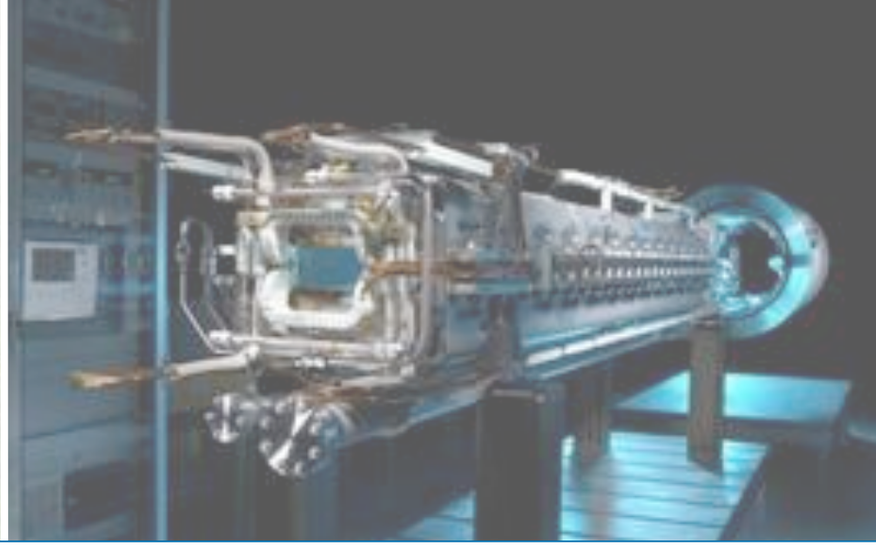


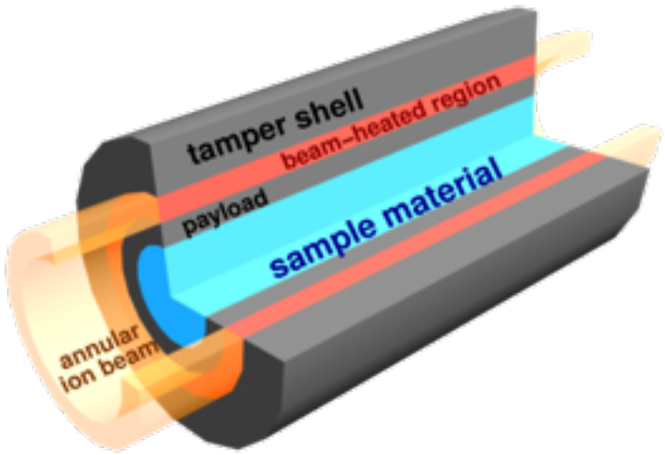


Experimental facilities for plasma physics experiments at FAIR

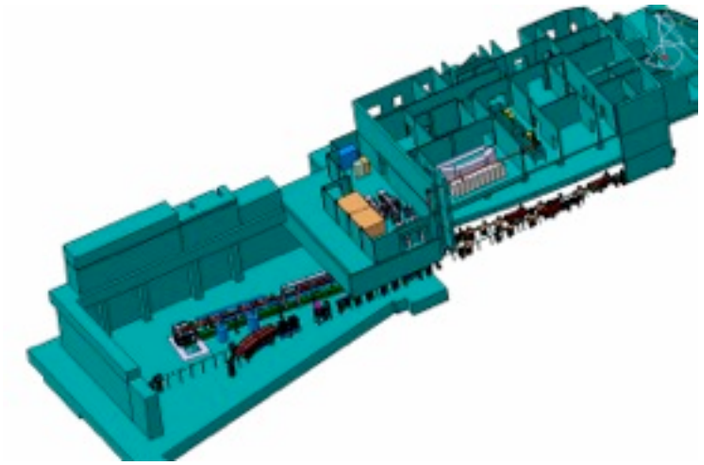
Stephan Neff
Facility for Antiproton and Ion Research in Europe GmbH

Finland France Germany India Poland Romania Russia Slovenia Spain Sweden

This presentation will give an overview of the planned plasma physics facilities at FAIR



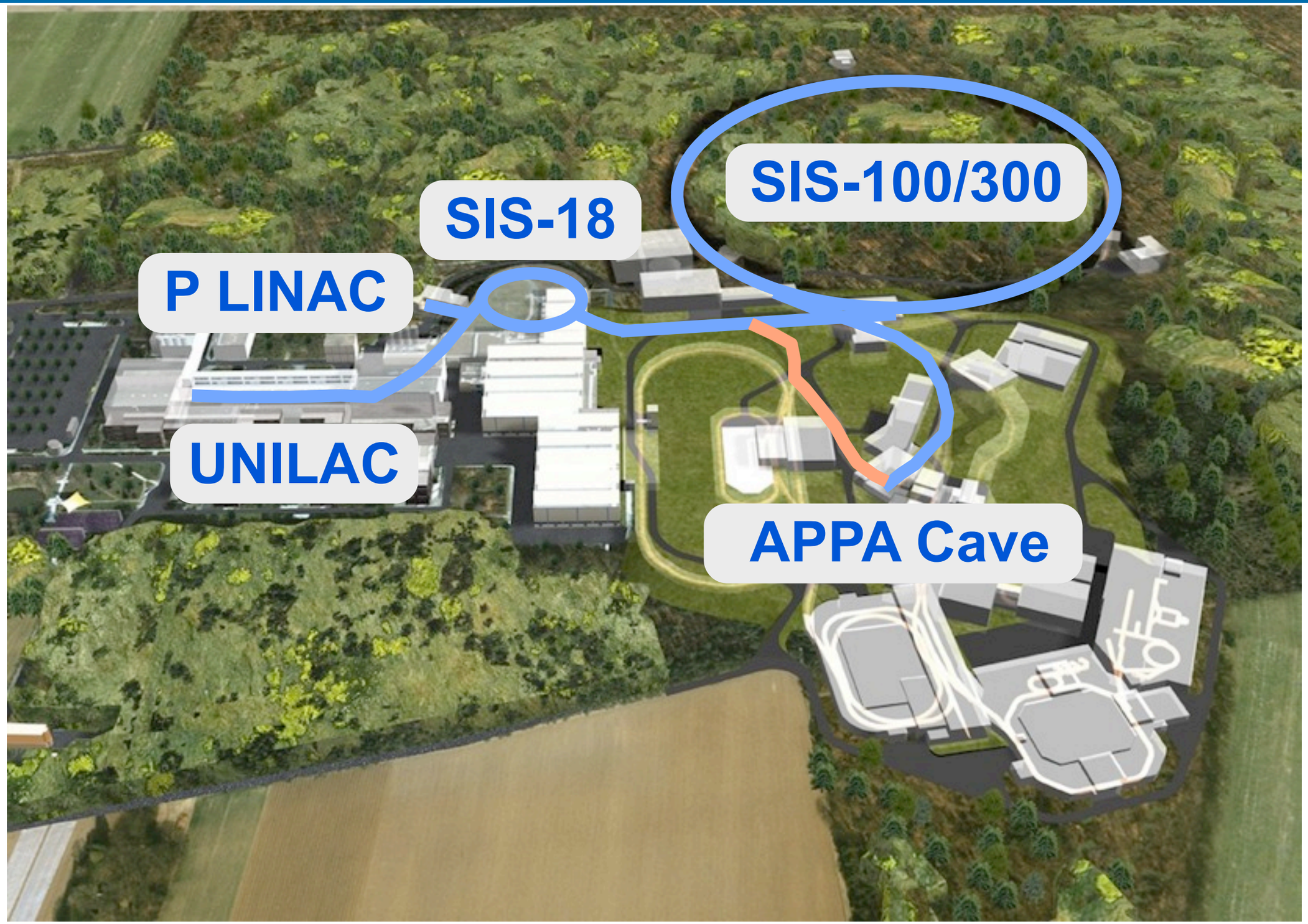
Plasma Physics at FAIR



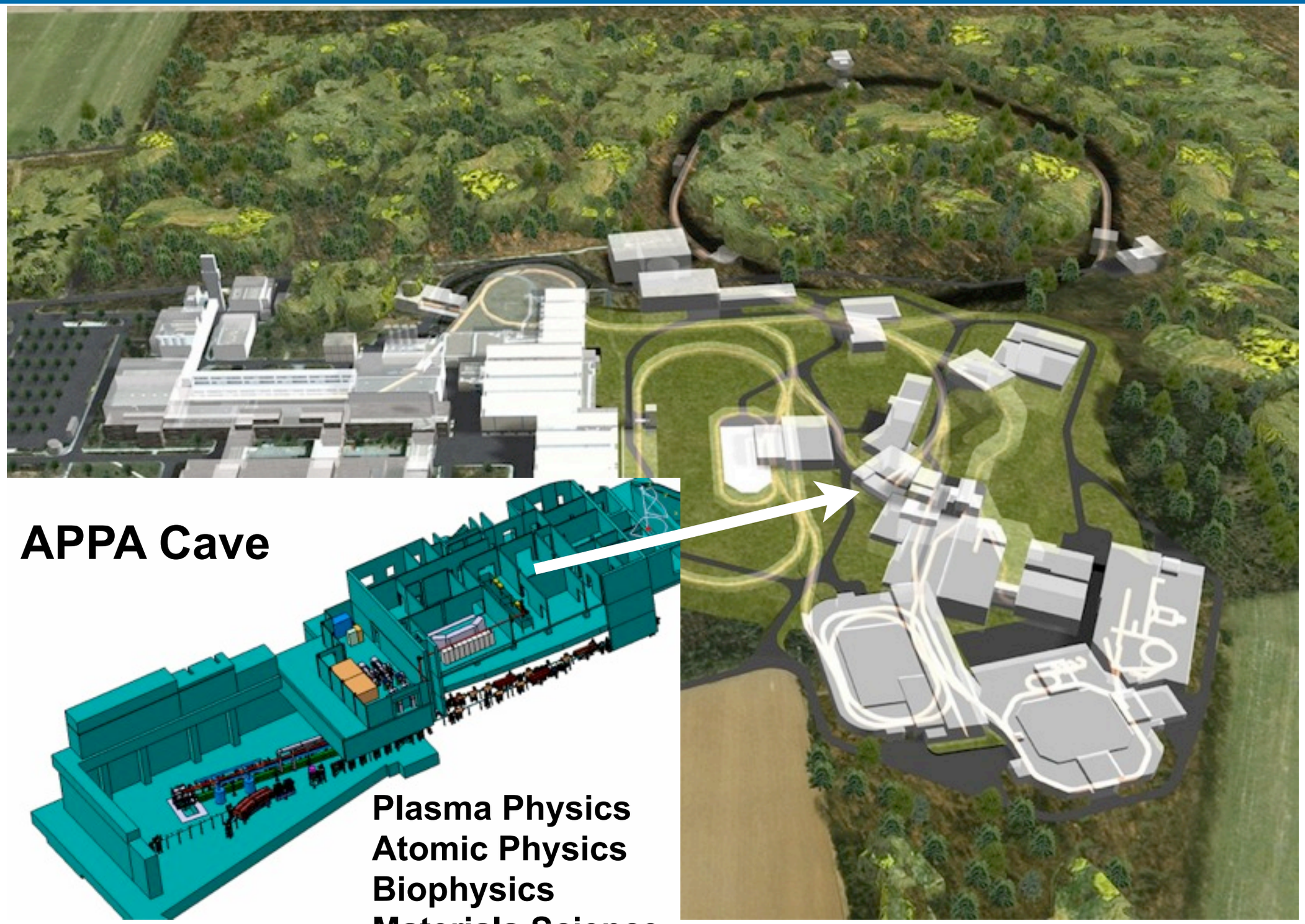
Experimental Equipment and Technical Design Reports

Current Status & Timeline

FAIR - Facility for Antiproton and Ion Research



Plasma physics experiments will take place in the APPA cave



Plasma physics experiments will use a dedicated beamline in the APPA cave

Proton beam

Energy: 10 GeV
Ions/bunch: $2.5*10^{13}$

HEDgeHOB/WDM beamline

SPARC/BioMat beamline

U^{28+} beam

Ion energy: 2 GeV/u
Ions/bunch: $5*10^{11}$

First-day experiments should make optimal use of available beam

Uranium beam parameters at FAIR and corresponding specific energy deposition in aluminum and lead

E (GeV/u)	Charge	2σ (mm)	N_{ion}/100 ns	E_s (kJ/g)		T (kK)
Stage I: SIS-18 as a bypass beam and SIS-18 upgrade (before SIS-100 is operational)						
0.2	28^+	1.3	$3\text{-}4\times10^{10}$	6.1 (Pb)	9.8 (Al)	2-6
0.4	39^+	1.2	$3\text{-}4\times10^{10}$	5.5 (Pb)	8.3 (Al)	
1.0	73^+	0.9	$0.5\text{-}1\times10^{10}$	1-2 (Pb)	1.5-3 (Al)	
Stage II: SIS-100 operational						
2.0	28+	0.8	$1\text{-}2\times10^{11}$	20-40 (Pb)	30-60 (Al)	12-40
8.4	92^+	1.2	3×10^{10}	3.4 (Pb)	5 (Al)	1-5

Heated target reaches temperatures ranging from 2-6 kK (melting) up to several electronvolts (WDM states)

Data by courtesy of O. Rosmej

HEDgeHOB - High Energy Density matter GEnerated with Heavy iOn Beams

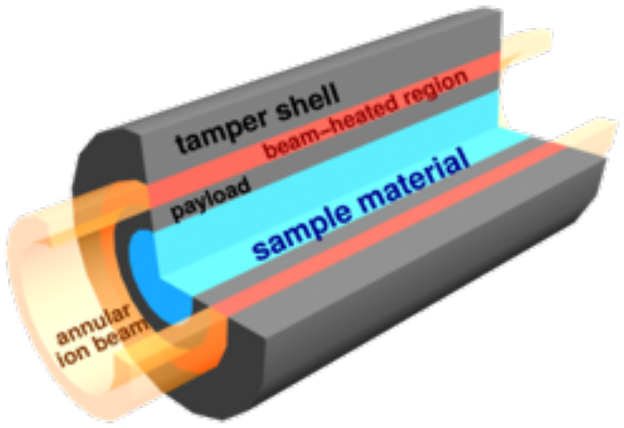
HIHEX

Heavy Ion Heating and Expansion

Uniform quasi-isochoric heating, isentropic expansion
EOS and transport properties
T = 1-10 eV; solid density

U^{28+}, 2 GeV/u, $5*10^{11}$/bunch

LAPLAS



Laboratory Planetary Sciences

Mbar, low temperatures
Metallic hydrogen,
interior of planets

U^{28+}, 1 GeV/u, $5*10^{11}$/bunch

PRIOR

Proton Microscope for FAIR

Diagnose high-density samples
(Shock physics,
biophysics (PaNTERA), etc.)

Protons, 5-10 GeV,
$2.5*10^{13}$/bunch

HEDgeHOB - High Energy Density matter GEnerated with Heavy iOn Beams

HIHEX

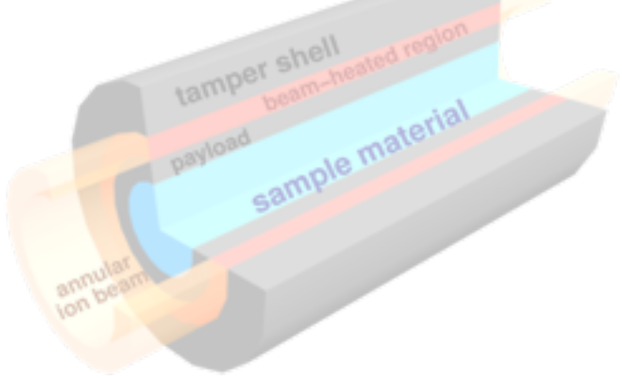
Heavy Ion Heating and Expansion

Uniform quasi-isochoric heating, isentropic expansion
EOS and transport properties
T = 1-10 eV; solid density

U^{28+}, 2 GeV/u, $5*10^{11}$/bunch

Science case is currently being updated !

LAPLAS



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Mbar, low temperatures
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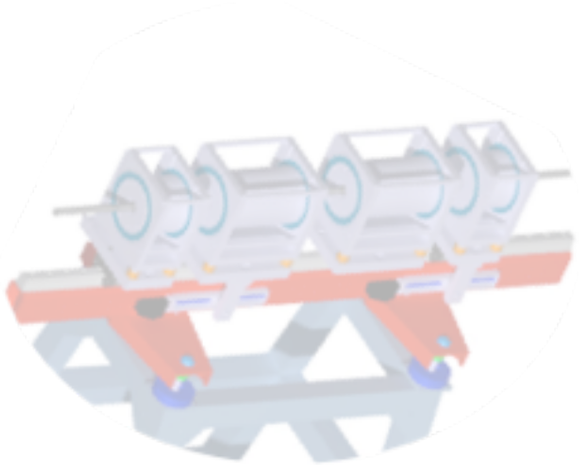
PRIOR

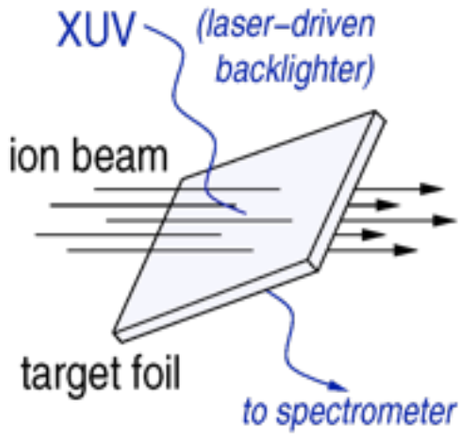


Proton Microscope for FAIR

Diagnose high-density samples
(Shock physics,
biophysics (PaNTERA), etc.)

Protons, 5-10 GeV,
$2.5*10^{13}$/bunch

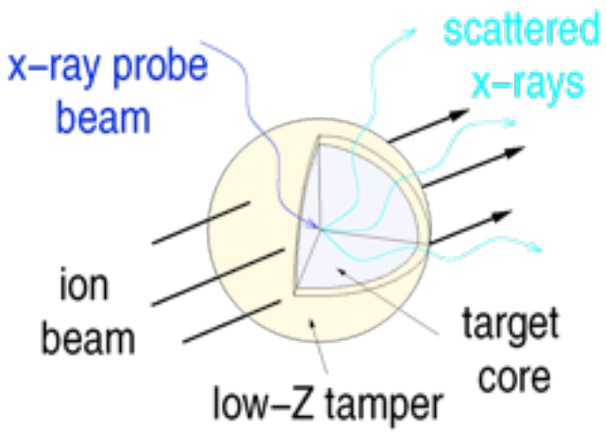
WDM - Warm Dense Matter



Opacity Measurements at Constant Temperatures

Isothermal expansion of thin targets

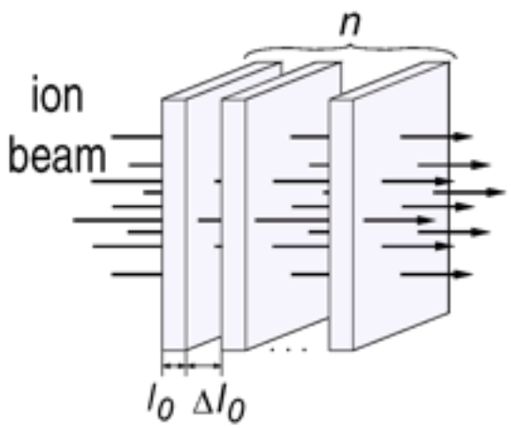
- **Opacities are very sensitive to electronic levels and population** (test of atomic physics in dense environments)
- **Benchmark for theoretical approaches** (existing models strongly diverging)



Optical Diagnostics at Constant Volume

Dynamic confinement of low-Z targets

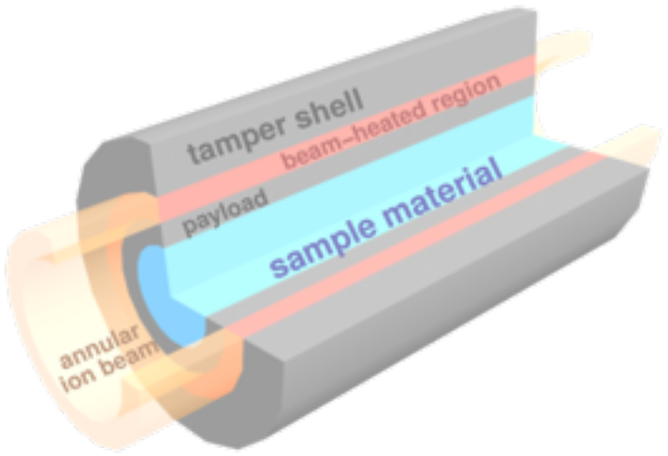
- **Investigation of WDM with emphasis on Optical properties** (atomic physics in dense environments)
- **Laser as key diagnostics tool** (XANES, X-ray scattering)



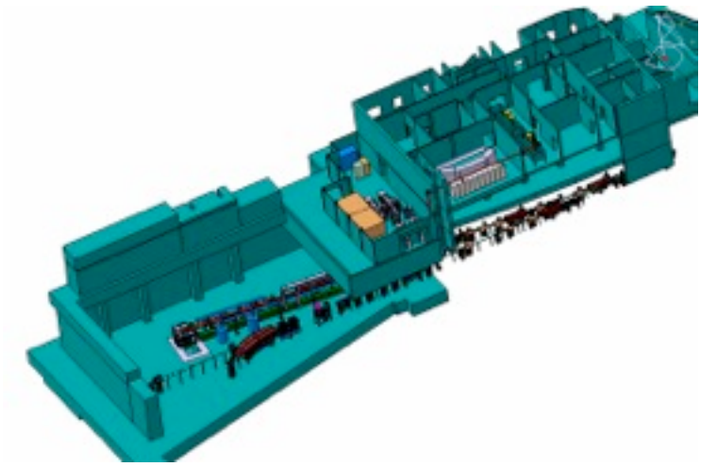
EOS Measurements at Constant Pressure

Quasi-static heating of stacked foils

- **Thermophysical properties along the two-phase boundary**
- **Quasistatic heating ensures homogeneous pressure, density and temperature**



Plasma Physics at FAIR



Experimental Equipment and Technical Design Reports

Current Status & Timeline

An approved Technical Design Report (TDR) is necessary to get funding

Technical design reports contain

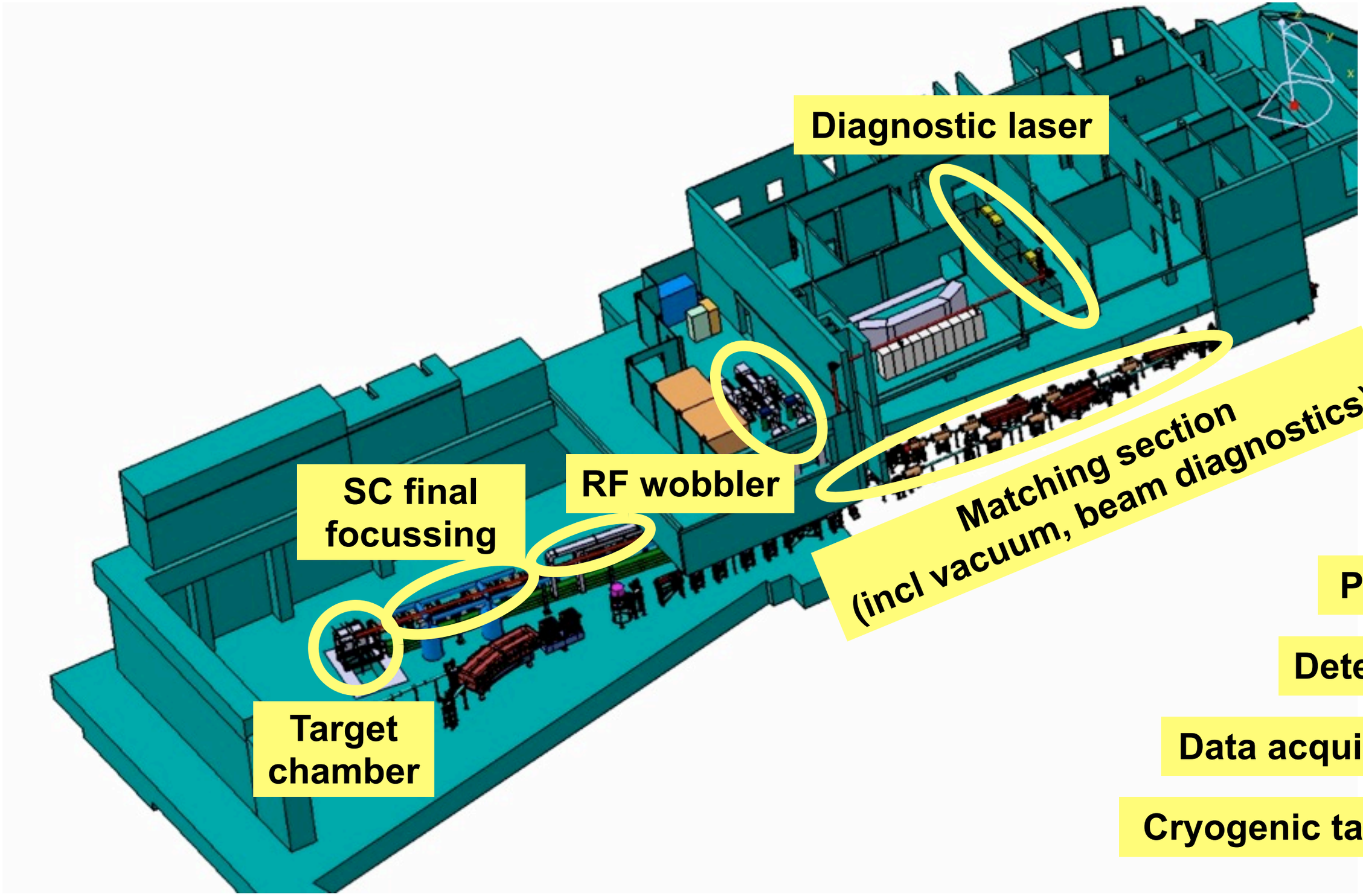
- **Detailed design of equipment**
- **Scientific motivation**
- **Estimated costs and required resources (manpower, etc.)**
- **Timeline**

A TDR has to be submitted to the Expert Committee Experiments (ECE) for technical evaluation

Once a TDR has been approved by the ECE, it has to be submitted to the FAIR council for final approval

An approved TDR is required to obtain funding through collaboration contracts (Russia), in-kind contracts or BMBF Verbundforschung.

Technical design reports are needed for all major parts of equipment



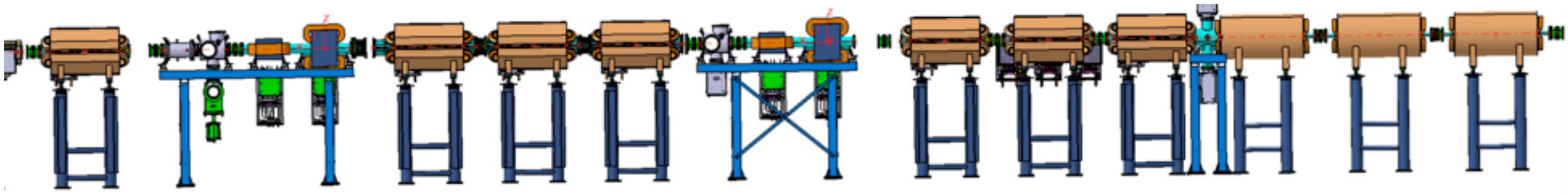
PRIOR

Detectors

Data acquisition

Cryogenic targets

The design of the ion beam matching section is currently being finalized



Work package

- **Normally conducting magnets**
- **Vacuum system**
- **Beam diagnostics**

Purpose

- **To match ion and proton beams from SIS-100 to wobbler and final focussing system**

Current status

- **Final ion-optical layout ongoing**
- **Design of vacuum system completed**
- **Ion beam diagnostics designed**

TDR to be submitted in Q3/2015
Planned funding: BMBF/Hesse

TDR for superconducting final focussing system has been approved by ECE

Work package

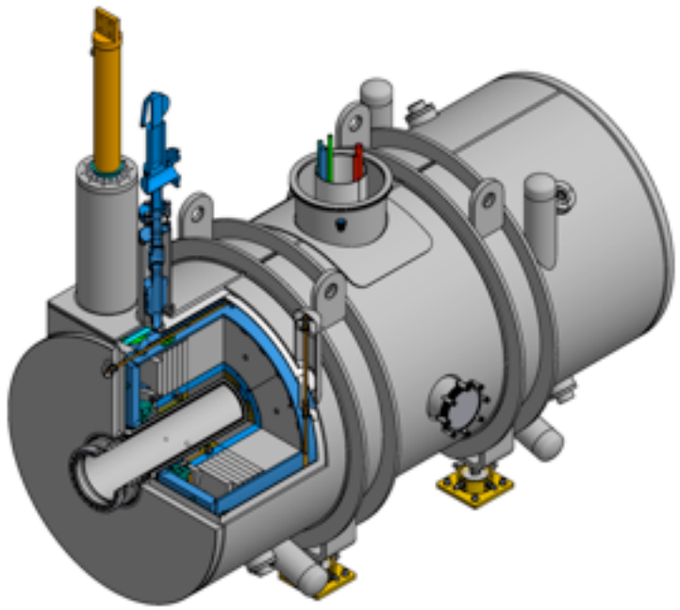
- **Four superconducting large aperture quadrupoles**

Purpose

- **Final focussing for experiments**
- **Ion optical system for PRIOR**
- **Needed for all experiments**

Current status

- **TDR approved by ECE**
- **Waiting for approval by FAIR council**
- **Final specifications for quadrupoles and HTS current leads in progress (will reuse existing (R3B) cryo plant)**



Collaboration contract with ROSATOM planned for Q1/2015
Funding for power supplies: BMBF/Hesse

TDR for RF beam rotator currently under review by ECE

Work package

- 2 RF deflectors (x and y)
- RF infrastructure (power supplies, klystrons, wave guides, etc.)

Purpose

- Use a fast rotating (352 MHz) pencil beam to create annular focal spot for LAPLAS

Current status

- Prototype built at ITEP, Moscow
- Tests on single cell performed successfully
- Necessary infrastructure included in building plans
- TDR submitted in November 2014

Wobbler prototype at ITEP

Currently under review by ECE
Planned funding for RF cavities: ROSATOM
Funding for RF infrastructure unclear

First tests of proton microscopy (PRIOR) have been carried out at GSI

Work package

- **Proton microscopy setup using either existing superconducting FFS or dedicated ion-optical system**
- **Second target chamber, specification of drivers for experiments**

Purpose

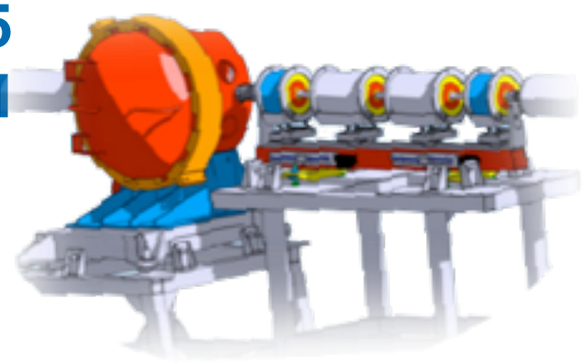
- **Large field-of-view setup (uses SC Quadrupole FFS): Dynamic compression (shocks, ramp pressure) or fast heating experiments**
- **High-resolution setup (dedicated ion optics): Applied studies and PaNTERA**

Current status

- **Prototype with permanent magnets tested at GSI**

TDR for PRIOR and target chamber planned for Q4/2015
Planned funding: ROSATOM

Large field-of-view (15 cm) setup for static and dynamic experiments



High-resolution (10 µm) setup with permanent quadrupoles or electromagnets

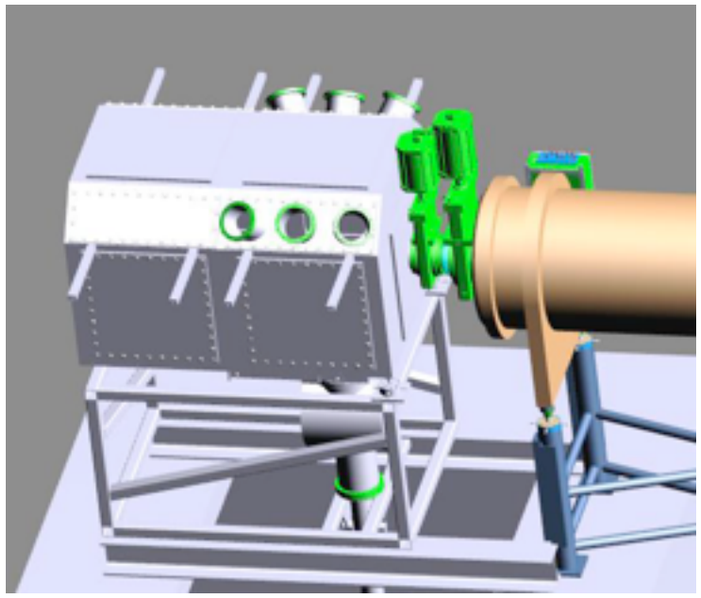
TDR for the target chamber is currently under review by the ECE

Work package

- **Target chamber for interaction experiments**
- **Target manipulators**
- **Target exchange mechanism**
- **Vacuum system**

Purpose

- **Needed for all experiments**
- **Modular system will provide possibility to use a wide range of diagnostics**
- **Will accommodate final laser optics**
- **Will offer the possibility to use cryogenic targets for LAPLAS**



Current status

- **Conceptual design has been finished**
- **TDR has been submitted to ECE (June 2014)**
- **Reviewers have requested further information**
- **Answer to reviewers currently in preparation**

Cryogenic system for LAPLAS targets will be handled in a separate TDR

Planned funding: ROSATOM or BMBF

The TDR for the diagnostic laser is currently under review by the ECE

Work package

- **Diagnostic laser and laser beamline**

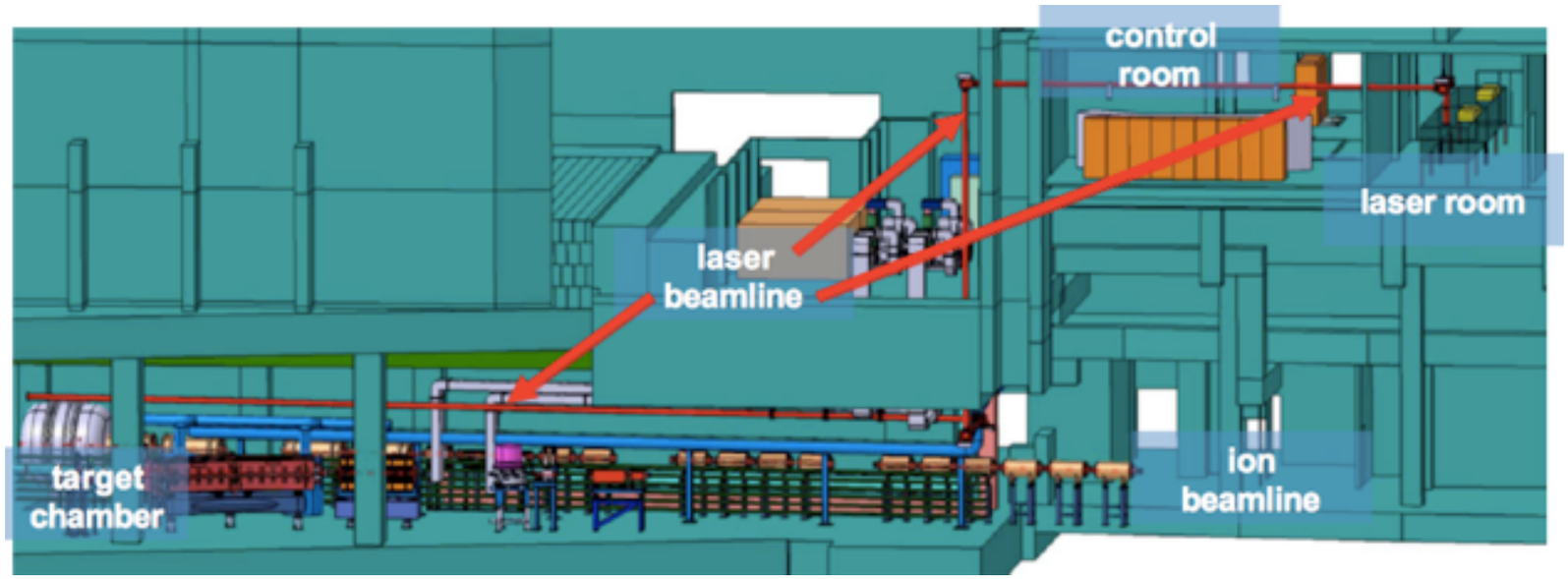
Purpose

- **Provide essential diagnostics for experiments**
- **Can be used as driver**
- **Testbed for technology in Helmholtz Beamlines Laser**

Current status

- **Conceptual design finished**
- **TDR under review by ECE (submitted May 2014)**
- **Procurement of test samples for critical components initiated**

Planned funding: BMBF



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

TDR for diagnostic instrumentation under review by ECE

Work package

- **Optical diagnostics, e.g. spectroscopy**
- **X-ray diagnostics, e.g. backlighter**
- **Particle diagnostics (p, n, e)**

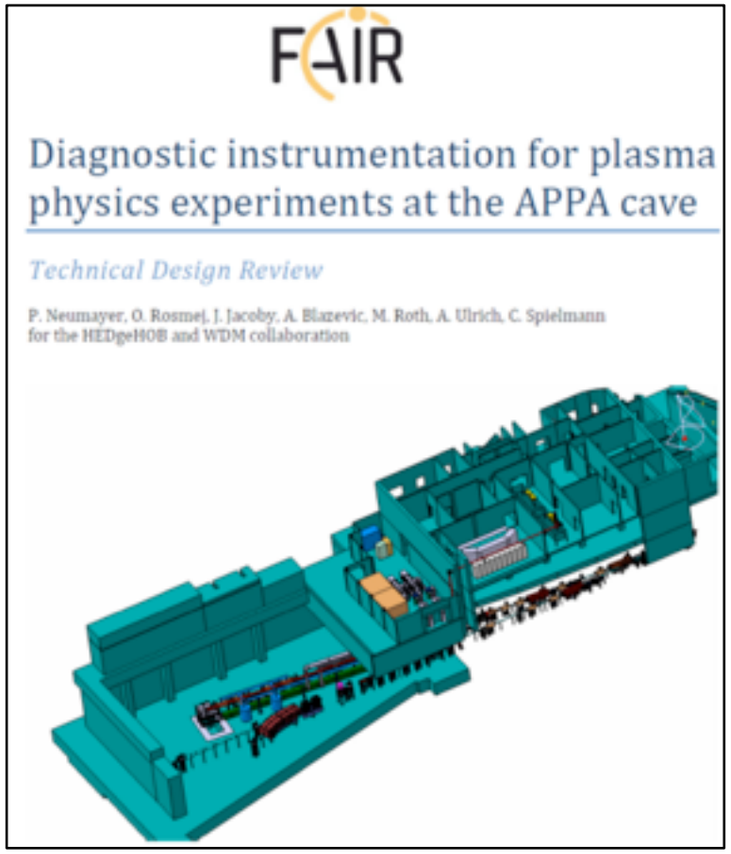
Purpose

- **Provide comprehensive and flexible diagnostics for all experiments**
- **Use of the laser system for diagnostics**

Current status

- **TDR submitted to ECE (June 2014)**
- **Currently under review**

Planned funding: BMBF



TDR for data acquisition is under review by ECE

Work package

- Control system for experimental area
- Data acquisition system
- Trigger system
- Control room equipment, networking hardware

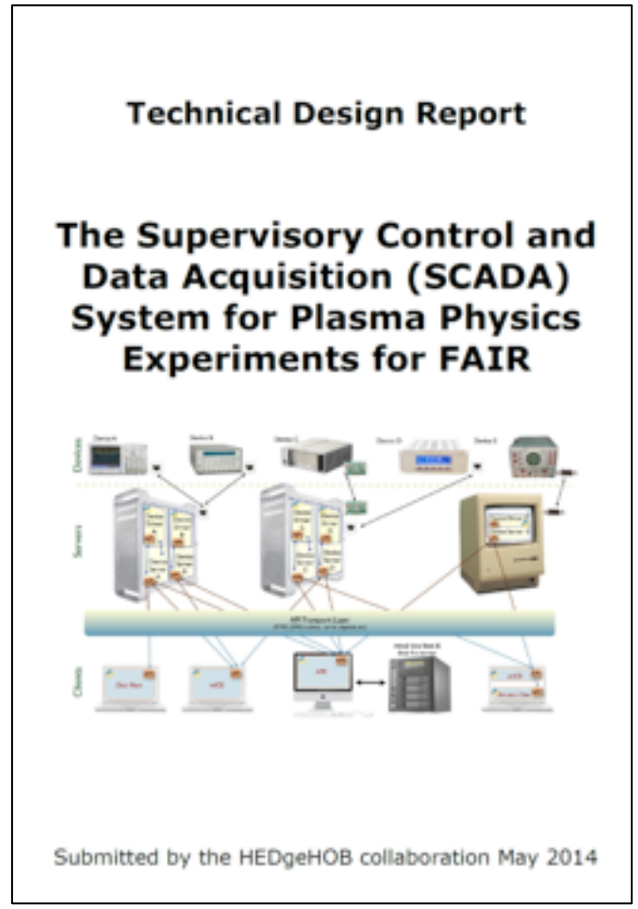
Purpose

- Provide control of experiments from the control room
- Enable synchronizing and triggering of diagnostics
- Provide data read out, processing and storage

Current status

- TDR has been submitted to ECE in June 2014
- Currently under review

Planned funding: BMBF


Technical Design Report

The Supervisory Control and Data Acquisition (SCADA) System for Plasma Physics Experiments for FAIR

Submitted by the HEDgeHOB collaboration May 2014

TDR for cryogenic target system will be submitted in 2016

Work package

- **Cryogenic target fabrication system**
- **Automated positioning of targets**

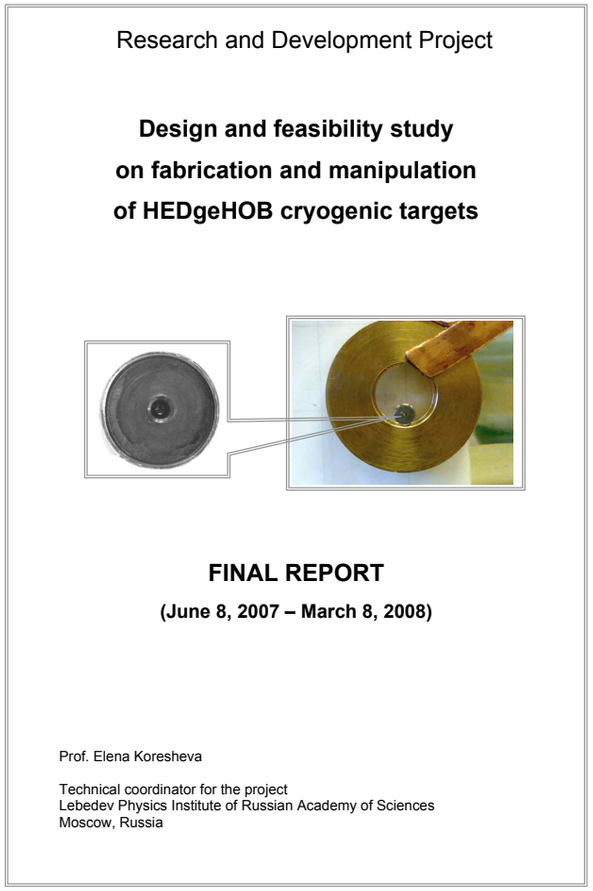
Purpose

- **Provide cryogenic targets for LAPLAS experiments**

Current status

- **Design and Feasibility Study has been completed in 2008**
- **TDR will be based on the final point design of the target chamber**
- **TDR will be submitted in 2016**

Planned funding: ROSATOM



Research and Development Project

Design and feasibility study
on fabrication and manipulation
of HEDgeHOB cryogenic targets

FINAL REPORT

(June 8, 2007 – March 8, 2008)

Prof. Elena Koresheva

Technical coordinator for the project
Lebedev Physics Institute of Russian Academy of Sciences
Moscow, Russia

TDRs for WDM instrumentation will be submitted in 2016

Work package

- **Instrumentation for XUV absorption (opacity measurements)**
- **XANES (X-ray absorption near edge structure)**
- **X-ray scattering**
- **Backlighter systems**

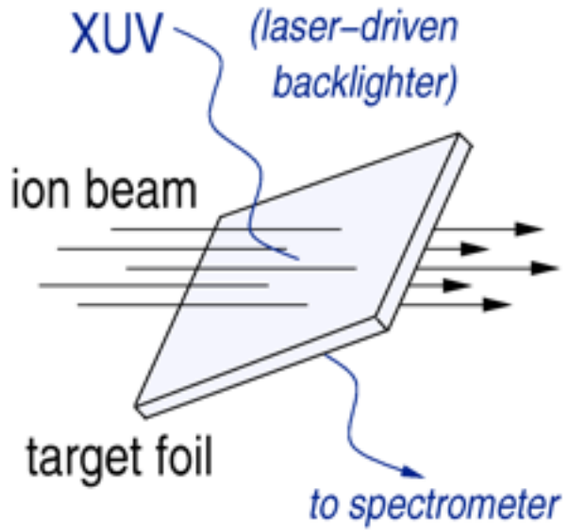
Purpose

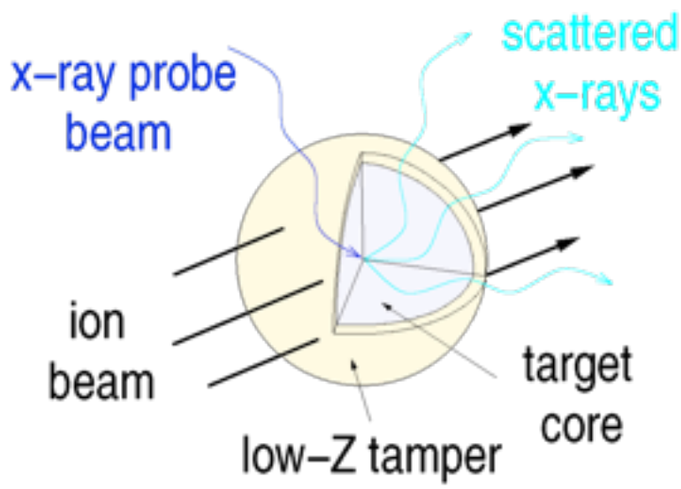
- **Provide additional diagnostics needed for WDM experiments**

Current status

- **Point design depends on laser parameters**
- **Point design and TDR will be finished by 2016**

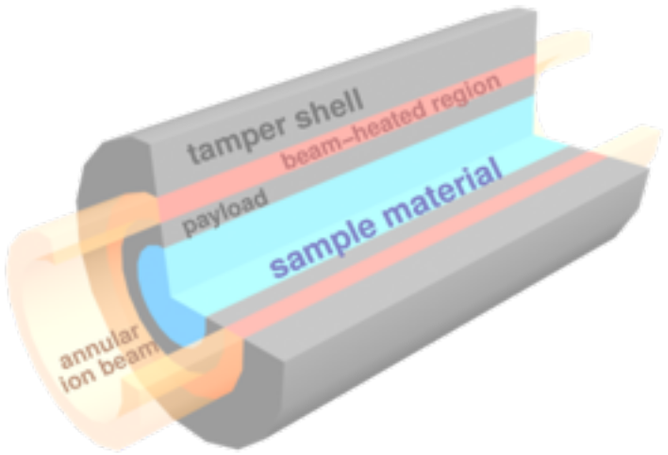
Planned funding: ANR, BMBF



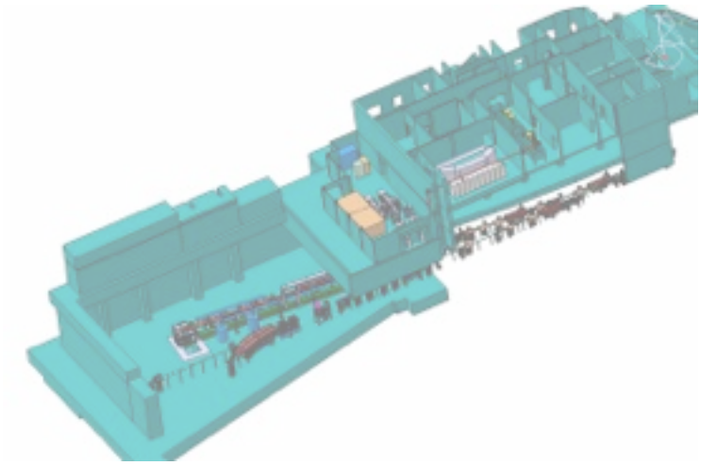


One TDR approved, 5 TDRs submitted to ECE, 5 TDRs left

Instrumentation	PSP code	Status TDR	Planned funding
HEDgeHOB			
Beam matching section	1.3.2.1.1	To be submitted in Q3/2015	BMBF/Hesse
SC final focussing system	1.3.2.1.2	Approved by ECE, pending approval by FAIR council	Magnets: ROSATOM Power suppl.: BMBF/Hesse
Wobbler	1.3.2.1.4	Submitted to ECE	Cavities: ROSATOM
PRIOR	1.3.2.1.5	To be submitted in Q4/2015	ROSATOM
Target station	1.3.2.2	Submitted to ECE	ROSATOM or BMBF
Detectors	1.3.2.3	Submitted to ECE	BMBF
Diagnostic laser	1.3.2.4	Submitted to ECE	BMBF
LAPLAS targets	1.3.2.5	To be submitted in 2016	ROSATOM/BMBF
Data acquisition	1.3.2.6	Submitted to ECE	BMBF
WDM			
X-ray scattering	1.3.3.2	To be submitted in 2016	ANR
Emission spectroscopy	1.3.3.3	To be submitted in 2016	BMBF



Plasma Physics at FAIR



Experimental Equipment and Technical Design Reports

Current Status & Timeline

Delays in civil construction have shifted the expected start of FAIR to 2021

Timeline Civil Construction

- **Preparatory work (clearing, stabilizing pillars) completed on time and on budget**
- **Many changes in planning necessary (fire safety & radiation safety regulations)**
- **Changes resulted in delay by ~ 1 year and significant cost increases**
- **Tendering expected in 2015, start of construction by the end of 2015**

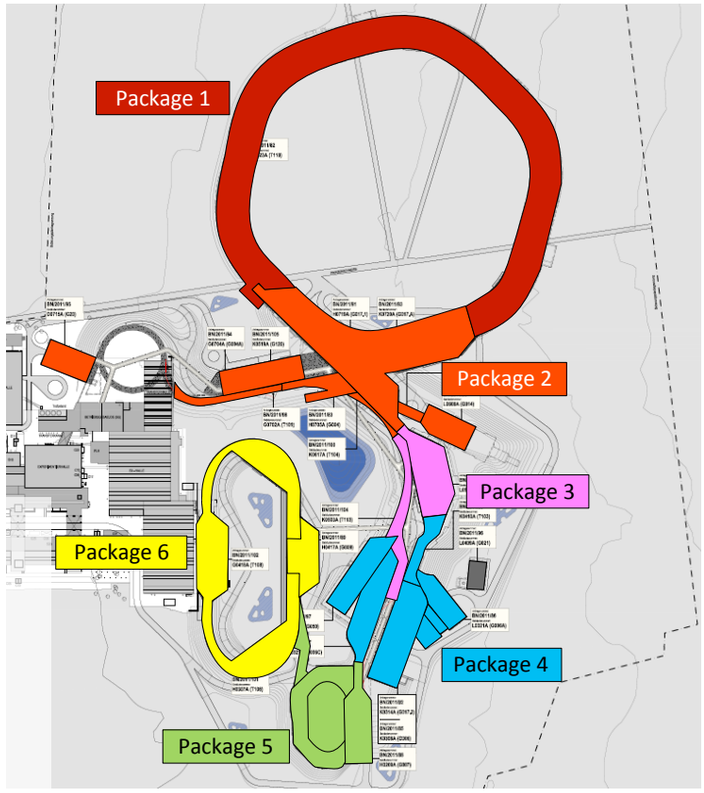
Timeline Accelerator

- **Accelerator currently on schedule**
- **Installation SIS-100 starting in 2018, finished end of 2020**

Timeline Plasma Physics Beamline (APPA cave)

- **Building ready for installation in 2019**
- **First beam expected beginning of 2021**

Currently only preliminary planning. Accelerator department is working on consolidated timeline.



Conclusions

Funding for experiments

- **Decision by BMBF on financing via Verbundforschung in the first half of 2015**
- **Proposal by Russia to increase funding for experiments**
  → no decision by FAIR council yet
- **If we do not get all requested funding from BMBF or ROSATOM:**
  Funding from other countries possible?

Cost increases for FAIR

- **Current cost increases (mostly civil construction) will be covered by shareholders**
- **Should there be additional cost increases, there is a risk of a further de-scoping of the Modularized Start Version**

TDRs

- **TDRs for all essential work packages will be submitted by the end of 2015**

“First-day experiments”

- **HEDgeHOB is currently working on updating the science case and the experiment proposals**

Once a reliable timetable is available, detailed planning on installation and commissioning of plasma physics experiments will start.