High-Precision Momentum Measurements of Projectile Fragments in Sn+Sn Collisions at 1 AGeV

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ESF Exploratory Workshop - PESC: How To Constrain The High Density Symmetry Energy , 15-18 October, 2009

Outline

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Motivation

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Fundamental interests

- Properties of nuclear matter
  - static: compressibility, symmetry energy, phase transitions...
  - dynamic: viscosity, momentum dependence of the mean field...
- Astrophysical and cosmological phenomena
  - Formation and stability of neutron stars
  - Supernova explosions
  - Evolution of the early universe

Experimental observables

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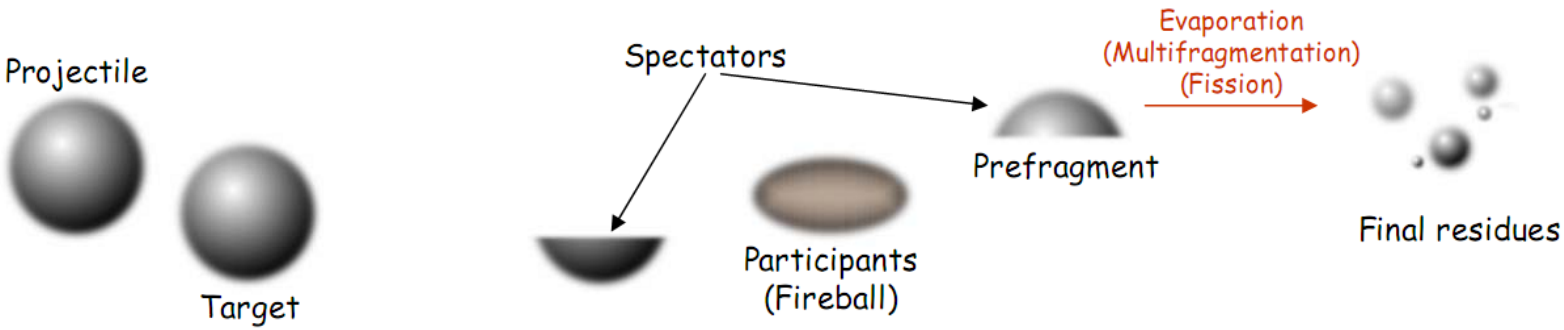

Observables

1. Participants
   - Flow
2. Spectators
   - Kinematical properties

History of spectator kinematics

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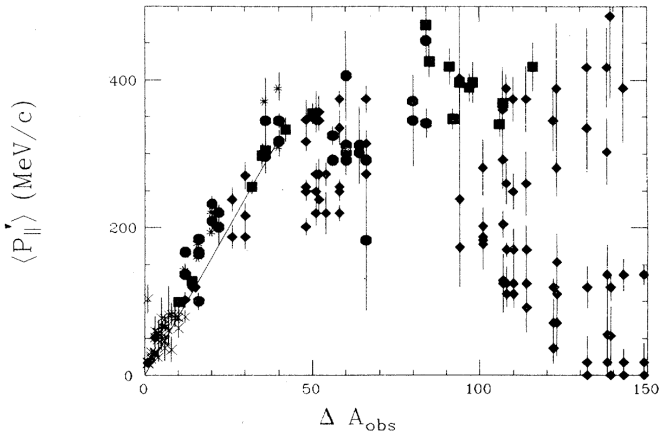
Morrissey systematics

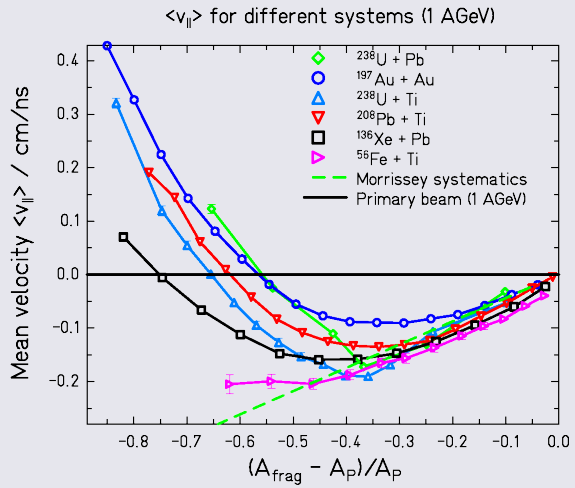
Phys. Rev. C39 (1989)

- Explained low mass losses



High resolution measurements

^{238}U + Pb	T. Enqvist et al. NPA 658(1999)47
^{208}Pb + Ti	T. Enqvist et al.NPA 703(2002)435465
^{238}U + Ti	V. Ricciardi et al. PRL 90(2003)212302
^{197}Au + Au	V. Henzl, PhD thesis (2005)
^{56}Fe + Ti	C. Villagrasa-Canton et al. PRC 75(2007)044603
^{136}Xe + Pb	A. Bacquias, PhD thesis (2009)



Theoretical investigations

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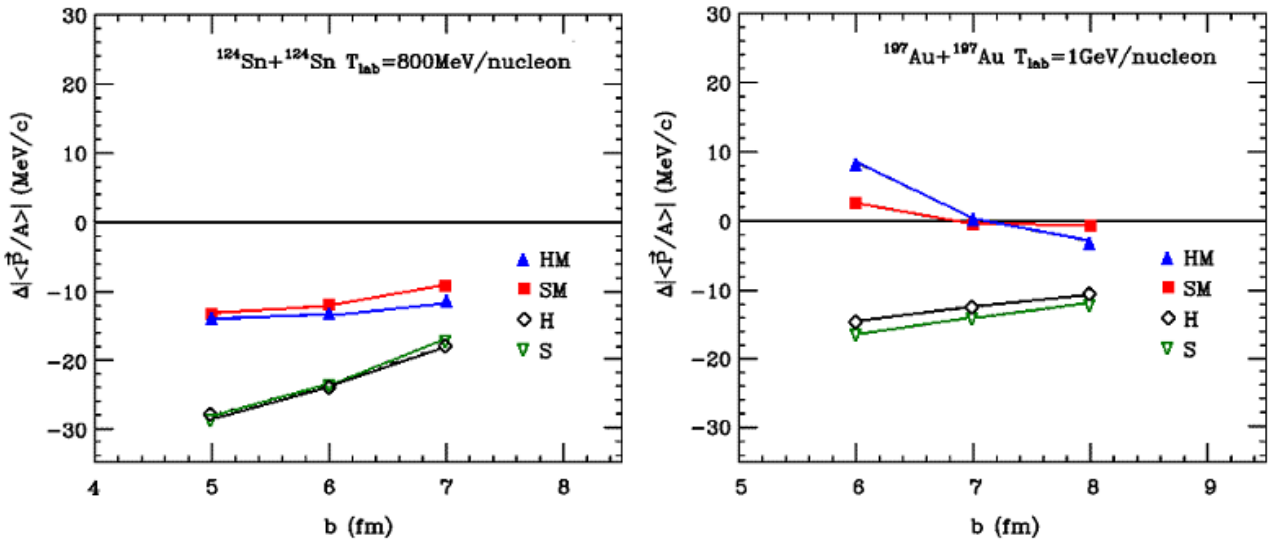
Spectator Response to the Participant Blast

L. Shi, P. Danielewicz, R. Lacey, PRC 64 (2001) 034601



BUU calculations

- Sensitivity to
  - Momentum dependence of the mean field
  - NN cross section
- Almost no sensitivity to stiffness of the EOS

S276 Experiment

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Why ^{112,124}Sn + ^{112,124}Sn at 1 A GeV?

- Isospin influence on the re-acceleration
- Symmetric systems assures constant N/Z of the participant zone for all possible impact parameters
- Low fission cross section compared to heavier systems
- High enough energy

Experiment setup

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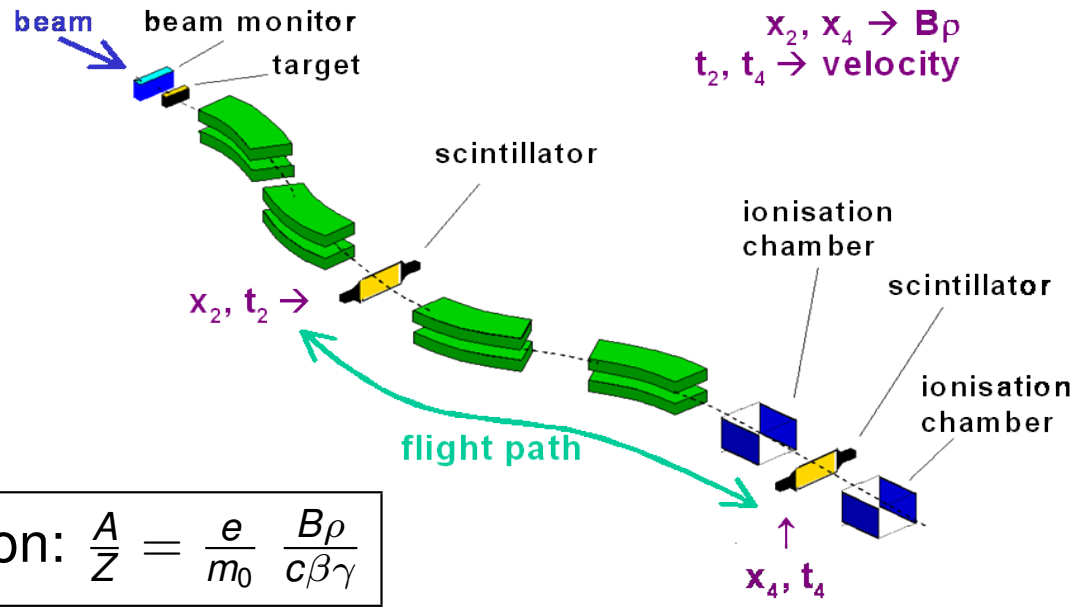
The Fragment Separator



Z from IC: $\Delta E \propto Z^2$

$\frac{A}{Z}$ from time and position: $\frac{A}{Z} = \frac{e}{m_0} \frac{B\rho}{c\beta\gamma}$

After mass and charge have been identified the velocity is calculated from Bρ (A, Z are integers): $\beta\gamma = \frac{e}{cm_0} \frac{Z}{A} B\rho$

Very high precision: $\Delta P/P = 10^{-4}$

Mass and nuclear charge identification

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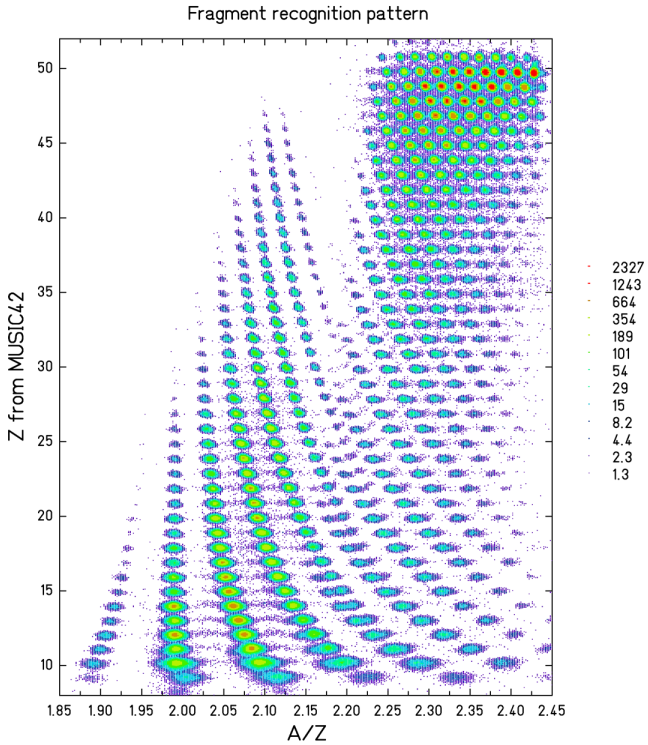
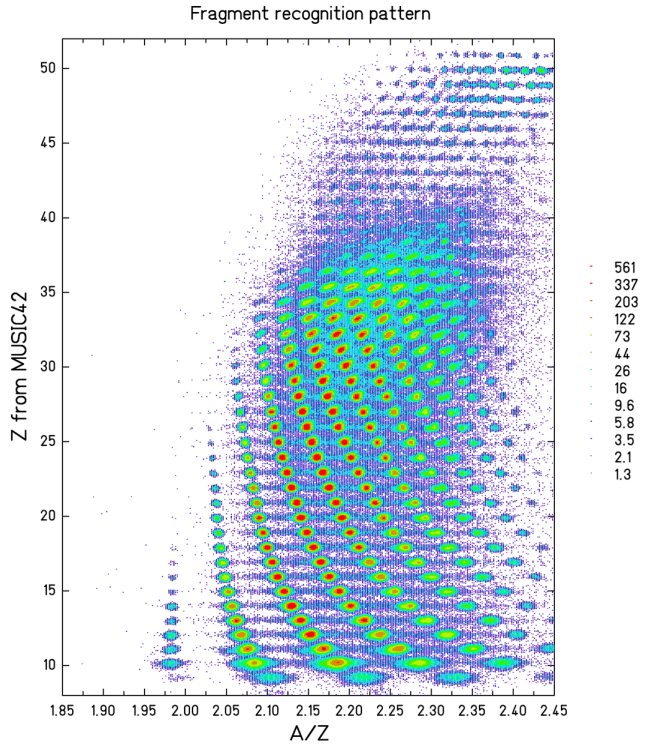
^{124}Sn + ^{124}Sn @ 1 A GeV

Heavy residues



Light residues



$A/\Delta A \approx 400$

$\Delta Z \approx 0.4$

Obtaining the velocity distributions

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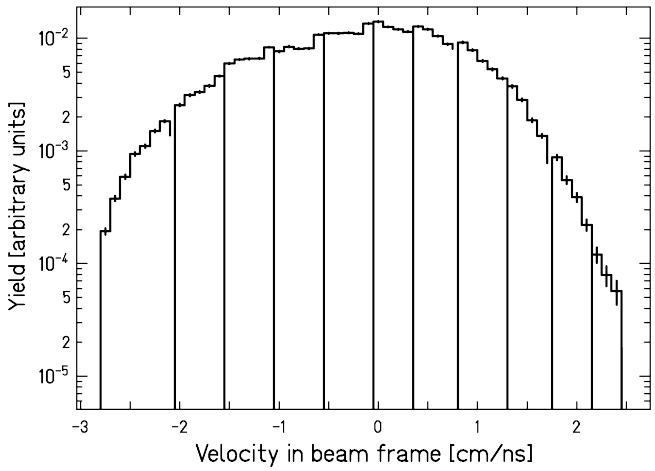
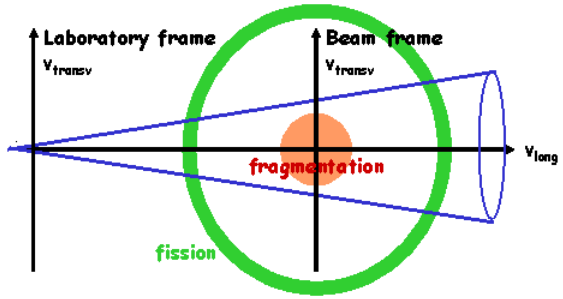
Corrections

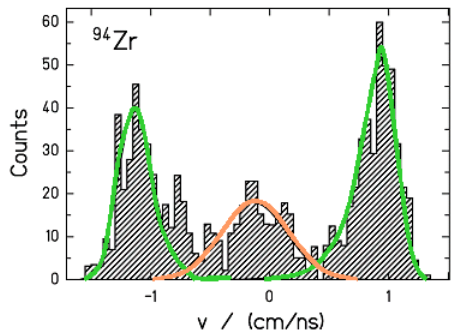
Limited momentum acceptance



- Combining data from several magnetic settings

Limited angular acceptance





- Advantage in separating different production mechanisms

Longitudinal velocity distributions

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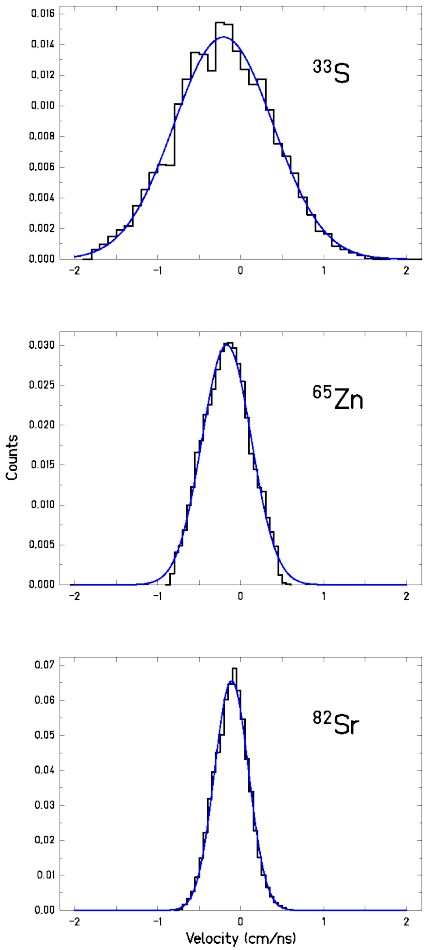
$^{124}Sn + {}^{124}Sn$



Three observables

1. Area
2. Width
3. Mean value

Production cross sections

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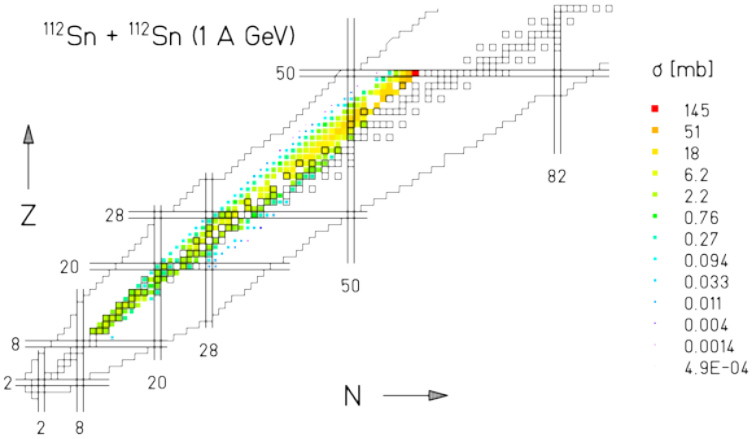
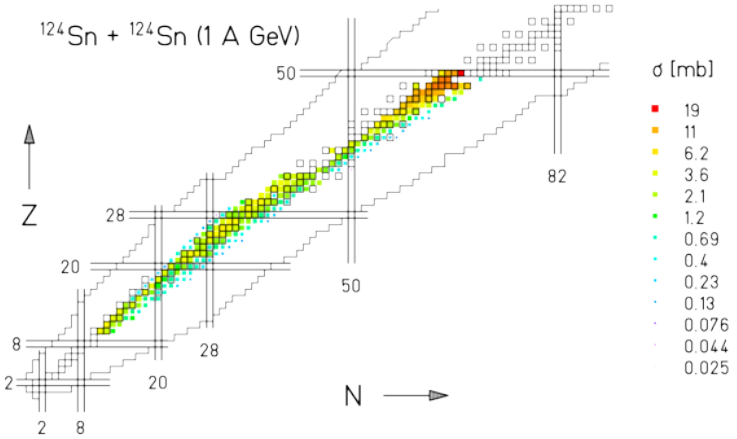
- Integrals of velocity distributions





Width of the distribution

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"Well understood" physics:

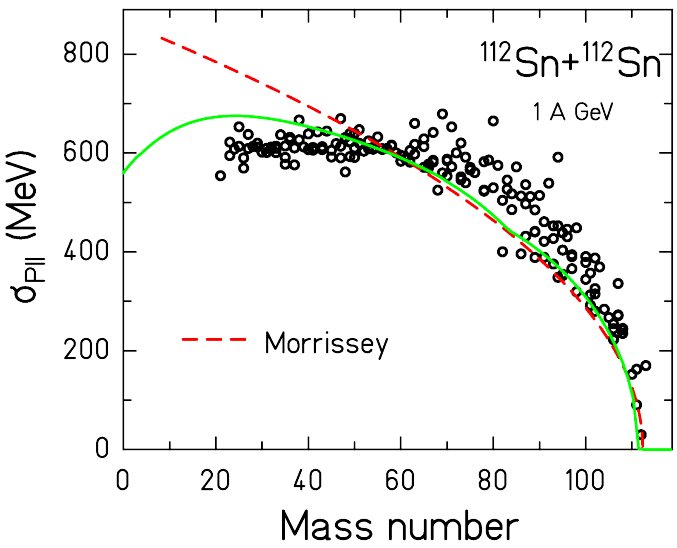
- Based on Goldhaber model

  A.S. Goldhaber. Phys.Lett. B53(1974)306

- Corrected for Coulomb repulsion, multifragmentation and evaporation

  A. Bacquias, PhD thesis (2009)

- Reveals different production steps during de-exitation



Mean value of the distribution

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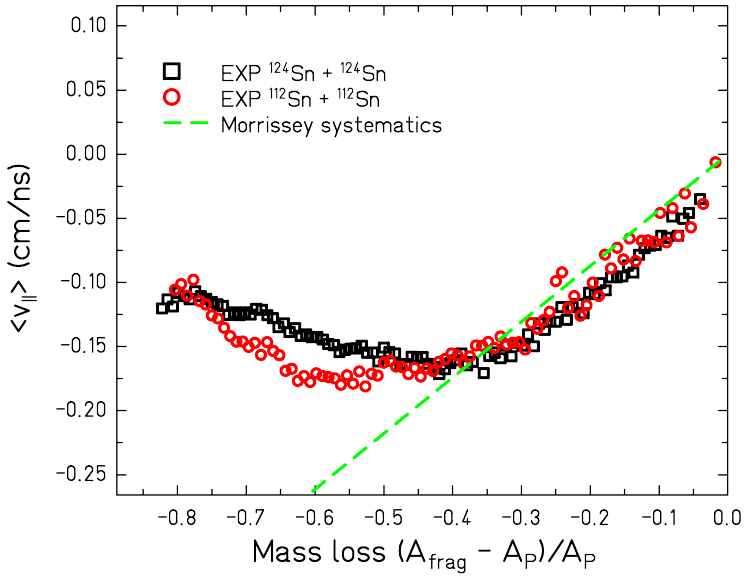
Peripheral collisions:

- No clear difference seen

More central collisions:

- Sensitivity to collision violence
- Signs of N/Z dependence ?



Comparison with other systems

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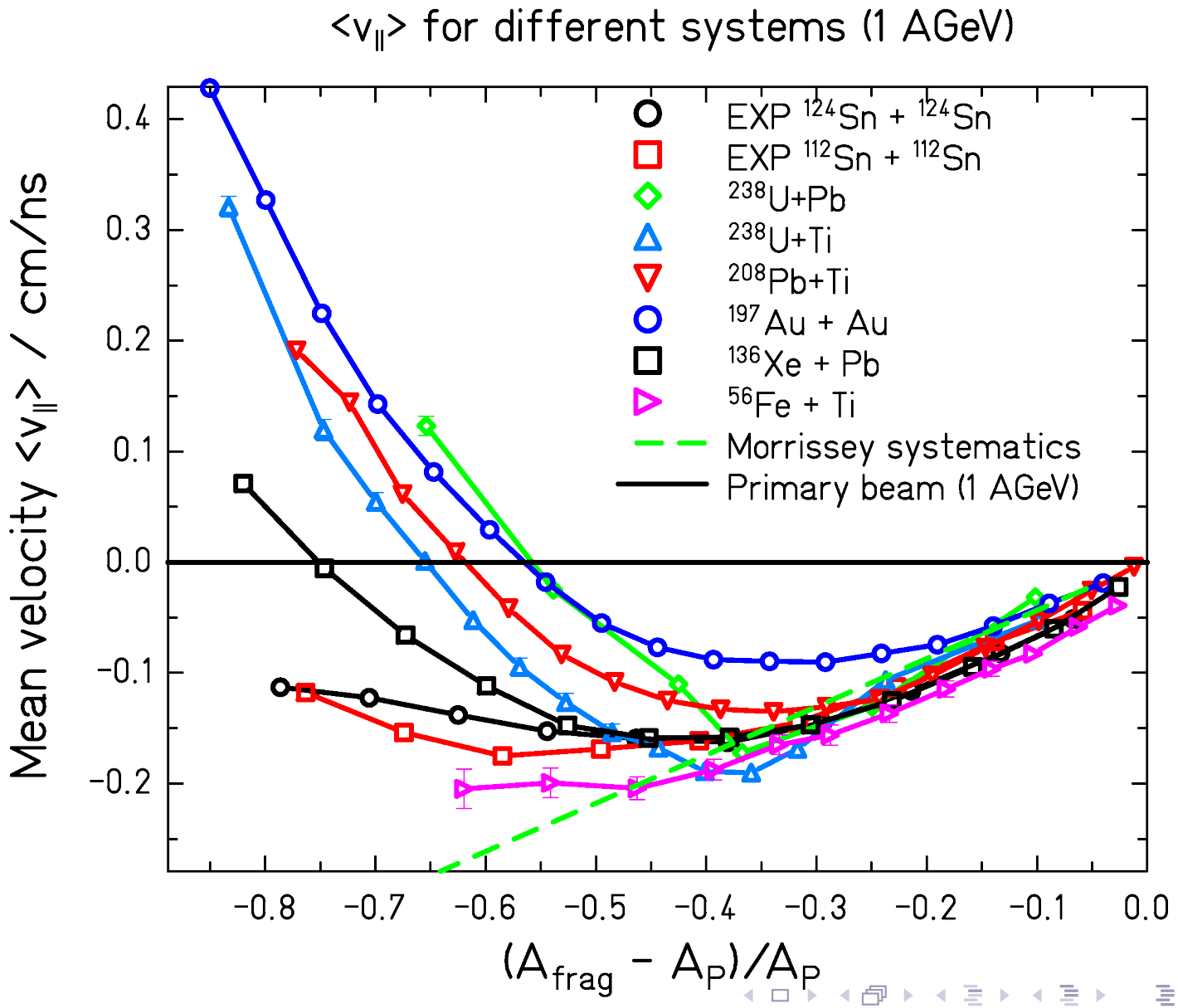

Theoretical calculations

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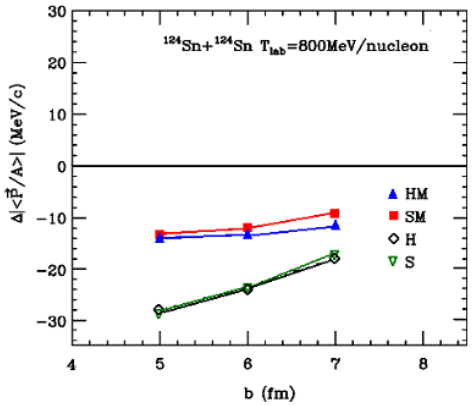

- BUU calculation cannot be compared directly with data
- Need to establish connection between impact parameter and final residue mass

1. ABRABLA
   - \+ Proven to have good prediction power
   - \- Geometrical model of collision
   - \- Can't study microscopical effects
2. BUU
   - \+ Microscopical model
   - \- Difficult to define E*,A,Z
   - \- Time consuming
   - \- No evaporation stage

BUU results

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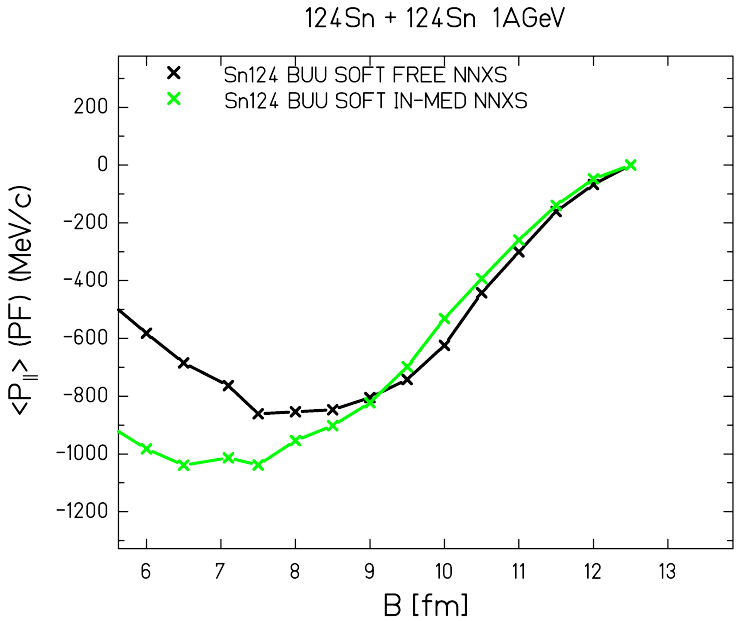
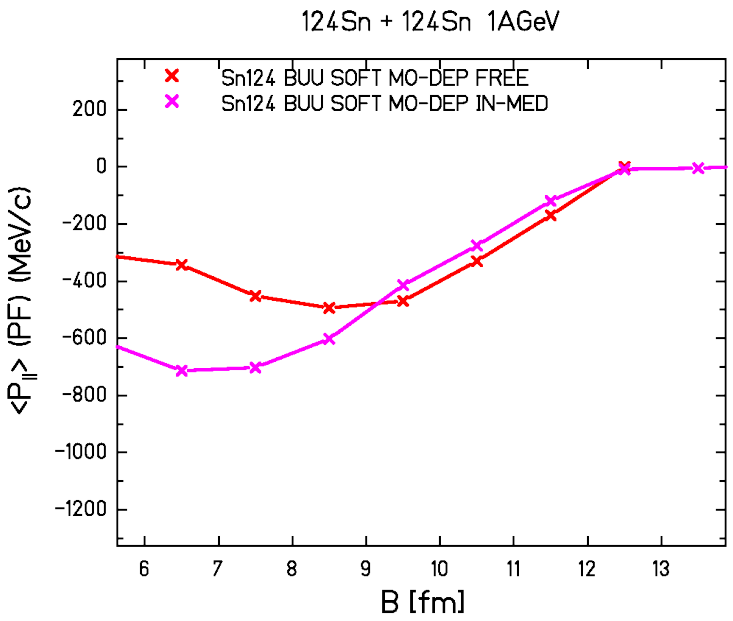
With momentum independent (MI) meanfield:



With momentum dependent (MD) meanfield:



This used as input for the statistical code ABRABLA

Comparison with data

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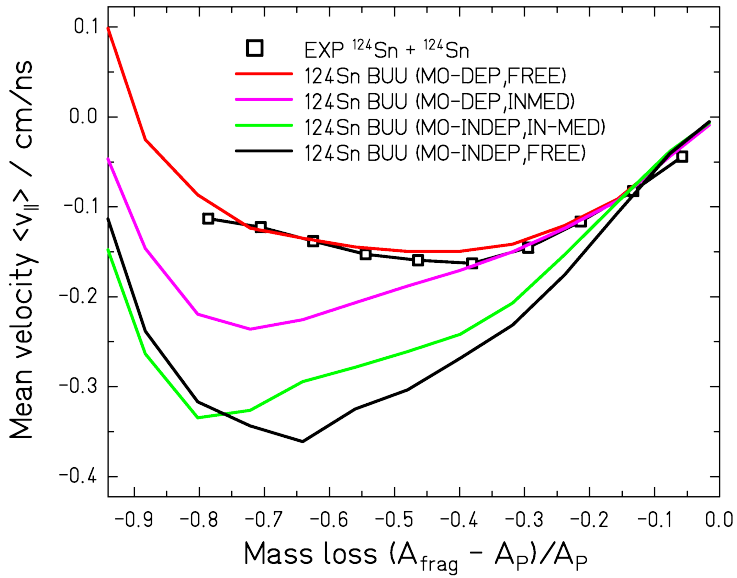

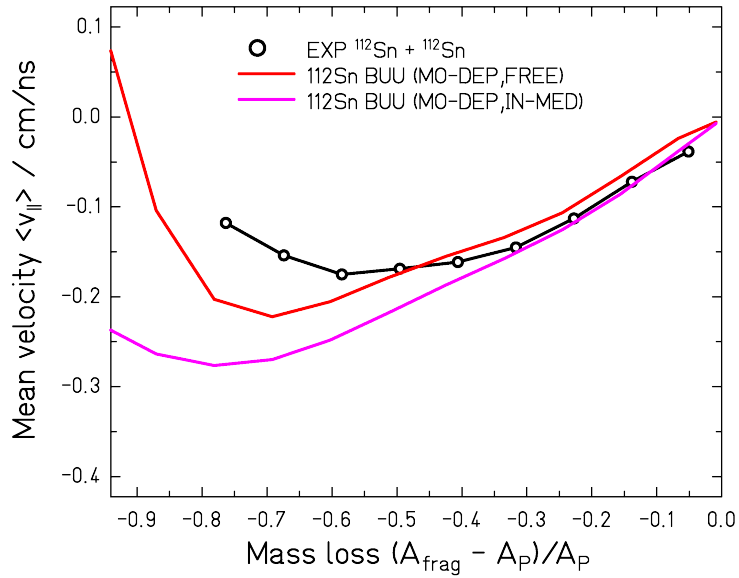

Best correlation seen with MD + NN cross section

Comparison with data

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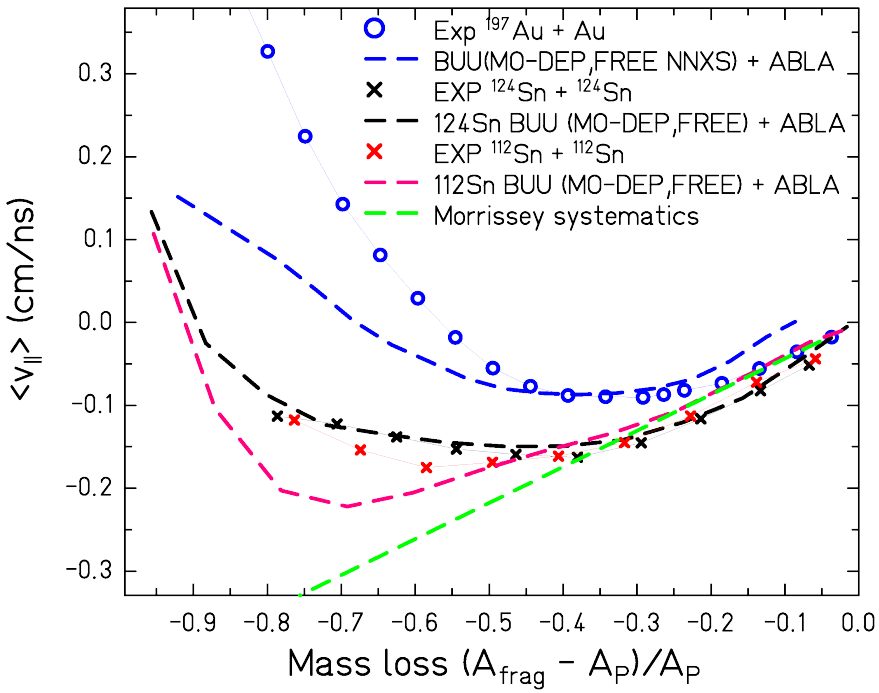
Same model parameters for 3 different systems



^{197}Au + Au data by V.Henzl, PhD thesis (2005)

Qualitative agreement very good!

Summary

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- Re-acceleration phenomena is seen in all systems, its strength depends on the "violence" of the collision
- Results support momentum dependent mean field and free NN cross section

- Outlook
  - Disentanglement of N/Z from other degrees of freedom
  - Better correlation between impact parameter and final fragment mass

Acknowledgements

CHARMS
(Collaboration for High-Accuracy Experiments on Nuclear Reaction Mechanisms with Magnetic Spectrometers)

A. Kelic[1], M.V. Ricciardi[1], K.-H. Schmidt[1,4]

Previous members:
A. Bacquias[2], V. Henzl[3], D. Henzlova[3], S. Lukic[5], P. Napolitani[4]

Special thanks to Pawel Danielewicz[3]

http://www-w2k.gsi.de/charms/

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