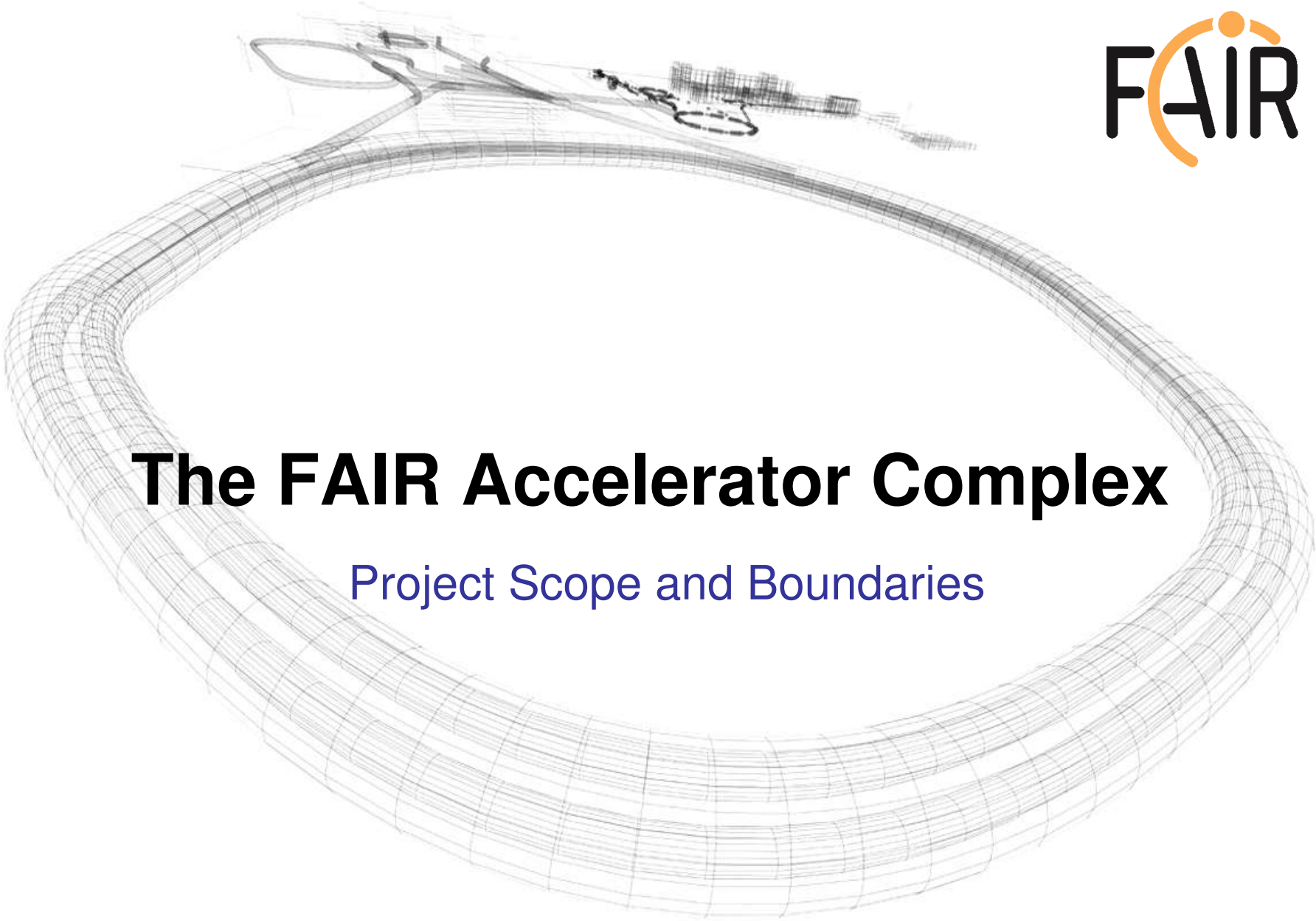


The FAIR Accelerator Complex

Project Scope and Boundaries

D. Krämer GSI-FAIR Div.

18 December 2006

FAIR: Motives and Objectives

- Provide the European research area with a world-leading scientific infrastructure for nuclear and hadron research

- Realize FAIR in an international cooperation

FAIR: The Science Case

- To deepen our understanding of the structure and properties of matter:
  Nuclear and Hadron Structure, theory of the strong interaction (QCD) within the nucleus, phase diagram of nuclear matter, quark-gluon plasma, atomic physics
- To contribute to our knowledge about the evolution of the Universe:
  Nuclear astrophysics
- To use ion beams for technology and applied research:
  plasma physics, materials science, radiobiology, tumor therapy

FAIR Baseline Technical Report:
18 Technical (Experiment) Proposals
by 2200 scientists from 44 countries

Consequences of the approach:

- Early definition of scope of the project, costs, funding profile, schedule, financing of experiments etc.. (FBTR, convention ..)

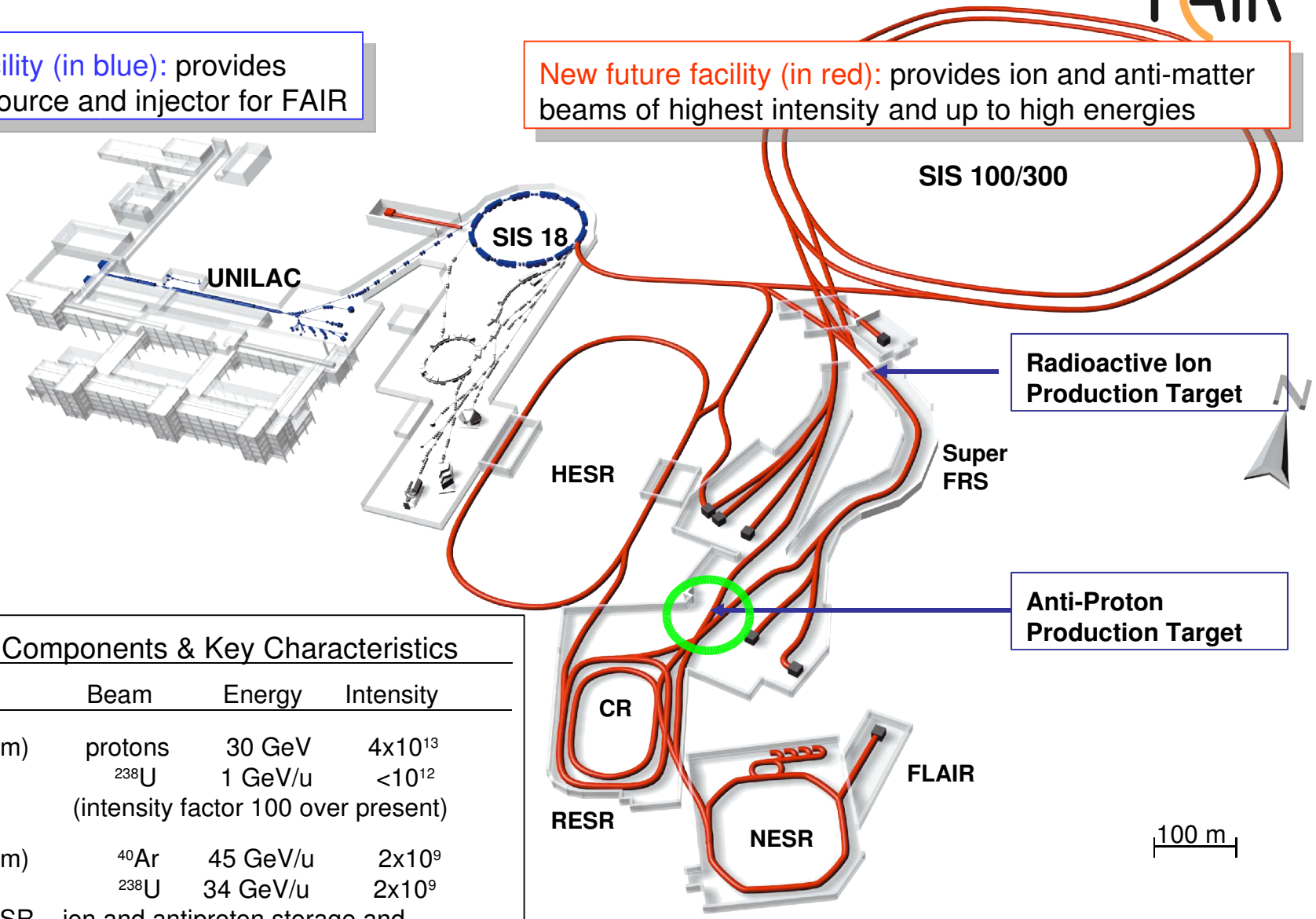
- Binding documents dictated by administrators and politicians rather than scientists.

- From technical / user perspective: prepare also the time following the construction phase.

Technical Realization of FAIR

Existing facility (in blue): provides ion-beam source and injector for FAIR

New future facility (in red): provides ion and anti-matter beams of highest intensity and up to high energies



Accelerator Components & Key Characteristics

Ring/Device	Beam	Energy	Intensity
SIS100 (100Tm)	protons	30 GeV	4×10^{13}
	^{238}U	1 GeV/u	$<10^{12}$
	(intensity factor 100 over present)		
SIS300 (300Tm)	^{40}Ar	45 GeV/u	2×10^{9}
	^{238}U	34 GeV/u	2×10^{9}
CR/RESR/NESR	ion and antiproton storage and experiment rings		
HESR	antiprotons	14 GeV	$\sim 10^{11}$
SuperFRS	rare-isotope beams	1 GeV/u	$<10^{9}$

Unprecedented System Parameters at FAIR

(a multi-purpose facility)

Beam Intensity:

- primary heavy-ion beam intensity increases by x 100 – x 1000
- secondary beam intensity increases by up to x 10000

Beam Energy:

- heavy-ion energy : x 30

Beam Variety:

- antiprotons
- protons to uranium & radioactive ion beams

Beam Precision:

- cooled antiproton beams
- intense cooled radioactive ion beams

Beam Pulse structure:

- optimized for experiments: from dc to ultra-high bunch compression

Parallel Operation:

- full accelerator performance for up to four different and independent experiments and experimental programs

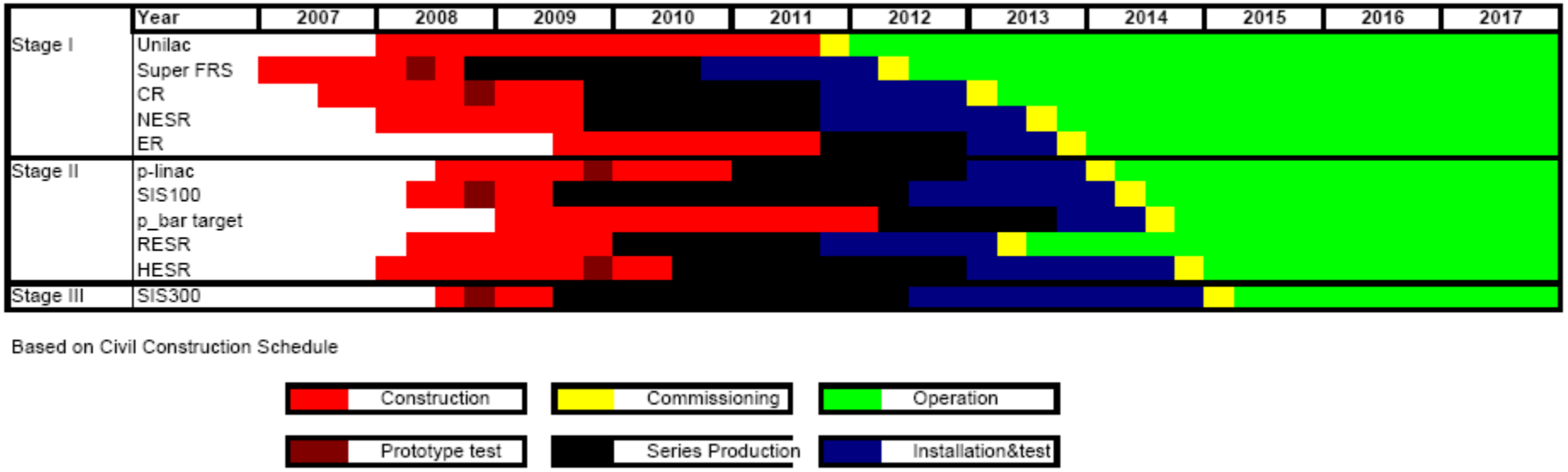
Project Costs

Costs scrutinized by CORE-A/E, TAC, STI and 7 mini-TACs, documented in Costbook

Accelerator investment costs	**533.0 M€**
Civil construction costs	**[illegible]3.7 M€**
Baseline experim[illegible]	
([illegible] budget	**180.0 M€**
	1001,7 M€
Manpower (2400 person-years)	**184,8 M€**
Total Construction Costs	**1186,5 M€**
Commissioning Costs	**26,5 M€**
Annual operation cost	**118 M€/y**
i.e. cost up to 2025	**2697,6 M€**

25% of cost have to be covered by external partners

Time Schedule



First experiments scheduled for beginning of 2012 (Super-FRS) – Phase I
End of project scheduled for beginning of 2015

Schedule determined by civil construction progress

The International Committee Structure

China Finnland France Germany Greece India Italy Poland Spain Sweden Russia Great Britain Romania

ISC
International Steering Committee
H. Schunck

STI Working Group

- Baseline Technical Report
  - accelerator TR's
  - experiment proposals
  - civil construction plans
  (~ 3500 pages)
- PAC & TAC Review Reports
- Cost Book
- Cost Review Reports
  - accelerator & civil construction (CORE-A)
  - experiments (CORE-E)

FAIR Project

AFI Working Group

- Convention
- Articles of Association
- By-Laws
- Final Act Document
- Legal Framework Report (LFI)
- Full Cost Structure Report (FCI)

Observer:

FAIR Baseline Technical Report

FAIR Baseline Technical Report (3024 pages)

Volume 1: Executive Summary (58 pages)
Volume 2: Technical Report Accelerators and Scientific Infrastructure (738 pages)
Volume 3: Techn. Experiment Proposals on QCD physics (Volume 3A: 438 pages, Volume 3 B: 580 pages)
Volume 4: Techn. Experiment Proposals on Nuclear Structure and Astrophysics (520 pages)

Status of Signatures to the Memorandum of Understanding for the FAIR project

Country	Signatory	signed at
China	Meng Shuguan Ma Yanhe	24.11.2005
Finland	Prof. Dr. D. Riska	22.09.2004
France	Dr. E. Giacobino	08.12.2004
Germany	Dr. H. Schunck	13.09.2004
Greece	Prof. Dr. C. Fotakis	11.11.2004
India	Dr. Y.P. Kumar	17.11.2005
Italy	Dr. L. Criscuoli	06.12.2004
Poland	Prof. Dr. R. Kulessa	18.01.2005
Romania	Prof. Dr. A. Anton	07.04.2006
Russian Federation	Prof. Dr. S. Mazurenko	11.11.2004
Spain	Dr. S. Ordónez Delgado	06.10.2004
Sweden	Dr. P. Omling	21.09.2004
United Kingdom	Prof. Dr. J. Wood	13.09.2004

Status of Technical Negotiations

- **FAIR China**: *prototype of CR and Super FRS dipole magnets R&D - positive meeting by BMBF in Dec. 06*
- **Finland:** *looking into appropriate Polish contributions* - positive meeting in Nov. 06
- **France**: *Technical discussions on proton source and SIS300 dipole magnets – is interested in stage I only*
- **Germany**: *Continuous* work on HESR, GSI active on all fields
- **Greece** – no contacts
- **India**: production of 4 sc dipoles for energy buncher, discussions on p-linac components - positive statements by politics
- **Italy**: *R&D work on SIS300 has started* (INFN) – MoU signed in Dec. 06
- **Poland**: *looking into appropriate Polish contributions* – positive meeting
- **Russia**: *R&D contracts with **BINP (Novosibirsk)** on*
  - *radiation resistant nc dipoles & quadrupoles (SFRS target area)*
  - *design of ER ring*
  - *antiproton target*
  - *sc septum magnets*
  - *production of components for SIS18 upgrade (chambers, collimator)*
  - *design of ferrit loaded cavities (and prototype)*
  - *with **JINP (Dubna)***
  - *development of low loss rapid cycling dipoles and quadrupoles for SIS100*
  - *with **IHEP (Protvino)***
  - *study on SIS300 dipoles – positive signs by funding agency*
- **Romania**: *looking into appropriate contributions* – positive statements by politics
- **Spain**: NESR magnets, power supplies, vacuum – positive meeting at ministry of technology
- **Sweden**: Cryring for FLAIR experiments – positive signs by politics
- **UK**: involved in various experiments (NuSTAR, PANDA), plans for active participation of accelerator experts
- - unable to react before new structure of funding agencies is established.

FAIR: Work Packages

FAIR WPs

		WBS 2.3	2.4	2.5	2.6	2.7	2.8	2.9	2.10	2.11	2.12	2.13	2.14	3.0	1.0	Sum
		HEBT	**Supere FRS**	**CR**	**NESR**	**p-lianc**	**SIS100**	**pbar-target**	**RESR**	**HESR**	**SIS300**	**ER**	Com. Sys.	Civ. Constr.	Experiments	
	CostBook 3.0 (M€)	79.2	72.9	37.8	23.4	13.5	81.9	4.5	20.7	59.4	95.4	11.7	104.4	289.8	108	1002.6
TS-2	**Magnets**	Bend	Bend	Bend	Bend	Bend	Bend	Bend	Bend	Bend	Bend	Bend				
	Cost	12.2	15	9	4	0.22	7	0.7	4		24			GSI		
	Who		China	China	Es		Rus			S & G	RUS & I					
		Quad	Quad	Quad	Quad	Quad	Quad	Quad	Quad	Quad	Quad	Quad				
		14	23	2.2	2.7	0.7	8	0.7	2.6		19					
					Es		Rus				Rus & F					
			Sextupoles	Sextupoles	Sextupoles		Sextupoles			Sextupoles	Multipoles	Sextupoles				
			8	0.5	0.4		1.1				7					
					Es		Rus				RUS & I					
		Other	Other	Other	Other		Other			Other	Other	other				
		3	3.3	1.5	0.4		1.3		0.4		0.6					
							Rus				Rus					
TS-3	**Power Converter**	Power Conve	Power Conve	Power Conve	Power Conve	Power Conve	Power Conve	Power Conve	Power Conve	Power Conve	Power Conve	Power Converter				
		16	3	2.4	2.3	2.3	5	1.1	2.4		5.2					
					Es											
TS-4	**RF-System**			RF	RF	RF	RF		RF	RF	RF	RF				
				4.4	3.8	7	31		0.1		6.8					
						Ind./Rus/G	Rus		GSI		Rus					
TS-5	**Inj/Extraction**			Inj/Extr.	Inj/Extr.		Inj/Extr.		Inj/Extr.	Inj/Extr.	Inj/Extr.	Inj/Extr.				
				3.5	2		6		3		7					
							Rus				Rus					
TS-6	**Diagnostics**	Diagnostics	Diagnostics	Diagnostics	Diagnostics	Diagnostics	Diagnostics	Diagnostics	Diagnostics	Diagnostics	Diagnostics	Diagnostics				
		10	4.5	2	1.8	1.3	5.5	0.3	1.8		5.4					
TS-7	**Vacuum**	Vacuum	Vacuum	Vacuum	Vacuum	Vacuum	Vacuum	Vacuum	Vacuum	Vacuum	Vacuum	Vacuum				
		12	5.4	3.4	3.4	0.7	8	0.7	2.9		8					
					Es											
TS-8	**Part. Sources**					EZR						Linac				
						0.7										
						F										
TS-9	**ECOOL**				ECOOL					ECOOL						
					2.7											
					Rus											
TS-10	**St. Cooling**			St. Cool												
				6												
				GSI												
TS-11	**Special inst.**	Special	Special													
		0.1	5.5						0.8							
TS-12	**Local Cryo**	Local Cryo					Local Cryo				Local Cryo		Refrigerator			
							6.8				12		49			
													GSI			
TS-14	**Common S**												Controls/Interfaces			
													24			

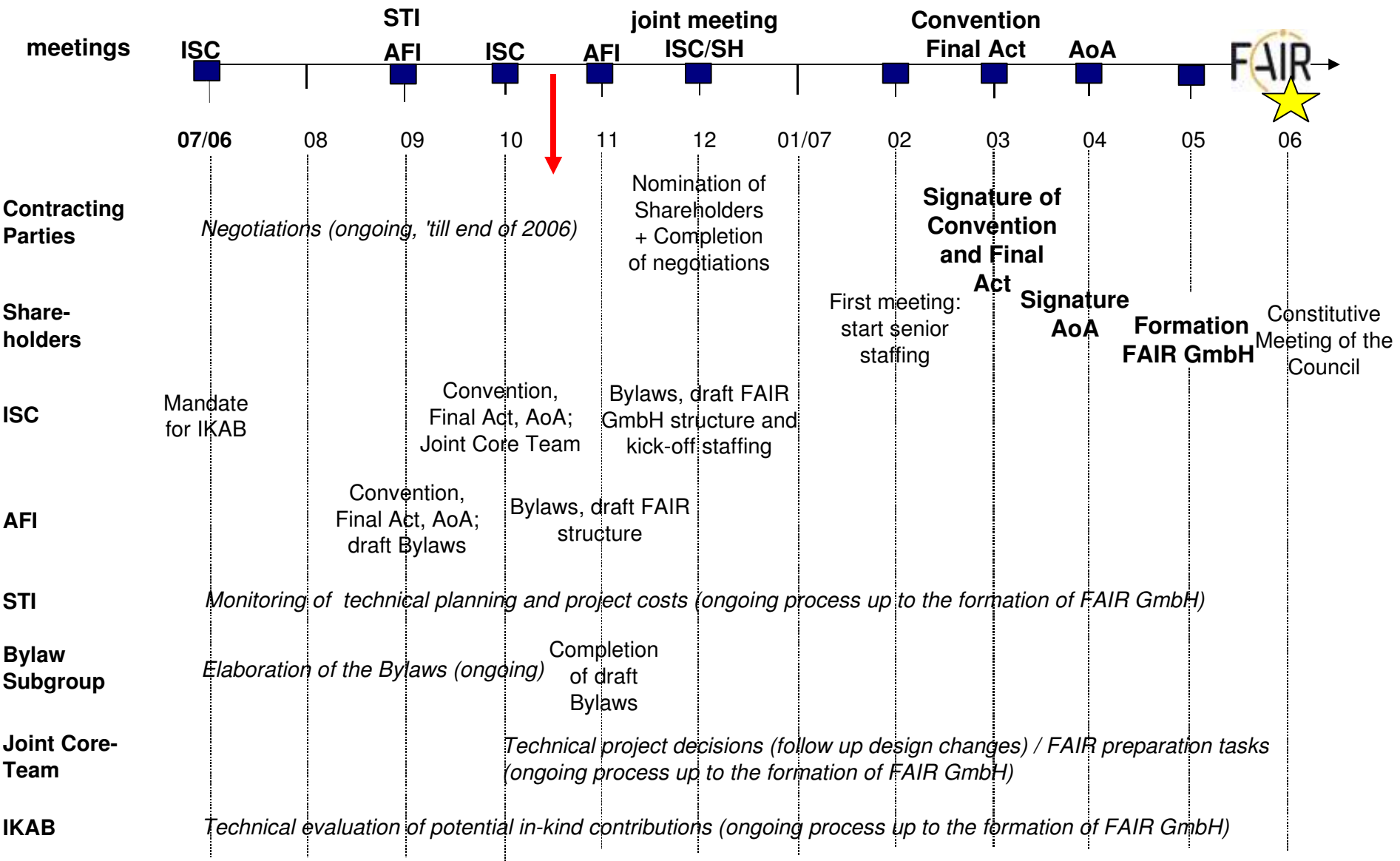
Nothing decided – just interest indicated !!

WP for discussion

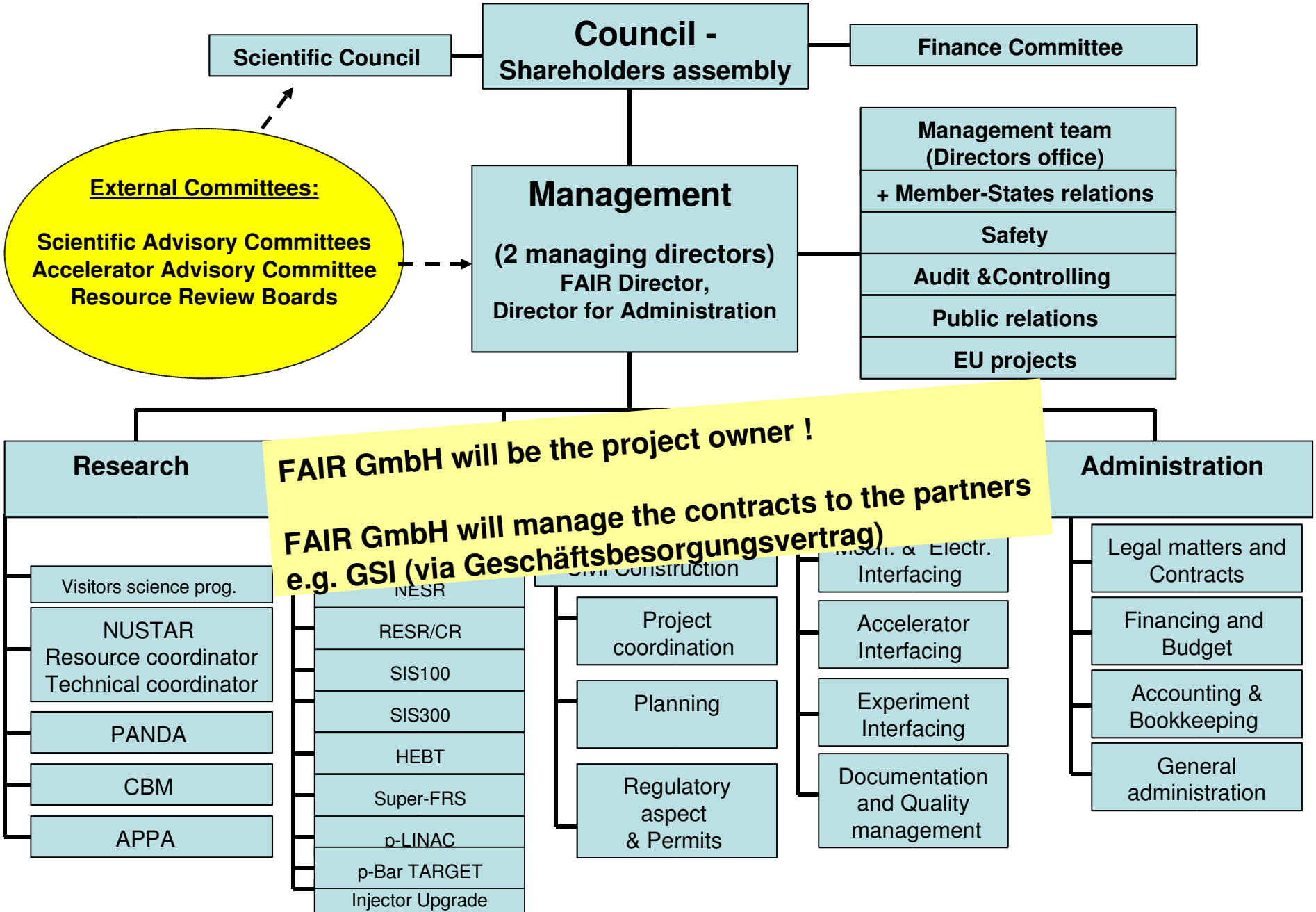
Intension to take WP

Meeting of IKAB on Jan. 8th, 2007

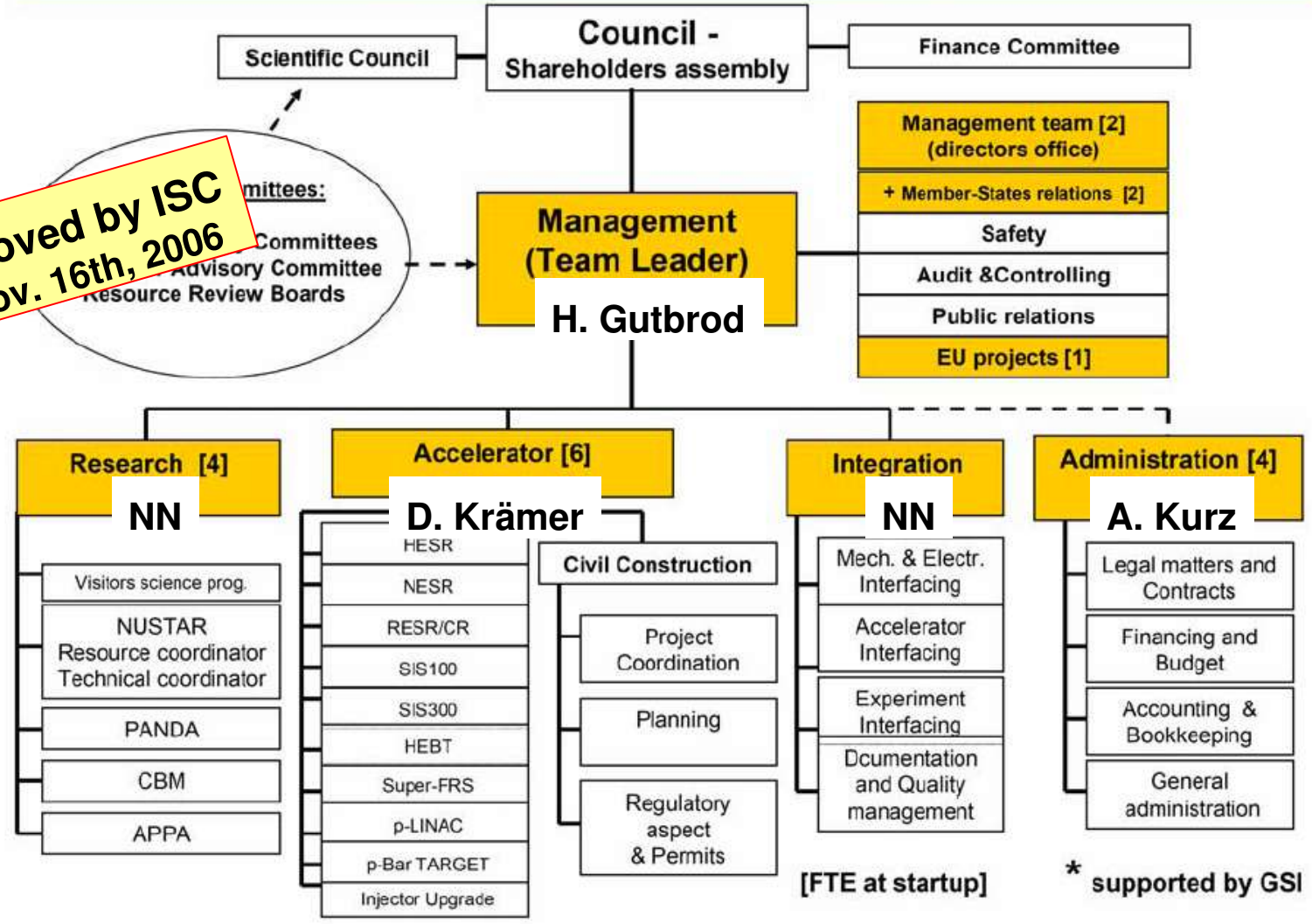
Proposed FAIR – Roadmap: Establishment of FAIR GmbH



Proposed Organization Chart of the FAIR GmbH



DRAFT: FAIR Joint Core Team



Will work until die Council nominates the positions in FAIR GmbH
Goal: prepare necessary steps towards FAIR GmbH

R&D on Key-Components during Preparatory Phase

by GSI & Partner Institutes

INFN Istituto Nazionale di Fisica Nucleare

BROOKHAVEN NATIONAL LABORATORY

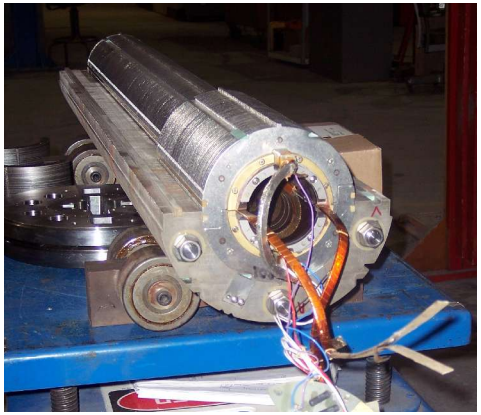
IHEP ИФВЭ

IHEP
Protvino

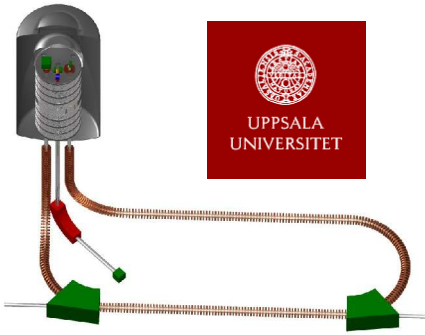
CEA / CNRS

BINP Novosibirsk

SIS300 sc magnets



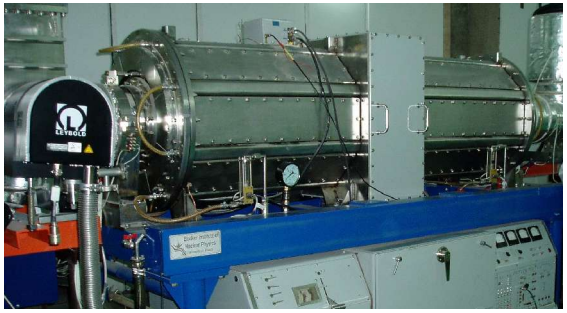
NESR Electron Cooling



UPPSALA UNIVERSITET

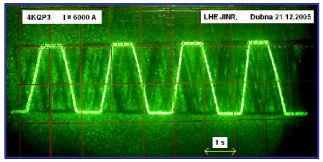
Forschungszentrum Jülich
in der Helmholtz-Gemeinschaft

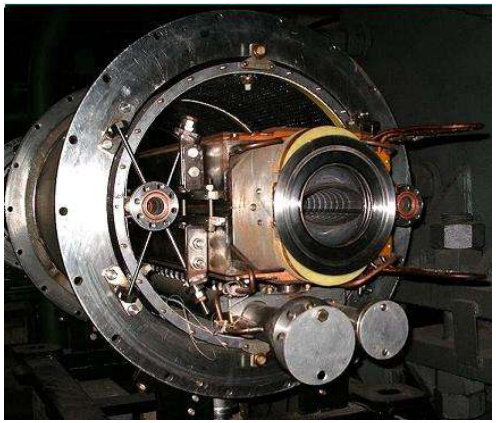
Variable frequency ferrit loaded cavities



SIS100 rapidly cycling sc magnets

Joint Institute for Nuclear Research Dubna

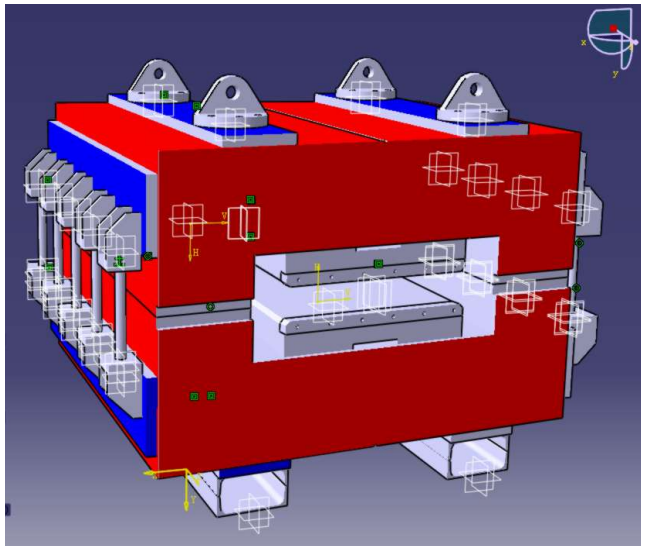




FAIR CHINA R&D Activities

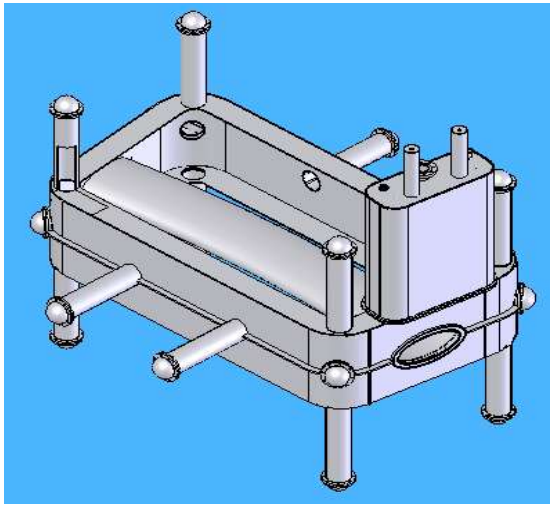
on large aperture magnets
for FAIR CR / Super FRS machines

Institute of Modern Physics, CAS (IMP Lanzhou)
Institute of Plasma Physics, CAS (IPP, Hefei)
Institute of Electric Engineering, CAS (IEE, Beijing)



3D animation of CR dipole

Die ready for stamping of laminations



Cryostat for sc coil

R&D Collaboration Partners cont'd

on NESR magnets, vacuum system, power converters

Medioambientales y Technologicas
Madrid, Spain

Raja Ram **l Technology**
Indore, Ind

Bhaba Atomic Reaearch Centre
Mumbai, India

on Super-FRS energy buncher, high power beam dumps

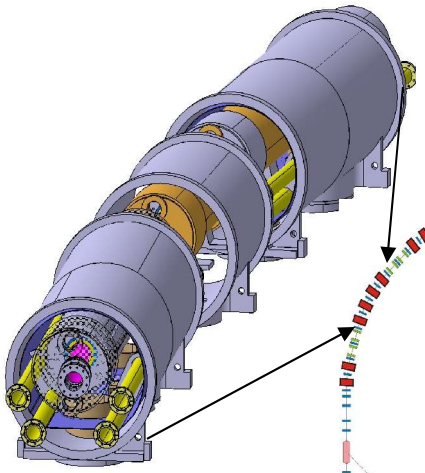
Dec. 2006: signature to MoU on SIS300 dipole
INFN will invest 4.7 M€ on R&D in a prototype
GSI will invest 1.0 M€

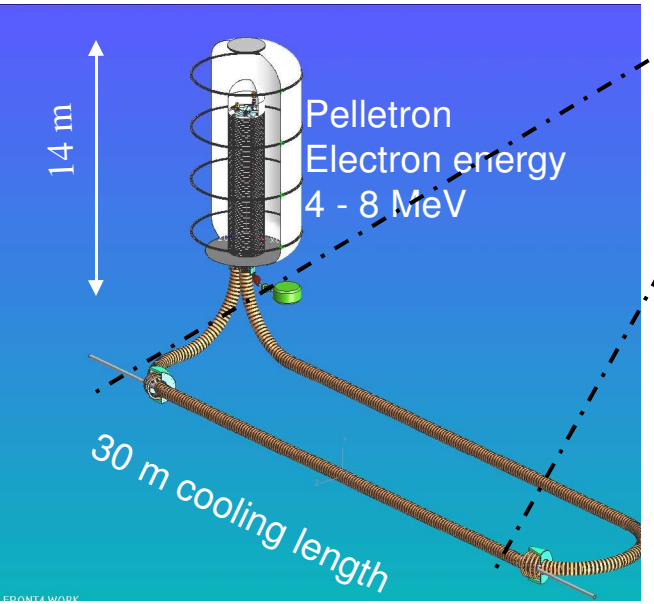
HESR Consortium FZ Jülich, TSL Sweden

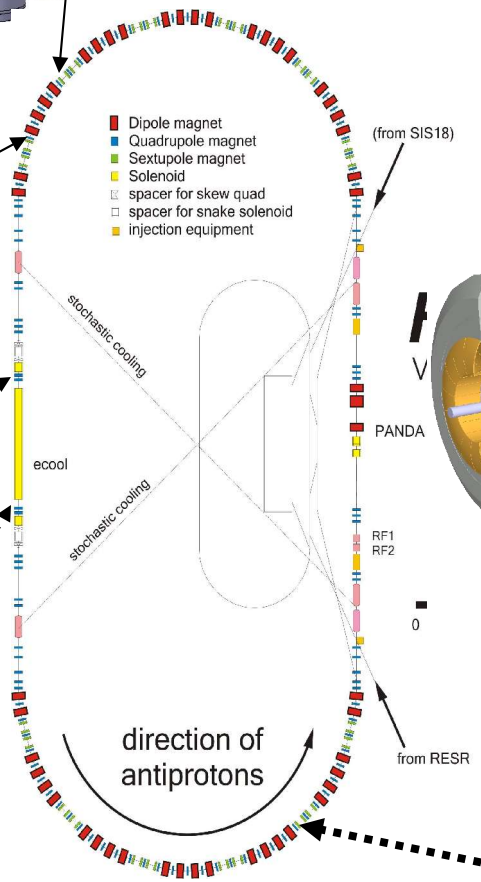
Forschungszentrum Jülich
in der Helmholtz-Gemeinschaft

UPPSALA UNIVERSITET

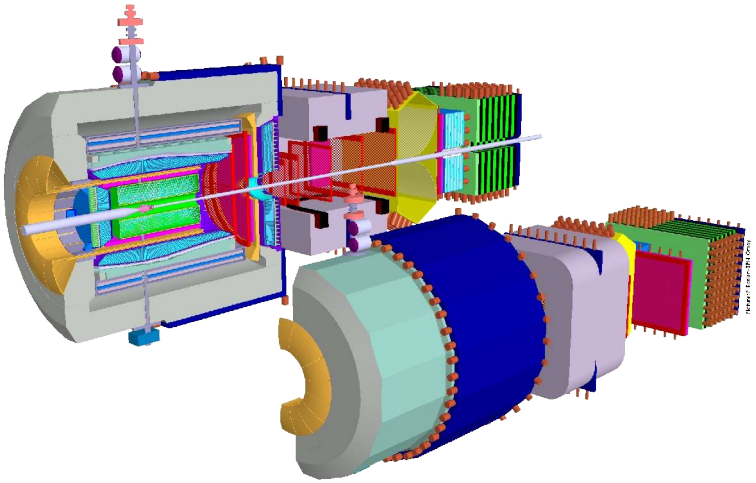
TSL

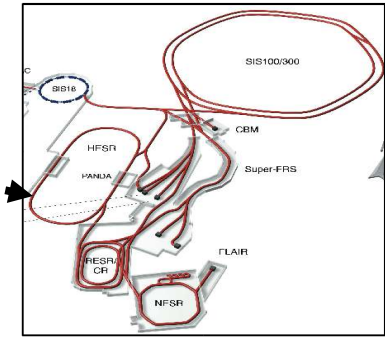




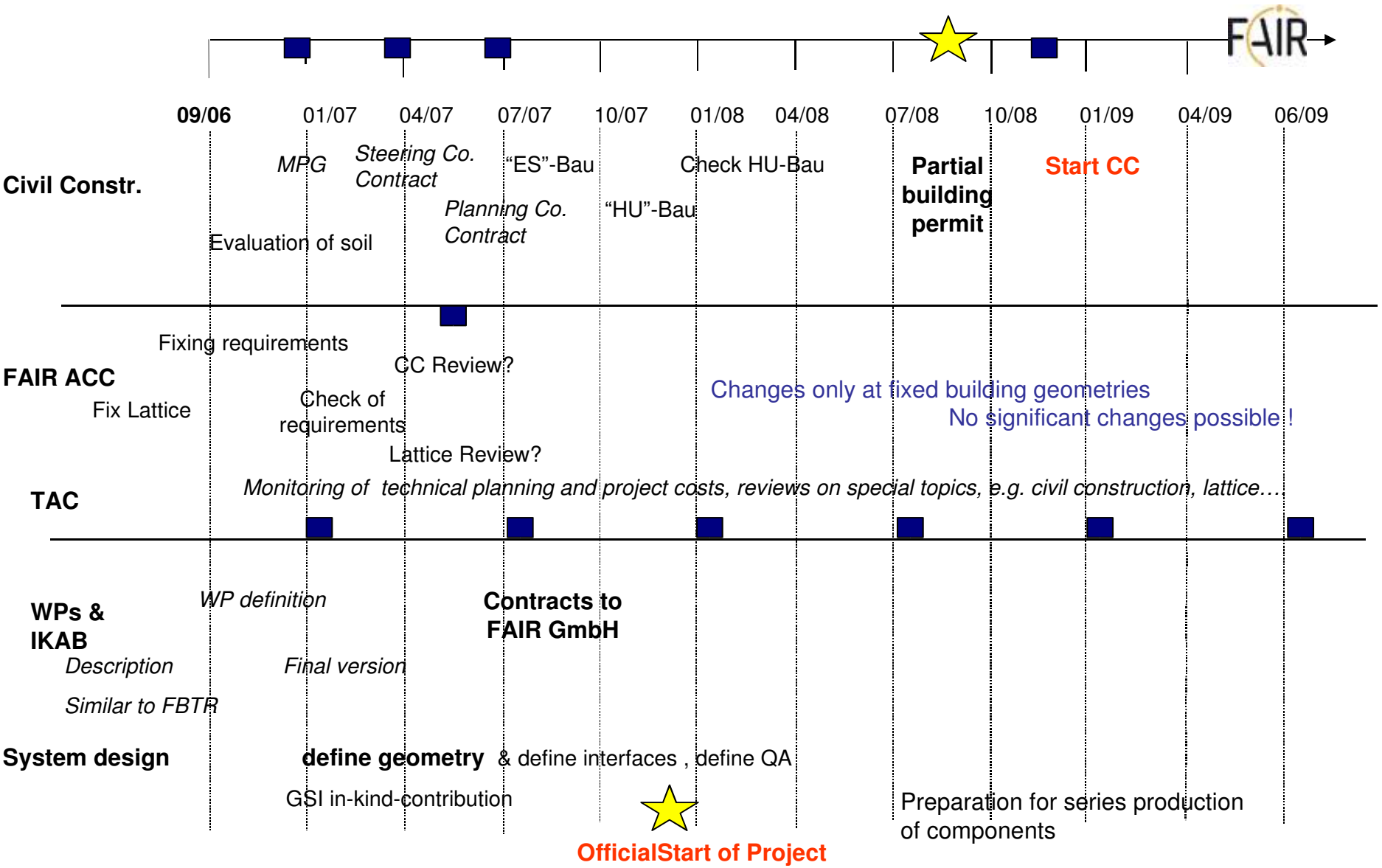


panda
Collaboration





Roadmap: Civil Construction and Accelerators



International documents define scope of the project

AND

functionality in terms of guaranteed parameters

which define end of commissioning/start of operation
as well as the ultimate goals.

Base Parameters of the Project

No.	Accelerator unit	Stage of Construction	Current, or number of particles		Repetition rate		Bunch length		dp/p		slow extraction	
			start of operation	final	start of operation	final	start of operation	final	start of operation	final	start of operation	final
1	UNILAC	1	2 mA U^{73+}	3.5 mA U^{73+}								
		2	5 mA U^{28+}	15 mA U^{28+}								
2	SIS 18	1	1×10^{10} U^{73+} per cycle	3×10^{10} U^{73+} per cycle	1 Hz	4 Hz	50 ns	25 ns				
		2	2×10^{10} U^{28+} per cycle	1.5×10^{11} U^{28+} per cycle	1 Hz	4 Hz						
3	CR	1	1×10^{5} $^{132}Sn^{50+}$ in the ring	Any ion up to space-charge limit						5×10^{-4}		
4	NESR	1	5×10^{4} $^{132}Sn^{50+}$ in the ring	Any ion up to space-charge limit					5×10^{-4}	1×10^{-4}		
5	RESR	2	5×10^{4} $^{132}Sn^{50+}$ in the ring	Any ion					1×10^{-3}	5×10^{-4}		
6	SIS 100	2		U^{28+} per cycle	0.5 Hz	nearly 1 Hz	150 ns	60 ns				
7	Proton Linac	2	3 mA protons	15 mA protons								
8	FLAIR	2	10^{8} anti- protons per NESR cycle	up to space-charge limit in CR, RESR, NESR								
9	HESR	2	5×10^{10} anti-protons in ring	1×10^{11} anti-protons i.ring					5×10^{-4}	1×10^{-4}		
10	SIS 300	3	2×10^{10} U^{28+} per cycle	4×10^{10} U^{28+}- per cycle							10^{10} U^{28+} / s	3×10^{11} U^{28+} / s

From the FBTR - Chapt. 2.9.1.2:

Role of Antiproton Production in the FAIR Project

The concept for the production of antiproton beams at FAIR is basically determined by the luminosity requirement of Lpbar,p = 1×10^{32} cm^{-2} s^{-1} for experiments with cooled antiproton beams colliding with an internal H_2-target in the kinetic energy range from 0.8 GeV to 15 GeV at the High Energy Storage Ring HESR[5]. Assuming a maximum value of 100 mb for the total inelastic antiproton-proton cross section $\sigma_{pbar,p}$ the maximum antiproton consumption rate is $R_{pbar,p} = \sigma_{pbar,p} L = 1 \times 10^7$ s^{-1}. It has to be compensated by a corresponding net rate of antiproton production and accumulation.

Present layout (3.5×10^{10} h^{-1}) is compatible with this requirement.

As pointed out: improvements by a factor of 4 .. 5 seem possible on the long run to be realized with additional investments in phase II.

If there are good arguments: lets discuss about later upgrades (options) that need to be included in the present planning - within the limitations given !

Approved Budget for p_bar Separator

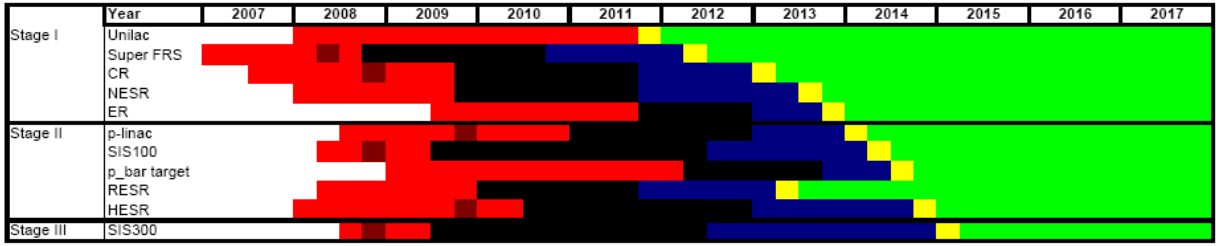
2.9 Power Converter	**p Bar Separator**		**4.510**
.9.1	System Design		
2.9.2	Magnets	1.654	
2.9.3	Power Converters	1.050	
2.9.4	RF Systems		
2.9.5	Injection/ Extraction		
2.9.6	Beam Diagnostics	248	
2.9.7	Vacuum	721	
.9.8	Particle Sources		
2.9.9	Electron Cooling		
.9.10	tochastic Cooling		
.9.11	pecial Installations	92	
.9.12	ryogenics (local)	45	

From Costbook 3.0 and committees

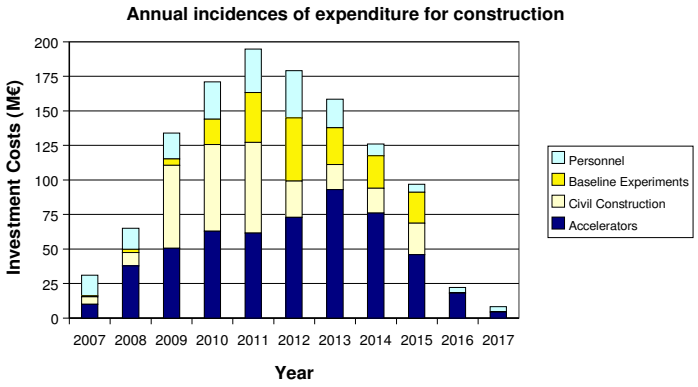
Similar budgets exist for SIS100, CR, RESR .. the budgets are very tight as the Validated costs had to be cut by 10% (design to budget).

Additional boundaries:

- schedule, especially civil construction, system design, spending profile etc.



Based on Civil Construction Schedule



Funding profile according to the annex to the convention

Summary Project Status

- ✓ 60 M€ available for the preparatory phase 2001 – 2008
- ✓ Regional Development plan (Bebauungsplan) legally settled
- ✓ All environmental impact studies are accepted
- ✓ Call for Construction Steering and Planning Offices under way
- ✓ Prototyping is on a good way with successful models, and prototypes in 2007
- ✓ Core facility defined
- ✓ Layout defined
- ✓ Scientific base program defined (ISC will decide in Feb. 07 distribution of 108 M€)
- ✓ Project cost estimates (WBS, cost book) scrutinized and validated by expert groups
- ✓ Legal documents and Governance structure (two-company model) finalized and agreed upon by the ISC (by-laws to be completed)

Goal: foundation of FAIR GmbH mid 2007, project start in autumn ‘07

CN DE ES FI FR GB GR IN IT PL RO RU SE

Roadmap: Civil Construction and Accelerators