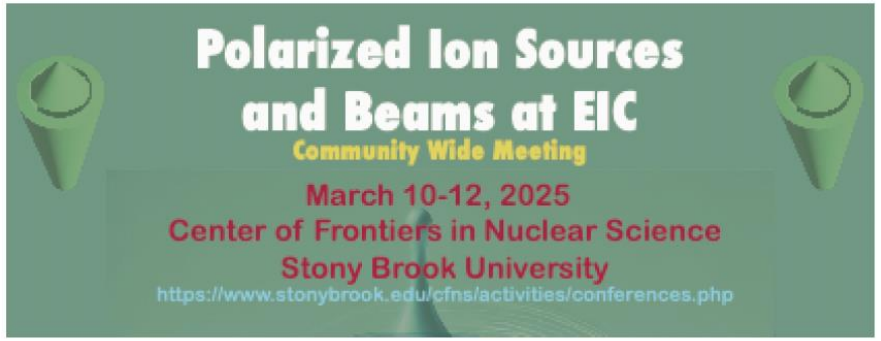


Community-wide meeting

Polarized Ion Sources and Beams

Organized by Deepak Raparia (BNL), Frank Rathmann (BNL),
Jaydeep Datta (SBU), Richard Milner (MIT), and Zein-Eddine Meziani (ANL)

Center for Frontiers
in Nuclear Science

Goals of the meeting

- to raise the visibility in the EIC and spin communities of the exciting scientific case for spin measurements;
- to assess, in the context of the considerable scientific motivation, the status of ion source development for EIC;
- to identify critical path R&D essential for a successful polarized EIC program that can be implemented on day-1;
- to motivate the education and training of a new generation of young physicists with expertise in spin polarization technology. This will be essential for realization of the EIC polarized program.

Perspective

- It must be realized that the adaption of a well-understood polarization technique into a reliable ion source operating at maximum performance injecting with high reliability into an accelerator requires a sustained R&D effort by a critical mass of suitably skilled personnel for about a decade.

- If we consider the major polarization experimental efforts in nuclear physics over the last half century, university-based research groups played an essential role in developing the technical capabilities and in attracting and training the generations of physicists who carried out the research.

- The EIC science demands the widest available range of polarized ions and innovative source technologies must be pursued.

- It is recommended that a specific amount of funding be set aside to target R&D associated with the realization of polarized ion beams at EIC. This would support education and training of young physicists with the necessary expertise.

- It is recommended that a focused multiweek program on the science case for polarized ion beams at EIC being organized at the Institute for Nuclear Theory in the next year

- It is recommended that an annual summer school for young physicists on the science and technical realization of polarized ion beams at EIC be organized

Scale of task before us

- OPPIS: multi-decade, 30 physicists, 10 engineers, 5 postdocs/students
- HERMES H/D target: 40 graduate student years, 50 postdoc/senior years
- HERMES He-3 target: 10 graduate student years, 12 postdoc senior years, two years of engineering
- SLAC He-3 target: 35 person years
- SLAC H/D target: 20 person years
- Ongoing He-3 source development at BNL: 12 physicists, 4 postdocs

Polarized Ion Sources

Overall status and availability

- The EIC will use
  - polarized **protons** ($\vec{\frac{1}{2}}$) and **helions** ($\vec{\frac{1}{2}}$),
  - later on possibly **deuterons** ($\vec{1}$), and
  - heavier nuclei like **lithium**, i.e., $^6\mathrm{Li}$ ($\vec{1}$) and $^7\mathrm{Li}$ ($\vec{\frac{3}{2}}$).
- **Ion sources** for
  - polarized protons (available)
  - polarized ^{3}He (needs work)
  - polarized deuterons
    - will be inherited from Jülich (soon, then needs work)
    - not trivial for HSR as $G_d = -0.143$ small (needs work)
  - polarized lithium (needs a lot of work)

Meeting on Polarized Ion Sources and Beams I

- Sponsered by and carried out at SBU's Center for Frontiers in Nuclear Science
- **Organizers:** Deepak Raparia (BNL), Frank Rathmann (BNL), Jaydeep Datta (SBU), Richard Milner (MIT), and Zein-Eddine Meziani (ANL)
- 2-day meeting with ample time for discussions
  - 62 participants: about 35 present, 25 via zoom
  - Talks at https://indico.cfnssbu.physics.sunysb.edu/event/343/
- 8 Sessions:
  1. Overview EIC & Spin

Meeting on Polarized Ion Sources and Beams II

2. Spin physics

	Nuclear Gluonometry	*James Maxwell* 11:15 - 11:45
	Spin Structure of the Nucleon	*Renee Fatemi* 11:45 - 12:15
12:00		
	Spin-dependent EMC effect	*Ian Cloet* 12:15 - 12:45

3. Polarized fusion, EicC, polarized electrons

14:00	**Polarized Fusion**	*Andy Sandorfi* 14:00 - 14:30
	Polarized Beams and Spin Physics at IMP	*Boxing Gou* 14:30 - 15:00
15:00	**Polarized electron beams at EIC**	*Dave Gaskell* 15:00 - 15:30
	Posters	*Minxiang Li et al.* 15:30 - 16:00

Meeting on Polarized Ion Sources and Beams III

4. Polarized ion source for $\vec{p}$, $\vec{d}$, $^3\overrightarrow{\mathrm{He}}$, and $^6\overrightarrow{\mathrm{Li}}$

	Polarized proton source OPPIS	*Grigor Atoian* 16:30 - 17:00
17:00	Polarized deuteron sources	*Ralf Gebel* 17:00 - 17:30
	Polarized He-3 source	*Noah Wuerfel* 17:30 - 18:00
18:00	Polarized Li-6 source	*Chao Peng* 18:00 - 18:30

5. Beam polarimetry: $\vec{p}$ absolute, pC relative, and $^3\overrightarrow{\mathrm{He}}$ absolute

09:00	Absolute hadron beam polarimetry at EIC	*Frank Rathmann* 09:00 - 09:30
	pC polarimetry at EIC	*Haixin Huang* 09:30 - 10:00
10:00	Absolute polarized He-3 polarimeter	*Prajwal MohanMurthy* 10:00 - 10:30

Meeting on Polarized Ion Sources and Beams IV

6. Few body scattering, snakes, and lessons from AGS for EIC

11:00	**Few-body elastic scattering polarimetry**	*Nigel Buttimore* 11:00 - 11:30
	Snakes in AGS and EIC	*Kiel Hock* 11:30 - 12:00
12:00	**What should be learned for the EIC from accelerating polarized protons in the AGS**	*Thomas Roser* 12:00 - 12:30

7. EIC injector optimization, spin rotation in IRs, existing spin manipulators

14:00	**Polarization and intensity optimization in the injector chain for the EIC**	*Vincent Schoefer* 14:00 - 14:30
	Ion spin rotation at both IRs	*Vadim Ptitsyn* 14:30 - 15:00
15:00	**Existing spin manipulators at RHIC**	*Haixin Huang* 15:00 - 15:30

8. New spin tools

16:00	**Spin tune determination and feedback**	*Volker Hejny* 16:00 - 16:30
	Lorentz-force free RF spin manipulator	*Jamal Slim* 16:30 - 17:00

Polarimetry requirements for hadron beams in EIC

- **The EIC promises to provide proton beam polarizations of $P \geq 0.7$ with a relative uncertainty of $\Delta P/P \leq 1\%$.**
- **Absolute proton beam polarization calibration relies on measured nuclear polarization of atomic jet using Breit-Rabi polarimeter.**
- Polarization calibration needed for each ion species, as presently applied to for protons:
  - elastic scattering of identical particles $\Rightarrow$ beam polarization inferred from known target polarization.
  - $\vec{p}\vec{p}$ elastic scattering,
  - ${}^3\overrightarrow{\mathrm{He}} - {}^3\overrightarrow{\mathrm{He}}$ elastic scattering,
  - $\vec{d}\vec{d}$ elastic scattering, and,
  - ${}^6\overrightarrow{\mathrm{Li}} - {}^6\overrightarrow{\mathrm{Li}}$ elastic scattering.
- **Polarization calibration of other species also from nuclear polarization measurement of atomic targets using BR or similar type polarimeter**

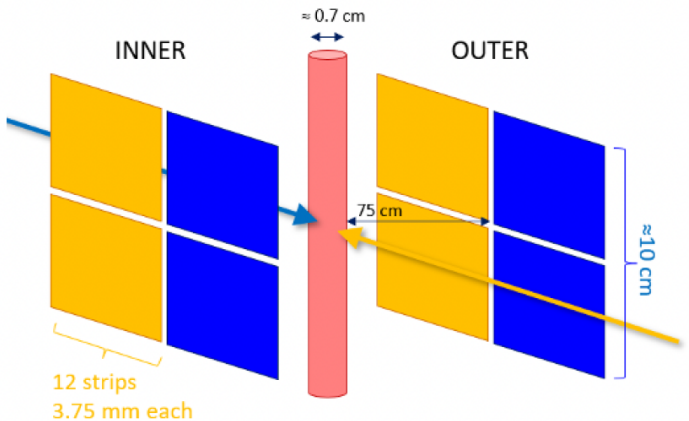
Absolute polarization from polarized hydrogen jet I

Breit-Rabi polarimeter

- Instrument capable to determine absolute polarization Q of atomic beam, i.e., electron and proton polarization of hydrogen atoms, with accuracy $\Delta Q/Q \lesssim 1\%$.
  - No solid estimates available for EIC yet that fully encapsulate the BRP measurement systematics at the HJET on the $\approx 1\%$ level.

Beam polarization calibration

1. Proton beam passes through target of polarized H atoms of known polarization Q



Absolute polarization from polarized hydrogen jet II

Beam polarization calibration

2. Measure number of scattered particles in left (L) and right (R) detectors
3. Sign of Q periodically reversed to compensate for asymmetries caused by differences in detector geometry or efficiency in L and R directions.
4. This determines target asymmetry

$$\epsilon_{\text{target}} = \frac{\text{L} - \text{R}}{\text{L} + \text{R}} = A_y \cdot Q \cos\phi \,. \tag{1}$$

5. Measurement of corresponding asymmetry with beam particles determines ϵ_{beam}. In elastic pp scattering, and more general in the elastic scattering of *identical* particles, A_y same regardless of which proton is polarized.
6. Absolute beam polarization given by

$$\boxed{P = \frac{\epsilon_{\text{beam}}}{\epsilon_{\text{target}}} \cdot Q} \tag{2}$$

The path forward

- We have formed

  EPIOS (**E**IC **P**olarized **IO S**ource) scientific consortium

  to continue to advance the realization of polarized ion beams at EIC.
- Plan meetings about every six months: Stony Brook, ANL, MIT,……
- Immediate tasks:

  - Write and publish the whitepaper based on the meeting
  - Propose INT scientific workshop for 2026
  - Explore initiation of annual summer school, starting in 2026
- DNP Workshop ***Polarized Ion Beams at EIC***, proposed by Z.-E. Meziani and R. Milner approved. DNP meeting in Chicago Oct 17-20, 2025. EPIOS meeting at DNP meeting.