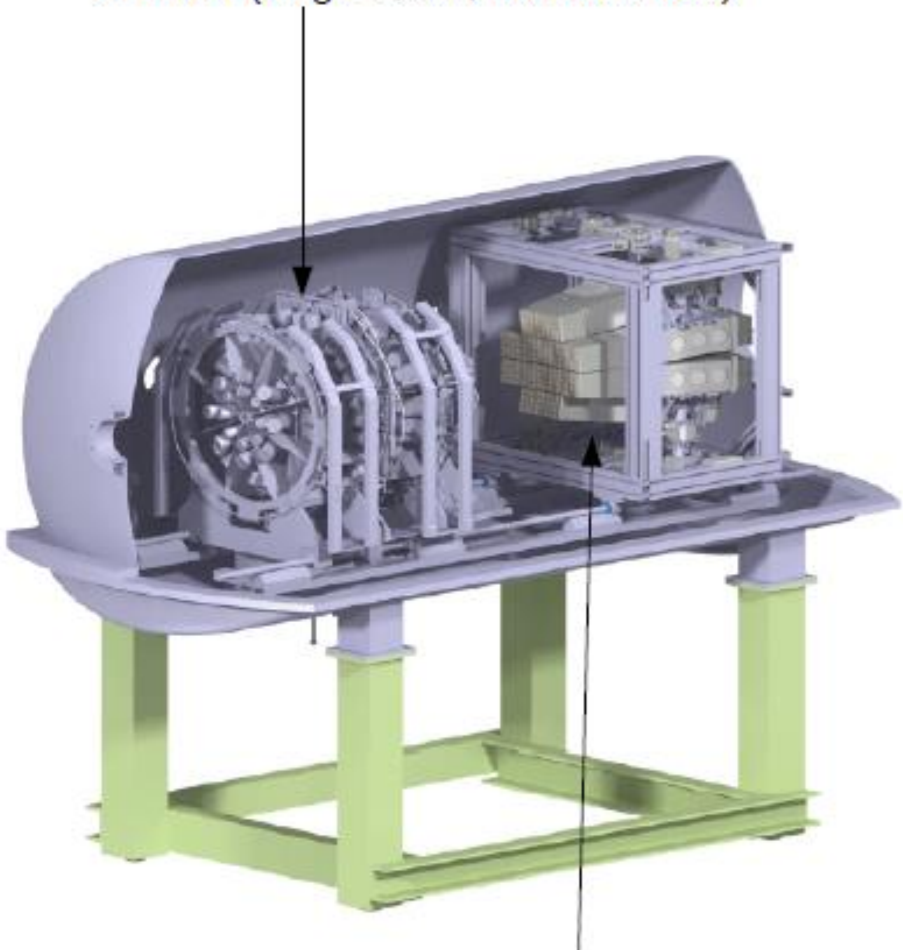
Concluding Remarks

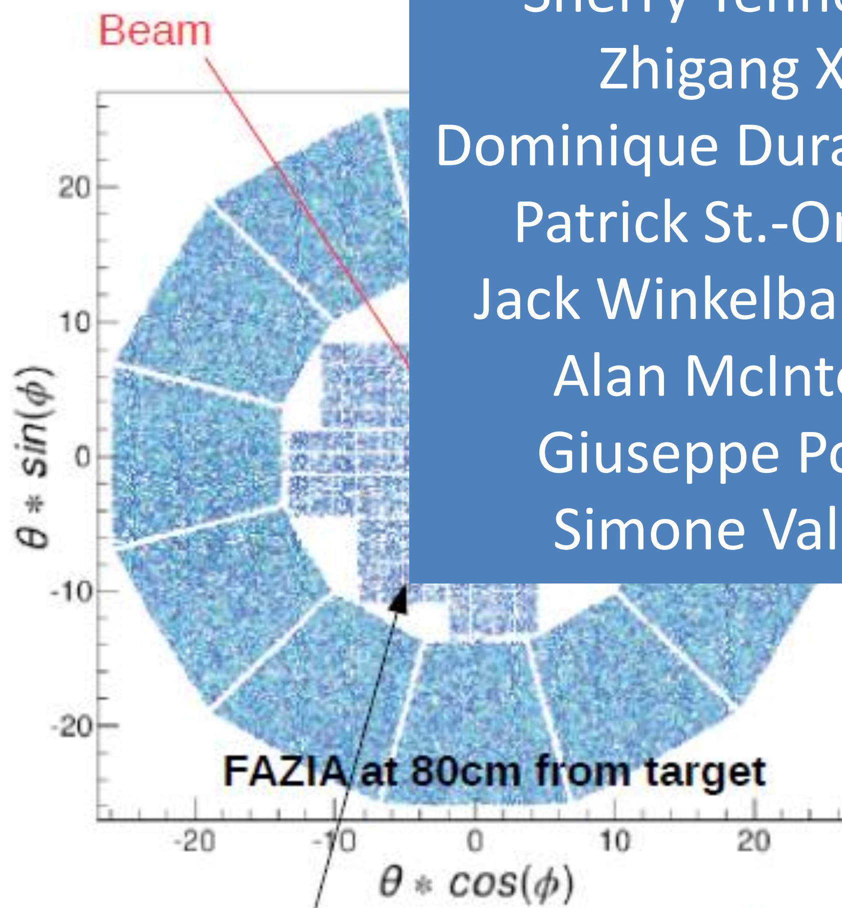
W. Trautmann, GSI Helmholtzzentrum Darmstadt, Germany

Coupling FAZIA demonstrator with INDRA

Olivier Lopez
Angelo Pagano
Sherry Yennello
Zhigang Xiao
Dominique Durand
Patrick St.-Onge
Jack Winkelbauer
Alan McIntosh
Giuseppe Politi
Simone Valdré

INDRA (rings 1,2/3,4/5 removed)





Transverse plane

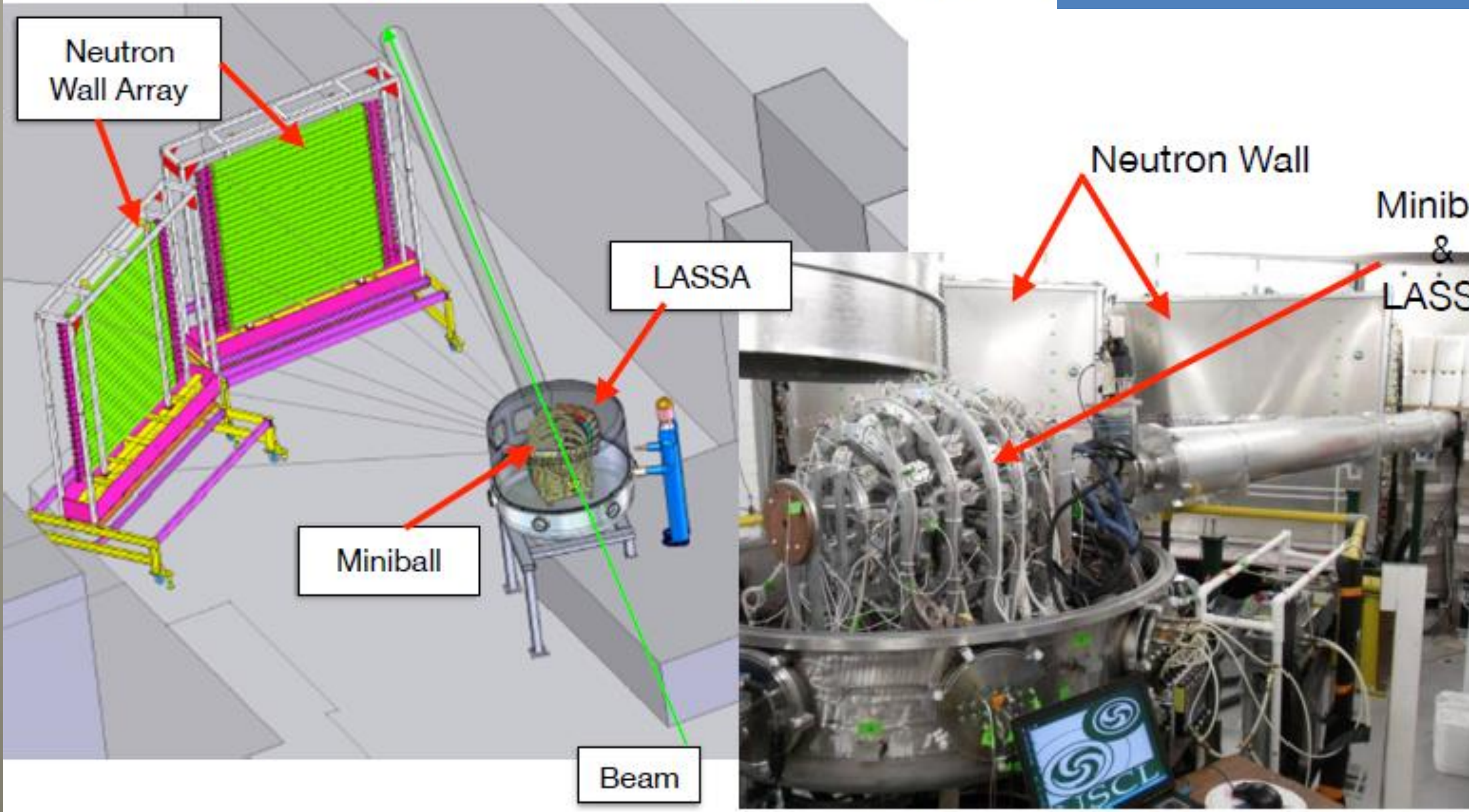
FAZIA demonstrator (est. 2016), 12 blocks :
192 20x20mm^2 high-quality *Si-Si-CsI* telescopes
from 2 to 14 deg. + customized full digital electronics

Between 2-14 deg.
FAZIA geom. acceptance 82% (90%)
Granularity x2 as compared to *INDRA*

n/p effective mass splitting

Bill Lynch
Pierre Morfouace
Kyle Brown

In November 2009: $^{112}Sn+^{112}Sn$ and $^{124}Sn+^{124}Sn$



SπRIT Experiment

Betty Tsang
Kaneko Masanori
Nishimura Mizuki
Jerzy Łukasik
Tadaaki Isobe

- SπRIT TPC
  are installe
  magnet so
  uniform magnetic field inside the
  field cage.
- NeuLAND is placed at 8.8 m from the target at the angle of 30 degrees.

model dependence

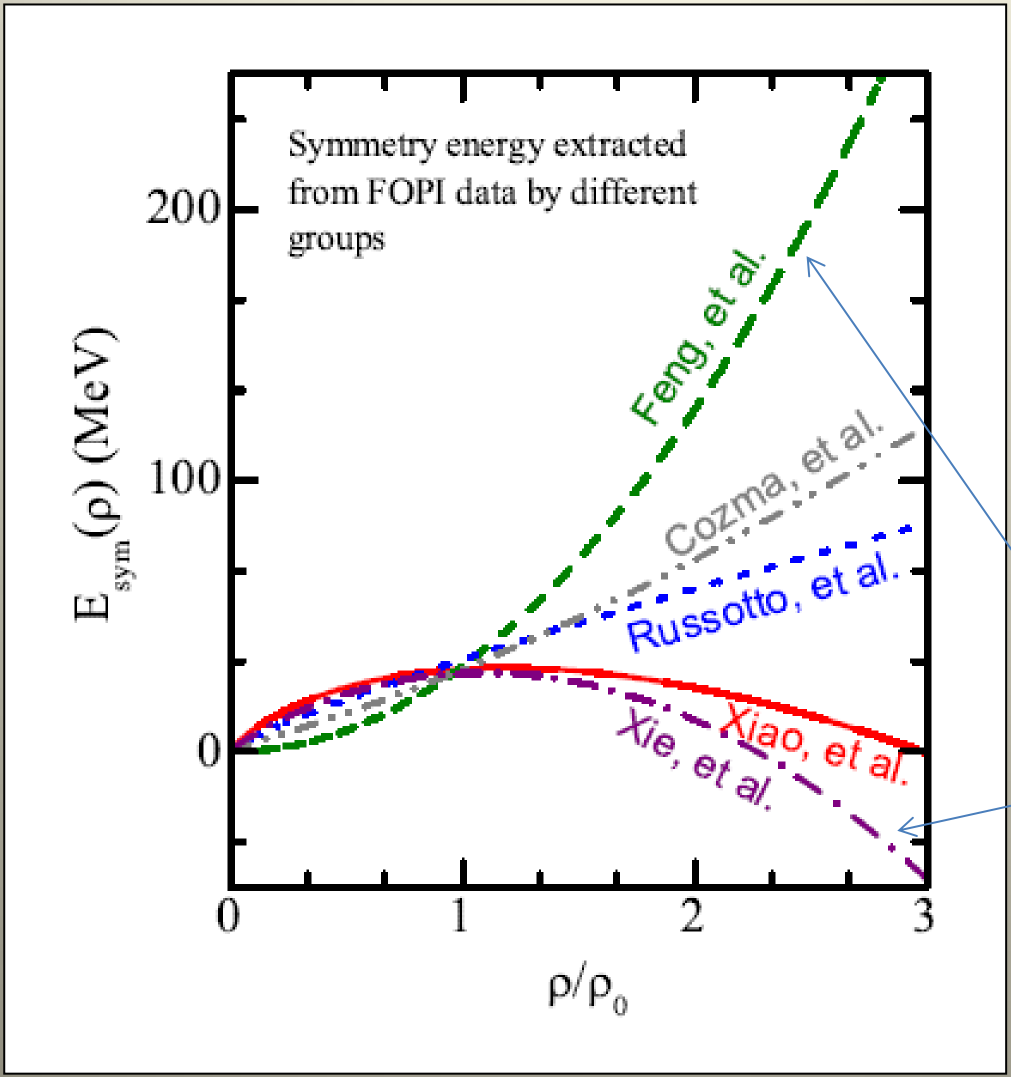


figure from
Wenmei Guo et al.,
PLB 738, 197 (2014)

elliptic flow
ratio (FOPI-LAND)

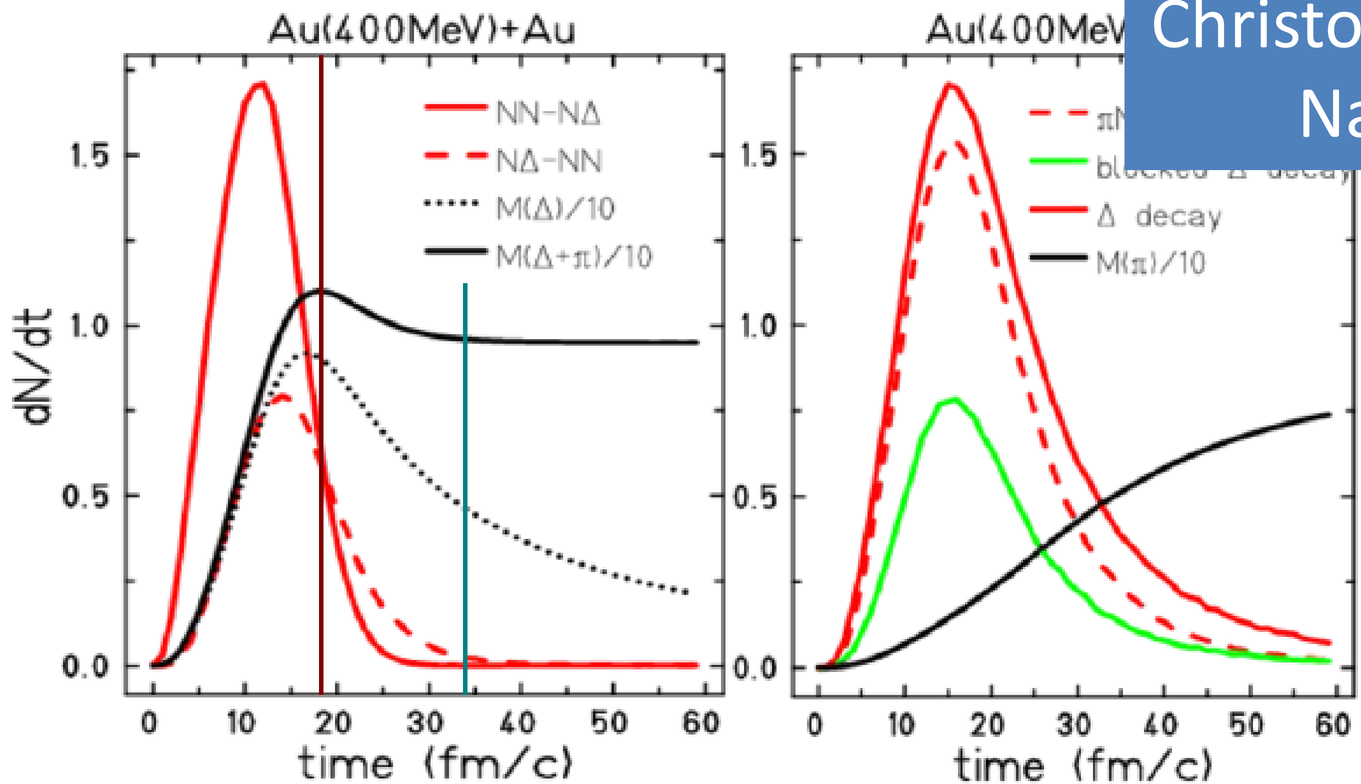
pion ratios

(from analyses
of the **same**
FOPI exp. data)

TIME EVOLUTION

- Channels for production and absorptio

Che-Ming Ko
Dan Cozma
Christoph Hartnack
Natsumi Ikeno



- Maximum reached when Δ absorption dominates over production
- Total yield stabilized when absorption stops.

Number of free pions grows slowly due to strong interplay between Δ decay and π absorption

NUSYM 2017

7th international symposium on nuclear symmetry energy

SEPTEMBER 4TH - 7TH / GANIL, CAEN, FRANCE

Comparison of heavy-ion transport simulations: Collision integral in a box

Yingxun Zhang (张英逊)
China Institute if Atomic Energy

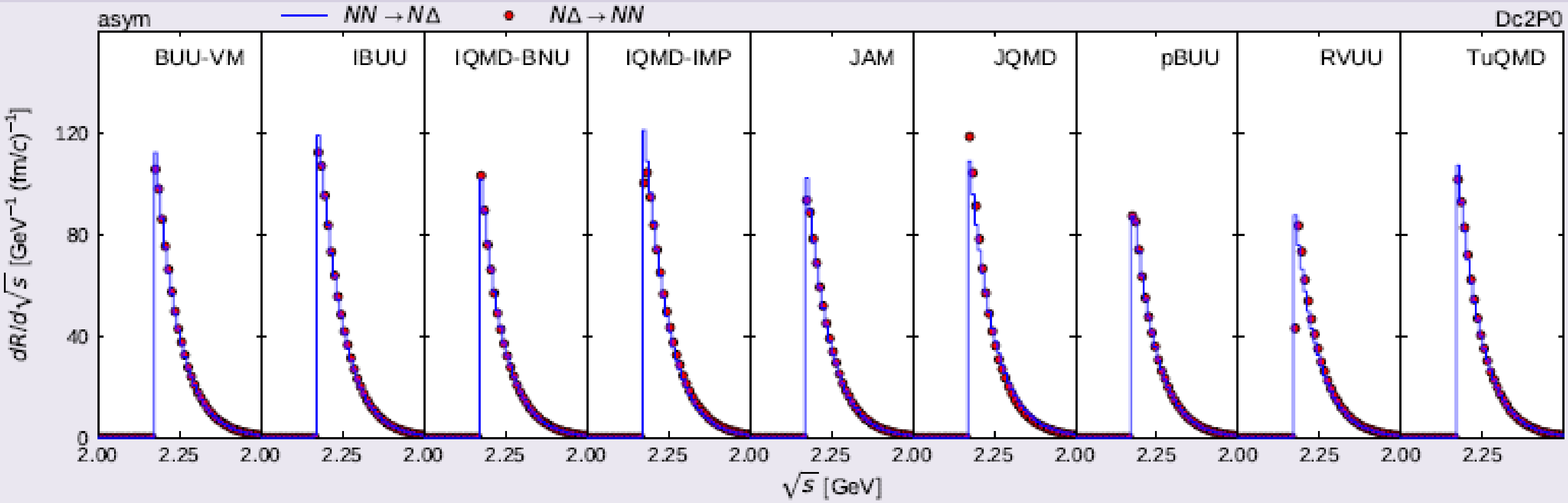
Yongjia Wang, Maria Colonna, Pawel Danielewicz, Akira Ono, Betty Tsang, Hermann Wolter, Jun Xu,
Lie-Wen Chen, Dan Cozma, Zhao-Qing Feng, Che-Ming Ko, Bao-An Li, Qing-Feng Li, S. Das Gupta, N. Ikeno, C.M. Ko, B.A.Li, Q.F.Li, Z.X. Li, S. Mallik, T. Ogawa, D. Oliinychenko, M. Papa, H. Petersen, Jun Su, Taesoo Song, Janus Weil, Ning Wang, Feng-Shou Zhang, Guo-Qiang Zhang, and Zhen Zhang,
……..

Option Dc2P0: Two-way $NN \leftrightarrow N\Delta$ with a constant Δ mass

Akira Ono

Detailed balance: $\sigma(N\Delta \to NN) = \frac{1}{g}\frac{p_{NN}^2}{p_{N\Delta}^2}\sigma(NN \to N\Delta)$ (diverges at the threshold)

Distribution of $\sqrt{s}$ for $NN \to N\Delta$ and $N\Delta \to NN$

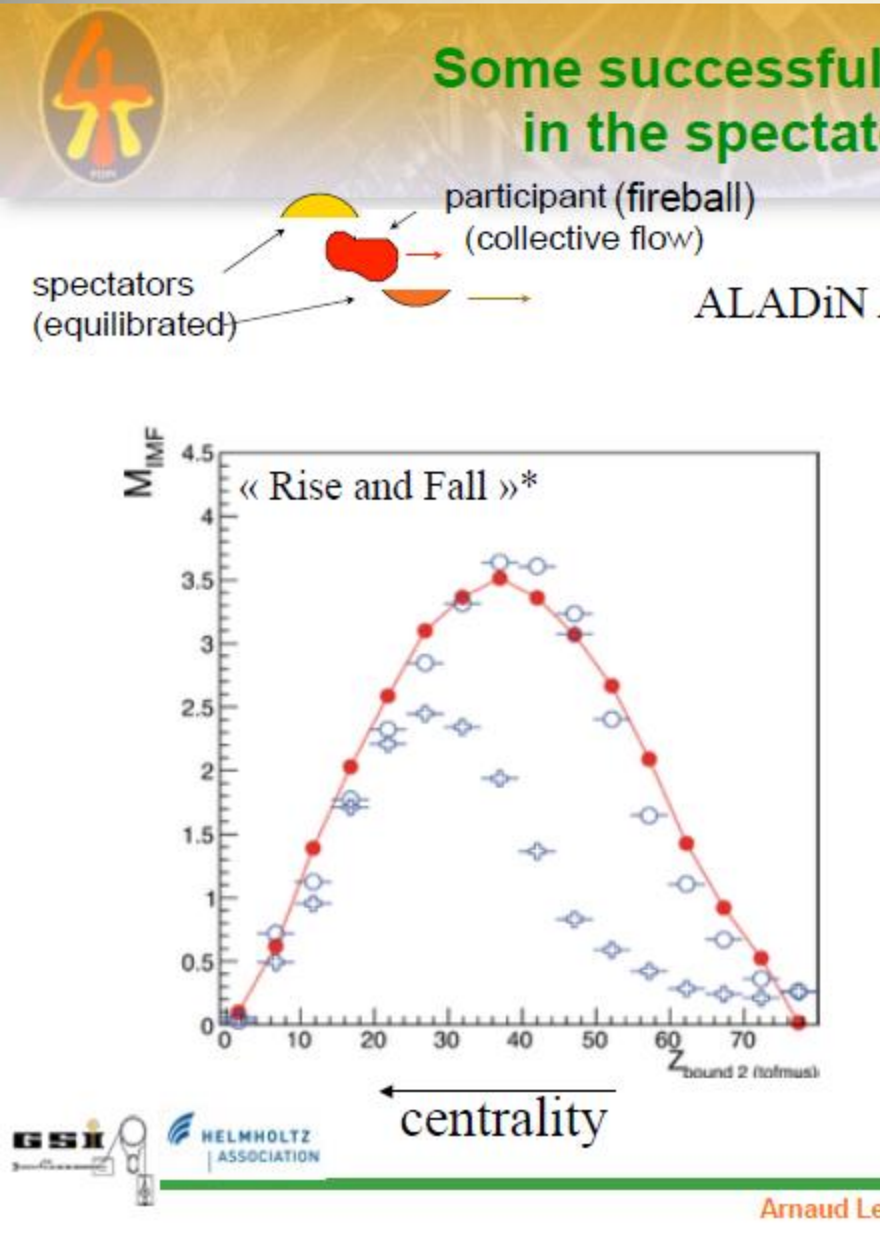


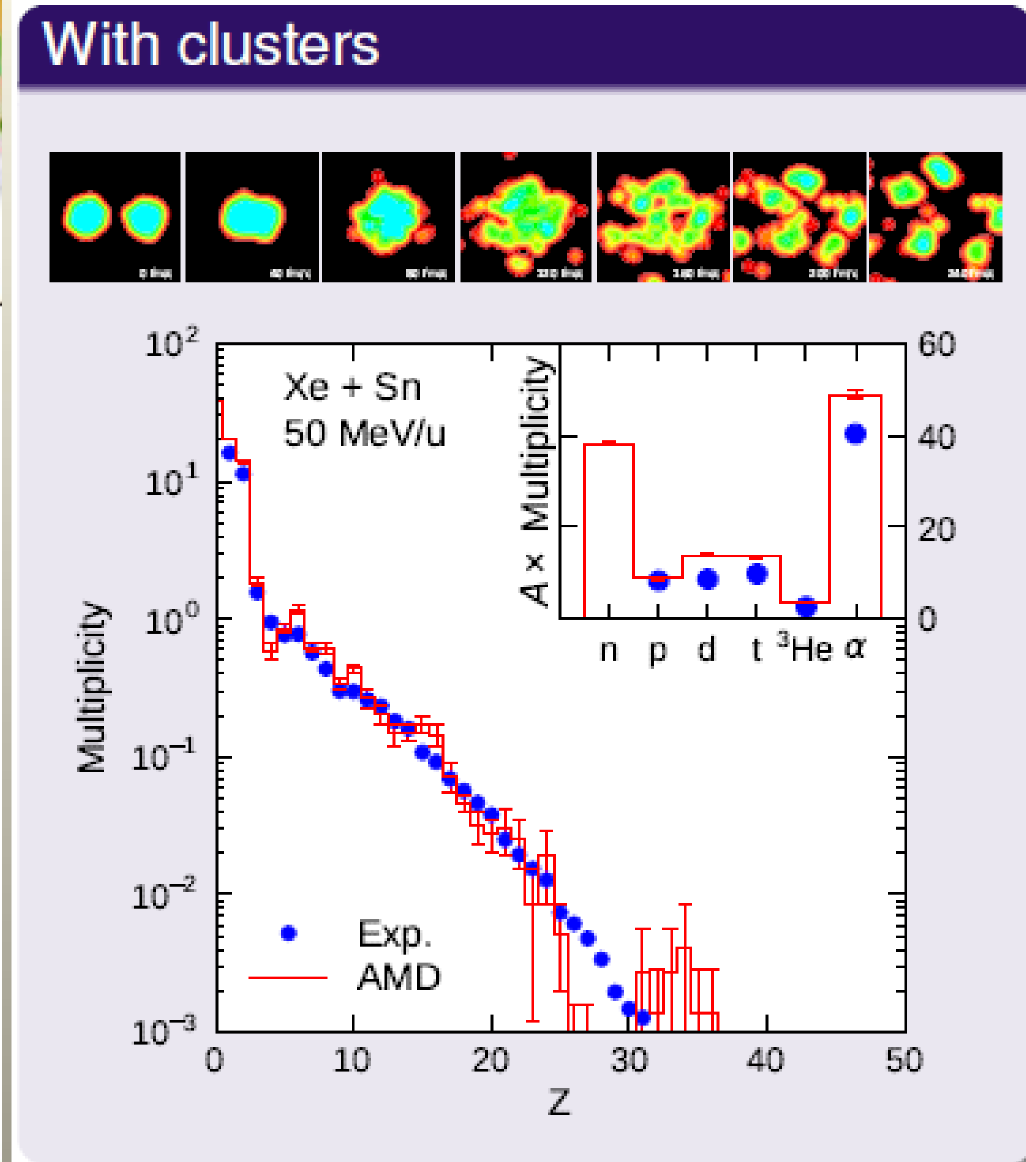
- Forward and reverse reactions don't balance in some codes.
- $(N\Delta \to NN) < (NN \to N\Delta)$ may be expected for the lowest bin due to the finite box size, i.e. $\sigma < (1 \sim 3)\pi(L/2)^2$.

peripheral
Au+Au @ 600 AMeV

central
Xe + Sn @ 50 AMeV

Arnaud Le Fèvre
Akira Ono



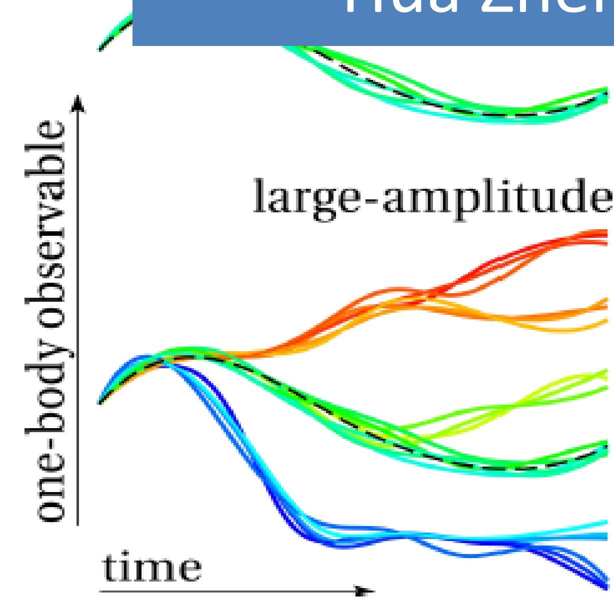


fluctuations and correlations

Describing large-amplitude dynamics of nucle

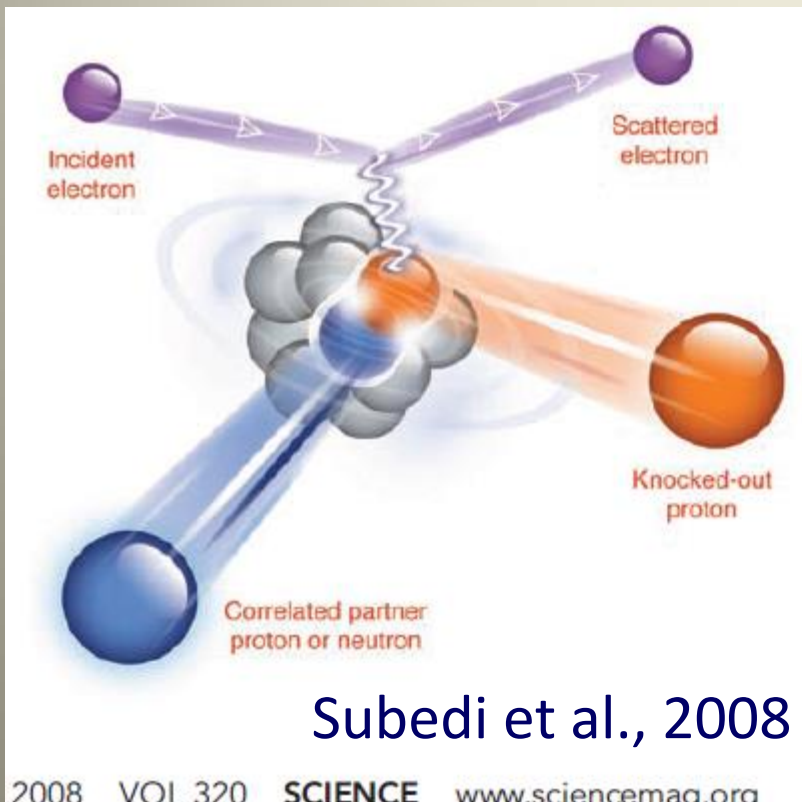
Paolo Napolitani
Maria Colonna
Hermann Wolter
Yoritaka Iwata
Hua Zheng

- *small amplitude-limit at low energy*
  → correlated channels, coherent states
  [TDGCM: Reinhard,Goeke RepPrPh50(1987), Goutte et al PRC 71 (2005), Balian-Vénéroni (1981,1992), Simenel EPJA 48 (2012),...]
- *large-amplitude regimes at low energy* →
  → non-correlated states beyond single-part. picture [Lacroix arXiv:1504.01499 (2015)]
- *excitation beyond Pauli blocking* →
  → observables width spread, dissipation
  [ETDHF: Wong,Tang PRL 40 (1978), Lacroix et al ProgPartNucPhys 52 (2004),...]

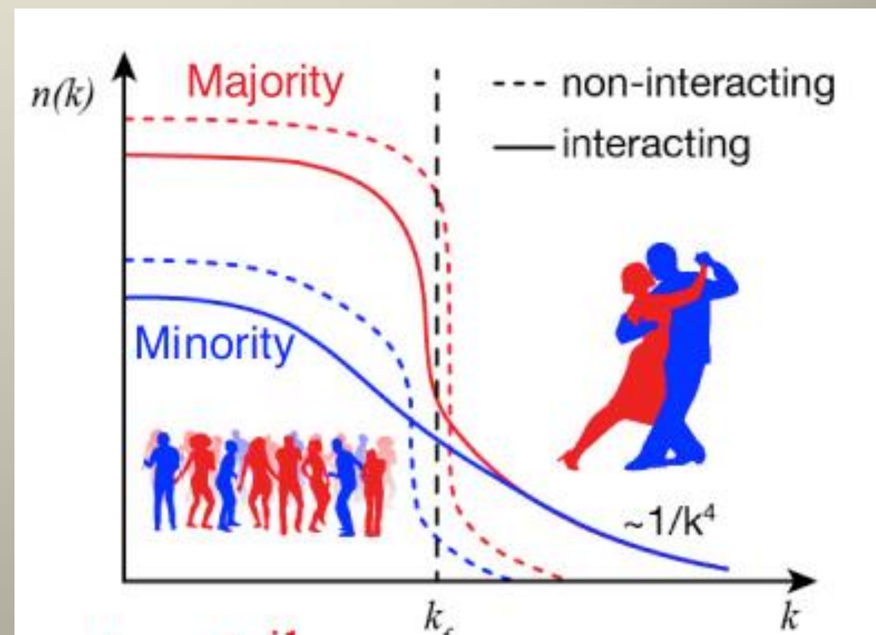


- *chaotic regime, bifurcation*
  → highly non-linear, possibly unstable
  [STDHF / Boltzmann-Langevin: Reinhard,Suraud AnnPhys 216(1992), Slama,Reinhard,Suraud AnnPhys 355 (2015),...]
  ⇒ (1) Clusterisation from one-body density fluctuations
  ⇒ (2) n, p transport between fragments and the medium

short range correlations



Subedi et al., 2008

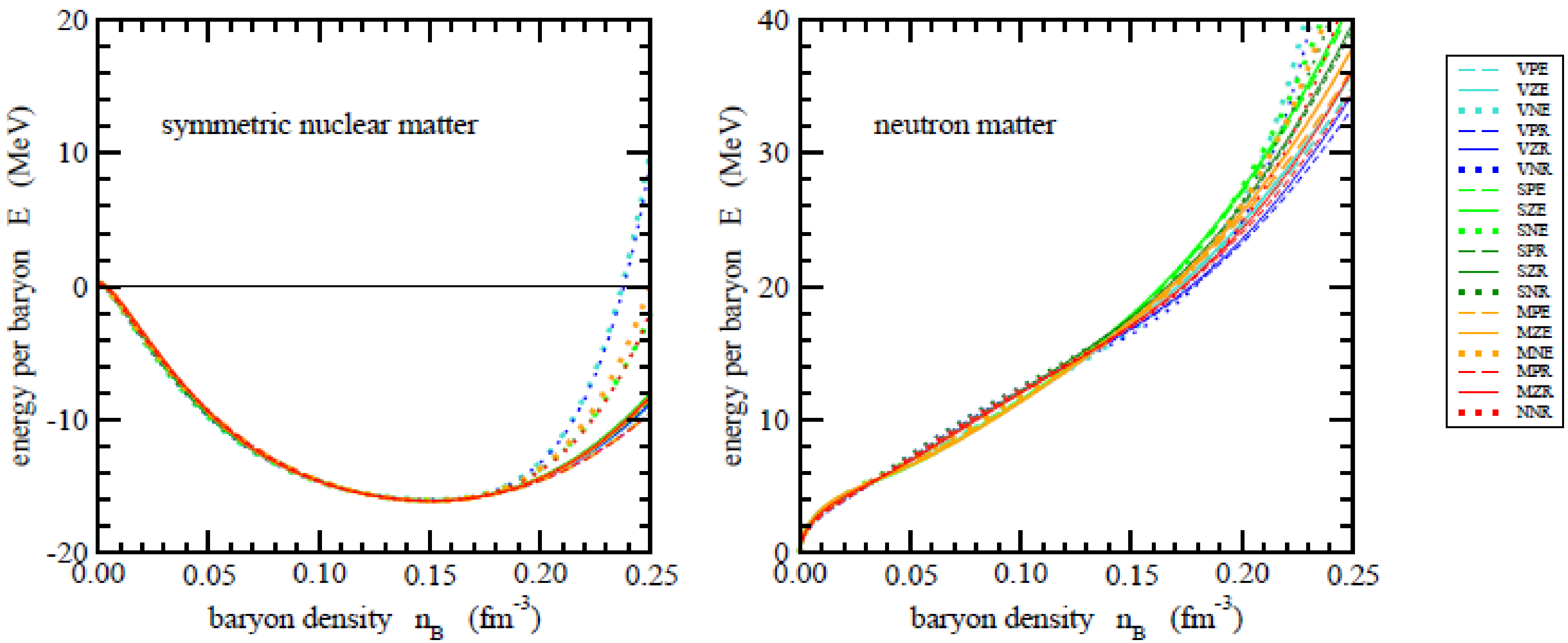


Stefan Typel

EOS: RMF with density dependent couplings

Results (Preliminary)
Equations of State

TECHNISCHE UNIVERSITÄT DARMSTADT



- very similar below saturation density
- divergence above saturation density
- strong stiffening for 'N' parametrisations


RIKEN 2010
NuSYM10
astrophysics
International Symposium on
Nuclear Symmetry Energy
RIKEN, Wako, Japan
July 26-28, 2010
NuSYM10

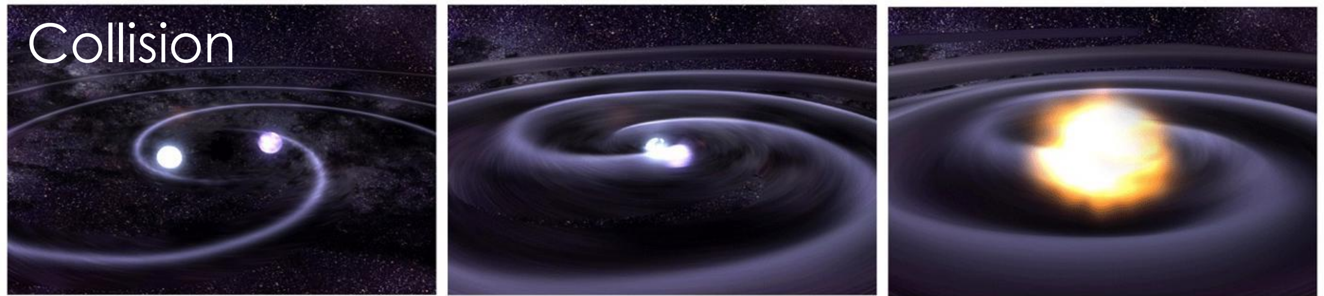
Sandrine Courtin

Carbon burning: a crucial phase in the stellar nucleosynthesis

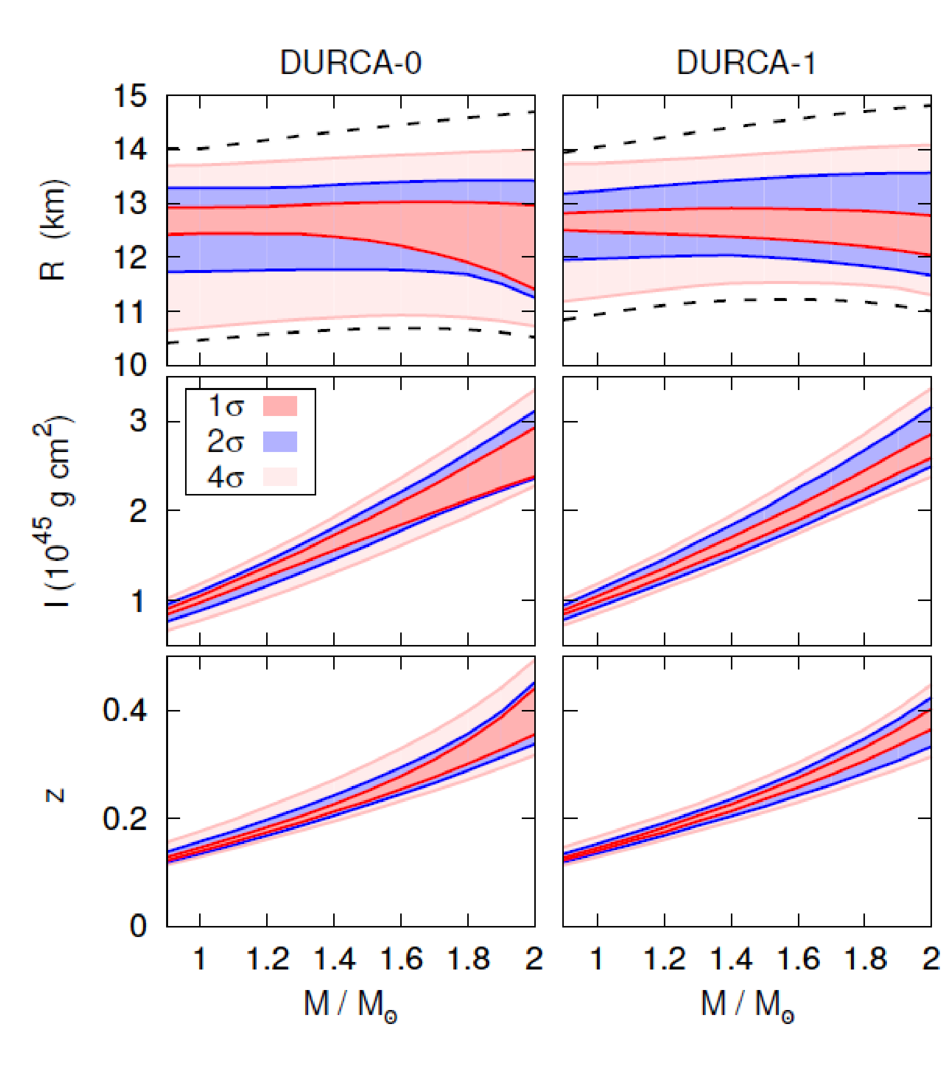
- $M < 8\text{-}9\ M_\odot$ -> these stars are expected to shed their envelopes during helium burning and become white dwarfs, which may generate Type Ia supernovae

- $M = 9\text{-}11\ M_\odot$ -> burning could occur under a degenerate condition, carbon flash

- $M > 11\ M_\odot$ -> burning in a non-degenerate contracting core ($T > 10^8$ K, $\rho > 3.10^6$ g.cm^{-3})

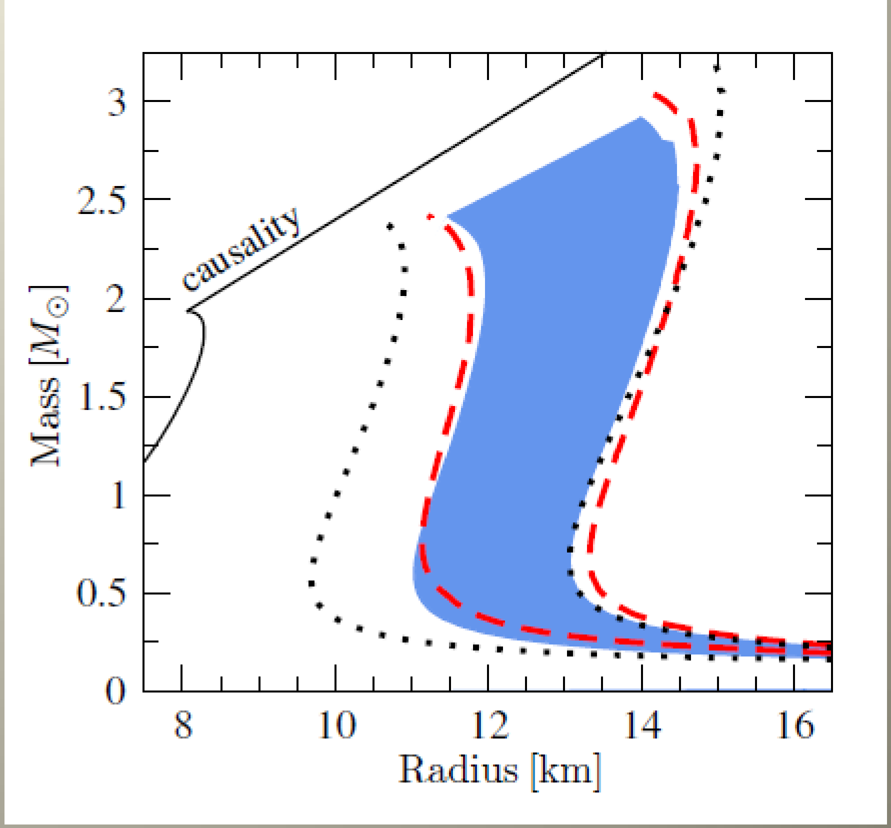


25 Mio models from empirical parameters



11.5 < R < 13.5 km

ChEFT + minimum constraint from neutron stars

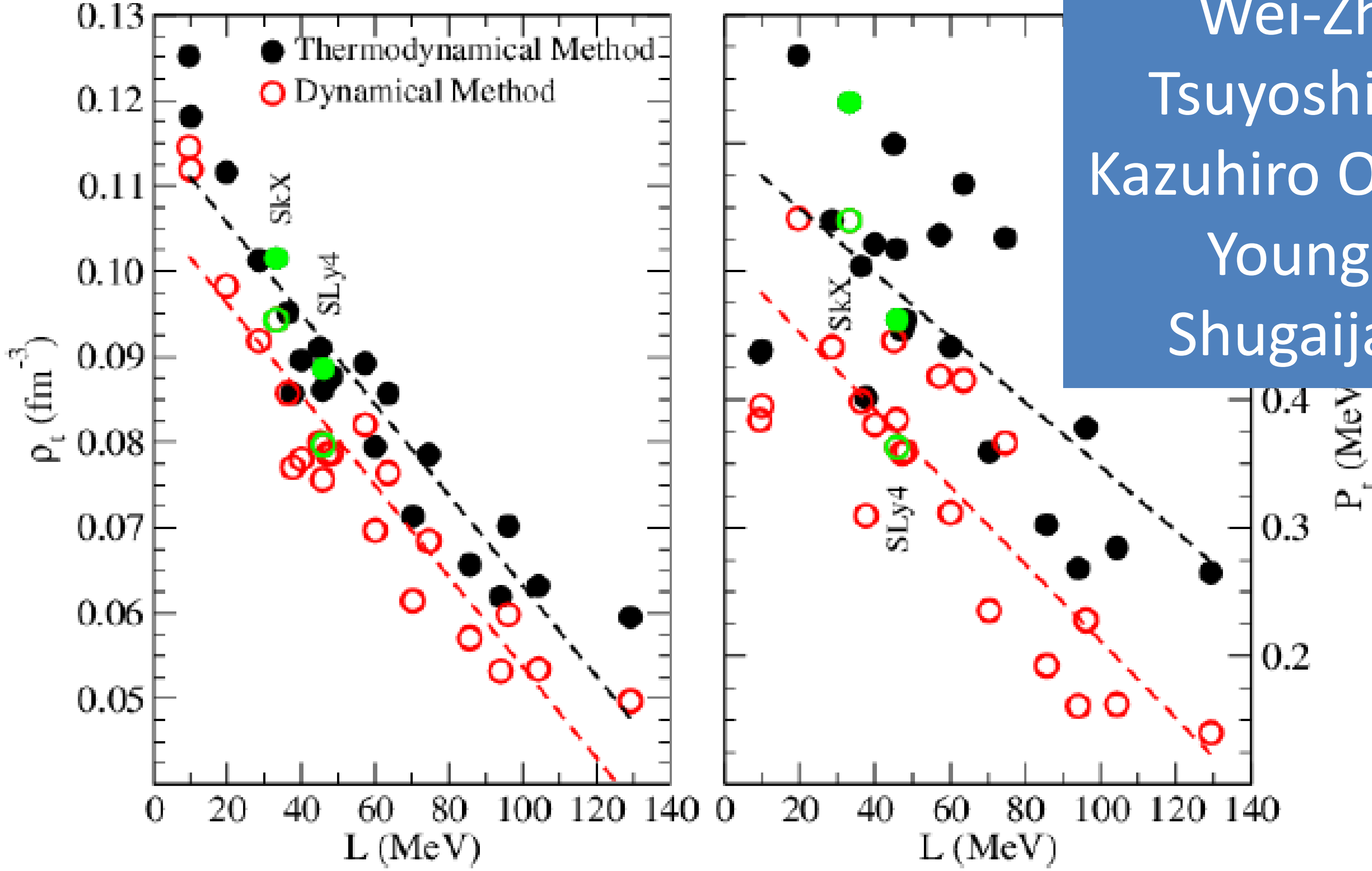


Hebeler, Lattimer, Pethick, Schwenk, ApJ 773 (2013) 11

neutron stars

Xavier Viňas
Lie-Wen Chen
Claudio Dorso
Wei-Zhou Jiang
Tsuyoshi Miyatsu
Kazuhiro Oyamatsu
Youngman Kim
Shugaijam Singh

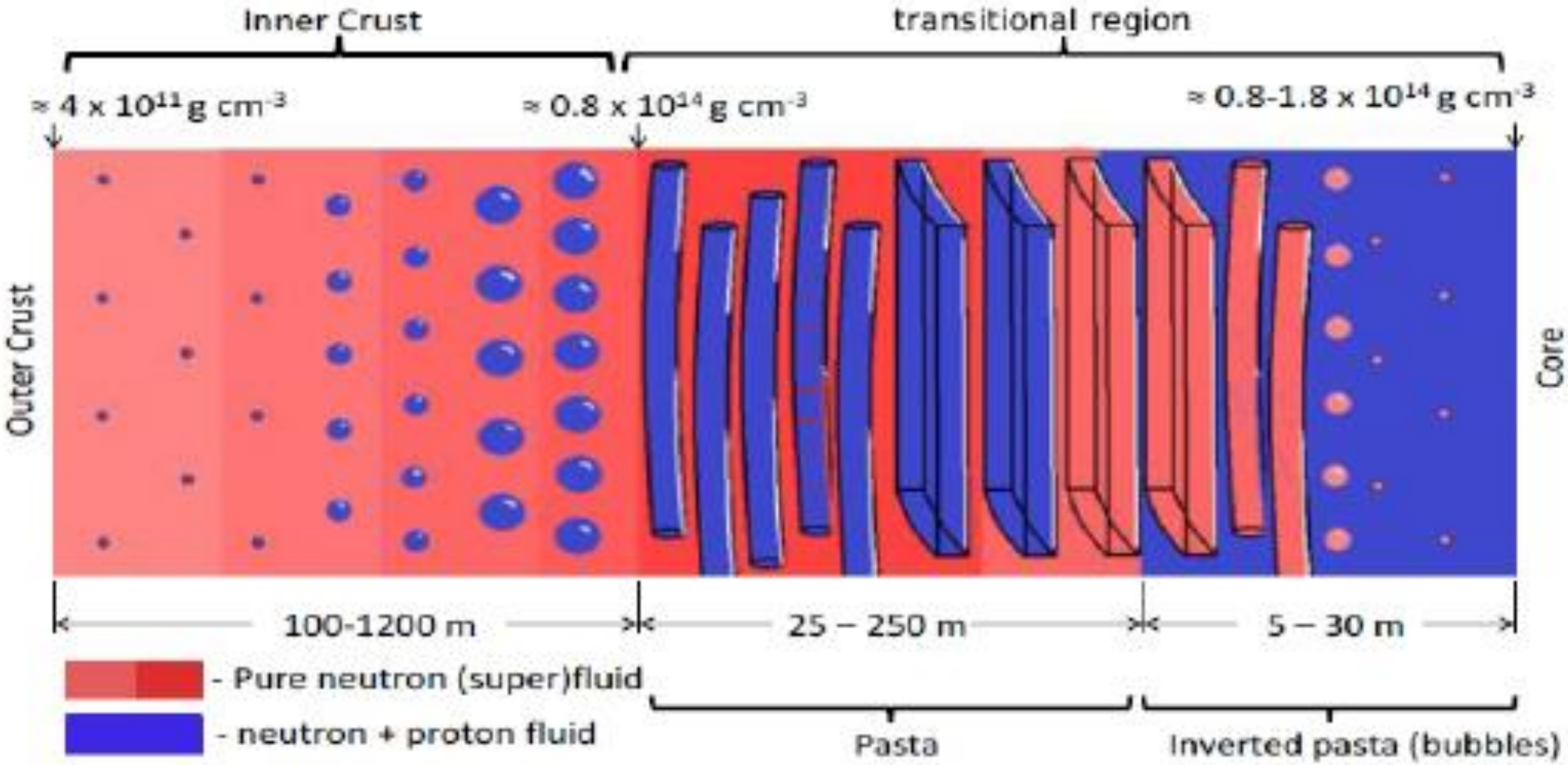
crust-core transition density and pressure

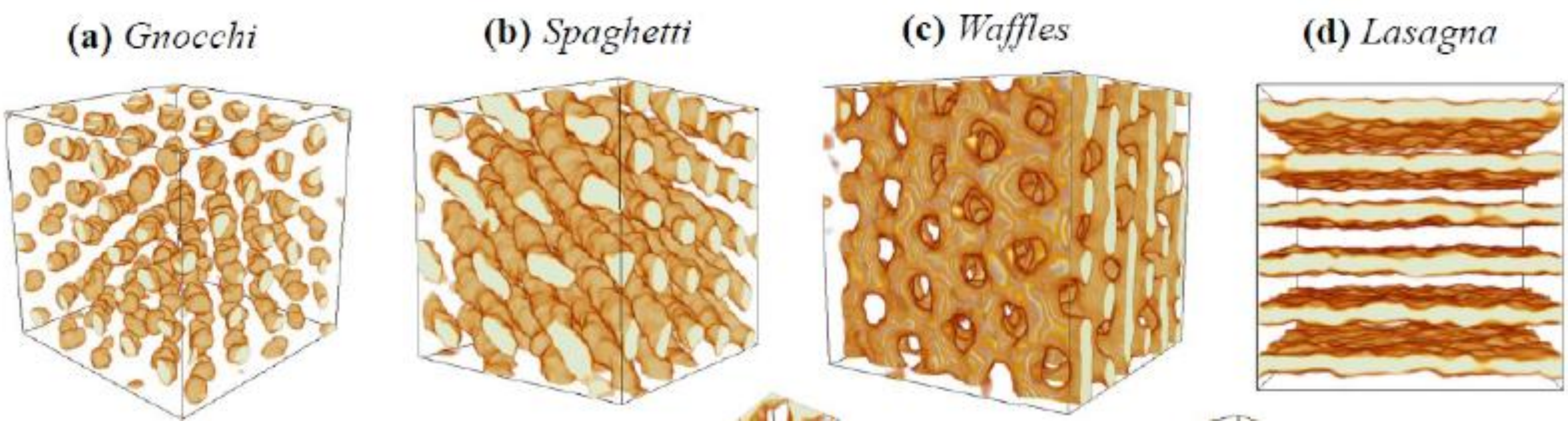


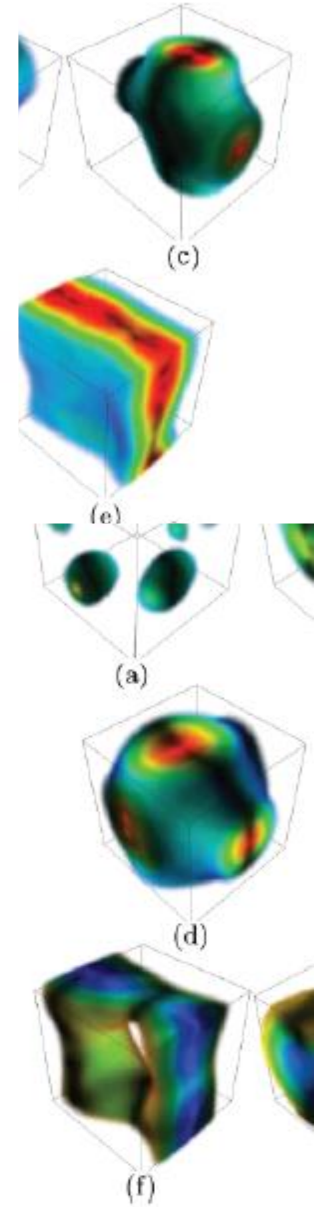
to determine the mass-radius relationship in a neutron star requires the knowledge of the EOS in the core but also in the crust.

Sebastian Kubis

pasta phases in the transition region



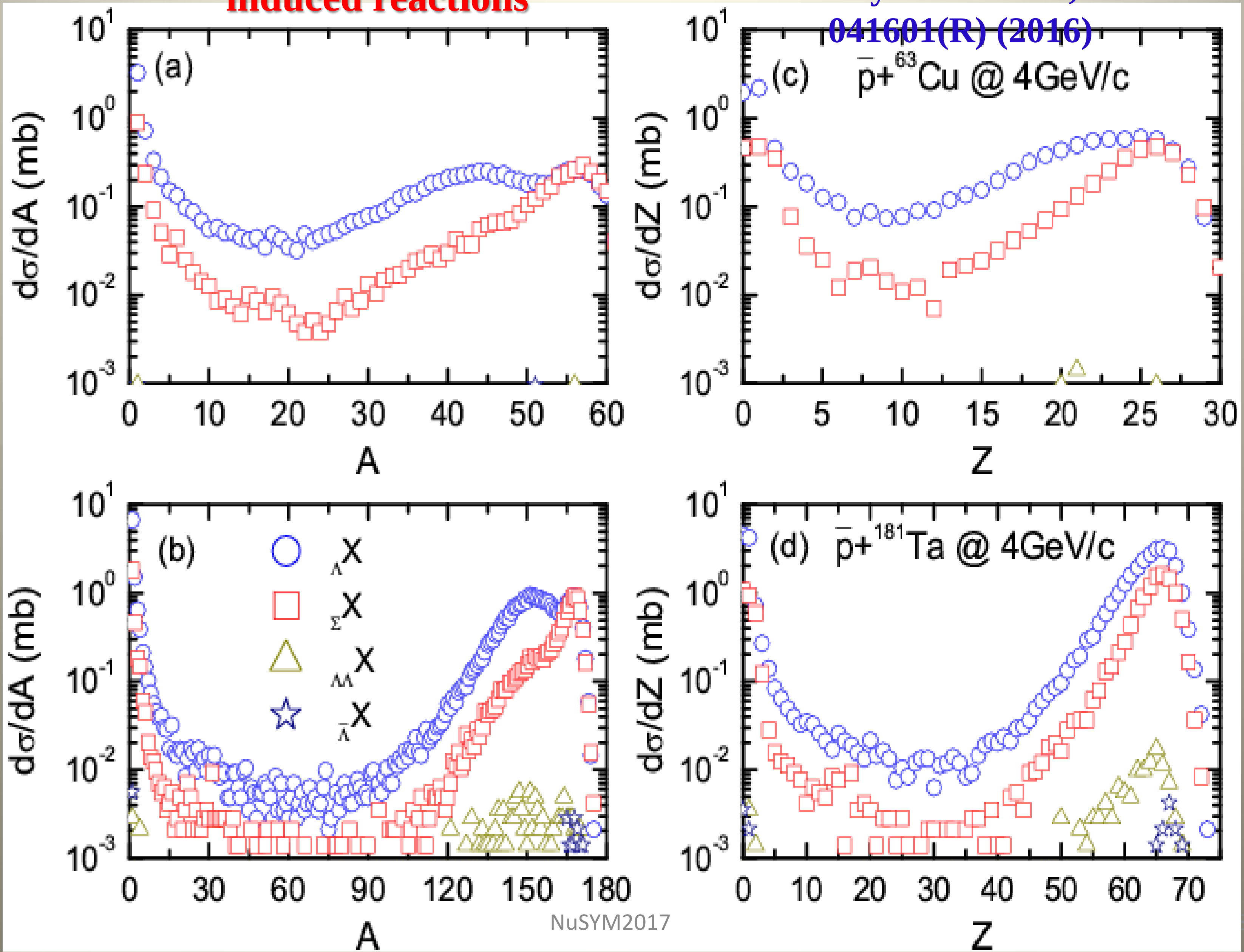




Hyperfragments production in the antiproton induced reactions

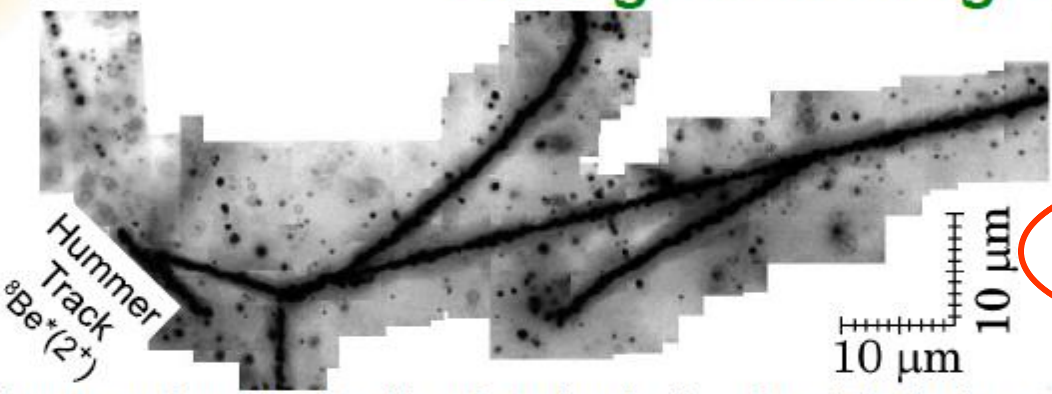
Zhao-Qing Feng

Phys. Rev. C 93, 041601(R) (2016)



hyperons in neutron stars (E07 @ J-Park)

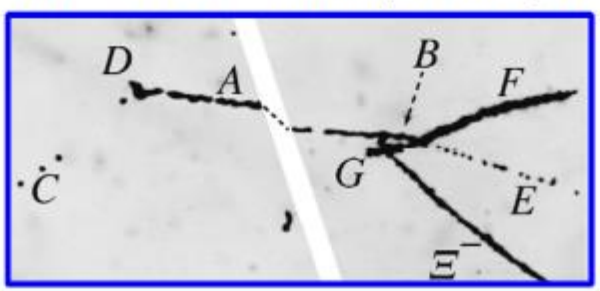
Under test operation of "Overall-scanning"
among 8 M micrographs

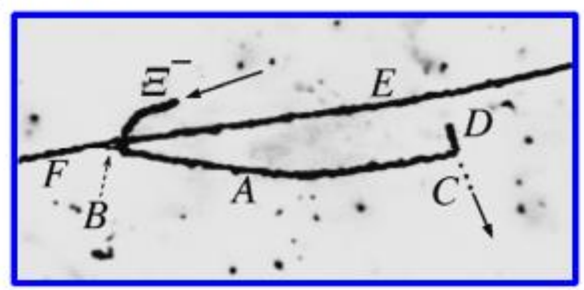


KISO event

Single hypernucleus emitted back-to-back direction (**Twin** hypernuclei event)
➔ Topology seems to be consistent with the past events of twin hypernuclei (E176).

Results of KEK-E176: S.Aoki et al., NP. A828 (2009) 191-232





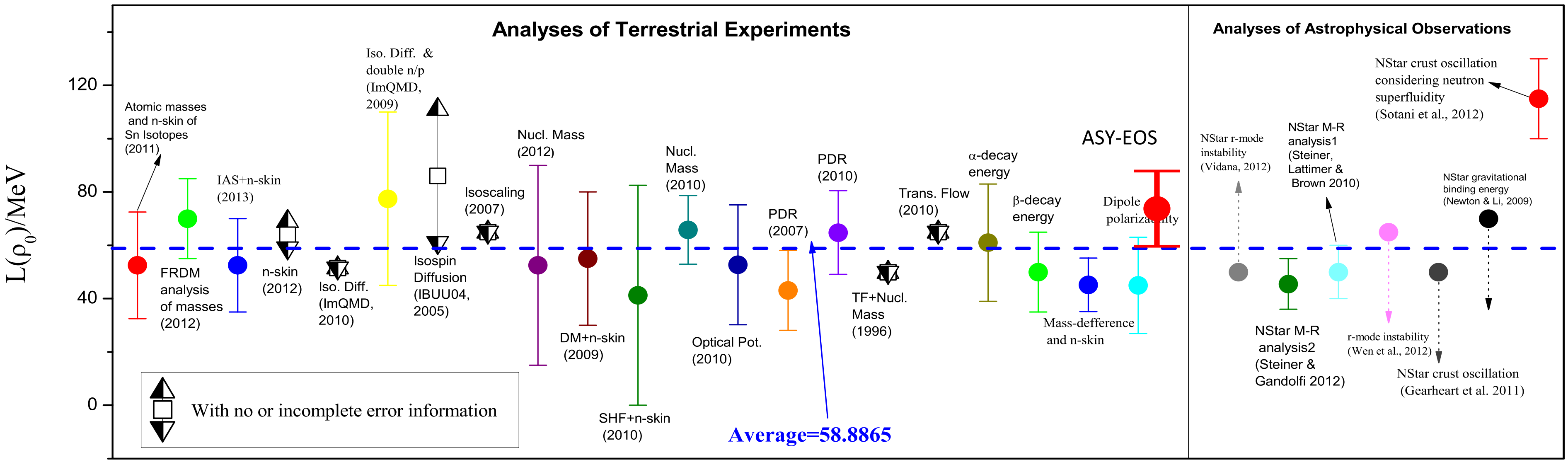
=> Consistent with Ξ^- capture reaction occurred on C, N or O.

source:
Kazuma Nakazawa, NSMAT2016, http://lambda.phys.tohoku.ac.jp/nstar/en/Information/NSMAT2016.html

the world average: L = 58.8865 MeV

Li and Han, PLB 727 (2013)

($L=3p_0/\rho_0$)



from **n-skins**

observation of neutron stars

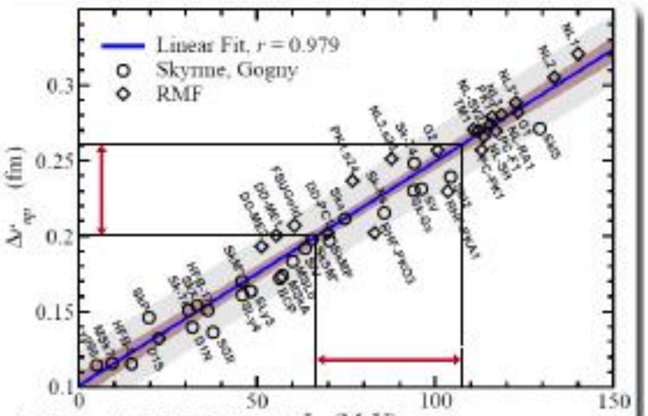
neutron skins
masses
collective excitations ⟵
isospin diffusion

Maria Colonna
Nils Paar

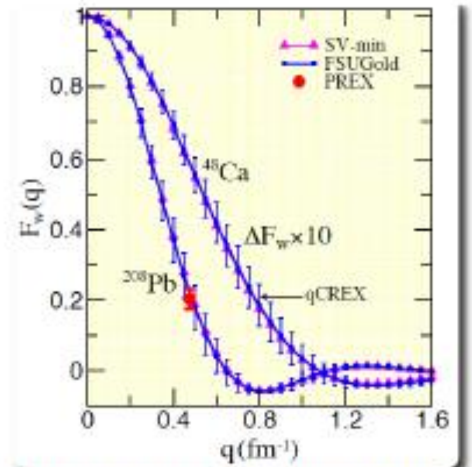
crust oscillations
r-mode instabilities
mass-radius analysis

Kent Paschke
Concettina Sfienti

MREX



X. Vinas et al., EPJA 50 (2014) 27



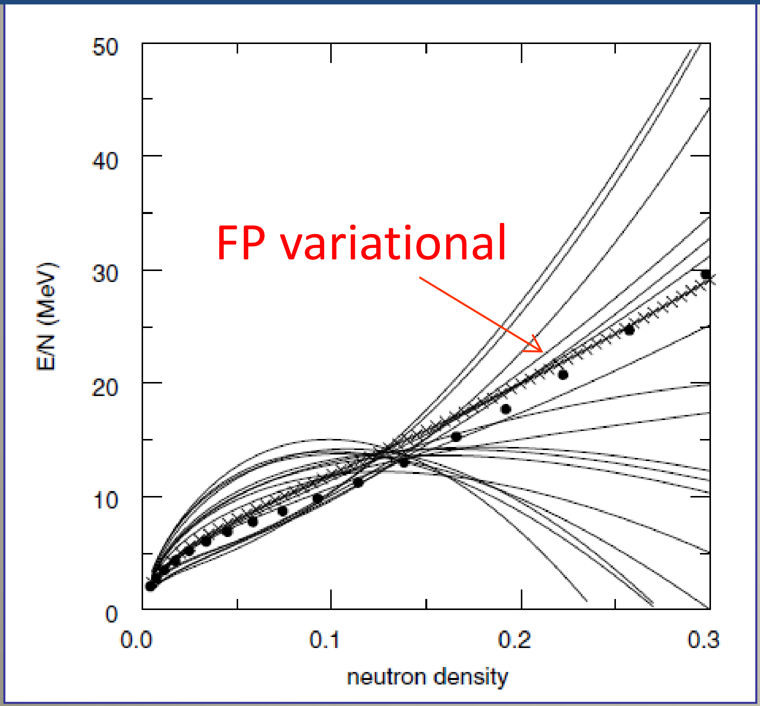
P.-G. Reinhard et al., Phys. Rev. C 88 (2013) 034325

- **PREX-II & CREX Results needed**
- **$\delta R_n/R_n$ = 0.5%**
  → L ± 20 MeV

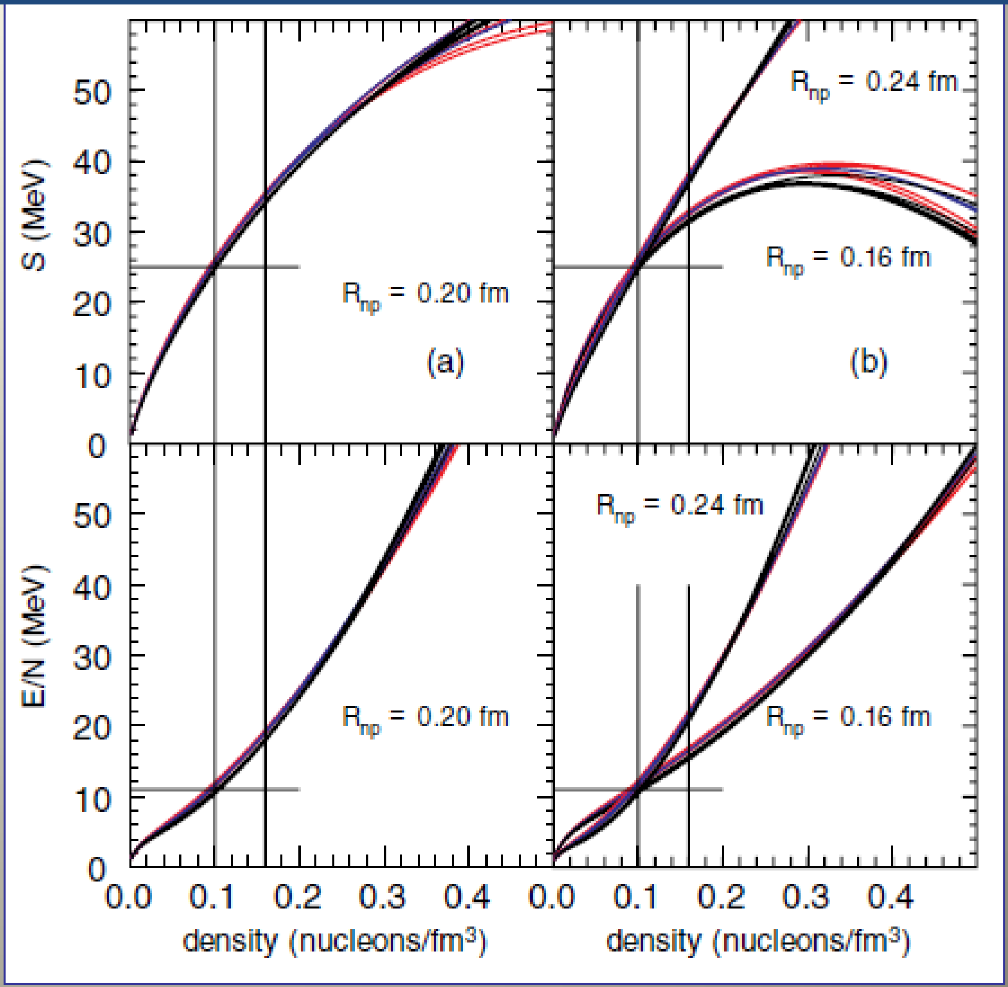
	^{208}Pb @ MREX	^{48}Ca @ MREX	PREX-II	CREX
E_{beam}	155 MeV / 105 MeV	155 MeV / 105 MeV	≈ 1 GeV	2.2 GeV
Q	86 MeV / 58 MeV 0.44 fm^{-1} / 0.29 fm^{-1}	143 MeV / 75 MeV 0.73 fm^{-1} / 0.38 fm^{-1}	86 MeV 0.44 fm^{-1}	154 MeV 0.78 fm^{-1}
$\delta A_{PV}/A_{PV}$	1.3%	1.3%	3.6%	2.4%
$\delta R_n/R_n$	0.52%	0.38%	1.0%	0.5%

Bill Lynch

sensitivity to density



Brown, PRL 85 (2000)



Brown, PRL 111 (2013)

13 Skyrme sets fitted to ground-state properties of doubly magic nuclei

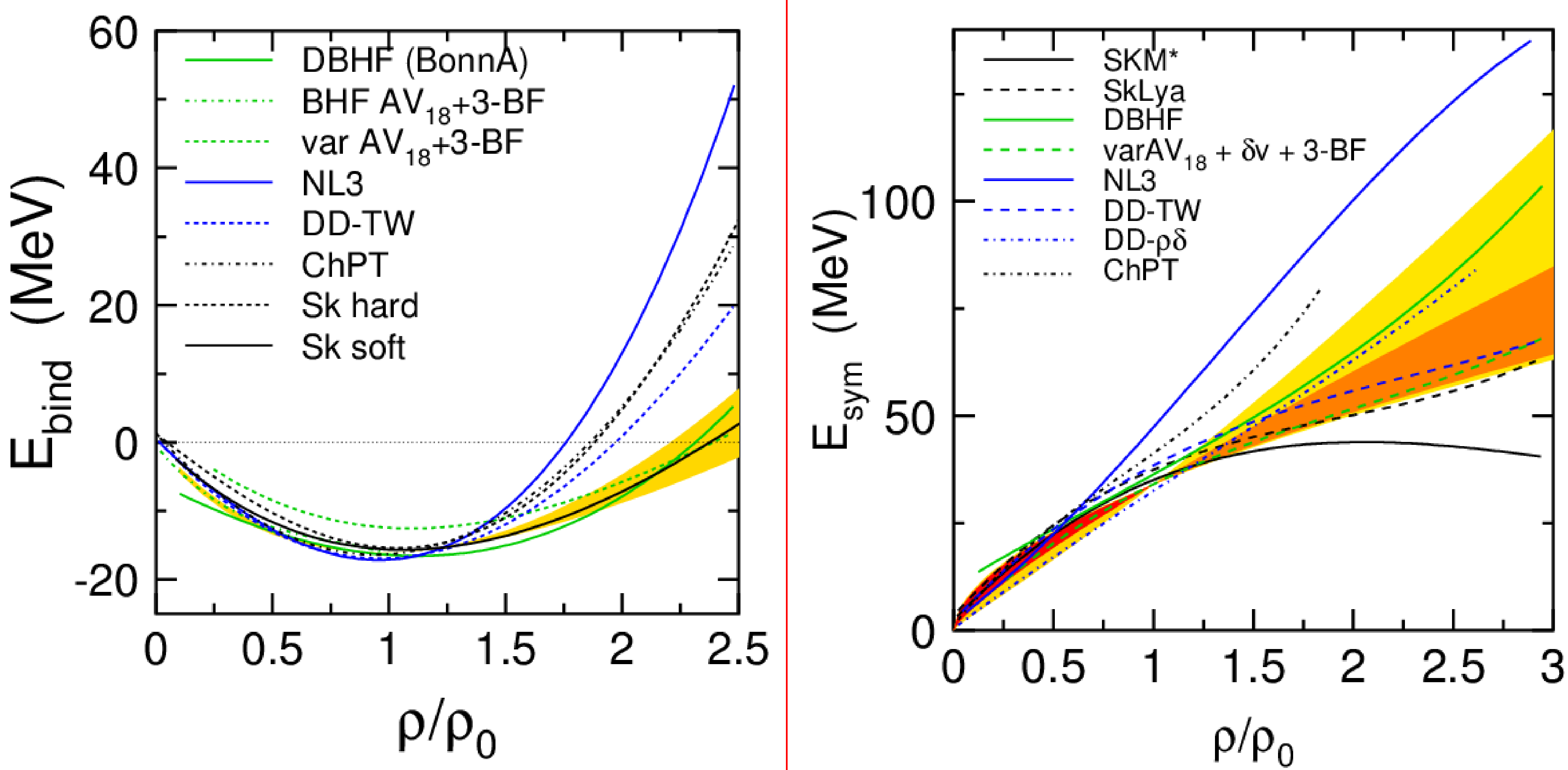
E_{sym} determined at 0.1 fm^{-3}

neutron skin determines slope at 0.1 fm^{-3}

Yvonne Leifels

status at present (GSI/FAIR)

FOPI ASY-EOS



model predictions from
Fuchs and Wolter,
EPJA 30 (2006)

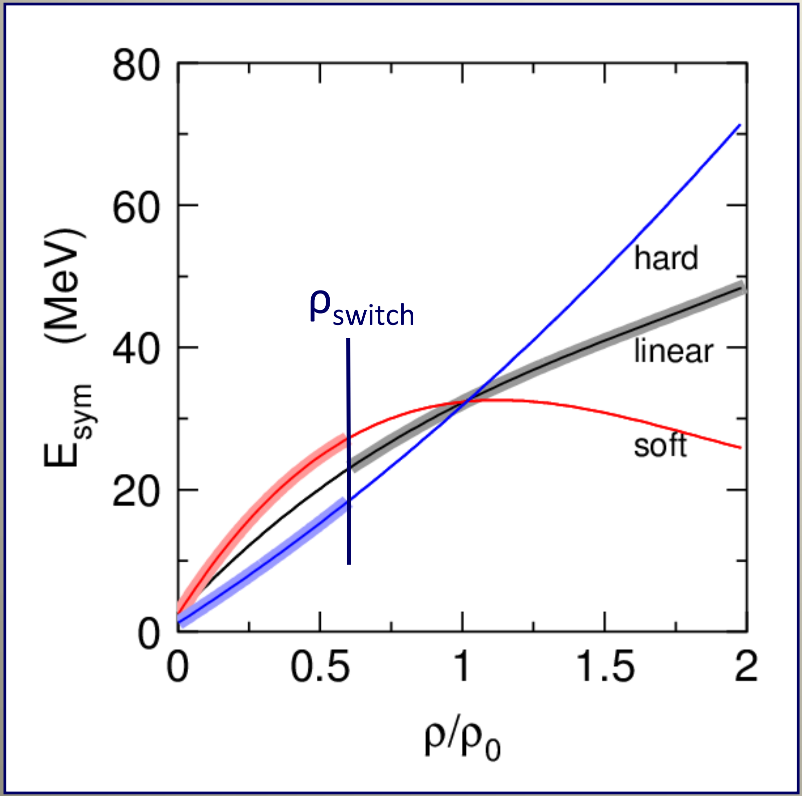
········ APR --------

graphics by Y. Leifels

sensitivity to density

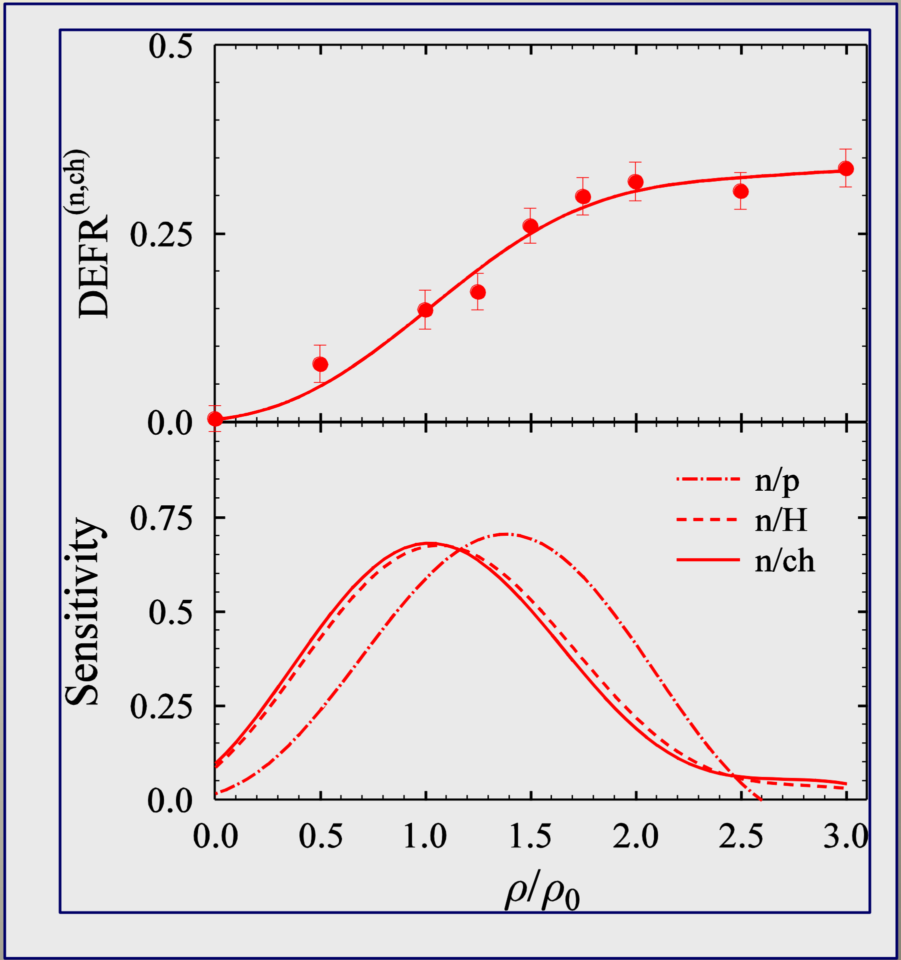
Yongjia Wang
Paolo Rusotto
Yvonne Leifels

Dan Cozma using Tübingen QMD



P. Russotto et al., PRC 94, 034608 (2016)

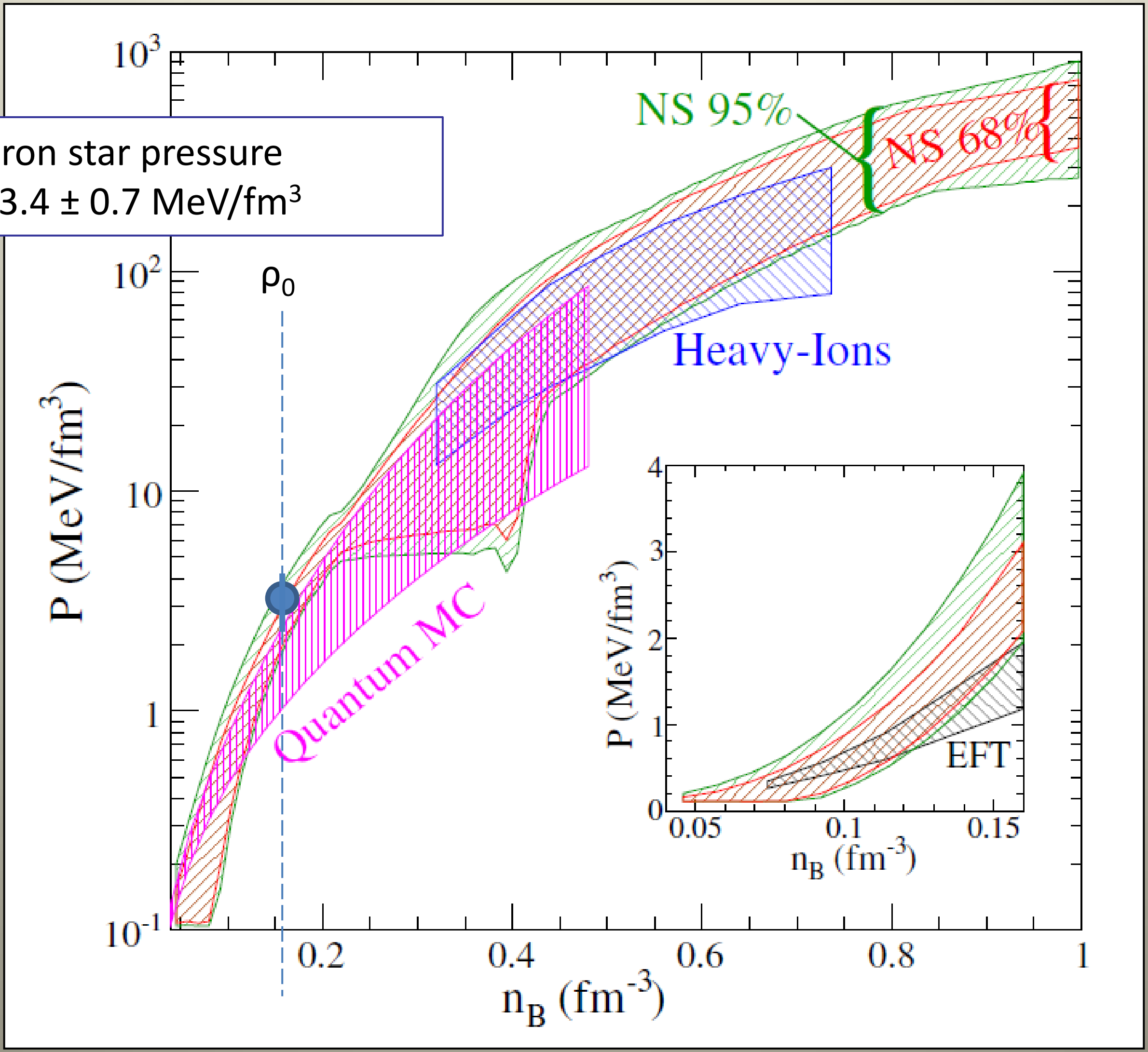
Difference of **E**lliptic-**F**lo



Bill Lynch

ASY-EOS: symmetry pressure p_0 = 3.8 ± 0.7 MeV/fm^3

neutron star pressure
p_0 = 3.4 ± 0.7 MeV/fm^3



Steiner, Lattimer, and Brown, ApJ 765, L5 (2013)

Paolo Rusotto

ASY-EOS II proposal

Proposal for Beam-time in 2018/2019

for

Determination of Symmetry Energy at Supra-Normal Densities: a feasibility study

Spokesperson: P. Russotto[1]

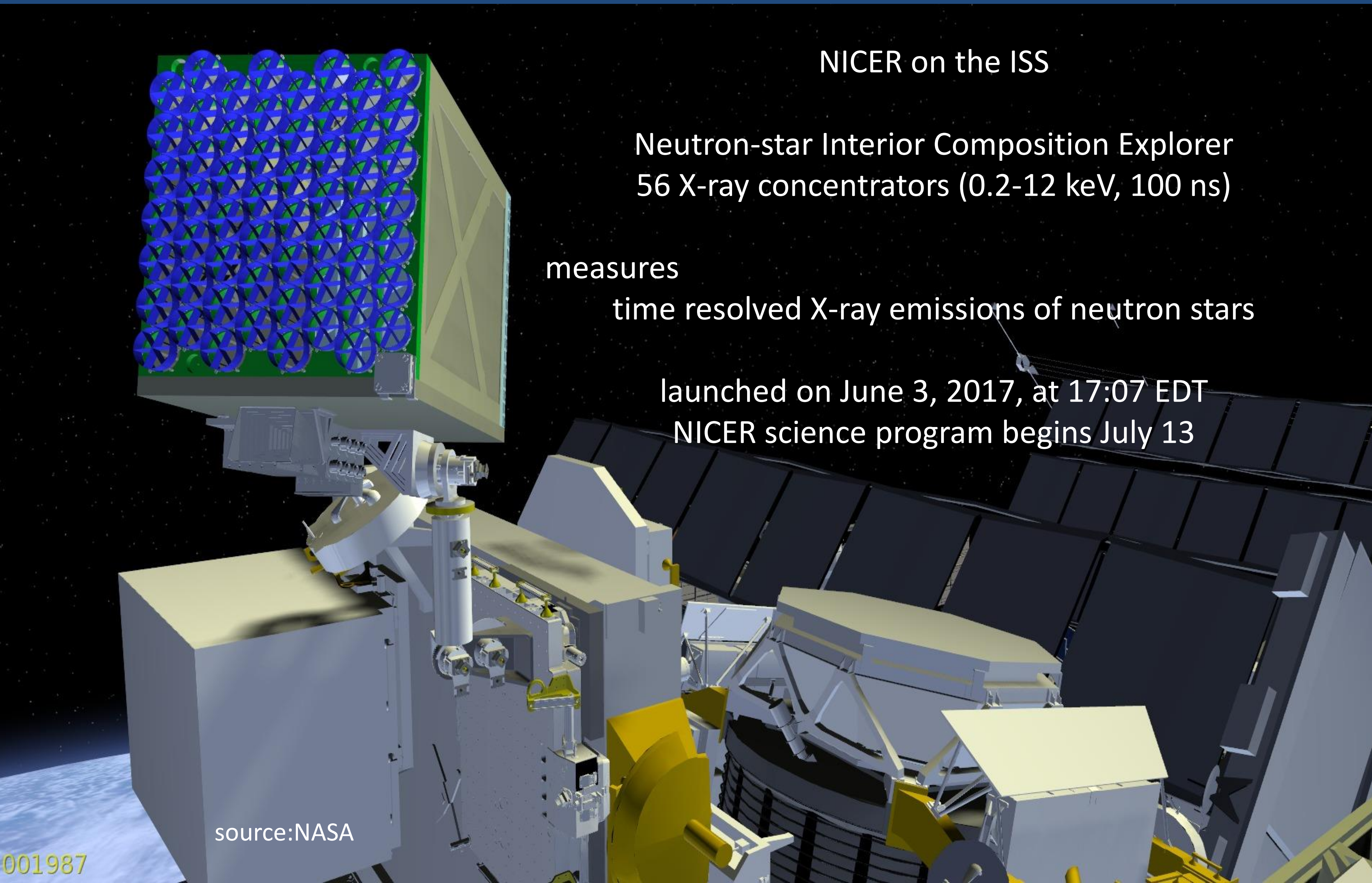
Principal Investigators: A. Le Fèvre[2], Y. Leifels[2], J. Łukasik[3], P. Russotto[1]

Participants: M. Adamczyk[4], J. Benlliure[5], E. Bonnet[6], J. Brzychczyk[4], Ch. Caesar[2], P. Cammarata[7], Z. Chajecki[8], A. Chbihi[9], E. De Filippo[11], M. Famiano[12], I. Gašparić[13], B. Gnoffo[11,20], C. Guazzoni[21], T. Isobe[14], M. Jabłoński[4], M. Jastrząb[3], J. Kallunkathariyil[22], K. Kezzar[15], M. Kiš[2], P. Koczoń[2], A. Krasznahorkay[16], P. Lasko[3], K. Łojek[4], W.G. Lynch[8], P. Marini[18], N.S. Martorana[1,20], A.B. McIntosh[7], T. Murakami[19], A. Pagano[11], E.V. Pagano[1,20], M. Papa[11], P. Pawłowski[3], G. Politi[11,20], K. Pysz[3], L. Quattrocchi[11,20], F. Rizzo[1,20], W. Trautmann[2], A. Trifirò[23], M. Trimarchi[23], M.B. Tsang[8], A. Wieloch[4] and S.J. Yennello[7]
Theory Support: J. Aichelin[6], M. Colonna[1], M.D. Cozma[10], P. Danielewicz[8], Ch. Hartnack[6], Q.F. Li[17] and Y. Wang[17]

Institutions: [1]INFN-LNS, Catania, Italy; [2]GSI, Darmstadt, Germany; [3]IFJ PAN, Kraków, Poland; [4]Jagiellonian University, Kraków, Poland; [5]Universidade de Santiago de Compostela, Spain; [6]SUBATECH, Nantes, France; [7]Texas A&M University Cyclotron Institute, College Station, USA; [8]NSCL/MSU, East Lansing, USA; [9]GANIL, Caen, France; [10]IFIN-HH, Bucharest, Romania; [11]INFN-Sezione di Catania, Italy; [12]Western Michigan University, Kalamazoo, MI, USA; [13]RBI, Zagreb, Croatia; [14]RIKEN, Wako-shi, Japan; [15]King Saud University, Riyadh, Saudi Arabia; [16]Institute for Nuclear Research, Debrecen, Hungary; [17]School of Science, Huzhou University, P.R. China; [18]CEA, DAM, DIF, Arpajon, France; [19]Kyoto University, Japan; [20]Università di Catania, Italy; [20] Politecnico di Milano and INFN-Sezione di Milano, Italy; [22]CEA, Saclay, France; [23]Dipartimento di Scienze MIFT, Univ. di Messina, Italy.

GSI-PAC in 2 weeks

opportunities for astrophysical observations



NICER on the ISS

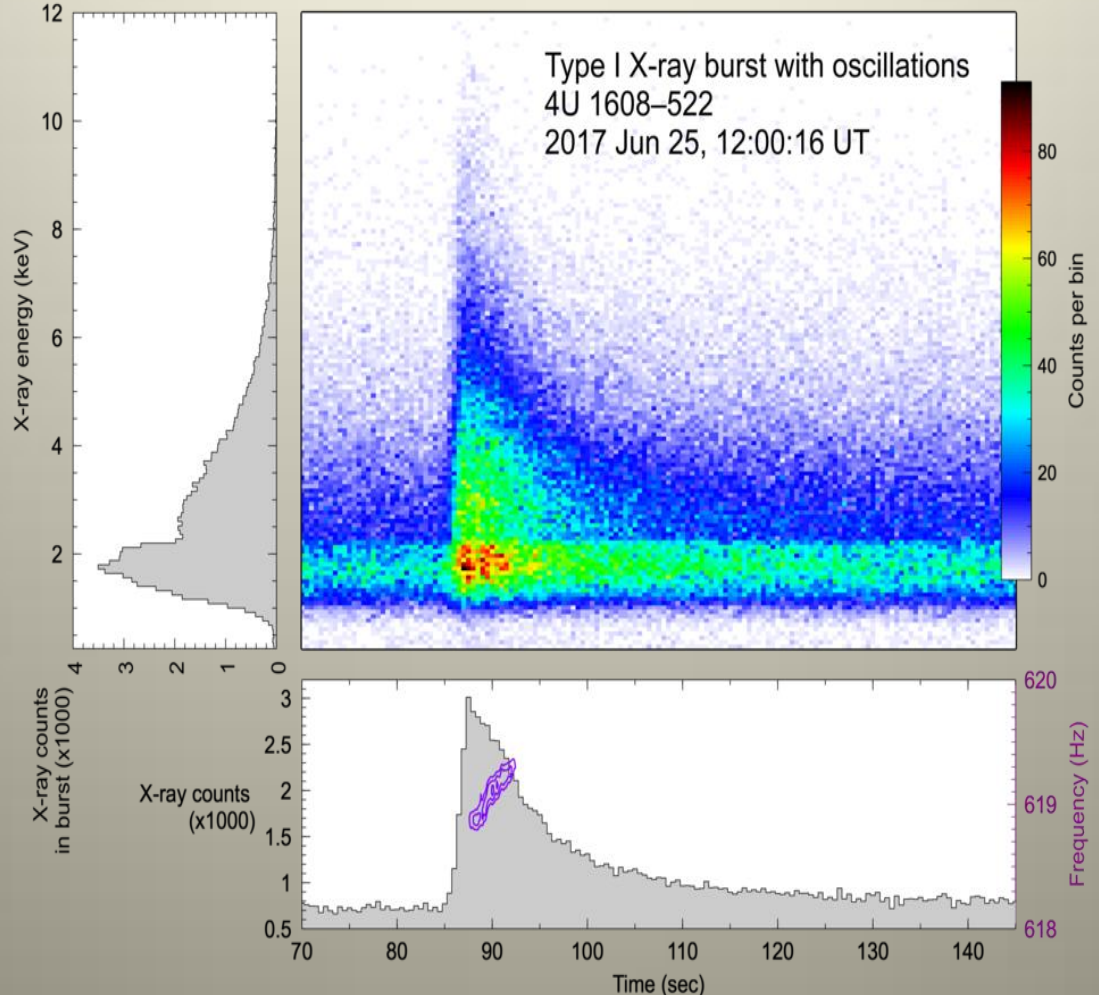
Neutron-star Interior Composition Explorer
56 X-ray concentrators (0.2-12 keV, 100 ns)

measures
time resolved X-ray emissions of neutron stars

launched on June 3, 2017, at 17:07 EDT
NICER science program begins July 13

source:NASA

Type I X-ray burst with oscillations, June 25, 2017

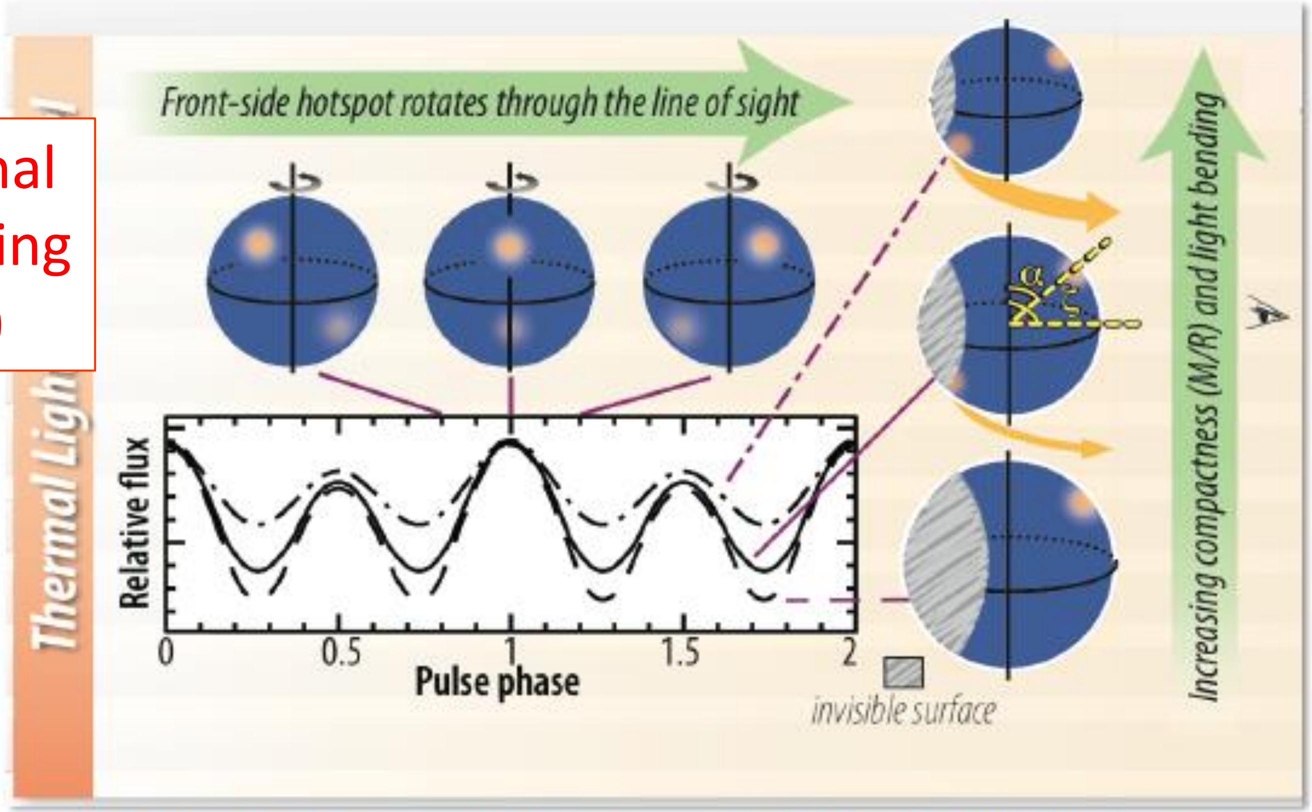


source:NASA

Science Measurements

NICER

Reveal stellar structure through lightcurve modeling, long-term timing, and pulsation searches



gravitational light bending ±5% (3σ)

Lightcurve modeling constrains the compactness (*M*/*R*) and viewing geometry of a non-accreting millisecond pulsar through the depth of modulation and harmonic content of emission from rotating hot-spots, thanks to gravitational light-bending…

EOS: lattice predictions

Nuclear phyics form QCD on lattice — Takashi Inoue

arXiv:1511.04871v4

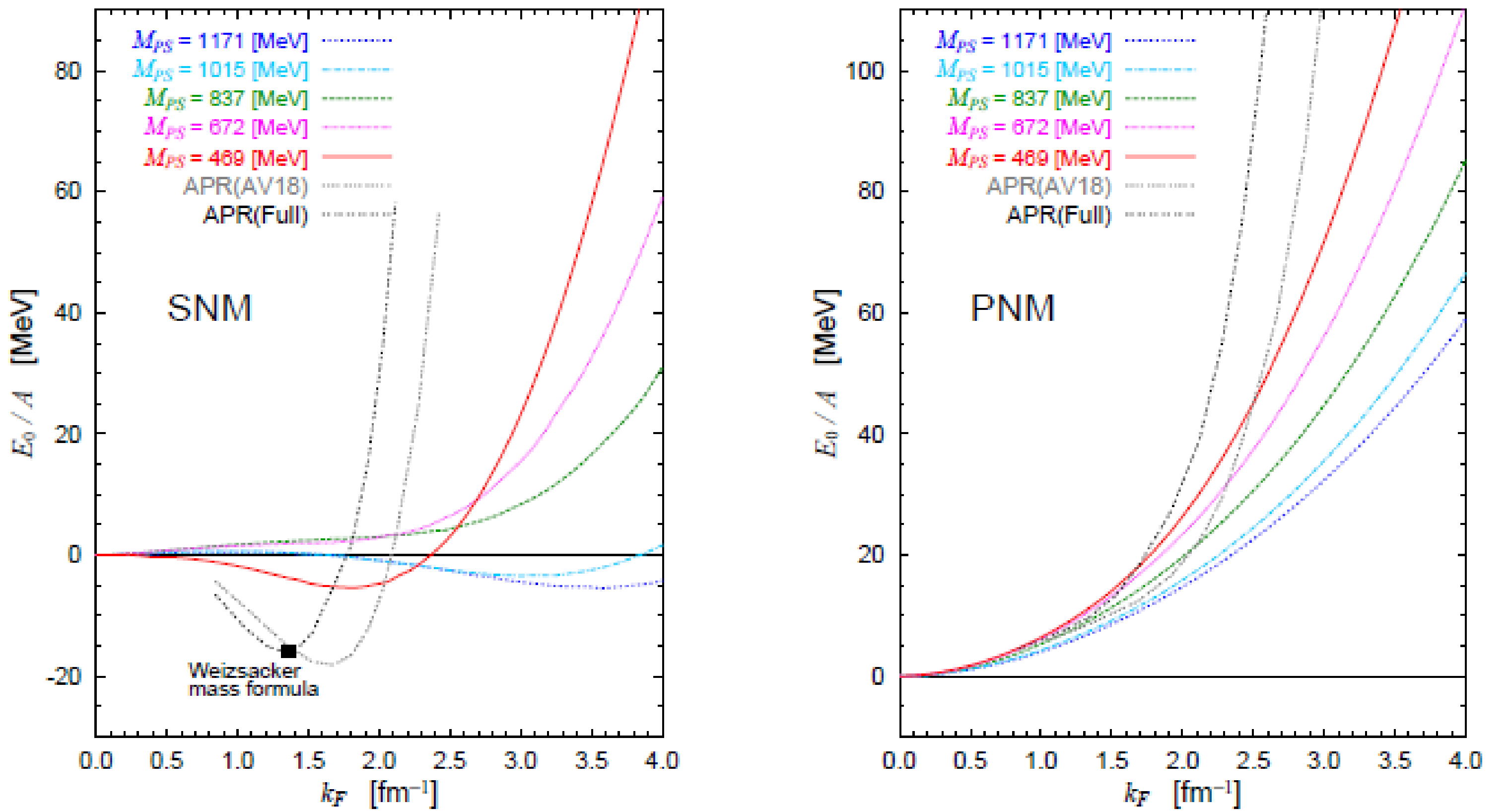


Figure 13: Ground state energy per nucleon E_0/A for symmetric nuclear matter in the left panel and pure neutron matter in the right panel, as a function of the Fermi momentum k_F. The empirical saturation point is also indicated in the left panel. The curves labeled APR are taken from ref. [39]

Byungsik Hong

NuSYM 2018

Sep. 12-15, (or May/June) 2018
Haeundae, Busan