward Drell-Yan measurements with sPHENIX and STAR
  - Constrain antiquark distributions in the proton and in nuclei
  - Also significant effects on the small-x gluon nPDF
  - “Sweet-spot” in x and Q^2 lever arms vs. fixed-target and LHC measurements





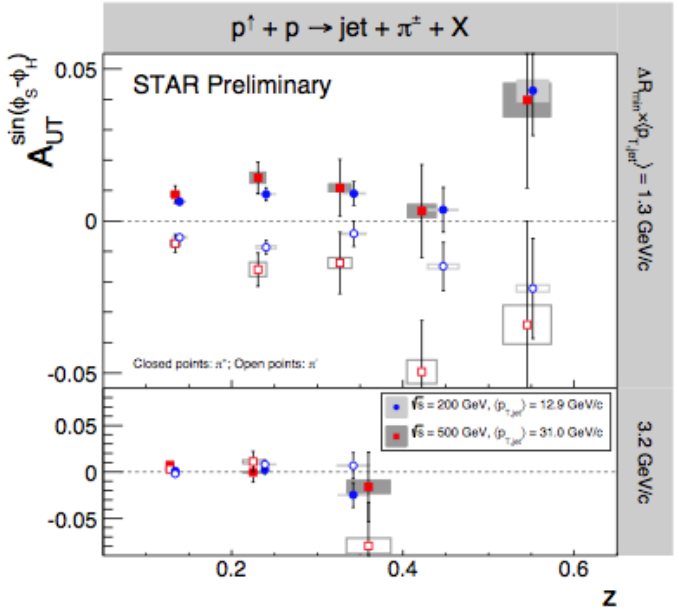
6<Δy<9.4

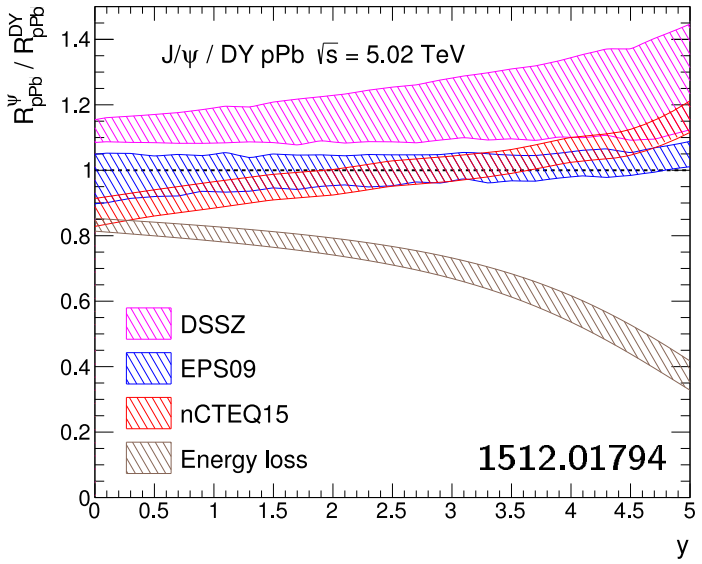


- Direct photon R_{pA} at forward rapidities: a test of CGC vs. "nuclear effects"
  - Significant differences between Ducloue et al and Rezaeian et al CGC calculations
  - Not a reliable discriminator / "flagship measurement"?

- Ultraperipheral collisions: diffraction for measuring nPDFs
  - A A → jet X
  - A A → jet1 jet2 X
- Possible factorization-breaking issues?

- Mueller-Navelet jets as a test of BFKL evolution?
  - What about in p+Pb at the LHC?





- Hadron in jet observables like p p → (h in jet) X
  - Constrain fragmentation and medium modifications of fragmentation
  - New input for J/psi production mechanisms and NRQCD matrix elements

- [$R_{pA}^{J/psi}$] / [R_{pA}^{DY}] to discriminate between CGC and energy loss mechanisms

Some Priority Tasks

(Suggestions Welcome!)

Community Building:

•How can we use the LHC to bridge between the RHIC Cold QCD Plan and an EIC?
- Depending on what programs are funded, there could be a significant gap.
- Complementarity is essential: just having DIS measurements is not enough.

•Need to write clear dictionaries between related formalisms. How can we most effectively break down the language barriers between all of our sub-communities?
- •How can we publicize / integrate especially the heavy ion / hot QCD community?

•Can we agree on a priority list of measurements and analyses that we need from current and future RHIC / LHC running?
- It may be valuable to document this in some fashion

•Establish / maximize collaboration on detector technology (e.g. ALICE + FoCal) which can be applied to the EIC

Essentials of Factorization:

- Develop a robust set of baseline predictions which assume factorization in processes where we expect factorization may be violated.

- Compare the same observables at fixed x and vary Q^2 to identify the "scale of factorization breaking" and/or suppress higher-twist effects [200 GeV RHIC vs 500 GeV RHIC vs LHC]
  - p p (or p A) → γ (or γ *) jet X
  - p p (or p A) → jet1 jet2 X

- Need to absolutely establish whether twist-3 factorization holds

- Need a broad study of what evidence we have for and against the presence of strong (or any) TMD evolution.
  - Can we constrain this, especially the nonperturbative kernel?
  - What data would be needed to help constrain the TMD evolution?
  - Should we be looking to asymmetries or absolute cross-sections? How much cancellation would we expect?

Other High-Priority Targets:

- Establish whether “hybrid factorization,” being in between collinear and TMD factorization, suffers from factorization-breaking effects
  - e.g. UPCs A + A → jet1 jet2 X

- Reduction in PDF uncertainties which limit BSM searches

- Need to improve the photon PDF to improve hadronic PDF extractions:
  - NNLO in QCD
  - NLO in EW corrections
- Also relevant for resolved photons in UPCs?

- Consistently incorporate both small-x and CSS (Q^2) evolution for the linearly polarized gluon distribution:
  - Small x and large Q^2 work against each other and compete for the size of the effect…

Software Applications?

- Compile some first attempt at a comprehensive architecture to test multiple signals for saturation simultaneously.
  - Possibly develop a software package like PARTONS or the work done by JetScape to take input on, say, the dipole scattering amplitude, and use it to calculate as many observables as possible which are straightforwardly related to it.
  - Ideally this would allow users to input a variety of dipole amplitudes and quickly scan their impact on multiple observables.
  - Combine / interface with pre-existing JetScape architecture?
  - Horizon 2020: European collaboration opportunities?
  - Future dedicated session / workshop to specifically combine expertise? Dedicated day at POETIC 2018?

Where Do We Want to Be in 6 – 12 Months?