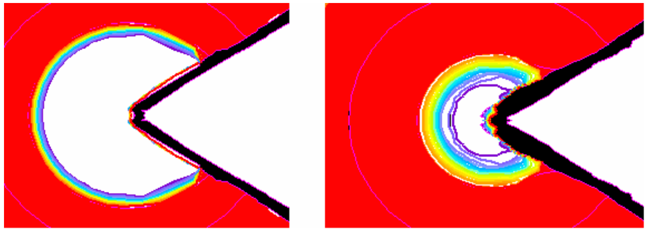
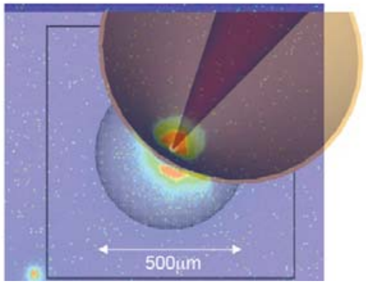
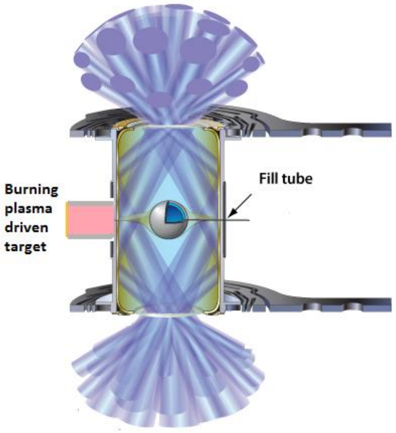
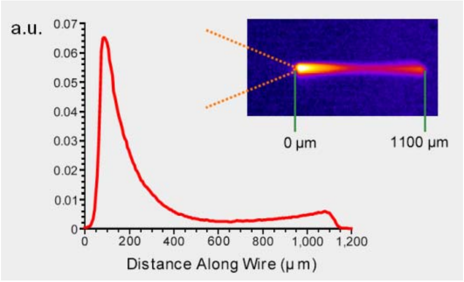




ICF Research at York
Looking beyond ignition at the NIF

John Pasley





York academic staff

Plasma Physics and Fusion Group

Geoff Pert (EUV Lasers)

Greg Tallents (EUV lasers, opacity)

Howard Wilson (plasma instabilities NTMs, ELMs and transport)

Kieran Gibson (Thompson scatter, spacecraft protection)

Nigel Woolsey (laboratory Astro, fast Ignitor …)

Ben Dudson (simulation of ELMs)

John Pasley (ICF and related)

Roddy Vann (magnetic diagnostics, Vlasov codes)

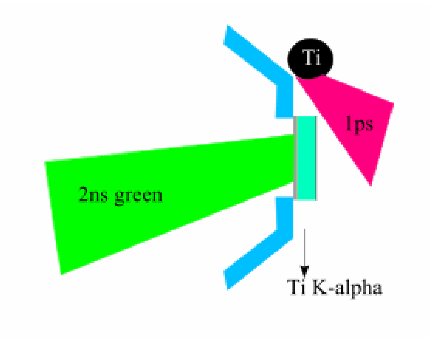
Post-docs and students

- Post-docs Il’dar Al’miev (collisional radiative calcs), Nicola Booth (HiPER), Hongpeng Qu (NTMs), Erik Wagenaars (opacity experiments), David Whittaker (opacity calculations).
- 17 PhD students.

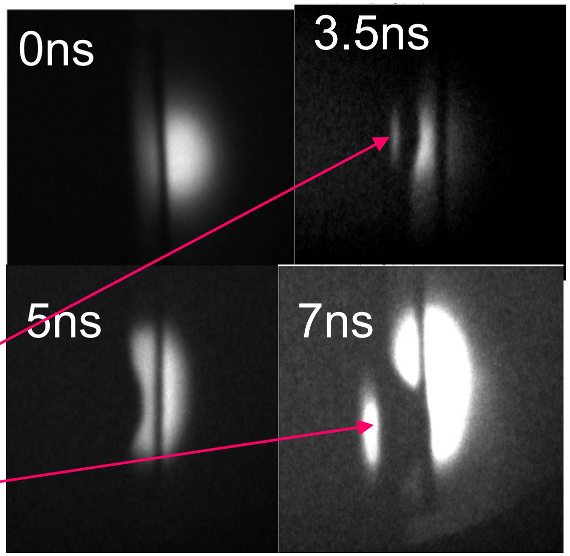
ICF related work at York

- Laser to energetic electron coupling + electron transport and heating studies relevant to FI
- Burning plasma related projects
- Studies of plasma opacity - using plasma-based EUV lasers and FELs
- IFE reactor vessel physics tie-in with MCF work
- Small local laser laboratory (0.5 J, 170 ps) set-up for diagnostics testing, training and experiments

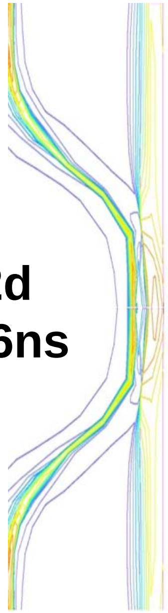
Transport studies in compressed/ heated matter for FI applications



Side-on Ti k-α radiography



Bremsstrahlung from long pulse interaction.

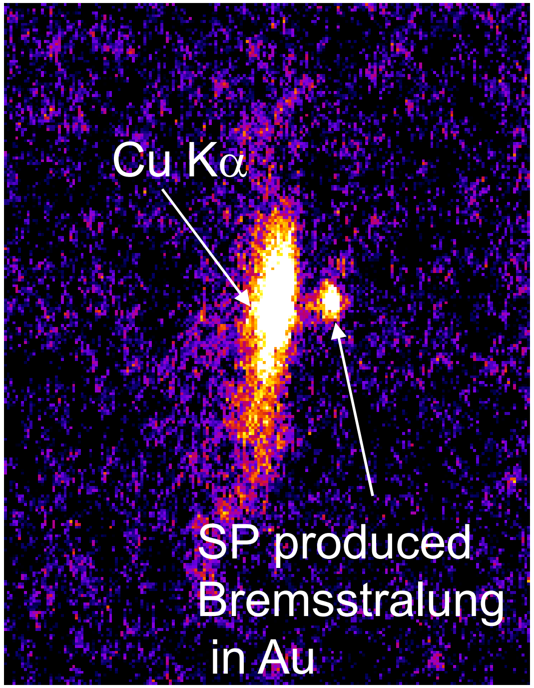


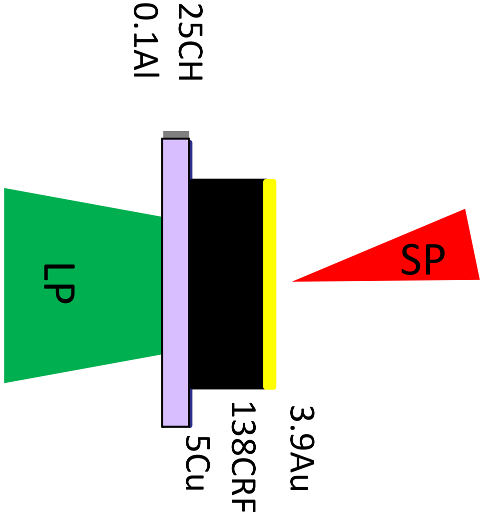
h2d 5.6ns

Titan 2006 WDM formation experiment

S. Le-Pape et al, *RSI, 2008*

Ongoing collaboration between LLNL/ UCSD/ OSU/ GA (and now York!)

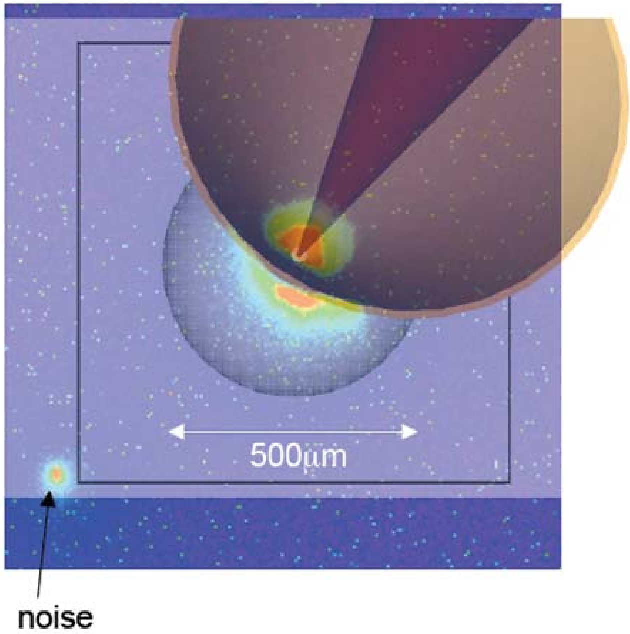




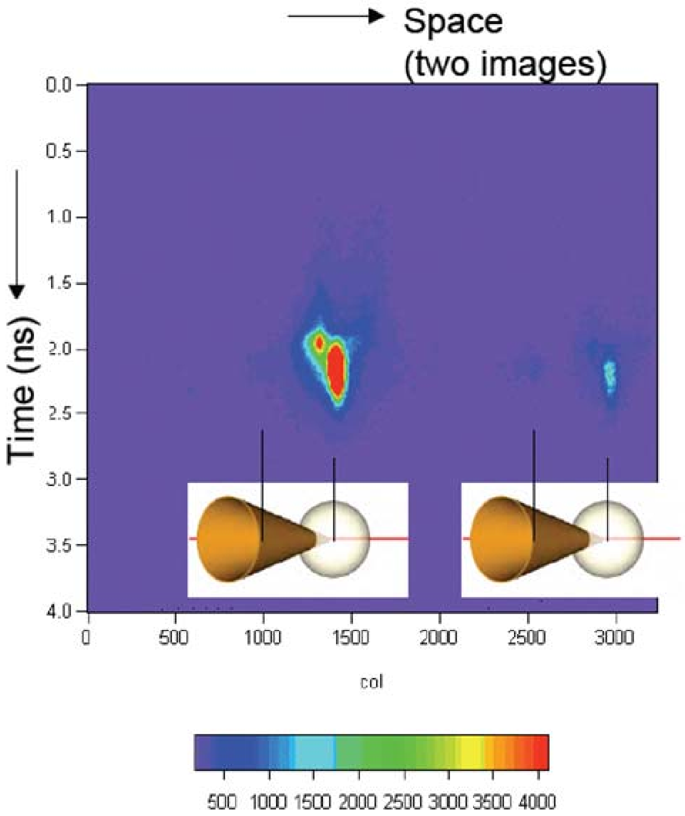
New data from July 2009 Titan WDM transport experiment
(led by M.S. Wei)

Ongoing collaboration between LLNL/ UCSD/ OSU/ GA (and now York!)

X-ray pinhole camera observing from the cone side (time integrated)



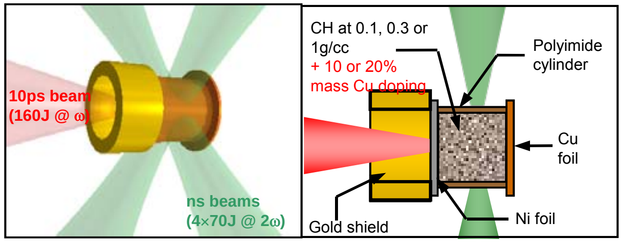
X-ray streak camera (time resolved)

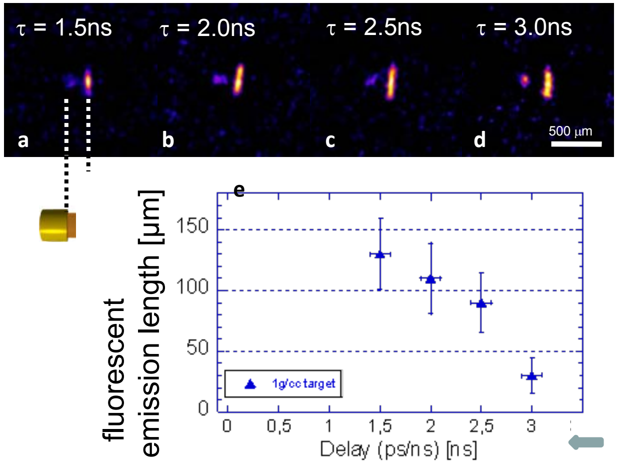


ILE Osaka/ RAL/ LLNL/York "Nature repeat" experiment using LFEX as heater beam

Sept/Oct 2009

HiPER WP 10 Experiment, RAL TAW



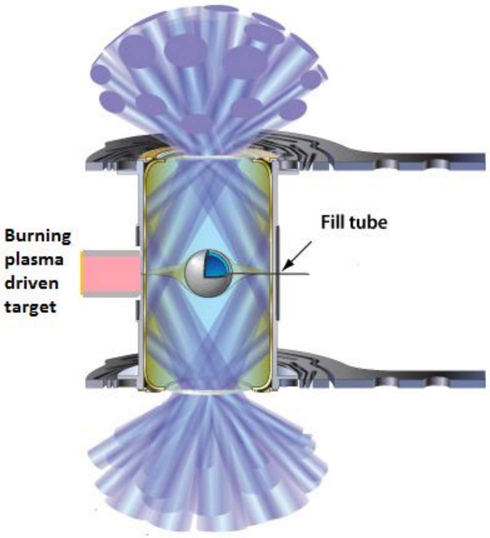


LP to SP delay

Performed by the HiPER collaboration (inc. York)

Experiment Nov/ Dec 2008

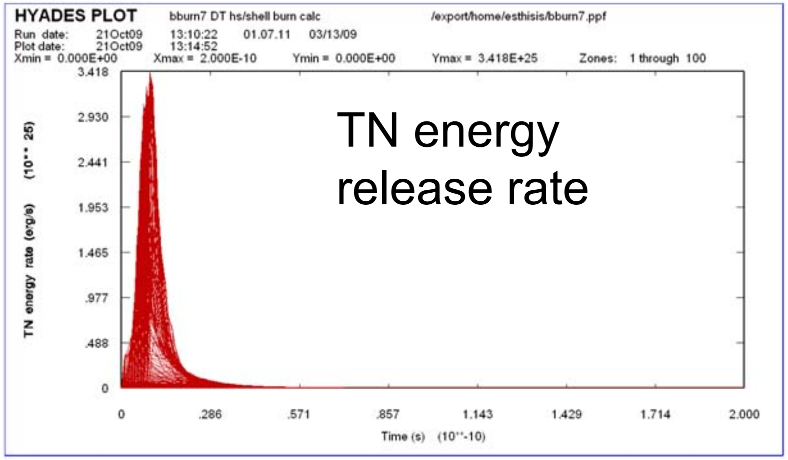
Exploring possible burning plasma driven experiments for NIF



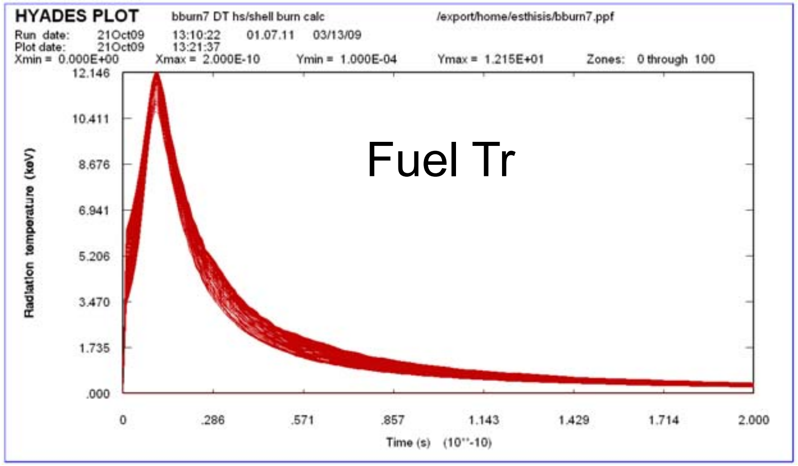
1) Idea: stick a package on the side of a burning NIF target!

(original image courtesy of LLNL)

2) Fuel ignition and burn modelled in 1D Hyades



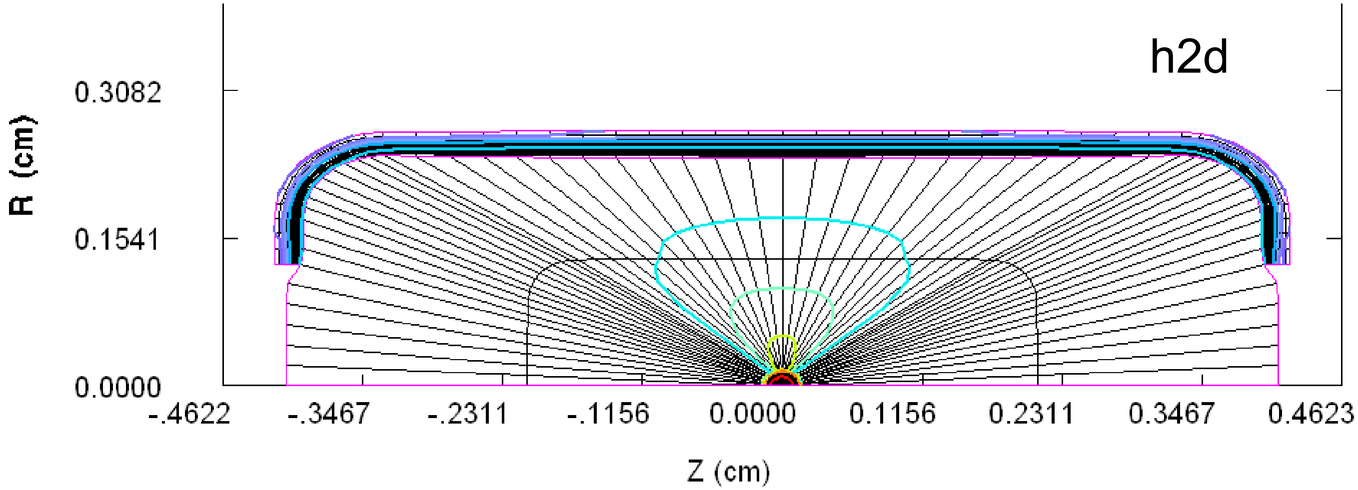
TN energy release rate



Fuel Tr

Collaboration with Imperial College looking at possibilities for burning plasma experiments on NIF (others welcome to join in)

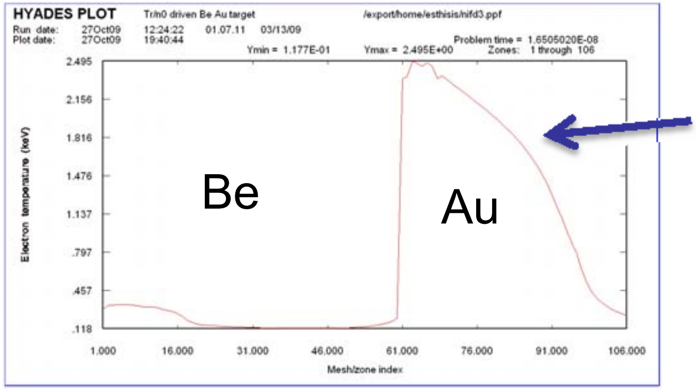
3.) Model hohlraum driven by burning capsule drive



Gas fill is Au plasma to simulate late time state. Walls pre-heated to 300eV for same reason.

4.) roughly calculate neutron drive for target package based on TN output, taking into account view factor of different planes in target package

5.) drive target package with combined x-ray radiation drive and neutron drive (energy deposition source)



Marshak wave in Au

Quite a few difficulties with designing such experiments

- Lack of sufficiently high temperature EOS data
- Lack of adequate opacity data
- Lack of codes incorporating neutron transport
- Lack of codes incorporating more sophisticated radiation transport (e.g. better than diffusion; IMC etc)

- These are all areas in which AWE has superior capabilities, so it seems to be a fertile area for collaboration

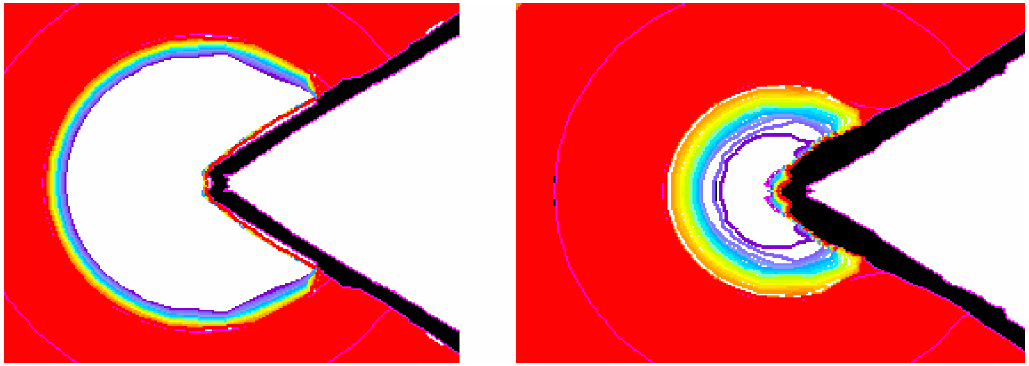
Just starting on this, but initial work throws up some interesting ideas

- May be interesting to investigate targets in which balance of x-ray to neutron heating is varied (e.g. using x-ray shine shields)

- Essentially instantaneous volume heating of large samples appears ideal for opacity studies

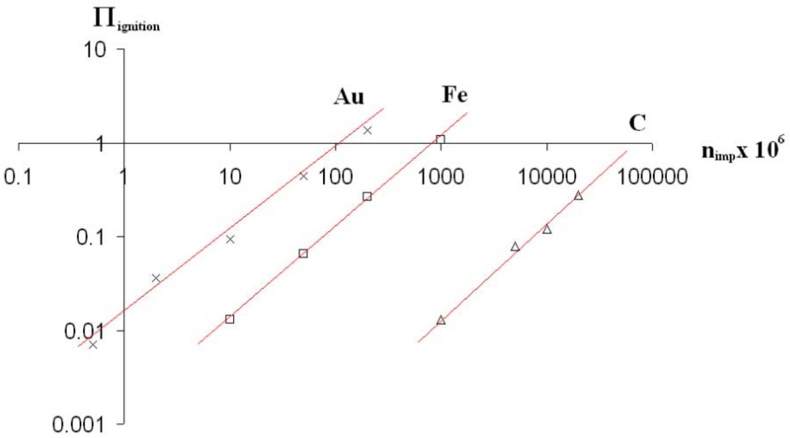
- Intense neutron fluxes may enable interesting nuclear physics experiments (e.g. Multiple neutron capture rate measurements)

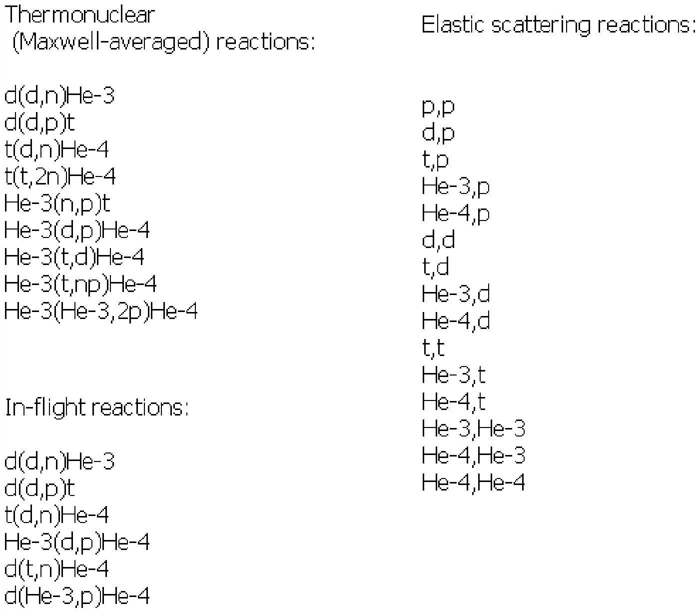
Gold/ fuel mixing work for cone FI



Au motion driven by preheat contaminates fuel

(See Pasley and Stephens Phys. Plasmas May 2007)





Thermonuclear
(Maxwell-averaged) reactions:

d(d,n)He-3
d(d,p)t
t(d,n)He-4
t(t,2n)He-4
He-3(n,p)t
He-3(d,p)He-4
He-3(t,d)He-4
He-3(t,np)He-4
He-3(He-3,2p)He-4

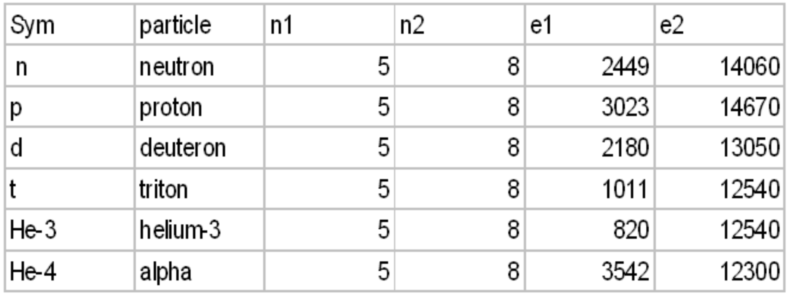
In-flight reactions:

d(d,n)He-3
d(d,p)t
t(d,n)He-4
He-3(d,p)He-4
d(t,n)He-4
d(He-3,p)He-4

Elastic scattering reactions:

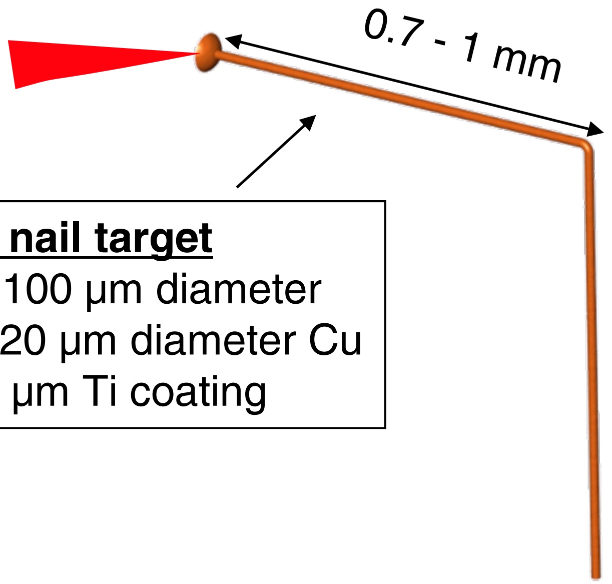
p,p
d,p
t,p
He-3,p
He-4,p
d,d
t,d
He-3,d
He-4,d
t,t
He-3,t
He-4,t
He-3,He-3
He-4,He-3
He-4,He-4

TN burn in Hyades/ h2d (CAS code)



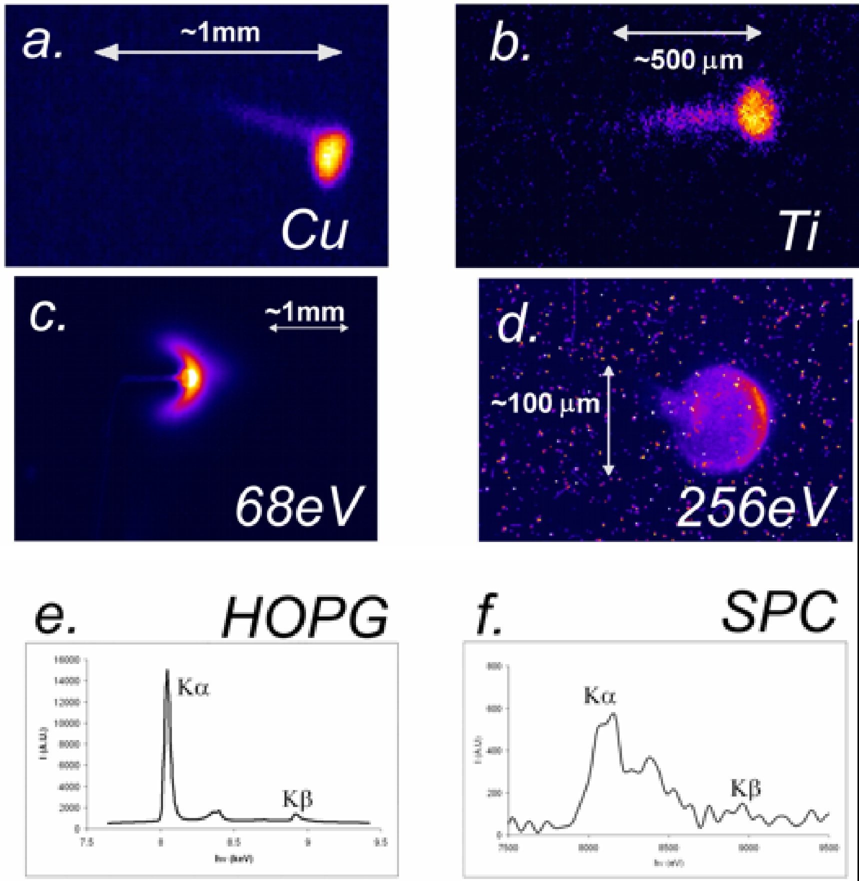
Sym	particle	n1	n2	e1	e2
n	neutron	5	8	2449	14060
p	proton	5	8	3023	14670
d	deuteron	5	8	2180	13050
t	triton	5	8	1011	12540
He-3	helium-3	5	8	820	12540
He-4	alpha	5	8	3542	12300

Electron transport studies



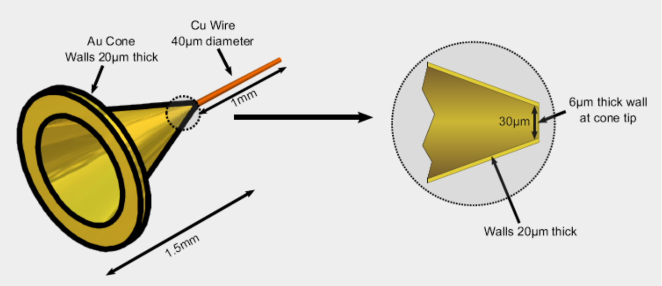
Cu-Ti nail target
Head:100 μm diameter
Wire: 20 μm diameter Cu
with 2 μm Ti coating

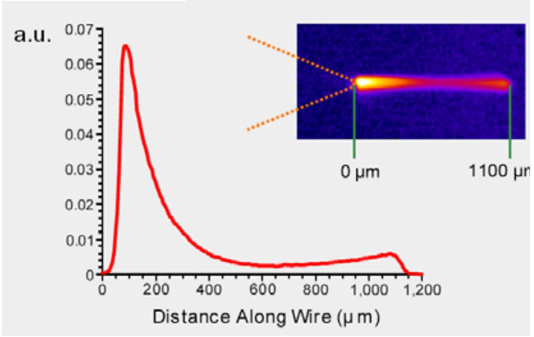
LLNL Titan experiment, 2006 with LLNL/ GA/ UCSD/ OSU collaboration

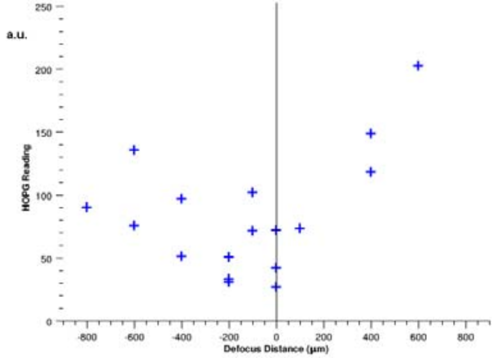


Pasley, *et al*, POP letter 2007

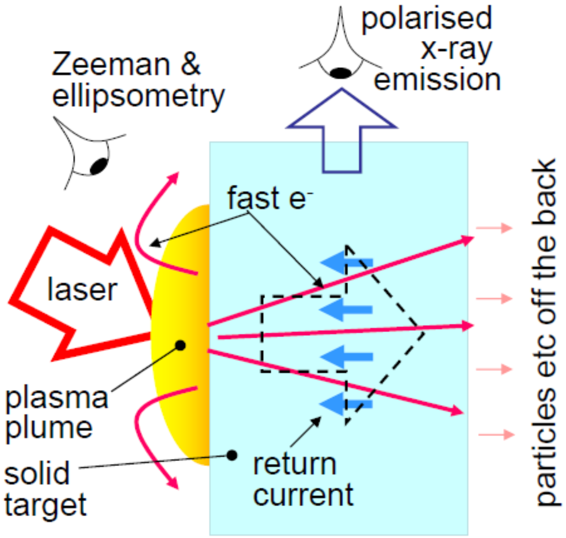
RAL PW experiment late 2008 (York/ RAL/ UCSD/ LLNL/ GA)

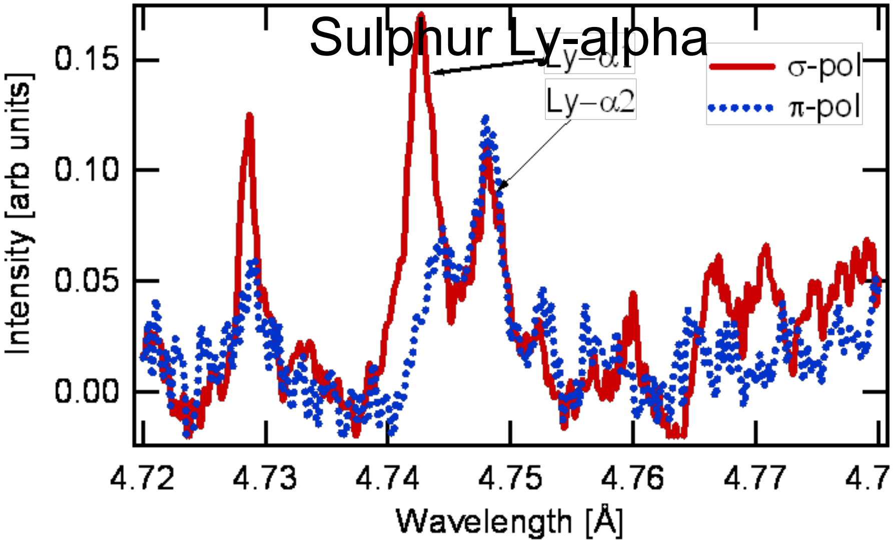






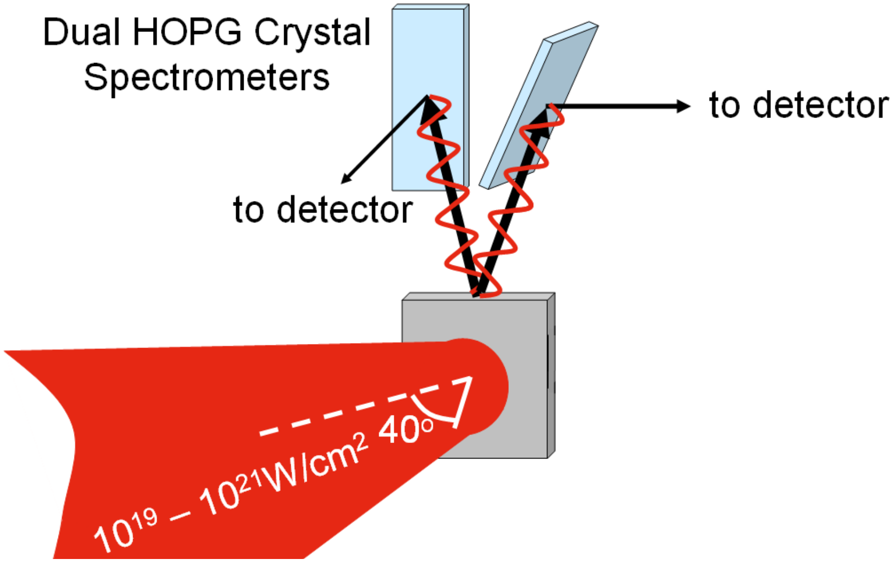
Advanced diagnostics for fast electron studies

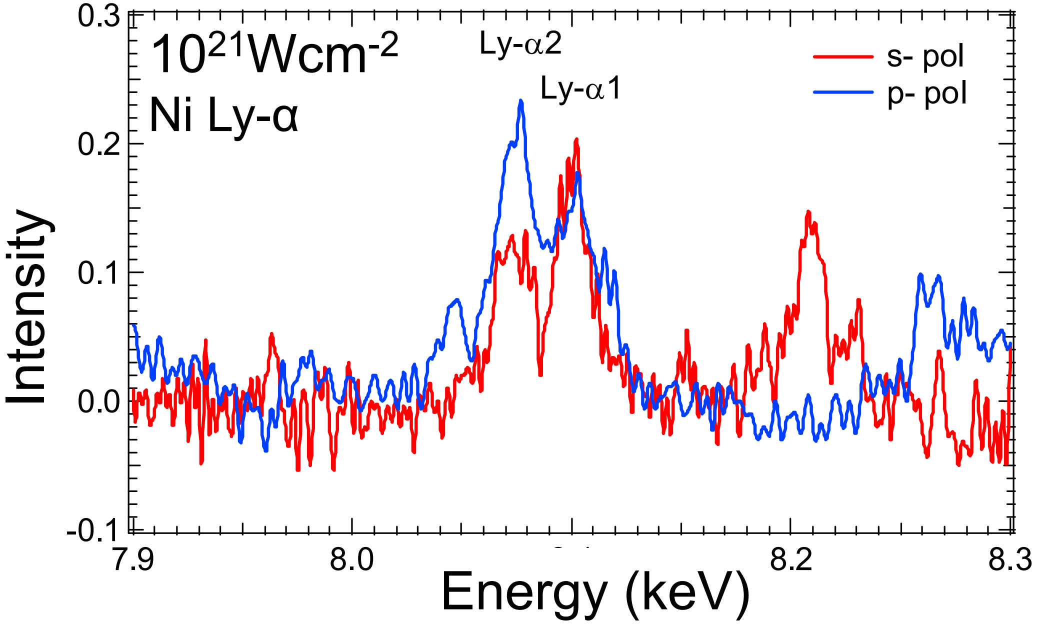




- Fast electron beam orientates M_J sub-levels & preferentially populates certain M_J's
- X-ray emission polarised
- Degree of polarisation, *P*, related to velocity distribution
- Classical scattering shows no p-polarised scattering at 90°.
- Use in spectroscopy with Bragg crystals at 45°
- Two orthogonal spectrometers needed to determine *P*

In situ diagnostics of fast electrons

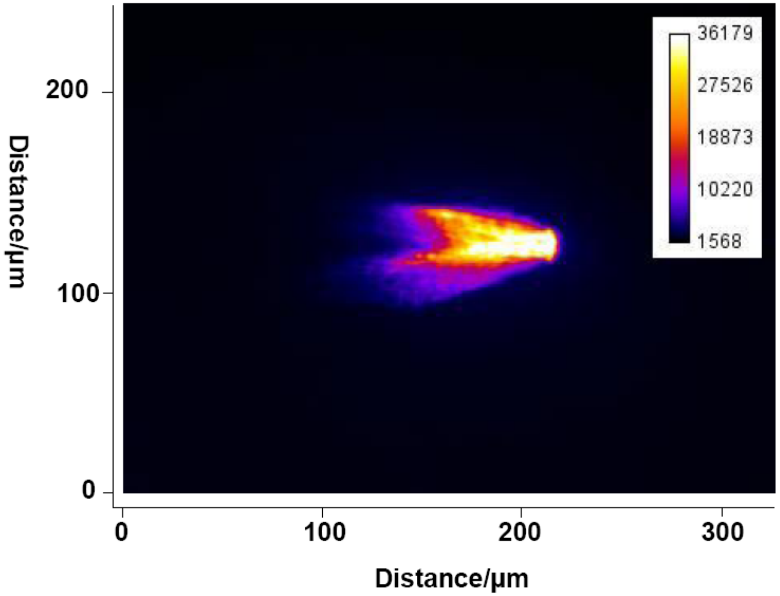




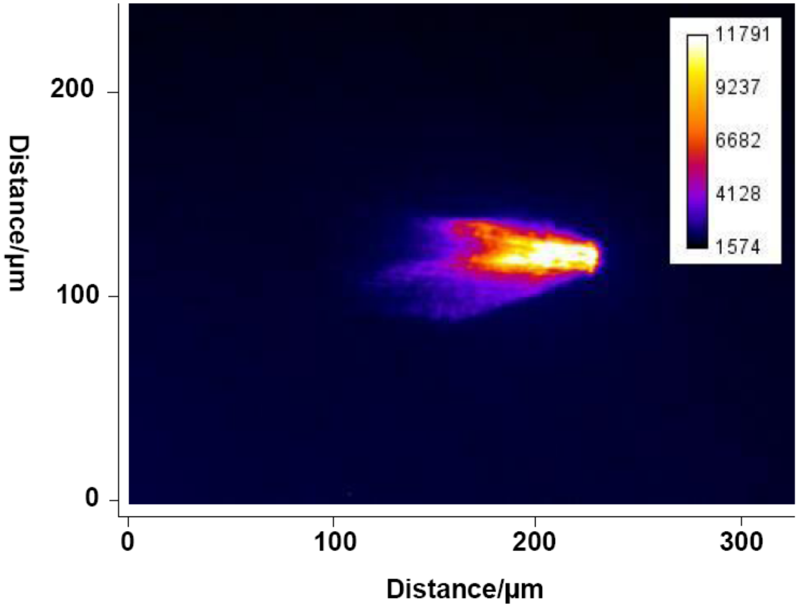
- Fast electron beam orientates M_J sub-levels & preferentially populates certain M_J's
- X-ray emission polarised
- Degree of polarisation, *P*, related to velocity distribution
- Classical scattering shows no p-polarised scattering at 90°
- Use in spectroscopy with Bragg crystals at 45°
- Two orthogonal spectrometers needed to determine *P*
- Used to study transport in solid targets doped with S and Ni

Transmission of **focussed** moderate irradiance EUV laser thru Al target – simultaneous heating and diagnosis

90 ps pulses, 59 eV photon energy



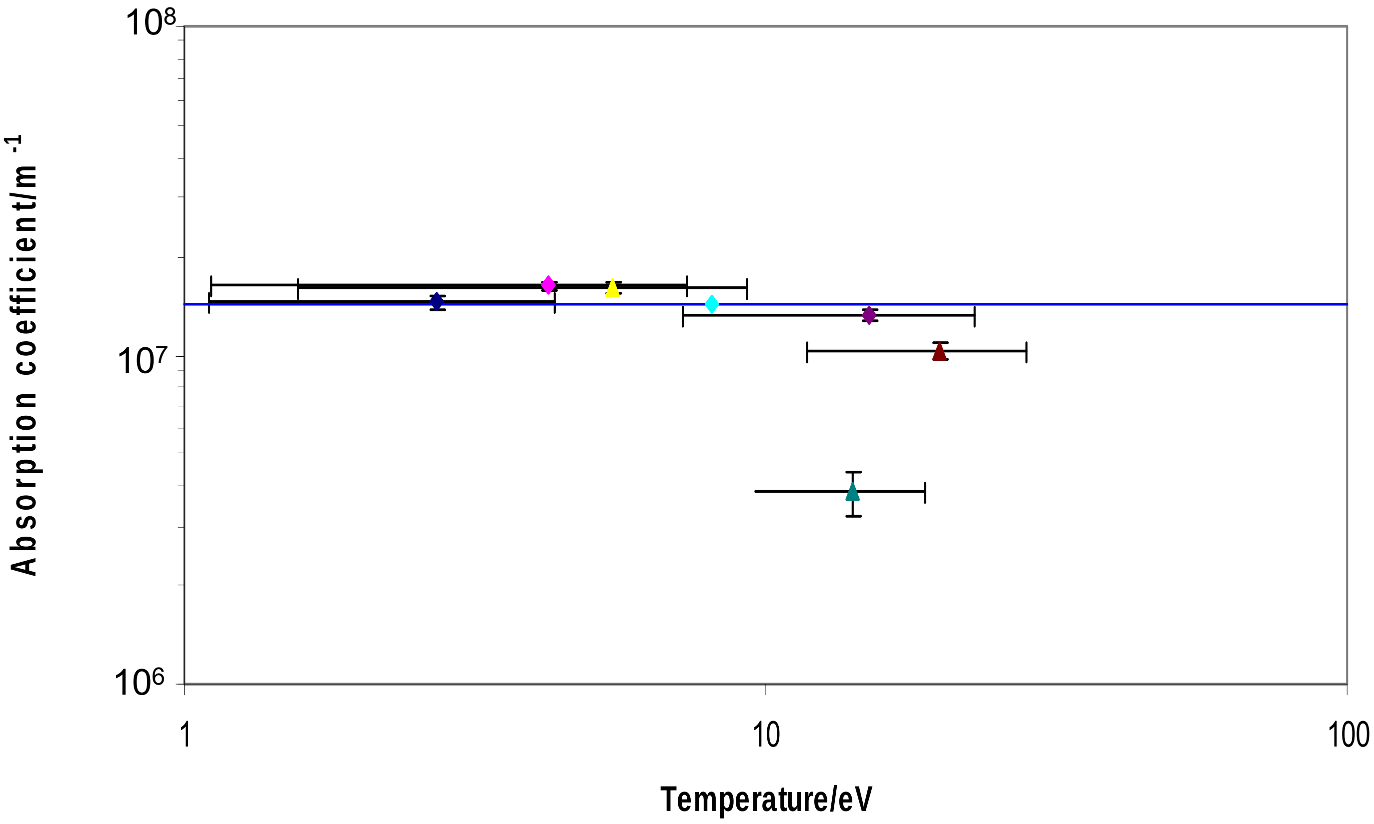
Footprint of x-ray laser
at focus position (no target).



Footprint of x-ray laser
transmission through
500 nm Al target.

No additional optical laser heating

Absorption coefficient of polyimide as a function of temperature as heated by EUV laser

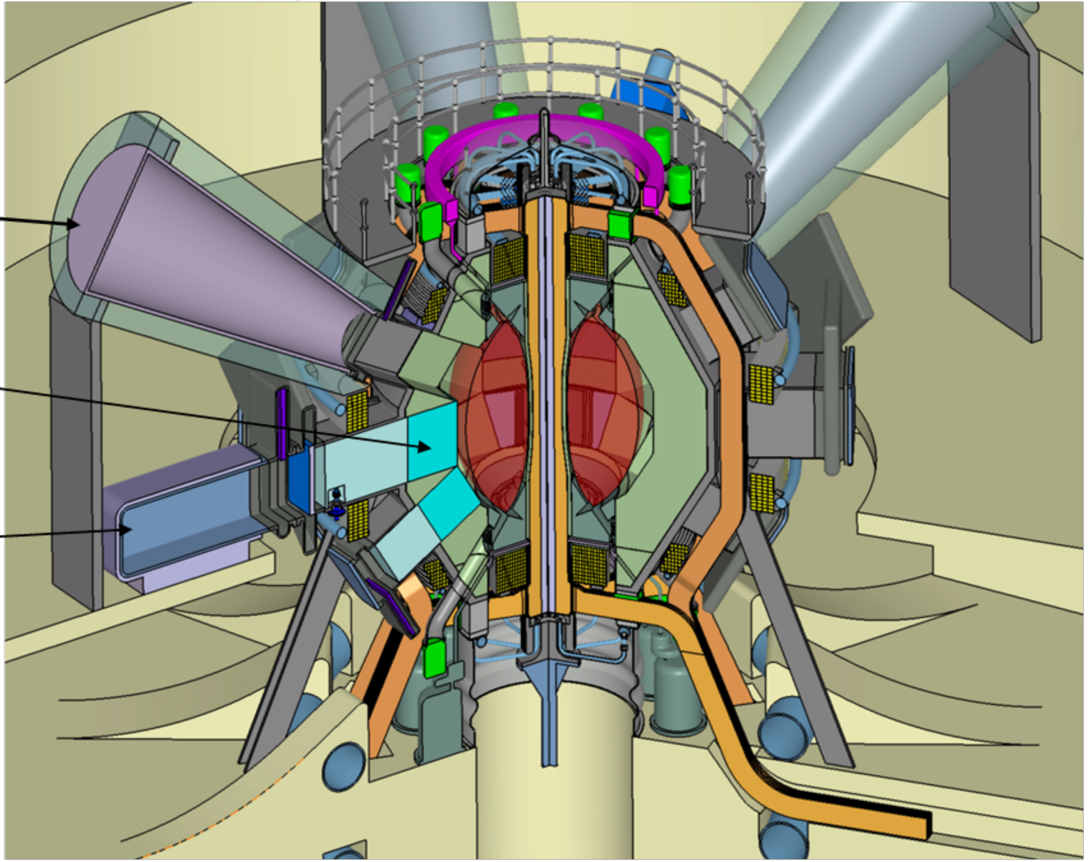


Fusion Components Test Facility

In collaboration with UKAEA Culham, we are involved in the design of a MCF components test facility (CTF)

The device is similar in size to MAST, but would operate in steady state, and produce a steady 40MW of fusion power

Its mission is to provide a fusion-spectrum of neutrons for materials and components testing before, or in parallel to, DEMO



High power neutral beam (heating and current drive)

Testing module

Cassette in place, ready to withdraw module

~1m

Conclusions

- York has a unique combination of 4X MFE and 3X IFE academics
- Range of high profile research relevant to IFE
- Interested in getting involved with experiments driven by burning NIF targets
- Good contacts with labs: CLF, LLNL, General Atomics, Osaka, PALS, …