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Computational challenges in modeling the physics of ICF ignition scale hohlraums & ICF implosions

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My principal collaborators in the material presented here:

- **H. Scott, D. Callahan, D. Hinkel. R. Town, E. Williams, L. Suter, N. Meezan, J. Lindl, J. Edwards, N. Landen, C. Thomas, R. Olson, D. Hicks, P. Springer, C. Cerjan, O. Jones, G. Zimmerman, J. Harte, P. Michel, L. Divol, J. Kline, G. Kyrala, M. Schneider, C. Li, W. Kruer, E. Dewald, R. London, J. Moody, S. Dixit, J. Castor, S. MacLaren, and J. Hammer**

The entire NIC team for their all of their hard work and incredible accomplishments

And for their support & encouragement, my thanks to:

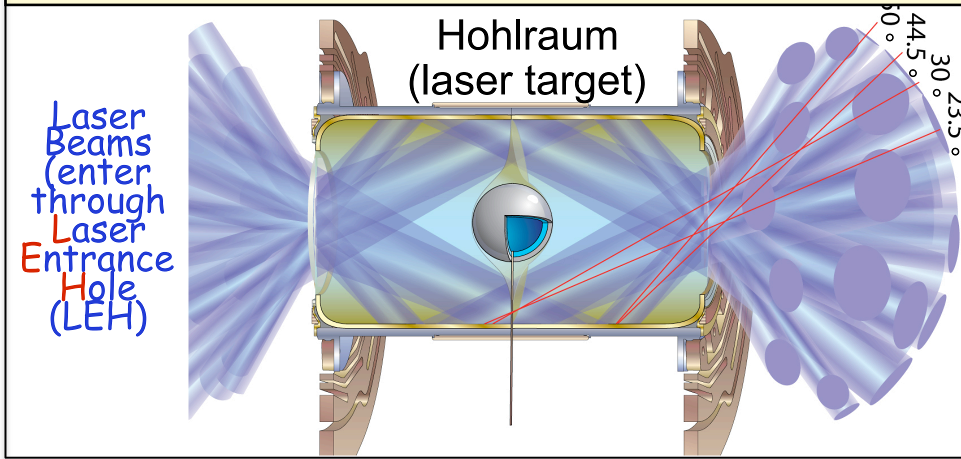
- **E. Moses, J. Atherton, B. MacGowan, D. Pilkington, C. Verdon, B. Goodwin, and J. Nuckolls**

Abstract:

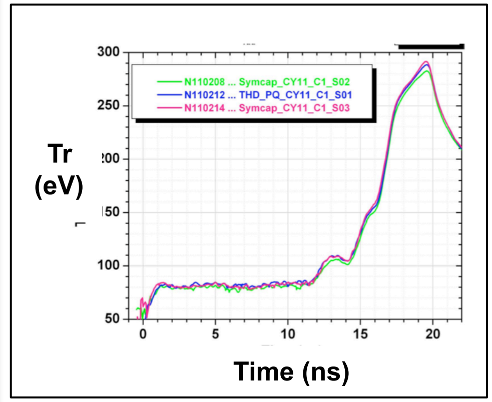
We present an overview of computational modeling issues encountered when we analyze data from the National Ignition Campaign (NIC). Challenges include the need for precision as we proceed into scale lengths ~ 4x larger than previous experience. Plasma conditions are governed by non-linear and non-local processes of electron heat and radiative transport. Both non-LTE high Z atomic physics and Laser Plasma Interactions (LPI) affect the plasma conditions which, in return, then affect them both. All of the above "non-easy physics" can also lead to non-Maxwellian particle distributions. Implosion dynamics with low Z ablators doped with high Z materials is a challenge in 1-D, and certainly in 3-D, given the likelihood of (possibly non-linear) hydrodynamic instabilities and mix. The NIC empirical tuning campaign to reach ignition could benefit from having improved understanding of the current experimentally measured target performance. Improved computational modeling is likely to contribute to that understanding.

The National Ignition Facility, the world's most powerful laser, is on the path to ignition

<u>Coupling:</u> laser energy couples to hohlraum and converts to x-rays



<u>Drive</u>: x-rays bathe capsule, heating it up - it then expands



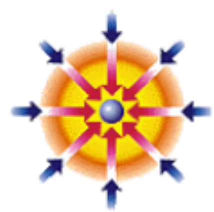
Ablator heats up

<u>Symmetry:</u> A radiation driven "rocket" compresses capsule and then it implodes

Rocket effect

- <u>conservation of momentum</u>: ablated shell expands outward, rest of shell (frozen DT) is forced inward

<u>Fusion</u> initiates in a central hot spot and a burn front propagates outward



Ignition

Burn wave

The questions we seek to answer:

Since NIF / NIC operates at unprecedented scales,

— E_L ~ 40x any previous laser

— Target scale size ~ 4x any previous target

& since ignition requires very tight specs* on accuracy and precision,

1) What excursions beyond these tight specs should we expect, as we extrapolate from the previous data base derived at the smaller scales ?

— Will these excursions still leave us in the "tunable" regime?

2) What computational advances are required to help us accomplish these goals?

*Haan, Lindl, Callahan et al PoP 051001 (2011)

The plan has always been to reach ignition via an empirical tuning campaign, informed by simulations:

Ignition at ~1.8 MJ requires tight specifications on accuracy and precision

- The NIF has shown that it is impressively up to this task
- Target fabrication has also progressed admirably
- BUT the physics uncertainties of target design lead to the need for this empirical tuning approach

Before NIC began (for real), we ran* a Red Team / Blue Team (virtual) exercise

Red Team phase 1: Change the physics model

Made the point design fail … & a re-design that worked

Red Team phase 2: Play the role of NIF

Virtually shoot the targets proposed by the Blue Team

Return synthetic data to Blue team

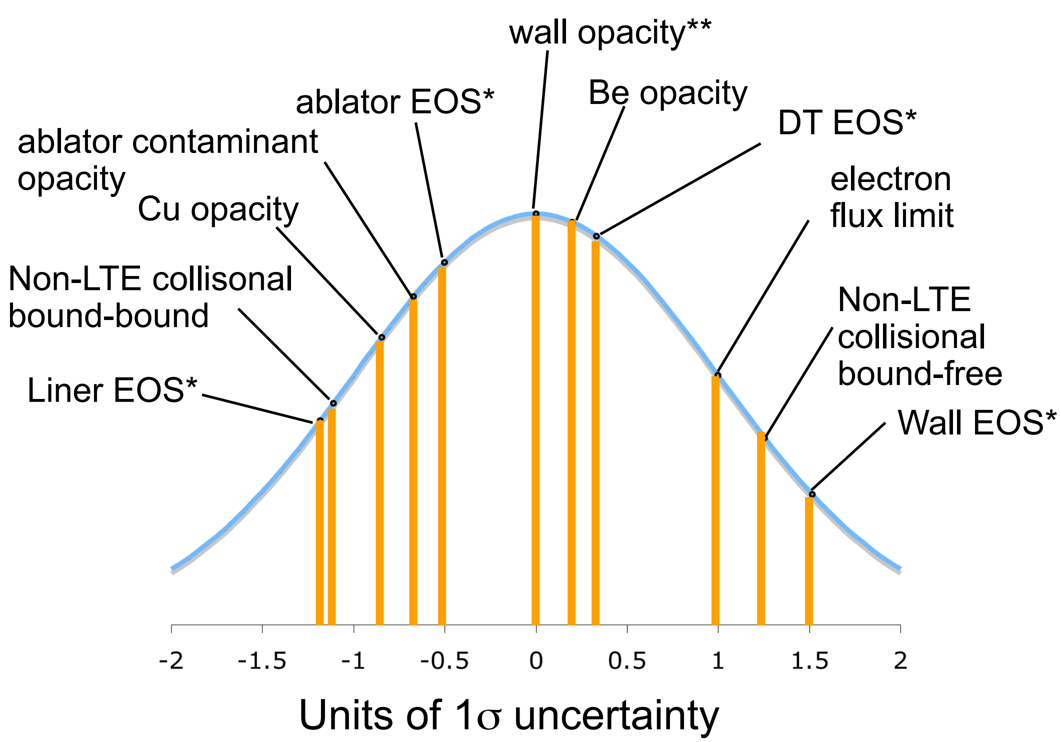
Blue Team : Go through a tuning campaign

Get ignition, despite using the "wrong" physics

*Rosen, Edwards, Suter et al IFSA 2009

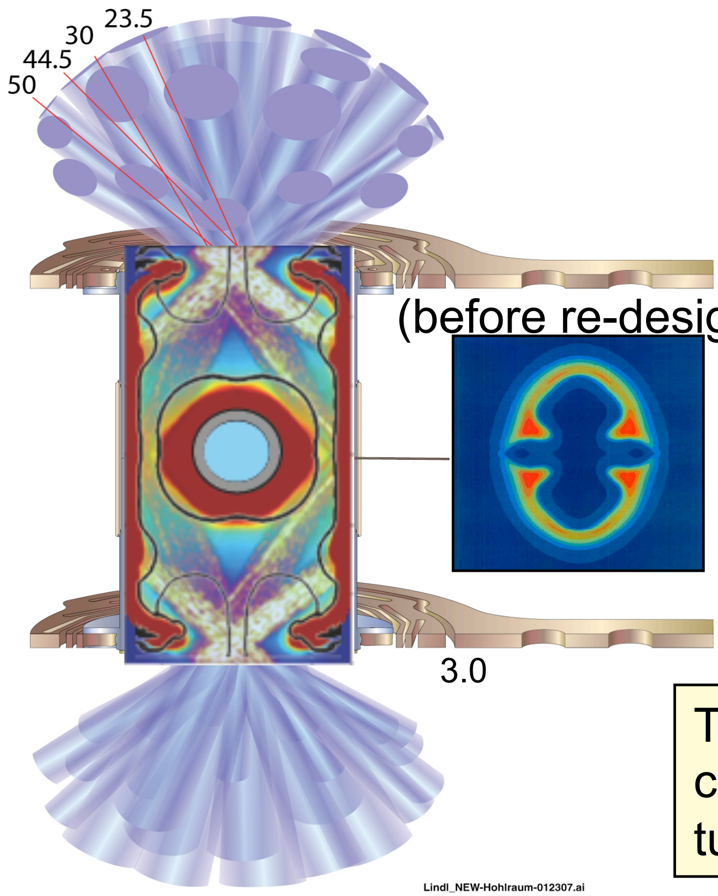
The Red Team developed an alternate 2D target physics reality based on model uncertainties estimated by subject matter experts

A roll of the dice determined the model "off-set" compared to the standard (blue team) model



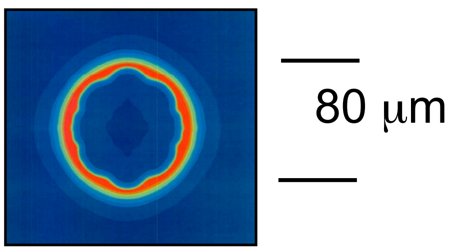
Note the multi-scale offline / reduced-description in-line nature of these issues

The point design target failed to ignite after the red team physics was introduced: It needed re-design



(before re-design)

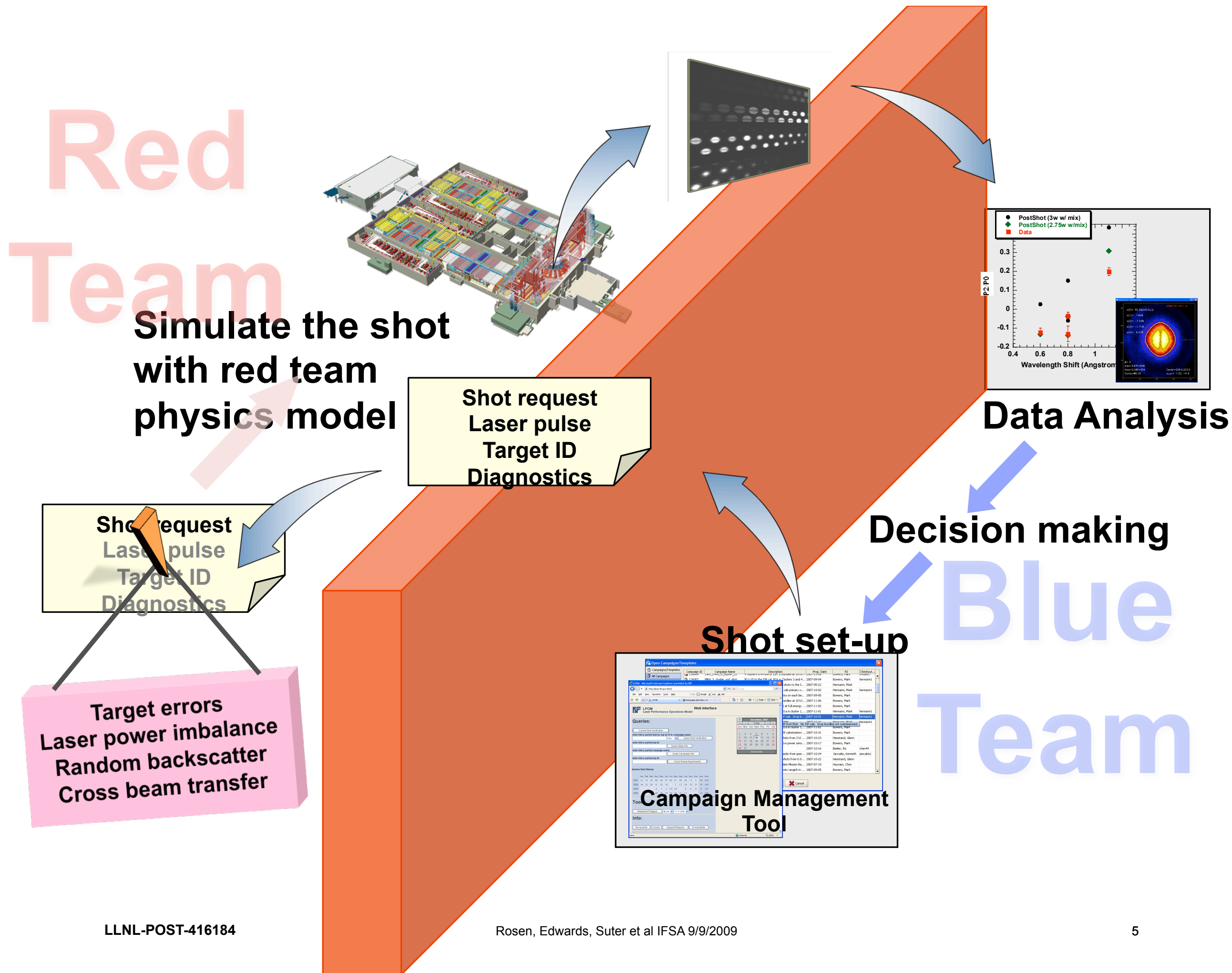
(after re-design)



After re-design, (laser pulse(t), laser pointing, etc) the “red team” target had good performance / ignited

The Blue Team did not know what physics changes were made, so they could only re-tune “experimentally”.

The virtual tuning campaign lasted 30 shots…



…and culminated in ignition

From virtual reality we now turn to reality…

In the summer of 2009 full NIF began shooting hohlraums

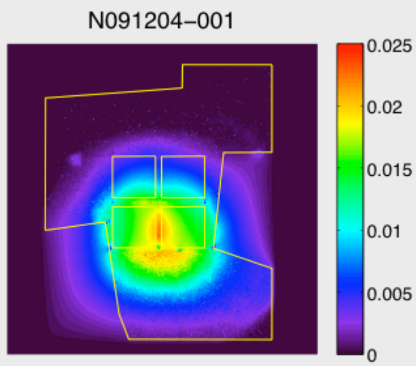
NIF / Mother Nature puts the Red Team out of business

Can “Blue Team” physics be close enough to tunability to reach ignition? What improvements in computational models can help?

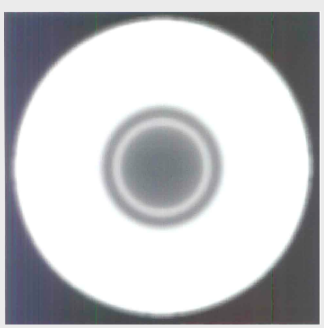
In this talk, (after some basic background material is presented first) , we will trace what we have learned about these questions since that time.

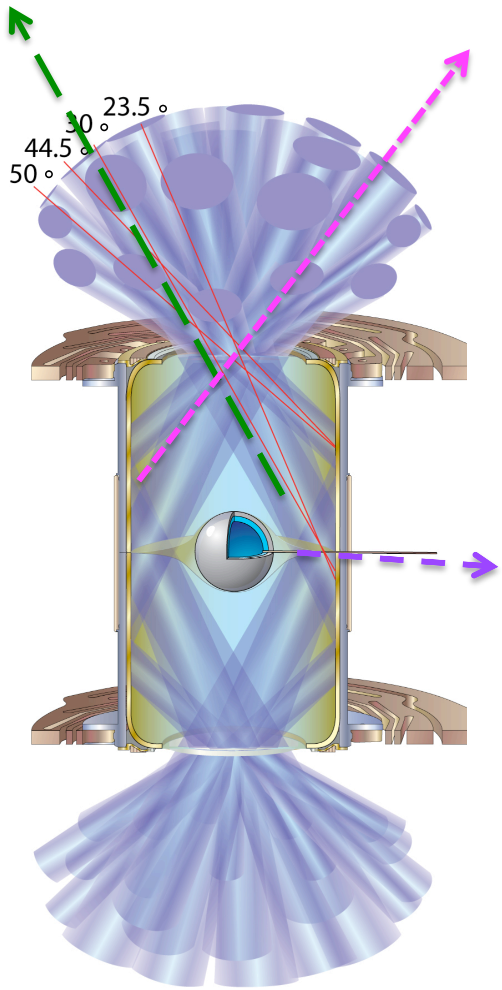
An ignition-scale hohlraum must provide good Coupling, Drive, & Symmetry

Coupling: LPI must be low enough, so that enough energy is available for drive

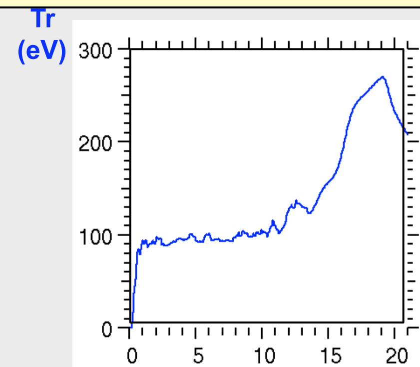


Coupling: LPI must be low enough, so hot electrons do not pre-heat the target

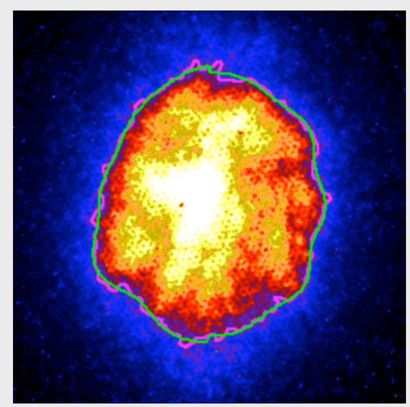




Drive: Must be high enough to implode a stable shell fast enough to get hot & ignite



Symmetry: Must be round enough at high convergence to get dense & ignite



To be reasonably close to expectations, and be in a tuning regime, we'd like to know the plasma conditions:

We'd like to know the hohlraum's n, v, T_e, T_R, Z, I_L vs. space and time

- For Laser Plasma Interactions (LPI)
- For beam propagation & symmetry

Modeling challenges include:

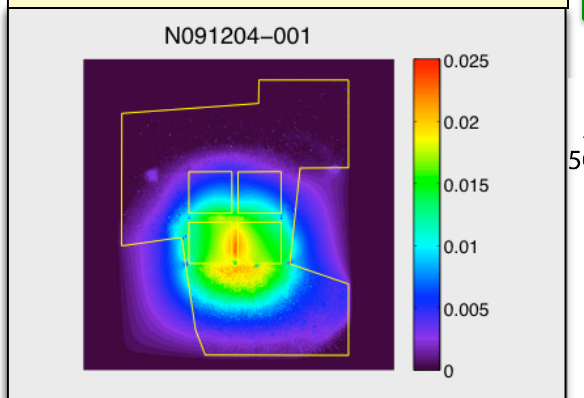
The long pulse laser propagating through:

- The high Z walls moving into the large gas filled hohlraum
- Ablator dynamics that contribute to the hohlraum plasma
- The evolving laser entrance hole (LEH)
- Non-LTE high Z atomic physics
- Non-local electron transport
- Hot electrons production and transport

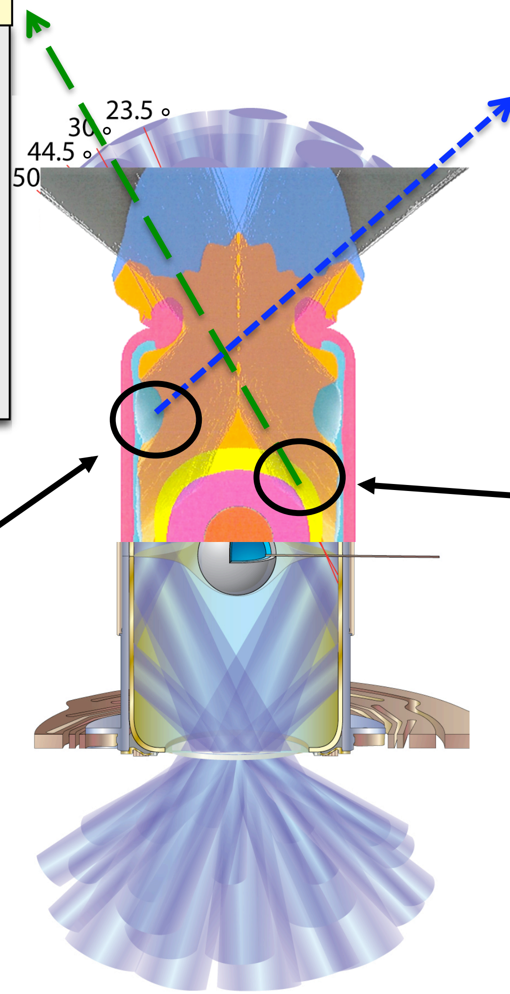
Then comes the LPI issues in that large plasma medium…

Coupling: Stimulated scatter within the hohlraum can lead to energy loss: incoming laser reflects back out

Coupling: LPI must be low enough, so that enough energy is available for drive



LPI Gains ~ $(n\, I_L / T)\, \underline{L}$



SBS of outer cone beams in "gold bubble": Laser reflects off of ion wave

SRS of inner cone beams in fill-gas & ablator blow-off: Laser reflects off of electron plasma wave

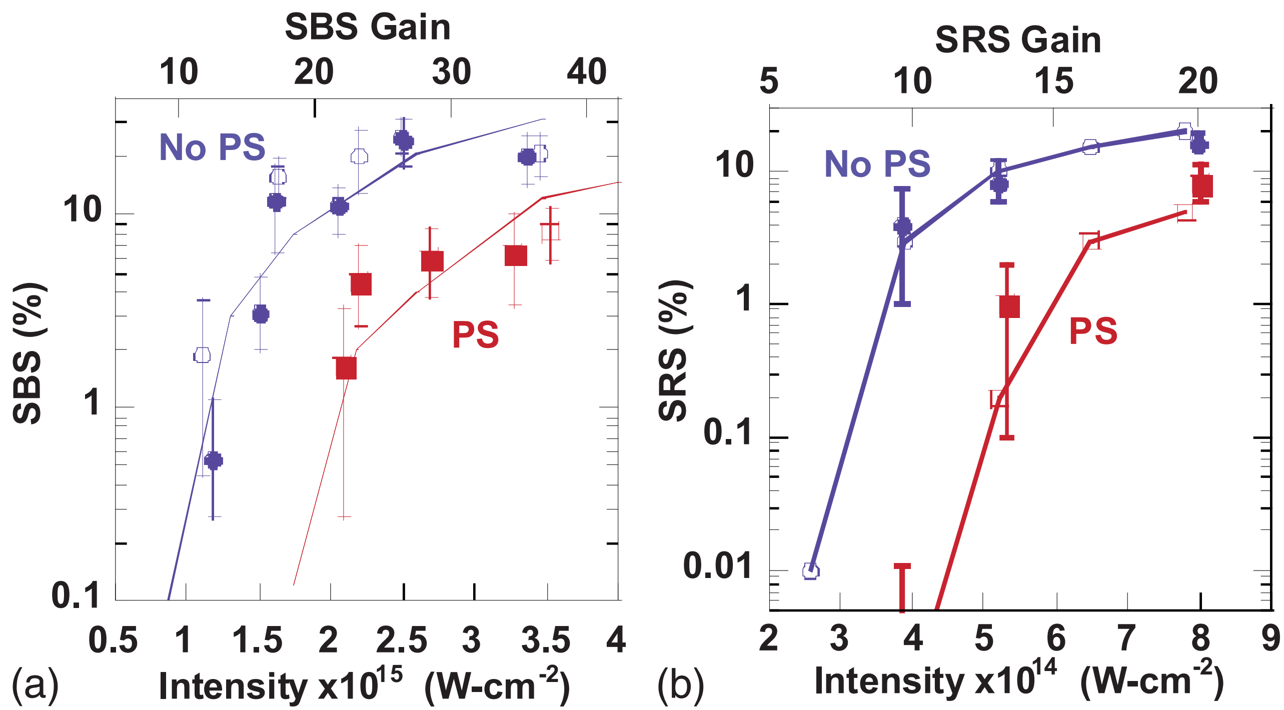
Besides reflecting the incident power, that plasma wave also makes hot electrons

Smaller scale experiments at Omega helped validate the theoretical tools that evaluate / predict LPI

Great care taken to create & characterize uniform plasma

Solid lines: pF3D

(PS = Polarization Smoothing)



Froula, Divol, London et al PoP 056302 (2010)

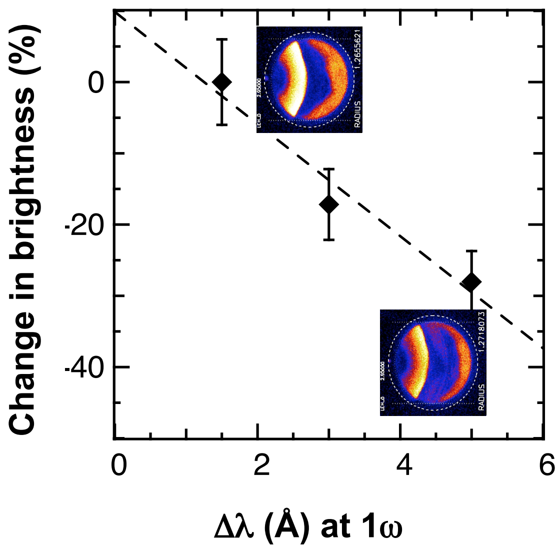
In NIC hohlraums multi-beam overlap and non-uniform cross-beam transfer complicate the "L" in LPI.
The plasma conditions, "P", in NIC need to be known

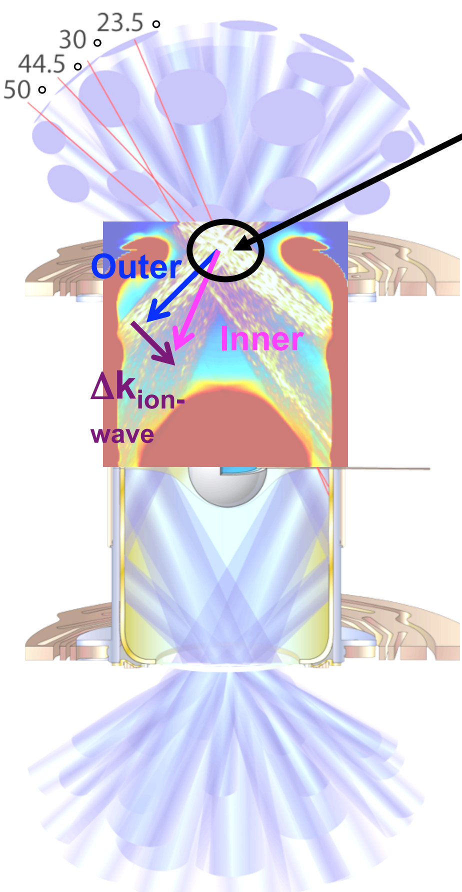
Symmetry: requires a controlled energy balance between the inner and outer beams

We use a plasma-optical-switch, & transfer energy from outer to inner beams by increasing $\Delta\lambda = \lambda_{inners} - \lambda_{outers}$

Direct evidence of the effect:

Outer beam brightness diminishes vs. $\Delta\lambda$





The beams transfer energy to one another via forward (Brillouin) scatter from ion acoustic waves

For symmetry & LPI we need to accurately calculate the beam propagation :

Inverse bremsstrahlung (= collisional) absorption:

$\sim (Z\, n / T^{3/2})\, \underline{L}$

Symmetry: requires a controlled energy balance between the inner and outer beams

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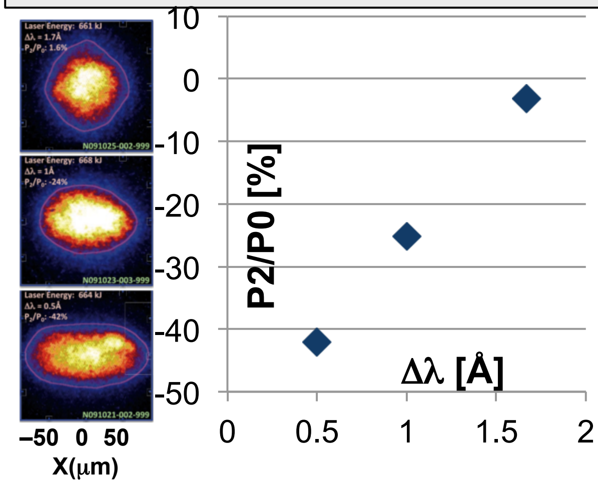
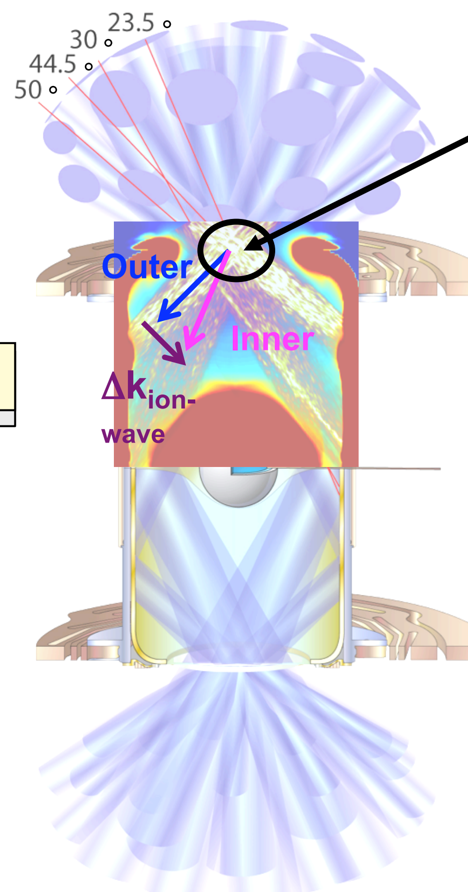
Indirect evidence of the effect, with very useful implications:

NIC '09 9 keV Capsule emission





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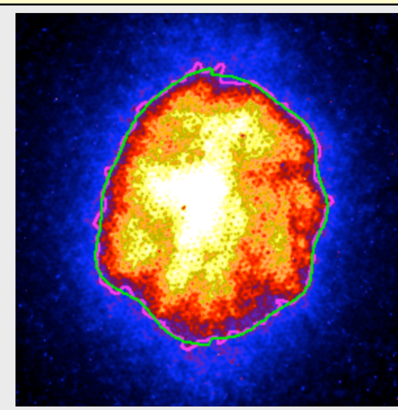
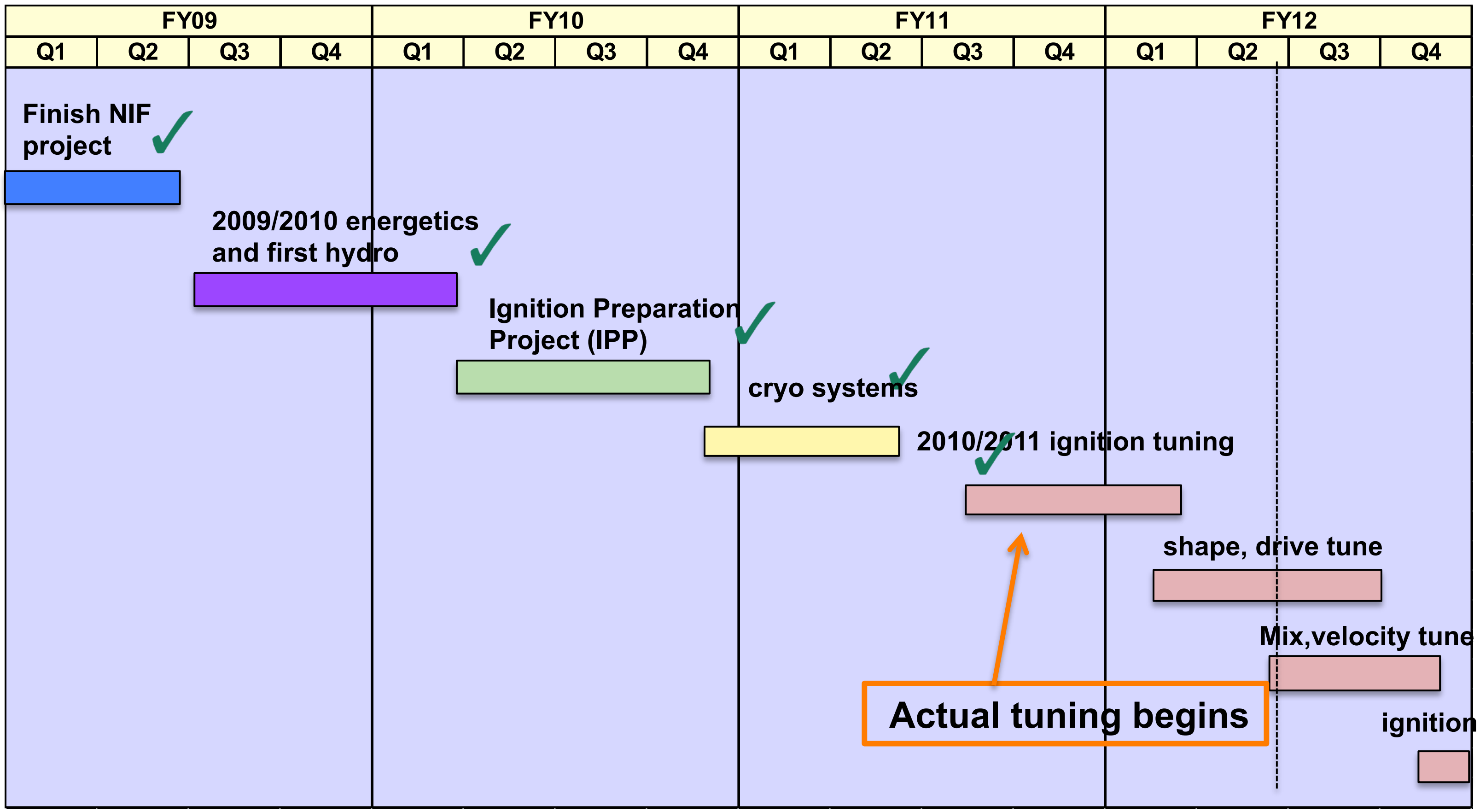
Symmetry: Must be round enough at high convergence to get dense & ignite



The "actual" NIC tuning campaign is ~ 10 months old



So far, in each phase of the NIC, we have encountered excursions from expectations that we have overcome:

2009 Energetics Campaign:

- Inconsistencies in SRS spectrum & offset of implosion symmetry
- A "High Flux Model" (HFM) with better physics,
  - Better suited to the long scale plasma emission
  - Led to an improved hohlraum, which is now in use

2010 Target Cryogenics Campaign:

- Inconsistencies in target performance & ice layer quality
- Moved rapidly up the technological learning curve

2011 Tuning Campaign

- Finding the actual time dependent symmetry, adiabat, & r(t), v(t)
- Adjusting laser powers, pulse shape, pointing, ablator dopant etc while using the improved hohlraum

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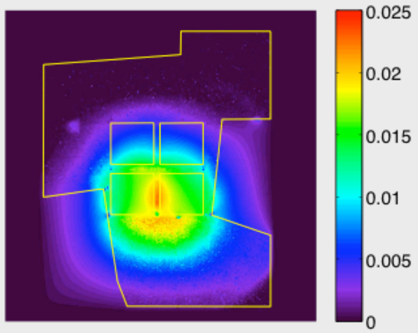
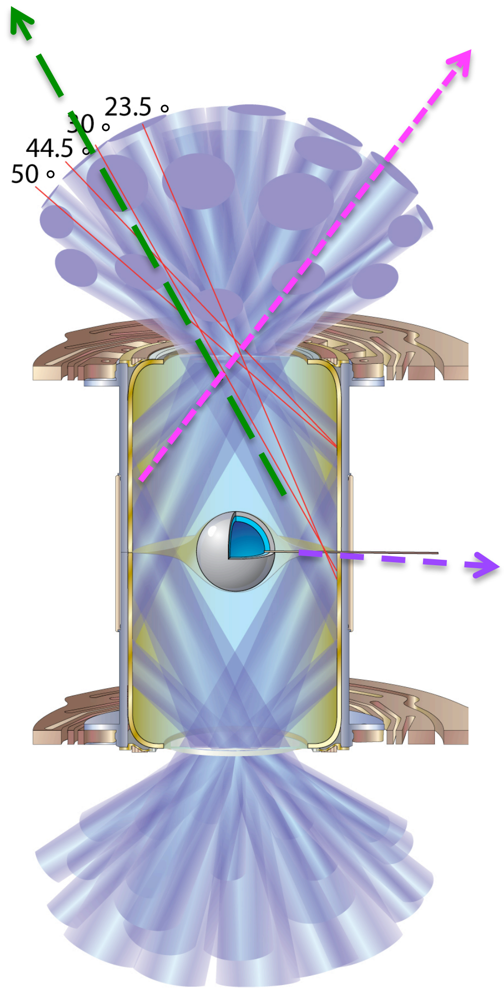
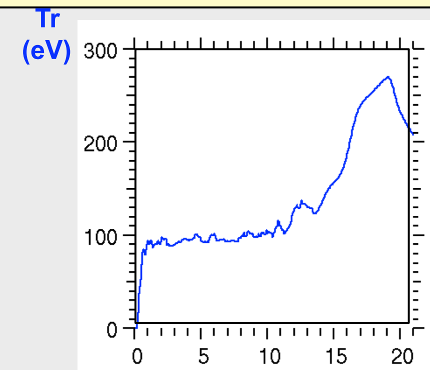
The Dec. '09 1 MJ shot provided very good Coupling, Drive, & Symmetry…

Coupling: ~ 90% of incident laser stayed inside the hohlraum

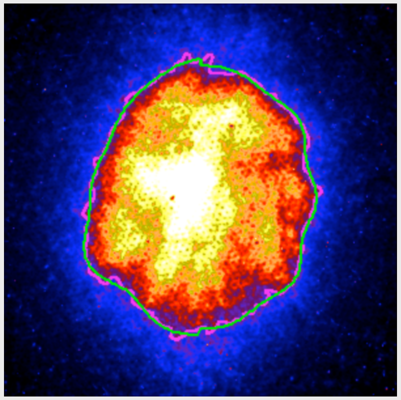




Drive: ~ 285 eV which is already quite close to that needed for ignition



Symmetry: To within ~ 10% of round, and tunable via $\Delta\lambda$



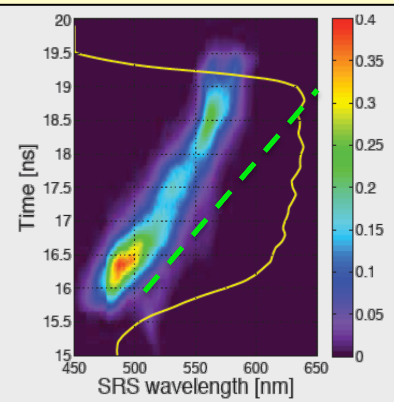
S. Glenzer et al., *Science* 327, 1228 (2010)

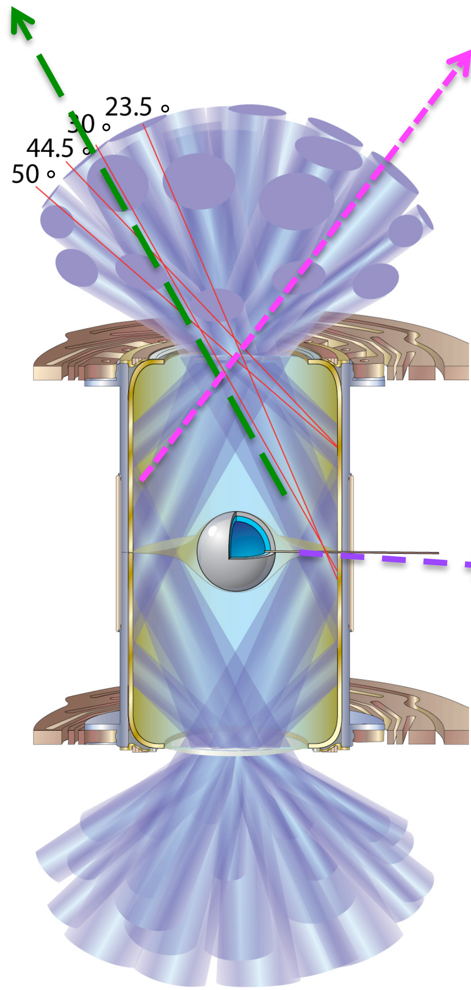
N. Meezan et. al. PoP 17, 056304 (2010)

P. Michel et. al. PoP 17, 056305 (2010)

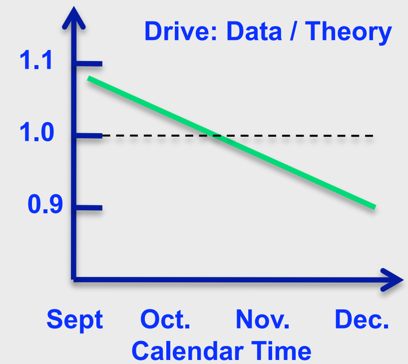
…but, there were inconsistencies within each category

Coupling: Color & level of Raman scattered light not what was expected

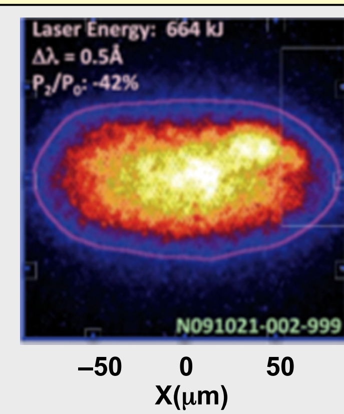




Drive: Energy accounting was off: Surplus in Sept., and a Deficit in Dec.



Symmetry: Why was the implosion pancaked *prior* to the $\Delta\lambda$ symmetry tune?



We deployed a hohlraum simulation model with improved physics: The High Flux Model ("HFM")

High (radiation & electron) Flux Model* ("HFM") has 2 main physics improvements, that lead to a cooler hohlraum T_e.

1) Better Non-LTE atomic physics (DCA)
   - 100s of levels vs. older 10 level Non-LTE XSN model
   - Radiates more efficiently: dielectronic recombination re-populates "active" levels

2) Better treatment of electron conduction
   - Flux limited diffusion, fnvT, has a "liberal" flux limiter: f = 0.15
     - vs. older model's more restrictive f = 0.05
   - Conducts more efficiently, & agrees with non-local transport model

This better model was needed to more accurately model the NIF scale
   - But we will show examples why it is still not quite good enough….

"Volume emission becomes more important <u>at large scales</u>" - L. Suter

*M. D. Rosen, H. A. Scott, D. E. Hinkel et al HEDP 7, 180 (2011)

HFM does a better job than XSN / f = 0.05

2005 / 0-D: DCA High Z emissivities match more detailed models (L. Suter, S. Hansen, H. Scott et al)

Au Emissivity (TW/cc)
@ T_e= 2 KeV, ρ = 0.01 g/cc

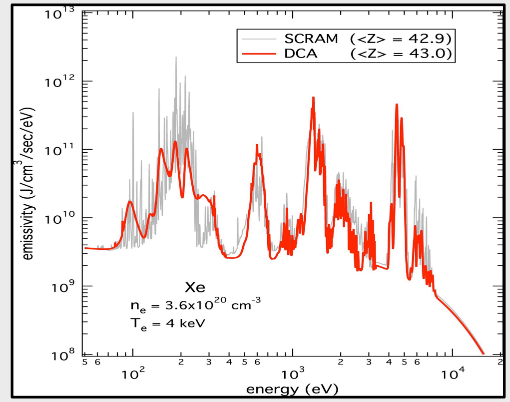
SCRAM: 7.4
DCA: 7.9
XSN: 3.1

IFSA 2009

Xe Emissivity:
@ T_e= 4 KeV,
ρ = 0.002 g/cc

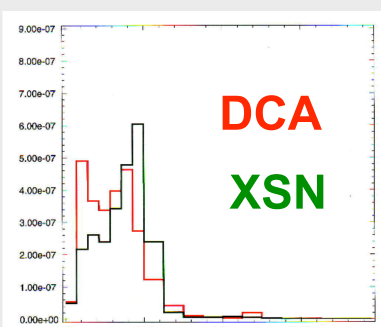
SCRAM: vs. DCA

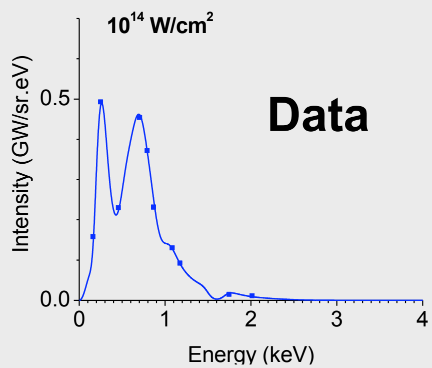
HEDP **6**, 39 (2010)

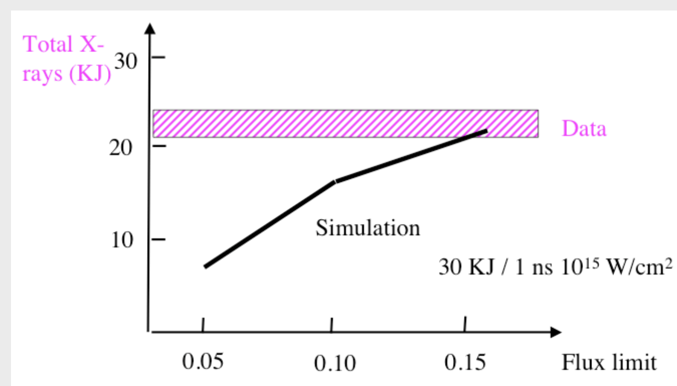


2007 / 1-D: Ω Au Sphere: HFM matched sub-keV data: (E. Dewald, M. D. Rosen, et al PoP 15 072706 (2008))

DCA ~matches shape, f=0.15 ~matches level



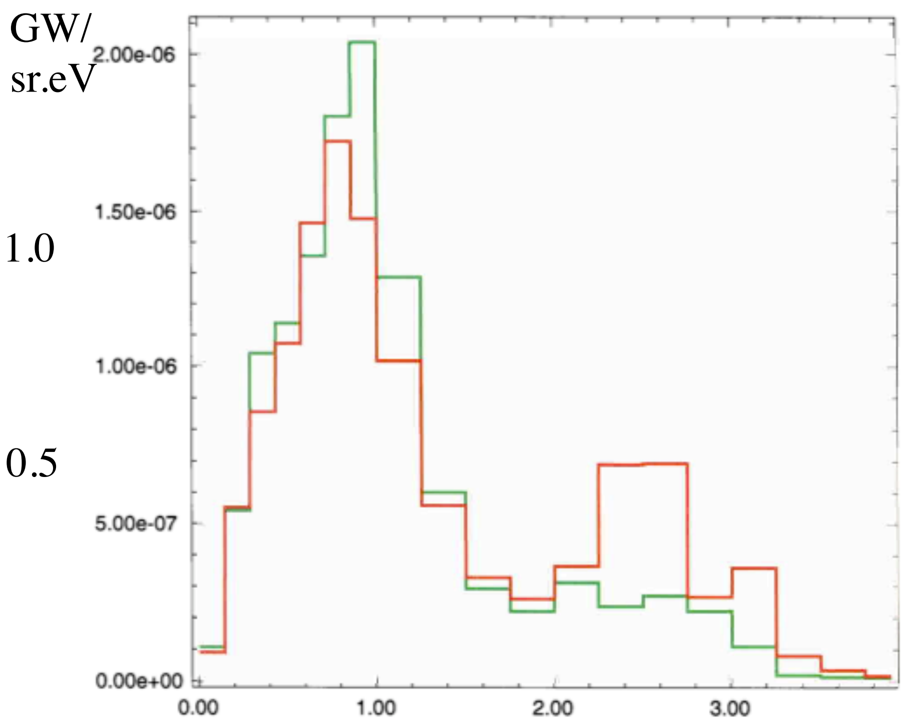


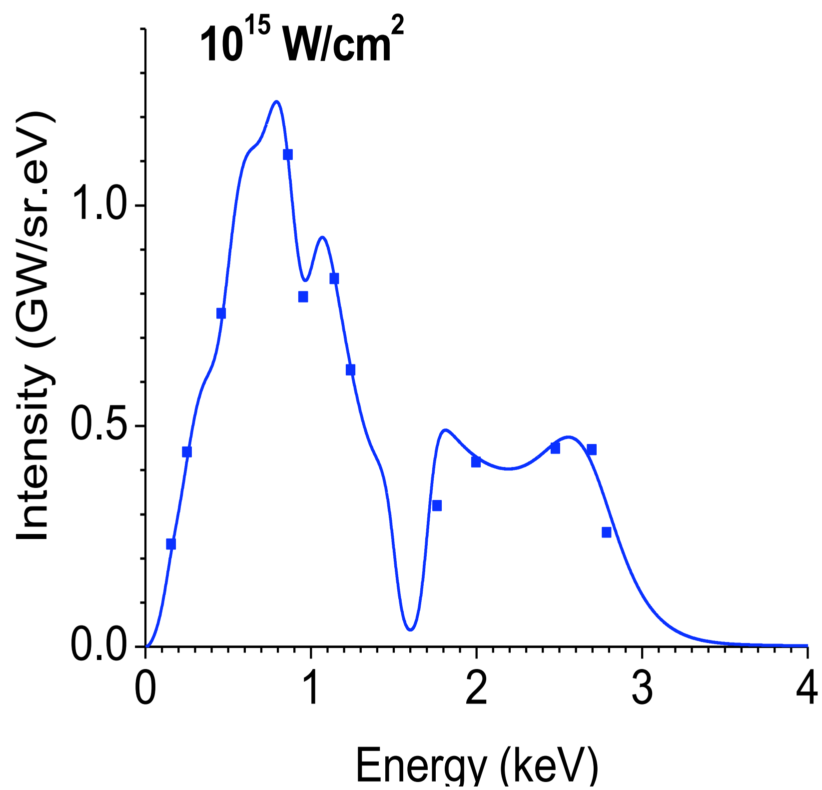


DCA agrees better with the spectral shape for Au than XSN (@ 10^{15} W/cm^2)

XSN, DCA Simulations

Data

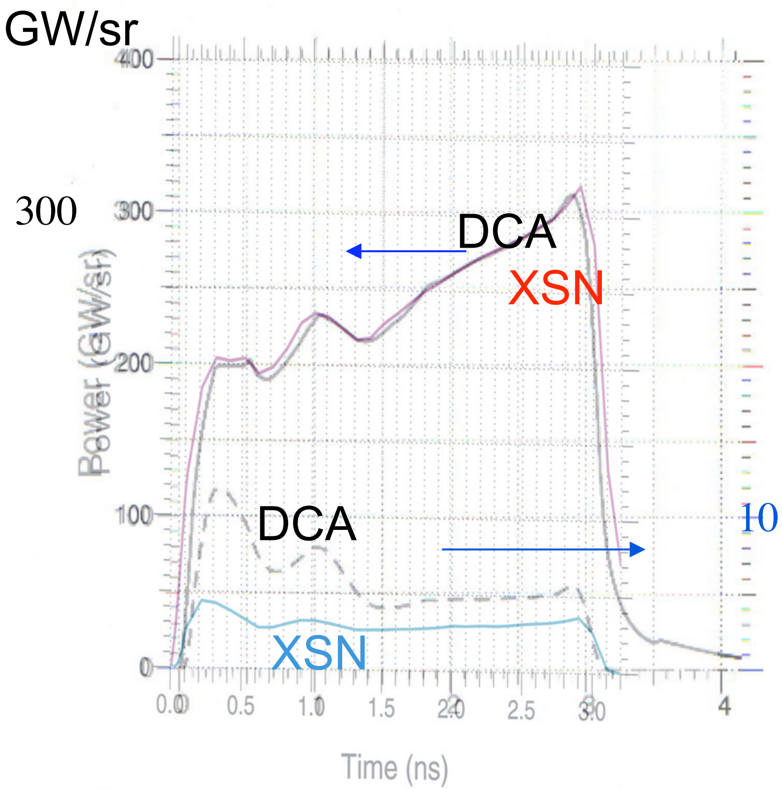




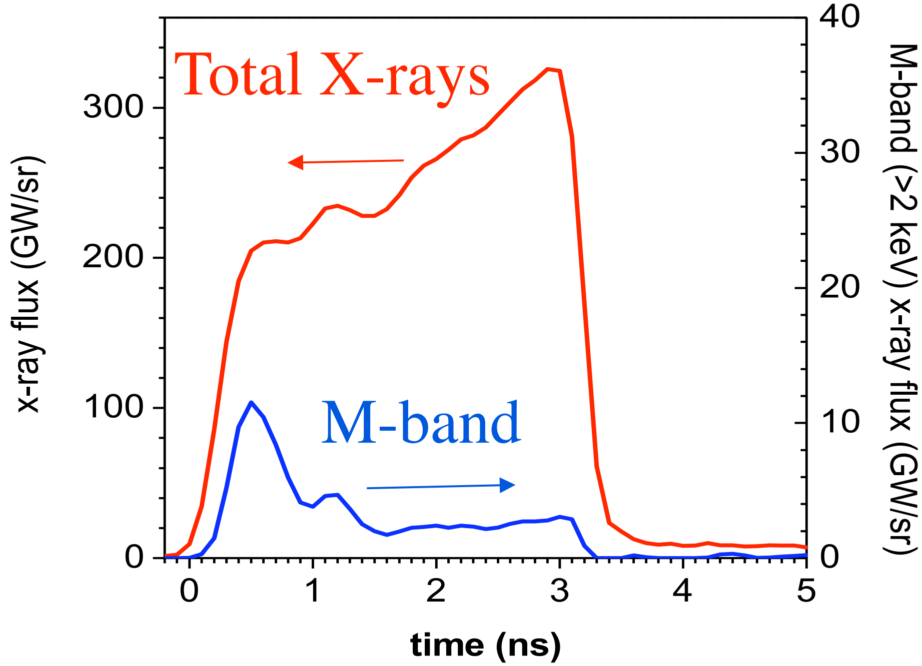
Au sphere @ 30 KJ / 1 ns 10^{15} W/cm^2 at t = 0.9 ns

DCA M-band vs. time agrees better with the data than XSN (@ 10^{14} W/cm^2)

DCA & XSN Simulations



Data

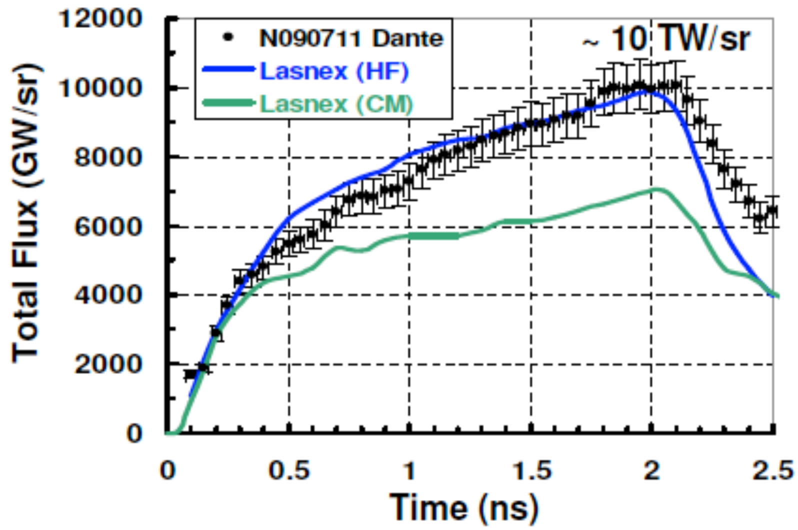


Au Sphere @ 10 KJ / 3 ns 10^{14} W/cm^2

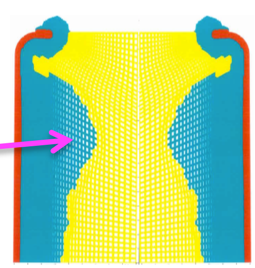
Empty hohlraums accentuate the "large scale plasma emission" effect on drive

NIC Empty hohlraums ~ 30% effect

Kline, Olsen, Rosen, Callahan, Suter et al '09

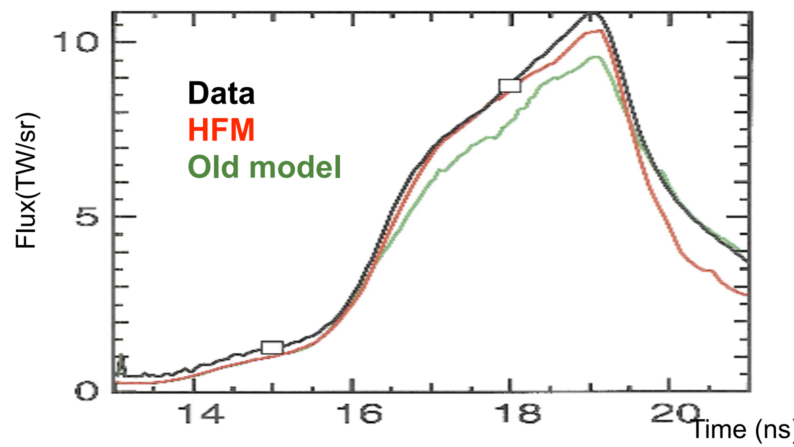


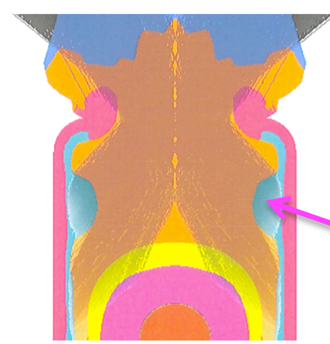
Empty hohlraums have large, ~ uniform "gold bubble" / corona dynamics



Gas-filled NIC hohlraums~ 10 % effect

R. Town, M. Rosen et al PoP 2010



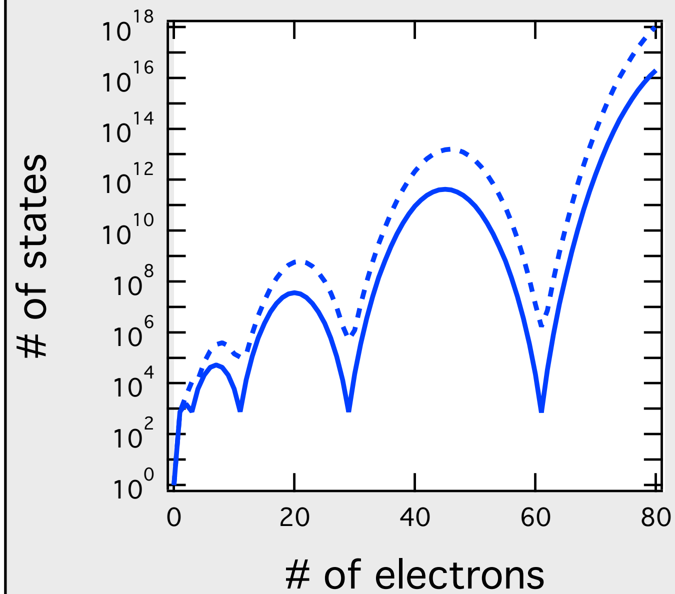


Gas-filled ignition hohlraums : Smaller, ***restricted*** "gold bubble" / corona dynamics

Using accurate and detailed models in-line is still computationally intractable

- Must model any element(s) over a wide range of conditions
  - — high-Z
  - — near-neutral to fully stripped
- Completeness is required for accuracy ⇒ averaging is necessary
- Number of levels varies by 10^5 between models, runtime varies by many orders of magnitude

States required for good ionization balance



Complexity and cost increase exponentially with Z

NLTE models used in integrated simulations must be highly averaged

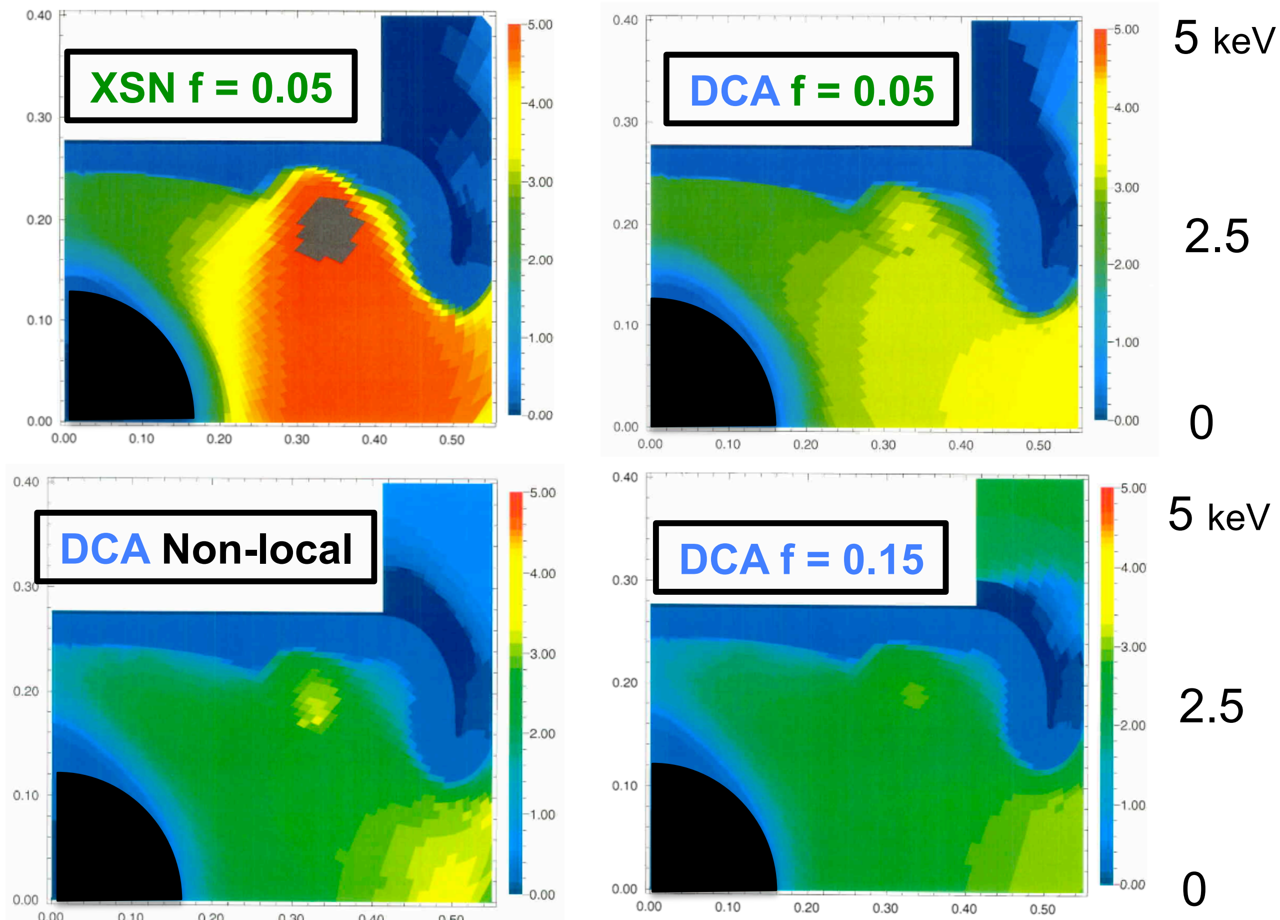
Limitations of NLTE simulations

- DCA provides in-line opacities, emissivities and EOS
  - — more detailed than average atom, but still highly-averaged
  - — benchmarked against more-detailed codes

    Atomic (LANL), Enrico (LLNL), SCRAM (SNL)
- NLTE data is limited in accuracy by
  - — limited detail in underlying atomic physics
  - — crude models for high-density effects
- Computational controls on choosing LTE vs NLTE treatment are inadequate
  - — improved control algorithm is in testing phase
- Radiation transport algorithms do not model dependence of emission on radiation spectrum

The non-local electron transport model acts like the "liberal" flux limit of f =0.15

T_e (0-5 keV contours) in 1 MJ hohlraum at 18 ns (middle of main pulse)



Electron transport in hot plasma has L<< λ_{mfp} , an inherently non-local process

The non-local model is Shurtz et al adapted by Harte, Zimmerman et al

Previous hohlraums, with tight beam spots, may have introduced other sources of flux inhibition

Hohlraum / capsule modeling methodology

- Use 2-D and 3-D radiation hydrodynamic codes (Lasnex, Hydra)
  - Model laser propagation, absorption, electron conduction, non-LTE x-ray production, radiation drive on capsule,…

- Step 1: Use full incident laser into hohlraum
- Step 2: Apply cross-beam transfer model with those plasma conditions
  - Set a Δn saturation parameter once
- Step 3: Re-run calculation with new (post cross-beam transfer) predicted beam balance as the incident beams

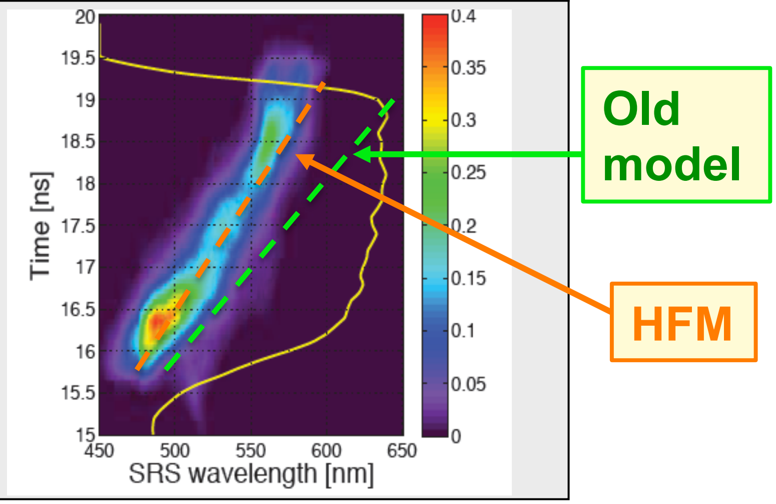
- An in-line self-consistent cross-beam transfer is being implemented to replace Steps 1-3

- Step 4: But first subtract from those incident beams the measured SRS and SBS losses.

- We've begun using a more self-consistent package that locally legislates / SRS / SBS & sends their light back through the plasma. Replaces step 4.

Coupling: HFM explains SRS color (vs. time) and its level

Coupling: Color of Raman light: λ_{SRS} vs. time



Intensity Level of SRS

HFM's cooler plasma leads to the observed higher levels of SRS

-due to less Landau Damping

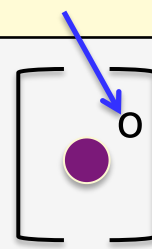
Massive pf3D simulations are in progress (D. E. Hinkel, M.D. Rosen, E. A. Williams, et al PoP 18, 056312 (2011))

What changed?

The plasma T_e:

Old Model T_e: 4.4 keV

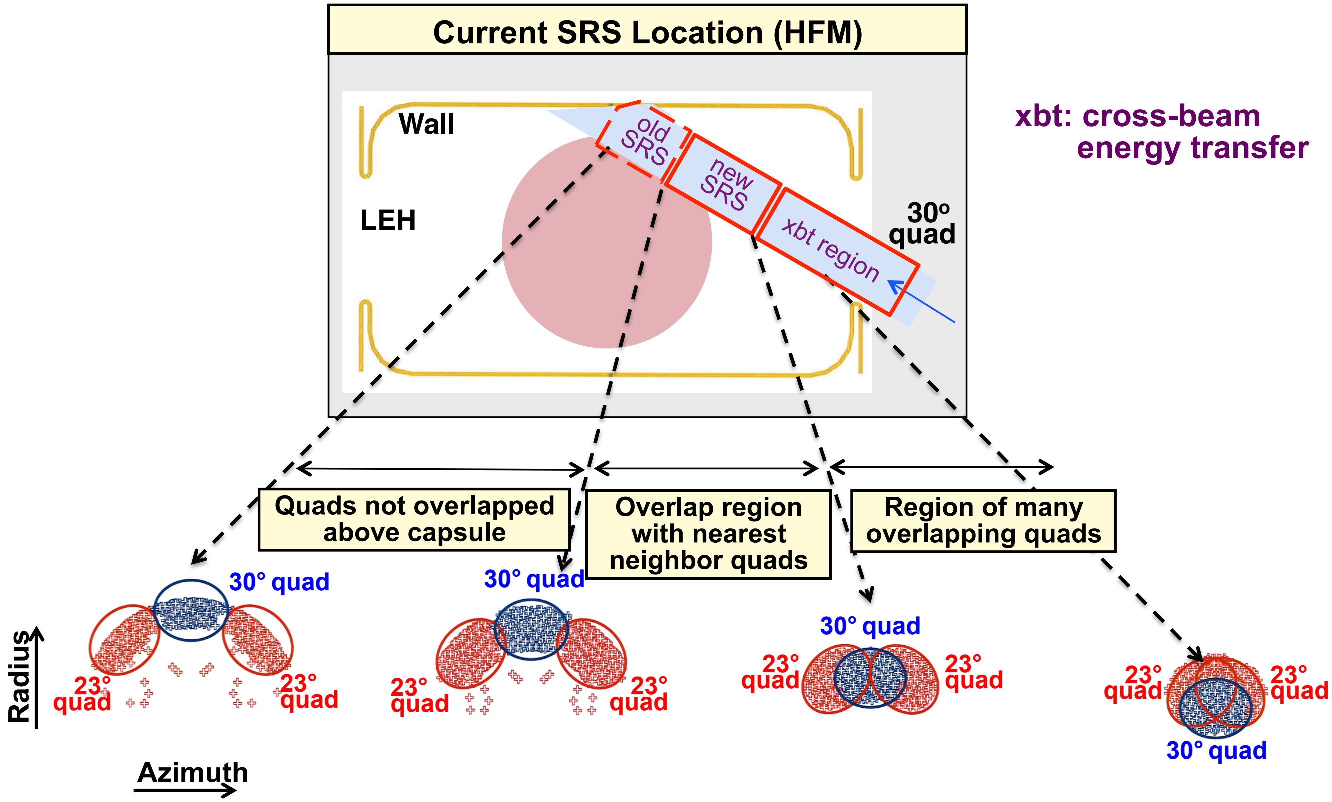
HFM T_e: 2.6 keV



(1 MJ shot, at SRS site, at 0.1 n_{crit}, at 19 ns)

HFM's cooler hohlraum plasma is key to matching the SRS spectrum and to the observed higher levels of SRS

The HFM allows SRS to occur where beams overlap azimuthally. Previous model's high T damped SRS there

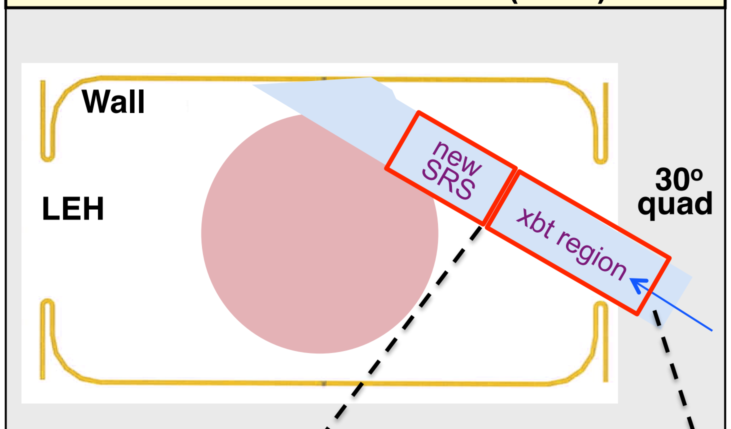


xbt: cross-beam energy transfer

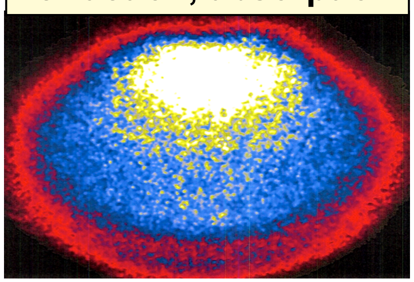
Beam overlap increases SRS levels

Cross beam transfer occurs non-uniformly

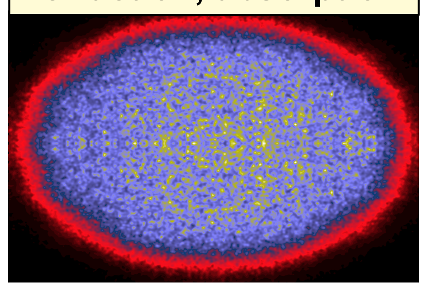
Current SRS Location (HFM)



Beam after xbt, refraction, absorption

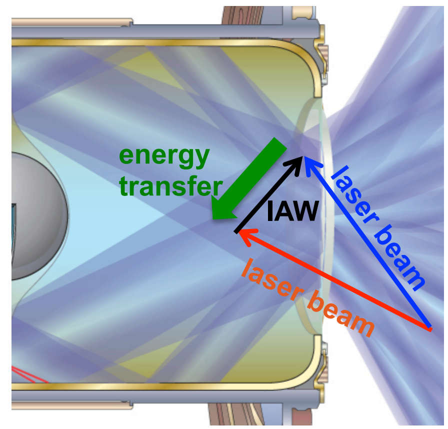


Beam before xbt, refraction, absorption



- <u>Cross Beam Energy Transfer (xbt):</u>
  - — Laser forward scatters off ion acoustic waves

    (P. A. Michel *et al.*, PoP, May 2010)



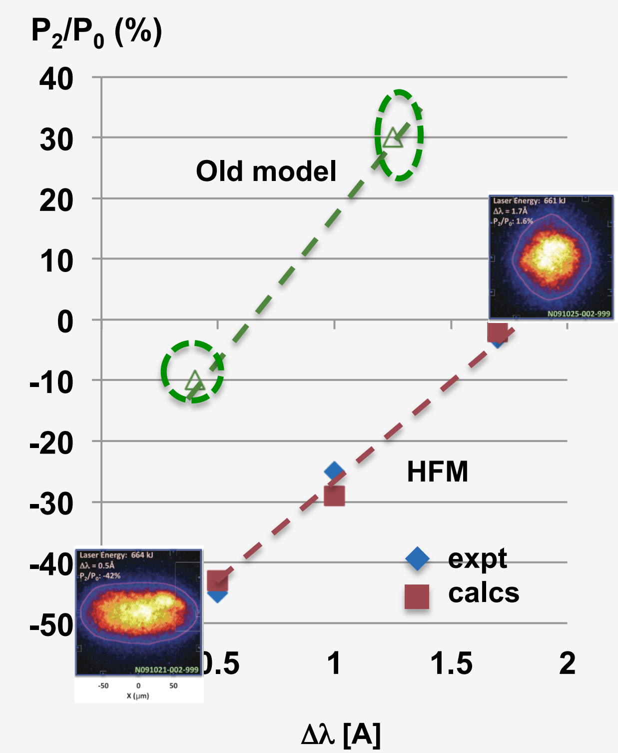
The locally intense laser increases SRS levels too, & can affect symmetry

A new in-line cross-beam transfer model can capture this important effect

Symmetry: Our cross-beam-transfer model, coupled to the HFM beam propagation agrees with data

R.P.J. Town, M.D. Rosen,
P. Michel, et al
PoP 18, 056302 (2011)

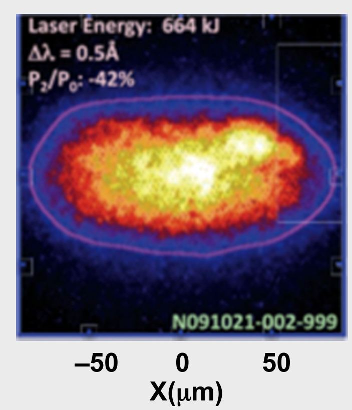
Only HFM matches Symmetry



What changed ?

HFM more pan-caked:
-**Outer** beams convert laser energy to x-rays better:
They shine on poles
-**Inner** beams have difficulty propagating, through the cooler plasma
Can't get to equator

Symmetry: Why was the implosion pancaked prior to the Δλ symmetry tune?



HFM's cooler plasma and higher coronal flux key to pan-caked symmetry behavior

Drive: The HFM + Re-evaluating SRS & Debris Shield losses have helped "balance the energy books"

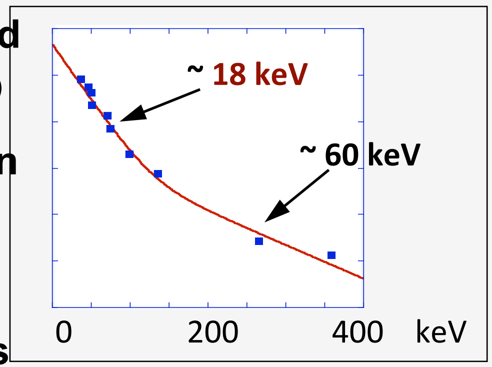
Re-evaluated losses

1) Disposable Debris Shield (DDS) aging (C. Haynam et al)

~ 5% scattering losses in Nov-Dec shots

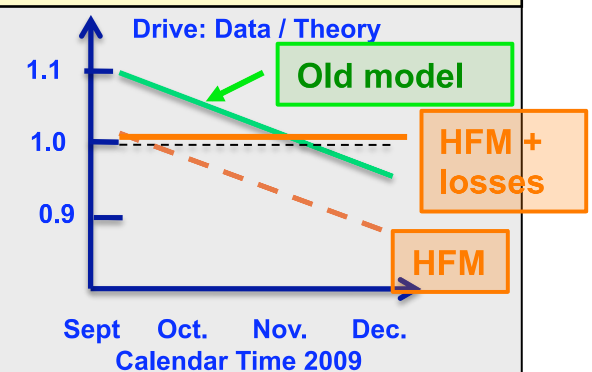
2) Hard x-ray spectrum re-interpreted as "2 – T_{hot}"s

(P. Michel, R. Town, L. Divol ,M. D. Rosen, et al Phys Rev E 83, 046409 (2011))



From $f_{18\ keV}$ get $SRS_{total\text{-}new}$: > SRS_{old}

Drive: Energy accounting was off: Surplus in Sept., and a Deficit in Dec.



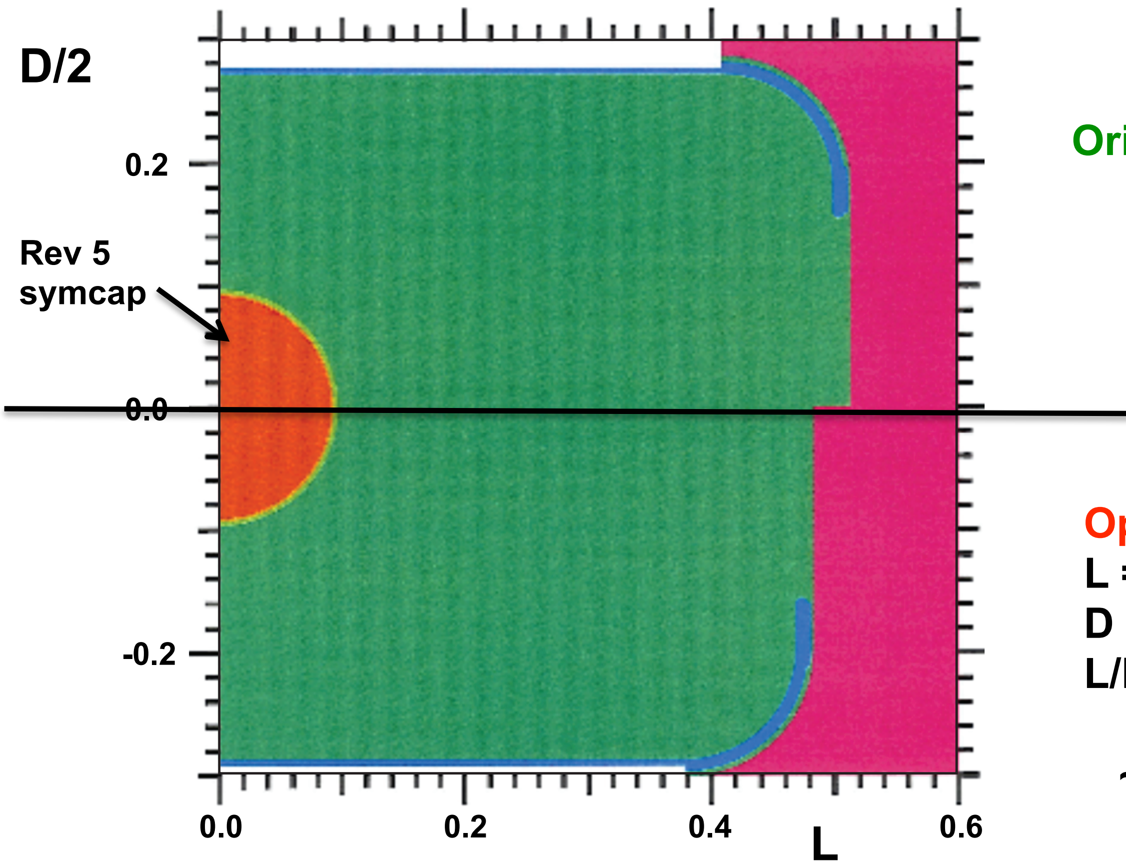
What changed?

HFM's high flux solves "surplus"

Re-evaluation of optical and SRS losses solves "deficit"

Implosion times were later than predicted. We'll return to that issue later in this talk…

Using HFM, D. Callahan re-optimized the hohlraum



Original aspect ratio:
L = 10.01 mm
D = 5.44 mm
L/D = 1.84

Optimized aspect ratio:
L = 9.41 mm
D = 5.75 mm
L/D = 1.64

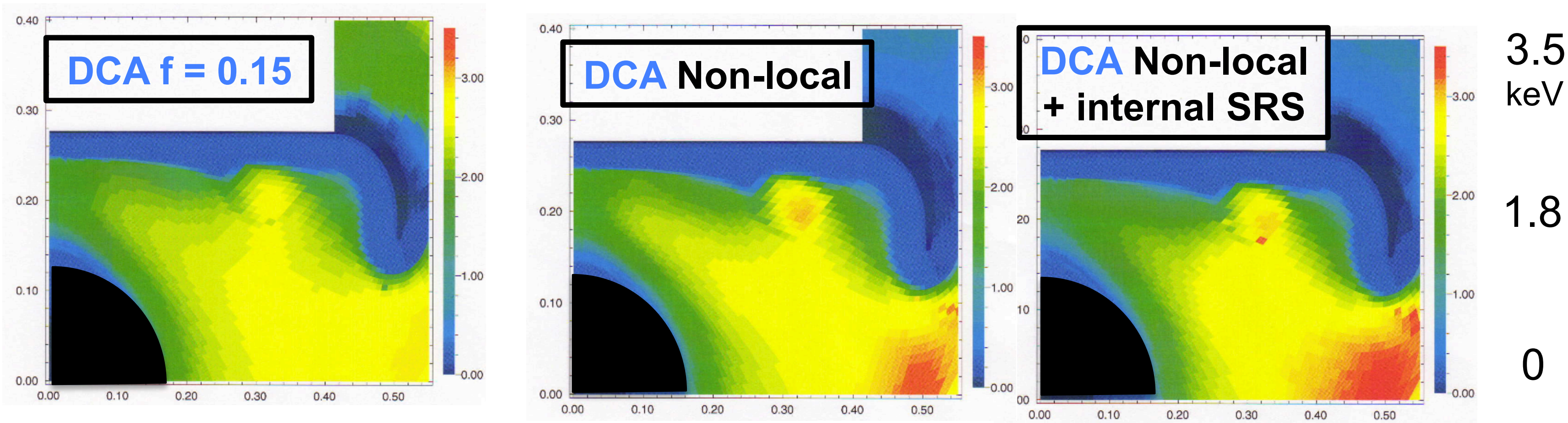
~ **Golden Ratio** !
("**Gol**R**aum**" ?)

In GolRaum, capsule pole sees larger Ω_{LEH}: helps reduce pancaking

With the longer (shock tuned) pulses of 2011, this improved shape has been crucial

The plasma conditions at the LEH are sensitive to the level of sophistication of the HFM simulation

T_e (0-3.5 keV contours) in 1 MJ hohlraum at 18 ns (middle of main pulse)



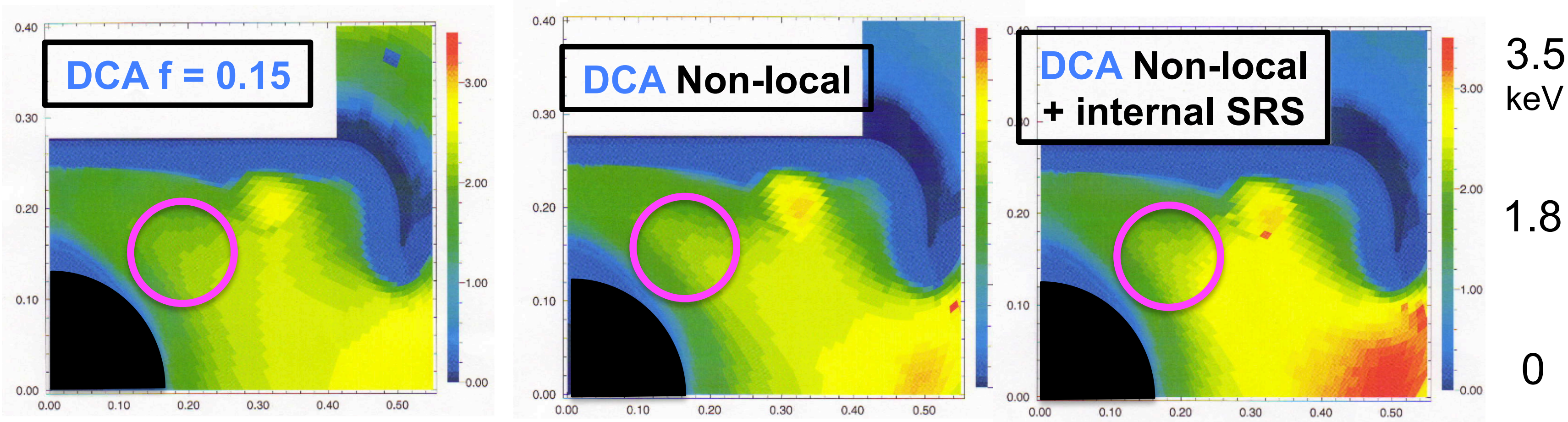
All 3 simulations use the *incident* laser pulse

Plasma conditions at the LEH affect cross-beam transfer

This may be an example of SRS, after the rise of the main pulse, heating the LEH and lowering the amount of cross-beam transfer. An in-line SRS package *and* an in-line cross beam transfer package could, in tandem, capture this physics.

The plasma conditions at the interior, SRS site, are less sensitive to the exact choice of simulation HFM

T_e (0-3.5 keV contours) in 1 MJ hohlraum at 18 ns (middle of main pulse)



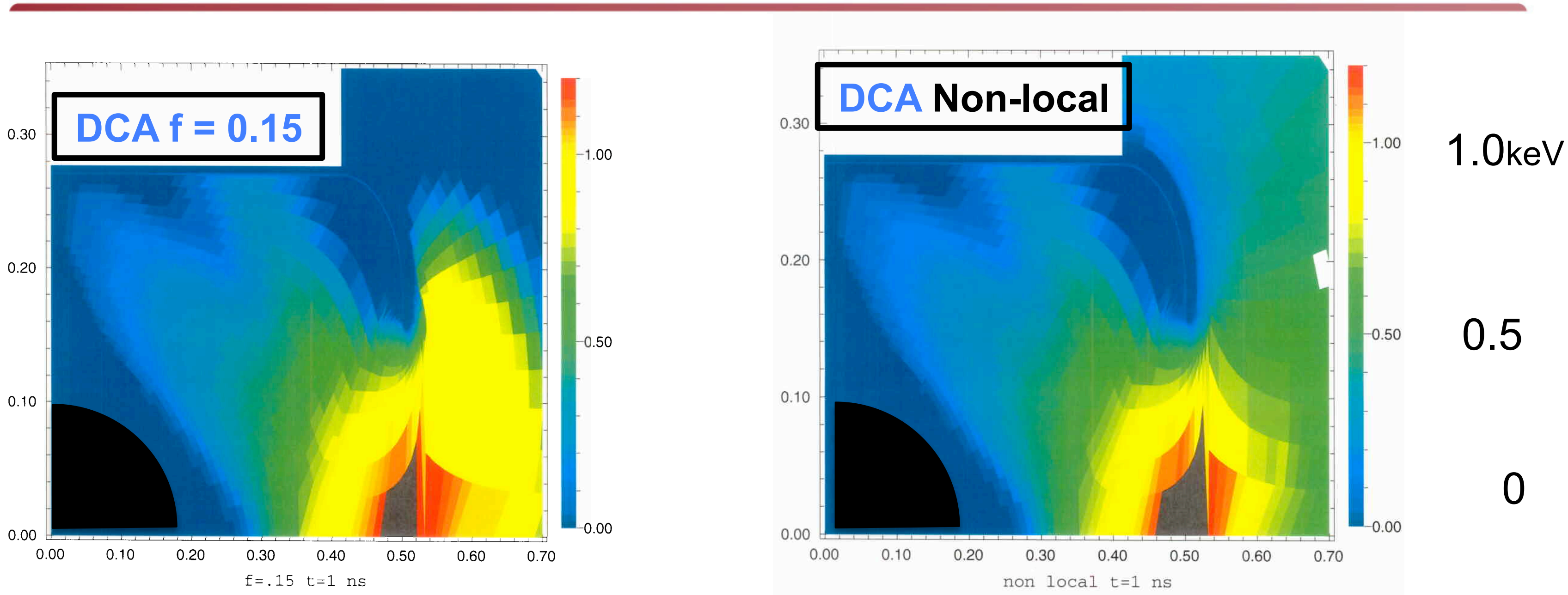
All 3 simulations use the incident laser pulse *with* SRS subtracted

Plasma conditions at the SRS site affect level & spectrum of the SRS

We are testing the package that produces hot-electrons from the SRS. These hot-e s can directly preheat the target, or indirectly through atomic physics excitation of higher frequency photons.

Currently, the package transports the hot-e s isotropically.

Early time plasma conditions at the LEH are sensitive to the level of sophistication of the HFM simulation



T_e (0-1.2 keV contours) in 1 MJ hohlraum at 1 ns (first picket)

Plasma conditions at the LEH affect cross-beam transfer:

Outside the LEH: T_e (non-local) = 0.6 T_e (f=0.15)

Inside the LEH: they are about the same

So far, in each phase of the NIC, we have encountered excursions from expectations that we have overcome:

2009 Energetics Campaign:

- **Inconsistencies in SRS spectrum & offset of implosion symmetry**
- **A “High Flux Model” (HFM) with better physics,**
  - **Better suited to the long scale plasma emission**
  - **Led to an improved hohlraum, which is now in use**

2010 Target Cryogenics Campaign:

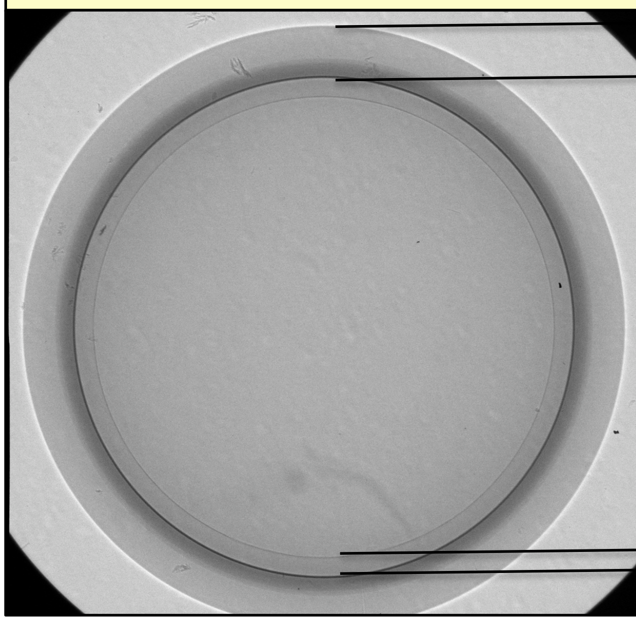
- **Inconsistencies in target performance & ice layer quality**
- **Moved rapidly up the technological learning curve**

2011 Tuning Campaign

- **Finding the actual time dependent symmetry, adiabat, & trajectory**
- **Adjusting laser powers, pulse shape, pointing etc while using the improved hohlraum**

Cryogenic fuel layers are imaged with x rays through slots in the hohlraum and through the LEH

73 μm thick THD layer in LEH view

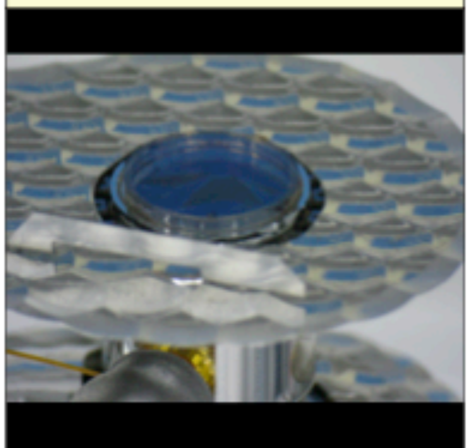


- **X-ray images from 3 orthogonal directions**
- **Temperature: 18 K ±0.001 K control**
- **Target position stability for X-ray imaging : < 2 μm p-p**

THD substitutes H for the D of DT to prevent neutron damage to x-ray diagnostics

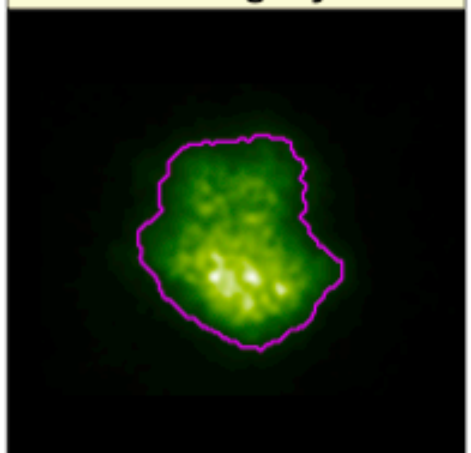
We have resolved issues as they have arisen

Frost on LEH Window



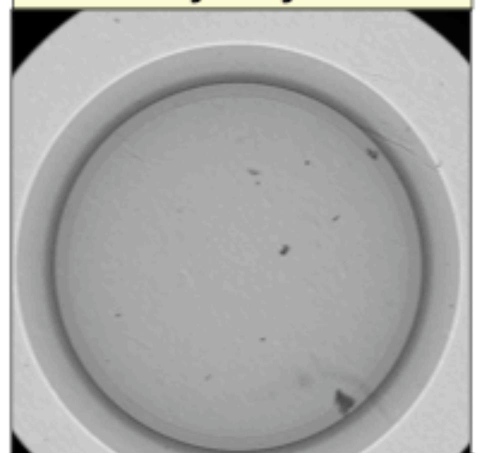
2nd "storm" window to prevent condensation

THD/Symcap Shape Surrogacy



Rev. 5 pulse w/ storm window

Defects in the THD Cryo-layer



Revised layering protocol

We currently do not model the details of this storm window

We currently do not model the physics of ice-defect formation

So far, in each phase of the NIC, we have encountered excursions from expectations that we have overcome:

2009 Energetics Campaign:

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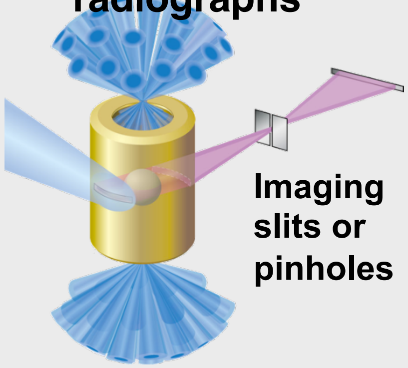
- Finding the actual time dependent symmetry, adiabat, & trajectory
- Adjusting laser powers, pulse shape, pointing etc while using the improved hohlraum

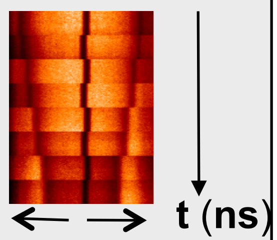
Backlit Capsule give valuable implosion trajectory / velocity information

Experimental Geometry

Backlit D-^{3}He-filled capsule or THD Cryo-layered capsule

Streaked or gated X-ray radiographs





Observables:
Limb contrast for mass remaining
Limb v_{imp} at r = 300 µm

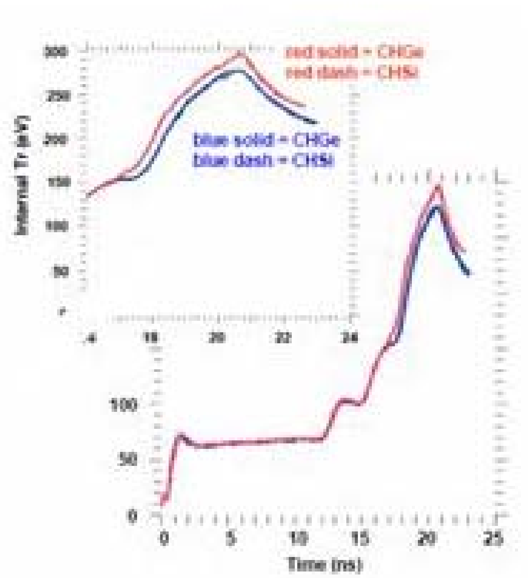
These experiments indicate the velocity is ~ 10 ± 5% lower than expected based on measured x-ray drive

This measured lower velocity is consistent with previously observed late "bang times"

Preliminary NIC data

D. Hicks, RSI and PoP (2010)

The laser power's rise time & peak value are adjusted to match the measured implosion trajectory

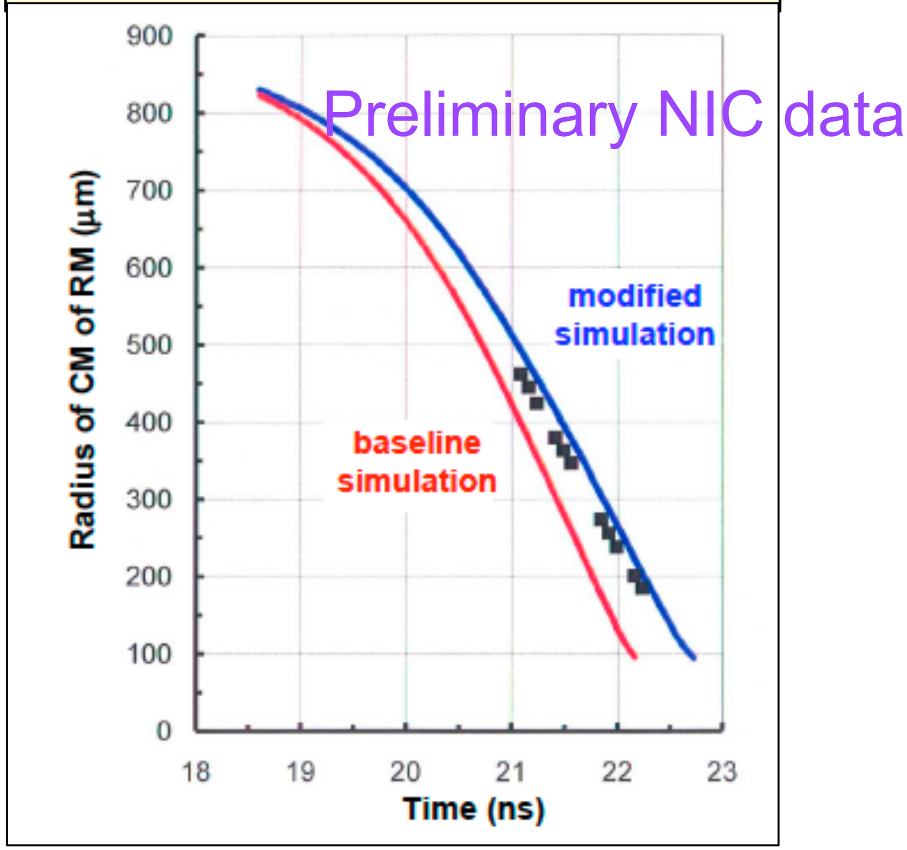


Modified simulation*:

Delays rise of 4th (main) pulse

Peak power turned down by ~10%

1D Implosion trajectory vs time compared with experimental data



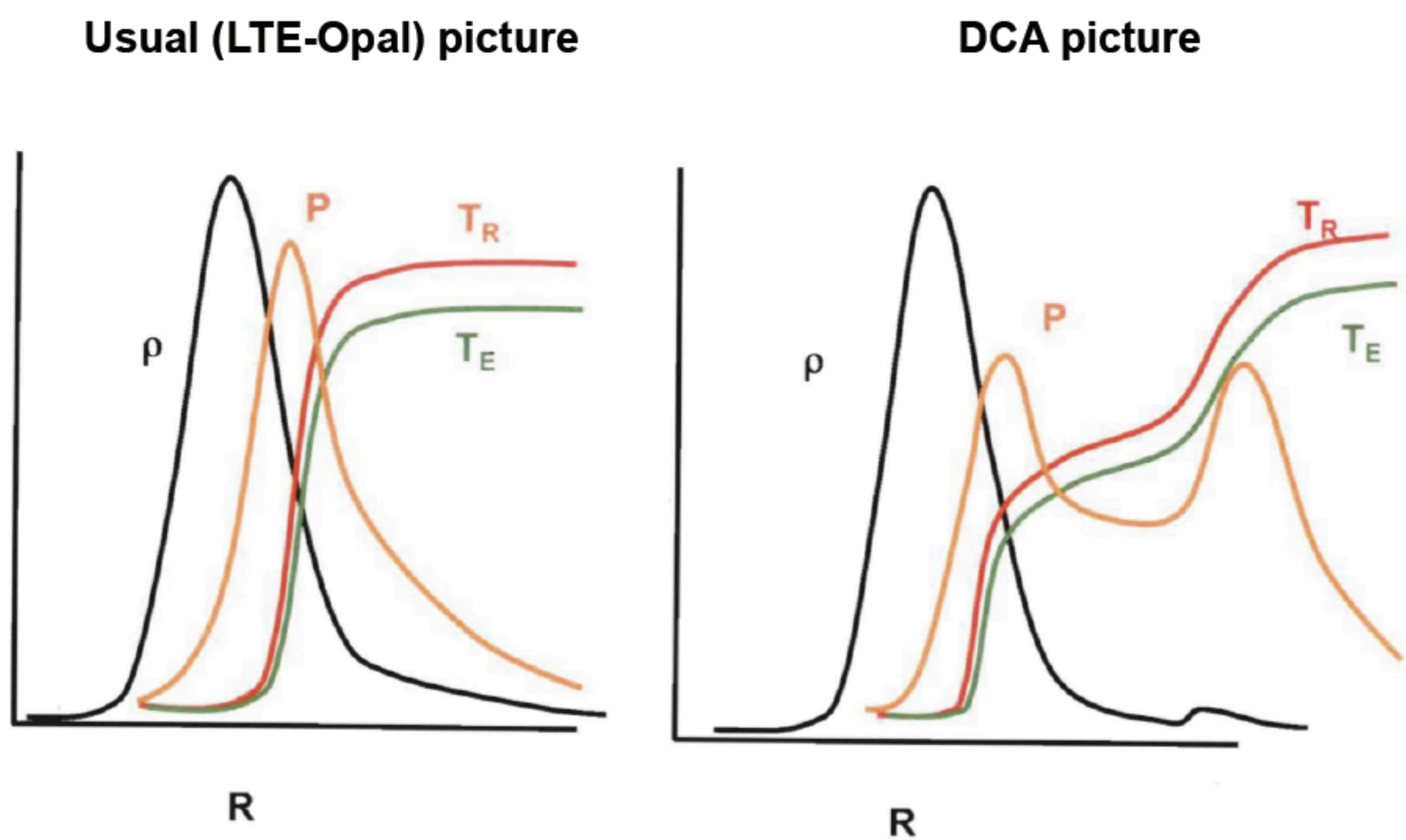
*R. Olson, et al IFSA 2011

We are exploring hypotheses for the "adjusted" drive that is needed to match the velocity history

Delay of drive during rise of the main pulse

1) Ablator non-LTE, EOS, opacity issues
   - Some promising results with better EOS & non-LTE DCA in ablator
2) Internal LPI (T_e low, scattered light not necessarily observed, energy absorbed in ineffective places)
   - Using a more consistent "internal LPI" package
   - Side scatter not presently modeled
3) Beam propagation through low-Z gas/ Hi-Z gold mixture (T_e low, Hi Z in the way, scale (t, L) dependent)
   - Using sub-grid mix models
4) LEH dynamics (same issues as #3)
   - More detailed modeling schemes of all relevant geometry & hardware needed

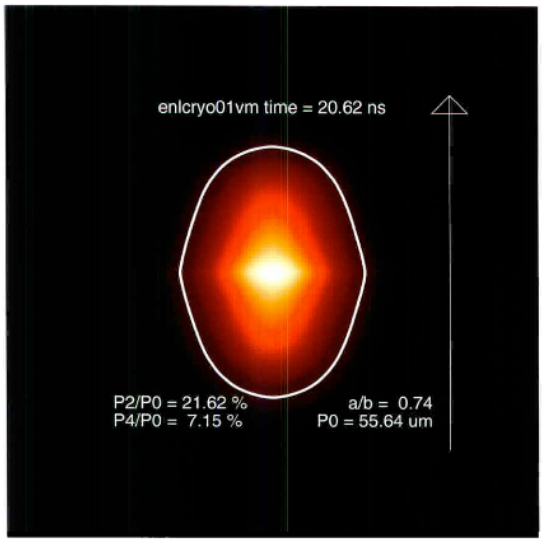
The "non-LTE DCA + better EOS" shows an early – time double structure in the CH Ablator



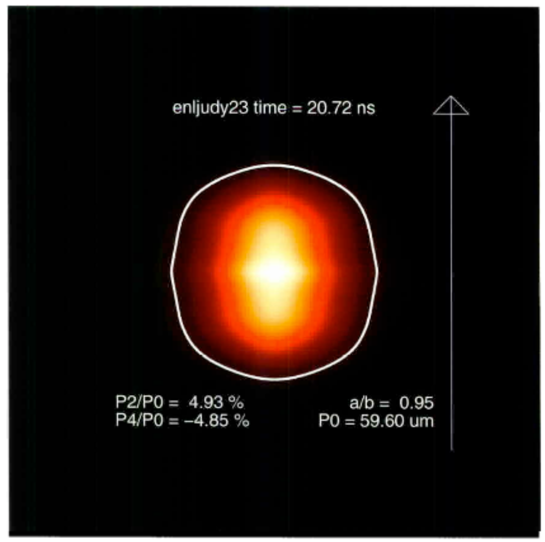
J. Hammer, H. Scott, P. Sterne, et al

Internal reflection of the laser light can delay the "bang time" by ~ 150 psec

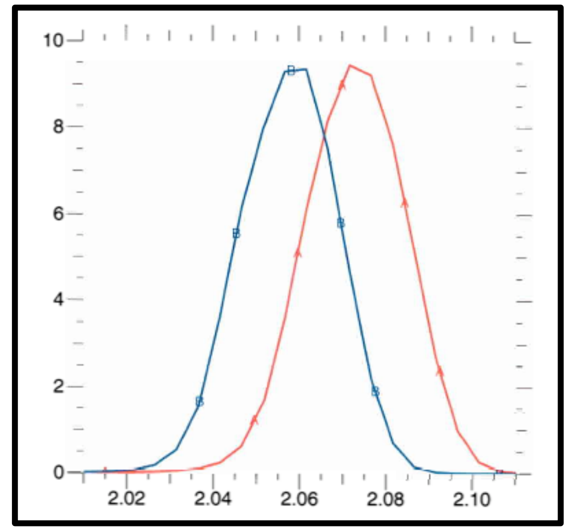
Standard



Internal reflection



X-ray Brightness (t)



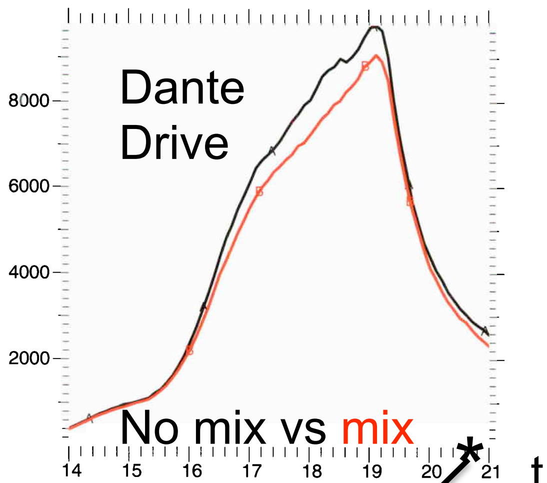
20.4 20.8 t (ns)

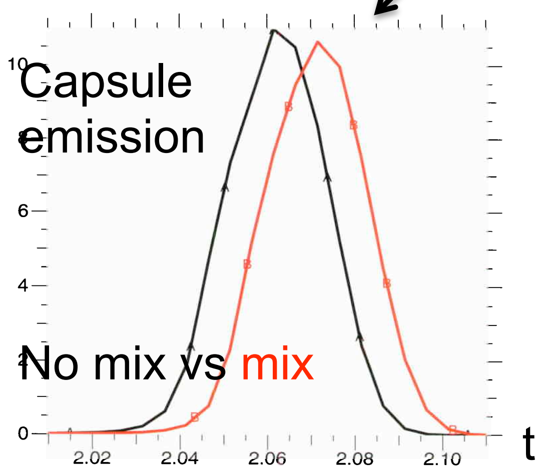
To get 150 psec delay: We deny the "waist" of the hohlraum laser light, by back reflecting 90% of it, (*__during main pulse rise__*) at longer λ (green) Raman back Scatter

This green light does not make it out of the hohlraum , "consistent" with observations

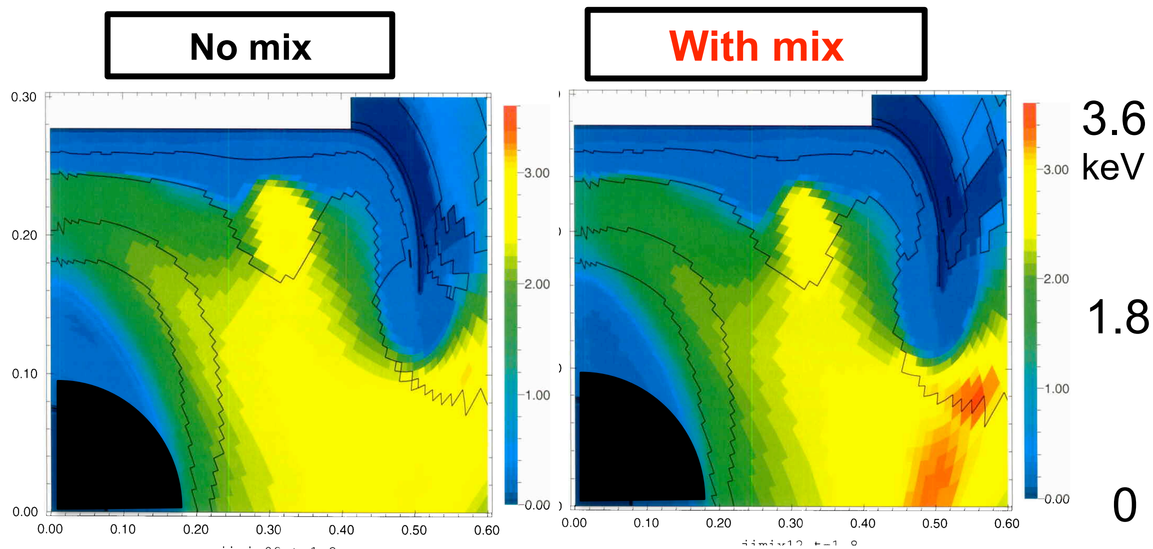
If this SRS made hot-electrons, we must invoke B fields to keep these hot-electrons from depositing in the Au walls & emitting bremsstrahlung

A sub-grid model of mixing of high Z with low Z in the hohlraum delays the drive and the implosion





T_e (0.- 3.6 keV contours) in 1 MJ hohlraum
at 18 ns (in the main pulse)



The mix simulation delayed capsule "bang time" by ~150 psec

We are exploring hypotheses for the "adjusted" drive that is needed to match the velocity history

NIC

Lower peak drive power by ~ 10%

Drive might really be lower by 10% yet we match Dante (~ $A_{LEH}T^4$) because of compensating error in LEH size*

1) LEH dynamics are quite computationally challenging
2) Resolving the x-ray conversion layer in steep T, n gradients is difficult too
3) DCA is not perfect, nor should it be, & there are subtleties of transition from non-LTE-model to tabular-LTE-model for EOS & opacity

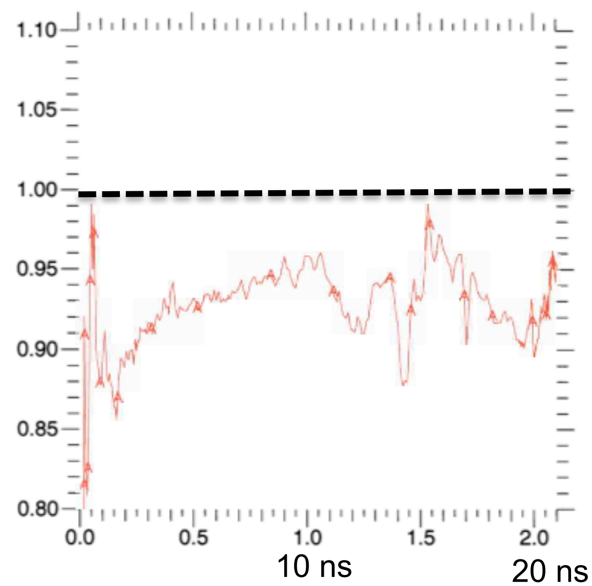
Are 2-D / 3-D ablator/fuel mix issues affecting the 1-D dynamics?

*N. Meezan et al, IFSA 2011

D. Callahan pointed out sensitivity of the calculations to the choice of Te at which we switch to NLTE

Ratio of drive: Switch from LTE Table to NLTE DCA:@ T_e=T_r(t) vs. T_e=300 eV

$$\frac{T_R^4\ (\text{switch @ } T_e(t) = T_R(t))}{T_R^4\ (\text{switch @ } T_e = 300\text{ eV})}$$



T_r(t) switch from LTE table to NLTE DCA delays "bang time" by ~ 200 psec

but: for T= 100-150 eV: LTE Table's Opacity > DCA's

The questions we sought to answer:

1) What excursions beyond the tight NIC specs should we expect, as we extrapolate from the previous data base derived at the smaller scales ?

- Hohlraum plasma conditions (improved hohlraum helps tunability)
- LPI –depends on L & P
- Doped-Ablator dynamics / opacity / EOS / mix
- Beam propagation: depends on plasma conditions
  - Issues in play: Hi-Z/lo-Z mix, internal LPI, LEH dynamics…

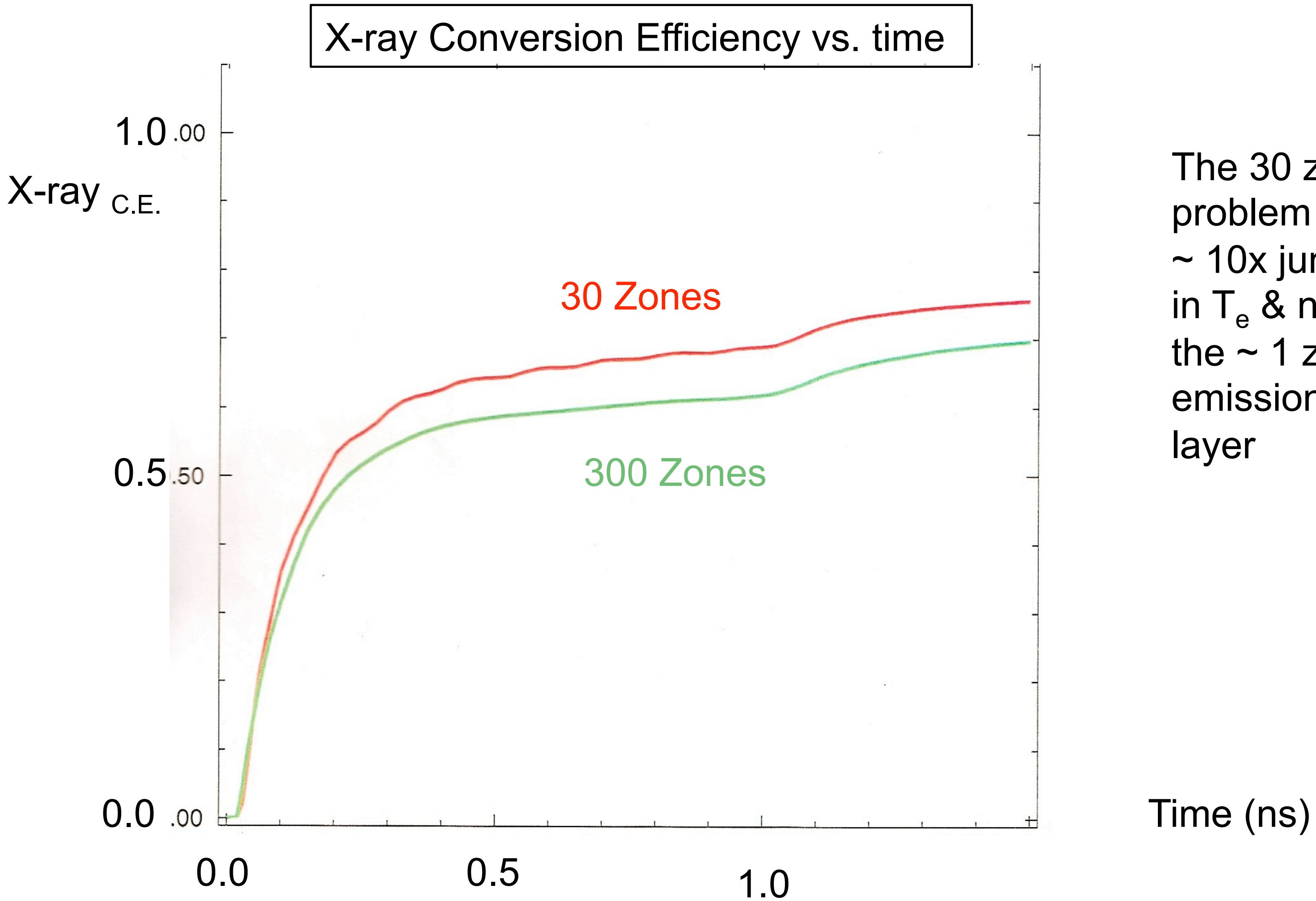
2) What computational advances would be helpful?

- Improved self consistent packages of x-beam transfer and internal LPI, including the proper beaming and transport of SRS created hot electrons.
- Improved NLTE high Z treatments
- Validating sub-grid mix models
- Improved zoning resolution and high fidelity modeling of as-built targets

Welcome to the most exciting time in ICF history!


NIC

For the Omega Au sphere data, zoning matters



The 30 zone problem has ~ 10x jump in T_e & n_e in the ~ 1 zone emission layer