CHIMERA at GSI

The ASY-EOS Project 2005-2025+

dedicated to the memory of Angelo Pagano

W. Trautmann
GSI Helmholtzzentrum Darmstadt

FATA2025
8. - 10. October 2025
Catania

FOPI Days in Split, Croatia, 26th-28th May 2005

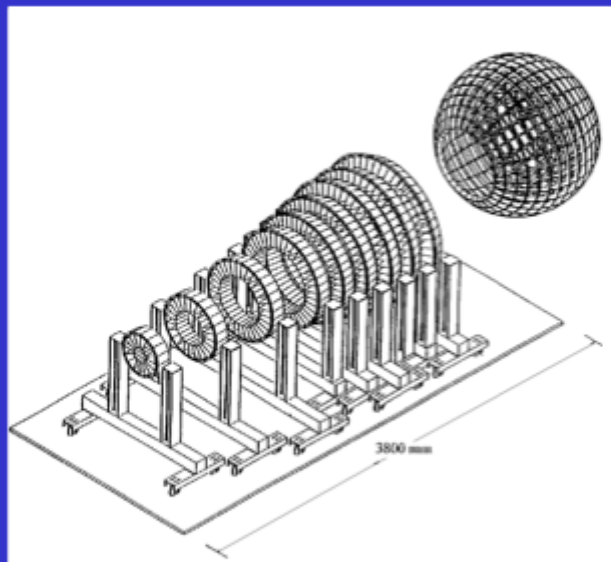
Friday, 27th May, 9:00-12:30 --- **Isospin physics, stopping and flow**

09:00 W. Reisdorf, GSI	Pion physics
09:30 Bao-An Li, Arkansas	Determining the **symmetry energy** at high densities with relativistic HIC
10:00 Massimo Di Toro, Catania	**Nuclear EOS** at high baryon and isospin density: sensitive observables
10:30-11:00 Coffee break	
11:00 Herrmann H. Wolter, Munich	**Symmetry energy**: flow, pion production and isospin transport
11:30 Marcello Baldo, Catania	The **nuclear equation of state** from low density to just above saturation
12:00 W. Trautmann, GSI	**Symmetry energy** and recent ALADIN results

earlier FOPI + LAND data on neutron flow mentioned in the discussion …

IWM 2005 in Catania November 29 – December 1st
slide shown during discussion session:

Information needed on impact parameter orientation and modulus



program:

1) theor. predictions for neutron rich AND poor systems

2) feasibility study (targets, geometry, count rates, background (GEANT), financing

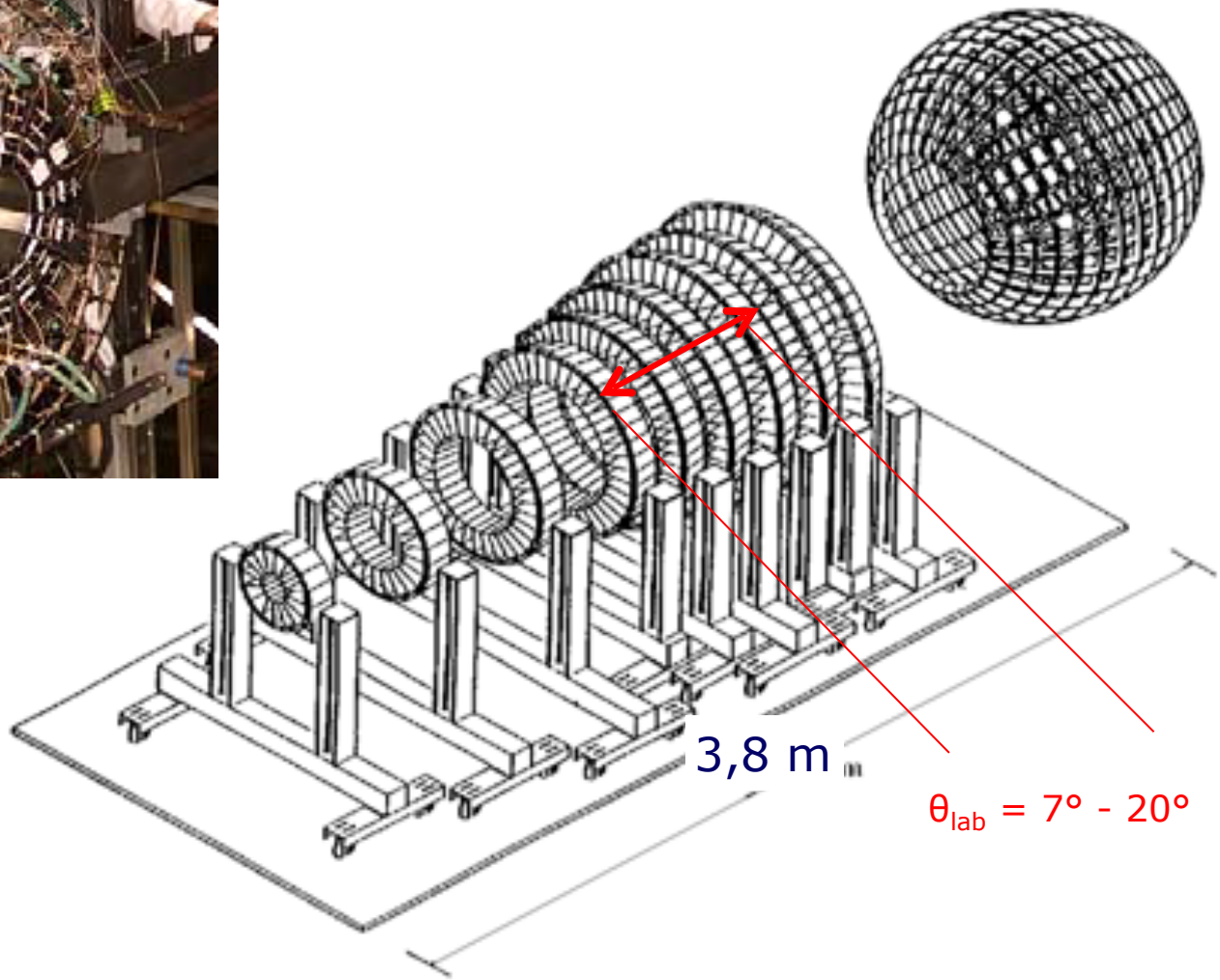
3) get attention of FOPI, LAND, work within NUSTAR/R3B

CHIMERA + LAND

CHIMERA – GSI Workshop Dec 2006
"Symmetry Energy in Nuclear Reactions"

4 double rings
of CHIMERA,
352 modules

➡ GSI ?

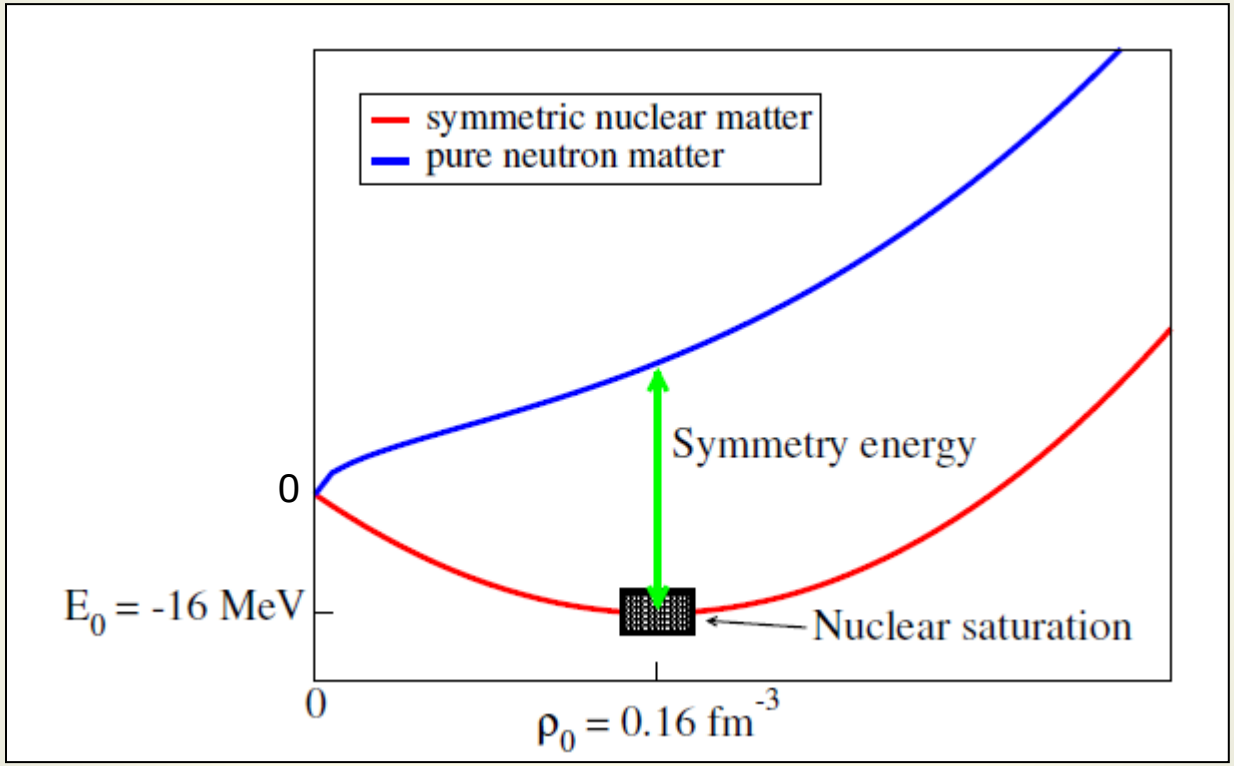


on CHIMERA:
Pagano+,
Nucl. Phys. A 734,
504 (2004)

Nuclear Equation of State (EoS)

asymmetry $\delta = (\rho_n - \rho_p)/\rho$

Stefano Gandolfi

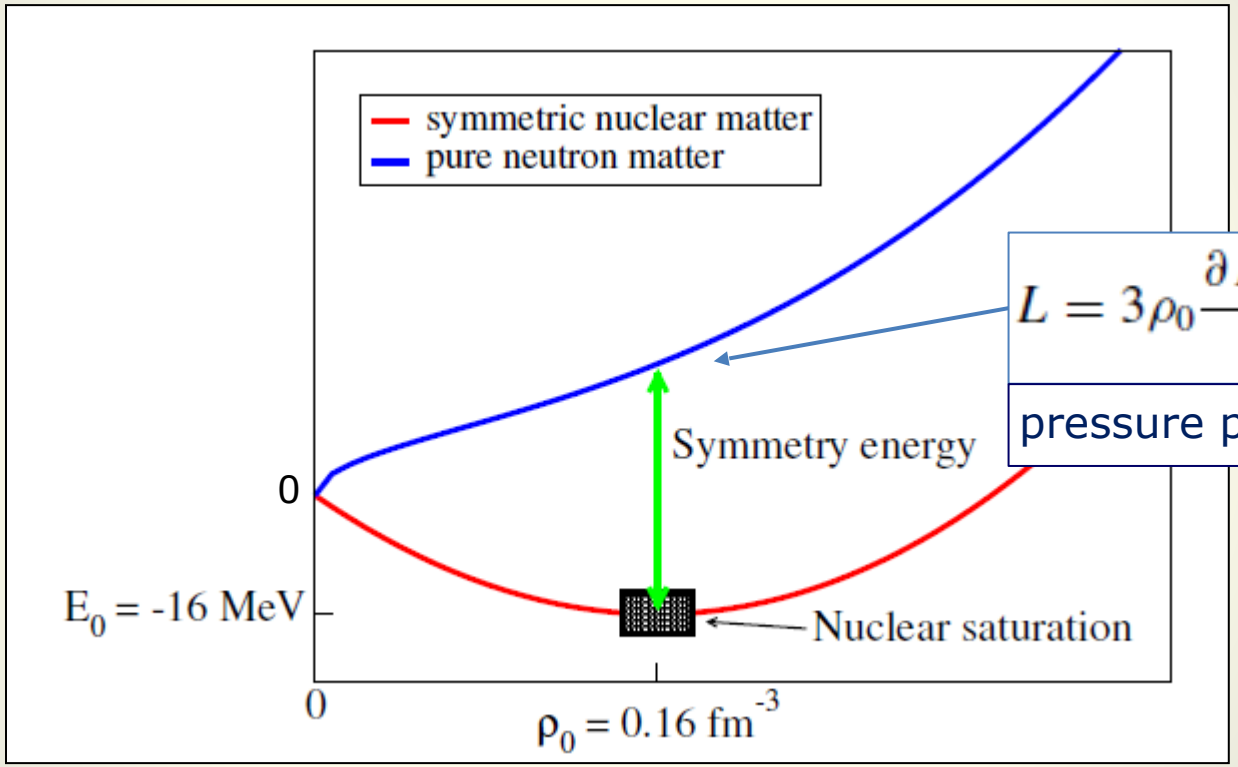


$E_A(\rho,\delta) = E_A(\rho,0) + \mathbf{E_{sym}(\rho) \cdot \delta^2} + O(\delta^4)$

Nuclear Equation of State (EoS)

asymmetry $\delta = (\rho_n - \rho_p)/\rho$

Stefano Gandolfi



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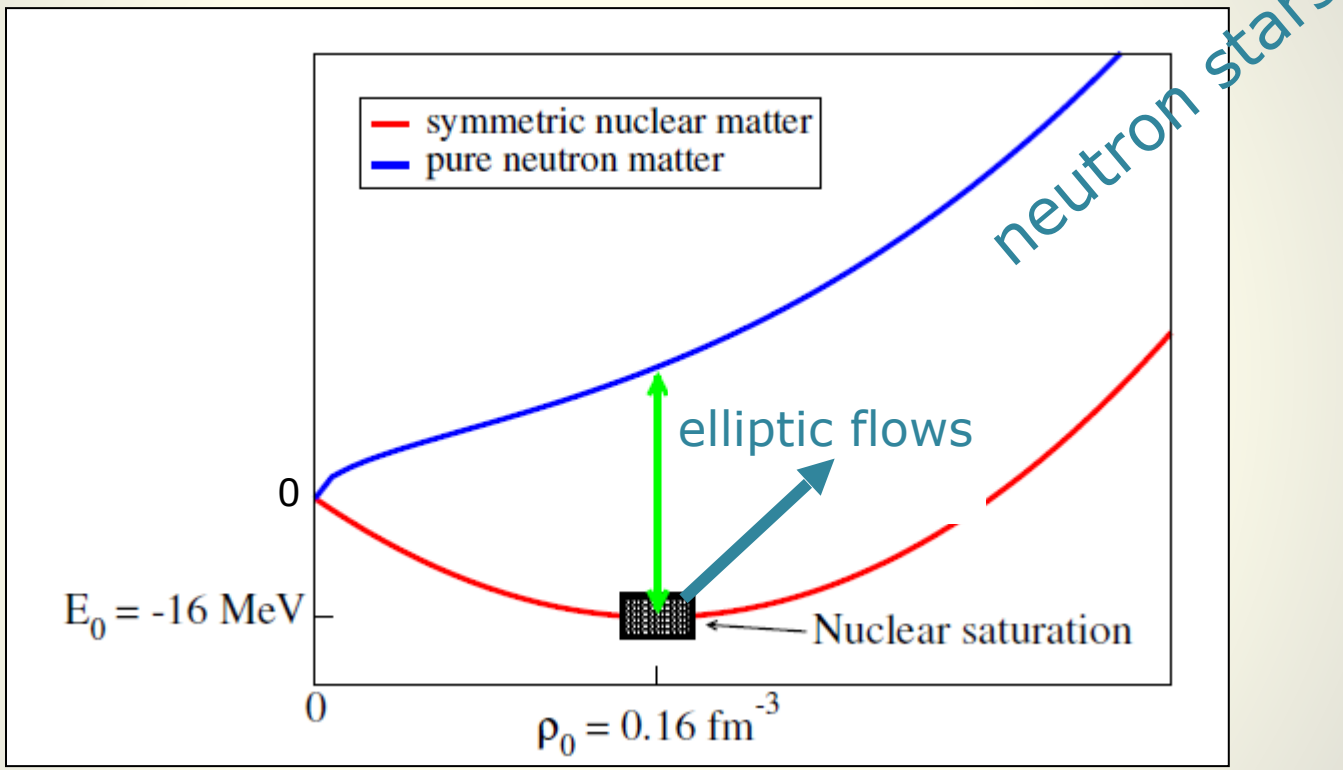
Nuclear Equation of State (EoS)

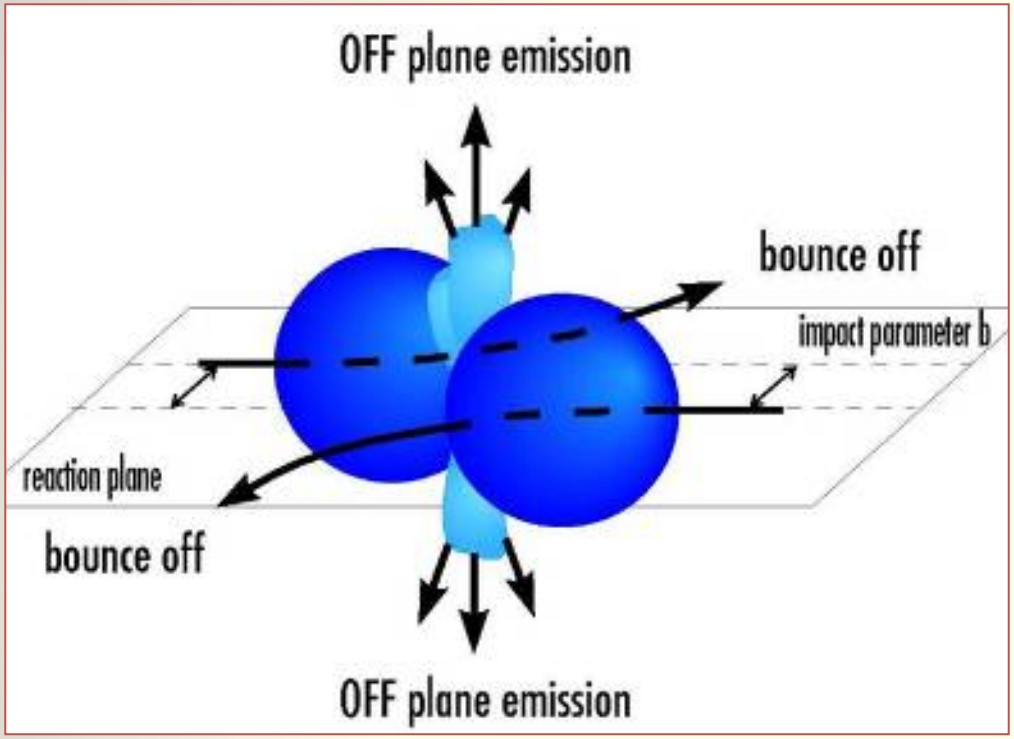
asymmetry $\delta = (\rho_n - \rho_p)/\rho$



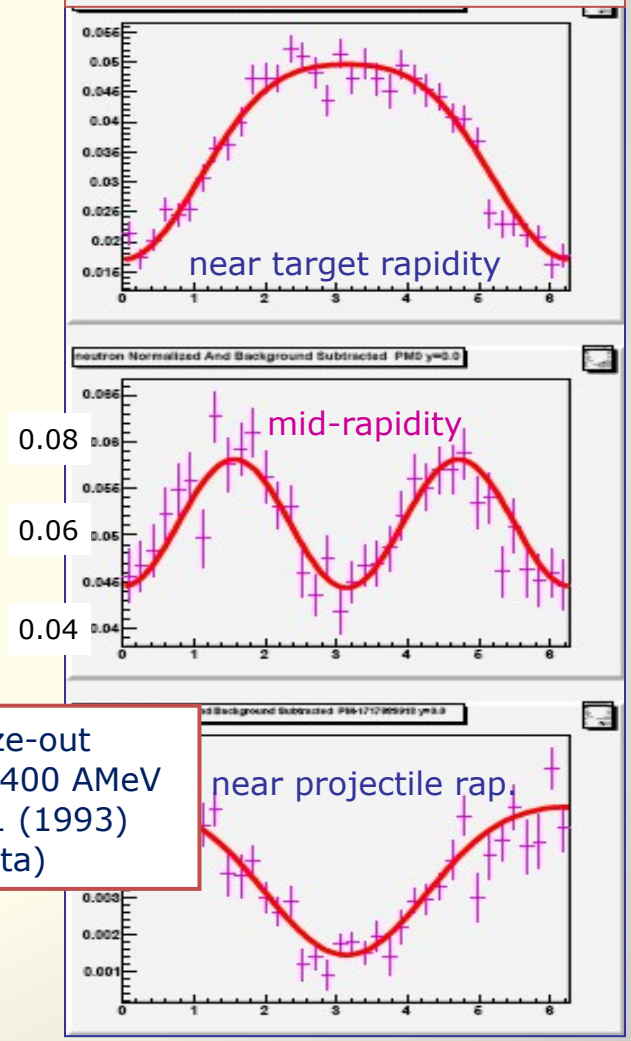
$E_A(\rho,\delta) = E_A(\rho,0) + \mathbf{E_{sym}(\rho) \cdot \delta^2} + O(\delta^4)$

elliptic flow: a pressure gauge for nuclear matter

Buchwald/Frankfurt



neutrons, azimuthal.distr.
fit with Fourier expansion



used for EoS:
SNM: FOPI, AGS, BNL
Le Fèvre+ NPA 945, 112 (2016)

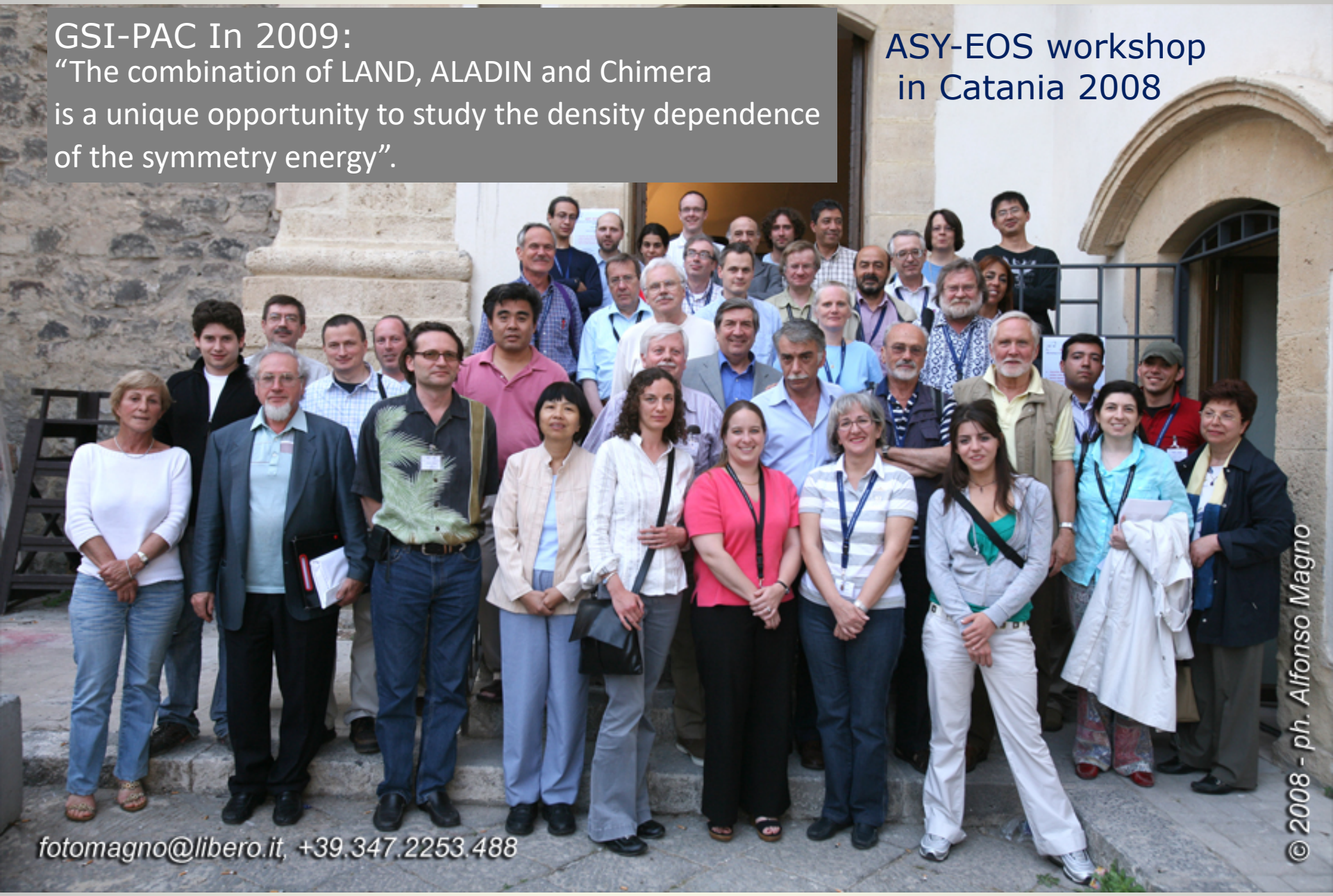
PNM: FOPI-LAND, ASY-EOS
Russotto+ PRC 94, 034608 (2016)

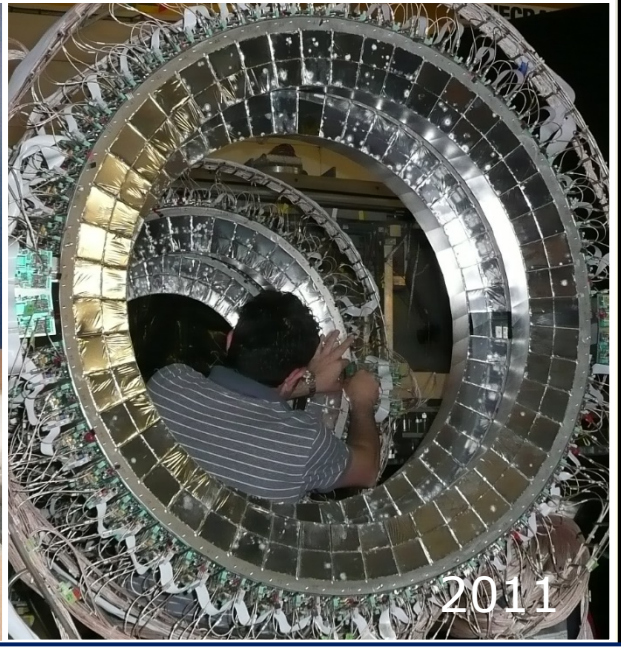
neutron squeeze-out
for Au + Au @ 400 AMeV
Leifels+ PRL 71 (1993)
(FOPI-LAND data)

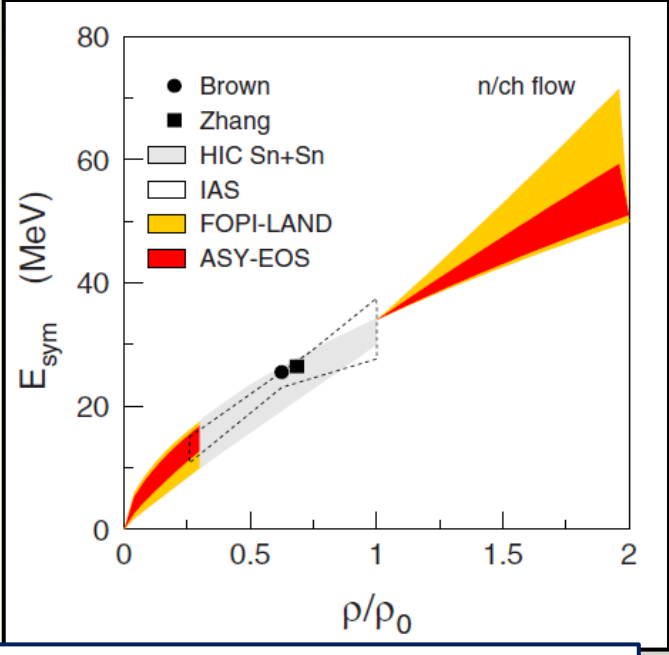

ASY-EOS workshop
in Catania 2008
fotomagno@libero.it, +39.347.2253.488
© 2008 - ph. Alfonso Magno

GSI-PAC In 2009:

"The combination of LAND, ALADIN and Chimera is a unique opportunity to study the density dependence of the symmetry energy".







93 authors:

PHYSICAL REVIEW C **94**, 034608 (2016)

Results of the ASY-EOS experiment at GSI: The symmetry energy at suprasaturation density

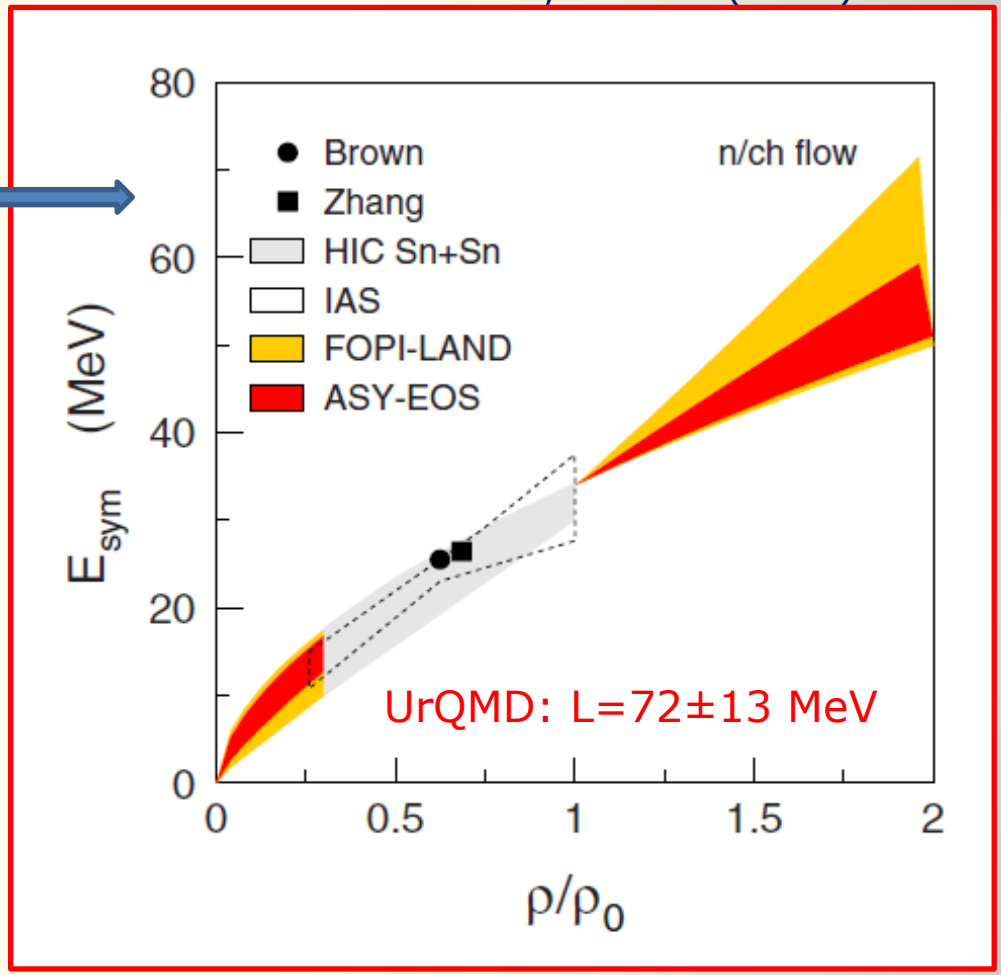
P. Russotto,[1] S. Gannon,[2] S. Kupny,[3] P. Lasko,[3] L. Acosta,[4,5] M. Adamczyk,[3] A. Al-Ajlan,[6] M. Al-Garawi,[7] S. Al-Homaidhi,[6] F. Amorini,[4] L. Auditore,[8,9] T. Aumann,[10,11] Y. Ayyad,[12] Z. Basrak,[13] J. Benlliure,[12] M. Boisjoli,[14] K. Boretzky,[11]

ASY-EOS: neutron vs charged-particle elliptic-flow ratios

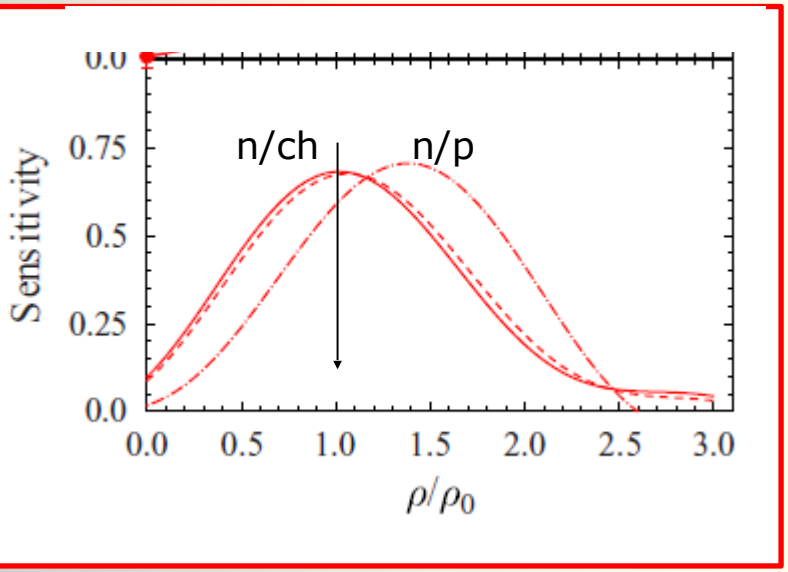
Au+Au @ 400

compiled by
Horowitz+
JPhysG (2014)

P. Russotto+ PRC 94, 034608 (2016)

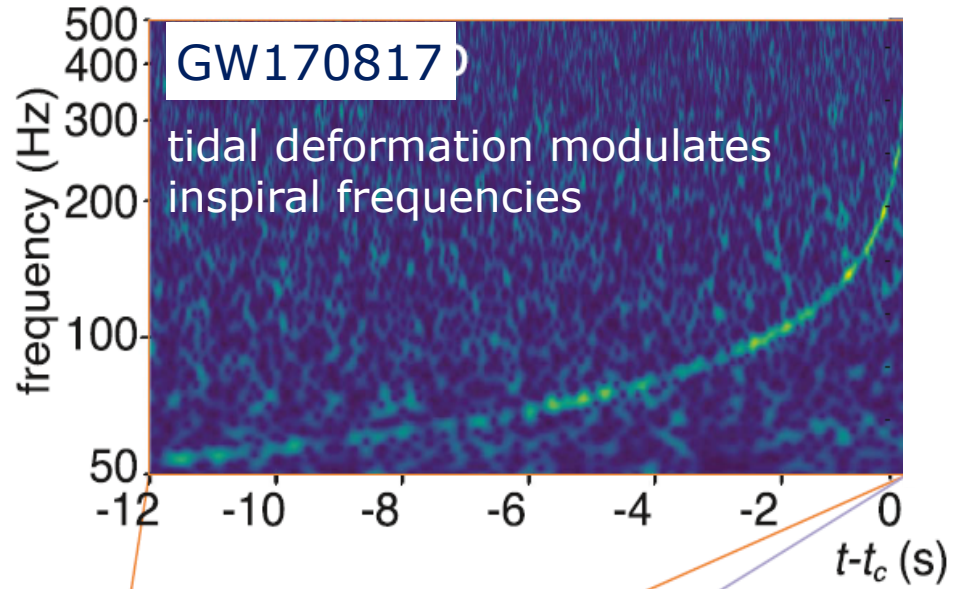


sensitivity to density



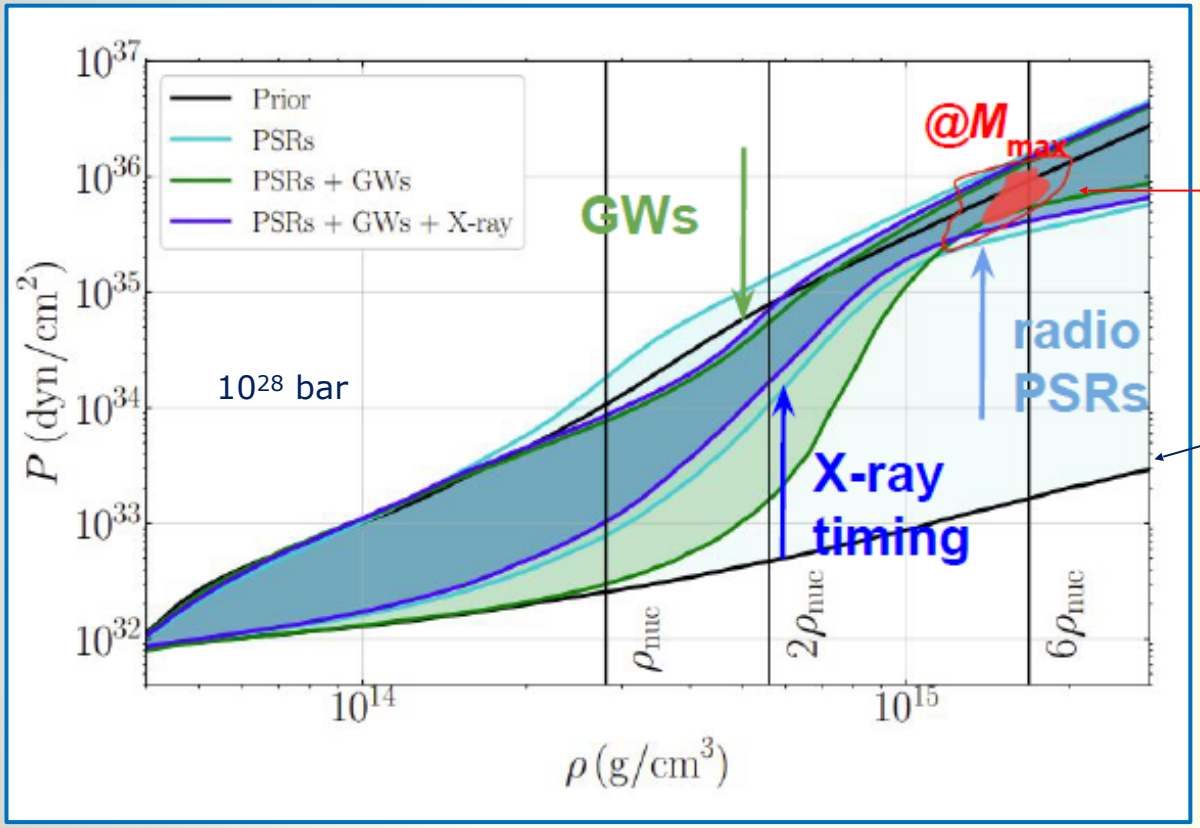
density probed extends to 2.5 ρ_0
maximum near **saturation density**

$E_{sym}(\rho_0)$ = 34 MeV => L= 72±13 MeV
$E_{sym}(\rho_0)$ = 31 MeV => L= 63±11 MeV



B.P. Abbott et al., LIGO and Virgo Collab.
The Astrophys. J. Letters, 848:L12 (2017)

Reed Essick at NuSym22 in Catania



Legred+, PRD 104, 063003 (2021)

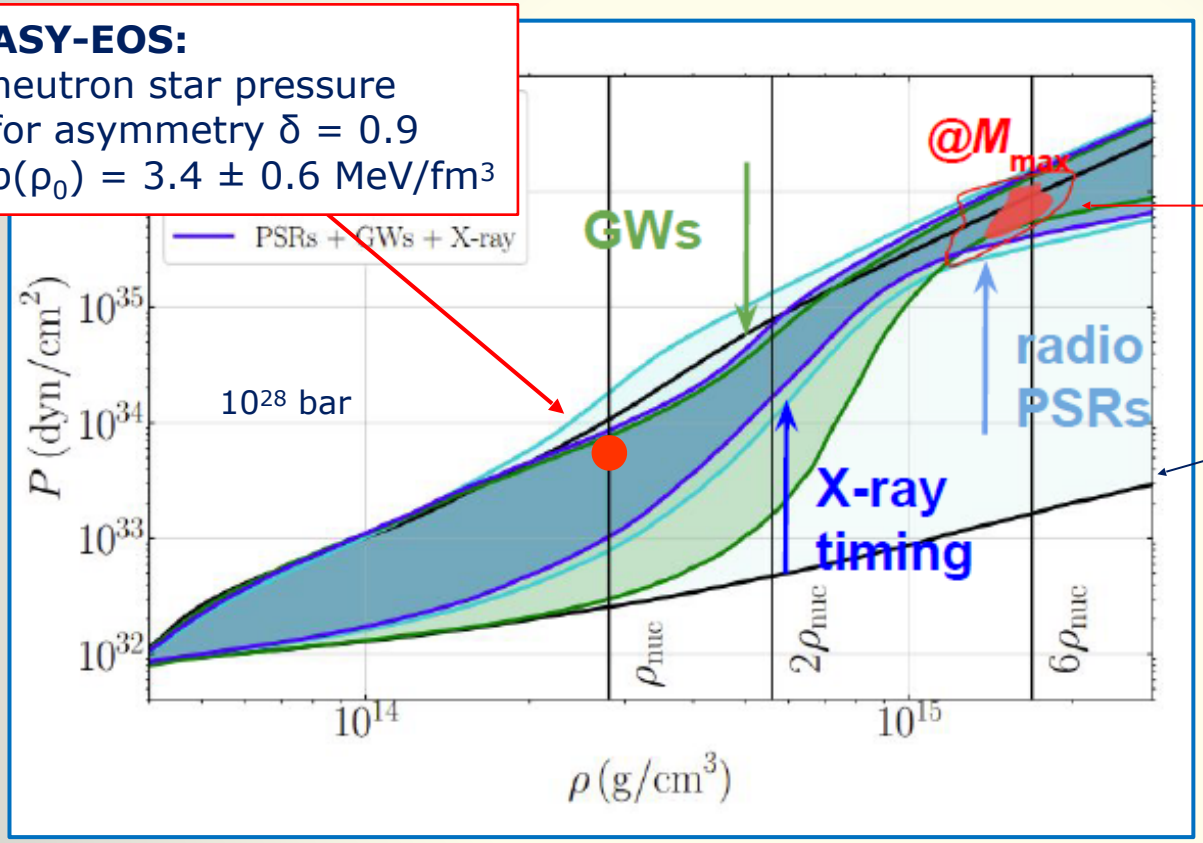
50%/90% contours
90% shadings

model-agnostic prior

red contours from mass 2.08 M_{sun} and radius for **PSR J0740+6620**

Reed Essick at NuSym22 in Catania

ASY-EOS:
neutron star pressure
for asymmetry δ = 0.9
$p(\rho_0) = 3.4 \pm 0.6$ MeV/fm^3



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red contours from mass 2.08 M_{sun} and radius for **PSR J0740+6620**

Huth et al., Nature 606 (2022): χEFT prior + HIC + astro

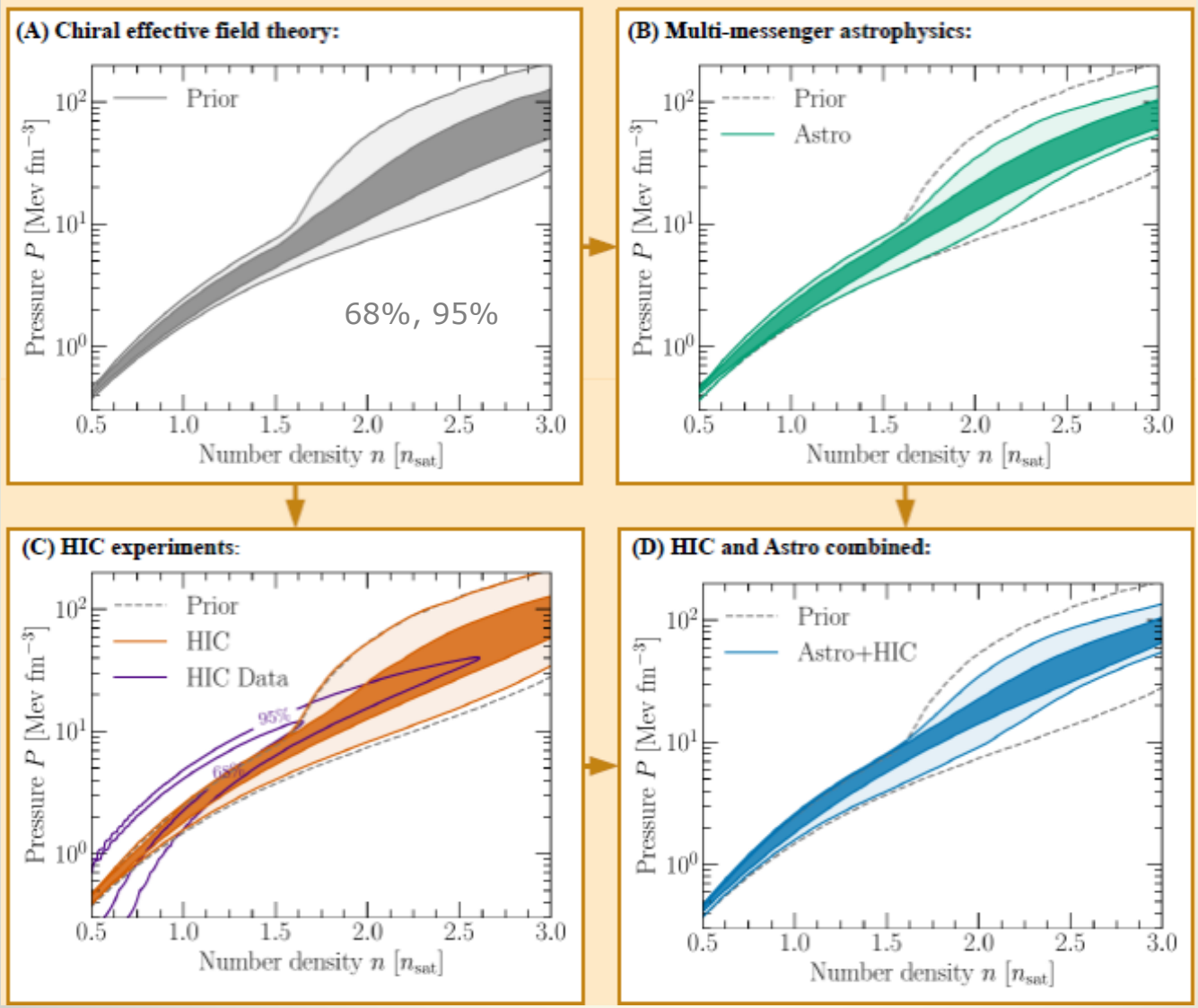


Fig. 1 neutron star matter

contours at 68% and 95% credibility

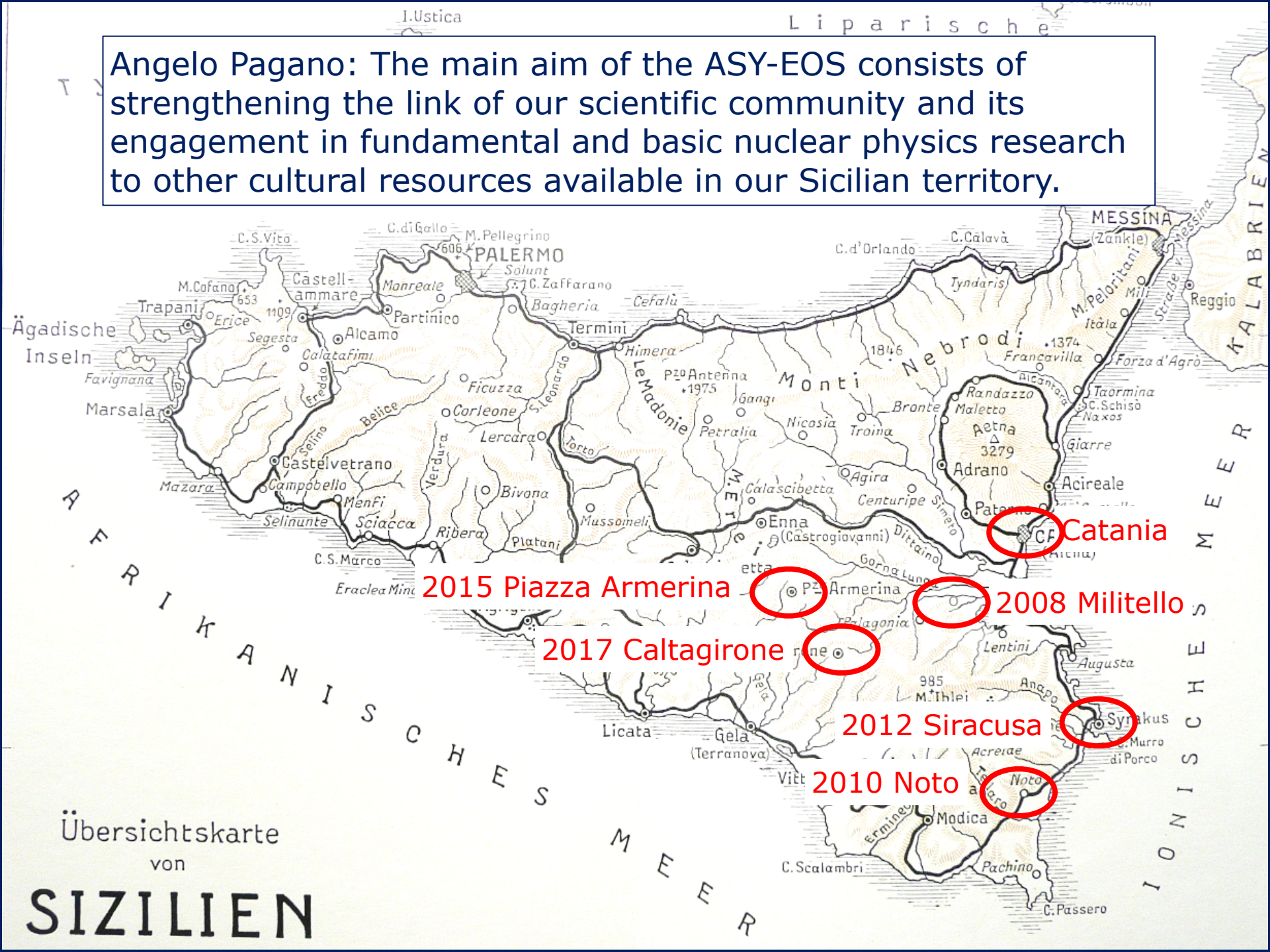
prior:
χEFT up to 1.5 ρ_0
c_s extension
$M_{max} \geq 1.9\ M_{sun}$

astro:
GW170817
+kilonova
GW190425
NICER 2 stars
XMM-Newton
$M_{max} \leq 2.17\ M_{sun}$

HIC:
PNM: ASY-EOS
SNM: FOPI, AGS


ASY-EOS II in March 2025

Angelo Pagano: The main aim of the ASY-EOS consists of strengthening the link of our scientific community and its engagement in fundamental and basic nuclear physics research to other cultural resources available in our Sicilian territory.



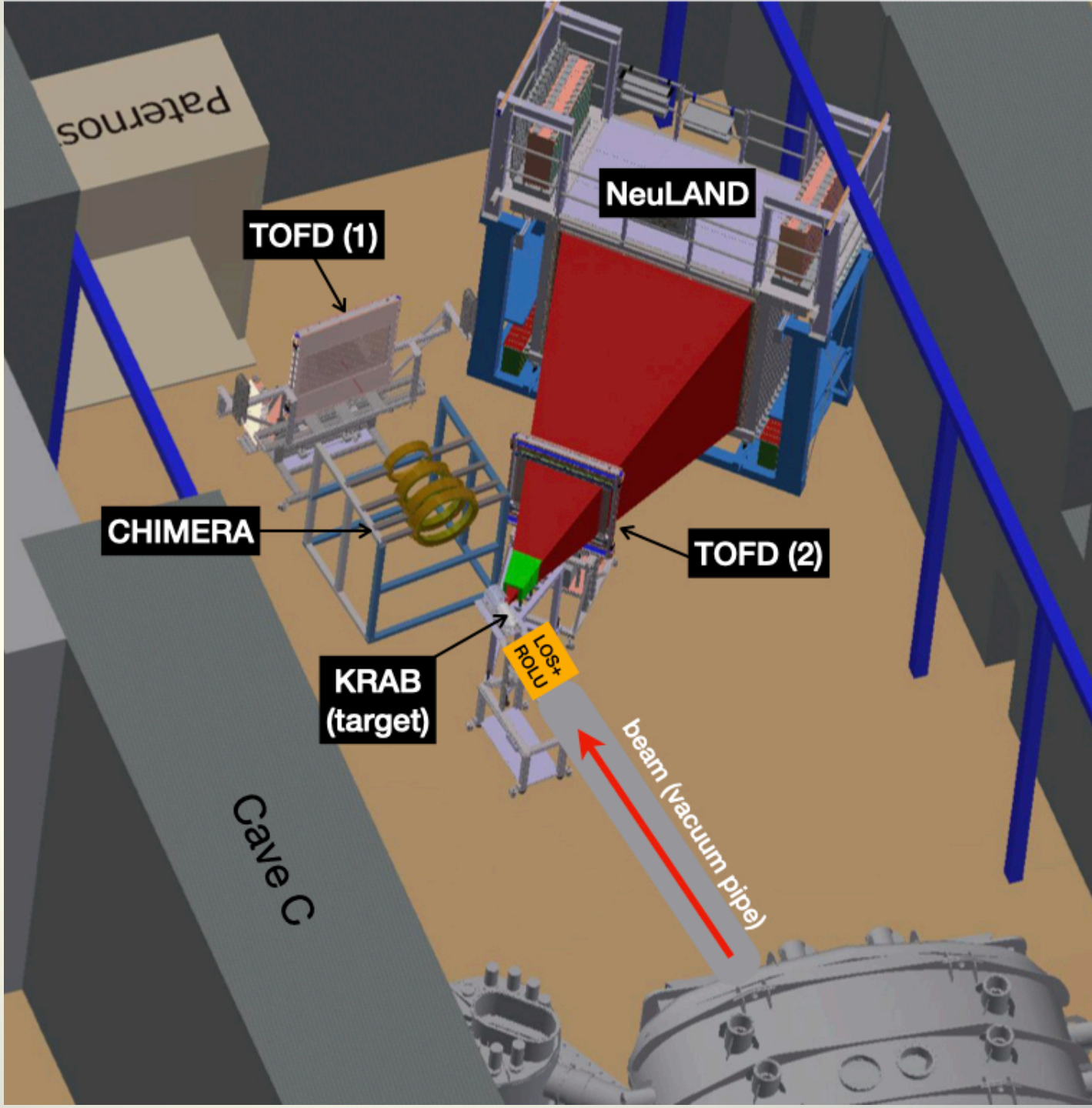

2012 Siracusa

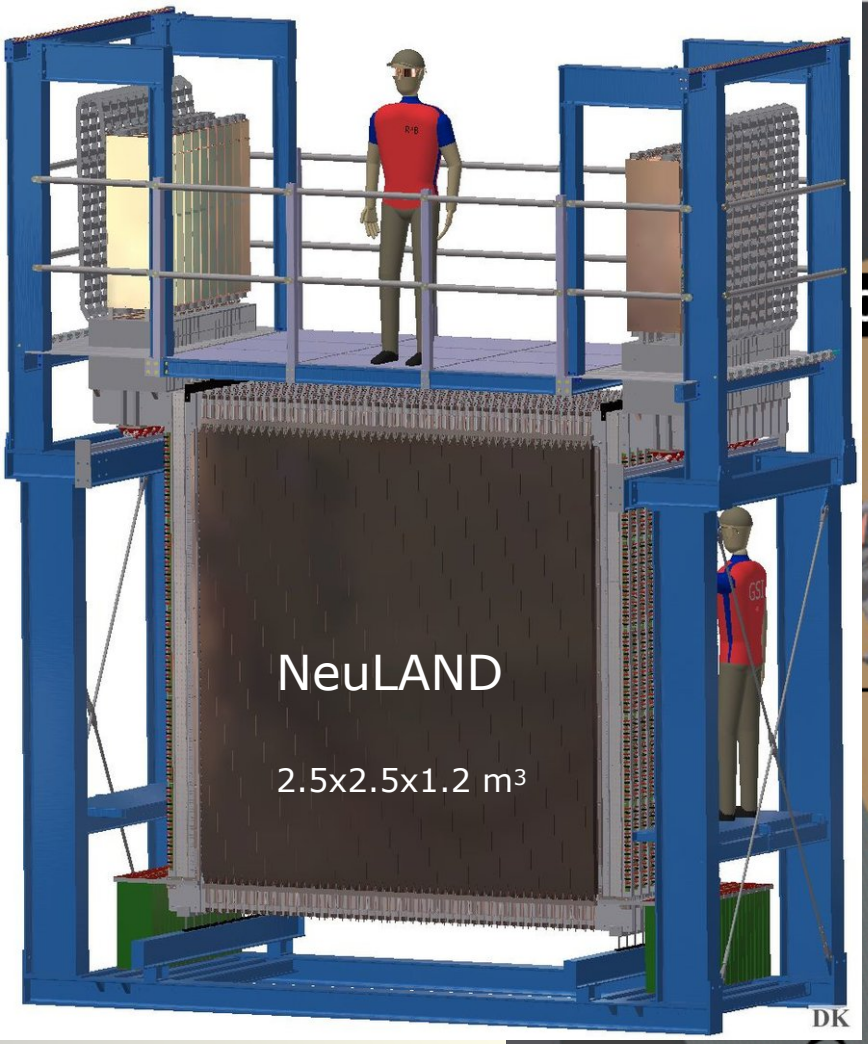
Public Session on **Archimede**
Introduction by Angelo Pagano
and
Panel Discussion with
Angelo Pagano

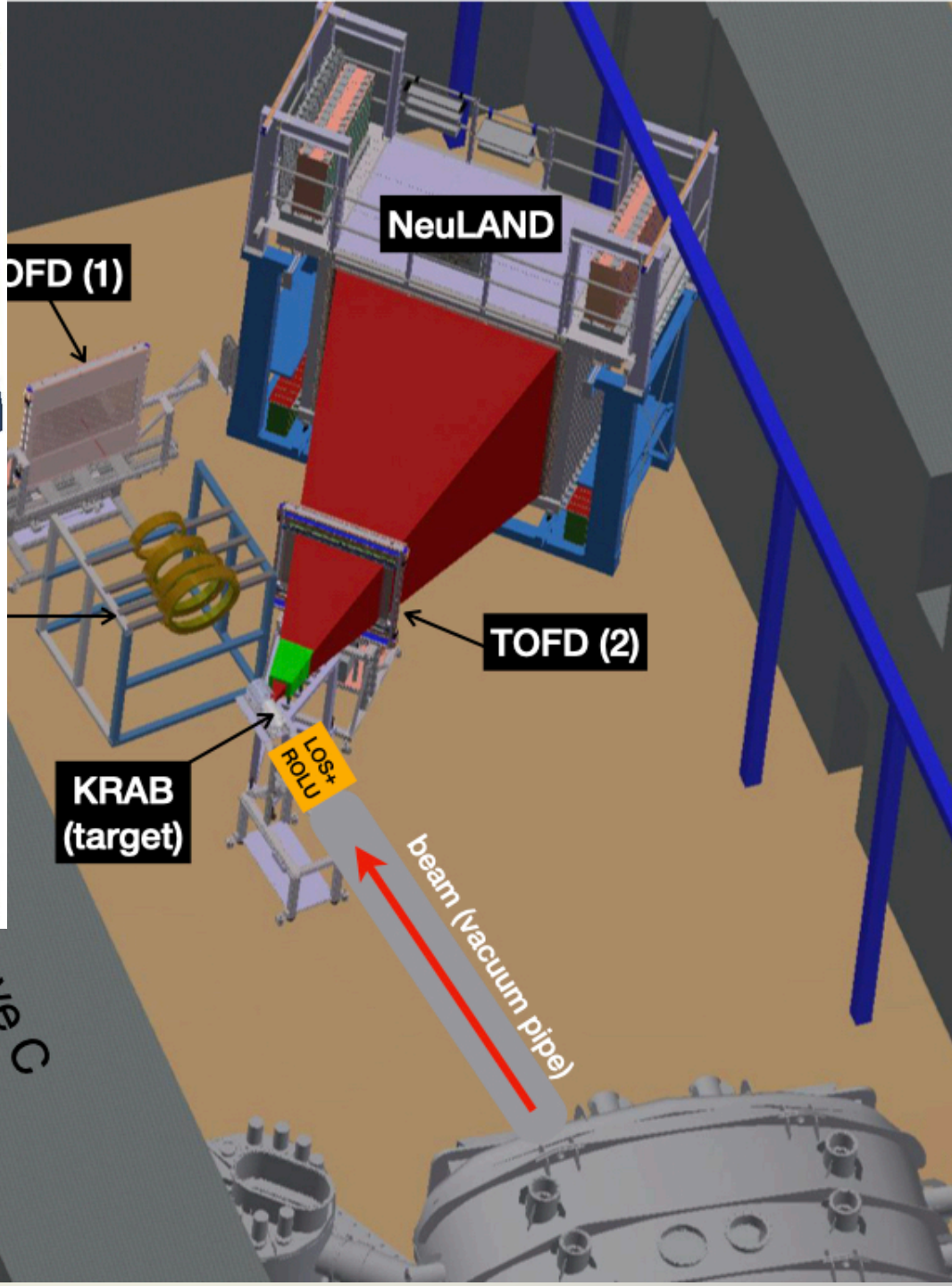
December 2017
in the bus to
Caltagirone

Extras

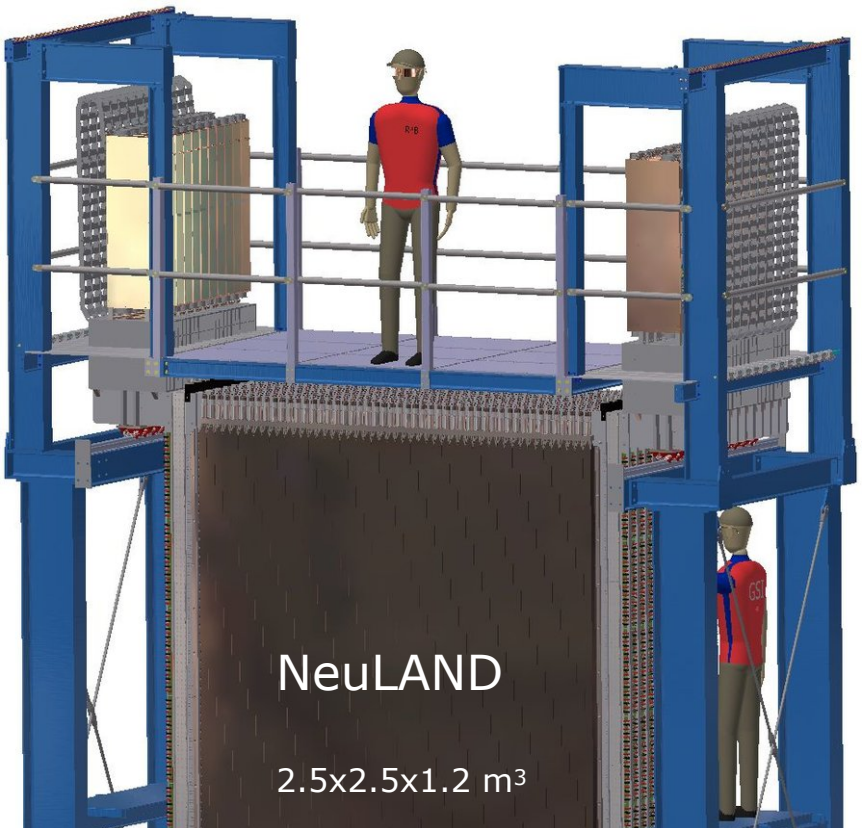
ASY-EOS II
March 2025



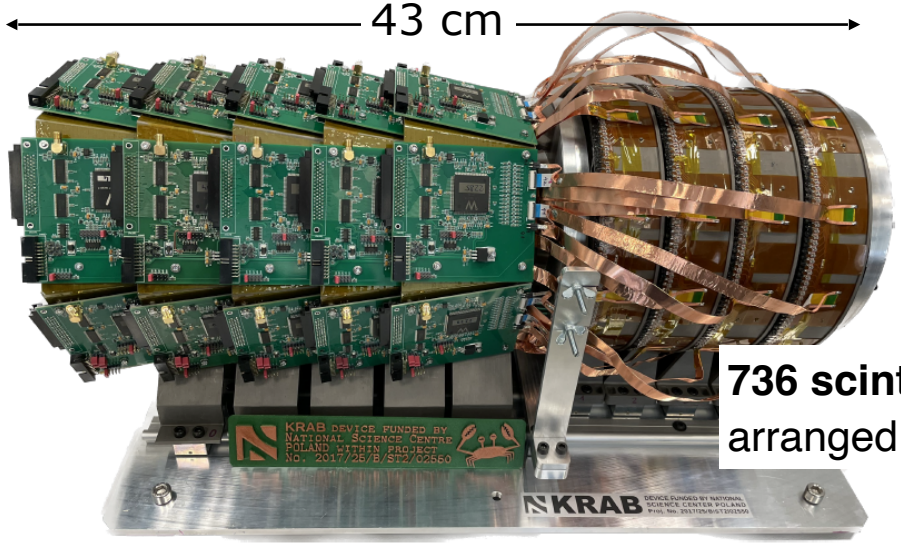




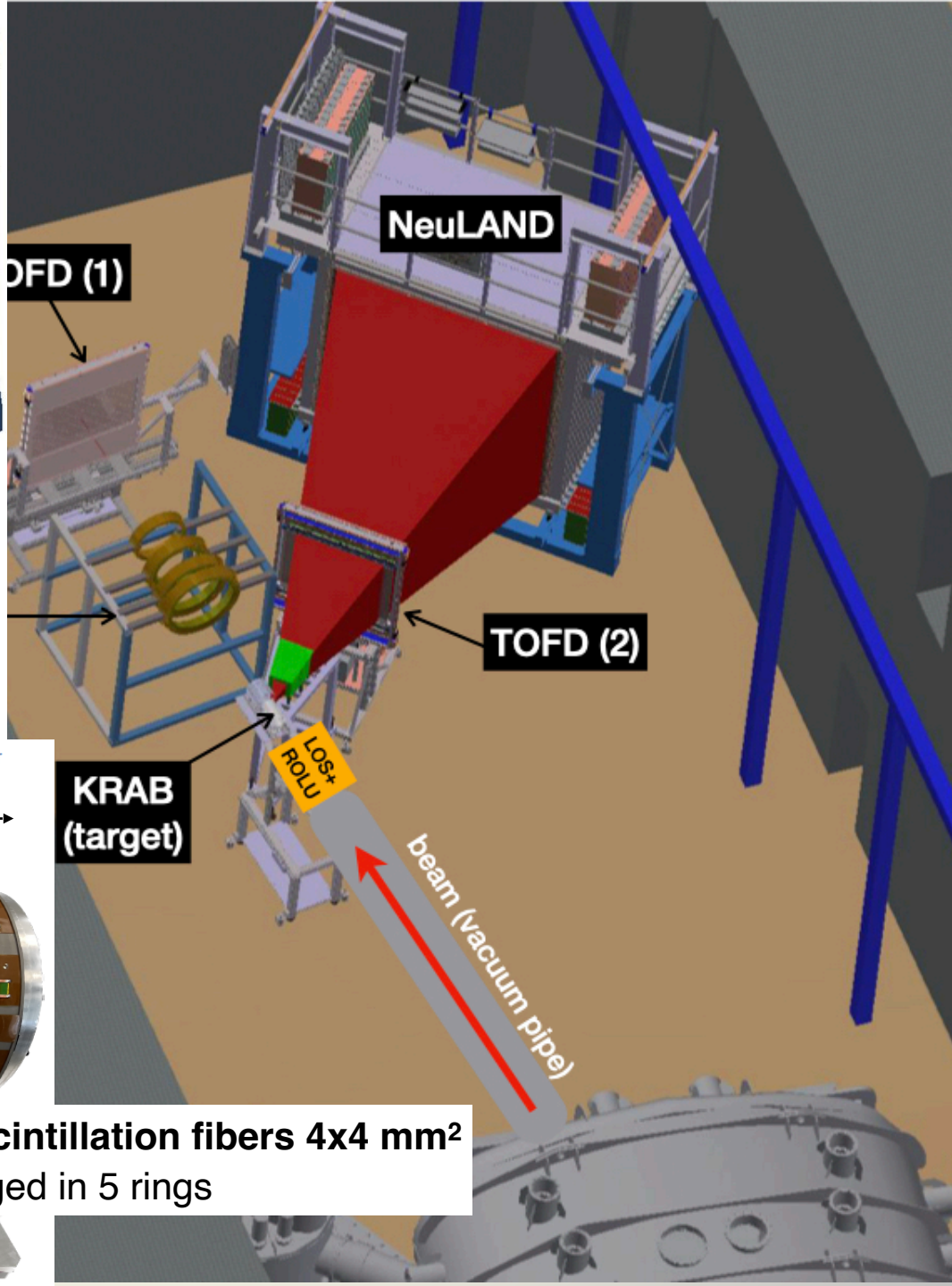
ASY-EOS II
March 2025



KRAB multiplicity trigger, reaction plane and centrality detector for the ASYEOS II experiment at GSI/FAIR



736 scintillation fibers 4x4 mm²
arranged in 5 rings




December 18, 2018
FAIR construction site
Roberto Bassini

December 18, 2018