

INDRA@GSI : Collective Flow from Fermi to Relativistic Energies

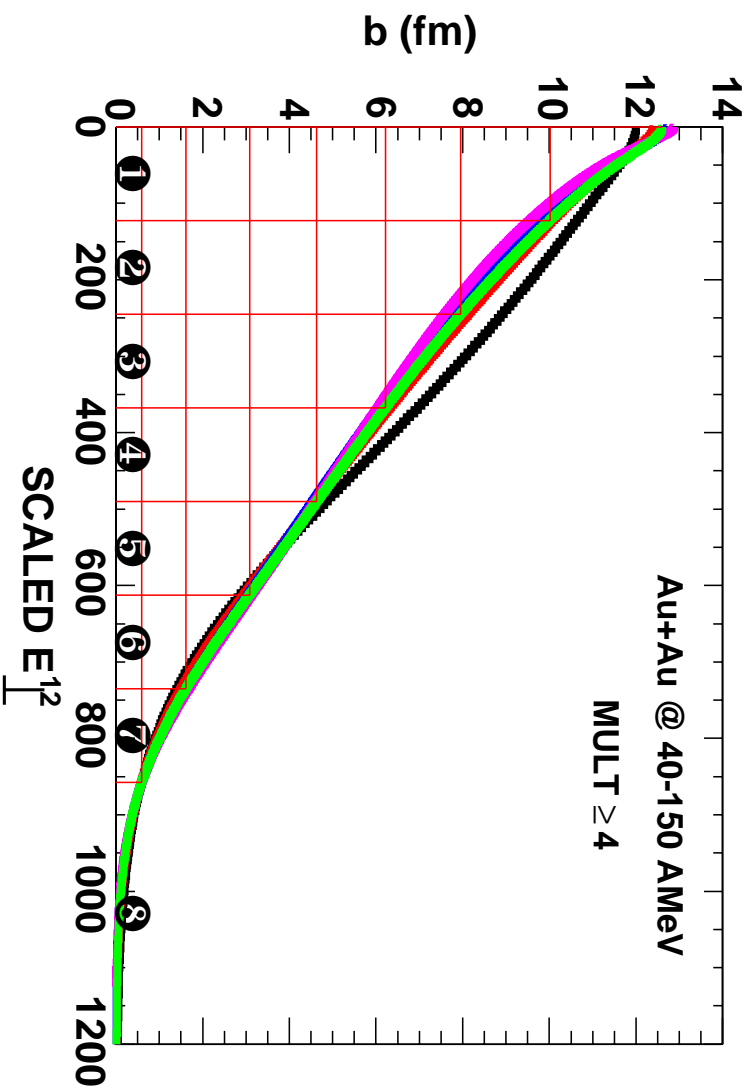
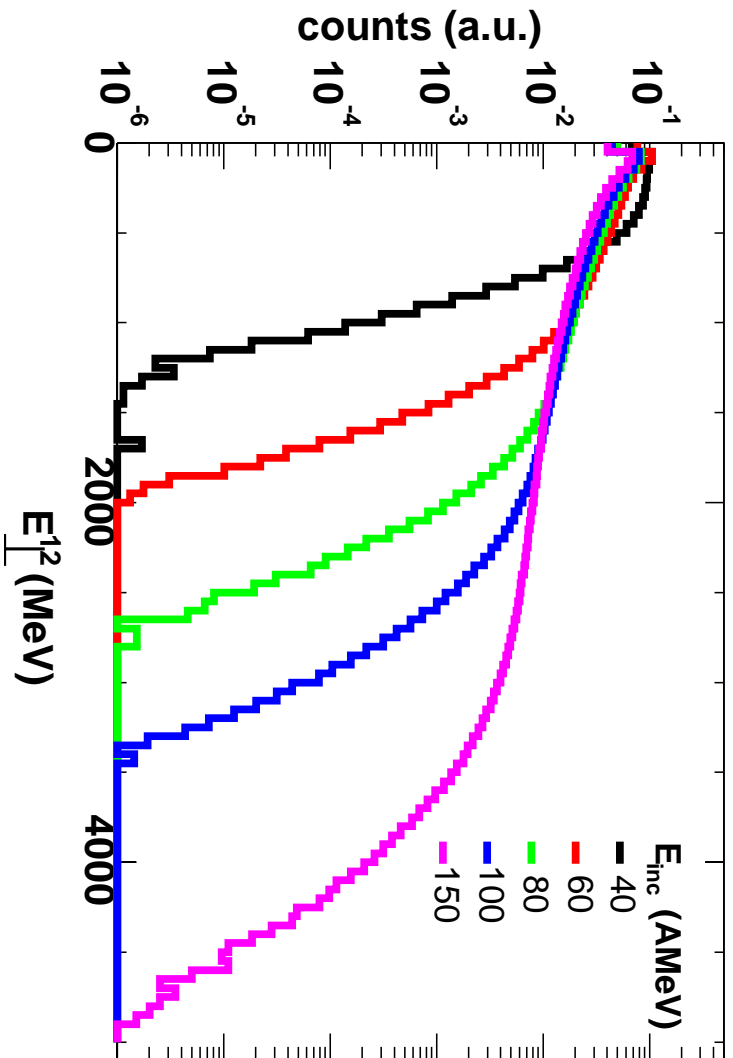
J. Lukasik,^{1,10} W. Trautmann,¹ G. Auger,² M.L. Begemann-Blaich,¹ N. Bellaize,⁴ R. Bittiger,¹ F. Bocage,⁴
B. Borderie,³ R. Bougault,⁴ B. Bouriquet,² J.L. Charvet,⁵ A. Chbihi,² R. Dayras,⁵ D. Durand,⁴
J.D. Frankland,² E. Galichet,⁶ D. Gourio,¹ D. Guinet,⁶ S. Hudan,² B. Hurst,⁴ P. Lautesse,⁶ F. Lavaud,³
A. Le Fèvre,¹ R. Legrain,⁵ O. Lopez,⁴ U. Lynen,¹ W.F.J. Müller,¹ L. Nalpas,⁵ H. Orth,¹ E. Plagnol,³
E. Rosato,⁷ A. Saija,⁸ C. Sfienti,¹ C. Schwarz,¹ J.C. Steckmeyer,⁴ B. Tamain,⁴ A. Trzeciński,⁹ K. Turzó,¹
E. Vient,⁴ M. Vigilante,⁷ C. Volant,⁵ B. Zwiegliński⁹
(The INDRA and ALADIN Collaborations)

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

Au+Au @ 40-150 MeV/nucleon

- Squeeze angle and squeeze-out ratio
- Directed and elliptic flow
- Summary and Conclusions

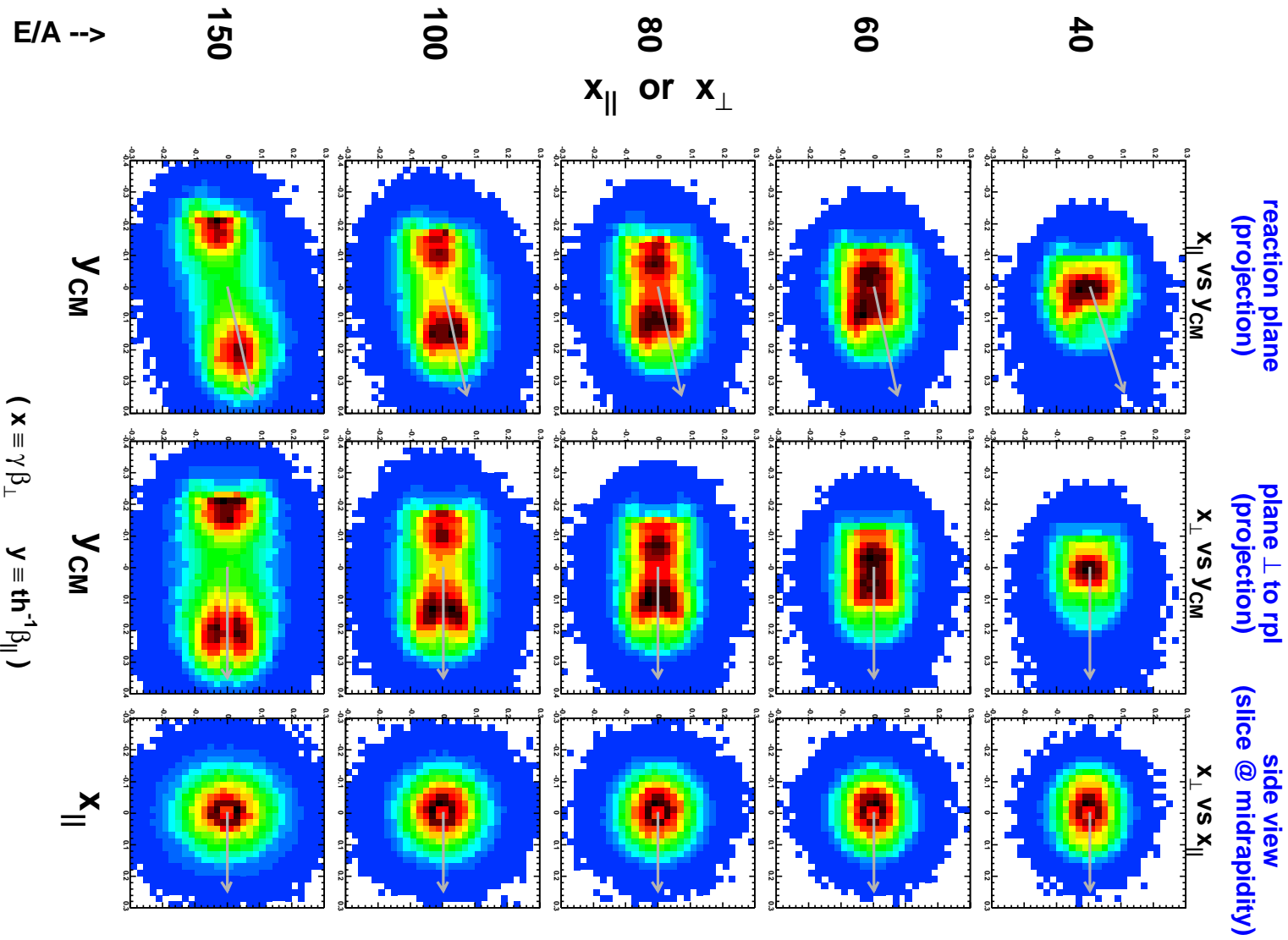
INDRA: Centrality selection



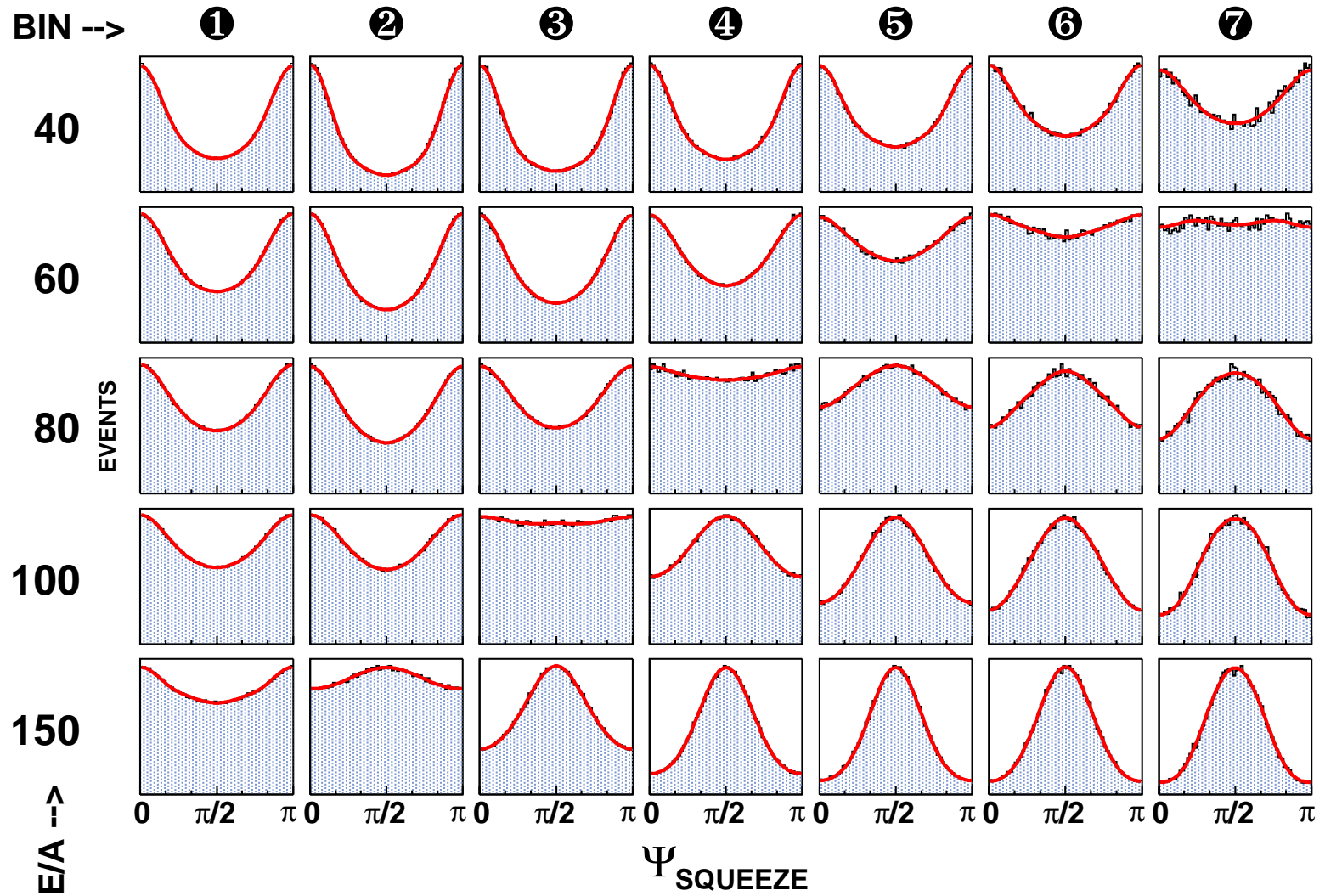
INDRA: Events in velocity space

BIN ③ Z = 3-6

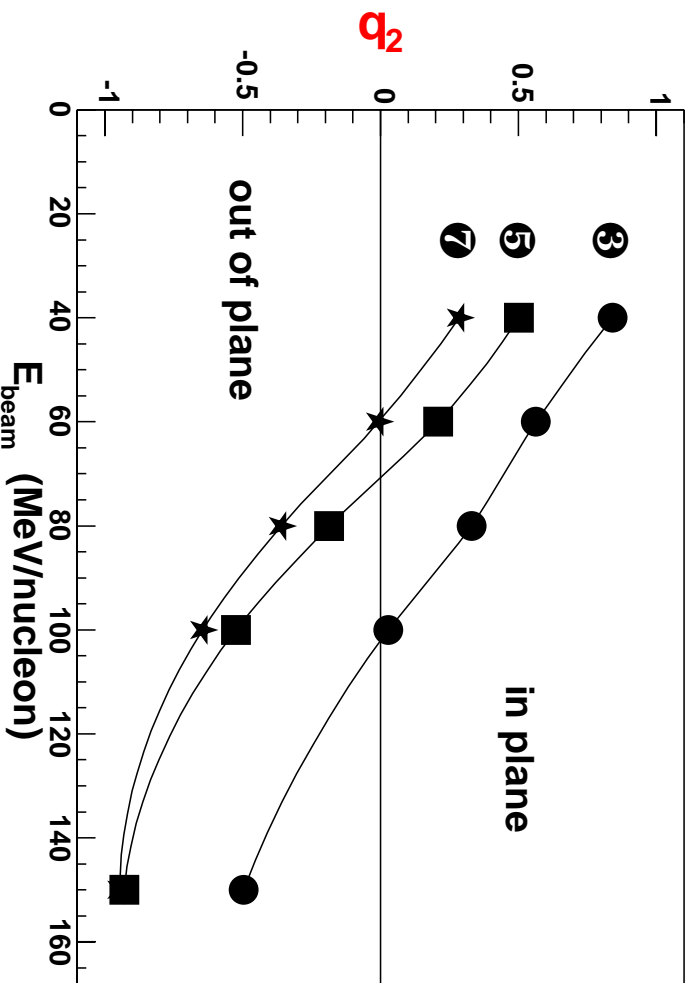
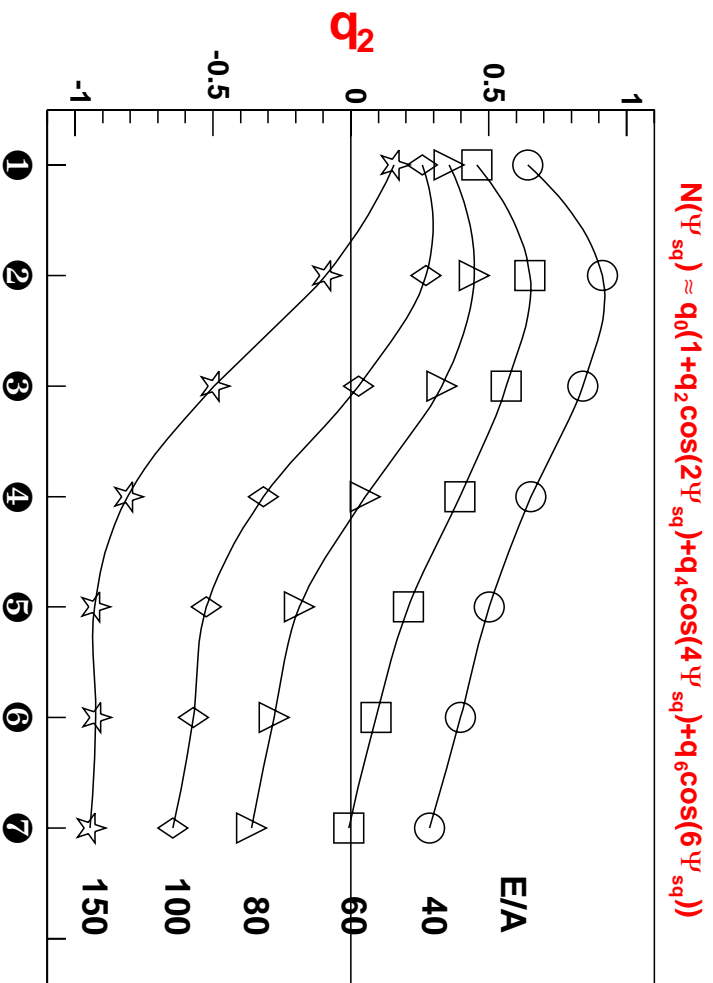
Tens. 1/frag.



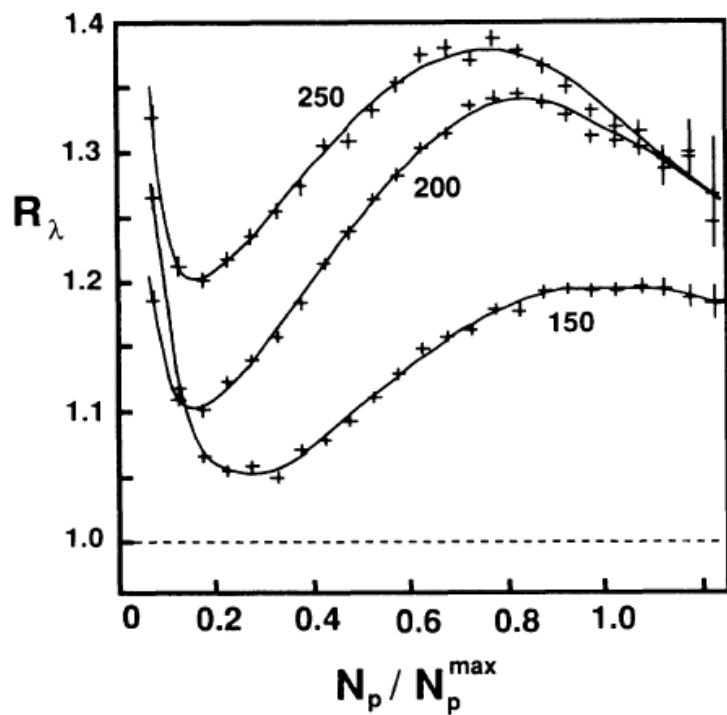
INDRA: Squeeze angle distributions (1)



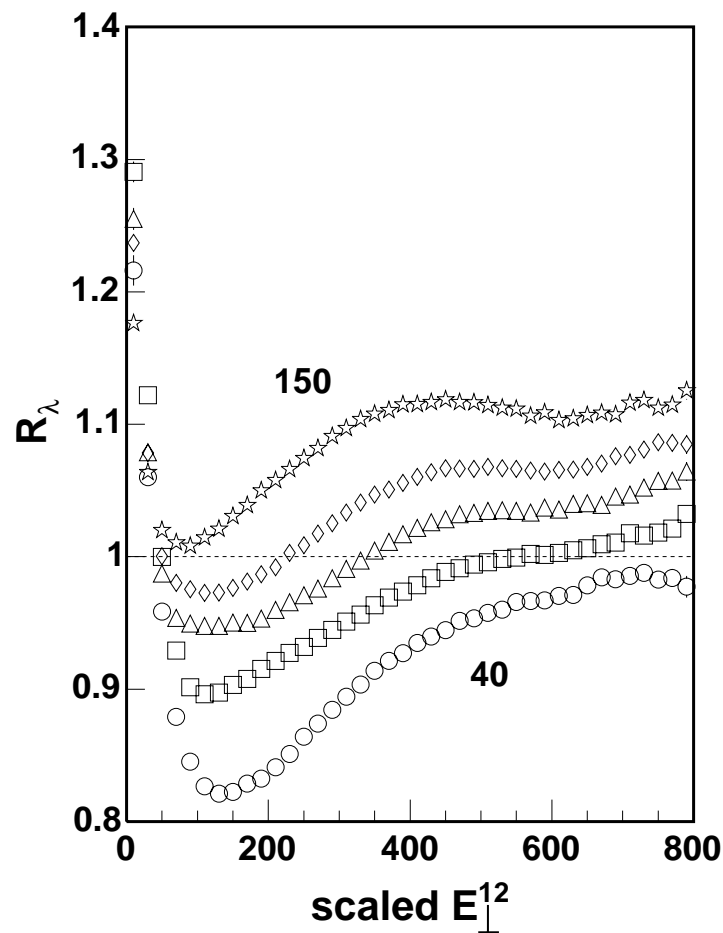
INDRA: Squeeze angle distributions (2)



Squeeze-out Ratio, R_λ

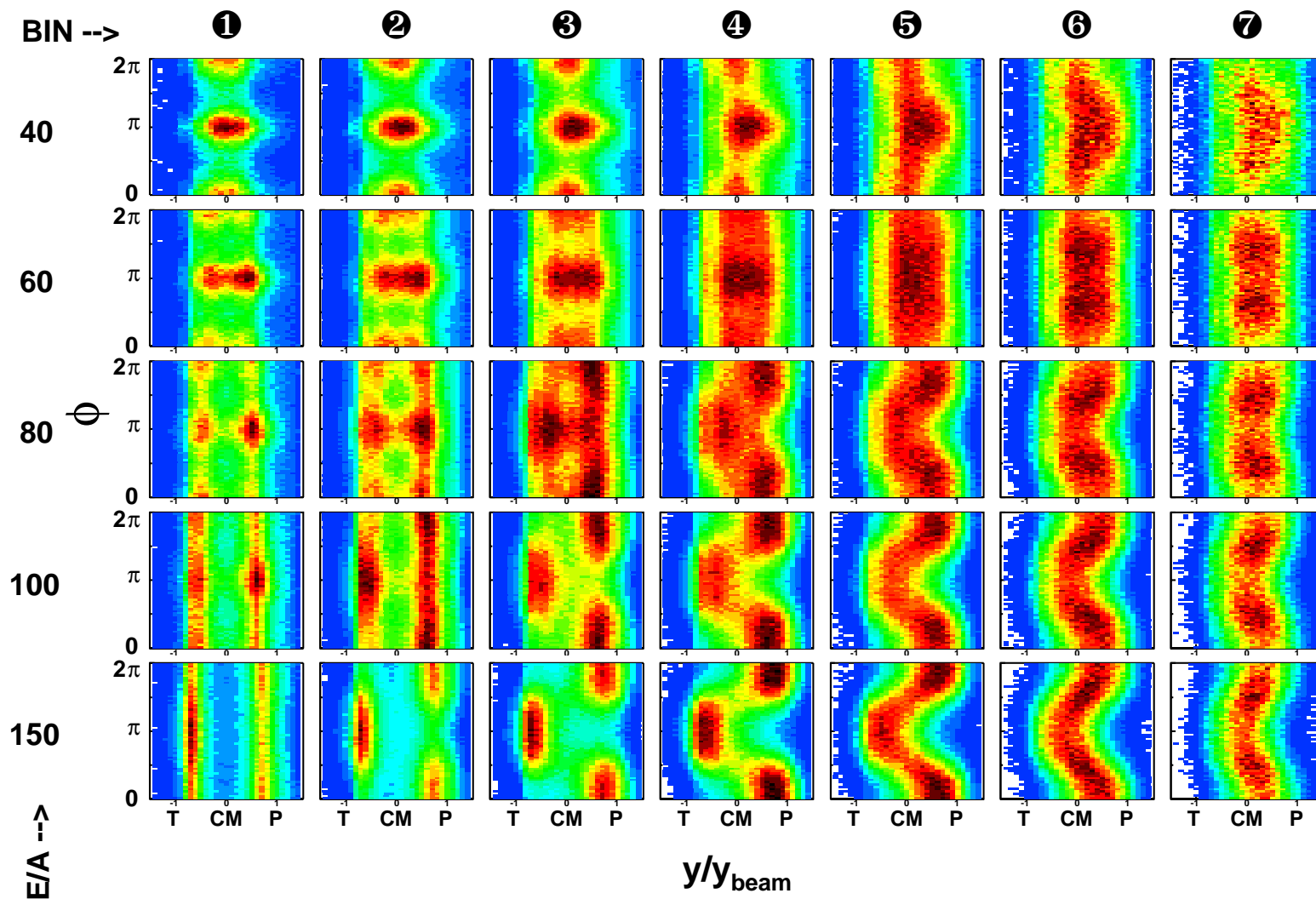


H.H. Gutbrod et al.
Au+Au, Plastic Ball data

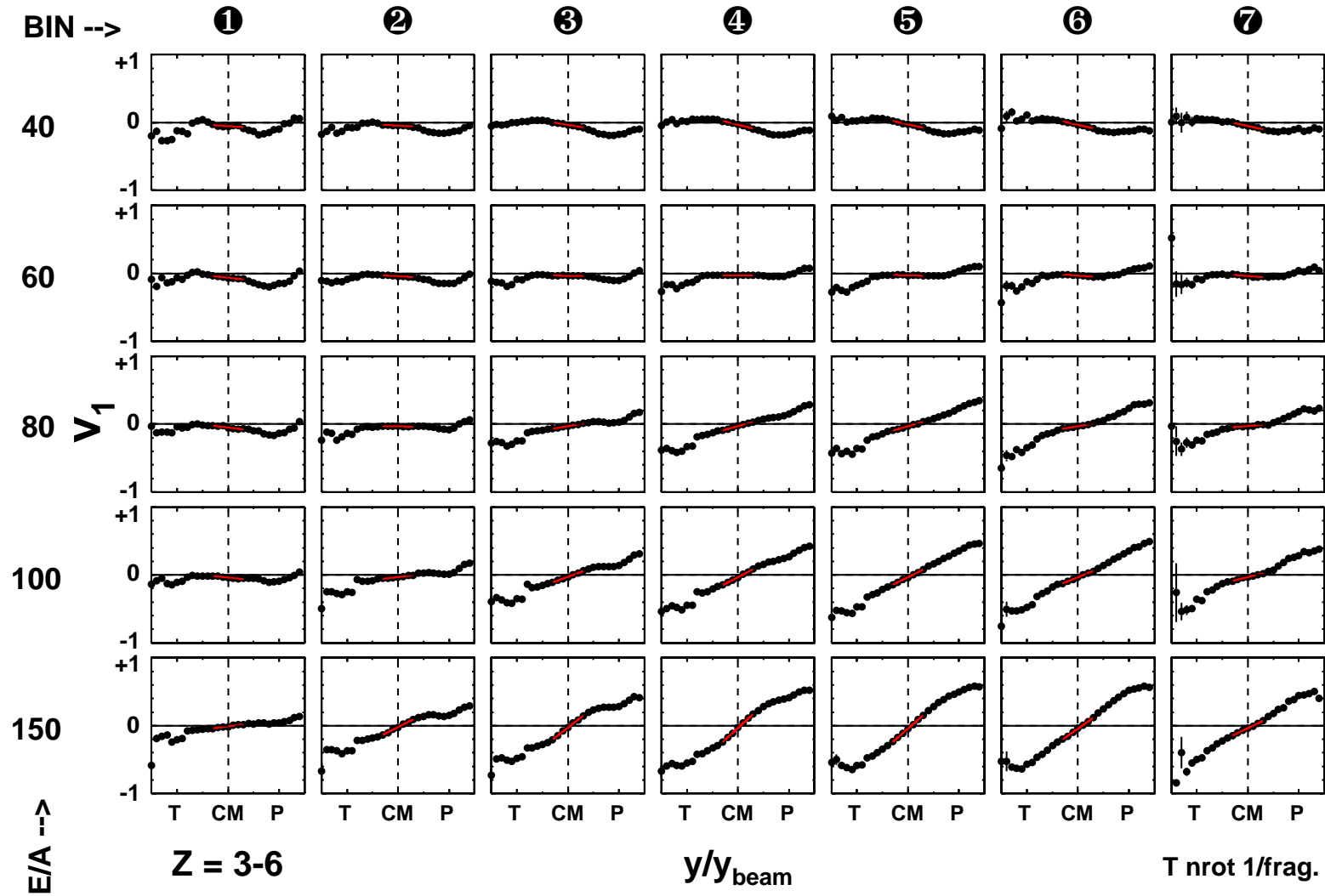


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INDRA: Azimuthal distributions, $Z=3-6$, non-rot., tens, 1/frag.



INDRA: Directed Flow, $v_1 = \langle \cos(\phi) \rangle$, $Z=3-6$, tens, 1/frag.

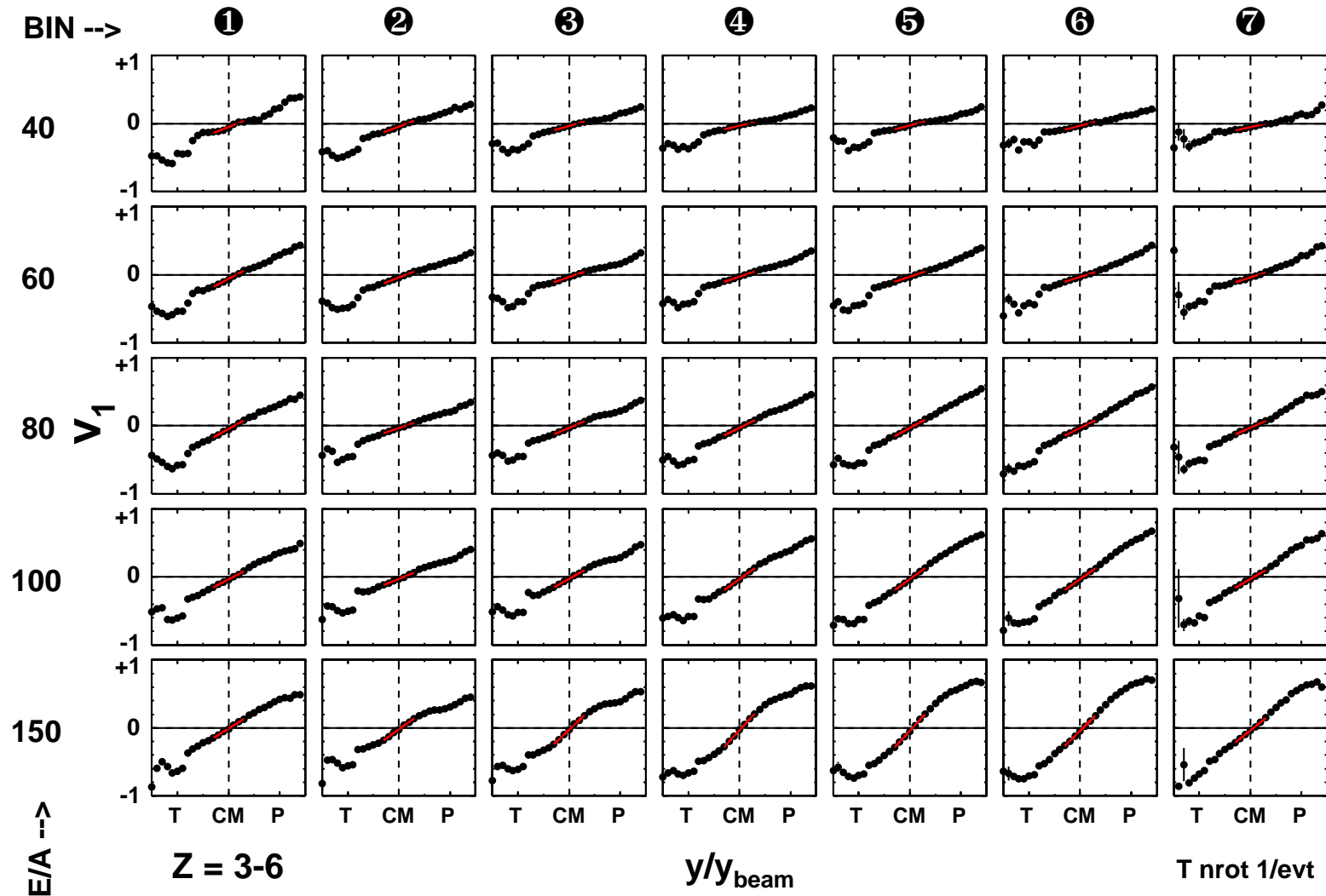


$$\frac{dN}{d\phi} \propto 1 + 2v_1 \cos(\phi) + 2v_2 \cos(2\phi);$$

$$v_1 = \langle \cos(\phi) \rangle;$$

$$v_2 = \langle \cos(2\phi) \rangle$$

INDRA: Directed Flow, $v_1 = \langle \cos(\phi) \rangle$, Z=3-6, tens, 1/evt.

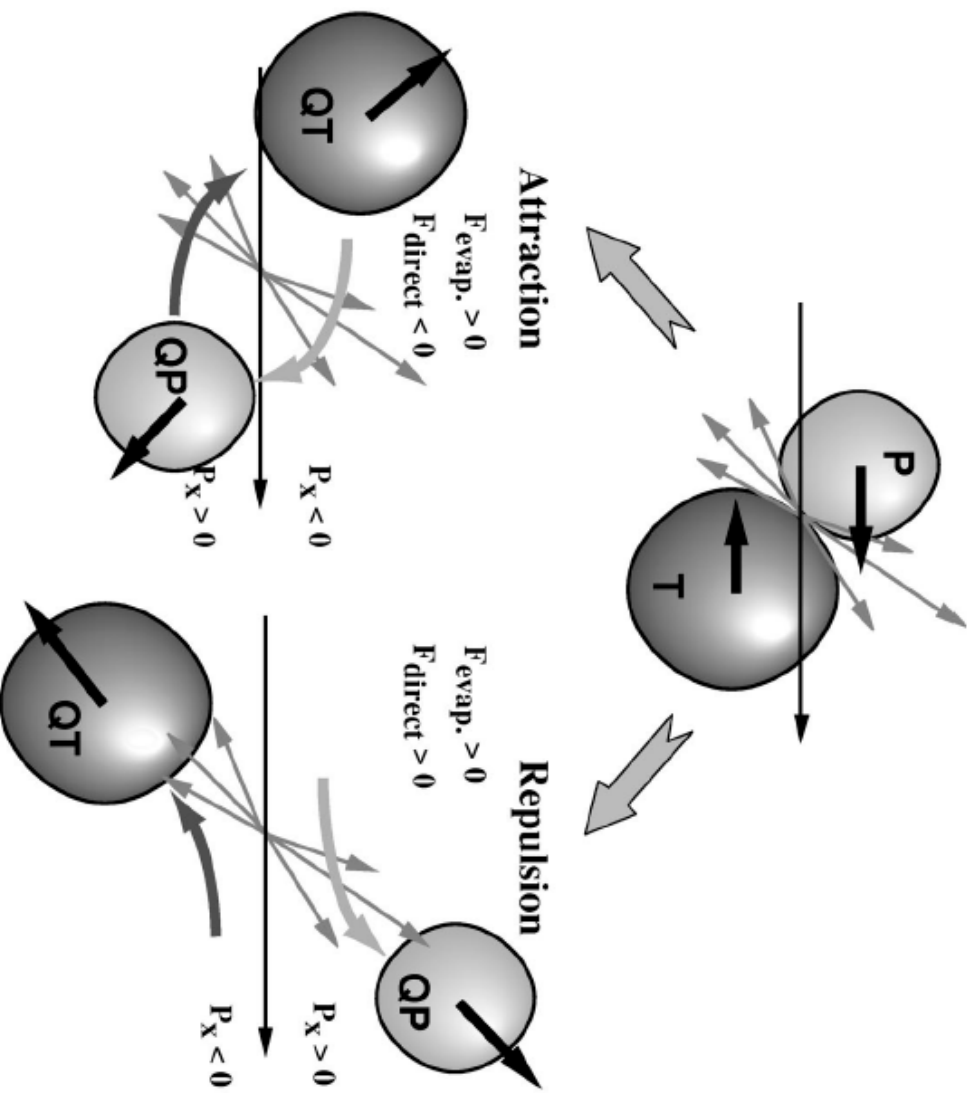


$$\frac{dN}{d\phi} \propto 1 + 2v_1 \cos(\phi) + 2v_2 \cos(2\phi);$$

$$v_1 = \langle \cos(\phi) \rangle;$$

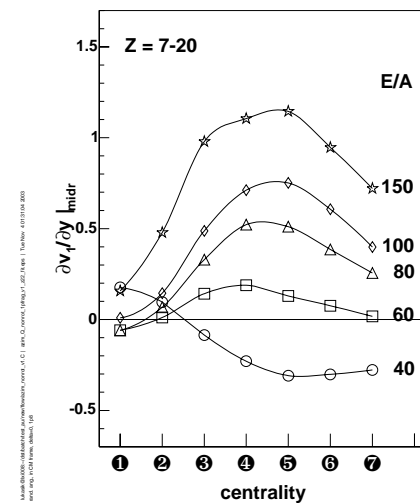
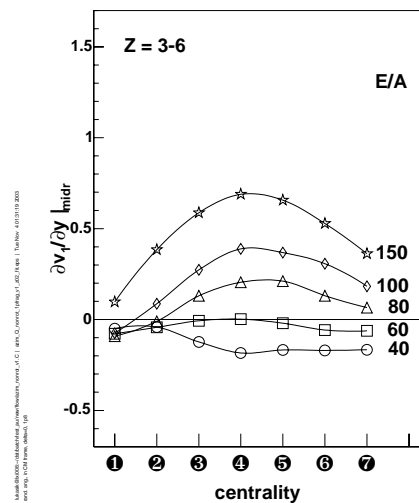
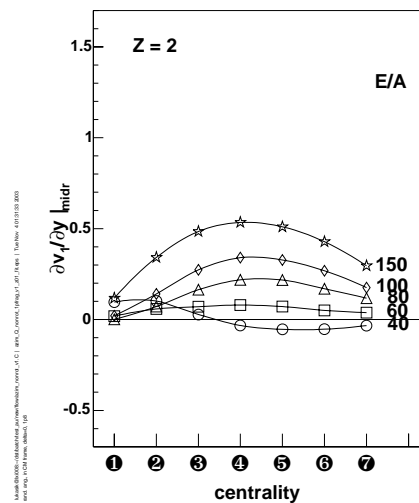
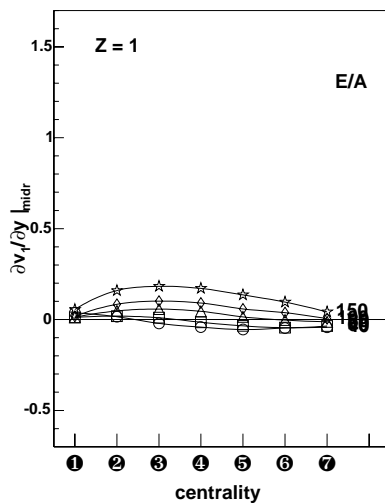
$$v_2 = \langle \cos(2\phi) \rangle$$

Negative flow



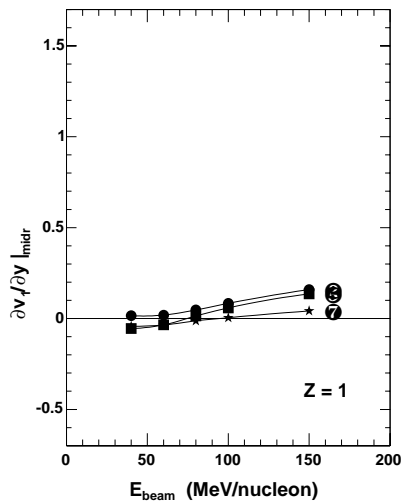
INDRA: Directed Flow, 1 reaction plane/fragment

Slope parameter $\partial v_1/\partial y|_{midr}$ vs centrality

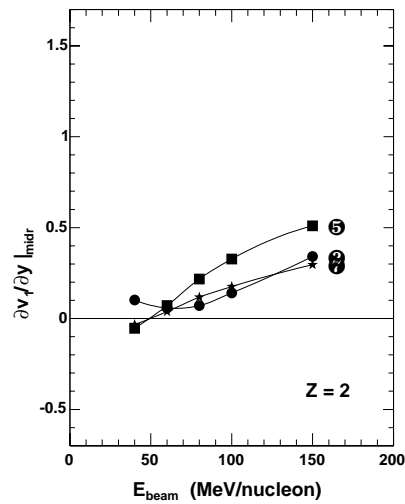


INDRA: Directed Flow, 1 reaction plane/fragment

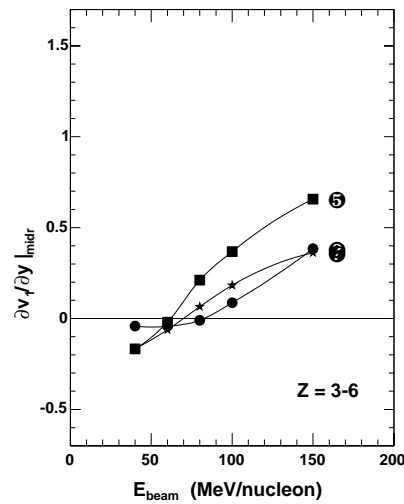
Slope parameter $\partial v_1 / \partial y|_{midr}$ vs E_{beam}



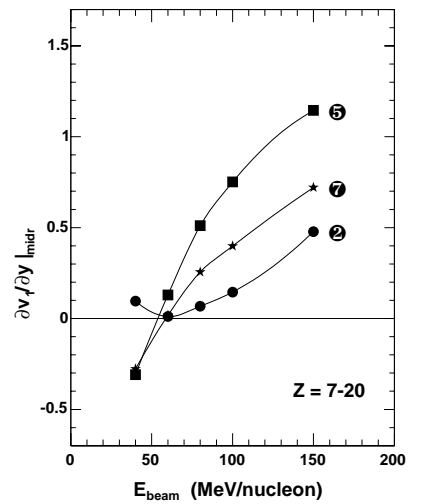
Ludvig Björnsen, Institut für Experimentelle Kernphysik, Universität Wien, Austria
 and INFN, Laboratori Nazionali del Sud, Catania, Italy



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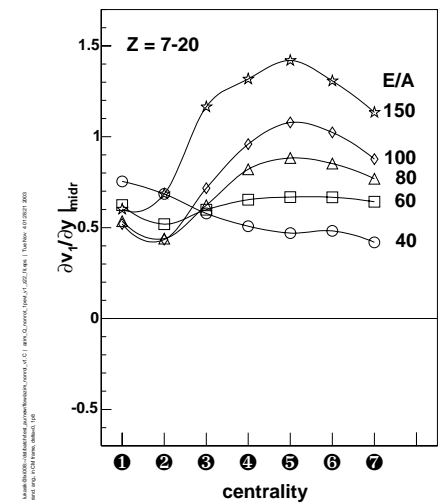
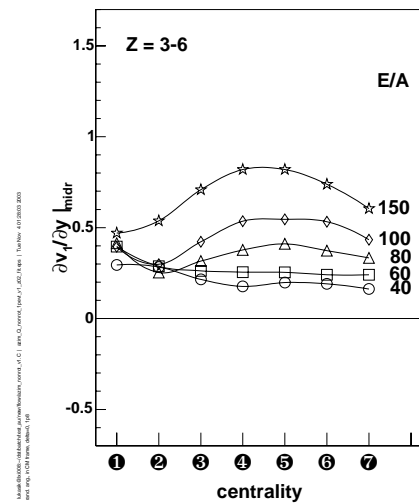
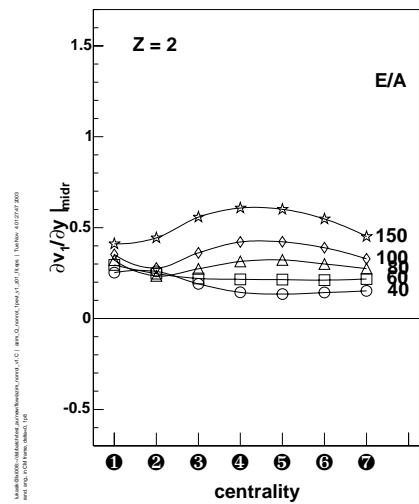
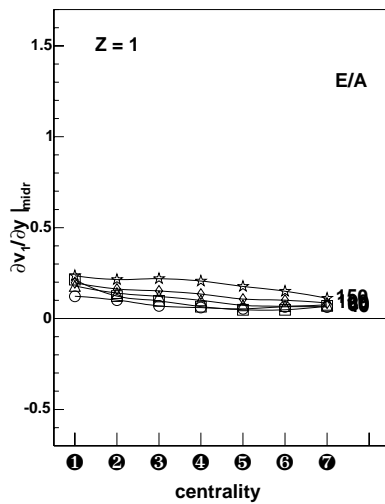
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 and INFN, Laboratori Nazionali del Sud, Catania, Italy



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 and INFN, Laboratori Nazionali del Sud, Catania, Italy

INDRA: Directed Flow, 1 reaction plane/event

Slope parameter $\partial v_1/\partial y|_{midr}$ vs centrality



L. B. et al. (INDRA Collaboration), Phys. Rev. Lett. 123, 122701 (2020)

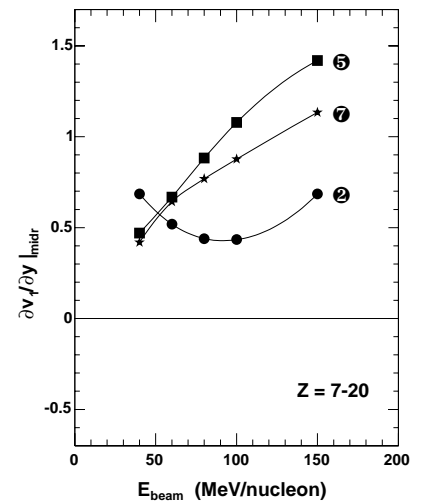
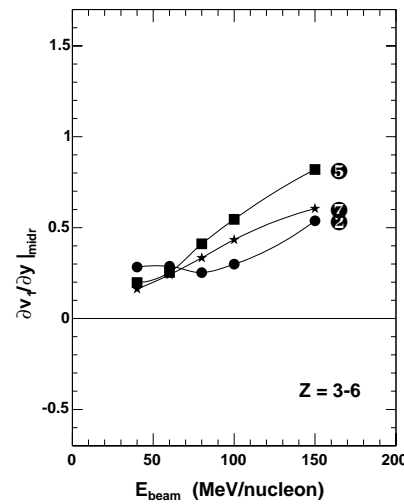
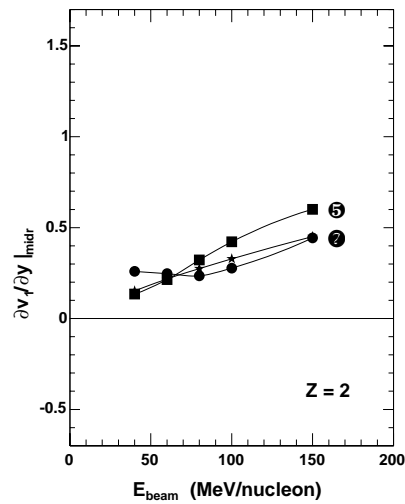
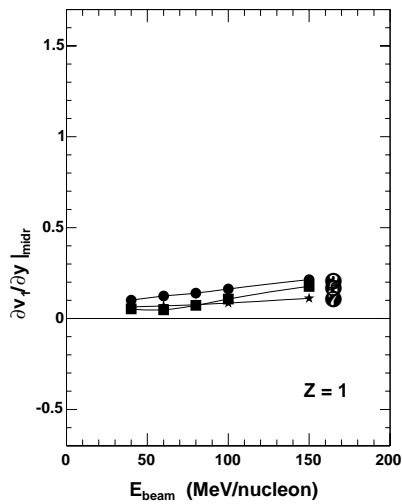
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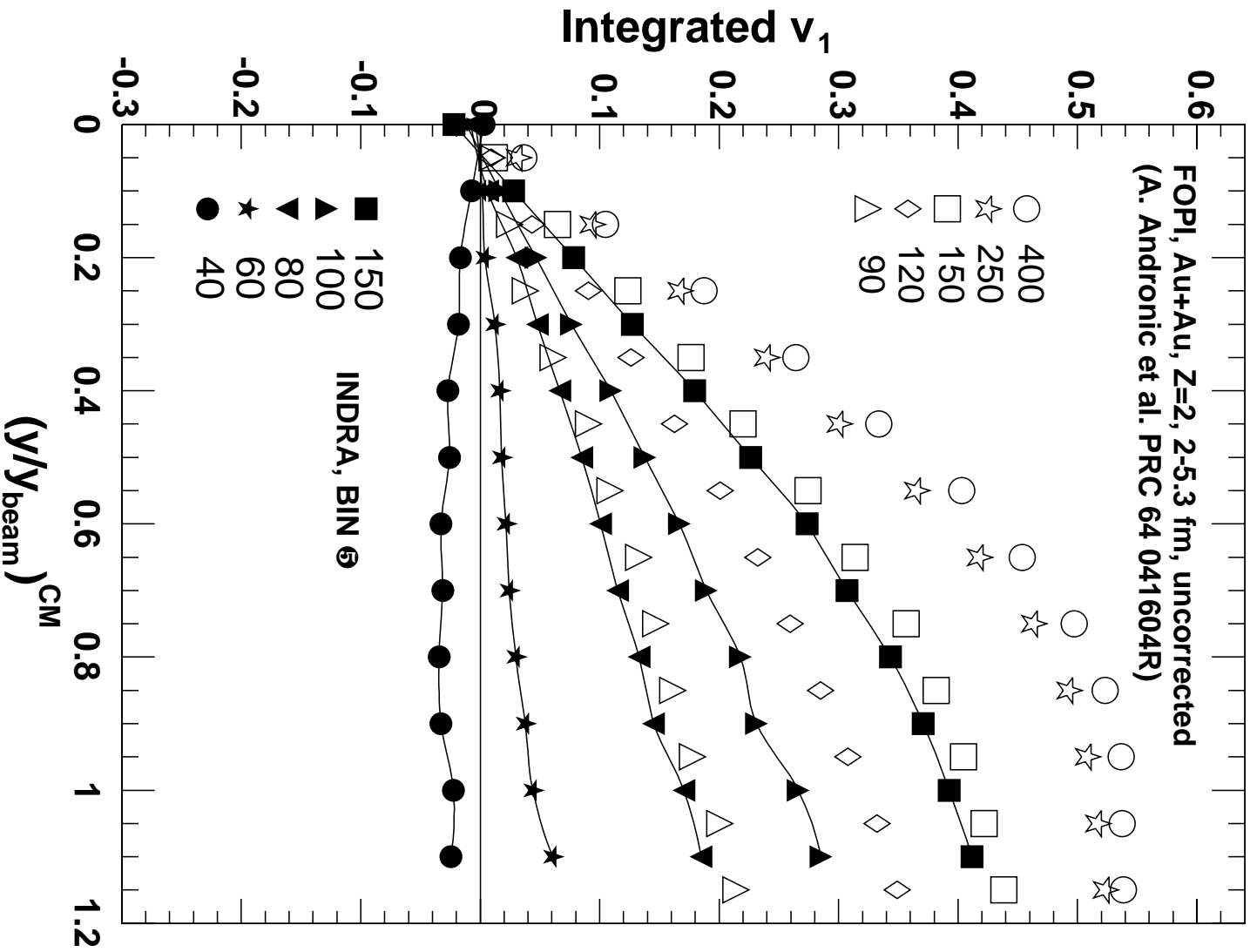
L. B. et al. (INDRA Collaboration), Phys. Rev. Lett. 123, 122701 (2020)

INDRA: Directed Flow, 1 reaction plane/event

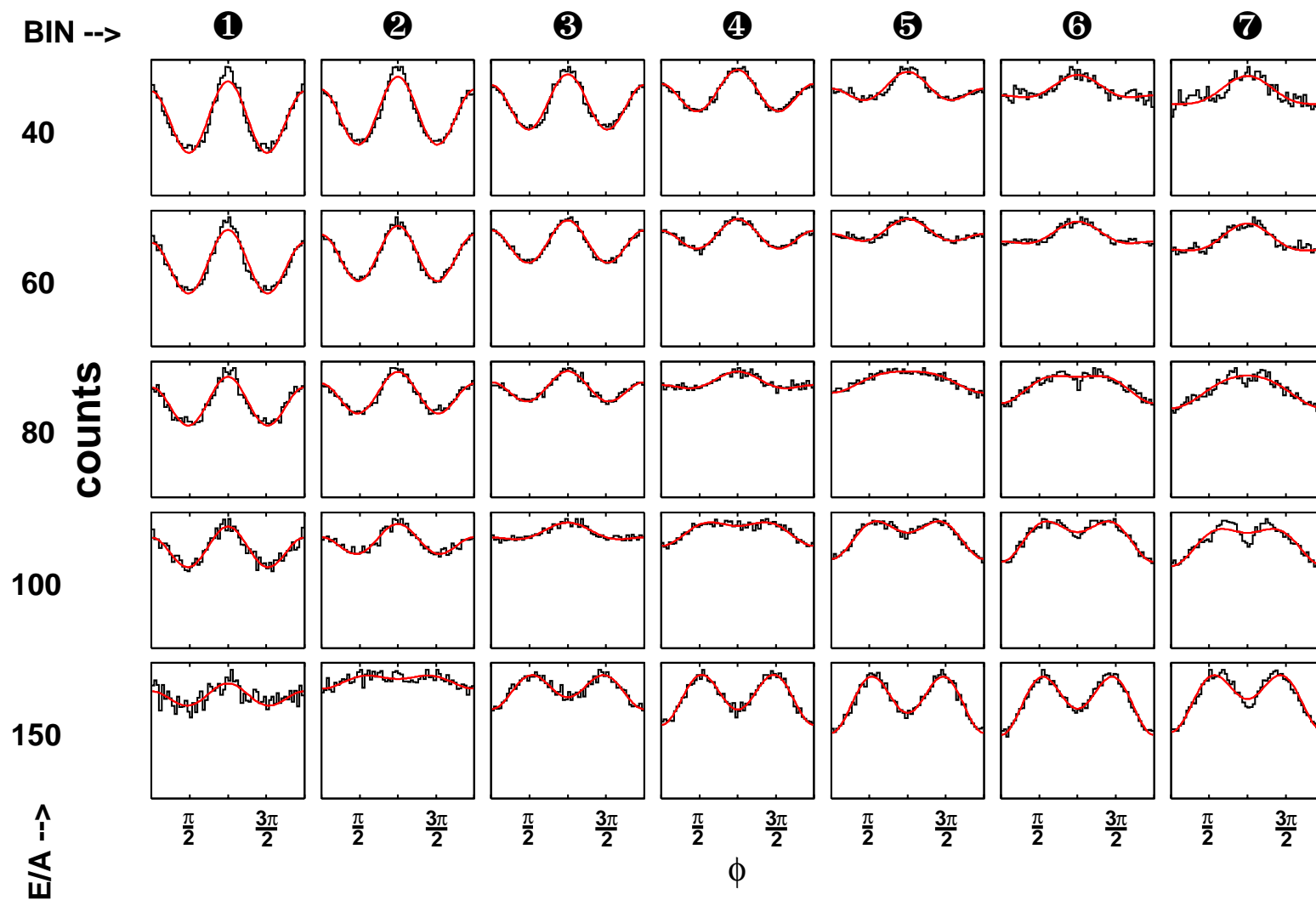
Slope parameter $\partial v_1/\partial y|_{midr}$ vs E_{beam}



v_1 for mid-central collisions, comparison with
FOPI

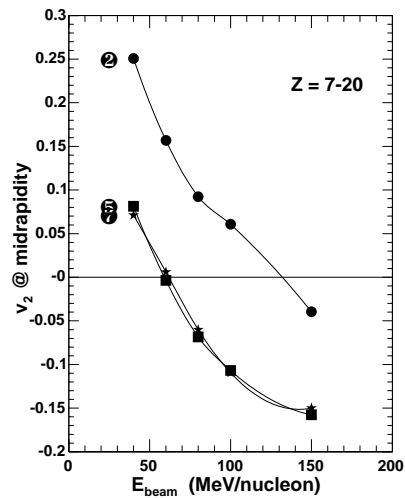
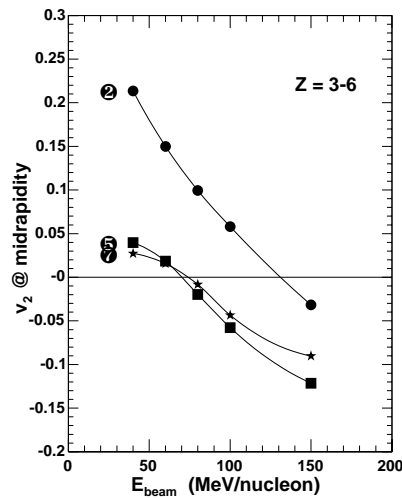
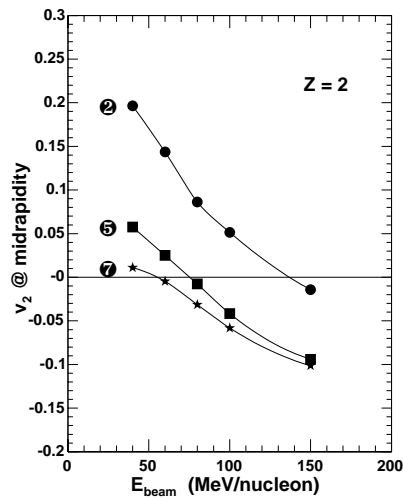
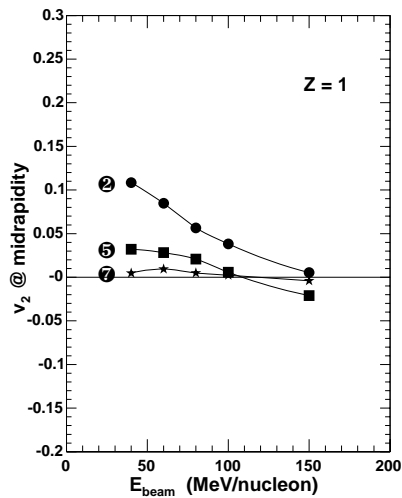


INDRA: Azimuthal distributions, $Z=3-6$



INDRA: Elliptic Flow, 1 reaction plane/fragment

$$v_2 = \langle \cos(2\phi) \rangle \text{ at midrapidity vs centrality}$$



L. B. Goldberger, et al., Phys. Rev. Lett. 102, 152701 (2009)

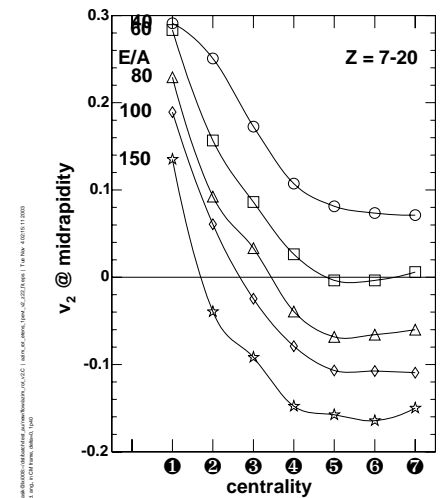
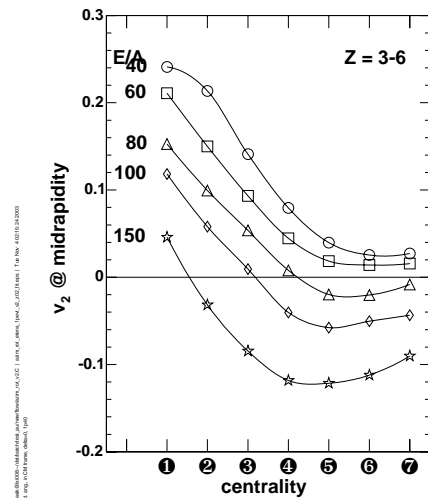
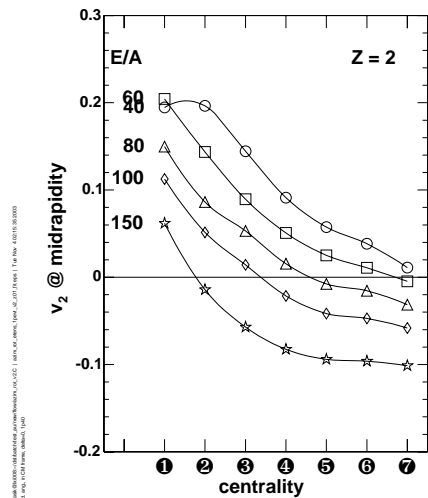
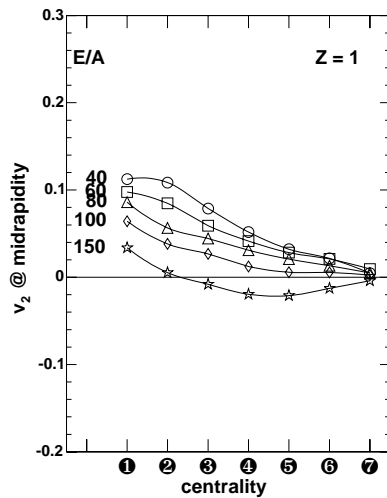
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INDRA: Elliptic Flow, 1 reaction plane/event

$v_2 = \langle \cos(2\phi) \rangle$ at midrapidity vs centrality



Laboratoire National d'Accélérateurs Moleculaires, CNRS, UMR 106, IN2P3, Université de Strasbourg, F-67037 Strasbourg, France

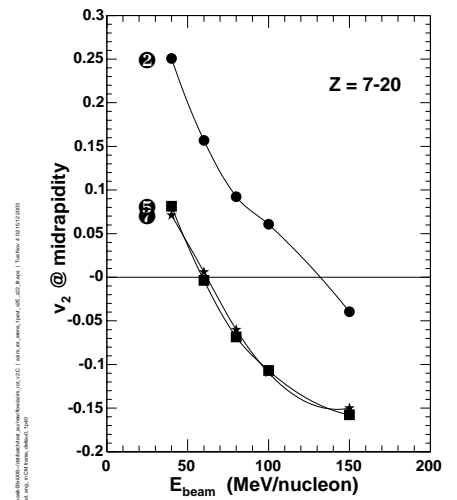
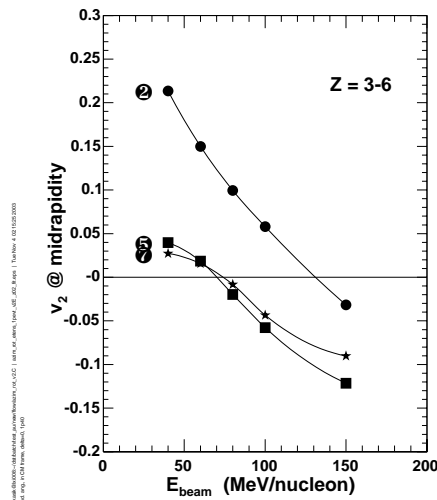
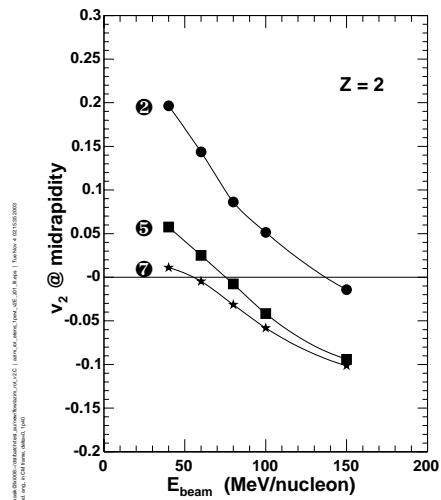
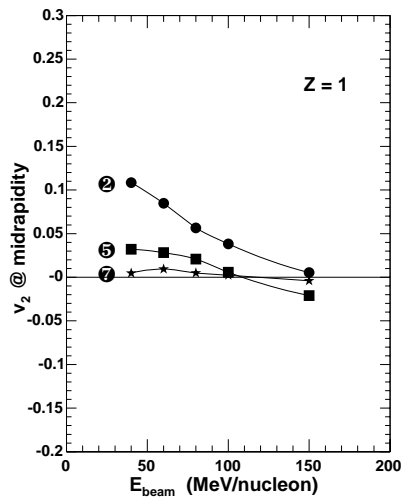
Laboratoire National d'Accélérateurs Moleculaires, CNRS, UMR 106, IN2P3, Université de Strasbourg, F-67037 Strasbourg, France

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Laboratoire National d'Accélérateurs Moleculaires, CNRS, UMR 106, IN2P3, Université de Strasbourg, F-67037 Strasbourg, France

INDRA: Elliptic Flow, 1 reaction plane/event

$v_2 = \langle \cos(2\phi) \rangle$ at midrapidity vs centrality



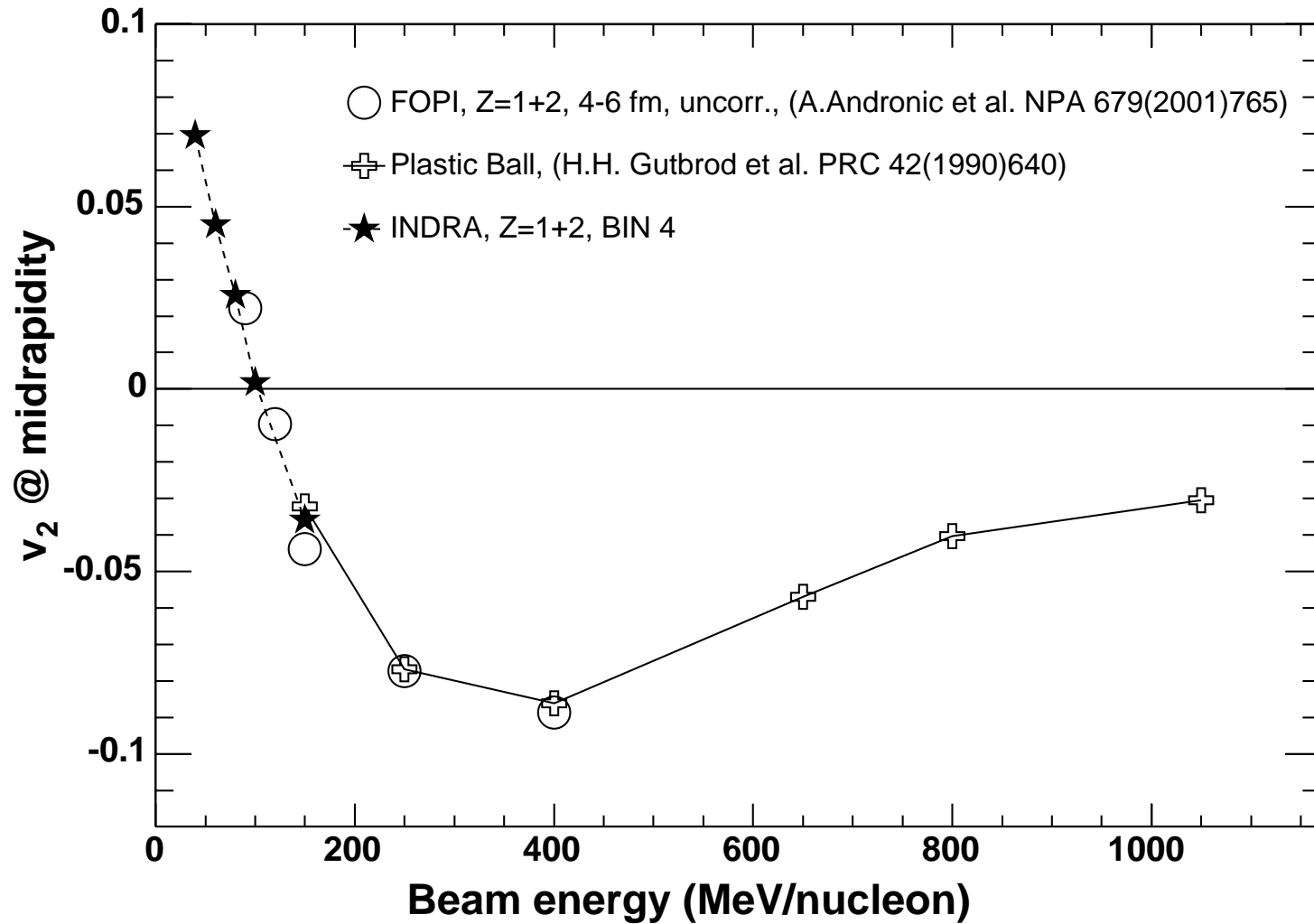
LAURENCE BARON, Institut de Physique Nucléaire de Strasbourg, UMR 7520 - CNRS, UFR de Physique, BP 20716, F-67037 Strasbourg Cedex 2, France. E-mail: baron@ipn.cnrs.fr

LAURENCE BARON, Institut de Physique Nucléaire de Strasbourg, UMR 7520 - CNRS, UFR de Physique, BP 20716, F-67037 Strasbourg Cedex 2, France. E-mail: baron@ipn.cnrs.fr

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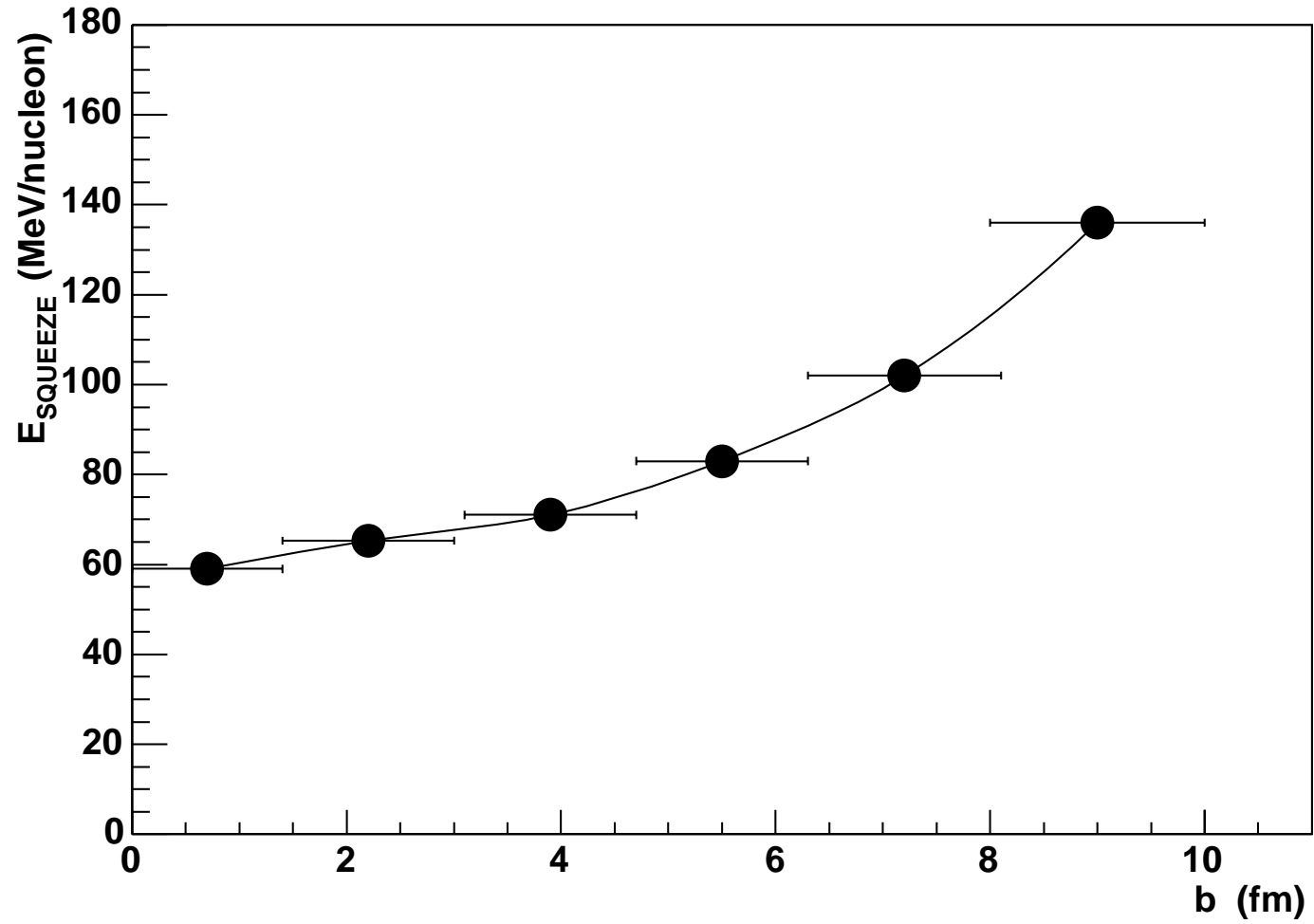
Elliptic Flow, $Z=1+2$, rotated



$E_{tran} \simeq 104$ A MeV (!)

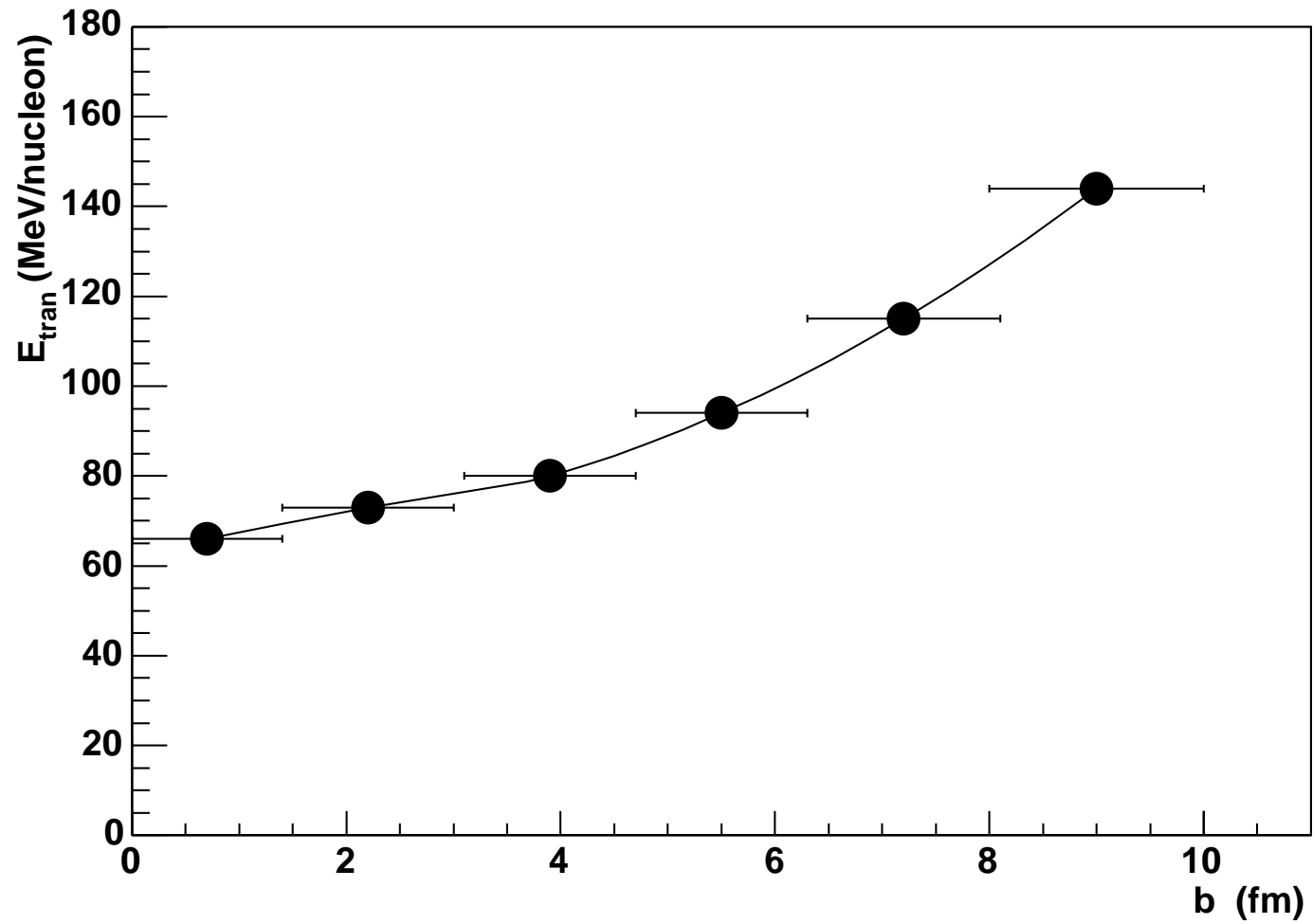
Summary: $E_{SQUEEZE}$

INDRA | Au+Au



Summary: E_{tran} for $Z=2$

INDRA | Au+Au



Summary and Conclusions

- ✚ INDRA@GSI provides a broad and reliable systematics of data on collective phenomena.
- ✚ INDRA@GSI helps to resolve the experimental uncertainty on the E_{trann} .
- ✚ INDRA@GSI calls for theoretical support.
- ✚ INDRA@GSI needs a reliable reaction plane reconstruction procedure suitable for low energy collisions.