NuSYM13 at NSCL/FRIB July 22-26

The SAMURAI TPC: Constraining The EOS For Isospin Asymmetric Nuclear Matter At Supra-Saturation Densities

W. Powell For The SAMURAI TPC Collaboration

Equation Of State

- Nuclear equation of state (EOS) describes the relationship between energy, temperature, density, pressure and isospin asymmetry for nuclear matter
- Density dependence of the EOS is well determined for symmetric matter, but unconstrained for asymmetric matter at high density
- Unconstrained density dependence of symmetry energy

Energy per nucleon of cold nuclear matter

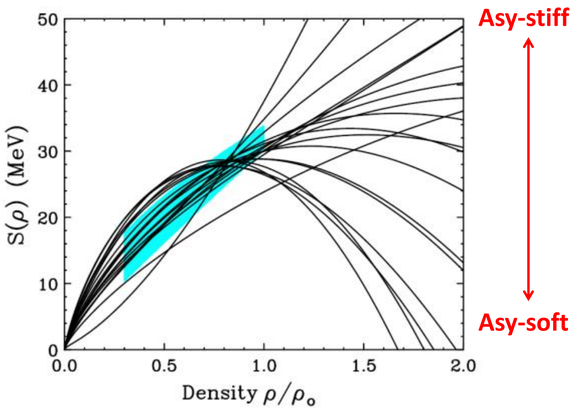
$$\frac{E}{A}(\rho,\delta) = \frac{E}{A}(\rho,\delta=0) + S(\rho)\delta^2 \qquad \delta = \frac{\rho_n-\rho_p}{\rho_n+\rho_p} \qquad S(\rho)\ \alpha\ C\left(\frac{\rho}{\rho_0}\right)^{\gamma}$$

Symmetric Matter — Asymmetry Term — Symmetry Energy

UrQMD transport model predictions are dominated by the value of γ, which is unknown

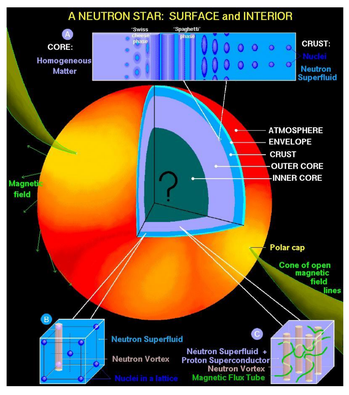
- Stiff = Strongly density dependent → γ > 1
- Soft = Weakly density dependent → γ < 1

Trend is unknown!

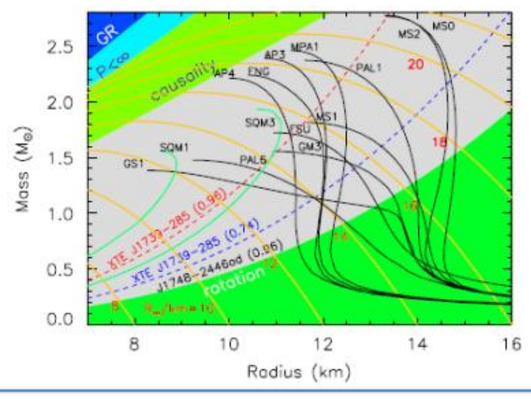


Density dependence of the symmetry energy from Skyrme interactions. Shaded region is from HIC.
B. A. Brown, Phys. Rev. Lett. 85, 5296 (2000)

Neutron Star Internal Structure

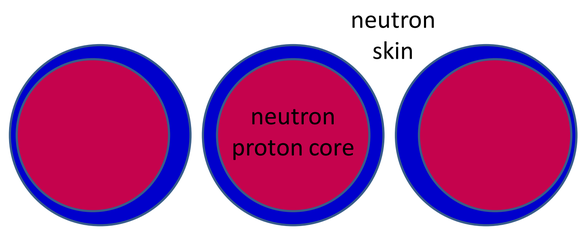


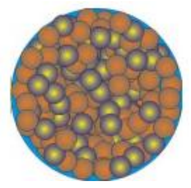
Neutron Star Mass and Radius



Lattimer et al., Phys. Rep. 42, 109(2007)

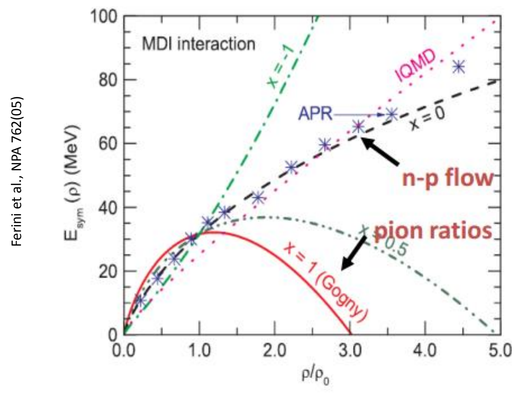
N-Rich Nuclei Radii





Symmetry Energy Observables

- Heavy ion collisions (HIC) with beams and targets at high incident energy (E/A > 150 MeV) can produce supra-saturation densities ($\rho>\rho_0$) in the lab environment
- Compare SAMURAI TPC measured observables, which are sensitive to isospin asymmetries, with transport model calculations (BUU, UrQMD..)
- Semi-central collisions compress matter to produce a hot dense region at mid-rapidity



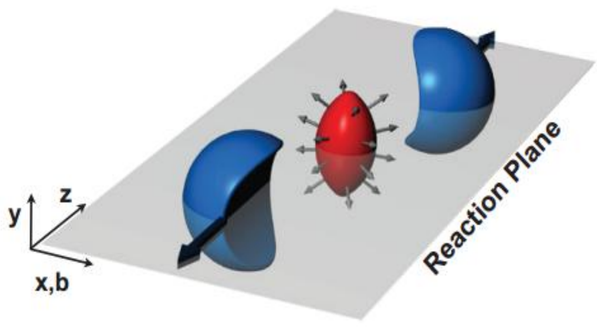
Ferini et al., NPA 762(05)

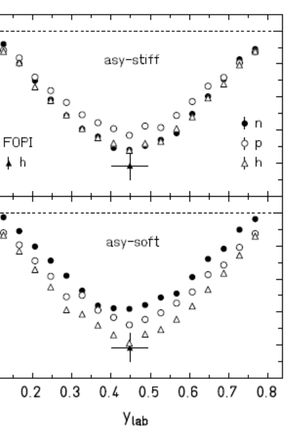
Pressure gradients cause spatial anisotropy to evolve into momentum anisotropy → particle azimuthal anisotropy can be described via the fourier expansion:

$$\frac{dN}{d(\varphi_r-\varphi)} = \frac{N_0}{2\pi}\left[1+2\sum_{n\geq 1} v_n cosn(\varphi_r-\varphi)\right]$$

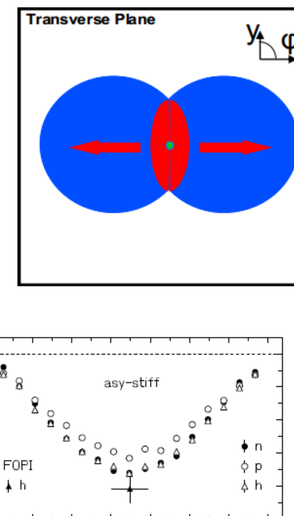
$v_1 = Directed\ flow\ (in-plane\ at\ large\ rapidity)$

$v_2 = Elliptic\ flow\ (out-of-plane\ at\ mid\ rapidity)$



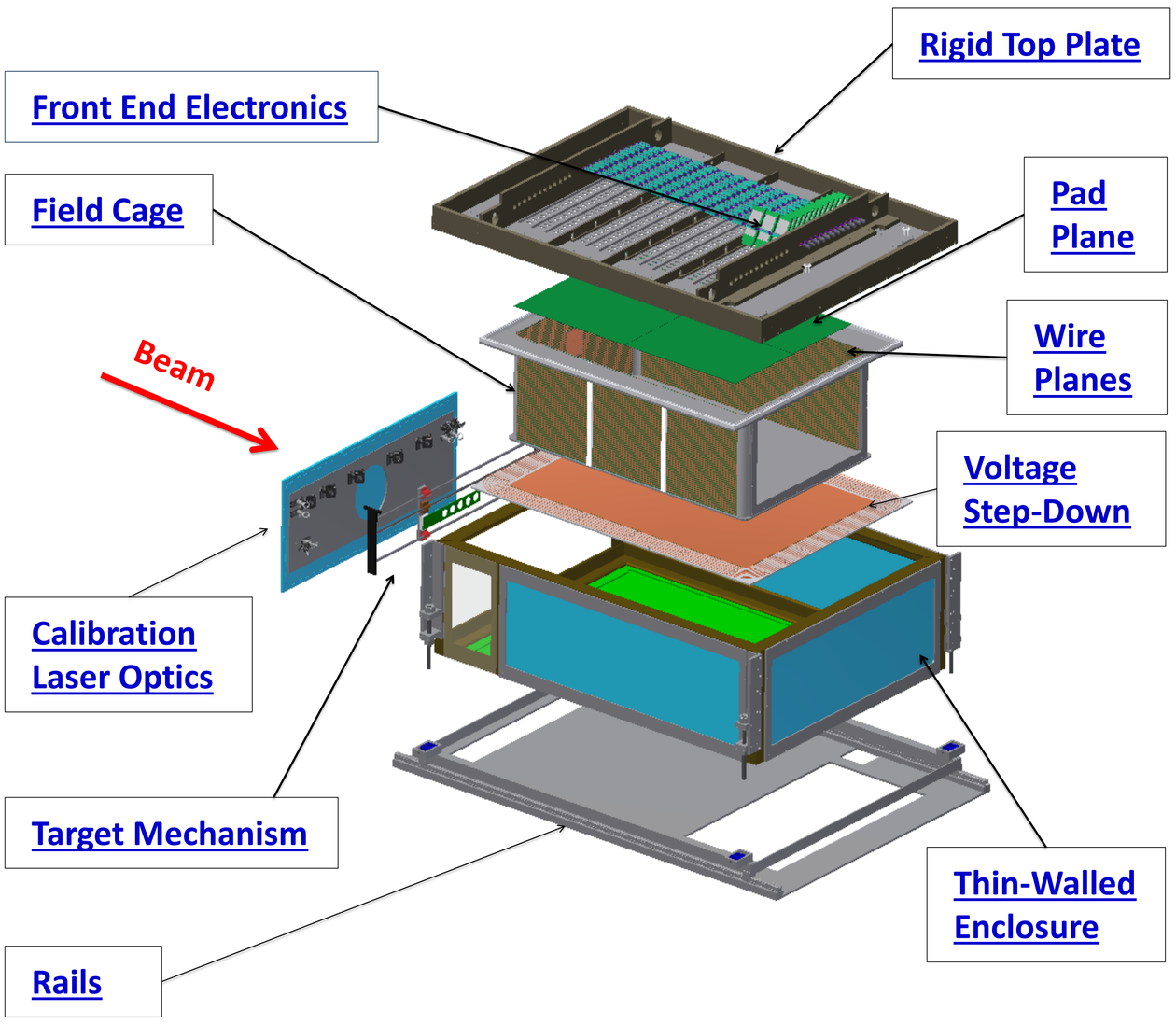


Elliptic flow in ^{197}Au ^{197}Au
P. Russotto et al, Physics Letters B 697, 471 (2011)



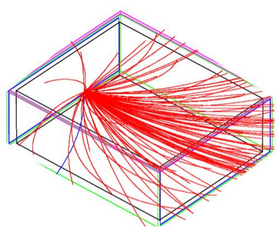
Experimental Observables For SAMURAI TPC

- **Neutron-Proton Double Ratios and Flow:** Measurement of the nucleon yields
- **Proton-Proton Correlations:** Measure of how emitted protons interacted just before being ejected
- **Triton-^{3}He Ratios:** Neutron detectors aren't very efficient
- **Pion Double Ratios and Flow:** π^- and π^+ production rates are correlated with p-p and n-n collision rates respectively



SAMURAI TPC

- A series of experiments is planned for 2014 to investigate and constrain the symmetry energy at ~ $2\rho_0$
- Situated within SAMURAI dipole magnet at RIKEN where an intense Rare Isotope Beam (RIB) will be provided by RIBF
- Particle identification and tracking of pions and light clusters up to Li
- Study central collisions and measure pion and nucleon yield ratios



- Charged fragments from collisions ionise the gas along their trajectories
- **Field cage** defines a uniform electric field which drifts ionisation electrons towards the **pad plane** where **wire planes** induce avalanching and a corresponding image charge is induced on the charge sensitive pads
- **Pad plane:** 108x112 individual gold plated pads which are connected to the **GET** electronics AsAd (Asic and ADC) boards.
- **Thin-walled**: Allows efficient propagation of neutrons to ancillary detectors
- **Laser optics:** Calibrate the electric field of the **field cage**
- TPC can be operated at atmospheric pressure with different gases and different cathode voltages
- **Voltage step-down:** Prevents sparking from the cathode (up to 20kV)