Enrico De Filippo (INFN Catania) per le collaborazioni NEWCHIM / ASYEOS

L'esperimento ASYEOS (S394) al GSI: Studio dell'energia di simmetria ad alta densità: Risultati e prospettive future

La motivazione: il termine di simmetria della materia nucleare asimmetrica ad alta densità

Il metodo: la misura dei flussi ellittici di neutroni e particelle cariche

La misura : l'esperimento ASYEOS al GSI (Au+Au, Ru+Ru, Zr+Zr) a 400 A.MeV e la deteminazione dei flussi collettivi.

I risultati: Parametrizzazione della dipendenza dalla densità del termine di simmetria dedotta dal confronto dei dati con il modello UrQMD.

Il futuro: Prospettive per esperimenti futuri al GSI e FAIR

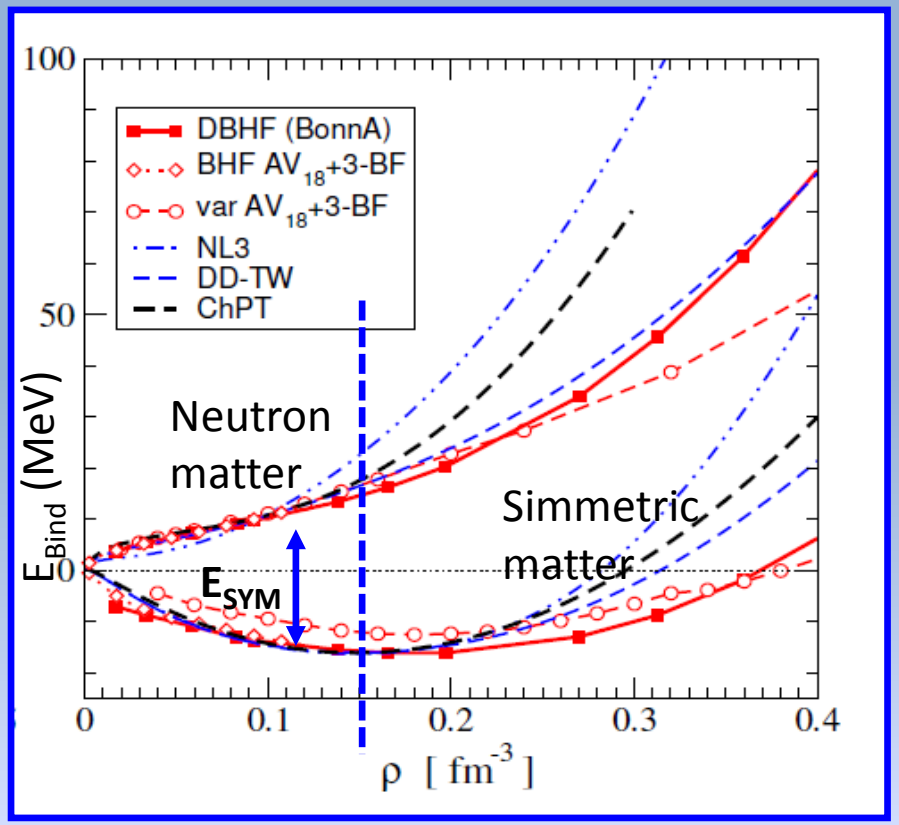
The key problem: the symmetry energy as a function of the barionic density

$$E(\rho,\delta) = E(\rho,\delta=0) + S(\rho)\delta^2$$

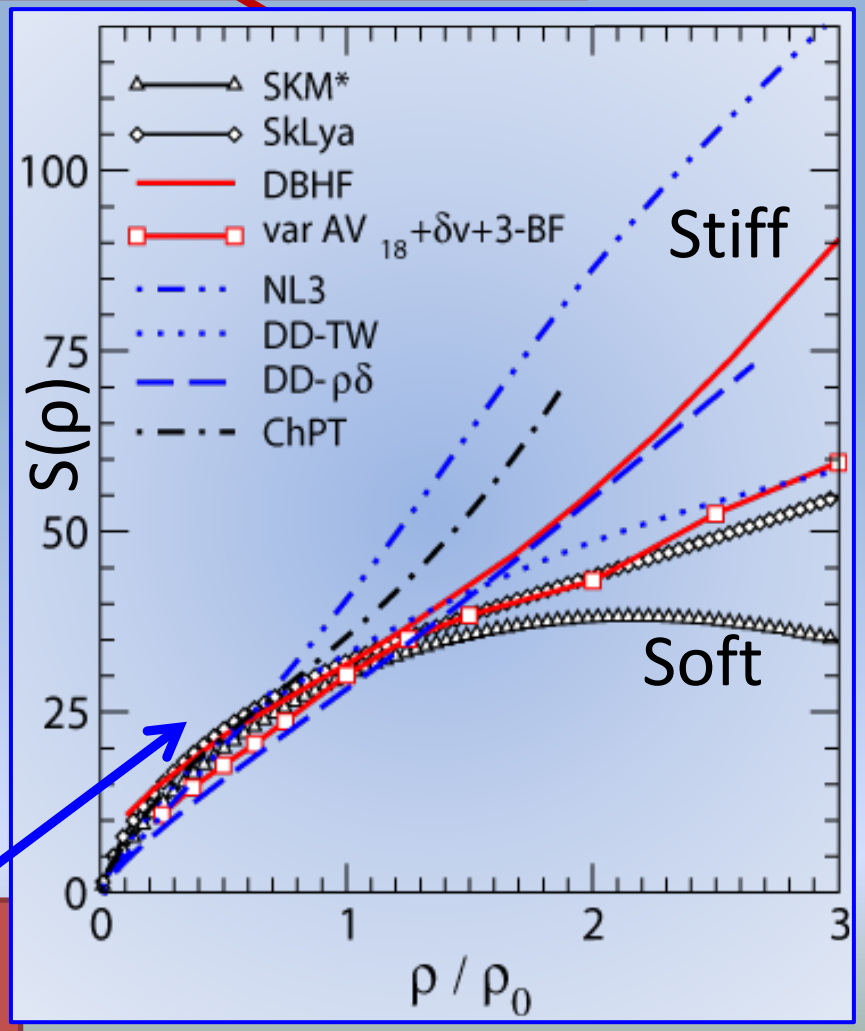
$$\delta = \frac{\rho_n - \rho_p}{\rho_n + \rho_p} = \frac{N-Z}{A}$$

$$S(\rho) = S_0 + \frac{L}{3}\left(\frac{\rho-\rho_0}{\rho_0}\right) + \frac{K_{sym}}{18}\left(\frac{\rho-\rho_0}{\rho_0}\right)^2 + \ldots.$$

Large deviations at high densities, lack of experimental probes



Fuchs and Wolter, EPJA 30, 5 (2006)



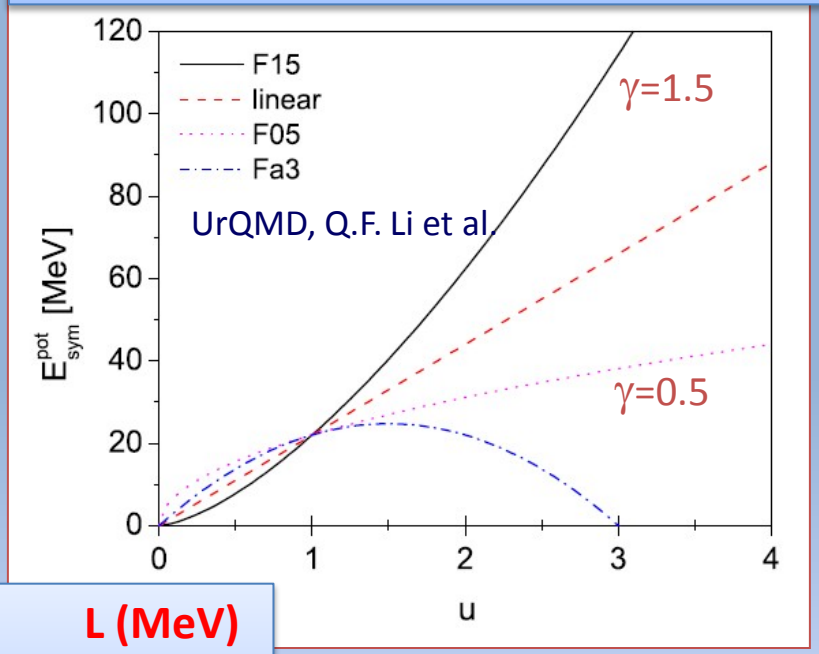
Sensitivity to observables based on N/Z asymmetry

The key problem: the symmetry energy as a function of the barionic density

Kinetic contribution (Fermi gas model)

$$E_{sym} = E_{sym}^{kin} + E_{sym}^{pot}$$
$$= 12\text{MeV}\cdot(\rho/\rho_0)^{2/3} + 22\text{MeV}\cdot(\rho/\rho_0)^{\gamma}$$

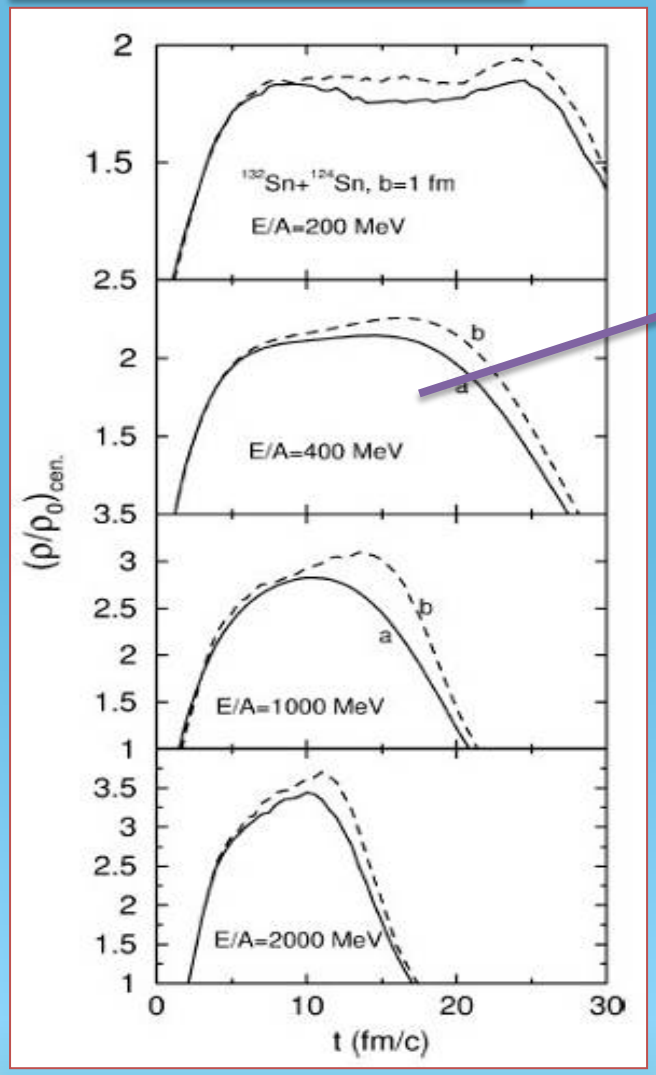
Isospin dependence of the effective interaction



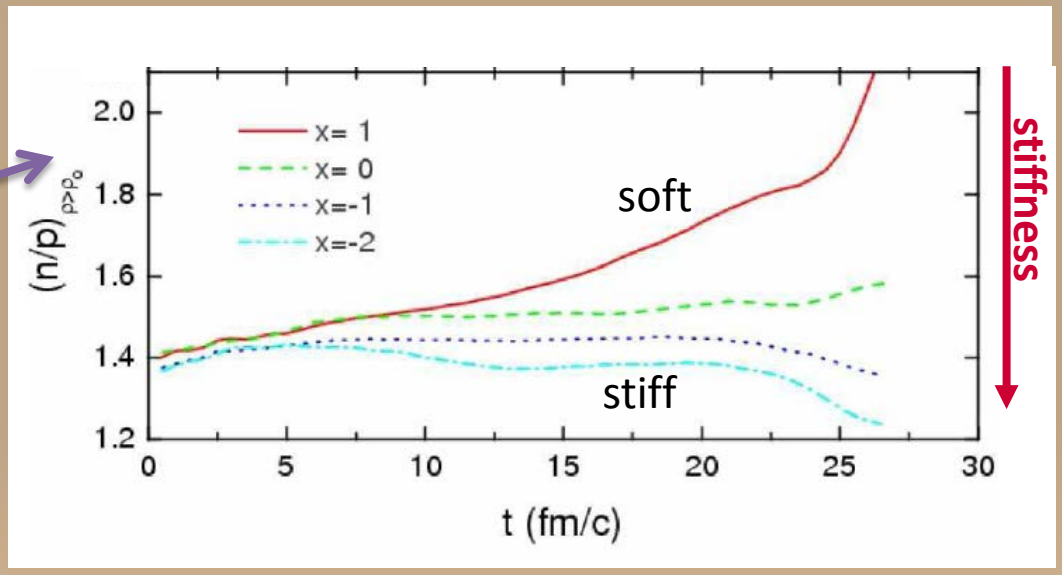
γ	L (MeV)
0.5	57
1.0	90
1.5	123

High density symmetry energy in relativistic heavy ion collisions

Bao-An Li, NPA 708 365 (2002)



Bao-An Li, PRC 71, 014608 (2005)



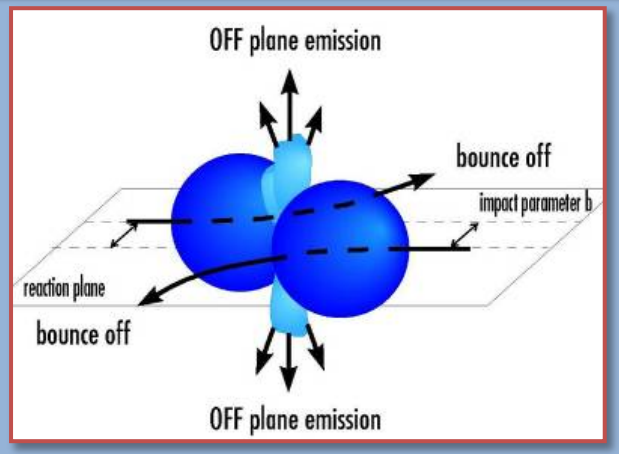
A stiffer symmetry energy at high density is more repulsive for neutrons. This influence the **N/Z** ratio of the interaction zone

Pion ratio observable

Δ resonance:
$Y(\pi^-)/Y(\pi^+) \approx (N/Z)^2_{dense}$

With HIC large density variations (density gradients) in nuclear matter can be obtained in a short timescale.

COLLECTIVE FLOWS



$$\frac{dN}{d(\phi-\phi_R)}(y,p_t)=\frac{N_0}{2\pi}\left(1+2\sum_{n\geq 1}v_n\cos n(\phi-\phi_R)\right)$$

Transverse flow

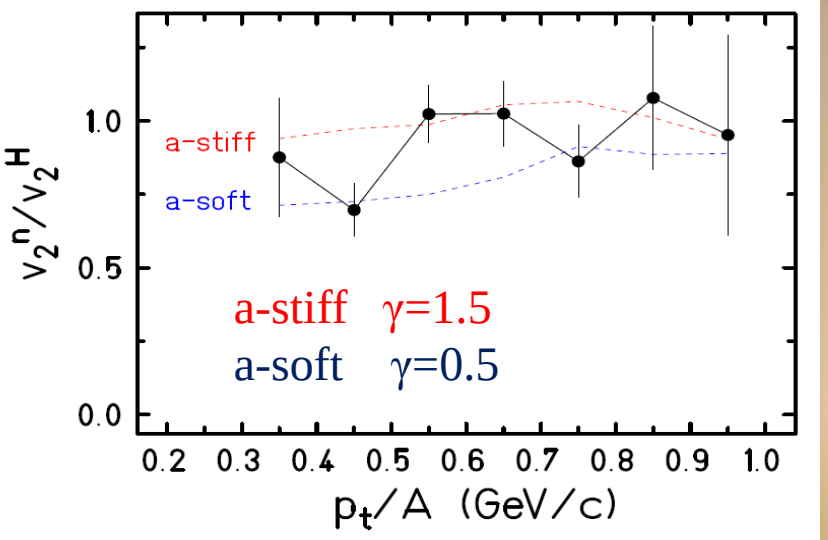
$$V_1(y,p_t)=\left\langle\frac{p_x}{p_t}\right\rangle$$

Elliptic flow

$$V_2(y,p_t)=\left\langle\frac{p_x^2-p_y^2}{p_t^2}\right\rangle$$

Elliptic flow: competition between in plane ($V_2>0$) and out-of-plane ejection ($V_2<0$)

Transverse flow: *it provides information on the azimuthal anisotropy in the reaction plane*



Elliptic flow from FOPI /LAND experiment Au+Au 400 A.MeV

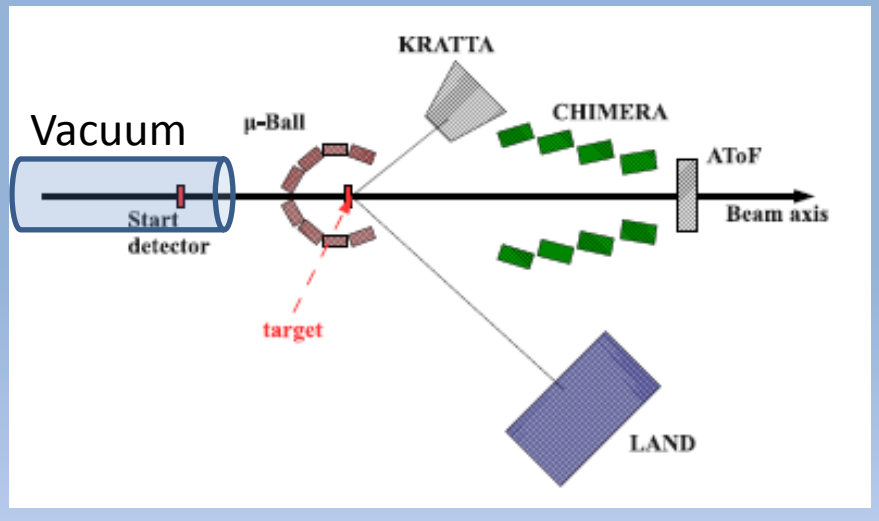
Ratio of elliptic flow paramer *V2* for neutrons and hydrogens compared with the UrQMD predictions

adopted: $\gamma = 0.9 \pm 0.4$

P. Russotto et al., Phys. Lett. **B697,** 471 (2011)

ASY-EOS S394 experiment @ GSI Darmstadt (May 2011)

Au+Au, ^{96}Zr+^{96}Zr , ^{96}Ru+^{96}Ru @ 400 AMev



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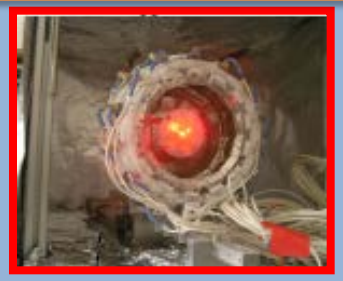
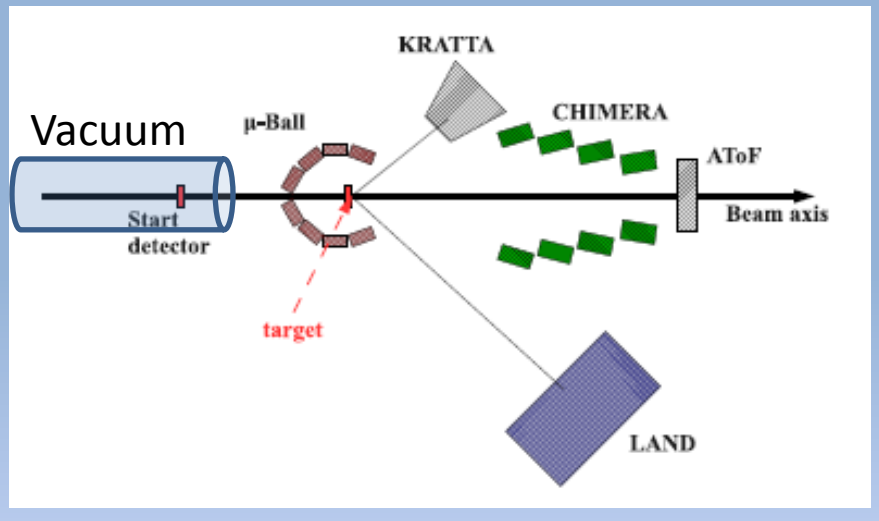


μBall: 4 rings 50 CsI(Tl), Θ>60°. Discriminate target vs. reactions with air. Multiplicity and reaction plane measurements.



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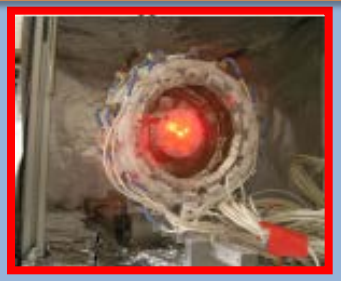

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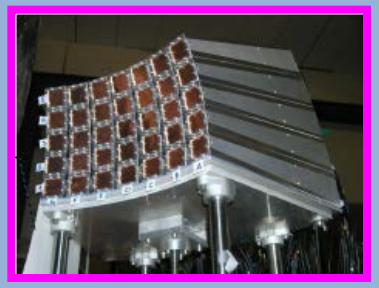
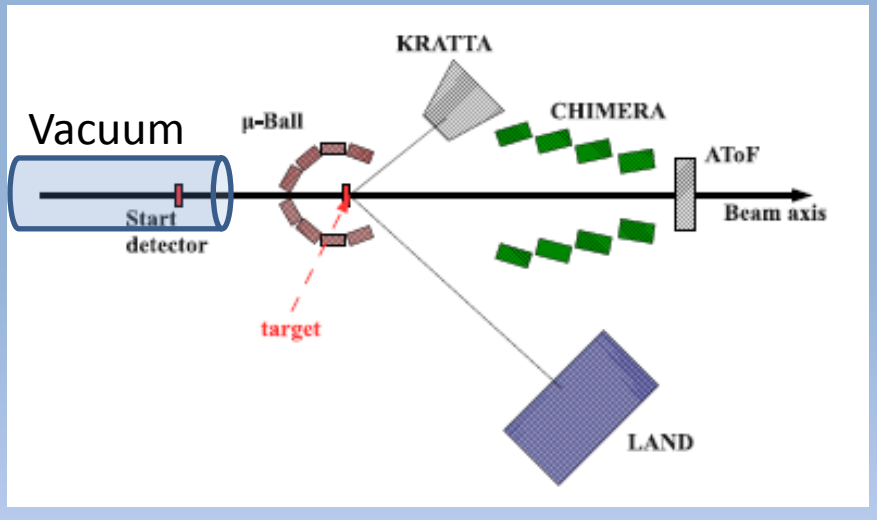


KraTTA: 35 (5x7) triple telescopes (Si-CsI-CsI) placed at 21°<Θ<60° with digital readout . Light particles and IMFs emitted at midrapidity



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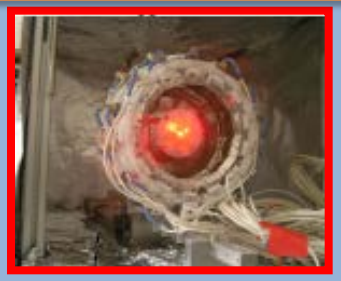

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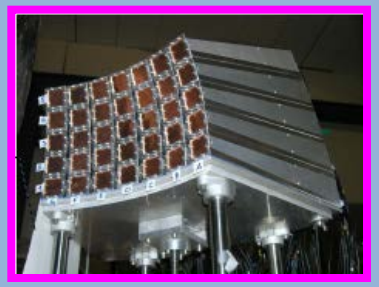

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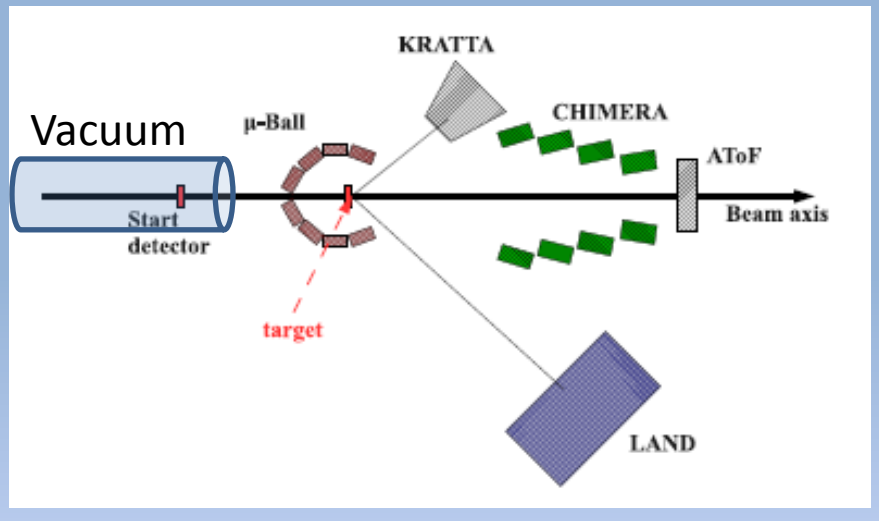

TOFWALL: 96 plastic bars; ToF, ΔE, X-Y position. Trigger, impact parameter and reaction plane determination

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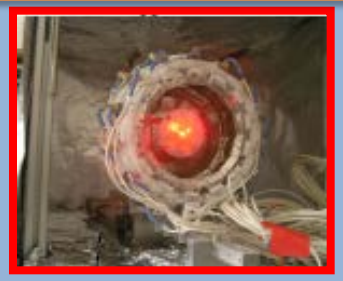

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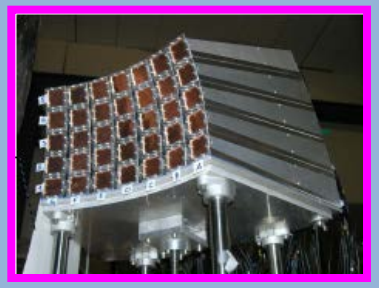

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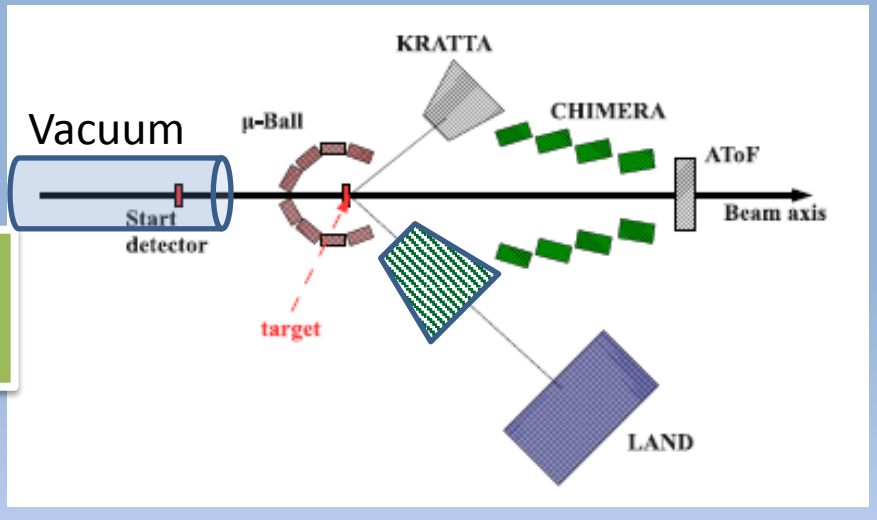
Shadow bar: evaluation of background neutrons in LAND



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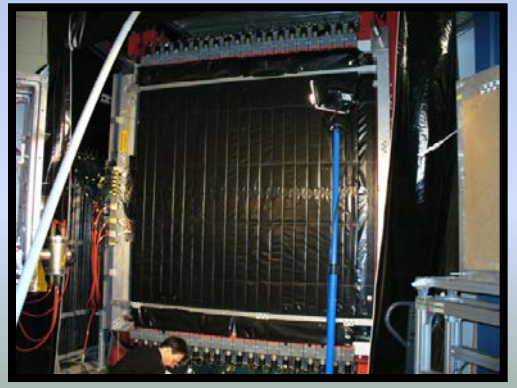

LAND: Large Area Neutron Detector . Plastic scintillators sandwiched with Fe 2x2x1 m^3 plus plastic veto wall. New Taquila front-end electronics. Neutrons and Hydrogen detection. Flow measurements

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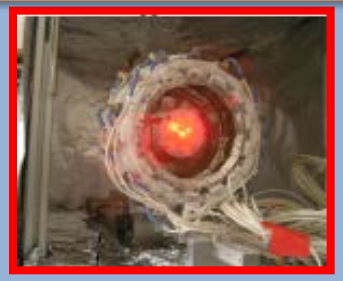

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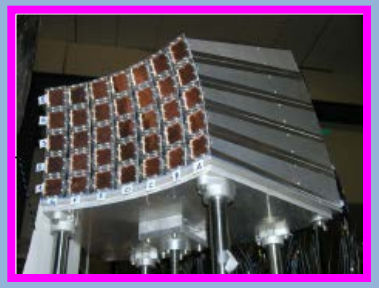

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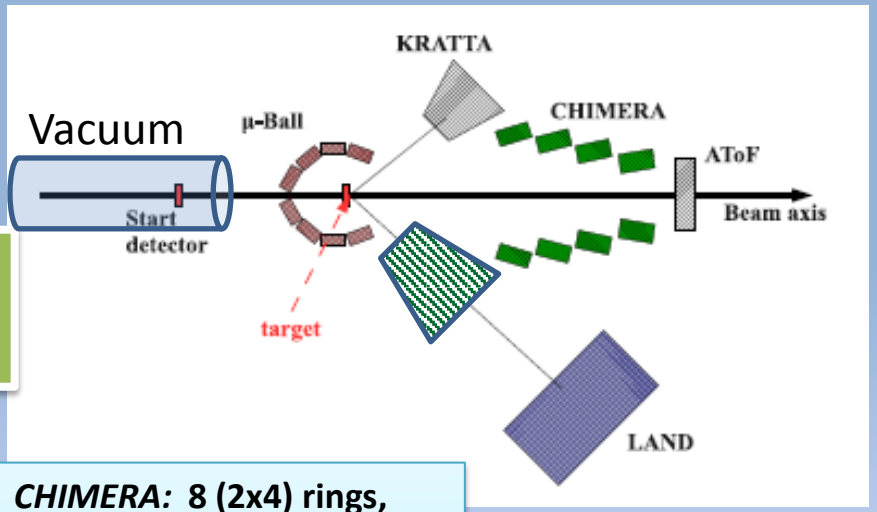

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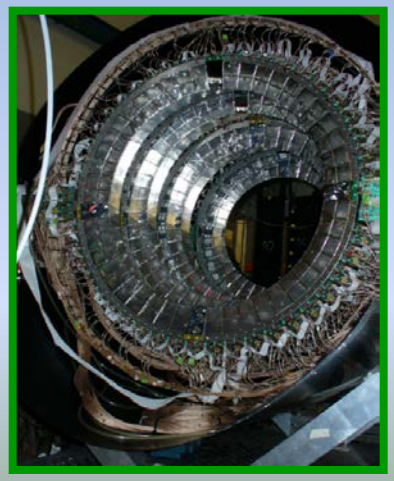
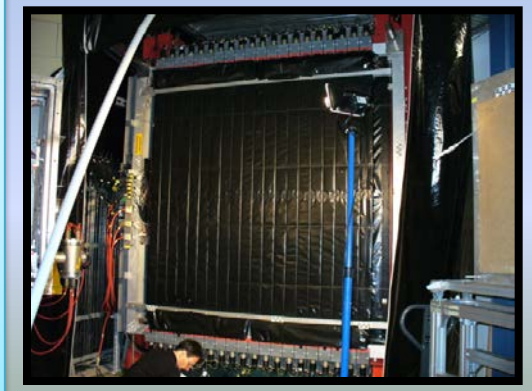


CHIMERA: 8 (2x4) rings, high granularity CsI(Tl), 352 detectors 7°<θ<20° + 16x2 pads silicon detectors. Light charged particle identification by PSD. Multiplicity, Z, A, Energy: impact parameter and reaction plane determination



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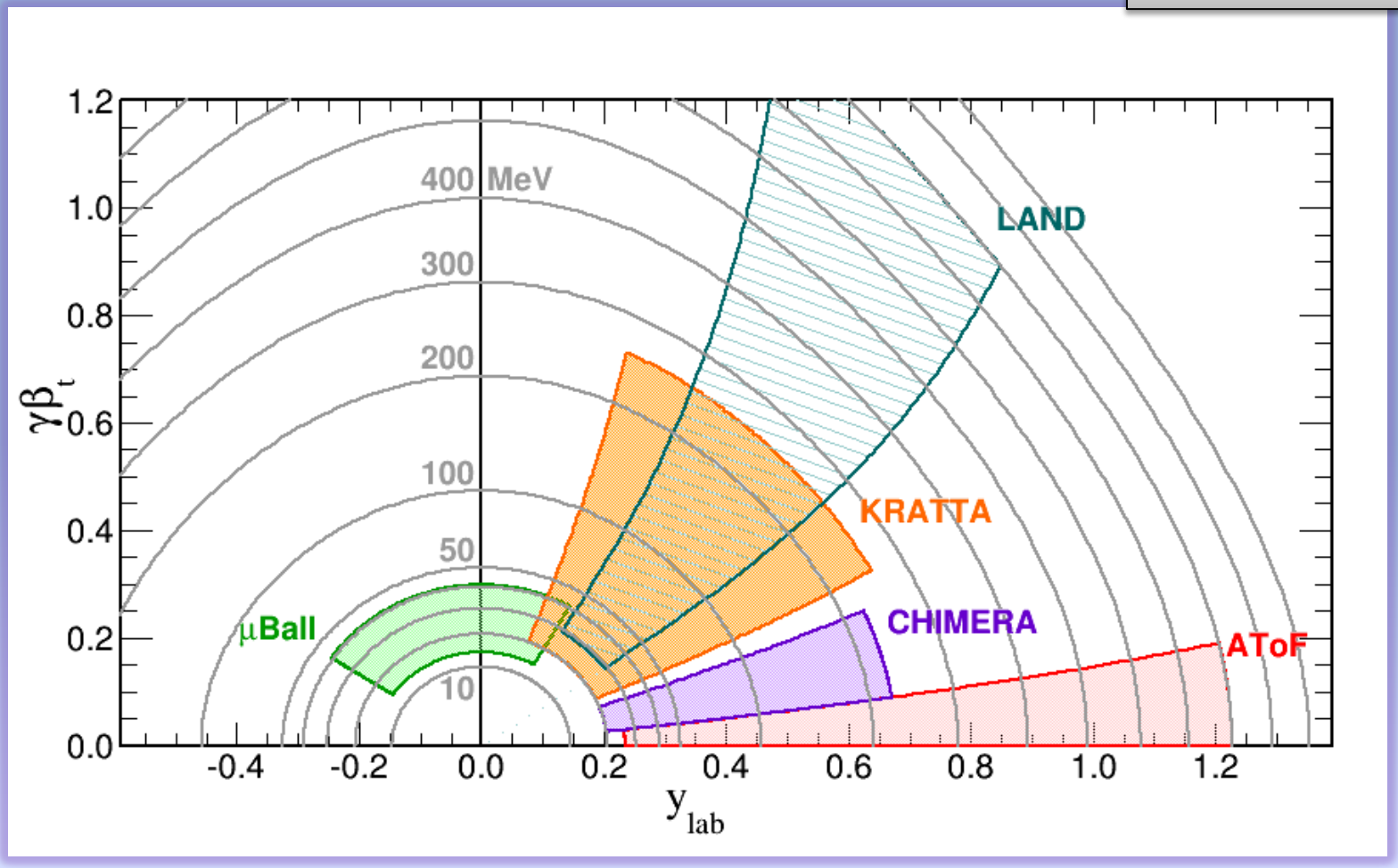
THE KINEMATICS COVERAGE AND REGIMES OF PARTICLES EMISSION IN:

Au + Au 400 A.MeV

Protons only



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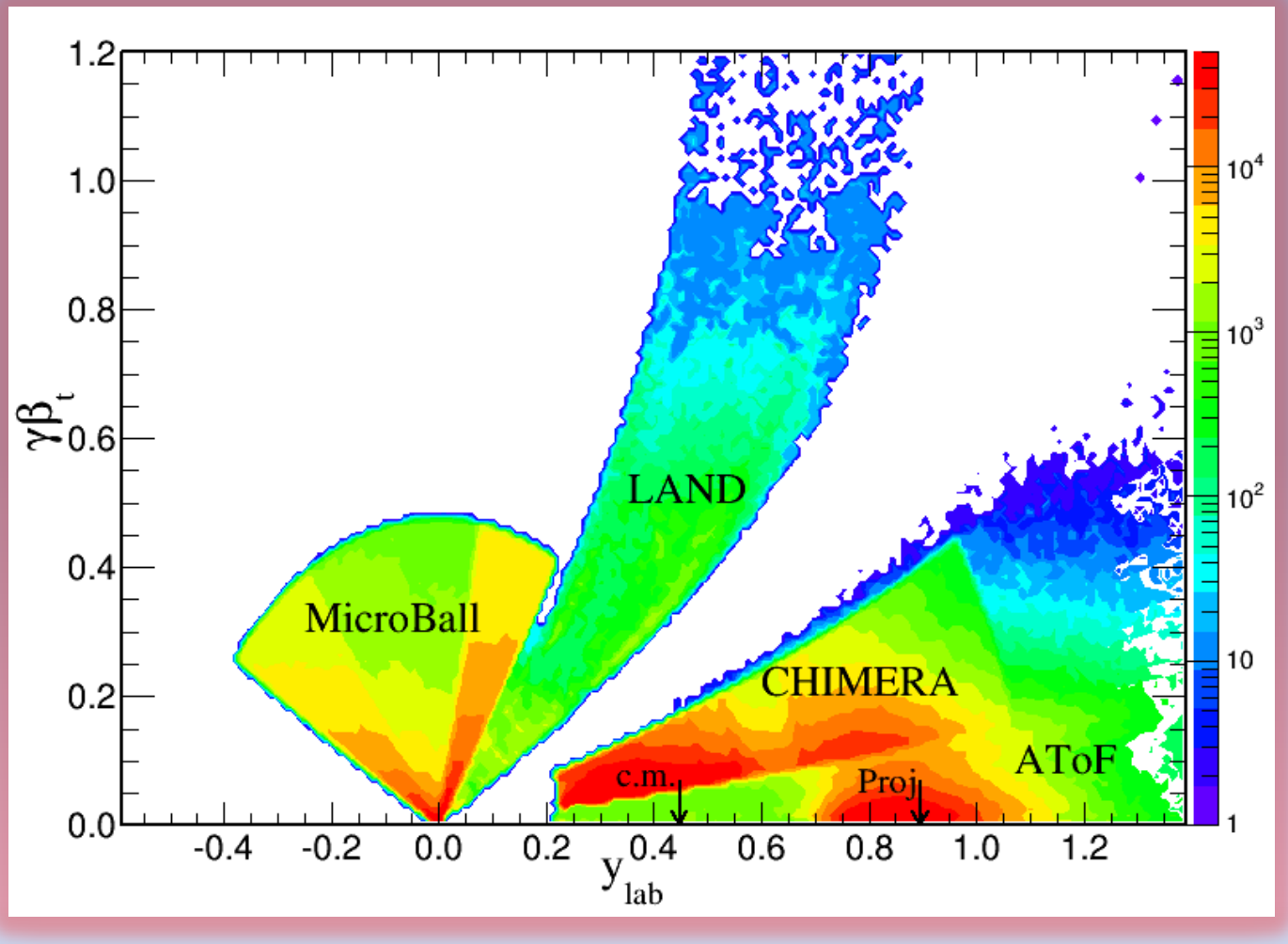
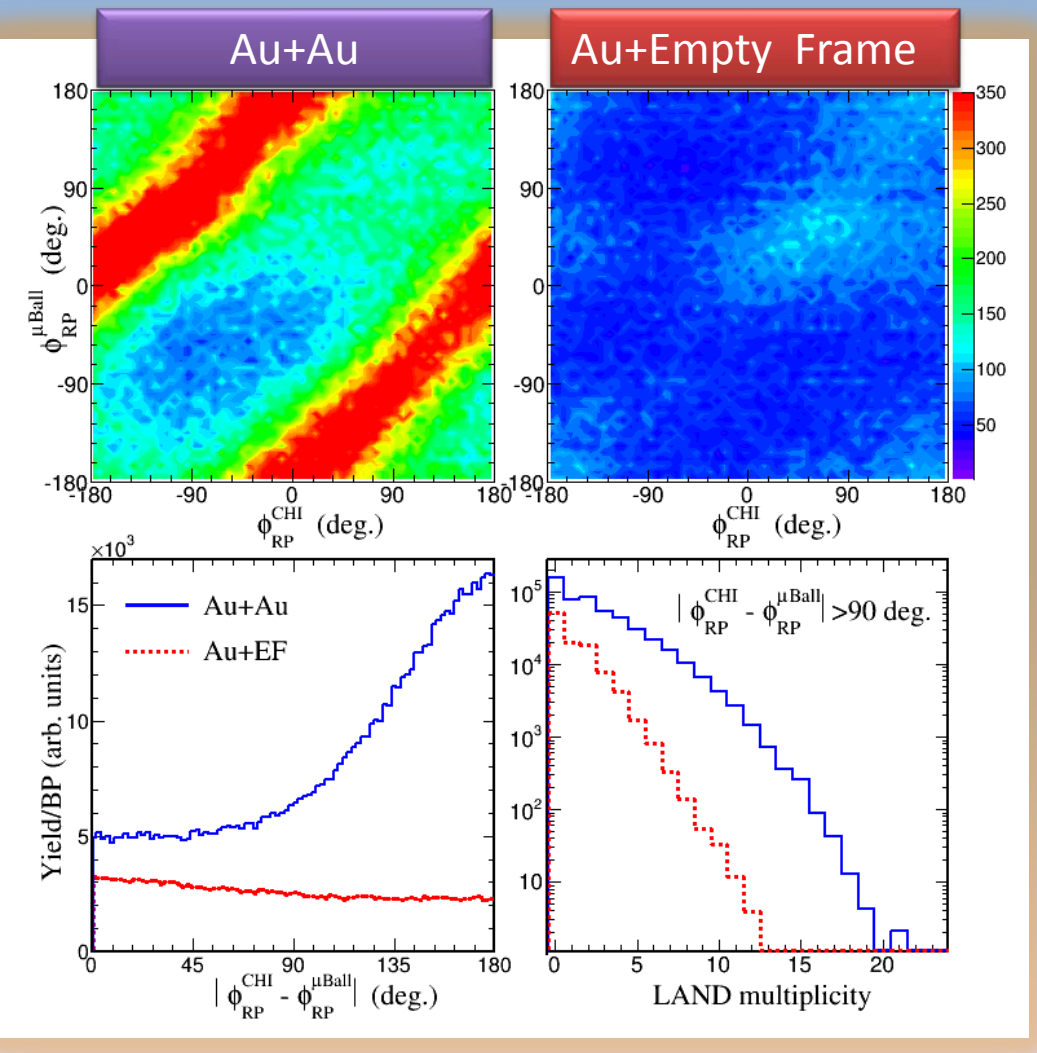


REACTION PLANE ORIENTATION AND BACKGROUND CORRECTIONS: AN EXAMPLE



CHIMERA $M(Y_{cm}>0.1) \geq 4$

$$\vec{Q}_{CHI} = \sum_{i=1}^{M} w_i Z_i \gamma \vec{\beta}_t^i$$

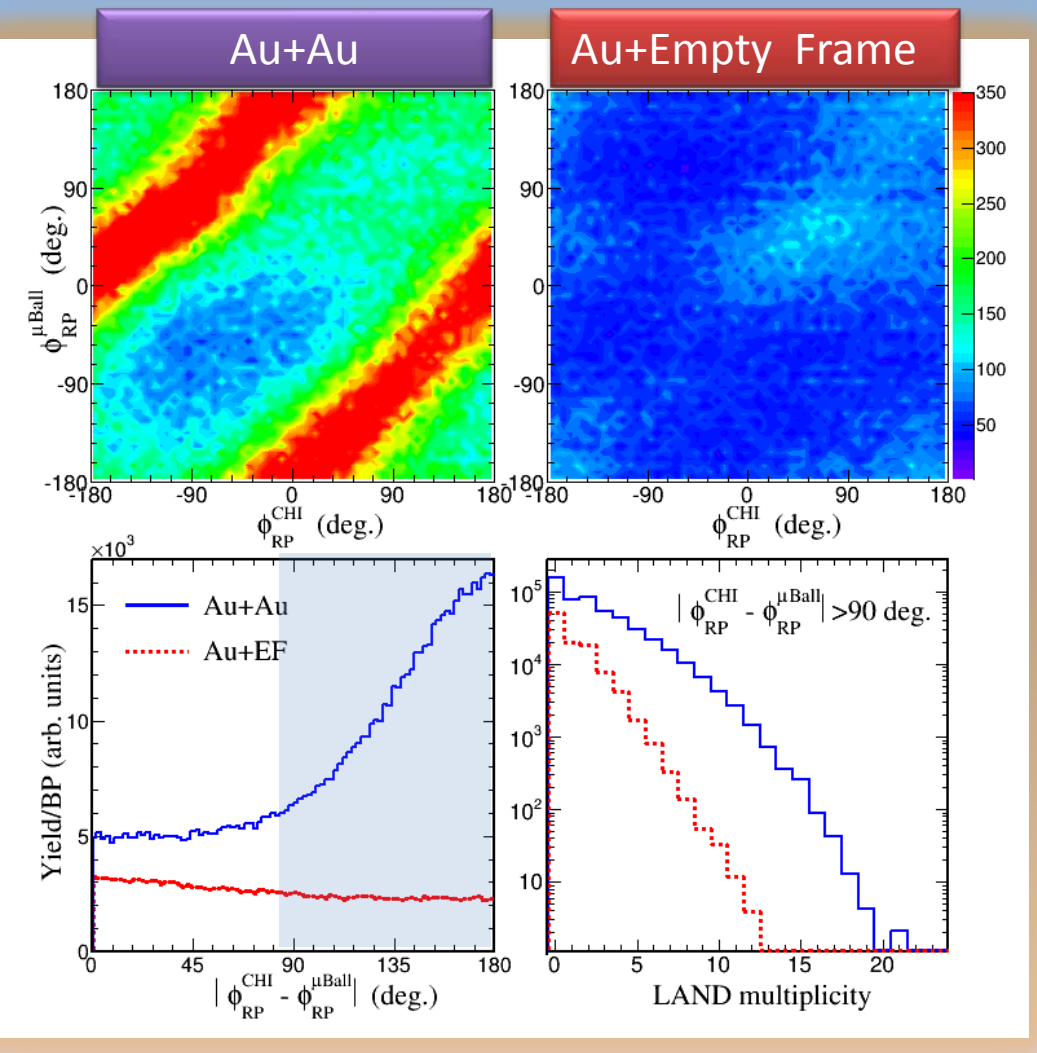
$$w_i = \begin{cases} 1 & \text{for } Y_{cm}>0.1 \\ 0 & \text{for } Y_{cm}<0.1 \end{cases}$$

Q-vector method

P. Danielewicz and G. Odyniek
PLB 157, 146 (1985)

Correlation between reaction plane orientation between CHIMERA and the MicroBall

REACTION PLANE ORIENTATION AND BACKGROUND CORRECTIONS: AN EXAMPLE



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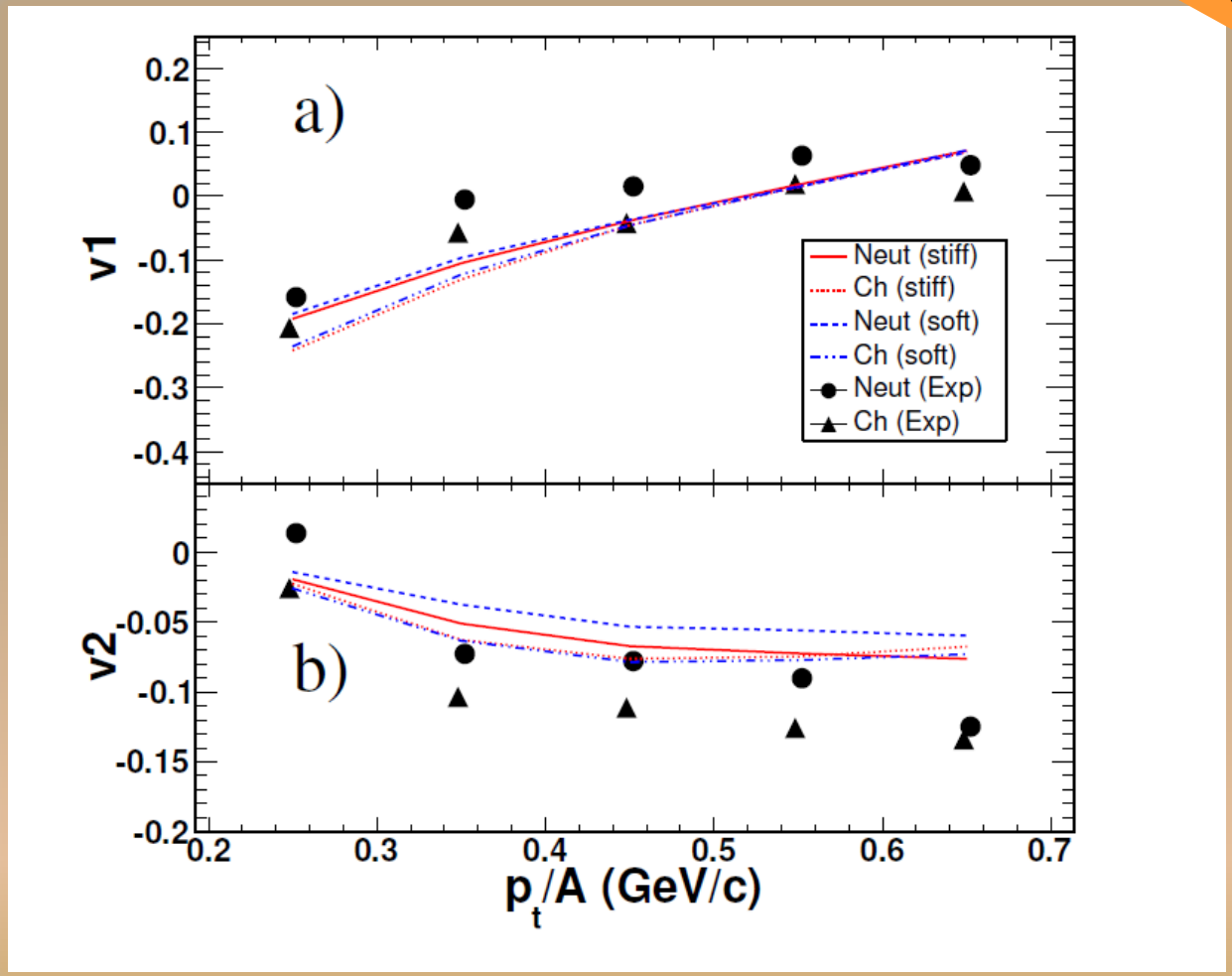
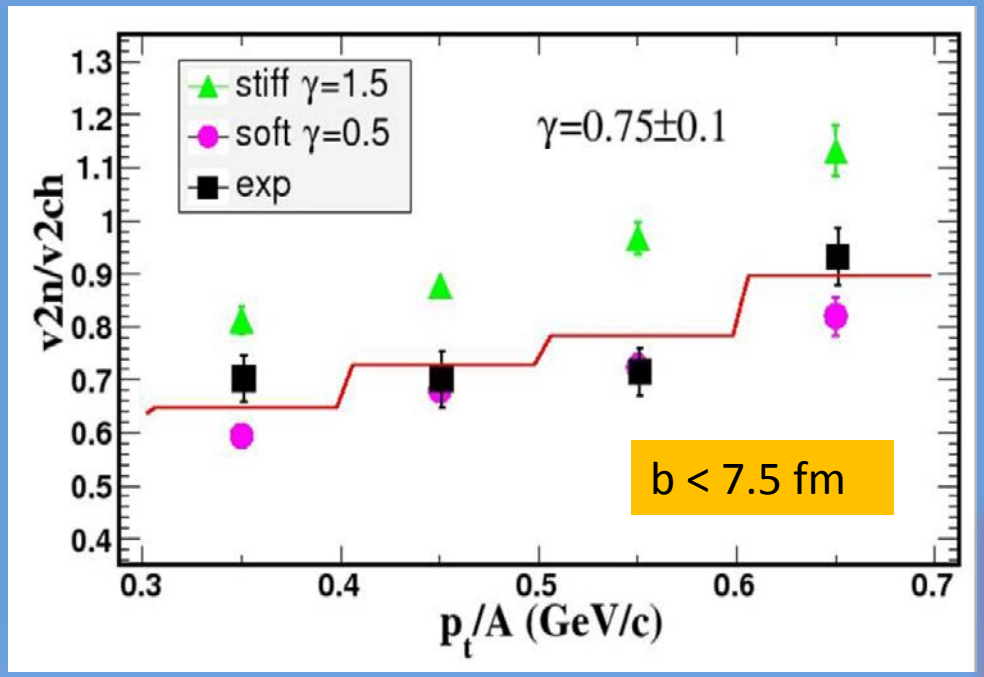
EXPERIMENTAL FLOW PARAMETERS V1 and V2 and UrQMD predictions for neutrons (●)and light carged particles (▲)



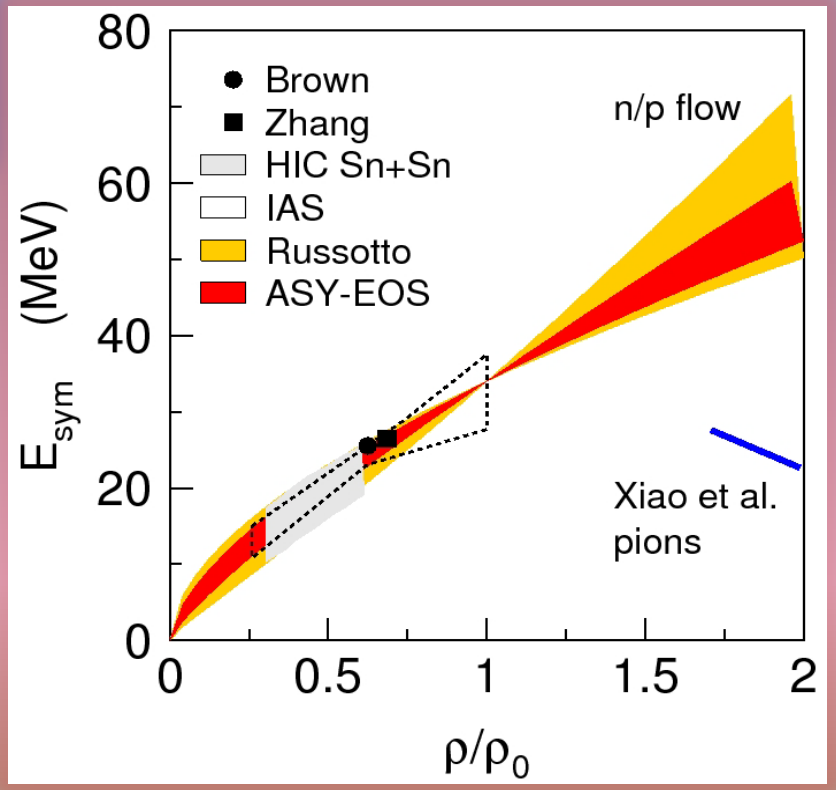
ASYEOS data to be published

Flow ratios of neutrons/Charged particles in comparison with UrQMD predictions



ASYEOS data

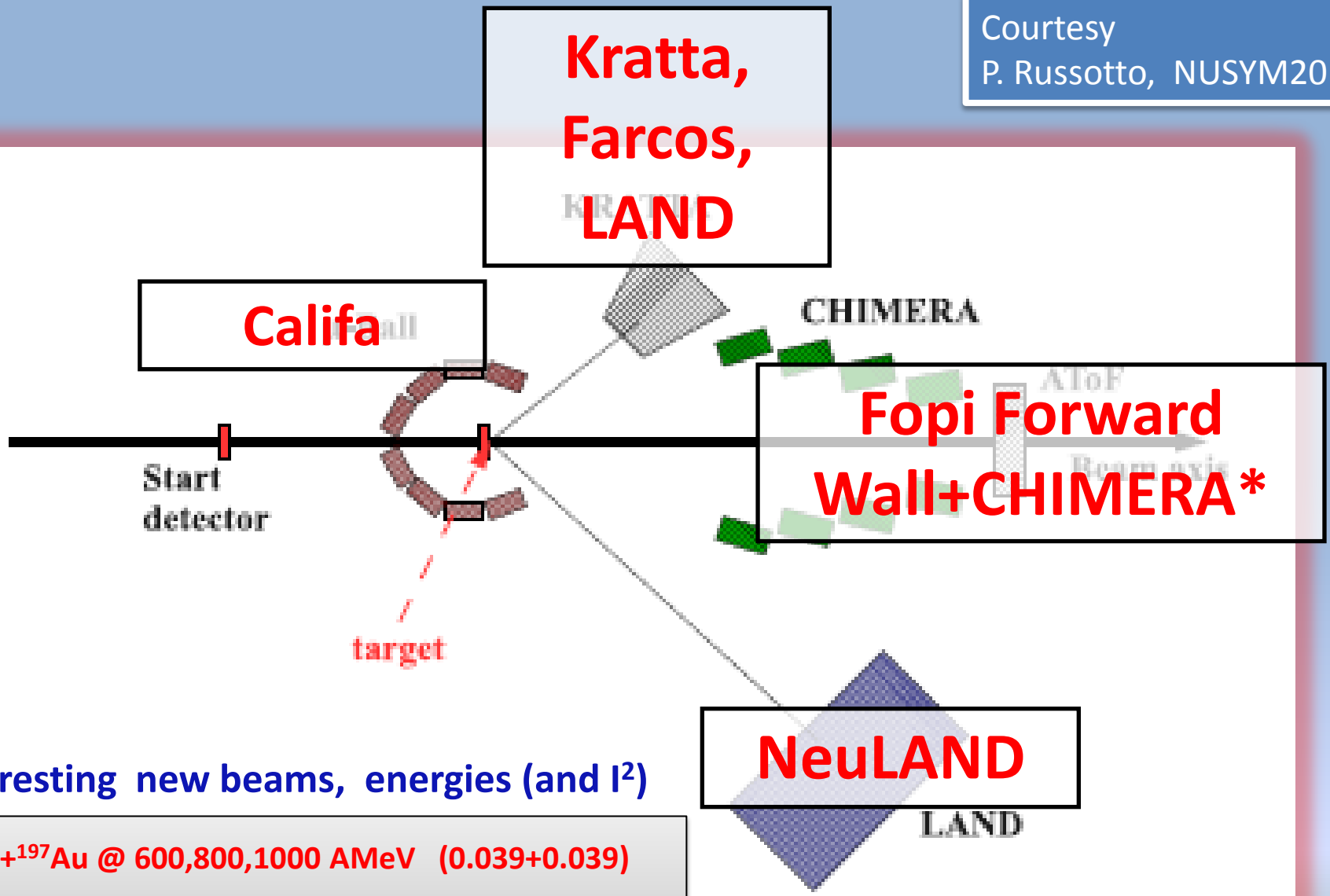
P. Russotto et al.
To be submitted to Phys. Rev. C



HIC: (mainly Sn+Sn . . .)
M.B. Tsang et al., PRC 86, 015803 (2012)
Neutron skin thickness, binding energies,….: *B.A. Brown, PRL 111, 232502 (2013); Zhang and Chen, Phys. Lett. B 726 (2013).*
FOPI DATA : P.Russotto et al., Phys. Lett. B 697 (2011) : $\gamma = 0.9 \pm 0.4$; $L=83\pm26$
ASYEOS DATA: THIS WORK
$\gamma = 0.77\pm 0.17$; $L=75\pm11$

OUTLOOK: PROJECTS FOR FUTURE EXPERIMENTS AT GSI/FAIR

Courtesy
P. Russotto, NUSYM2015



Interesting new beams, energies (and I^2)

$^{197}Au+^{197}Au$ @ 600,800,1000 AMeV (0.039+0.039)

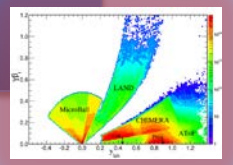
$^{132}Sn+^{124}Sn$ @ 400, 800, 1000 AMeV (0.059+0.037)

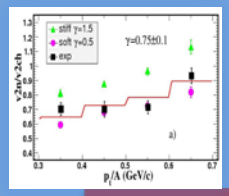
$^{106}Sn+^{112}Sn$ @ 400, 800, 1000 AMeV (0.003+0.011)

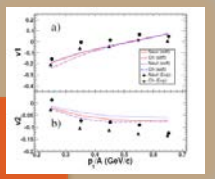
* Ring 1-2-3 (θ<7°)

SUMMARY

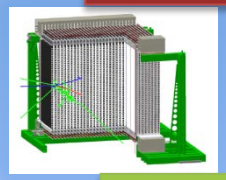
Symmetry energy at high densities has been probed at SIS energies in the S394 experiment .

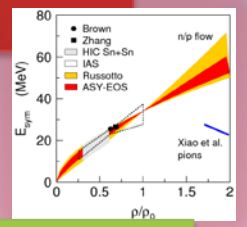






From the comparison of the elliptic flow ratio of neutrons and light charged particles with the UrQMD model the value γ=0.77±0.17 (L=75±11 has been obtained inclusive of statistical and systematic errors





Result of the present experiment are a strong starting point for future experiments to higher energies and other reaction systems by using new generation detectors (as NeuLand), stable beams and future radioactive beams.

THE ASYEOS COLLABORATION

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