INDRA@GSI : Collective Flow from Fermi to Relativistic Energies

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[5] DAPNIA Saclay, France ♦ [6] IPN Lyon, France ♦ [7] INFN Napoli, Italy ♦ [8] INFN Catania, Italy
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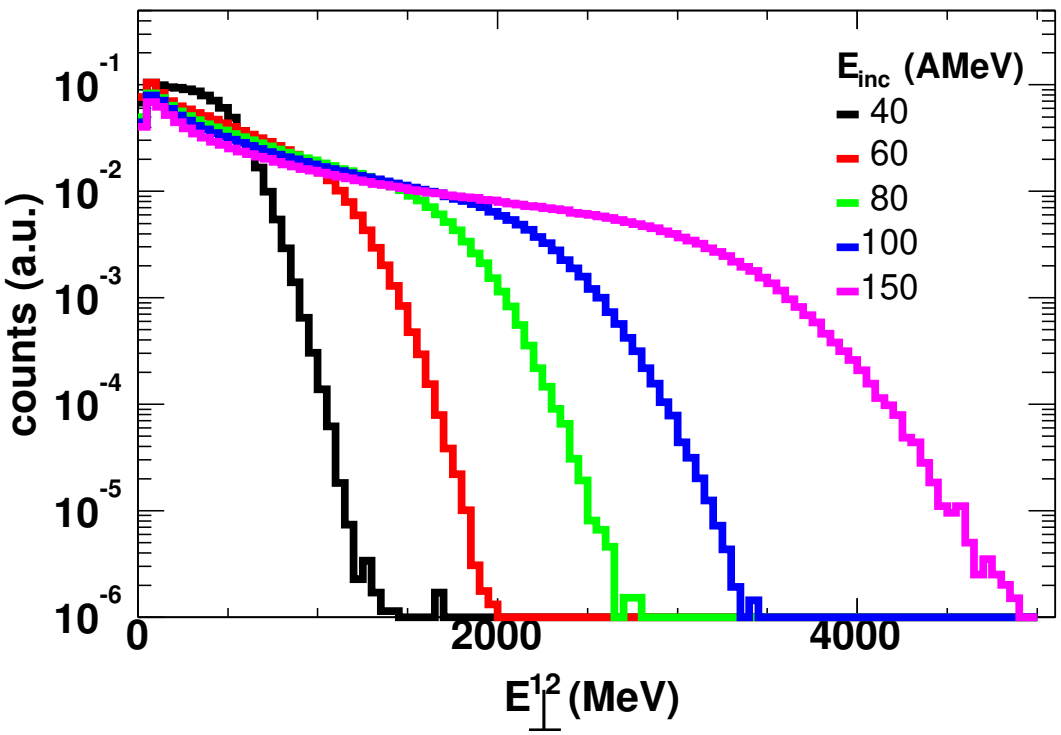
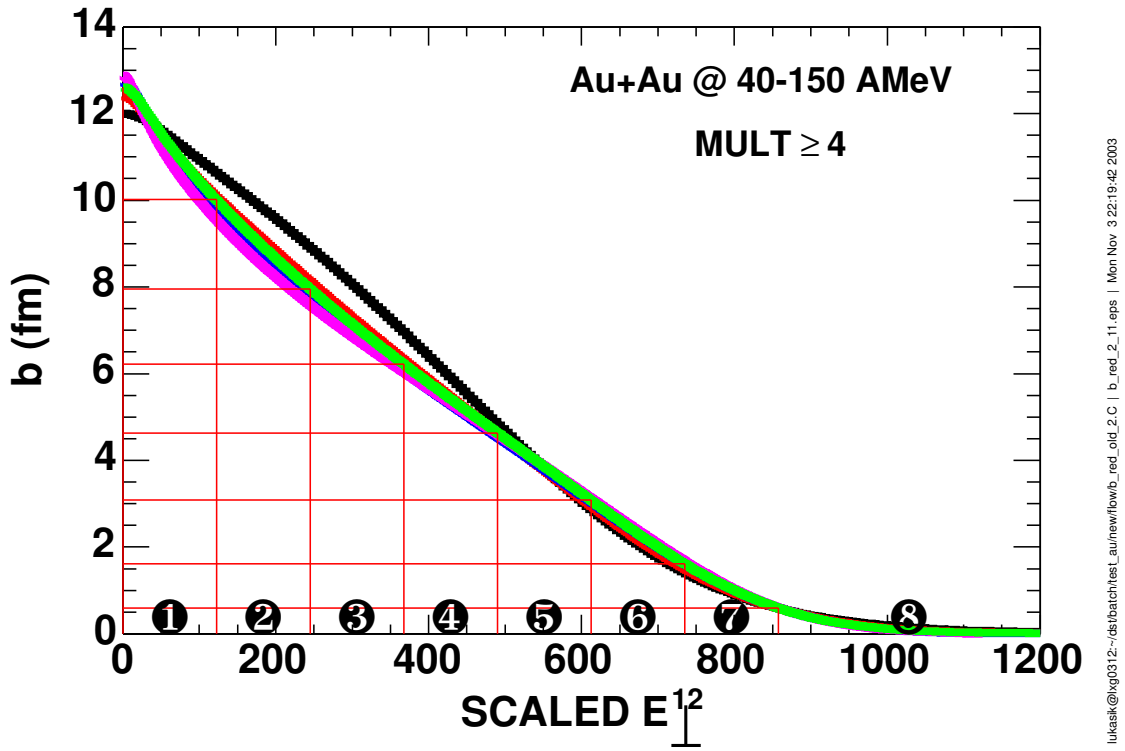
Au+Au @ 40-150 MeV/nucleon

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

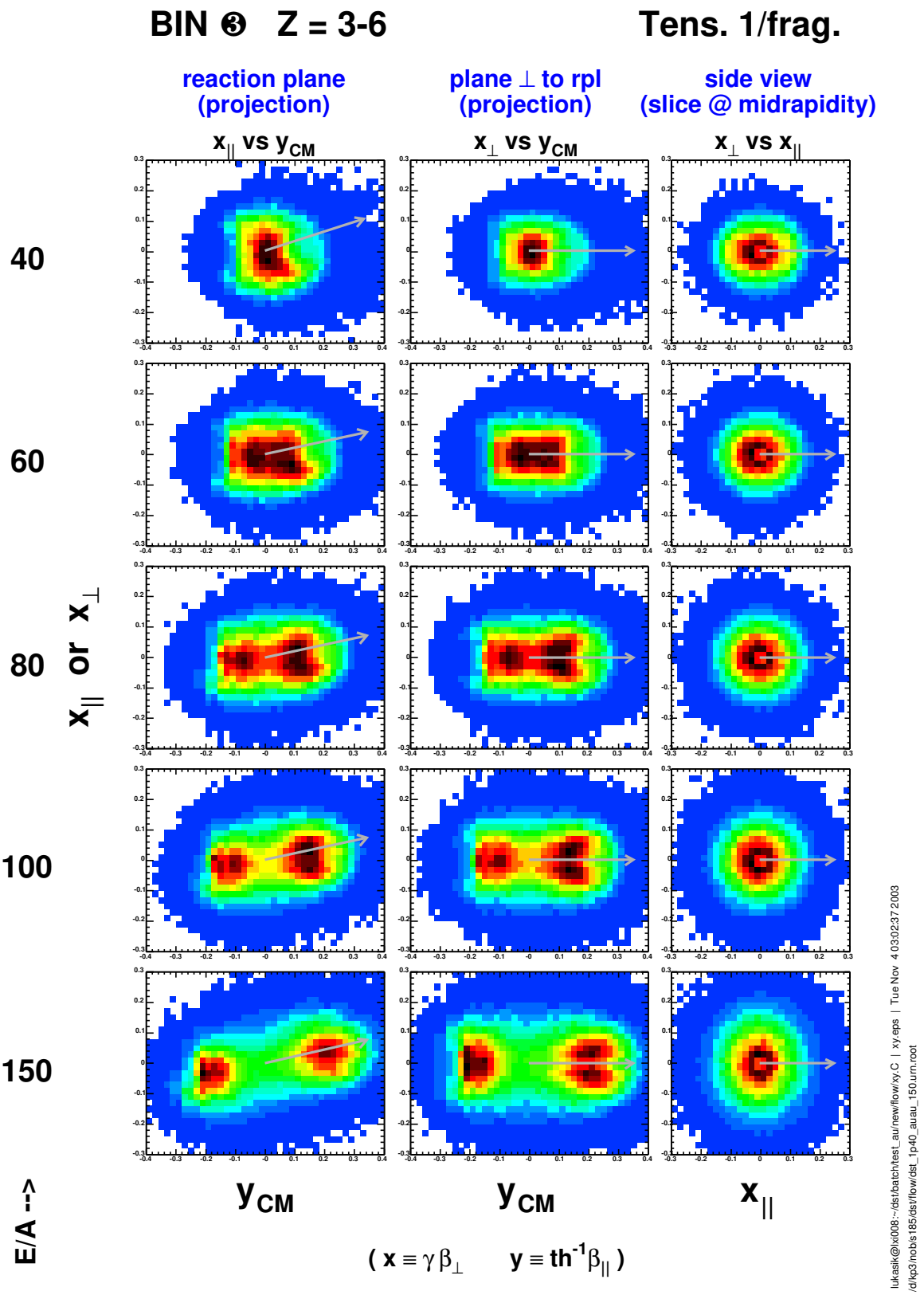
GANIL, IWM2003, 5-7 Nov.

INDRA: Centrality selection





INDRA: Events in velocity space



Squeeze Angle, Ψ_{sq}, and Squeeze-out Ratio, R_λ

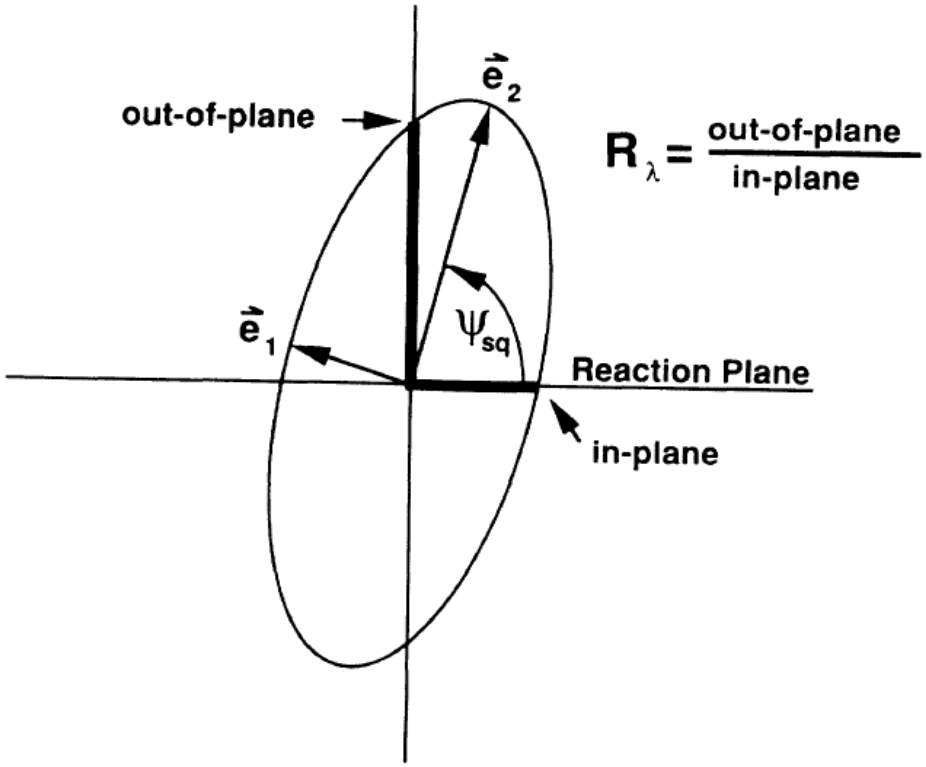


FIG. 5. The plane perpendicular to the flow axis through the origin, showing how R_λ is calculated from the two smaller eigenvalues and the reaction plane.

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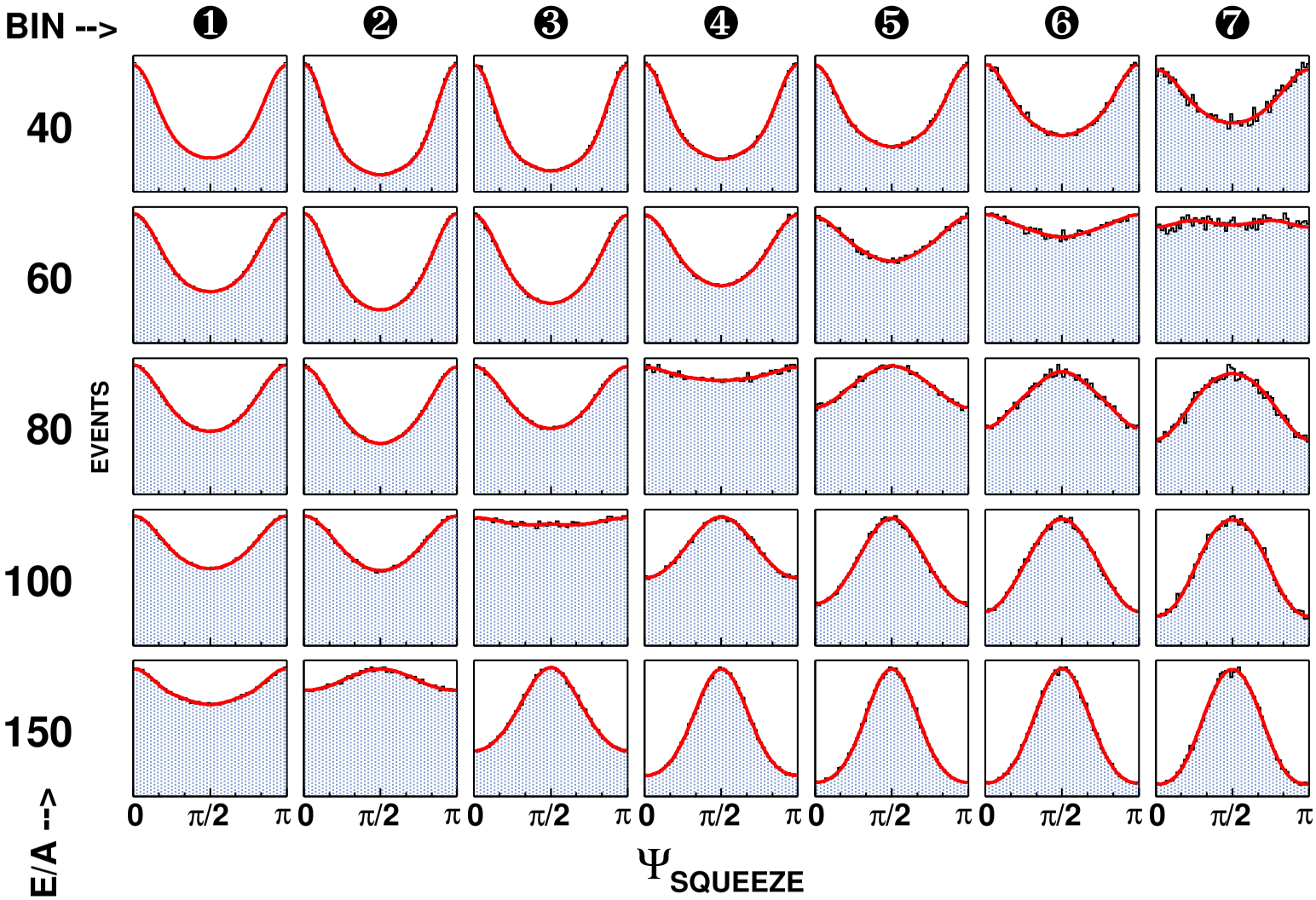
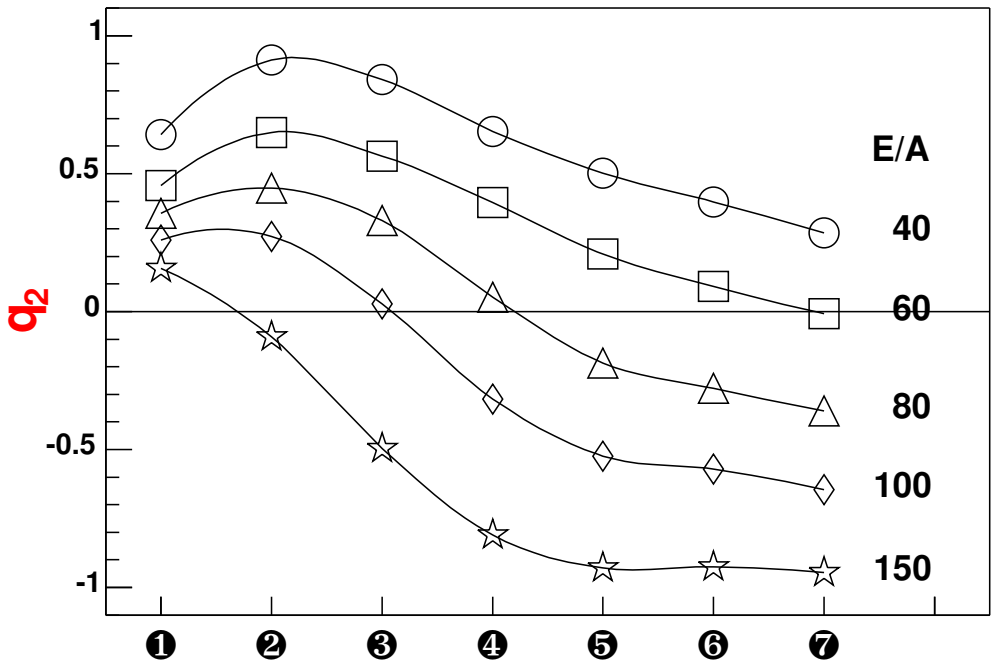
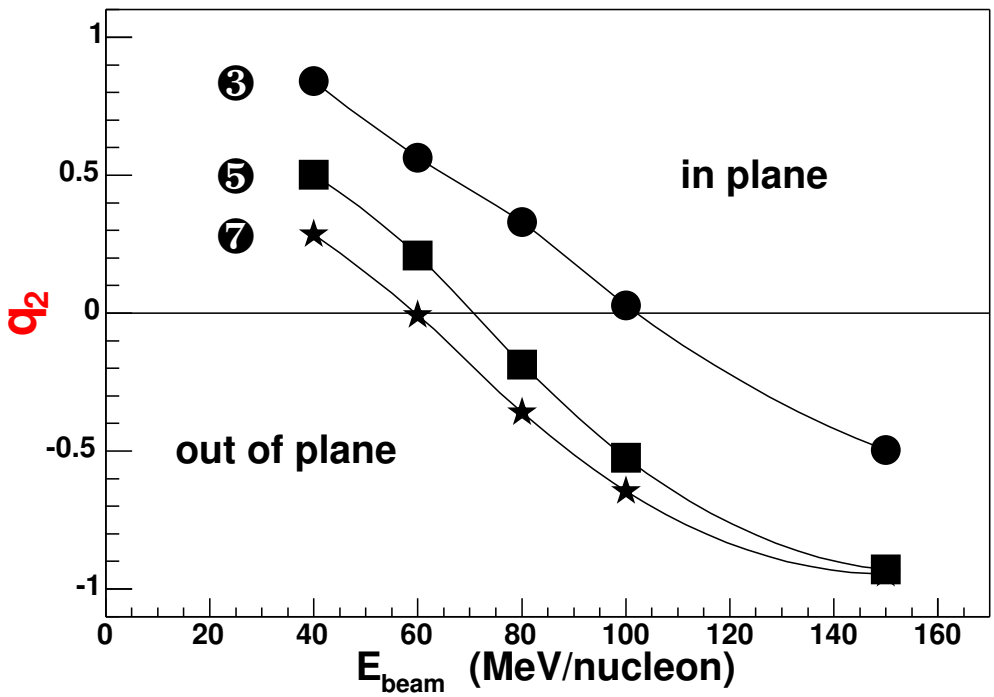
INDRA: Squeeze angle distributions (1)



INDRA: Squeeze angle distributions (2)

$N(\Psi_{sq}) \approx q_0(1+q_2\cos(2\Psi_{sq})+q_4\cos(4\Psi_{sq})+q_6\cos(6\Psi_{sq}))$





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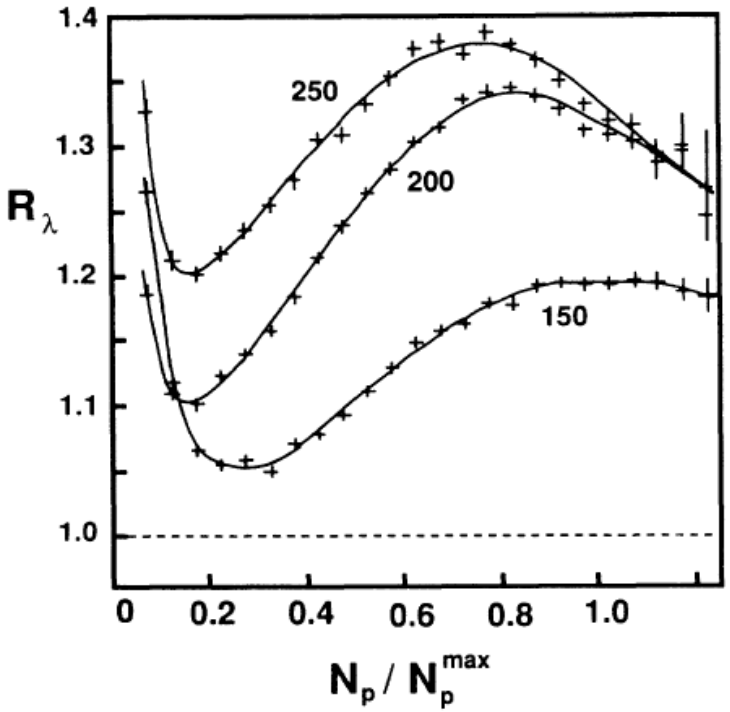
Squeeze-out Ratio, R_λ



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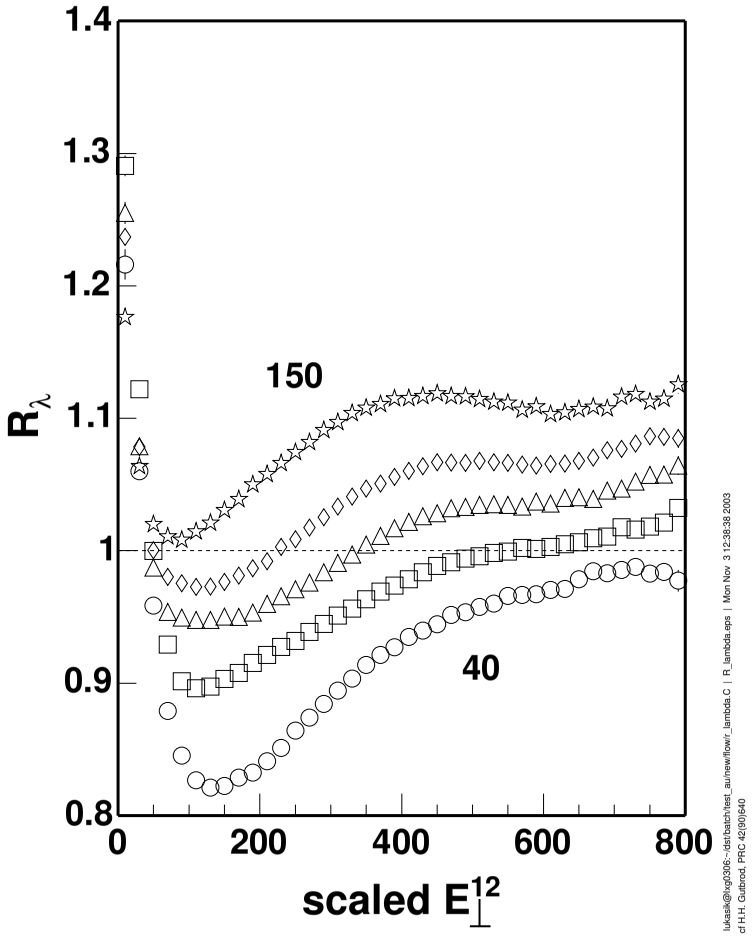
Au+Au, Plastic Ball data



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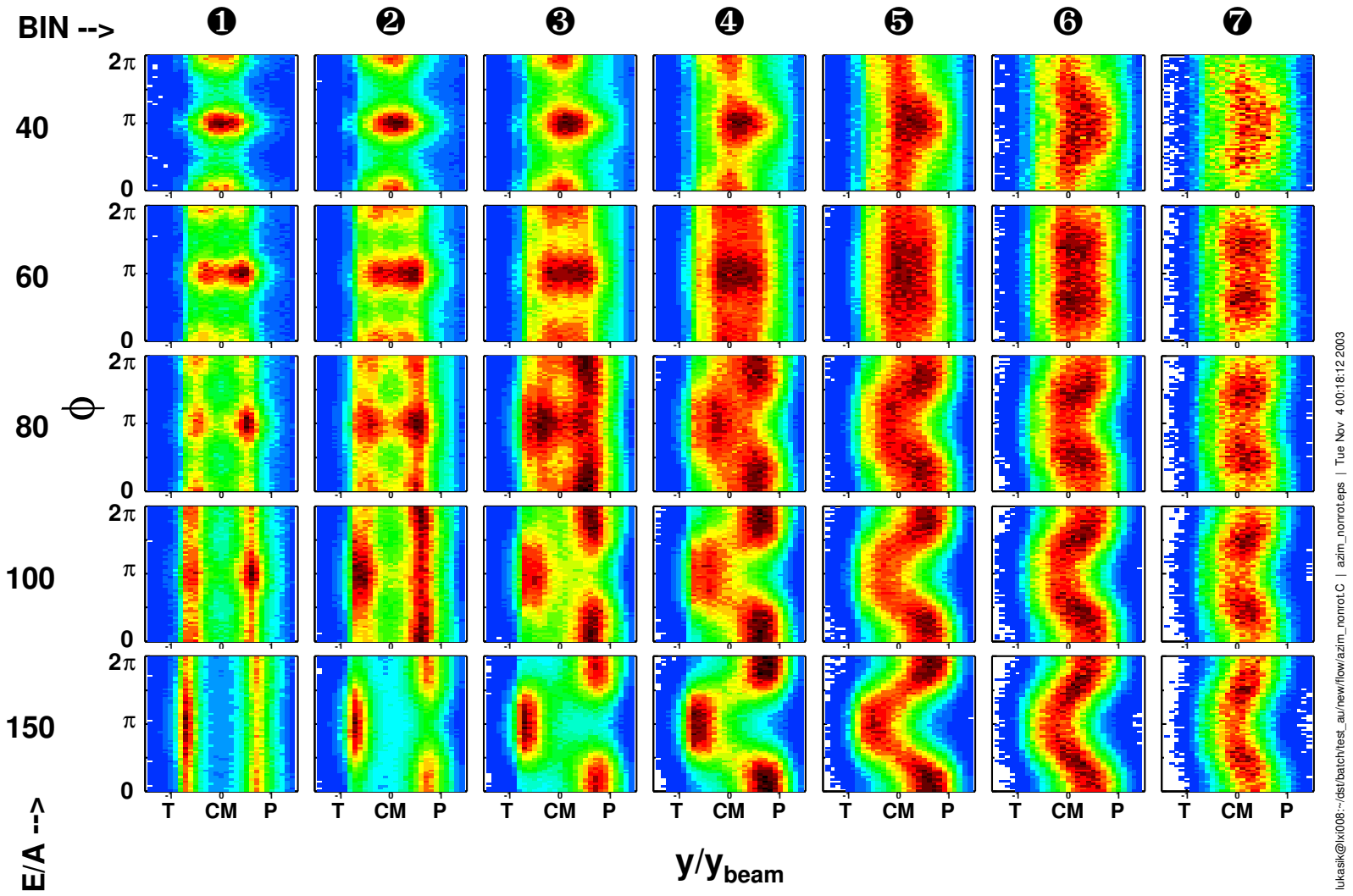
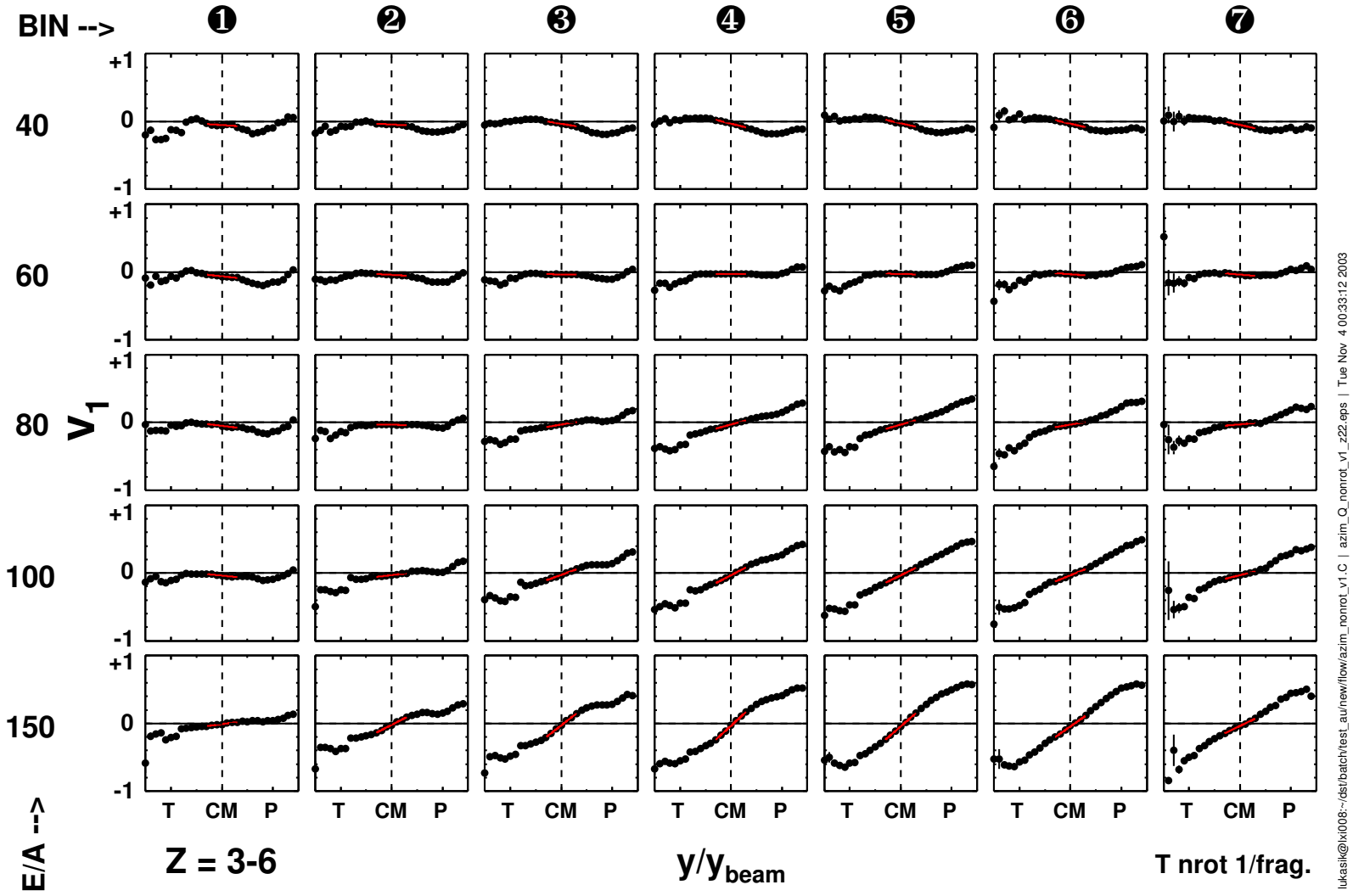
INDRA: Azimuthal distributions, Z=3-6, non-rot., tens, 1/frag.

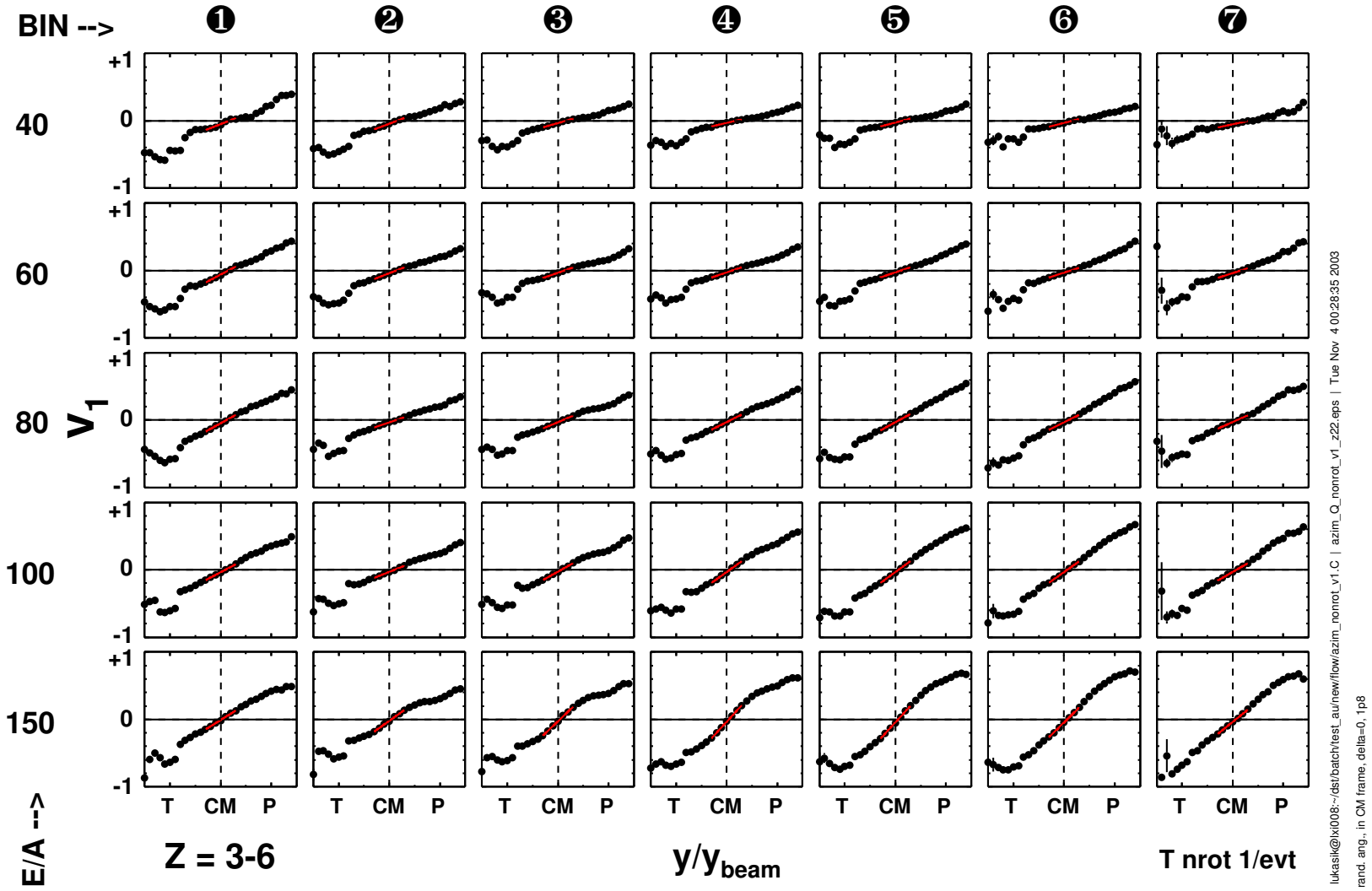


INDRA: Directed Flow, $v_1 = <\cos(\phi)>$, Z=3-6, tens, 1/frag.



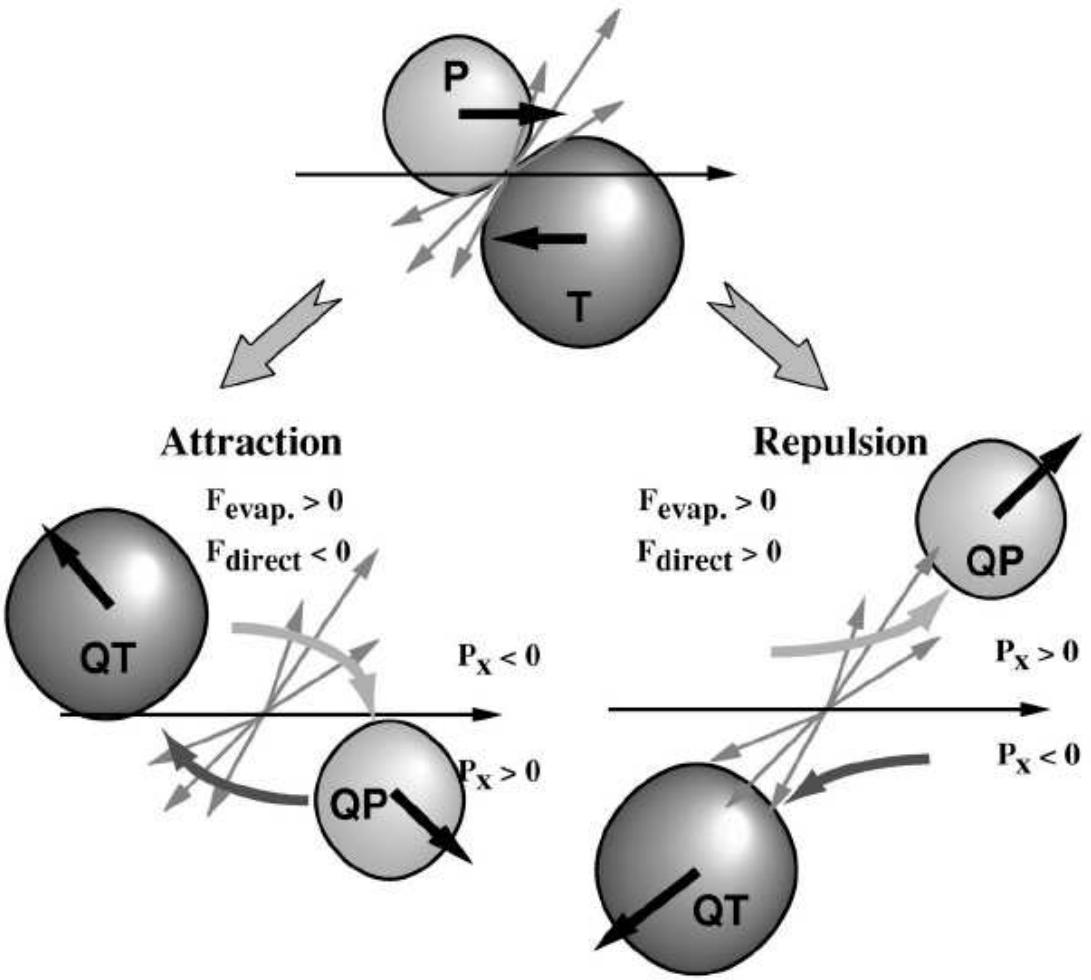
$$\frac{dN}{d\phi} \propto 1 + 2v_1\cos(\phi) + 2v_2\cos(2\phi); \qquad v_1 = <\cos(\phi)>; \qquad v_2 = <\cos(2\phi)>$$

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



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

Negative flow



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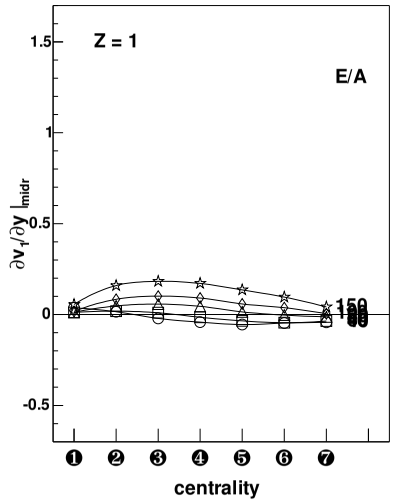
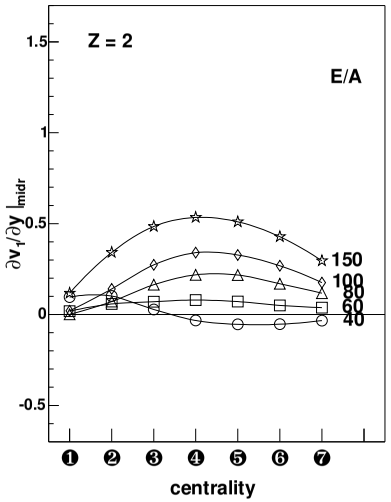
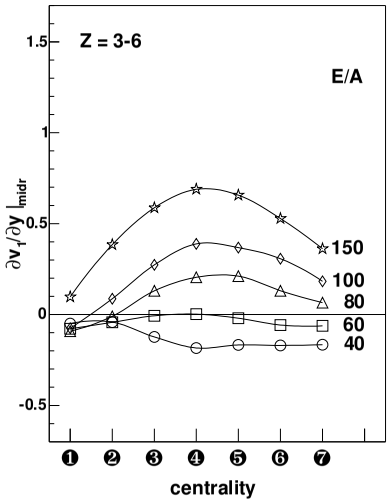
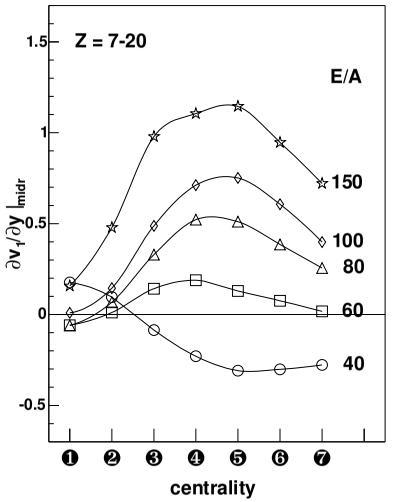
INDRA: Directed Flow, 1 reaction plane/fragment

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



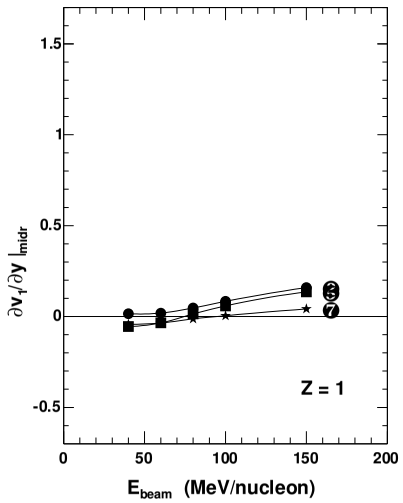


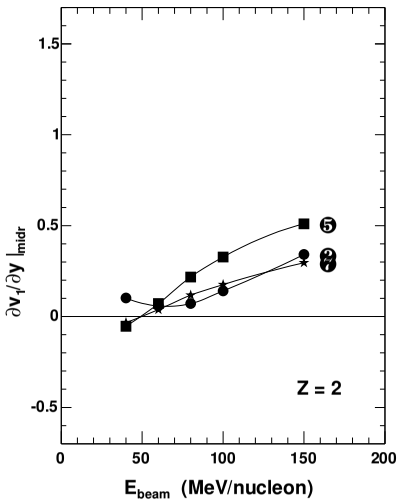


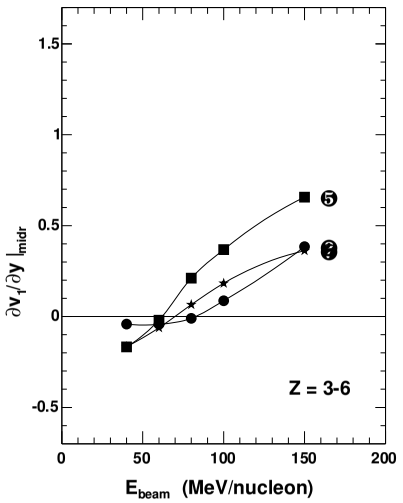


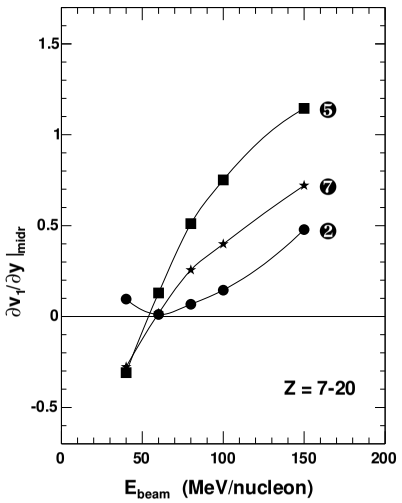
INDRA: Directed Flow, 1 reaction plane/fragment

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



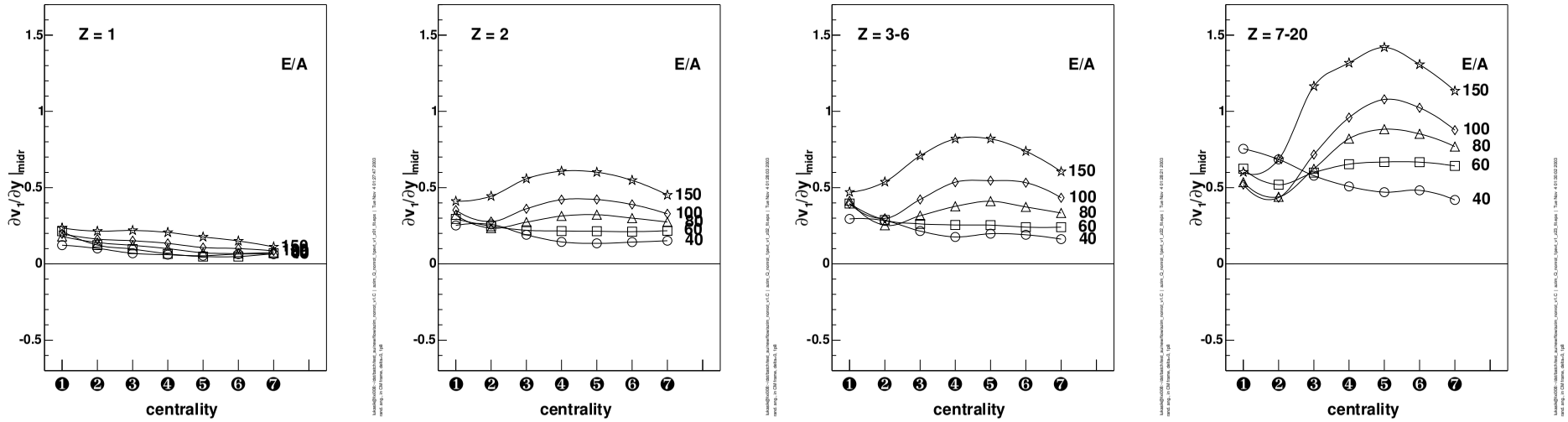






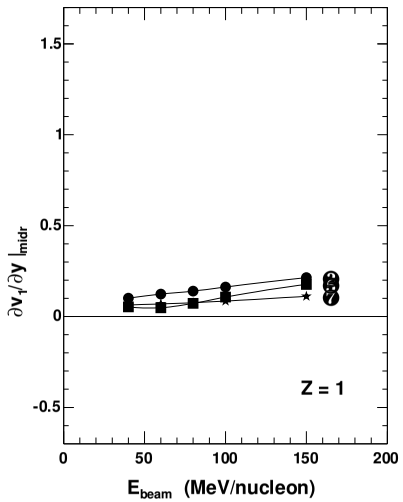
INDRA: Directed Flow, 1 reaction plane/event

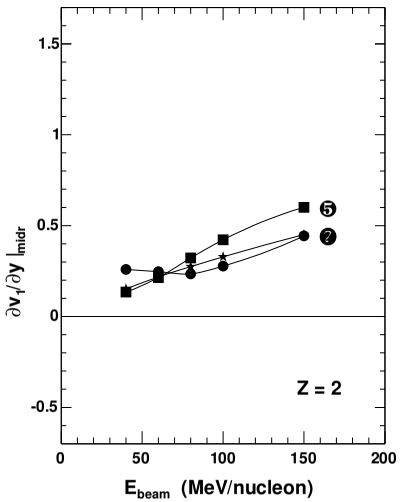
Slope parameter $\partial v_1/\partial y|_{midr}$ vs centrality

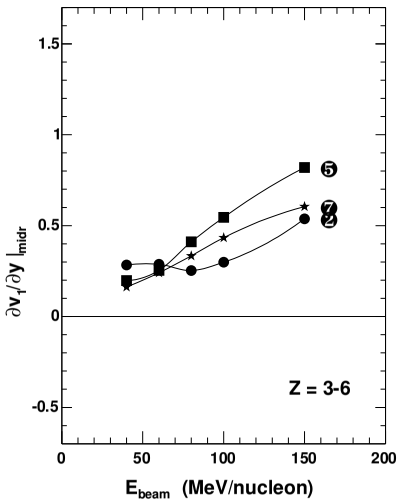


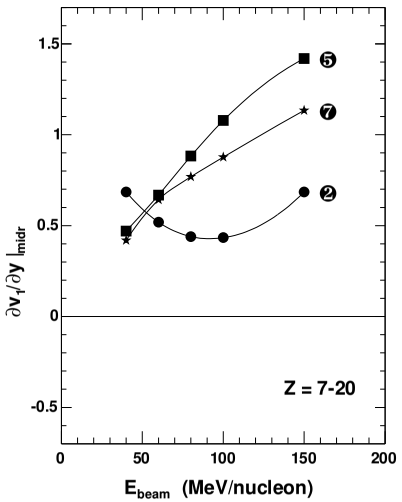
INDRA: Directed Flow, 1 reaction plane/event

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

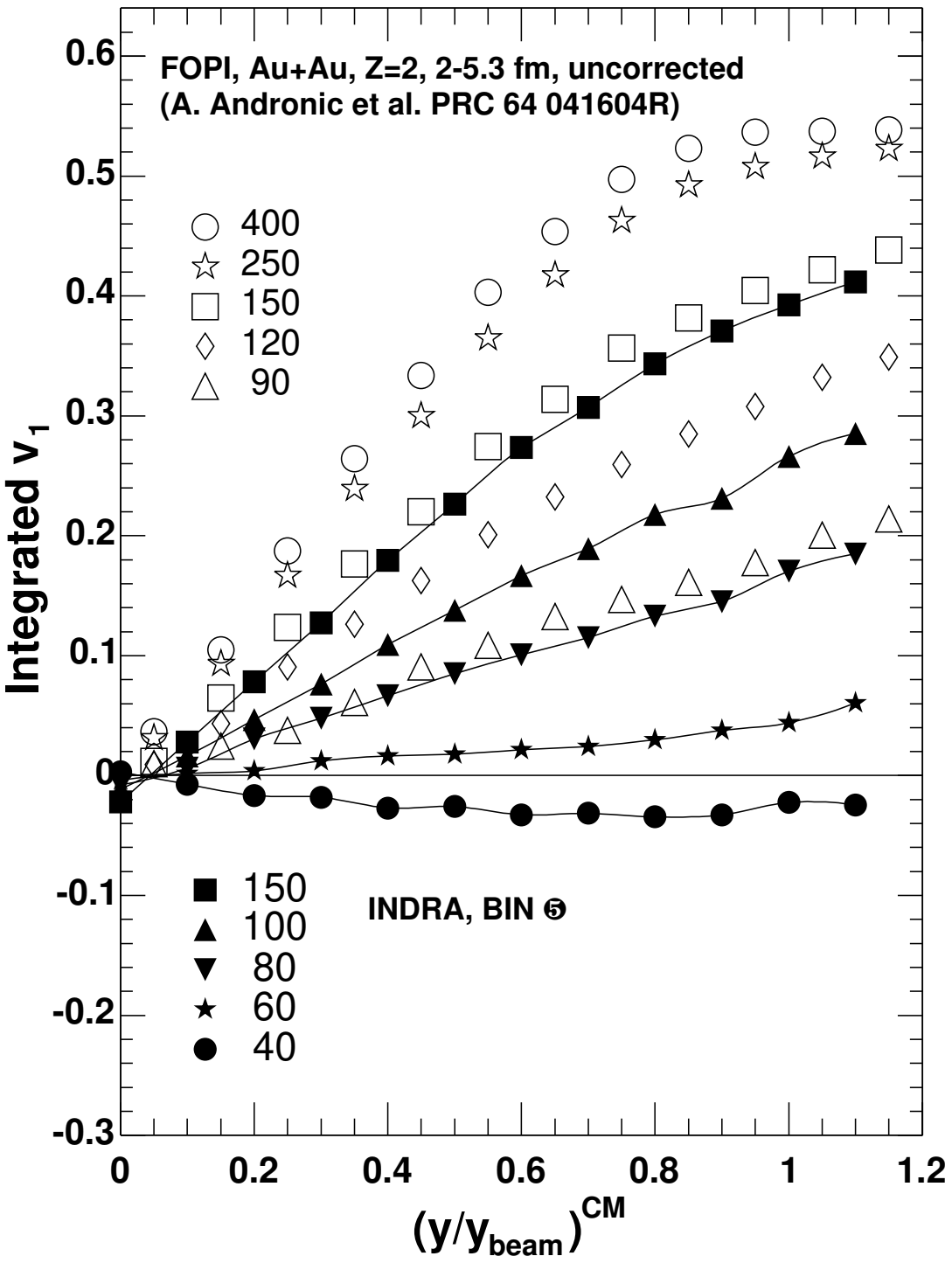








v_1 for mid-central collisions, comparison with FOPI



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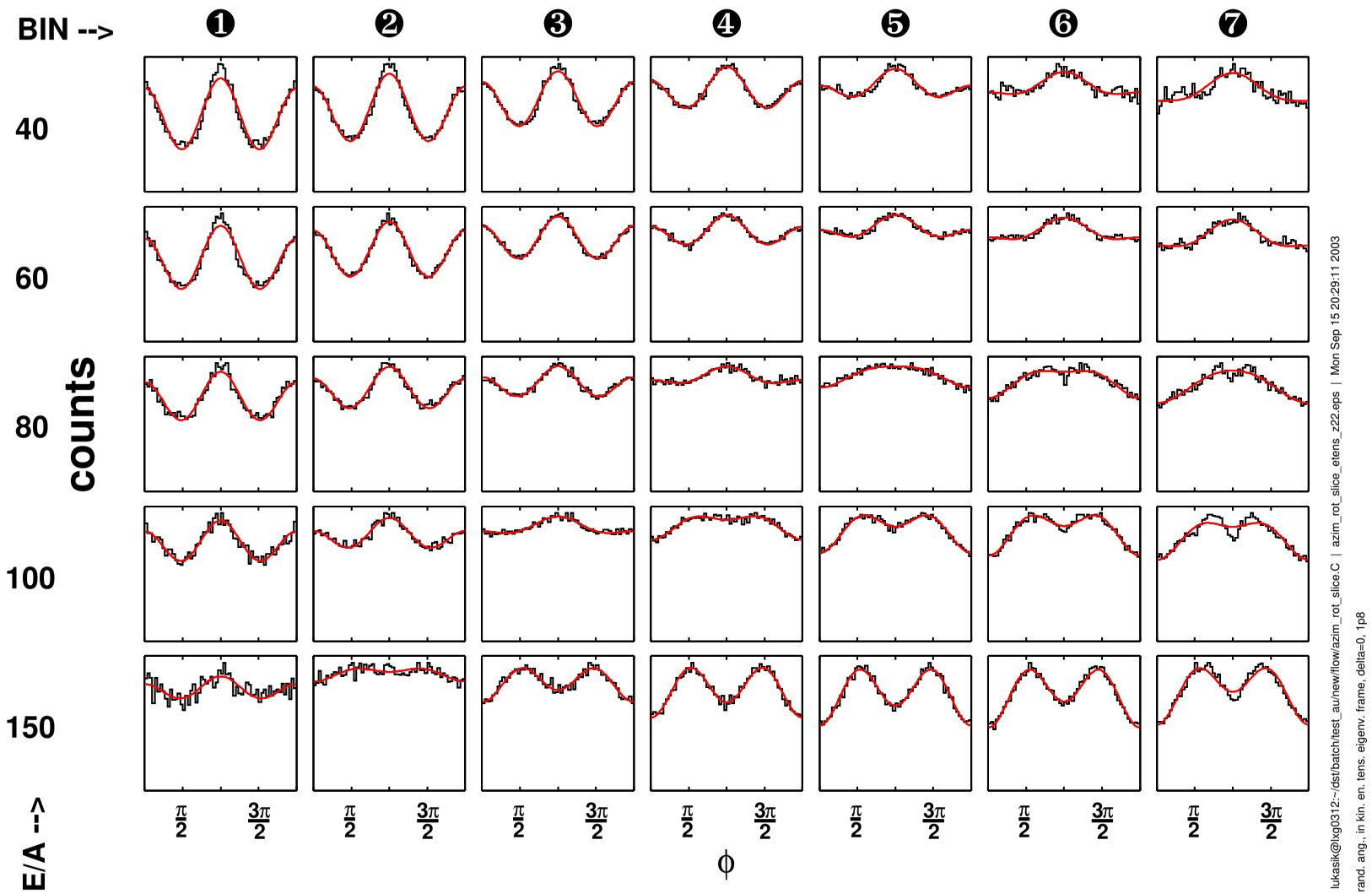
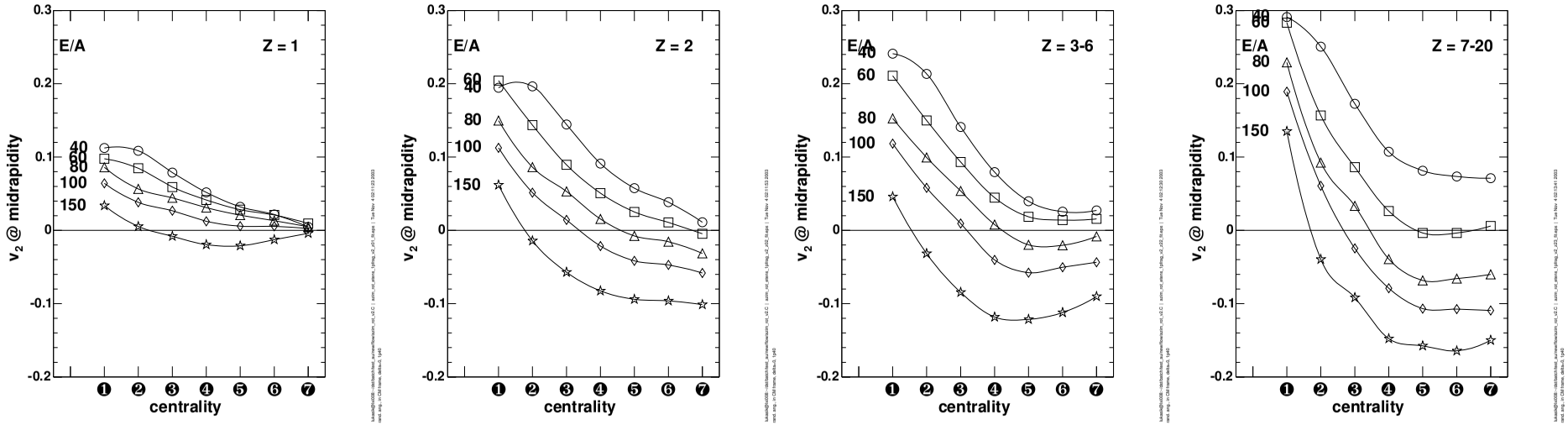
rand. ang., in CM frame, delta=0, 1p40

INDRA: Azimuthal distributions, Z=3-6



INDRA: Elliptic Flow, 1 reaction plane/fragment

$v_2 = < \cos(2\phi) >$ at midrapidity vs centrality



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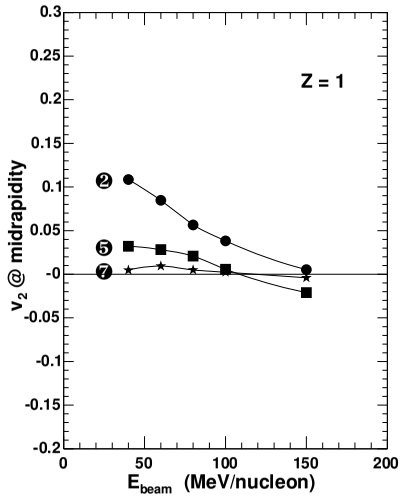
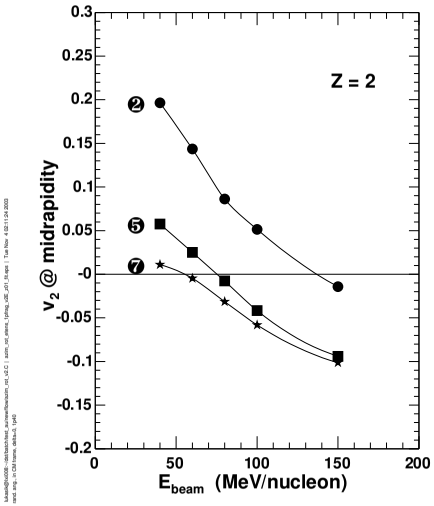
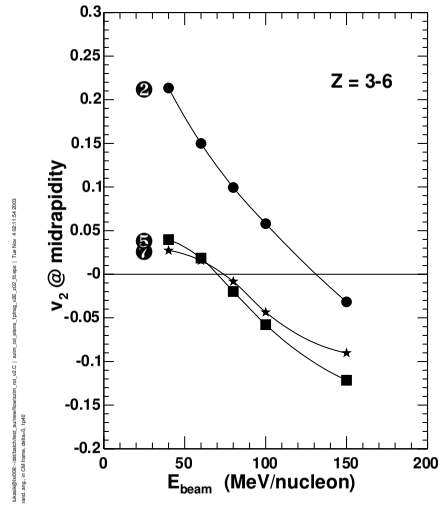
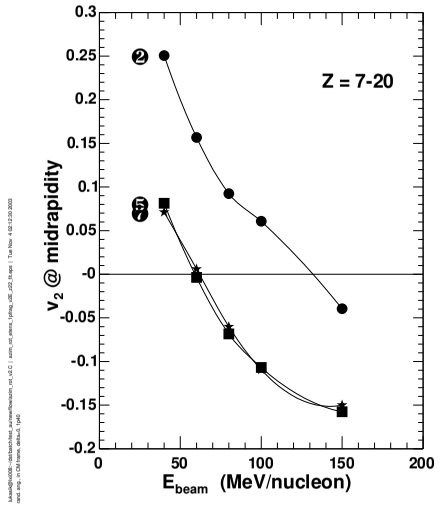
$v_2 = < \cos(2\phi) >$ at midrapidity vs centrality



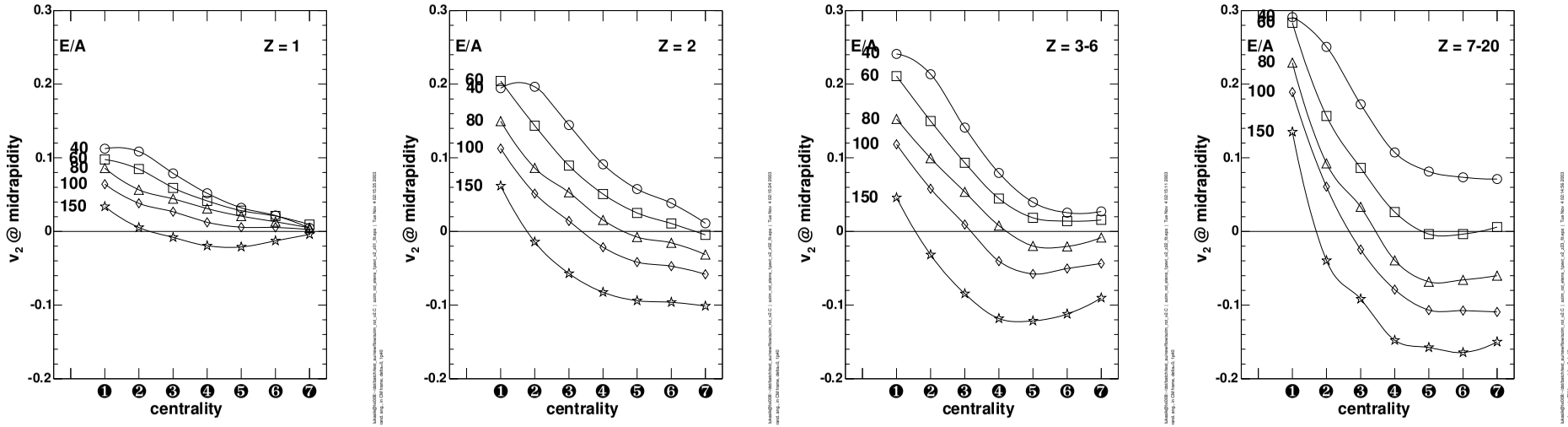






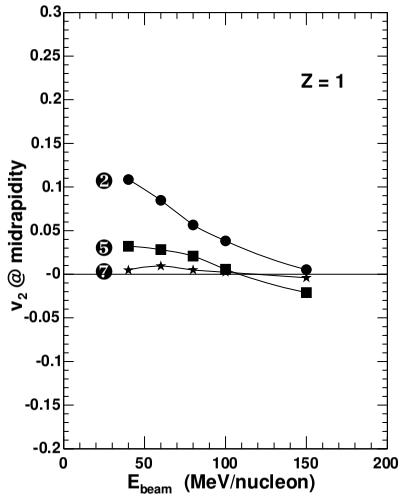
INDRA: Elliptic Flow, 1 reaction plane/event

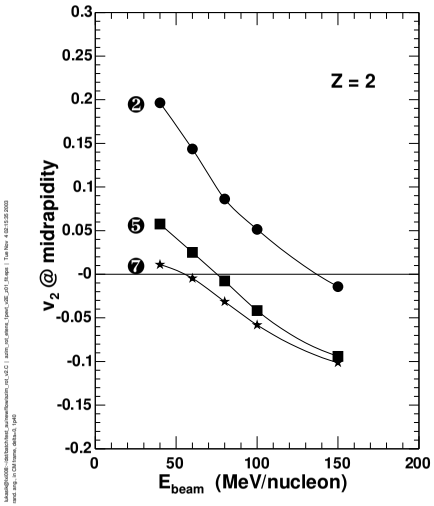
$v_2 = < \cos(2\phi) >$ at midrapidity vs centrality

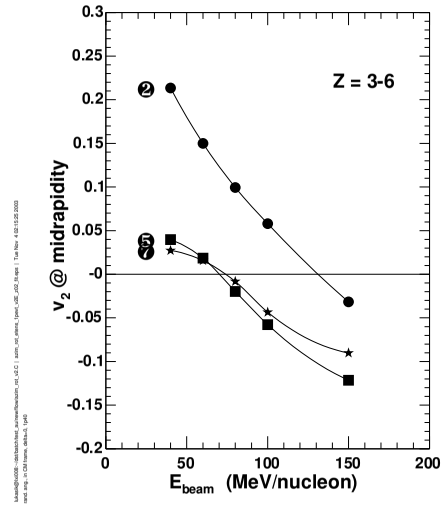


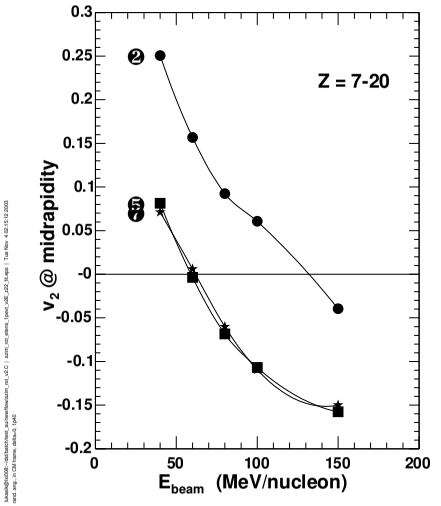
INDRA: Elliptic Flow, 1 reaction plane/event

$v_2 = < \cos(2\phi) >$ at midrapidity vs centrality

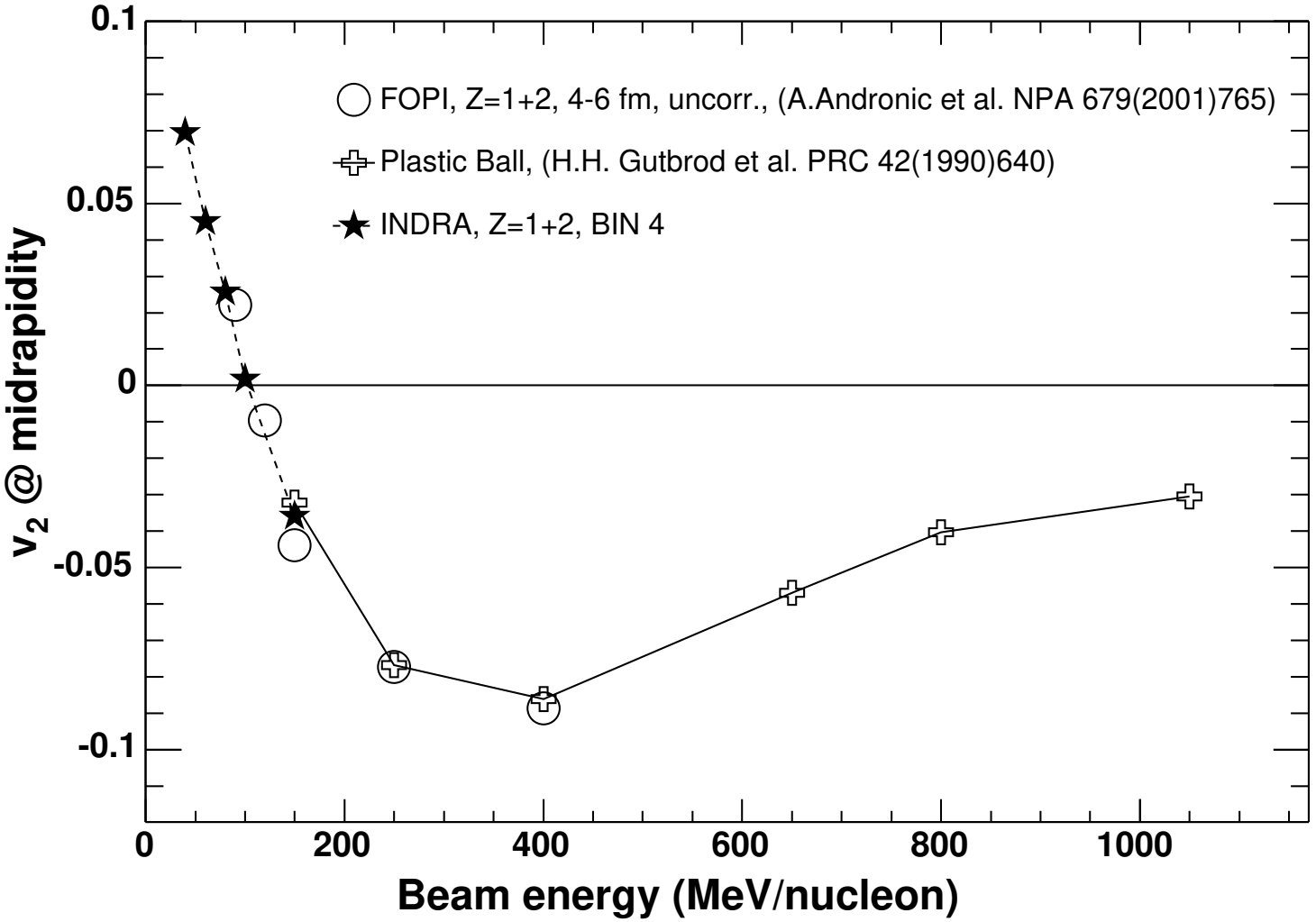








Elliptic Flow, Z=1+2, rotated



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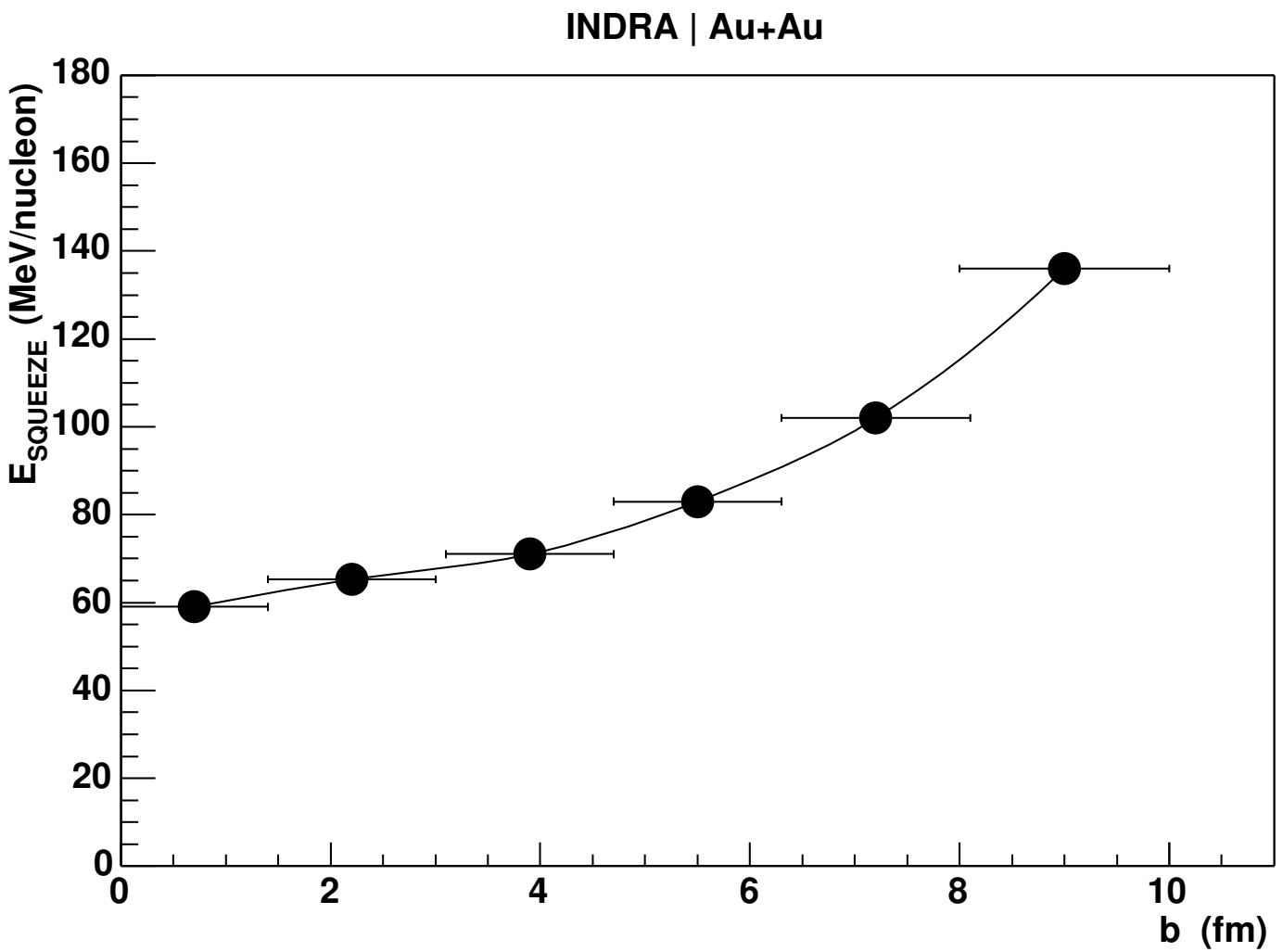
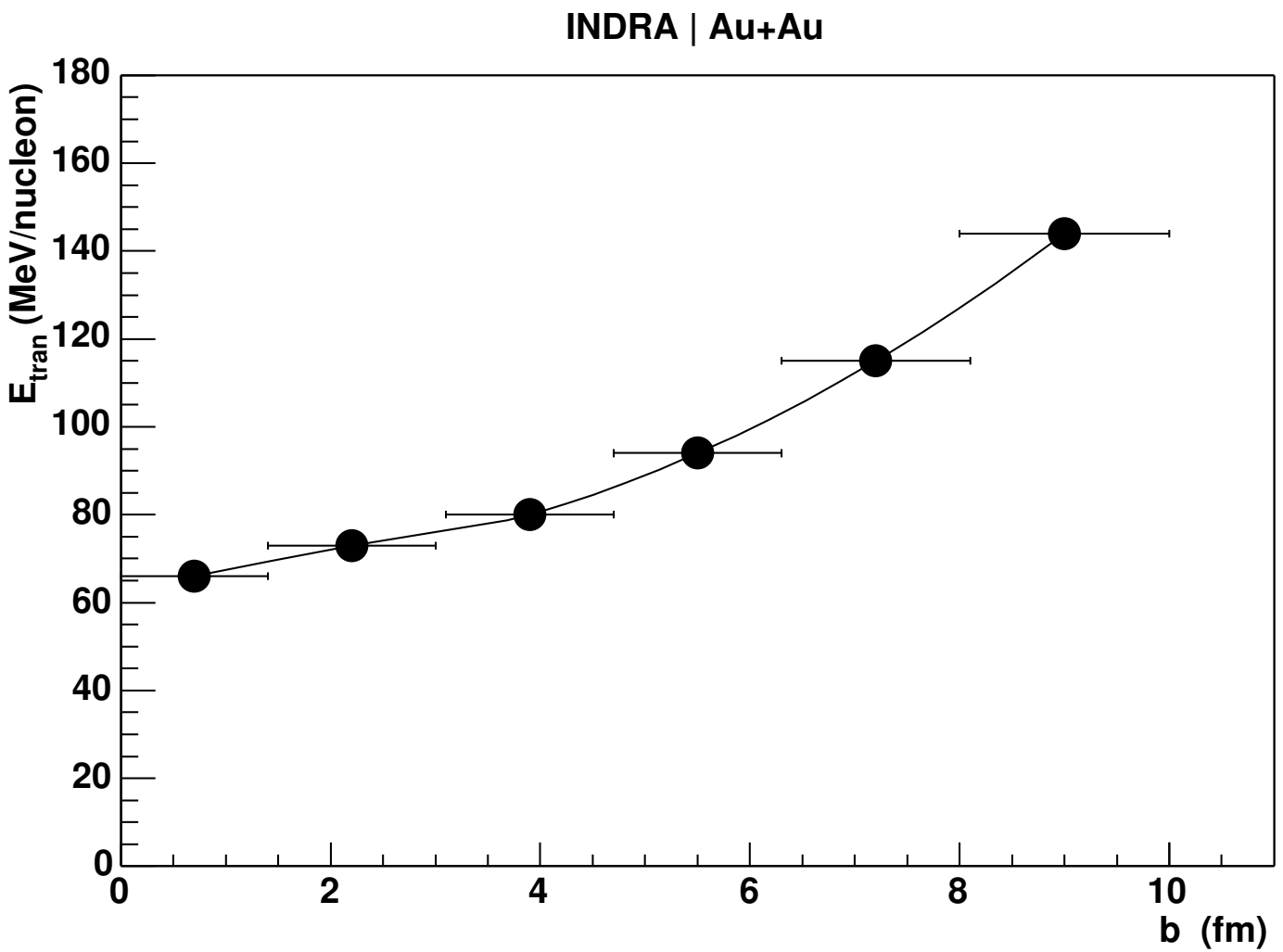
rand. ang., in CM frame, delta=0, 1p40, azi_rot_etens_E1pf_e%dz%02db%d

$E_{tran} \simeq 104$ AMeV (!)

Summary: $E_{SQUEEZE}$



Summary: E_{tran} for Z=2



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_{tran}.

☛ INDRA@GSI calls for theoretical support.

☛ INDRA@GSI needs a reliable reaction plane reconstruction procedure suitable for low energy collisions.