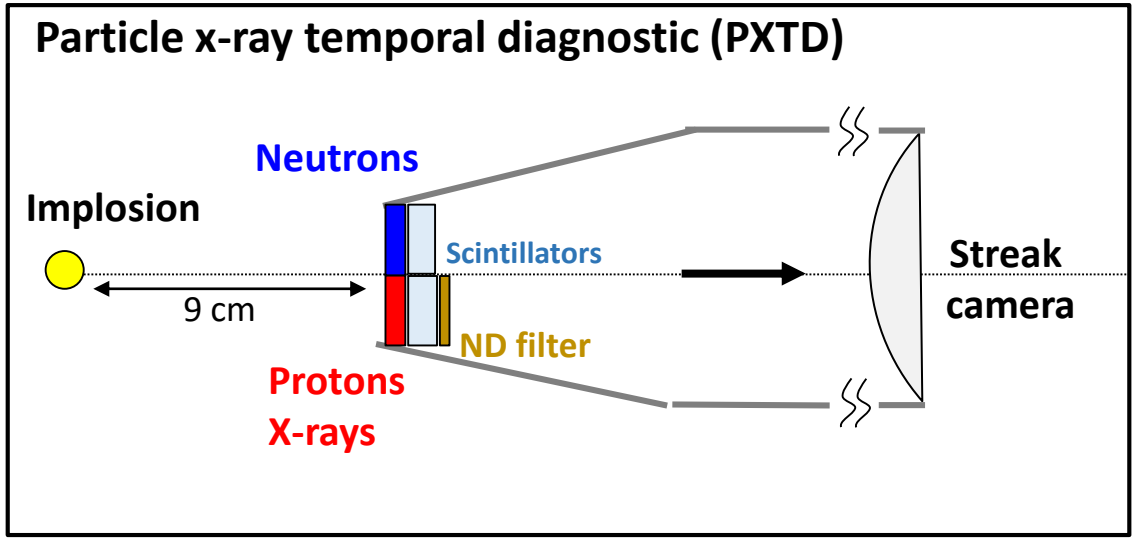
Kinetic, multi-ion effects, and i-e equilibration studies in ICF plasmas using multiple nuclear and xray emission histories



Timing precision now on the **same** diagnostic	
Xray	10 ps
D3He-p	10 - 15 ps
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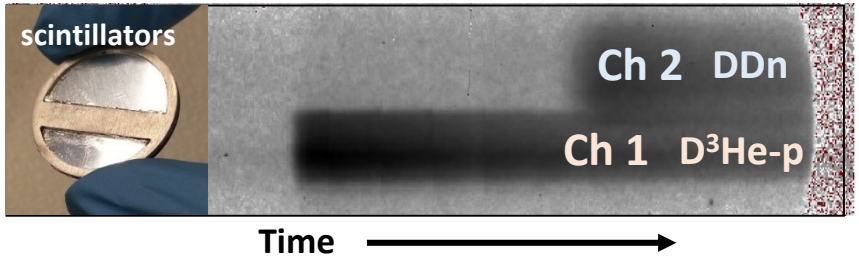
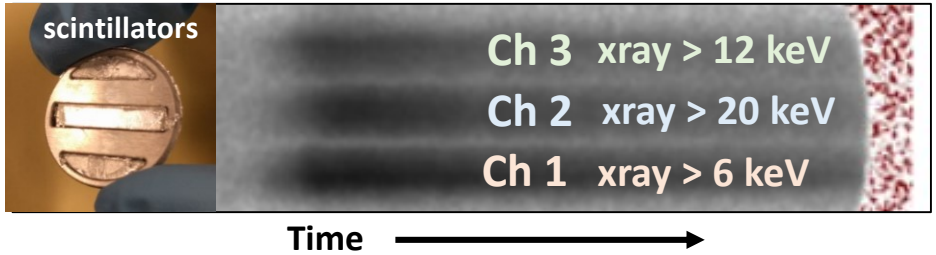
Shot 75694

Streak of D3He and DD neutrons



Shot 80705

Streak of X-rays at three different energies



Hong Sio, MIT
April 5th, 2016, Kinetic Workshop
Livermore, CA

Collaborators

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T. C. Sangster, V. Glebov, R. Betti, F. J. Marshall, W. Seka, …

Laboratory for Laser Energetics, University of Rochester

H. Rinderknecht, P. Amendt, S. Wilks, L. Berzak-Hopkins, …

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Los Alamos National Laboratory

S. Atzeni

Universita di Roma

R. Mancini

University of Nevada, Reno

Kinetic, multi-ion effects, and i-e equilibration studies in ICF plasmas using multiple nuclear and xray emission histories

- Goal of the Particle Xray Temporal Diagnostic (PXTD) is to simultaneously provide precision time-resolved data on several nuclear reactions, as well as core xray continuum (timing precision ± 10-20 ps)

- Simultaneously measured nuclear and xray emission histories - Ti(t) and Te(t) - enables study of i-e equilibration / Coulomb logarithm at various plasma conditions

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  - April 13th, 2016
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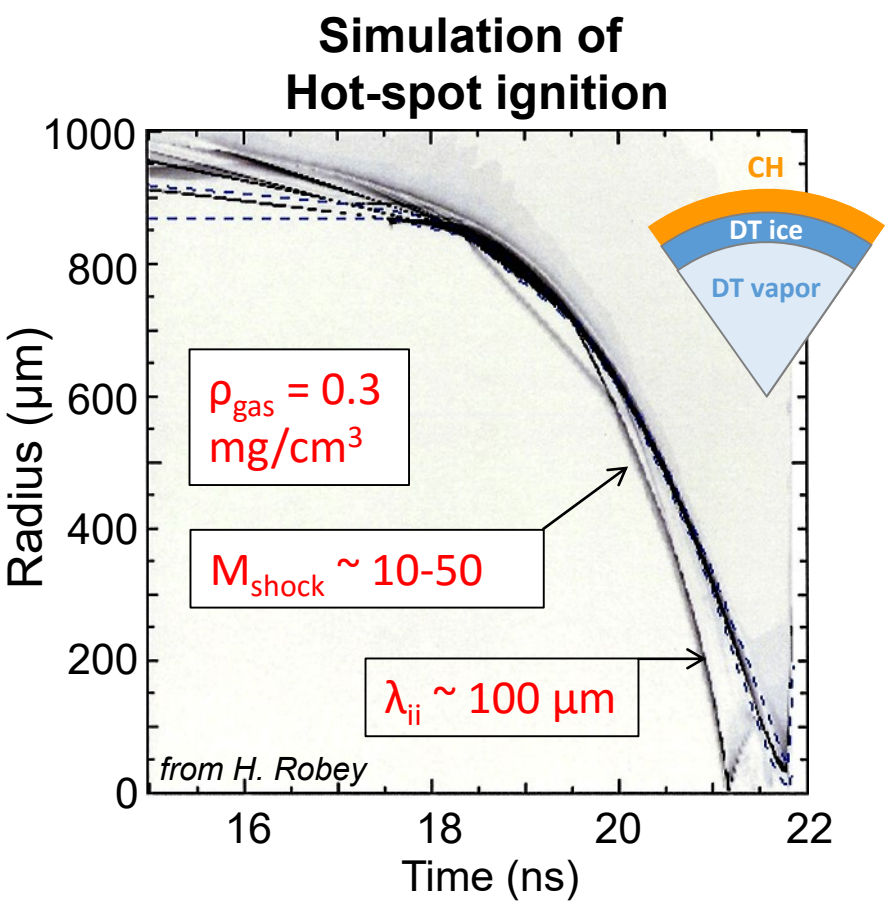
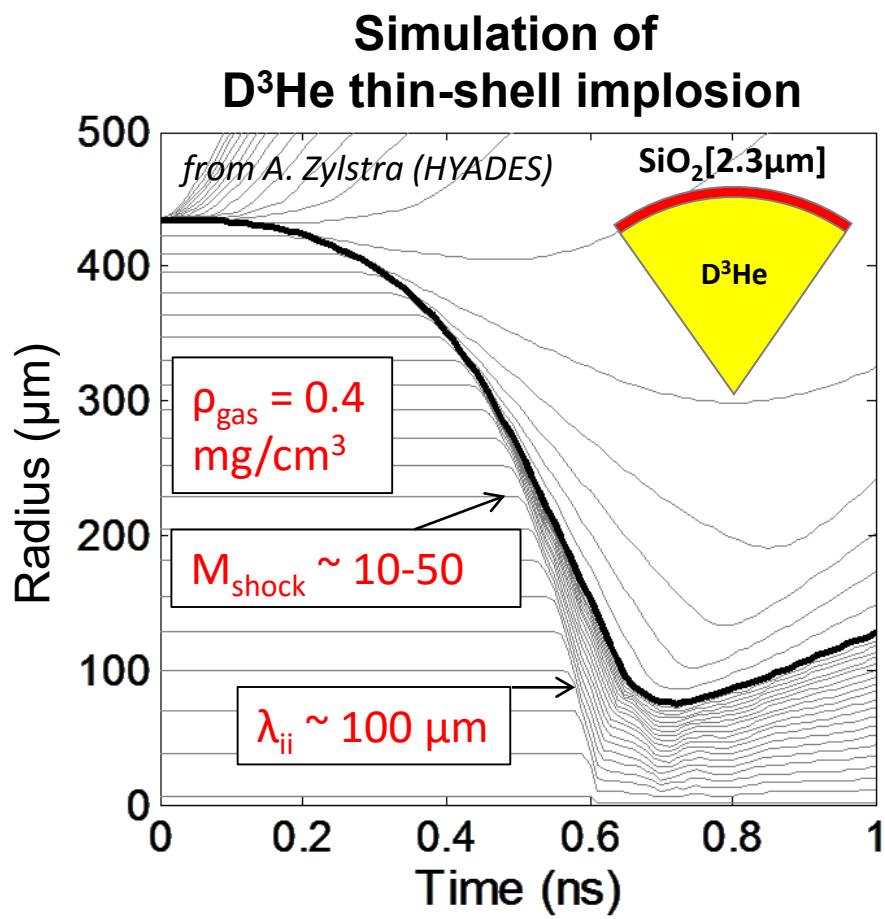
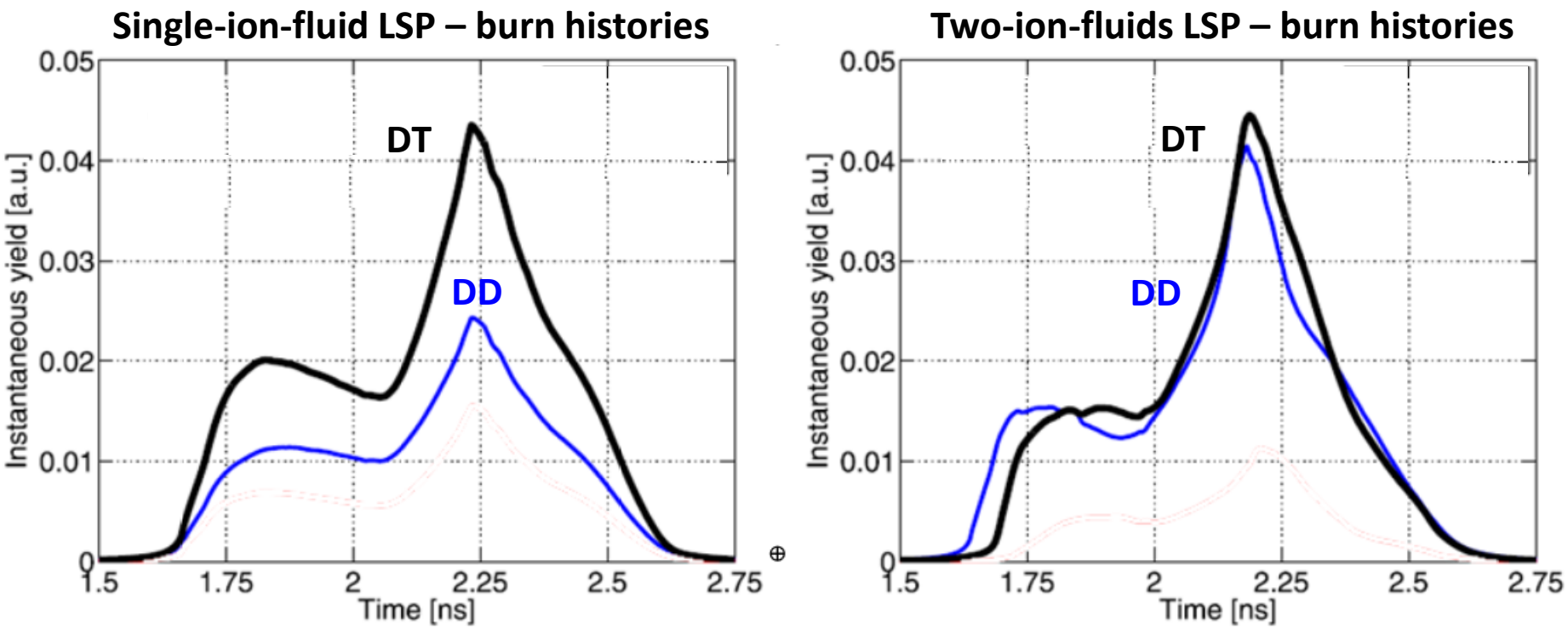
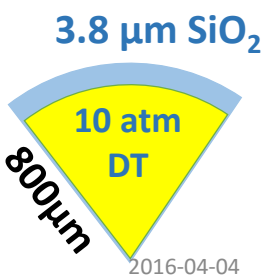
Kinetic conditions in shock-driven, thin-shell implosions are similar to the shock propagation phase of hot-spot ignition experiments





Different aspect of the burn histories (burn onset, bang-time, absolute rate) are being compared to different simulations to infer kinetic and multi-ion fluid effects





When comparing single-ion-fluid to multi-ion-fluid simulations, we observe:

~ 40% higher DD burn rate (relative to DT rate)

~ 50 ps earlier DD burn onset (relative to DT burn onset)

~ 30 ps earlier DD bang-time (relative to DT bang-time)

Bellei et al., PoP 2013

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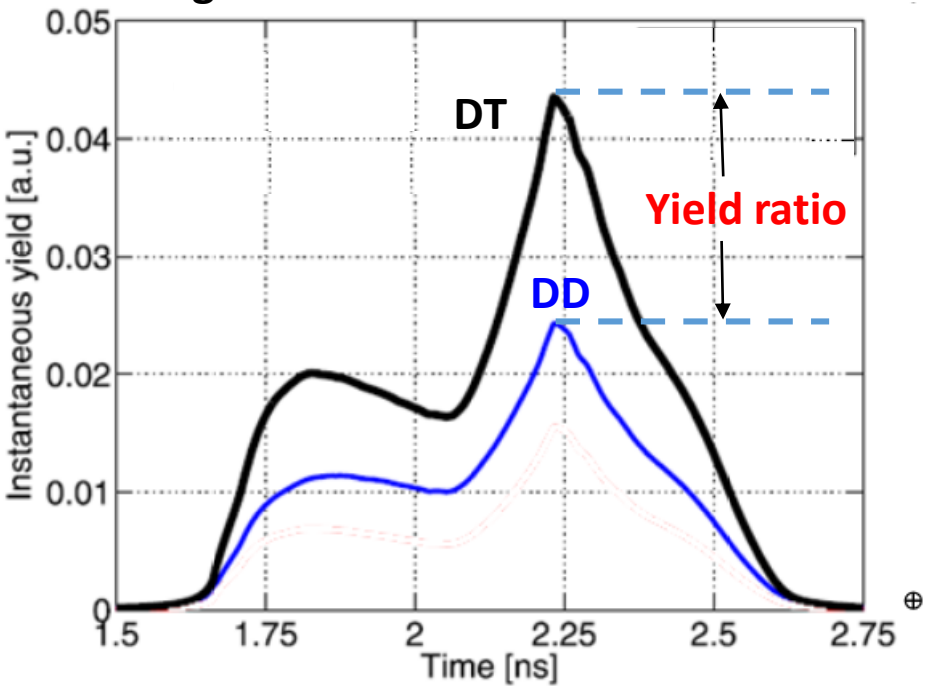
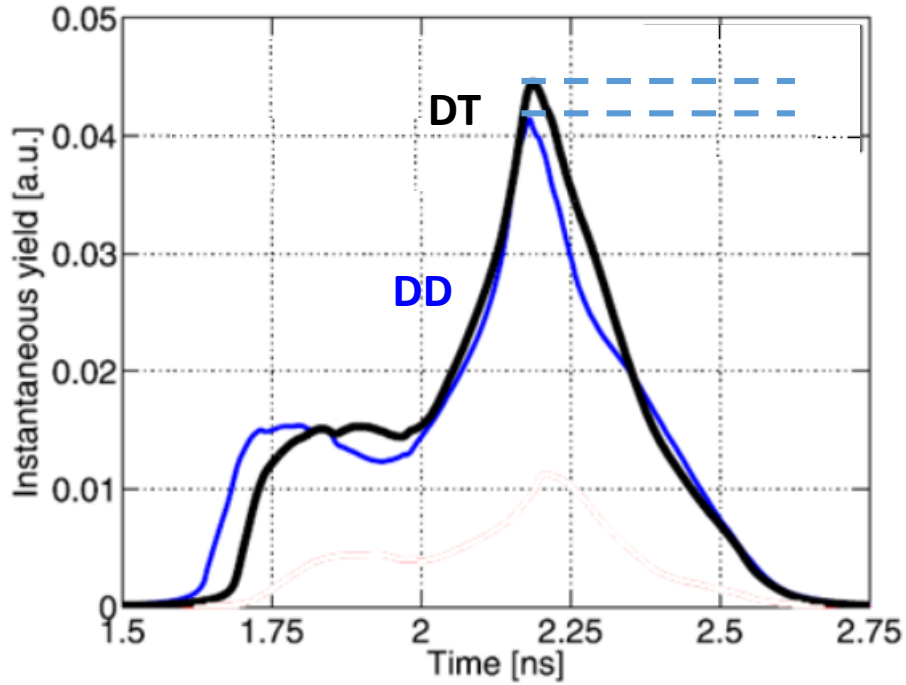
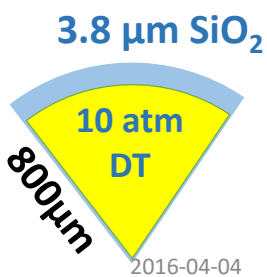
Single-ion-fluid LSP – burn histories



Two-ion-fluids LSP – burn histories





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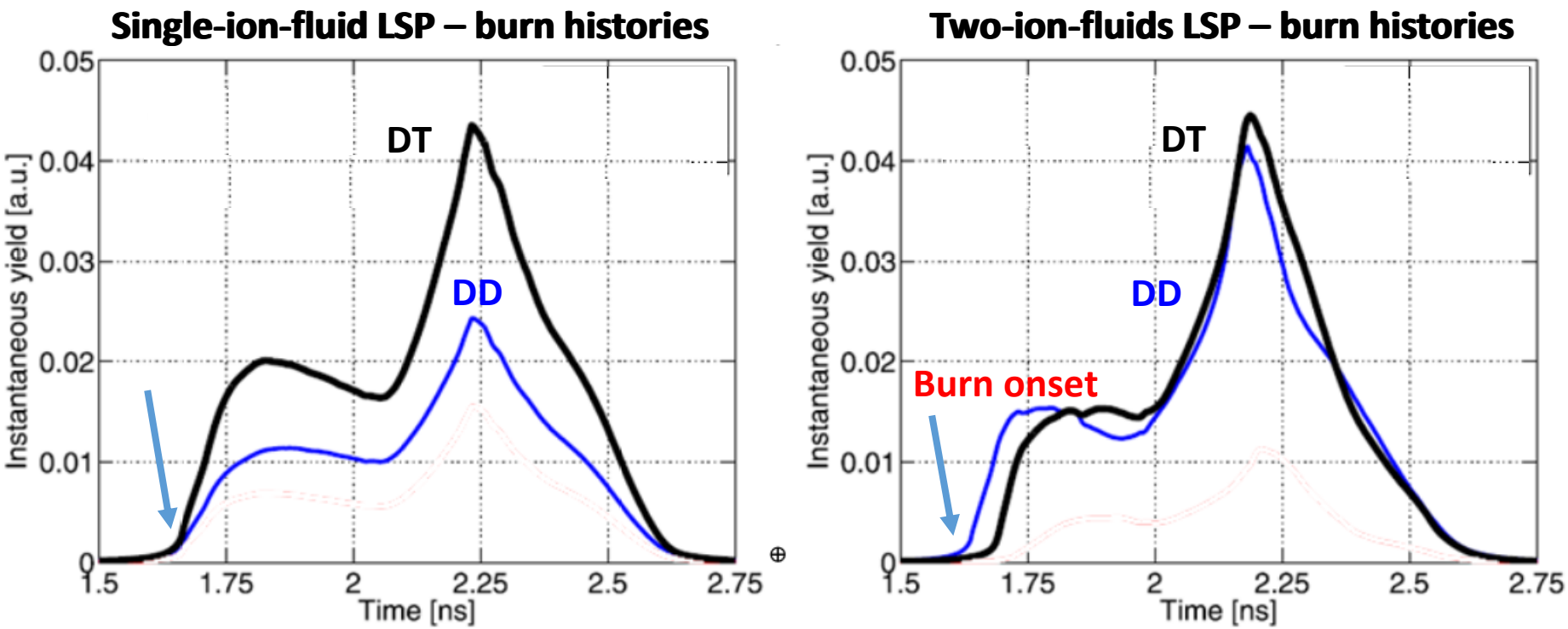

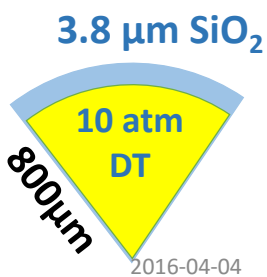

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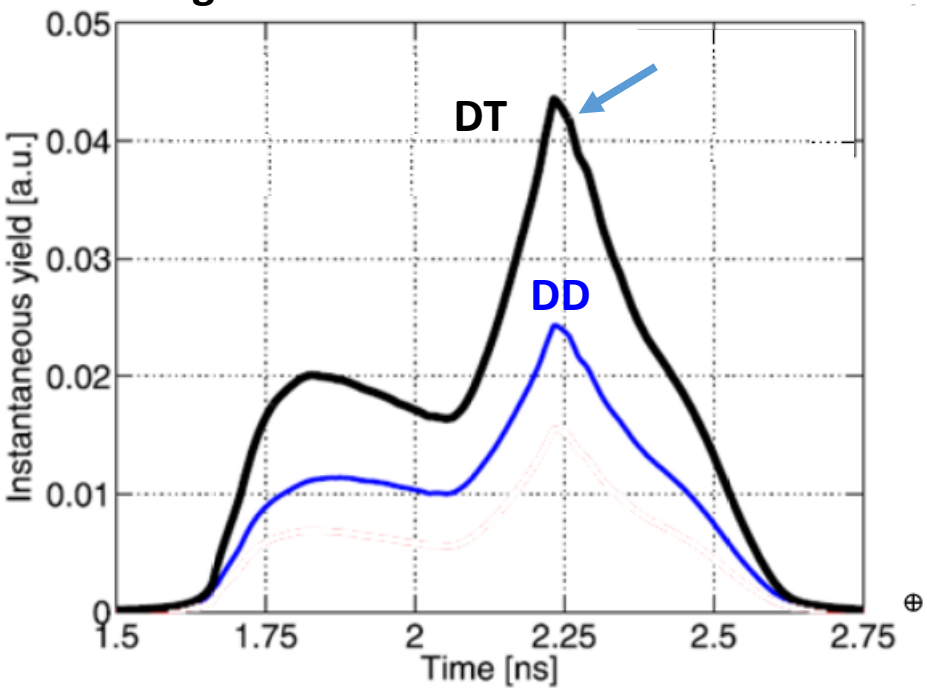
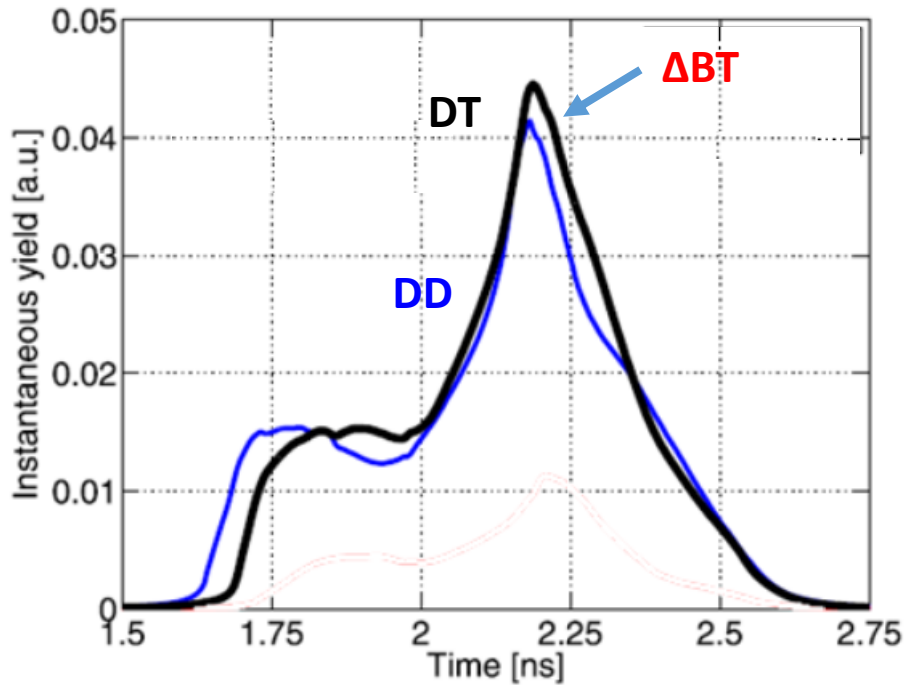
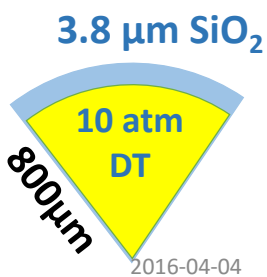


Two-ion-fluids LSP – burn histories





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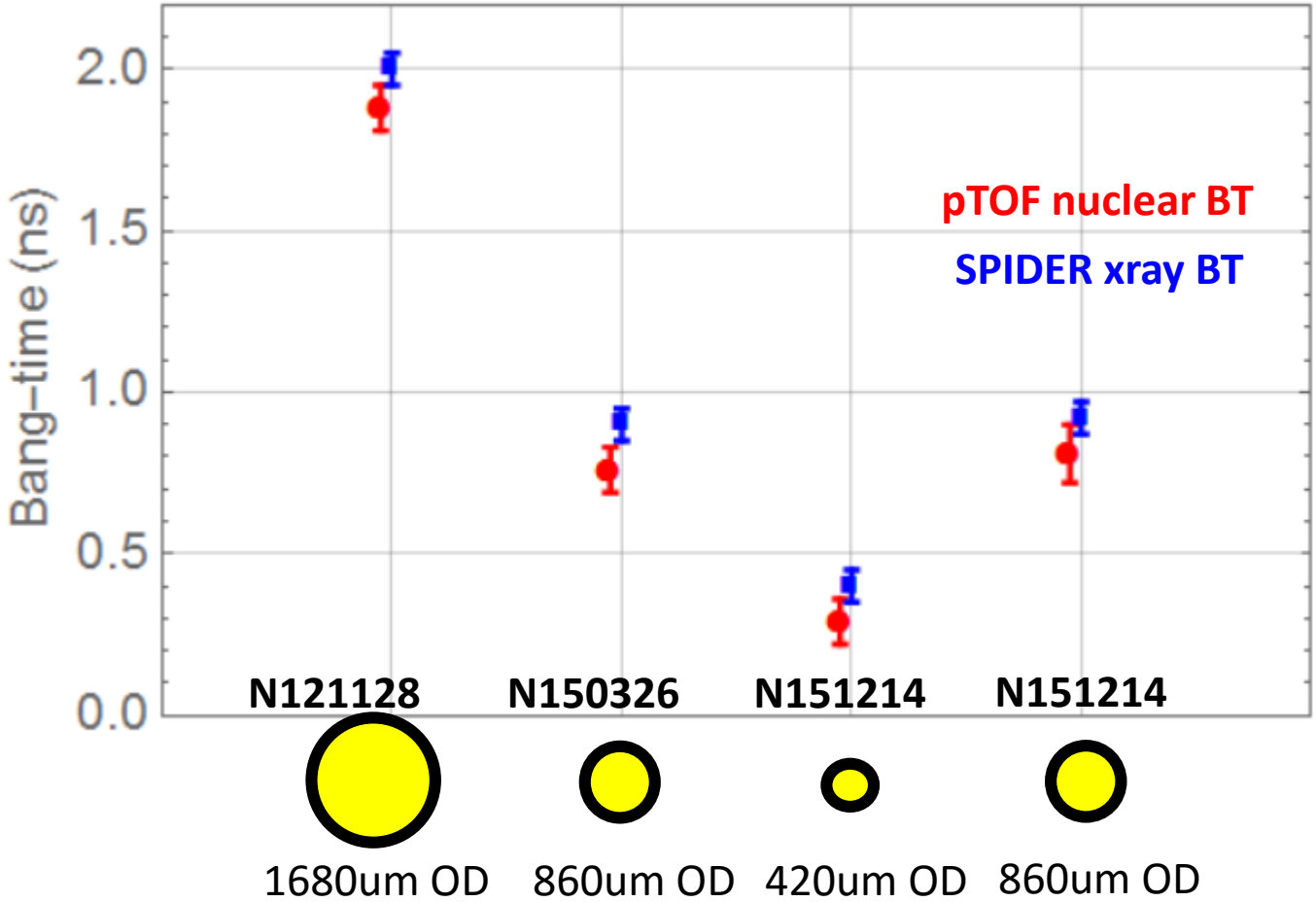
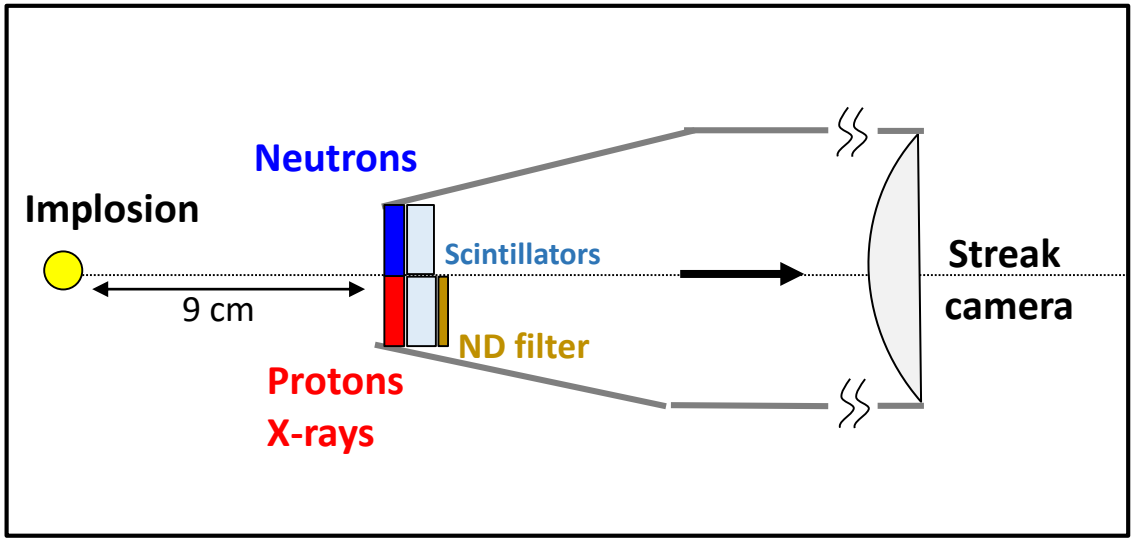
In NIF exploding pusher implosions, nuclear and xray bang times are measured with two different diagnostics to a precision of ~70ps



On OMEGA, we can make x-ray and nuclear bang-time measurements with much higher precision using PXTD (10-20 ps vs. ~ 70 ps)

The new PXTD will simultaneously provide precision time-resolved data on several nuclear reactions, as well as core x-ray continuum



Timing precision on the same diagnostic	
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D3He-p	10 - 15 ps
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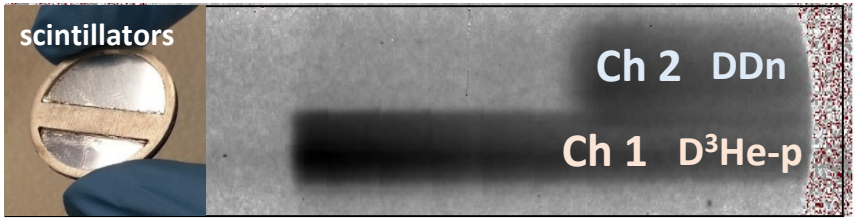
Shot 75694

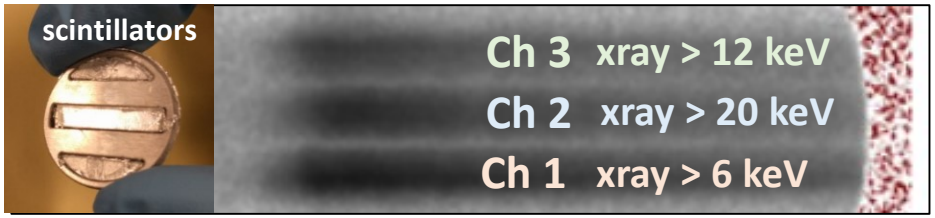
Streak of D3He and DD neutrons



Time →

Shot 80705

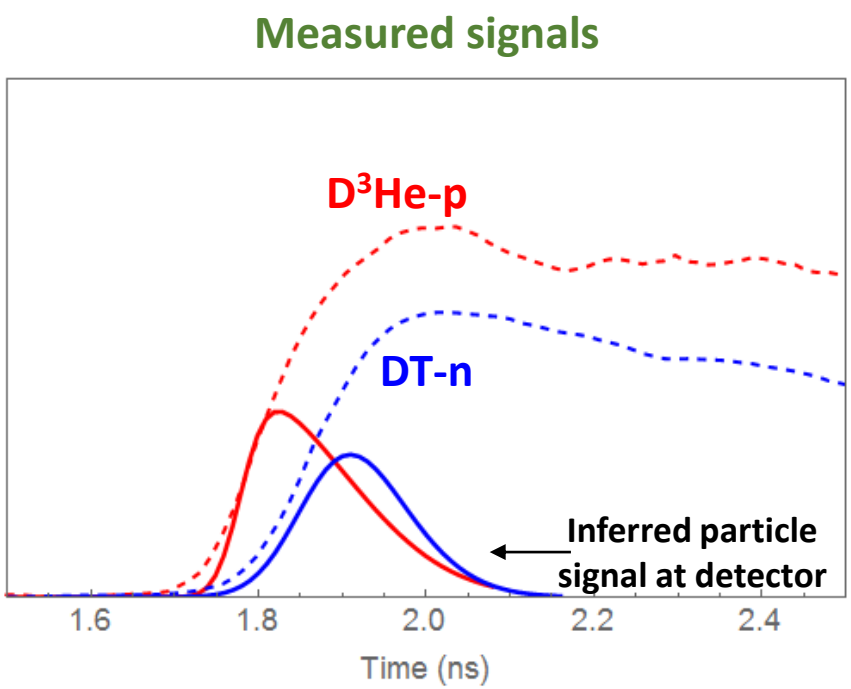
Streak of X-rays at three different energies

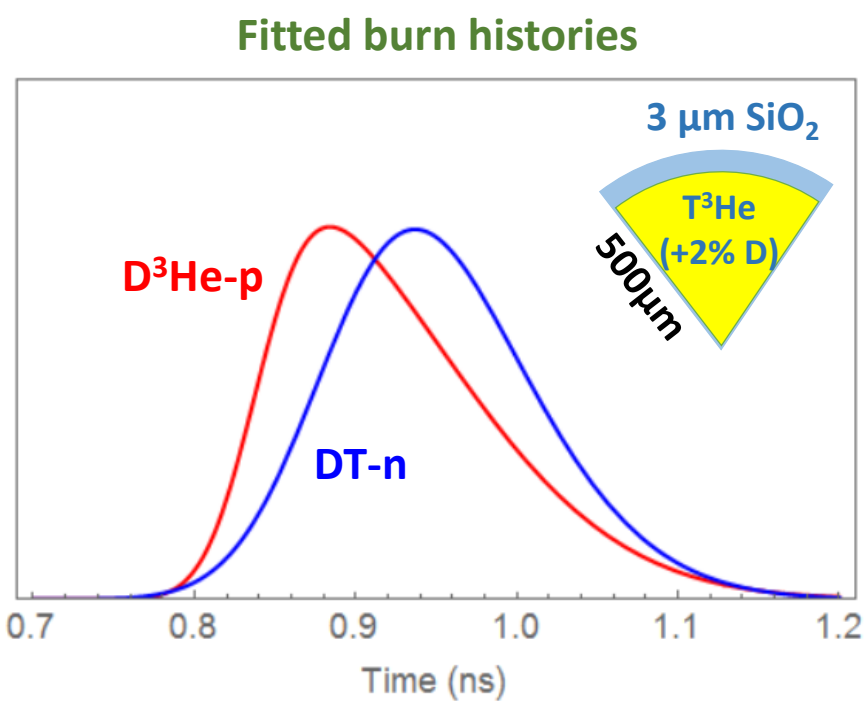


Time →

Stoeckl *et al.*, RSI 2003
Sio *et al.*, RSI 2016 (in progress)

The burn histories is recovered from the leading edge of the streak signal using a deconvolution or forward fit approach

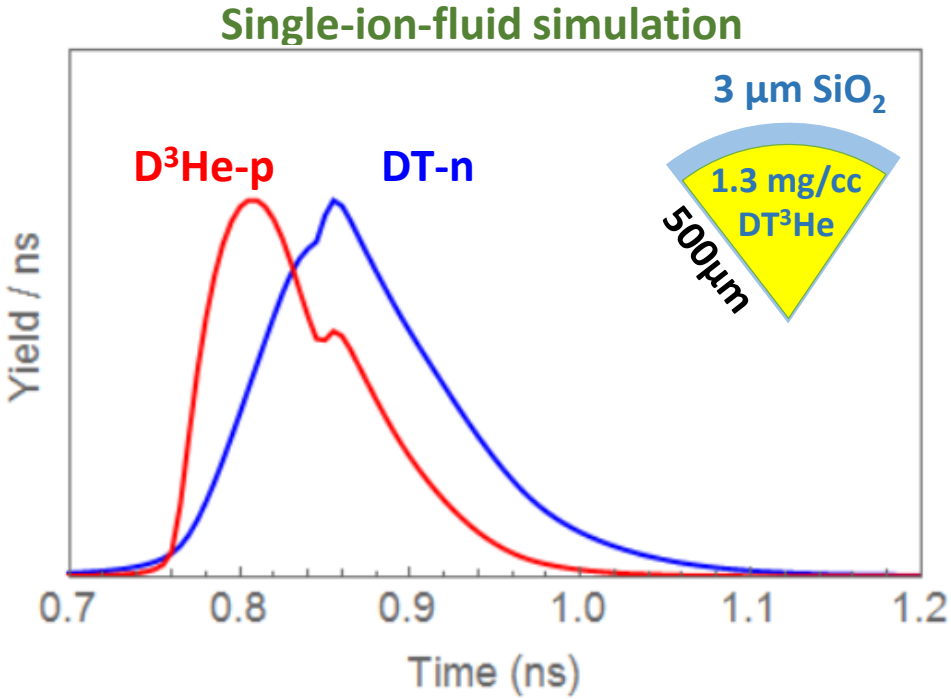


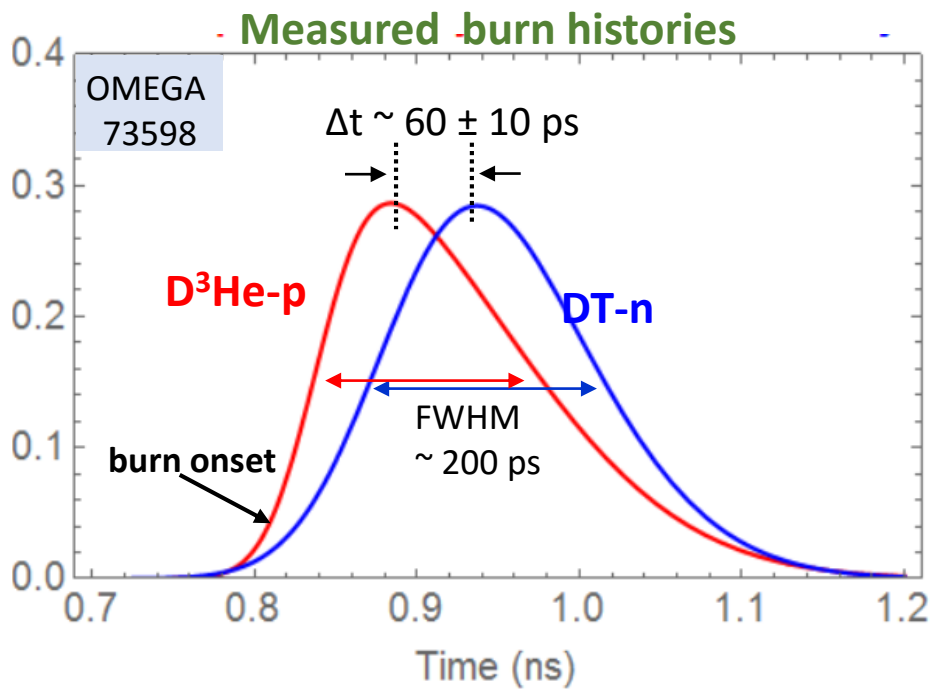


$D + {}^3He \rightarrow {}^4He$ (3.6 MeV) + **p (14.7 MeV)**

$D + T \rightarrow {}^4He$ (3.5 MeV) + **n (14.1 MeV)**

Different aspects of the burn histories (bang-time, width, onset) can be quantitatively compared with different simulations



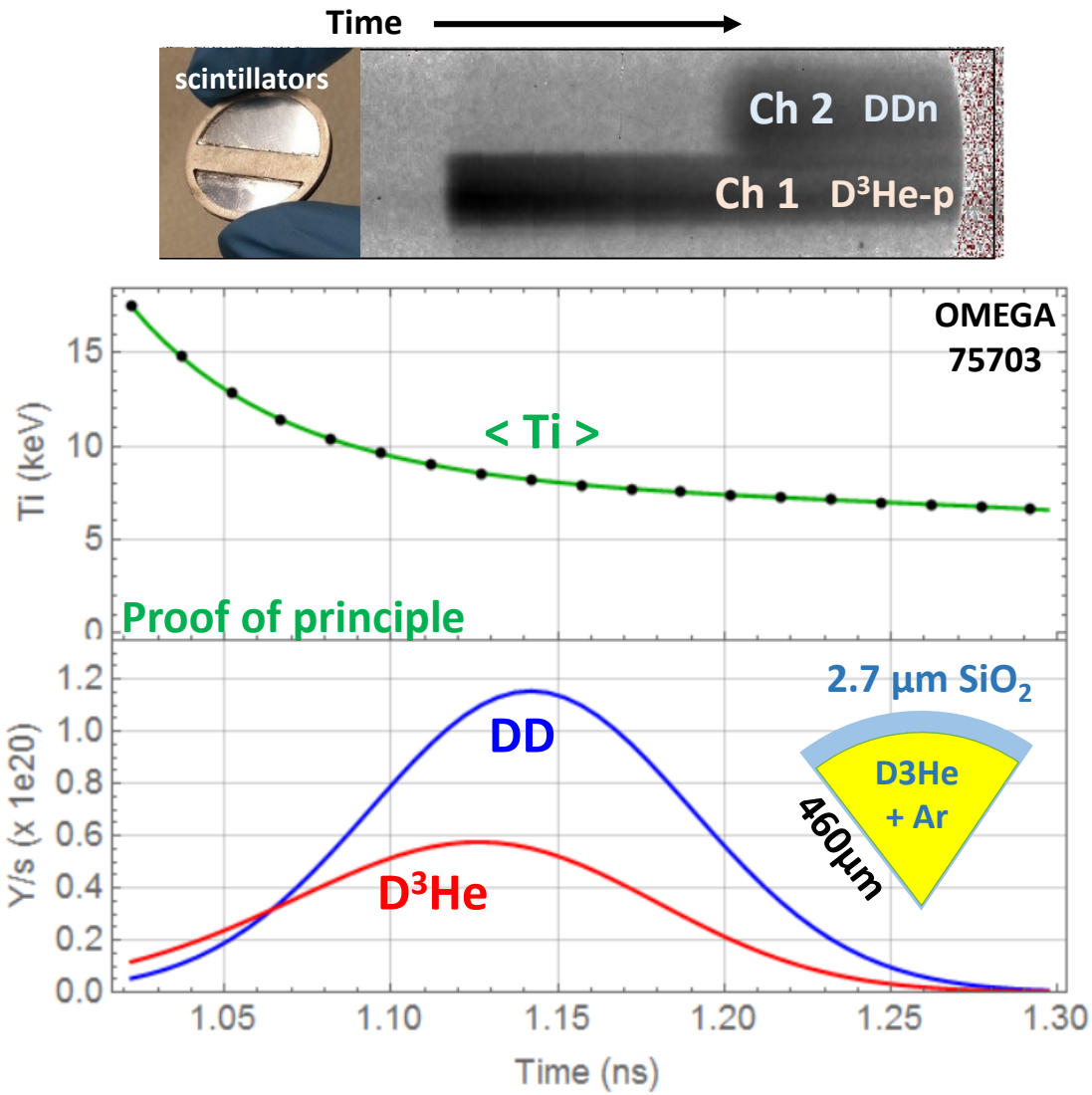


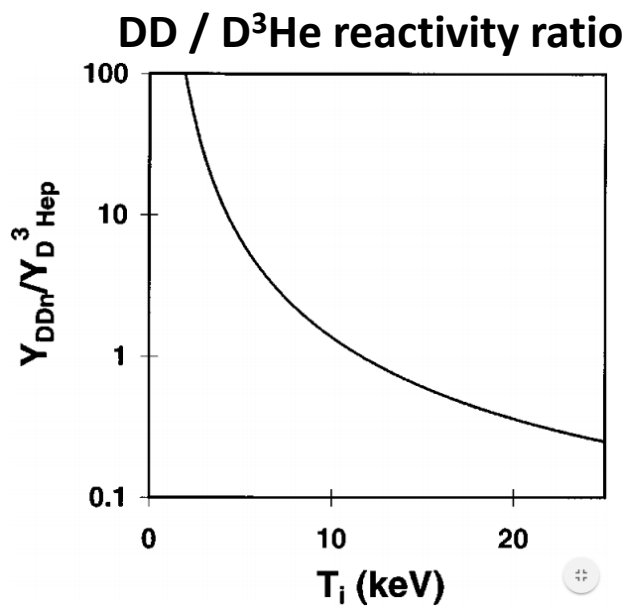
When comparing burn histories measurements to single-ion-fluid , we observe:

- D^3He burn onset and bang-time are earlier relative to DT, in good agreement with simulation. Longer burn duration (~ 150 ps) than simulation (~ 120 ps)

- For this relatively hydrodynamic-like implosion (1.3 mg/cc), maybe we do expect fairly good agreement between measurements and single-fluid simulation

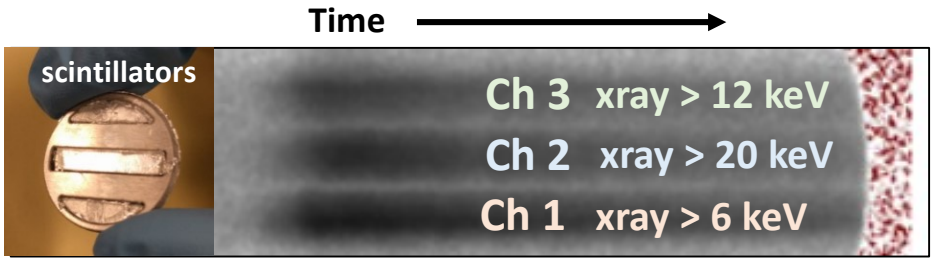
To understand i-e equilibration rate, we need to determine < Ti (t) > from the temperature-dependent ratio of two nuclear reaction histories

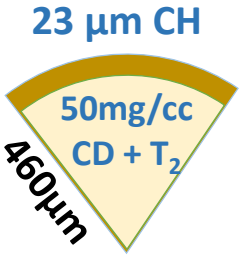


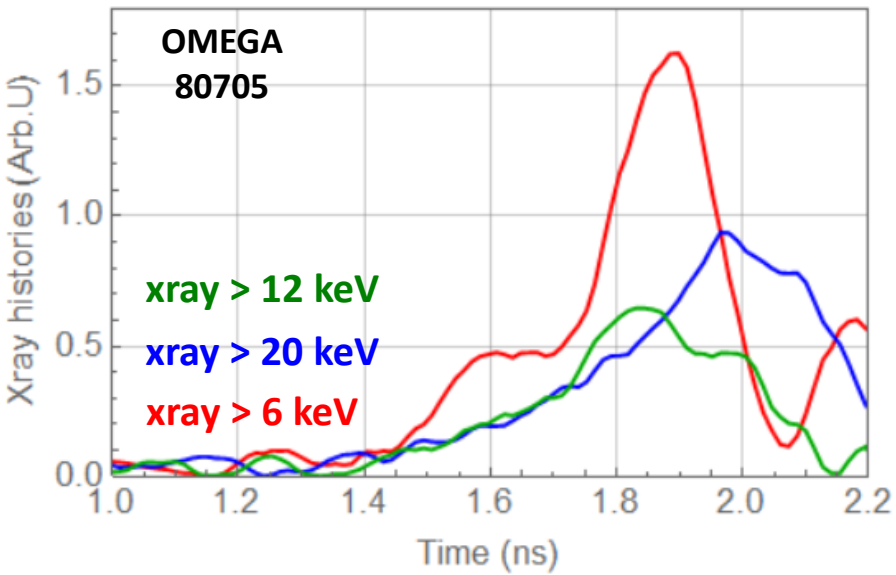


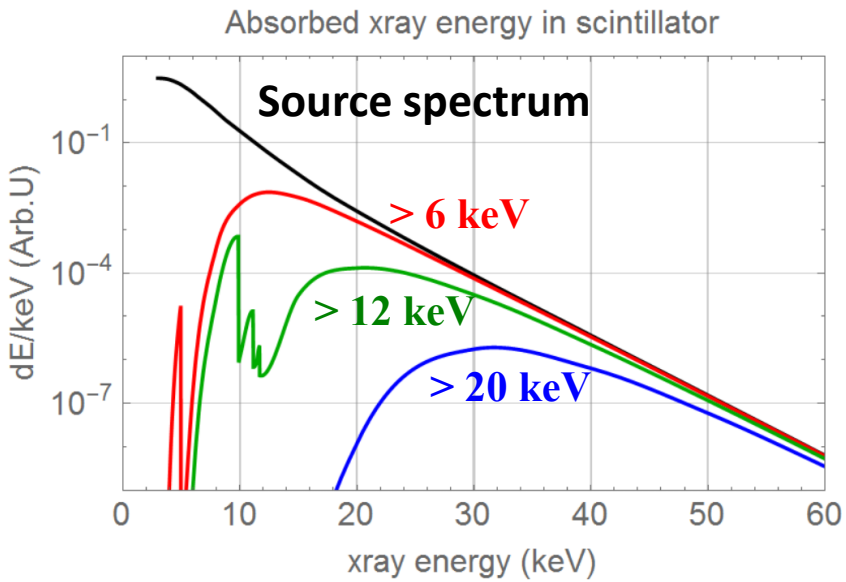
Making both burn history measurements on a single diagnostic eliminates cross-timing issue

To understand i-e equilibration rate, we need to determine < Te(t) > from the slope of the core xray continuum



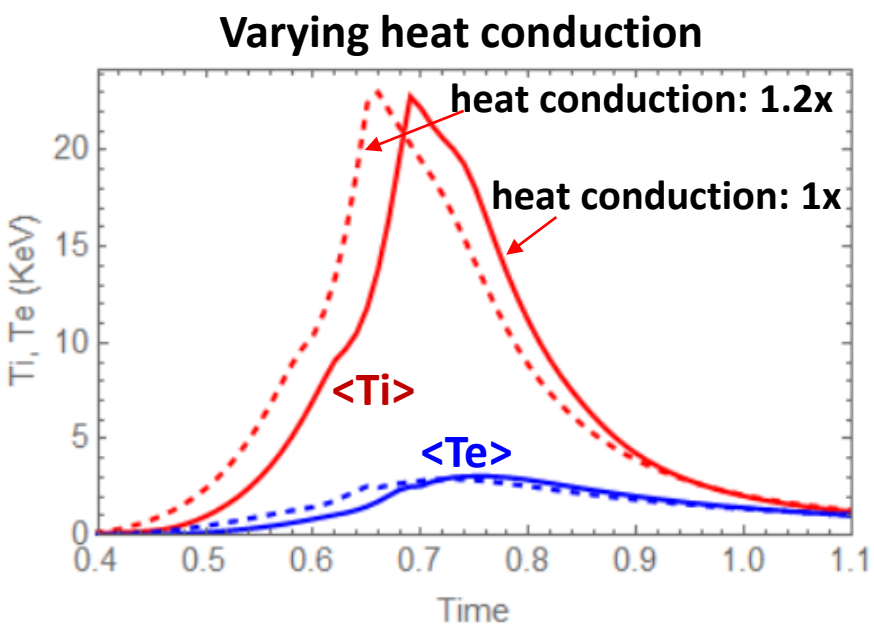


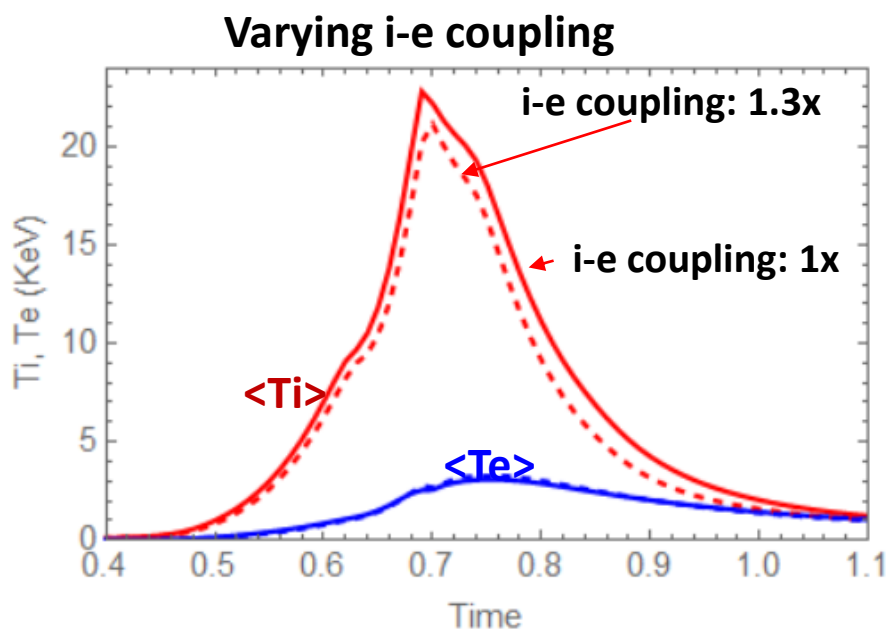




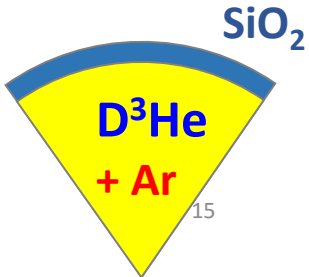
A similar approach is being used on the NIF

Shock-driven exploding pusher is a promising system to study ion-electron equilibration because shock passage primarily heats the ions





To make the best measurements the plasma temperature should be sensitive to i-e coupling, and other energy-transfer mechanisms (i.e. thermal conduction) need be well-understood



The OMEGA experiment next week will focus on measuring both nuclear and xray emission histories in kinetic and more hydrodynamic-like ICF implosions

14.6 kJ/0.6 ns

	860 µm OD SiO2, 2.3um	860 µm OD SiO2, 2.3um
Fuel Pressure	**5 atm D3He**	**15 atm D3He**
Ion-ion MFP	**~ 150 µm**	**~ 40 µm**
λ_{ii} / R_{BT}	**~ 1**	**~ 0.3**
	More kinetic	**More hydro**

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OMEGA experiments in August will use trace tritium to measure both D^3He and DT reaction histories, in addition to xray emission histories

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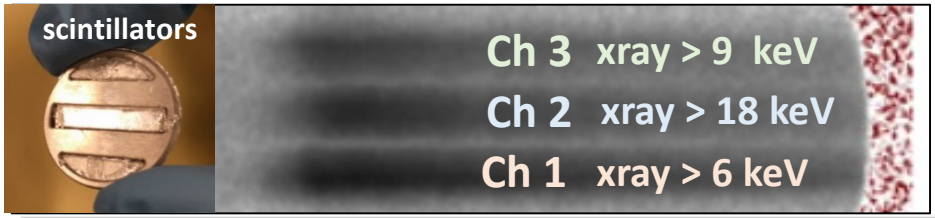
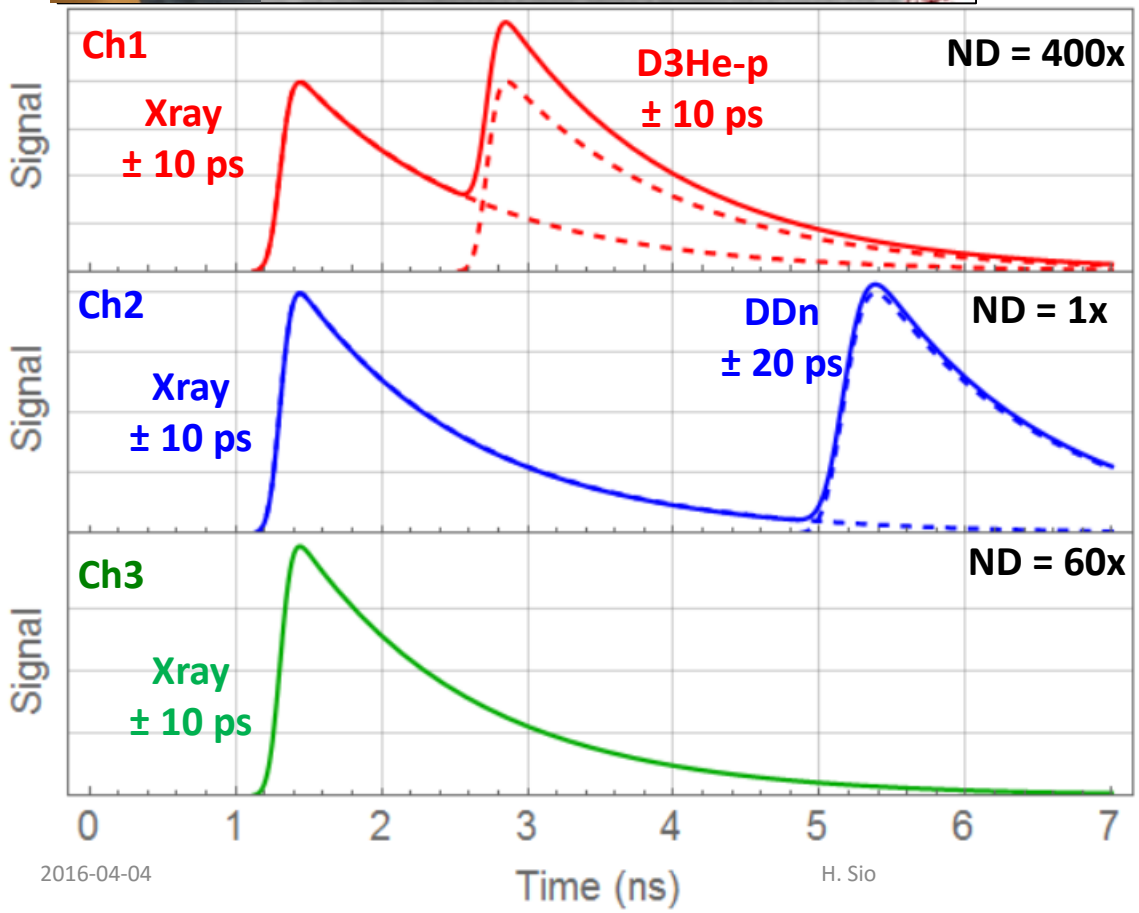


EXPECTED x-ray and nuclear streak signals



180um Al + 50um Ti
(xray > 6 keV)

180um Al + 600um SS
(xray > 18 keV)

1500um Al
(xray > 9 keV)

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