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Asy-EOS Meeting

May 22, 2010

ISOTOPIC OBSERVABLES OF THE SYMMETRY ENERGY APPROACHING SATURATION DENSITY

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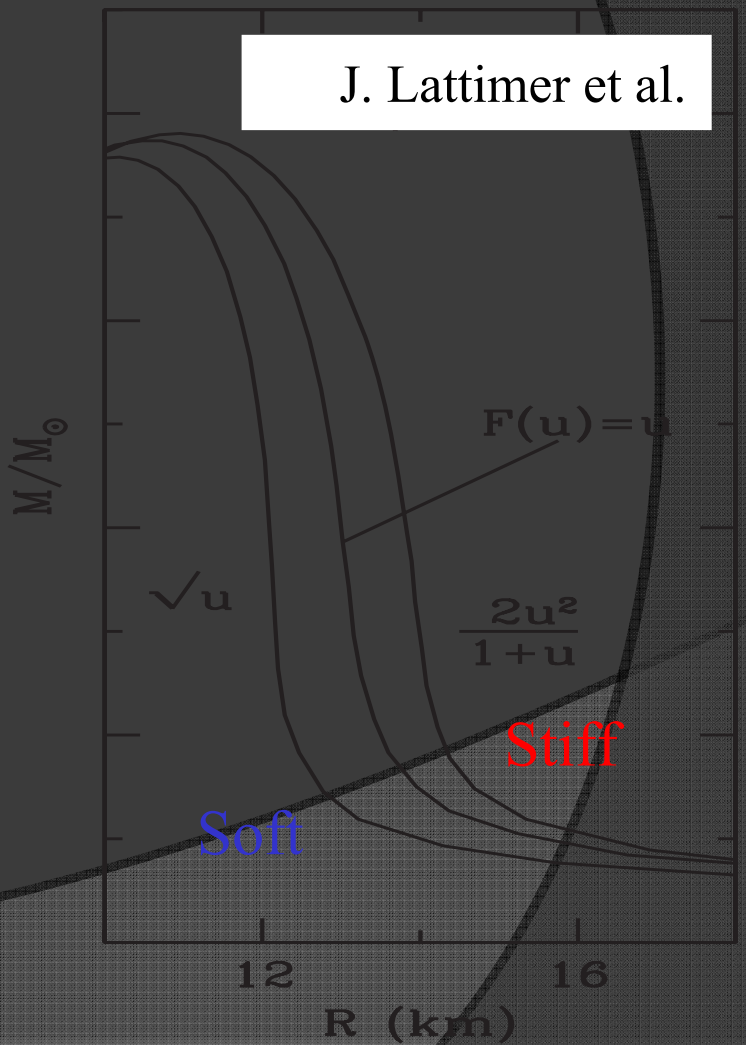
Introduction

- Significance of the symmetry energy at low and high density
- Isotopic observables near saturation density
  - Improving neutron-proton ratios
  - Constraining parameters
  - Experimental meaning of saturation density
- Experimental plans
  - Exceeding nuclear saturation density

Astrophysical Importance of the Nuclear Asymmetry Term

- Macroscopic properties:
  - Neutron star radii, moments of inertia and central densities.
  - Maximum neutron star masses and rotation frequencies.
- Thickness of the inner crust.
  - Frequency change accompanying star quakes.
- Role of Kaon condensates and mixed quark-hadron phases in the stellar interior.
- Proton and electron fractions throughout the star.
  - Cooling of proto-neutron star.

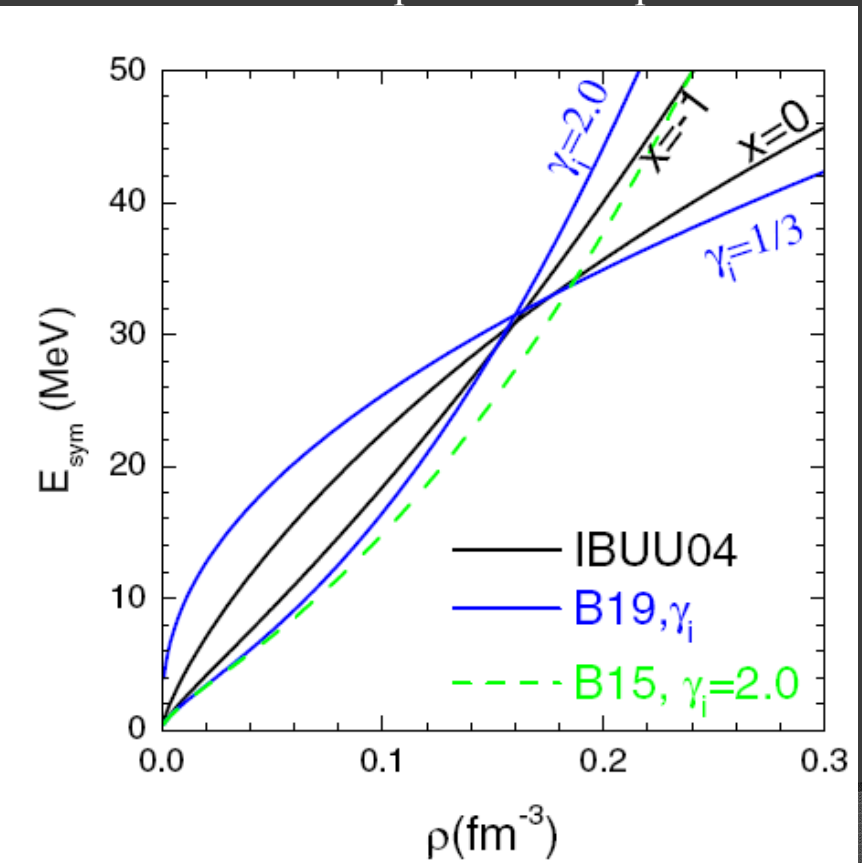


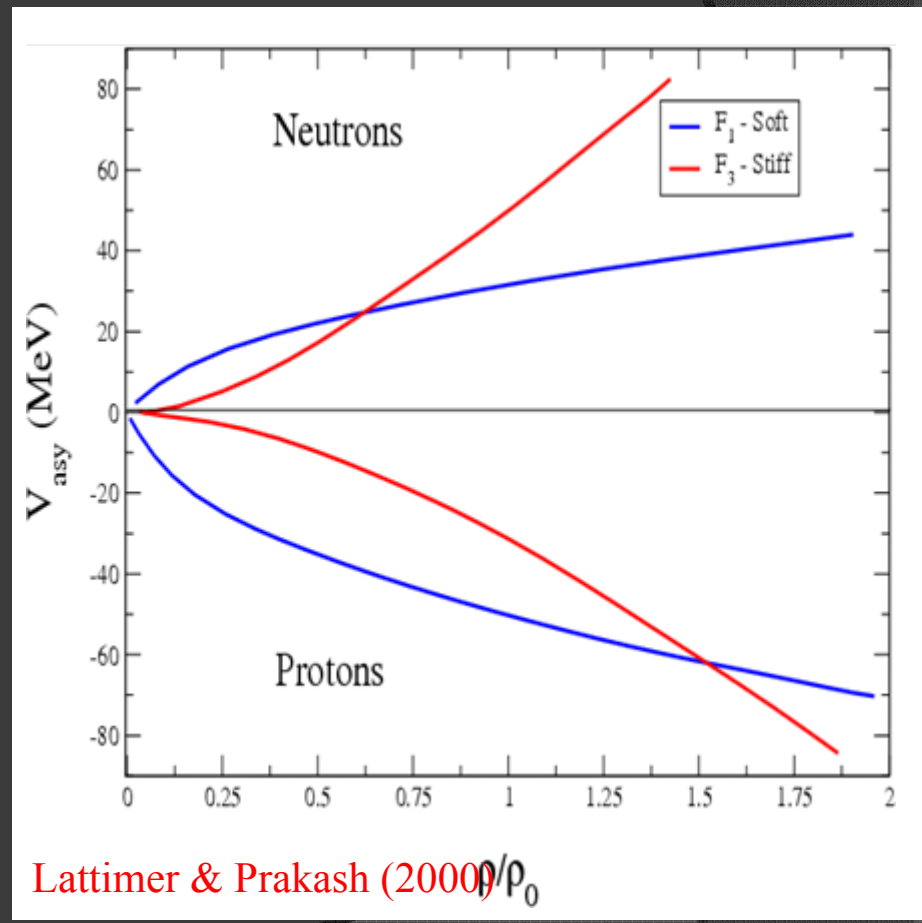
$$S_{pot}(\rho) = const. \cdot F(u); u = \rho / \rho_0$$

Asymmetric Nuclear Matter

$E/A(\rho, \delta) = E/A(\rho,0) + \delta^2 \cdot S(\rho)$

$\delta = (\rho_n - \rho_p)/(\rho_n + \rho_p) = (N-Z)/A$



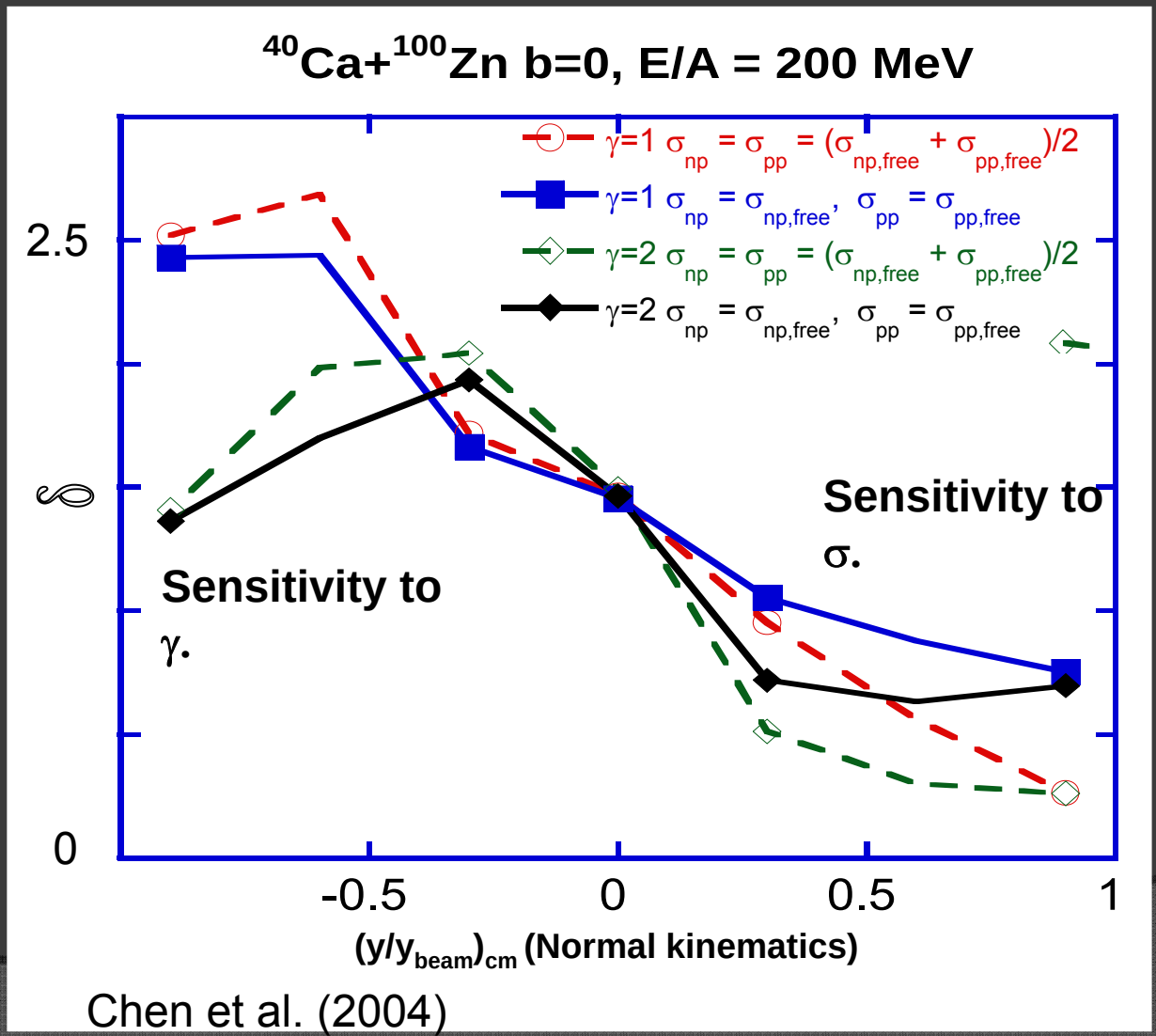


Lattimer & Prakash (2000)

Symmetry energy $S(\rho)$

$S(\rho) = S_{kin} \cdot (\rho/\rho_0)^{2/3} + S_{int} \cdot (\rho/\rho_0)^{\gamma_i}$

Effective Masses Alter In-Medium Cross-Sections



Chen et al. (2004)

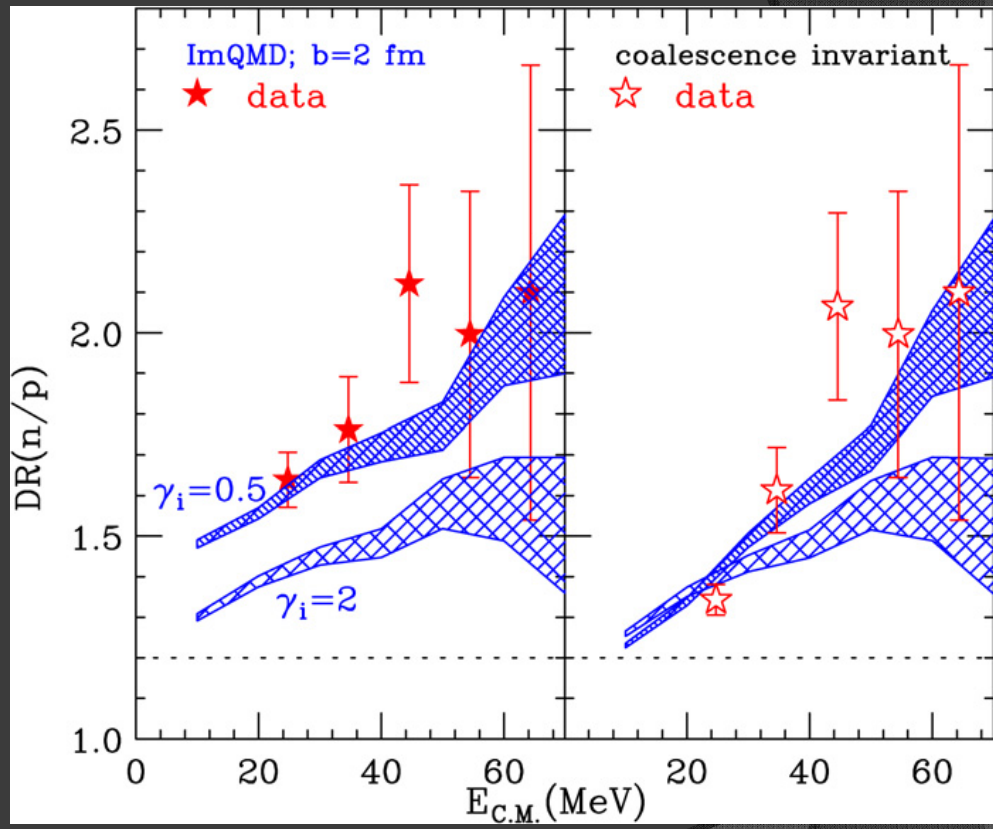
Same Line Type:
Different γ but same in-medium σ.

Diamonds:
Same γ and different in-medium σ.

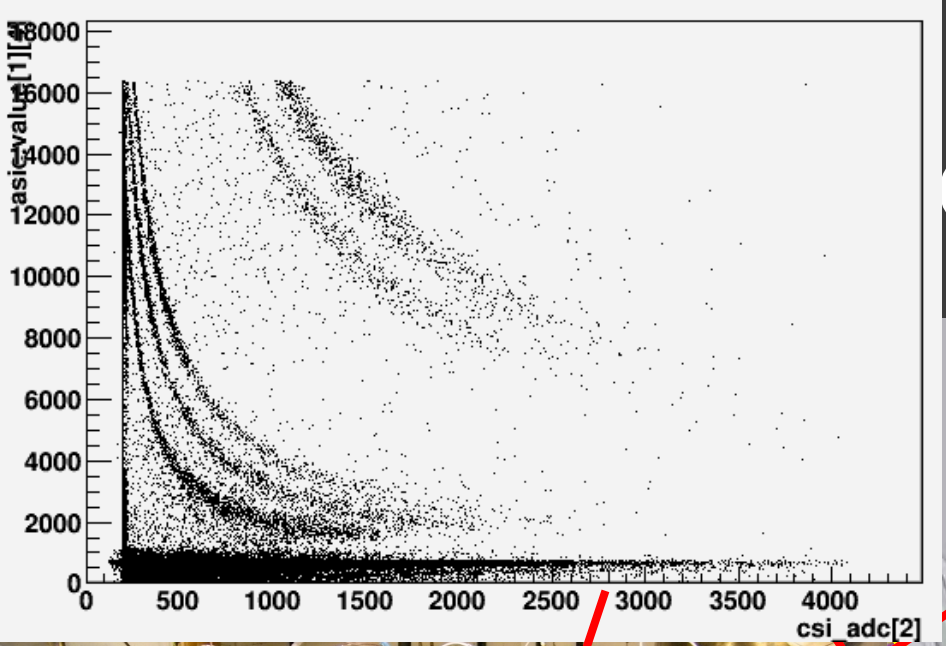
$$\sigma_{medium} / \sigma_{free} \approx \left(\frac{\mu^*_{NN}}{\mu_{NN}} \right)^2$$

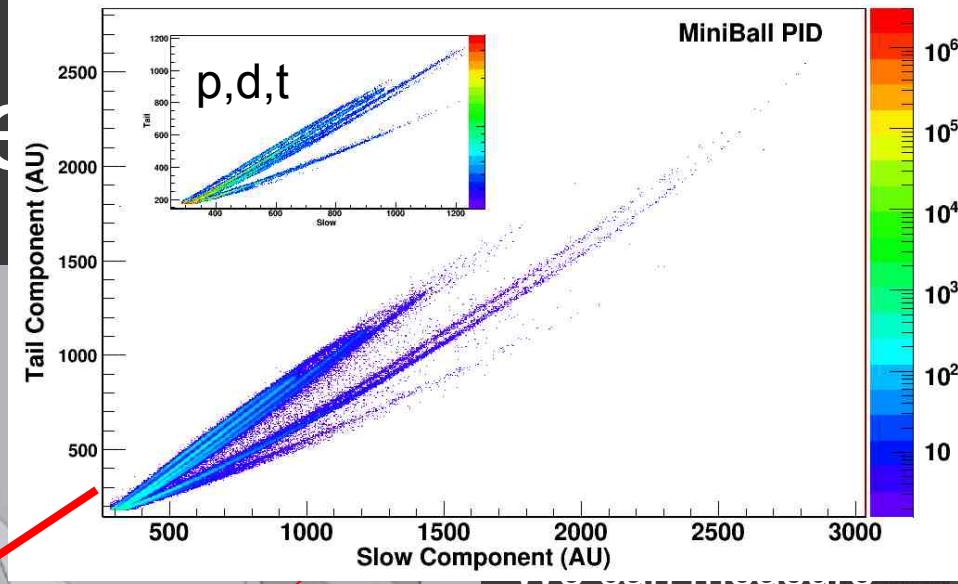
Experimental Details

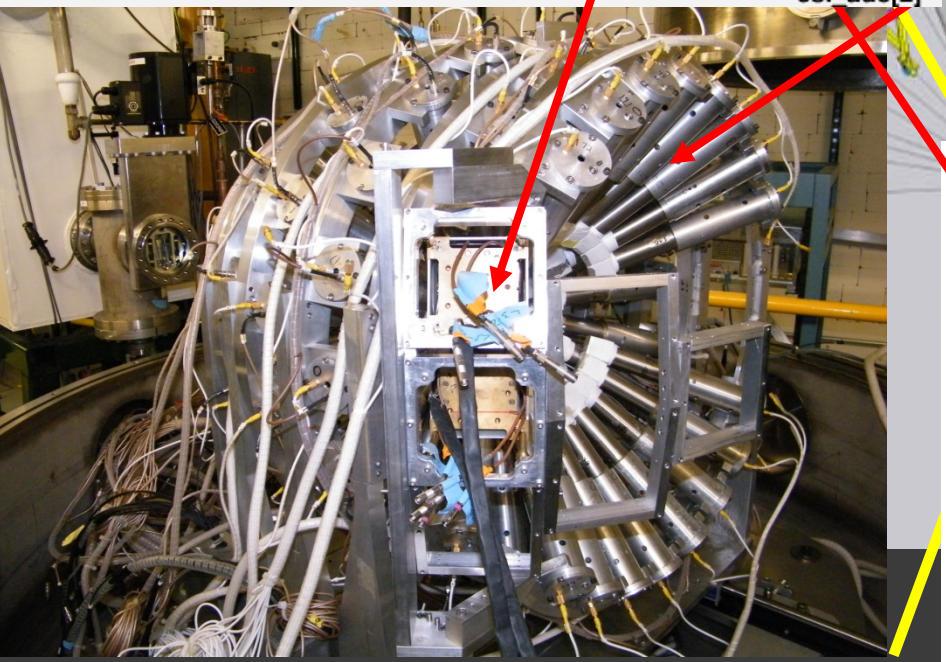
- Beam: ^{40,48}Ca +^{112,124}Sn 140MeV/A
- Also ^{112,124}Sn +^{112,124}Sn 50 MeV/A
- Neutron-proton observables
  - N/P ratios
  - Average rapidity dist.
  - N-P correlations?
- Sensitivity near saturation
- Data necessarily includes clustering in exactly the right amounts



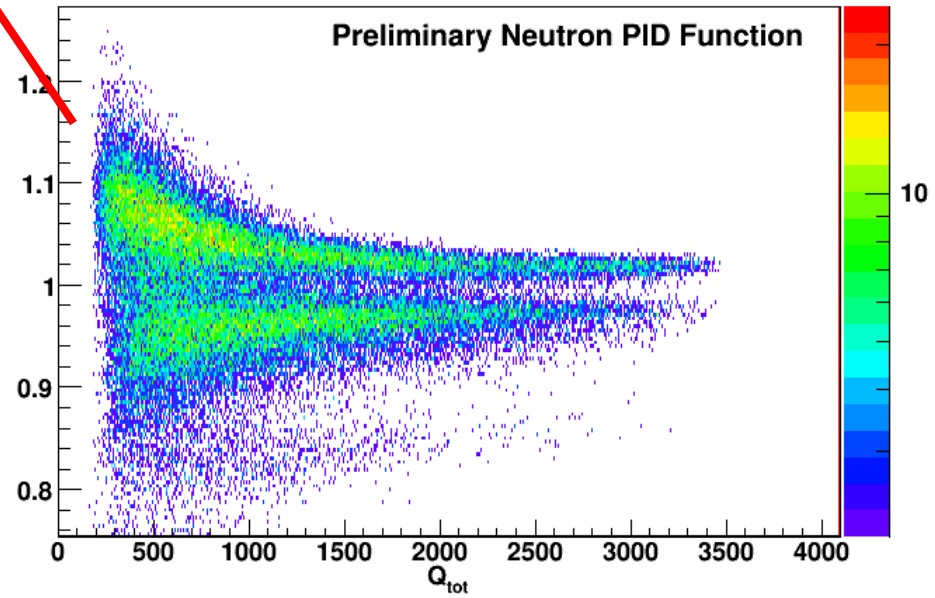
Chen et al., PRC 68, 14605 (2003)







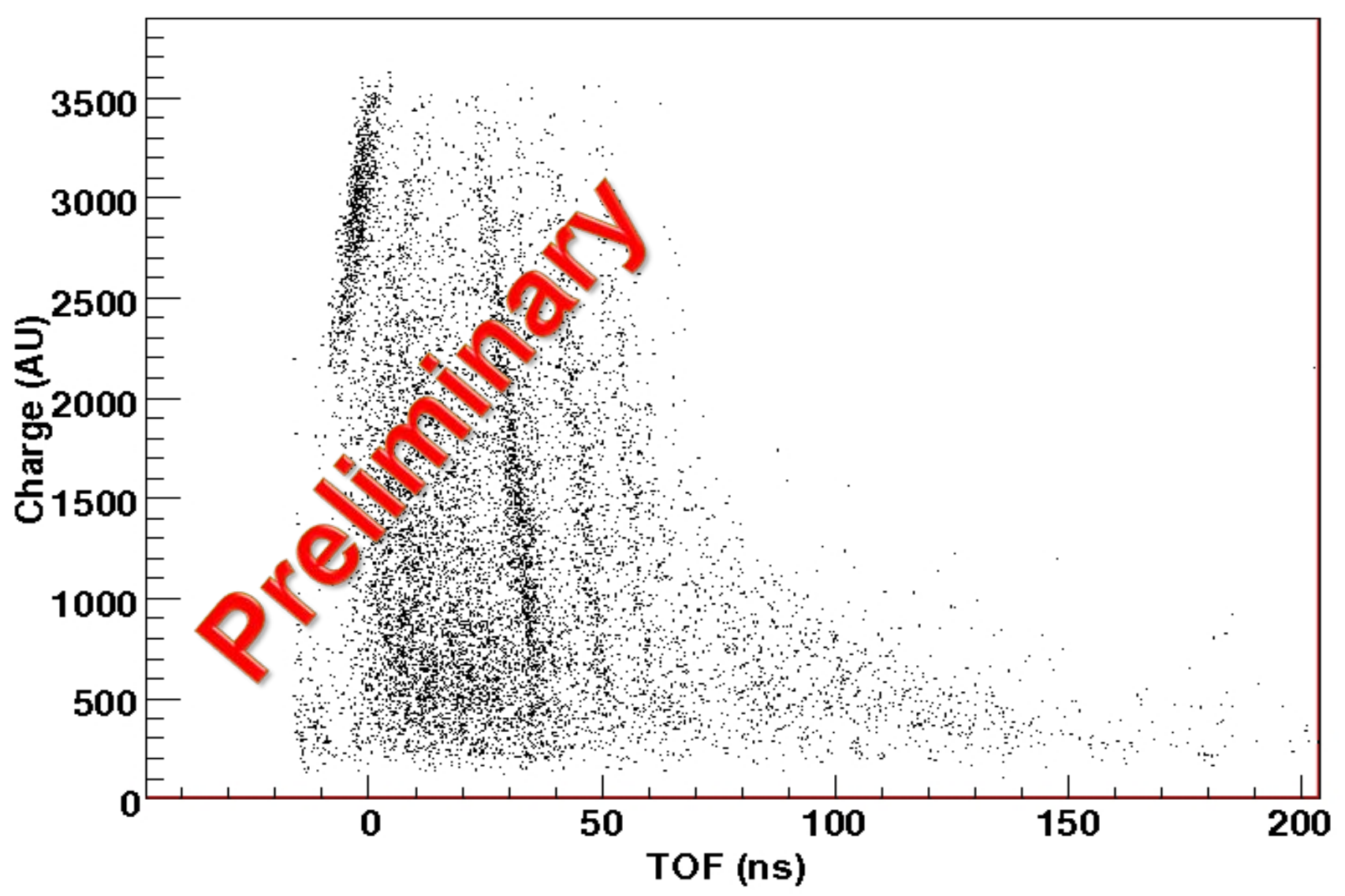
m*, AND get
Increased statistics



Experimentation complete May 29, 2009

Experimental Configuration

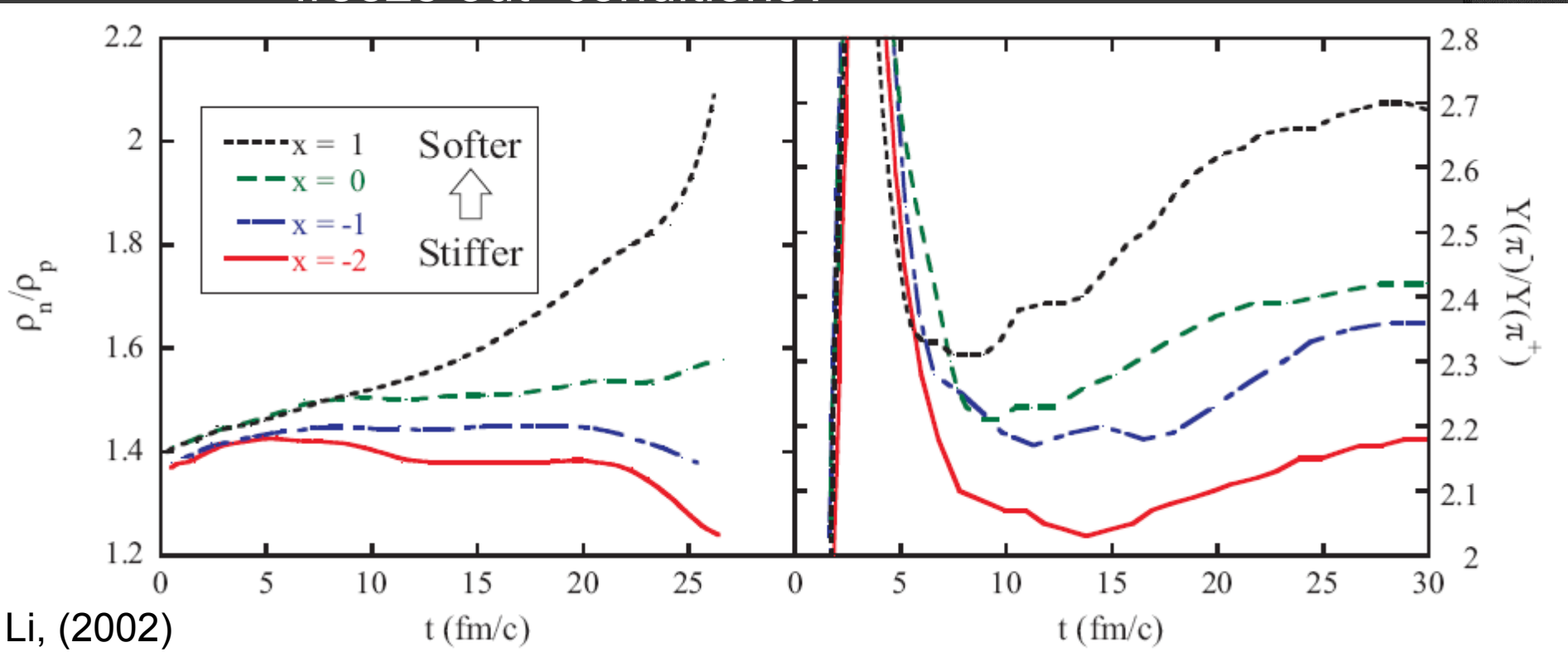
Neutron Spectra, Correlations



Towards Higher Density

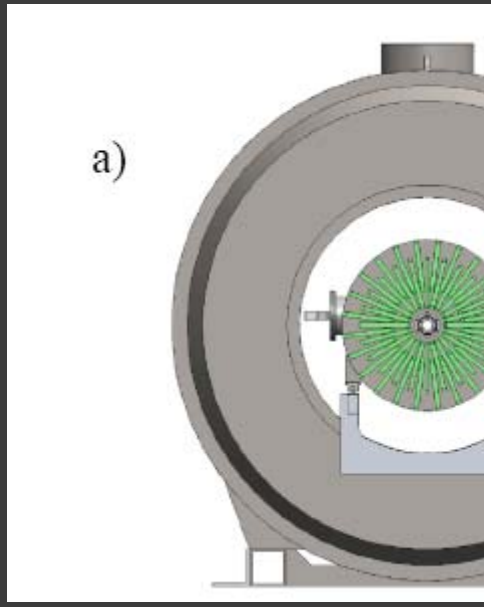
- Isotopic observables
  - Possible difficulties in "freeze out" conditions?

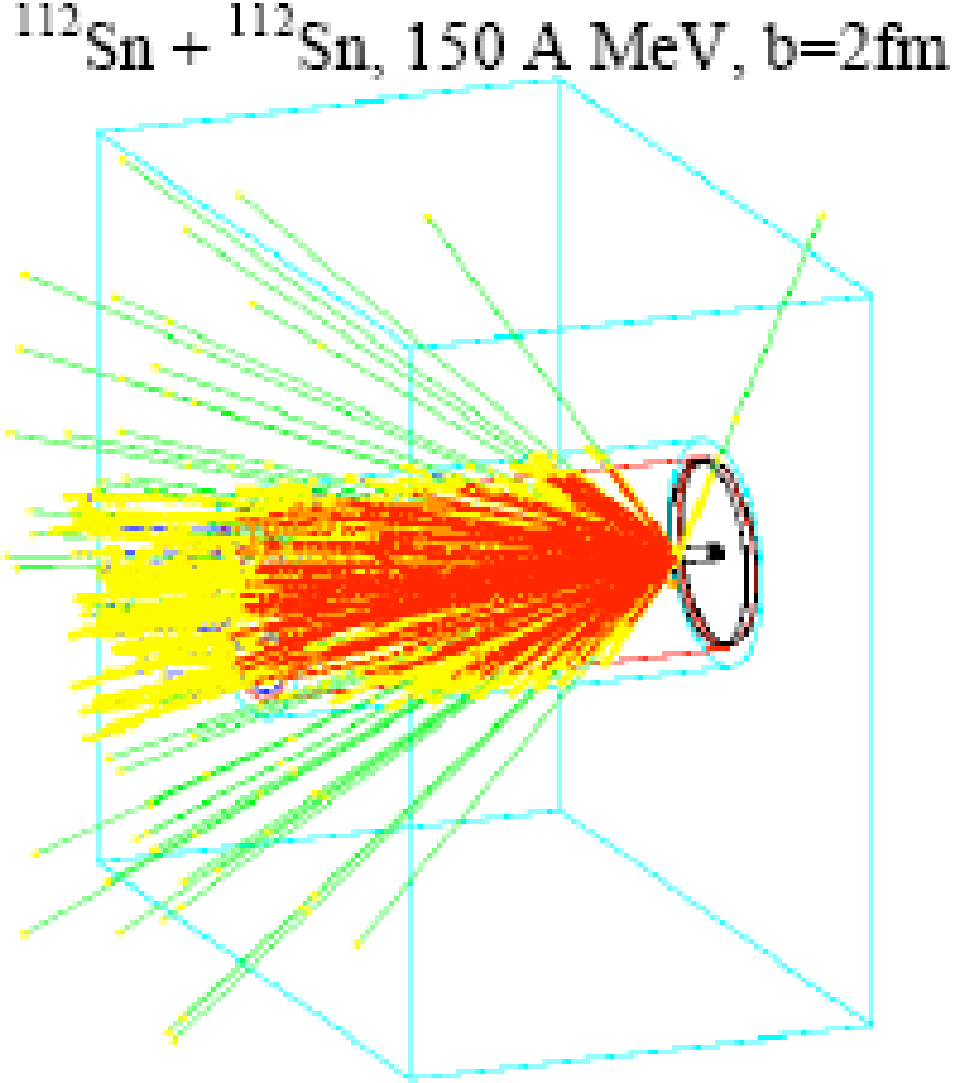
Stiffer EOS favors symmetric
Dense regions: More +: Lower π^-/π^+.
Softer EOS is less strongly
Symmetric: Suppression of π^+.



Li, (2002)

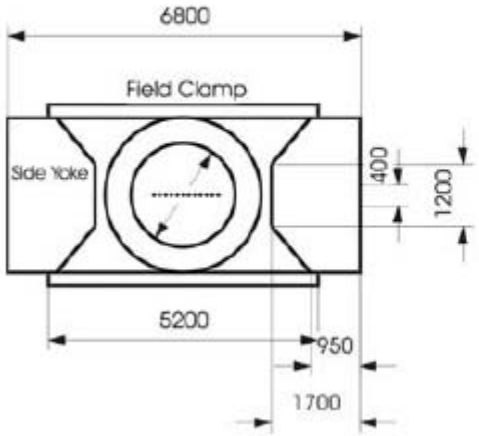
AT-TPC

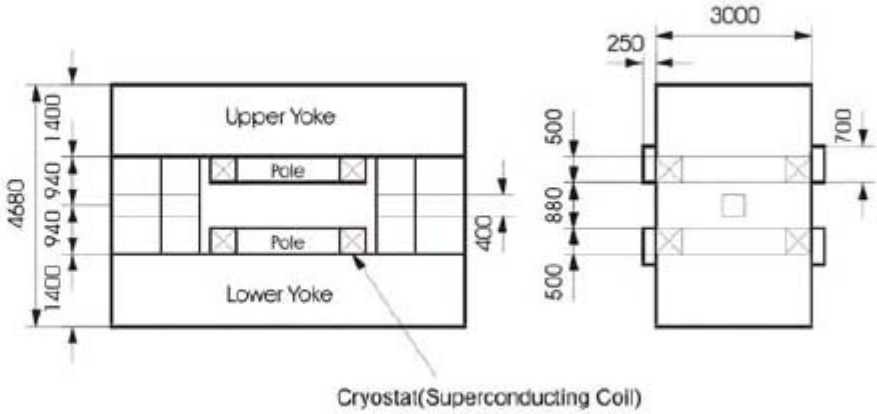




	Density R
✓	t/^{3}He production
✓	Pre-equilibrium nuclec
✓	Isospin fractionation
✓	Isoscaling
✓	Isospin diffusion
×	Neutron-proton correl

SAMURAI Configuration





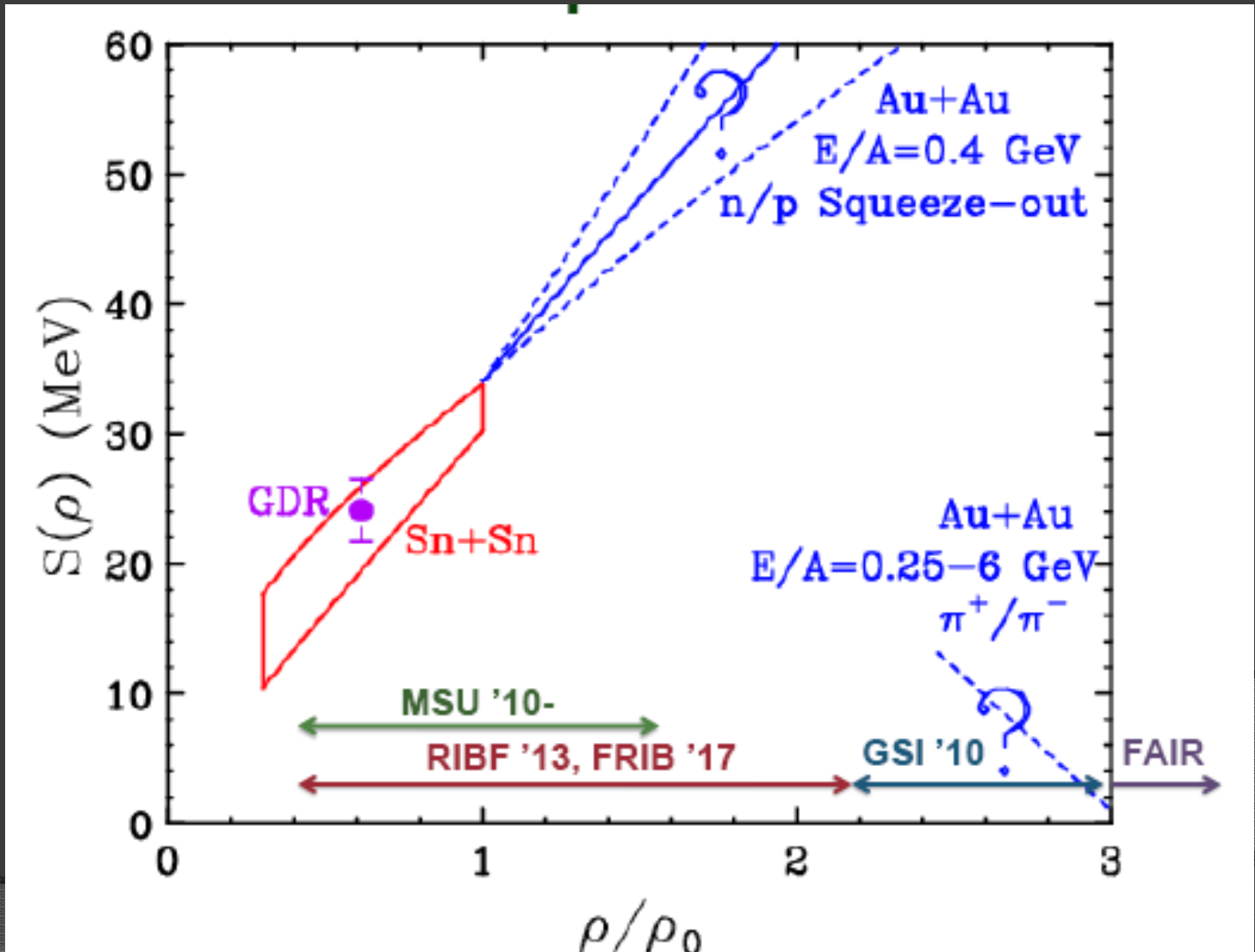
Current Concept: Modification of EOS TPC.

SAMURAI Dipole Specifications	
Magnet Type	H
Maximum Rigidity	7 Tm
Pole Diameter	2m
Return Yoke Dimensions Top and Bottom	6.8m x 3m x 1.4 m
Return Yoke Dimensions Sides	1.7m x 0.7m x 1.88m
Central Field	0.4-3 T (at the center)
Magnet Gap	0.88 m – 0.8 m with vacuum chamber
Mounting	Rotatable Base
Total Weight	630 T

SAMURAI TPC Parameters

Pad Plane Area	1.3m x 0.9 m
Number of Pads	11664 (108 x 108)
Pad Size	12 mm x 8 mm
Drift Distance	55 cm
Pressure	1 atm
Gas Composition	90% Ar + 10% CH_4
Gas Gain	3000
E Field	120 V/cm
Drift Velocity	5cm/μs
dE/dx range	Z=1-8, π, p,d,t,He,Li-O
Two Track Resolution	2.5 cm
Multiplicity Limit	200

Current Landscape



Summary

- Recent progress in isotopic observables of the low-density asy-EOS: Many isotopic observables at low density
- Work towards expansing isotopic observables to the high-density asy-EOS
  - Ratios
  - Correlations
- Constraining theory: effective masses
- Equipment for the high-density asy-EOS