Directed flow of Λ from HICs and hyperon puzzle of NSs

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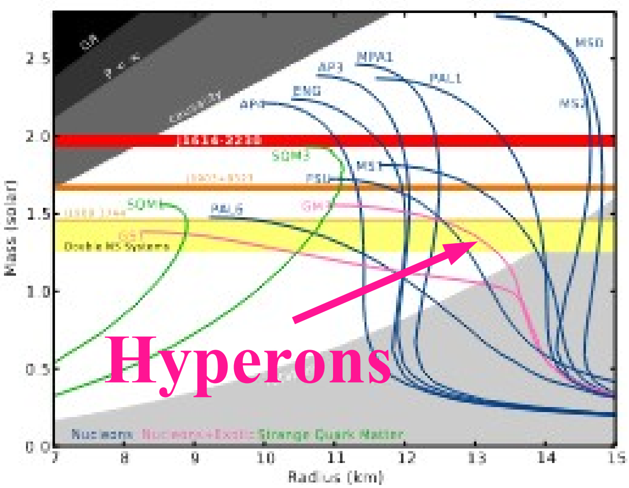
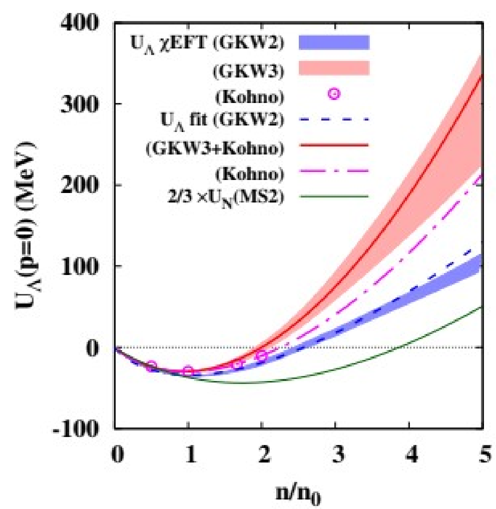
- **Does three-body ΛNN repulsion solve the hyperon puzzle ?**
  - **E.g. Chiral EFT w/ 2+3-body int. can give repulsive potential.**
    Gerstung, Kaiser, Weise (2001.10563)(GKW), Kohno (1802.05388)
- **Examination of U_Λ via directed flow (v_1) of Λ** *Data: STAR (1708.07132)*
  - **Studied in JAM2/RQMDv (explains v_1 of p) + U_Λ from chiral EFT**

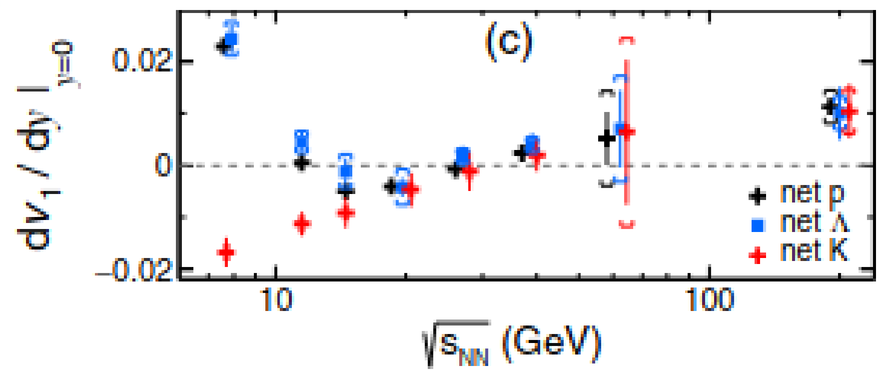
$$U_{\rm sk}(\rho) = a(\rho/\rho_0) + b(\rho/\rho_0)^{4/3} + c(\rho/\rho_0)^{5/3} \qquad U^0_{\rm m}(\boldsymbol{p}) = \frac{C}{\rho_0}\int \frac{d\boldsymbol{p}'}{(2\pi)^3}\frac{f(\boldsymbol{r},\boldsymbol{p}')}{1+(\boldsymbol{p}-\boldsymbol{p}')^2/\mu^2}$$



Demorest+(1010.5788)



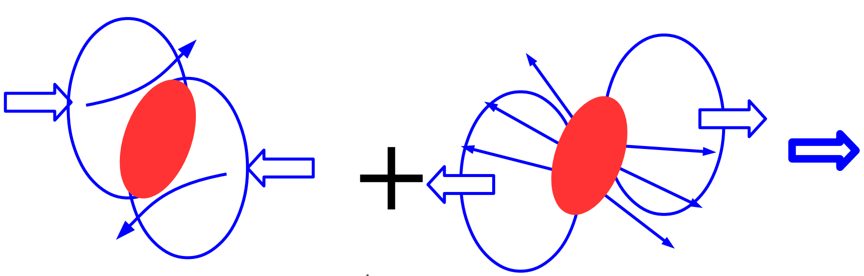
Nara+(in prep.)

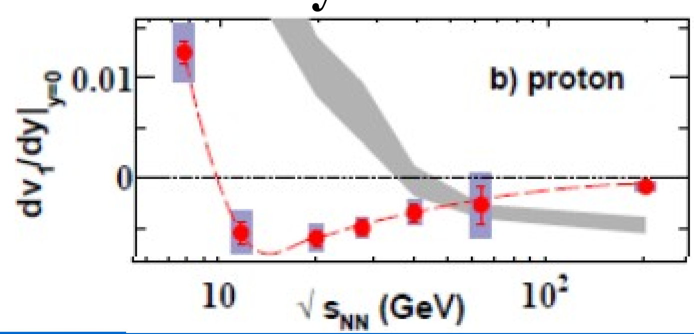


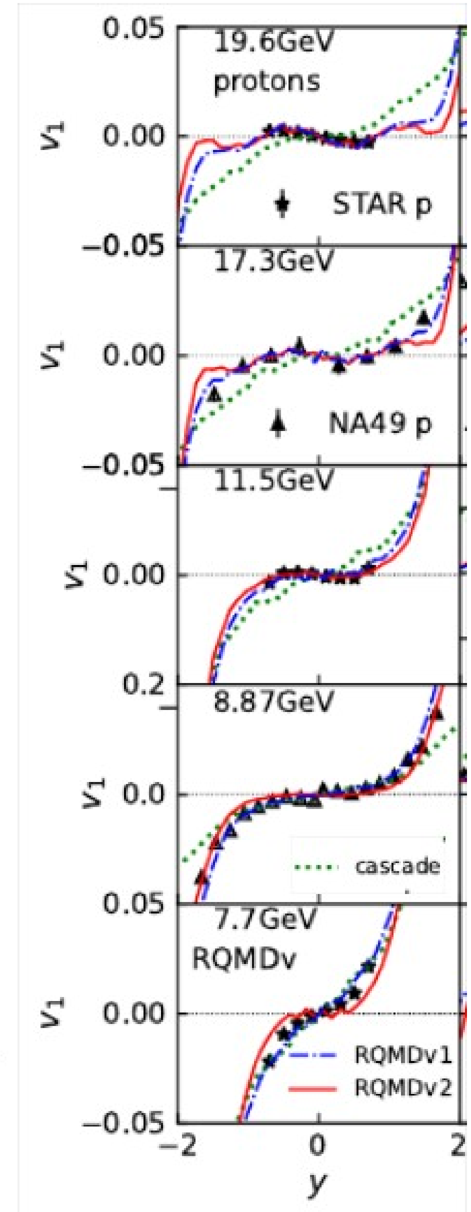
STAR, PRL('18) [1708.07132]

Directed flow (v_1) of protons

- Directed flow (v_1 or $<p_x>$) has been utilized to constrain EOS
  E.g. Sahu, Cassing, Mosel, AO (nucl-th/9907002), Snellings+(nucl-ex/9908001)
- Proton v_1 slope *STAR (1401.3043), Nara+(2109.07594)*
  - Non-monotonic beam E. dep. of v_1 slope
  - Sign change of v_1 slope at $\sqrt{s_{NN}} \sim 10$ GeV
  - None of fluid and hybrid models explain the colliding energy dependence using a single EOS
  - An answer *Nara, AO (PRC'('22), 2109.07594)*
    - Compression (positive) and expansion (negative) contributions cause non-monotonicity.

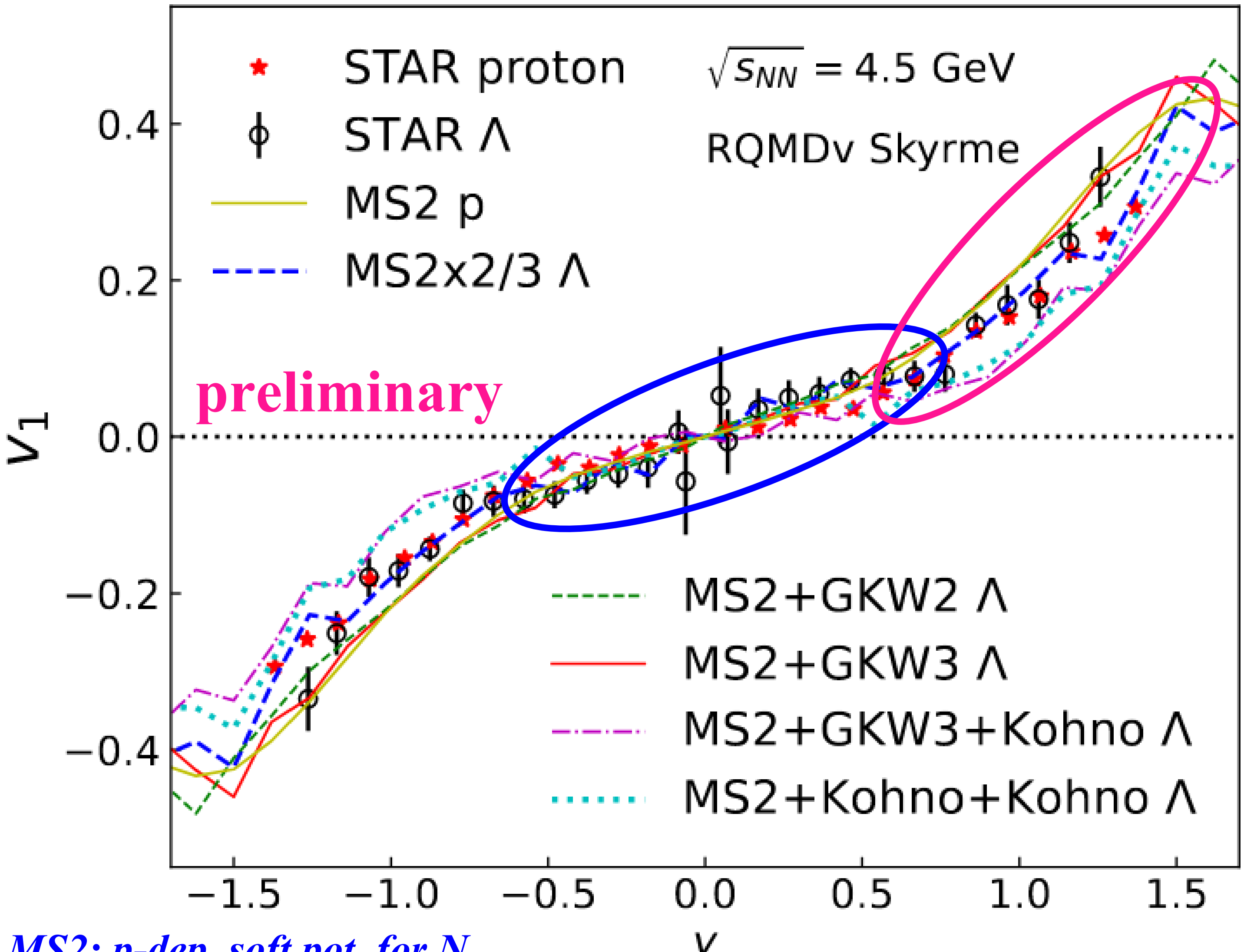






STAR, PRL112('14) 162301 (1401.3043)

Directed flow (v_1) of Λ at $\sqrt{s_{NN}}$=4.5 GeV



Calculation with JAM2/RQMDv

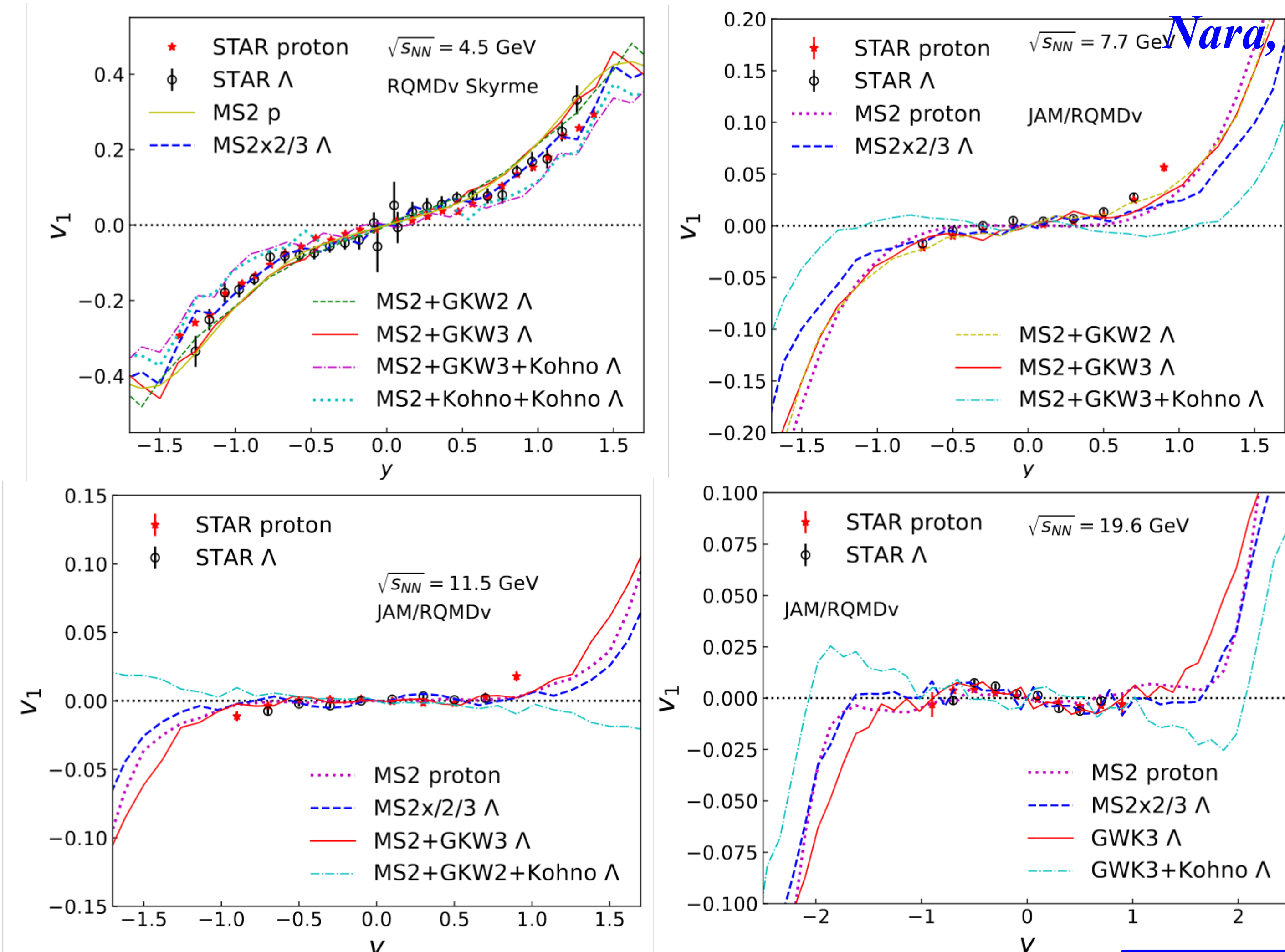
- **Slope (y=0) is OK with**
  - **chiral EFT U_Λ (p-indep.)**
  - **U_Λ = 2/3 U_N**
- **v_1 at large |y| needs stiffer U_Λ**
  - **chiral EFT (p-indep.)**
- **p-dep. U_Λ seems to underestimate v_1**

MS2: p-dep. soft pot. for N
GKW2: chiral EFT with 2-body int.
GKW3: chiral EFT with 2+3 body int.
GKW3+Kohno: GKW3 with p-dep. from Kohno
Kohno+Kohno: ρ- and p-dep. from Kohno

Nara, Jinno, Murase, AO, in prep.

Directed flow of Λ at $\sqrt{s_{NN}}$=(4.5-19.6) GeV

Nara, Jinno, Murase, AO, in prep.



MS2: p-dep. soft pot. for N
GKW2: chiral EFT with 2-body int.
GKW3: chiral EFT with 2+3 body int.
GKW3+Kohno: GKW3 with p-dep. from Kohno
Kohno+Kohno: ρ- and p-dep. from Kohno

U_Λ having the ρ-dep. in chiral EFT roughly explains the v_1 slopes.

Summary

- **The directed flow (v_1) of Λ from HICs at $\sqrt{s_{NN}}$=(4.5-19.6) GeV is studied by using the Λ potential from chiral EFT.**
  - **U_Λ from chiral EFT contains strong repulsion from the 3-body interactions and suppresses Λ to appear in neutron stars.**
  - **The Λ v_1 slopes at midrapidity are roughly explained by the Λ potentials having ρ-dep. from the chiral EFT with 2+3 body int.**
    [Similar results for <px> at √sNN=3.0 GeVare obtained by D.C. Zhang+ (2107.00277)]
  - **U_Λ = 2/3 U_N and U_Λ from 2-body chiral EFT also explains the slopes. (Strong repulsion in U_Λ at high densities is not verified yet.)**
  - **The p-dep. of U_Λ seems to reduce the slopes significantly. While the p-dep. of U_Λ enhances the slope in the compression stage, it reduces the slope in the tilted matter expansion stage. (The simultaneous fit to ρ- and p-dep. would be necessary.)**
  - **The forward and backward v_1 values seem to be sensitive to the Λ potential at high densities.**

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