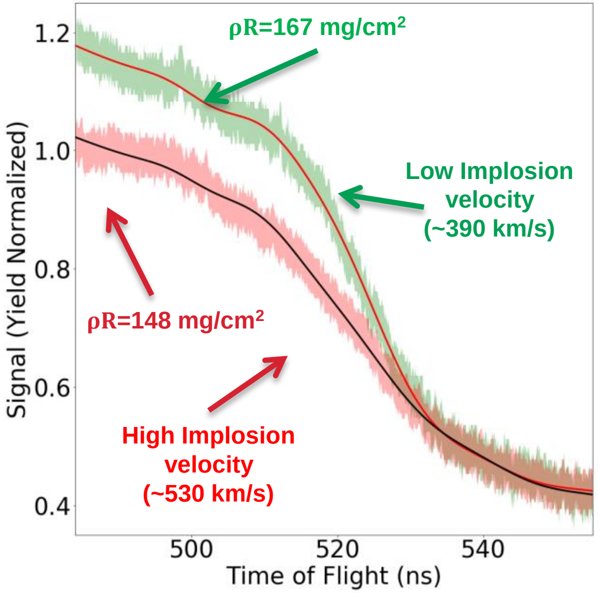
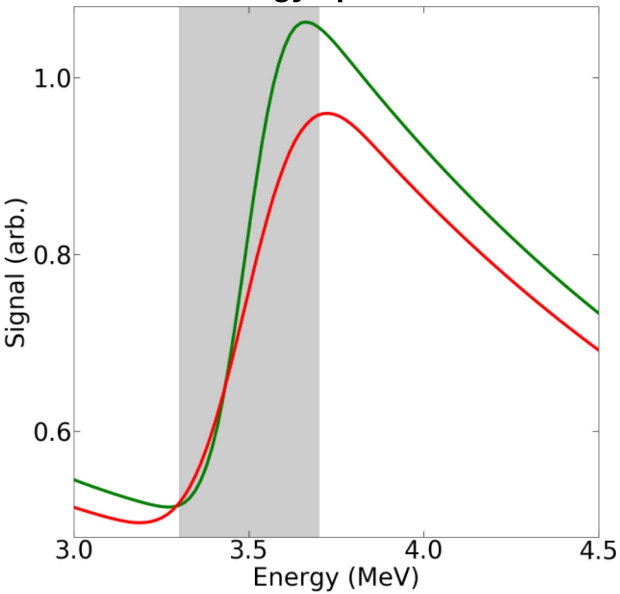
Experimental Analysis of nT Kinematic Edge Data on OMEGA

nToF measurements of nT edge



Forward modeled nT edge energy spectrum



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Collaborators

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An analysis of the nT kinematic end point has been developed to infer the moments of the triton velocity distribution in DT cryogenic implosions on OMEGA

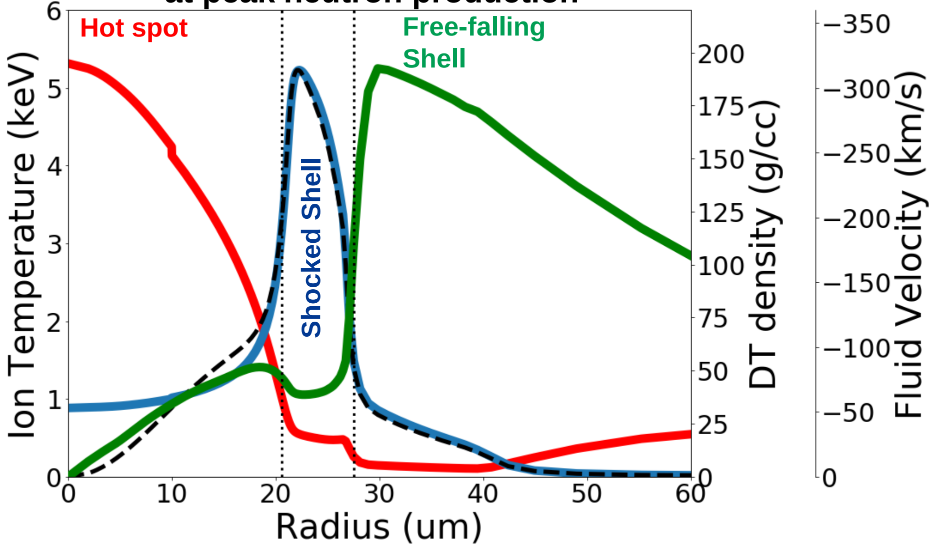
- The mean and variance of the scattered averaged triton velocity distribution as well as areal density* are inferred from the spectral line shape of the measured nT edge
- The mean of the scatter averaged triton velocity distribution shows no dependence on experiment design in both experiment and simulations
- The variance of the scattered averaged triton velocity distribution increases with implosion velocity in both experiment and simulation; however, the inferred values indicate a systematically broader triton velocity distribution in experiment

This novel measurement is the first step in diagnosing the temperature and velocity of the dense fuel layer near stagnation.

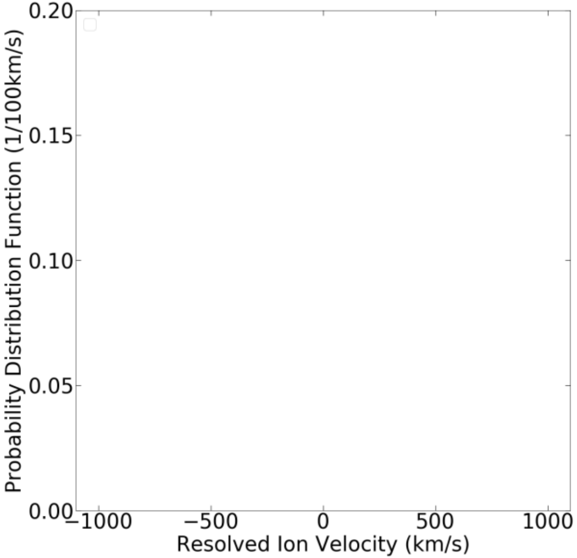
*See Z. L. Mohamed *et al*., Y05.00008.

Primary DT neutrons scatter off populations of tritons at different velocities (thermal and non-thermal) as they exit the compressed target

1-D LILAC hydrodynamic profiles at peak neutron production



Scatter-averaged triton velocity distributions



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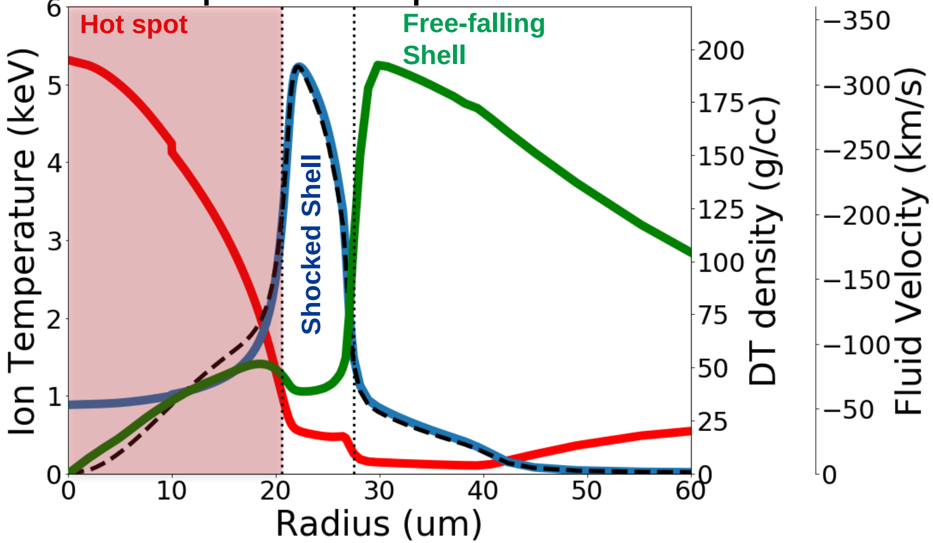

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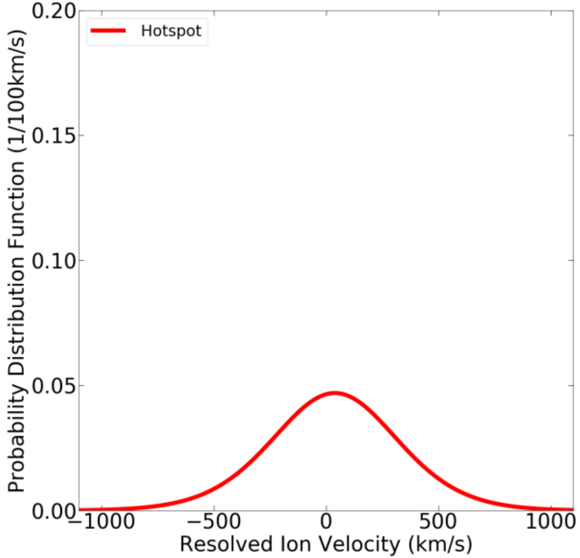

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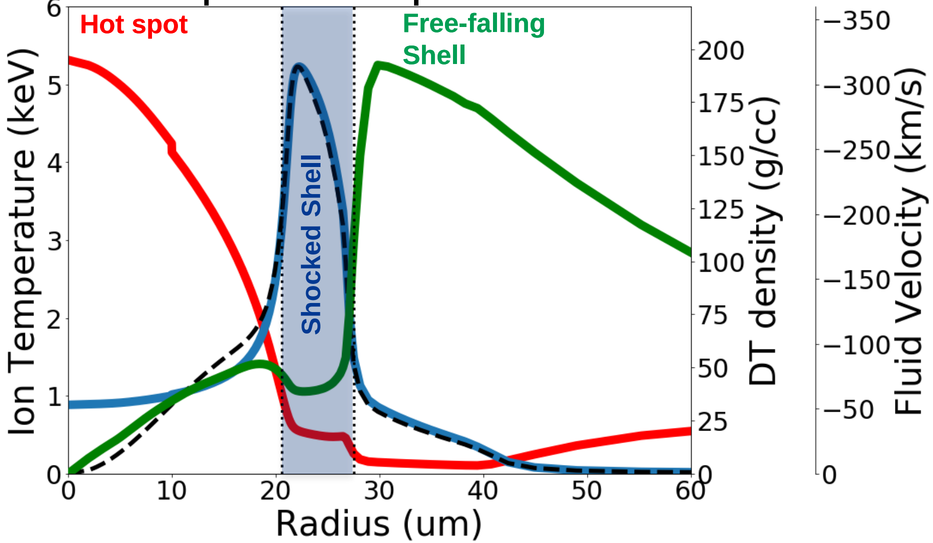

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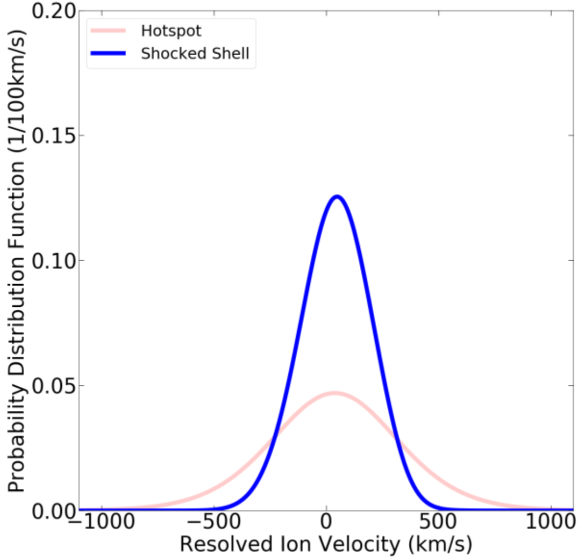

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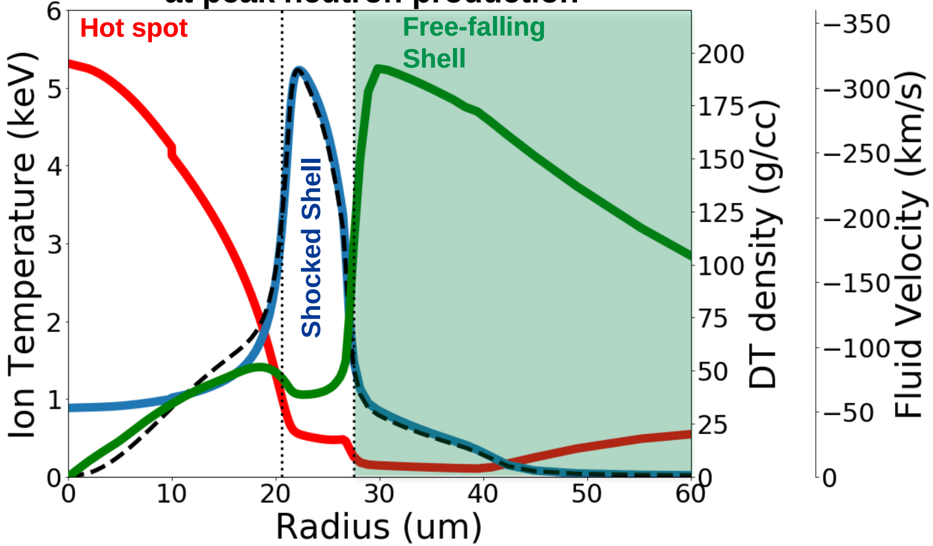

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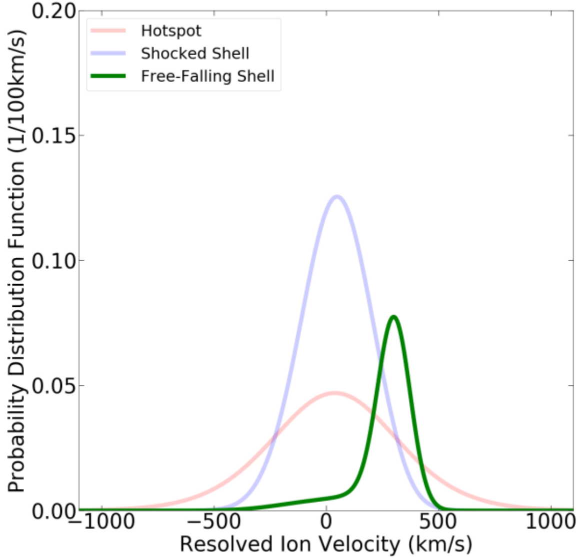

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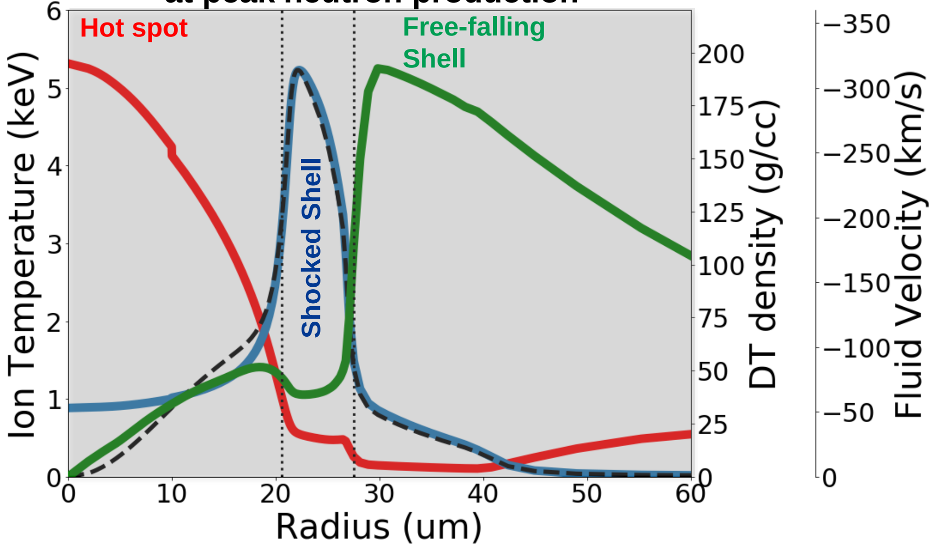

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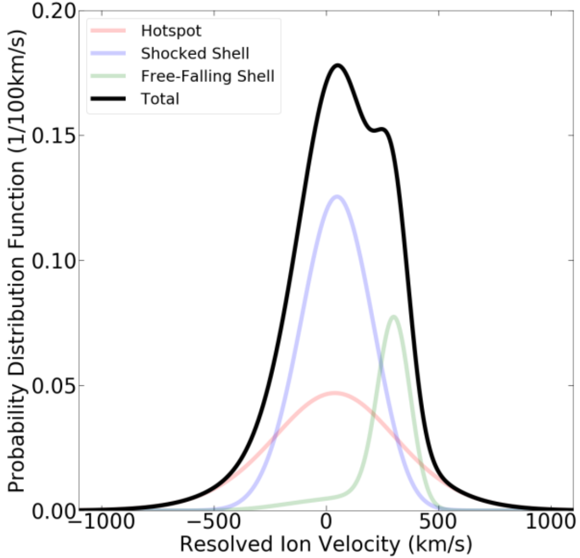

The scatter weighted triton velocity distribution contains information on the areal density, ion temperature, and velocity of each region.

Primary DT neutrons scatter off populations of tritons at different velocities (thermal and non-thermal) as they exit the compressed target

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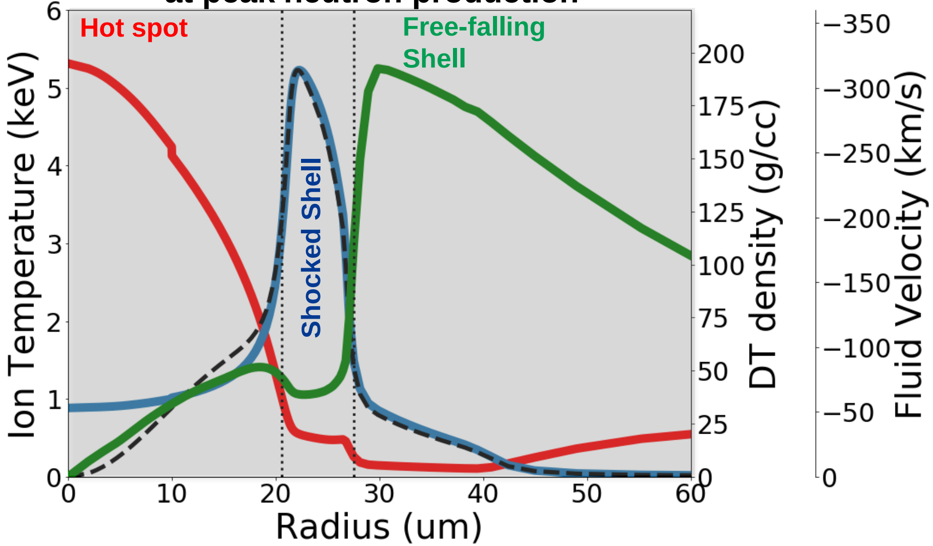

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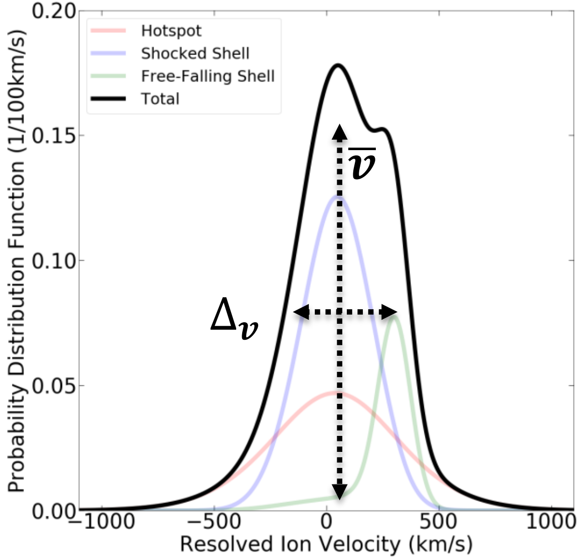
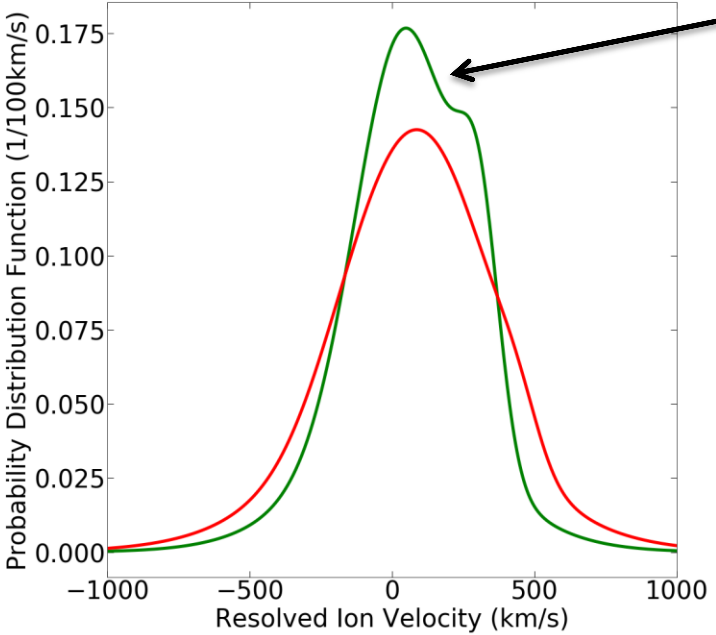


In this work we measure the mean and variance of the total scatter averaged triton velocity distribution

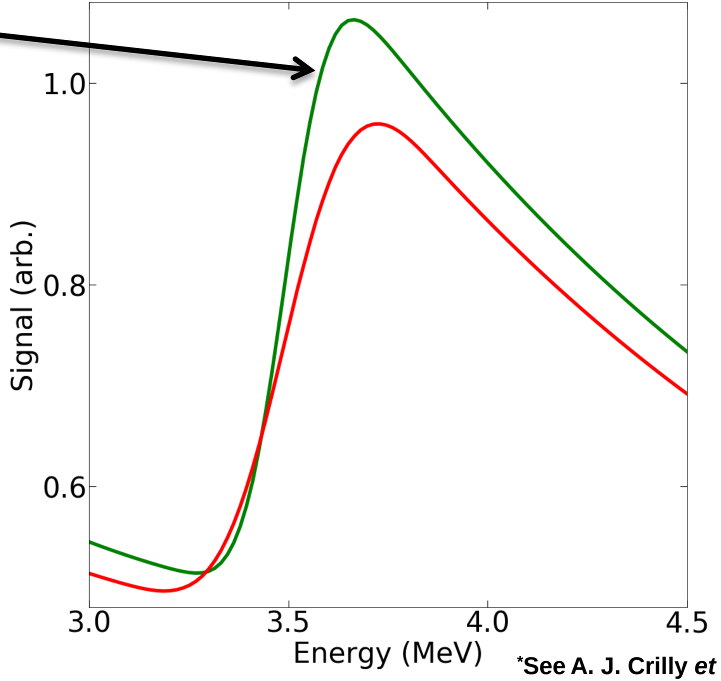
The nT edge is a distinct diagnostic feature in the neutron energy spectrum that can be used to infer information about the triton velocity distribution

1-D Simulation scatter averaged triton velocity distributions



ρR

Theoretical nT edge Spectrum*



*See A. J. Crilly *et al*., T05.00001.

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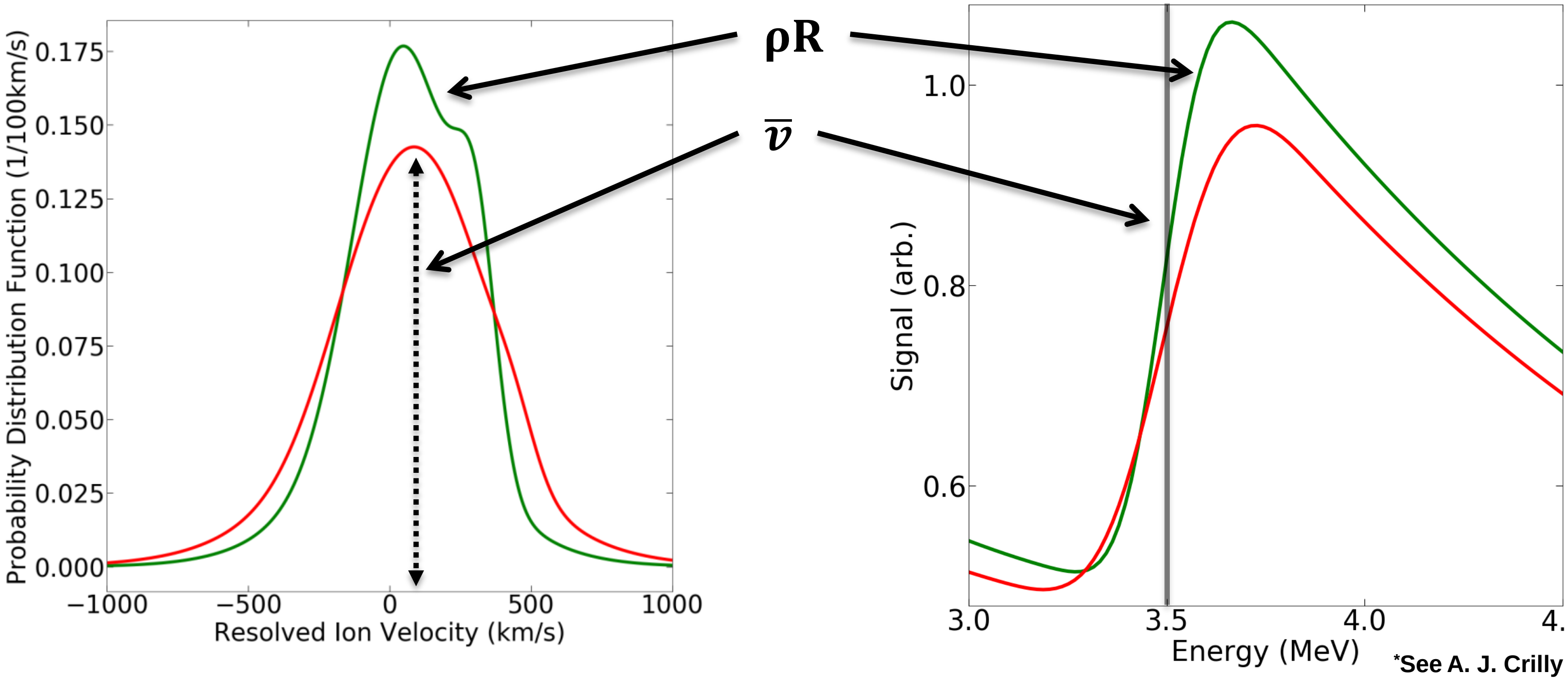

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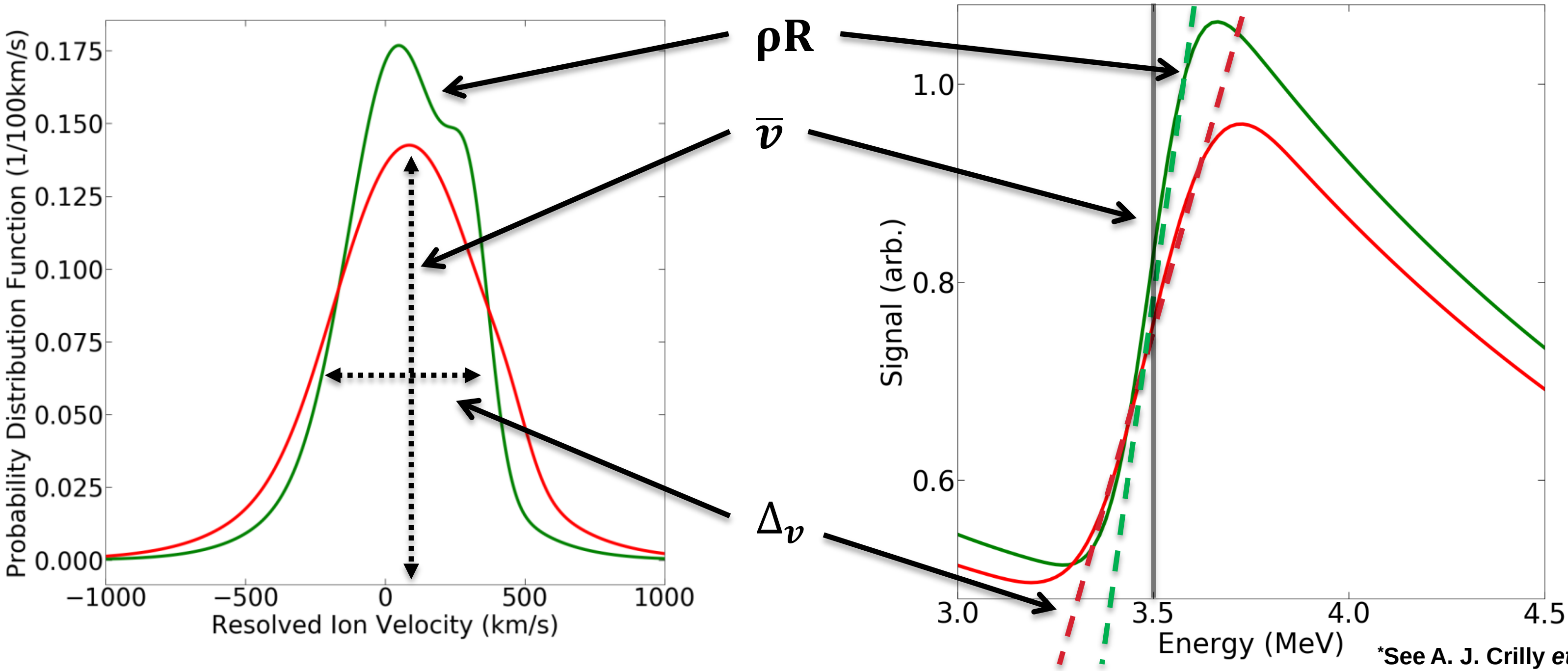
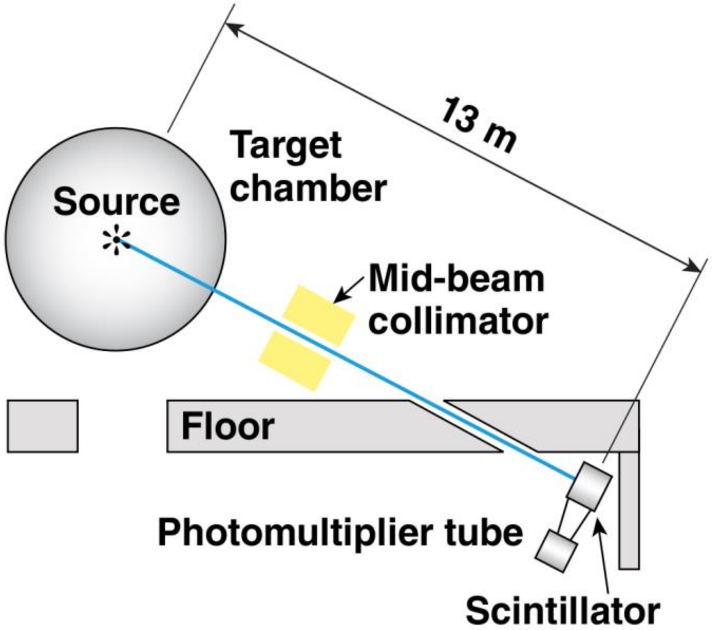
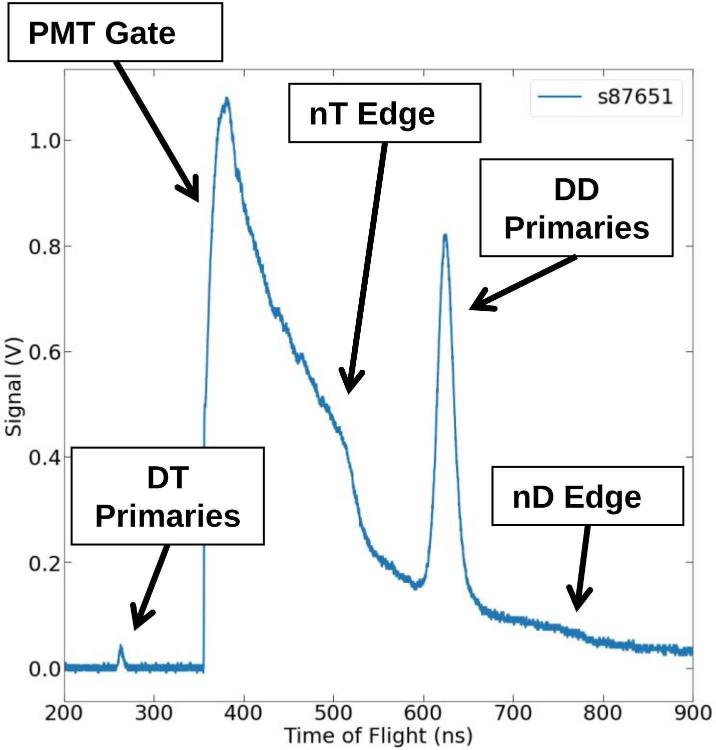


*See A. J. Crilly *et al*., T05.00001.

Neutron time of flight (nToF) detectors are used to measure the nT edge in cryogenic implosions on OMEGA*

nToF detector configuration on OMEGA



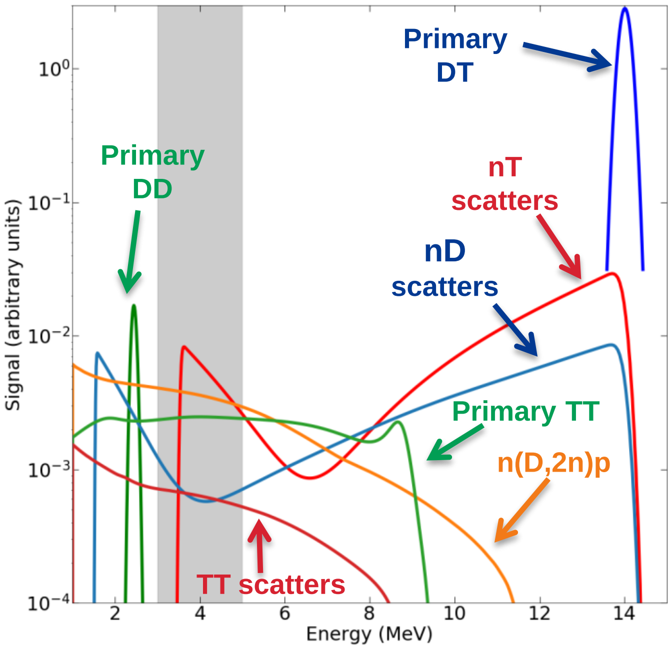


*C. J. Forrest *et al*., Rev. Sci. Instr. 87, 11D814 (2016).

A model has been developed* to enable a forward fit to be performed on experimental data

- The model includes
  - Primary DT, DD, and TT fusion neutrons
  - Single scatters of DT fusion neutrons which include nD, nT elastic scattering and the n(D,2n)p break up
- The TT fusion spectrum is scaled by the reactivity ratio and the ion temperature
- The apparent ion temperature and hot spot motion** along the LOS are included in the calculation of the nT edge shape

Model Neutron Energy Spectrum*



*See A. J. Crilly *et al*., T05.00001.
**See S. P. Regan *et al*., YO5.00002.

The detector instrument response function (IRF), detector sensitivity, and backgrounds have been characterized to enable a forward fit

- The IRF has been constructed by using a measured x-ray response and a simulation neutron response at 3.5 MeV*
- The neutron energy dependent detector sensitivity has been simulated using MCNP
- The backgrounds generated from DT neutrons and other sources have been characterized using low areal density experiments

Detector sensitivity

Neutron energy spectrum

$$m(t) = \left[s(E(t))a(E(t))I(E(t))\frac{dE}{dt}(t) \right] \otimes R(t)$$

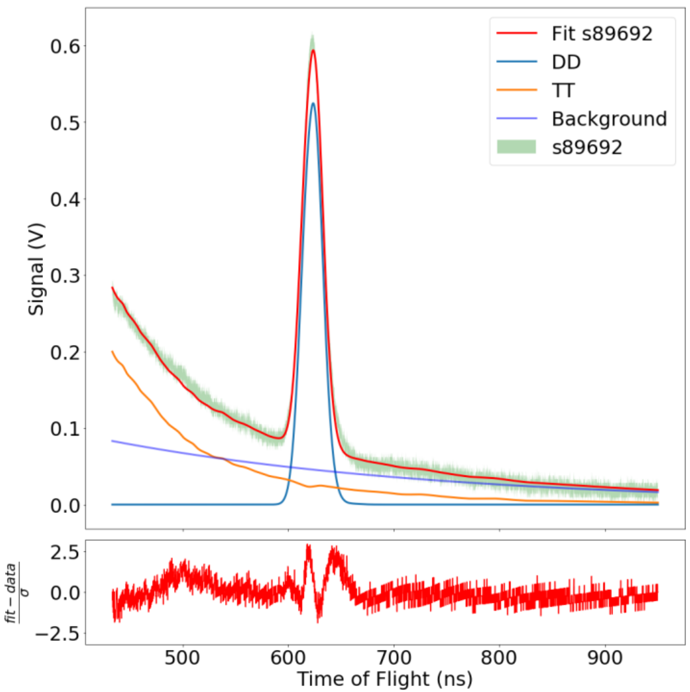
Measured nToF signal

Beam line attenuation

Jacobian

IRF

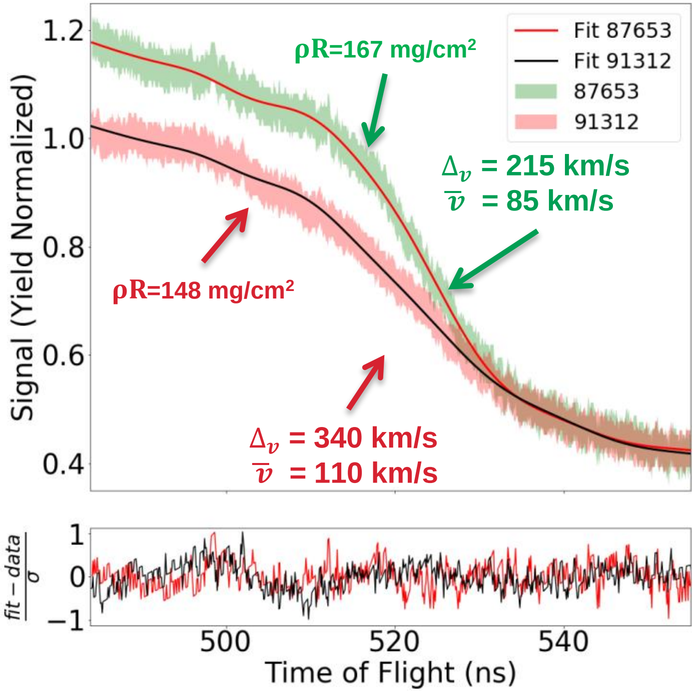
Low Areal Density Forward Model



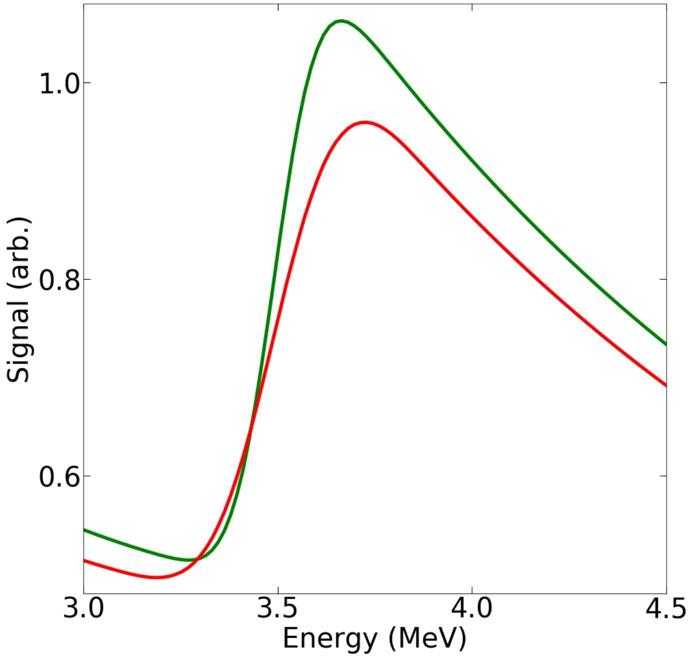
*R. Hatarik *et al.*, J. Appl. Physics. 118, 184502 (2015).

A forward fit method is applied to infer the areal density and moments of the triton velocity distribution

Forward modeled nToF Signals

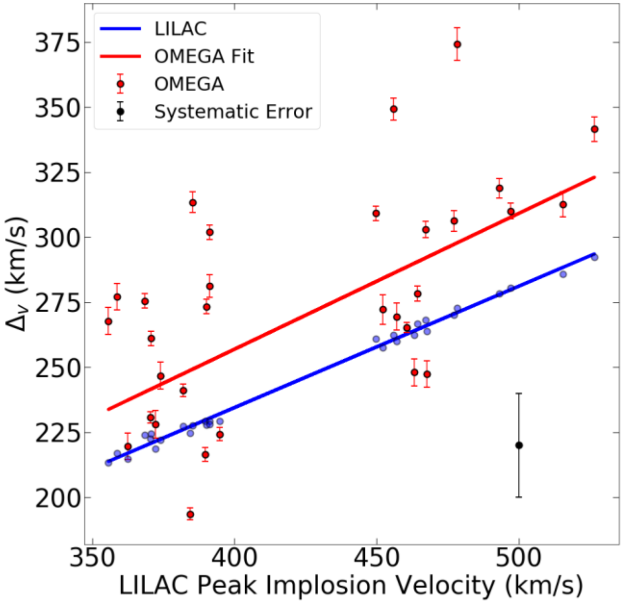


Forward modeled nT edge energy spectrum

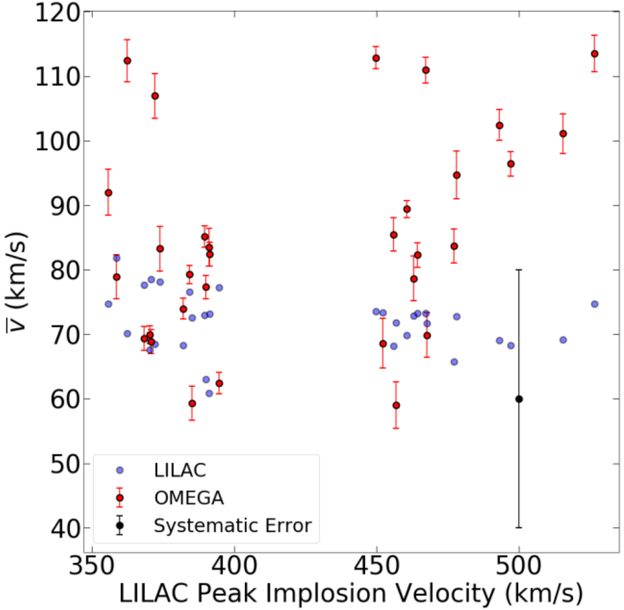


The measured Δ_v shows a sensitivity to peak implosion velocity while $\bar{v}$ is independent of target design

Δ_v vs implosion velocity



$\bar{v}$ vs implosion velocity



* Experiments from 8/8/2017 with $\rho R > 100\ mg/cm^2$ and T_{ion} asymmetry < 500 eV

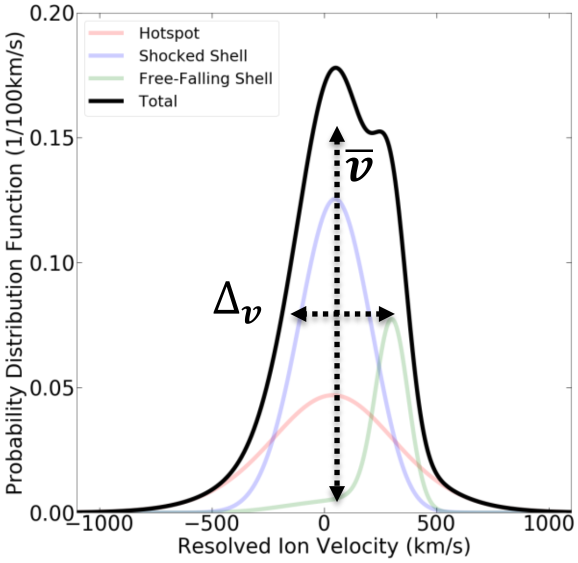
Future work will incorporate other measurements and calculations to infer the conditions of the dense shell

- **The areal density of each region determines their relative importance to the total measurement**
- **The neutron averaged hot spot ion temperature is measured on OMEGA**
- **The hot spot and shocked shell move together with the hot spot velocity which is measured on OMEGA**

$$\overline{v} = A_{HS}\overline{v}_{HS} + A_{SS}\overline{v}_{SS} + A_{FS}\overline{v}_{FS}$$

$$\Delta_v^2 = A_{HS}(\Delta_{v,HS})^2 + A_{SS}(\Delta_{v,SS})^2 + A_{FS}(\Delta_{v,FS})^2$$

Scatter-averaged triton velocity distributions



Summary

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