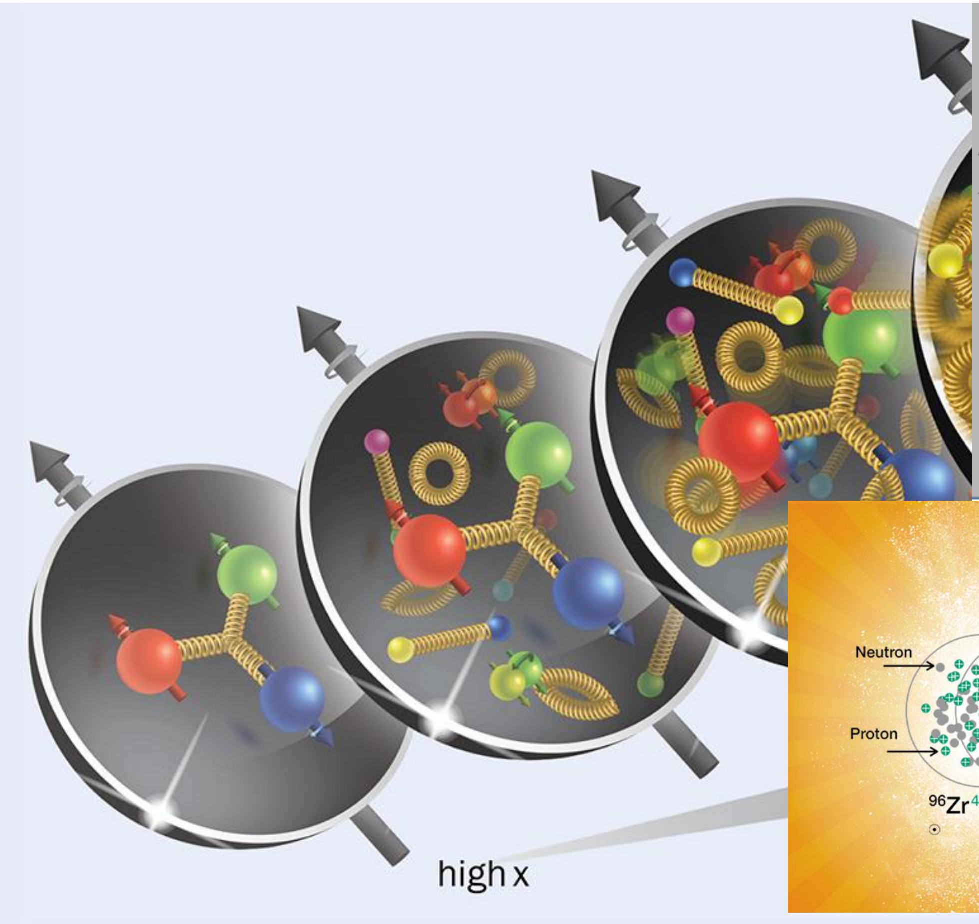
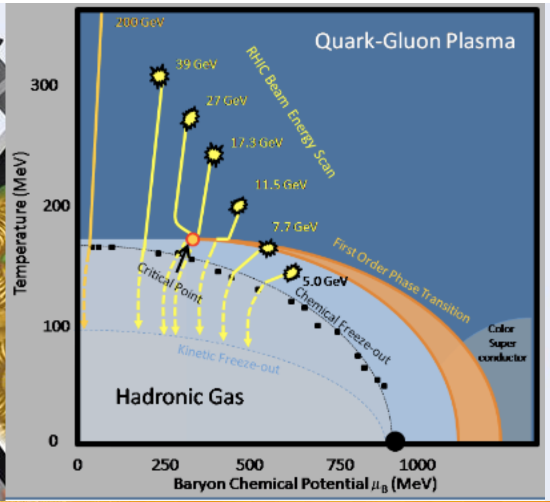
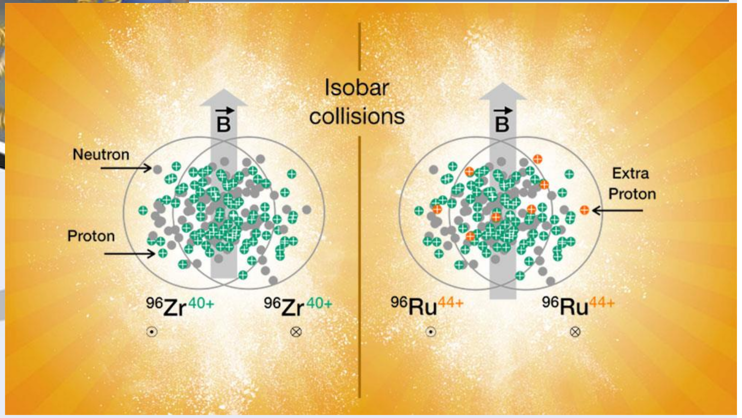
Baryon Junction at AGS?







Zhangbu Xu

Kent State University

BNL

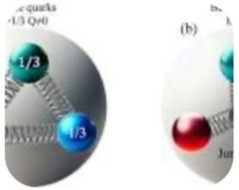
- baryon number carrier
- Three experimental approaches at RHIC (3+1)
- Other experimental results at FXT
- Future with AGS proton beam?

Google AI overview:

AI Overview

Listen

A baryon junction is **a point where three string operators merge in a baryon wave function**. The baryon junction is a significant factor in the dynamics of baryon stopping at high energies.



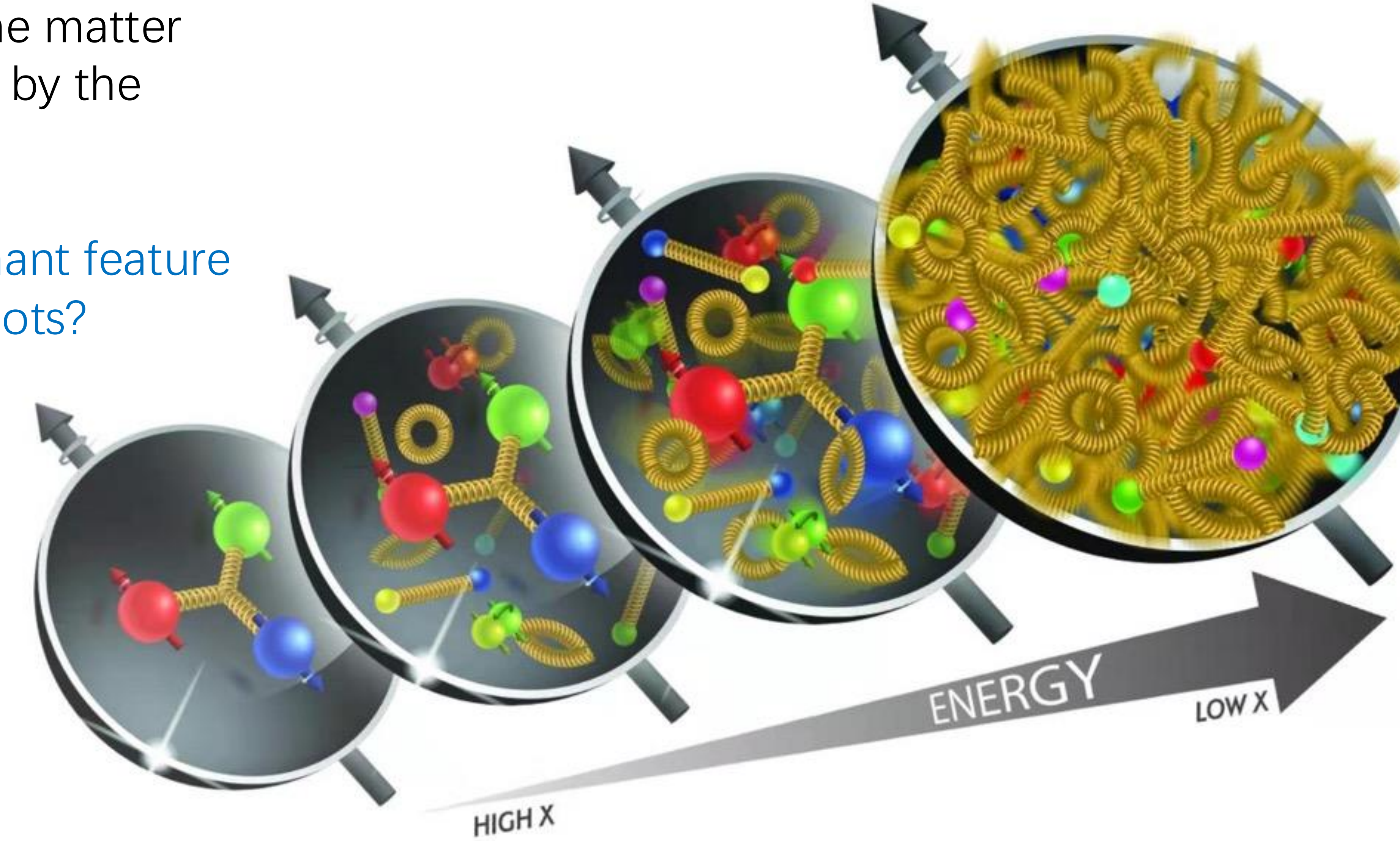
Explanation

- The baryon junction is a result of the local gauge invariance of the baryon wave function.
- The baryon junction has been observed in data from the Relativistic Heavy Ion Collider (RHIC).
- The baryon junction can be tested in semi-inclusive deep inelastic scattering at the Jefferson Laboratory and the Electron Ion Collider.
- The baryon junction can be used to explain the baryon excess in the midrapidity region of ultra-relativistic nucleus-nucleus collisions.
- The transport of baryonic gluon junctions can lead to an exponential distribution of net-baryon density.

Quantum Chromodynamics (QCD)

In nuclei, 99% of the matter mass is generated by the strong interaction

What is the dominant feature in all these snapshots?



Model implementations of baryons at RHIC

- Many of the models used for heavy-ion collisions at RHIC (HIJING, AMPT, UrQMD) have implemented a nonperturbative baryon stopping mechanism

V. Topor Pop, *et al,* Phys. Rev. C **70**, 064906 (2004)

Zi-Wei Lin, *et al*, Phys. Rev. C **72**, 064901 (2005)

M. Bleicher, *et al,* J.Phys.G **25,** 1859-1896 (1999)

- Baryon Stopping
  - Theorized to be an effective mechanism of stopping baryons in pp and AA

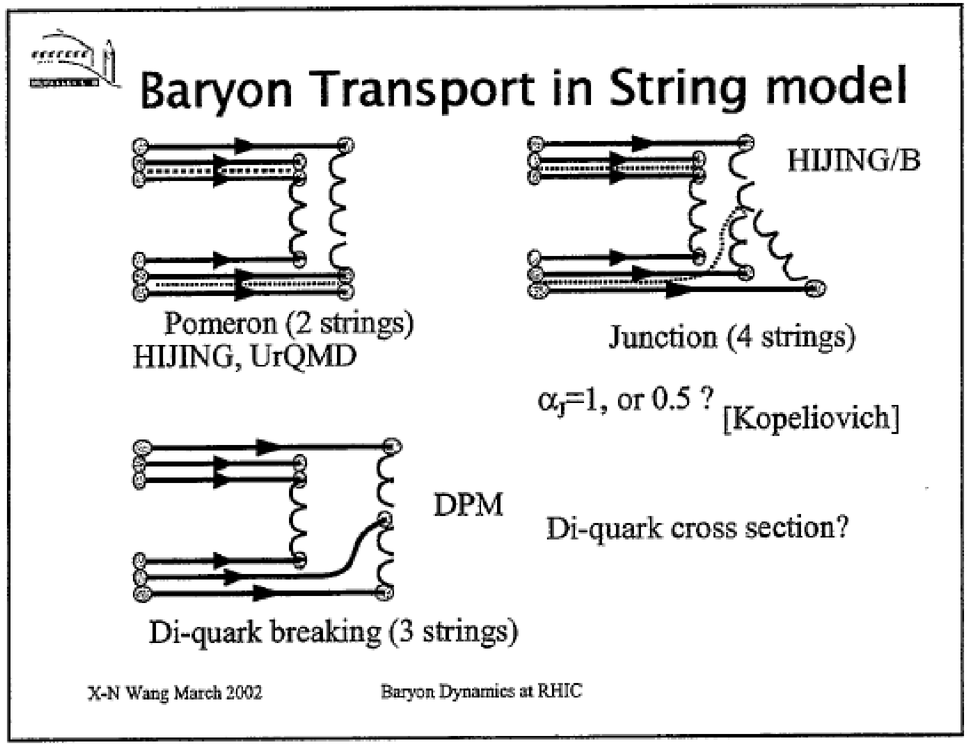
D. Kharzeev, Physics Letters B **378**, 238-246 (1996)

- Specific rapidity dependence is predicted:

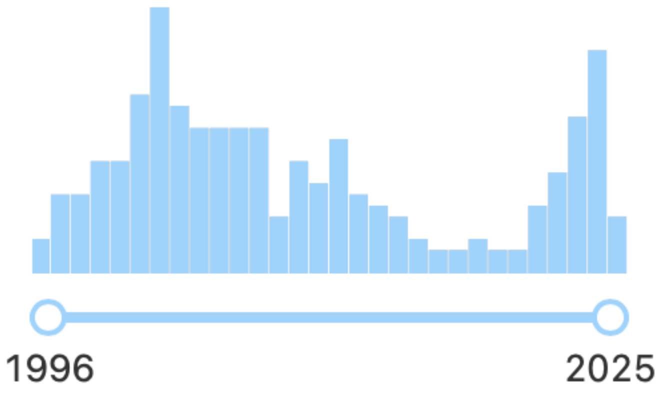
$$p = \sim e^{-\alpha_B y}$$

α_B ~=0.5

2003 RBRC Workshop on "Baryon Dynamics at RHIC"
Organized by D. Kharzeev, M. Gyulassy, N. Xu



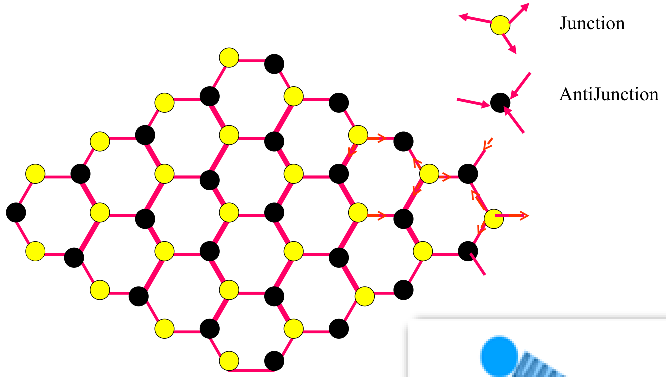
D. Kharzeev, Physics Letters B **378**, 238-246 (1996)
"Can gluons trace baryon number?"

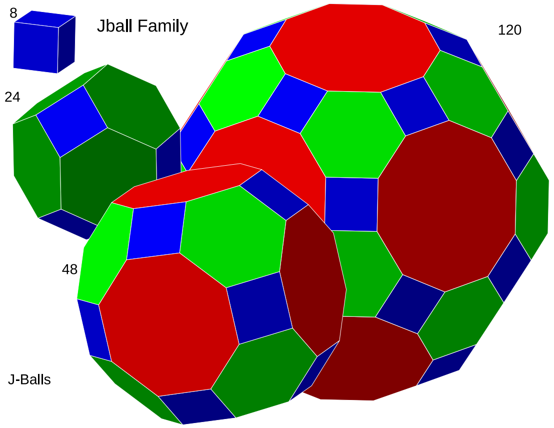


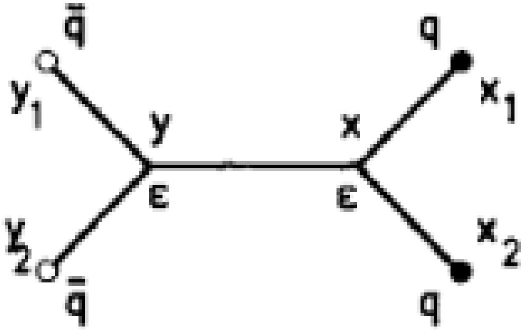
"Science, however, is never conducted as a popularity contest..." --- Michio Kaku

BUT citations ARE

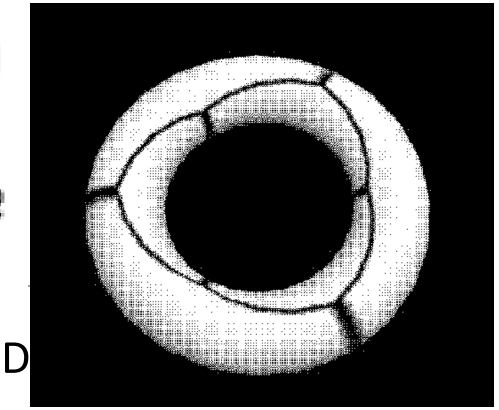
Junction anti Junction Gluon
"Graphite"



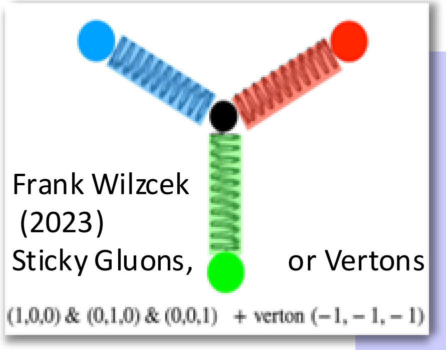




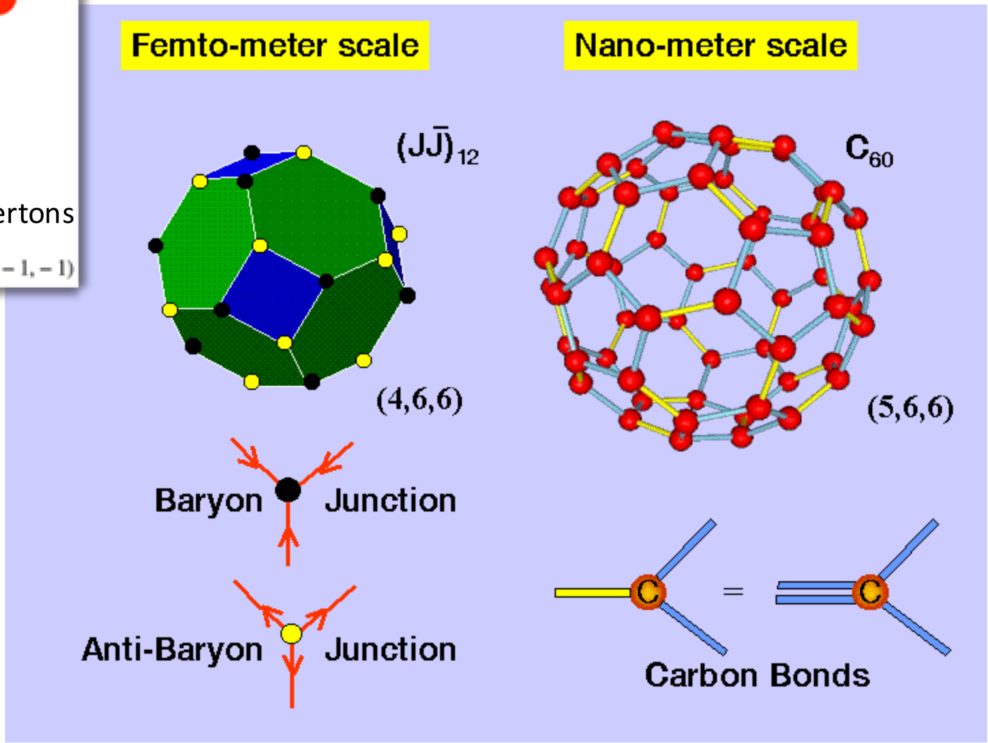
Veneziano, 50 years of QCD
arXiv:1603.05830

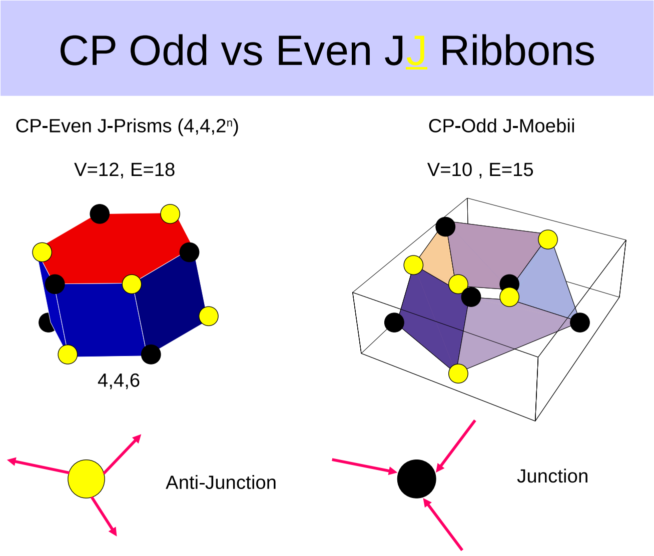


Baryonium Torus, O.I. Piskounova
hep-ph/1909.08536



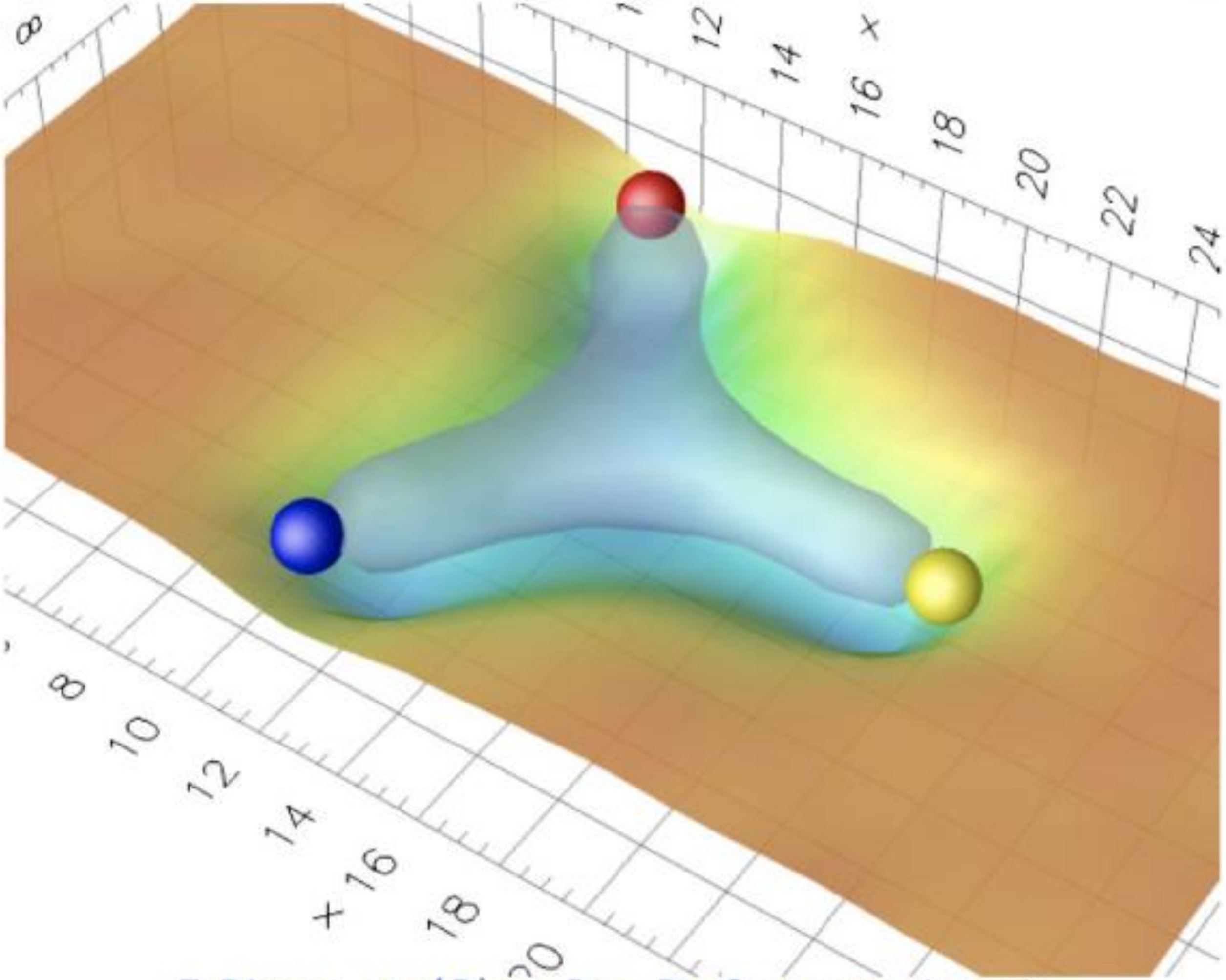
Buckyballs and gluon junction networks on the femtometre scale





D. Kharzeev, PLB 378 (96)
S. Vance, M. Gyulassy, XN Wang, PLB 443 (98)
T. Csorgo, M. Gyulassy, D. Kharzeev, JPG 30 (2004) L17

Y-Shaped Baryon Flux-Tube in Lattice QCD



F. Bissey, *et al* Phys. Rev. D **76**, 114512 (2007)

- Some lattice calculations have suggested the formation of a Y-shaped color flux tube among the three quarks at long distances

  T. T. Takahashi, *et al* Phys. Rev. Lett. **86**, 18 (2001).

  T. Takahashi, *et al*, Phys. Rev. D **65**, 114509 (2002)

  Takahashi, RBRC workshop 2003
- Still under investigation

Finite Temperature LQCD?

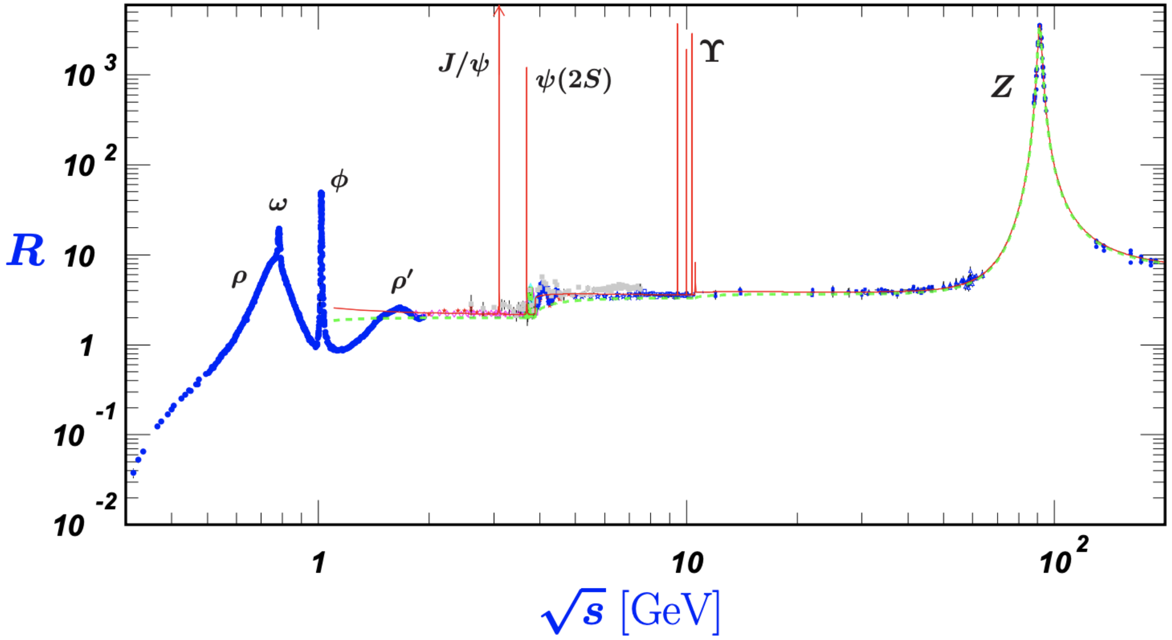
Measurements of quark electric charges

Scattering cross section $\sigma \propto e_q^2$

$(2/3)^2+(1/3)^2+(1/3)^2=2/3$

$(2/3)^2+(2/3)^2+(1/3)^2=1$

$(1/3)^2+(1/3)^2+(1/3)^2=1/3$



PDG

Figure 53.2: World data on the total cross section of $e^+e^- \to hadrons$ and the ratio $R(s) = \sigma(e^+e^- \to hadrons, s)/\sigma(e^+e^- \to \mu^+\mu^-, s)$. $\sigma(e^+e^- \to hadrons, s)$ is the experimental cross section corrected for initial state radiation and electron-positron vertex loops, $\sigma(e^+e^- \to \mu^+\mu^-, s) = 4\pi\alpha^2(s)/3s$. Data errors are total below 2 GeV and statistical above 2 GeV. The curves are an educative guide: the broken one (green) is a naive quark-parton model

Riordan, Science 1992

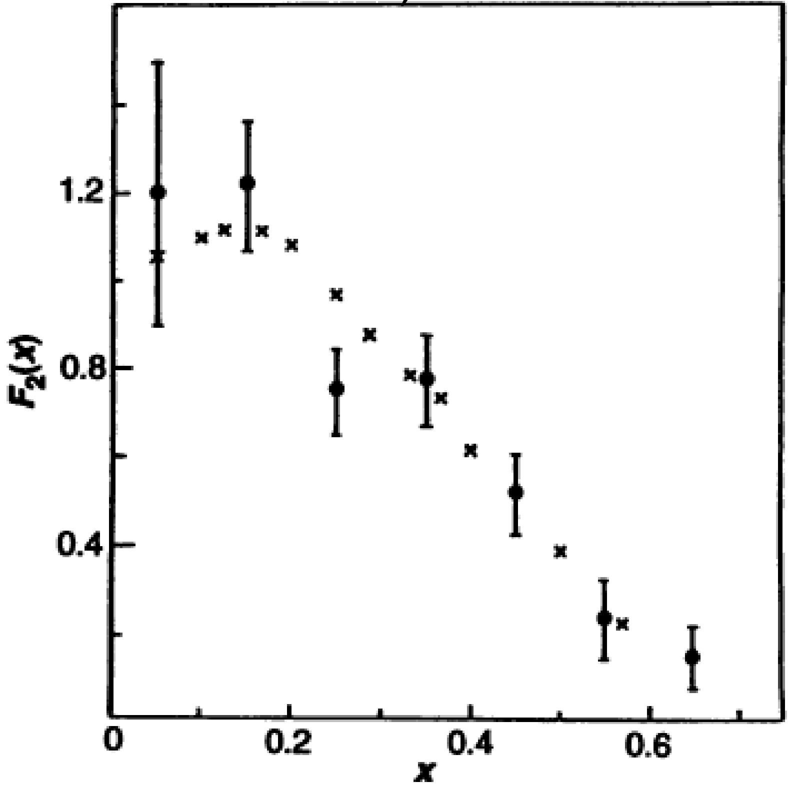
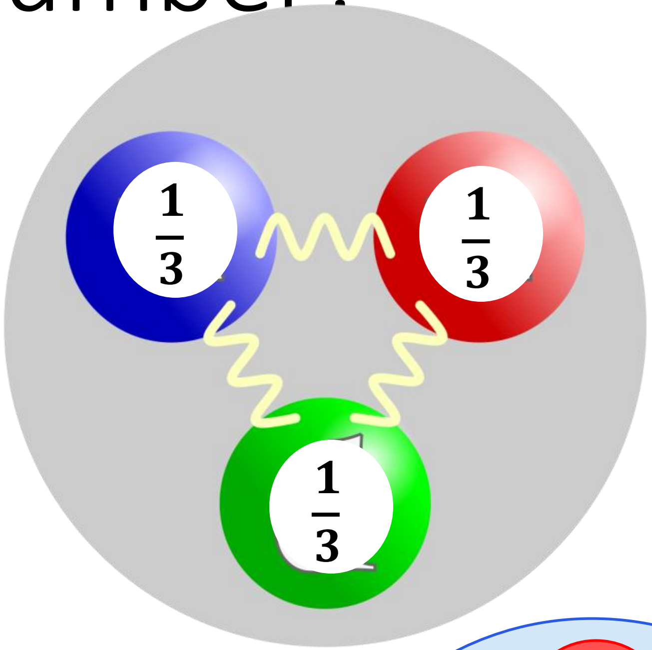
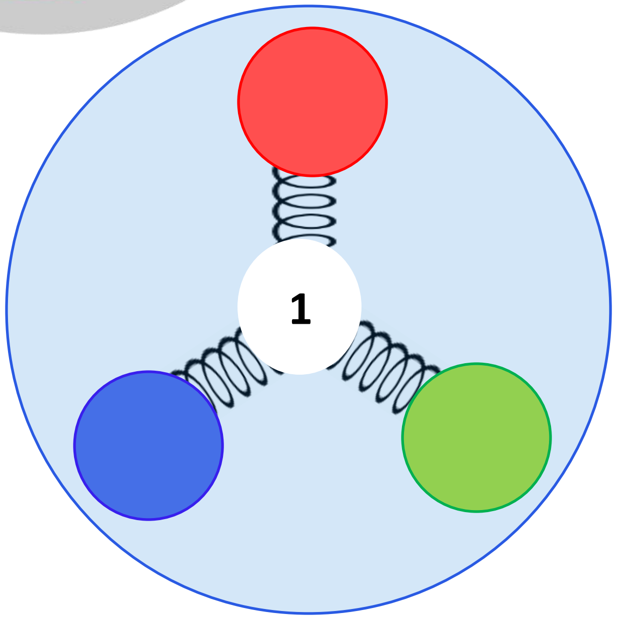


Fig. 8. Comparison of structure functions measured in deep inelastic neutrino-nucleon scattering experiments on the Gargamelle heavy-liquid bubble chamber with the MIT-SLAC data [(●), Gargamelle, $F_2^{\nu N}$; (×), MIT-SLAC, $(18/5)F_2^{eN}$]. When multiplied by 18/5, a number specified by the quark-parton model, the electron scattering data coincide with the neutrino data.

Measurements of quark baryon number?



- Textbook picture of a proton
  - Lightest baryon with strictly conserved baryon number
  - Each valence quark carries 1/3 of baryon number
  - Proton lifetime >10^{34} years
  - Quarks are connected by gluons
- Alternative picture of a proton
  - Proposed at the Dawn of QCD in 1970s
  - A Y-shaped gluon junction topology carries baryon number (B=1)
  - The topology number is the strictly conserved number
  - Quarks do not carry baryon number
  - Valence quarks are connected to the end of the junction always
- **Neither of these postulations has been verified experimentally**

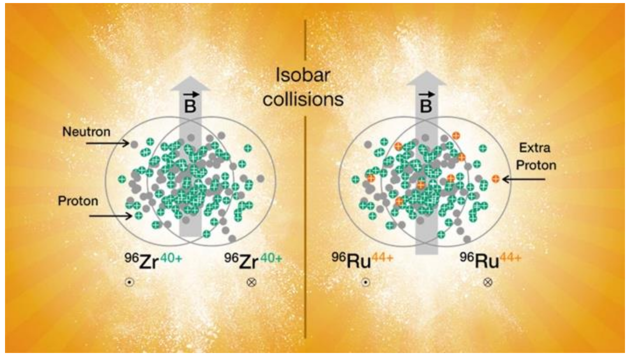


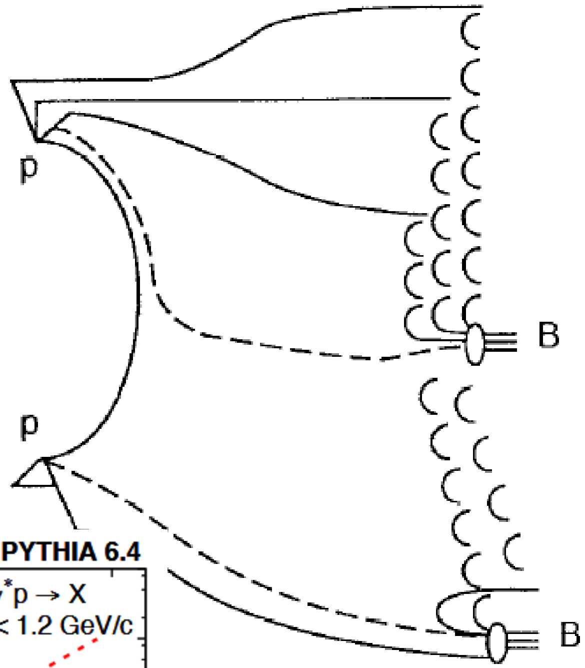
[1]: Artru, X.; String Model with Baryons: Topology, Classical Motion. Nucl. Phys. B 85, 442–460 (**1975**).
[2]: Rossi, G. C. & Veneziano, G. A; Possible Description of Baryon Dynamics in Dual and Gauge Theories. Nucl. Phys. B 123, 507–545 (**1977**)

Three approaches toward tracking the origin of the baryon number

N. Lewis, *et al.*, arXiv:2205.05685

1. STAR Method:
   Charge (Q) stopping vs baryon (B) stopping:
   if valence quarks carry Q and B, Q=B at middle rapidity



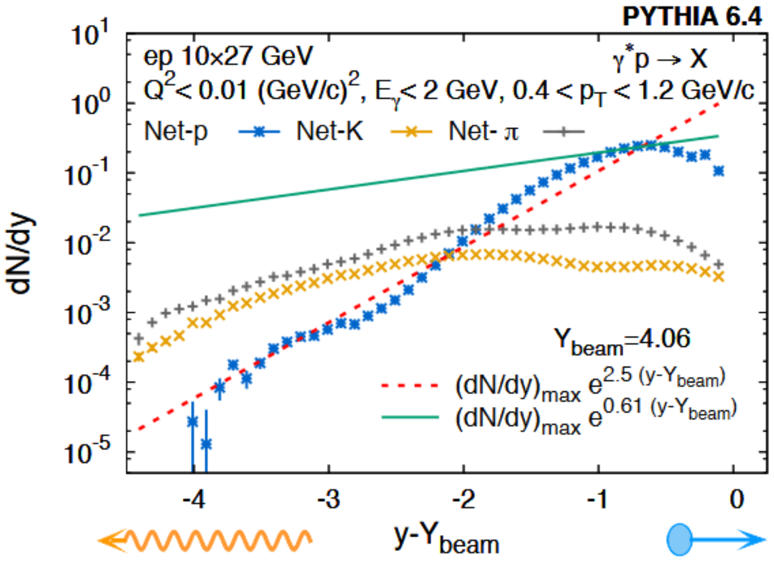


2. Kharzeev-STAR Method:
   If gluon topology (J) carries B as one unit, it should show scaling according to Regge theory

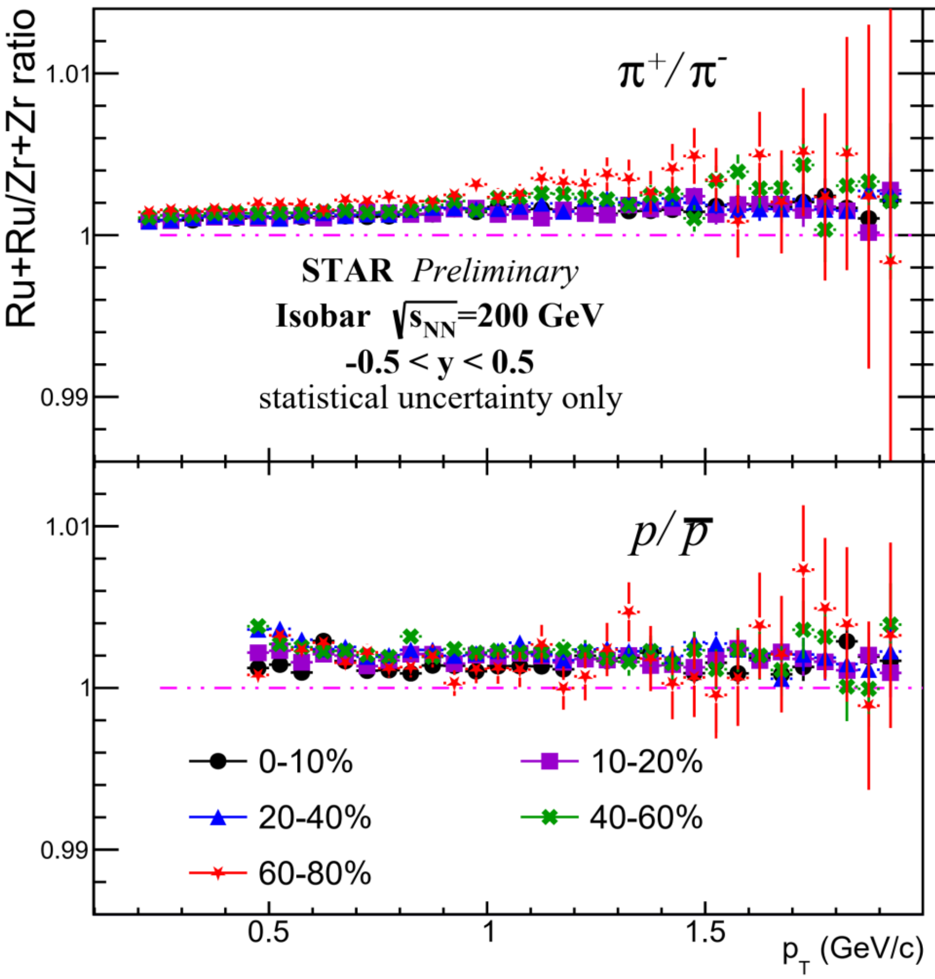
$$p = \sim e^{-\alpha_B y}$$

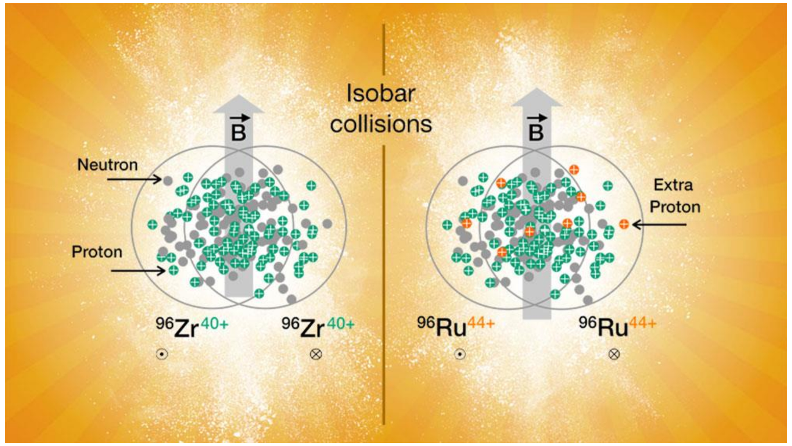
α_B ~=0.5

3. Artru Method:
   In γ+Au collision, rapidity asymmetry can reveal the origin



Double ratios between Ru+Ru and Zr+Zr collisions





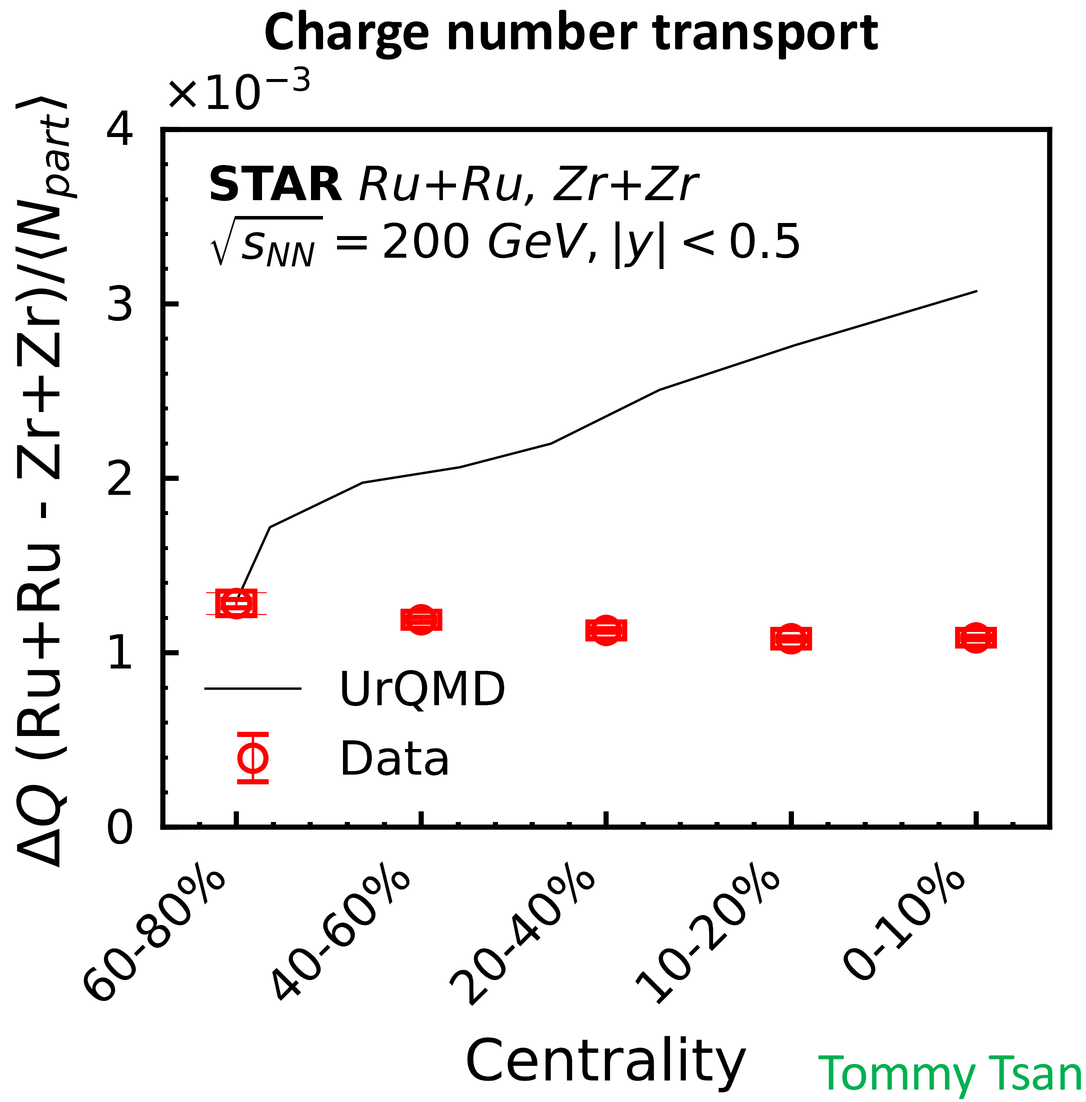
- The double ratios of π^+/π^- and $p/\bar{p}$ are larger than 1. Due to extra charge in Ru?
- The double ratios of K^-/K^+ is consistent with unity within uncertainties.

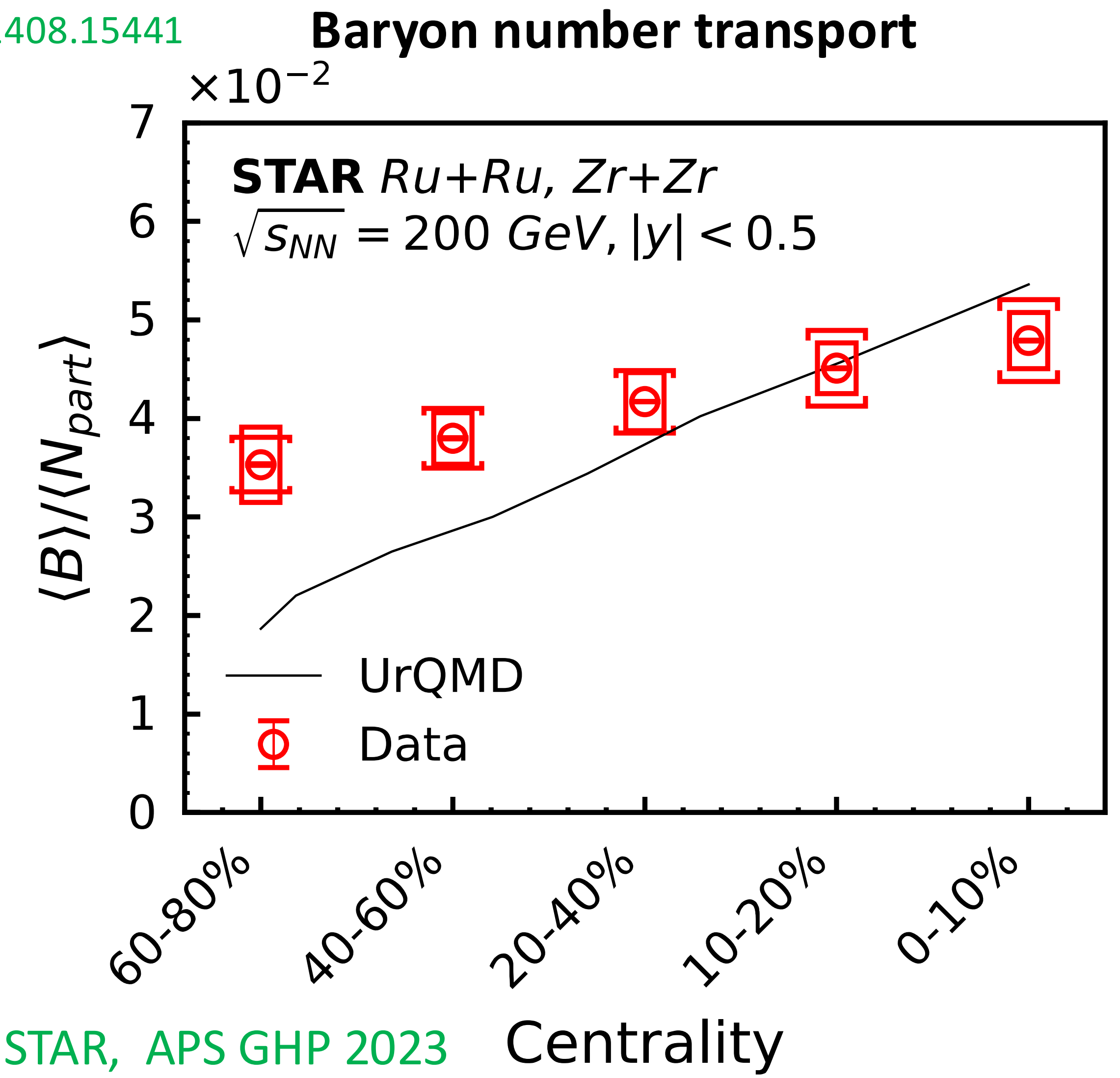
From baryon stopping: B*(ΔZ/A)~=2x10^{-3}

Charge stopping: ΔQ ~=1x10^{-3}

Separate charge and baryon transports

STAR, arXiv:2408.15441





Tommy Tsang (KSU) for STAR, APS GHP 2023

UrQMD matches data on charge stopping better in peripheral; better on baryon stopping in central
overpredicts charge stopping in central; underpredicts baryon stopping in peripheral

FXT baryon rapidity loss

The average close to beam rapidity
(limiting Fragmentation)
does not reflect the "tail" at high rapidity

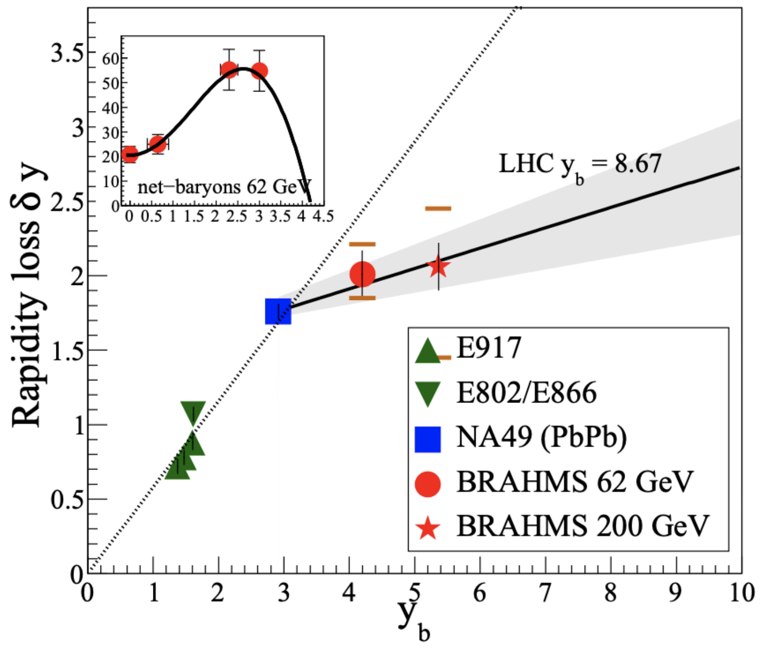


Figure 3: Rapidity losses from AGS, SPS and RHIC as a function of beam rapidity. The solid line is a fit to SPS and RHIC data, and the band is the statistical uncertainty of this fit. The dashed line is a linear fit to AGS and SPS data from [15].

BRAHMS 2009

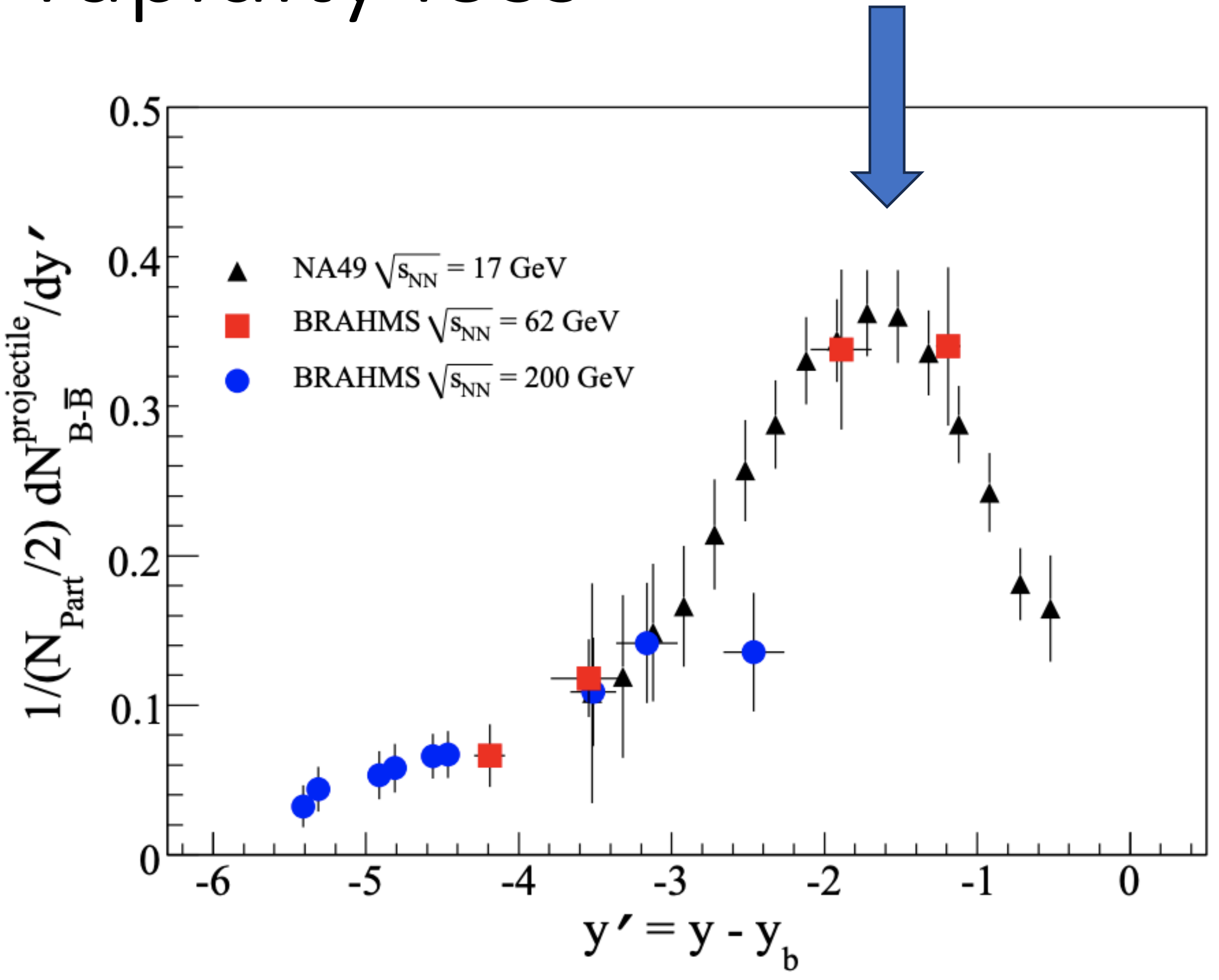


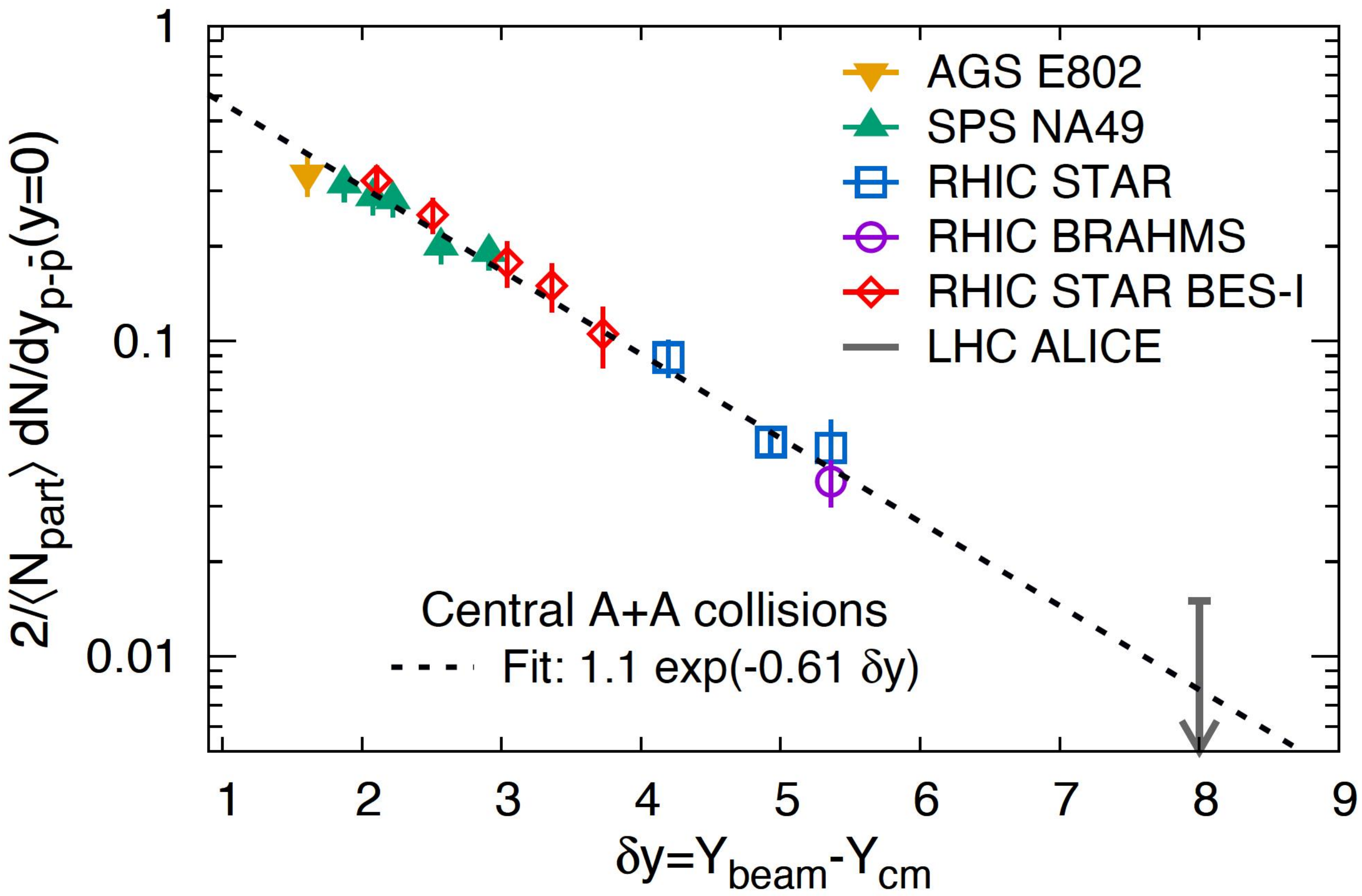
Figure 5: Projectile net-baryon rapidity density $(1/N_{part}/2)dN^{projectile}_{B-\bar{B}}/dy'$ from SPS and RHIC after subtraction of the target net-baryon contribution (see Fig. 4).

Quantifying baryon number transport

- RHIC Beam Energy Scan (BES-I) span large range of rapidity shift
- Exponential with slope of α_B =0.61±0.03
- Consistent with the baryon junction transport by gluons: α_B~=0.5+Δ Δ~=0.1

STAR, Phys. Rev. C **79** (2009) 34909; **96** (2017) 44904

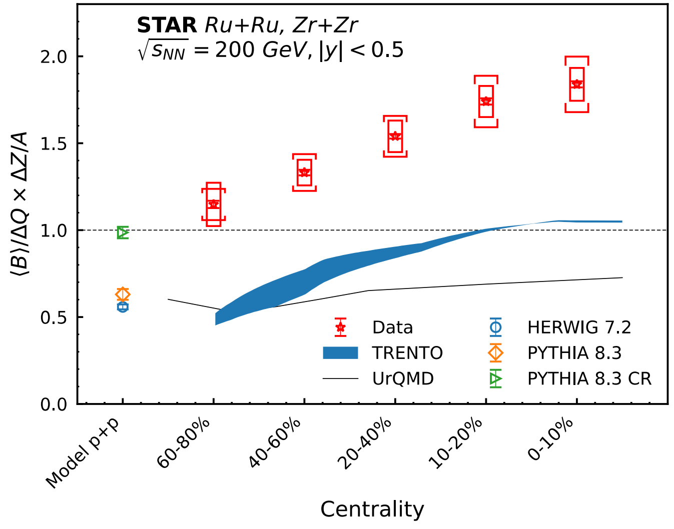
N. Lewis, et al., arXiv:2205.05685



Three approaches toward tracking the origin of the baryon number

STAR, https://arxiv.org/pdf/2408.15441

1. STAR Method:
   Charge (Q) stopping vs baryon (B) stopping:
   if valence quarks carry Q and B, Q=B at middle rapidity
   B/Q=2

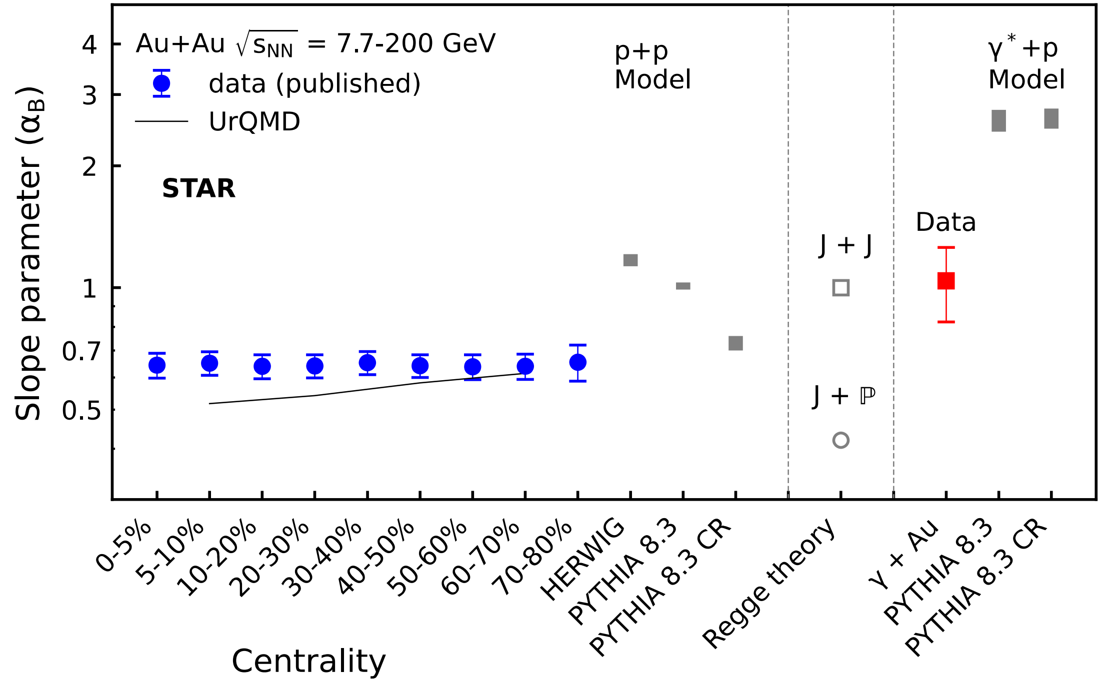


STAR, arXiv:2408.15441

2. Kharzeev-STAR Method:
   If gluon topology (J) carries B as one unit, it should show scaling according to Regge theory
   α_B=0.61

$$p = \sim e^{-\alpha_B y}$$

α_B ~=0.5



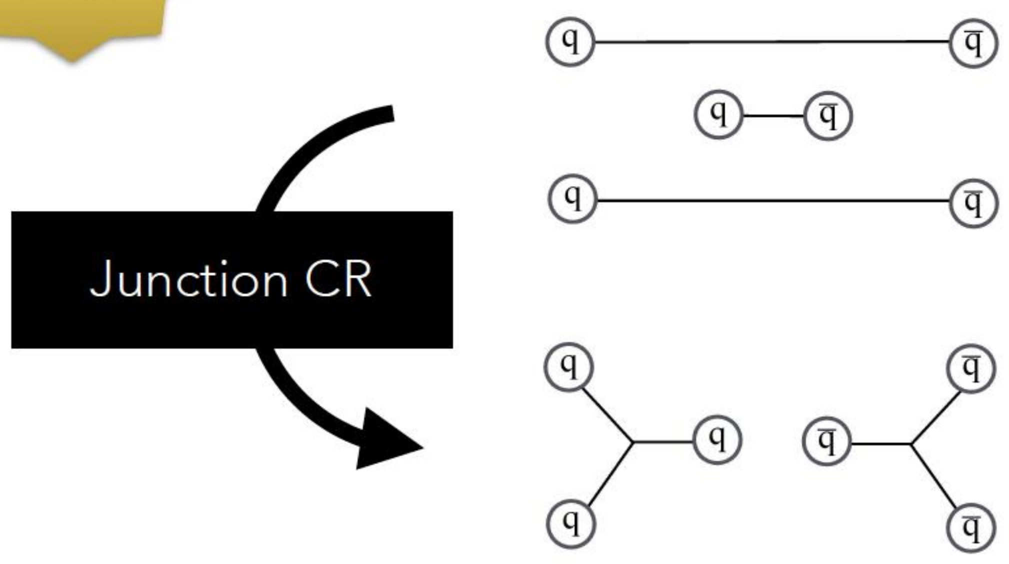
3. Artru Method:
   In γ+Au collision, rapidity asymmetry can reveal the origin
   α_B(A+A)=0.61< α_B(γ+A)=1.1< α_B(PYTHIA)

“Final-State” baryon junction in PYTHIA 8.x

new!

Peter Skands, 2021

Illustrations by J. Altmann



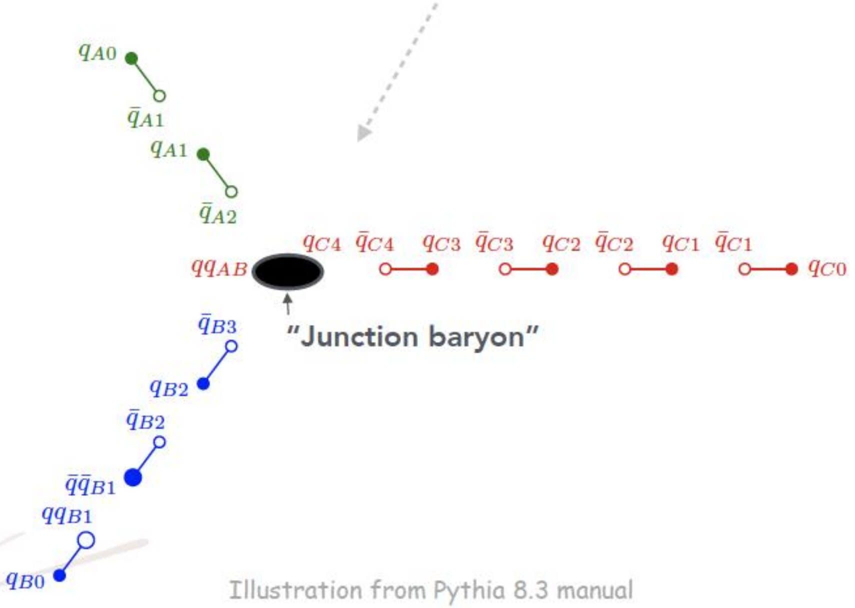


Illustration from Pythia 8.3 manual

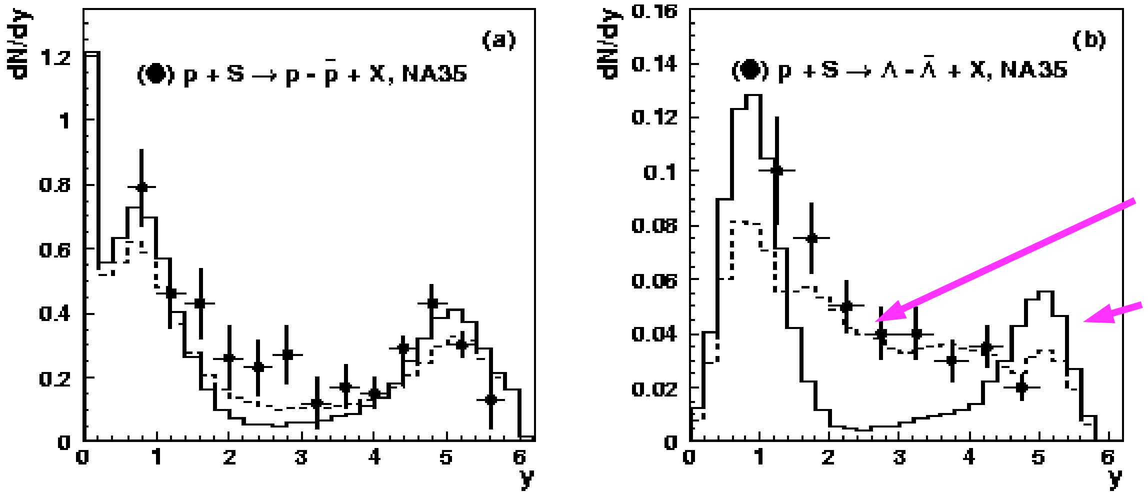
Junction treatment (PYTHIA MANUAL 8.x)

A junction topology corresponds to an Y arrangement of strings i.e. where three string pieces have to be joined up in a junction. Such topologies can arise if several valence quarks are kicked out from a proton beam, or in baryon-number-violating SUSY decays. Special attention is necessary to handle the region just around the junction, where the baryon number topologically is located. The junction fragmentation scheme is described in [Sjo03, 2003]. The parameters in this section should not be touched except by experts.

MCnet

NET BARYON NUMBER TRANSPORT VIA GLUONIC JUNCTIONS vs SPS data

S Vance, MG, XN Wang Phys.Lett.B443:45-50,1998



HIJING/B dashed

HIJING   solid

Distribution of final Y=rapidity of proton = $\tanh^{-1}(v_z)$

Miklos Gyulassy

Prepared in 08/18/2022

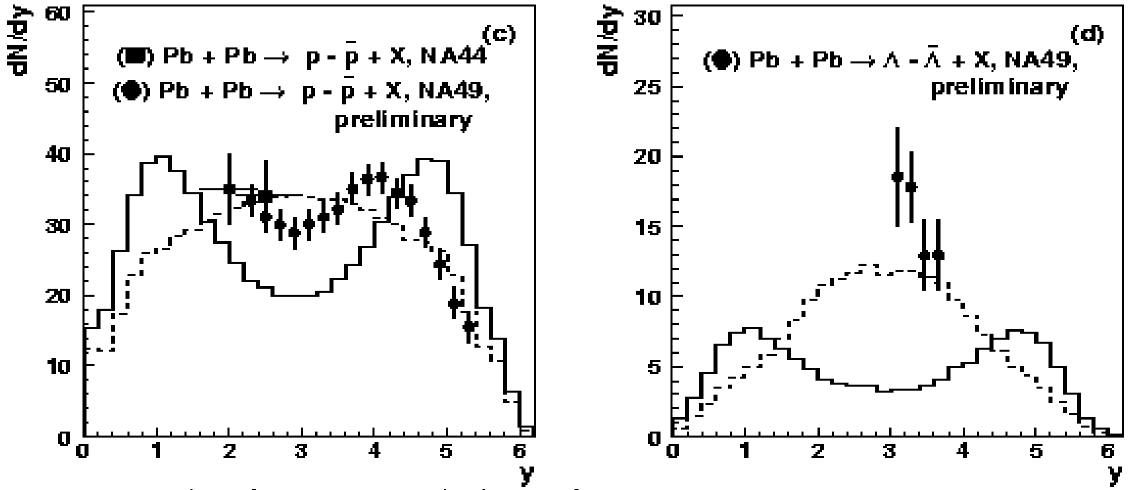
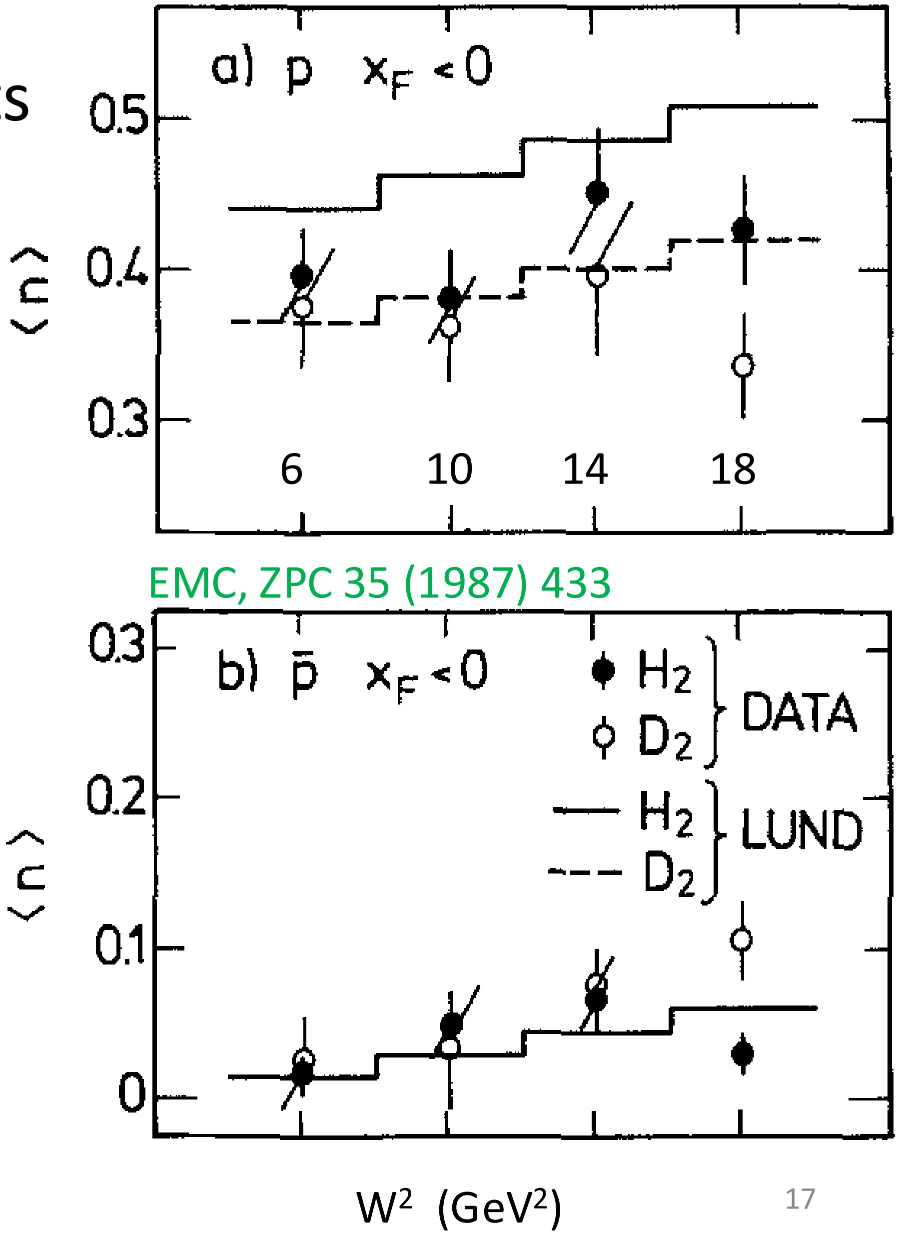


FIG. 1. HIJING (solid) and HIJING/B (dashed) calculations of the valence proton and hyperon rapidity distributions are shown for minimum bias $p+S$ collisions at 200 AGeV and central $Pb+Pb$ collisions at 160 AGeV. The data are from measurements made by the NA35 [1,2], NA44 [3] and NA49 [5] collaborations.

What do we know about μ+p (d) collisions

280 GeV muon on hydrogen and deuterium targets

Diquark Lund model predicts a flavor dependence of backward proton production (20%) while data shows little-to-no dependence



EMC, ZPC 35 (1987) 433

Fig. 5a-d. Average multiplicities from the H_2 (full circles) and the D_2 target (open circles) vs. W for backward protons a, backward antiprotons b. The histograms show the Lund model predictions (full line: H_2 target, dashed line: D_2 target, full line only where both are the same)

the Lund model (JETSET62) predicts a higher yield of backward going protons from hydrogen than from deuterium, an effect which is less pronounced in the data.

Total citations: 19

Simulation at present day

Niseem Magdy (SBU), arXiv:2408.08713

Same kinematics as EMC,
reproduce the simulation result

Next, using EIC kinematics,

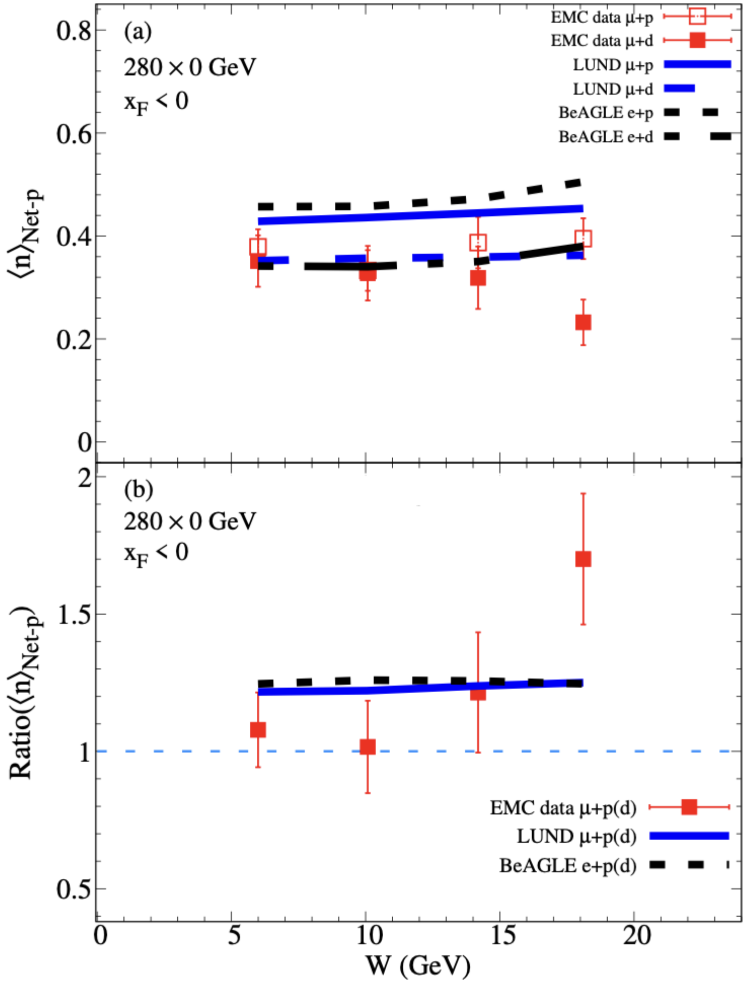


FIG. 7. The W dependence of the net-proton for μ+p and μ+d at 280-GeV muon on fixed targets are shown in panel (a). The ratios between μ+p and μ+d are presented in panel (b). Data and LUND model calculations are extracted from Ref. [15].

Does proton transport
independent of target flavor

AGS FXT p+A collisions

E910 (Spokesperson: Brian Cole)

E910, Phys.Rev.C77:015209,2008

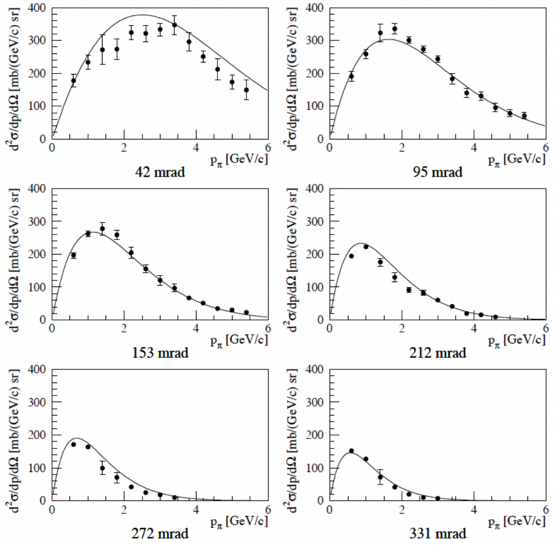


FIG. 7: Inclusive p-Be π^+ production cross section data and fits vs. π^+ momentum, at 17.5 GeV/c incident proton momentum. Fits are defined in Table II.

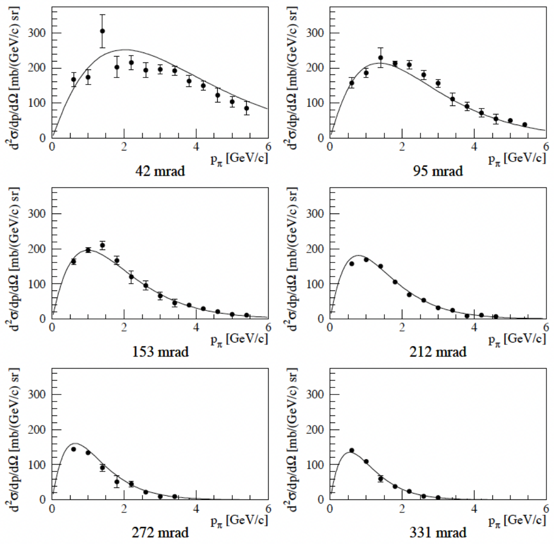


FIG. 8: Inclusive p-Be π^- production cross section data and fits vs. π^- momentum, at 17.5 GeV/c incident proton momentum. Fits are defined in Table II.

E941 (Spokesperson: Huan Z. Huang)

E941, PHYSICAL REVIEW C 65 014904 (2001, 2003)

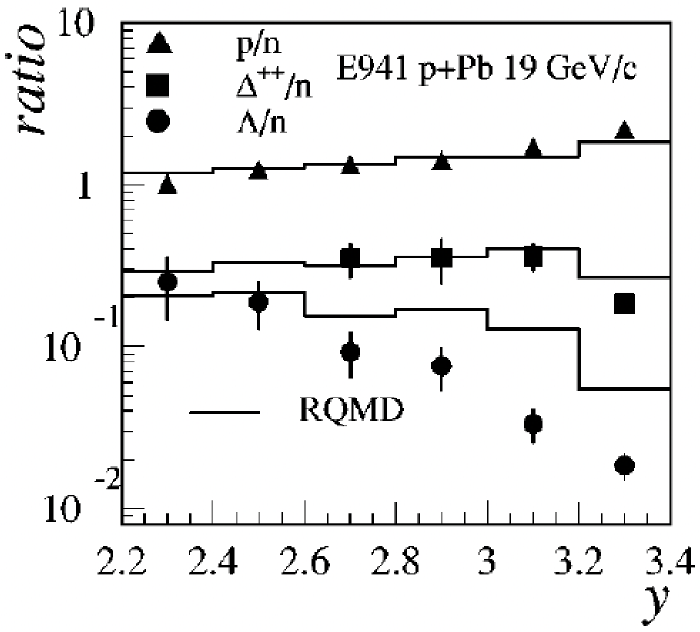


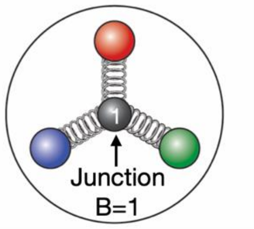
FIG. 6. Relative yields of protons, Δ^{++}'s, and Λ's with respect to neutrons as a function of rapidity in $p+$Pb collisions at 19 GeV/c compared with RQMD predictions.

AGS leading baryon study in p+A collisions

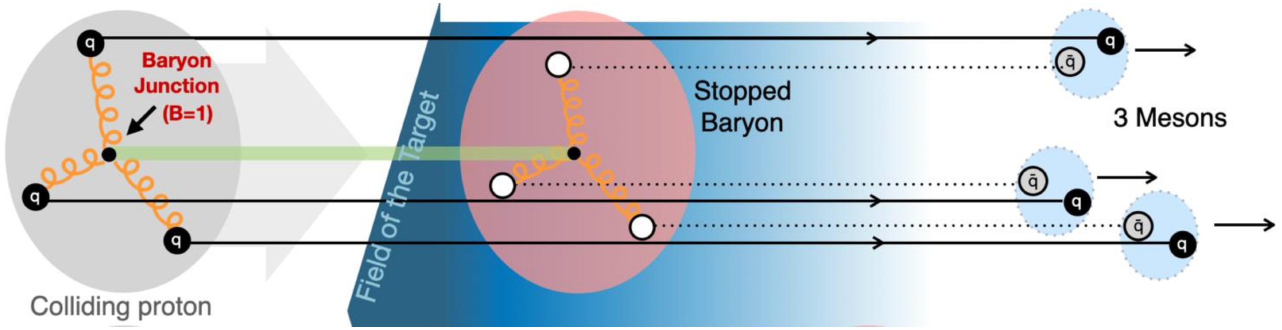
The E941 p/n ratio indicates that the simple diquark-quark fragmentation scheme, which predicts a proton-to-neutron ratio of 2, is unlikely to be the only relevant process in $p+A$ collisions for leading baryons in our rapidity acceptance. In order to explain a p/n ratio of unity we have to include other fragmentation schemes, perhaps even dominating over the diquark-quark fragmentation in the relevant kinematic region, such as three-quark fragmentation and/or gluon junction fragmentation. Our measurement is a unique constraint to these additional fragmentation functions. The significant presence of three-quark and gluon junction fragmentation processes would indicate that the incident proton is very brittle in nuclear collisions and is likely to fragment into pieces.

through a gap of five units of rapidity. In order to understand the dynamics of baryon number transport and, in particular, to possibly study the gluon junction interaction process, we should measure exclusive leading charged and neutral particles in the proton hemisphere in $p+A$ collisions at RHIC. A gluon junction interaction event is likely to produce a topology with exclusive leading mesons from valence quarks. Comprehensive measurement of all leading particles will provide more constraints on the dynamics of baryon number transport and energy deposition at midrapidity in nuclear collisions.

E941, PHYSICAL REVIEW C 67, 014902 (2003)

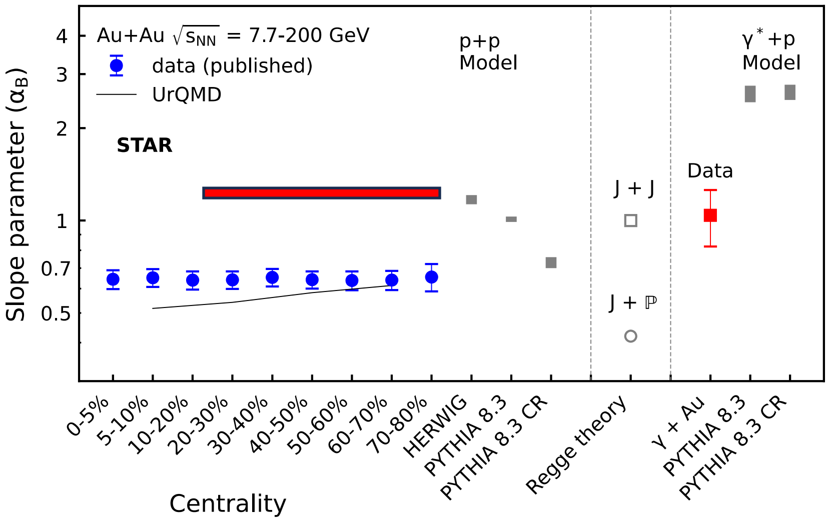


Junctions as baryon carrier



Isobar (p+Be/Li)

Measure rapidity dependence of **charges and baryons** using p+A (isobar) collisions



E941, PHYSICAL REVIEW C 65 014904 (2001)

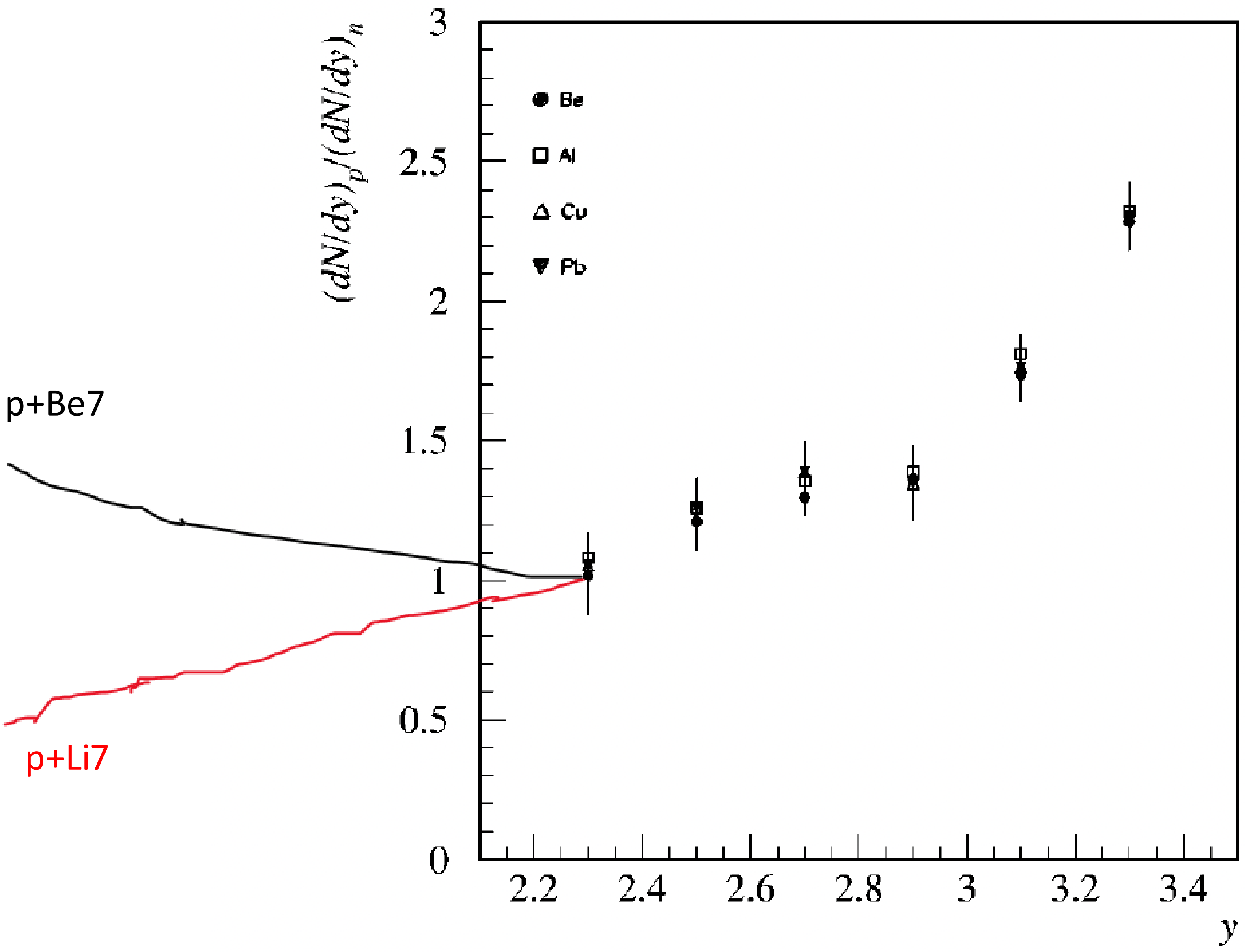


FIG. 9. p/n ratios as a function of rapidity in $p+$Be, $p+$Al, $p+$Cu, and $p+$Pb collisions at 19 GeV/c.

Detector for AGS FXT p+A collisions

E910 (Spokesperson: Brian Cole)

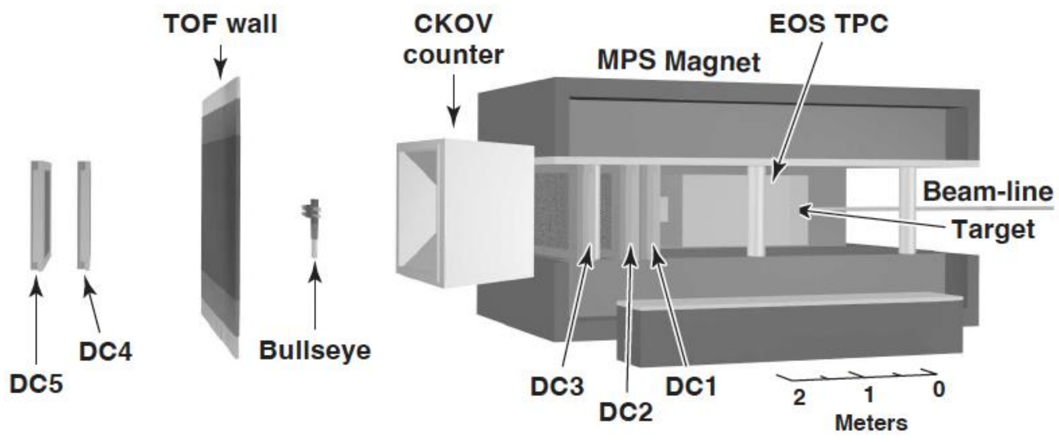
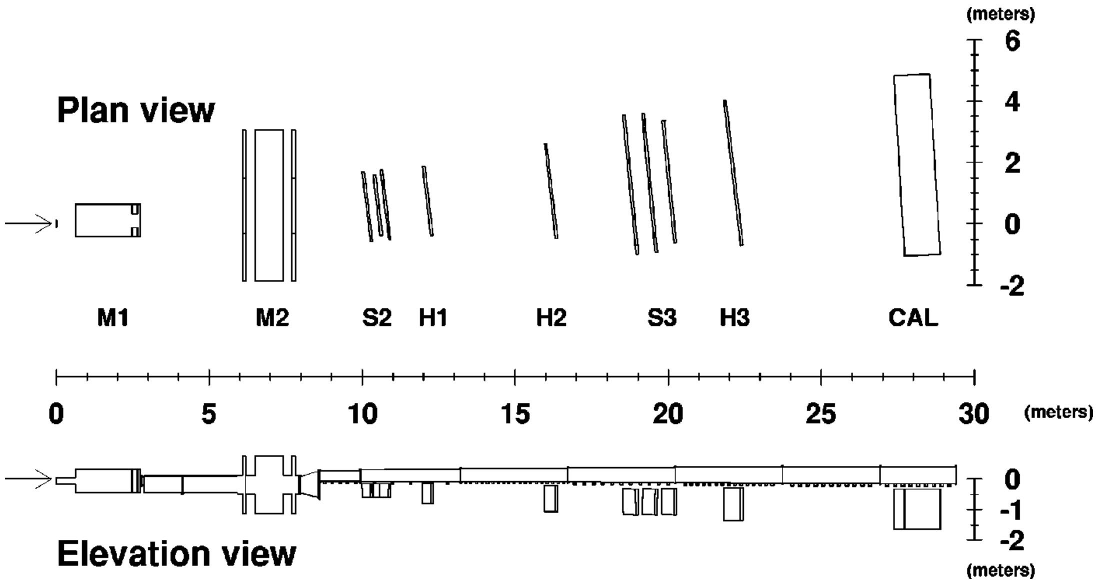


FIG. 2: The E910 spectrometer layout.

E941 (Spokesperson: Huan Z. Huang)



Combine the best of E910 and E941,

E910 EOS TPC→ Silicon Tracker

E941 *spaghetti hadronic calorimeter with time*→*Imaging Calorimeter*

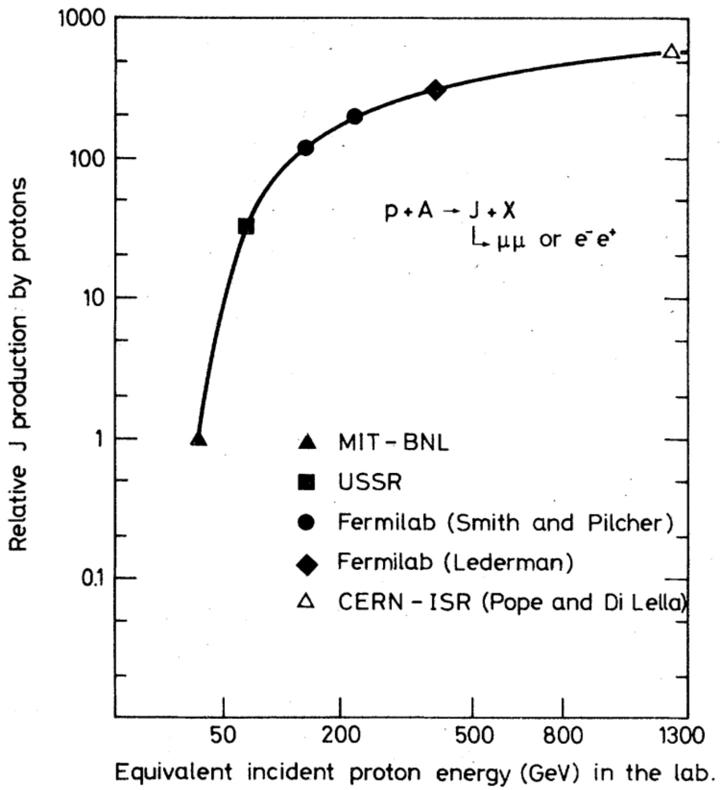
E941 Hodoscope TOF → AC-LGAD TOF+ Scintilating fibers + high-p PID

Separation of charge and baryon transports at RHIC and AGS

The discovery of the *J* particle: A personal recollection*

Samuel C. C. Ting

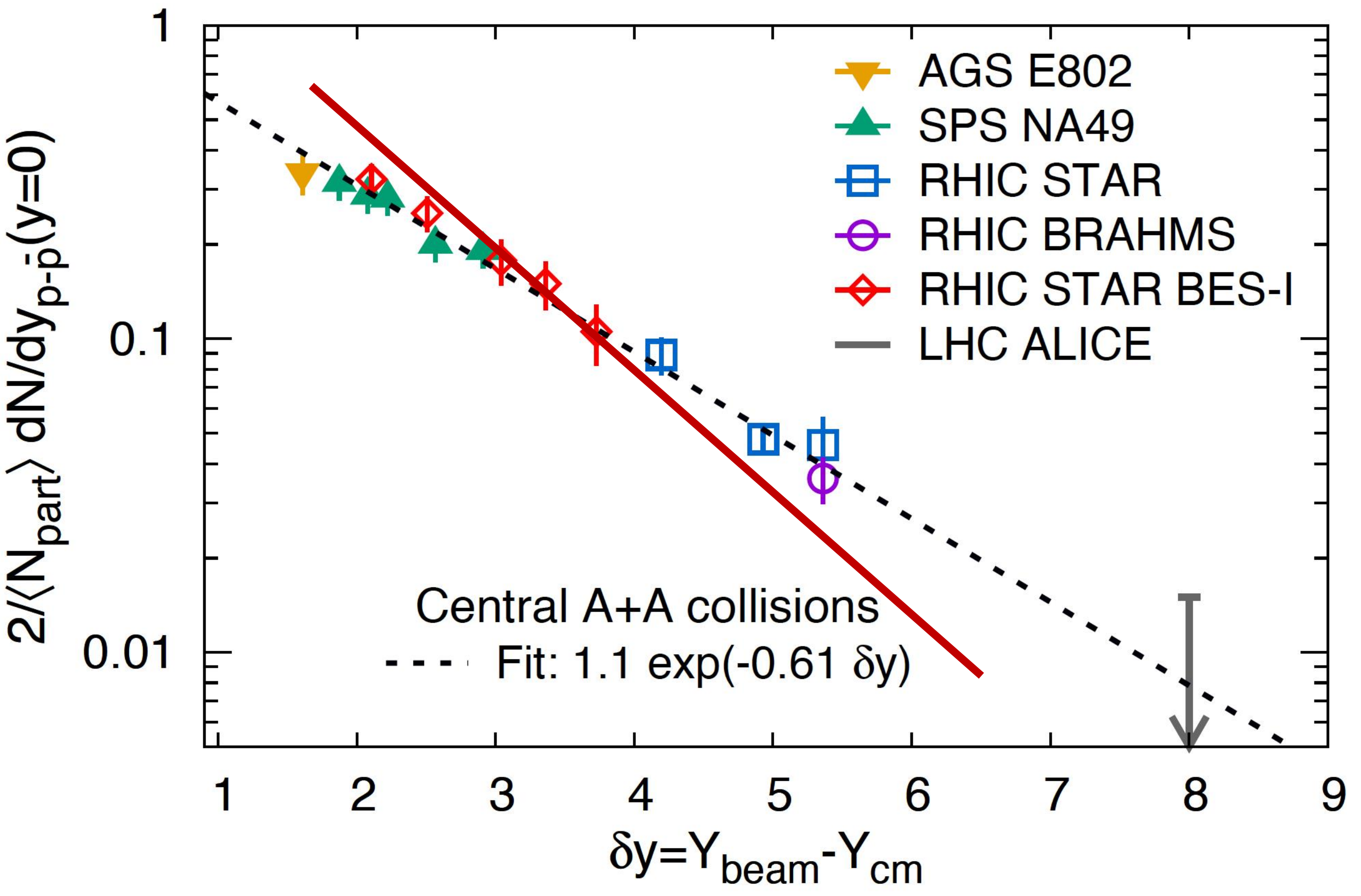
Massachusetts Institute of Technology, Cambridge, Massachusetts, USA and CERN, European Organization for Nuclear Research, Geneva, Switzerland



In Fig. 15 are listed some of the relative yields of *J* production from various proton accelerators. It seems that I had chosen the most difficult place to discover the *J*.

STAR, Phys. Rev. C **79** (2009) 34909; **96** (2017) 44904

N. Lewis, et al., arXiv:2205.05685



AGS isobar

RHIC isobar

Conclusions and Perspectives

- Baryon number is a strictly conserved quantum number,
  keeps the Universe as is
- We did not know what its carrier is;
  It has not been experimentally verified one way or the other until now
- RHIC Beam Energy Scans provide unique opportunity in studying baryon number transport over large unit of rapidity
- RHIC Isobar collisions provide unique opportunity in studying charge and baryon transport
- Experimental verification of the simplest QCD topology

- Baryon junction (if exists) is a non-perturbative object
- AGS FXT with 25 GeV proton beam is at the limit of where we can test baryon junction
- Isobar collisions to measure charge transport (quark transports),

  Zr/Ru; ^{7}Li/^{7}Be
- AGS can measure the baryon junction transports using its full rapidity range
- Explore other signatures with baryon-multiplicity correlations, Omega+3meson correlations

APS

DNP 2025

Fall Meeting of the APS Division of Nuclear Physics

Chicago, IL | Oct. 17-20, 2025

Workshops

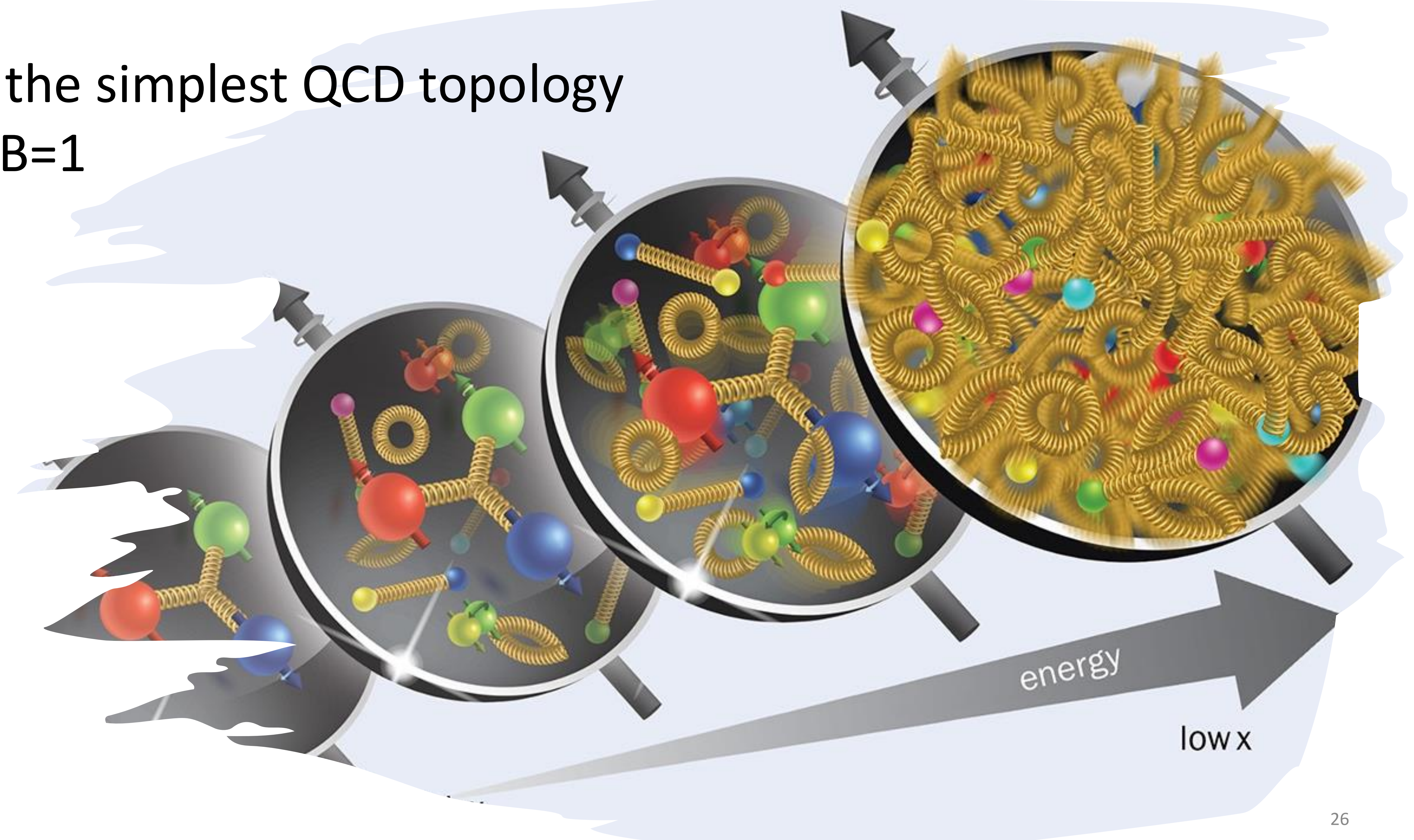
Each workshop will consist of around six 30 min invited presentations, with workshops being held on the morning of 17 October 2025 and the afternoon of 20 October 2025. The agenda for each workshop is given in the DNP Epitome.

Workshops: 9:00 am — 12:30 pm 17 October 2025

1. *Advanced Sensors for Nuclear Decay Experiments*
   Organizers: Joe Formaggio (MIT), Kyle Leach (CO School of Mines), Dave Moore (Yale), and Joel Ullom (NIST)
   This workshop will explore cutting-edge sensor technologies that are revolutionizing precision measurements in nuclear decay studies. Topics will include advancements in superconducting and other cryogenic devices, optomechanical sensors, and Cyclotron Radiation Emission Spectroscopy (CRES), highlighting their role in probing fundamental physics beyond the Standard Model. This workshop aims to foster collaboration across many disciplines to drive innovation in next-generation detection techniques for rare isotope studies, weak interaction measurements, and new physics searches.
2. *Aspects of Weak Binding Effects in Nuclear Structure and Reactions*
   Organizers: Heather Crawford (LBNL) and Augusto Macchiavelli (ORNL)
   This workshop will focus on the impacts of weak binding on nuclear structure and reactions. Studies of near-dripline, dripline and beyond-the-dripline nuclei will be presented and discussed across a range of experimental techniques and observables. Theoretical advances to describe these systems and their dynamics will also be discussed.
3. *Baryon Number Transport in Hadronic and Photon-induced Collisions*
   Organizers: Rongrong Ma (BNL), Prithwish Tribedy (BNL), and Zhangbu Xu (Kent State)
   In this workshop, we will bring together leading experts in theory and experiment to discuss the current understanding of what carries the baryon number and the baryon number transport mechanism in nuclear collisions, and provide guidance on future directions of exploration.
4. *Data Science for Nuclear Physicists*
   Organizers: Julie Butler (Mount Union) and Cristano Fanelli (W&M)
   As data science, machine learning, and artificial intelligence are becoming increasingly important tools for performing research, this workshop aims to introduce machine learning and artificial intelligence approaches in the context of solving nuclear physics problems. The workshop will start with an introduction to machine learning and neural networks and will also cover convolutional neural networks, graph neural networks, and generative AI for fast simulations.
5. *Fundamental Symmetry Tests and BSM Searches at η-η' Factories*
   Organizers: Liping Gan (UNCW) and Alexander Somov (JLab)

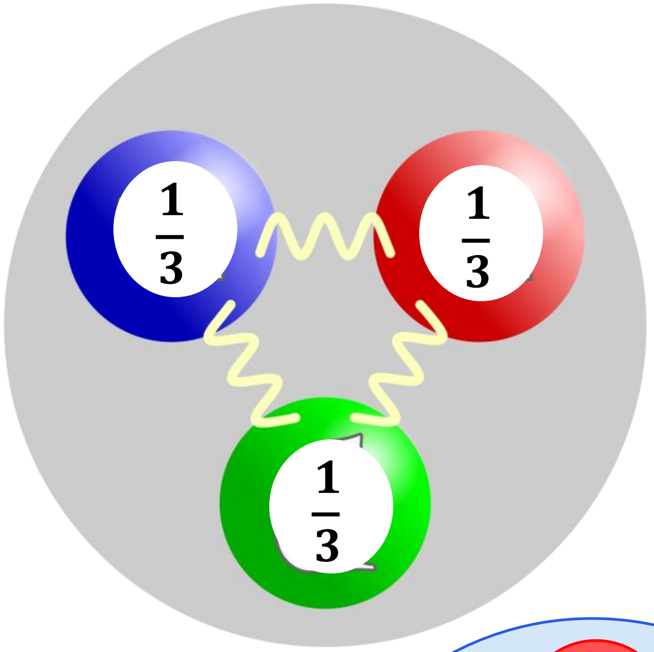
the simplest QCD topology

B=1

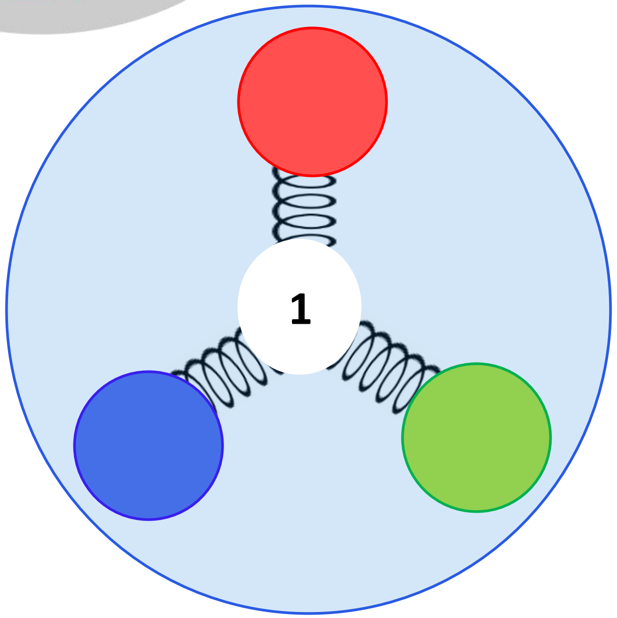


https://en.wikipedia.org/wiki/Quark

Baryon Number (B) Carrier



- Textbook picture of a proton
  - Lightest baryon with strictly conserved baryon number
  - Each valence quark carries 1/3 of baryon number
  - Proton lifetime >10^{34} years
  - Quarks are connected by gluons
- Alternative picture of a proton
  - Proposed at the Dawn of QCD in 1970s
  - A Y-shaped gluon junction topology carries baryon number (B=1)
  - The topology number is the strictly conserved number
  - Quarks do not carry baryon number
  - Valence quarks are connected to the end of the junction always
- Neither of these postulations has been verified experimentally



[1]: Artru, X.; String Model with Baryons: Topology, Classical Motion. Nucl. Phys. B 85, 442–460 (**1975**).
[2]: Rossi, G. C. & Veneziano, G. A; Possible Description of Baryon Dynamics in Dual and Gauge Theories. Nucl. Phys. B 123, 507–545 (**1977**)

20 June 1996

PHYSICS LETTERS B

Physics Letters B 378 (1996) 238–246

Can gluons trace baryon number?

D. Kharzeev

Theory Division, CERN, CH-1211 Geneva, Switzerland
and Fakultät für Physik, Universität Bielefeld, D-33501 Bielefeld, Germany

Received 15 March 1996
Editor: R. Gatto

Abstract

QCD as a gauge non-Abelian theory imposes severe constraints on the structure of the baryon wave function. We point out that, contrary to a widely accepted belief, the traces of baryon number in a high-energy process can reside in a non-perturbative configuration of gluon fields, rather than in the valence quarks. We argue that this conjecture can be tested experimentally, since it can lead to substantial baryon asymmetry in the central rapidity region of ultra-relativistic nucleus-nucleus collisions.

In QCD, quarks carry colour, flavour, electric charge and isospin. It seems only natural to assume that they also trace baryon number. However, this latter assump-

There is only one way to construct a gauge-invariant state vector of a baryon from quarks and gluons

which is ignored in most of the naive quark model formulations. This constraint turns out to be very severe; in fact, there is only one way to construct a gauge-invariant state vector of a baryon from quarks and gluons [1] (note however that there is a large amount of freedom in choosing the paths connecting x to x_i):

$$B = \epsilon^{ijk}\left[P\exp\left(ig\int_{x_1}^{x} A_\mu dx^\mu\right)q(x_1)\right]_i \times \left[P\exp\left(ig\int_{x_2}^{x} A_\mu dx^\mu\right)q(x_2)\right]_j \times \left[P\exp\left(ig\int_{x_3}^{x} A_\mu dx^\mu\right)q(x_3)\right]_k . \quad (1)$$

quark fields (see Fig. 1a). The B in Eq. (1) is a set of gauge invariant operators representing a baryon in QCD. With properly optimised parameters extensively in the first principle computations tice Monte Carlo attempting to determine the mass. The purpose of this work is to study nomenological impact on baryon number in the central region of nucleus-nucleus coll

It is evident from the structure of (1) that of baryon number should be associated not valence quarks, but with a non-perturbative tion of gluon fields located at the point x – the junction" [1]. This can be nicely illustrat string picture: let us pull all of the quarks a

It is evident from the structure of (1) that the trace of baryon number should be associated not with the valence quarks, but with a non-perturbative configuration of gluon fields located at the point x - the "string junction" .

0370-2693/96/$12.00 Copyright © 1996 Elsevier Science B.V. All rights reserved.
PII S0370-2693(96)00435-2

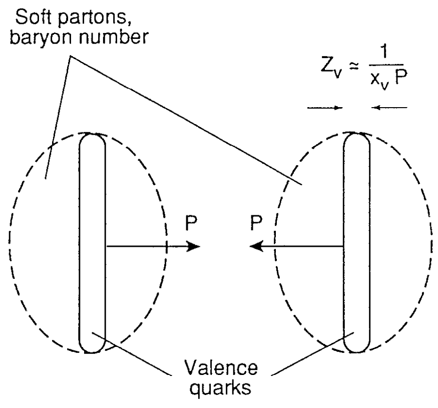


Fig. 2.

of the produced baryons will in general differ from the composition of colliding protons.

Why then is the leading baryon effect a gross feature of high-energy pp collisions? The reason may be the following. The string junction, connected to all three of the valence quarks, is confined inside the baryon, whereas pp collisions become on the average more and more peripheral at high energies. Therefore, in a typical high-energy collision, the string junctions of the colliding baryons pass far away from each other in the impact parameter plane and do not interact. One can however select only central events, triggering on high multiplicity of the produced hadrons. In this case, we expect that the string junctions will interact and

[4]. These two observations combined indicate the existence of an appreciable baryon stopping in central pp collisions even at very high energies [3].

Where else do we encounter central baryon-baryon collisions? In a high energy nucleus-nucleus collision, the baryons in each of the colliding nuclei are densely packed in the impact parameter plane, with an average inter-baryon distance

$$r \simeq (\rho\, r_0)^{-1/2} A^{-1/6}, \quad (4)$$

where ρ is the nuclear density, $r_0 \simeq 1.1$ fm, and A is the atomic number. The impact parameter b in an individual baryon-baryon interaction in the nucleus-nucleus collision is therefore effectively cut off by the packing parameter: $b \le r$. In the case of a lead nucleus, for example, r appears to be very small: $r \simeq 0.4\ fm$, and a central lead-lead collision should therefore be accompanied by a large number of interactions among the string junctions. This may lead to substantial baryon stopping even at RHIC and LHC energies.

We shall now proceed to more quantitative considerations. In the topological expansion scheme [1], the separation of the baryon number flow from the flow of valence quarks in baryon-(anti)baryon interaction can be represented through a t-channel exchange of the quarkless junction-antijunction state with the wave function given by

$$M_0^J = \epsilon_{ijk}\epsilon^{i'j'k'}\left[P\exp\left(ig\int_{x_1}^{x_2} A_\mu dx^\mu\right)\right]^i_{i'} \times \left[P\exp\left(ig\int_{x_1}^{x_2} A_\mu dx^\mu\right)\right]^j_{j'} \times \left[P\exp\left(ig\int_{x_1}^{x_2} A_\mu dx^\mu\right)\right]^k_{k'} . \quad (5)$$

The structure of the wave function (5) is illustrated in Fig. 1b – it is a quarkless closed string configuration composed from a junction and an antijunction. In the topological expansion scheme, the states (5) lie on a Regge trajectory; its intercept can be related to the baryon and reggeon intercepts [1]:

$$\alpha_0^J(0) \simeq 2\alpha_B(0) - 1 + 3(1-\alpha_R(0)) \simeq \frac{1}{2}, \quad (6)$$