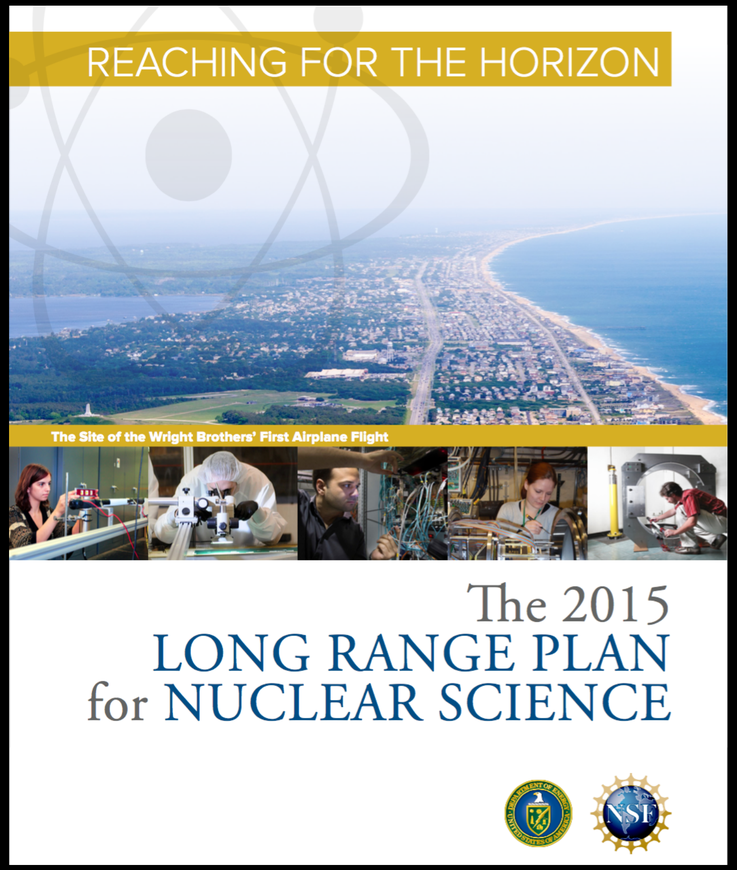
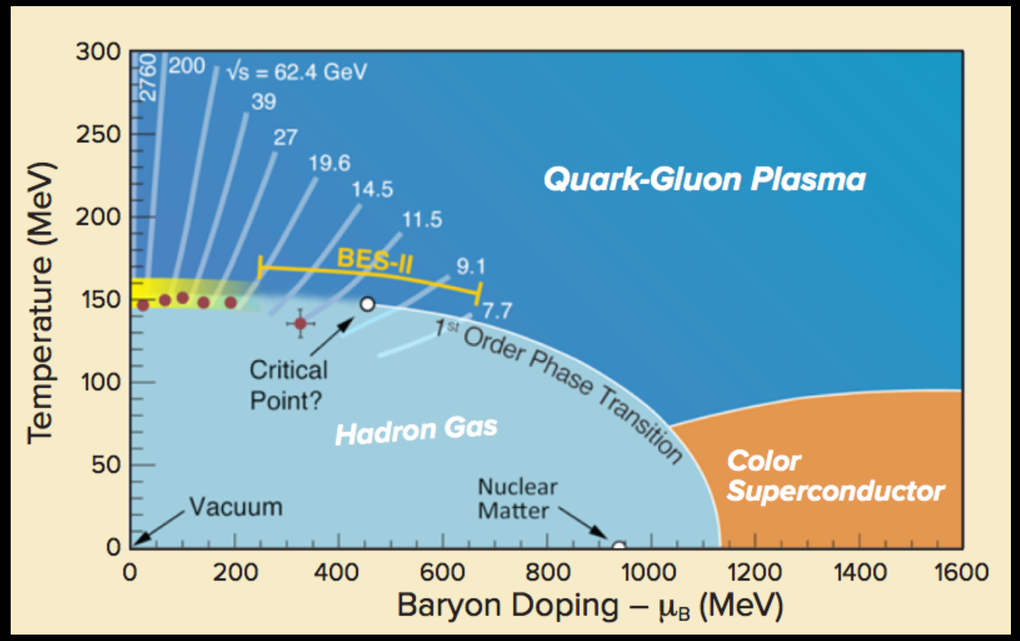
Search for baryon junction in heavy-ion and electron-ion collisions

Daniel Brandenburg, Nicole Lewis, Prithwish Tribedy, Zhangbu Xu

From the last NSAC LRP 2015

A primary goal : map QCD phase diagram and discover the QCD critical point





Doping the QGP with baryons: a necessary prerequisite for QCD phase transition near critical point

DOPING QGP WITH QUARKS TO MAP ITS PHASE DIAGRAM

In the highest energy RHIC and LHC collisions and in the early universe, liquid QGP contains almost as many

of QCD as a function of both temperature and doping, in this case doping QGP with an excess of quarks over antiquarks.

During the last decade, nuclear theorists have developed new tools for computing the cosmic baryon asymmetry and have utilized them to delineate the implications of present and future electric dipole moment searches for the origin of baryonic matter. They

electric dipole moment (nEDM). This experiment would improve sensitivity by two orders of magnitude over the best existing searches for CP violation beyond the Standard Model, as needed to account for the baryon asymmetry of the universe.

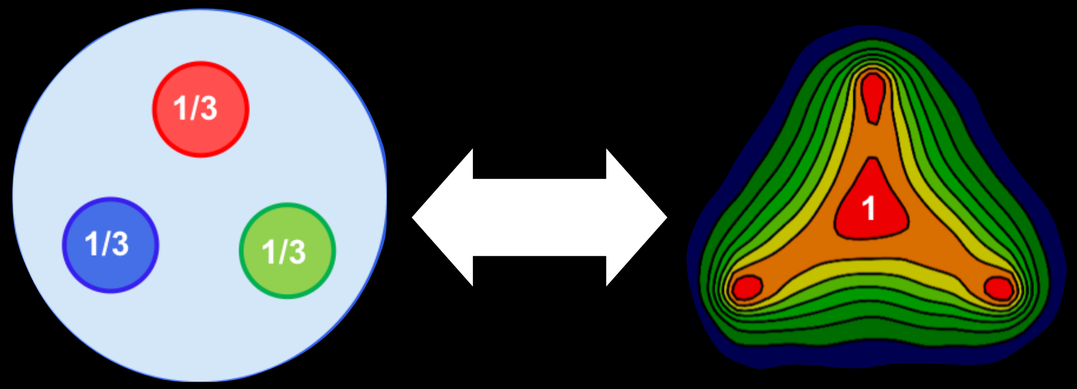
The Three-Quark Arena: Chasing the Missing Baryons

A major experimental initiative continues to be the search for the so-called "missing baryons." If each of the three quarks in a baryon interacted equally, one would predict the existence of more baryons than observed by experiments. The experimental data are, therefore,

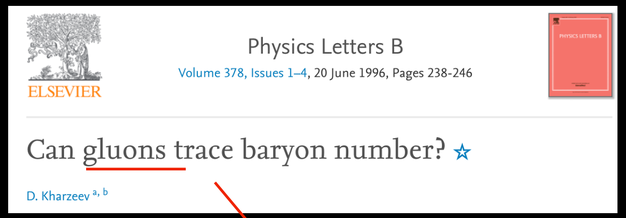
How the baryon doping happens in QGP at the microscopic level is not known

What carries the baryon number?

In the conventional picture valence quarks carry it but this has been never proven

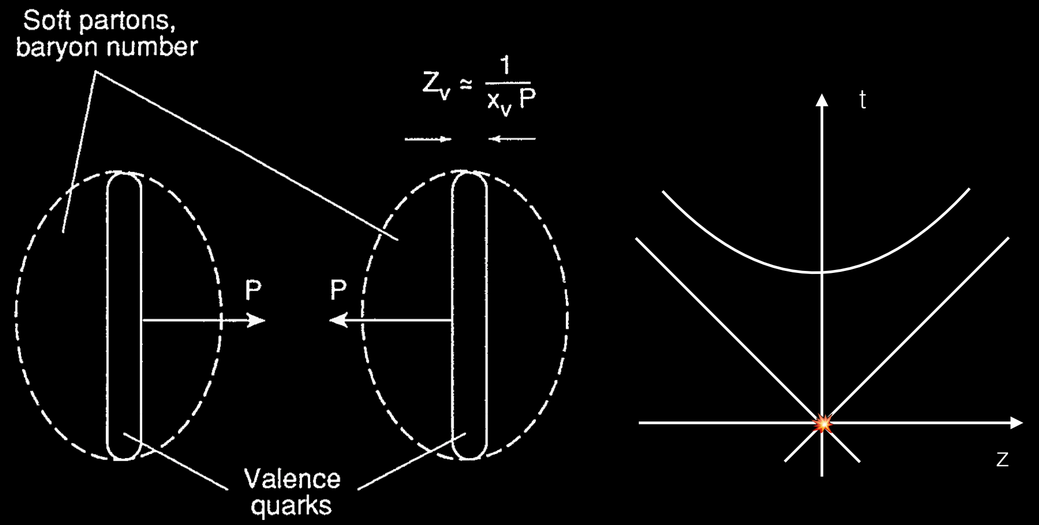


G.C. Rossi and G. Veneziano, Nucl. Phys.B123(1977) 507; Phys. Rep.63(1980) 149
Kharzeev, Phys. Lett. B, 378 (1996) 238-246



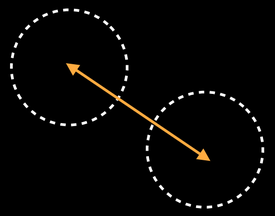
carry

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



$$t_{\rm coll} \sim (x_V P)^{-1} = (1/3 \times 100)^{-1}\ {\rm GeV}^{-1} = 0.006\ {\rm fm}$$

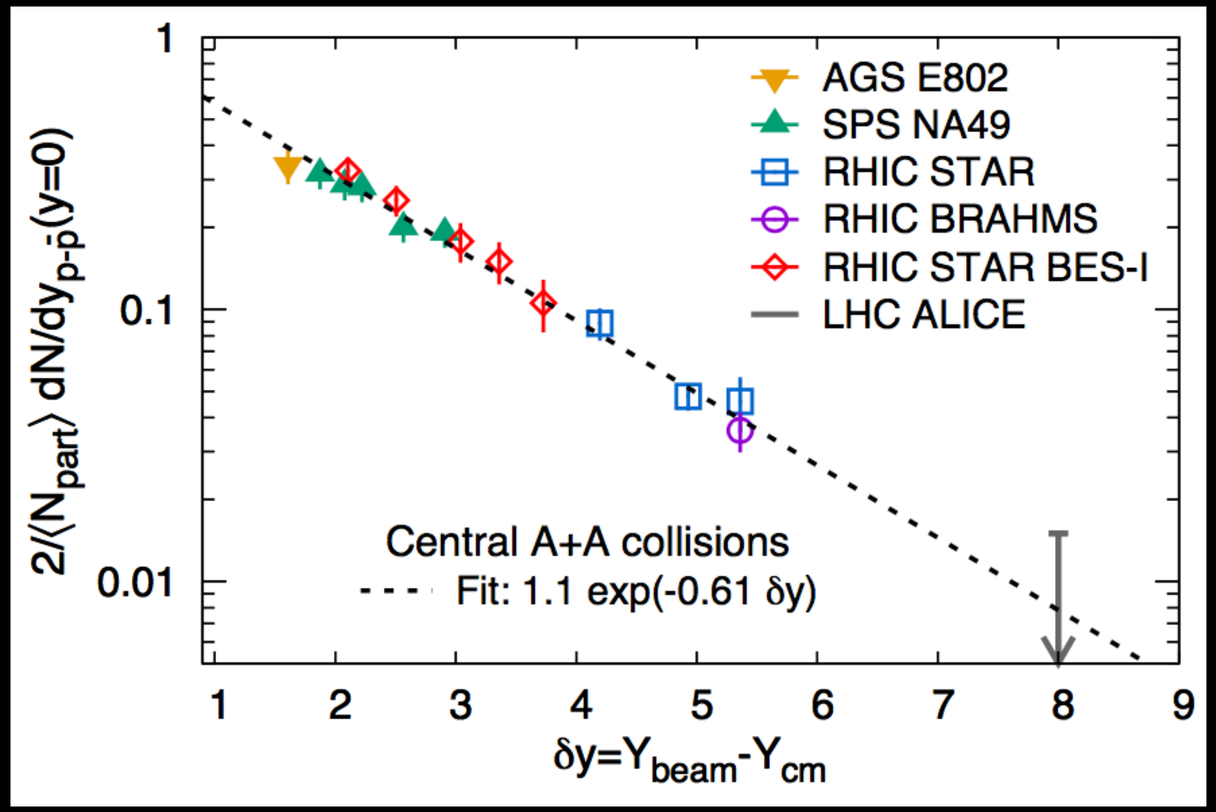
$$t_{\rm int} \sim \mathcal{O}(1)\ {\rm fm}$$



The time available for valence quarks is too short to be stopped in collisions

Midrapidity baryon production in A+A collisions

Brandenburg, Lewis, Tribedy, Xu, arXiv:2205.05685



Kharzeev, Phys. Lett. B, 378 (1996) 238-246

Fit to global data on central A+A:

$$\frac{2}{N_{\rm part}}\left.\frac{dN_{\rm p-\bar{p}}}{dy}\right|_{A+A} = N_B\, e^{-\alpha_B (Y_{\rm beam}-Y_{\rm cm})}$$

$$\boxed{\alpha_B = 0.61 \pm 0.03}$$

Predictions form Regge theory & baryon junction picture:

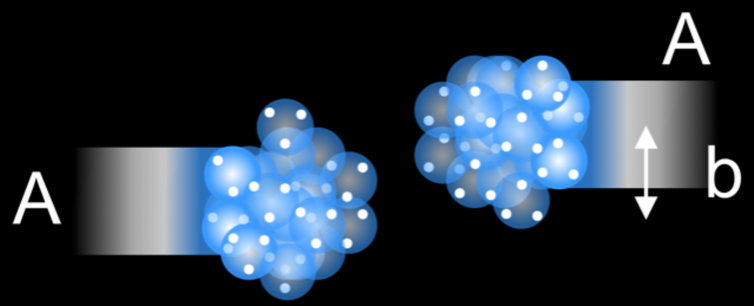
$$\boxed{0.42 \leq \alpha_B \leq 1}$$

Consistent but more tests are needed

Isobars collisions: most controlled HIC systems

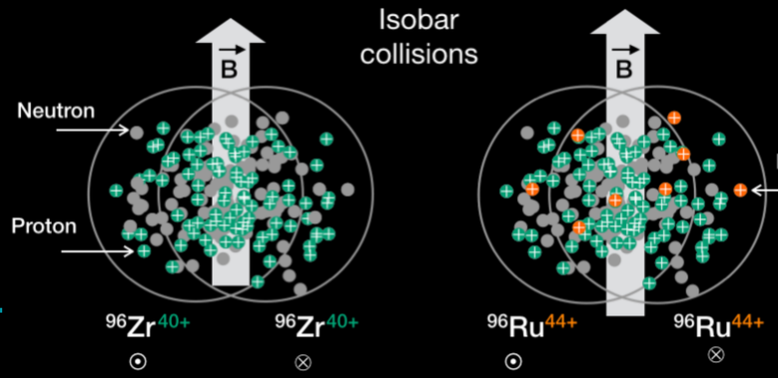
Brandenburg, Lewis,Tribedy, Xu, arXiv:2205.05685

Scenario 1: Valence quarks carry electric charge & baryon number



A=Mass number = Baryon number
Z=Atomic number = Electric charge

$$\text{Charge stopping} \simeq \frac{Z}{A} \times \text{Baryon stopping}$$



Zirconium:
A=96 (Total baryon)
Z=40 (Total charge)

Ruthenium:
A=96 (Total baryon)
Z=44 (Total charge)

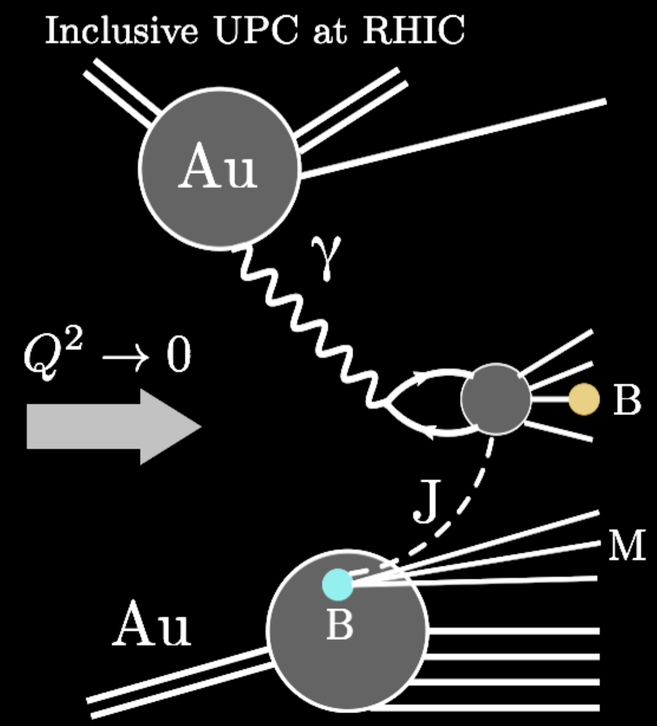
Scenario 2: Valence quarks carry electric charge & junctions cary baryon number

$$\text{Charge stopping} < \frac{Z}{A} \times \text{Baryon stopping}$$

$$\Delta Q \leftrightarrow \frac{\Delta Z}{A} \times B$$

Baryon free projectile: photon-induced processes

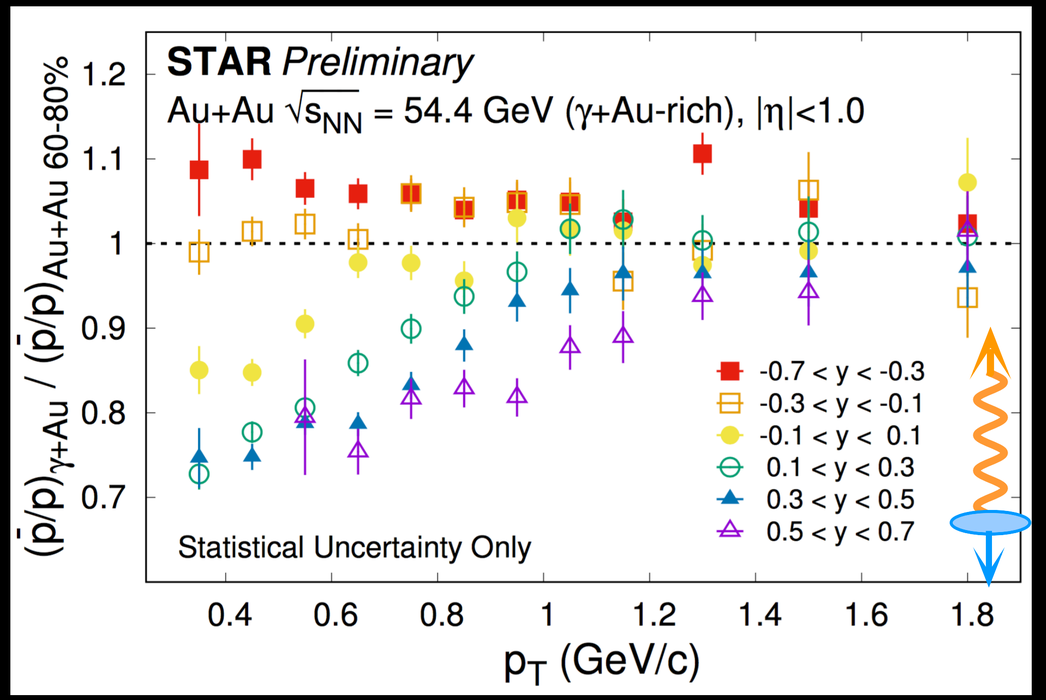
Brandenburg, Lewis,Tribedy, Xu, arXiv:2205.05685



Triggering photonuclear processes using Au+Au UPCs

Nicole Lewis (STAR collaboration), QM 2022

First look at photonuclear events: stronger rapidity dependent stopping in γ+Au » Au+Au

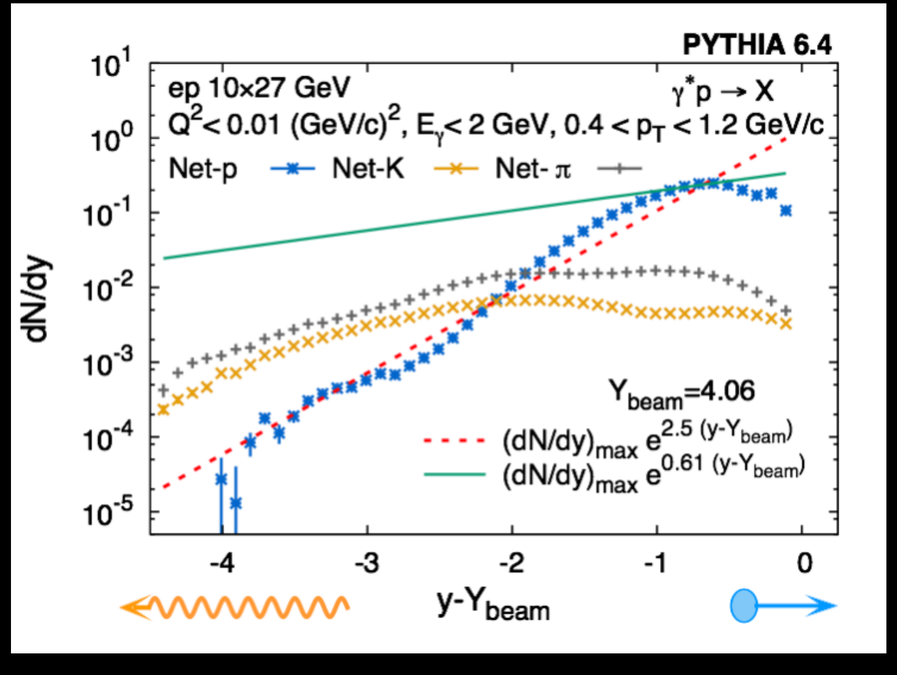


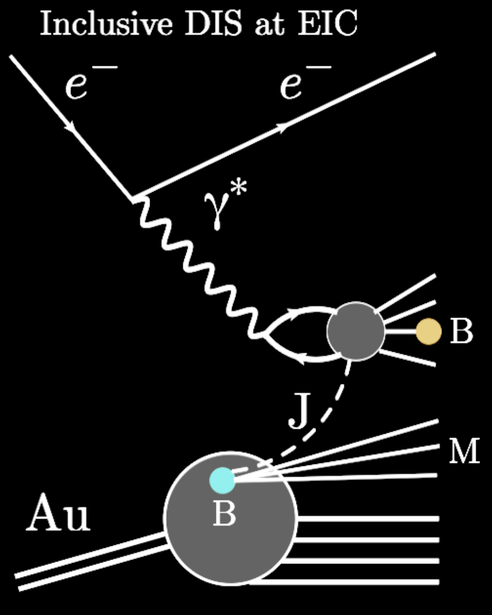
Interesting rapidity dependence of soft baryon stopping observed in RHIC photonuclear events

Low momentum PID (TOF) @ EIC needed to perform these measurements

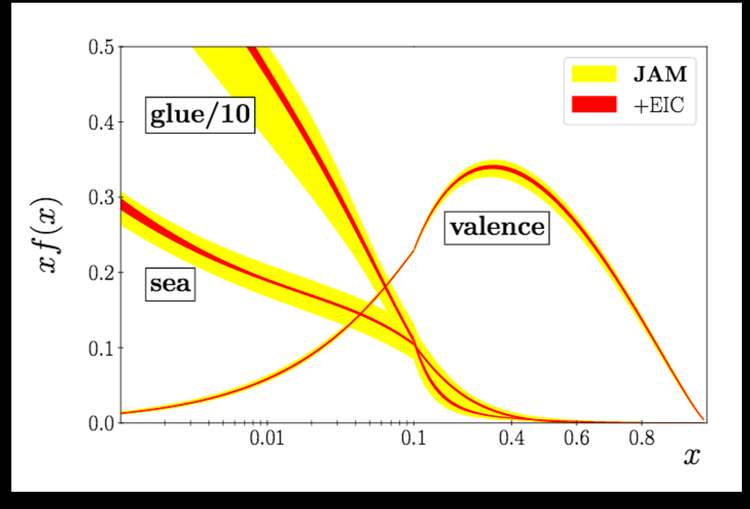
Baryon Distributions in x & Q^2: cleaner environment at EIC

Brandenburg, Lewis, Tribedy, Xu, arXiv:2205.05685

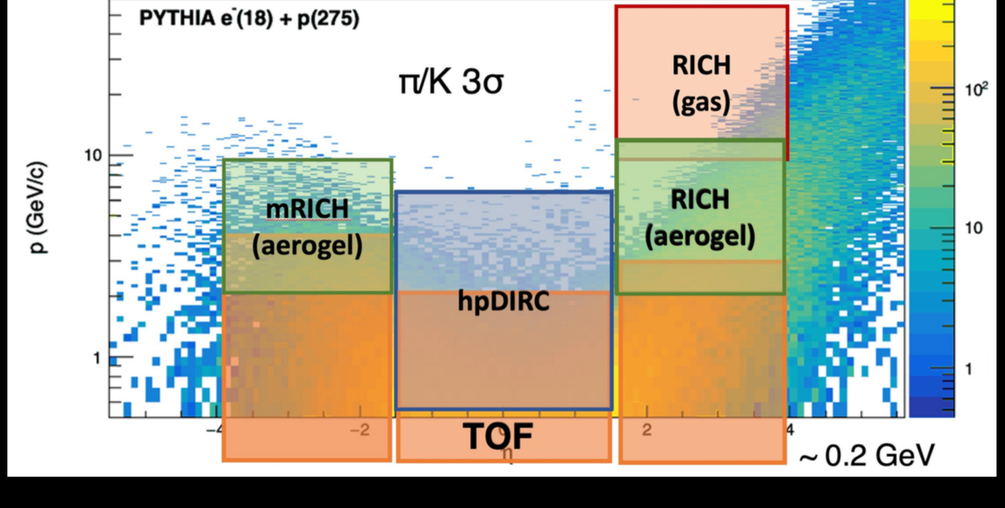


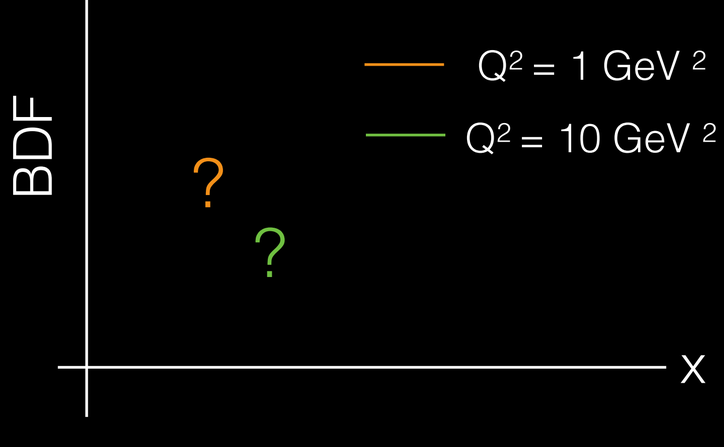


EIC yellow report, arXiv:2103.05419



What is the PDF equivalent of baryons ?





Low momentum PID capable detectors (TOF) at EIC will provide unique opportunity