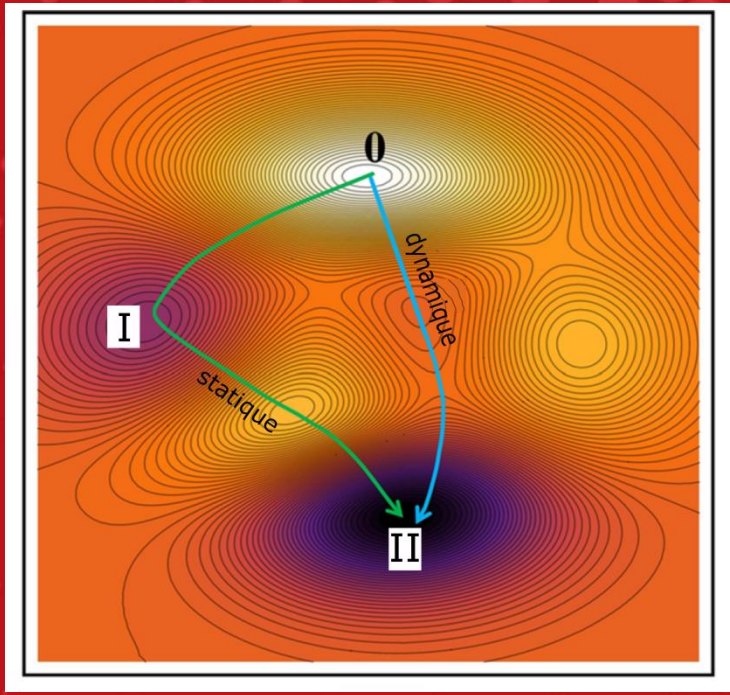
X-rays as a probe for dynamic compression experiments

C. Pépin, A. Sollier,
F. Occelli, P. Loubeyre
CEA, DAM, DIF
F-Arpajon Cedex



DE LA RECHERCHE À L'INDUSTRIE

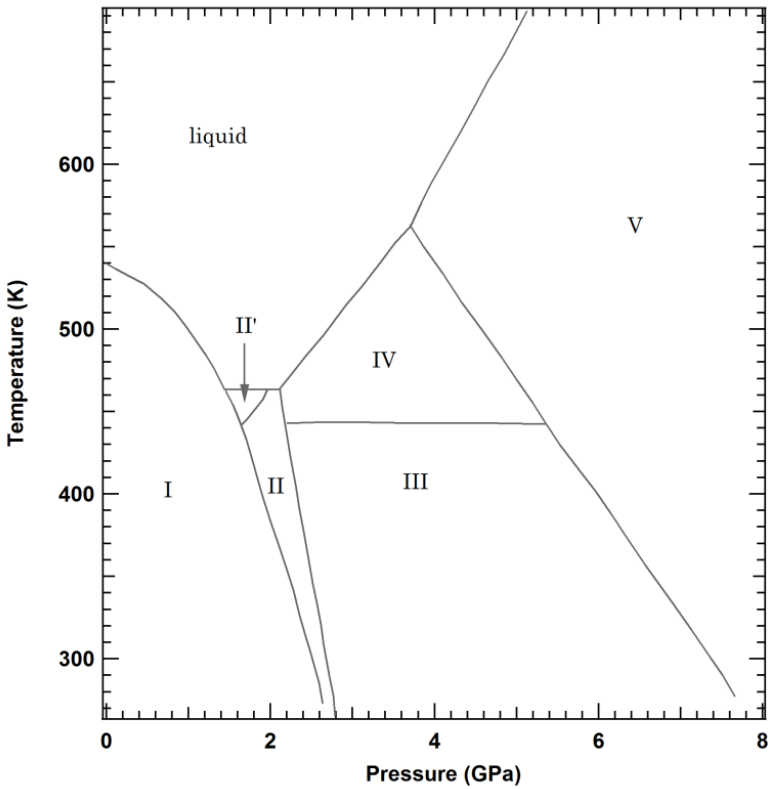
3rd DyCoMaX workshp

COUPLING X-RAYS WITH DYNAMIC COMPRESSION

- Dynamic compression produces extreme conditions on very short time scales
- Usually macroscopic diagnosis are used (VISAR, PDV)
- Recent development of microscopic diagnosis on large facilities
  - KJ laser (XRD, XAS)
  - XFEL

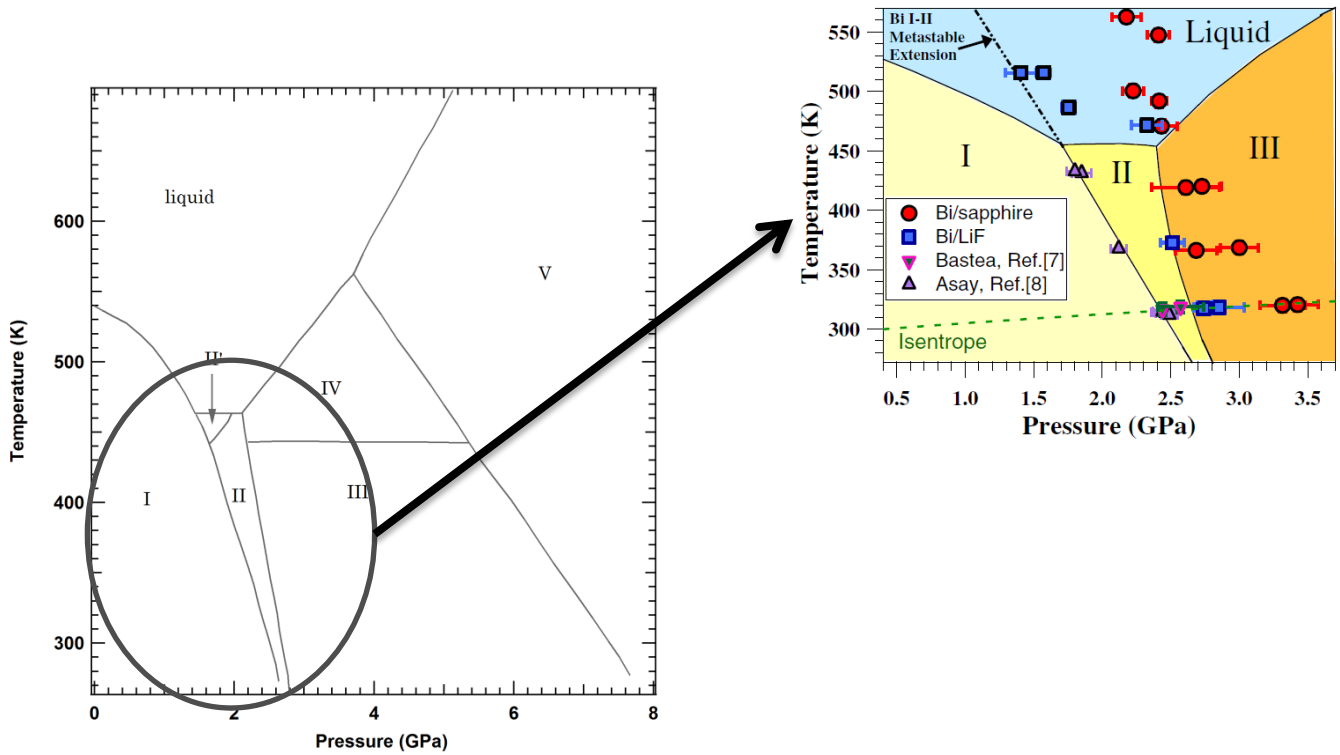
→ More detailed information available, directly comparable with static experiments

- EB-ESRF can perform such studies with a very high level of accuracy and data quality
- Take advantage of the stability and energy resolution


liquid
V
II'
IV
I
II
III
600
500
400
300
Temperature (K)
0
2
4
6
8
Pressure (GPa)

PRL **101,** 065701 (2008) PHYSICAL REVIEW LETTERS week ending 8 AUGUST 2008

Ultrafast Dynamic Compression Technique to Study the Kinetics of Phase Transformations in Bismuth



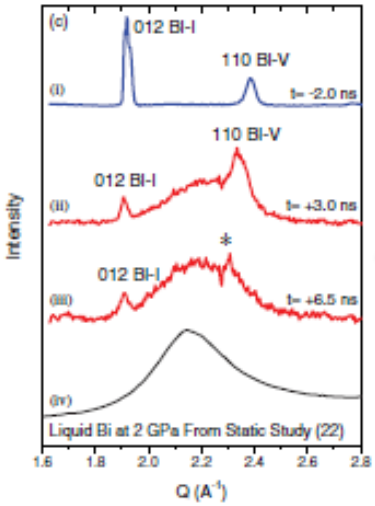
Shift of the phase transition observed by VISAR

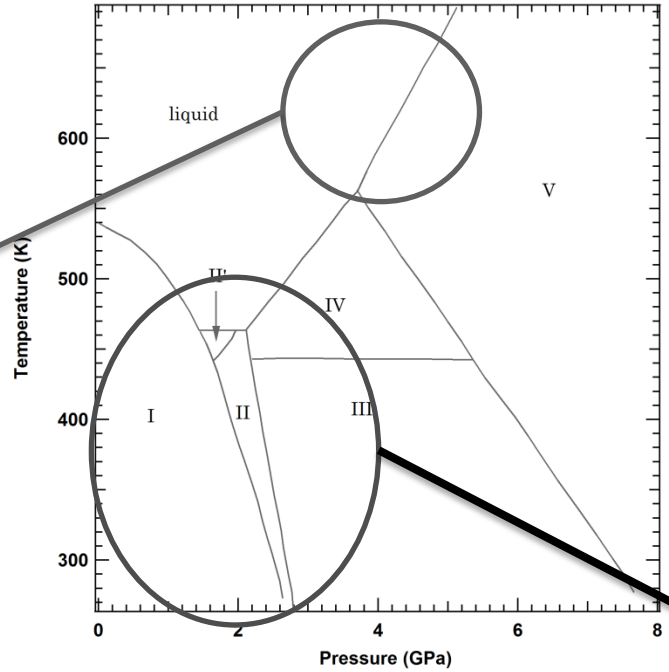
Smith et al, PRL 101, 065701
Gorman et al. PRL 115, 095701

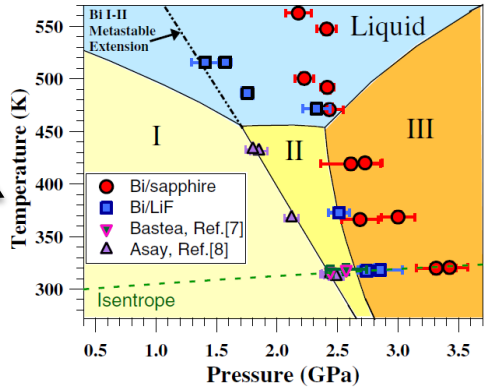
PRL **115,** 095701 (2015) PHYSICAL REVIEW LETTERS week ending 28 AUGUST 2015

Direct Observation of Melting in Shock-Compressed Bismuth With Femtosecond X-ray Diffraction

M. G. Gorman,[1] R. Briggs,[1] E. E. McBride,[1,2] A. Higginbotham,[3] B. Arnold,[4] J. H. Eggert,[5] D. E. Fratanduono,[5] E. Galtier,[4] A. E. Lazicki,[5] H. J. Lee,[4] H. P. Liermann,[2] B. Nagler,[4] A. Rothkirch,[2] R. F. Smith,[5] D. C. Swift,[5] G. W. Collins,[5] J. S. Wark,[3] and M. I. McMahon[1]

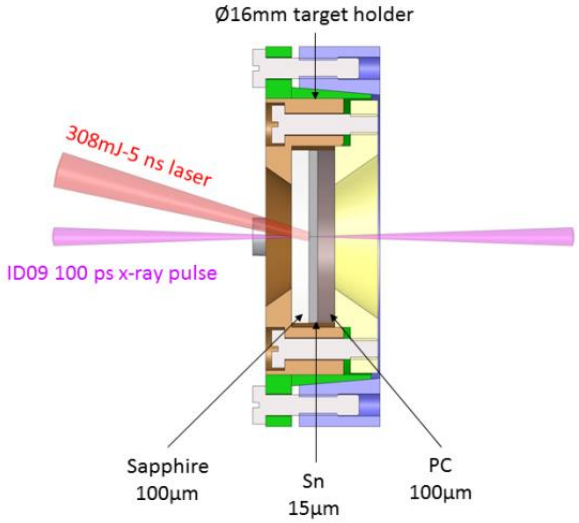


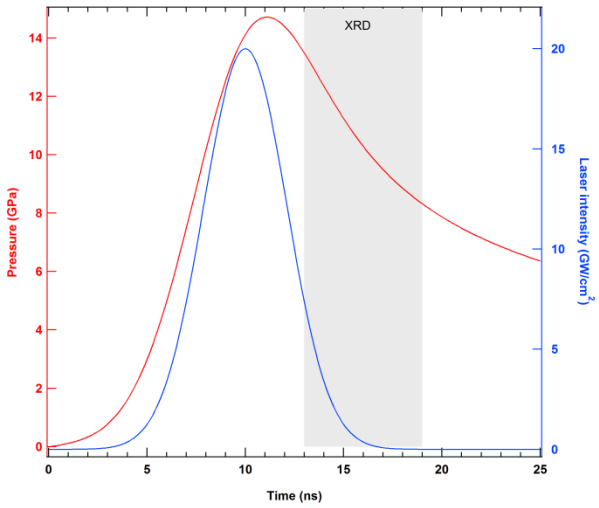




Smith et al, PRL 101, 065701
Gorman et al. PRL 115, 095701

- Adaptation of the target to the beamline and to the available laser: « confined geometry », very good reproductibility



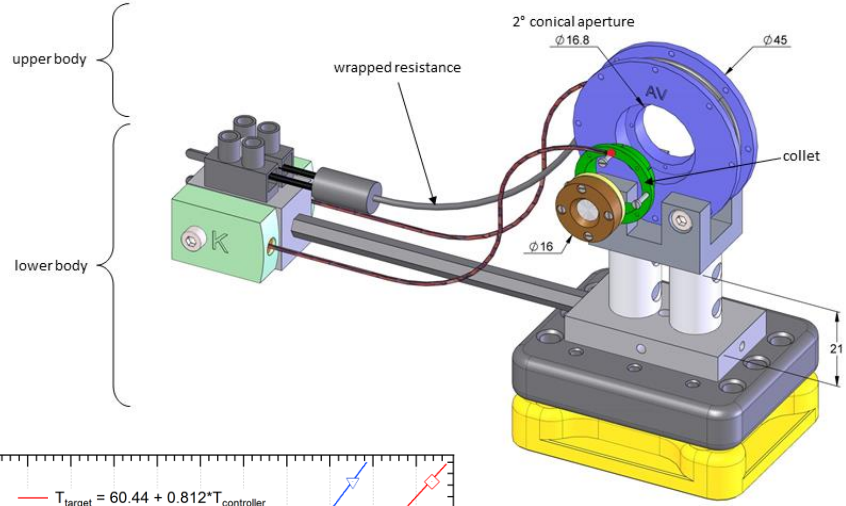


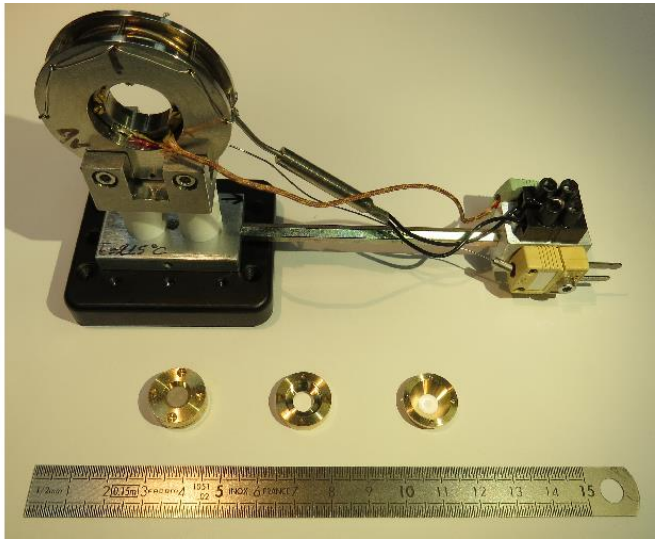
Pressure estimated from a numerical model

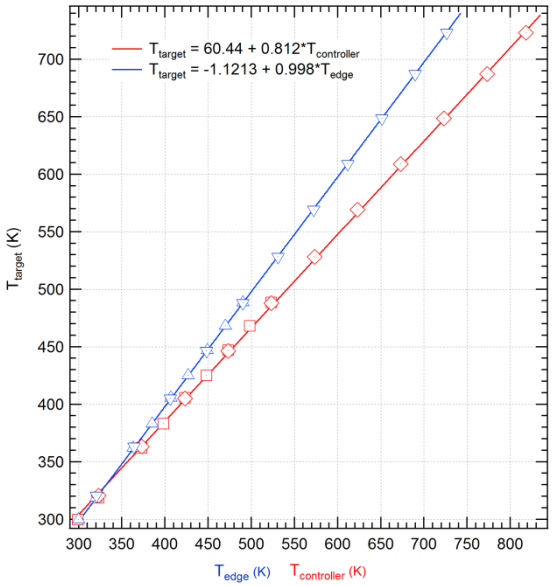
+ hydrodynamic code

+ equation of state of bismuth

- Exploring the phase diagram at high temperature: development of a furnace

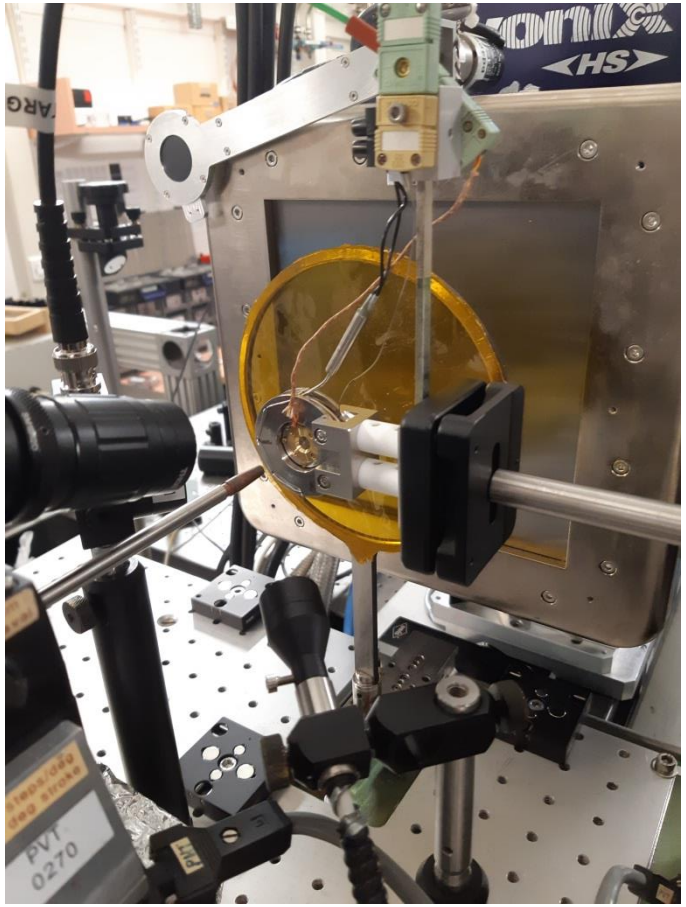


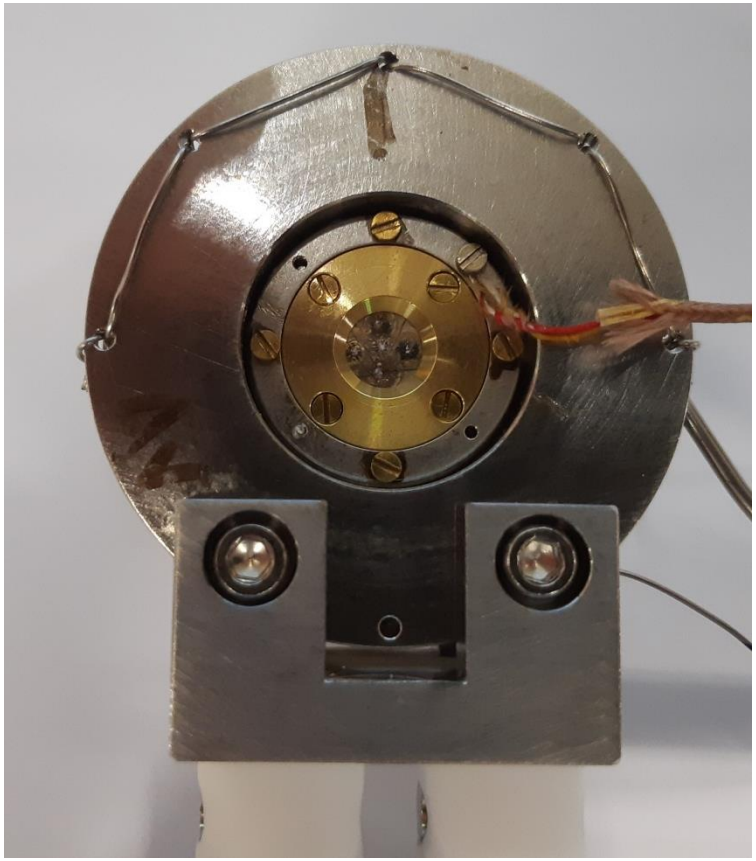




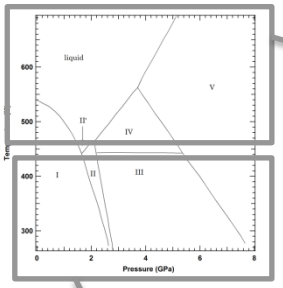
Very small thermal gradients

EXPERIMENTAL DEVICES

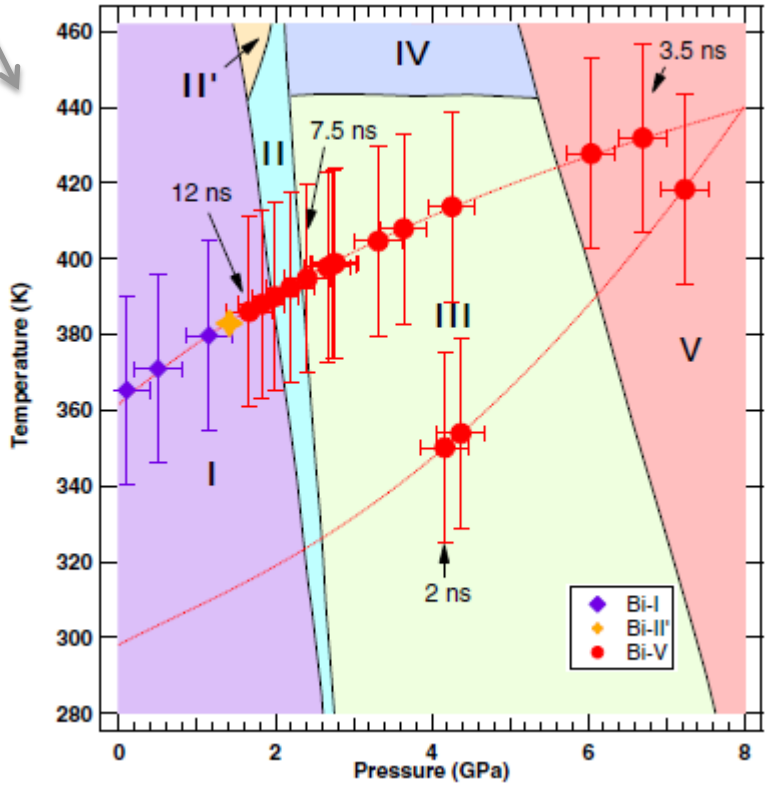


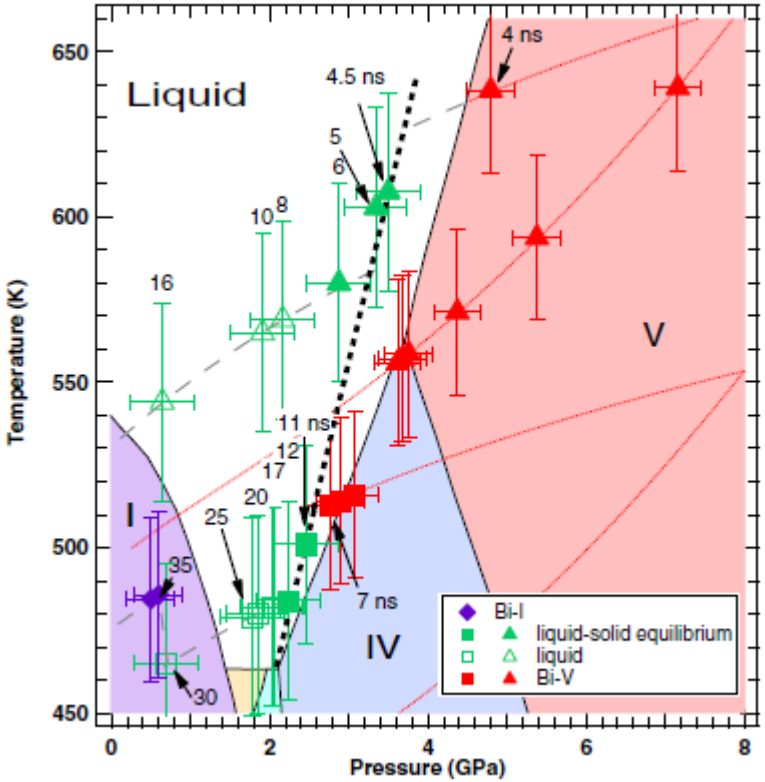


A DIFFERENT PHASE DIAGRAM

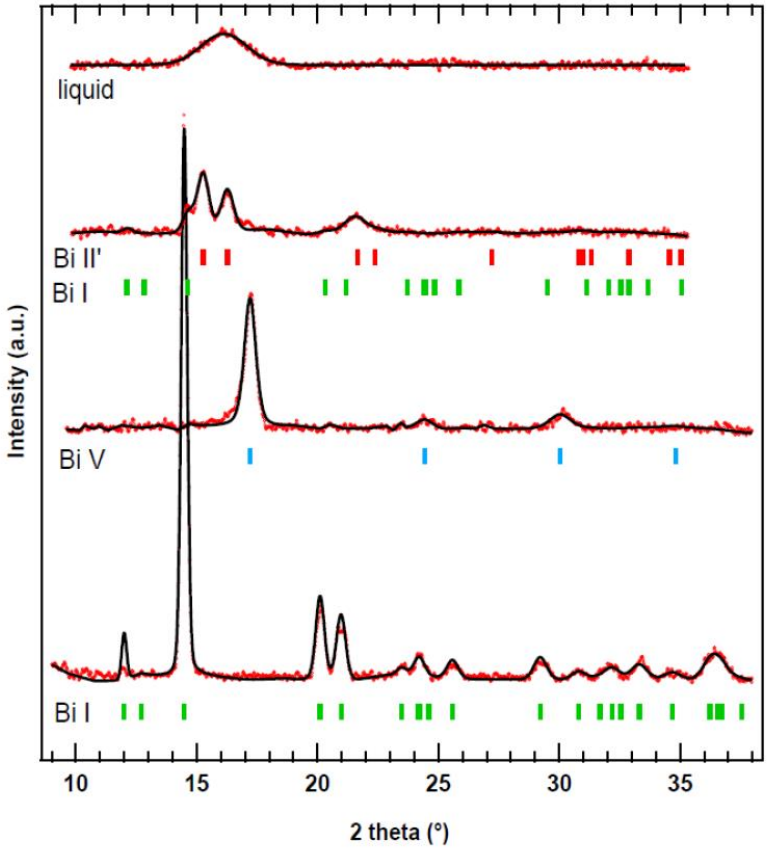


Very different phase diagram observed under dynamic compression!





QUALITY OF THE DATA



- 3 initial temperatures: 300, 400, 500K →exploration of the phase diagram up to 8 Gpa / 600 K
- Very good quality of the data: possibility to perform a LeBail refinement
- The different phases can be unambiguously distinguished

Improvements expected with the upgrade

A TREND OBSERVED ON OTHER MATERIALS

PHYSICAL REVIEW LETTERS **122,** 255704 (2019)

Identification of Phase Transitions and Metastability in Dynamically Compressed Antimony Using Ultrafast X-Ray Diffraction

A. L. Coleman,[1,2,*] M. G. Gorman,[1,2] R. Briggs,[1,2] R. S. McWilliams,[1] D. McGonegle,[3] C. A. Bolme,[4] A. E. Gleason,[4,5] D. E. Fratanduono,[2] R. F. Smith,[2] E. Galtier,[6] H. J. Lee,[6] B. Nagler,[6] E. Granados,[6] G. W. Collins,[7] J. H. Eggert,[2] J. S. Wark,[3] and M. I. McMahon[1]

PHYSICAL REVIEW LETTERS **123,** 045701 (2019)

Measurement of Body-Centered Cubic Gold and Melting under Shock Compression

R. Briggs,[1,*] F. Coppari,[1] M. G. Gorman,[1] R. F. Smith,[1] S. J. Tracy,[2] A. L. Coleman,[1] A. Fernandez-Pañella, M. Millot,[1] J. H. Eggert,[1] and D. E. Fratanduono[1]

nature physics ARTICLE
https://doi.org/10.1038/s41567-018-029

Phase transition lowering in dynamically compressed silicon

E. E. McBride[1,10,11*], A. Krygier[2], A. Ehnes[1], E. Galtier[3], M. Harmand[2], Z. Konôpková[1,11], H. J. Lee[3], H.-P. Liermann[1], B. Nagler[3], A. Pelka[4], M. Rödel[4], A. Schropp[1], R. F. Smith[5], C. Spindloe[6], D. Swift[5], F. Tavella[3], S. Toleikis[1], T. Tschentscher[7], J. S. Wark[8] and A. Higginbotham[9]

PHYSICAL REVIEW LETTERS **125,** 215702 (2020)

Crystal Structure and Melting of Fe Shock Compressed to 273 GPa: *In Situ* X-Ray Diffraction

Stefan J. Turneaure,[1] Surinder M. Sharma,[1] and Y. M. Gupta[1,2]

Recovery of metastable dense Bi synthesized by shock compression

Cite as: Appl. Phys. Lett. **114**, 120601 (2019); doi: 10.1063/1.5085678
Submitted: 13 December 2018 · Accepted: 27 January 2019 ·
Published Online: 25 March 2019

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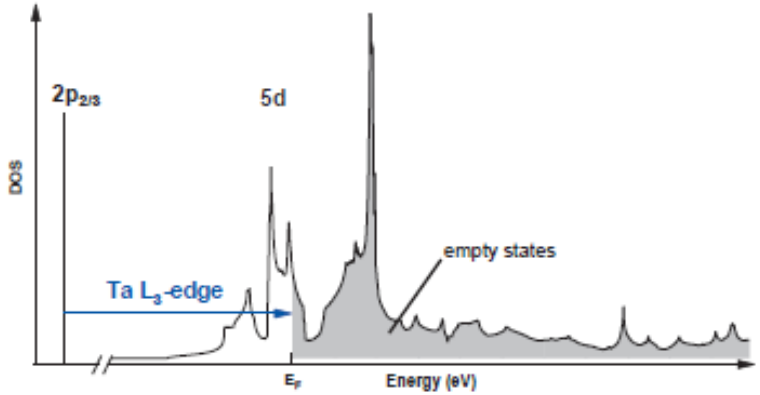
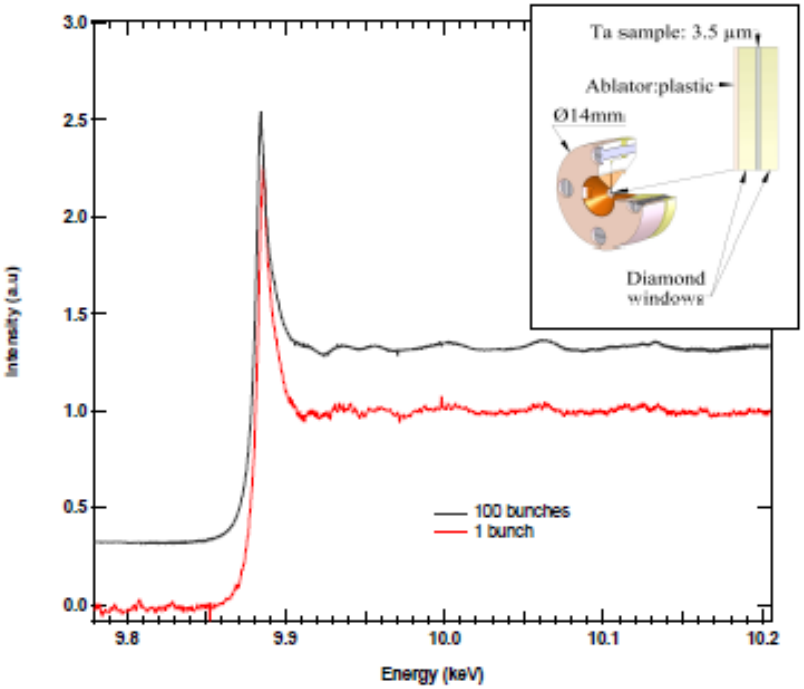
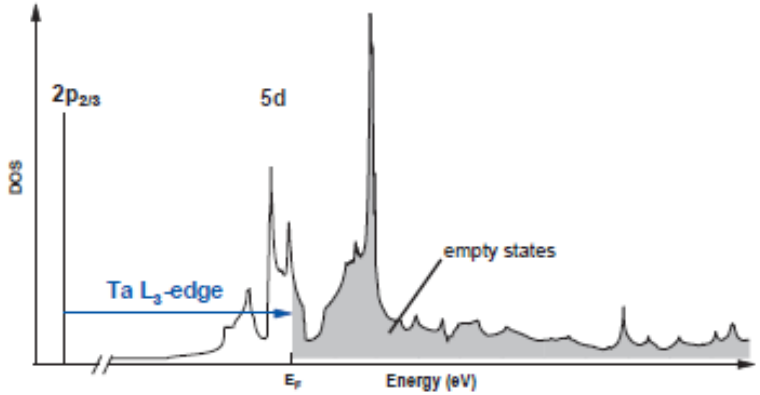
M. G. Gorman,[1,2,a)] A. L. Coleman,[1] R. Briggs,[1,2] R. S. McWilliams,[1] A. Hermann,[1] D. McGonegle,[3] C. A. Bolme,[4] A. E. Gleason,[5] E. Galtier,[6] H. J. Lee,[6] E. Granados,[6] E. E. McBride,[1,7] S. Rothman,[8] D. E. Fratanduono,[2] R. F. Smith,[2] G. W. Collins,[9] J. H. Eggert,[2] J. S. Wark,[3] and M. I. McMahon[1]

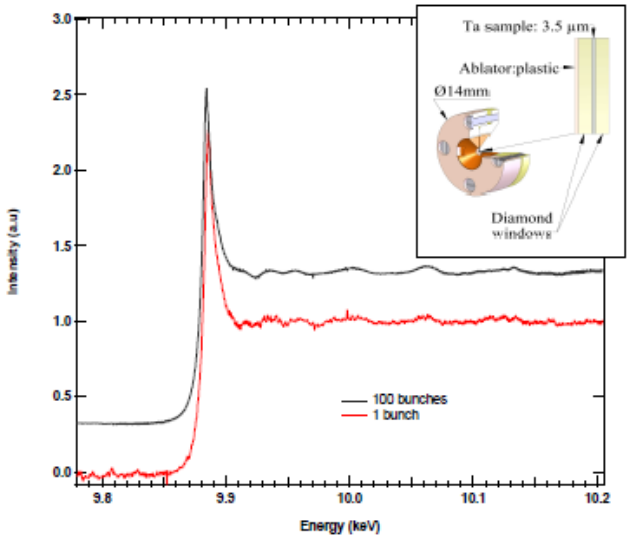
Probing the L3-edge on ID24

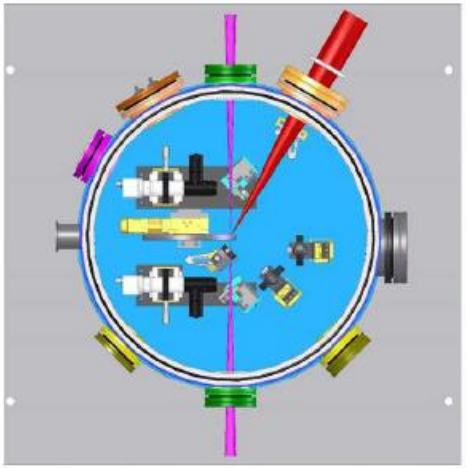


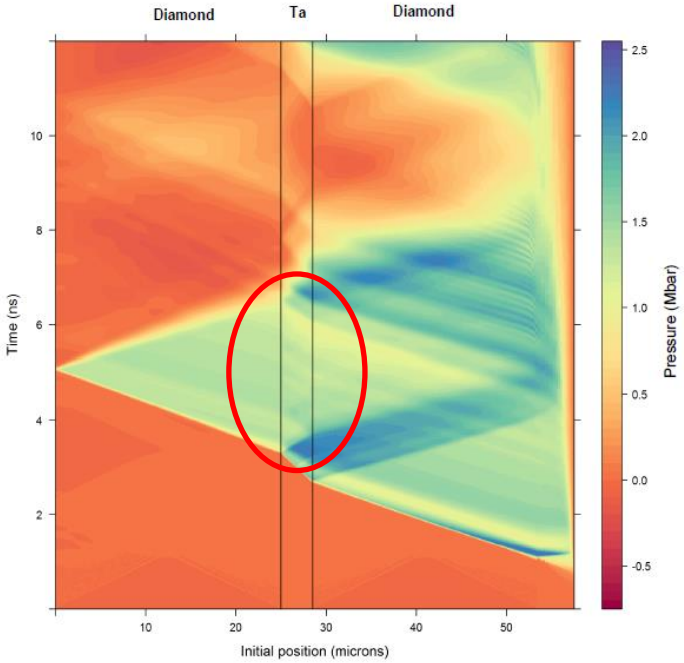


Probing the L3-edge on ID24

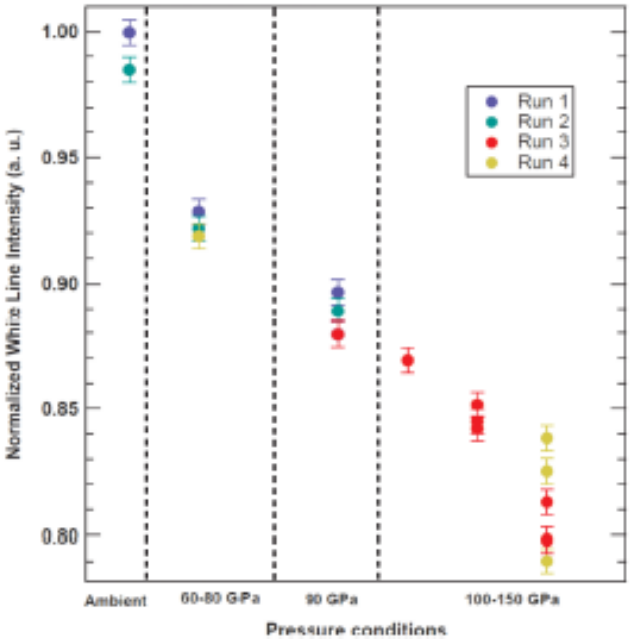


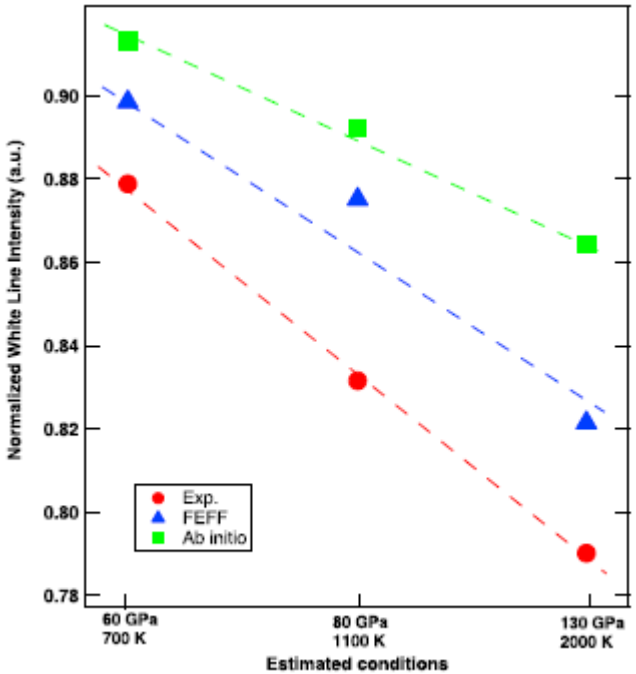






STRONG TESTS FOR AB-INITIO CALCULATIONS





FUTURE DEVELOPMENTS

X-ray diffraction:

- Explore new materials on ID09
- Development of a new VISAR/PDV equipment allowing us to perform velocimetry measurements with x-rays
- Possible implementation of a 5J ns-laser

X-ray Absorption Spectroscopy

- Looking forward for the opening of HPLF
- Complementary experiments XRD/XAS
- Dedicated laser/platform should allow us to probe new P-T states with a great data quality