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Overview of NIF TARDIS Shots

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JoWoG 32Mat
Livermore, CA, United States
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Disclaimer

HEDP
high energy density physics

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TARDIS Post-Shot Summary

Overview of NIF TARDIS Shots JoWoG 32Mat

Jon Eggert
03/14/14

Lawrence Livermore National Laboratory • High Energy Density Physics

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Program requirements for diffraction

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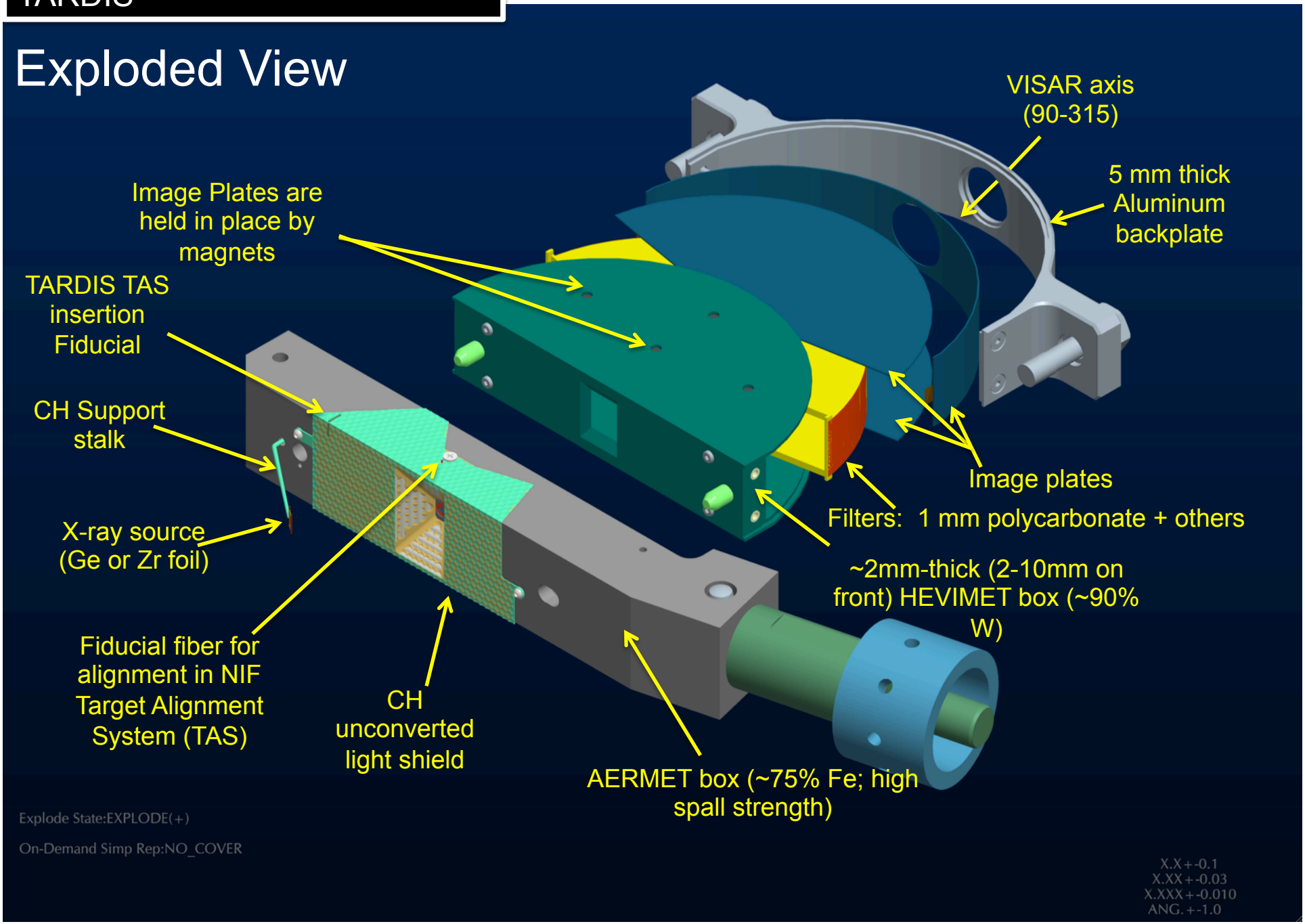
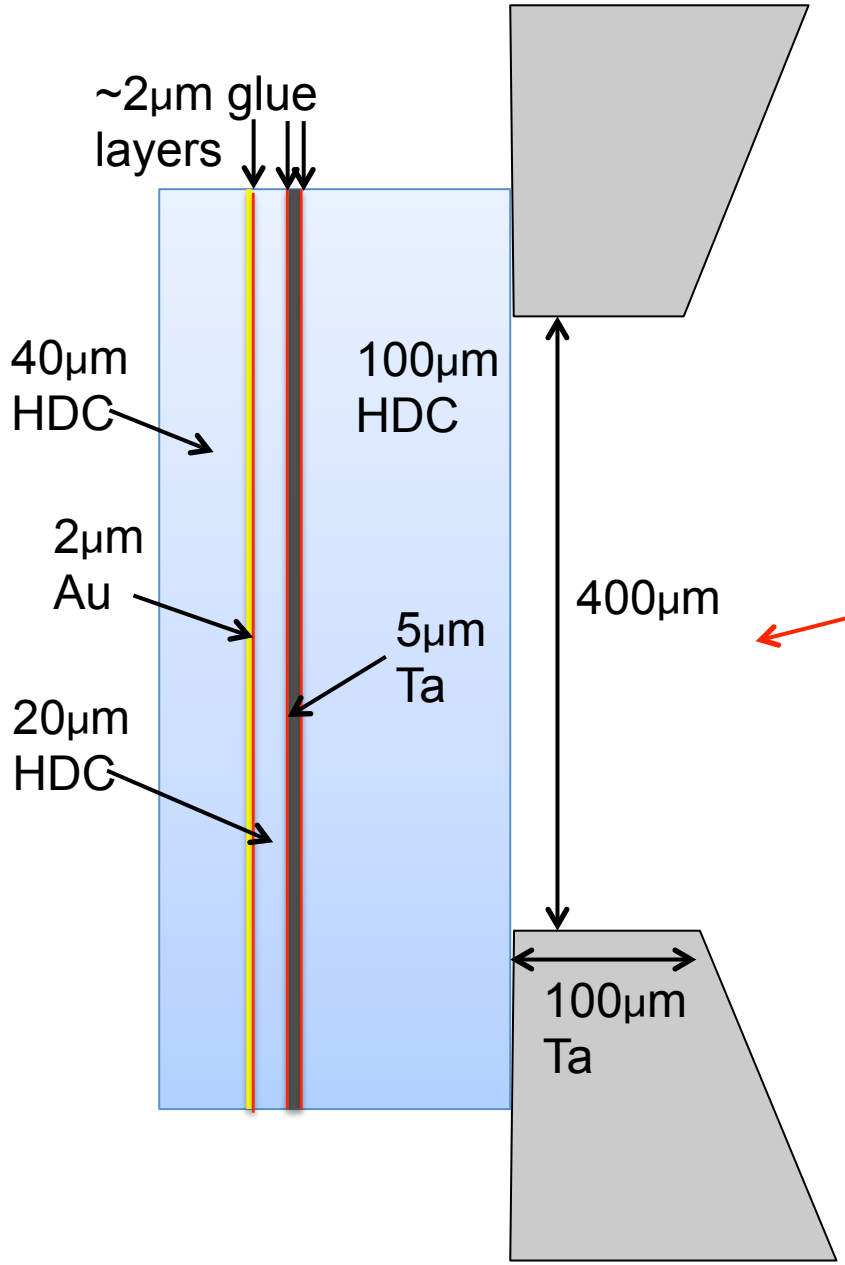
High-Z diffraction experiments with hold pressures in the range of 1-7 Mbar, pressure uncertainty less than 5%, and enough diffraction signal to differentiate between candidate phases.

TARDIS

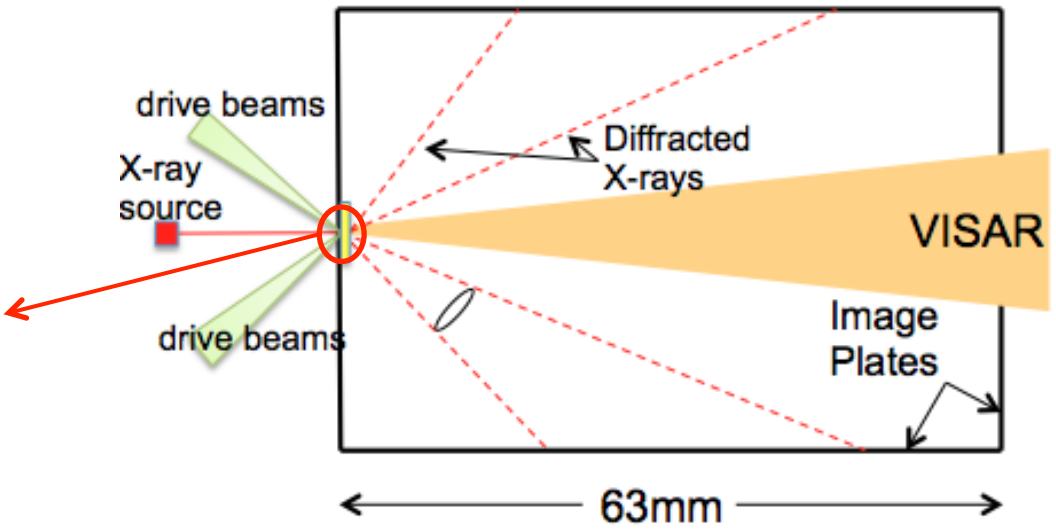
Exploded View



Target:



TARDIS interior:



Physics requirements for TARDIS to meet program requirements

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1. **5% accuracy in pressure**
   i. Visar data (fringe-shift) quality must yield 100 ps accuracy in timing and ±2% accuracy in phase. – **Demonstrated**
      a. *Routine performance at NIF.*
   ii. Uniform peak pressure (±5%) over 1.2 mm diameter central spot. – **Demonstrated**
      a. *Demonstrated on N130919 and N131203.*
   iii. We need a single crystal diamond EOS with better than 5% accuracy – **In Progress**
      a. *H_Mat_EOSHDCP_AAA scheduled for Q3 coupled with an Omega campaign on single crystal diamond EOS should achieve this calibration.*
2. **Signal / background ratio**
   i. Estimates suggest that backgrounds less than several PSL are required. – **In Progress**
      a. *These estimates need to be demonstrated and tested experimentally in Q2*
3. **Diffraction accuracy**
   i. Linewidths (FWHM) of less than 1°. – **Demonstrated**
      a. *Demonstrated for Ge (N130729, N130806) and Zr (N131209).*
   ii. Determination of 2θ to within 0.2°. – **In Progress**
      a. *Consistent with current shots and analyses, but needs further experimental demonstration in Q2, Q3, Q4.*

List of issues at High-Z workshop, plus issues we have identified since then

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1. **Physics Issues:**
   - i. Transition to a high-energy x-ray source (XRS) – **In Progress**
     - a. *Ge XRS showed good diffraction from Sn (0 Mbar) and driven Ta (2 Mbar) in FY13Q4.*
     - b. *Zr XRS showed weak diffraction (1 line) on driven Ta (3 Mbar, N131209).*
     - c. *Direct comparison of Ge and Zr to be done in Q2.*
   - ii. Ramp Drive Quality – **Demonstrated**
     - a. *Shock-less compression to 3 Mbar achieved (N131209).*
     - b. *Nearly shock-less compression to 7 Mbar achieved (N131203).*
     - c. *Epoxy bond thicknesses are critical (currently < 2μm)*
     - d. *Drive planarity over 1.2 mm to within ±3% of maximum pressure achieved in two shots (N130919, N131203).*
   - iii. Level of Sample Preheat – **In Progress**
     - a. *Ramp drive quality is good.*
     - b. *Direct tests using Pb and DU samples TBD in Q2, Q3.*
2. **Engineering Issues:**
   - i. TARDIS, drive and probe co-alignment and co-timing accuracy – **Demonstrated**
     - a. *All alignment and timing issues have been demonstrated and resolved.*
   - ii. Sample preparation (microstructure and texturing risk) – **In Progress**
     - a. *7 μm thick high-Z targets have been demonstrated (5-10 μm thickness required).*
     - b. *Tests of epoxy reactivity with thin High-Z targets is proceeding—no reaction after 45 days in ongoing test.*
   - iii. Quantification of Uncertainty – **In Progress**
     - a. *Diagnostic / target builds have met specification*
     - b. *Driven diffraction line-widths are consistent with design.*

List of issues at High-Z workshop, plus issues we have identified since then

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3. Safety and Security Issues:

i. Classified Operations (VISAR, TARDIS) – **In Progress**
   a. *Classified VISAR has been used previously.*
   b. *Classified IP handling is under discussion.*
   c. *Targets and target design are all unclassified.*

ii. TARDIS as sufficient catcher – **In Progress**
   a. *Working group established, design concepts have been presented and are under evaluation.*
   b. *Qualification shots scheduled to begin in Q3.*

iii. Pre and Post-Shot handling – **In Progress**
   a. *Evaluation of facility procedures and concerns has begun.*

4. Newly identified issues:

i. X-ray source (backlighter) has unexpectedly large high-energy background – **In Progress**
   a. *Q1 shots employed a temporary 1-mm thick Ta "patch" to partially block background.*
   b. *New Ta10W target mount will be used in Q2 and beyond.*
   c. *High-energy background is independent of XRS material, level of pre-pulse, or the use of DPPs.*
   d. *New, smaller area XRS will be tested in Q2.*

ii. IP background is dominated by target and image-plate fluorescence – **In Progress**
   a. *Q1 and all future shots use a fluorescence shield to block IP fluorescence from the direct beam.*
   b. *New, thicker pinhole designs will be used in Q2 to reduce sample fluorescence.*

iii. We need to quantify ablation plasma contribution to background – **In Progress**
   a. *Good agreement of LASNEX simulation and IP results when dominant background is ablation plasma. (N130919, N131125).*
   b. *We will compare drive-pressure scaling of ablation plasma between experiment and LASNEX in Q2.*

X-Ray source has a large amount of high-energy background

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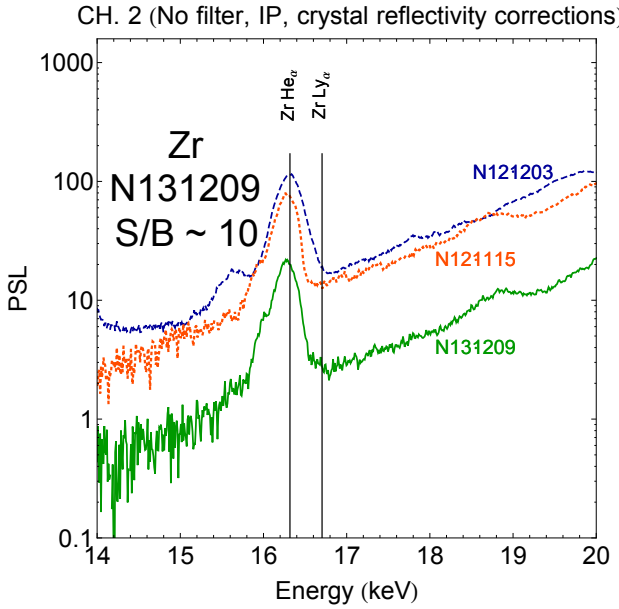
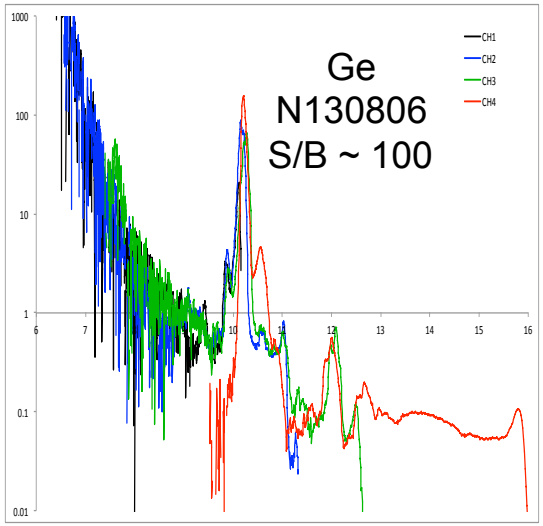
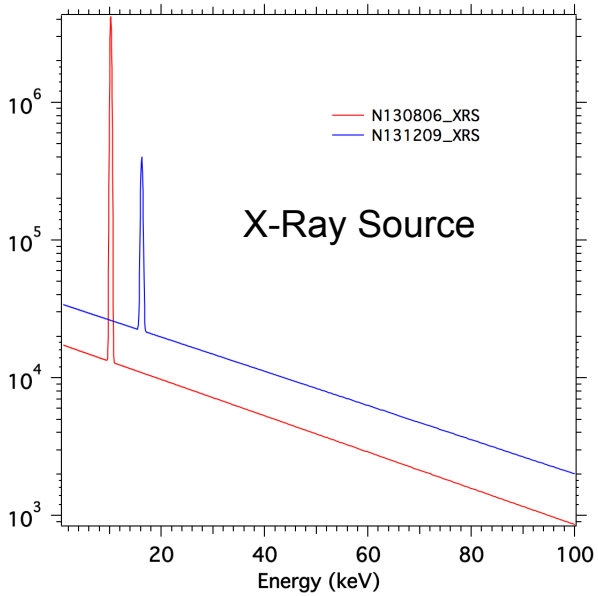
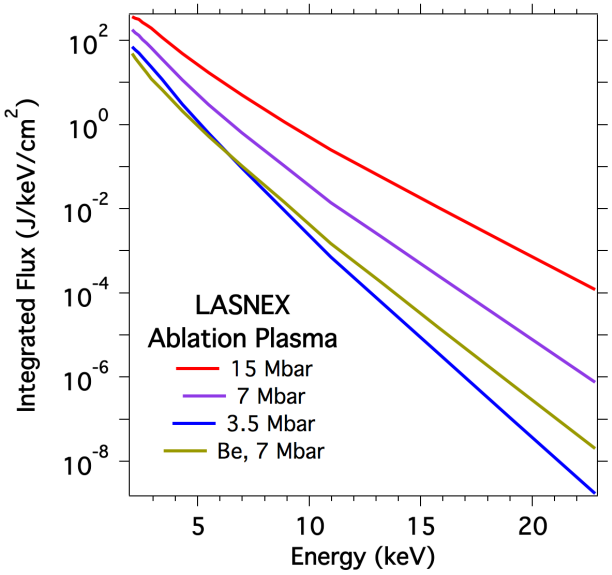






FLEX Data			
Shot	**Backlighter**	E (J)	T (keV)
N131209	**Zr (1-sided)**	424	35
N130924	**Zr (2-sided)**	458	37
N130919	**Ge (2-sided)**	392	33
N130806	**Ge (1-sided)**	216	33
N130729	**Ge (2-sided)**	370	35

$$I\left[\frac{\text{keV}}{\text{keV}\cdot\text{sr}}\right] = \frac{5\times10^{11}}{4\pi}\cdot\frac{Z^*}{79}\cdot E_{\text{hot}}[J]\exp\left[-\frac{h\nu}{kT_{\text{hot}}}\right].$$



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N130729
H_Mat_Xray_Diff_S01c

Undriven Sn
Germanium Source

N130729: Sn target, Ge x-ray source, 2.5 Mbar drive

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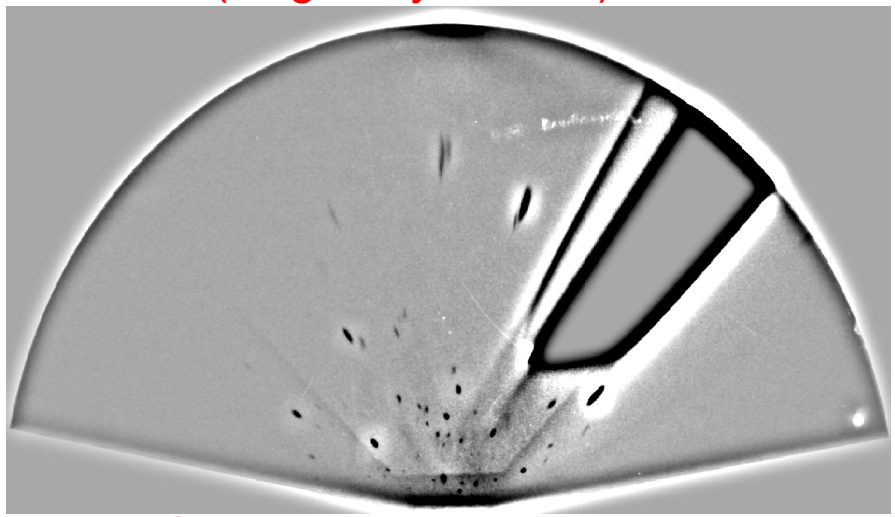
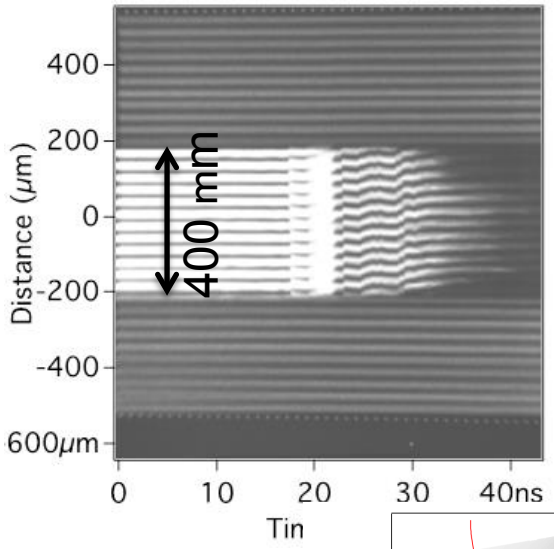
Primary objectives for this shot:

- ✓ Measure x-ray diffraction from ambient pressure Sn.
- ✓ Evaluate direct drive on NIF
- ✓ Ensure damage incurred on x-ray diffraction box is within expected levels.

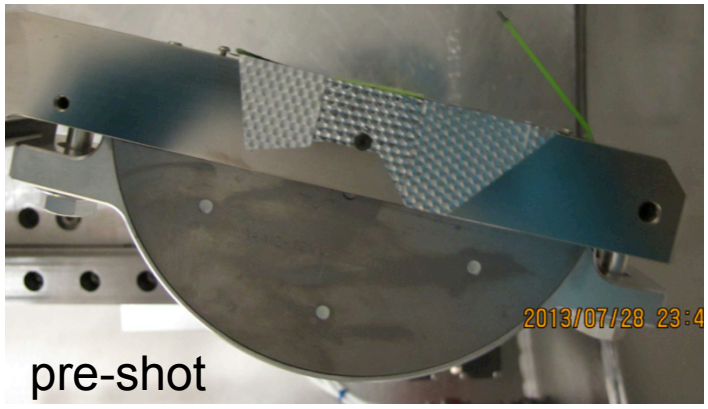
textured (single-crystal-like) diffraction:

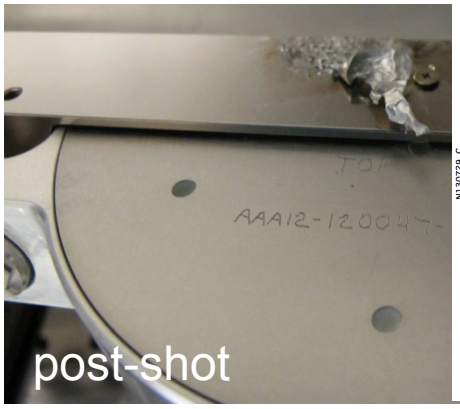


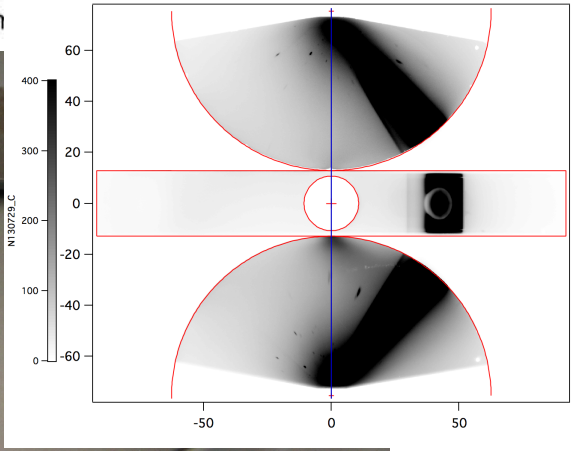
planar ramp drive:



TARDIS survived:







N130729: Sn target, Ge x-ray source, 2.5 Mbar drive

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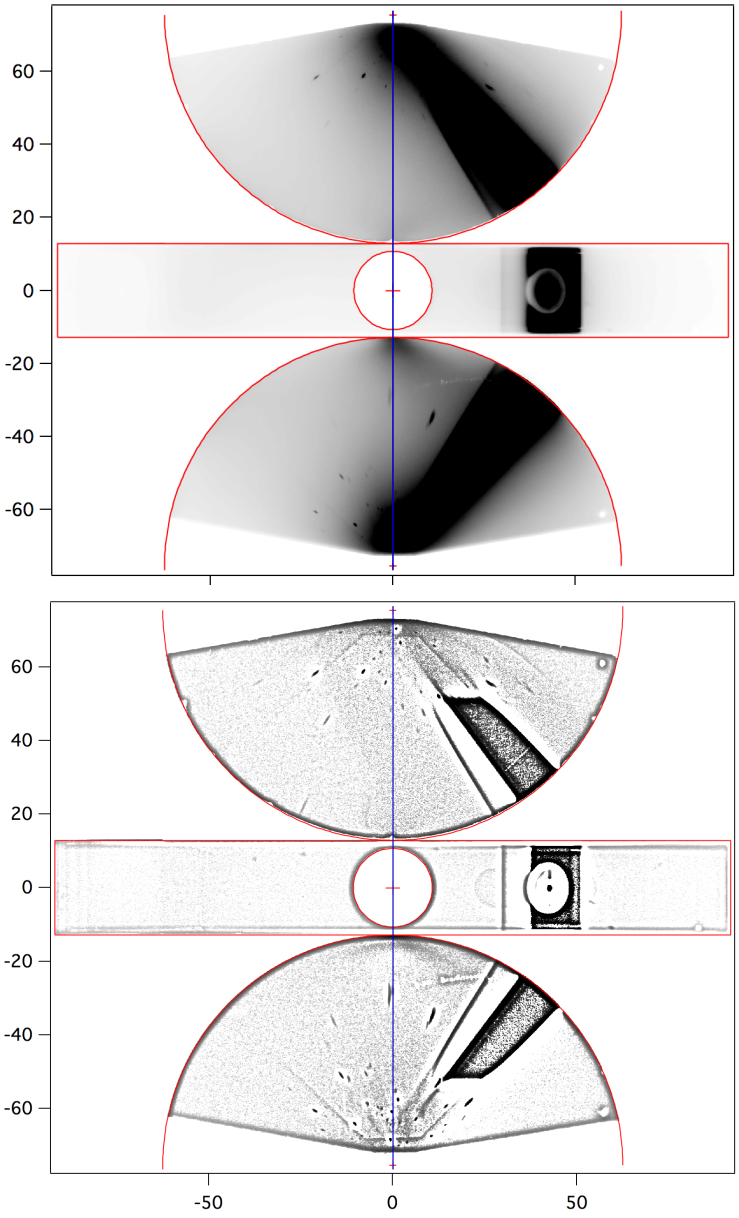

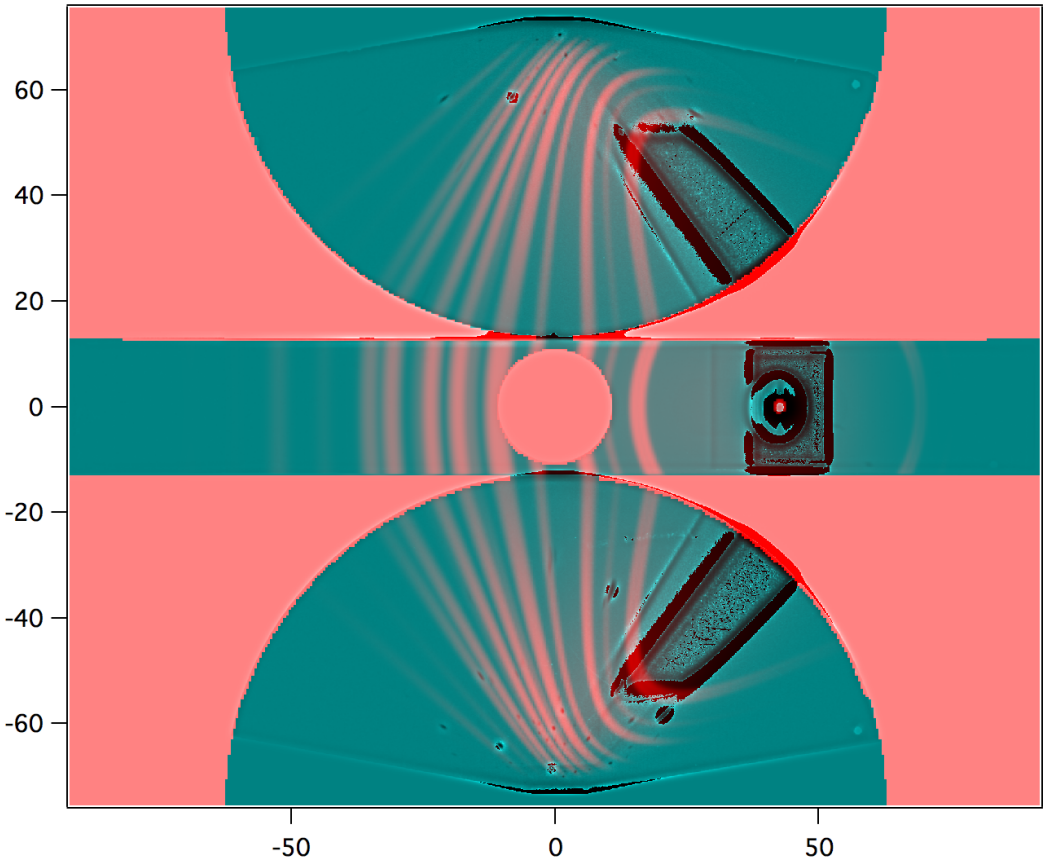

- Excellent diffraction was observed on undriven Sn
- Large transmission through AERMET body
- Due to large amount of high-energy background (FFLEX: E=370J, T=35keV)

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N130806
H_Mat_Xray_Diff_S03a

2 Mbar Ta

Germanium Source

N130806: Ta target, Ge x-ray source, 2.5 Mbar drive

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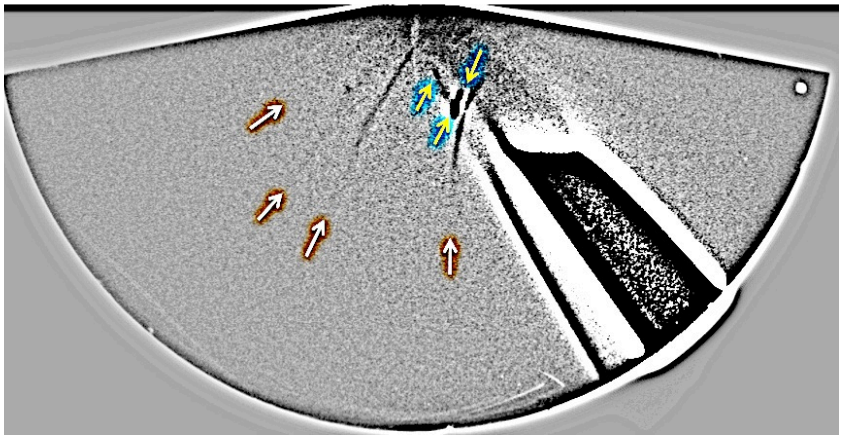
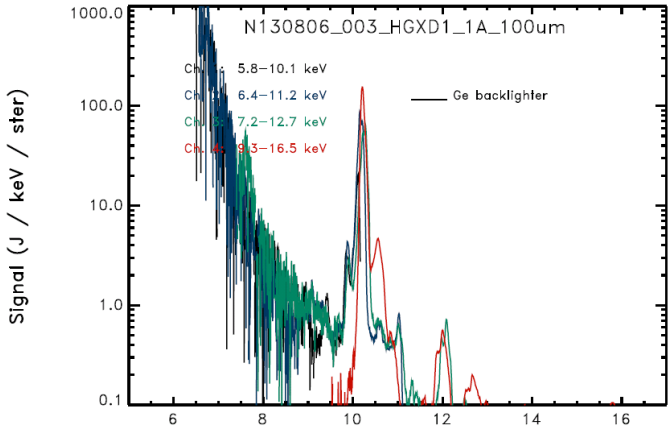
Primary objectives for this shot:

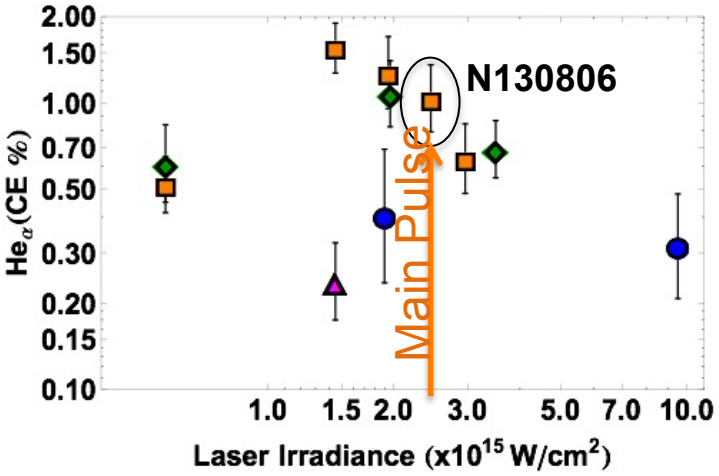
- ✓ Measure x-ray diffraction from a driven Ta target.
- ✓ Evaluate performance of backlighter with phase plates on all beams (single-sided drive).

up to four peaks from driven Ta:



Super snout data:
Ge line source with consistent conversion efficiency:





N130806: Ta target, Ge x-ray source, 2.5 Mbar drive

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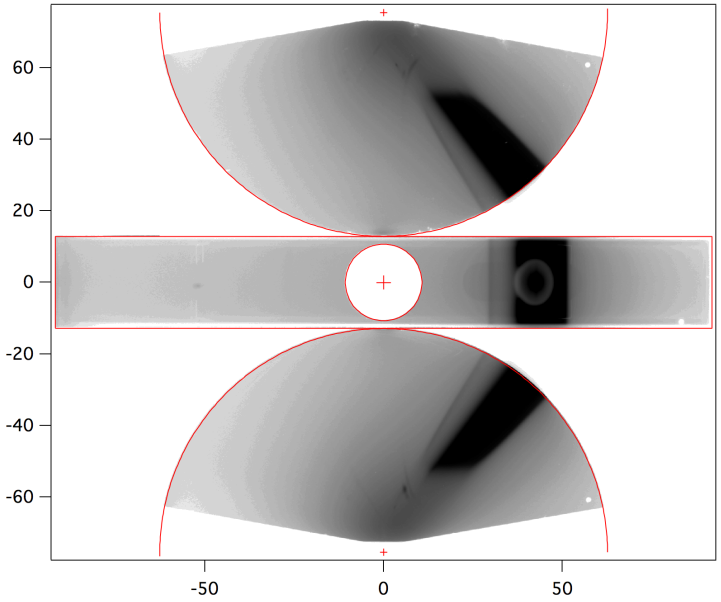

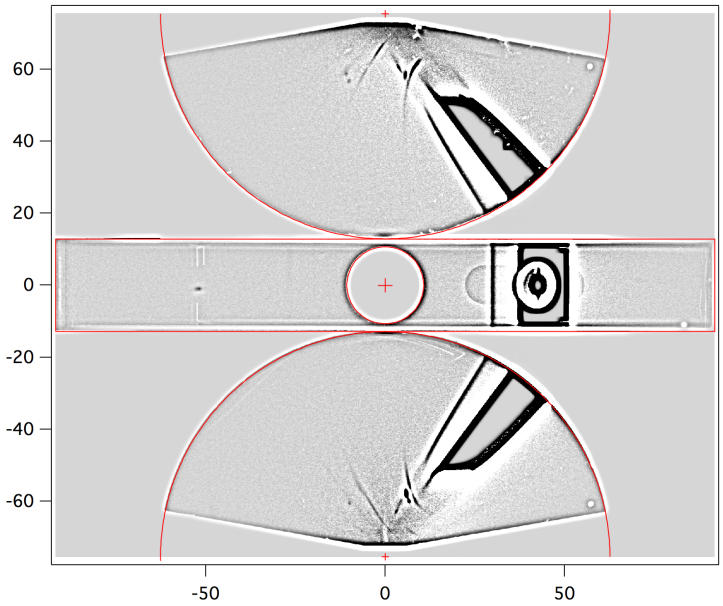

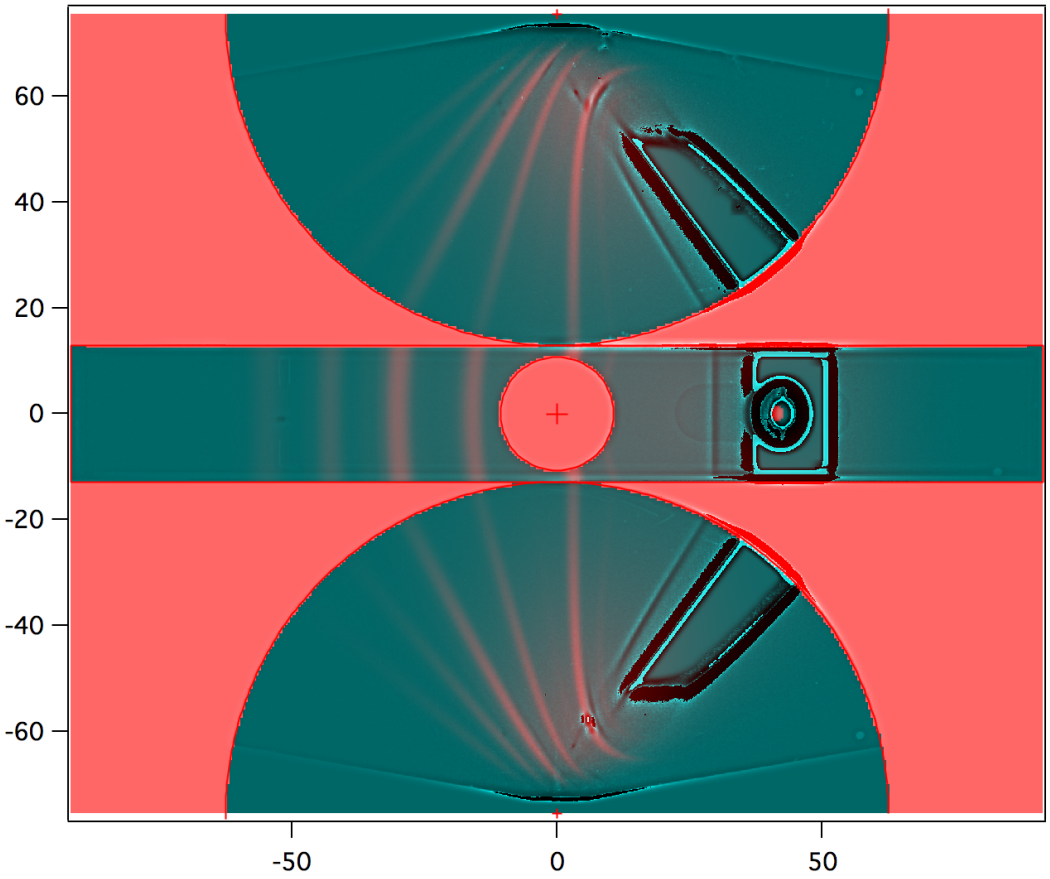

- Diffraction was observed on Ta at 2Mbar
- Large transmission through AERMET body
- Due to large amount of high-energy background (FFLEX: E=216J, T=33keV)
- Phase plates did not eliminate background

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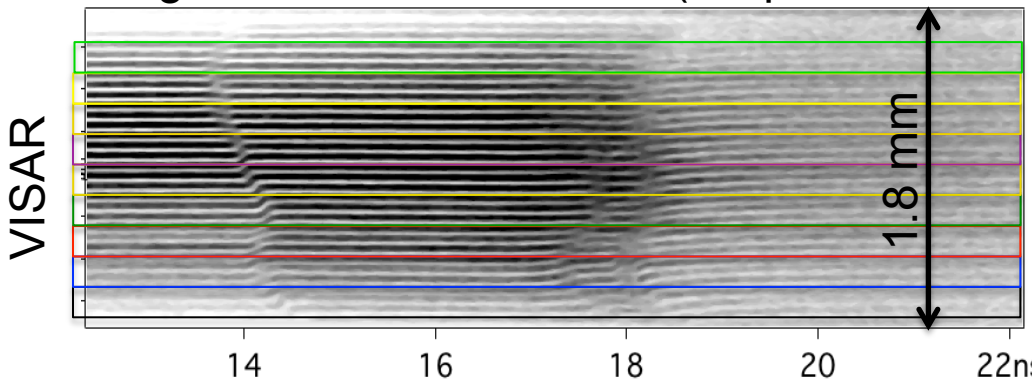
N130919
F_Diff_Xray_Diff_S01a

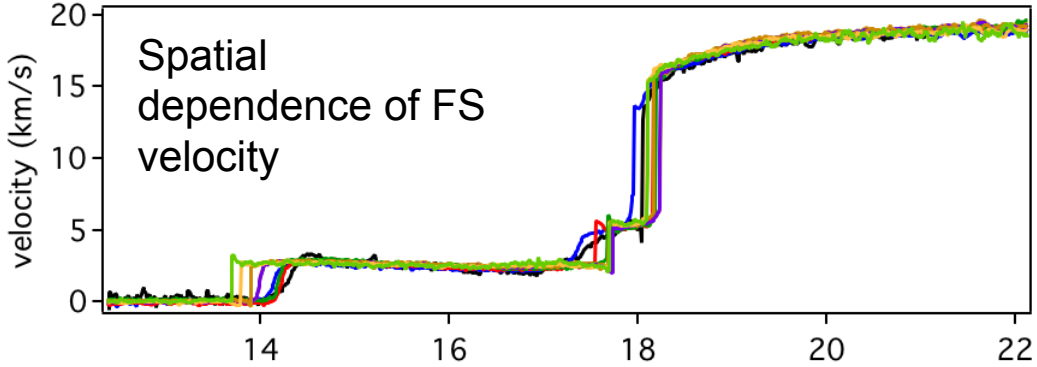
7 Mbar diamond
Germanium Source
Large (1.8mm) pinhole to demonstrate drive planarity

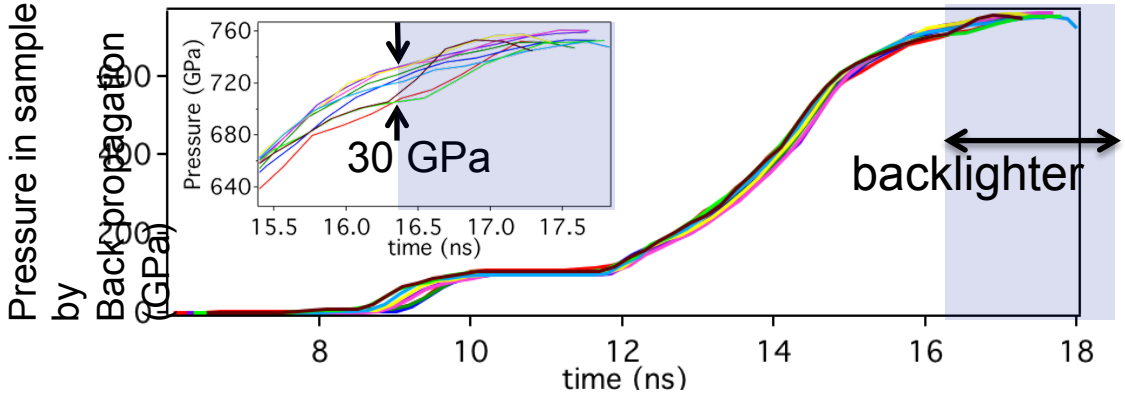
N130919: C target, Ge backlighter, 7 Mbar drive

Primary objectives for this shot:

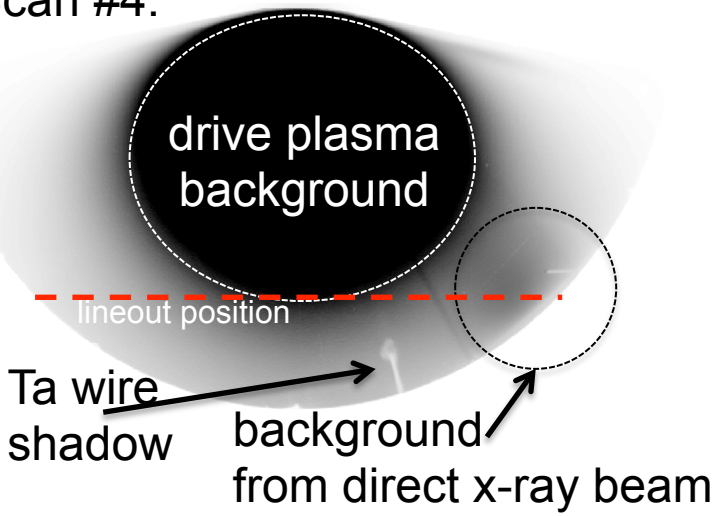
- ✓ Quantify drive planarity (1.8 mm pinhole).
- ✓ mitigate high energy background using Ta patch
- ✓ background characterization (suspended Ta wire)



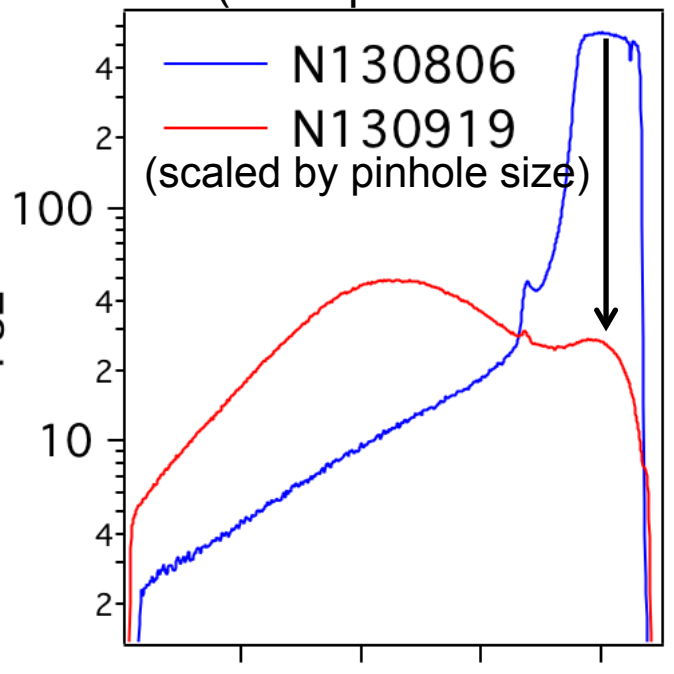




Scan #4:



Direct x-rays through Aermet reduced (drive plasma increased



N130919, Image-Plate Analysis

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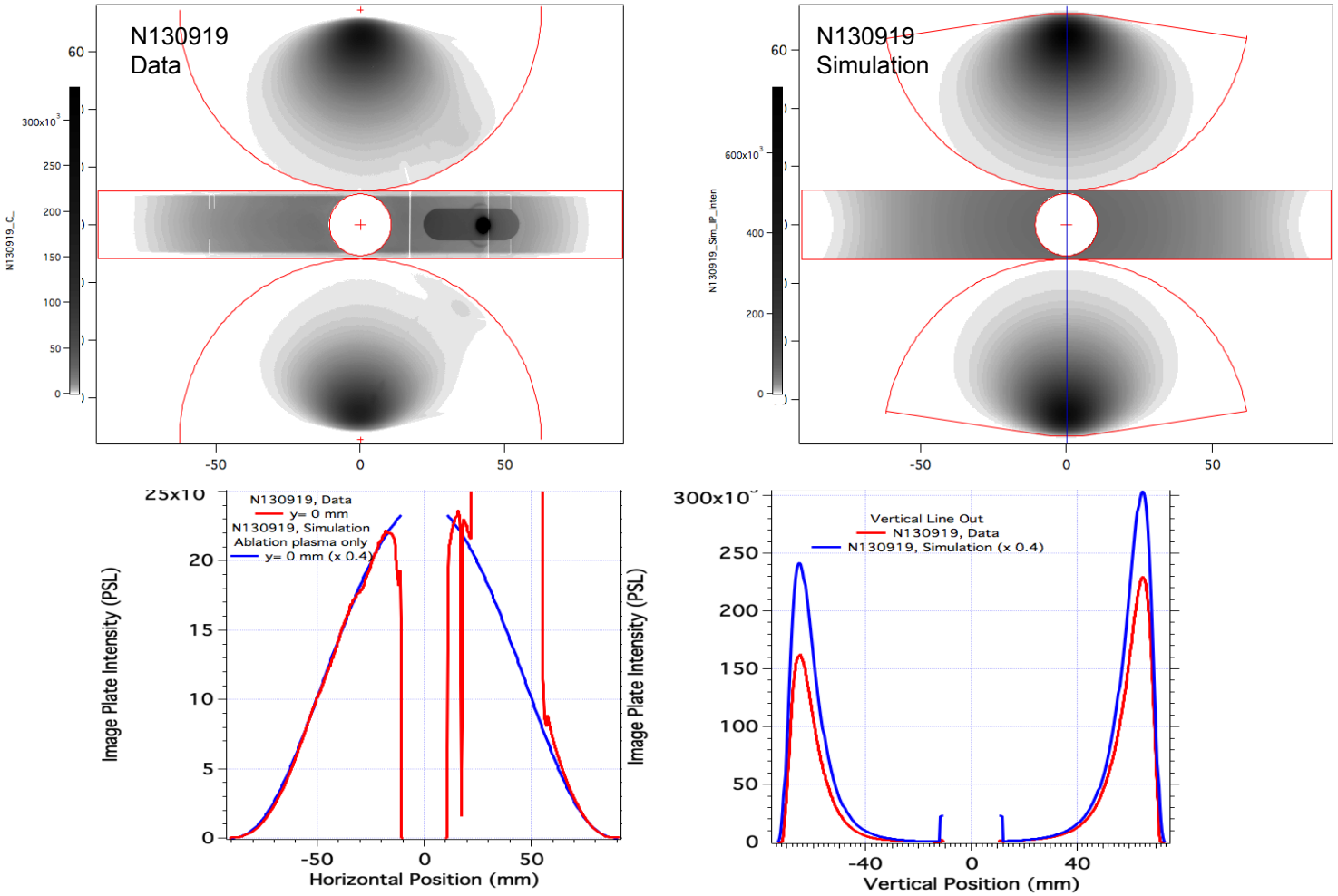
Image plate N130919 data and simulation comparison.



Large (1.8mm) pinhole leads to dominant background source being due to ablation plasma

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N130924
H_Mat_Xray_Diff_S08a

6.4 Mbar Ta

Zirconium Source

N130924: Ta target, Zr backlighter, 7 Mbar drive

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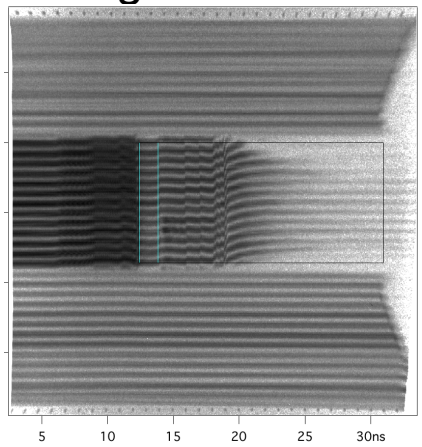
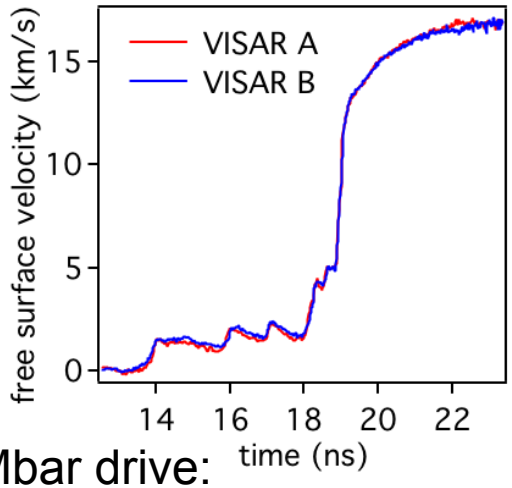
Primary objectives for this shot:

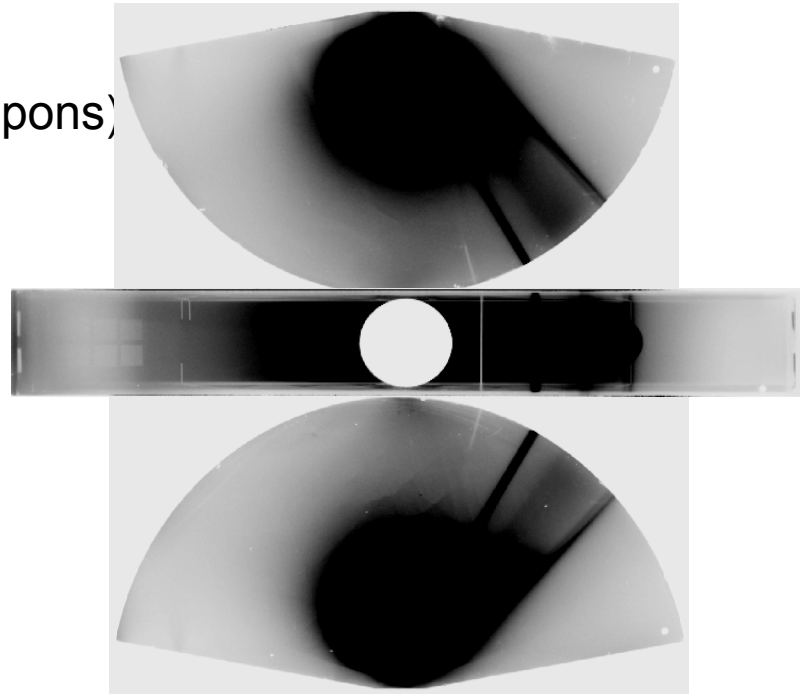
- ✓ 7 Mbar drive development
- ○ Zr backlighter development
- ✓ background characterization (Ta wire, filter coupons)



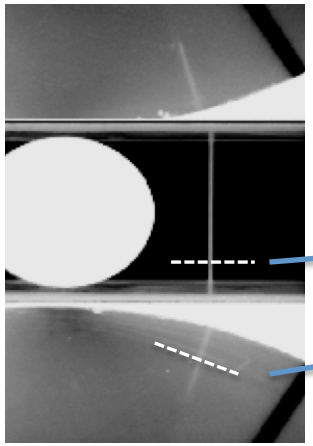


Wave profile for 6.4 Mbar drive:

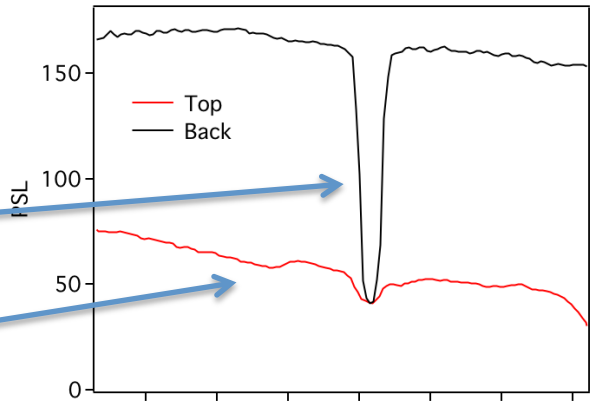
Image plates:



Ta wire shadow:



IP lineouts of 500 mm Ta wire shadow



40 PSL background level in regions shadowed by 500 mm Ta wire indicate spatially uniform, high-energy x-rays coming through the box (chamber glow through Al Back Plate, or HeviMet transmission)

N130924: Ta target, Zr backlighter, 7 Mbar drive

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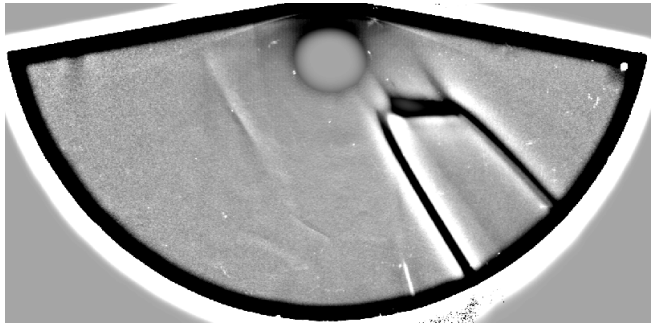
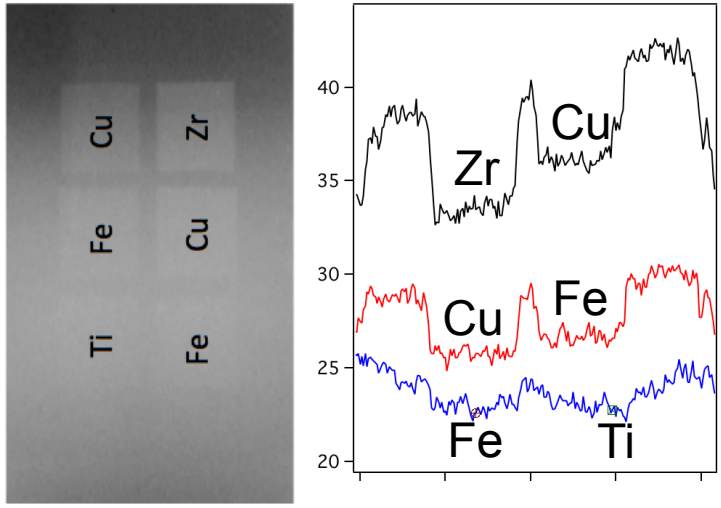
What else we learned:

1) We see no diffraction signal; we do not know if we have line emission from Zr because we had to drop SuperSnout. Zr backlighter still needs development.

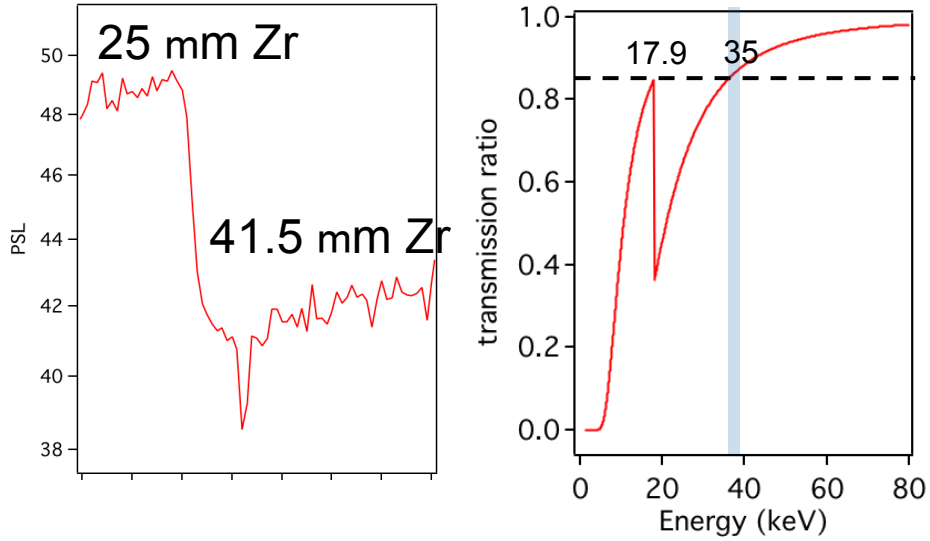


Background-subtracted image

2) Low contrast for on filter coupons suggests high-energy x-ray source



3) Relative transmission through variable-thickness Zr indicate high-energy source



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N131125
H_Mat_TARDIS_Bkgd_S01

7 Mbar Ta
No Source
Ross Pairs

N131125, Image-Plate Analysis

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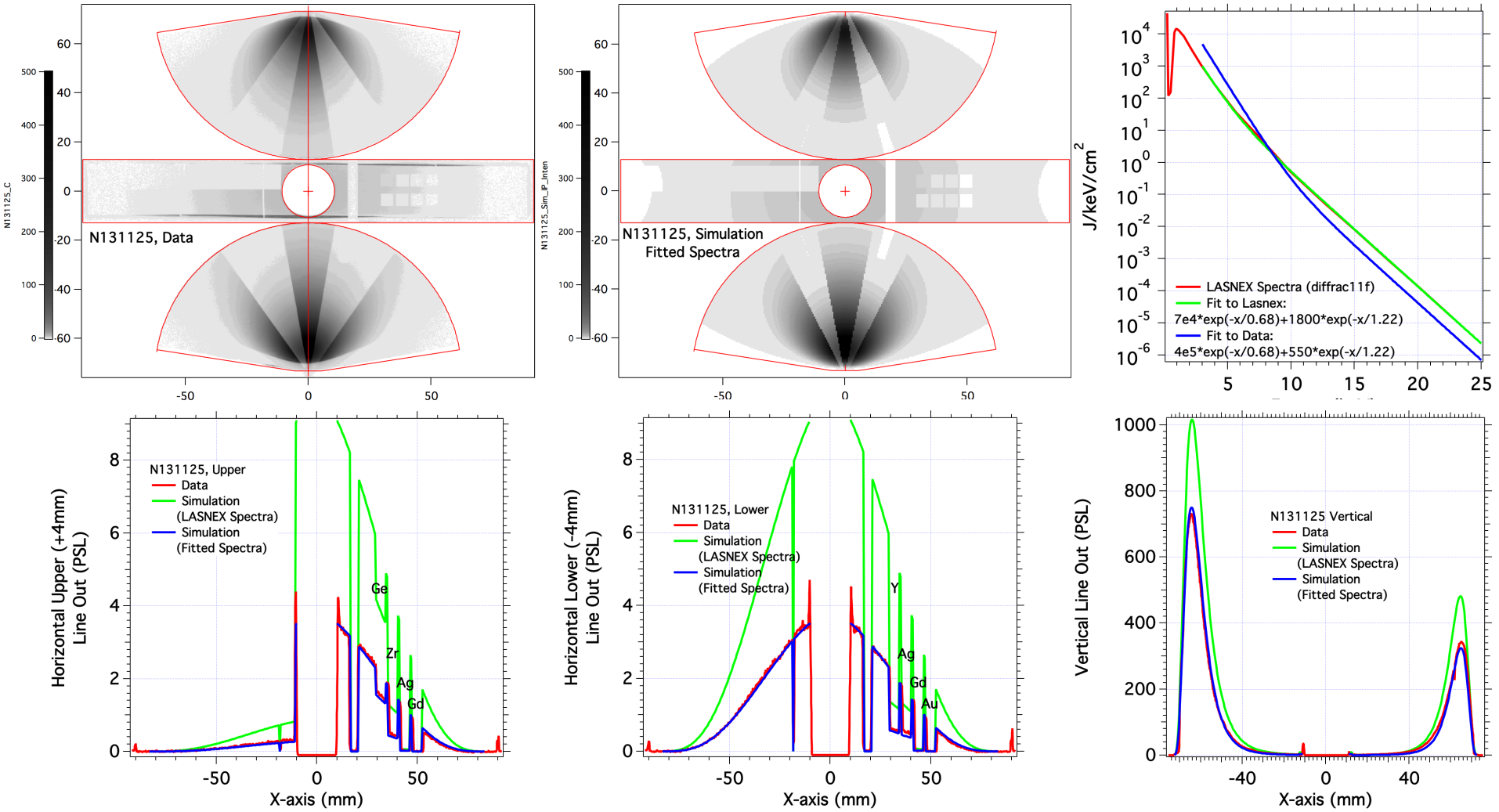
No backlighter: Image plate N131125 data and simulation comparison.

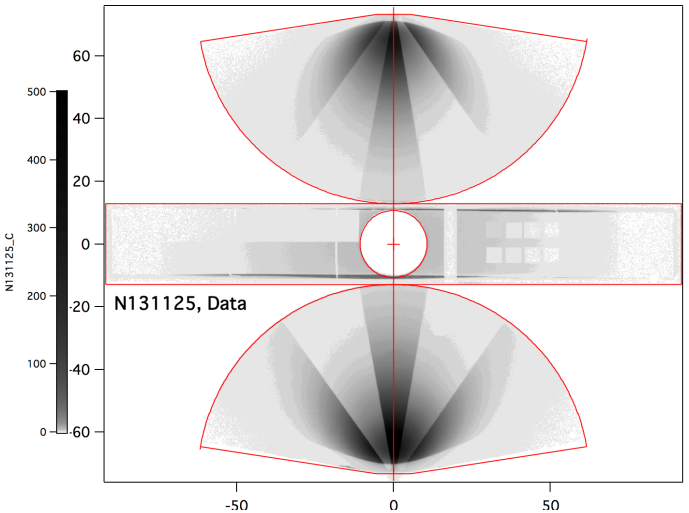


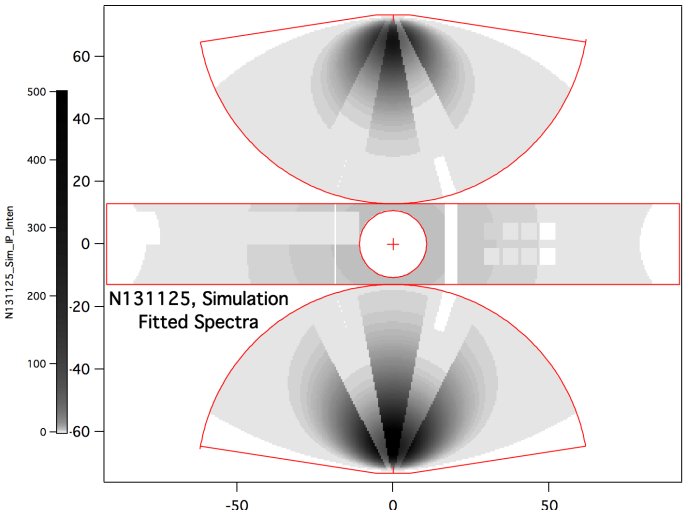
Slight change in LASNEX-predicted ablation-plasma spectra gives excellent agreement with image-plate data.

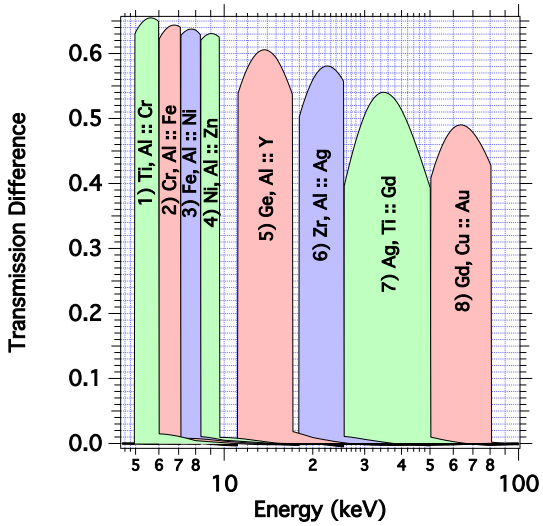
12/10/13, Jon Eggert

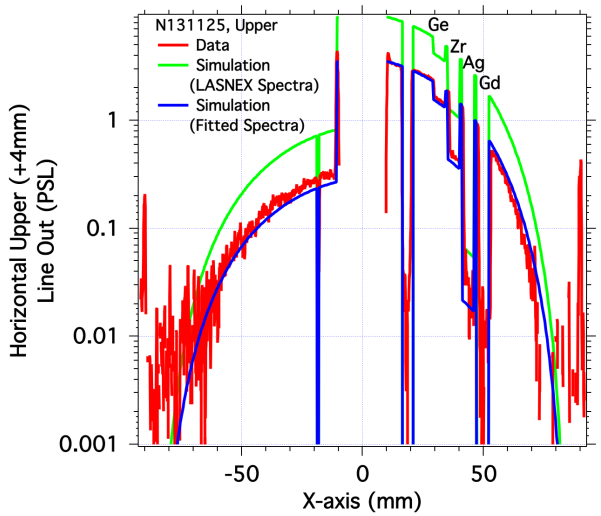
N131125, Image-Plate Analysis

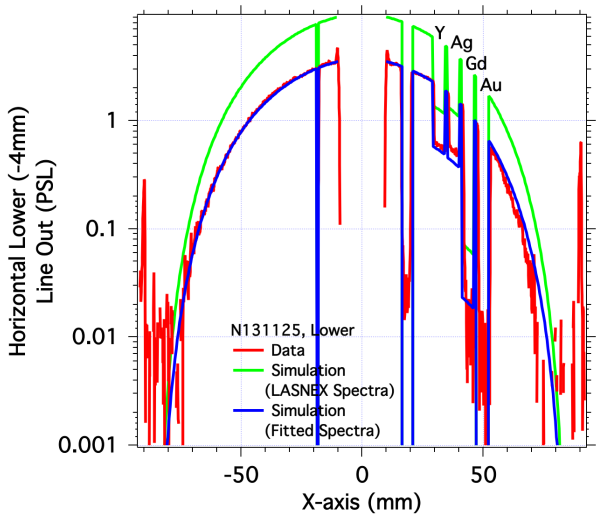
Image plate N131125 data and simulation comparison.

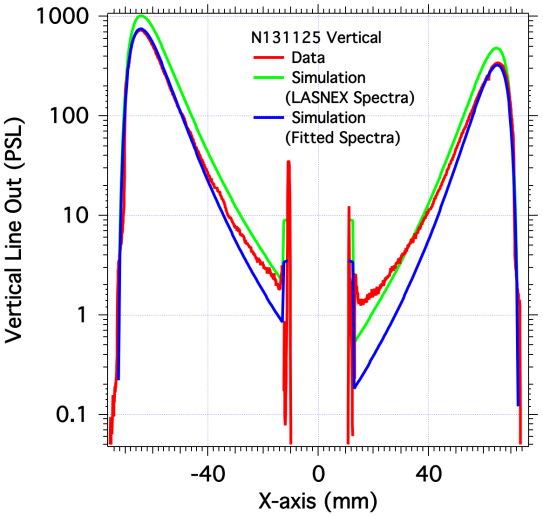












Slight change in LASNEX-predicted ablation-plasma spectra gives excellent agreement with image-plate data.

12/10/13, Jon Eggert

N131203
H_Mat_DiffDrv_S01

12 Mbar Ta drive
No diffraction
No X-ray Source

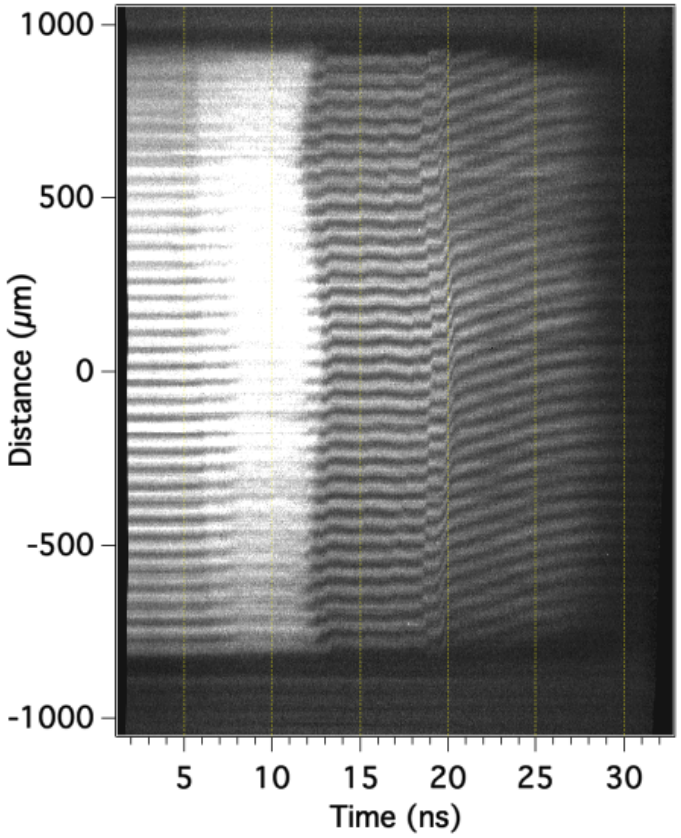
N131203 – Operational Firstlook

Campaign RI: Eggert
Platform RI: Smith
Shot RI's: Smith/Fratanduono/Lazicki/ Rygg/Eggert
Designer: Braun

Primary objectives for this shot:

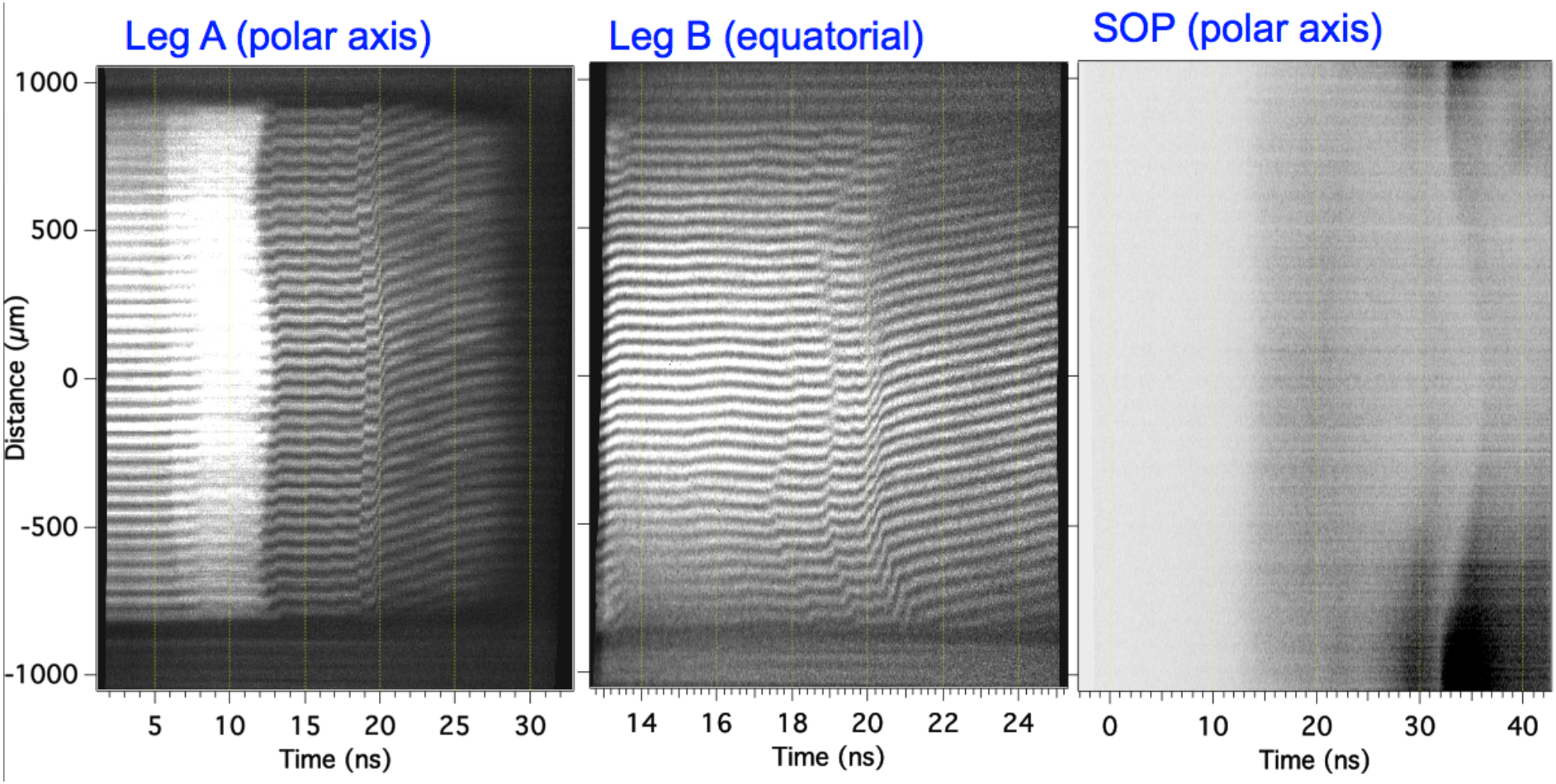
- Demonstrate planarity of drive to < 5% over 1.2x1.2 mm region through optimization of drive beam tiling.
- Ramp compress sample to greater than 10 Mbar.
- Measure spectra of ablation plasma over 4-16 keV range (SuperSnout II on 90-78 and Dante on 64-350).
- Measure Ta debris embedded on VISAR blast shield.

Drive planarity measurement on VISAR Leg A



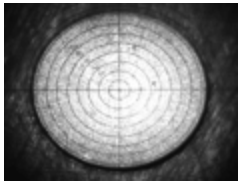
VISAR preliminary analysis

Good information on drive planarity obtained by VISAR/SOP



We have established that Target reflectivity is preserved at pressures in excess of 10Mbar.

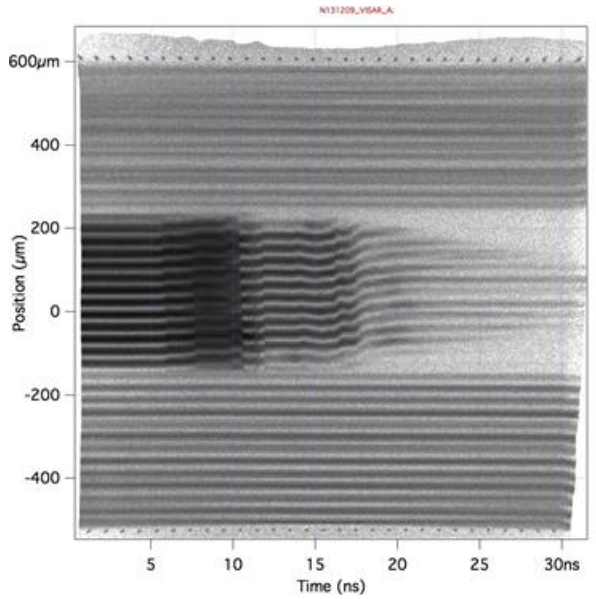
Target on VISAR alignment camera

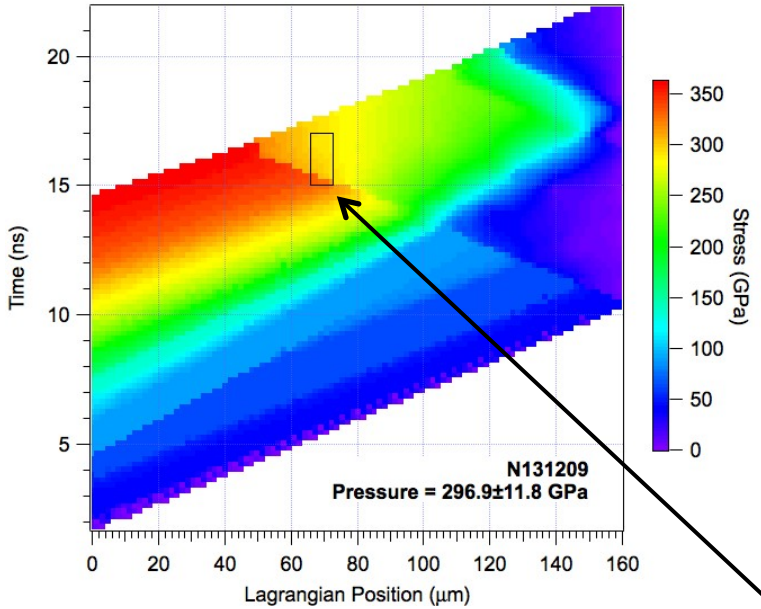


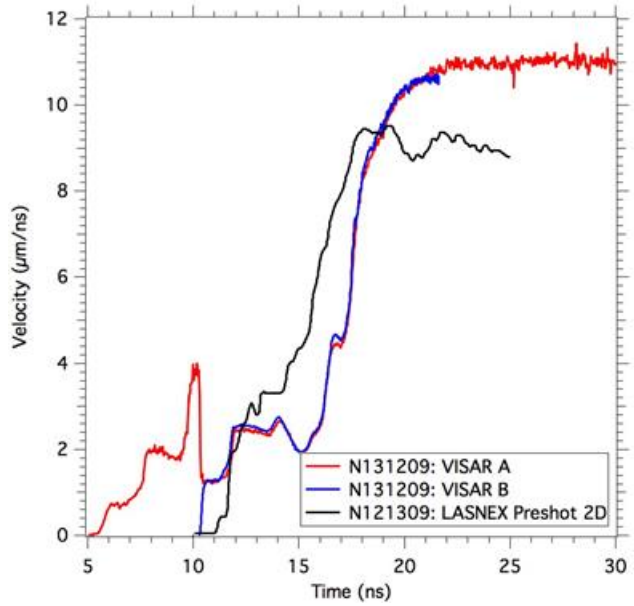
N131209
H_Mat_TARDIS_Bkgd_S01

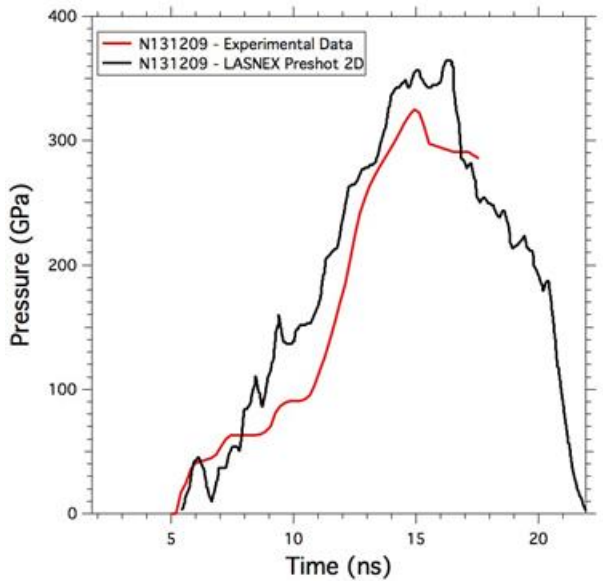
3 Mbar Ta
Zirconium Source
Ross Pairs

VISAR









-Backlighter probed a peak compression in the sample.
-Sample pressure at probe time is 296.9+/-11.8 GPa

N131209, Details of image plates

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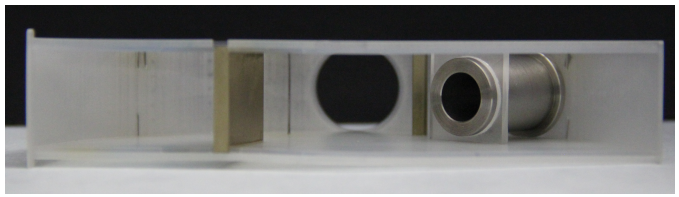
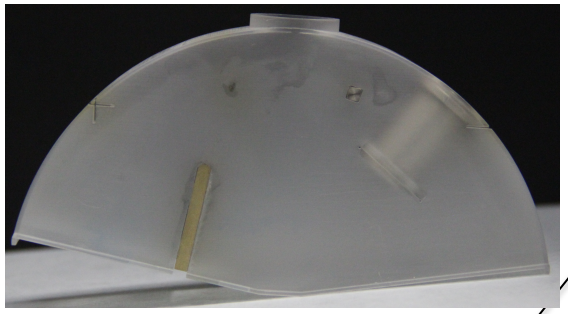
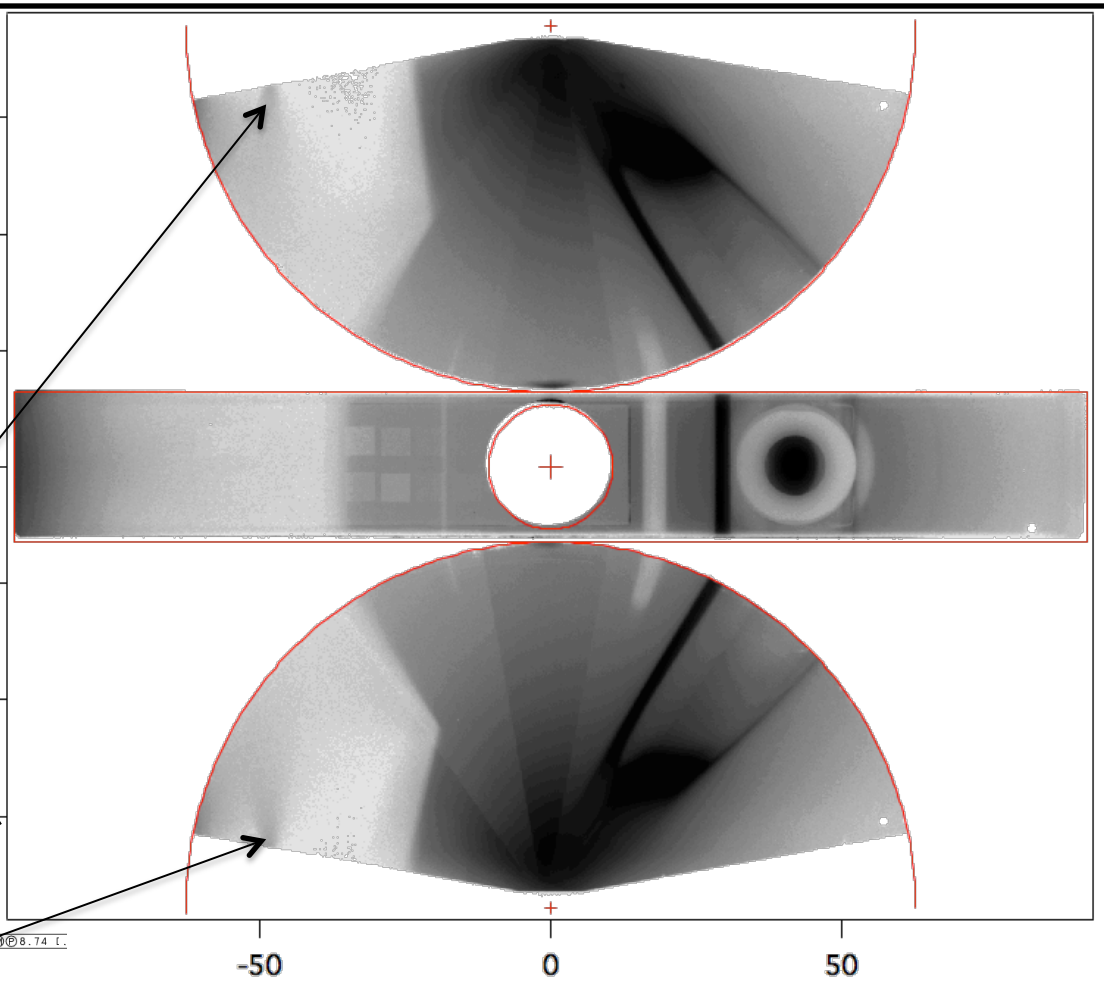
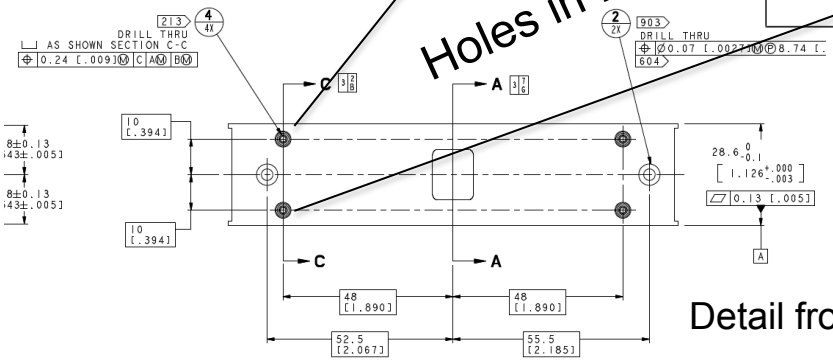






Holes in Hevimet



Detail from AAA12-120047-AA

N131209, Views of five image plates

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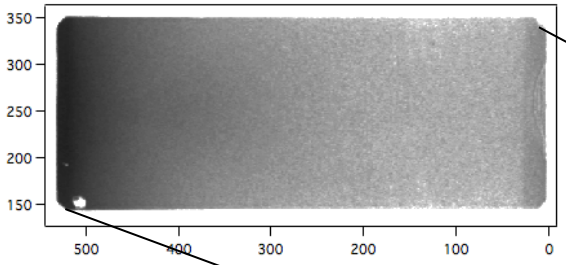
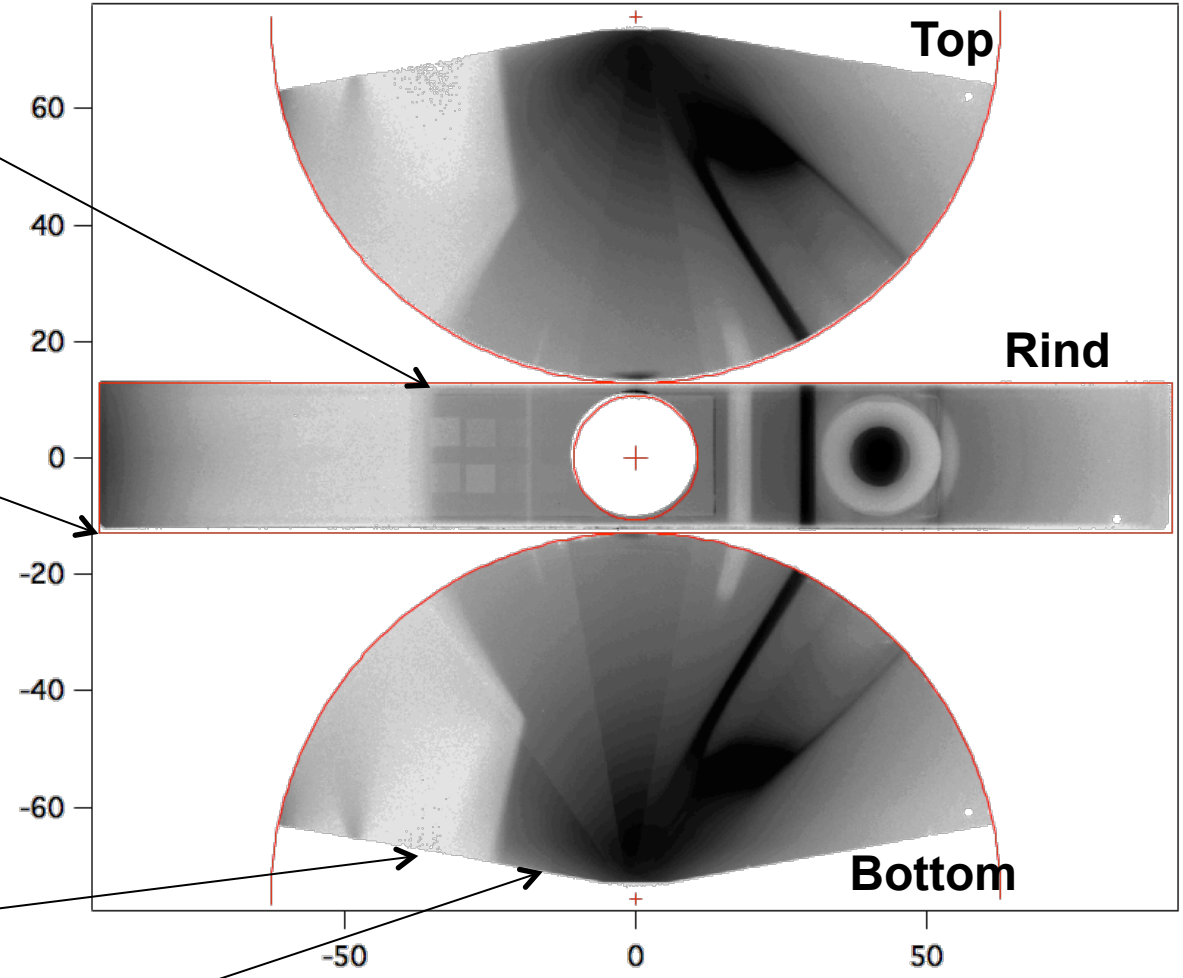
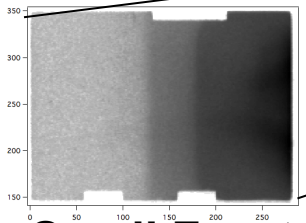
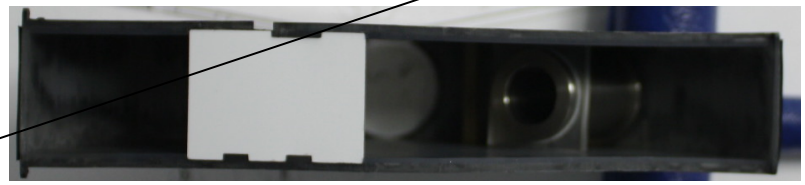
Small Back

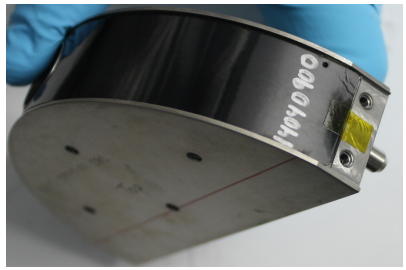






Small Front





Bottom image plate overlaid with TARDIS Drawing

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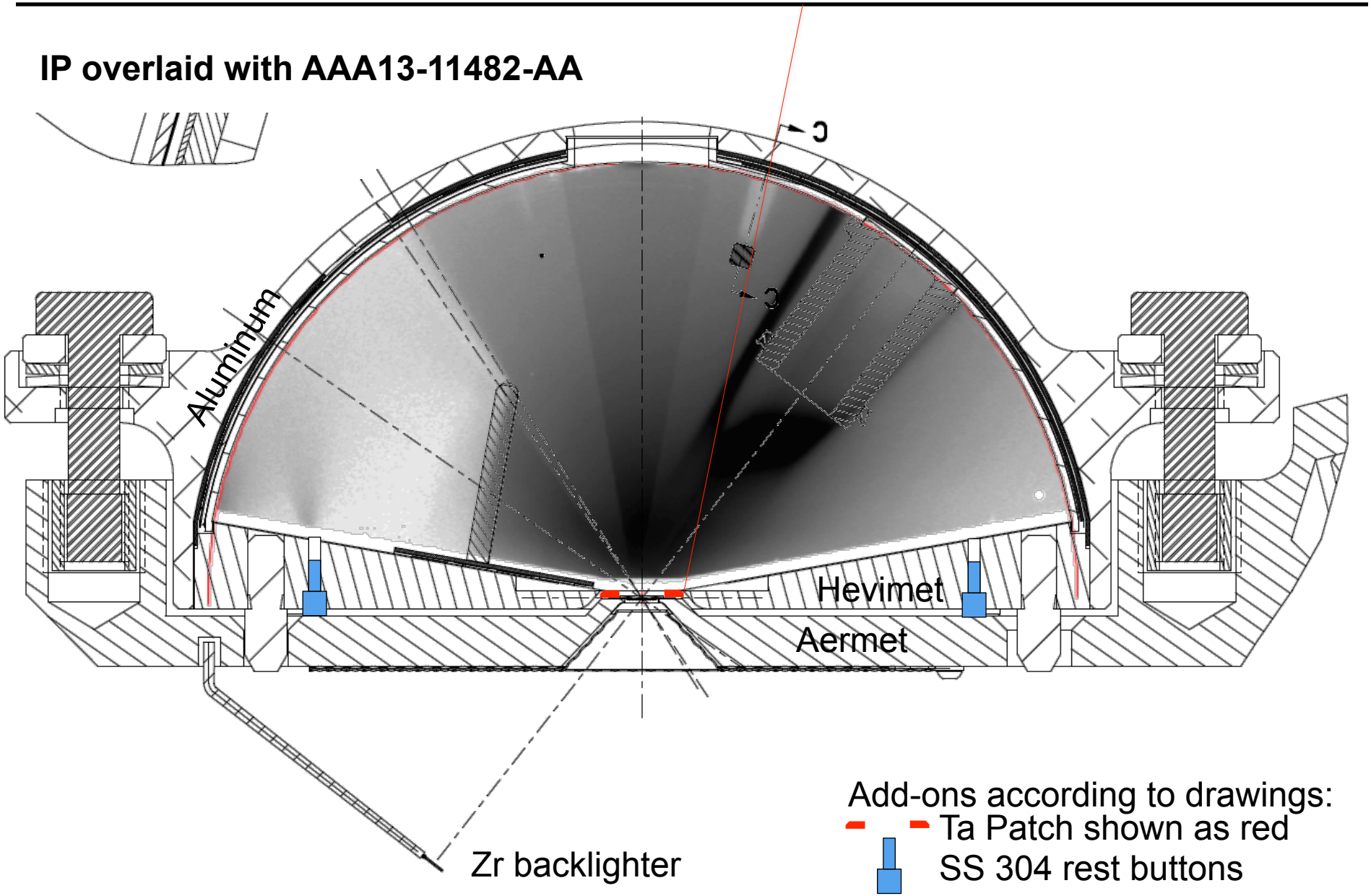
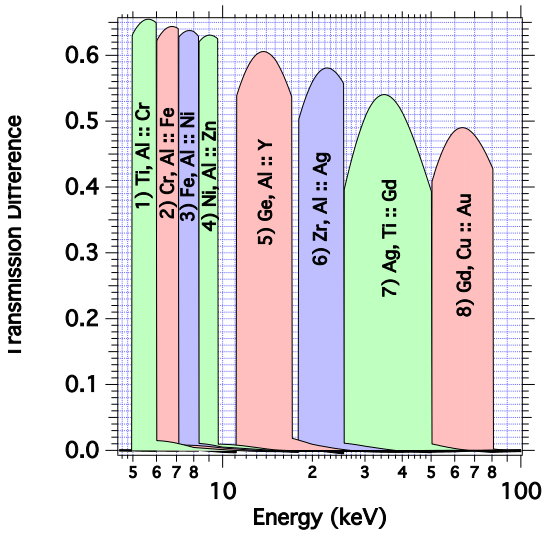
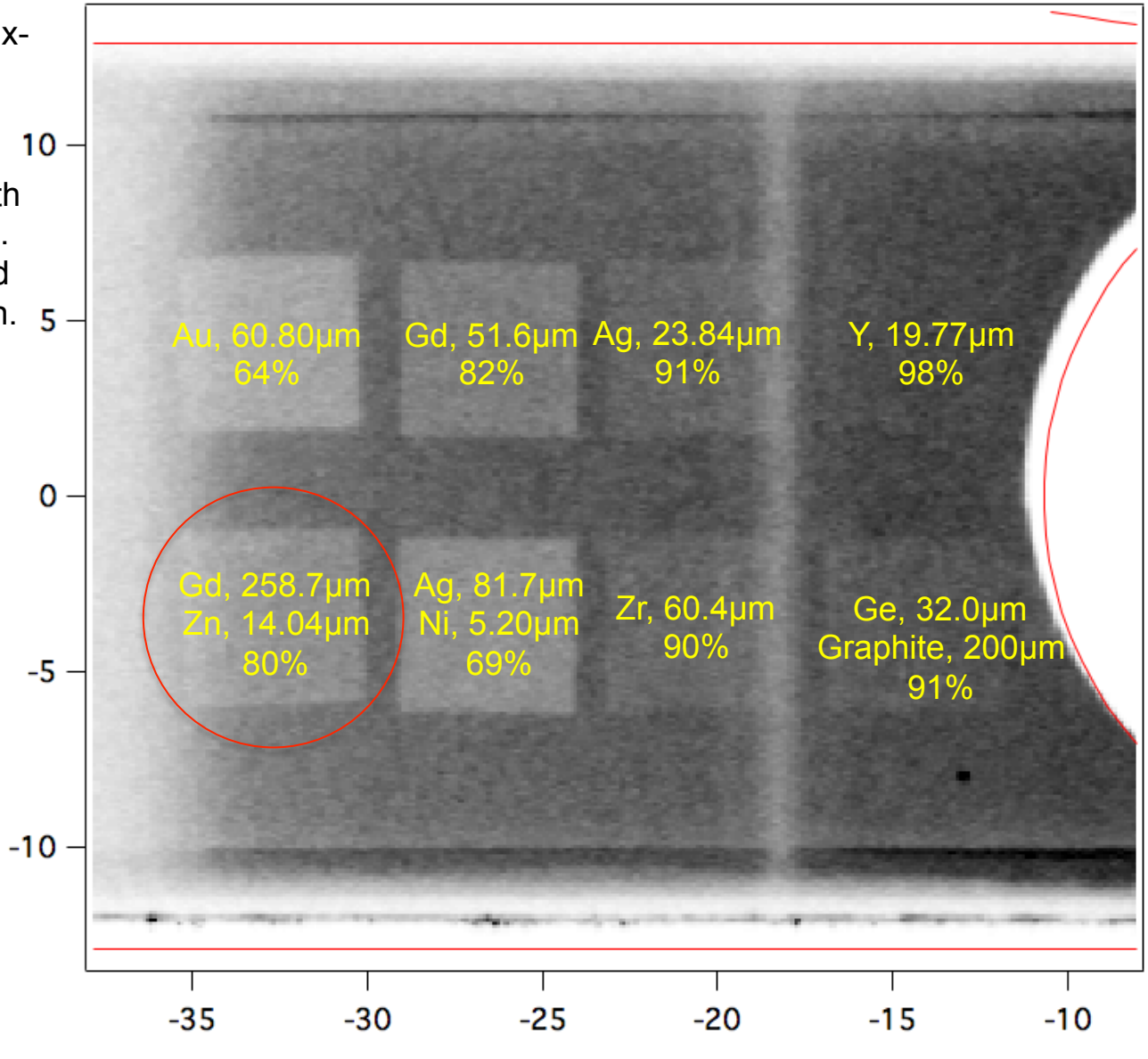
IP overlaid with AAA13-11482-AA



Ross pair analysis

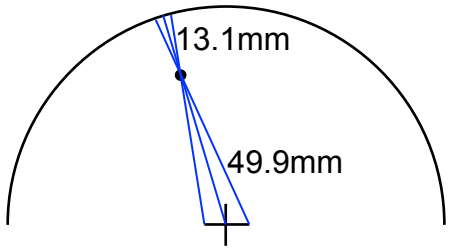
The 258.7μm Gd filter must be wrong. There is no way that any x-ray spectra can give more absorption in 60.80μm of Au than in 258.7μm of Gd. It looks like what happened was that a foil with ~51.6μm of Gd was used instead. the extra 2% absorption observed is probably due to the 14μm of Zn.



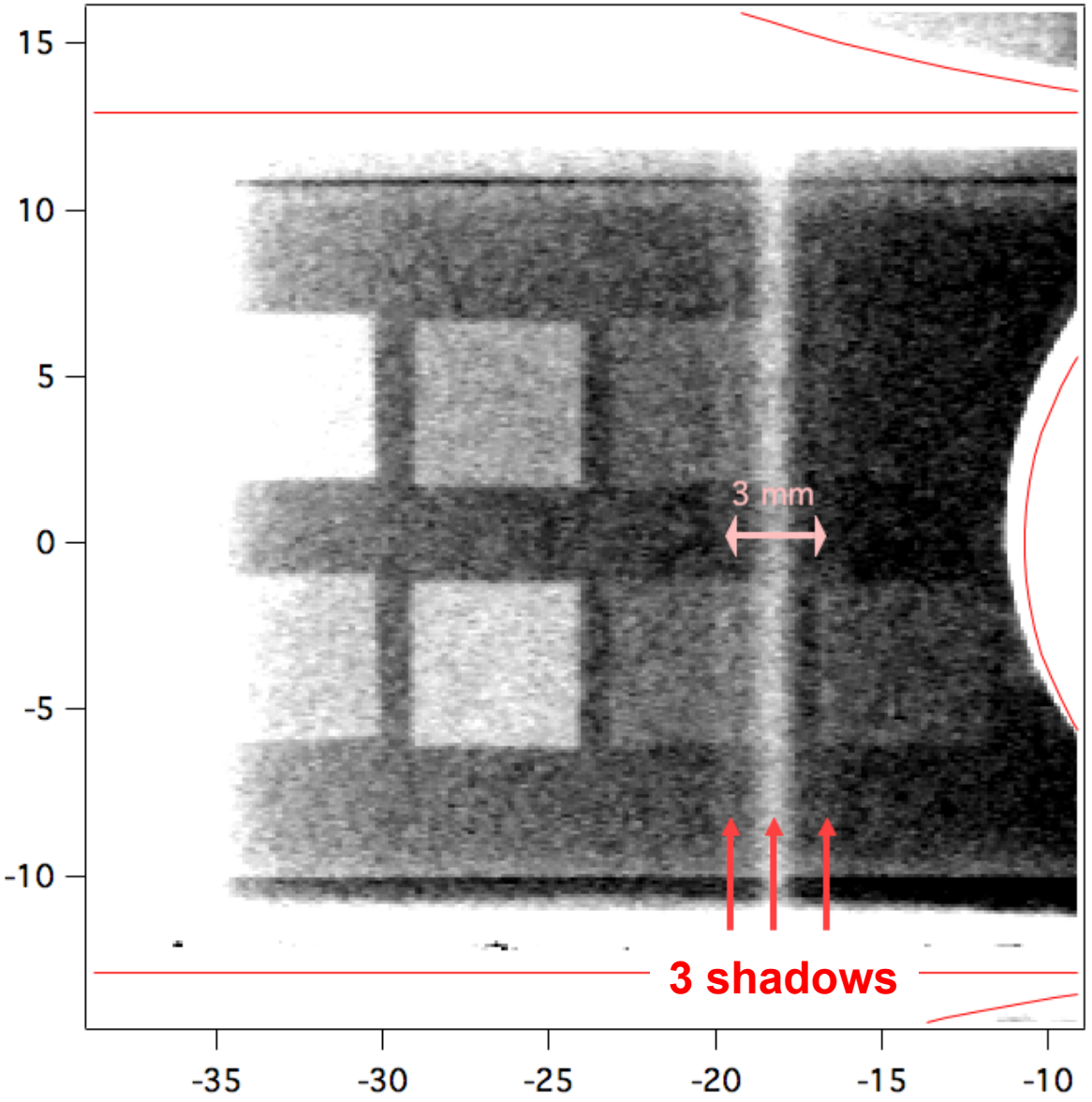


Evidence for three sources near the pinhole

I noticed that there are 3 shadows cast by the 500μm Ta wire, 1 strong central shadow, 1 moderate shadow to the left and 1 weak shadow to the right. The separation of the outer shadows are about 3mm. The wire is at a position 49.9mm, 16.3° from the pinhole (AAA13-111484-AA) and 13.1mm from the rind image plate (AAA12-120050-AA).



Thus, the separation of the two outer shadows correspond to about 12mm in the plane of the pinhole. Note that the patch is 11.3mm wide (AAA13-101730-AA). Thus, it appears that the wire does have sufficient resolution to resolve the pinhole and the patch. It is still uncertain how much of the pinhole xrays are due to the ablation plasma and how much to fluorescence.



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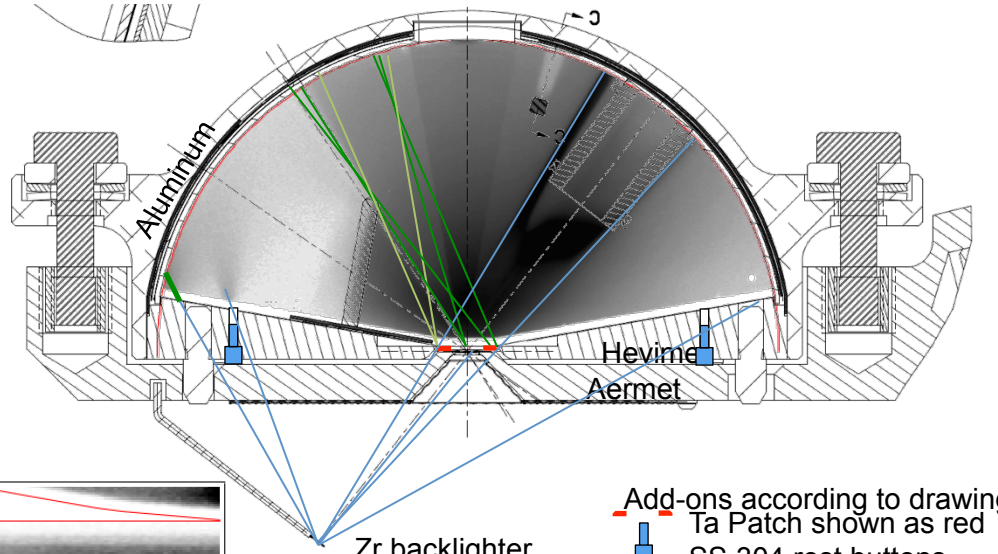
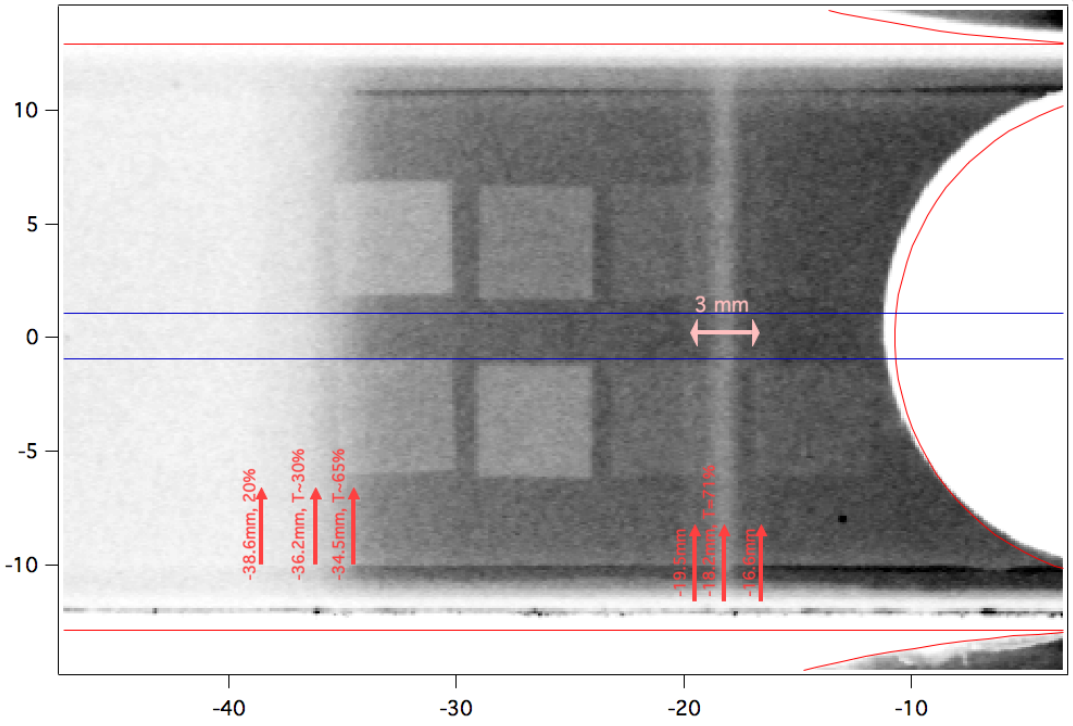


Add-ons according to drawings:
Ta Patch shown as red
SS 304 rest buttons



N131209, We see (at least) two Ta diffraction lines

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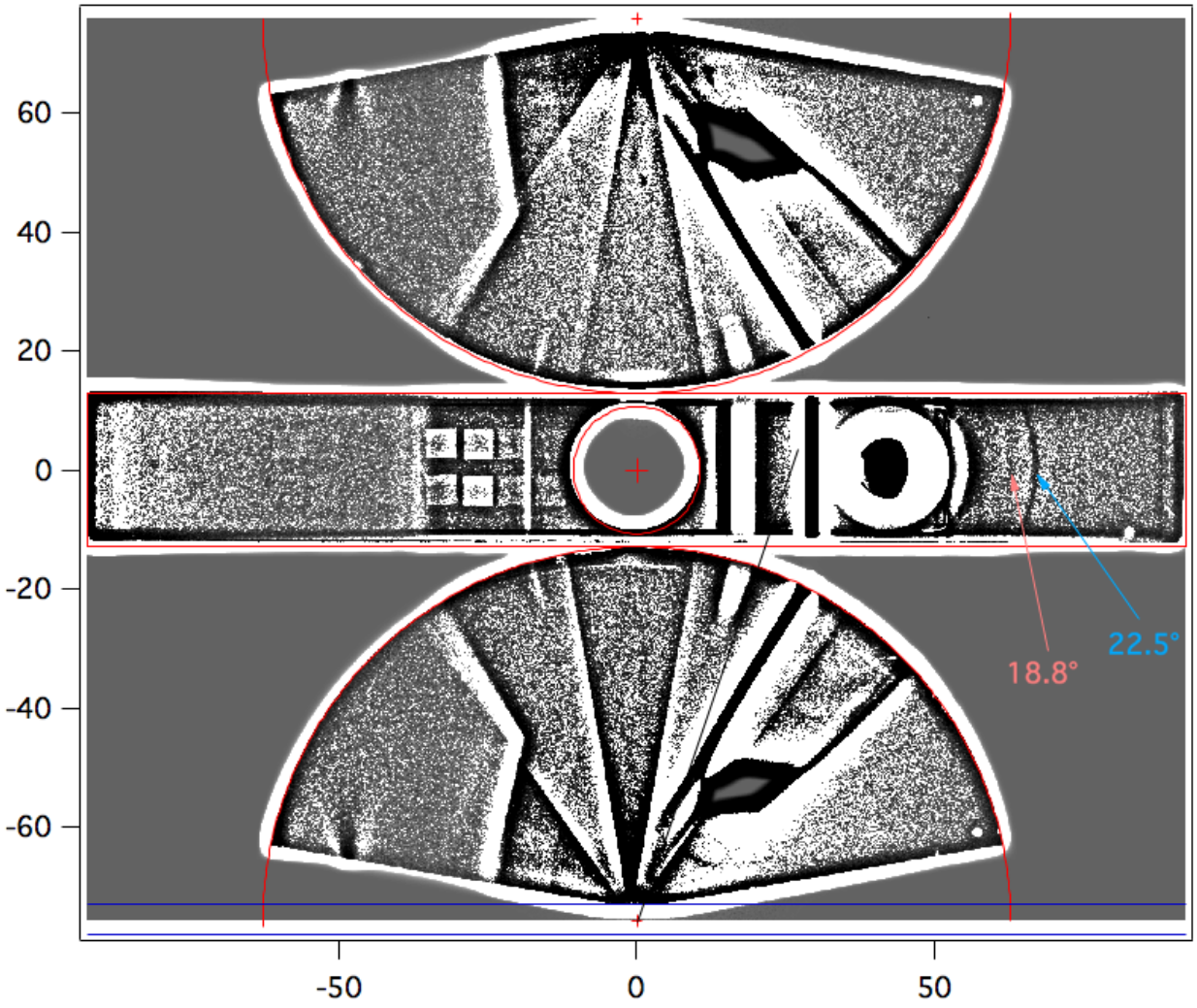
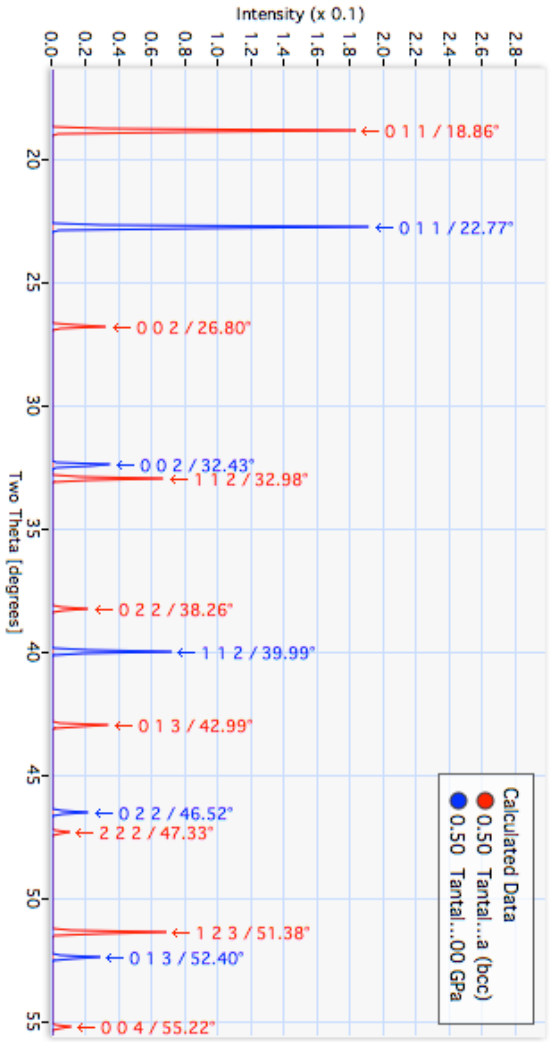
Both lines are BCC 011 at pressures of 0 and ~300 GPa





Lower signal is observed for no pre-pulsed Zr foil in comparison to pre-pulsed Zr targets

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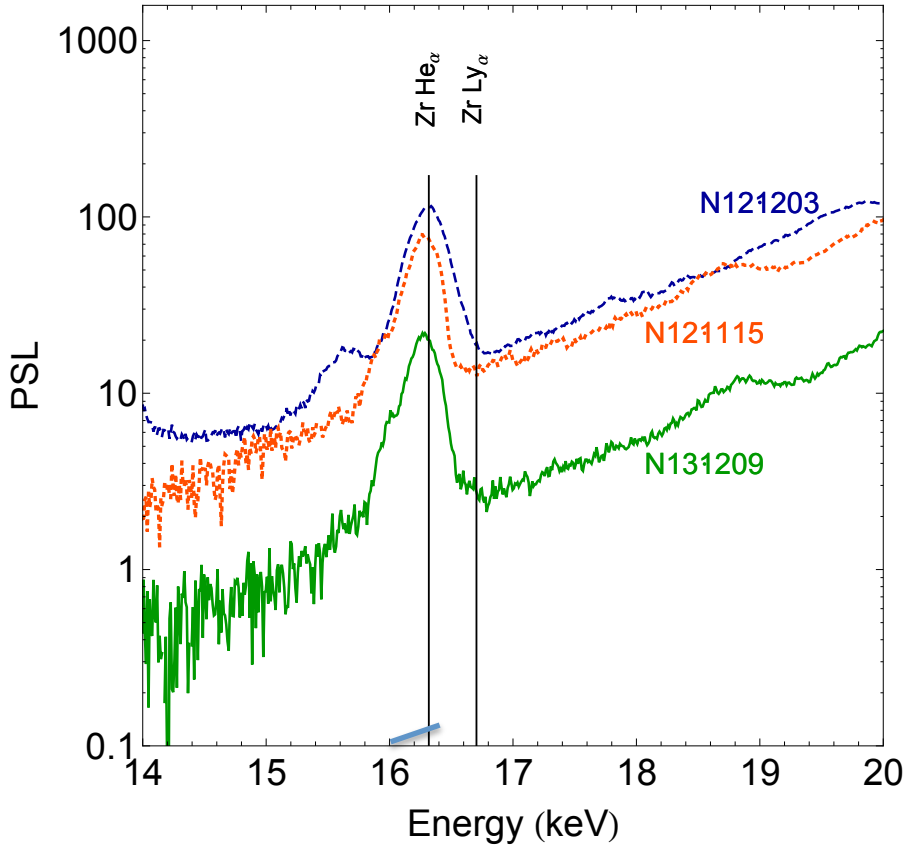
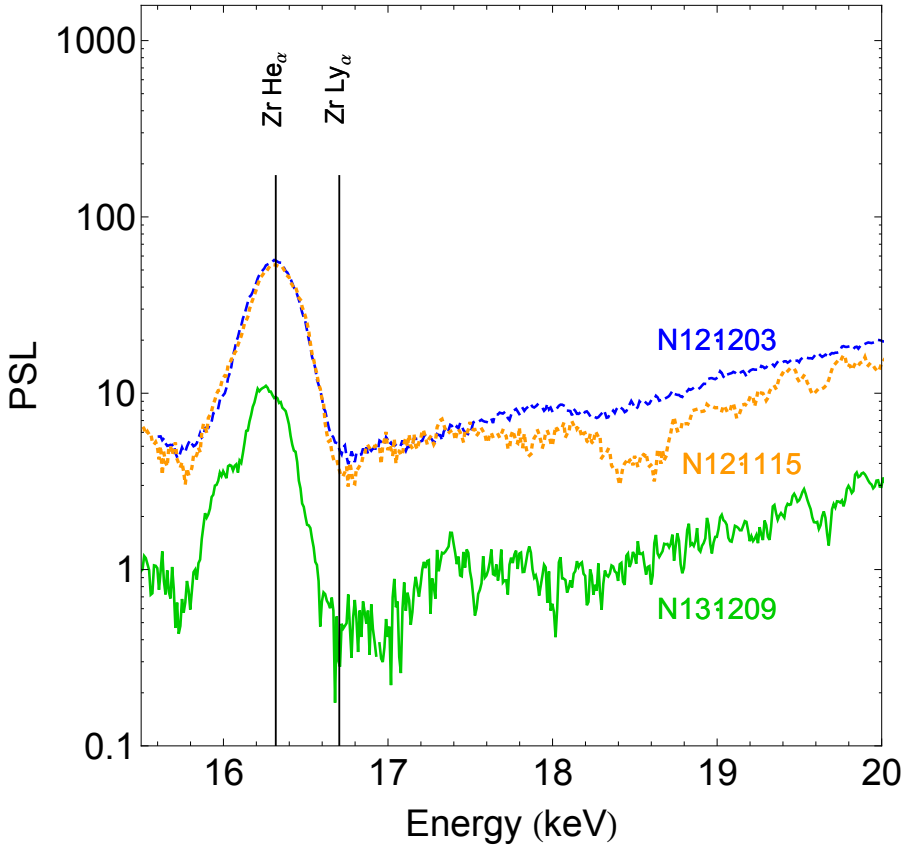
CH. 2 (No filter, IP, crystal reflectivity corrections)



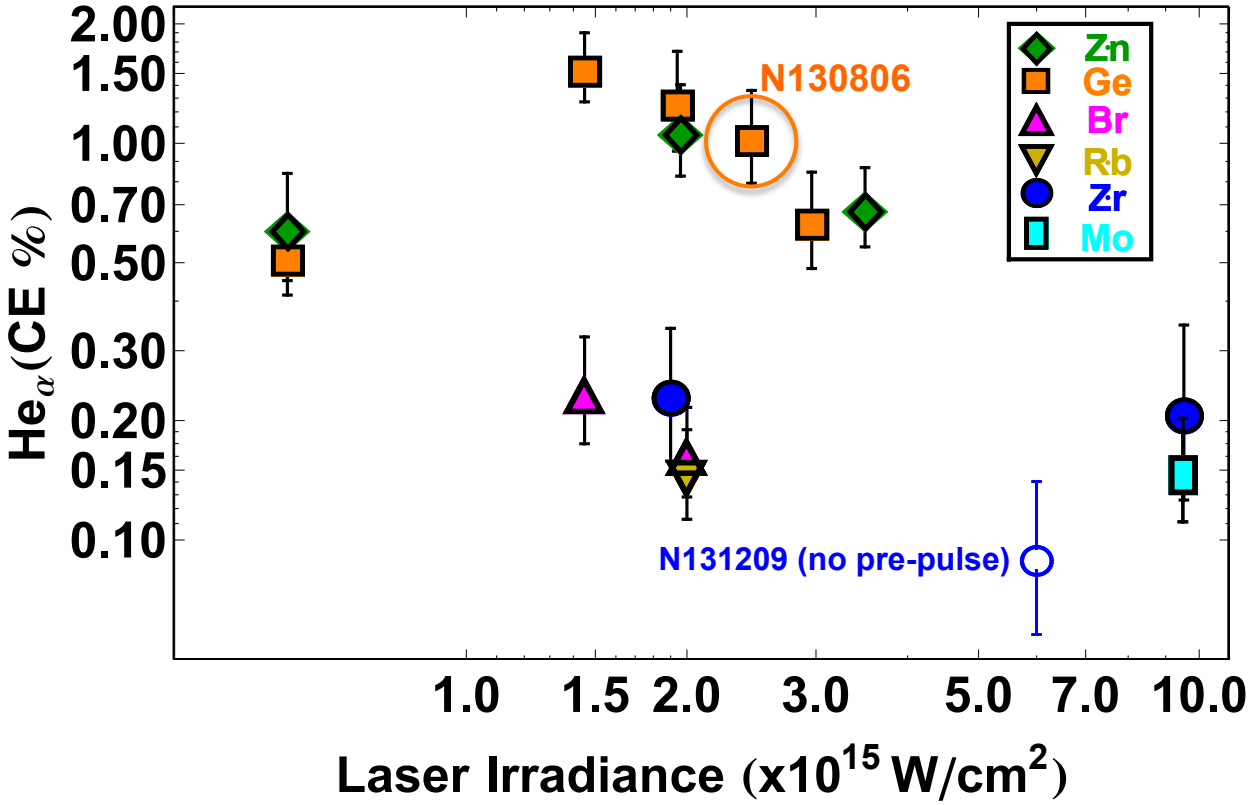
CH. 3 (No filter, IP, crystal reflectivity corrections)



~ 5X decrease in peak signal of He-alpha line when comparing N131209 (no pre-pulse) with N121115 and N121203 (both with pre-pulse)

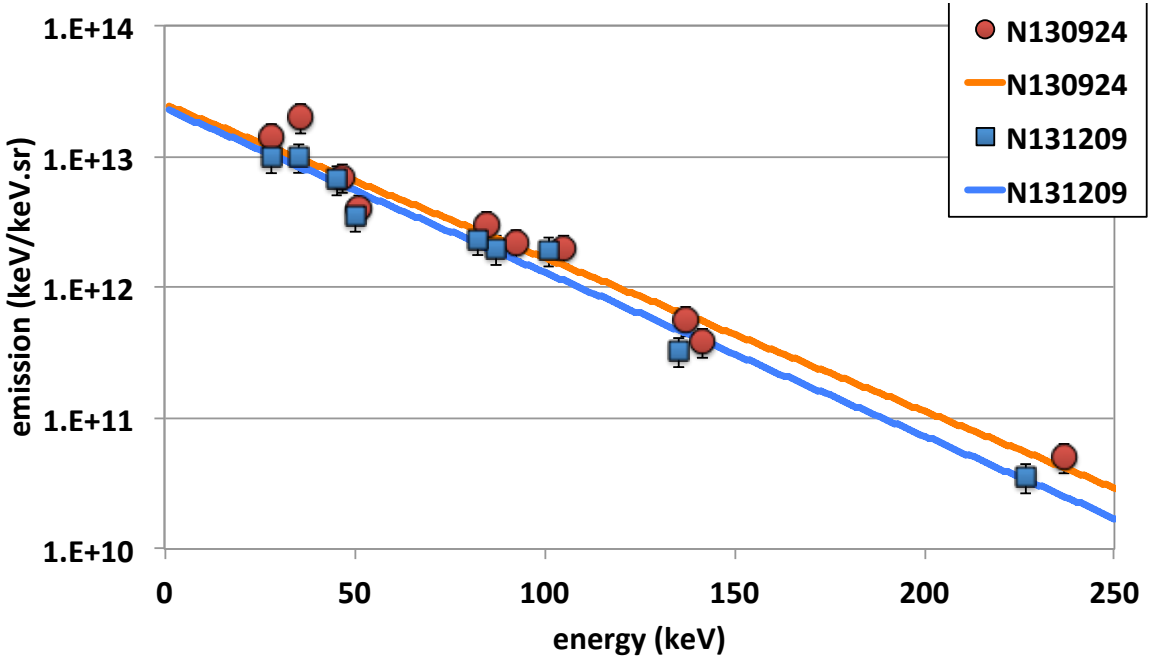
*** N121115, N121203, and N131209 ran with same filter configuration**

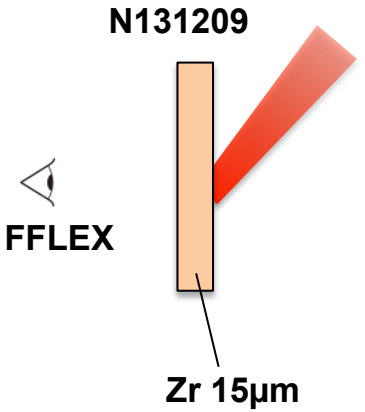
Conversion efficiency into material He_α



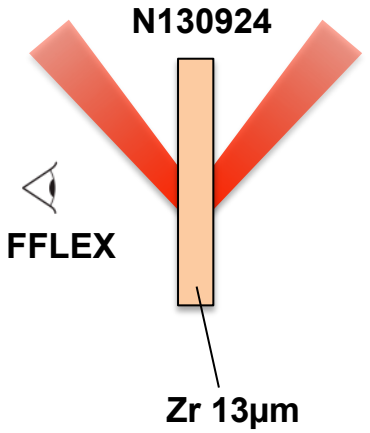
Shot	CE(%) into Zr He_α	Laser Energy (kJ)	Irradiance (x10^{15} W/cm^2)	Pre-Pulse
N131209-002	0.09 ± 0.04	19.0	6.0	No
N121203-001	0.23 ± 0.09	51.7	1.9	Yes
N121115-001	0.20 ± 0.10	49.3	9.53	Yes

FFLEX: N131209 vs N130924





Shot	Backlighter	E (J)	T (keV)
N140314	Ge (2-sided)	225	38
N140224	Ge (1-sided)	22	28
N131209	Zr (1-sided)	424	35
N130924	Zr (2-sided)	458	37
N130919	Ge (2-sided)	392	33
N130806	Ge (1-sided)	216	33
N130729	Ge (2-sided)	370	35



Summary of Q2 shots and goals

The National Ignition Facility

1) **H_Mat_TARDIS_Bkgd_CCC: MD_TAXRD-C-01:**
   Goals:
   - Direct comparison of efficiency of diffraction using Ge and Zr XRS. {1.i., 4.i., 4.ii.}
   - Reduce high-energy background by using Ta10W target body. {4.i.}
   - Reduce high-energy background using smaller-area XRS. {4.i.}
   - Reduce target fluorescence using larger-angle pinhole. {4.ii.}
   - Test thin (0.5 mm) polycarbonate frame and thicker Ge filters to reduce background. {4.ii.}

2) **H_Mat_TARDIS_Bkgd_DDD: MD_TAXRD-C-02:**
   Goals:
   - Test background scaling with drive pressure. {4.iii.}
   - Test hot-electron mechanism for sample fluorescence by comparing 1- and 2-sided Ge XRS. {4.ii.}
   - Reduce high-energy background by using Ta10W target body. {4.i.}
   - Reduce high-energy background using smaller-area XRS. {4.i.}
   - Reduce target fluorescence using larger-angle pinhole. {4.ii.}
   - Test thin (0.5 mm) polycarbonate frame and thicker Ge filters to reduce background. {4.ii.}

3) **H_Mat_TARDIS_PbDiff_AAA: MD_PBXRD-A-01:**
   Goals:
   - Test reduced area Zr XRS. {4.i.}
   - Background scaling with drive pressure. {4.iii.}
   - Option to use 1 or 2-sided x-ray source (backlighter). {4.i.}
     - Decision based on FFLEX results: If ($E_{2\text{-sided}} > 3*E_{1\text{-sided}}$) or ($T_{2\text{-sided}} - E_{1\text{-sided}} > 6\text{keV}$) then use 1-sided XRS, otherwise use 2-sided XRS
   - Drive qualification: Pb is a low melt-temperature metal; do we observe solid diffraction? {1.iii.}
   - Quantify sample (Pb) deposition on VISAR blast shield {3.ii.}
   - Reduce high-energy background by using Ta10W target body. {4.i.}
   - Reduce high-energy background using smaller-area XRS. {4.i.}
   - Reduce target fluorescence using larger-angle pinhole. {4.ii.}
   - Test thin (0.5 mm) polycarbonate frame and thicker Ge filters to reduce background. {4.ii.}

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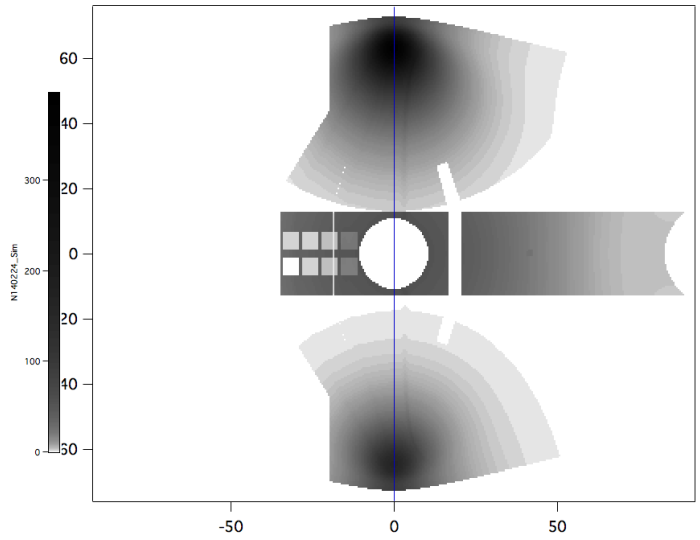
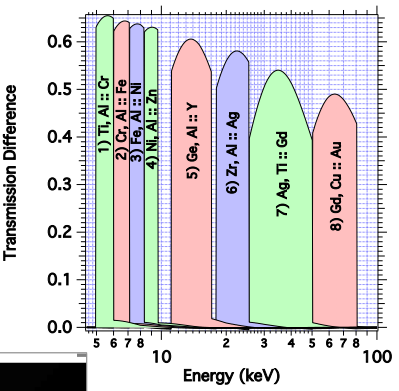
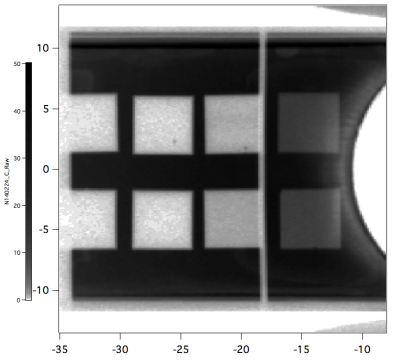
Lineouts and Ross Pairs

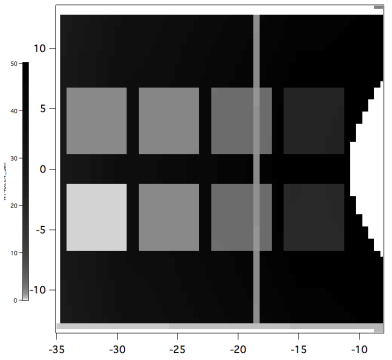


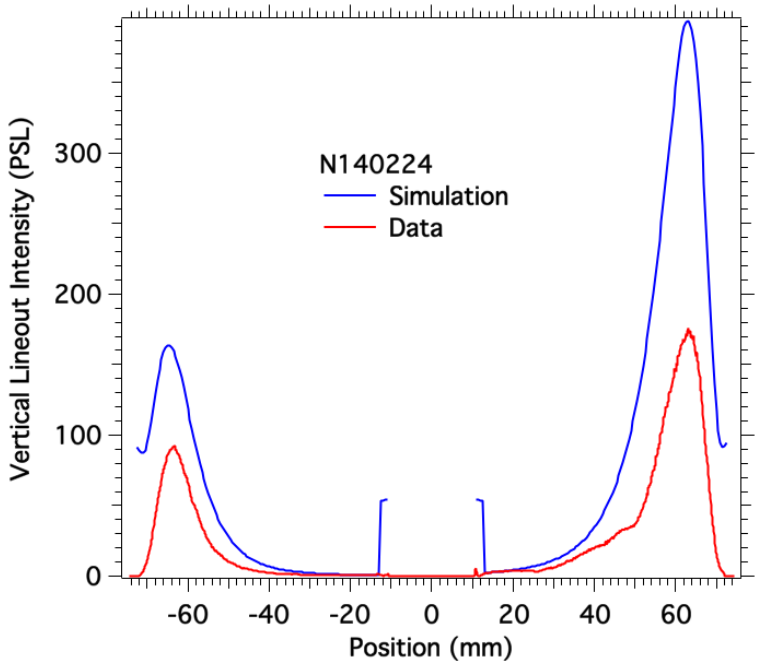


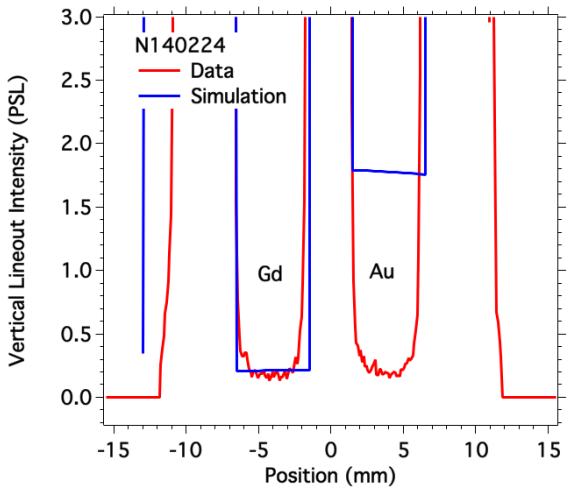
N140224, Data



Pre-shot Simulation



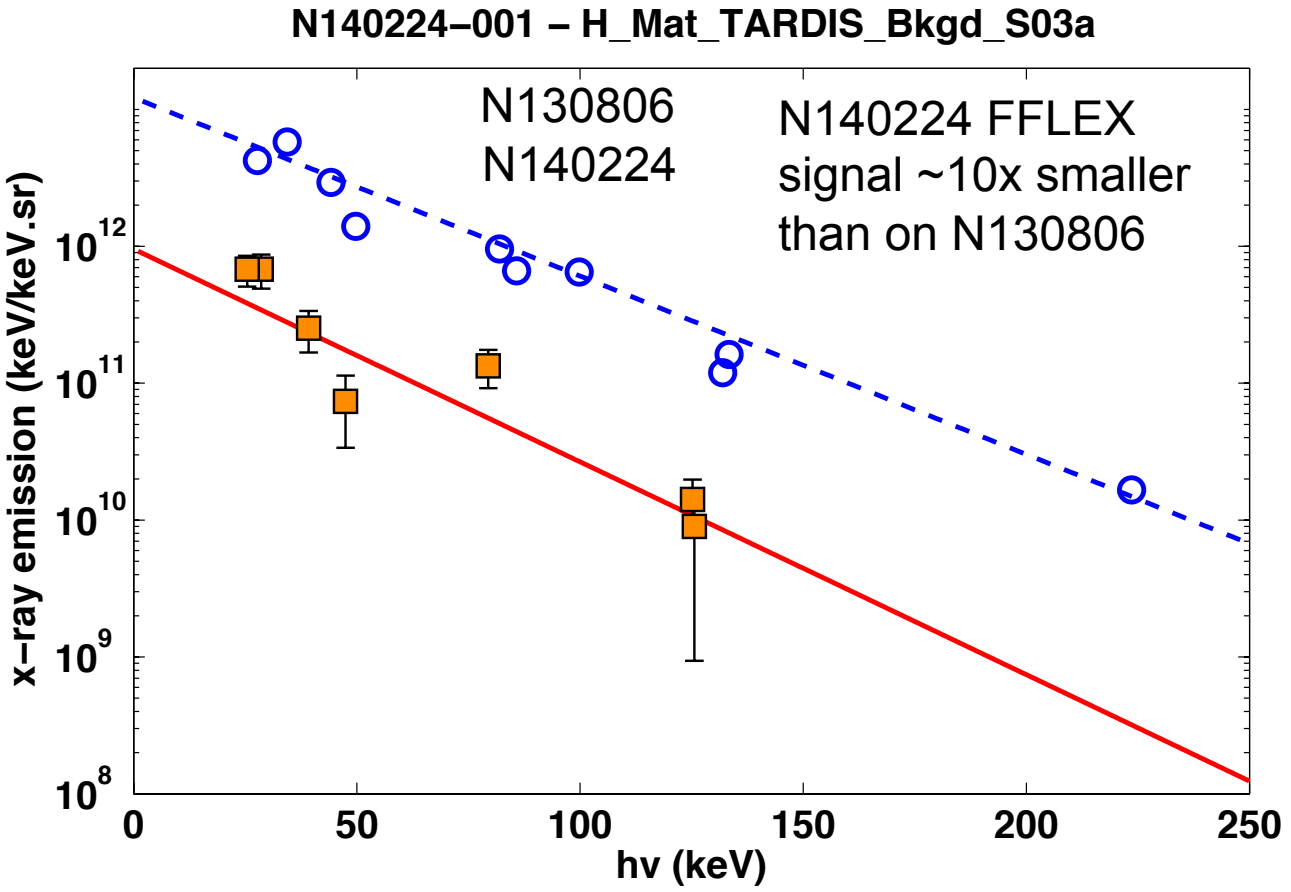




Expected ~2 PSL difference in the Au and Gd.

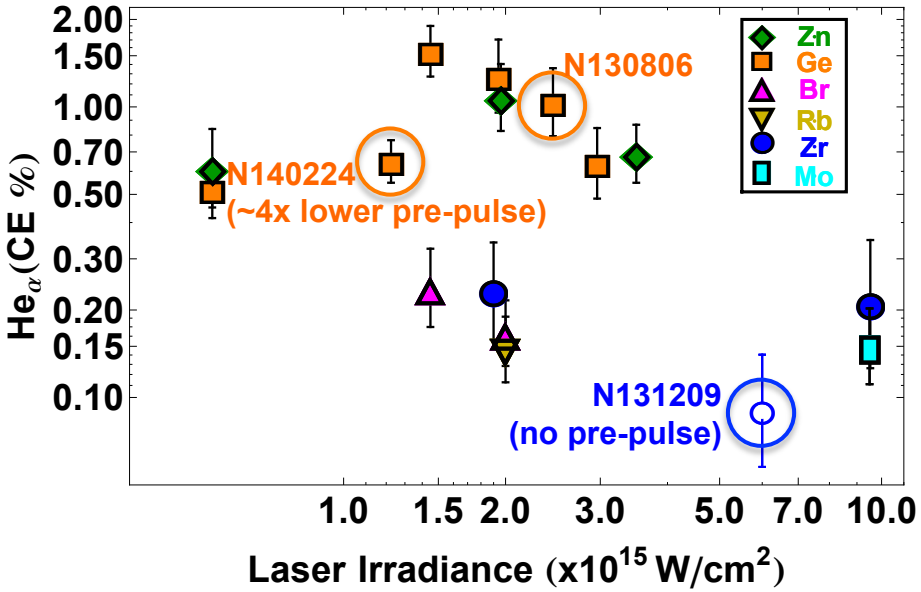
=> Almost no Ta fluorescence!

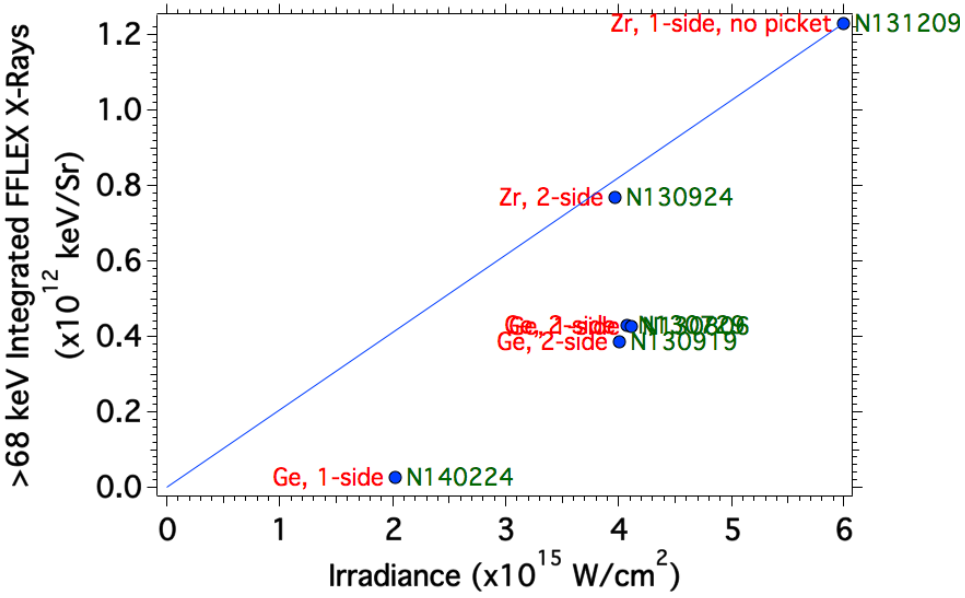
N140224 vs N130806



	<Z>	E1 (kJ)	T1 (keV)
N130806	32	216	33
N140224	32	22	28

He-alpha Efficiency and Integrated High-Energy Background from FFLEX





Initial results : TARDIS Image plates

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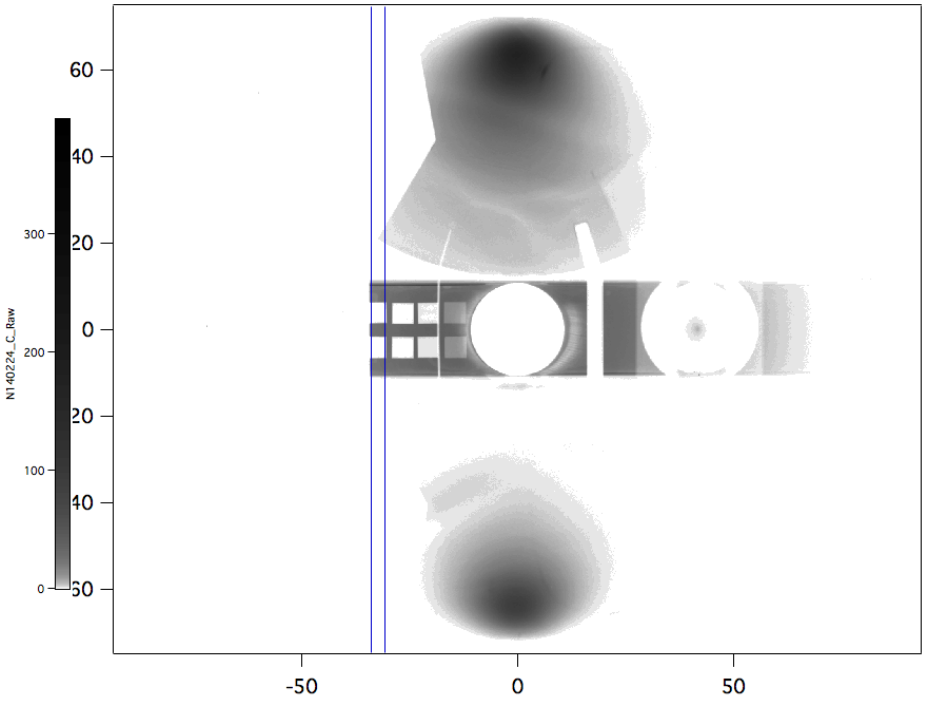
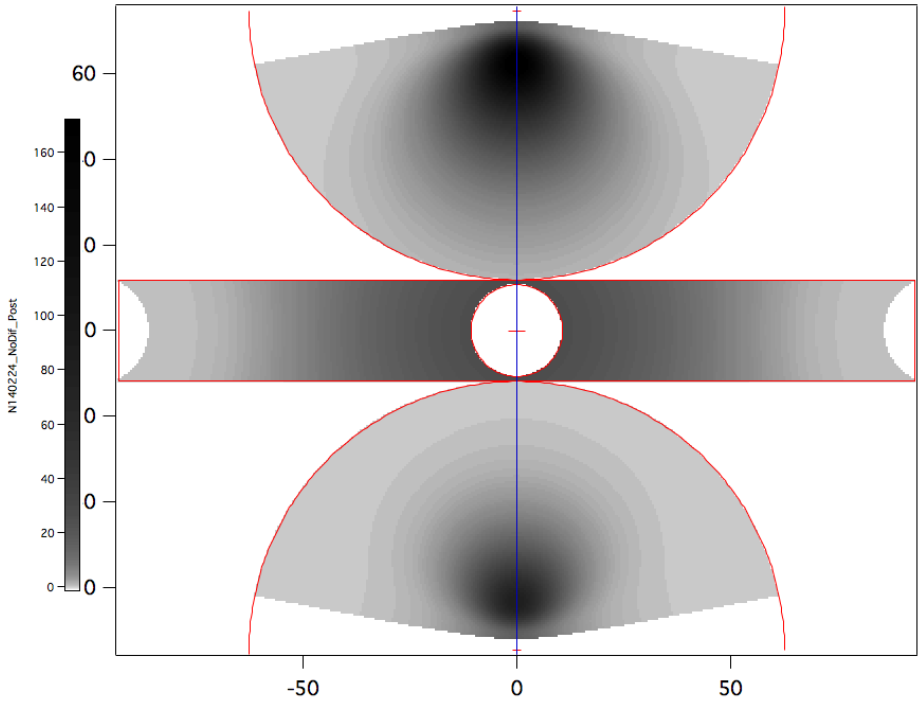
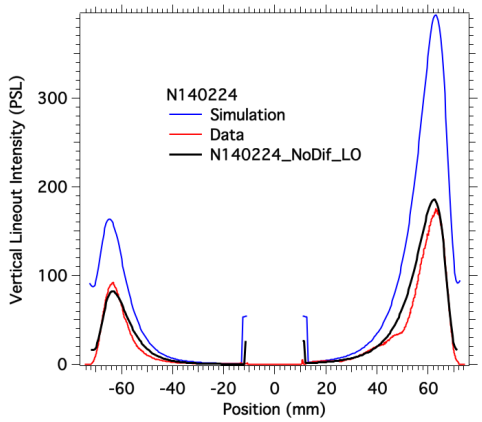
N140224, Data



Post-shot Simulation
No Diffraction





Subtract / Divide Post-Shot from Data

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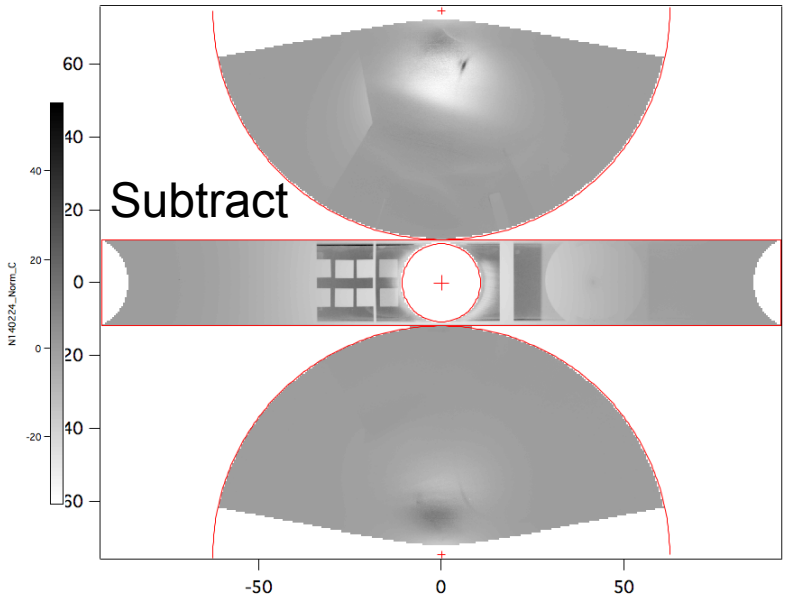

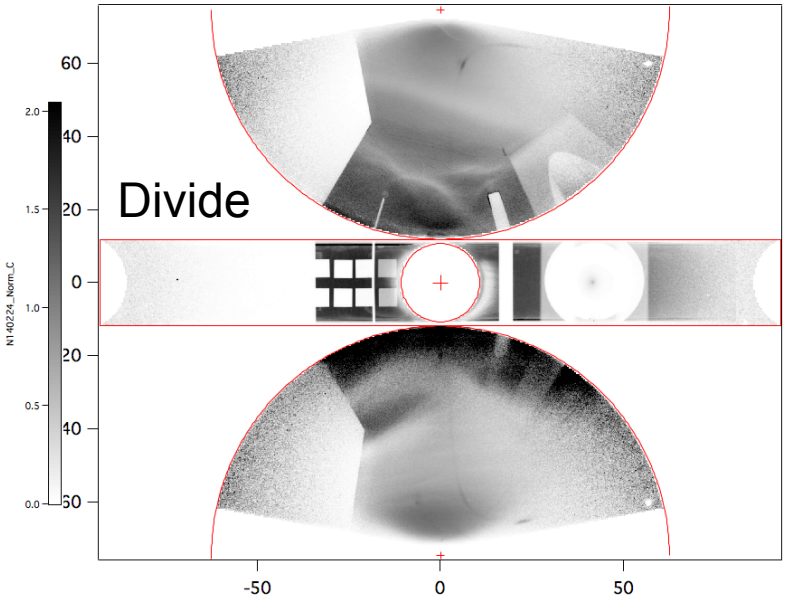

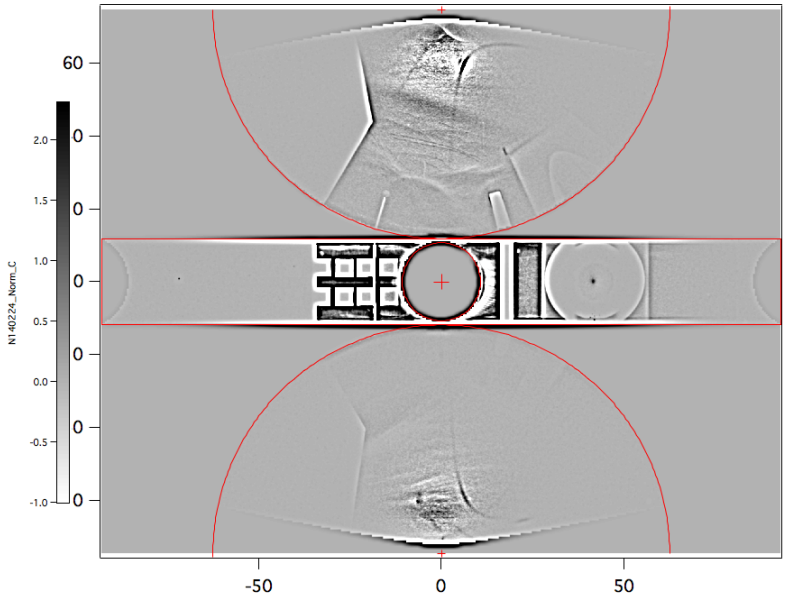

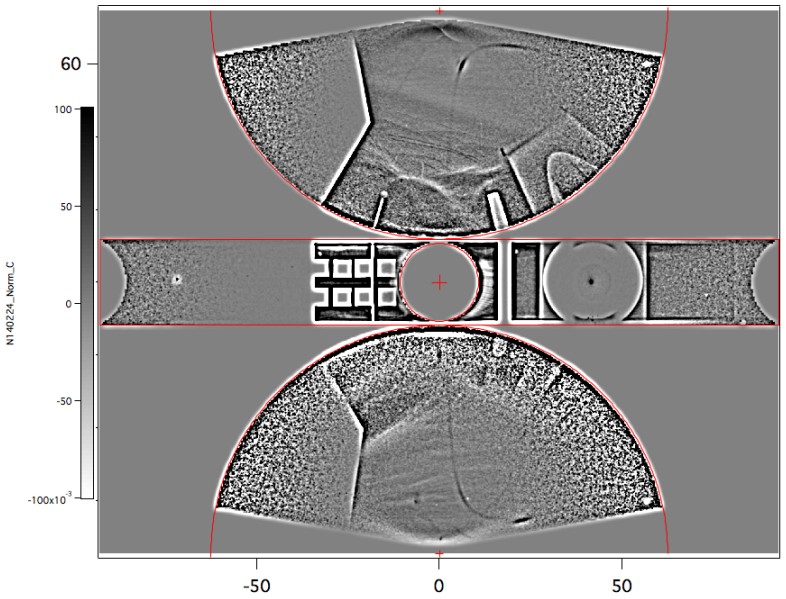

TARDIS FLIP Proposal Plan, (131228)

FY14:

Q1:

- ✓ **N131125, H_Mat_TARDIS_Bkgd_AAA: MD_TAXRD-B-02 (H5):**
  - Isolate and evaluate sources of background.
  - Ta, 7 Mbar, Drive only.
- ✓ **N131203, H_Mat_DiffDrv_AAA:** Evaluate 12 Mbar Ta drive planarity.
- ✓ **N131209, H_Mat_TARDIS_Bkgd_BBB: MD_TAXRD-B-03 (H6):**
  - Isolate and evaluate sources of background.
  - Ta, 3 Mbar, Zr XRS.

– Q2:

- **02/24/14, H_Mat_TARDIS_Bkgd_CCC: MD_TAXRD-C-01:**
  - Minimize high-energy background.
  - Ta, 3 Mbar, 1-sided small-area Ge XRS.
  - Ta10W target body, large-angle PH.
- **03/20/14, H_Mat_TARDIS_Bkgd_DDD: MD_TAXRD-C-02:**
  - Drive-pressure scaling, high-E XRS test.
  - Ta, 5 Mbar, 2-sided small-area Ge XRS.
  - Ta10W target body, large-angle PH.
- **03/21/14, H_Mat_TARDIS_PbDiff_AAA: MD_PBXRD-A-01:** Phase identification, Drive qualification
  - Pb, 1 Mbar, 1 or 2-sided small-area Zr XRS.
  - Ta10W target body, larger-angle PH.
  - Contingent on H_Mat_TARDIS_Bkgd_DDD for 1 or 2 sided backlighter.

– Q3:

- **06/16/14, H_Mat_TARDIS_PbDiff_BBB: MD_PBXRD-A-02:**
  - Phase identification, Drive qualification
  - Pb, 3 Mbar
  - Catcher OQ
  - Contingent on Q2 shots to determine PH and XRS.
- **06/23/14, H_Mat_TARDIS_DUDiff_AAA: MD_DUXRD-A-01:**
  - Phase identification, Drive qualification
  - DU, 1 Mbar
  - Catcher PQ
  - Classified operations
  - Contingent on Q2 shots to determine PH and XRS.
- **07/29/14, H_Mat_TARDIS_DUDiff_BBB: MD_DUXRD-A-02:**
  - Phase idenification, Drive qualification
  - DU, 3 Mbar
  - Catcher
  - Classified operations
  - Contingent on Q2 shots to determine PH and XRS.
- **05/28/14, H_Mat_EOS_HDCPcal_AAA: MD_HDCPCAL-A-01:**
  - Calibrate single-crystal diamond stress vs sound speed
  - Single crystal diamond to 10 Mbar
  - Strength vacuum hohlraum
  - 4 thicknesses, EOS-type target

– Q4:

- **08/22/14, H_Mat_TARDIS_DUDiff_CCC: MD_DUXRD-B-01:**
  - Glassy PH (AB comparison)
  - DU, 1 Mbar
  - Catcher
  - Classified operations
  - Contingent on Contingent on Q2 shots to determine PH and XRS.
- **09/23/14, H_Mat_TARDIS_DUDiff_DDD: MD_DUXRD-B-02:**
  - Glassy PH (AB comparison)
  - DU, 3 Mbar
  - Catcher
  - Classified operations
  - Contingent on Q2 shots to determine PH and XRS.
- **09/30/14,**
  - Ta diffraction
  - 3-7 Mbar(contingent on Q2, Q3 shots)

13 shots in FY14

Plus: XRS Campaign, shot in combination with TARDIS shots

- Reduce high-energy background
- Improve He-alpha efficiency
- Differences between Ge and Zr

TARDIS Proposal Plan, (FY15, Q1, Q2)

Goals:

- Optimize XRD signal quality (XRS Campaign, filtering, Pinhole)
- Optimize drive
- Demonstrate that data should be believed
  - structural determination and phase transitions in DU, Pb, and Ta

FY15:

Q1:

- **1: Ta diffraction**
  - Fill in needed pressure (3 to 7 Mbar)
- **2: DU diffraction**
  - Fill in needed pressure (0.5 to 7 Mbar)
- **3: Pb diffraction**
  - Fill in needed pressure (0.5 to 7 Mbar)

Since FY14, Q2:

Ta: 4 shots: 3, 5 Mbar, + 2 TBD

Pb: 4 shots: 1, 3 Mbar, + 2 TBD

DU: 6 shots: 1, 3 Mbar, 1,3 Mbar Glassy PH), +2 TBD

–Q2:

- **4: DU diffraction**
  - Fill in needed pressure (0.5 to 7 Mbar).
- **5: Pb diffraction**
  - Fill in needed pressure (0.5 to 7 Mbar)
- **H_Mat_TARDIS_HZDiff_AAA: MD_HZXRD-A-01:**
  - High-Z diffraction
  - High-Z, 1 Mbar
  - Catcher
  - Classified operations