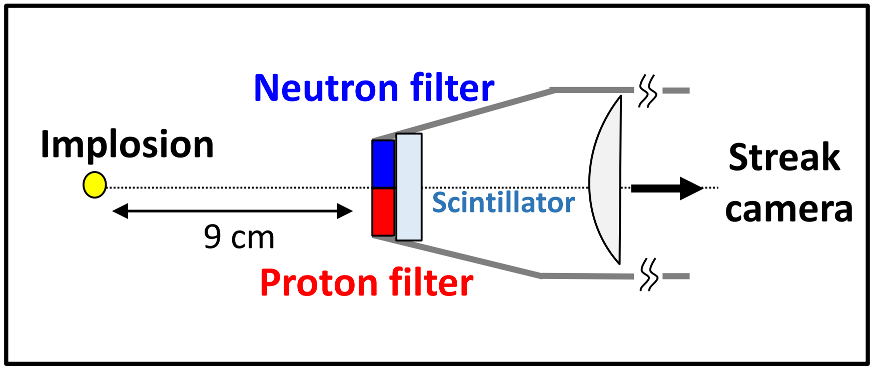
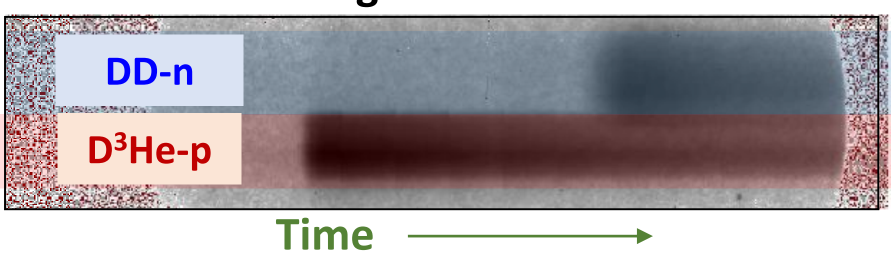
Measurements of multiple nuclear bang times and burn histories to probe implosion dynamics and kinetic effects at OMEGA and the NIF

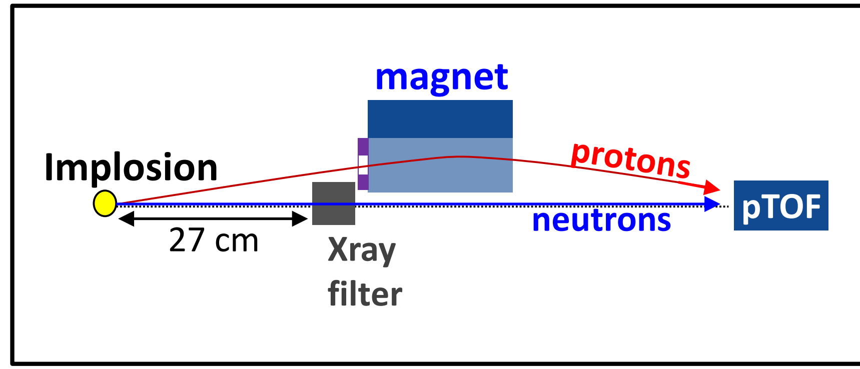
multiPTD on OMEGA

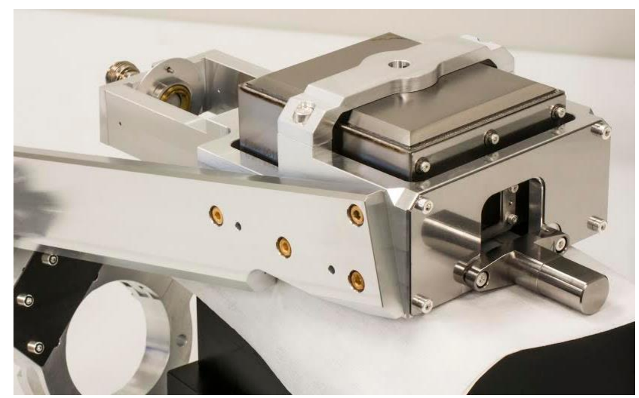


Scintillator signal on streak camera



magPTOF on NIF





Hong Sio, MIT

October 6th, 2015, Los Alamos, NM

Kinetic effects and shock dynamics are studied in ICF plasmas on OMEGA and the NIF using burn history and bang-time diagnostics

- multiPTD is a streak diagnostic for measuring multiple nuclear burn histories to probe kinetic / multi-ion effects on OMEGA
    - Moving closer to TCC will improve relative timing of burn histories to ~ 10 – 20 ps
    - New filtering will be used to measure nuclear-burn and x-ray emission simultaneously
- magPTOF is a bang-time diagnostic for measuring shock and compression nuclear bang-times to study shock dynamics on the NIF
    - Improved positioning and larger x-ray shielding will reduce x-ray background to acceptable level
    - can also function as a low-energy charged-particles spectrometer for diagnosing various basic science and ICF experiments

Collaborators

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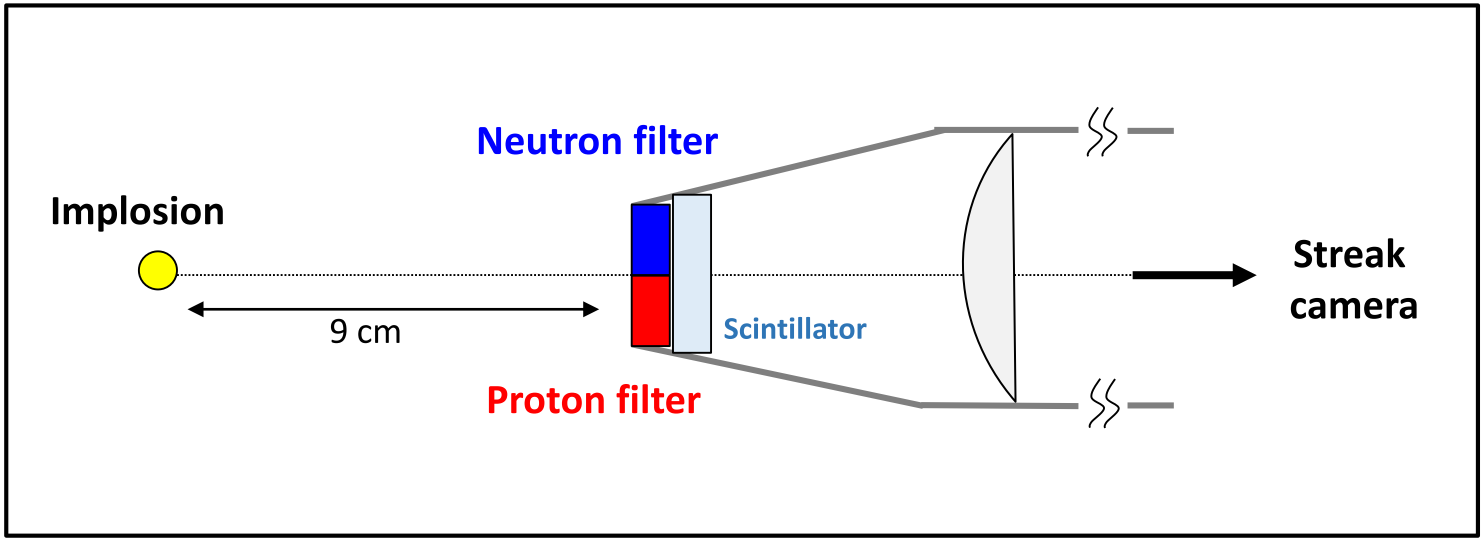
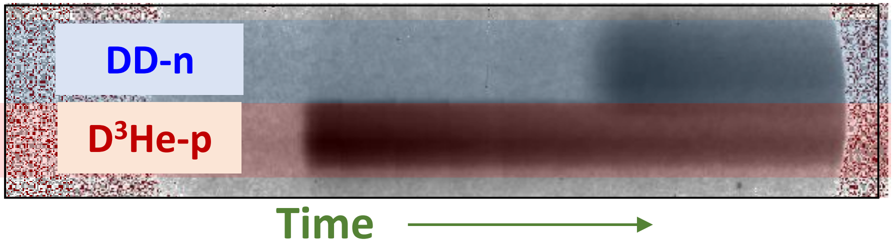
The multiple Particle Temporal Diagnostic (multiPTD) is a streak-based burn-history diagnostic that has been implemented and used on OMEGA



Simultaneous measurements of multiple nuclear burn histories on the **same** diagnostic is critical for timing accuracy

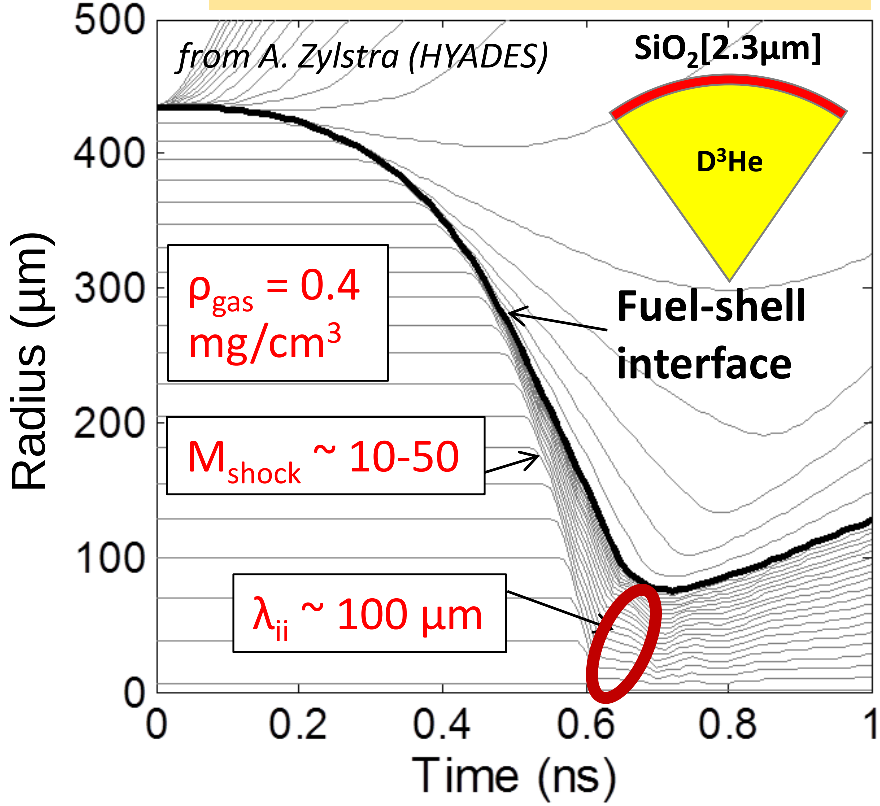
Scintillator signal on streak camera



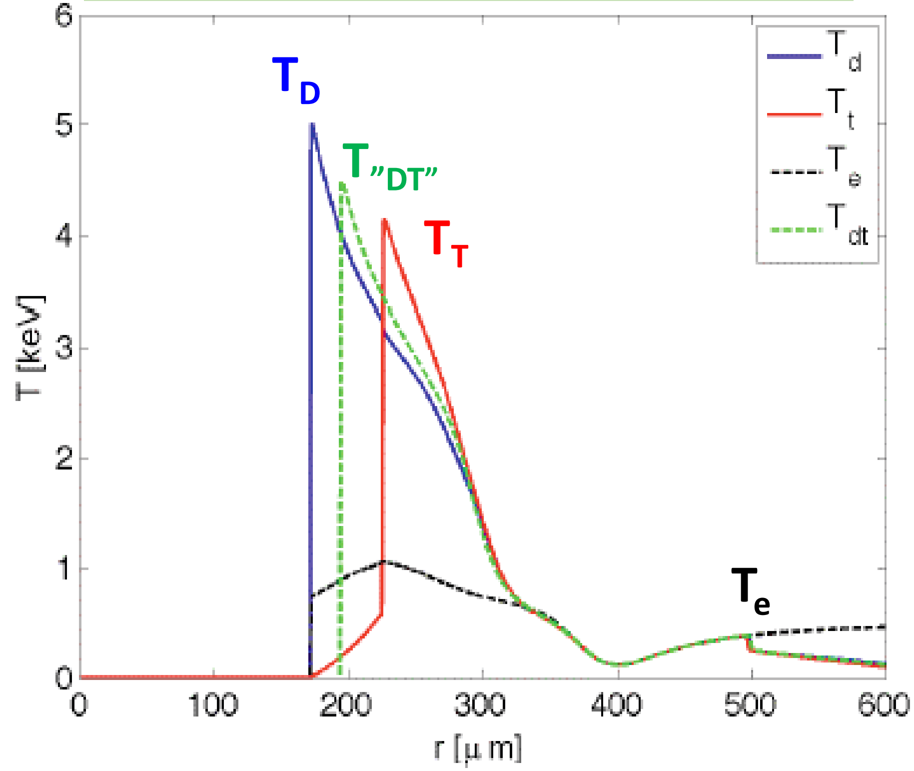
Stoeckl *et al.*, Rev. Sci. Instrum. **74**, 1713 (2003)

Kinetic effects during shock convergence and rebound leads to temperature and profile effects not captured in standard hydro simulations

exploding pusher simulation



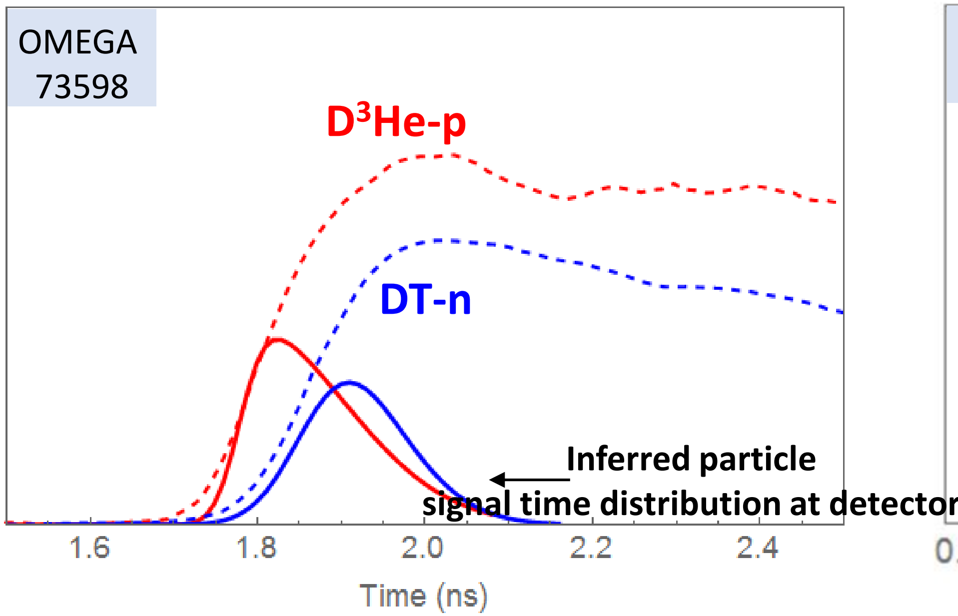
Multi-ion-fluid LSP: Temperature



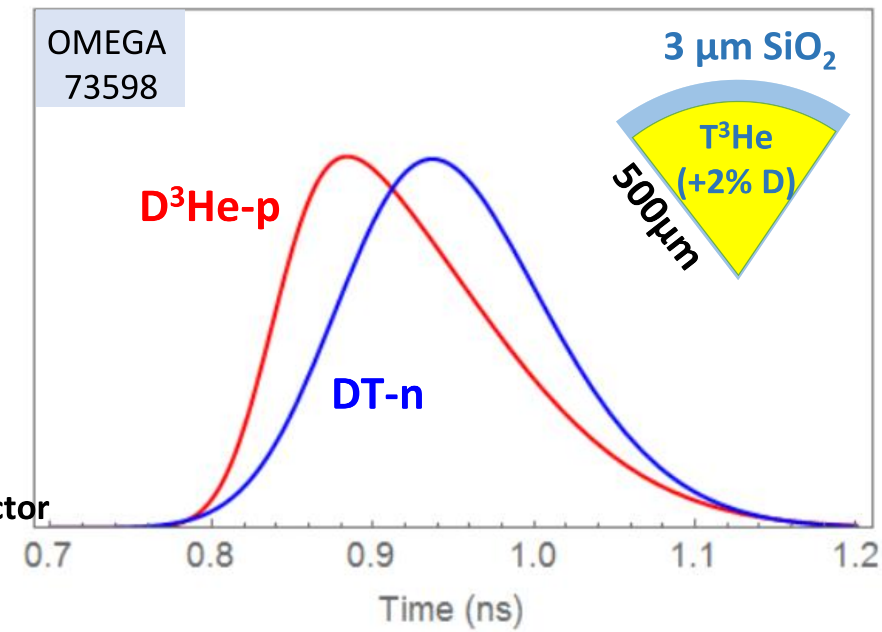
We measure multiple nuclear burn histories to look at differences in temperature and density profiles not predicted by hydro models

In a series of DT^{3}He shock-driven implosions, D3He and DT nuclear bang times are measured to investigate kinetic / multi-ion effects

Scintillator streak signal lineout

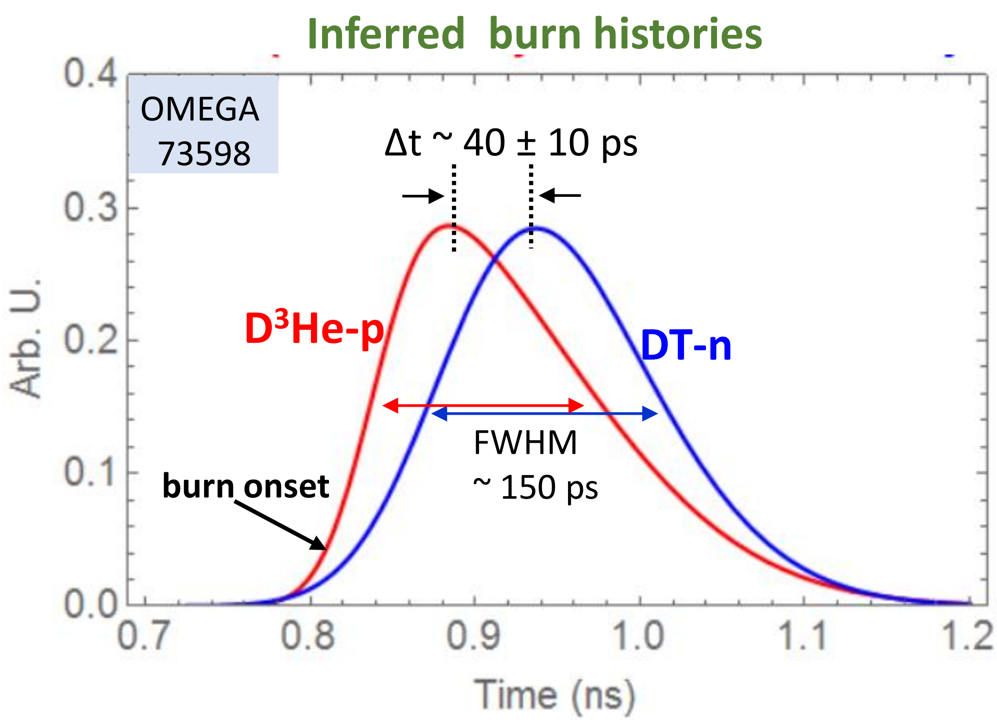


Fitted burn histories



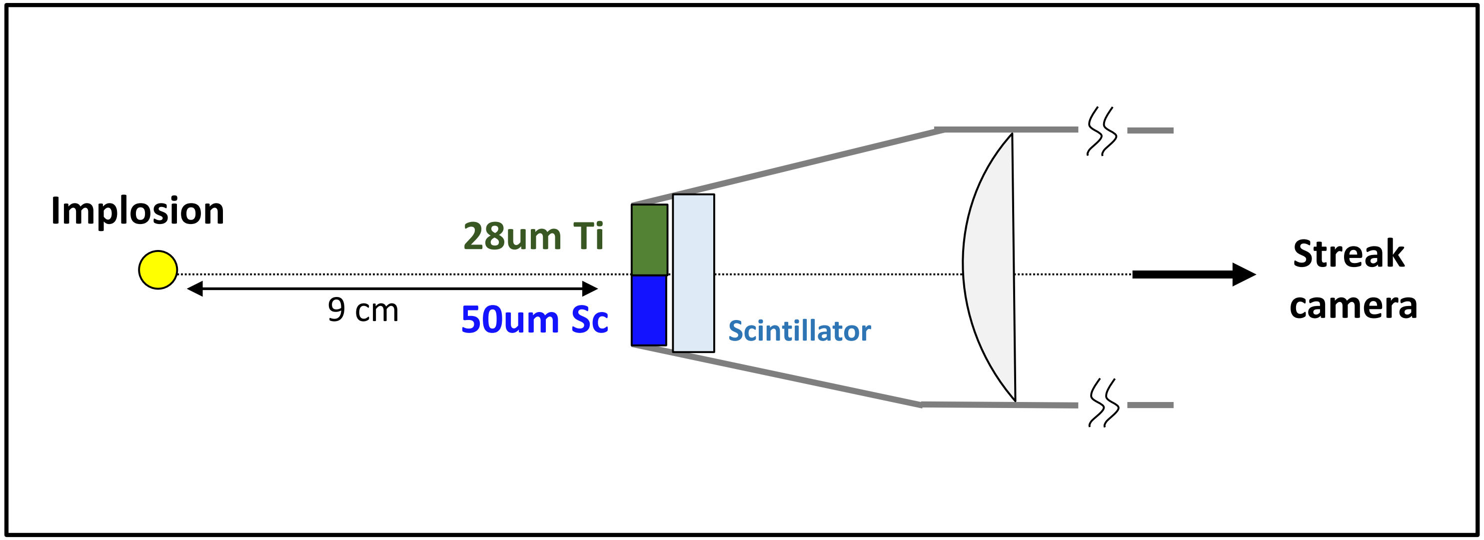
Burn histories are measured with relative timing uncertainty < 20 ps

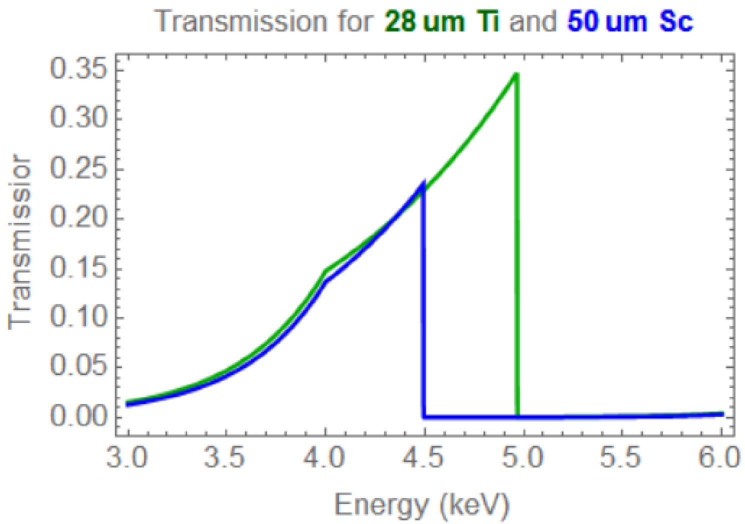
Different aspects of the burn histories (bang-time, width, onset) can be compared to infer ion-kinetic effects in DT³He implosion

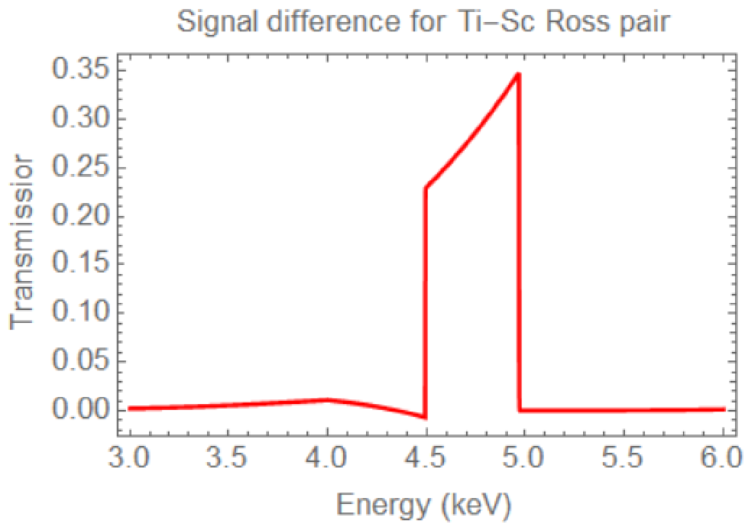


These nuclear measurements will be compared directly with hydrodynamic (average-ion) and LSP (multiple kinetic ion species) simulations

Ross-pair x-ray filters allow nuclear and x-ray emission to be measured simultaneously with the same diagnostic

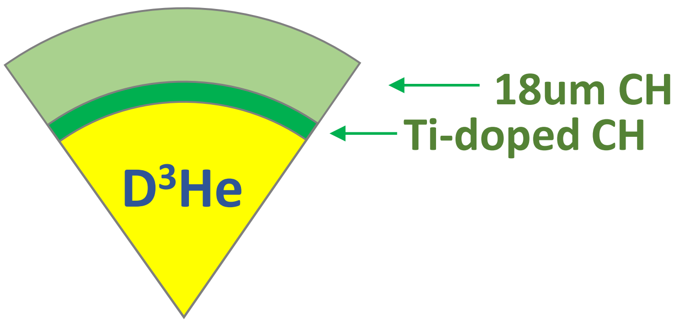






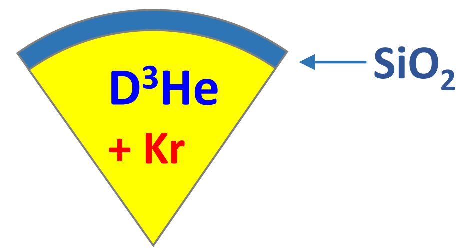
Precise timing information about nuclear and x-ray emission can also provide physics insights about mix and ion-electron equilibration

Mix study



Look at shell-dopant x-ray emission history relative to the nuclear burn history to study ion diffusion mechanism across interface

Ion-electron equilibration study



Look at time difference between xray-emission and nuclear-burn histories and compare with simulation with different ion-electron coupling

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Collaborators

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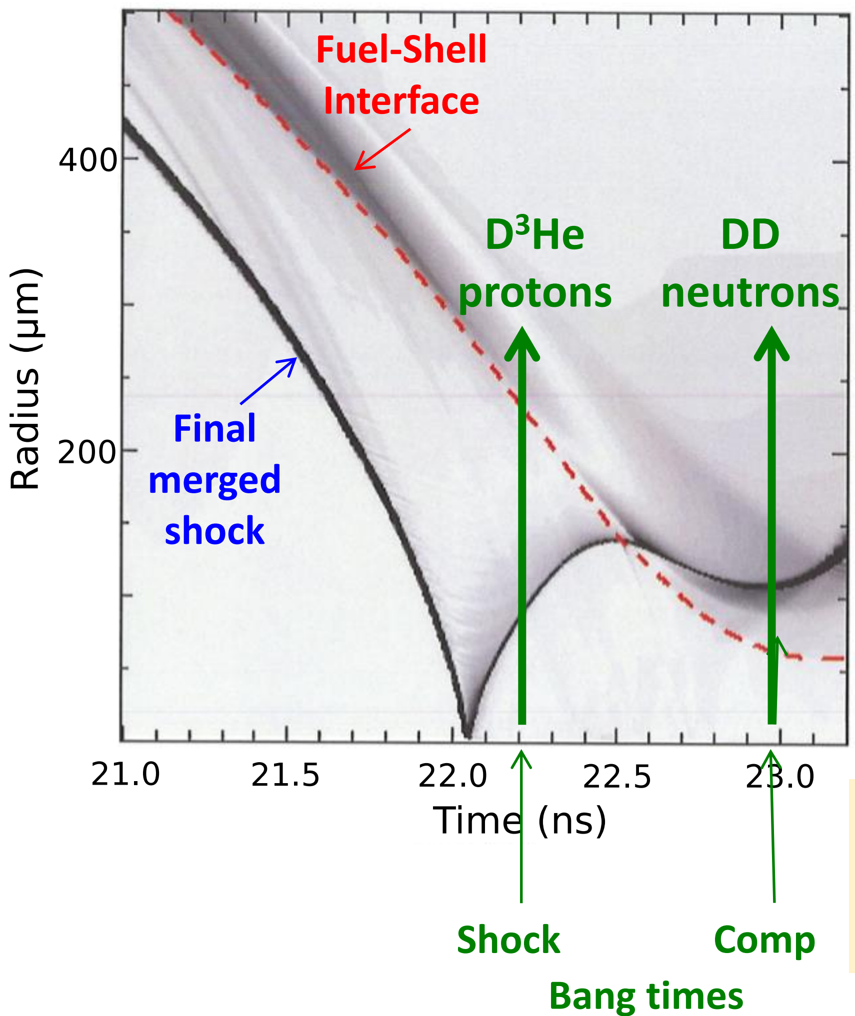
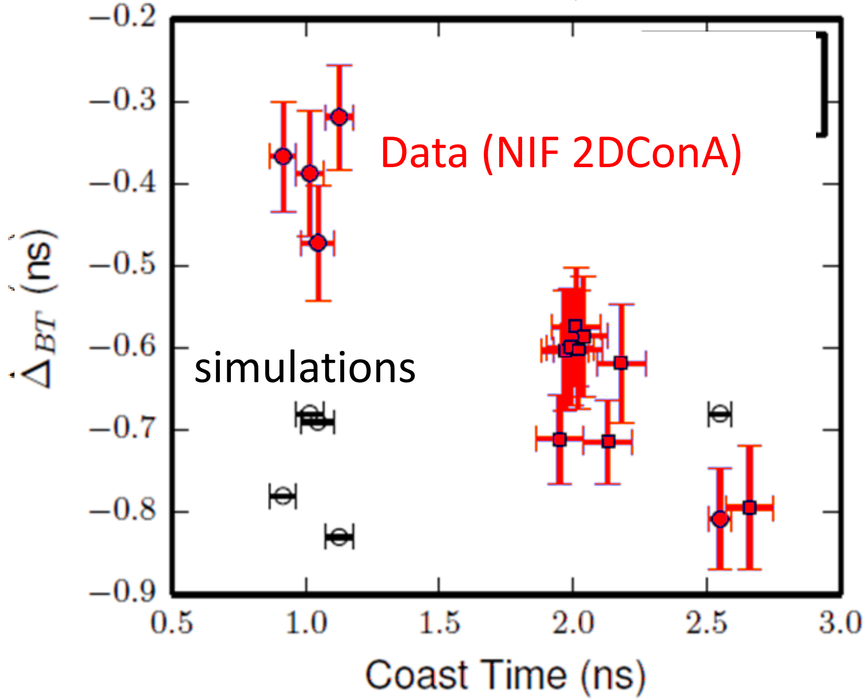
On NIF implosions, the inferred time difference between shock- and compression-burn disagrees with simulation

HYDRA simulation: H. Robey



Inferred difference ΔBT (ns)
Between shock and compression BT

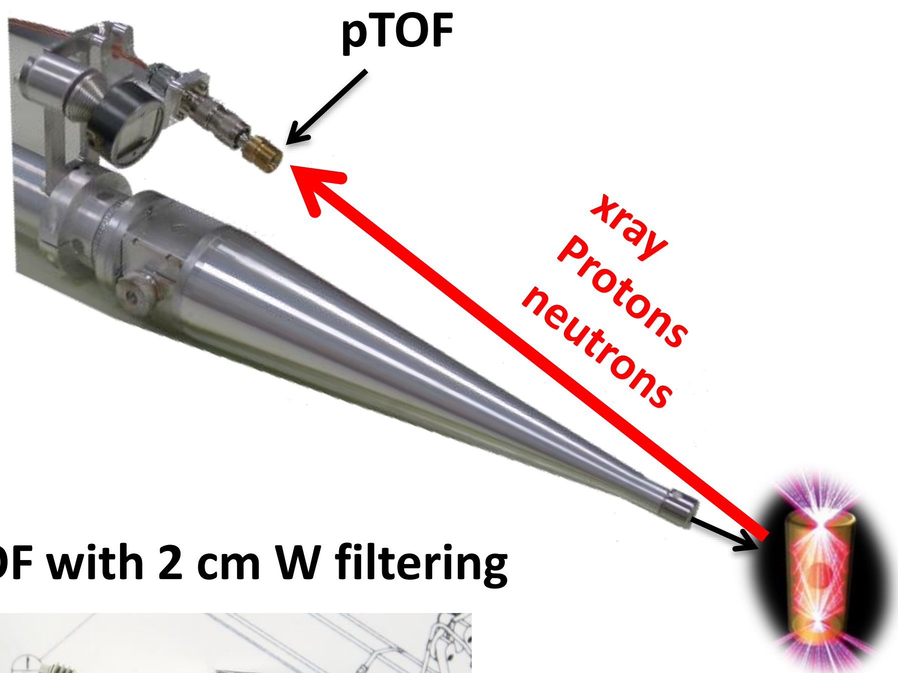


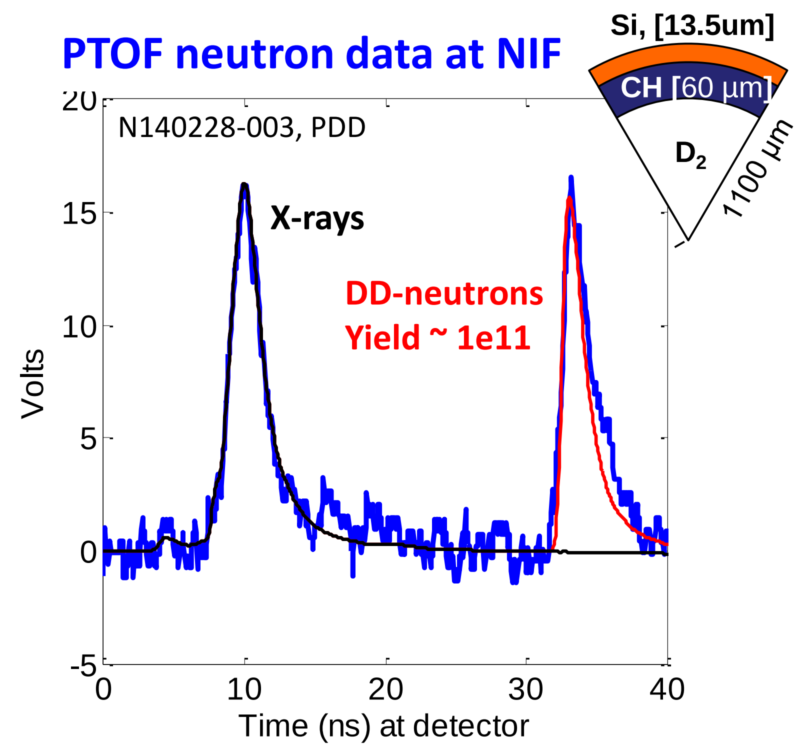
magPTOF will measure the important time difference between shock- and compression-bang time to < ±100 ps

A. Zylstra, PoP **21** 112701 (2014)

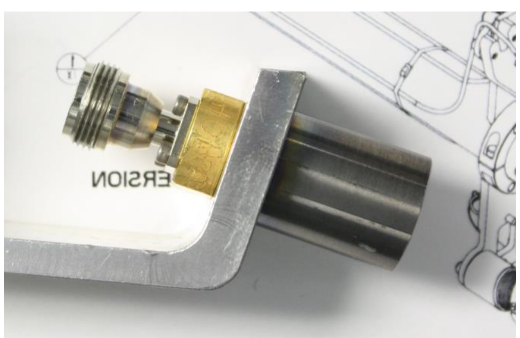
Particle Time-of-Flight (pTOF) is a nuclear bang-time diagnostic.
The active detector (CVD diamond) is sensitive to xrays, protons, and neutrons

DIM (90,78) snout assembly:





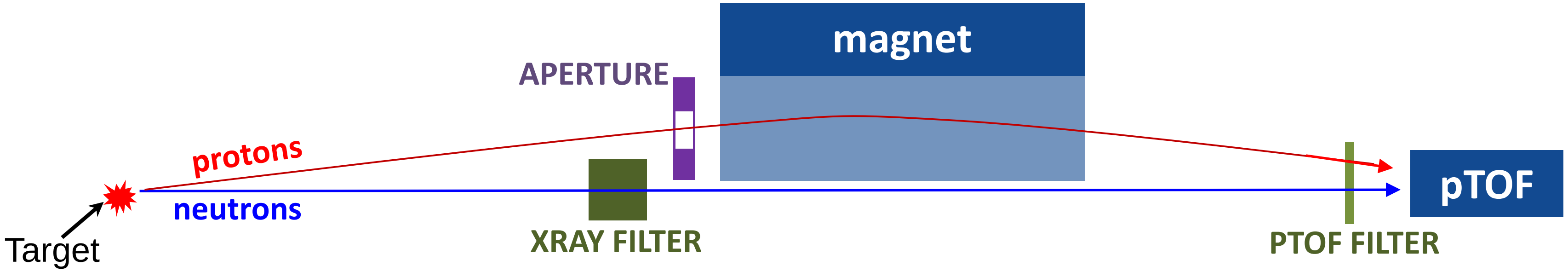
pTOF with 2 cm W filtering

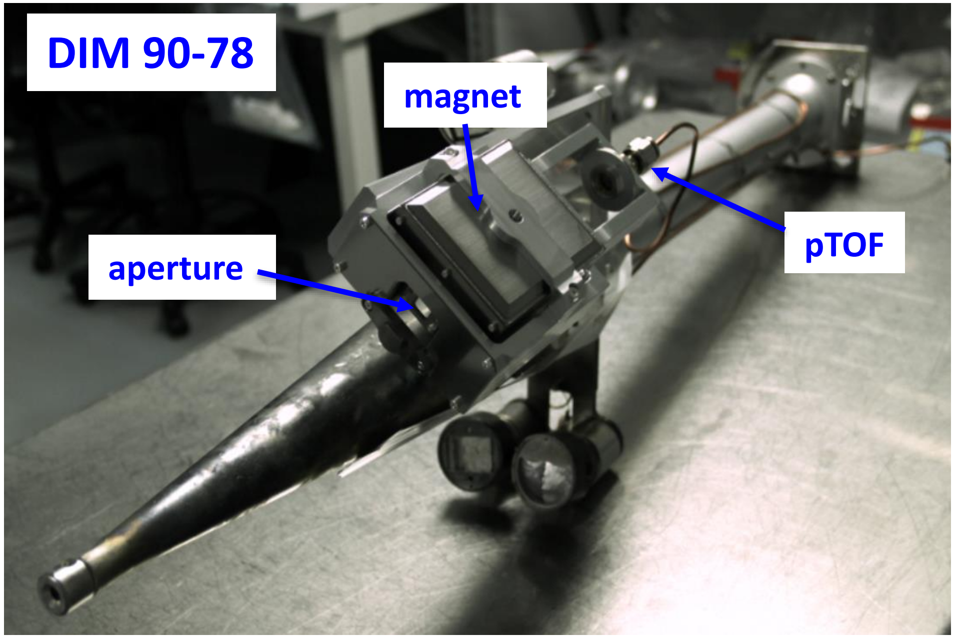


To measure shock-bang time, we need to eliminate x-ray background *without* also blocking the proton signal.

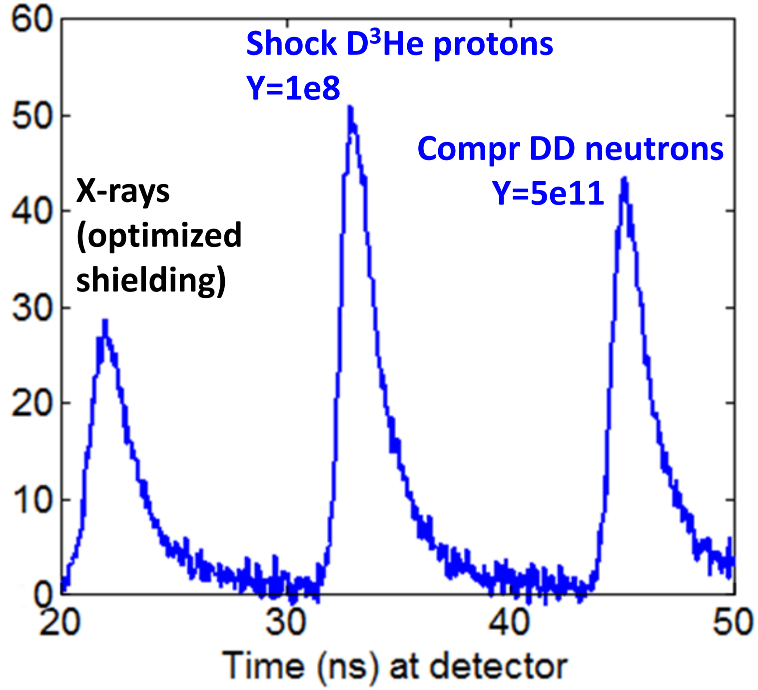
H.G. Rinderknecht, et al. Rev. Sci. Instrum. 83, 10D902 (2012)

In the magPTOF upgrade, magnet and x-ray shielding allow x-ray, proton and neutron signals to be measured with similar amplitudes

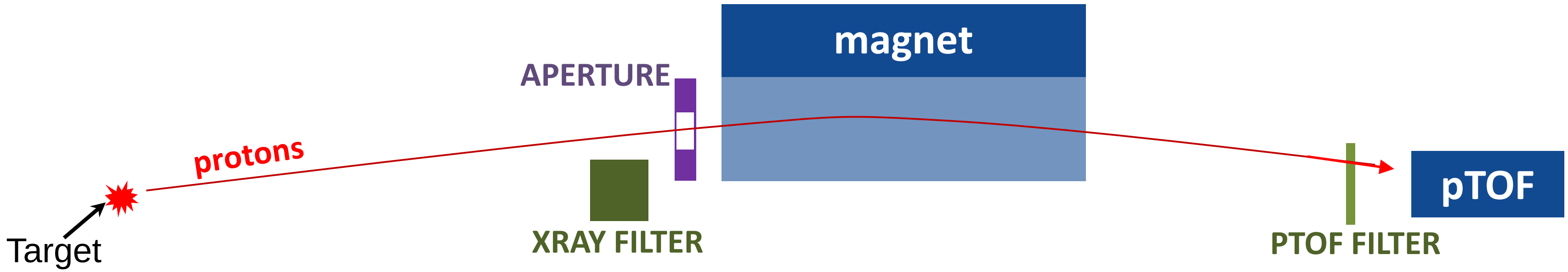




Simulated MagPTOF data

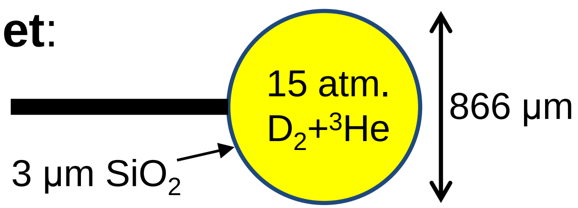


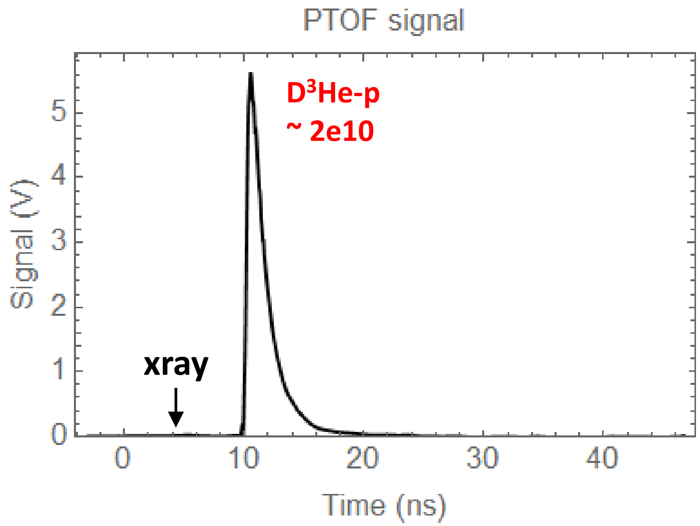
magPTOF recorded great data on the N150326 D^3He exploding pusher shot, confirming proton transport through the magnet



Laser: 40 kJ, ~ 0.8 ns pulse

Target:

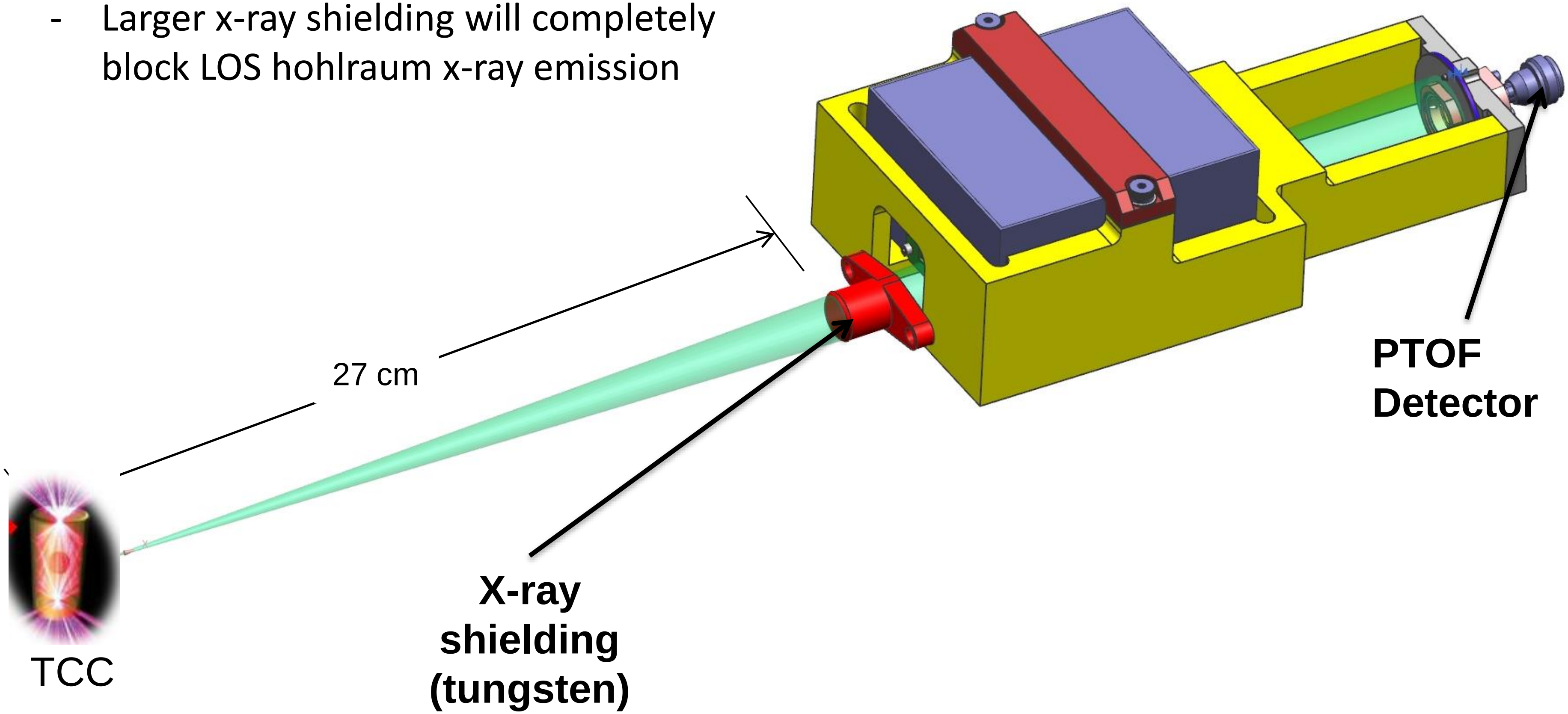




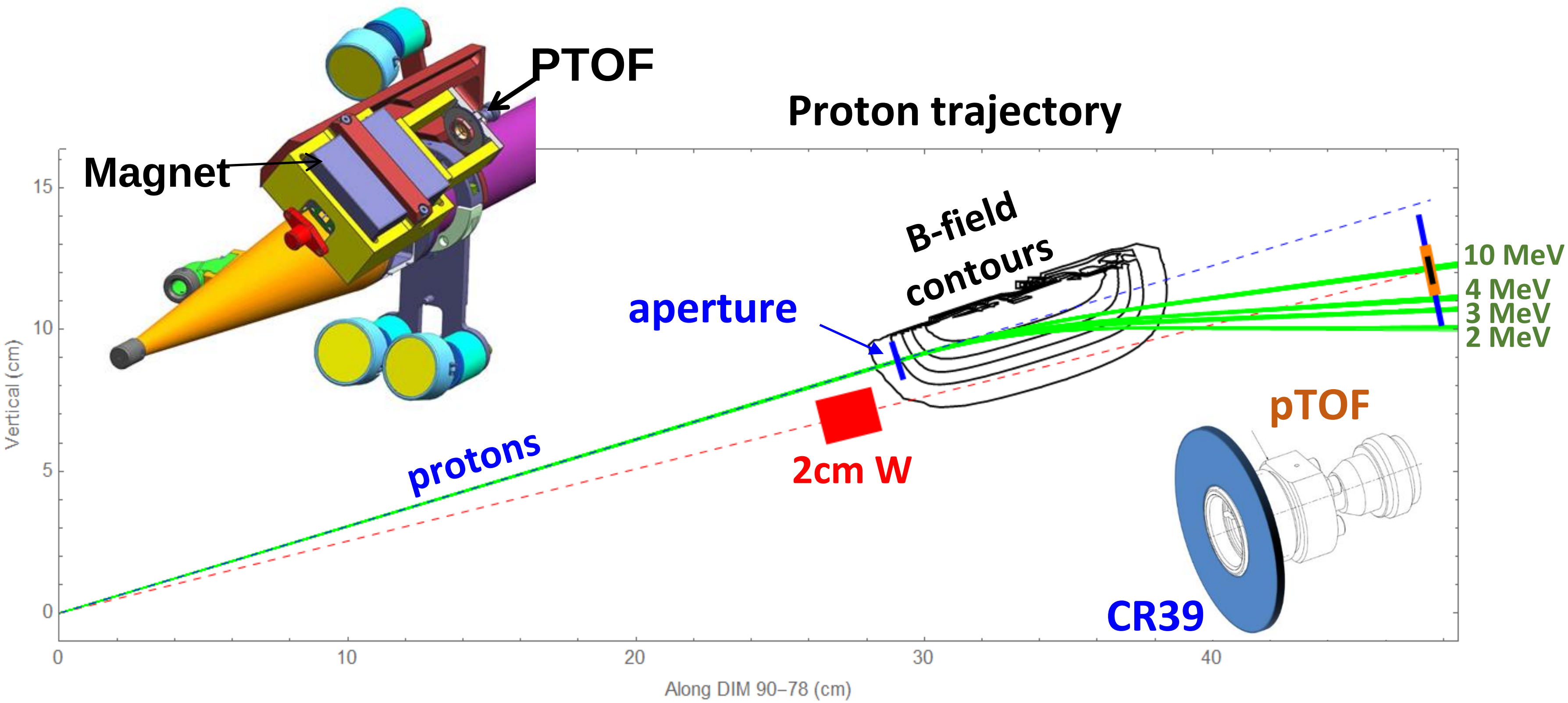
The first gas-fill hohlraum shot at NIF demonstrate that alignments and x-ray shielding need to be improved

- New mounting brackets will improve pointing accuracy

- Larger x-ray shielding will completely block LOS hohlraum x-ray emission



MagPTOF can also functions as a low-energy charged-particles spectrometer for diagnosing various basic science and ICF experiments

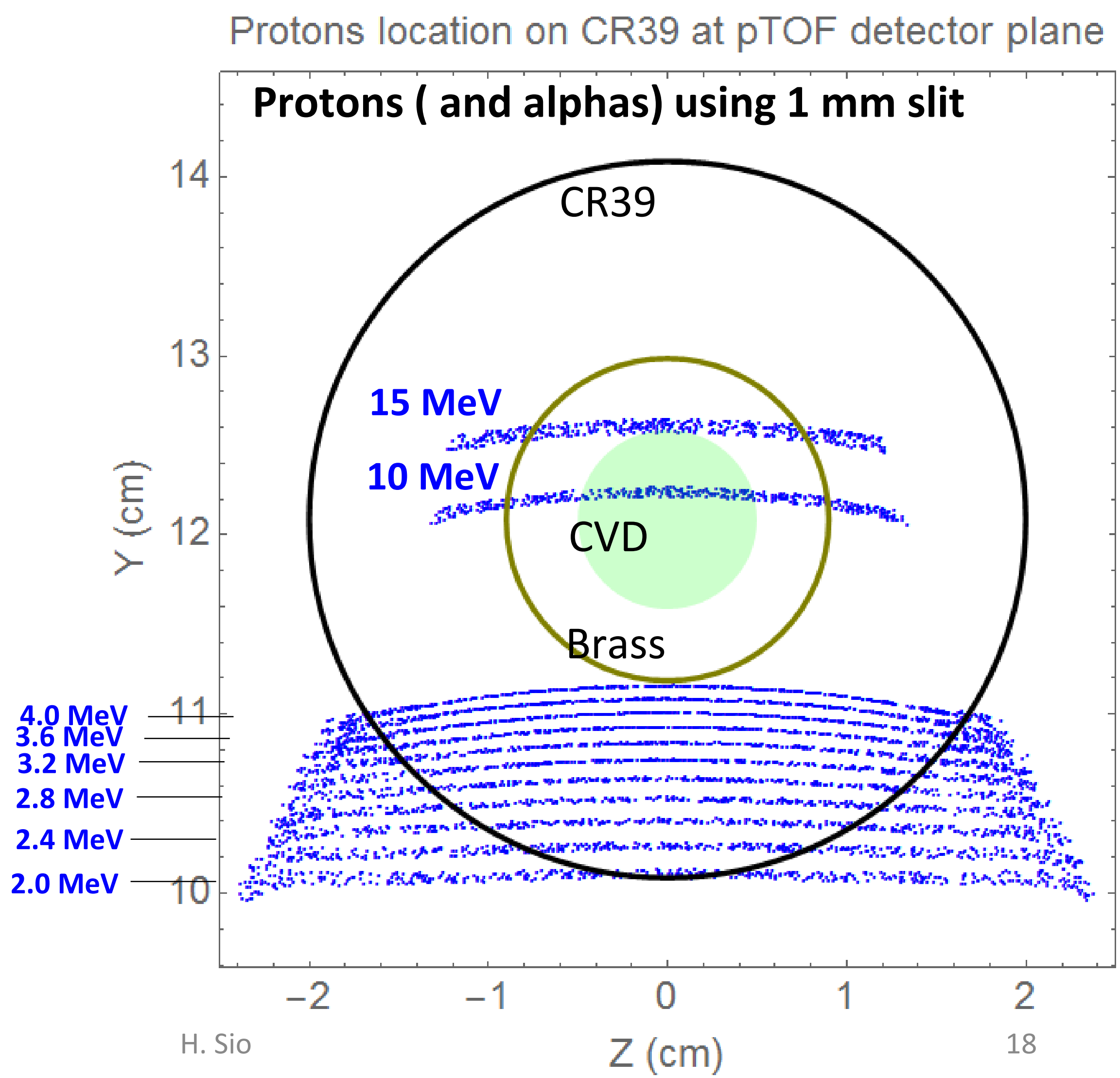


This new capability plays an important role in several Discovery Science experiments

- Stellar Nucleosynthesis (T + T, T + ^{3}He, ^{3}He + ^{3}He)
- Monoenergetic backlighter development (D + ^{3}He, D + D)
- Collisionless shock (D + D)

Charged particles are deflected by the magnet and detected by a CR39 detector

magPTOF has < 5% resolution (ΔE / E) for charged particles between 1-5 MeV



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