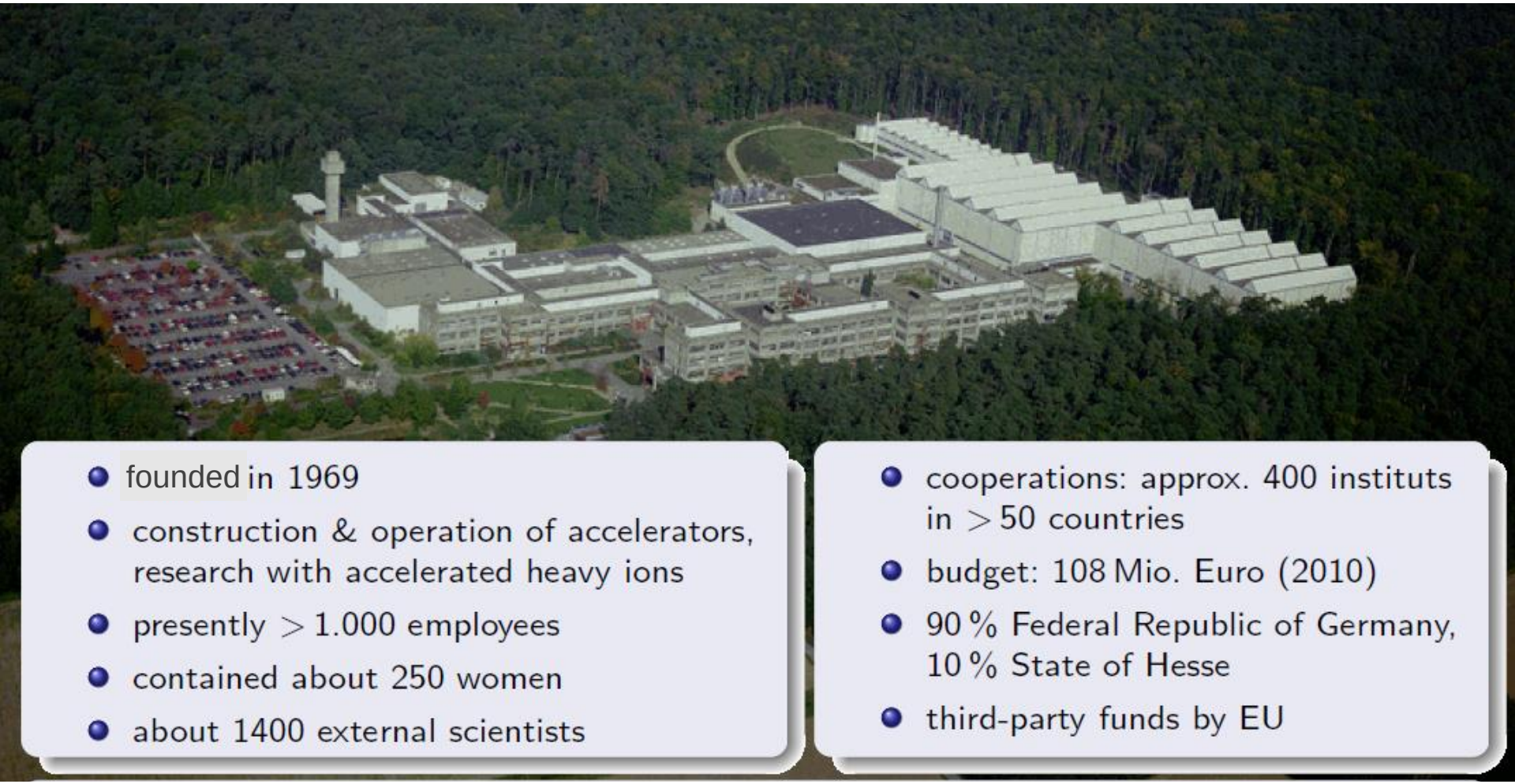
Primary Beams in FAIR
Status and Challenges

Peter Spiller

Space Charge Workshop
16.4.2013

GSI Helmholtzzentrum für Schwerionenforschung

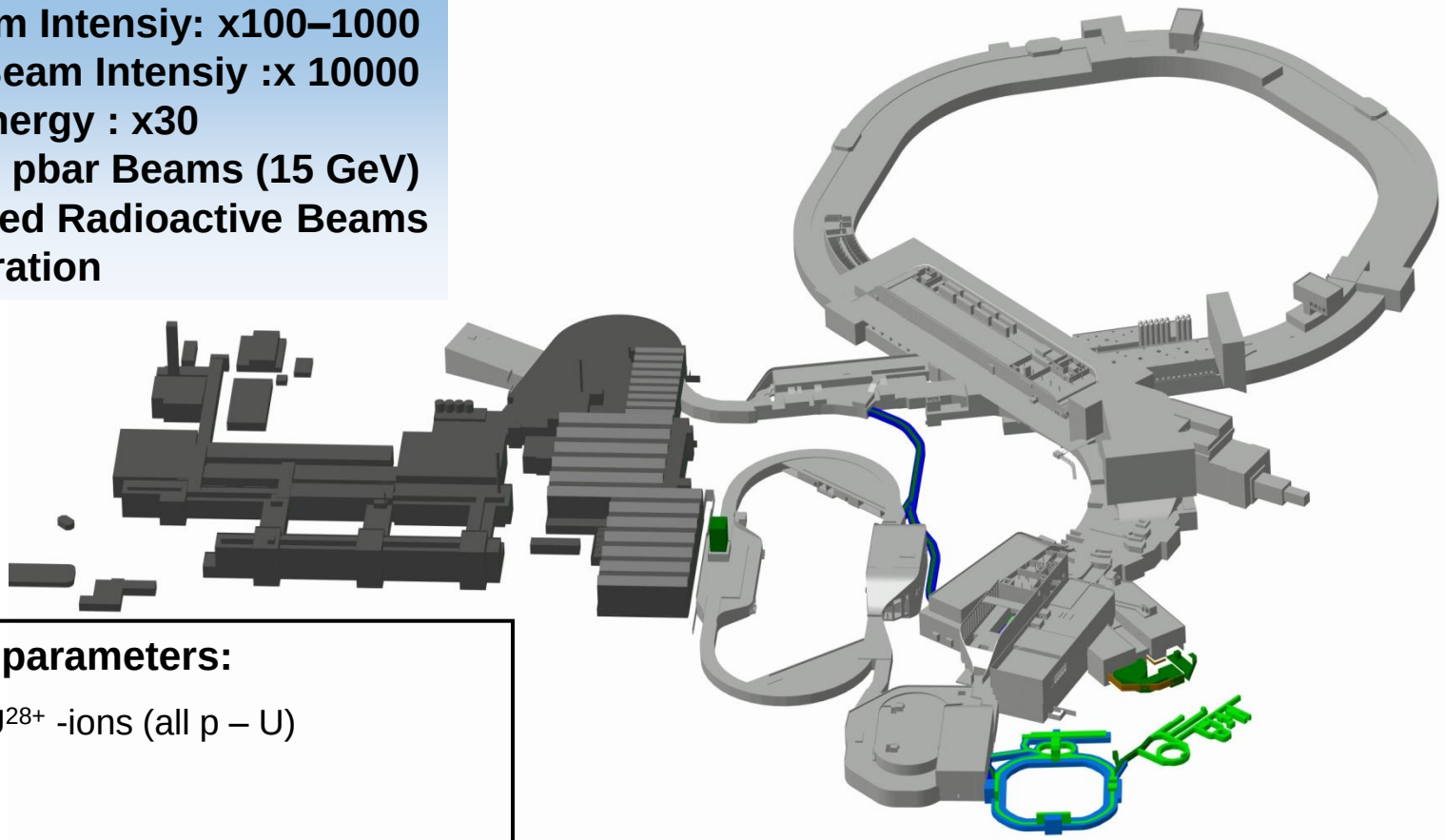


- founded in 1969
- construction & operation of accelerators, research with accelerated heavy ions
- presently $>$ 1.000 employees
- contained about 250 women
- about 1400 external scientists

- cooperations: approx. 400 instituts in $>$ 50 countries
- budget: 108 Mio. Euro (2010)
- 90 % Federal Republic of Germany, 10 % State of Hesse
- third-party funds by EU

FAIR – Beam Parameters

- **Primary Beam Intensiy: x100–1000**
- **Secondary Beam Intensiy :x 10000**
- **Heavy Ion Energy : x30**
- **New: Cooled pbar Beams (15 GeV)**
- **Intense Cooled Radioactive Beams**
- **Parallel Operation**



SIS100 beam parameters:

Reference ion: U^{28+} -ions (all p – U)

N: $5x10^{11}$ /cycle

Rep. rate: 0.5 Hz

Energy : 400 – 2715 MeV/u

Pulse length : 30 – 90 ns

The FAIR Start Version (Modules 0-3)

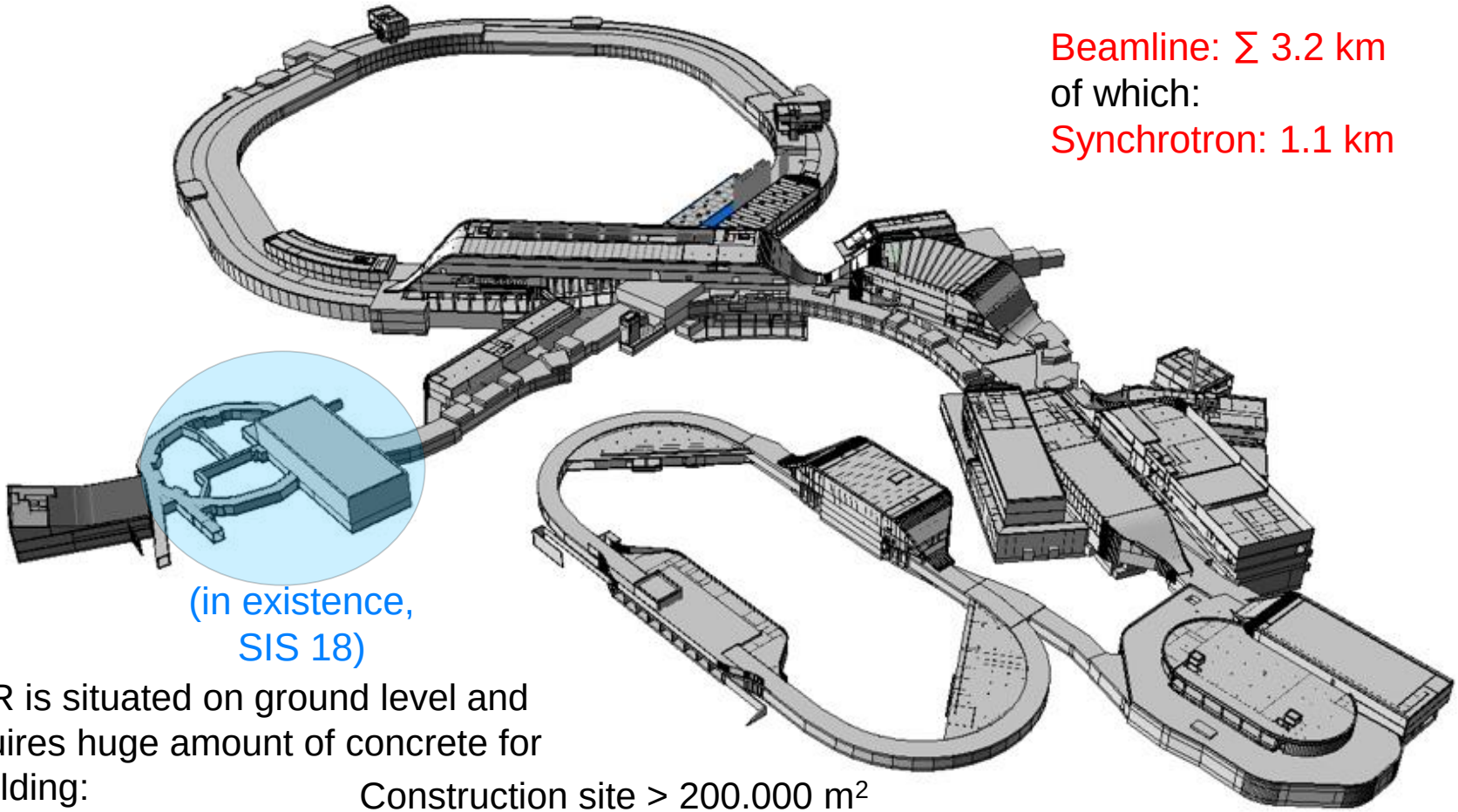
Modul 0
SIS100

Modul 1
CBM,
APPA

Modul 2
Super-FRS

Modul 3
Antiproton-
target, CR,
p-Linac,
HESR

FAIR Site and Buildings



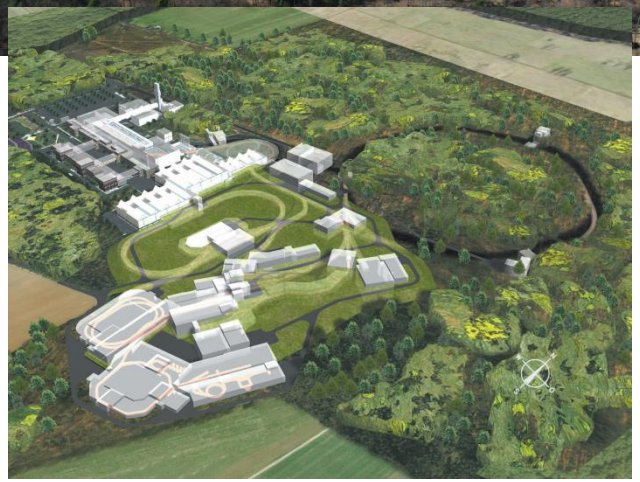
Beamline: ∑ 3.2 km
of which:
Synchrotron: 1.1 km

(in existence,
SIS 18)

FAIR is situated on ground level and requires huge amount of concrete for shielding:

Construction site > 200.000 m^2
Footprint ~ 98 ‘000 m^2
Floor Space ~ 135 ‘000 m^2
(Cubature ~ 1 ‘049 ‘000 m^3)

Preparation of FAIR Construction Side



Civil construction and procurement of major accelerator components and series has started

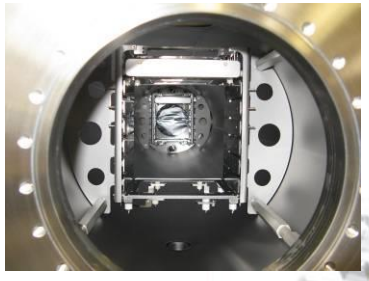
Frame Schedule

SIS100	All major contracts closed for building and infrastructure	All contracts closed for major component	All major component series Production started	Building and infrastructure ready for assembly (***)	All components ready for installation (incl. testing)	Assembly and alignment finished	Building and infrastructure ready for commissioning	Commissioning without beam finished
Dipole Moduls	-	Q1/2012	Q4/2013	-	Q1/2017	Q3/2017	Q1/2017	-
Quadrupole modules	-	Q2/2013	Q4/2014	-	Q2/2017	Q4/2017	Q1/2017	-
Rf system	-	Q1/2013	Q4/2014	-	Q2/2017	Q4/2017	Q4/2017	-
Magnet testing dipole moduls	Q2/2013	Q1/2013	Q4/2014	Q2/2014	Q1/2017	-	-	-
Magnet testing quad moduls	-	Q1/2013	Q4/2014	Q1/2012	Q2/2017 (5)	-	-	-
Stringtest	Q2/2013	Q2/2013	Q2/2013	Q2/2014	Q4/2014	Q1/2015	-	-

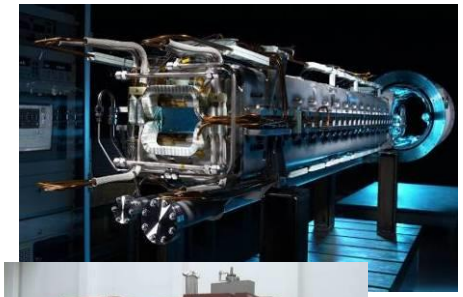
Frame schedule matched to a two years old civil construction planning.

FAIR Accelerator Challenges

Diagnostic and XHV at highest intensities



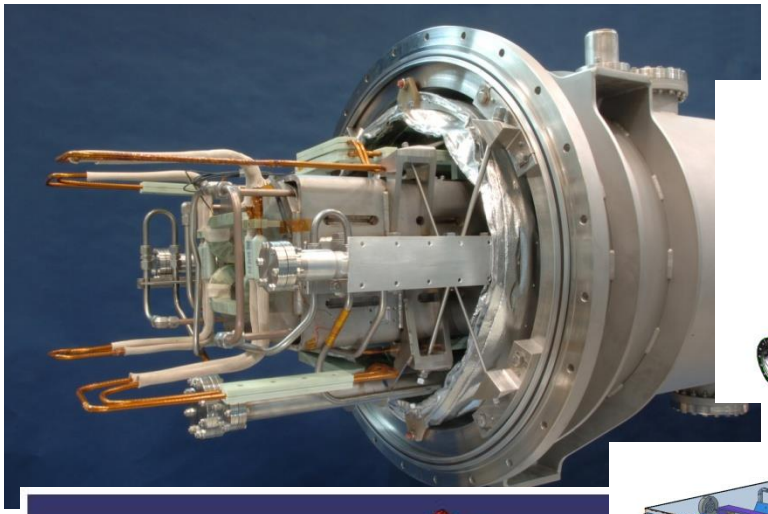
Superconducting magnets

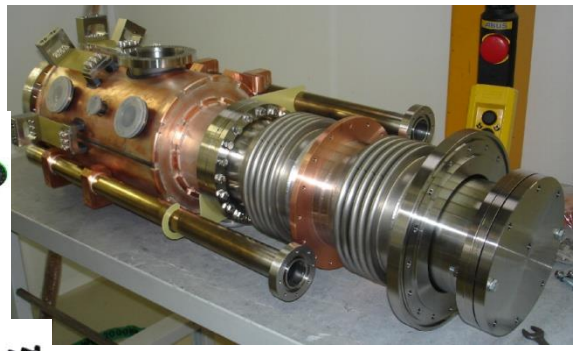


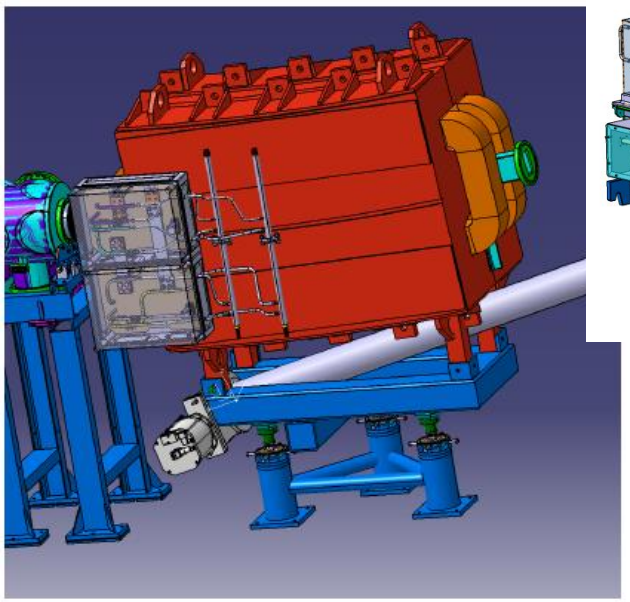
Rf-cavities

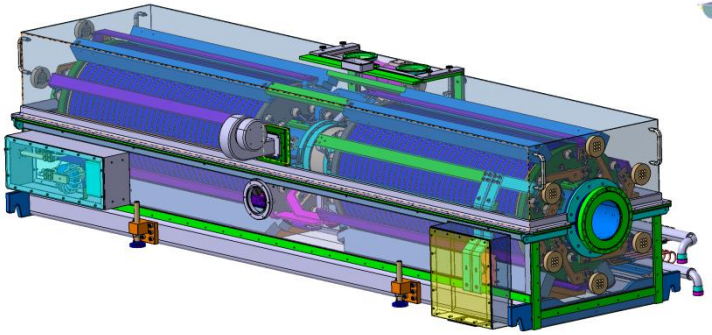
Beam cooling

Major Procurements for Accelerator Components Started









Status of Major Procurements - Examples

Status Procurements:
-SIS100 dipole modules: contract signed, FDR completed, preseries magnet in production
-SIS100 quadrupole modules preseries (including all components): Detailed design(at GSI) and specifications close to be completed
-SIS100 quadrupole module series: Tendering process of module design running
-Power converter upgrade for s.c. magnet test stand (20 kA): in production
-High current HTS current leads (for test stand and option for series): type 1 in production
-Sc. wire (all s.c. SIS100 magnets): ordered
-SIS100 dipole magnet chambers: contract signed – production running
-SIS18 h=2 acceleration cavity: Test of first module in January, installation in May 2013 - Remaining procurements in Q1 2013
-SIS18 main dipole power converter upgrade: Contract signed – production running
-SIS18 correction coils PC: production running
-Main specifications (long lead items)
-SIS100 acceleration system: spec completed (transfered to FAIR) – tendering in preparation
-SIS100 bunch compression systems: specs. completed – procurement in preparation
-HEBT nc magnets (incl. chambers and support) batch 1: specifications completed (transferred to FAIR) inkind contract in preparation – UHV system components signed
-HEBT nc magnets batch 2 and 3: specification almost completed
-SIS100 dipole series test stands cryogenics plant and local cryogenics: production started
-CR Bunch compression cavities

Next main goal: Completion of design and specifications for the preseries SIS100 quadrupole module, including all components until end of March
Completion of Specifications for local cryogenics components

Project Funding

- The project funding application (PMA) for the German inkind contributions to the accelerator facilities and the civil construction of the FAIR buildings as been approved and excepted.

- Important international contributions to the subproject accelerators and experiments:

Russia joins FAIR with the biggest shares.

Large fraction of the accelerator components are asigned to international partners.

Several countries wait for specifications for starting the production (e.g. Slowenia, India, Poland etc.)

Inkind contracts with international partners signed or in preparation.

GSI Technical Supervisor for FAIR Accelerator

In-kind contract on the Technical Supervision on accelerator components between FAIR and GSI has been signed, i.e.: 1450 FTE will be provided by GSI to the project for technical follow-up of accelerator components approved by Council. (equ. of 110 M€ for GSI within Ger funding for FAIR)

- Manpower (FTEs will be deduced from the time schedule):
  - Project coordination (recruitment in progress)
  - Additional personnel for technical departments and groups
  - Collaboration with large scale facilities:
    Helmholtz centers (KIT, FZJ), CERN, IMP Lanzhou, DOE labs
  - "Buying" support from industrial partners

Industrialization of Accelerator Projects

Experiences with large scale public projects (e.g. airport Berlin, train station Stuttgart), with tramedous cost increase and delays request implementation of „industrial standards“ in management of public projects. The FAIR project is closely followed by the funding agencies.

Each project member shall acknowledge its responsibility for the society and for all future large scale accelerator projects.

GSI consultants:

- *Brunini automotiv* support for project leader and management – mutual support and interaction of divisions etc.

- *IMPECH* support for follow up of procurement and specification status – direct reporting to BMBF

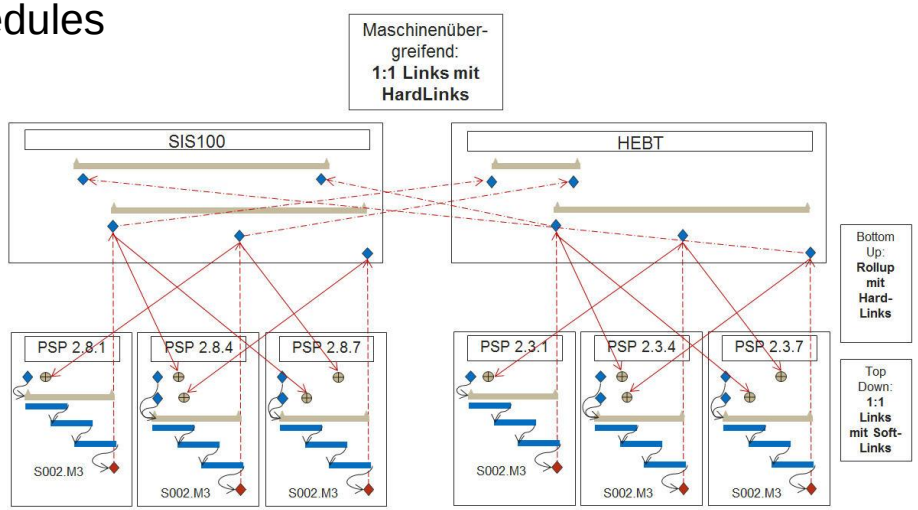
- *Dornier Fichtner* Quarter Year Reports

- *BTO* Analysis of organisation units and use of staff at GSI

- *MAC* Machine advisory committee (organized by FAIR)

Integrated Project Tools

- Definition of a frame schedule for the subprojects and the major (long lead) procurements.
- Set-up of MS project based, detailed time schedules for each subproject and each work package.
- Linking and interaction of project plans within one subproject and across the subprojects.



- Goal: Meeting the official milestones „building readiness“ for all components needed for comissioning with beam. For SIS100 and HEBT primary beam lines: 4. 2016.
- Planning and estimate of (human resources) and the cross support of the project devisions
- Identification of (time) critical components (long lead items) and setting of priorities.
- Integration of budget profiles and payment milestones.
- Final goal:

  Tool for the follow-up of the subprojects, the budget flow and the resources.

Link Existing (Accelerator) Facility

- Upgrade and preparation of the injector chain for the FAIR booster operation

(High current sources, UNILAC and SIS18)

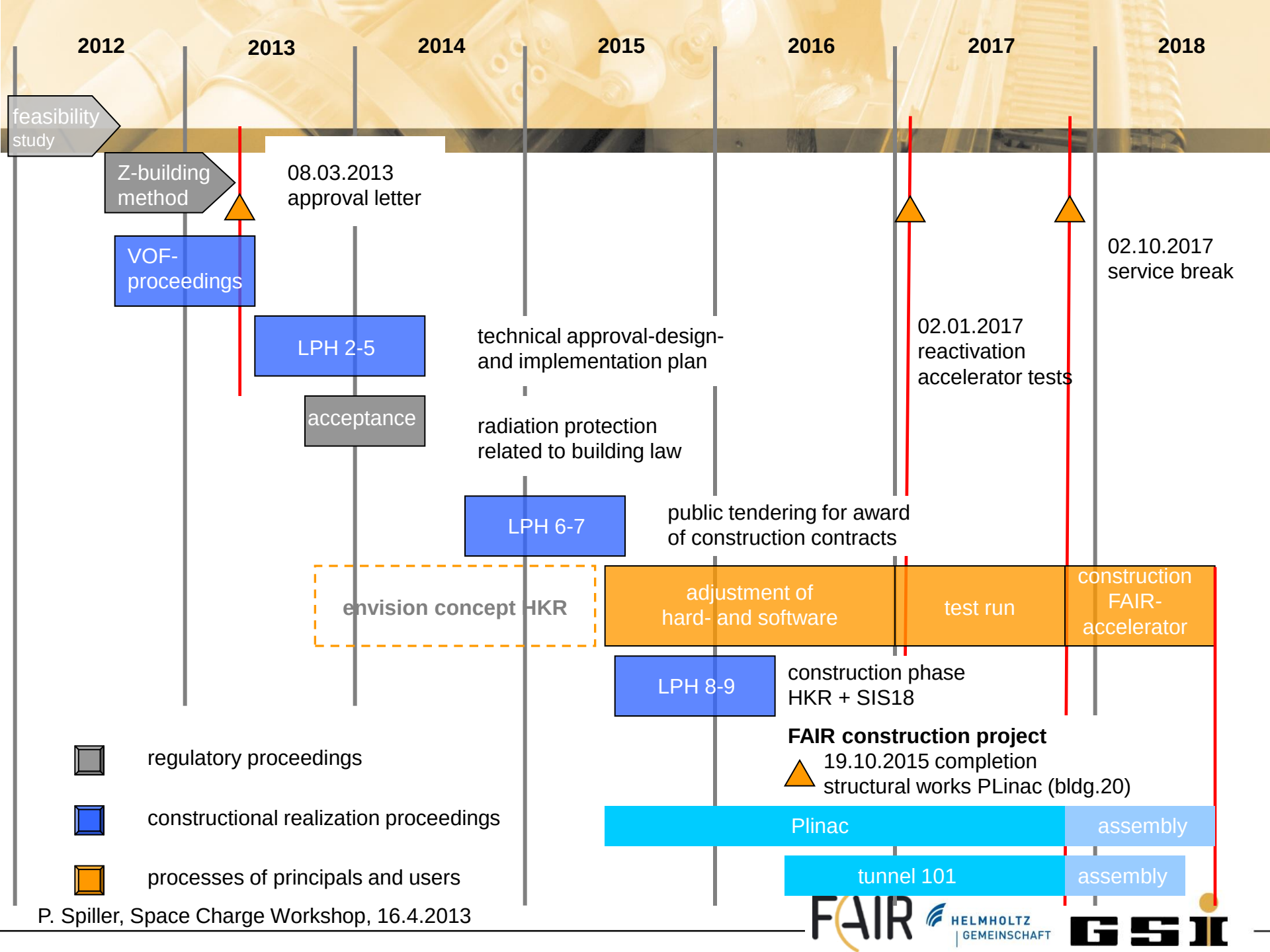
Civil Construction Measures:

- Modifications in the transfer channel for linking the proton linac.
- Modifications in the HEBT system for linking the FAIR HEBT system.
- Upgrade of the shielding of SIS18 and other radio protection issues
- Set-up of a new main control room (probably in a FAIR building)

Tenporary shut down of the GSI accelerators and interruption of machine operation in 2014. Machine experiments and device developments need to be continued at partner labs (CERN, BNL, Lanzhou etc.)

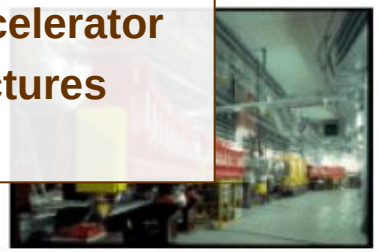
Link Existing (Accelerator) Facility

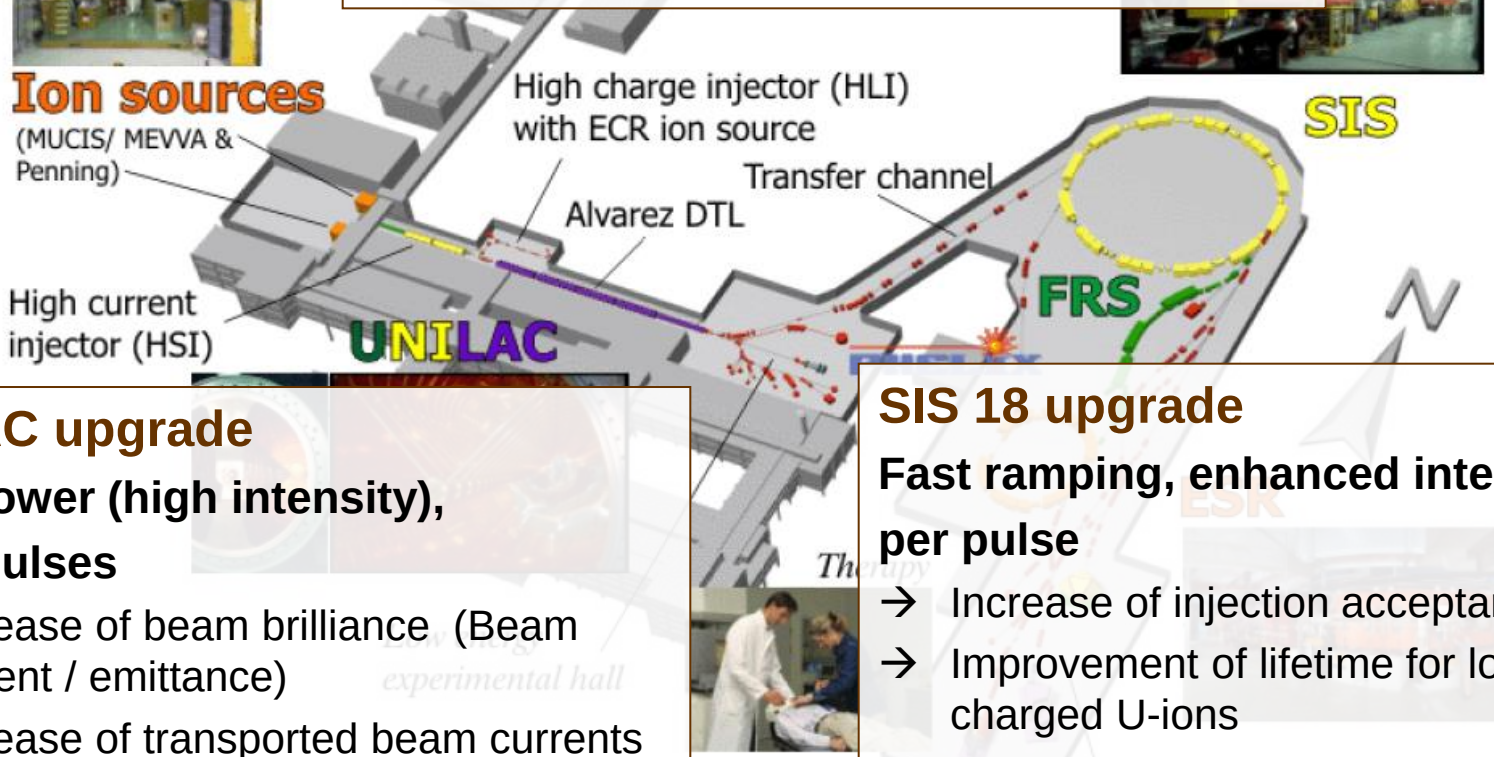
- Upgrade and preparation of the injector chain
  (high current sources,UNILAC and SIS18)
  Considerations for ALVAREZ replacement.
- Modifications in the transfer channel for linking the proton linac.
- Modifications in the HEBT system for linking the FAIR HEBT system.
- Upgrade of the shielding of SIS18 and other radio protection issues
- Construction of a new main control room


2012
2013
2014
2015
2016
2017
2018
feasibility study
Z-building method
08.03.2013
approval letter
VOF-proceedings
LPH 2-5
acceptance
technical approval-design- and implementation plan
radiation protection related to building law
02.01.2017
reactivation
accelerator tests
02.10.2017
service break
LPH 6-7
public tendering for award of construction contracts
envision concept HKR
adjustment of hard- and software
test run
construction FAIR-accelerator
LPH 8-9
construction phase HKR + SIS18
FAIR construction project
19.10.2015 completion
structural works PLinac (bldg.20)
Plinac
assembly
tunnel 101
assembly
regulatory proceedings
constructional realization proceedings
processes of principals and users

Preparing the Injector Chain – UNILAC upgrade

Exchange of 35 years old Alverez accelerator
With modern interdigital H-type structures
Higher intensities → 28 GHz ECRIS





UNILAC upgrade

High power (high intensity), short pulses

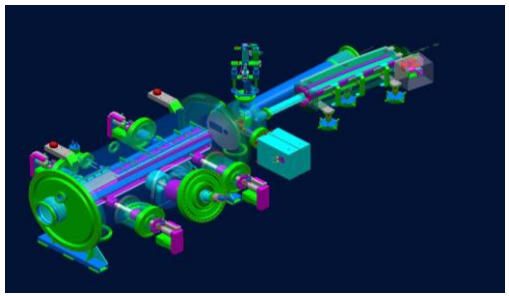
- → Increase of beam brilliance (Beam current / emittance)
- → Increase of transported beam currents
- → Improvements of high current beam diagnostics / operation

SIS 18 upgrade

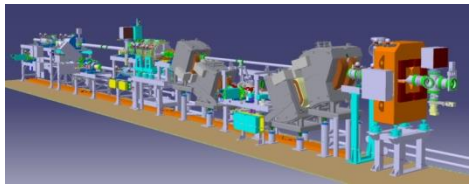
Fast ramping, enhanced intensity per pulse

- → Increase of injection acceptance
- → Improvement of lifetime for low-charged U-ions
- → Increase of beam-intensity per time due to reduction of SIS18- cycle time

Preparing the Injector Chain - SIS18 Upgrade

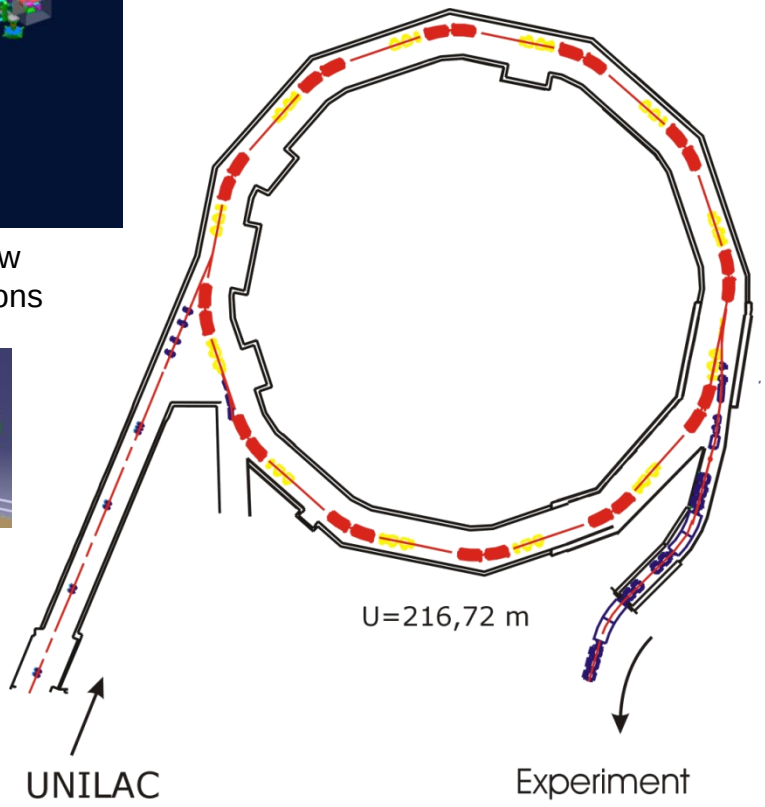


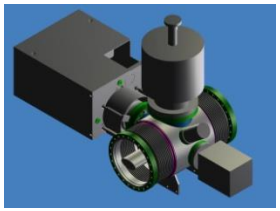
Injection system for low charged state heavy ions



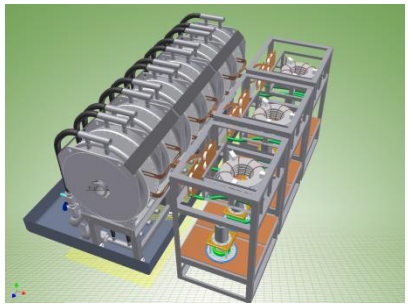
Charge separator for higher intensity and high quality beams

Power grid connection





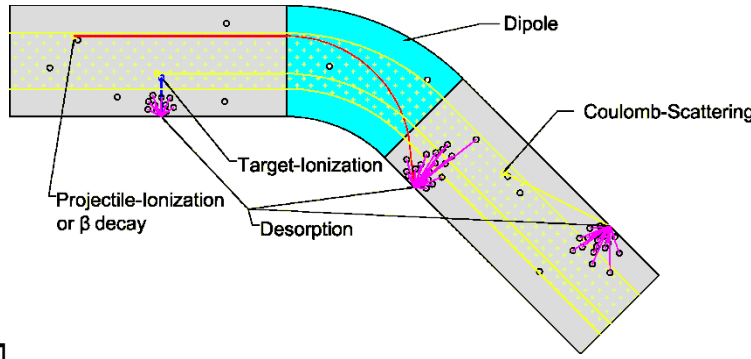
Scrapers and NEG coating for pressure stabilization

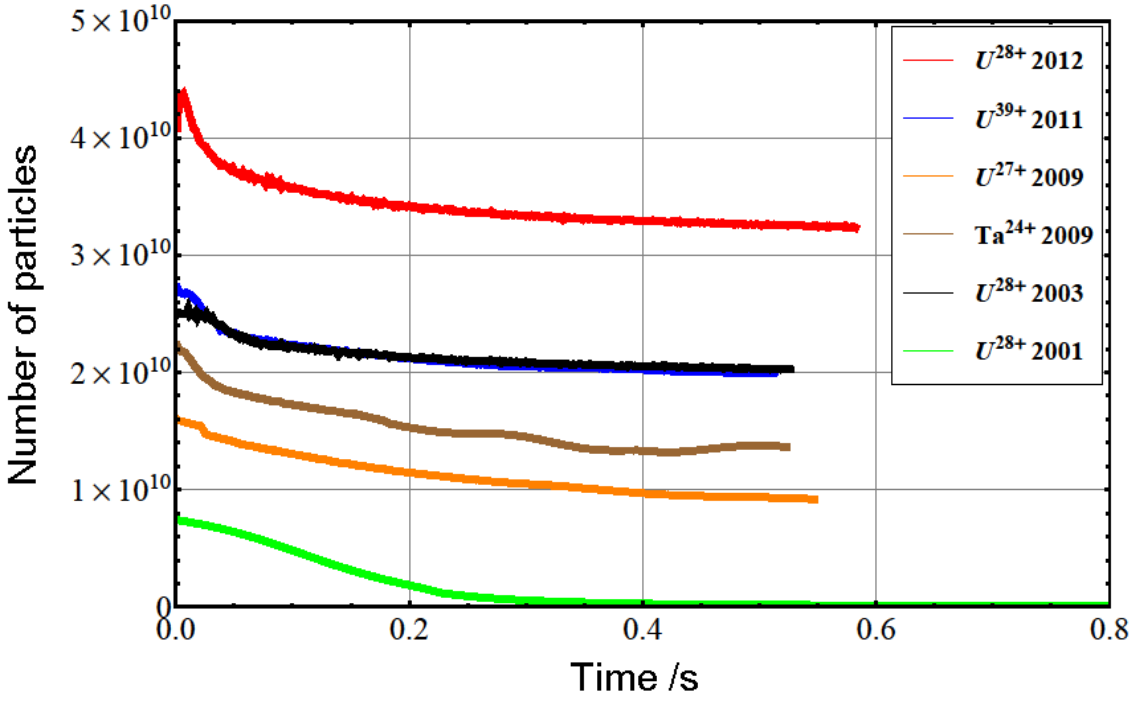


h=2 acceleration cavity for faster ramping

The SIS18upgrade program: Booster operation with intermediate charge state heavy ions

Intensity Record for Intermediate Charge State Heavy Ions





Ionization Beam Loss, Gas Desorption, Dynamic Vacuum

S.C. Magnet Testing

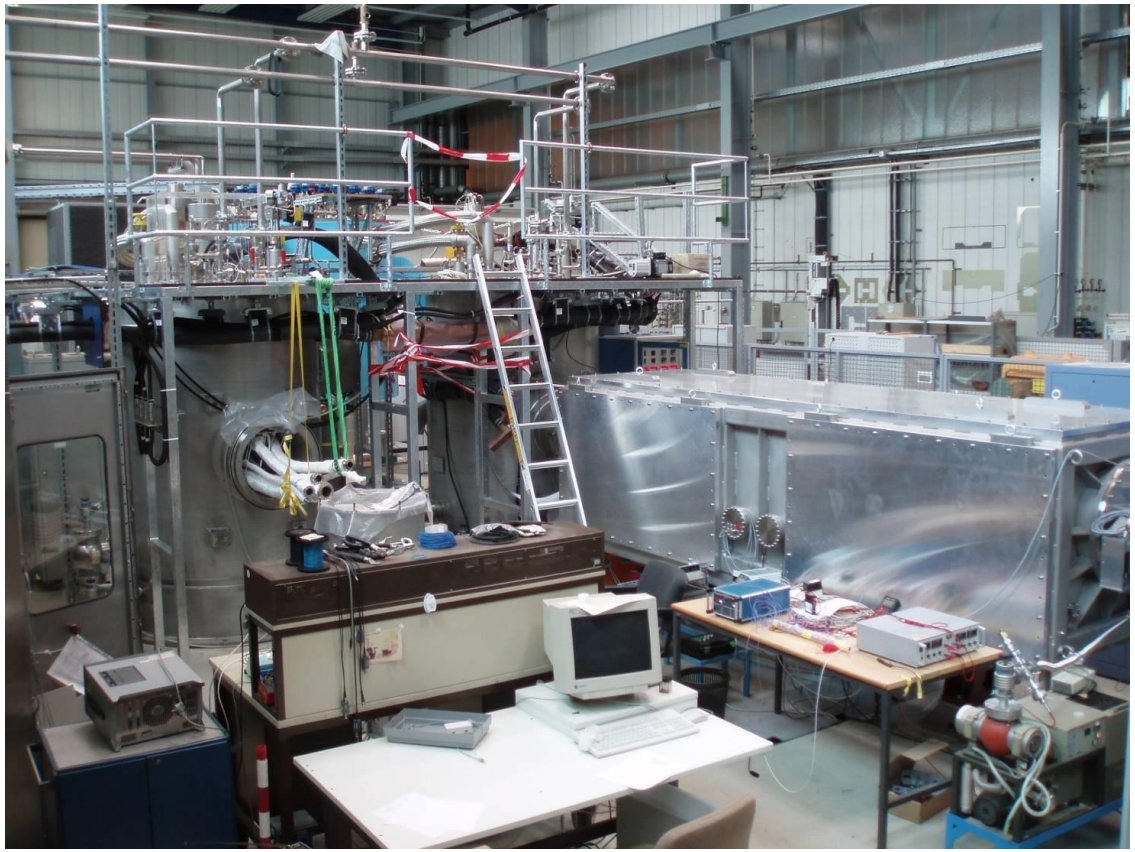
- SIS100 dipole units will be tested at GSI
- SIS100 quadrupole units potentially tested at JINR
- Super-FRS magnets potentially tested at CERN

Since the testing is strongly linked to the magnet production – all missing decisions must be taken soon.

For the SIS100 dipole testing and the SIS100 string test, an existing large building plus annex buildings are prepared. SIS300 magnet testing has been considered as later option.

Major procurements are launched (e.g. cryogenic plant and feed boxes)

Upgrade GSI Magnet Teststand



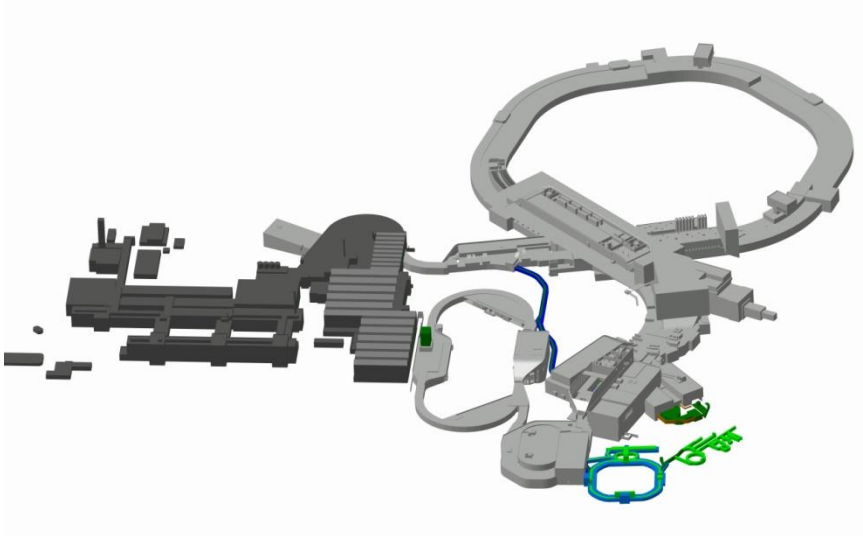
20 kA upgrade of the test facility at GSI in preparation

- Power converter upgrade contracted
- New HTS current leads contracted

Interaction with Civil Engineering

- Room specific data (temperature tolerance, humidity..)
- Cable data for cable routing and cable trays
- Component data (in the supply areas)
- Planning of suppy areas in detail
- Full integration of infrastructure and collision checks

- Input for radioprotection/shielding design

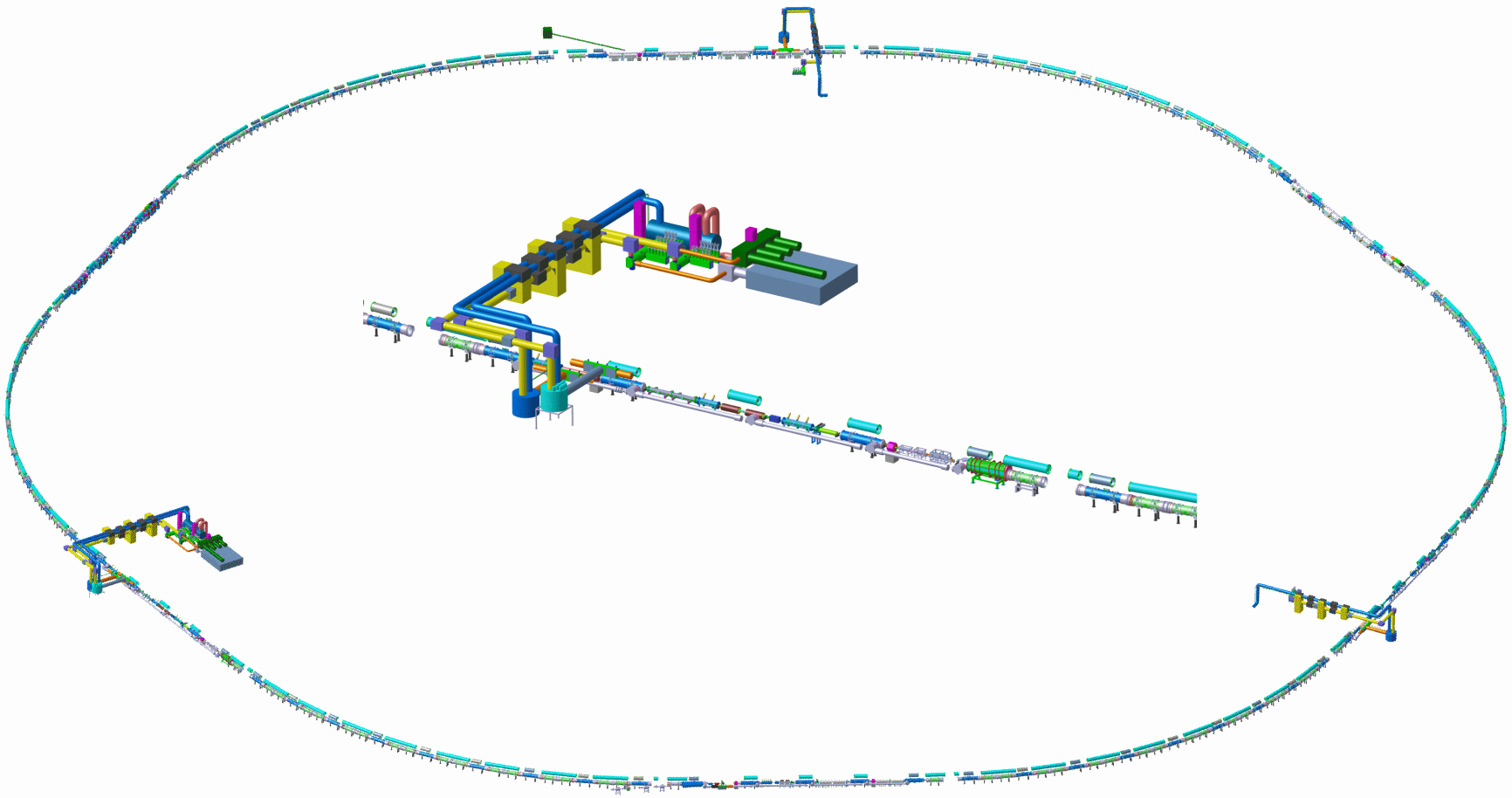


Next civil construction milestones in 2013:

- Construction of building pillars

- Preparation of construction side

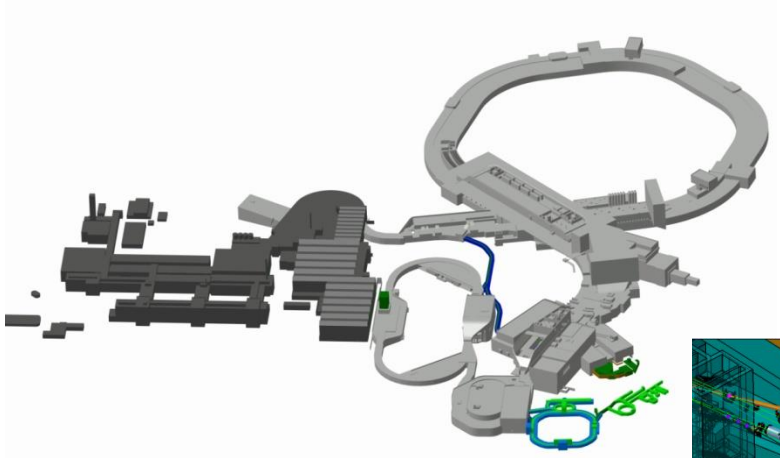
System Design - DMU/Integration



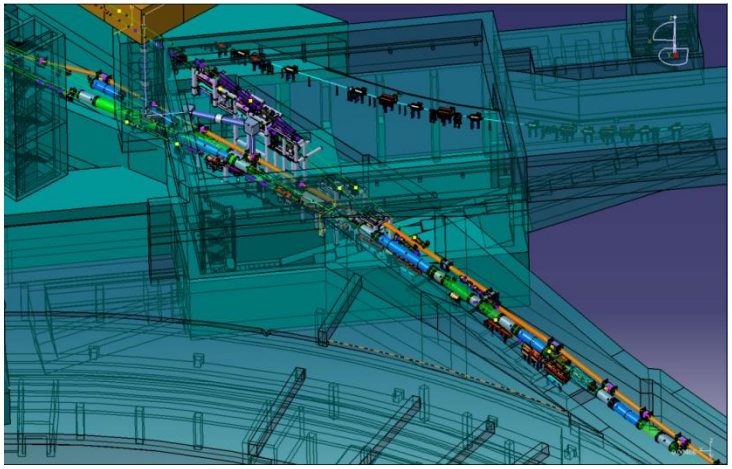
SIS100

‚Come together' of Building and Accelerator

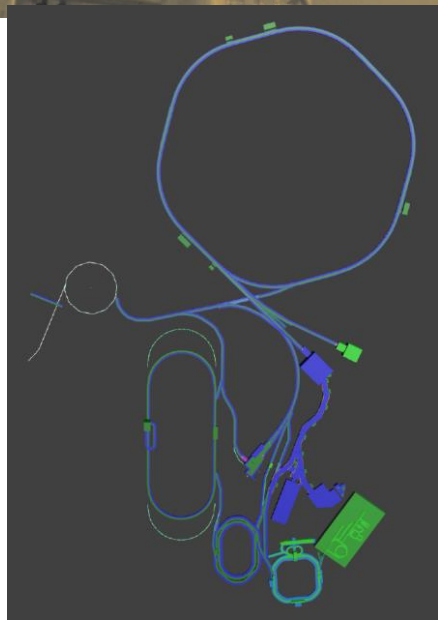
Integration of 3D CATIA envelope models and DMU machine models into civil construction design. Collision checks with „concrete" and accelerator infrastructure.



Civil construction design



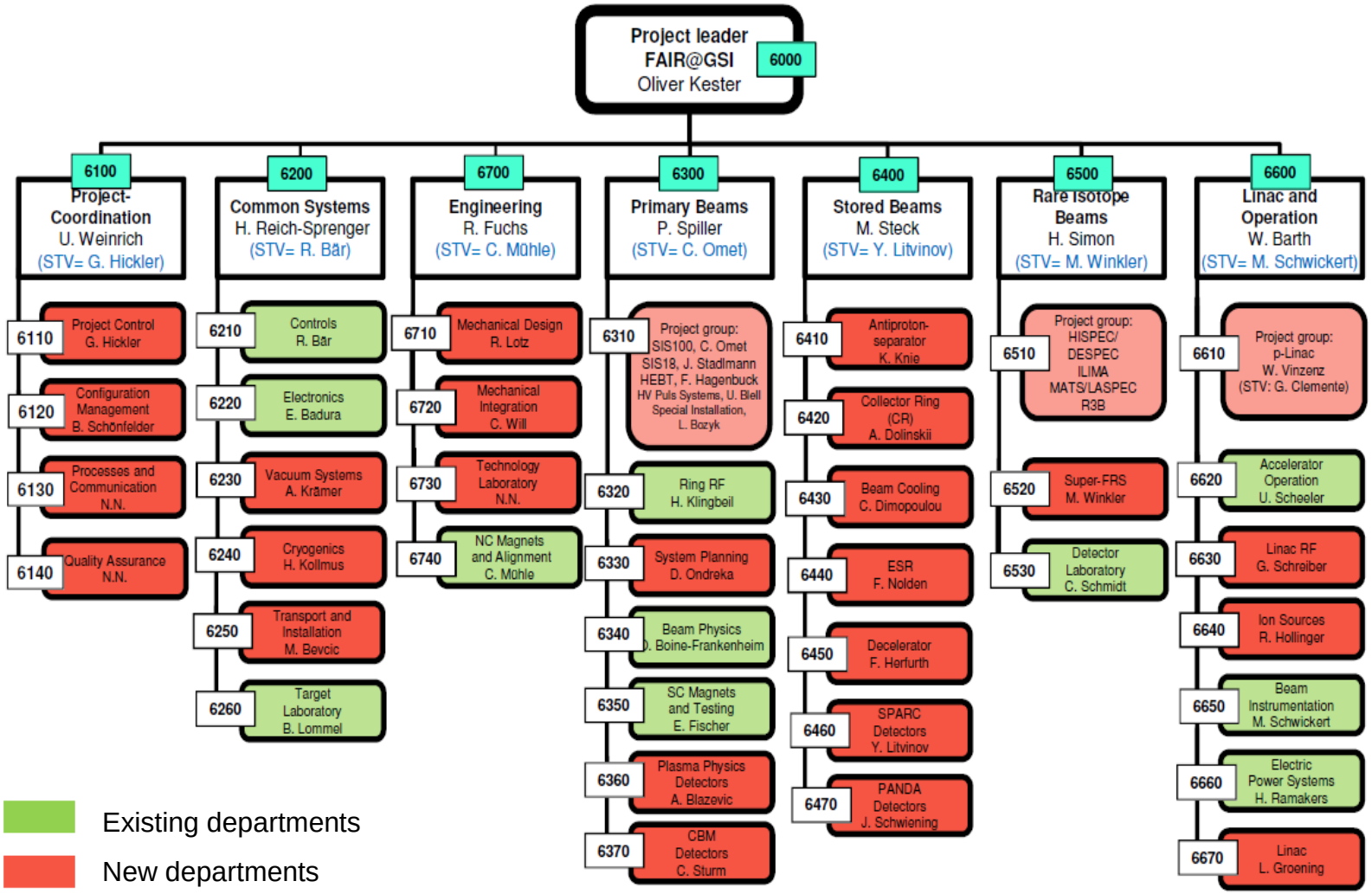
3D acclerator DMU in building with infrastructure



Envelope model

of FAIR accelerator

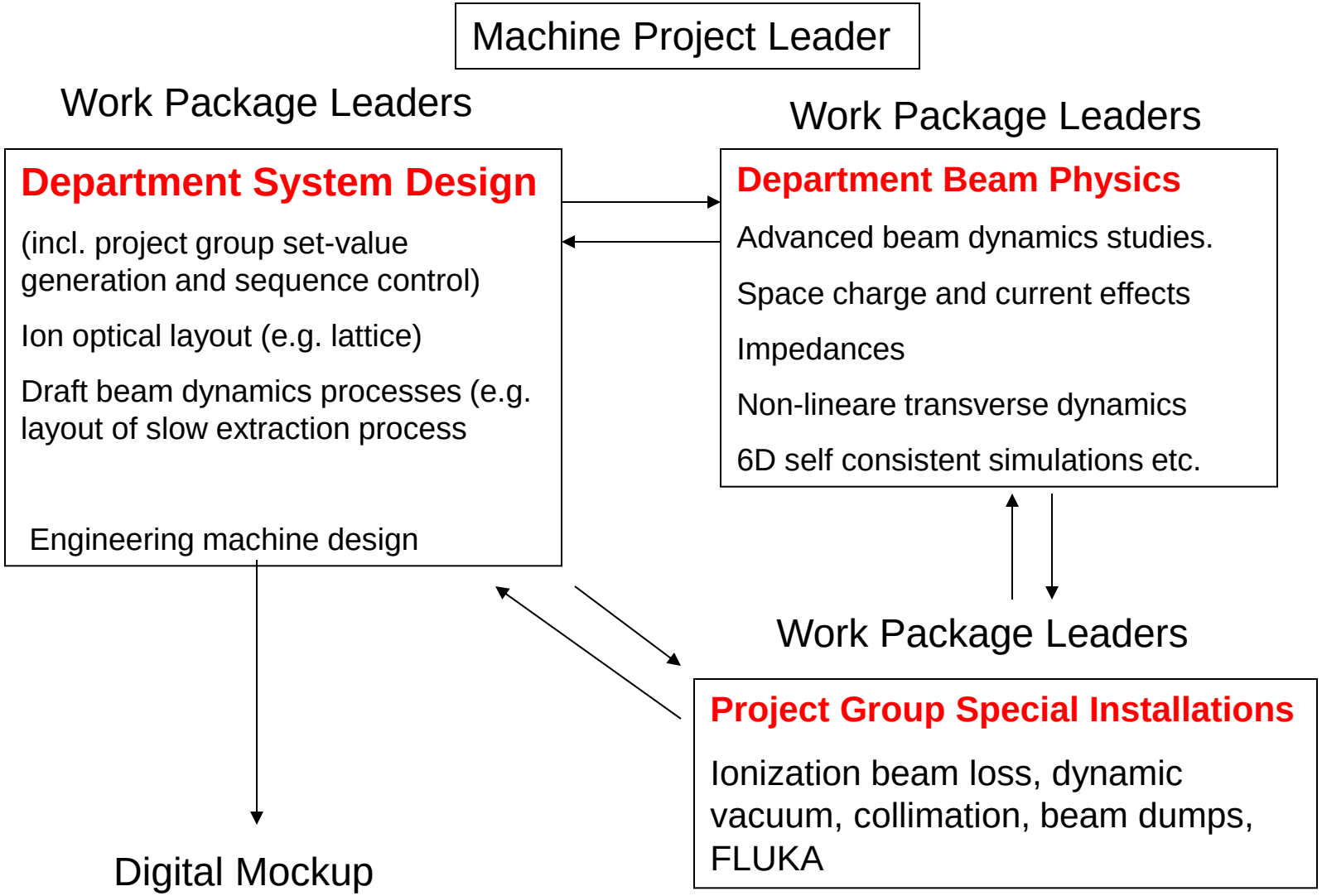
Focusing on the Construction of FAIR: Restructuring of GSI



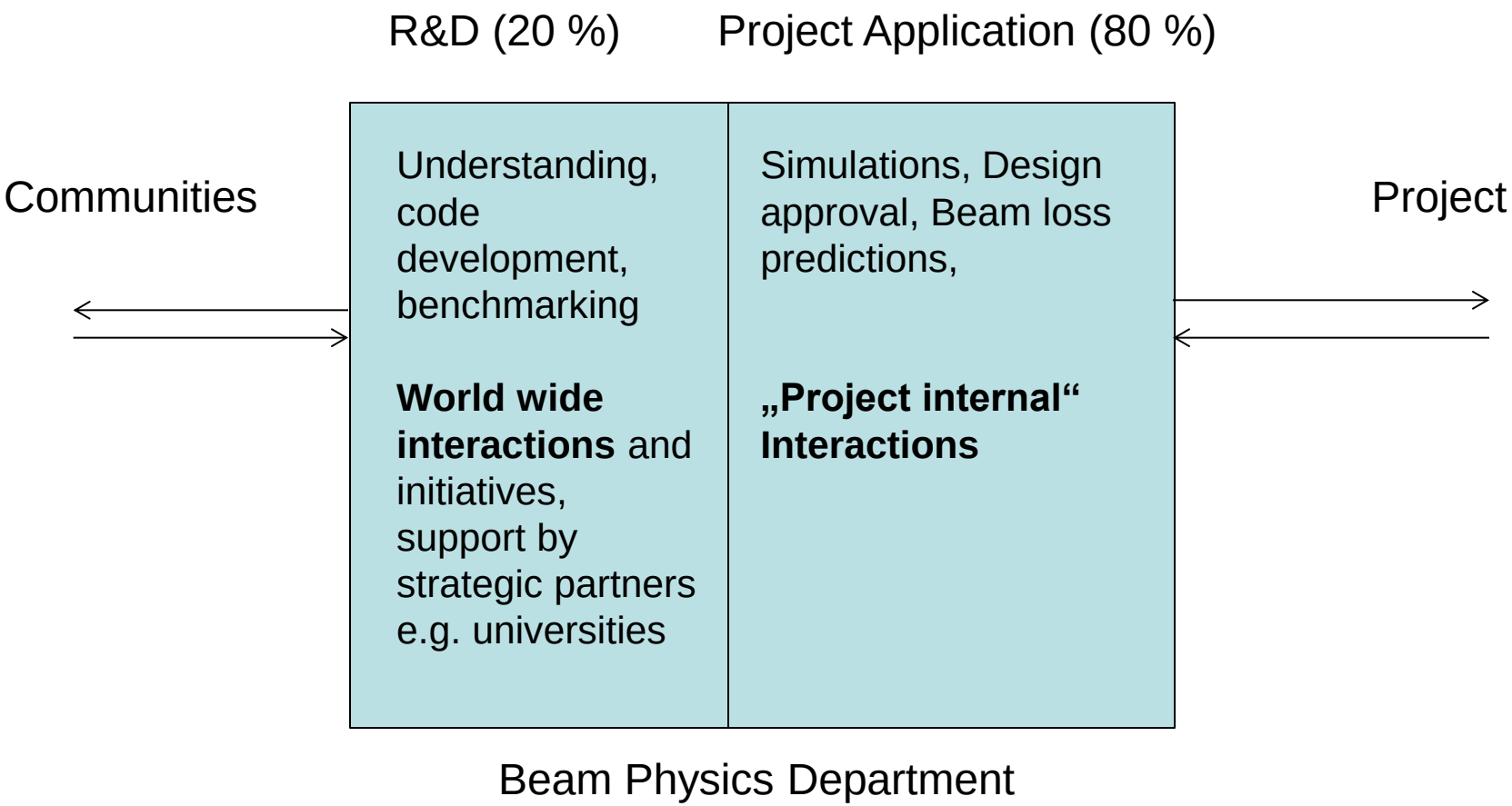
Work Packages of the Accelerator Subprojects

09.10.2011	HEBT 2.3 F. Hagenbuck	Super FRS 2.4 M.Winkler	CR 2.5 M.Steck	p-Linac 2.7 L.Groening	SIS100 2.8 P.Spiller	pbar-Separator 2.9 K.Knie	HESR 2.11 D. Prasuhn	Common Systems 2.14 H. Kollmus
System design	HEBT F. Hagenbuck	Super-FRS M. Winkler	CR M. Steck	p-Linac L. Groening	SIS100 P. Spiller	pbar-separator K. Knie	HESR D. Prasuhn	
Beam Dynamics	HEBT Beam Dynamics	Super-FRS Beam Dynamics	CR Beam Dynamics	p-Linac Beam Dynamics C.Clemente	SIS100 Beam Dynamics O. Boine-Frankenheim	pbar-separator Beam Dynamics	HESR Beam Dynamics	
Magnets	HEBT Magnets 2.3.2 C.Mühle	Super-FRS Magnets 2.4.2 H. Leibrock	CR Magnets 2.5.2 C.Mühle	p-Linac Magnets 2.7.2 C.Mühle	SIS100 Magnets 2.8.2 E. Fischer	pbar - Separator Magnets 2.9.2 C.Mühle	HESR Magnets 2.11.2 U. Bechstedt	Electrical Power 2.14.1 H.Ramakers
Power Converters	HEBT Power Converter 2.3.3 H.Ramakers	Super-FRS Power Converters 2.4.3 H.Ramakers	CR Power Converters 2.5.3 H.Welker	p-LINAC Power Converters 2.7.3 H.Ramakers	SIS100 Power Converters 2.8.3 H.Ramakers	p-bar Separator Power Converters 2.9.3 H.Ramakers	HESR Power Converters 2.11.3 M. Retzlaff	Detector gas supply 2.14.2 M.Schwickert
RF-Systems			CR RF-Systems 2.5.4 U.Laier	p-Linac RF-Systems 2.7.4 G.Schreiber	SIS100 RF-Systems 2.8.4 H.Klingbeil		HESR RF-Systems 2.11.4 R. Stassen	Cryogenics supply 2.14.8 M.Kauschke
Injection/Extraction			CR Inj/Extr 2.5.5 U.Blell		SIS100 Inj/Extr 2.8.5 U.Blell		HESR Inj/Extr 2.11.5 R. Tölle	Survey and Alignment 2.14.9 I.Pschorn
Beam Diagnostics	HEBT Beam Diagnostics 2.3.6 B.Walasek-Höhne	Super-FRS Beam Diagnostics 2.4.6 H. Simon	Beam diagnostics 2.5.6 G.Schepers	Beam diagnostics 2.7.6 P.Forck	Beam diagnostics 2.8.6 P.Kowina	p-bar Seperator Beam diagnostics 2.9.6 A. Reiter	HESR Beam diagnostics 2.11.6 J. Dietrich	Accelerator Control System 2.14.10 R.Bär
Vacuum	HEBT Vacuum 2.3.7 A.Krämer	Super-FRS Vacuum 2.4.7 A.Krämer/Mukha	CR Vacuum 2.5.7 A.Krämer	p-Linac Vacuum 2.7.7 A.Krämer	SIS100 Vacuum 2.8.7 A.Krämer	p-bar Separator Vacuum 2.9.7 A.Krämer	HESR Vacuum 2.11.7 M. Esser	Link Existing Facilities 2.14.11 O.Kester
Particle Sources				P-linac ion source 2.7.8 R.Hollinger				Installations / Assembly 2.14.12 H.Reich-Sprenger
Stochastic Cooling			CR Stochastic Cooling 2.5.10 F.Nolden				HESR Stochastic Cooling 2.11.10 R. Stassen	Magnet Testing 2.14.13 P. Schnizer
Special Installations	HEBT Special Installations 2.3.11 F. Hagenbuck	Super-FRS Special Installations 2.4.11 H. Weick		p-Linac Special Installations 2.7.11 L. Groening	SIS100 Special Installations 2.8.11 H.Kollmus	pbar- Separator Special Installations 2.9.11 K.Knie	HESR - Special Installations 2.11.11 D. Prasuhn	Quench Detection and Protection 2.14.14 E.Floch
Cryogenics		Cryogenics 2.4.12 Y.Xiang			Cryogenics 2.8.12 M. Kauschke			

Planning Departments in Primary Beams Division



Beam Physics Department in FAIR@GSI



Beam Physics in the Primary Beam Projects

Beam physics workpackages relevant in all phases of the project

Conceptual Design > Engineering Design and Specification > Procurement and Realization > Comissioning

1. Conceptual Design

Accelerator- and accelerator configuration concepts (CDR) - analytic estimates of beam intensities, intensity thresholds and beam loss – First definition of devices and device parameters (> cost estimates). Beam parameter tables.

2. Engineering Design

(Multiple) adaptation of simulations to modifications of machine layout and device properties.
Detailed beam dynamics studies. Proposal of correction schemes and correction systems.
Input for machine protection and radioprotection (beam loss) – Physics models and algorithms of set-value generation – Decisions of final system design

3. Procurement and Realization

Approval of technical specifications, especially of acceptance criteria (e.g. field quality)
Feed back from production process and approval - Magnet sorting schemes.

4. Commissioning

Measurement of machine properties and parameters - Optimization of operation (e.g. beam loss) - Empirical correction of set-value generation. Implementation of correction schemes based on measurements.

Present Beam Physics Issues - Examples

Tranverse, nonlineare beam dynamics including space charge, longitudinal motion, realistice field errors and closed orbit distortion.

- Resonance trapping at high beam currents during one second injection plateau. Beam loss prediction and resonance correction schemes. SIS100 has several working points: a) low charge state operation, b) slow extraction operation and c) Proton operation and a small aspect ration between beam and aperture.

Impedance studies for the determination of energy deposition of image currents in the cryogenic system.

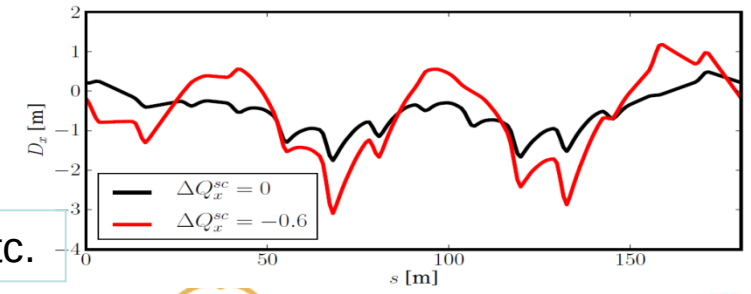
-Proton beam at full energy deposits 2 kW in the cryogenics system (major contribution to the power budget of the cryogenics system) > Sequence control starts Proton cycle only after request from secondary beam facility

Definition of acceptance tolerance for the magnet fields. Implementation of the measured field harmonics in the simulations. Definition of sorting schemes etc.

-Field mappin in elliptical aperture with anticryostat covers only a certain fraction of the aperture. The edge of the measurement area lies within the beam edge.

Modification of the dispersion by strong

space charge effects during bunch compression.



see talks of Oliver Boine-Frankenheim, G. Franchetti etc.

Summary

• GSI has strengthend the project activities by a major restructuring and focusing of the resources and the implementation of professional mangement tools

• FAIR civil construction has been started (side preparation and pillars)

• Production of major FAIR accelerator components has been started
The goal is commissioning of SIS100 and primary beam lines in Q1 2018
(depending on the subproject civil construction)

• Structuring of the primary beam division with a strong link between system design, beam physics, set-value generation and special installations.

• The „investment“ in high level beam dynamics experts accounts for the responsibility of the science community for a careful and successful use of public funding and for the future of large scale particle accelerators projects.