Brookhaven National Laboratory

U.S. DEPARTMENT OF ENERGY

FY2024 NPP LDRD Type B Pre-Proposal

Exploring the Gluon Saturation Origin of Two-Particle Angular Decorrelation

Principal Investigator: Xiaoxuan Chu

Date: 02/08/2023

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FY2024 NPP LDRD Type B Pre-Proposal

Proposal title: **Exploring the Gluon Saturation Origin of Two-Particle Angular Decorrelation**

Primary Investigator: **Xiaoxuan Chu (BNL)**

Other Investigators: **Elke-Caroline Aschenauer (BNL), Farid Salazar (UCLA/LBL), Zhoudunming Tu (BNL)**

Indicate if this is a cross-directorate proposal. Yes ___ No ✓

Not eligible for ECA proposal

Proposal Term: **24 month** From: **October 2023** To: **September 2025**

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FY2024 NPP LDRD Type B Pre-Proposal

Proposal title and brief abstract:

Exploring the Gluon Saturation Origin of Two-Particle Angular Decorrelation

At sufficiently high energies (small-x) it is expected that the rapid growth of gluon densities inside hadrons and nuclei is tamed by non-linear effects leading to the phenomena of gluon saturation. Many studies have shown "hints" of gluon saturation, however, there is no MC framework or an analysis tool available that enables a quantitative "apple-to-apple" comparison between the saturation mechanism and the experimental data, rendering the current analyses not fully understood from saturation theory. We propose to develop an analysis tool based on an existing MC framework to **understand the recent findings of A-scaling and the absence of broadening in two-particle correlations from STAR, in addition to other QCD effects that don't have saturation as the origin.**

Program: NP

Return on Investment: Training of the next generation of scientists

Broader impact on the activities at the laboratory: The planned framework has the potential to be used for global analysis to comprehensively study saturation physics across different colliders.

Total planned funding per year in FY24 and FY25: $200K for each year

Motivation

Brookhaven National Laboratory Newsroom Media & Communications Office

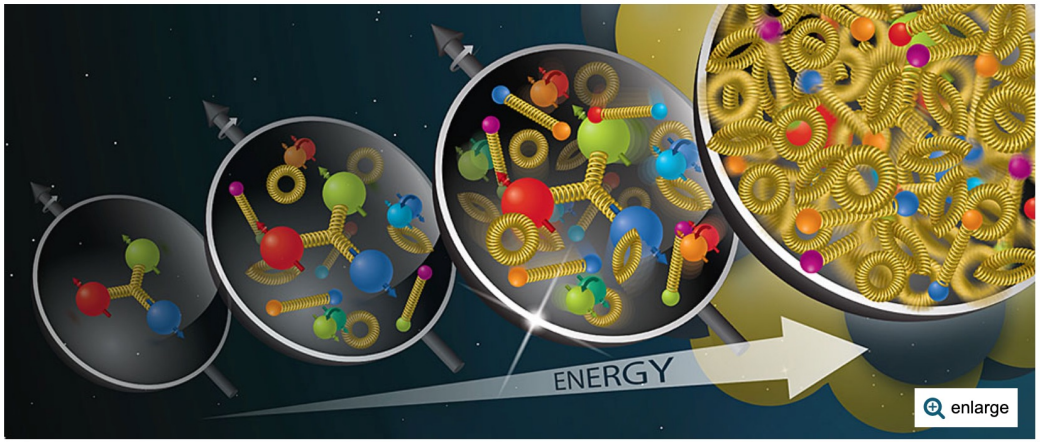
Newsroom Photos Videos Fact Sheets Lab History News Categories

Contact: Karen McNulty Walsh, (631) 344-8350, or Peter Genzer, (631) 344-3174 share:

Signs of Saturation Emerge from Particle Collisions at RHIC

Suppression of a telltale sign of quark-gluon interactions presented as evidence of multiple scatterings and gluon recombination in dense walls of gluons

August 31, 2022



Members of the STAR collaboration report new data that indicate nuclei accelerated to very high energies at the Relativistic Heavy Ion Collider (RHIC) may be reaching a state where gluons are starting to saturate.

CERN COURIER
November/December 2022 cerncourier.com Reporting on international high-energy physics


BNL

Colourful *The STAR detector.*

QCD gets hotter

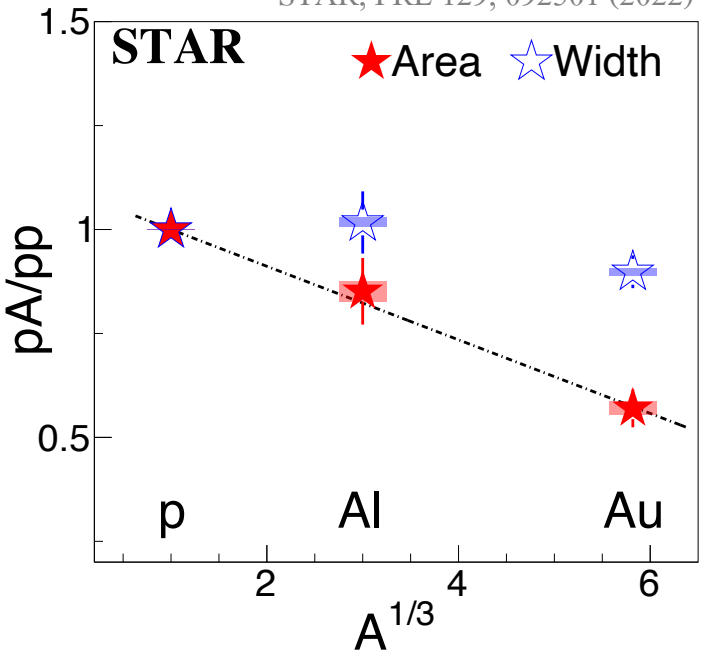
The STAR collaboration at Brookhaven's Relativistic Heavy Ion Collider has reported evidence of gluon saturation – a prediction of QCD whereby gluons at low transverse momenta recombine. If the rate of two gluons recombining into one balances out the rate of single gluons splitting, the gluon density reaches a steady state, or plateau. A smoking gun of such nonlinear gluon dynamics is a suppression in the yield of back-to-back decays of two neutral pions. By colliding protons with other protons as well as with aluminium and gold ions, the STAR team found the suppression to be proportional to the ion's mass number, as predicted by models of gluon recombination

The STAR Collaboration observed strong evidence for the nonlinear QCD effects through two-particle correlations.

Motivation

- Despite the strong evidence for nonlinear gluon dynamics, **many questions remain unsolved**, which can only be addressed via a tool that this LDRD proposes:
  - nuclear mass A-dependent gluon saturation scale (Q_s) → A-dependent two-particle angular decorrelation
  - Resolving the contradiction between different theoretical predictions and the data in broadening phenomena
  - other novel effects that don't have saturation as their origin (e.g. multiple parton scattering, shadowing)

STAR, PRL 129, 092501 (2022)



- So far, there is **no Monte Carlo (MC) framework or an analysis tool available** that enables a quantitative "apple-to-apple" comparison between the saturation mechanism and the experimental data

Approach and deliverables

We propose to develop an analysis tool based on an existing MC framework:

I. **Find out the best MC generator for non-saturation:**
   - Investigate the available generators and choose the best one to start with, e.g., PYTHIA, Hijing, EPOS, DIPSY, etc., all of which are reasonable baseline MC models but are dedicated for specific interaction processes or collision systems. We will work with the MC community.

II. **Expand the identified event generator by implementing saturation:**
   - Apply unintegrated gluon distribution functions, which effectively reflect the physics of gluon saturation.

III. **Use the modified generator to quantitatively investigate the data:** the manifestation of saturation physics into two-particle angular decorrelation to understand the findings from **RHIC and the LHC***. Publications are expected from this work.

IV. Use the developed framework to guide more precise measurements with **different observables with RHIC Run2024 and LHC Run4 data*;** it can be expanded for *e+A* data at the EIC.

*Current dijet data from ATLAS
*Future data from LHC with Focal upgrade in 2029

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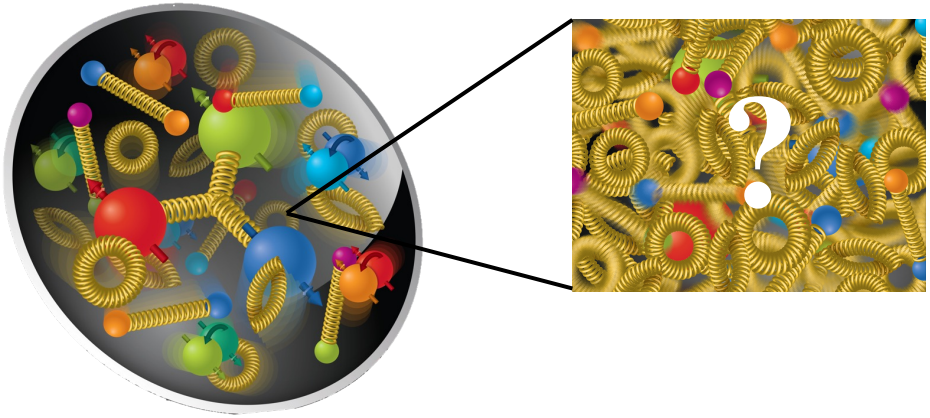
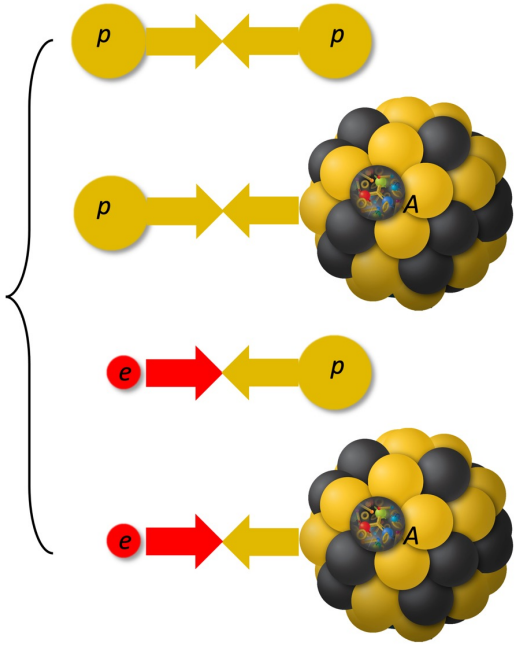
Summary





This proposal will:

- advance our understanding of saturation phenomena.
- provide a solid theoretical and phenomenological framework to build a General-Purpose Saturation (GPS) MC model in the near future.

It will be one of the ultimate tools to understand QCD under extreme parton density.

RHIC **LHC** **EIC**