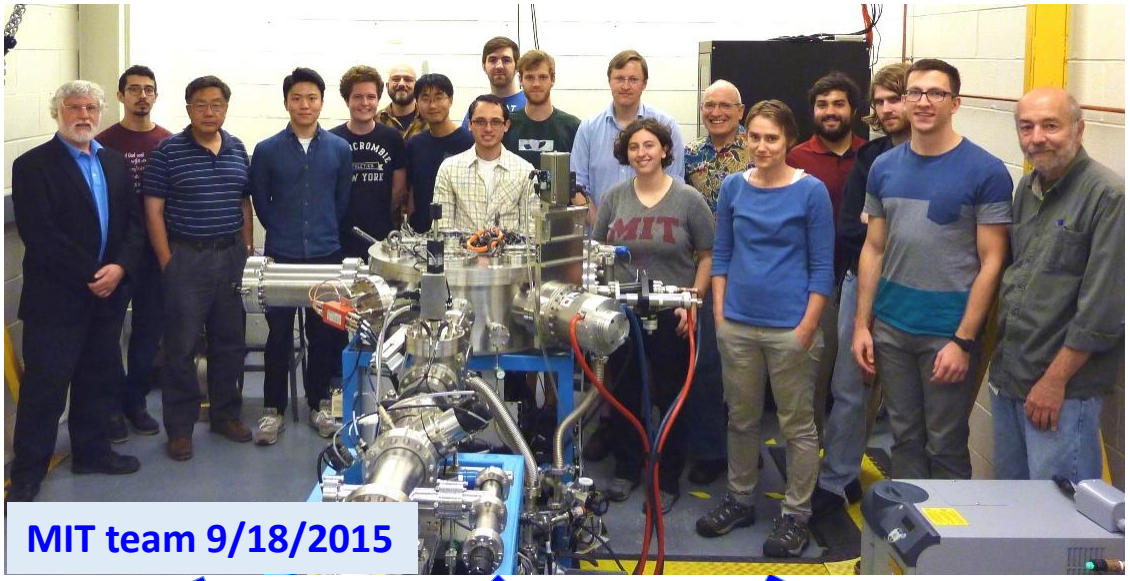
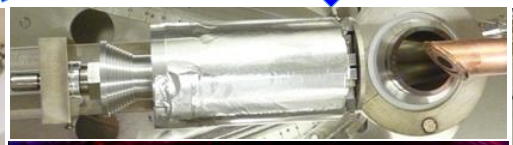
Studying ICF & HED Physics at NIF, OMEGA & Z using MIT-developed nuclear diagnostics & platforms



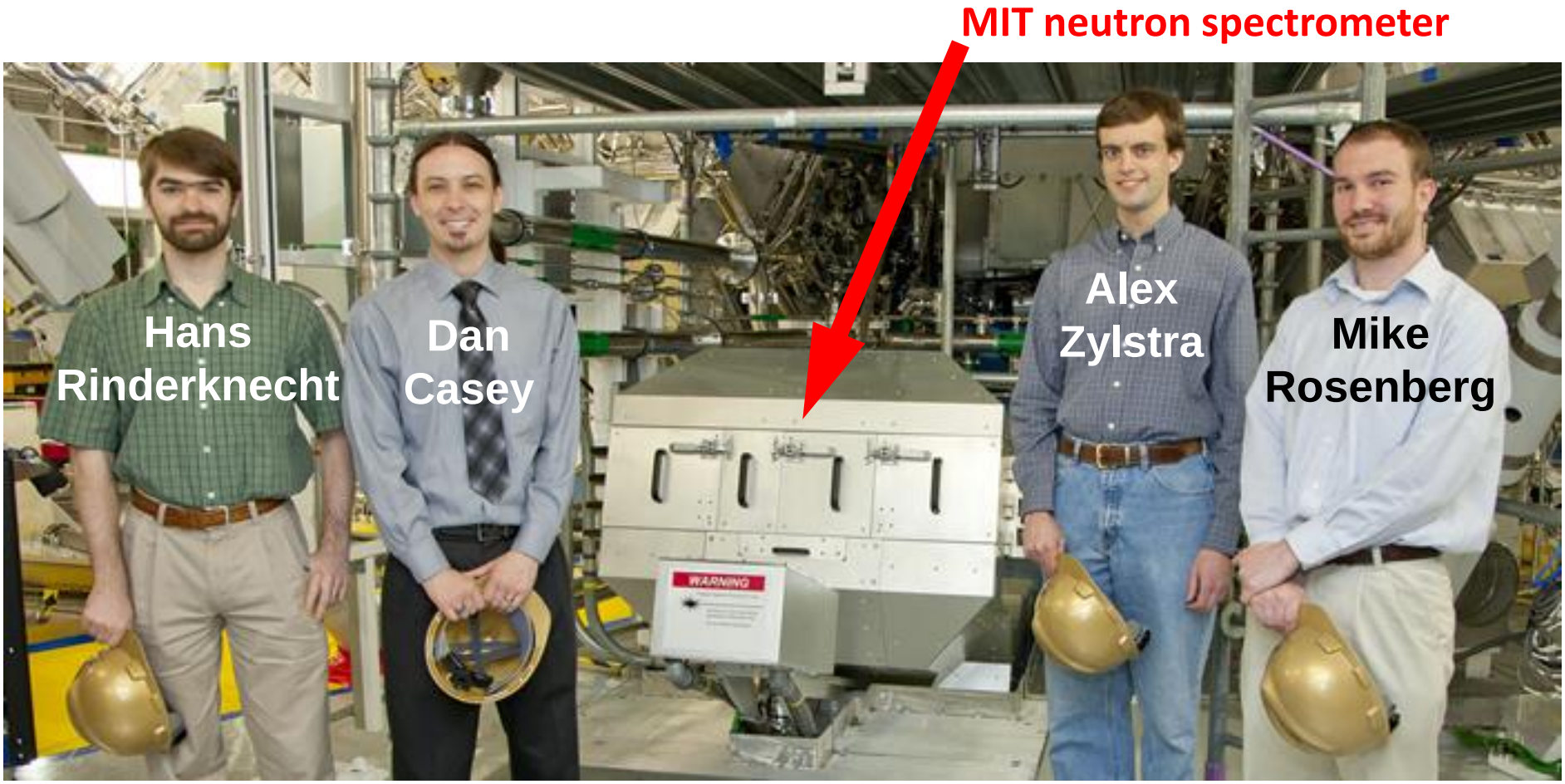
OMEGA Laser facility | **Z** | **National Ignition Facility (NIF)**



Richard Petrasso, for the MIT team

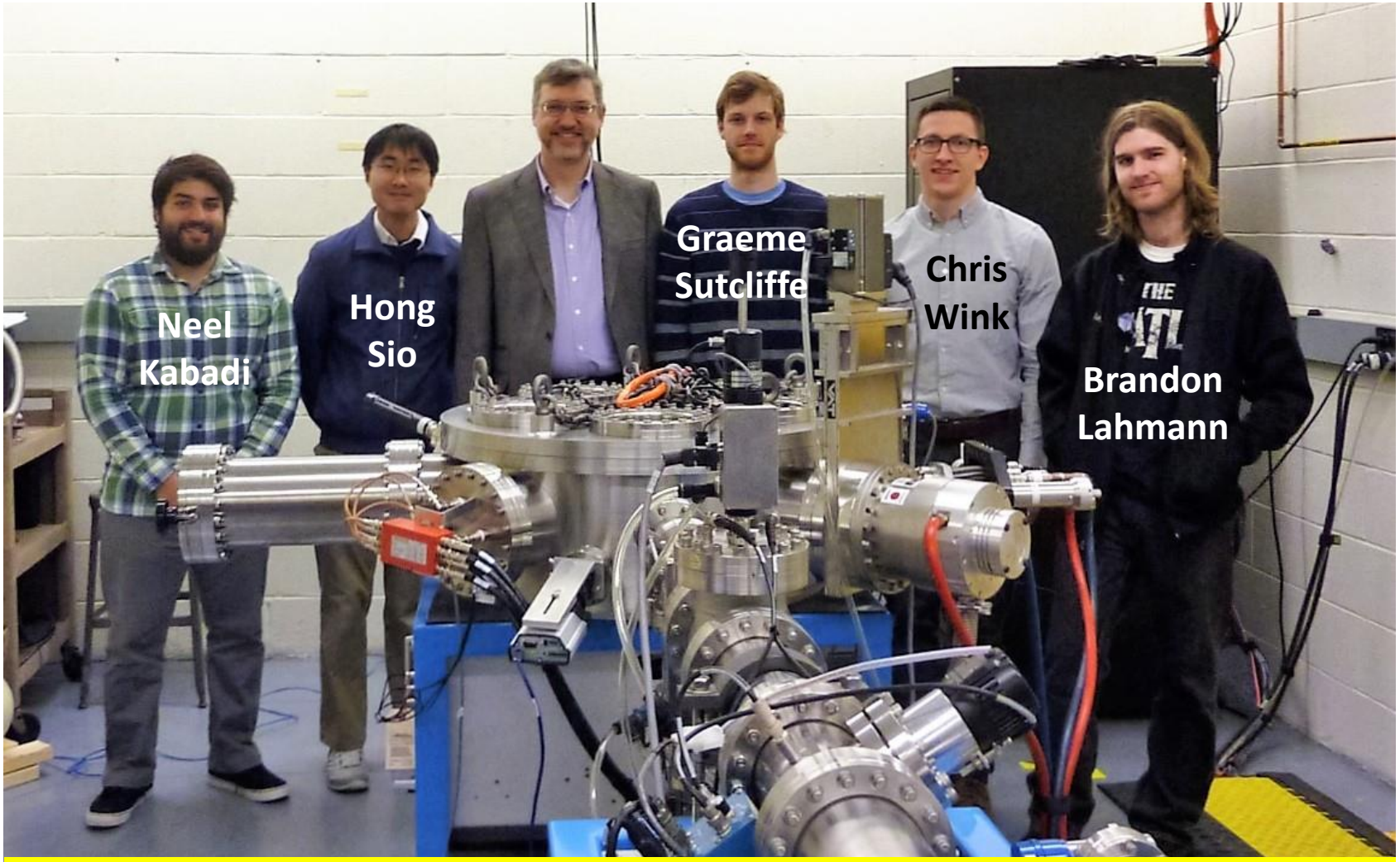
SSAP, Feb 17th 2016

MIT graduated the first four PhDs that used NIF data in theses – All have joined National Labs/LLE



Lawrence Fellow, LLNL	Staff Scientist, LLNL	Reines Fellow, LANL	Research Associate, LLE

NIF director Mark Herrmann met last month with MIT students to discuss their diagnostic & platform work on the NIF



This talk will focus on student work,
which will be presented at this evening's poster session by the students

Project participants

MIT Scientists	*MIT Graduate Students*	*Undergrads*	*Tech Staff*
Johan Frenje	Neel Kabadi	Emily Armstrong	Andrew Birkel
Maria Gatu Johnson	Brandon Lahmann	Jimmy Rojas	Ernie Doeg
Chikang Li	Hong Sio	Lucio Milanese*	Bob Frankel
Fredrick Séguin	Graeme Sutcliffe		
Richard Petrasso	Chris Wink		

**Student at Imperial College*

Major Collaborating Institutions

Laboratory for Laser Energetics
Lawrence Livermore, Los Alamos, and Sandia National Laboratories,
University of Rome, University of Nevada (Reno)

Sponsors

Outline

I. MIT research and platform development at NIF, OMEGA and Z
---Student research is featured

II. Utilization of the MIT proton-backlighter platform
for NNSA-sponsored Programs/PIs at OMEGA and the NIF

III. OLUG: 8th OMEGA Laser Users Group workshop 27-29 April
(wonderful setting for student-postdoc interactions)

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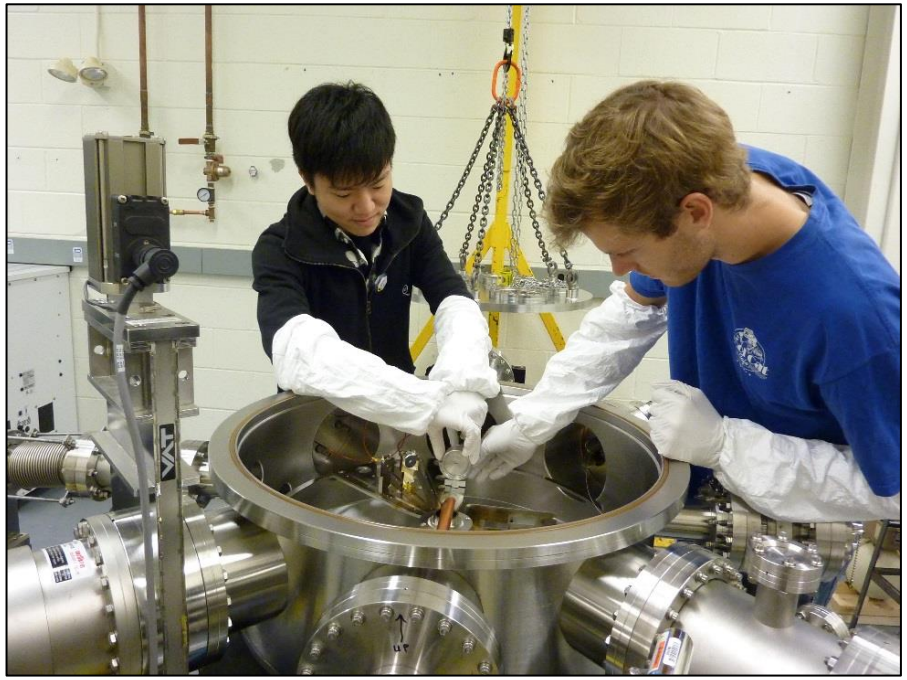
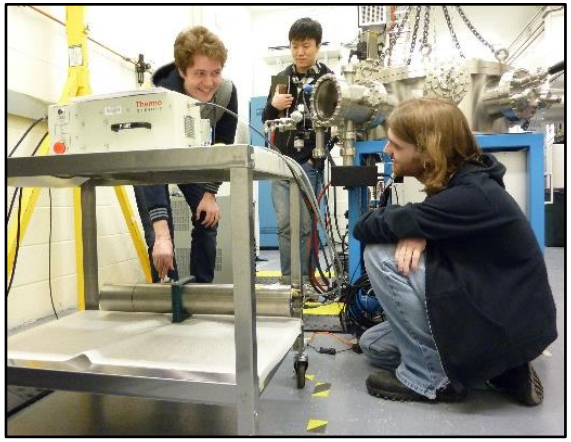
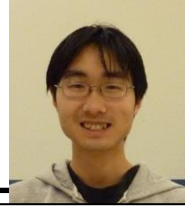
Students develop and test MIT diagnostics at the MIT HEDP Accelerator Facility before fielding at NIF, OMEGA & Z

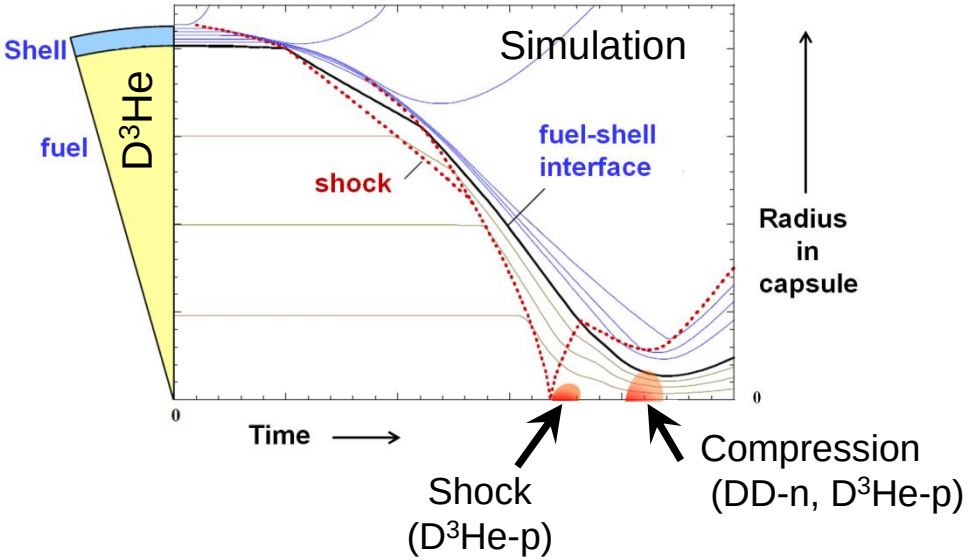


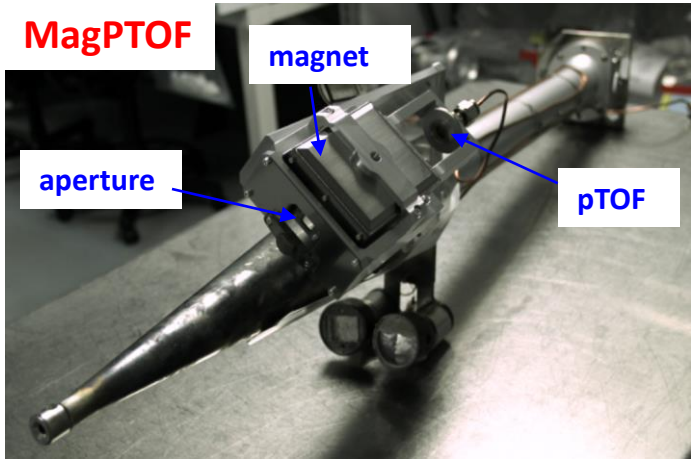


At NIF, MIT diagnostics precisely measure bang times and areal densities at shock & compression



Hong Sio





High temporal precision is achieved by measuring both shock and compression times on a *single* diagnostic

See posters: H. Sio NLUF-10, B. Lahmann HEDP-24

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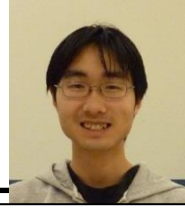
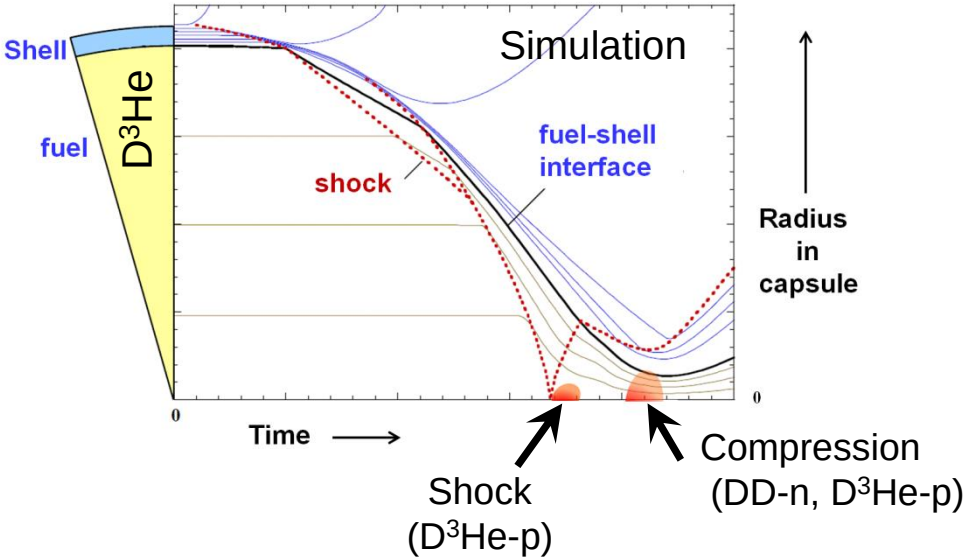
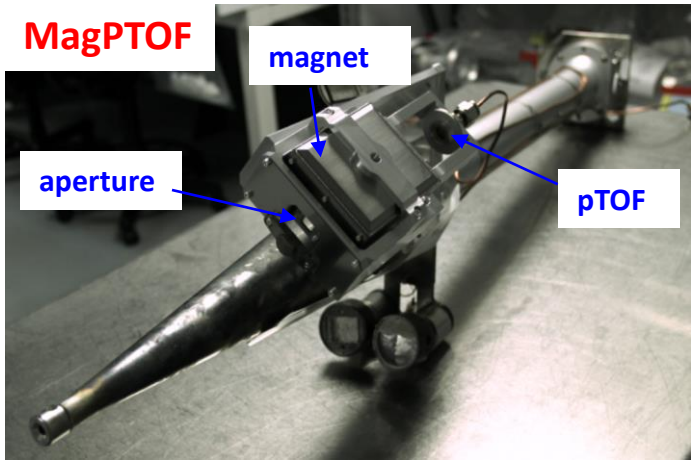


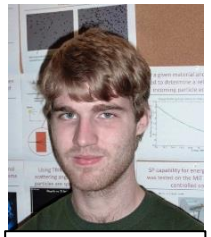
Hong Sio



MagPTOF



WRF



Brandon Lahmann

See posters: H. Sio NLUF-10, B. Lahmann HEDP-24

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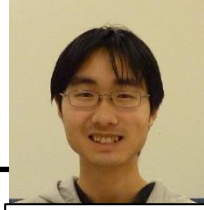
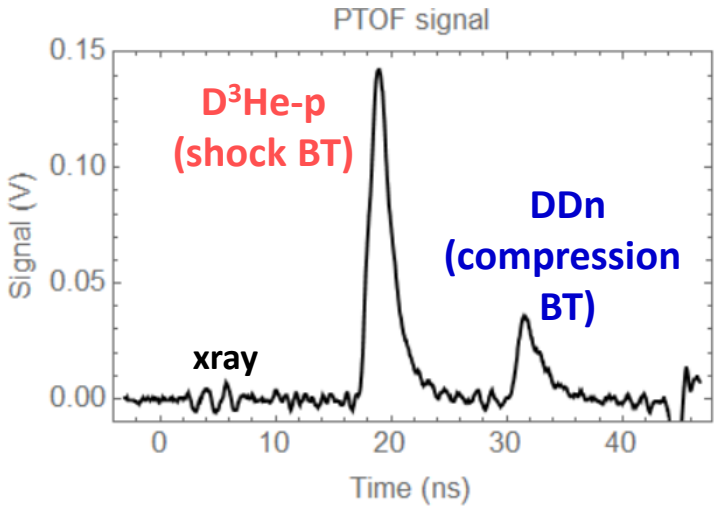


Hong Sio

NIF surrogate shot N151221



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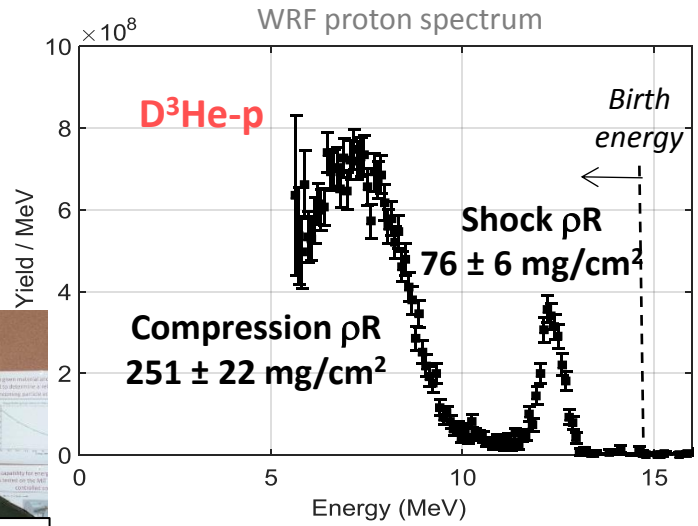

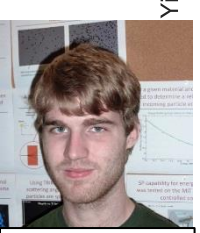

Brandon Lahmann

See poster: H. Sio NLUF-10

See poster: B. Lahmann HEDP-24

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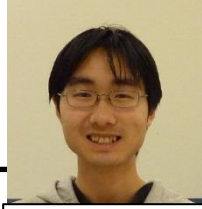

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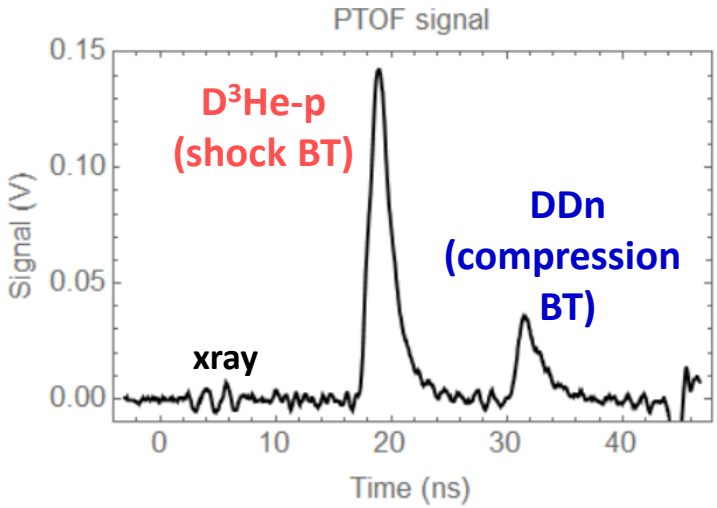
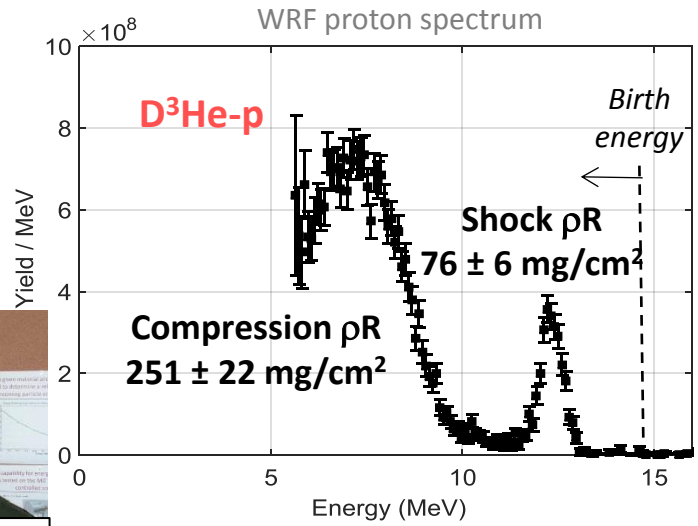
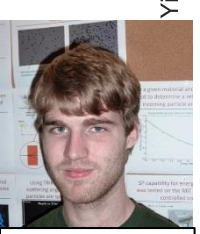
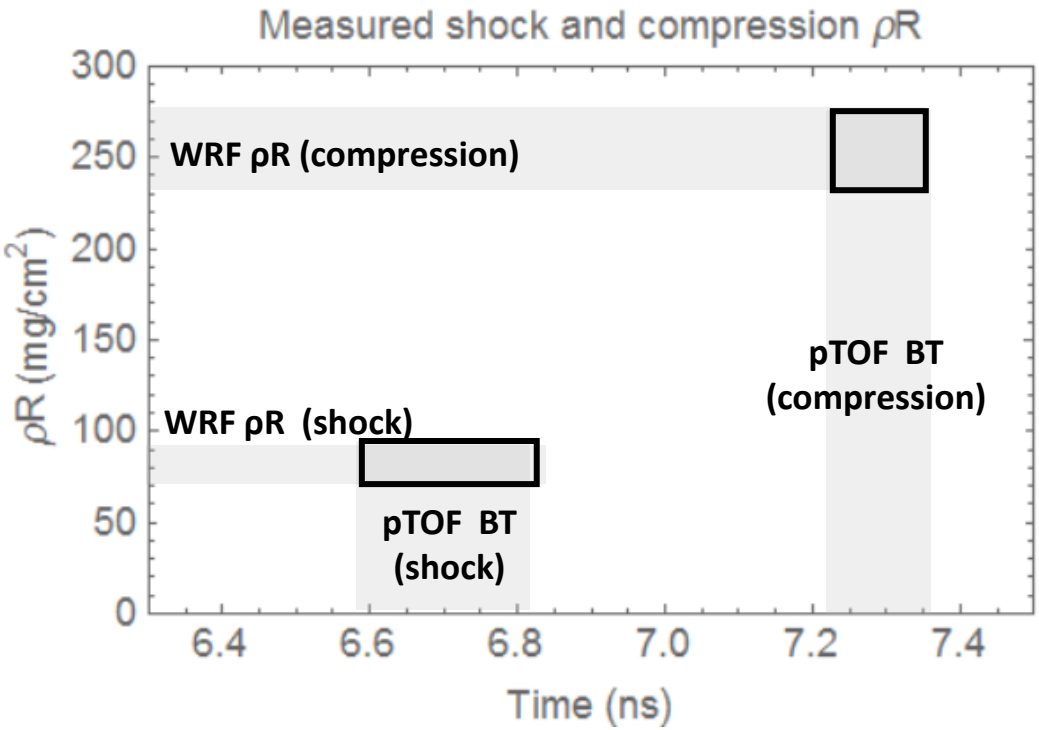






Brandon Lahmann



grey bars denote measurement uncertainty

See poster: H. Sio NLUF-10

See poster: B. Lahmann HEDP-24

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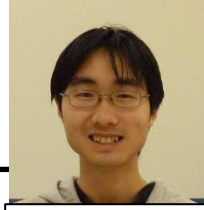

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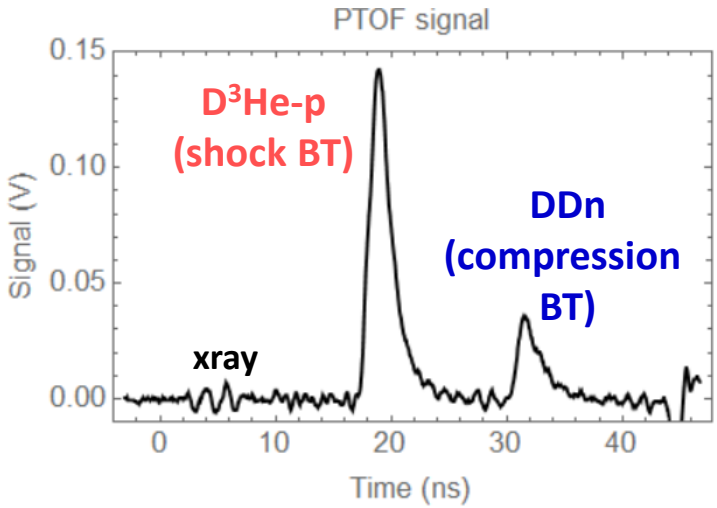
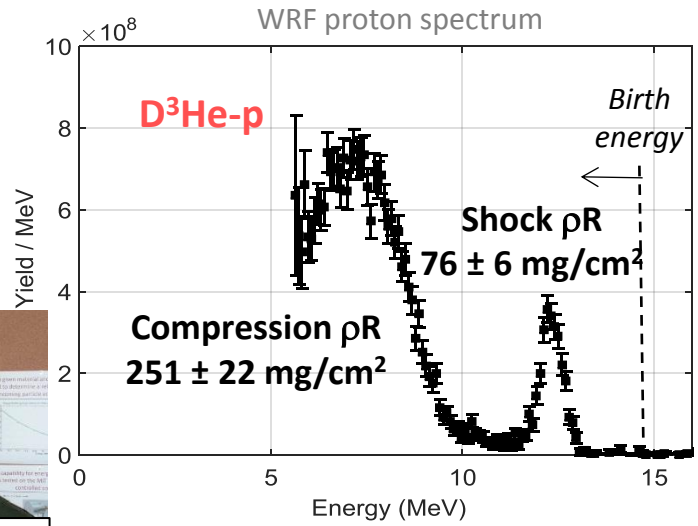
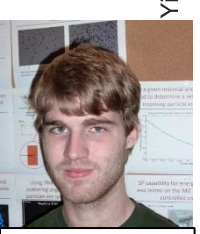
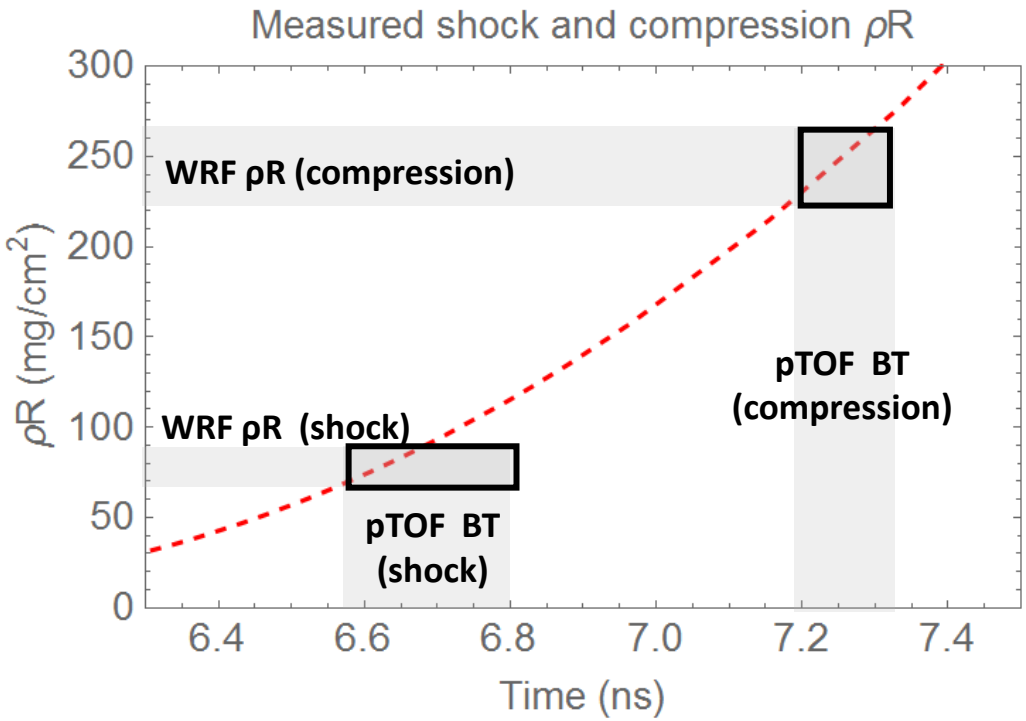






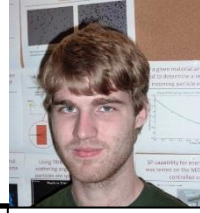
Brandon Lahmann



See poster: H. Sio NLUF-10

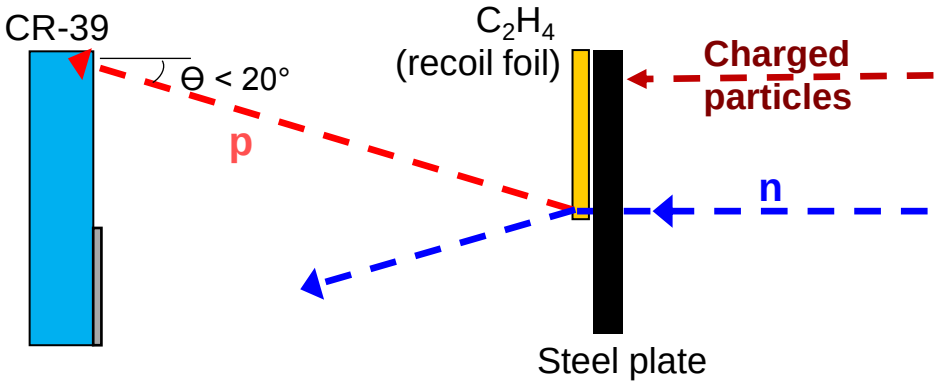
See poster: B. Lahmann HEDP-24

At Z, NIF and OMEGA: MIT is developing a neutron spectrometer to measure DD neutron yields and spectra



Brandon Lahmann

CR-39 records recoil protons from *n,p* elastic scattering in a CH foil

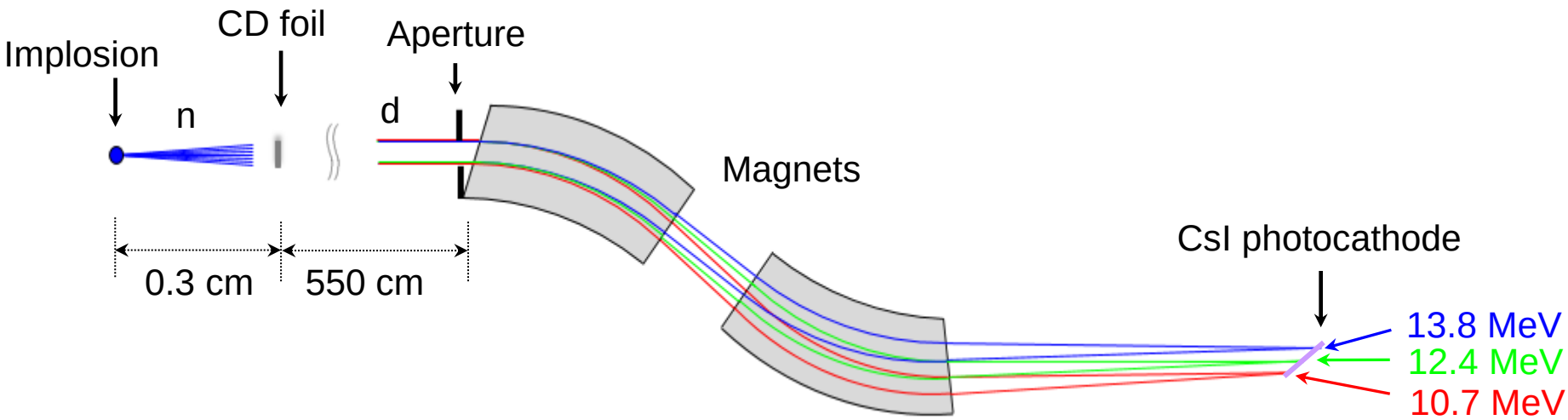


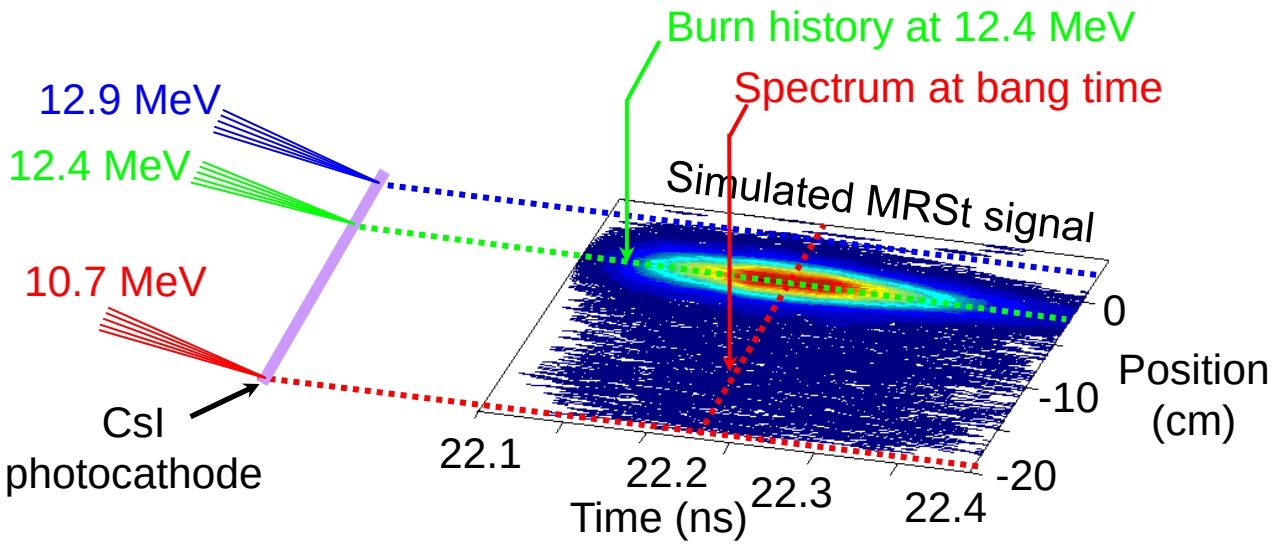
$$D + D \rightarrow n(2.5\ MeV) + {}^3He$$

This will be used to measure Yield, T_{ion} and ρR asymmetries

See poster: B. Lahmann HEDP-24

To study ICF physics at the NIF, MIT is developing a time-resolved neutron spectrometer called MRSt for yield, T_i and ρR

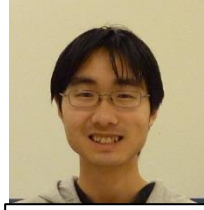




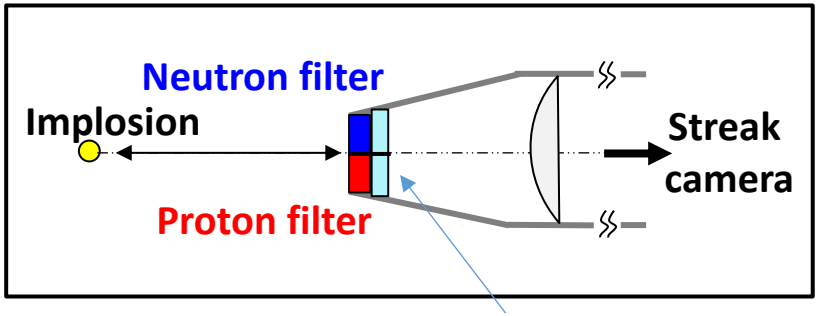
Chris Wink

See poster: C. Wink HEDP-06

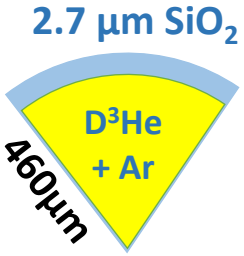
To study kinetic/multi-ion effects at OMEGA, multiple nuclear burn histories are obtained with high precision on a single diagnostic



Hong Sio



Split scintillator



D + D → ^{3}He (0.8 MeV) + **n (2.45 MeV)**

D + ^{3}He → ^{4}He (3.6 MeV) + **p (14.7 MeV)**

See poster: H. Sio NLUF-10

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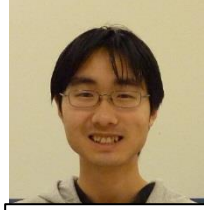

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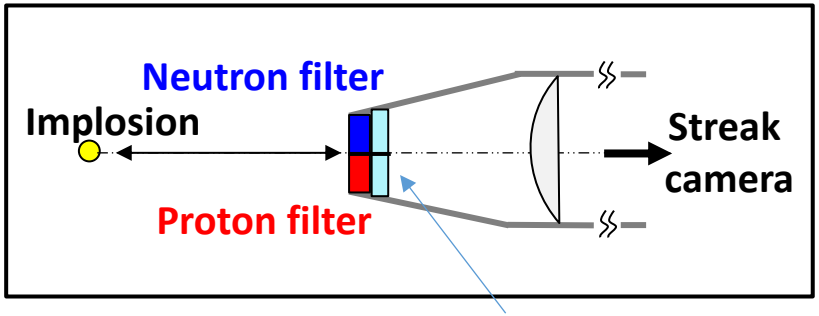
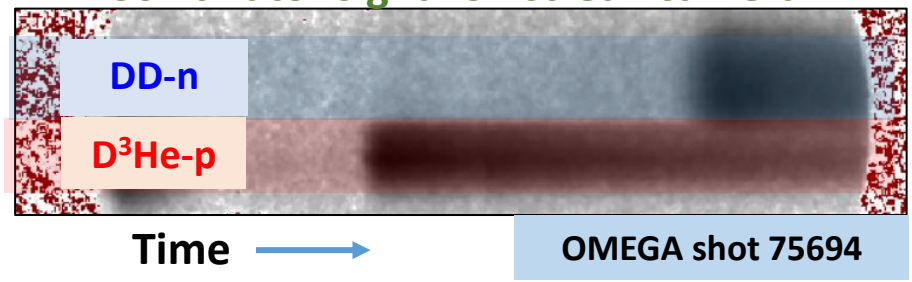


Scintillator signal on streak camera



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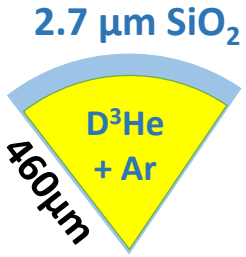

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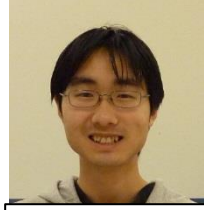

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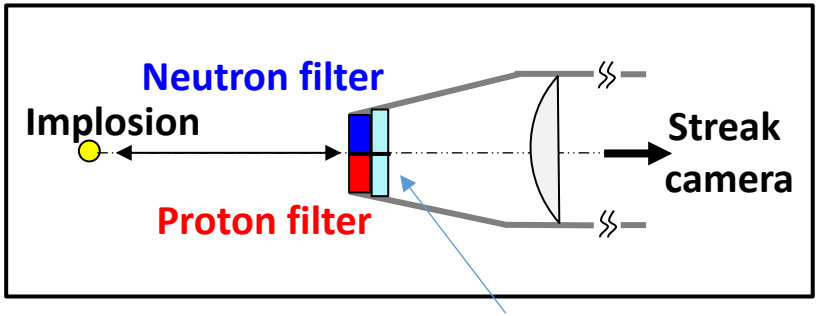

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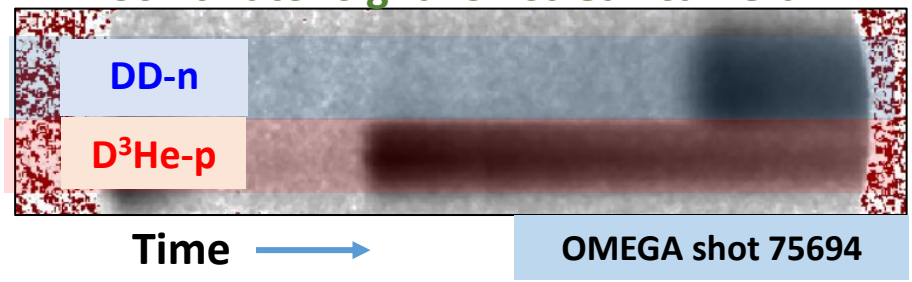

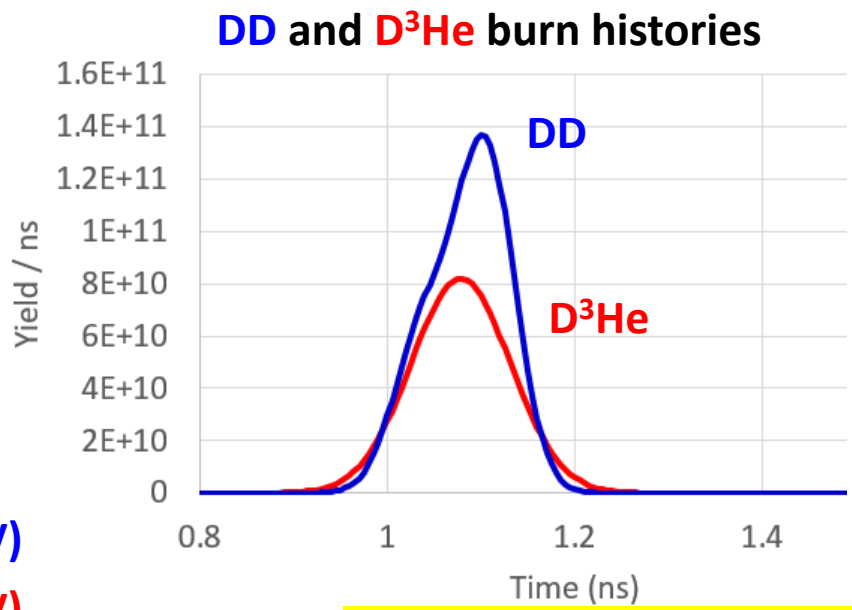

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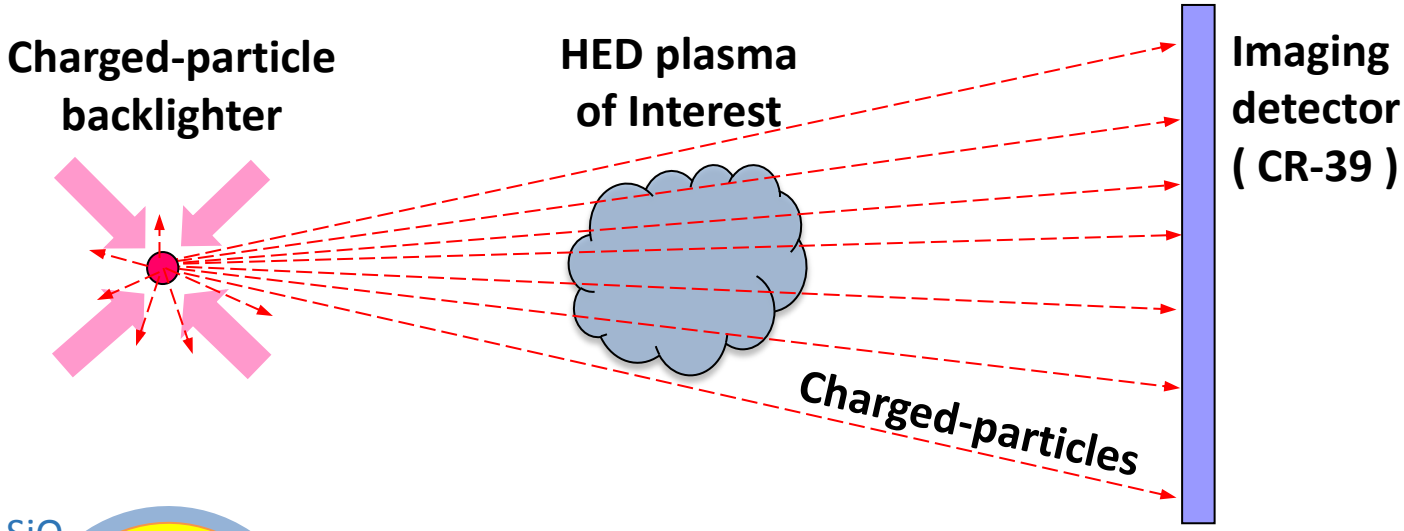
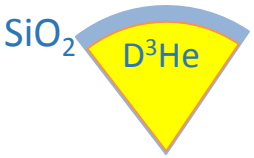
The mono-energetic D^3He-proton backlighter platform is used to probe HED plasma phenomena at OMEGA and NIF





$D + {}^3He \rightarrow p\ (14.7\ MeV) + \alpha\ (3.7\ MeV)$

$D + D \rightarrow p\ (3.0\ MeV) + T$

See poster: Kabadi HEDP-16

Neel Kabadi

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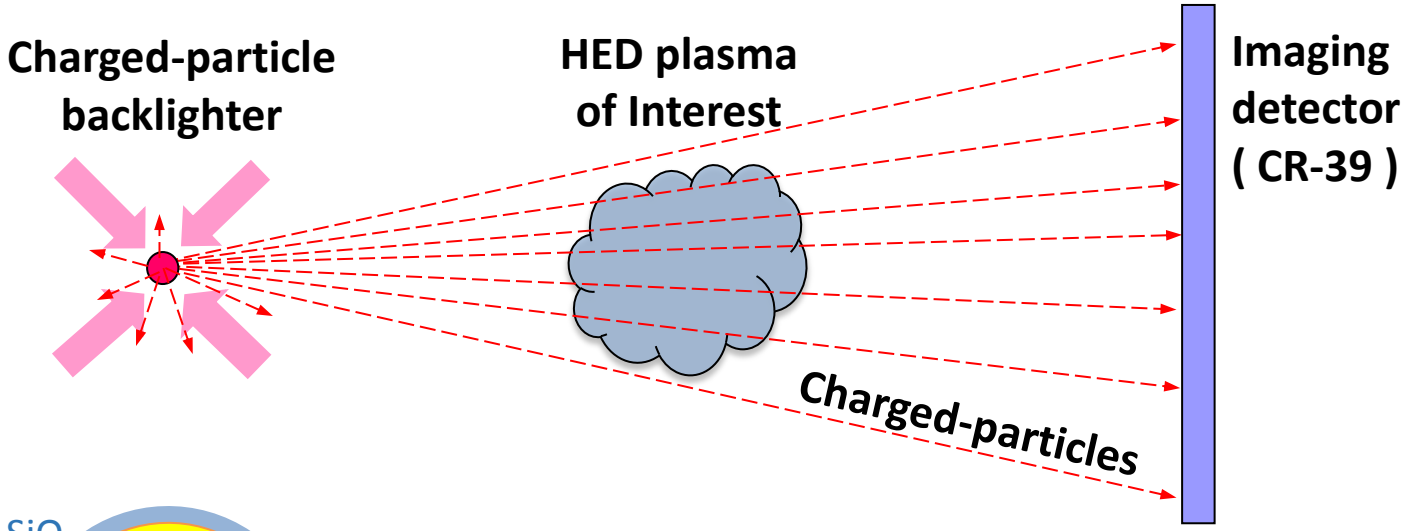

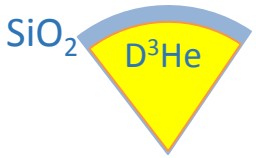

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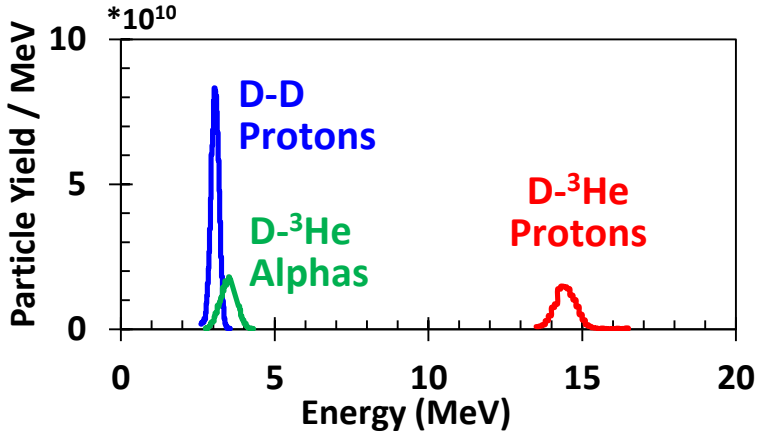

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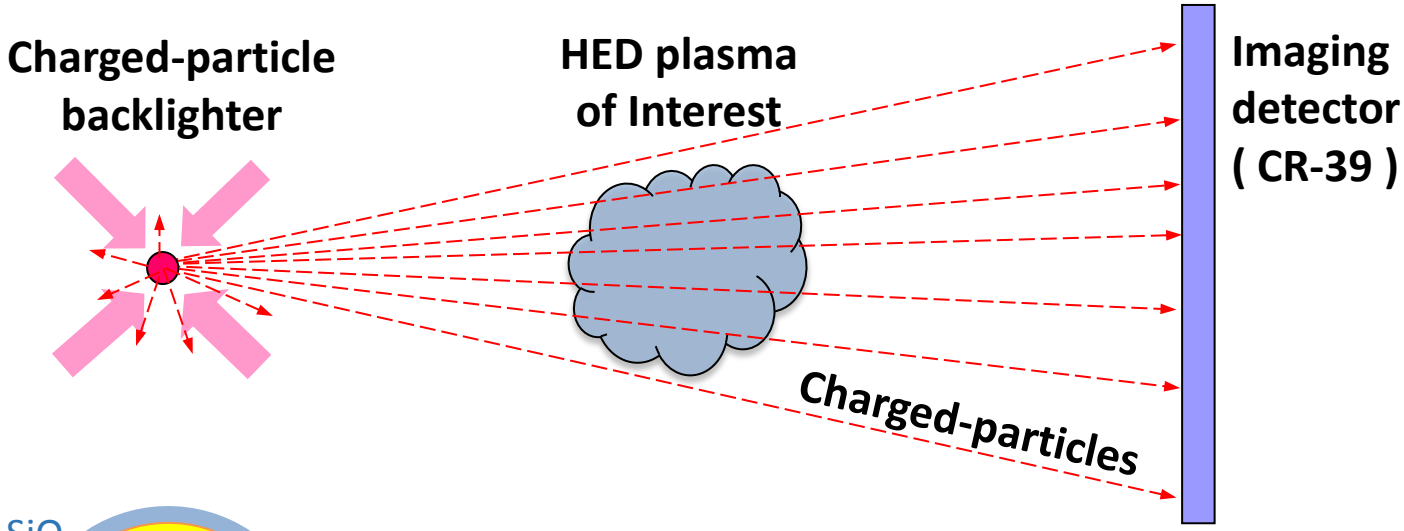
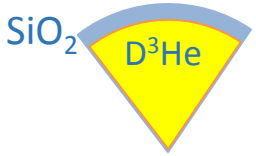
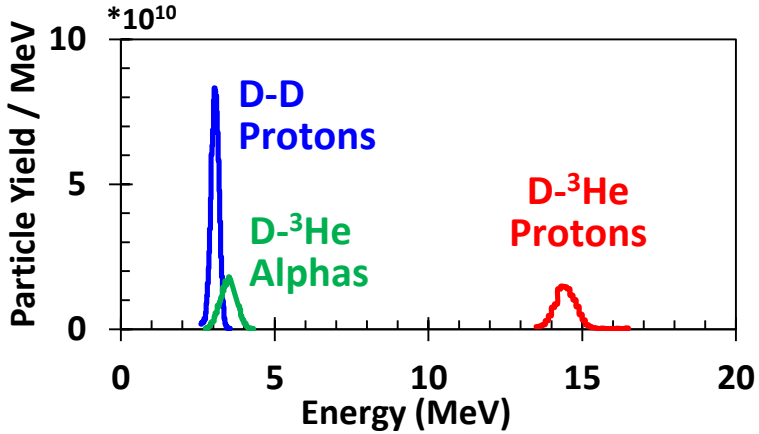




$D + {}^3He \rightarrow p\ (14.7\ MeV) + \alpha\ (3.7\ MeV)$

$D + D \rightarrow p\ (3.0\ MeV) + T$



Multiple mono-energetic particles break **E/B** degeneracy

The Lorentz Force:

$\mathbf{F} = q\,[\mathbf{E} + \mathbf{v} \times \mathbf{B}]$

MIT is using the proton backlighter platform to support many NNSA-sponsored experiments/PIs at OMEGA and NIF

OMEGA

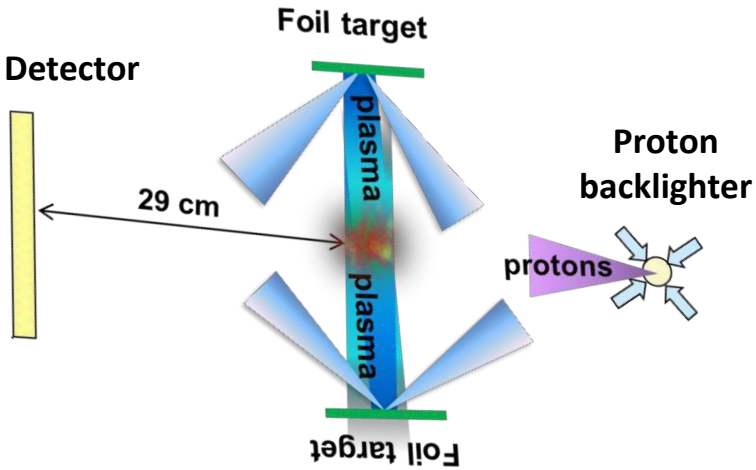
- **Astrophysical shocks (LLNL, Princeton, … –Huntington, Park, Spitkovsky *et al*.)**
- **Magnetized ICF (LLE – Chang, Betti *et al*.)**
- **Colliding jets (U. Mich – Drake, Young, Kuranz *et al*.)**
- **Magnetized Hohlraums (LLNL – Pollock *et al*.)**
- **MCLSW (LLNL – Pollock *et al*.)**
- **Astrophysical shocks (Rice, U. Mich – Hartigan, Kuranz *et al*.)**
- **Magnetic dynamos (Oxford, U. Chicago, U. Wisc, LLNL – Gregori, Lamb, Forest, Park *et al*.)**
- **Stopping power (LANL - Zylstra *et al*.)**
- **Kinetic shock (LLNL – Rinderknecht *et al*.)**

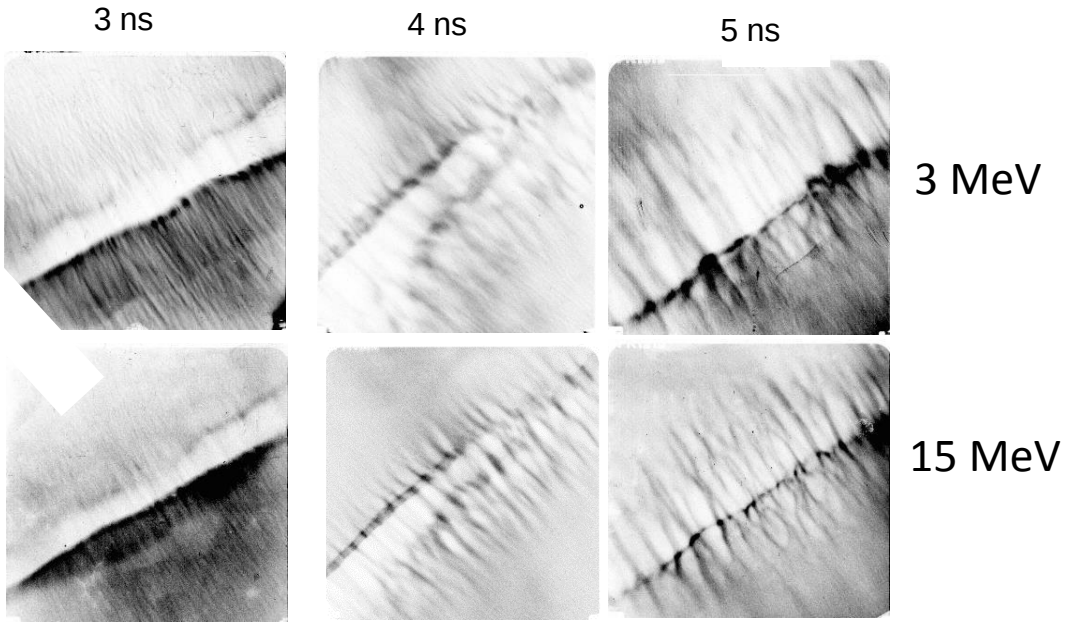
NIF

- **Collisionless shock (Osaka, LLNL, … - Sakawa, Park *et al*.)**
- **Turbulent Dynamos (Oxford, … - Gregori *et al*.)**
- **Stopping power (LANL, LLNL, MIT - Zylstra, Rygg *et al*.)**
- **Fields in Hohlraums (MIT, LLNL - Li *et al*.)**
- **Kelvin-Helmholtz mix experiments (LANL - Flippo *et al*.)**
- **Reconnection (Princeton – Fox *et al*.)**

OMEGA example: A proton backlighter was used to study the astrophysical phenomenon of interpenetrating plasma flows

C. Huntington et al., Nature Physics (2015):





Magnetic field generation via the Weibel instability was observed in these experiments

+ Univ. Michigan, Oxford, Osaka, Princeton U., MIT……

MIT is using the proton backlighter platform to support many NNSA experiments at OMEGA and the NIF

OMEGA

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NIF

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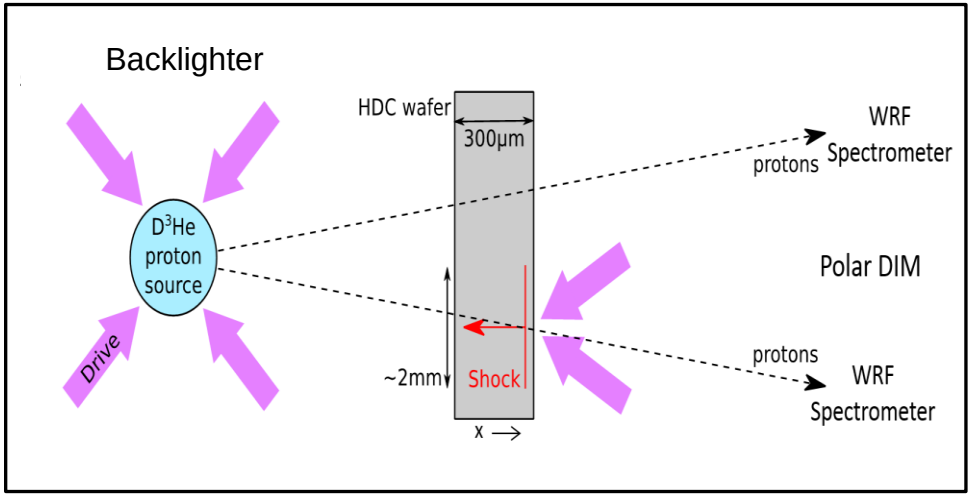
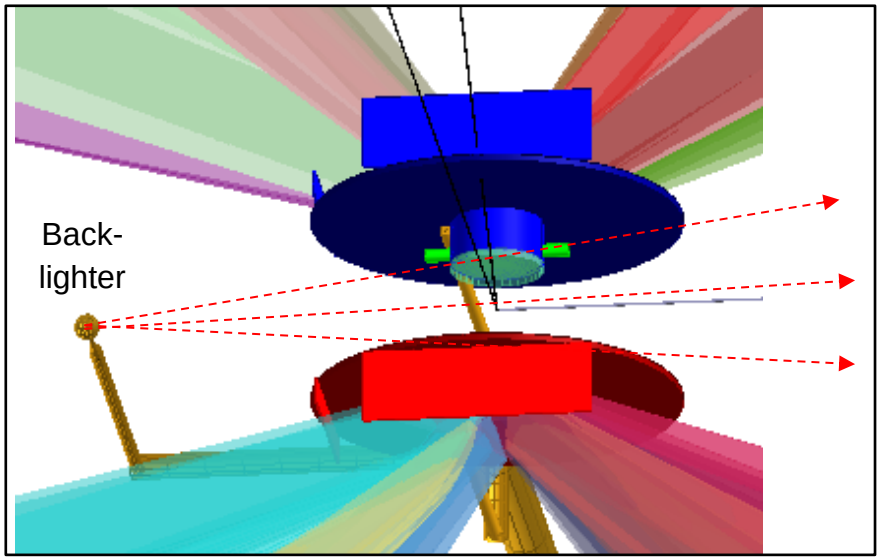
Mono-energetic proton backlighting is being used for Programmatic and Discovery Science Experiments on the NIF today and tomorrow

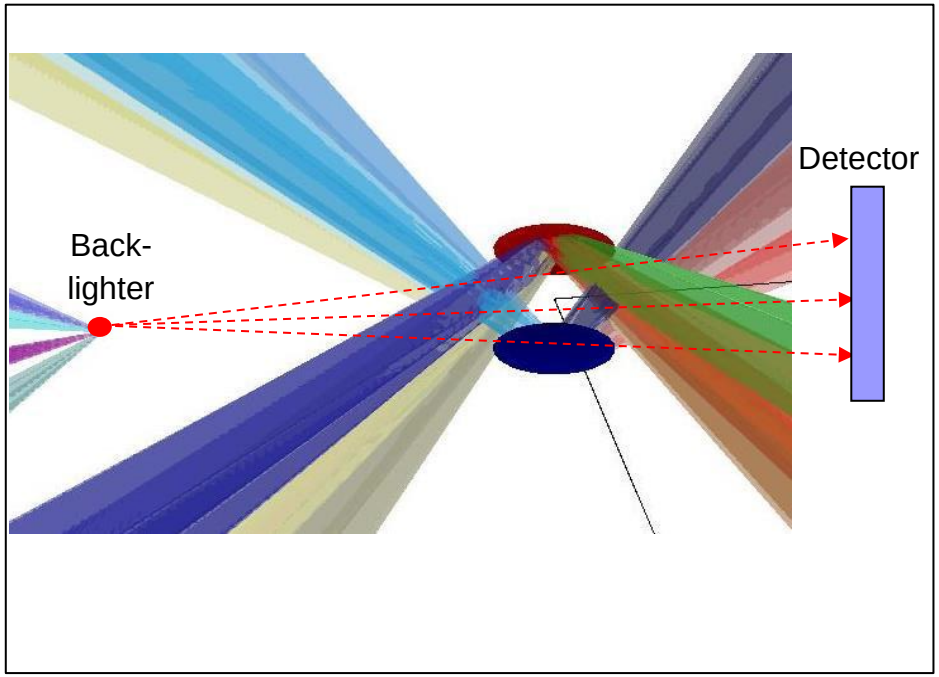


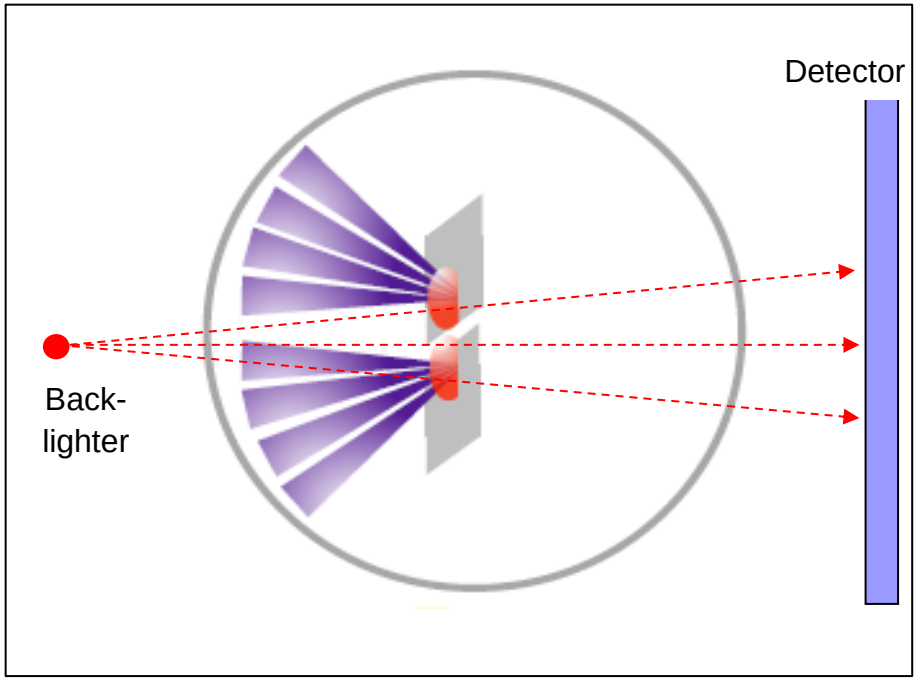


<u>Stopping power</u>
Zylstra, Rygg *et al.*
LANL & LLNL
(15 feb 2016)

<u>Turbulent Dynamo</u>
Gianluca Grigori *et al.*
Oxford University …
(18 feb 2016)

More NIF Discovery Science Experiments will explore collisionless shocks and magnetic reconnection





<u>Collisionless shock</u>
Sakawa, Hye-Sook Park et al
(Osaka,LLNL,…)

(June 2016)

<u>Magnetic reconnection</u>
Will Fox et al (Princeton,..)
(2017)

Outline

I. MIT research and platform development at NIF, OMEGA and Z
---Student research is featured

II. Utilization of the MIT proton-backlighter platform
for NNSA-sponsored Programs/PIs at OMEGA and the NIF

III. OLUG: 8th OMEGA Laser Users Group workshop 27-29 April
(wonderful setting for student-postdoc interactions)

About 50 students and postdocs will receive travel assistance to attend Omega User's workshop 27-29 April 2016

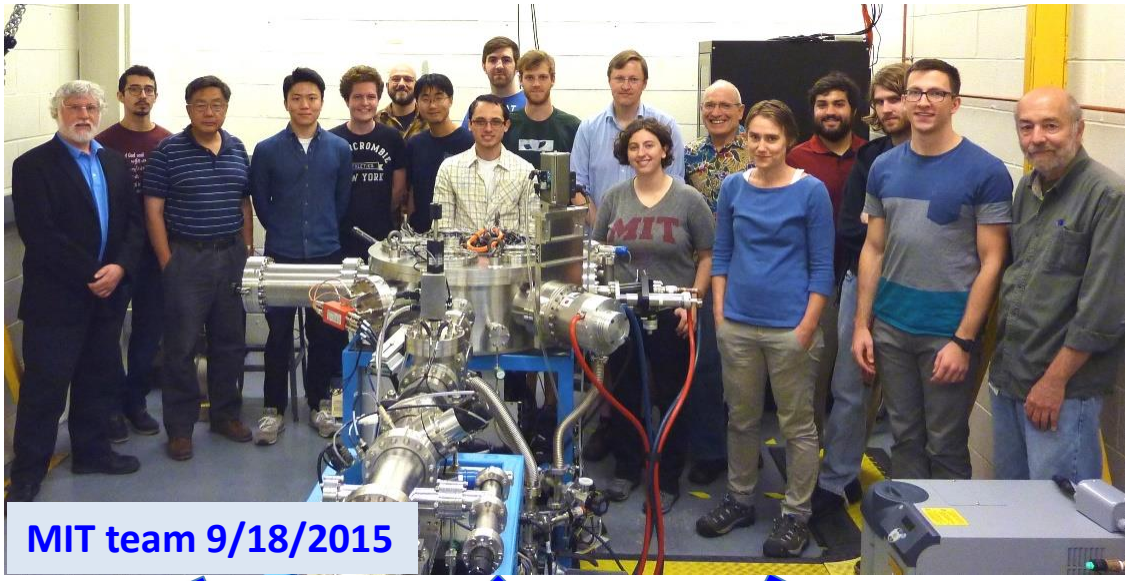
Thanks to NNSA, financial support for student and postdocs is available (contact R. Petrasso or R. Mancini)

From 3 poster sessions, Awards will be given to the outstanding student-postdoc posters

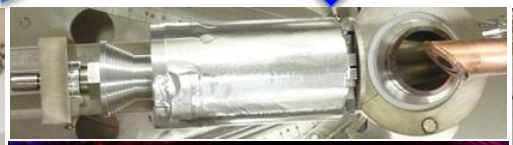
2015 Workshop

A student-post "jobs fair" happens on last day, 29 April 2016.

Studying ICF & HED Physics at NIF, OMEGA & Z using MIT-developed nuclear diagnostics & platforms



OMEGA Laser facility | **Z** | **National Ignition Facility (NIF)**

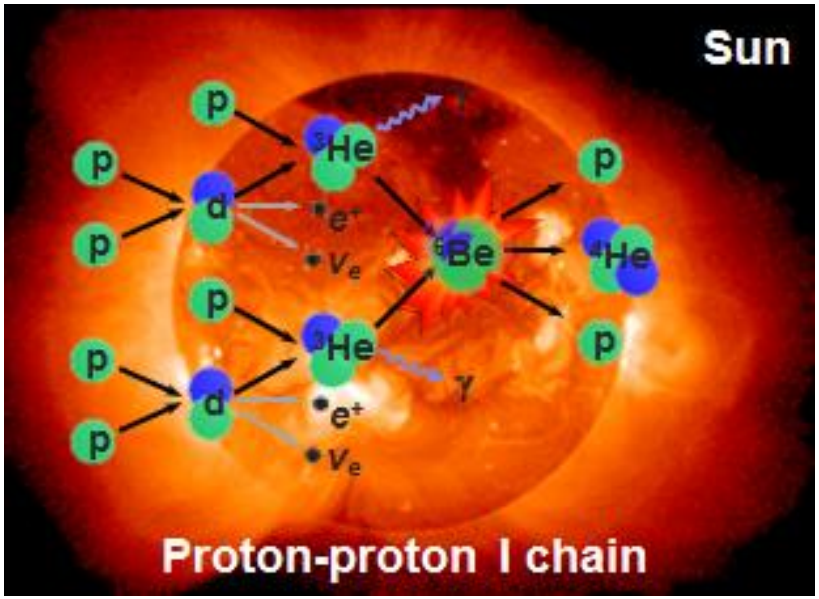


Richard Petrasso, for the MIT team

SSAP, Feb 17th 2016

EXTRAS

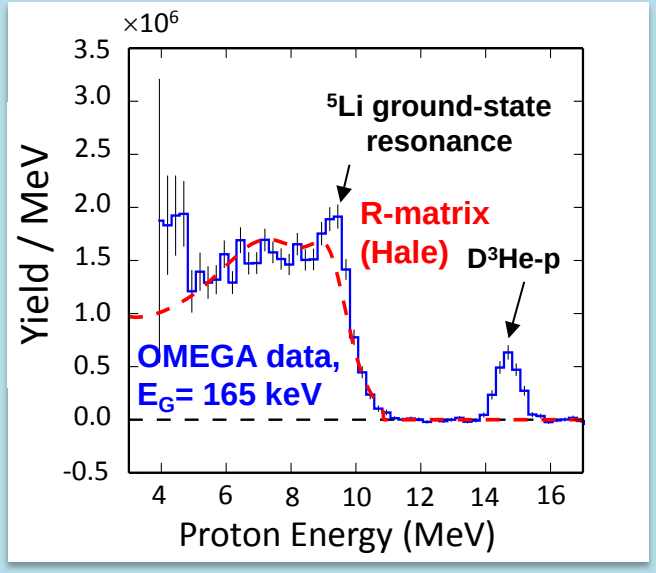
MIT-led NIF Discovery Science experiments will use shock-driven implosions to probe nuclear reactions relevant to Stellar Nucleosynthesis



^{3}He+^{3}He → α+p+p

Excellent preliminary WRF proton spectrometer data from Omega:

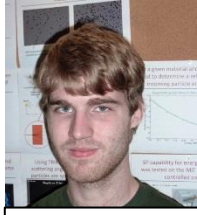
^{3}He+^{3}He-proton spectrum



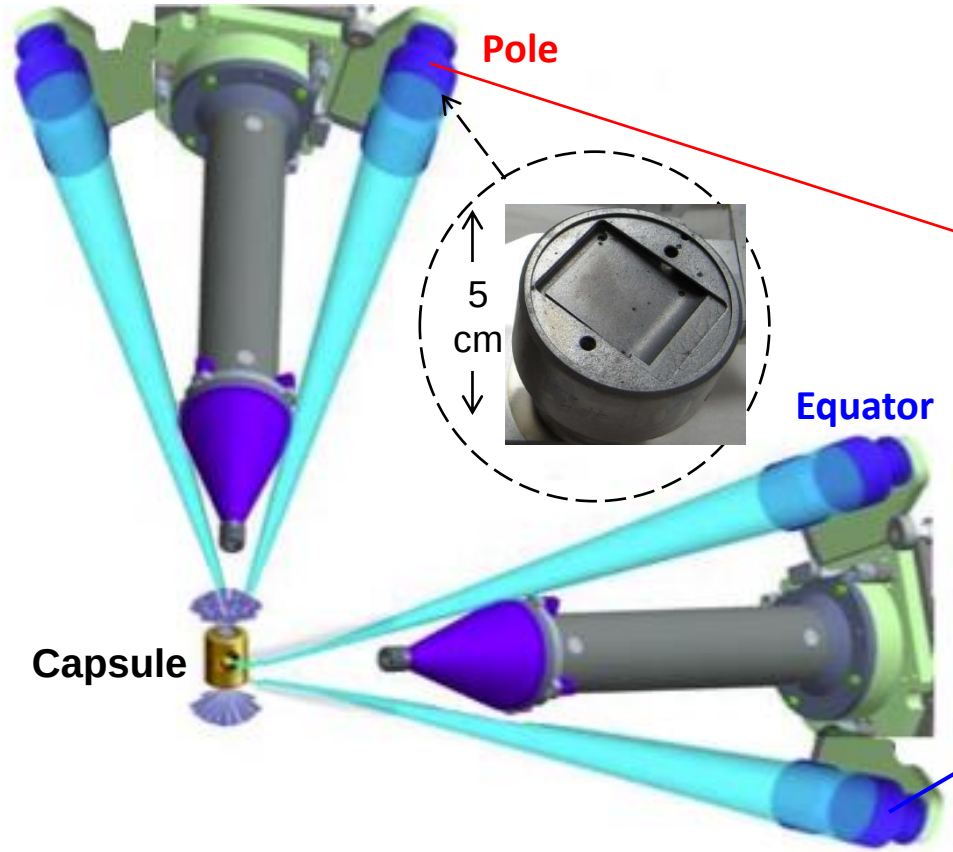
Predicted NIF E_G: 45-90 keV

See poster: M. Gatu Johnson HEDP-23

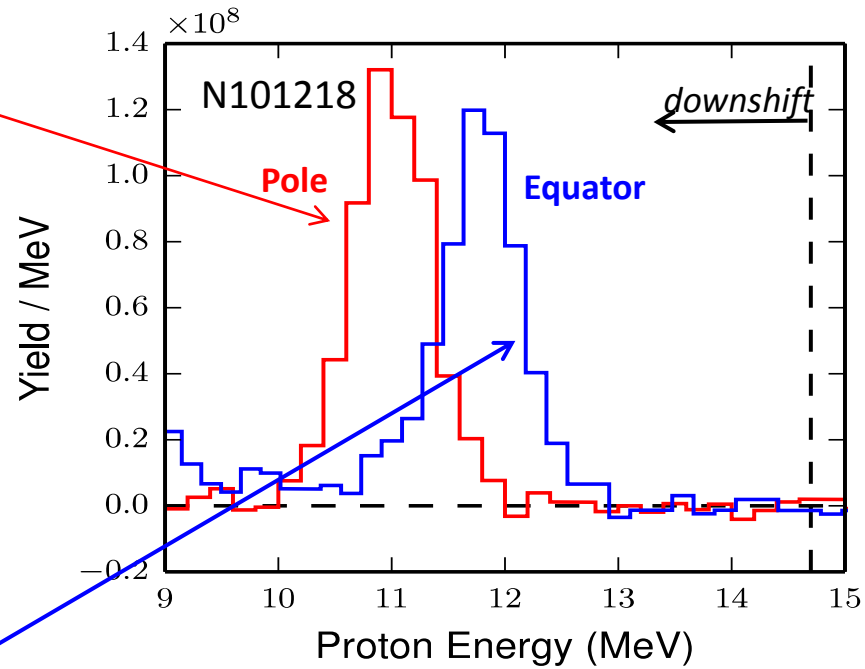
At NIF: Multiple proton spectrometers are routinely fielded on implosions, allowing for ρR-asymmetry measurements



Brandon Lahmann



D + ^{3}He -> α + **p (14.7 MeV)**



Pole Shock ρR: 107 ± 2_{ran} ± 6_{sys} mg/cm²

Equator Shock ρR: 81 ± 2_{ran} ± 6_{sys} mg/cm²

A. B. Zylstra *et al.* Physics of Plasmas **22**, 056301 (2015)

See poster: B. Lahmann HEDP-24

The National Implosion Stagnation Physics (NISP) effort

1st NISP workshop at LLNL on Oct. 27-28, 2015

Johan Frenje
Massachusetts Institute of Technology

2016 Stewardship Science Academic Programs Symposium
Bethesda, MD, February 17-18