

Projectile Fragmentation of ^{86}Kr at RIKEN

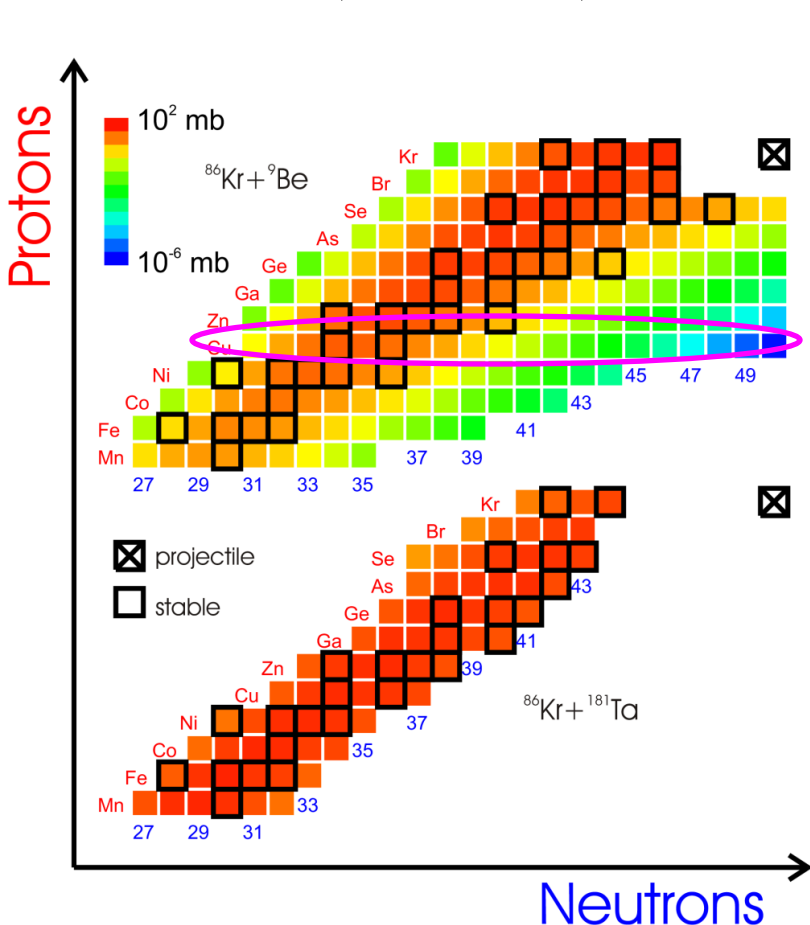
M. Mocko, M. B. Tsang, Z. Y. Sun, N. Aoi, J. M. Cook, F. Delaunay, M. A. Famiano, H. Hui, N. Imai, H. Iwasaki, W. G. Lynch, T. Motobayashi, M. Niikura, T. Onishi, A. M. Rogers, H. Sakurai, A. Stolz, H. Suzuki, E. Takeshita, S. Takeuchi, and M. S. Wallace



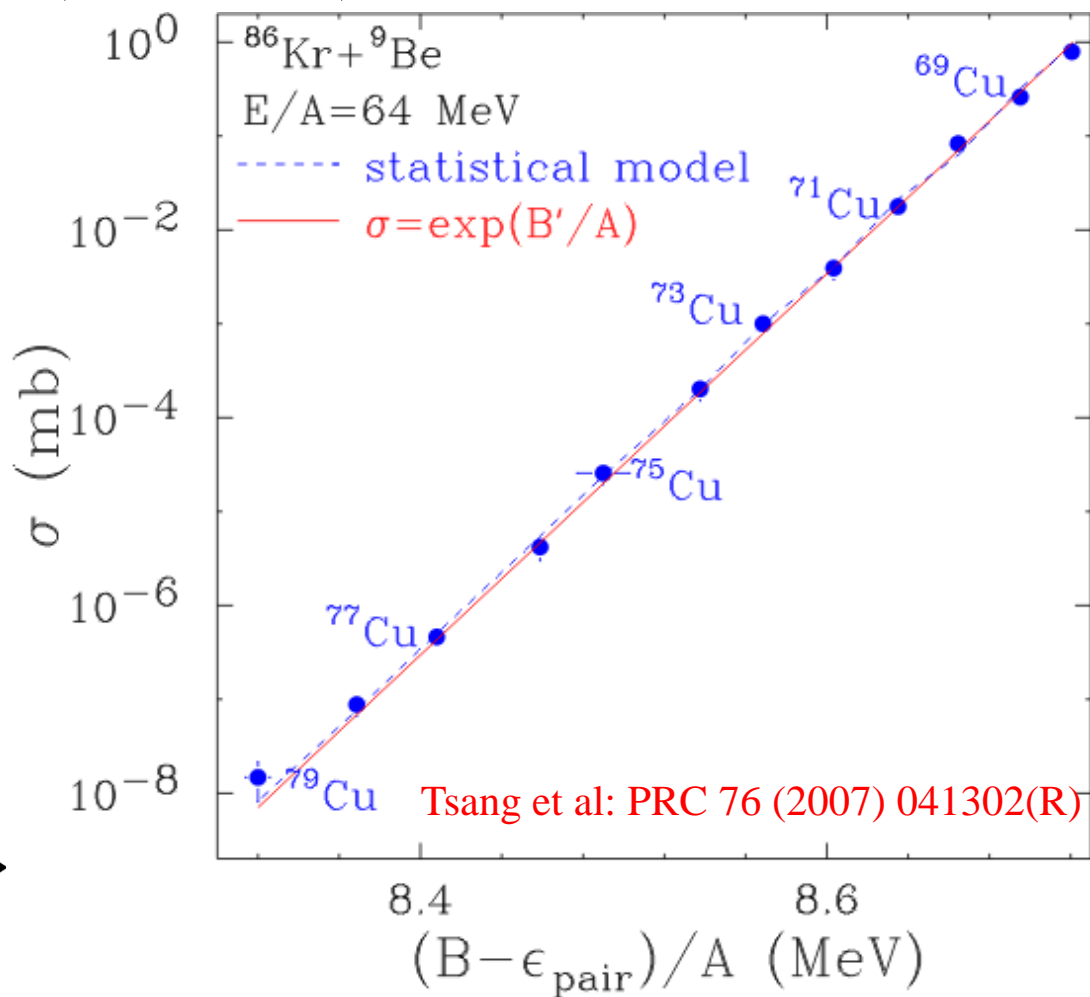
May 2004

Projectile Fragmentation ^{86}Kr at RIKEN

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Tsang et al: PRC 76 (2007) 014609



Symmetry Energy Project

Outline:

- 1. Scientific goals of SEP*
- 2. SEP's plan in RIKEN*
- 3. Funding plans for SEP*
- 4. Objectives of JUSEIPEN*

JUSEIPEN Work Shop, Berkeley, USA
Sept 9-10, 2009



Betty Tsang

The National Superconducting
Cyclotron Laboratory
Michigan State University

Nuclear Equation of State

$$\begin{aligned} E/A(\rho, \delta) &= E/A(\rho, 0) + \delta^2 \cdot S(\rho) \\ \delta &= (\rho_n - \rho_p) / (\rho_n + \rho_p) = (N - Z) / A \end{aligned}$$

$$E_{sym} = S_o + \frac{L}{3} \left(\frac{\rho_B - \rho_0}{\rho_0} \right) + \frac{K_{sym}}{18} \left(\frac{\rho_B - \rho_0}{\rho_0} \right)^2 + \dots$$

$$L = 3\rho_0 \left. \frac{\partial E_{sym}}{\partial \rho_B} \right|_{\rho_B = \rho_0} = \frac{3}{\rho_0} P_{sym}$$

Research with rare isotope beams

- ✓ *Nuclear Structure – What is the nature of the nuclear force that binds protons and neutrons into stable nuclei and rare isotopes?*
- ✓ *Nuclear Astrophysics – What is the nature of neutron stars and dense nuclear matter? What is the origin of elements heavier than iron in the cosmos? What are the nuclear reactions that drive stars and stellar explosions?*
- ✓ *Tests of Fundamental Symmetries – Why is there now more matter than antimatter in the universe?*

Nuclear Equation of State

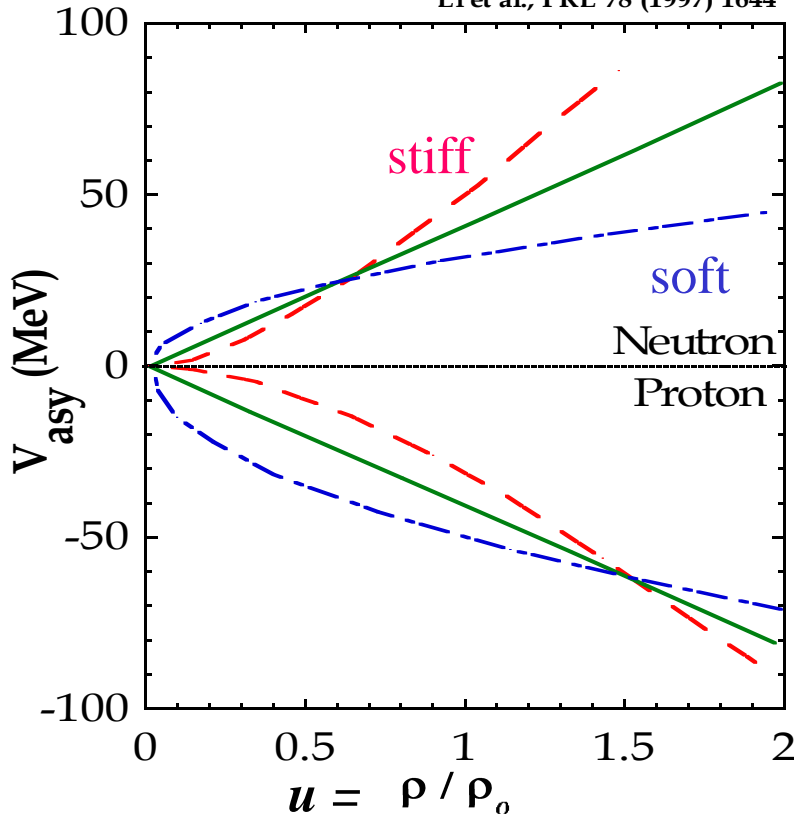
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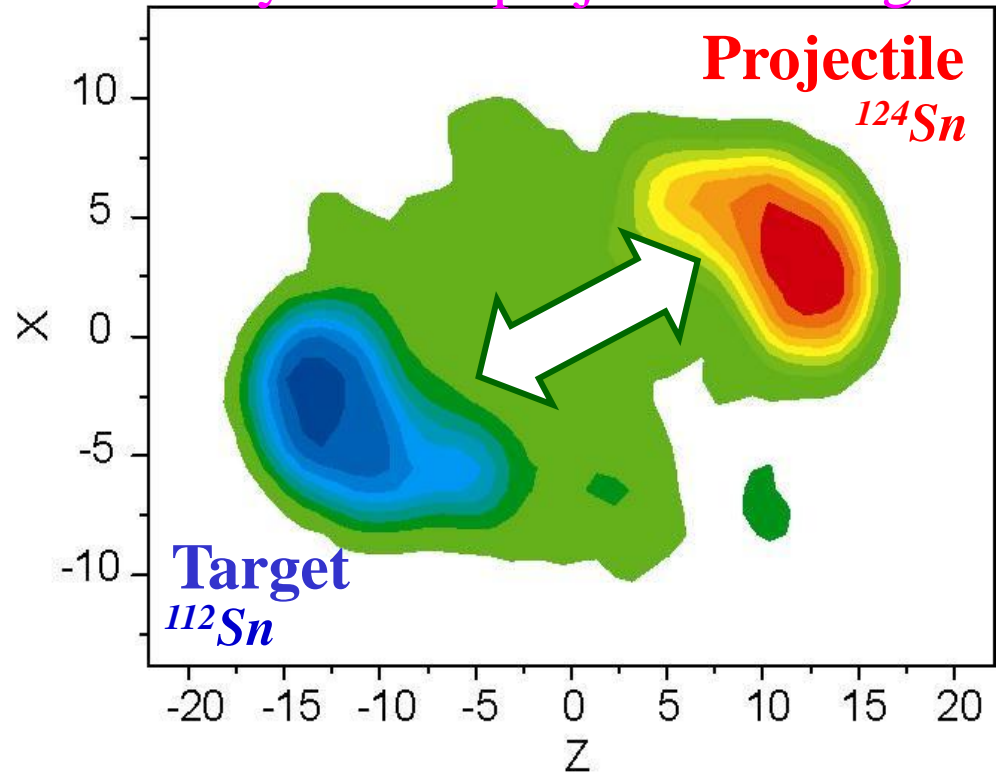
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Li et al., PRL 78 (1997) 1644



$Y(n)/Y(p); t^3\text{He}, \pi^+/\pi^-$
 $\rho, E_{beam} \longrightarrow$

Vary N/Z of projectile & target

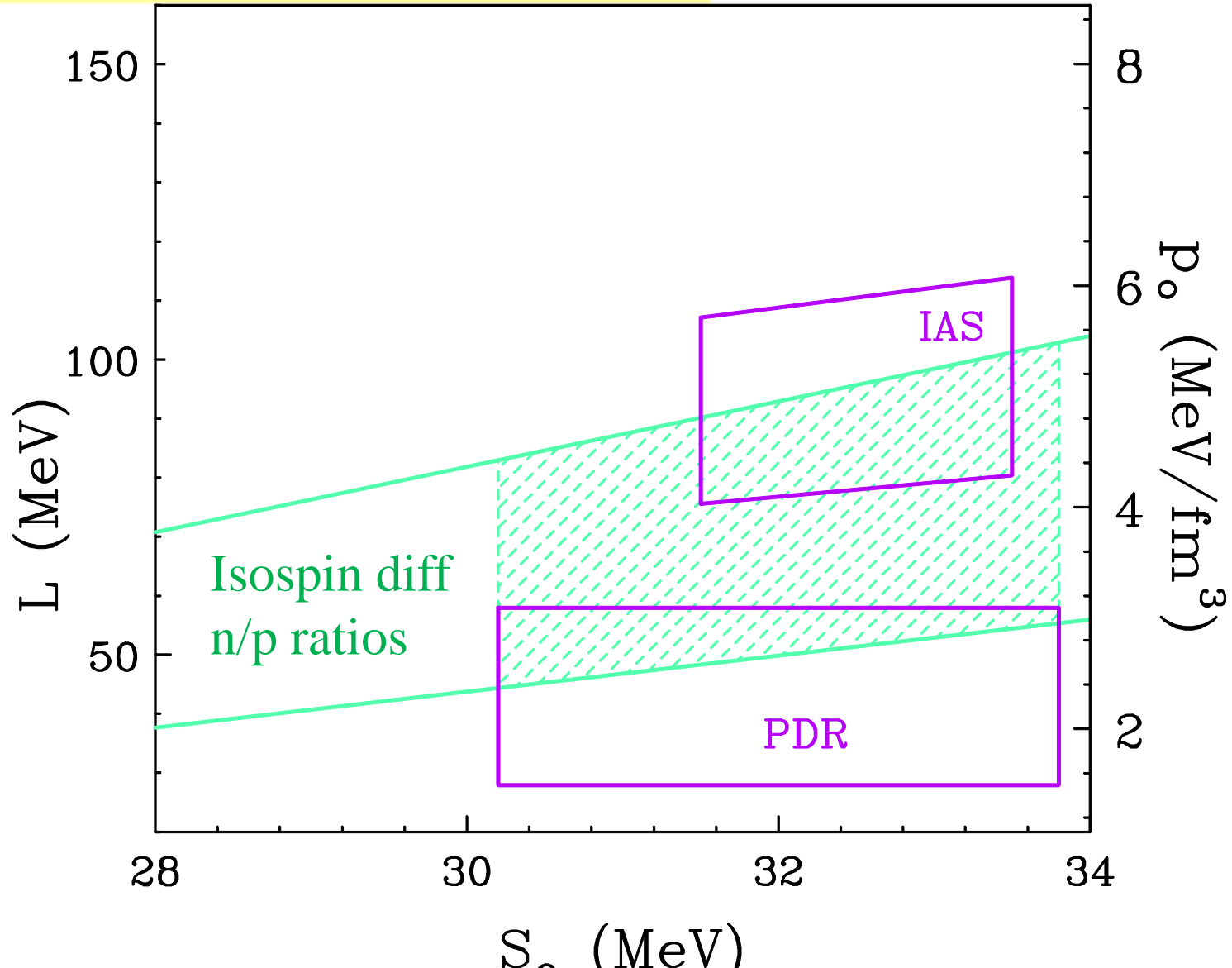


Isospin Diffusion; low ρ, E_{beam}

Current constraints on symmetry energy from HIC

$$E_{sym} = S_o + \frac{L}{3} \left(\frac{\rho_B - \rho_0}{\rho_0} \right) + \frac{K_{sym}}{18} \left(\frac{\rho_B - \rho_0}{\rho_0} \right)^2 + \dots$$

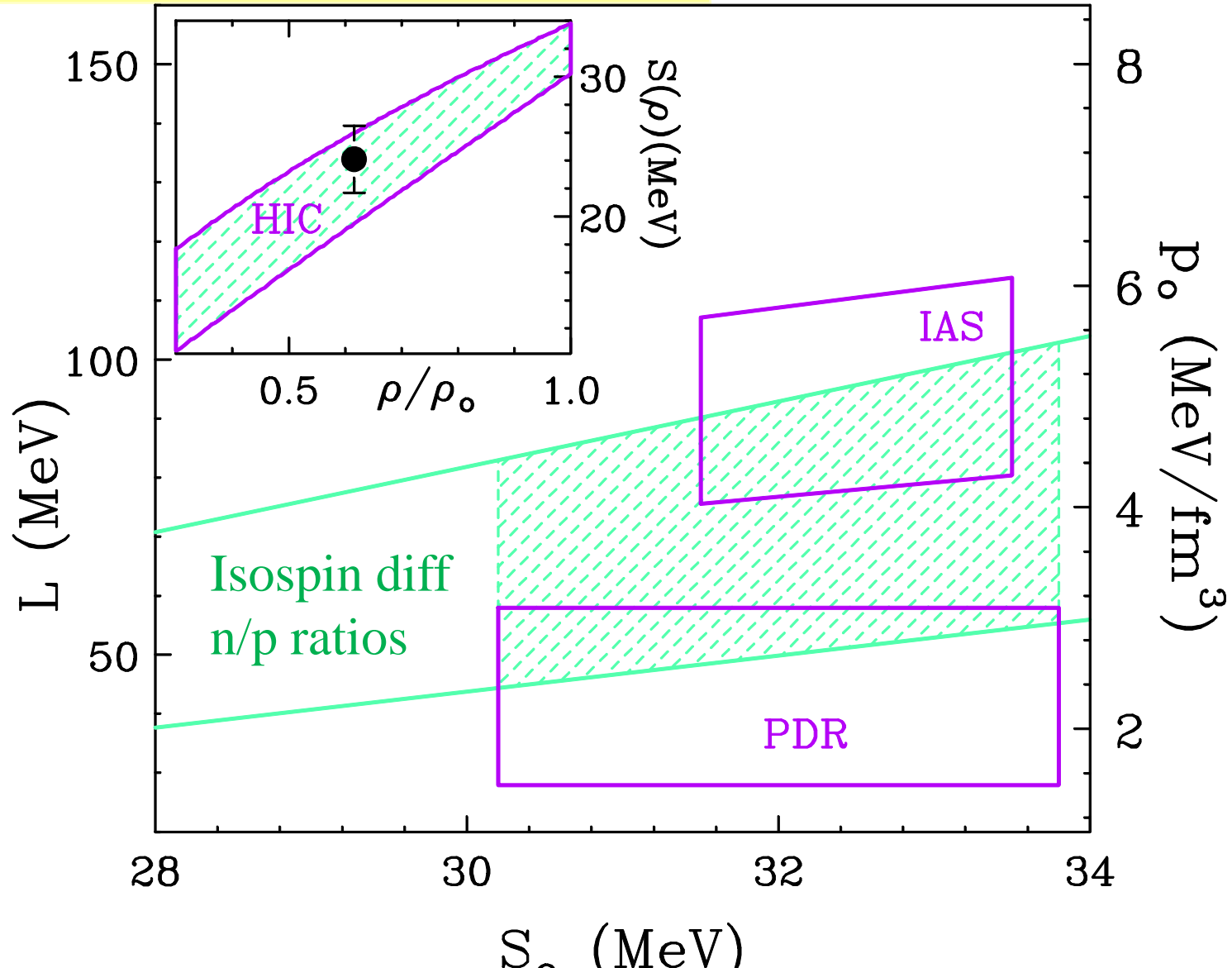
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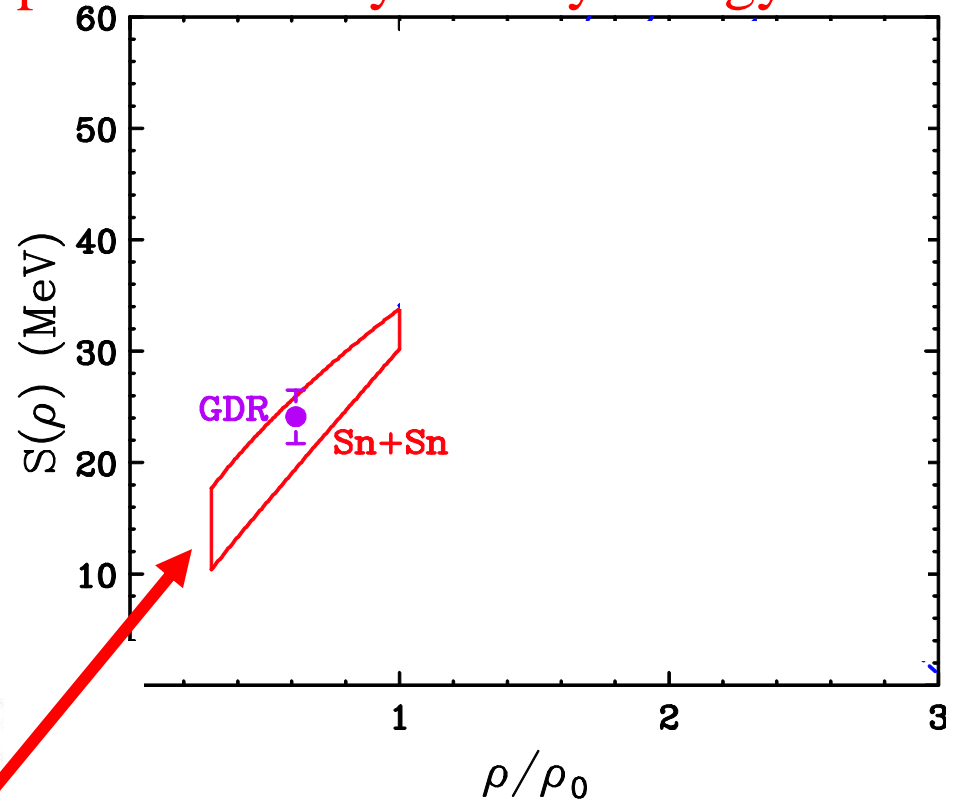
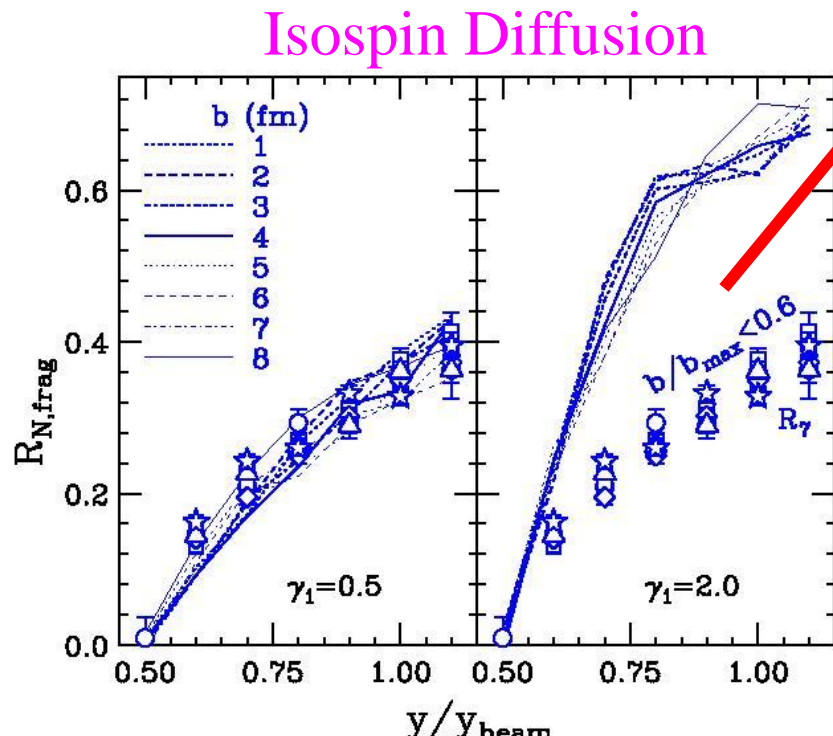
Current constraints on symmetry energy from HIC

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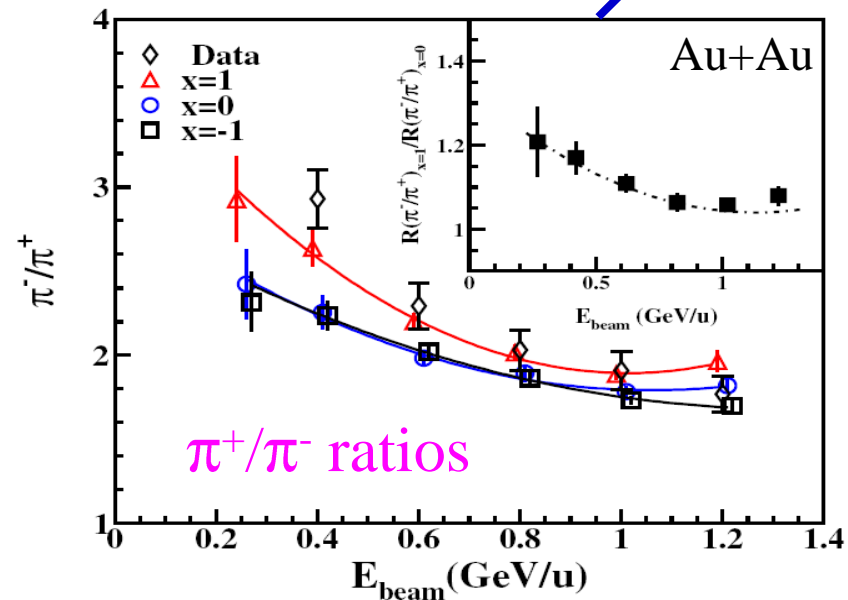
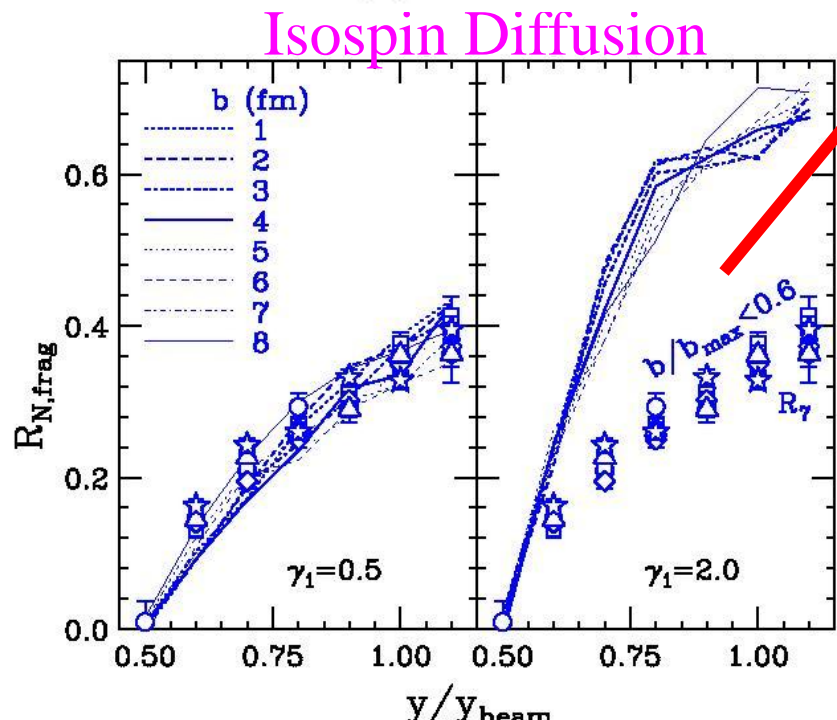
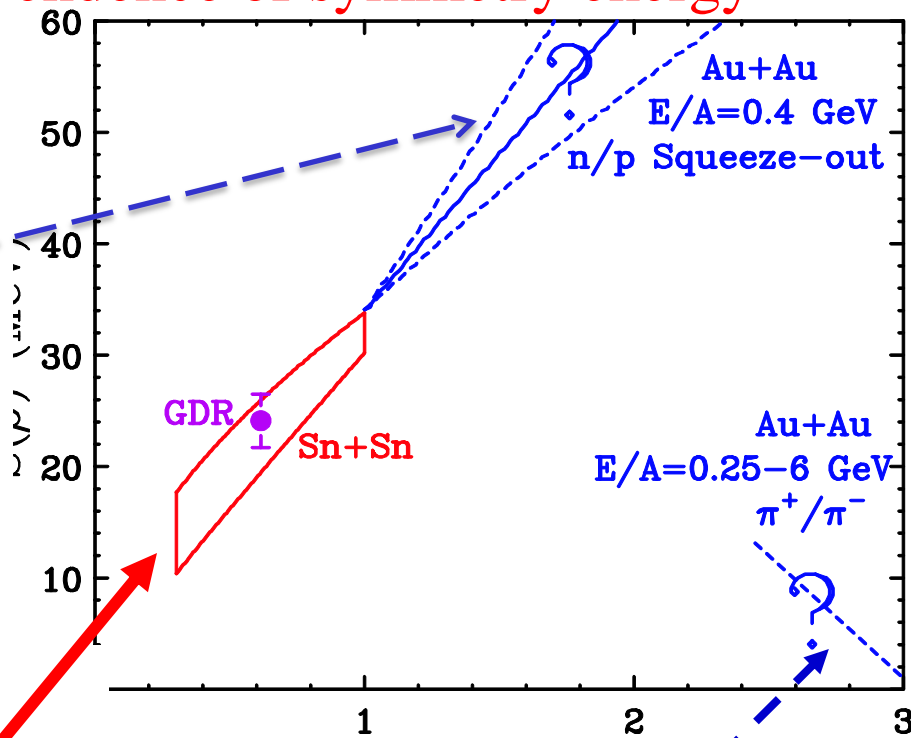
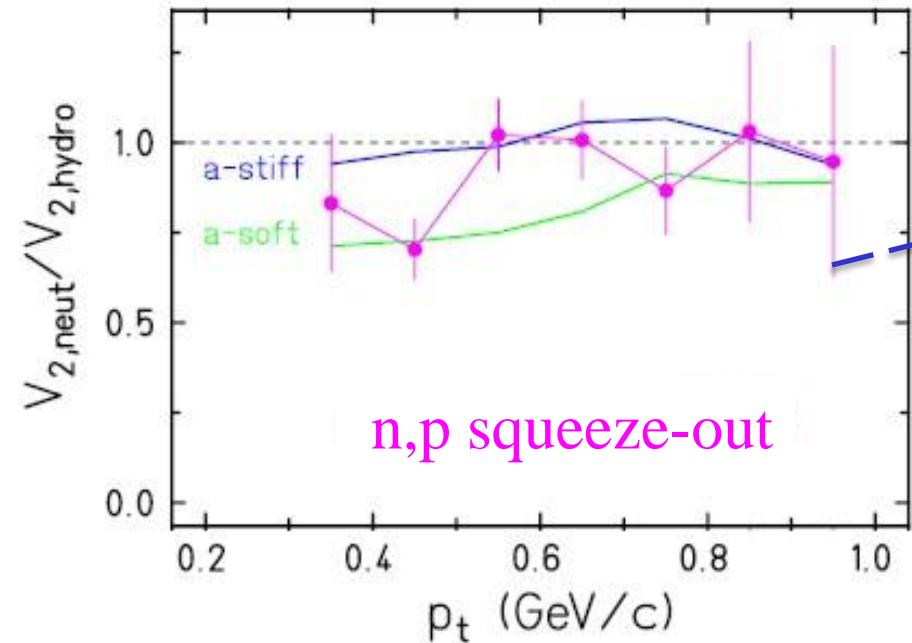
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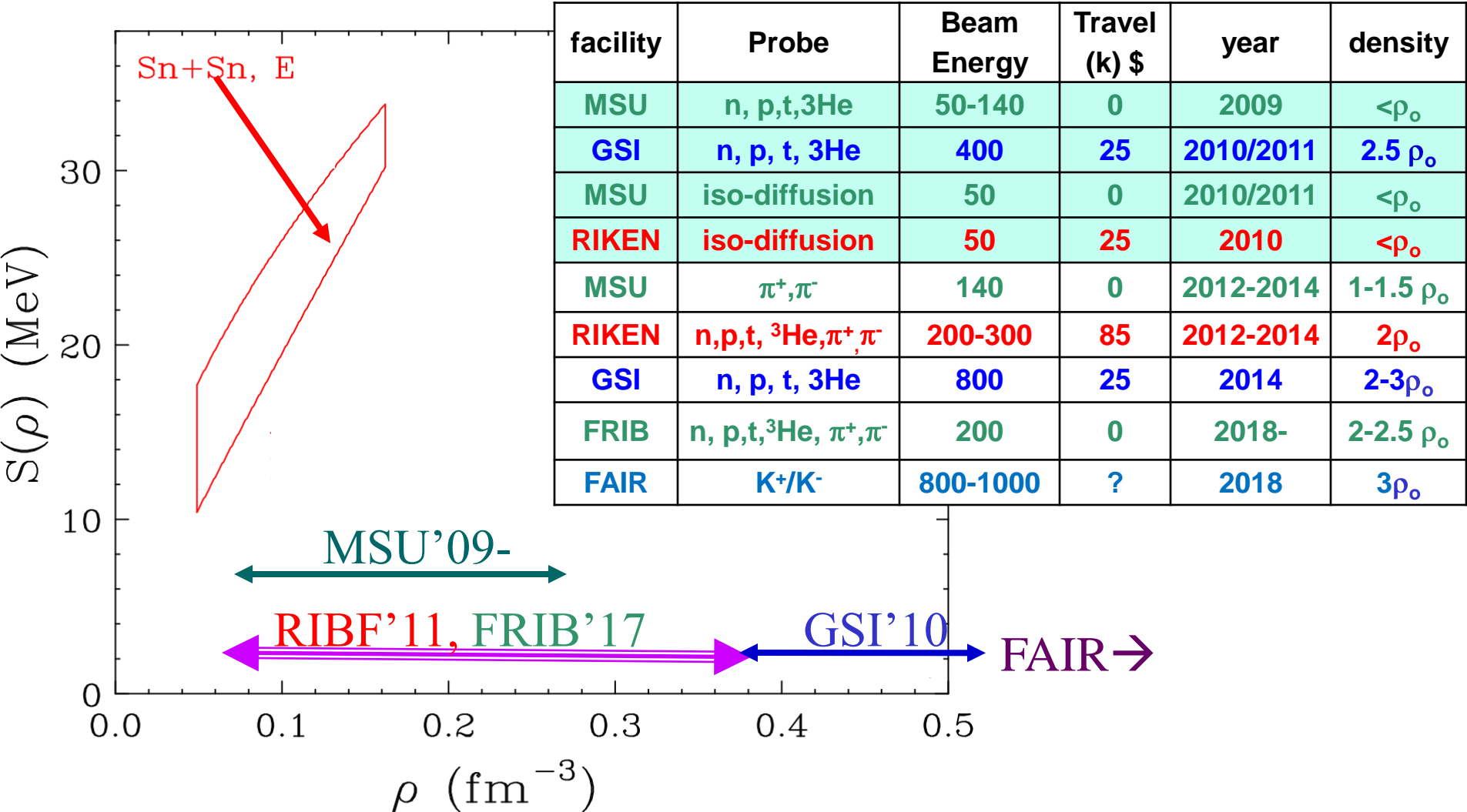


Constraints on the density dependence of symmetry energy



Constraints on the density dependence of symmetry energy





Symmetry Energy Project → International collaboration to determine the symmetry energy over a range of density

Require: New Detectors (TPC), travel money, theory support

Symmetry Energy Project (SEP) collaboration

Determination of the Equation of State of Asymmetric Nuclear Matter

NSCL MSU, USA: B. Tsang & W. Lynch,
Abigail Bickley, Gary Westfall, Pawel Danielewicz,
Edward Brown, Andrew Steiner
Rutgers University: Jolie Cizewski,
Smith College : Malgorzata Pfabe
University of Texas, El Paso: Jorge Lopez
Texas A&M University : Sherry Yennello
Western Michigan University : Michael Famiano
RIKEN, JP: Hiroshi Sakurai, Shunji Nishimura,
Yoichi Nakai, Atsushi Taketani
Kyoto University: Tetsuya Murakami
Rikkyo University, JP: Jiro Murata, Kazuo Ieki
Tohoku University: Akira Ono
GSI DE: Wolfgang Trautmann , Yvonne Leifels, Marcus Bleicher
Daresbury Laboratory, UK: Roy Lemmon
INFN LNS Catania, IT: Giuseppe Verde, Angelo Pagano,
Paulo Russotto, Massimo di Toro, Maria Colonna,
Aldo Bonasera, Vincenzo Greco
SUBATECH FR: Christoph Hartnack
GANIL FR: Abdou Chbihi, John Frankland, Jean-Pierre Wieleczko
China Institute of Atomic Energy: Yingxun Zhang, Zhuxia Li
Brazil: Sergio Souza, Raul Donangelo, Brett Carlson

**5th RIKEN PAC recommends
completion of TPC in 2013.**

**DOE FOA proposal (12/18/08):
\$1.2 M includes US contributions
to SAMARAI TPC**

**NSF PIRE proposal (9/18/2009):
\$3.6 M includes JREU, extended
visits by PD & GS to Japan &
Europe**

**International Symposium on Symmetry Energy,
July 26-30, 2010, RIKEN, Japan.**

Tetsuya Murakami, Akira Ono, Hiro Sakurai, Betty Tsang

What is the role of JUSEIPEN?

To foster US scientists to do experiments in RIKEN

Funds requested: ~\$100k/year

2k/trip → 50 person trips a year to Japan

funding of whole experimental program is not practical

How to best use the resources?

- a. Facilitate funding applications by US collaborators
- b. Fund Proposal presentations at RIKEN PAC?
- c. Fund Collaboration workshops?
- d. Fund Summer schools for experimental students?
- e. ...

Riken US user organization

-- streamline the collaborations, exchange ideas and consolidation of resources (e.g. video presentations to RIKEN PAC) etc