Introduction to Heavy Ion Collisions – Experimental

Part4 Vorticity and Polarization

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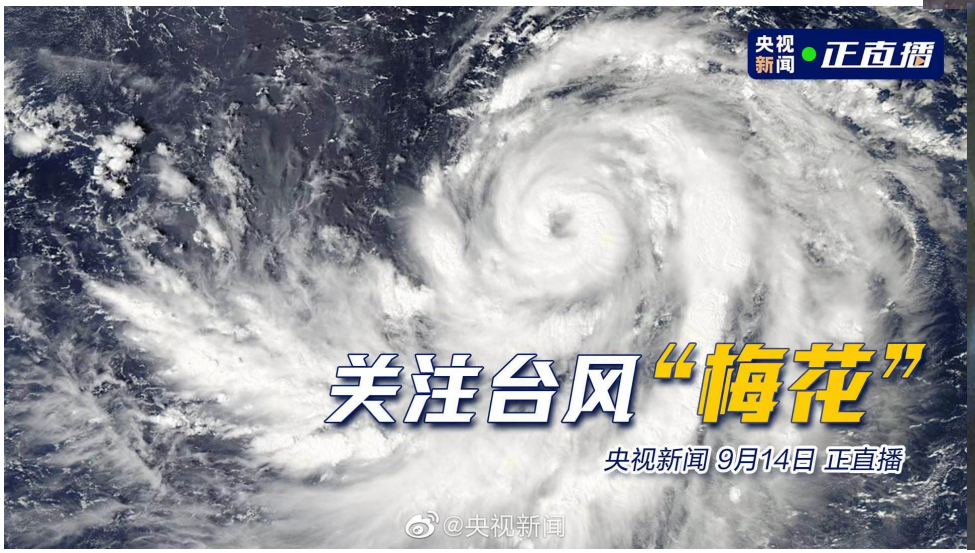
Vorticity


3D
旋涡虹吸式冲水
回旋漩涡水流，360°冲刷坐便器内壁
攻克节水效能与冲水效果兼具的难题
少水量，大冲净，污垢无从粘附


From HST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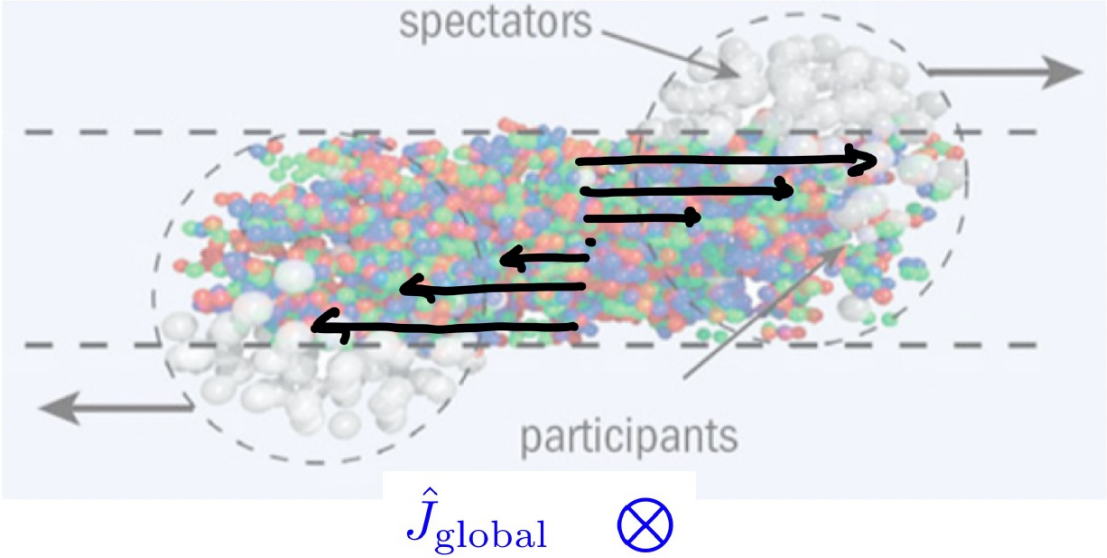
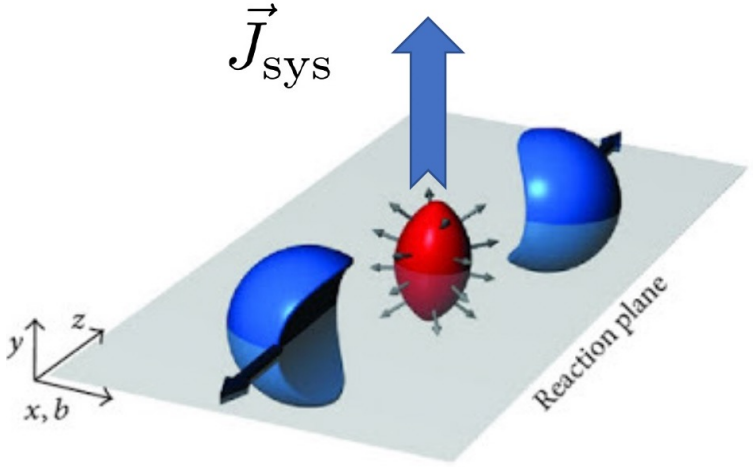
就能使出最強的螺旋丸了

Rotation of HI collision





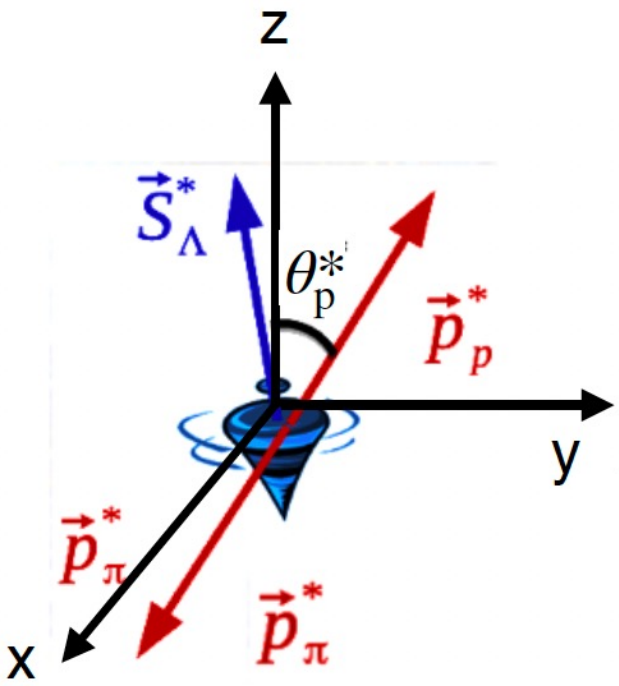
Large initial orbital angular momentum

Can polarize particles through spin-orbit coupling

Z.-T. Liang and X.-N. Wang, PRL94, 102301 (2005)

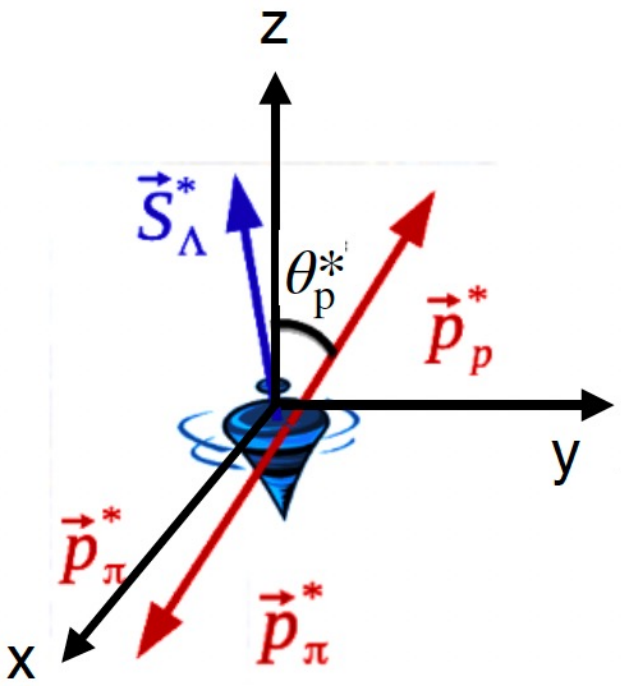
S. A. Voloshin, nucl-th/0410089

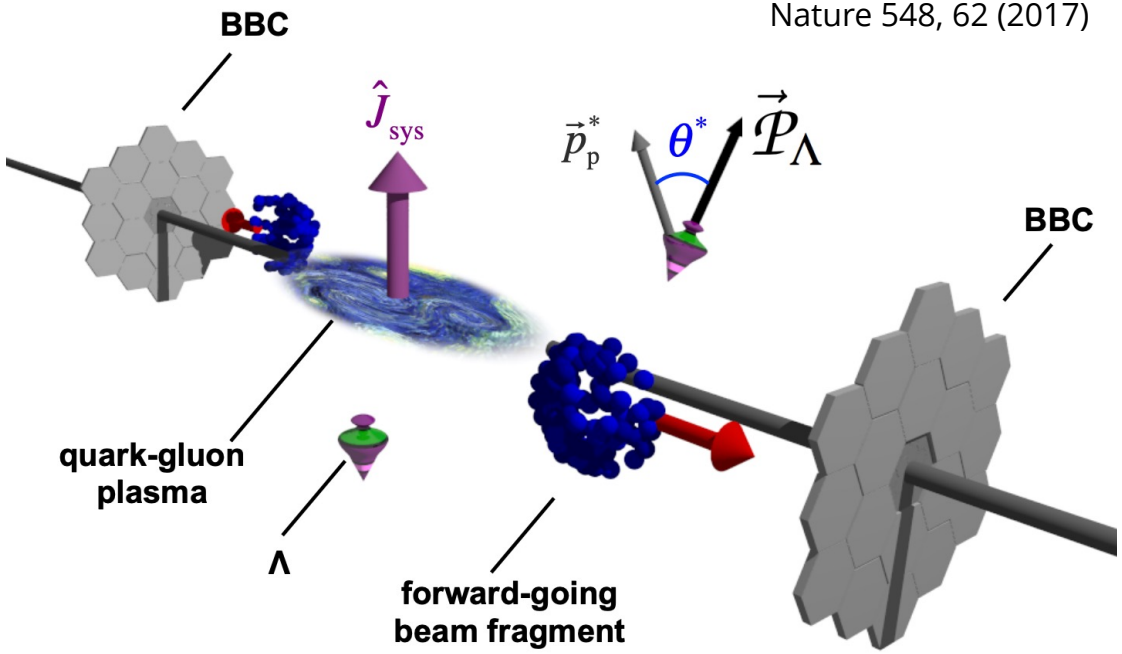
Hyperon global polarization



Hyperons parity violating weak decay:
Daughter baryon preferentially emitted in the direction of spin

Hyperon global polarization





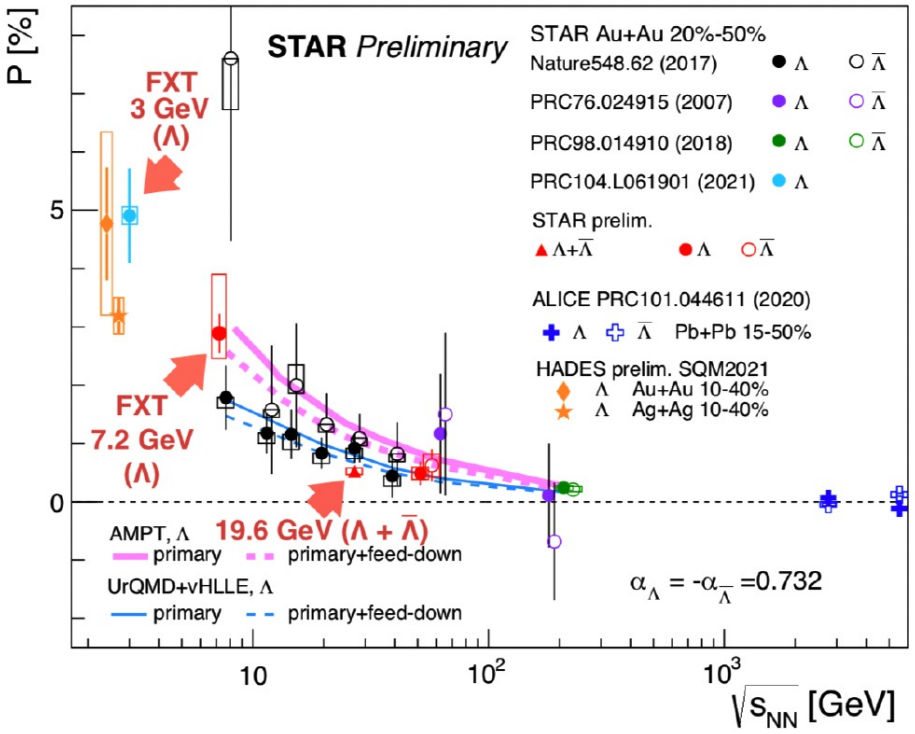
Nature 548, 62 (2017)

Hyperons parity violating weak decay:
Daughter baryon preferentially emitted in the direction of spin

Deflection of the spectators determines the direction of L

$$P_H = \frac{3}{\alpha_H}\langle(\hat{p}^*_p \cdot \hat{L})\rangle \qquad \boxed{P_H = -\frac{8}{\pi\alpha_H}\frac{\langle\sin(\varphi^*_p - \Psi_{SP})\rangle}{R^1_{SP}}}$$

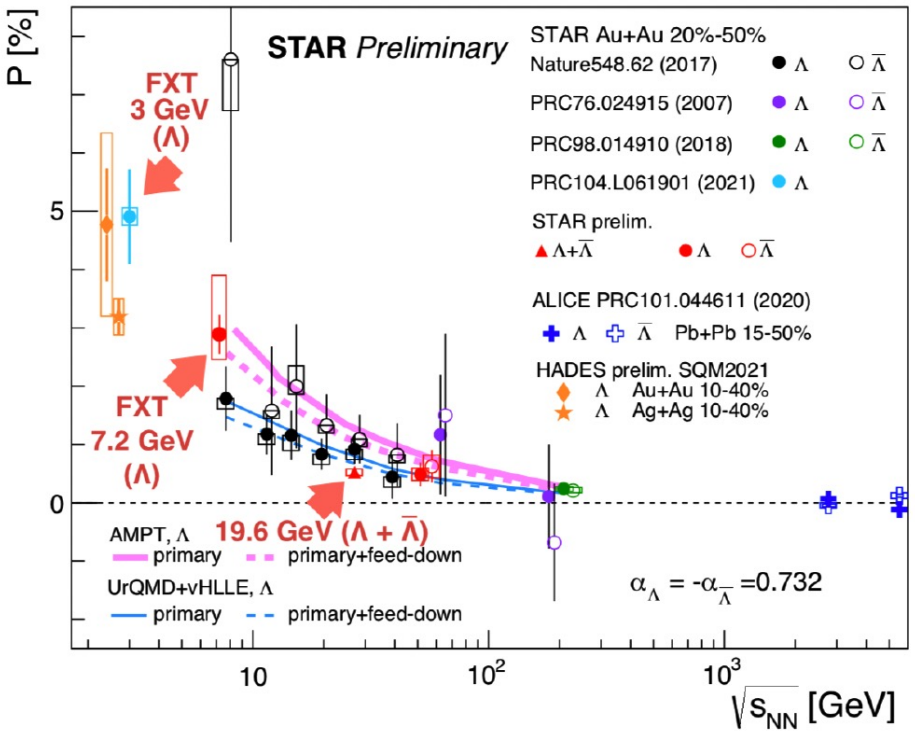
Hyperon global polarization

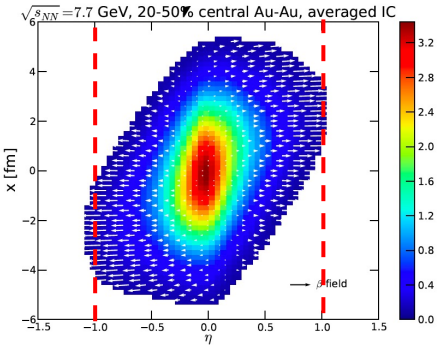


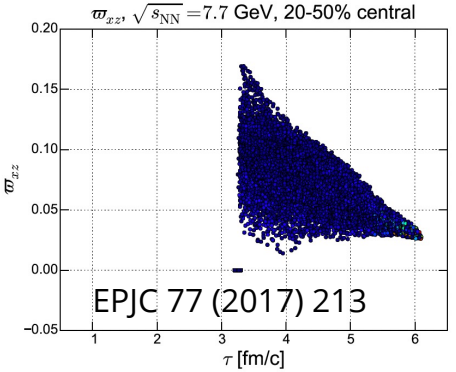
$$\omega \approx (9 \pm 1) \times 10^{21}\ \mathrm{s}^{-1}$$

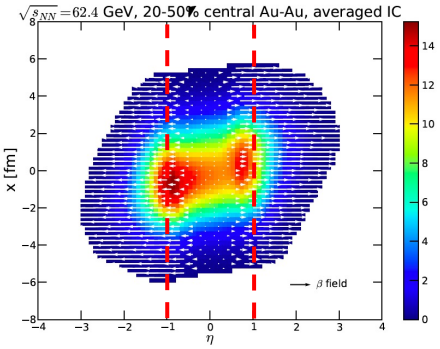
Polarization at mid-rapidity decreases with collision energy
In good agreement with hydro and transport models

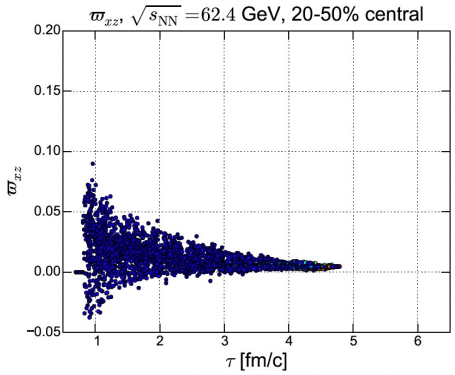
Hyperon global polarization





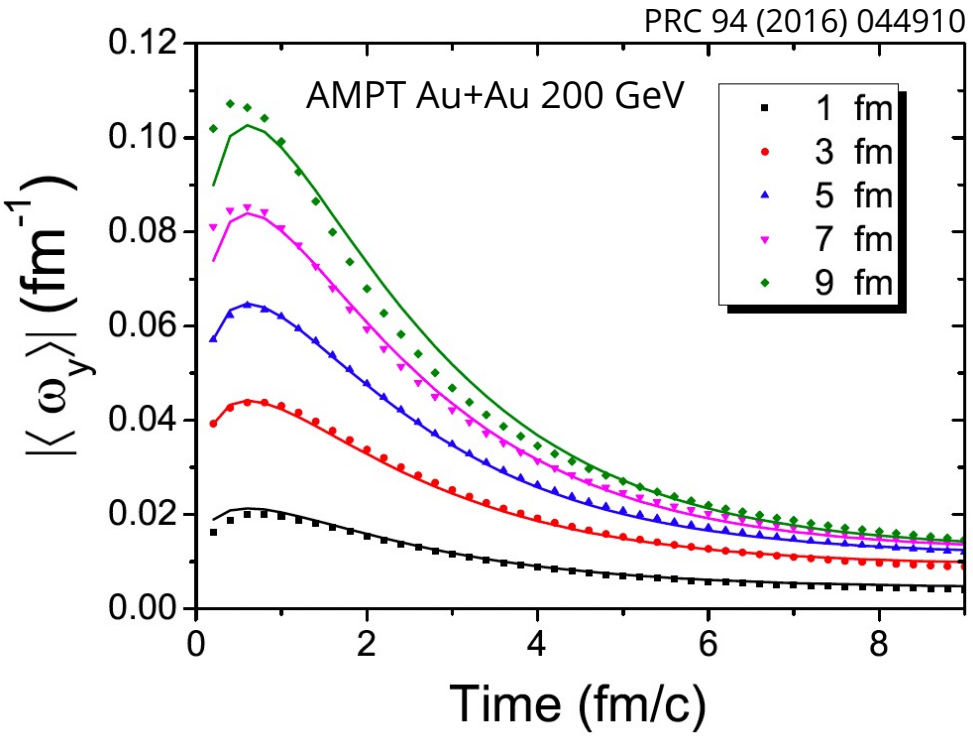


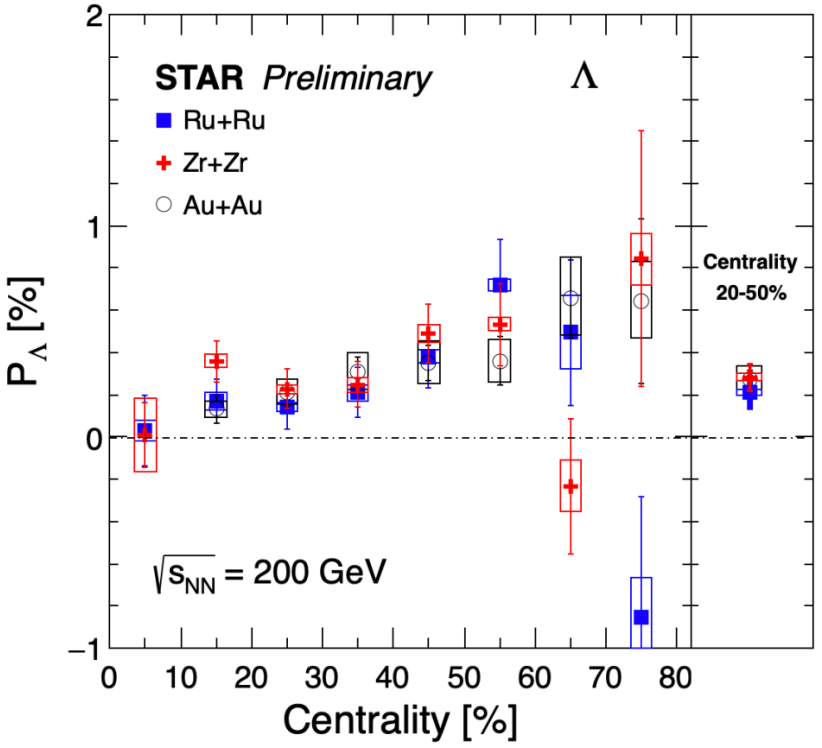




Polarization at mid-rapidity decreases with collision energy
In good agreement with hydro and transport models

Hyperon global polarization

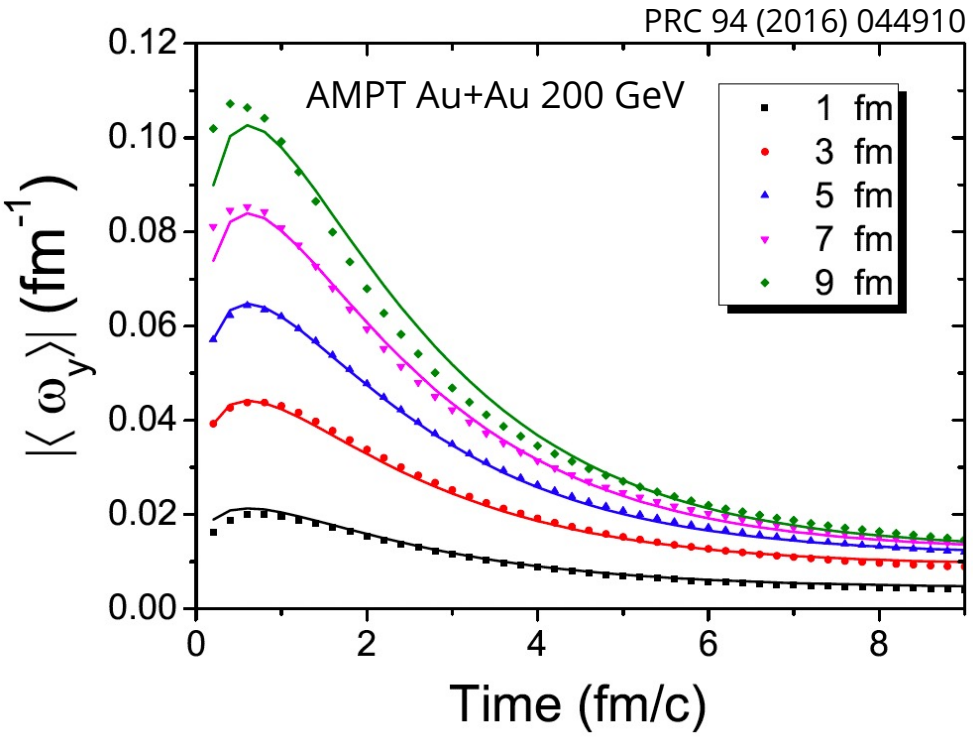


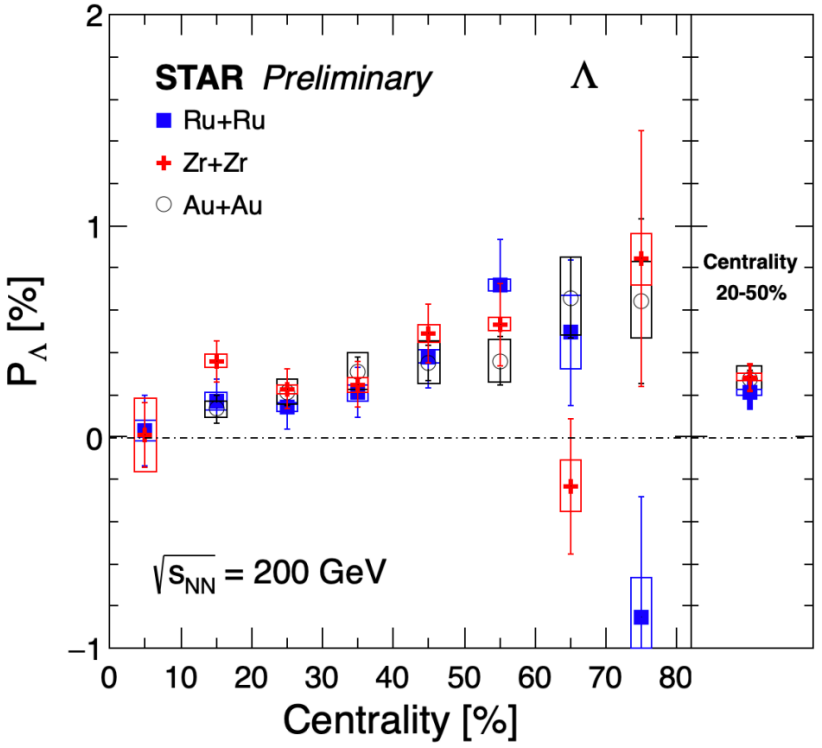


Polarization at mid-rapidity decreases with collision energy
In good agreement with hydro and transport models

Centrality dependence follows impact parameter dependent vorticity

Hyperon global polarization





Polarization at mid-rapidity decreases with collision energy
In good agreement with hydro and transport models

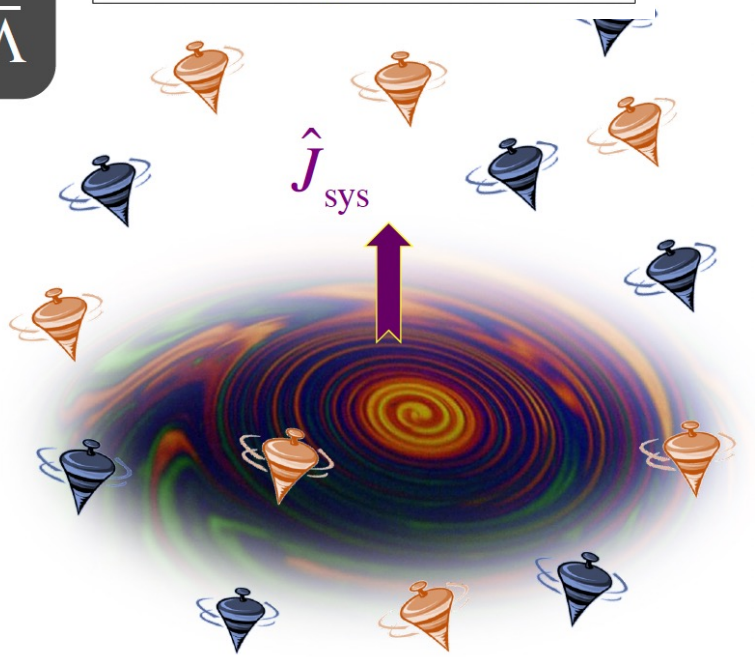
Centrality dependence follows impact parameter dependent vorticity

No obvious collision size dependence

Hyperon global polarization with B field

Vortical coupling: $P \propto \omega$

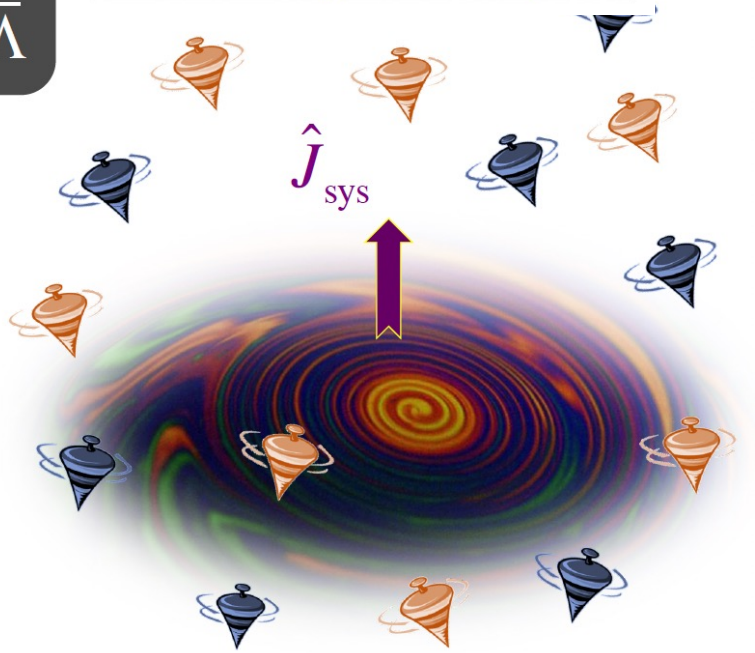
$\vec{\bar{P}}_{\Lambda} \parallel +\hat{J}_{sys}$ $\vec{\bar{P}}_{\bar{\Lambda}} \parallel +\hat{J}_{sys}$



Hyperon global polarization with B field

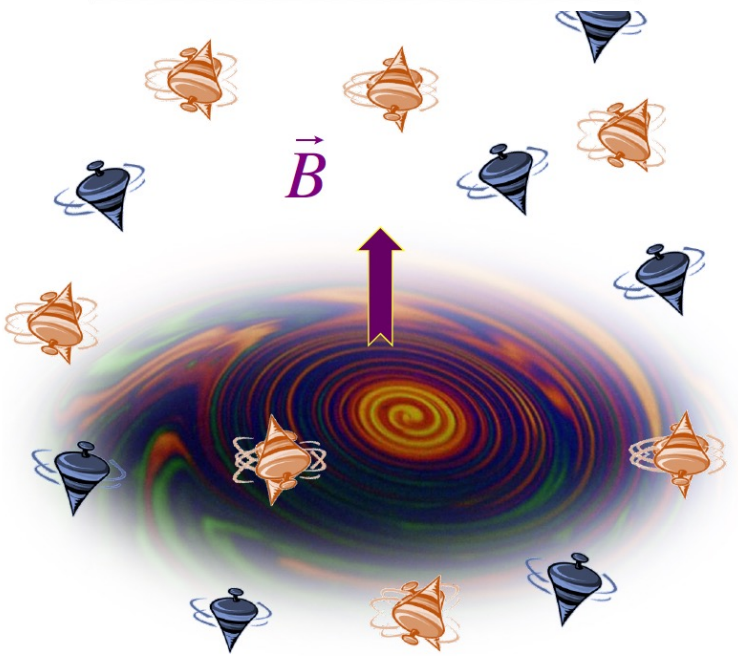
Vortical coupling: $P \propto \omega$

$\vec{\bar{P}}_{\Lambda} \parallel +\hat{J}_{sys} \quad \vec{\bar{P}}_{\bar{\Lambda}} \parallel +\hat{J}_{sys}$



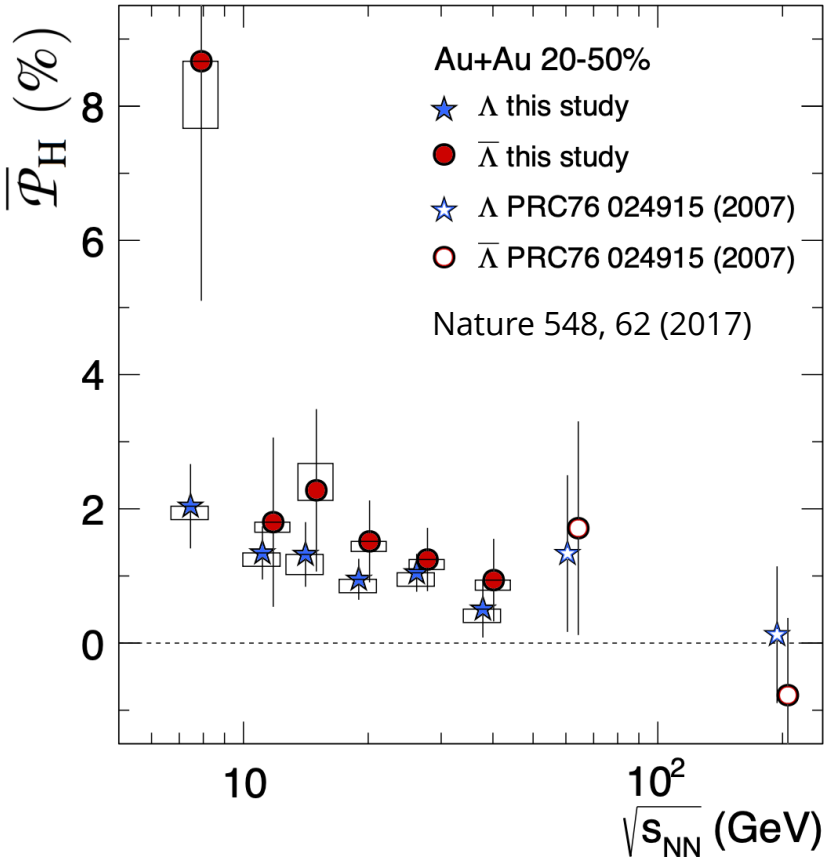
Magnetic coupling: $P \propto \vec{\mu} \cdot \vec{B}$

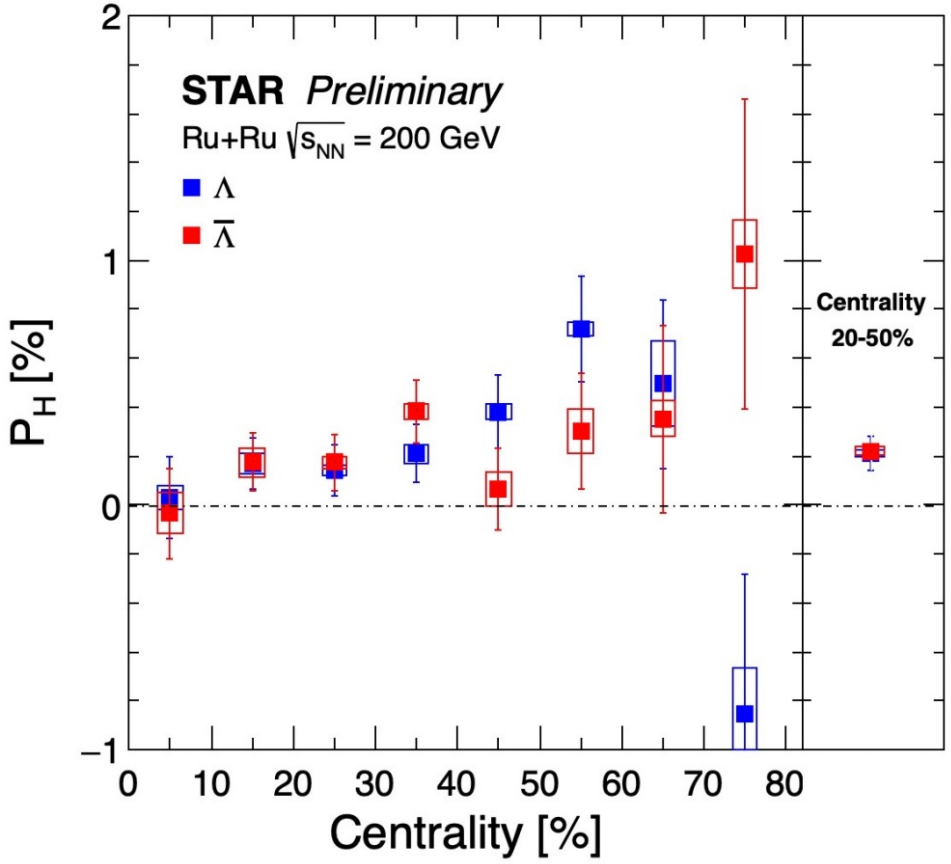
$\vec{\bar{P}}_{\Lambda} \parallel -$ B $\quad \vec{\bar{P}}_{\bar{\Lambda}} \parallel +$ B



Magnetic field leads to splitting between hyperon/anti-hyperon

Hyperon global polarization with B field





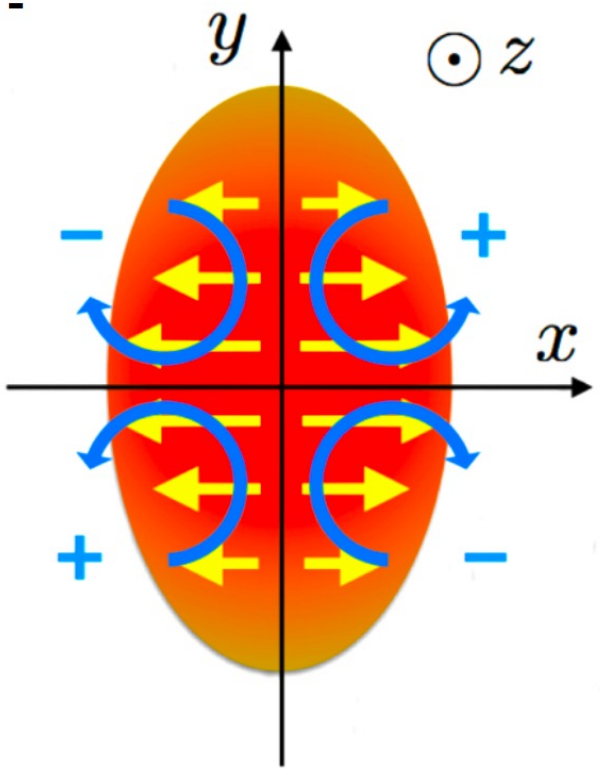
Magnetic field leads to splitting between hyperon/anti-hyperon

So far no experimental evidence

More precise measurements on the way

Hyperon local polarization

Elliptic flow -

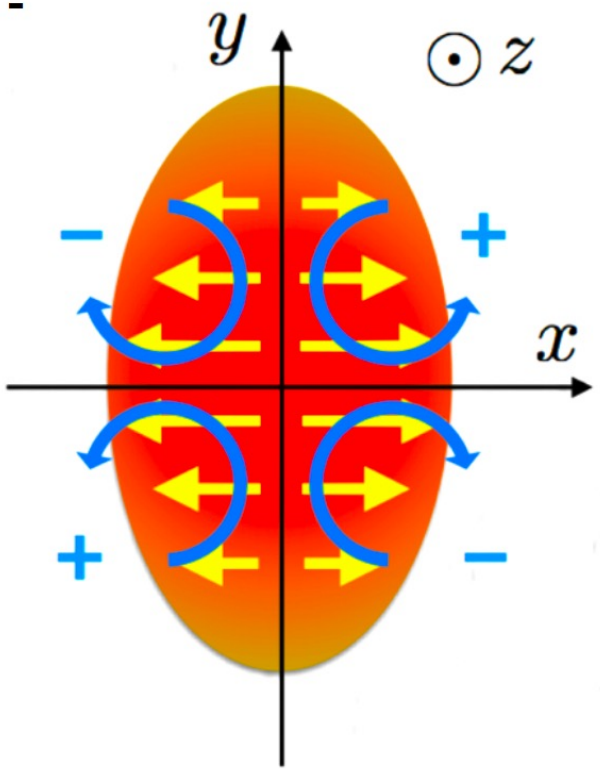


S. Voloshin, EPJ Web Conf.171, 07002 (2018)

Pressure gradient leads to polarization along beam direction

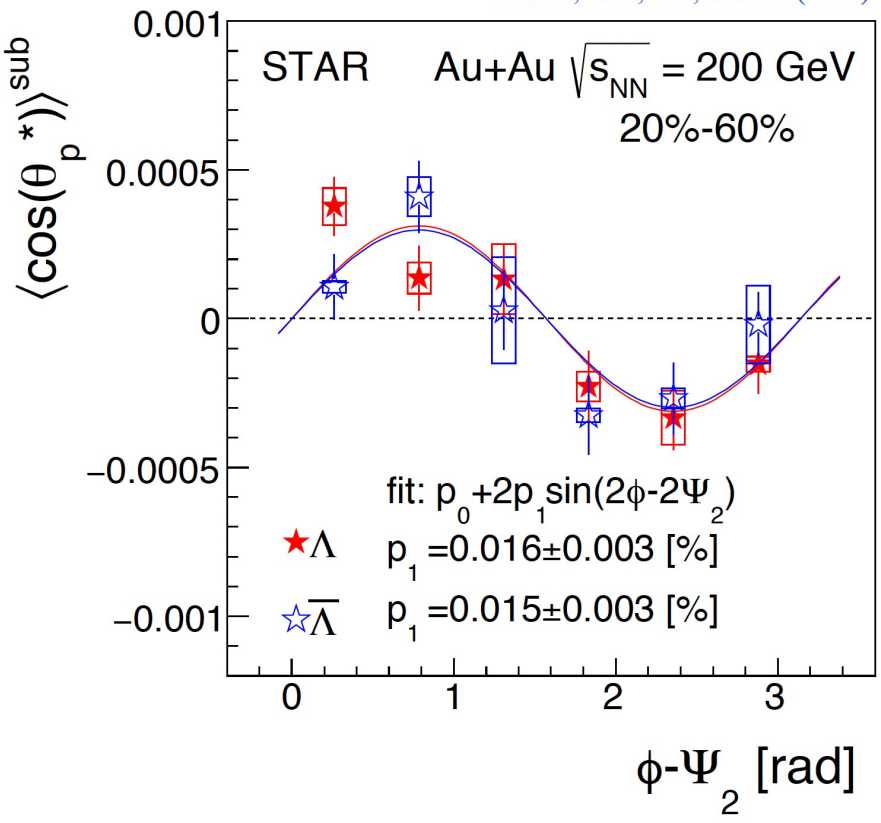
Hyperon local polarization

Elliptic flow -



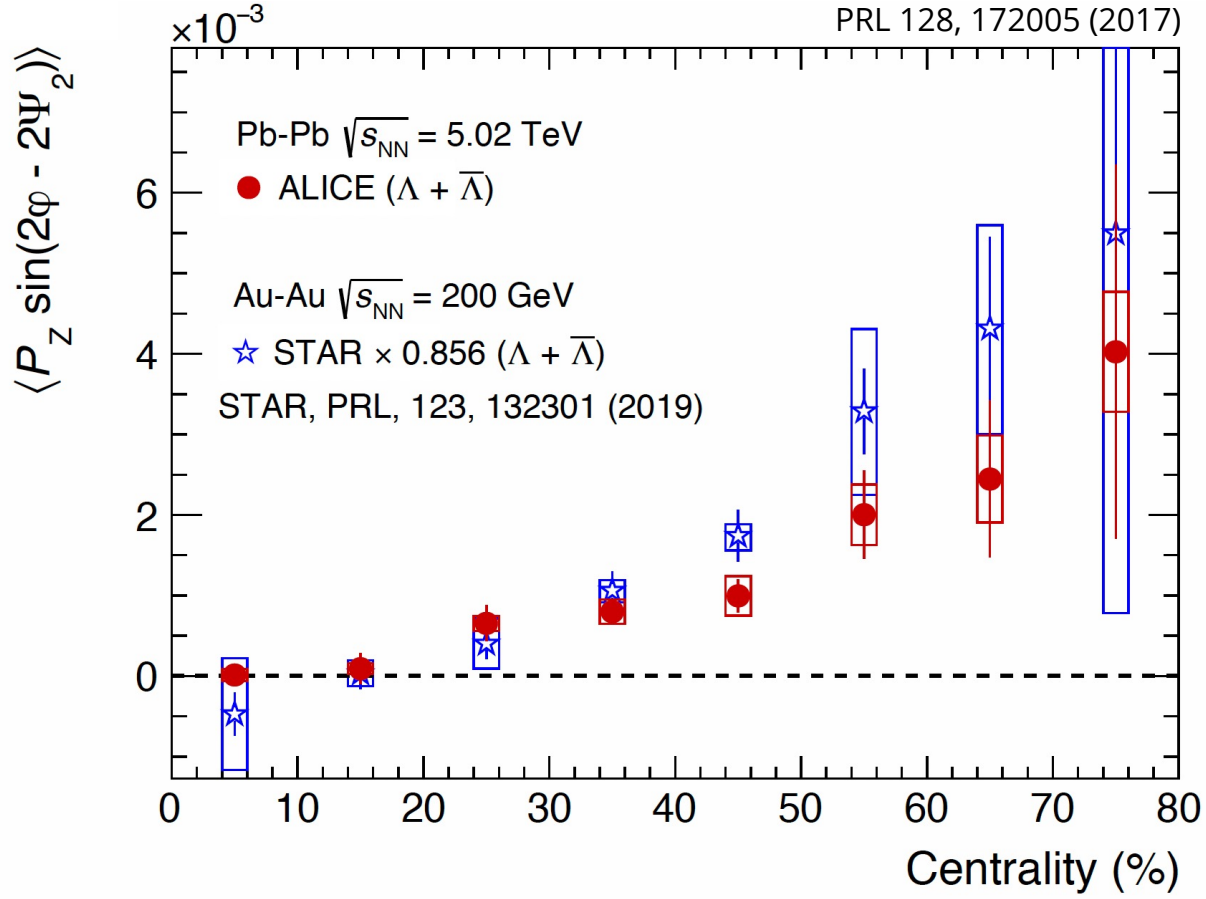
S. Voloshin, EPJ Web Conf.171, 07002 (2018)

STAR, PRL, 123, 132301 (2019)



Pressure gradient leads to polarization along beam direction

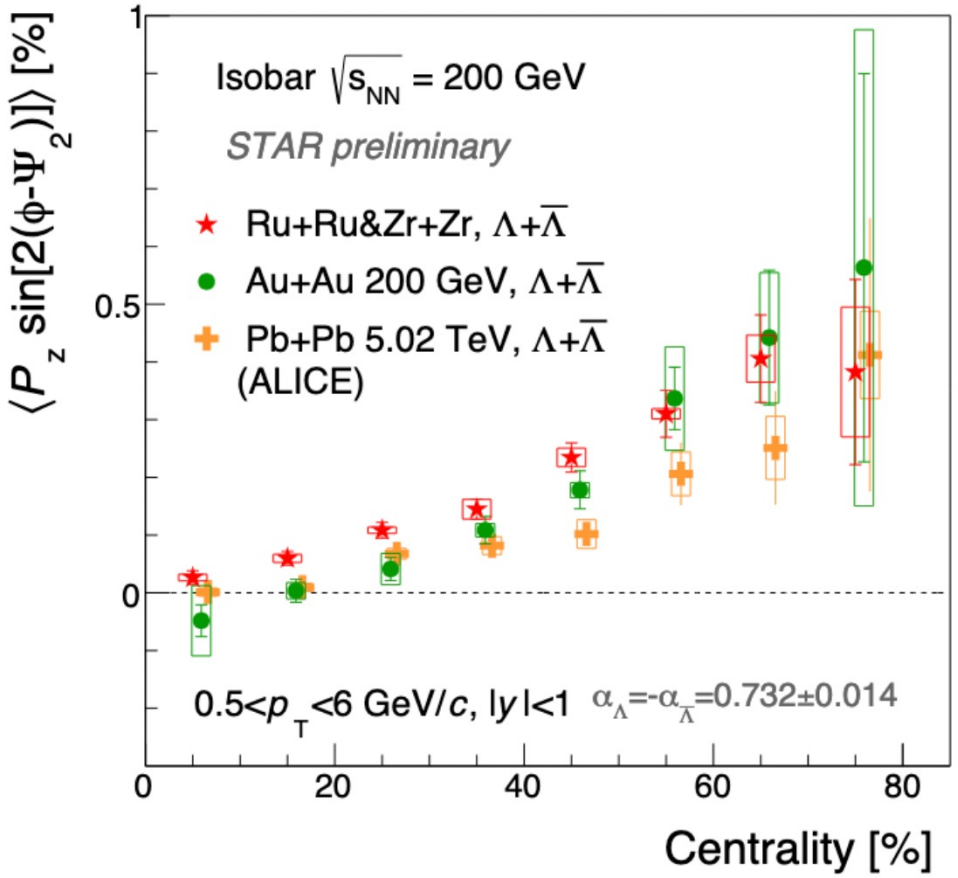
Hyperon local polarization



Pressure gradient leads to polarization along beam direction

No obvious energy dependence

Hyperon local polarization

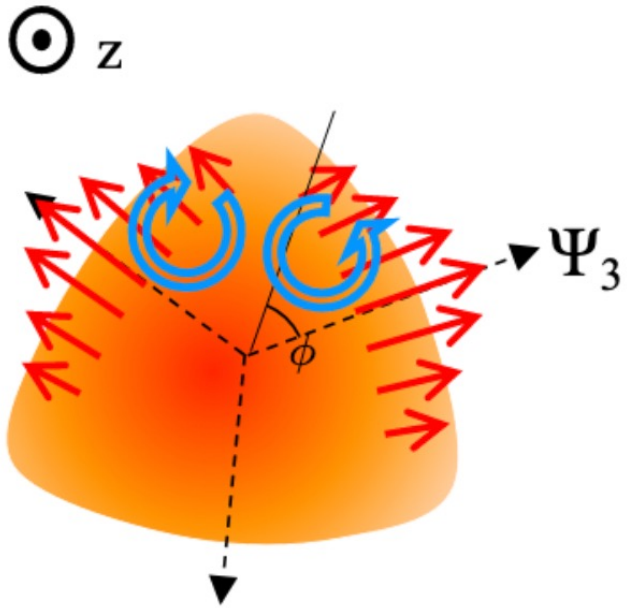


Pressure gradient leads to polarization along beam direction

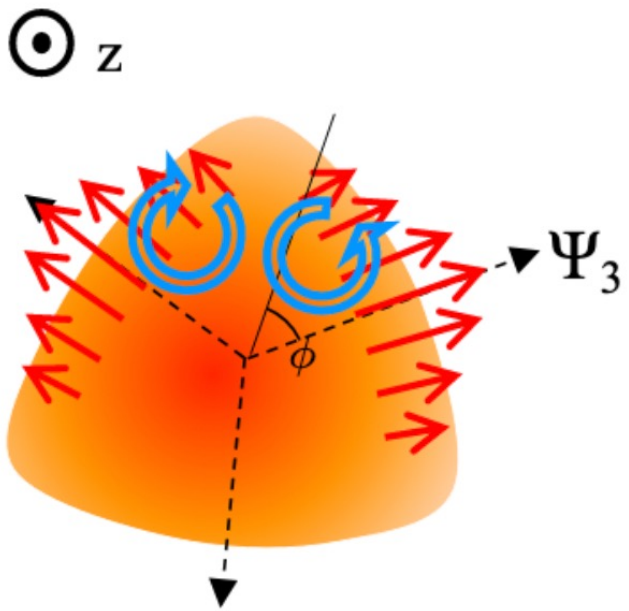
No obvious energy dependence

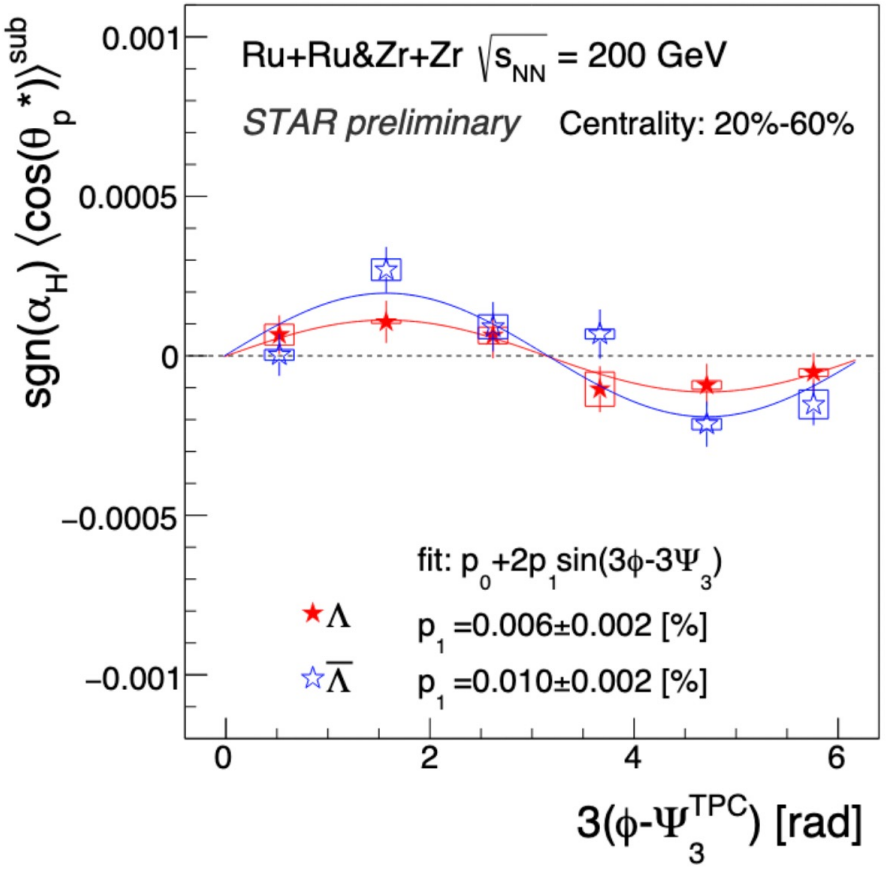
Hint of system size dependence

Hyperon local polarization



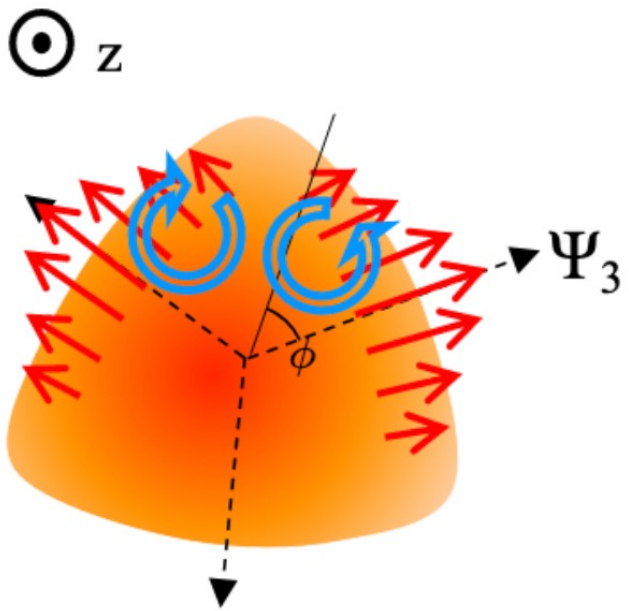
Hyperon local polarization

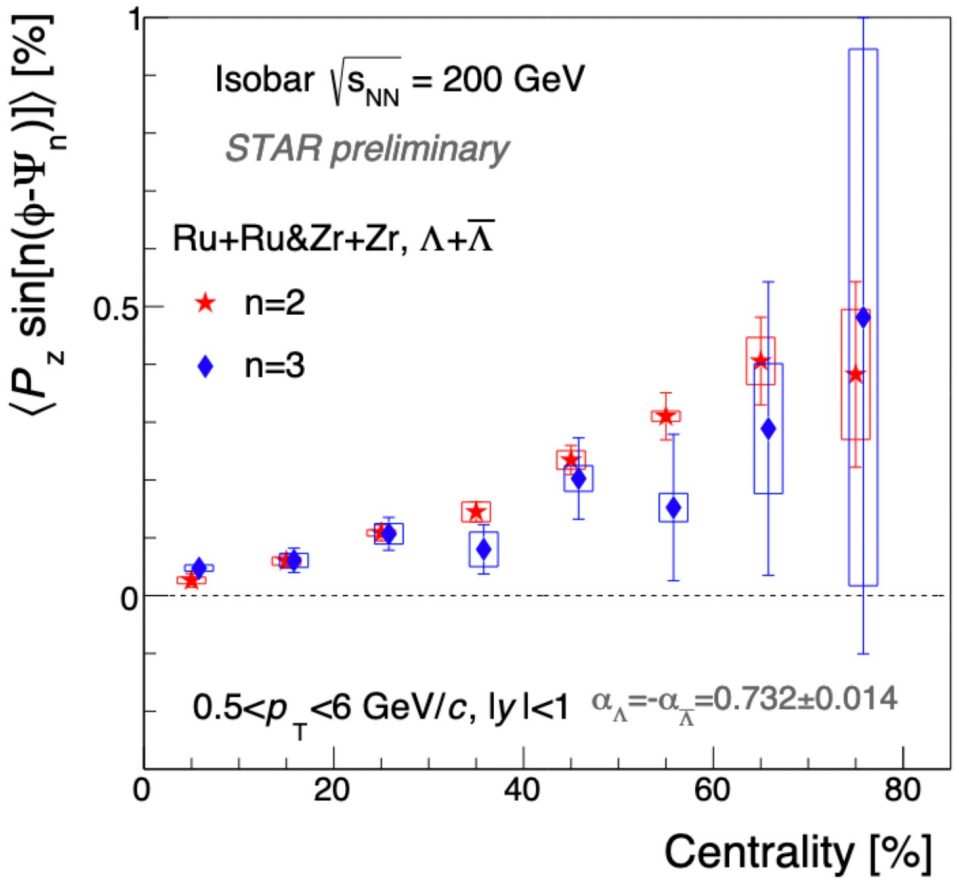




First observation of 3rd order Pz

Hyperon local polarization





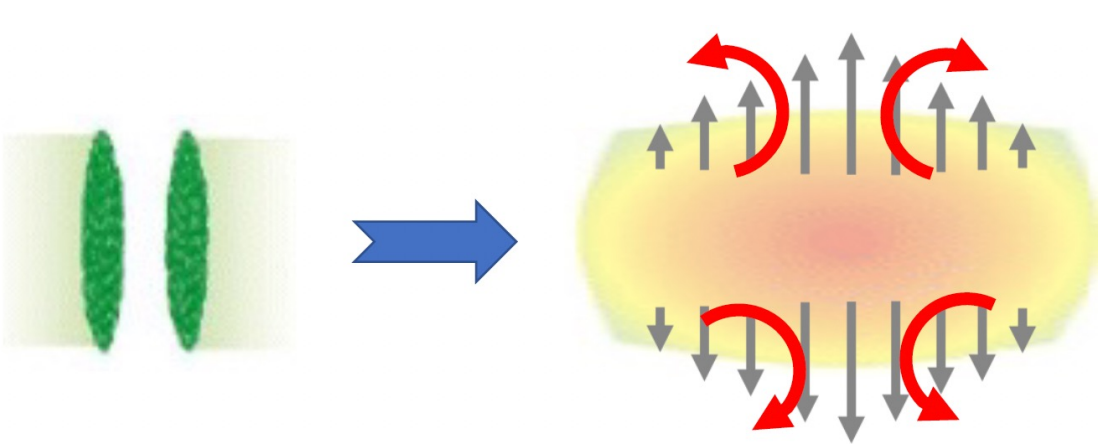
First observation of 3rd order Pz

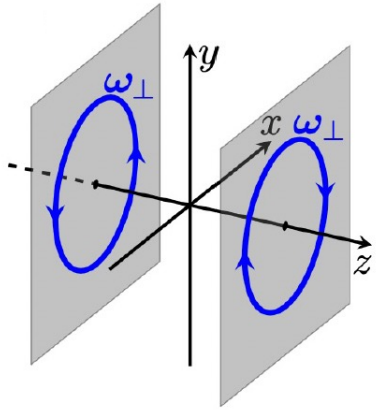
Comparable to 2nd order Pz

Why? (v2 and v3 are different)

Hyperon polarization - rings

Ring from longitudinal gradient of transverse flow





Xia, Li, Tang, Wang PRC 98, 024905 (2018)

Ring from jet and asymmetric collision