Discovery-Science X-ray Diffraction Experiments on NIF

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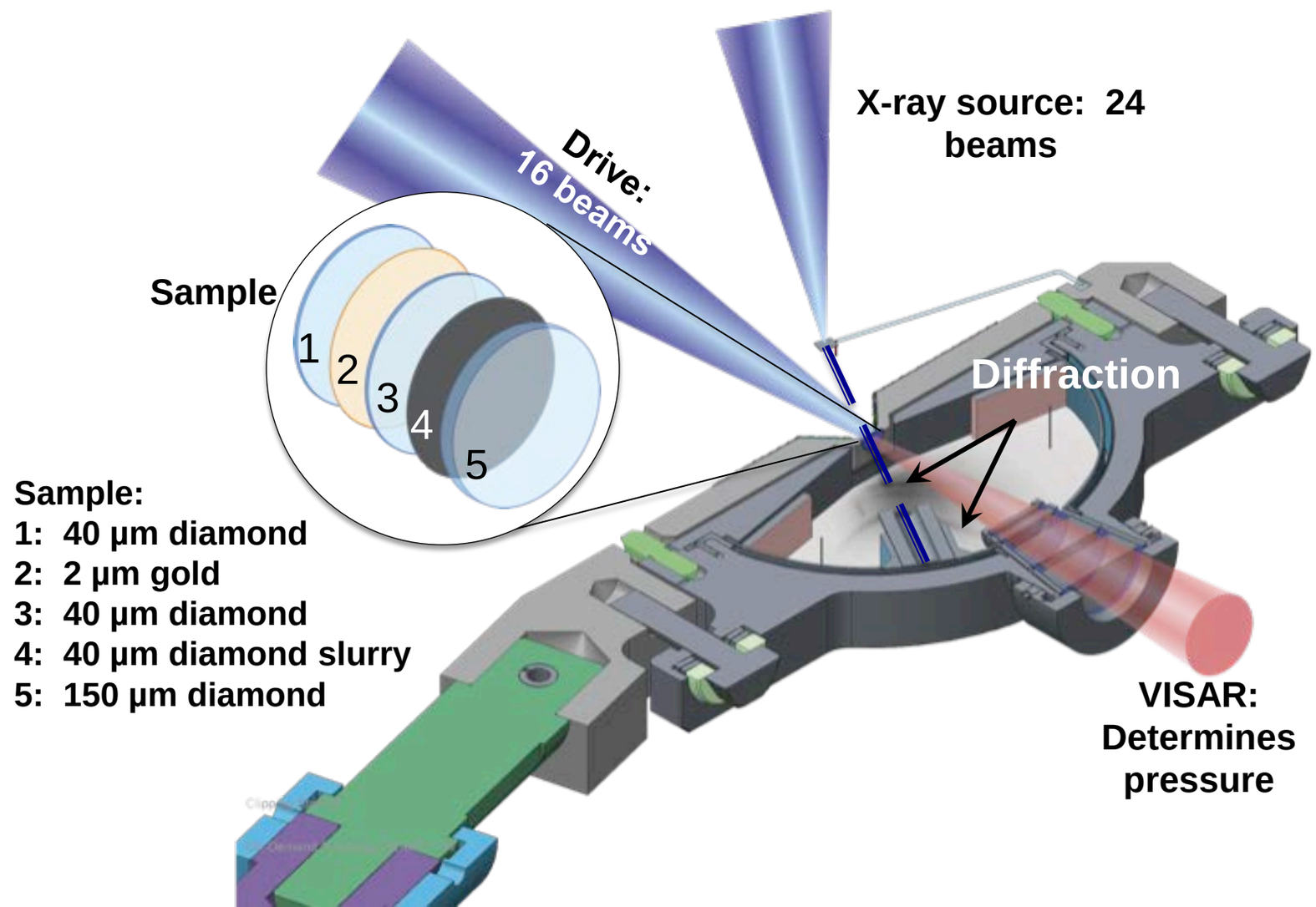
Lawrence Livermore National Laboratory

NIF and JLF User Group Meeting, February 9, 2015

LLNL-PRES-667199
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



Sample:
1: 40 μm diamond
2: 2 μm gold
3: 40 μm diamond
4: 40 μm diamond slurry
5: 150 μm diamond

Outline

1) **Overview of TARDIS on NIF**

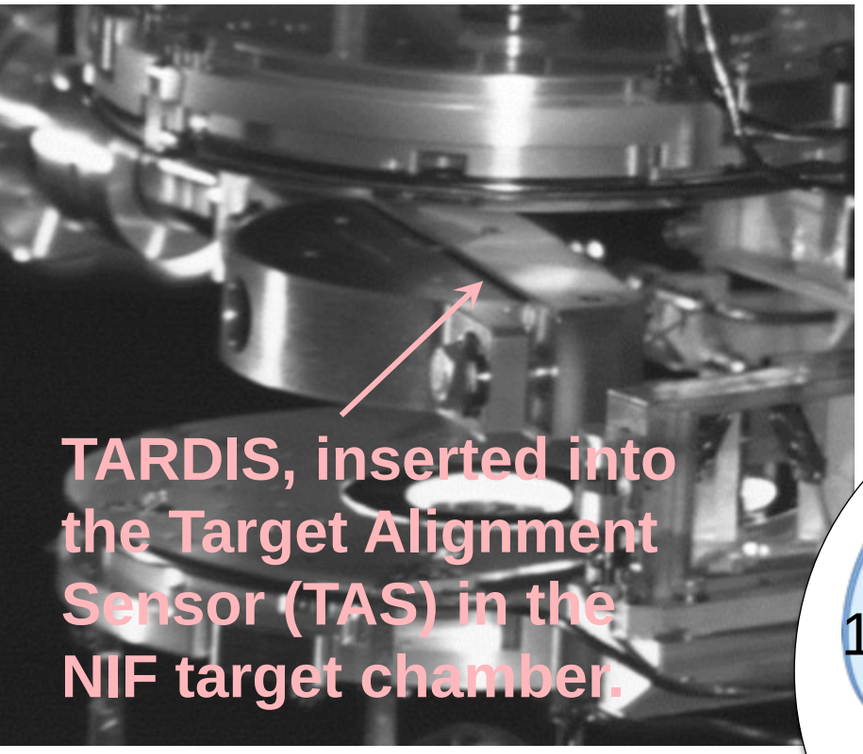
2) **Fundamental-science diffraction shots, so far.**

3) **Next year's Discovery science campaigns:**

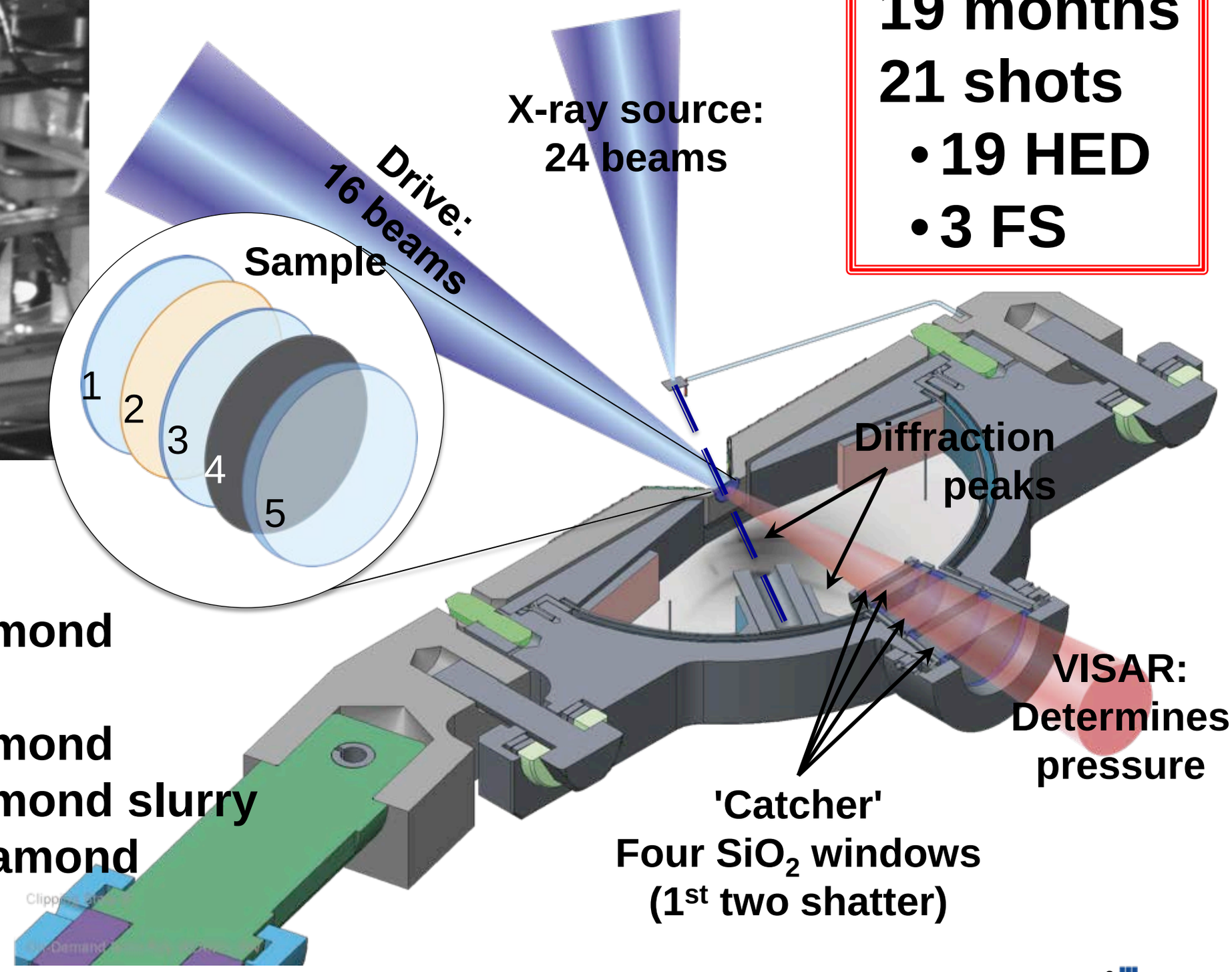
   a) **"*Release and Metastability of Dynamically Compressed Carbon*" – Justin Wark**

   b) **"*The Iron Melting Curve and Magnetospheres of Habitable Super Earths*" – next talk, Sarah Stewart**

TARDIS: TARget Diffraction In-Situ diagnostic for x-ray diffraction experiments on NIF



19 months
21 shots
- **19 HED**
- **3 FS**



Sample:
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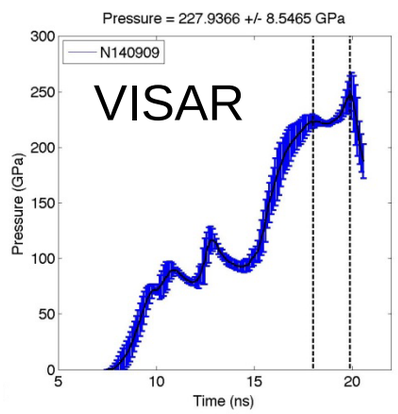
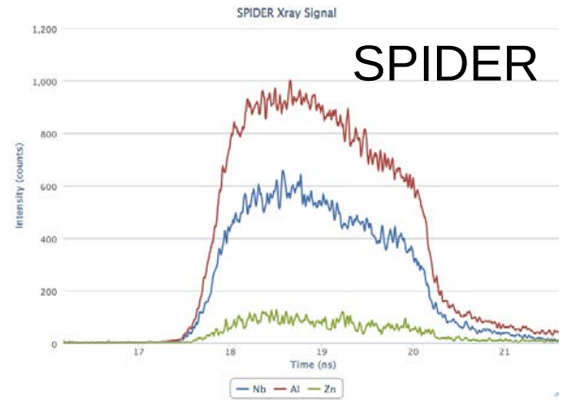
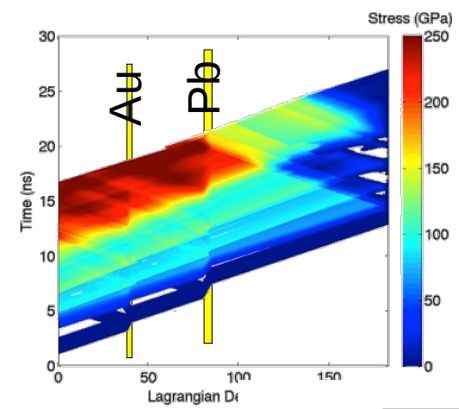
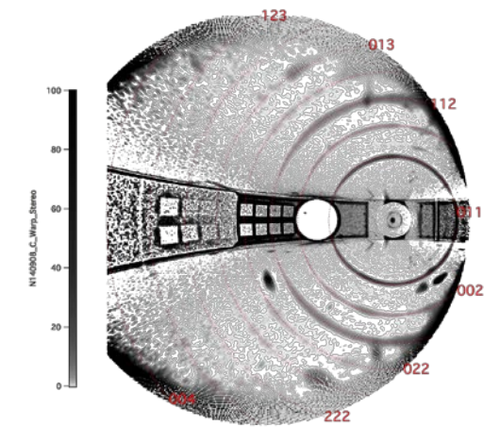
5: 150 µm diamond

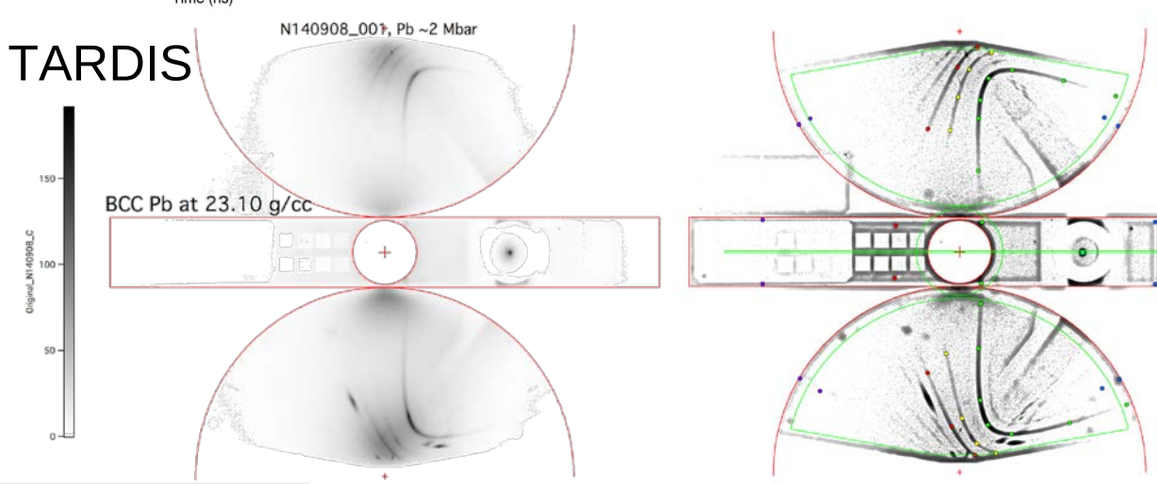
N140908, Pb, 2.28±0.09 Mbar
Detailed Analysis

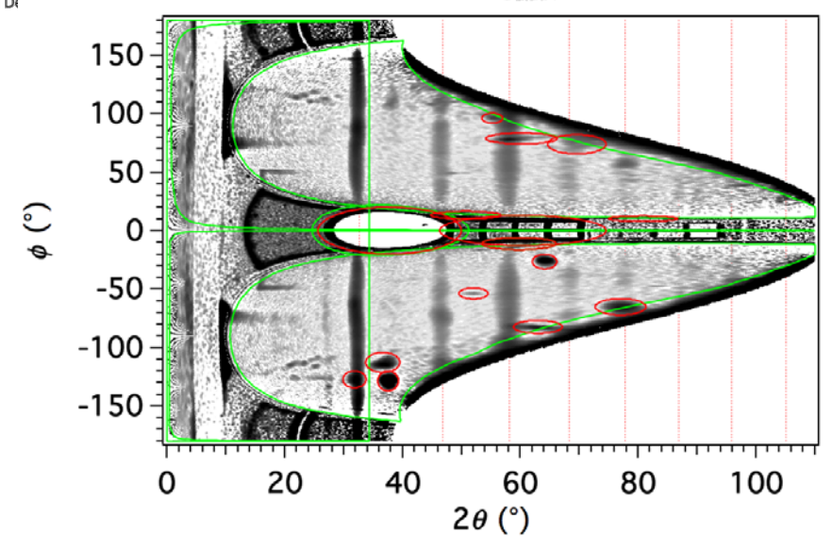


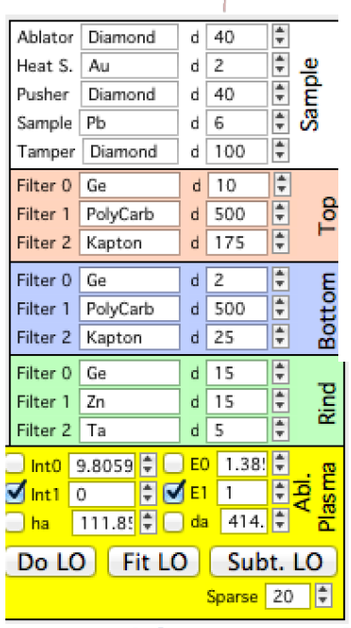


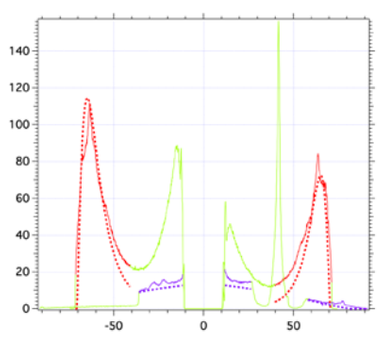


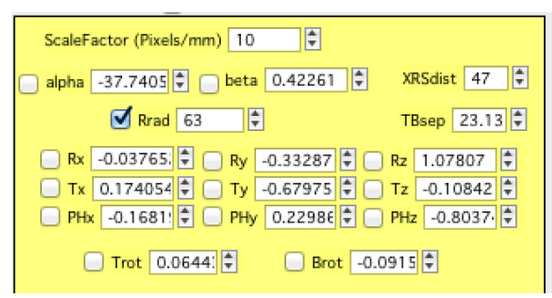












Position Error:

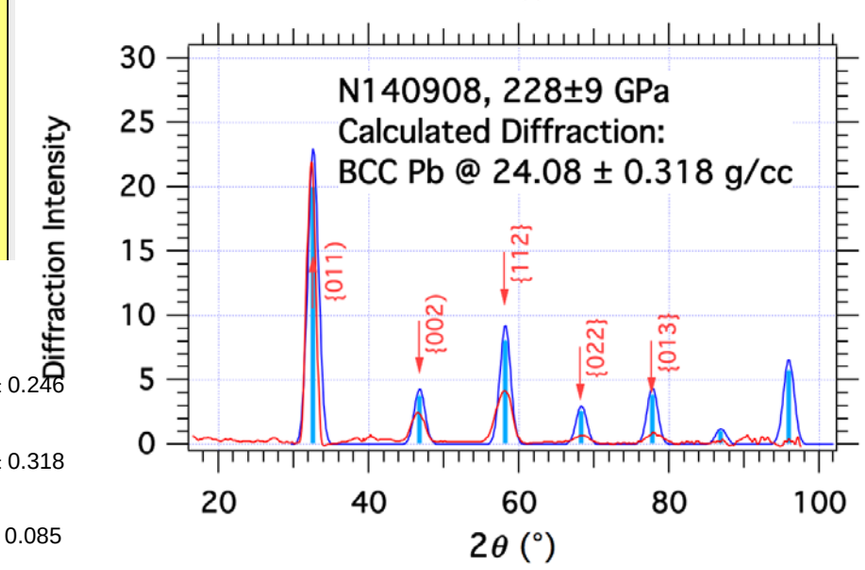
Cubic Fit: a = 3.079 ± 0.030; Volume per Atom = 14.59 ± 0.152; Density = 23.58 ± 0.246

Linewidth:

Cubic Fit: a = 3.057 ± 0.039; Volume per Atom = 14.29 ± 0.189; Density = 24.08 ± 0.318

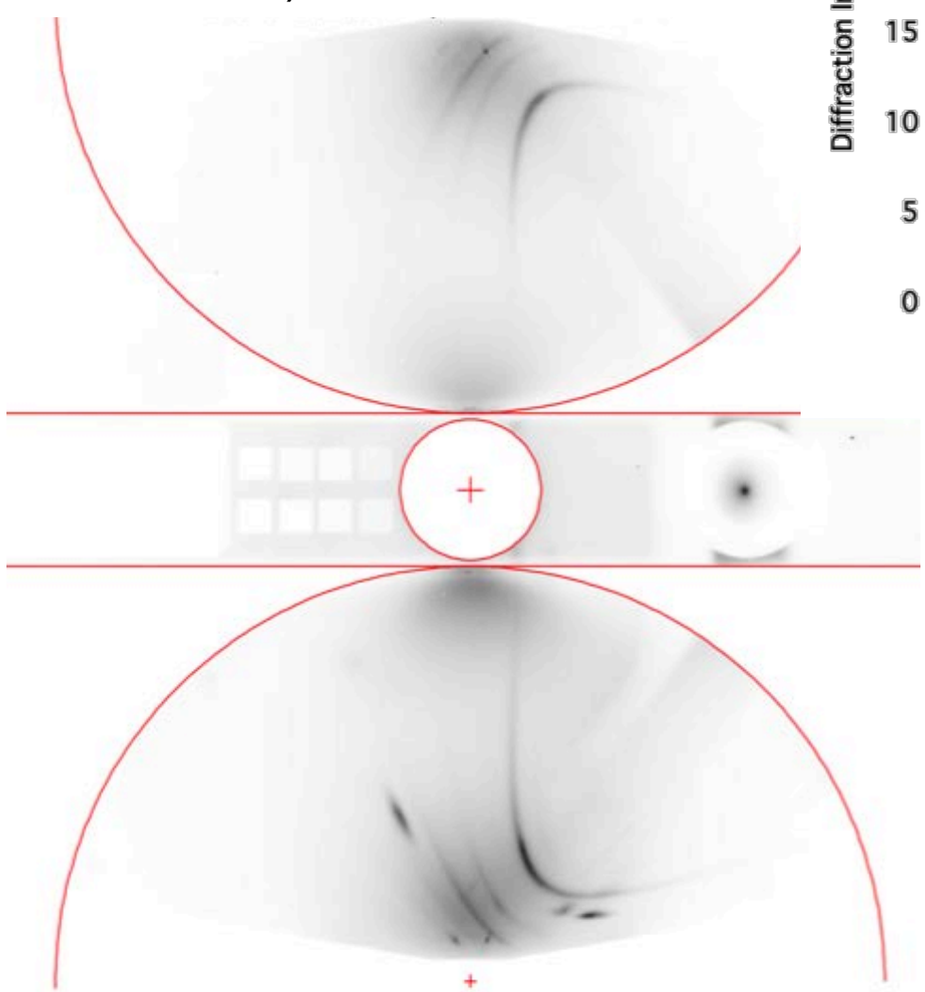
Constant:

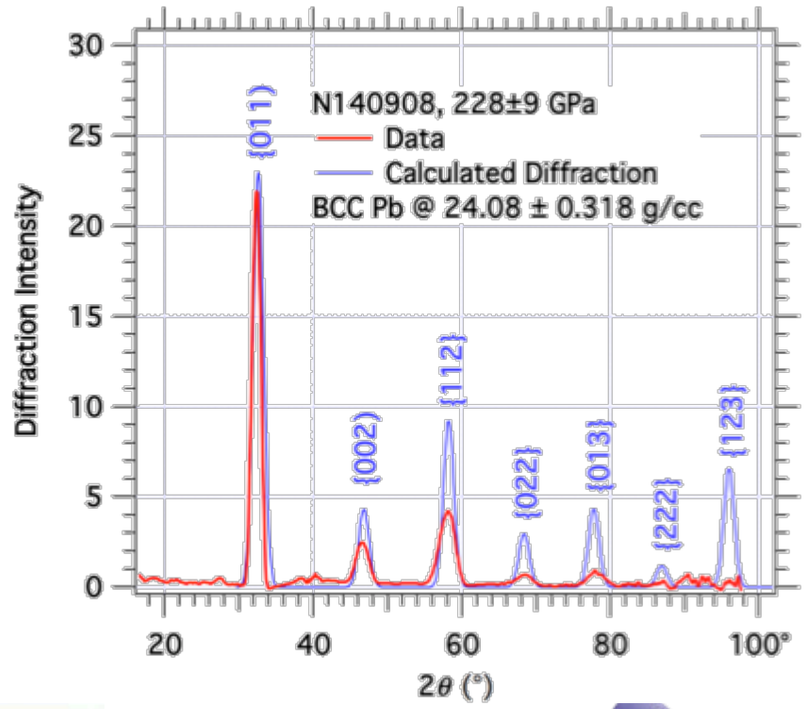
Cubic Fit: a = 3.056 ± 0.010; Volume per Atom = 14.28 ± 0.050; Density = 24.10 ± 0.085

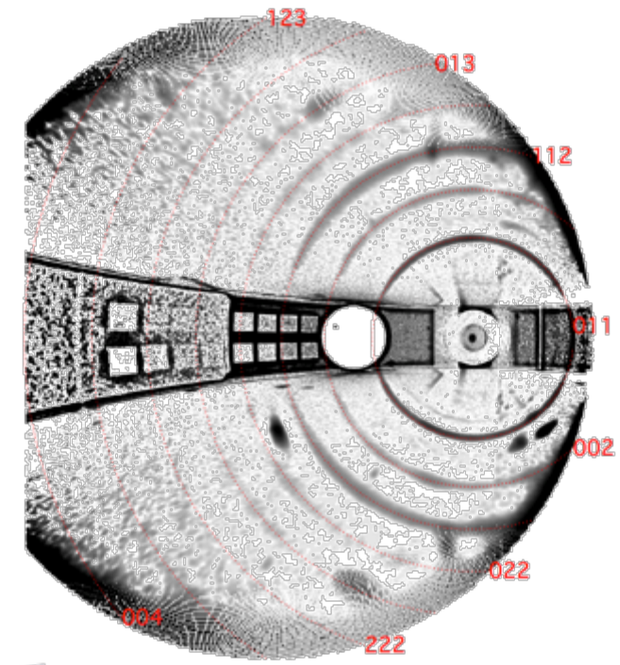


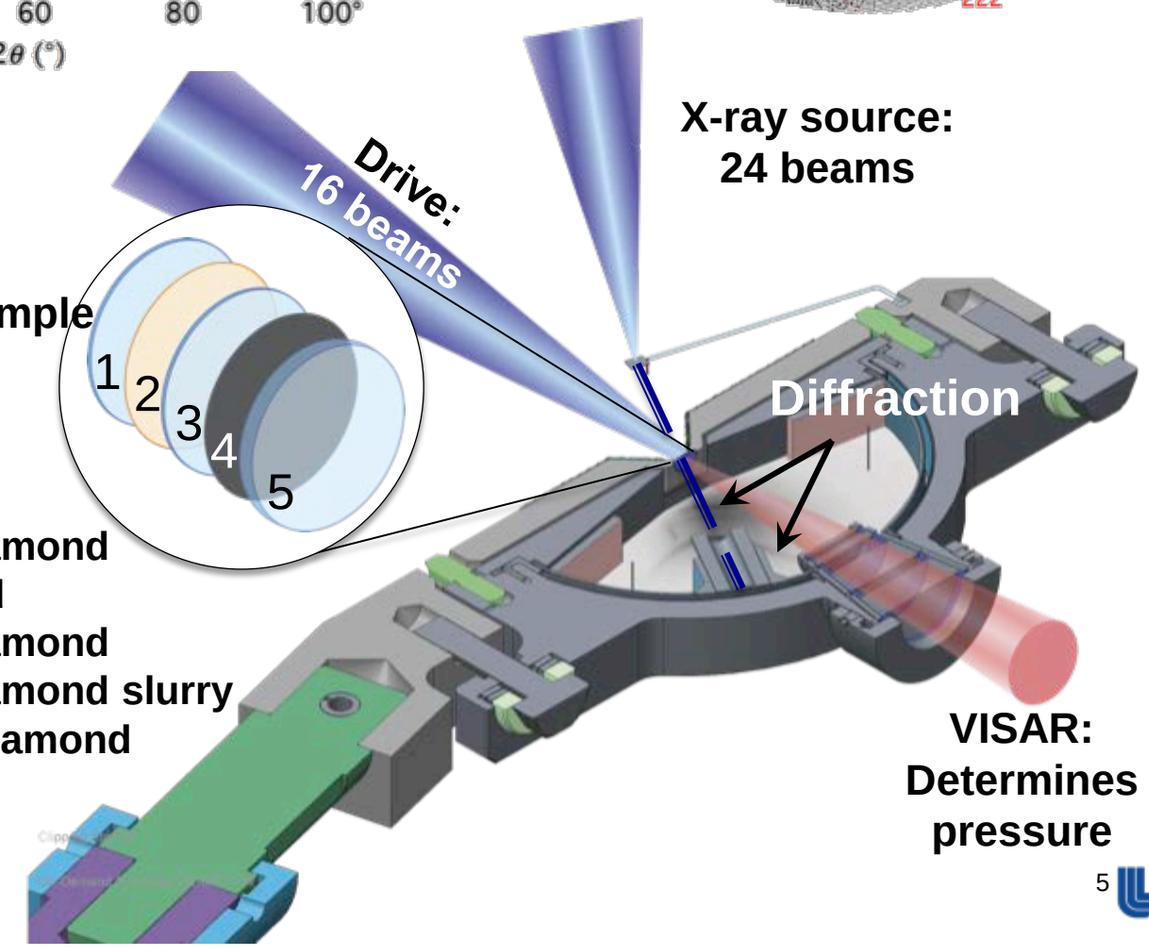
TARDIS: TARget Diffraction In-Situ diagnostic is currently working well for high-Z (Z>50) samples

N140908, Pb 2.3±0.2 Mbar









Sample:
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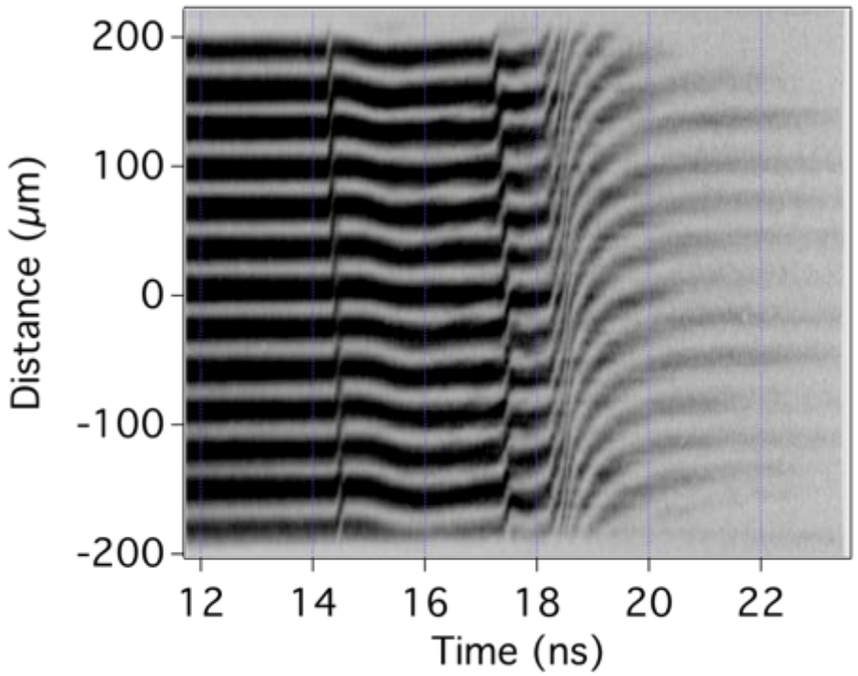
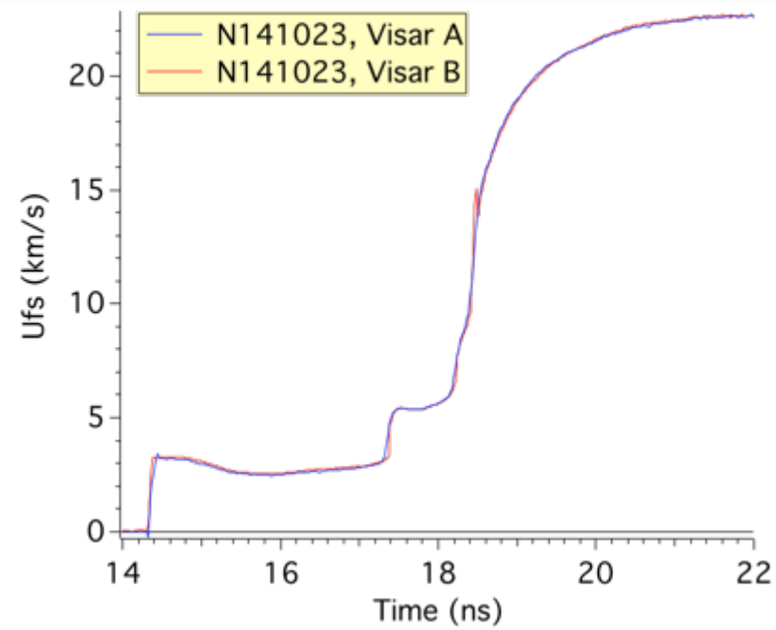
4: 40 μm diamond slurry
5: 150 μm diamond

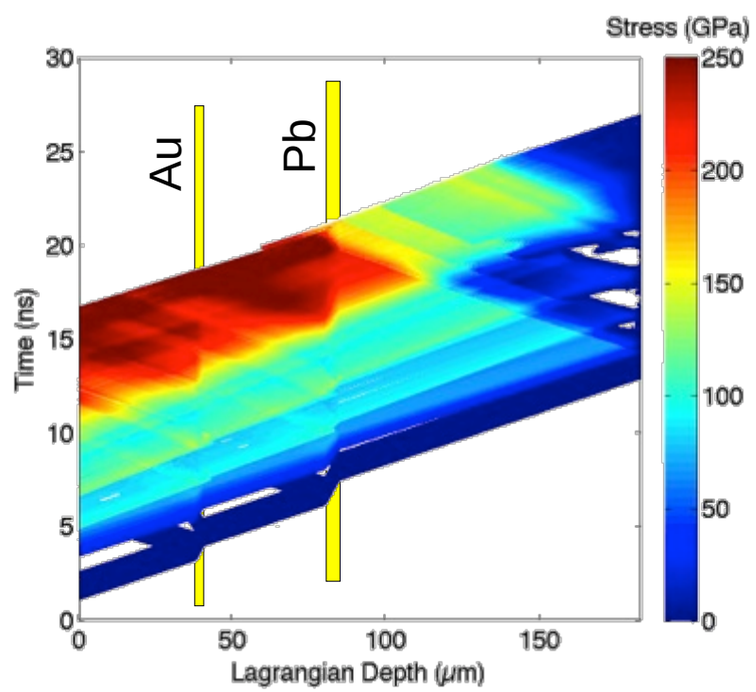
Signal to detection limit ~500:1

We use VISAR to determine stress in the sample

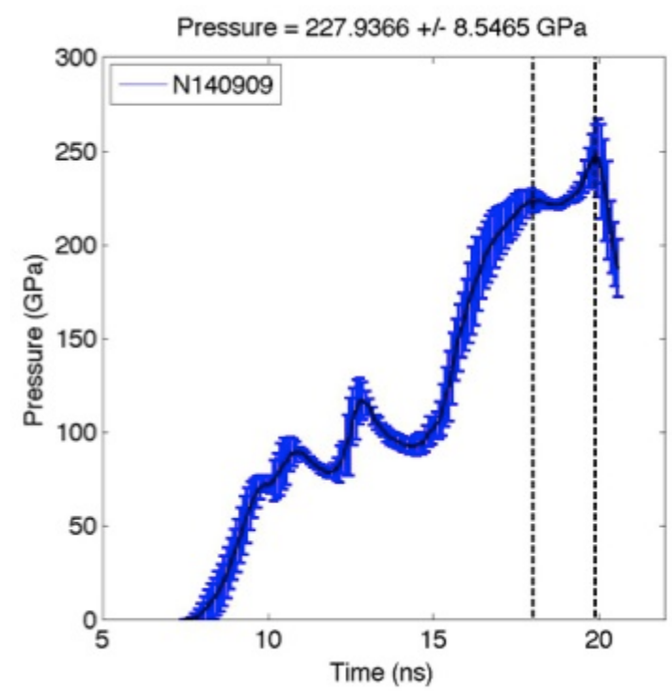




Back-propagated stress history

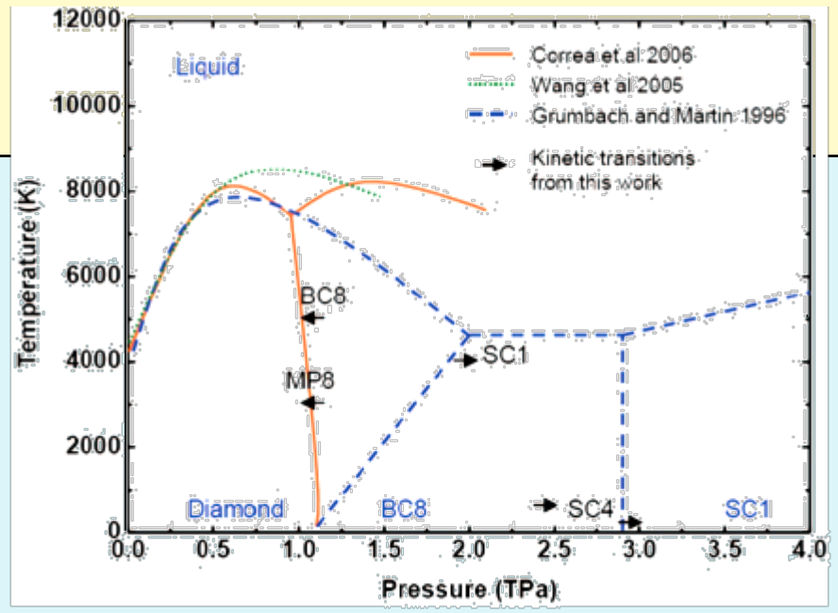


Stress within sample

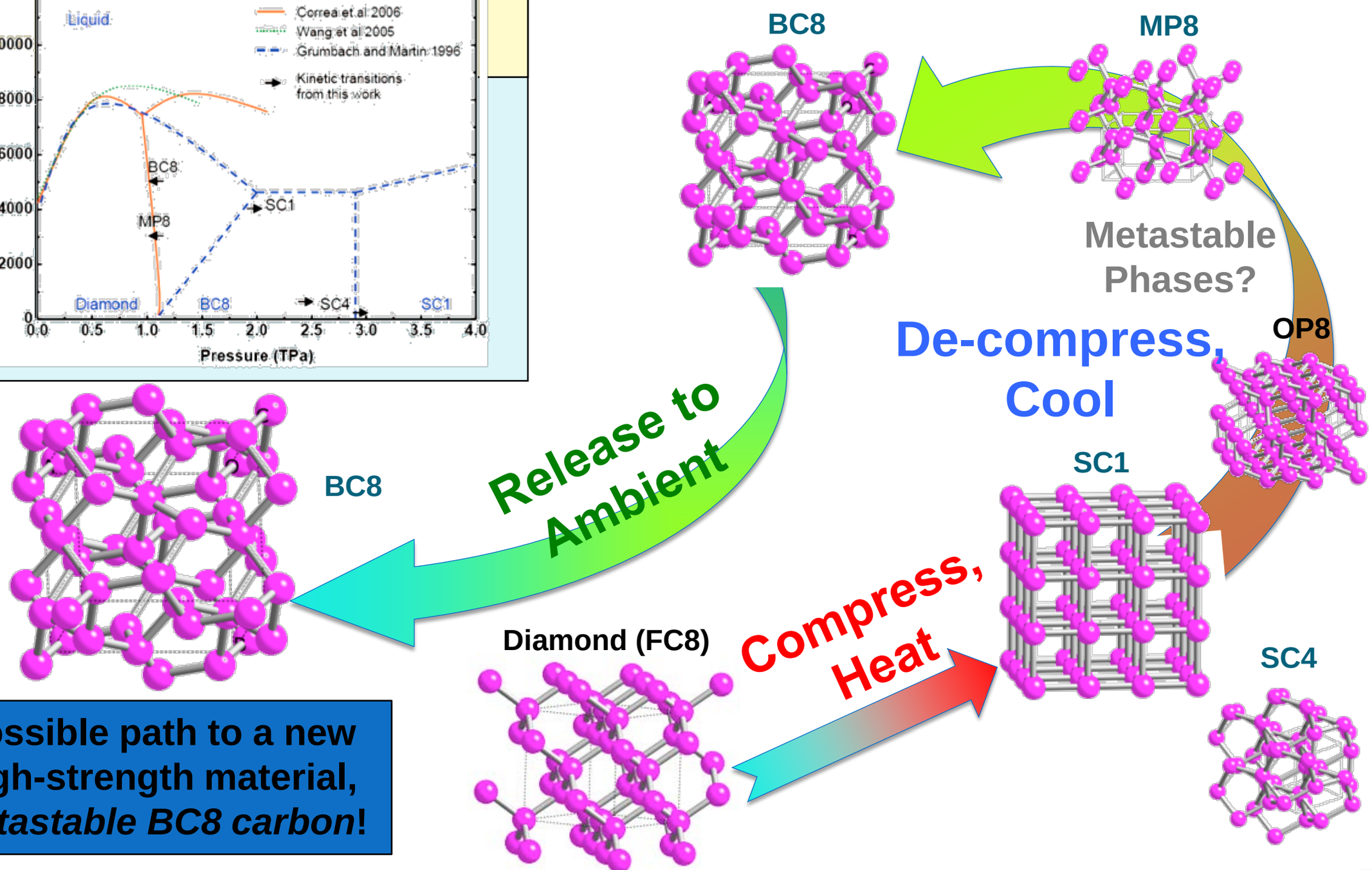


Current Fundamental Science on NIF campaign to try to locate BC8 phase of carbon

Carbon Phase

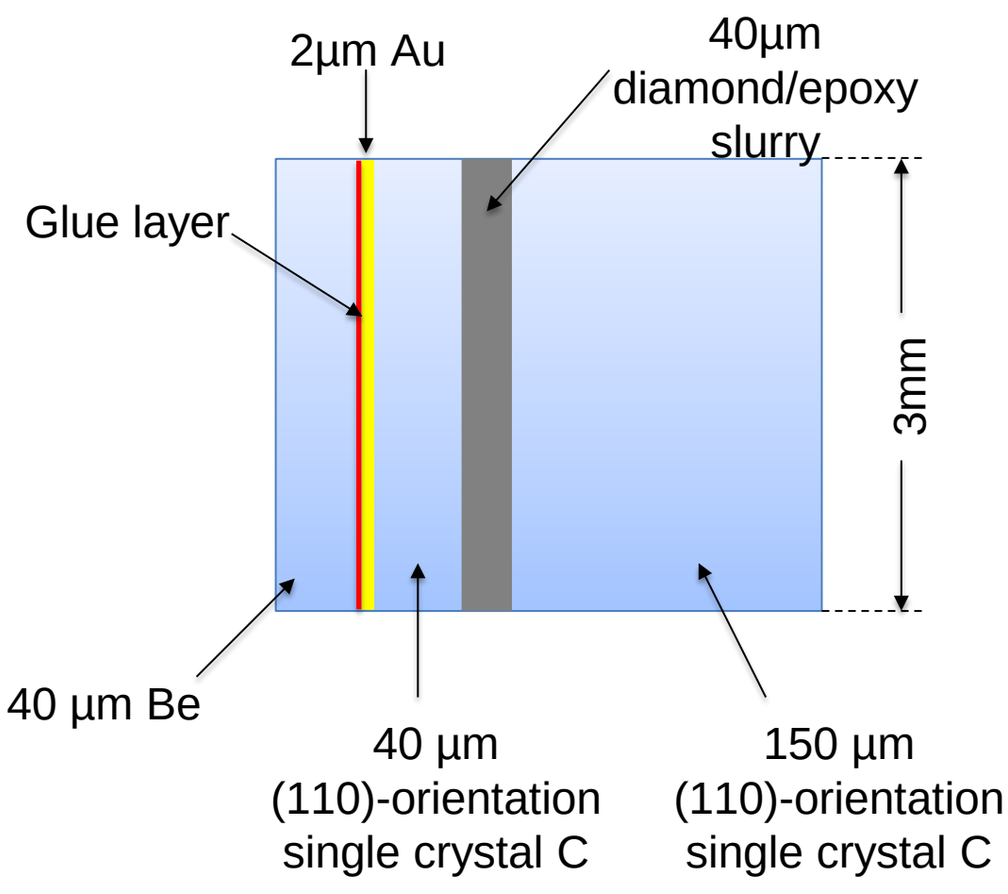


Sun, Klug, and Martonak, JCP 2009



Possible path to a new high-strength material, *Metastable BC8 carbon*!

So far we have taken 3 shots on diamond



Target is a diamond/epoxy slurry with ~ 50% diamond by volume

N130919—6.8 Mbar, Test of drive planarity, Ge XRS, 1.8 mm pinhole: Very high background and no discernable diffraction

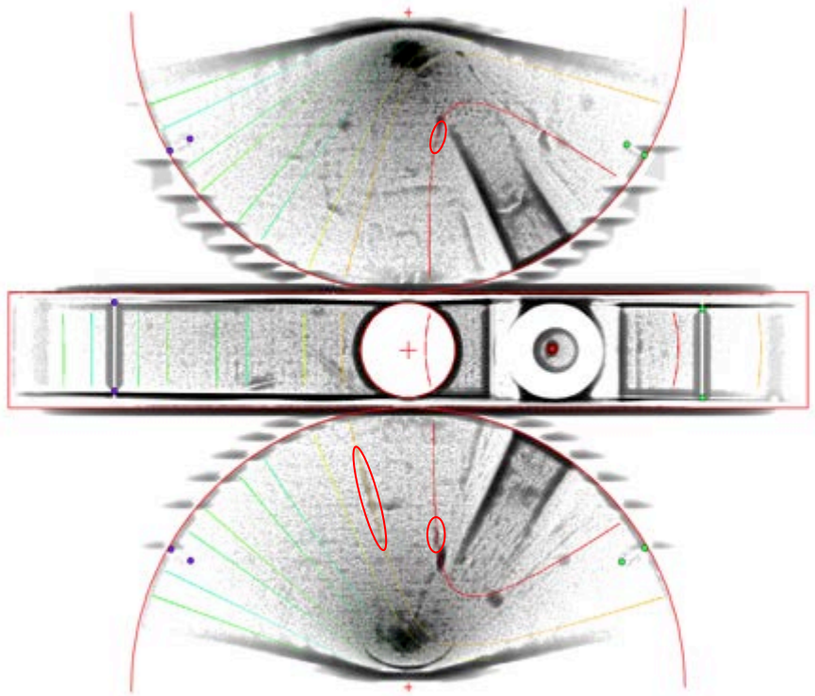
N141002—6.8 Mbar, Zr XRS to eliminate fluorescence background: Two highly textured diffraction lines.

N141023_002—8.2 Mbar, Zr XRS: Two highly textured diffraction lines.

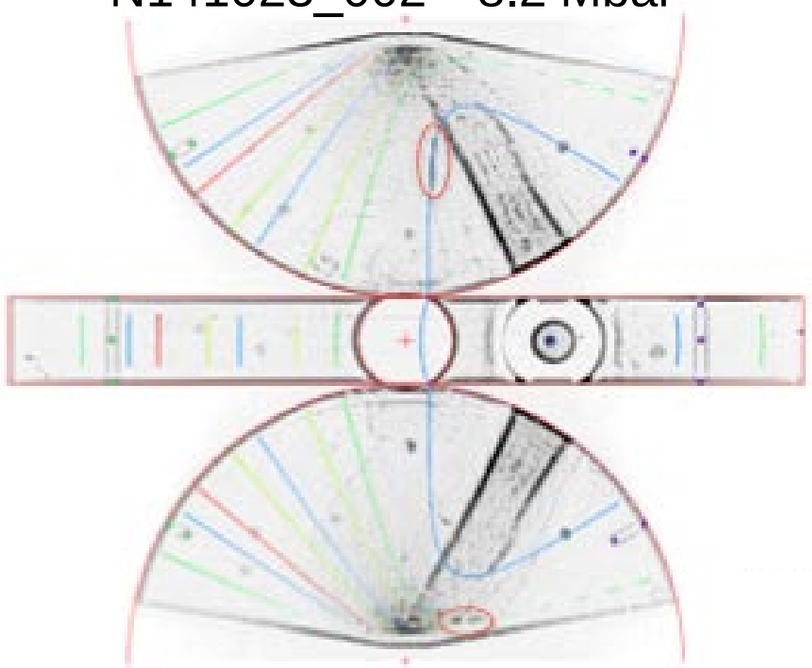
- Signal to detection-limit ratio (S/DL) >500 for the strongest lines in 6 µm Pb (using Ge XRS)
- Diffraction proportional to Z^2 so the signal in diamond should be $(92/6)^2$ ~235x weaker in C.
- But our sample is ~6 times thicker and the absorption is 2x less, so we should have S/DL > 25.

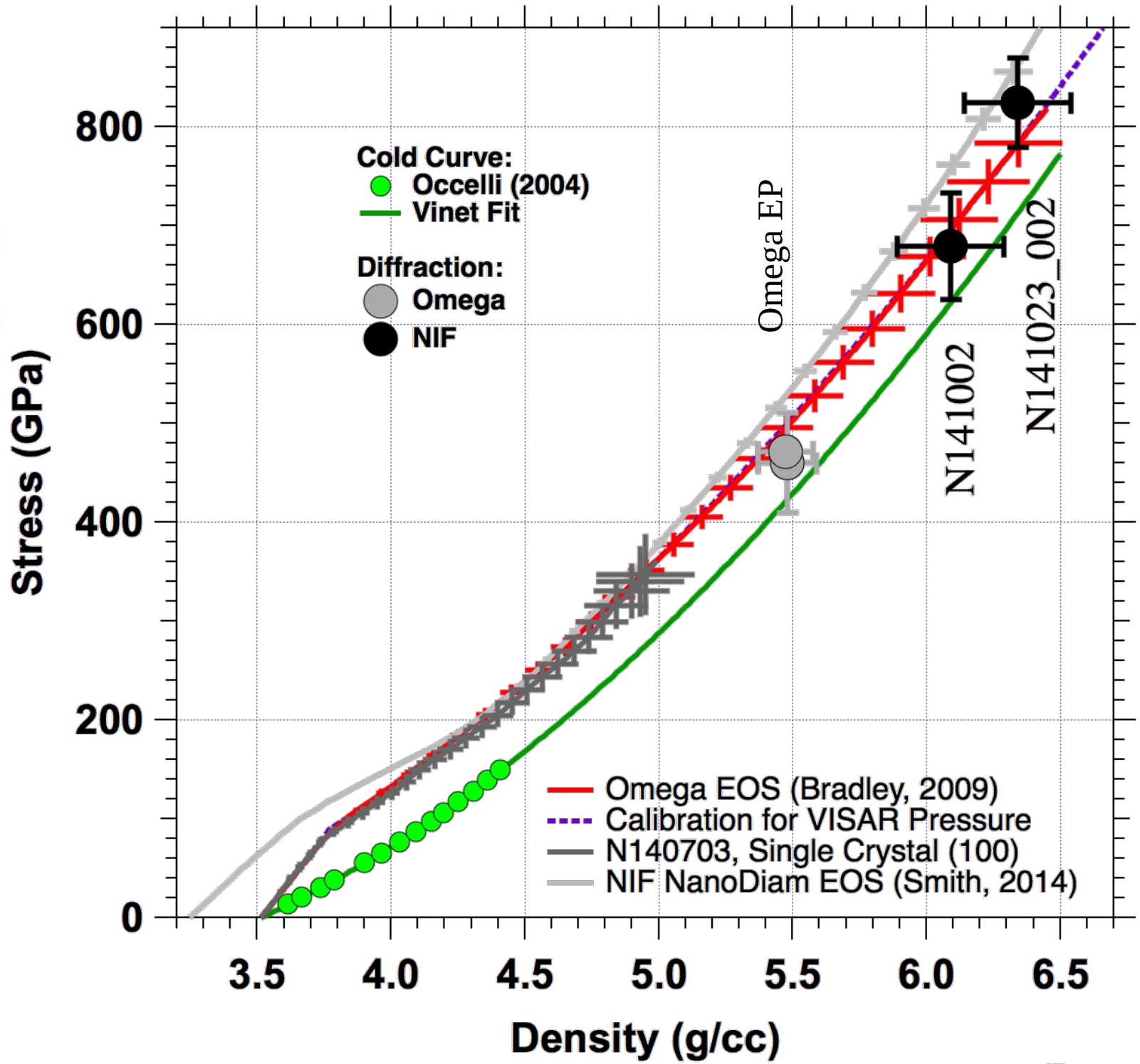
Using a Zr XRS we have seen highly structured diffraction from diamond on two FS shots

N141002—6.8 Mbar



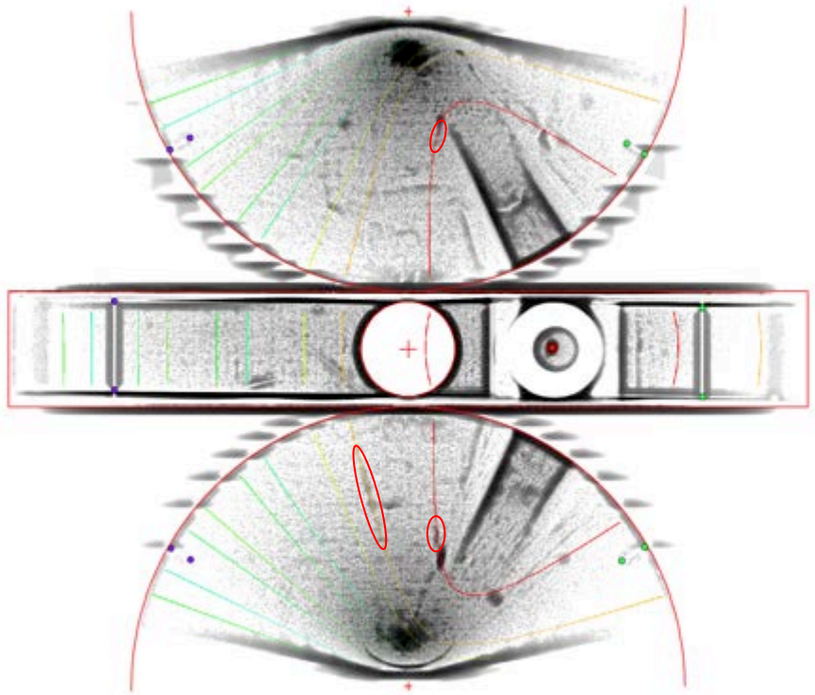
N141023_002—8.2 Mbar



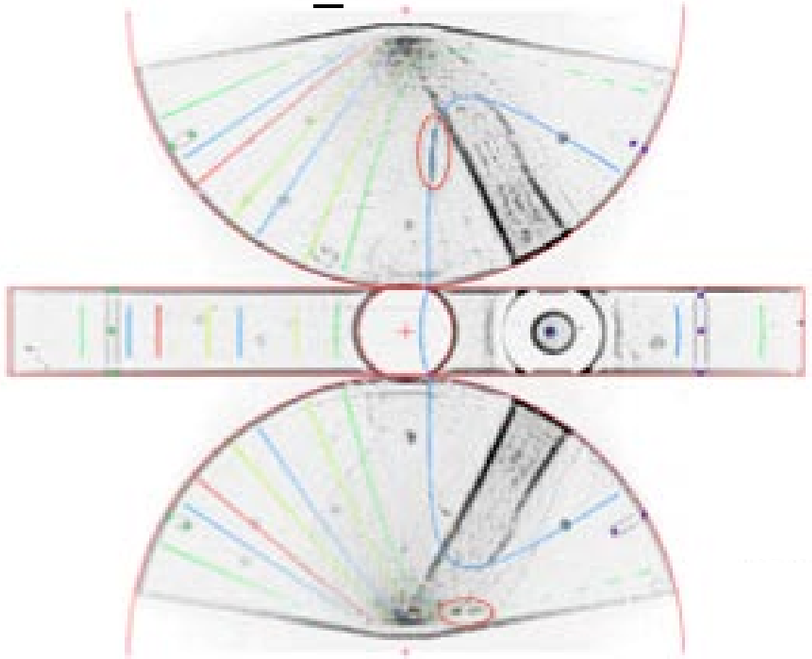


Issues with Carbon diffraction to date

N141002—6.8 Mbar



N141023_002—8.2 Mbar



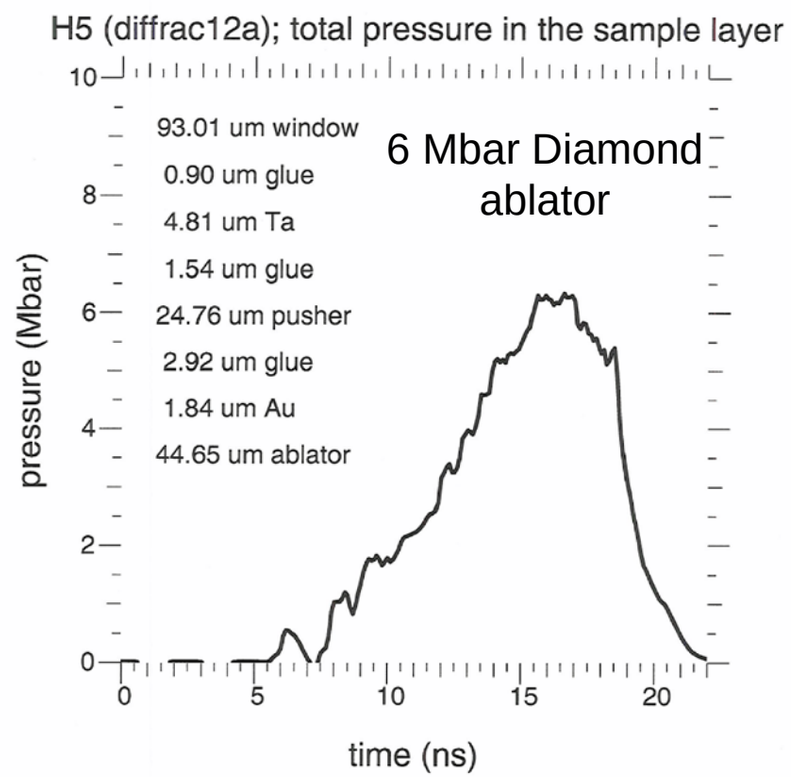
Issues:

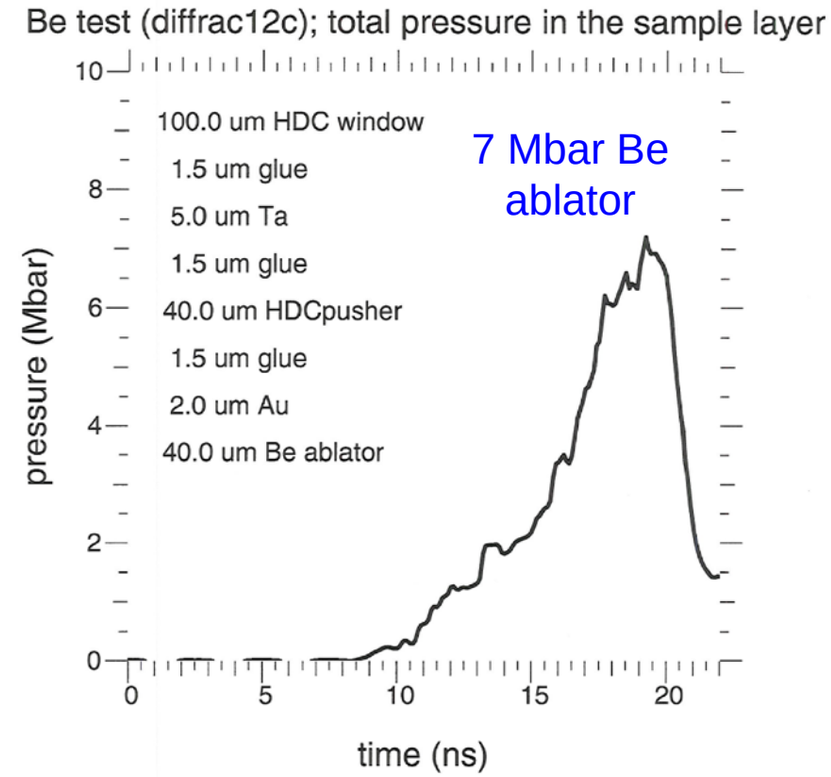
- Zr XRS is too weak.
  - o We will transition to Ge in Q2
- Ablation plasma is primary contributor to background.
  - o We will test Be ablator in Q2
- Observed texture implies diffraction may be from single crystal windows, not from slurry sample
  - o We will test higher density micro-crystalline CVD diamond sample in Q2
- We have four more shots this FY

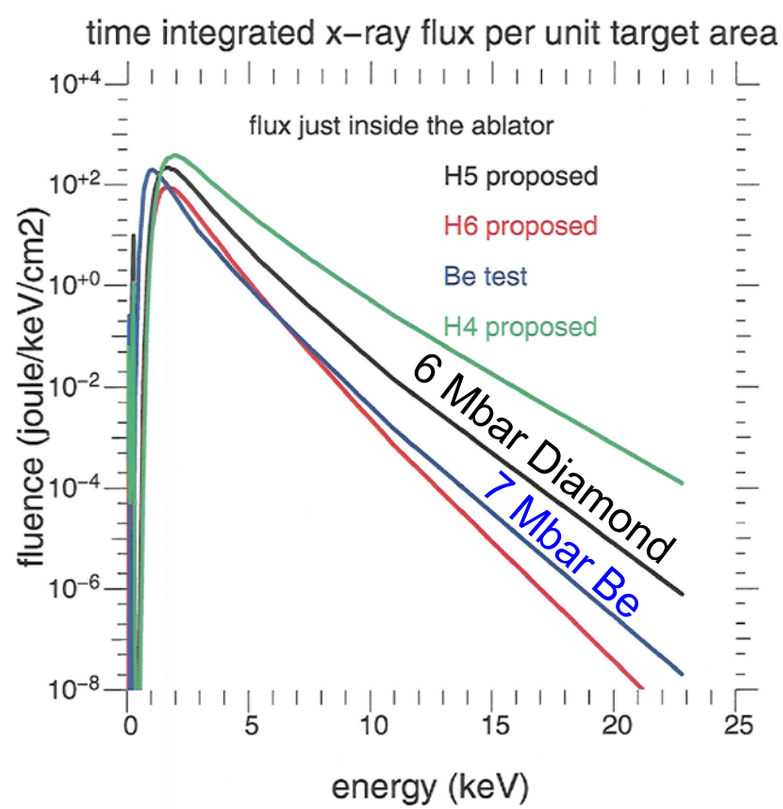
Comparison of ablation plasma for Diamond vs Be ablators

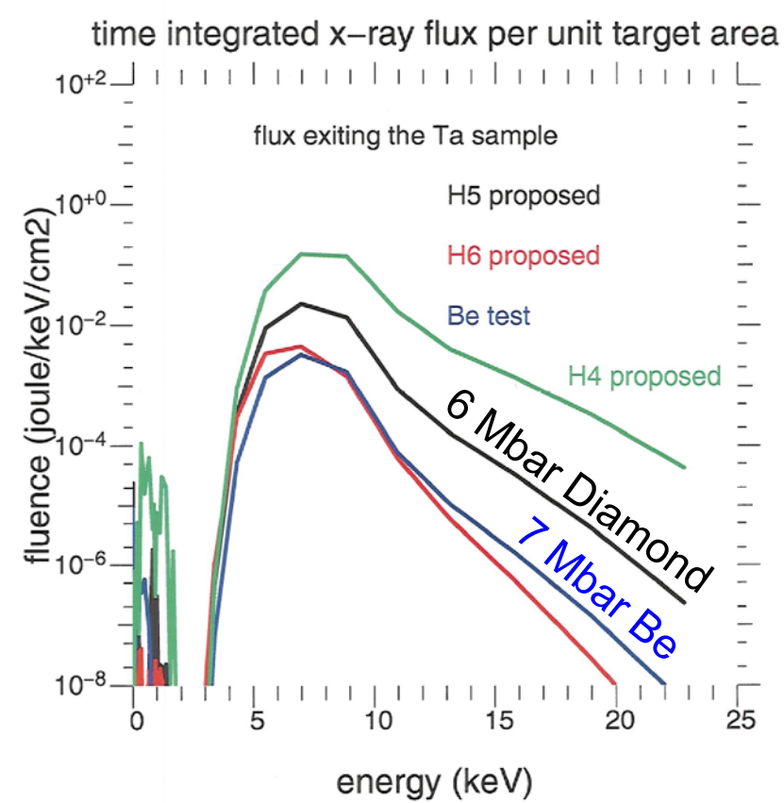
Alternate ablators may allow reduction in ablation plasma background.

LASNEX predicts ablation plasma background may be lowered by a factor of ~4.5







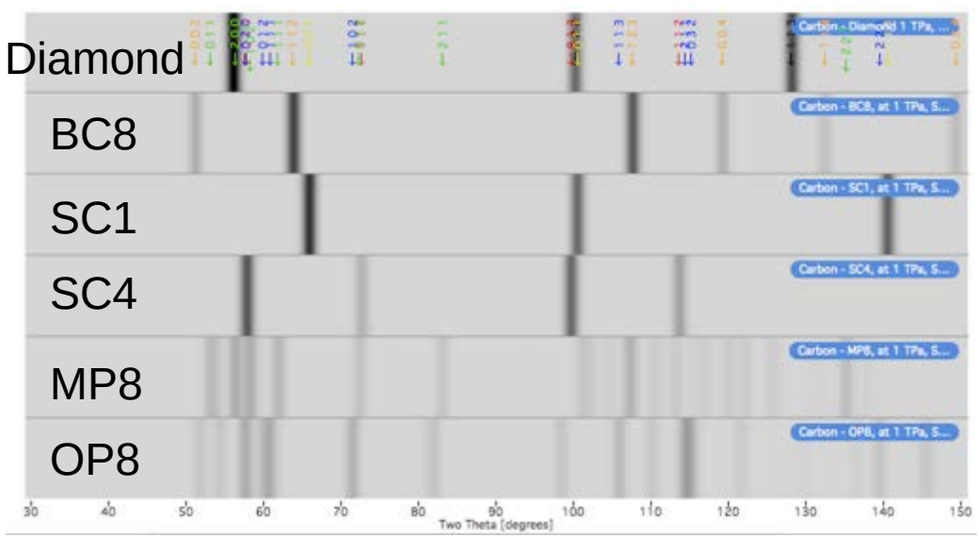


Next year, we will get 6 shots to study phases of carbon and hopefully metastability

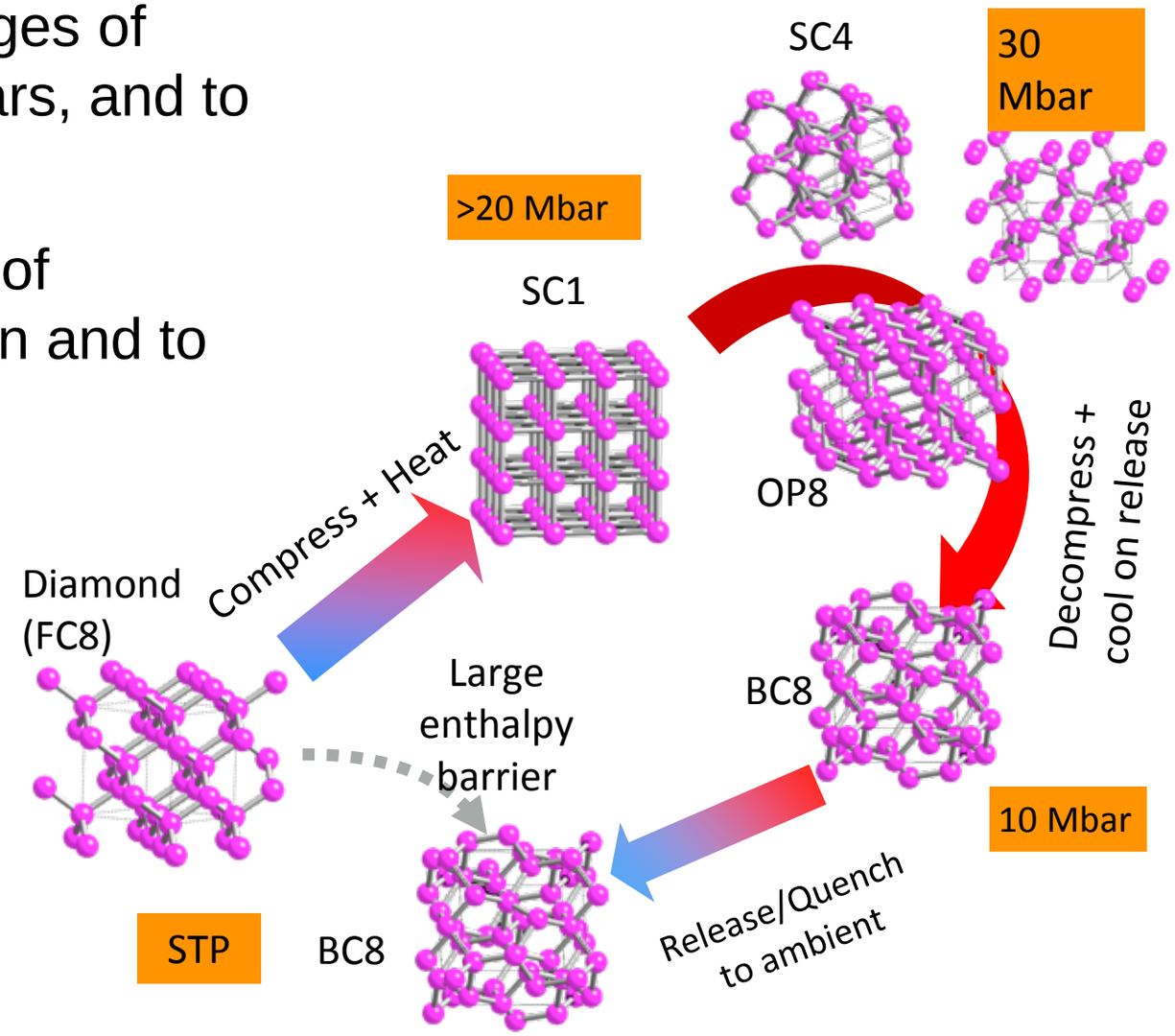
"Release and Metastability of Dynamically Compressed Carbon"

FY15 will aim to overcome the technical challenges of measuring diffraction from carbon at 10's of Mbars, and to search for new phases.

The new proposal (FY16) will explore the range of metastability of phases identified on compression and to search for new phases formed on release.



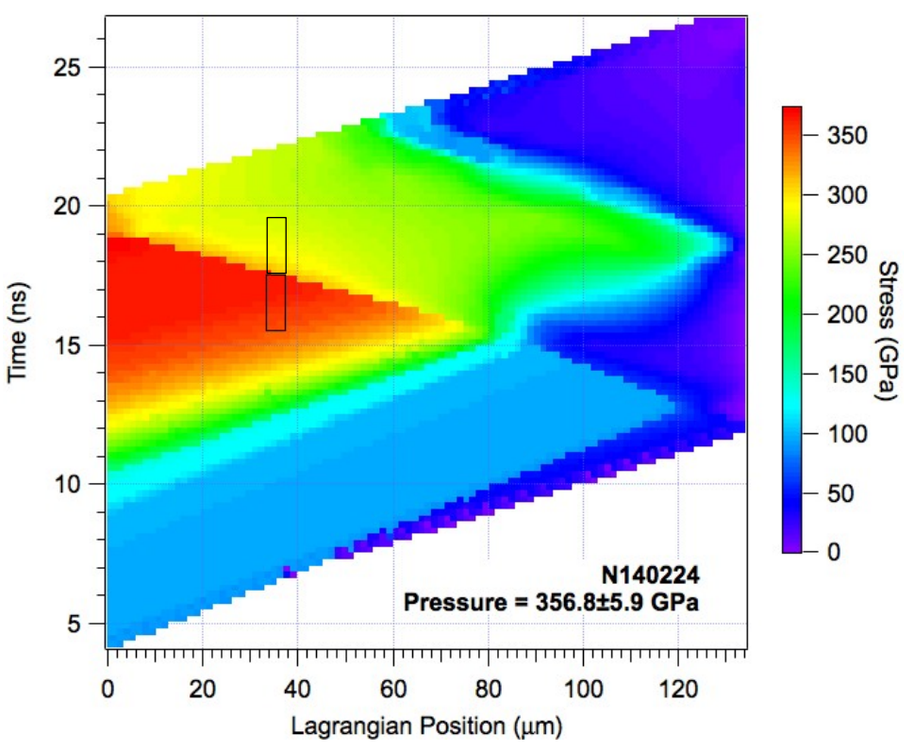
Diffraction of carbon structures at 1 TPa (Cu-He$_\alpha$)

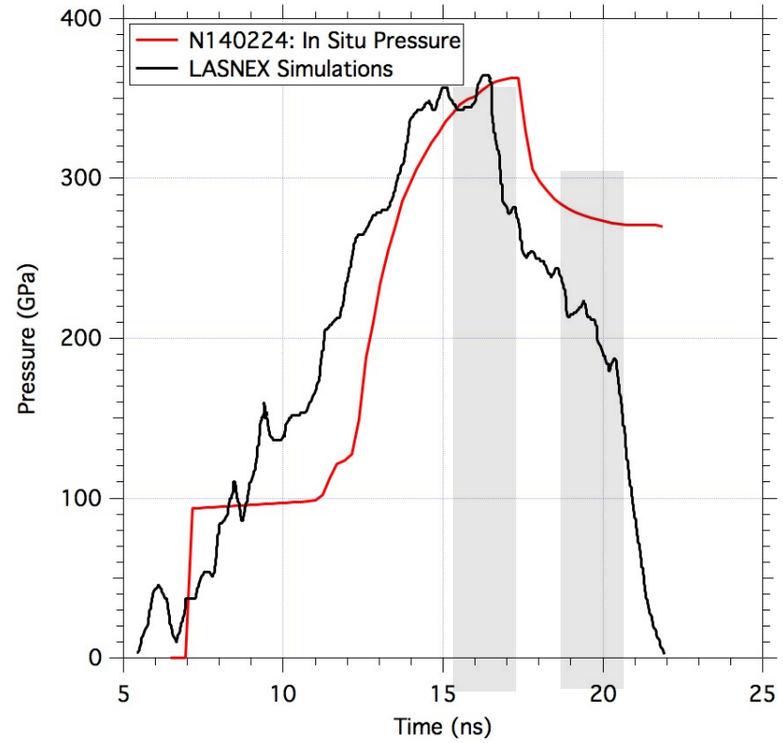


- Direct observation of a new high-pressure phase of carbon will be high-impact science.
- If the BC8 phase is indeed metastable at STP—and can be recovered—enormous technological impact will follow.

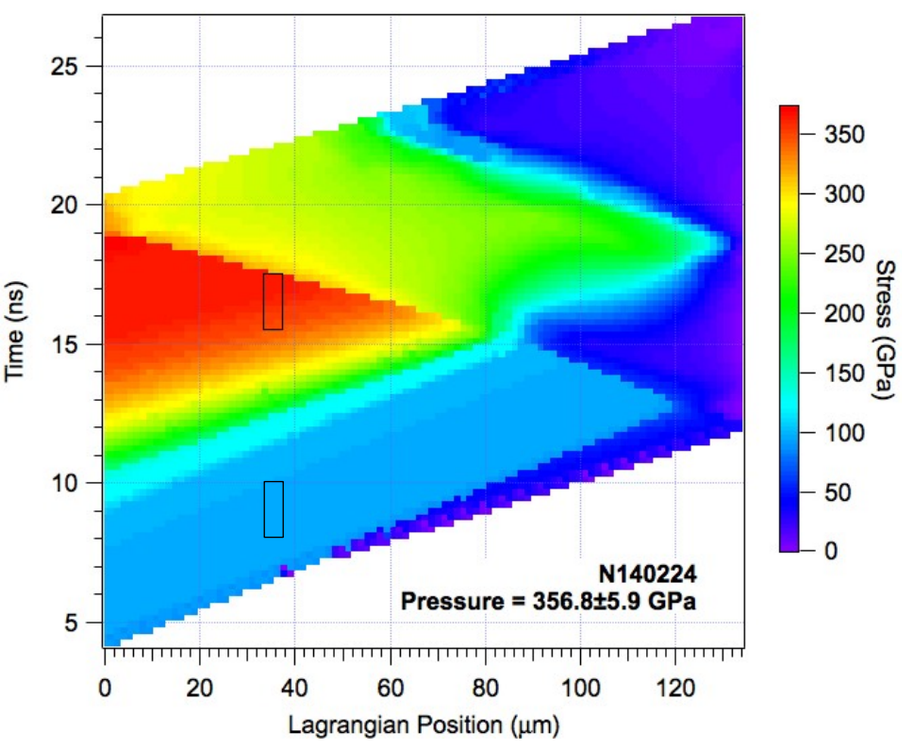
Justin Wark, Andy Higginbotham, Dennis Klug

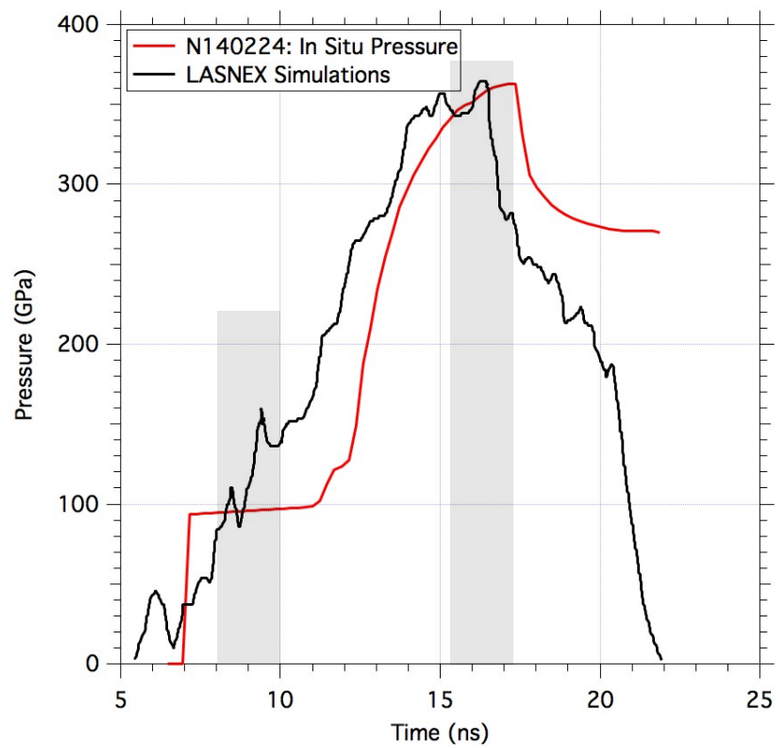
We would like to obtain two snapshots in time to measure both compression and release states





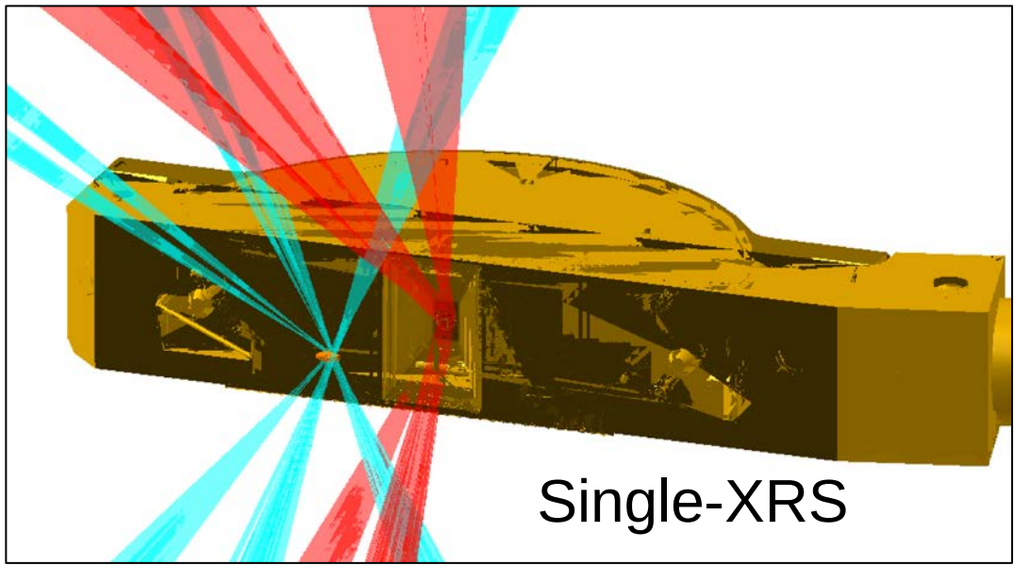
Compression-Release:
Allows us to observe hysteresis in a single shock.

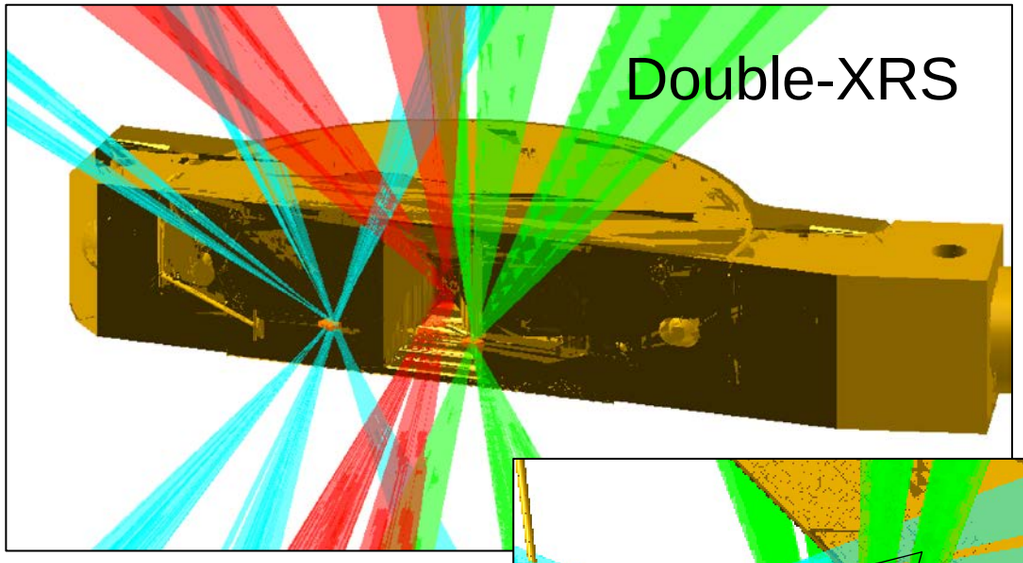


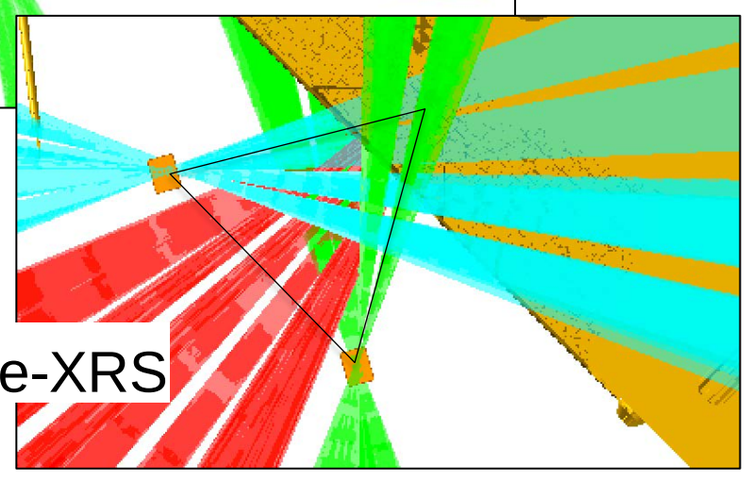


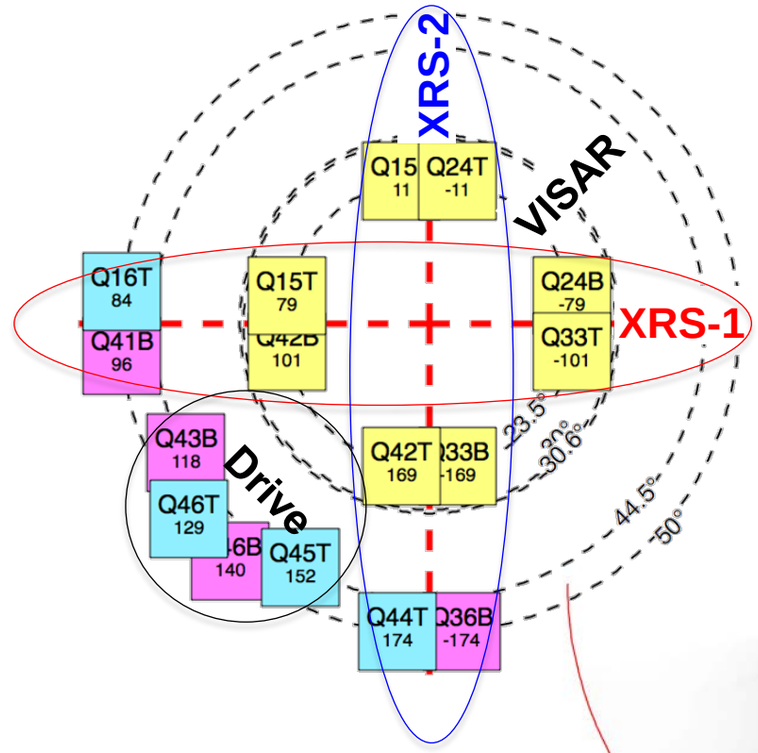
Shock-Ramp:
Allows us to observe two phases in a single experiment.

Using the Double-XRS geometry, to obtain in-situ compression—release data:

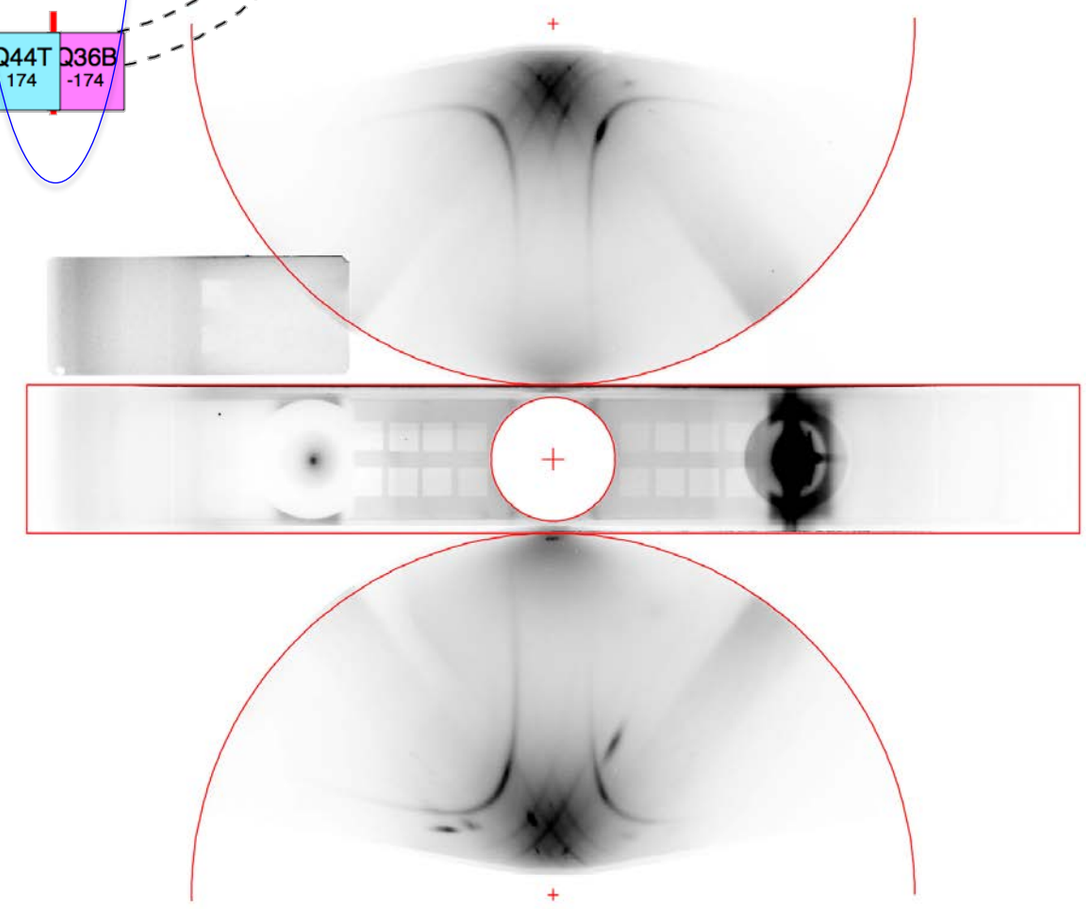








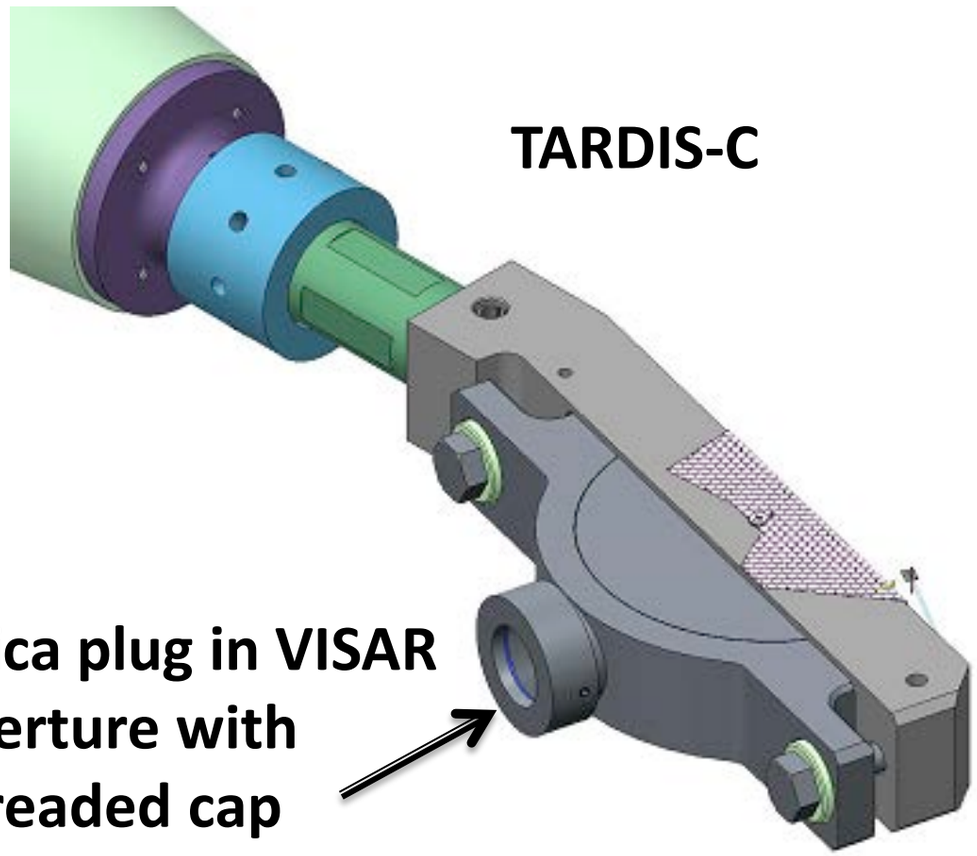
4-fold symmetry of NIF enables perfectly symmetric geometry

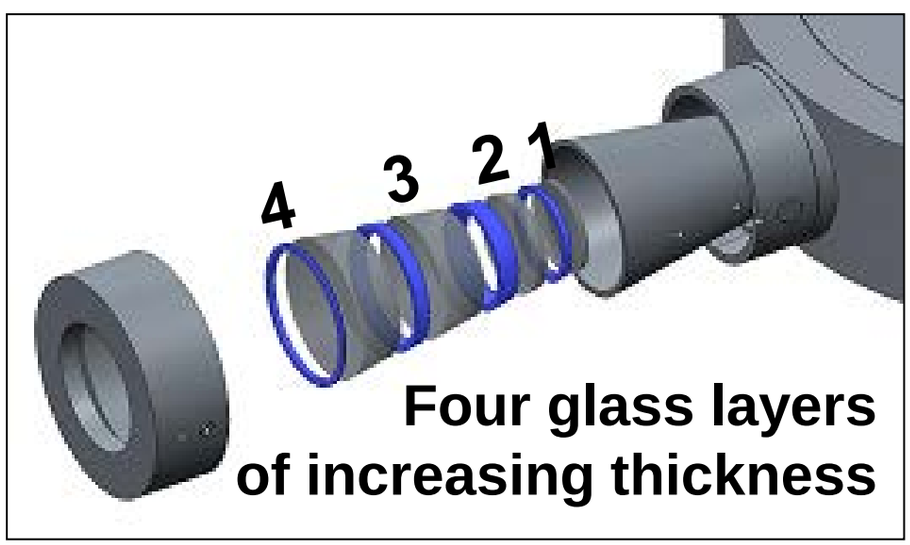


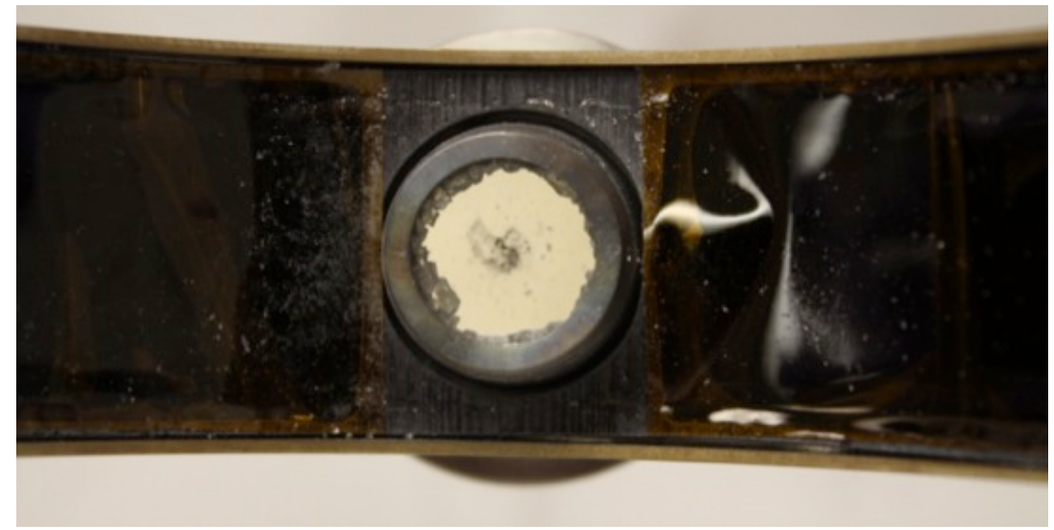
Double-XRS Data simulated by summing N140605 and N140908

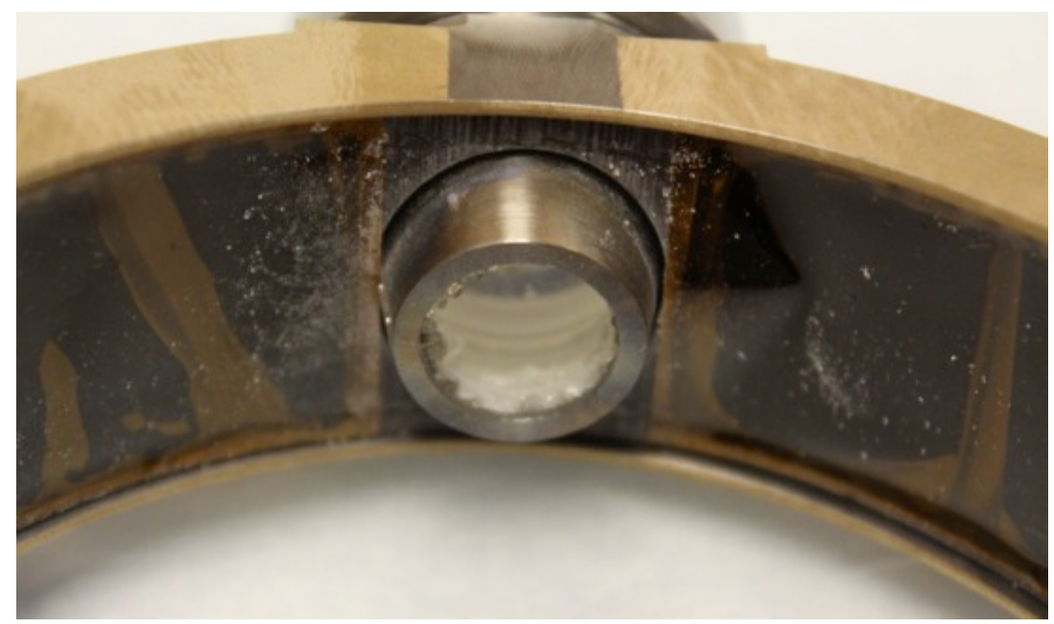
The TARDIS-C catcher (fielded twice, N140930 and N141213) will be used to recover carbon.

An optically clear barrier blocks debris from exiting the diagnostic









- First two glass layers were broken (as designed, the third has some damage but no significant cracking
- Material on the glass plug is evident

The TARget Diffraction In-Situ (TARDIS) diagnostic on NIF gives excellent diffraction data on high-Z (Z>50) materials up to 7 Mbar.

The Discovery-Science campaigns aim to extend this performance to low-Z materials to higher pressure.

The challenge is tough but the payoff for HED materials physics will be substantial.