MOPAB015

Feasibility of Polarized Deuteron Beam in the EIC

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Polarized Deuterons in EIC

- There are interests from EIC user group to study neutron spin property in EIC.
- Since neutron can not be accelerated, the next two candidates are He3 and deuteron.

Small deuteron G:

- Much higher magnetic field required for spin rotation

(Siberian Snakes not feasible)

- But:
  - Weaker resonances
  - Small number of resonances

(makes it possible to deal with individual resonances)

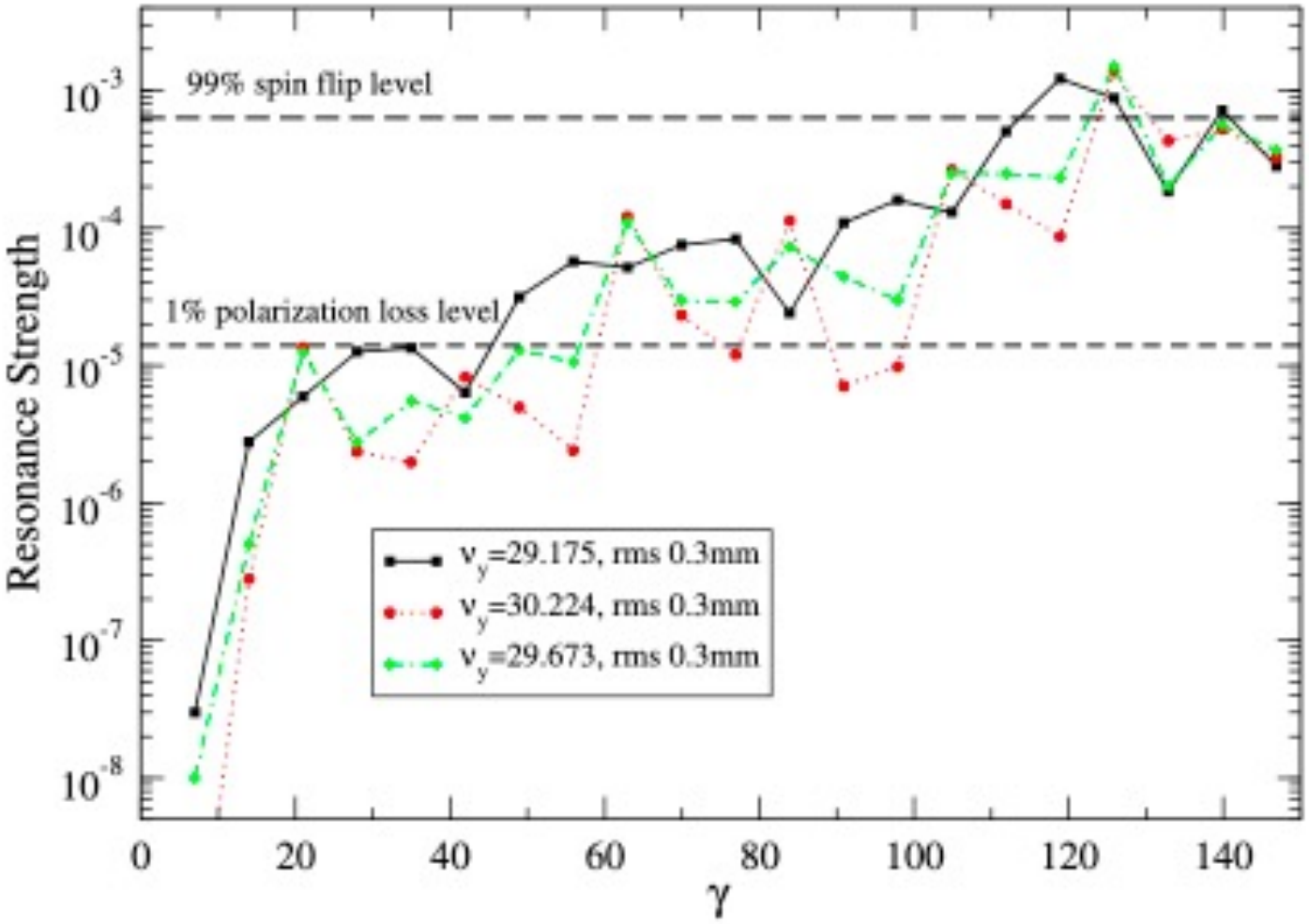
In EIC hadron ring

	p	$^3He^{+2}$	d
m, GeV	0.938	2.808	1.876
G	1.79	-4.18	-0.143
E/u, GeV	24-275	10-183	12-137
$\lvert G\gamma \rvert$	45.5-525.5	48.5-818	1.6-20.9

Polarized Deuterons in the Injectors

- Gγ range in the Booster: -0.14 to -0.22. No imperfection resonance. If fractional tune is not between 0.14 and 0.22 (or 0.78-0.86), no need to concern about intrinsic one either.
- Gγ range in the AGS: -0.22 to -1.6. One very weak imperfection resonance. Three intrinsic resonances but none of them is enhanced with superperiod of 12. For the given AGS ramp rate, none of these causes polarization loss.
- AtR line: With such a small G value and no snake in the AGS, the spin match in the AtR line is not an issue. Tracking shows that there would be no visible spin mismatch.

Imperfection Resonance Strength and Partial Snakes



Analysis shows that a partial snake of .45% is enough to overcome these resonances. Indeed, the solenoid field of the detector is 15Tm which is 0.45% at top energy.

Imperfection Resonance for Deuterons

- Gγ range: -1.6 to -20.9. Total of 19 imperfection resonances. With rms orbit error of 0.3mm, the strongest resonance strength is less than 0.0015. From the nominal ramp rate in RHIC d-Au run in 2016, the ramp rate is about dγ/dt= 90/220s =>resonance crossing rate α=1.2E-7.
- A partial snake can be used to overcome these resonances. The required partial snake snake strength is 0.45%. The existing snake is not strong enough. Adding a solenoid is a solution. 15Tm warm solenoid (0.45% partial snake) should work.

Single Detector Solenoid Case

- In this case, the spin is naturally longitudinal at Gγ=int. at the IR. When θ=0, sin (Gγπ)=0, polarization will be along the longitudinal direction at every Gγ=integer.

Stable spin direction for a partial snake with longitudinal rotating axis is:

Vertical

$$\cos\alpha_3 = \frac{1}{\sin\pi\nu_s}\sin(\pi G\gamma)\cos(\frac{\mathcal{S}}{2}),$$

Horizontal

$$\cos\alpha_1 = -\frac{1}{\sin\pi\nu_s}\sin G\gamma(\pi-\theta)\sin(\frac{\mathcal{S}}{2}),$$

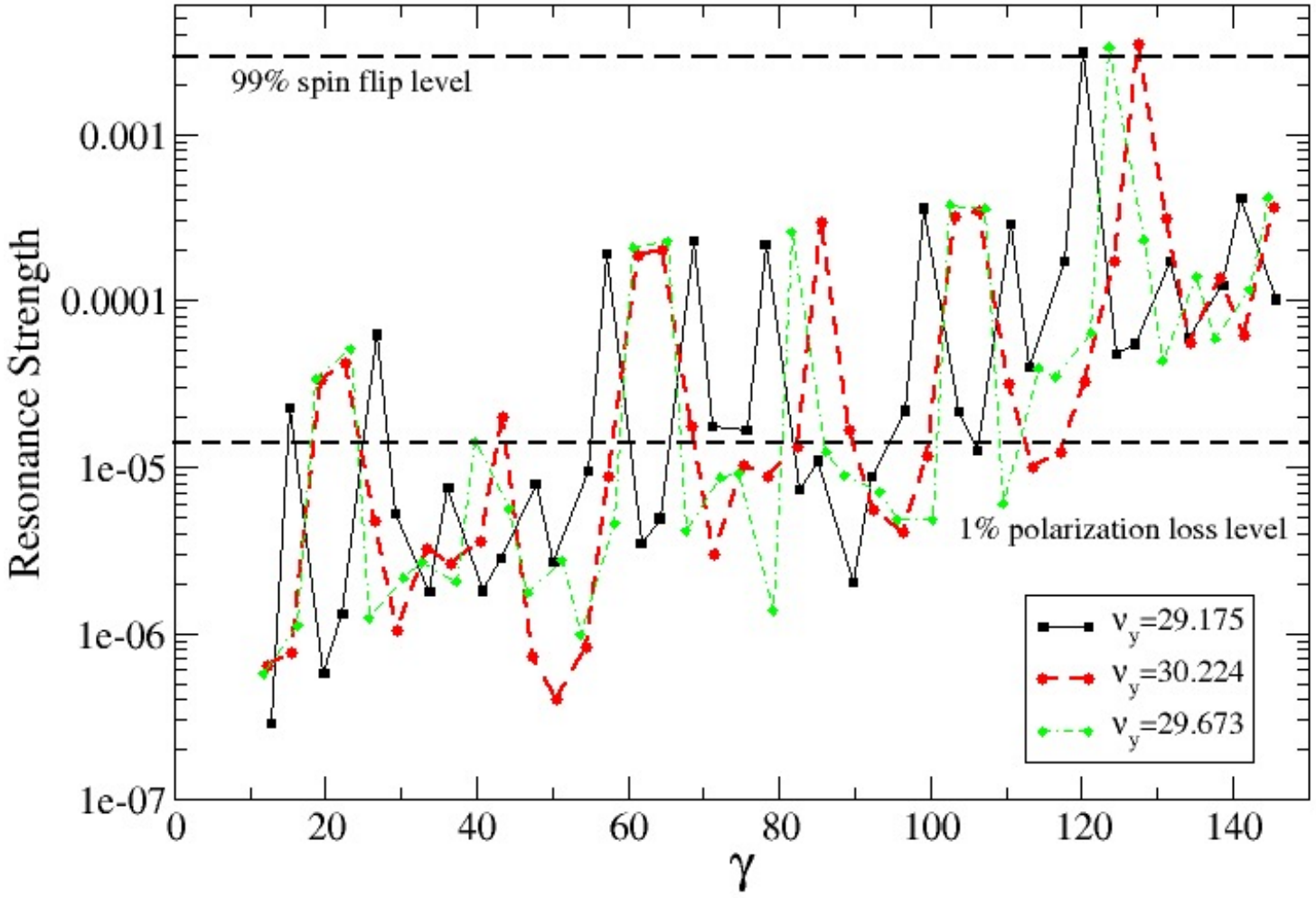
Longitudinal

$$\cos\alpha_2 = \frac{1}{\sin\pi\nu_s}\cos G\gamma(\pi-\theta)\sin(\frac{\mathcal{S}}{2}).$$

Intrinsic Resonances

- The 3-symmetry means the stronger resonance strength occurs at $G\gamma=3n+-\nu_y$. However, due to the slow ramp rate, other resonances also can cause polarization loss.
- The strongest resonance is at $|G\gamma|=|12-\nu_y|$, the strength is around 3.5e-3 for 2π beam. This resonance can fully flip spin. Others require a tune jump of 0.03 in 50 turns (increase the crossing speed by 800 times) for over 99% spin flip.
- Consider the 3-fold symmetry, we will use three jump quads each can jump vertical tune by 0.01 in fifty turns.

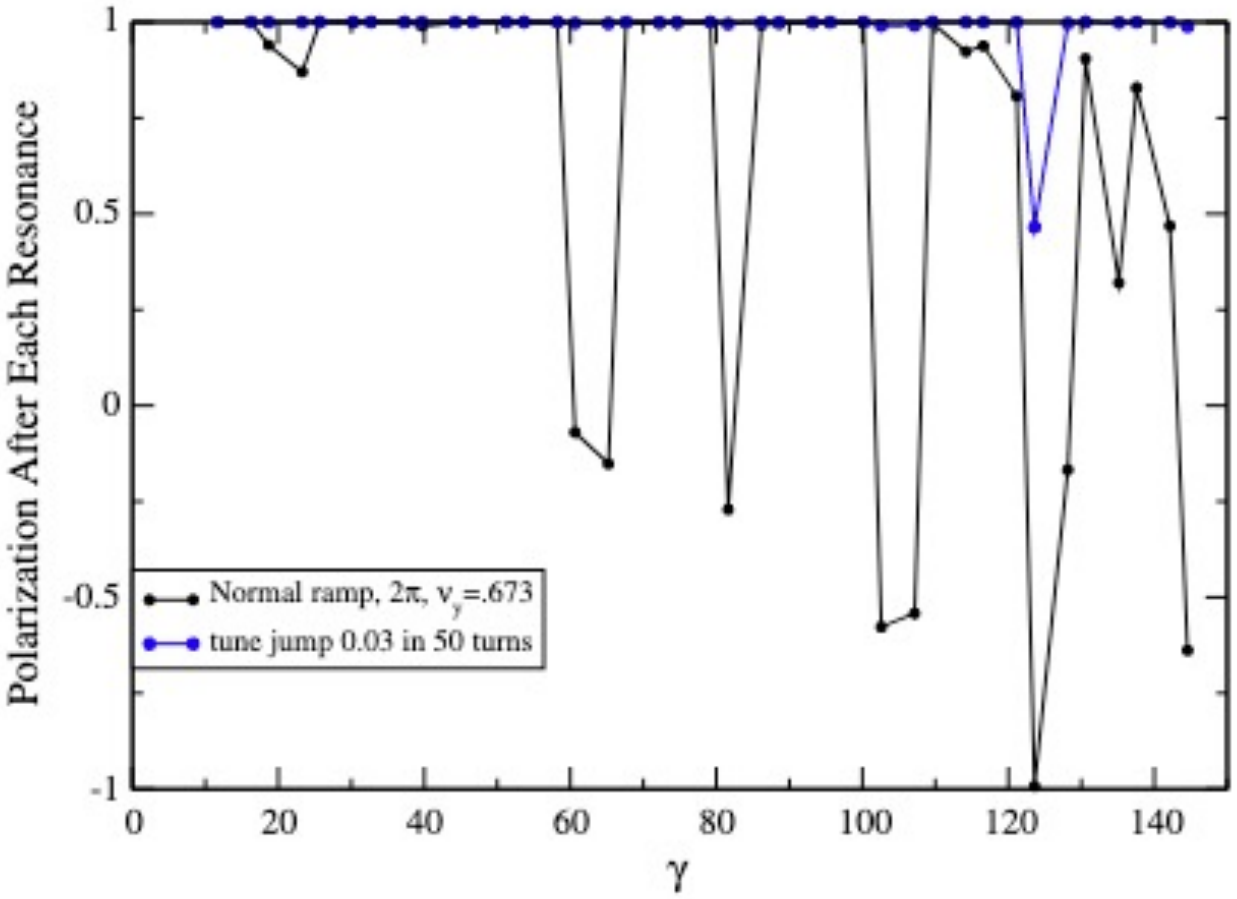
Intrinsic Resonance Strength for Three lattices



The two dash-lines are calculated with Gaussian distribution of 2π rms emittance.

The strongest resonance at $|\nu_y-12|$ will flip spin fully by itself.

Polarization after Each Intrinsic Resonance



The polarization after each intrinsic resonance with Gaussian distribution of 2π rms emittance. The modest tune jump is good except at $|\nu_y-12|$, which can be overcome by normal ramp without firing tune jump quads. The overall efficiency for the tune jump method plus normal ramp across $|\nu_y-12|$ is 95%.

Summary

- Polarized deuteron possibility in EIC has been explored.
- The imperfection resonances can be overcome by the planned detector solenoid for EIC (15Tm).
- At Gγ =integer, longitudinal polarization can be reached at the detector.
- The intrinsic resonances can be overcome with modest vertical tune jump of 0.03 over 50 orbit turns.