Building a Target Network for Advanced Laser Light Sources

Workshop

29-31 August 2016

Helmholtz-Zentrum Dresden-Rossendorf

Organizing Committee

M Cernaianu, T Cowan, G Fiquet, Z Konopkova, D Margarone, S Pascarelli, I Prencipe, M Tolley

i.prencipe@hzdr.de

Credits Anna Ferrari

Advanced Laser Light Source User Facilities
→ Emerging demands for high repetition-rate targetry

High repetition rate lasers:

from **shot(s)/hour** → **shot-on-demand** → **0.01-10 Hz**

→ Efficient use of major X-ray User Facilities

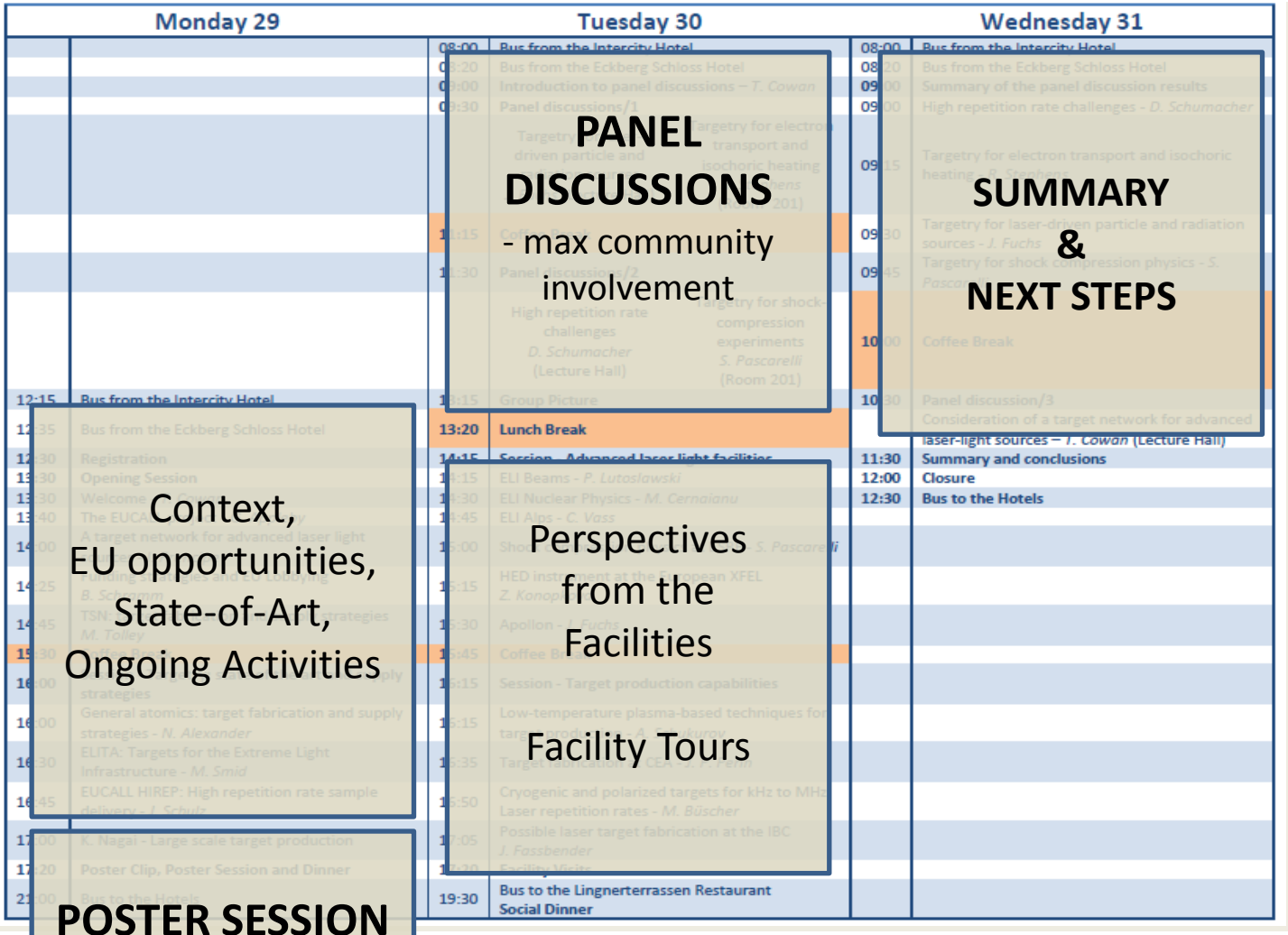
HIBEF @ HED / XFEL, **HPLF @ ID24 / ESRF**

→ Realizing the Promise of the **ELI** infrastructures

→ Long-term development of our User Community

- lower the Barriers-to-Entry for new users/small groups
- exploit synergies between Euro-, national & institutional laser facilities
- promote innovation, education & training

Meeting Agenda



Advanced Laser Light Source User Facilities
→ Panel Discussions

Science topic	European XFEL	ESRF	eli
• Particle & Radiation Generation	2	-	1
• Electron transport & isochoric heating	1	-	1
• Compression & material dynamics	1	1	2
• High Rep-rate Challenges	1	1	1

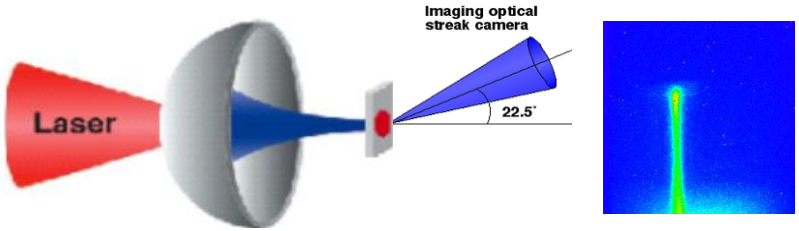
Synergies & Complementarities:

- XFEL: fs, coherent, narrow band → XRD, CXDI, resonant SAXS, FR, ultrafast pp
- ESRF: 100 ps, pink → absorption, XRD
- ELI: fs, multi-beams → absorption, ultrafast, multi-species p-p

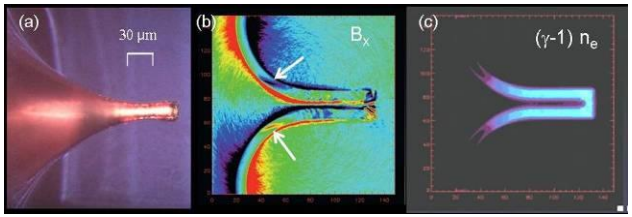
Improve basic understanding ←→ Develop new techniques

Example: Extreme matter in relativistic laser-plasma interactions

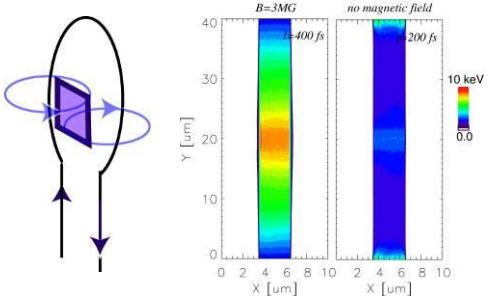
Isochoric heating with laser-accelerated protons
Patel *et al.*, Phys. Rev. Lett. **91**, 125004 (2003)



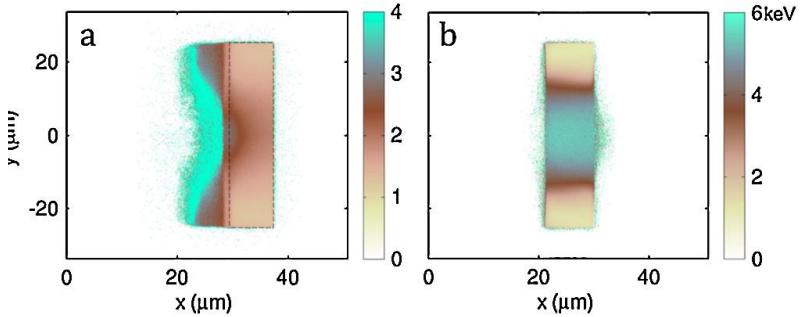
Self-generated magnetic confinement of hot electrons and enhanced heating
Rassuchine *et al.*, PRE **79**, 036408 (2009)



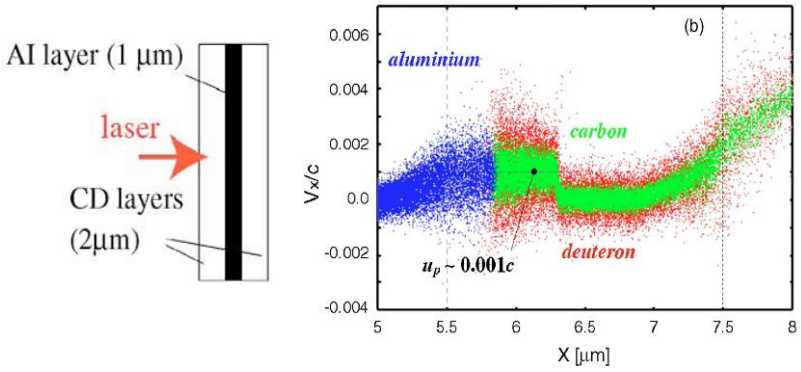
Pulsed external ~MG magnetic transport inhibition
Bakeman *et al.*, Megagauss XI (2007)
http://conferences.theiet.org/mg-xi/mgxi-final-v7.0.pdf



Electrostatic-confinement of hot electrons using reduced-mass targets
Perez *et al.*, Phys. Rev. Lett. **104**, 085001 (2010)



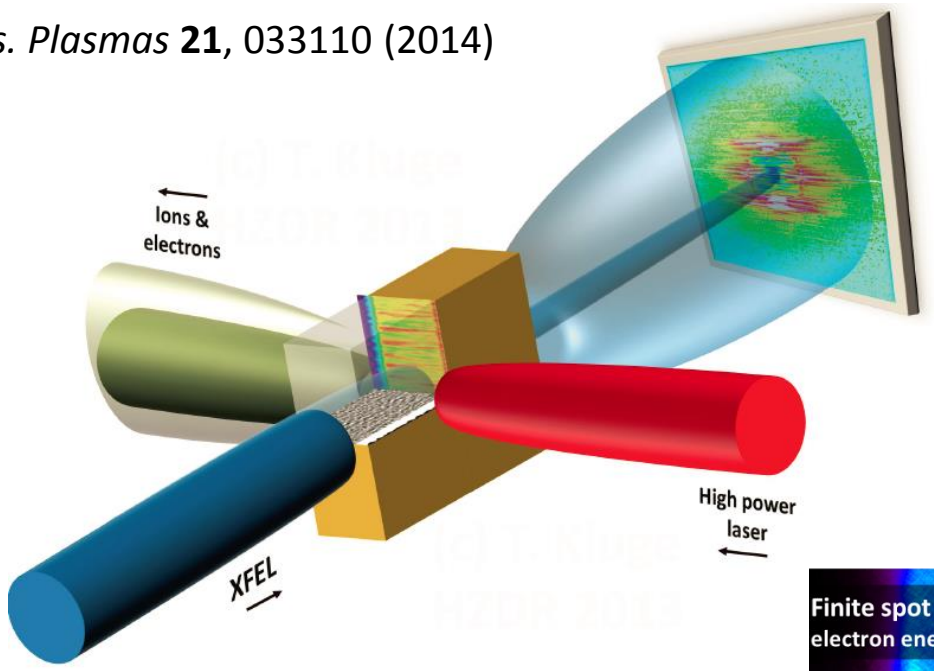
Interface shock heating in heterogenous targets
Sentoku *et al.*, Phys. Plasmas **14**, 122701 (2007)

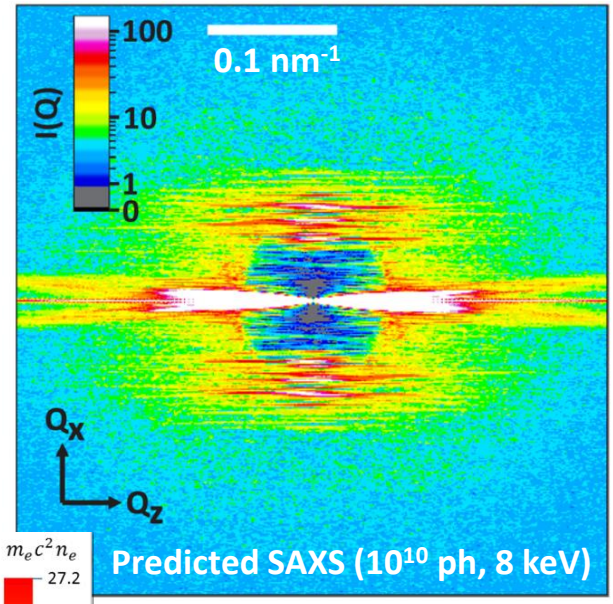


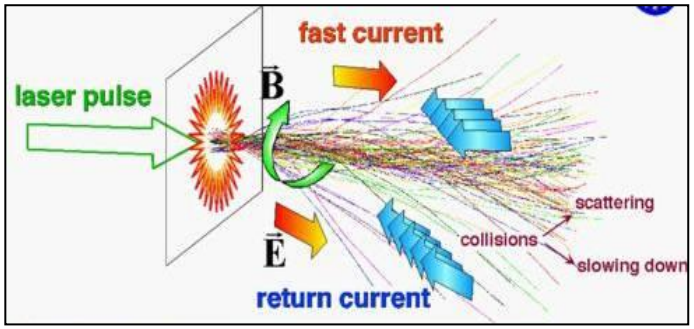
→ XFEL to probe and understand spatial- & temporal-gradients → improve PW science

HIBEF: Relativistic laser-matter interactions -- Probing solid-density plasma with coherent x-ray diffraction

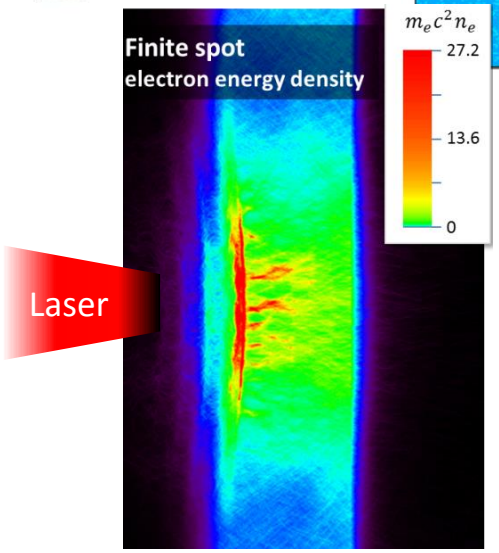
Phys. Plasmas **21**, 033110 (2014)







10^{13} A/cm^2, > 1000 T, 10^{13} V/m, ~keV solid density



- ionization dynamics, heating & resistivity
- electron transport, return current neutralization
- filamentation, hole boring
- e-e & e-i equilibration
- quasi-static fields
- ....

DRESDEN concept HZDR

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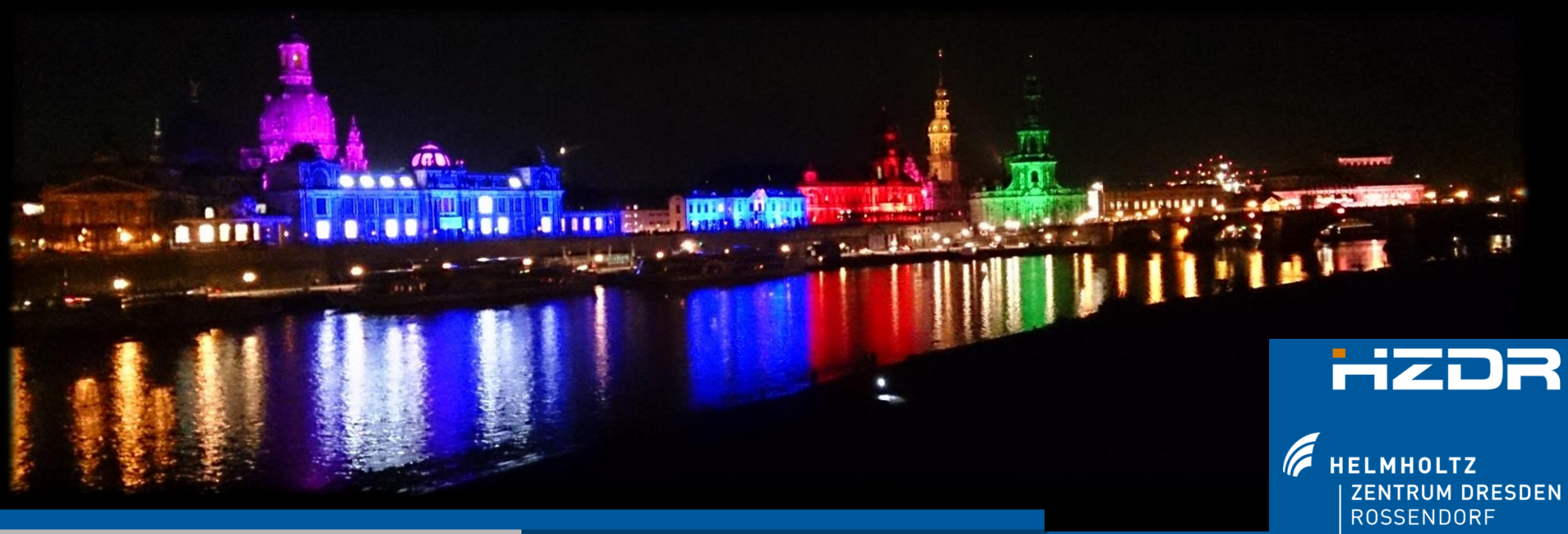
Conclusions

- Welcome to Dresden
- And let us have a very productive workshop

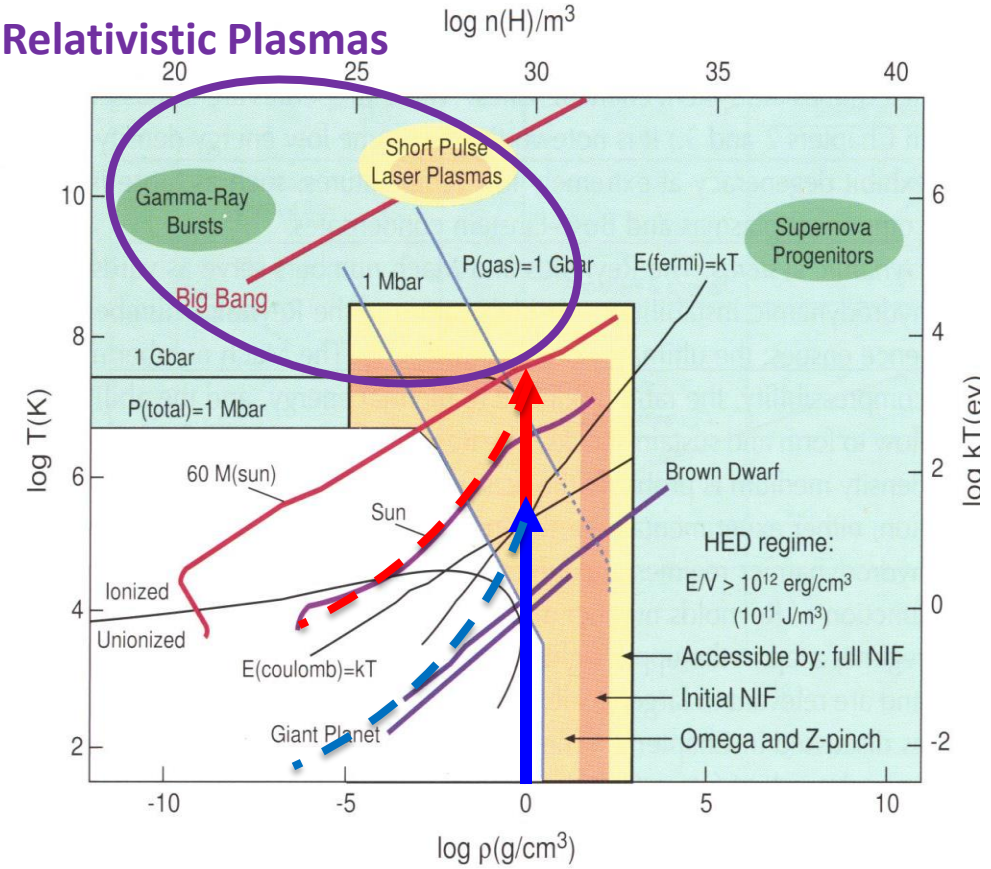


HZDR

HELMHOLTZ ZENTRUM DRESDEN ROSSENDORF

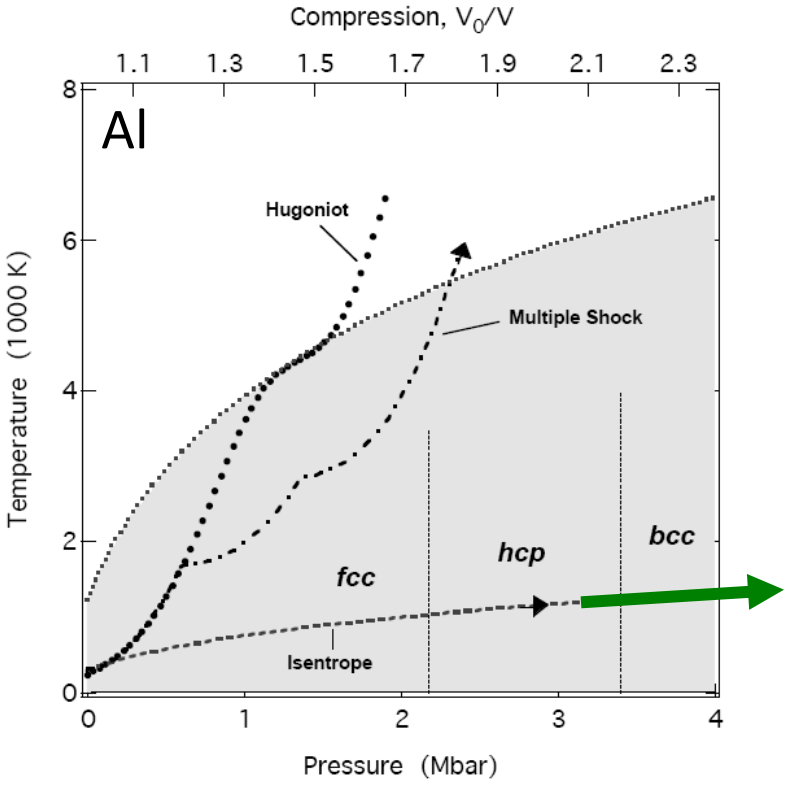
HIBEF @ XFEL: extending HED Science at XFEL

Isochoric Heating



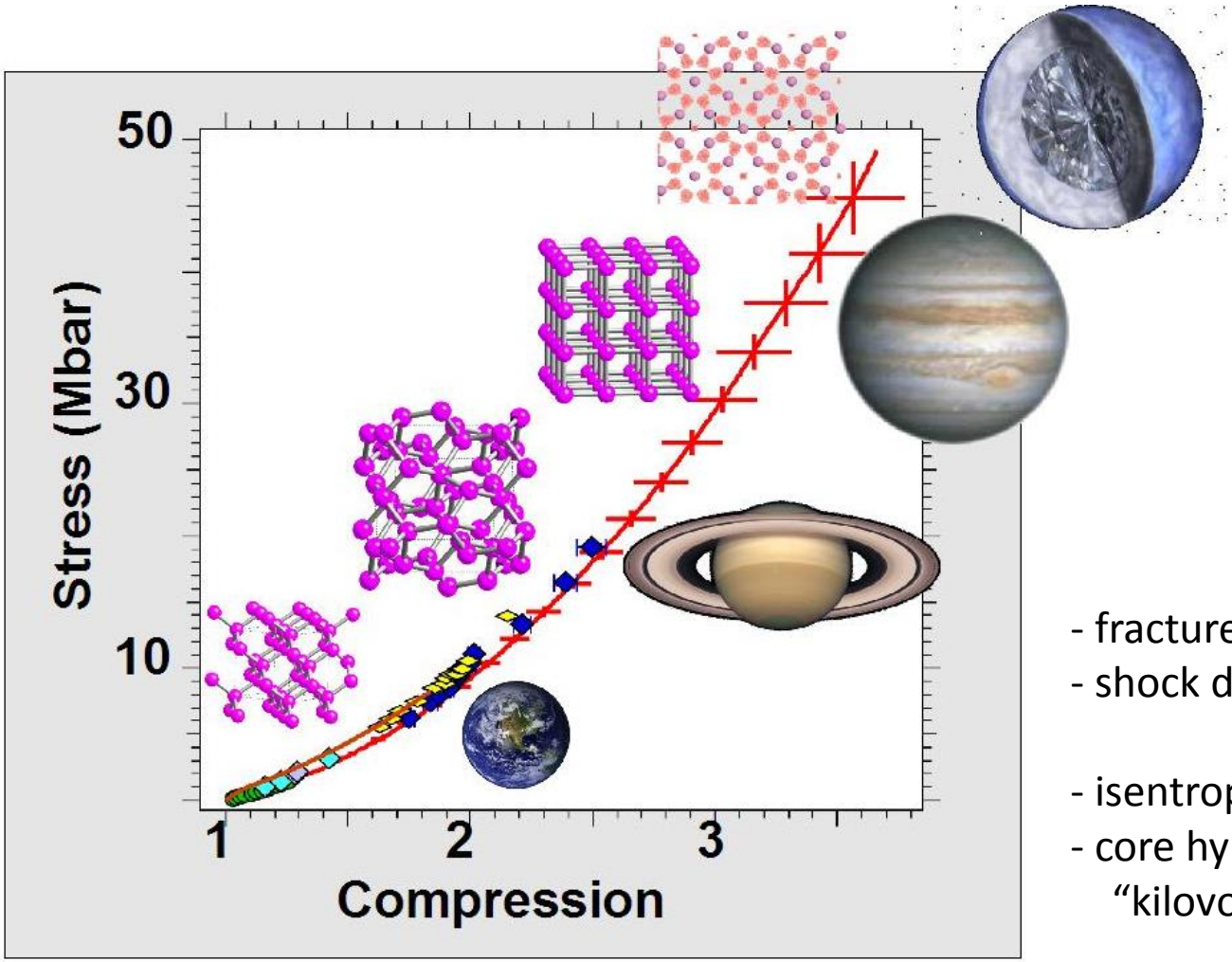
- Short-pulse laser-driven
- XFEL-driven

Compression



- Ramped (~kJ, ~ns) cold compression to TPa

Extreme States of Matter at High Compression



- fracture & deformation
- shock dynamics

- isentropic compression
- core hybridization
  "kilovolt chemistry"

- "materials by design"

with Rostock, Oxford, DESY, Edinburgh, LLNL, LANL, LCLS, LULI, CEA, CELIA-Bordeaux, IOE-MUT, and many more….

Courtesy G. Collins

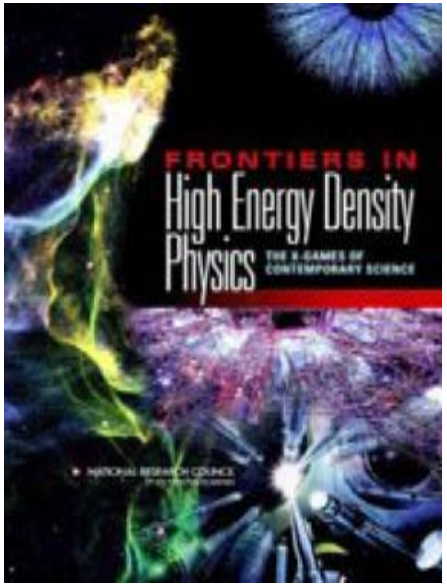
Scientific synergies: ultra-intense laser physics & applications

XFEL-quality probing inside of dense plasma (with time-resolved, brilliant, and fully coherent x-rays) will:

→ revolutionize our fundamental understanding of laser-matter interactions…

→ advance High Energy Density Physics with ultra-intense lasers…

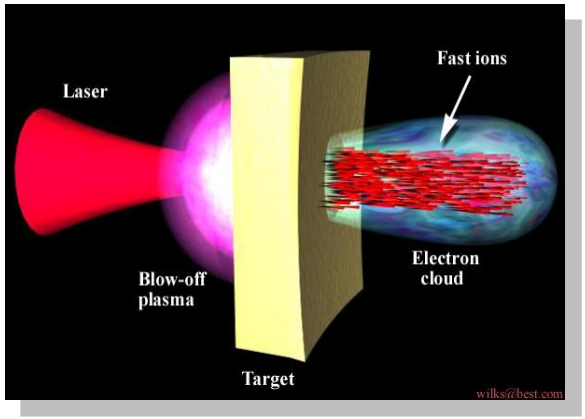
→ benefit ultra-intense laser research worldwide, in many fundamental & applied areas…



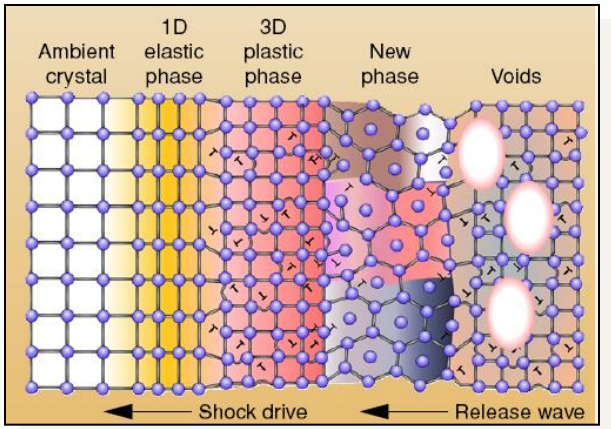
- Compact Accelerators
- Table-top light sources
- Radiation research in Oncology
- Fusion energy research
- Material dynamics
- Ultrafast physics, attosec. sources
- Warm Dense Matter
- Hot Dense Plasma
- Planetary Science
- Laboratory Astrophysics

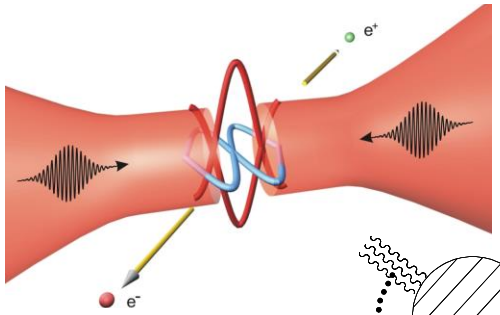
Extreme Conditions with Ultra-intense & High-energy Lasers

Extreme particle beams

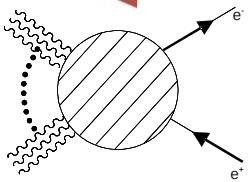


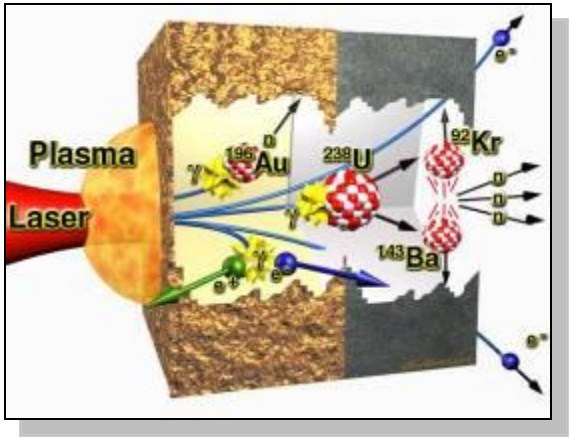
Extreme pressures





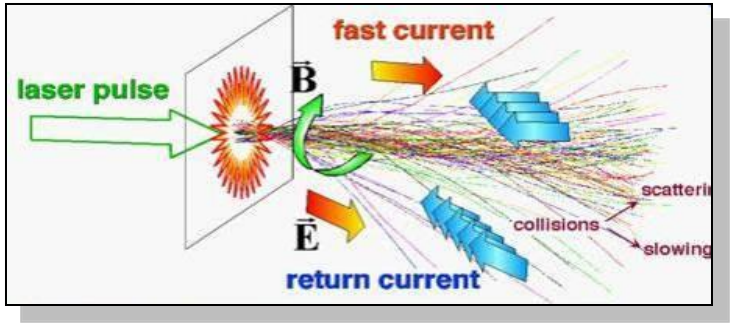
Strong Fields





Extreme radiations

Extreme currents



Helmholtz-Zentrum Dresden-Rossendorf

EUCALL Satellite Meeting
“Building a Target Network for Advanced Laser Light Sources”
29 August 2016

Research for the World of Tomorrow

HZDR – Facts and Figures

- Member of the **Helmholtz Association**

- **Foundation** 01.01.1992 (e.V.)

- **Employees** **approx. 1,100**
  350 scientists
  150 doctoral students
  > **50** countries

Zertifikat seit 2008 audit berufundfamilie

- **Sites** **DRESDEN**
  Leipzig, Freiberg, Grenoble
  Hamburg (coming soon…)
  organized in 8 Institutes

Credits: Killig, Schmidtfoto, ESRF/Ginter

Images: 1. HZDR Entrance Building | Cyclotron at the HZDR Research Site Leipzig | 3. European Synchrotron Radiation Facility in Grenoble

DRESDEN concept HZDR

HERMANN VON HELMHOLTZ – His Name is Our Mission
Strategic Research for National Needs

H. von Helmholtz
(1821 - 1894)

- **Solving major challenges** with cutting-edge research
- Commitment to **interdisciplinary research**
- **Think big, act big:** Developing and operating **complex infrastructures** and **large-scale facilities** for the national and international scientific community
- **Creating wealth** for society and industry through knowledge transformation and innovation

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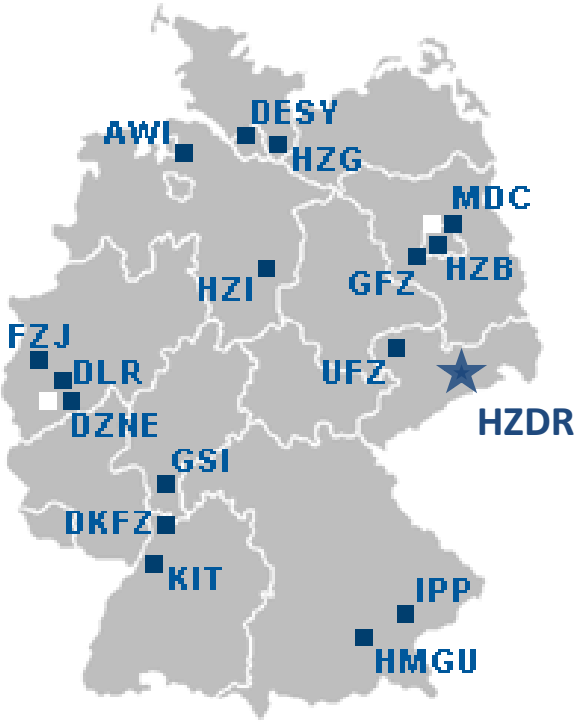

Helmholtz Association of Research Centers (HGF)

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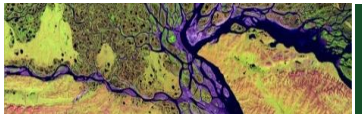
Cutting-Edge Science in Networks

The six research fields of the Helmholtz Association

ENERGY*



EARTH AND ENVIRONMENT

HEALTH*

AERONAUTICS, SPACE AND TRANSPORT

KEY TECHNOLOGIES

MATTER*

* HZDR Participation

HZDR Research Programs

- addressing Grand Challenges in the research fields Energy, Health, and Matter

ENERGY

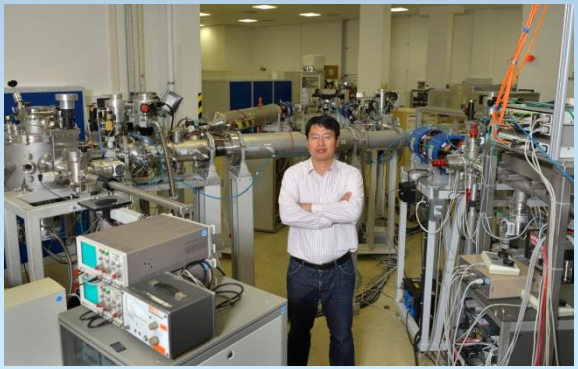
How can energy and resources be utilized in an efficient, safe, and sustainable way?

HEALTH

How can malignant tumors be more precisely visualized, characterized, and more effectively treated?

MATTER

How do matter and materials behave under the influence of strong fields and in smallest dimensions?



Credits: Weisflog, Bierstedt, Rietschel

Images: 1. At the TOPFLOW Facility | 2. PET/MRI-Full-Body Scan Tomograph | 3. Ion Beam Center

Large Research Infrastructures

ELBE – Center for High-Power Radiation Sources

Electron accelerator (ELBE), free electron lasers (FELBE), terahertz facility (TELBE), and high-intensity lasers (DRACO & PENELOPE)

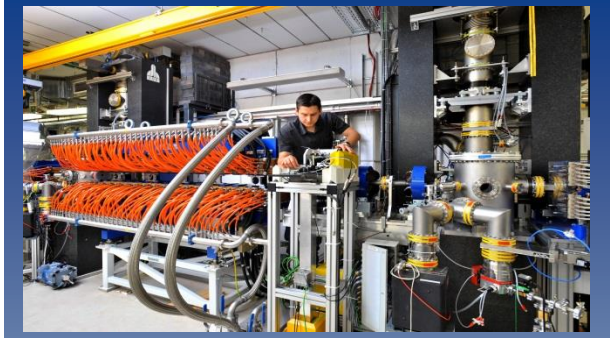
→ generating electron, positron, proton, neutron, X-ray, infrared, terahertz, & gamma-ray beams

Dresden High Magnetic Field Laboratory (HLD)

Producing Europe's highest pulsed magnetic fields for materials research

Ion Beam Center (IBC)

Nanoscale surface analysis and modification



Credits: Bierstedt, Killig (2 x)

Images: 1. THz Source TELBE | 2. Magnet Coil at the HLD | 3. Accelerator (6 MV) at the Ion Beam Center

Projects for the Future

DRESDYN – European platform for dynamo experiments and thermohydraulic studies with liquid sodium

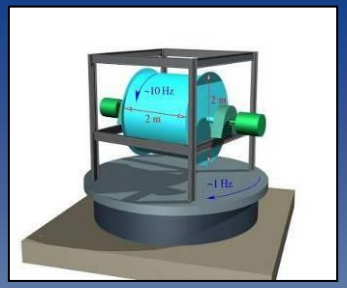
Center for Radiopharmaceutical Tumor Research

New research platform integrating and expanding the experimental infrastructure

Helmholtz International Beamline for Extreme Fields

at High Energy Density beamline at the European XFEL

- 200 TW @ 5 Hz, 100 J-ns @ 10 Hz, 50-60 T - ms
- User Consortium HIBEF, 100 institutions, 20 countries
- future kJ, PW

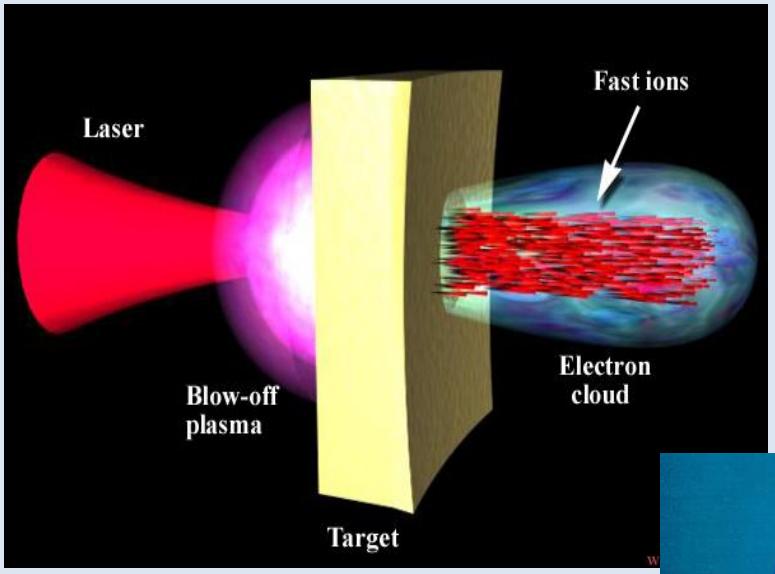


Credits: Bierstedt, HZDR, XFEL

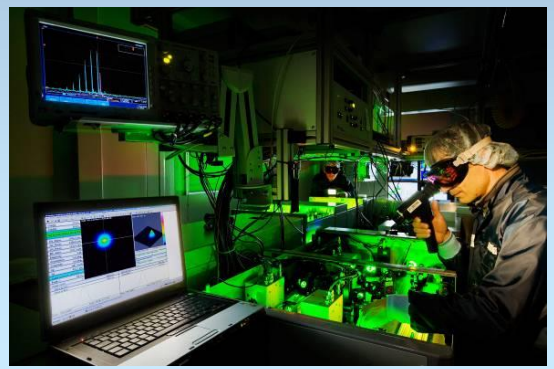
Images: 1. Precession Dynamo | 2. Center for Radiopharmaceutical Tumor Research | 3. Accelerator Tunnel at European XFEL

Unique environment for world-leading multi-disciplinary research

MATTER + HEALTH



Laser-acceleration of ion beams for research in radiation oncology

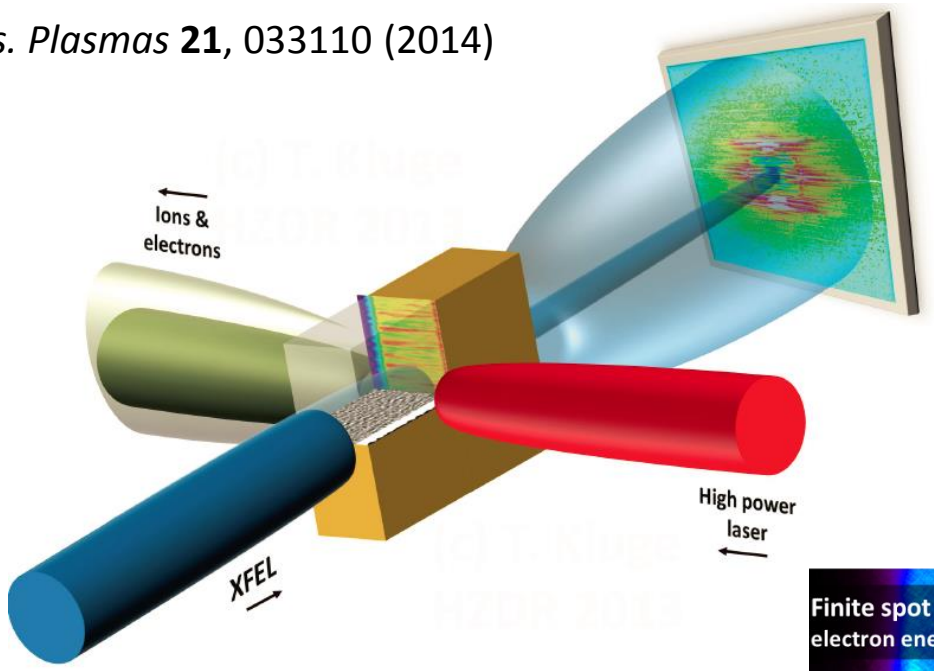


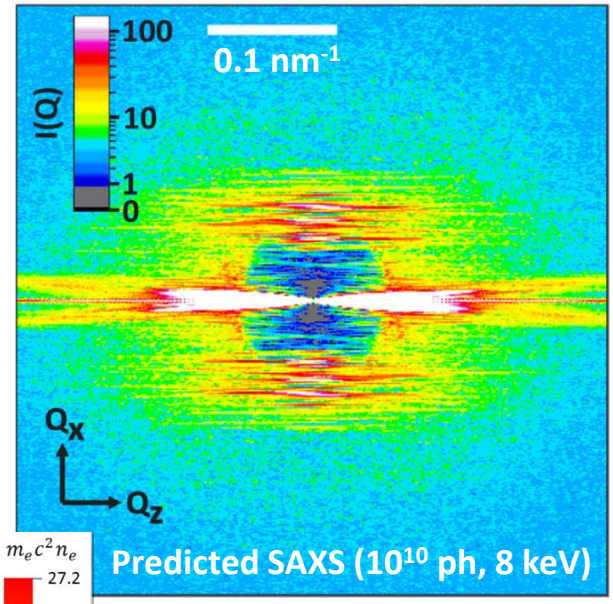
Credits: Bierstadt, Lösel

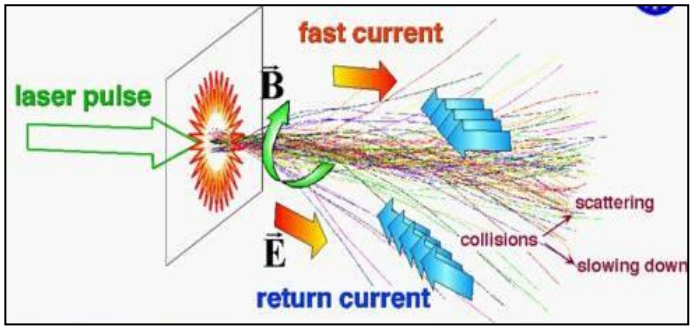
Images: 1. ELBE accelerator facility | 2. Proton therapy cave at OncoRay | 3. Particle Acceleration at the DRACO Laser

HIBEF: Relativistic laser-matter interactions -- Probing solid-density plasma with coherent x-ray diffraction

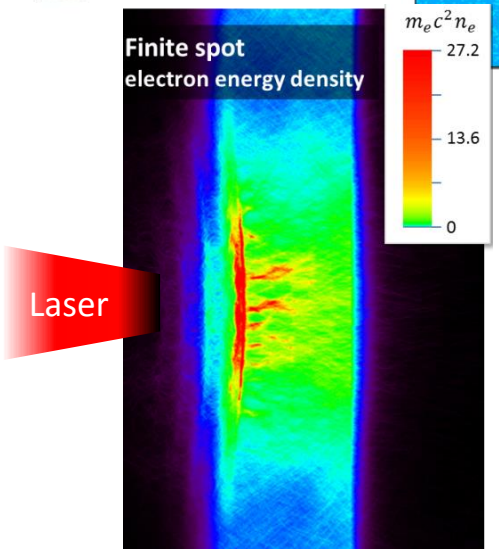
Phys. Plasmas **21**, 033110 (2014)







10^{13} A/cm^2, > 1000 T, 10^{13} V/m, ~keV solid density



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- electron transport, return current neutralization
- filamentation, hole boring
- e-e & e-i equilibration
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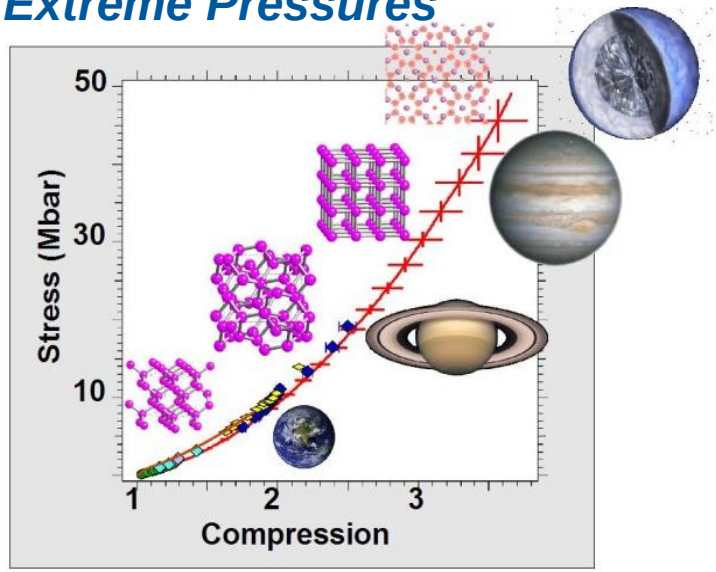
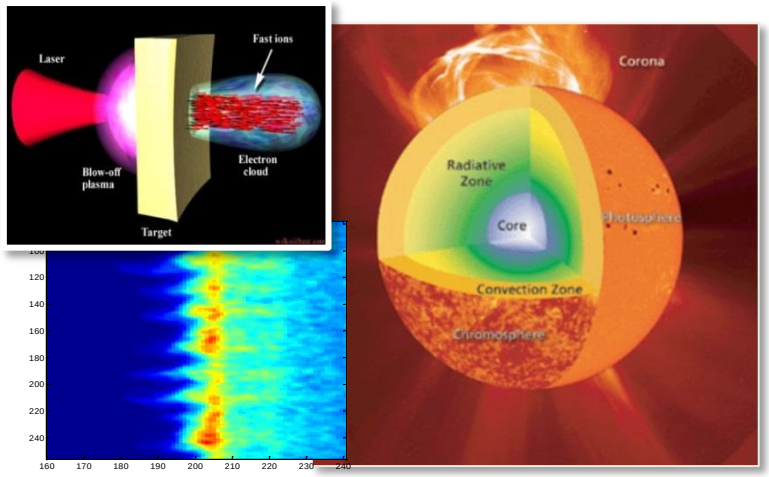
DRESDEN concept HZDR

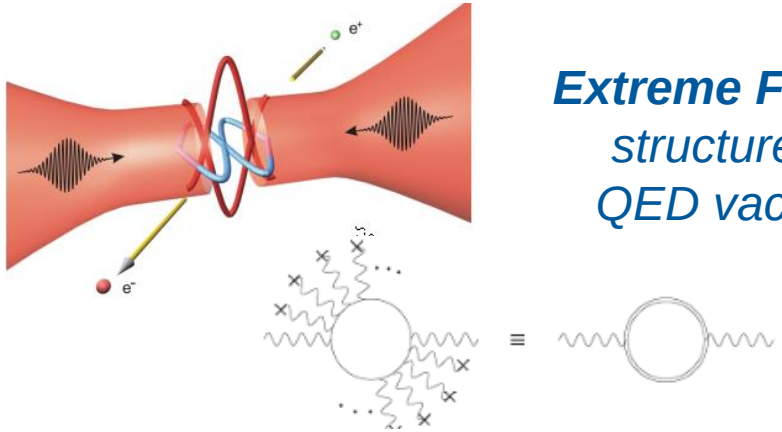
HIBEF: New States of Matter

Extreme Pressures



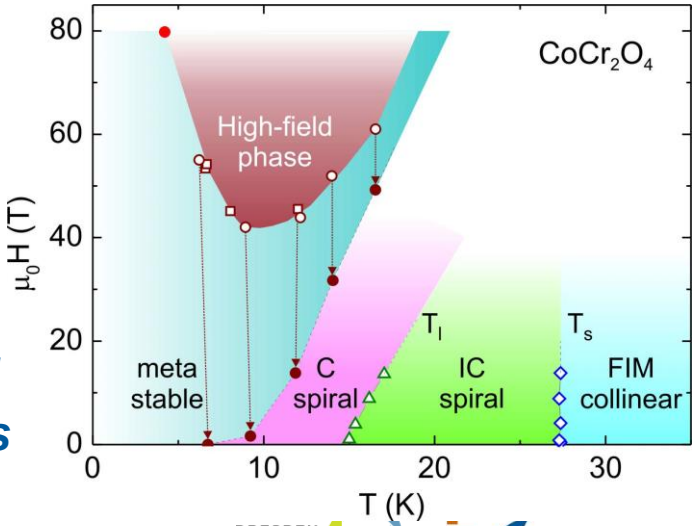
Extreme Temperatures





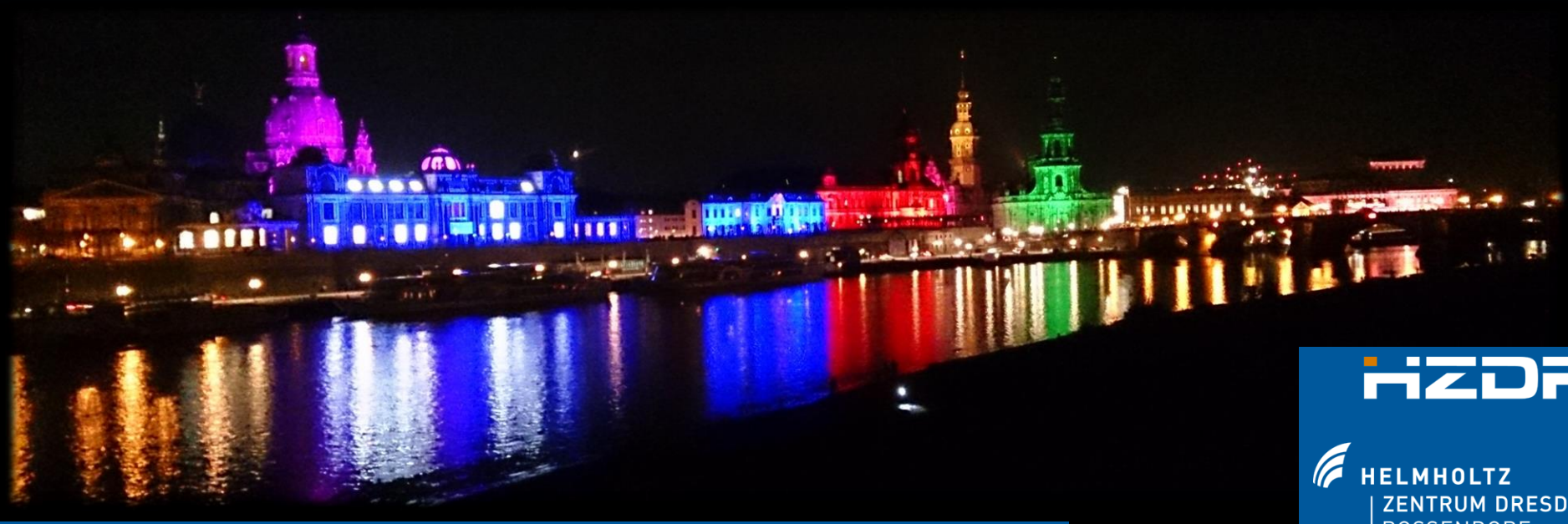
Extreme Fields:
structure of QED vacuum

Magneto-structural transitions



Nat Mater **9**, 624 (2010), Rev Mod Phys **84**, 1607 (2012); Phys Plasmas **21**, 033110 (2014); New J Phys **16**, 023008 (2014); Opt Comm **267**, 318 (2006); Phys Rev Lett **110**, 115502 (2013)

Thank you for your attention!



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HELMHOLTZ ZENTRUM DRESDEN ROSSENDORF