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High Foot Implosion Experiments in Rugby Hohlraums

J. Ralph

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Disclaimer

High Foot Implosion Experiments in Rugby Hohlraums

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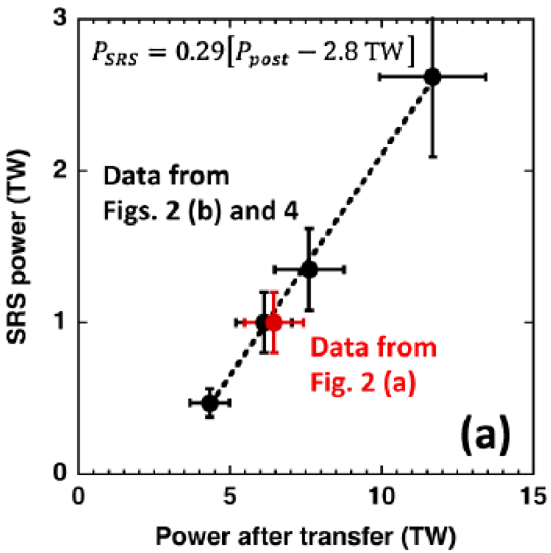
Joseph Ralph

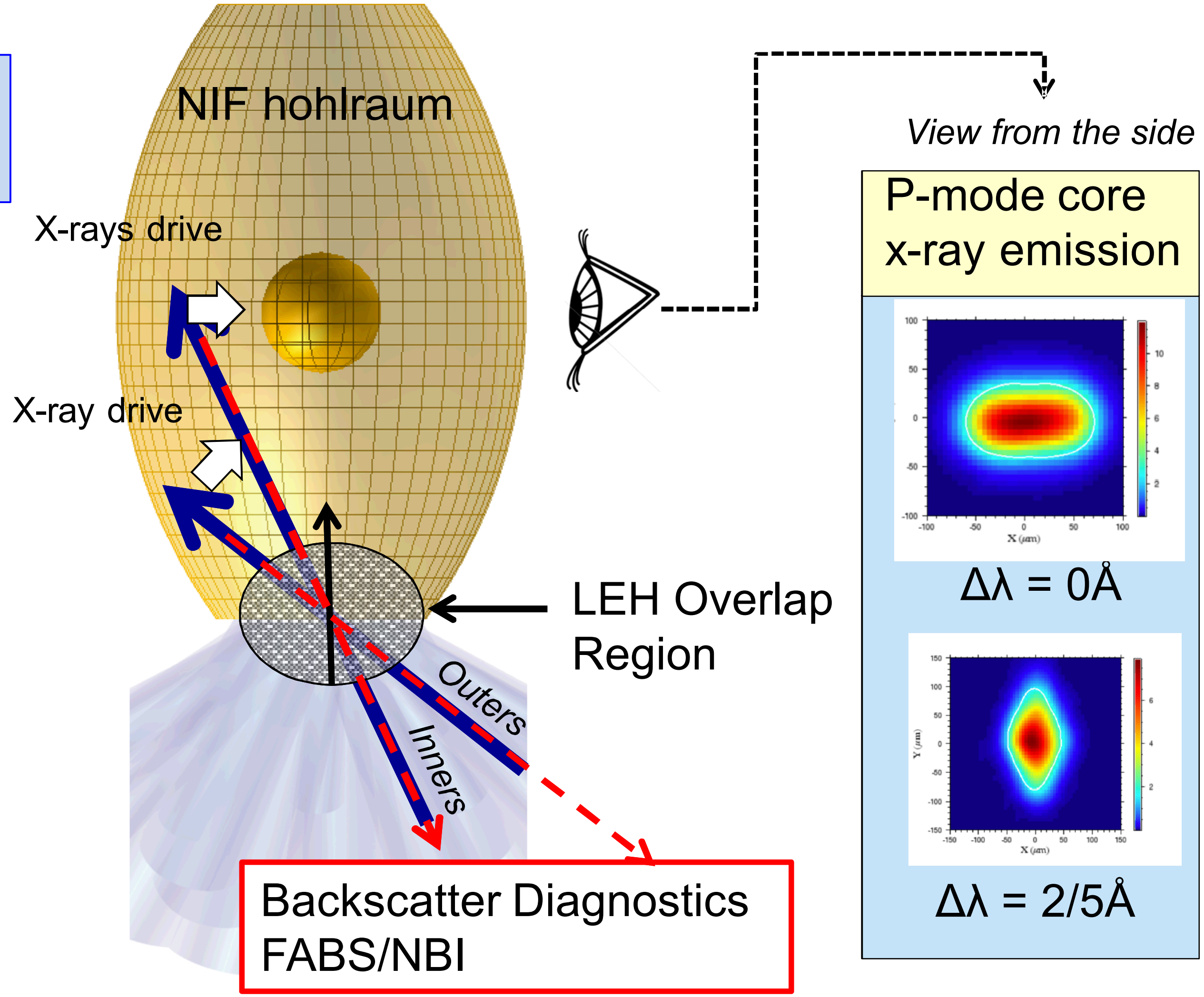
November 16th , 2015

LLNL-PRES-XXXXXX
This work was performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under contract DE-AC52-07NA27344. Lawrence Livermore National Security, LLC

Power after cross beam transfer can be measured using Inner beam SRS backscatter

The power of inner cone beams has been shown to scale with inner SRS power*

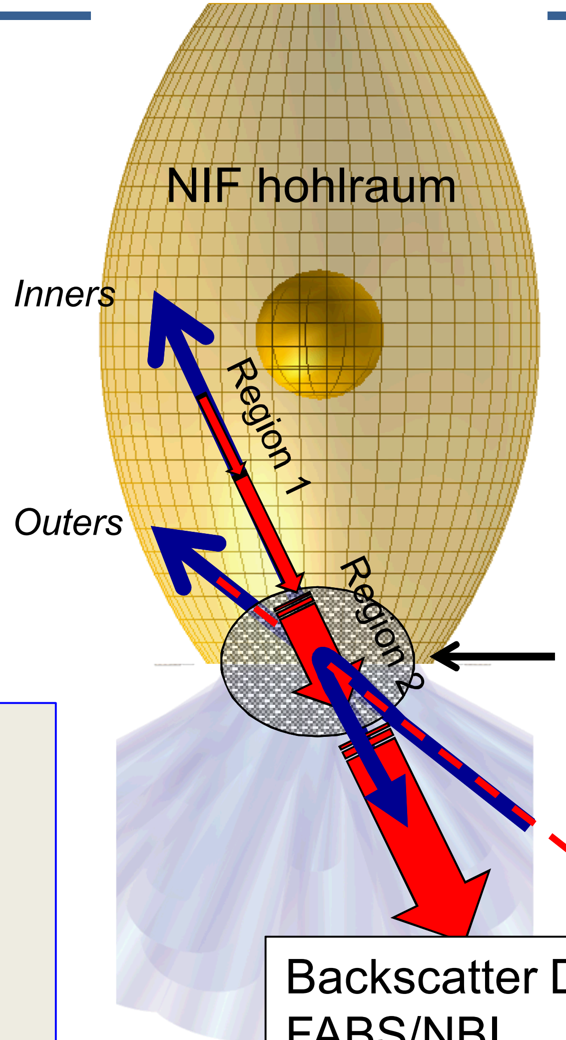




*Moody J. D., Strozzi D. J., et. al. PRL 111, 025001 (2013)

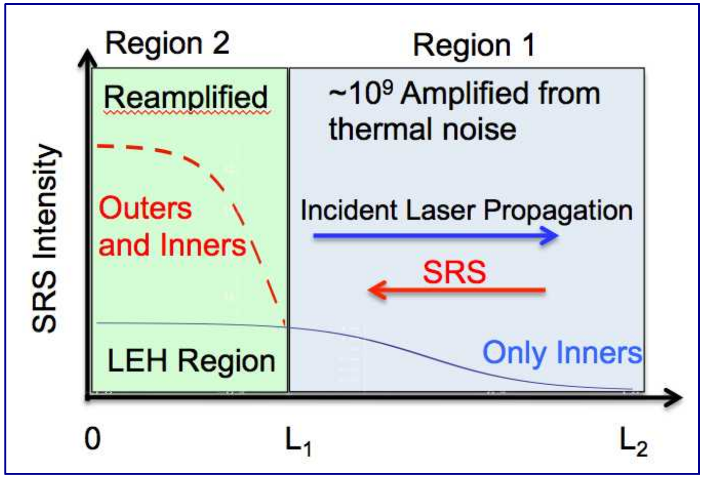
Reamplification of SRS and SBS, like CBET, was predicted* to occur in the LEH region where all the beams overlap

Backscattered light from SRS or SBS can be amplified at the LEH by seeded side-scattering from the 24 crossing quads



Backscatter Diagnostics FABS/NBI

2-Stage Amplification of Raman

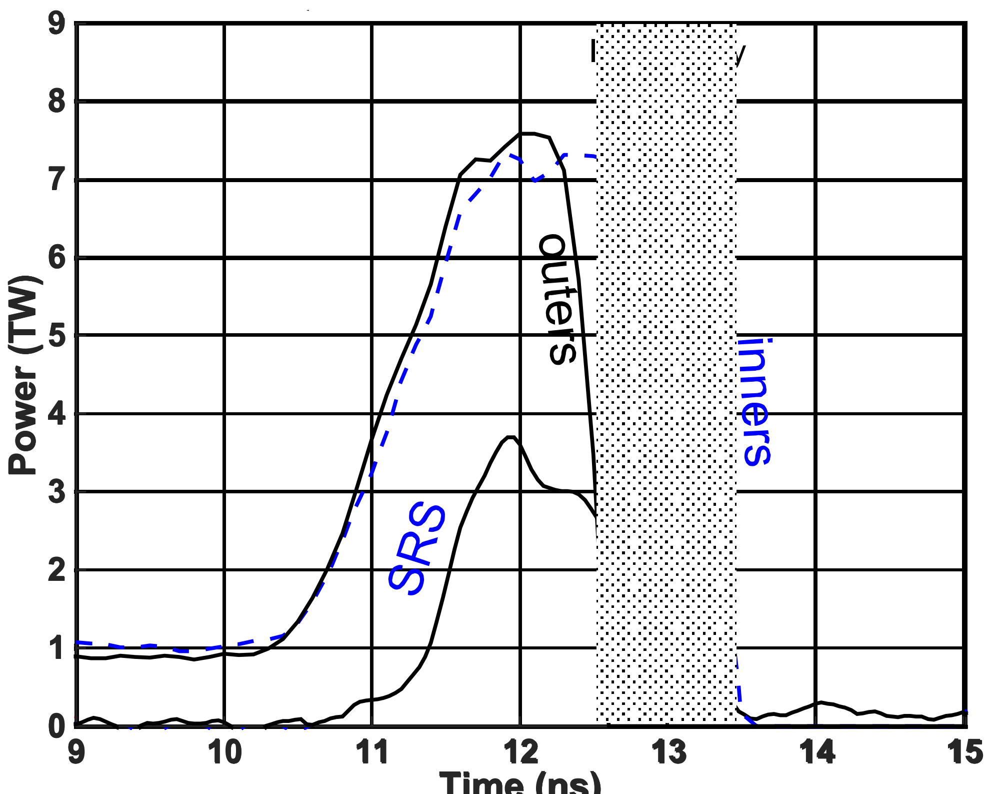


Recent results have successfully quantified SBS and glint reamplification in near vacuum hohlraums on NIF**

*R. K. Kirkwood,1, P. Michel et. al. POP 18, 056311 (2011) **D. Turnbull et. al. Phys. Rev. Lett. 114, 125001(2015)

The SRS at the end of the pulse allows us to determine an SRS reflectivity independent of Outer beams

These 2 shots are enough to provide a no CBET/Reamp saturation model.
an early and a late time model using either CBET or reamp.



SRS Reflectivity Saturation Model

$$R = R_0\left(1 - \frac{P_{thr}}{P_0}\right)$$

R_0: Max reflectivity

P_{thr}: threshold power

P_0: Inner Power Level

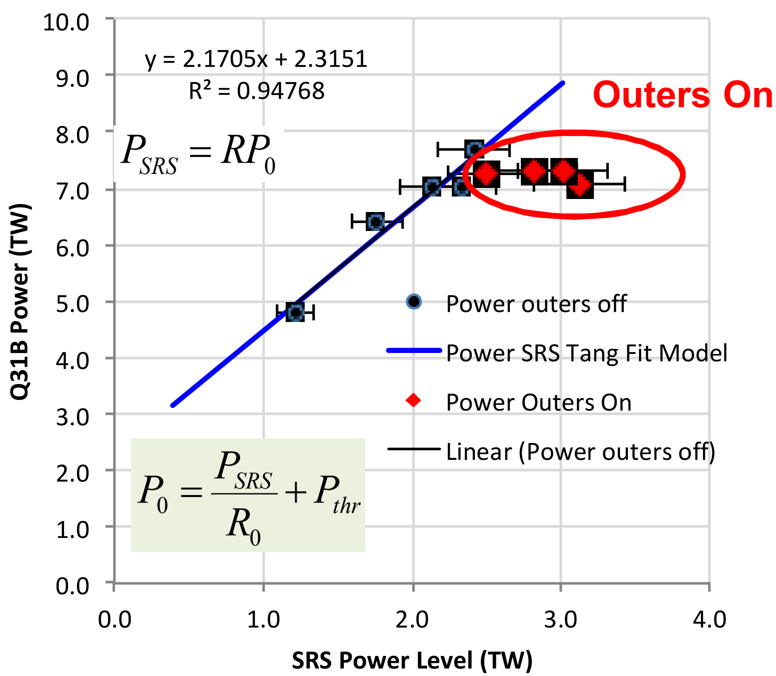
$$P_{SRS} = RP_0$$

$$P_0 = \frac{P_{SRS}}{R_0} + P_{thr}$$

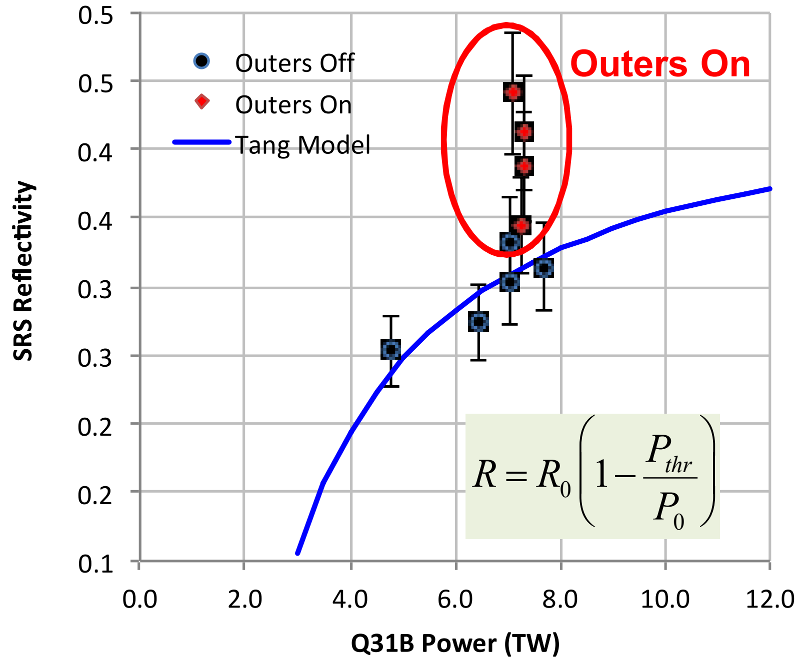
The AM ripples and inner falloff provide power data to fit to the model

Data from the AM ripples provide enough information to fit a "Tang" curve in the case of no outers

"Tang" model fit in terms of measured powers



"Tang" SRS pump depletion model fit



R_0: Max reflectivity

P_{thr}: threshold power

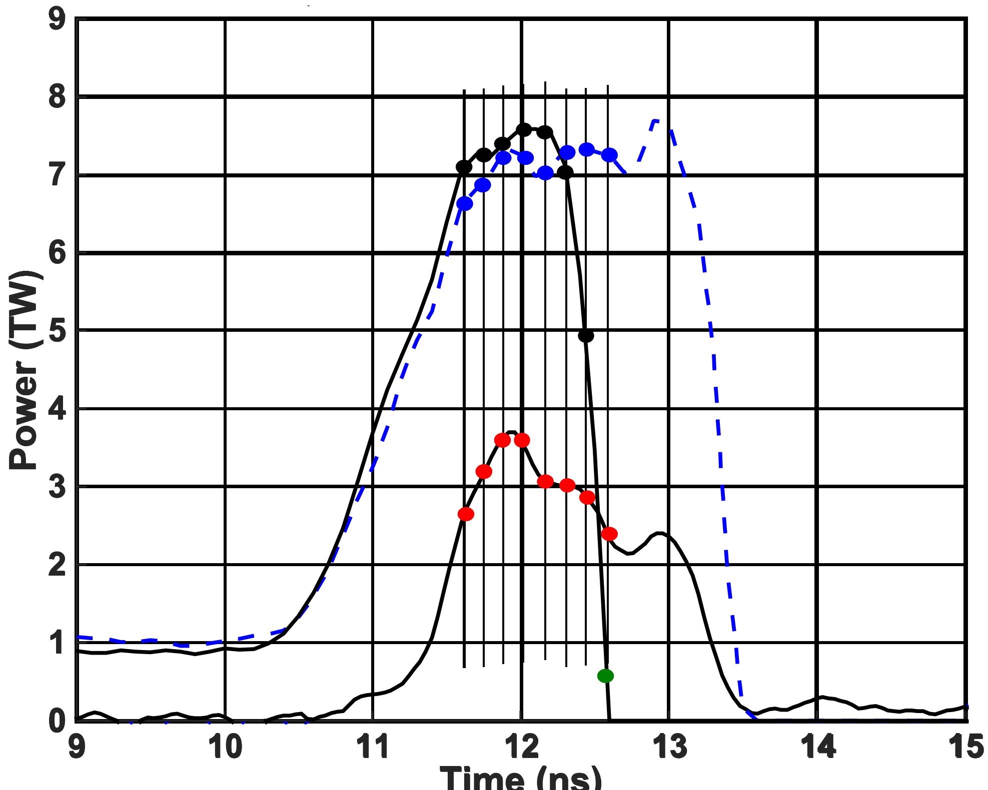
P_0: Inner Power Level

The points with outer on do not lie on the curve indicating CBET or Reamplification of SRS

Using the pump depletion model, the amount of transfer can be estimated

The only unknown is T, assuming the R_0 and P_{thr} do not change significantly.

If R_0 and P_{thr} do change, the result should be obvious as points fall of with time.



The AM ripples and inner falloff provide power data to fit to the model

SRS Reflectivity Saturation Model

$$R = R_0\left(1 - \frac{P_{thr}}{P_{inner}(1+\gamma P_{outer})}\right)$$

R_0: Max reflectivity

P_{thr}: threshold power

P_0: Inner Power Level

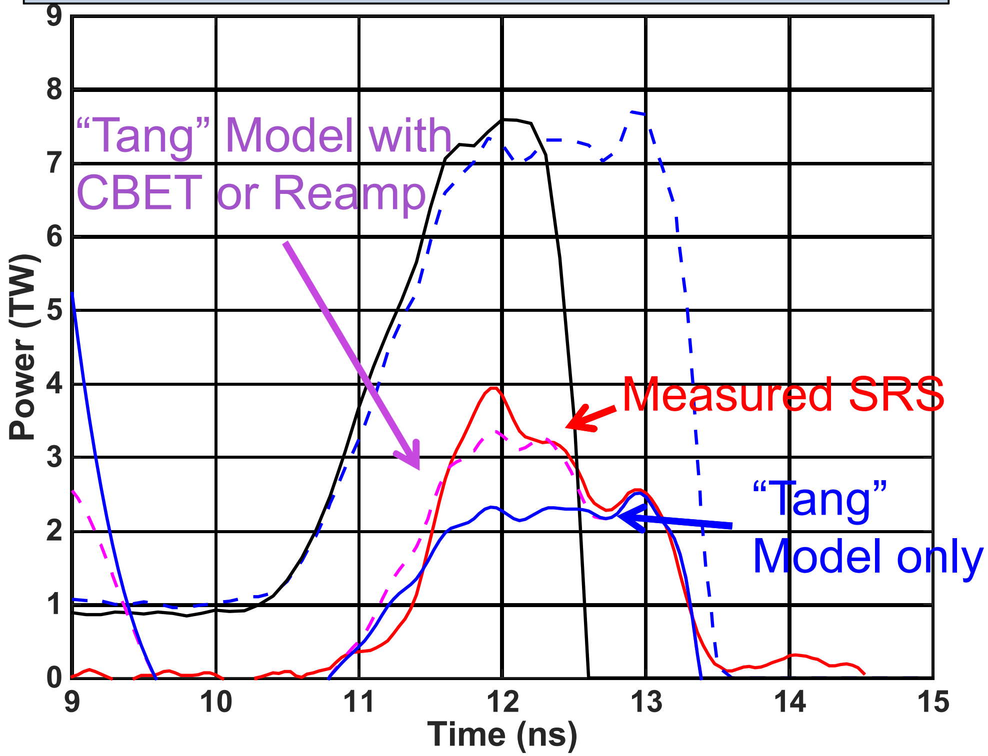
$$P_{SRS} = RP_0$$

$$T = \gamma_{transfer} P_{inner}$$

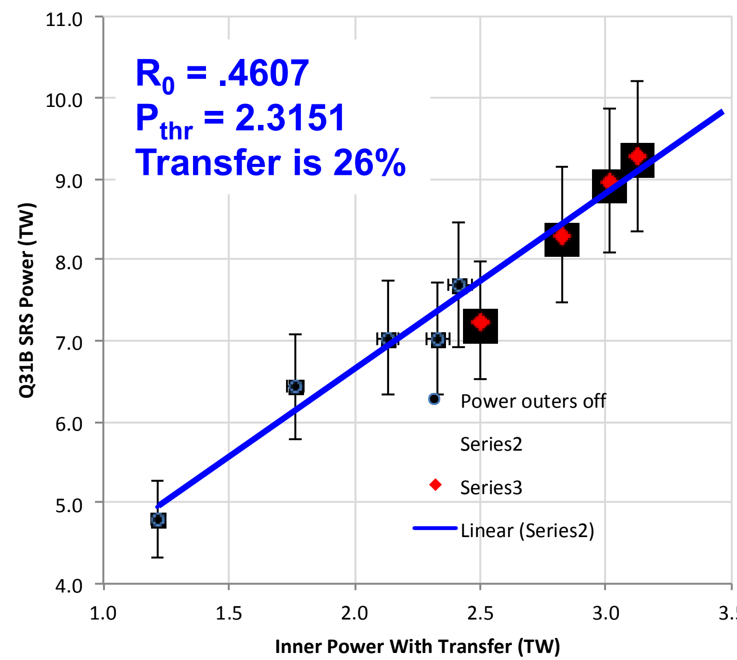
$$P_{inner} = \frac{P_{SRS}}{R_0} + P_{thr} - \gamma_{transfer} P_{outer}$$

The increase from the outers @ $\Delta\lambda$ = 0,0 is consistent 26% transfer or

The effective measured SRS with increases from Reamp or CBET can estimated using the same model



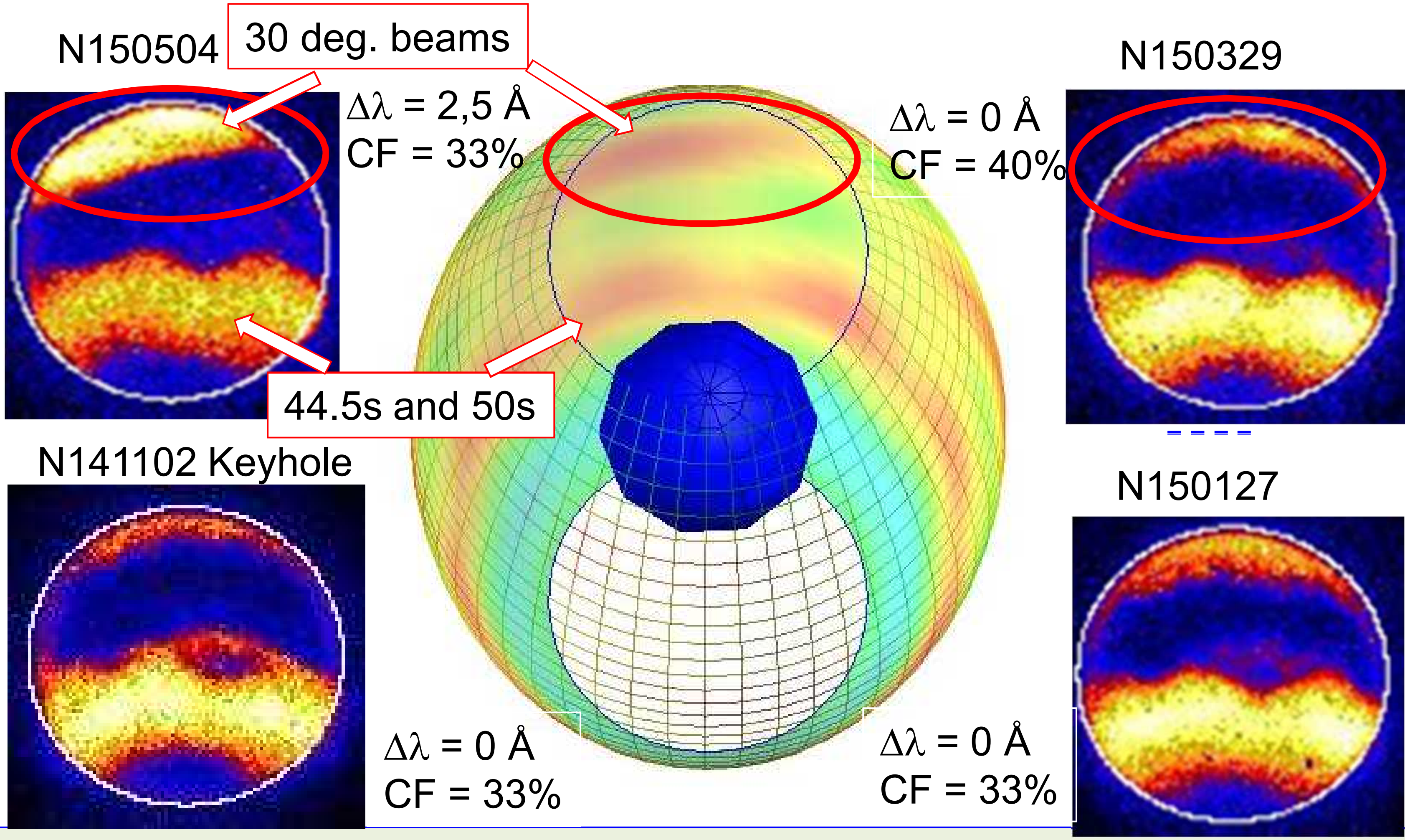
Data and fit comparison across time steps when outers are on and off showing the instrument and effect of timing error



Model for estimating SRS

$$P_{SRS} = \left[P_{inner}(1+\gamma P_{outer})\right] R_0 \left(1 - \frac{P_{thr}}{P_{inner}(1+\gamma P_{outer})}\right)$$

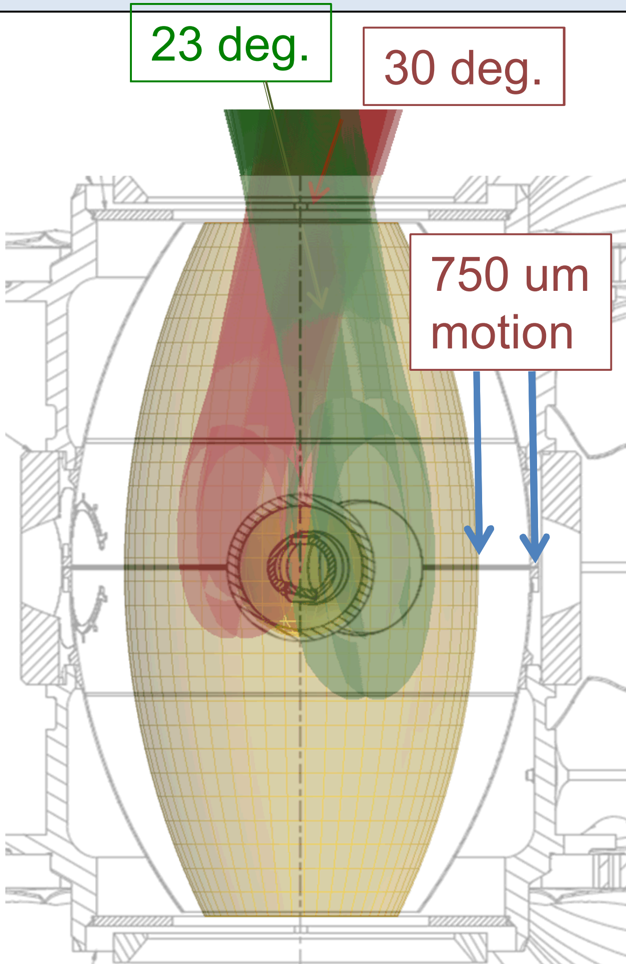
The 30 deg. beams are are visible in SXI only on the shot with intensional transfer to the 30s, $\Delta\lambda$ = 2 – 5 Å



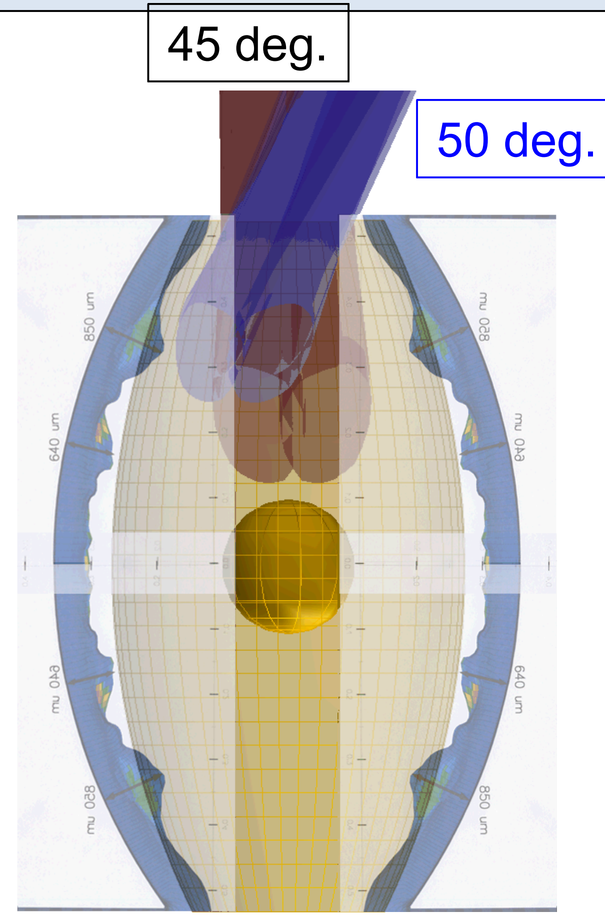
Best Match of Outer Beams Position from SXI is consistent with 750 (+200/-100) μm microns of Wall Motion. SXI 161-326 views are also consistent with 750 μm wall motion

CEA simulations show wall motion was between 640 μm and 850 μm at the beam locations, consistent with SXI

Inner Cone Quads Appear to be pointed at equator after wall motion



Outer Cone Quad Position Comparison with simulated wall

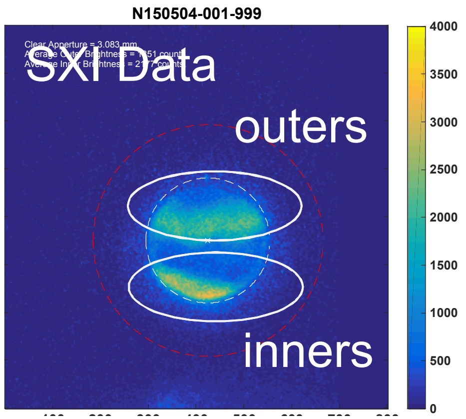


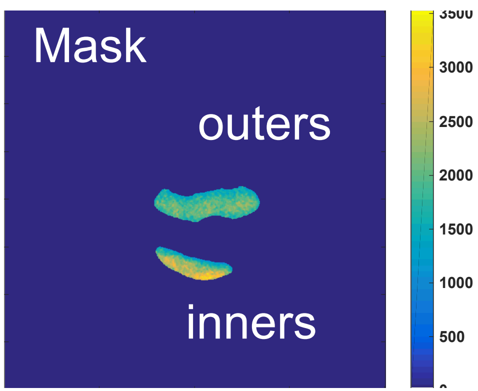
*Simulation data courtesy of J.-P. Leidinger

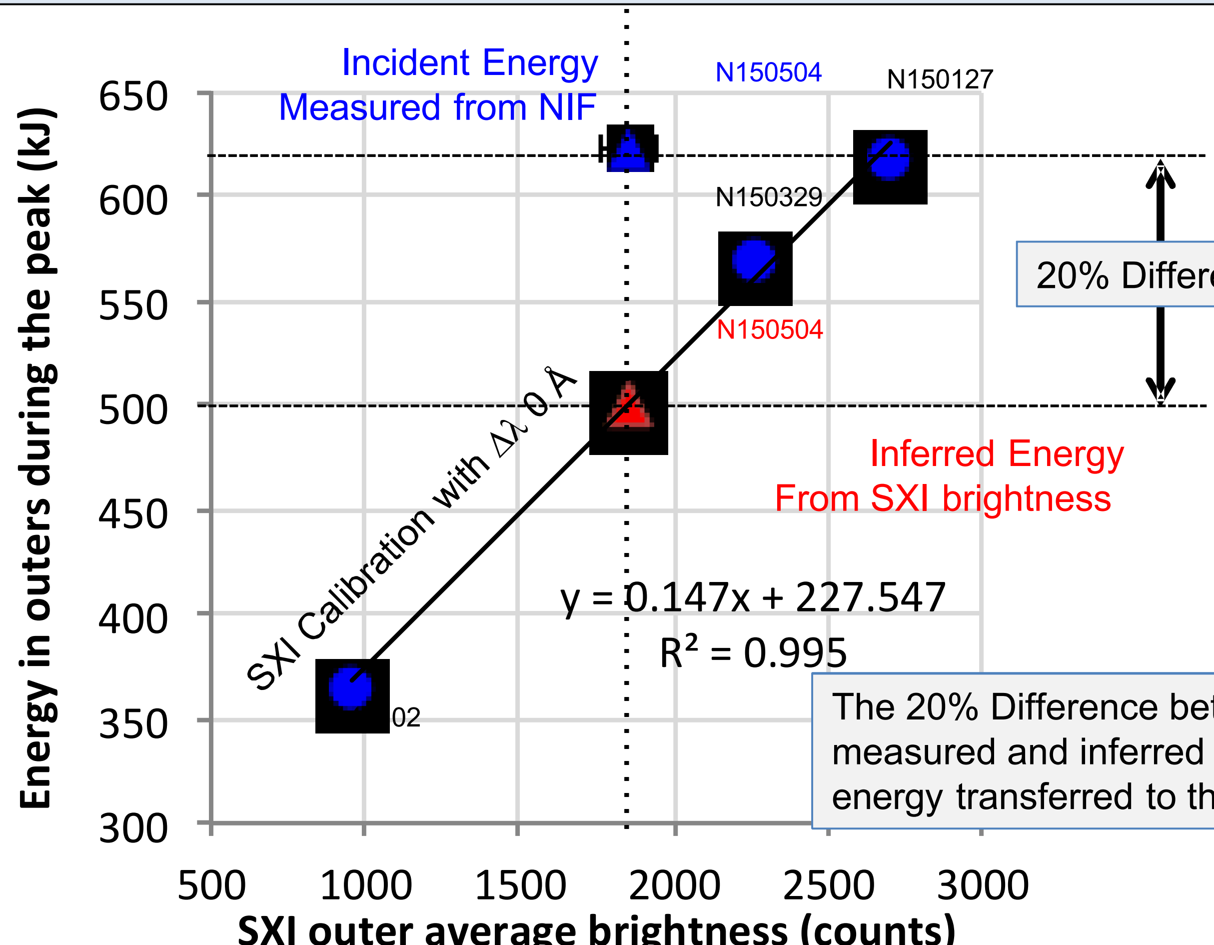
Refraction is not taken into Account in this physical picture, but could be significant in Rugby Hohlraums

20% transfer from the outers to the inners was measured when $\Delta\lambda$ = 2 , 5 Å

Outer beam SXI brightness scales with energy in peak allowing absolute calibration of the outer beam energy on the hohlraum wall





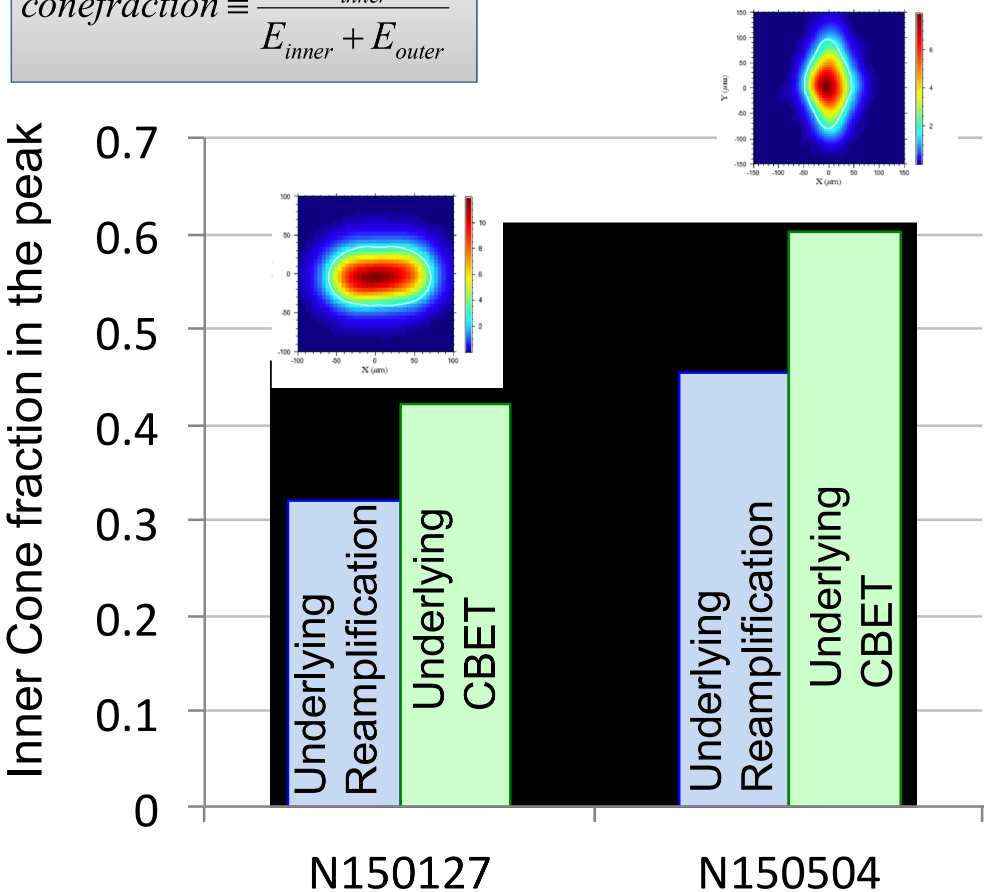


The 20% Difference between measured and inferred is the energy transferred to the inners

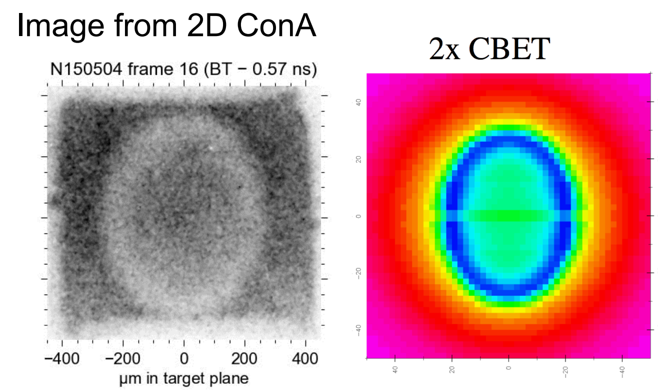
SRS measurements would indicate 21% transfer to the inners

Simultion results are more consistent with underlying CBET then reamp.

$$conefraction \equiv \frac{E_{inner}}{E_{inner} + E_{outer}}$$



Simulation Results* Indicate 2x more CBET then anticipated is needed to match the shape.



Right shows shape after +160% energy transfer to the 30 deg. SRS results indicate either +108% increase with with no pre CBET or +178% increase with underlying CBET.

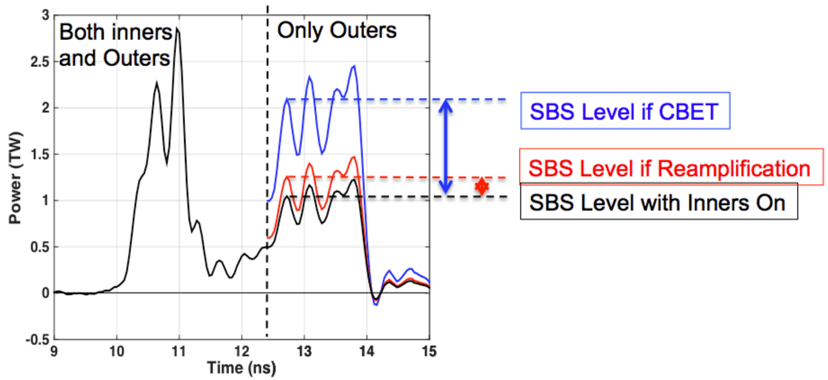
*Simulations courtesy of J. P. Leidinger CEA, France

How do we know whether we have underlying CBET or Reamp?

Experimental options:

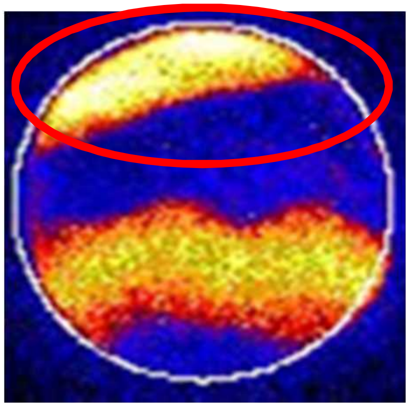
1. Using a keyhole target, we could try to exploit the difference in energy from the outers by turning off the inners early in time
   - The observable would be the difference in outer SBS when the inners turn off

Expected Outer SBS Data



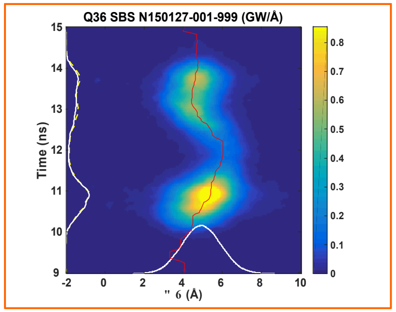
2. Using a quartraum or halfraum with a high-z witness plate to measure the the difference in inner cone power when the outers turn off
   - If the SRS is mainly reamp, the power difference will be marginal when the outers turn off
   - If the SRS increase is due to increase power from CBET

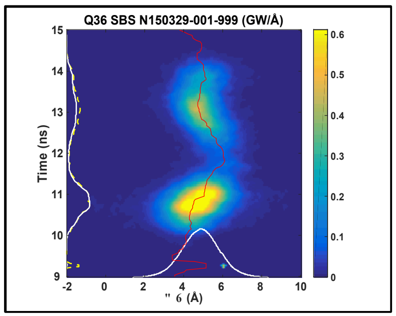
Witness Plate will look at Inner beams

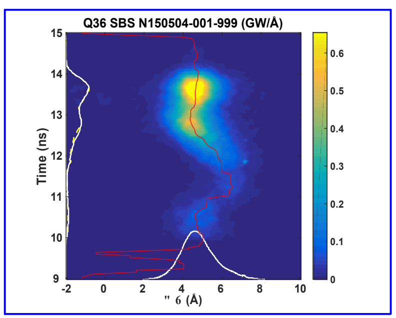


Backup

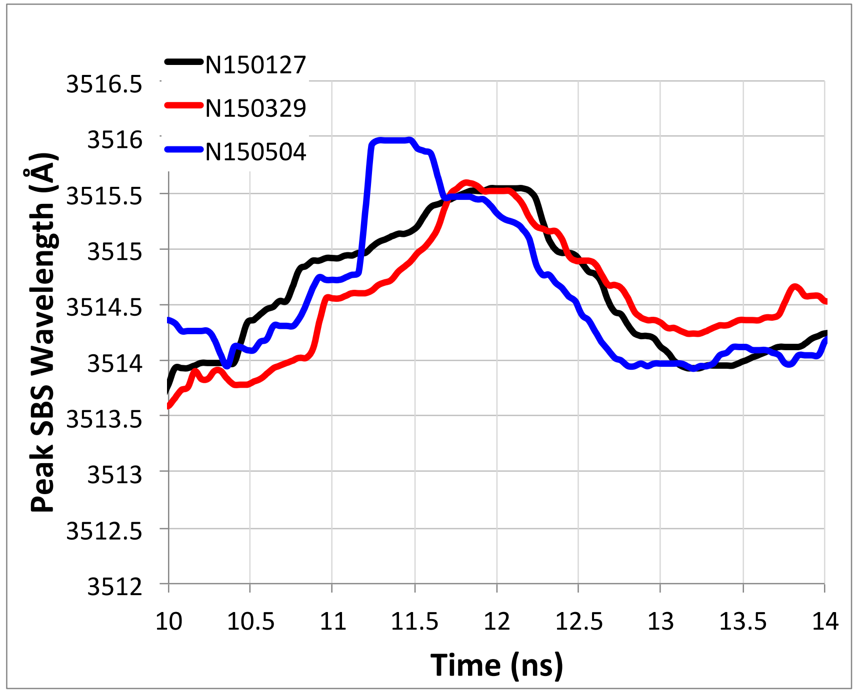
The 50 deg. cone SBS streak spectra show differences in power but similar wavelength vs. time





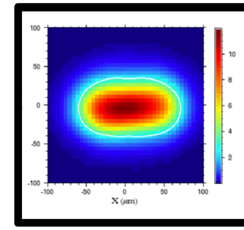


50 deg, SBS centroid power vs. time shows the extent of the similarity in wavelength between the 3 experiments

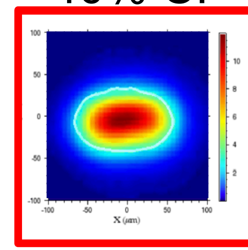


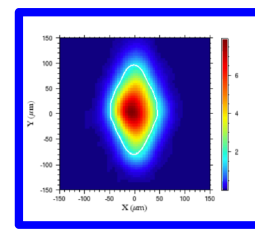
SBS spectral measurements are consistent with similar 50 deg. plasma conditions and flows

33% CF



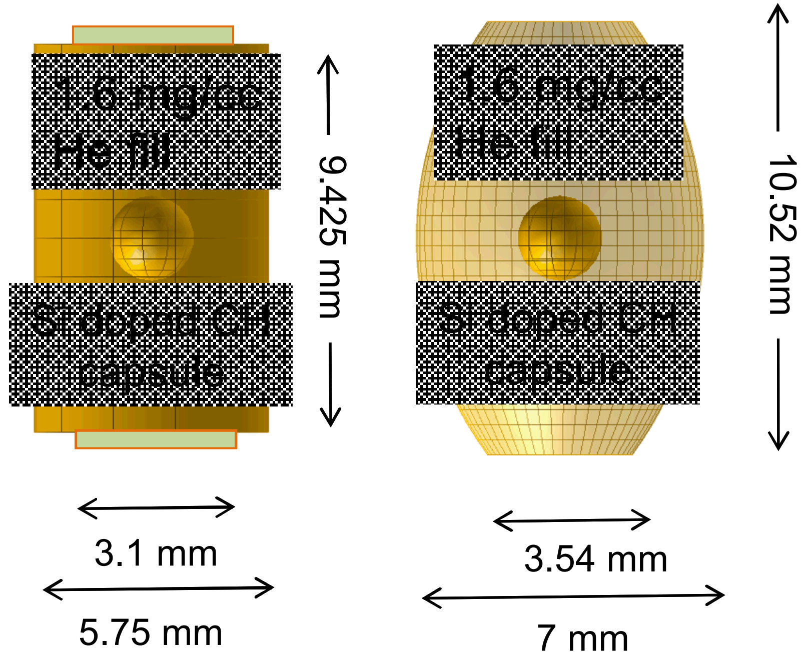
40% CF





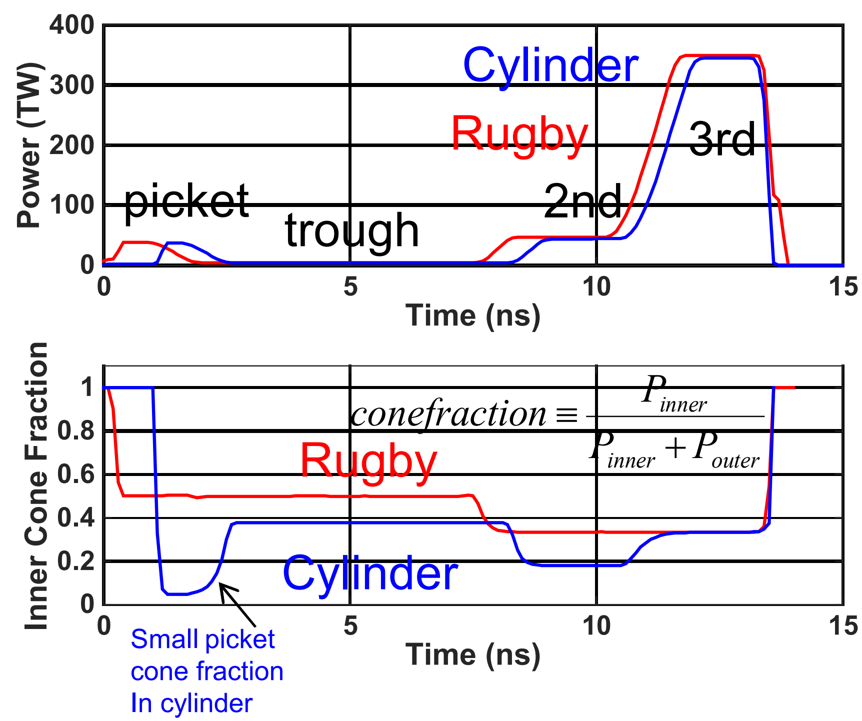
The Rugby experiments are based on the high foot design using 575 hohlraums but without deliberate energy transfer

The rugby uses the same gas fill and CH capsule as the cylinder



The rugby uses a 60/40 AuB layer on the wall to mitigate Brillouin backscatter

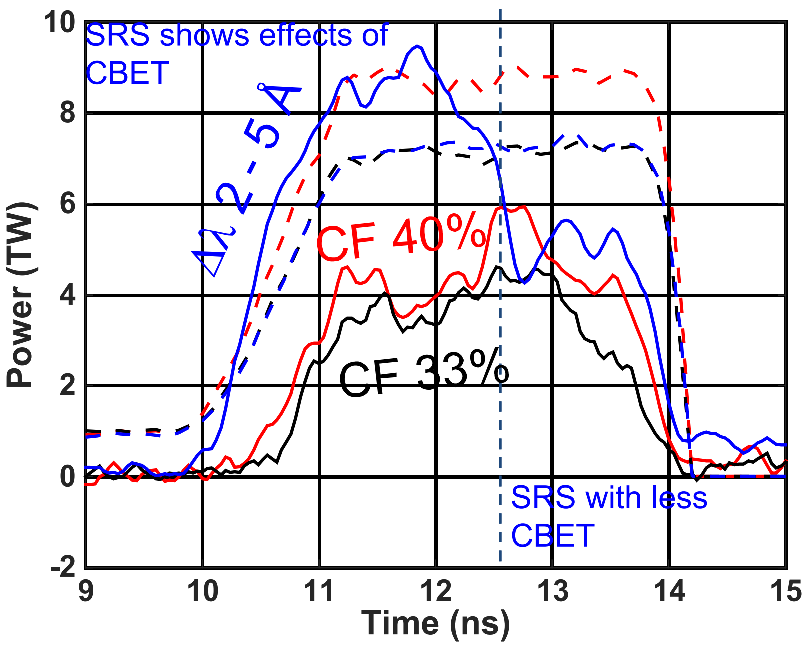
The high foot CH pulse in the CH compensates for CBET with changes in cone fraction in the picket and trough



The cylinder require very low cone fractions in the picket because CBET is stronger in the picket then in the peak

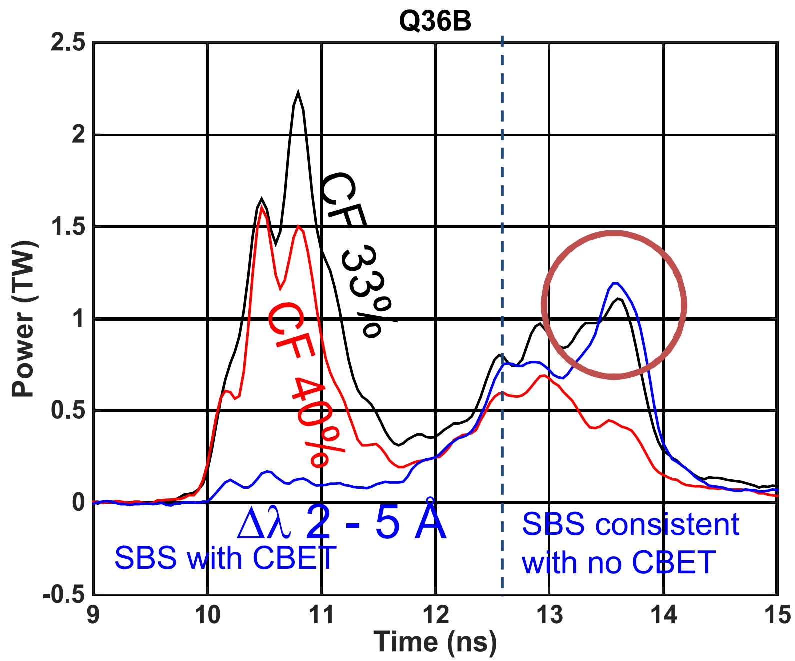
The 3-color Δλ on N150405 was designed to transfer energy to the 30 deg. beams from the outers and 23s

The blue curves provide the 30 deg. SRS levels for a cone fraction of 33% and Δλ = 2 - 5 Å



The SRS power level is more than 2x higher early in the peak and drops down to the level slightly higher then the 40% inner cone fraction later

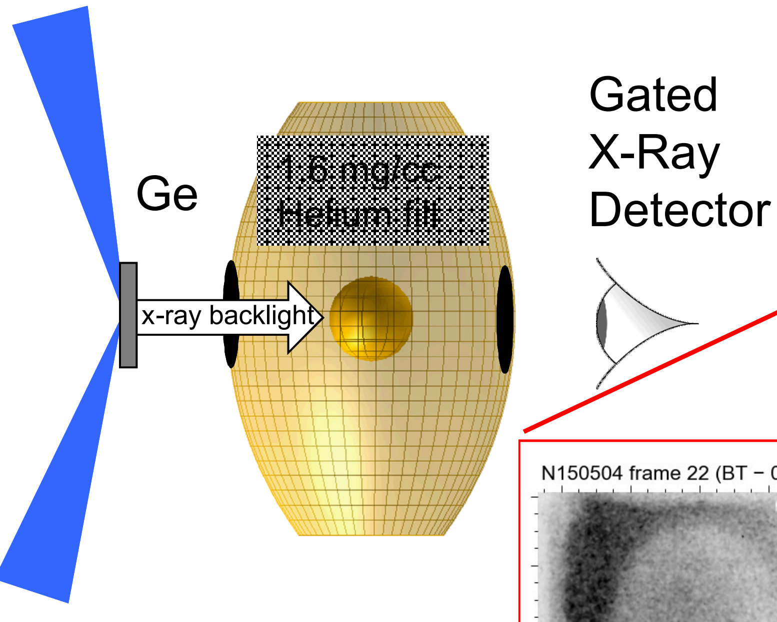
The blue curve provide the 50 deg. SBS levels for a cone fraction of 33% and Δλ = 2 - 5 Å

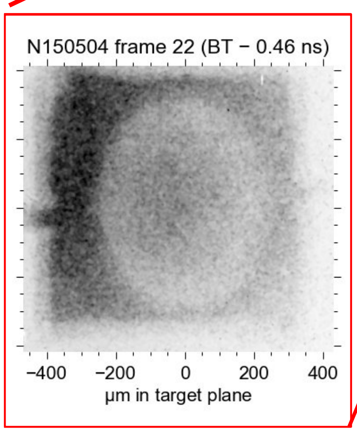


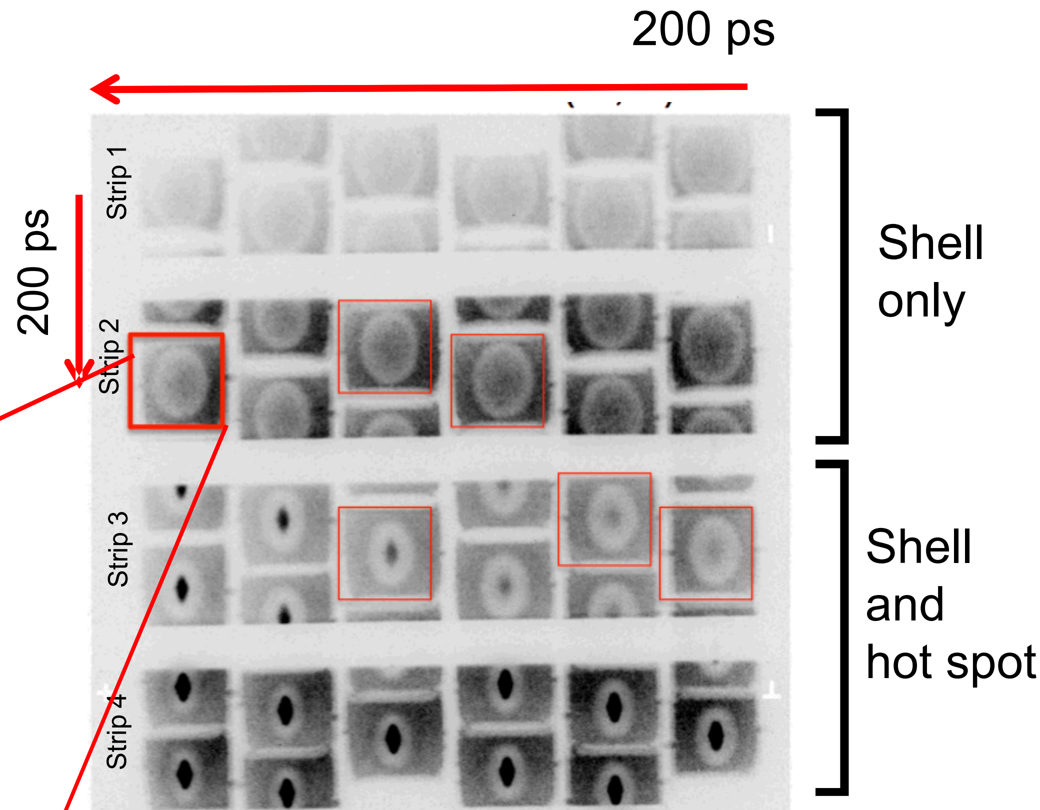
The 50 deg. SBS power is ~16x lower early in the peak with CBET and rises to the level of the SBS very near that of 0 – 0 Δλ by the end of the pulse

Excellent 2D Convergent Ablator data was collected providing in-flight and hot spot P2 data

Germanium x-ray backlighter was used to measure in-flight shape



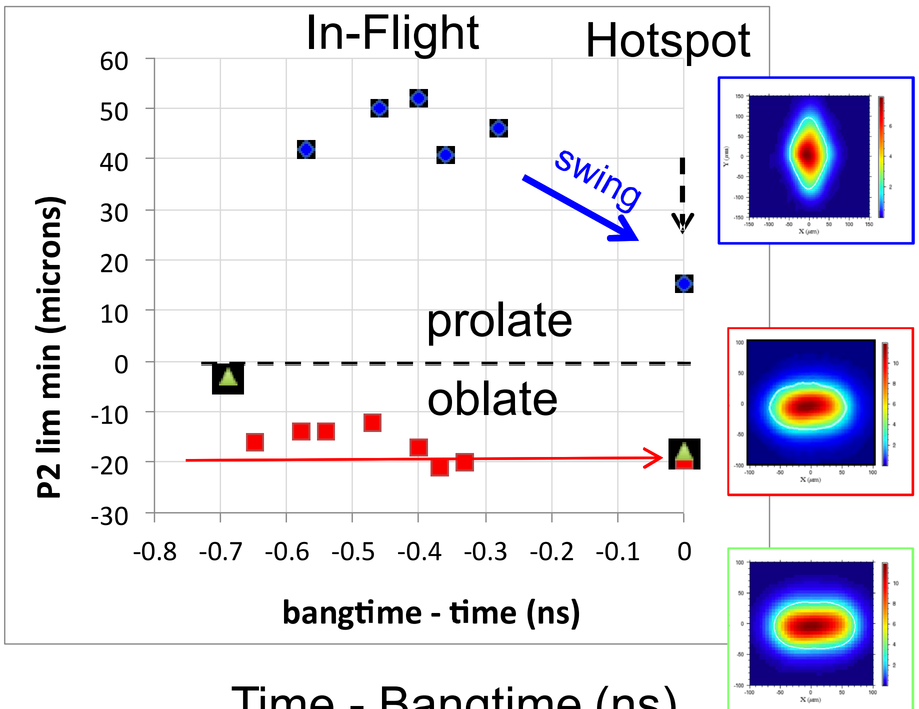




The in-flight P0 converges to hotspot P0 at a velocity of 326±20 km/s

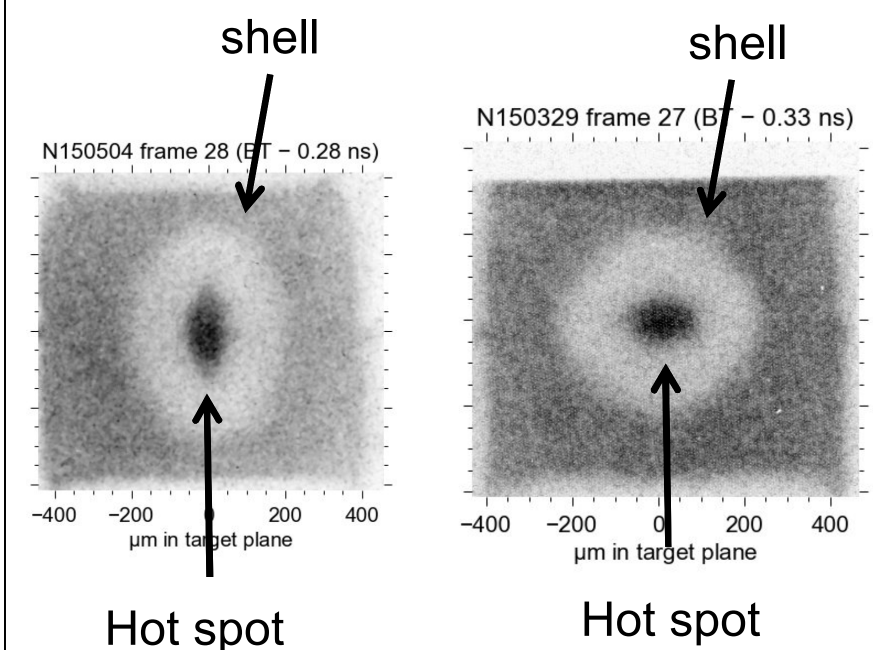
The In-Flight sign of P2 shape is consistent with the sign of the Hot Spot P2 Shape on all 3 shots

The P2 shape of the shot with Δλ of 2/5 Å has the largest shape swing



The P2 is **non-evolving** when changing the cone fraction in the peak at Δλ 0/0 Å

The hotspot and shell are conformal in rugby experiments to date.



Radiography Analysis: Rygg   Hot Spot Analysis: Khan

The measured x-ray bang time for all 3 ConAs was within 50 ps of 16 ns.

The early part of the pulse can model equally with CBET ot Reamp

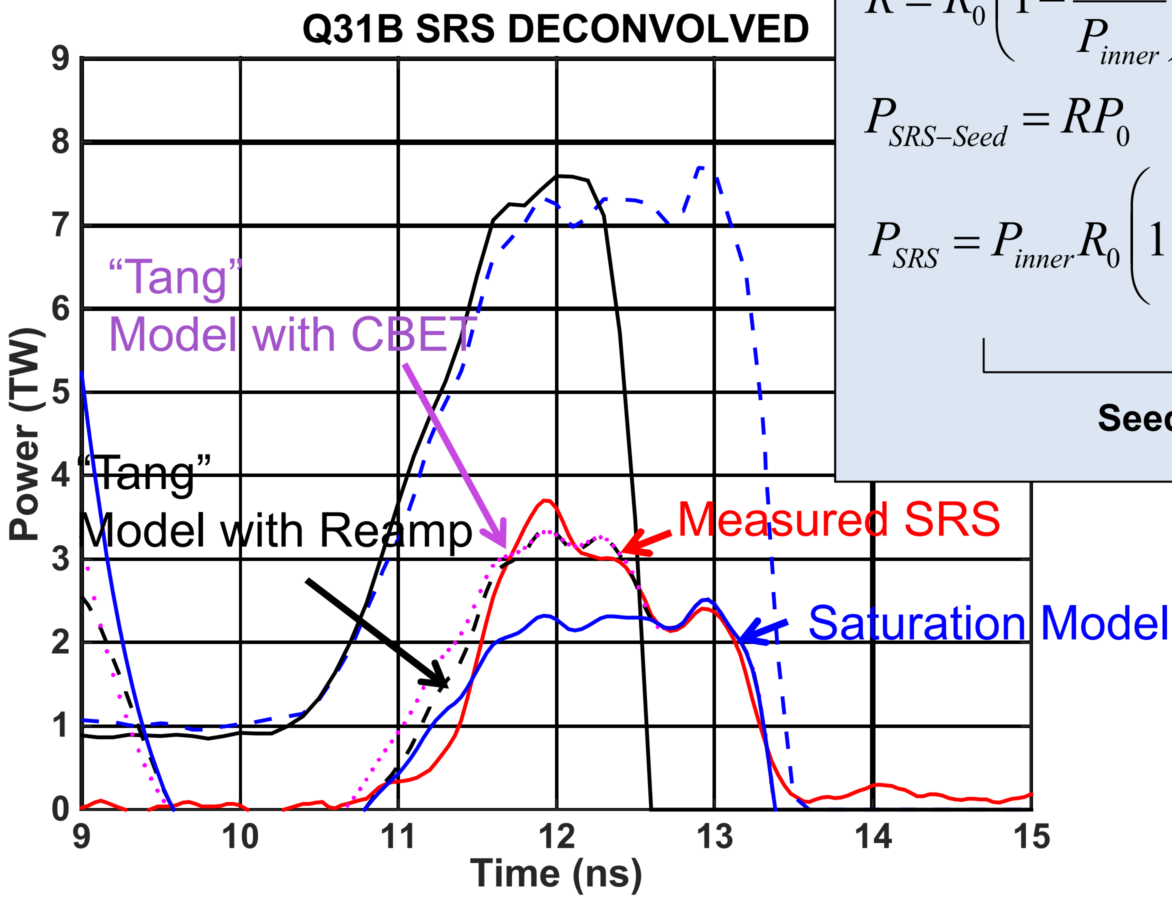
$$P_0 = P_{inner}$$

$$R = R_0\left(1 - \frac{P_{thr}}{P_{inner}}\right)$$

$$P_{SRS-Seed} = RP_0$$

$$P_{SRS} = P_{inner}R_0\left(1 - \frac{P_{thr}}{P_{inner}}\right)e^{GP_{out}}$$

Seed | **Amplification from Outers**



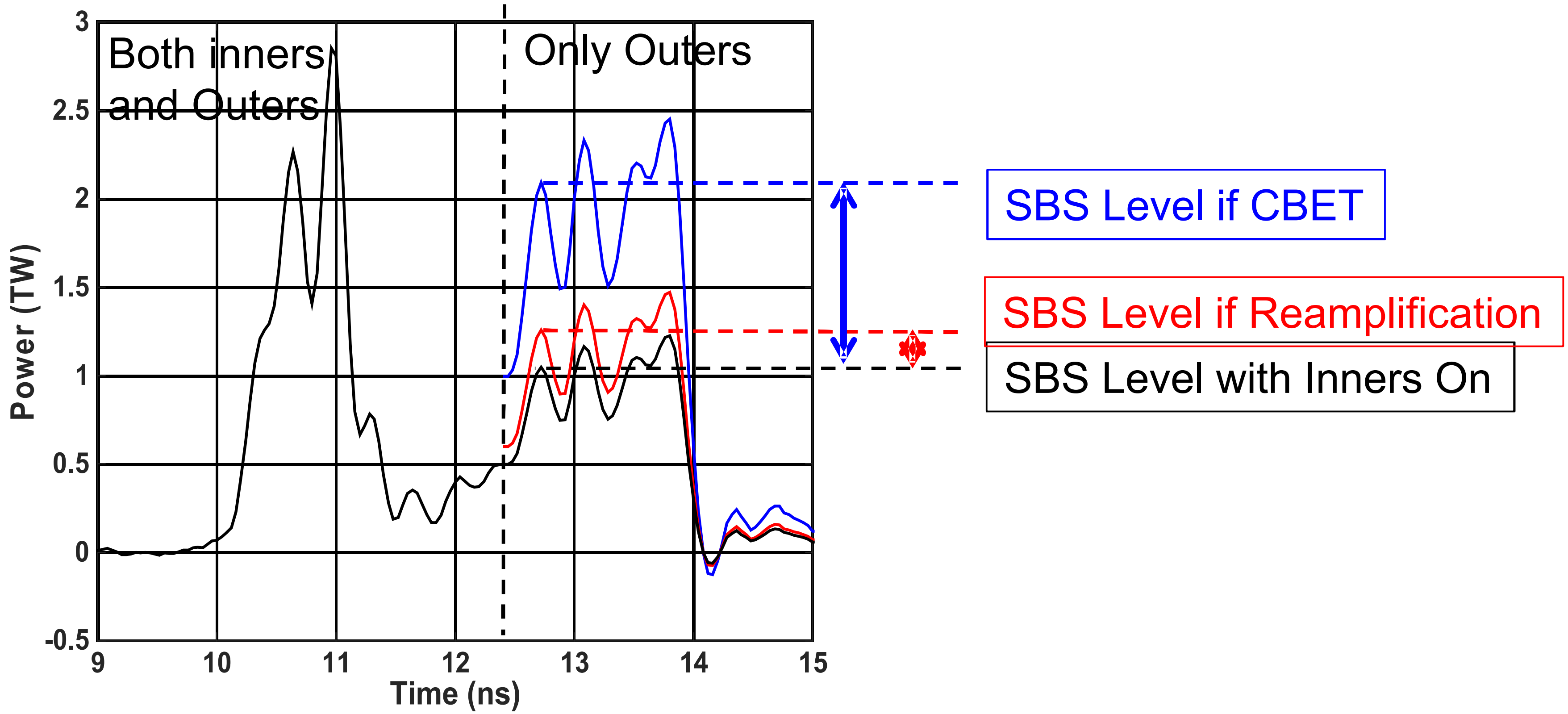
R_0 = .4607
P_{thr} = 2.3151
G = 0.049
T = 0.26

If Results from the First Experiment indicate a combination of CBET and Reamp, We need a Follow-up experiment

Follow up Experiment:

1. Use a delta lambda to counteract the CBET, and repeat the previous experiment
   1. Ideal case: CBET is perfectly counteracted turning off the outers leads to no change in transmitted beam,
      1. a decrease in inner SRS would indicate the level of reamp
   2. Over compensated: turning off the outers leads to an increase in inner power
      1. If the SRS goes down, this indicates reamp
      2. If the SRS goes up, see if it differs from the established "Tang" curve, the difference will be the difference in SRS from inners only and
      3. If the SRS does not change, this would indicate the SRS increase from reamp while the outers were on (but the inner power was lower from CBET) is at the same level as the normal SRS from the "Tang" model
   3. Under compensated: turning off the outers leads to a decrease in inner power, we still have some CBET
      1. We will have 2 powers with the outers on, this should allow for a "Tang" with outers on

How do we know whether we have CBET or Reamp?



The difference in Level SBS between CBET and Reamplification will be large compared to both inners and outer on

High Foot Rugby Experiments Summary

1. Outstanding shock symmetry with $\Delta\lambda$ = 0-0 through 1-2-3 merger

1. Hot spot P2 is consistent with in-flight P2 (implosion is well-behaved)

2. The final inner beam positions on the wall at peak power are at the equator

3. Changes in cone fraction from 33% to 40% do not effect oblate in-flight or -35% P2 hot spot shape and result in measurable but minor changes to backscattered power

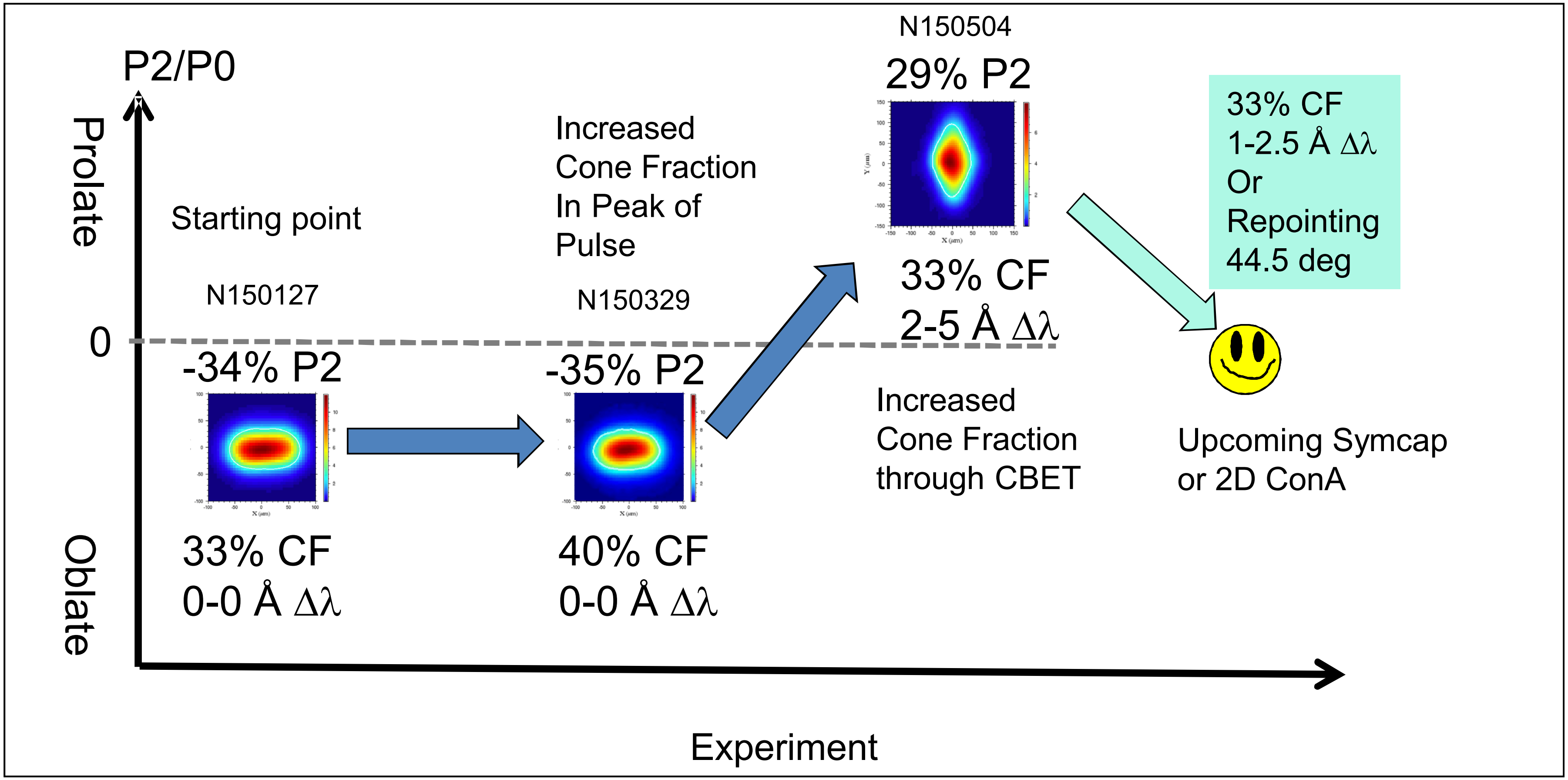
4. Using 3 color (λ_{23} □ λ_{outer} = 2 Å, λ_{30} □ λ_{outer} = 5 Å) successfully transfers energy to the 30 deg. cone resulting in a prolate implosion (suggesting that it may be possible to make a round implosion)

5. Backscatter suggests that CBET from $\Delta\lambda$ tune may be diminishing throughout the pulse

6. Hohlraum x-ray drive and x-ray bang time are consistent for shots with same laser peak power and energy

7. Observed symmetry changes toward round in keyhole experiments due to $\Delta\lambda$ (λ_{23} □ λ_{outer} = 1 Å, λ_{30} □ λ_{outer} = 2.5 Å) and repointing of the 44.5 degree beams 200 μm

Rugby Shape Tuning Campaign Indicates that a round shape may be possible with Energy Transfer



A shape change was possible to prolate only after increasing the inner cone fraction through crossed beam transfer preferably to the 30 degree beams.

Proposed Next Rugby Keyhole Experiment would Truncate Inners by 400 ps to determine whether the high SRS is from reamplification or from amplified inner beams from CBET

If we are seeing Reamp Outers amplify only SRS ~ 0.3 Inner Power

80% SRS is from outers from experiment

$$P^1_{OUT} = P_{OUT} - 0.8(P_{SRS} + P_{hot})$$

Assuming 30% SRS Inner Reflectivity

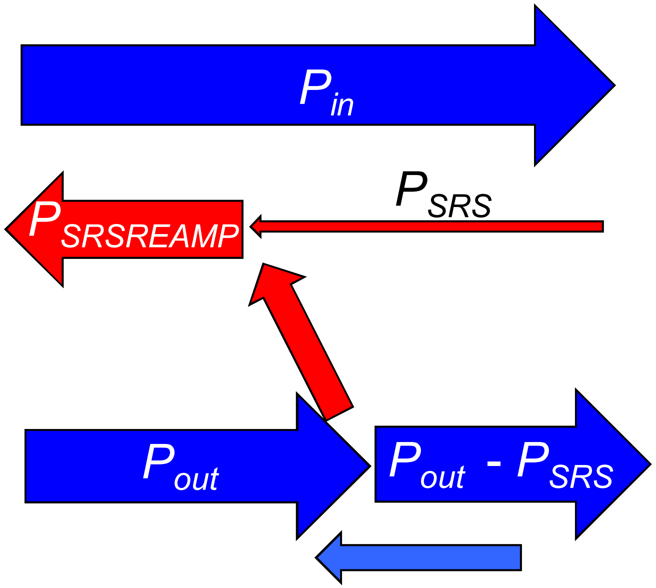
$$P_{SRS} = 30\% P_{IN} = 15\% P_{OUT}$$

After Inner SRS Reamplification

$$P^1_{OUT} \approx 0.85 P_{OUT}$$

After Inner Beams turn off

$$P^1_{OUT} = P_{OUT}$$



$P_{SBS} = R_{SBS}\ (P_{out} - P_{SRS})$

Outer SBS Power will increase by greater than ~18% after Inners turn off. Much less than 2X

$P_{SRSREAMP} = 0.5*0.8*P_{IN}$

$P_{SRSREAMP}=40\% P_{in}=0.5*40\% P_{out}$

$P_{SBS} = R_{SBS}\ (80\% P_{out})$

Proposed Next Rugby Keyhole Experiment would Truncate Inners by 400 ps to determine whether the high SRS is from reamplification or from amplified inner beams from CBET

If we are seeing CBET, Outers will be significantly depleted from transfer to inner cone

$$P_{IN}^{1} = P_{IN}(1+T) \qquad P_{OUT} = 2P_{IN}$$

$$P_{OUT}^{1} = P_{OUT}(1-\frac{T}{2})$$

Worst case: T = 2

$$P_{IN}^{1} = 3P_{IN}$$

$$P_{OUT}^{1} = 0$$

Transfer all
**Not Physical*

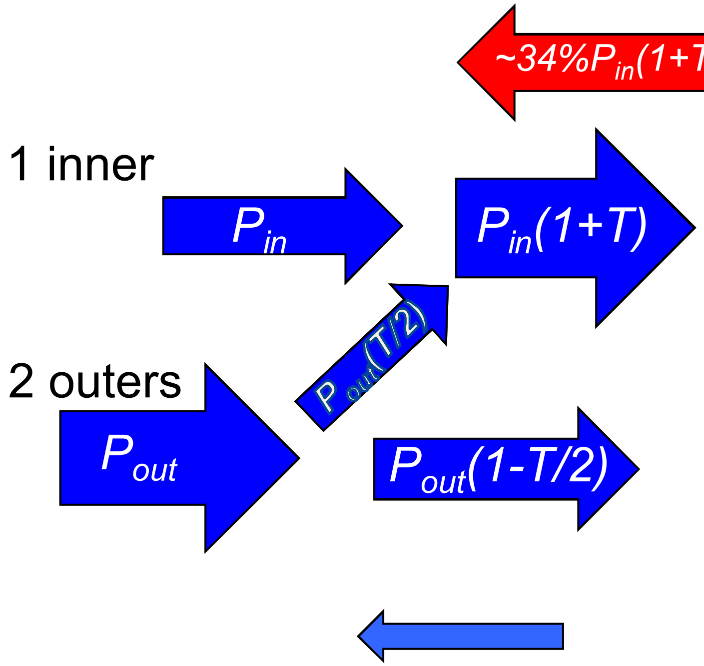
Power of outer SBS in not 0.
Therefore, $P'_{out} \neq 0$
For CBET, If T = 1

$$P_{OUT}^{1} = \frac{1}{2}P_{OUT}$$

CF = 67% Post Transfer

$$P_{IN}^{1} = 2P_{IN}$$

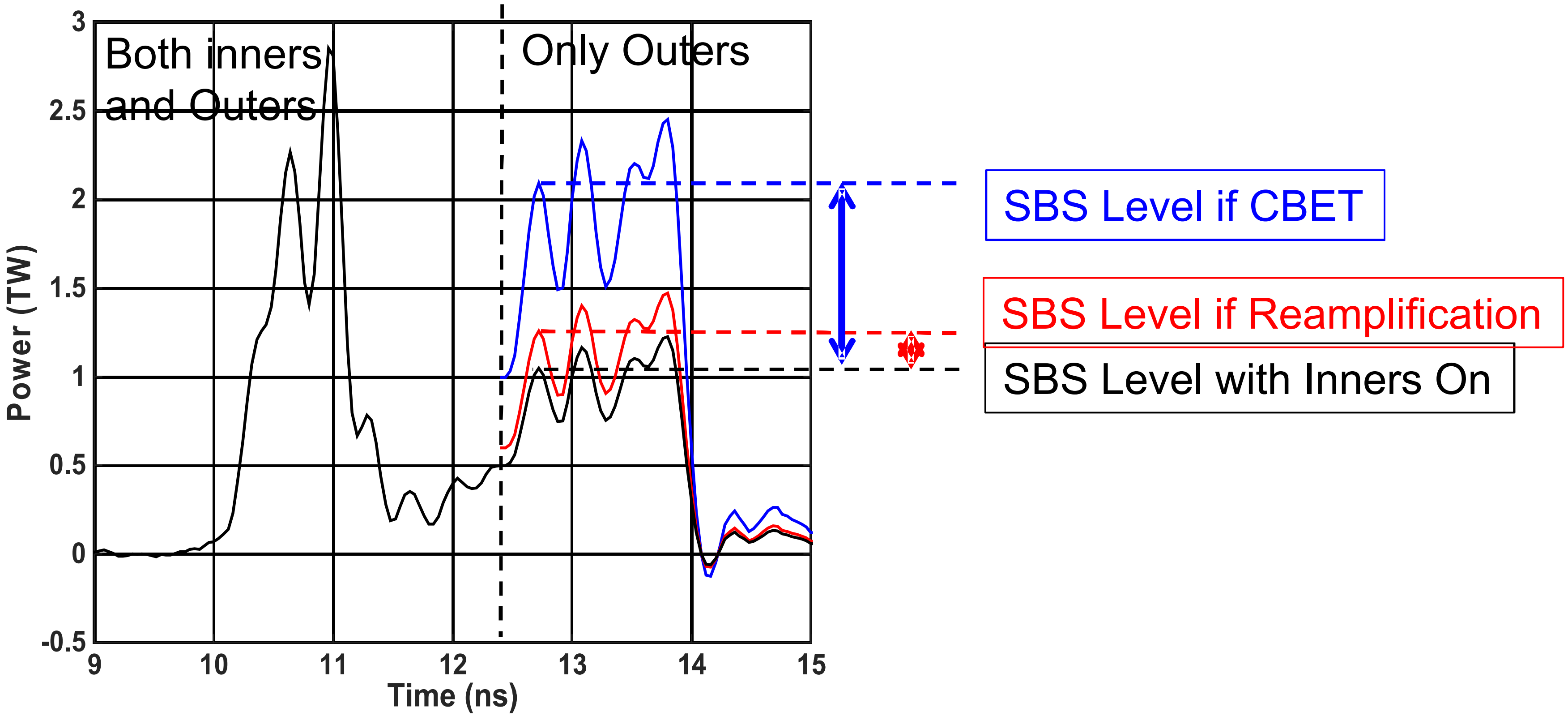
Truncating the Inner will Result in a 2x Increase the Outers



$$P_{SBS} = R_{SBS}\, P_{OUT} * (1-T/2)$$
$$P_{SBS} > R_{SBS}\, P_{OUT} * (1/2)$$

-> at least 2x increase in Outer SBS

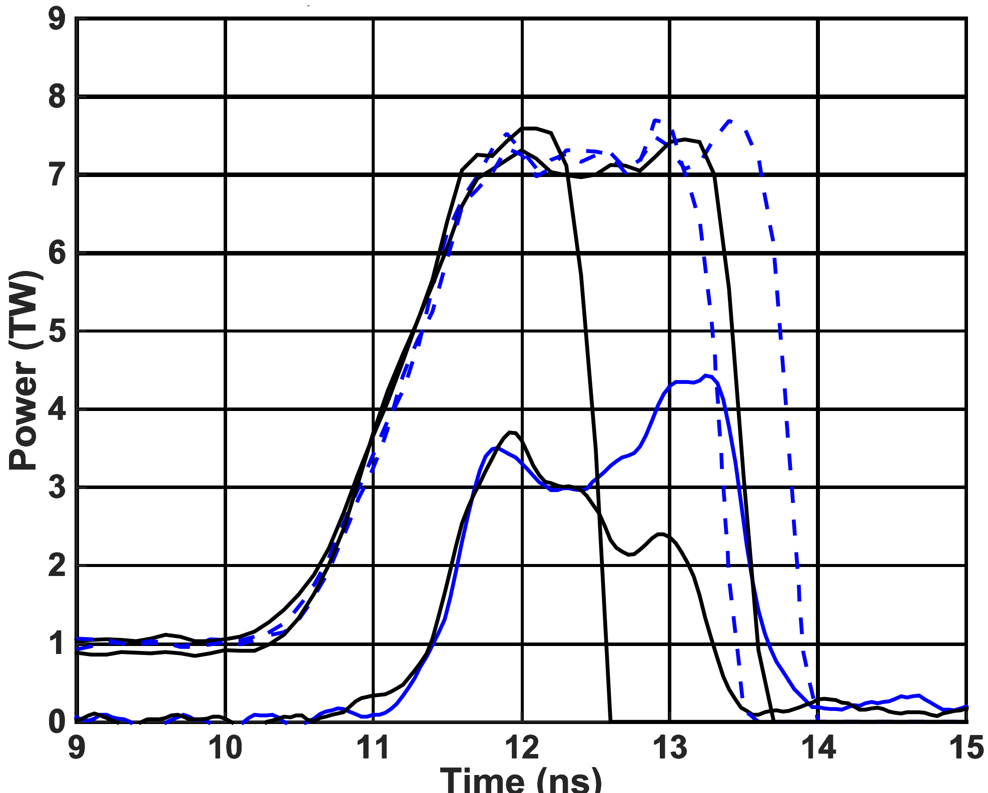
Proposed Next Rugby Keyhole Experiment would Truncate Inners by 400 ps to determine whether the high SRS is from reamplification or from amplified inner beams from CBET



The difference in Level SBS between CBET and Reamplification will be large compared to both inners and outer on

The effect of reamp or CBET can be determined now at 2 different times *at least!*

These 2 shots are enough to provide a no CBET/Reamp saturation model.
an early and a late time model using either CBET or reamp.



The AM ripples and inner falloff provide power data to fit to the model

SRS Reflectivity Saturation Model

$$R = R_0\left(1 - \frac{P_{thr}}{P_0}\right)$$

R_0: Max reflectivity

P_{thr}: threshold power

P_0: Inner Power Level

$$P_{SRS} = RP_0$$

$$P_0 = \frac{P_{SRS}}{R_0} + P_{thr}$$

High Foot Rugby Campaign Experiments Overview

Shock Timing
0.75 MJ N140822

First High Foot Rugby Experiment Produced the most symmetric shocks measured on a NIF ignition hohlraum

Shock Timing
1.1 MJ N141102

2nd Shock tuning High Foot Rugby Experiment Continued to refine the shock timing while extending the pulse length and included a "ride along" to look at CBET

Early Time Shape
0.04 MJ

Results of Rugby Reemit experiment were a measured early time P2/P0 of 5.6 %

Peak Shape
1.4 MJ N150127

First 2D ConA High Foot Rugby experiment produced an oblate implosion at a cone fraction of 33% P2/P0 -> -34%

Shape
1.4 MJ N150329

2nd 2D ConA High Foot Rugby experiment produced an oblate implosion at a cone fraction of 40% P2/P0 -> -35%

Shape
1.4 MJ N150405

3rd 2D ConA High Foot Rugby experiment produced a prolate implosion at a cone fraction of 33% 2 - 5 $\Delta\lambda$ P2/P0 -> 29% λ_{23} □ λ_{outer} = 2 Å λ_{30} □ λ_{outer} = 5 Å

Shock Timing
1.1 MJ N150810

3rd shock timing shot with CBET showed early shocks at equator
λ_{23} □ λ_{outer} = 1 Å λ_{30} □ λ_{outer} = 2.5 Å

Shock Timing
0.75 MJ N150822

4th shock timing shot with changed 44.5 deg. cone pointing showed early shocks at equator

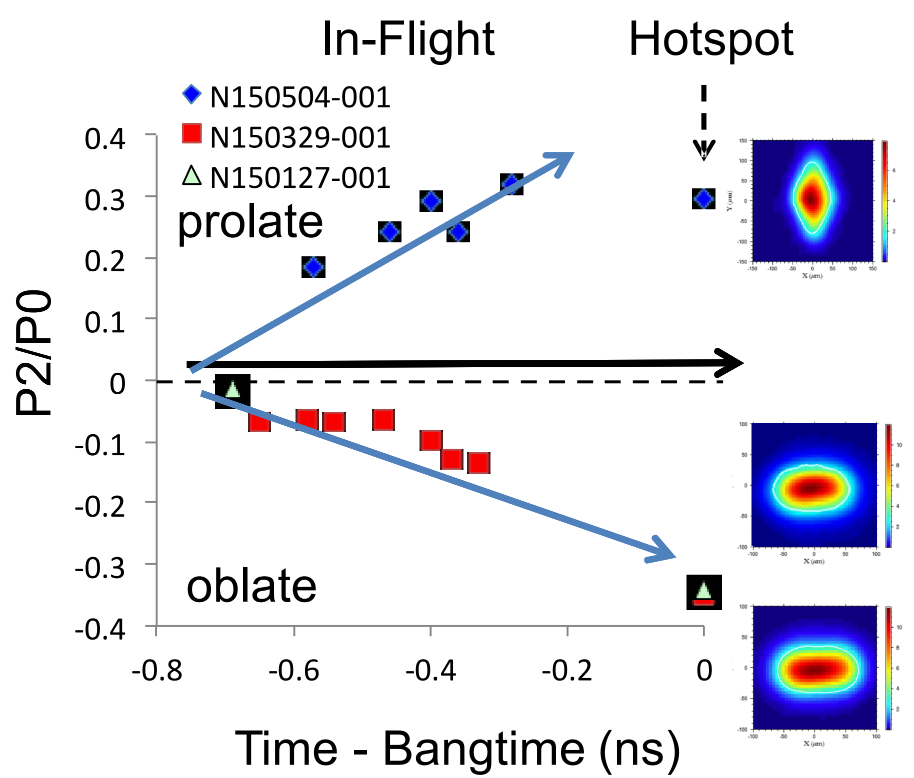
X-Ray Bangtime and DANTE were consistent throughout the 3 2DConA shots

	N150504	N150329	N150127
Changes	2-5 $\Delta\lambda$ (23^0s-30^0s)	0-0 $\Delta\lambda$ 40% CF	0-0 $\Delta\lambda$ 33% CF
Bangtime (ns)	15.95	16.05	15.95
Peak Trad (eV)	260.3	260	264
Flux (TW/sr)	11.8	11.6	11.2
FFLEX preheat (J)	367.9	334.8	109.1
FFLEX E1 (J)	4785.9	2803.6	4864.4
FFLEX T1 (keV)	18	18	18
FFLEX E2 (J)	557.3	502.5	152.3
FFLEX T2 (keV)	100.8	103.3	102.7

Preheat measured from FFLEX has been consistently about 4 to 5x lower then comparable high foot shots *This is consistent with SRS wavlength

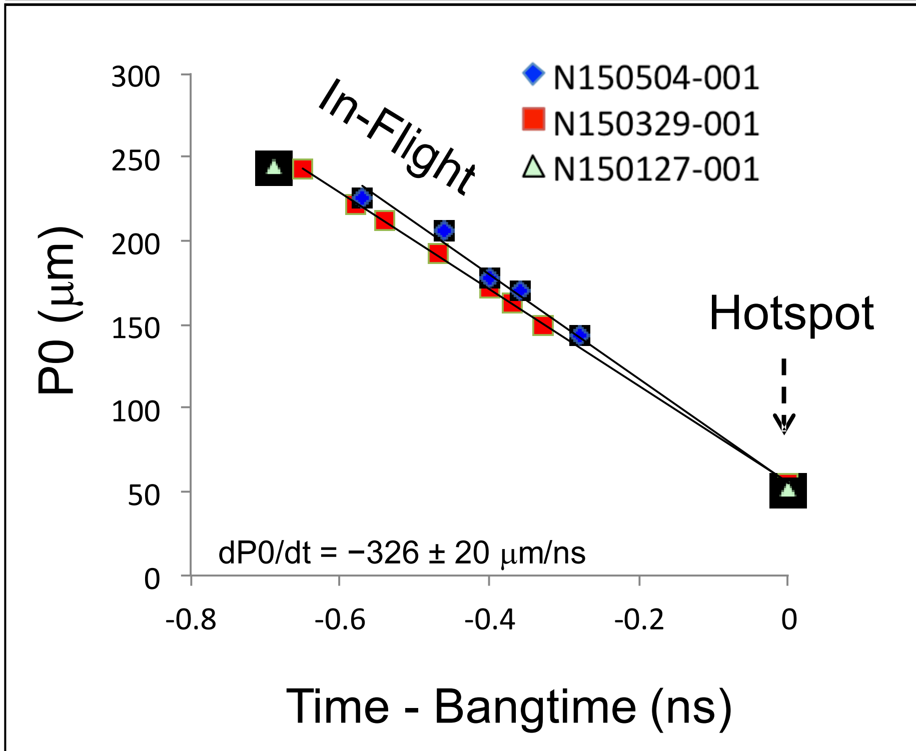
The In-Flight shape and Shell Velocity appear to be consistent with Hot Spot P2 Shape and P0 on all 3 shots

The in-flight P2 and hot spot P2
Trend toward there hot spot counterpart



These shape trajectories may indicate a **non-evolving** shape is possible near round

The in-flight P0 converges to hotspot P0 at a velocity of 326±20 km/s



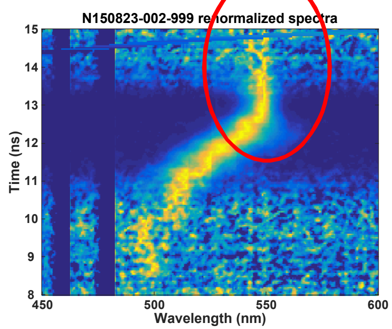
Radiography Analysis: Rygg Hot Spot Analysis: Khan

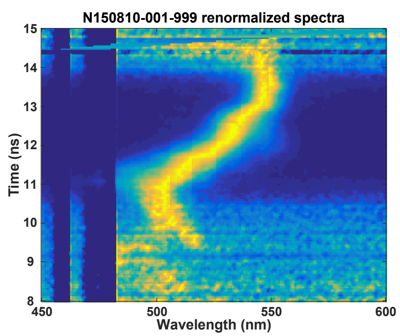
The measured bang time for all 3 ConAs was within 50 ps of 16 ns.

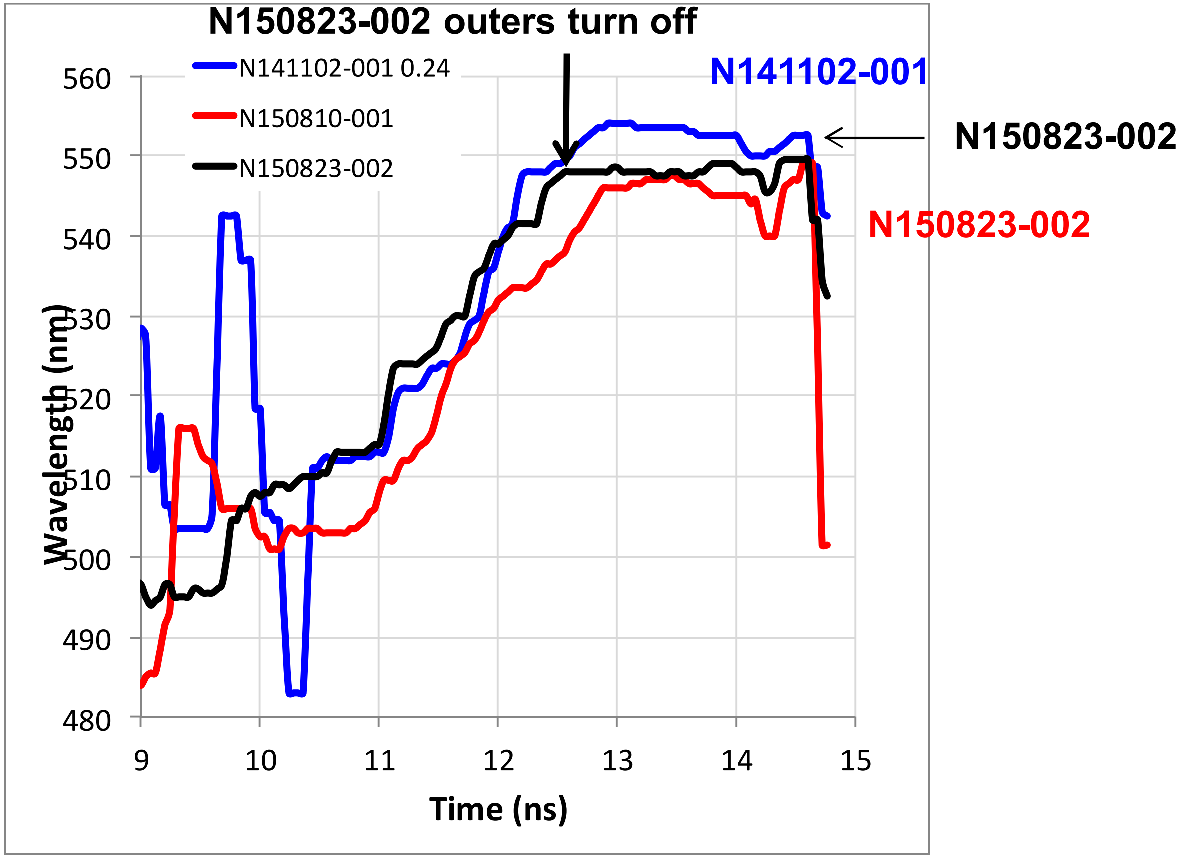
Spectrum Indicates stable plasma conditions after outers turn off for N150823-001

30 deg. SRS Peak Spectrum

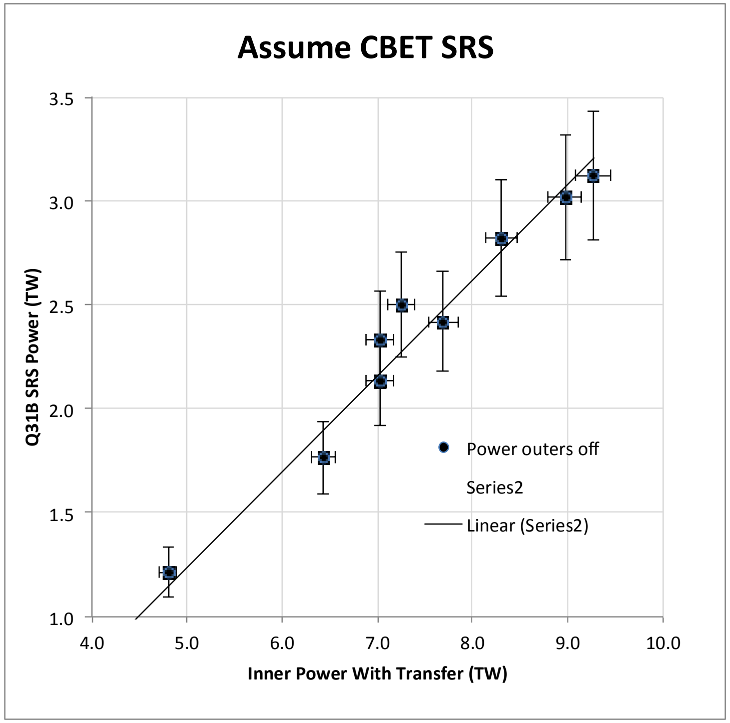
Normalized spectrum







Data from the AM ripples provide enough information to fit a "Tang" curve in the case of no outers



SRS CBET Model

$$P_{SRS} = (P_{inner} + TP_{outer})R_0\left(1 - \frac{P_{thr}}{P_{inner} + TP_{outer}}\right)$$

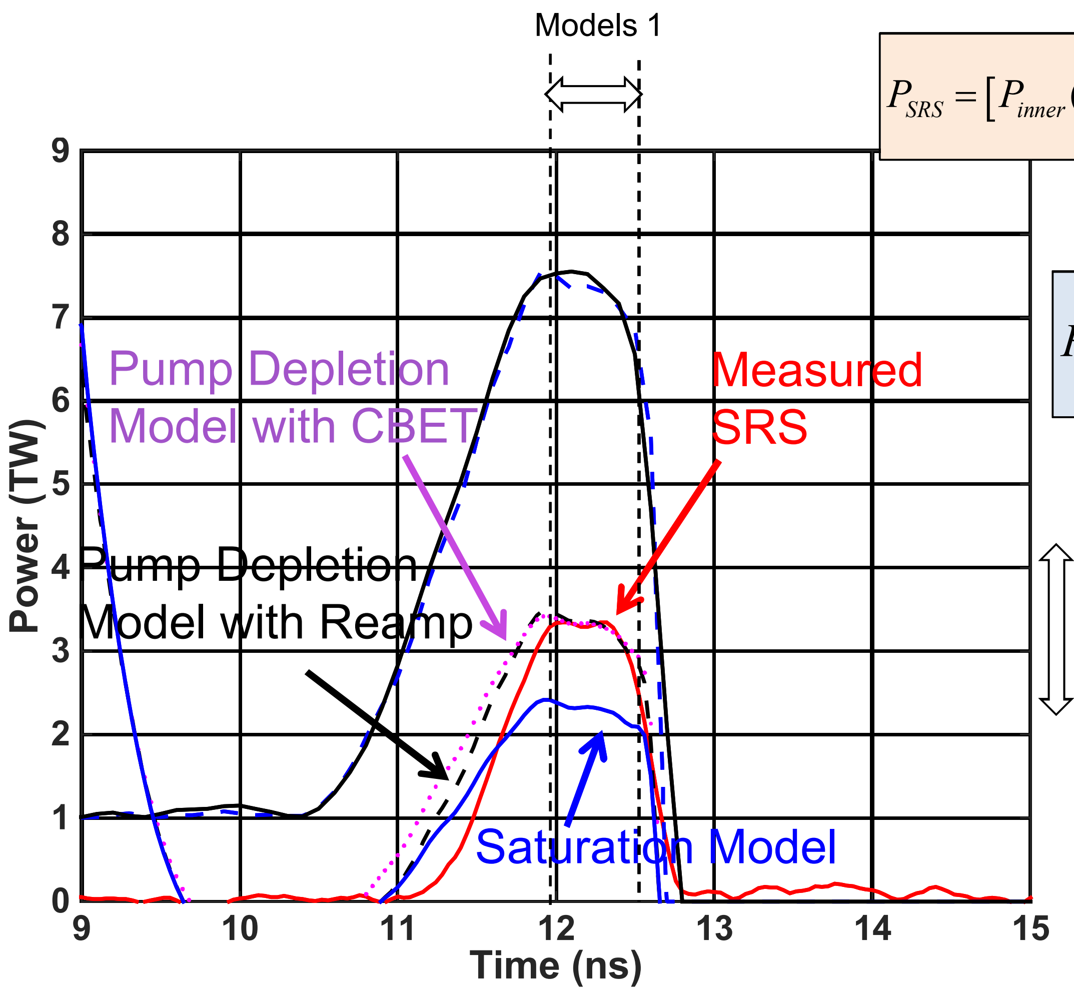
$$P_{SRS} = P_0 R_0 - P_{thr}$$

P_{thr}: threshold power

P_0: Inner Power Level

The points with outer on do not lie on the curve indicating CBET or Reamplification of SRS

The early part of the pulse can model equally with CBET ot Reamp



SRS CBET Model

$$P_{SRS} = [P_{inner}(1+TP_{outer})]R_0\left(1-\frac{P_{thr}}{P_{inner}(1+TP_{outer})}\right)$$

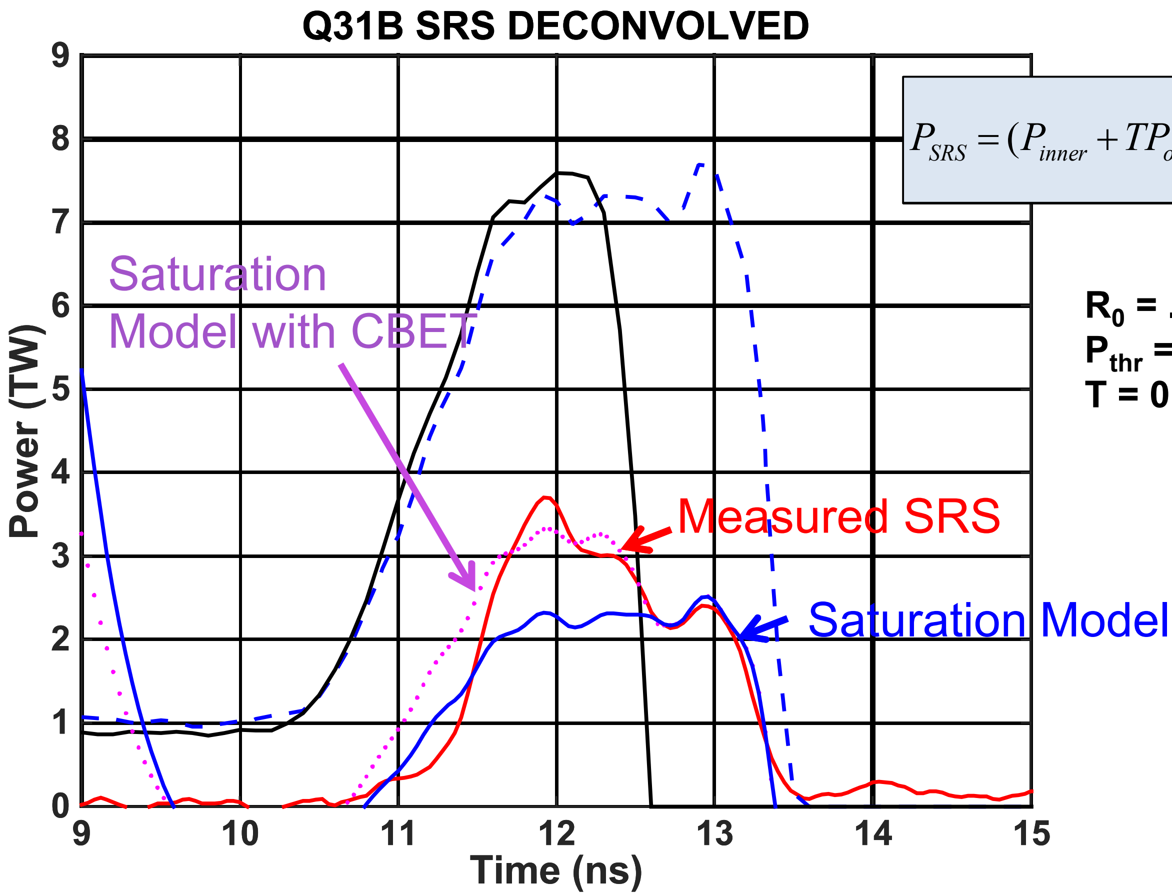
Reamp Model

$$P_{SRS} = P_{inner}R_0\left(1-\frac{P_{thr}}{P_{inner}}\right)e^{GP_{out}}$$

R_0 = .4607
P_{thr} = 2.3151

	Early peak		Late peak
G =	0.049	->	0.093
T =	0.29	->	0.65

Assuming CBET while the outers are on, we can find the transfer coefficient T

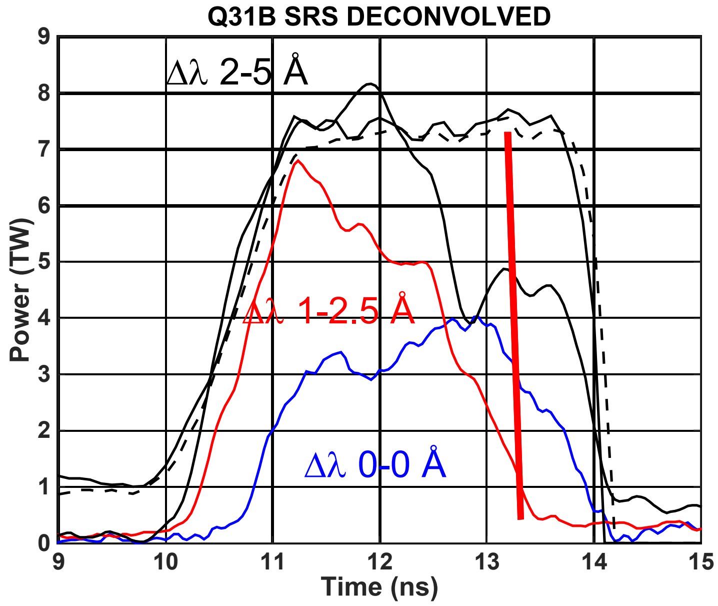


$$P_{SRS} = (P_{inner} + TP_{outer})R_0\left(1 - \frac{P_{thr}}{P_{inner} + TP_{outer}}\right)$$

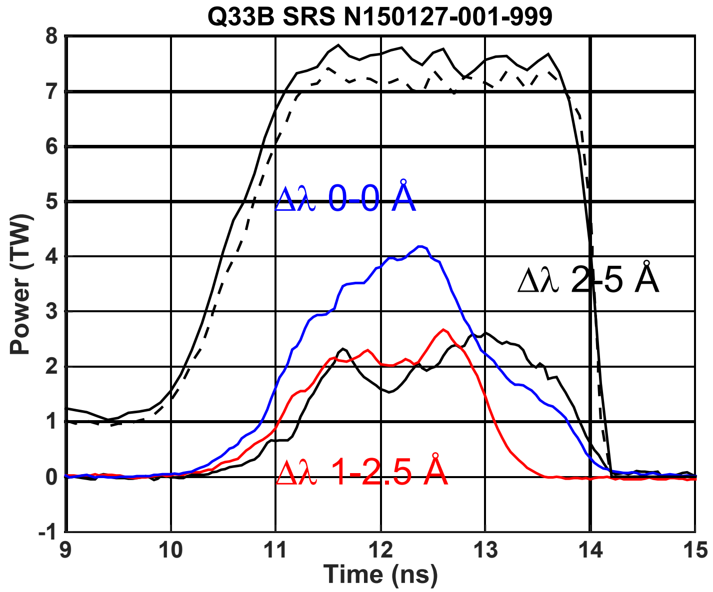
R_0 = .4607
P_{thr} = 2.3151
T = 0.26

SRS Rugbys

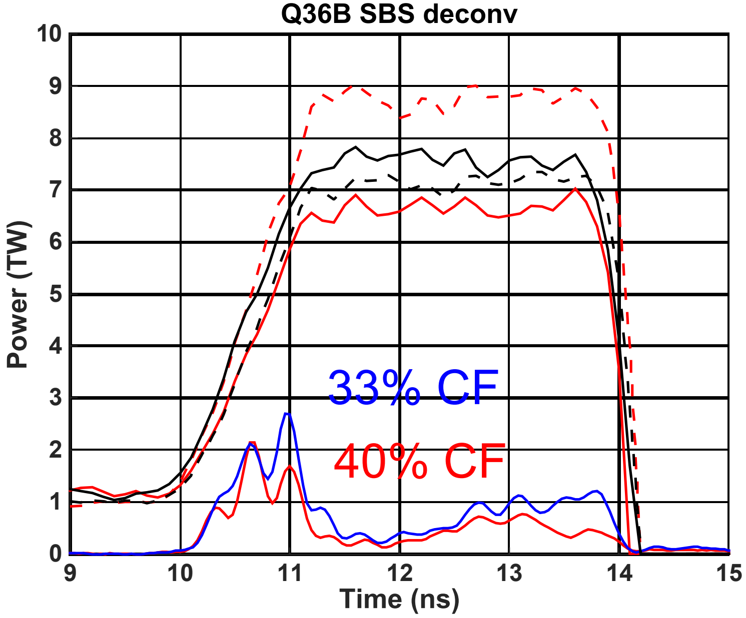
30 deg. SRS

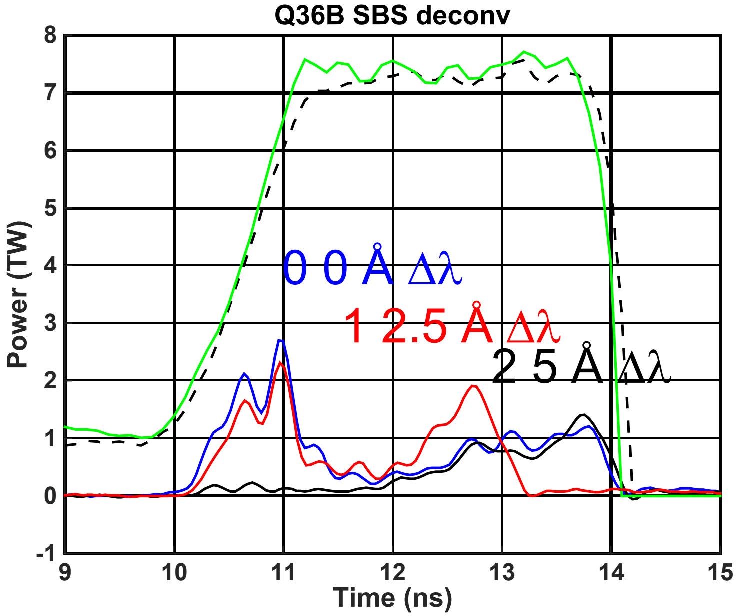


23 deg. SRS



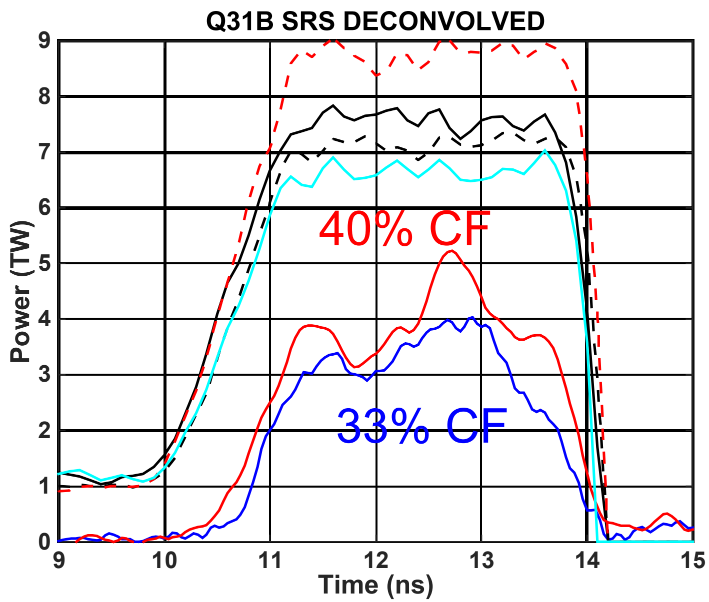
50 deg. SBS


Q36B SBS deconv
Power (TW)
Time (ns)
33% CF
40% CF

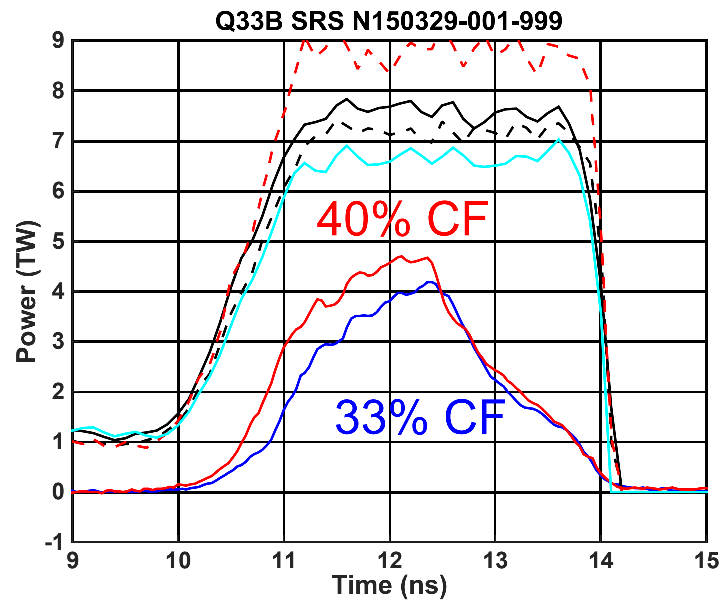

Q36B SBS deconv
Power (TW)
Time (ns)
0 0 Å Δλ
1 2.5 Å Δλ
2 5 Å Δλ

Inner SRS with Cone Fraction

30 deg. SRS



23 deg. SRS



The second of 2 Rugby designs has lower backscatter and improved shock symmetry

Delta-Lambda Tune Design

N150810-001

I_Hohl_Key_Rugby_DDD
$\Delta\lambda$ 1/ 2.5 Å

- High Inner SRS lead to low coupling with this $\Delta\lambda$
- Low coupling resulted in significantly lower hohlraum drive
- Asymmetric shocks may suggest a prolate implosion with this $\Delta\lambda$

Repointing 44 deg. Design

N150823-001

I_Hohl_Key_Rugby_EEE
Unsplit 44s and move them in by 200 um
$\Delta\lambda$ 0/ 0 Å

- Much lower inner SRS lead to higher overall laser coupling
- SBS was well below damage threshold
- Improved Shock Symmetry
- 44.5 deg beams were brighter in SXI

CONA

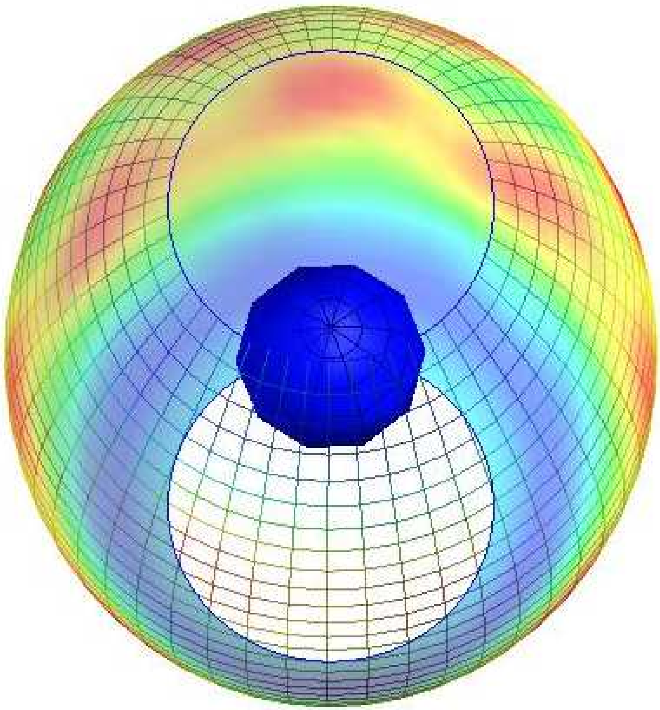
DT

SXI VIEW of Original Size Rugby Hohlraum Showing Beam Locations With no Wall Motion

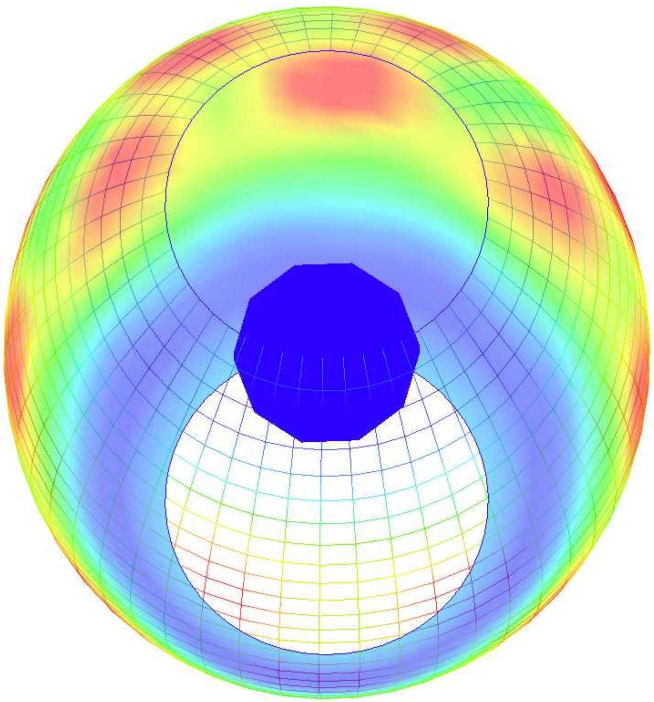
Full Sized Rugby
Length 10.515 mm
Equator Radius 3.54 mm
LEH Radius 1.77 mm

Visrad Models

Split 44s

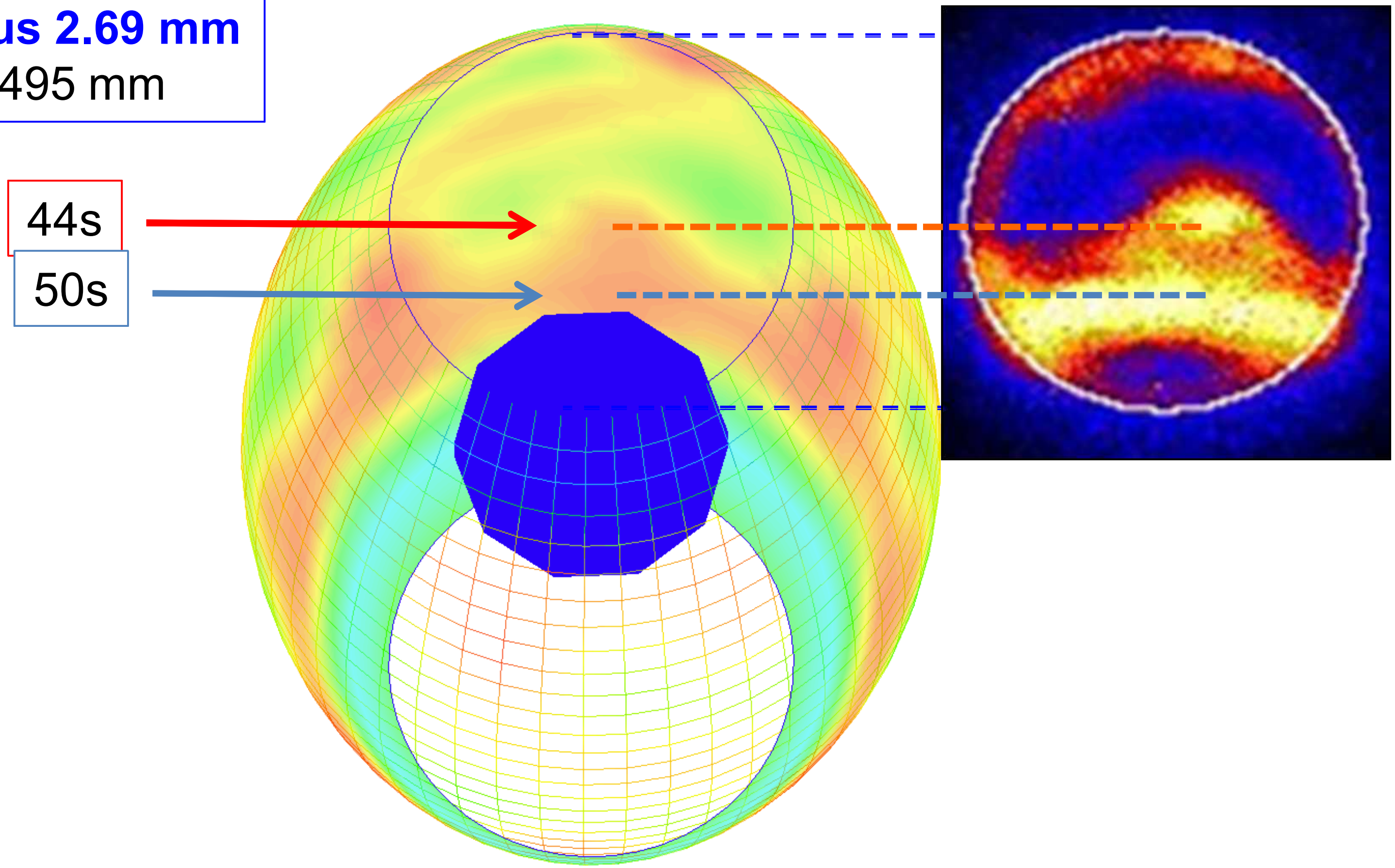


UNSplit 44s moved 200 microns



SXI matches with 850 micron of wall motion with unsplit 44.5 deg. and split 50 deg. pointing

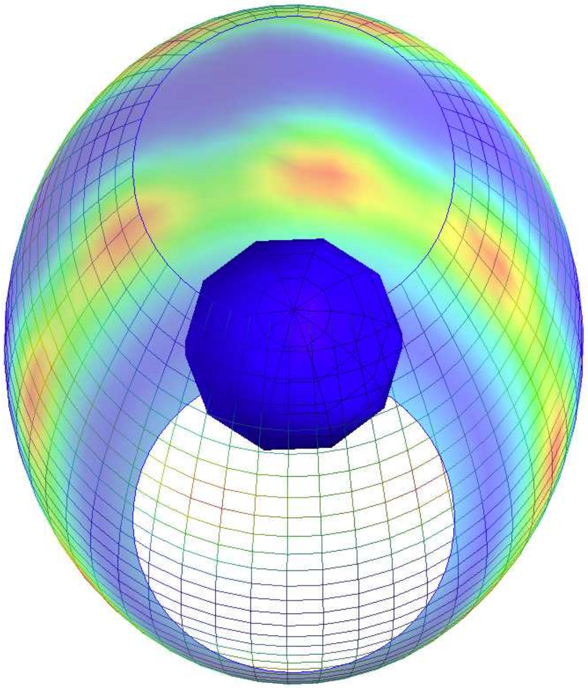
Converging Rugby
Length 10.515 mm
Equator Radius 2.69 mm
LEH Radius 1.495 mm



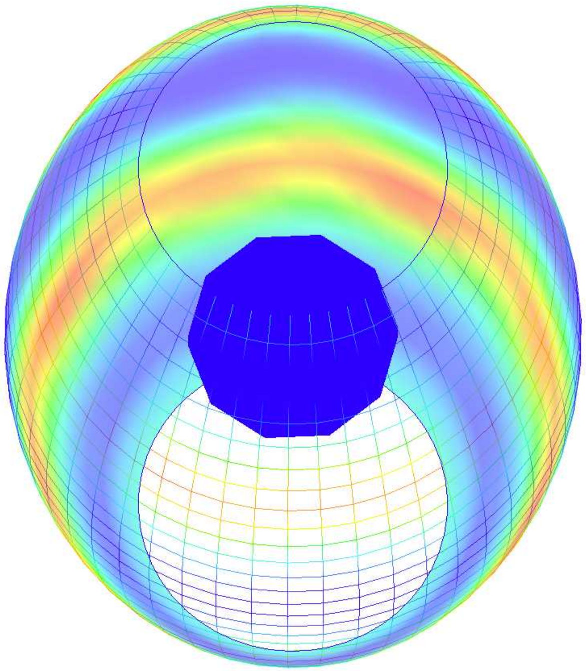
Best Match of Outer Beams Position

Comparison of SXI view using visrad showing only the location of the 44 deg. cone with split and unsplit pointing.

SXI matches with 850 micron of wall motion with unsplit 44.5 deg. and split 50 deg. quad pointing

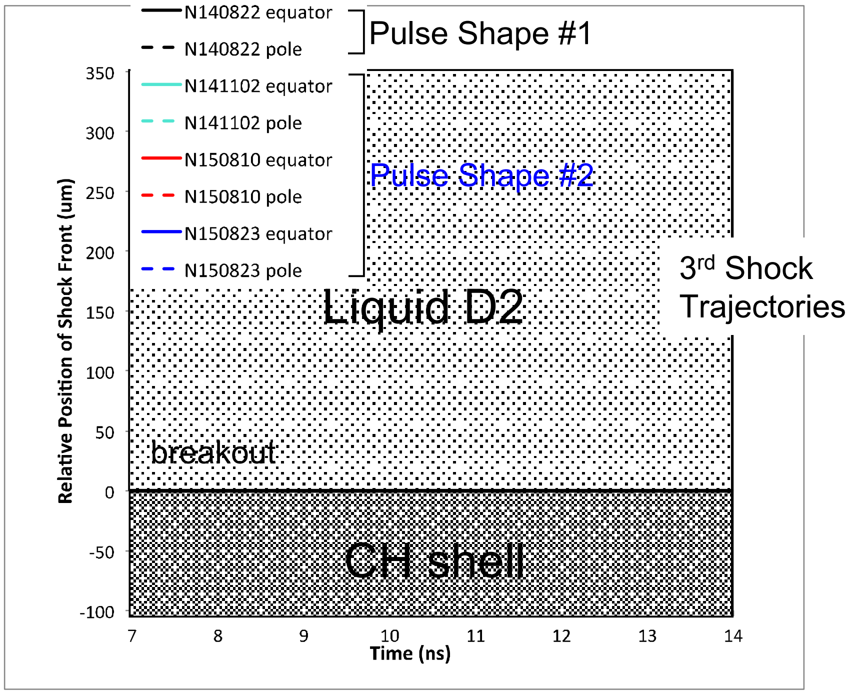


SXI matches with 750 micron of wall motion with split 44 deg. and 50 deg. quad pointing

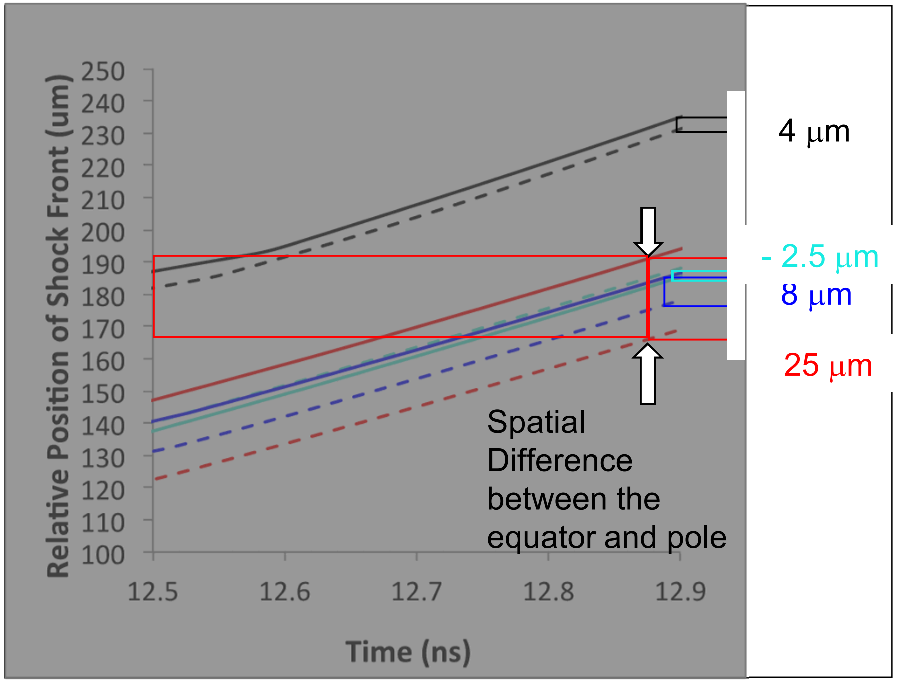


The Largest difference in shock symmetry was measured on the shock timing shot with Δλ of 1 - 2.5 Å

Analysis of the data from VISAR is used to track the shock radius



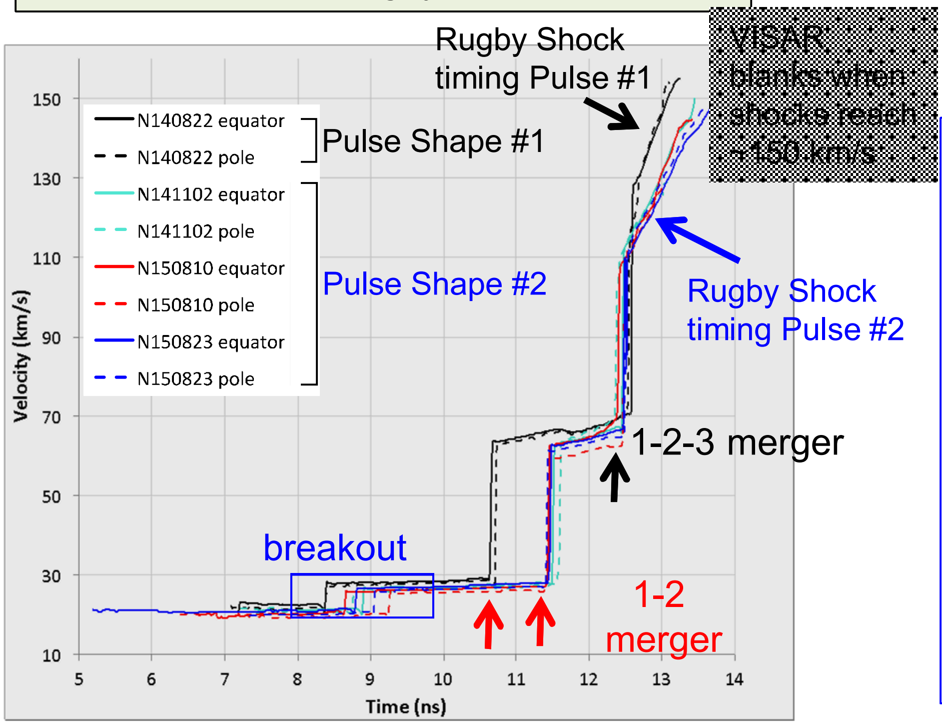
The Equator leads the pole on the only 0 - 0 Δλ shot with the revised pulse shape

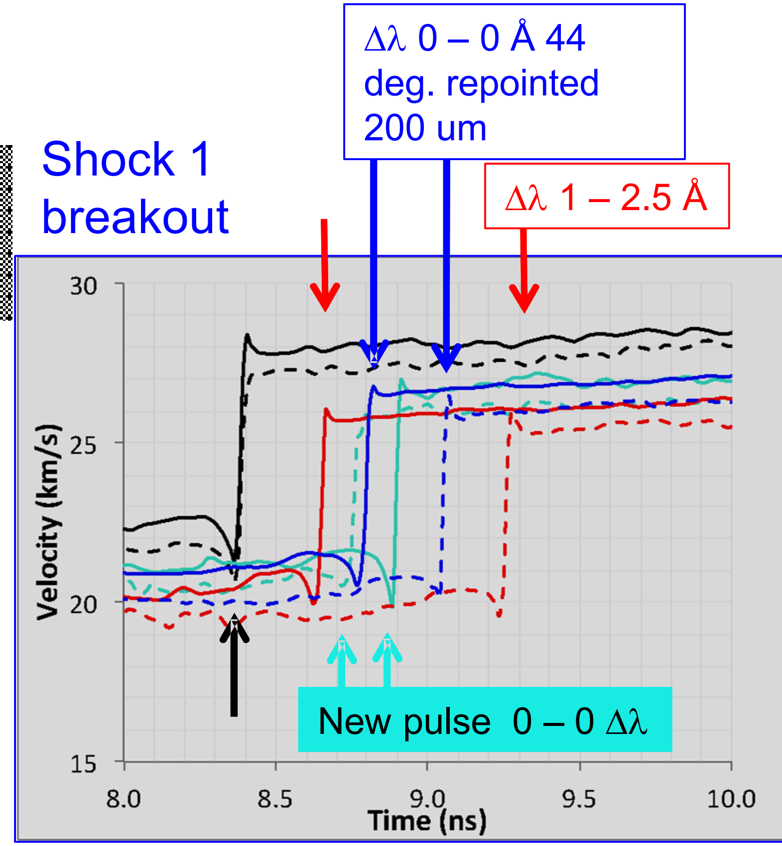


Late time positions of the shock indicate shock P2 ranging from -2.5 to 25 μm

The initial Rugby pulse produced highly symmetric shocks

Experiments using 2 keyhole pulses have been conducted in rugby hohlraums





Experiments using 2 keyhole pulses have been conducted in rugby hohlraums

The increased drive at the equator due repointing and CBET increase the breakout of the equator with respect to the pole

What about when the outers are on? Can we include the effect of the outers?

Assume CBET

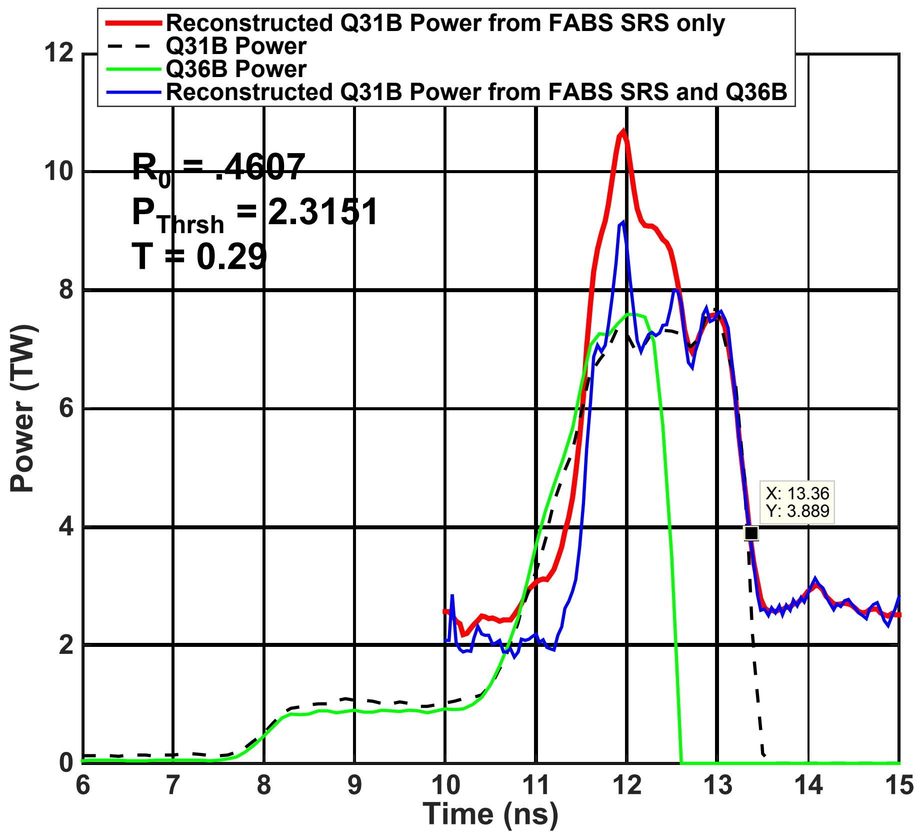
$$P_0 = P_{inner} + TP_{outer}$$

$$R = R_0\left(1 - \frac{P_{thr}}{P_{inner} + TP_{outer}}\right)$$

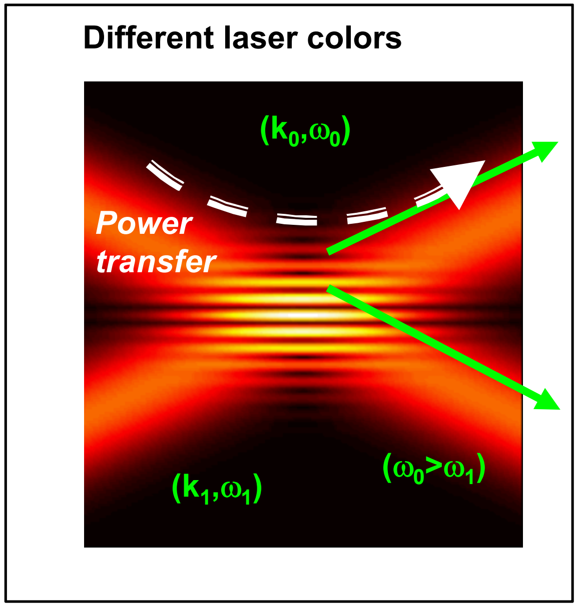
$$P_{SRS} = RP_0 = R(P_{inner} + TP_{outer})$$

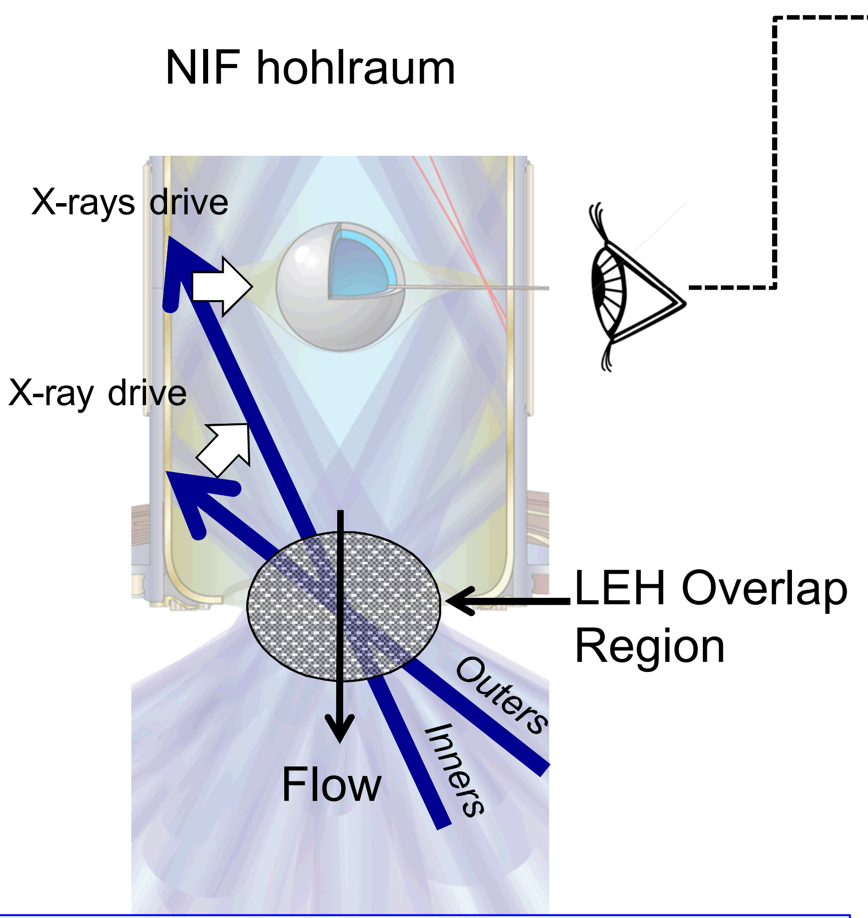
New Model with CBET

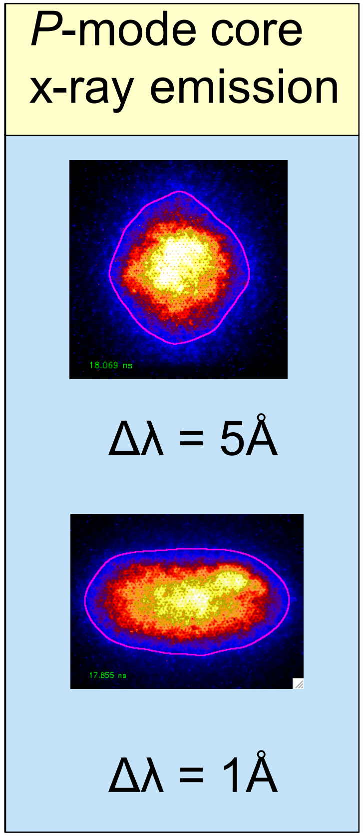
$$P_{inner} = \frac{P_{SRS}}{R_0} + P_{thr} - TP_{outer}$$



Cross-beam energy transfer (CBET) occurs at the LEH in all gas filled hohlraums and is routinely used to tune P2 implosion shape





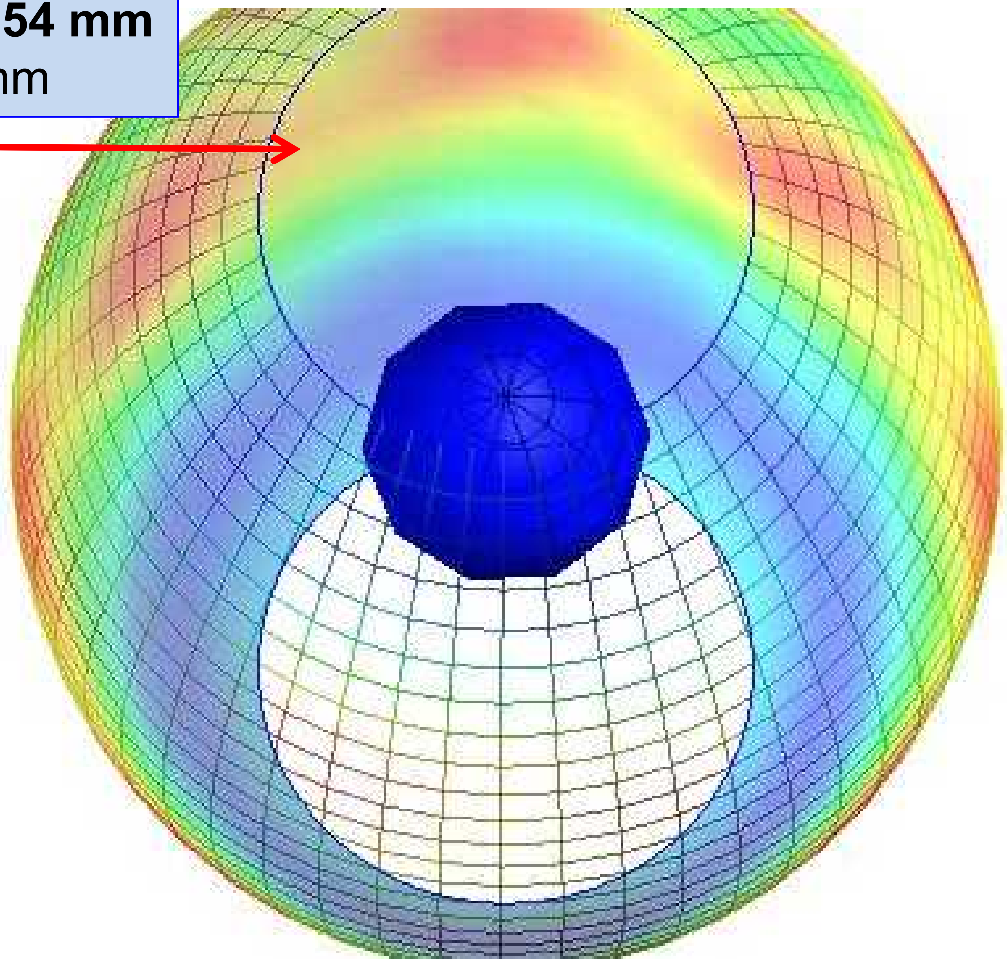


In the absence on delta-lambda tuning, the flow at the laser entrance hole (LEH) governs the transfer

SXI 18-123 VIEW of Original Size Rugby Hohlraum Showing Beam Locations With no Wall Motion

Full Sized Rugby
Length 10.515 mm
Equator Radius 3.54 mm
LEH Radius 1.77 mm

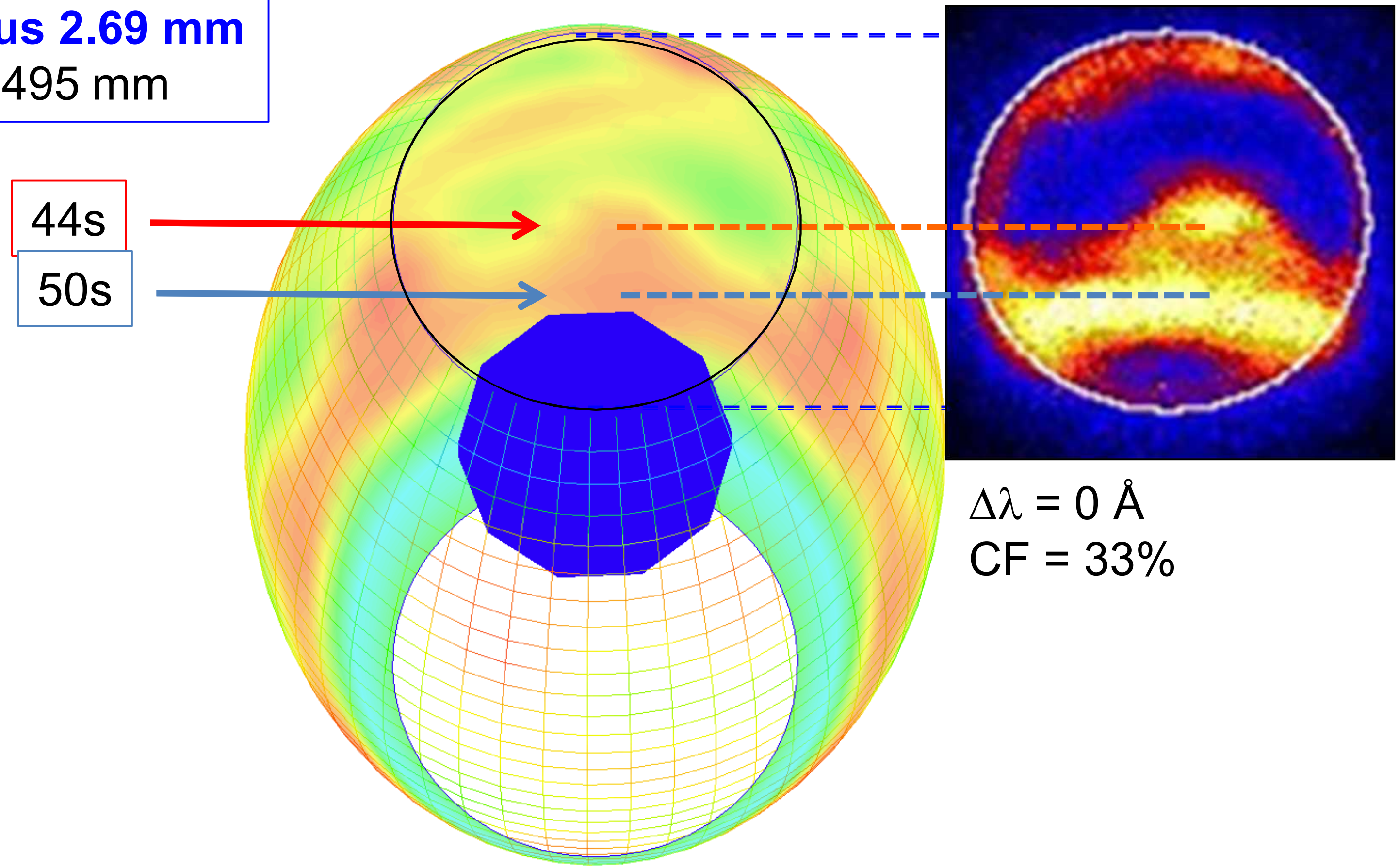
Outers



Visrad Model

SXI matches with 850 micron of wall motion with unsplit 44.5 deg. and split 50 deg. pointing

Converging Rugby
Length 10.515 mm
Equator Radius 2.69 mm
LEH Radius 1.495 mm

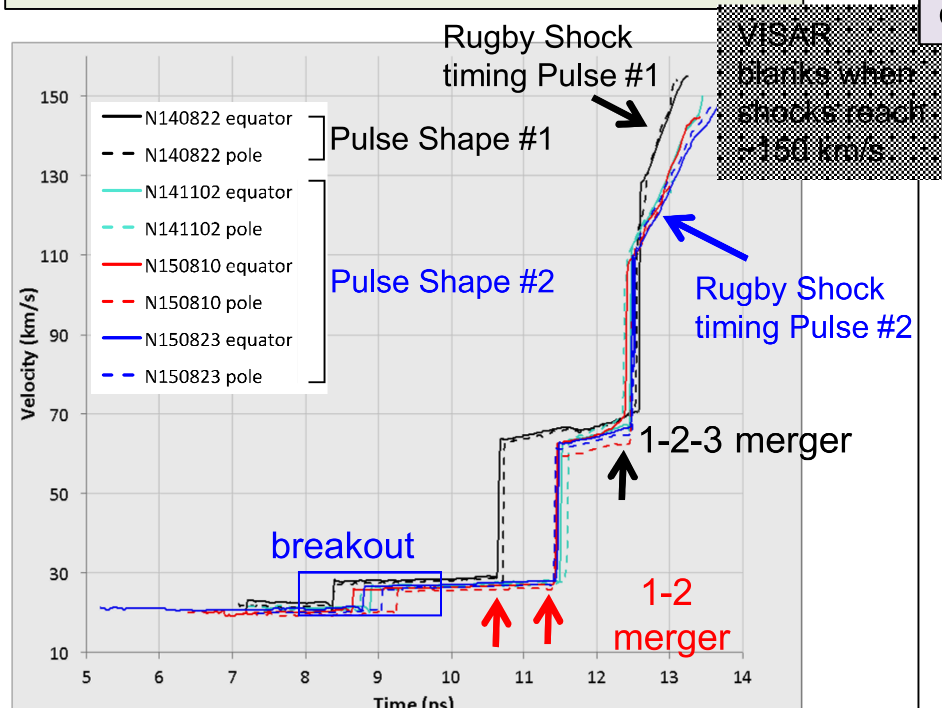


$\Delta\lambda$ = 0 Å
CF = 33%

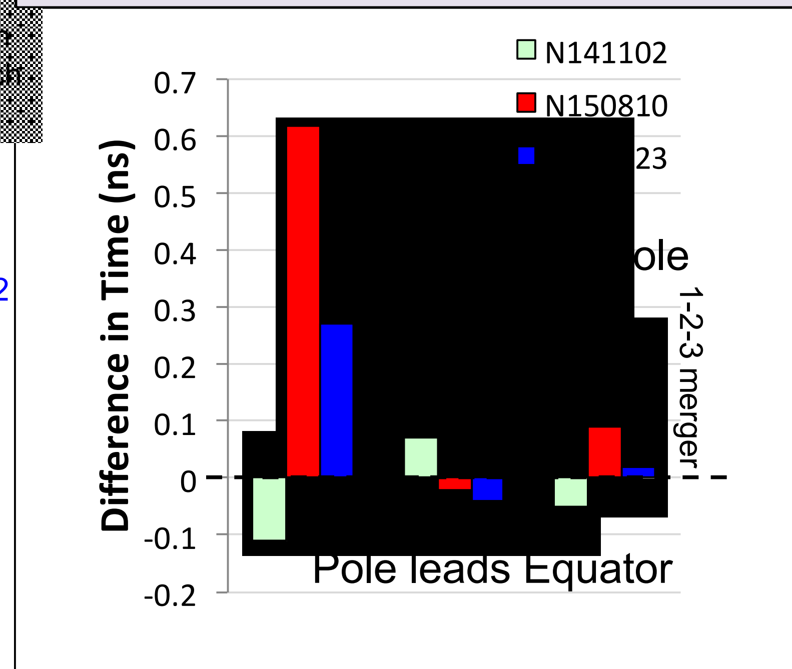
Best Match of Outer Beams Position

The initial Rugby Experiments produced highly symmetric shocks

Four 2-axis VISAR keyhole experiments have been conducted in rugby hohlraums



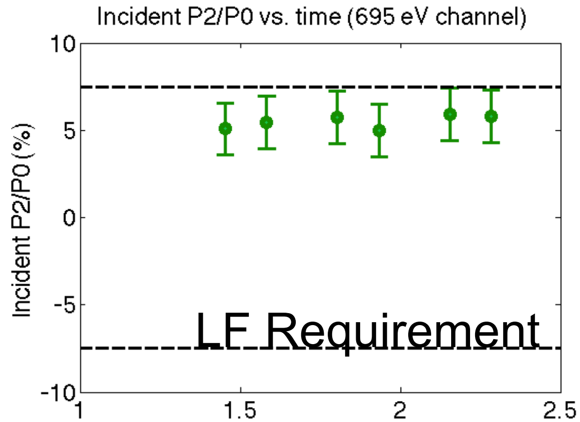
The increased drive at the equator due repointing and CBET increase the breakout of the equator with respect to the pole

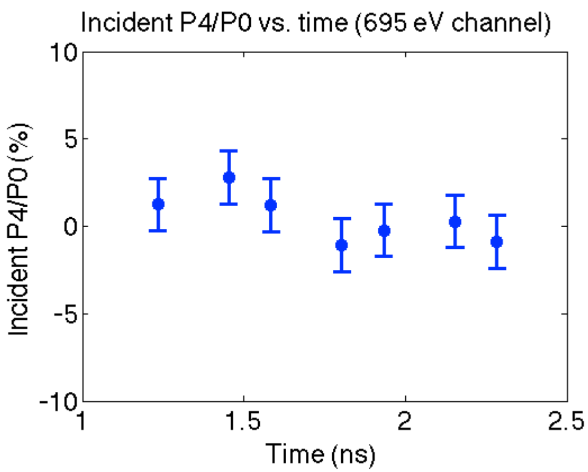


The shocks are slightly faster after the 1-2-3 merger in the equator and may indicate a more prolate implosion in the experiments with CBET or repointing

Picket radiation symmetry relatively constant in time and within requirement with Δλ = 0

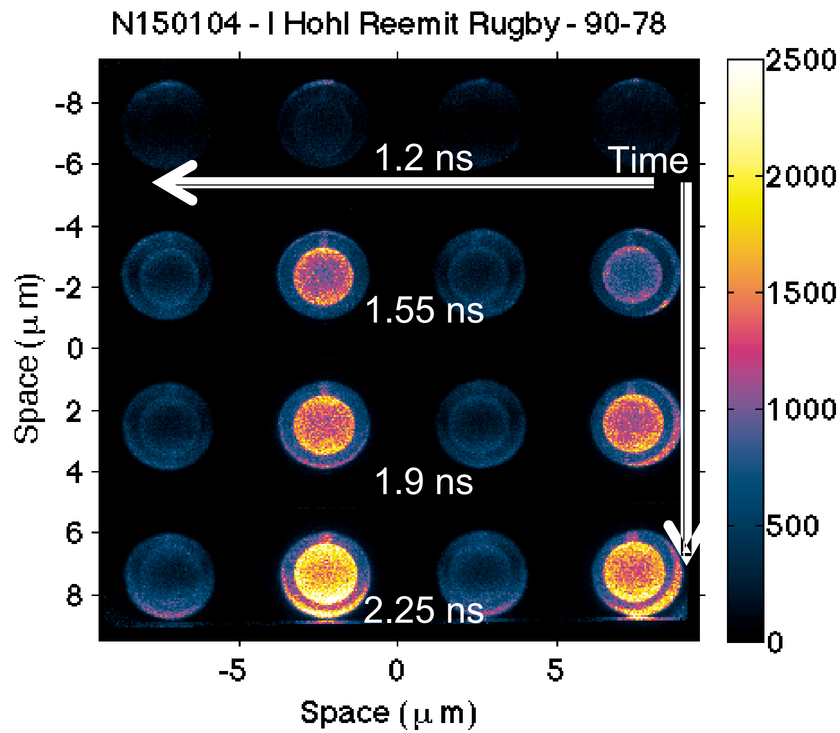
Temporal symmetry history





Emission primarily from the gas and is observed to be enhanced when Neon is added

High quality equatorial symmetry data was obtained

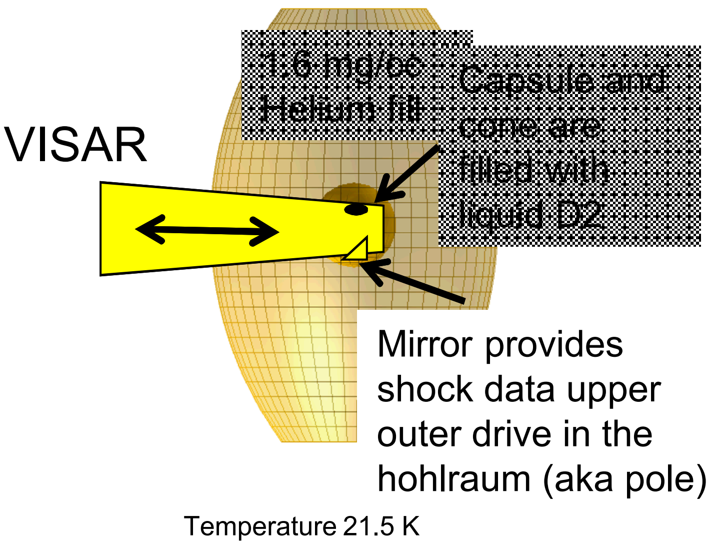


6 μm Al 100 μm PH ~875 eV	2.5 μm Al 50 μm PH ~695 eV	6 μm Al 100 μm PH ~875 eV	2.5 μm Al 50 μm PH ~695 eV

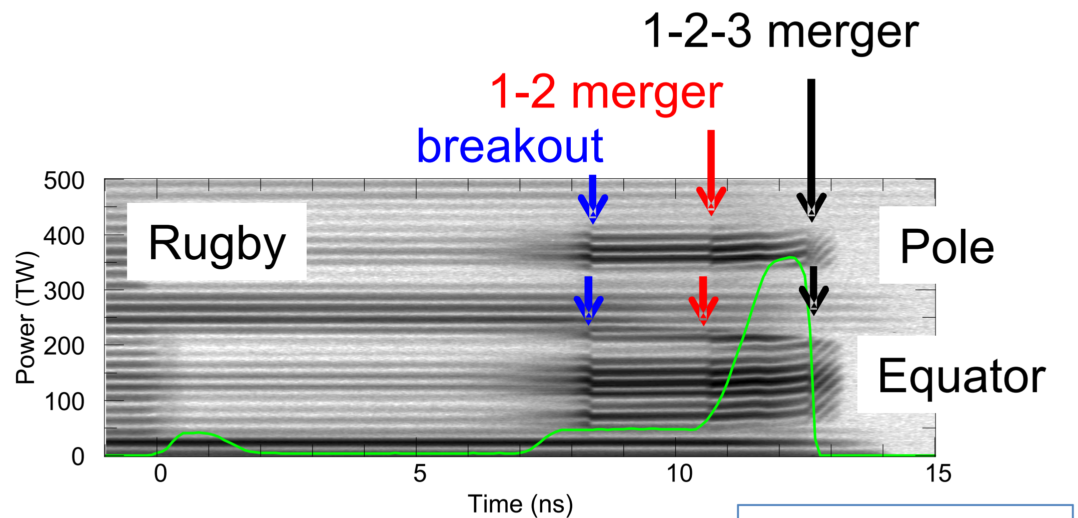
Two different PH – Filter combinations used to measure remission at two hν was used.

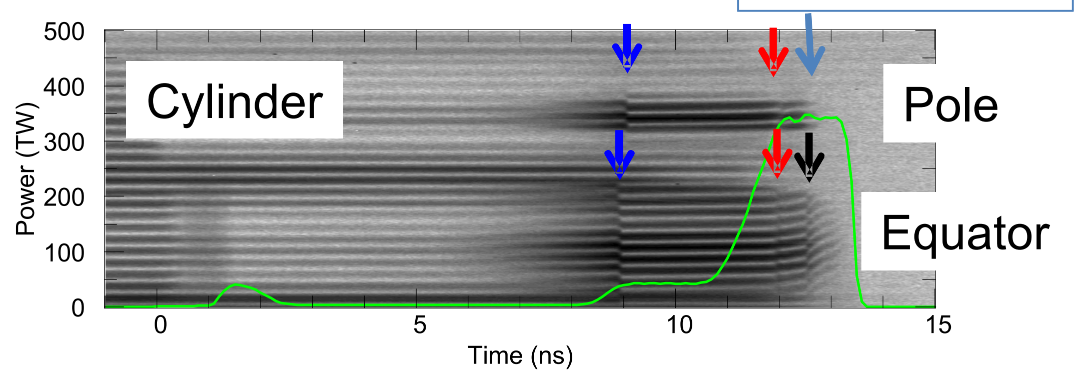
Excellent data was recorded in Rugby keyholes with no blanking in either pole or the equator

Rugby Keyhole Target



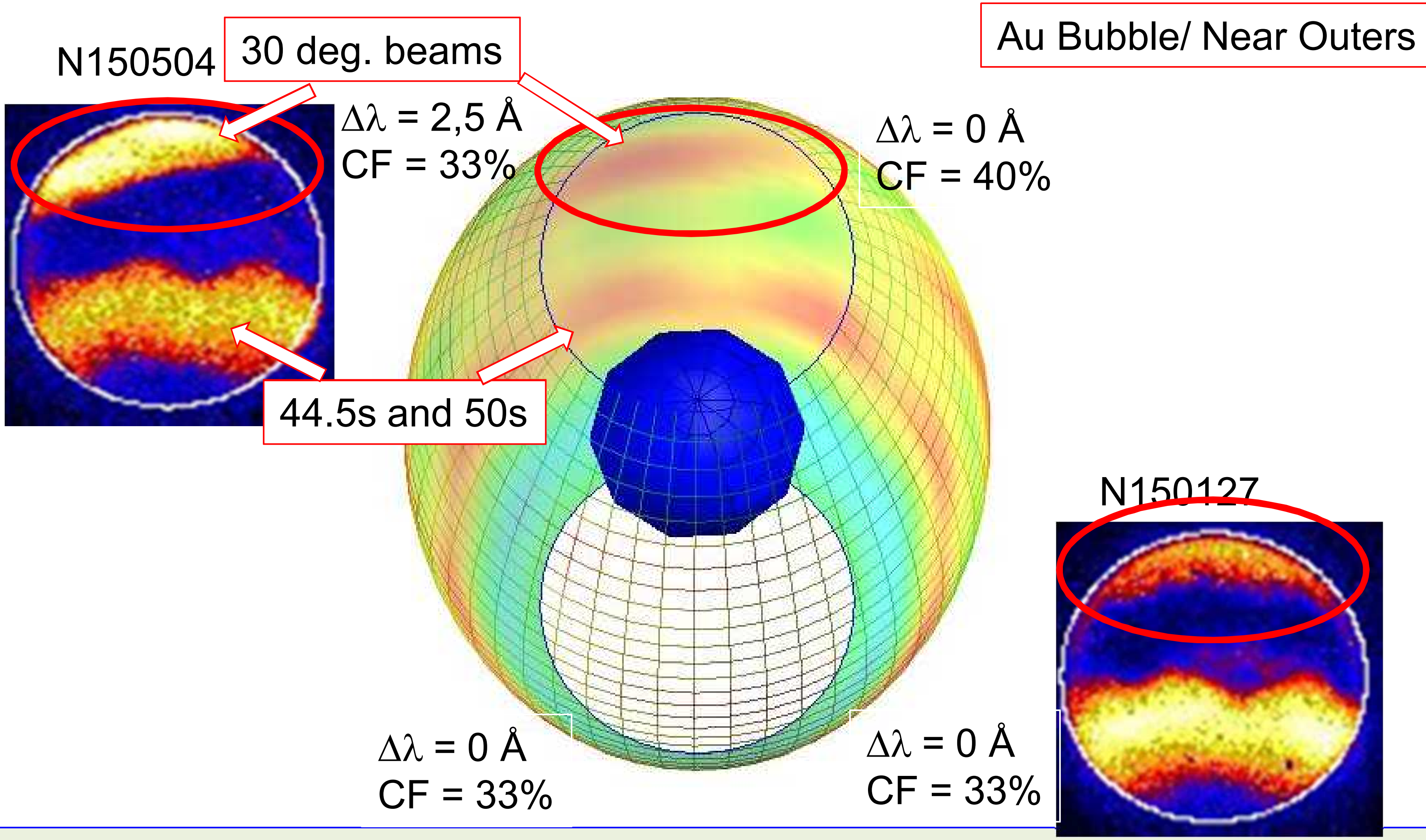
VISAR measures the shocks after they breakout on the CH ablator into the liquid Deuterium fill





Lower preheat and m-band allows us to probe 1-2-3 merger on both channels late in time

The 30 deg. beams are are visible in SXI only on the shot with $\Delta\lambda$ = 2 – 5 Å and appeared where they are expected from wall motion



Best Match of Outer Beams Position from SXI is consistent with 750 (+200/-100) μm microns of Wall Motion. SXI 161-326 views are also consistent with 750 μm wall motion