

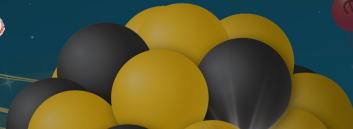
# Realizing the Scientific Program with Polarized Ion Beams at the future BNL Electron Ion Collider

Why the R&D on polarized sources, beams and polarimetry must start now

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on behalf of the EPIOS Scientific Consortium  
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# Outline

1. The opportunity: what only polarized light ions give us
2. EPIOS, from the source to colliding beams
3. Sources: where each species stands
4. Spin transport, manipulation, polarimetry
5. The decade ahead: the effort it takes
6. Where you can work on this *now*

All of this R&D can be carried out before the EIC turns on.

# Why polarized light ions

## Beyond polarized protons and unpolarized ions

### Nuclear spin resides in the valence nucleons

- The unpolarized core dominates the scattering: spin asymmetries dilute roughly as  $1/A$ . Polarized beams are of interest for  $A \lesssim 20$
- For  $A \leq 7$ , ab initio structure calculations supply the nuclear corrections needed to extract nucleon-level quantities

|               | $J^\pi$         | access                                 |
|---------------|-----------------|----------------------------------------|
| $^2\text{H}$  | $1^+$           | tensor pol.: $b_1$ ; tagged free $n$   |
| $^3\text{He}$ | $\frac{1}{2}^+$ | effective $\vec{n}$ beam               |
| $^6\text{Li}$ | $1^+$           | $\vec{d}$ inside an $\alpha$ core      |
| $^7\text{Li}$ | $\frac{3}{2}^-$ | $p$ -dominated spin: in-medium $g_1^p$ |

Species set of the EPIOS perspective, PRC 113, 060501 (2026)

*PSTP26: Y. Zhai (this session): polarized  $p$ ,  $d$ ,  $h$  beams at the EicC*

$\vec{d}$ ,  $^3\text{He}$ ,  $^6\text{Li}$  and  $^7\text{Li}$  give neutron spin structure, tensor observables and in-medium nucleon structure. Protons reach none of these.

# Flavour separation of quark helicities

Inclusive  $g_1$  on  $p$  and  $n$  replaces SIDIS flavour tagging

There is no free neutron target

Flavour separation by SIDIS depends on fragmentation functions and their systematics. Inclusive  $g_1^p$  and  $g_1^n$  measurements do not.

Two routes to  $g_1^n$

$^3\text{He}$ :  $S$  state, the  $n$  carries the nuclear spin;  $\Delta$ -isobar and shadowing corrections.  $^2\text{H}$ : spectator- $p$  tagging; the free neutron follows at zero virtuality.

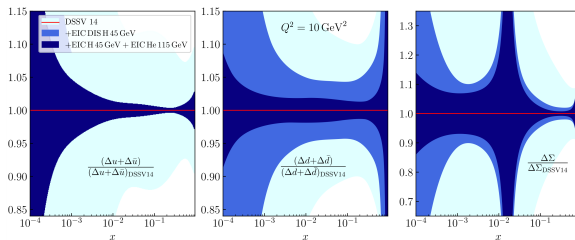


Fig. 2, EPIOS perspective; Borsa *et al.*, PRD **102**, 094018 (2020)

Inclusive  $e\vec{p}$  and  $e\ ^3\text{He}$  data separate  $\Delta u$  and  $\Delta d$ ; the Bjorken sum yields  $\alpha_s$ .



# Mapping the full 3D structure

## GPDs, TMDs, and the spin sum rule

### One framework, two projections

Wigner distributions reduce to GPDs: parton position in the transverse plane, spatial tomography; and to TMDs: intrinsic transverse momentum, spin–momentum correlations.

### The unmeasured term

$$J_{q,g} = \frac{1}{2} \int_0^1 dx x [H_{q,g} + E_{q,g}] (x, \xi, t=0)$$

Helicities are constrained by DIS and RHIC data. Orbital angular momentum has never been measured.

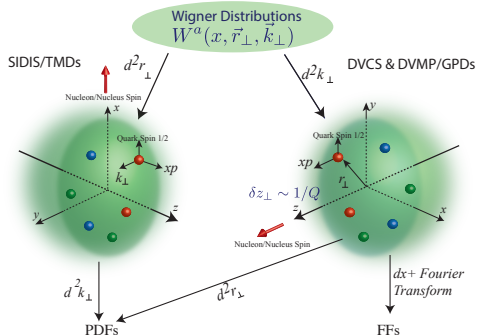


Fig. 3, EPIOS perspective, PRC 113, 060501 (2026)

OAM, the missing term of the spin sum rule, is accessible at the EIC via diffractive dijet asymmetries.

# From spin 1/2 to spin 1

## New leading-twist structure at higher spin

| leading twist |                            | quark operator              |                              |                                    |
|---------------|----------------------------|-----------------------------|------------------------------|------------------------------------|
|               |                            | $\gamma^+$                  | $\gamma^+\gamma_5$           | $\gamma^+\gamma^i\gamma_5$         |
|               | T<br>E<br>N<br>S<br>O<br>R | $f_{LL}(x, \mathbf{k}_T^2)$ |                              | $h_{1LL}^\perp(x, \mathbf{k}_T^2)$ |
|               |                            | $f_{LT}(x, \mathbf{k}_T^2)$ | $g_{1TT}(x, \mathbf{k}_T^2)$ | $h_{1TT}, h_{1TT}^\perp$           |
|               |                            | $f_{TT}(x, \mathbf{k}_T^2)$ | $g_{1LT}(x, \mathbf{k}_T^2)$ | $h_{1LT}, h_{1LT}^\perp$           |

Tensor sector of Fig. 24, EPIOS perspective, PRC 113, 060501 (2026); full table behind the button

### Tensor polarization opens a new sector

- Spin 1 adds three  $T$ -even and seven  $T$ -odd quark TMDs at leading twist
- $b_1$  measures the difference between the  $m=0$  and  $m=\pm 1$  parton distributions
- Stable spin-1 nuclei:  $^2\text{H}$ ,  $^6\text{Li}$ ,  $^{14}\text{N}$

► full TMD table

$b_1$ , gluon transversity and ten additional TMDs: none of them exists for a spin-1/2 target.

# The polarized EMC effect

## Is nucleon spin structure modified in the medium?

### Two discoveries, never combined

Quarks carry little of the nucleon spin; valence quarks in a nucleus carry less momentum than in a free one. Spin structure in the medium: unmeasured after 40 years.

### The observable

$$\Delta R_{\text{EMC}}^A = g_{1A} / (P_p g_1^p + P_n g_1^n)$$

$P_{p,n}$ : effective nucleon polarizations. Predicted to deviate from unity at least as strongly as the unpolarized ratio.

$g_1$  of  ${}^6\text{Li}$  and  ${}^7\text{Li}$ : the first measurement of nucleon spin structure inside a nucleus.

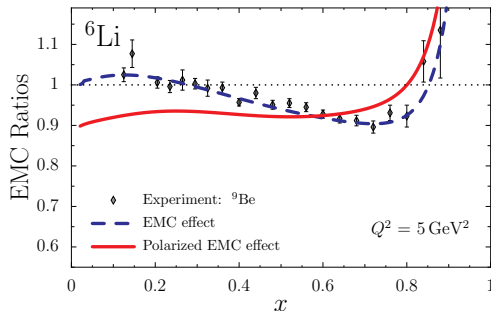


Fig. 4, EPIOS perspective; Cloët, Bentz and Thomas, PLB 642, 210 (2006) [▶ definitions](#)

# Exotic gluon states in nuclei

## Gluon transversity in targets with $J \geq 1$

### A purely gluonic structure function

$\Delta(x, Q^2)$  requires a photon helicity flip of two units. No bound nucleon or pion can supply  $\Delta J_z = 2$ : only glue contributes.

### Where to look

Requires  $J \geq 1$ , transverse polarization. Lattice QCD sees a clear signal. Expected enhanced in compact nuclei; candidates  ${}^6\text{Li}$ ,  ${}^{14}\text{N}$  (spin 1),  ${}^7\text{Li}$ ,  ${}^{23}\text{Na}$  (spin 3/2).

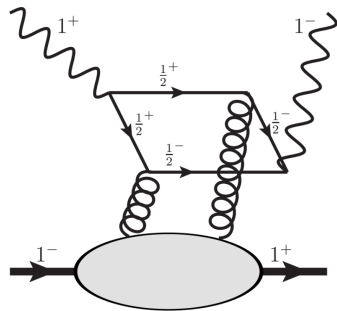


Fig. 5, EPIOS perspective

► the expression

*PSTP26: W. Milner (S&T II): a  $^{10}B$  route to  $\Delta(x, Q^2)$*

A nonzero  $\Delta(x, Q^2)$  is direct evidence for gluonic states not associated with any nucleon.

# EPIOS, and the machine it serves

## HSR from the yellow RHIC ring, plus a new electron ring

### EIC Polarized IOn Source consortium

- Formed at the community-wide meeting, Stony Brook, March 2025
- Mandate: **drive and coordinate** the R&D across laboratories and universities
- 30+ institutions, 8 countries; perspective published as PRC **113**, 060501 (2026)

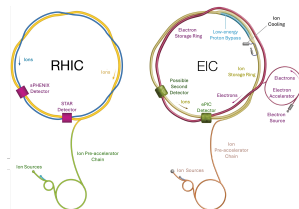


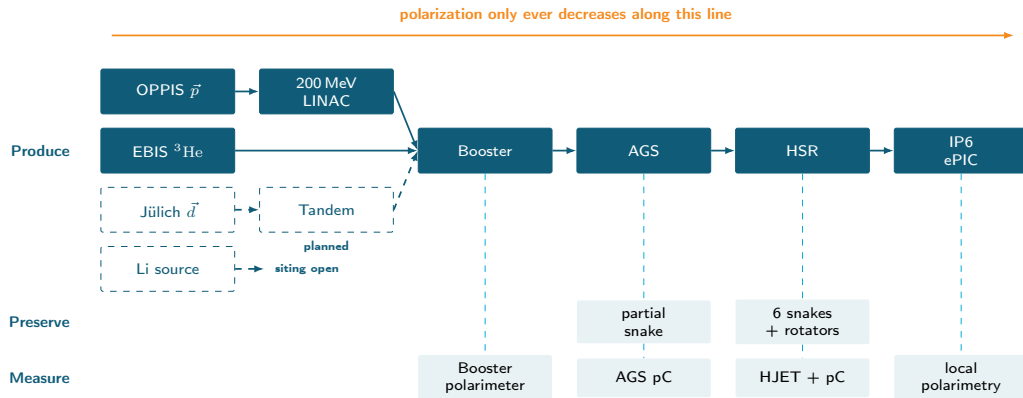
Fig. 7, EPIOS perspective

- $P > 0.7$ ,  $\Delta P/P \leq 1\%$  for  $\vec{p}$ ,  $^3\text{He}$ ; 1160 bunches at 10 ns; six snakes
- RHIC ends Jan 2026; CD-4 in 2034

No single group owns the whole system, and the system is what has to work.

# Source, transport, manipulation, polarimetry

## One system, not four projects



Polarization lost anywhere is never recovered downstream.

# Sources: protons and deuterons

## One mature, one arriving

### OPPIS (available)

- Run25: 82% at 420  $\mu\text{A}$  average current
- Supported all RHIC runs, >60% in collisions
- R&D is reliability, not principle

### COSY deuteron source (then needs work)

- No longer required in Germany, transferring to BNL
- Likely at the Tandem: no room at EBIS
- Tensor polarimetry is the open problem

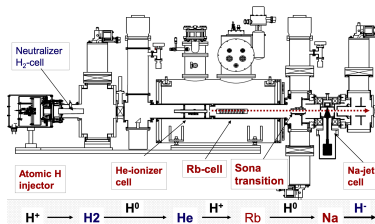


Fig. 12, OPPIS schematic

*PSTP26: A. Cannavo (OPPIS Run25, S&T III); V. Fimushkin (JINR, this session); S. J. Puetz (Lamb-shift polarimetry)*

$G_d = -0.143$  makes the deuteron a spin-transport problem, not just a source problem.

## Sources: $^3\text{He}$ now, Li next

One with hardware in the machine this year, one wide open

### $^3\text{He}$ : MEOP inside the 5 T EBIS solenoid

- 90% sealed, 80% open cell, 60% in EBIS
- Gas system installed in the 2026 EBIS shutdown
- Booster: tests with new polarimeter using  $^3\text{HeC}$  and pC scattering in 2027
- AGS:  $^3\text{HeC}$  CNI polarimeter after AGS refurbishment

### $^6\text{Li}$ , $^7\text{Li}$ : optical pumping at the oven

- ANL with Kentucky: oven plus de Laval nozzle, 671 nm optical pumping, built
- Still to build: rf transitions, ionizer, extraction grid

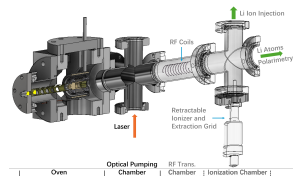


Fig. 15, Li source concept

*PSTP26:  $^3\text{He}$ : N. Wuerfel (S&T III), Hock et al. (Polarimetry II): Booster polarimeter, P. Pandey (Targets II);  $^6\text{Li}$ : W. Korsch (S&T II)*

$^3\text{He}$  hardware is in the machine this year; the Li source is where the field is still open.



# Injector chain and the AGS

## Where the polarization is actually lost

- AGS must deliver  $3 \times 10^{11}$  protons at 70%.  
Present optimum: 65%
- Two helical partial snakes; spin-tune gap differs per species (0.061  $p$ , 0.094  $h$ , 0.025  $^7\text{Li}$ )
- Tune jump since 2011; skew quadrupoles being commissioned for 5 to 10% relative gain
- $^2\text{H}$  and  $^6\text{Li}$  cross only imperfection resonances
- New Booster polarimeter in the current injector upgrade, closing the diagnostic gap upstream of the AGS

► species parameters

*PSTP26: K. Hock (S&T III):  $^3\text{He}$  through Booster and AGS; Hock et al. (Polarimetry II): Booster polarimeter*

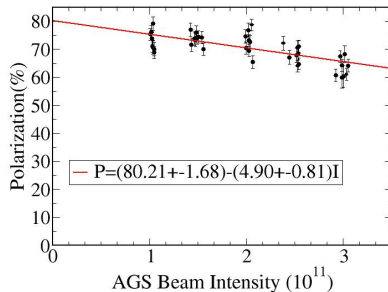


Fig. 20, AGS polarization versus intensity per bunch

The AGS is responsible for most of the loss from source to top energy.

# Snakes and rotators in the HSR

## Six snakes, and an interaction region that is not symmetric

- Six snakes, four helical dipoles each. Full for  $p$  and  $h$
- $^2\text{H}$  and  $^6\text{Li}$ : solenoid partial snake, plus a jump quadrupole system
- Rotators at 97.8 and 107.8 m, bends  $-17$  and  $61.35$  mrad: net bend is **not zero**
- Spin tune shifts by  $\sim 0.01$  on the rotator ramp

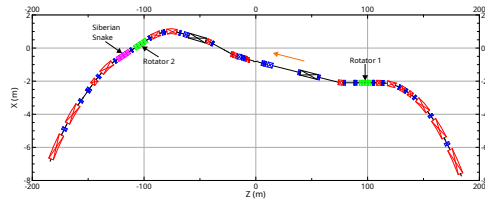


Fig. 21, provided by S. Berg (BNL)

► configuration table

*PSTP26: E. Hamwi et al.: polarization preservation strategy in the HSR*

Solutions exist on paper for every species. Few are demonstrated at EIC parameters.

# Novel spin tools, from COSY and JEDI to the EIC

## The benchmark, and what replaces it

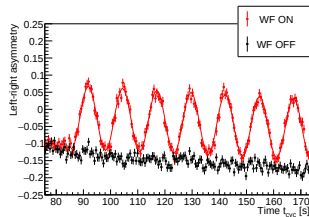
### The benchmark: Froissart-Stora spin flipping at RHIC

Nine magnets, a dedicated  $\gamma_{tr}$ -jump lattice, a swept resonance: **measured best about 97%** at 24 and 255 GeV.

► [the benchmark in detail](#)

### Lorentz-force-free rf Wien filter

- Waveguide in TEM mode:  $\vec{E} \perp \vec{B} \perp$  beam *by construction*
- Standing waves cancel  $\vec{F}_L$ ; driven spin oscillations with 1 mW of rf power
- Online spin tune from betatron-excited halo: continuous, non-destructive



Driven vertical spin oscillation, rf WF on and off

**Orbit distortion** 430 nm: continuous spin flips without a Froissart-Stora scan.

PSTP26: P. Lenisa (deuteron EDM at COSY, S&T IV); A. Piccoli (spin-tune model)

# Polarimetry

Absolute, at  $\Delta P/P \leq 1\%$ , for four species

- HJET: the only absolute route. Holding field 120 to 400 mT to suppress beam-induced depolarization
- pC: fast relative measurement and profiles. 10 ns spacing breaks the present event selection
- $^3\text{He}$ : cryogenic ABS at 95%, storage cell for thickness
- Li: atomic-beam target reusing the source hardware

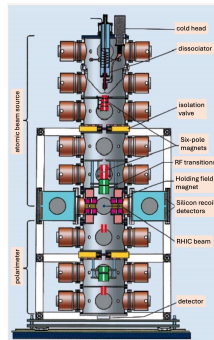


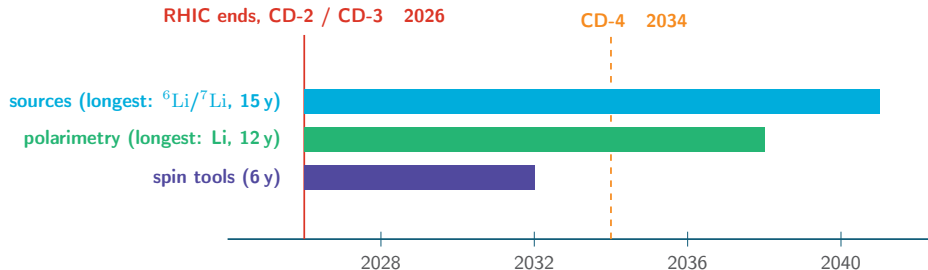
Fig. 18, HJET layout

*PSTP26: F. Rathmann, Hadron Beam Polarimetry for the EIC (Polarimetry II, Tue 09:00); V. Shmakova (HJET/BRP); A. Poblaguev (depolarization); K. Hock (Booster polarimeter)*

Absolute polarimetry exists for one species; the other three are the program.

# The decade ahead: the effort it takes

## R&D durations from Table V, and the people they need



$\approx 200$  FTE-years:  $\approx 20$  FTE per annum for a decade,  $\approx 80$  FTE of it graduate students. AI/ML, already tuning OPPIS and the transfer lines, accelerates all of it.

[► full breakdown](#)

Durations from PRC Table V; start of 2026 assumed, nothing is yet scheduled

The source programs run past CD-4 even if they start today. This cannot be improvised later.

# The injector complex, between RHIC and the EIC

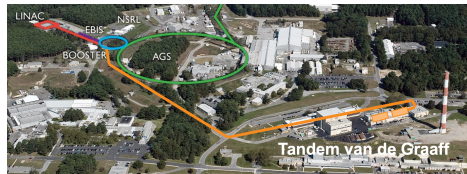
## A polarized synchrotron chain with no collider run to protect

### What can be measured, starting now

- **Booster polarimeter**, in the injector upgrade: spin transmission to Booster extraction
- **$^3\text{He}$  to the Booster and the AGS in 2026**, read out with the existing carbon CNI polarimeter
- **Booster-to-AGS transfer at 1.7 GeV to 2.8 GeV: less space charge, more resonances. Only measurement settles it**

### What the AGS already taught

- 1983 to 1988: 45 resonances by brute force, 42%. Partial snakes made it routine
- Tuning by repeated polarization measurement is no operating model: tracking and diagnostics replace it



RHIC ends Jan 2026; the AGS is refurbished for the EIC

Every later species starts where the proton started in 1983, on a machine with no collider schedule to defend.

# Places to plug in

## Concrete, funded or approved, near-term

- **BNL Tandem:** home for the  $d$  and  ${}^6\text{Li}$  sources
- **INT program** *Towards Realizing the Program with Polarized Ion Beams at EIC:* Seattle, 22 March to 2 April 2027; applications via the INT web form
- **Annual summer school:** under development, USPAS can be leveraged
- **DNP workshop:** Philadelphia, 11 to 14 Oct 2026
- **Consortium meetings:** every six months, next spring 2027
- Windowless internal gas targets open a possible fixed-target program

Synergistic with atomic physics and with fusion energy science.

## Get in touch

Students at every level, undergraduate to postdoc

If you are interested in polarized sources, beams or polarimetry, contact the consortium.

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The expertise is maintained by practice. That means people, working on machines, now.



# Summary

- Polarized  $^2\text{H}$ ,  $^3\text{He}$ ,  $^6\text{Li}$ ,  $^7\text{Li}$  unlock physics that polarized protons cannot reach: the polarized EMC effect, gluon transversity, tensor observables, a clean neutron
- EPIOS coordinates a chain no single group owns, from source through transport and manipulation to polarimetry
- $\approx 200$  FTE-years over a decade, against CD-4 in 2034 ▶ personnel
- The binding constraint is trained people, and the AGS gives this community somewhere to train them starting now

Phys. Rev. C **113**, 060501 (2026)    arXiv:2510.10794

# References

- [1] EPIOS Scientific Consortium, Phys. Rev. C **113**, 060501 (2026), arXiv:2510.10794.
- [2] I. Borsa *et al.*, Phys. Rev. D **102**, 094018 (2020).
- [3] I. C. Cloët, W. Bentz and A. W. Thomas, Phys. Lett. B **642**, 210 (2006).
- [4] Y. Ninomiya, W. Bentz and I. C. Cloët, Phys. Rev. C **96**, 045206 (2017).
- [5] R. L. Jaffe and A. Manohar, Phys. Lett. B **223**, 218 (1989).
- [6] F. Rathmann *et al.*, Phys. Rev. Accel. Beams **29**, 021001 (2026), arXiv:2508.01366.

# Spare: Leading-twist TMDs, spin 1/2 and spin 1

Table from Ninomiya, Bentz and Cloët, PRC **96**, 045206 (2017)

|                     |                            | quark operator                                                 |                                                 |                                                                                                      |
|---------------------|----------------------------|----------------------------------------------------------------|-------------------------------------------------|------------------------------------------------------------------------------------------------------|
|                     |                            | $\gamma^+$                                                     | $\gamma^+ \gamma_5$                             | $\gamma^+ \gamma^i \gamma_5$                                                                         |
| target polarization | U                          | $f_1 = \odot$<br>unpolarized                                   |                                                 | $h_1^+ = \odot - \ominus$<br>Boer-Mulders                                                            |
|                     | L                          |                                                                | $g_1 = \rightarrow - \leftarrow$<br>helicity    | $h_{1L}^+ = \rightarrow - \leftarrow$<br>worm gear 1                                                 |
|                     | T                          | $f_{1T}^+ = \uparrow - \downarrow$<br>Sivers                   | $g_{1T} = \uparrow - \leftarrow$<br>worm gear 2 | $h_1 = \uparrow - \downarrow$<br>transversity<br>$h_{1T}^+ = \uparrow - \rightarrow$<br>pretzelosity |
|                     | T<br>E<br>N<br>S<br>O<br>R | $f_{LL}(x, k_T^2)$<br>$f_{LT}(x, k_T^2)$<br>$f_{TT}(x, k_T^2)$ | $g_{1TT}(x, k_T^2)$<br>$g_{1LT}(x, k_T^2)$      | $h_{1LL}^+(x, k_T^2)$<br>$h_{1TT}, h_{1TT}^+$<br>$h_{1LT}, h_{1LT}^+$                                |

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## Spare: Gluon transversity $\Delta(x, Q^2)$

$$\Delta(x, Q^2) = -\frac{\alpha_s(Q^2)}{2\pi} \text{Tr } \mathcal{Q}^2 x^2 \int_x^1 \frac{dy}{y^3} [g_{\hat{x}}(y, Q^2) - g_{\hat{y}}(y, Q^2)]$$

$g_{\hat{x}, \hat{y}}$ : probability of a gluon with momentum fraction  $y$  linearly polarized along  $\hat{x}$  or  $\hat{y}$ , in a target polarized along  $\hat{x}$ ;  $\mathcal{Q} = \text{diag}(2/3, -1/3, -1/3)$ .

Sec. III C, EPIOS perspective; Jaffe and Manohar, PLB 223, 218 (1989)

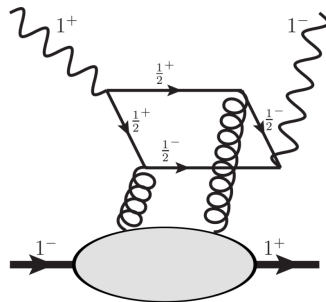


Fig. 5, EPIOS perspective

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## Spare: EMC and polarized EMC, definitions

$$R_{\text{EMC}}^A = \frac{F_{2A}(x)}{Z F_2^p(x) + N F_2^n(x)}$$

$$\Delta R_{\text{EMC}}^A = \frac{g_{1A}(x)}{P_p g_1^p(x) + P_n g_1^n(x)}$$

$P_p, P_n$ : effective nucleon polarizations from  
ab initio structure calculations.

Eqs. (1), (2), EPIOS perspective, PRC **113**,  
060501 (2026)

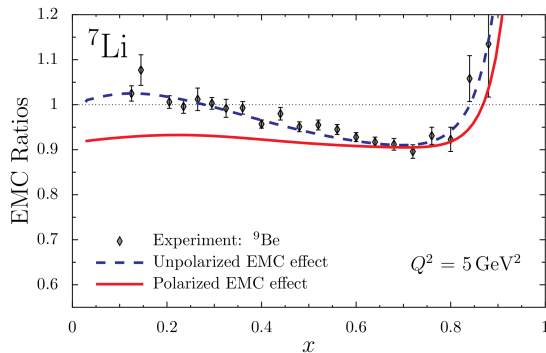


Fig. 4,  ${}^7\text{Li}$  panel, EPIOS perspective

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## Spare: Flipping the spin, the way it is done now

Froissart-Stora: sweep an artificial resonance across  $\nu_{sp}$

$$\frac{P_f}{P_i} = 2 \exp \left[ -\frac{\pi}{2} \frac{|\epsilon|^2}{\alpha} \right] - 1$$

A single rf rotator also drives a **mirror resonance** at  $1 - \nu_{osc}$ : harmless at low energy, fatal where  $\nu_{sp}$  sits near half integer and the two overlap.

What it takes to make it work at RHIC

- **Five ac plus four dc dipoles**: kills the mirror resonance, closes two vertical orbit bumps
- $\Delta D' \approx 0.045$  gives  $\Delta \nu_s \approx 0.007$  at  $\delta p/p = 10^{-3}$ ; fixed with  $\gamma_{tr}$  jump quads
- Predicted 99%; **measured best about 97%** at 24 and 255 GeV

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## Spare: Polarized species and spin parameters

PRC Table III. Dash: not applicable or not yet determined.

| Parameter                 | $p$           | $d$     | $h$           | ${}^6\text{Li}$ | ${}^7\text{Li}$ |
|---------------------------|---------------|---------|---------------|-----------------|-----------------|
| $m$ (MeV/c <sup>2</sup> ) | 938.27        | 1875.61 | 2808.92       | 5601.52         | 6533.83         |
| $\mu/\mu_N$               | 2.7928        | 0.8574  | -2.1275       | 0.8220          | 3.2564          |
| $S$                       | $\frac{1}{2}$ | 1       | $\frac{1}{2}$ | 1               | $\frac{3}{2}$   |
| $G$                       | 1.793         | -0.143  | -4.184        | -0.178          | 1.532           |
| $mc^2/G$ (GeV)            | 0.523         | 13.116  | 0.671         | 31.466          | 4.264           |
| $\chi/\chi_p$             | 1             | 0.0399  | 1.5572        | 0.0497          | 0.3668          |
| $\chi_c, \chi_w$ (%)      | 14, 9         | -       | 21.8, 14      | -               | 5.2, 3.3        |
| $\nu_s$ gap               | 0.061         | -       | 0.094         | -               | 0.025           |

$\chi_c, \chi_w$  are rotations by the *existing* AGS cold and warm snakes. Deuterons and  ${}^6\text{Li}$  have no useful snake rotation there:  $G$  is small, so the resonance spacing  $mc^2/G$  is tens of GeV and a solenoid partial snake is used instead.

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## Spare: HSR snake configuration

PRC Table IV. Six sets of helical dipoles for  $p$ ,  $h$  and  ${}^7\text{Li}$ ; a solenoid for  $d$  and  ${}^6\text{Li}$ .

| Parameter              | $p$            | $d$          | $h$            | ${}^6\text{Li}$ | ${}^7\text{Li}$ |
|------------------------|----------------|--------------|----------------|-----------------|-----------------|
| $I_{\text{out}}$ (A)   | 100            | -            | 62             | -               | 174 (238)       |
| $I_{\text{in}}$ (A)    | 322            | -            | 206            | -               | 231 (322)       |
| $\phi$                 | $\pm 45^\circ$ | -            | $\pm 45^\circ$ | -               | 0               |
| $BL_{\text{sol}}$ (Tm) | -              | 15           | -              | 15              | -               |
| $\chi$ ( $\% \pi$ )    | 100            | 0.45         | 100            | 0.42            | 17 (31)         |
| $\nu_s$                | 1.5            | 0.01 to 0.99 | 1.5            | 0.01 to 0.99    | 0.2 to 0.8      |

$p$  and  $h$  get full snakes,  $\chi = \pi$ .  ${}^7\text{Li}$  runs partial, with a spin-tune gap wide enough to be useful; values in parentheses are the alternative setting.  $d$  and  ${}^6\text{Li}$  avoid imperfection resonances with a solenoid partial snake, and both need a jump quadrupole system for vertical intrinsic resonances.

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## Spare: Personnel, by subsystem and stage

PRC Table V, condensed. Each project runs prototyping, then testing, then installation and commissioning.

| R&D project                        |                                            | Dur. (yr) | Total FTE  |
|------------------------------------|--------------------------------------------|-----------|------------|
| <b>1. Ion source development</b>   |                                            |           |            |
| 1.1                                | OPPIS reliability and performance          | 10        | 15         |
| 1.2                                | Polarized deuteron source                  | 12        | 25         |
| 1.3                                | Polarized $^3\text{He}^{++}$ source        | 10        | 17         |
| 1.4                                | Polarized $^6\text{Li}/^7\text{Li}$ source | 15        | 25         |
| <b>Subtotal</b>                    |                                            | <b>47</b> | <b>82</b>  |
| <b>2. Beam polarimetry systems</b> |                                            |           |            |
| 2.1                                | HJET polarimeter upgrade                   | 6         | 15         |
| 2.2                                | pC polarimeter upgrade                     | 6         | 11         |
| 2.3                                | $^3\text{He}$ atomic beam polarimeter      | 10        | 22         |
| 2.4                                | $^6\text{Li}/^7\text{Li}$ polarimeter      | 12        | 26         |
| <b>Subtotal</b>                    |                                            | <b>34</b> | <b>74</b>  |
| <b>3. Spin tools and detectors</b> |                                            |           |            |
| 3.1                                | Spin tune determination                    | 6         | 13         |
| 3.2                                | RF Wien filter spin flipper                | 6         | 11         |
| 3.3                                | Detector systems upgrade                   | 6         | 11         |
| <b>Subtotal</b>                    |                                            | <b>18</b> | <b>35</b>  |
| <b>Grand total</b>                 |                                            | <b>99</b> | <b>191</b> |

| Area         | PhD       | Eng.      | Sci.      |
|--------------|-----------|-----------|-----------|
| Ion sources  | 33        | 23        | 26        |
| Polarimetry  | 32        | 15        | 27        |
| Spin tools   | 14        | 8         | 13        |
| <b>Total</b> | <b>79</b> | <b>46</b> | <b>66</b> |

Graduate students carry **79 of 191 FTE**, the single largest block. That is the recruiting argument: roughly eight new students per year, sustained for a decade.