Summary of the Parallel Sessions:

- Nuclear Structure at Large and Small x
- Nucleon Structure and Interactions

Matthew D. Sievert

BROOKHAVEN NATIONAL LABORATORY

Saturday July 9, 2016

EIC User Group Meeting 2016

Argonne NATIONAL LABORATORY

Our Charge as Conveners

- Solicit contributions from experts in the field to present recent work which builds the science case for the EIC, beyond the scope of the White Paper...
  - ➡ Subsequent developments
  - ➡ New ideas
- ...with possible bearing on the pending NAS review:
  - ➡ What is the merit and significance of the science?
  - ➡ What is its importance in the overall context of nuclear physics research?
  - ➡ What are the benchmarks of interest to the broader scientific community?
  - ➡ What is the value proposition to society?

Contributed Talks

Nuclear Structure at Large and Small x

V. Skokov	Azimuthal Anisotropy in Deep Inelastic Scattering Dijet Production at High Energy
A. Tarasov	Rapidity Factorization Approach and EIC
M. Sievert	Quark Helicity at Small x
R. Ent	Nuclear Structure at Large x with an EIC

Nucleon Structure and Interactions

D. Sokhan	Opportunities for Studying GPDs at the EIC
C. Mezrag	GPDs and the PARTON Software Project
C. Weiss	Exploring Nucleon-Nucleon Interactions in QCD with EIC
O. Hen	Bound Nucleon Structure Studies with an EIC

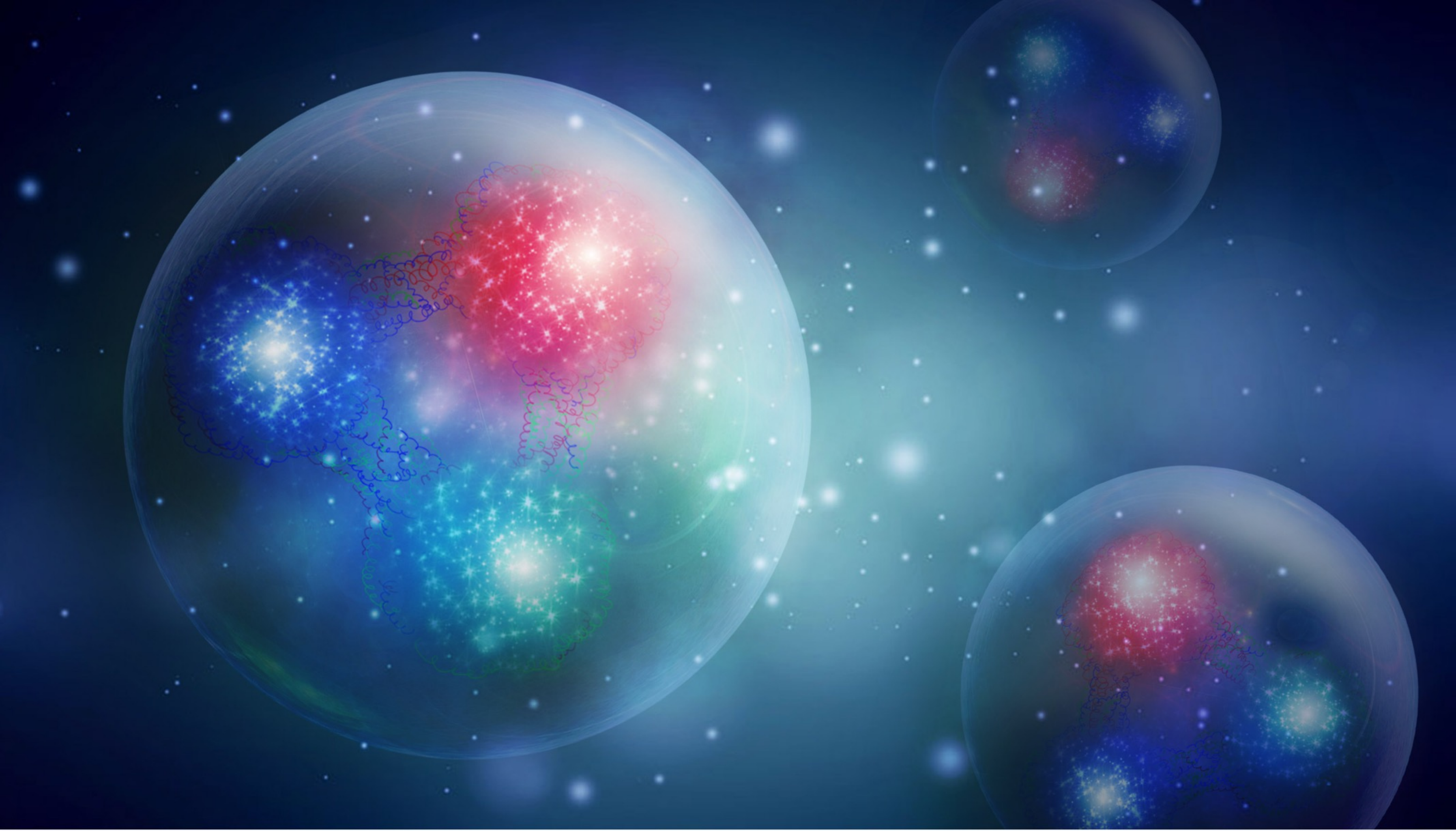
Nuclear Structure at Large and Small x

V. Skokov

A. Tarasov

M. Sievert

R. Ent



Rapidity factorization approach and EIC

Andrey Tarasov

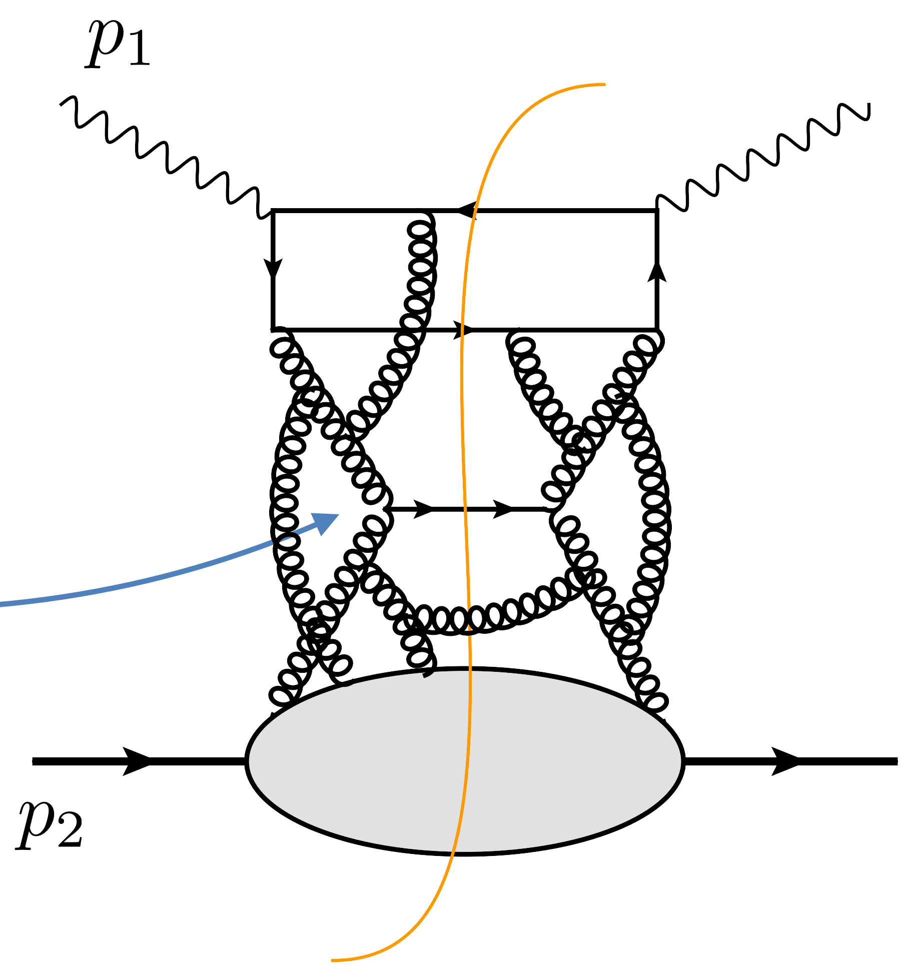
Electron Ion Collider User Group Meeting 2016, July 8, 2016

U.S. DEPARTMENT OF ENERGY JSA Jefferson Lab

Particle production at EIC

Scalar particle production (toy model, same approach can be applied to any observable):

$$S_\Phi \;=\; \lambda\int d^4z\; F^a_{\mu\nu}(z)F^{a\mu\nu}(z)\Phi(z)$$



Rapidity Factorization - separation in rapidity:

$$p^\mu = \alpha p_1^\mu + \beta p_2^\mu + p_\perp^\mu$$

$$A \to A|_{\alpha>\sigma} + A|_{\alpha<\sigma}$$

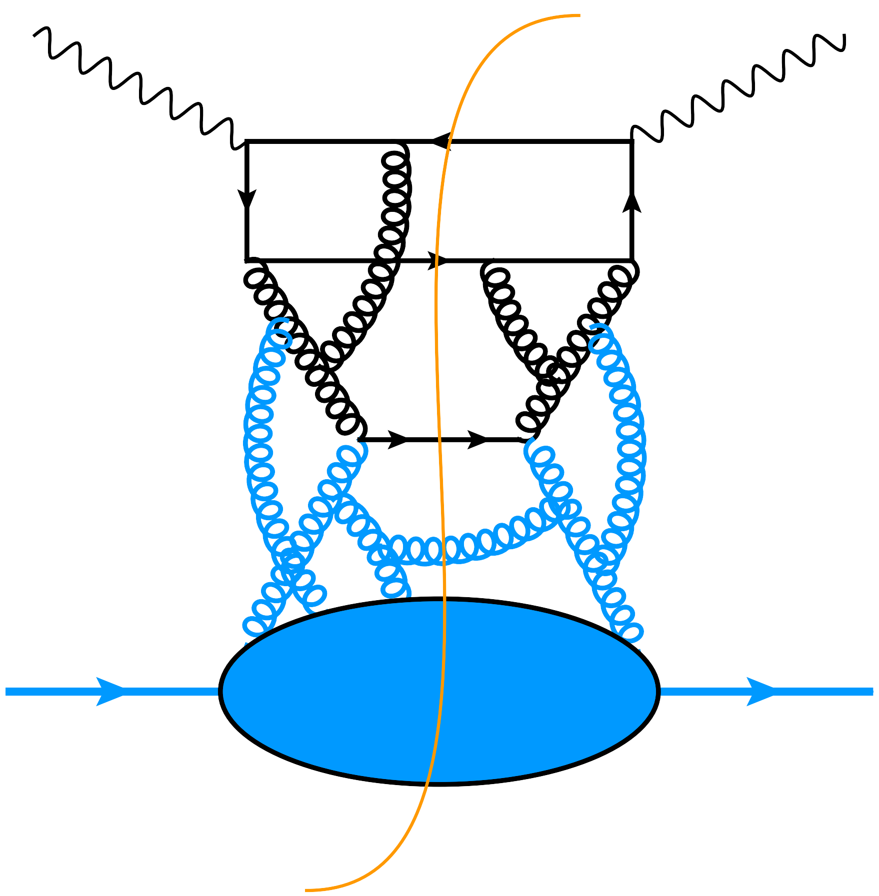
Rapidity cutoff

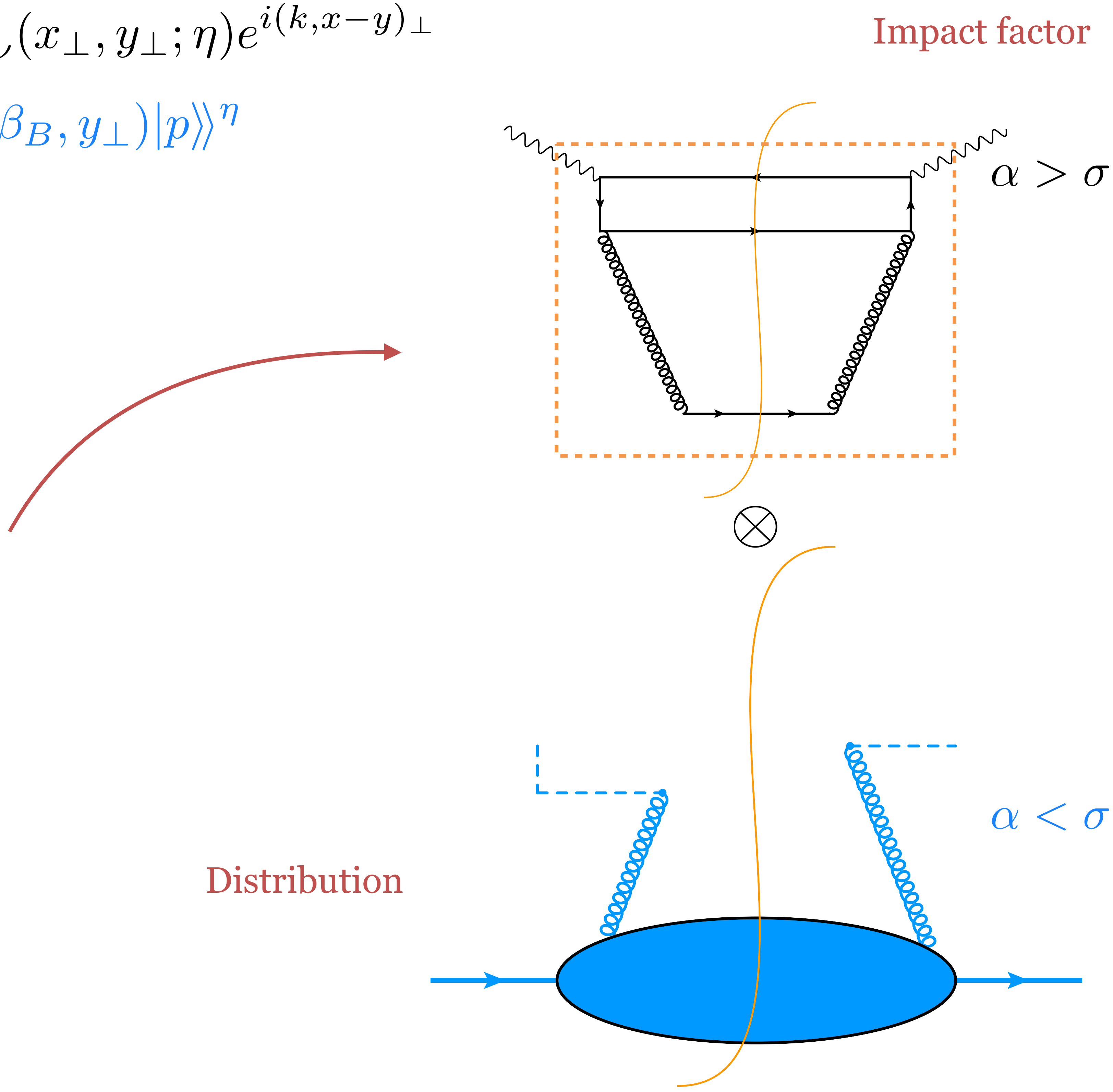
RAPIDITY FACTORIZATION

$$\lambda^{-2}\sigma_{\mu\nu} = \int d^2x_\perp d^2y_\perp\ \mathcal{I}^{ij}_{\mu\nu}(x_\perp, y_\perp; \eta) e^{i(k,x-y)_\perp}$$

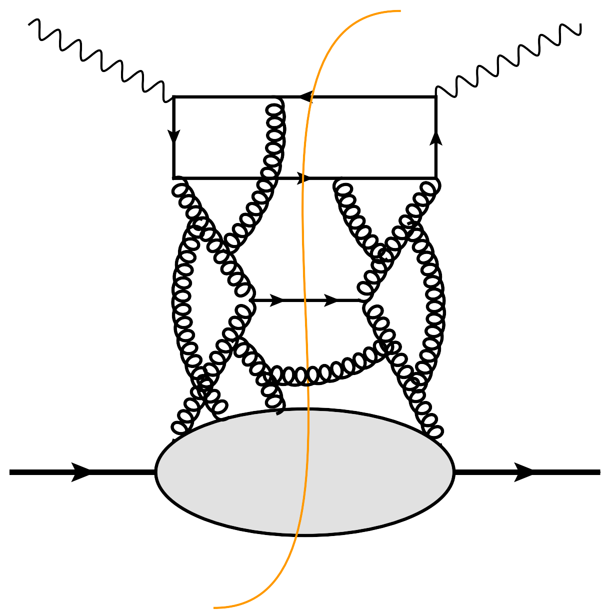
$$\times \langle\langle p|\tilde{\mathcal{F}}^a_i(\beta_B, x_\perp)[x_\perp, y_\perp]^{ab}_{-\infty}\mathcal{F}^b_j(\beta_B, y_\perp)|p\rangle\rangle^\eta$$

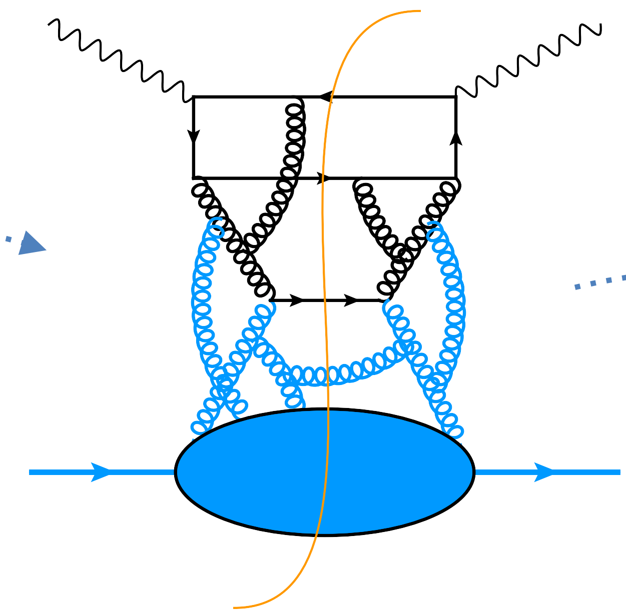
$$A \to A|_{\alpha>\sigma} + A|_{\alpha<\sigma}$$

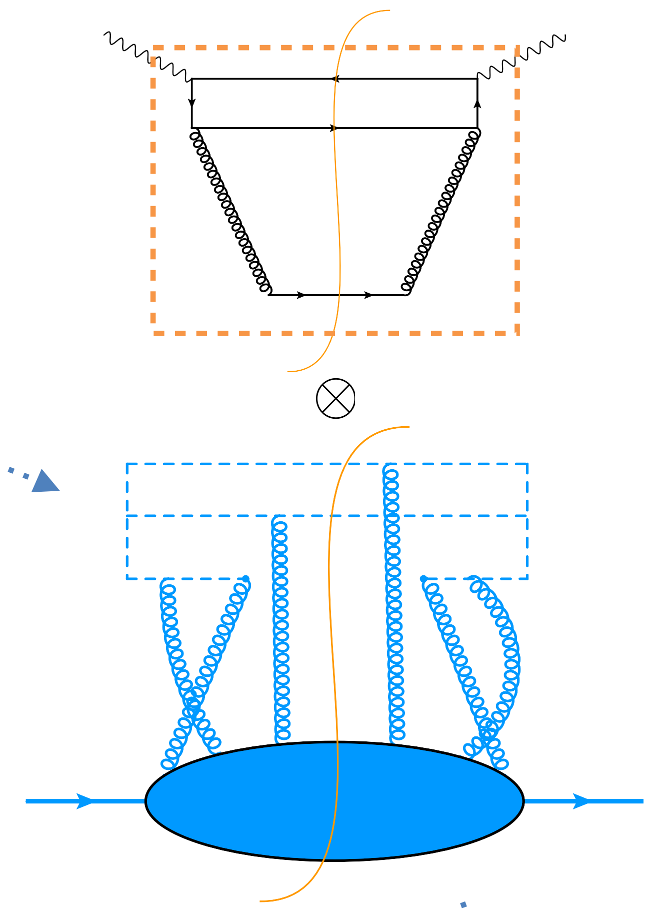


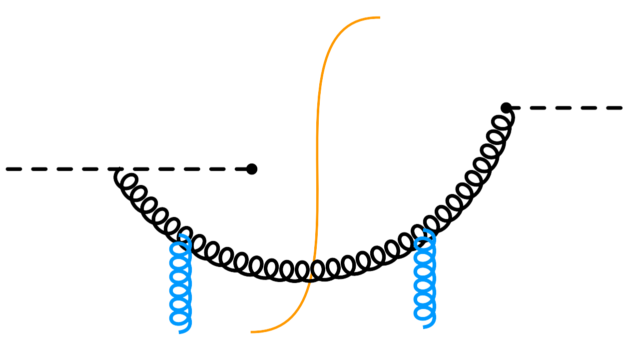


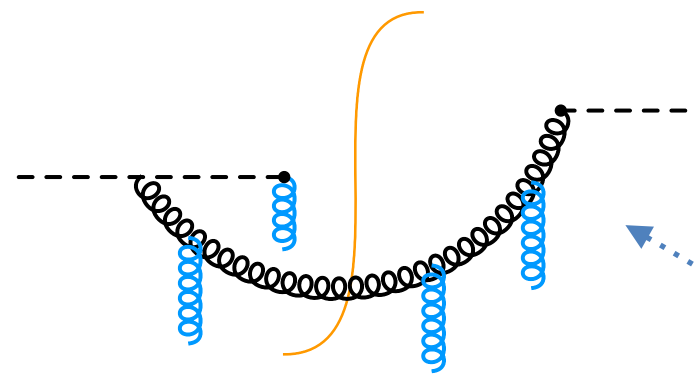
GENERAL STRUCTURE

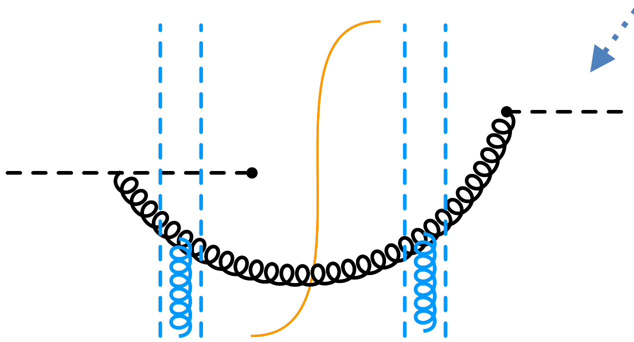


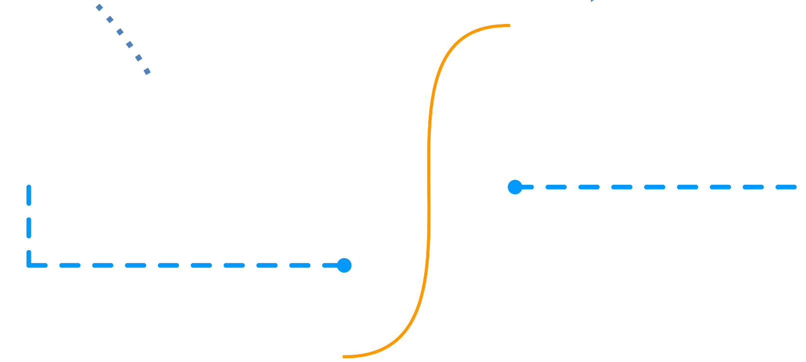




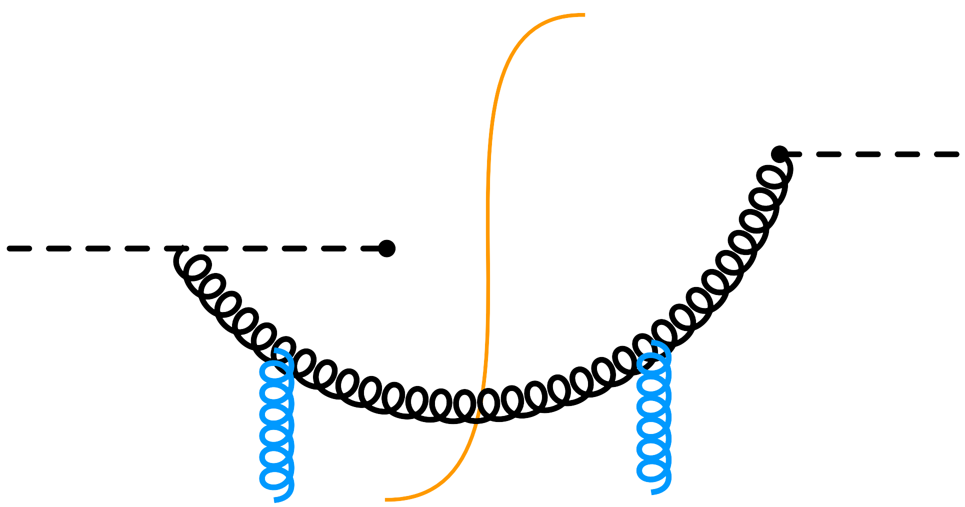








INTERMEDIATE REGIME



The approach can describe transition between different kinematic limits

Linear evolution equation (we can solve it)

$$
\begin{aligned}
&\frac{d}{d\ln\sigma}\mathcal{R}_{ij}(\beta_B,p_\perp;\sigma)\\
=\ &-\alpha_s N_c\int đ^2k_\perp\Big\{\Big[\Big(\frac{(2p-k)_k}{\sigma\beta_B s+p_\perp^2}\frac{\sigma\beta_B s g_{\mu i}-2(p-k)^\perp_\mu(p-k)_i}{\sigma\beta_B s+(p-k)_\perp^2}-2\frac{(p-k)^\perp_\mu g_{ik}+p_i g_{\mu k}}{\sigma\beta_B s+p_\perp^2}\Big)\\
\times\ &\Big(\frac{\sigma\beta_B s\delta^\mu_j-2(p-k)^\mu_\perp(p-k)_j}{\sigma\beta_B s+(p-k)_\perp^2}\frac{(2p-k)_l}{\sigma\beta_B s+p_\perp^2}-2\frac{(p-k)^\mu_\perp g_{jl}+\delta^\mu_l p_j}{\sigma\beta_B s+p_\perp^2}\Big)\\
+\ &2g_{ik}\Big(\frac{(p-k)_j(2p-k)_l-2p_j(p-k)_l}{(p-k)_\perp^2(\sigma\beta_B s+p_\perp^2)}+\frac{(p-k)_j(2p-k)_l}{(\sigma\beta_B s+(p-k)_\perp^2)(\sigma\beta_B s+p_\perp^2)}+\frac{2g_{jl}}{\sigma\beta_B s+p_\perp^2}\Big)\\
+\ &2g_{lj}\Big(\frac{(p-k)_i(2p-k)_k-2p_i(p-k)_k}{(p-k)_\perp^2(\sigma\beta_B s+p_\perp^2)}+\frac{(p-k)_i(2p-k)_k}{(\sigma\beta_B s+(p-k)_\perp^2)(\sigma\beta_B s+p_\perp^2)}+\frac{2g_{ik}}{\sigma\beta_B s+p_\perp^2}\Big)\Big]\\
\times\ &\theta\Big(1-\beta_B-\frac{(p-k)_\perp^2}{\sigma s}\Big)\mathcal{R}^{kl}\Big(\beta_B+\frac{(p-k)_\perp^2}{\sigma s},k_\perp\Big)\\
-\ &\frac{2}{k_\perp^2}[\delta^k_i(k_j p^l-2k^l p_j)+\delta^l_j(k_i p^k-2p_i k^k)]\mathrm{V.p.}\frac{1}{\sigma\beta_B s-(p-k)_\perp^2}\mathcal{R}_{kl}(\beta_B,p_\perp;\eta)\\
-\ &4\Big[\frac{\theta\big(1-\beta_B-\frac{(p-k)_\perp^2}{\sigma s}\big)}{(p-k)_\perp^2}\mathcal{R}_{ij}\Big(\beta_B+\frac{(p-k)_\perp^2}{\sigma s},k_\perp;\eta\Big)-\mathrm{V.p.}\frac{\sigma\beta_B s}{k_\perp^2(\sigma\beta_B s-k_\perp^2)}\mathcal{R}_{ij}(\beta_B,p_\perp;\eta)\Big]\Big\}
\end{aligned}
$$

Moderate-x (DGLAP).
$\beta_B\sim 1$ and $p_\perp^2\sim(x-y)_\perp^{-2}\sim s$

Sudakov evolution
$\beta_B\sim 1$ and $p_\perp^2\sim(x-y)_\perp^{-2}\ll s$

Small-x (BFKL).
$\beta_B\ll 1$ and $p_\perp^2\sim(x-y)_\perp^{-2}\ll s$

Ian Balitsky, A.T. 2016

Azimuthal Anisotropy in Deep Inelastic Scattering Dijet Production at High Energy

Vladimir Skokov (RBRC BNL)

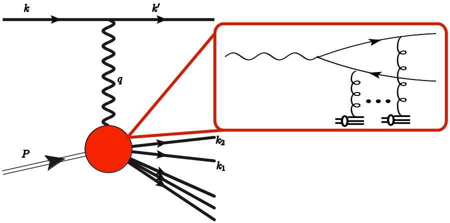
July 8, 2016

A. Dumitru, T. Lappi and V. S. Phys.Rev.Lett. 115 (2015) 25, 252301

A. Dumitru and V. S., arXiv:1605.02739

A. Dumitru, V. S. and T. Ullrich, work in progress

DIJET PRODUCTION IN DIS AT SMALL X



- DIS dijet production: $\gamma^* A \rightarrow q\,\bar{q}\,X$
- Multiple scatterings of (anti) quark are accounted for by ressumation:

$$U(\mathbf{x}) = \mathbb{P}\exp\left\{ig\int dx^- A^+(x^-, \mathbf{x}_\perp)\right\}$$

- In color dipole model this process corresponds to

$$\frac{d\sigma^{\gamma^* A\rightarrow q\bar{q}X}}{d^3k_1 d^3k_2} =$$

$$N_c\alpha_{em}e_q^2\delta(p^+ - k_1^+ - k_2^+)\int\frac{d^2x_1}{(2\pi)^2}\frac{d^2x_2}{(2\pi)^2}\frac{d^2y_1}{(2\pi)^2}\frac{d^2y_2}{(2\pi)^2}\exp\left(-i\mathbf{k}_1(\mathbf{x}_1-\mathbf{y}_1)-i\mathbf{k}_2(\mathbf{x}_2-\mathbf{y}_2)\right)$$

$$\sum_{\gamma\alpha\beta}\psi^{\mathrm{T,L}\gamma}_{\alpha\beta}(\mathbf{x}_1-\mathbf{x}_2)\psi^{\mathrm{T,L}\gamma *}_{\alpha\beta}(\mathbf{y}_1-\mathbf{y}_2)\left[1+\frac{1}{N_c}\Big(\langle \mathrm{Tr}\,U(\mathbf{x}_1)U^\dagger(\mathbf{y}_1)U(\mathbf{y}_2)U^\dagger(\mathbf{x}_2)\rangle\right.$$

$$\left.-\langle \mathrm{Tr}\,U(\mathbf{x}_1)U^\dagger(\mathbf{x}_2)\rangle - \langle \mathrm{Tr}\,U(\mathbf{y}_1)U^\dagger(\mathbf{y}_2)\rangle\Big)\right] \quad \uparrow \text{Quadrupole contribution}$$

- Splitting wave function of $\gamma^\star$ with longitudinal momentum p^+ and virtuality Q^2
- This expression can be computed without any further simplifications with quadrupole, but no direct relation to TMD result

DiJet cross section

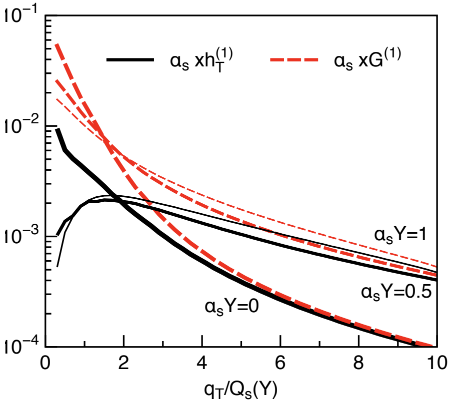
DiJet cross section to this order

$$\frac{d\sigma^{\gamma_T^* A\to q\bar{q}X}}{d^2k_1 dz_1 d^2k_2 dz_2}$$
$$= \alpha_s \alpha_{em} e_q^2 \left(z_1^2 + z_2^2\right)\left[\frac{P^4 + \epsilon_f^4}{(P^2+\epsilon_f^2)^4}\left(xG^{(1)}(x,q^2) - \frac{2\epsilon_f^2 P^2}{P^4+\epsilon_f^4} xh^{(1)}(x,q^2)\cos 2\phi + \mathcal{O}\left(\frac{1}{P^2}\right)\right)\right.$$
$$\left. - \frac{48\epsilon_f^2 P^4}{\sqrt{2}\,(P^2+\epsilon_f^2)^6}\Phi_2(x,q^2)\cos 4\phi\right]$$

$$\frac{d\sigma^{\gamma_L^* A\to q\bar{q}X}}{d^2k_1 dz_1 d^2k_2 dz_2}$$
$$= 8\alpha_s \alpha_{em} e_q^2 z_1 z_2 \epsilon_f^2 \left[\frac{P^2}{(P^2+\epsilon_f^2)^4}\left(xG^{(1)}(x,q^2) + xh^{(1)}(x,q^2)\cos 2\phi + \mathcal{O}\left(\frac{1}{P^2}\right)\right)\right.$$
$$\left. + \frac{48 P^4}{\sqrt{2}\,(P^2+\epsilon_f^2)^6}\Phi_2(x,q^2)\cos 4\phi\right] .$$

A. Dumitru and V. S., arXiv:1605.02739

Small x evolution



Reminder of McLerran-Venugopalan model results

$$xh_\perp^{(1)} = \frac{S_\perp}{2\pi^3\alpha_s}\frac{N_c^2-1}{N_c}\int_0^\infty drr\frac{J_2(q_\perp r)}{r^2\ln\frac{1}{r^2\Lambda^2}}\left(1-\exp\left(-\frac{1}{4}r^2Q_s^2\right)\right)$$

$$xG^{(1)} = \frac{S_\perp}{2\pi^3\alpha_s}\frac{N_c^2-1}{N_c}\int_0^\infty drr\frac{J_2(q_\perp r)}{r^2}\left(1-\exp\left(-\frac{1}{4}r^2Q_s^2\right)\right)$$

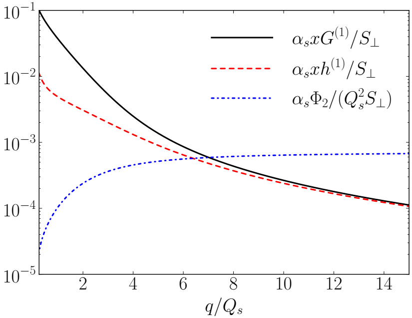
Large $q_\perp \gg Q_s$: $xh_\perp^{(1)} = xG^{(1)} \propto 1/q_\perp^2$

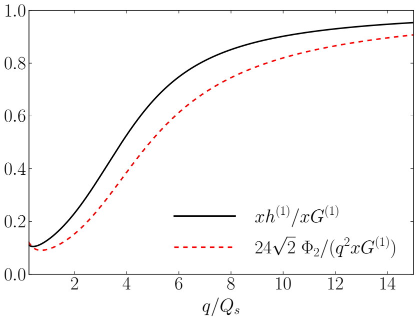
Small $q_\perp \ll Q_s$: $xh_\perp^{(1)} \propto q_\perp^0 \quad xG^{(1)} \propto \ln\frac{Q_s^2}{q_\perp^2}$

- at large $q_\perp$, saturation of positivity bound $h_\perp^{(1)} \to G^{(1)}$, as also was found in pert. twist 2 calculations of small x field of fast quark
- at small $q_\perp$, $h_\perp^{(1)}/G^{(1)} \to 0$
- both functions decrease fast as functions of $q_\perp$: best measured when $q_\perp \approx Q_s$. Nuclear target!

A. Dumitru, T. Lappi and V. S. Phys.Rev.Lett. 115 (2015) 25, 252301

MV results





These functions determine the amplitudes of the $\cos 2n\phi$ contributions to the dijet angular distributions for $n = 0, 1, 2$, respectively.

A. Dumitru and V. S., arXiv:1605.02739

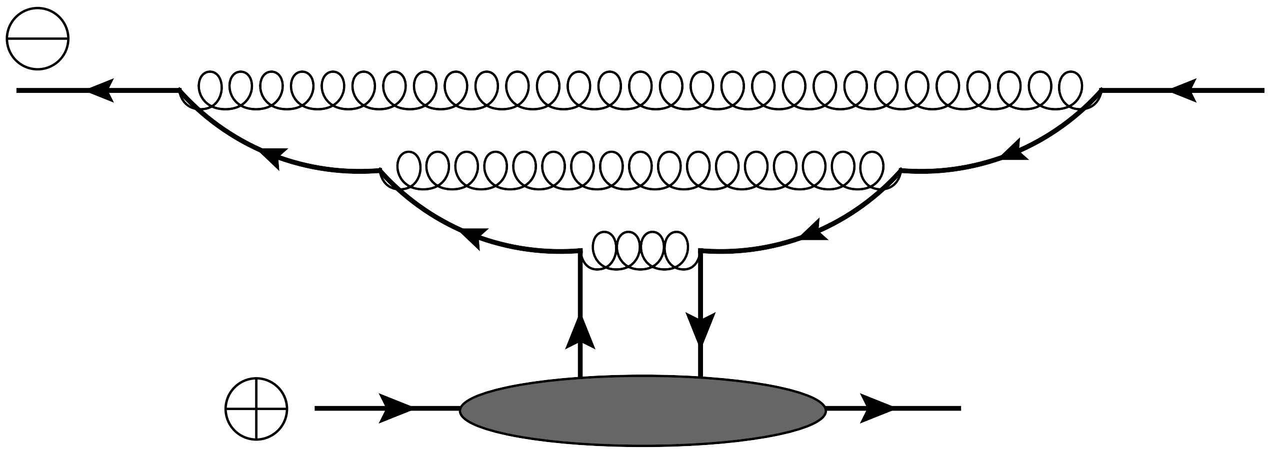
Quark Helicity at Small x

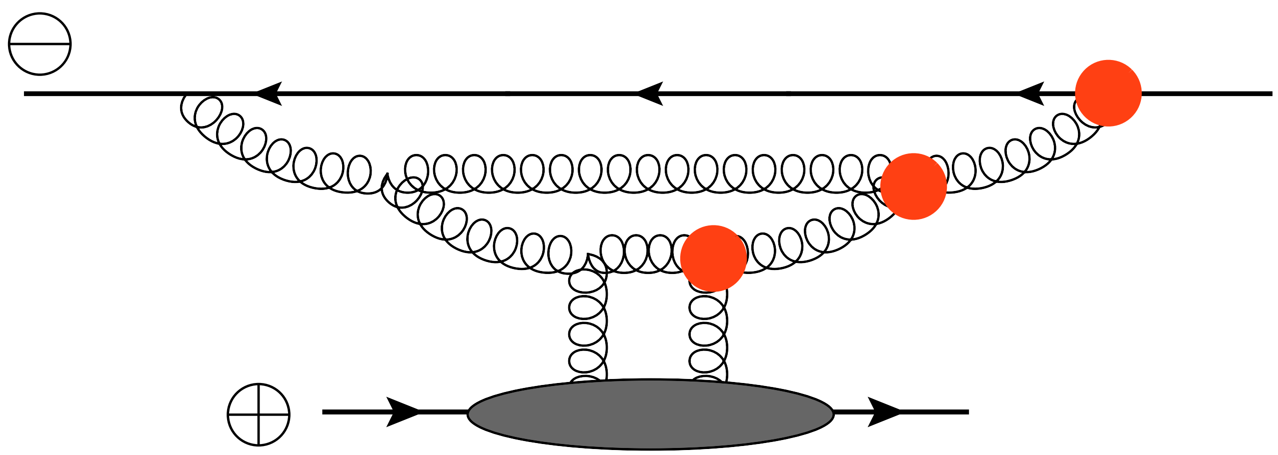
Matthew D. Sievert
with Daniel Pitonyak
and Yuri Kovchegov

Friday July 8, 2016

EIC User Group Meeting 2016

Constructing Polarized Splitting Kernels





- Kernels: Spin-dependent quark / gluon wave functions

➡ Soft quarks and soft gluons can mix (same order)

- Requires longitudinal ordering and lifetime ordering

$$1 \gg z_1 \gg z_2 \gg \cdots \gg x \qquad \frac{k_{1T}^2}{z_1} \ll \frac{k_{2T}^2}{z_2} \ll \cdots$$

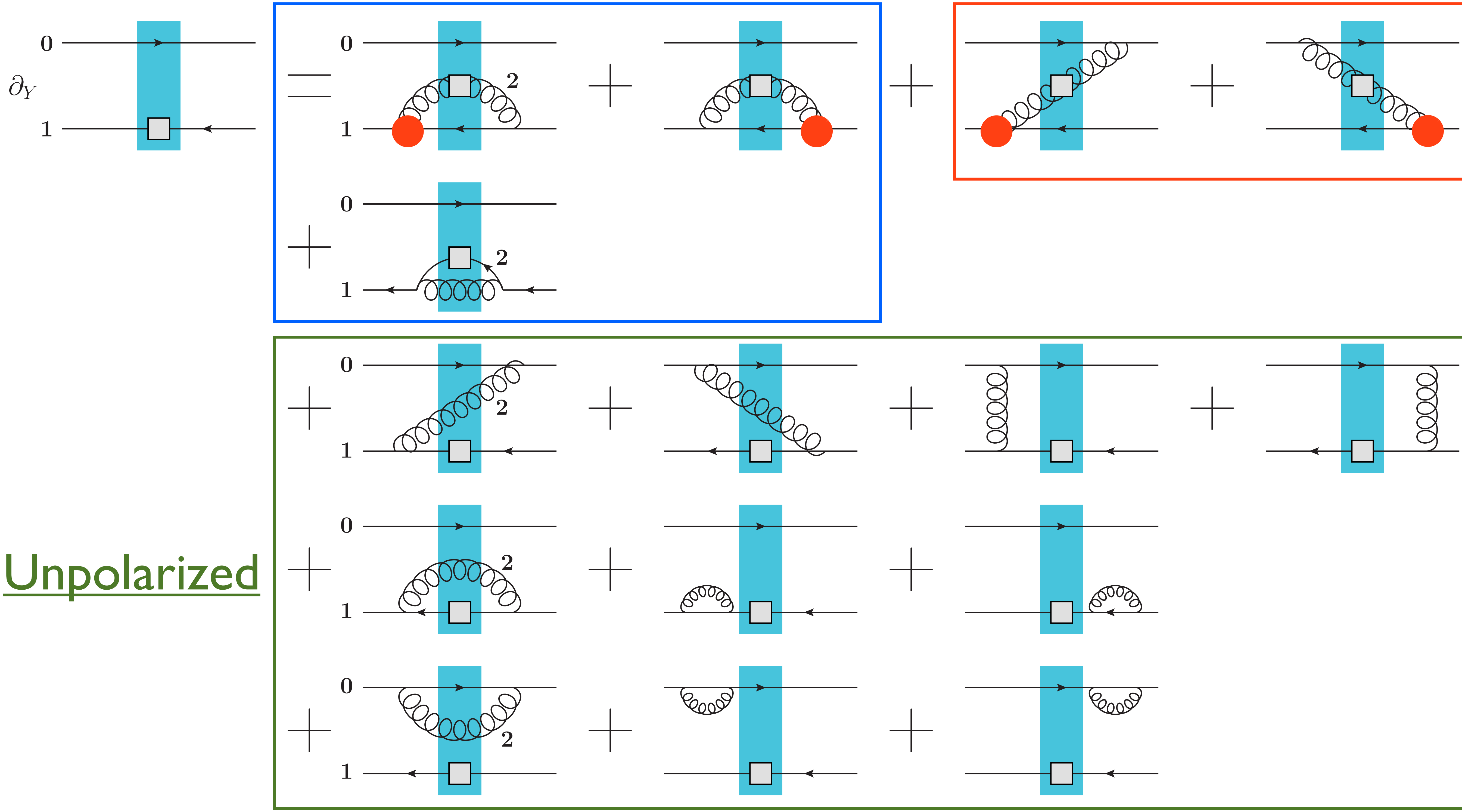
➡ Includes "infrared" phase space: $k_{1T}^2 \gg k_{2T}^2 \gg k_{1T}^2 \frac{z_2}{z_1}$

- Leads to double-log evolution.

➡ Faster evolution than unpolarized BK!

$$\alpha_s \ln^2 \frac{1}{x} \sim 1$$

Ladder: **Non-Ladder:**



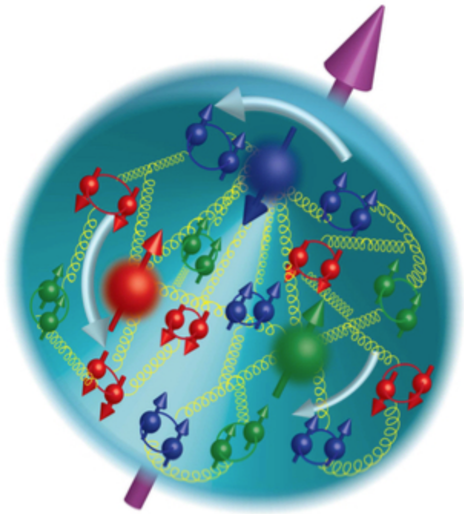
Unpolarized

Summary

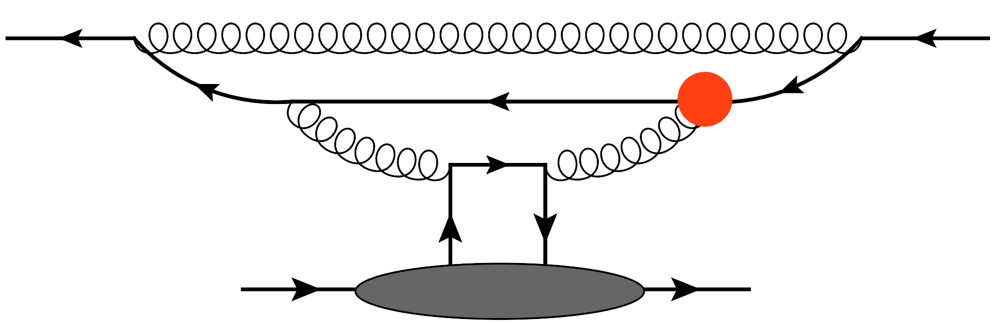
- Up to 35% of the proton angular momentum is unaccounted for.
  - ➡ Is there significant polarization at small x?

$$0.001 < x < 1$$

$$\Delta\Sigma \approx 0.25 \ \ (25\%)$$
$$\Delta G \approx 0.2 \ \ (40\%)$$



- Quark / gluon splitting leads to rich double-logarithmic evolution equations



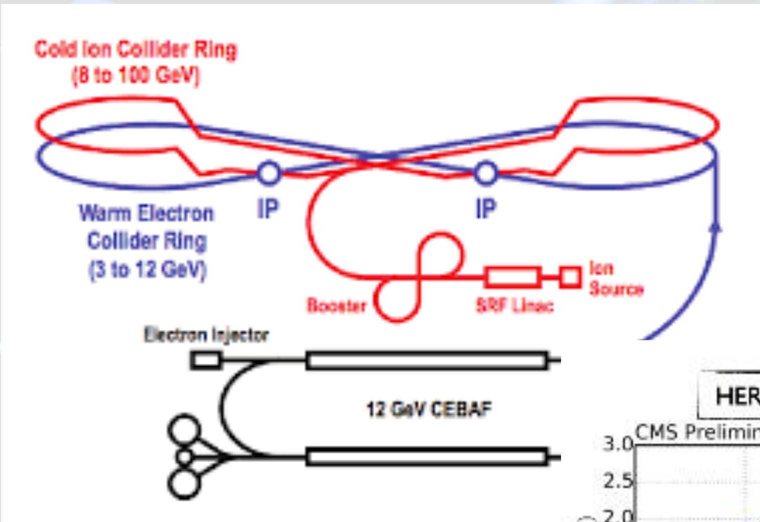
  - ➡ Slows down the decrease at small x

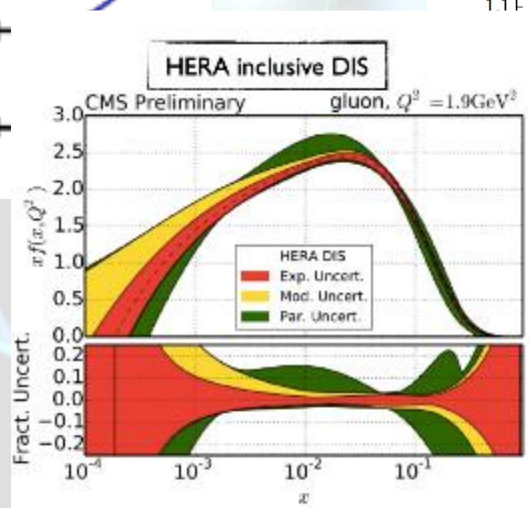
- We estimate behavior on the borderline between weak suppression and weak growth at small x.

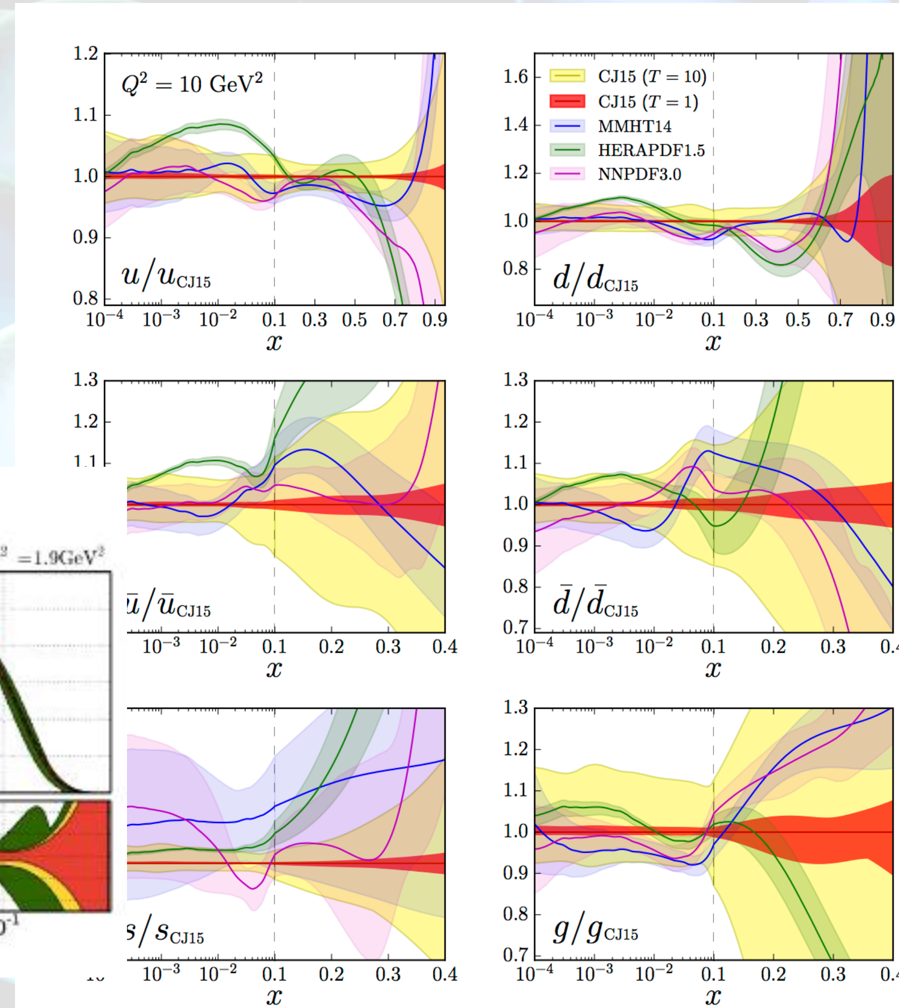
$$\alpha_s = 0.3 \div 0.4$$

$$x g_1 \sim \left(\frac{1}{x}\right)^{0.02} \div x^{0.11}$$

Determining Large x PDFs at JLEIC – *a work in progress*

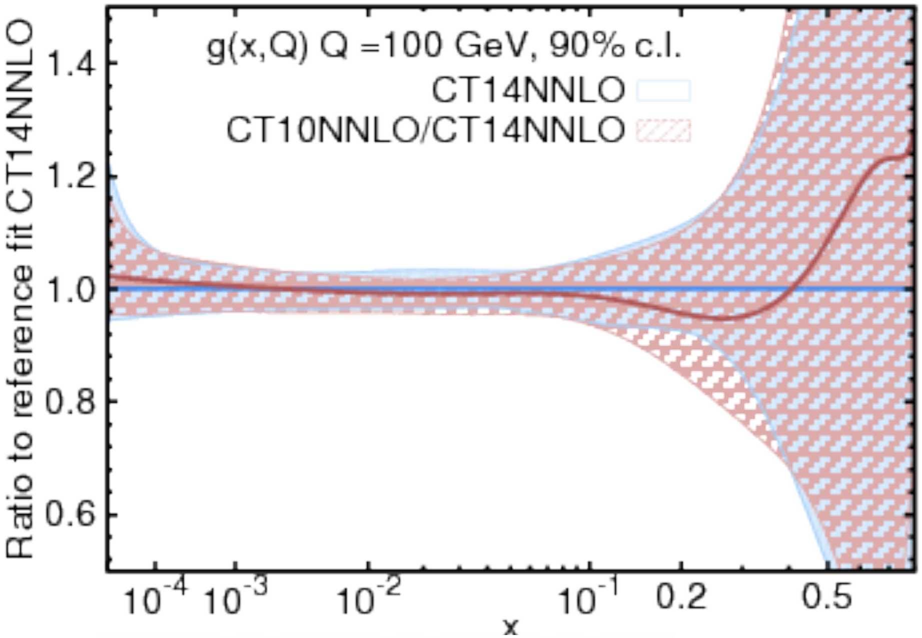


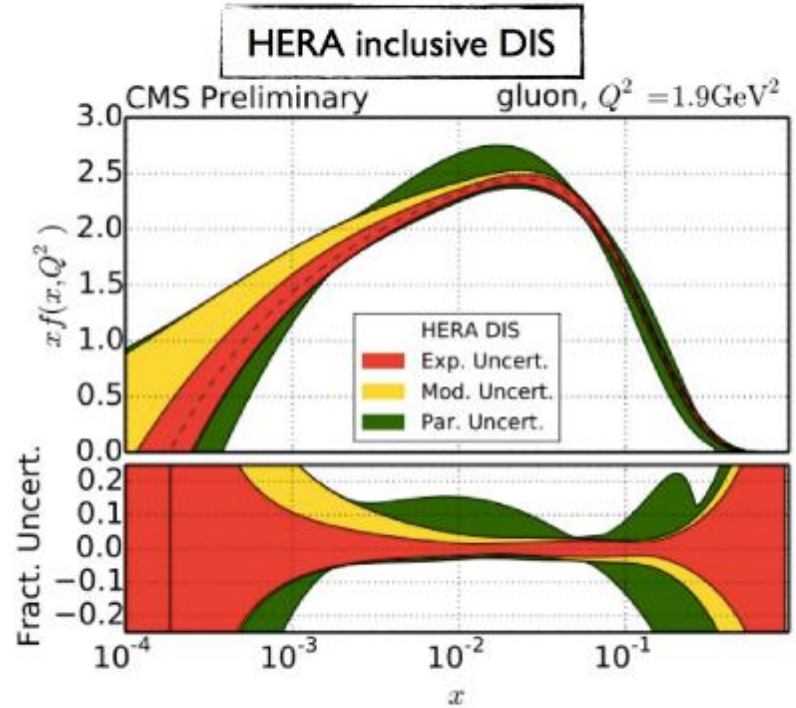


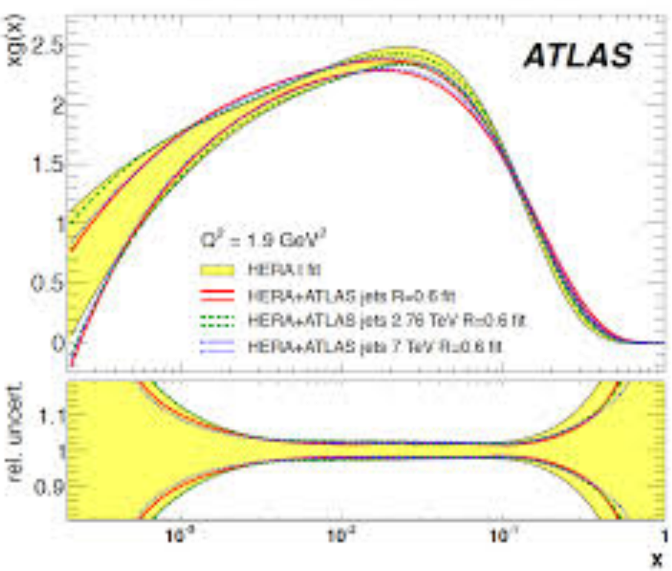


A. Accardi (Hampton),
R. Ent, C. Keppel,
K. Park, R. Yoshida (JLab),
M. Wing (UC London)

g(x) is poorly known at large (and small) x…



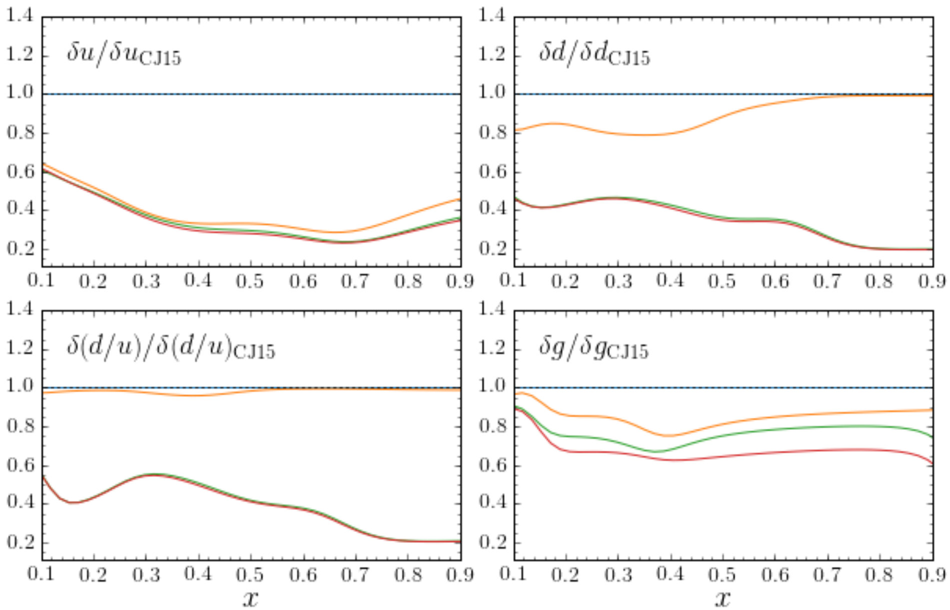


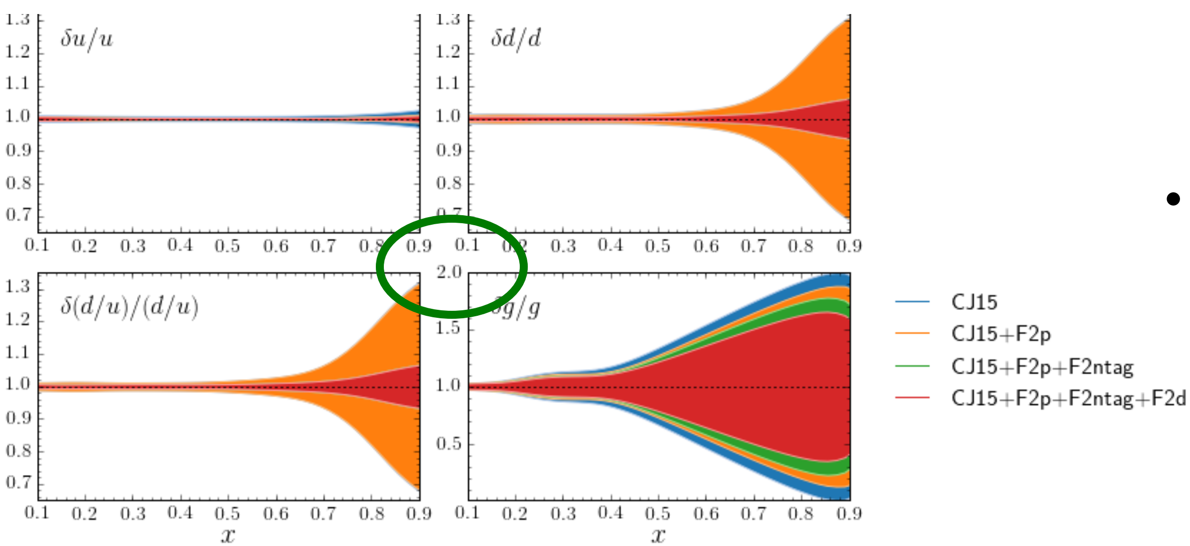


Most knowledge comes from
- (small) scaling violations in the evolution of the F_2 str. fn.
- Jets in p+p (and e+p)

Both are limited to x<~0.3

100/fb luminosity





- *d quark precision will become comparable to current u!!*
- similar improvement in g(x)
- The u quark uncertainty becomes less than ~1%; may be important for large mass BSM new particles.
- With d quark nailed by F_2^n, fitting F_2^d data will explore details of nuclear effects

Improved g(x) precision also good news

- The gluons improve by a bit less than 10% per data set included, with the improvement seemingly independent of luminosity
  - Possibly gluons are accessed by the F_2 shape in Q^2, so that the precision of each data point is not very important, while the lever arm in Q^2 matters most
- If true, expect that adding new measurements we will continue to improve the gluons: for example, adding energy scans at 3+100 and 6+100 may reach a global improvement in the large-x gluons closer to 80%.
- Energy scans could also allow for direct access of gluons from F_L.
- Need more work to confirm above

Summary: Nuclear Structure at Large and Small x

- Unified picture of high-energy particle production which bridges DGLAP evolution, TMD evolution, and small-x evolution
- New quantitative predictions for linearly polarized gluons and azimuthal modulations at small x, including evolution.
- Novel small-x dynamics govern helicity distributions at small x and may make an important contribution to the proton spin.
- New study: spectator tagging at the EIC can constrain large-x PDFs so well that they can discriminate between models for nuclear corrections.

Nucleon Structure and Interactions

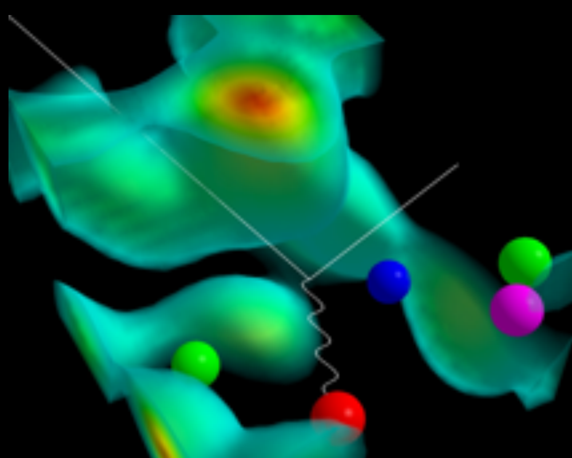
D. Sokhan

C. Mezrag

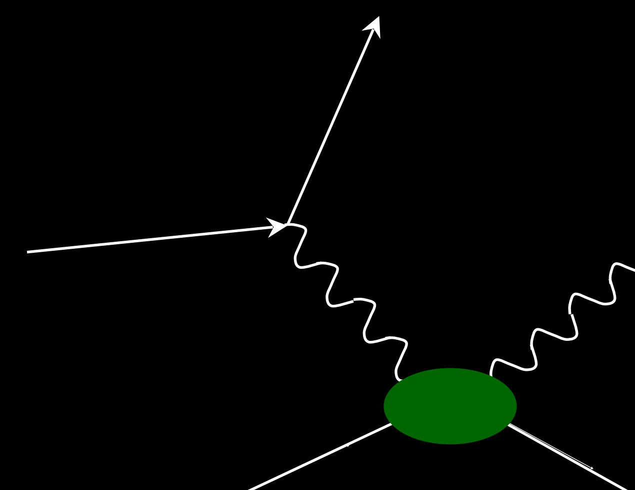
C. Weiss

O. Hen

Towards Generalised Parton Distributions at the Electron Ion Collider



Derek Leinweber



Daria Sokhan

University of Glasgow, UK

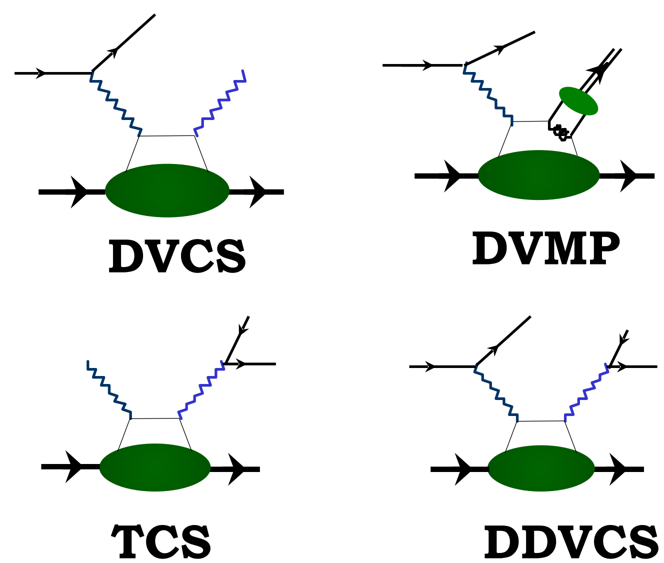
EIC User Group Meeting, Argonne National Lab, USA — 8 July 2016

Generalised Parton Distributions

- **Tomography** of the nucleon: transverse spacial distributions of quarks and gluons in longitudinal momentum space.

- Information on **spin-orbit correlations** and the orbital angular momentum contribution to nucleon spin: **the spin puzzle.**

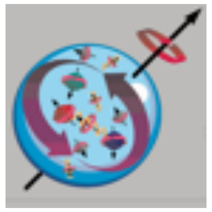
- Accessible in:
  - Deeply Virtual Compton Scattering (DVCS)
  - Deeply Virtual Meson Production (DVMP)
  - Time-like Compton Scattering (TCS)
  - Double DVCS



- Four GPDs (at LO) accessible in DVCS: $E^q, \tilde{E}^q, H^q, \tilde{H}^q(x,\xi,t)$

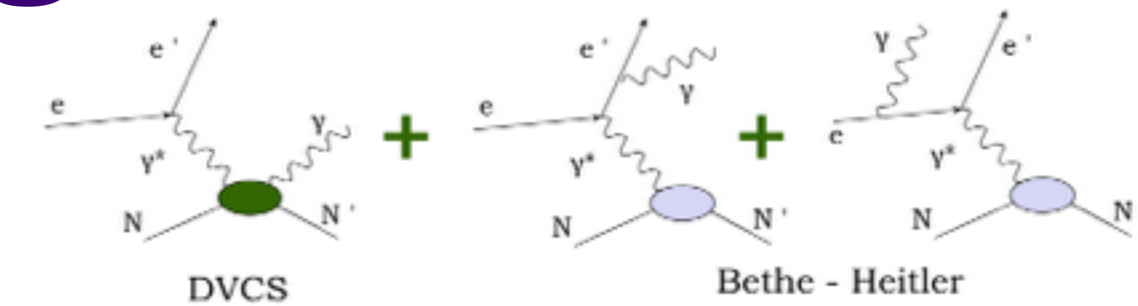
- Additional four transversity GPDs in DVMP: $E^q_T, \tilde{E}^q_T, H^q_T, \tilde{H}^q_T(x,\xi,t)$

Ji's relation: $J^q = \frac{1}{2} - J^g = \frac{1}{2}\int_{-1}^{1} x\,dx \left\{ H^q(x,\xi,0) + E^q(x,\xi,0) \right\}$



Accessing GPDs

- DVCS accessible mainly through interference term with Bethe-Heitler.

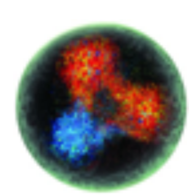


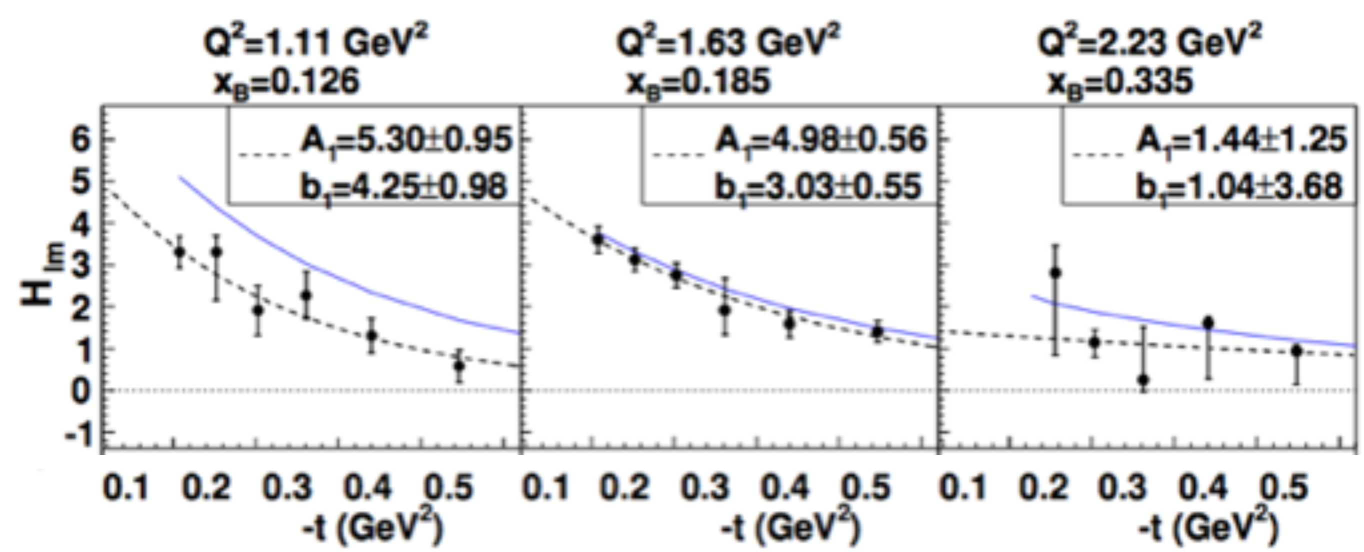
- Cross-sections, spin asymmetries parametrised in terms of Compton Form Factors: complex functions whose real and imaginary parts are related to GPD integrals or values of GPDs at certain kinematics. **Need polarised beams!**

- Momentum fraction *x* not directly accessible in DVCS, DVMP or TCS, but *can* be accessed in Double-DVCS.

- **Flavour separation**: DVCS off proton and neutron, DVMP.

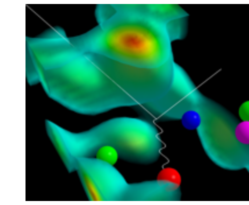
- Exclusive measurements from **Jefferson Lab** and **HERMES** provided validation of the GPD formalism and glimpses of nucleon structure in the **valence region**: e.g., CFF slope in *-t* becomes shallower at higher x_B, suggests valence quarks might be more centrally located than sea ones.





H.-S. Jo *et al* (CLAS Collaboration), ***PRL*** **115** (2015) 212003

GPDs @ EIC



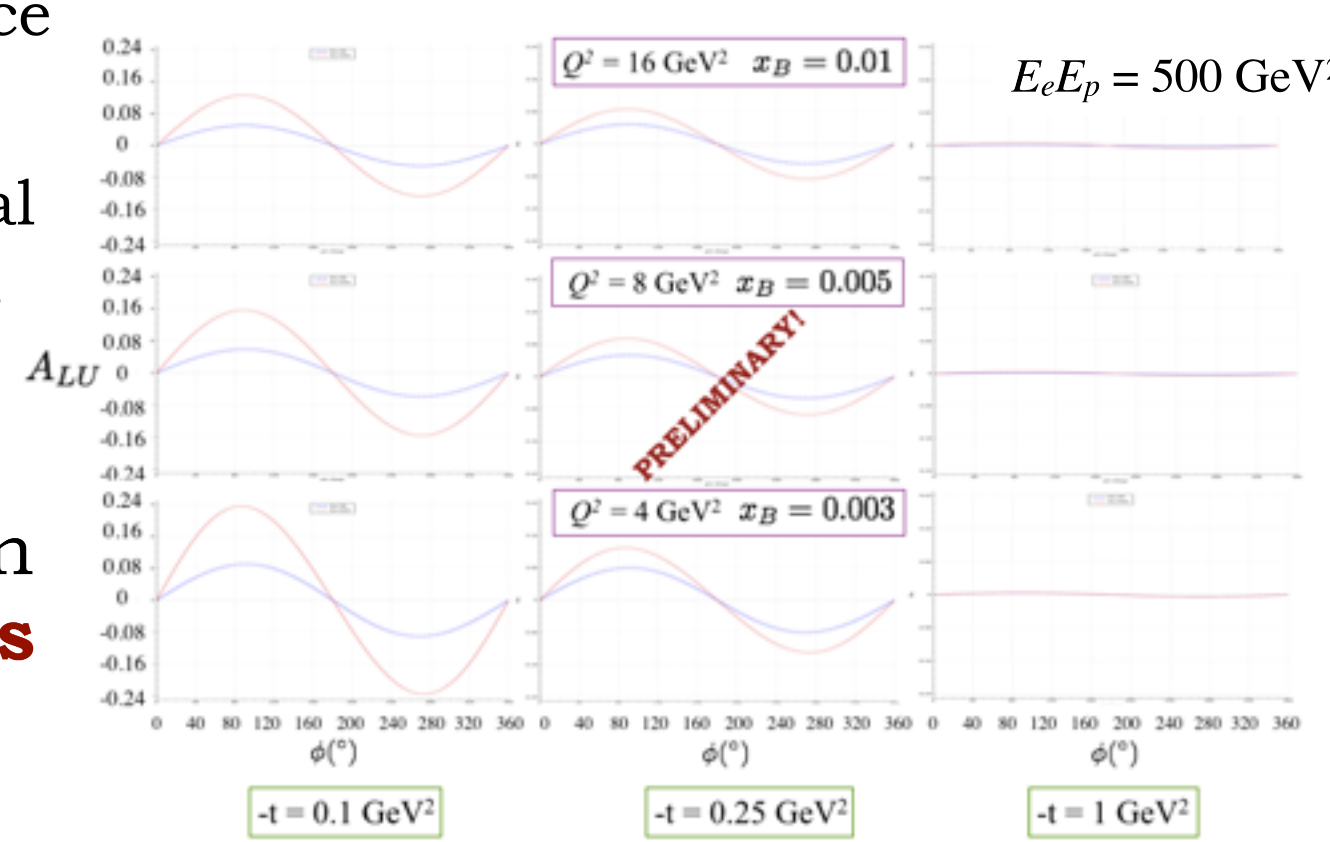
- **DVCS** — Nucleon tomography at low x: sea quarks and gluons (via Q^2 dependence), contribution of sea quark orbital angular momentum to nucleon spin. Phase of Compton amplitude accessible with positron beams in beam charge asymmetry or with **TCS**.

- **DVMP** — Flavour-separation, clearer access to gluon GPDs in J/Ψ production, separation of longitudinal and transverse photon polarisation cross-sections, differences in q and $\bar{q}$ distributions.

- **DDVCS** — Direct access to x-dependence of GPDs.

- Measurements off other hadrons (virtual pions, light nuclei) — parton saturation, flavour-separation, short-range correlations.

- EIC is crucial in exploring nucleon structure at the level of **sea quarks and gluons**; it needs to have *high luminosity, high polarisations, full acceptance detectors, a range of CM energies and nucleon and nuclear beams.*



Predictions for VGG (red) and GK11 (blue): PARTONS project (L. Colaneri, N. Chouica).

- Model predictions vital to inform and guide EIC design!

Generalised Parton Distributions and the PARTONS project

C. Mezrag

Argonne National Laboratory

On behalf of the PARTONS team

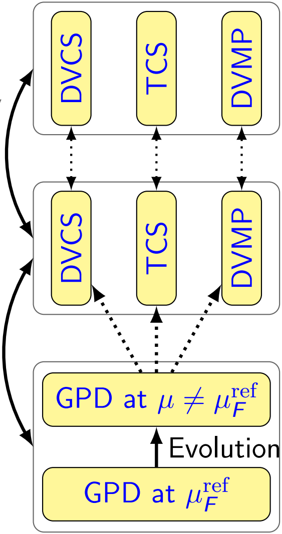
Computing chain design.

Differential studies: physical models and numerical methods.

Experimental data and phenomenology

Computation of amplitudes

First principles and fundamental parameters



Towards the first beta release

Where we are now

- **Design**
  - the first release will be restrained to **DVCS** only, but will cover a kinematical range **from JLab to EIC**,
  - **four different GPD models** based on Double Distributions will be provided,
  - the BMJ (Nucl. Phys. **B878**, 214 (2014)) formalism will be used for computations of observables,
  - **both LO and NLO** kernels will be available for the computation of CFFs, including computations with heavy flavours,
  - evolution will be available at **fixed** flavour number,
  - only leading twist approximation will be available.
- **Validation**
  - Non-regression tests have been systematically performed over **200,000** GPD kinematics (x, ξ, t, μ_R, μ_F).
- **Performance**
  - With two threads, it is now possible to compute **500,000** GPD kinematics per second with the Goloskokov-Kroll model.

- **What will be released?**
  - Release will take the form of a virtual machine, including ready-to-use IDE and mySQL Database.
  - Binaries and headers will be available, but not the source code.
- **When is the release planned?**
  - Extensive tests of evolution module and database transactions have still to be performed.
  - The first beta release is expected this summer.
- **I am afraid to be lost in the code, where can I find help?**
  - We plan to release also various examples to help new users.
  - A documentation will be also available online.
- **What if I find a bug?**
  - We try to make the software as reliable as possible. But if you still find a bug please contact us.
  - We will face the good side of Murphy's law: users will find a way to use PARTONS developers will not have thought about.

Probing nucleon interactions in QCD with EIC

C. Weiss (JLab), EIC User Group Meeting, ANL, 7-9 July, 2016

Jefferson Lab

- Unifying perspective on ep and eA physics

  Include large – intermediate – small x

  Adopt rest frame view: Longitudinal structure, nuclear physics intuition

  Focus on dynamical system, not formal descriptors

- EIC measurements exploring nucleon interactions

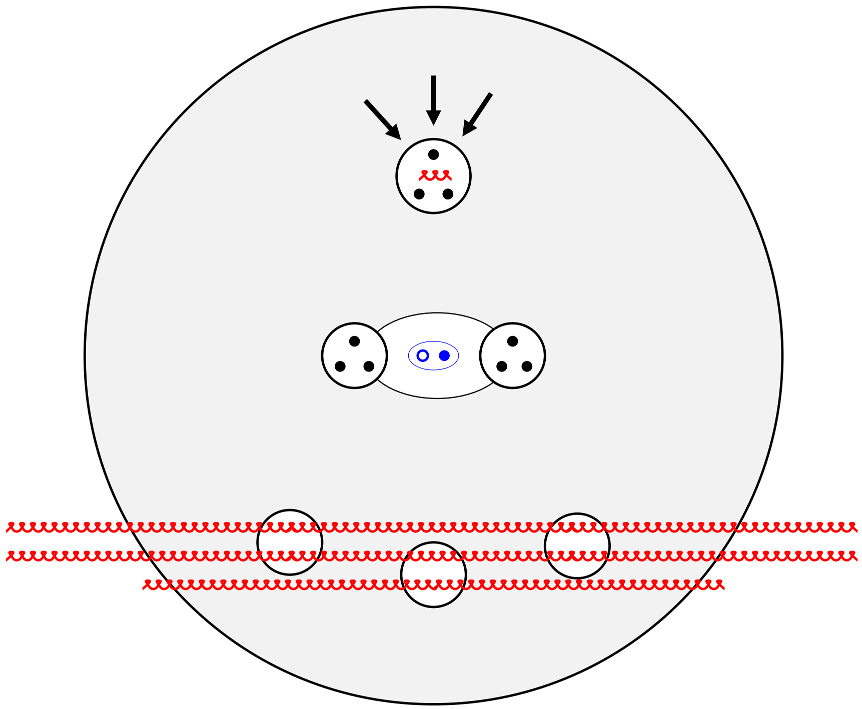
  $x > 0.3$ Gluon suppression in nuclei? Gluonic EMC effect?
  Modified nucleon structure

  $x \sim 0.1$ Sea quark and gluon enhancement? Charge–flavor separation?
  QCD structure of exchange interactions

  $x < 0.01$ Emergence of collective gluon fields – shadowing, saturation
  High-energy nucleon interactions, diffraction

How do nuclei emerge from the microscopic theory of strong interactions?

Nucleon interactions: $A \neq \sum N$



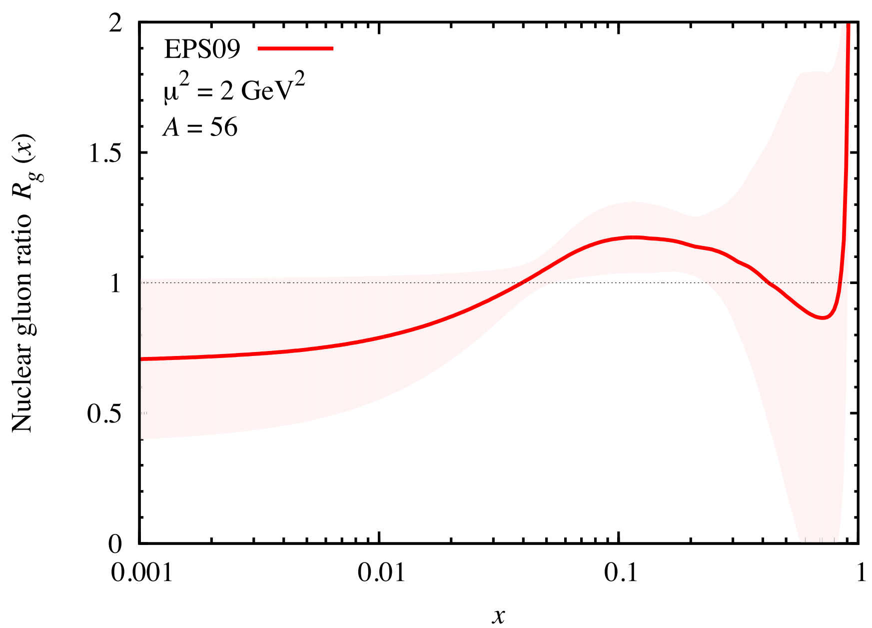
$x > 0.3$ "EMC effect"
Modified single-nucleon stucture?
Non-nucleonic degrees of freedom?

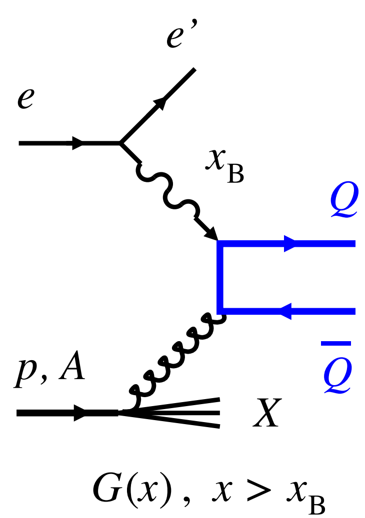
$x \sim 0.1$ "Antishadowing"
QCD structure of pairwise NN
interaction, exchange mechanisms

$x < 0.01$ "Shadowing"
QM interference,
collective gluon fields

- Nuclear modification of quark/gluon structure reveals QCD origin of nucleon interactions
- Distinct dynamical mechanisms in different regions of x
- Alternative viewpoint: Coherence length of DIS process $l_{\mathrm{coh}} \sim 1/(M_N x)$

EIC: Nuclear gluons at $x > 0.3$





- Are gluons suppressed at $x > 0.3$?
  Cf. Valence quarks: EMC effect, JLab 6 & 12 GeV

  Modification of nucleon's gluonic structure due to interactions?

  Non-nucleonic DOF in nucleus?

- Poorly known: Global fits

- EIC: Nuclear gluons from inclusive F_{2A}, F_{LA} and DGLAP evolution

  Limited sensitivity to large x

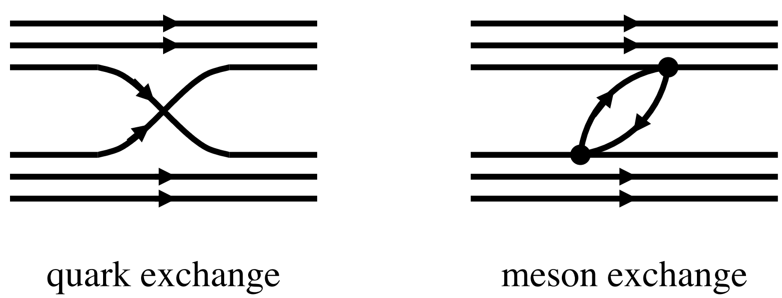
- EIC: Nuclear gluons with heavy quarks

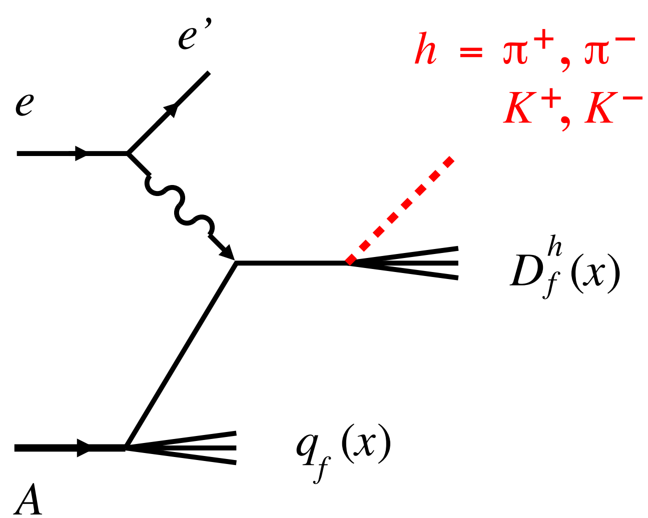
  Direct probe, unique sensitivity

  Used in HERA ep at $x_B < 0.01$

  EIC enables eA at large x_B

EIC: Nuclear quarks and antiquarks at $x \sim 0.1$





- Are quarks and/or antiquarks in nuclei enhanced at $x \sim 0.1$?

  NN interaction by quark or meson exchange?

  Flavor decomposition?

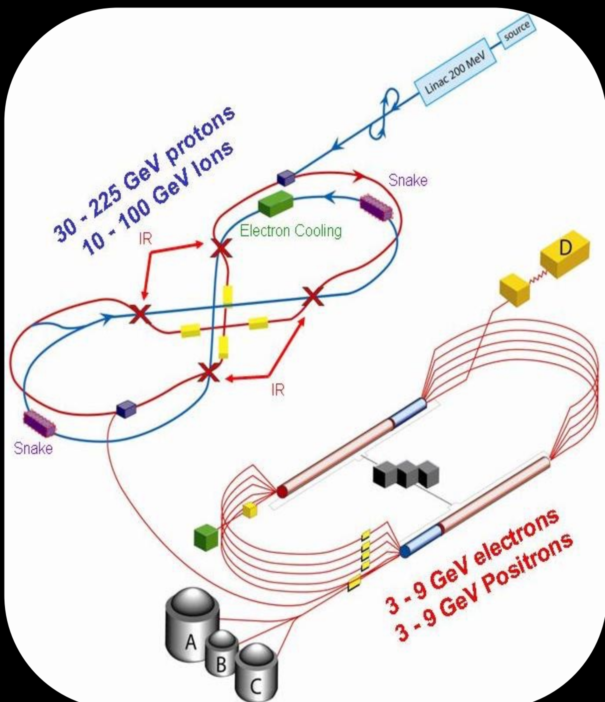
- EIC: Charge-flavor separation with semi-inclusive π, K

  Extensive experience with ep

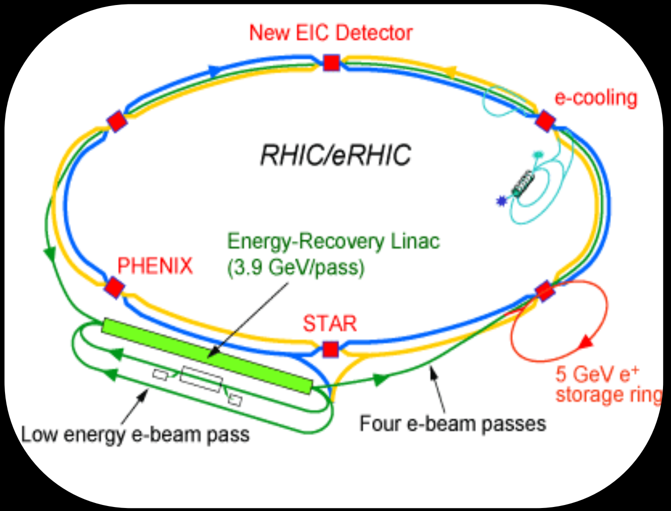
  eA: Separate initial-state modifications from nuclear final-state interactions using A–dependence

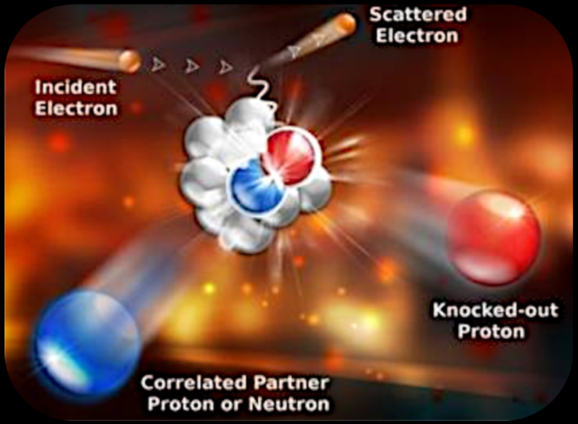
- Simulations in progress
  Zhihong Ye, D. Higinbotham, CW

Bound Nucleon Structure Studies with an EIC



Or Hen
MIT

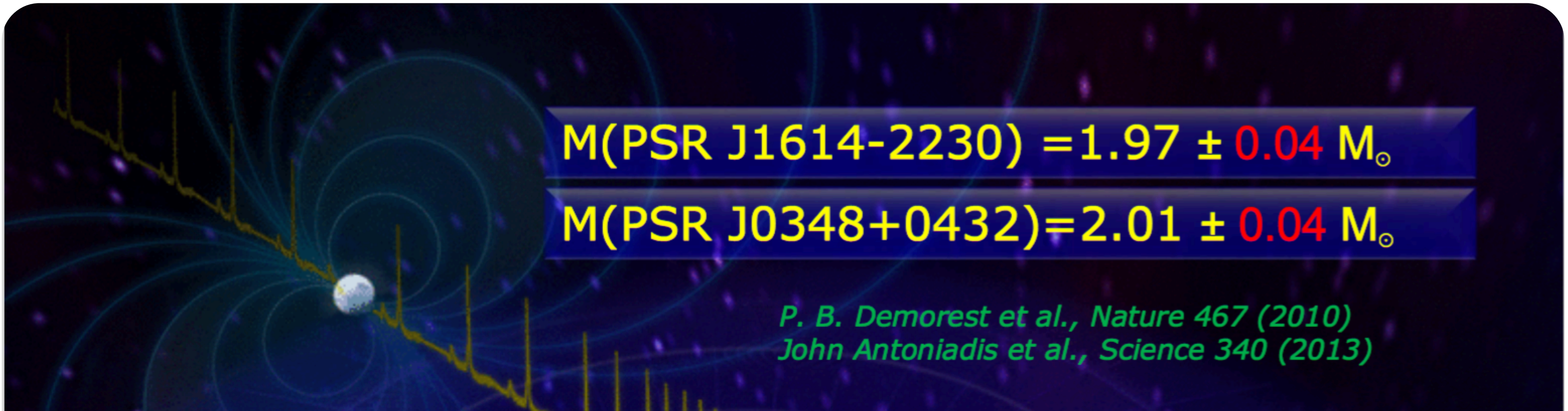




Electron Ion Collider

EIC Users Group Meeting, ANL, July 8th, 2016

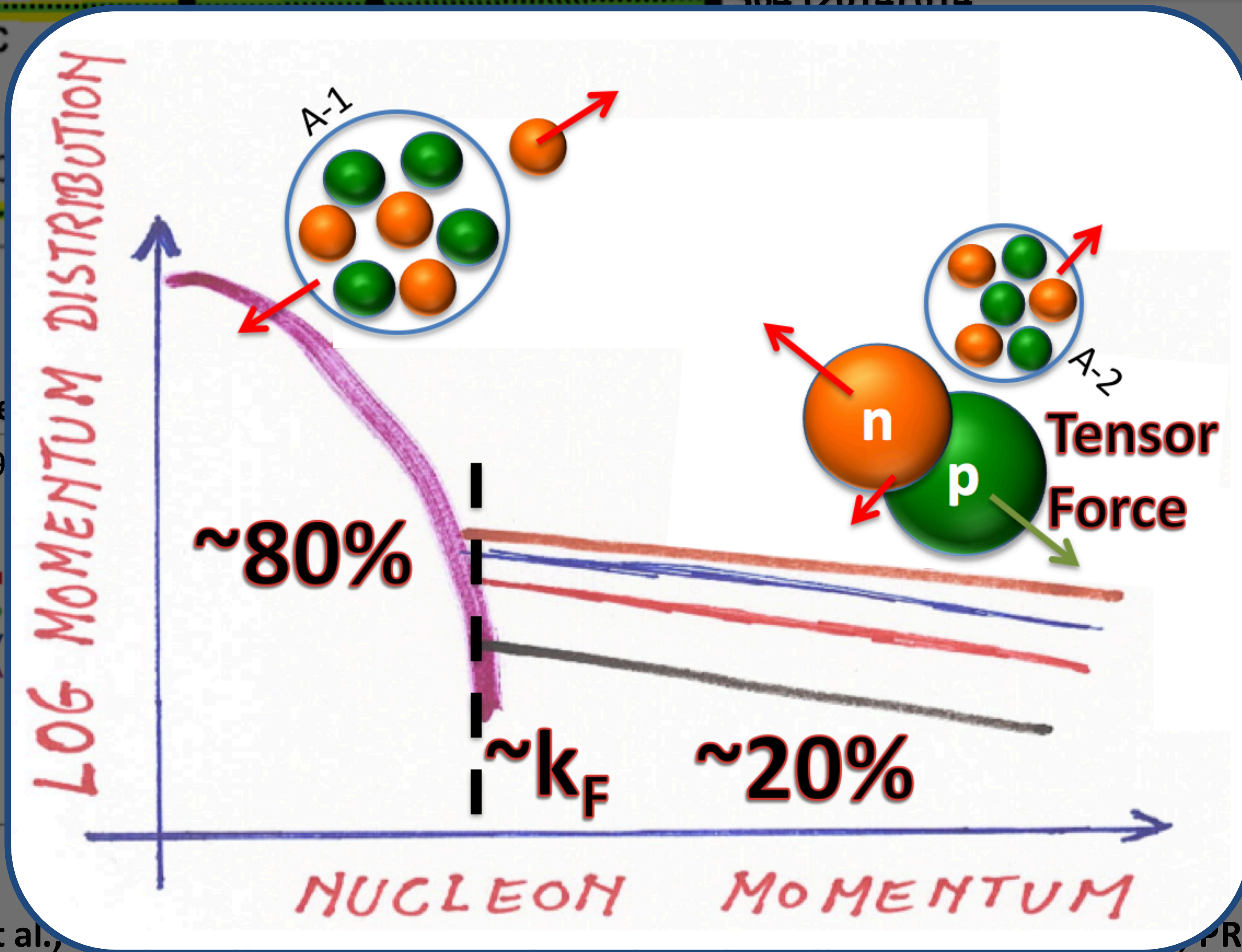
From Black Holes to Neutron Stars



1. **Formation of our universe:**
   r-process nuclear-synthesis is likely due to n. stars merges
2. **Fundamental nature of gravity:**
   n. stars are a unique lab for testing models of gravity-matter couplings in the strong-field regime.

=> Requires input on COLD dense nuclear matter *in small gravitational fields (e.g. on earth)*.

Universal structure of nuclear momentum distributions



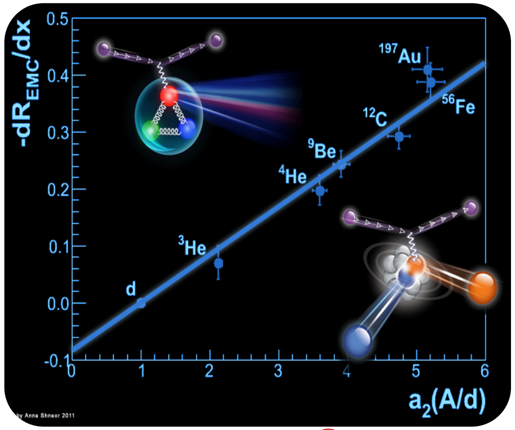
R. Sube

022501

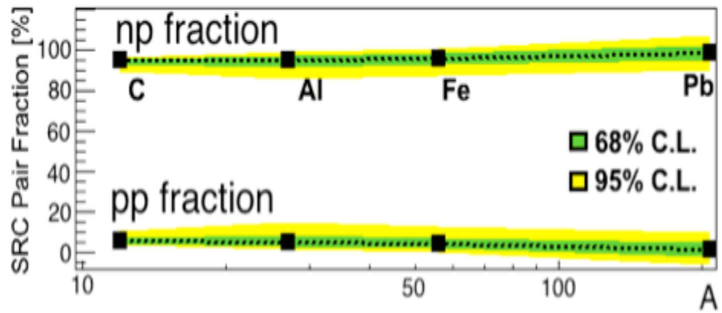
A. Tang et al.,

PRL (2007)

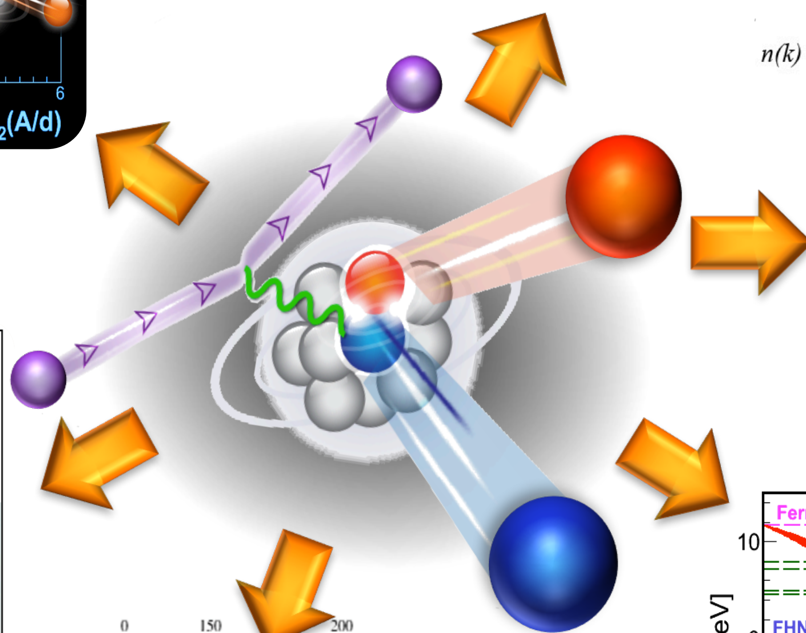
Importance of SRC Properties



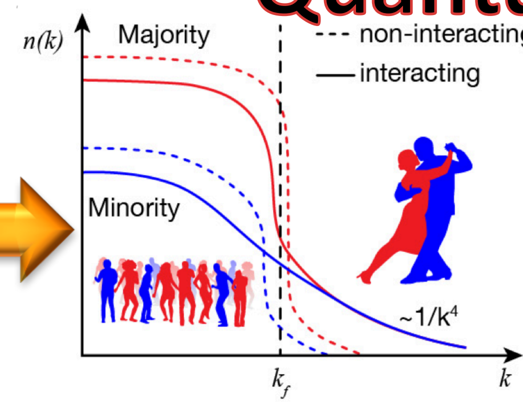
Particle

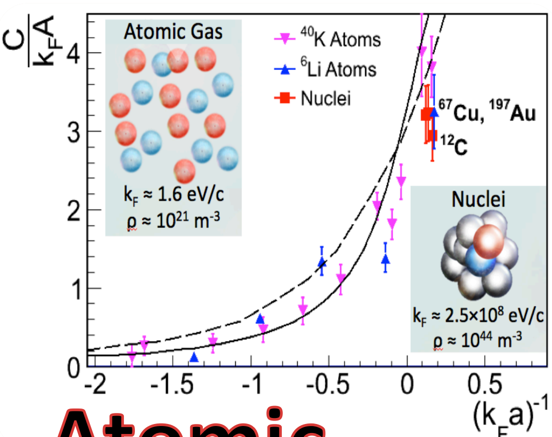


Nuclear

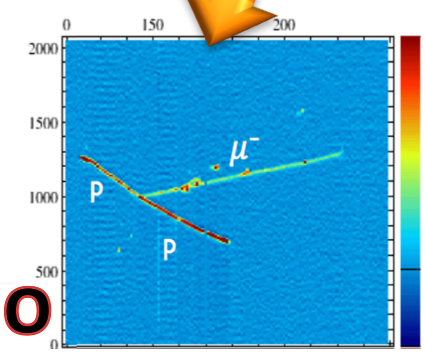


Quantum

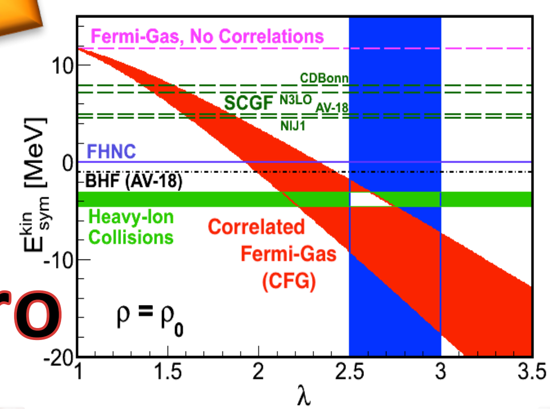




Atomic



Neutrino



Astro

Summary: Nucleon Structure and Interactions

- Validation of the GPD formalism in the valence region allows tomography of sea quarks and gluons at the EIC.
- New software suite empowers the community to explore GPD model space by automating the computation of observables.
- Unified picture of nuclear structure across length scales bridges the EMC effect, NN scattering, and nuclear shadowing.
- Universal nuclear momentum distributions links fields of physics from the EMC effect to cold atomic gases to neutron stars.