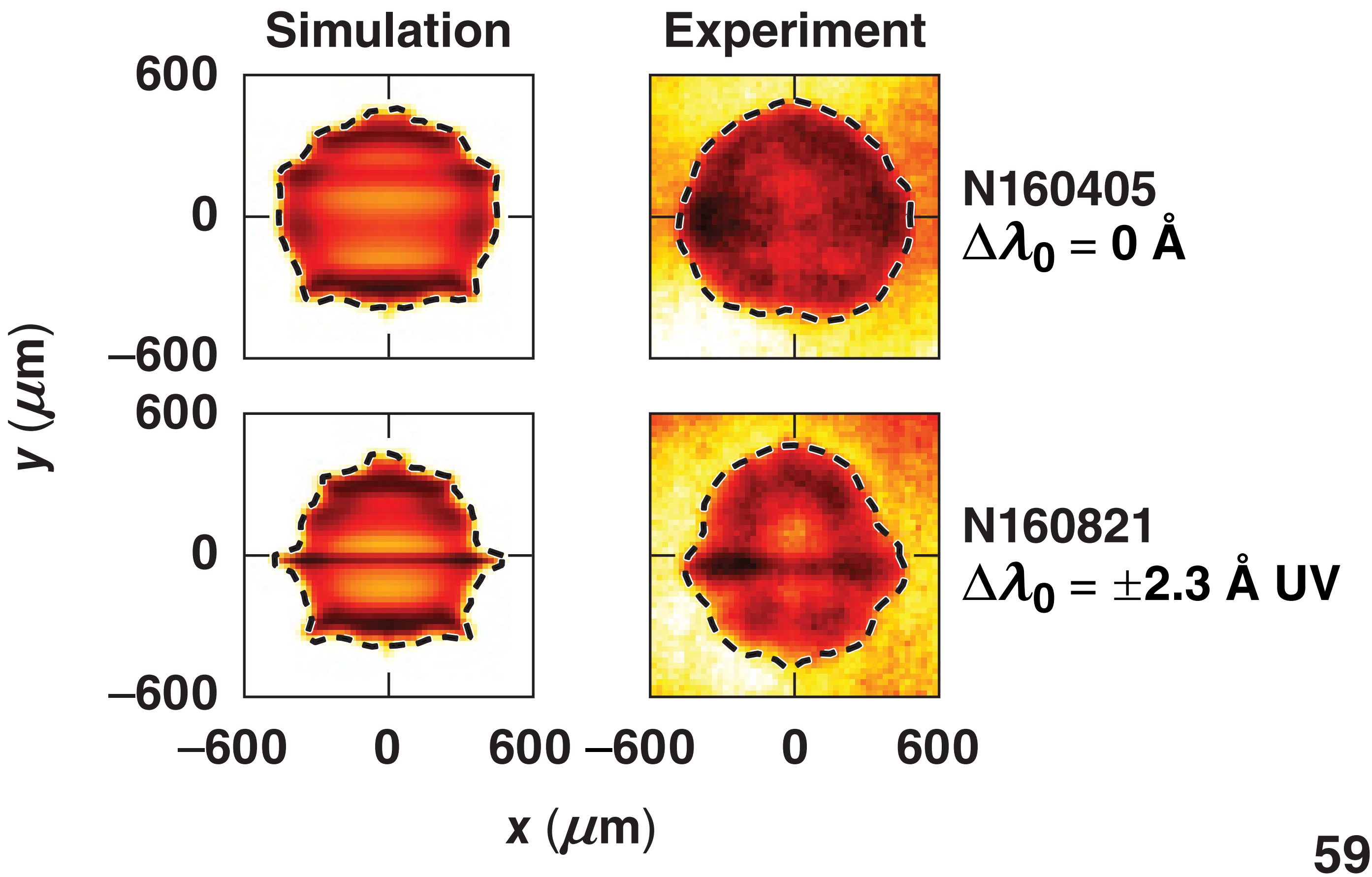
Wavelength Detuning Cross-Beam Energy Transfer Mitigation Scheme for Direct-Drive: Modeling and Evidence from National Ignition Facility Implosions



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Laboratory for Laser Energetics

59th Annual Meeting of the
American Physical Society
Division of Plasma Physics
Milwaukee, WI
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Summary

A wavelength detuning ($\Delta\lambda_0$) cross-beam energy transfer (CBET) mitigation scheme improves coupling in direct drive

- Initial proof-of-principle $\Delta\lambda_0$ experiments on the NIF* successfully demonstrated CBET mitigation in polar direct drive (PDD)
  - the first $\Delta\lambda_0$ experiments measured changes in shape, shell trajectory, and scattered light as predicted by simulations
- The successful NIF $\Delta\lambda_0$ experiments lay the foundation for future improvements
  - larger $\Delta\lambda_0$, multiple wavelengths, flexible wavelength distribution, optimized spot shapes, larger targets, and lower adiabats
- Symmetric direct drive (SDD) on OMEGA benefits from $\Delta\lambda_0$
  - *DRACO* simulations indicate that $\Delta\lambda_0$ achieves >100 Gbar

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*NIF: National Ignition Facility

Collaborators

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Lawrence Livermore National Laboratory

Outline

Wavelength detuning CBET mitigation scheme for direct-drive

- CBET overview
- CBET mitigation schemes
- Wavelength detuning ($\Delta\lambda_0$) on the NIF
  - experimental results
  - next steps
- Wavelength detuning ($\Delta\lambda_0$) on OMEGA

TC13872

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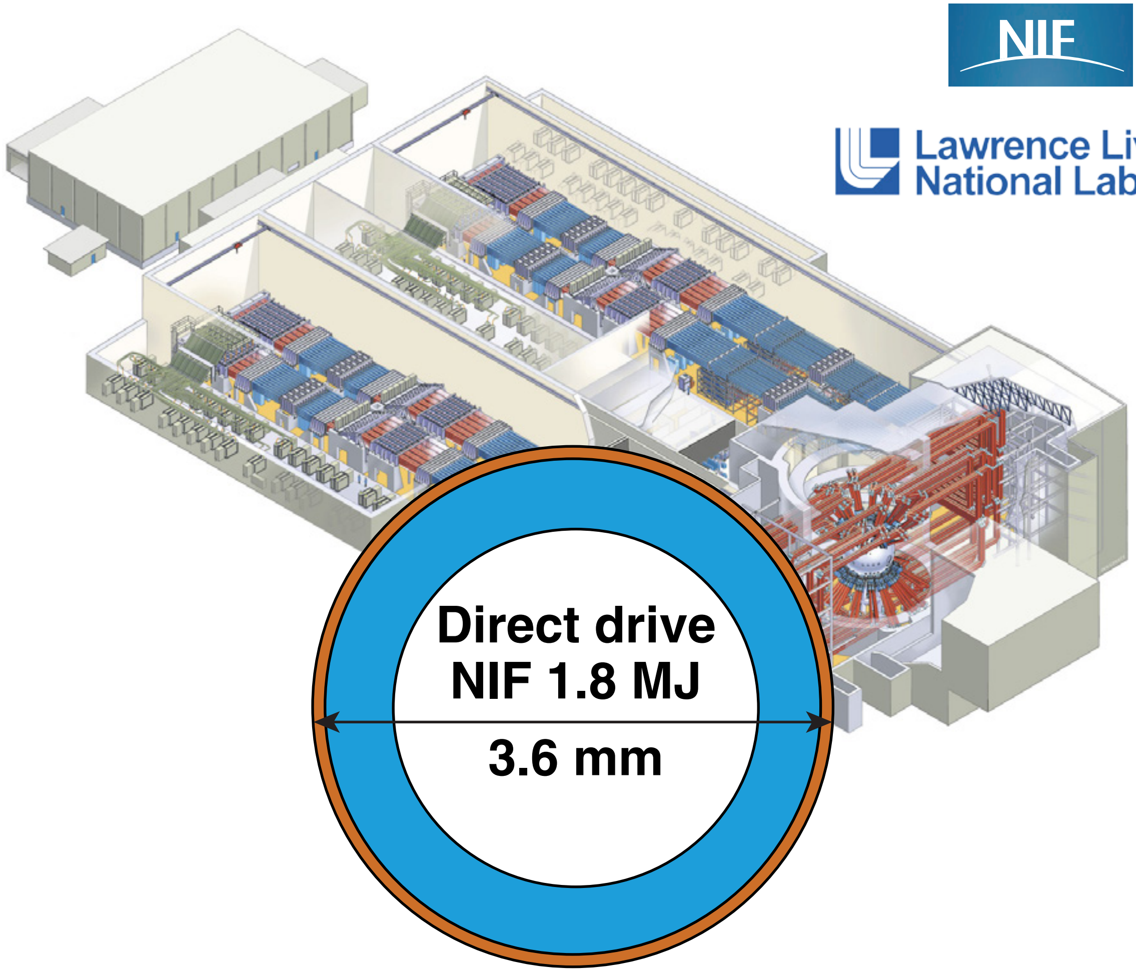
TC13872a

Wavelength-detuning studies on the NIF are part of the National ICF* Program

NIF

Lawrence Livermore National Laboratory



Direct drive NIF 1.8 MJ

3.6 mm

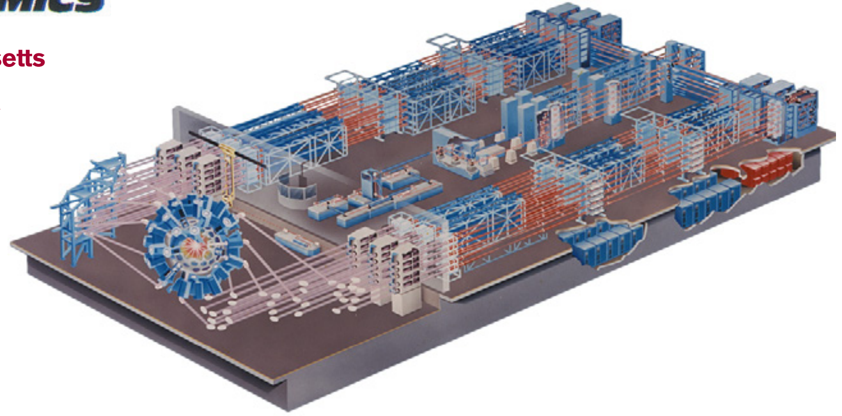
- **Laser energy coupling (e.g., $\Delta\lambda_0$)**
- **Imprint**
- **Preheat**

GENERAL ATOMICS

Massachusetts Institute of Technology

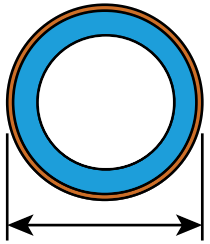
U.S.NAVAL RESEARCH LABORATORY

Interlaboratory Collaboration



Scale 1:70 in energy

OMEGA 26 kJ



0.86 mm

- **Cryogenic implosions scaled from NIF ignition designs**

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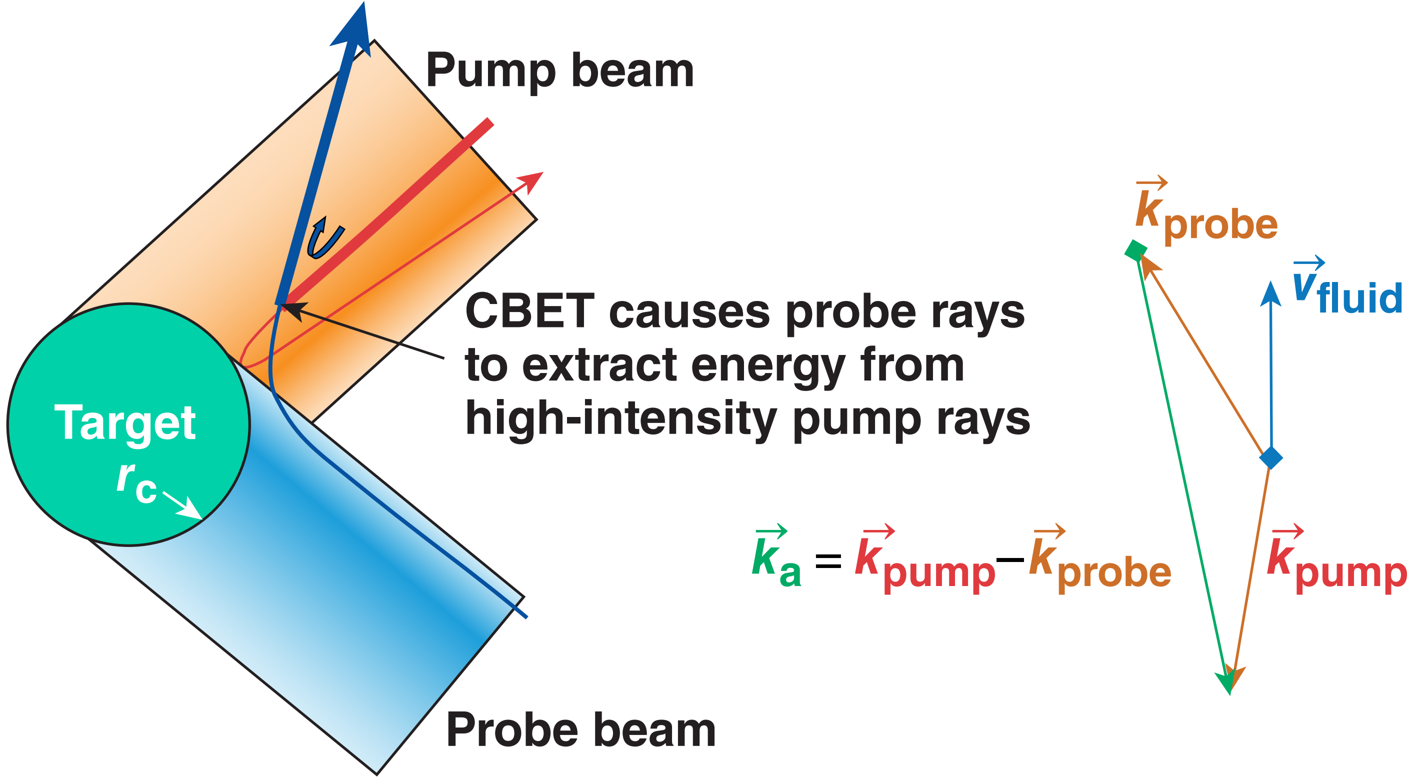
*ICF: inertial confinement fusion

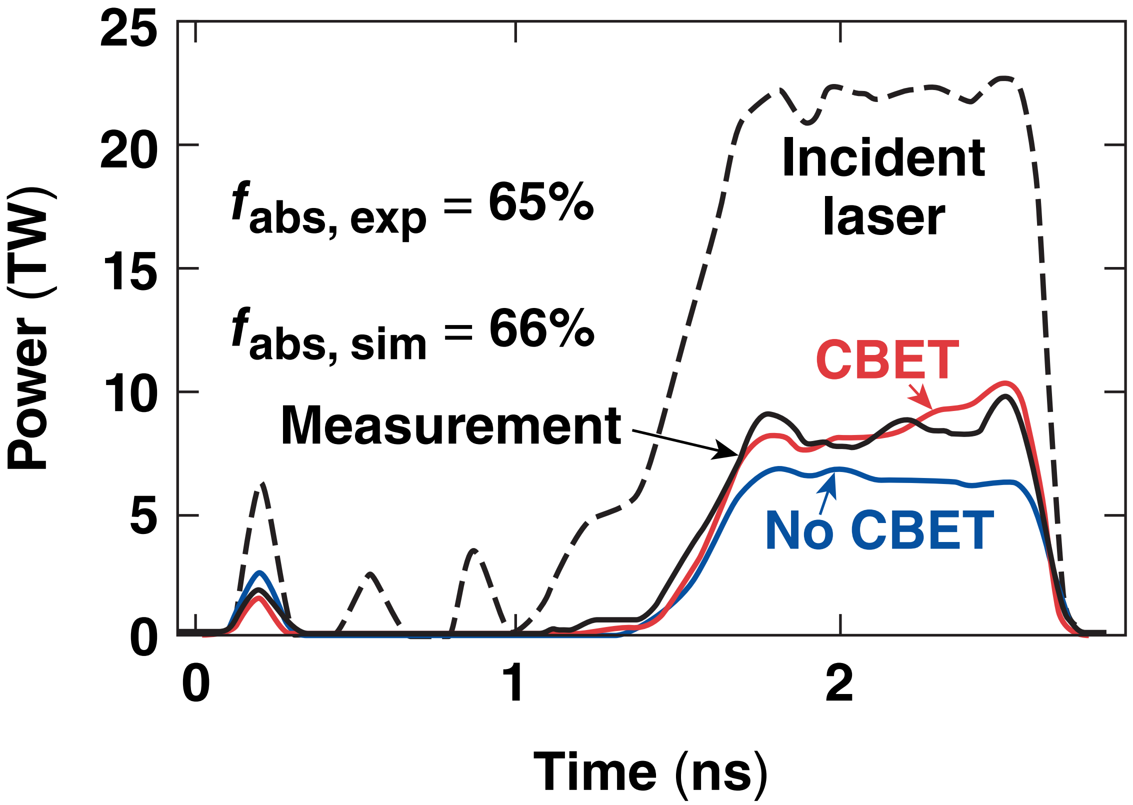
CBET losses are included in the modeling to agree with multiple experimental measures

The backscatter mode occurs for opposing beams



- The outbound ray always gains energy regardless of color $\left(\Delta\lambda_0 < \left| \pm 20\ \text{Å UV} \right|\right)$
- Leads to shell nonuniformity; mitigation can correct

OMEGA experiment and simulation

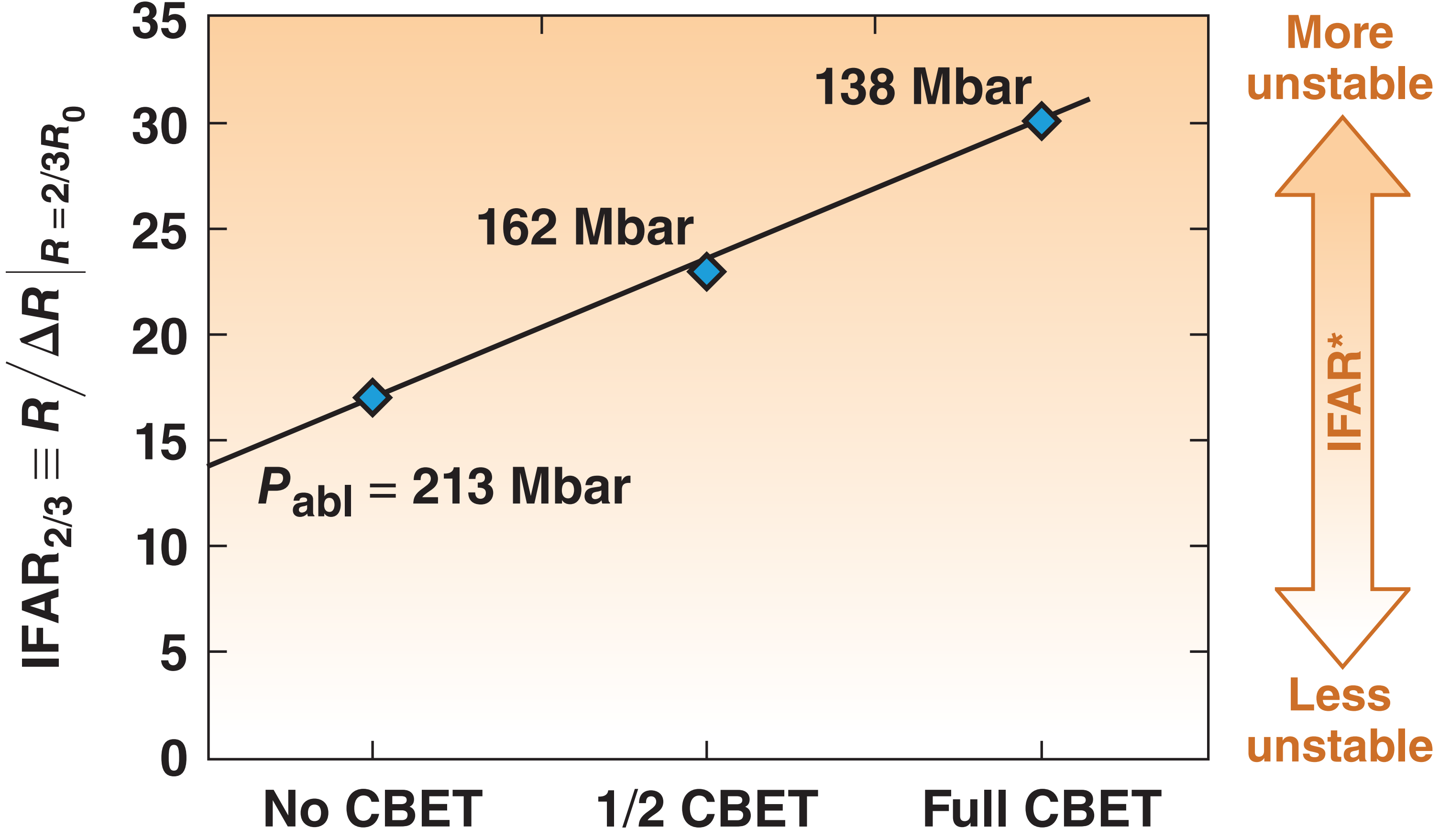


- Measurement constraints: scattered light, shell trajectory, bang time, and shock timing

Mitigating CBET is important for high-yield, robust implosions

- Compensating for CBET losses by thinning the shell compromises its integrity
- CBET mitigation is the best option

OMEGA designs* with $V_{\text{imp}} = 3.7 \times 10^7$ cm/s



V. N. Goncharov *et al.*, Phys. Plasmas 21, 056315 (2014).

*IFAR: in-flight aspect ratio

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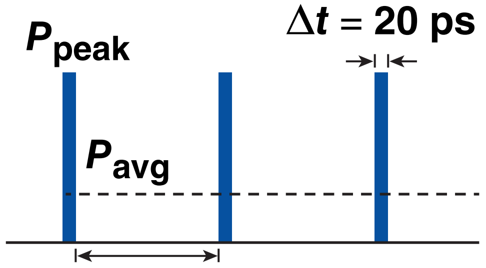
Laser energy coupling loss caused by CBET can be mitigated in different domains that can be combined; temporal

- **Temporal domain**
  - multiplexing the beams reduces interaction



  - STUD* pulses

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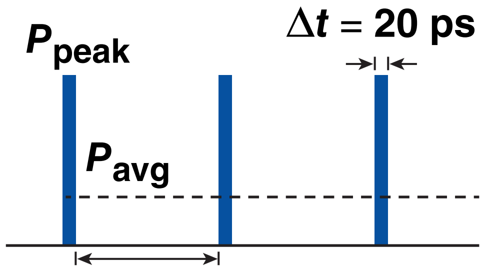
*STUD: spike trains of uneven duration and delay; B. Afeyan and S. Hüller, presented at IFSA 2011, Bordeaux, France, 12–16 September 2011.

TC13871

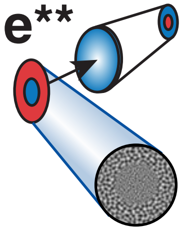
Laser energy coupling loss caused by CBET can be mitigated in different domains that can be combined; temporal, spatial

- **Temporal domain**
  - multiplexing the beams reduces interaction

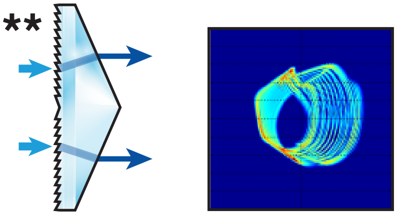


  - STUD* pulses

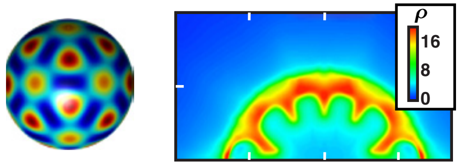
- **Spatial domain** (reduce interaction volume)
  - dynamic spot shape
    - two stage**



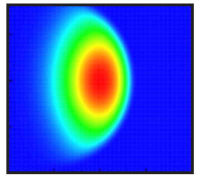
    - Graxicon***



    - KrF lasers (NRL)
  - spots smaller than target (e.g., R75)†



  - spot-masking apodization (SMA)



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*STUD: spike trains of uneven duration and delay; B. Afeyan and S. Hüller, presented at IFSA 2011, Bordeaux, France, 12–16 September 2011.

** D. H. Froula *et al*., Phys. Plasmas 20, 082704 (2013).

*** T. J. Kessler and H. Huang, presented at IFSA 2015, Seattle, WA, 20–25 September 2015.

† S. P. Regan *et al*., Phys. Rev. Lett. 117, 025001 (2016); 117, 059903(E) (2016).

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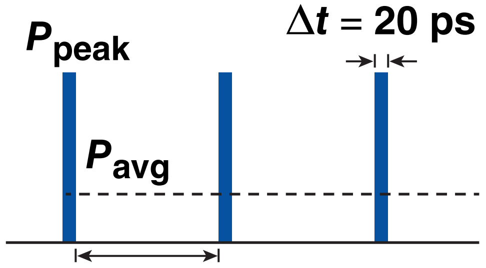
Laser energy coupling loss caused by CBET can be mitigated in different domains that can be combined; temporal, spatial, and spectral

- **Temporal domain**
  - multiplexing the beams reduces interaction



  - STUD* pulses

- **Spatial domain** (reduce interaction volume)
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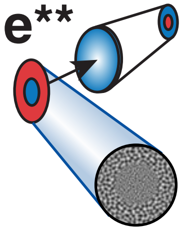
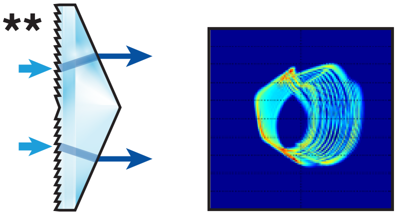


    - Graxicon***



    - KrF lasers (NRL)
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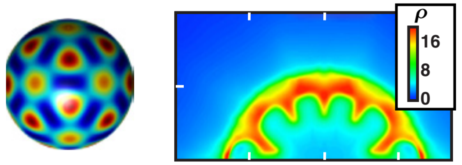
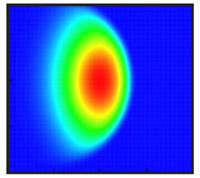
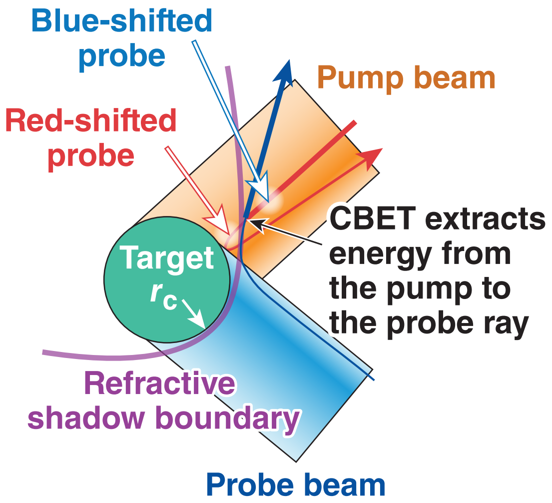


  - spot-masking apodization (SMA)



- **Spectral domain**
  - wavelength detuning; $\Delta\lambda_0$



  - wide bandwidth within each beam (e.g., SRRS‡)
  - lower intensity per band and incoherence disrupts growth

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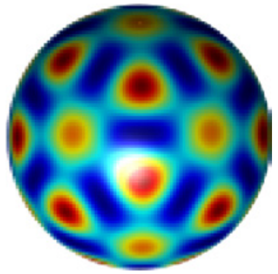
*** T. J. Kessler and H. Huang, presented at IFSA 2015, Seattle, WA, 20–25 September 2015.

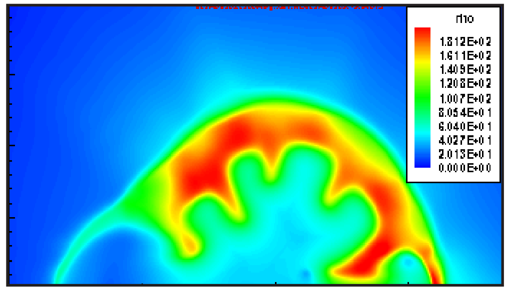
† S. P. Regan *et al.*, Phys. Rev. Lett. 117, 025001 (2016); 117, 059903(E) (2016).

‡ SRRS: stimulated rotational Raman scattering; J. Weaver *et al.*, "Spectral and Far-Field Broadening due to Stimulated Rotational Raman** Scattering Driven by the Nike Krypton Fluoride Laser," to be published in Applied Optics.

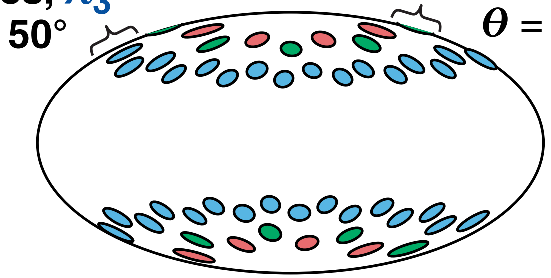
CBET mitigation is being explored on the NIF and OMEGA

- **Spatial domain**
  - **OMEGA is planning to explore R75 distributed phase plates (DPP's)**





- **Spectral domain**
  - **wavelength detuning on the NIF; $\Delta\lambda_0$**



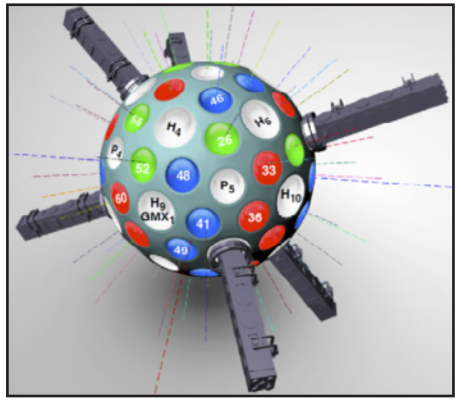
Outer cones, λ_3
θ = 45°, 50°

Inner cones, $\{\lambda_1, \lambda_2\}$
θ = 23°, 30°

$\Delta\lambda_0 = \{\lambda_1, \lambda_2, \lambda_3\}$

- **$\Delta\lambda_0 \sim \pm 6$ Å UV; great performance**
- **recent *LPSE* simulations indicated TPD* mitigation**

- **OMEGA's three-legged layout could be modified to support wavelength detuning**



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*TPD: two-plasmon decay

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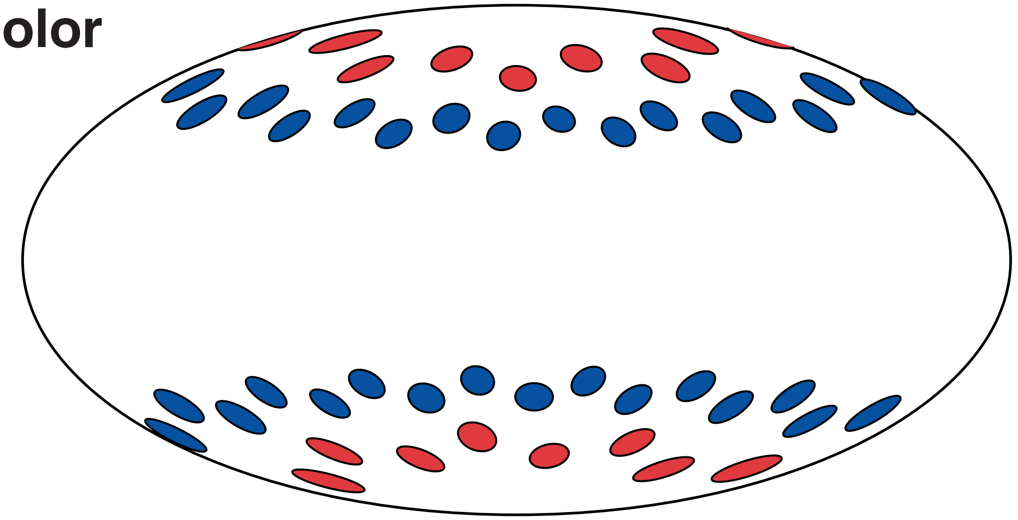
TC13868a

Cone-swapping in one hemisphere on the NIF induces a wavelength difference about the equator for the proof-of-principle experiments

Port-color arrangement

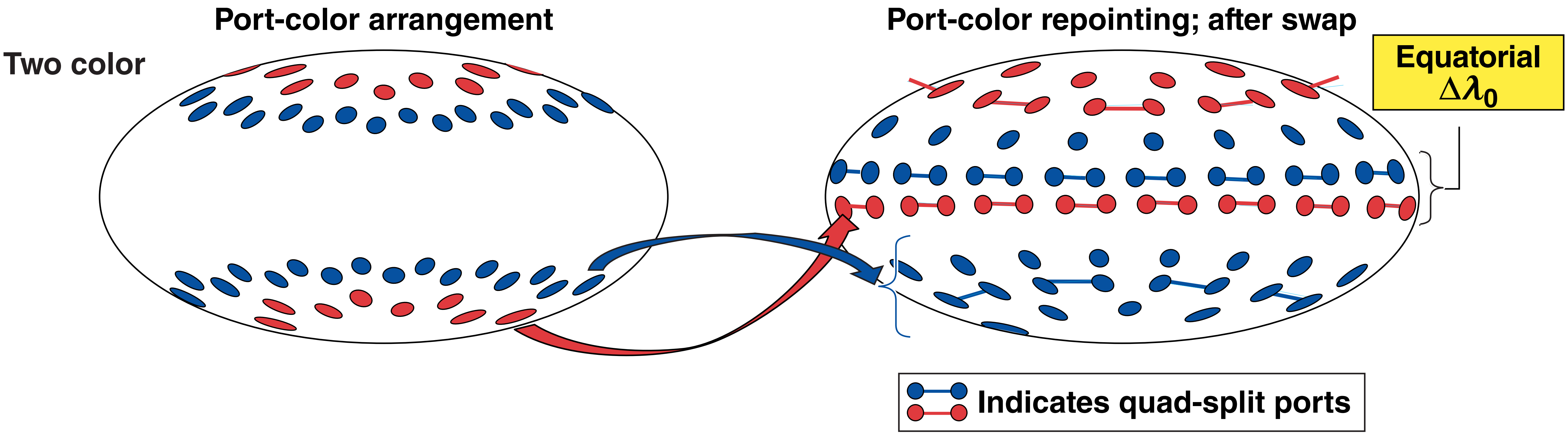
Two color



- NIF's current port-color mapping can be configured for $\Delta\lambda_0 = \pm 2.3$ Å (UV)
  - armor glass support clips limit range

TC11736j

Cone-swapping in one hemisphere on the NIF induces a wavelength difference about the equator for the proof-of-principle experiments

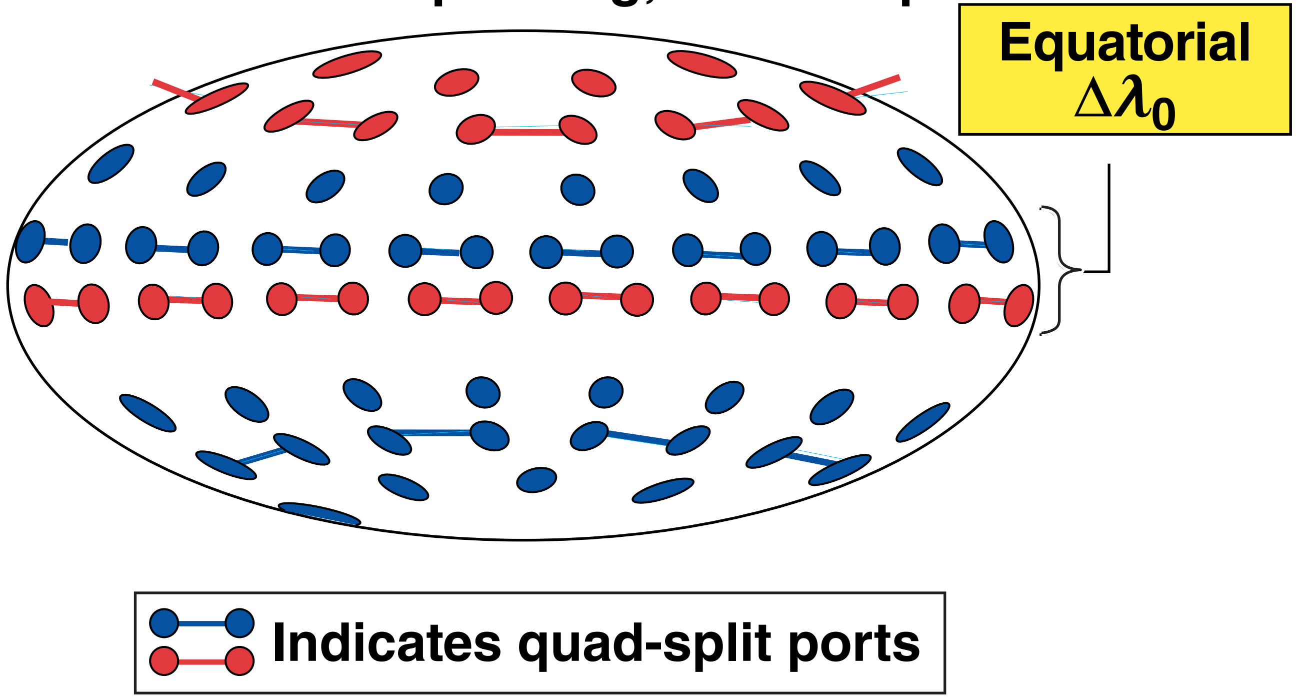


- NIF's current port-color mapping can be configured for $\Delta\lambda_0 = \pm 2.3$ Å (UV)
  - – armor glass support clips limit range
- Cone-swapping can be done in either hemisphere

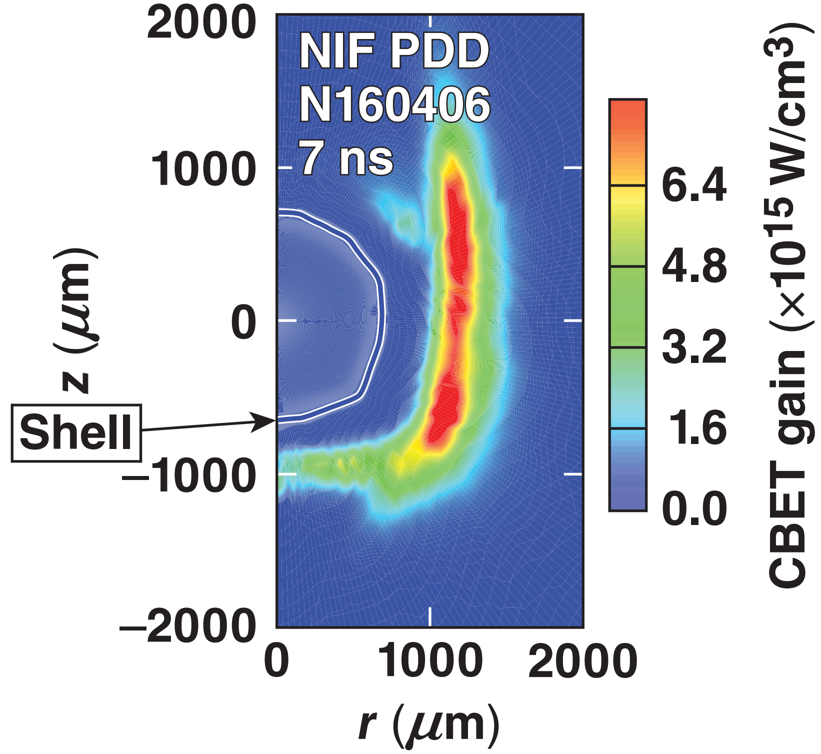
TC11736k

The equatorial wavelength difference concentrates CBET mitigation in the region dominated by losses

Port-color repointing; after swap



***DRACO* CBET simulation**



CBET mitigation in PDD predominantly affects the equatorial region.

- Cone-swapping leads to an asymmetric configuration
  - – remapping the fiber front end alleviates this constraint

TC11736I

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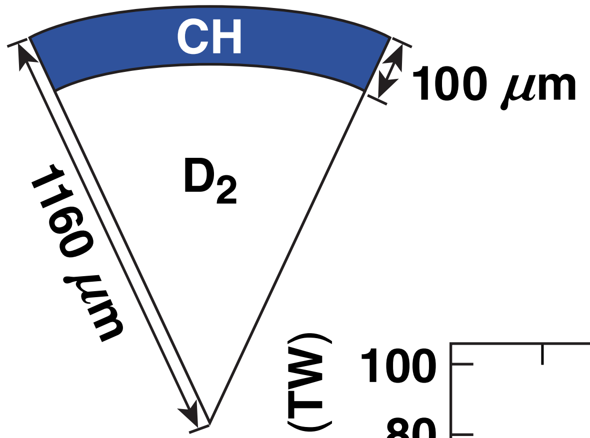
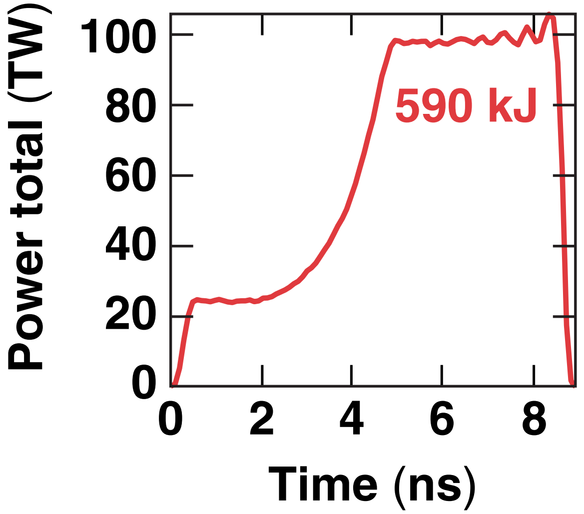
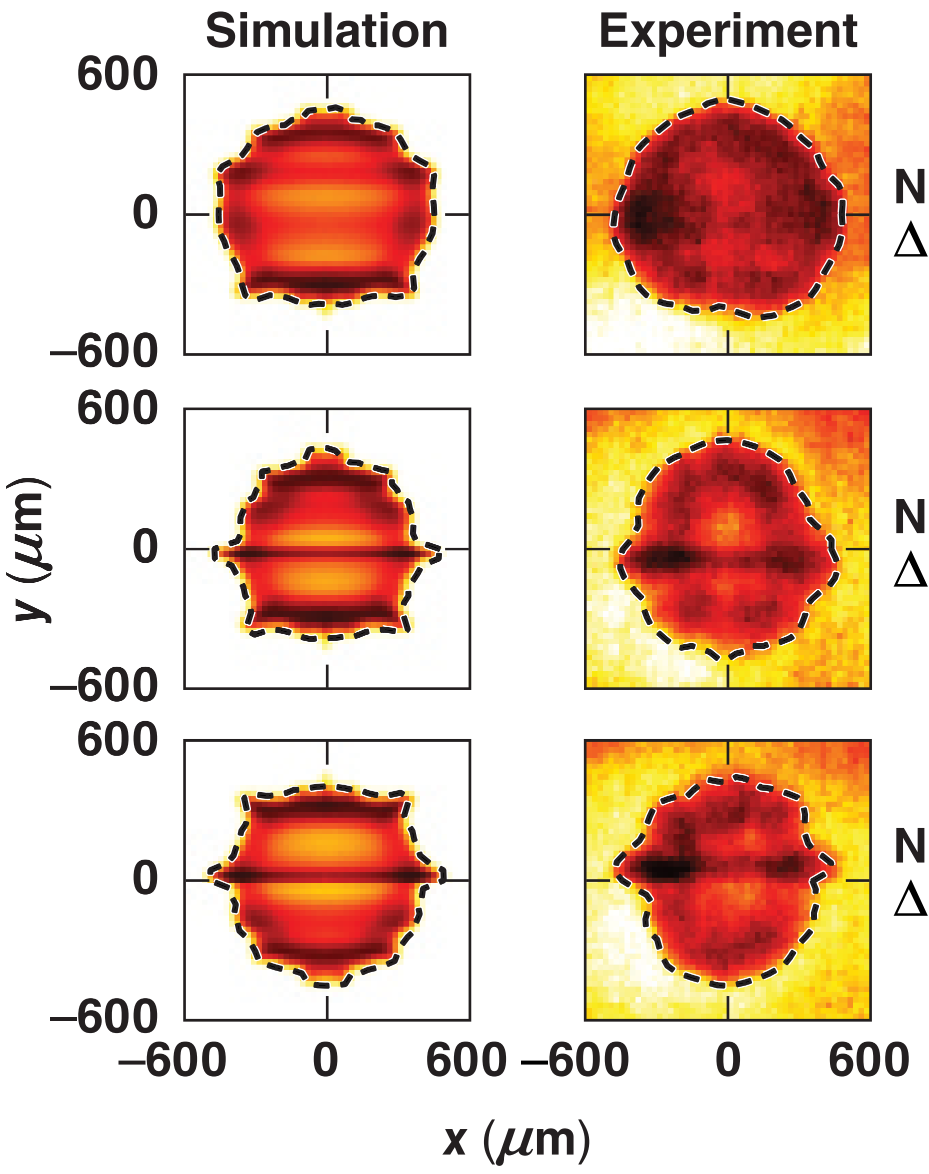
Initial $\Delta\lambda_0$ experiments on the NIF demonstrated CBET mitigation using cone-swapping comparing detuning on/off

NIF Equatorial $\Delta\lambda_0$ Campaign:
Designer: J. A. Marozas
RI: M. Hohenberger/M. J. Rosenberg/D. Turnbull







N160405
$\Delta\lambda_0$ = 0 Å

Cone-swap south

N160821
$\Delta\lambda_0$ = ±2.3 Å UV

Cone-swap north (view of antipodal pole)

N170102
$\Delta\lambda_0$ = ±2.3 Å UV

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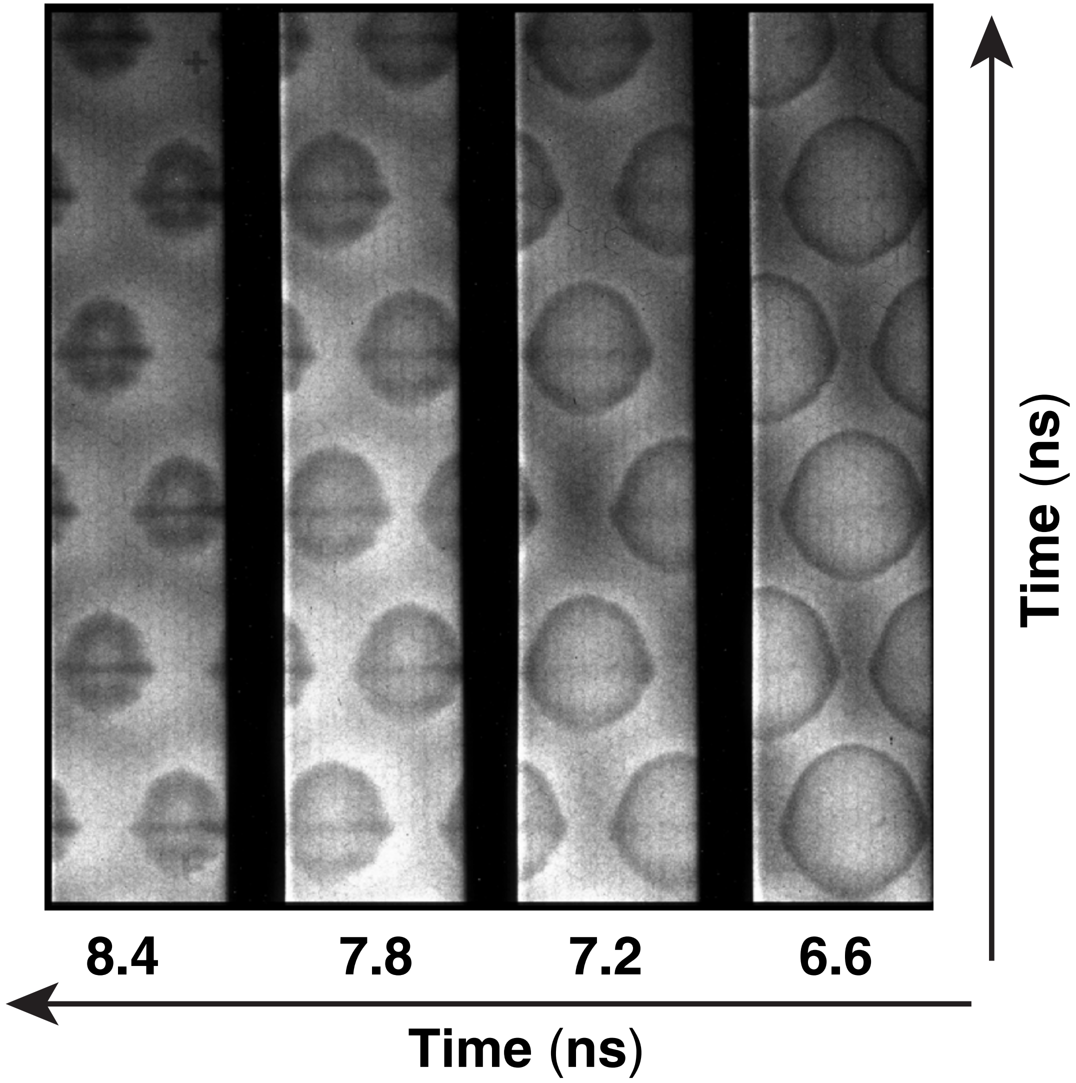
*Analysis by D. Turnbull

Gated backlit radiographs (experimental or simulated) are used to infer the shell trajectory

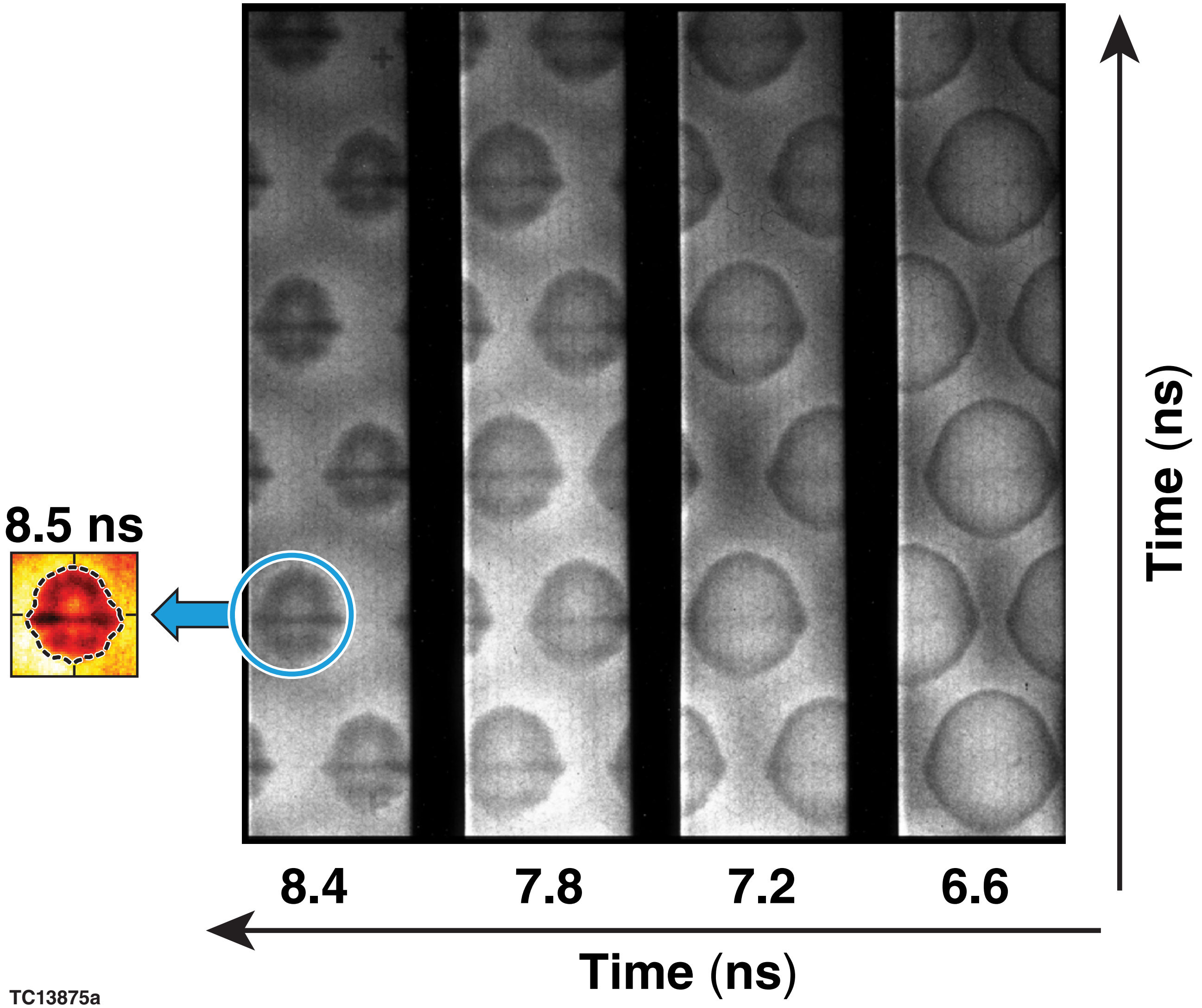
N160821-001 $\Delta\lambda_0$ = ±2.3 Å UV
(southern hemisphere cone swapping)



TC13875

Gated backlit radiographs (experimental or simulated) are used to infer the shell trajectory

N160821-001 $\Delta\lambda_0 = \pm 2.3$ Å UV
(southern hemisphere cone swapping)

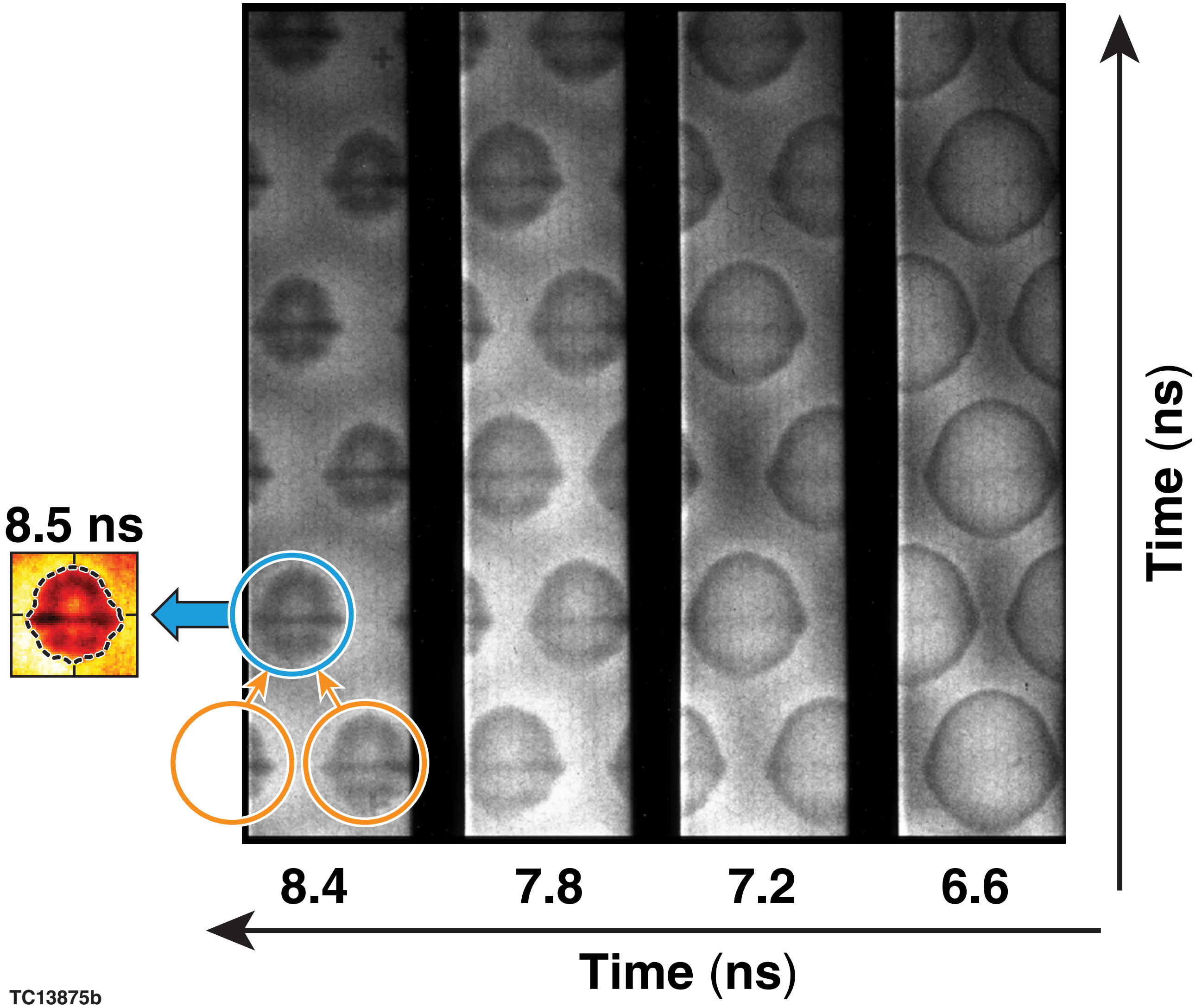


- Each whole image is post-processed to extract the shell

TC13875a

Gated backlit radiographs (experimental or simulated) are used to infer the shell trajectory

N160821-001 $\Delta\lambda_0$ = ±2.3 Å UV
(southern hemisphere cone swapping)

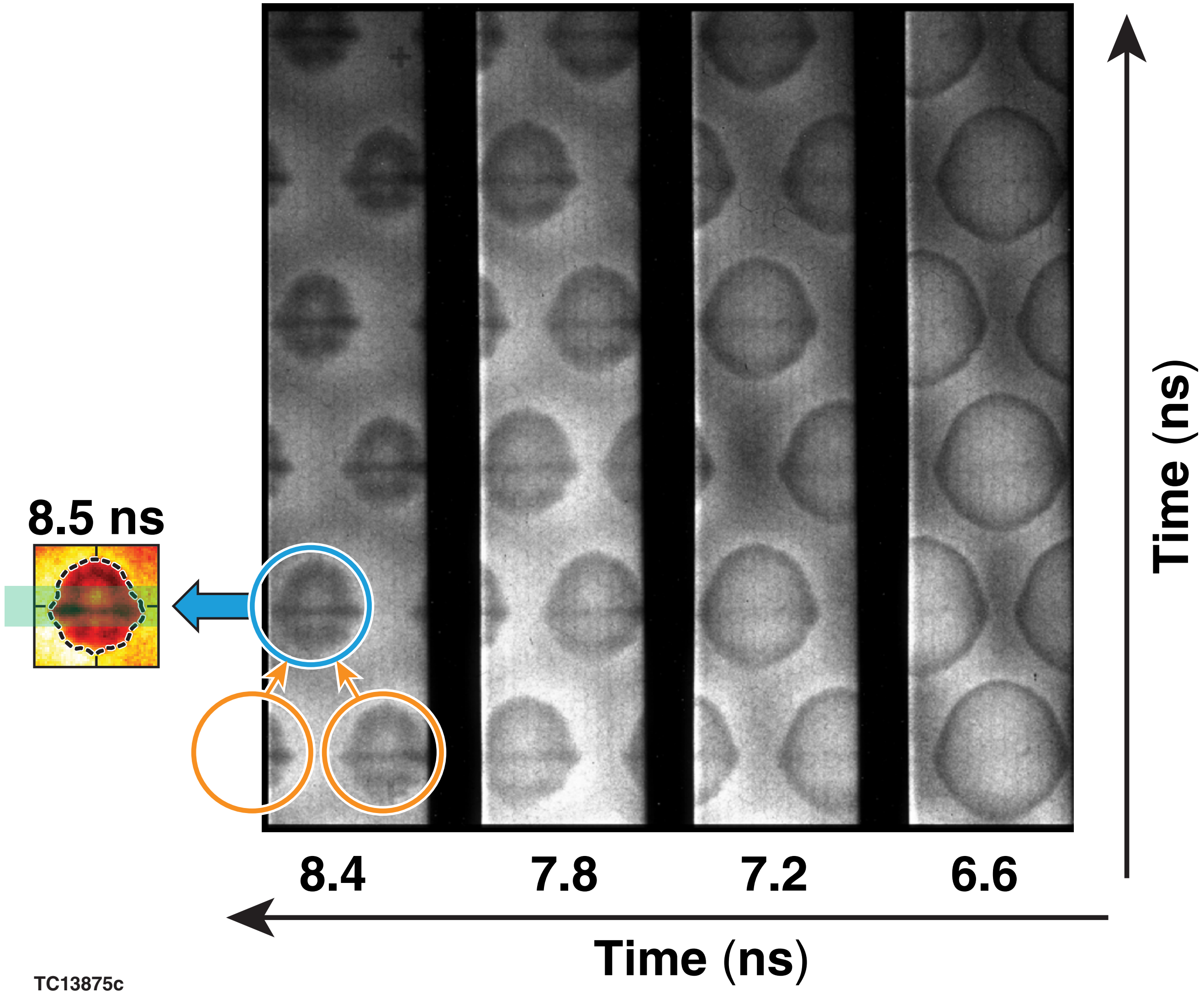


- Can be combined with nearest-neighbor partial images to enhance the signal-to-noise ratio

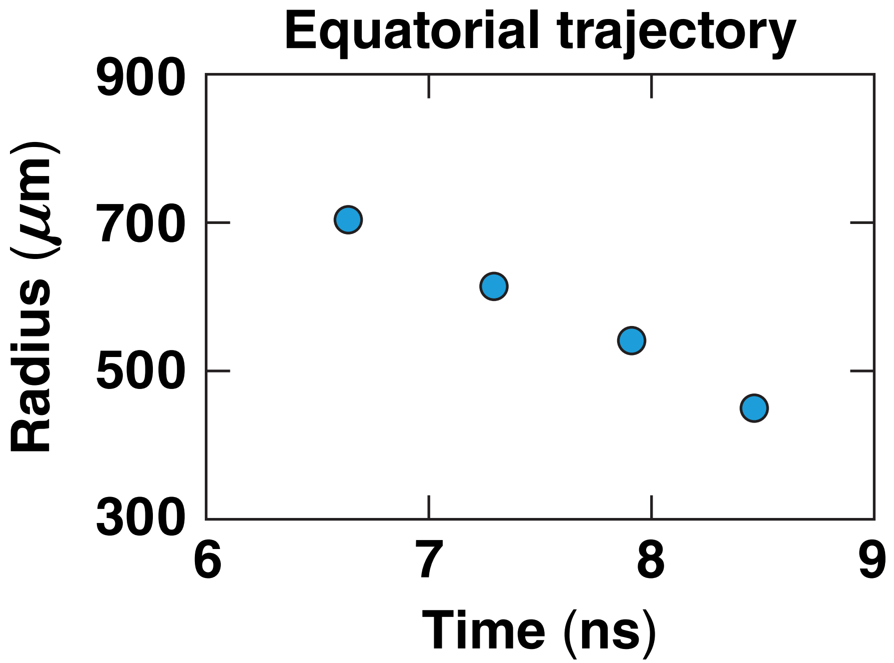
TC13875b

Gated backlit radiographs (experimental or simulated) are used to infer the shell trajectory

N160821-001 $\Delta\lambda_0 = \pm 2.3$ Å UV
(southern hemisphere cone swapping)

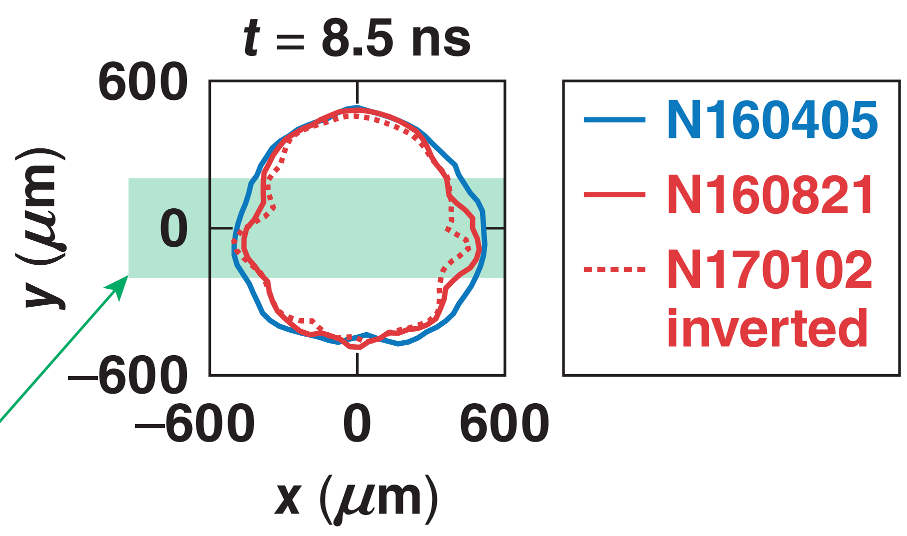


- **A trajectory is then inferred by plotting the surface-weighted radial average**

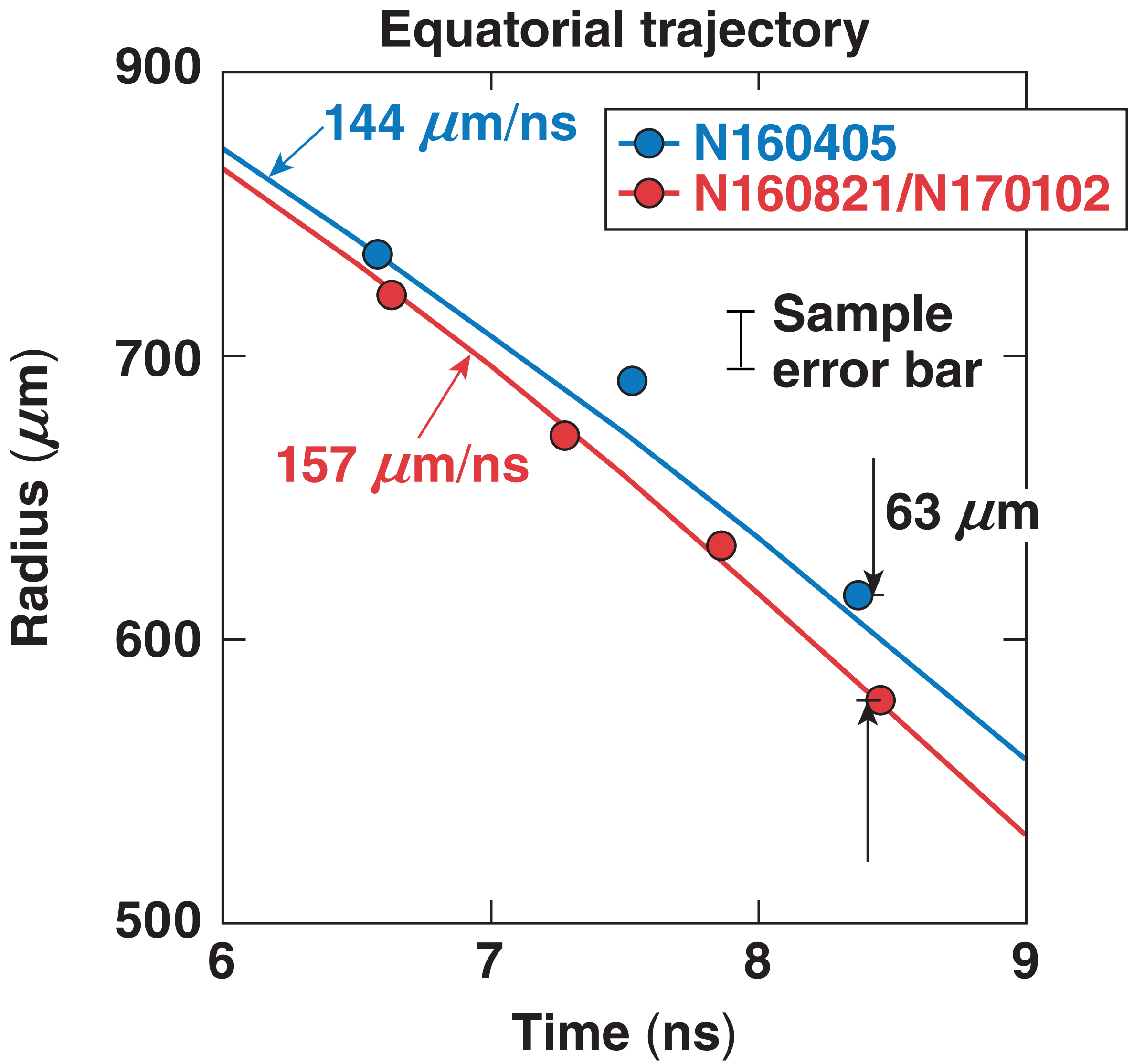


Improved equatorial coupling from wavelength detuning is inferred from gated radiographs

- **The predicted and measured trajectories* show the expected faster implosion speeds near the equator**



The surface-weighted average ±15° defines the equatorial trajectory



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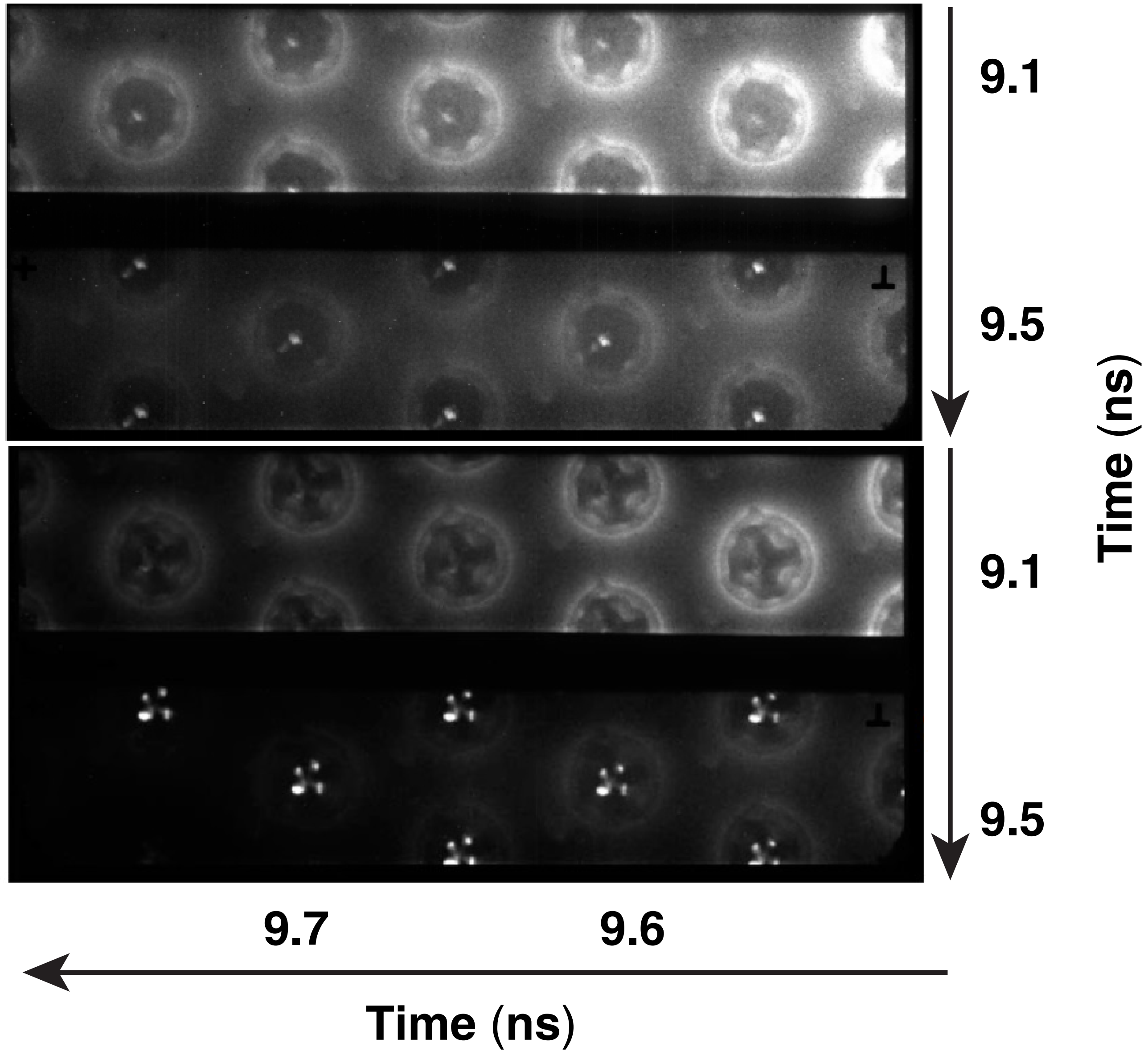
*Analysis by D. Turnbull

The polar self-emission measurements of the cone-swapping $\Delta\lambda_0$ experiments showed late-time core emission and m = 4 and 8 ring structures

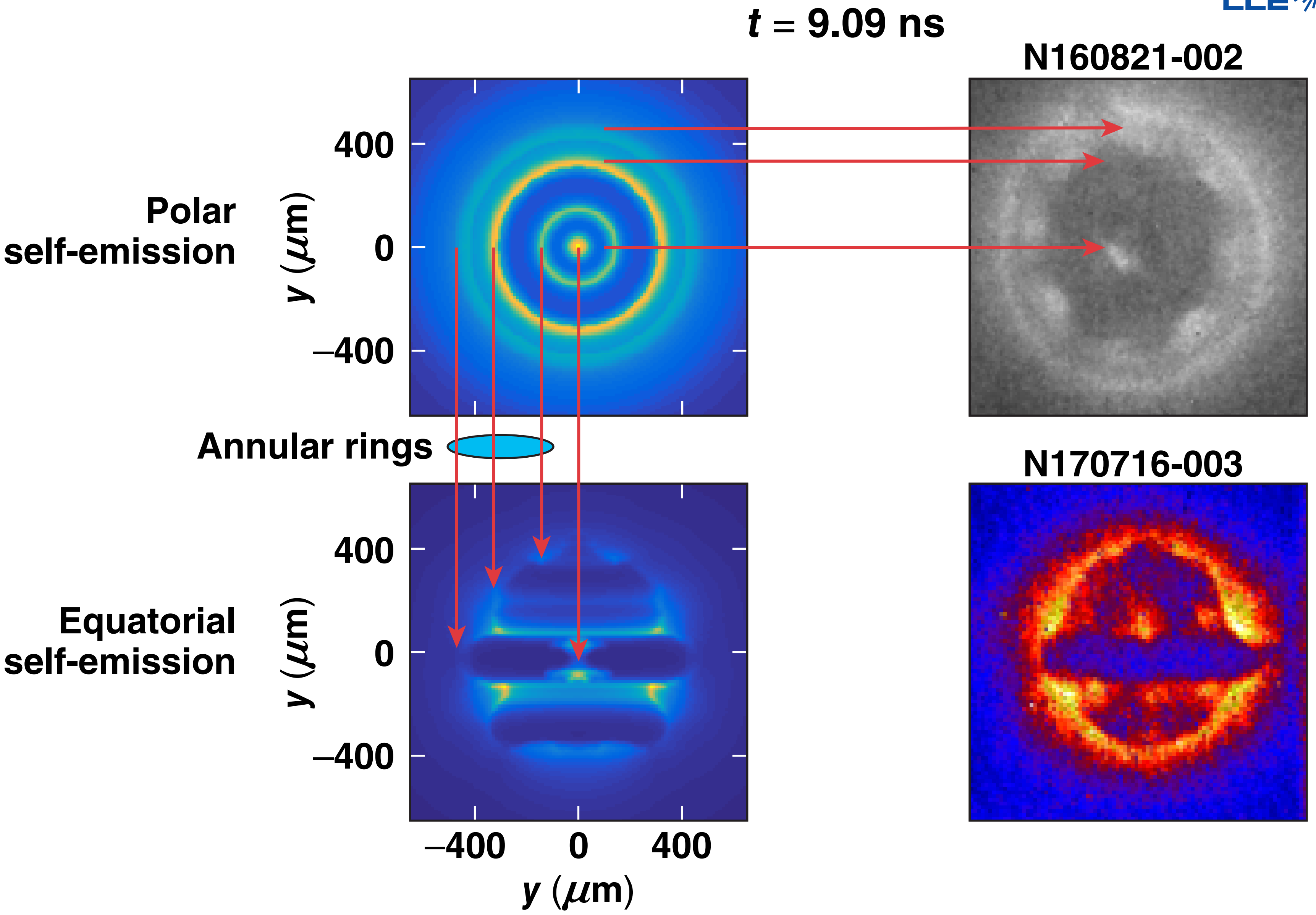
N160821-002 $\Delta\lambda_0 = \pm 2.3$ Å UV
(southern hemisphere cone swapping)

N170103-001 $\Delta\lambda_0 = \pm 2.3$ Å UV
(northern hemisphere cone swapping)



The source of the polar self-emission structure is reproduced in *DRACO* simulations

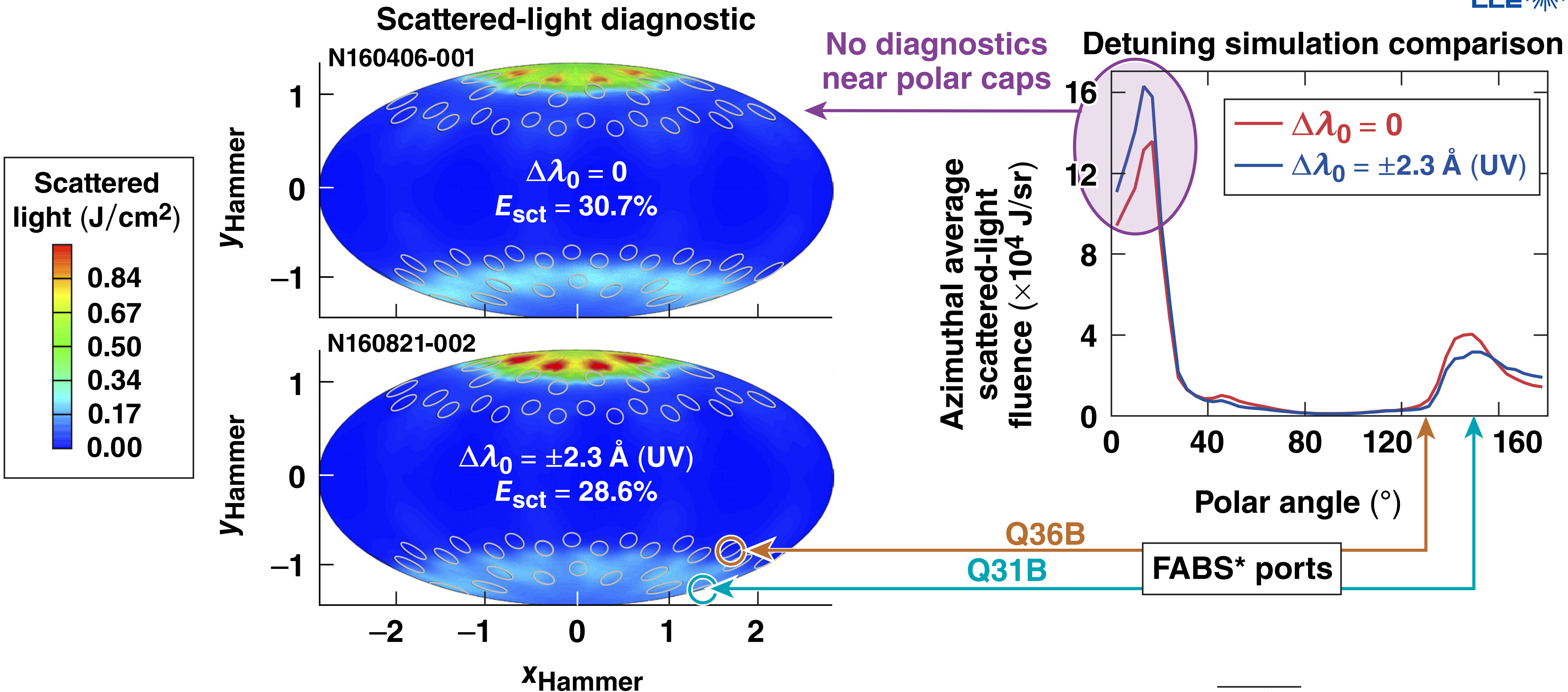
- The self-emitting sources in the equatorial view map onto rings in 2-D *DRACO*
- These 2-D rings map onto the four- and eightfold ring structure in the measurements
- The 3-D *HYDRA* hydrocode will be used to investigate this further


t = 9.09 ns

N160821-002

N170716-003

Scattered-light measurements can be used to diagnose wavelength-detuning CBET mitigation



No diagnostics near polar caps

FABS* ports

TC13038f

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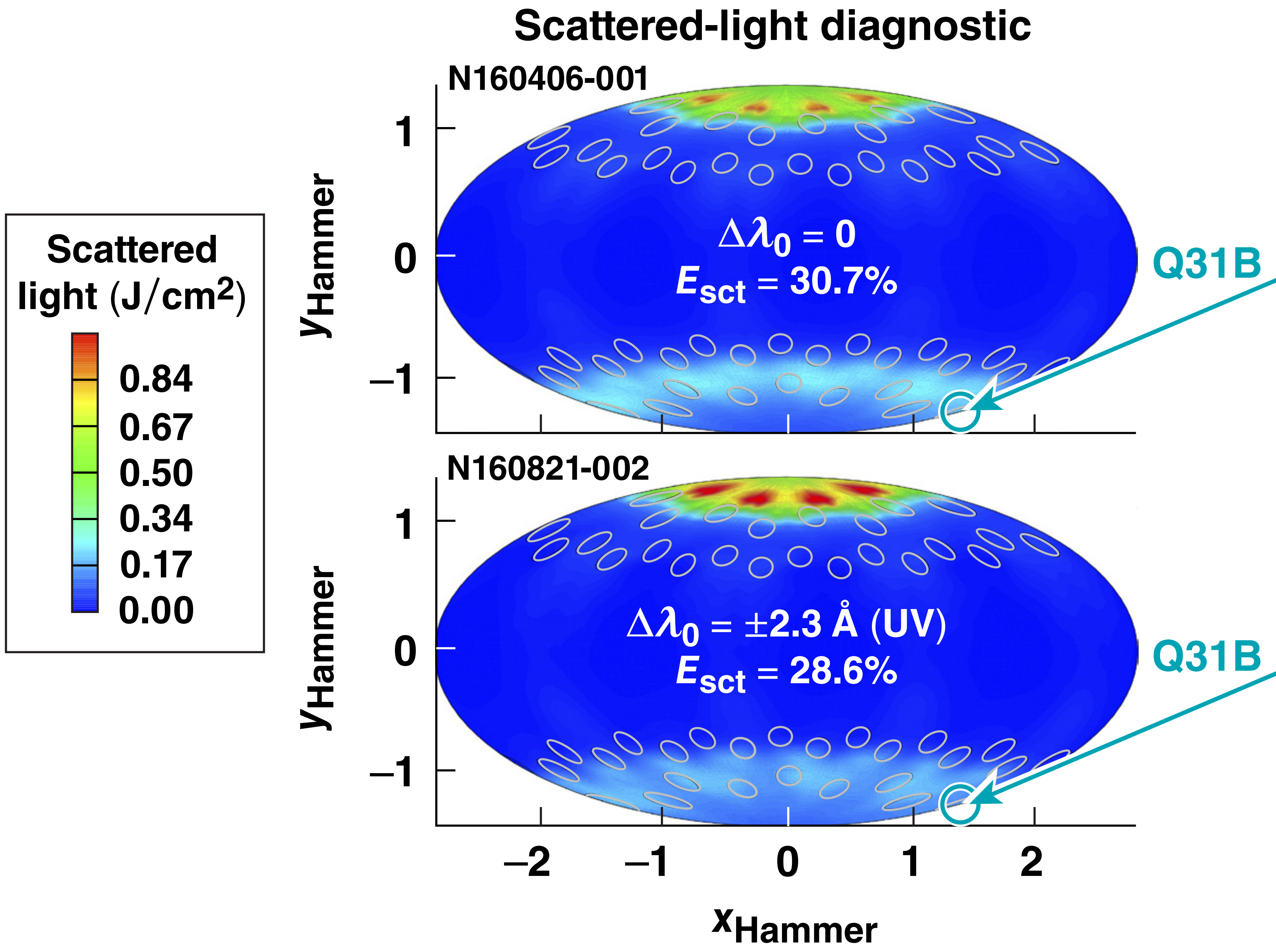
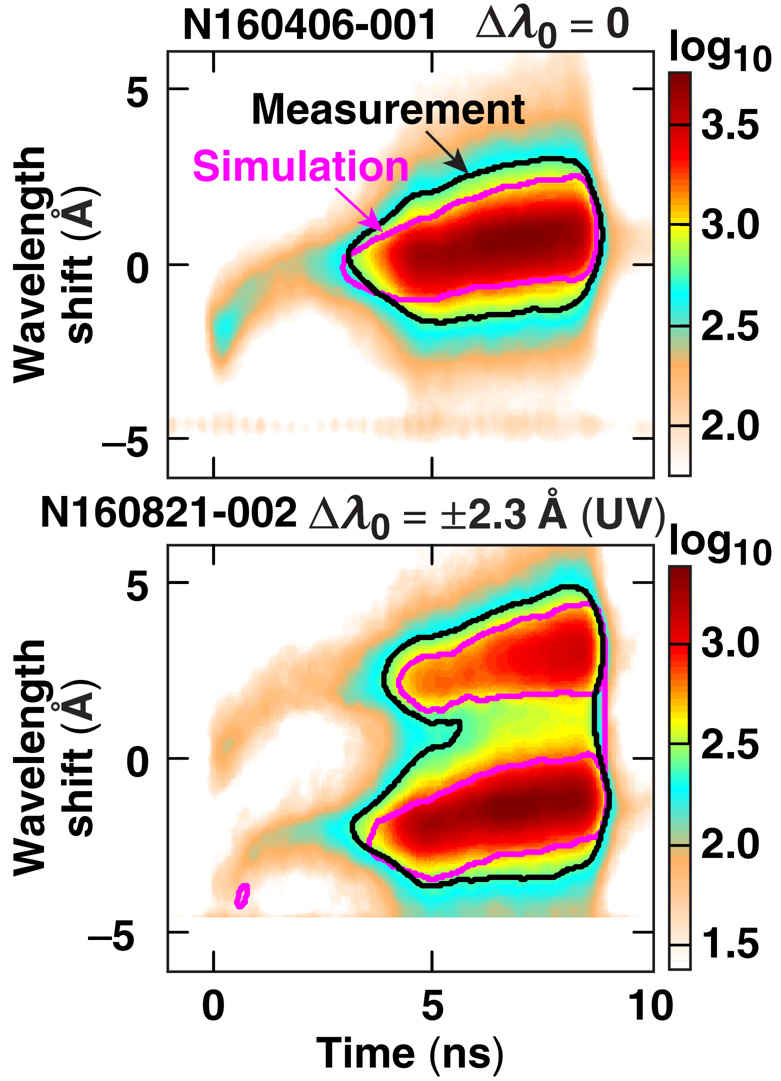
*FABS: full-aperture backscatter station

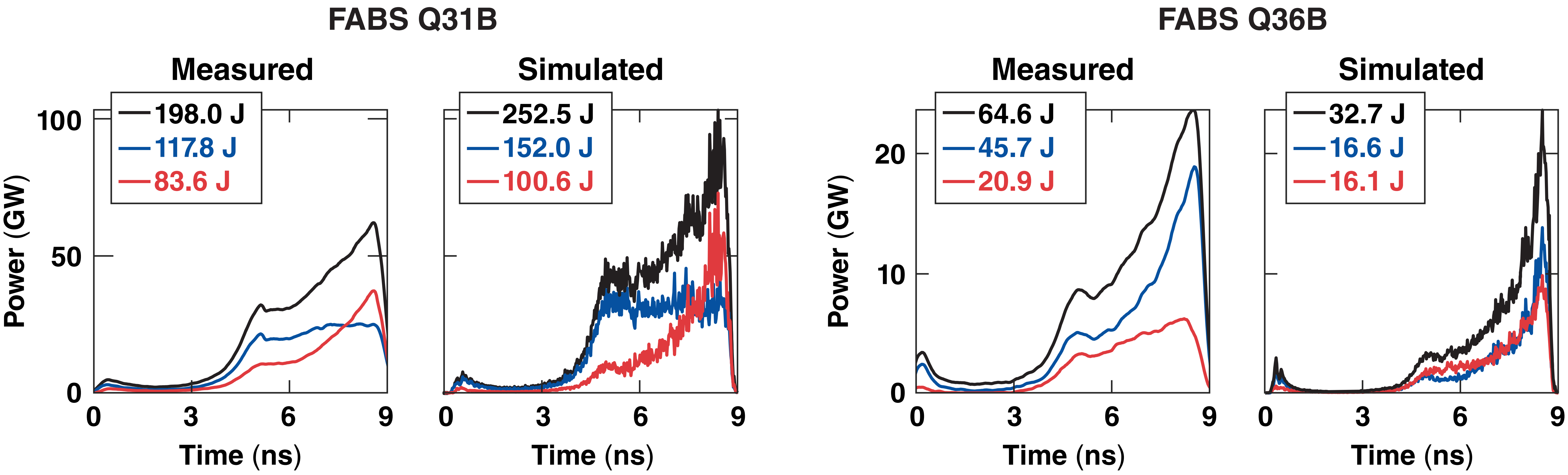
Scattered-light measurements can be used to diagnose wavelength detuning CBET mitigation





- Contours are at 10% of peak for measurement and simulation

The integrated scattered-light data show some qualitative agreements with simulations for $\Delta\lambda_0$ shot N160821-002



- Adding more diagnostic ports would help resolve these discrepancies

TC13878

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*Analysis by D. Turnbull

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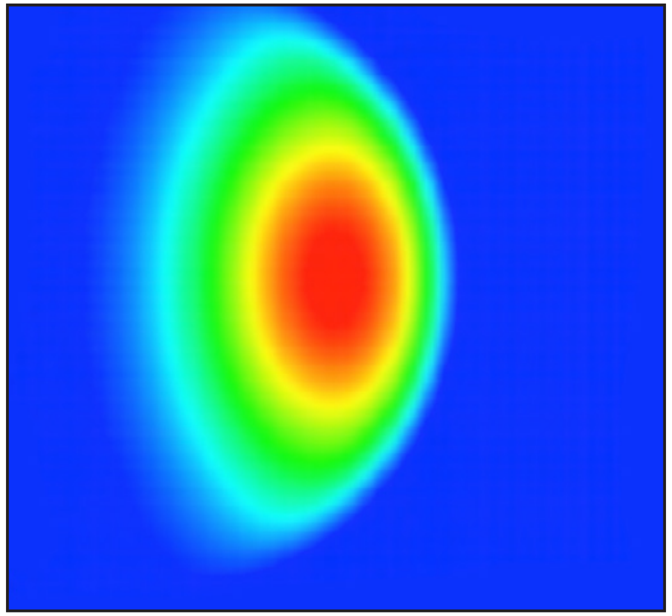
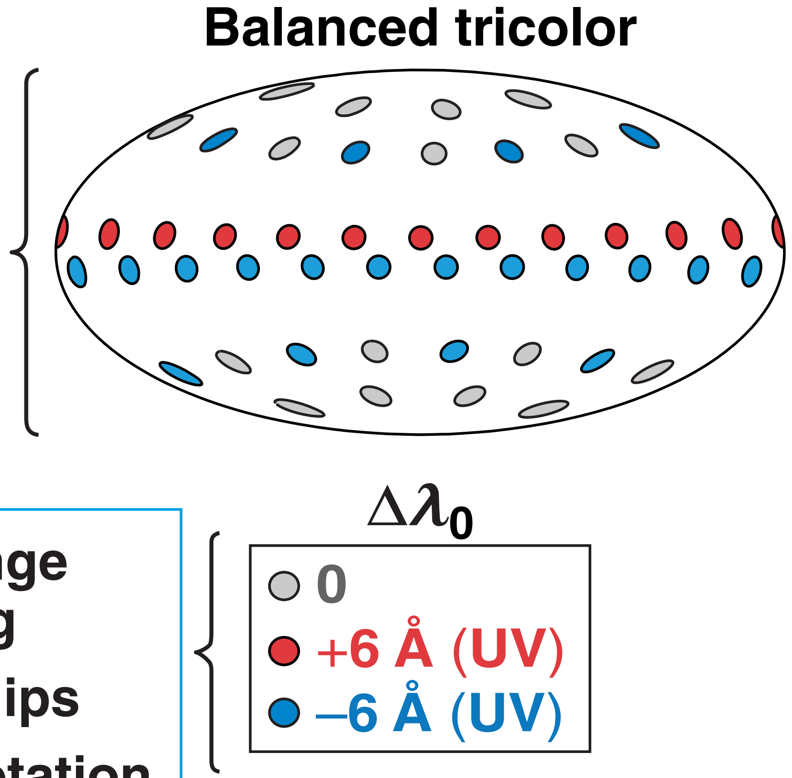
Additional capabilities on the NIF improve PDD target-energy coupling according to simulations



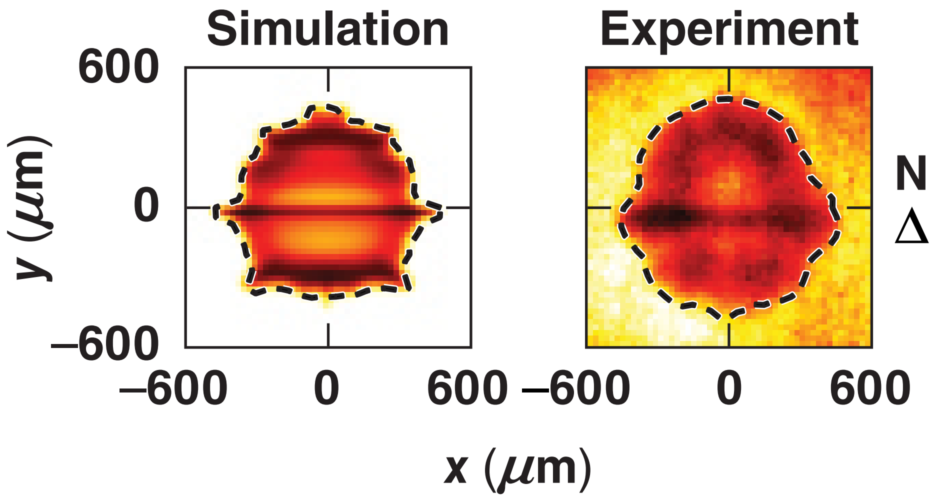
- Optimized spot-masking apodization; SMA-DPP's
  - – tailored shape
    - \- improves energy efficiency
    - \- improves uniformity
  - – minimize over-the-horizon energy
    - \- CBET reduction

- Flexible color to port mapping
  - – fiber front end



- Increased $\Delta\lambda_0$ range improves coupling
  - – armor-glass clips
  - – polarization rotation

Symmetry control with wavelength detuning requires the additional NIF facility capabilities

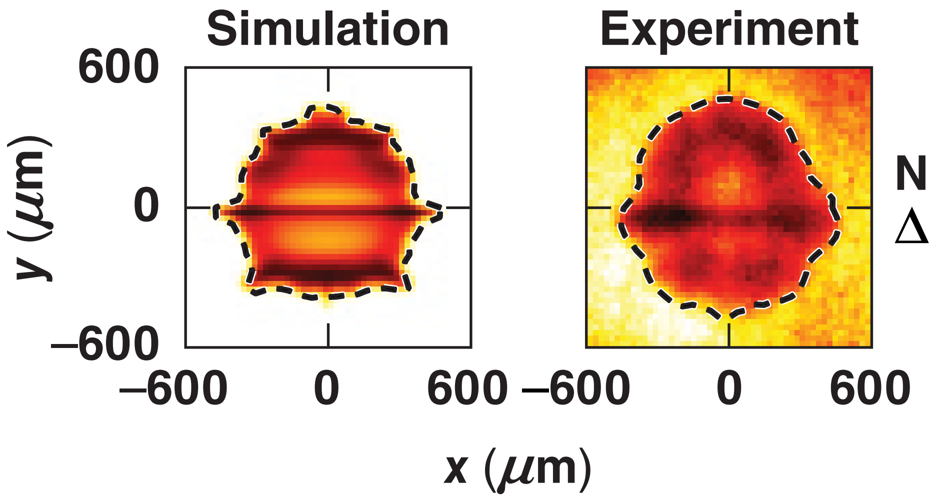


N160821
$\Delta\lambda_0 = \pm 2.3$ Å

- The first $\Delta\lambda_0$ PDD experiments were successful
- Results were limited by:
  - spot shape; phase plates
  - color separation; larger $\Delta\lambda_0$
  - color-to-port mapping → cone swapping

TC13885

Symmetry control with wavelength detuning requires the additional NIF capabilities



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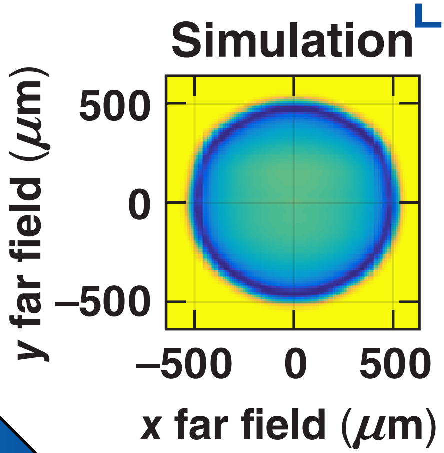

Beyond 2020...

- The first $\Delta\lambda_0$ PDD experiments were successful
- Results were limited by:
  - spot shape; phase plates
  - color separation; larger $\Delta\lambda_0$
  - color-to-port mapping → cone swapping

- The iPDD* design demonstrates the benefits of all improvements
  - optimized SMA spots; all ports
  - large color separation with balanced tricolor; $\Delta\lambda_0 = \{-6, 0, 6\}$ Å, UV
  - flexible color-to-port mapping
- Achieved high convergence, yields, and uniformity for a triple-picket pulse

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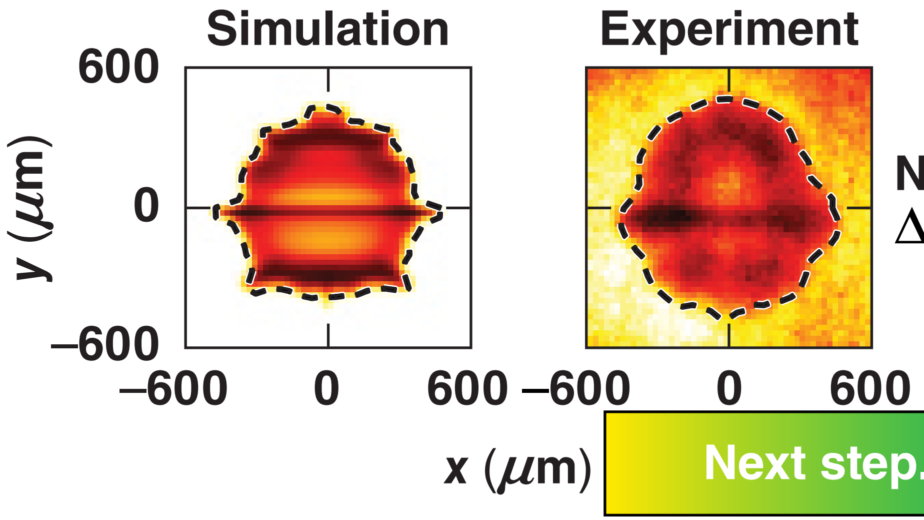
*D. Cao *et al.*, Bull. Am. Phys. Soc. 60, 29 (2015); J. A. Marozas *et al.*, Bull. Am. Phys. Soc. 60, 167 (2015).

Symmetry control with wavelength detuning requires the additional NIF facility capabilities

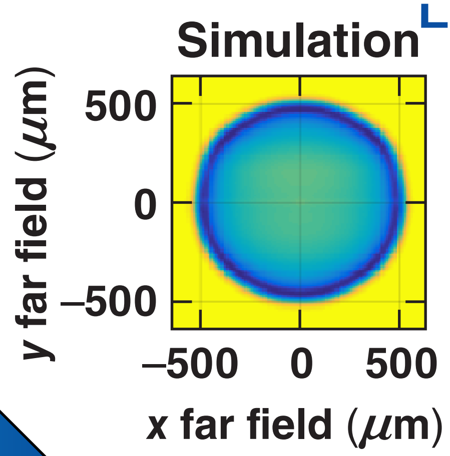


N160821
$\Delta\lambda_0 = \pm 2.3$ Å

Proposal: improve symmetry with SMA spots

Next step...

Beyond 2020...



- The first $\Delta\lambda_0$ PDD experiments were successful
- Results were limited by:
  - – spot shape; phase plates
  - – color separation; larger $\Delta\lambda_0$
  - – color-to-port mapping → cone swapping

- SMA-DPP's optimized for PDD
  - – improve shell uniformity
  - – higher convergence
  - – rounder shells and hot spots
- Populating the 16 quads repointed to the equator
  - – demonstrates improvements
- Swapping current DPP's would also help

- The iPDD* design demonstrates the benefits of all improvements
  - – optimized SMA spots; all ports
  - – large color separation with balanced tricolor; $\Delta\lambda_0 = \{-6, 0, 6\}$ Å, UV
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*D. Cao *et al.*, Bull. Am. Phys. Soc. 60, 29 (2015);
J. A. Marozas *et al.*, Bull. Am. Phys. Soc. 60, 167 (2015).

TC13885b

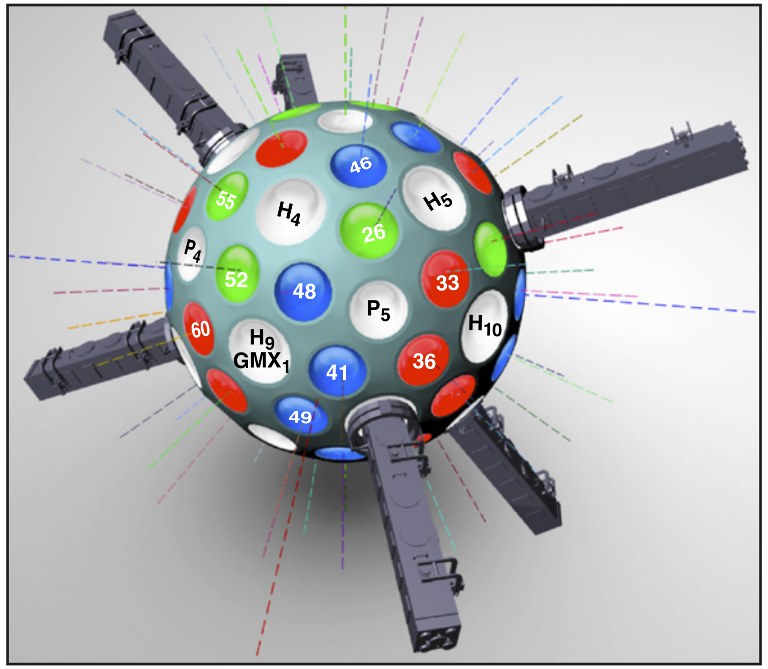
Outline

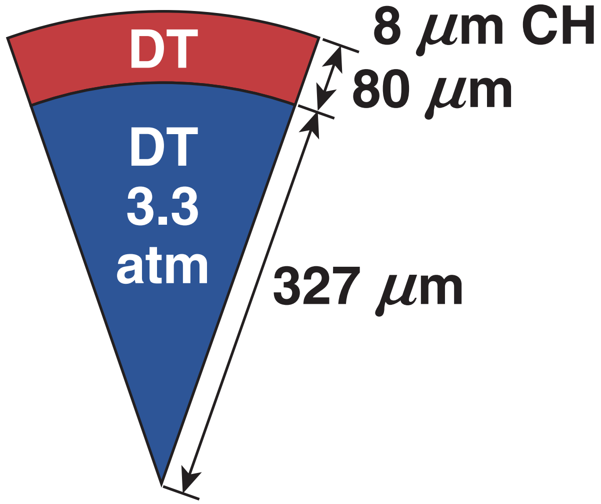
Wavelength detuning CBET mitigation scheme for direct-drive

- CBET overview
- CBET mitigation schemes
- Wavelength detuning ($\Delta\lambda_0$) on the NIF
  - experimental results
  - next steps
- **Wavelength detuning ($\Delta\lambda_0$) on OMEGA**

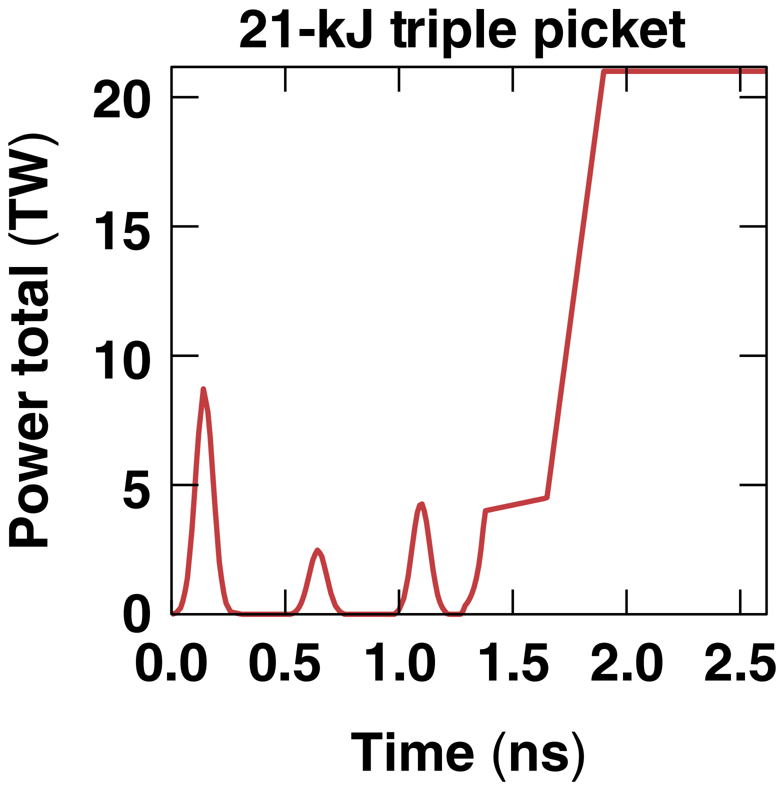
TC13868e

Simulations predict that combining $\Delta\lambda_0$ and SMA-DPP's achieves >100 Gbar with good shell uniformity on OMEGA cryo



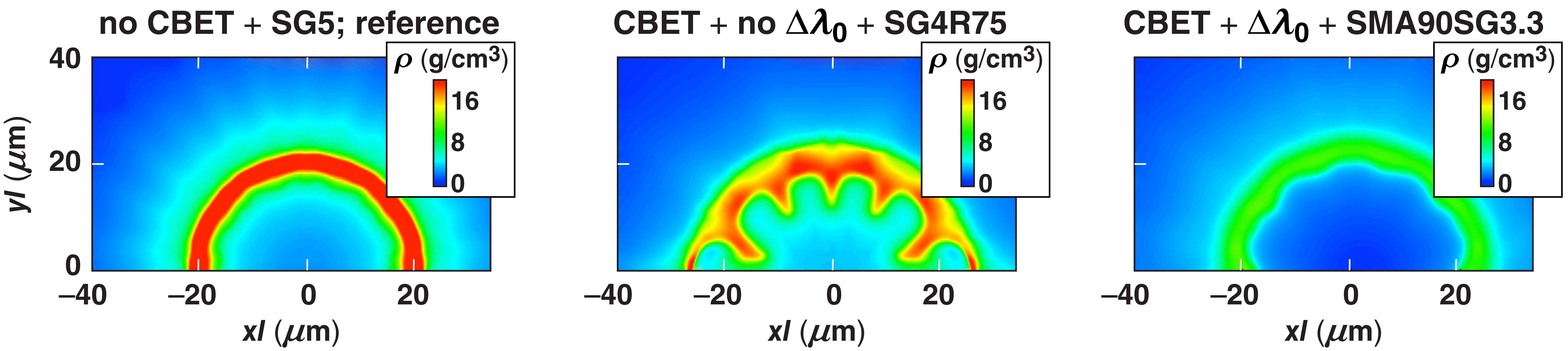


Full system energy, ~26 kJ, possible with laser-glass upgrades.



- OMEGA's three-legged layout could be modified to support wavelength detuning
- A tuned non-CBET simulation is employed as the reference to judge mitigation success
  - successful mitigation schemes converge to this reference run

Simulations without imbalances (everything ideal) and with imbalances (numbers only) demonstrate that $\Delta\lambda_0$ can achieve >100 Gbar with good uniformity



CBET	$\Delta\lambda_0$, UV	Far-field spot	E_{abs} (%)	P_{hs} (Gbar)	Y_{DT} ($\times 10^{14}$)	Note
No	0	SG5	78.0 (78.7)	169 (166)	2.29 (2.67)	Reference
Yes	0	SG5	55.1	32	0.09	Worst case
Yes	0	R75SG4	65.2	72 [69]	0.36	R75
Yes	{±6,0} Å	SMA 90%, SG3.3	73.6	119 [111]	1.17	$\Delta\lambda_0$

CBET bracket

TC13887

Summary/Conclusions

A wavelength detuning ($\Delta\lambda_0$) cross-beam energy transfer (CBET) mitigation scheme improves coupling in direct drive

- Initial proof-of-principle $\Delta\lambda_0$ experiments on the NIF* successfully demonstrated CBET mitigation in polar direct drive (PDD)
  - the first $\Delta\lambda_0$ experiments measured changes in shape, shell trajectory, and scattered light as predicted by simulations
- The successful NIF $\Delta\lambda_0$ experiments lay the foundation for future improvements
  - larger $\Delta\lambda_0$, multiple wavelengths, flexible wavelength distribution, optimized spot shapes, larger targets, and lower adiabats
- Symmetric direct drive (SDD) on OMEGA benefits from $\Delta\lambda_0$
  - *DRACO* simulations indicate that $\Delta\lambda_0$ achieves $>$100 Gbar

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*NIF: National Ignition Facility

The CBET effect is modeled by generalizing collinear interacting plane waves to include arbitrary incidence angles and polarization*

- The exponential CBET gain or loss factor is given by

$$d\tau_{\text{CBET}} = \zeta_{\text{pol}} \left[\frac{e^2}{c^3 m_e} \frac{n'_e}{1-n'_e} \frac{\lambda_0 \langle Z \rangle}{\langle Z \rangle T_e + 3T_i} \right] \underbrace{P(\eta)}_{\text{ASR}} I_{\text{pump}}\, ds$$

$$P(\eta) = \frac{\eta \nu_a}{(\eta \nu_a)^2 + (1-\eta^2)^2}$$

Resonance function;**

$P = \pm 1/\nu_a$, when matched; i.e., $\eta = \pm 1$

$$\eta = \frac{(\omega_{\text{pump}} - \omega_{\text{probe}}) - k_a \cdot v_{\text{fluid}}}{|k_a| c_a}$$

Matching condition

$$\begin{cases} \eta > 0; \text{gain} \\ \eta < 0; \text{loss} \end{cases}$$

- Random polarization ζ_{pol} is included using either a constant 1/2 factor or $1/4 \left\{1 + \left[\hat{k}_{\text{pump}} \cdot \hat{k}_{\text{probe}}\right]^2\right\}$***
- Probe energy is gained or lost as $E_0 \left[e^{d\tau_{\text{IB}^\dagger}} e^{d\tau_{\text{CBET}}} - 1\right]$ in a cell

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*C. J. Randall, J. R. Albritton, and J. J. Thomson, Phys. Fluids 24, 1474 (1981).

**ASR = angular-spectrum representation

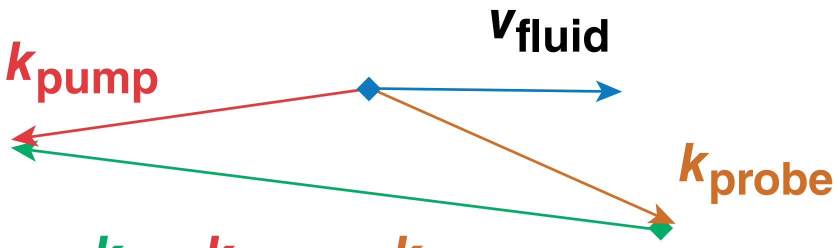
***P. Michel, LLE/LLNL Meeting (May 2014).

†IB = inverse bremsstrahlung

TC11307b

The interaction of crossed laser beams within an expanding plasma causes CBET between beams

- This stimulated Brillouin scattering (SBS)-based interaction leads to a resonance condition for transferring energy between a pump ray and a probe ray by means of an ion-acoustic wave k_a*



$$k_a = k_{\text{pump}} - k_{\text{probe}}$$

- The resonance condition peaks when the matching condition is met

$$\eta = \frac{(\omega_{\text{pump}} - \omega_{\text{probe}}) - k_a \cdot v_{\text{fluid}}}{|k_a| c_a}$$

$$\begin{cases} \eta > 0; \text{gain} \\ \eta < 0; \text{loss} \end{cases}$$

Resonance (±1) occurs in the neighborhood of the Mach-1 surface under typical conditions.

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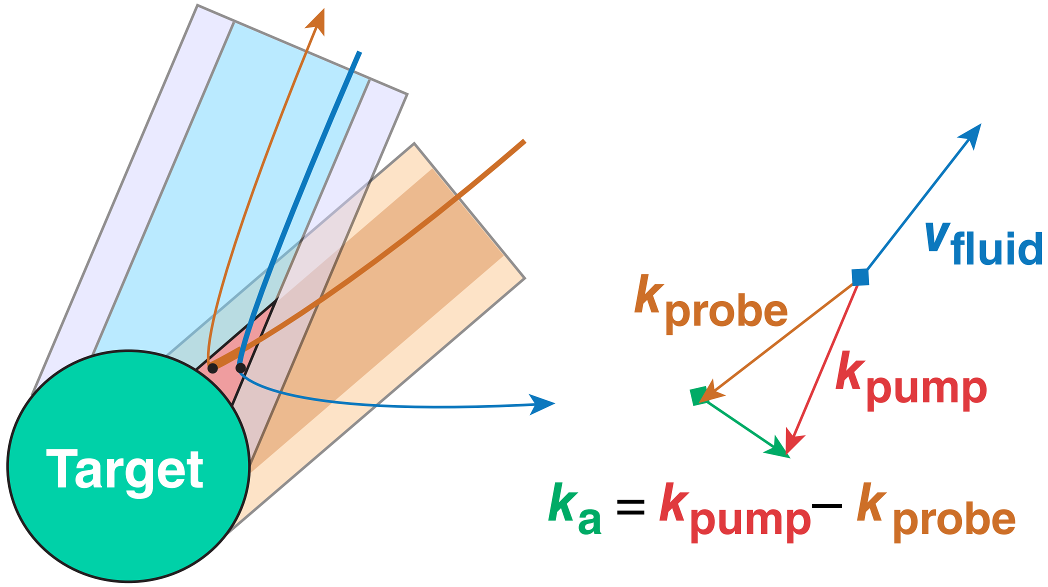
*C. J. Randall, J. R. Albritton, and J. J. Thomson, Phys. Fluids 24, 1474 (1981).

The sidescatter mode causes an inbound beam-to-beam CBET exchange

- The sidescatter mode occurs when both beams are inbound or outbound

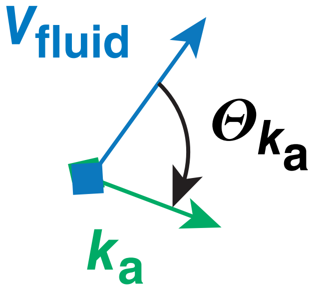
Sidescatter mode



Matching condition

$$\Delta\omega = \omega_{\text{pump}} - \omega_{\text{probe}} = |k_a| c_a + k_a \cdot V_{\text{fluid}}$$

$$\lim_{V_{\text{fluid}} \to M c_a \hat{r}} \Rightarrow \eta = \frac{\Delta\omega - |k_a| c_a M \cos\theta_{k_a}}{|k_a| c_a}$$



This mode leads to nonuniformity without altering total deposition when activated in SDD*

- The resonance condition still peaks where the fluid is supersonic (small $\Delta\omega$)
- The $|k_a|$ is much smaller, however, and the angle θ_{k_a} can be near orthogonal, which implies that the $k_a \cdot V_{\text{fluid}}$ term no longer dominates
  - – the sign of the $\Delta\omega$ can now determine gain/loss for smaller values

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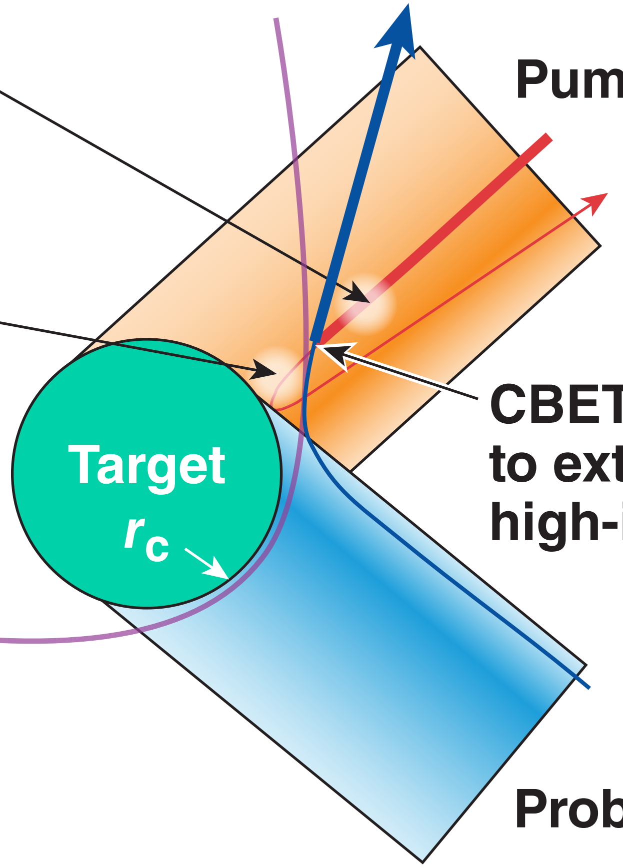
* J. A. Marozas *et al*., presented at the 44th Annual Anomalous Absorption Conference, Estes Park, CO, 8–13 June 2014.

Successful wavelength detuning shifts the resonance location sufficiently to mitigate CBET

When probe rays are blue-shifted, the resonance shifts to a higher Mach number where intersecting probe rays are negligible

When probe rays are red-shifted, the resonance shifts to a lower Mach number where probe rays are blocked and/or have negligible intensity



Pump beam

CBET causes probe rays to extract energy from high-intensity pump rays

Parabolic locus of turning points

Probe beam

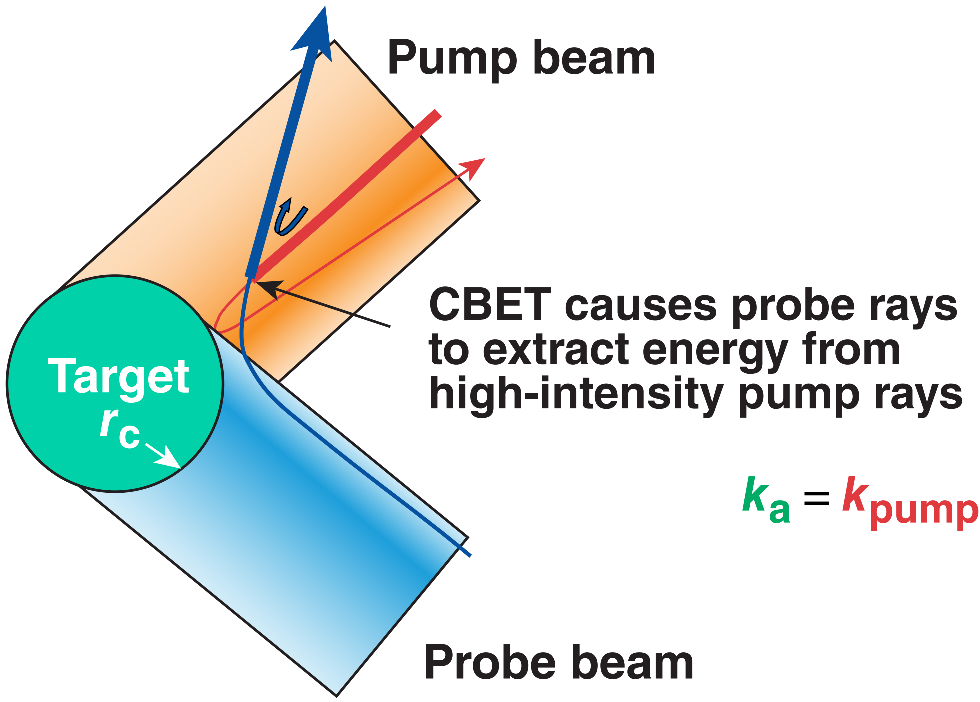
- The magnitude of $\Delta\lambda_0$ determines the mitigation duration
  - – works for both symmetric and PDD
  - – tailoring the spot shape will help limit the required $\Delta\lambda_0$

TC11766f

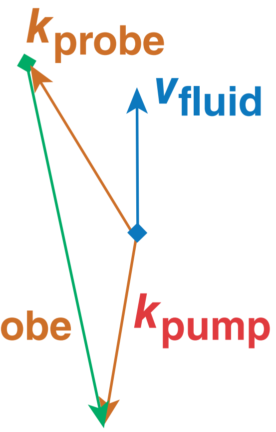
The backscatter mode dominates the CBET loss for directly driven targets

- The backscatter mode occurs for opposing beams

Backscatter mode



CBET causes probe rays to extract energy from high-intensity pump rays

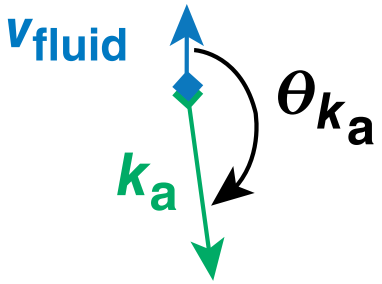


$k_a = k_{pump} - k_{probe}$

Matching condition

$$\Delta\omega = \omega_{pump} - \omega_{probe} = \left| k_a \right| c_a + k_a \cdot V_{fluid}$$

$$\lim_{V_{fluid} \to Mc_a \hat{r}} \Rightarrow \eta = \frac{\Delta\omega - \left| k_a \right| c_a M\cos\theta_{k_a}}{\left| k_a \right| c_a}$$



This mode leads to nonuniformity and alters total deposition when activated in SDD*

- The resonance condition peaks where the fluid is supersonic (small $\Delta\omega$)
- As the frequency difference increases, the resonance condition shifts to lower/higher sonic speeds depending on the sign (e.g., $M = \{0.4, 1.6\}$ for ±6-Å UV)
  - dominated by the $k_a \cdot V_{fluid}$ term; its sign determines whether there is gain/loss
  - frequency difference cannot alter the gain/loss unless it can counter the large $k_a \cdot V_{fluid}$ term (e.g., ±20-Å UV)

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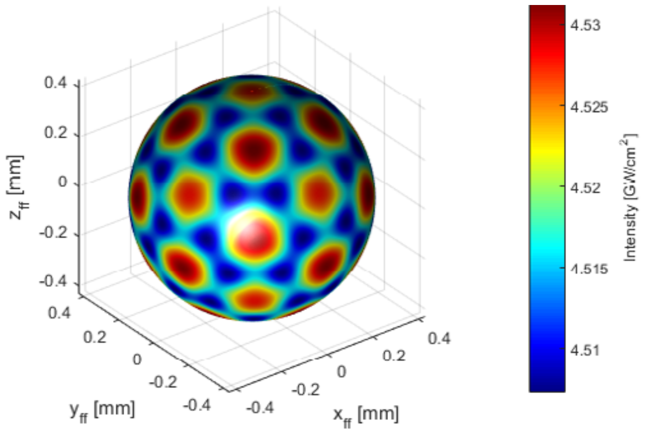
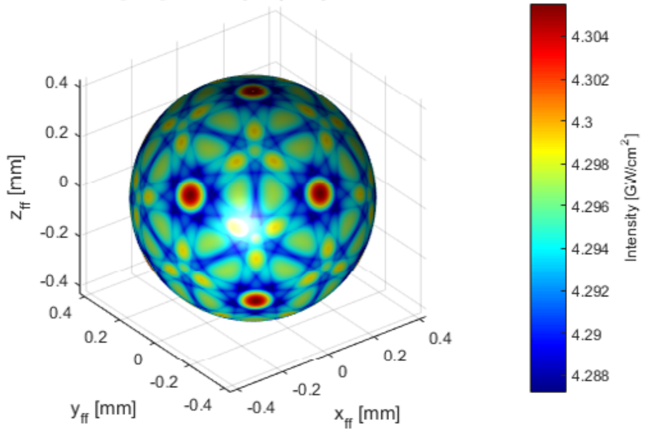
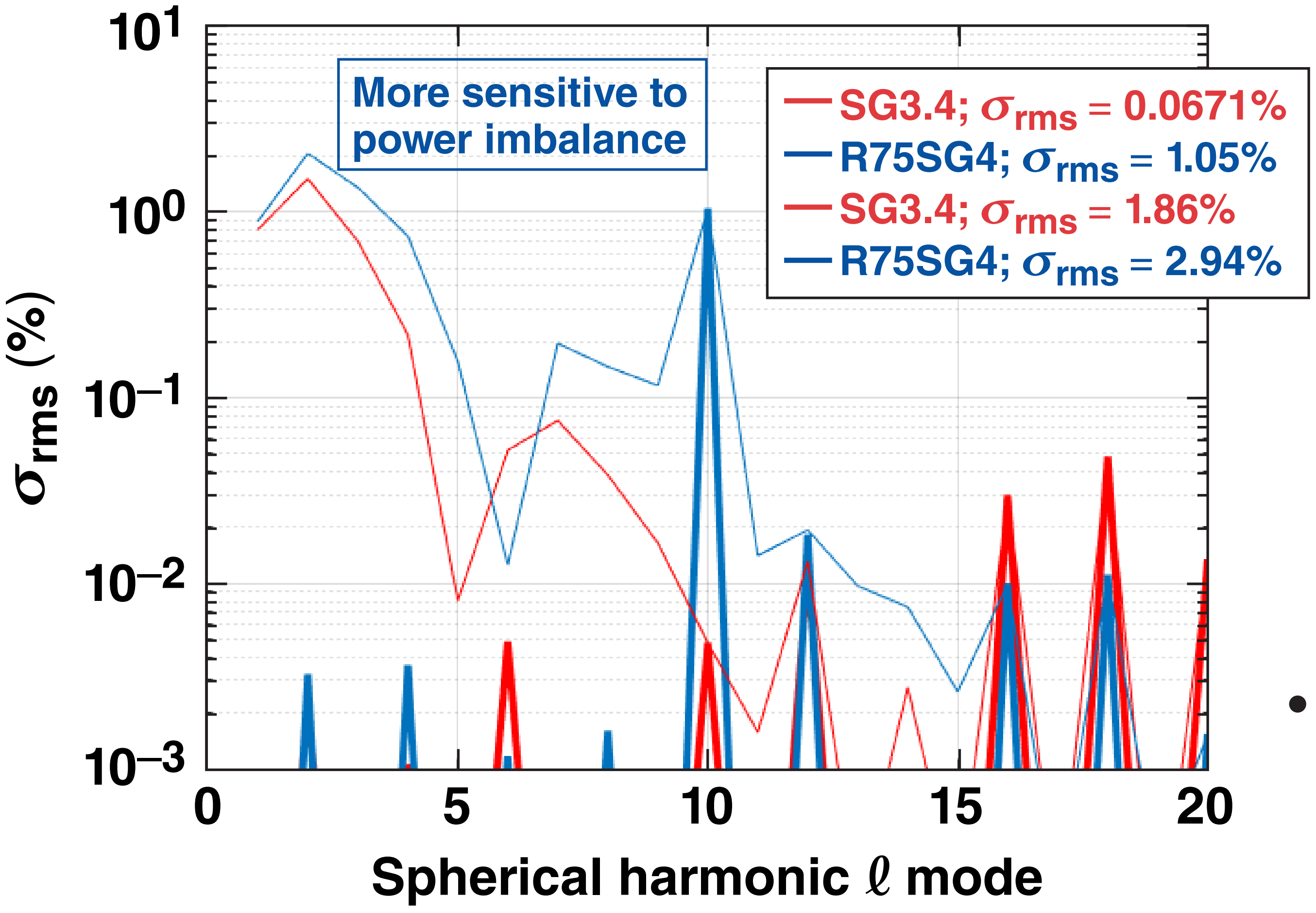
*A. Shvydky *et al*., Bull. Am. Phys. Soc. 54, 307 (2009).

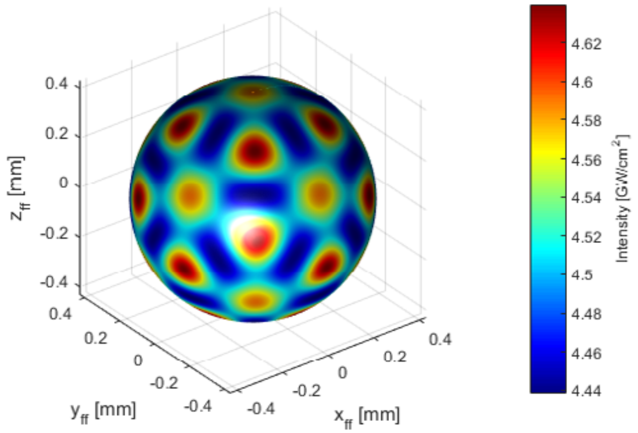
The R75 SG4 induces a large $\ell = 10$ that is responsible for poor performance







More sensitive to power imbalance

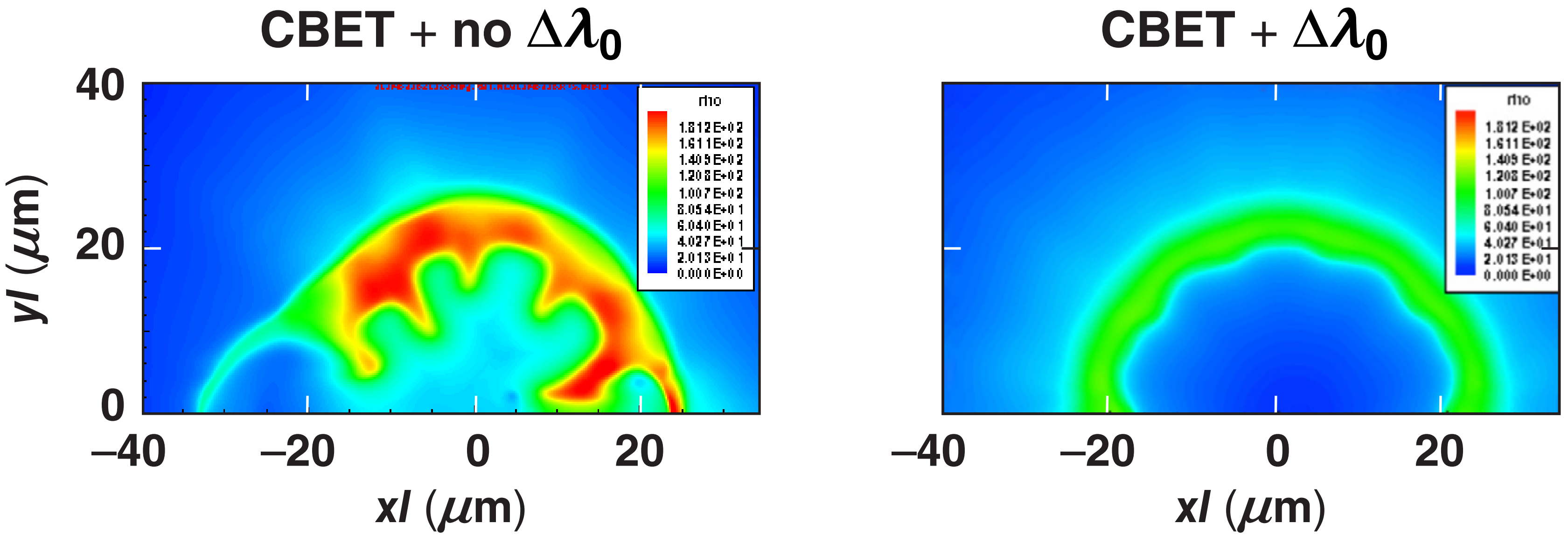


- The R75 induces large perturbations at every Pent; *DRACO* captures this 3-D feature on the poles
- The hex centers are worse
- The Pk2Pk is 10× worse than SMA90

Results with imbalances show that $\Delta\lambda_0$ can acheive 100 Gbar

Power imbalance = 10% rms, mistiming = 5-ps rms, mispointing = 10-μm rms

The performance of R75 suffers as result of the imbalances but not as severe as from the smaller spot (i.e., $\ell = 10$); the performance will be worse in 3-D.



CBET	$\Delta\lambda_0$, UV	Far-field spot	E_{abs} (%)	V_{imp} (μm/ns)	P_{abl} (Mbar)	P_{hs} (Gbar)	IFAR 2/3 R_0	Y_{DT} ($\times10^{14}$)	Note
No	0	SG5		410 (410)					Reference
Yes	0	SG5	55.0	281	57	30	16.2	0.07	Worst case
Yes	0	R75SG4	65.1	340	64	69	17.8	0.32	R75
Yes	{±6,0} Å	SMA 90%, SG3.3	73.5	381	88	111	22.1	0.97	$\Delta\lambda_0$

CBET bracket

Compared to CBET mitigation strategies; summary

no CBET + SG5

- Reference run
- Successful mitigation strategies converge toward this run
- Intentionally achieves over 100 Gbar

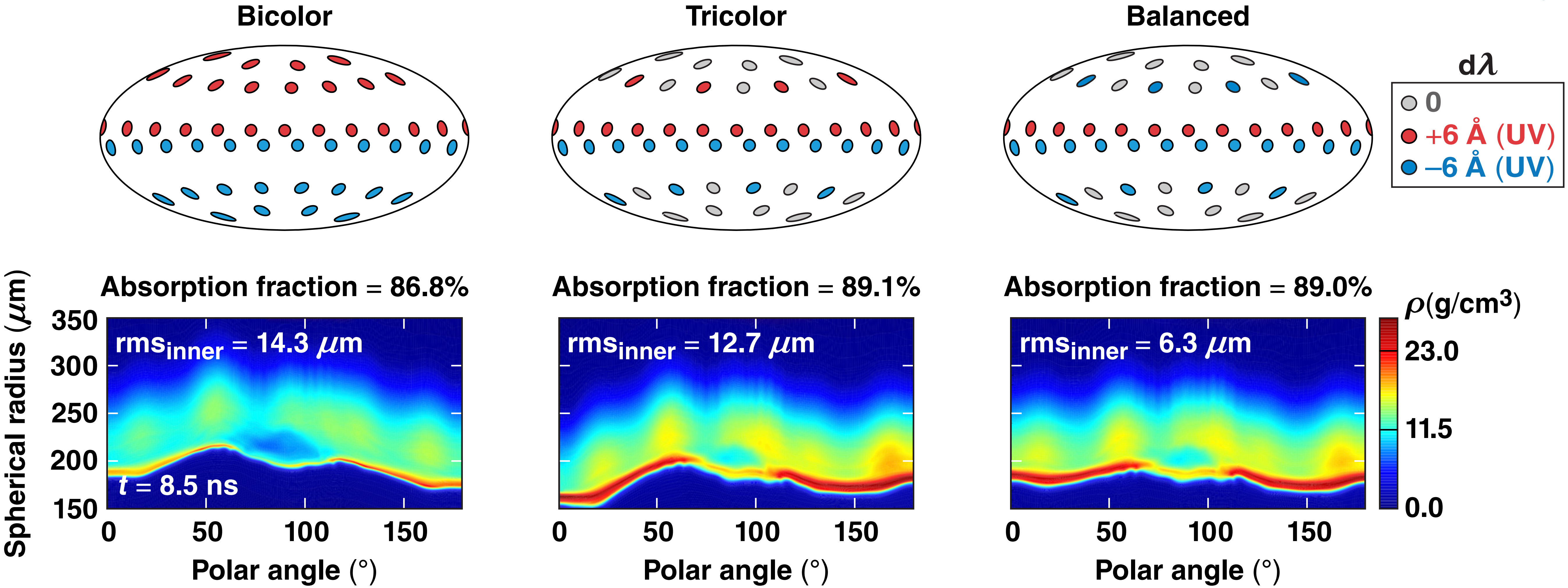
CBET + NOdλ0 + SG4R75

- Increases P_{abl} and P_{hs} and Y_{DD}; but achieves <100 Gbar when everything is perfect; ~72 Gbar
- Comes at the expense of
  - higher sensitivity to port-geometry modal structure; i.e., $\ell = 10$
  - more sensitive to imbalances
  - smaller and distorted hot spot
  - on verge of compromised shell; will be worse in 3-D
- Any increase in laser drive will exacerbate all mode growth (low to high modes) and further degrade P_{abl}, P_{hs} and YDD
- Larger targets decrease the mispointing sensitivity but adapting to smaller DPP's in not advised

CBET + 6Å, (UV) + sma90SG3.3

- The best mitigation strategy to date
  - highest P_{abl}, P_{hs}, and Y_{DD}
- Closely matches the reference run in drive and imprinted structure
- Potentially higher laser drive headroom going to 26 kJ; will improve P_{abl}, P_{hs}, and YDD

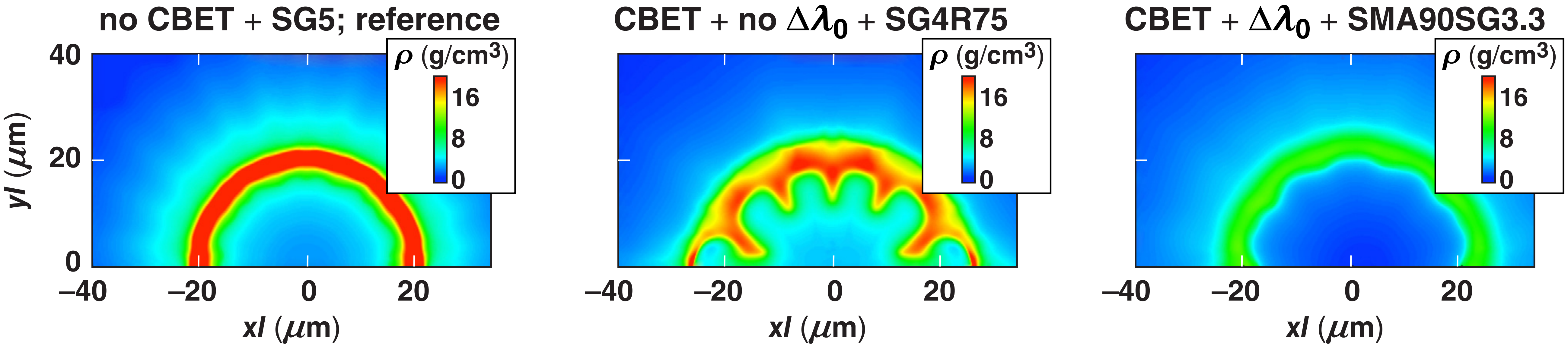
The balanced hemispheric detuning uses three wavelengths to improve drive and symmetry



- These detuning configurations all recover more laser absorption in PDD relative to SDD

TC12464

Simulations without imbalances (everything ideal) and with imbalances (numbers only) demonstrate that $\Delta\lambda_0$ can achieve >100 Gbar with good uniformity



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Yes	{±6,0} Å	SMA 90%, SG3.3	73.6	382	89	119 [111]	21.6	1.17	$\Delta\lambda_0$

CBET bracket

TC13887b