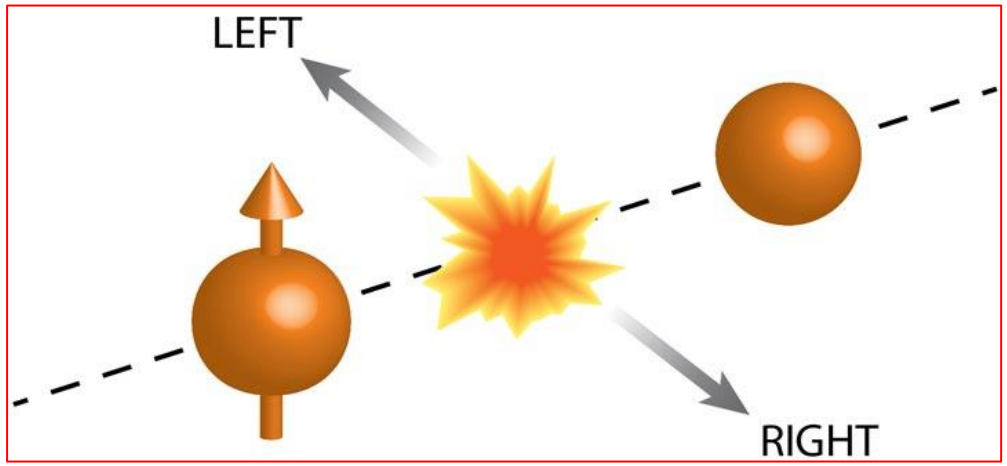
WHY DOES POLARIZED PROTON-PROTON COLLISION MATTER?

Polarized proton-proton collision

When an unpolarized proton beam collides with a proton polarized transverse to its direction of travel, there is a net deflection—an imbalance in the probability for a particle to go to the left versus to go to the right



Credit: bnl.gov

RHIC
Located at Brookhaven National Laboratory (BNL) in Upton, New York

Polarization of proton beam

Polarization of the beam

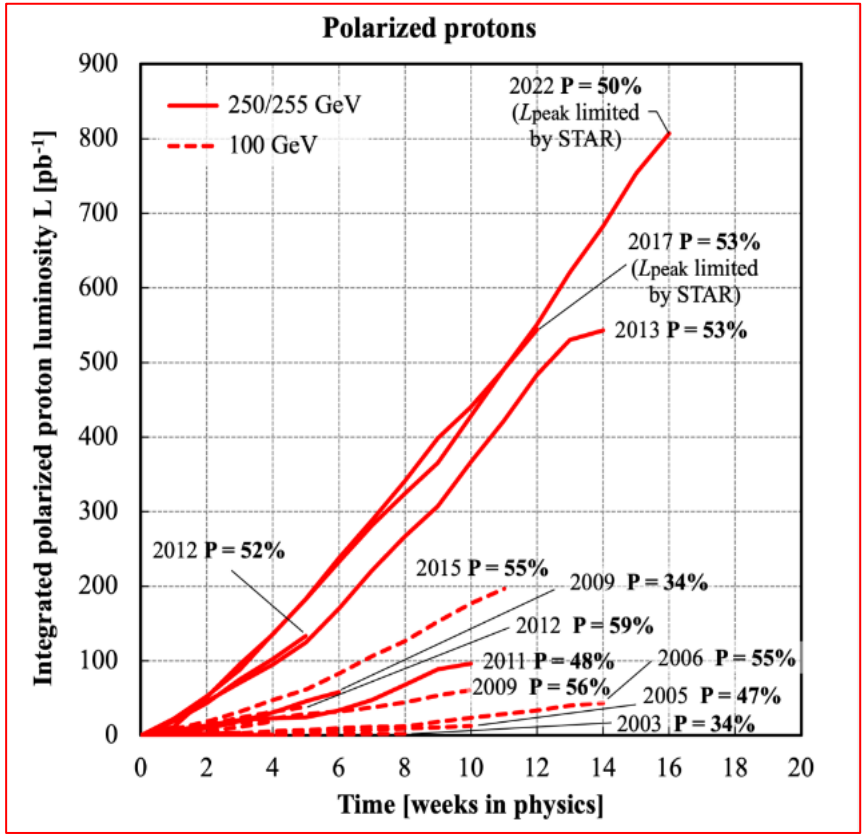
Polarizing means aligning the spins of the protons in a specific direction

- **Methods of Polarization:**

Optically Pumped Polarized Ion Source (OPPIS)

- was developed in the early 80's at KEK (Japan)

- This technique is based on spin transfer collisions between a proton or atomic hydrogen beam of a few keV beam energy and optically-pumped alkali metal vapors *LW Anderson et al. 1979*



Source: bnl.gov

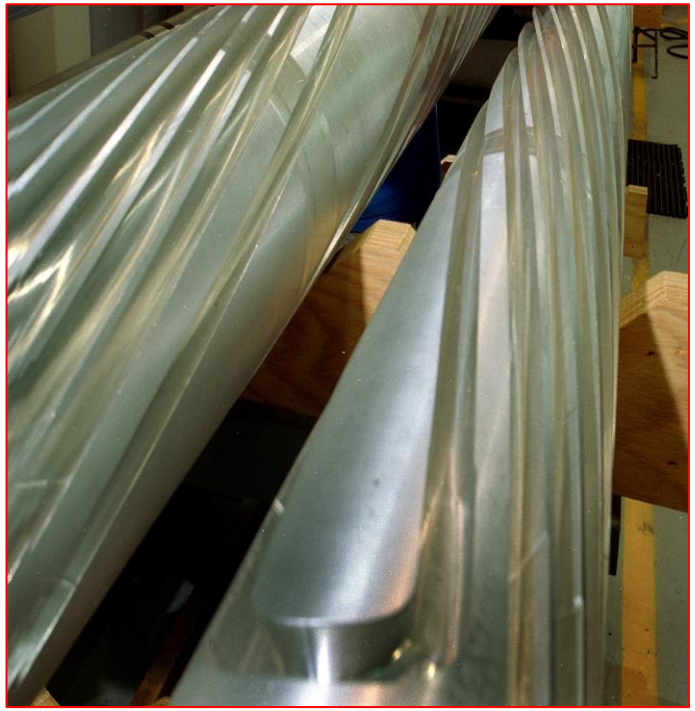
Siberian Snake

- Magnetic field errors,
- Quadrupole misalignments,
- Spin resonances

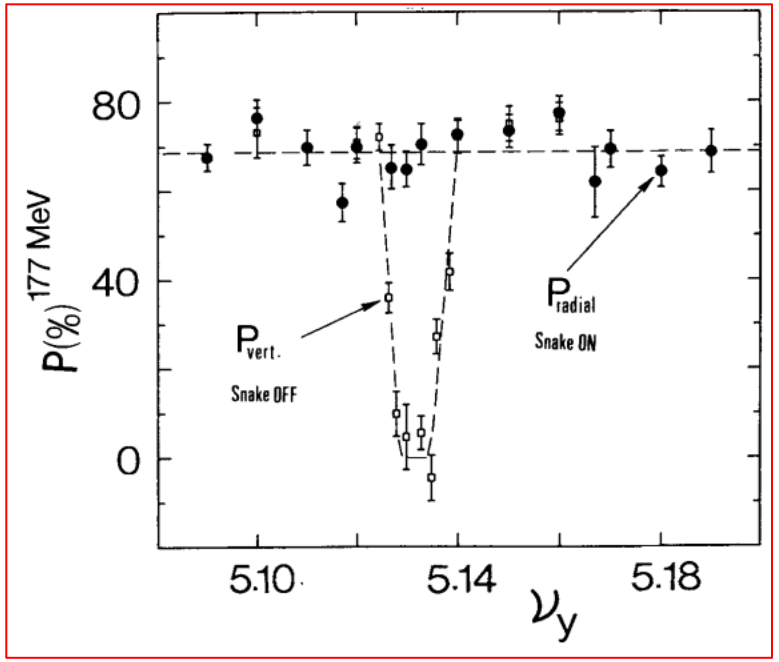
Mechanism:
Siberian snakes are special magnetic devices that rotate the spin of protons as they move through the accelerator.

Design:
Magnetic arrangement: Siberian snakes use a combination of dipole and quadrupole magnets.

Helical path:
This ensures that the spin direction remains aligned with the desired polarization direction throughout the acceleration process.



Siberian Snake
Credit: Brookhaven Laboratory



Polarization measurements with and without Snake at 177 MeV plotted against the vertical betatron tune ν_y.
T. Roser, 1992 American Institute of Physics

Why Polarized p-p Collision?

Studying Proton Spin Structure

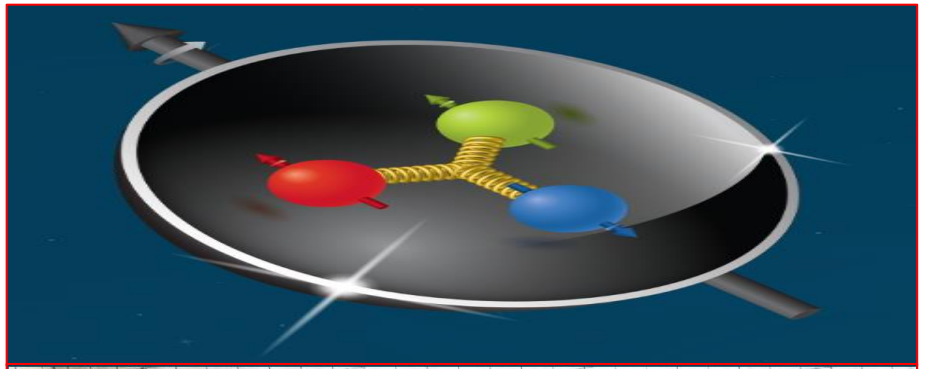
- Summing up the spin of quarks
- EMC experiment at CERN (1988)

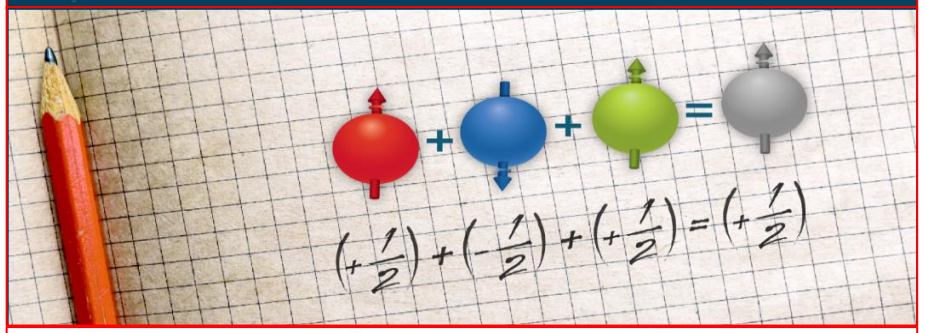
The remaining contribution ?

- The spins of **gluons.**
- The **orbital angular momentum** of quarks and gluons.

$$\frac{1}{2} = \frac{1}{2}\Delta\Sigma + \Delta G + L_q + L_g$$

Jaffe and Manohar 1990





Credit: bnl.gov

"RHIC has conclusively, for the first time ever in the world, taken measurements to tell us that the gluon contribution to spin is about equal to the contribution of the quarks."

--RHIC physicist Renee Fatemi,
University of Kentucky

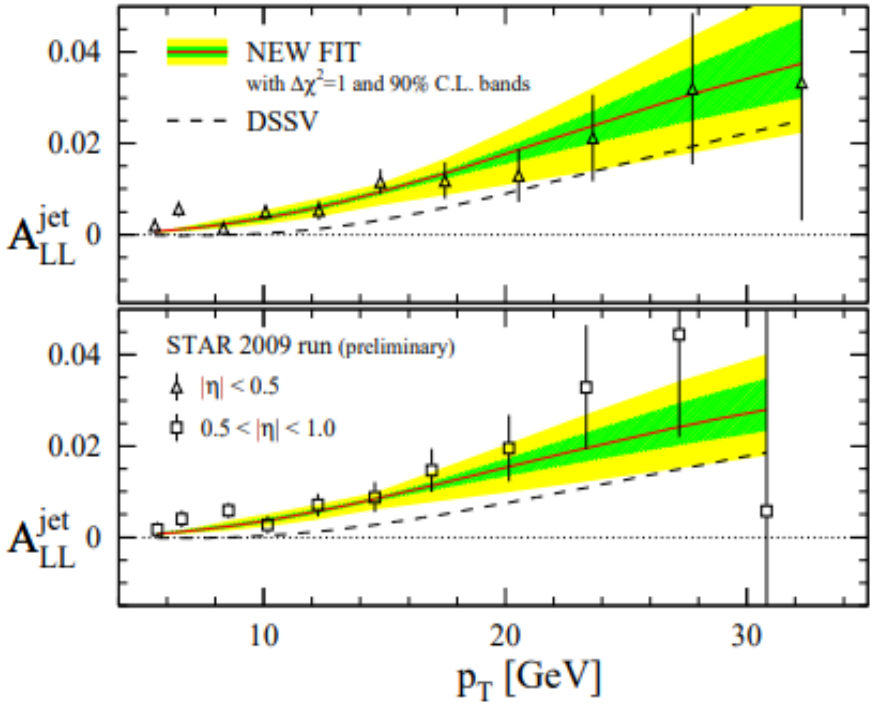
Evidence for polarization of gluons in the proton

- Comparison to the new STAR jet data obtained with new set of spin-dependent distributions.
- Two rapidity ranges, $|\eta| < 0.5$ and $0.5 < |\eta| < 1$.
- It is evident that the new fit describes the data very well in both ranges.

- **Longitudinal double spin asymmetry**

$$A_{LL} = \frac{\sigma_{++} - \sigma_{+-}}{\sigma_{++} + \sigma_{+-}}$$

If gluon polarization is present, it introduces a non-zero asymmetry in the final state of the collisions.



Daniel de Florian et al. 2014

Gluon Sivers Function

Our group works on understanding the Gluon Sivers function using different probes including open and closed charm production, prompt photon production in polarized proton scattering.

I am working on J/ψ production and comparing results obtained using different models of charmonium production e.g.

Color Evaporation Model and **Improved Color Evaporation Model (ICEM)** in processes like $e + p^{\uparrow} \rightarrow e + J/\psi + X$

and $\mathrm{p} + p^{\uparrow} \rightarrow J/\psi + X$

Transverse single spin asymmetry (TSSA) observed in J/ψ production using Improved Color Evaporation Model can be used as a **Clean probe of gluon Sivers Function**.

If the **Gluon Sivers function is found to be non-zero,** this would indicate that gluons inside the proton are distributed asymmetrically with respect to the proton's spin.

Process Proposed to Probe GSF (In preparation):
"TSSA in $e + p^{\uparrow} \rightarrow e + J/\psi + X$ in ICEM" -- *G. Suraj, M. Himanshu, M. Anuradha, P. Siddhesh, R. Vaibhav*

Future Collider

Electron Ion Collider (EIC):

High-energy electrons into head-on collisions with high-energy protons or nuclei.

- **Solving the mystery of proton spin**

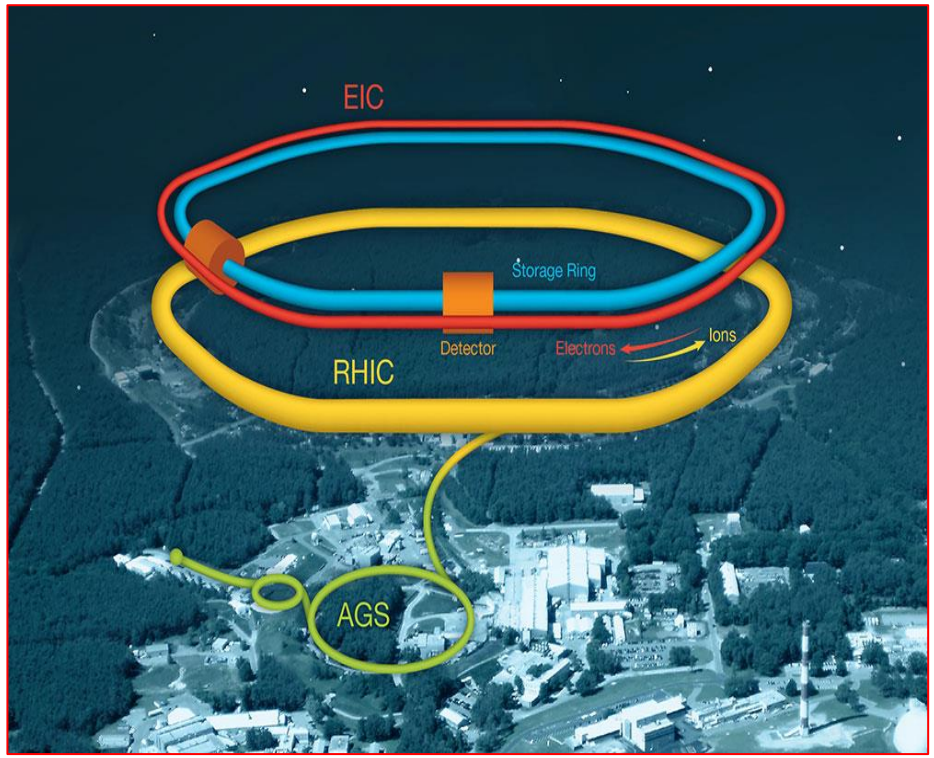
An EIC will reveal how the teeming quarks and gluons inside the proton combine their spins to generate the proton's overall spin.

- **Search for Saturation**

A unique form of matter, the color glass condensate, may be produced for study for the first time by an EIC, providing deeper insight into gluons and their interactions.

- **Quark and Gluon Confinement**

Experiments at an EIC will cast fresh light on the mystery of why quarks or gluons can never be observed in isolation but must remain confined within protons and nuclei.



Credit: bnl.gov

The Electron-Ion Collider will be built at Brookhaven National Laboratory, reusing components of the existing Relativistic Heavy Ion Collider (RHIC).