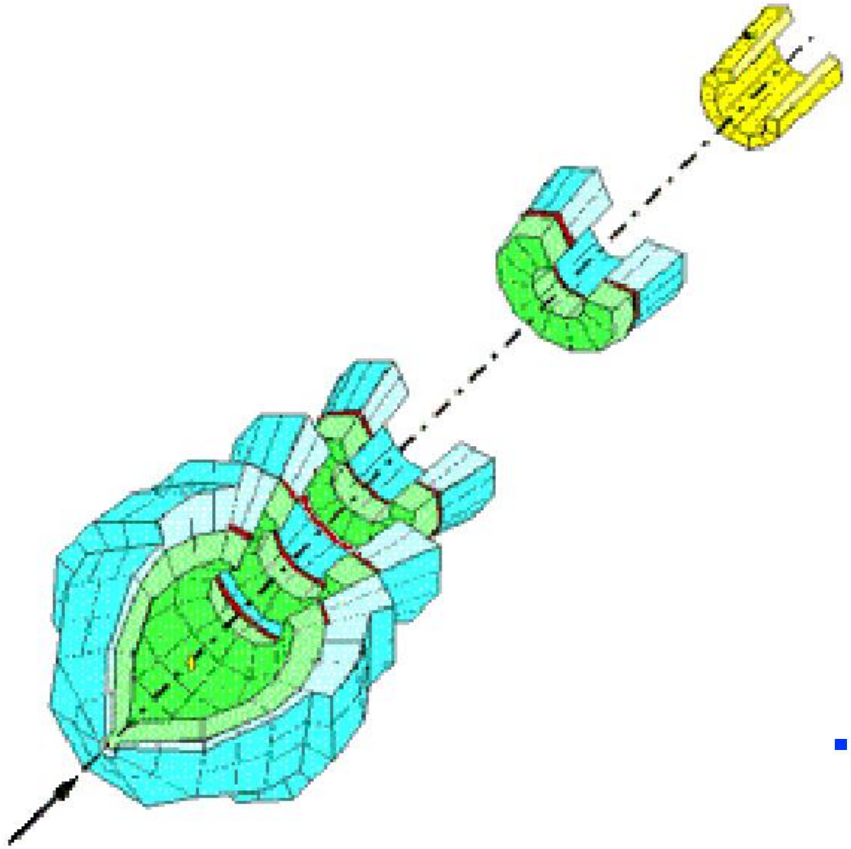
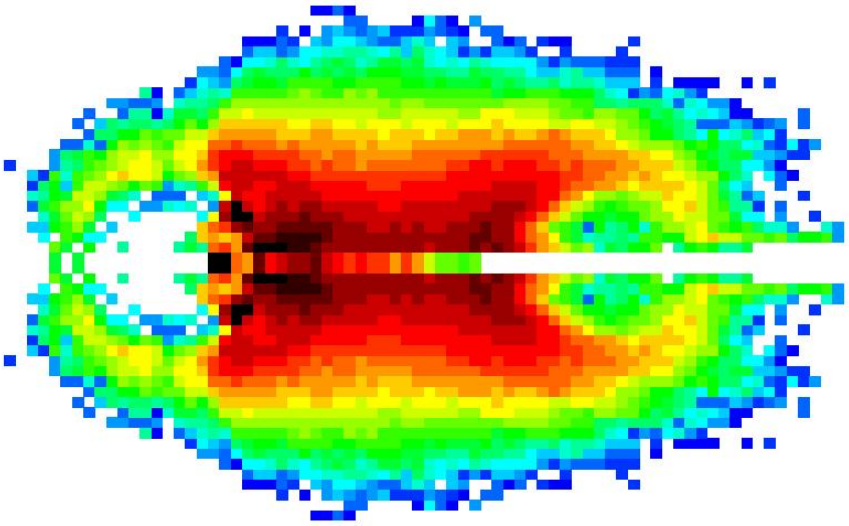
INDRA at GSI

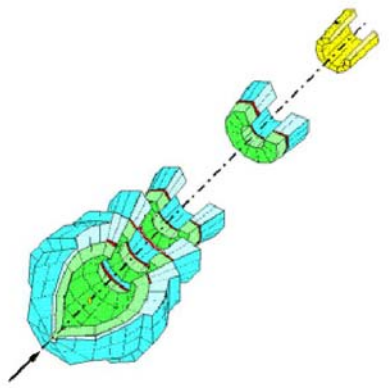
November 1997 – April 1999



Z=3
Au + Au
80 AMeV
Very peripheral



INDRA at GSI



Systems:
Au + Au 40 to 150 AMeV
Xe + Sn 50 to 250 AMeV
C + Au 95 to 1800 AMeV

INDRA at GSI

Transverse Velocity Scaling in ^{197}Au + ^{197}Au Fragmentation

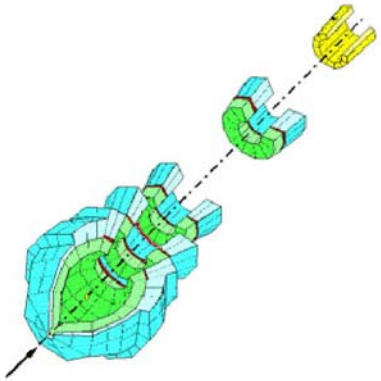
J. Łukasik,[1,10] S. Hudan,[2] F. Lavaud,[3] K. Turzó,[1] G. Auger,[2] Ch.O. Bacri,[3] M.L. Begemann-Blaich,[1] N. Bellaize,[4] R. Bittiger,[1] F. Bocage,[4] B. Borderie,[3] R. Bougault,[4] B. Bouriquet,[2] Ph. Buchet,[5] J.L. Charvet,[5] A. Chbihi,[2] R. Dayras,[5] D. Doré,[5] D. Durand,[4] J.D. Frankland,[2] E. Galichet,[6] D. Gourio,[1] D. Guinet,[6] B. Hurst,[4] P. Lautesse,[6] J.L. Laville,[2] C. Leduc,[6] 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] G. Tăbăcaru,[2] B. Tamain,[4] W. Trautmann,[1] A. Trzciński,[9] E. Vient,[4] M. Vigilante,[7] C. Volant,[5] B. Zwieglíński,[9] and A.S. Botvina[1,11]

(The INDRA and ALADIN Collaborations)

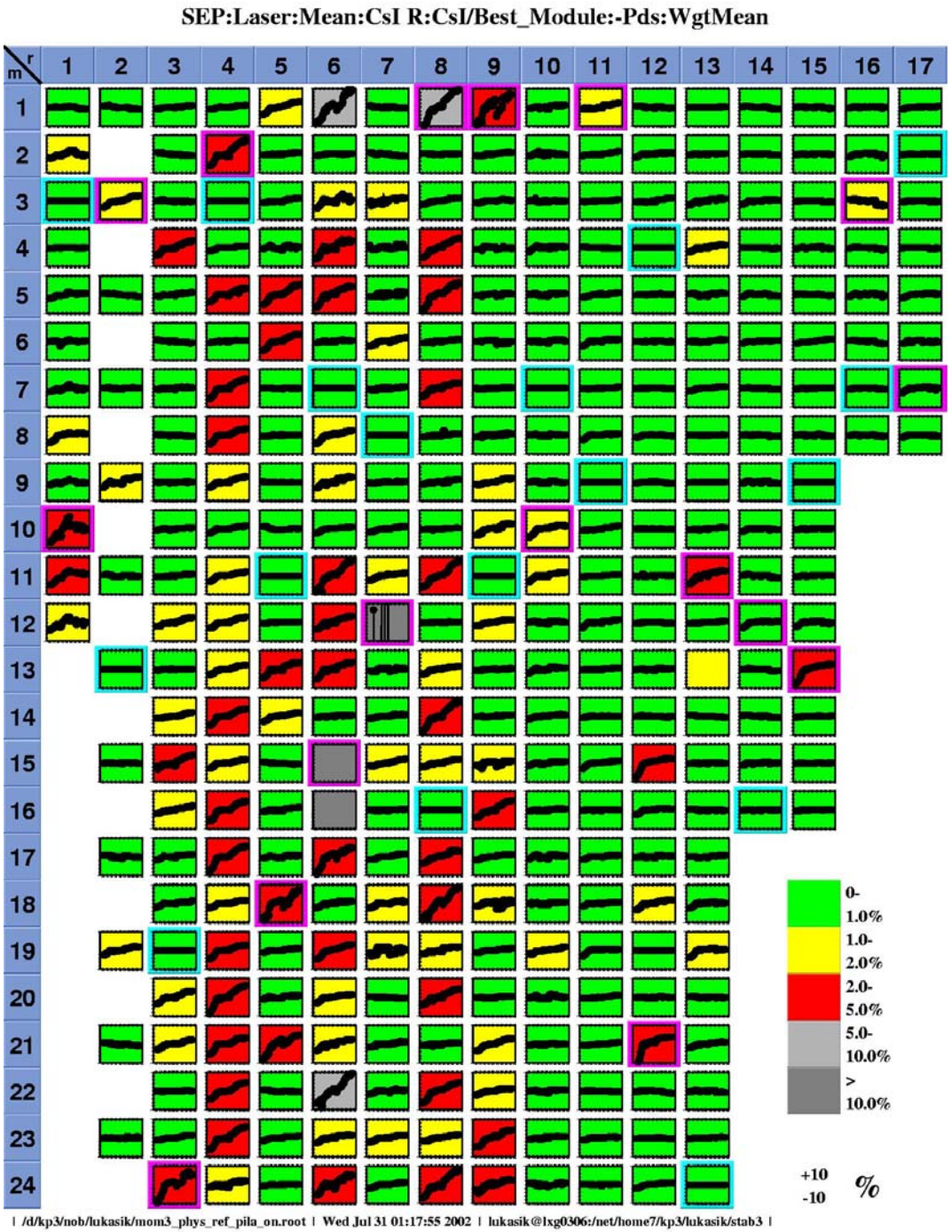
[1] *Gesellschaft für Schwerionenforschung mbH, D-64291 Darmstadt, Germany*
[2] *GANIL, CEA et IN2P3-CNRS, F-14076 Caen, France*
[3] *Institut de Physique Nucléaire, IN2P3-CNRS et Université, F-91406 Orsay, France*
[4] *LPC, IN2P3-CNRS, ISMRA et Université, F-14050 Caen, France*
[5] *DAPNIA/SPhN, CEA/Saclay, F-91191 Gif sur Yvette, France*
[6] *Institut de Physique Nucléaire, IN2P3-CNRS et Université, F-69622 Villeurbanne, France*
[7] *Dipartimento di Scienze Fisiche e Sezione INFN, Univ. Federico II, I-80126 Napoli, Italy*
[8] *Dipartimento di Fisica dell' Università and INFN, I-95129 Catania, Italy*
[9] *A. Sołtan Institute for Nuclear Studies, Pl-00681 Warsaw, Poland*
[10] *H. Niewodniczański Institute of Nuclear Physics, Pl-31342 Kraków, Poland*
[11] *Institute for Nuclear Research, 117312 Moscow, Russia*

Phys. Rev. C 66, 064606 (2002)

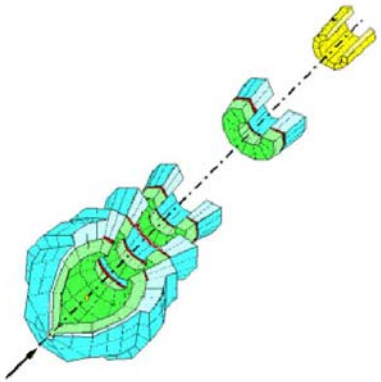
Stability



336 CsI(Tl)

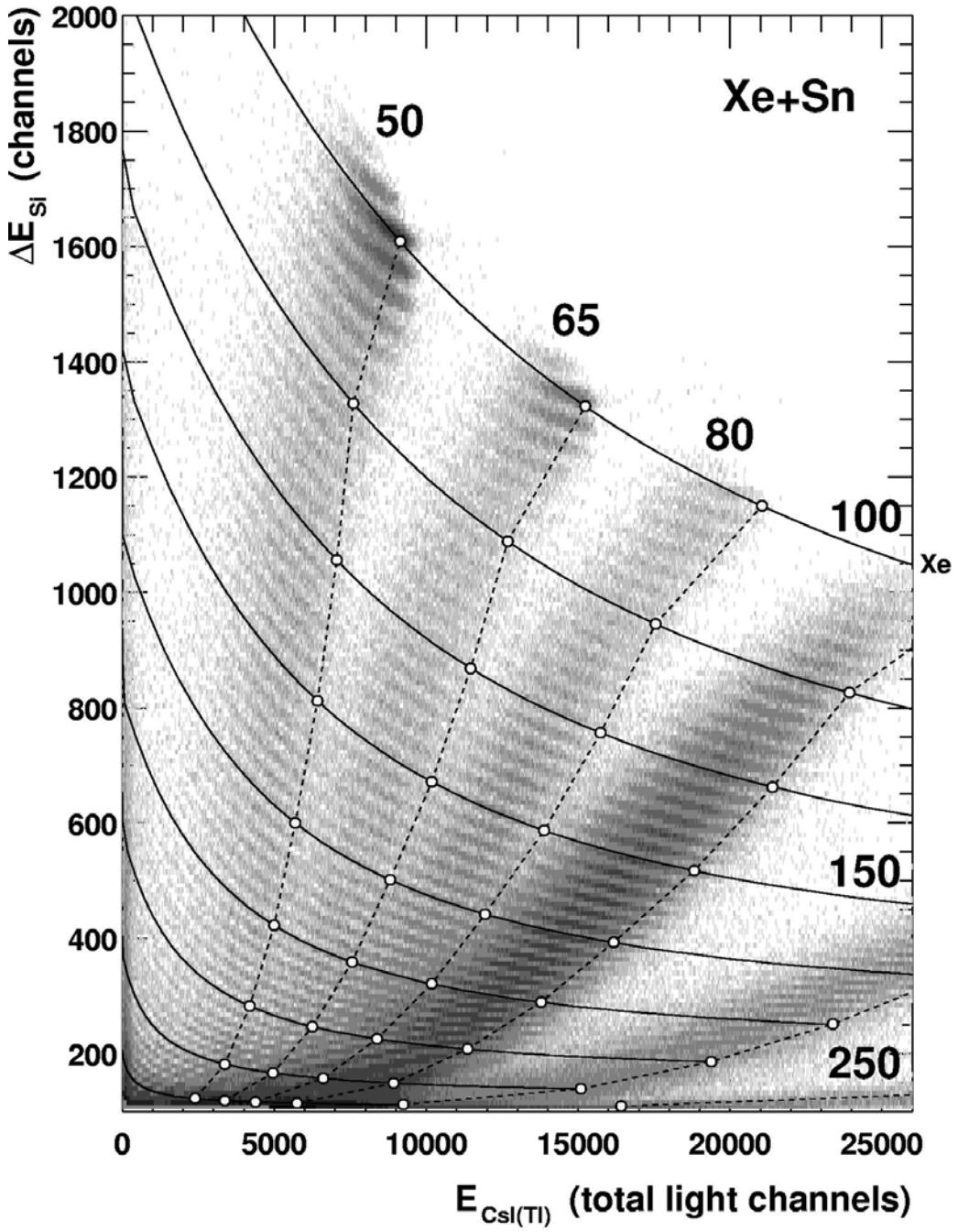


Identification



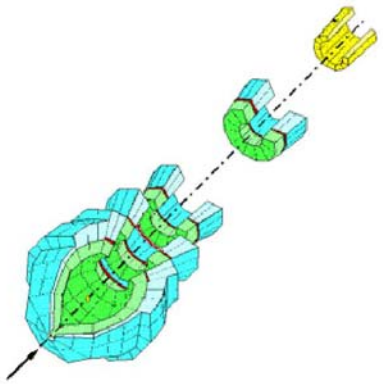
Ring 1

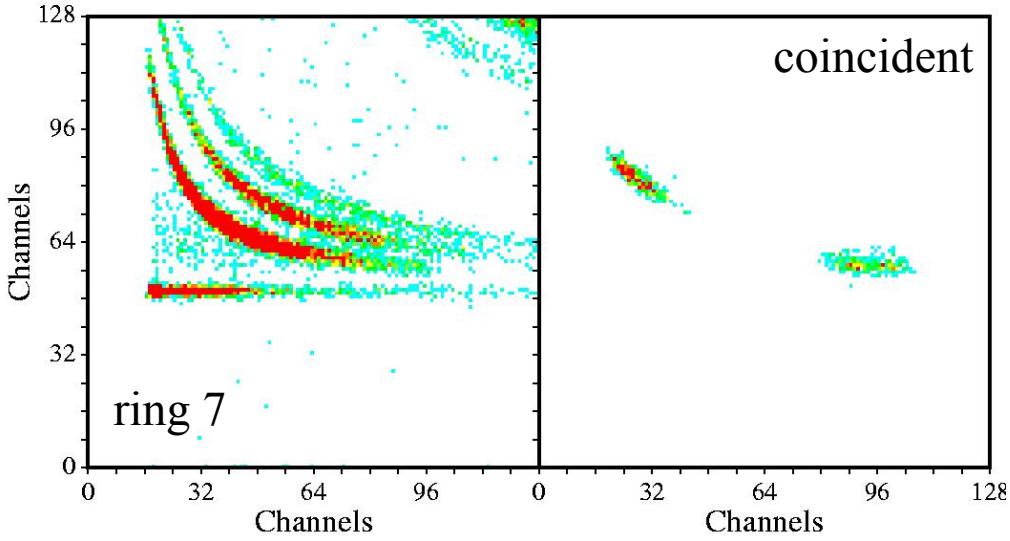
Pârlog parameterization

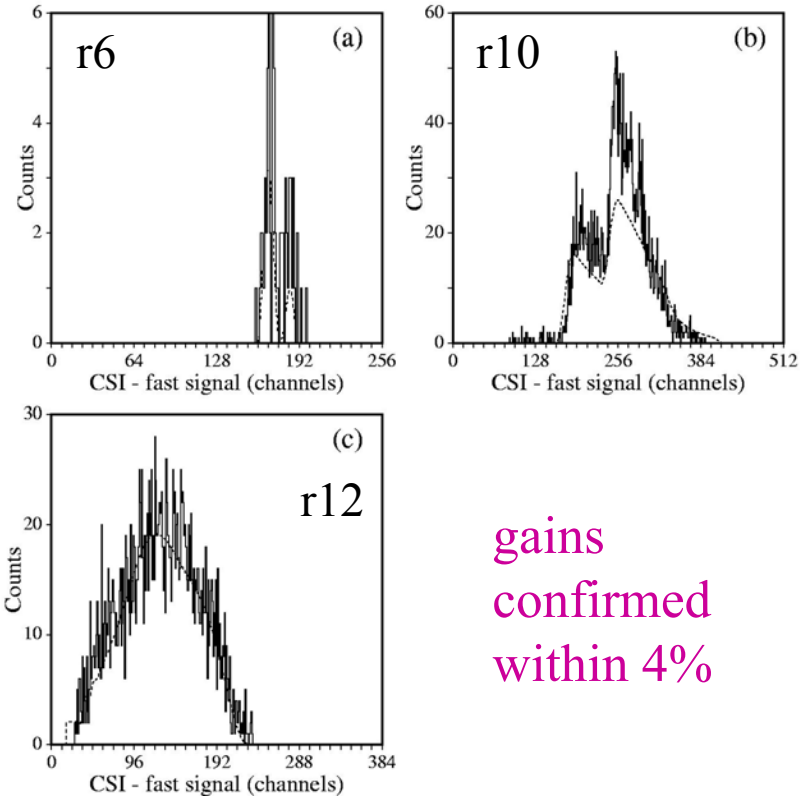


Calibration check

$^{12}C + {}^{1}H$ at 30 AMeV



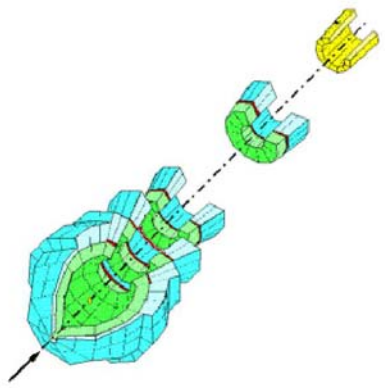




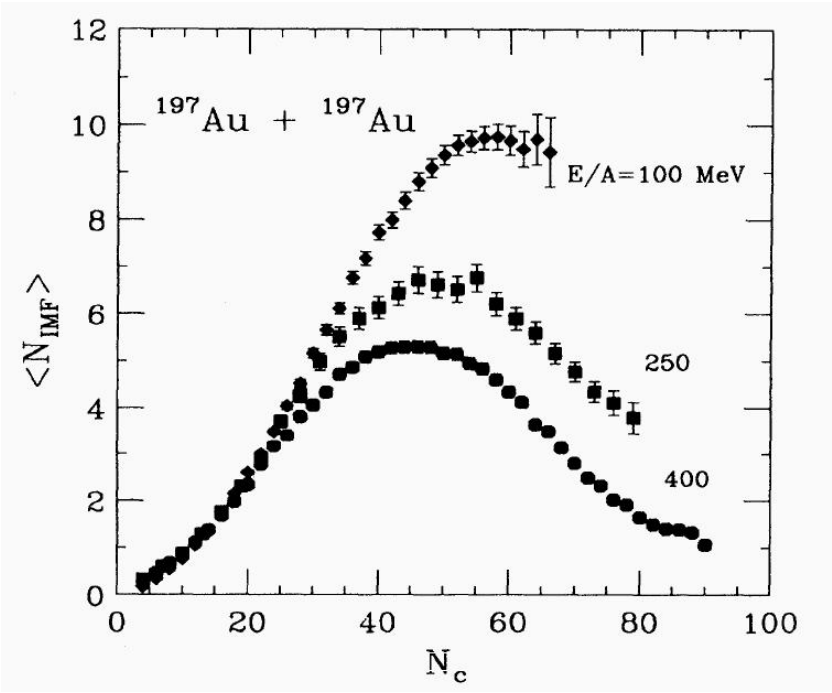
gains confirmed within 4%

A. Trzciński et al., NIM A 501 (2003) 367

Motivation

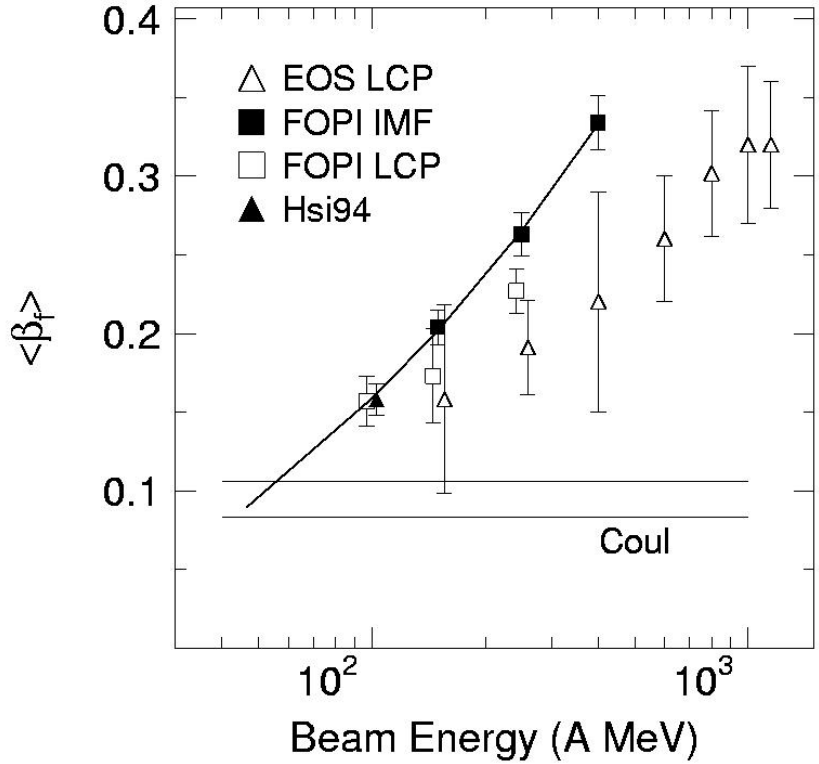


Tsang et al. PRL 71, 1502 (1993)



Centrality ⟶

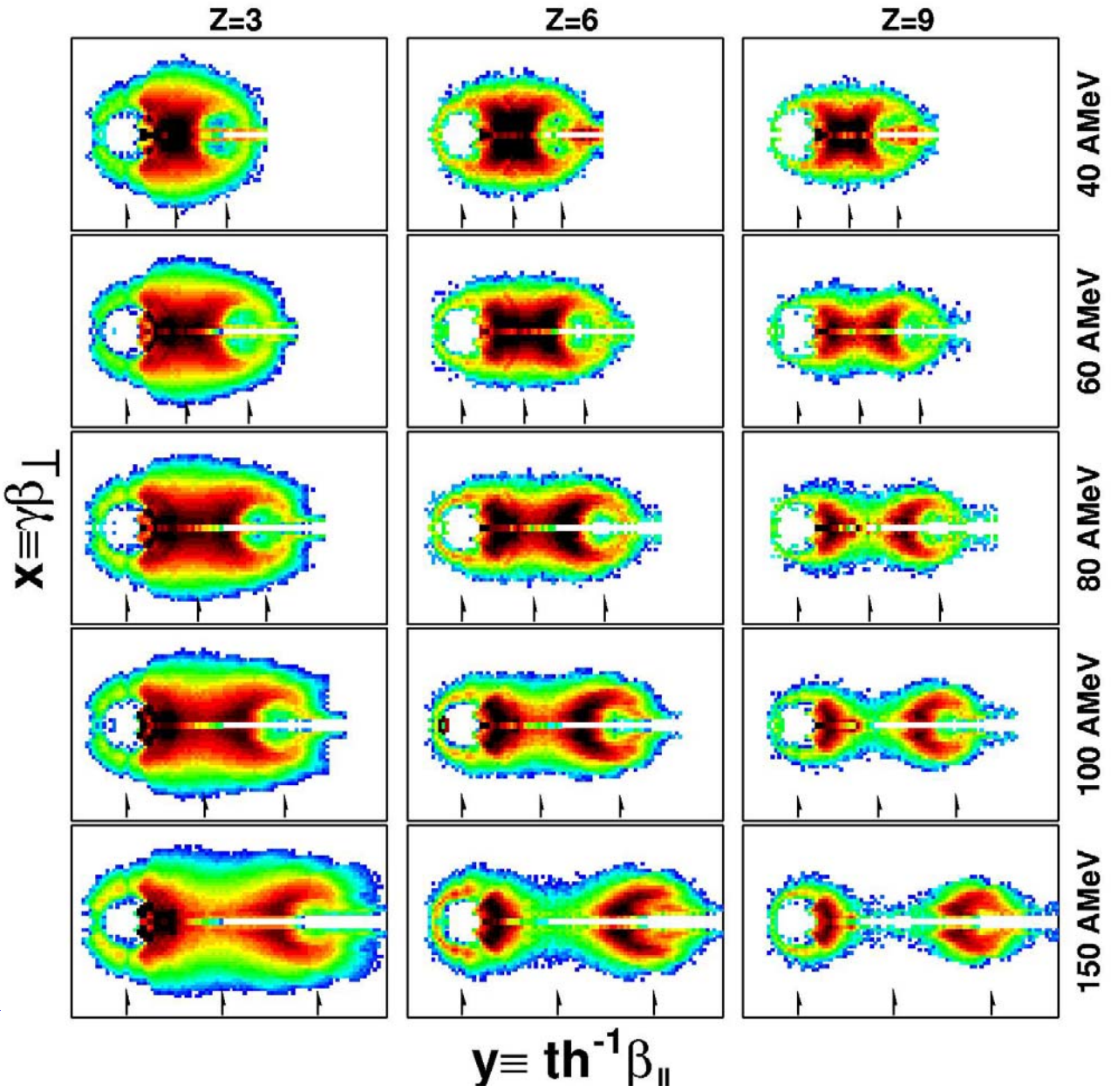
Reisdorf & Ritter, Ann. Rev. Nucl. Part. Sci.



Motivation

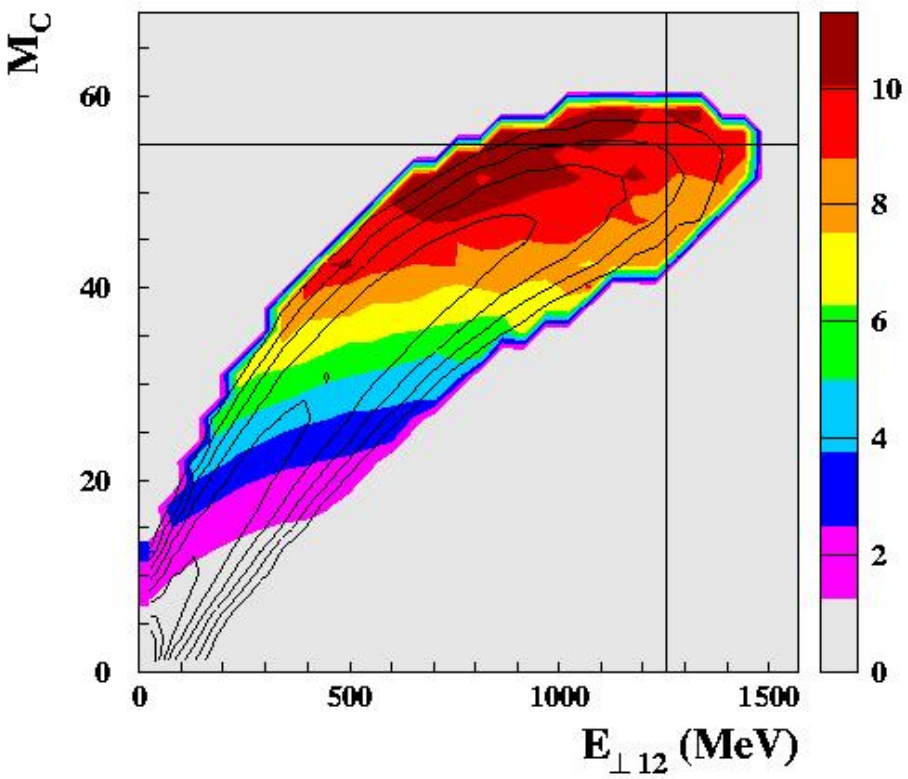
Invariant
cross sections
for Au + Au
at peripheral
impact parameters

From the Fermi
to the
relativistic domain

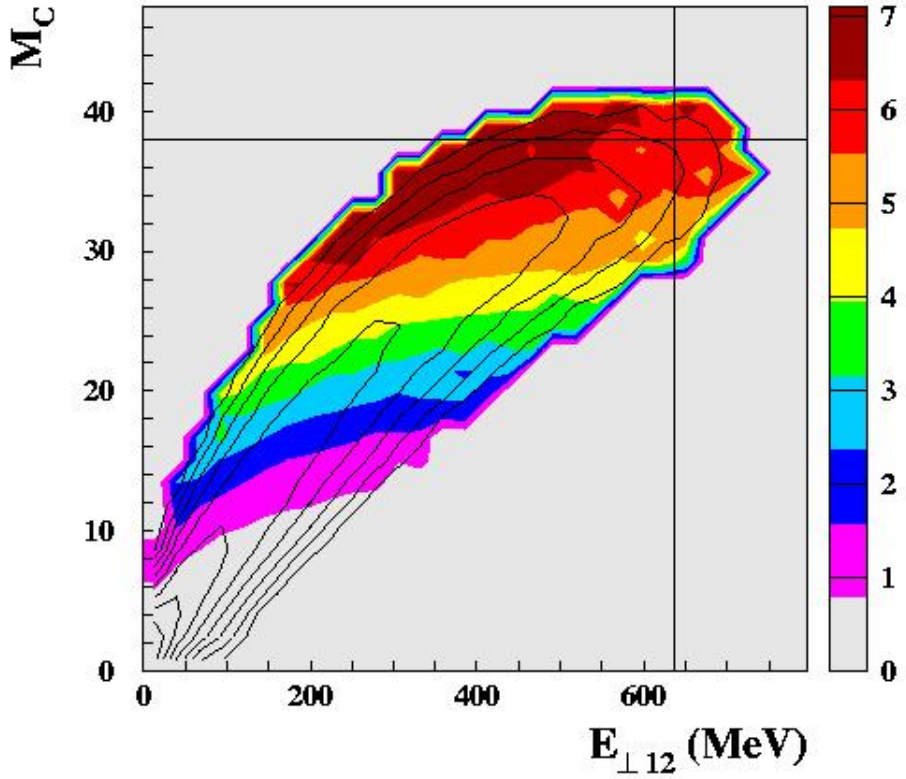


Global variables and impact parameter

Au + Au at 60 A MeV

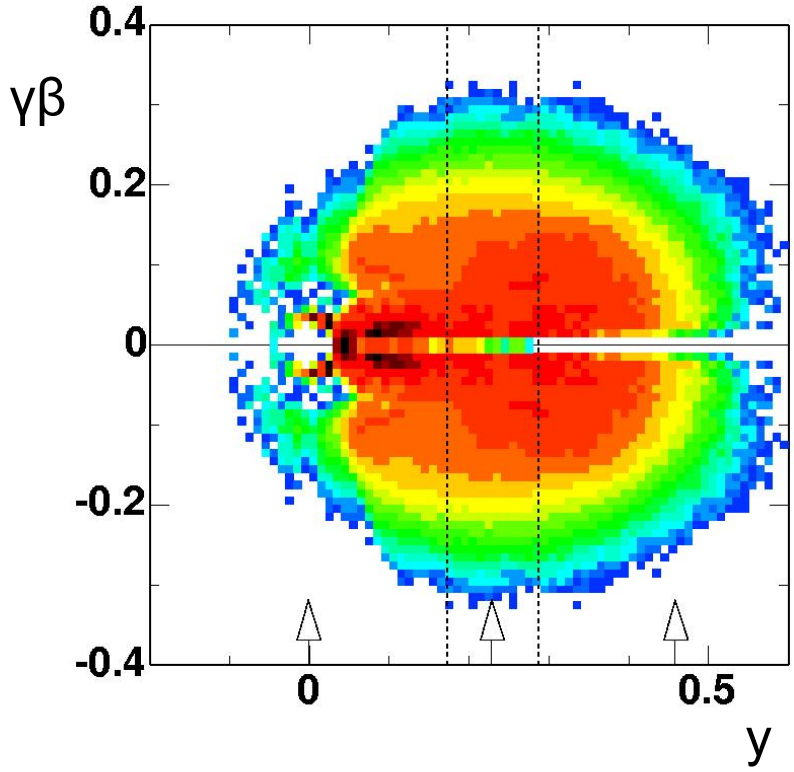


Xe + Sn at 50 A MeV



Part I:

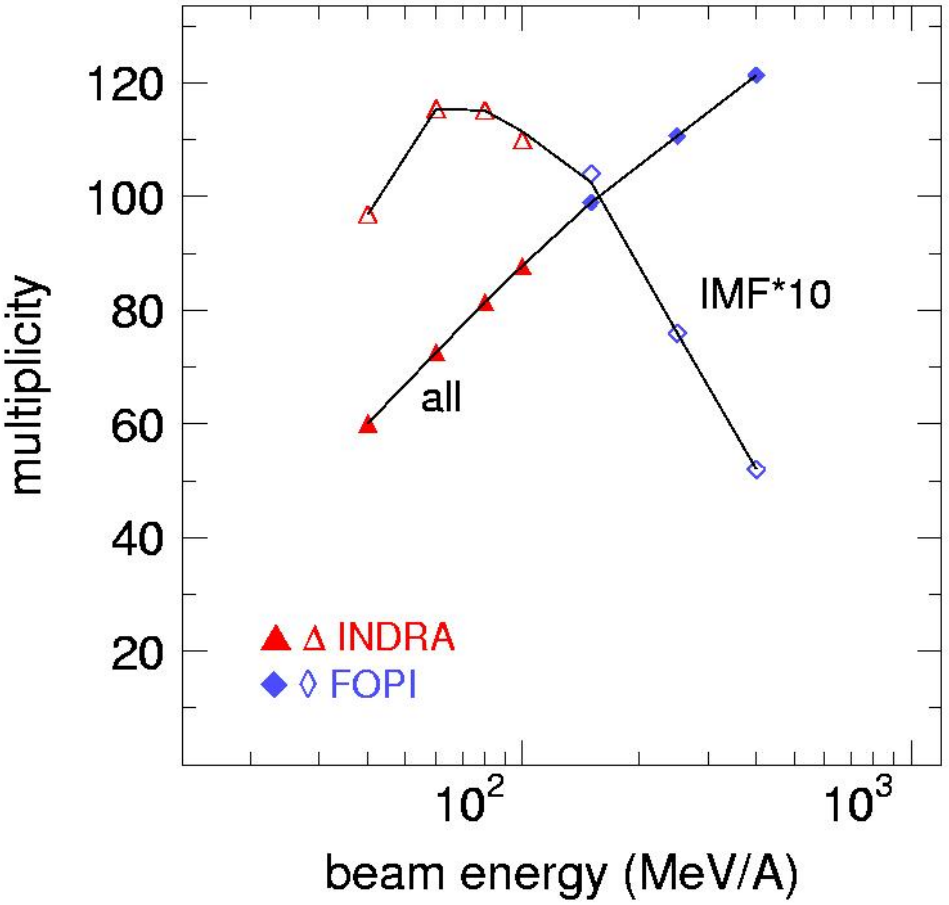
Central Au + Au



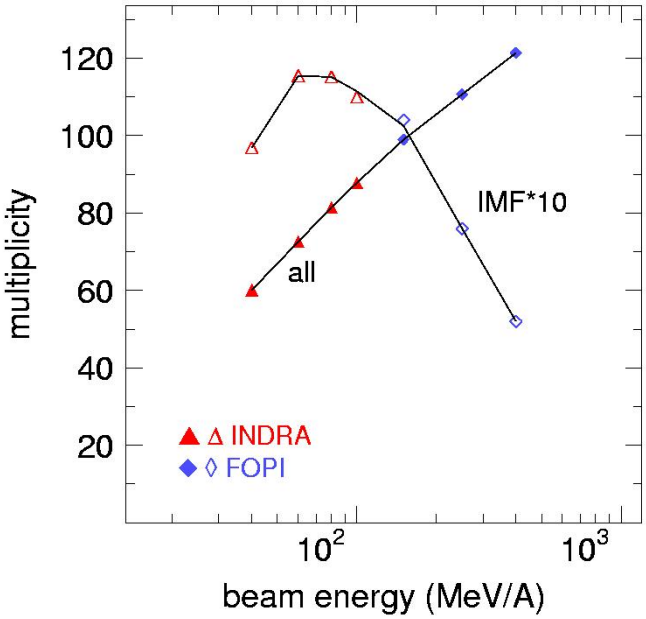
Z = 3 at 100 A MeV

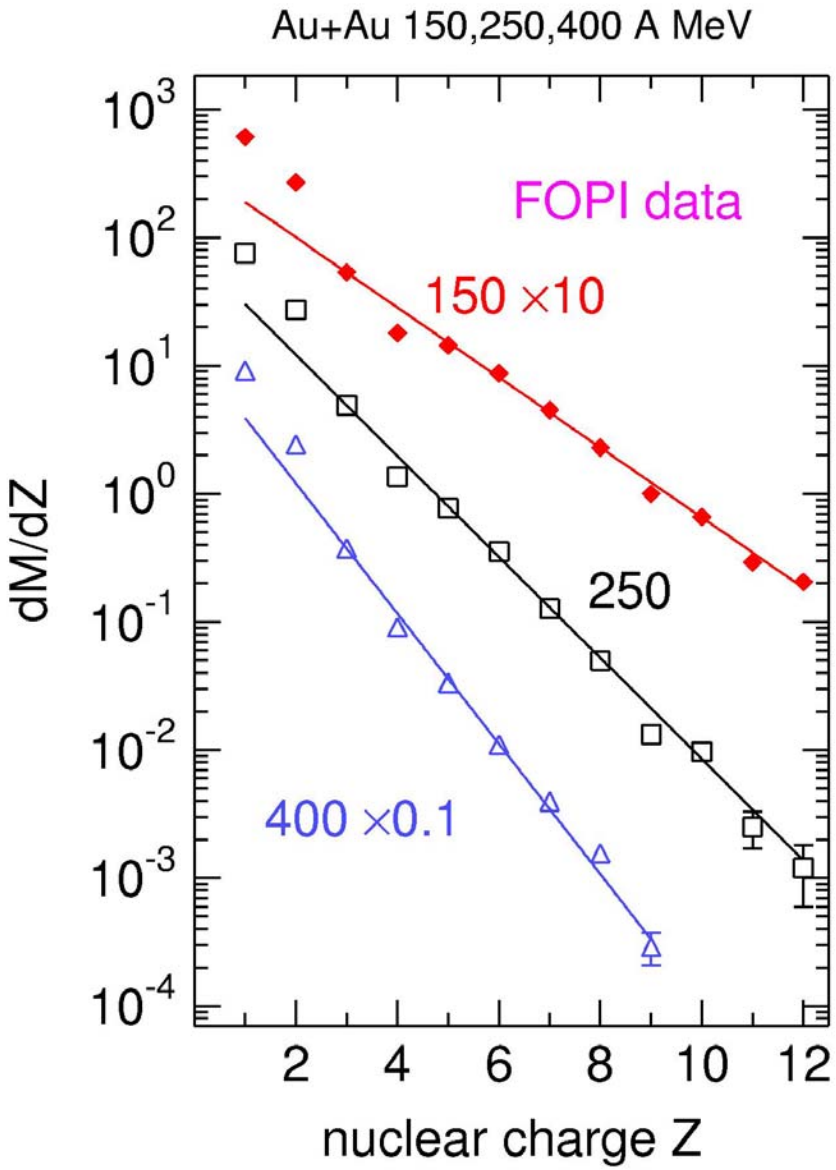
Multiplicities

in central collisions

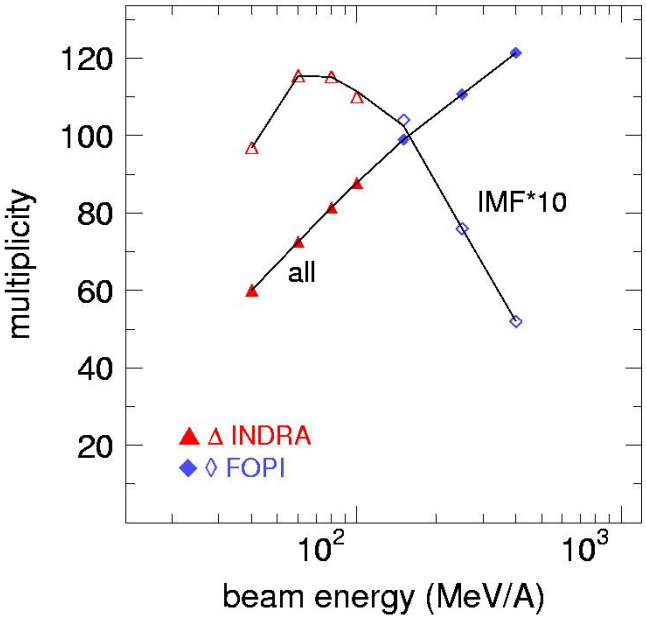


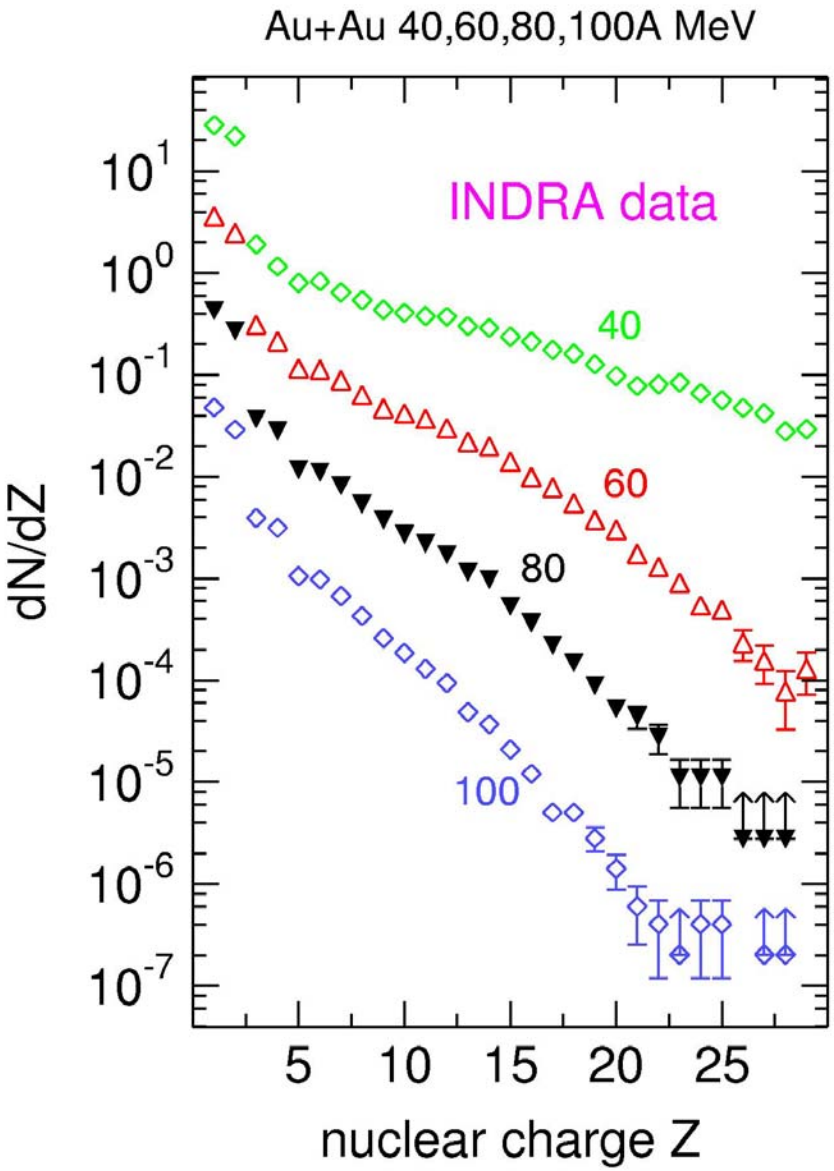
Multiplicities





Multiplicities



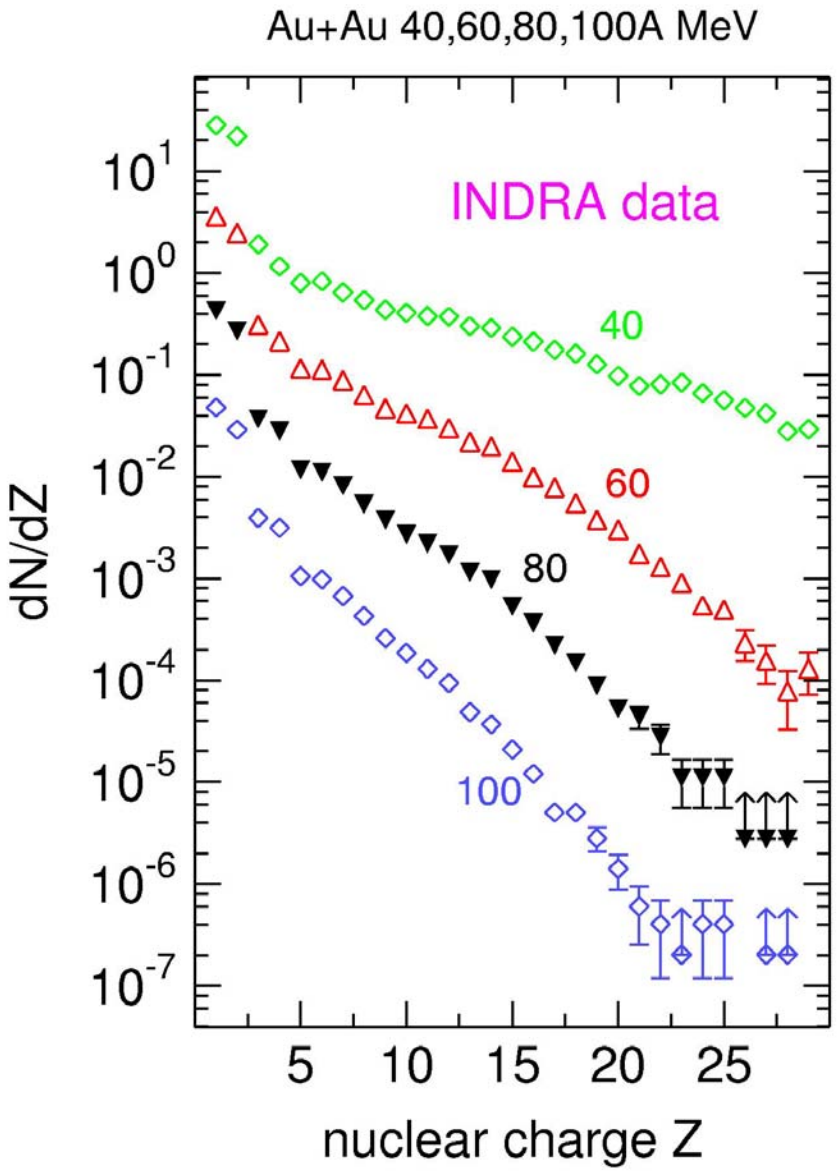


Flow and fragmentation

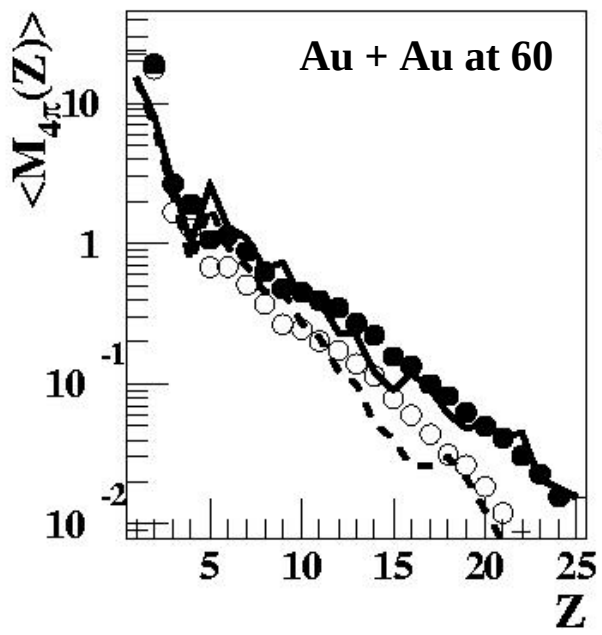
Statistical model descriptions with decoupled flow

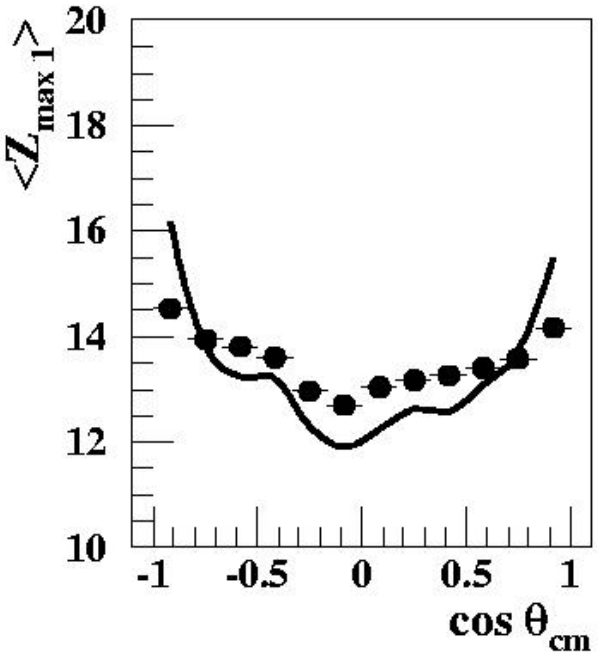
SMM:
F. Lavaud, thesis

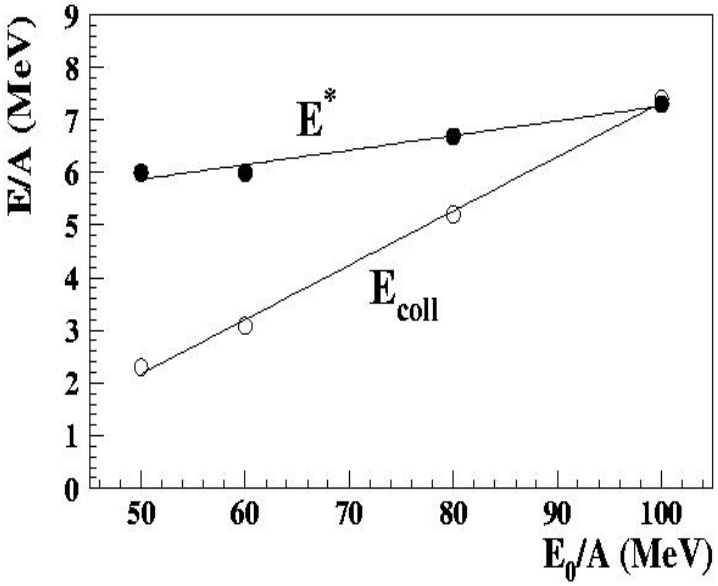
MMMC:
A. Le Fèvre et al., subm. to NPA



Flow and fragmentation







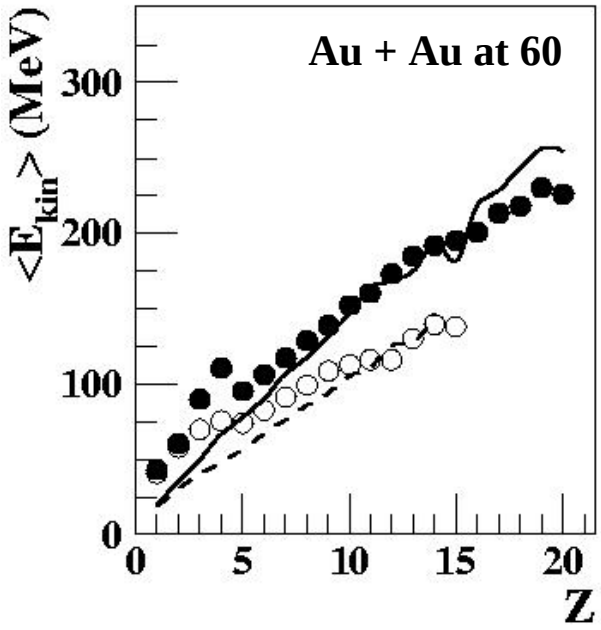
● longitudinal

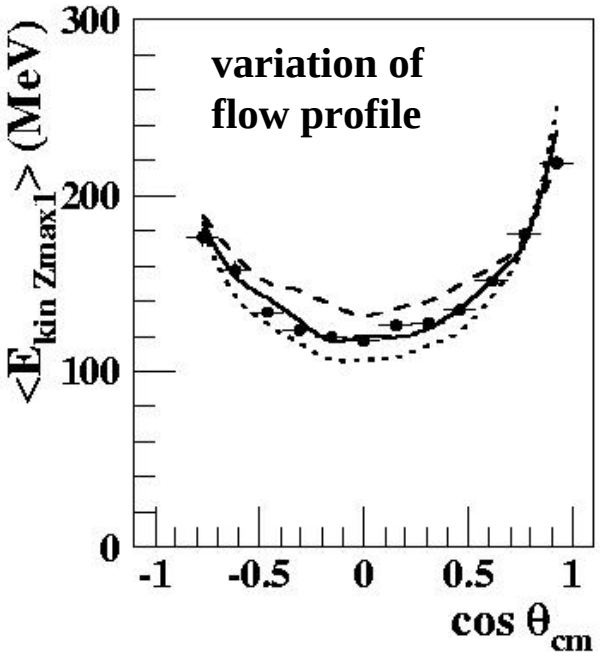
○ transverse

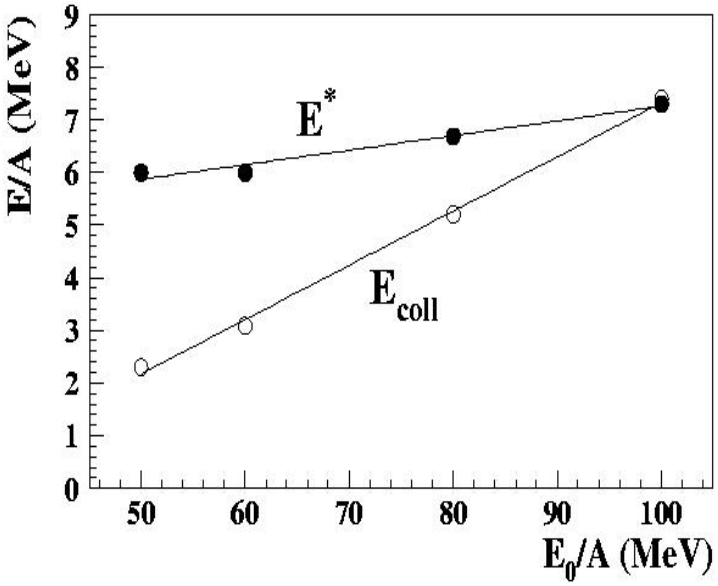
from MMMC model description
with deformed source (0.7:1)
and with decoupled flow

A. Le Fèvre et al., subm. to NPA

Flow and fragmentation







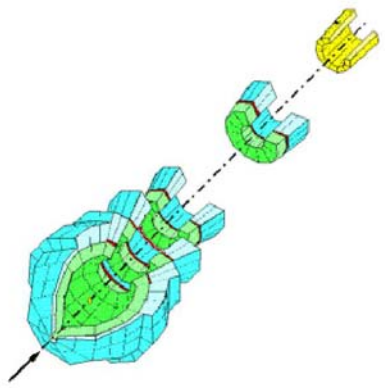
● longitudinal

○ transverse

from MMMC model description
with deformed source (0.7:1)
and with decoupled flow

A. Le Fèvre et al., subm. to NPA

Questions



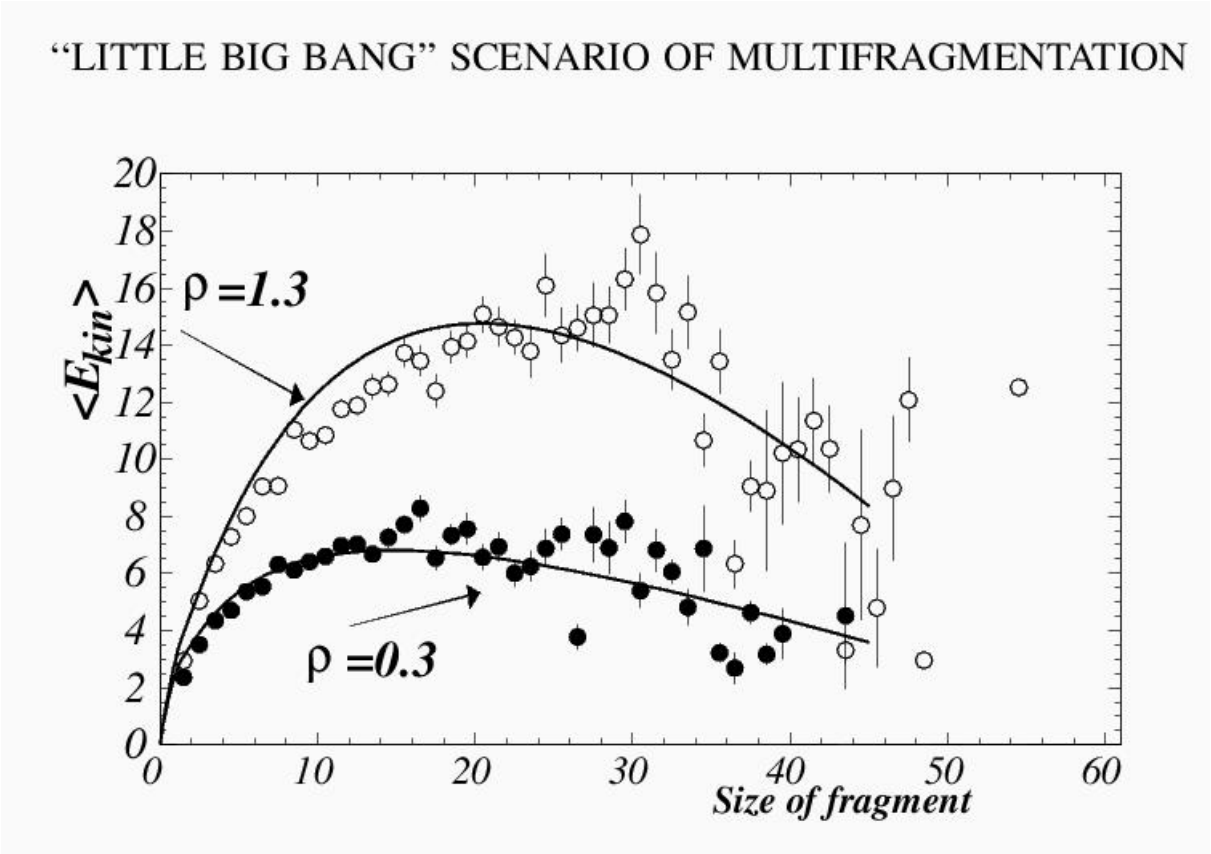
1) Why does the SMM or MMMC work so well in a dynamical situation ?

2) Deformation as a dynamical constraint !

3) Radial flow should be another constraint !
Implicitly contained in parameters ?
Alternatively: early fragment formation ?

Flow and fragmentation

X. Campi et al.,
Phys. Rev. C 67,
044610 (2003)



… shape of these distributions is
characteristic of the presence of Coulomb forces and close to what is observed …

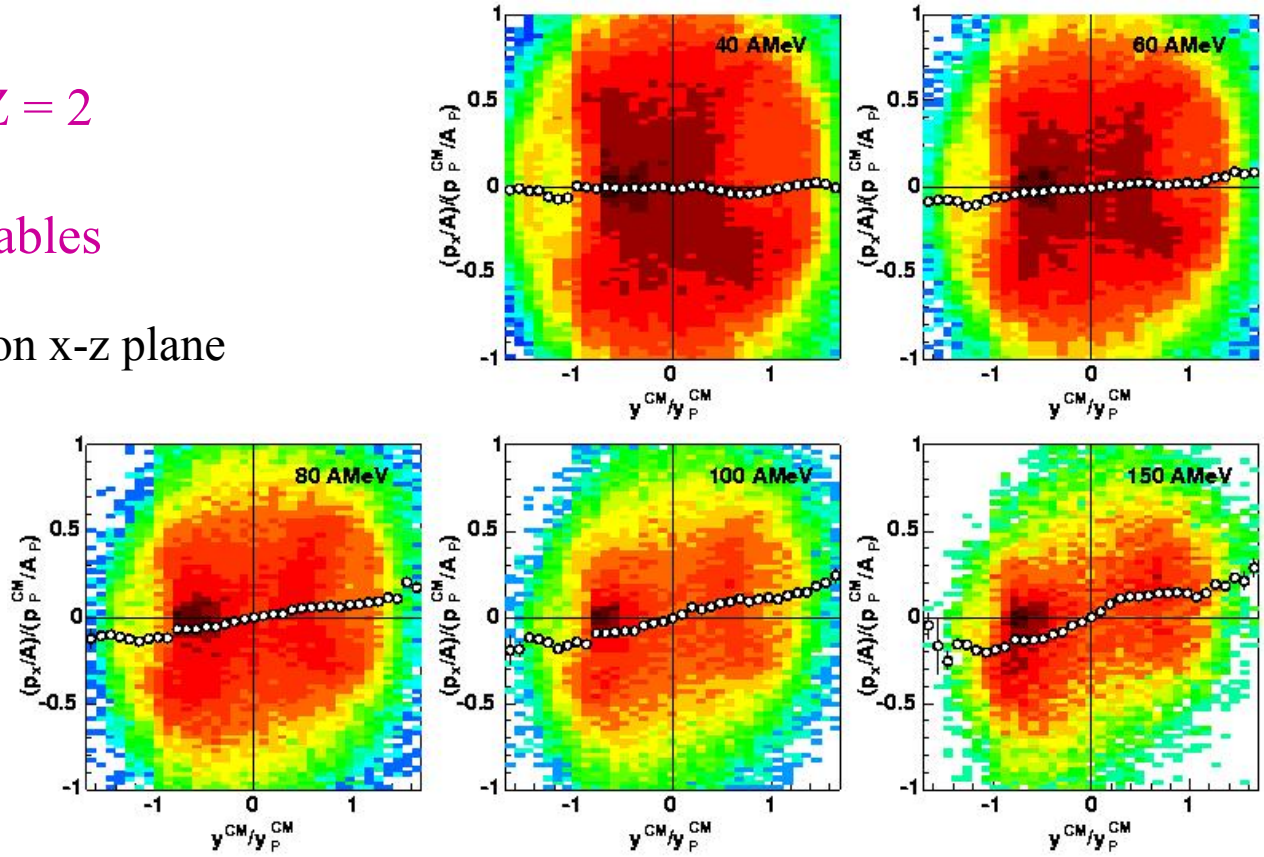
for early fragment formation
see also Danielewicz and Pan, Dorso and Aichelin, Barz et al. and others

work in progress
J. Łukasik et al.

Directed flow

Au + Au, Z = 2
midcentral
scaled variables

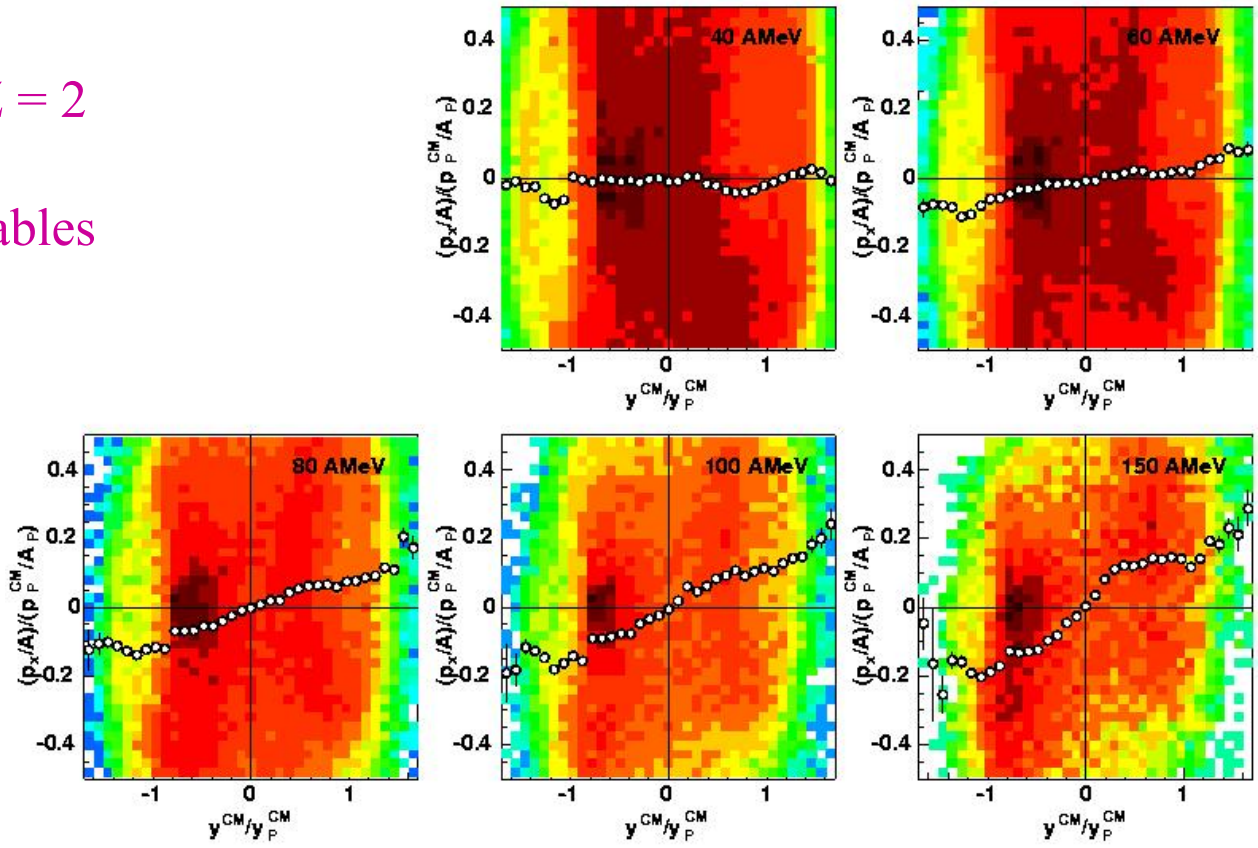
projections on x-z plane



work in progress
J. Łukasik et al.

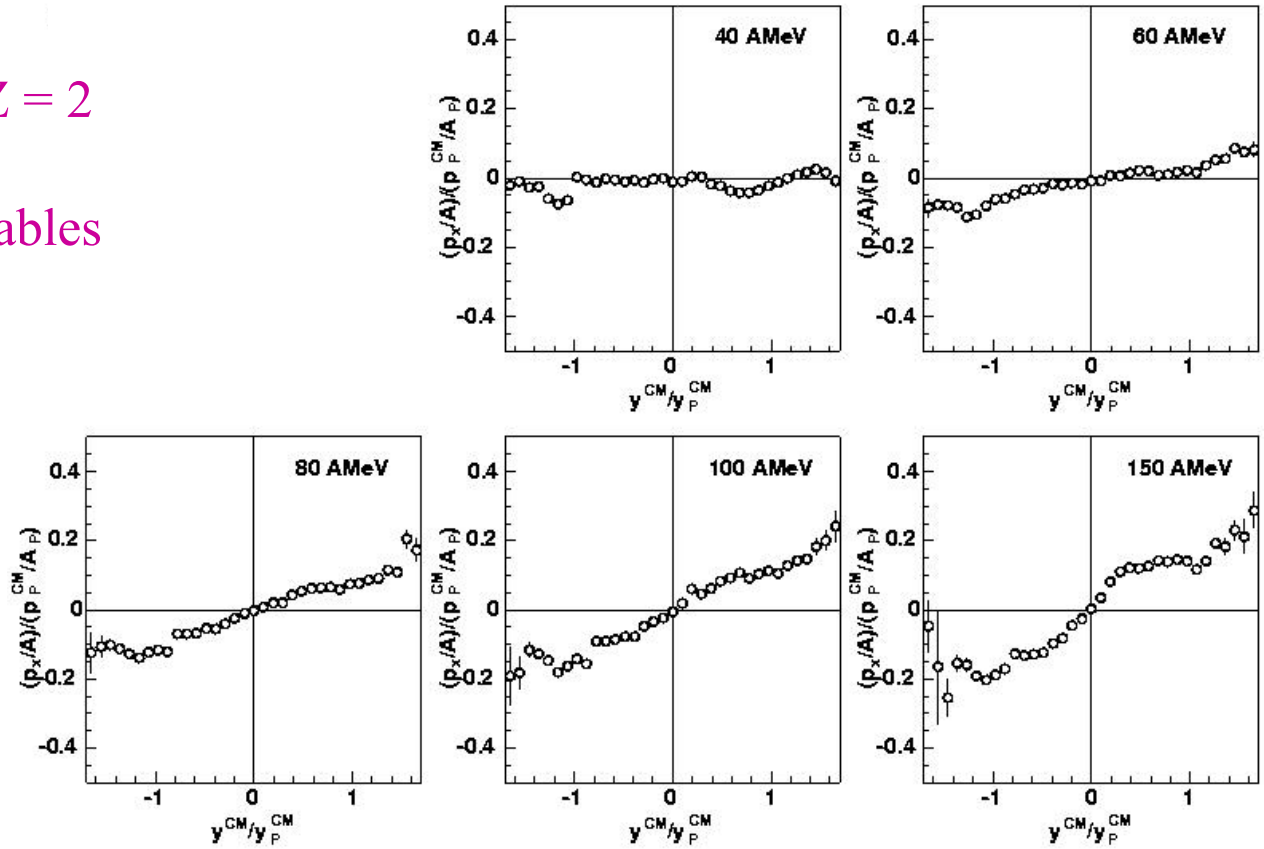
Directed flow

Au + Au, Z = 2
midcentral
scaled variables



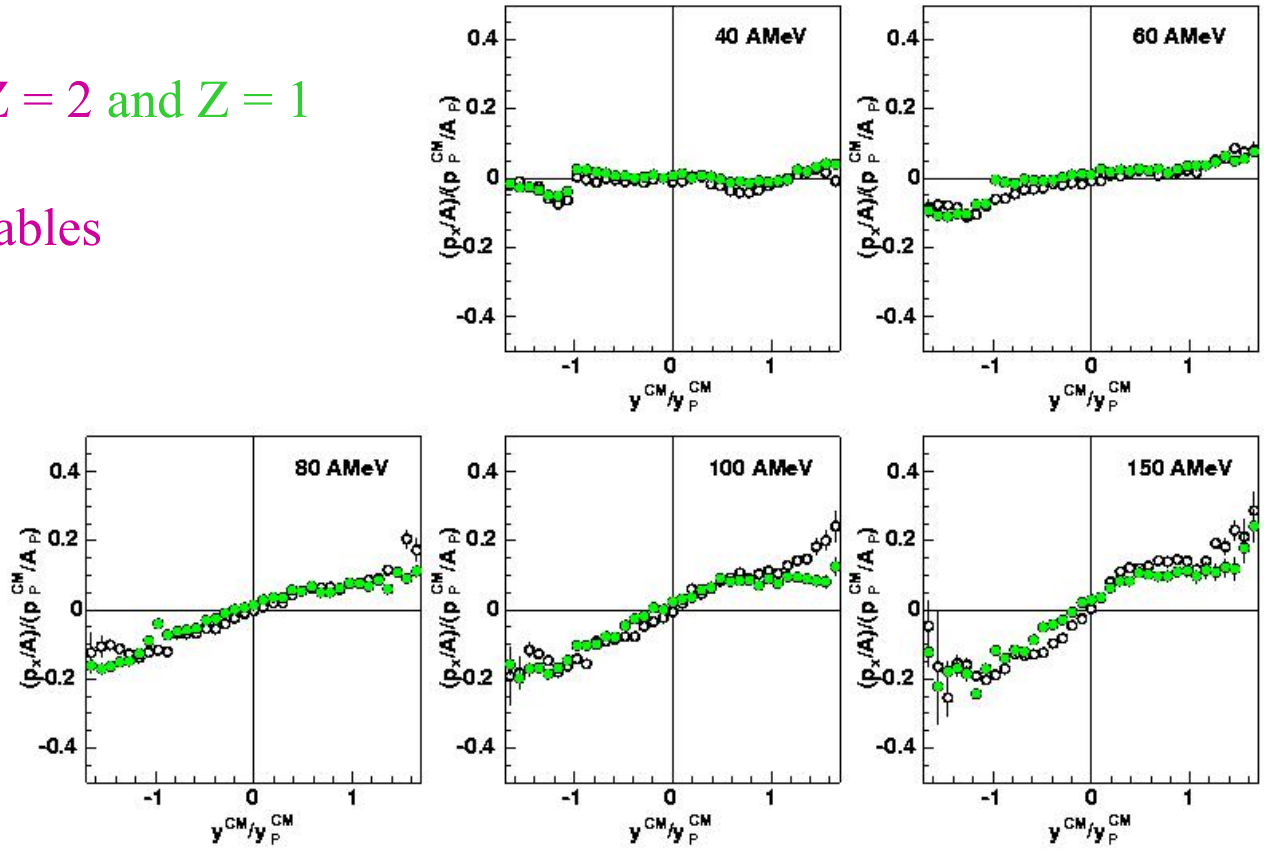
Directed flow

Au + Au, Z = 2
midcentral
scaled variables



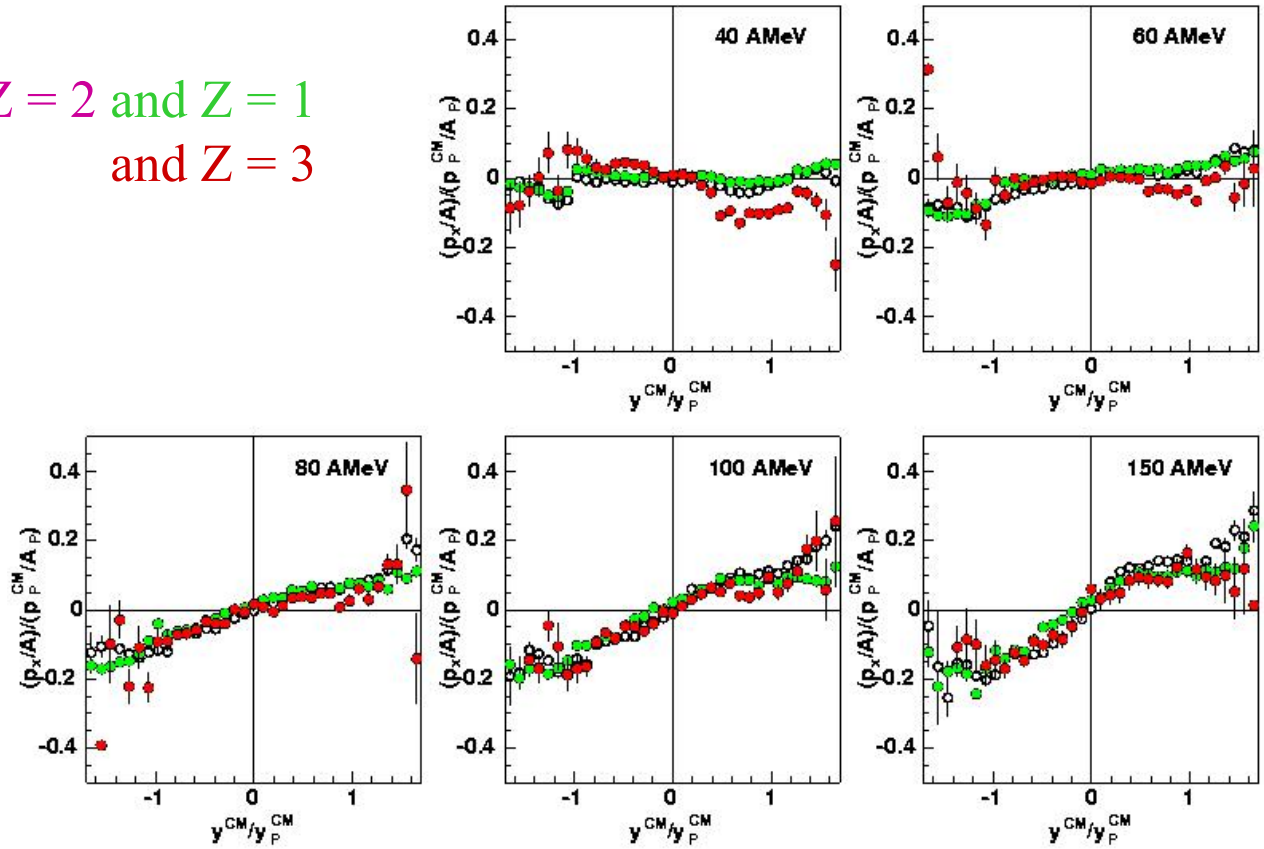
Directed flow

Au + Au, Z = 2 and Z = 1
midcentral
scaled variables



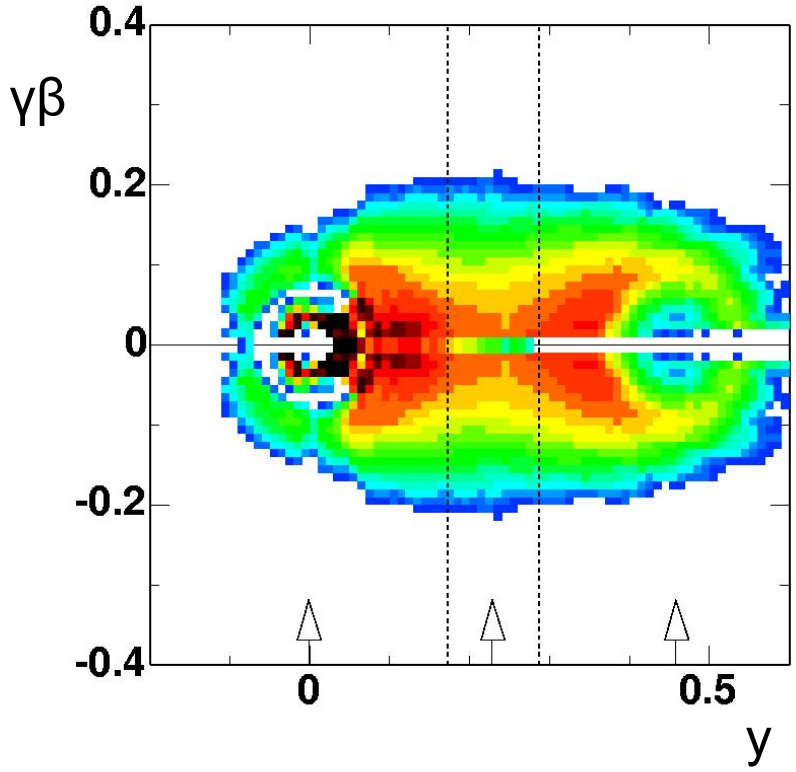
Directed flow

Z = 2 and Z = 1
and Z = 3



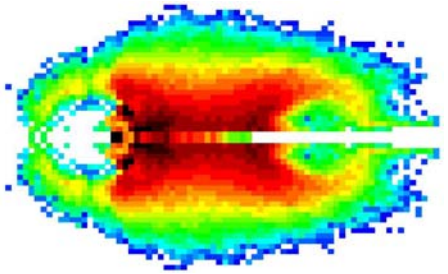
Part II:

Peripheral Au + Au

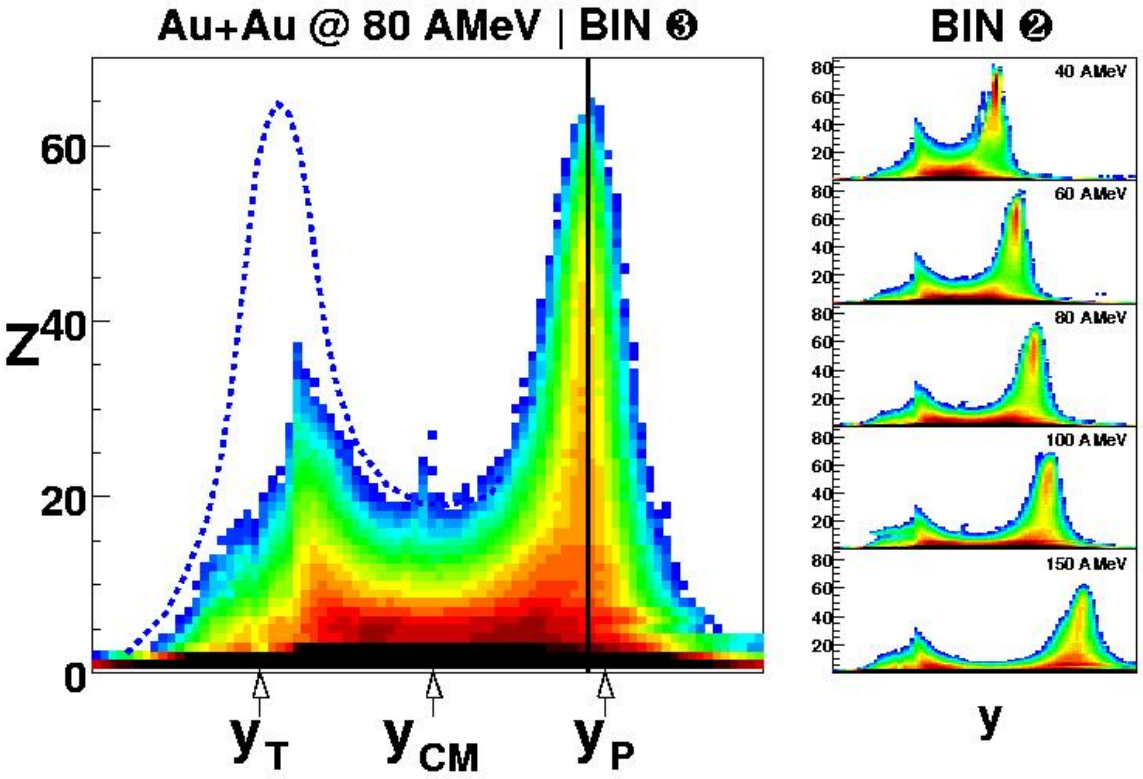


Z = 3 at 100 A MeV

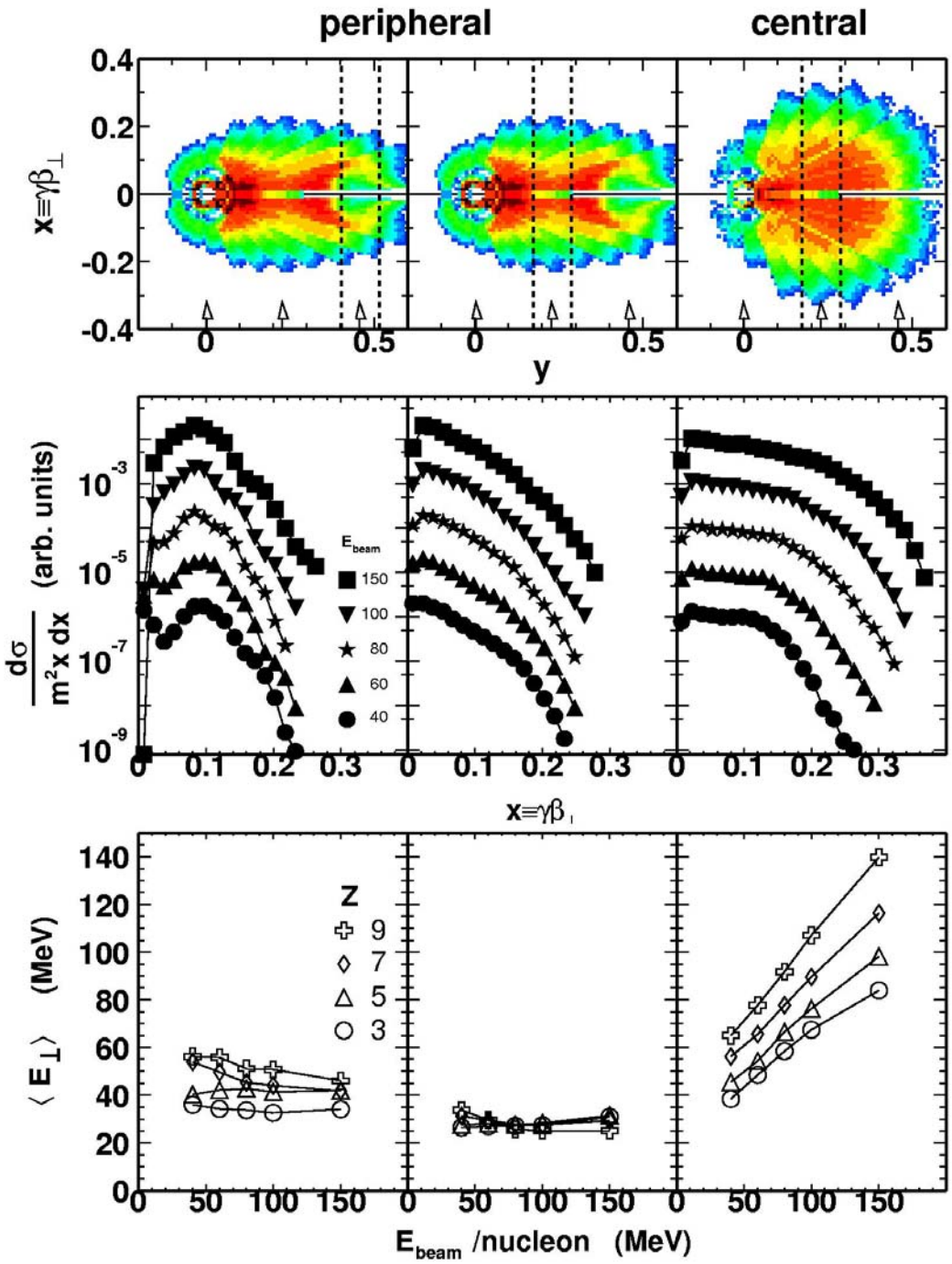
Rapidity distributions



Z = 3 at 80 A MeV



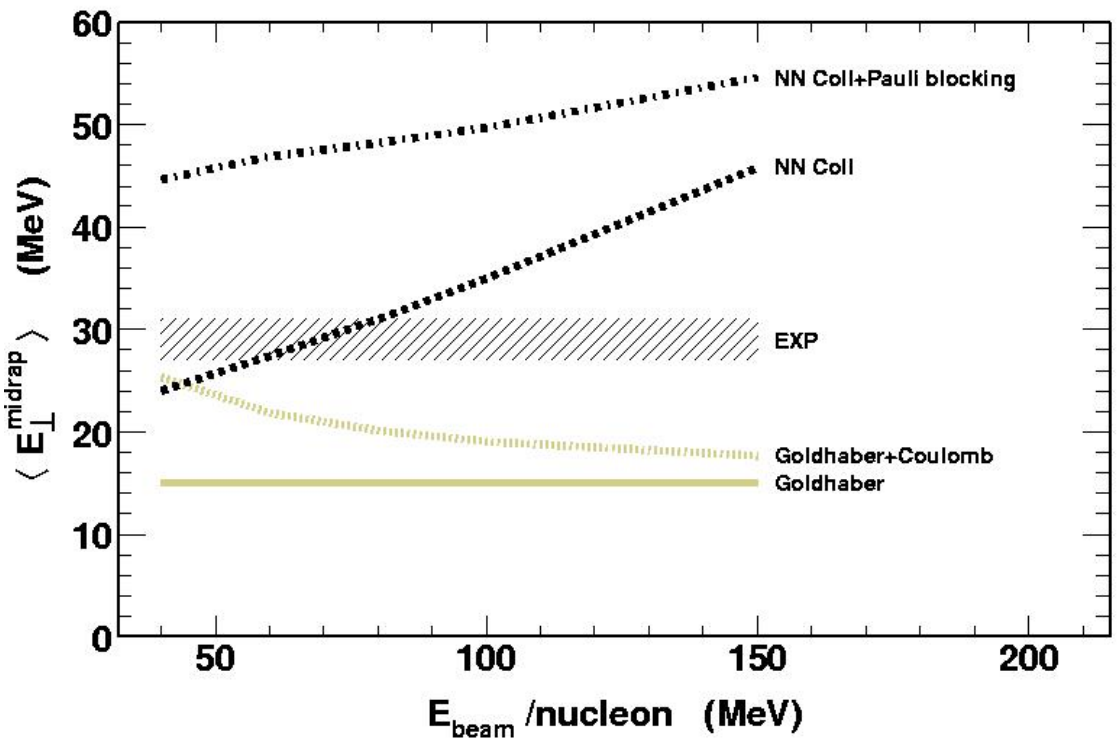
Transverse velocity spectra



J. Łukasik et al., Phys. Rev. C 66, 064606 (2002)

Contributions to transverse energies

at midrapidity



Fermi motion is not enough

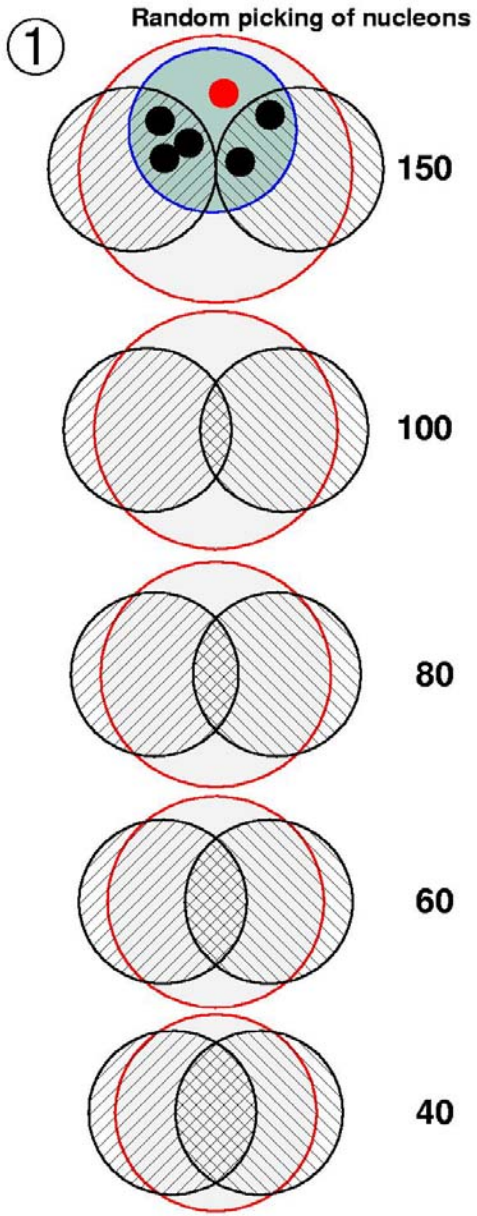
N-N scattering is too much

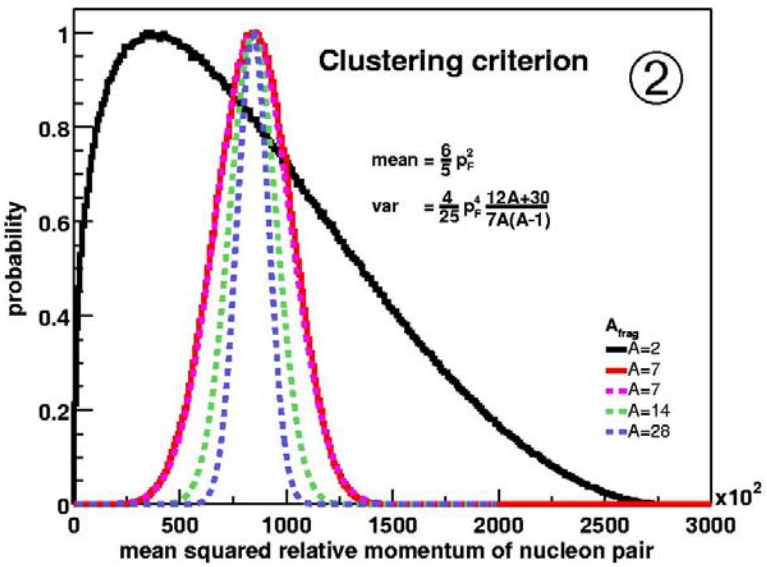
Compensation due to Coulomb

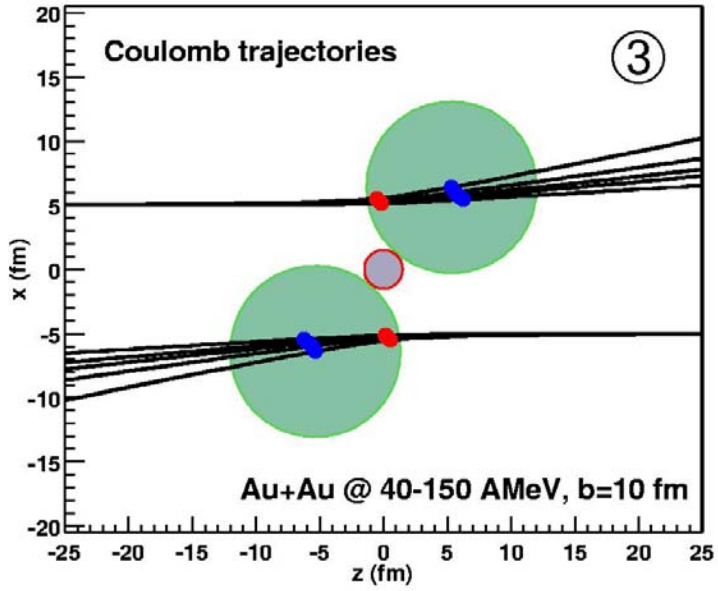
Extended Goldhaber model

in 3 steps

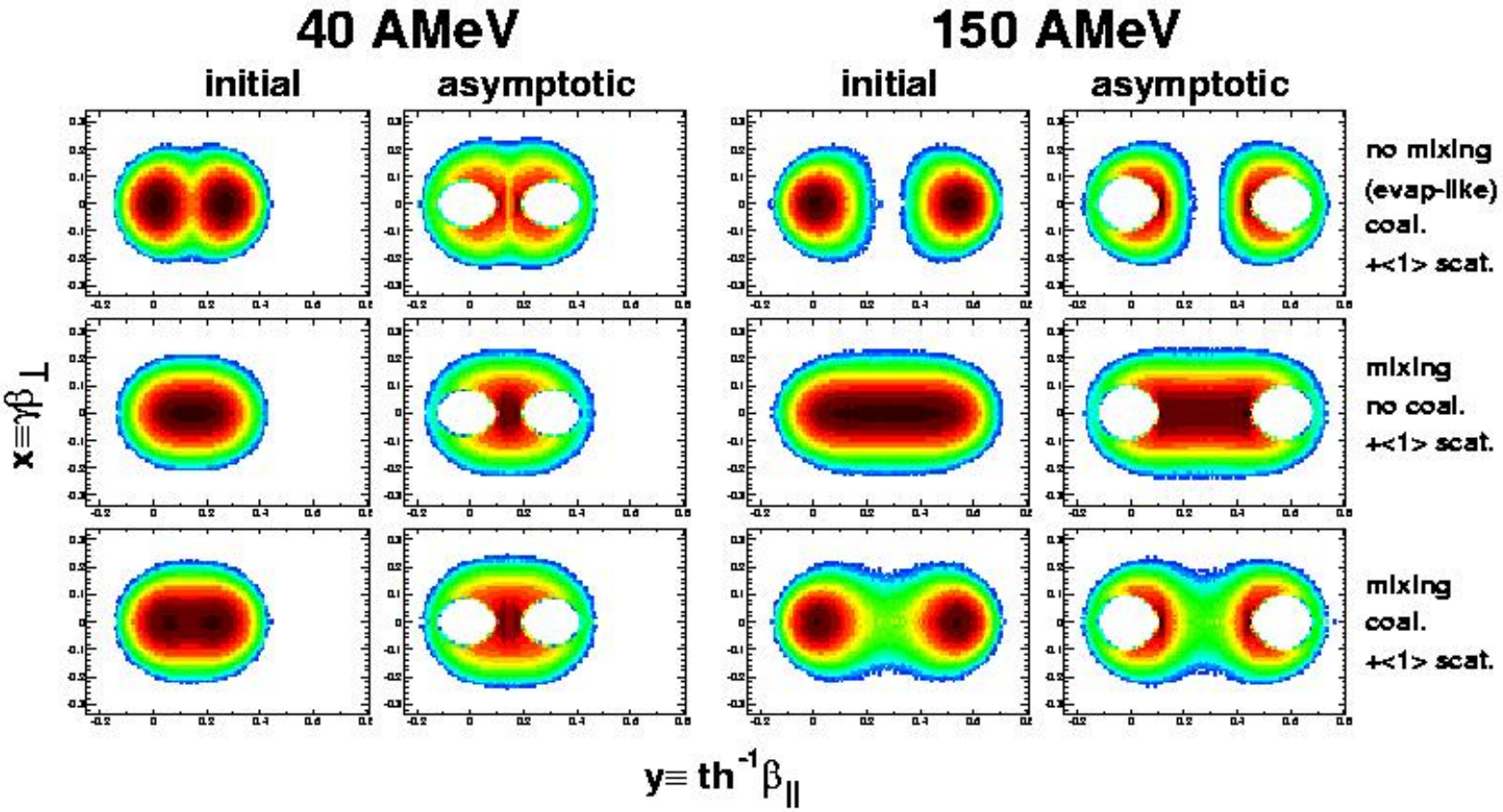
J. Łukasik et al.,
Phys. Lett. B,
in print (2003)



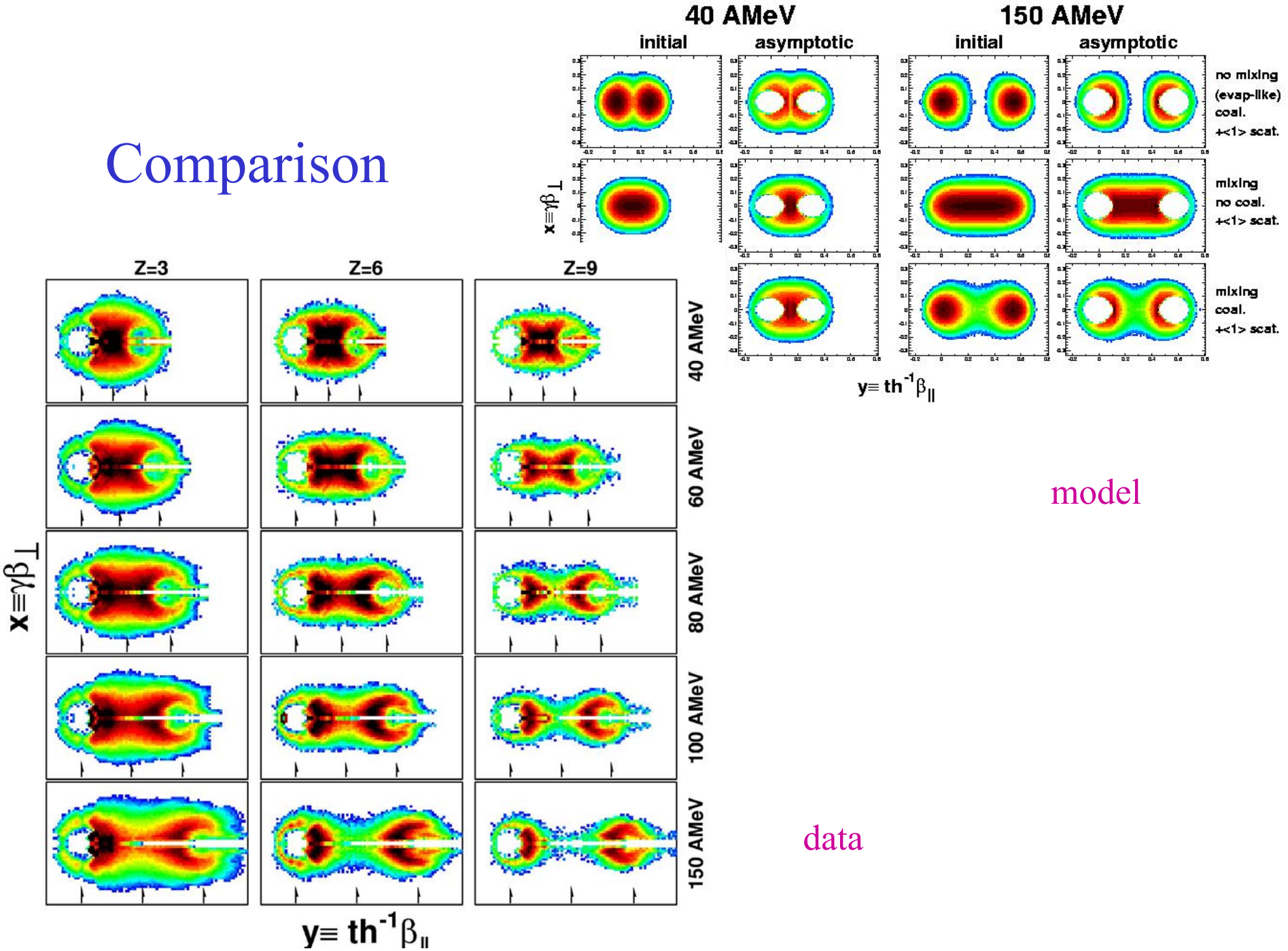




Model results



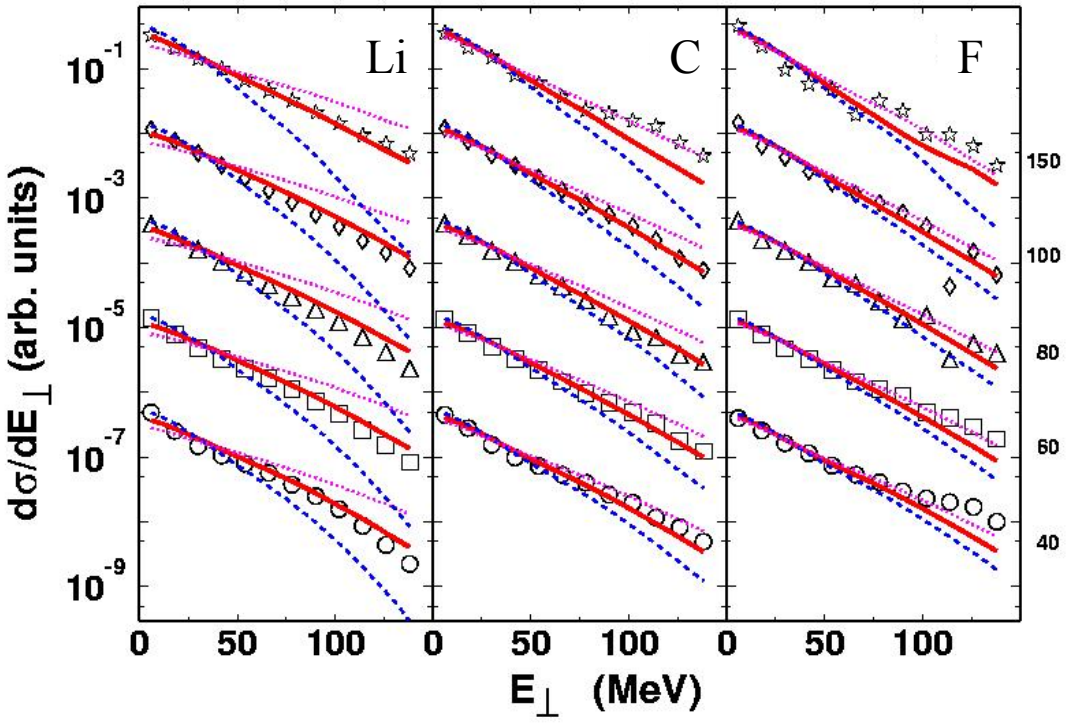
Comparison



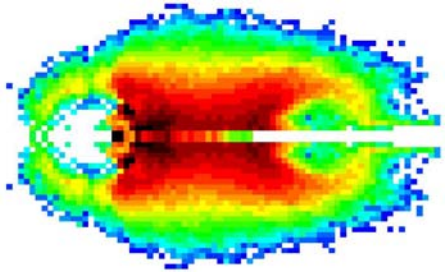
model

data

Quantitative description of data



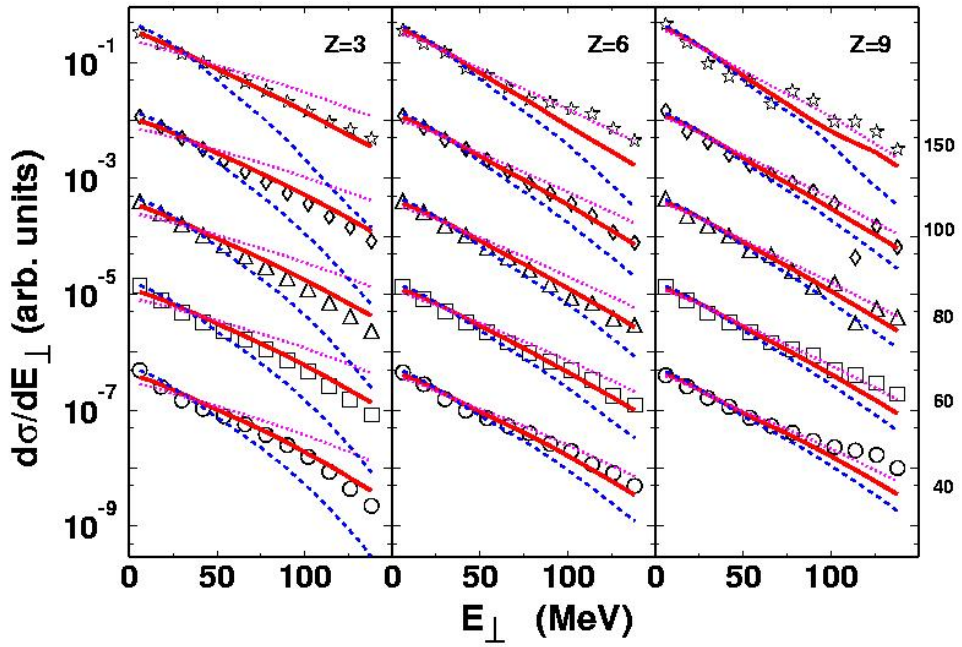
Transverse energy spectra



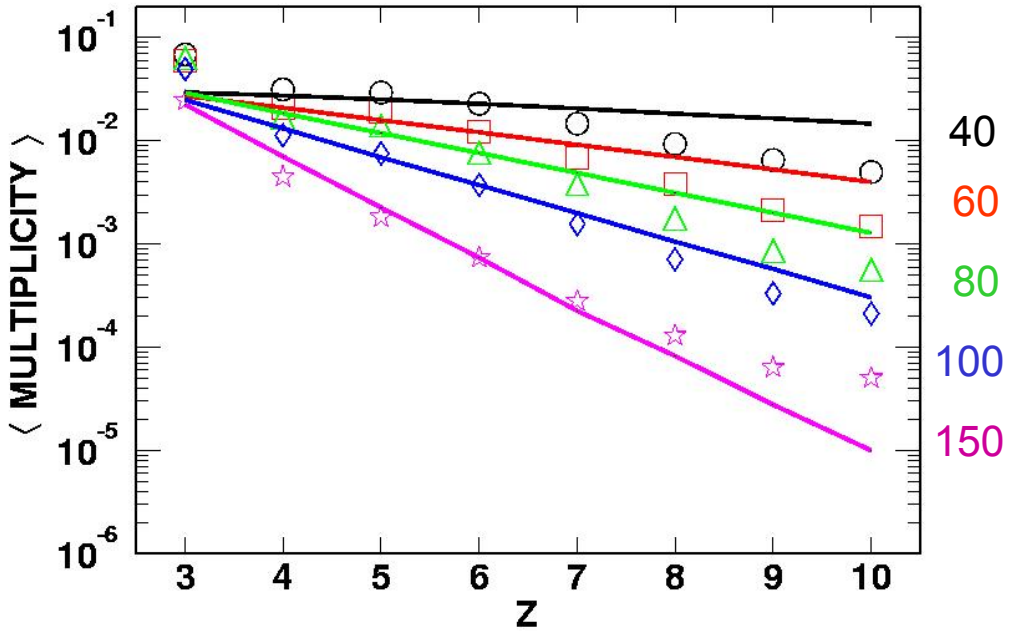
2 hard scattered
1 nucleons
0

Quantitative description of data

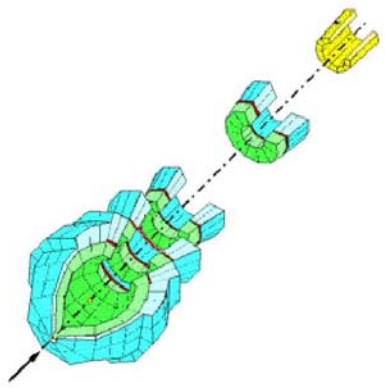
Transverse energy spectra



Atomic number Z spectra



Questions



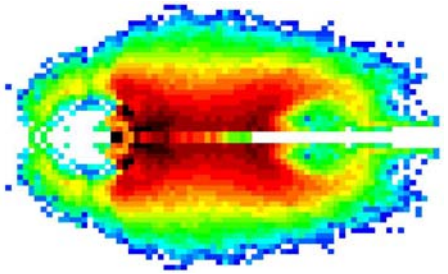
1) Where is the equilibrated neck ?

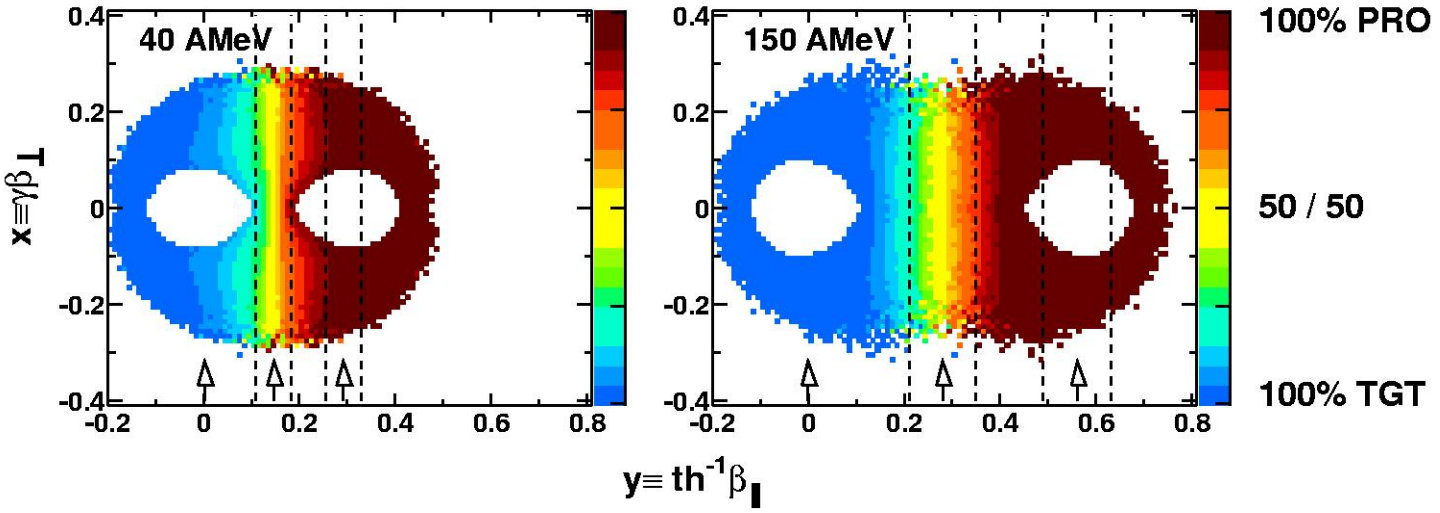
2) Where is the equilibrated target/projectile residue ?

3) Clustering criterion on a nucleon distribution seems to be a general principle !

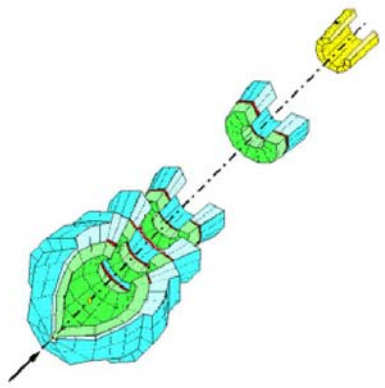
see also Gaitanos et al., Odeh et al., Gadioli et al. and others

Origin of fragments





Summary

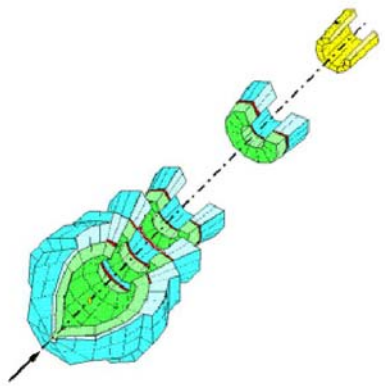


1) Central:
   Good description with deformed statistical source and decoupled radial flow; directed and elliptic flow in progress.

2) Peripheral:
   Good description with extended Goldhaber model (clustering criterion!).

3) New results also for Xe + Sn and C + Au.

the end



J. Łukasik,[1,10] S. Hudan,[2] F. Lavaud,[3] K. Turzó,[1] G. Auger,[2] Ch.O. Bacri,[3] M.L. Begemann-Blaich,[1] N. Bellaize,[4] R. Bittiger,[1] F. Bocage,[4] B. Borderie,[3] R. Bougault,[4] B. Bouriquet,[2] Ph. Buchet,[5] J.L. Charvet,[5] A. Chbihi,[2] R. Dayras,[5] D. Doré,[5] D. Durand,[4] J.D. Frankland,[2] E. Galichet,[6] D. Gourio,[1] D. Guinet,[6] B. Hurst,[4] P. Lautesse,[6] J.L. Laville,[2] C. Leduc,[6] 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] G. Tăbăcaru,[2] B. Tamain,[4] W. Trautmann,[1] A. Trzciński,[9] E. Vient,[4] M. Vigilante,[7] C. Volant,[5] B. Zwiegliński,[9] and A.S. Botvina[1,11]

(The INDRA and ALADIN Collaborations)

[1] *Gesellschaft für Schwerionenforschung mbH, D-64291 Darmstadt, Germany*
[2] *GANIL, CEA et IN2P3-CNRS, F-14076 Caen, France*
[3] *Institut de Physique Nucléaire, IN2P3-CNRS et Université, F-91406 Orsay, France*
[4] *LPC, IN2P3-CNRS, ISMRA et Université, F-14050 Caen, France*
[5] *DAPNIA/SPhN, CEA/Saclay, F-91191 Gif sur Yvette, France*
[6] *Institut de Physique Nucléaire, IN2P3-CNRS et Université, F-69622 Villeurbanne, France*
[7] *Dipartimento di Scienze Fisiche e Sezione INFN, Univ. Federico II, I-80126 Napoli, Italy*
[8] *Dipartimento di Fisica dell' Università and INFN, I-95129 Catania, Italy*
[9] *A. Sołtan Institute for Nuclear Studies, Pl-00681 Warsaw, Poland*
[10] *H. Niewodniczański Institute of Nuclear Physics, Pl-31342 Kraków, Poland*
[11] *Institute for Nuclear Research, 117312 Moscow, Russia*