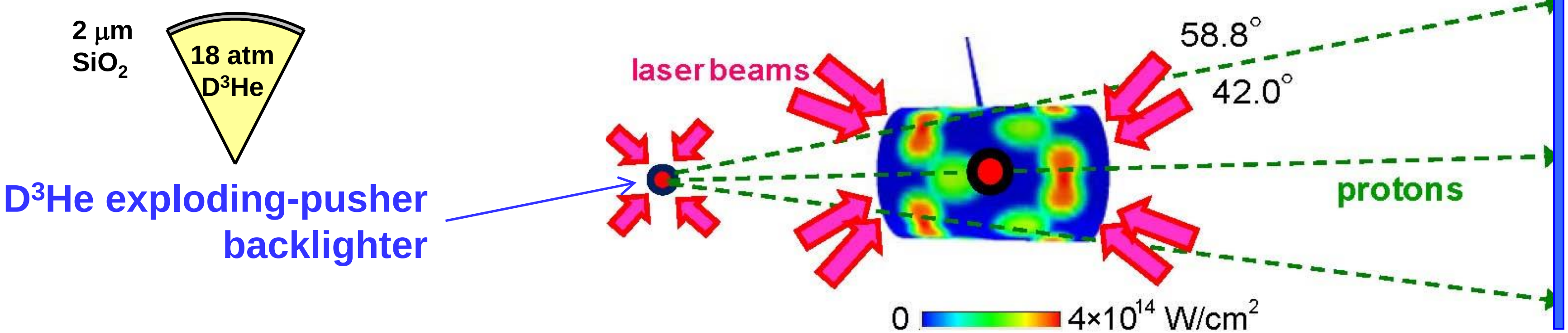
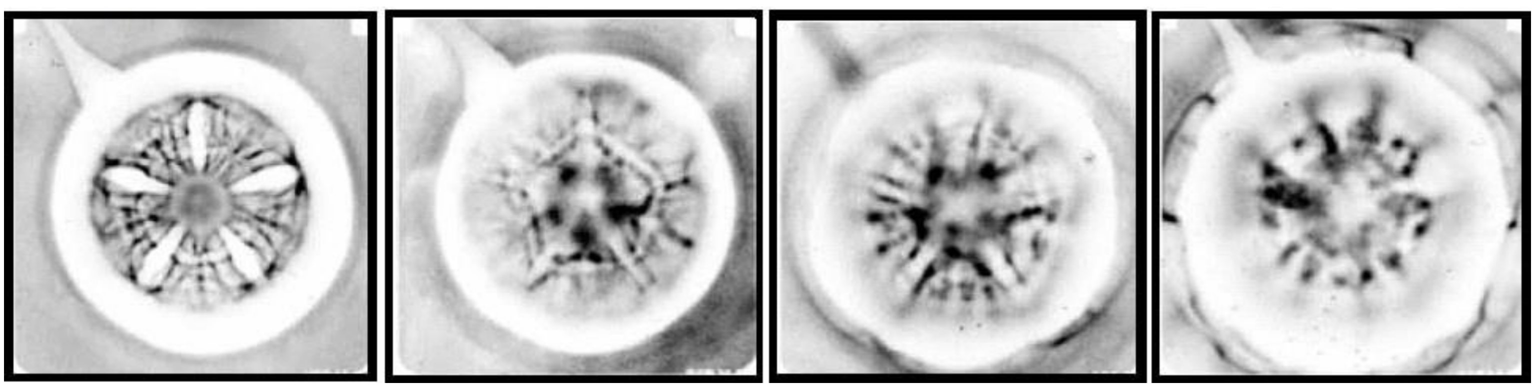
Development of a monoenergetic proton backlighter at the NIF





0.5 ns | 1 ns | 1.5 ns | 1.8 ns

C.K. Li et al., Science (2010)

Collaborators

MIT	LLNL	LLE-UR
F. H. Séguin	J. R. Rygg	S. Craxton
J. A. Frenje	S. Le Page	P. McKenty
R. D. Petrasso	H. S. Park	T. C. Sangster
H. Sio	B. A. Remington	
A. Zylstra		

Summary

- Proton radiography on OMEGA has provided unique information for studying HED plasmas, ICF dynamics, and astrophysical phenomena

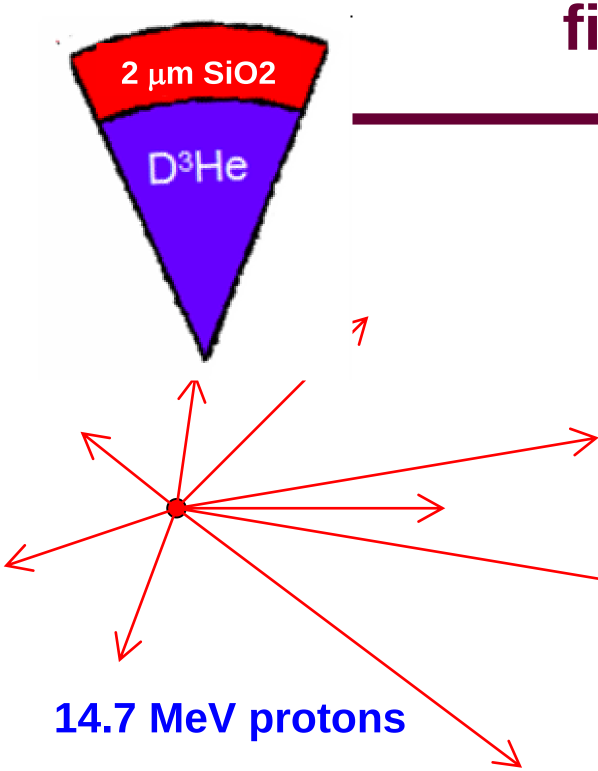
- Proton radiography have been proposed for NIF experiments

- Significant progresses have been made for developing a proton backlighter at the NIF

Outline

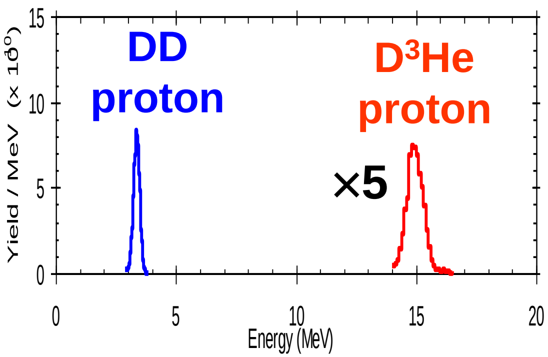
- ❑ Proton radiography on OMEGA
- ❑ Proton backlighter for the NIF
- ❑ Plan for the first NIF Discovery Science shots

The proton backlighter is a laser-driven glass capsule filled with D_2 and ^3He gas



$$D + {}^3He \rightarrow {}^4He + p\ (14.7\ MeV)$$
$$D + D \rightarrow T + p\ (3.0\ MeV)$$

Emission of protons is pulsed, monoenergetic, and isotropic

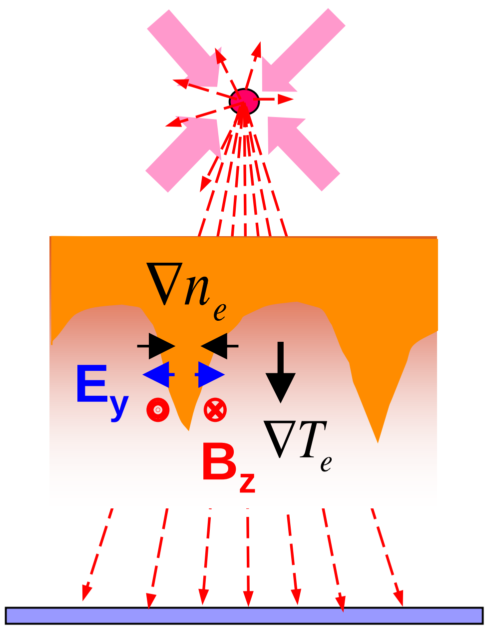


Spatial resolution: ~ 40 μm (FWHM)
Energy resolution: ~ 3%
Temporal resolution: ~ 130 ps

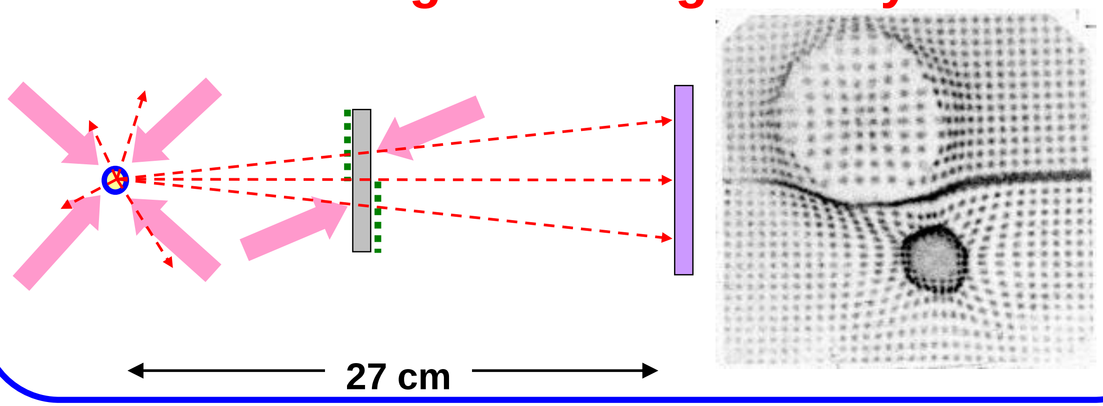
C. K. Li et al., PRL (2006)
C. K. Li *et al.*, RSI (2006)

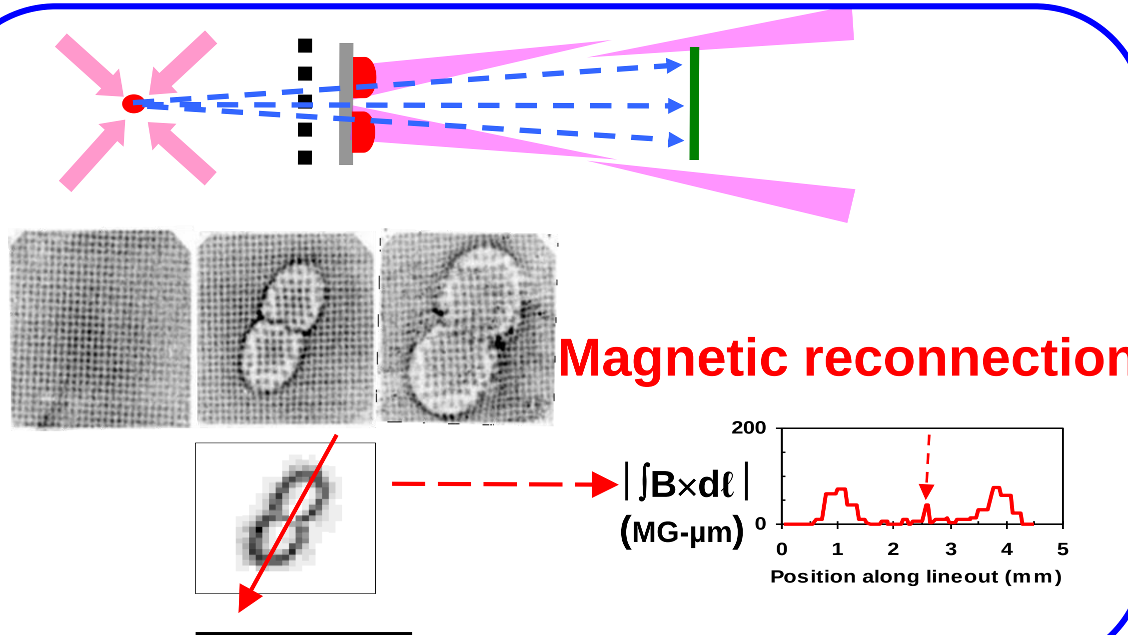
Proton radiography has been routinely used to study fundamental HED plasmas at OMEGA

RT induced B fields



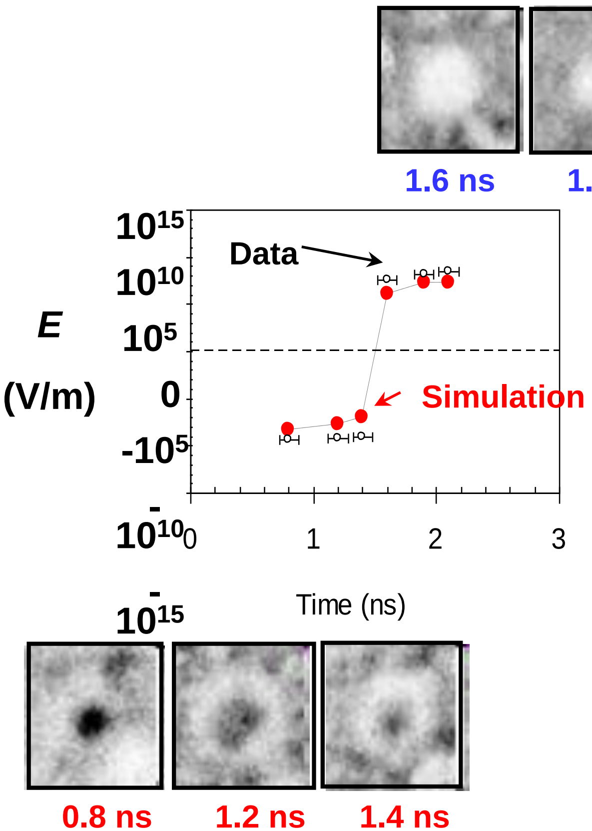
Breaking E & B degeneracy

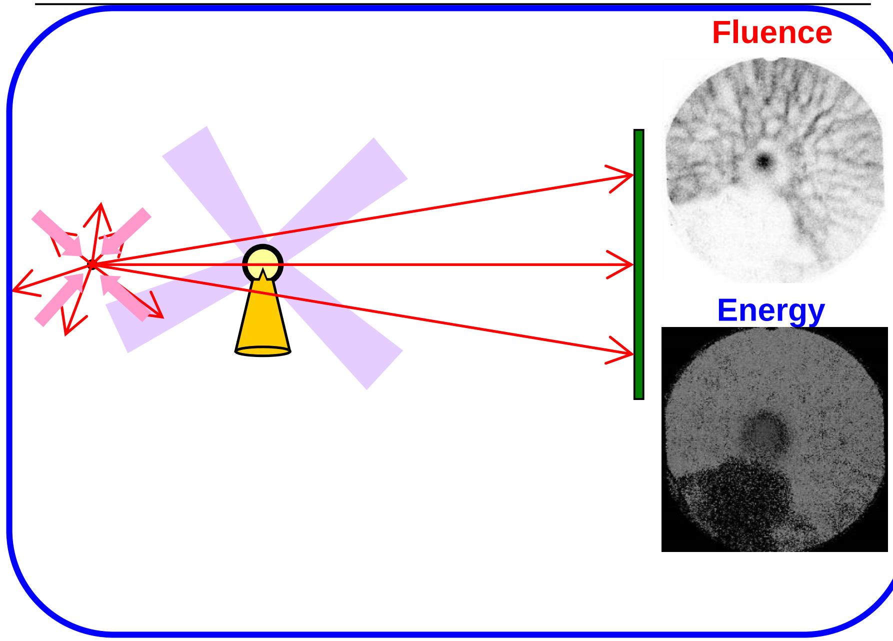


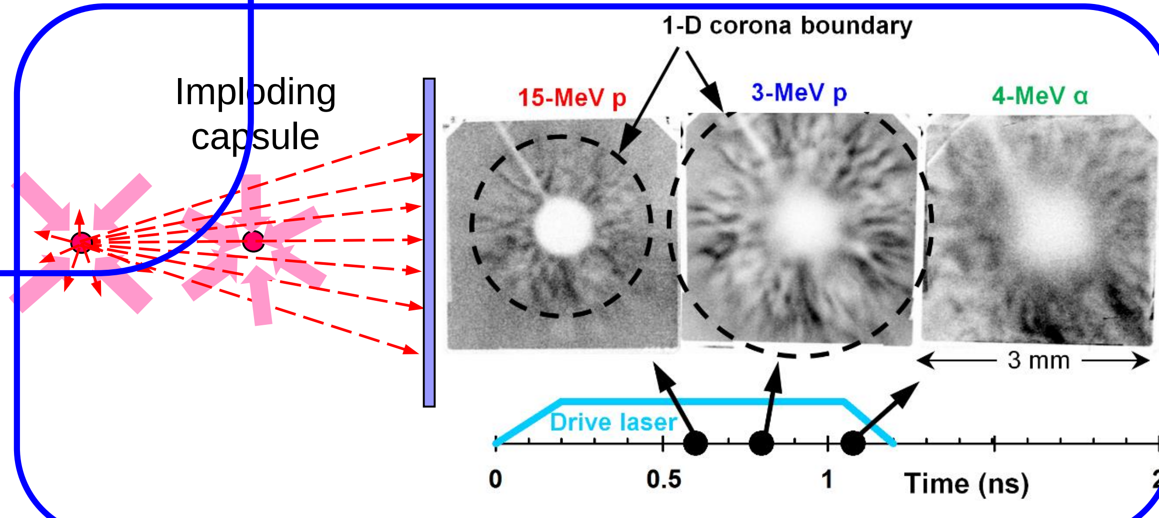


C. K. Li *et al*., PRL (2007)
R. D. Petrasso *et al*., PRL (2009)
M. Manuel *et al*., PRL (2012)

Time-resolved proton radiographs reveal the structure and dynamics of direct-drive ICF implosions at OMEGA

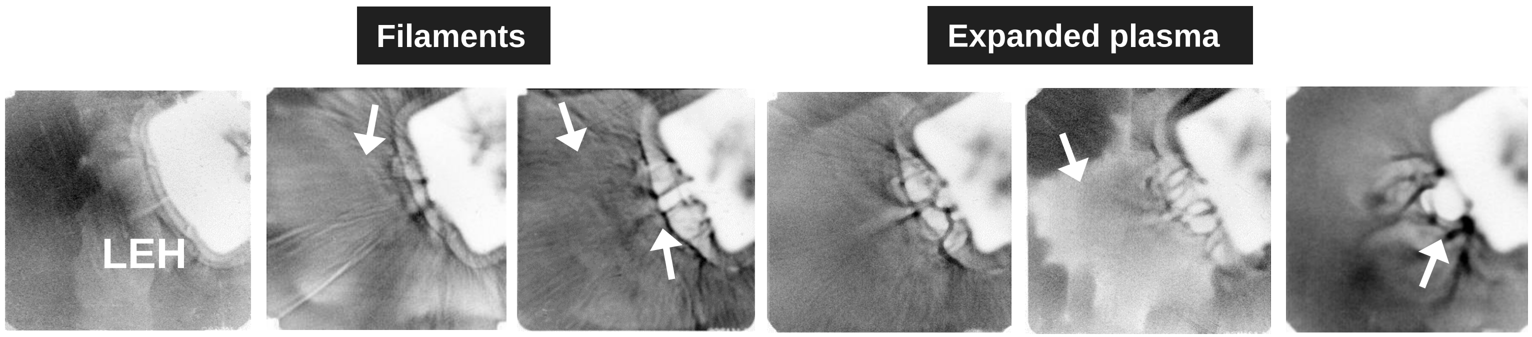


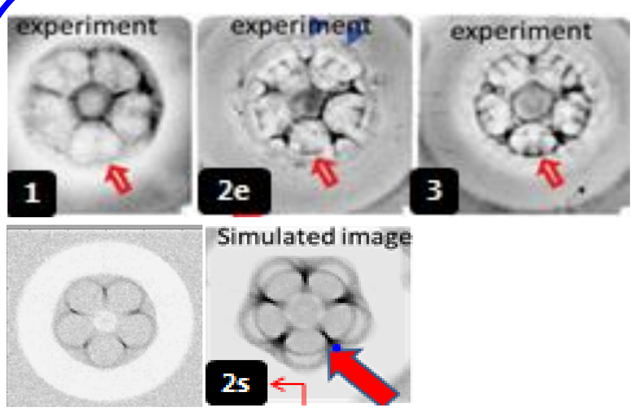


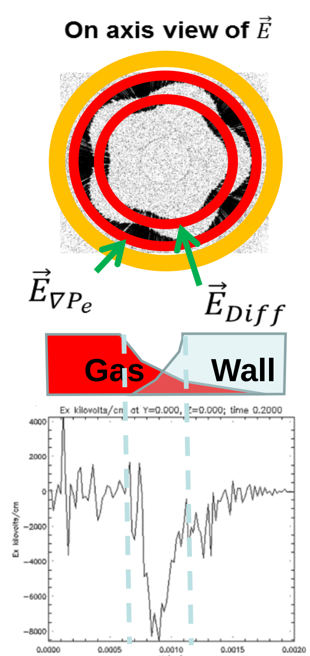


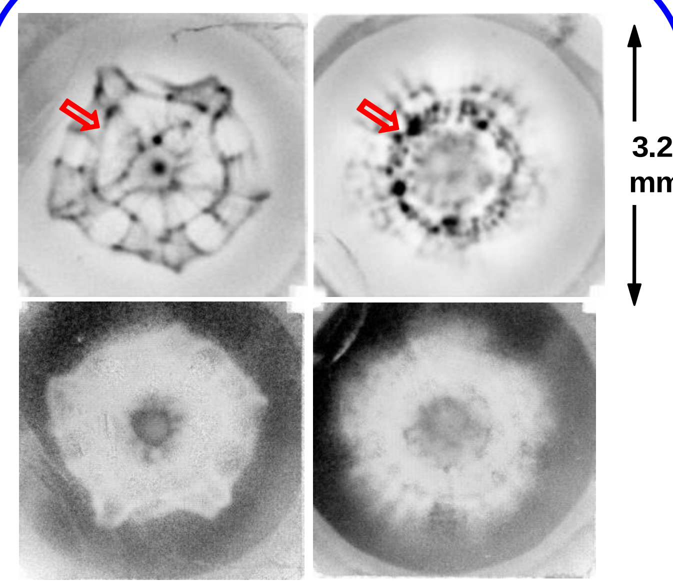
J. R. Rygg *et al*., Science (2008)
C. K. Li *et al*., PRL (2008)
F. H. Seguin *et al*., PoP (2012)

Proton images provide new insight into plasma flow, RT instabilities and diffusive-mix in laser-driven hohlraums





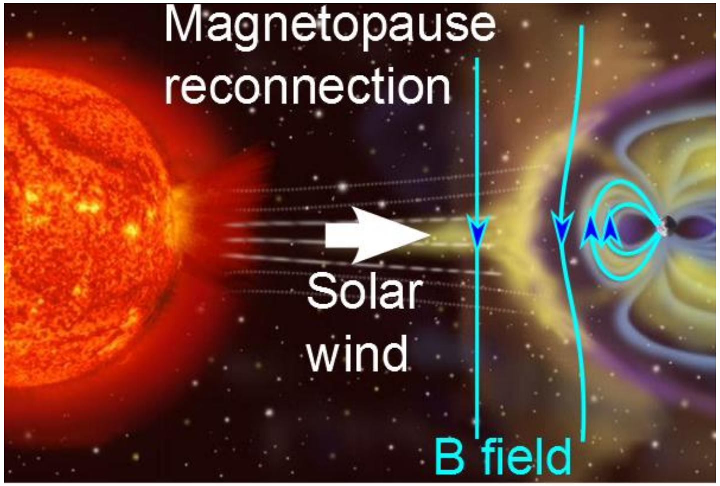


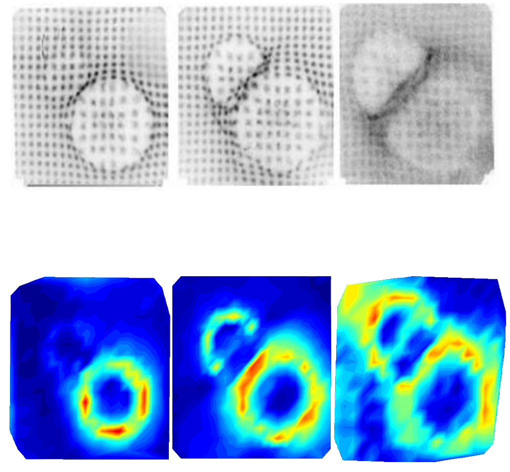


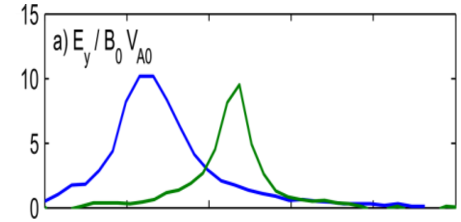
0.8 ns 1.6 ns

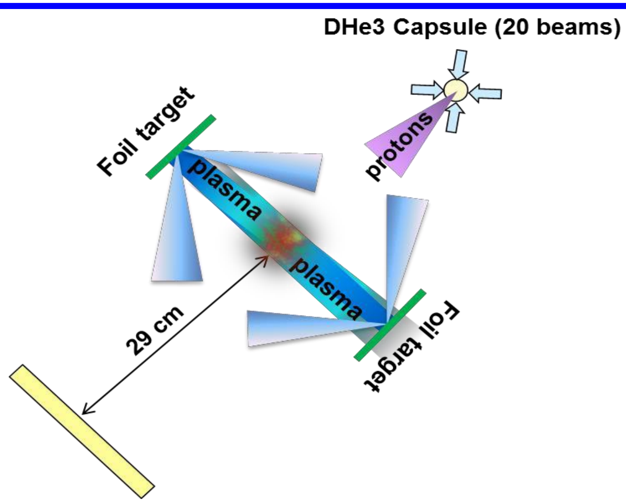
C. K. Li *et al*., Science (2010)
C. K. Li *et al*., PRL (2012)
S. C. Wilks *et al*., to be submitted (2015)

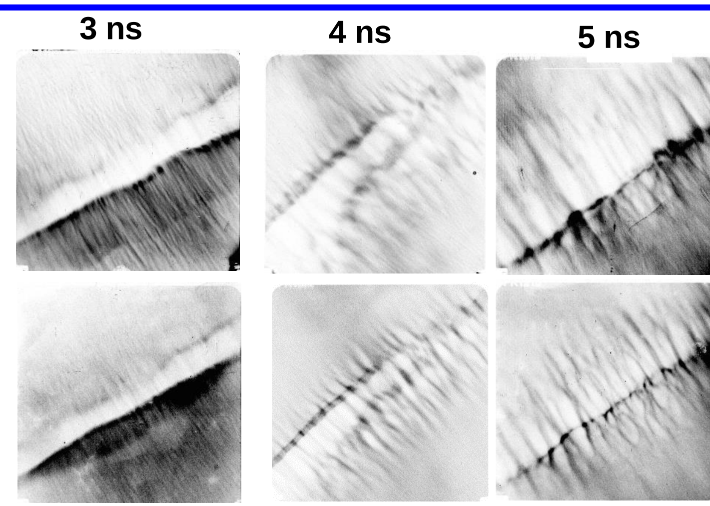
Proton radiography provide a powerful diagnostics for studying astrophysical phenomena in laboratory









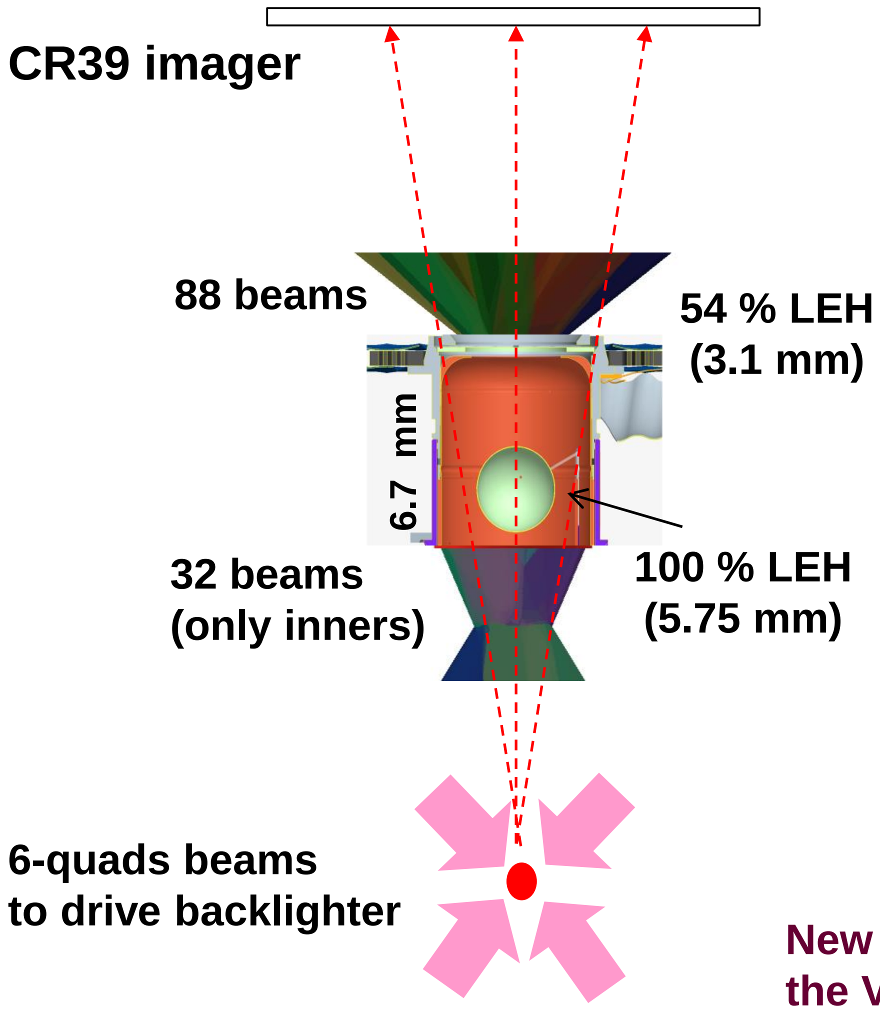


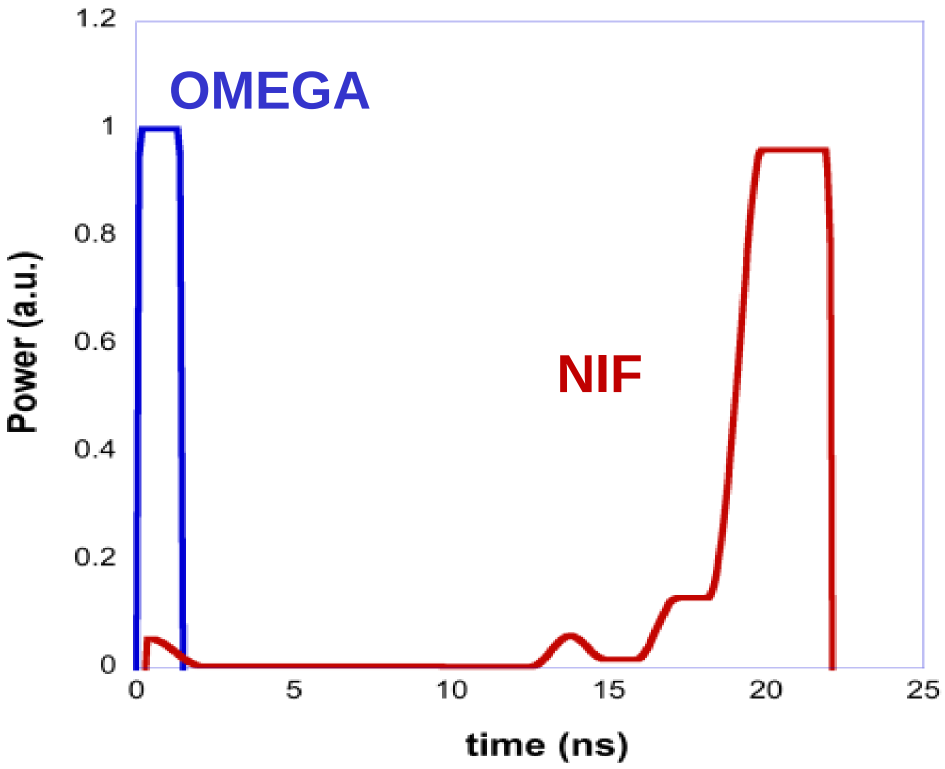
M. J. Rosenberg *et al*., Nature Comm. (2015)
C. Huntington *et al.,* Nature Phys. (2015)

Outline

- ❑ Proton radiography on OMEGA
- ❑ Proton backlighter for the NIF
- ❑ Plan for the first NIF Discovery Science shots

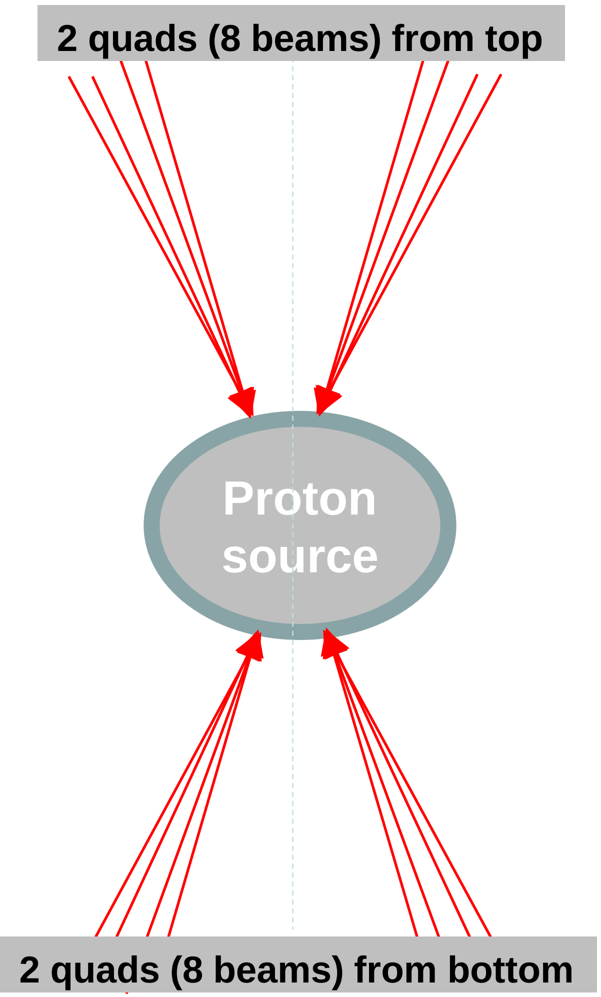
Proton radiography is highly desired at the NIF to provide unique diagnostic information for various experiments





New experiments are being planned for backlighting the ViewFactor indirect-drive implosions at the NIF

A fundamental requirement of NIF backlighter is the polar-drive configuration



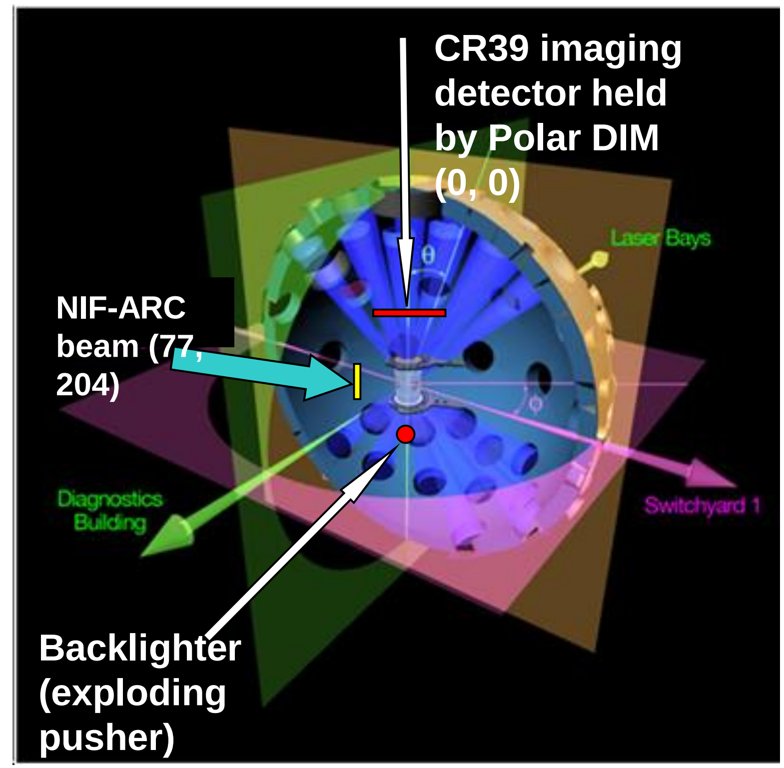
Dhe3 exploding pusher target
0.4-0.8 mm diameter

Only 4-8 quartz beams are used versus 192 on the standard exploding pusher

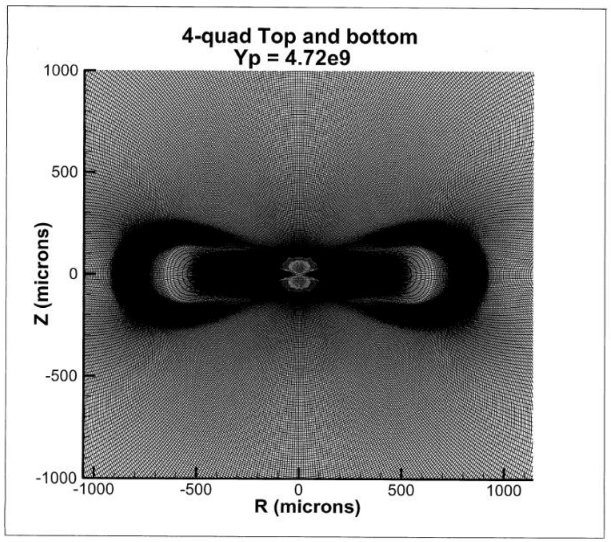
<u>Laser:</u>
- **1-3ns pulse**
- **2.5 kJ/beam**

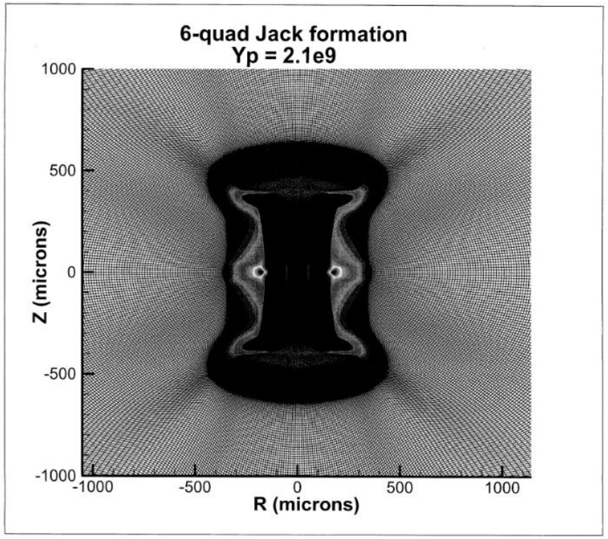
<u>Simulation results:</u>

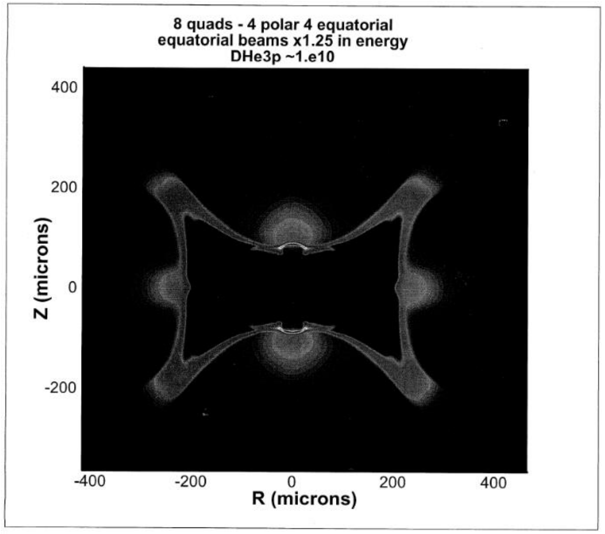
- **Yp: 3.4E11**
- **Yn: 3.92E11**
- **Bangtime: 1.69ns**
- **Hot spot: 82 um**
- **Ti: 9.93 keV**
- **Fuel rR: 5.5 mg/cm2**

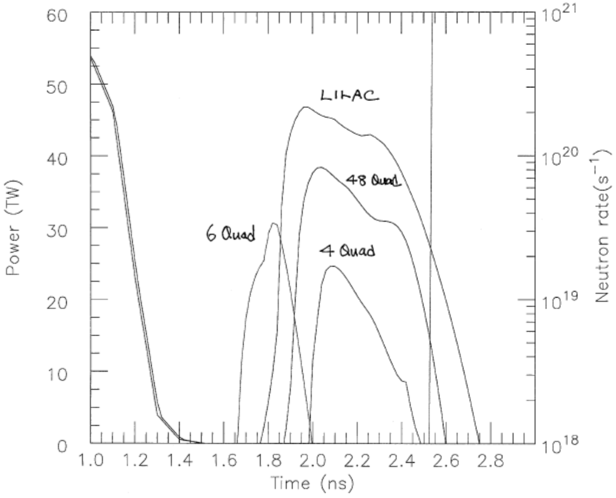


2D simulations haven been conducted for NIF backlighter at different drive configurations and conditions



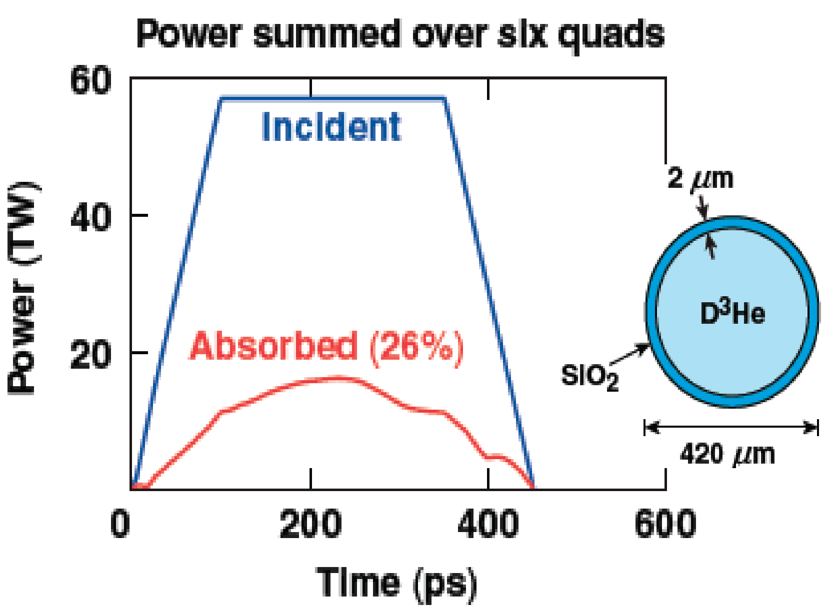




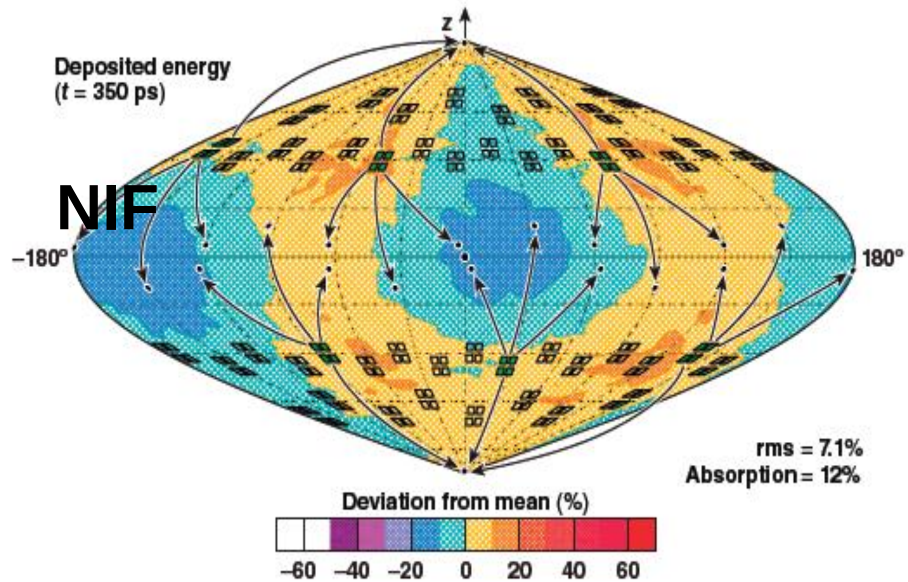


An optimized design has been made for the NIF

(a)

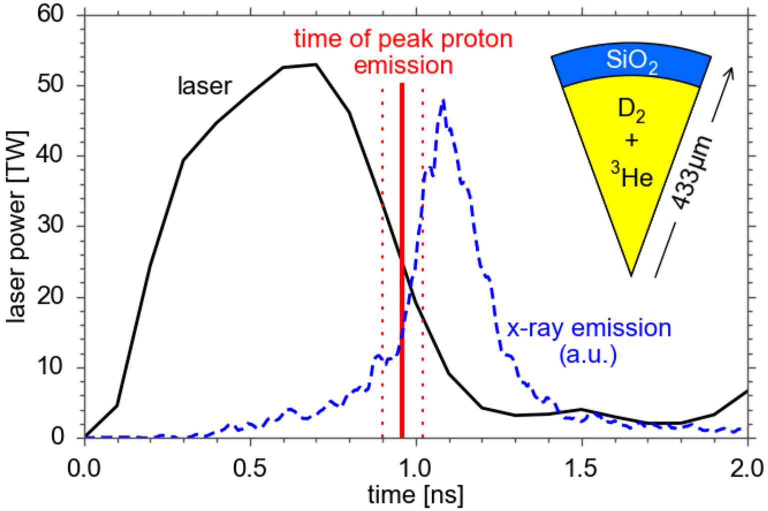


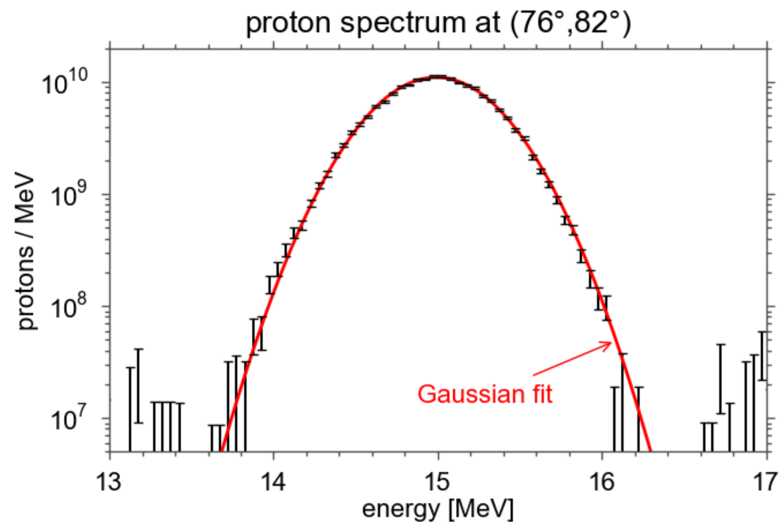
(b)

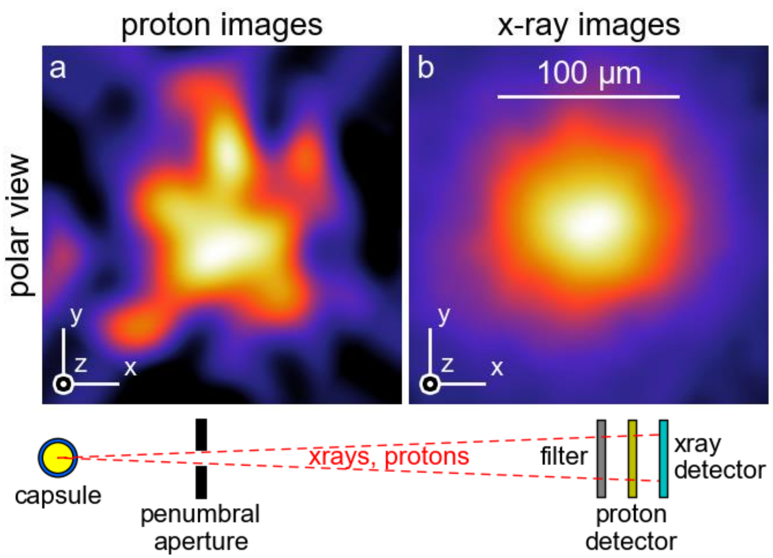


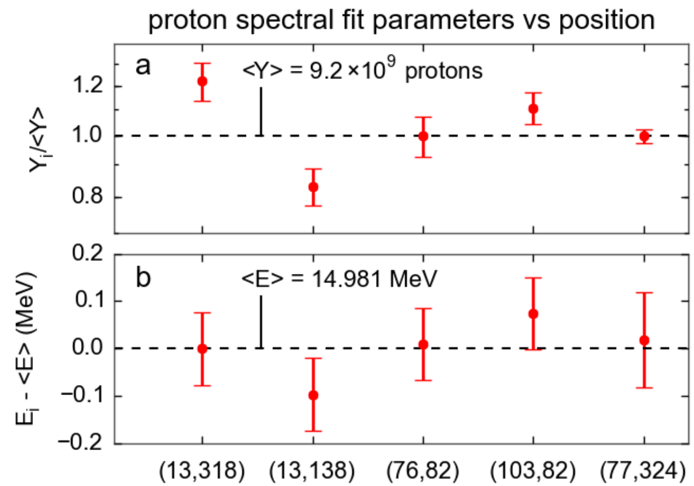
It is proposed to use 24 NIF beams (providing 20 kJ of energy) to implode a 210-µm-radius, thin D^3He-filled glass shell. This design achieves an energy deposition uniformity of 9.6% rms, which will generate proton yields > 10^{10} .

Recent NIF exploding-pusher implosions demonstrated the feasibility of a proton backlighter



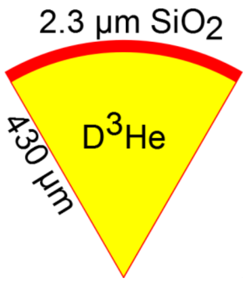


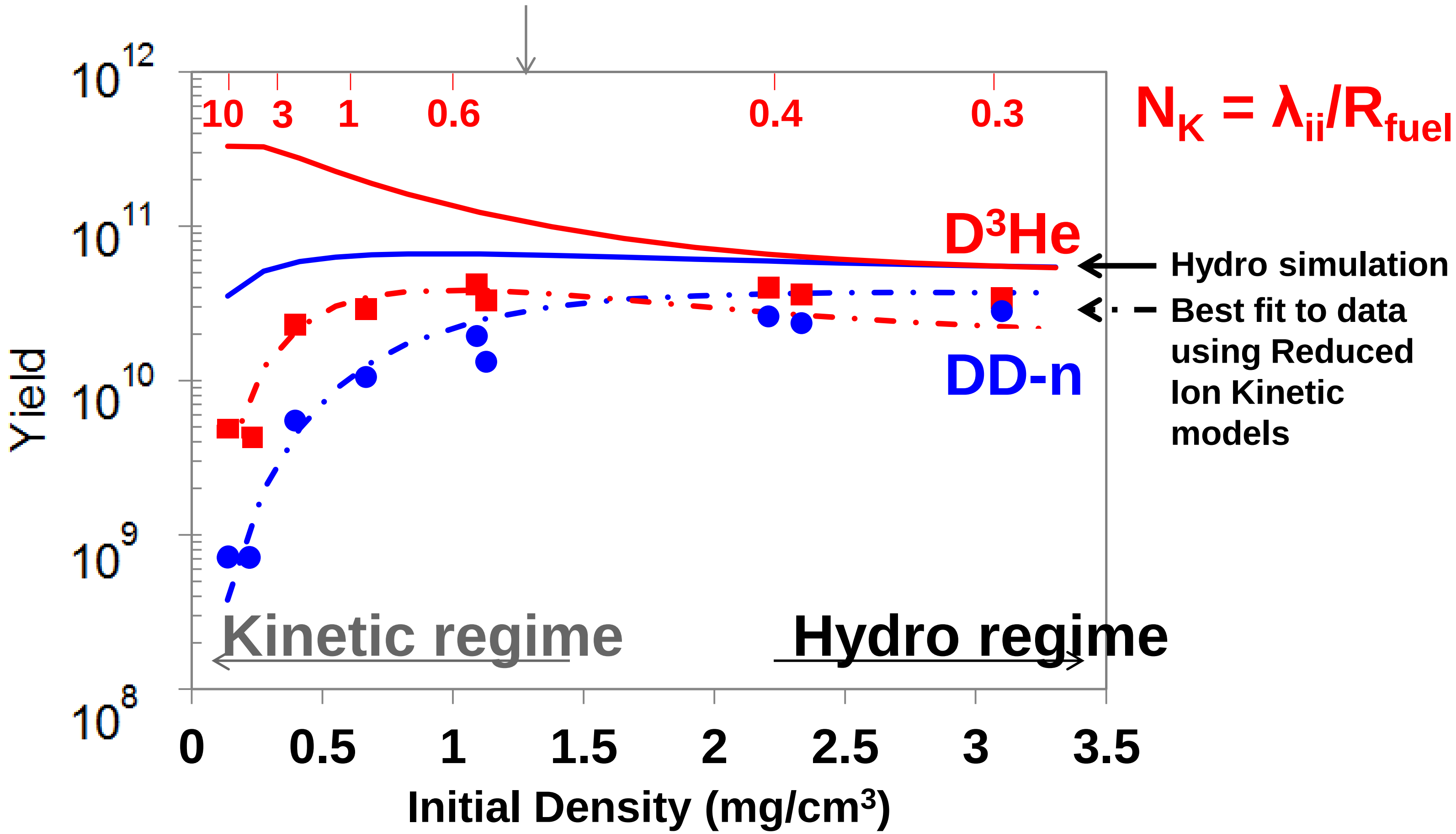




In the coming months, we will investigate proton yield and source size as a function of various capsule and laser parameters

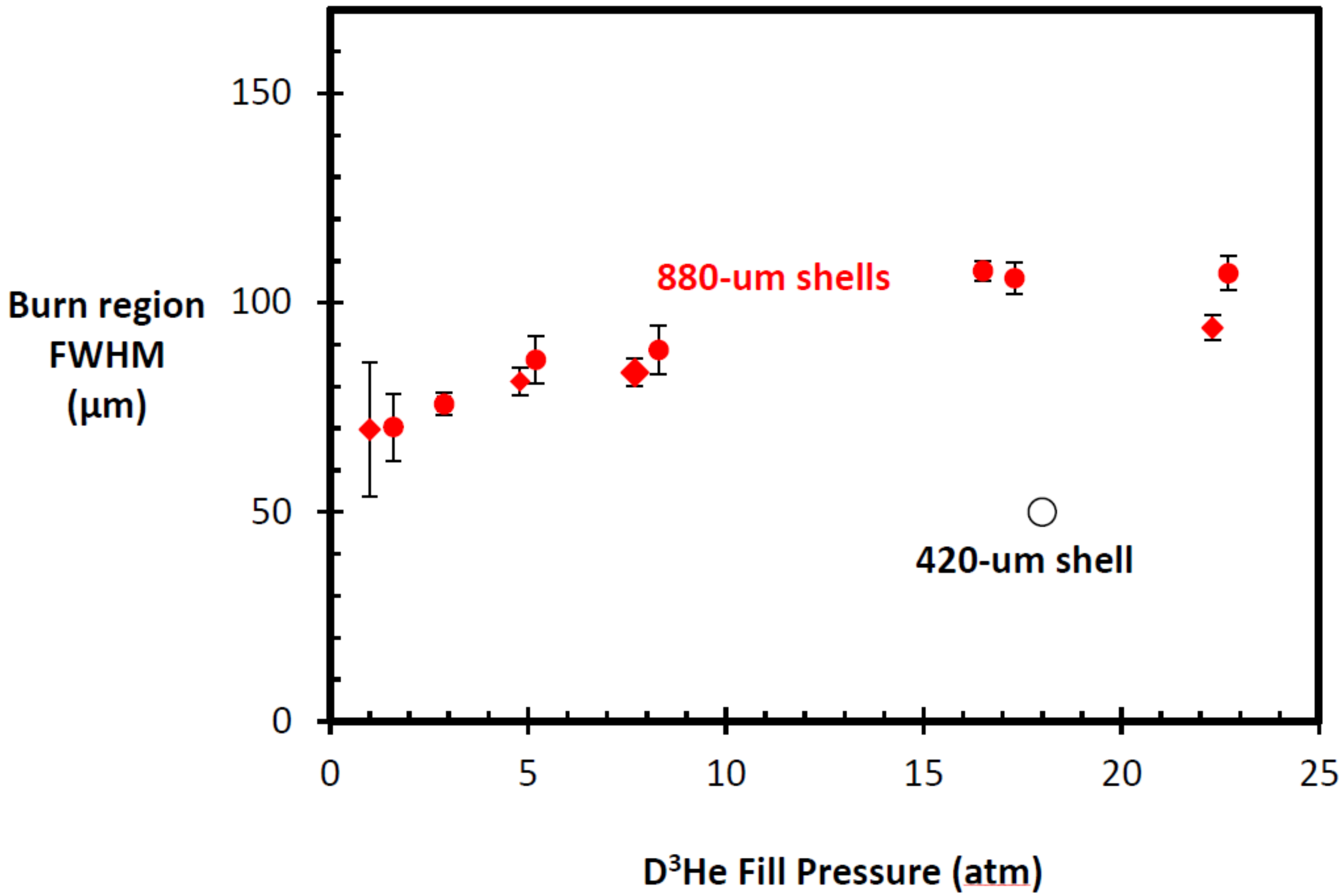
OMEGA experiments have provided critical information for developing a proton backlighter at the NIF





N. M. Hoffman *et al.* PoP (2015)
M. J. Rosenberg *et al*., PRL (2013)
K. Molvig *et al.* PRL (2012)

OMEGA experiments indicate that a smaller target resulted in a smaller burn region, providing higher spatial resolution



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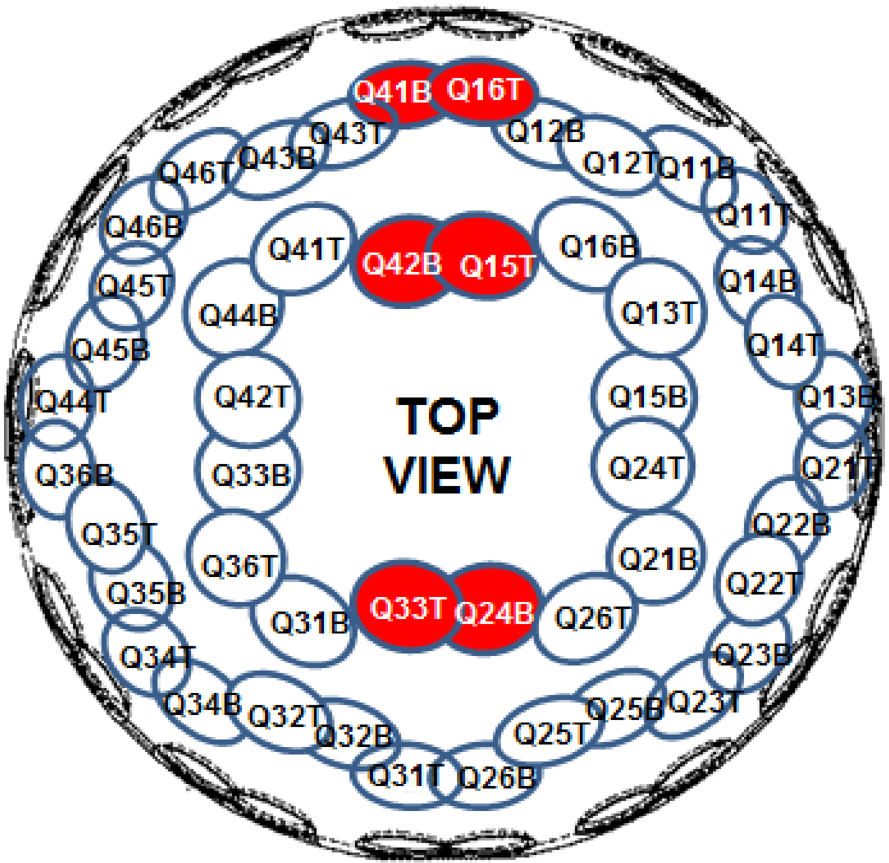
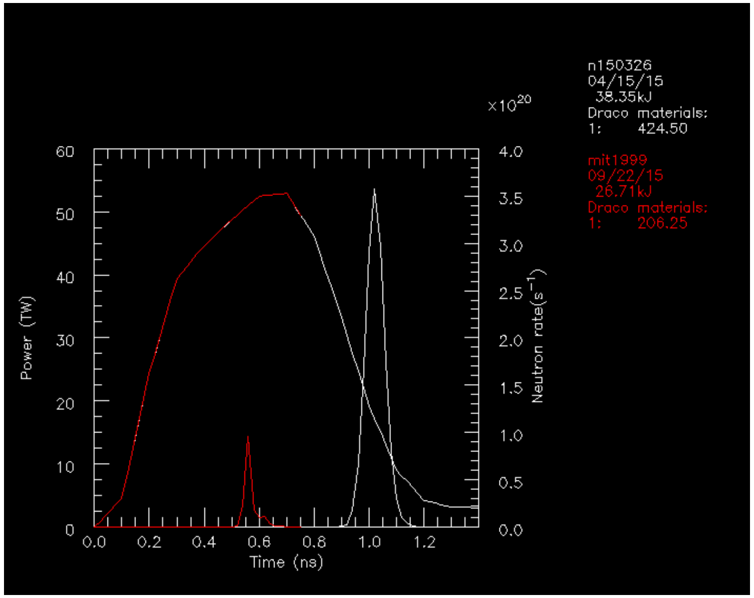
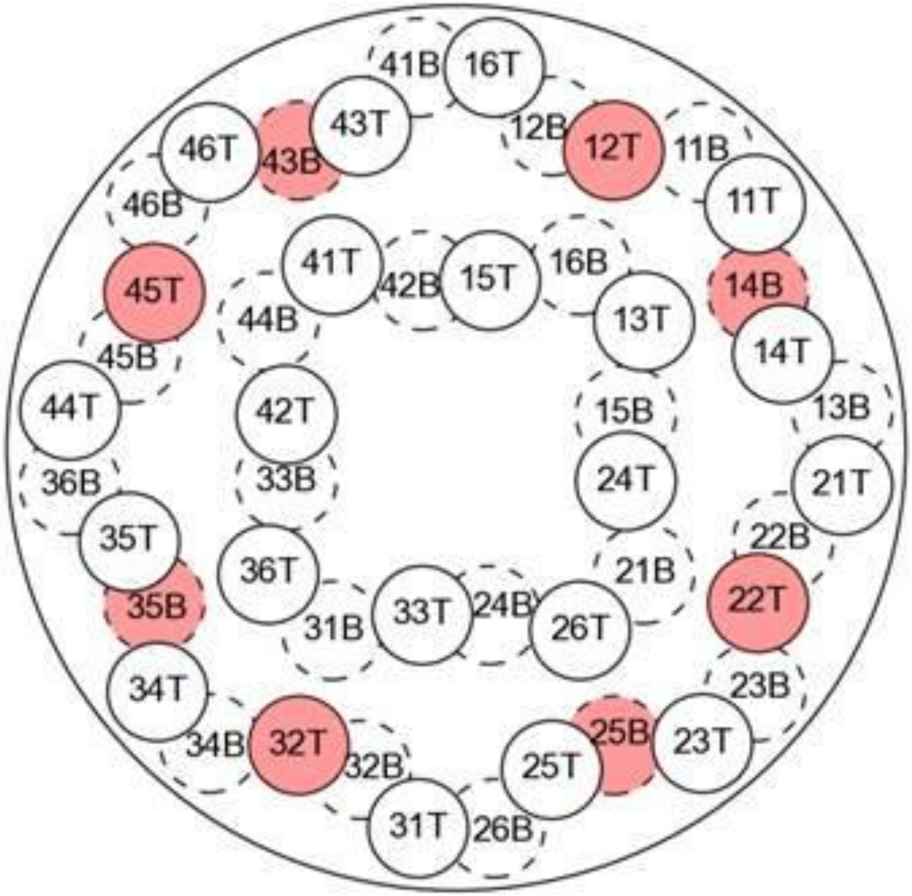
The first NIF Discovery Science shot will explore a higher spatial resolution backlighter with a smaller target





The second NIF Discovery Science shot will explore a backlighter implosion with phase plates



Systematic quantifying the NIF backlighter implosions will provide temporal, spatial and spectral radiography resolutions

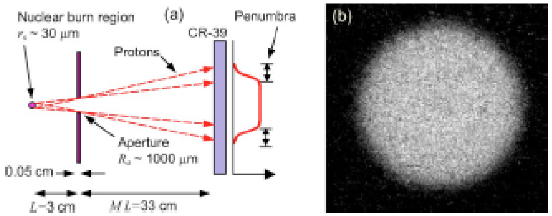
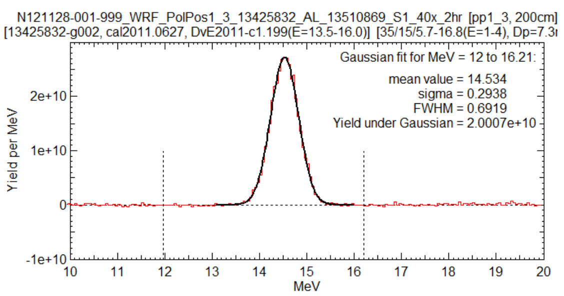
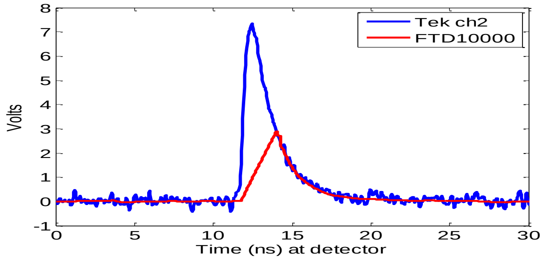


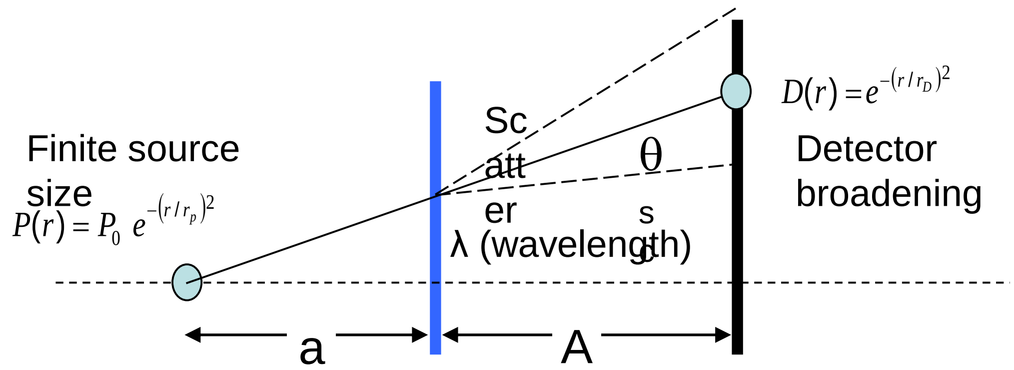
FIG. 2. (Color online) (a) Diagram showing the parameters of a penumbral imaging camera. (b) A sample penumbral image. Brightness is proportional to the number of protons per unit area on the detector.

WRF : Proton spectra using



Ptof : Proton BT





Three independent sources of smearing, scaled to object position:

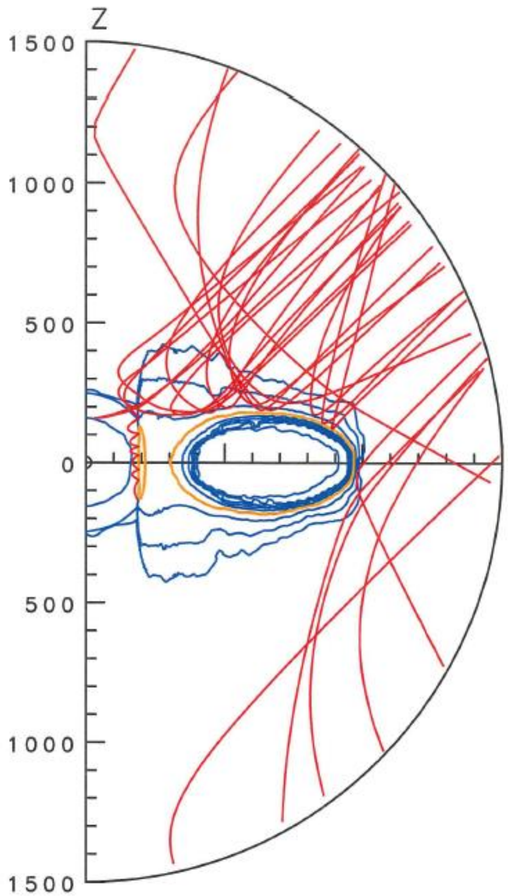
$$R_p = \frac{A}{a+A} r_s$$ **Finite source size**

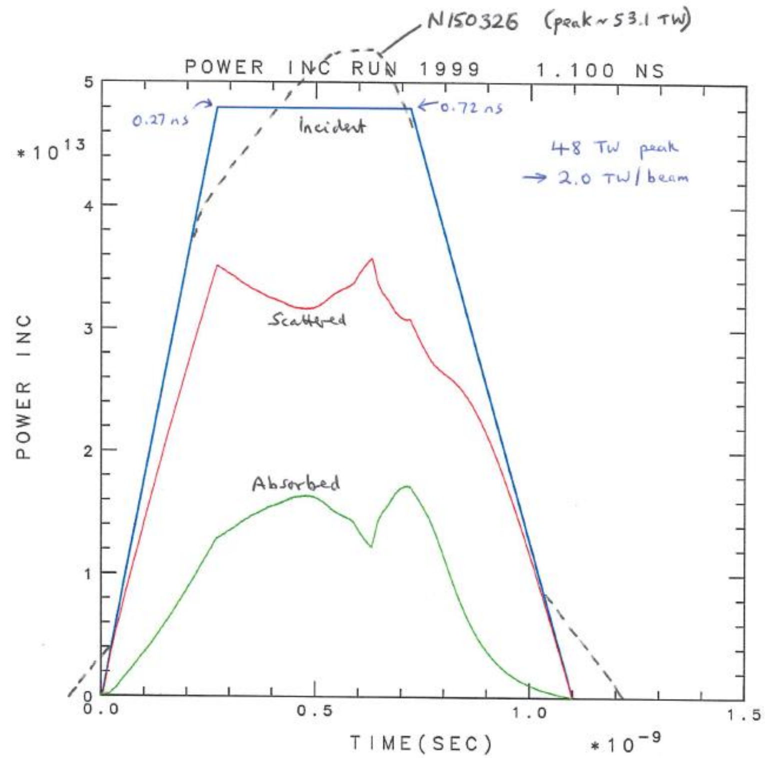
$$R_D = \frac{a}{a+A} r_D$$ **Broadening in detector**

$$R_{sc} = \frac{aA}{a+A} \theta_{sc}$$ **Scattering at subject**

$$R_{tot} = \sqrt{R_p^{\ 2} + R_D^{\ 2} + R_{sc}^{\ 2}}$$ **Total smearing radius at subject**

We will explore aspects important to an advanced proton radiography at the NIF





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