

# **Experiment 09042:** **Density dependence of the symmetry energy with emitted neutrons and protons**

Daniel Coupland

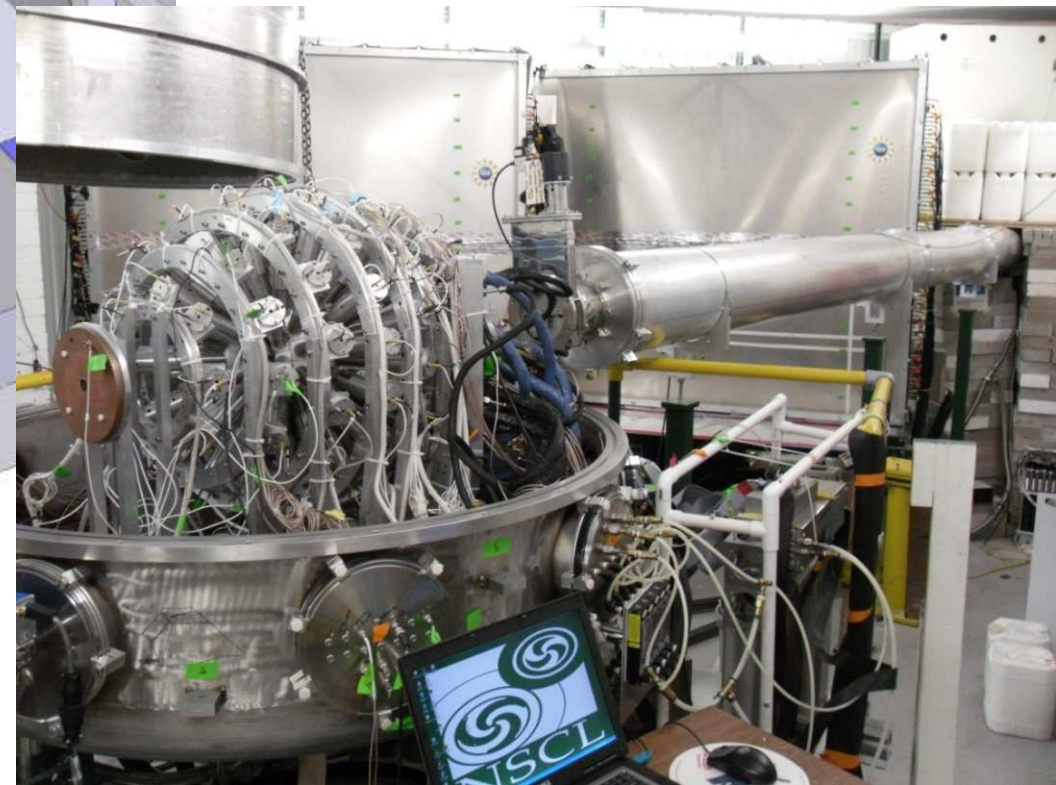
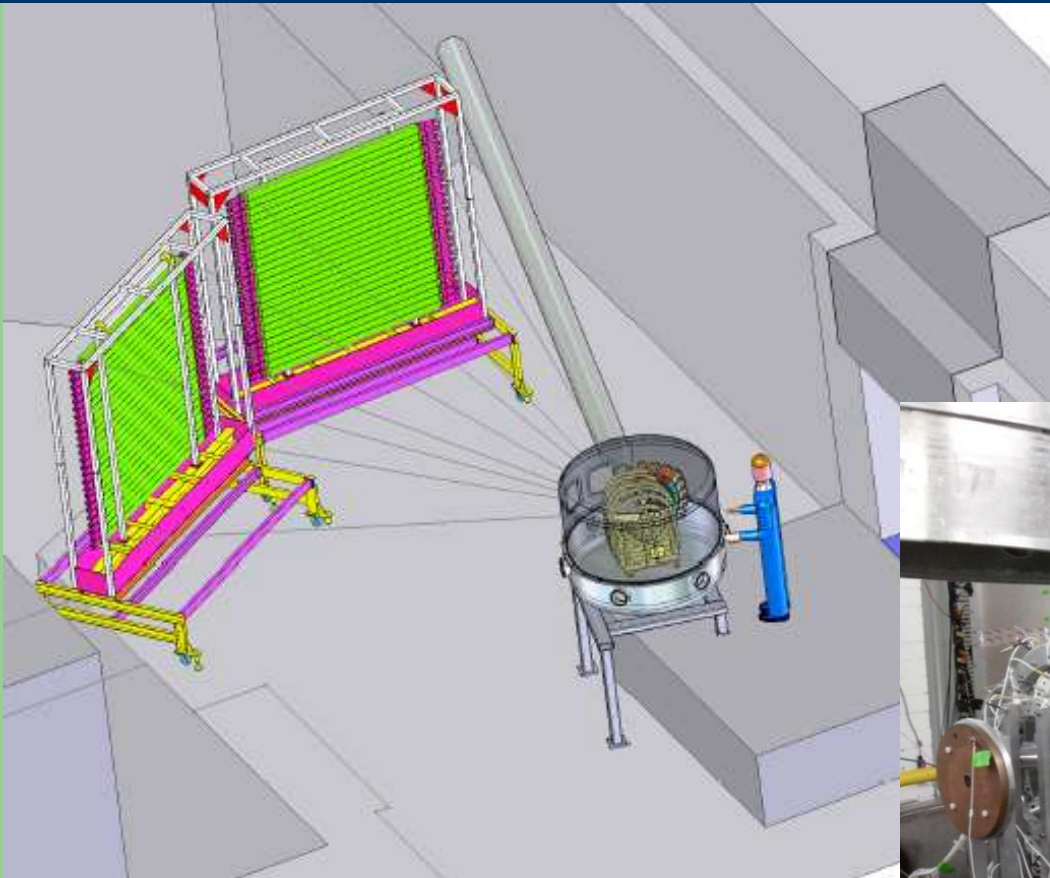
NSCL Research Discussion

December 10<sup>th</sup>, 2009



# Vault Layout

The S2 vault, reconfigured for neutron experiments



Courtesy Mike Famiano

First experiment: 05049 by  
Mike Famiano, May, 2009

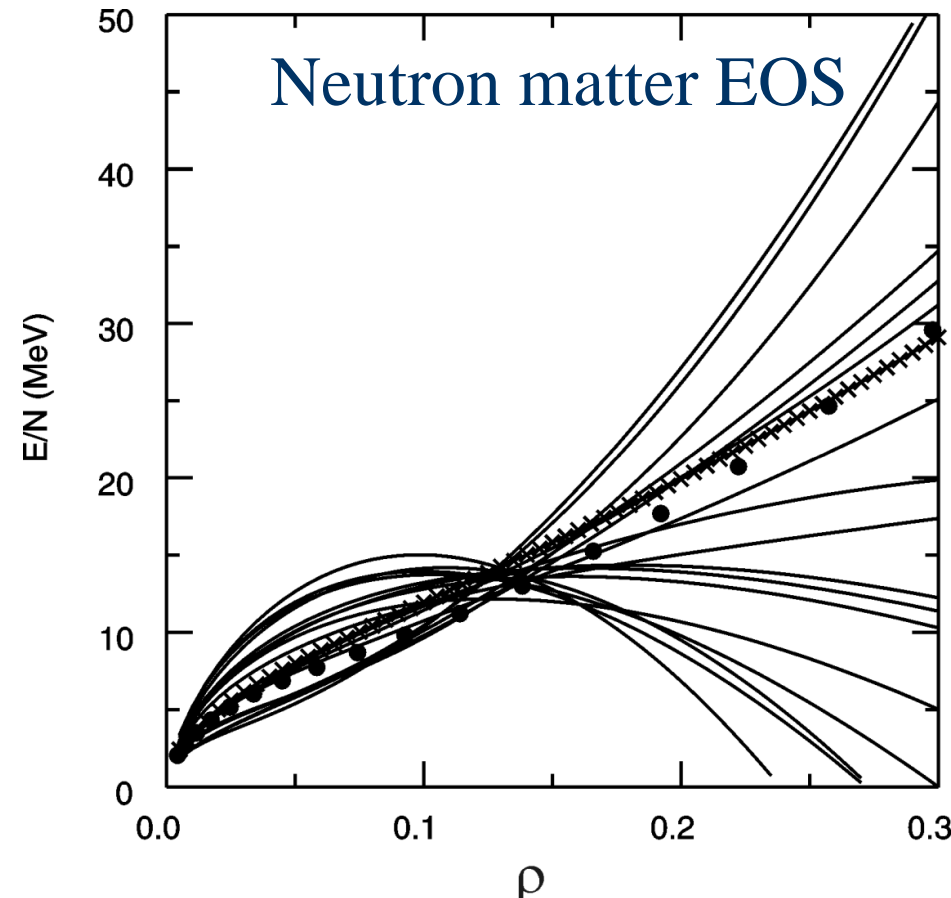


# Motivation

Constrain the density dependence of the symmetry energy  $S(\rho)$  in the nuclear equation of state

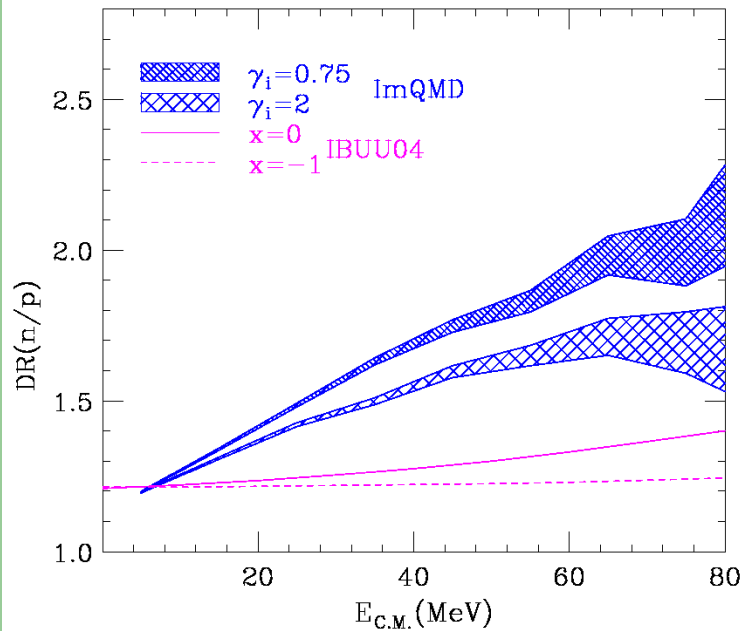
$$E/A(\rho, \delta) = E/A(\rho, 0) + \delta^2 \cdot S(\rho)$$

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



Brown, Phys. Rev. Lett. 85, 5296 (2001)

# Motivation



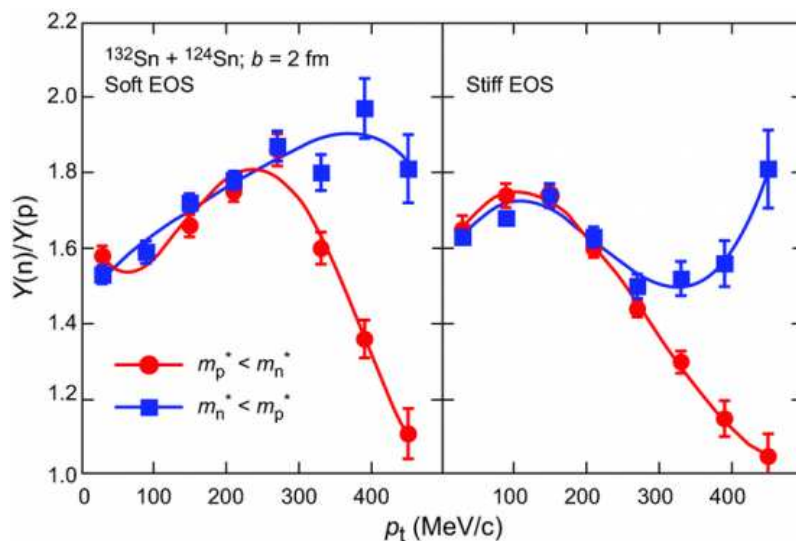
Double Ratio:

$$DR(n/p) = \frac{n_{asym}/p_{asym}}{n_{sym}/p_{sym}}$$

$E_{beam} = 50$  A MeV

Density dependence of the symmetry energy

Figure courtesy Betty Tsang



$E_{beam} = 100$  A MeV

In-medium effective mass

Adapted from J. Rizzo et al, Phys. Rev. C72, 064609 (2005).

# Experimental Idea

Measure neutron and proton spectra from central collisions of reaction systems:



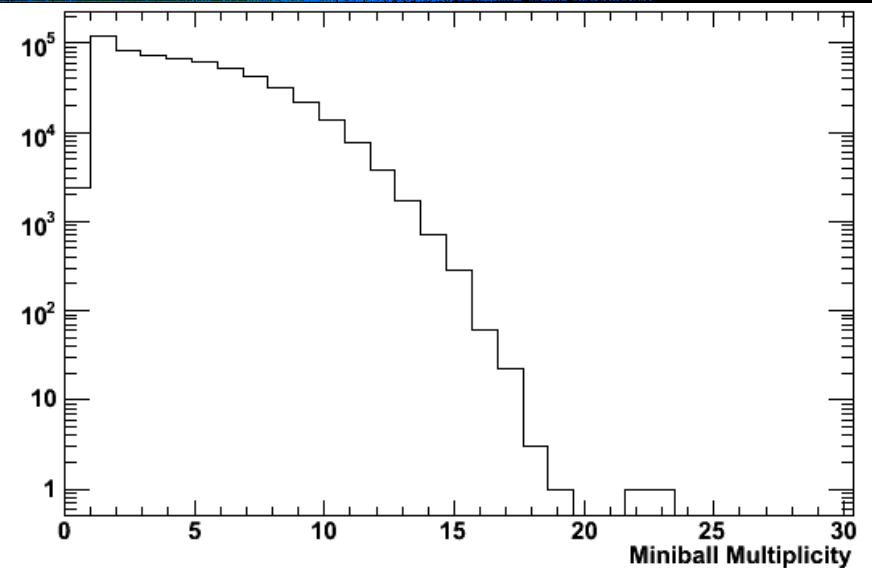
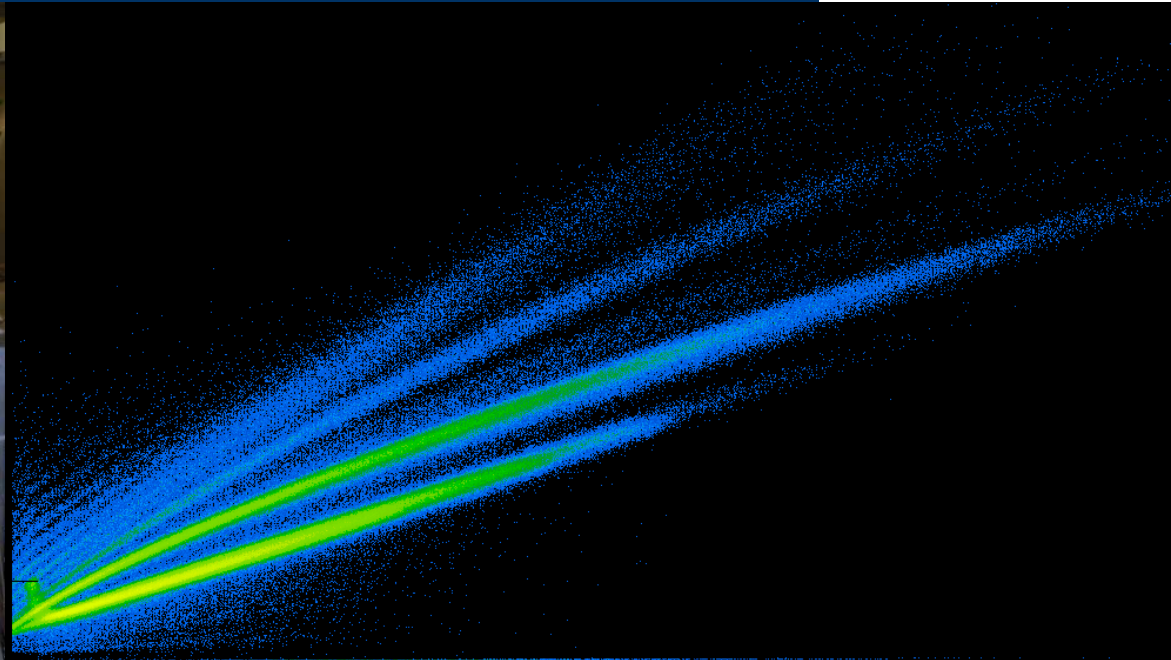
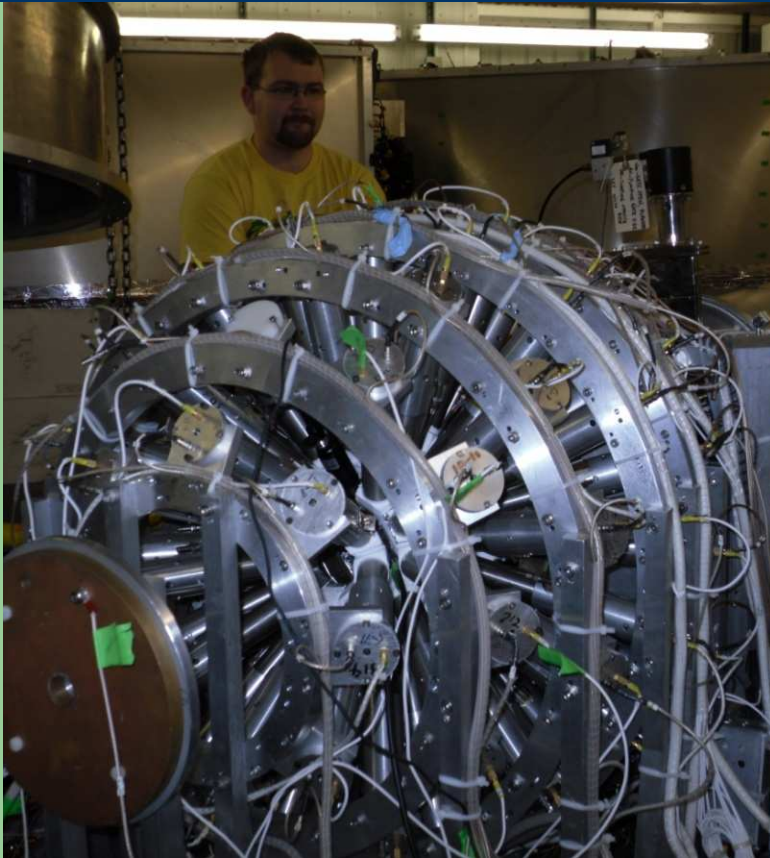
at

50 AMeV

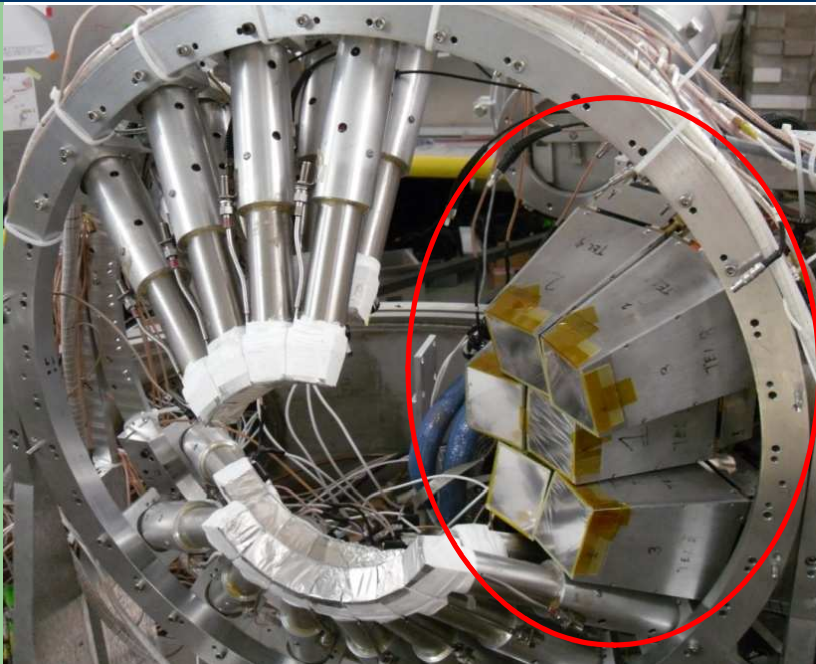
120 AMeV

Challenge: We need 5 detector systems to do this!

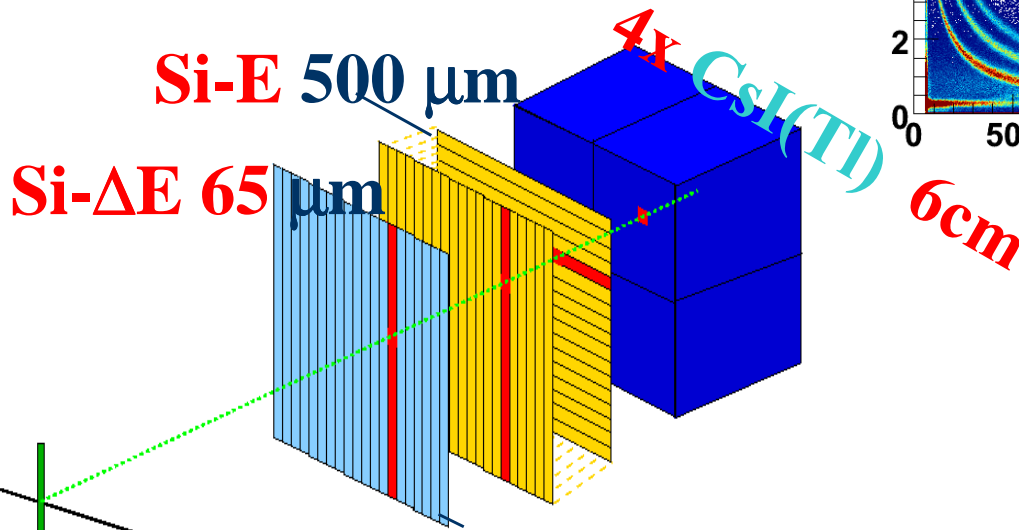
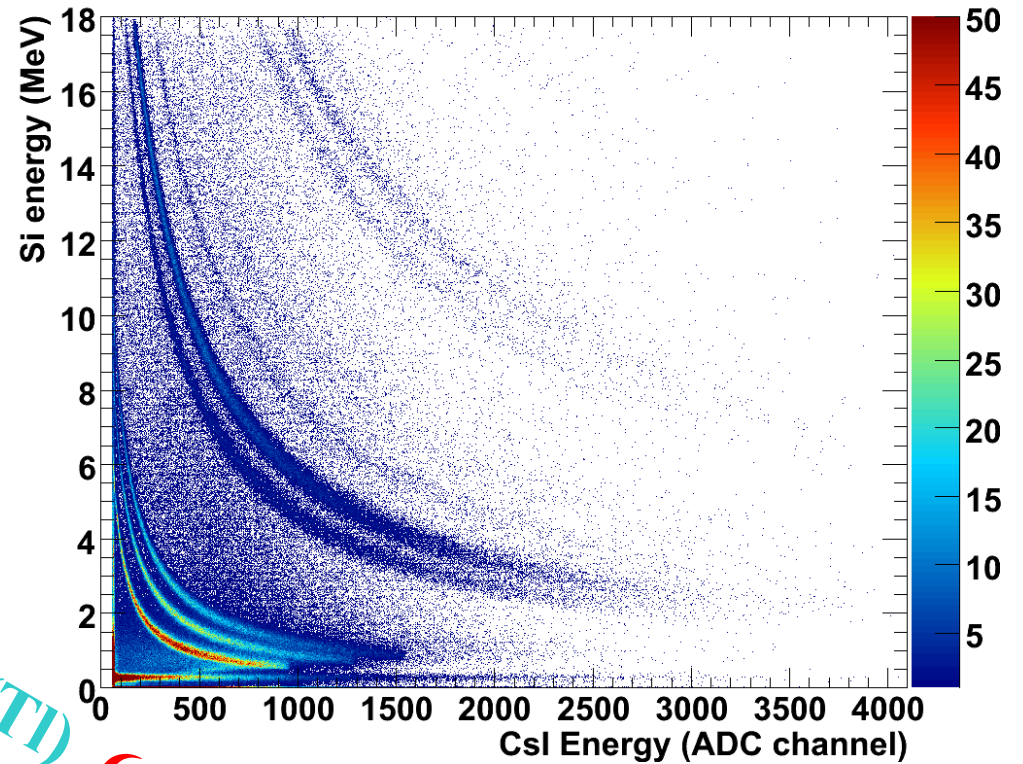
# Centrality Cut – the MSU Miniball



# Detecting Protons - LASSA



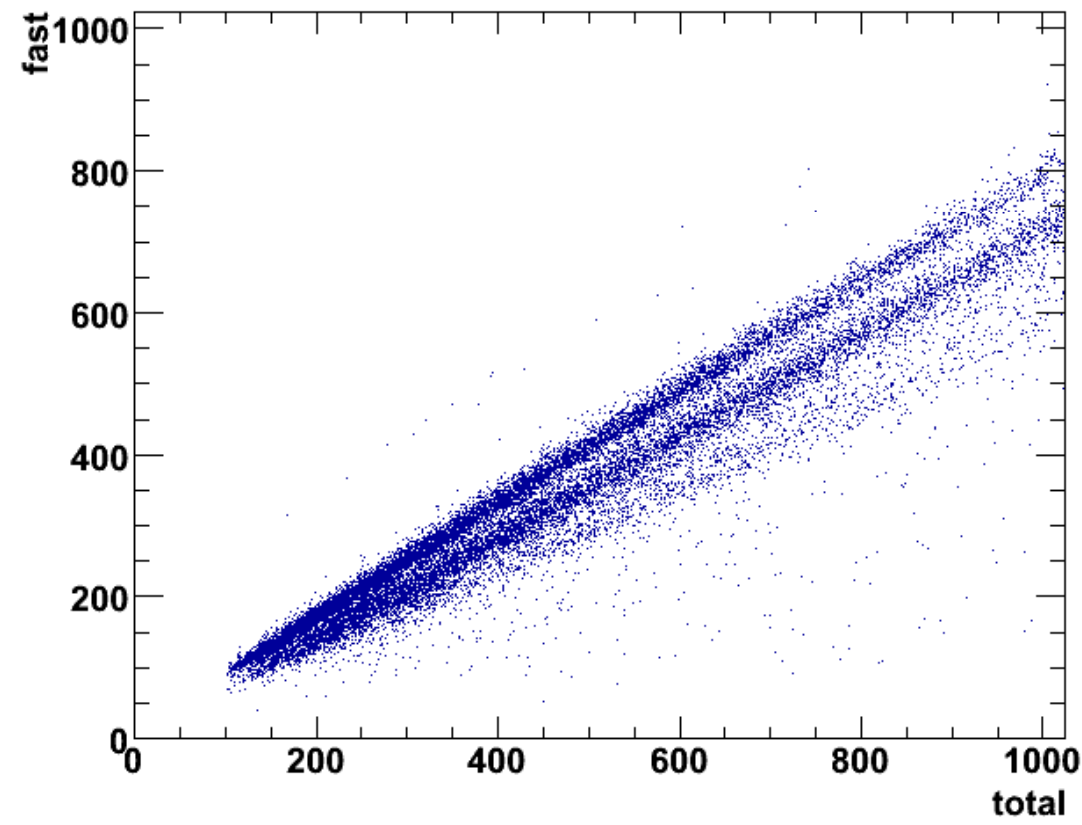
LASSA PID



# Detecting Neutrons – the Neutron Walls

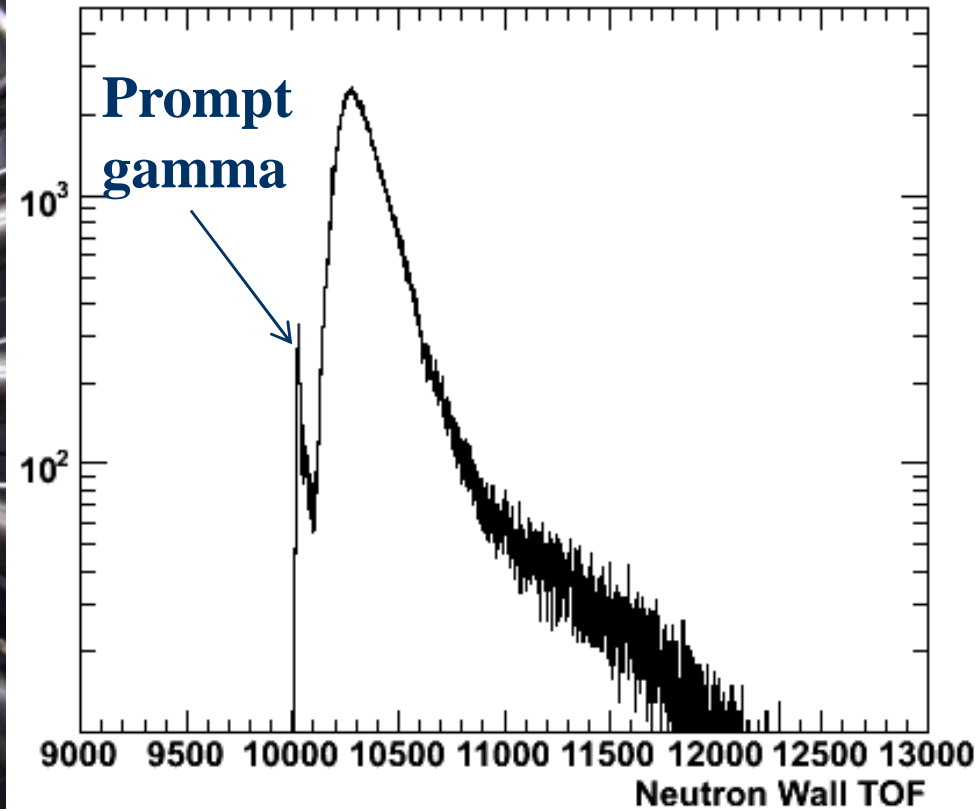
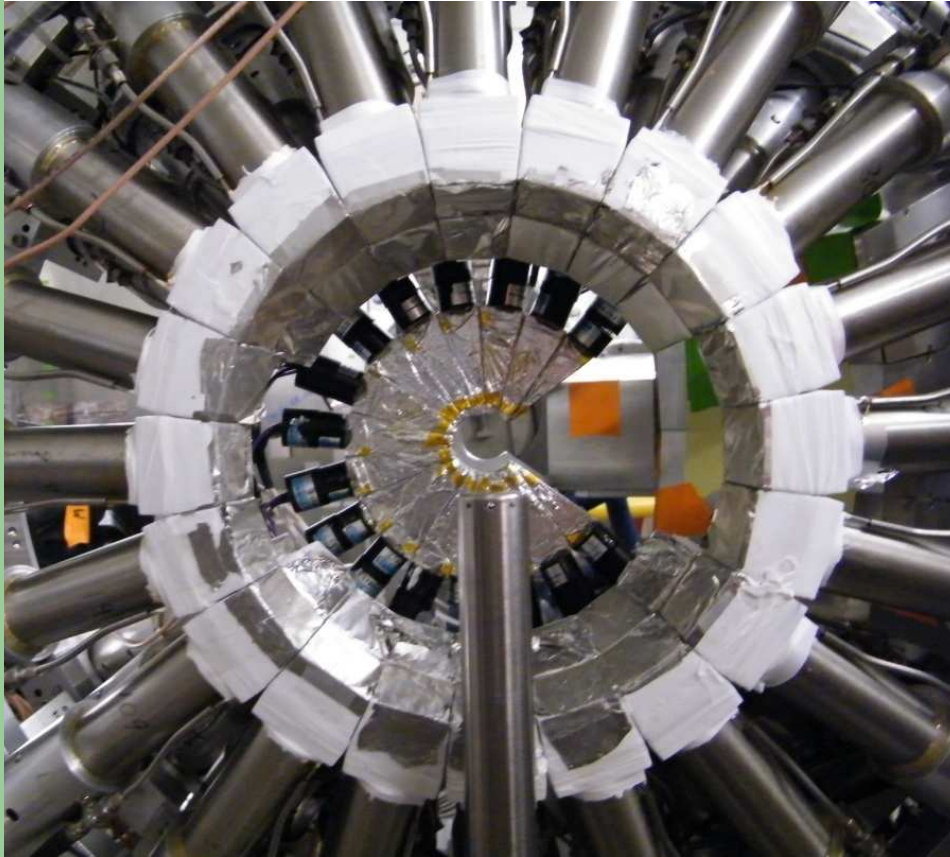


Neutron Wall PSD

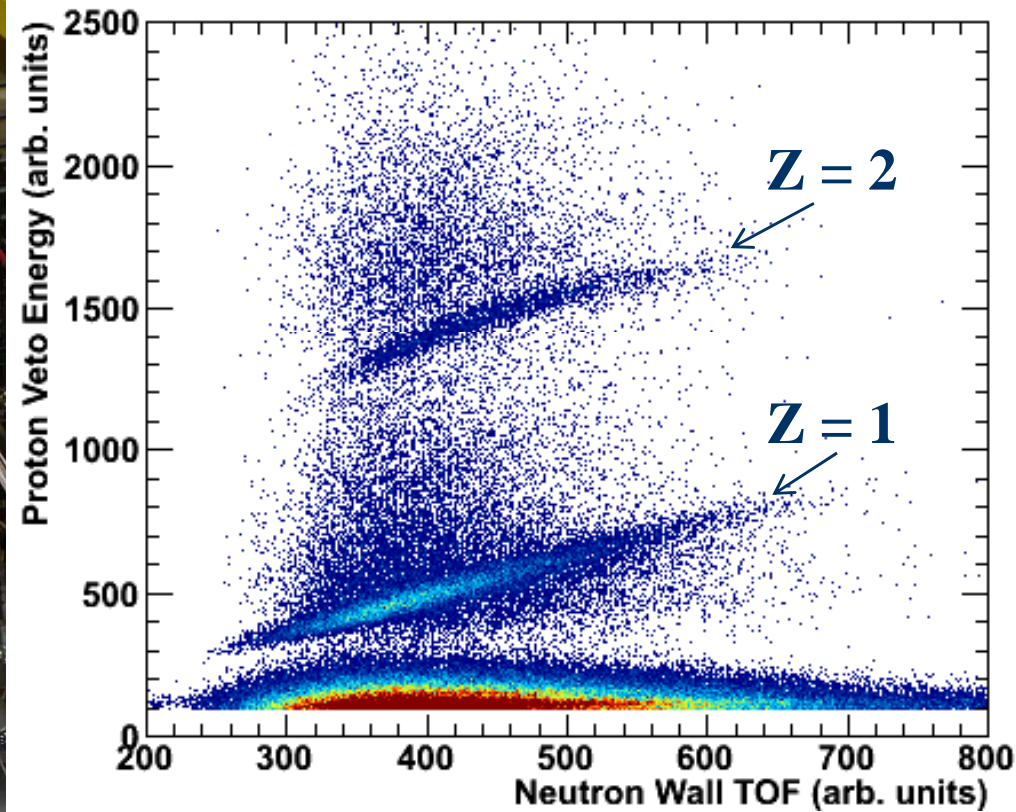
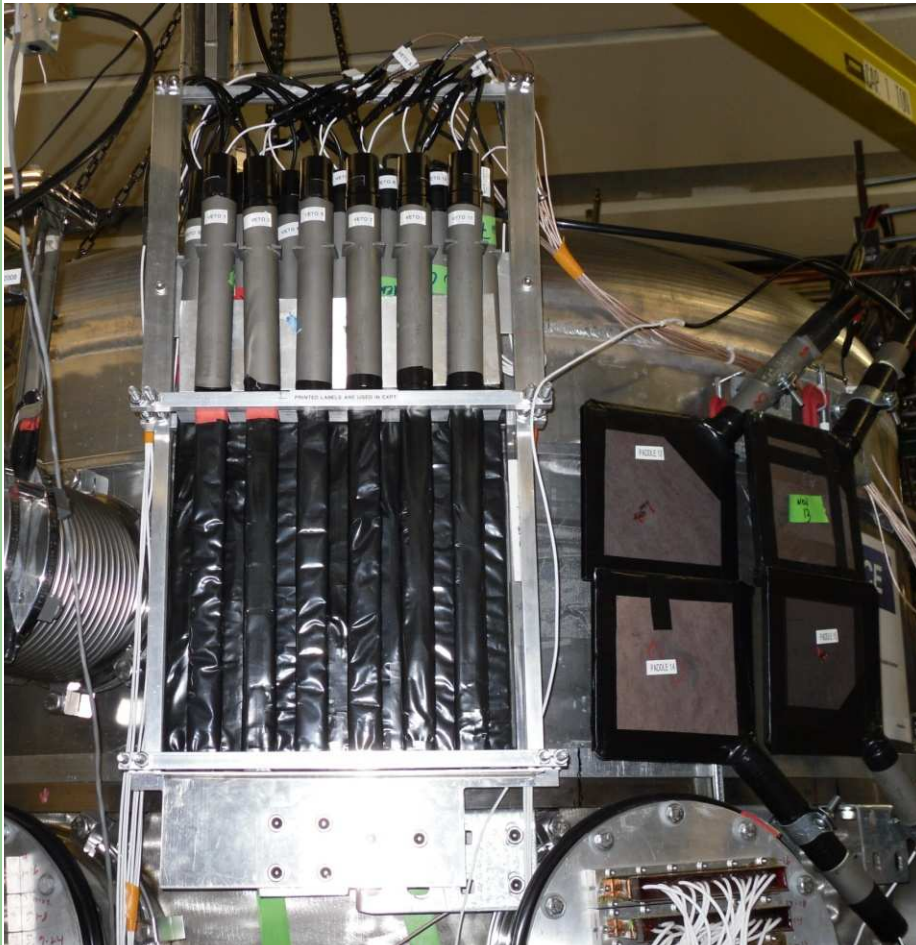




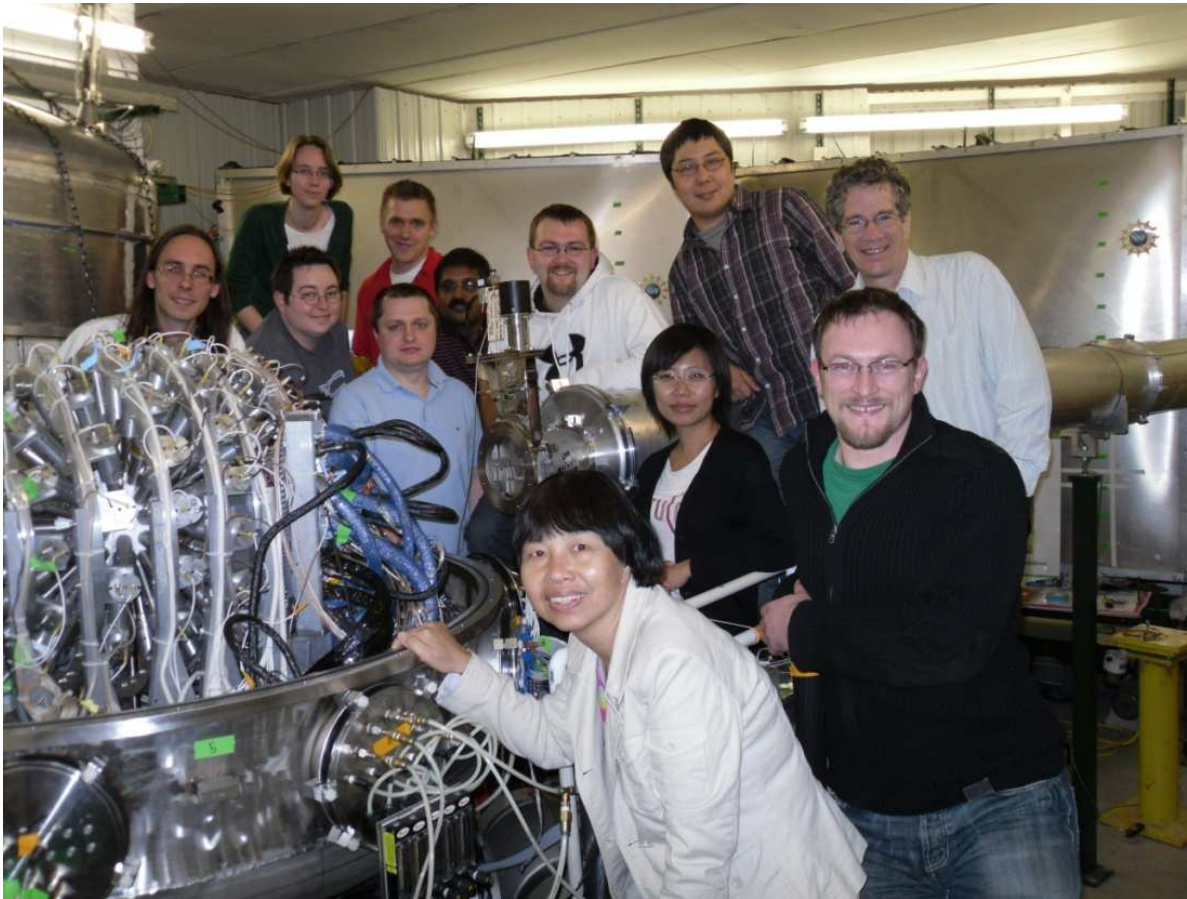
# Timing Start – the Forward Array



# The Proton Vetoes



# Collaborators



**Pictured: Dan Coupland, Rachel Hodges, Micha Kilburn, Jack Winkelbauer, Zbigniew Chajeki, Tilak Ghosh, Mike Youngs, Alisher Sanetullaev, Jenny Lee, Andy Rogers, Bill Lynch, Betty Tsang**

**Not pictured: Fei Lu, Michael Famiano, Brenna Giacherio, John Novak, Paulo Russotto, Concettina Sfienti, Giuseppe Verde**