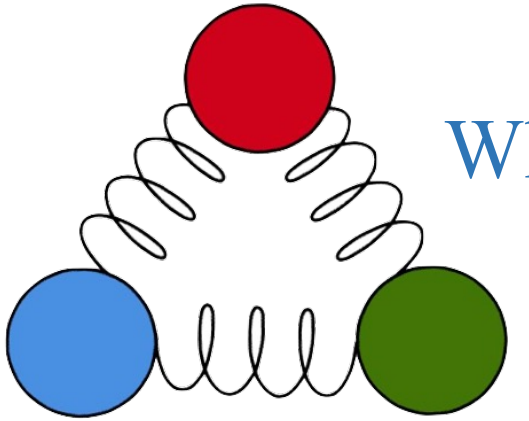
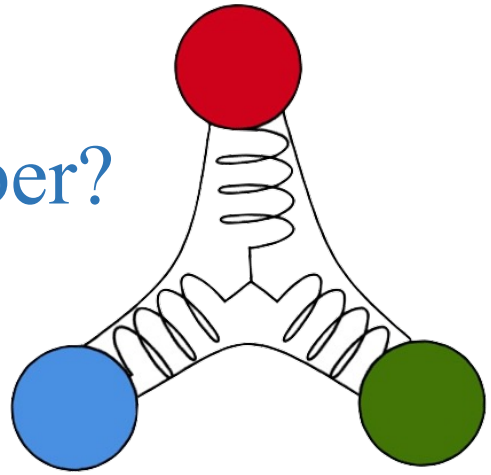
Search for baryon junctions in isobar collisions at EIC

Niseem Magdy, Prithwish Tribedy, Zhangbu Xu, Roy Lacey,
Wenliang Li, Abhay Deshpande



What carries the baryon number?



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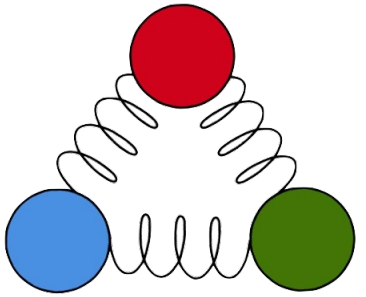
G.C. Rossi and G. Veneziano, Nucl. Phys.B123(1977) 507
Kharzeev, Phys. Lett. B, 378 (1996) 238-246

What carries the baryon number?

$$B = \frac{1}{3}(n_q - n_{\bar{q}})$$

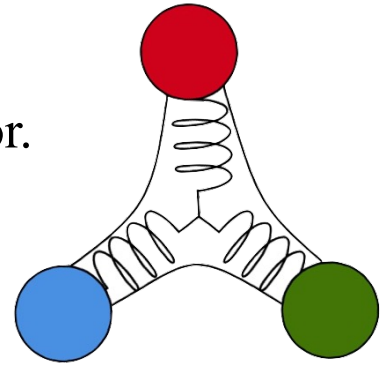
Baryon number: carried by the valence quarks? This is an assumption

- ✓ $\pm\frac{1}{3}B$ to each quark and antiquark cannot be inferred from QCD's first principles for baryons!
- ✓ Valence quarks carry most of the momentum and are contracted into thin "pancakes" at high energy.
- ✓ Quarks have less time to interact due to contracted longitudinal length



The string junction?

- ✓ Non-perturbative configuration of gluons represented by a locally gauge-invariant state vector.
- ✓ Carries lower momentum and is less contracted
- ✓ Made of low-x gluons and has more time to interact with other partons
- ✓ Enhanced baryon transport to mid-rapidity



Neither of these scenarios has been verified experimentally.

What carries the baryon number?

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

- 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
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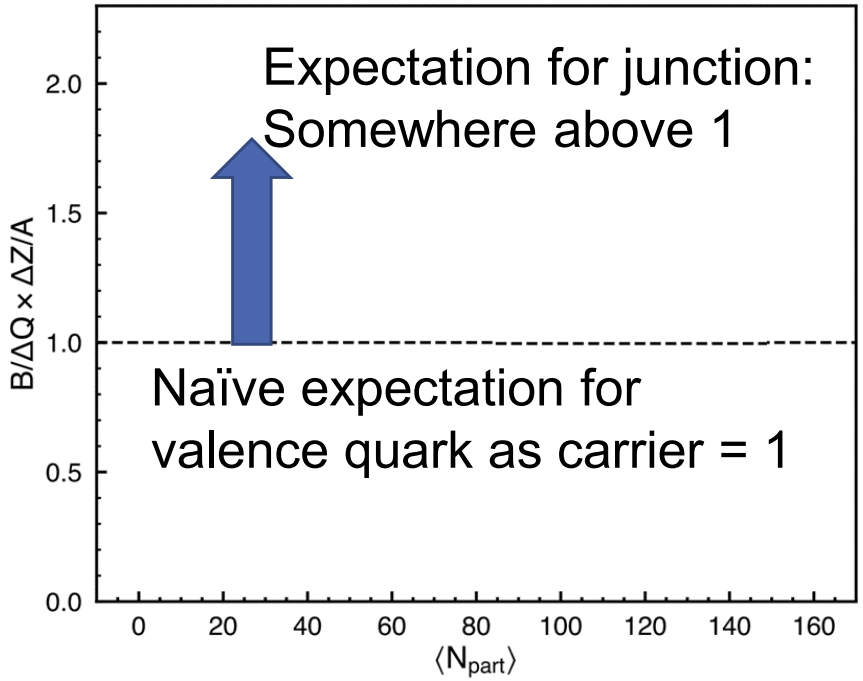


At the RHIC

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

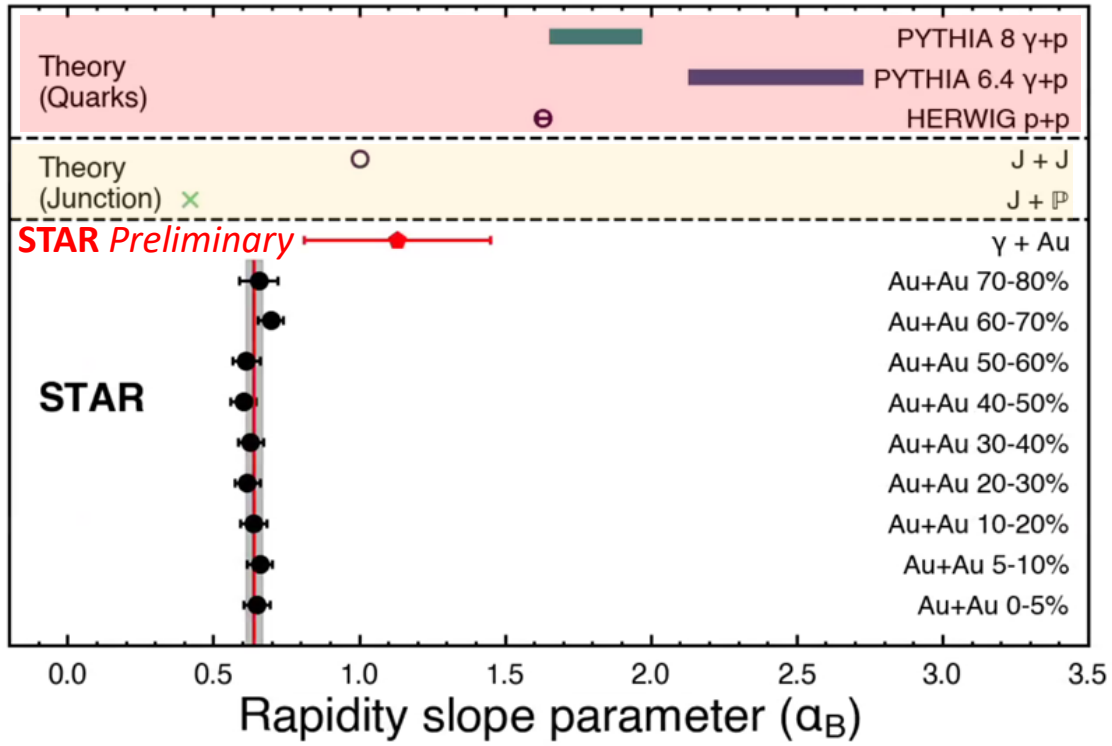
If the junction hypothesis is true:

- 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 ($\alpha_B \sim 0.5$)

STAR preliminary results point out that:

- $\alpha_B \sim 0.6$ for Au+Au
- $\alpha_B \sim 1.0$ for γ+Au
- Predicted values from:
  - ✓ HERWIG and PYTHIA disagree with the data
  - ✓ Junction-Junction (J+J) and Junction-Pomeron (J+P) are more compatible with data

Chun Yuen Tsang (QM 2023)



[1] STAR, PRC **79**, 034909 (2009)
[2] STAR, PRC **96,** 044904 (2017)
[3] Christiansen, J. R. & Skands, P. Z. JHEP 08, 003 (2015)
[4] Kharzeev, Phys. Lett. B 378, 238– 246 (1996)

At the RHIC
Isobaric ratio

Chun Yuen Tsang (QM 2023)

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 $(B/\Delta Q^{*}\Delta Z/A) = 1$
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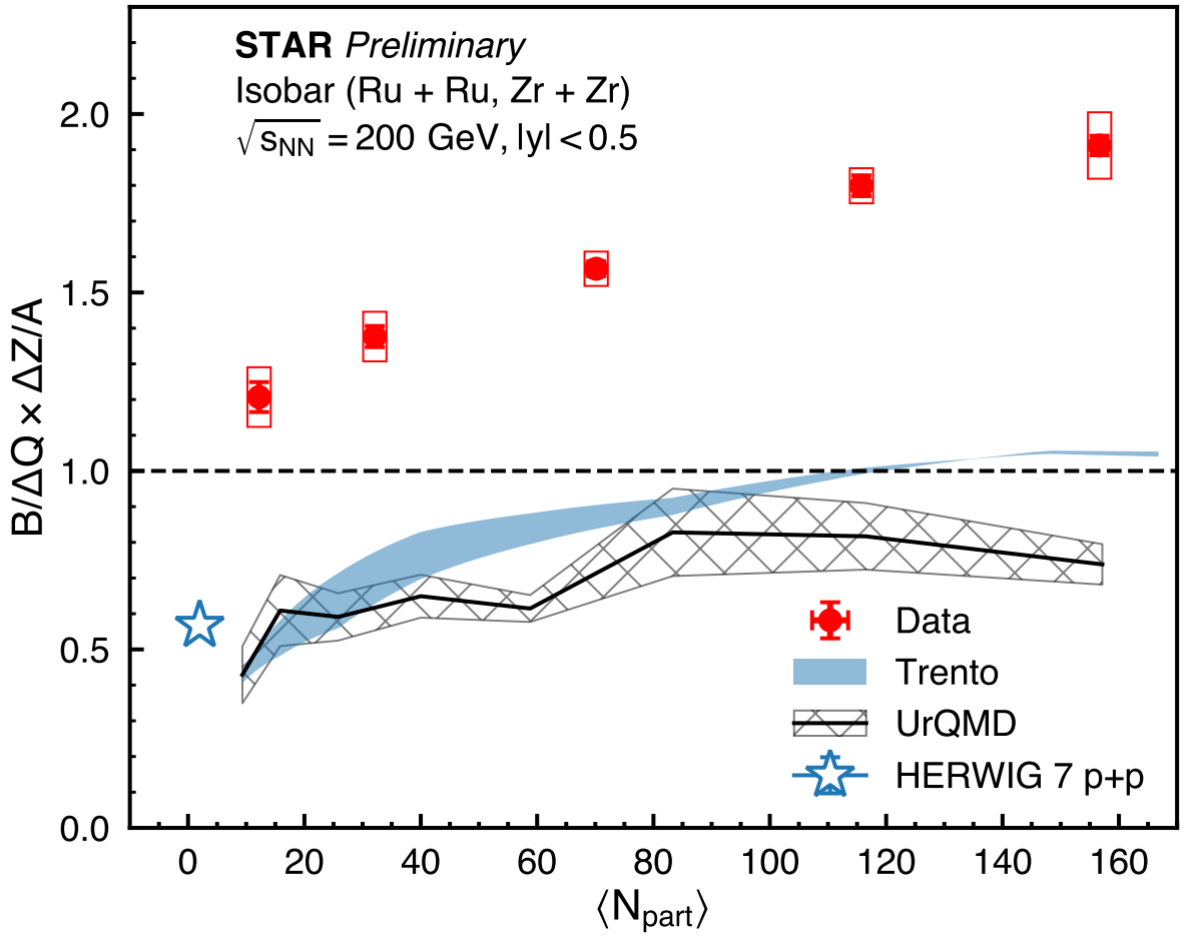
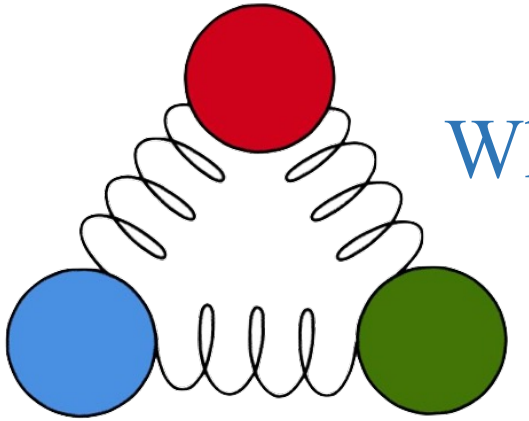


STAR preliminary results point out that:

- $(B/\Delta Q^{*}\Delta Z/A) > 1$
- Model calculations:
  - ✓ All presented models cannot describe the data
  - ✓ Trento model accounts for initial conditions only, and it's consistent with changes in neutron skin thickness differences



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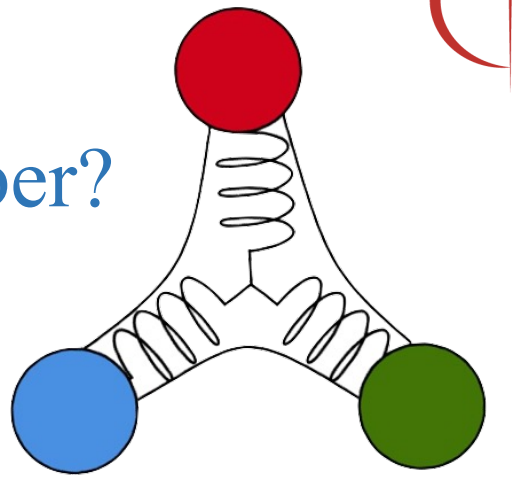


At RHIC:

- RHIC nuclear energy is at a sweet spot but has limited acceptance in rapidity Q2 and x

At EIC:

- Suitable energy range, good acceptance in rapidity (extended from 2.5 to 6.0) Q2 and x
  - ✓ Low-pt PID is needed to study the charge and baryon transports

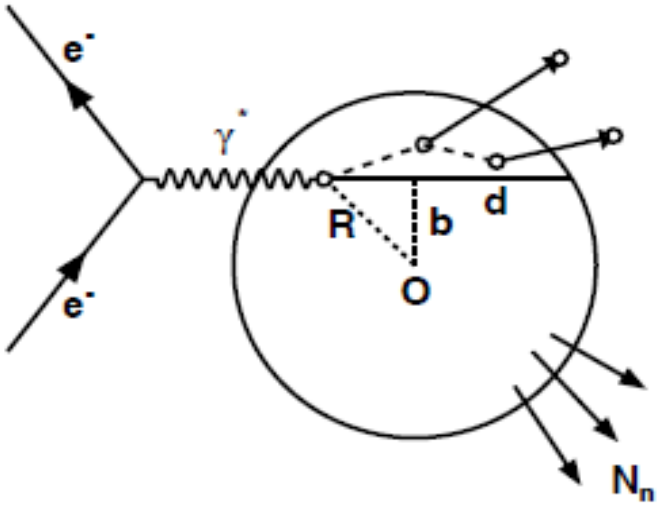
Can EIC answer such a question?

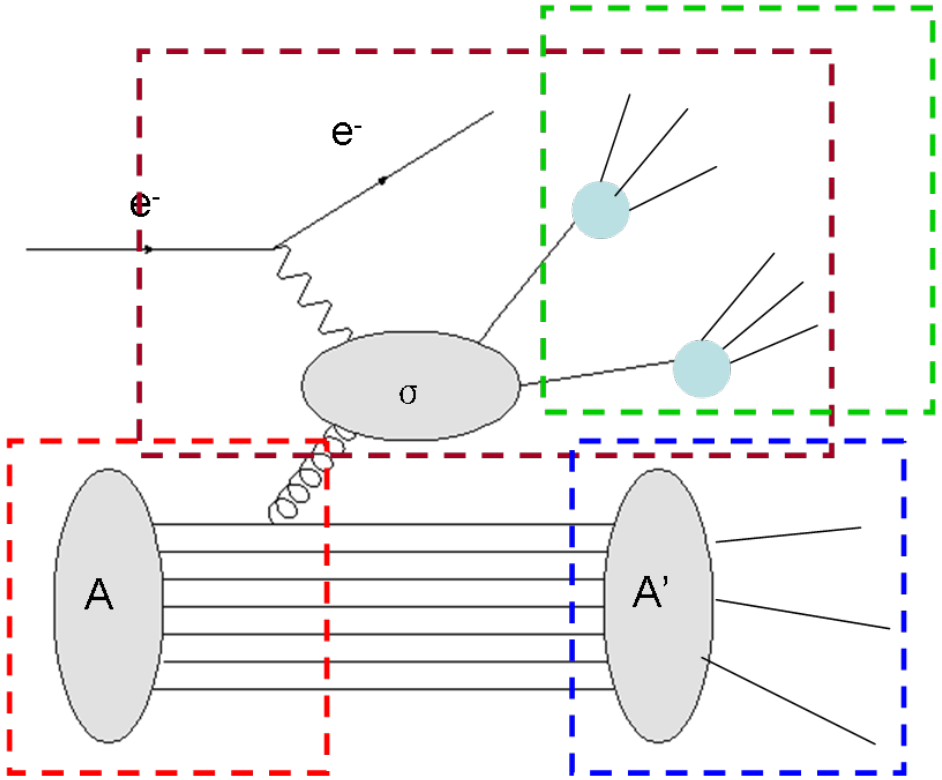
What carries the baryon number?

The models used in this work:

- PYTHIA 6.4
- BeGALE

PRD 106, 012007 (2022) BeAGLE





A hybrid model consisting of DPMJet and PYTHIA with nPDF EPS09.

Nuclear geometry by DPMJet and nPDF provided by EPS09.

Parton level interaction and jet fragmentation completed in PYTHIA.

Nuclear evaporation (gamma dexcitation/nuclear fission/fermi break up) treated by DPMJet

Energy loss effect from routine by Salgado&Wiedemann to simulate the nuclear fragmentation effect in cold nuclear matter

In BeAGLE, quarks carry the flow of baryon number.

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

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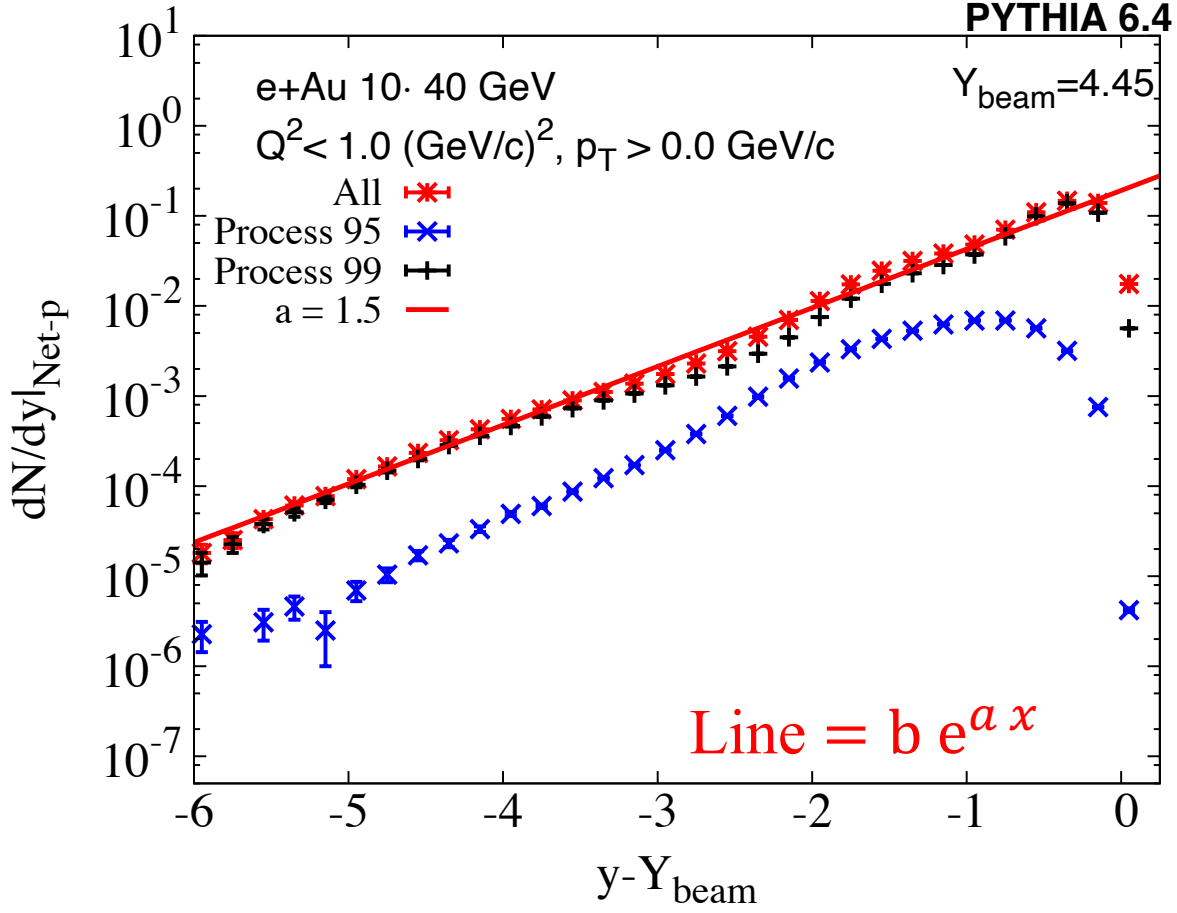
α_B from PYTHIA is larger than the prediction for the junction expectation

What is the x and Q^2 dependence of α_B?

Ongoing work



95 is soft, non-diffractive VMD low p_T

99 is LO DIS

(J. D. Brandenburg, N. Lewis, P. Tribedy, Z. Xu, arXiv:2205.05685 (2022)).

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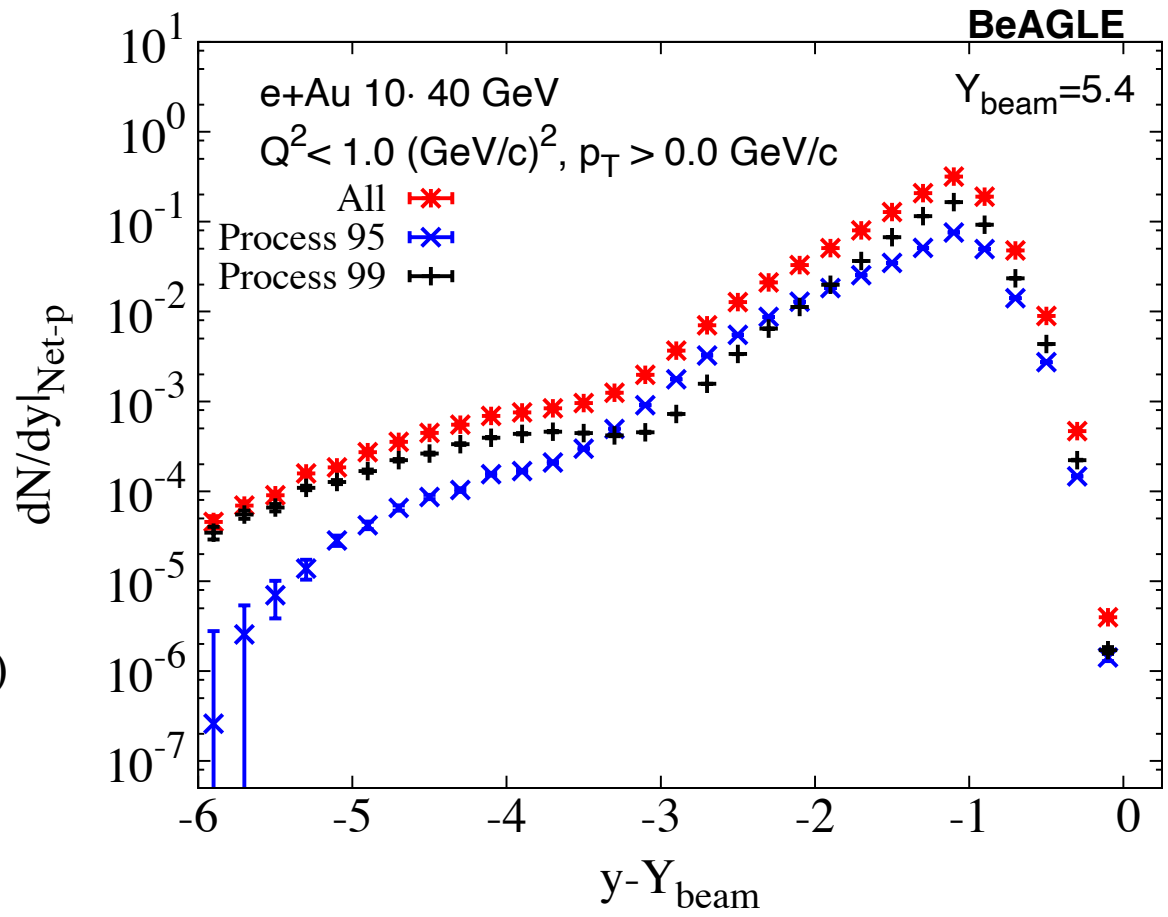

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BeAGLE results suggest two slopes (larger than 1.0) depending on the rapidity range

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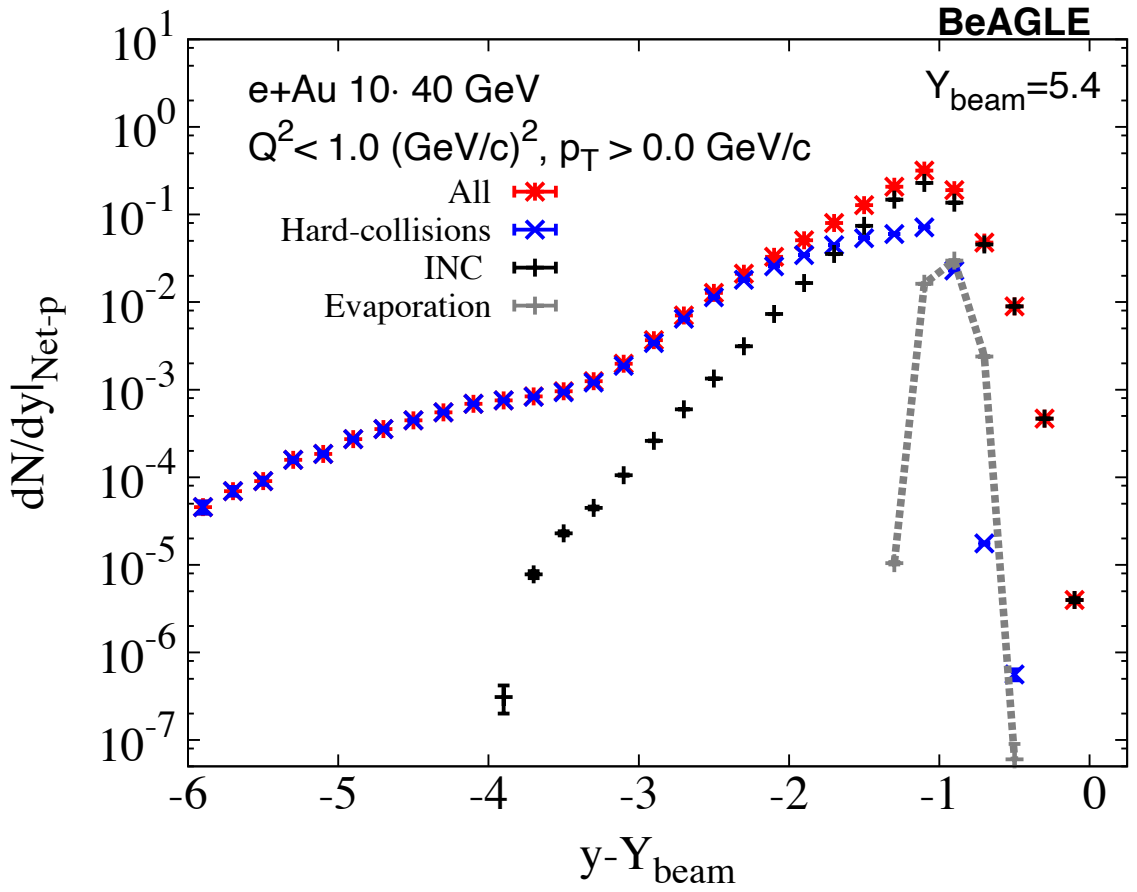

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Isobaric ratio

- 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
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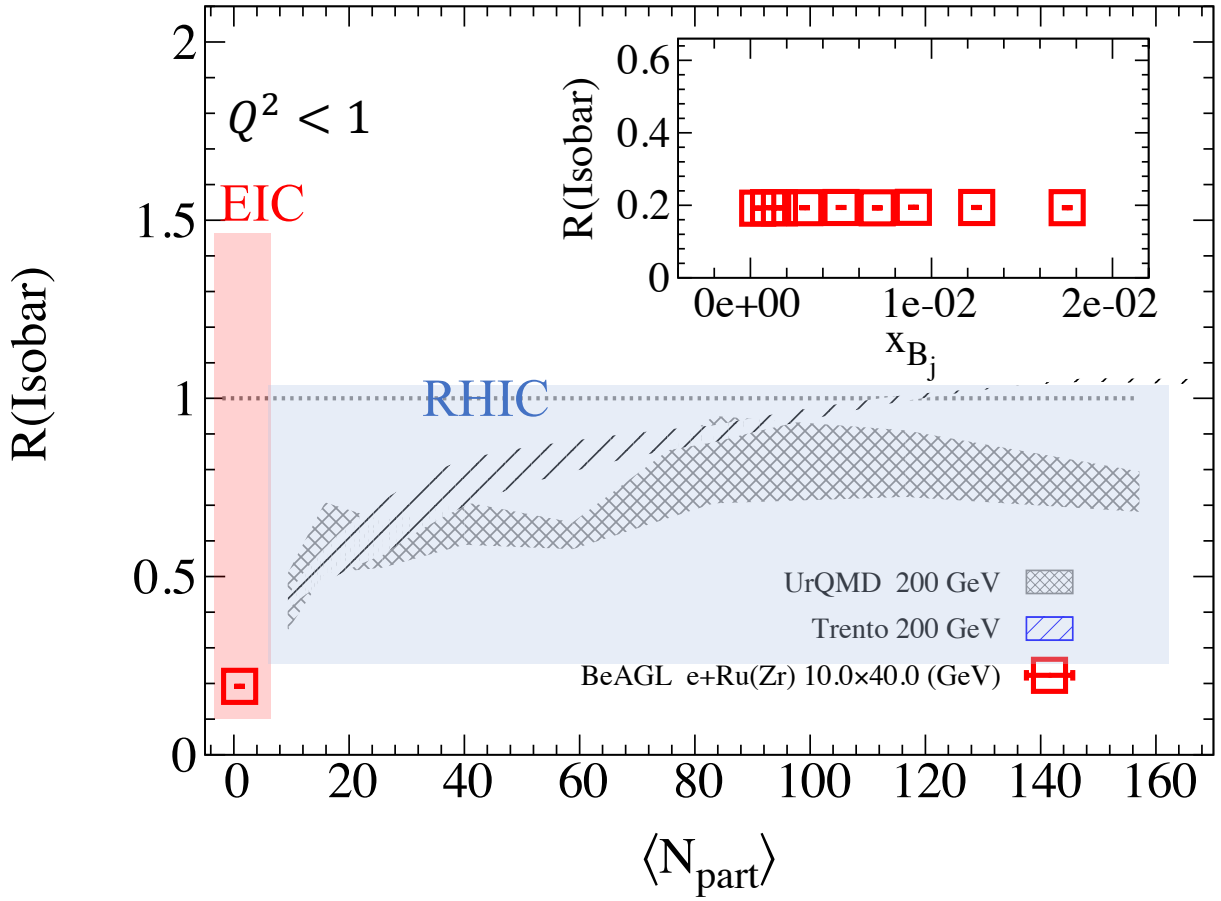
- $R(Isobar)$ is independent of x_{B_j}
  - ✓ Consistent with the quark's scenario

BeAGLE shows value consistent with the quark's scenario



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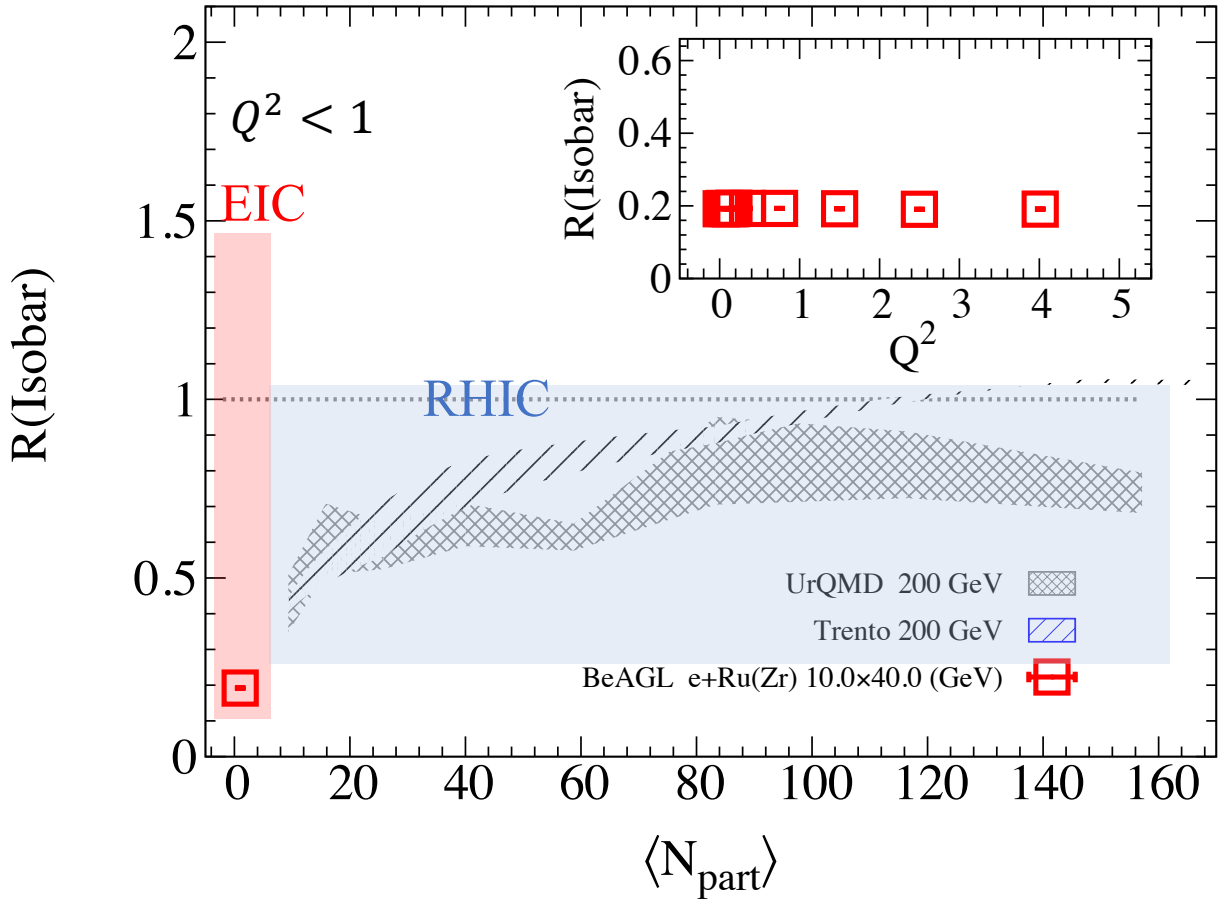

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- $R(Isobar)$ show dependence on the BeAGLE processes

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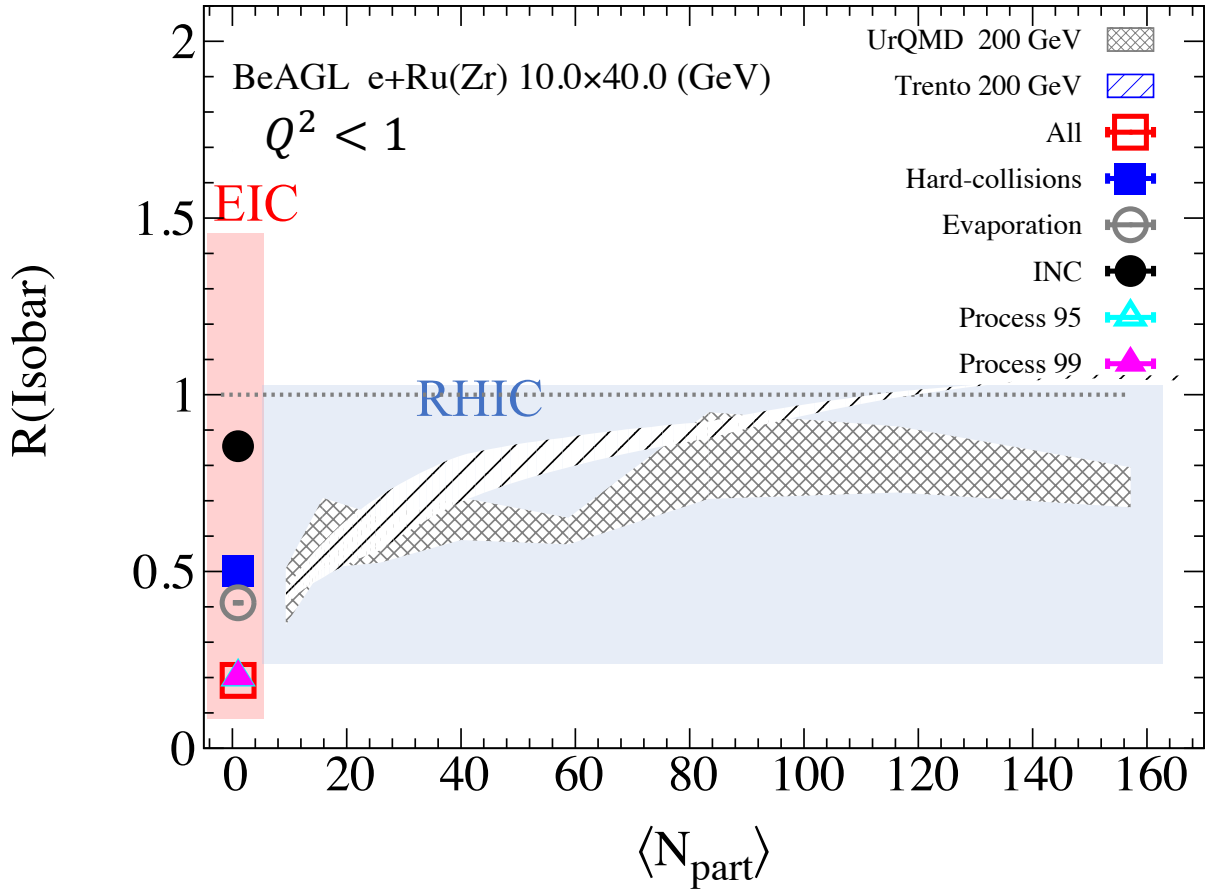

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Conclusions

- 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
  - ✓ Consistent with the quark's scenario

At EIC

- Need small Q^2 and low-momentum hadron particle identification
- Isobar collisions to measure charge transport (quark transports)

Thank You