Comparison of collective flow parameters for different isotopic combinations in Xe+Sn collisions from 65 to 150 MeV/u

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Physics Motivation

- Nuclear Equation of State

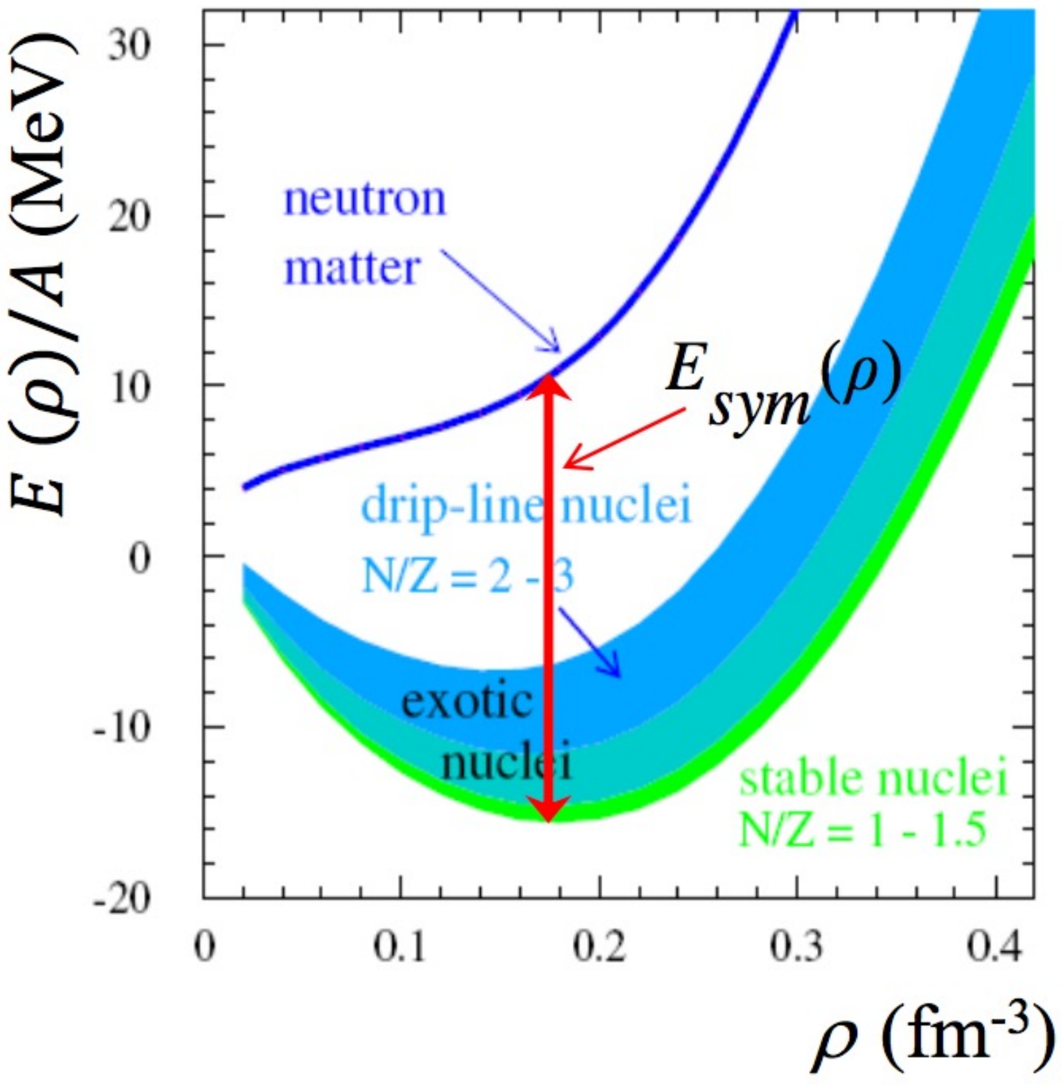
$$E(\rho,\delta)/A = \underbrace{E(\rho_n=\rho_p)}_{\text{Iso-scalar}} + \underbrace{E_{sym}(\rho)\delta^2}_{\text{Iso-vector}}$$

$$E_{sym}(\rho) = \frac{1}{2}\frac{\partial^2 E}{\partial\delta^2} \approx E(\rho)_{\substack{pure\ neutron\\ matter}} - E(\rho)_{\substack{symmetric\\ nuclear\ matter}}$$

$$with\quad \rho = \rho_n + \rho_p\ , \qquad \delta = (\rho_n - \rho_p)/\rho$$

- Nuclear Symmetry Energy

$$E_{sym}(\rho) = S + \frac{L_{sym}}{3}\left(\frac{\rho-\rho_0}{\rho_0}\right) + \frac{K_{sym}}{18}\left(\frac{\rho-\rho_0}{\rho_0}\right)^2 \ \ldots$$



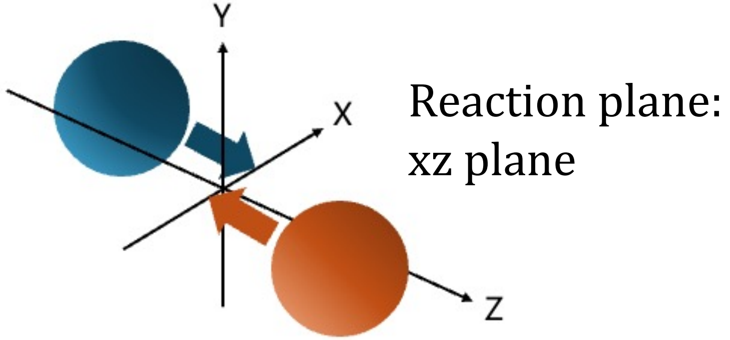
Analysis

- Collective flow

- Fourier expansion of azimuthal distributions :

$$\frac{dN}{d(\phi - \psi_r)} = \frac{N_0}{2\pi}\left(1 + 2\sum_{n\geq 1} v_n \cos n(\phi - \psi_r)\right)$$

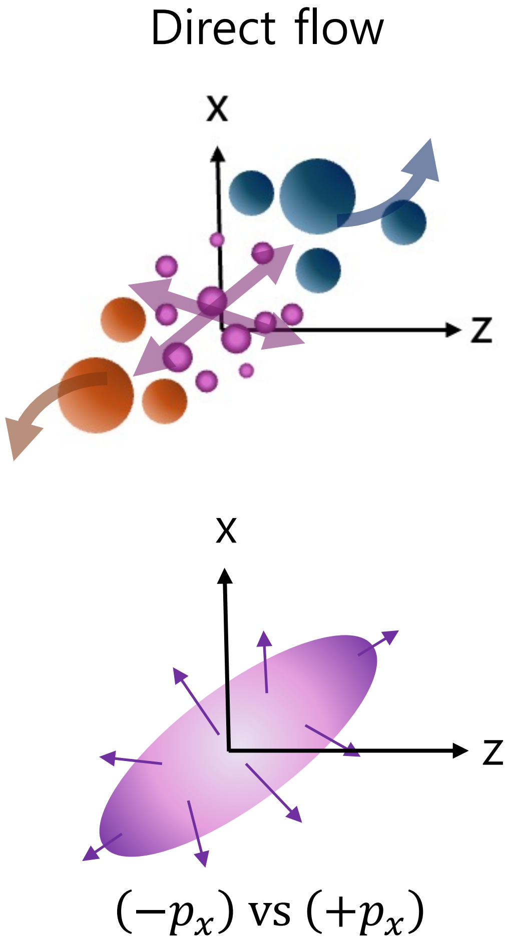
where, ψ_r : azimuthal angle of reaction plane

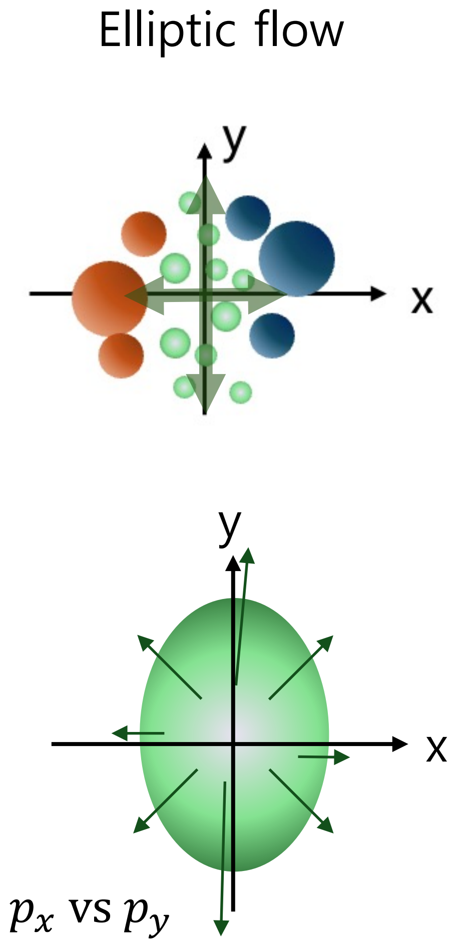


- v_1 is direct flow and v_2 is elliptic flow.

$$v_1 \equiv \langle \cos(\phi - \psi_r) \rangle = \left\langle \frac{p_x}{p_t} \right\rangle$$

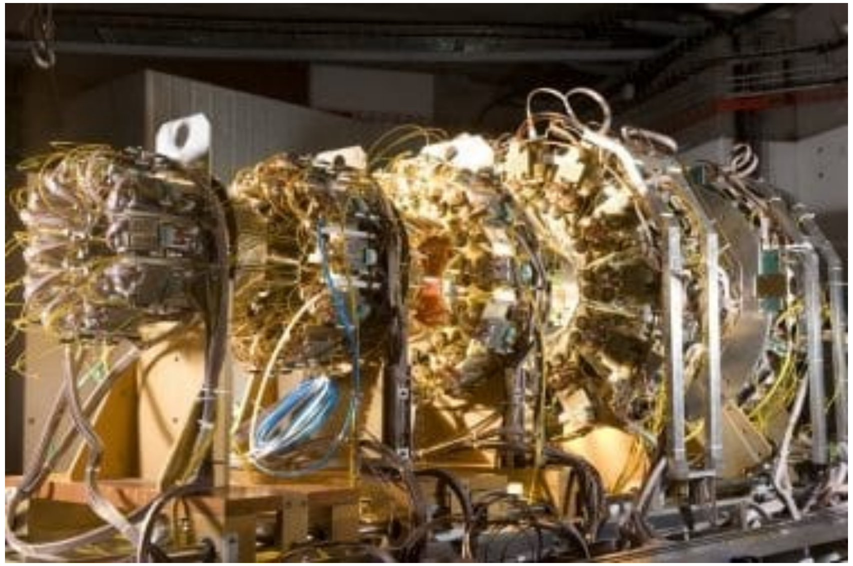
$$v_2 \equiv \langle \cos 2(\phi - \psi_r) \rangle = \left\langle \frac{p_x^2 - p_y^2}{p_t^2} \right\rangle$$





Experiment & Model

❖ INDRA Campaign 4th



- $^{129}_{54}\mathrm{Xe} + ^{124}_{50}\mathrm{Sn}$@ $150, 80$ and 65 MeV/u
- $^{129,124}_{54}\mathrm{Xe} + ^{124,112}_{50}\mathrm{Sn}$@ 100 MeV/u

  $\rightarrow$ N/Z : 1.433, 1.386, 1.317 and 1.269

❖ ImQMD model

Improved Quantum Molecular Dynamics with Skyrme parameter set SkM* and SLy4 are used.

Para.	ρ_0	E_0	K_0	S_0	L	K_{sym}	m^*/m	m_n^*/m	m_p^*/m
SLy4	0.160	-15.97	230	32	46	-120	0.69	0.68	0.71
SkM*	0.160	-15.77	217	30	46	-156	0.79	0.82	0.76

Y. Zhang et al. / Physics Letters B 732 (2014) 186–190

$v_{1,2}^{s}$ vs p_t^0 from Experiment and ImQMD

- Flow parameters of isotopes of LCPs and IMFs are calculated at IW1($0.21 < b_0 < 0.42$) window.
  Z = 1 : 1H, 2H 3H Z = 2 : 3He, 4He, 6He -> LCPs
  Z = 3 : 6Li, 7Li, 8Li Z = 4 : 7Be, 9Be, 10Be -> IMFs

- A consistent correlation with the N/Z ratio of collision system and N/Z ratio of particle of interest is founded by difference of v_1^s.

- Experimental data analysis results(Xe+Sn@100AMeV) are compared with ImQMD model with SkM* and SLy4 parameter sets

Summary

- Flow parameters are calculated using Xe + Sn isotopic collision systems from INDRA campaign 4th experiment.

- Relation between N/Z ratio of collision system and N/Z of poi is founded

- Analysis results are compared with ImQMD model with its two parameter sets.

Thank you for your attention!

Merci de votre attention !

Acknowledgement

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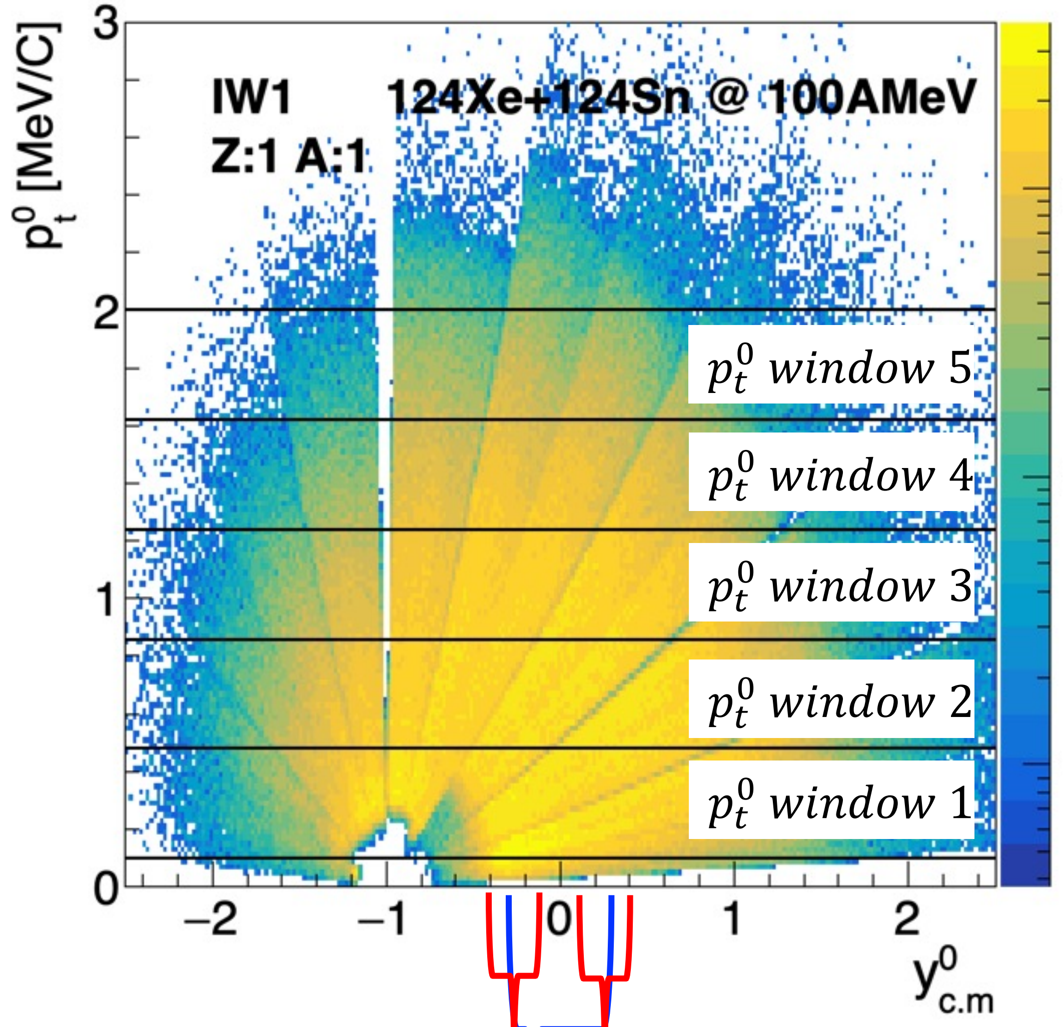
Back up



$v_2^s : -0.3 < y^0_{cm} < 0.3$

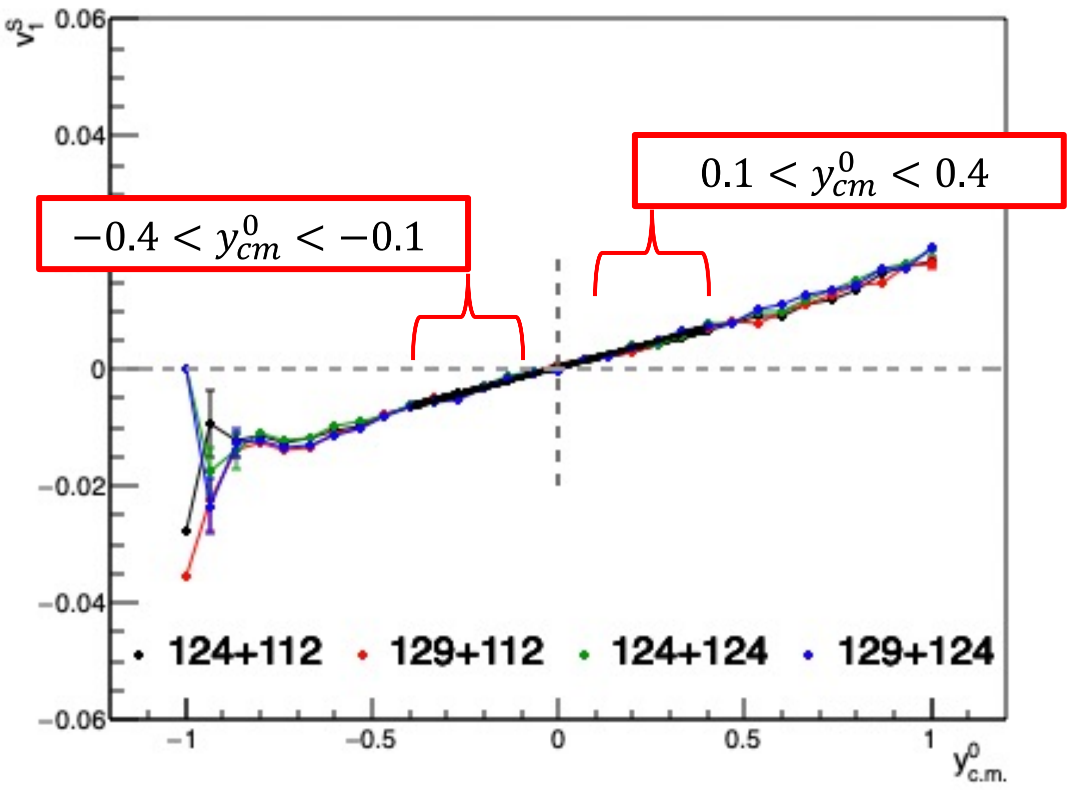
v_1^s : $0.1 < y^0_{cm} < 0.4$
$-0.4 < y^0_{cm} < -0.1$

$$p_t^0 \equiv \left(p_t^{cm}/_A\right) * \left(\left(\frac{A_P + A_t}{2}\right)\Big/ p_{beam}^{cm}\right)$$

$$y^0_{cm}(y > 0) = (y/|y_p|)^{cm}$$
$$y^0_{cm}(y < 0) = (y/|y_t|)^{cm}$$

System size scaled parameter

$$v_n^s = v_n\langle p_t^0\rangle / \left(A_P^{1/3} + A_T^{1/3}\right)$$



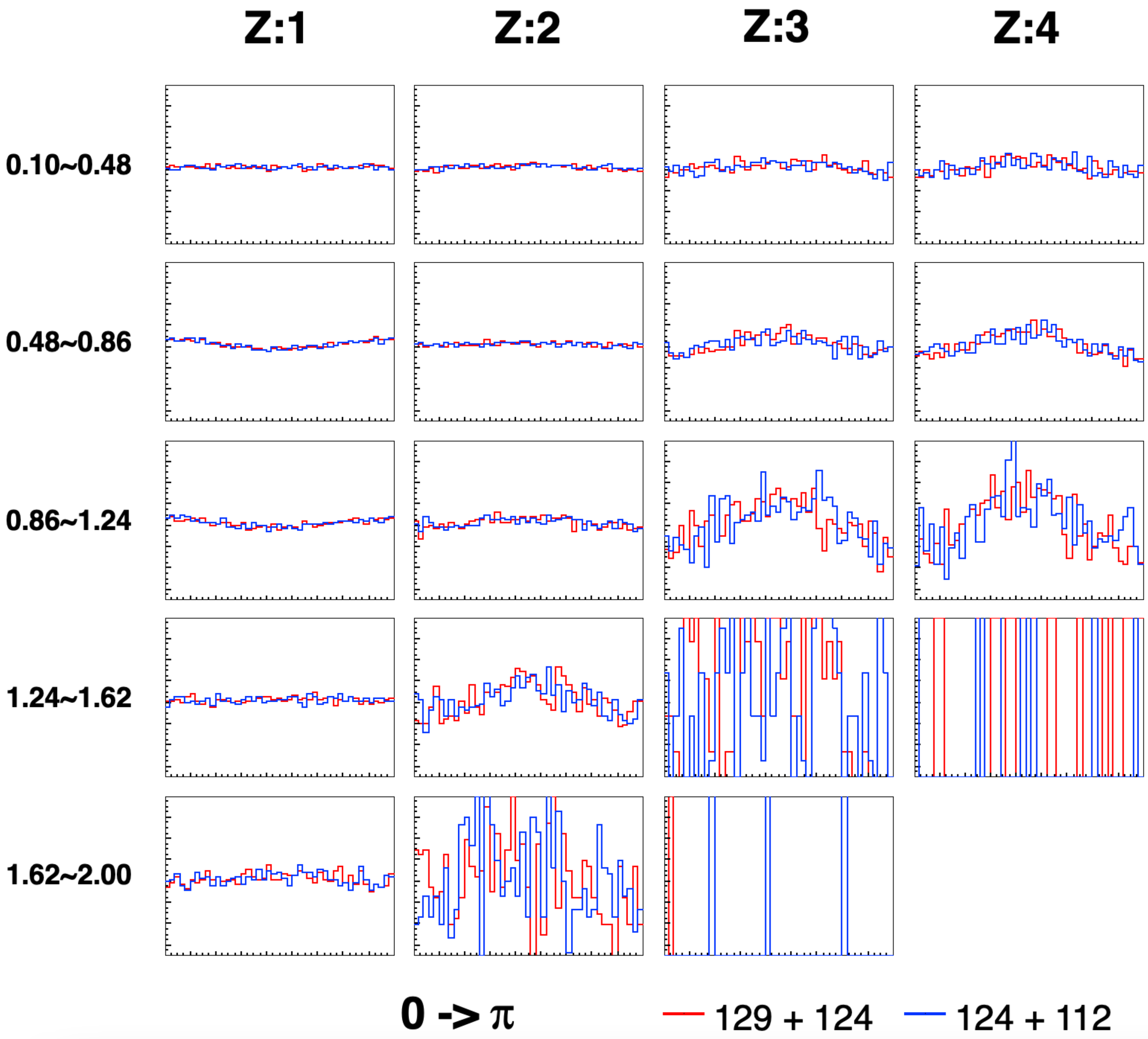
v_1^s :

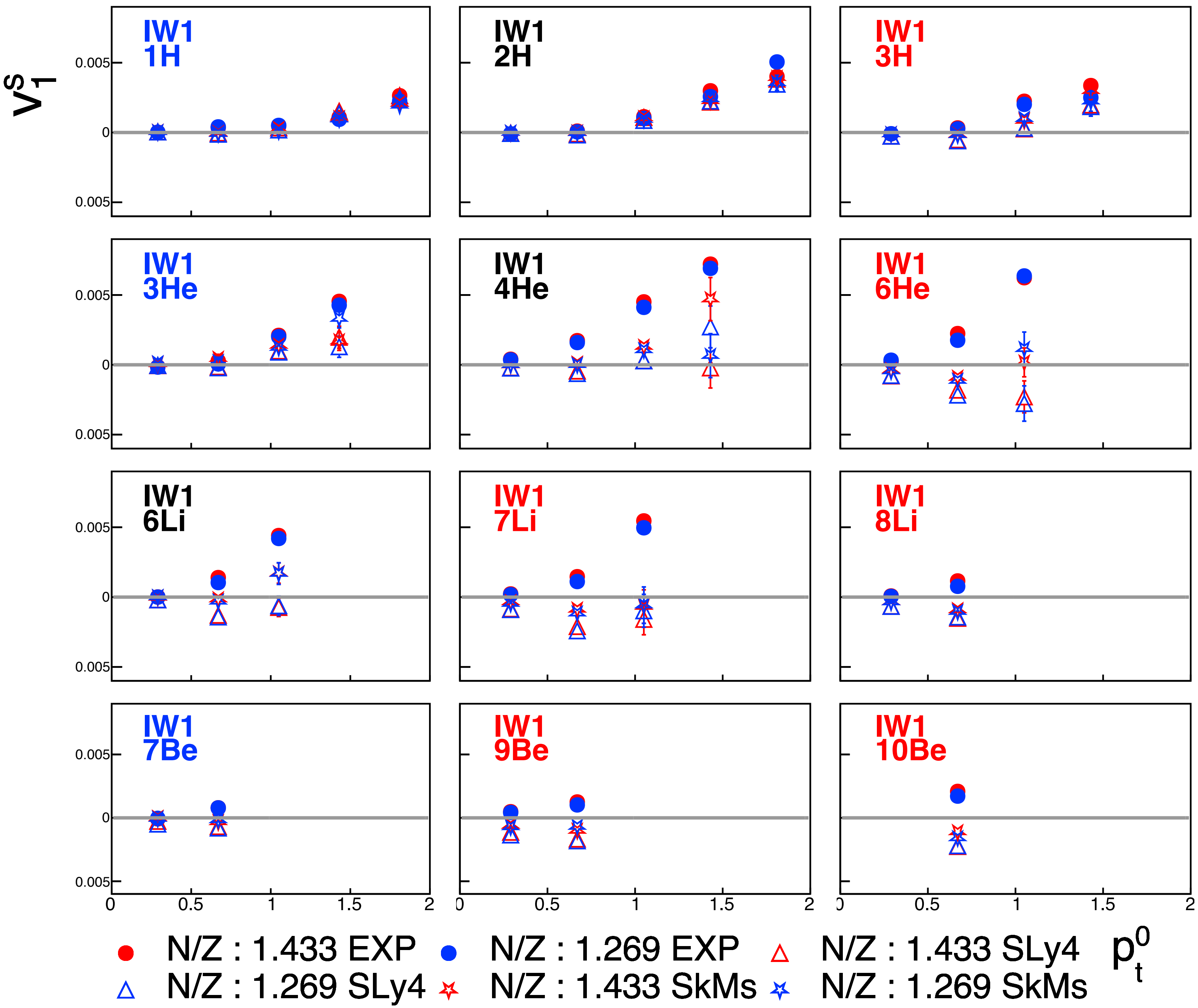
$0.1 < y^0_{cm} < 0.4 \;\rightarrow\; p_x/p_t$

$-0.4 < y^0_{cm} < -0.1 \;\rightarrow\; -(p_x/p_t)$

Squeeze out angle distribution

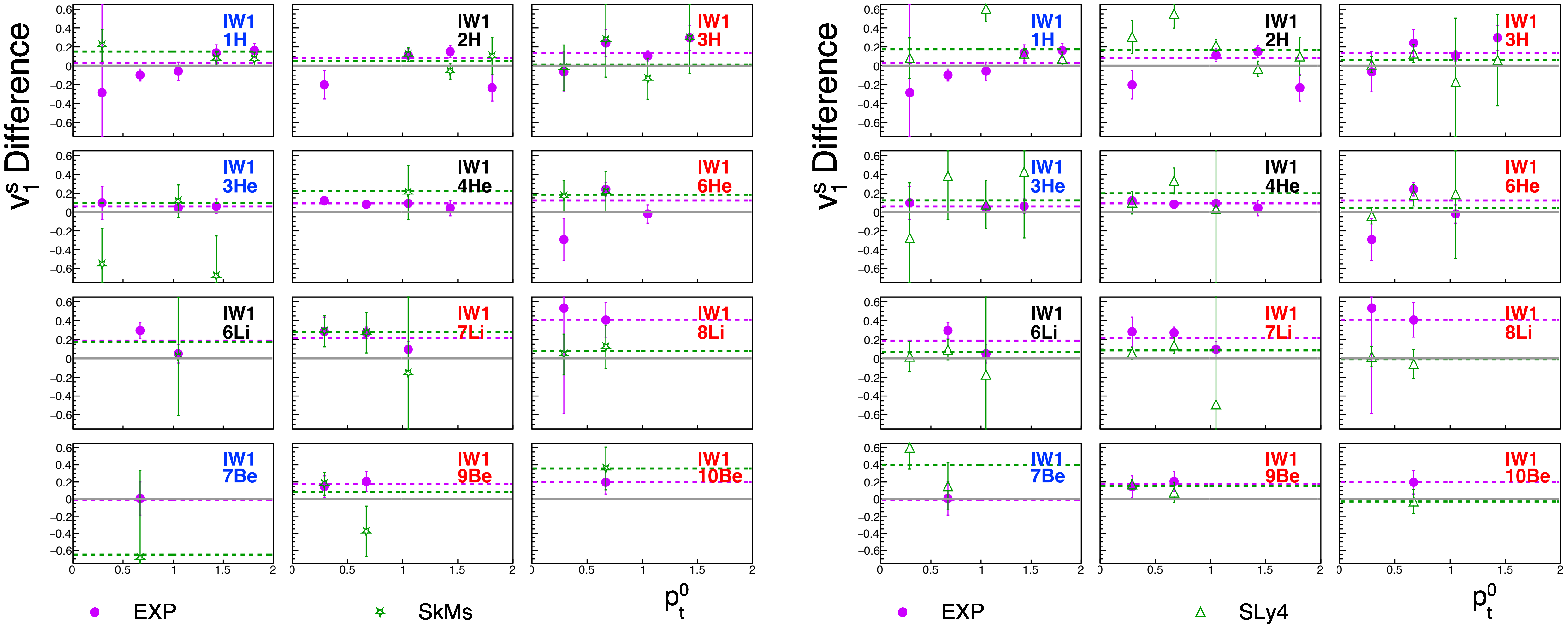
$-0.3 < y_{cm}^{0} < 0.3 \;\rightarrow\; (p_x^2 - p_y^2)/p_t^2$

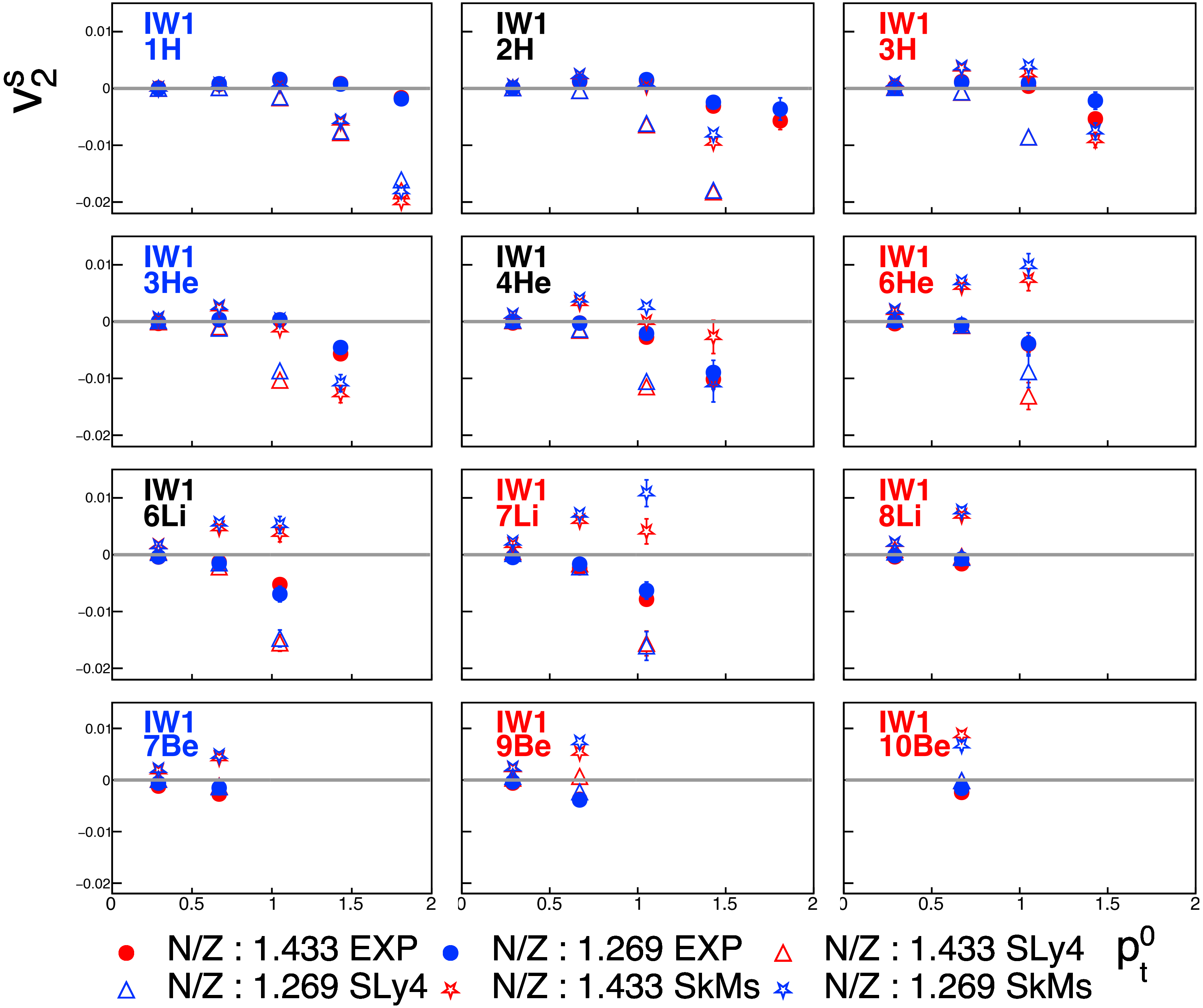




v_1^S
IW1 1H
IW1 2H
IW1 3H
IW1 3He
IW1 4He
IW1 6He
IW1 6Li
IW1 7Li
IW1 8Li
IW1 7Be
IW1 9Be
IW1 10Be
0.005
0
0.005
0 0.5 1 1.5 2
N/Z : 1.433 EXP
N/Z : 1.269 EXP
N/Z : 1.433 SLy4
N/Z : 1.269 SLy4
N/Z : 1.433 SkMs
N/Z : 1.269 SkMs
p_t^0

$$v_1^s \text{ Difference} \equiv \frac{v_1^s(\text{N/Z higher}) - v_1^s(\text{N/Z lower})}{\sqrt{v_1^s(\text{N/Z higher})^2 + v_1^s(\text{N/Z lower})^2}}$$





IW1 1H
IW1 2H
IW1 3H
IW1 3He
IW1 4He
IW1 6He
IW1 6Li
IW1 7Li
IW1 8Li
IW1 7Be
IW1 9Be
IW1 10Be
v_2^S
p_t^0
0.01
0
−0.01
−0.02
0
0.5
1
1.5
2
N/Z : 1.433 EXP
N/Z : 1.269 EXP
N/Z : 1.433 SLy4
N/Z : 1.269 SLy4
N/Z : 1.433 SkMs
N/Z : 1.269 SkMs

$$v_2^s \text{ Difference} \equiv \frac{v_2^s(N/Z \text{ higher}) - v_2^s(N/Z \text{ lower})}{\sqrt{v_2^s(N/Z \text{ higher})^2 + v_2^s(N/Z \text{ lower})^2}}$$