

PAPER • OPEN ACCESS

Probing the Symmetry Term of the Nuclear Equation of State at High Baryonic Densities

To cite this article: P Russotto *et al* 2017 *J. Phys.: Conf. Ser.* **863** 012059

View the [article online](#) for updates and enhancements.

Related content

- [The ASY-EOS experiment at GSI: investigating the symmetry energy at supra-saturation densities](#)
P Russotto, M Chartier, E De Filippo *et al.*
- [Colour superconductivity in an external B](#)
Efrain J Ferrer, Vivian de la Incera and Cristina Manuel
- [Possible scenario for MaVaN's as the only neutrino flavor conversion mechanism in the Sun](#)
P.C. de Holanda



IOP | ebooks™

Bringing you innovative digital publishing with leading voices to create your essential collection of books in STEM research.

Start exploring the collection - download the first chapter of every title for free.

Probing the Symmetry Term of the Nuclear Equation of State at High Baryonic Densities

P Russotto¹, L Acosta^{2,3}, M Adamczyk⁴, A Al-Ajlan⁵, M Al-Garawi⁶, S Al-Homaidhi⁵, F Amorini², L Auditore^{7,8}, T Aumann^{9,10}, Y Ayyad¹¹, Z Basrak¹², J Benlliure¹¹, M Boisjoli¹³, K Boretzky¹⁰, J Brzychczyk⁴, A Budzanowski^{14,35}, C Caesar⁹, G Cardella¹, P Cammarata¹⁵, Z Chajęcki¹⁶, M Chartier¹⁷, A Chbihi¹⁰, M Colonna², M D Cozma¹⁸, B Czech¹⁴, E De Filippo¹, M Di Toro^{2,19}, M Famiano²⁰, S Gannon¹⁷, I Gašparić^{9,12}, L Grassi¹², C Guazzoni^{21,22}, P Guazzoni^{21,23}, M Heil¹⁰, L Heilborn¹⁵, R Introzzi²⁴, T Isobe²⁵, K Kezzar⁶, M Kiš¹⁰, A Krasznahorkay²⁶, S Kupny⁴, N Kurz¹⁰, E La Guidara¹, G Lanzalone^{2,27}, P Lasko⁴, A Le Fèvre¹⁰, Y Leifels¹⁰, R C Lemmon²⁸, QF Li²⁹, I Lombardo^{30,31}, J Łukasik¹⁴, W G Lynch¹⁶, P Marini^{13,15}, Z Matthews¹⁷, L May¹⁵, T Minniti¹, M Mostazo¹¹, A Pagano¹, E V Pagano^{2,19}, M Papa¹, P Pawłowski¹⁴, S Pirrone¹, G Politi^{1,19}, F Porto^{2,19}, W Reviol³², F Riccio^{21,22}, F Rizzo^{2,19}, E Rosato^{30,31,35}, D Rossi^{9,10}, S Santoro^{7,8}, D G Sarantites³², H Simon¹⁰, I Skwirczynska¹⁴, Z Sosin^{4,35}, L Stuhl²⁶, W Trautmann¹⁰, A Trifirò^{7,8}, M Trimarchi^{7,8}, M B Tsang¹⁶, G Verde¹, M Veselsky³³, M Vigilante^{30,31}, Yongjia Wang²⁹, A Wieloch⁴, P Wigg¹⁷, J Winkelbauer¹⁶, H H Wolter³⁴, P Wu¹⁷, S Yennello¹⁵, P Zambon^{21,22}, L Zetta^{21,23} and M Zoric¹²

¹INFN-Sezione di Catania, Catania, Italy

²INFN-Laboratori Nazionali del Sud, Catania, Italy

³Universidad Nacional Autónoma de México, Mexico

⁴Marian Smoluchowski Institute of Physics, Jagiellonian University, Kraków, Poland

⁵KACST Riyadh, Riyadh, Saudi Arabia

⁶King Saud University, Riyadh, Saudi Arabia

⁷INFN-Gruppo Collegato di Messina, Messina, Italy

⁸Università di Messina, Messina, Italy

⁹Technische Universität, Darmstadt, Germany

¹⁰GSI Helmholtzzentrum, Darmstadt, Germany

¹¹University of Santiago de Compostela, Santiago de Compostela, Spain

¹²Ruder Bošković Institute, Zagreb, Croatia

¹³GANIL, Caen, France

¹⁴H. Niewodniczański Institute of Nuclear Physics, Kraków, Poland

¹⁵Texas A&M University, College Station, USA

¹⁶NSCL Michigan State University, East Lansing, USA

¹⁷University of Liverpool, Liverpool, UK

¹⁸IFIN-HH, Magurele-Bucharest, Romania

¹⁹Università di Catania, Catania, Italy

²⁰Western Michigan University, USA

³⁵ deceased



Content from this work may be used under the terms of the [Creative Commons Attribution 3.0 licence](https://creativecommons.org/licenses/by/3.0/). Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI.

²¹INFN-Sezione di Milano, Milano, Italy²²Politecnico di Milano, Milano, Italy²³Università degli Studi di Milano, Milano, Italy²⁴INFN, Politecnico di Torino, Torino, Italy²⁵RIKEN, Wako, Japan²⁶Institute of Nuclear Research, Debrecen, Hungary²⁷Università Kore, Enna, Italy²⁸STFC Laboratory, Daresbury, UK²⁹Huzhou Teachers College, China³⁰INFN-Sezione di Napoli, Napoli, Italy³¹Università di Napoli, Napoli, Italy³²Washington University, St. Louis, USA³³Institute of Physics, Slovak Academy of Sciences, Bratislava, Slovakia³⁴LMU, München, Germany

E-mail: russotto@lns.infn.it

Abstract. In the ASY-EOS experiment flows of neutrons and light charged particles were measured for $^{197}\text{Au}+^{197}\text{Au}$ collisions at 400 MeV/nucleon, in order to investigate the strength of the symmetry term of the nuclear equation of state at supra-saturation densities. By comparing the experimental data with the UrQMD transport model predictions, we have extracted a new constraint in agreement with the moderately soft to linear density dependence obtained in the former analysis on FOPI-LAND data, but reducing the associated uncertainty by a factor ~ 2 .

1. ASY-EOS experiment results

The neutron-proton elliptic flow ratio has proved to be an effective probe of the high-density behavior of the symmetry energy contribution to nuclear equation of state [1]. By comparing data for the Au+Au system from the FOPI-LAND experiment [2] with calculations performed with the UrQMD transport model [3], an estimate of a moderately soft to linear behavior of the symmetry energy was obtained, although with a considerable statistical uncertainty. The same data set was also compared to calculations performed with the Tübingen QMD model and a constraint compatible with the UrQMD result was obtained [4]. It is worth pointing that in the latter study different parameterizations of the isovector part of the equation of state, the Gogny inspired (momentum dependent) vs. the power law (momentum independent) potential, lead to

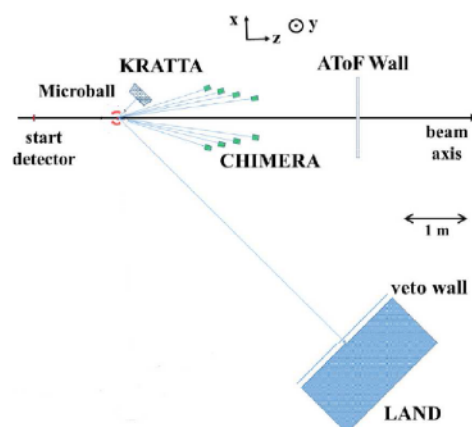


Figure 1. Schematic view of the experimental set-up of the ASY-EOS experiment at GSI.

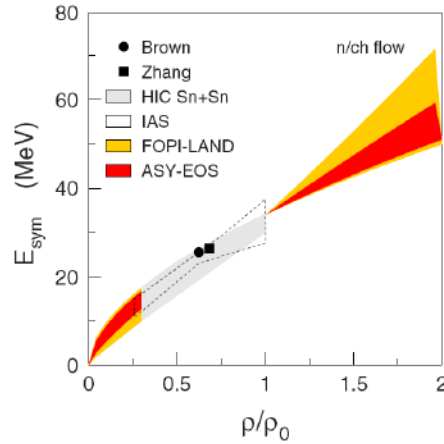


Figure 2. Constraints deduced for the density dependence of the symmetry energy from the ASY-EOS experiment in comparison with the FOPI-LAND result of Ref. [1] as a function of the reduced density ρ/ρ_0 . See Ref. [10] for more details.

very similar results, suggesting the possibility to obtain a model independent constraint.

In order to improve the statistical accuracy, the neutron-charged particles elliptic flow ratio in the symmetric collision system $^{197}\text{Au}+^{197}\text{Au}$ at 400 MeV/nucleon incident energies was re-measured in the ASY-EOS experiment, carried out at the GSI laboratory in May 2011 (S394 experiment), by coupling the Large Area Neutron Detector (LAND) [5], the Kraków Triple Telescope Array (KRATTA) [6], the ALADIN Time-of-Flight (AToF) wall [7], 8 rings of the CHIMERA multidetector [8] and 4 rings of the Washington-University Microball array [9], as schematically shown in Fig. 1. More details can be found in Ref. [10].

By comparing the experimental ratio with the UrQMD predictions, a value $\gamma=0.72\pm0.19$ is obtained for the power-law coefficient of the potential part of the symmetry energy parametrization adopted in the UrQMD model, as shown in Fig. 2 ; the density region probed is $\sim 1.5 \rho_0$. This new result agrees with the older one from the FOPI-LAND data, but reduces by a factor ~ 2 the total uncertainty.

The results of the ASY-EOS experiment confirms the effectiveness of the elliptic flows ratio in probing the symmetry energy at high-densities. We plan to extend such a kind of measurements at GSI to higher beam energies, up to ~ 1 GeV/nucleon, in order to explore higher densities (up to about $2.5 \rho_0$), profiting of the unique opportunity offered by the NeuLAND detector, presently under construction as part of the R3B experimental setup [11] and the availability of very asymmetric radioactive ion beams that will be delivered by the FAIR facility.

References

- [1] Russotto P *et al* 2011 *Phys. Lett. B* **697** 471; Russotto P *et al* 2014 *Eur. Phys. Jour. A* **50** 38
- [2] Leifels Y *et al* 1993 *Phys. Rev. Lett.* **71** 963
- [3] Li Q *et al* 2005 *J. Phys G* **31** 1359
- [4] Cozma M D *et al* 2013 *Phys. Rev. C* **88** 044912
- [5] Blaich Th *et al* 1992 *Nucl. Instr. and Meth. A* **314** 136
- [6] Łukasik J *et al* 2013 *Nucl. Instr. and Meth. A* **709** 120
- [7] Schütttauf A *et al* 1996 *Nucl. Phys. A* **607** 457
- [8] Pagano A *et al* 2004 *Nucl. Phys. A* **734** 504
- [9] Sarantites D G *et al* 1996 *Nucl. Instr. and Meth.* **381** 418
- [10] Russotto P *et al* 2016 *Phys. Rev. C* **94** 034608
- [11] see <https://www.gsi.de/r3b>.