Temperature and Density in Heavy Ion Reactions at Intermediate Energies

C.Sfienti for the ALADiN and FIASCO-TEMPERATURE Collaborations

XLII INTERNATIONAL WINTER MEETING ON NUCLEAR PHYSICS
Bormio (Italy) January 25 - February 1, 2004

Temperature and Density in Heavy Ion Reactions at Intermediate Energies

Motivations:

Central Collisions: Size and Isospin Effects

Peripheral Collisions: Features of Neck Emission

The Experiment

$^{93}Nb+^{93}Nb$ $^{93}Nb+^{116}Sn$
$^{116}Sn+^{93}Nb$ $^{93}Nb+^{124}Sn$
$^{116}Sn+^{116}Sn$ $^{120}Sn+^{124}Sn$

17÷ 40 AMeV

C.Sfienti et al. XLII INTERNATIONAL WINTER MEETING ON NUCLEAR PHYSICS
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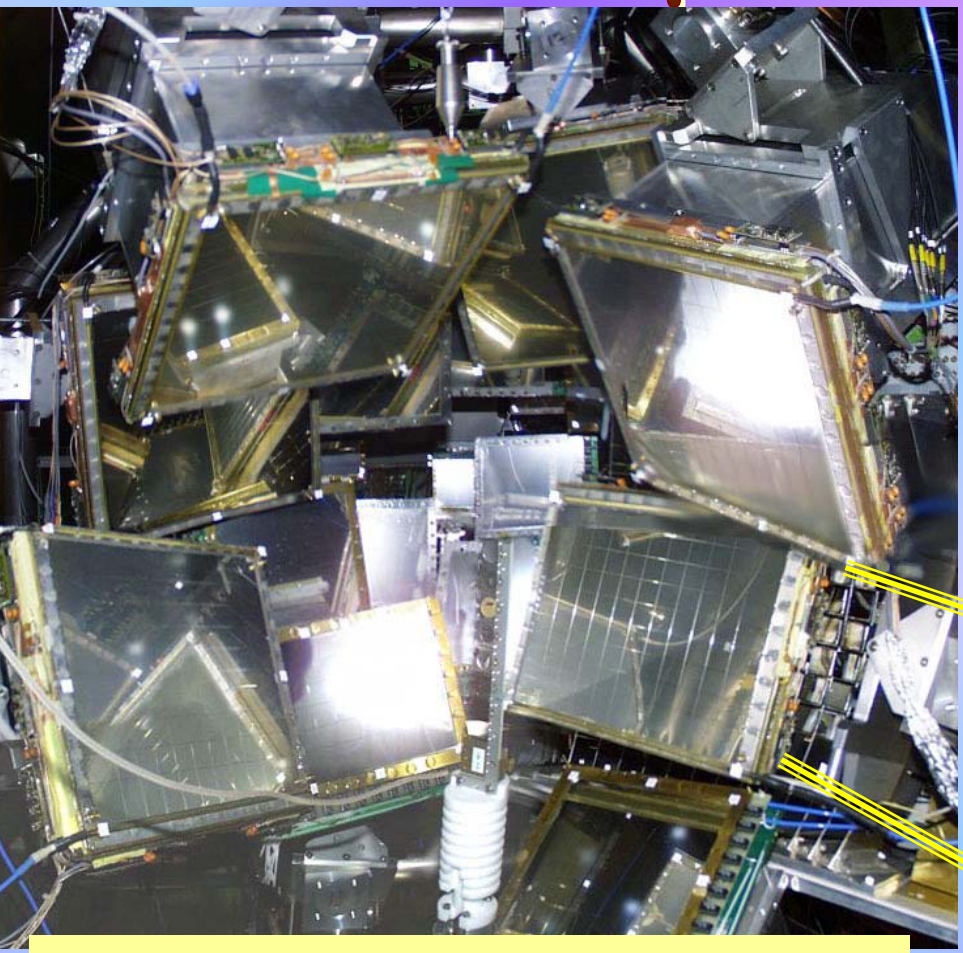
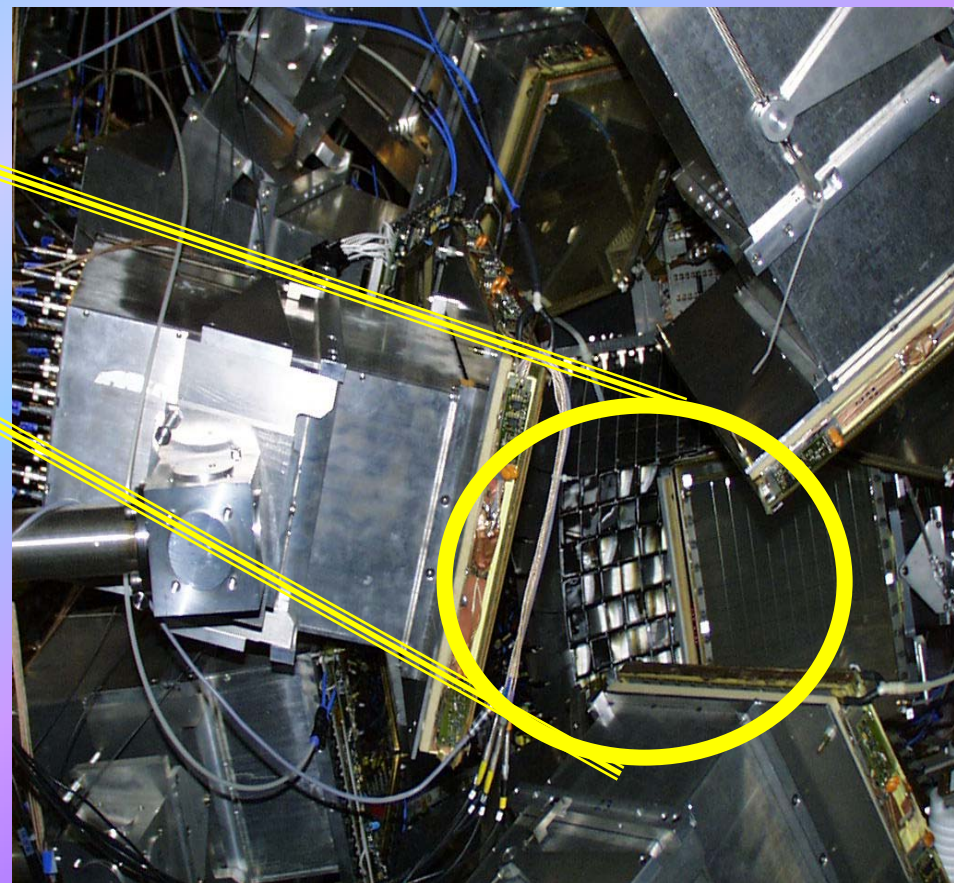
Experimental Setup



- Velocity and Charge of ALL QP emitted particles and fragments.
- Complete characterization of QP decay.

- High Granularity and Low Thresholds Hodoscope

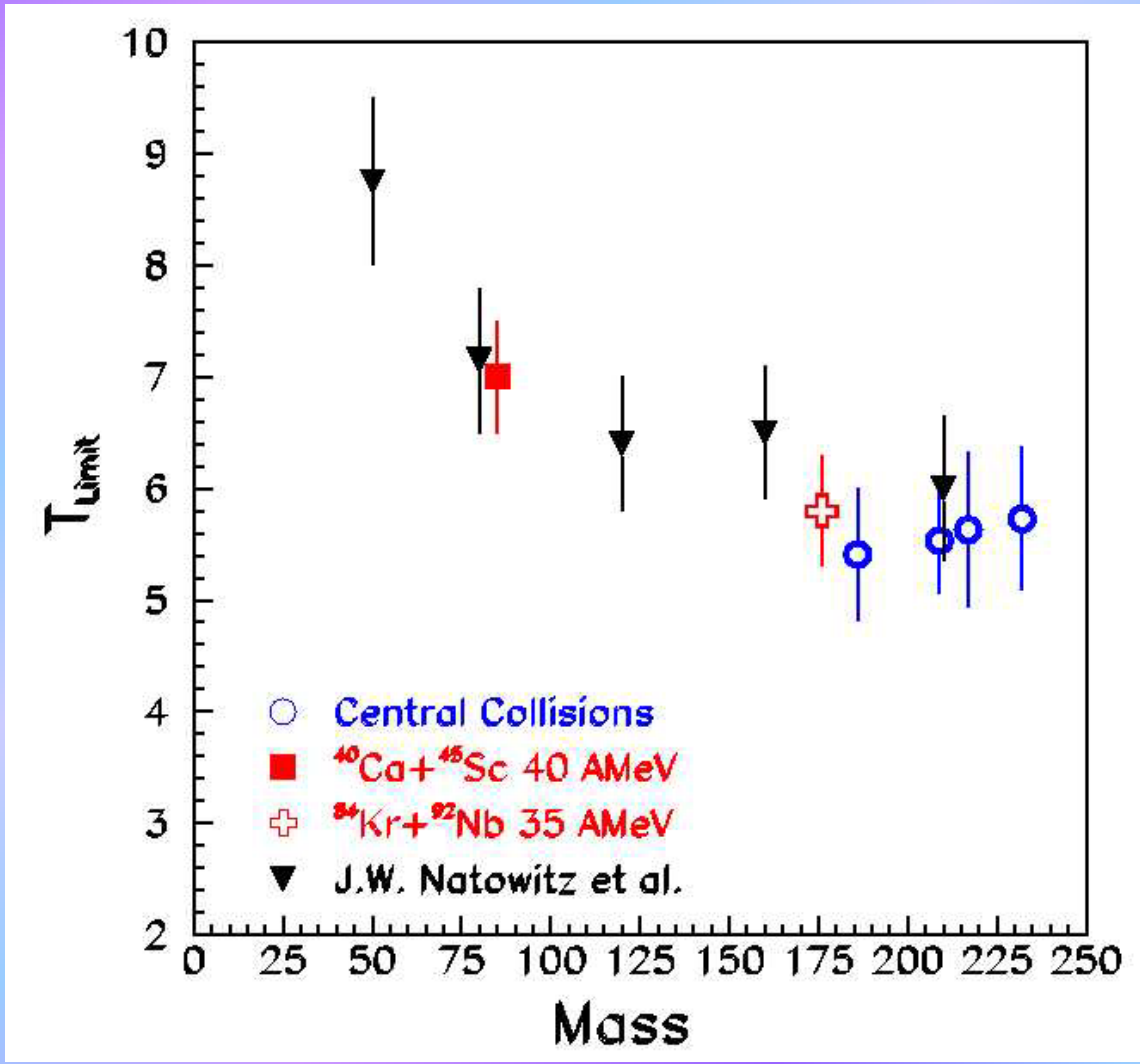


Size Effect in Central Collisions

☺ Observed Mass dependence in Central Collisions agrees with the systematics

Coulomb + Surface Effects could also explain the latent heat mass dependence

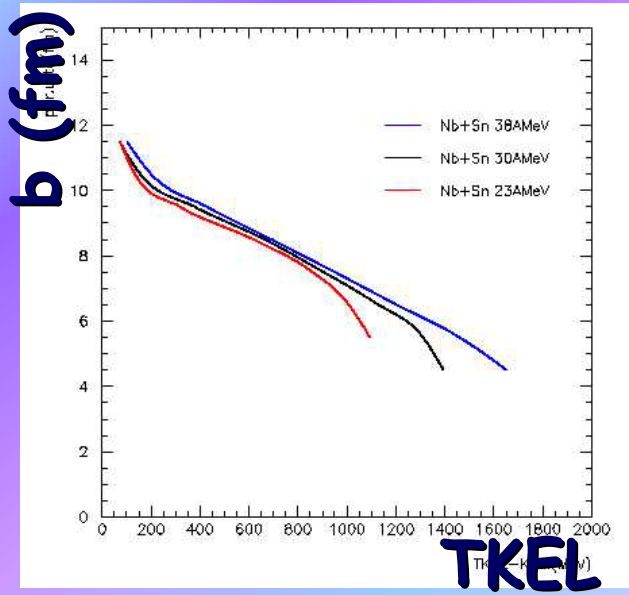
(P.Danielewicz Nucl.Phys. A727 (2003) 233-268)



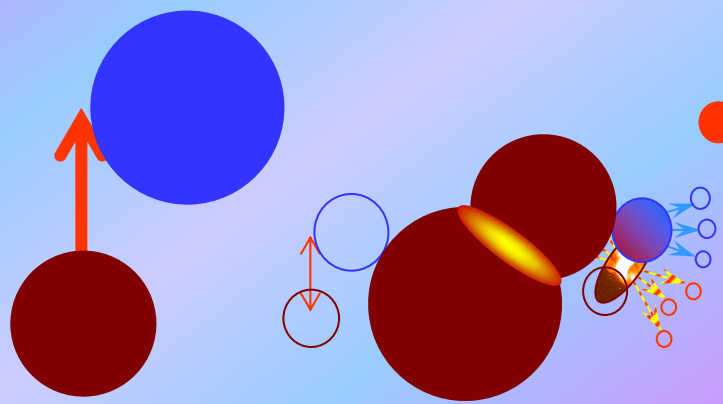
Thermodynamics of finite systems

The Quest for the Neck decay

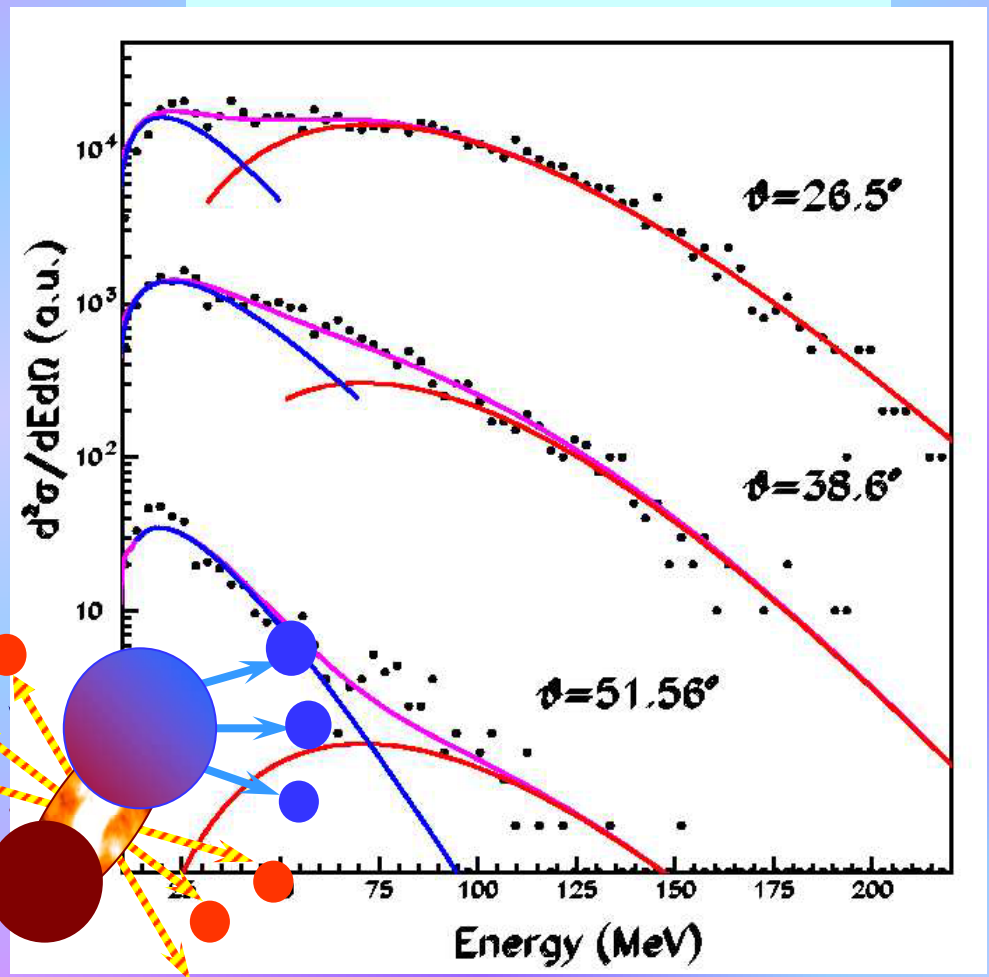
TKEL is a measure of the impact parameter.



TKEL ⇔ Excitation Energy

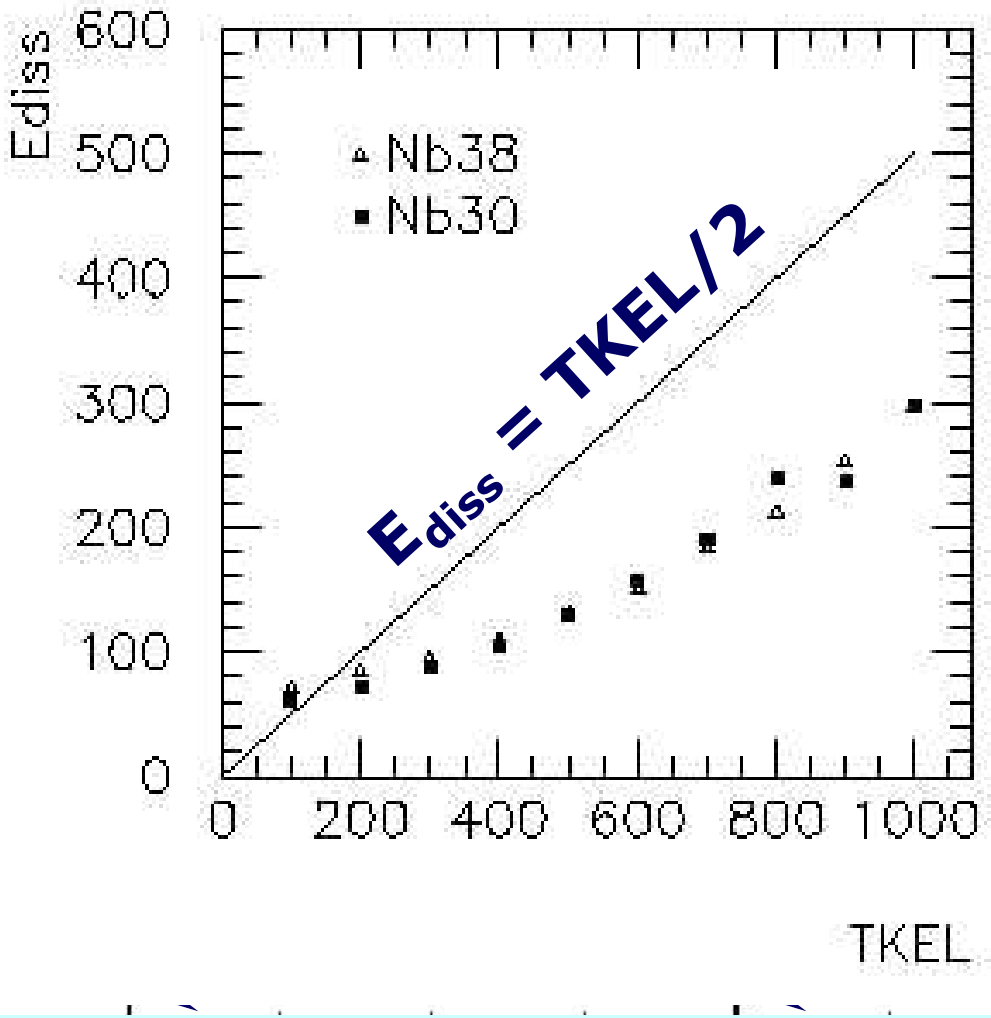


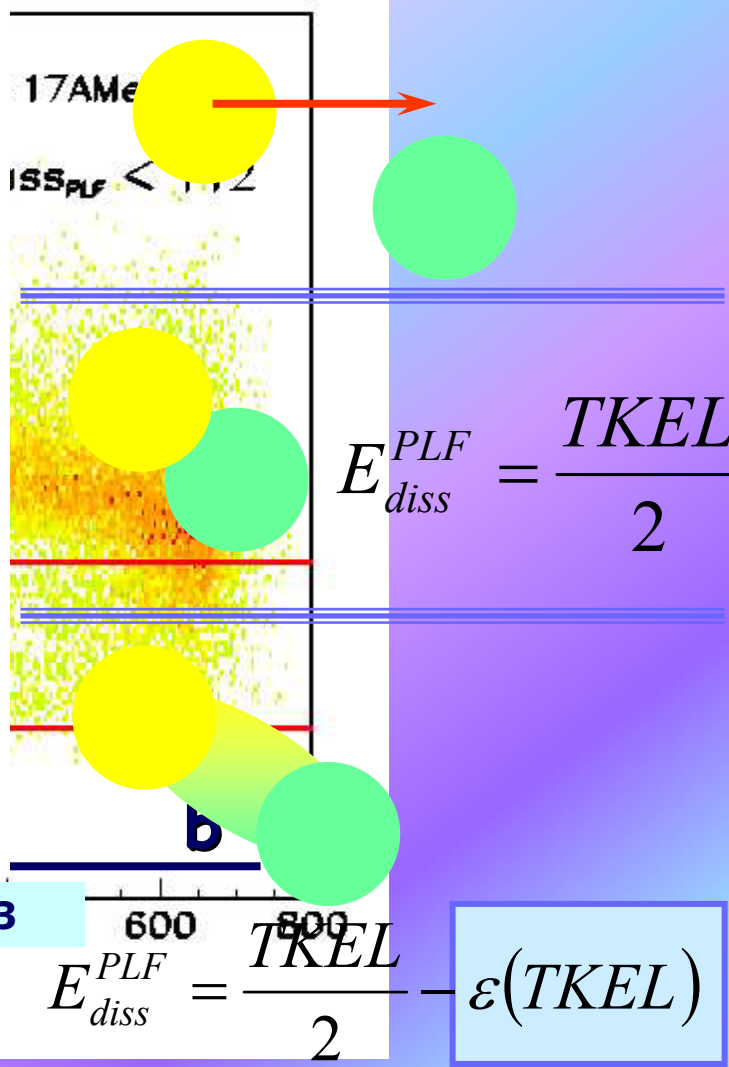
^{116}Sn+^{93}Nb 38AMeV



Neck Emission

PLF analysis of symmetric systems





$$E_{diss}^{PLF} = \frac{TKEL}{2}$$

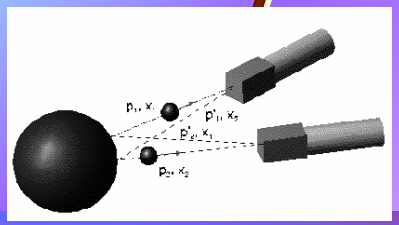
$$E_{diss}^{PLF} = \frac{TKEL}{2} - \varepsilon(TKEL)$$

A.Mangiarotti PhD Thesis -University of Firenze- 2003

- Partition of the dissipated energy (TKEL) @ intermediate energies

Space-Time Distribution Determination

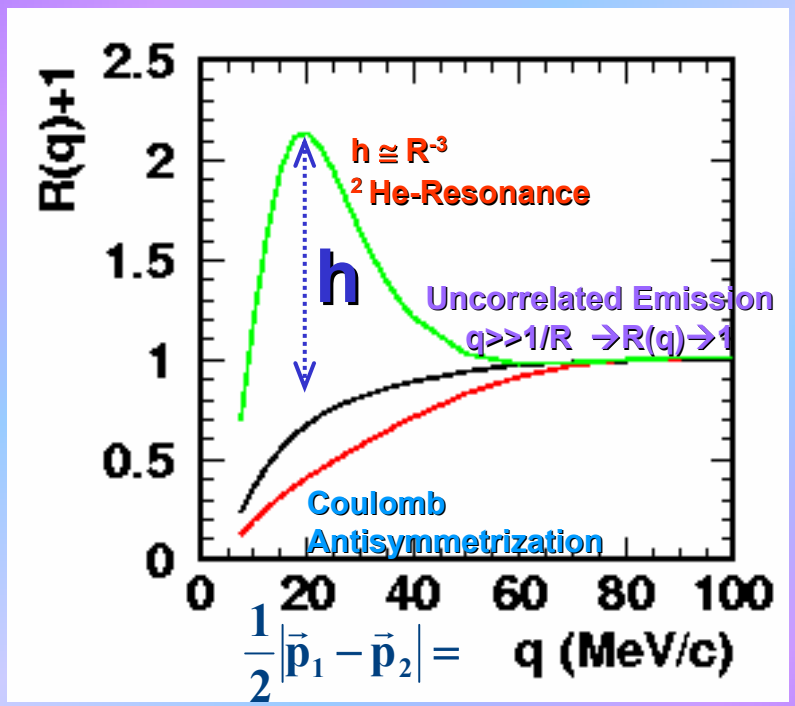
Intensity Interferometry VS. Imaging Technique



Hanbury-Brown-Twiss

Nature, 177, 27 (1956)

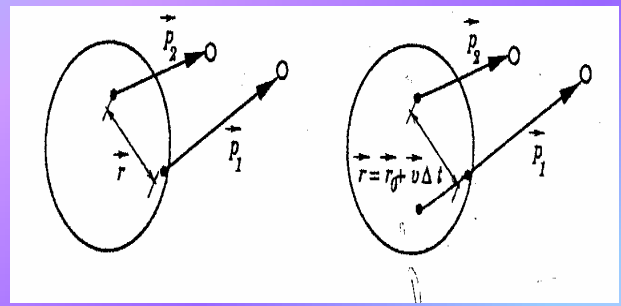
$$R(\vec{k}_1,\vec{k}_2)=\frac{\langle n_{12}\rangle}{\langle n_1\rangle\cdot\langle n_2\rangle}-1$$



The Source Function S(R) is obtained from direct numerical inversion of the Koonin-Pratt equation

$$R(q)=C_{\vec{P}}(q)-1=4\pi\int_0^\infty drr^2K_0(q,r)S_{\vec{P}}(r)$$

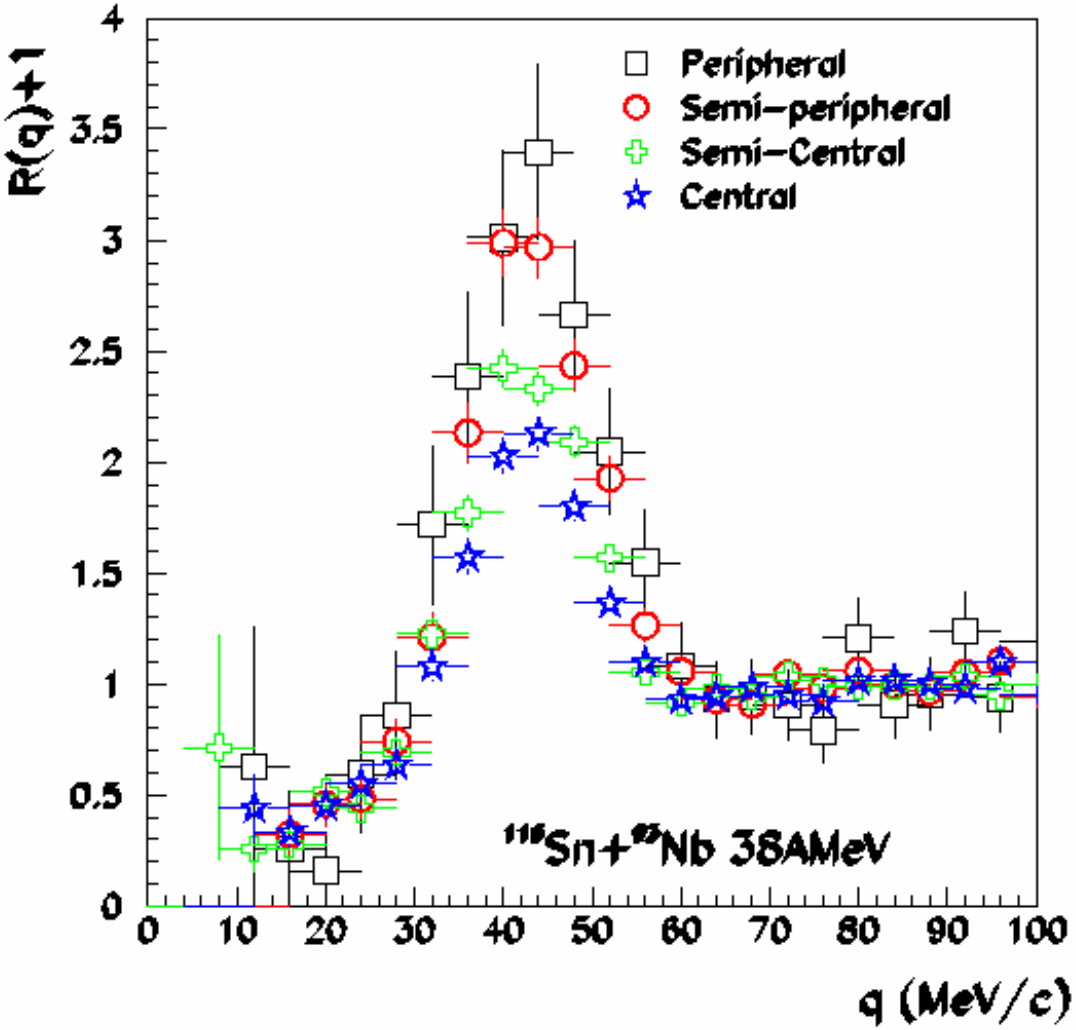
Model Independent BUT different emission times remains indistinguishable



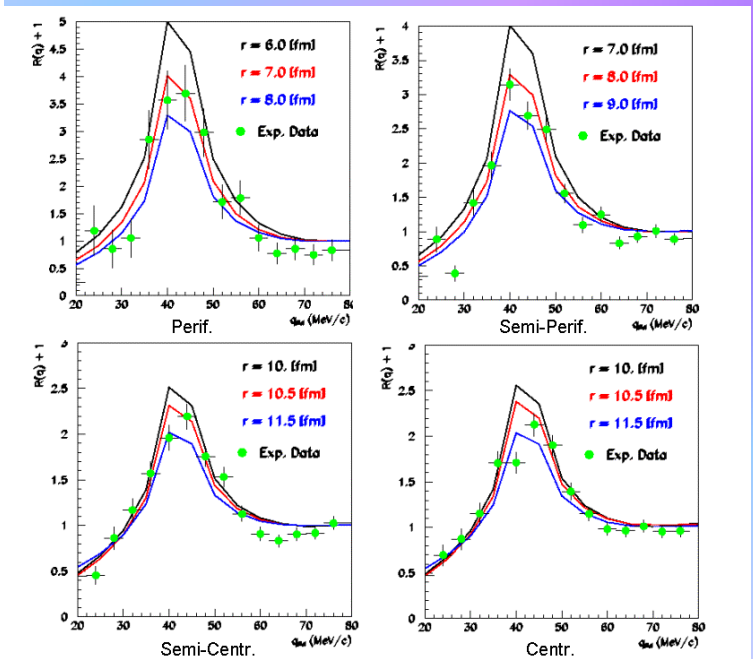
P.Danielewicz and D.A.Brown PRC57, 2474 (1998)

Unlike-particle Correlations

D.Boal and J.Shillock PRC33(1986)549
S.Fritz et al. PLB461(1999)315

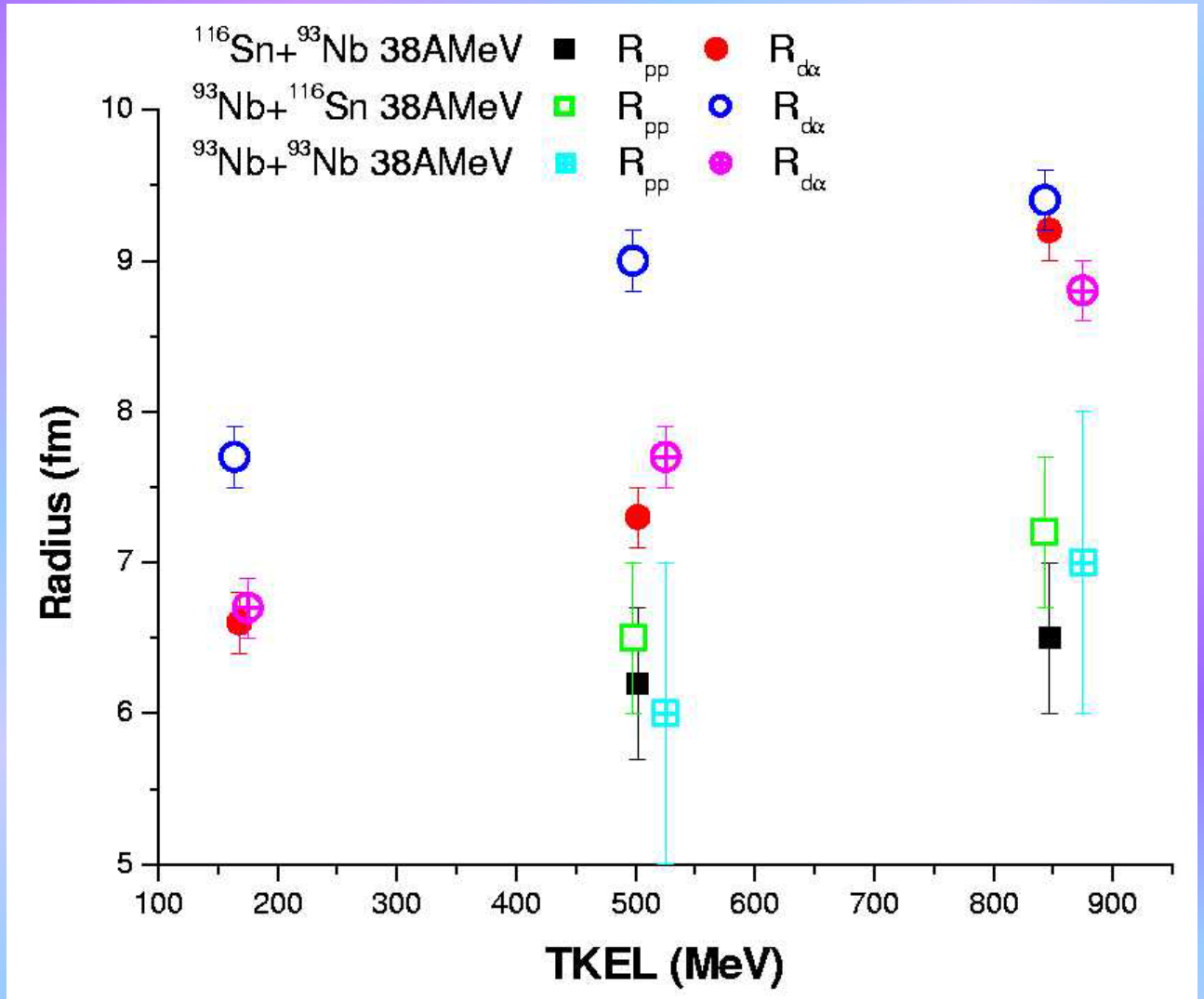


- Unfolded numerical results are available
- Experimental setup efficiency
  - Cross comparison between experimental and calculated integrals



Radii Measurement

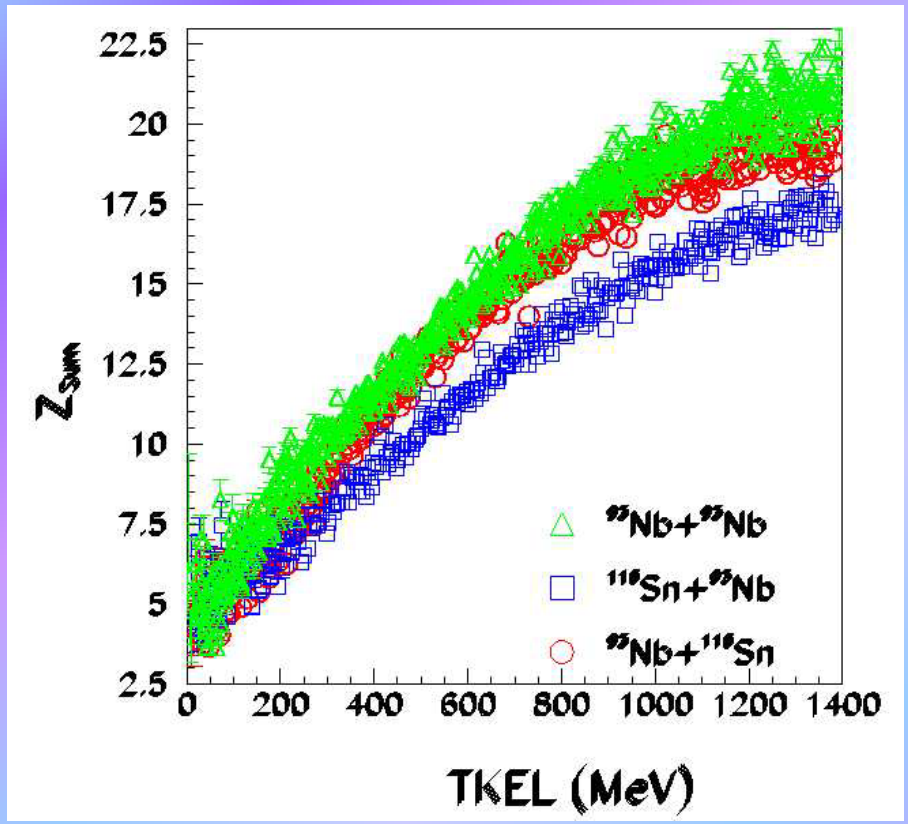
- Radii extracted from pp CF are always smaller than the one from dα CF.
- Emission Times effects in the pp CF would just increase this difference.

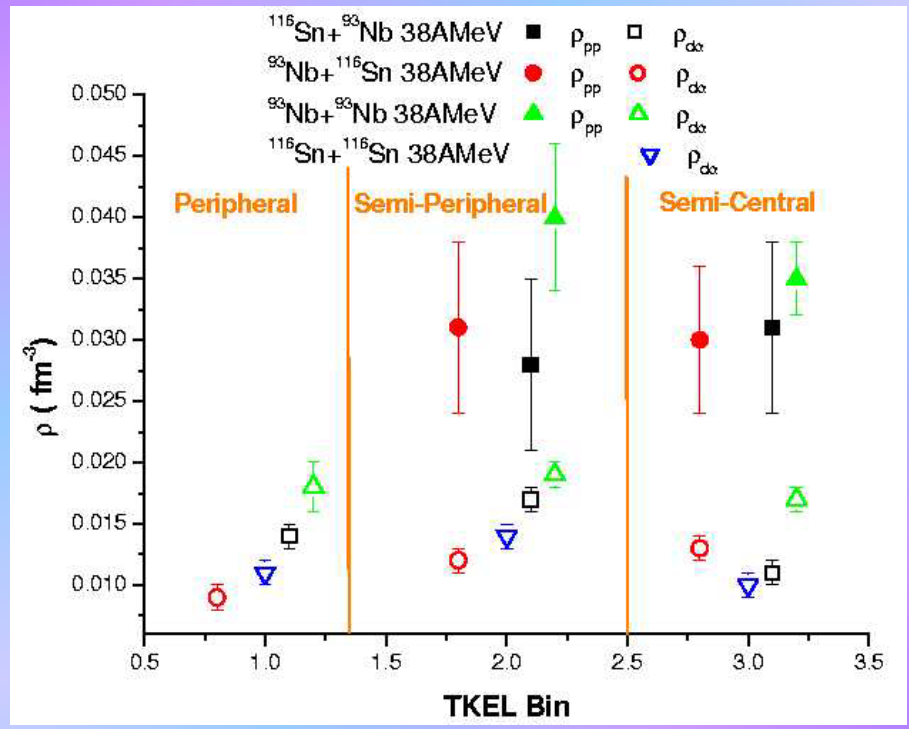


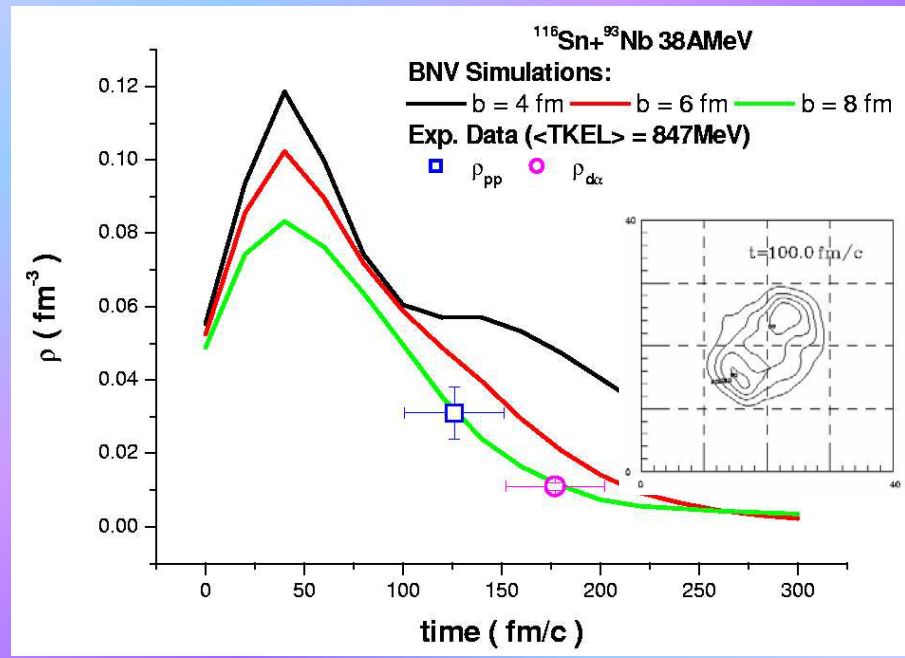
☞ Going towards central collisions the difference between the ^{93}Nb^{116}Sn and ^{116}Sn^{93}Nb systems vanishes.

Midrapidity Mass " Rough" Assumption

$$\langle A \rangle \approx 2 \cdot Z_{sum}$$







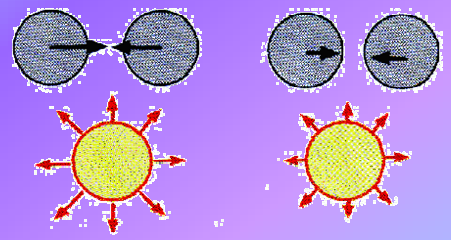
Confirmed by PLF analysis:

$$\langle Z_{pri} \rangle = \langle Z_{\sec}^{PLF} \rangle_{MEASURED} + \langle Z_{stat.evap}^{PLF} \rangle_{THEO}$$

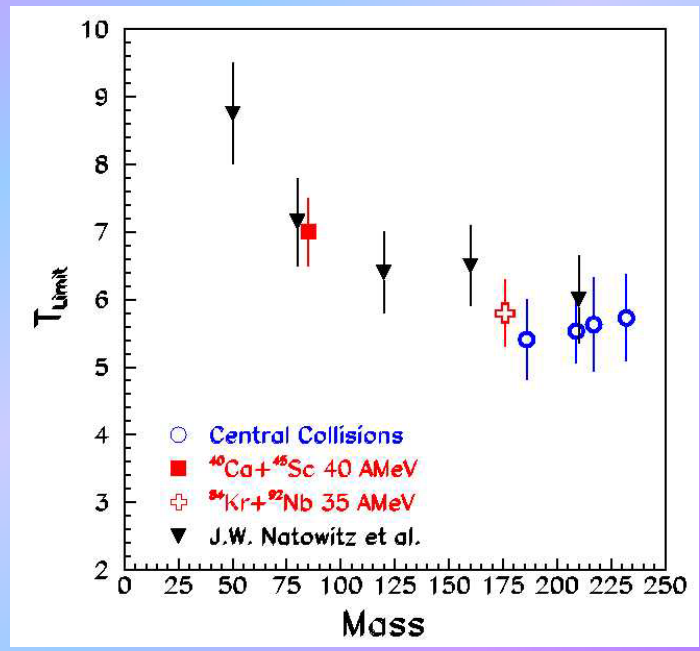
$$\langle Z_{tot} \rangle_{MEASURED} = \langle Z_{pri} \rangle + \langle Z_{mid} \rangle$$

Outlook: what we have learnt

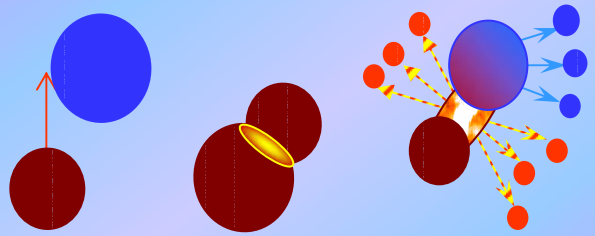
I- Central Collisions



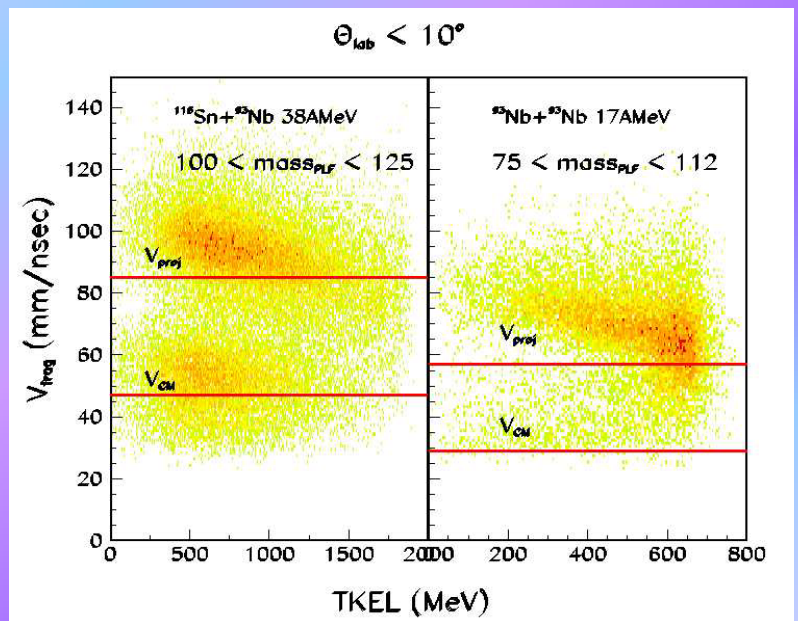
Size effect in the limiting temperature



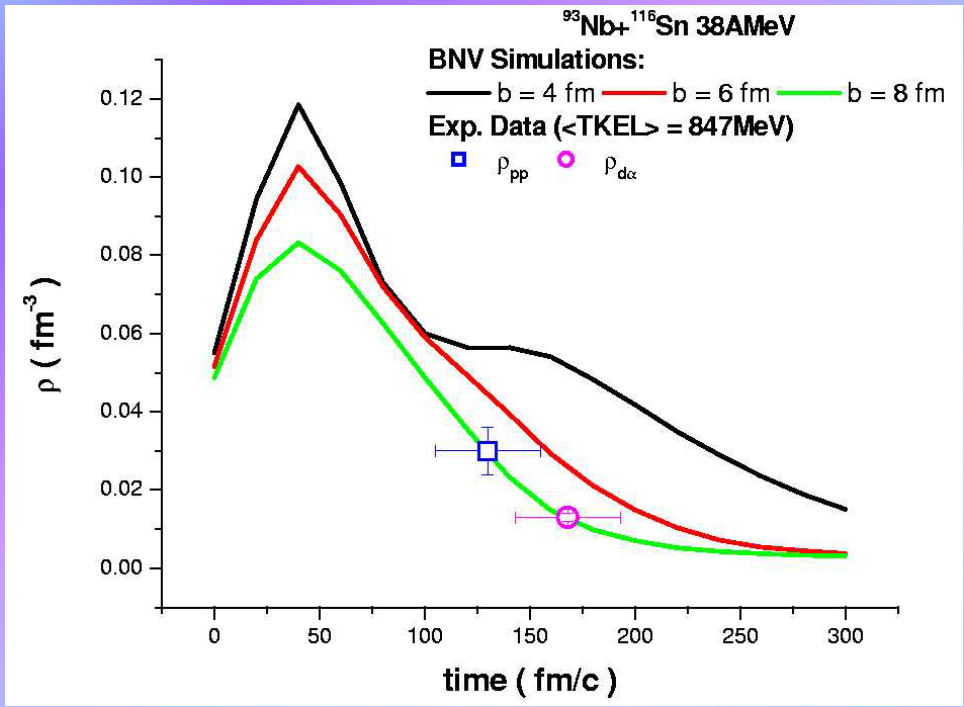
II- Peripheral Collisions



Investigating *diluite* neck matter



Perspective I:
Neck density measurement

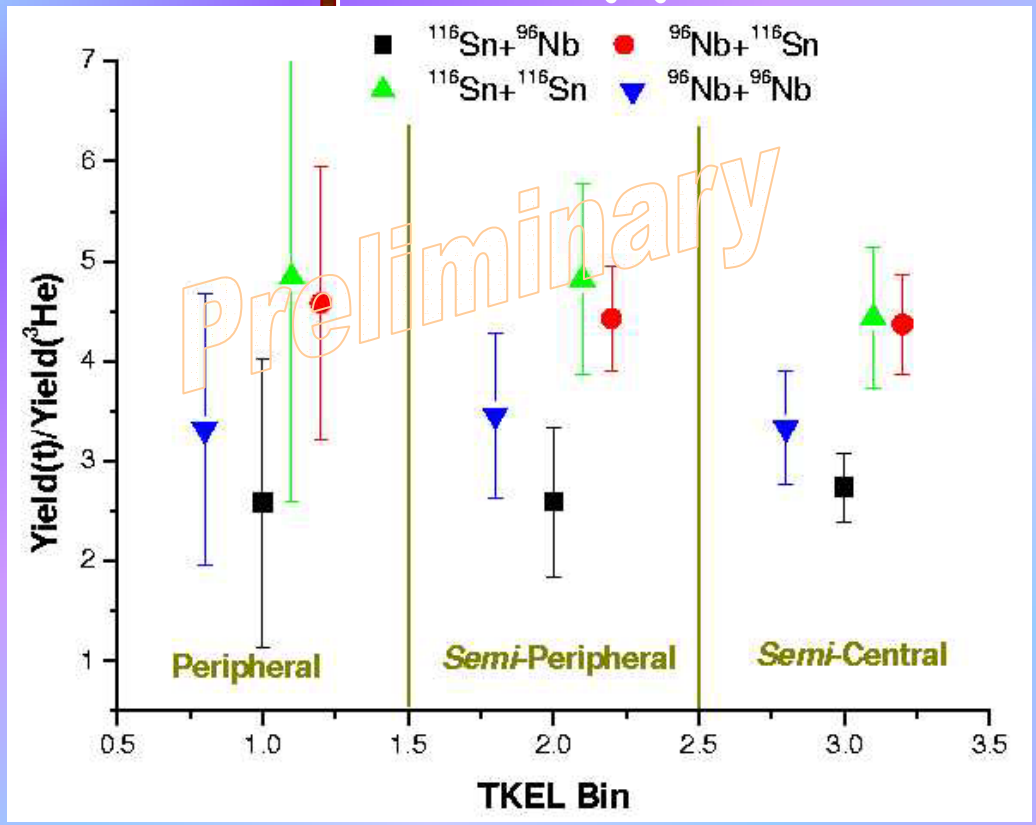


- Beyond the spherical neck assumption
- Better determination of the mass (Analysis in Progress)
- Emission Time Dependence → IMF-IMF Correlation Function (in progress)

- Coupling with another "clock" : γ and high energy protons detection → Cross-check of the A ≈ const assumption

Perspective II:

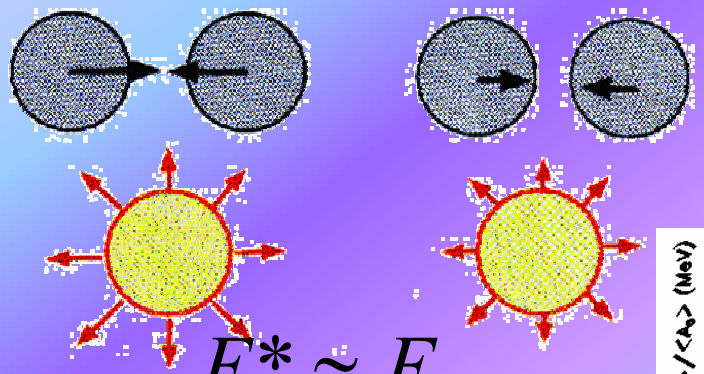
Isospin Diffusion in neck emission



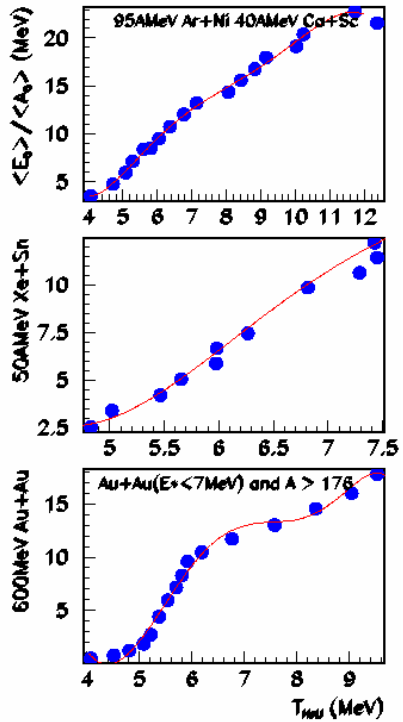
- Studying Isospin Dependence in target emission (in progress)
- Comparing ^{124}Sn with ^{112}Sn projectiles

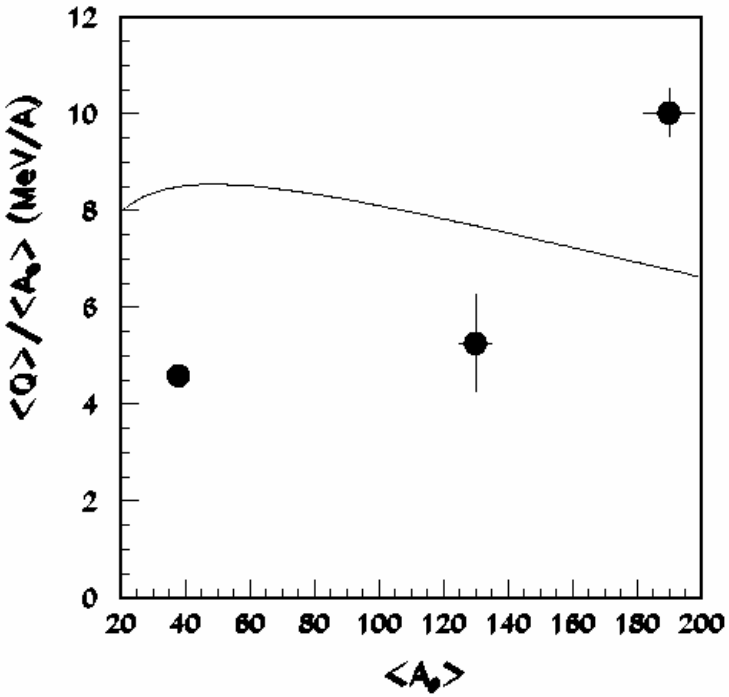
☞Increase the N/Z asymmetry in the entrance channel to investigate isospin dependences in neck emission

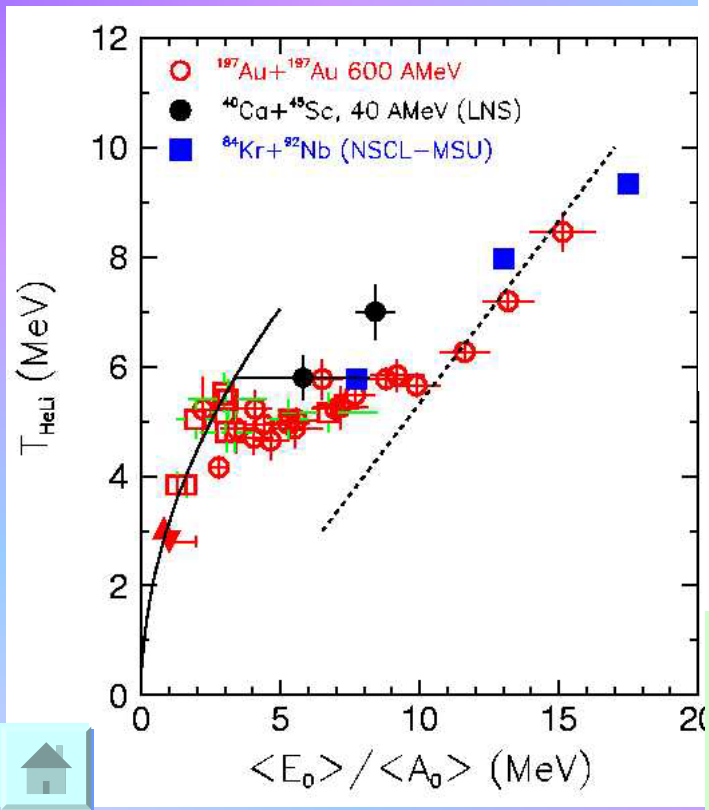
Central Collisions:
A tool to study Size Effect



$$E^* \approx E_{Beam}$$



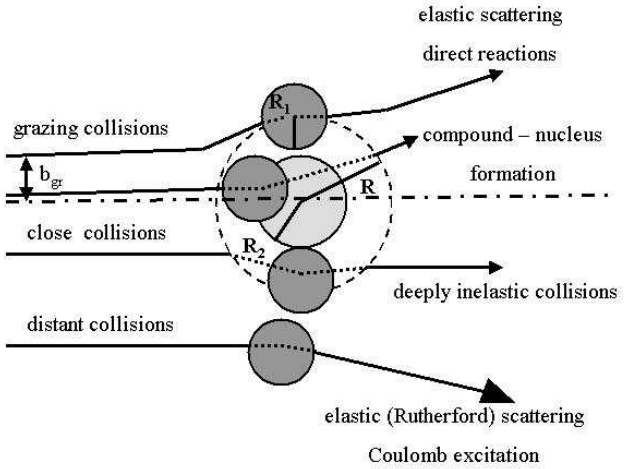


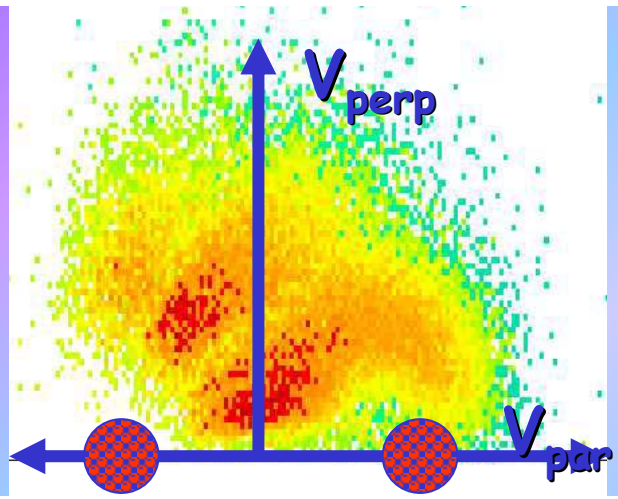


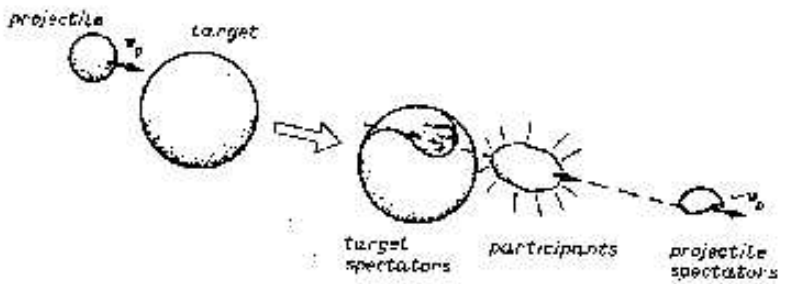
☝ **Size effect already observed @ relativistic energies**

A = Cost ☞CENTRAL Collisions
A @ 170 -180 (Kr+Nb@NSCL)
A @ 80 (Ca + Sc@LNS)

The Quest for the Neck decay







Incident Energy