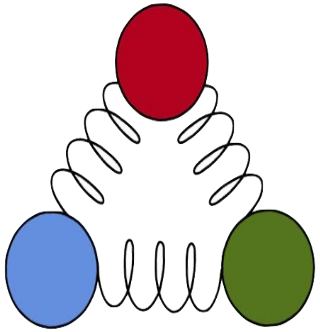
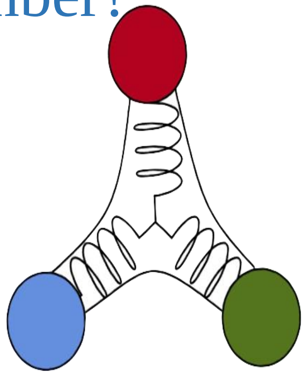
Opportunities at EIC for testing baryon number carrier

Niseem Magdy

niseemm@gmail.com
Inspire-hep: 1305036
ORCID: 0000-0002-6458-6552

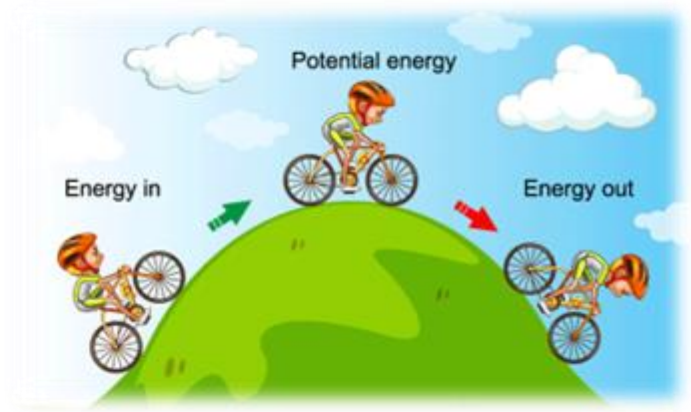
What carries the baryon number?





N.Magdy, et al, Opportunities at EIC for testing baryon number carrier, in preparation

Questions in the Electron-Ion Collider research

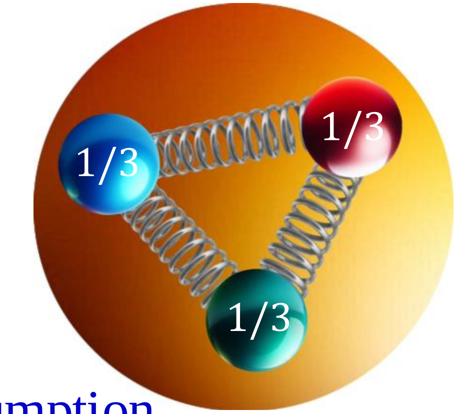


Conservation laws

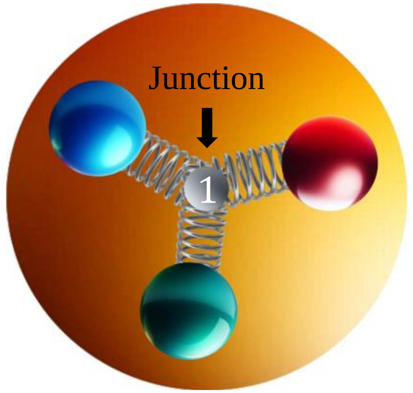
Baryon Number Conservation:

Any system's total number of baryons (particles made up of three quarks) remains constant. This conservation law is a cornerstone of the Standard Model of particle physics.

(a) Valence quarks, B=1/3 and Q≠0



(b) Baryon Junction, B=1and Q=0



This is an assumption

Valence quarks?

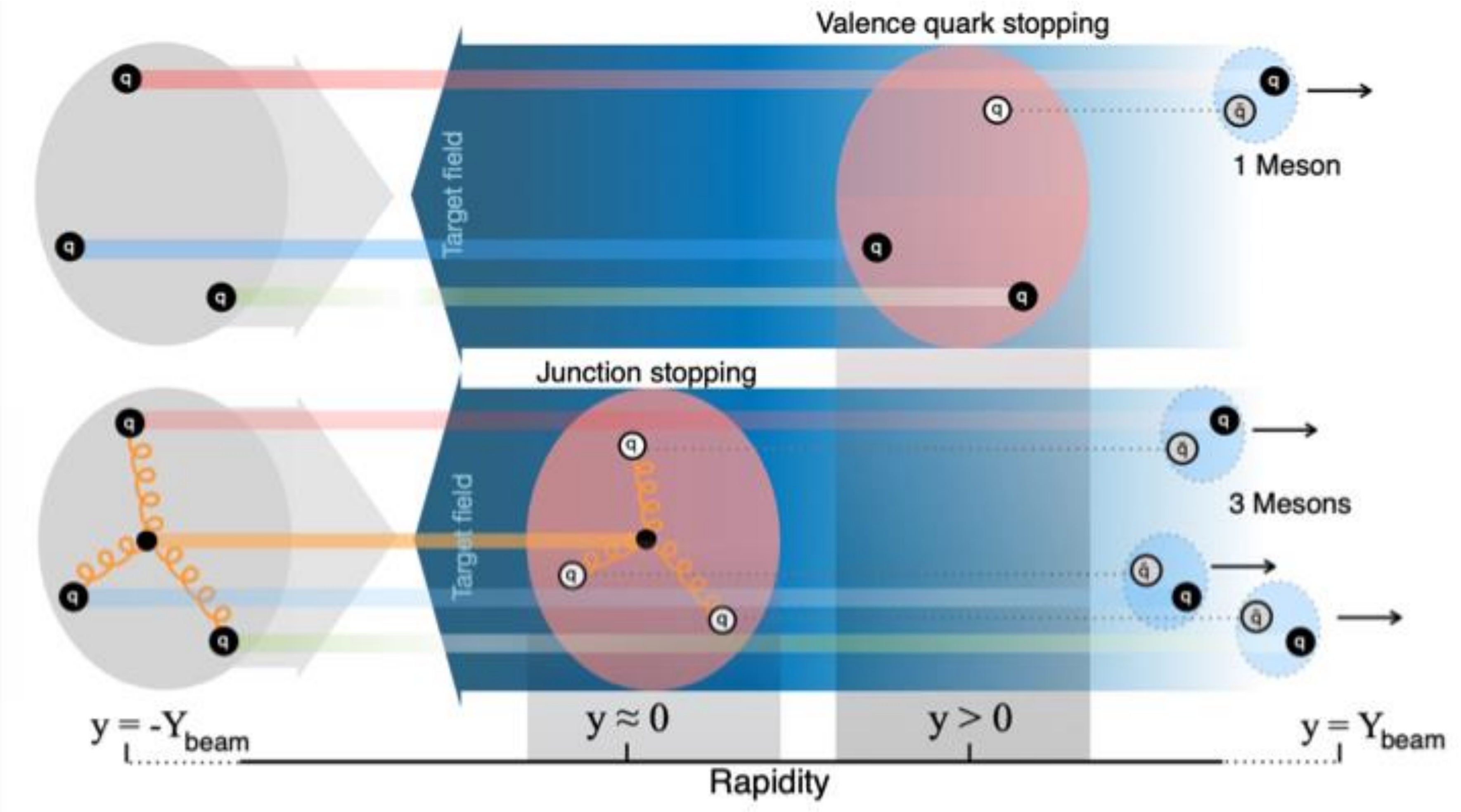
- ✓ $\pm\frac{1}{3}B$ to each quark and antiquark
- ✓ Valence quarks carry most of the momentum

String junction?

- ✓ Non-perturbative configuration of gluons
- ✓ Carries less momentum and is less contracted

Questions in the Electron-Ion Collider research

STAR
Arxiv:2408.15441



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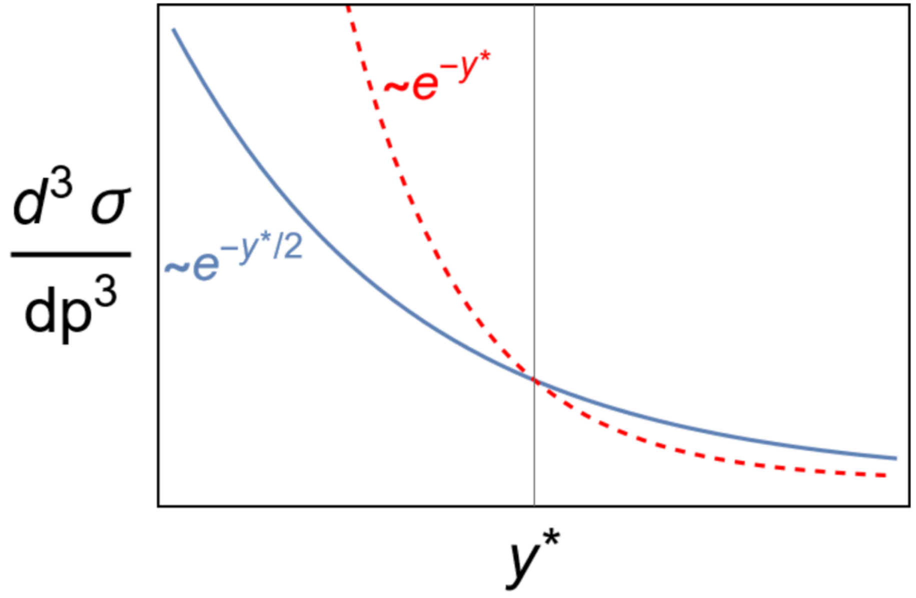
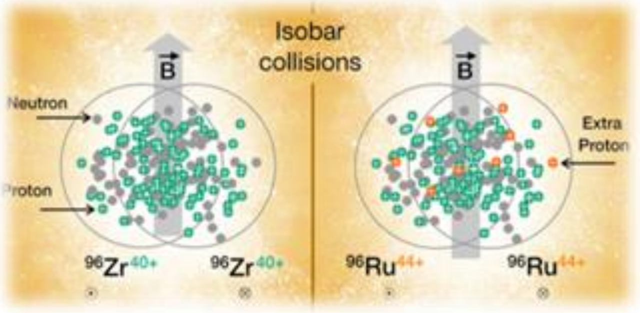
Questions in the Electron-Ion Collider research

David Frenklakh, Dmitri E. Kharzeev, Wenliang Li, et al. e-Print: 2312.15039

- Regge theory prediction:
  - ✓ $\frac{dN}{dy} \propto e^{\alpha_B (y - y_{beam})}$
  - ✓ α_B is related to Regge intercept of junctions ($\alpha_B \sim 0.5$)



Niseem Magdy, et al. e-Print: 2408.07131



$$B = [N_p + N_n] - [N_{\bar{p}} + N_{\bar{n}}]$$
$$Q = [N_{\pi^+} + N_{K^-} + N_p] - [N_{\pi^-} + N_{K^-} + N_{\bar{p}}]$$

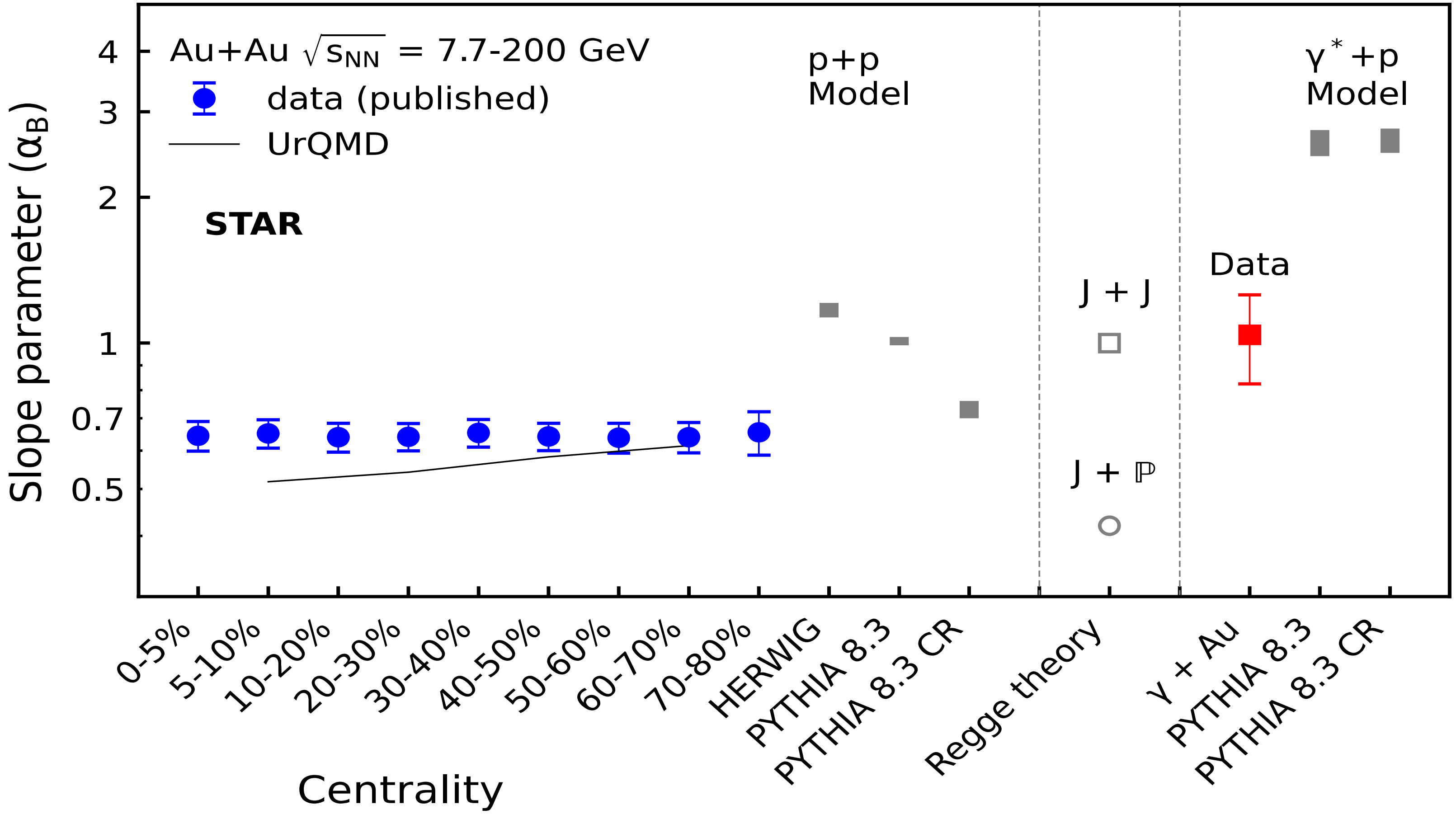
$$\Delta Q = Q^{Ru} - Q^{Zr}$$
$$\Delta Z = Z^{Ru} - Z^{Zr} = 4$$
$$A = 96$$

- Net-Baryon vs. Net-Electric charge in Isobar collisions
  - ✓ The ratio B/ΔQ*ΔZ/A can be used to differentiate different carriers
    - Valence quarks carry B and Q if (B/ΔQ*ΔZ/A) <= 1
    - Junction carry B (i.e., B is enhanced) if B/ΔQ*ΔZ/A > 1

❖ Motivation

Several methods are suggested to test the hypothesis:

- ➢ Net-Baryon in e+A collisions
  - ✓ The photon excepted has almost zero virtuality
  - ✓ Probes the nucleus at low-x



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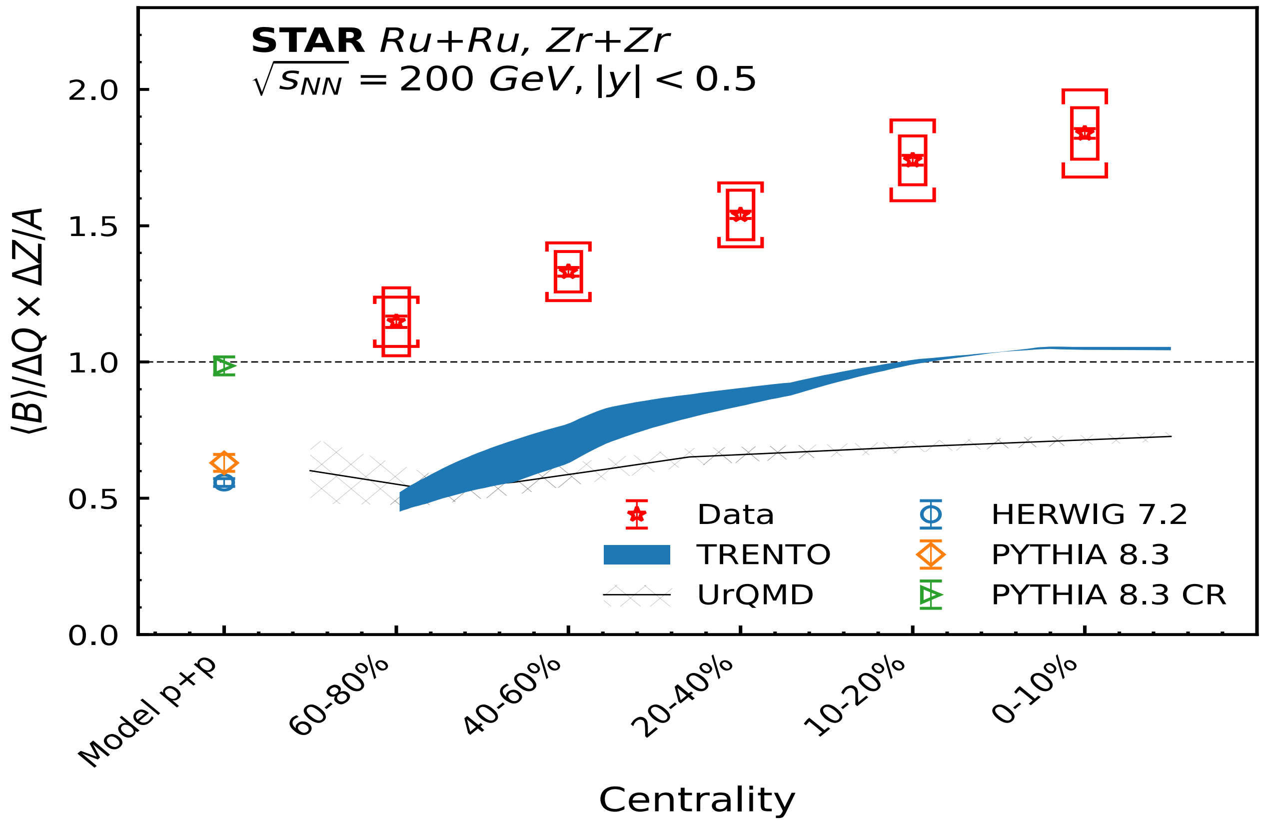
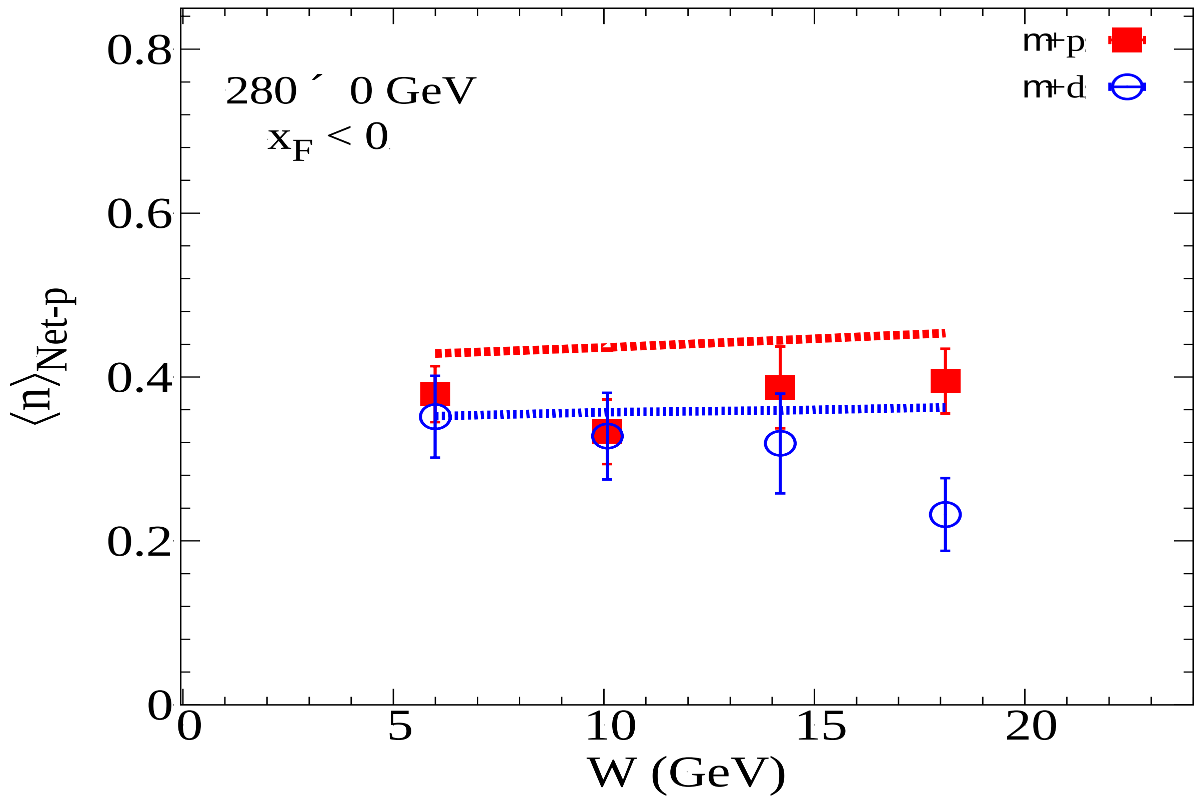


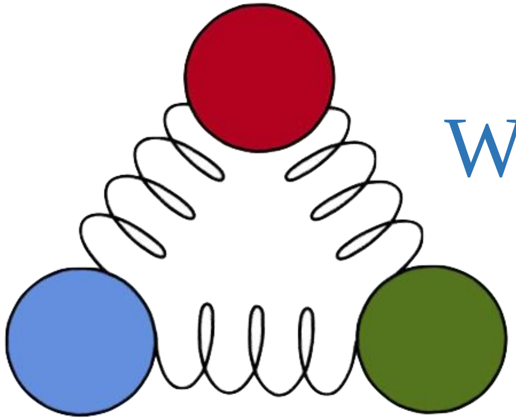
❖ Motivation

Several methods are suggested to test the hypothesis:

- Net-Proton differences between $\mu + p$ and $\mu + d$
  - ✓ EMC, minor differences
  - ✓ Diquark Lund model shows a 20% difference



EMC
Z.Phys.C 35 (1987) 433



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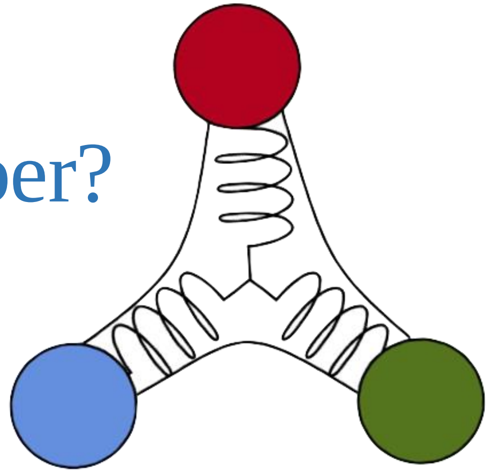


At RHIC:

- ➢ RHIC nuclear energy is at a sweet spot but has limited acceptance in rapidity, Q^2 and x

At EIC:

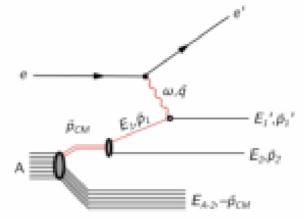
- ➢ Suitable energy range, good acceptance in rapidity (extended from 2.5 to 6.0) Q^2 and x
  - ✓ Low-p_T PID is needed to study the charge and baryon transports

Can EIC answer such a question?

The BeAGLE Model

❖ The BeAGLE model:

Wan Chang et al., PRD 106, 012007 (2022)



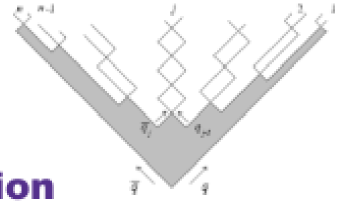
Primary interaction

Primary interaction treated by **PYTHIA6** for the hard collision.

Glauber handled by BeAGLE

PyQM: Nuclear Geometry + optional gluon radiation in medium.

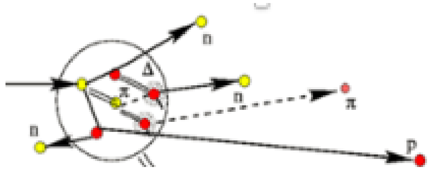
Hadronization handled by **PYTHIA6.**



Hadronization

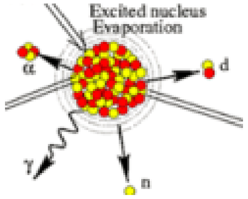
Cascade process handled by **DPMJET.**

Formation time. Stochastic.



Intra-nuclear cascade

Nuclear remnant evaporation and break up by **FLUKA.**



Nuclear remnant evaporation & breakup

Some Nuclear Effects

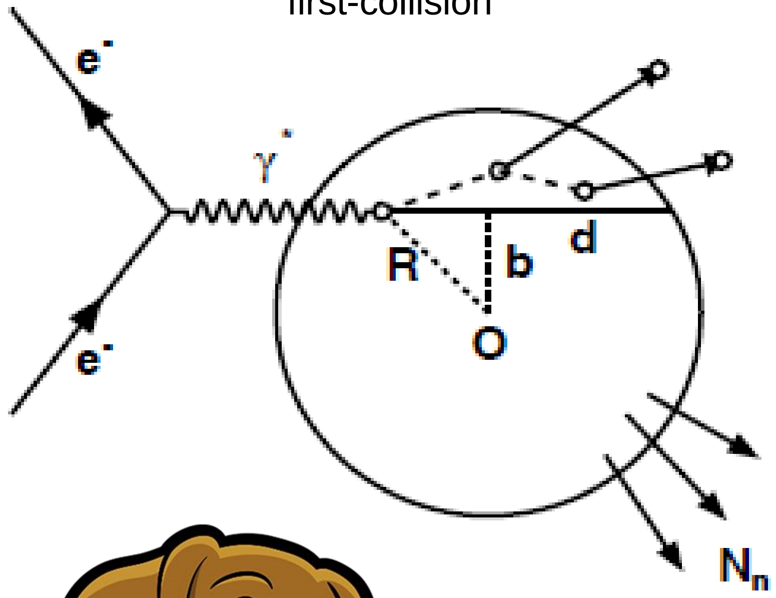
	In BeAGLE
• Parton distribution functions	✓
• Parton saturation (CGC etc.)	
• Short-range correlations	✓ (GCF)
• "Fermi motion"	✓
• Partonic (or "dipole") MS	✓
• Partonic gluon radiation	✓
• Medium-modified hadronization	
• Formation times	✓
• Hadronic Cascade	✓
• Nuclear evaporation, breakup	✓
• Photonic de-excitation of A*	✓

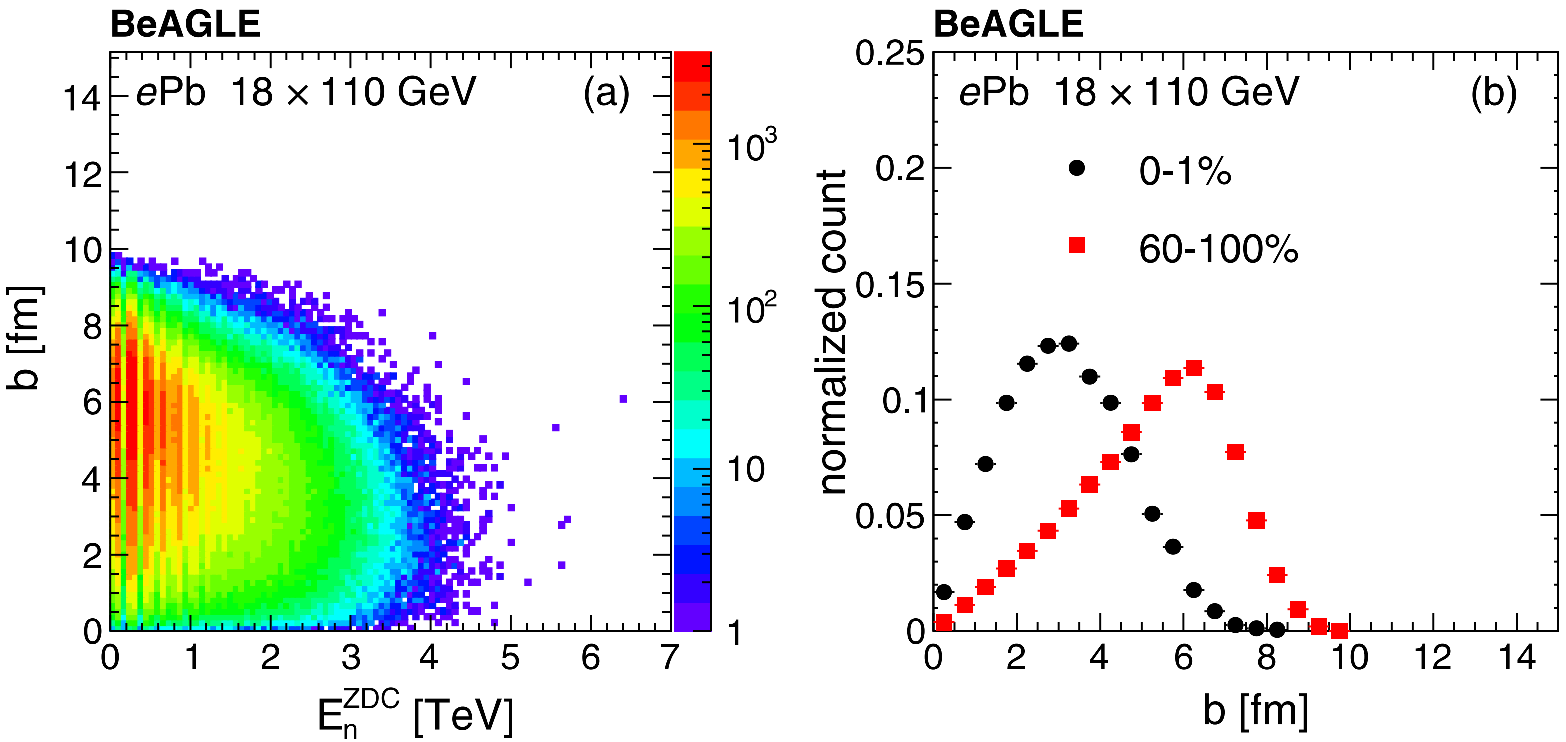
❖ The BeAGLE model:

$d \equiv \int dz\, r/r_0$

from $Z_{\text{first-collision}} \rightarrow \infty$

Wan Chang et al., PRD 106, 012007 (2022)





Neutrons in ZDC can be used for centrality definition?

❖ At the EIC

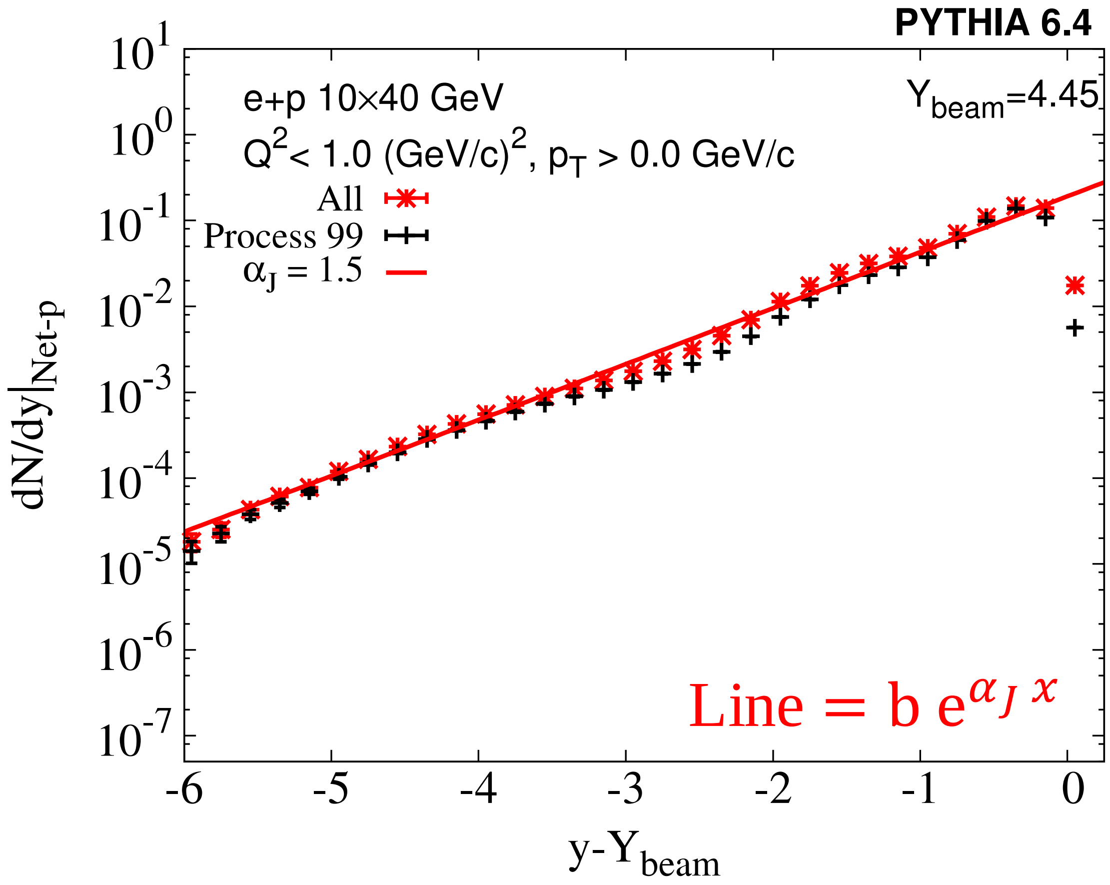
The $dN/dy|_{Net-p}$

If the junction hypothesis is true:

- Interact with a junction in the target nucleus

- Enhanced creation of mid-rapidity baryons
  - ✓ Junction interaction time > quark interaction time
  - ✓ More baryons are stopped in the junction picture

- Regge theory prediction:
  - ✓ $\frac{dN}{dy} \propto e^{\alpha_B (y - y_{beam})}$
  - ✓ α_B is related to Regge intercept of junctions ($\alpha_B \sim 0.5$)



99 is LO DIS

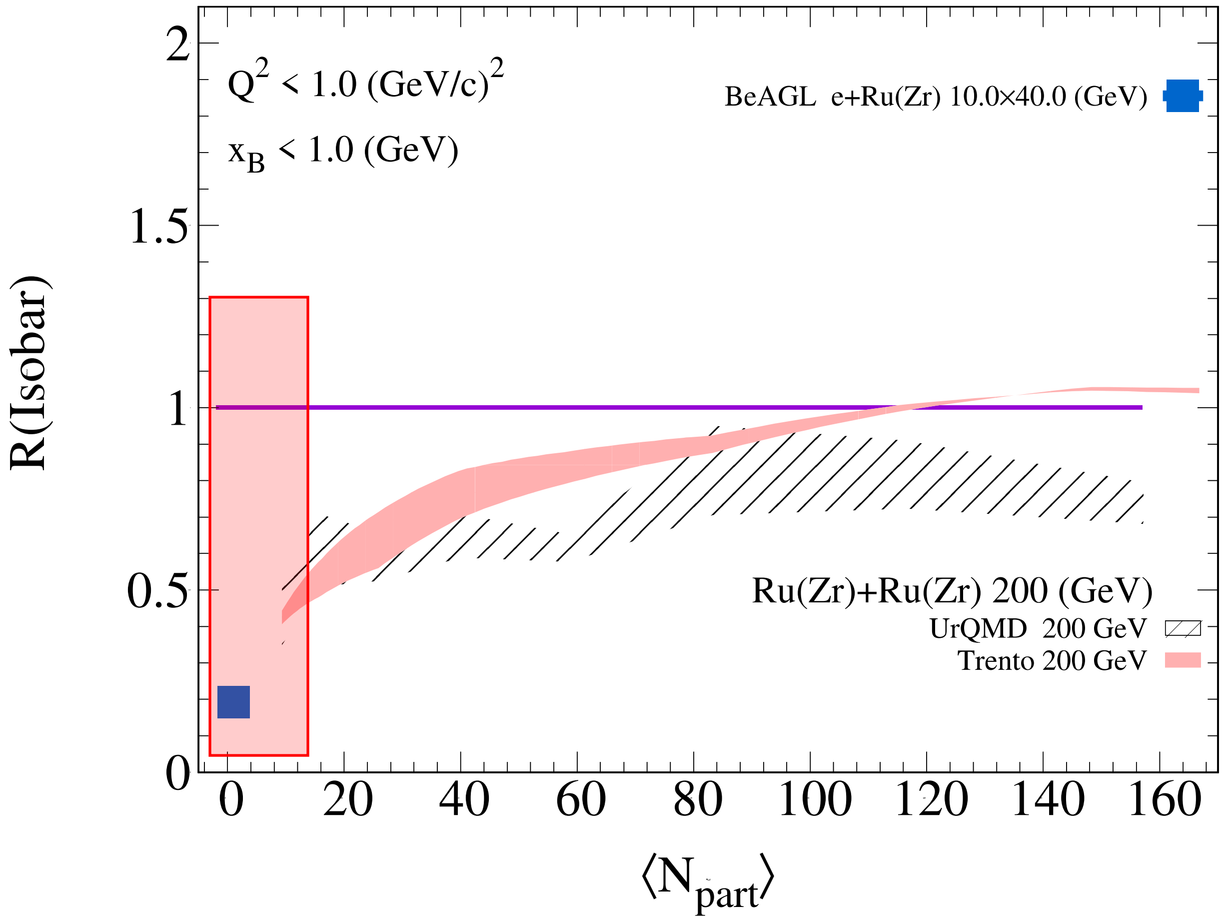
α_B from PYTHIA is larger than the prediction for the junction expectation

❖ At the EIC

Isobaric ratio

- Net-Baryon vs. Net-Electric charge in Isobar collisions
  - ✓ The ratio $B/\Delta Q*\Delta Z/A$ can be used to differentiate different carriers
    - Valence quarks carry B and Q if ($B/\Delta Q*\Delta Z/A$) <= 1
    - Junction carry B (i.e., B is enhanced) if $B/\Delta Q*\Delta Z/A > 1$

- R(Isobar) shows dependence on the BeAGLE processes



BeAGLE shows value consistent with the quark's scenario

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- $R(Isobar)$ is independent of Q^2, x_{B_j} and p_T

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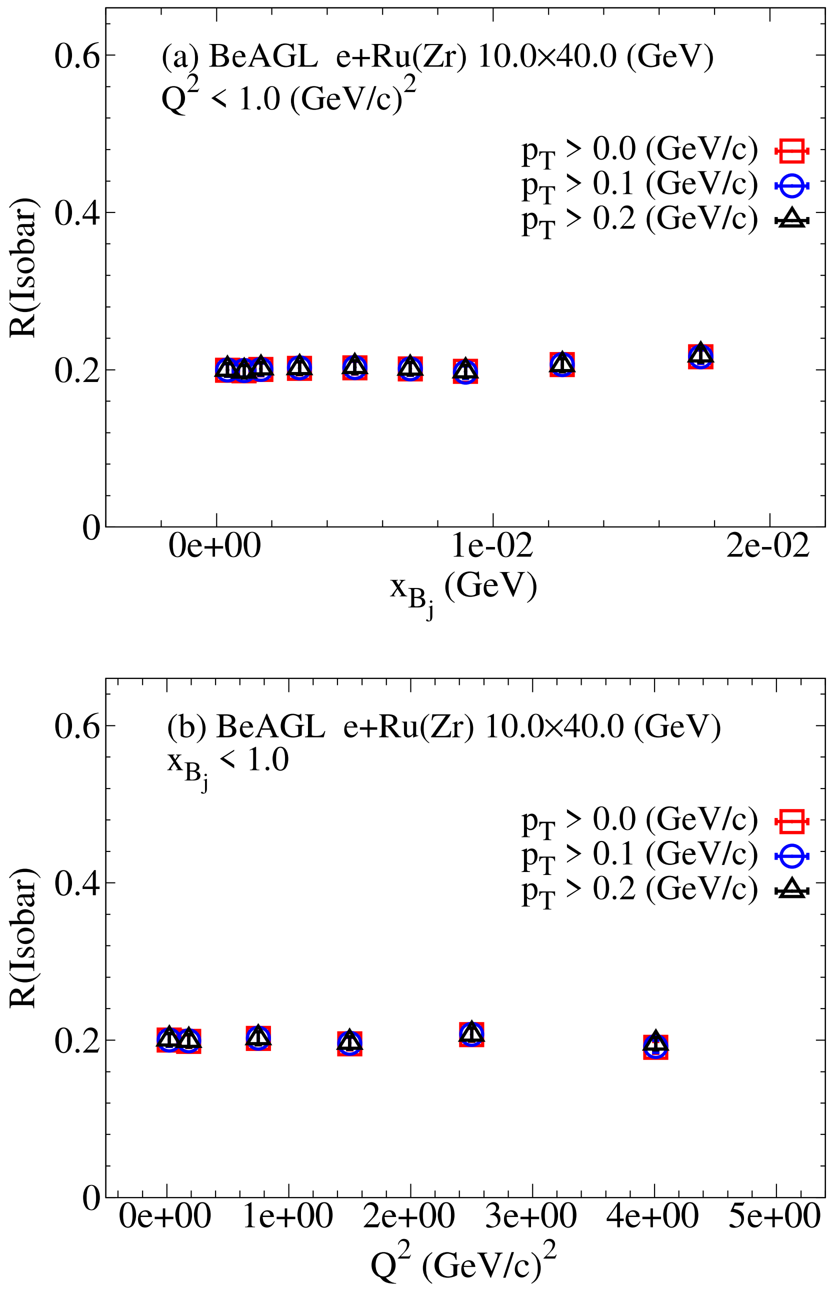


❖ At the EIC

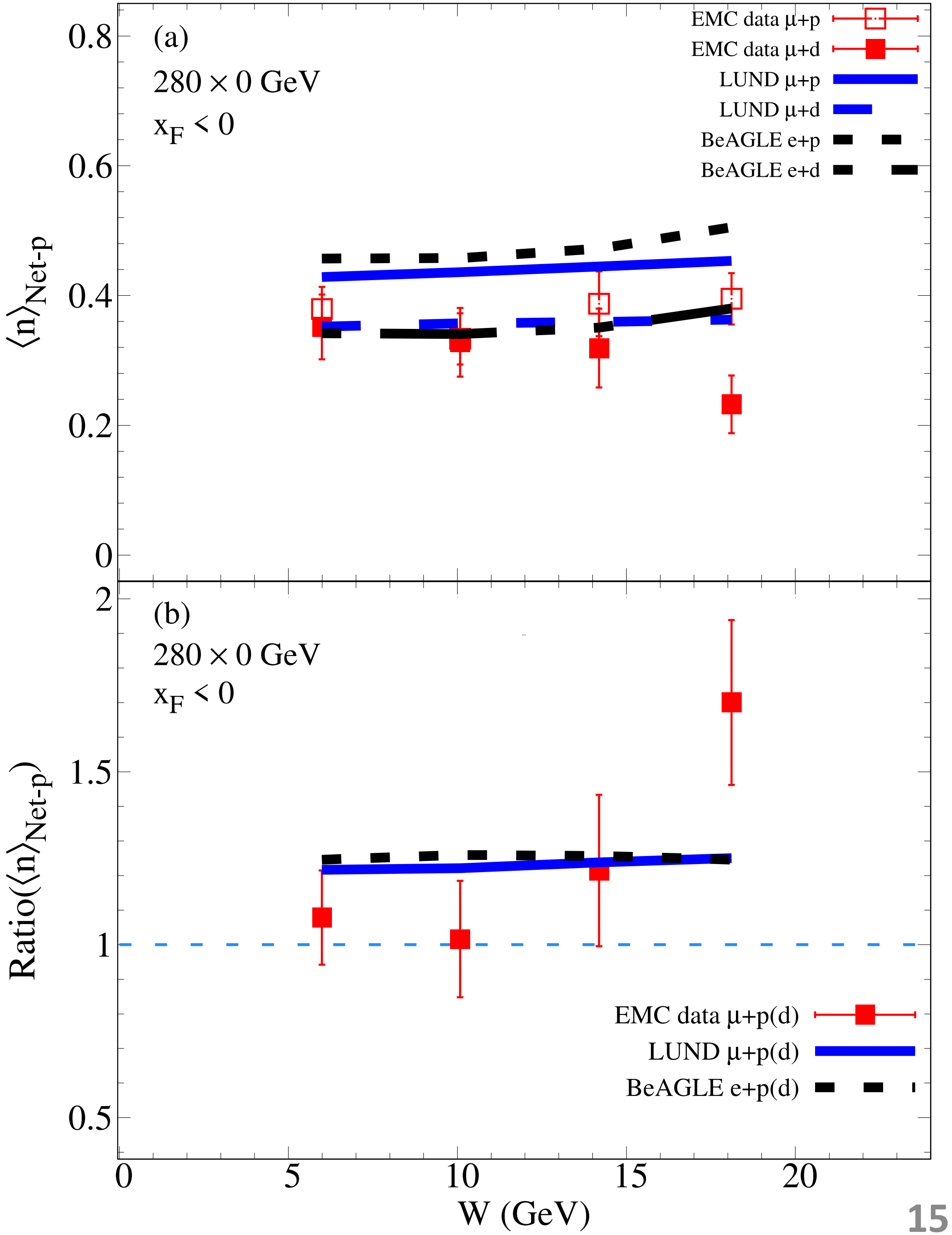
➢ Net-Proton of $\mu(e) + p(d)$

Within uncertainty, EMC measurements show minor differences between $\mu + p$ and $\mu + d$

Diquark Lund model shows a ~20% difference

BeAGLE shows value consistent with the Diquark Lund model

Can EIC do better?



Conclusions

We investigated the ability to use the EIC to study baryon junctions in e+A and the isobar collisions:

- The net-baryon yield slopes from PYTHIA and BeAGLE simulations are much steeper than expected from the baryon junction picture

- The isobaric ratios in BeAGLE are shown to be less than 1.0
  - ✓ Independent of x_B
  - ✓ Independent of Q^2

- Net-Proton of $\mu(e) + p(d)$
  - ✓ BeAGLE shows value consistent with the Diquark Lund model

Consistent with the quark's scenario.

Thank You