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# Directed flow in HIC at FAIR and NICA energies

Part of materials has been already published:

Bravina L.V.; Y.K., Sivoklov S.Y.; Vitiuk O.V.; Zabrodin E.E. Directed flow in Microscopic Models in Relativistic A+A Collisions. MDPI Universe 2019, 5, 69.

21 March, Oslo, Norway

# What is Flow?...

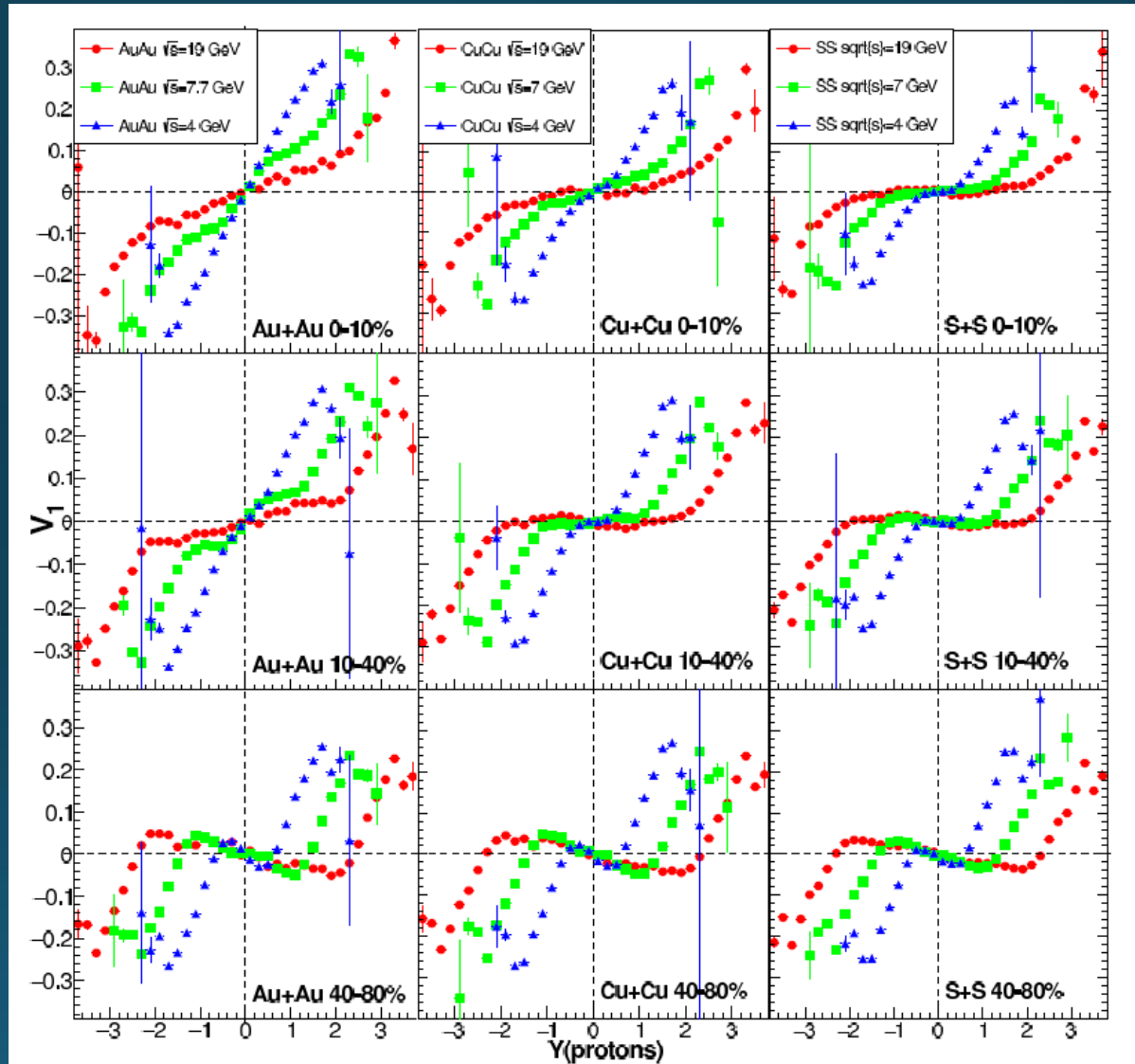
$$E \frac{d^3 N}{d^3 p} = \frac{d^2 N}{2\pi p_T dp_T dy} \left\{ 1 + 2 \sum_{n=1}^{\infty} v_n \cos [n(\phi - \Psi_n)] \right\}$$

Coefficients of the expansion  $v_n = \langle \cos(n(\varphi - \Psi)) \rangle$  are called directed, elliptic, triangular, etc.

# What do we know?

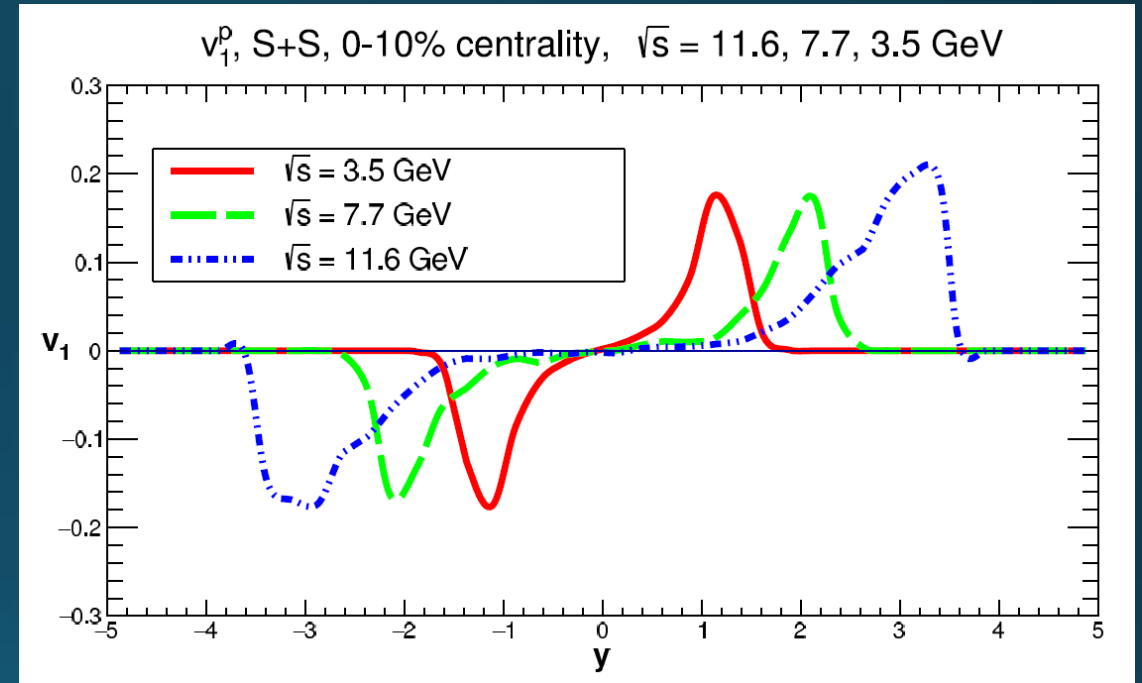
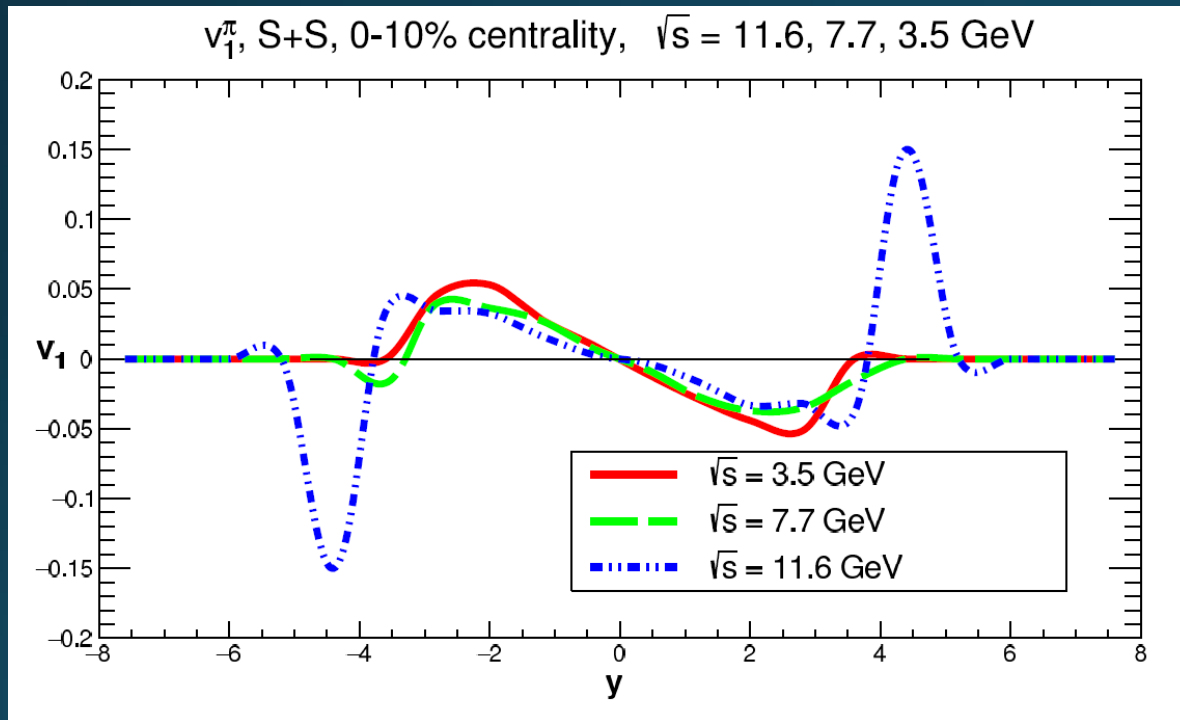
- Directed flow of protons changes sign at midrapidity region from flow to antiproton flow in the  $\sqrt{s}$  range between 10 and 4 GeV, while the one of mesons remain unchanged.
- Directed flow of hadrons experience reduction in the midrapidity region in case of QGP-hadron gas phase transition

# Directed flow in QGSM



# Directed flow in S+S collisions, UrQMD

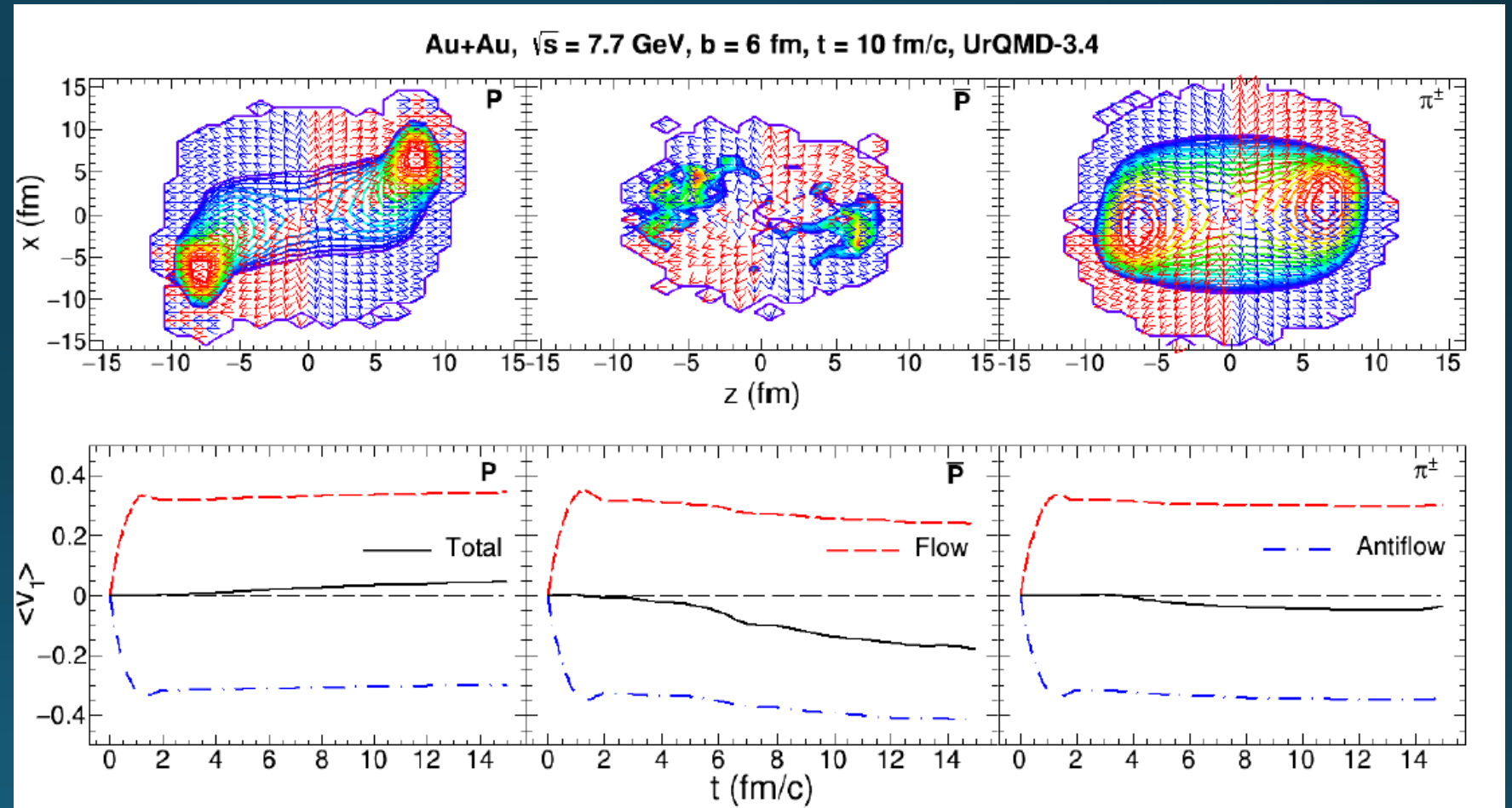
pions



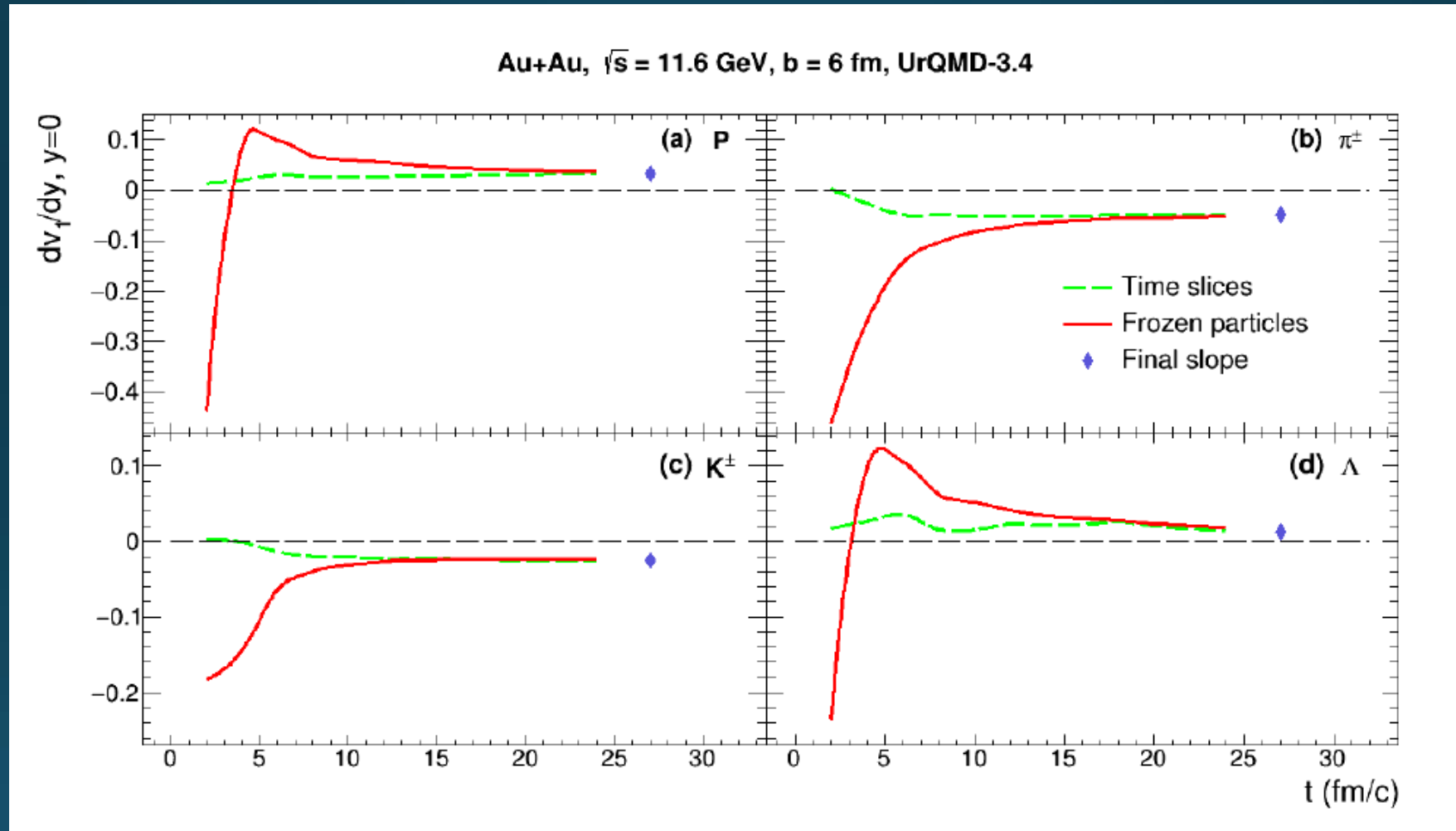
protons

# Flow and baryon density

Upper row: baryon density(contour plot) and collective velocity of each  $3 \text{ fm}^3$  cell at  $10 \text{ fm}/c$   
Bottom row: Time development of total flow as a sum of normal flow and antiflow.



# Flow formation



# Influence of mean-field potentials

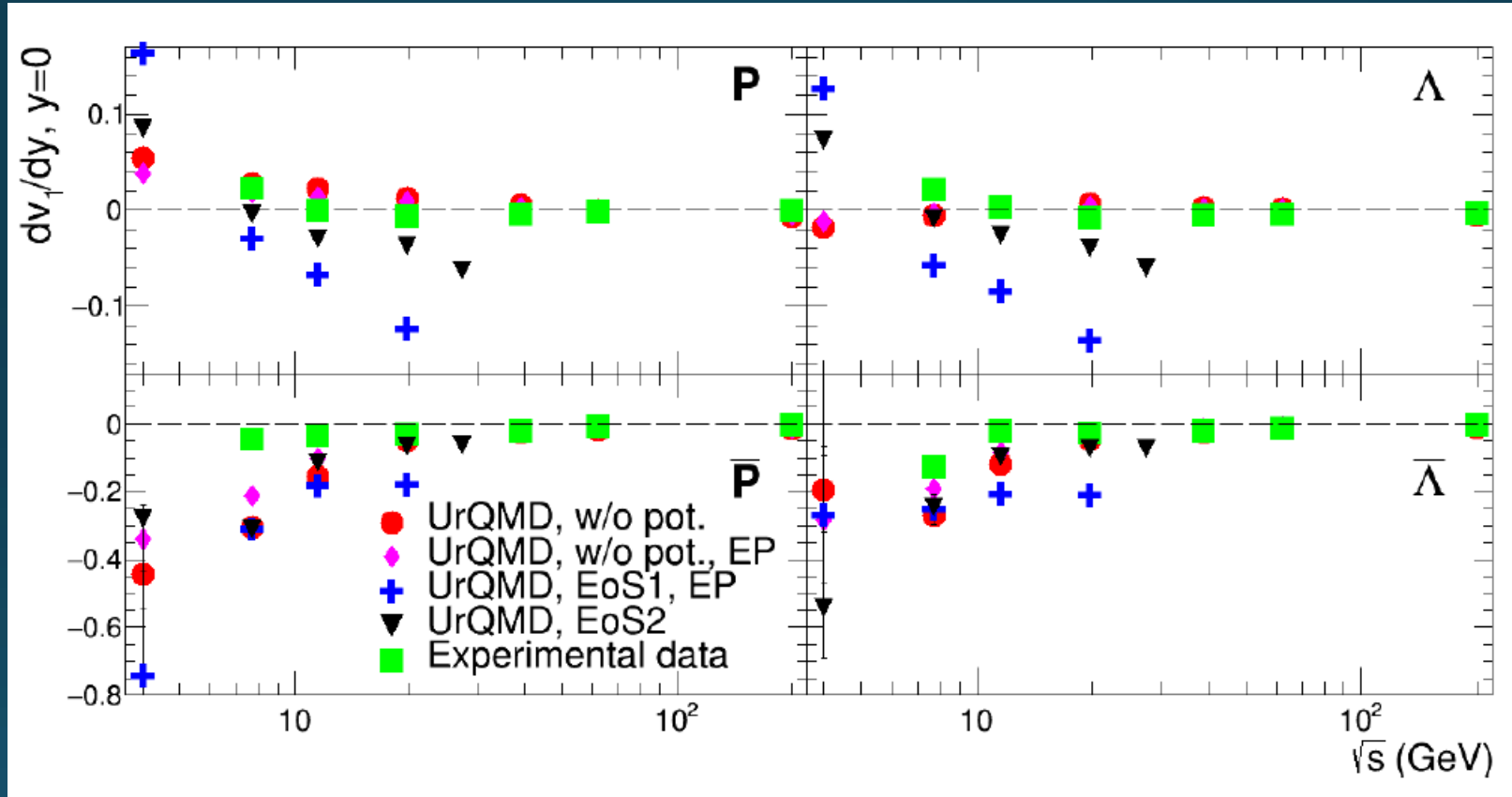
$$V = V_0^{Yuk} \frac{e^{-|\vec{r}_i - \vec{r}_j|/\gamma_Y}}{|\vec{r}_i - \vec{r}_j|} + \frac{Z_i Z_j e^2}{|\vec{r}_i - \vec{r}_j|} + t_1 \rho_j^{int} + t_\gamma (\gamma + 1)^{-3/2} (\rho_j^{int})^\gamma,$$

$$\rho_j^{int} = \left(\frac{\alpha}{\pi}\right)^{3/2} e^{-\alpha r_j^2}$$

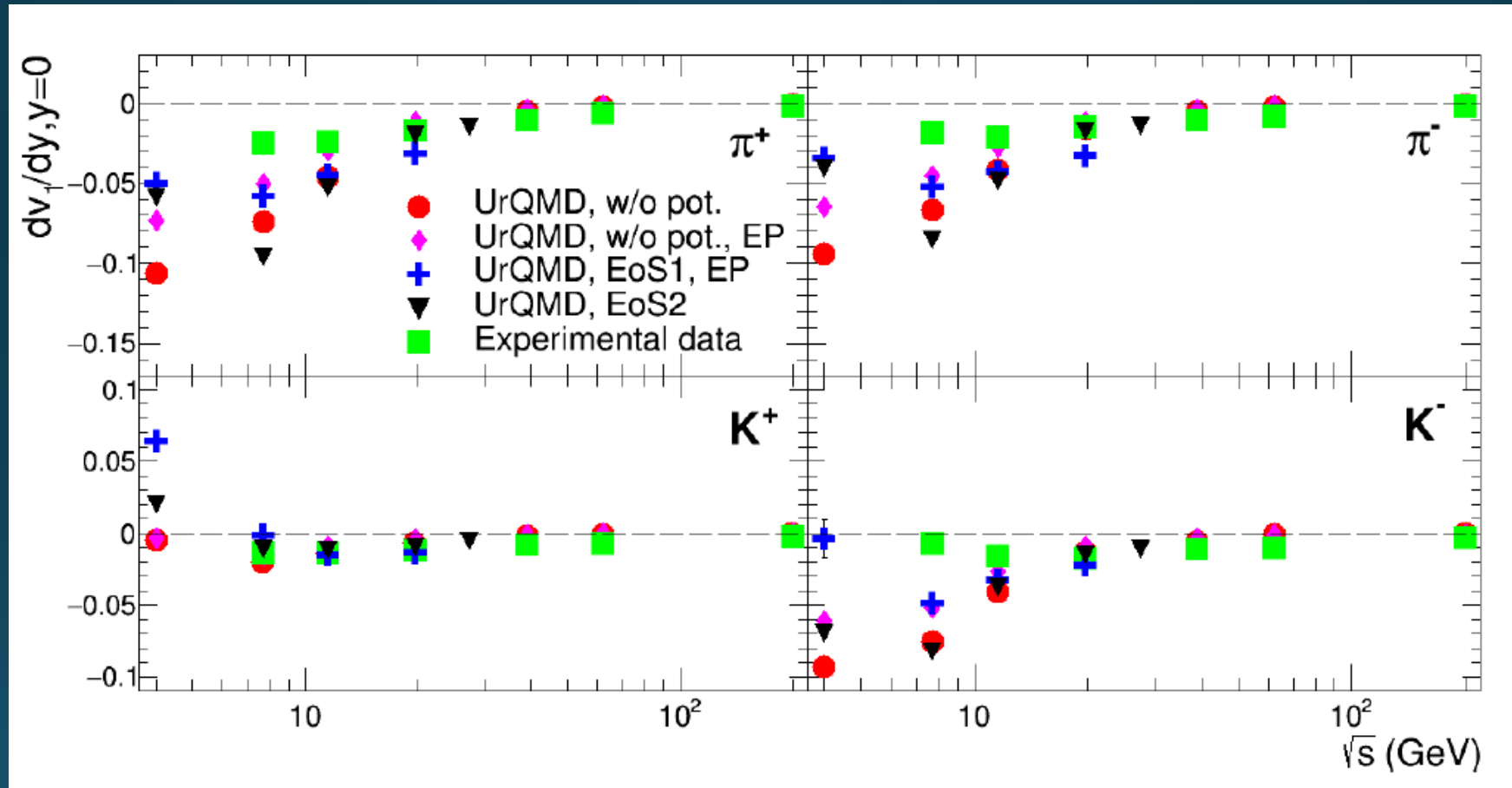
Parameter	Hard Potential (EoS1)	Soft Potential (EoS2)
$\alpha$ (fm <sup>-2</sup> )	0.25	0.25
$t_1$ (MeV fm <sup>3</sup> )	-163	-353
$t_\gamma$ (MeV fm <sup>6</sup> )	125.93	304
$\gamma$	1.676	1.167
$V_0^{Yuk}$ (MeV fm)	-0.498	1.0038
$\gamma^{Yuk}$ (fm)	1.4	1.4



# Baryons

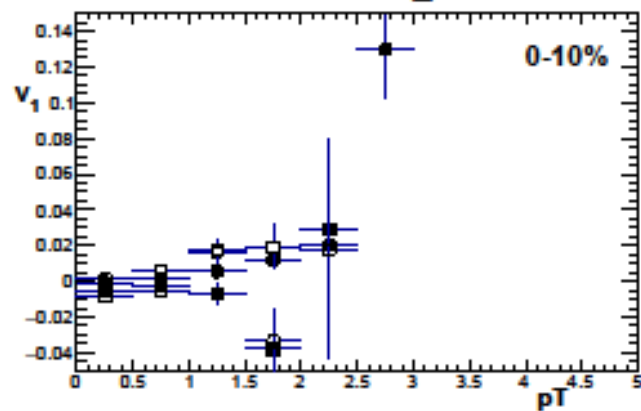
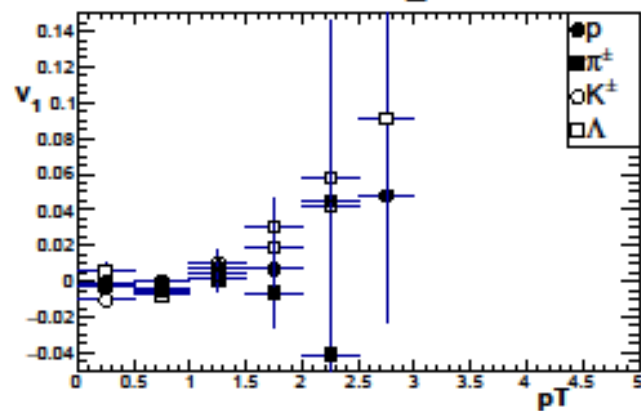


# Mesons

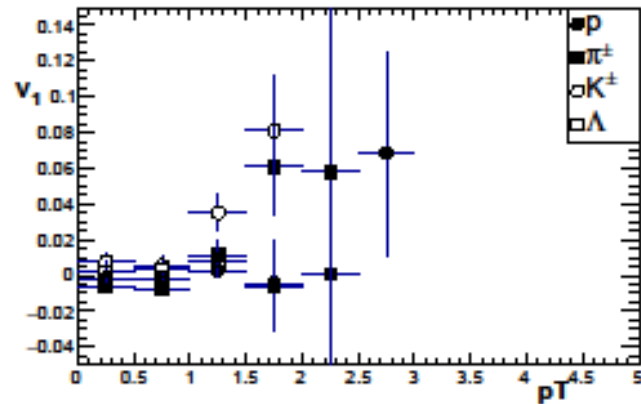
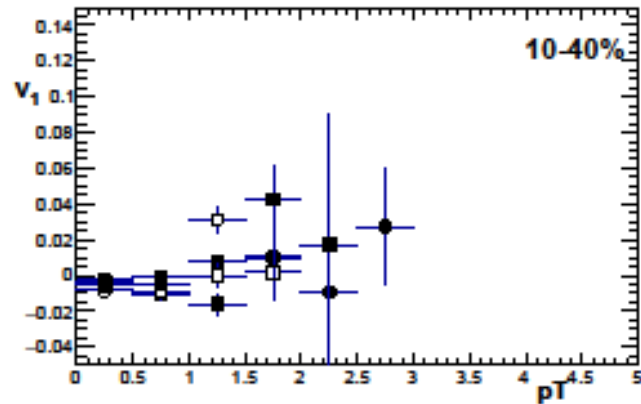


# Current work

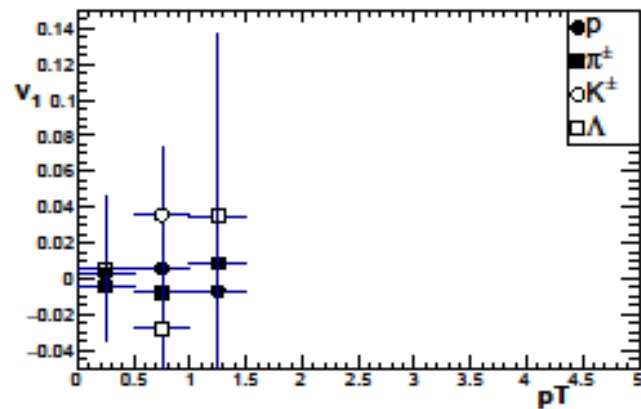
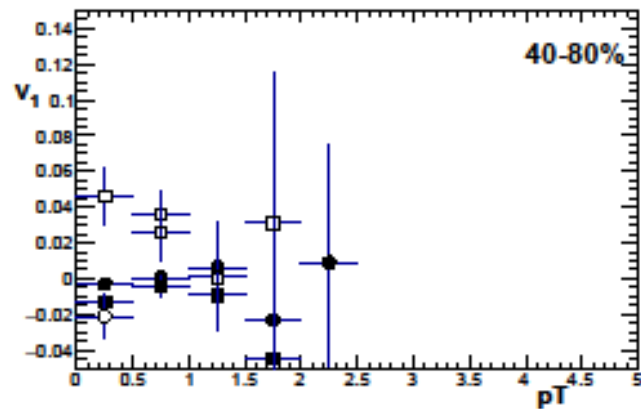
- 3.5, 5.5, 7.7, 11.6 GeV
- Xe+Xe and Au+Au
- 0-10%, 10-40%, 40-80%
- directed and elliptic flows
- $\gamma$  and  $p_T$  dependence
- time evolution

Au+Au,  $\sqrt{s} = 3\text{--}5\text{ GeV}$ Xe+Xe,  $\sqrt{s} = 3\text{--}5\text{ GeV}$ 

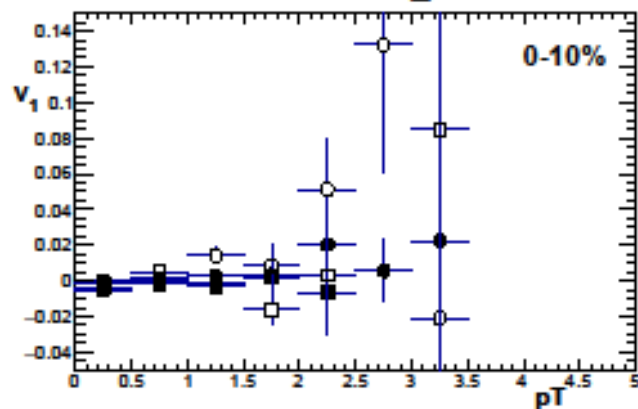
10-40%



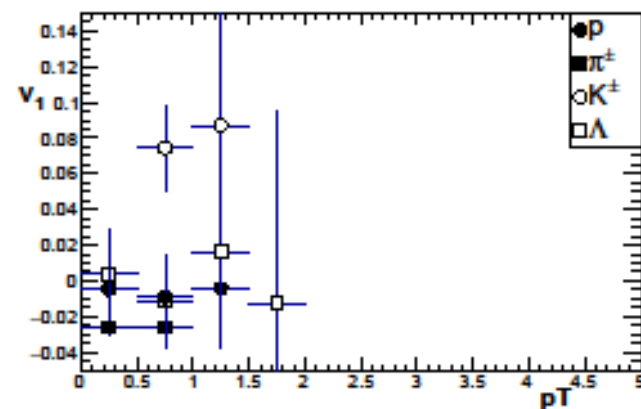
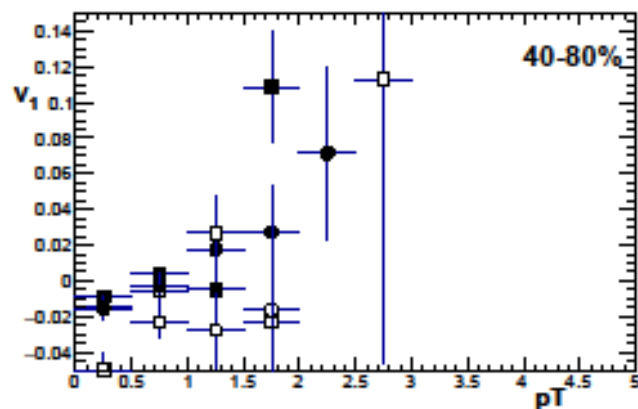
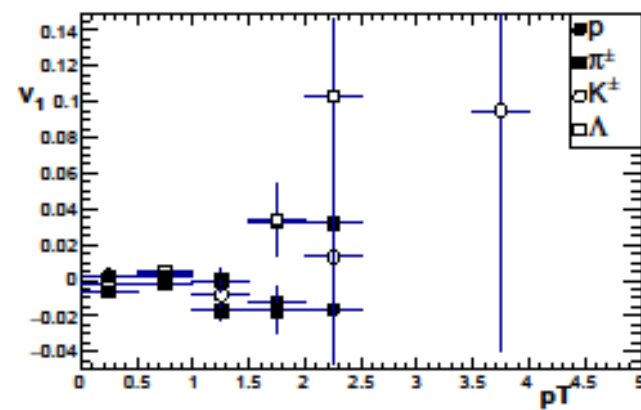
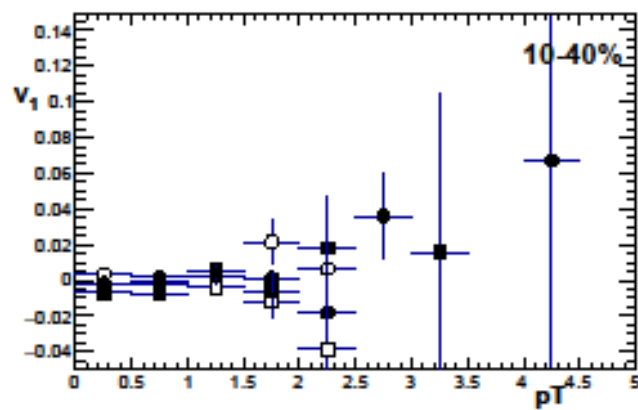
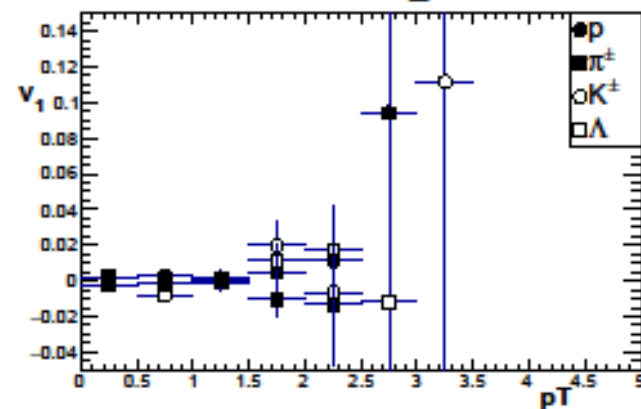
40-80%

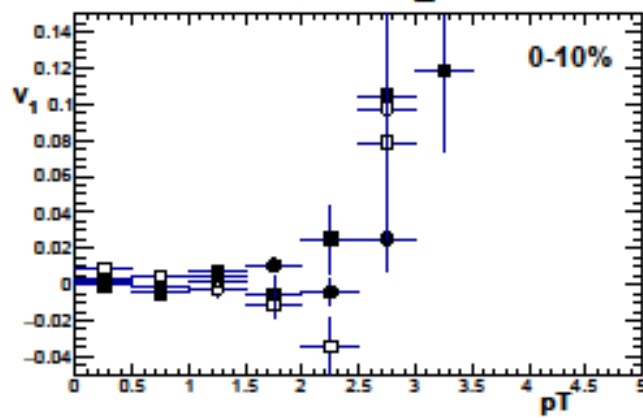
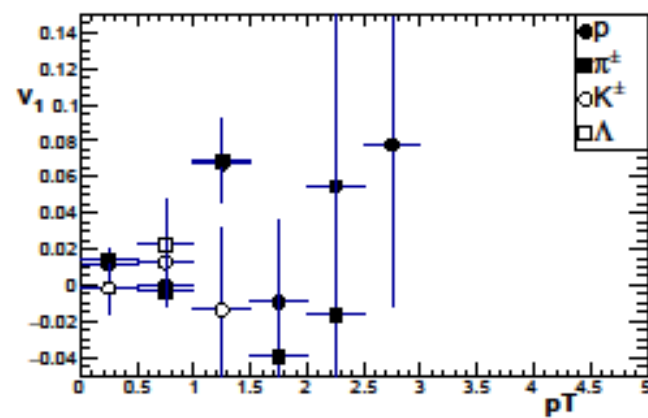
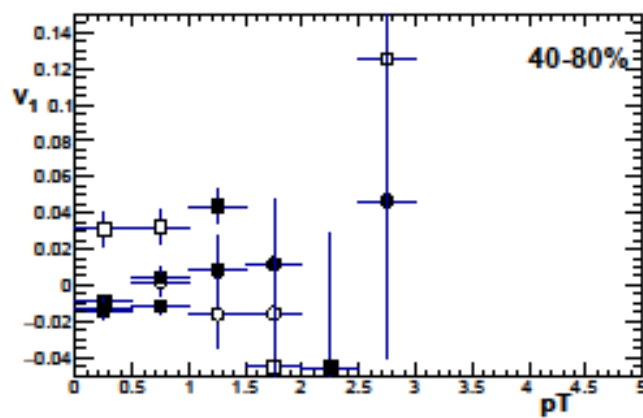
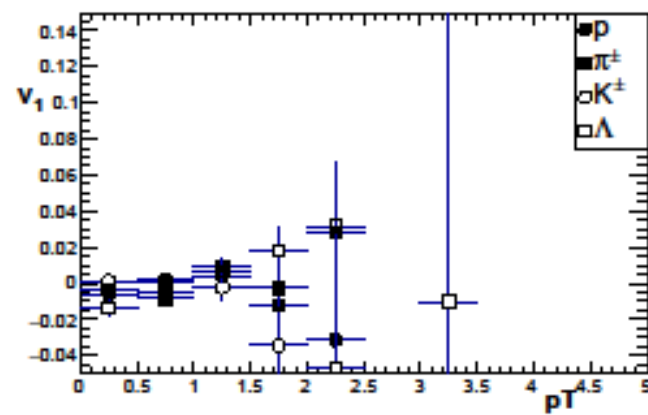
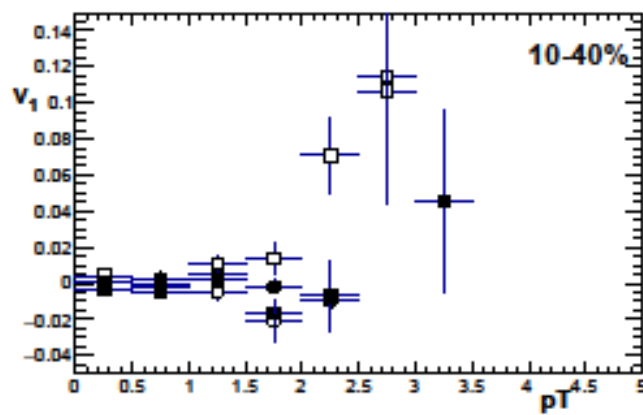
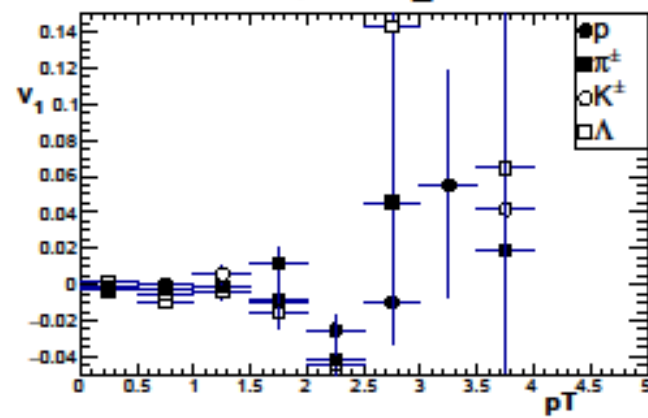


Au+Au,  $\sqrt{s} = 5.5$  GeV

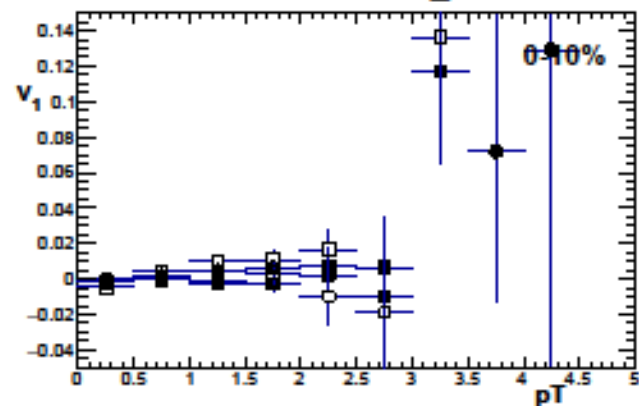


Xe+Xe,  $\sqrt{s} = 5.5$  GeV



Au+Au,  $\sqrt{s} = 7.7$  GeVXe+Xe,  $\sqrt{s} = 7.7$  GeV

Au+Au,  $\sqrt{s} = 11.6$  GeV



Xe+Xe,  $\sqrt{s} = 11.6$  GeV

