High Energy Density Physics with Intense Heavy Ion Beams

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Plasma Physics

GSI

HED geHOB

FAIR

*see details at the end

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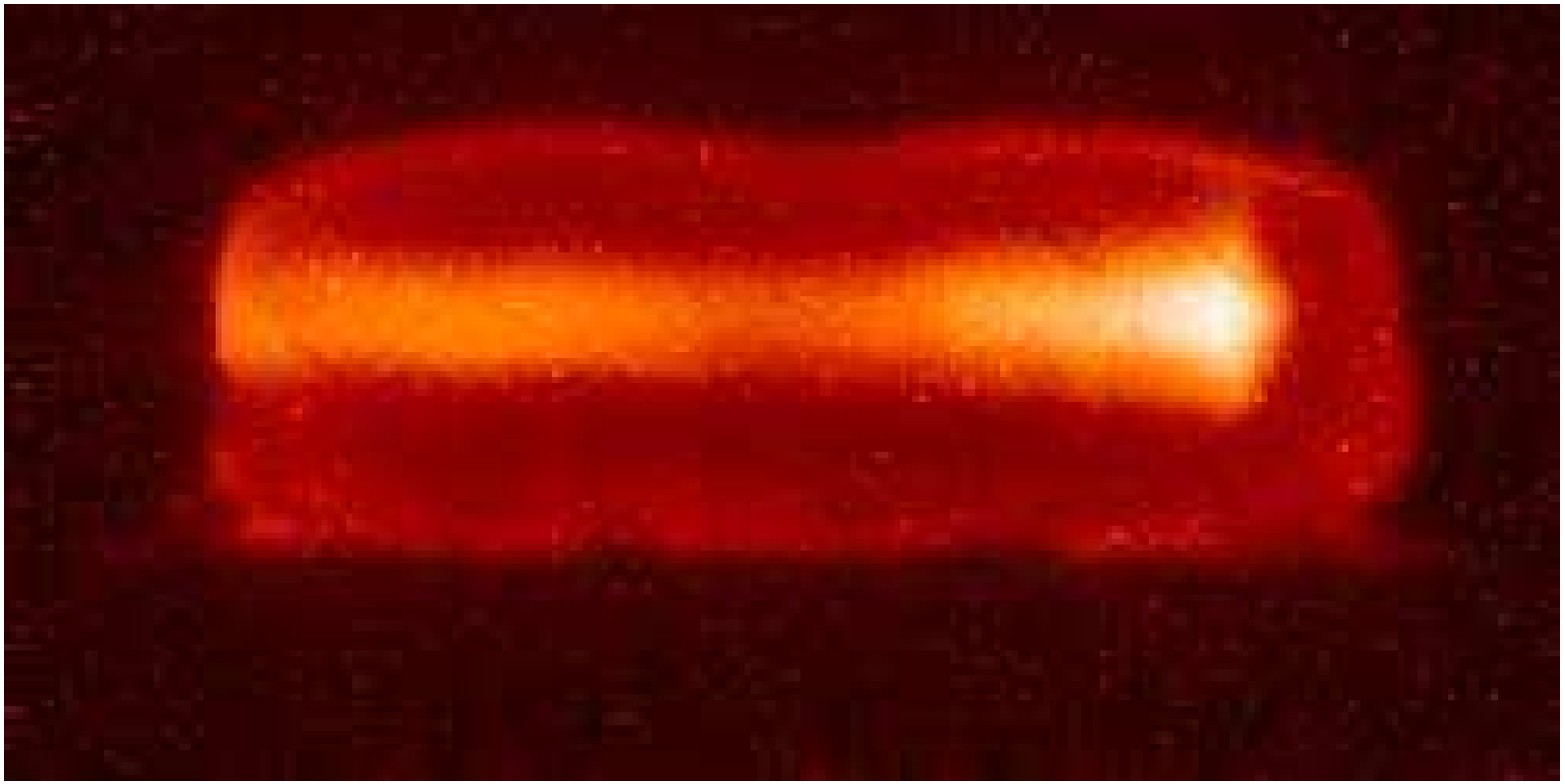
Ion Beam Facilities for HEDP

ИТЭФ, Москва

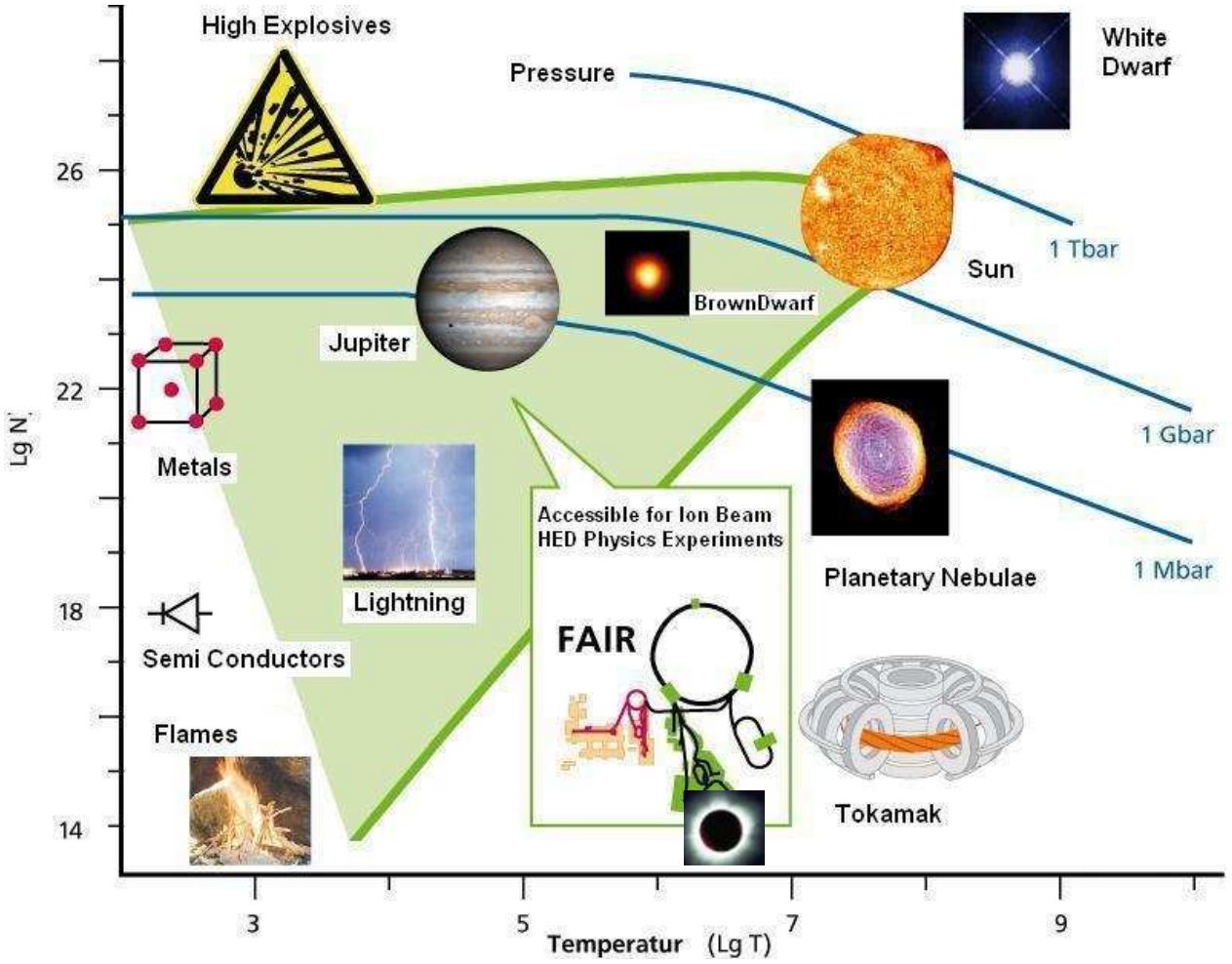
HIFS-VNL, Berkeley

IMP, Lanzhou

Heating matter with Heavy Ion beams



Phase Diagram of Matter



density (logN)

Temperature (log T)

Physics of Generating High Energy Density in Matter with Ion Beams

$$P_\rho = \frac{E_\rho}{\tau_b} = 1.602 \cdot 10^{-19} \cdot \frac{\frac{dE}{dx} \cdot \frac{N}{\tau_b}}{\pi r^2} \quad \left[\frac{J}{g \cdot s}\right]$$

E_ρ : Specific Deposition Energy [J/g]

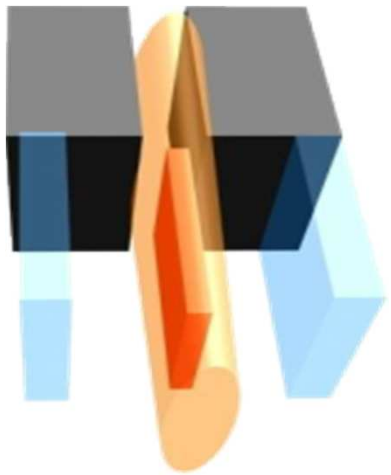
τ_b: Beam bunch length [s]

P_ρ : Specific Deposition Power [W/g]

HEDgeHOB collaboration scheme: HIHEX and LAPLAS

HIHEX

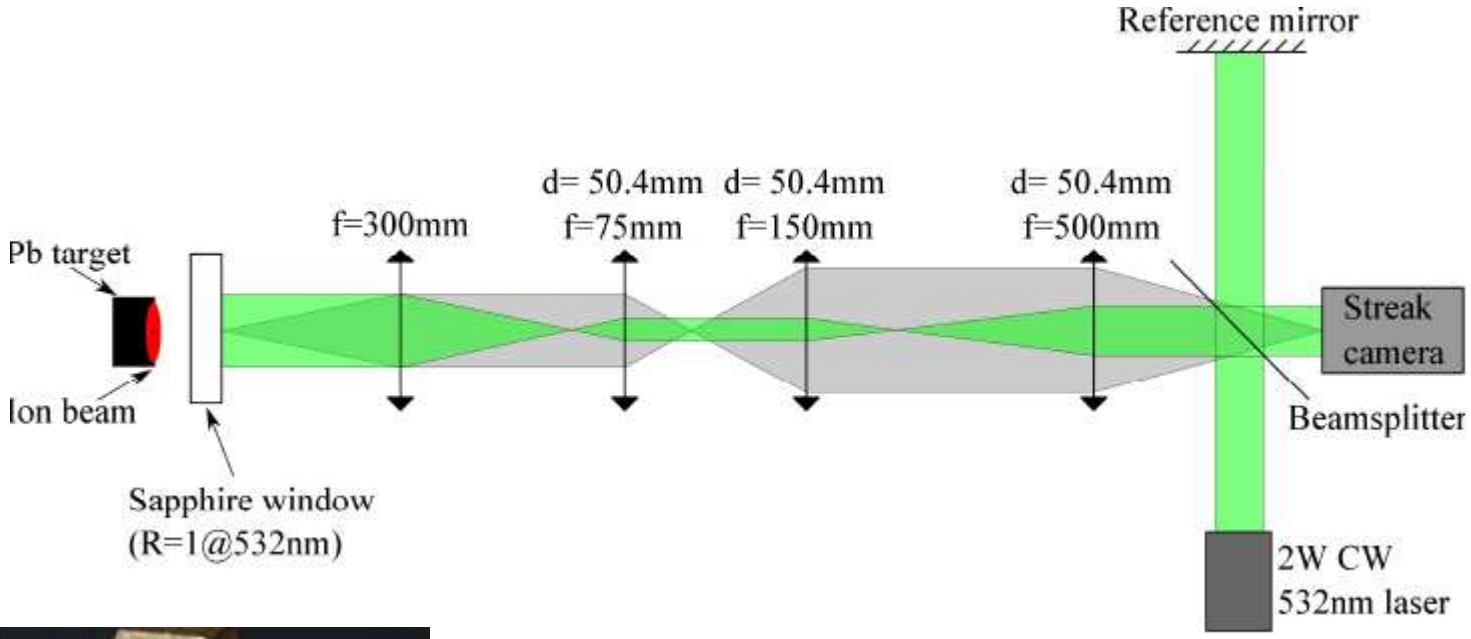
Heavy Ion Heating and Expansion

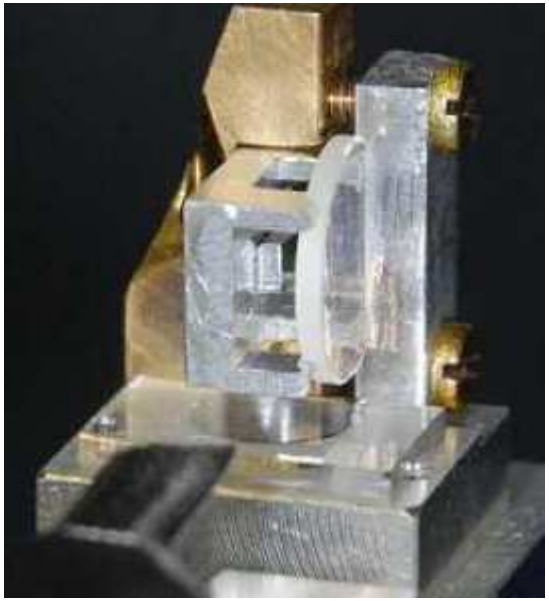


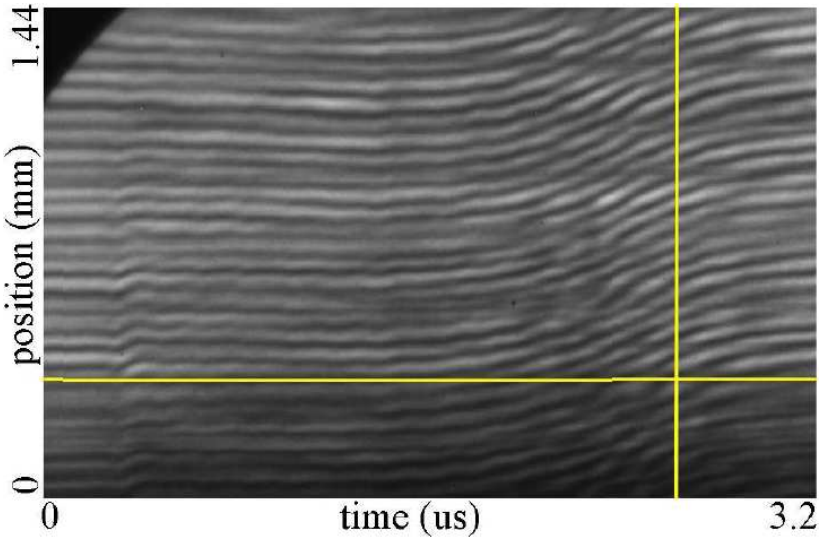
- **Numerous high-entropy HED states:**
  EOS and transport properties of e.g., non-ideal plasmas, WDM and critical point regions for various materials

- uniform quasi-isochoric heating of a large-volume dense target
- isentropic expansion in 1D plane or cylindrical geometry

Imaging Interferometer

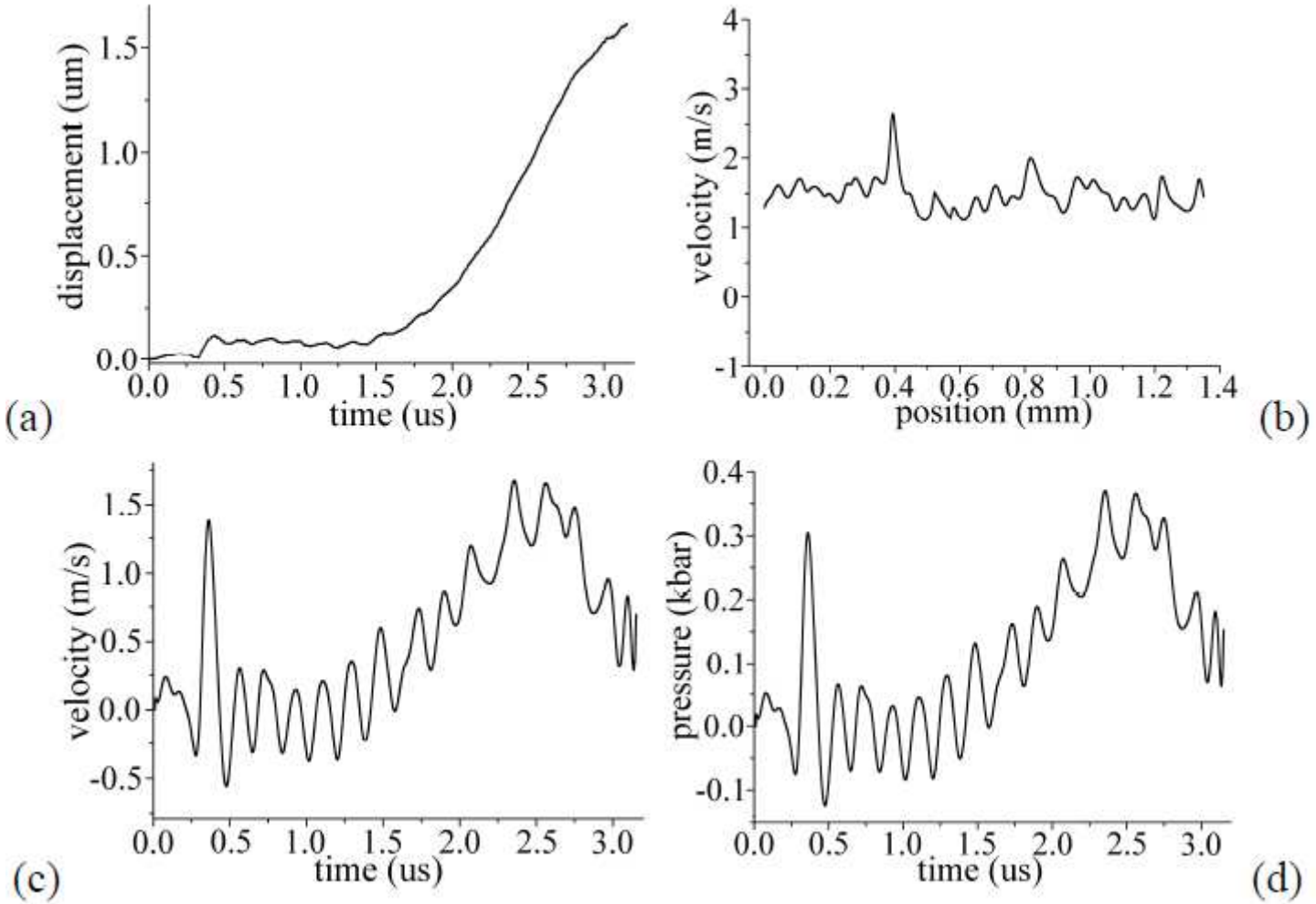




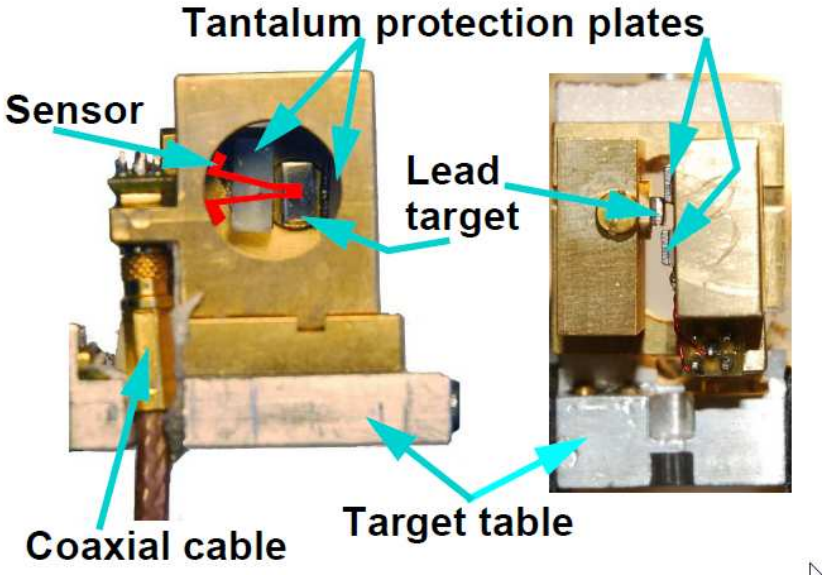


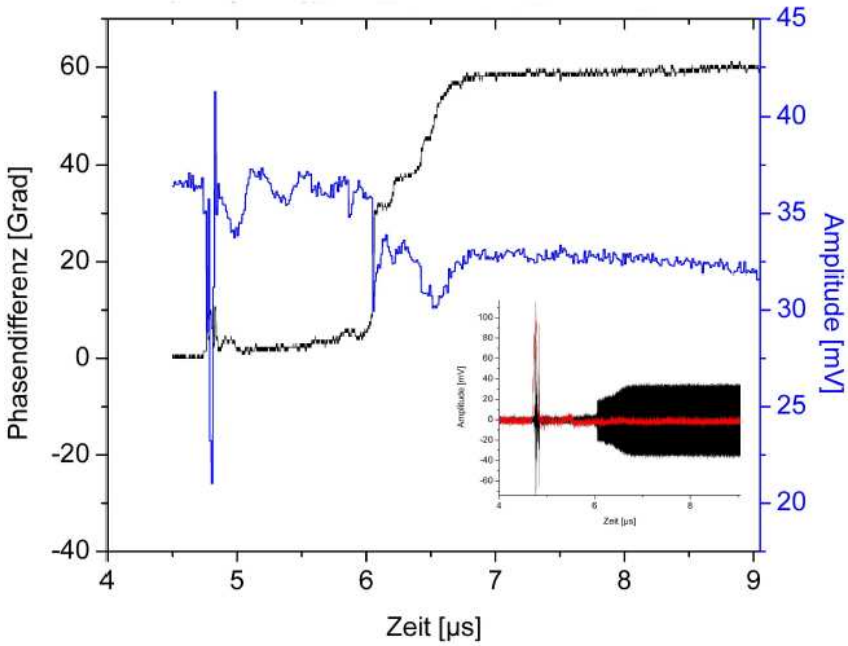
B. Ionita et al.

Imaging Interferometer



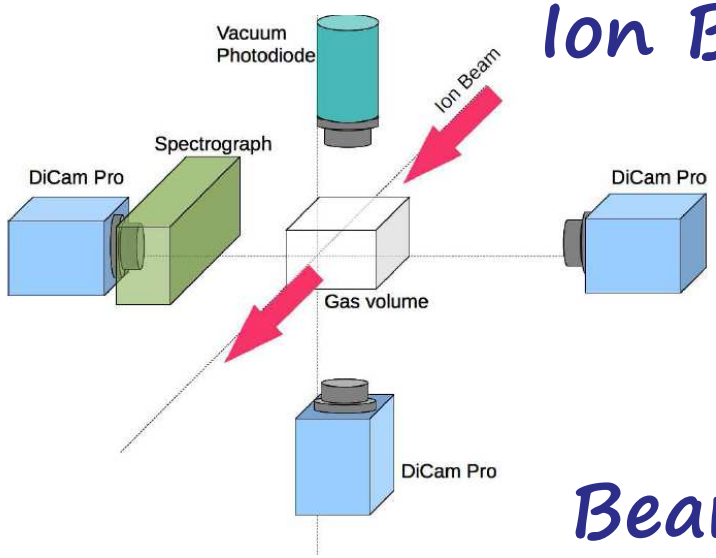
Non Contact Measurement of Electrical Conductivity of Ion Beam heated Target



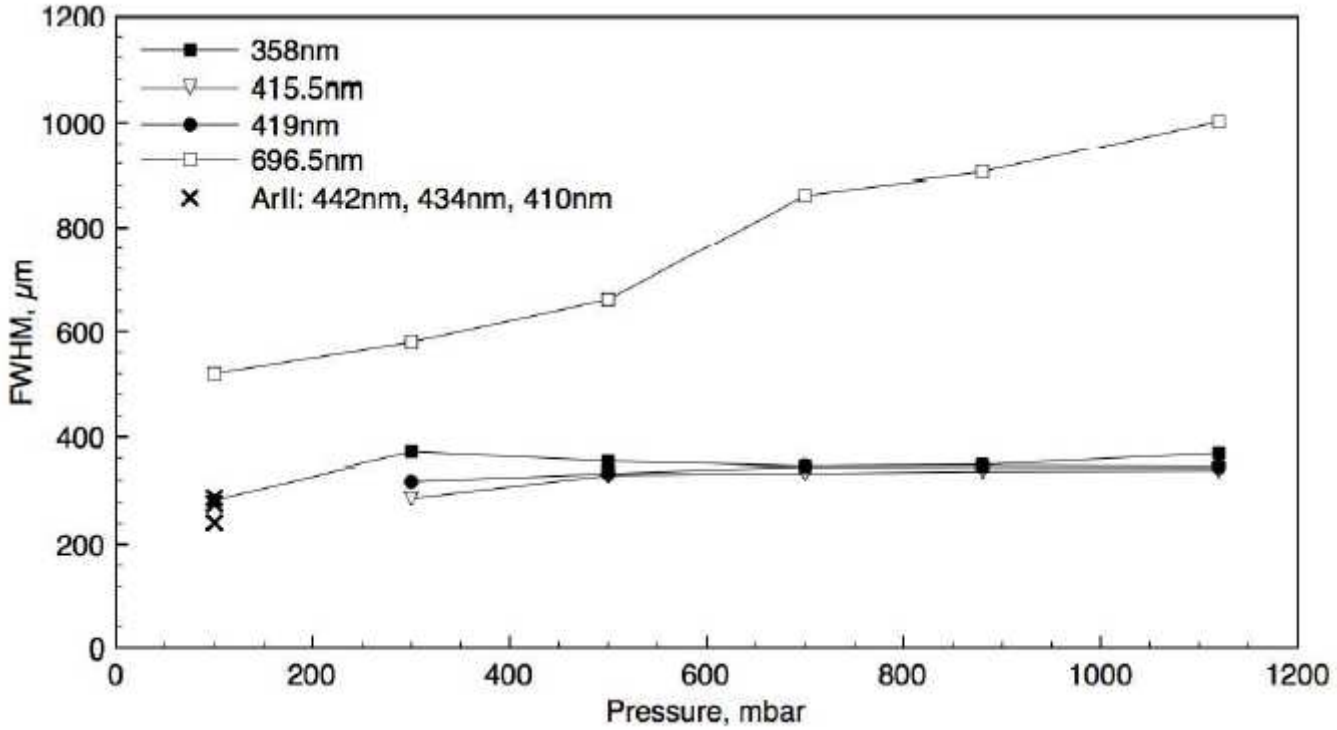


J.Ling et al.

Ion Beam Induced Light Emission

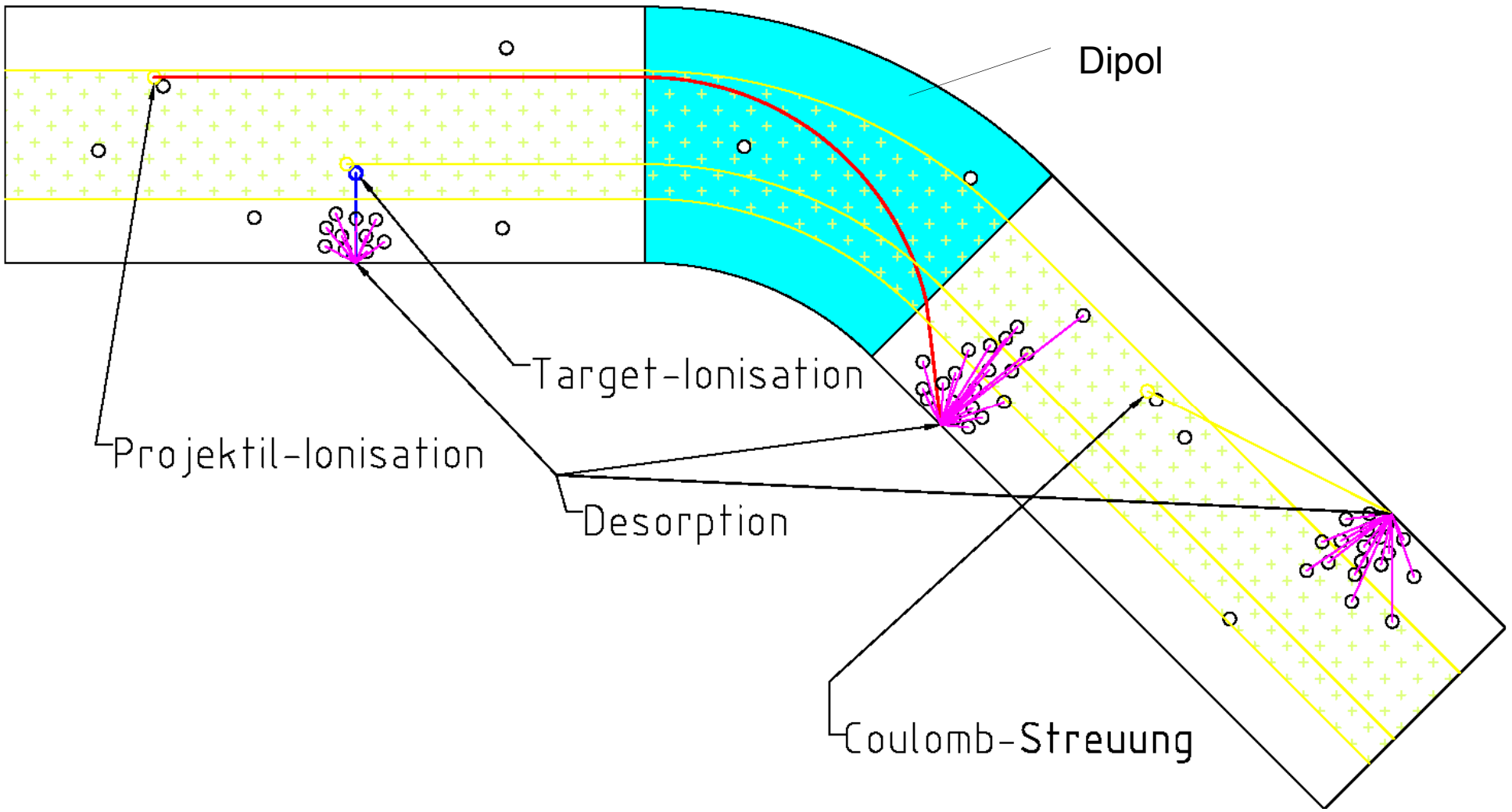


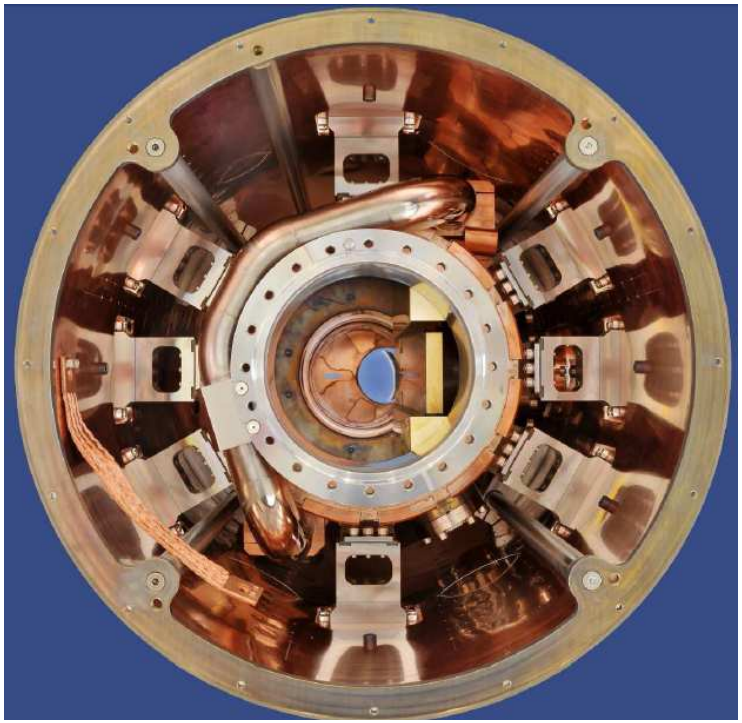
Beam Size



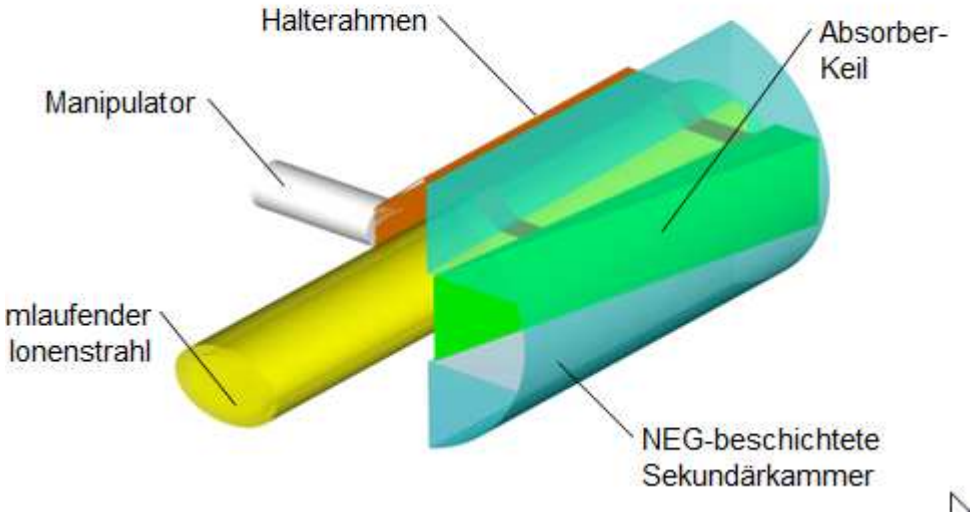
Fedenev, Moussati, Fertman et al.,

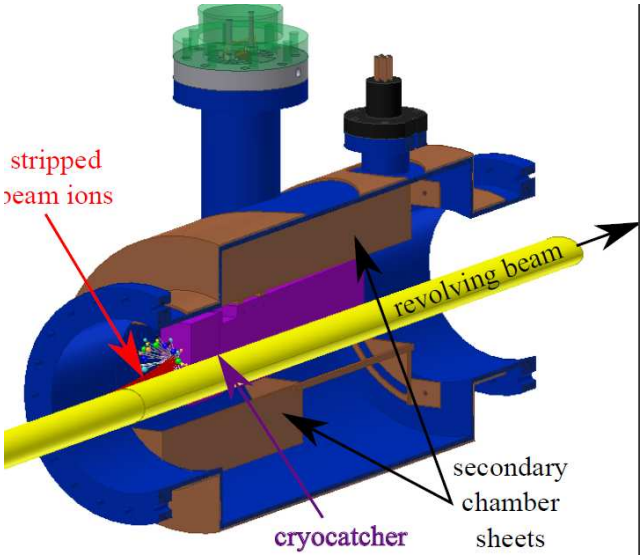
Loss Processes





Collimator design

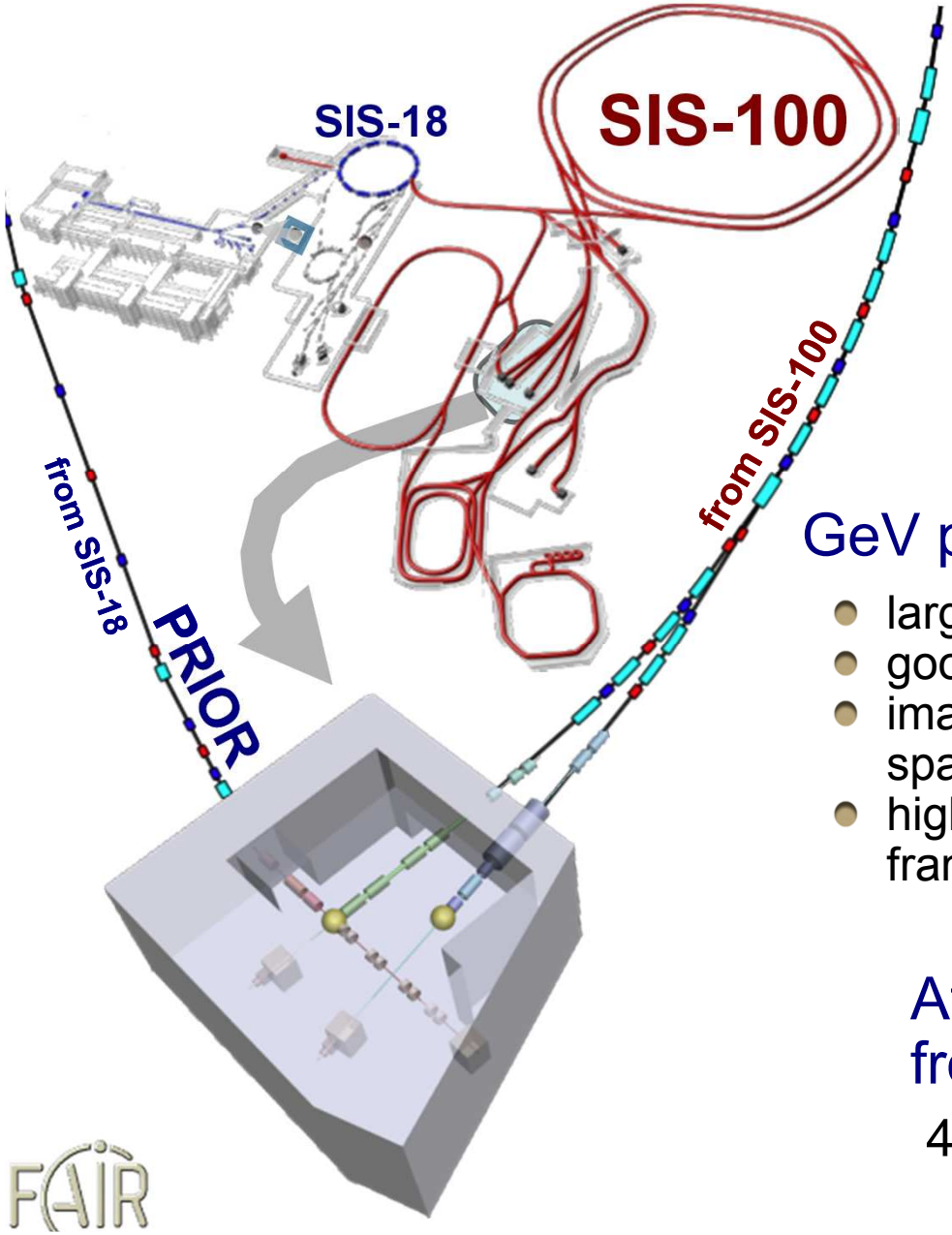




Cryo Catcher

L. Bozyk, Spiller et al.

PRIOR – Proton Radiography at FAIR



Challenging requirements for density measurements in dynamic HEDP experiments:

- up to ~20 g/cm^2 (Fe, Pb, Au, etc.)
- ≤10 µm spatial resolution
- 10 ns time resolution (multi-frame)
- sub-percent density resolution

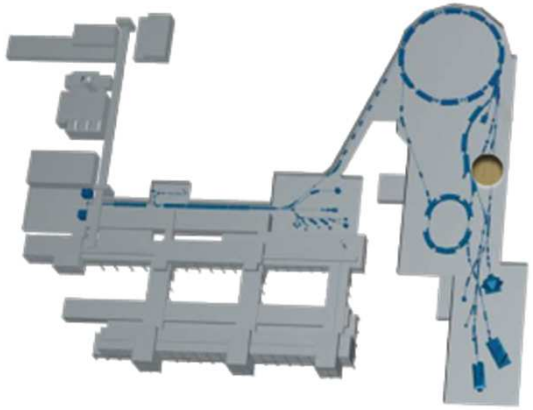
GeV protons:

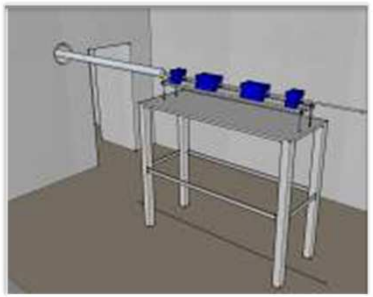
- large penetrating depth (high ρx)
- good detection efficiency (S/N)
- imaging, aberrations correction by magnetshigh spatial resolution (microscopy)
- high density resolution and dynamic rangemulti-frame capability for fast dynamic events

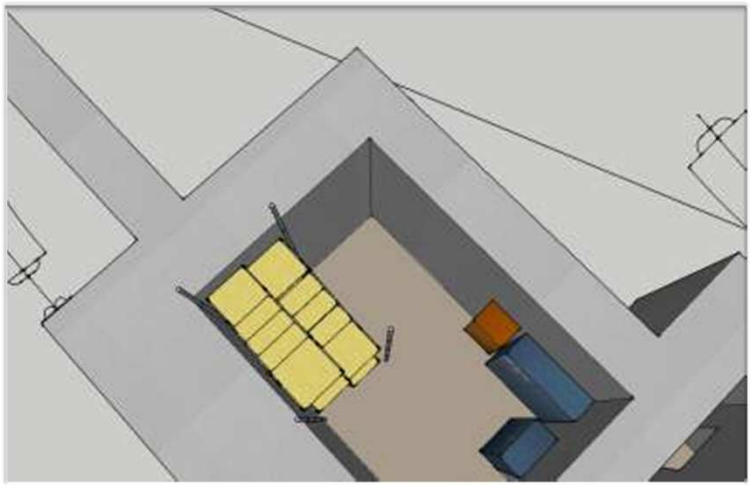
At FAIR: a dedicated beam line from SIS-18 for radiography

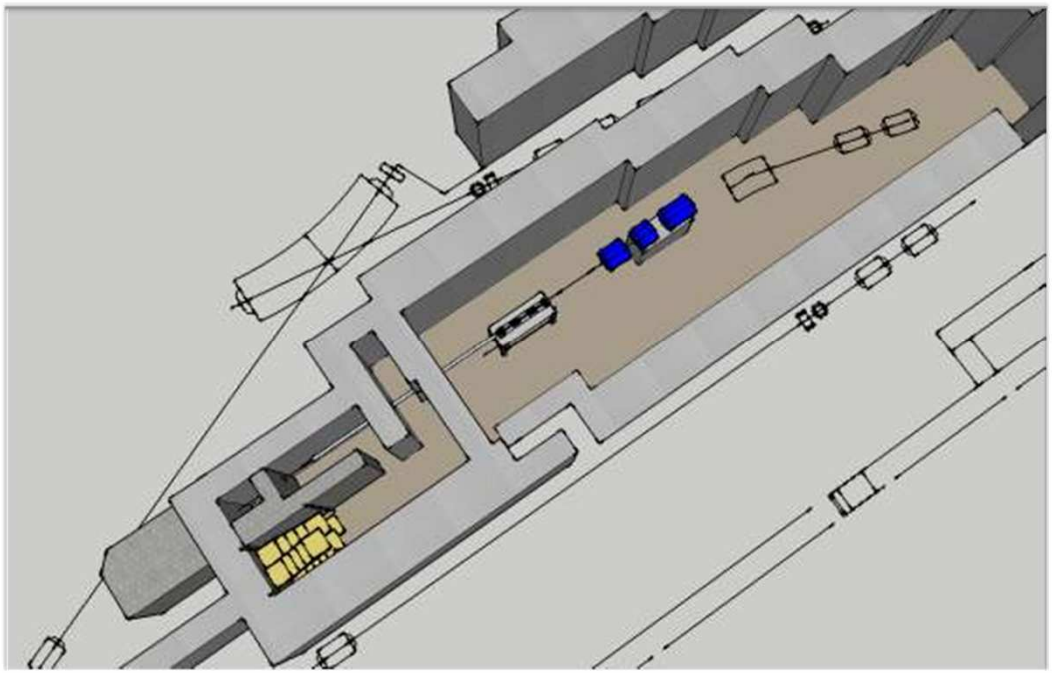
4.5 GeV, 5·10^{12} protons

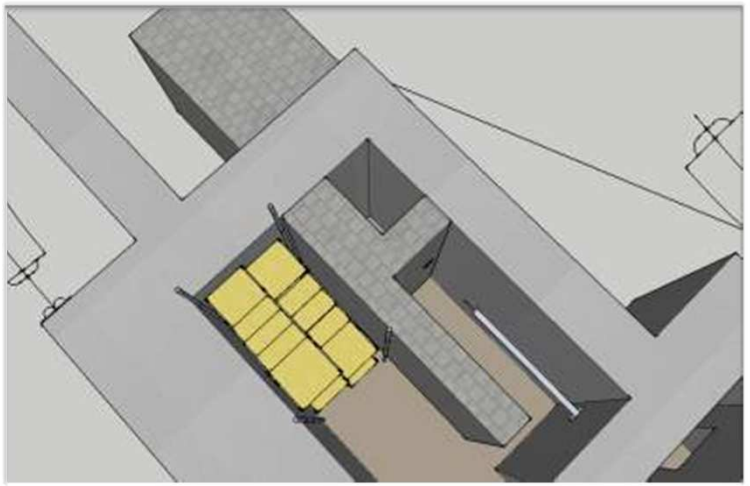
Fielding at GSI – a minor reconstruction of the HHT cave







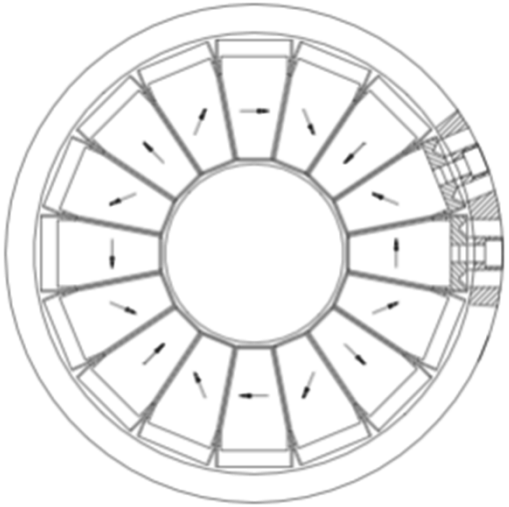


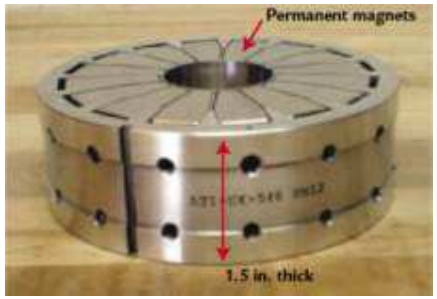


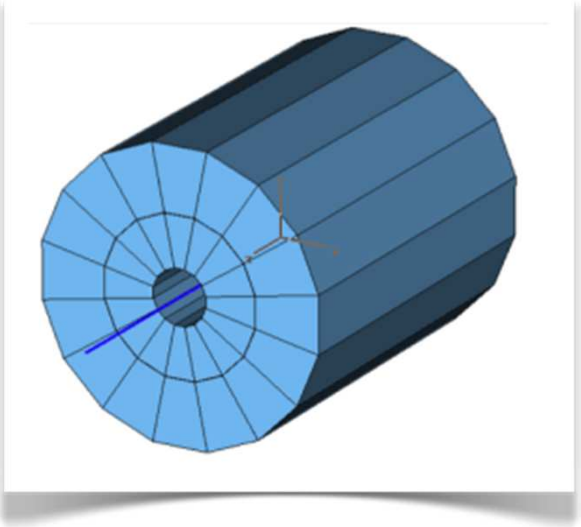
- a compact system but long drift is needed for the microscope

Permanent Magnetic Quadrupoles (PMQ) – design

High Gradient Split-Pole Quadrupole

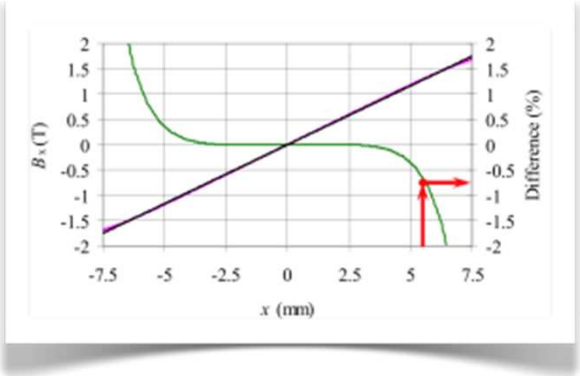


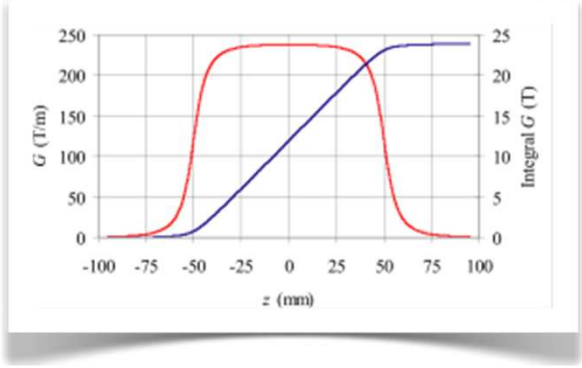




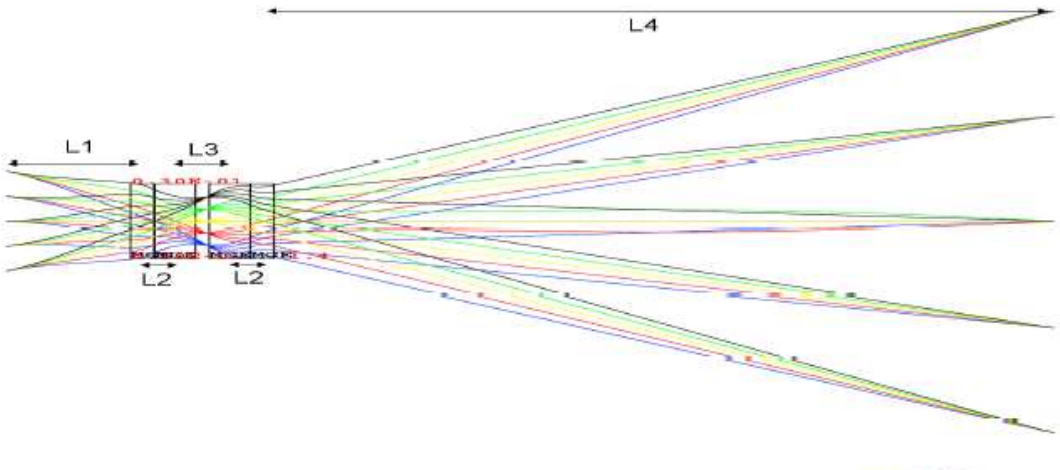
- Extremely High-Level **Gradient** - Maximal Demagnetization Factor
- Flexible Choice of the REPM **Coercivity** on Magnetization
- Minimal Demagnetization in Median Planes (in Critical Spaces)
- Gradient – Fixed

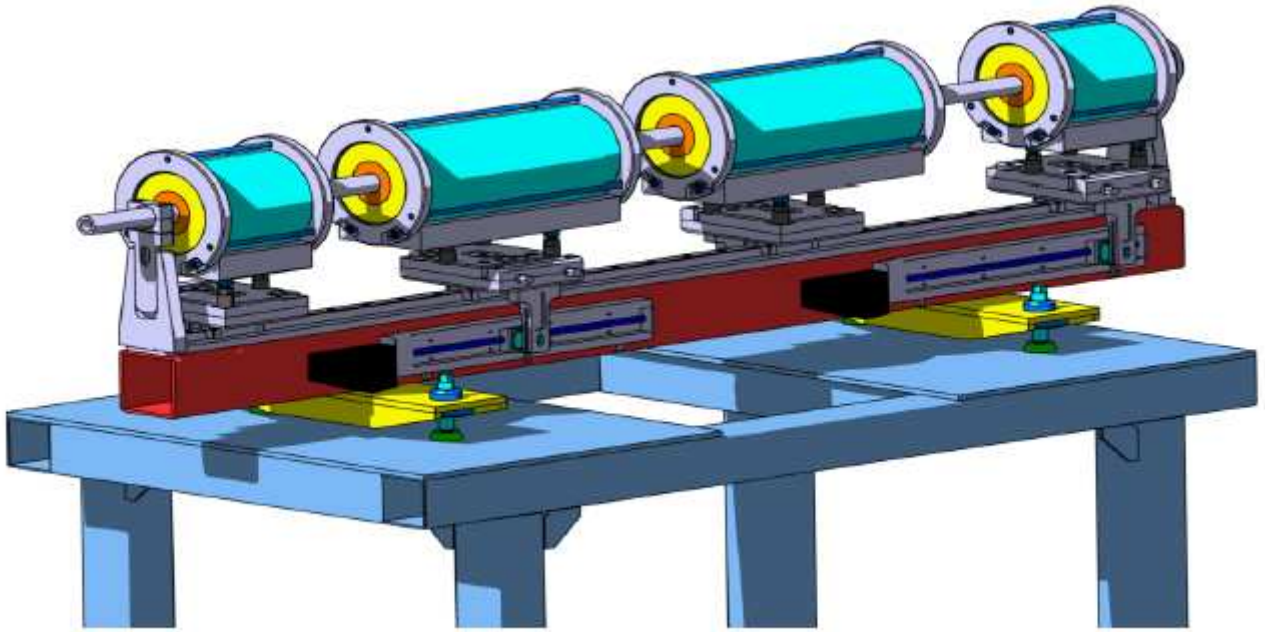
PMQ parameter	**Value**
Inner aperture, $2 \cdot R_i$	15 mm
Outer dimensions, $2 \cdot Ro$ x L	79 x 100 mm
Internal ring magnetization	1.16 T
External ring magnetization	1.19 T
Pole tip field	1.7 T



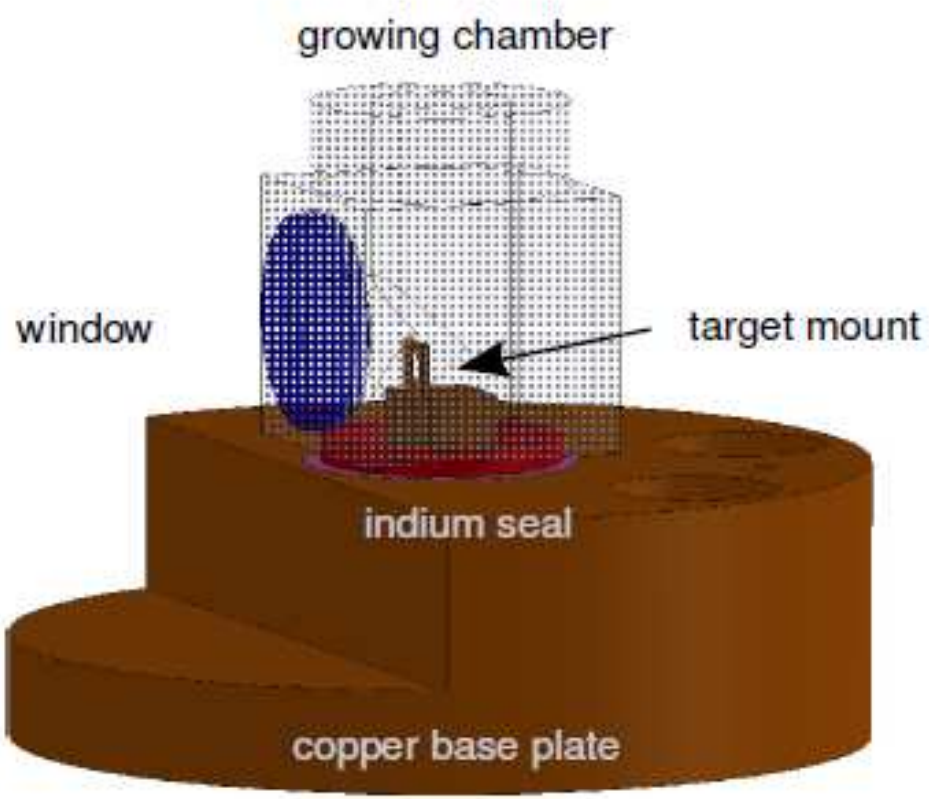


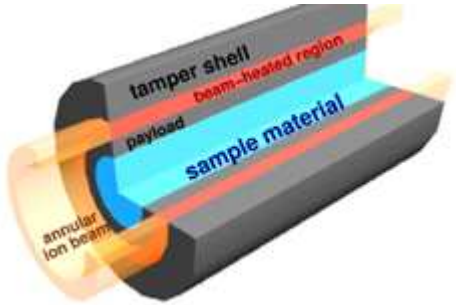
Beam Trajectories and Set-up





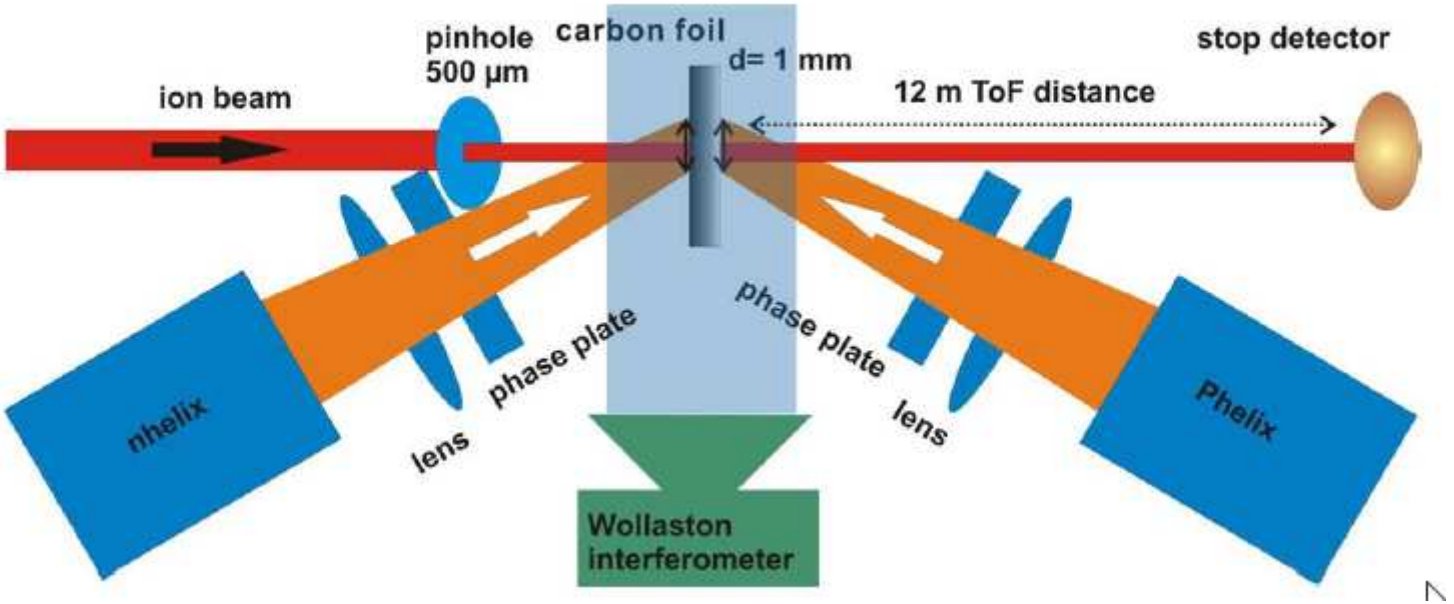
Cryo Targets for Beam Plasma Interaction Experiments





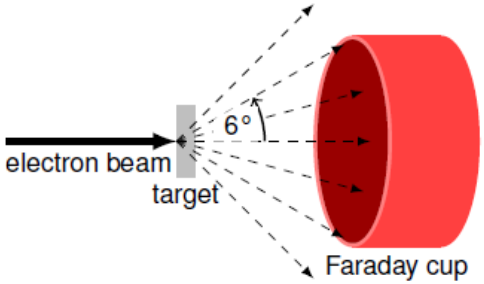
S. Bedacht, G. Schaumann et al.,

Laser- Plasma Target for Energy Loss Experiments

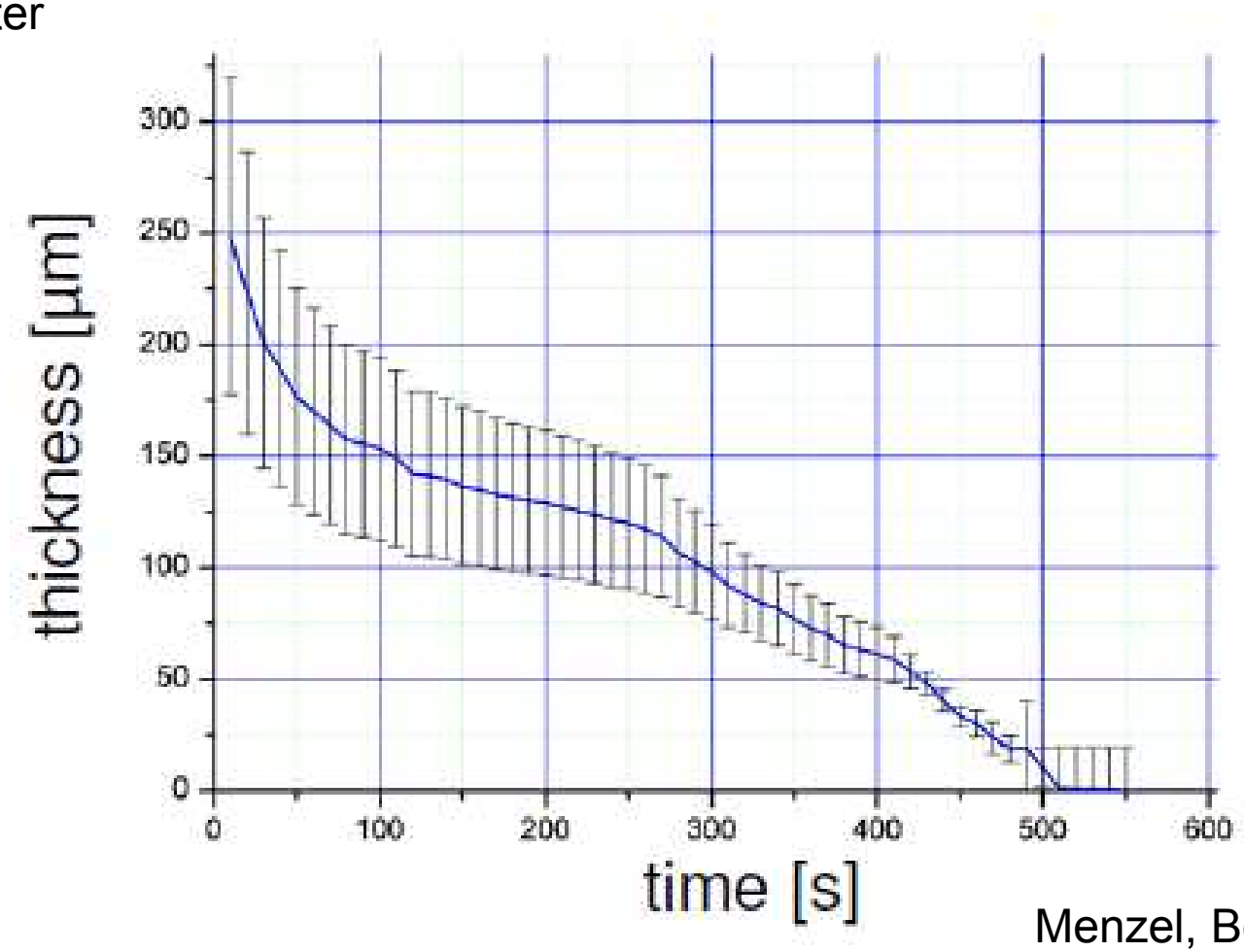


Free Standing Solid Hydrogen Target

Target Thickness as Function of Time Measured by Electron Scattering



electron beam: 14 kV, 5 µA,
2mm in diameter



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- ITEP
- TU-Darmstadt
- CERN
- IPCP-Chernogolovka
- VNIIEF, Sarov, Russia
- Joint Institute of High Temperature, Moscow, Russia
- Kurchatov Research Center, Moscow, Russia
- Lebedev Physical Institute, Moscow, Russia
- Lawrence Livermore National Laboratory, US
- Institute of Modern Physics, Lanzhou, China
- UCLM, Ciudad Real, Spain

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