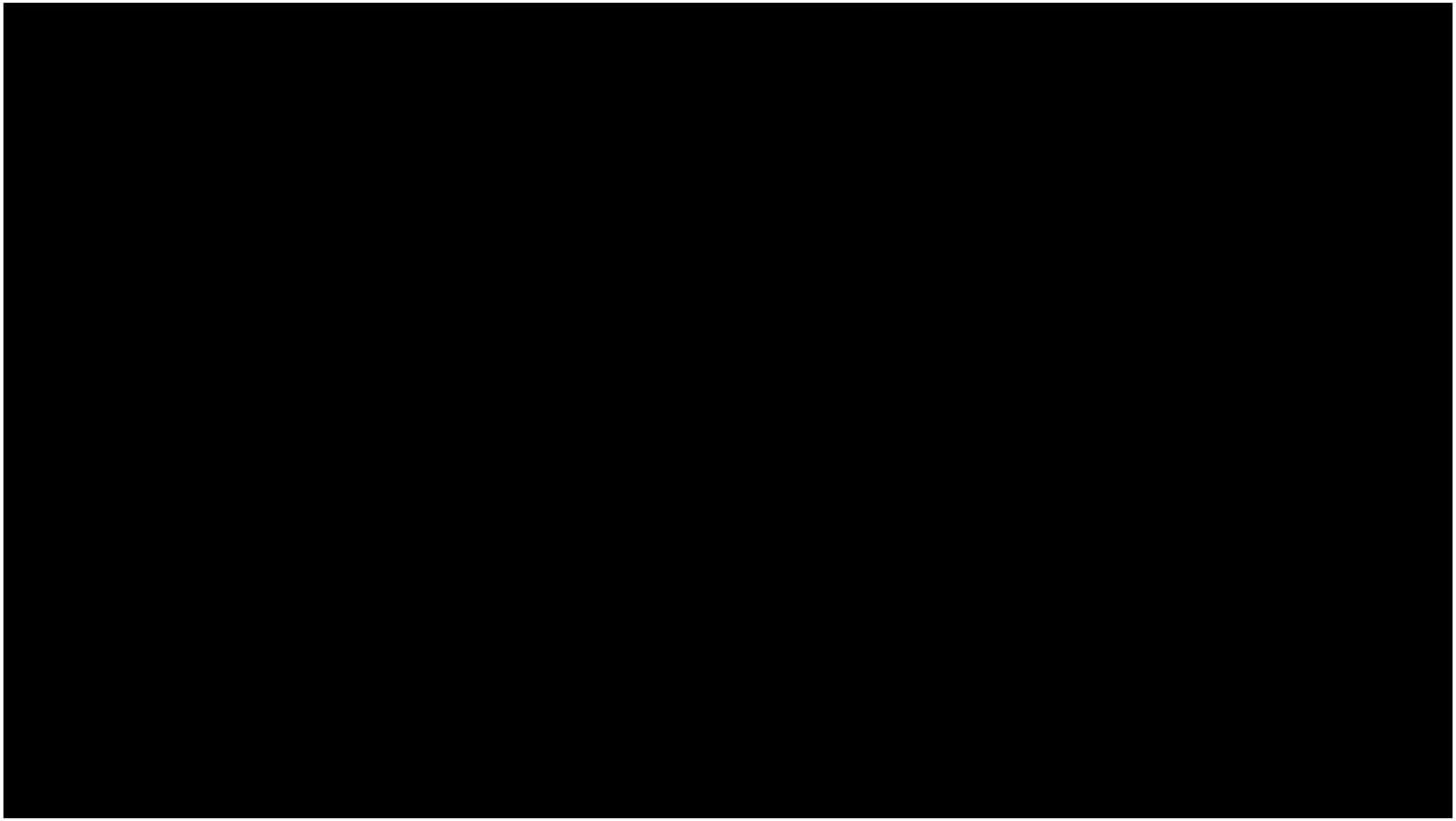
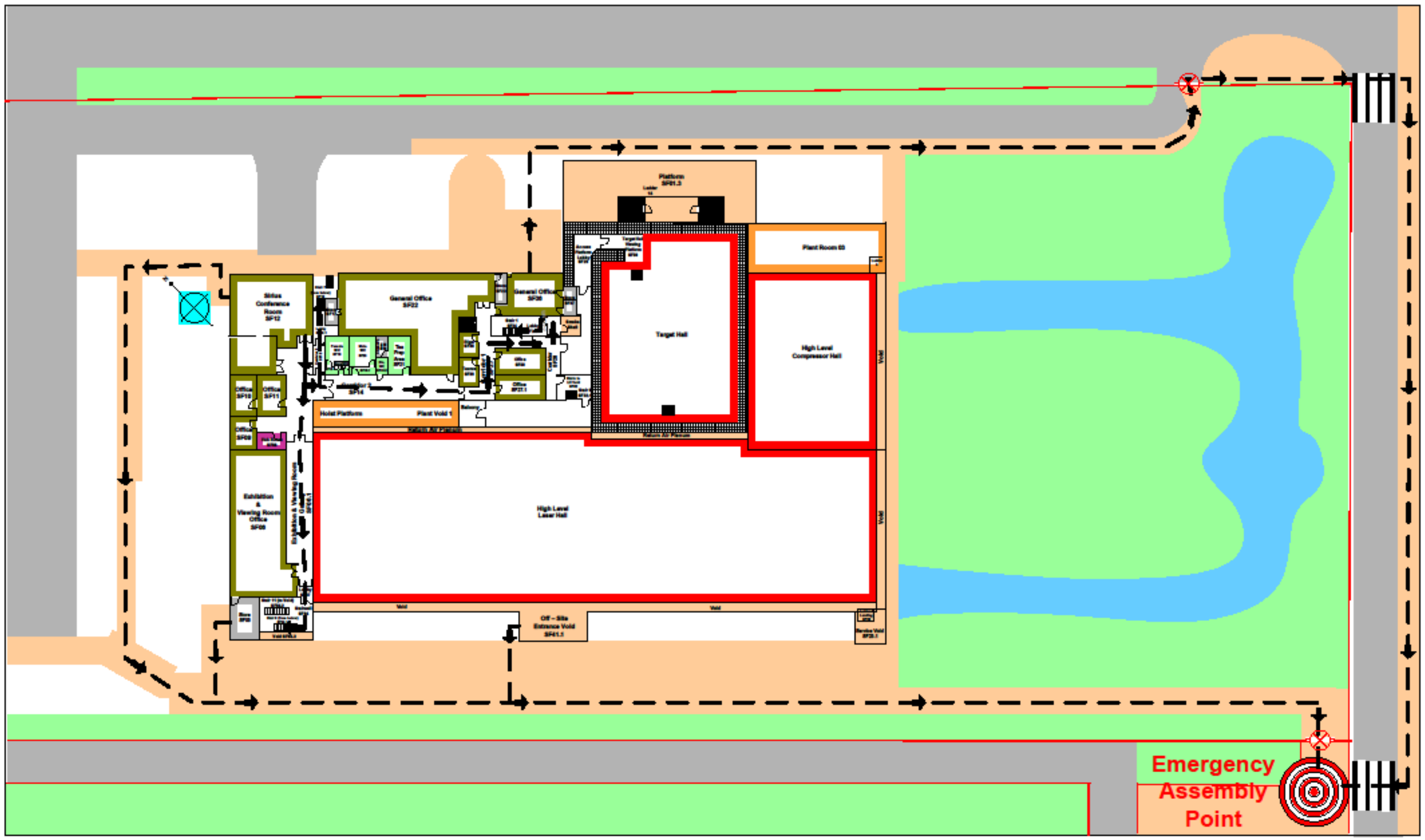
WELCOME

P D Roberts

Orion Induction Video



Evacuation Routes to the Emergency Assembly Point



Sirius Conference Room (SF12) – Do Not Remove

Second Annual Meeting of the Centre for Inertial Fusion Studies

Orion Building Conference Room, AWE Aldermaston, 15th March 2011

Agenda

9.30	Gate clearance at Orion Building	
9.45	Coffee	
10.15	Welcome	Peter Roberts
10.20	Academic Access to Orion	Tim Goldsack
10.30	Report from NIC review	Steve Rose/Peter Roberts
11.00	User Access to NIF	Justin Wark
11.20	Updates from university groups,	15 minutes each
	Oxford (including NIF User Access)	Justin Wark
	Imperial College	Mark Sherlock
	York	John Pasley
	Strathclyde	Paul McKenna
	QUB	Dave Riley
12.35	Lunch and ORION tour	

Agenda

13.55	University reports	
	Warwick	Tony Arber
	RAL	Alex Robinson
14.25	Report from Washington IFE Meeting	Chris Edwards
14.50	News and expectations for HiPER	Chris Edwards John Collier
15.20	CLF status following RC reviews	JohnCollier
15.40	Next Steps	Discussion
16.10	Tea and depart by 16.30	

CIFS Meeting March 2011

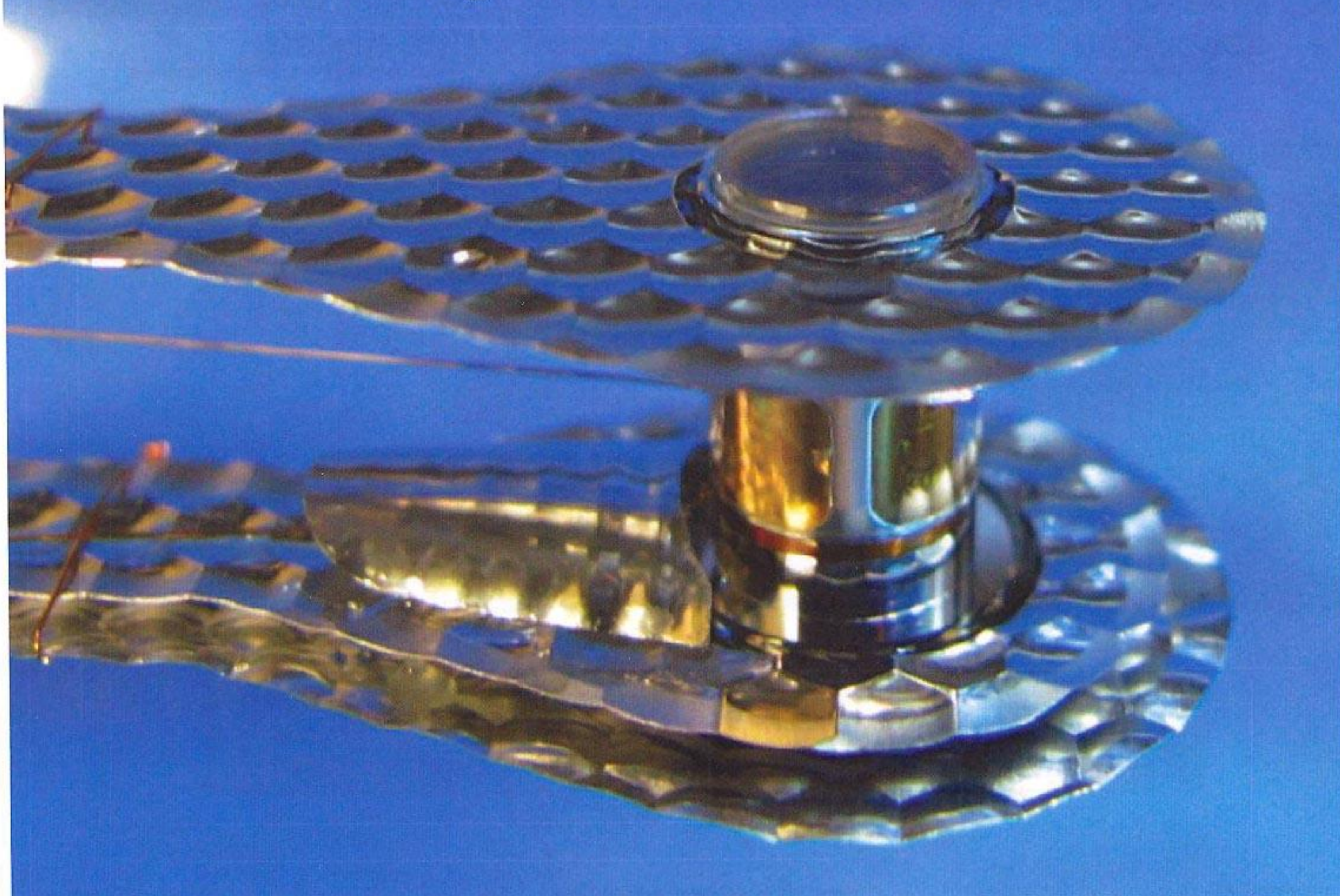
Fusion Progress

P D Roberts
&
S J Rose

NIC Review – Feb 23 - 25

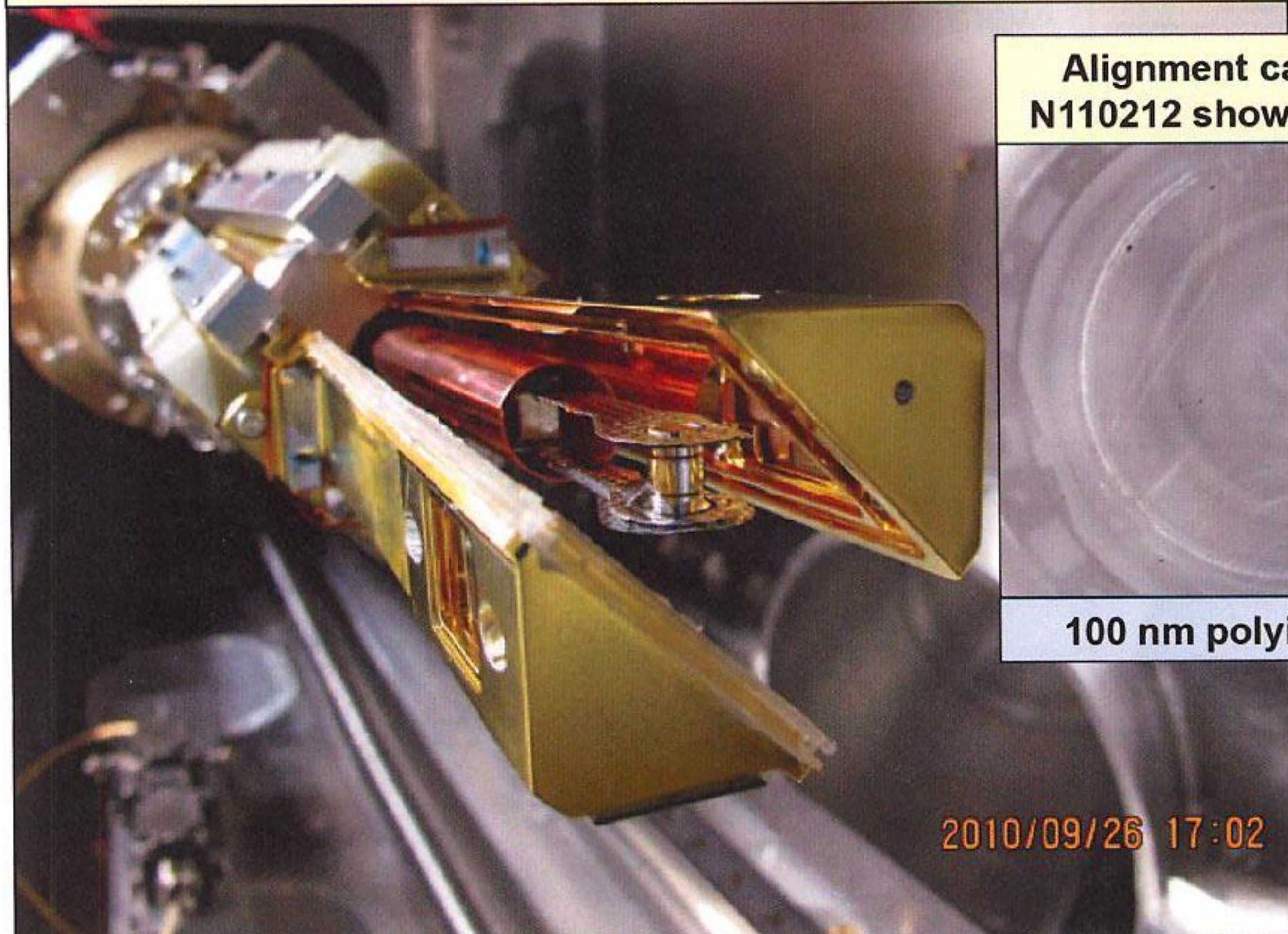
- ‘Storm Windows’ designed to overcome ice on LEH
- Limited number of cryo shots since then
- THD (6% D) now have neutron yields ~ 10^{14} , T ~ 3KeV
- Tr ~ 300 eV , Symmetry control good
- Compression and convergence poor (?) but inconsistent
- Implosion velocity ~10% lower than expected
- Fast electron preheat low and late
- Mix now seems not severe

THD target with LEH storm window



THD fuel layers are formed with the target mounted in a dedicated cryogenic target positioner thermally isolated by a removable shroud

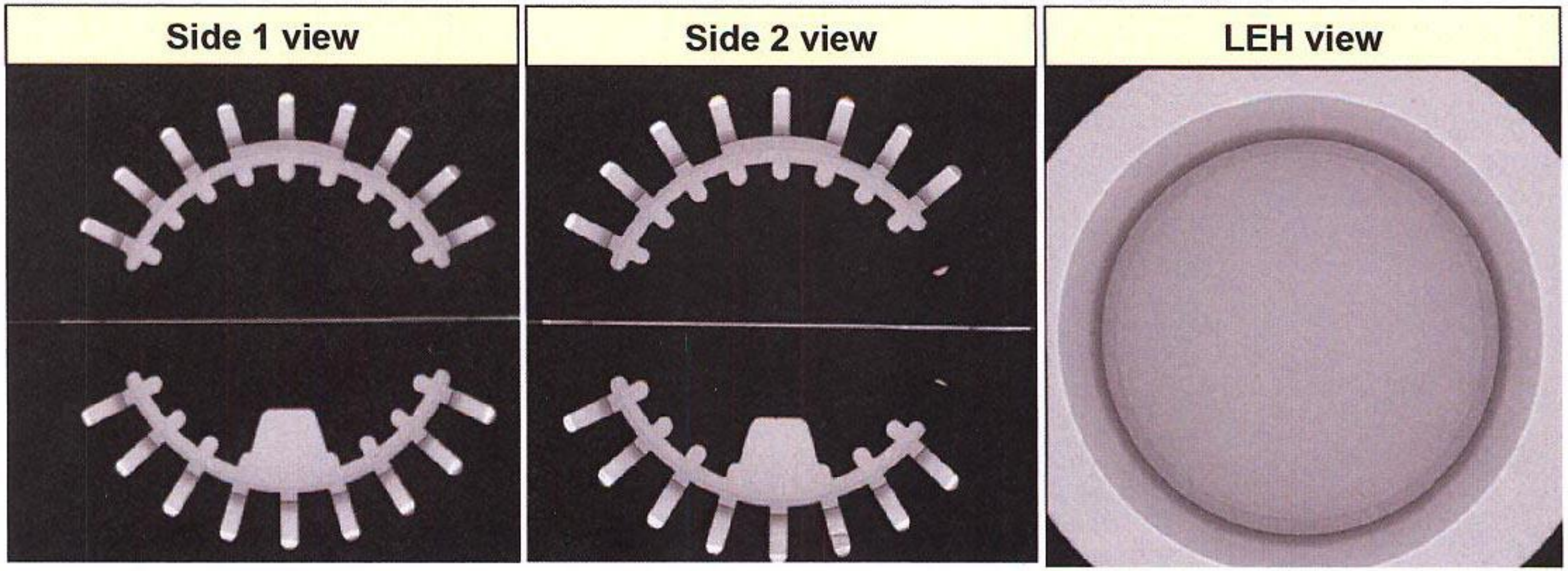
27850001 target in layering shroud



Alignment camera for shot N110212 shows storm window

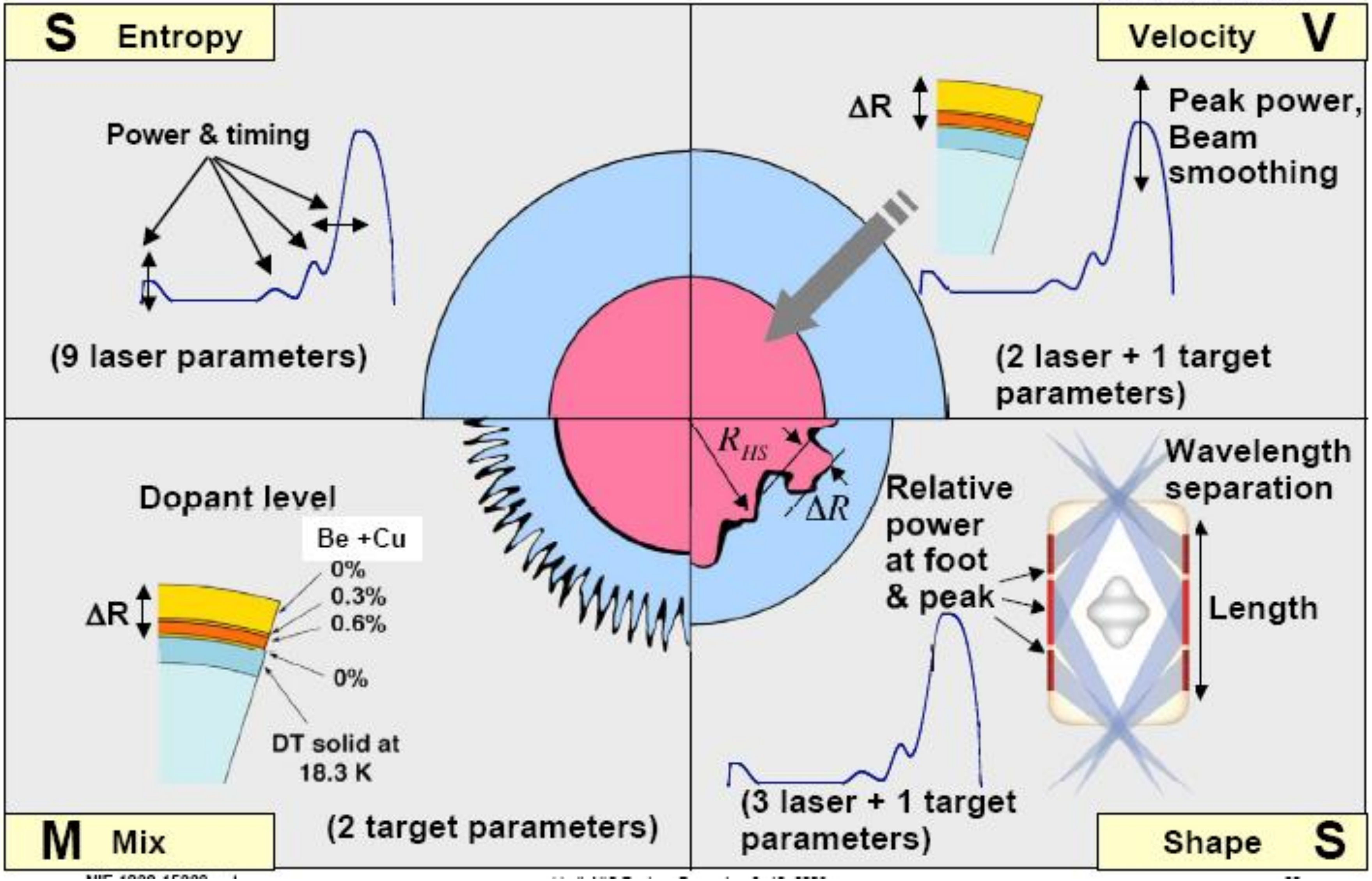
100 nm polyimide, 40 nm C

THD ice layers are characterized in situ and have met specifications on four integrated experiments to date

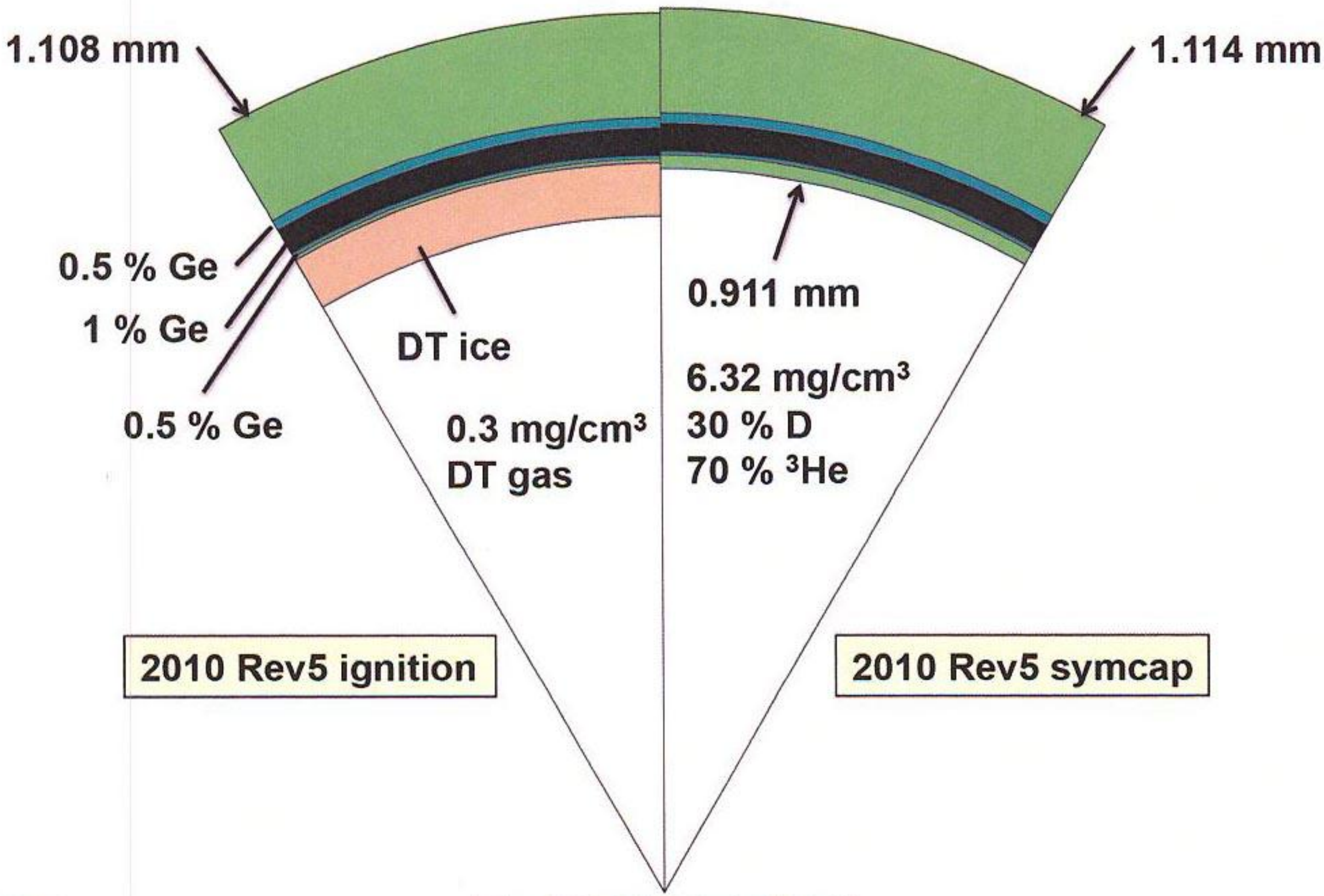


Independent tests have shown that the layer quality is not affected by shroud opening and quench (cooling from 18.8 K to 17.5 K in last 30s prior to shot)

On NIF this is assessed in 4 areas, with just 17 control parameters

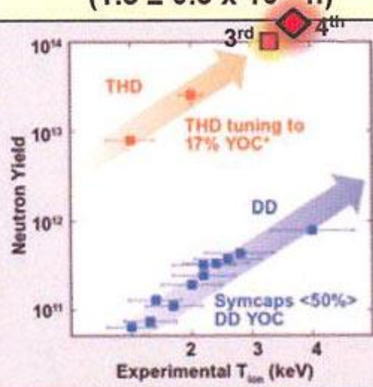


In a symmetry capsule, the DT or THD fuel is replaced with CH payload and high-density gas

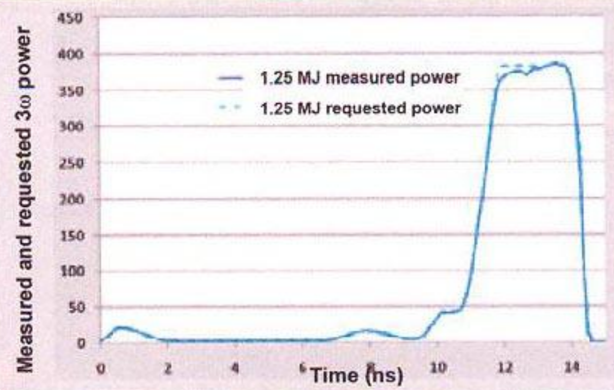


February 12, 2011– 4th THD Fuel Target (Preliminary data)

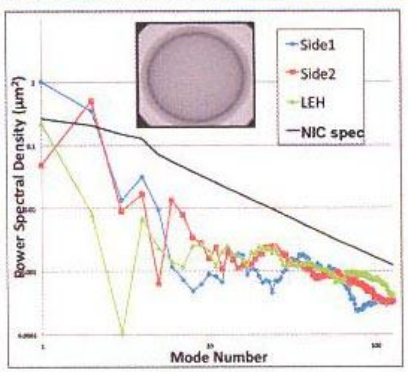
Record neutron yield for a laser facility for an x-ray–driven capsule ($1.3 \pm 0.3 \times 10^{14}$ n)



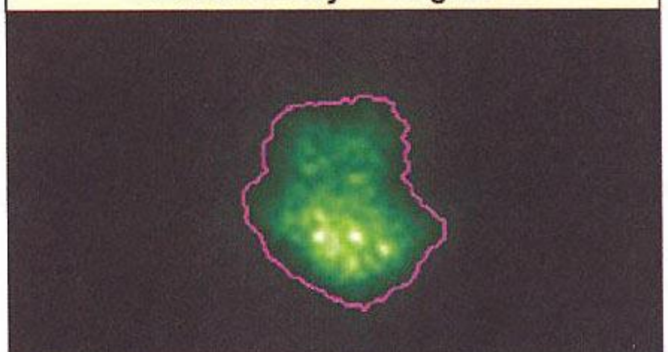
Highest energy (1.30 MJ) laser drive delivered to a THD target



THD layer met specifications



Areal density ~ 0.X g/cm²



Equatorial x-ray image

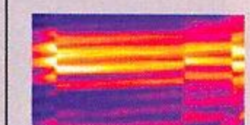
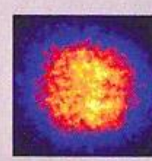
THD symmetry controllable

Status 1/24/2011:
We have commissioned implosion tuning techniques

Solid high-Z sphere

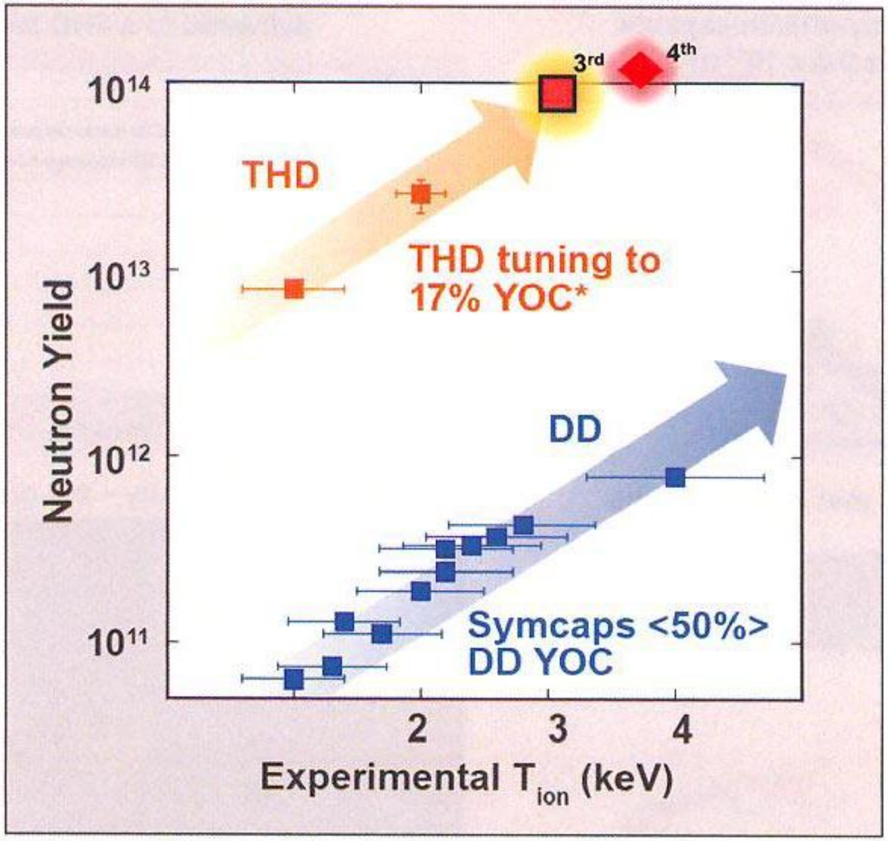
Liquid D_2-filled capsule

Gas-filled and THD Cryo-layered Capsules

Target	Reemit	Keyhole	Symmetry Capsule	Backlit Capsule
Implosion Parameter	Shape Early	Adiabat (Foot and 4th Rise)	Shape (Peak)	Velocity, Mix
Sample NIF Data	700 eV image 	VISAR streak 	8 keV core image 	8 keV Radiograph of capsule 
• Adjustable laser or target parameter	• Laser power, inner/outer cones	• Shape of the pulse	• Laser power inner/outer • $\Delta\lambda$ between cones	• Peak laser power • Capsule thickness • Capsule doping

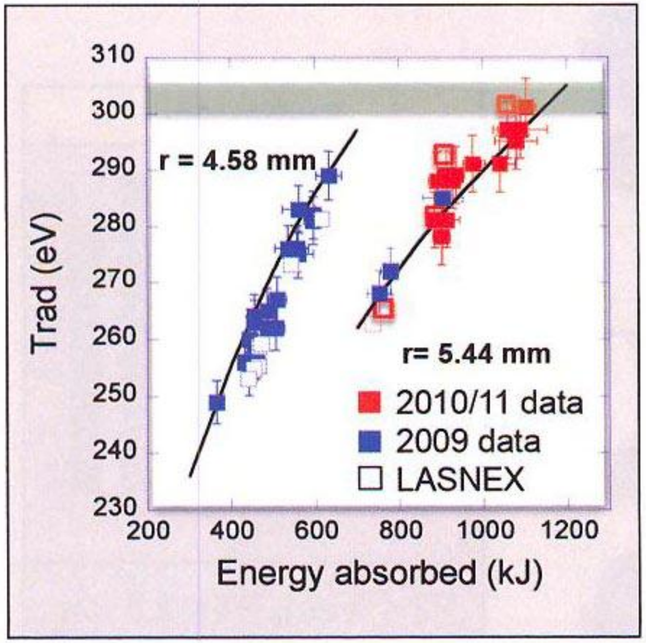
10EIM/mfm · NIF-0111-20908s2

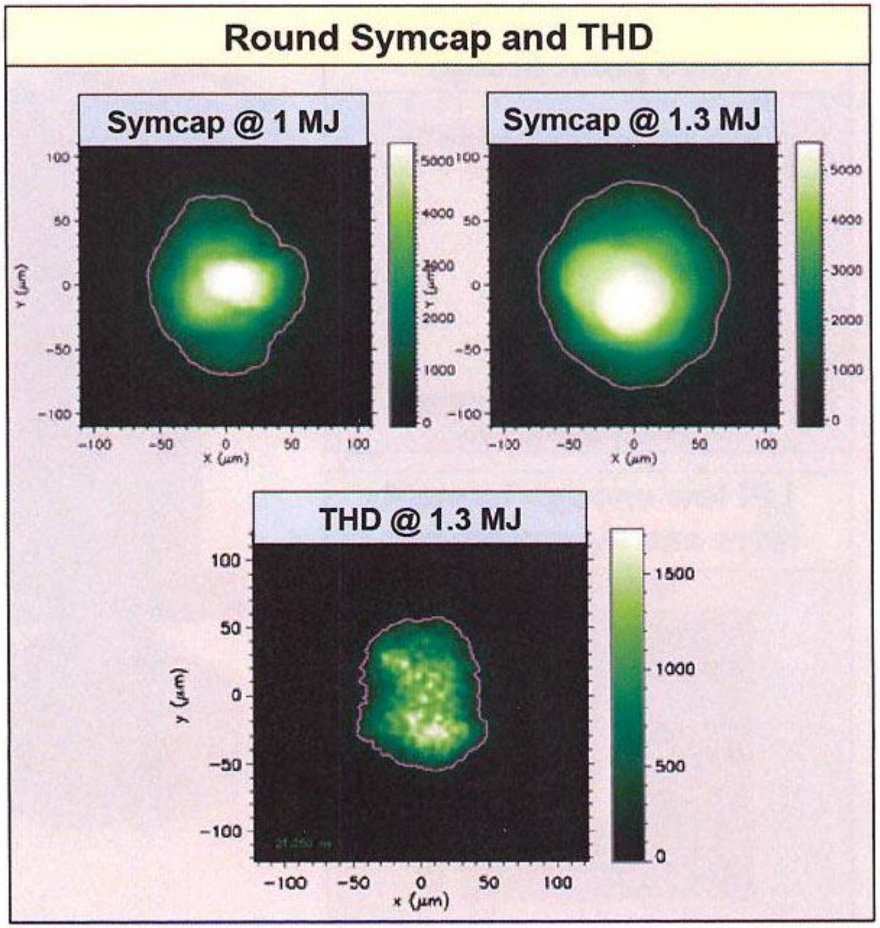
Implosion experiments are encouraging



*based on pre-shot calculation

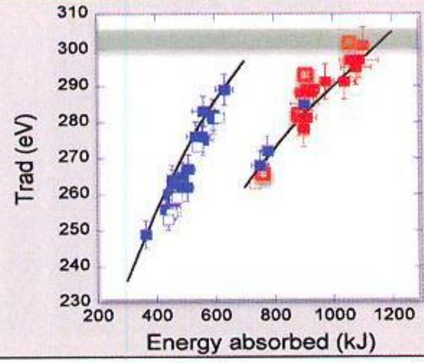
We have demonstrated hohlraum temperatures of 300 eV and round implosions at 1 and 1.3 MJ



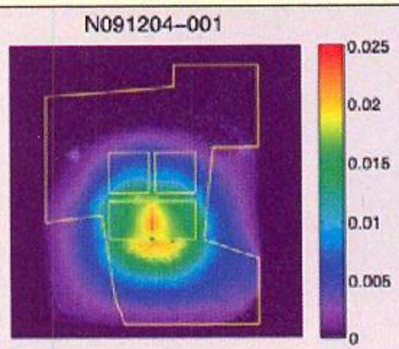


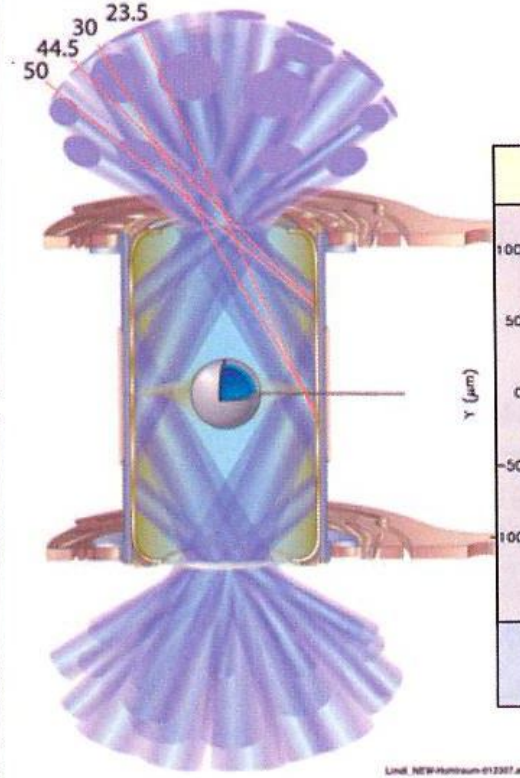
The hohlraum provides a hot, symmetric environment for the capsule

300 eV drive needed for Rev5 point design

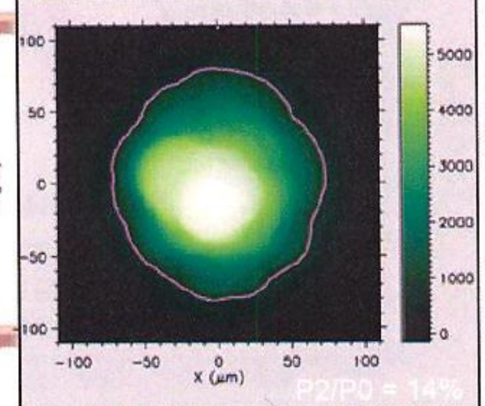


LPI low enough to meet drive and symmetry req.





Symmetry

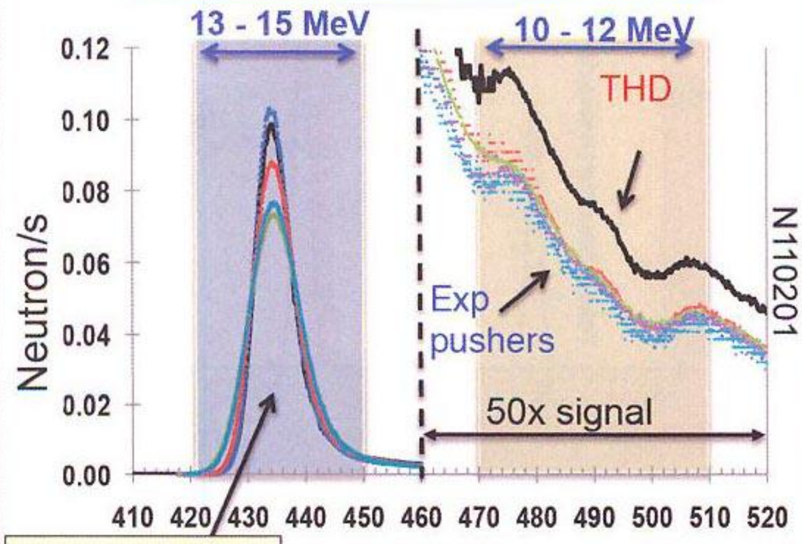


P2 < 4 um, P4 < 2.5 um

ρR: DSR measured by MRS and NToF20 are self consistent within the measurement error

NToF Signal clearly shows down scatter signal on all THD shots

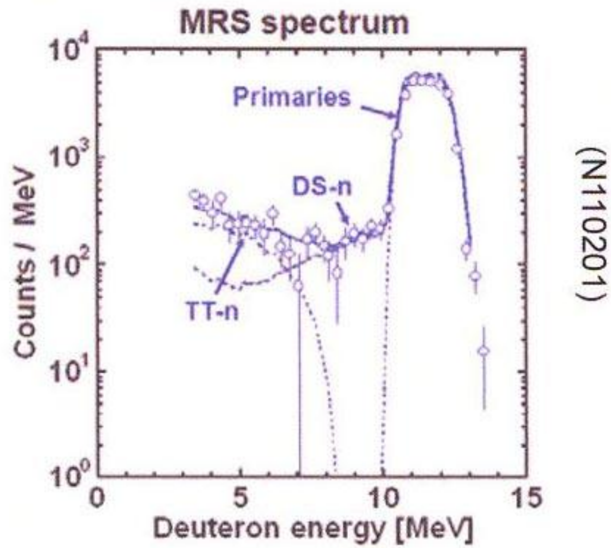
THD-3: DSR = 0.027 ± 0.005



Area normalized

MRS: DSR error < 10% for Yn >1e14 and ρ.R ~ 1g/cm²

THD-3: DSR = 0.024 ± 0.003



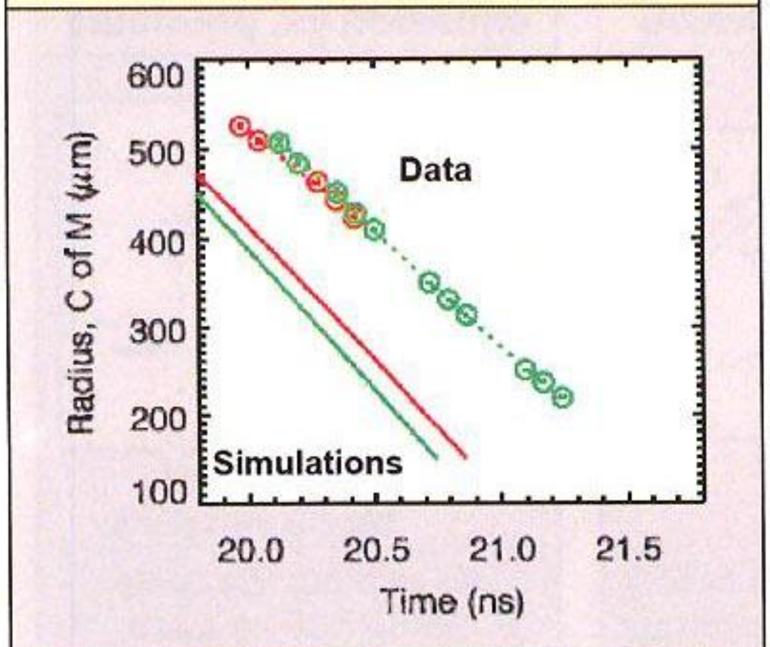
- **Background level from exploding pushers is reproducible**
- **Shorter cables planned for NTOF20 will reduce uncertainty**
  - **Lower cable induced background levels by ~3x**

Velocity

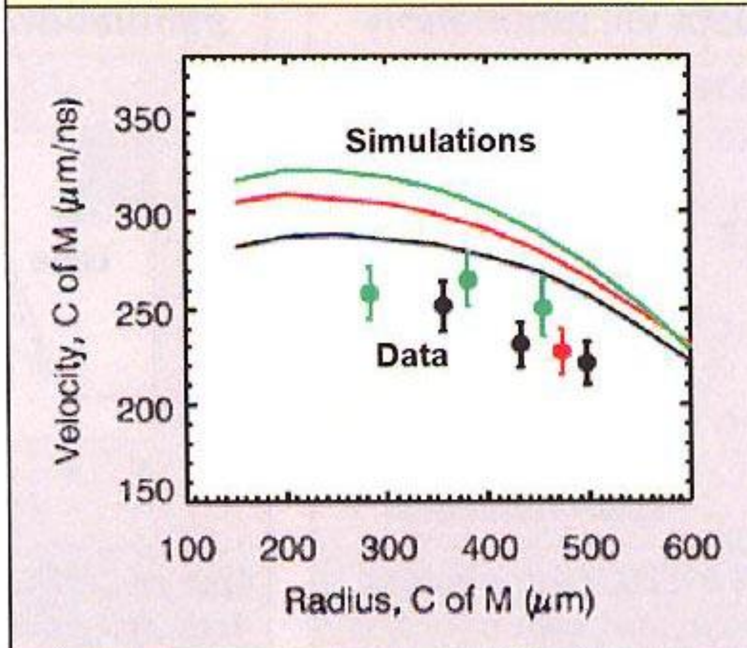
R vs. t trajectory is delayed ≈ 400 ps and implosion velocity is 10 5% lower than expected

Haan

R vs. t, data vs. simulation



Vimp vs. R, data vs. simulation



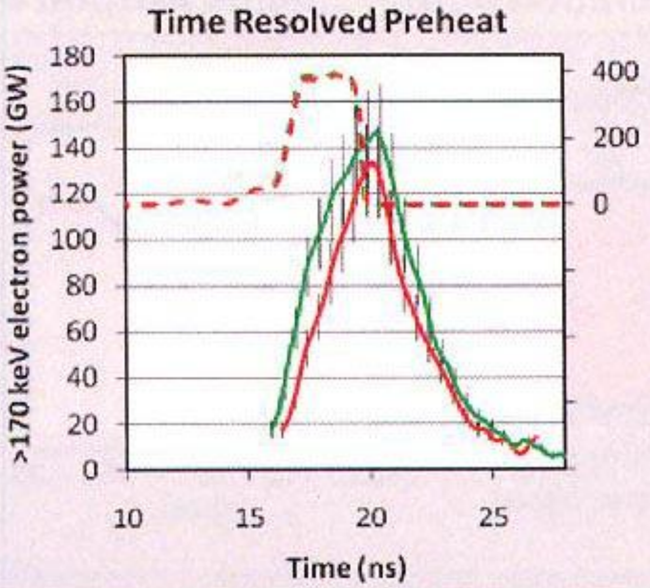
- Confirm velocity after shock tuning, with higher accuracy streak camera
- Assuming r vs. t delay discrepancy persists:
  - Radiograph acceleration onset as check of internal drive
  - Calibrate new shock flash – bangtime interval capability (pToF)
- Increase velocity using thinner capsule and/or more drive consistent with not crossing hot spot mix cliff

Adiabat

Hot electron preheat is negligible in foot, and is expected to increase adiabat by < 2% in peak

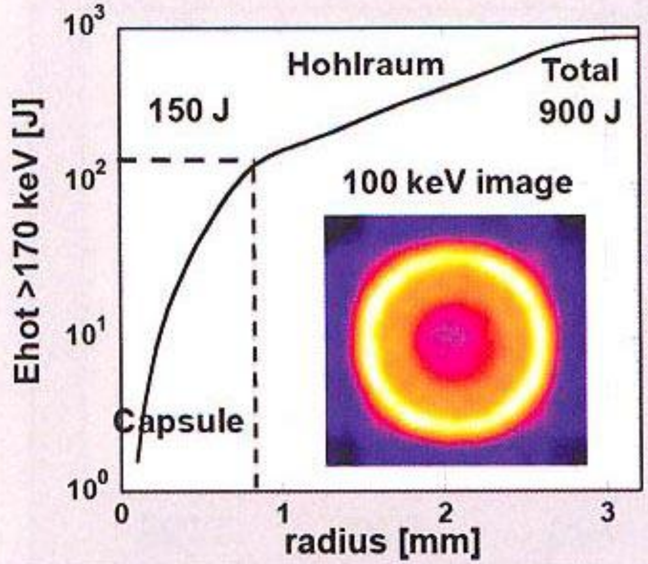
Robey

From hard x-ray spectrometer: > 170 keV* Hot e- @ Hohlraum



700 ± 100 J @ Hohlraum

From polar hard x-ray imager: > 170 keV Hot e- @ Capsule



150 +25,-100 J @ Capsule, close to 100 J budget

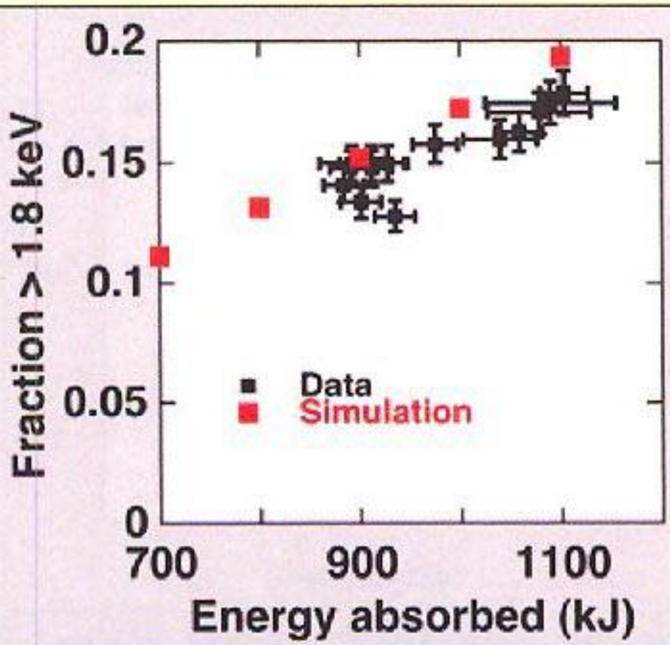
* Shorthand for energy content of hot electrons that could reach fuel

- **Confirm low hot electron preheat at capsule when it matters, at < 17 ns before 4th shock break-out using truncated pulse**

Parameters affecting interface mix (hard x-ray preheat and Atwood #) are close to design value or measurable

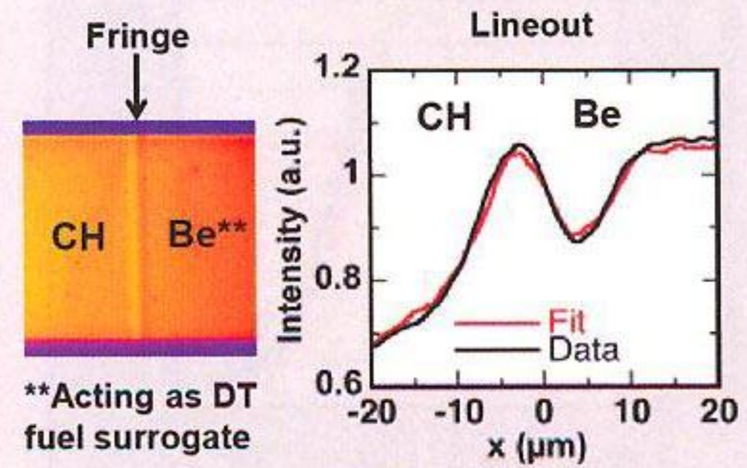
Haan

> 1.8 keV drive fraction from Dante vs. simulation



Confirms Ge % choice

X-ray refraction off CH/Be curved interface provides fringe* with separation ~ $\Delta n_e^{2/3}$, hence Atwood #



**Acting as DT fuel surrogate

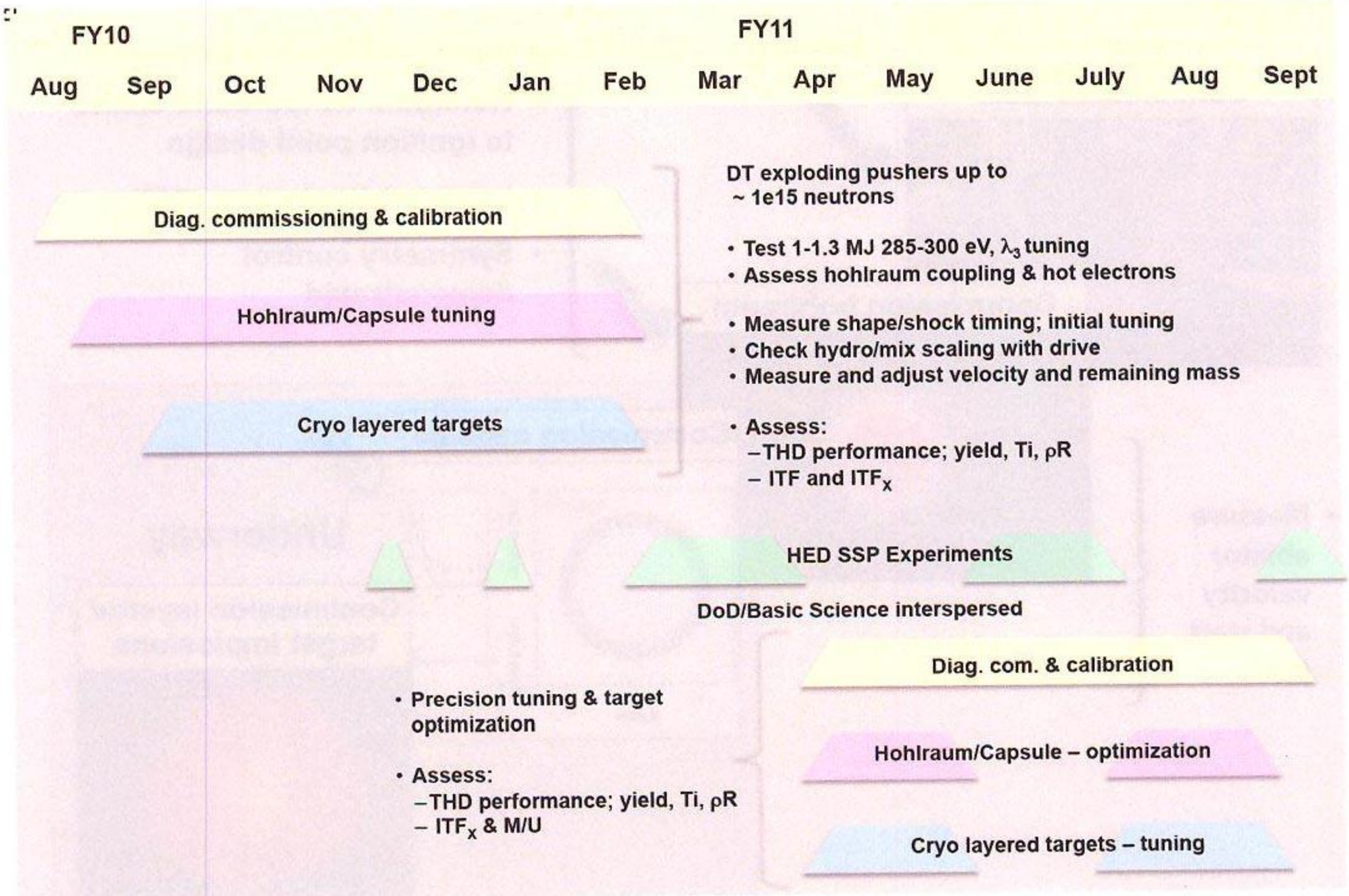
Time-resolved Atwood # capability now demonstrated (OMEGA)

*J. Koch, J. Appl. Phys (2009)

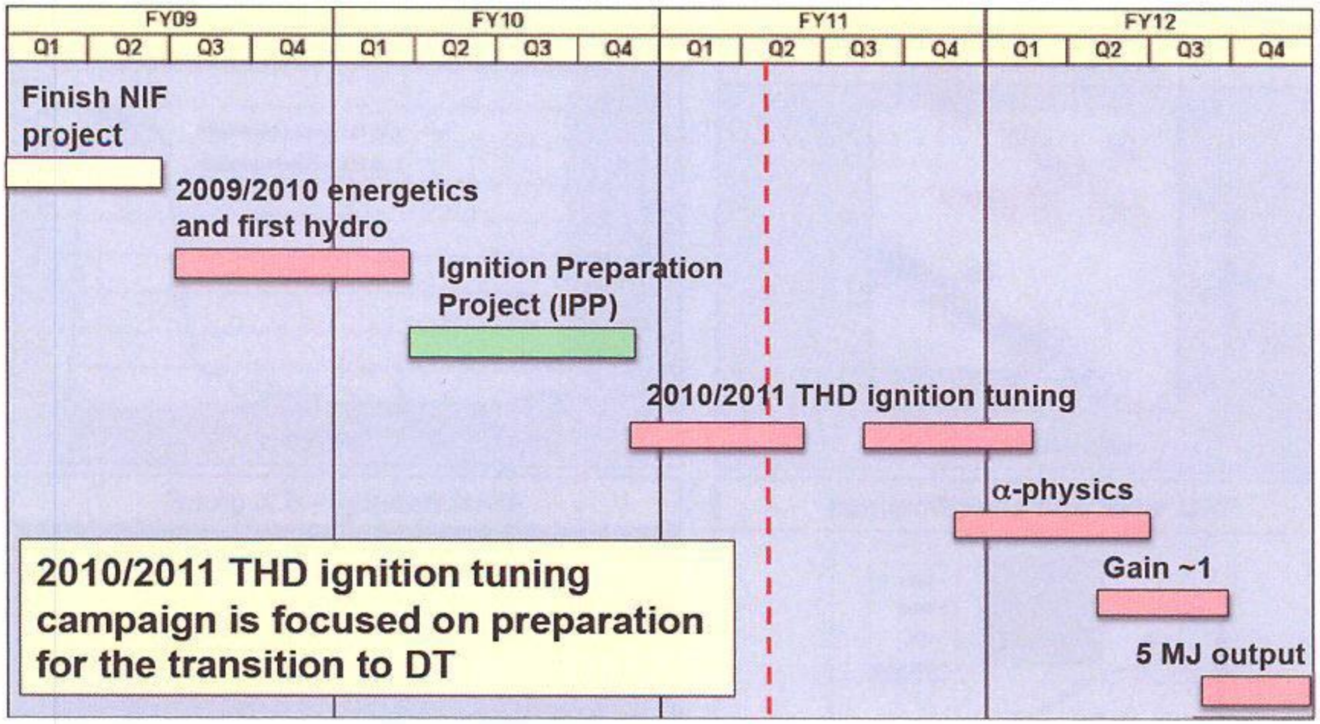
- Confirm hard x-ray preheat level after full tuning
- Measure ablator-fuel Atwood # in-flight if warranted

NIC

NIF experimental working schedule – 1/24/2011

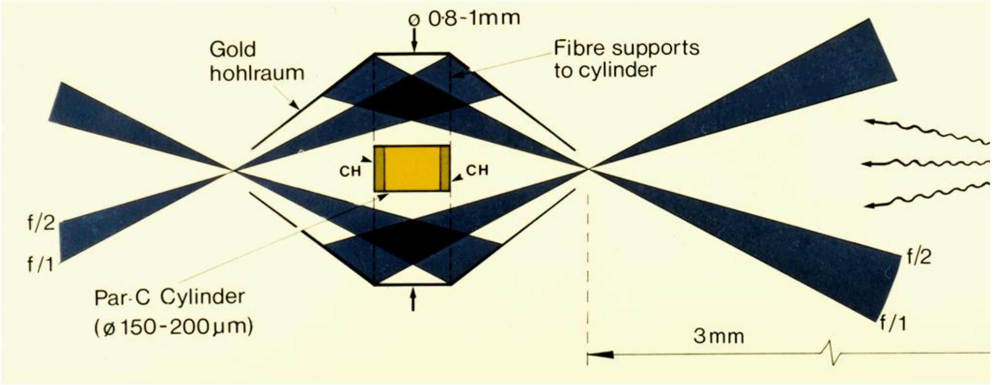


NIF/NIC summary schedule – FY2009-2012

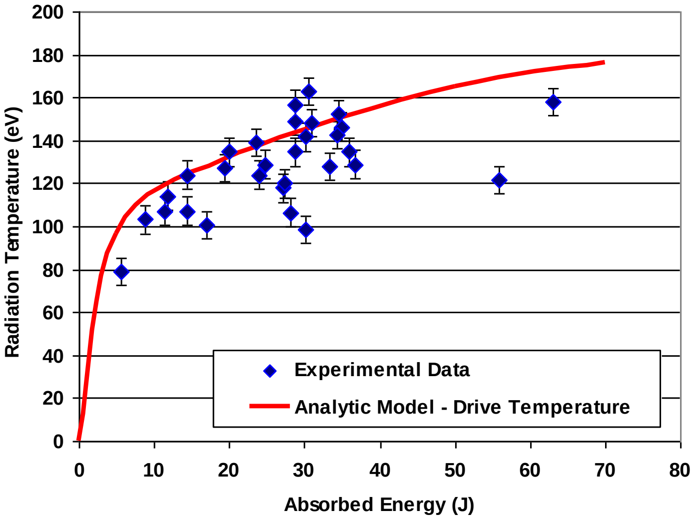


AWE has a long history of innovative hohlraum design

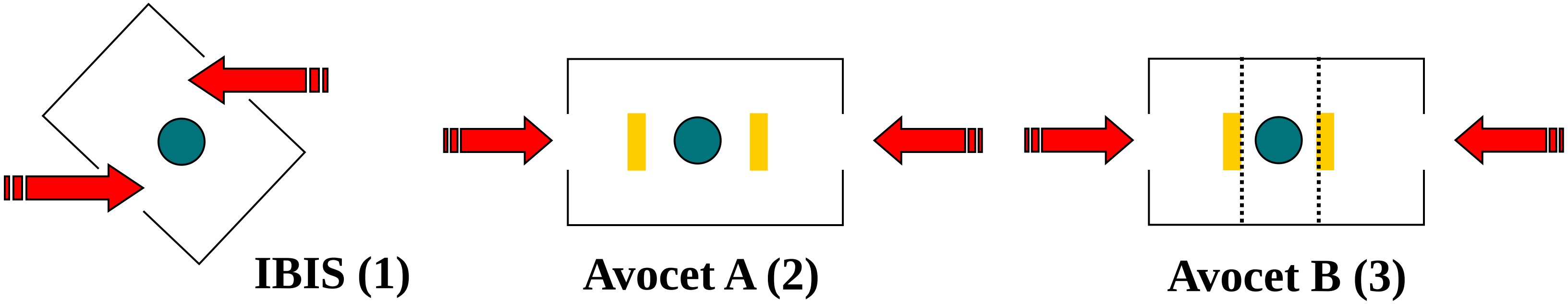
Novel scheme for uniform implosion with backlighter (1985)



Predictive hohlraum capability (1981)

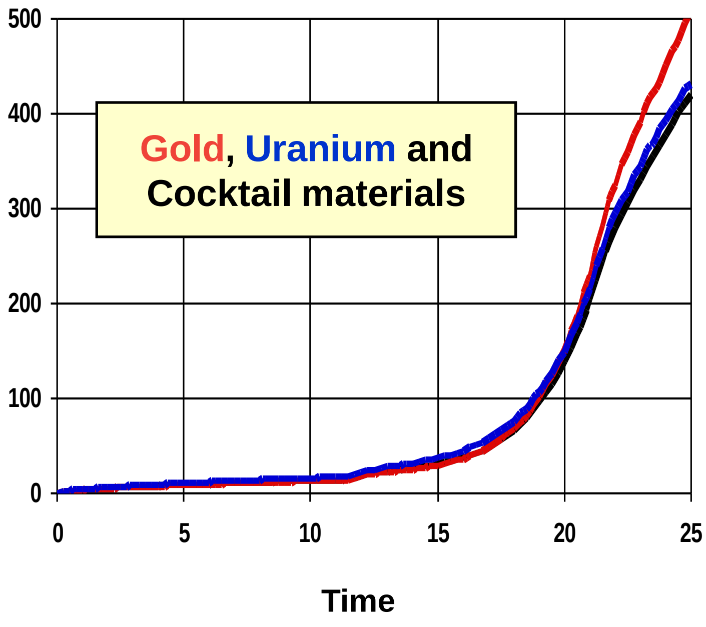


Complex hohlraums with baffles (1982)

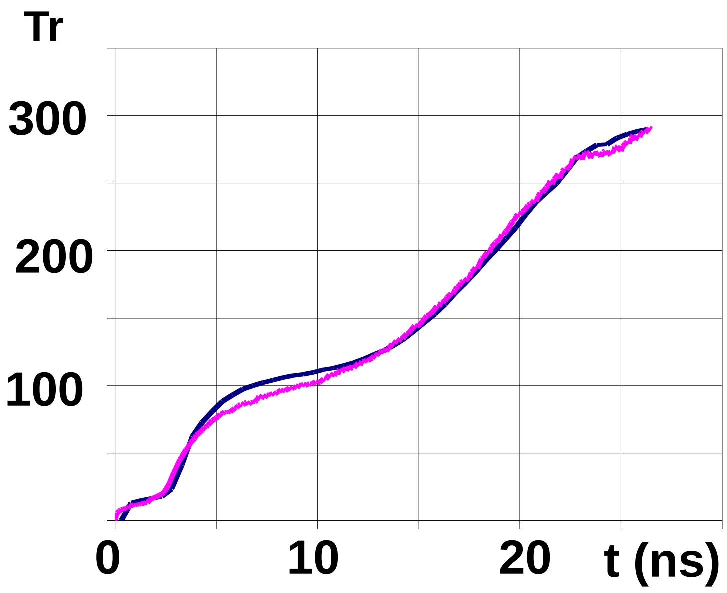


'Cocktail' materials for hohlraum wall have been modelled

Wall loss for an experimental pulse shape using Gold, Uranium and Cocktail materials

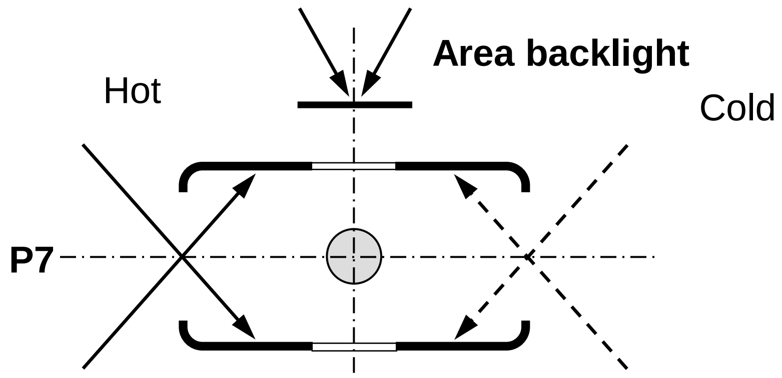


Comparison of 'LASNEX' and 'NYM' showed excellent agreement

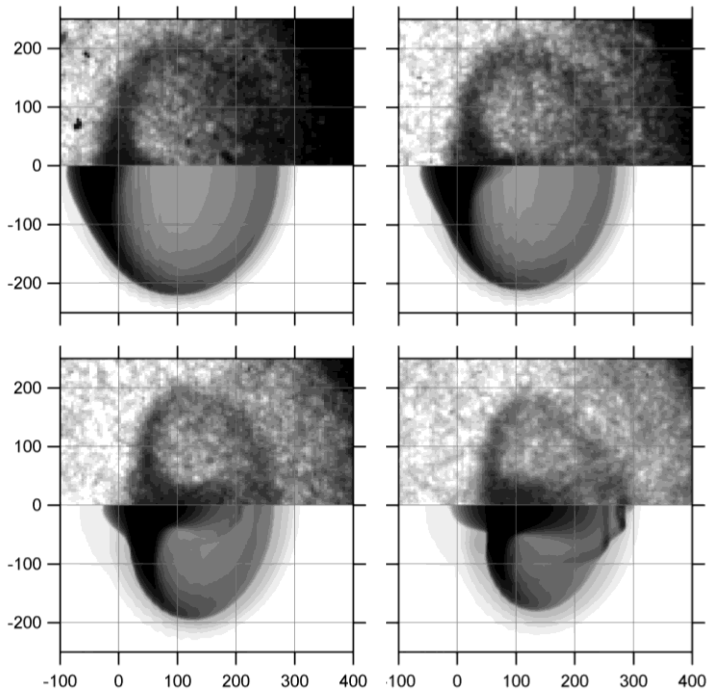


Asymmetric hohlraum campaign at OMEGA

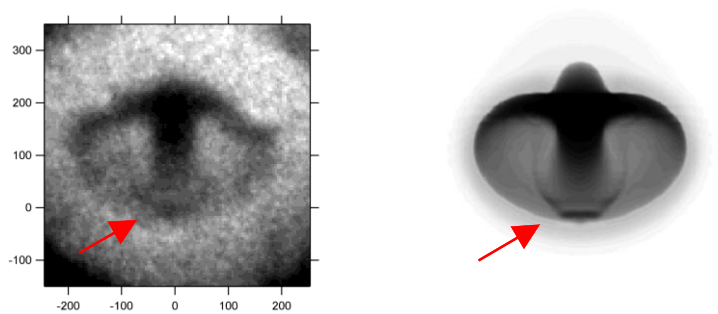
Asymmetric laser drive



Simulation reproduces many features of the experiment



The jet-wall bow shock is just resolved



Existing ICF code has much of the necessary physics capability

NYM Lagrangian ICF code:

- **Hydro**
  - 1D or 2D Lagrangian + SALE, subzone options, various Qs, variable by zone. Conservative.
- **Mix**
  - Fall-line(2D), SpH perturbation, Mixed EoS
- **Data**
  - Tabular data or non-LTE opacity
- **Transport**
  - Multigroup diffusion or IMC
  - Multigroup hot electron & α
  - Monte Carlo neutronics + depletion etc.
- **B fields**
  - grad n x grad T source, Bohm or standard diffusion
  - Magnetic pressure included
- **Links**
  - to Eulerian or ALE codes

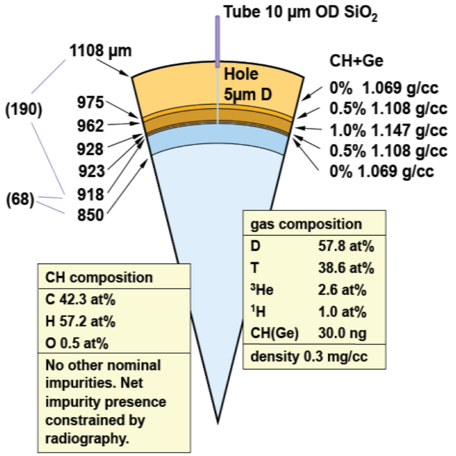
Work is underway to improve ICF modelling and code capabilities

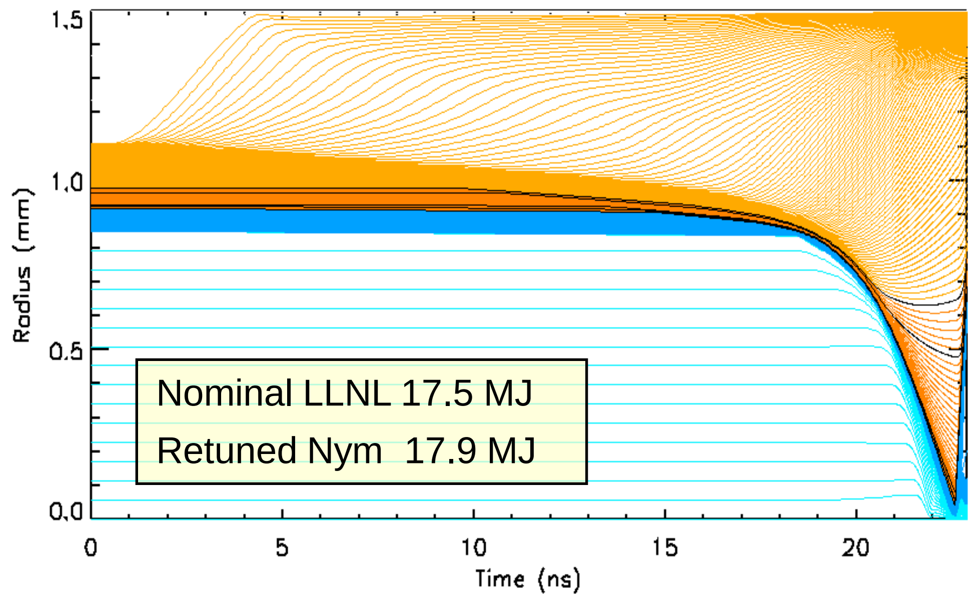
Current status of next generation Corvus ALE ICF code:

Package	**Comments**	**Status**
3T	Necessary for NIC modelling (Integrated hohlraum and capsule-only)	Prototype available now Testing underway
TN burn	Necessary for NIC modelling	Prototype available now
Alpha transport	Necessary for NIC modelling	Prototype available ~ mid CY 11
3D laser	Required for modelling of polar direct drive for HiPER and shock ignition on NIF. Desirable for modelling NIF hohlraums.	In progress Estimate available mid CY 11
Hohlraum physics	Additional physics models to capture LPI in gas filled hohlraums	Not started

Recent modelling demonstrates developing ICF code capability

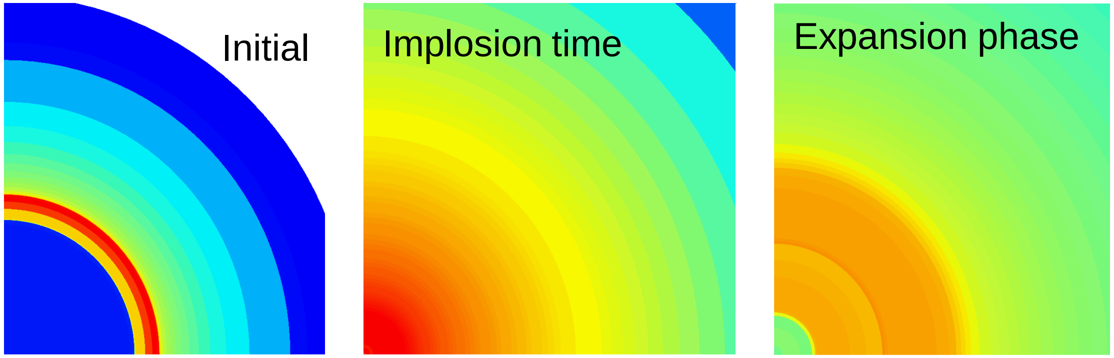
1D capsule-only calculations of the Rev5 CH design give close to nominal performance





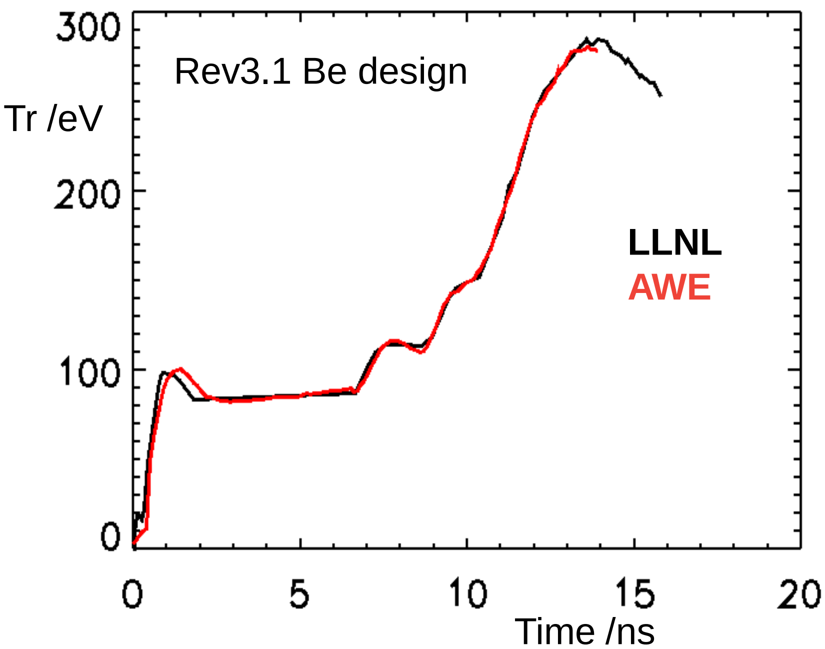
Rev3.1 Be design – density plots

Initial 2D Capsule-only calculations in Corvus (ALE) show excellent implosion symmetry

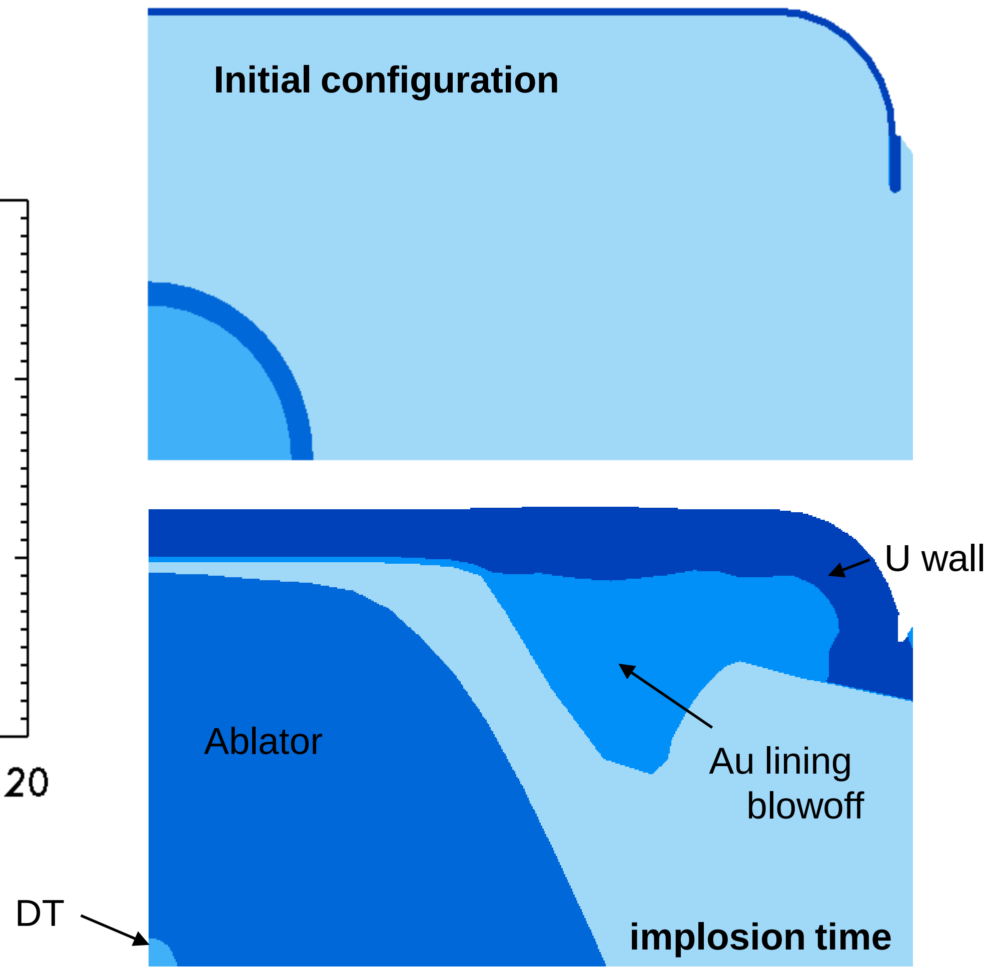


Integrated ICF capsule-hohlraum calculations have now been successfully run for the first time using NYM

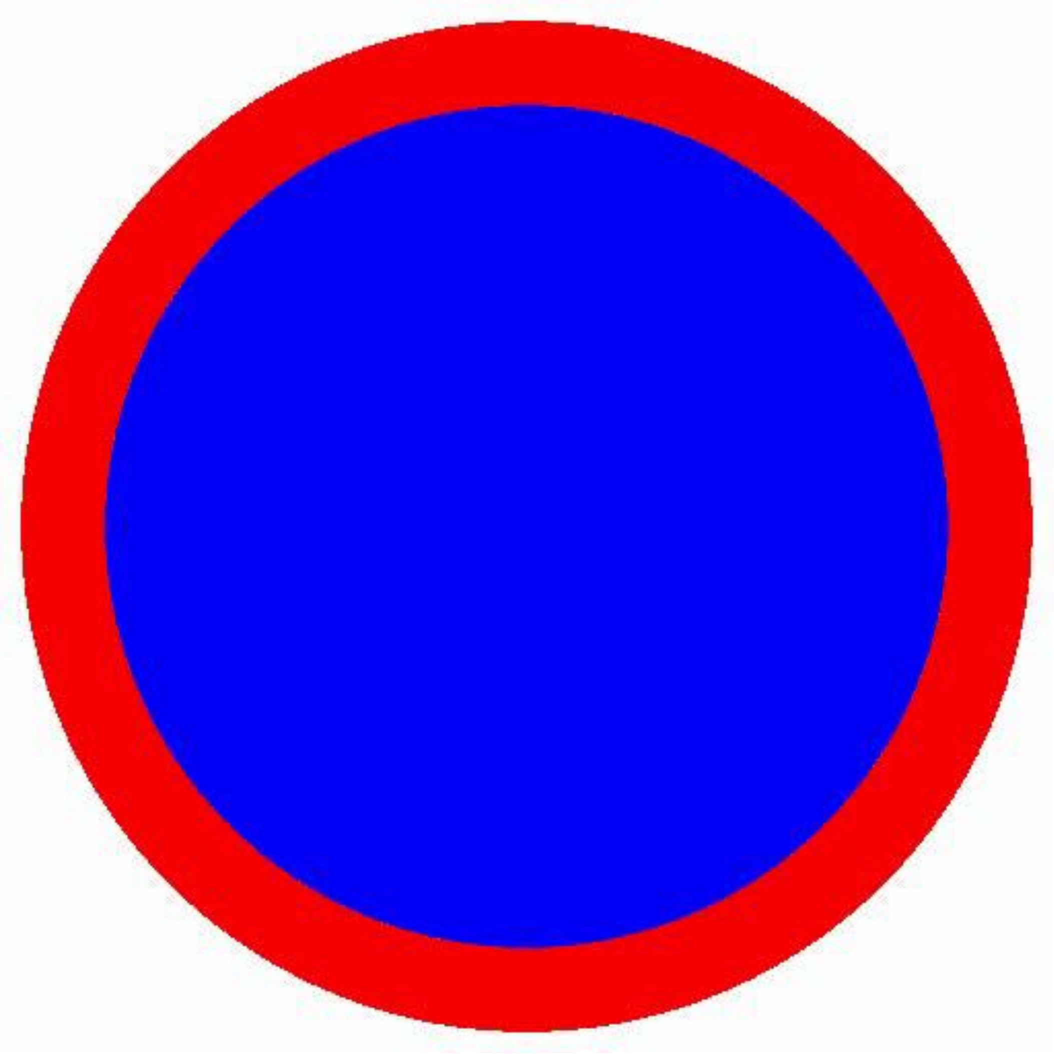
- **2D Lagrangian calculations**
- **Performance agrees well with LLNL calculations**



Material plots



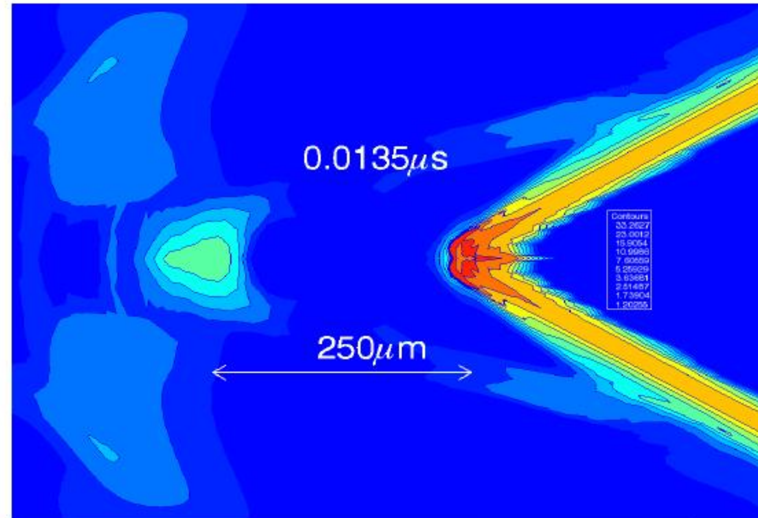
Implosion instability modelling

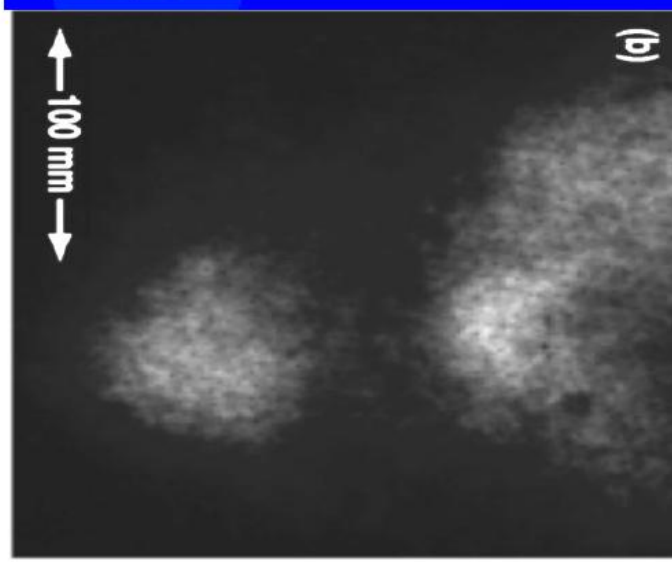


Cone-guided Fast Ignition Simulations (Corvus)

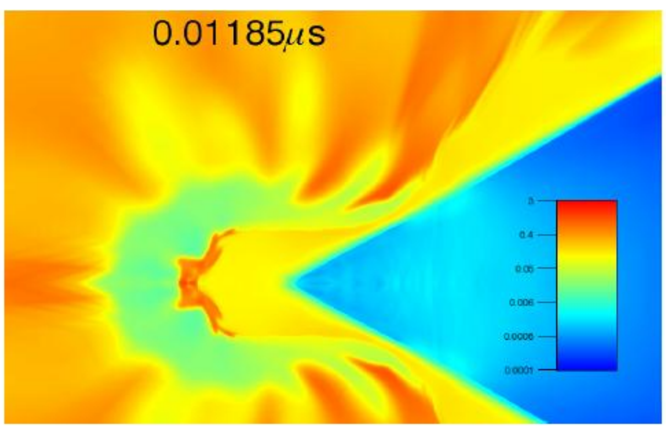
FI Cone - difficult test problem

- High density (~200g/cc) Au shield formed
- Turbulent SP interaction region
- High levels of mix
- Highly asymmetric collapse & RTI

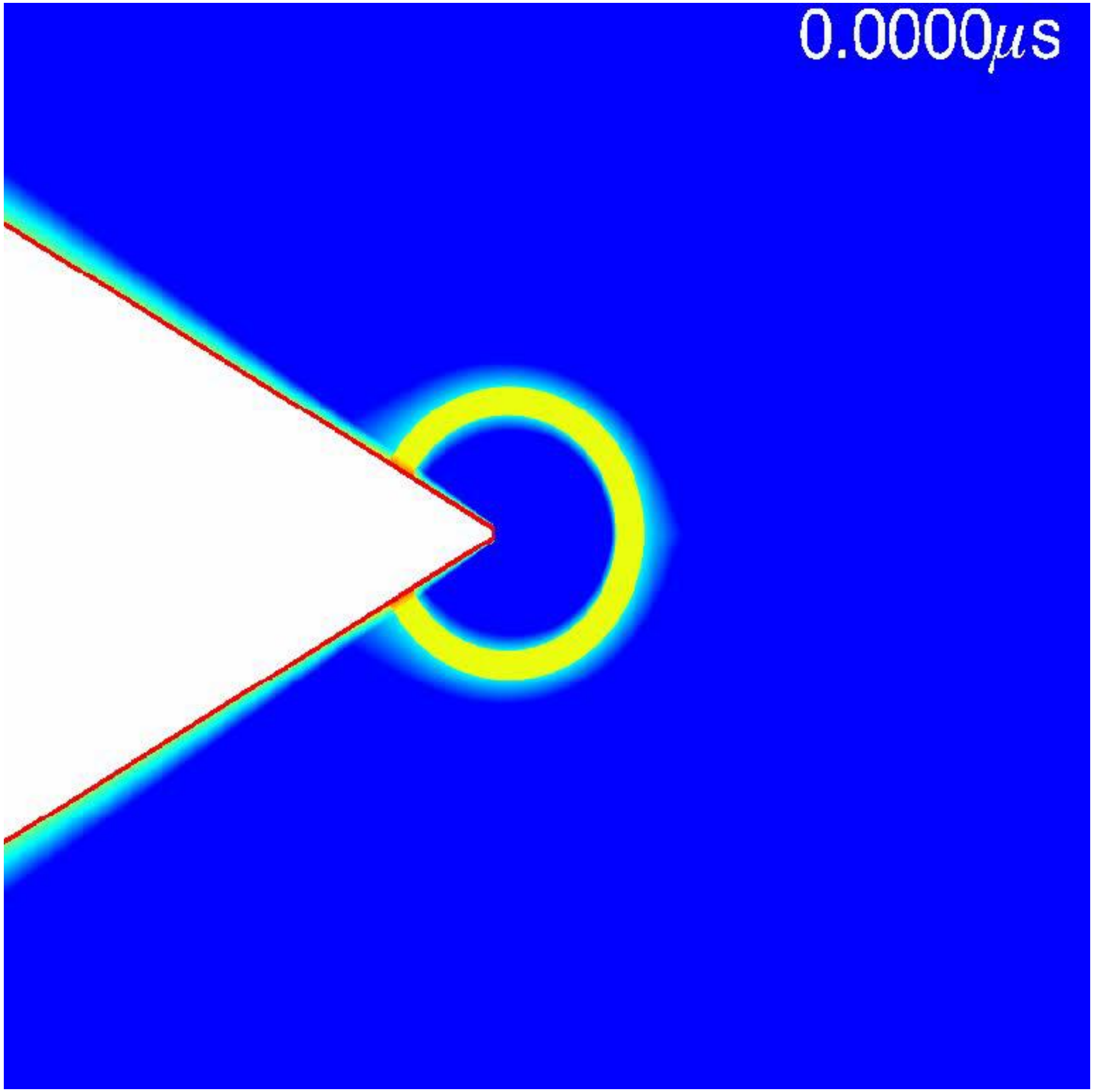




Data from Stephens (LLNL) 2005 PoP **12**, 2005



Cone-guided Fast Ignition Simulations (Corvus)

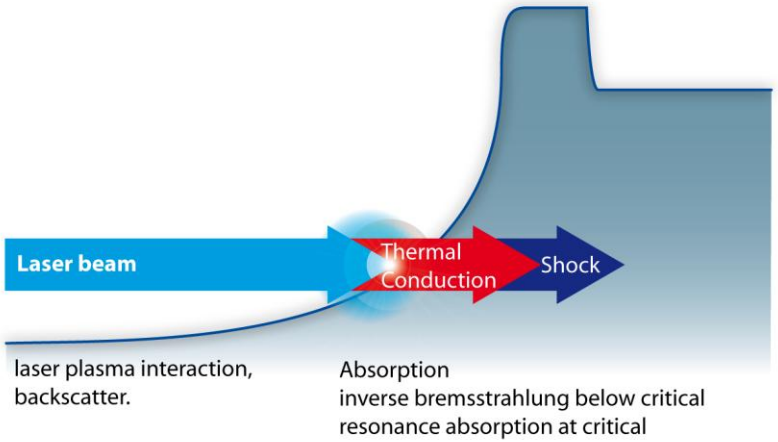


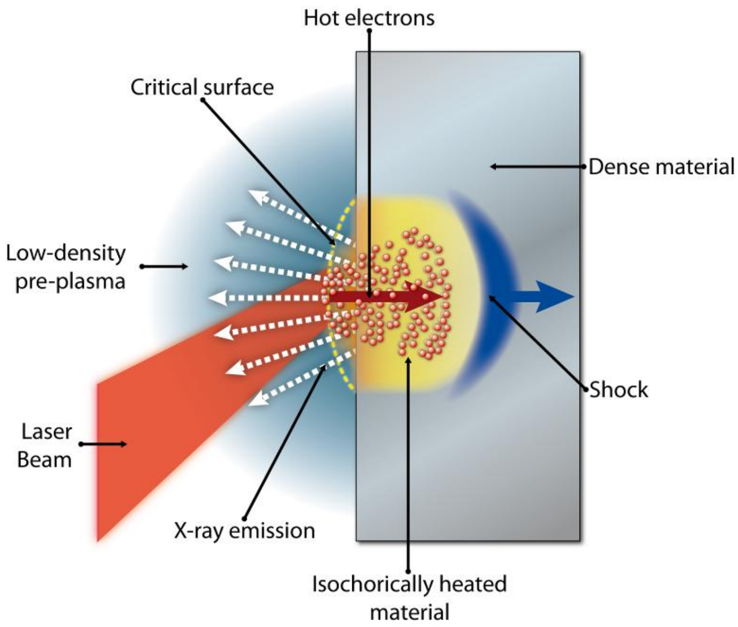
AWE are developing world-leading kinetic modelling capabilities

Kinetic models

- Some key physics of laser-plasma interaction (LPI) occurs below the temporal-spatial scales found in hydrocodes.
  - Parametric instabilities (Raman backscatter etc.)
  - Particle acceleration (e.g. plasma wakefield, and proton acceleration from solid targets)
  - Hot electron transport

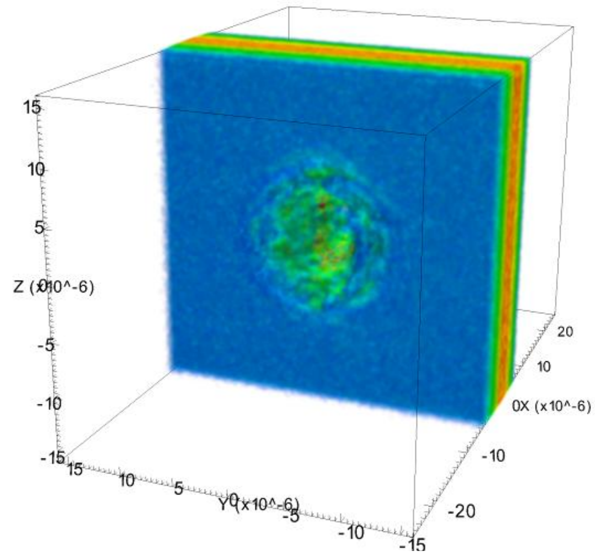
- AWE Plasma Physics applies a number of kinetic codes developed in-house or in collaboration with academic partners, in particular:
  - CIFS (Imperial College London)
  - CFSA (Warwick University)

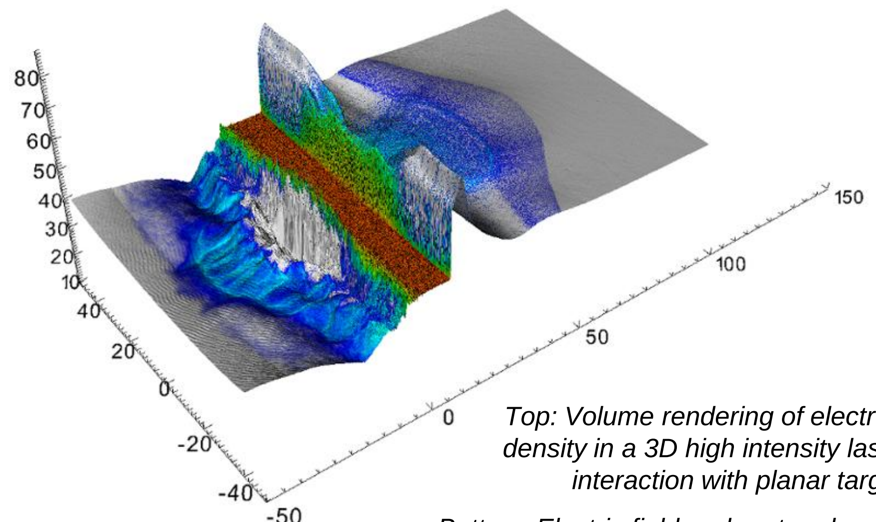




Kinetic models : EPOCH

- UK Plasma Physics code developed as part of an EPSRC Collaborative Computational Project (CCP)
  - Developers at: Warwick; Oxford; Imperial; and AWE.
- An explicit, relativistic particle-in-cell (PIC) code
- 1, 2 & 3D
- Proven scaling on AWE's HPC systems
- FENRIS link code allows initialisation from AWE hydrocodes
- Collisional and hybrid algorithms under development
- Key role: characterisation of hot electron and proton spectra generated in short-pulse LPI

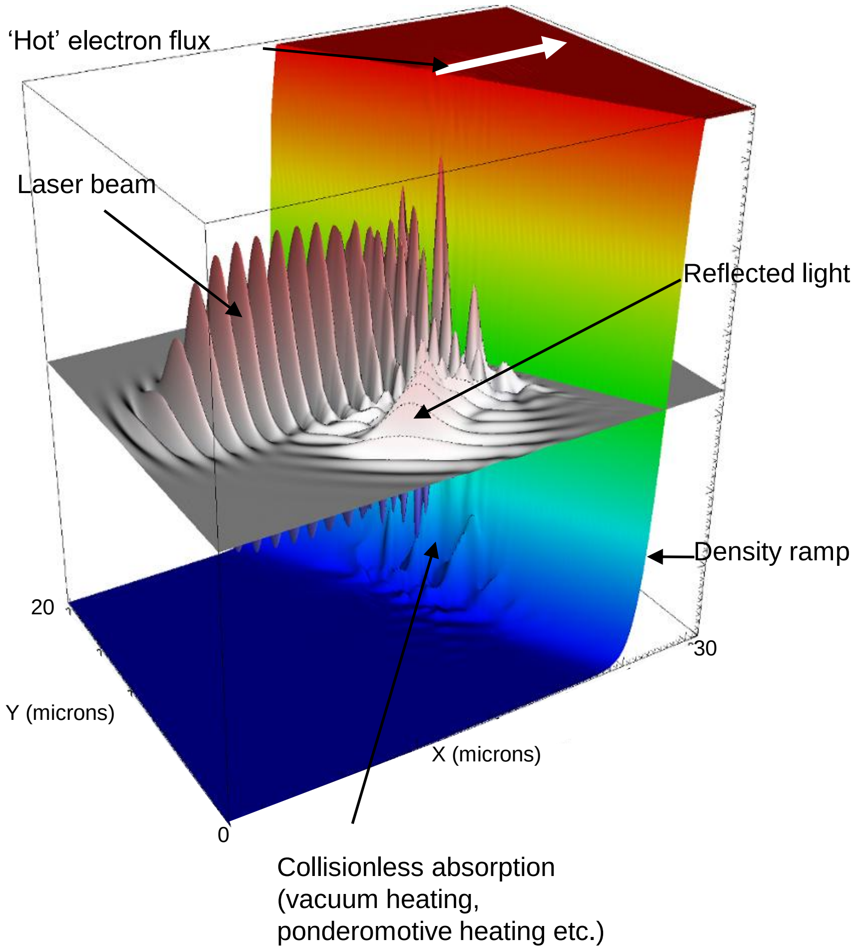




Top: Volume rendering of electron density in a 3D high intensity laser interaction with planar target

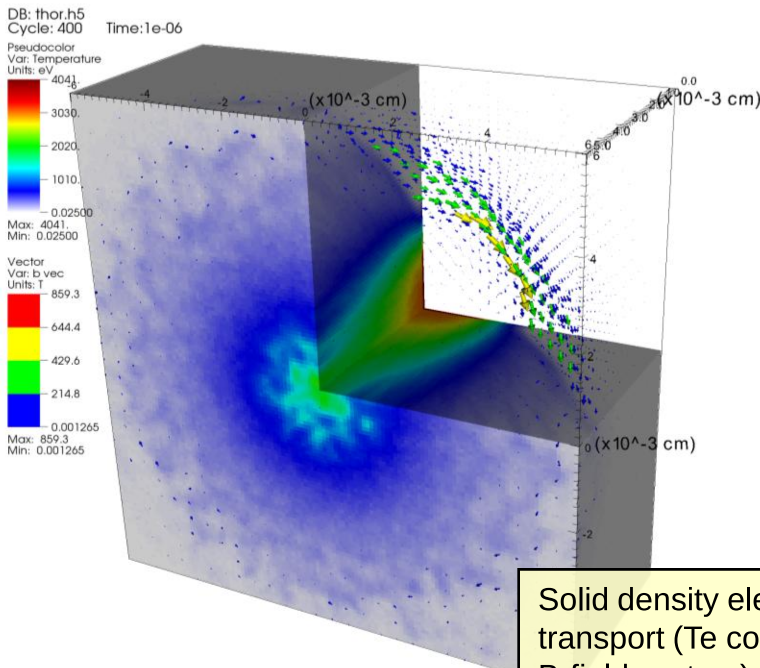
Bottom: Electric field and proton density in a proton acceleration simulation

Kinetic models : VALIS



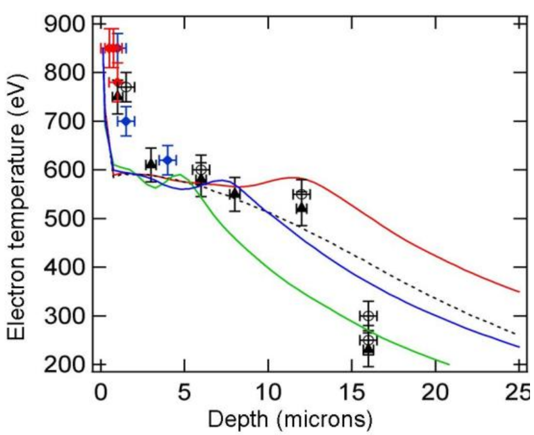
- 2D2P Direct Vlasov Solver
- Explicit, Conservative, Split scheme using PPM advection
- Multi-species (kinetic ions)
- Domain decomposition over 4D (2D2P) phase space
- BGK collision operator
- Key Roles:
  - High fidelity modelling of LPI problems
  - 1D transport problems

Transport Model: THOR

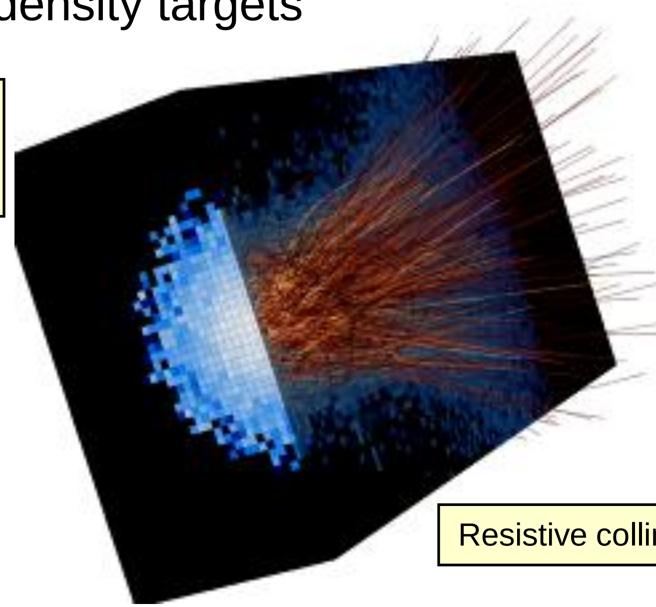


- Hybrid electron transport code
- Monte-Carlo, explicit
- Various EOS/resistivity models available
- Ionisation effects included
- Linked to CORVUS 2D ALE hydrocode
- Model hot electron heating of high density targets

Solid density electron transport (Te contours, B-field vectors)



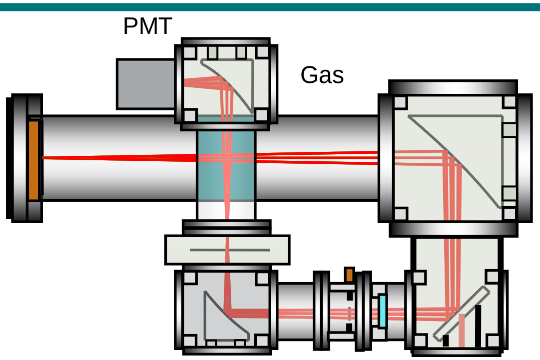
HELEN buried layer heating experiments

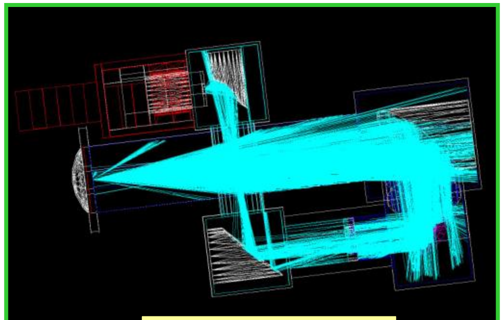


Resistive collimator

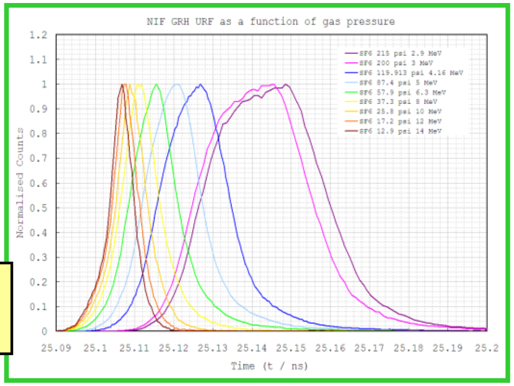
Collaboration on NIC burn diagnostics

- Working on GCD, GRH and nToF development at OMEGA and NIF with LANL, LLNL and LLE
- Using Geant4, (a particle tracking code from CERN), to model the performance of these diagnostics
- AWE and STFC are funding research into CVD diamond detectors in partnership with Photek, Bristol/Leicester Universities and RAL to improve GRH temporal response
- AWE perform P.I. role on LLNL/LANL DT-ratio experiments developing GCD at OMEGA





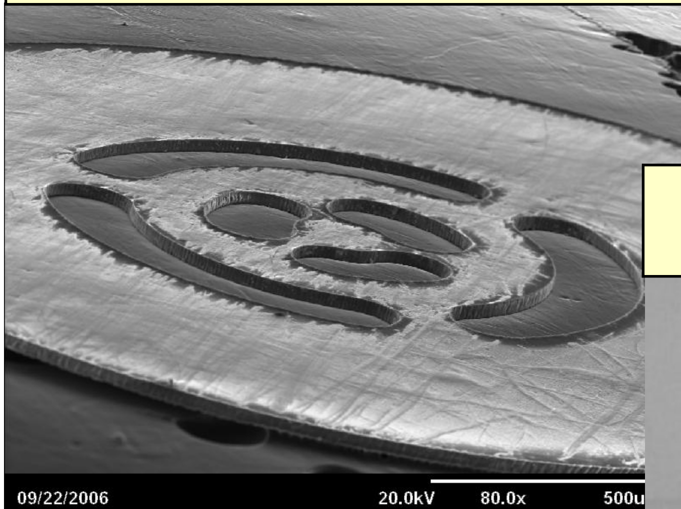
Model of GRH

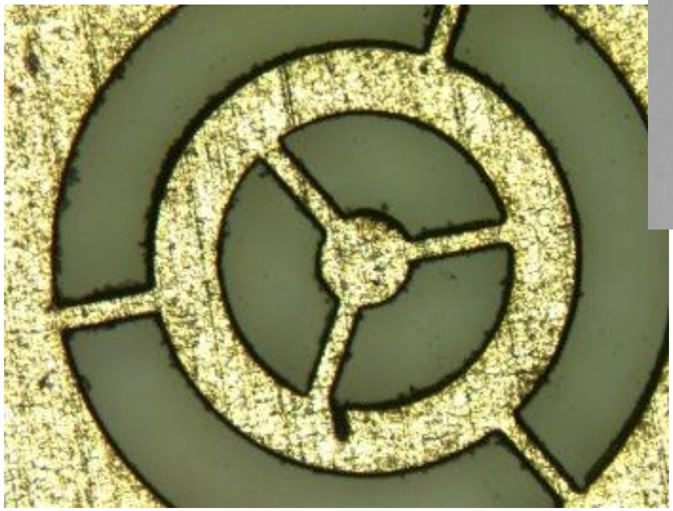


GRH at NIF temporal response variation with gas pressure

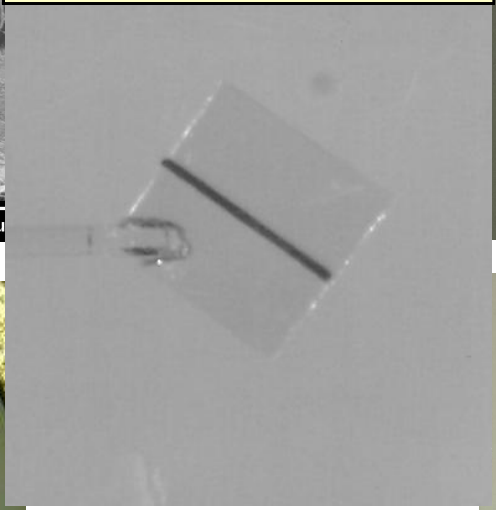
AWE have an experienced in-house target fabrication capability

Laser micro-machined foams

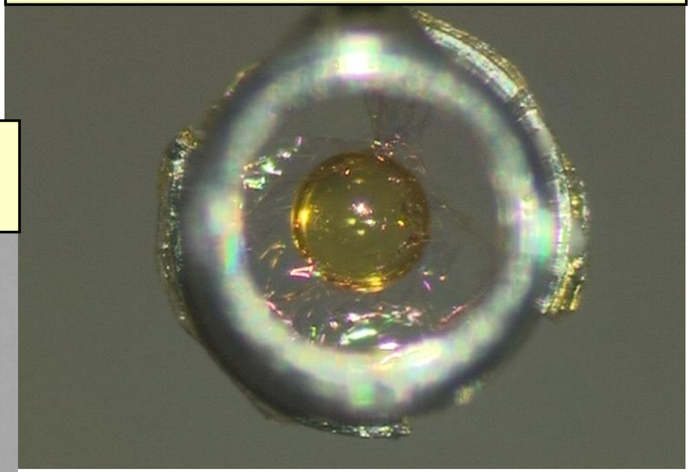


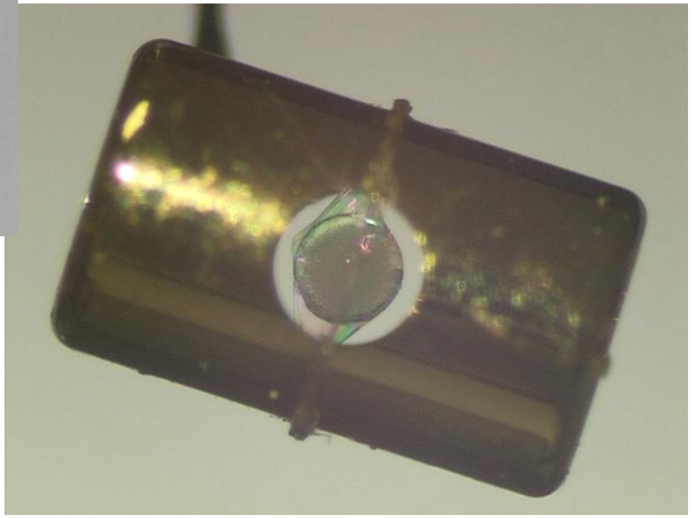


OMEGA EP high energy backlighter microwire

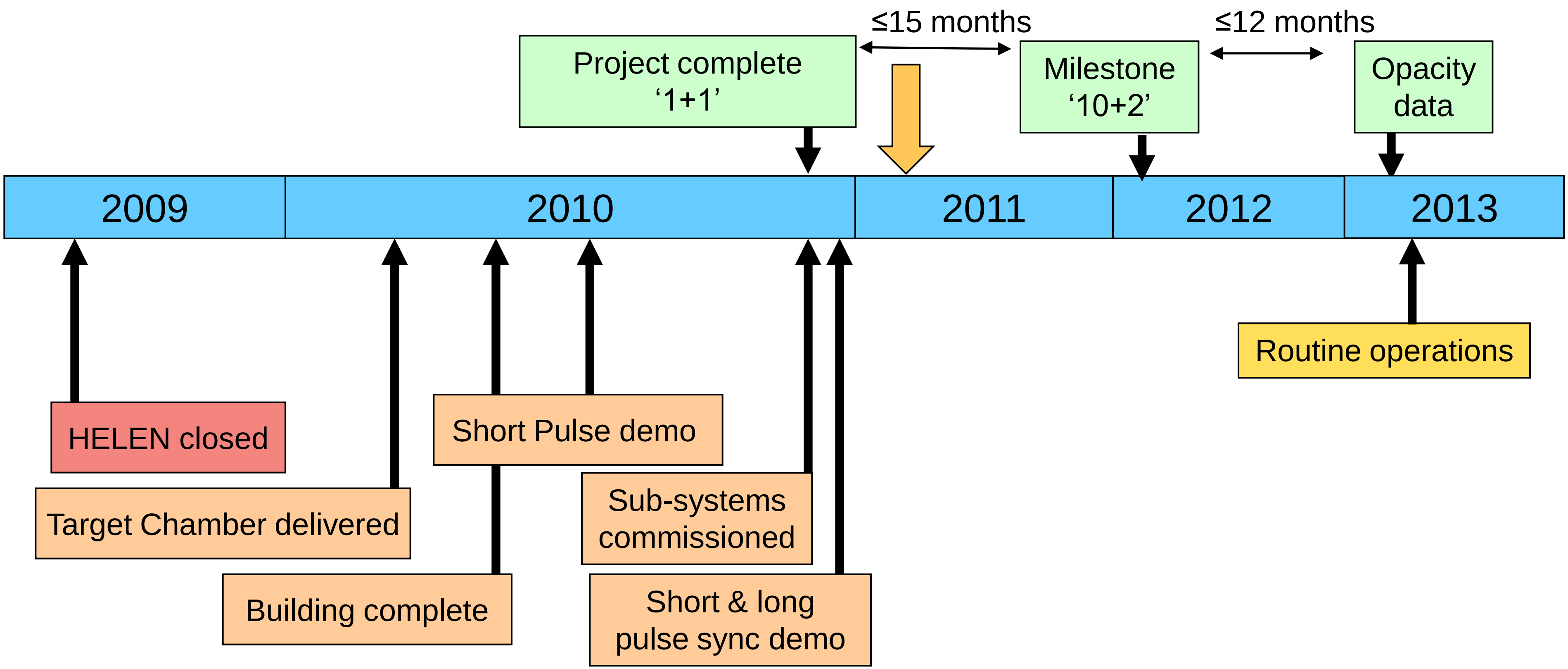


OMEGA asymmetric-hydro hohlraum and capsule





ORION Timeline



Summary

- NIF progress good and overcoming issues; key dates are IFSA (Sept 2011) and the ignition milestone (Sept 2012)
- The use of High Power Lasers at AWE to exploit indirect drive dates back about 40 years
- Collaboration with the US has been mutually beneficial throughout
- There has been no funded IFE programme but there is a strong synergy with the core programme (ignition etc.)
- AWE is keen to support the NIC & IFE efforts but there are resource issues