Differential study of Λ-hyperon polarization in a few-GeV regime within transport model approach

O. Vitiuk, L. Bravina, E. Zabrodin

Uniwersytet Wrocławski

UiO : University of Oslo

Λ-hyperon polarization in transport model (UrQMD)

In the assumption of local thermal equilibrium one can find expression for spin 4-vector: [PRC 95, 054902 (2017)]

$$S^{\mu}(p,x) \approx -\frac{1}{8m}\epsilon^{\mu\nu\rho\sigma}p_{\nu}\varpi_{\rho\sigma}(x), \qquad \varpi^{\mu\nu} = \frac{1}{2}\left(\partial^{\nu}\frac{u^{\mu}}{T} - \partial^{\mu}\frac{u^{\nu}}{T}\right)$$

From this one can find Λ polarization:

$$\vec{S}^{*}(x,p) = \vec{S} - \frac{(\vec{p}\cdot\vec{S})}{E(m+E)}\vec{p}, \qquad \langle\vec{S}\rangle = \frac{1}{N}\sum \vec{S}_{i}^{*}(x_i,p_i), \qquad P_{\Lambda} = 2\langle\vec{S}\rangle\cdot\vec{n}$$

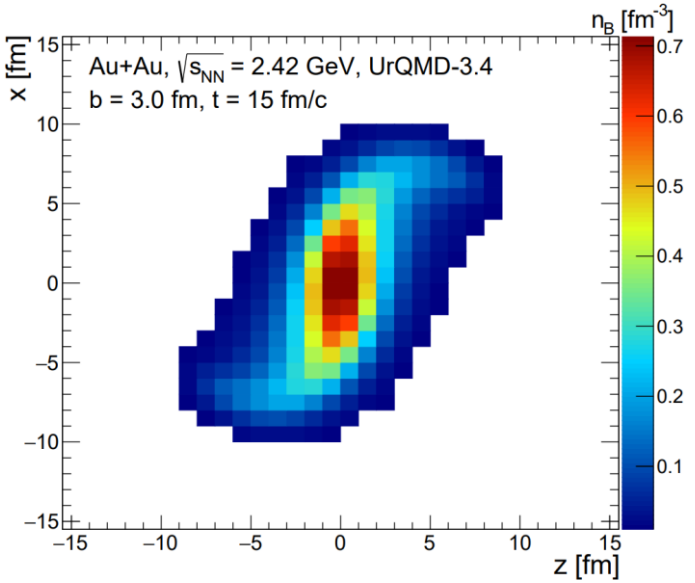
How to calculate it in the transport model?

Solution: Coarse-graining approach + HRG Model

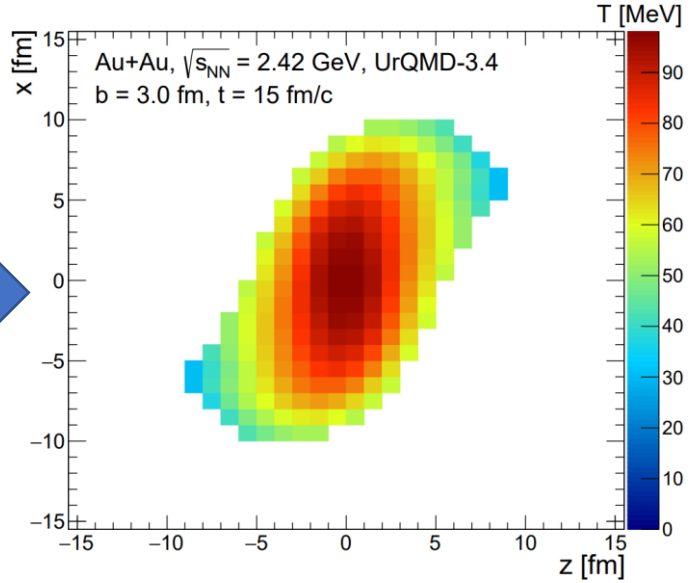
[PLB 803, 135298 (2020)]

Λ-hyperon polarization in transport model (UrQMD)

1. Data generated with timestep $\Delta t = 1\ fm/c$
2. For each timestep, whole space was subdivided into cubic cells with volume $V = 1\ fm^3$
3. Collective velocity as well as $\varepsilon, n_B, n_S, n_Q$ in the rest frame of each cell were calculated
4. Temperature field extracted with the help of HRG Model
5. With 4-velocity and T fields thermal vorticity field was obtained
6. For each Λ-hyperon we found spin 4-vector at its freeze-out position at its freeze-out time
7. Finally, global polarization and other observables were calculated

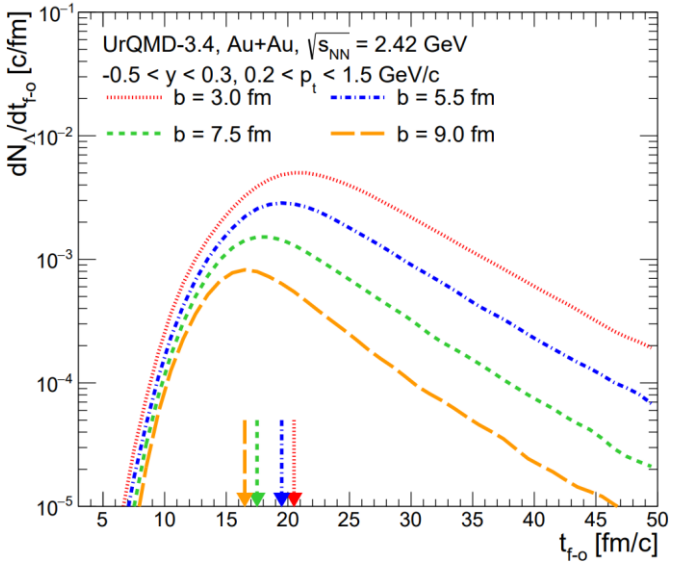


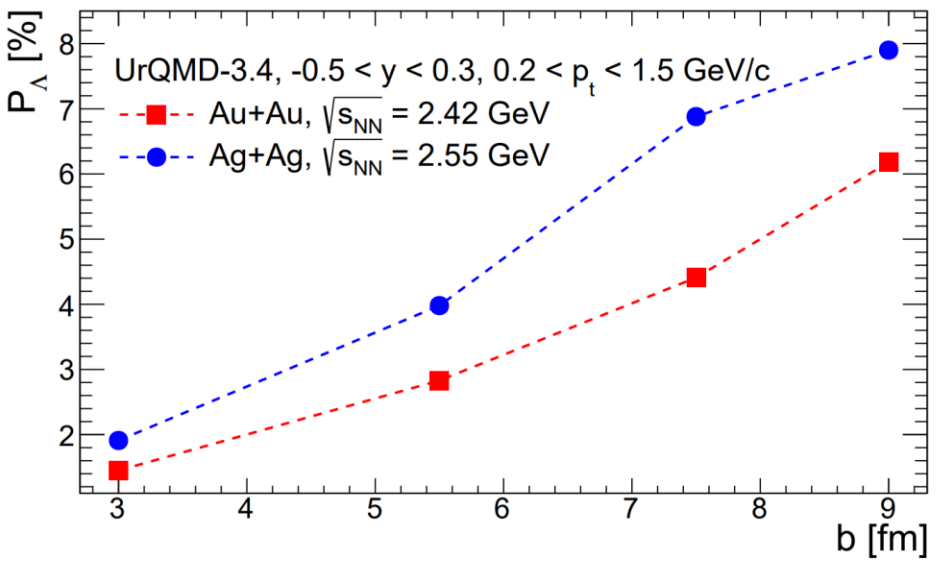
$$\begin{cases} \mathcal{E}^{UrQMD} = \sum \dfrac{g_i}{(2\pi\hbar)^3} \int \dfrac{E d^3p}{e^{(E-\mu)/T} + a_i} \\ n_X^{UrQMD} = \sum \dfrac{g_i X_i}{(2\pi\hbar)^3} \int \dfrac{d^3p}{e^{(E-\mu)/T} + a_i} \end{cases}$$

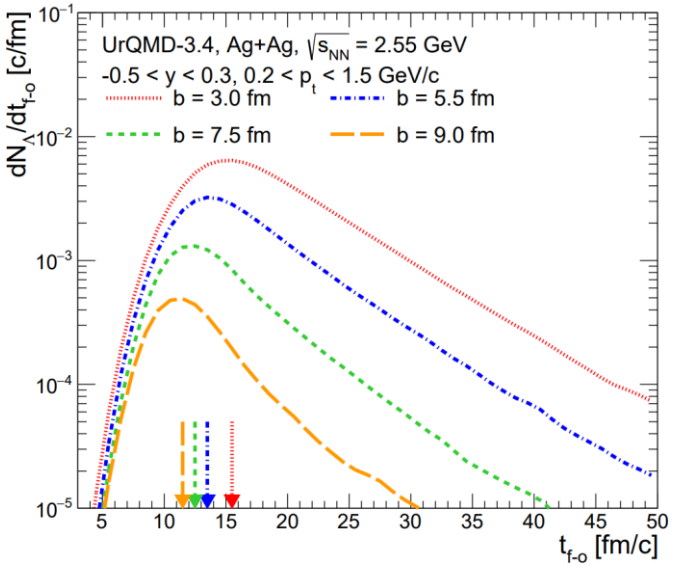


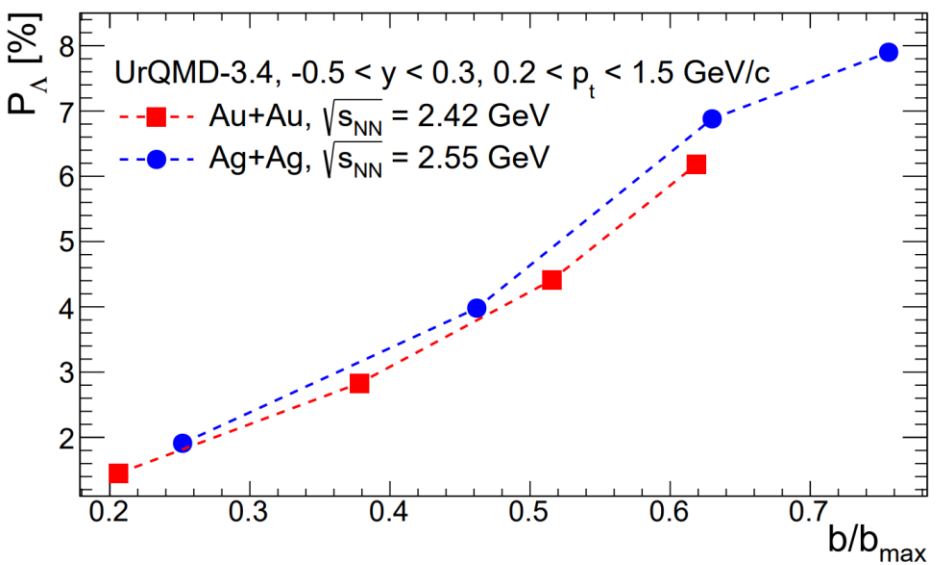
Freeze-out of Λ and Centrality Dependence of P_Λ

- Although the main amounts of both hyperons are emitted within 10-30 fm/c, there is continuous radiation of Λ up to the very late stage of system evolution.
- The time of maximum emission is decreasing with increasing impact parameter ⇒ Radiation from regions with higher vorticity ⇒ Higher polarization
- Polarization increases with impact parameter ⇒ Match qualitative explanations that the vorticity and angular momentum are also increasing towards more peripheral collisions.



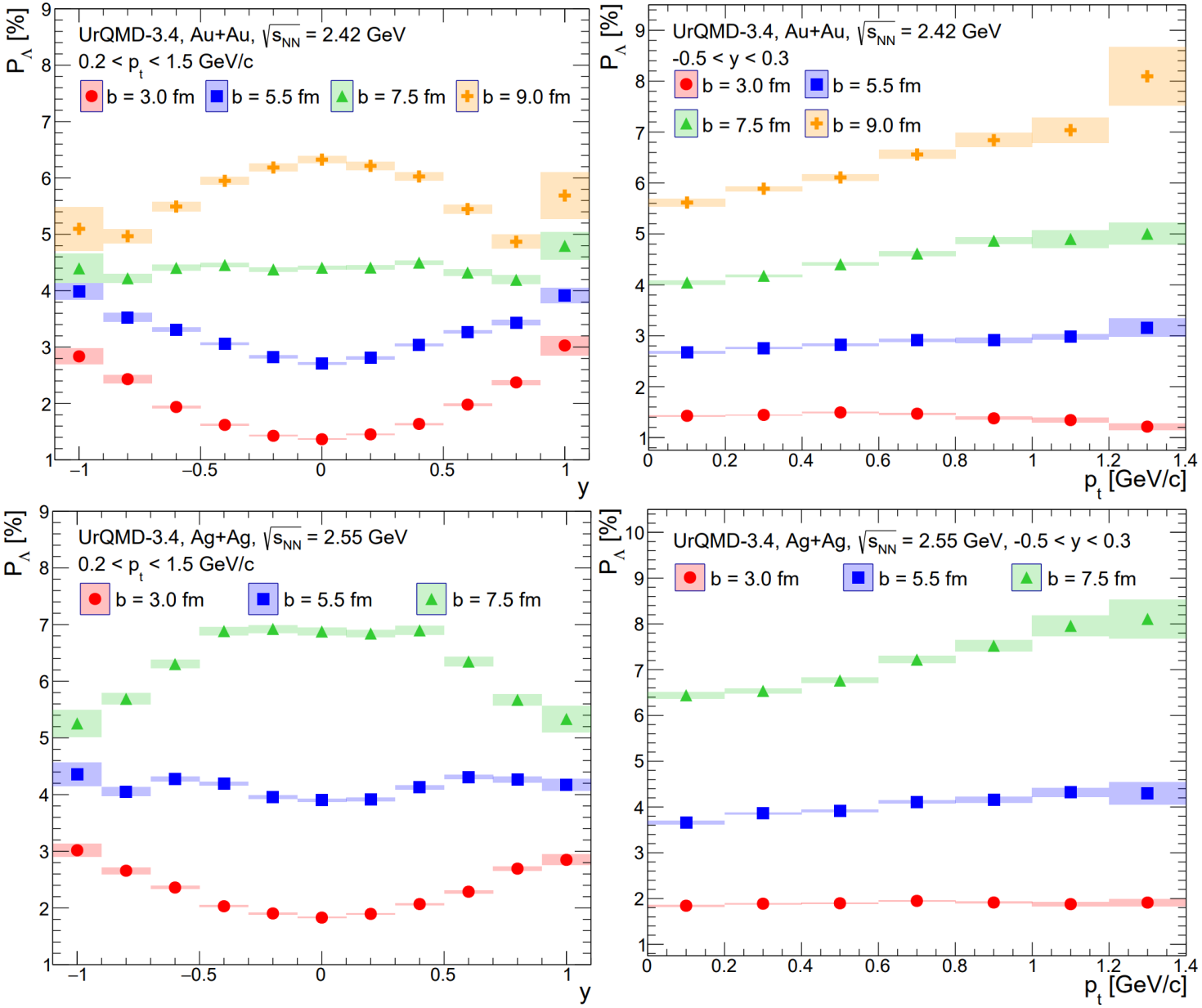






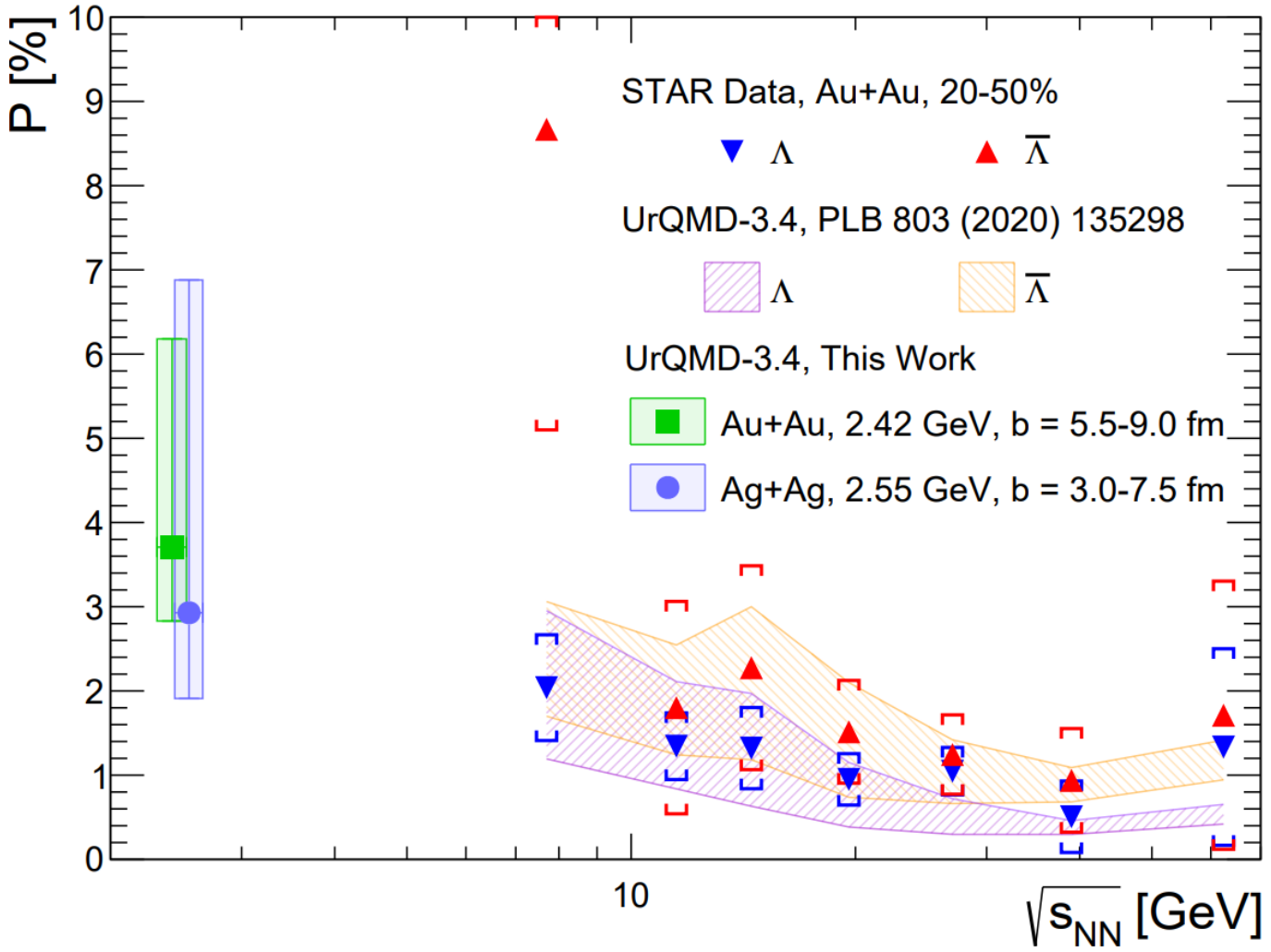
Study of p_t and y dependence

- Polarization is a linearly increasing function of p_t except of most central events where behaviour is more non-trivial.
- Non-trivial behaviour of polarization as function of rapidity and centrality
- Polarization distribution as a function of rapidity changes shape from concave to convex with increasing impact parameter



Global polarization & Conclusions

Global polarization values are in agreement with HADES preliminary data (for Au+Au $P_\Lambda[\%] = 4.609 \pm 0.966(stat.) \pm 1.22(sys.)$, while for the Ag+Ag run a value of is $P_\Lambda[\%] = 3.174 \pm 0.294(stat.) \pm 0.319(sys.)$)

Conclusions:

- Λ-hyperon polarization at HADES energies is studied in the UrQMD model within a coarse-graining approach in combination with the HRG model
- Differential studies show a non-trivial behaviour of Λ polarization as a function of transverse momenta, rapidity and impact parameter
- Obtained results are in agreement with the preliminary HADES data