Cross-Beam Energy Transfer (CBET) and Stimulated Brillouin Scattering (SBS) in NIF Hohlraums

Talk CO6.3

APS DPP 2018

Portland, OR, USA

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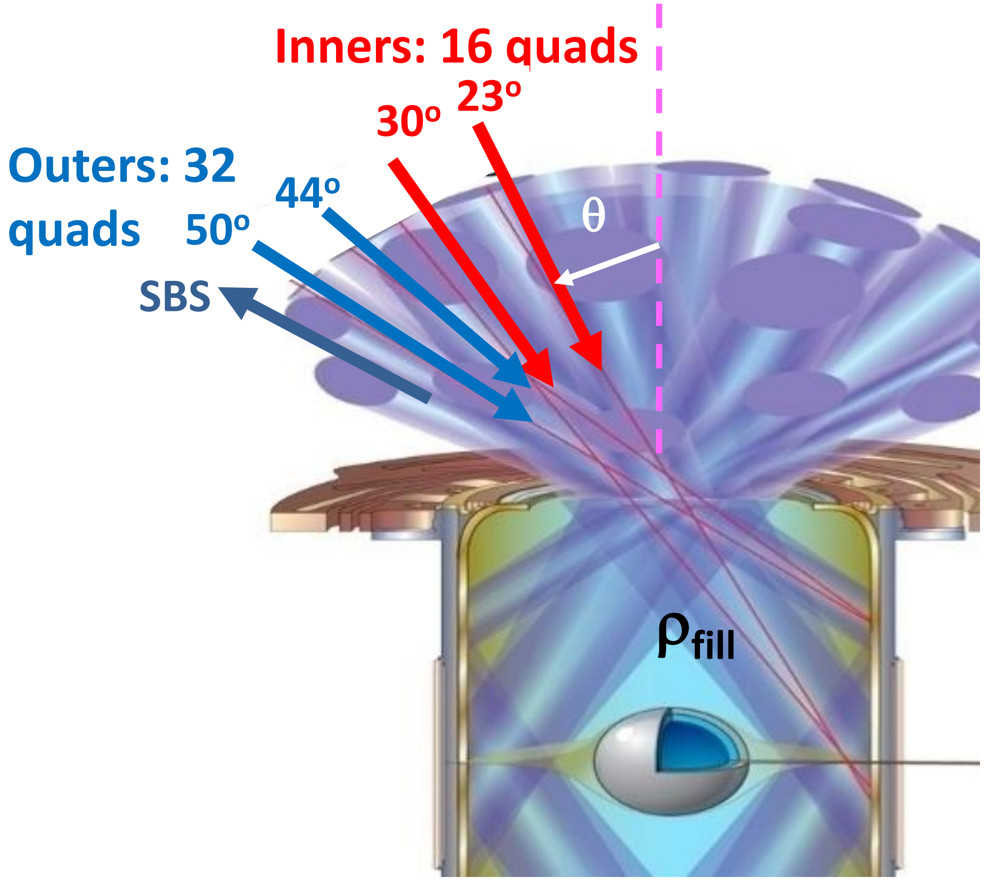
CBET and SBS on NIF

CBET transfers power to laser with longer wavelength in plasma rest frame (Doppler shifted by flow)



NIF cone wavelengths = "colors", $\Delta\lambda$

- Current: 23°, 30°, outers → " 3 colors"
- Summer 2019: 44° and 50° separate → "4 colors"

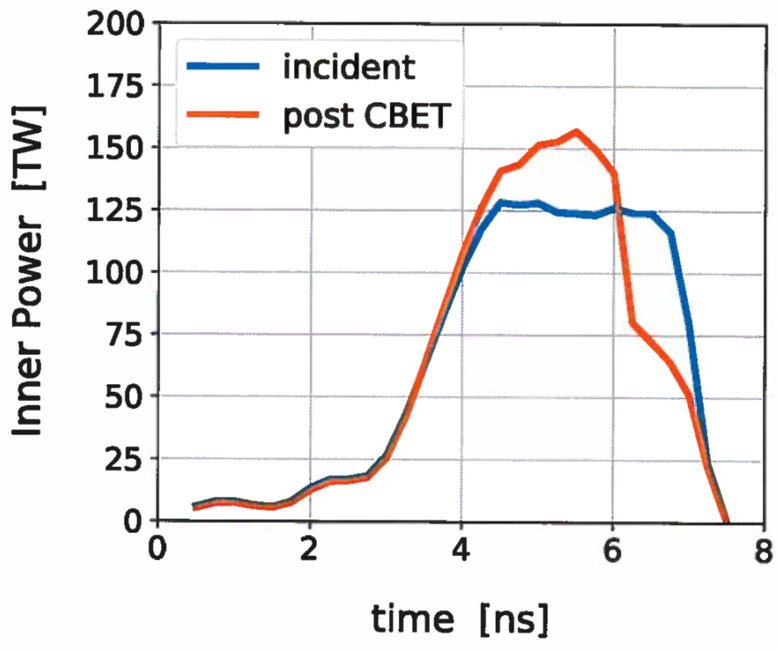
- **High-fill hohlraums:** 2009 – 2014
  - Large $\Delta\lambda$: CBET to inners
    - Needed for round implosion
  - Overcome absorption, Raman scattering
- **Low-fill hohlraums:** 2013 – present
  - Usually $\Delta\lambda$ = 0 for round implosion
  - Outer SBS at end of pulse, esp. on 50's

CBET can occur in low-fill hohlraums with or without Δλ, could mitigate 50º SBS

CBET without Δλ: Bigfoot shots on NIF

- CBET modeling: VAMPIRE code
- CBET swings: to inners early, outers late

Inner power: 23 + 30

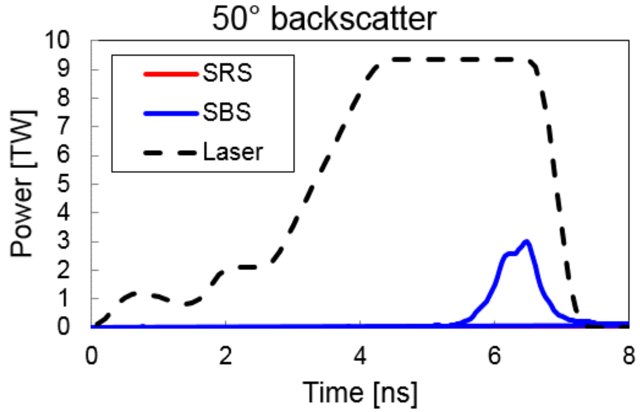


Reduce 50º SBS

$\lambda_{44} > \lambda_{in} > \lambda_{50}$

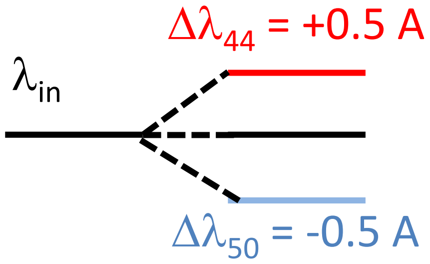
Goals:

- CBET from 50's, to 44's
- Same inner power
  → Same implosion shape



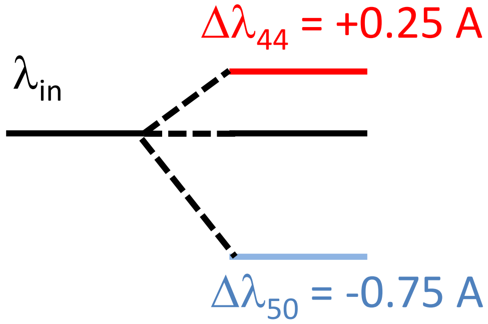
Courtesy C. Goyon, N. Lemos

Symmetric Δλ



- 50's to 44's ✓
- Reduce inner power
  → pancaked shape ✗

Asymmetric Δλ



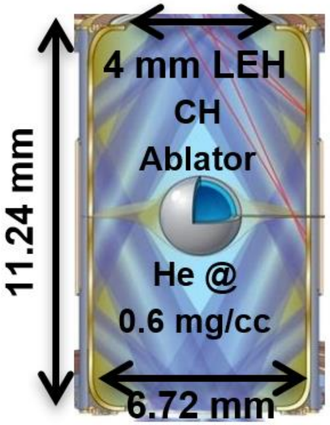
- 50's to 44's ✓
- Same inner power
  → round shape ✓

$\Delta\lambda$ = 0 and low fill can have CBET: “inline” modeling

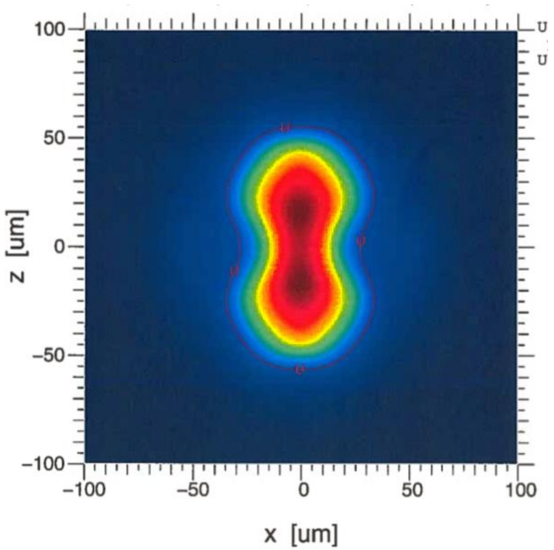
Lasnex simulations of NIF “BigFoot”[1] shots

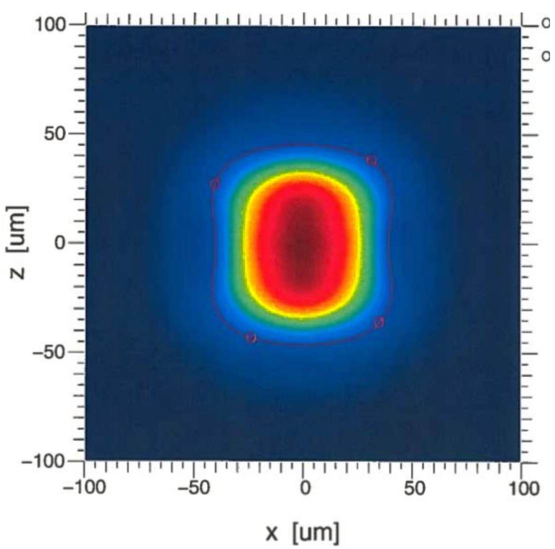
- O. Jones, CO6.9 – later this session
- Used for VAMPIRE modeling

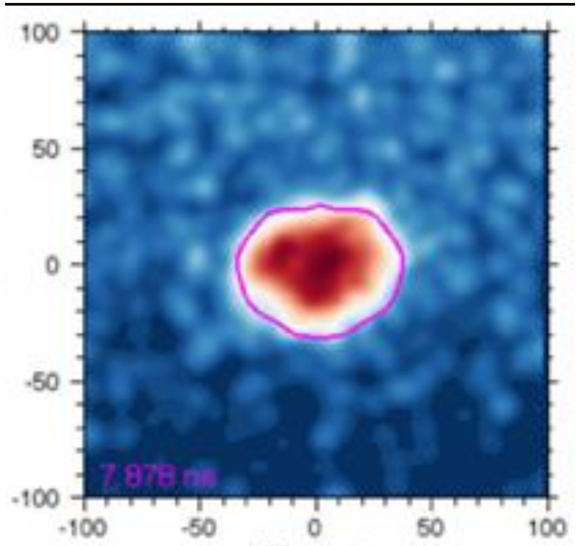
Inline Lasnex CBET model[2]: significant CBET to outer beams



Hotspot x-ray shape







[1] C. A. Thomas, APS-DPP 2016;
K. L. Baker et al., PRL 2018
[2] D. J. Strozzi et al., PRL 2017

VAMPIRE[1] CBET Code

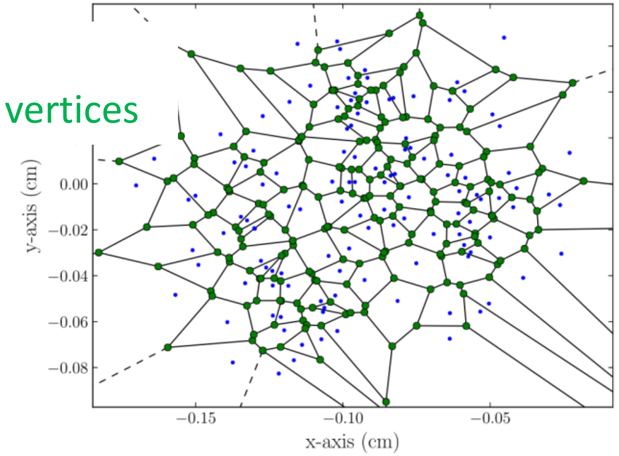
VAMPIRE: Voronoi Adaptive Method for Propagation and Interaction of Radiated Energy

[1]A. Colaitis, T. Chapman, D. Strozzi, L. Divol, P. Michel, Phys. Plasmas 2018

- Steady-state in time
- Ray tracing w/ refraction: $\frac{d\boldsymbol{r}}{d\tau} = \boldsymbol{p}\,, \quad \frac{d\boldsymbol{p}}{d\tau} = \frac{c^2}{2}\nabla\epsilon'(\boldsymbol{r})$

Voronoi tessellation: rays → 3D intensity plane normal to k-vector

blue: rays
green: cell vertices



Intensity evolution

- Inv. brem. absorption
- CBET: linear kinetic, strong damping limit

$$\partial_z I_n = -(\kappa_n + \Gamma_n) I_n,$$

$$\Gamma_n = \sum_{i \neq n} \frac{g_{ni}}{\omega_i} I_i$$

- Each quad treated as one unpolarized laser
- Polarization and phase neglected in this talk
  - Could be important: P. Michel, talk JO6.5 Tues PM
- Saturation clamp: $\delta n_e/n_e = 0.01$
- SSD and Dewandre effect available

$\Delta\lambda$ = 0: CBET first to inners, then to outers

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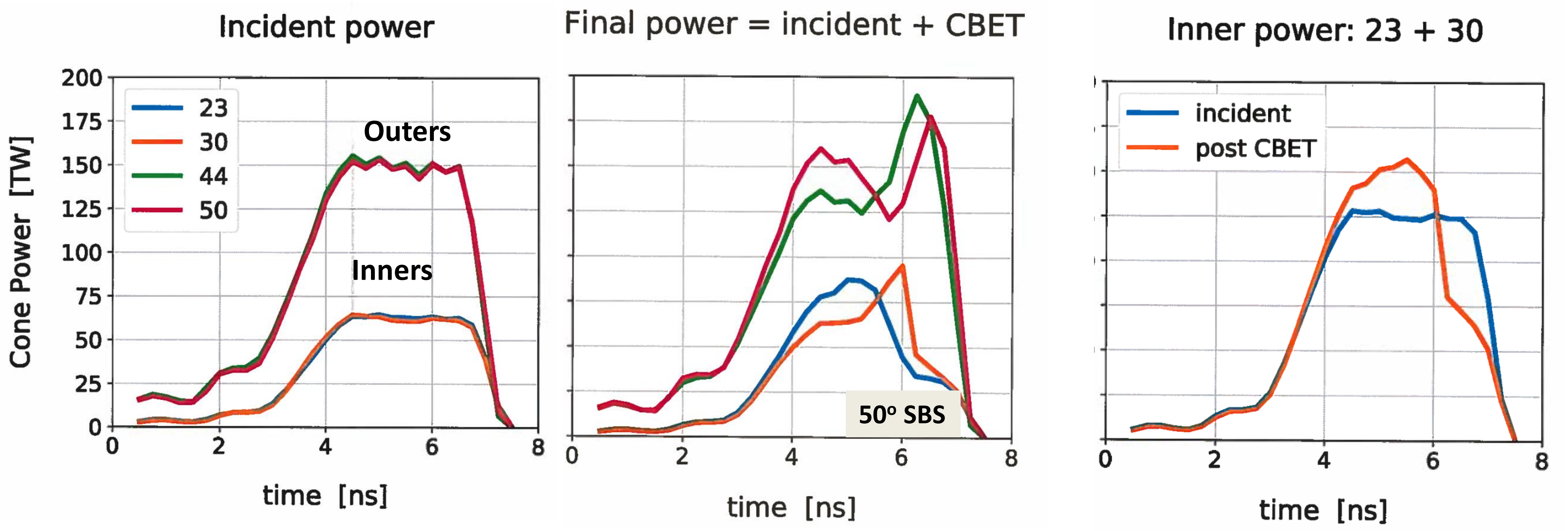

Adding Δλ: Redshifting just the 44's gives more CBET than redshifting just the 50's

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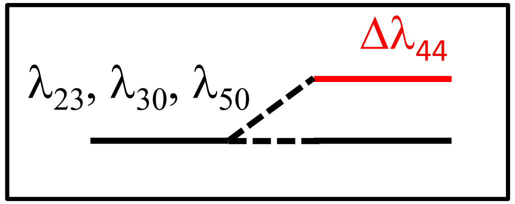
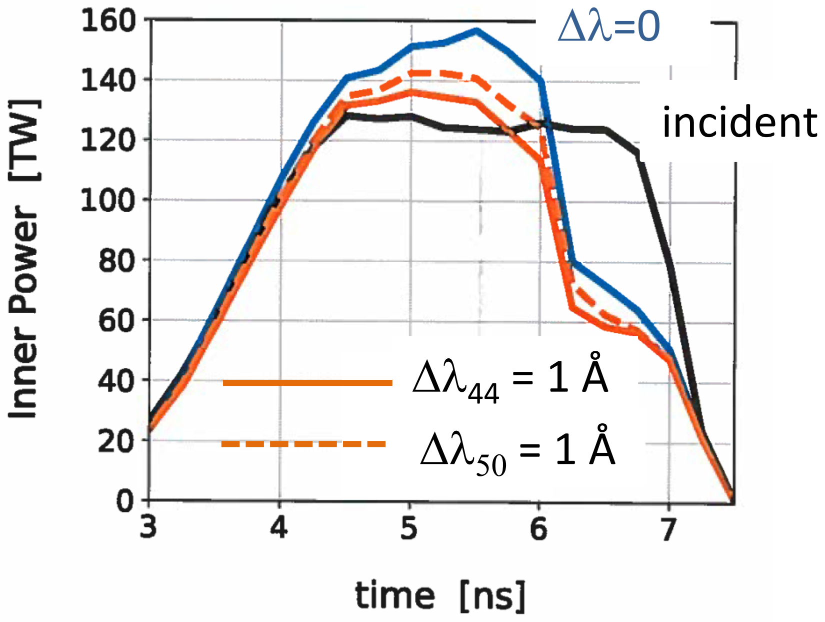
Single-cone Δλ

- Δλ on just 44's or 50's
- Not yet possible on NIF –summer 2019
- Δλ > 0: CBET ***TO*** one outer cone

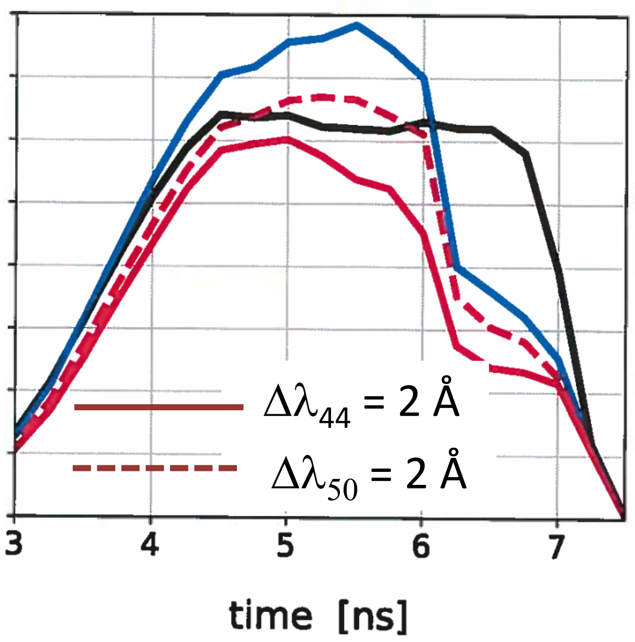
- Δλ = 1-2 Å → significant CBET
- Inners + 44's interact more than inners + 50's
- 44's and 50's **NOT** equivalent for implosion shape



Inner power: 23 + 30
Δλ = 1 Å



Inner power: 23 + 30
Δλ = 2 Å



Symmetric $\Delta\lambda$: $\lambda_{44} > \lambda_{in} > \lambda_{50}$: 50º SBS mitigation, but inner power reduced

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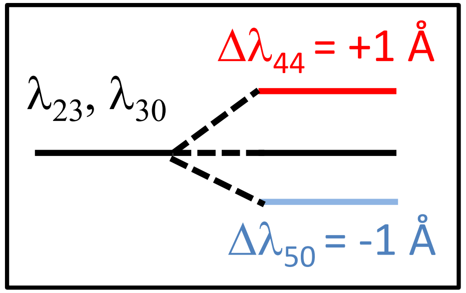
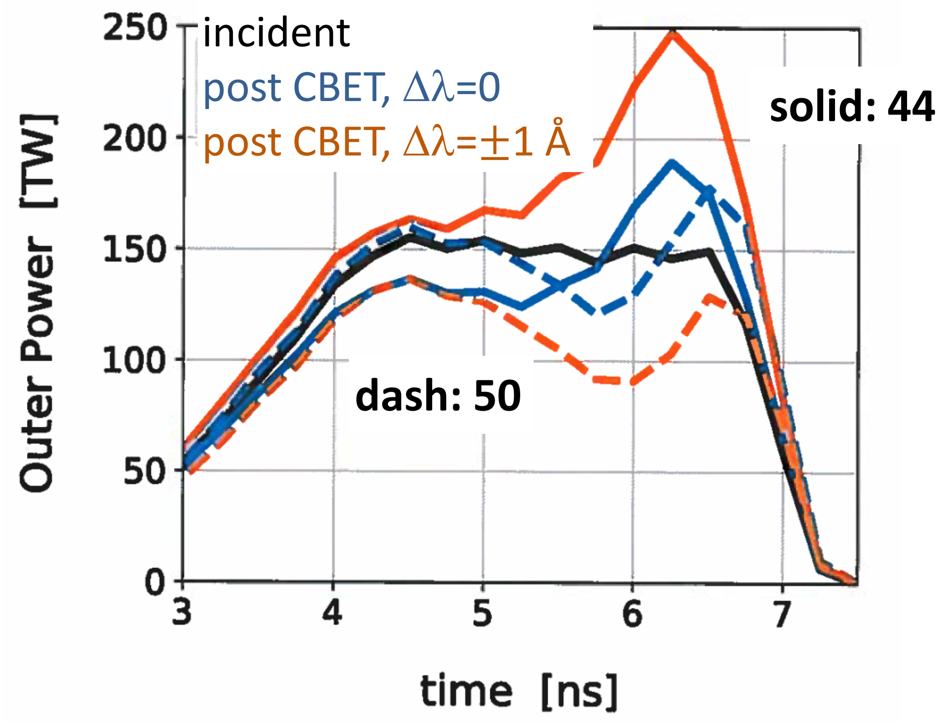
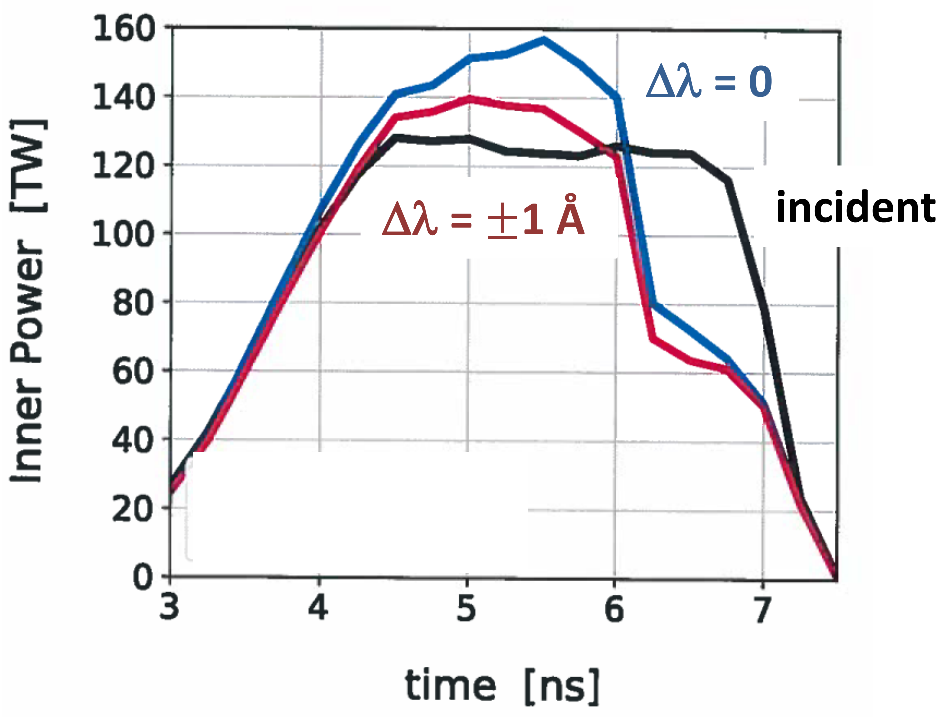


44's vs. 50's:
CBET from 50's, to 44's



Inners vs. Outers:
Inner power reduced, shape changed



Asymmetric $\Delta\lambda$: $\lambda_{44} > \lambda_{in} > \lambda_{50}$: 50° SBS mitigation, and inner power same

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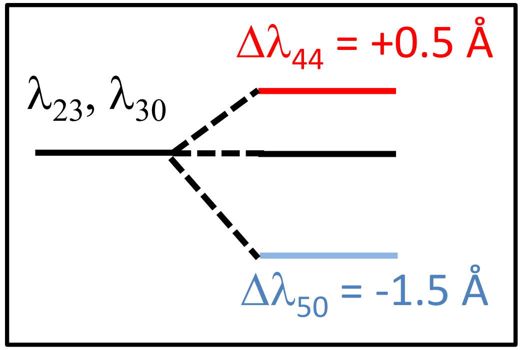
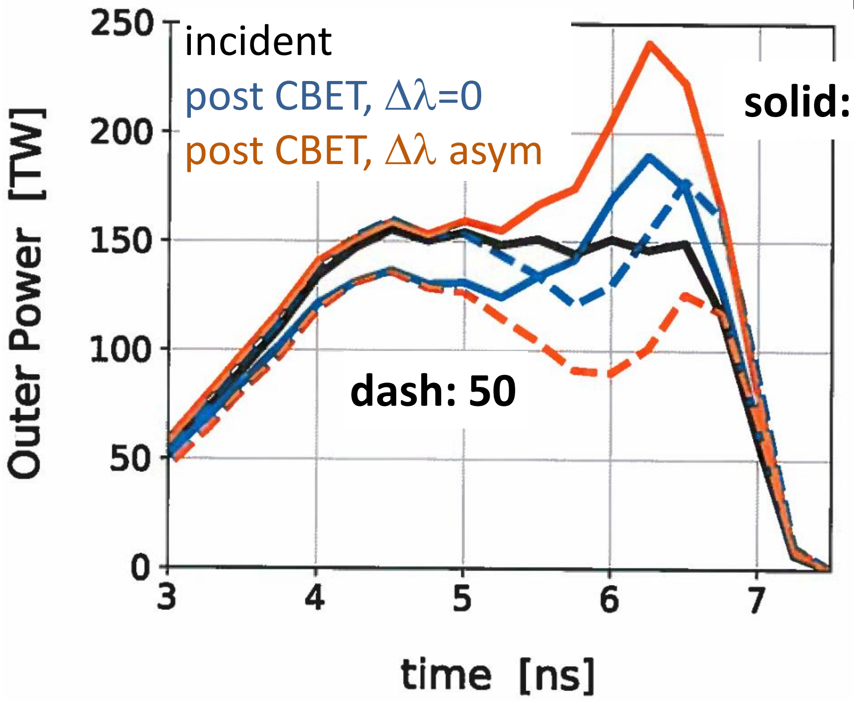
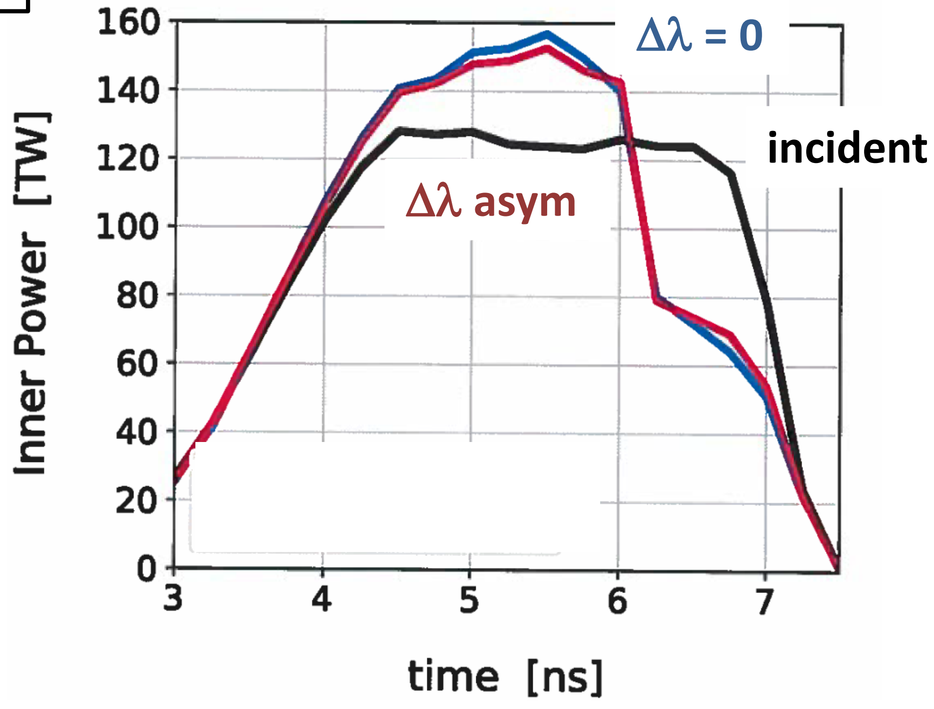


44's vs. 50's:
CBET from 50's, to 44's

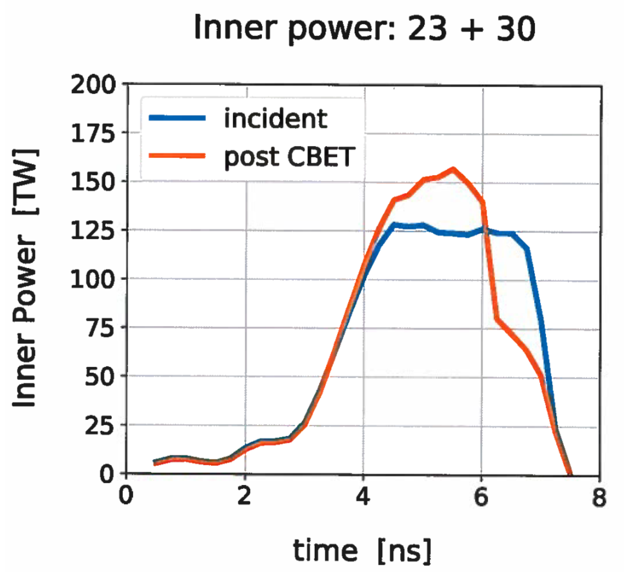


Inners vs. Outers:
Inner power same, shape same



Conclusion: CBET occurs in low gas fill hohlraums, with or without $\Delta\lambda$

Bigfoot shots on NIF: $\Delta\lambda$ = 0
CBET to inners early, outers late

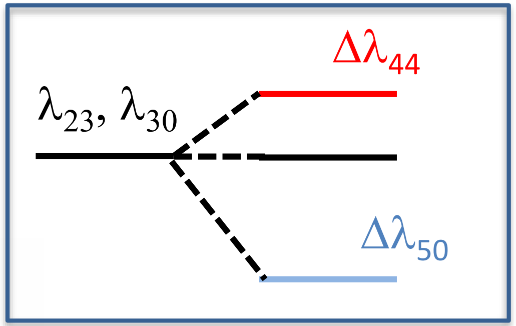


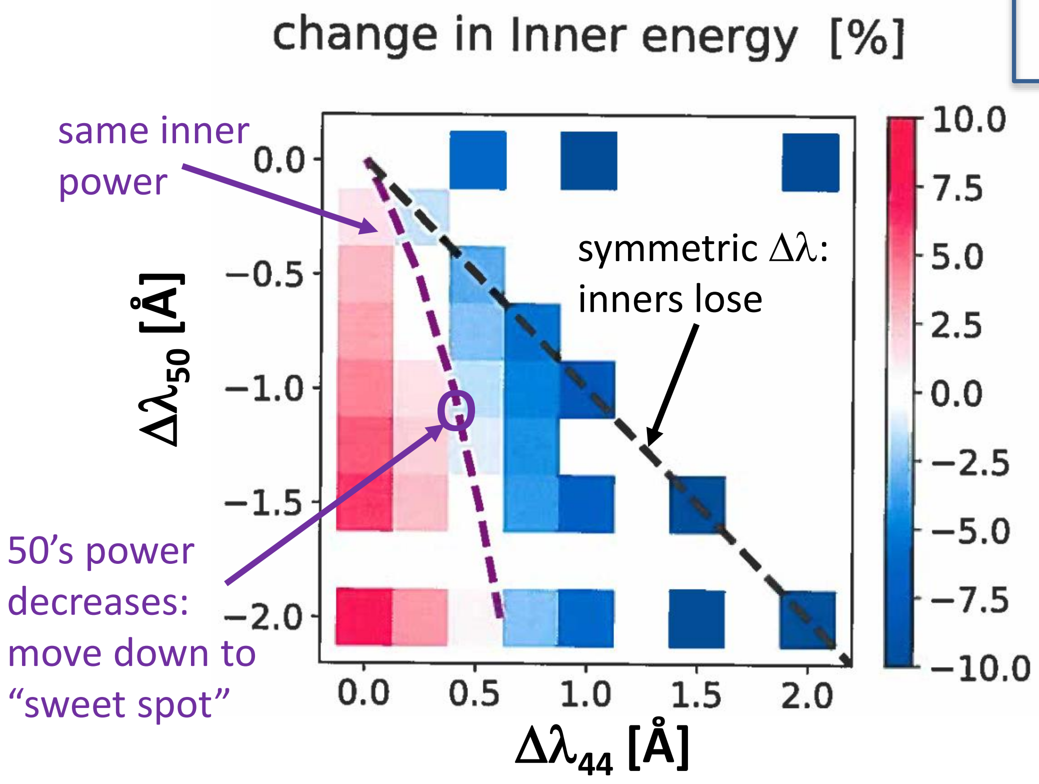
Future work

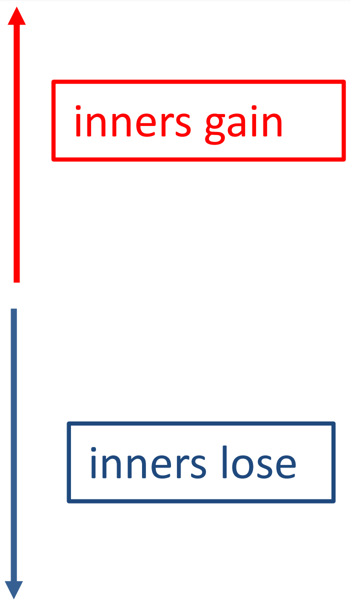
- Polarization and phase of each NIF beam
- Understand and mitigate CBET and SBS on beams within a quad

Mitigate 50° SBS: asymmetric $\Delta\lambda$

- CBET from 50's, to 44's
- Same inner power → same implosion shape





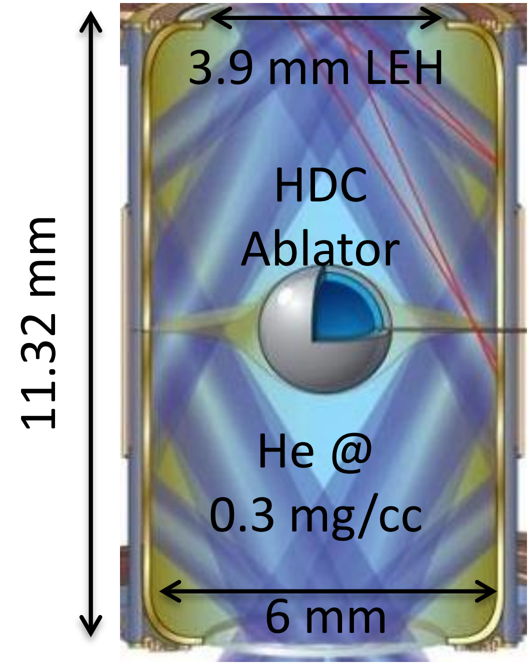


BACKUP BELOW

Δλ = 0 and low fill can have CBET

Lasnex simulations of 2017 NIF "BigFoot"[1] shots

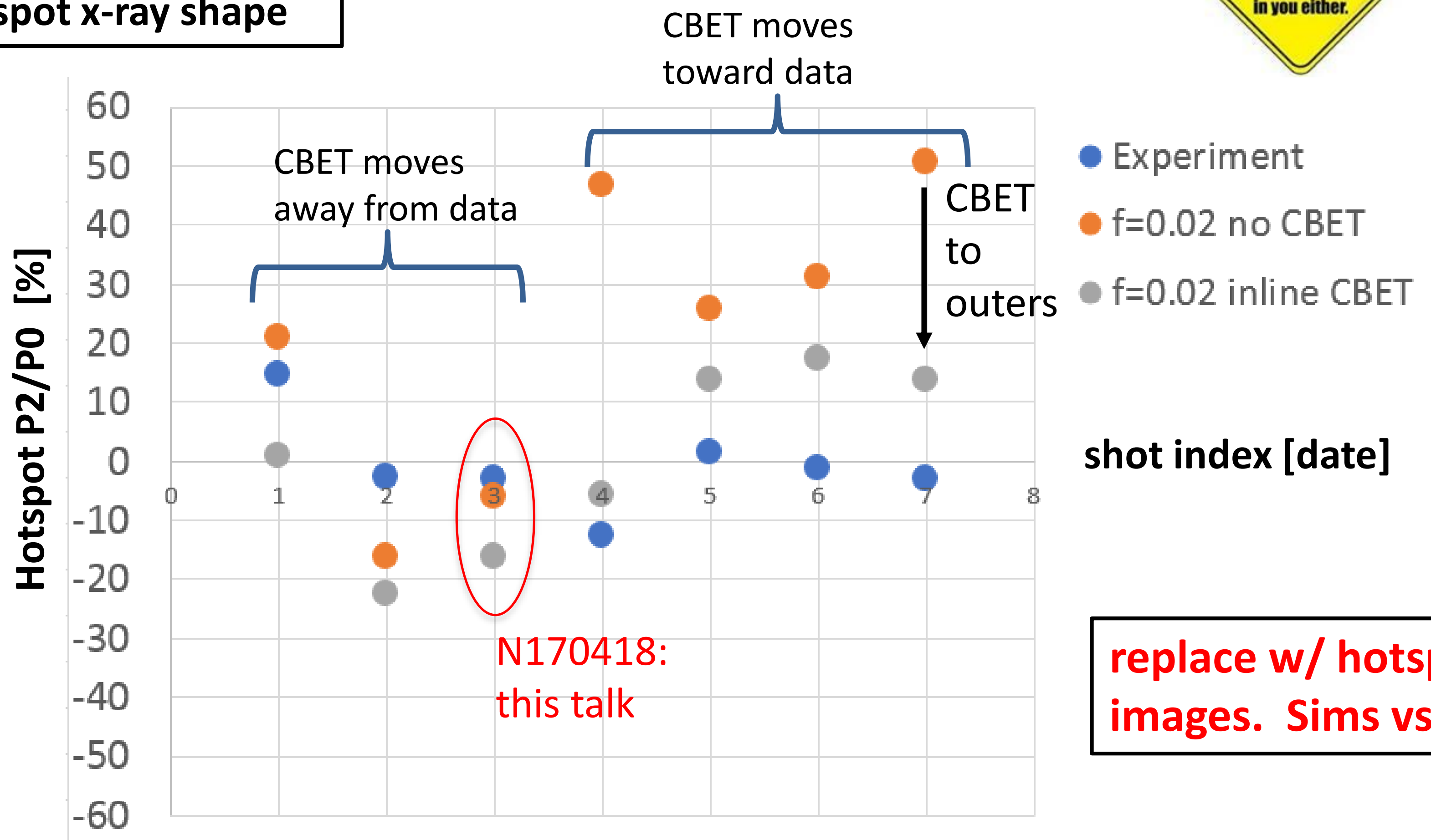
- O. Jones, talk CO6.9 – later this session
- Low e- flux limit f = 0.02



[1] C. A. Thomas, APS-DPP 2016; K. L. Baker et al., PRL 2018
[2] D. J. Strozzi et al., PRL 2017

Inline Lasnex CBET model[2]: significant CBET to outer beams

Hotspot x-ray shape

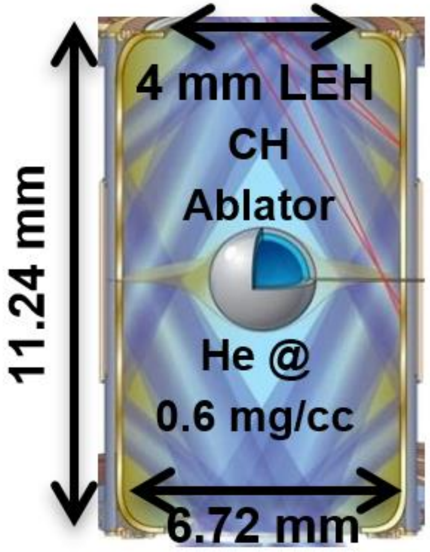


replace w/ hotspot images. Sims vs. expt

$\Delta\lambda$ = 1 Ang. and low fill: significant CBET to inner beams measured[1]

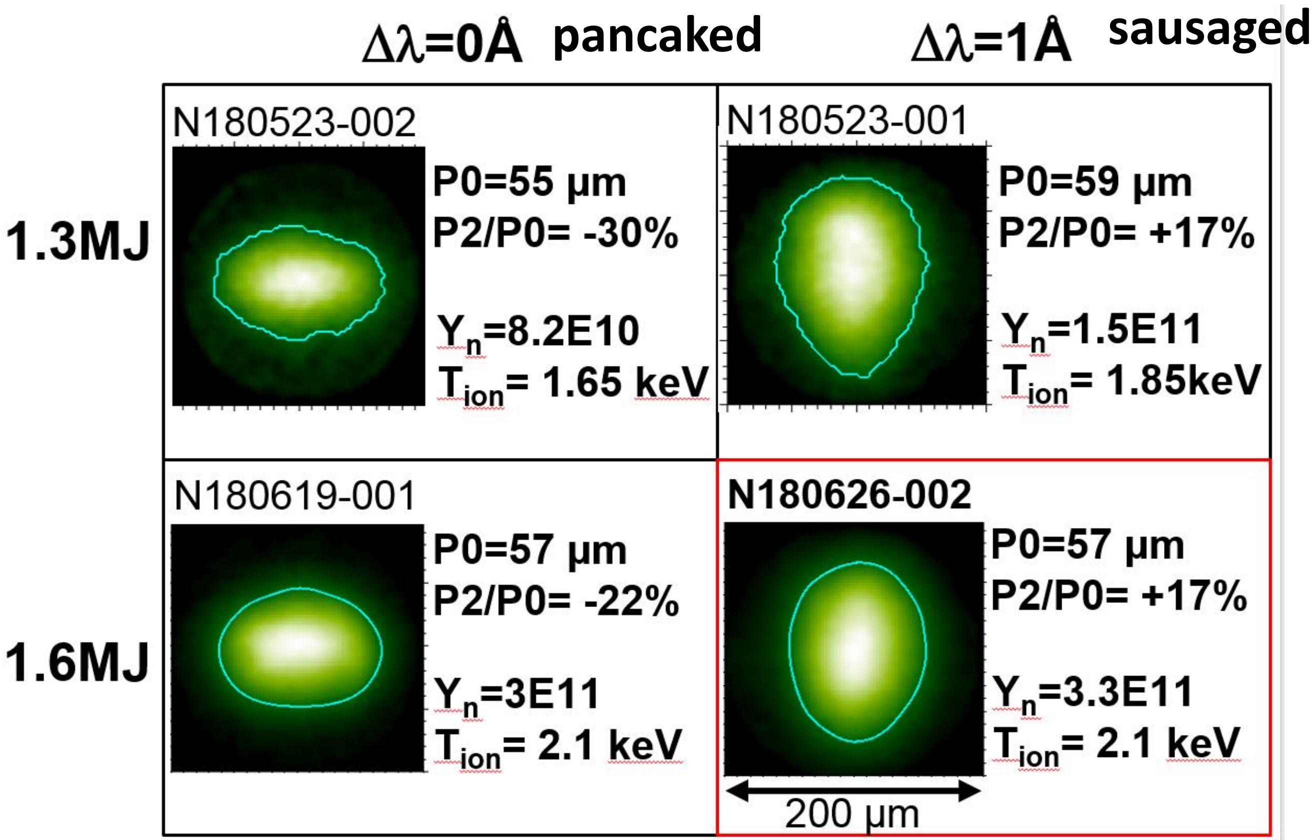
"Hybrid C" NIF campaign:

- CH capsule
- Hohlraum fill 0.6 mg/cc



Hotspot x-ray self emission

$\Delta\lambda$ = inners - outers



$\Delta\lambda$ at least as effective as in older, high gas fill hohlraums.

- Partly due to lower inner-beam SRS

This talk:
$\Delta\lambda$ quoted at "1ω":
$\Delta\lambda$ = 1 Ang. →
$\Delta\lambda$ / λ = 1 / 10528 = 9.5E-5

[1]A. Kritcher et al., PRE (accepted)

CBET vs. space: early peak power: 5.0 ns

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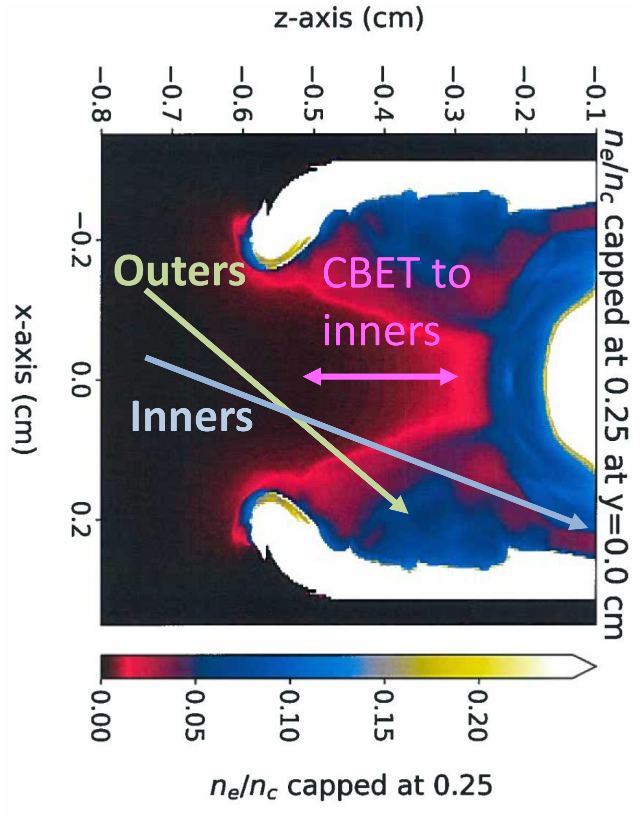

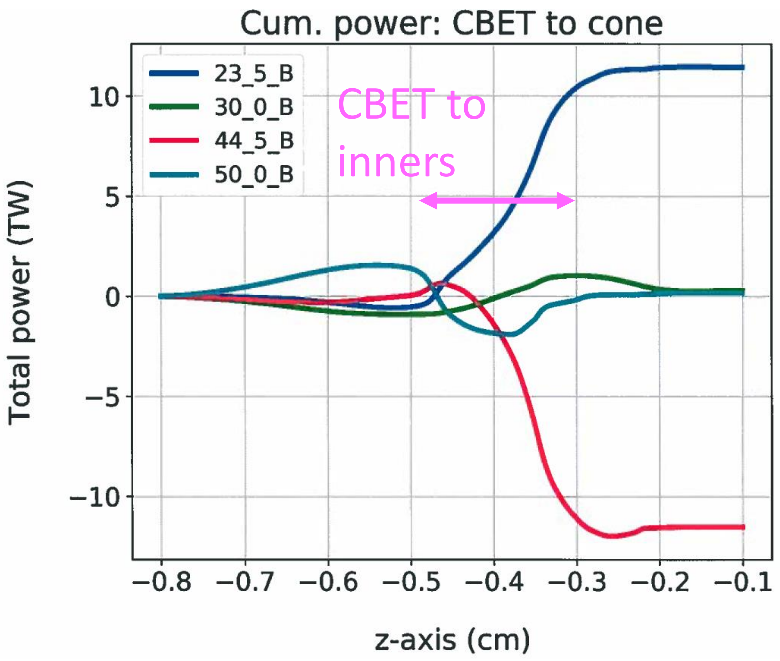

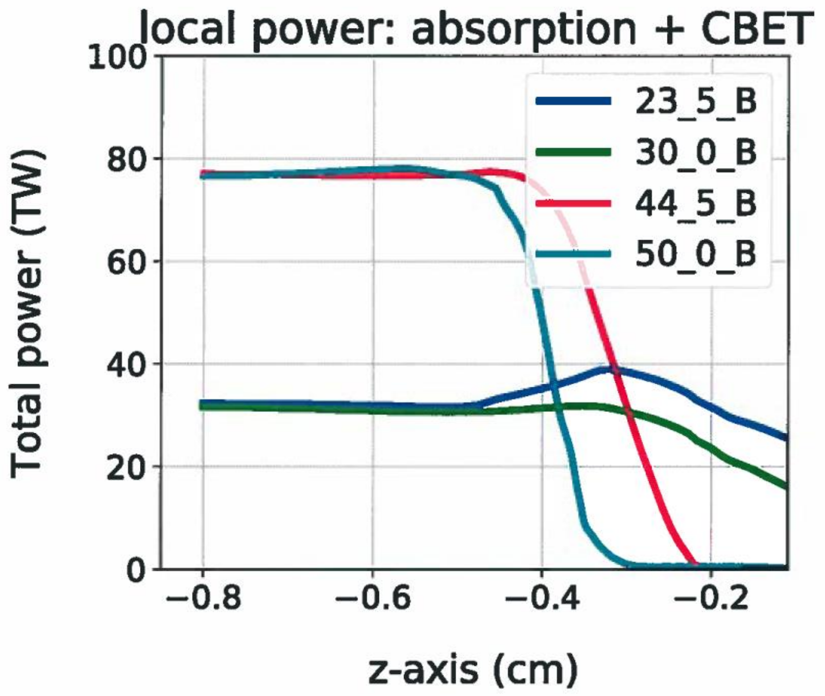

SSD and Dewandre Effect[1]

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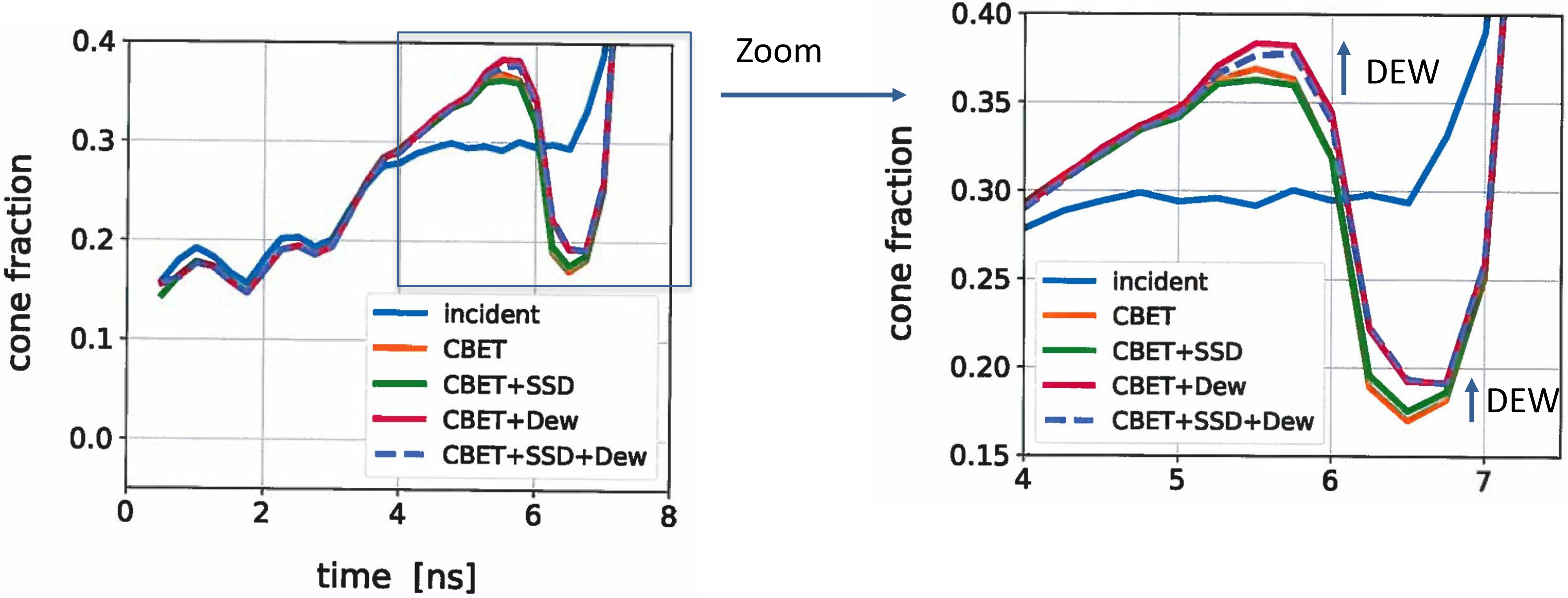
- **SSD:** smoothing by spectral dispersion → bandwidth:
  - Very slight CBET reduction

[1] T. Dewandre, J. R. Albritton, E. A. Williams, Phys. Fluids 1981

- **Dewandre effect[1]:** frequency change due to $\partial n_e / \partial t$:
  - Slight increase of effective inner-beam wavelength
  - More CBET to inners



Isolate effect of $\Delta\lambda$: $P_{CBET}(\Delta\lambda \neq 0) - P_{CBET}(\Delta\lambda = 0)$

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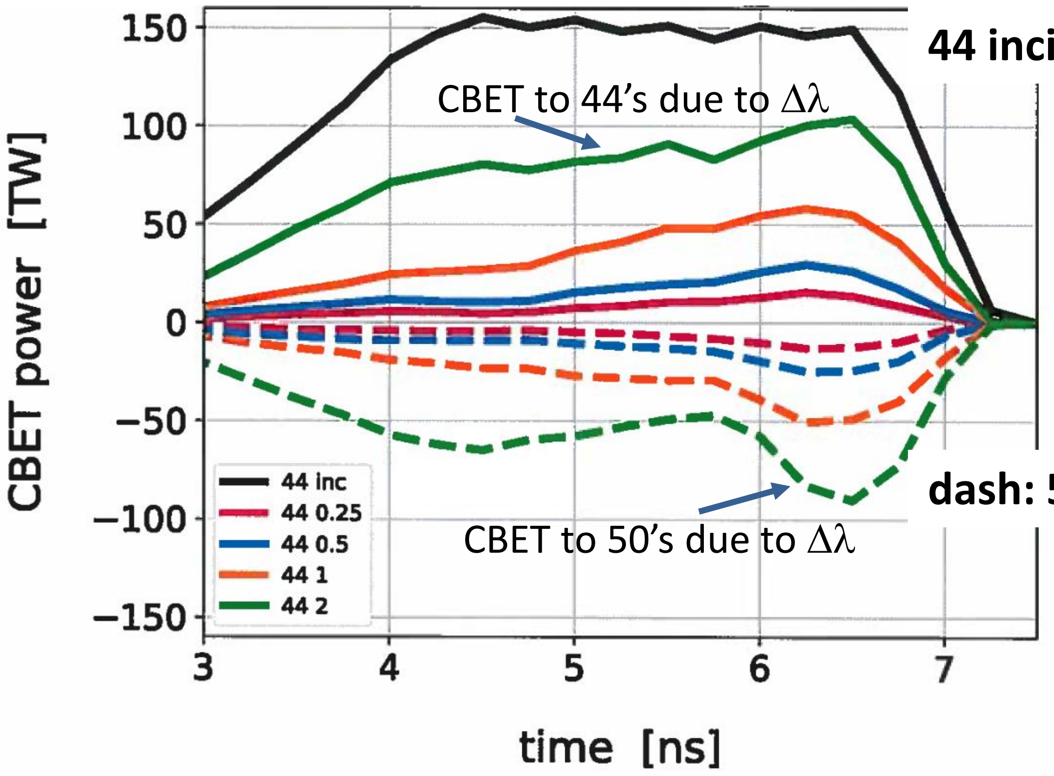
Step 2: symmetric outer 3-color:
- $\Delta\lambda_{44} = -\Delta\lambda_{50} = X$

solid: 44

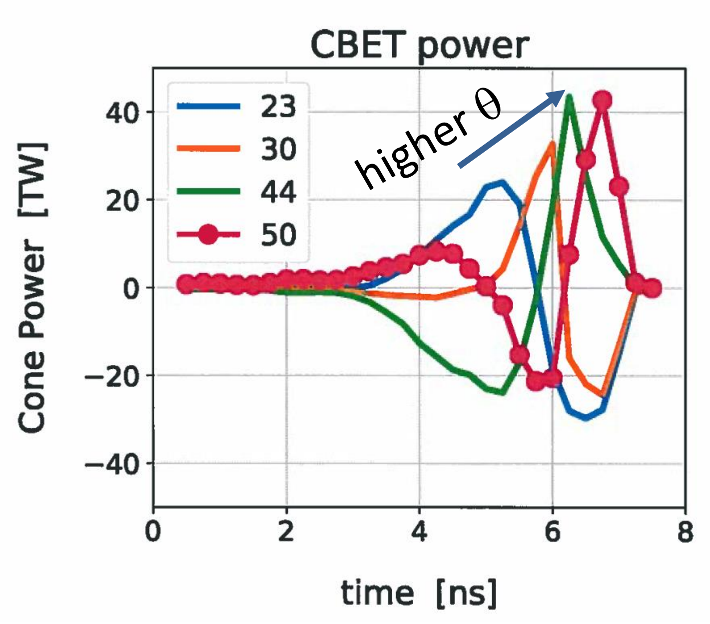
44 incident



dash: 50

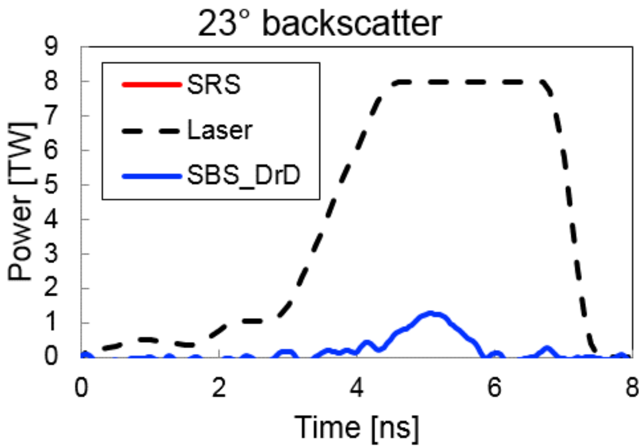
$\Delta\lambda_{44} = +X$
$\Delta\lambda_{50} = -X$
X = 0.25 A
0.5 A
1.0 A
2.0 A

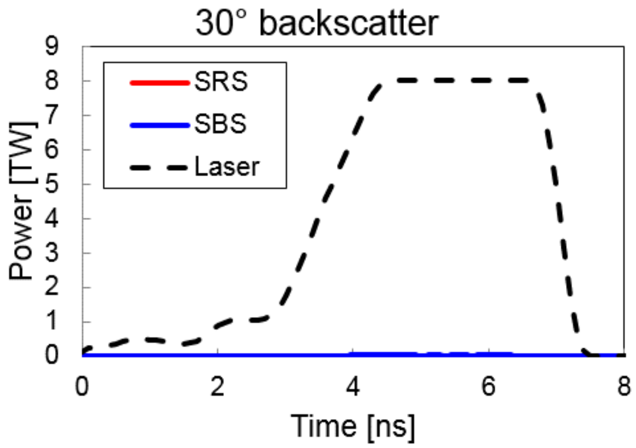
NIF BigFoot shot N170418: $\Delta\lambda = 0$



Backscatter

- Mostly 50° SBS late
- Some 23° SBS early





Mitigate 50º SBS: $\lambda_{44} > \lambda_{in} > \lambda_{50}$: CBET from 50's to 44's, maintaining cone fraction

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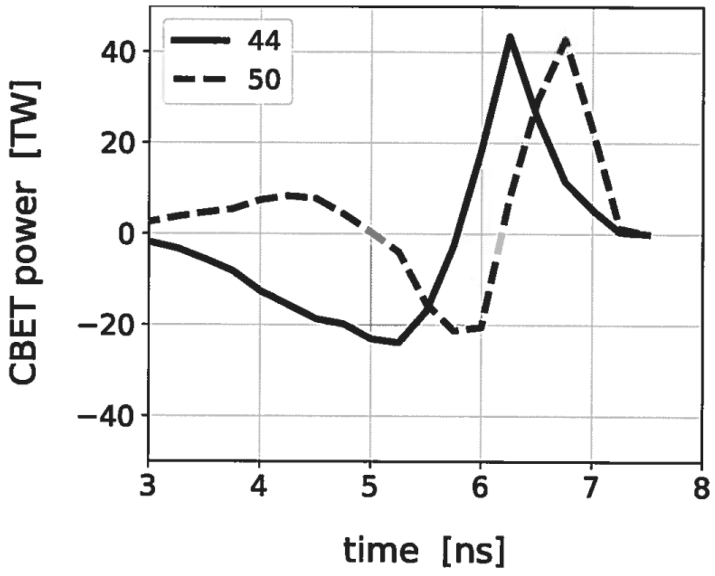
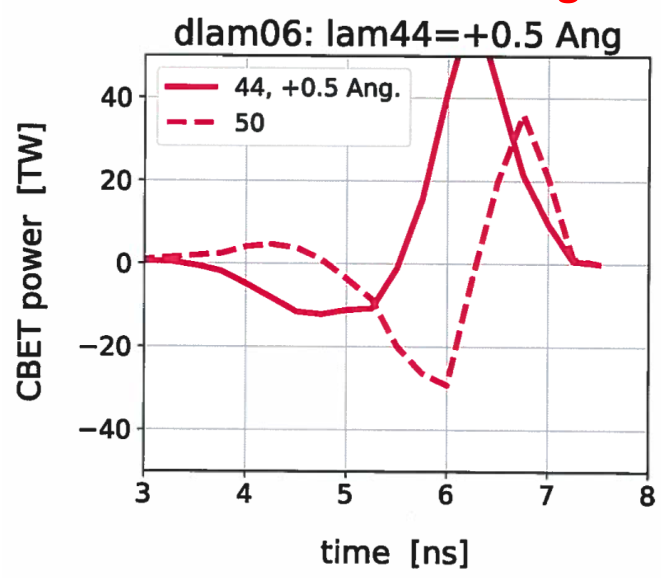
Plots are net CBET to 44 and 50,
from all other cones

Base case: Δλ=0



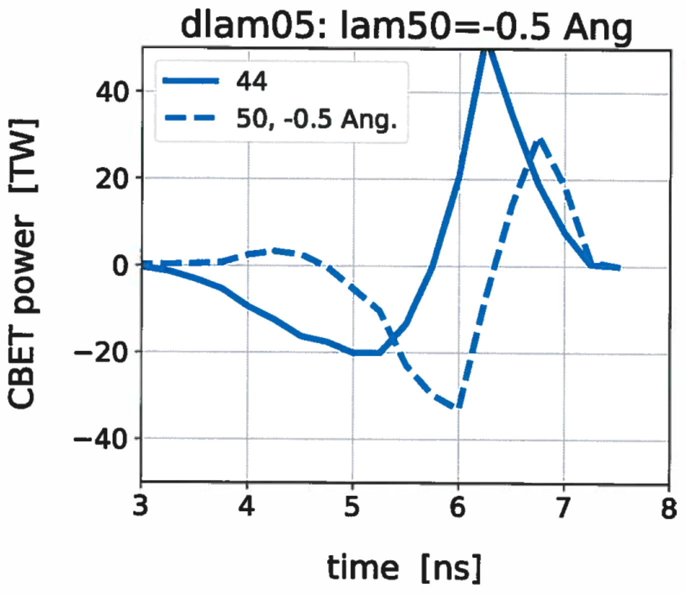
Post CBET cone frac: 28.2%

Case A: Δλ44 = +0.5 Ang.



Post CBET cone frac: 26.6%
ΔCBET from Δλ: -1.6%

Case B: Δλ50 = -0.5 Ang.



Post CBET cone frac: 29.0%
ΔCBET from Δλ: +0.8%

CBET to inners then outers, integrates to ~0

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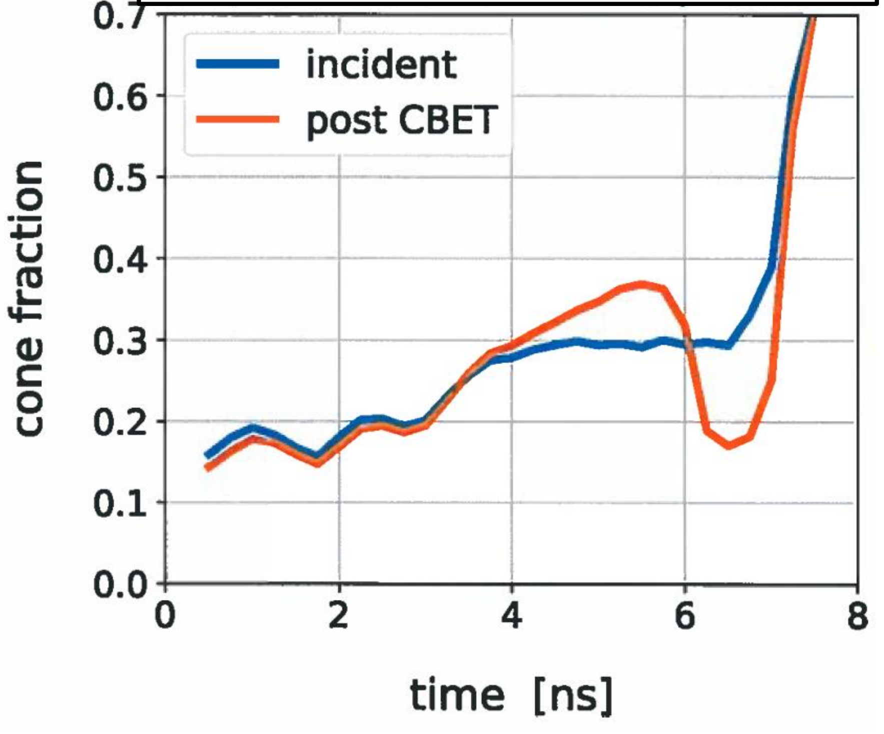
cone fraction:
inner power / total power



CONE	Incident energy [kJ]	CBET energy / incident [%]
23	237.4	0.1
30	235.2	-1.6
44	595.9	-2.2
50	588.4	+4.2
cone frac: inner / total [%]	28.5	28.2 post CBET

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