Isotopic Effects with INDRA@GSI

J. Łukasik,[1] W. Trautmann,[2] G. Auger,[3] M.L. Begemann-Blaich,[2] N. Bellaize,[5] R. Bittiger,[2] F. Bocage,[5] B. Borderie,[4] R. Bougault,[5] B. Bouriquet,[3] J.L. Charvet,[6] A. Chbihi,[3] R. Dayras,[6] D. Durand,[5] J.D. Frankland,[3] E. Galichet,[7] D. Gourio,[2] D. Guinet,[7] S. Hudan,[3] B. Hurst,[5] P. Lautesse,[7] F. Lavaud,[4] A. Le Fèvre,[2] R. Legrain,[6] O. Lopez,[5] U. Lynen,[2] W.F.J. Müller,[2] L. Nalpas,[6] H. Orth,[2] E. Plagnol,[4] E. Rosato,[8] A. Saija,[9] C. Sfienti,[2] C. Schwarz,[2] J.C. Steckmeyer,[5] B. Tamain,[5] A. Trzciński,[10] K. Turzó,[2] E. Vient,[5] M. Vigilante,[8] C. Volant,[6] and B. Zwiegliński[10]

(The INDRA and ALADIN Collaborations)

[1] IFJ-PAN, Kraków, Poland ♦ [2] GSI, Darmstadt, Germany ♦ [3] GANIL, Caen, France ♦ [4] IPN, Orsay, France
[5] LPC, Caen, France ♦ [6] DAPNIA, Saclay, France ♦ [7] IPN, Lyon, France ♦ [8] INFN, Napoli, Italy
[9] INFN, Catania, Italy ♦ [10] SINS, Warsaw, Poland

INDRA@GSI:

^{124}Xe+^{112}Sn @ 100 AMeV (N/Z=1.27)

^{129}Xe+^{112}Sn @ 100 AMeV (N/Z=1.32)

^{124}Xe+^{124}Sn @ 100 AMeV (N/Z=1.38)

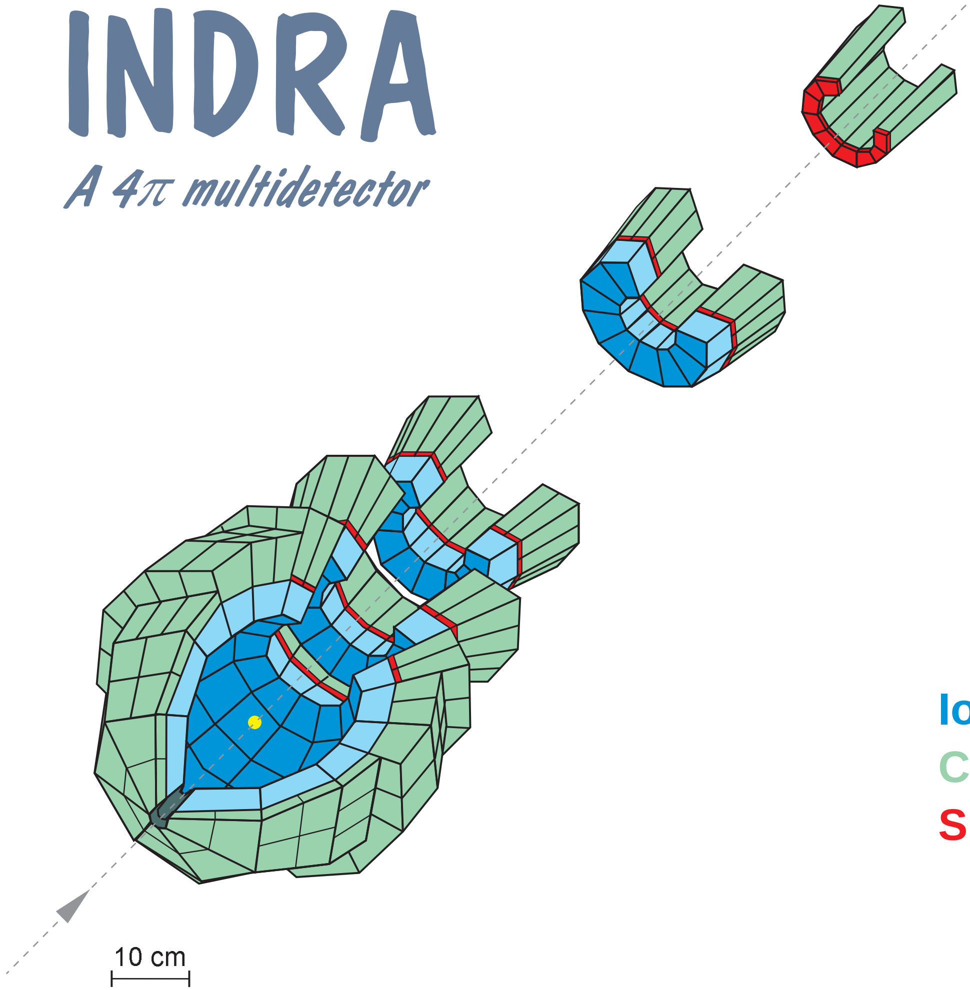
^{129}Xe+^{124}Sn @ 100 AMeV (N/Z=1.43)

^{124}Xe+^{124}Sn @ 150 AMeV (N/Z=1.38)

^{129}Xe+^{124}Sn @ 150 AMeV (N/Z=1.43)

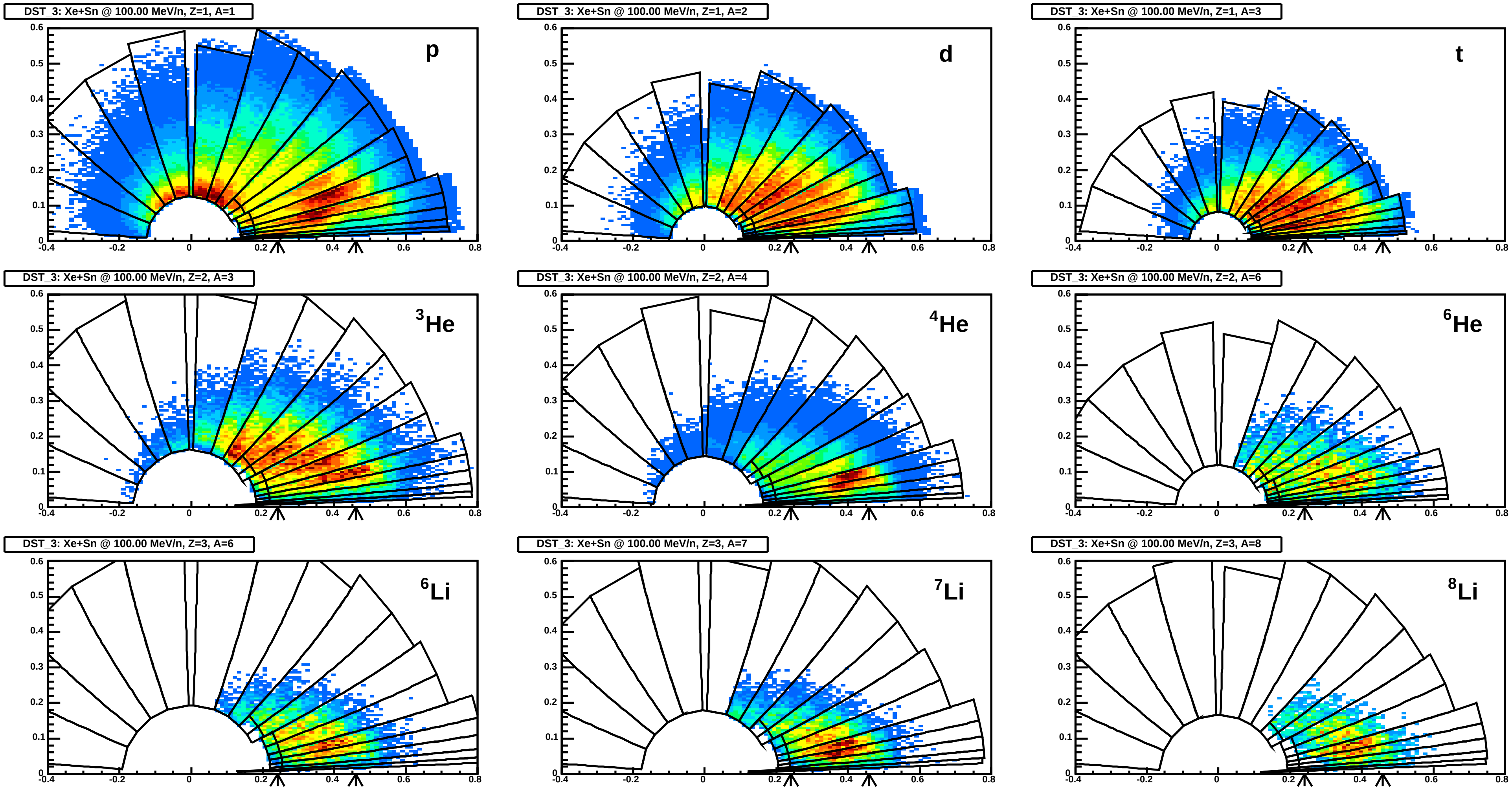
INDRA

A 4π multidetector



Ionization Chamber (96)
CsI(Tl) (336)
Silicon (192)

Yield distributions for $\gamma\beta_\perp$ vs y (Xe+Sn@100 AMeV)



Thresholds below mid-rapidity for isotopically resolved light fragments

Definitions: v_1, v_2 / Q-vector

Fourier decomposition of the azimuthal distributions with respect to the **reaction plane** (ϕ_R):

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

$$v_1 \equiv \langle \cos(\phi - \phi_R) \rangle \qquad \text{directed flow}$$

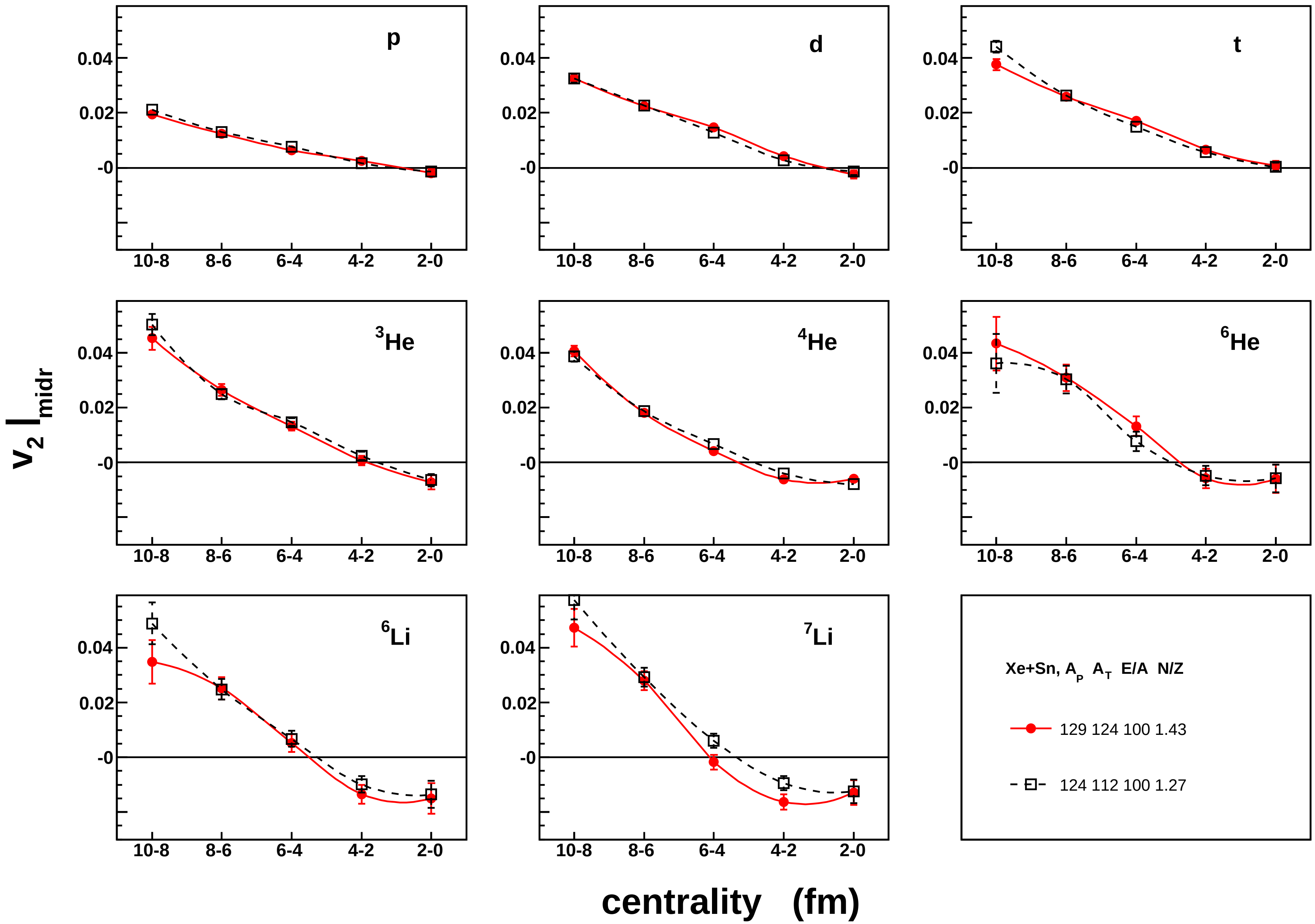
$$v_2 \equiv \langle \cos 2(\phi - \phi_R) \rangle \qquad \text{elliptic flow}$$

$$v_n = v_n(b, Z, A, y, p^{\perp})$$

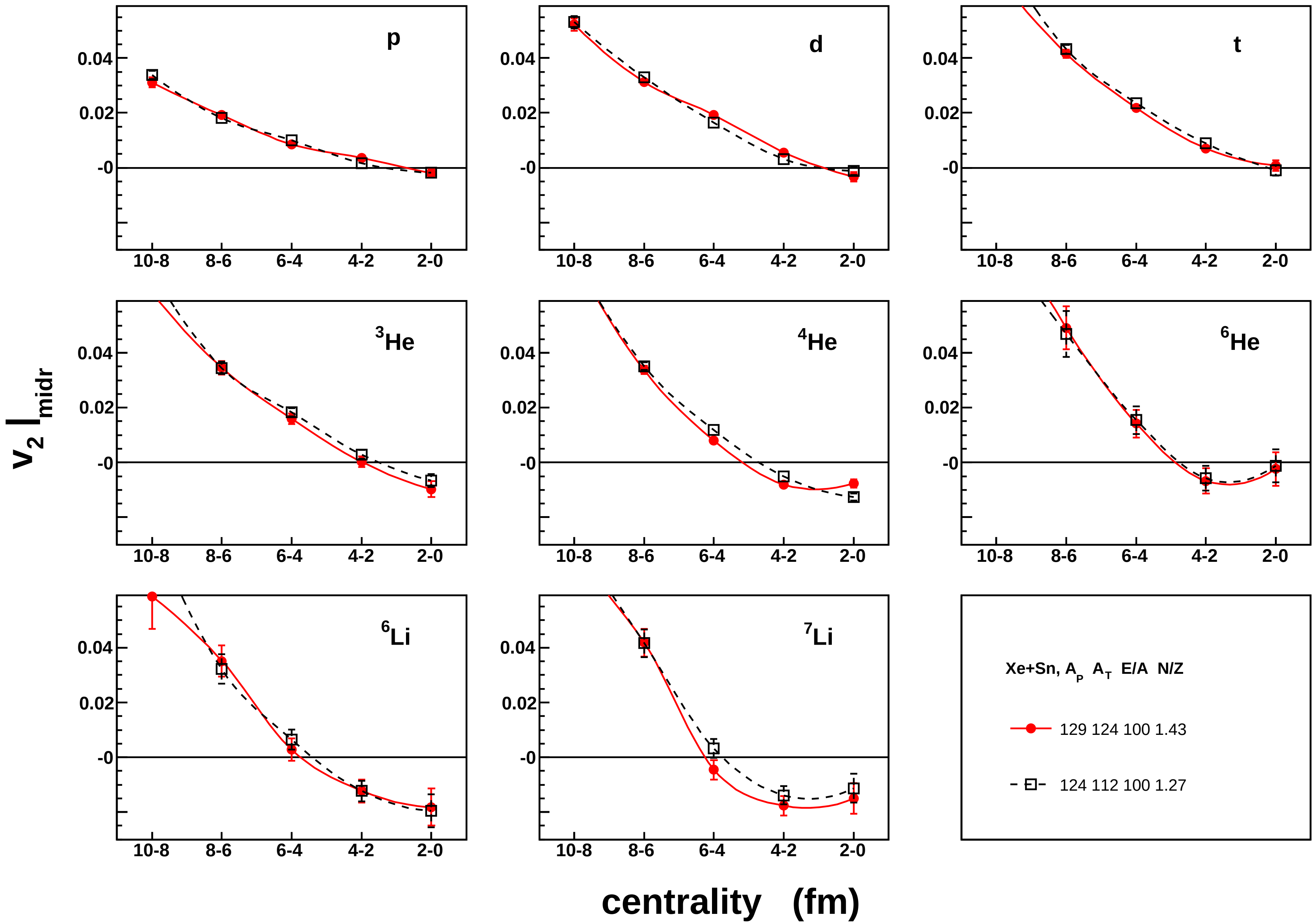
'Q-vector' method for reaction plane estimate (P. Danielewicz and G. Odyniec, Phys. Lett. B 157(1985)146):

$$\vec{Q} = \sum_{i=1}^{N} \omega_i \vec{p}_i^{\,\perp}, \qquad \omega_i = \mathrm{sign}(y_{cm})$$

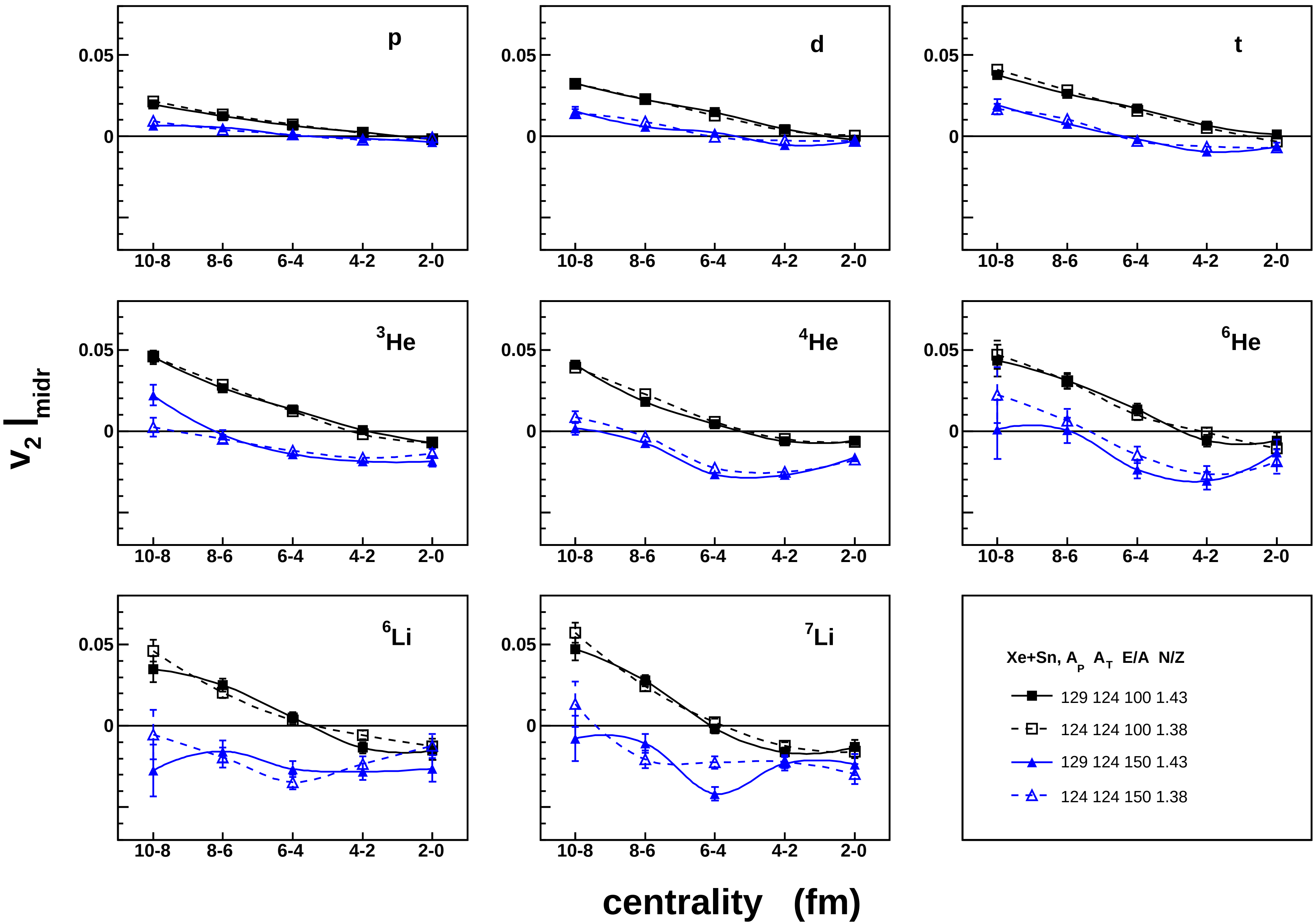
v_2 at midrapidity Xe+Sn@100AMeV, extreme N/Z



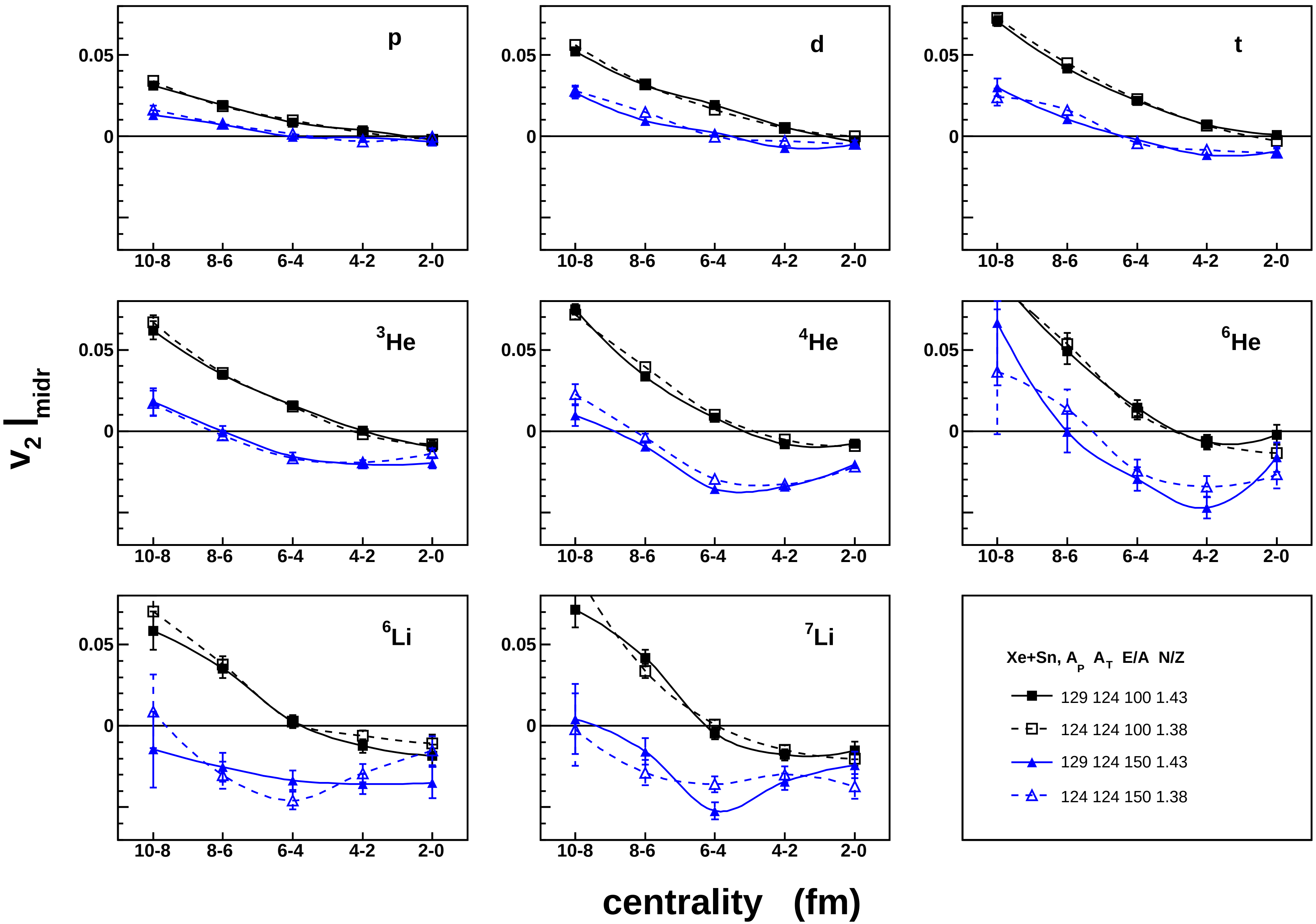
v_2 at midrapidity Xe+Sn@100AMeV, extreme N/Z, $\gamma\beta_\perp > 0.10$



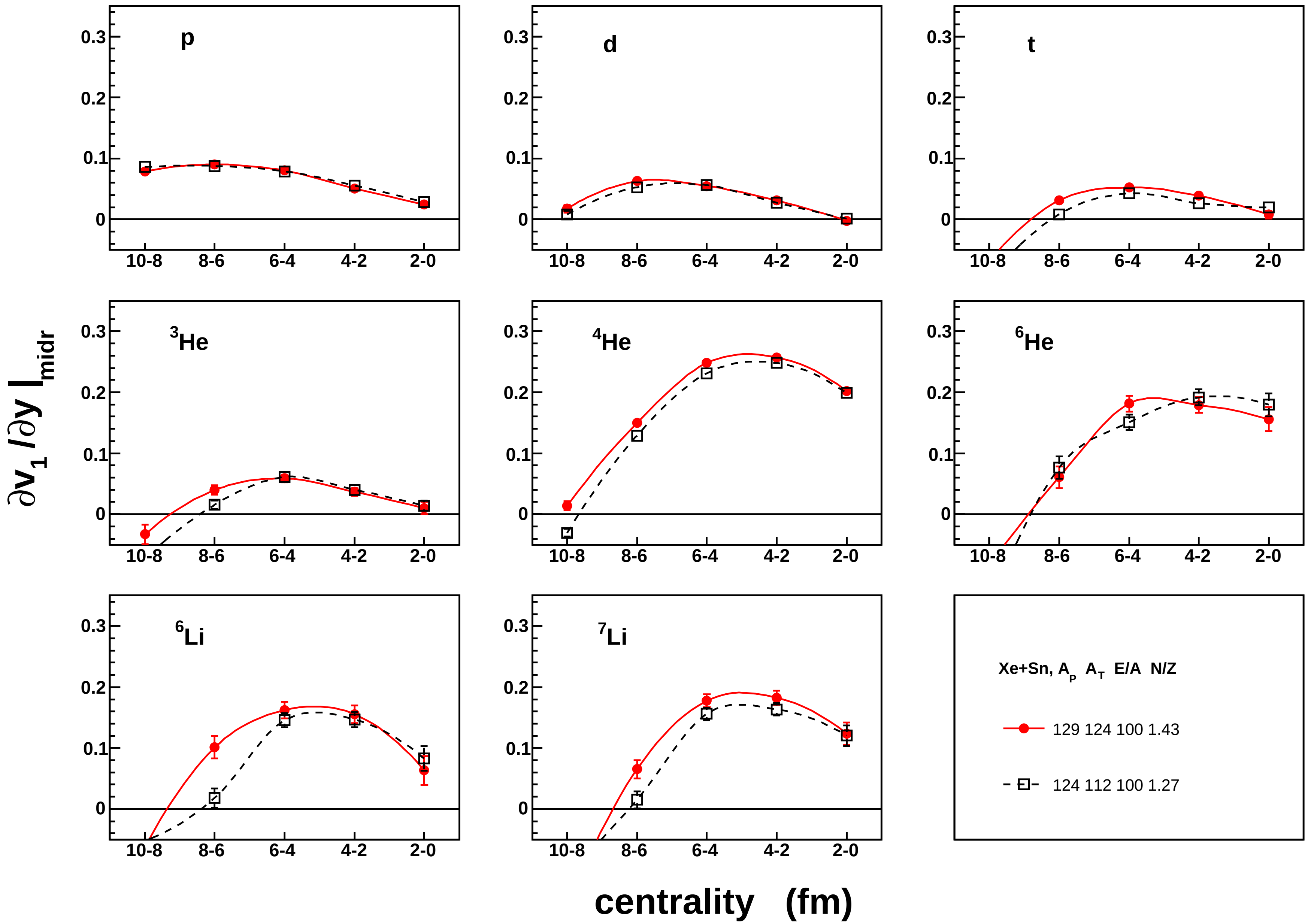
v_2 at midrapidity Xe+Sn@100 and 150 AMeV, same N/Z



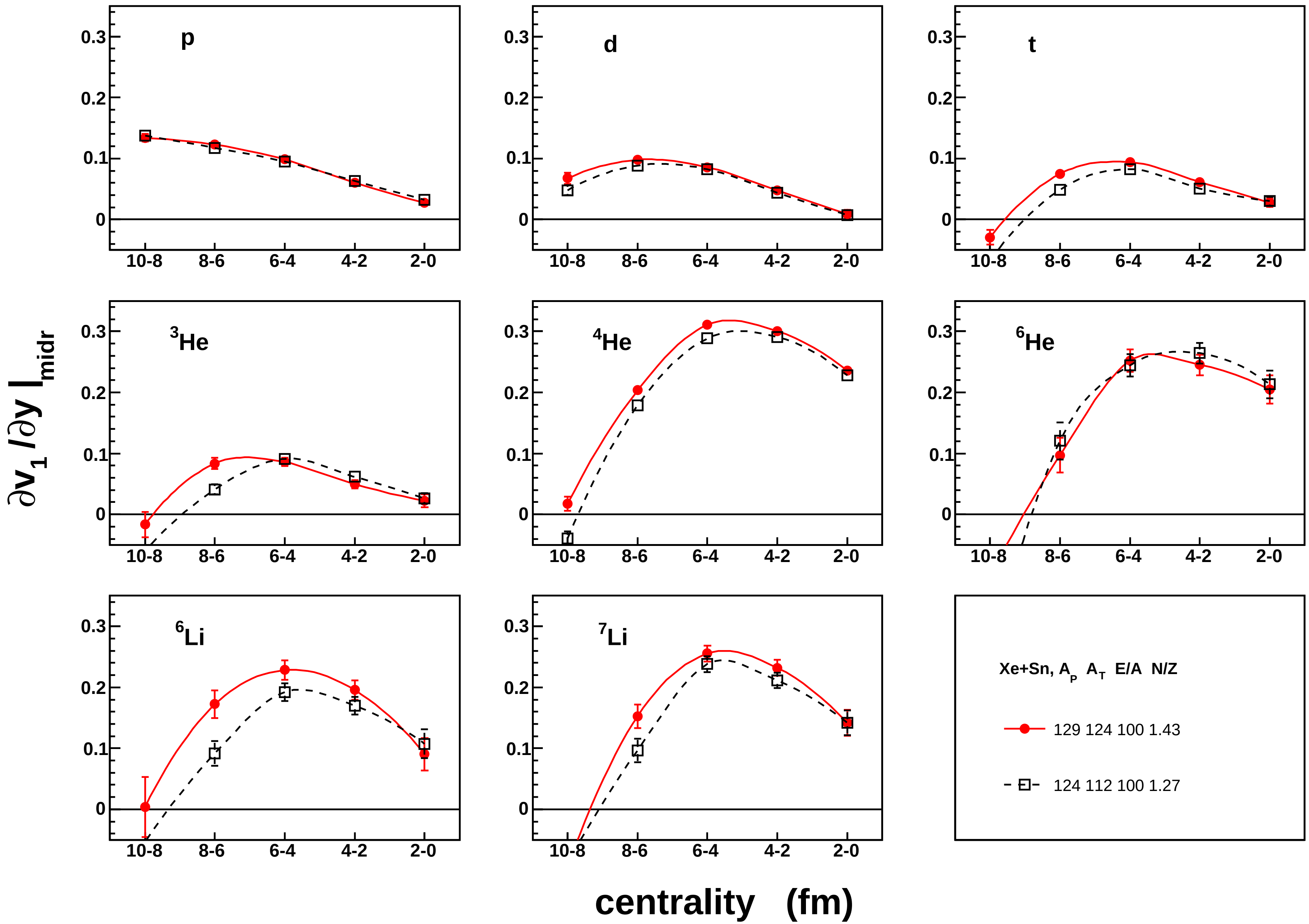
v_2 at midrapidity Xe+Sn@100 and 150 AMeV, same N/Z, $\gamma\beta_\perp > 0.10$



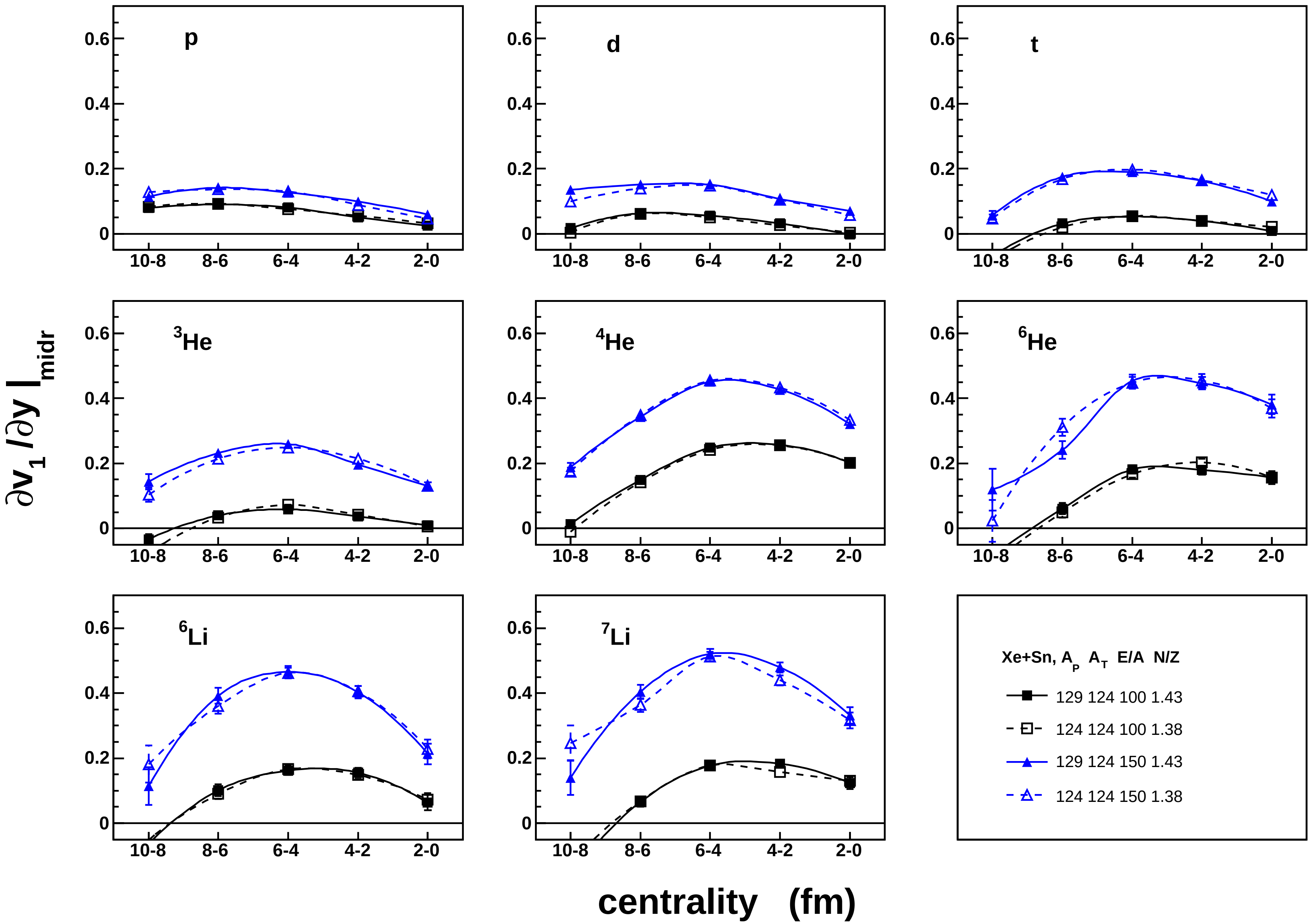
slope of v_1 at midrapidity Xe+Sn@100AMeV, extreme N/Z



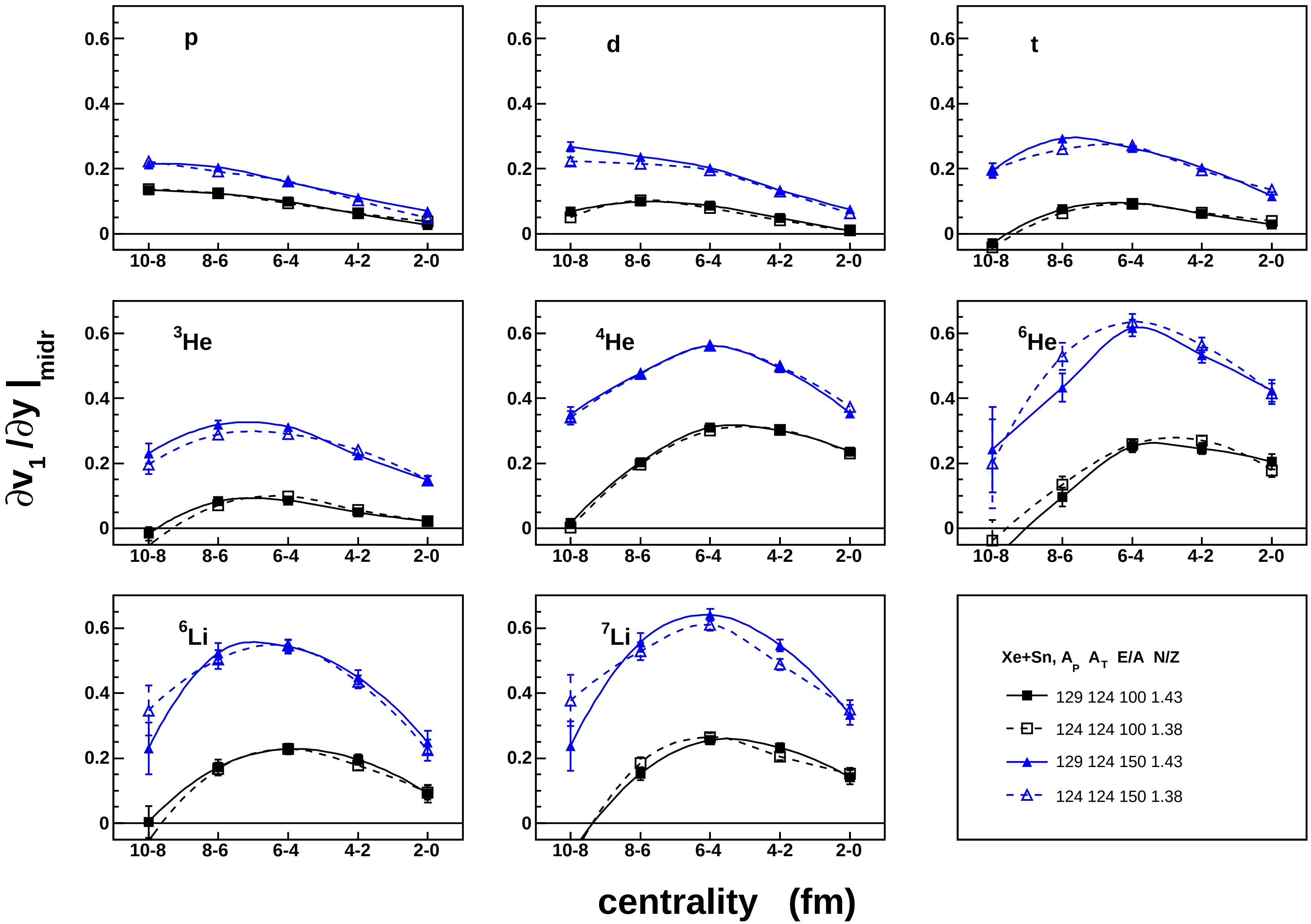
slope of v_1 at midrapidity Xe+Sn@100AMeV, extreme N/Z, $\gamma\beta_\perp > 0.10$



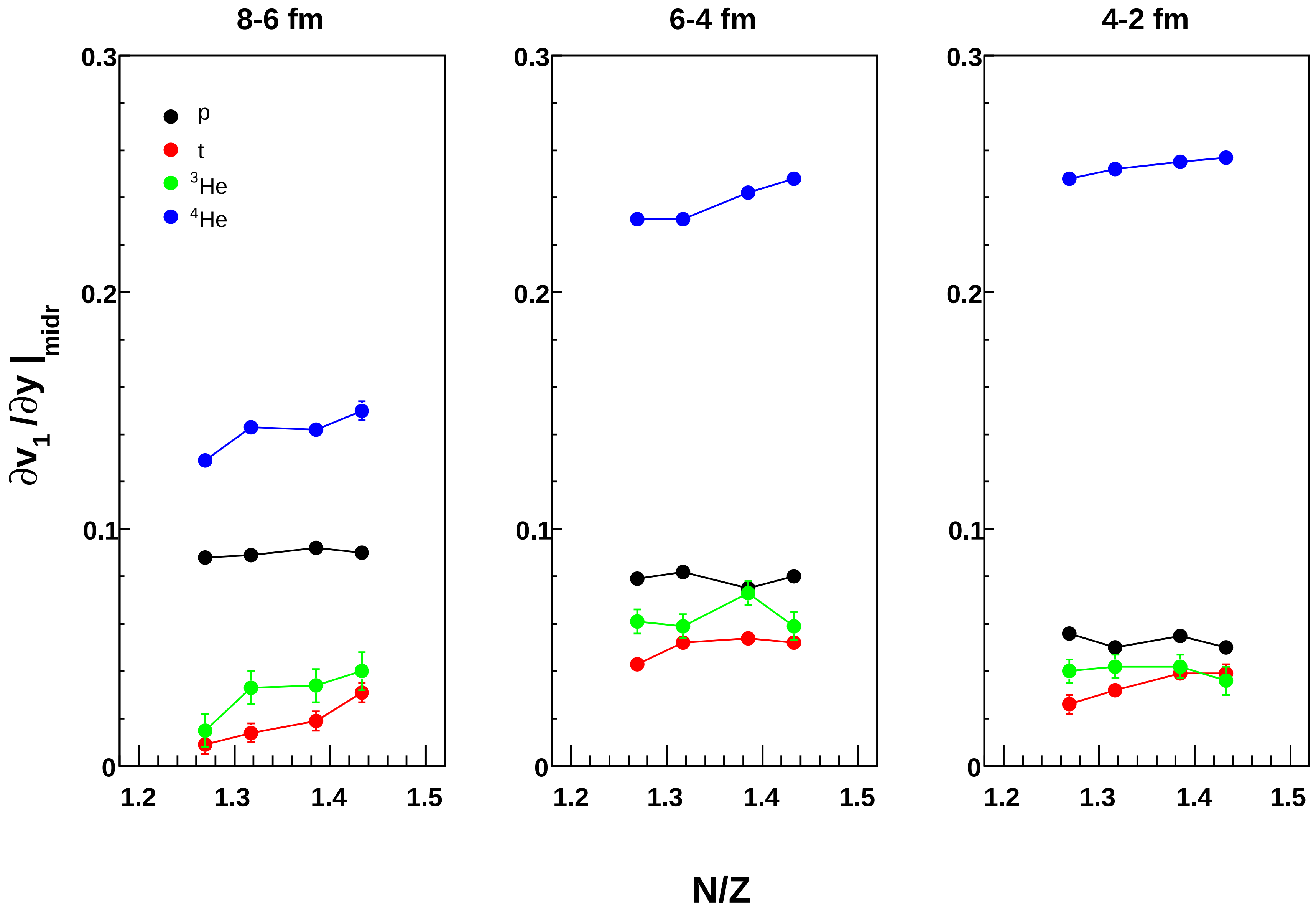
slope of v_1 at midrapidity Xe+Sn@100 and 150 AMeV, same N/Z



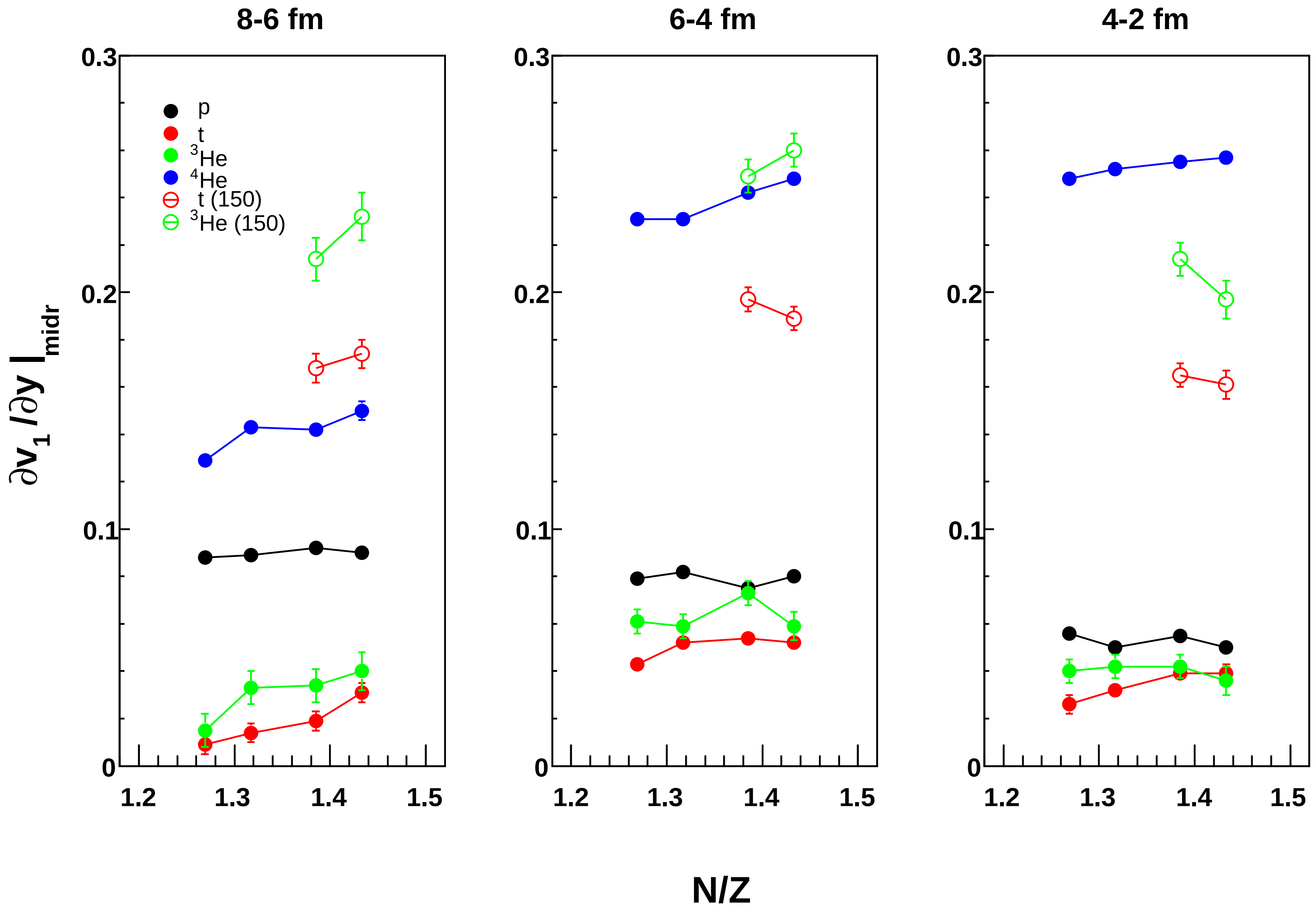
slope of v_1 at midrapidity Xe+Sn@100 and 150 AMeV, same N/Z, $\gamma\beta_\perp > 0.10$



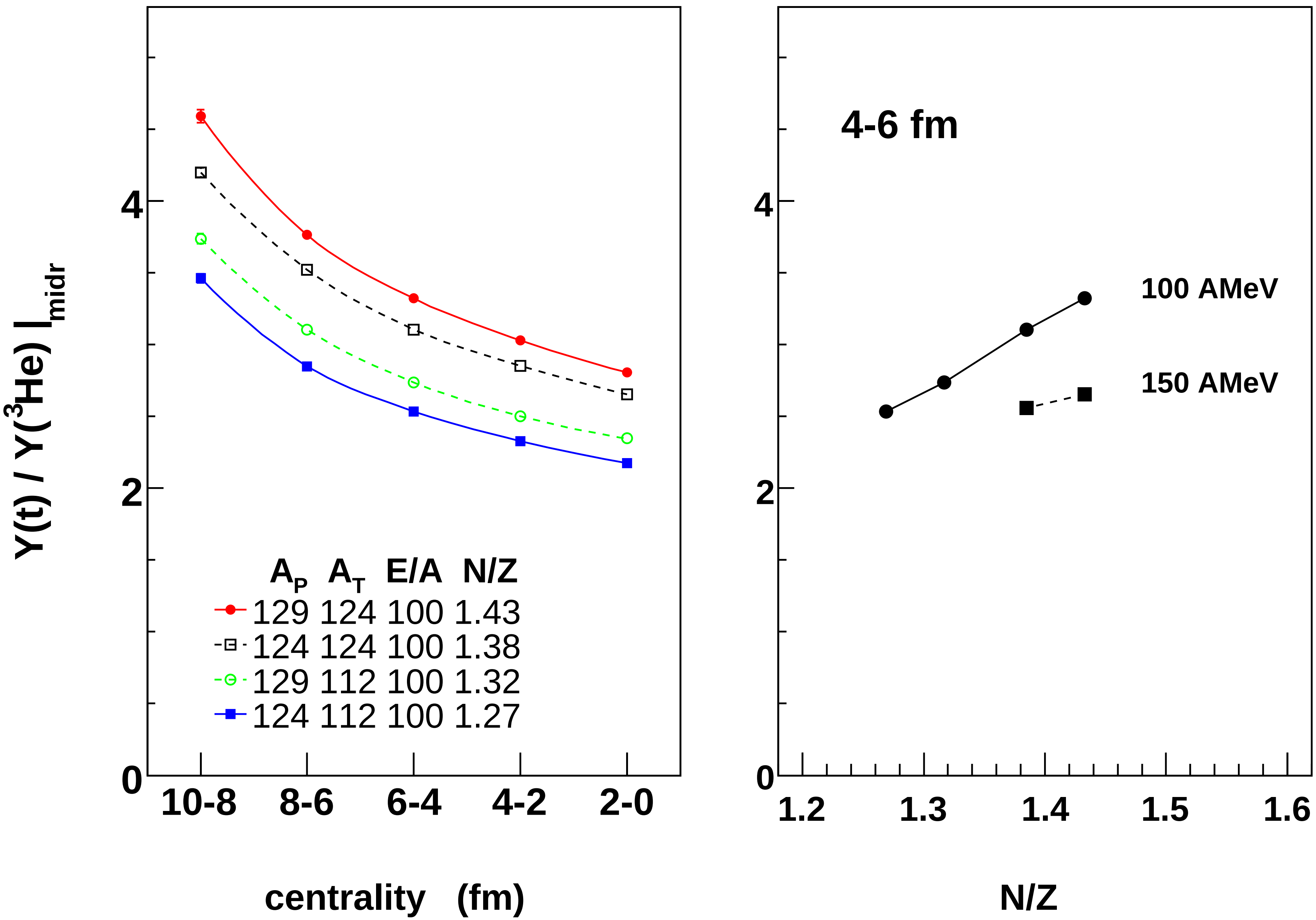
slope of v_1 at midrapidity Xe+Sn@100 vs. N/Z

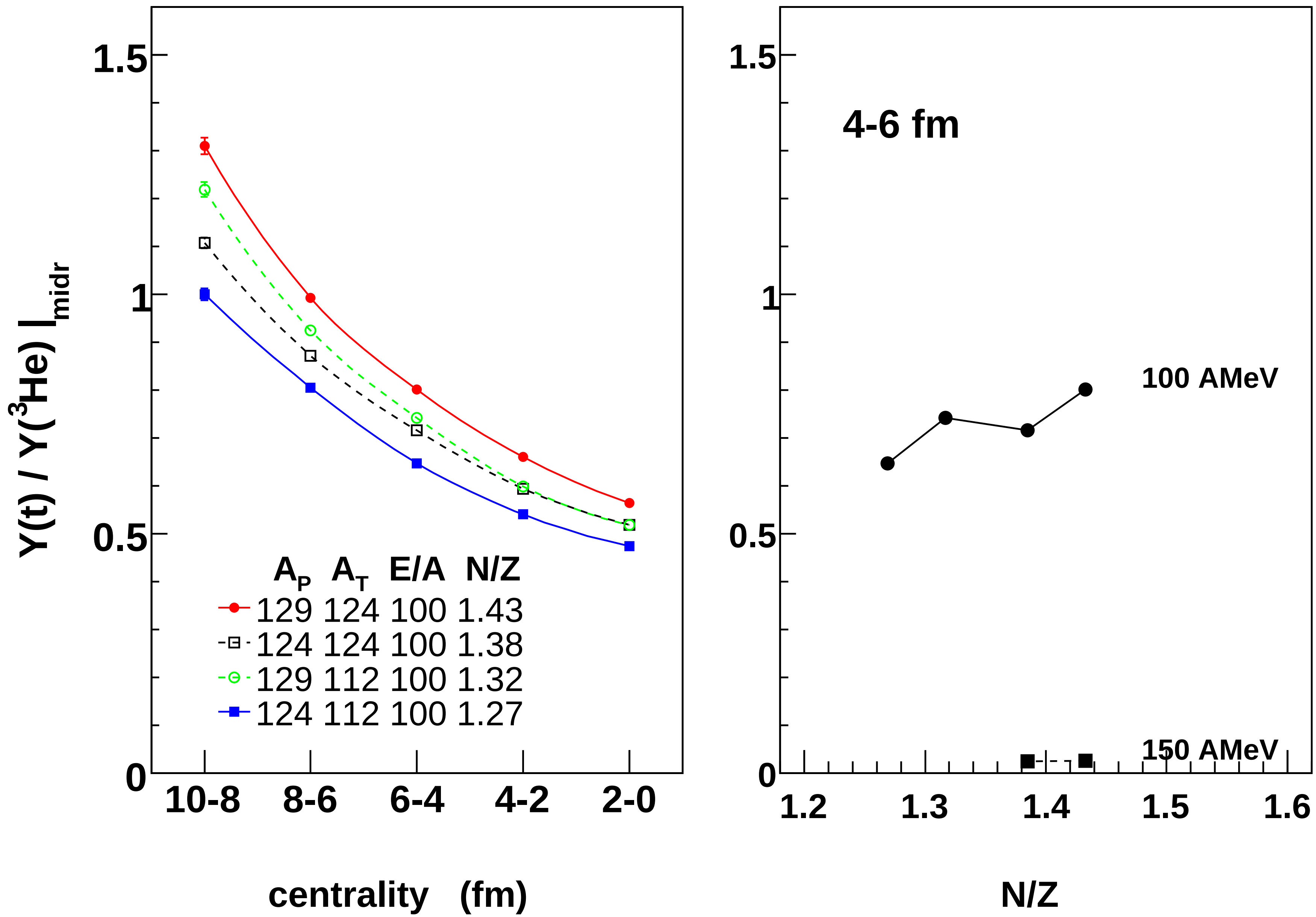


slope of v_1 at midrapidity Xe+Sn@100 and 150 AMeV vs. N/Z



$t/^3He$ at midrapidity Xe+Sn@100 and 150 AMeV




1.5
1
0.5
0
Y(t) / Y(3He) |midr
AP AT E/A N/Z
129 124 100 1.43
124 124 100 1.38
129 112 100 1.32
124 112 100 1.27
10-8
8-6
6-4
4-2
2-0
centrality (fm)
4-6 fm
100 AMeV
150 AMeV
1.2
1.3
1.4
1.5
1.6
N/Z

Neutron-proton differential flow (Bao-An Li PRL 80(2002)192701)

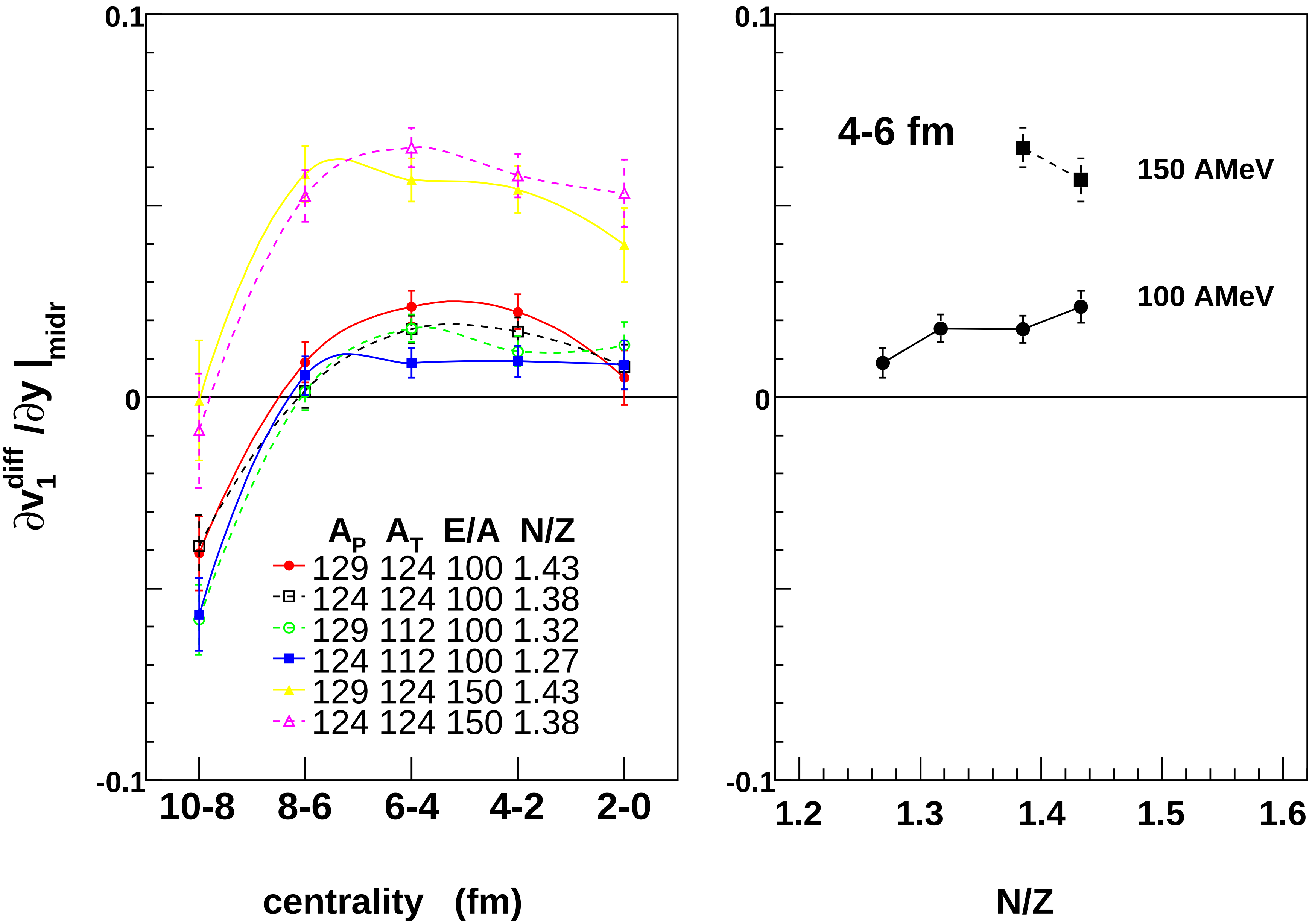
$$F^x_{n-p}(y) \equiv \frac{1}{N(y)} \sum_{i=1}^{N(y)} p^x_i(y)\tau_i = \frac{N_n(y)}{N(y)} \langle p^x_n(y) \rangle - \frac{N_p(y)}{N(y)} \langle p^x_p(y) \rangle$$

where $N_n(y)$, $N_p(y)$ are the numbers of free neutrons and protons at rapidity y,
$N(y) = N_n(y) + N_p(y)$, $p^x_n(y)$ - in-plane transverse momentum, $\tau_i = 1$ (-1) for neutrons (protons).

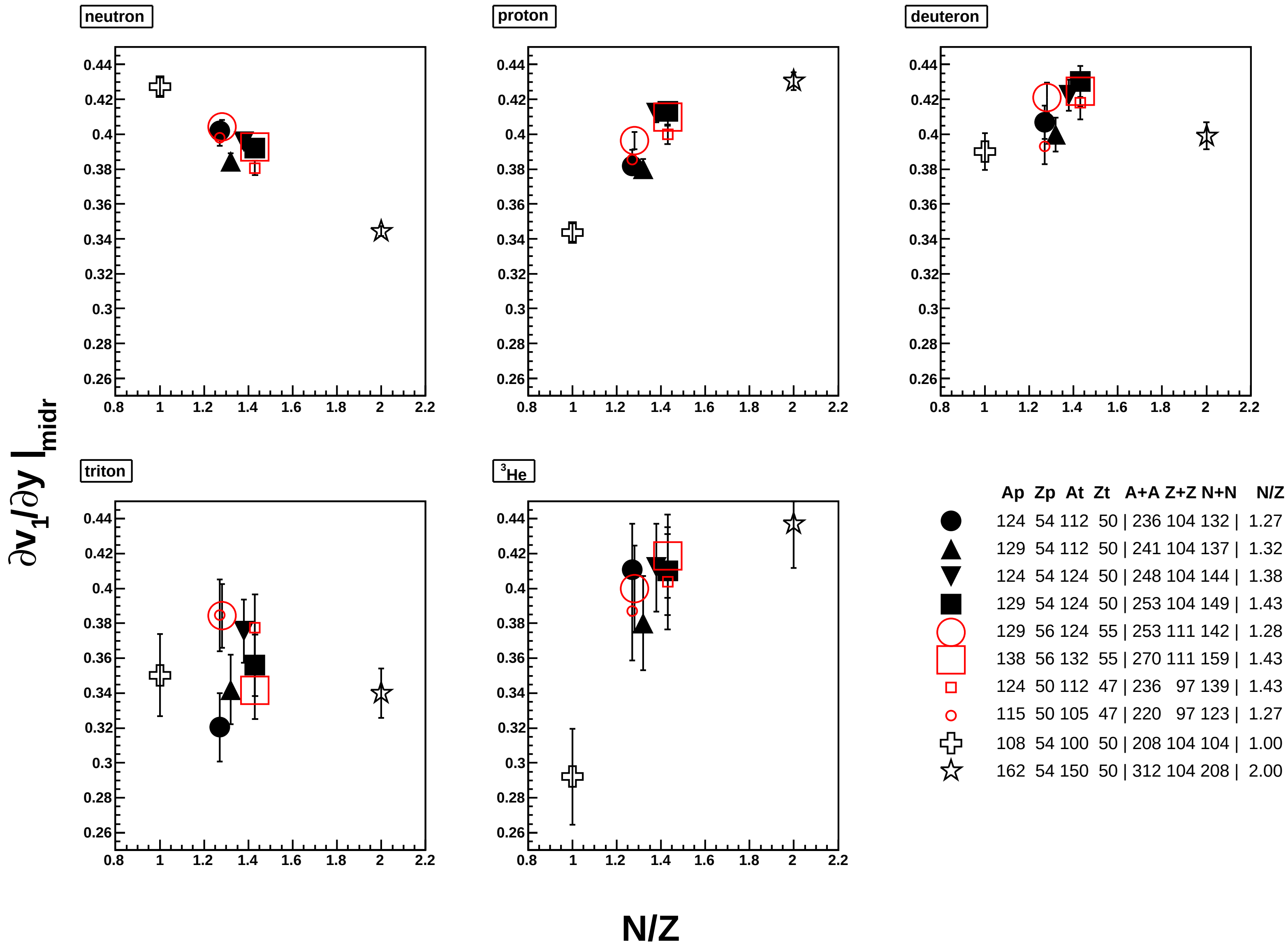
Modification for isobars $t \equiv (1)$ and $^3He \equiv (2)$ and v_1:

$$v_1^{diff}(y) = \frac{N_{(1)}(y)}{N(y)} \langle v_1^{(1)}(y) \rangle - \frac{N_{(2)}(y)}{N(y)} \langle v_1^{(2)}(y) \rangle$$

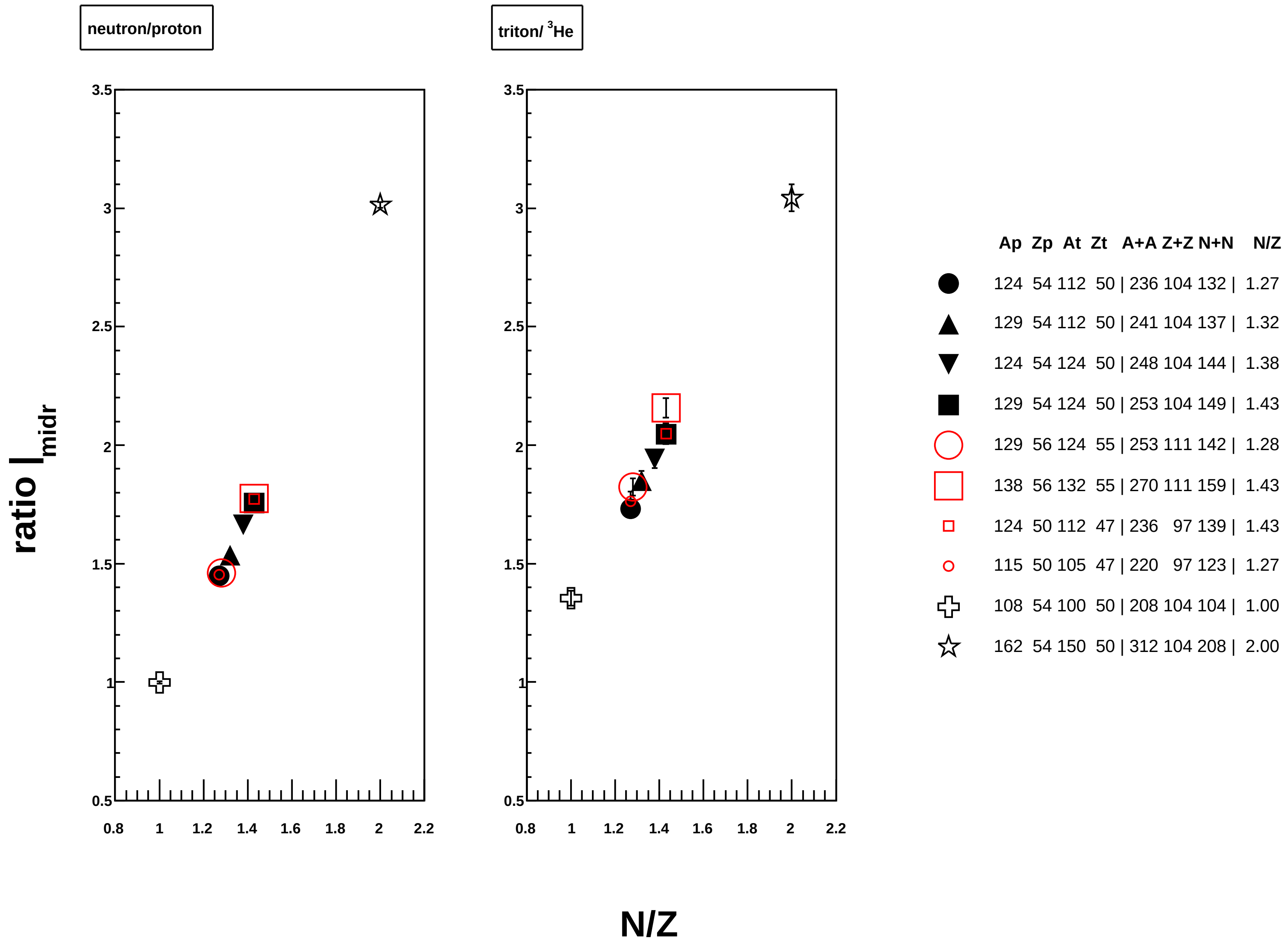
slope of $v_1^{diff}(y)$ at midrapidity Xe+Sn@100 and 150 AMeV



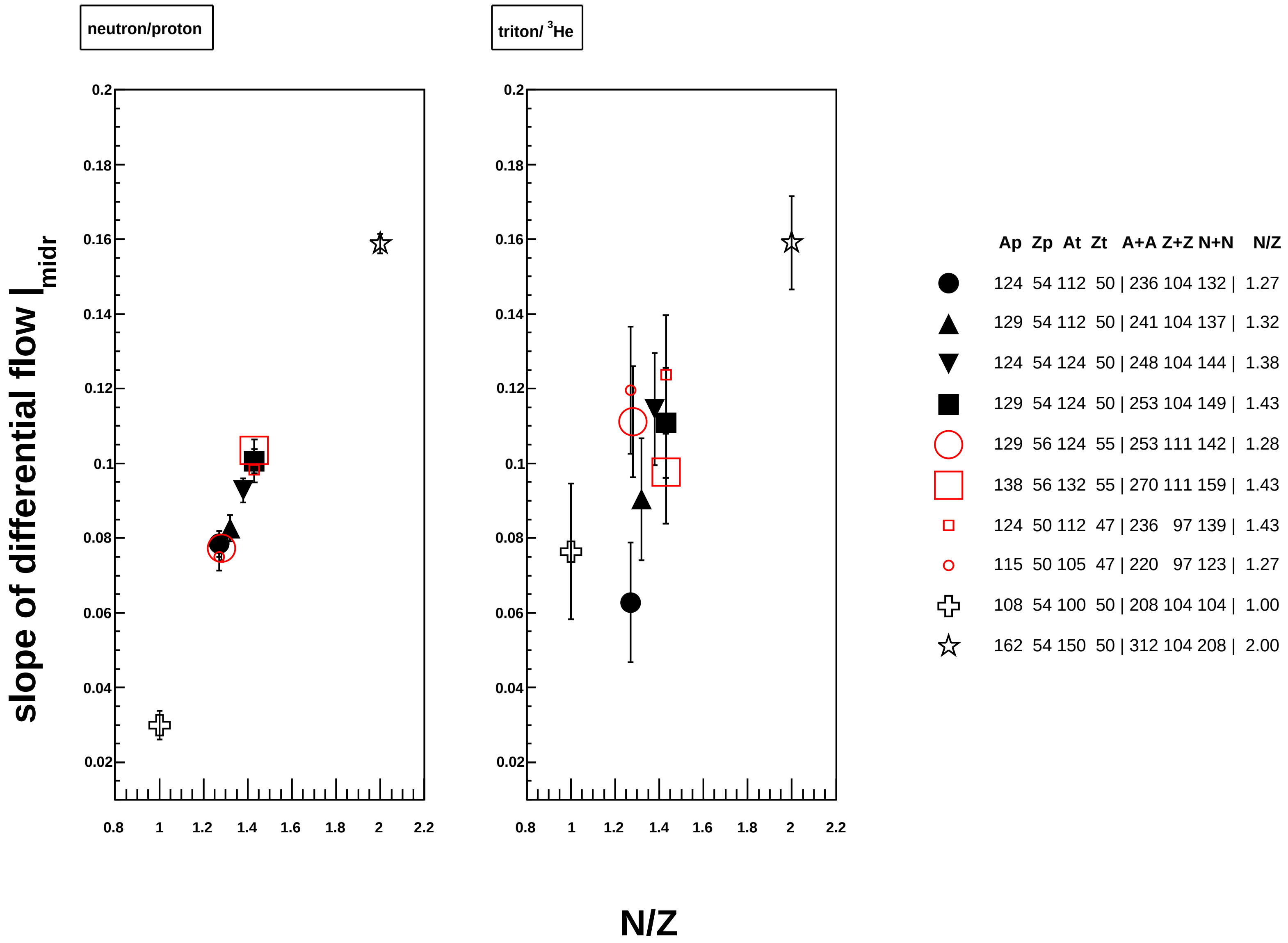
CHIMERA(QMD), slope of v_1 at midrapidity 100AMeV, 3<b<6 fm



CHIMERA(QMD), ratios at midrapidity 100AMeV, 3<b<6 fm



CHIMERA(QMD), differential flow at midrapidity 100AMeV, 3<b<6 fm



INDRA:

- Tiny isotopic effects for light isotopes (a bit better for heavier)
- Possible evolution with incident energy (small enhancements)
- Small enhancements with increasing p_T cuts
- Production of light isobars - sensitive

CHIMERA(QMD):

- Small system size effects
- Similar trends as in the experiment
- Exotic beams (and targets) needed...