Inline Modeling of Cross-Beam Energy Transfer and Raman Scattering in NIF Hohlraums

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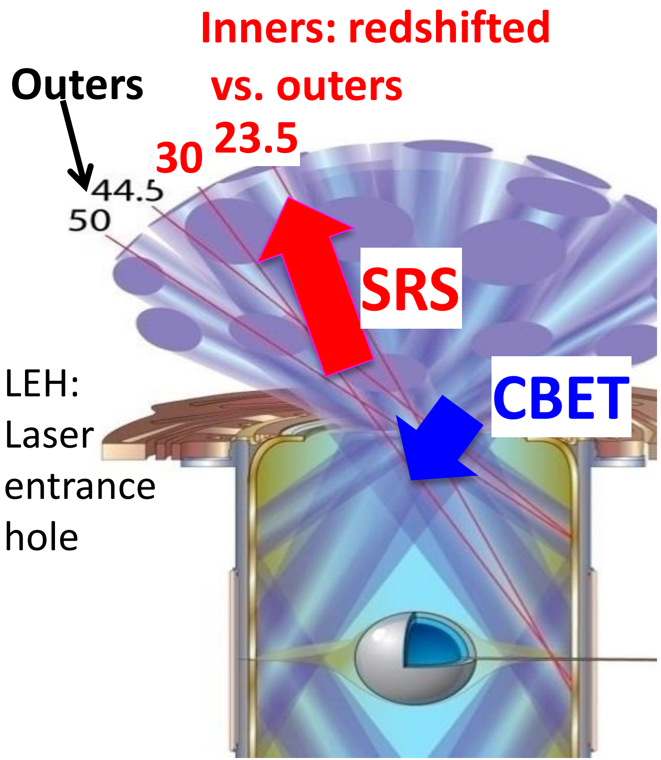
Cross-beam energy transfer (CBET) is used to control shape in hohlraums with high gas fill densities



- Low-foot and high-foot designs
- CBET from pump to probe with lower frequency in plasma frame
- Stimulated Raman scattering (SRS):

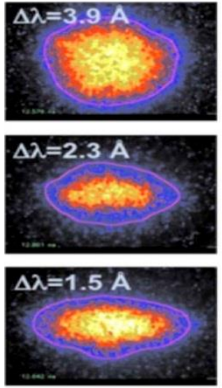
  Laser photon → scattered photon + Langmuir wave

Hotspot x-ray image

Prolate = 'Sausaged'

More $\Delta\lambda = \lambda_{in} - \lambda_{out}$:
More transfer to inners

Oblate = 'Pancaked'



Modeling shape in hohlraums is a significant challenge

Old script-based process [not shown here]

1. Rad-hydro run: no CBET or backscatter removed
2. CBET post-processing script [P. Michel]
3. 2nd rad-hydro run with CBET and SRS removed

- Gives more sausaged implosion than data
- Limit CBET with clamp on ion wave amplitude $\delta n_e/n_e$

Inline CBET, SRS removed at lens [D. Strozzi, APS-DPP 2014]

- CBET calculated internally
- Ion-wave energy deposition

Versus script:
- Picket: less CBET, due to inverse brem.
- Peak power: CBET similar

This talk: Inline CBET and SRS

- Pump laser depleted in target
- Langmuir-wave deposition
- Inverse brem. of SRS light

Summary of inline SRS results:
- Langmuir waves driven near laser entrance
- LEH hotter: reduces CBET
- Produces more pole x-ray drive
- Less need for δn_e clamp to agree with shape data

We use inline CBET and SRS models to simulate NIF shot N121130: an early high-foot plastic symcap

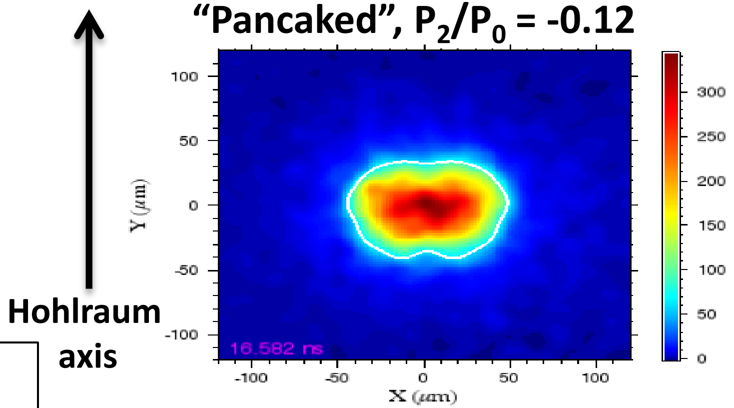
Shot description:

- E_{laser} = 1270 kJ P_{laser} = 350 TW
- $(\lambda_{23}, \lambda_{30}) - \lambda_{out}$ = (8.5, 7.3) Ang.
- CBET to inners: tune P2 shape
- CBET to 23's: tune azimuthal M4 shape
- Gold hohlraum: "575 scale", fill 1.45 mg/cc He

Two rad-hydro runs:

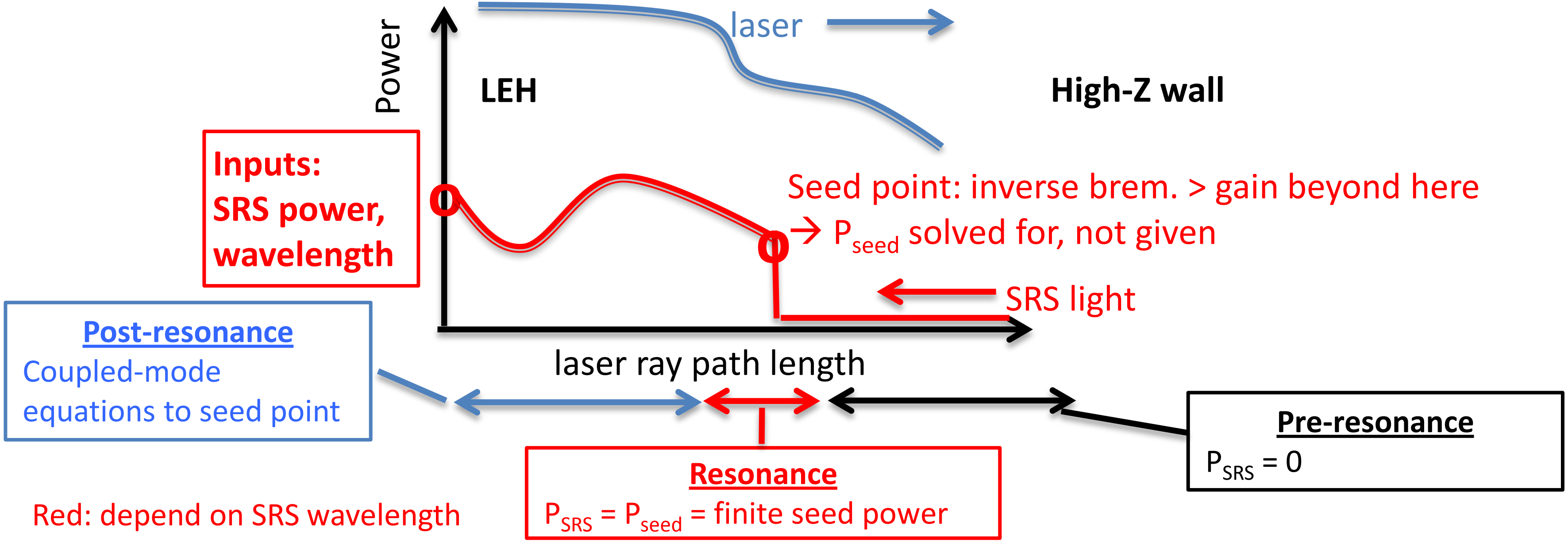
- Lagrange mesh management
- High-flux model: DCA opacities, f=0.15 electron flux limit
- Inline CBET, saturation clamp $\delta n_e/n_e = 10^{-3}$
- **"Lens SRS" run:** SRS light removed from incident laser
- **"Inline SRS" run:** Inline model of SRS

Hotspot x-ray image at bangtime: "Pancaked", P_2/P_0 = -0.12



Comparison with experimental data is ongoing

Inline SRS model: 1D coupled-mode equations in post-resonant region



Red: depend on SRS wavelength

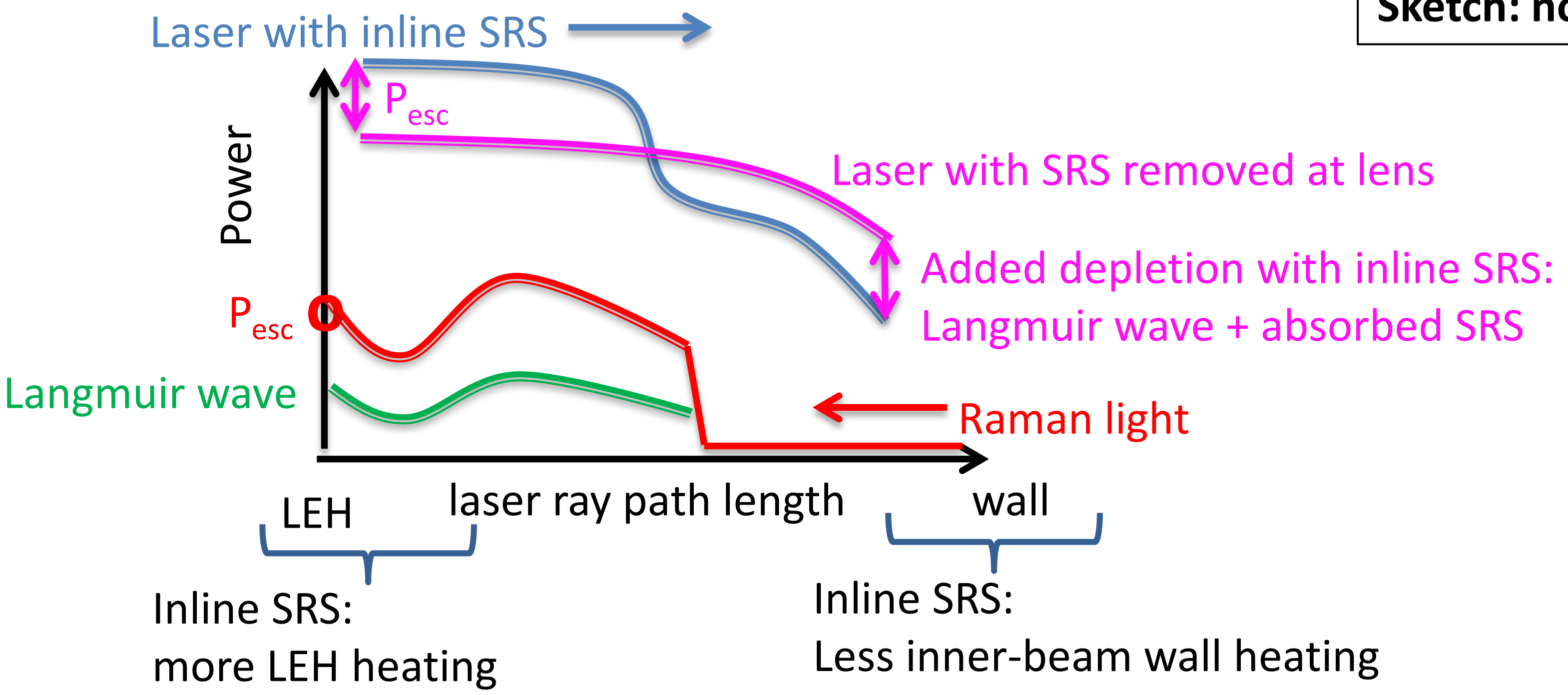
$$\partial_z I_0 = -\kappa_0 I_0 - \omega_0 K I_0 I_1 \qquad \text{pump laser}$$

$$-\partial_z I_1 = -\kappa_1 I_1 + \omega_1 K I_0 I_1 \qquad \text{scattered light}$$

$$p_{Lang} = \omega_0 - \omega_1 \; K I_0 I_1 \qquad \text{Langmuir wave power}$$

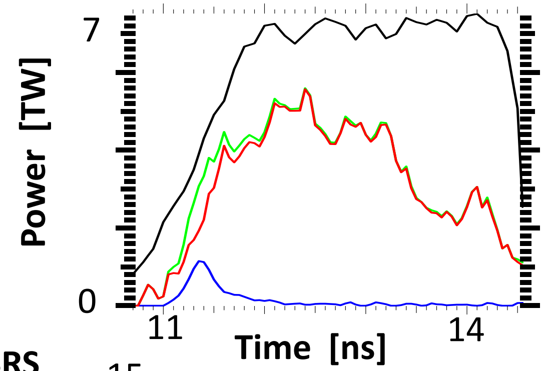
Inline SRS depletes inner beams more than SRS removed at lens: Langmuir waves and SRS inv. brem.

Sketch: not data



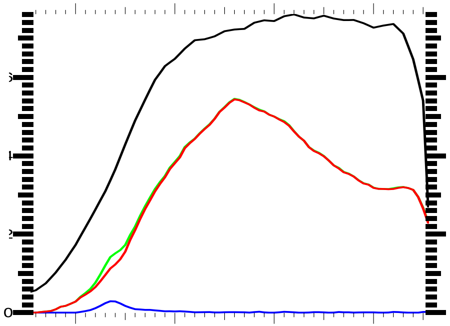
Inputs to inline runs: measured SRS power and maximum wavelength

23º inner cone

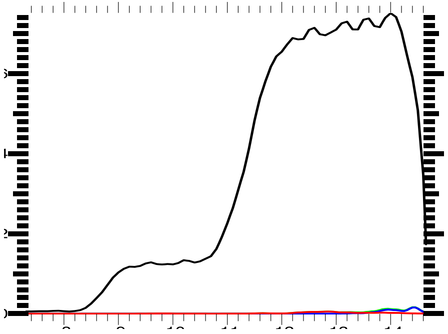


Incident
SRS
SBS
SRS+SBS

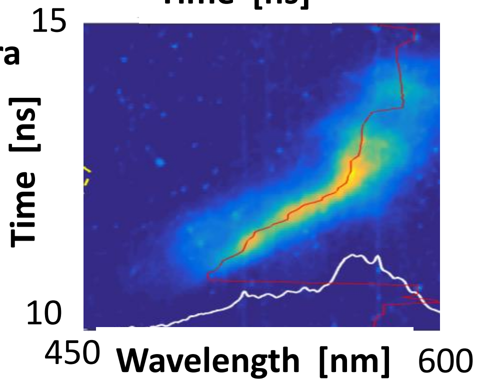
30º inner cone

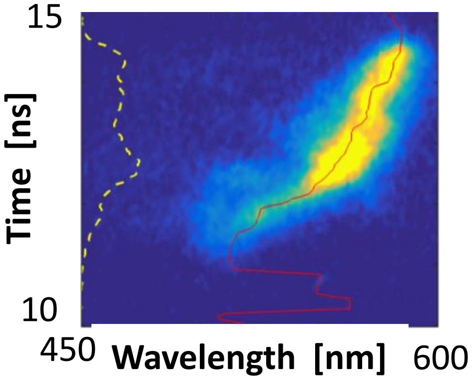


50º outer cone



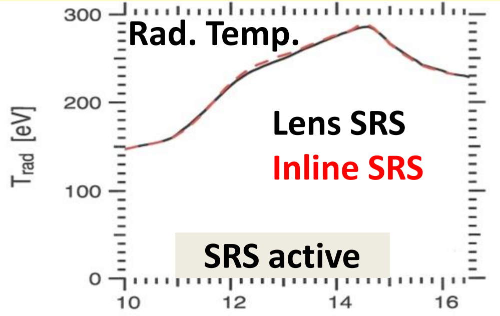
SRS spectra

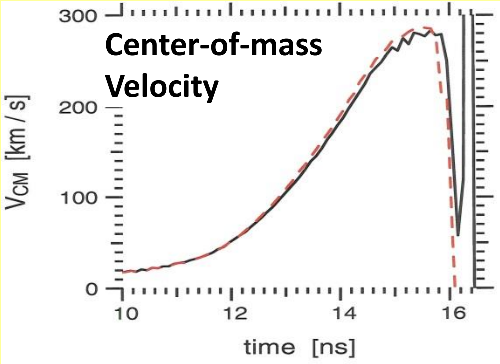




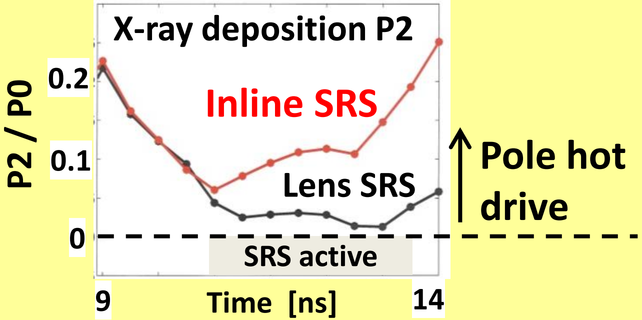
Inline SRS does not change total x-ray drive, makes implosion more pancaked

Total Drive

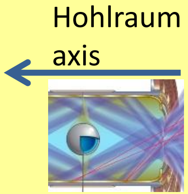


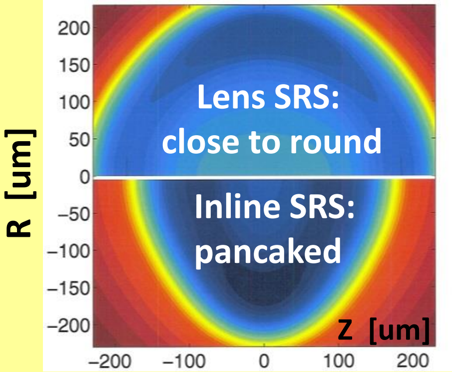


Shape

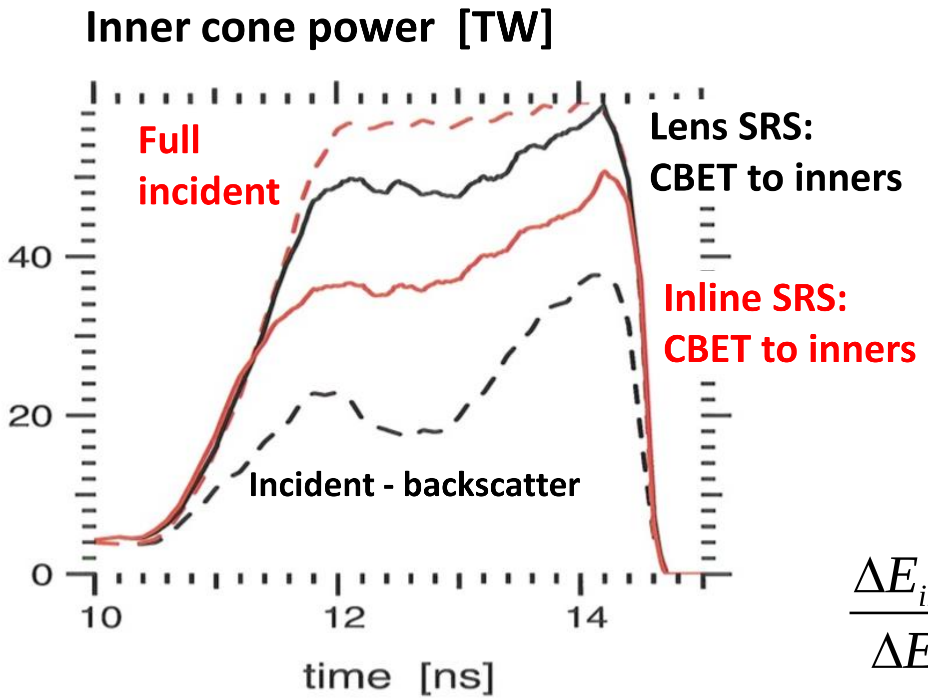


Simulated radiograph at 16 ns: ~ shell density





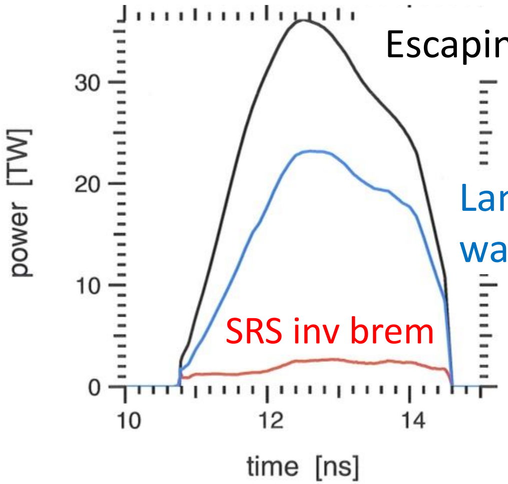
Inline SRS gives slightly less CBET to inners than SRS removal at lens



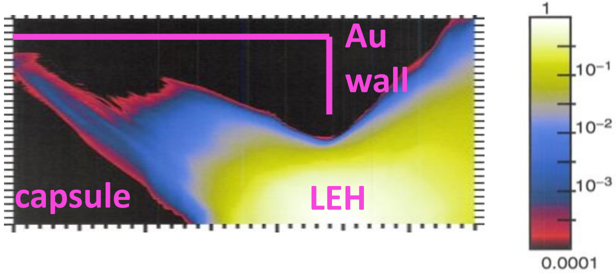
$$\frac{\Delta E_{inner}(\text{inline SRS})}{\Delta E_{inner}(\text{lens SRS})} = 0.83$$

SRS Langmuir waves dominate SRS inverse brem, mostly driven just inside LEH

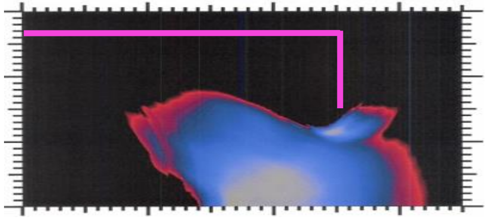
Inner cone powers



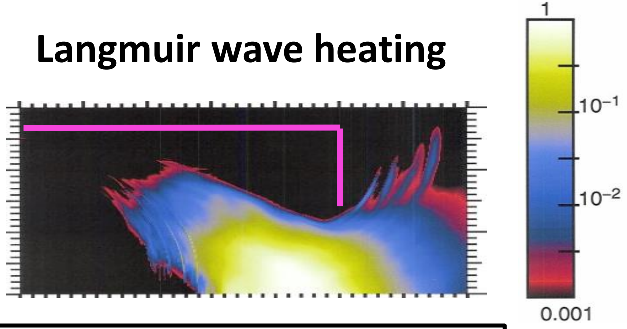
SRS light intensity
continuously grows:
coupling > inv. brem.



SRS Inv Brem heating
Same scale as Langmuir



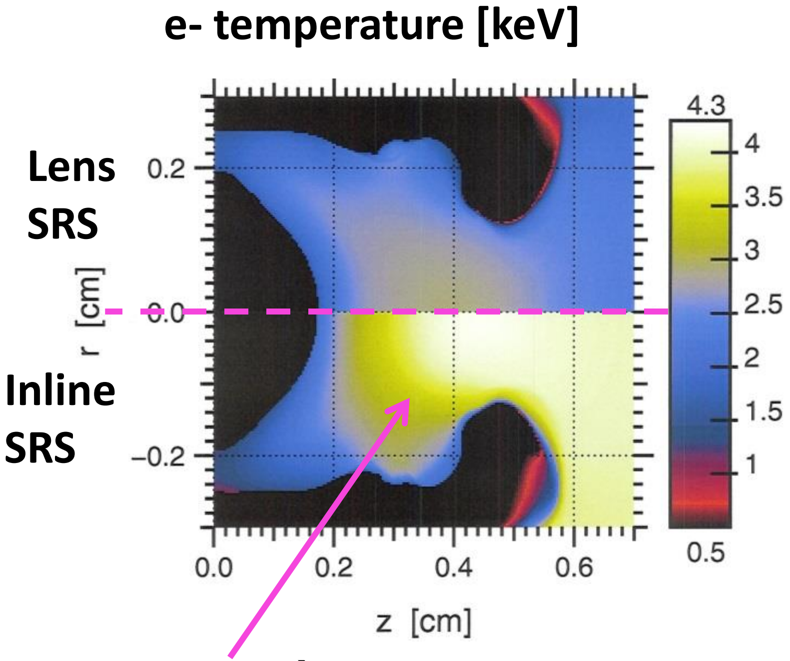
Langmuir wave heating

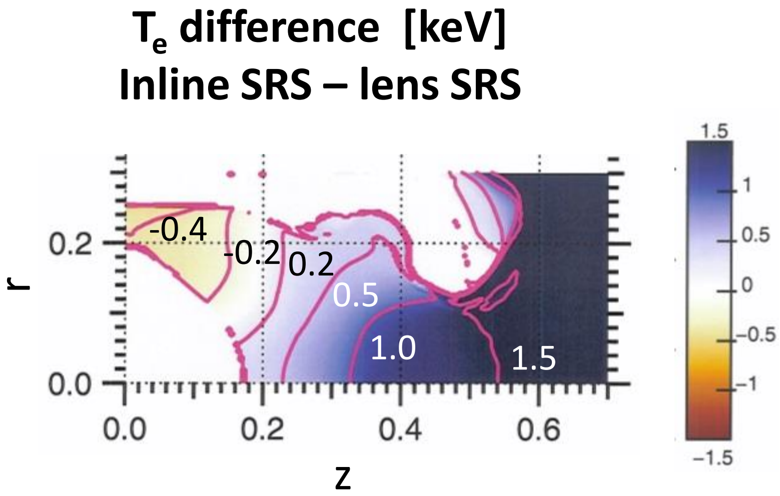


2D plots averaged over peak power

- SRS heats plasma near LEH, conducts to wall
- Appears as polar x-ray drive
- Acts like “transfer to outers”

Inline SRS model increases LEH temperature, decreases it at equator



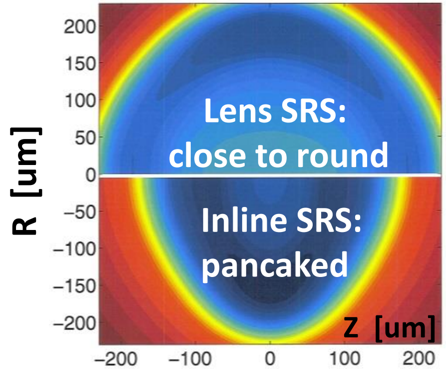


Conducts to wall → polar x-rays

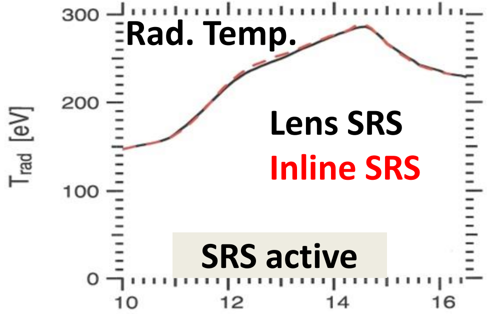
Maps at 13 ns (mid peak power)

Summary: inline SRS model heats LEH, reduces CBET, gives more pancaked shape

More pancaked with inline SRS



Total drive same with inline SRS



	Inners	Outers	SRS heating
	"Cone Fraction:" % of incident laser		
Incident	32	68	0
Escaping backscatter	15	0	0
CBET	+29 / +24	-29 / -24	0
SRS heating	0 / -11	0	0 / +11
lens SRS / inline SRS			
	Post-LPI: % of incident – backscatter + CBET		
	53 / 35	47 / 52	0 /13

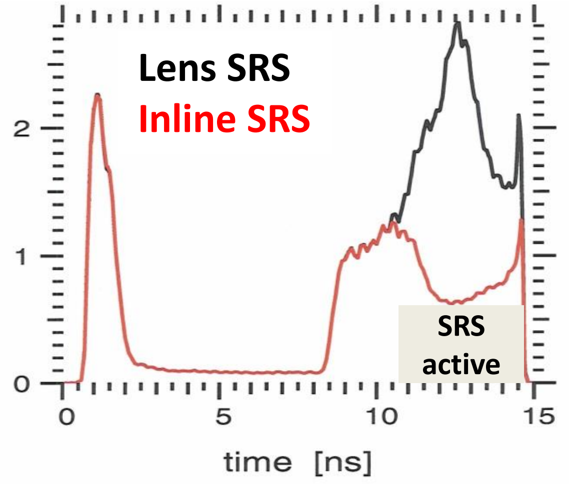
Occurs near LEH; increases polar x-rays

BACKUP BELOW

Path towards agreement with measurements: implosion shape, LEH temperature ("micro-dot" spectroscopy):

- Replace δn_e CBET clamp with better CBET physics, saturation model
- Electron transport: non-local effects, return current instability, Langmuir heating as superthermal electrons (fluid T_e shown here)

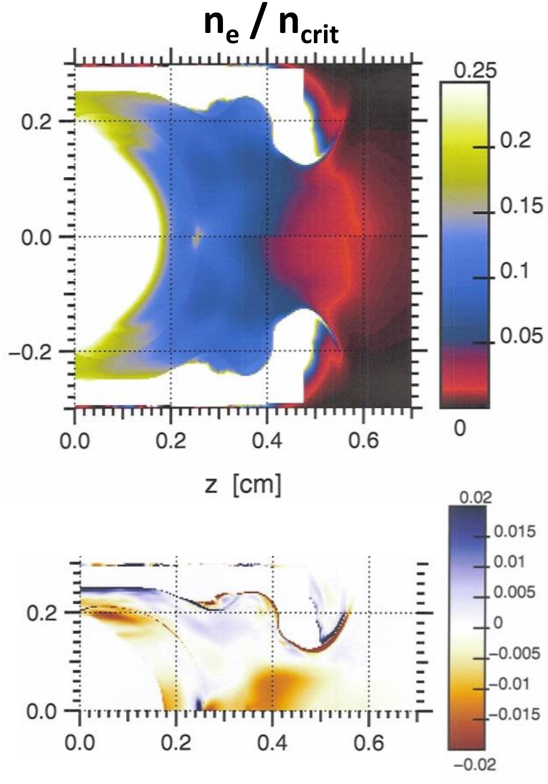
Power to inners / incident



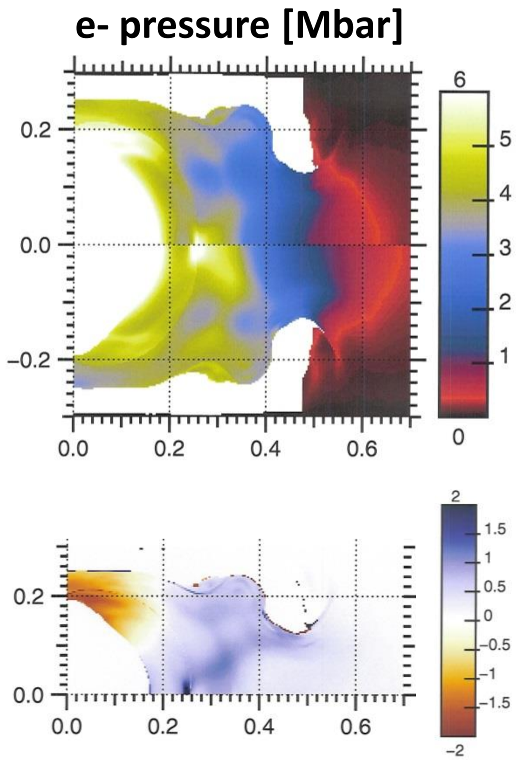
$$\frac{\partial I_{in}}{\partial z} = g I_{out} I_{in} \quad \rightarrow \quad \frac{I_{in}^{post}}{I_{in}^{inc}} = \exp\left[g I_{out} \right]$$

g(plasma conditions): less CBET gain with inline SRS

e- density and pressure



Maps at 13 ns
(mid peak power)



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