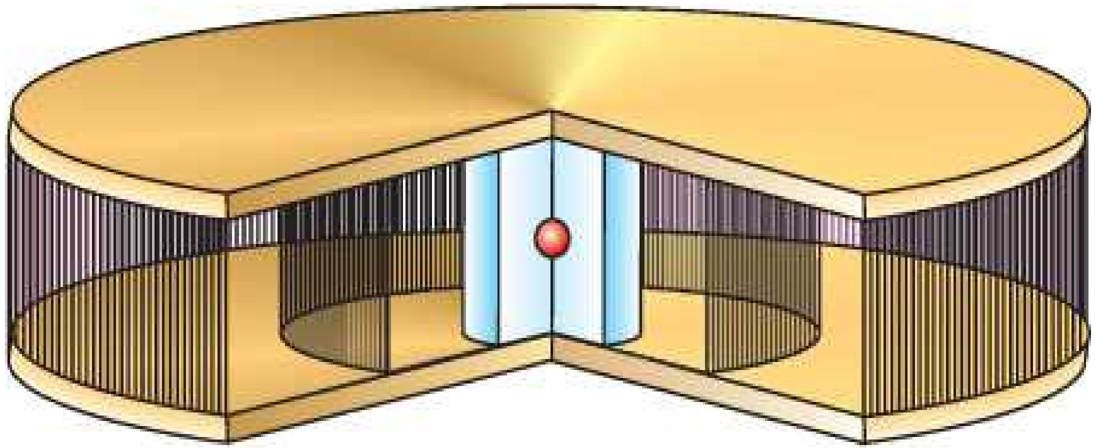
SAND2006-2932C

Diagnostics for Thermonuclear Neutron Production from Deuterium-Filled Capsule Implosion Experiments at Sandia National Laboratories' Z Facility



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Albuquerque, New Mexico

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Williamsburg, Virginia

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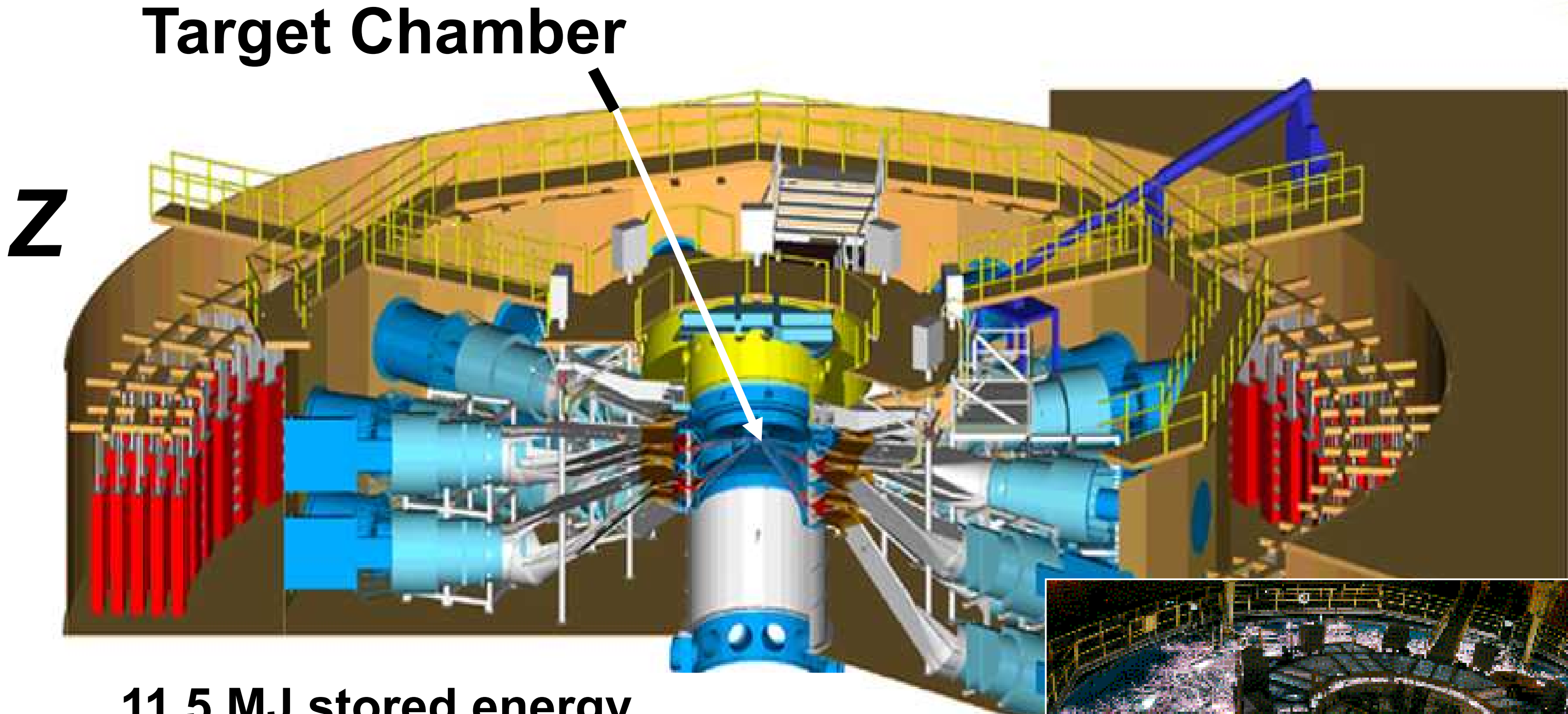
Outline of the presentation

- Introduction
- Description of Sandia National Laboratories' Z facility
- Dynamic hohlraum experimental layout on Z
- Neutron diagnostic strategy on Z
  - Concern of Z-pinch produced beam target neutrons
  - Measurement of neutron velocity and energy in two nearly orthogonal directions
  - Neutron activation measurements of neutron yield as function of angle
  - Use of "null targets" that had deuterium fill doped with Xe gas to induce "radiation cooling" of the compressed target core to turn off neutron production
- Results of neutron production experiments using dynamic hohlraum driven capsules
  - First observation of laboratory thermonuclear neutrons from capsules driven by a non-laser source
  - Neutrons were produced in Be, plastic, and glass targets
- Summary of paper

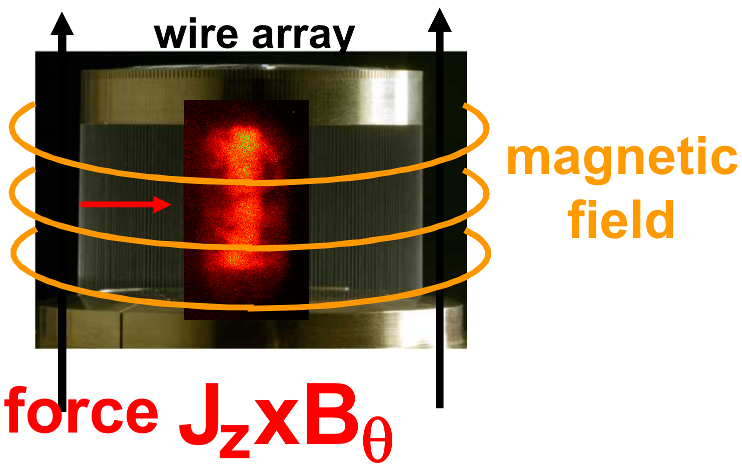
Pulsed-power accelerators with a variety of loads provide efficient time compression and power amplification

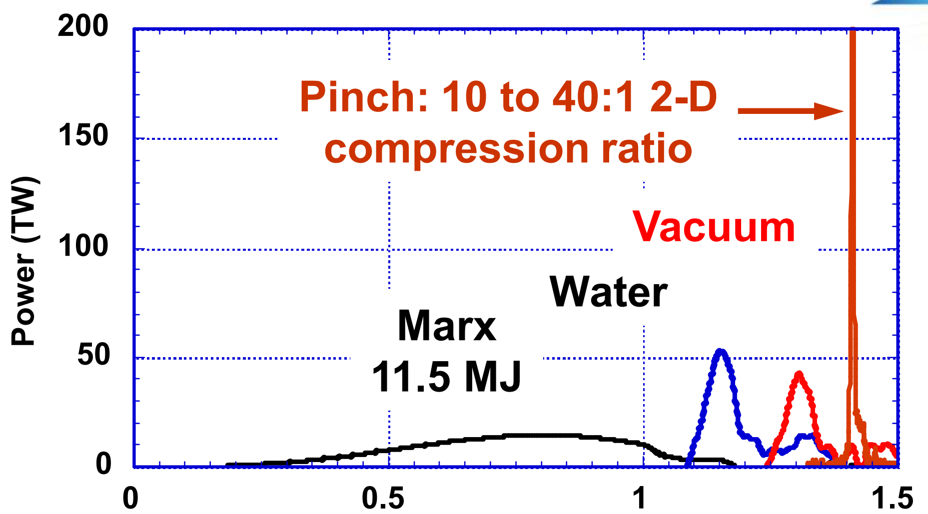


- 11.5 MJ stored energy
- 19 MA peak load current
- 40 TW electrical power to load
- 100-250 TW x-ray power
- 1-1.8 MJ x-ray energy
- Flyer plate velocities of 28 km/s

Z pinches are confined and accelerated by the self-B fields generated by an axial current

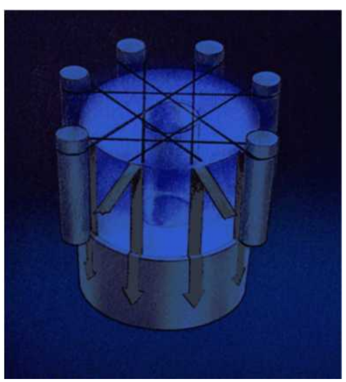
axial current ≈ 20 MA



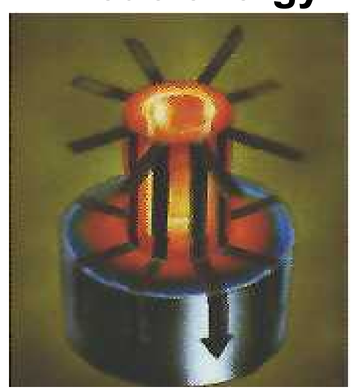


Kinetic and magnetic energy
↓
Internal energy
↓
X-rays

Electrical energy
↓
Kinetic energy



Initiation



Implosion

Stagnation

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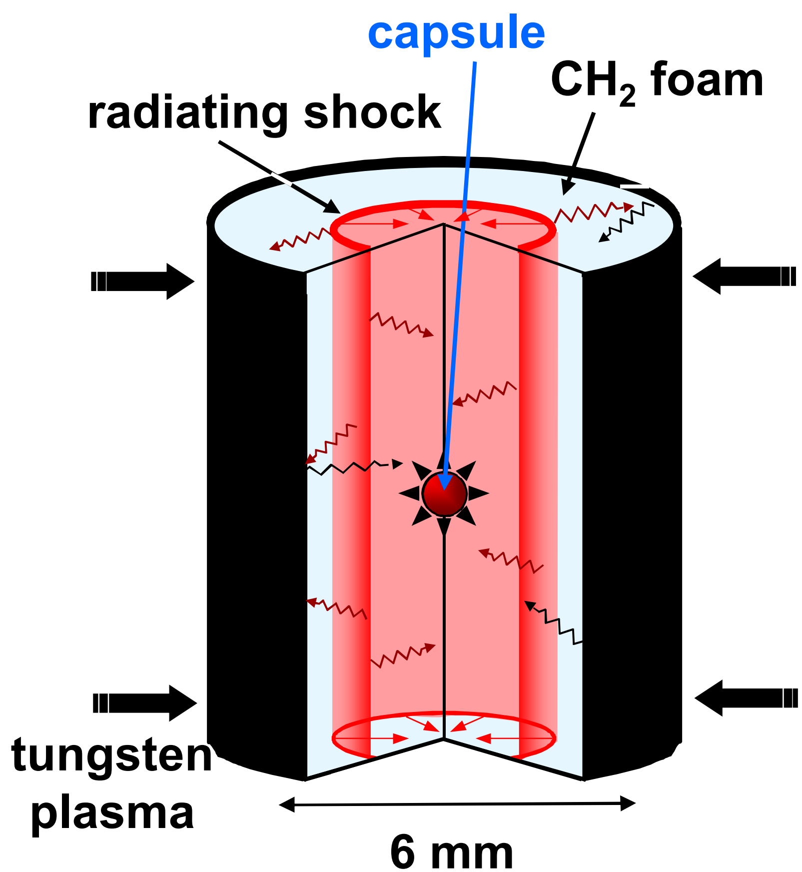
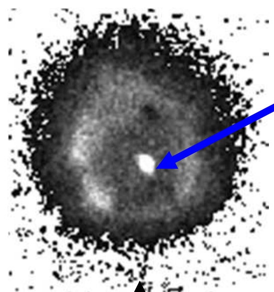
Dynamic hohlraums efficiently couple x-rays to capsules



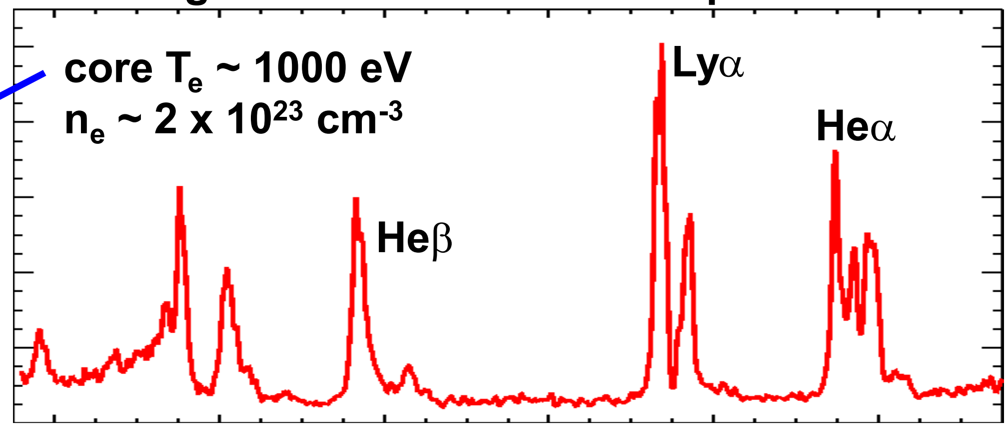
- Z-pinch plasma impacts foam converter
- The impact launches shocks in foam and tungsten
- The foam shock is a main radiation source
- The z-pinch confines the radiation
- Capsule heated mainly by re-emission from tungsten hohlraum wall
- Peak radiation drive temperatures of >200 eV are achieved in this system

Core temperature, density, and symmetry diagnosed in dynamic hohlraum-driven ICF implosions

Capsule absorbs ~ 24 kJ x-rays
Implosion creates a 200 μm diameter hot core

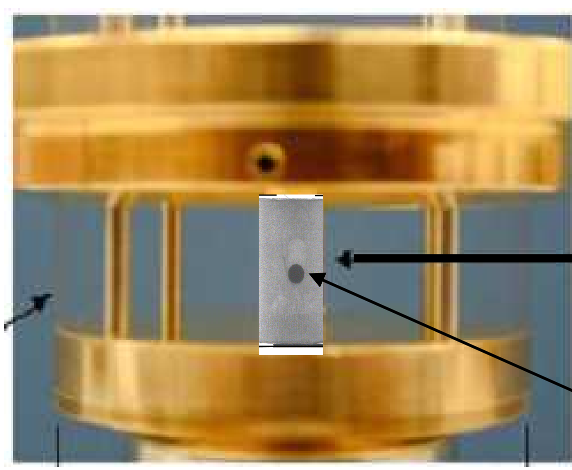


argon emission from ICF capsule

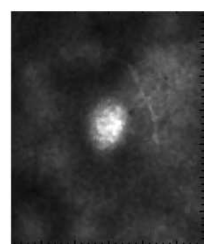


Wire impact on foam creates 200 eV dynamic hohlraum x-ray source

Wires

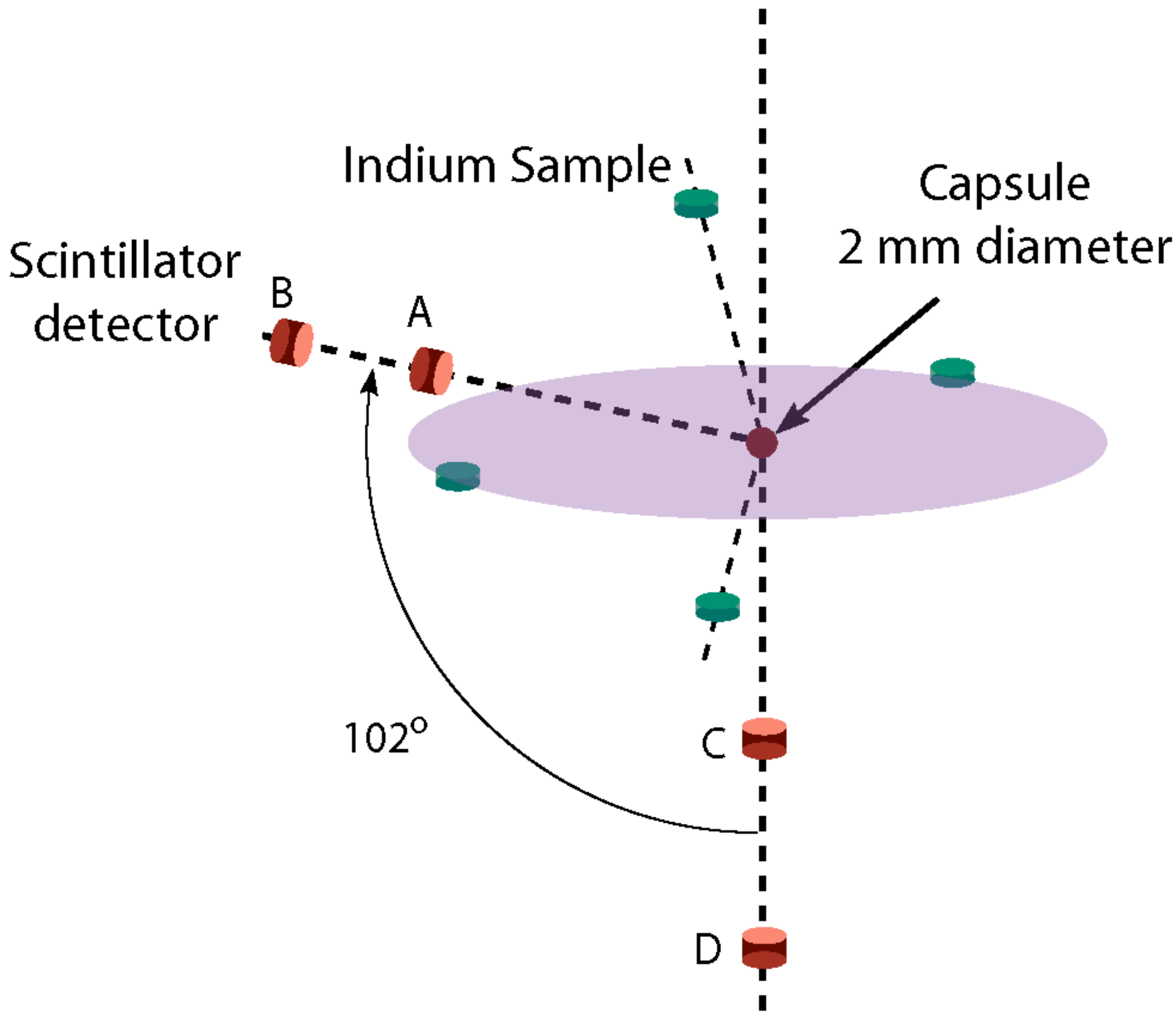


Imploded core (side-on image through pinch)



2.0 mm diameter, 50 μm CH wall D_2-filled capsule embedded in 14 mg/cc CH_2 foam

Schematic of the neutron diagnostic arrangement used in these capsule experiments is shown here



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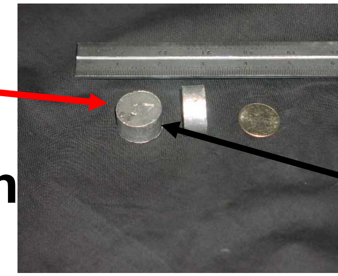
Indium samples

^{115}In (n,n') ^{115m}In

(E_{thres}=336.0 keV, E_{γ}=336.0 keV, $\tau_{1/2}$ = 4.49 h



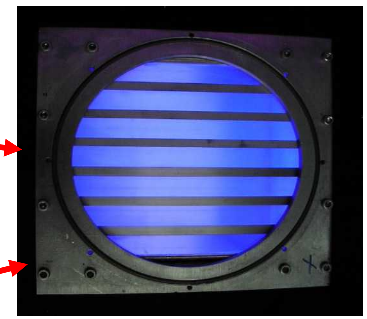
2.5 cm x 1.3 cm sample
5.5 grams

Lead layer cake

^{207}Pb(n,n') ^{207m}Pb

(E_{thres}=1633 keV, E_{γ}=569.7 keV,

E_{γ}=1063.6 keV, $\tau_{1/2}$ = 0.8 sec)



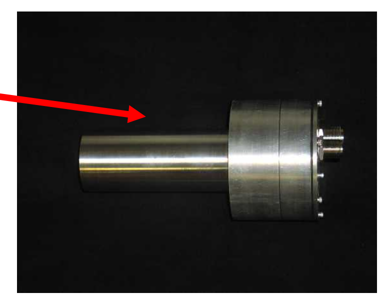
Under development

Beryllium layer cake or rod detector

^{9}Be (n,α) ^{6}He

(E_{thres}=0.67 MeV,

β^{-} with 3.5 MeV endpoint, $\tau_{1/2}$ = 0.8 sec)



See paper TP2, A. J. Nelson et al. for further details

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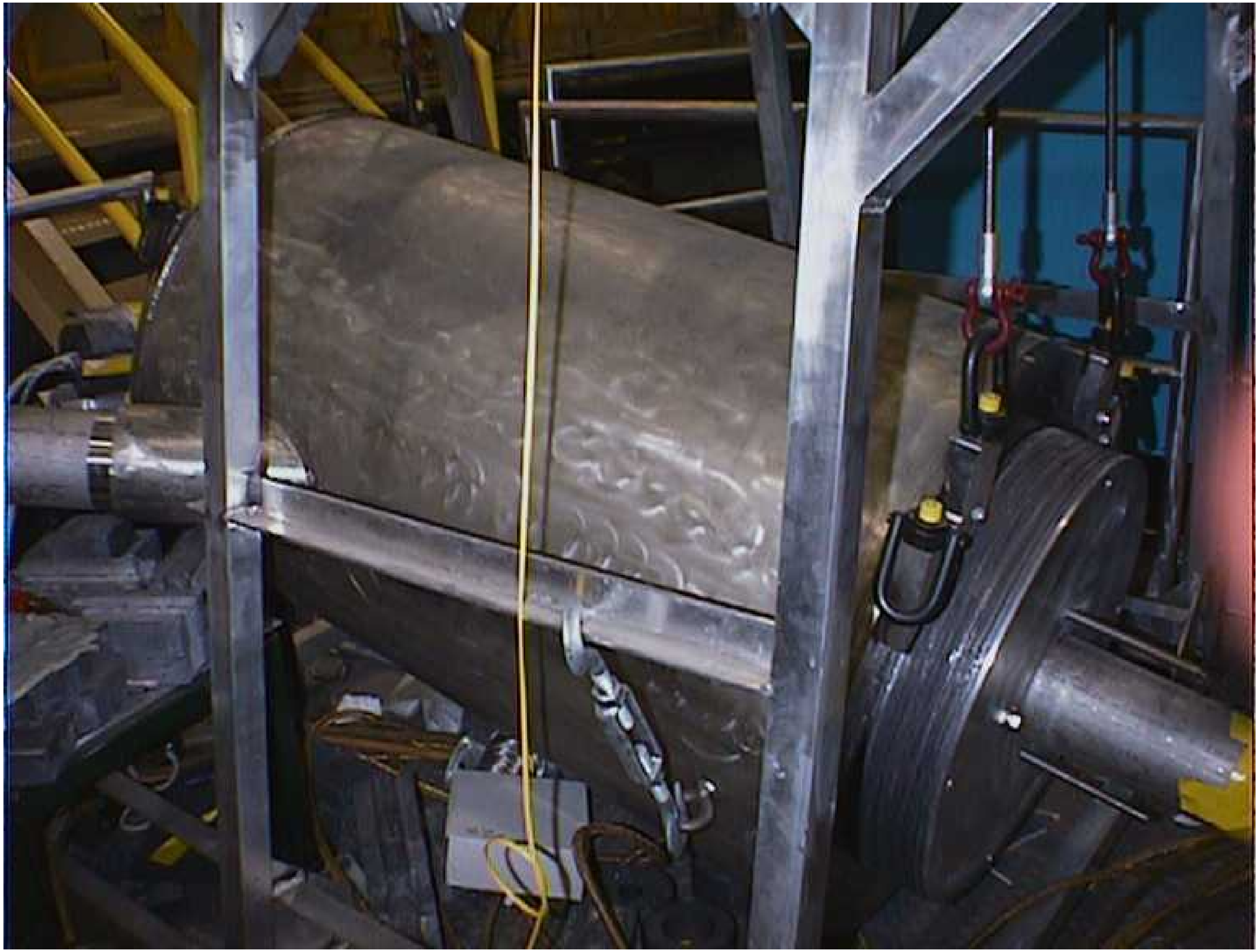
A heavy Pb shield (9000 lbs.) and collimator is required for neutron time-of-flight measurements on Z



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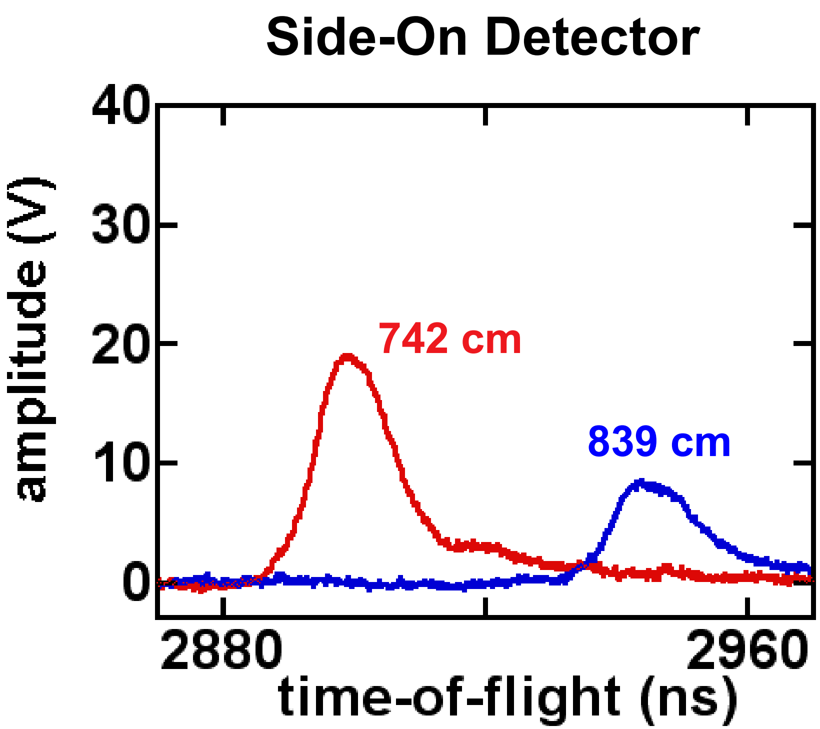
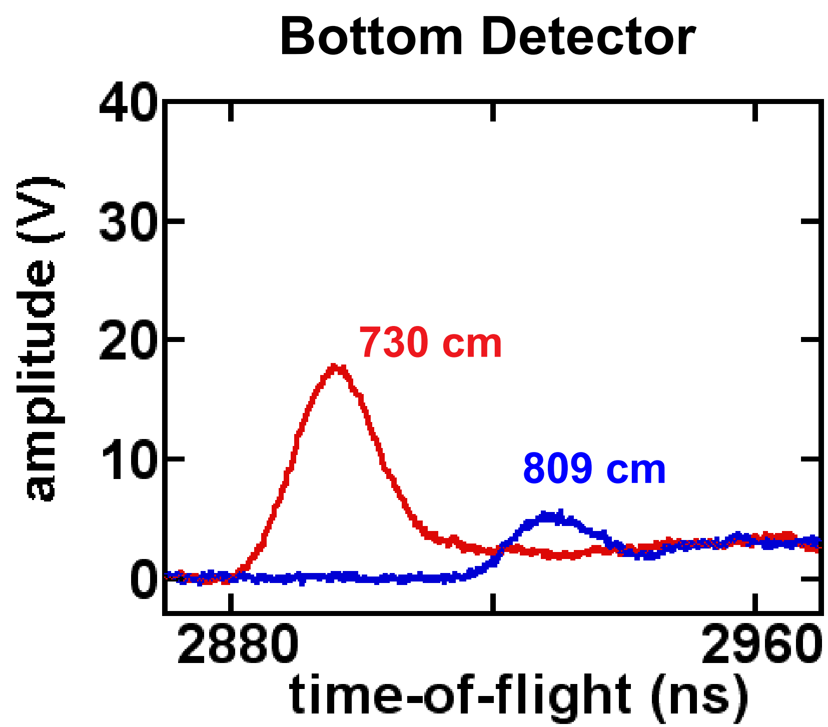
Fast signals are detected on both side-on and bottom neutron time-of-flight detectors





Data is from a standard 50 μm CH wall, 2-mm diameter capsule filled with 24 atm D_2 + 0.085 atm Ar

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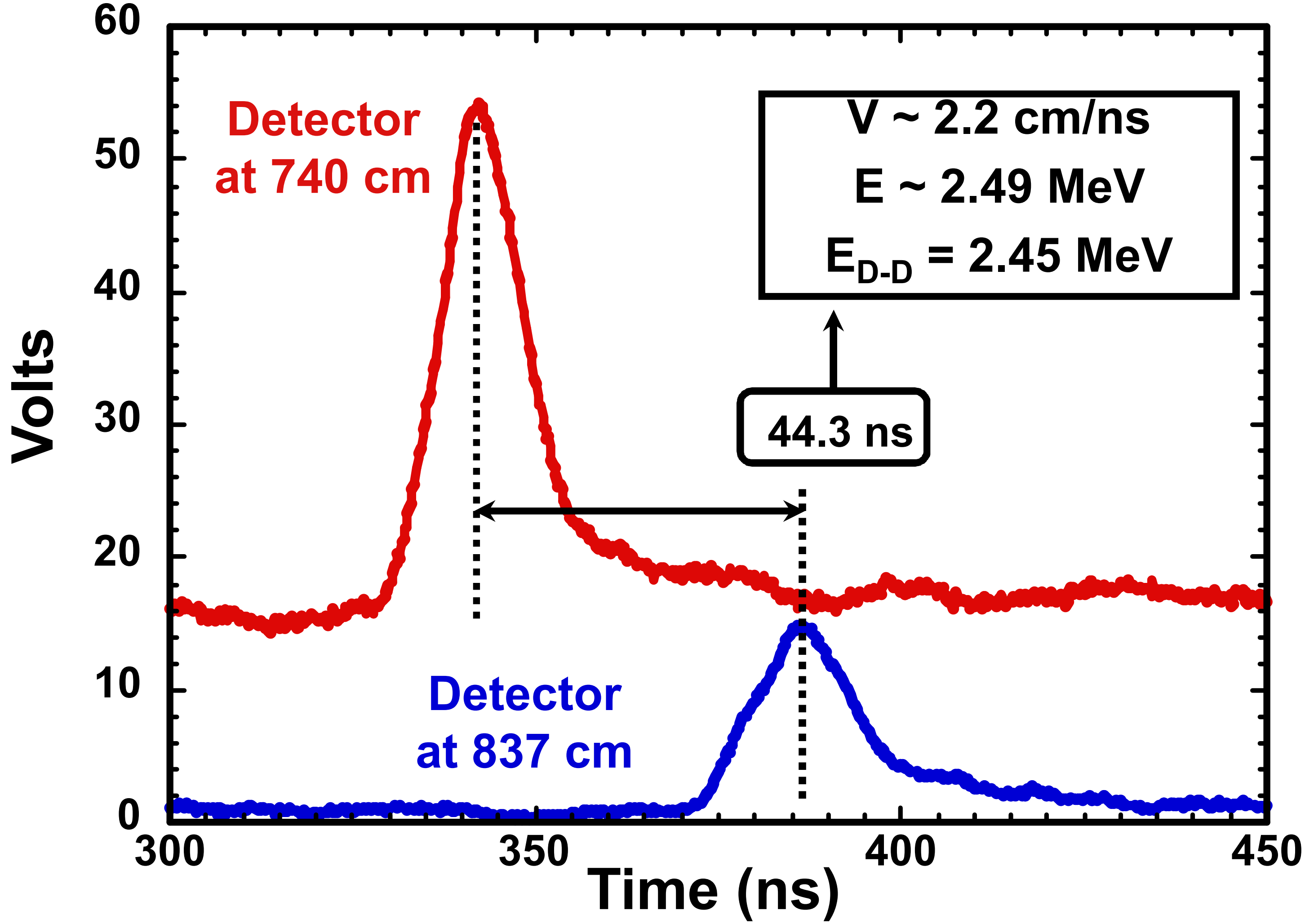
Side-on neutron time-of-flight data showing the detection of DD neutrons on a Be capsule shot



Data from 2-mm Be capsule with 33-μm Be wall on 18-μm plastic filled with ~16 atm DD

Z1642

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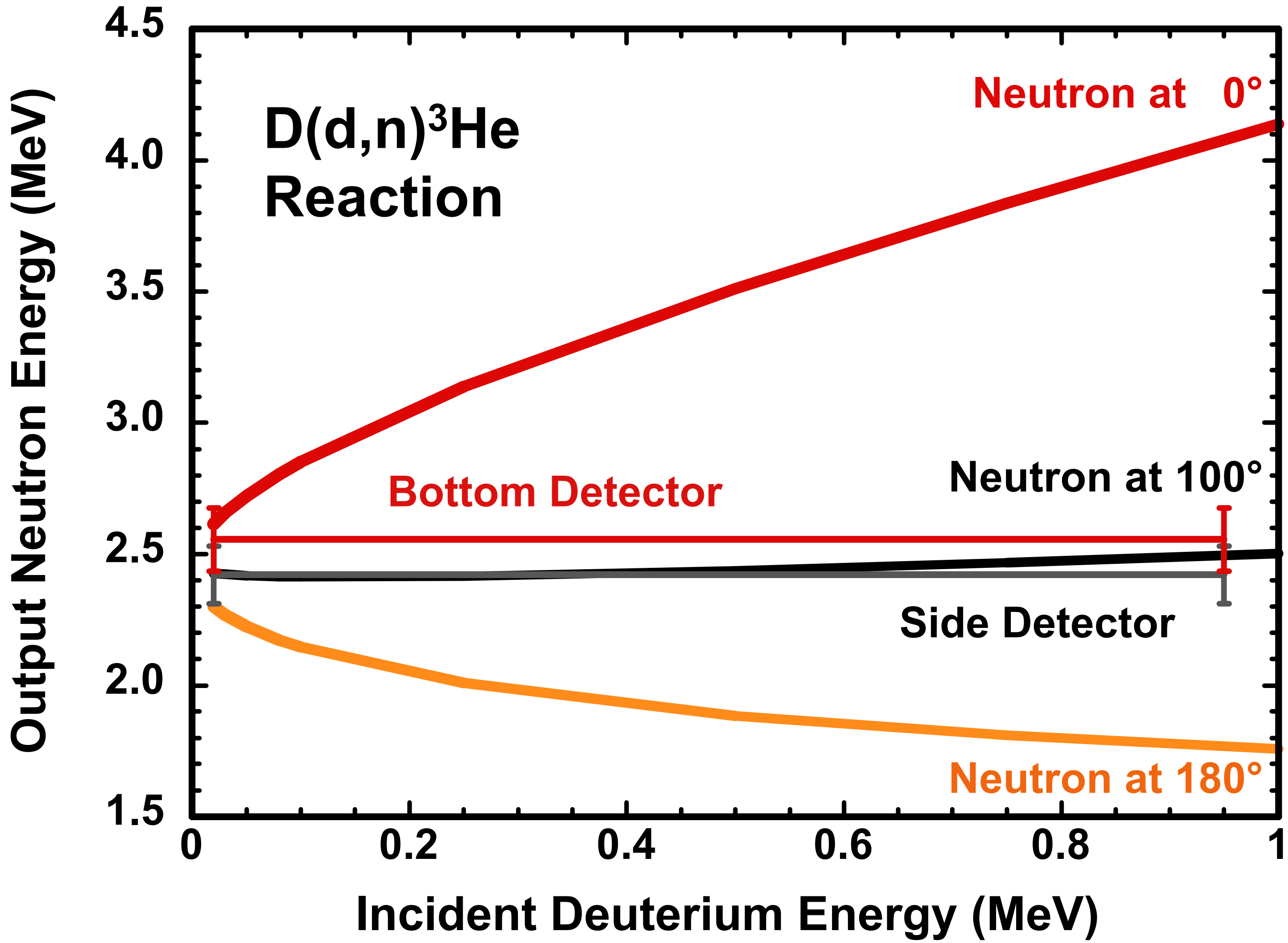
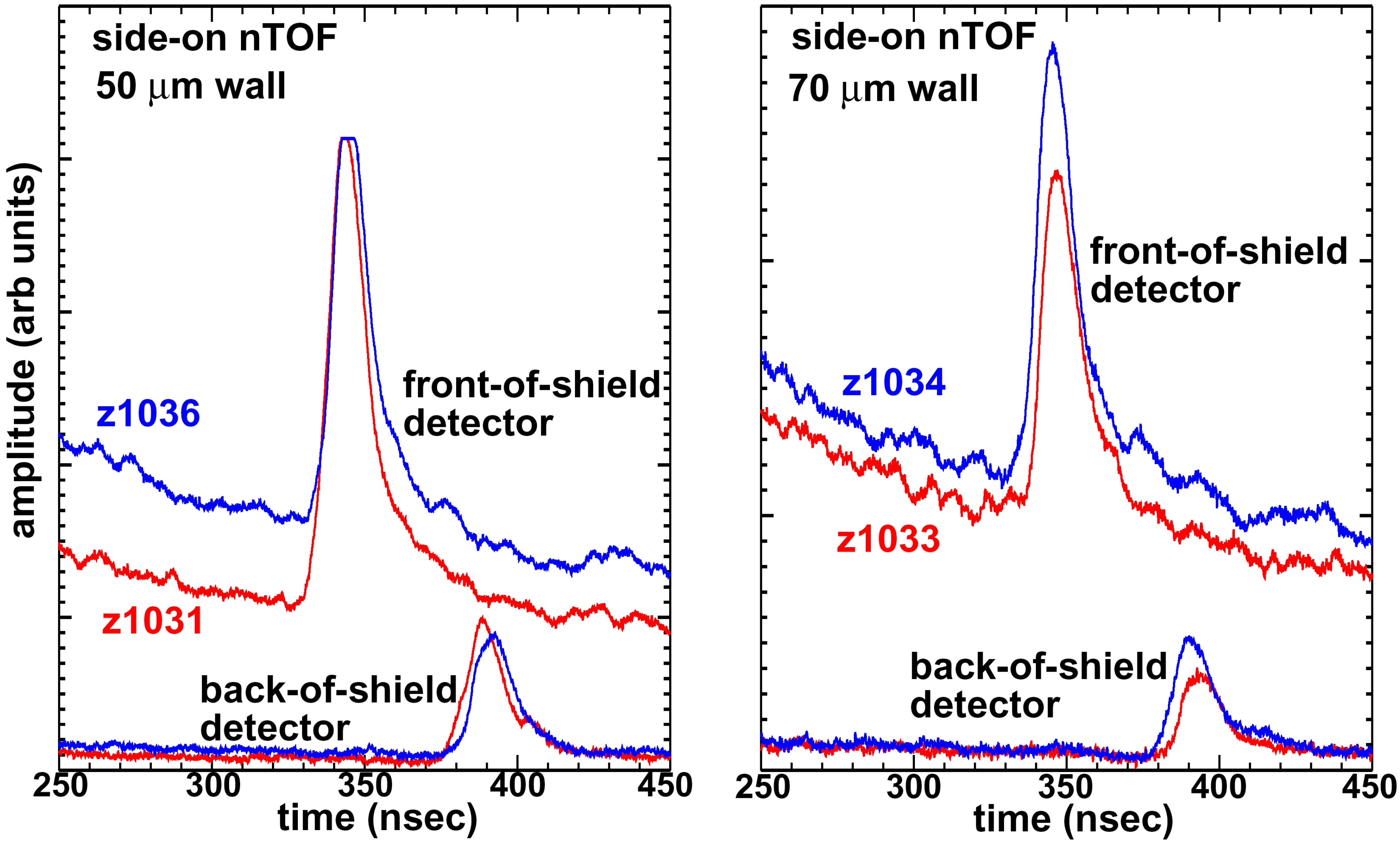
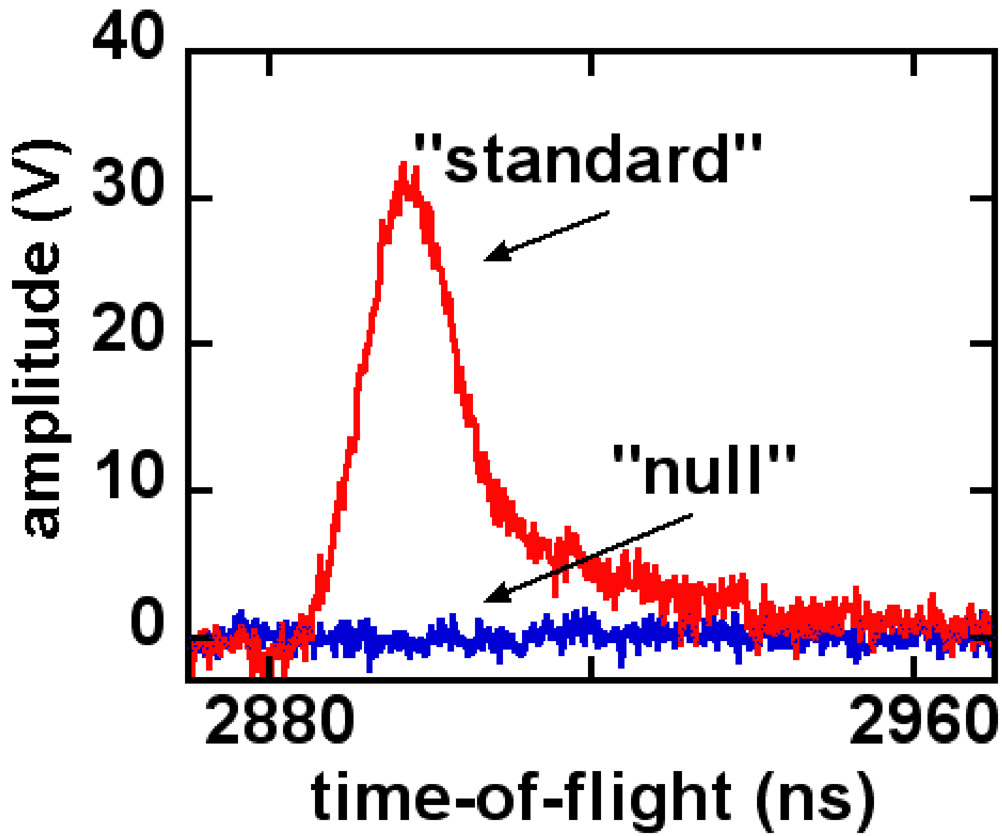
The measured side and bottom neutron energies restricts the possibility of a beam induced neutron mechanism



The neutron time-of-flight signals exhibit respectable reproducibility



Neutron time-of-flight signal dramatically decreases when Xe fill gas is added to “null” the production of thermonuclear neutrons



Z1031 “standard” fill (24 atm D_2 + 0.085 atm Ar)
Z1032 “standard” fill + 0.6 atm Xe

- On “null shots,” neutron yield measured by Be activation decreased by more than an order of magnitude

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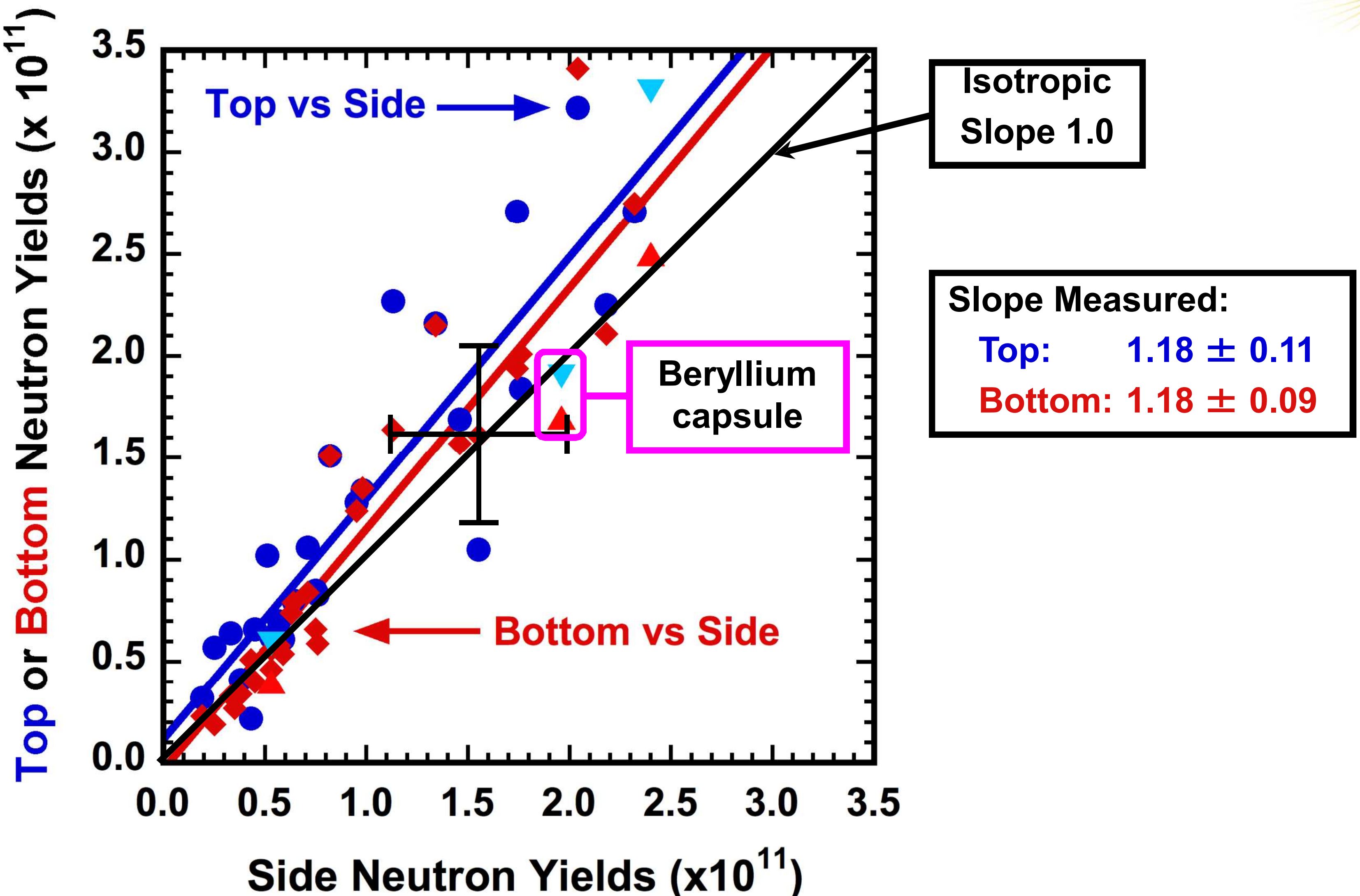
The top or bottom vs side neutron activation yield is isotropic to within ~25%



A summary of the largest DD neutron yields from Be, plastic, and glass capsules shot to date

Target Type (2-mm diameter)	DD Neutron Yield into 4π (In Activation)
Plastic (70-μm wall)	2.6×10^{11}
Glass (20-μm wall)	7.6×10^{10}
Be (33-μm wall on 20-μm plastic)	2.7×10^{11}

The evidence of thermonuclear neutron production in Z dynamic hohlraum experiments is convincing

- On "null shots" doped with 0.6 atm Xe gas, the fast neutron time-of-flight signal is substantially reduced on both side-on and bottom detectors in agreement with expectations from calculations
- On "null shots", the neutron yield decreased by more than an order of magnitude as measured by neutron activation in agreement with an expected decrease by a factor of ~ 20 from calculations
  - Any neutron yield from beam target interactions is at the level of the "null shots"
- On "null shots", Ar spectroscopy lines were not detected indicating a plasma of a much lower temperature in agreement with calculations that predict an electron temperature of 450 eV
- From a large number of capsule experiments, we infer neutron energies from side-on and on-axis detectors to be 2421 $\pm$ 110 keV and 2555 $\pm$ 120 keV, respectively, that provides evidence that ion beam neutrons are not being detected
  - If beam target interactions were responsible for the production of these neutrons, one would expect a shift in the neutron energy along the direction of the beam due to reaction kinematics
- Neutron yields in these experiments were found to be isotropic to ~ 25 %, providing further evidence of the thermonuclear origin of these neutrons
- Be capsules have been shot that were 2-mm diameter with 33-μm Be on 18-μm plastic walls filled with ~ 16 atm that produced 2.7 x 10^{11} neutrons that is comparable to predicted yields for this target