Brookhaven National Laboratory

Application for the CLAS 12 membership

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BNL/SBU

March 10th, 2026

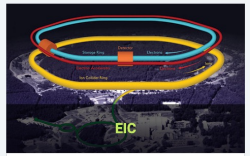
CLAS 12 Collaboration meeting, Mar 10-13, 2026

Brookhaven Lab

- Established in 1947, a multi-purpose lab including NSLS-2, RHIC, future EIC, and many other sciences
- ~a total of 3500 employees and more than a few hundreds scientists/engineers in Nuclear and Particle Physics.

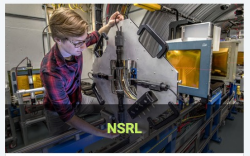
Facilities

The Nuclear and Particle Physics directorate operates the suite of particle / heavy ion accelerators used to carry out the program of accelerator-based experiments at Brookhaven National Laboratory. It supports the experimental physics program including design, construction and operation of the beam transports, and detector and research needs of the experiments.



Brookhaven Lab is building the world's first polarized electron-proton/ion collider, known as the Electron-Ion Collider (EIC). This discovery machine will unlock the secrets of the "glue" that binds the building blocks of visible matter.

Researchers from around the world use Brookhaven's Relativistic Heavy Ion Collider (RHIC) to study what the universe may have looked like in the first few moments after its creation by colliding two beams of gold ions at nearly the speed of light.

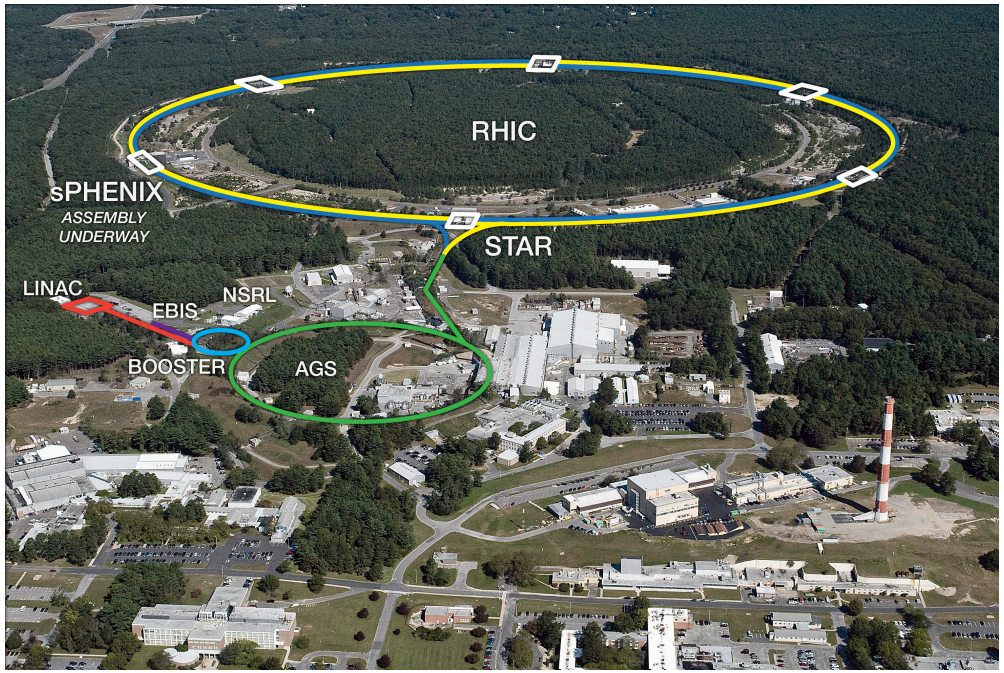


The NASA Space Radiation Laboratory (NSRL) uses beams of heavy ions from the accelerators that feed RHIC to simulate space radiation and study its effects on biological specimens—such as cells, tissues, and DNA—and industrial materials.

The Tandem Van de Graaff facility is a large electrostatic accelerator that can provide researchers with beams of more than 40 different types of ions, ranging from hydrogen to uranium.

The Brookhaven Linac Isotope Producer supports the Isotope Research and Production Department, preparing commercially unavailable radioisotopes for distribution to the nuclear medicine community and industry. Other supporting facilities include the Radionuclide Research and Production Lab and cyclotron.

The Scientific Data and Computing Center (SDCC) stores, distributes, and analyzes data for experiments at RHIC, the ATLAS experiment at the Large Hadron Collider in Europe, the Belle II experiment at Japan's SuperKEKB particle accelerator, and for certain Brookhaven Lab facilities and directorates.



Research group at BNL →NPP→ PO → EIC/RHIC

- Research personnels ~ 10 on EIC (ePIC) + 20-30s on RHIC (STAR, sPHINEX), including both HI and medium energy.
- Focus:
  - **EIC group** - ePIC detector project, especially the development and production of pfRICH (backward RICH detector in ePIC). Physics working group, PID, software.
  - **RHIC research group** – data analysis on existing RHIC data (our data-taking has just concluded in Feb, see news, https://www.bnl.gov/newsroom/news.php?a=122794)
  - **Transition -** from RHIC to EIC has started (slowly) and will continue for the next 10 years until the new machine operates.

My research - QCD confinement, including nuclear and particle experiments, phenomenology, and their connections to quantum information science (QIS)

Kong's short bio:

- SBU, 2025 – present, Associate Adjunct Professor,
- BNL, 2021 – present, Staff Scientist
- BNL, 2018 – 2021, Distinguished Goldhaber Fellow,
- Rice University, 2013 – 2018, PhD in heavy ion physics

Past and current experiments:
CMS @ LHC, H1 @ HERA, STAR @ RHIC, ePIC @ EIC

My research group:

- 2 postdocs:
  a) **Li Xu**, primarily on CLAS 12 (member since 2023, nDVCS, RGC chef);
  b) **Arjun Kumar**, development on next generation eA MC event generator, Saturation physics.
- 1 PhD student: **Feng Liu**, working on STAR and ePIC experiments
- 3 Undergraduate students: **Rojae Mighty, Mahmodol Mojumder, Aiden Cage**.

Why am I here?

- **Partnership.** BNL and Jefferson lab are partner on building the Electron-Ion Collider. Despite working on a 3-billion-dollar project together, the two labs had little physics interaction. (hot vs cold QCD) My goal is to work in this direction.

- **Timing.** RHIC has just ended its operation. Before EIC, Jefferson Lab is the only place for active running nuclear experiments – a training ground for the next-generation experimental physicists.

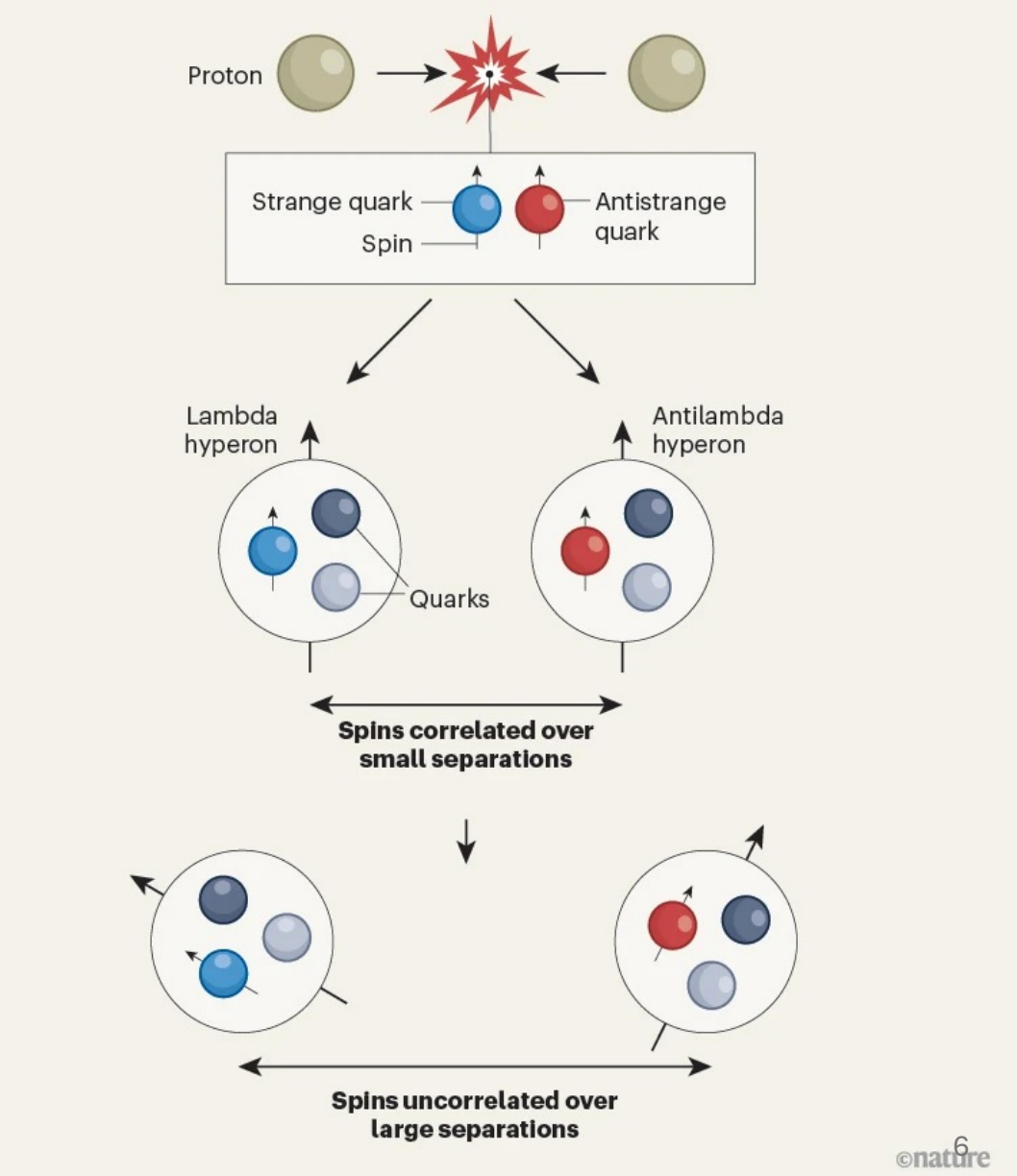
- **Physics.** CLAS 12 experiment has unique capabilities, especially the polarized target data, and their unique physics (more later.)

$\Lambda\bar{\Lambda}$ spin correlations probes the quantum vacuum and how quarks transition to hadrons.

Problem of interest:

Spin polarization as a probe of the quantum vacuum and hadronization.

[Nature, volume 650, pages 65–71 (2026)]



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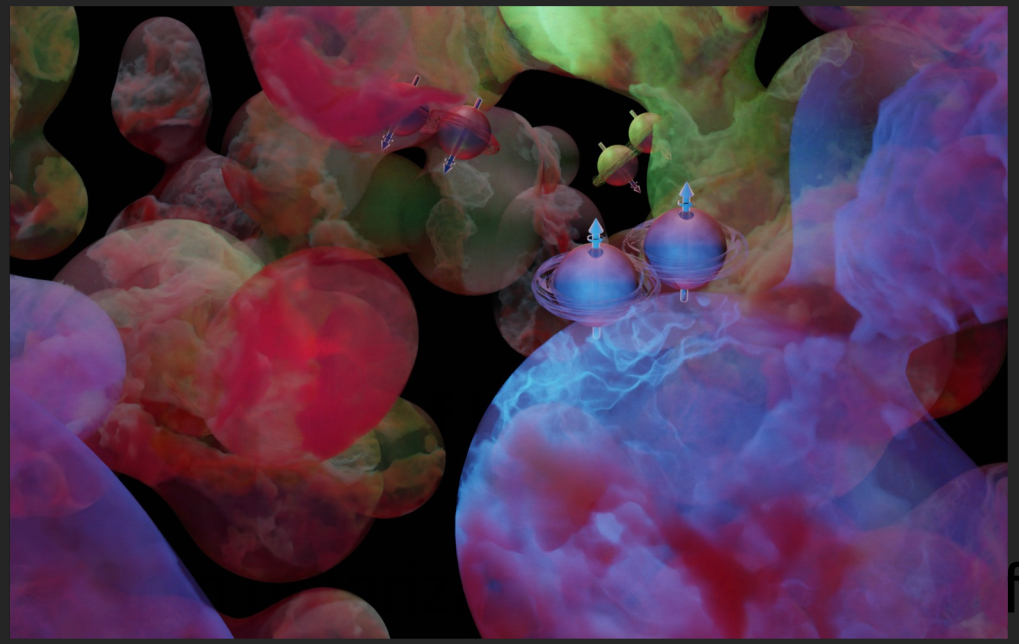

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the quantum vacuum and hadronization.

Nature, volume 650, pages 65–71 (2026)

Vacuum $< s\bar{s} >$ is in fact maximally entangled due to the vacuum quantum number 0^{++}
(if choosing a proper frame)

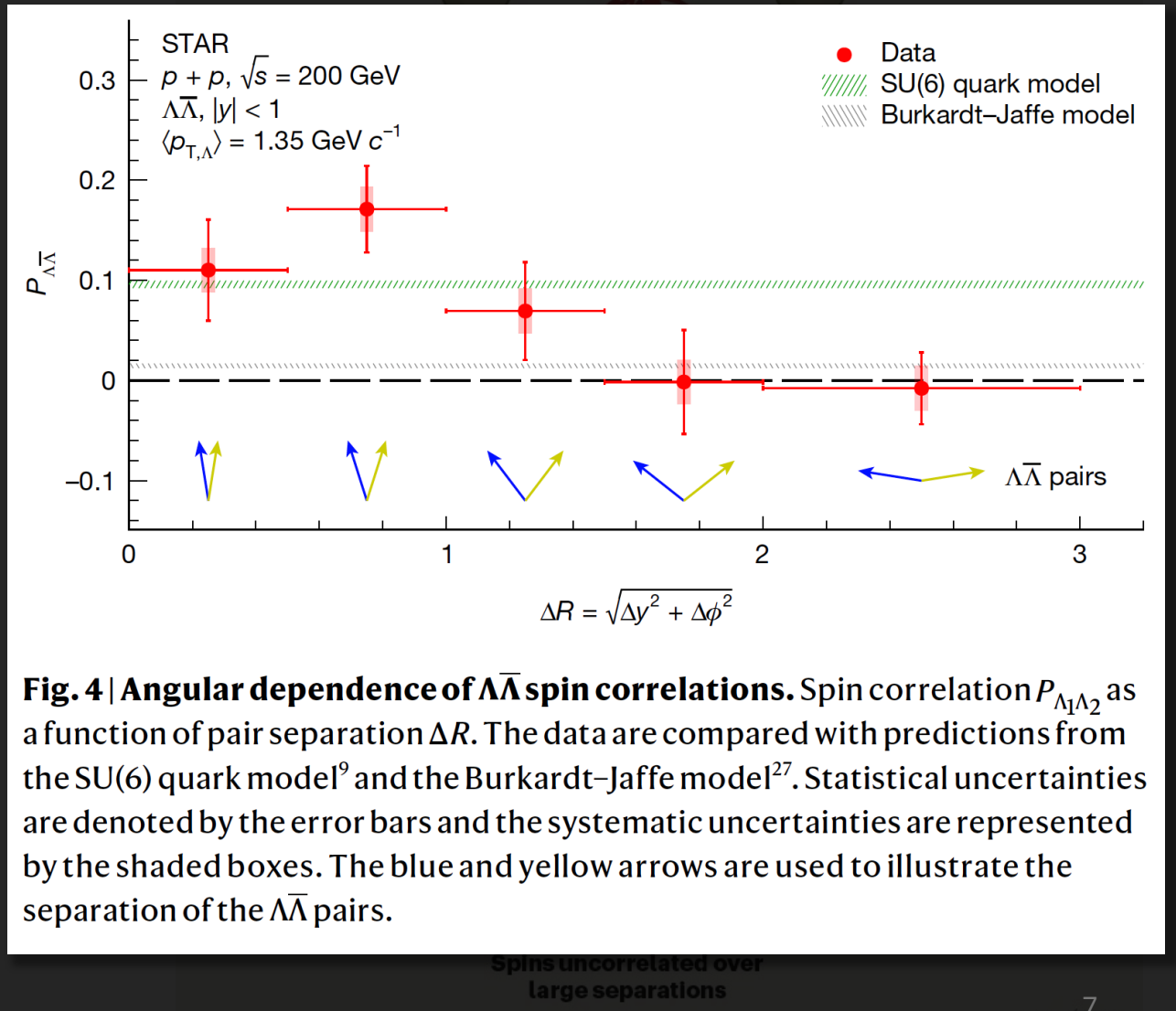


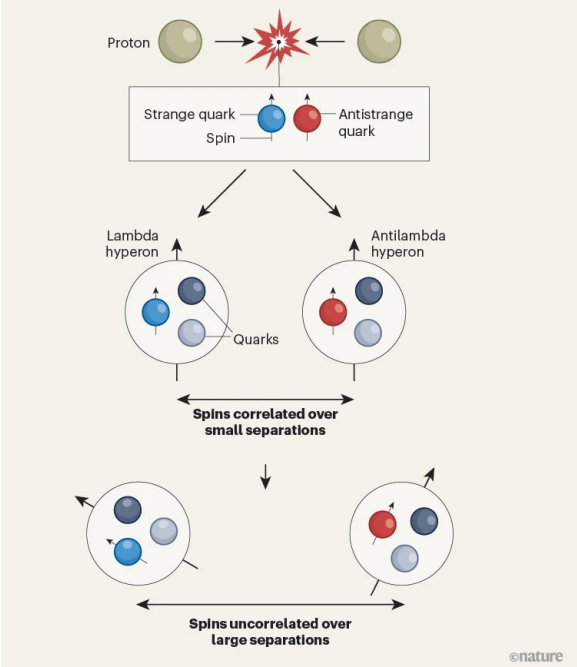
Fig. 4 | Angular dependence of $\Lambda\bar{\Lambda}$ spin correlations. Spin correlation $P_{\Lambda_1\Lambda_2}$ as a function of pair separation ΔR. The data are compared with predictions from the SU(6) quark model[9] and the Burkardt–Jaffe model[27]. Statistical uncertainties are denoted by the error bars and the systematic uncertainties are represented by the shaded boxes. The blue and yellow arrows are used to illustrate the separation of the $\Lambda\bar{\Lambda}$ pairs.

Common interest of Λ polarization from hot to cold QCD:

AA Collisions

Nature, volume 548, pages 62–65 (2017)

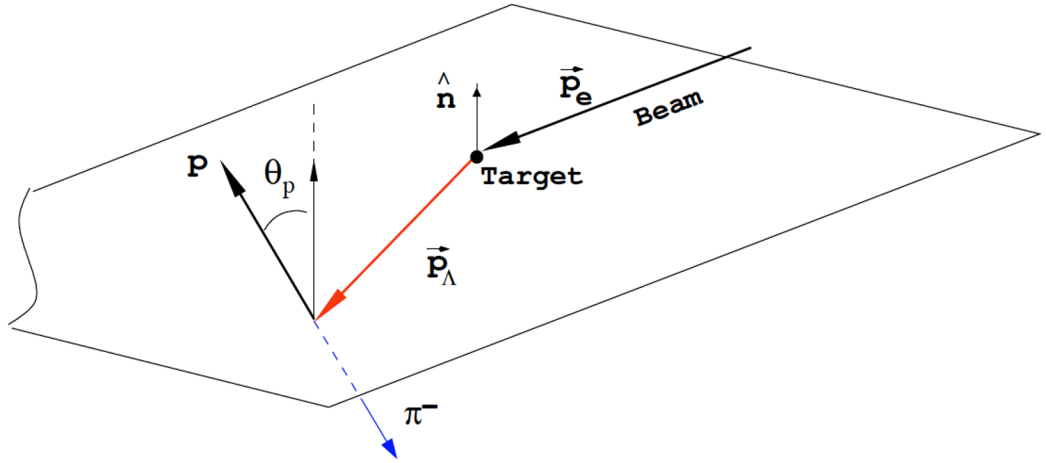
pp collisions



Nature, volume 650, pages 65–71 (2026)

Transverse Lambda polarization puzzle

Strong polarization signal in pp, pA, DIS, neutrino scattering, etc.



50 years of experimental efforts to understand the origin of this polarization.

Explanations are almost too many

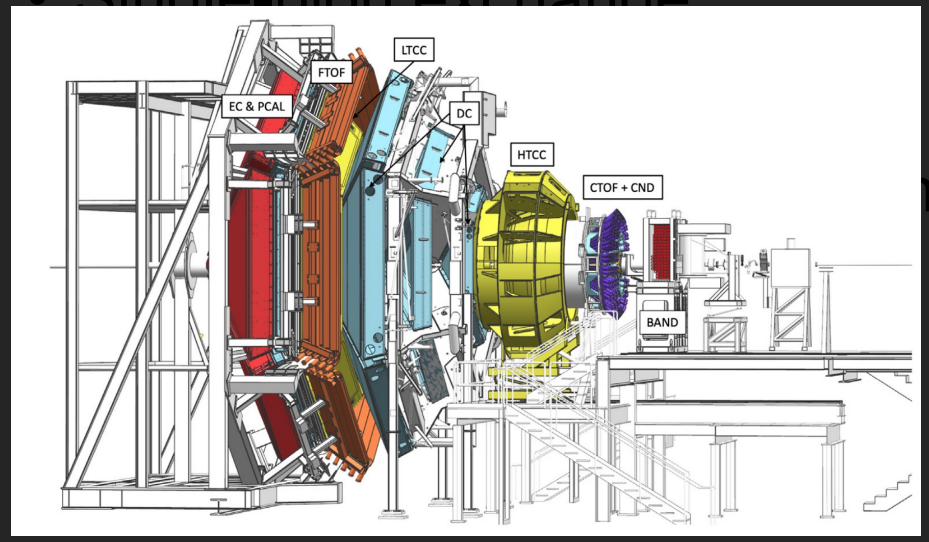
- Lund semi-classical fragmentation model, finite pT lambdas infers orbital angular momentum (ssbar) and s quark spin needs to balance that. The higher the pT, the larger the effect.
- Thomas precession mechanism – a semi-classical recombination model.
- Single-pion exchange.
- Interference from resonances decay.
- TMD polarizing Fragmentation Functions (more modern framework).
- …

We understand:

a) Λ polarization in heavy ion collisions – vorticity

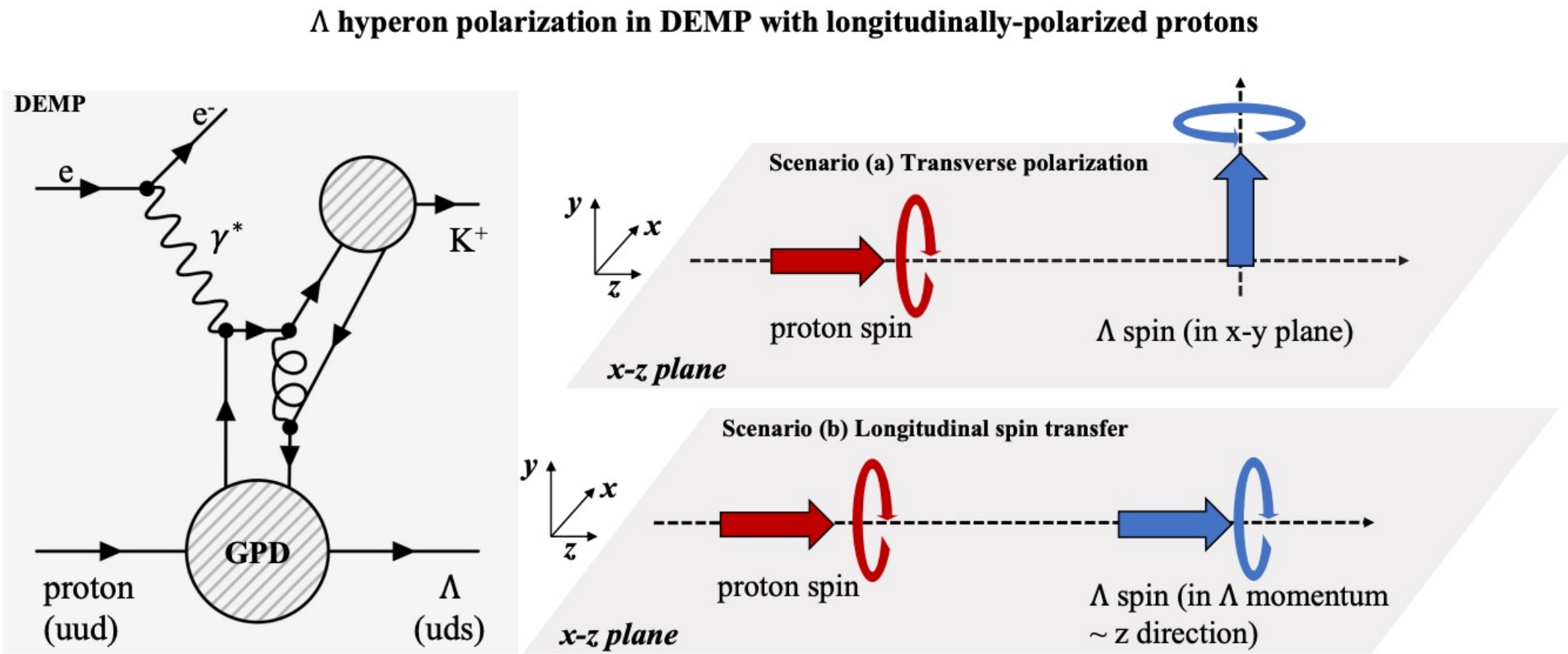
b) $\Lambda\bar{\Lambda}$ spin correlations in pp collisions – vacuum pair production.

But not single **Λ polarization in DIS, a system that is simpler?**



CLAS 12 might be able to put everything together

A new proposal – Deep Exclusive Meson Production (DEMP) as a probe of **Λ polarization**



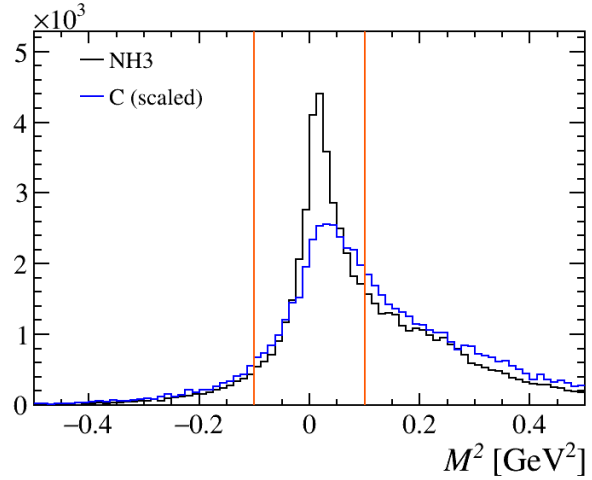
See details here, https://inspirehep.net/literature/2689260

Λ polarization in $ep \rightarrow eK^+\Lambda$

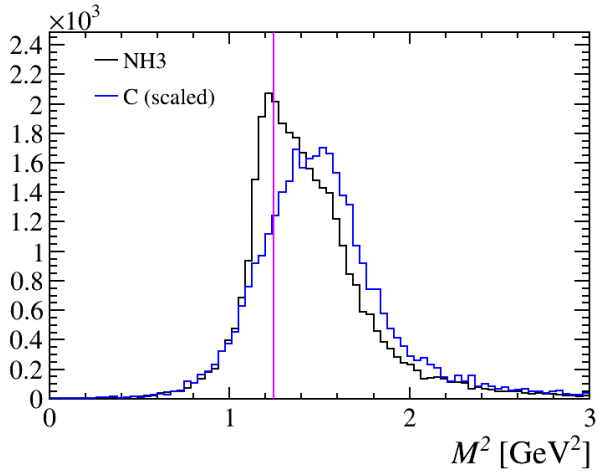
- Motivation: Probe the origin of Λ transverse polarization
  - Key question: the underlying mechanism of Λ polarization?
  - Approach: Use a longitudinally polarized target to study the spin transfer in the exclusive process
- **Run Group C (RGC) Data**
  - Collected in summer 2022, fall 2022 and spring 2023
  - Beam: 10.5 GeV highly polarized electron
  - Target: Longitudinally polarized NH3 + background targets
- Feasibility and performance
  - Channel: $ep \rightarrow eK^+\Lambda \rightarrow eK^+pX$ (ignore π^-)
  - Clear Λ signal extracted from a small subset of data (~4%)
  - Compared with area-normalized carbon background to validate the free proton signal
- **Team: UConn (Joo,), Saclay (Bossu), IJCLab (Nicolai), Mississippi state (Li), BNL/SBU (Tu).**

(Shohini Bhattacharya from UConn will be our theory collaborator on GPDs)

Frist look is promising with only 4% of data



m_X^2 for missing π^- $(ep \rightarrow eK^+pX)$



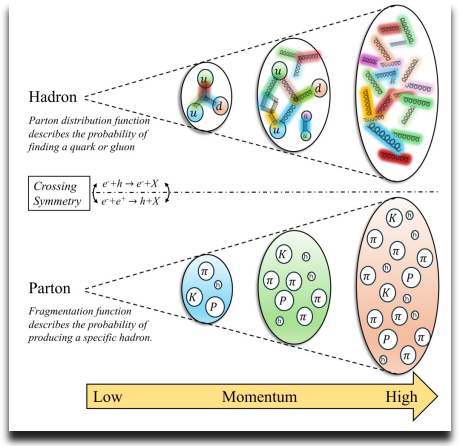
m_X^2 for missing Λ $(ep \rightarrow eK^+X)$

Other possible physics & detector projects

- BNL EIC group is developing pfRICH subdetector (with HRPPD) for ePIC. SBU is fabricating high quality conical mirrors. This has potential collaboration with dRICH in ePIC and SoLID experiments. These expertise and hardware R&D can be applied to CLAS 12, if there is an opportunity.
- Double Λ production near threshold → different mechanism? It could be interesting to probe a different initial quantum state.
- Entanglement entropy in DIS on nuclei (never done before.)

  Recent works on maximally entangled state in proton.

  1. *Phys.Rev.Lett. 134 (2025) 11, 111902*
  2. *Phys.Rev.Lett. 131 (2023) 24, 241901*
  3. *Phys.Rev.Lett. 124 (2020) 6, 062001*
  4. *Rept.Prog.Phys. 87 (2024) 12, 120501*
  5. *Eur.Phys.J.C 81 (2021) 3, 212*



- Entanglement enabled intensity interferometry using Vector Meson production (*Phys.Rev.Res.* 7 (2025) 1, 013131) → and its connection to the EIC.

Membership applications

1. Zhoudunming Tu (PI)
2. Li Xu (postdoc)

(only two for now)

- Our project's funding is secured for two years, based on a LDRD grant.
- Thus, we will fulfill all required institutional duties for the two requested members.
- We hope to continue, if possible, after this project ends and potentially bring in more people.

My engagement will be a **two-way street**. I am committed to the CLAS 12 physics program as well as a viable pathway to collaborations/opportunities for working on ePIC @ EIC & STAR @ RHIC.

THANK YOU