Target & Diagnostic Alignment Basics

NIF User Forum

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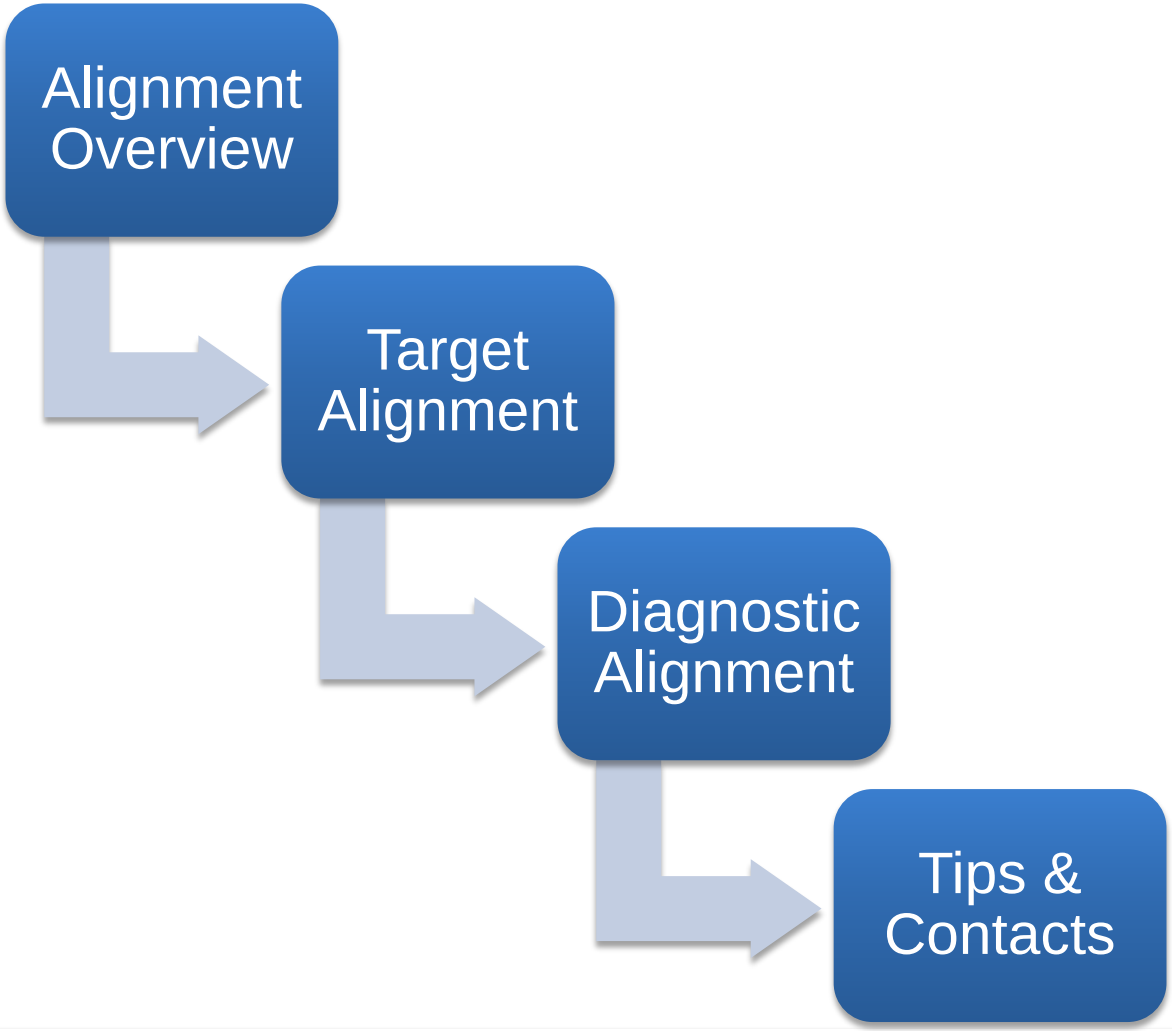
Overview

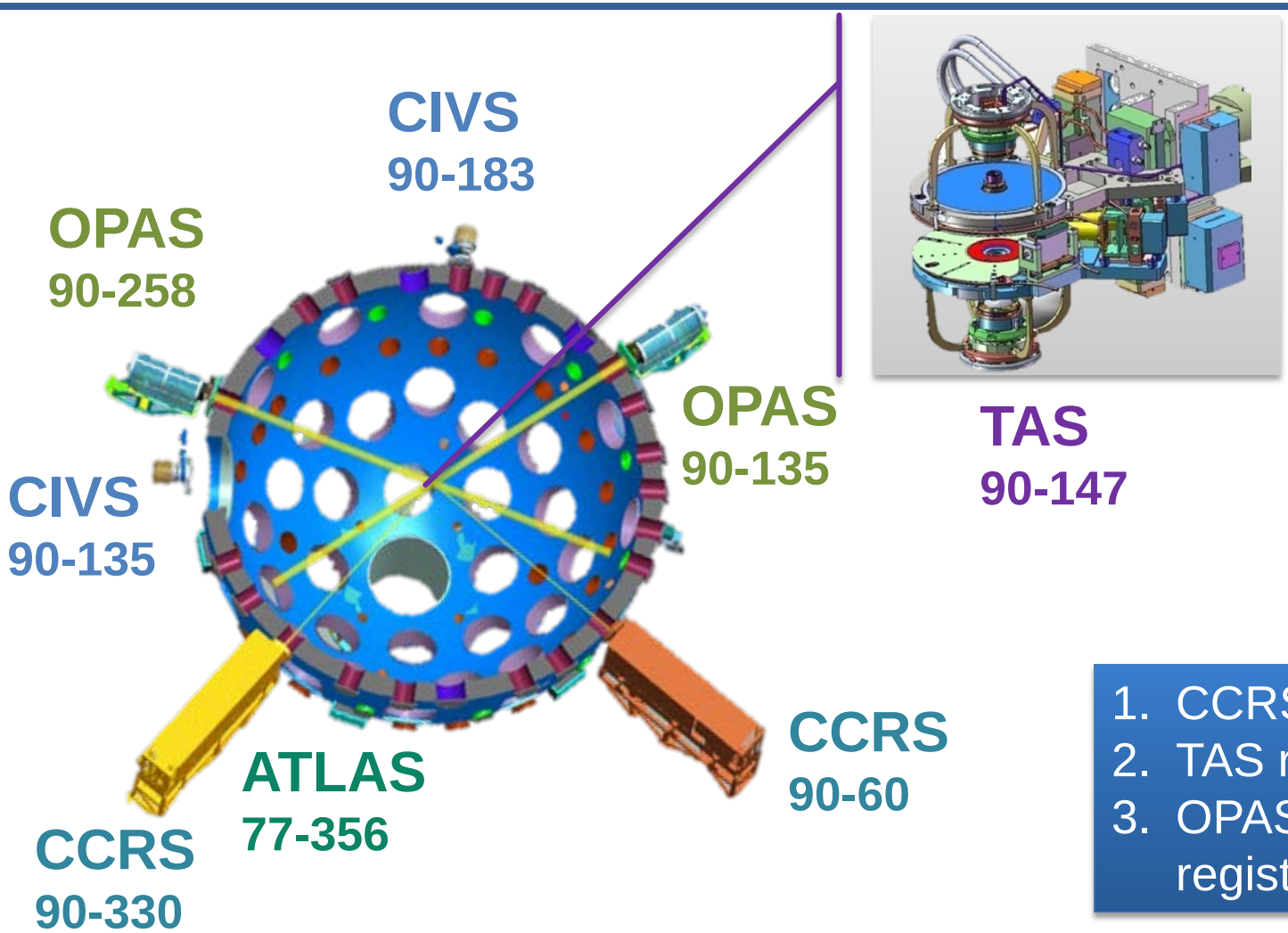

Alignment Overview
Target Alignment
Diagnostic Alignment
Tips & Contacts

Alignment Overview

Define TCC	**TAS**	CCRS		
Register Alignment Systems	**TAS**	OPAS	ATLAS *	
Beam Alignment	**TAS**	ARC AT **		
Target Alignment	**TAS**	CIVS	Target Positioner	
Diagnostic Alignment	OPAS	CIVS	ATLAS *	Diagnostic Positioner

* ATLAS coming soon; ** ARC AT only used for ARC beamlets

Define TCC and Register Alignment Systems



ATLAS: advanced tracking laser alignment system

CCRS: chamber center reference system

CIVS: chamber interior viewing system

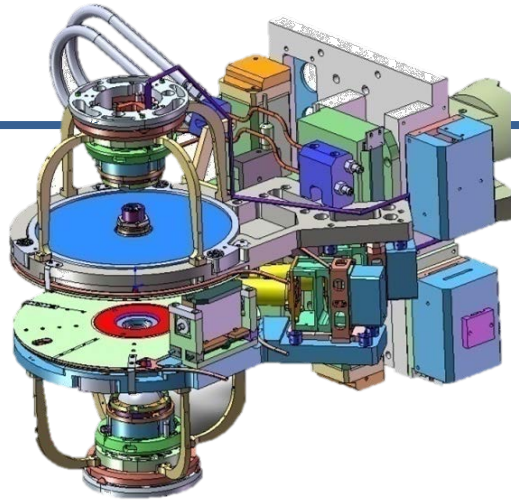
OPAS: opposed port alignment system

TAS: target alignment system

TCC: target chamber center

1. CCRS defines TCC
2. TAS registers to CCRS
3. OPAS & ATLAS register to TAS

Target Alignment



TAS (target alignment sensor)

- Side views at 90-95 (lower) and 90-109.5 (upper)
- TASPOS (TAS positioner) 90-147

TARPOS (90-239)

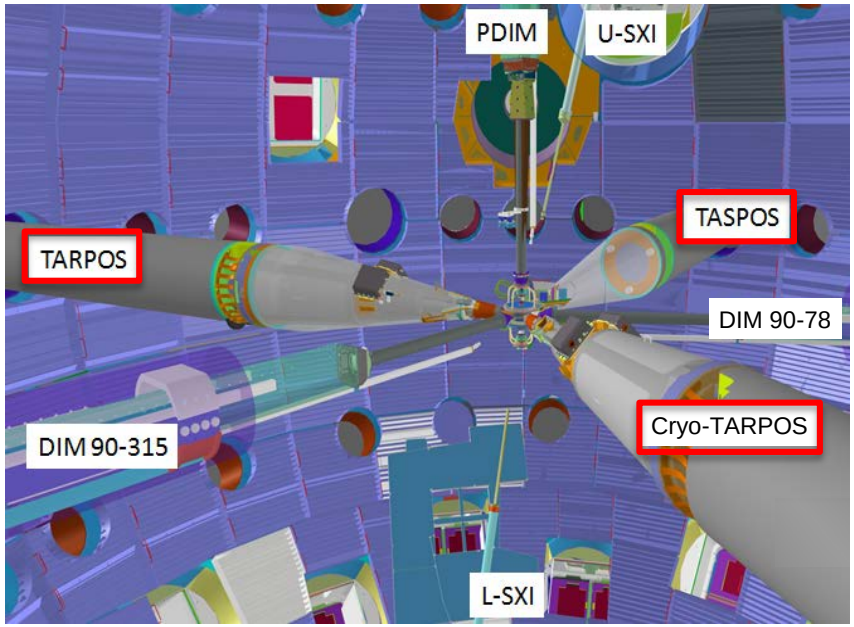
- Warm targets
- Gas-Filled targets
- Cold non-layered targets

Cryo-TARPOS (90-15)

- Warm targets
- Gas Filled targets
- Cold layered & non-layered targets

TANDM (90-348) - coming soon

- Warm targets
- Gas Filled Targets



There is limited space inside TAS and TAS4 is slightly more restrictive

- The maximum size target that can be inserted into TAS is a height of approx 36 mm (previously 38 mm)
  - No component can extend more than 18 mm (previously 19 mm) above the lowest aim-point for an upper beam
  - Reduced target height clearance will affect existing TARDIS targets
    - Beam pointing will need to be adjusted to allow for the required 5 mm clearance between target and TAS jaw features

- The maximum size target that can be inserted into TAS and still allow TAS to be withdrawn is a cylinder :

Positioner	Cylinder radius (mm)	Target Height (mm)
TARPOS (90-239)	60	36
C-TARPOS (90-15)	15	36

Target Alignment

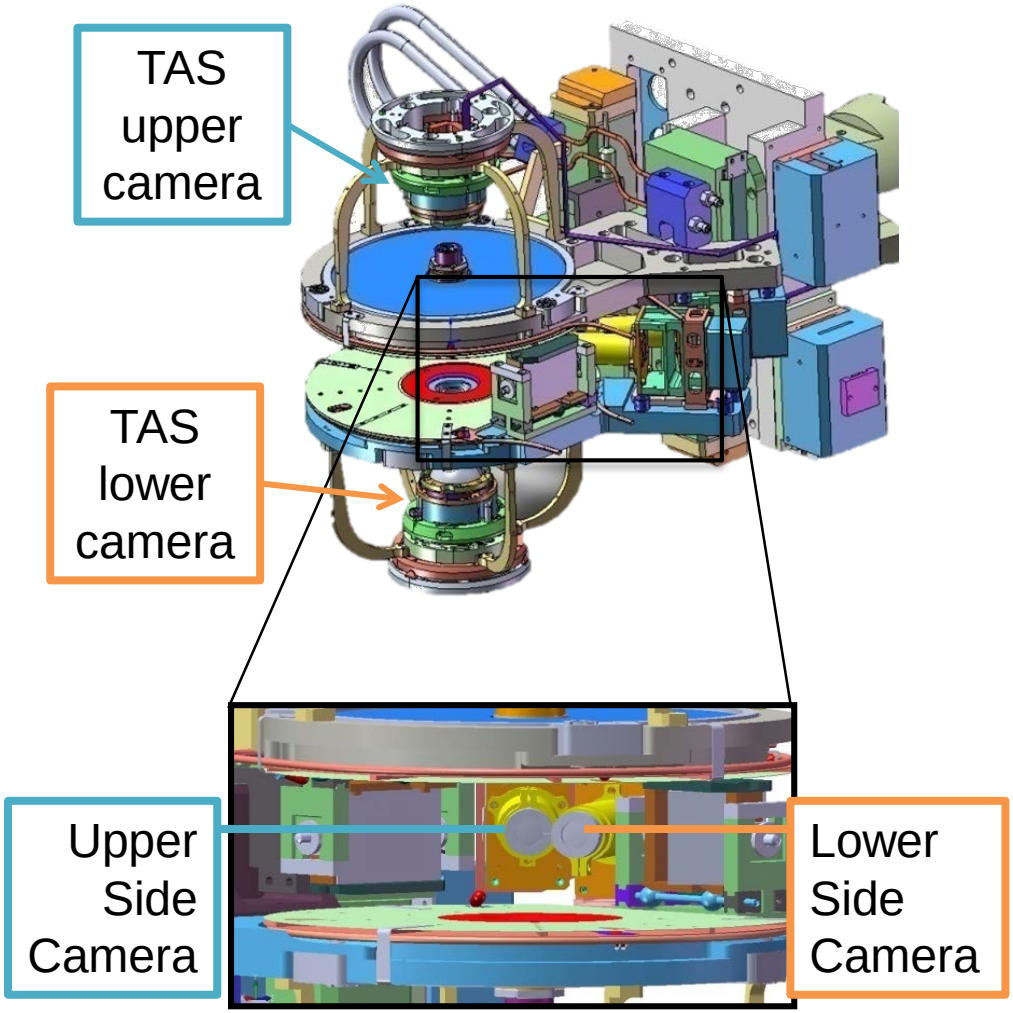
TAS jaws are adjusted vertically for target

Targets are inserted to TCC using a target positioner

- CIVS are used to view insertion

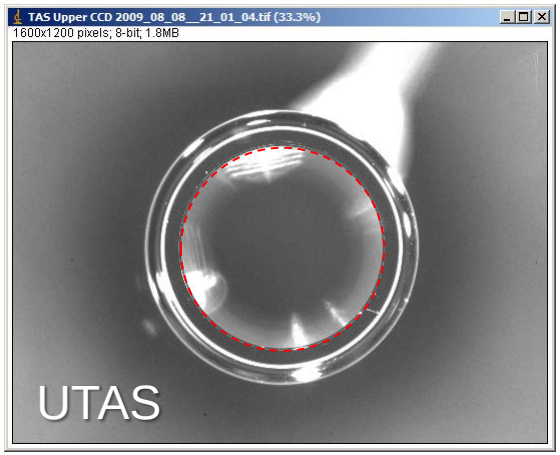
Targets are aligned using TAS cameras

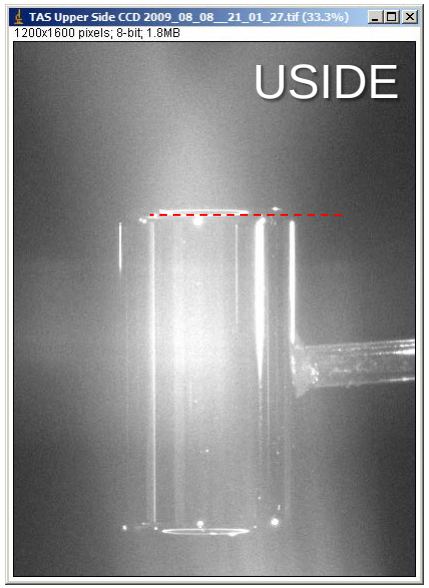
- TAS upper camera & Upper side camera
- TAS lower camera & Lower side camera

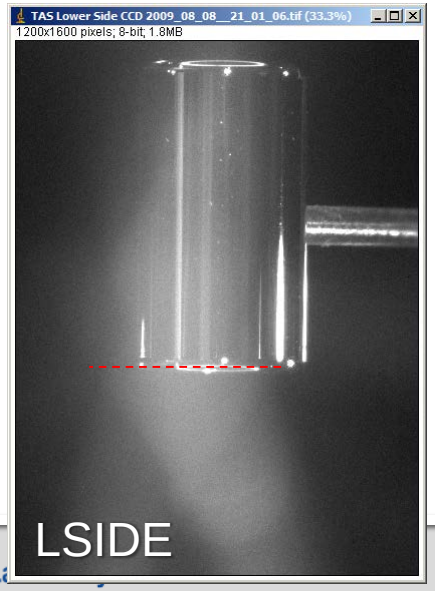


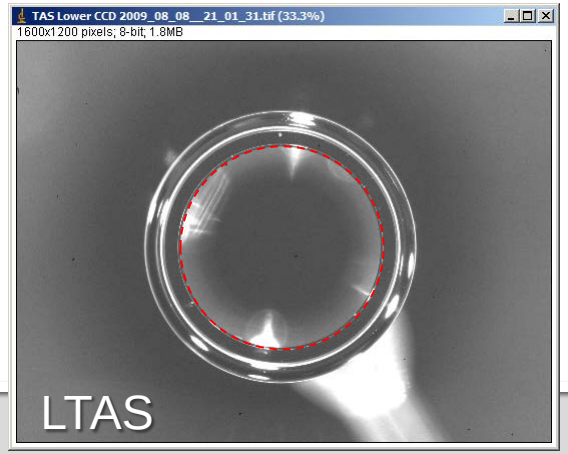
Example Images from TAS cameras during target alignment: Warm hohlraum

- TAS jaws are offset to match the hohlraum length
- Requires visibility in UTAS and LTAS to measure and correct roll and nod (orient the target) and all 4 cameras for positioning









N090808-003-999
Warm hohlraum

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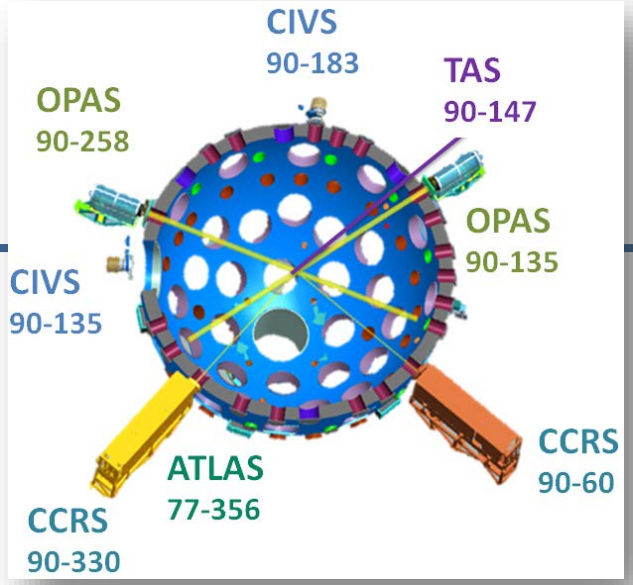
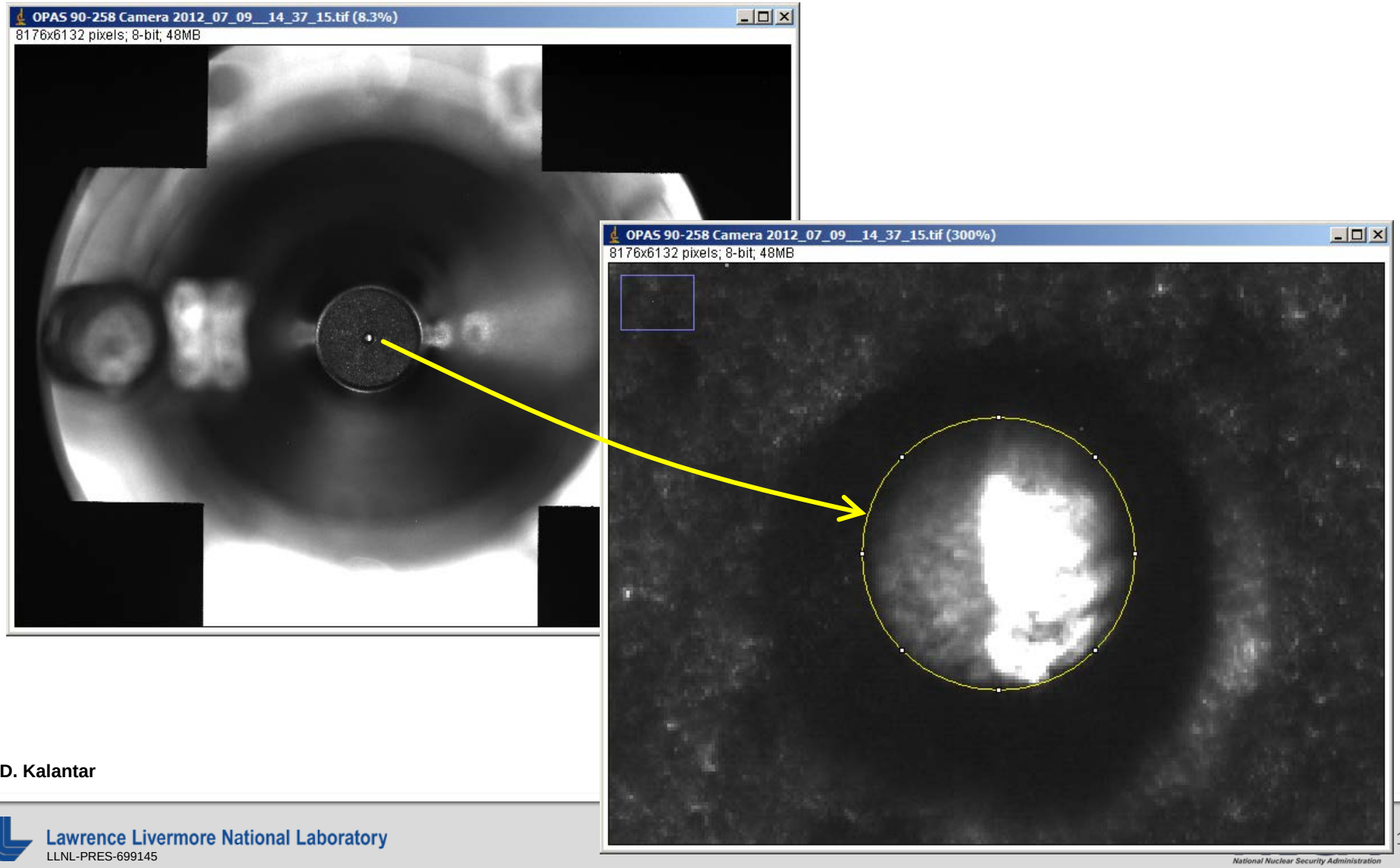
Diagnostic Alignment



- CIVS (chamber interior viewing system)
  - 90-183 wide (3.28 mm/pix) and narrow (0.299 mm/pix)
  - 90-278 wide (3.34 mm/pix) and narrow (0.301 mm/pix)
  - 7-315 wide (1.28 mm/pix) and narrow (0.42 mm/pix)
- OPAS (opposed port alignment system)
  - 90-135 (~0.020 mm/pix)
  - 90-258.75 (~0.020 mm/pix)
- ATLAS (Advanced Tracking Laser Alignment System) – coming soon
  - 77-356
- Diagnostic Positioners
  - eDIM 90-78 (equatorial Diagnostic Insertion Manipulator)
  - eDIM 90-315 (equatorial Diagnostic Insertion Manipulator)
  - pDIM 0-0 (polar Diagnostic Insertion Manipulator)
  - TANDM 90-348 – coming soon (Target and Diagnostic Manipulator)
- Standard alignment tolerances
  - ± 500 um in X & Y
  - ± 2000 um in Z

Equatorial (90-78 & 90-315) DIM-based diagnostics are inserted and aligned to OPAS



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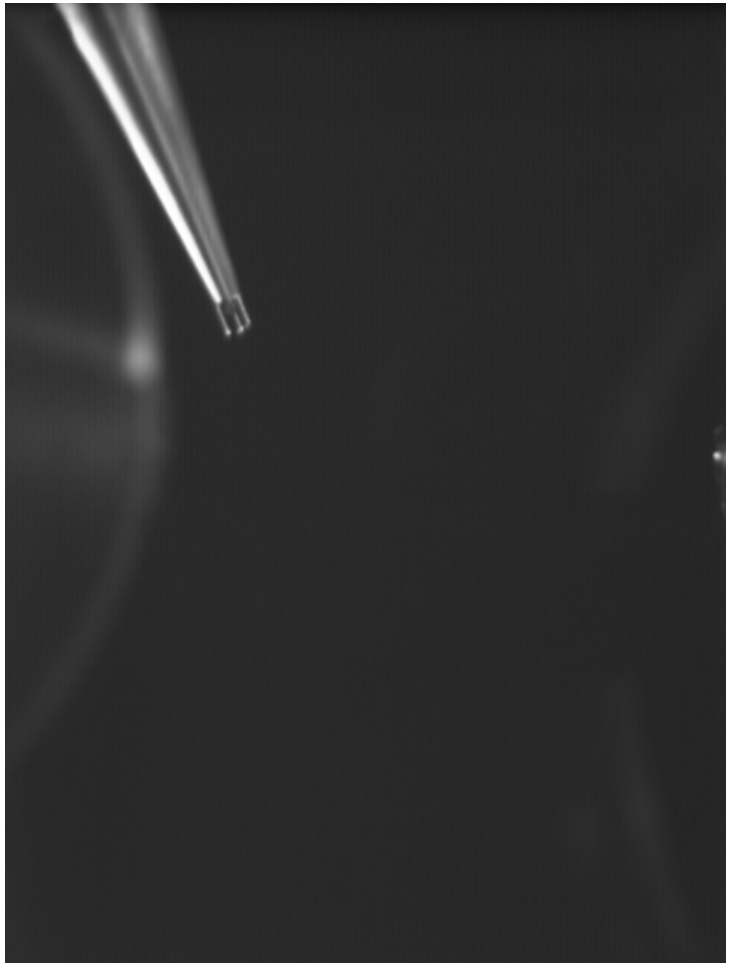
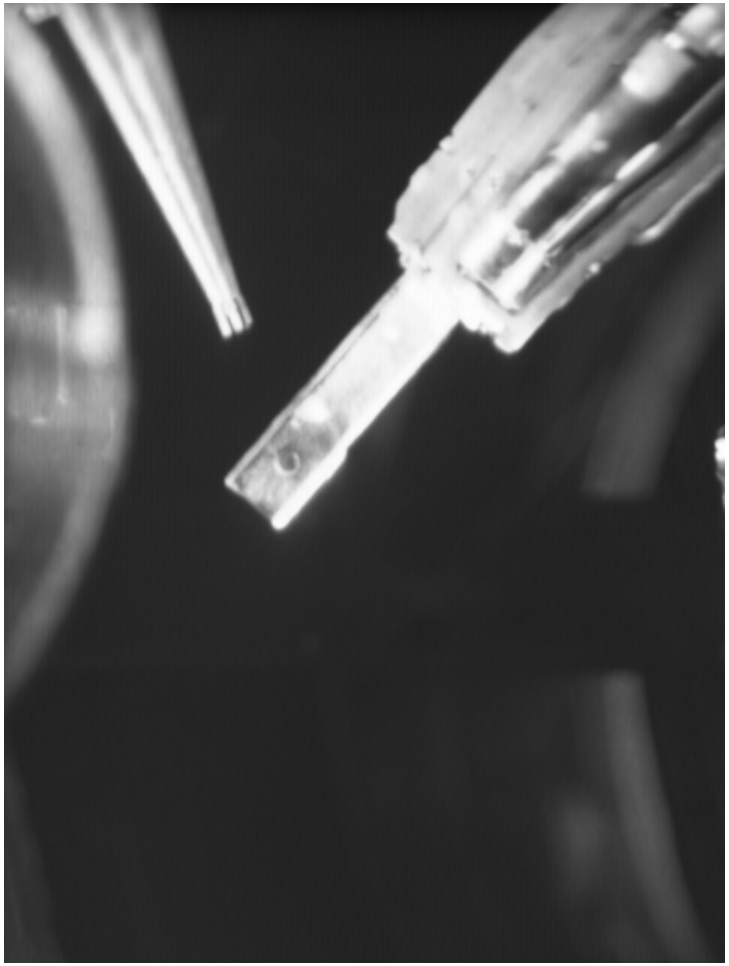
Equatorial (90-78 & 90-315) diagnostic insertion depth is verified with the 7-315 CIVS





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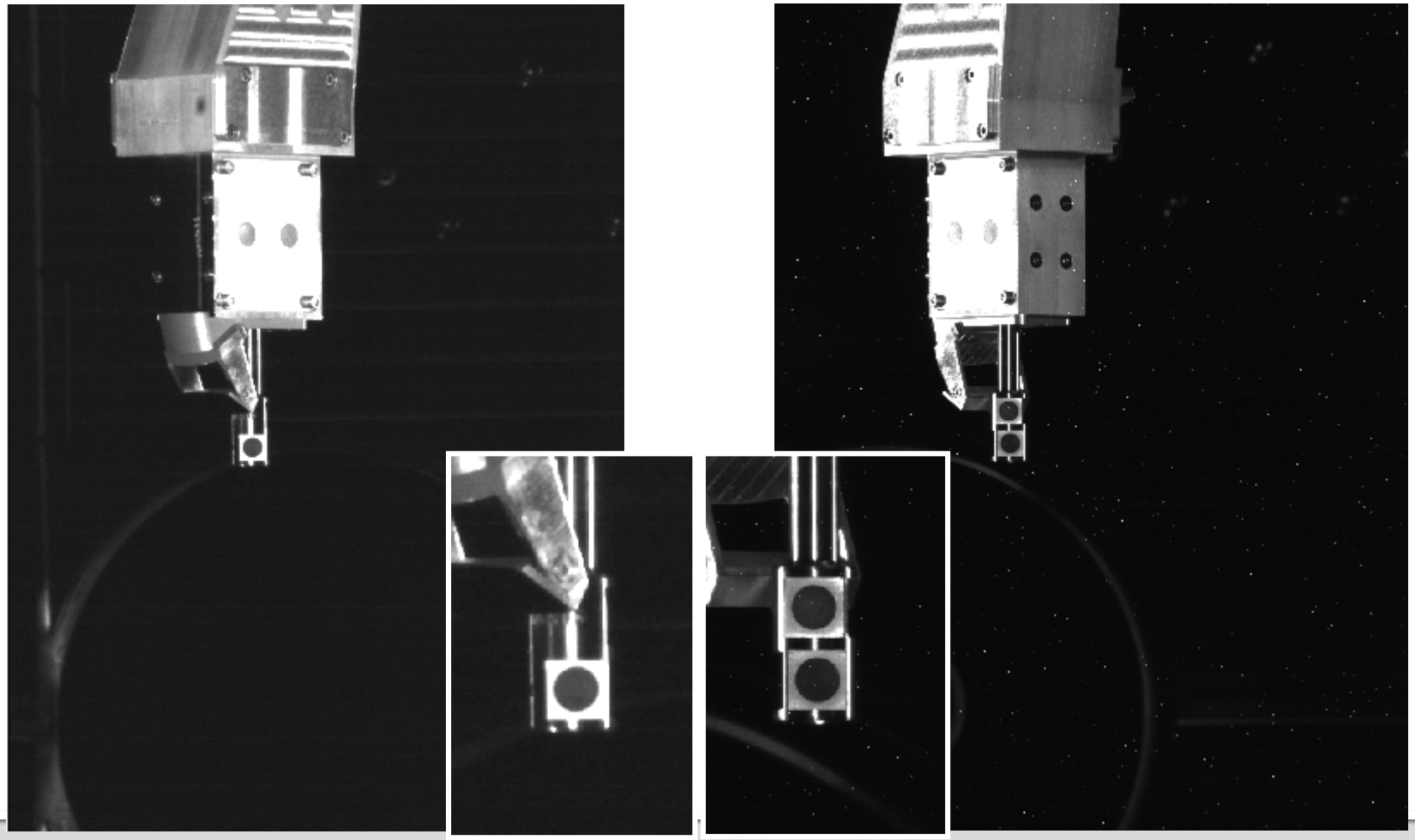
Polar DIM (0-0) alignment is achieved using the horizontal CIVS views

- Fiducials are added to the snout nose cone/nose cap



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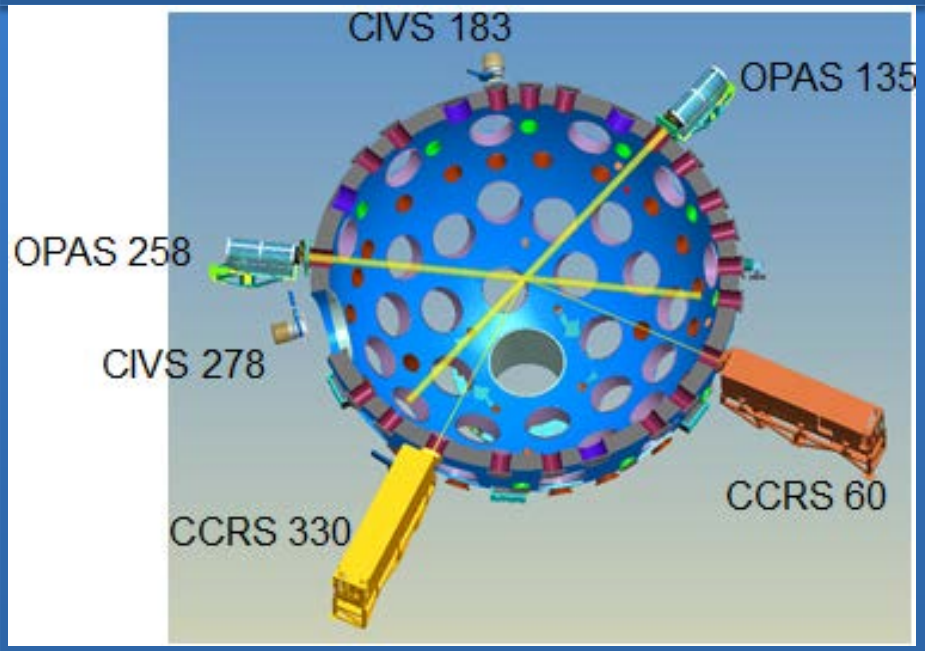
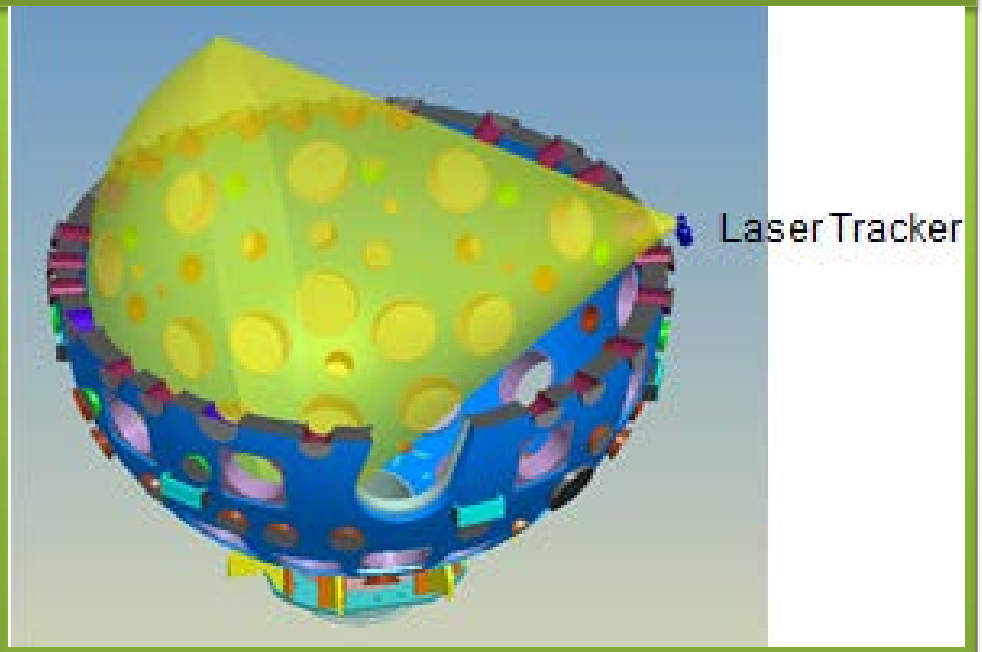
What is ATLAS?

Current Alignment Systems



Systems	Alignment
Equatorial DIMs	2x OPAS
Polar DIM	2x CIVS
SXIs	Motor Steps
TAS / TCC	2x CCRS

ATLAS Alignment System



Systems	Alignment
Equatorial DIMs	ATLAS
Polar DIM	
SXIs	Motor Steps
TAS / TCC	2x CCRS

Target Alignment Tips

- Engage your alignment specialist early
  - When you are designing your target to ensure fiducials are positioned in the best place possible
- Setup target Fiducial Reference Locations (FRLs) in CMT
- Review the 'Alignment Review Checklist' located in the Approval Manager
  - Verify the FRLs fall on the TAS CCDs
- Minimize last minute changes
  - Increased chance of errors
- Understand RI Staffing Method options during Target Alignment Verification (see next slide)

RI Responsibilities: Target Alignment Verification Discussion

- During the shot setup review a staffing plan is required, which is ultimately attached to approval manager:

Shot RI Function	Shot RI Staffing	Staffing Method	Owner
Pre shot conversation and briefing	Name	On-site	Facility requirement
Target alignment verification	Name	On-site	Campaign/program Decision
DIM alignment verification	Name	On-call	Campaign/program Decision
TD dry runs / Timing	Name	On-site	Campaign/program Decision
Rod shot evaluation	Name	Remote	Campaign/program Decision

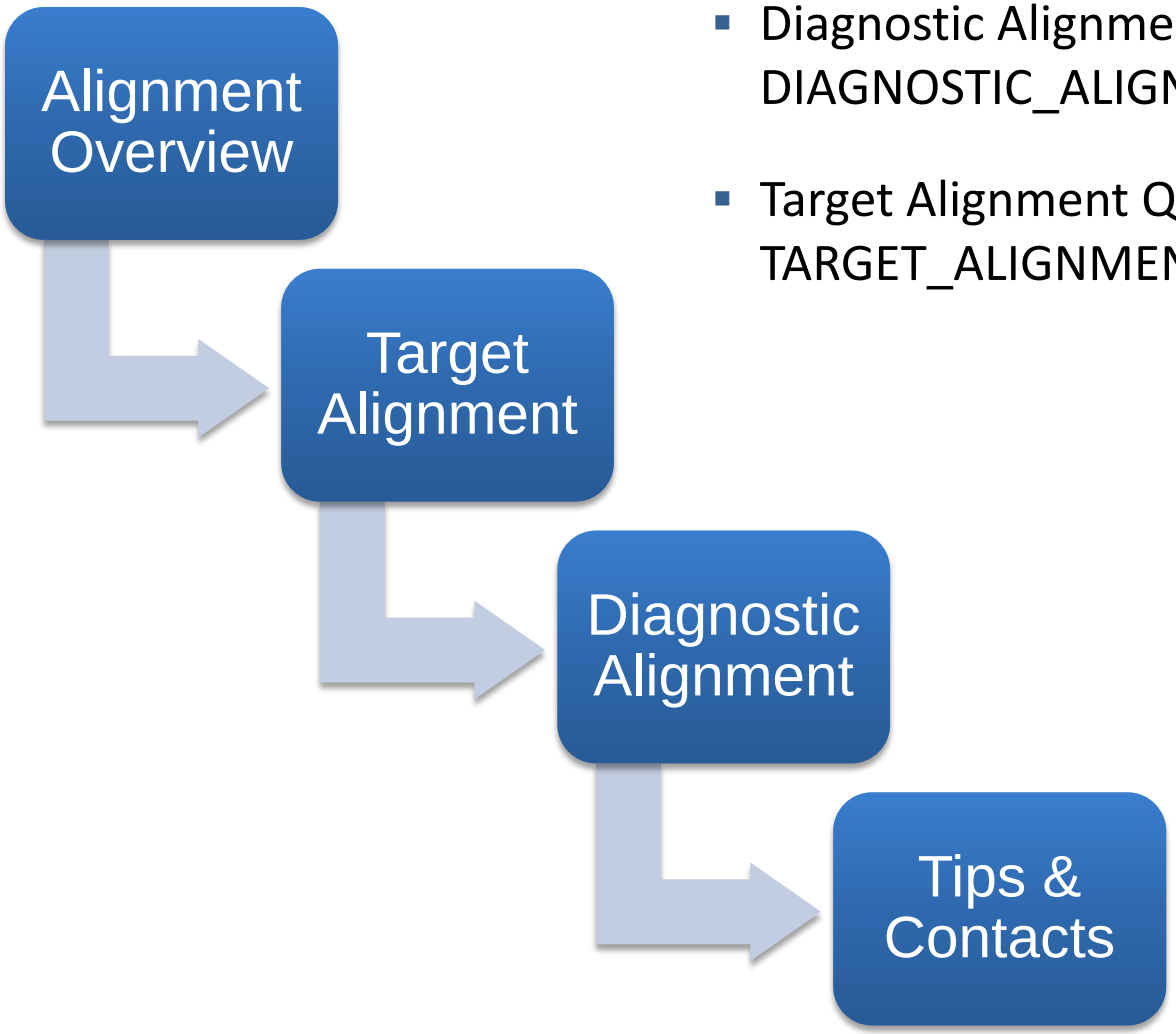
- For Target Alignment Verification there are three options:
  1. **On-Call** (Accept Operators judgement)
     - Operators will follow the procedure and proceed if the defined tolerance is met
  2. **On-Site** (RI Present to discuss alignment before proceeding)
     - Shot RI training (by D. Kalantar) required
  3. **Remote** (RI not present, but will remotely review alignment before proceeding)
     - Additional Shot RI training (by D. Kalantar) & NOM approval required
     - GAA (Graphical Alignment Aid) Tool Use required (MAC interface required)

Contacts

- Diagnostic Alignment Questions: DIAGNOSTIC_ALIGNMENT_SMES@llnl.gov
- Target Alignment Questions: TARGET_ALIGNMENT_SMES@llnl.gov
- For general information: NIF User Guide
  - https://lasers.llnl.gov/for-users
  - Chapter 5. Target Area
  - Chapter 7. Targets

If you aren't sure, just ask an Alignment SME and
Engaging your Alignment SME early can save you time and frustration

Questions?



- Diagnostic Alignment Questions: DIAGNOSTIC_ALIGNMENT_SMES@llnl.gov
- Target Alignment Questions: TARGET_ALIGNMENT_SMES@llnl.gov

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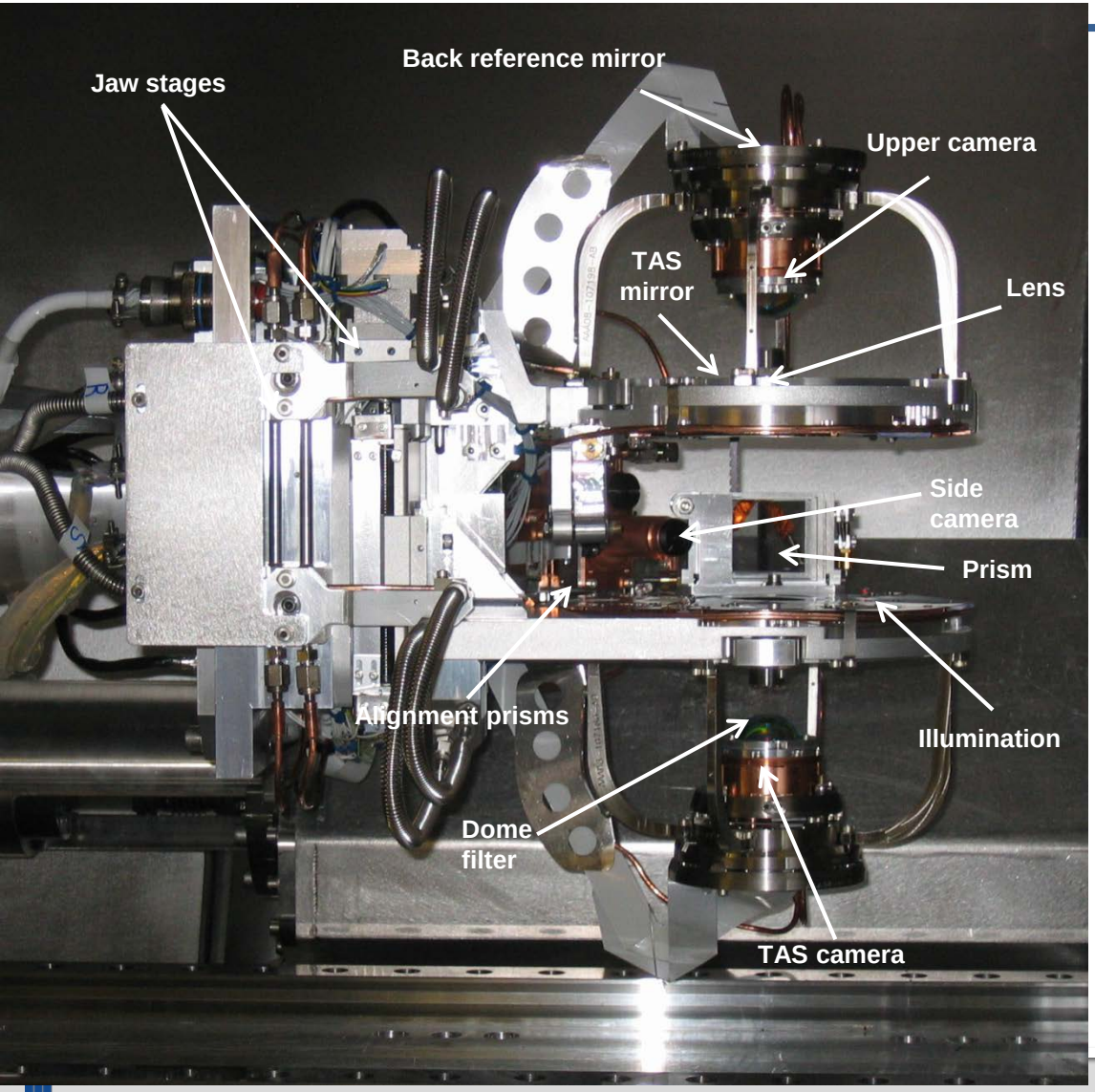
View of the TAS retracted into the positioner



- The TAS is positioned in the target chamber to the CCRS lines of sight using the prisms
- The TAS provides the views to align the target
- Final placement of the target depends on the adjustment and calibration of the TAS

Backscatter Risk Management For NIF

NIF User Forum

July 25 & 26, 2016

Brian MacGowan

LLNL-PRES-699145

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

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Summary

- All proposed laser/target configurations are reviewed for Risk of Stimulated Brillouin Scatter (SBS) damage to the final 1ω transport mirror (LM8)

- SBS damage risk is different to other risks dependent on laser/target configuration as a single shot can create catastrophic damage on multiple beams, exceeding spares capability and potentially leading to long term loss of facility availability

- The review process uses NIF experience of measured SBS and monitoring LM8 damage
  - SBS power traces are recorded on 58 separate beams with 3ω power sensors (DrDs), sampling almost all beam to beam and beam to target geometries
  - Regular optics inspections characterize the damage state of the LM8s
  - When SBS fluence is ~1 [Jcm^{-2} @ 3ns Gaussian Equiv.] we see either catastrophic damage or an increase in the number of hotspots in the NIF beam caused by damage on the LM8s. Both observations ultimately lead to LM8 replacement

- The review process sorts shots into those that are:
  - Similar to configurations in our experience base and/or intrinsically safe – 90% of shots
  - New experiments or extensions of experiments that have the potential for SBS fluence at the $1Jcm^{-2}$ level – 10% of shots

- We are evaluating ways to quantify facility risk for the latter case to see if we can increase flexibility without undue consequence

The risk of significant down-time due to damage to LM8s from SBS is higher than for other experimental configuration-related risks

Experiment Configuration Risk	Depends on details of experiment configuration (Laser/Target)	Demonstrated >1 week downtime	Potential for > 2 months downtime	Inherent robustness and predictability
LM8 - SBS	yes	yes	yes	low
PABTS VRT - ARC SBS	yes	no	no	medium
Diagnostics - shrapnel	yes	temporary loss of diagnostic	no	high
Optics - shrapnel	yes	temporary loss of beam	no	high
PABTS VRT - CP light	yes	no	no	high

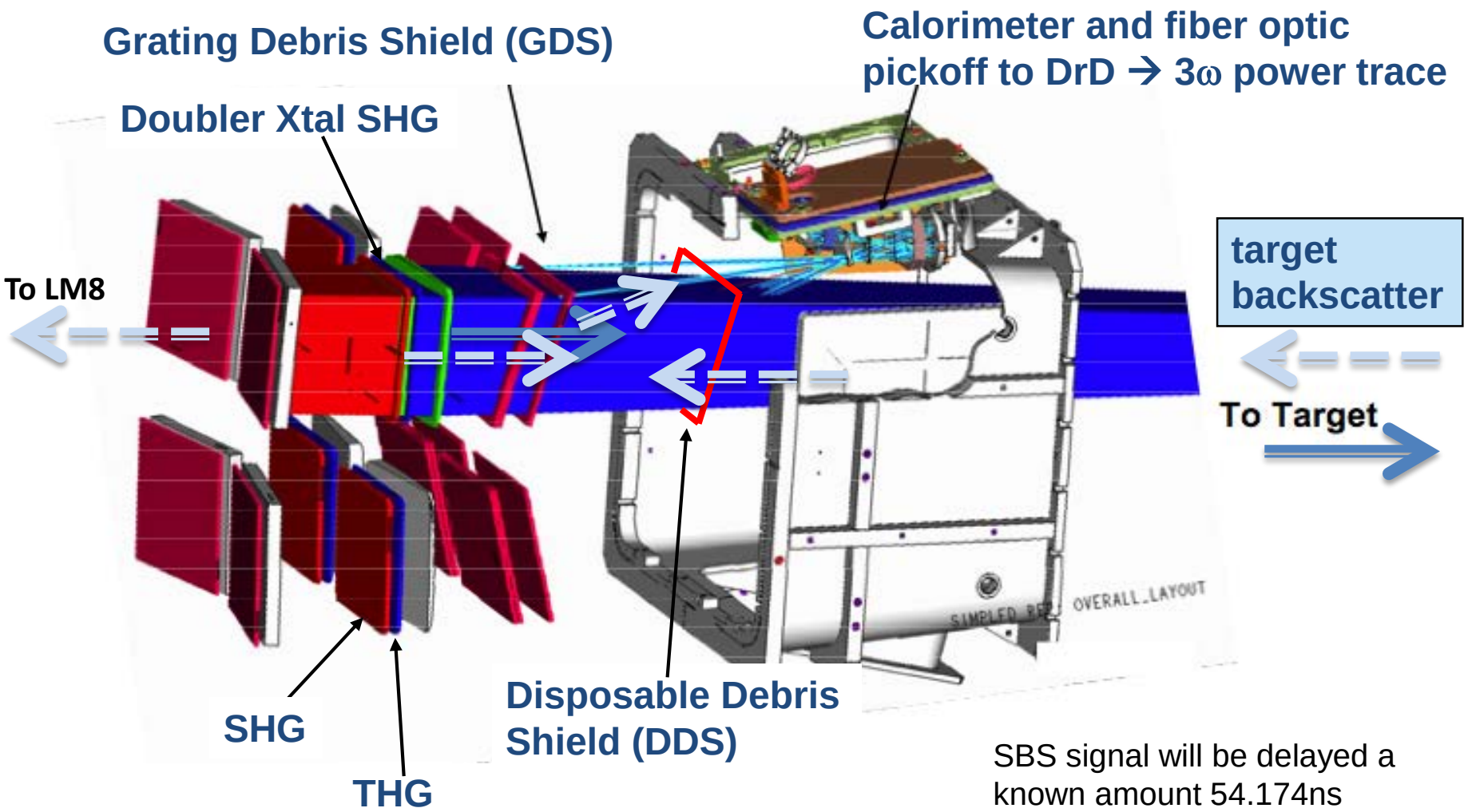
- It is labor and time-consuming to replace LM8 LRUs on the NIF
  - ~$30K to replace each LM8 that is damaged
  - Difficult rigging operation that requires several people and significant planning
  - Replacement optics have about a 1-year lead time, so important not to run out of spares
  - We replace ~24 LM8s/yr, 25% from SBS damage
- The real risk is that a single event can exceed spares capacity (there are 4 flavors of spares)

Spares availability LM8s (Roger Qiu 2/23/16), LM8s have 4 flavors

Mirror type	Beams	LM8s at medium risk of loss due to debris initiated damage	LM8s at high risk of catastrophic damage from SBS	SPARES in house	Rate of use [LM8s/yr]	Facility time to replace quad	Spares on Contract for 4FY16 receipt	Spares on Contract for 1QFY17	Time to refinish/recoat	Time to procure additional spares (incl blanks)
Inner Cone - LM8B	60	28	60	32	10	4 - 6 shifts	13	0	10 months nominal; 6 months rush	14 months nominal; 10 months rush
Outer Cone - LM8A	128	60	30	26	12		0	10		
31B FABS - LM8BT	4	4	4	4	1	up to a week	5	0		
36B FABS - LM8AT	4	4	2	9	2		0	0		
total	**192**	**96**	**96**	**71**	**24**	**4 - 6 shifts**	**18**	**10**	**6 months rush**	**10 months rush**

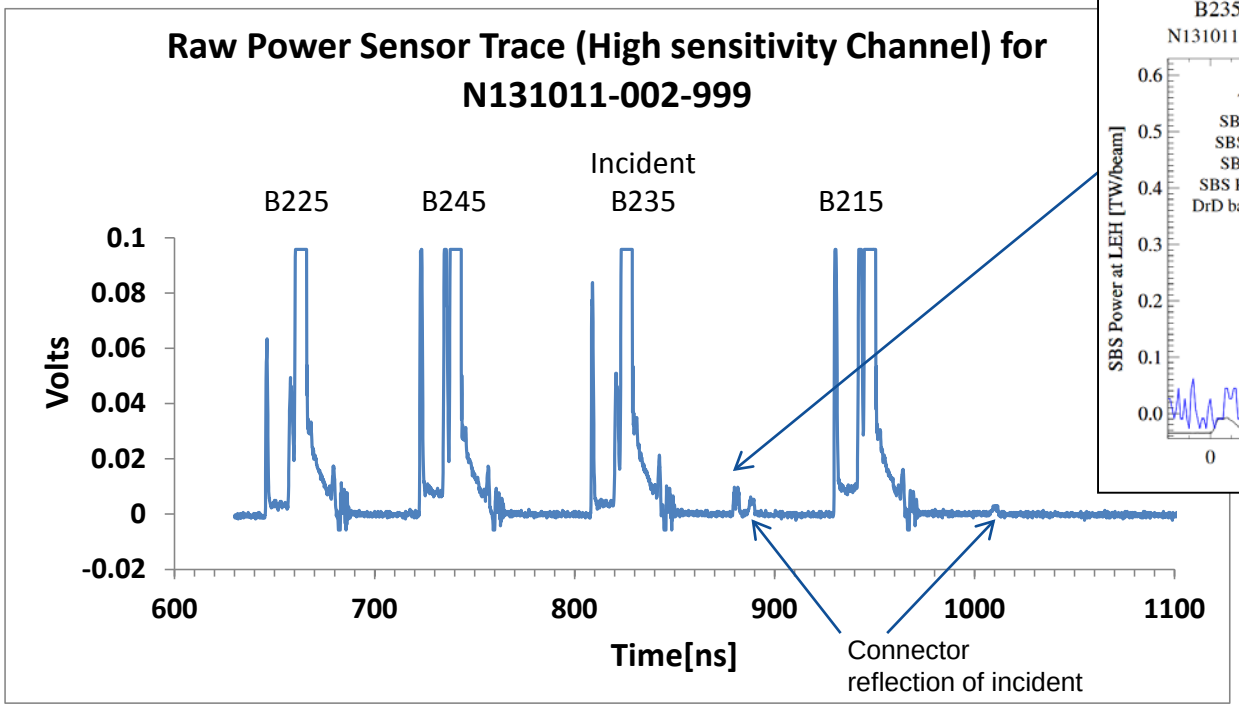
- A symmetric, high SBS experiment could damage a whole class of beams exceeding spares capability for a particular mirror type (e.g. 32 outer cone beams with LM8A & LM8AT mirrors)
- LM8 spares are consumed at a rate of 24/year, about 25% due to SBS initiated damage, 75% due to damage initiated by debris on lower beams

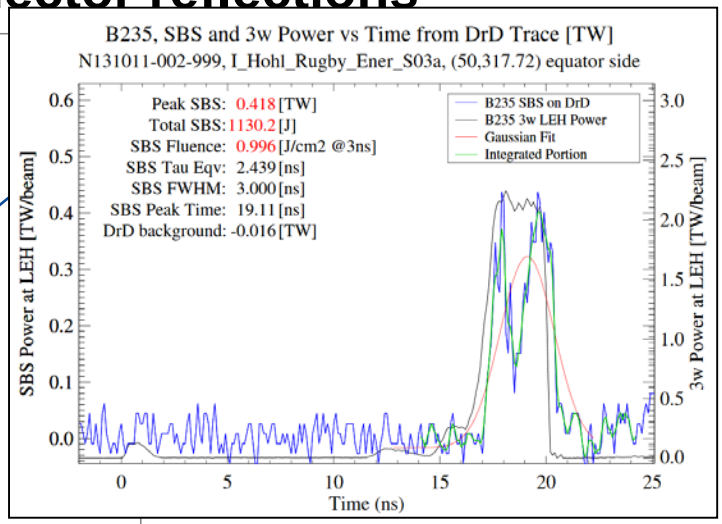
DrD power diagnostic gets signal from diffraction from GDS, either incident 3ω beam or backscattered light reflected from doubler (SHG)



SBS signal will be delayed a known amount 54.174ns

SBS extracted from highest sensitivity channel DrD power trace along with "noise" from incident pulses and connector reflections



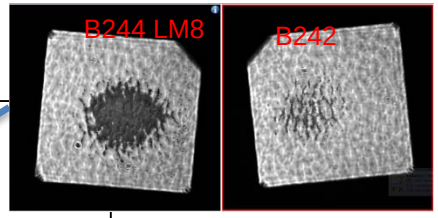


SBS delayed 54.174ns

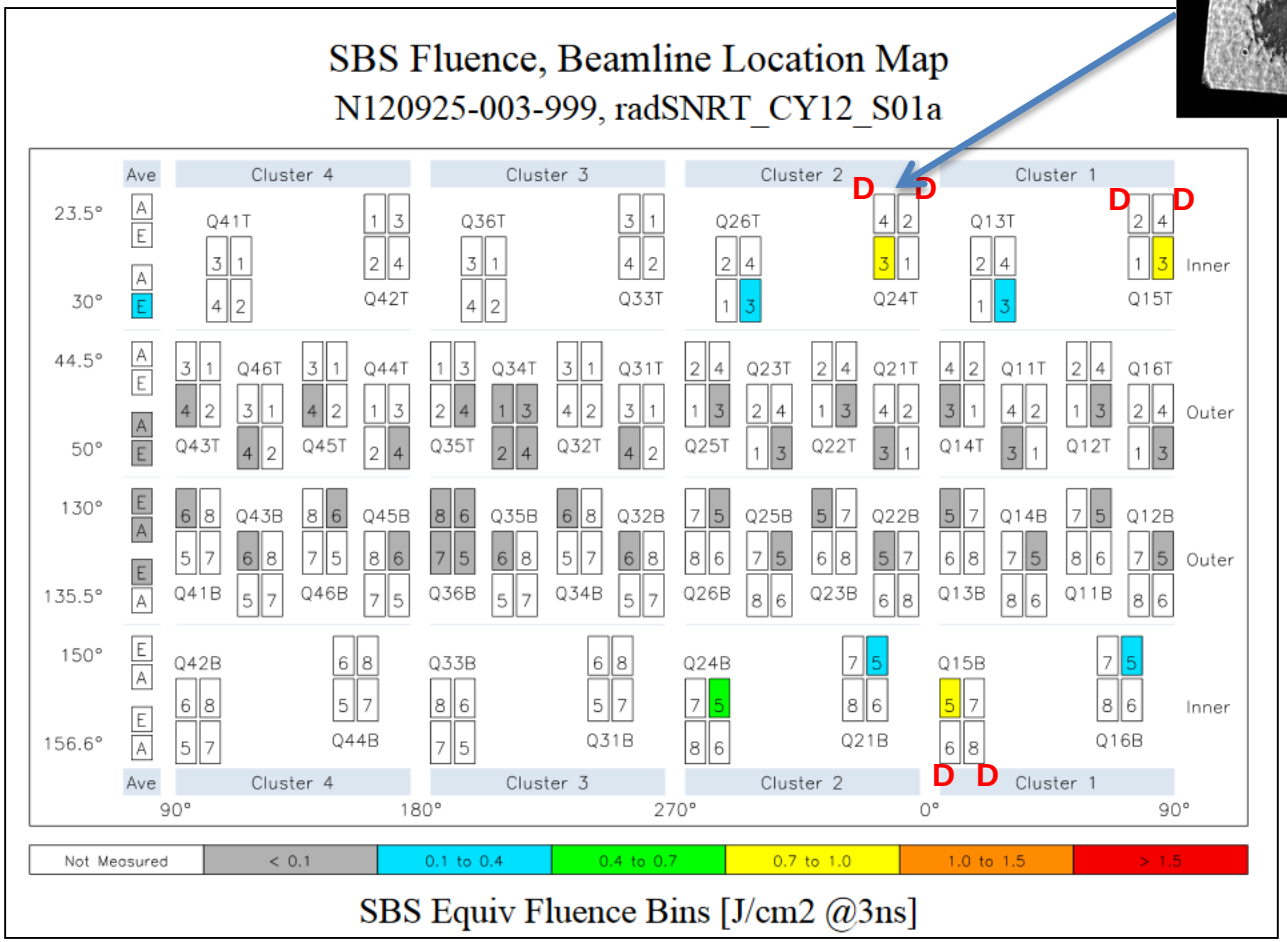
- **SBS power is "calibrated" against incident power trace and 3ω energy measurement with an estimate for the non common path differences in throughput (few % error)**

- **SHG coating reflectivity is chief source of error for high SBS signals (>0.3Jcm^{-2}):**
  - **SHG output coating reflectivity is ~4% and should be stable against the installed value**
  - **SHG input coating varies from 0 to 1% as installed, may be more sensitive to environment and may lead to a 25% error in SBS measurement**
  - **We are evaluating an *in situ* 1w measurement of input surface reflectivity to understand apparent sensitivity differences between beamlines**

SBS measurements using late time DrD signal allow us to sample 58 beams, only 1 of the type that damaged most heavily on 2012 SNRT shot (radSNRT_CY12_S01a, N120925-003-999)

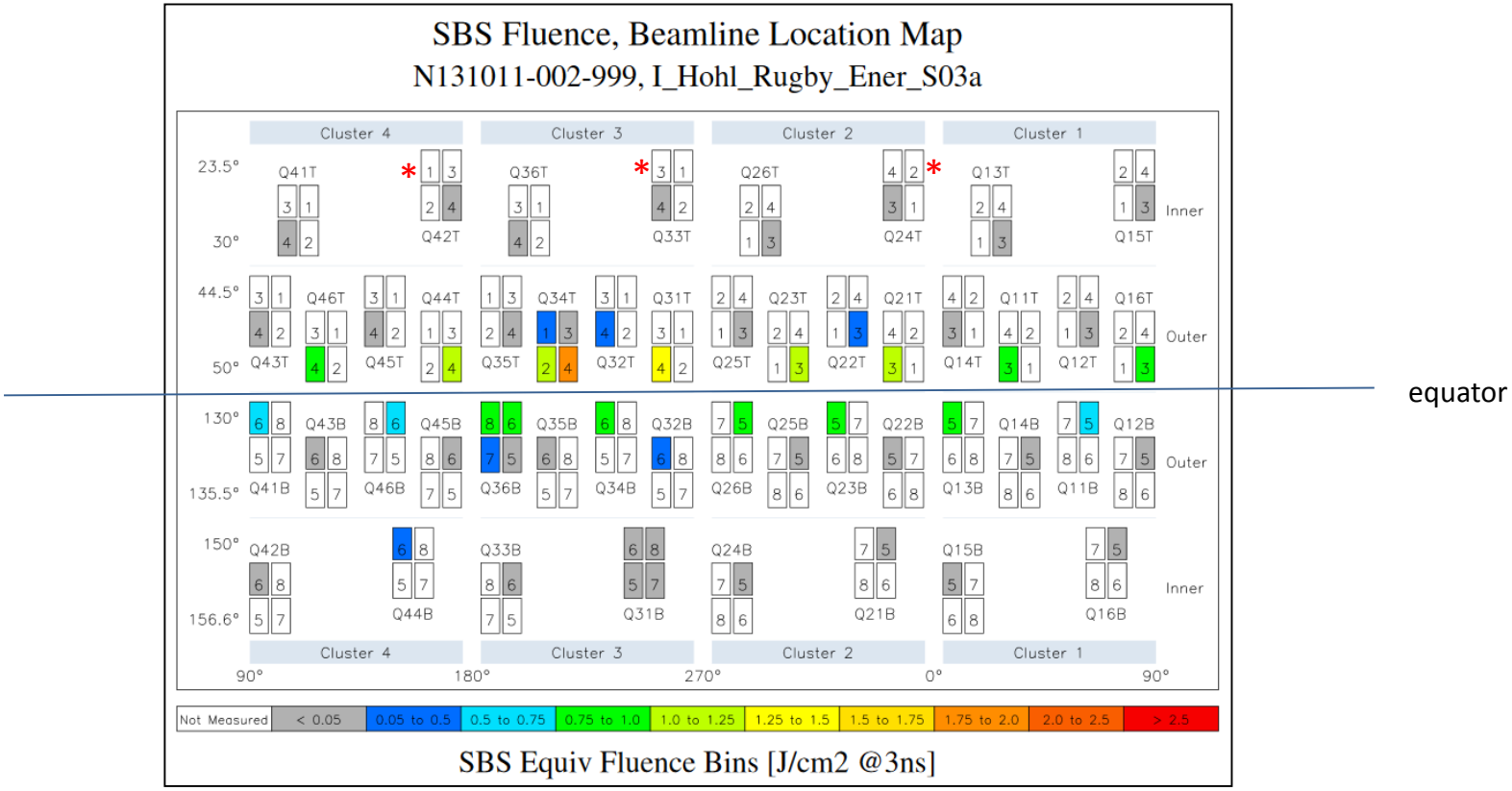


D = catastrophic damage



- **Shaded beams have DrD power sensors and SBS measurement capability, quads with no shaded beams did not participate**
  - **SBS more damaging on beams closer to pole ("23.5° and 156.5° axis side beams")**

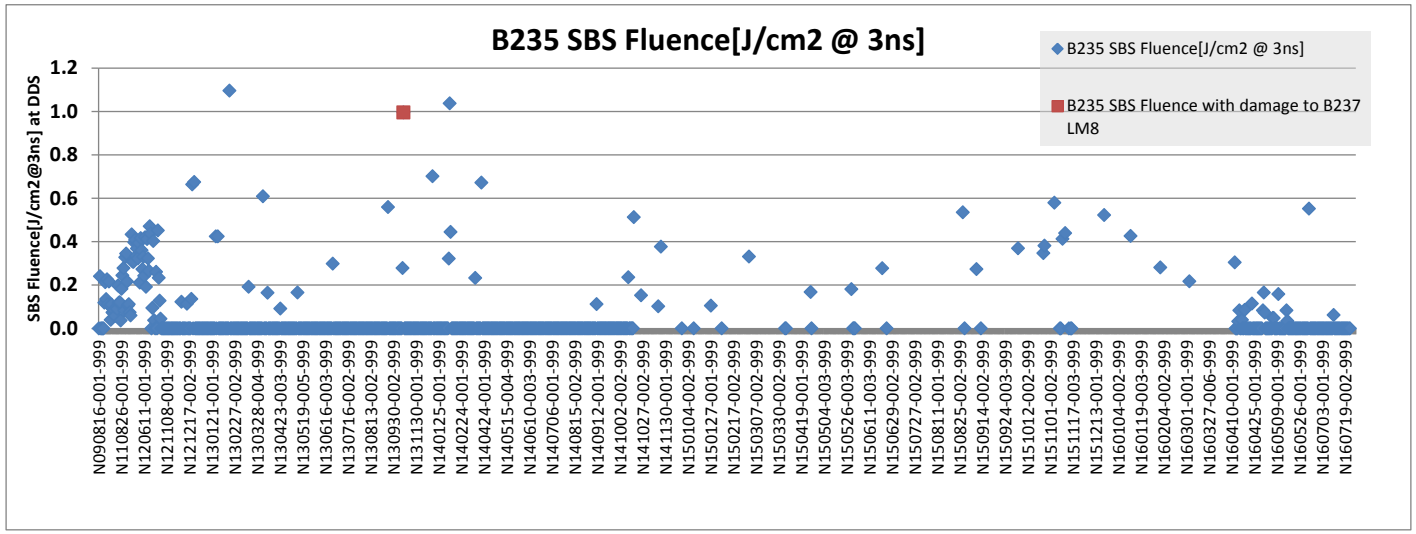
SBS is measured on 58 beams, predominantly beams on the equator side of each quad

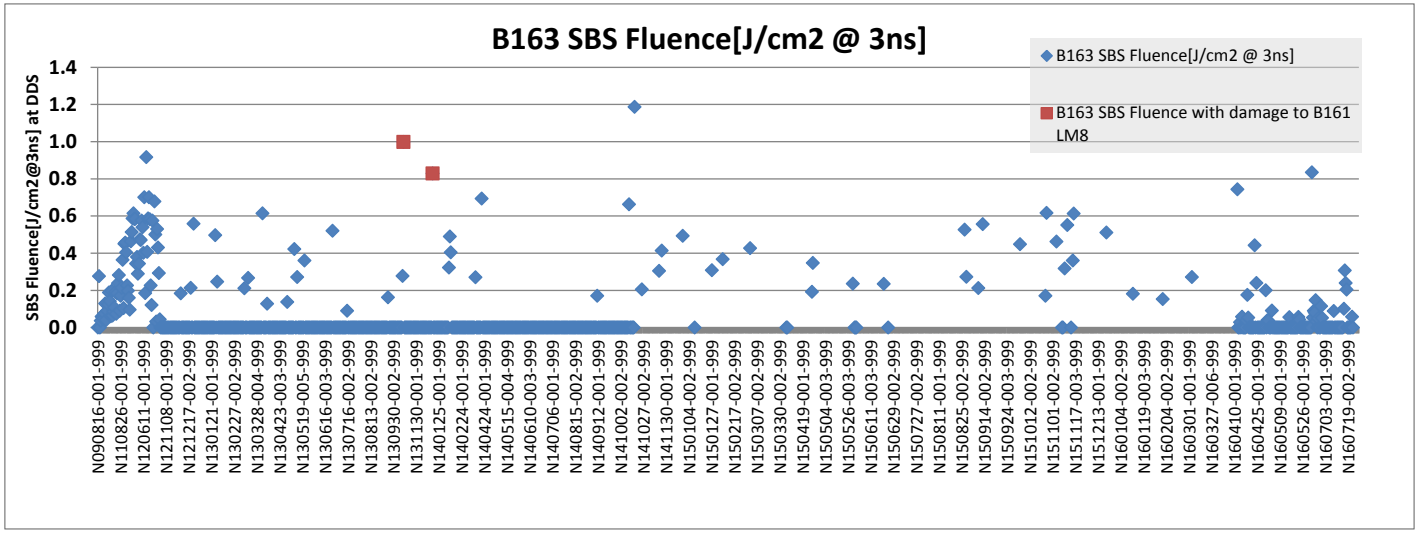


- **Shaded or colored beams have SBS measurement capability , sampling most beam types but most are on the equator side of each quad, fine for outer cone SBS but misses highest SBS on inner cone**

- *** B333 DrD capability was added, B243 DrD was moved to B242, and B424 DrD was moved to B421, in order to measure SBS on beams closer to the poles ("Axis side" of quad) for 23.5° quads, where most damage occurred for N120925-003-999 SNRT shot**

We have a wealth of data from shots that produced high SBS and/or damage to LM8s



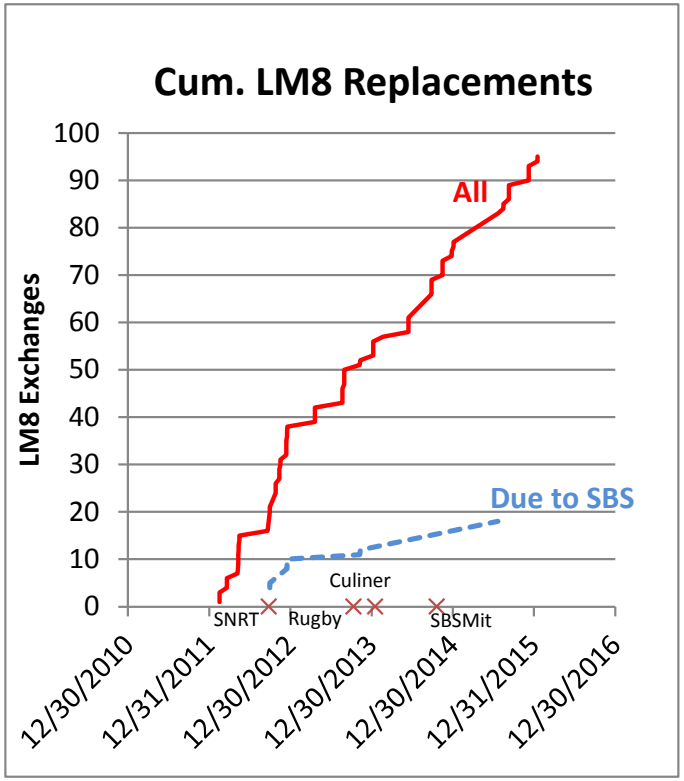


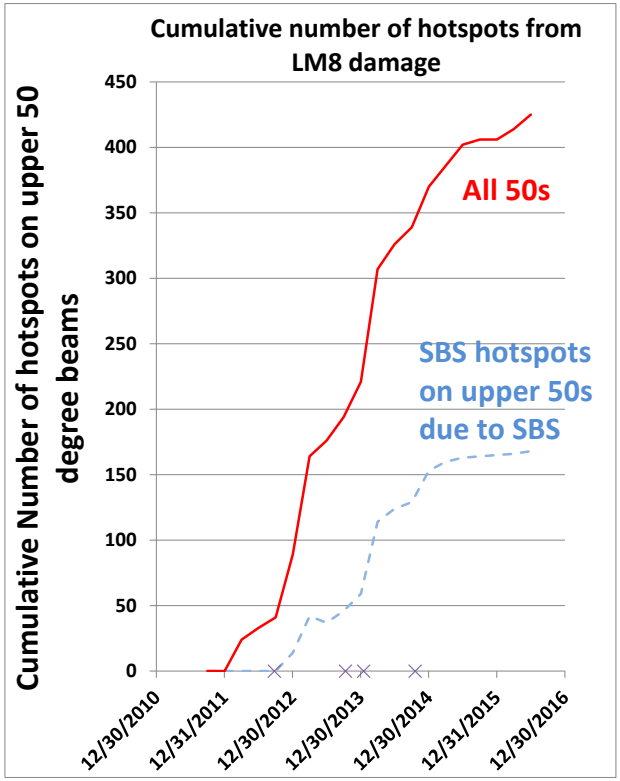
There have been two shots that produced catastrophic damage requiring immediate replacement of the LM8, at least 6 other shots have initiated damage

Shot Number	Experiment ID	Damage linked to this shot (LM8 inspection data used)	Cause of SBS damage
N120808-001-999	MXIT_8_DT_S02a	cat scratches on B153 (23.5_equator_S) corner and damage initiated on B151 (23.5_Equator_P)	Under review, B153 damage may have occurred on earlier shot
N120925-003-999	radSNRT_CY12_S01a	catastrophic damage B152(23.5_axis_S), 154(23.5_axis_P), 242(23.5_axis_P), 244(23.5_axis_S), 156(23.5_axis_S), 158(23.5_axis_P); damage initiated on B151(23.5_equator_P) note S polarization beams damaged more severely	High SBS on inner cones due to large delta lambda and CBET to inner cone, enhanced by sparse population of inner cone, target gas filled but no capsule implying better inner cone propagation
N121226-002-999	IT_0_Symcap_Warm_C1_S03a	damage initiated B342, 344	High outer cone SBS due to low delta lambda in C5H12 filled hohlraum resulting in low CBET away from outer cone, Q34T run at higher power
N130217-002-999	C_Hohl_Sym_Warm_S02a	additional damage initiated B342	High outer cone SBS due to low delta lambda in C5H12 filled hohlraum resulting in low CBET away from outer cone
N131011-002-999	I_Hohl_Rugby_Ener_S03a	catastrophic damage B135; damage initiated B161, 237, 342, 344, 464 (all 50_equator_S)	High outer cone SBS due to pointing change increasing propagation path of outer cone beams along Rugby wall plasma
N140116-004-999	I_Hohl_Key_3ShkCu_S01a	additional damage initiated B161(50_equator_S)	High outer cone SBS due to low delta lambda resulting in low CBET away from outer cone, Cu wall enhanced SBS
N140811-001-999	I_Shap_2DConA_SSw_S04a	damage initiated B241(23.5_equator_S)	Inner cone SBS high no particular reason why Q24T should be higher but it was. 23s higher with deltalambda between 23s and 30s 1.2A. A relatively low power shot (280TW)
N141020-002-999	I_Hohl_Sym_SBSmit_S06a	additional damage initiated B342	Suspect higher foot (~20%) than expected.

- Catastrophic damage = enough damage that intensification threatens the final optics for the next shot → beam must be taken out of use
- Damage Initiation = damage sites will grow subsequently and eventually produce hotspots that will either be blocked or LM8 replaced

SBS damage accounts for 25% of LM8 replacements, 30% of damage induced hotspots on outer cone beams are due to SBS (268 to date)





- Damage to LM8 will produce downstream intensification of the NIF beam ("hotspots")
  - These hotspots are an indicator of SBS damage rate
  - When there are too many to block (4 to 5) the LM8 must be replaced

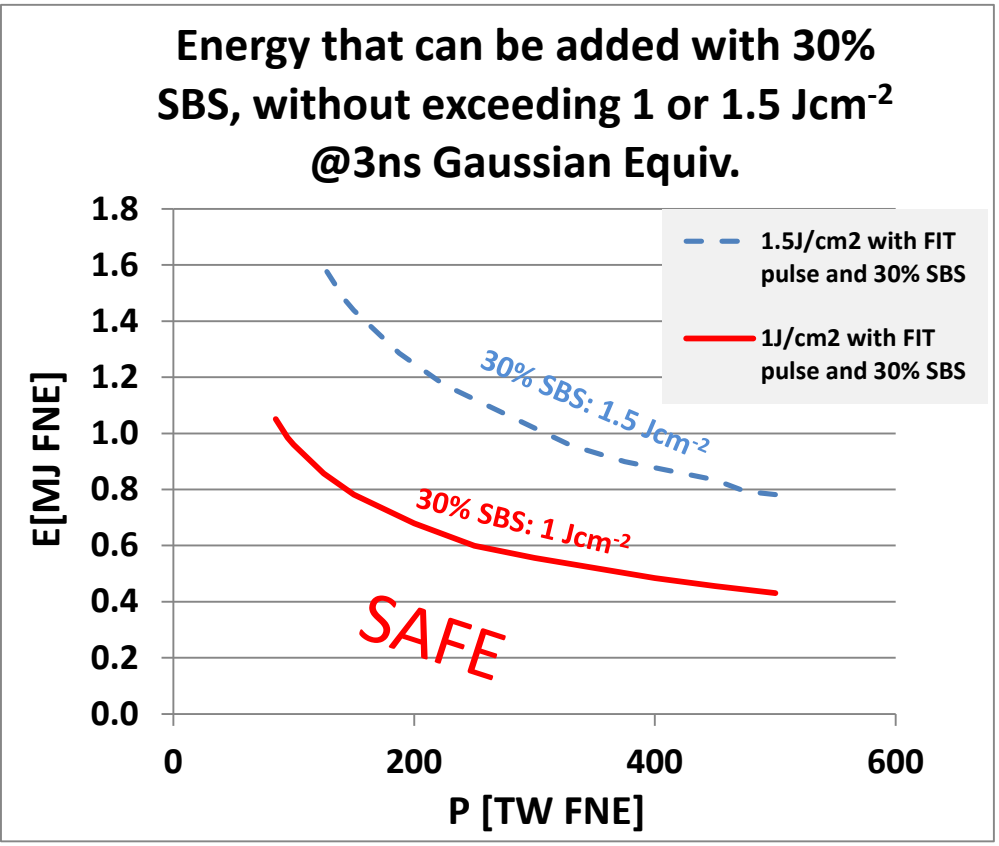
- Catastrophic damage and hotspots generation correlate with incidence of high fluence SBS events, rate has gone down in recent times

Backscatter Risk Mitigation Strategy – 30% rule

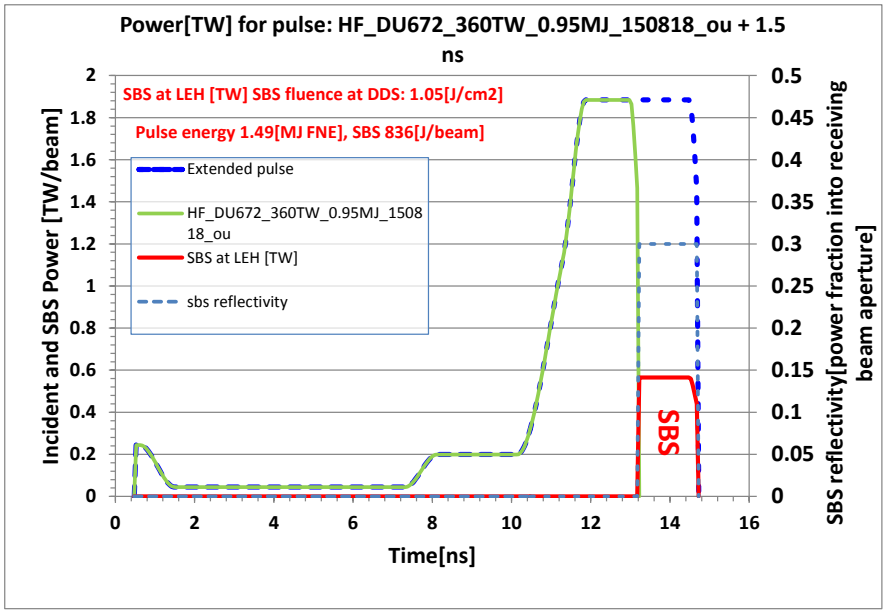
Shot Number	Experiment ID	Target	Why SBS high	delta Lambda [A]	Beams	Estimated Post Transfer Power/Beam[TW]	SBS Peak power[TW]	Reflectivity Psbs/Pincident into beam
N090809-003-999	Hohlraum_Act_E__S03m	CO2 gaspipe	pure CO2 large scalelength plasma low ion Landau damping, low SRS, small spot CPP	n/a	Q31B	1.06	0.4 - 0.49	**42%**
N090811-001-999	Hohlraum_Act_E__S01j	CO2 gaspipe	pure CO2 large scalelength plasma low ion Landau damping, low SRS, small spot CPP	n/a	Q31B	1.34	0.26 - 0.3	**21%**
N090816-001-999	Hohlraum_Act_E__S12f	CO2 gaspipe	pure CO2 large scalelength plasma low ion Landau damping, low SRS, small spot CPP	n/a	Q36B	1.07	0.27 - 0.4	**31%**
N091129-003-999	Hohlraum_Act_E__S17b	CO2 gaspipe	pure CO2 large scalelength plasma low ion Landau damping, low SRS, small spot CPP	n/a	Q36B	1.09	0.32 - 0.38	**32%**
N121226-002-999	IT_0_Symcap_Warm_C1_S03a	Warm CH filled 0.84 mg/cc scale 575 symcap	low deltalambda, long pulse, relatively high outer cone power (435TW FNE on one quad)	1.5	50 deg equator	1.6	0.32	**20%**
					Q23T	1.9	0.43	**23%**
					Q34T	2.2	0.6	**27%**
N131011-002-999	I_Hohl_Rugby_Ener_S03a	Rugby, low foot. 1.2 mg/cc He fill; some Ne fill, outers split in azimuth	repointing outer cone inward in z made laser cross plasma more conducive to SBS	1	50 deg equator	2	0.49	**25%**
N140116-004-999	I_Hohl_Key_3ShkCu_S01a	Cu-lined Scale 575 1.6mg/cm3 He fill	low ion damping in Cu, higher sound speed and less IB than gold --> longer laser path in Cu; low deltalambda, long pulse, relatively high outer cone power	3	50 deg equator	1.80	0.78	**43%**
N141020-002-999	I_Hohl_Sym_SBSmit_S06a	Au:B wall. 0.84 mg/cm3 C5H12 fill. Room temp.	suspect 20% high picket, or issues with Au-B target fab. Differed from Feb 2014 truncated Au-B shot.	3.5	50 deg equator	2	0.49	**25%**
N150301-003-999	I_Hohl_Sym_Fill_S03c	Scale 575 HDC 0.6mg/cm3 He fill	Au wall expands, modest tamping, SBS gain in gold going up late in time	0	50 deg equator	1.4	0.43	**31%**

- We have many instances of SBS recorded in a beam between 20 and 40% of estimated post cross beam transfer (CBET) power
- For an experiment outside our experience base we assume a worst case that the SBS reflectivity into a beam is 30% of the post CBET power
- The “30% rule” compares the SBS fluence with a guideline of 1Jcm-2 @ 3ns Gaussian Equivalent

Application of 30% rule can define regions of inherently safe operation for new experiments



Example of use of worst case 30% SBS assumption to estimate fluence with 1.5ns extension of keyhole experiment



- New 400TW experiments with 0.5 MJ FNE and no CBET should be below 1Jcm^{-2}
  - Alternatively a keyhole experiment with no SBS can have its pulse extended by 0.5MJ FNE (2.6kJ/beam)
  - If the limit were raised to 1.5Jcm^{-2} or a 20% max credible SBS were justified, extensions of 0.9MJ FNE (4.6kJ/beam) would be possible

Backscatter Risk Mitigation Strategy

- Setups are evaluated based on their similarity to previous shots and changes in the critical parameters that affect SBS
  - Target type and dimensions (e.g. 672 vs 575 hohlraum, cylinder or rugby)
  - Hohlraum fill density and material (e.g. 0.6mg/cm2 or addition of Ne dopants)
  - Hohlraum wall material (e.g. Cu liner, foam wall, AuB, DU etc)
  - Pulseshape (e.g. long pulses for filling hohlraums, changes to foot power
  - Beam pointing (e.g. split quads vs overlapped, rugby pointing changes)
  - Delta lambda (e.g. high Cross Beam Energy Transfer)
  - Beam participation, (e.g. SNRT, BeamCombiner)

- Large number of parameters that can be varied makes it difficult to use facility shots to define safe scalings for users for all conditions

- A better strategy might be to take on more risk with ramp up shots by allowing bigger steps and fewer shots
  - Ie increase max allowed SBS worst case to 1.2 or 1.5J/cm2 and accept more risk
  - That way we would be doing the scaling checks at the most relevant condition

Process for evaluation of SBS risk

Laser/Target Configuration	Example	Test	Additional Test	Action
Inherently Safe	Near Vac Hohlraum < 3kJ/beam	"30% rule" worst case SBS into a beam (30% of post CBET power) <1J/cm2		Approve configuration as defined
Similar to previous shot that had low SBS		Previous SBS < 0.5J/cm2 on worst beam, all cones < 0.3J/cm2 average	Similar power/energy/target/deltalambda/pointing/ per beam (expert opinion as to what similar means)	
Scaled from a previous shot that had low SBS	Scaling hohlraum fill or deltalambda, shortening pulse		scaling in direction expected to be benign or reduce SBS risk (expert opinion backed by experience)	
	Increasing pulse length, power; changing hohlraum fill or deltalambda		scaling in direction expected to increase SBS risk (expert opinion backed by experience)	
Similar to previous shot that had near damaging SBS		Previous SBS < 1J/cm2 on worst beam, all cones < 0.8J/cm2 average	Similar power/energy/target/deltalambda/pointing/ per beam (expert opinion as to what similar means)	
scaled from a previous shot that had near damaging SBS	Scaling hohlraum fill or deltalambda, shortening pulse		scaling in direction expected to be benign or reduce SBS risk (expert opinion backed by experience)	
	Increasing pulse length, power; changing hohlraum fill or deltalambda		scaling in direction expected to increase SBS risk (expert opinion backed by experience)	Recommend limited scaling that keeps worst case SBS below 1J/cm2
				Quantify impact of scaling, ie number of quads at risk vs scaled parameter, get facility acceptance of risk
Totally new experiment setup that is not inherently safe	Cu liner, Foam wall, Beam Combiner	"30% rule" worst case SBS into a beam (30% of post CBET power) > 1J/cm2		Truncate pulse (reduce energy) or modify deltalambda until worst case post CBET power * 30% is less than 1J/cm2
			Shot identified as high programmatic importance	*Quantify impact of scaling, ie number of quads at risk vs scaled parameter, get facility acceptance of risk*

- Very few experiments (~10%) get into the last two rows where modification of setup or acceptance of facility risk would occur

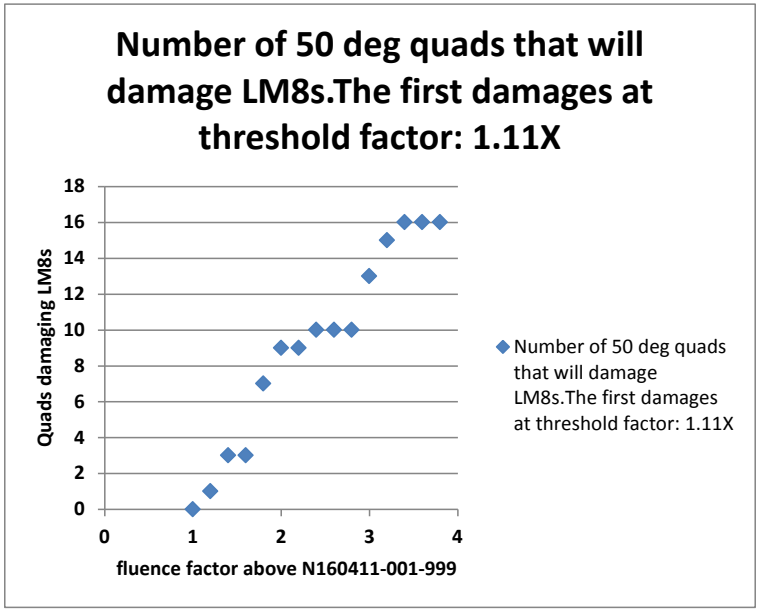
In period Jan to May 2016 the SBS review had recommended modifications to 5 out of 126 shots

Shots from 1/1/16 to date	Recommended modification?		
Experiment category at review	**yes**	**no**	**Total Shots**
Inherently Safe		24	24
Similar to previous shot that had low SBS		69	69
Scaled from a previous shot that had low SBS		21	21
Similar to previous shot that had near damaging SBS		7	7
Scaled from a previous shot that had near damaging SBS	4		4
New experiment setup that is not inherently safe	1		1
	5	**121**	**126**

- Mitigation of LM8 risk can require some users to do additional ramp up shots and so increase the cost of their campaigns
- The experiment SBS review process relates new experiment setups to prior experience and scaling of SBS damage risk as it is understood
- Review is by the Back Scatter Risk Assessment WG
  - Includes 5 core scientists, expert in Laser Plasma Interactions (LPI), who develop a consensus for any modification that is recommended

We're working on ways to use our experience over the past years to reduce the number of ramp-up shots that are required

- **Relax limit on fluence factor increase from comparable shots using historic damage fluence for each quad, rather than a hard 1J/cm^2 limit**
  - **Factor the number of quads that are at risk into assessments**



Example for N160411-001 shows rate at which LM8s should start to damage if each quad is scaled upward in fluence from that result

- **Apply a less conservative estimate of worst case SBS and CBET fractions (e.g. 30% current worst case → 20% worst case, could be a factor of 0.7 in expected fluence)**
  - **Puts more quads at risk but 20% may be more realistic for most targets**

- **Improve capability to replace damaged LM8s more rapidly**

Summary

- All proposed laser/target configurations are reviewed for Risk of Stimulated Brillouin Scatter (SBS) damage to the final 1ω transport mirror (LM8)

- SBS damage risk is different to other risks dependent on laser/target configuration as a single shot can create catastrophic damage on multiple beams, exceeding spares capability and potentially leading to long term loss of facility availability

- The review process uses NIF experience of measured SBS and monitoring LM8 damage
  - SBS power traces are recorded on 58 separate beams with 3ω power sensors (DrDs), sampling almost all beam to beam and beam to target geometries
  - Regular optics inspections characterize the damage state of the LM8s
  - When SBS fluence is ~1 [Jcm^{-2} @ 3ns Gaussian Equiv.] we see either catastrophic damage or an increase in the number of hotspots in the NIF beam caused by damage on the LM8s. Both observations ultimately lead to LM8 replacement

- The review process sorts shots into those that are:
  - Similar to configurations in our experience base and/or intrinsically safe – 90% of shots
  - New experiments or extensions of experiments that have the potential for SBS fluence at the $1Jcm^{-2}$ level – 10% of shots

- We are evaluating ways to quantify facility risk for the latter case to see if we can increase flexibility without undue consequence

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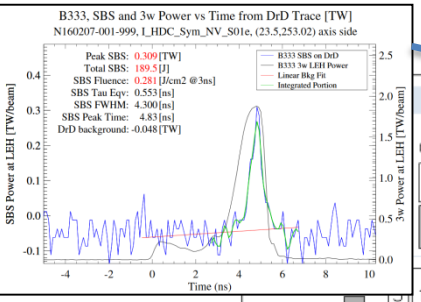
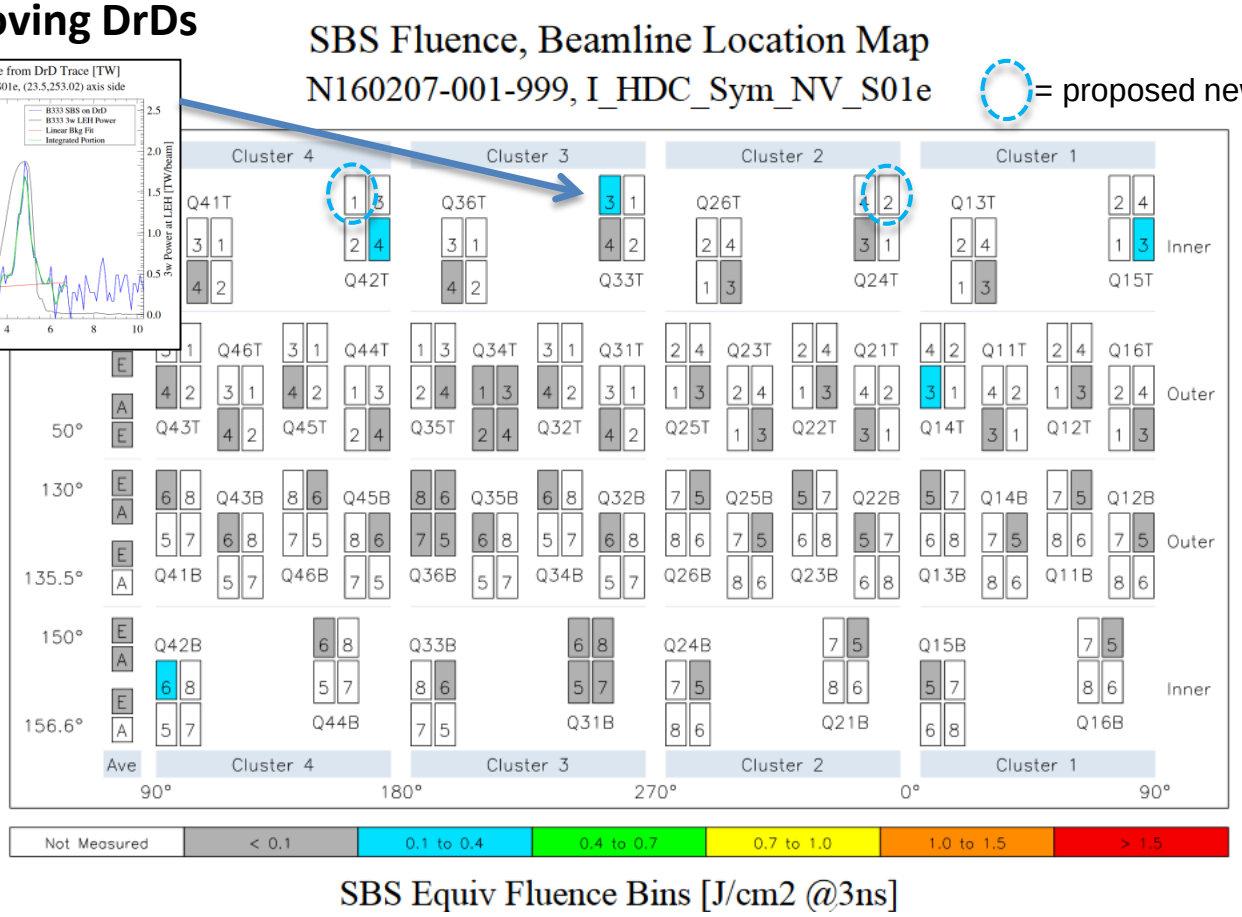
New experiments with HDC capsules in scale 672 hohlraums are beginning to show SBS on axis side 23 degree beam (B333), we may see more SBS as the experiment is scaled up in power → request is to get better coverage on the 23 degree axis side beams, 421 and 242 by moving DrDs





- **By moving two DrDs we will have 3 axis side 23.5° DrD power sensors to monitor the threat from upcoming experiments**
  - **B242 will be axis side non-PR beam, B421 will be axis side PR beam (as is B333)**