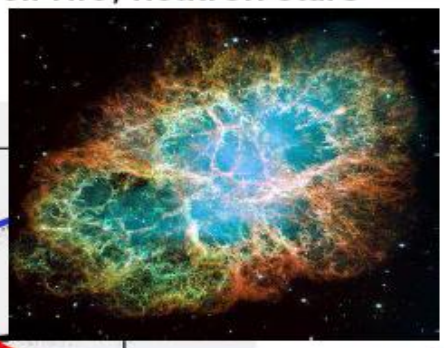
Investigating the asymmetry energy at GSI with the Asy-EOS experiment

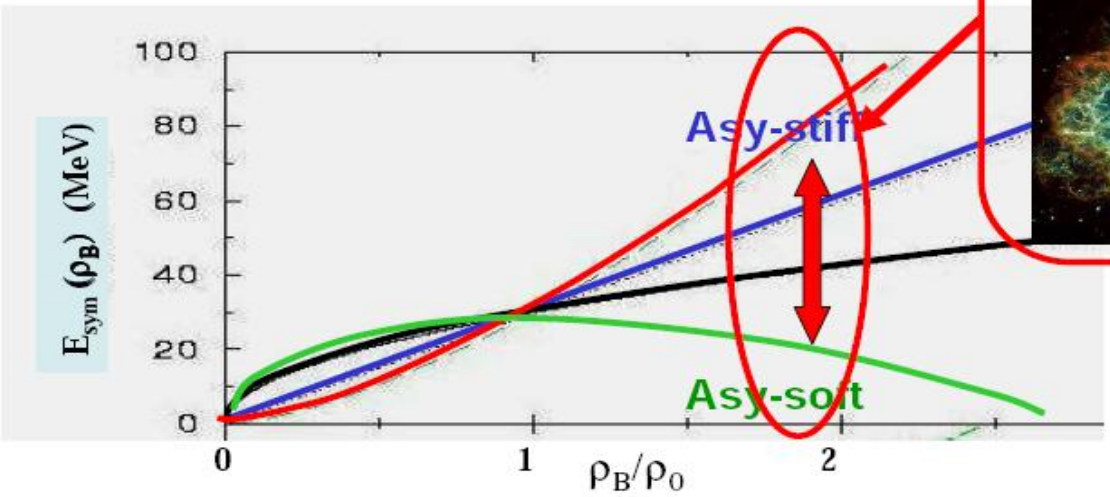
What is the asymmetry energy?

$$E(\rho_B, I)/A = E(\rho_B) + E_{sym}(\rho_B) I^2 + O(I^4) + \ldots$$

$$I = \frac{N-Z}{N+Z}$$

Suprasaturation densities
supernovae, nucleosynthesis
rel. HIC, neutron stars





H.Wolter at ASYEOS2010, Noto

Constraining the Nuclear Symmetry Energy

High density asymmetry energy in relativistic heavy ion collisions

Observable (qualitative):

Pre-equilibrium emission of p, n, light clusters

Particle production, π,K

Au+Au 1 AGeV:
High densities about 2.5 ρ_0

Differential and difference of collective flows

$$\frac{dN}{d\phi}(y, p_t) = 1 + V_1 \cos(\phi) + 2V_2 \cos(2\phi)$$

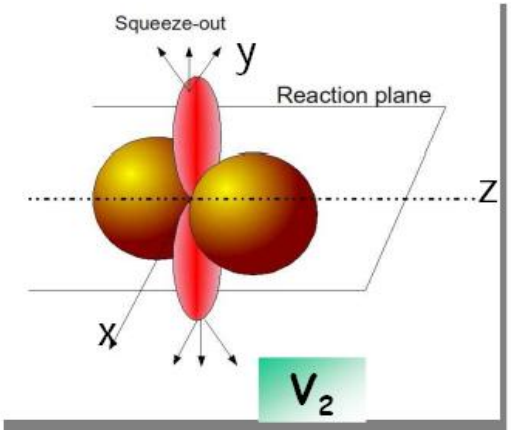
y = rapidity
p_t = transverse momentum

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

Transverse flow: it provides information on the angular distribution in the reaction plane

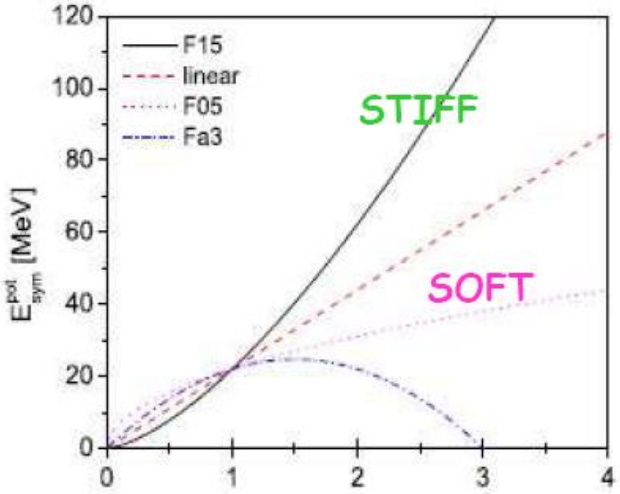
$$V_2(y, p_t) = \left\langle \frac{p_x^2 - p_y^2}{p_t^2} \right\rangle$$

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



Asymmetry energy at supra-saturation densities

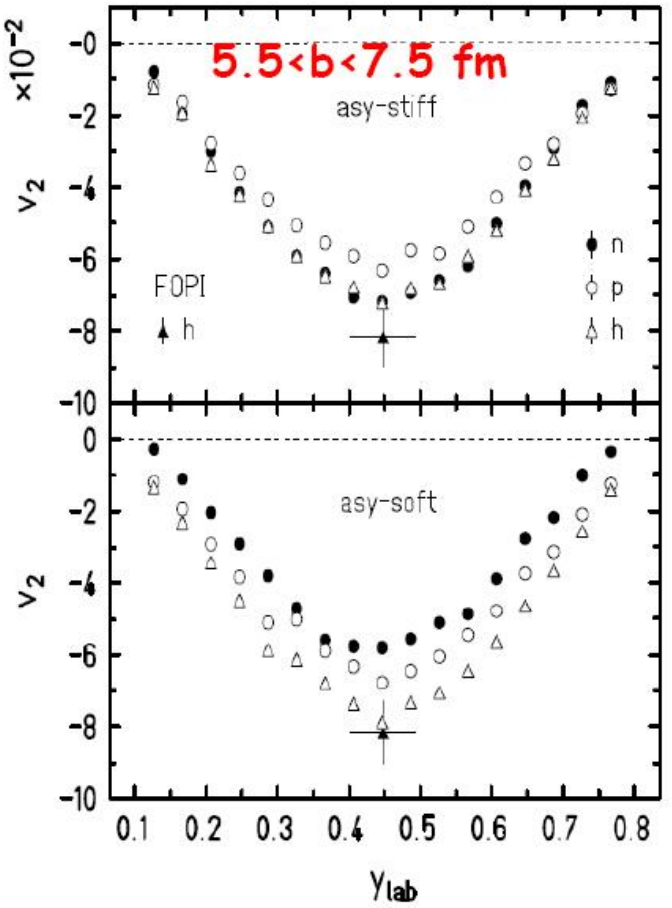
UrQMD model



$$u = \rho/\rho_0$$

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

UrQMD vs. FOPI data:
Au+Au @ 400 A MeV



Qingfeng Li, J. Phys. G31 1359-1374 (2005)
P.Russotto et al., Phys. Lett. B 697 (2011)

The experimental set-up in Cave C at GSI

ASY-EOS experiment carried out May 2011

(possible) 1st phase toward FAIR ???

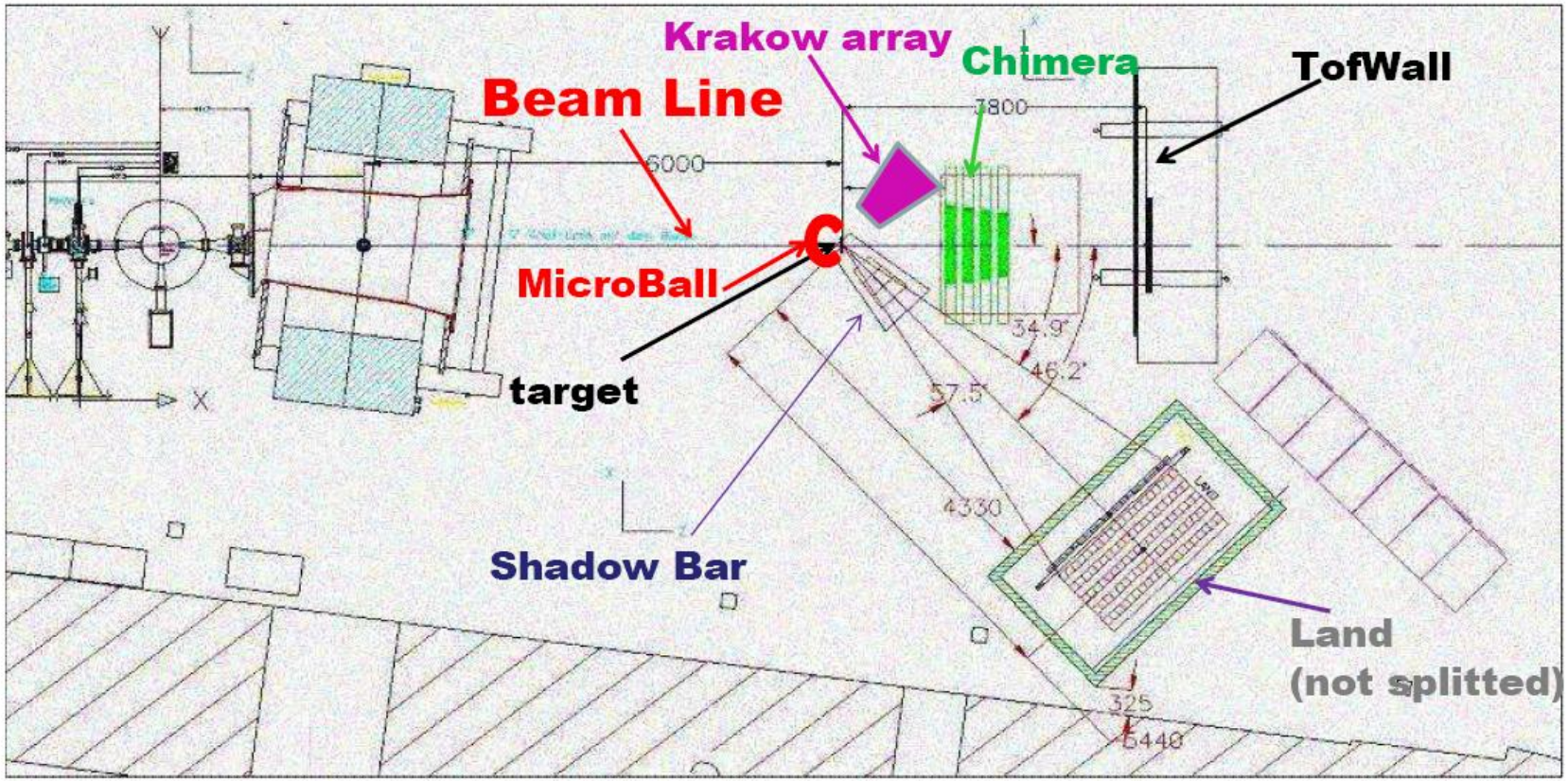
(e.g. ^{132}Sn, ^{106}Sn beams)

Au+Au @ 400 AMeV

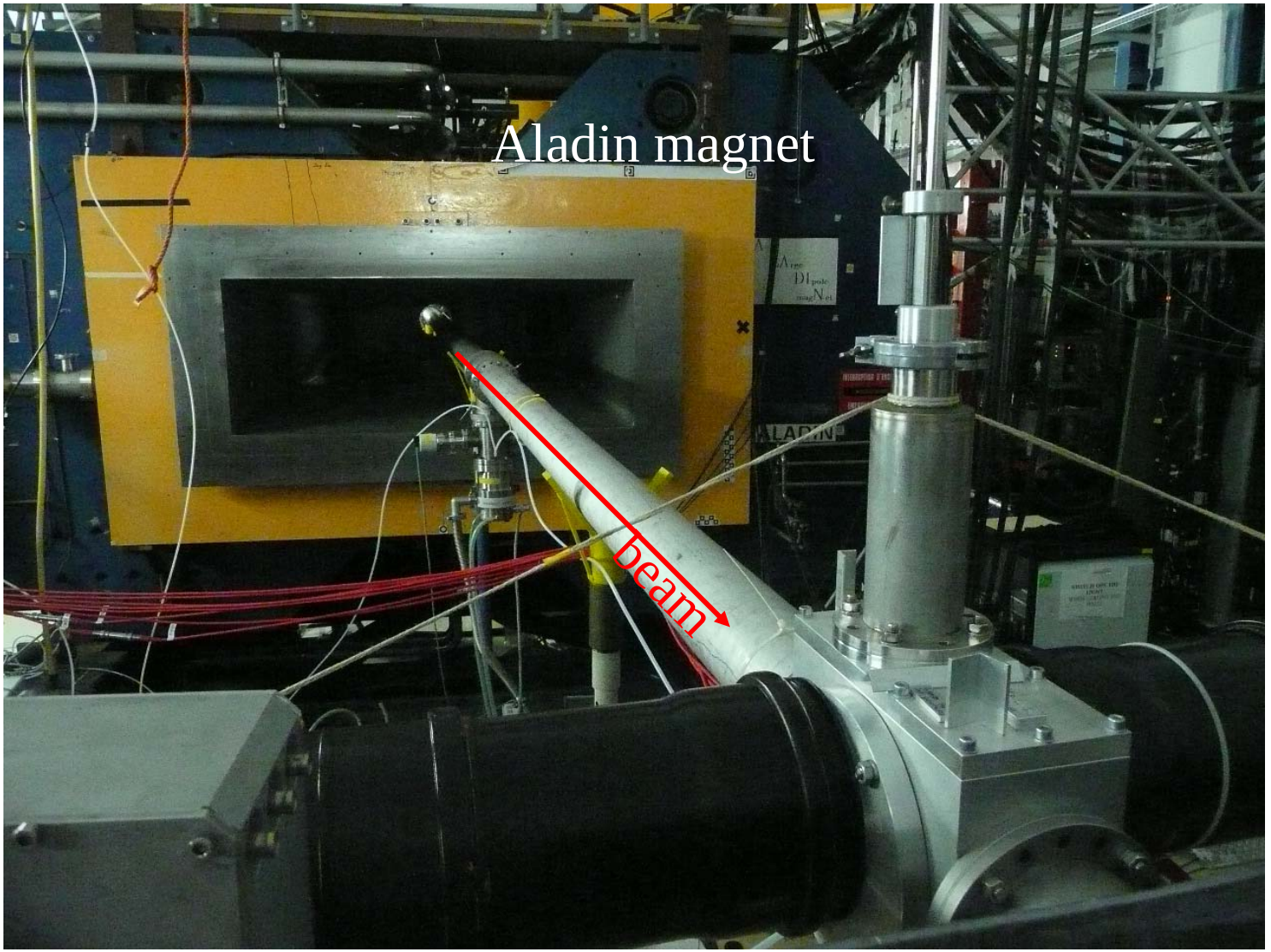
$^{96}Zr+^{96}Zr$ @ 400 AMeV

$^{96}Ru+^{96}Ru$ @ 400 AMeV

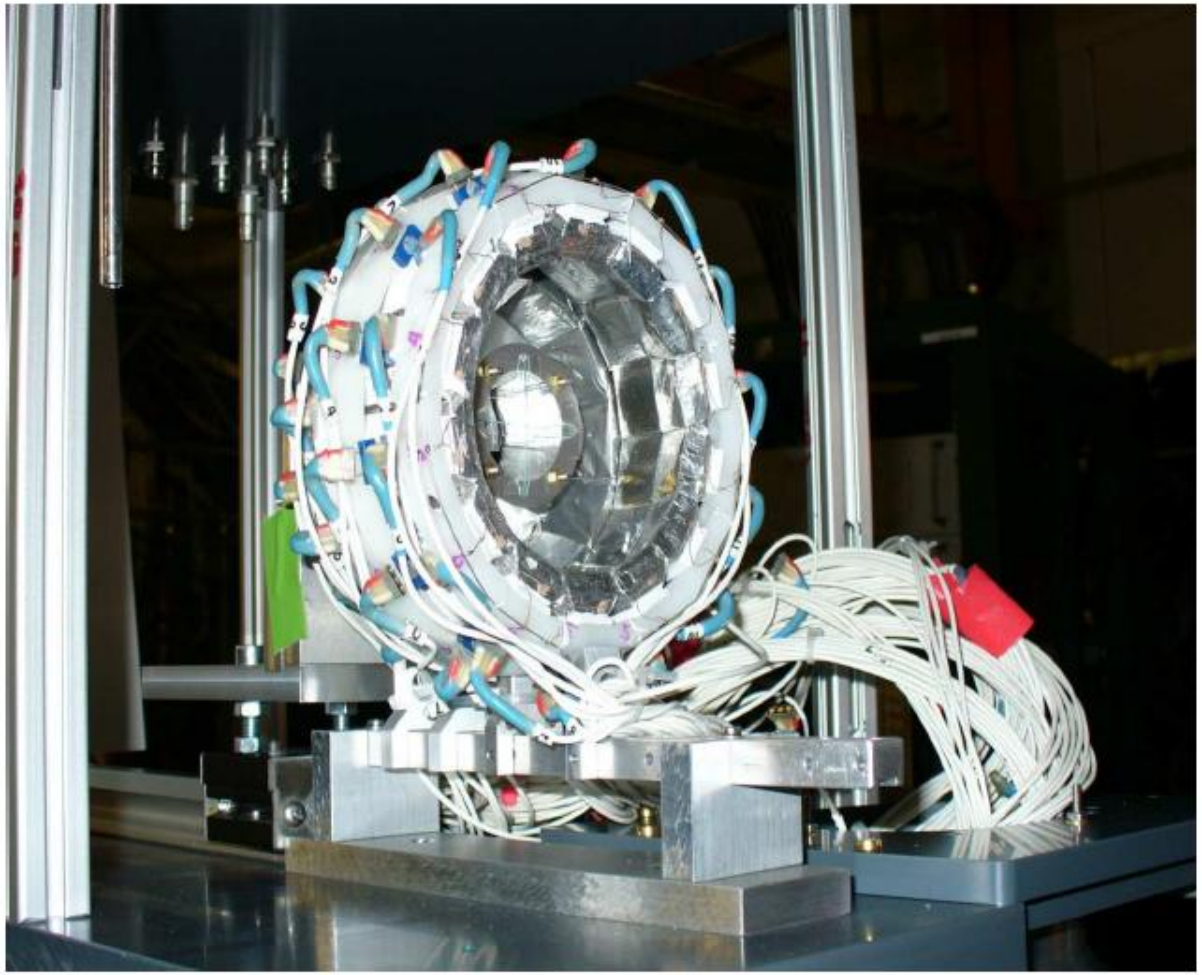
~ $5x10^7$ Events for each system



The experimental set-up in Cave C at GSI



MicroBall



μBall:

4 rings, 50 CsI(Tl)

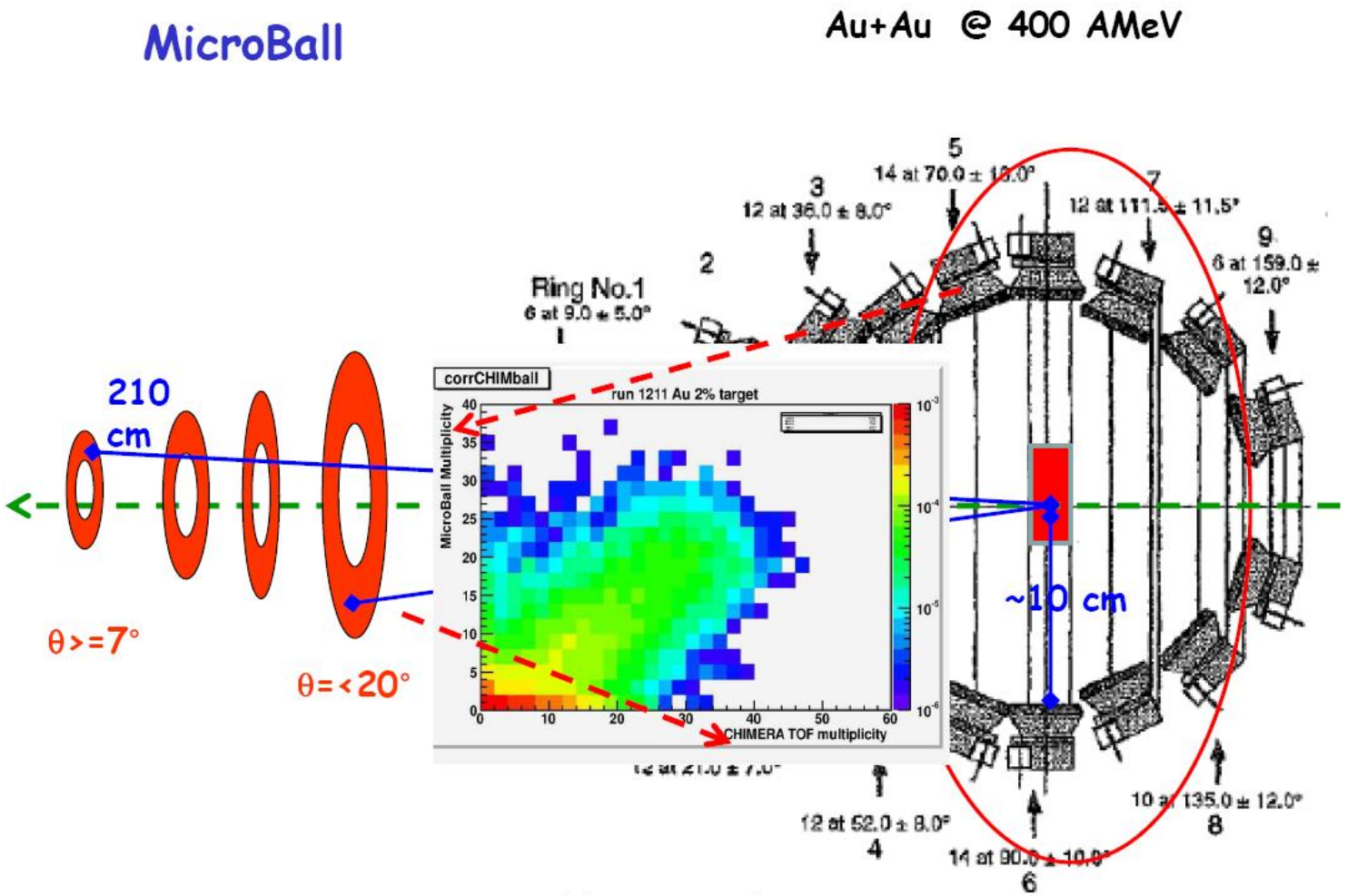
~ 1 cm thick

$60° < \theta < 147°$.

Discriminate target vs. air interactions (backward angles).

Multiplicity measurements.

MicroBall

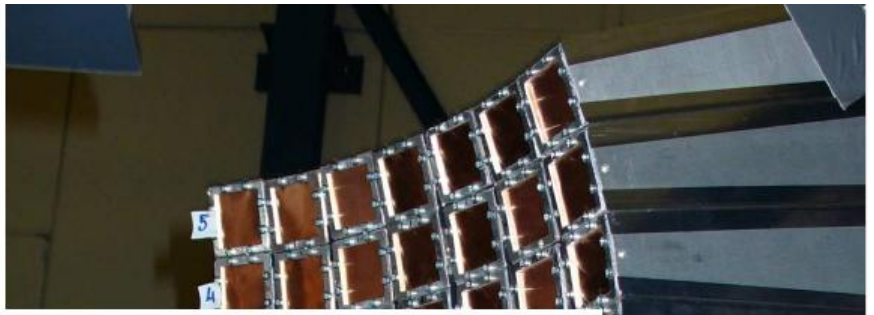


Not in scale
CHIMERA: MicroBall ~ 10:1

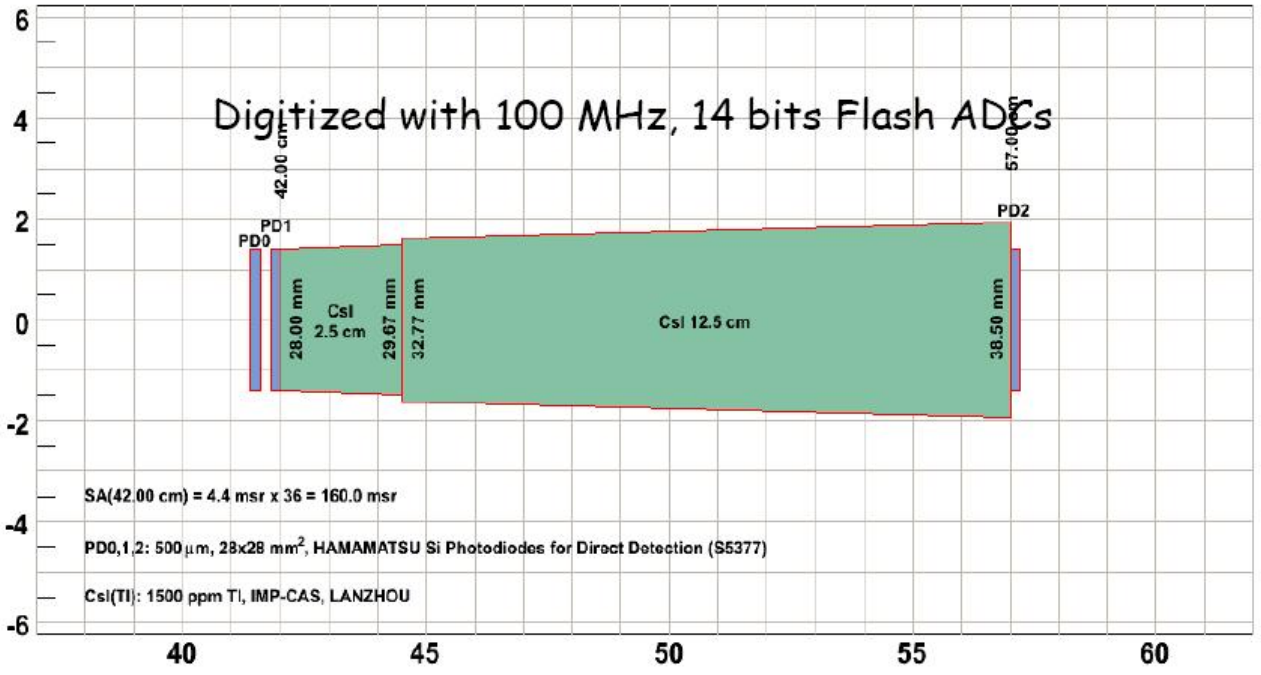
Krakow Array

Krakow Array

35 modules (5 x7), 20.7°<θ<63.5°
Distance from the target: 40 cm.
Light particles and IMFs emitted at midrapidity

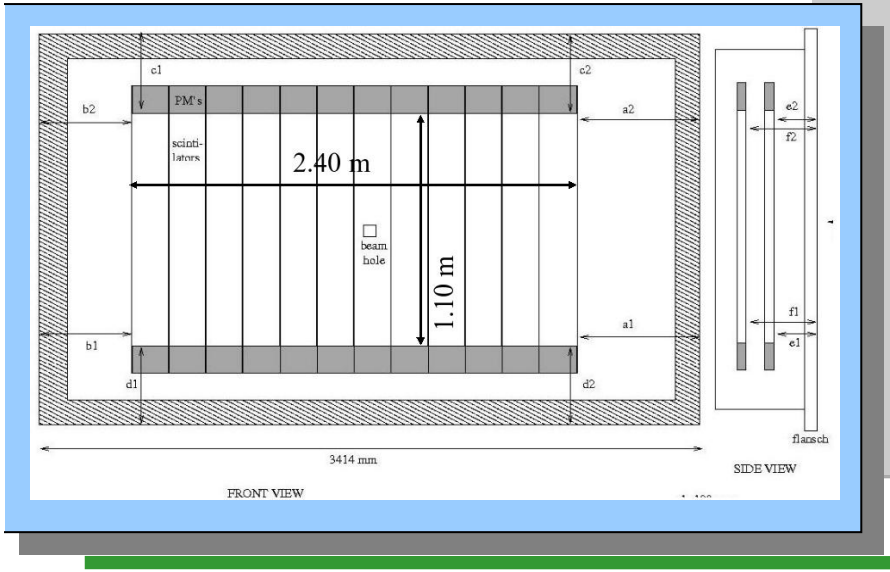


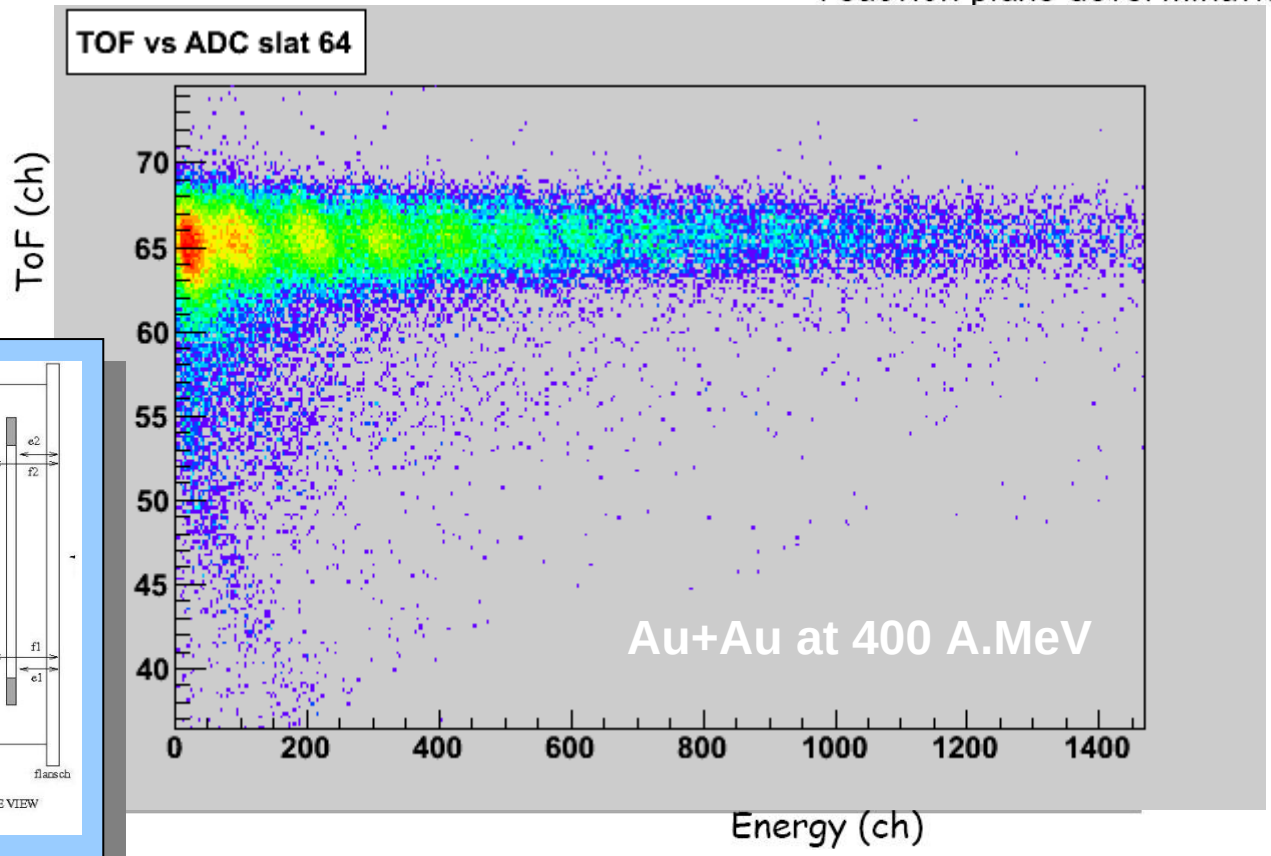
TRIPLE TELESCOPE



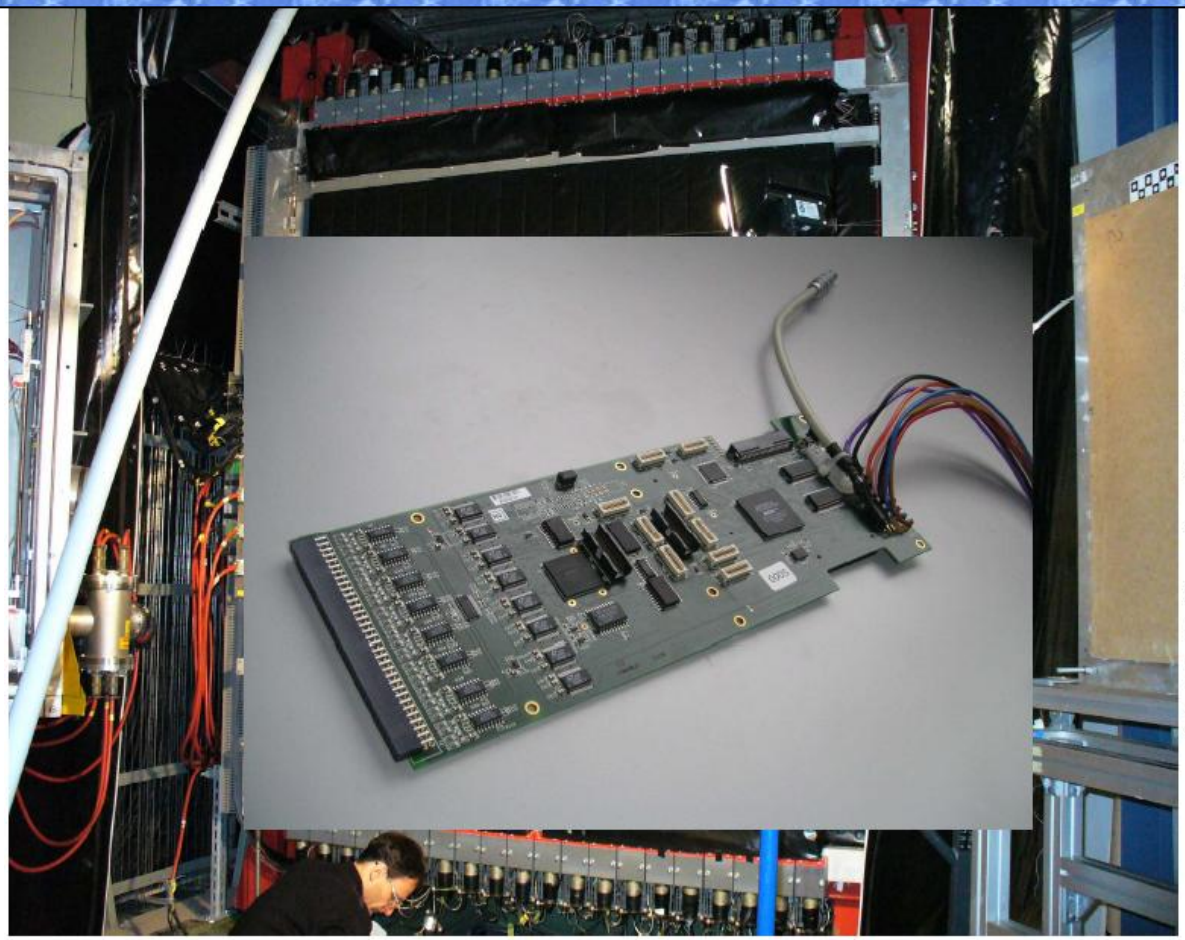
AlaDiN Time-Of-Flight Wall

96 plastic bars 2.5X 100 cm
2 walls (front and rear) $\theta < 7^\circ$
Z, velocity & X-Y position.
Impact parameter and
reaction plane determination





Large Area Neutron Detector (LAND)



new TACQUILA electronic

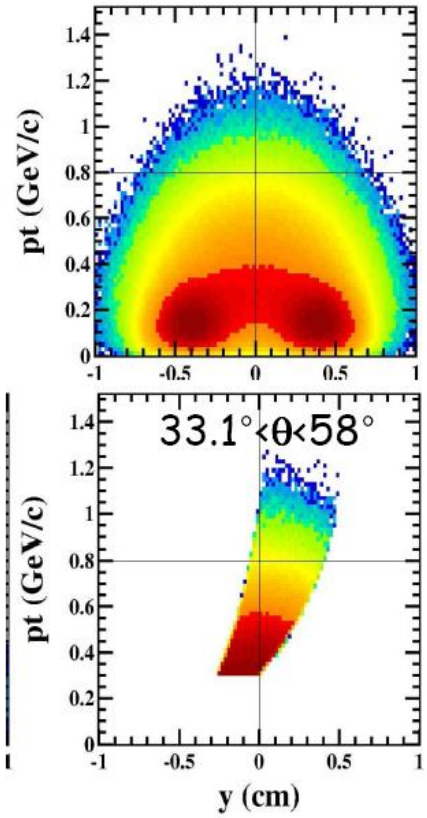
A compact electronics for time measurements with very high resolution ~ 10ps RMS.
Developed for the FoPi TOF-upgrade.
The PCB consists of 16 channels based on the TAC GSI-ASIC.
Optional with amplitude measurement card (QDC).

Neutrons and Hydrogen detection.
Flow measurements

Th.Blaich et al.,NIM A314 (1992)

Large Area Neutron Detector (LAND)

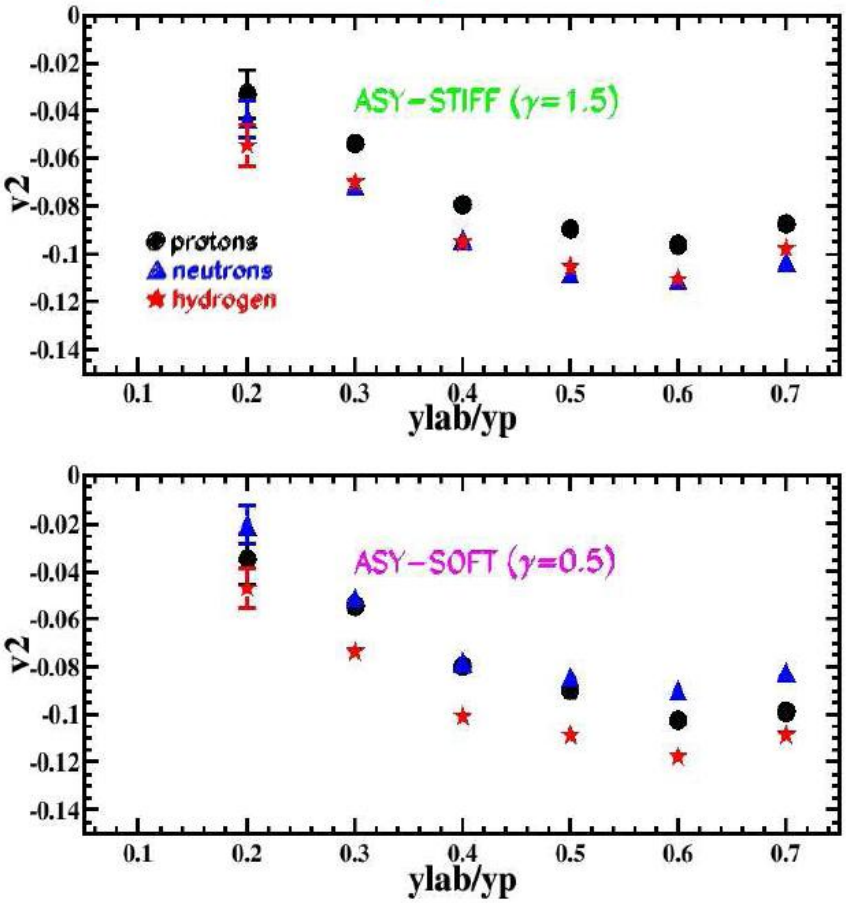
ASYEOS exp: "better" coverage of mid-rapidity



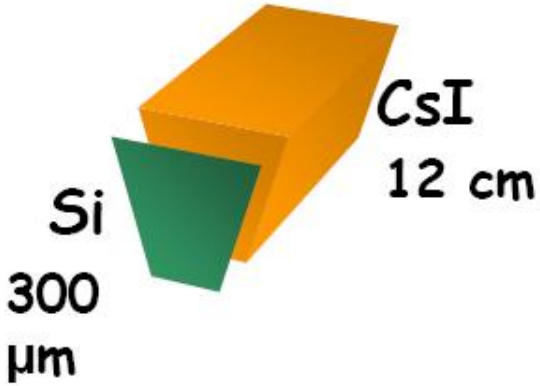
Au+Au @ 400 AMeV

b=5.5-7.5 fm

UrQMD simulations



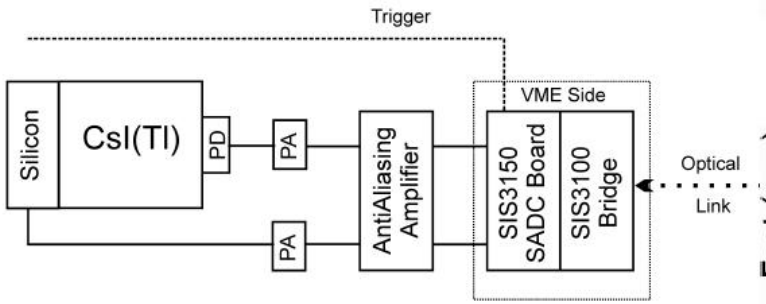
CHIMERA



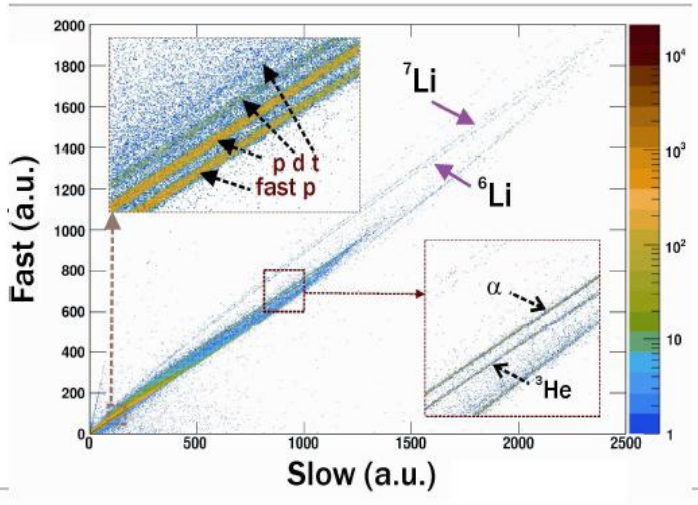
8 Rings
$7° < \theta < 20°$
352 CsI
32 Si

CHIMERA

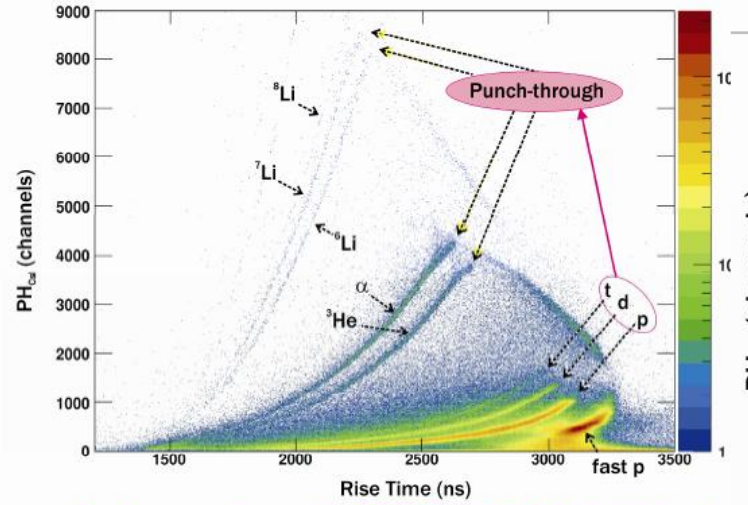
Digital ACQ 100 MHz, 14 bits resolution SADC

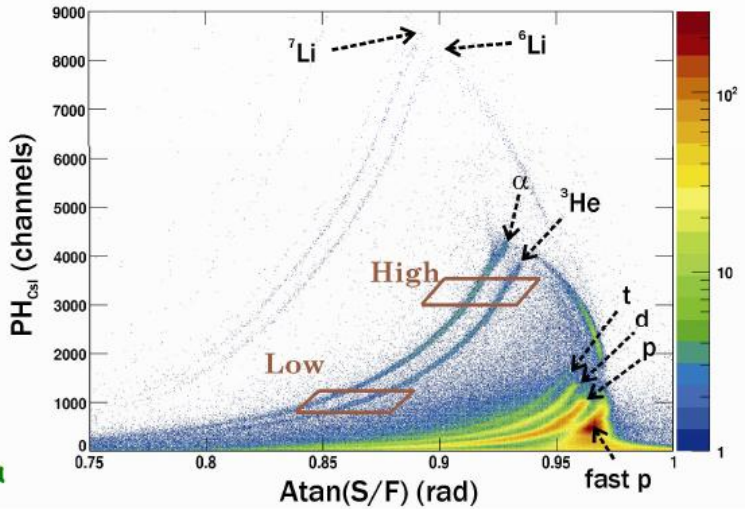


$^{96}Zr+^{96}Zr$ at 400 A.MeV



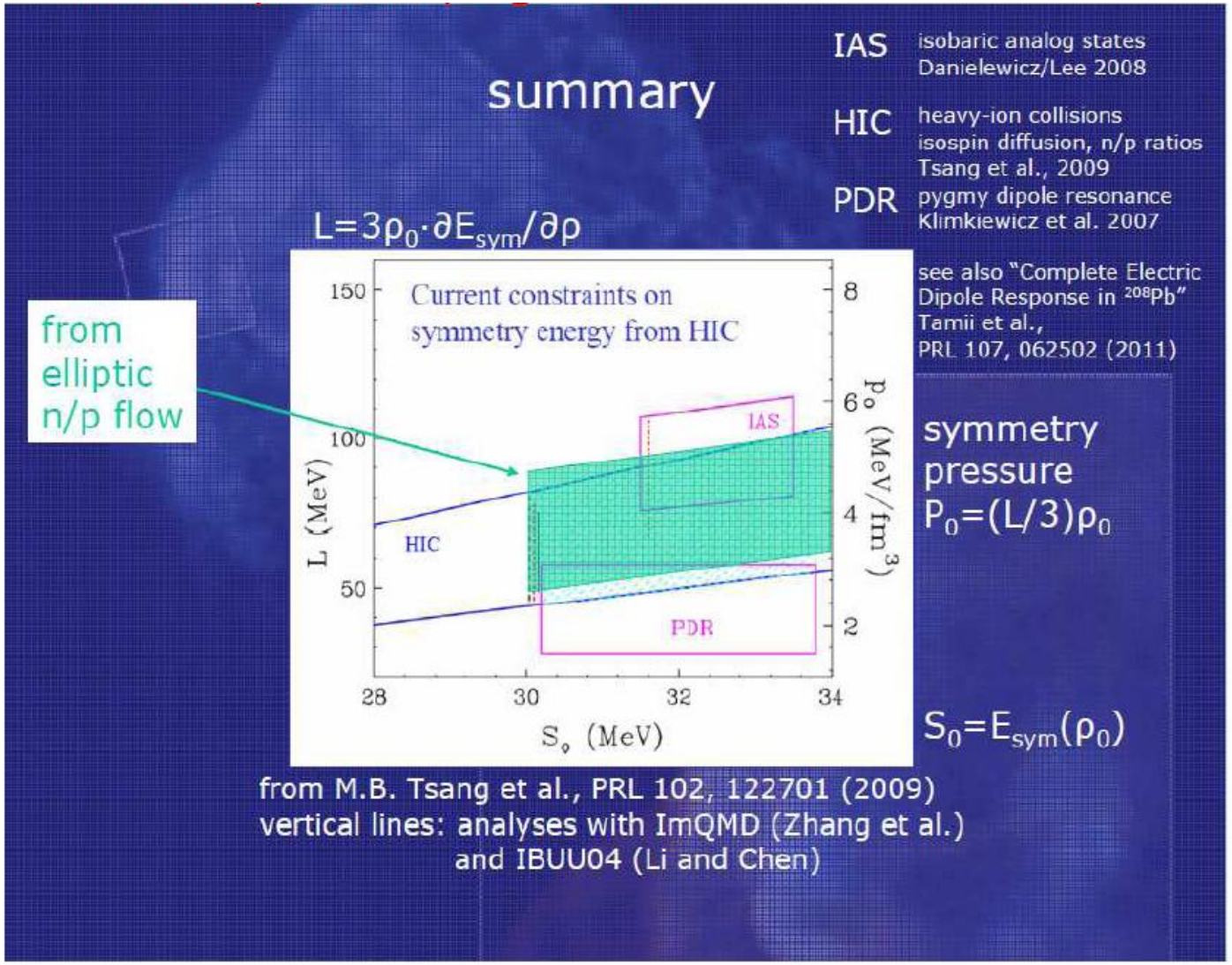
pulse height





C. Guazzoni et al.,IEEE-NSS 2011 Valencia

Conclusion



- CHIMERA worked "well" at GSI: reaction plane determination and impact parameter selection.
- The analysis is in progress.

W. Trautmann
talk at NUFRA2011
http://fias.uni-frankfurt.de/nufra2011/