Λ polarization in peripheral heavy ion collisions

L. P. Csernai[1], F. Becattini[2] and D.J. Wang[1,3]

394

[1] University of Bergen, Dept. of Physics and Technology, Allegaten 55, 5007, Bergen Norway
[2] University of Florence and INFN Florence, Florence, Italy
[3] Central China Normal University, 430079 Wuhan, China

Abstract

➢Due to the low viscosity and strongly interacting QGP at high LHC energies flow fluctuations were observed up to the 8th flow harmonics. Similarly rotation, turbulence and even Kelvin-Helmholtz Instability were predicted and these may be observable by different methods. Apart of the usual flow harmonics analysis, other methods like two particle correlations, or particle polarizations may arise as a consequence of these processes. Turbulent phenomena would be additional direct proofs of the low viscosity.

➢We observed in ***PICR*, 3+1D fluid dynamical calculations** at LHC and RHIC energies that Lambda polarization arising from thermal and mechanical equilibrium, can provide measurable signal in given azimuthal directions. The signal is predicted to be somewhat stronger at RHIC energies because the higher temperature at LHC decreases thermal vorticity (polarization) even if the angular momentum is larger at LHC. This mechanism is considerably stronger than the polarization arising from the direct electro-magnetic effect of the strong and rapidly changing fields during the collision.

The polarization

$$\mathbf{\Pi}(p) = \frac{\hbar\varepsilon}{8m}\frac{\int dV\, n_F\, (\nabla \times \boldsymbol{\beta})}{\int dV\, n_F}\,.$$

where $\beta^{\mu}(x) = [1/T(x)]u^{\mu}(x)$ and the ***thermal vorticity*** is ω= **rot** β, then the Π_0 polarization vector in the Λ's rest frame is:

$$\mathbf{\Pi}_0(p) = \mathbf{\Pi}(p) - \frac{\mathbf{p}}{\varepsilon(\varepsilon + m)}\mathbf{\Pi}(p)\cdot\mathbf{p},$$

F. Becattini, V. Chandra, L. Del Zanna, and E. Grossi, Ann. Phys. **338**, 32 (2013).

Model results

➢ Configuration:

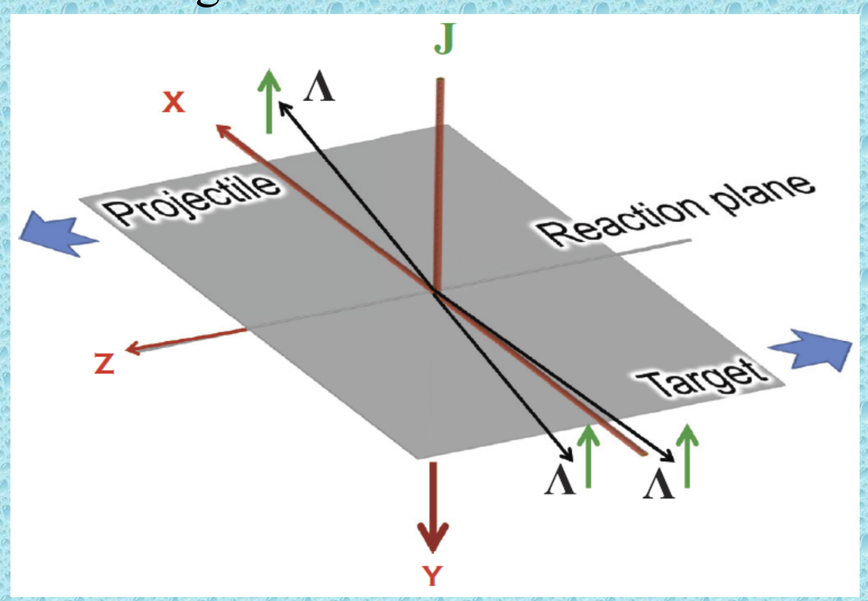

Fig. 1. Sketch of peripheral heavy ion collisions at high energy. The Λ polarization points essentially into the direction of the total angular momentum *(-y)* of the interaction region, orthogonal to the reaction plane. Λ's with the largest polarization are emitted into the (*xz*) reaction plane.

➢ Standard vorticity: See [Wang & Csernai Poster # 424]

➢ From the PICR, (3+1)D hydro:

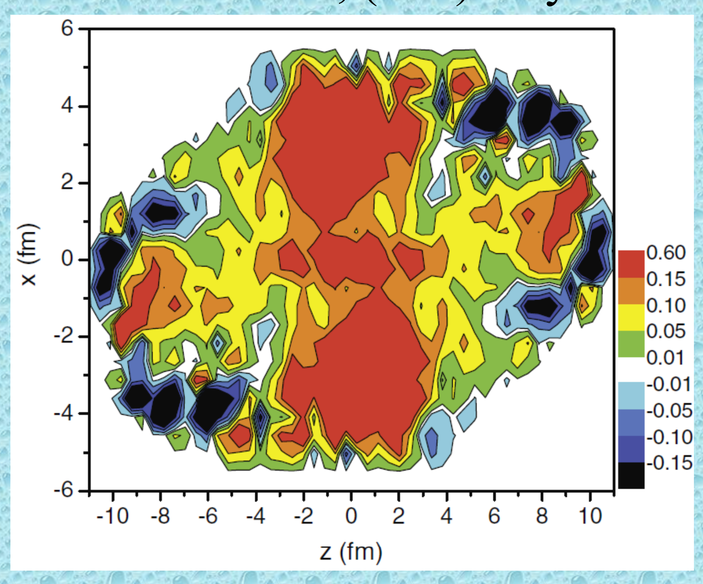

Fig. 2. The energy density weighted thermal vorticity Ω_{zx} *(x,z)* of the inverse temperature four-vector field βμ calculated for all *[x - z]* layers at t = 4.75 fm/c, corresponding to an energy density weighted temperature of 180 MeV. The collision energy is $\sqrt{s_{NN}}$ = 200 GeV, $b = 0.7\ b_{max}$. The cell size is $dx = dy = dz = 0.4375$ fm, while the average weighted vorticity is $\Omega_{zx} = 0.0453$. In most of the reaction plane, especially in the central regions the vorticity is positive, the forward and backward peripheral regions show smaller negative vorticities.

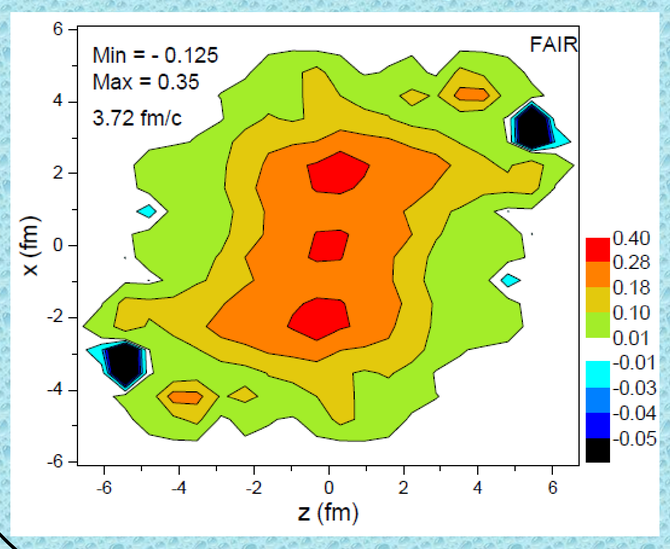

Fig. 4. Interestingly the vorticity is still significant at lower, FAIR energies: Calculated in the reaction plane at *t*=3.72 fm/c. The energy of the U+U collision is $\sqrt{s_{NN}}$ = 4.0 GeV, $b = 0.5\ b_{max}$, and the cell size is *dx* = *dy* = *dz* = 0.610 fm. The average vorticity Ω_{zx} is 0.0658. Preliminary results from:

L.P. Csernai[1], D.J. Wang[1], M. Bleicher[2,3], and H. Stöcker[2,3,4]

Simulation results

➢ Λ polarization:

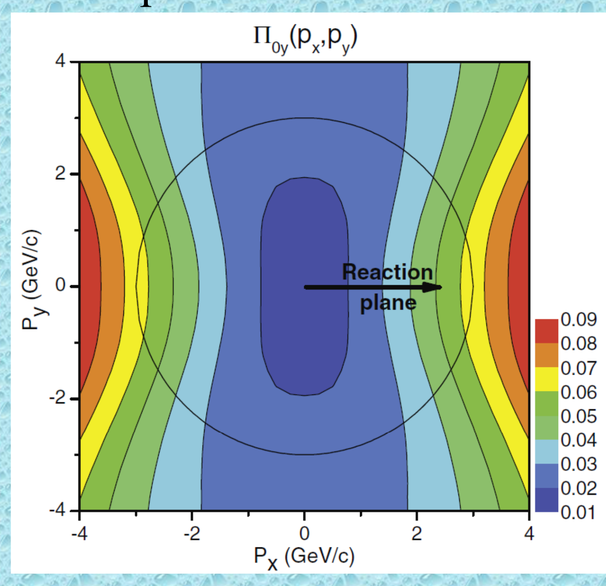

Fig. 3. The dominant y component of the observable polarization, $\boldsymbol{\Pi_0(p)}$ in the rest frame of the emitted *Λ*'s as a function of the *Λ* momentum in the transverse plane at the participant c.m. (i.e., at $p_z = 0$). In the participant center of mass frame the polarization is minimal for small and *y* directed *Λ* momentum, while it is maximal in the *x* directed momentum, i.e., in the reaction plane. Based on:

F. Becattini,[1,2] L. P. Csernai,[3] and D. J. Wang[3,4]
PHYSICAL REVIEW C **88**, 034905 (2013)

Conclusions

➢ Λ polarization is observable at lower energies, FAIR & NICA, also, because the lower temperature helps to maintain the polarization.

➢ The polarization is transverse and maximal to particles emitted in the reaction plane in the x direction, and polarized in the y direction.

➢ Therefore the EbyE identification of the Reaction Plane and of the participant c.m. is vital for the detection of this effect.