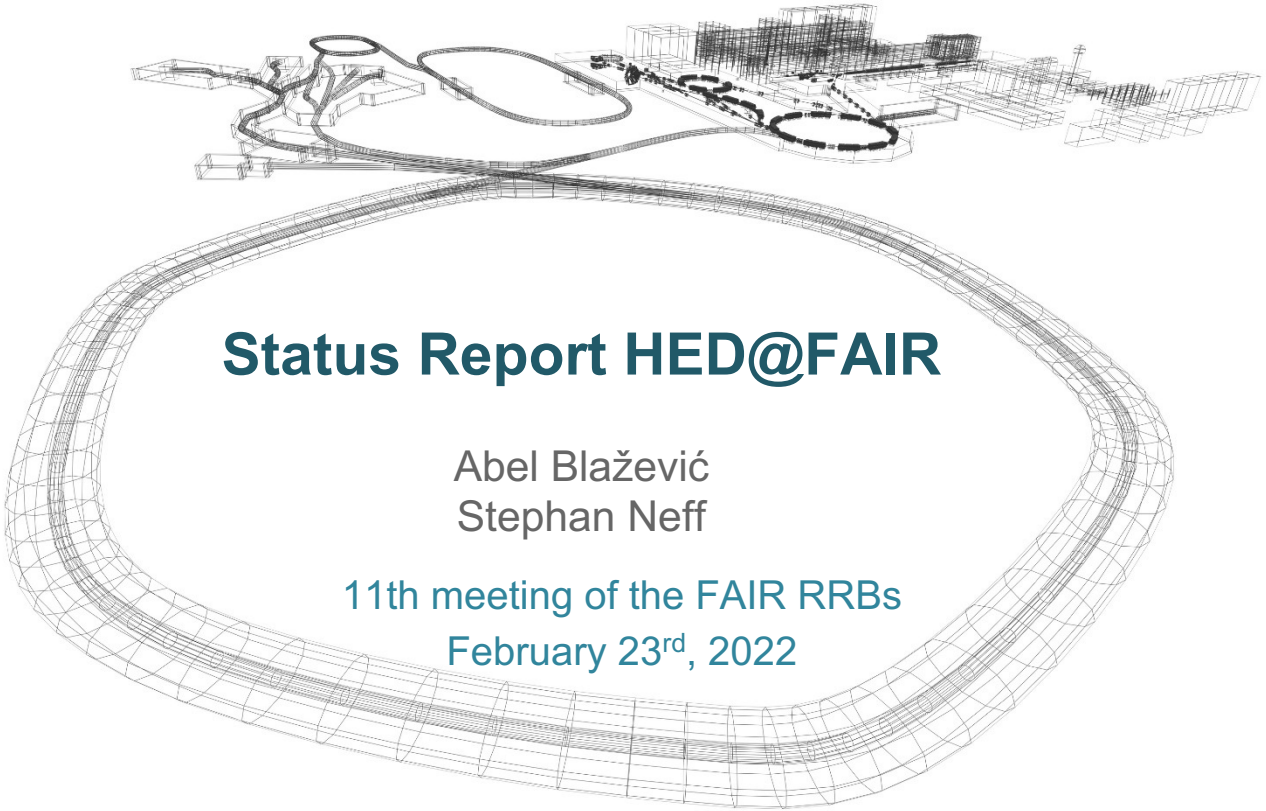


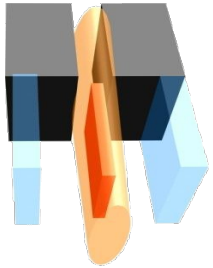
Status Report HED@FAIR

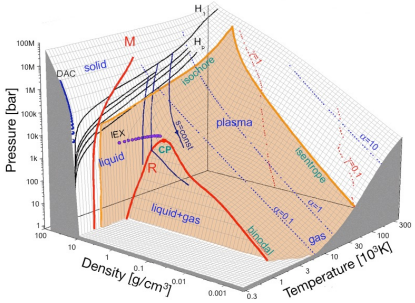
Abel Blažević
Stephan Neff

11th meeting of the FAIR RRBs
February 23rd, 2022

Three main experimental schemes will be used: HIHEX, PRIOR & LAPLAS

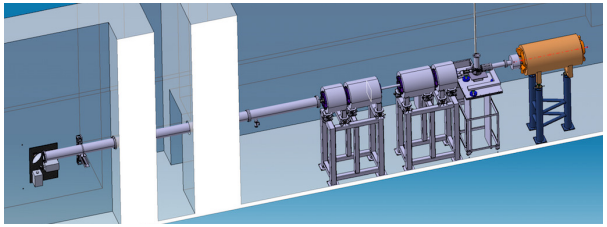
HIHEX
Heavy Ion Heating and Expansion

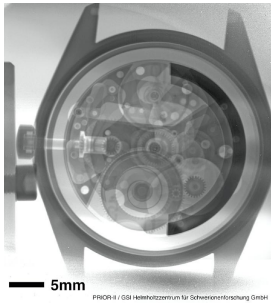




Create mm-sized samples
of warm dense matter

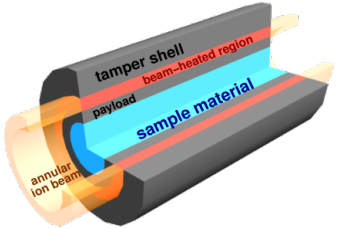
PRIOR
Proton Microscopy

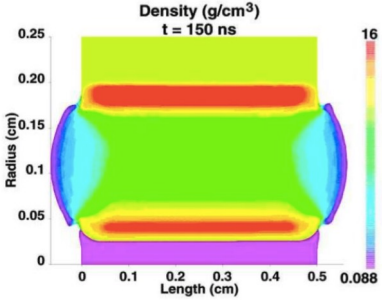




Use protons for precise
density measurements

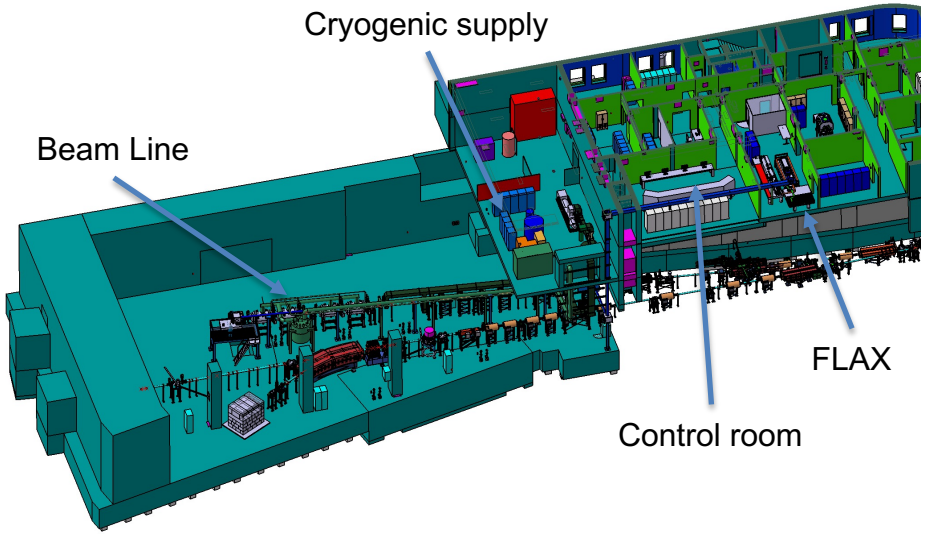
LAPLAS
Laboratory Planetary Science





Compress mm-sized samples
to Mbar pressures

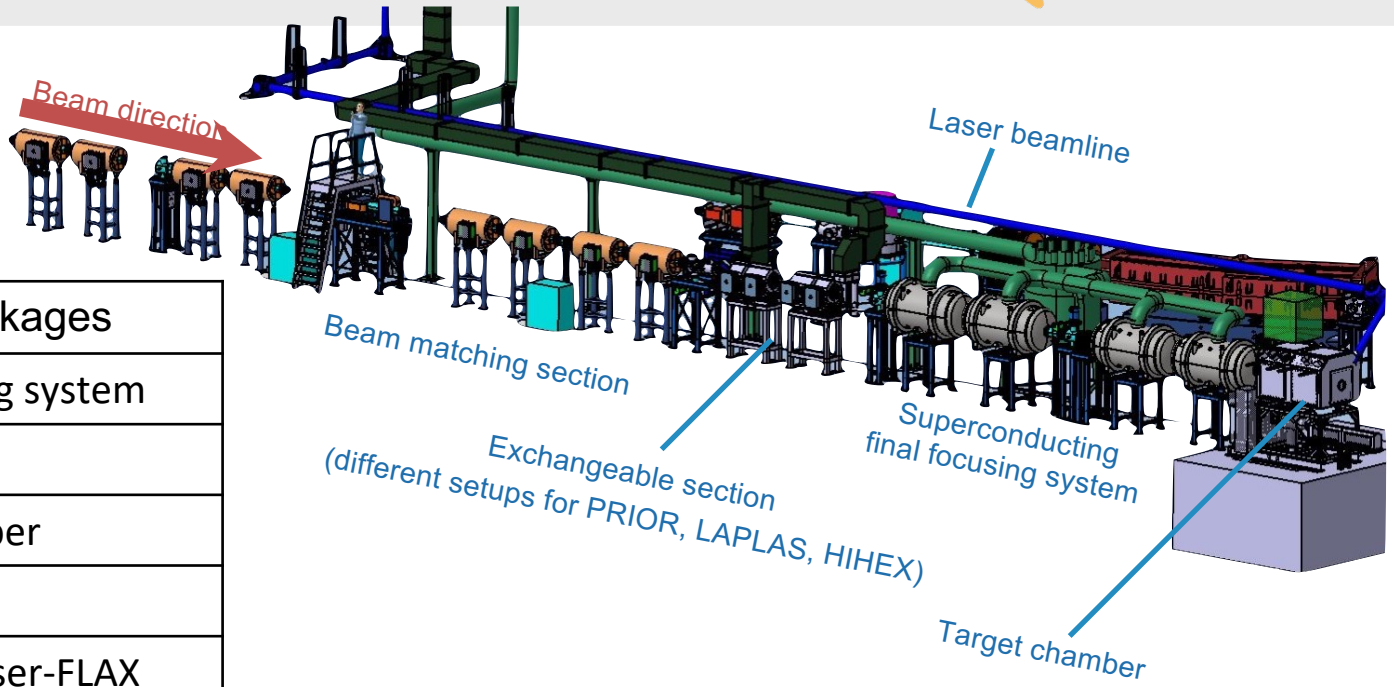
Construction work for the APPA cave is progressing



- Civil construction of the APPA cave is currently in progress
- The planning of the technical infrastructure for the APPA cave and the support building is currently being finalized
- Completion of the APPA building is scheduled for 2023, the main installation window is scheduled for 2024
- Beam expected in Q4/2025

The modular design of the HED@FAIR beamline accommodates all experimental setups

PSP	Working packages
1.3.2.1.2	Final fucussing system
1.3.2.1.5	PRIOR
1.3.2.2	Target Chamber
1.3.2.3	Detectors
1.3.2.4	Diagnostic Laser-FLAX
1.3.2.6	DAQ
1.3.2.7	Infrastructure

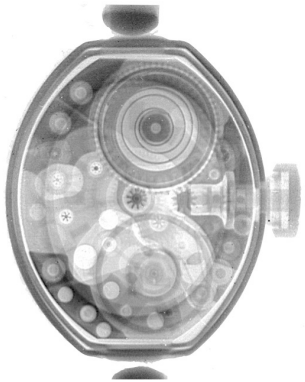


PRIOR II Facility at HHT (PSP 1.3.2.1.5)

PRIOR
Proton Microscope for FAIR

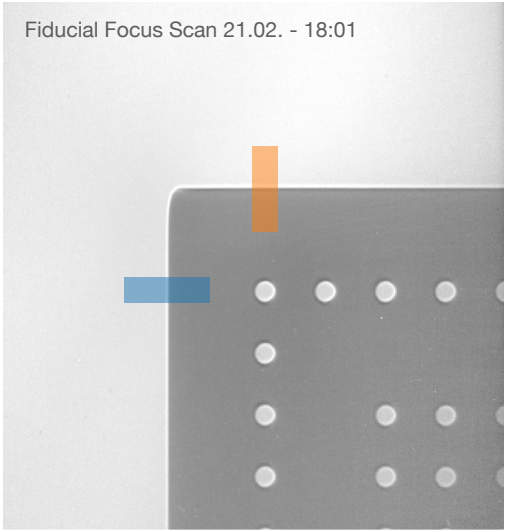
- New electric quadrupoles and power supplies built and installed at HHT
- Commissioning beam time in Feb21
- Tests with static and dynamic targets

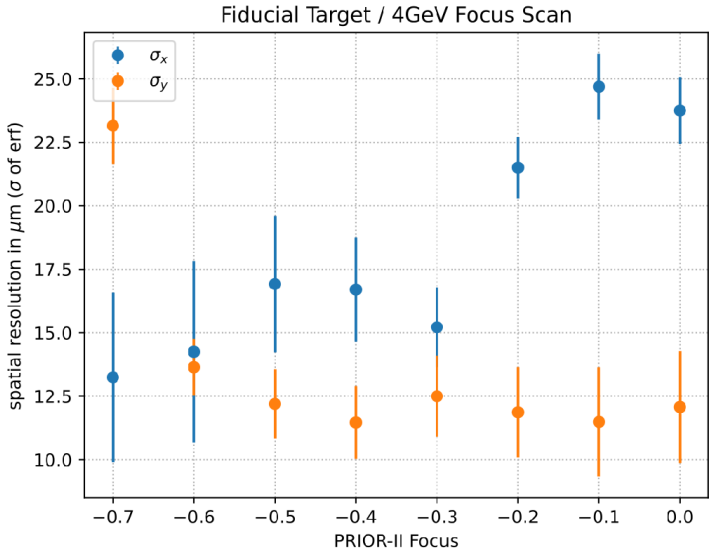
PRIOR I (2014)



PRIOR II (2021)

PRIOR-II commissioning beam time (Feb 2021): Spatial resolution revisited (fiducial target)





- 1px = 21.2 µm, magnification = 3.5 ▷ detector resolution 40-50 µm
- Spatial resolution of ∽15 µm, mostly limited by detector resolution

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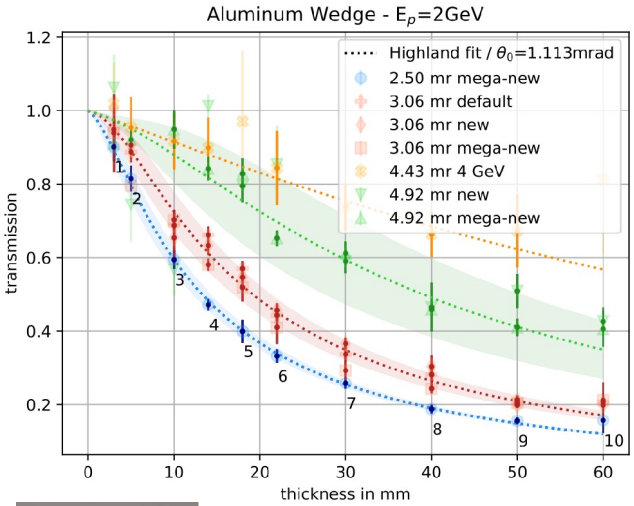
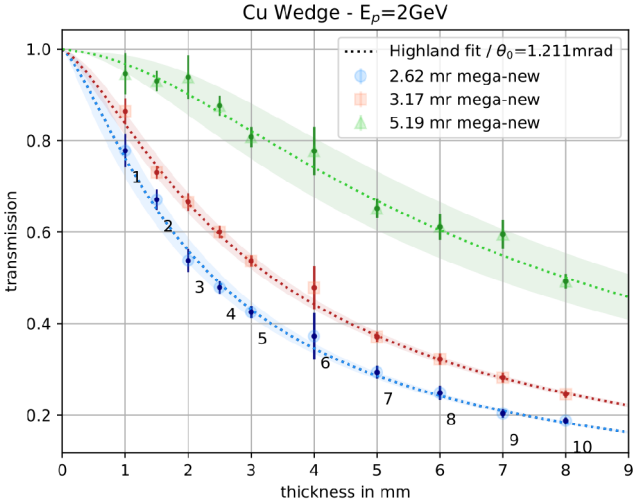
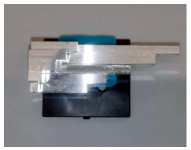
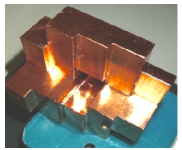
PRIOR-II commissioning beam time (Feb 2021): Density calibration / sensitivity (using step wedges)







- very good agreement between data and theory is achieved for the 2.5 and 3.0 mrad collimator
- Fluctuation greater for the 5 mrad collimator due to limited number of available beam pictures



2nd commissioning beam time running

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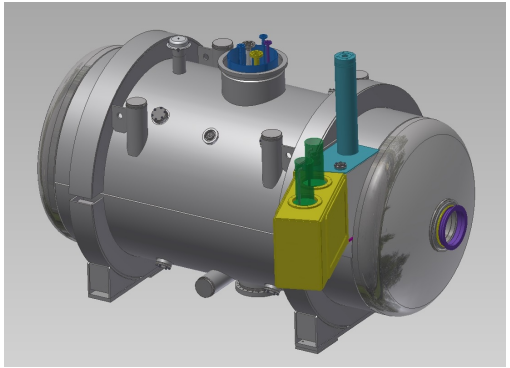
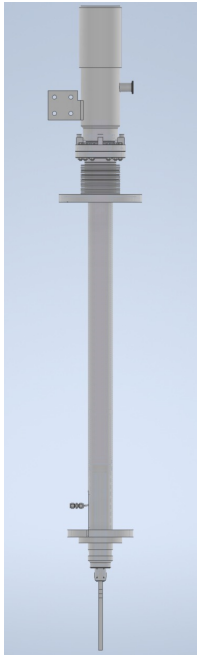
Status of the superconducting final focusing system

Superconducting magnets (PSP 1.3.2.1.2.1)
(Russian in-kind contribution, IHEP Protvino)

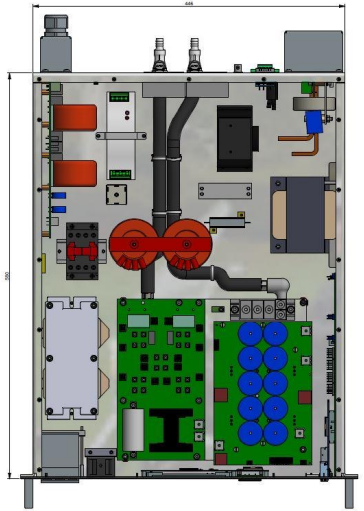
- FDR approved
- Material procurement finished
- Production has started





Current leads (PSP 2.8.2.13.1)
(German in-kind contribution)

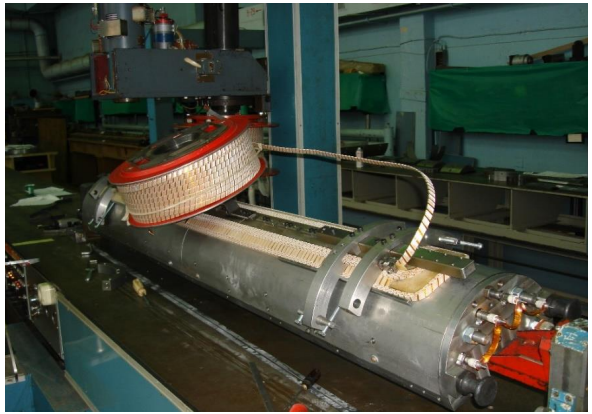
- Supplier contracted (Mark & Wedell)
- FDR expected by the end of March
- Production of first pair scheduled for Q2/22

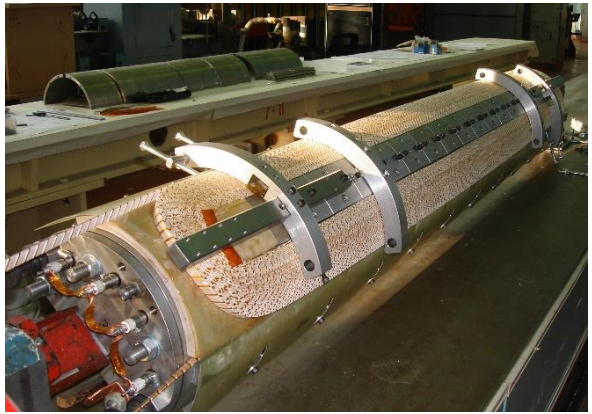
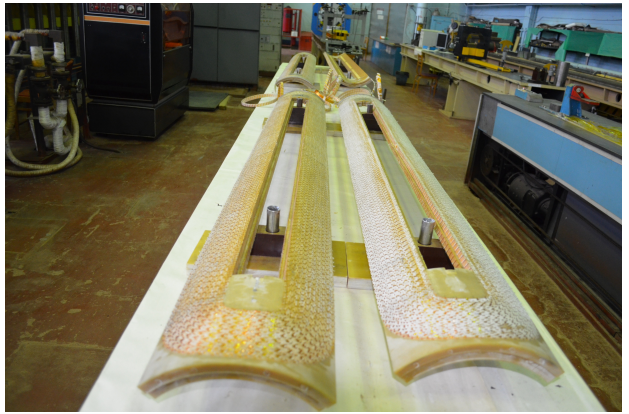
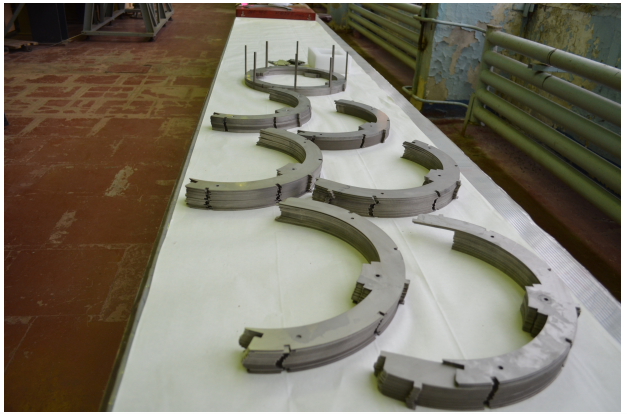


Power supplies (PSP 1.3.2.1.2.2)
(German in-kind contribution)

- Contracted to supplier (OCEM)
- Kick-off meeting with system/production details in July 21
- FDR expected in 2-3 weeks

Production of superconducting Quadrupoles



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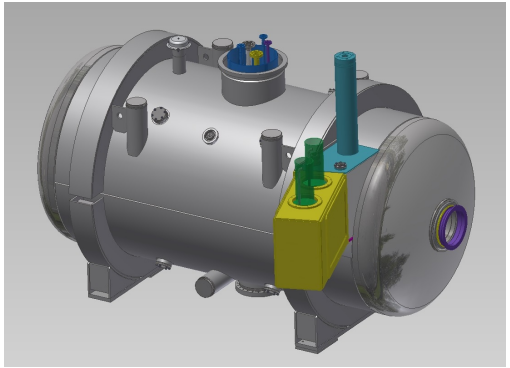

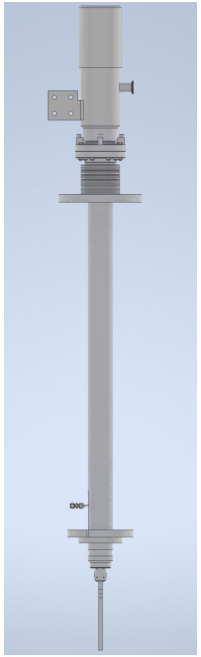

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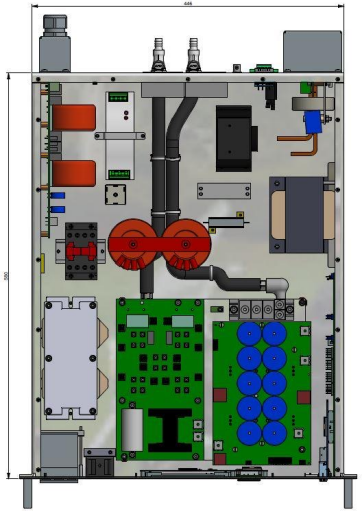
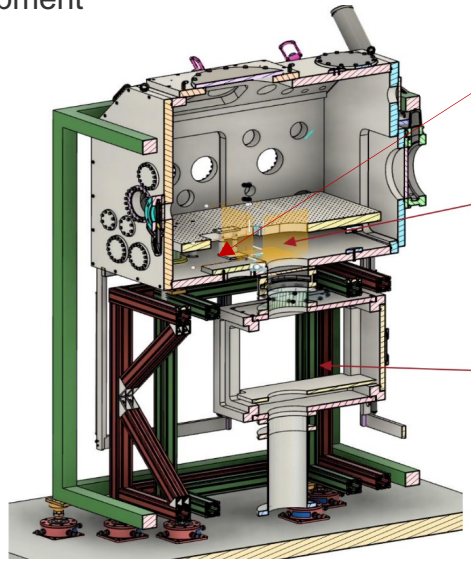
(German in-kind contribution)

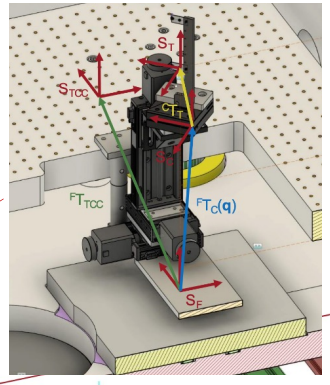
- Contracted to supplier (OCEM)
- Kick-off meeting with system/production details in July 21
- FDR expected in 2-3 weeks



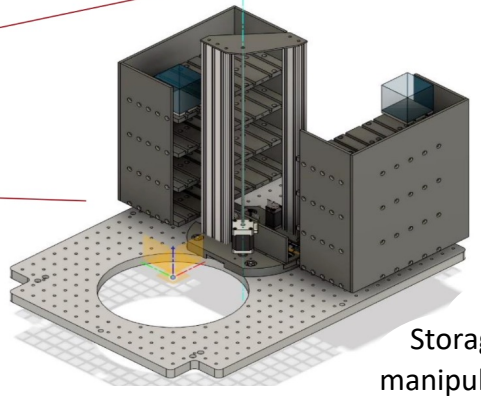
Target chamber (PSP 1.3.2.2):
The Target Supply System (TSS) is under development at TU Darmstadt

- Day-1 target chamber has been delivered and installed at HHT area
- Vacuum control system (GSI internal development) operational
- First target chamber successfully commissioned
- Second target chamber is used to test TSS at TU Da
- Control software is under development





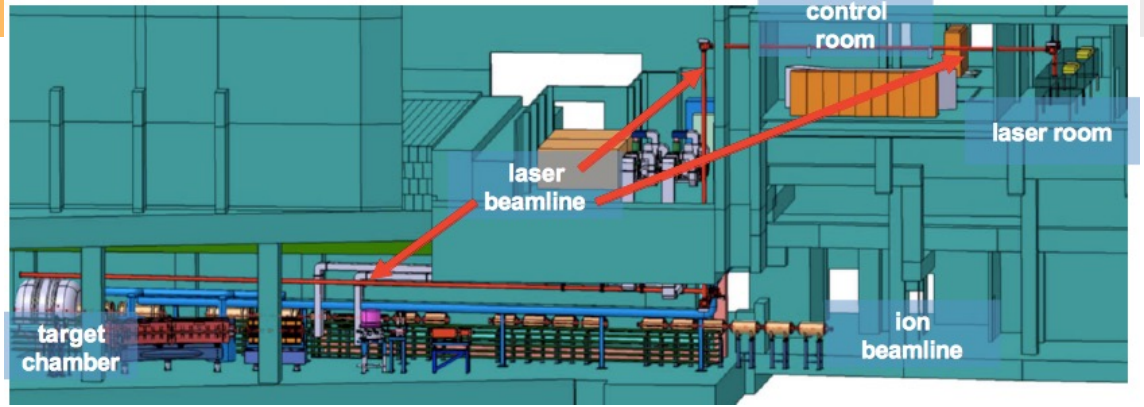
Target positioning robot: 4 axes



Storage manipulator: 2x32 target storage slots

Lift manipulator: Two grippers

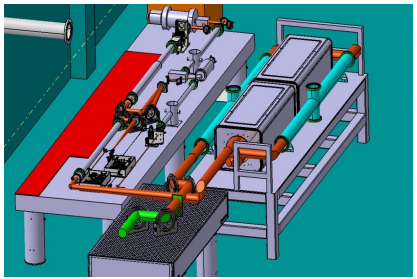
FLAX: First Laser for APPA eXperiments (PSP 1.3.2.4)



Flash lamp module prototype, TU Darmstadt

Energy	Repetition rate	Pulse length	Pulse shaping	Wavelength
100 J	up to 1 shot/minute	0.1 - 20 ns	Yes	532 nm

- FLAX under construction by PHELIX laser team
- Supported by German university projects (BMBF VBF):
  Laser frontend (U Jena)
  Prototype main amplifier (TU Darmstadt)
- Option to later on install a short-pulse laser (Helmholtz Beamlines) if funding becomes available



Laser frontend, U Jena

Amplifier prototype, TU Darmstadt

A PHELIX beamline to the HHT experimental area built for coupled laser beam - ion beam experiments in Phase 0

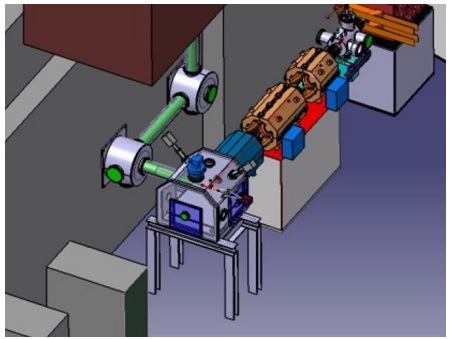
Goals

- Enable coupled experiments with laser beams and high-energy ion beams (HIHEX)
- Enable laser-driven volumetric X-ray diagnostics (absorption spectroscopy, radiography, X-ray diffraction, X-ray scattering)
- Commission Day-1 target chamber, laser sources and diagnostics at HHT
- Develop ion position and focus diagnostic

Clean room

Status of laser beam line construction

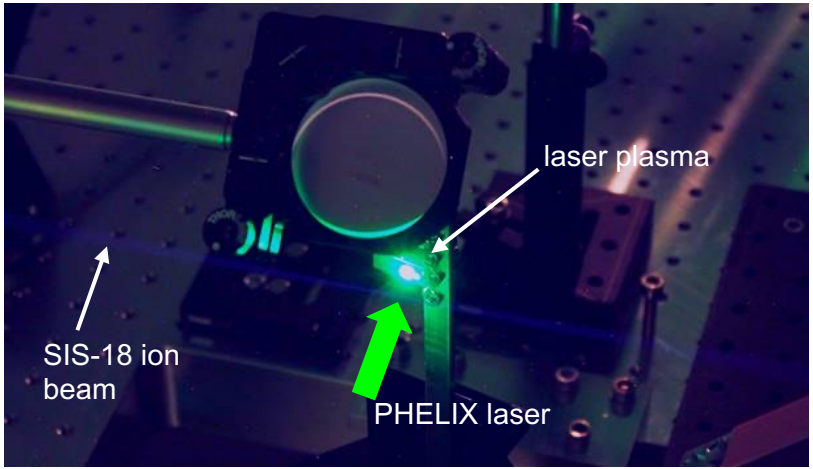
- Project started in 2019 after review by ECE
- Installation finished in spring 2021
- Commissioning performed successfully in 2021
- First laser-/ion-beam coupled experimentsin HIHEX scheme scheduled for April and May 2022

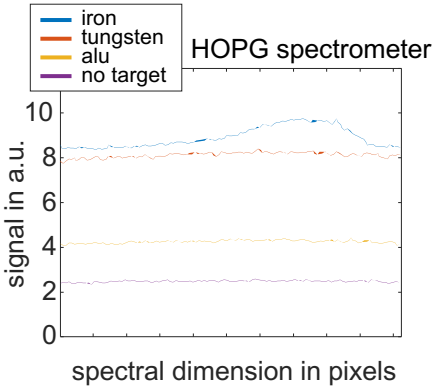


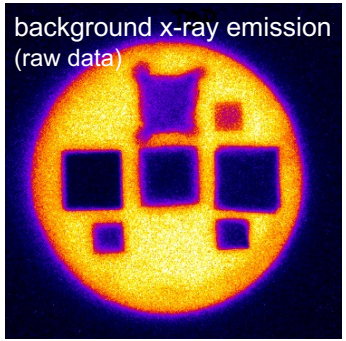
Laser-beam parameters at HHT
- 200 J
- 527 nm
- 0.33-1 ns,… up to ~10 ns
- 15 cm beam diameter

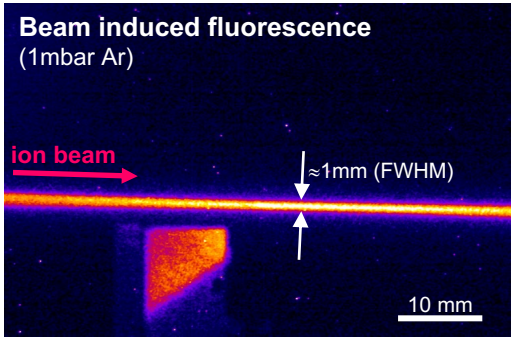
HED@FAIR - Diagnostics development for HED experiments

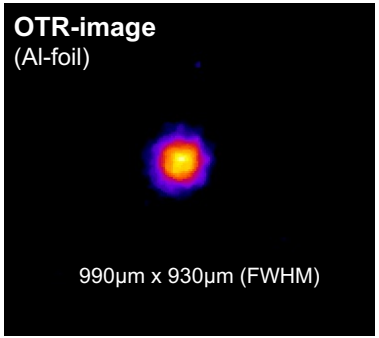
- **Target chamber commissioned**
  at HHT with up to $3 \cdot 10^9$ ions/bunch
- **In-focus beam diagnostic (beam induced fluorescence, optical transition radiation), fast imaging pyrometer successfully tested**
- **PHELIX-HHT laser-beamline commissioned**
  - ~50 µm focal spot, good stability, 100 J in HHT target chamber
  - Laser-driven x-ray source
  - Demonstrated x-ray probing of dense samples (diffraction, Thomson scattering)











Optical diagnostics overview

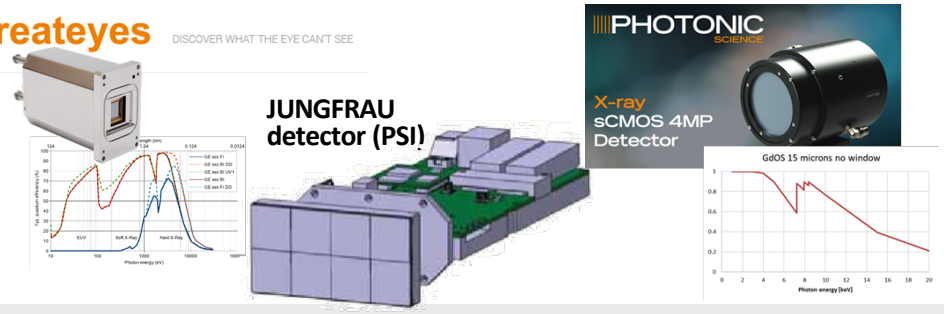
Measurement	principle	remark	Spatial resolution	Temporal resolution	Measurement resolution	Components
Thermal emission	Fibre-coupled photodetectors	Single point	>100 µm	5 ns (over µs)	ΔT/T potientially very small	Coupling optics, fibre, filters + photodetectors, **fast multi-channel digitizer (Pyrometer)**
	Dual-color imaging	Line imaging	50 µm (>2 mm FoV)	10 ns (over µs)	ΔT/T <10% (dep. on T, Δt)	imaging optics, filters, **streak camera**
Expansion	Shadowgraphy		<100 µm		<100m/s	illumination laser, imaging optics, **streak camera**
Displacement	Photon Doppler Velocimeter	Single point	100 µm		m/s (<1km/s)	Doppler Velocimeter, fast scope
	VISAR	Line imaging	100 µm		10m/s (1…50km/s)	VISAR setup, **streak camera**
Ion focus, PRIOR	Gas fluorescence, OTR, scintillators		<50 µm	5 ns		Imaging optics, **gated intensified camera**

- Gated camera: 2 new (1x GSI, 1x Prof. Jacoby/GUF, BMBF2019)
- Streak camera: 1 from GSI, 1 new (loan from IMP/Lanzhou), application for 1 new by Prof. Spielmann/FSU, BMBF2021
- Pyrometer: new system will be provided by Prof. Winkler/GUF, BMBF2021
- Photon Doppler Velocimeter: 1 (com.), new system will be designed/provided by NRNU/MEPhi
- VISAR: exists at GSI, new system will be designed/provided by NRNU/MEPhi

X-ray diagnostics overview

Measurement	principle	remark	Spatial resolution	Spectral resolution	Components
Absorption spectroscopy	Broadband-source, focusing spectrometer	Line imaging	>100 µm	<1 eV (@1.5keV)	Curved crystal (e.g. quartz, mica), **x-ray CCD camera (50k€)**, or **gated x-ray imager (100k€)**
X-Ray Thomson scattering	Line-source, spectrally resolved scattering, high collection efficiency	Single point	n/a	10 eV (@6keV)	Large-aperture HOPG crystal, **x-ray CCD camera**
X-Ray diffraction	Line source → Debye-Scherrer on large-area detector	Single point	100 µm	n/a	**Scintillator/sCMOS-camera (50k€)**, or **Large-area pixel detector (100k€)**
X-Ray radiography	Point-source, projection onto area detector	Limited in ρr (E_{ph} < 20keV)	< 50µm	n/a	**Scintillator/sCMOS-camera**

- Crystals: several (GSI + Prof. Spielmann/FSU, BMBF2015)
- X-ray CCD: 1 (Prof. Spielmann/FSU, BMBF2015)
- Gated x-ray imager: possibly loan by IMP/Lanzhou
- Scintillator/sCMOS: Prof. Jacoby/GUF, BMBF2019
- Pixel detector: applied for (Prof. Kraus/UR, BMBF2021→**X**)

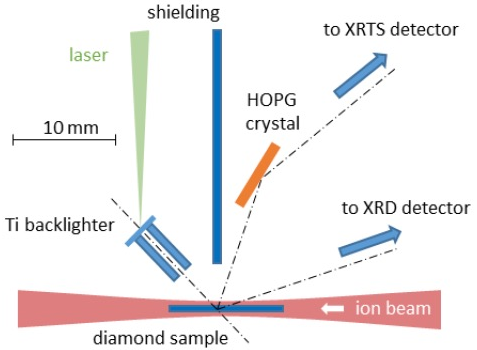


Two experiments in HIHEX scheme using combined laser and ion beams at HHT will be carried out in 2022 (S489)

Graphitization of diamond (D. Kraus)

- Heating a diamond turns it into graphite (time scale: minutes)
- Ultra-fast energy deposition in diamond turns it into graphite (time scale: fs!)
- With heavy-ions can do volumetric heating at intermediate time-scale

➔ Heavy-ion pulse **heats** diamond sample
➔ Laser-produced x-rays probe (x-ray diffraction detects phase transition, x-ray Thomson scattering can measure temperature)

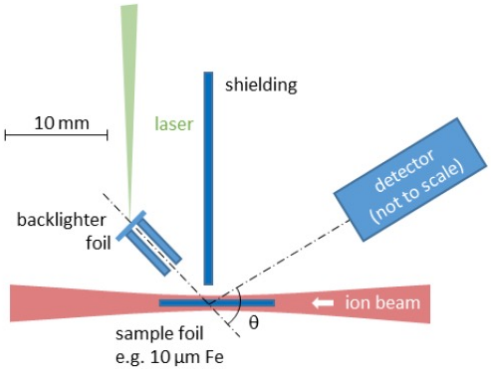


Commissioning experiments at HHT have shown that the laser parameters are sufficient to create the required x-ray source

Super-heating of iron (D. Riley)

- X-ray diffraction experiments at LCLS on shock-heated iron had shown significant super-heating
- Compare with heating by heavy-ion pulse (different heating/strain-rate)

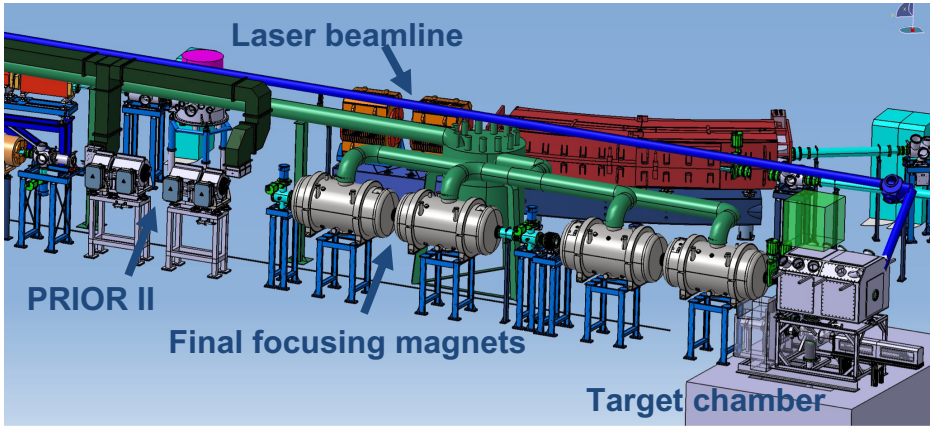
➔ Heavy-ion pulse **heats** Fe-foil
➔ Laser-produced x-rays probe (x-ray diffraction detects lattice vibration & melting)



HED@FAIR

Preparations for early experiments in the APPA cave

- All TDRs needed for Day-1 experiments have been approved
- Currently all components are on track
- Key components (target chamber, PRIOR-II) have already been commissioned at HHT
- Diagnostics will be tested and optimized in Phase-0 experiments at HHT in combination with PHELIX



HED@FAIR is progressing well for carrying out early experiments in 2025 with SIS-18 beam in the APPA cave