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Re-examining our inhibitions: A speculative re-analysis of data from Au spheres illuminated by URLLE's OMEGA laser

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Re-examining our inhibitions: A speculative re-analysis of data from Au spheres illuminated by URLLE's OMEGA laser

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LLNL-PRES-XXXXXX
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- Au Spheres at URLLE OMEGA
  - E. Dewald, K. Widmann, M. May, N. Whiting, CEA DMX Team, L. Suter

Two-Stream awareness

- N. Landen, J. Lindl, S. Glenzer

- Two-Stream issues
  - W. Rozmus, D. Berger, P. Young, W. Kruer, D. Froula
- Code implementation
  - G. Zimmerman, J. Harte, D. Bailey, H. Scott

High Flux Model (HFM): Spheres vs. Hohlraums

Spheres: HFM was born out of 2006 OMEGA Au spheres:

- DCA NLTE atomic physics
- **f = 0.15** (≈ non-local) matches x-ray emission (vs. usual f = 0.05)
  - 2013 Thomson Scatter(TS) Te(r,t): partial agreement with HFM

Hohlraums (HRs): HFM applied to NIF HRs:

- Fit '09 empties; gas-filled SRS spectrum, levels; (also '13 NVH drive)
  - ***But*** source multipliers needed for many gas-filled drive

Using f=0.05 or 2-stream (f=0.015) can help avoid multipliers

Consistency ?: Two branches of logic:

- **f =0.05**: Inhibition source possibly B fields around individual beams
  - NIF HR beams individualize vs. Au sphere beams overlap/smooth
- **"2-Stream"**: Ion Acoustic Turbulence scatters heat-transporting electrons
  - *This same scattering can enhance (= "anomalous") absorption (AA)*
    - Applied to Au sphere near n-crit, AA can help agree with TS data

In this talk we explore this speculative "AA" branch of logic

The 2 stream model operates when Z T_e / T_i >>1, and then f = 0.015

Heat carrying electrons stream one way, & return current carrying electrons stream the other

- These 2 streams have “free energy” to drive an instability

Ion acoustic turbulence (IAT) ensues

- Acts like an effective scatterer to inhibit the heat flux

- *That same scattering* can enhance collisional absorption
  - but *not* in the model, as implemented into the hydro codes

For an Au sphere Z T_e / T_i ~ 400, so 2-stream should be operative there

For the low Z gas in the hohlraum, may depend on when collisions raise T_i

This phenomenon has been discussed in the literature for > 40 years…

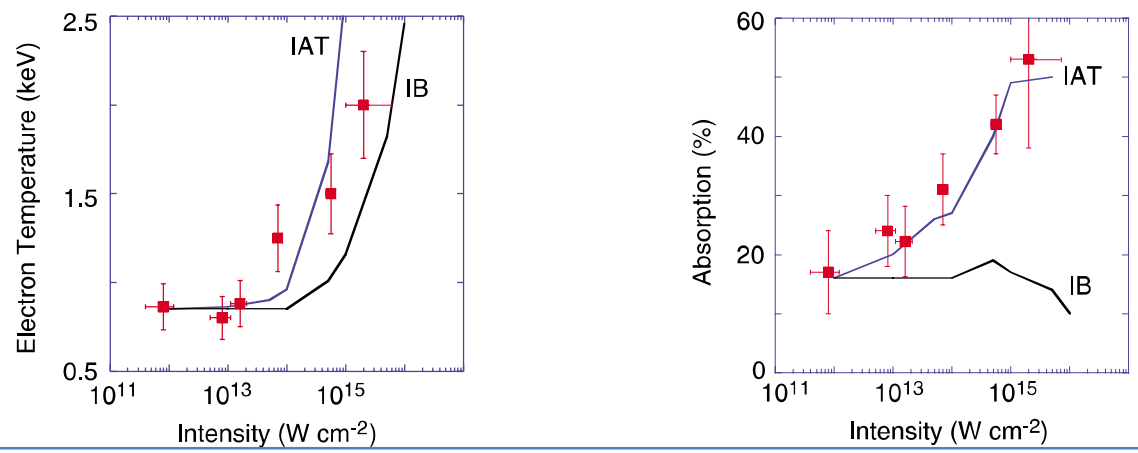
The 2-stream-induced ion-acoustic turbulence ("IAT") can enhance absorption

VOLUME 88, NUMBER 23 PHYSICAL REVIEW LETTERS 10 JUNE 2002

Anomalous Absorption of High-Energy Green Laser Light in High-*Z* Plasmas

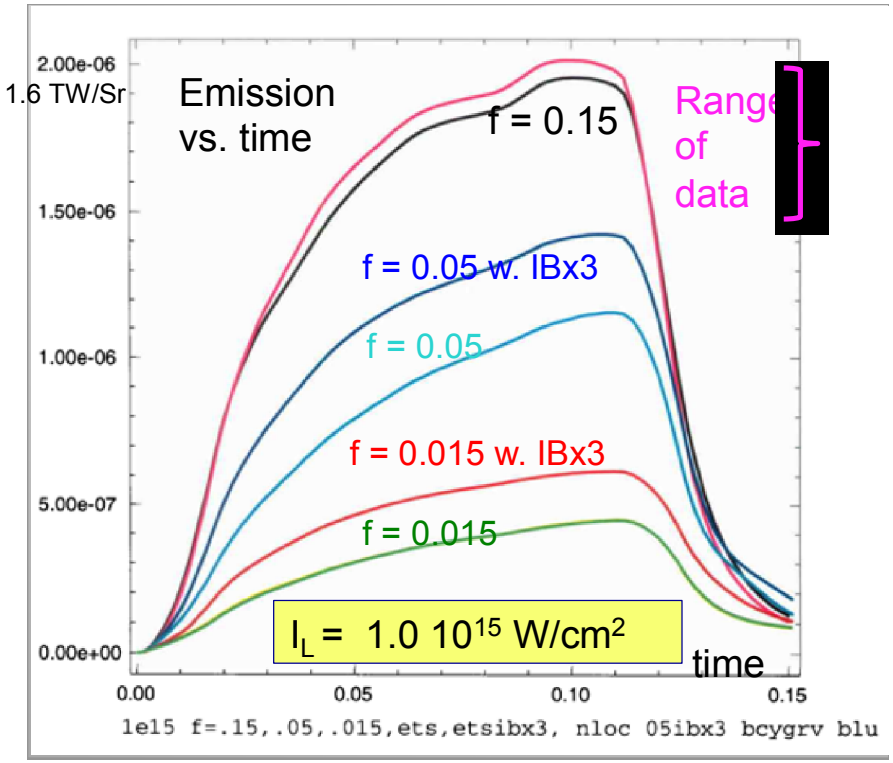
S. H. Glenzer,[1] W. Rozmus,[2,3] V. Yu. Bychenkov,[4] J. D. Moody,[1] J. Albritton,[1] R. L. Berger,[1] A. Brantov,[4] M. E. Foord,[1] B. J. MacGowan,[1] R. K. Kirkwood,[1] H. A. Baldis,[2] and E. A. Williams[1]

We observe strong anomalous absorption of green laser light in mm-scale high-temperature gold plasmas. Both the laser light absorption and the resulting increase of the electron temperature, which was measured independently with Thomson scattering, have been successfully modeled by including enhanced collisions due to heat-flux driven ion acoustic fluctuations. Calculations that include only inverse bremsstrahlung significantly underestimate the experimental laser absorption and the electron temperature.

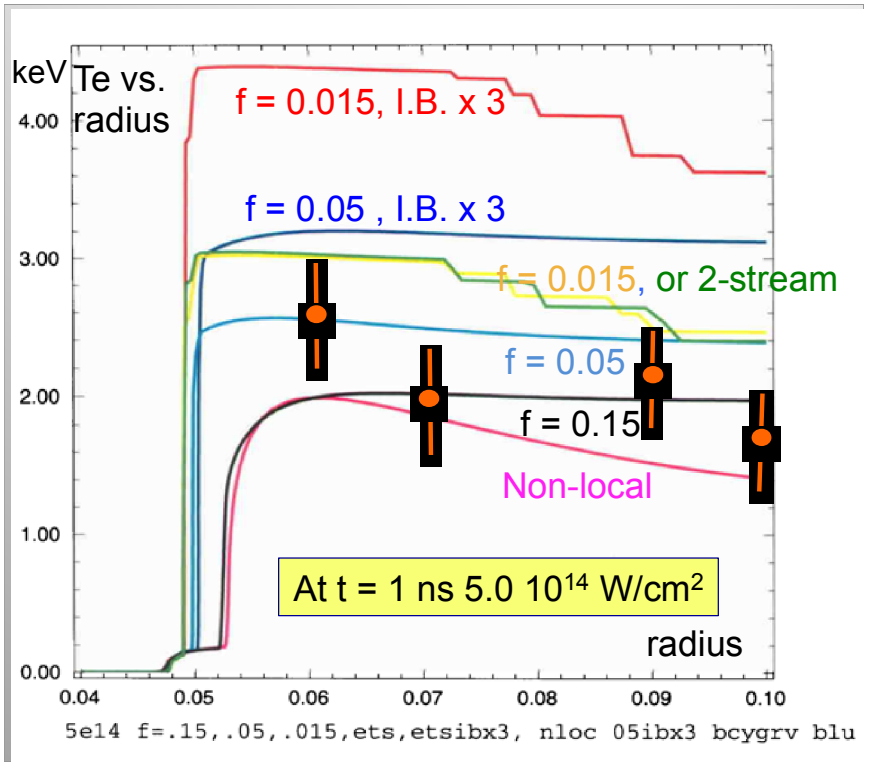


Based on this, we first tried to model this by IB x 3.

Enhancing absorption in 2-stream model by multiplying inverse bremsstrahlung x 3 does *not* agree with TS data



0 time 1 ns

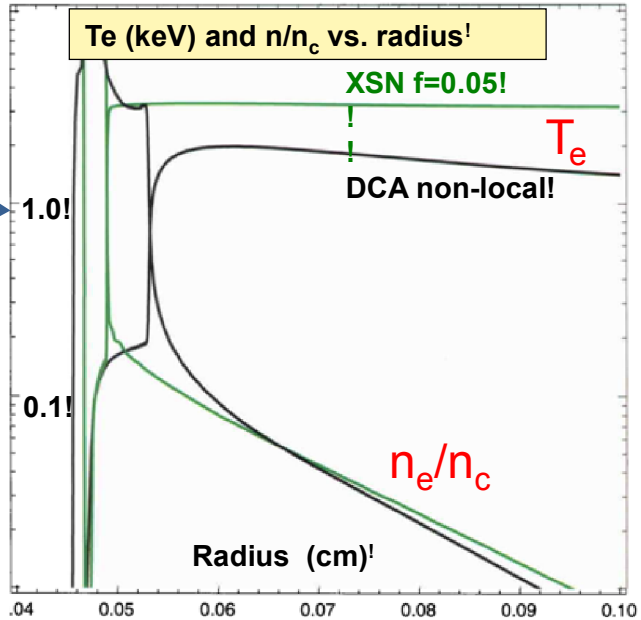


0.05 Radius (cm) 0.10

I.B. x 3 model enhances absorption in the low density corona, which does not radiate efficiently, and thus gets too hot vs. Au sphere TS Te data

Given the failure of the IBx3 attempt, we propose a new model that localizes the IAT enhanced absorption near n_c

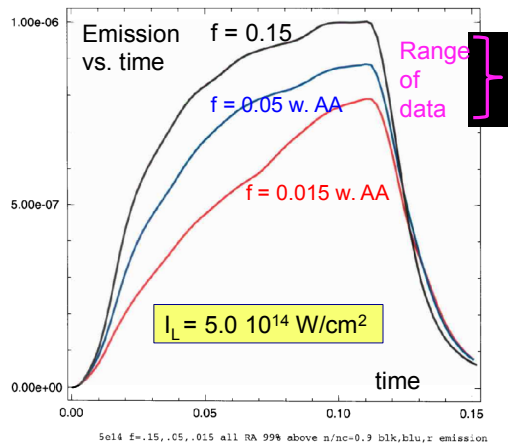
Localize the 2-stream-induced IAT near the steep heat front, near n_{crit}
- Enhance the ("anomalous") absorption (AA) *only there*

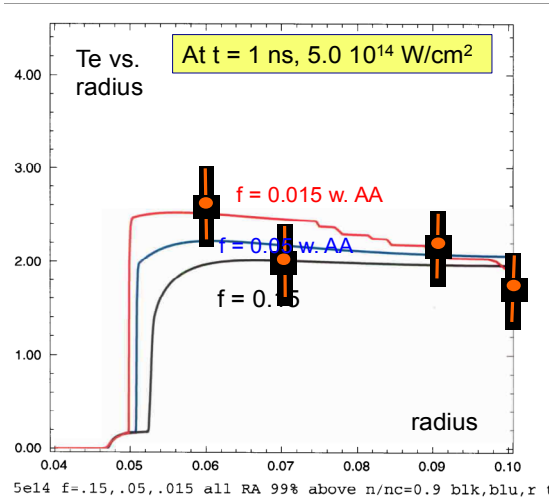


In practical terms:
Use the hydro-code's machinery for Resonance Absorption:
Do a "dump-all" (absorb 99%) of the laser energy that manages to propagate and to reach above 90% of the critical density.

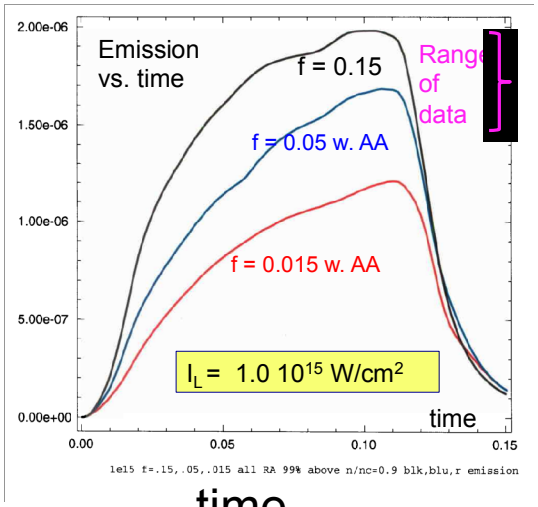
…or, maybe it is actually Resonance Absorption?

Enhanced absorption/2-stream Au sphere ≈ agrees with data

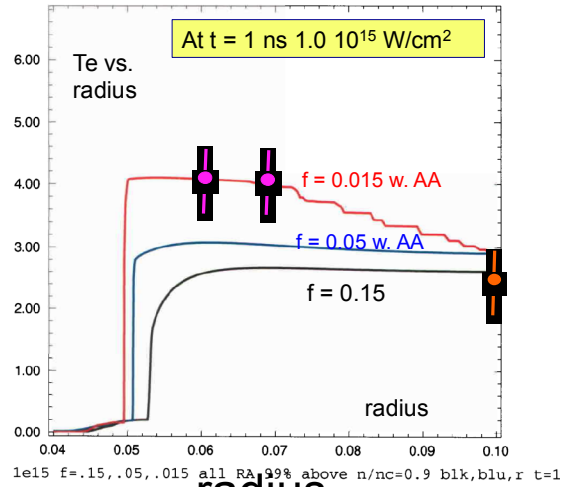




I_L = 5.0 10^{14} W/cm^2



time

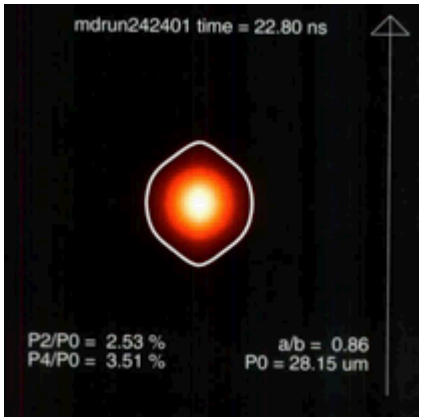


radius

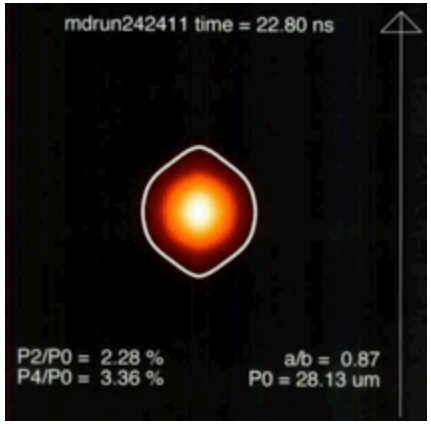
I_L = 1.0 10^{15} W/cm^2

How does this localized AA model do, when applied to hohlraums?

- The nominal absorption model, (along with DCA and 2-stream (~ f=0.015)), when applied to a hohlraum, does not need to invoke source multipliers



- In general*, the localized AA model, does *not change* the answers,(e.g. Dante drive, bang-times, implosion symmetry) compared to the nominal absorption model



- Laser beams have long paths in the hohlraum
  - 100s of μm in the Au sphere corona
  - vs. *millimeters* in hohlraums.
    - Thus, in HR laser's absorbed well before it reaches n_{crit}

*shot N120205, CH NIC, 0.96 mg/cc fill (b.t.: 22.7 ns) & also tested for "672 0.6 mg/cc fill happy hohlraum", & NVH HDCs

Thus, this same "AA" model can be applied to spheres *and* to hohlraums

How can we further study this issue?

- Can we probe the Au sphere nearer the surface?
  - Refraction issues of the probe beam?
  - X-ray Thomson Scatter
    - Could we see the turbulence ?
      - Would it affect the n_e, T_e, profiles? conversion efficiency ?

- Can we illuminate everywhere *but* the surface? See post deadline poster: Y. Frank et al*

- Repeat for a flat plate or other geometry?
  - Further analyze previous Ross/Froula data from Omega on a flat Au plate

- Explore other inhibition mechanisms
  - B fields
  - Azimuthal / axial quad splitting to enhance beam uniformity on the wall of a NIF HR

Also: Theoretically, what *is* the "right" enhanced absorption model to use ?

***The influence of the atomic modeling on integrated simulations of laser produced Au plasmas** Y. Frank, E. Raicher, M. Frankel, D. Shvarts et al.

Your ideas would be most welcome !

Summary

- The 2-stream inhibition model operates in hohlraum's Au bubble as f = 0.015
  - Can lower radiation drive - Helps obviate "Source Multipliers"
  - Can raise Te in Au bubble - Helps inner beam propagation in the NVHs

- The 2-stream model partially operates in the fill gas
  - May still have sufficiently low Te to agree with SRS spectra and levels

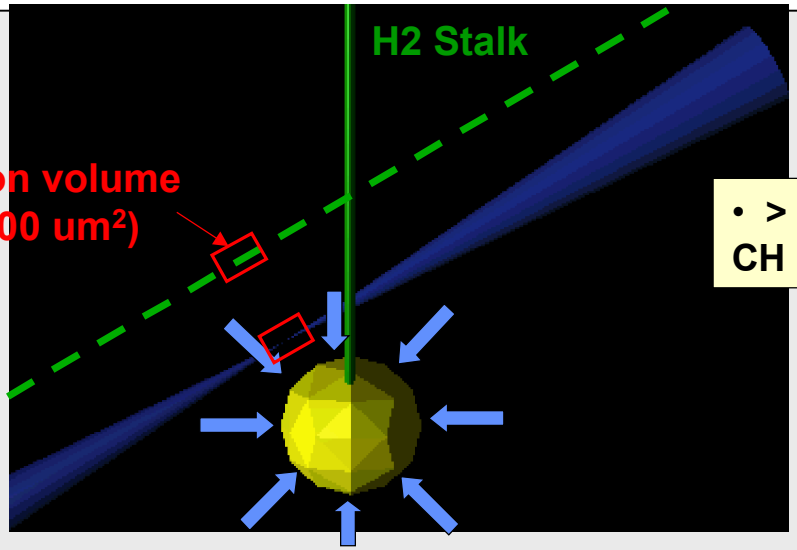
- The 2 stream model, with AA via "I.B. x 3", did *not* match Au sphere's radiative output nor the TS Te(r,t) measurements.

- *But*, localizing the AA, by a "dump-all" near the critical surface:
  - Can ≈ match all of the $T_e(r,t)$ data
  - Can ≈ match the absorption / emission levels.
  - Keeps the hohlraum calculation ≈ same as a *non*-AA-enhanced model
    - Because light gets absorbed by ≈ 0.1 critical
    - Thus, this model that can be applied to *both* Au spheres and to hohlraums

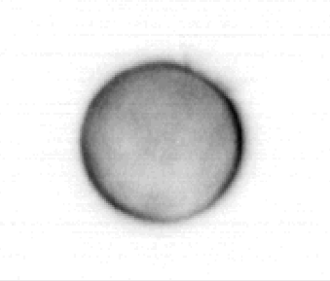
We may have identified a way to ≈ reconcile Au spheres with a 2 stream model

Back-ups start here

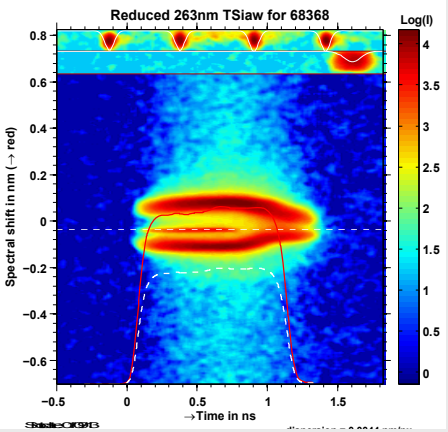
Starting in 2013, Thomson Scattering data gave us information on T(r,t) in Omega Au spheres



- > 5 um Au, DU, Ag coating on CH mandrels, 1 mm OD!



XRPHC Image 1E14!



TS spectra vs time!

LASER DRIVE: 59 beams (+4w TS probe)

10^{14} W.cm^{-2} / 1 ns square, 50 J/beam

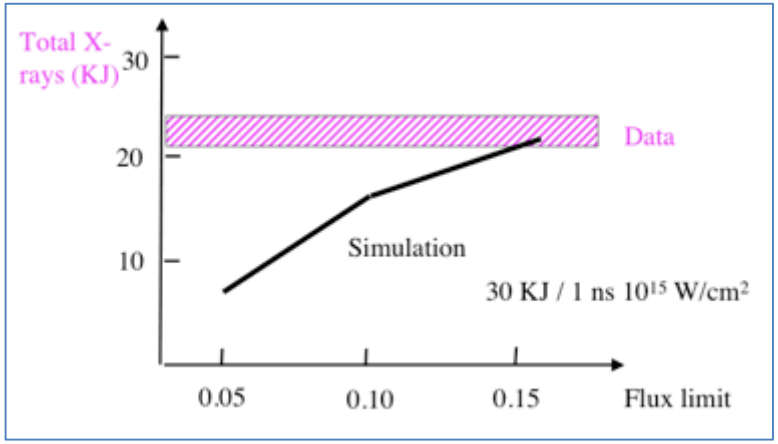
5×10^{14} W.cm^{-2} / 1 ns square, 250 J/beam

10^{15} W.cm^{-2} / 1 ns square, 500 J/beam

Au spheres shot on Omega: HFM successes:

Emission levels matched by f=0.15, (or non-local)

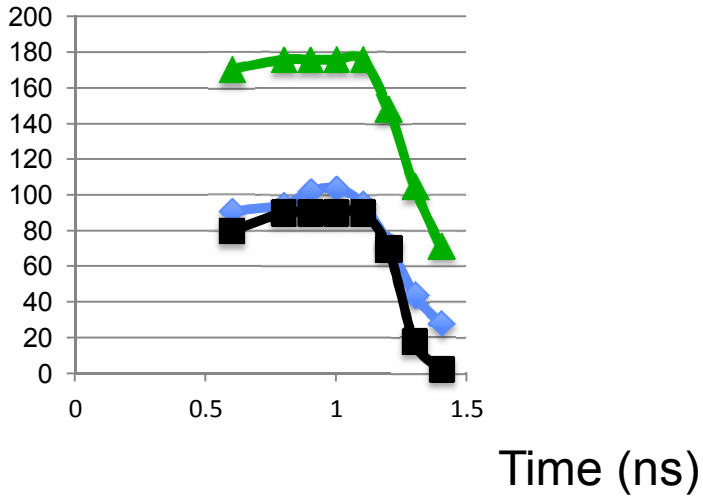
- More restricted f: absorbs less, & converts less to x-rays



TS: Z_BTe (keV) vs. time (ns)

For Au at r = + 200 μm

& I_L = 5. 10^{14} W/cm^2



XSN f = 0.05

Data

DCA non-local

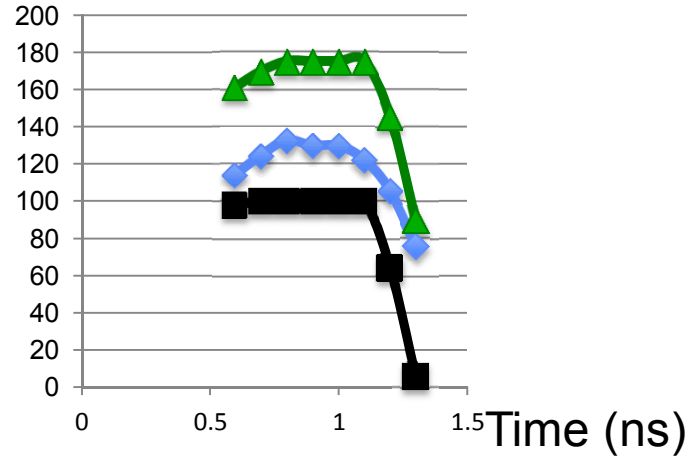
Au spheres shot on Omega: HFM not consistent with some TS data

Data hotter closer to surface

Z_BTe (keV) vs. time (ns)

For Au at r = + 100 μm

For I_L = 5. 10^{14} W/cm^2



XSN f = 0.05

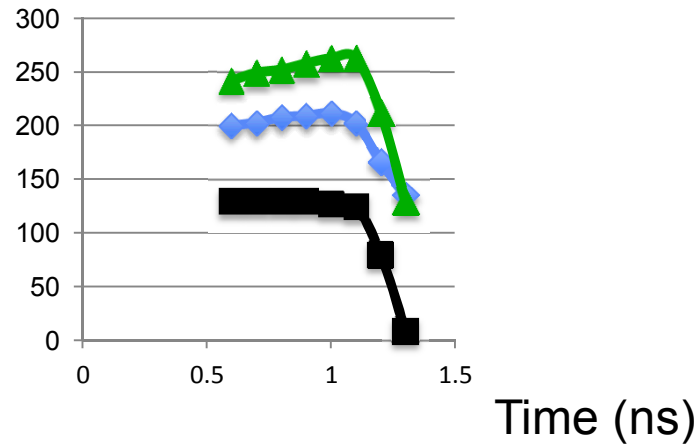
Data

DCA non-local

Z_BTe (keV) vs. time (ns)

For Au at r = + 100 μm

& I_L = 1. 10^{15} W/cm^2



XSN f = 0.05

Data

DCA non-local

(ZTe data also disagrees with HFM at r = + 200 μm for I_L = 1. 10^{15} W/cm^2)

Hohlraum modeling deficiencies ("source multipliers") have led to a re-examination of the HFM

Year	Sphere f	Hohlraum f	Comments	References
'10-'12	.15	.15	Until the view-factor* experiments were done, could argue late "bang times" due to ablator issues	- M. D. Rosen, H. A. Scott, D. E. Hinkel et al HEDP **7**,180 (2011); - M. D. Rosen, in "Laser Plasma Interactions & Applications" Ch. 8, 185-220, *Springer Press* (2013), P. McKenna et al, eds. Scottish Graduate Series.
'13-'14	.15	.05	Argued that in hohlraum, beams separate into single beams, not smooth	- M. D. Rosen, H. A. Scott, D. A. Callahan et al *Proceedings of the EPS Plasma Physics Meeting, Berlin, 2014,* LLNL-PROC-655722 6/24/14 paper # O2.206
'14-'15	.15	.015	Two-stream-model option, (ignores sphere results), being tested widely vs. data	C. Thomas, work in progress
'15	.015 ?	.015	This talk	

* S. A. MacLaren, M. B. Schneider, K. Widmann et al PRL **112**, 105003 (2014)

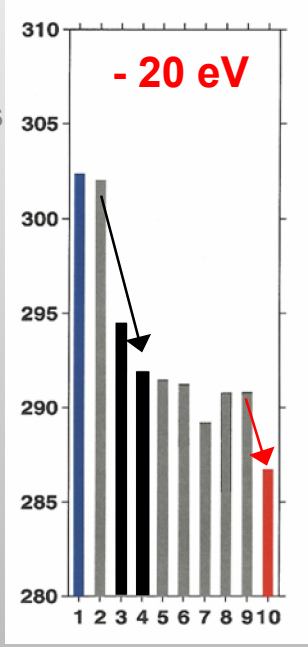
DCA + 2-stream hohlraum model ~ agrees with data

Drive vs. modeling variations

Simulation of N120122 LF

Peak T_r

1: Standard candle
2: small Δt & more zones
3: Lagrange to rise
4: Lagrange to peak
5: Lagrange to end
6: modern EOS
7: modern DCA
8: modern ν_{ei}
9: hot electron model
10: Flux-limited DCA



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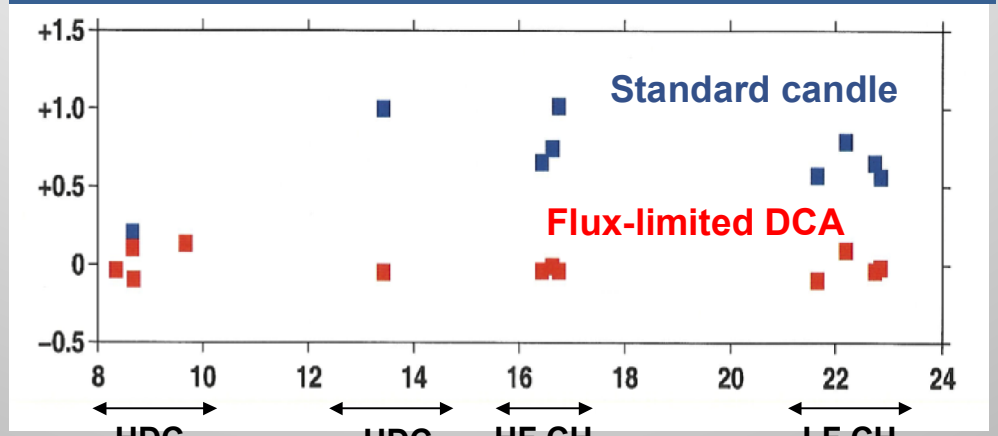
Implosions' peak emission time vs. data

Time of peak emission measured - simulated



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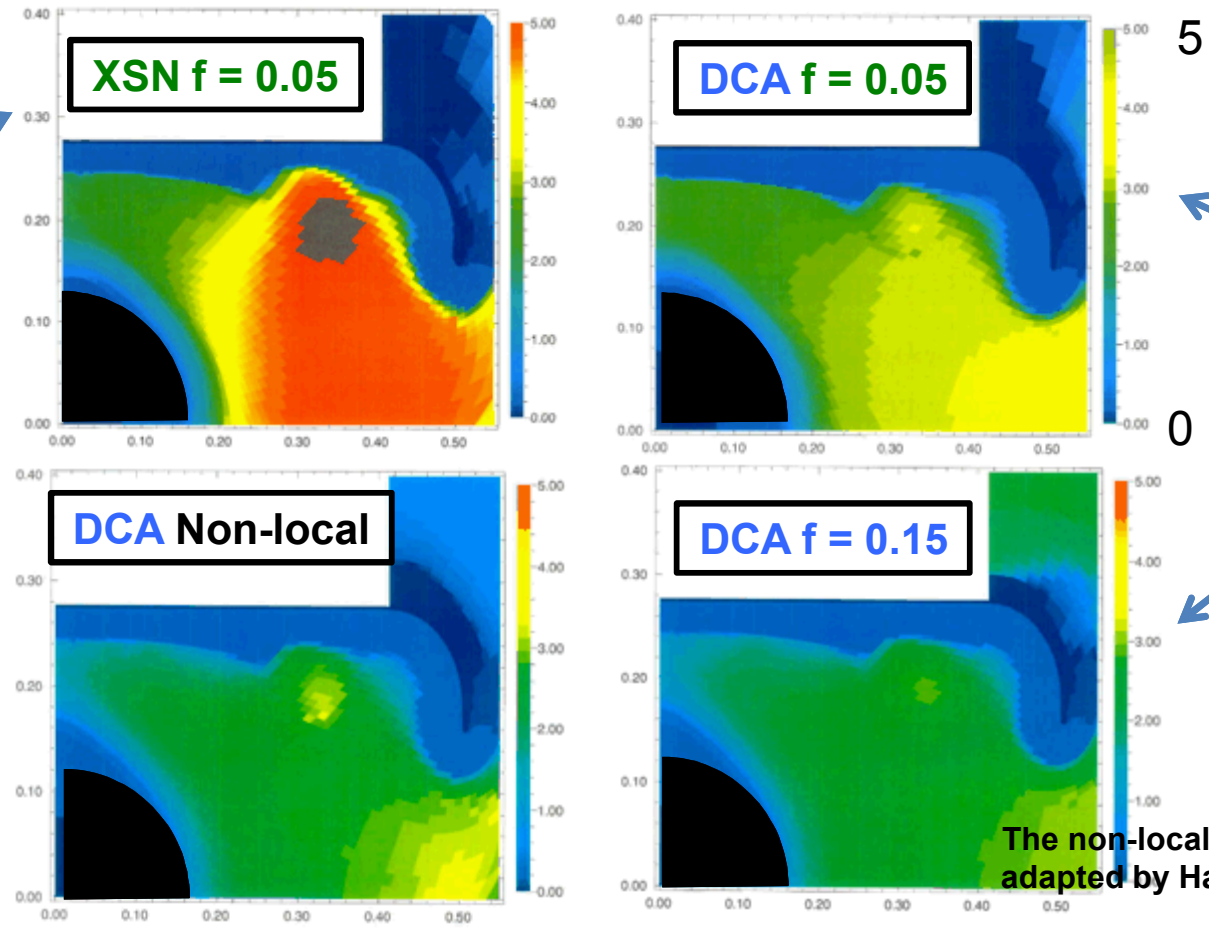
There are 2 key elements: Zoning/Re-zoning methods, & a 2-stream flux limiter

The HFM applied to an ignition scale hohlraum

T_e (0-5 keV contours) at 18 ns (middle of main pulse) for:

N091204
1 MJ gas filled

Old Model vs, HFM: Te higher by ~ 2.5 keV at "2 O'clock" SRS position



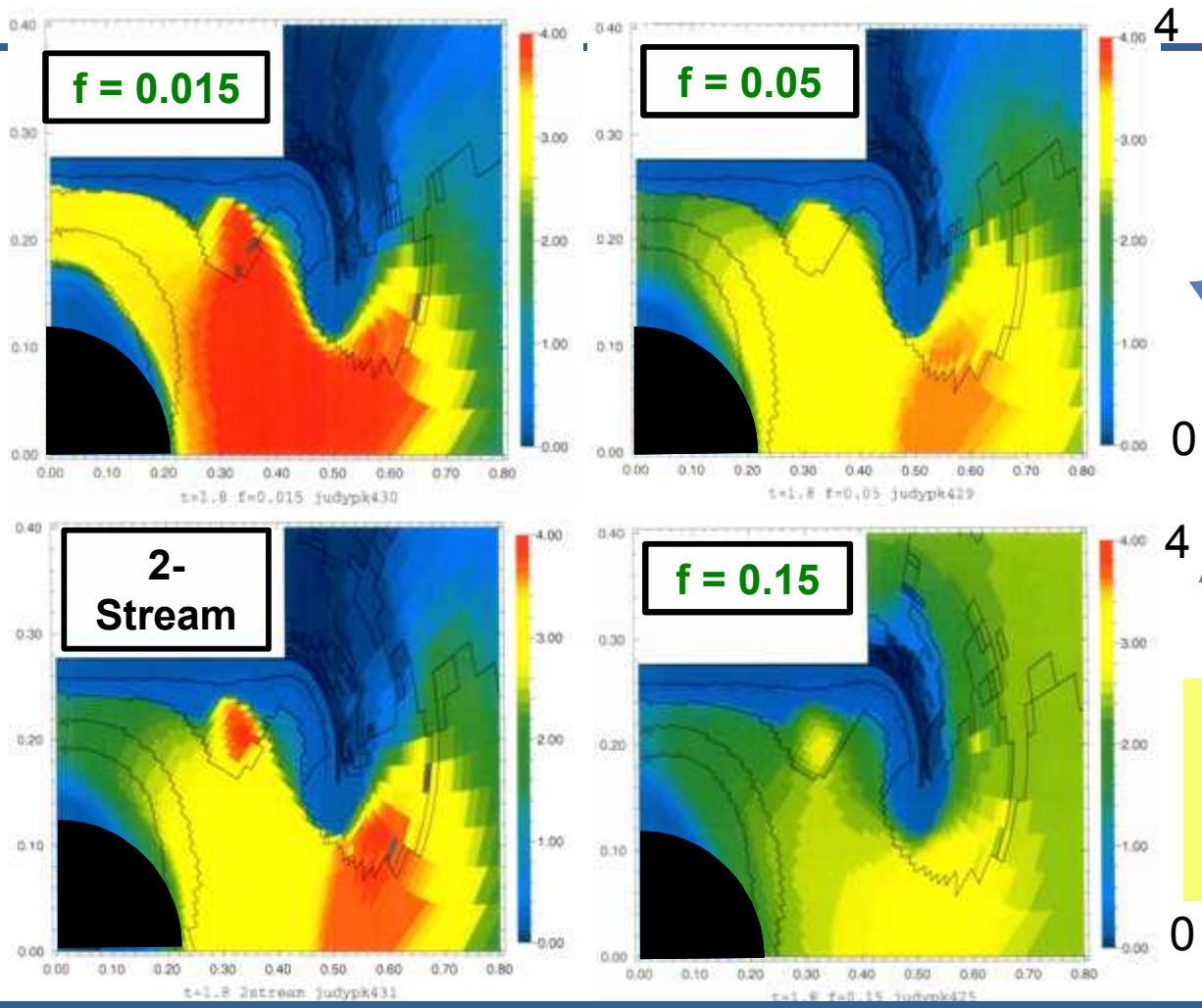
For DCA f=0.05 vs DCA f=0.15, Te higher only by ~ ½ keV at "2 O'clock" SRS position

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

XSN vs. DCA, and its interplay with " f " are major effects for Te

N091204 1 MJ gas filled hohlraum

T_e (0-4 keV contours) in 1 MJ hohlraum at 18 ns (middle of main pulse) (**All with DCA**)



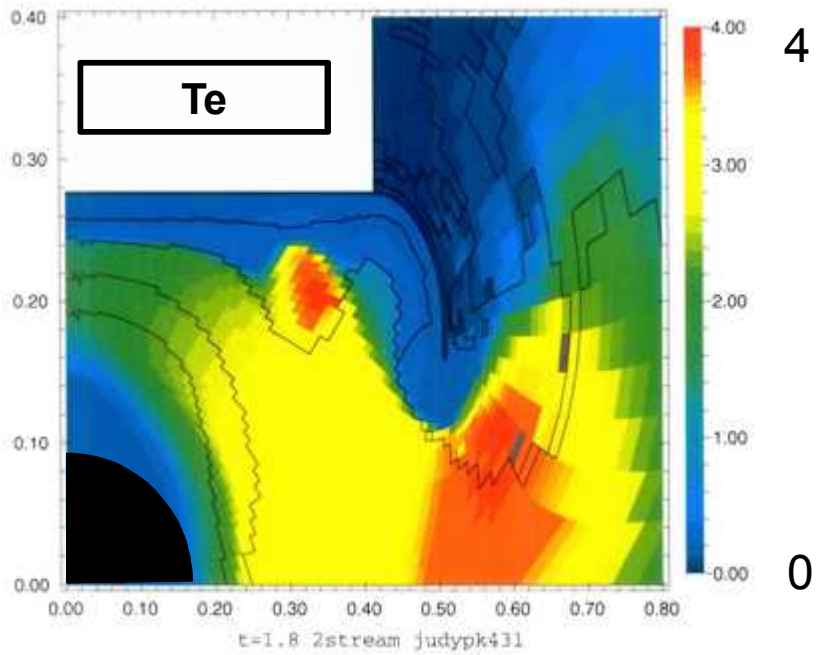
For DCA f=0.05 vs DCA f=0.15, Te higher only by ~ ½ keV at "2 O'clock" SRS position

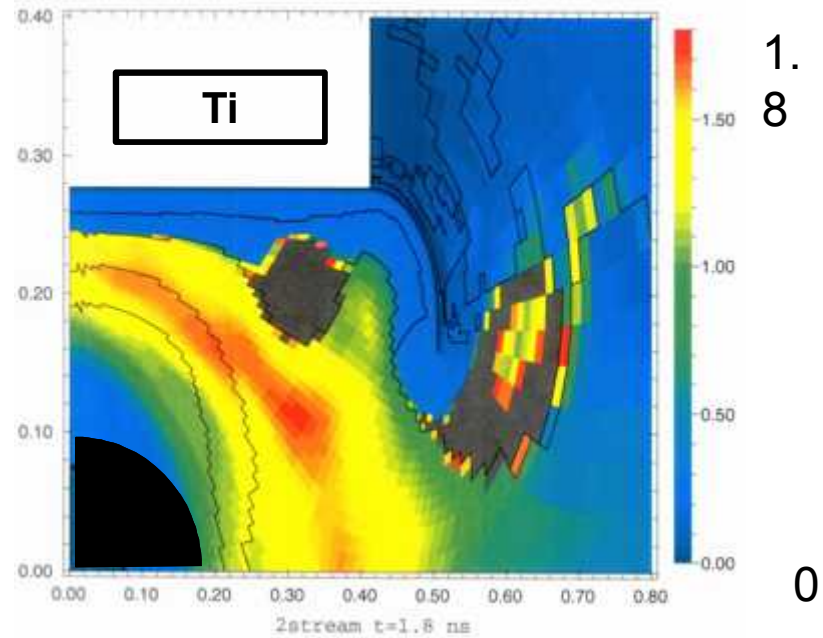
2-stream inhibitor is operative when ZT_e/T_i is large: So depends on how T_i varies within the hohlraum

The 2-Stream inhibitor looks like f = 0.015 *where it is operative*

N091204 1 MJ gas filled hohlraum: 2 stream model

T_e (0-4 keV contours) in 1 MJ hohlraum at 18 ns (middle of main pulse) (with DCA)





2-stream inhibitor is operative when ZT_e/T_i is large: So depends on how T_i varies within the hohlraum

Collisional dynamics within the hohlraum partially turns off 2 stream in the internal gas, at some times, and at some places