

Status of GSI-FAIR Project magnets

- open issues -

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GSI
CARE HHH AMT
November 23 2005

- All sc magnets
 - where
 - at which stage
 - which design
 - which parameters
- R&D overview (Status and outlook)
- open issues
 - magnet design
 - wire / cable design
 - other R&D
 - series measurement (wire, cable, magnets)

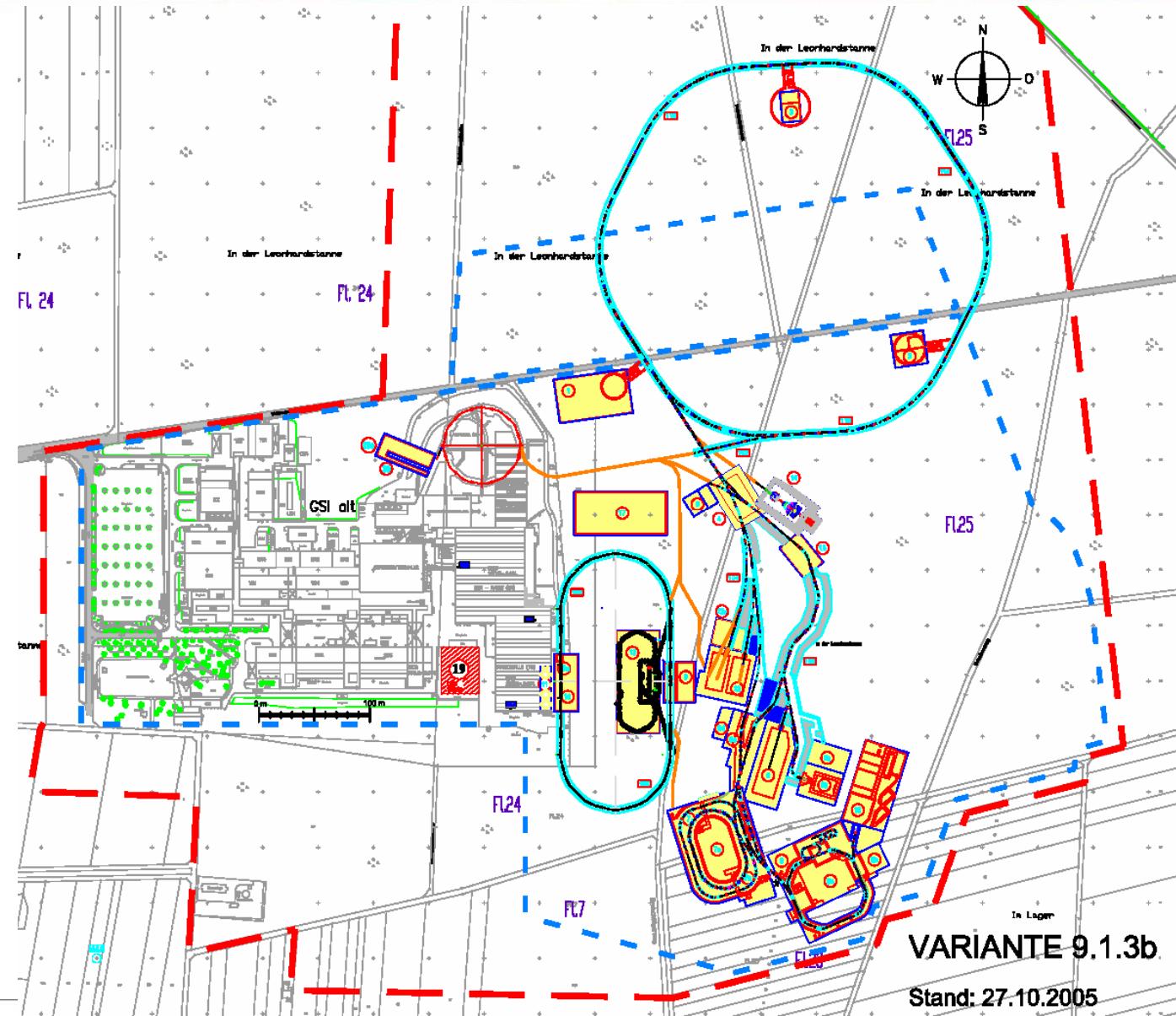
■ resistive:

- About 600 magnets
- 44 designs, but only 28 different cross sections
- largest series: 66 magnets

■ superconducting

- About 1540
- including correctors / steering magnets
- main magnets: 8 main designs
- largest series: 253

FAIR Topology overview



The FAIR Accelerator Complex



superconducting
magnets

Synchrotrons
SIS 100
SIS 300

HEBT

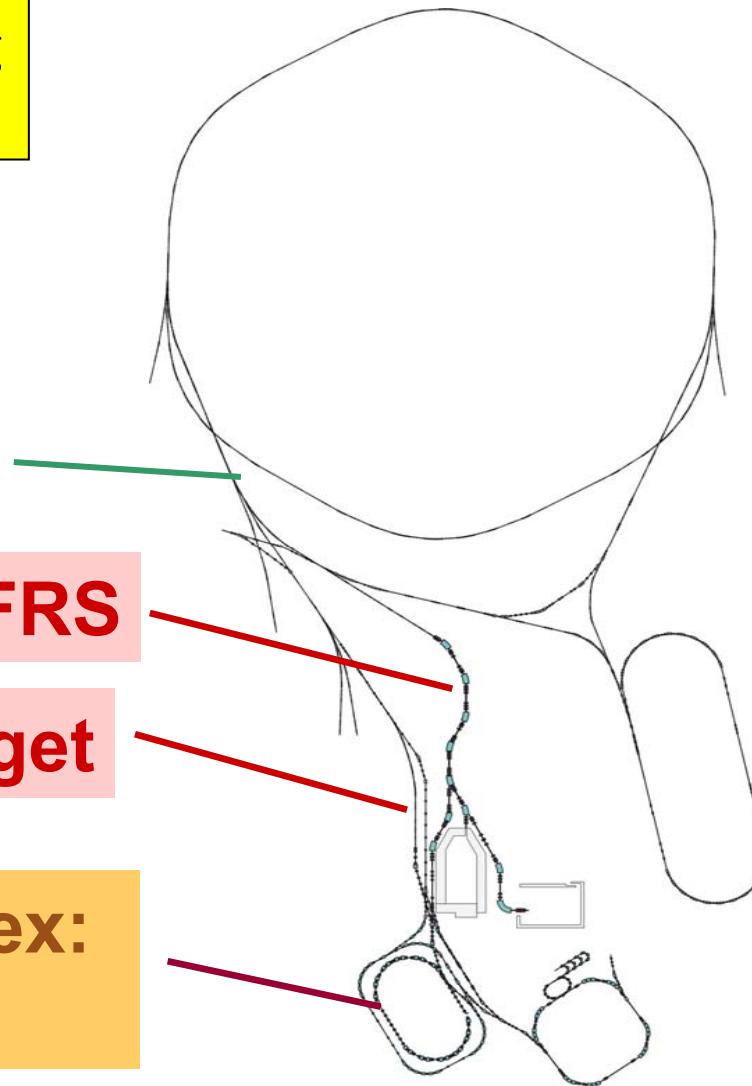
SuperFRS

Pbar target

CR-complex:
CR

Storage rings

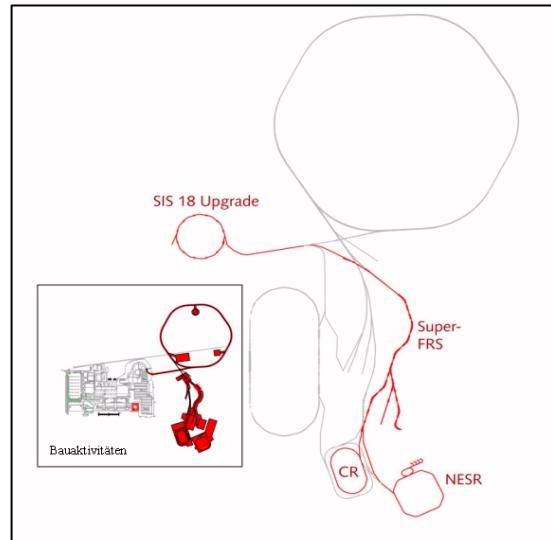
HESR



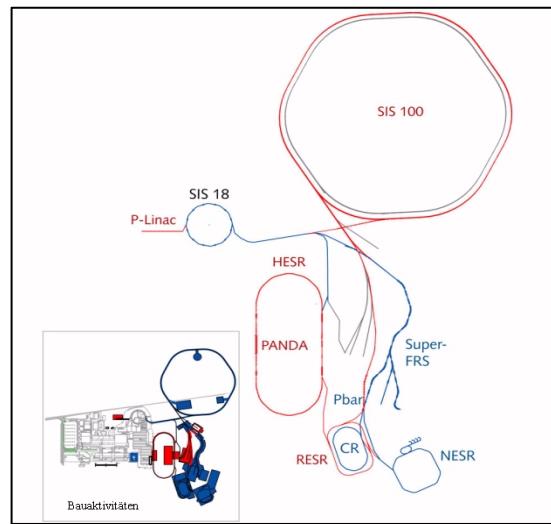
FAIR Project (staging-plan)



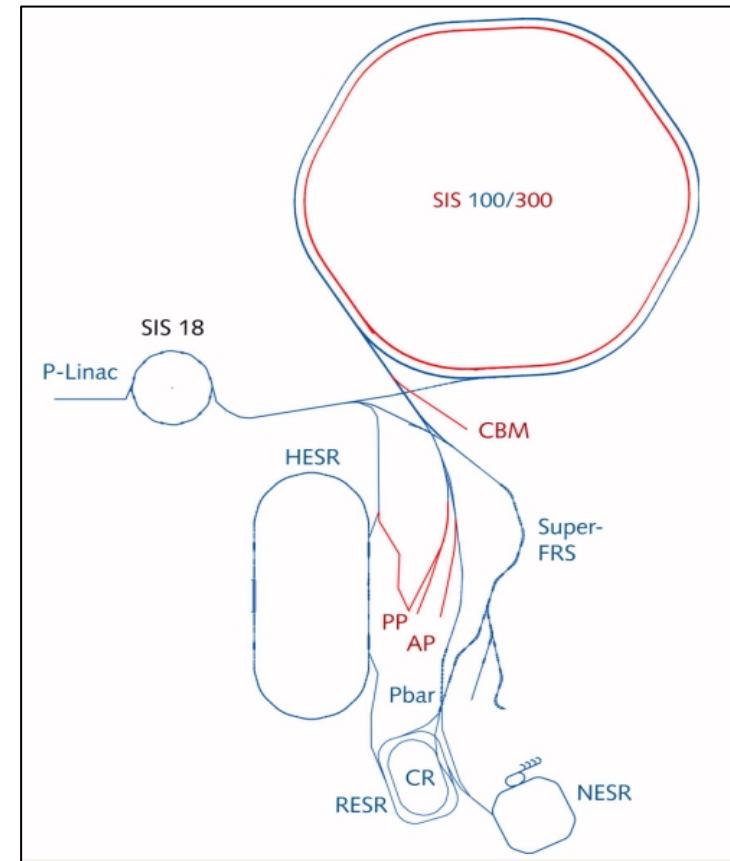
stage 1
(2007-2011)



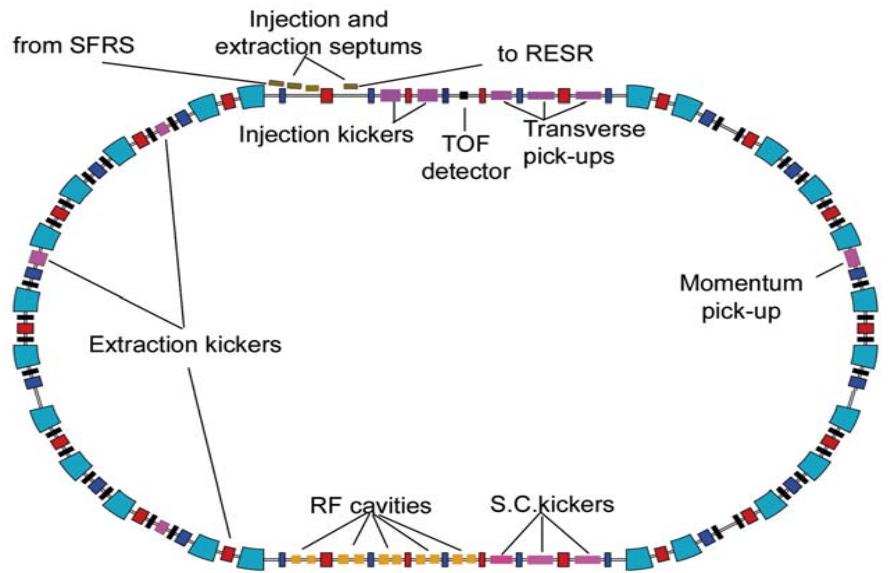
stage 2
(2011-2013)



stage 3
(2013-2015)



CR The Collector Ring



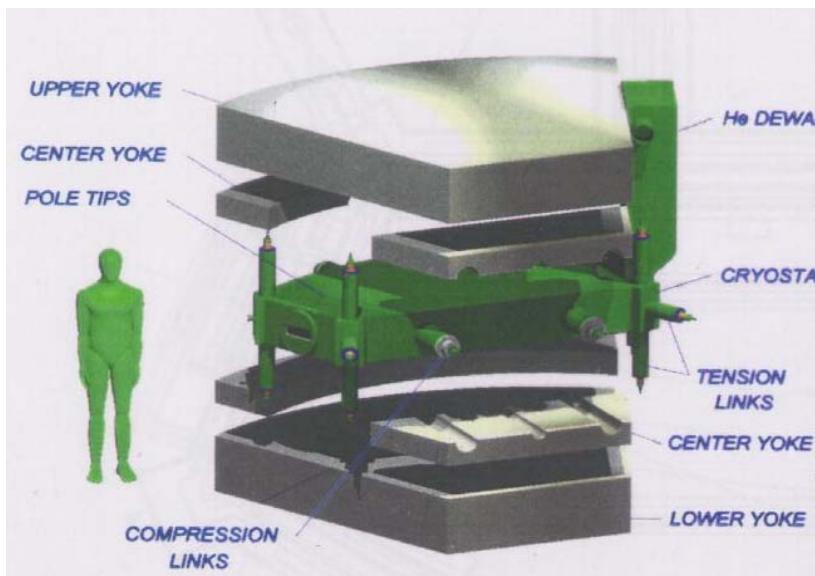
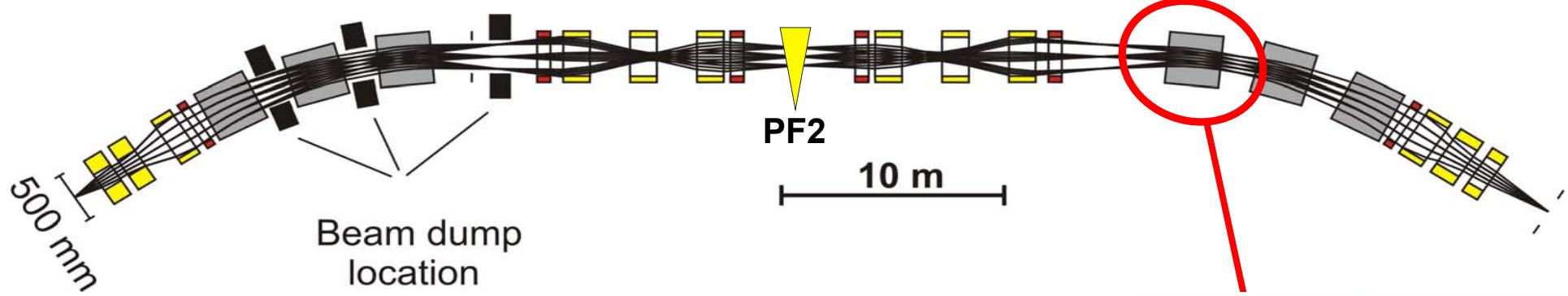
**dedicated ring for stochastic cooling,
optimized for large acceptance and fast cooling**

**circumference 206 m
magnetic bending power 13 Tm**

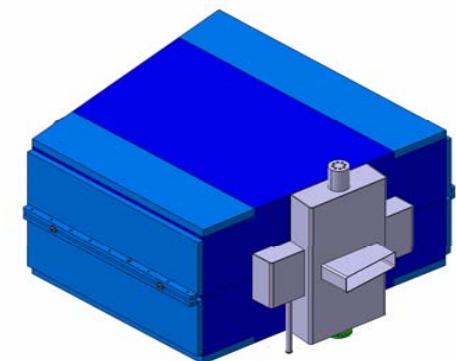
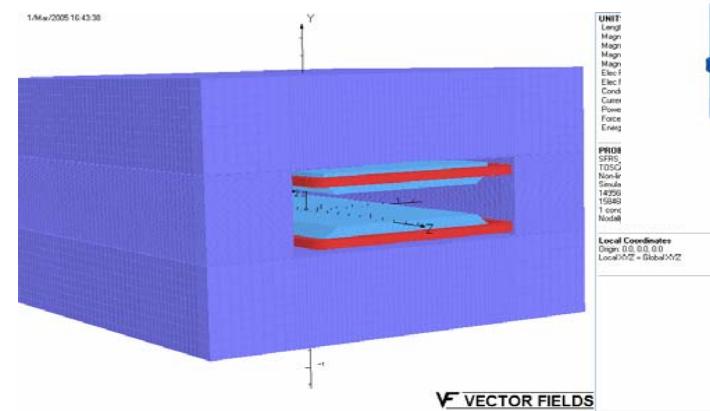
**TDR: only sc dipoles
option: cold arc**

CR	Magnet	Number of magnets	Magnet type	Field or Gradient	Effective Length/m	*Usable Aperture/m m	Max. Ramp Rate	Current (A)	Inductance (mH)	Total weight (kg)
2.5.2.1	Dipole	24	H-type superferric	0.8...1.6 T	2.126	380 x 140	—	166	34000	47500
2.5.2.6.3	horizontal	24'	auxilliary coils	200 Gs	—	380 x 140	—			

Superferric dipole of CR and Super-FRS

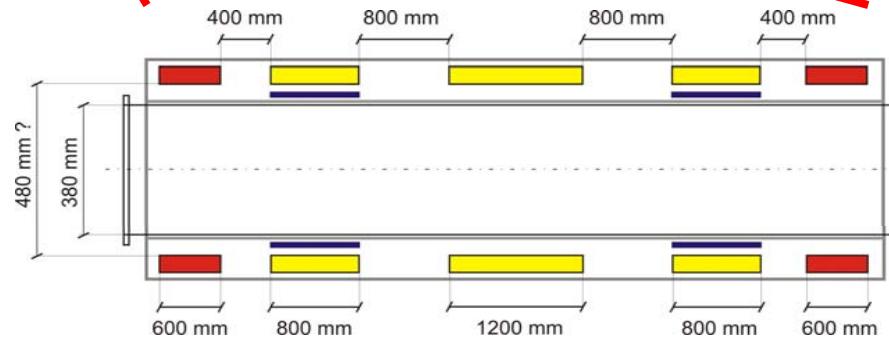
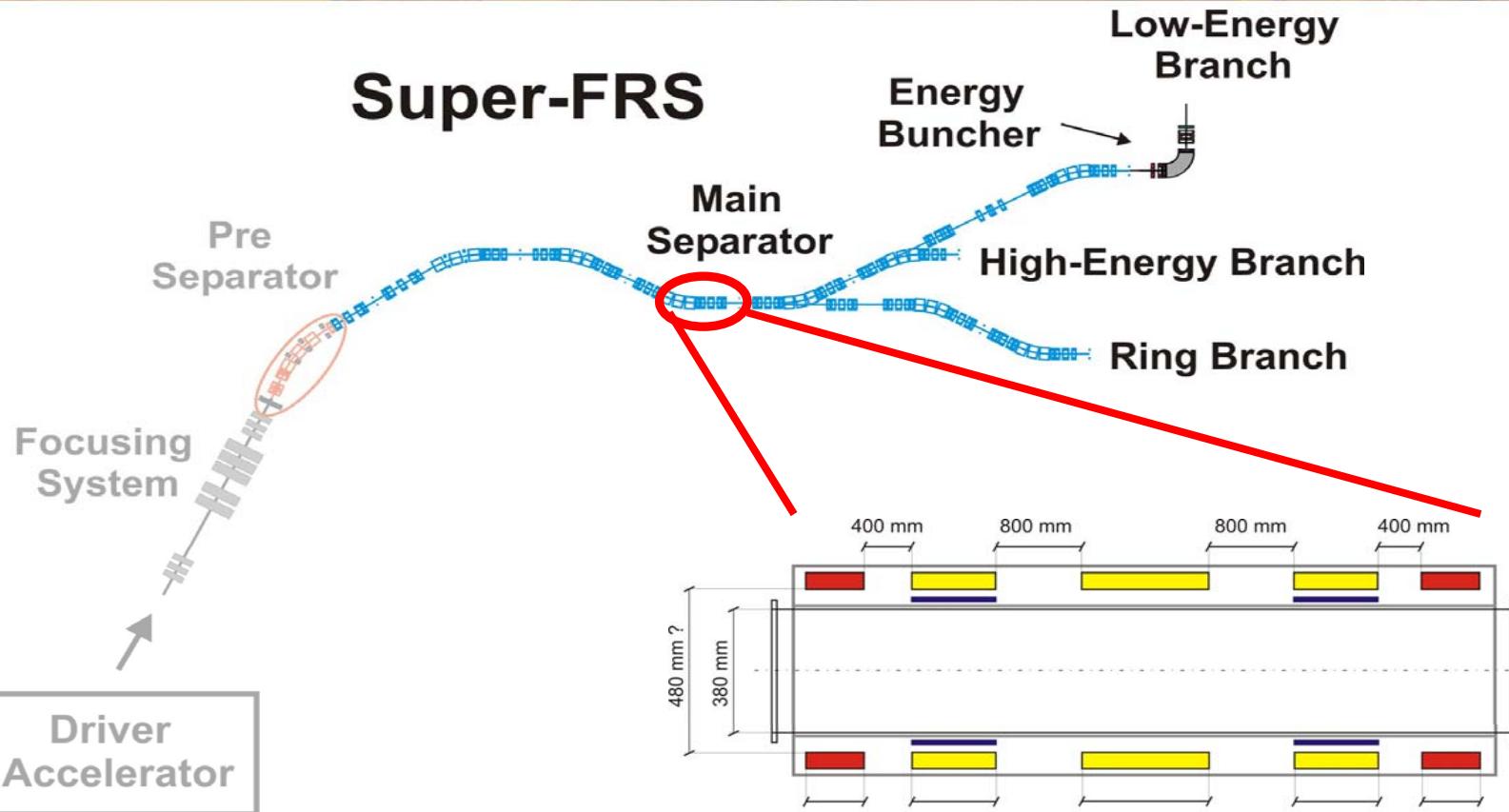


Existing superferric dipole for A1900
Fragment Separator, NSCL, MSU

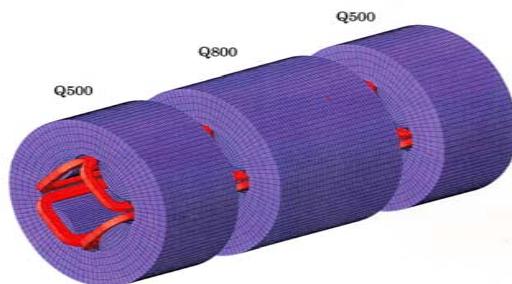


1.6 T, DC, large aperture
iron-dominated, warm iron, warm bore

Superferric Multiplets for the Super-FRS



Superferric
Triplet
(BigRIPS @
RIKEN)



Schematic view of the prototype quadrupole triplet

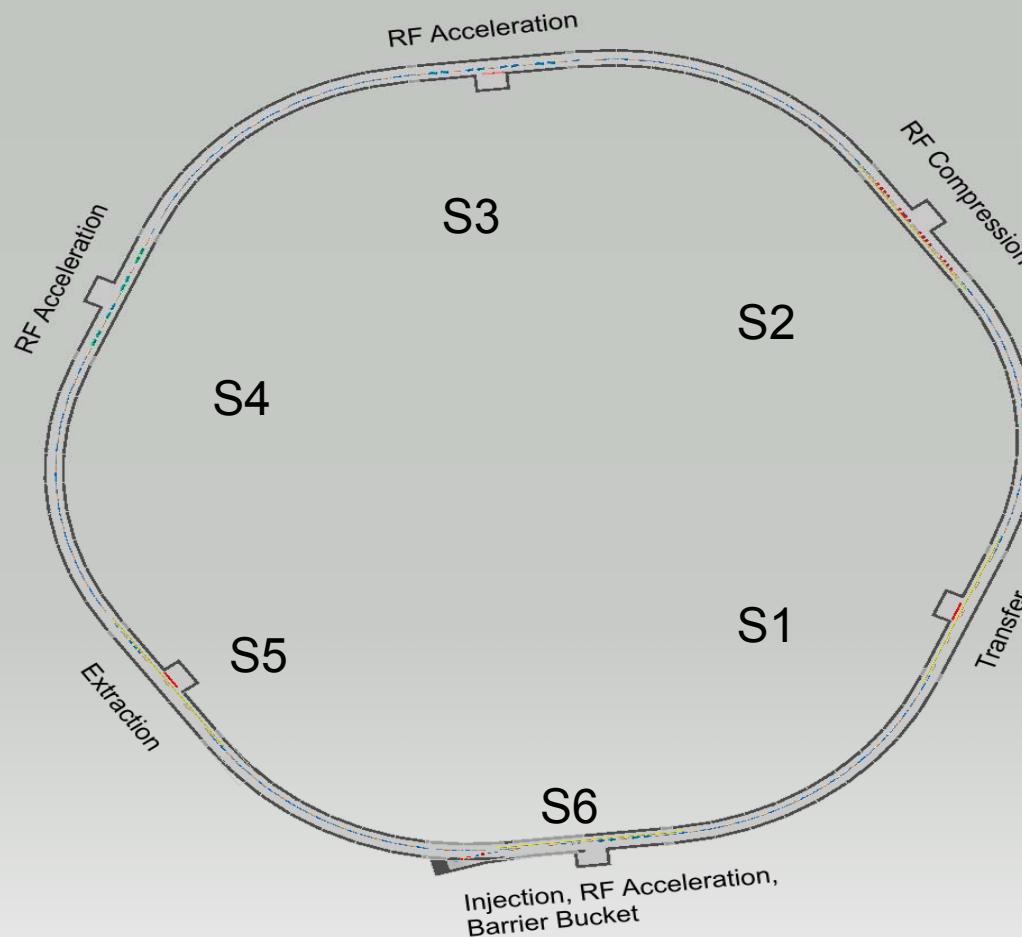
- Warm bore diameter of 38 cm
- cold iron, iron-dominated
- High pole-tip field (≈ 2.4 T)
- 17 Quadrupole triplet + separated sextupoles
- Octupole correction coils are embedded

Magnet Parameter SuperFRS



Super-FRS	Magnet	Number of magnets	Magnet type	Field or Gradient	Effective Length/m	*Usable Aperture/mm	Max. Ramp Rate	Current (A)	Inductance (mH)	Total weight (kg)
2.4.2.1	Dipoles									
2.4.2.1.2	Dipole 2	3	H-type, superferric	0.15...1.6 T	2.39	380 x 140	—	166	42700	56000
2.4.2.1.3	Dipole 3	20	(+1) [†]	H-type, superferric	0.15...1.6 T	2.04	380 x 140	—	166	36800
2.4.2.1.4	Dipole 4	4	H-type, superferric	0.15...1.6 T	2.43	600 x 200	—	200	50000	82000
2.4.2.2	Quadrupoles									
2.4.2.2.3	Quadrupole 3	32	(+2) [†]	Superferric	1...10 T/m	0.8	380 x 200	—	310	4240
2.4.2.2.4	Quadrupole 4	26	(+1) [†]	Superferric	1...10 T/m	1.2	380 x 200	—	310	6350
2.4.2.2.5	Quadrupole 5	2	Superferric	1...8 T/m	0.8	380 x 260	—	310	4240	11000
2.4.2.2.6	Quadrupole 6	5	Superferric	0.5...5 T/m	1.0	600 x 400	—	300	10000	TBD
2.4.2.3	Multipoles									
2.4.2.3.2	Hexapole 2	36	(+2) [†]	Superferric	1.5...15 T/m^2	0.6	380 x 200	—	264	744
2.4.2.3.3	Octupole1	32	(+2) [†]	Correction coils	5...45 T/m^3	0.8	380 x 200	—	432	25
2.4.2.4	Steering magnets									
2.4.2.3.1	Steering magnets 1	8	Surface coils		0.3	380 x 200	—	TBD	TBD	TBD
* (horizontal x vertical) or diameter if c † the number in bracket indicates the number of magnets to be built as prototype magnets during the R&D phase.										
These numbers are not counted in the Super-FRS cost book for the construction phase, since we intend to use this										

SIS 100: distribution of Technical Systems

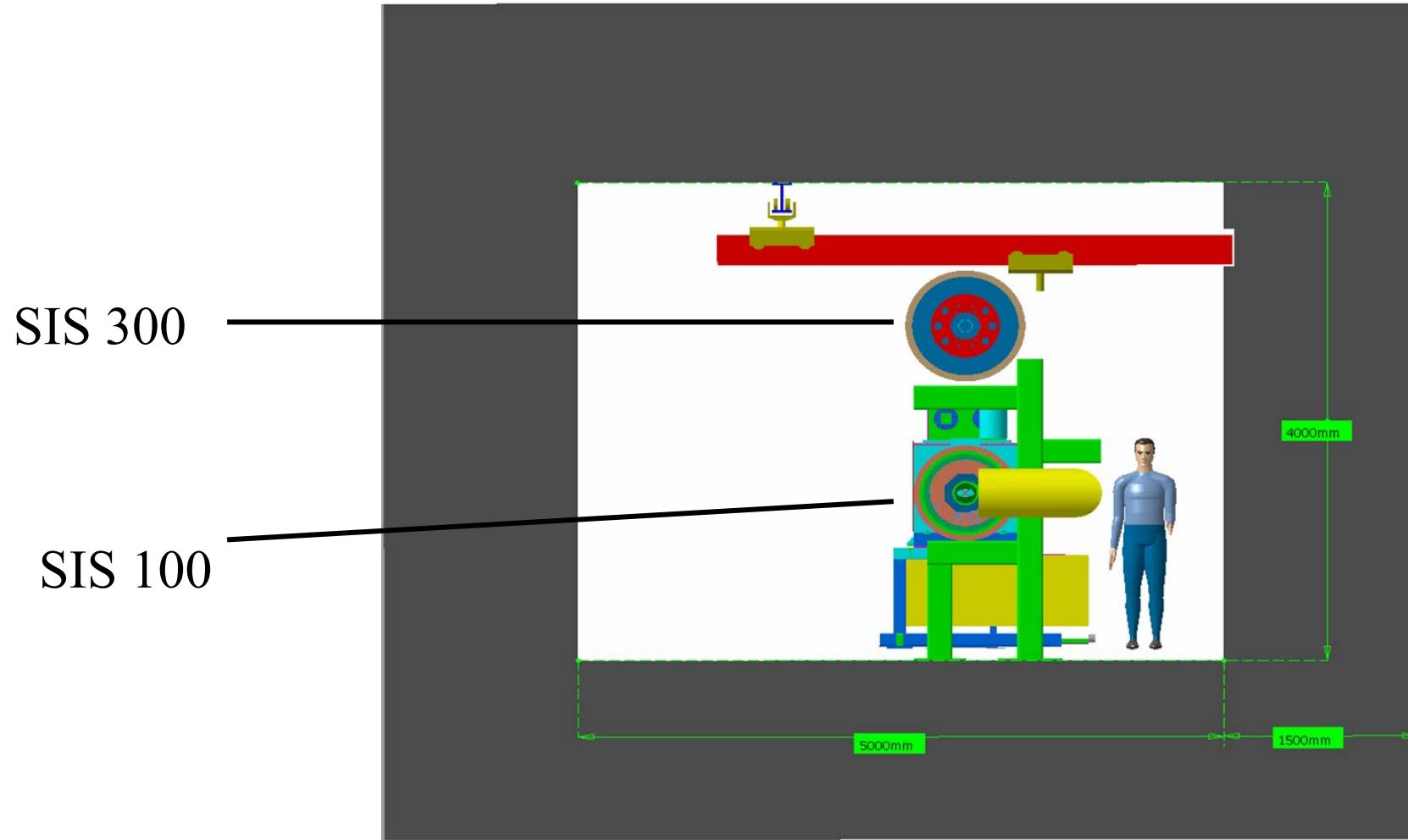


1. Rf Compression
2. Rf Acceleration
3. Rf Acceleration
4. Extraction
5. Injection System plus RF Acceleration and Barrier Bucket
6. Transfer to SIS300



• cold arcs
• warm straight sections
(but cells with sc quads)

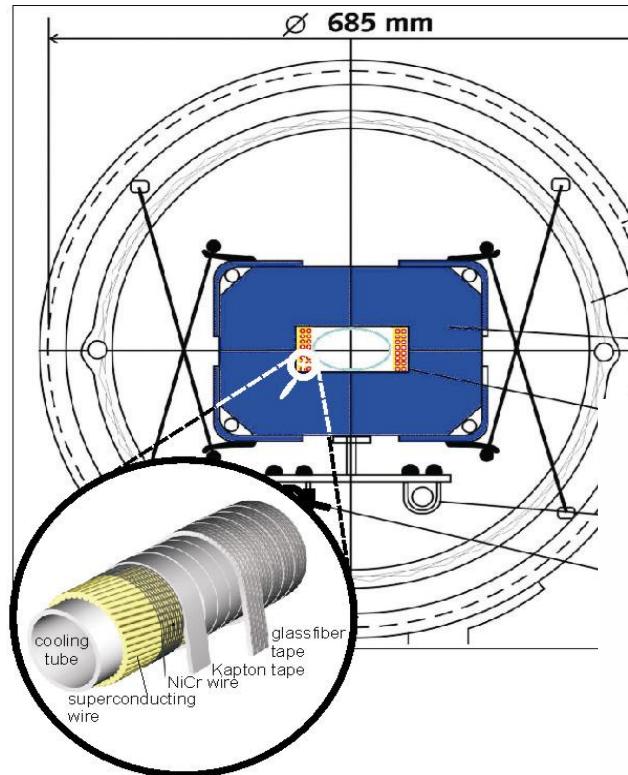
Tunnel Cross Section SIS 100 / 300



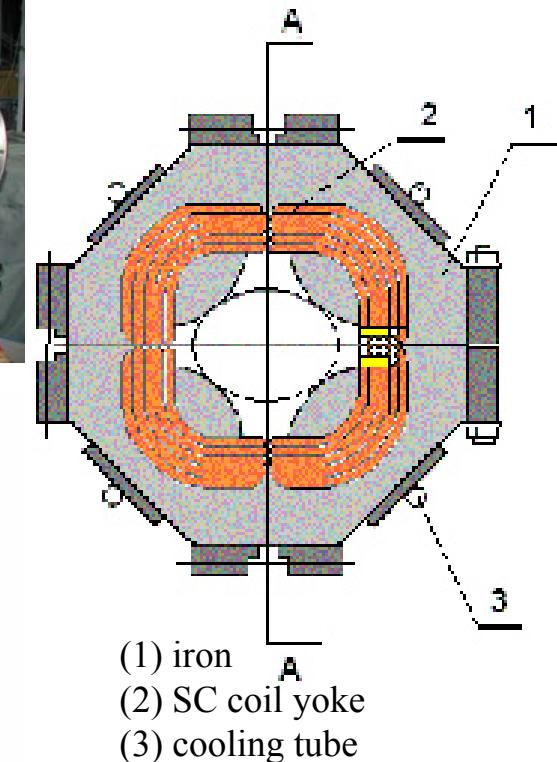
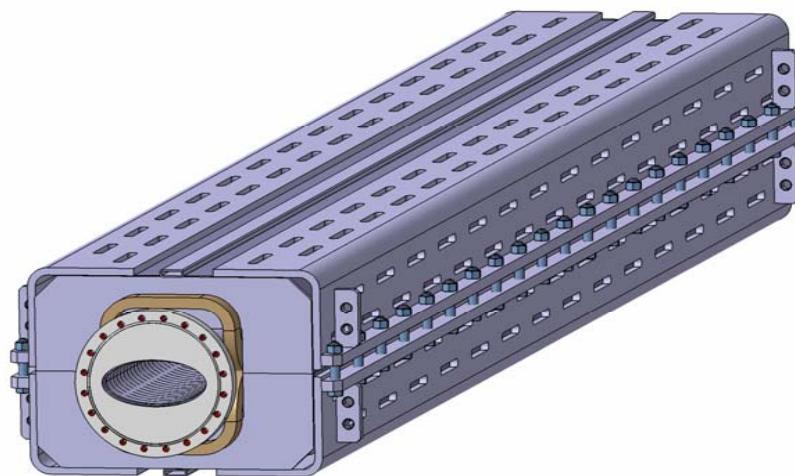
SIS100 magnets (iron-dominated,cold iron)



dipole (2T, 4T/s)



quadrupole (33.4 T/m, 66.8 T/m/s)



Magnet Parameter SIS 100



SIS100	Magnet	Number of magnets	Magnet design /type	Max. field (T) , gradient (T/m), etc.	Effective length (m)	Useable horizontal / vertical aperture (mm)	Max. ramp rate (T/s,...)	Current (A)	Inductance (mH)	Total weight (kg)
2.8.2.1	Dipole	108 + 1	superferric wf	2.1	2.756	130x60	4	7700	2	1900
2.8.2.2	Quadrupole	168 + 3	superferric	35	1.1	135x65				
2.8.2.3	Correction Magnets									
2.8.2.3.1	Error Comp. Quadrupoles	12	air coil	0.5 T/m	0.5	150		100	30	
2.8.2.3.2	Chromat. Sextupoles	48	air coil	200 T/m2	0.5	135x65		100	90	
2.8.2.3.3	Error Comp. Sextupoles	12	air coil	200 T/m2	0.5	150				
2.8.2.3.5	Error Comp. Octupoles	12	air coil	3000 T/m3	0.5	150				
2.8.2.4	Steerers									
2.8.2.4.1	Comb. h/v Steerers	84	comb. h/v	0.2	0.5	135x65	0.4	2x100	2x10	
2.8.2.5	Magnetic Septa									
2.8.2.5.4	Extraction Septum 2	1		2.0 T	3.5	80 / 30				
2.8.2.5.6	Transfer Septum 2	1		2.0 T	3.5	80 / 30				

Magnet Parameter SIS 300



SIS300	Magnet	Number of magnets	Magnet design /type	Max. field (T) , gradient (T/m), etc.	Effective length (m)	Useable horizontal / vertical aperture (mm)	Max. ramp rate (T/s,T/m/s...)	Current (A)	Inductance (mH)	Total weight (kg)
2.12.2.1	Dipole	108 + 1	costheta	6	2.908	86/86	1	6350	37.4	5500
2.12.2.2	Quadrupole	168 + 5	cos2theta	90	1	86/86	15	7830	4.4	2115
2.12.2.3	Multipole Correctors									
2.12.2.3.1	Error Comp. Quadrupoles	12	cos2theta	1.5 T/m	0,75	86				
2.12.2.3.2	Chromat. Sextupoles	48	cos3theta	600 T/m2	0,75	86	1			
2.12.2.3.3	Error Comp. Sextupoles	12	cos3theta	600 T/m2	0,75	86				
2.12.2.3.4	Extr. Sextupoles	12	warm iron		0,865	100				
2.12.2.3.5	Error Comp. Octupoles	12	cos4theta	9000 T/m3	0,75	86				
2.12.2.4	Steerers									
2.12.2.4.1	Comb. h/v Steerers	78	costheta/comb. h/v		0.75	86				
2.12.2.5	Magnetic Septa									
2.12.2.5.2	Transfer Septum 2	1	see SIS100	2 T	3,5					
2.12.2.5.6.	Extraction Septum 3	1	Jefferson Type	2.7 T	4					
2.12.2.6	Quadrupoles Transfer System									

HEBT: 100 and 300 Tm beamlines



SIS100-like
beam lines:

- from SIS100 to:
 - machine dump
 - Super-FRS,
 - pbar-Target
 - AP-Cave
 - PP-Cave (1)
 - PP-Cave (2)

- from SIS300 to:
Super-FRS



SIS300-like
beam lines:

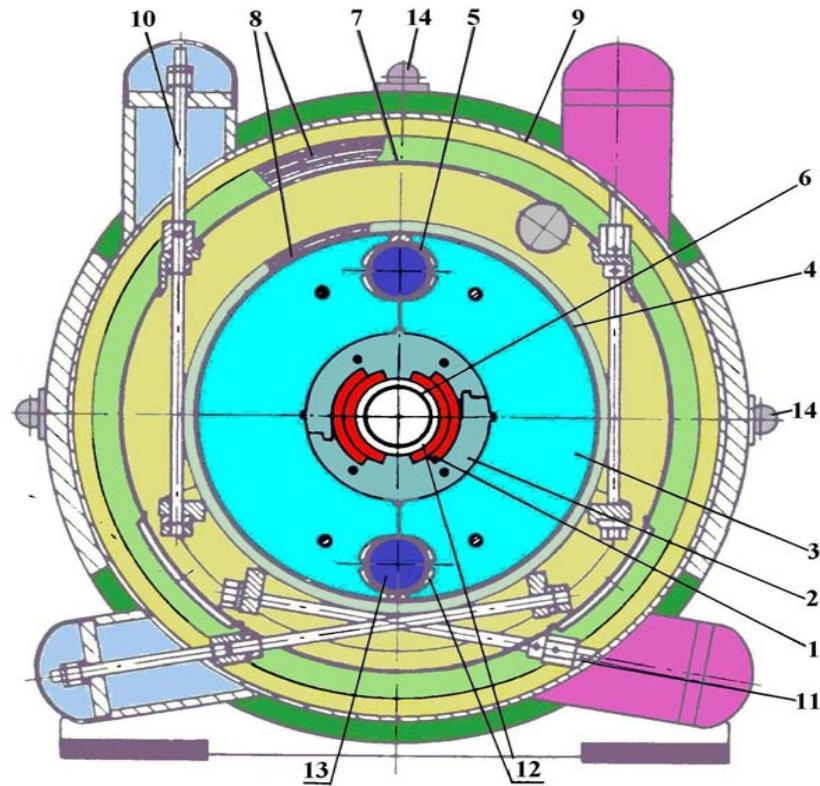
- from SIS300 to:
 - machine dump
 - CBM-Cave

same
magnets as
in SIS 100
and SIS 300

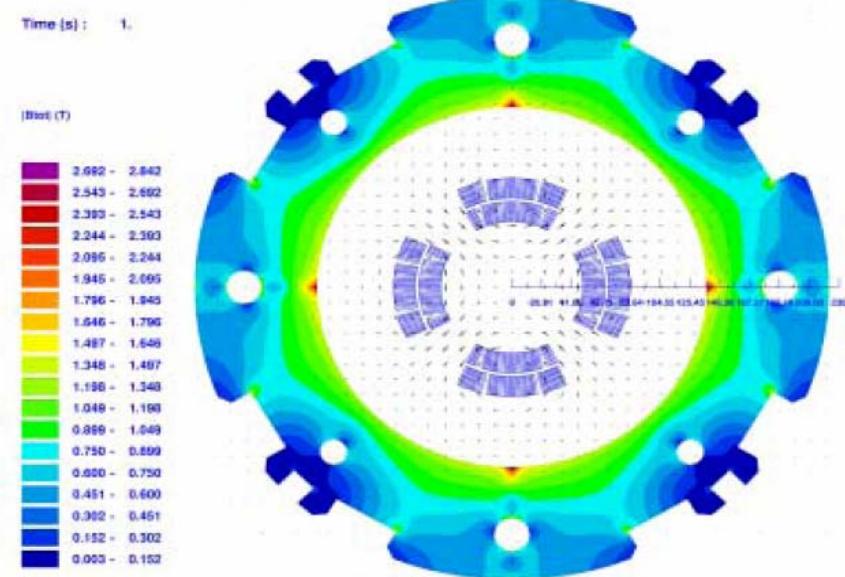
SIS300 magnets (coil-dominated, cos theta, 2-layer-coil, cored Rutherford-cable)



**dipole (6T, 1T/s)
100 mm coil ID
3 m long**



**quadrupole (90T/m, 15T/ms)
100 mm coil ID
1 m long**



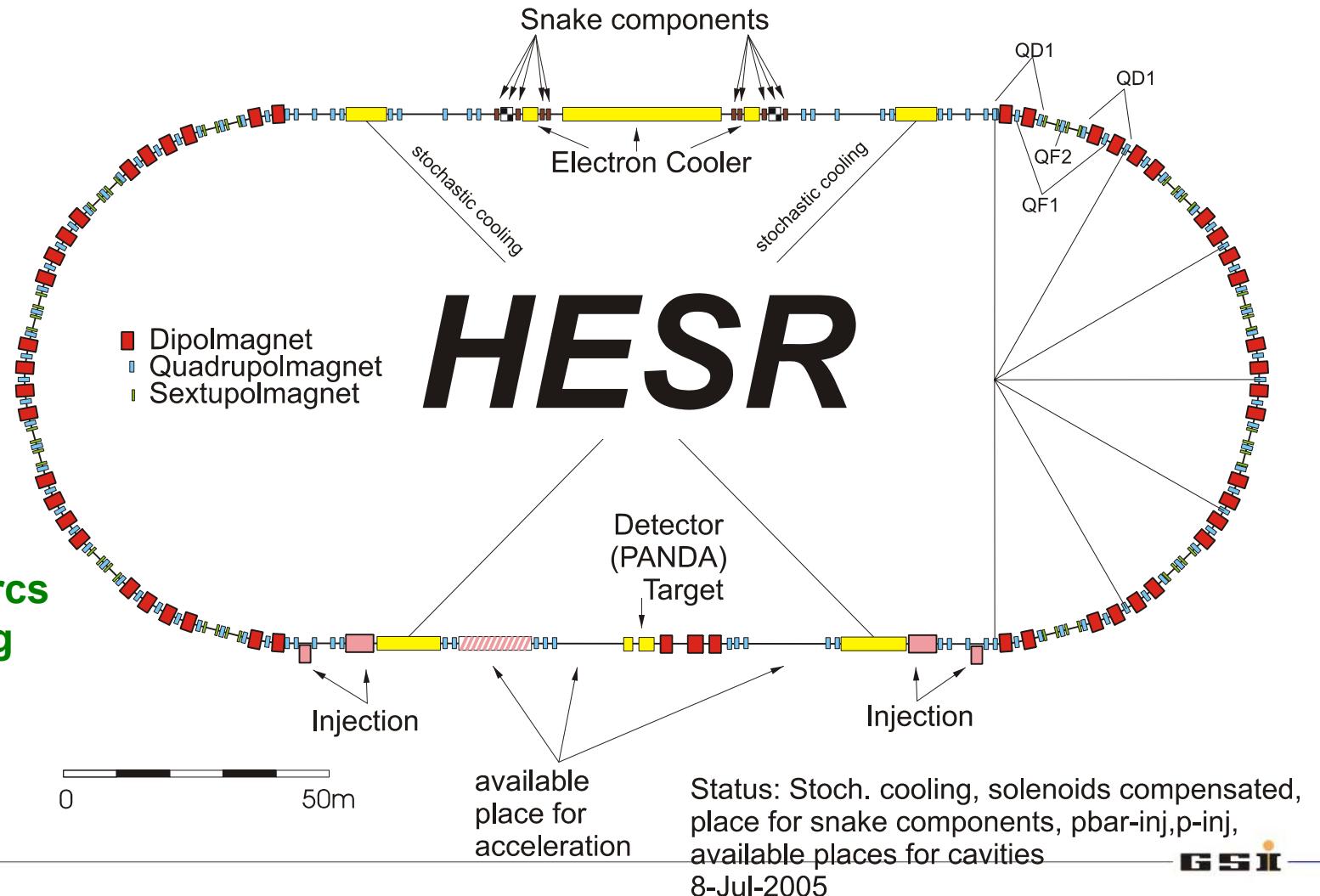
Alternative: 4.5T, 8m, curved ?

High Energy Storage Ring (HESR)



Designed by the HESR consortium
(FZ Jülich, TSL Uppsala, GSI)

by courtesy of R. Tölle, FZ Jülich

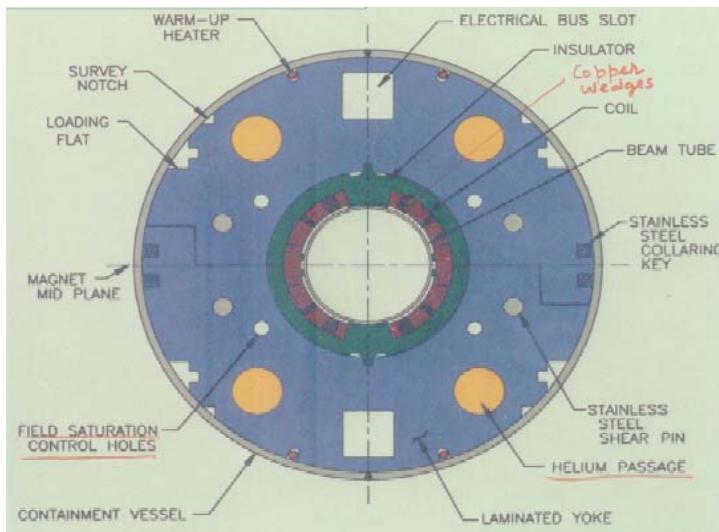


all magnets in the arcs
are superconducting
magnets!

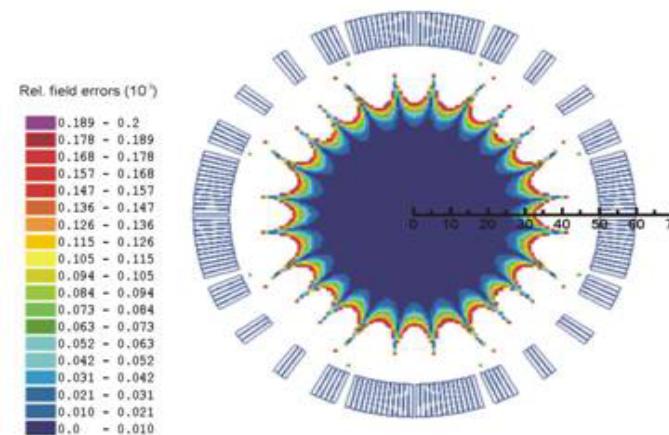
HESR cos θ -magnets: RHIC-type magnets



dipole, 3.6 T, low ramp rate
cos θ -magnet, one-layer coil
(RHIC D0), curved (13.7 m)?

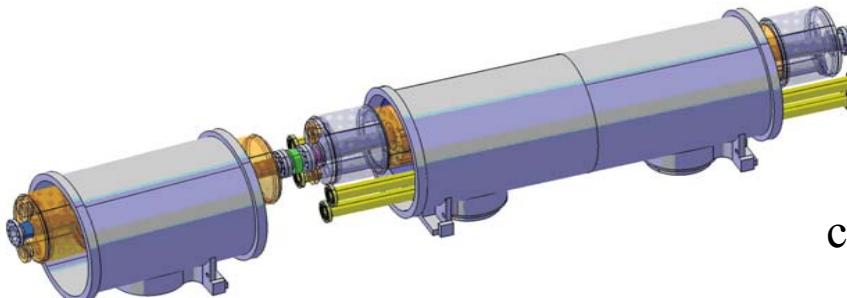


quadrupole, 60 T/m



MULTipoles @ 35 mm	
b 2:	10000.00000
b 6:	-0.00074
b10:	0.00001
b14:	-4.59065
b18:	1.01439

Magnets inside cryostats



courtesy of R. Tölle, R.
Eichhorn, FZ Jülich



Magnet Parameter HESR



HESR	Magnet	Number of magnets	Magnet design /type	Max. field (T), gradient (T/m), etc.	Effective length (m)	Useable horizontal / vertical aperture (mm)	Max. ramp rate (T/s,...)	Current (A)	Inductance (mH)	Total weight (kg)
2.11.2.1	Dipoles	48	costheta, RHIC D0	3,6	1,8	89	0,025	5000	10	tbd
2.11.2.2	Quadrupoles	112	costheta	60	0,5	89		5000	10	tbd
2.11.2.3	Sextupoles	48	costheta	460	0,5	89		5000	10	tbd
2.11.2.4	Correctors	tbd	costheta	tbd	tbd	89		tbd	tbd	tbd

R&D Status Main Magnets: Summary



CR / SuperFRS	
dipole	2D / 3D magnetic design, preliminary coil design, contract for full length prototype signed (China FAIR Group)
SuperFRS	
multiplet	2D/3D magnetic design, contract with Toshiba for conceptual design study signed.
SIS 100 / HEBT	
dipoles	EU-FP6 design (2005-2007) -> full length prototype (2x to be ordered)
quadrupoles	2D/ 3D magnet design, 2 models (Nuclotron type) tested
SIS 300 / HEBT	
dipoles	2D magnetic design completed, 3D design in progress (IHEP, CERN), technical design 3/06 (IHEP), models to be built
quadrupoles	only preliminary work (CEA Saclay)

no design started yet:

- fine focusing magnets in front of the targets
- all correctors / steering magnets
- many sc (?) septa

SIS 300

- R&D recommended based on modified lattice
→ bent dipoles !!

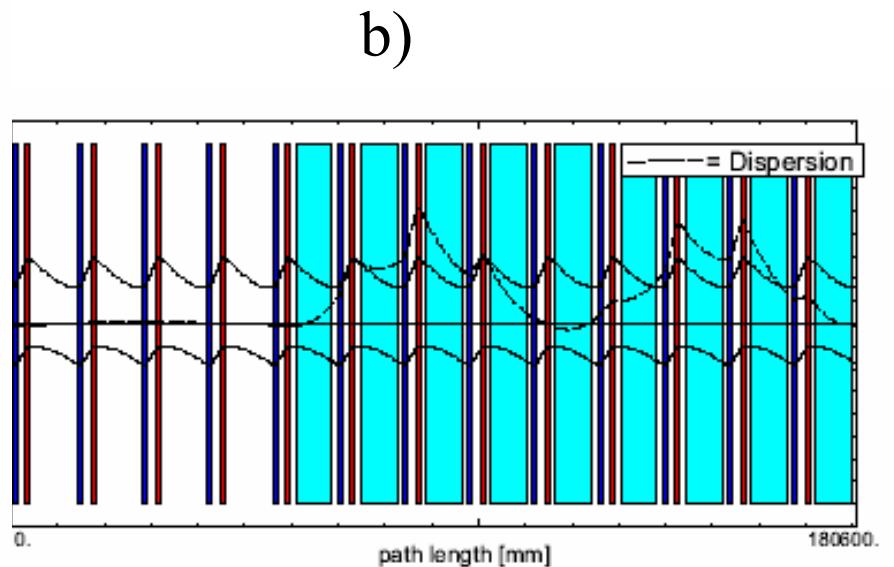
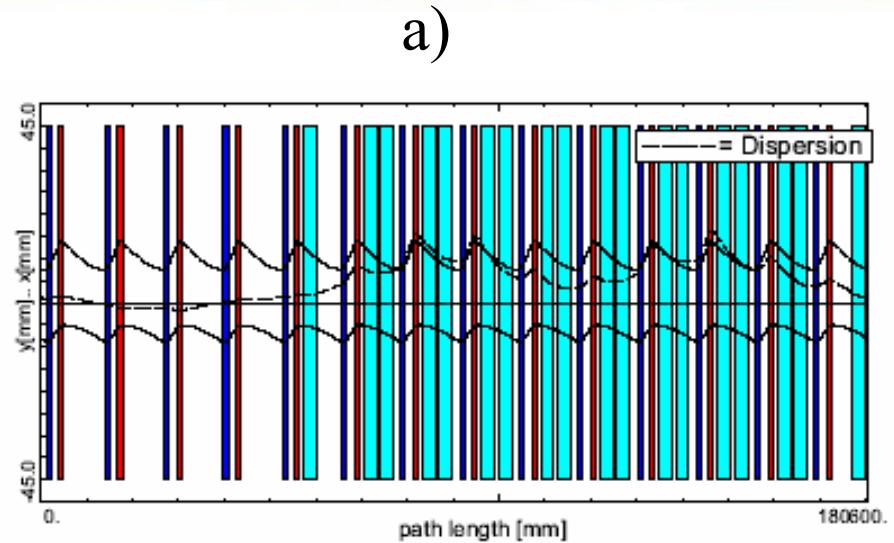
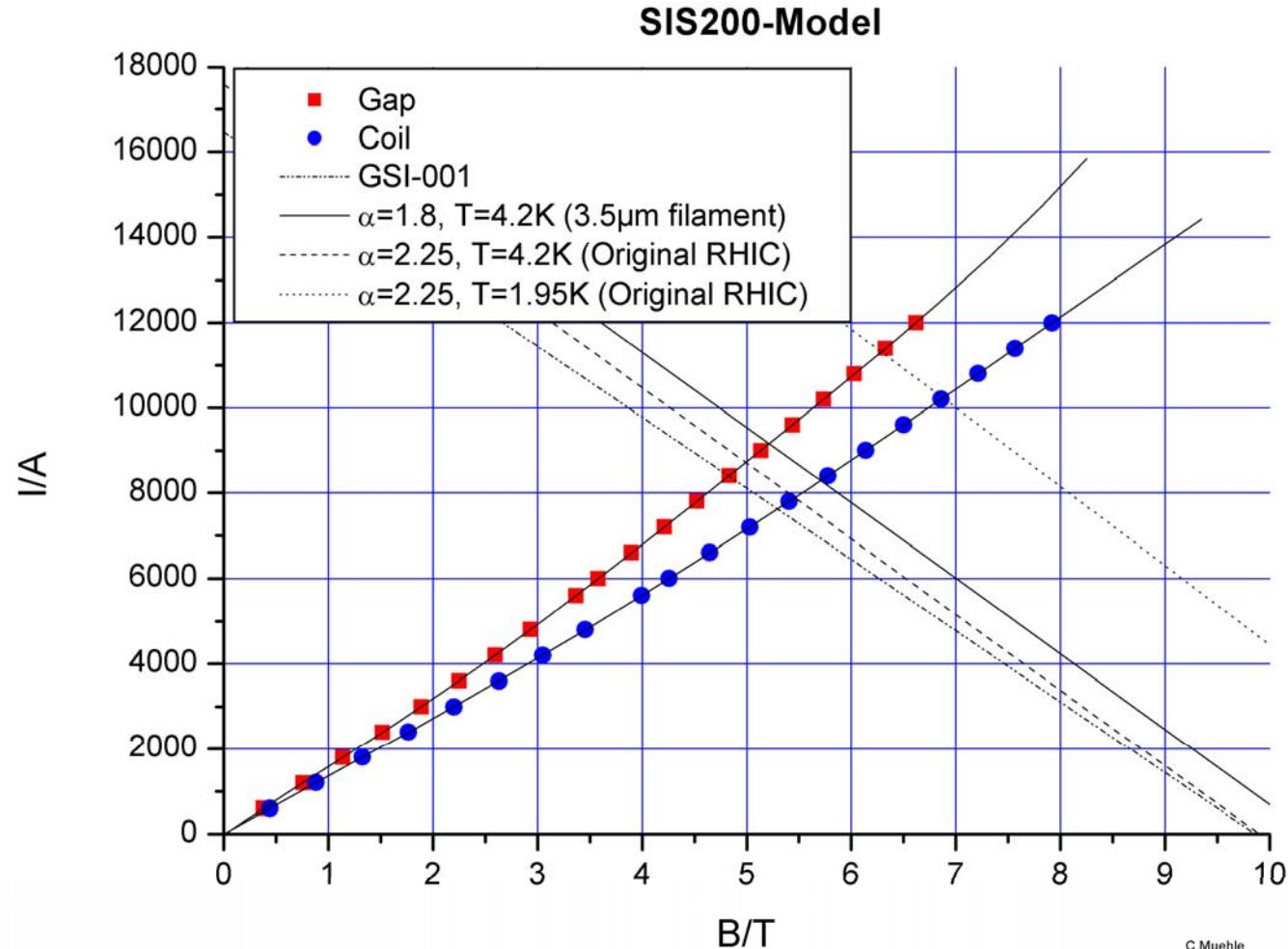


Table 1: Comparison of the lattice parameters.

SIS300 lattice	type a)	type b)
Number of superperiods	6	6
Number of regular cells	78 ¹	78
Dipole Magnets		
Type	Straight, short	Bent, longer
Coil	two layer coil	one layer coil
Number of dipole magnets	108	54
Magnetic field [T]	6	4.5
Length [m]	2.908	7.755
Bending radius [m]	50.00	66.667
Bending angle [deg]	3 1/3	6 2/3
Free aperture h / v [mm]	86 / 86 (circular)	78 / 78 (circular)

open issues: magnet design



C.Muehle

open issues: low loss wire design



existing designs (to be used for models)

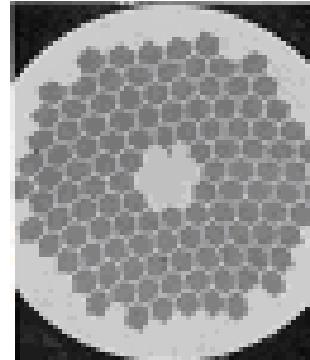


EAS double stacked

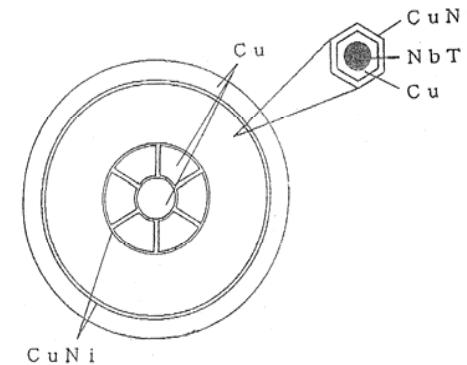


Alstom single stacked

design options



CuMn interfilamentary matrix



CuNi interfilamentary matrix

Wire parameters



Wire	Matrix	Fil. Dia. (μm), Fil. number	Matrix/NbTi	Stacking
EAS	Cu	4.3, 12318	1.75	double
Alstom	Cu	3.5, 19200	1.9	single
CuMn	Cu,Cu- 0.5%Mn	2.5, 40000	1.7	double
CuNi (1)	Cu, Cu-10%Ni	4.7, 13000	1.4	single
CuNi(2)	Cu, Cu-10%Ni	2.5, 35000	2.1	double

0.825 mm diameter wire, $J_c=2700 \text{ A/mm}^2$ @ 5 T, 4.2 K, 5 mm twist pitch

cable

present choice: cored cable ($R_c = 20 \text{ mOhm}$), $R_a = 200 \mu\text{Ohm}$

optimum curing cycle ?

heat transfer measurements

current distribution (joints)

mechanical stability

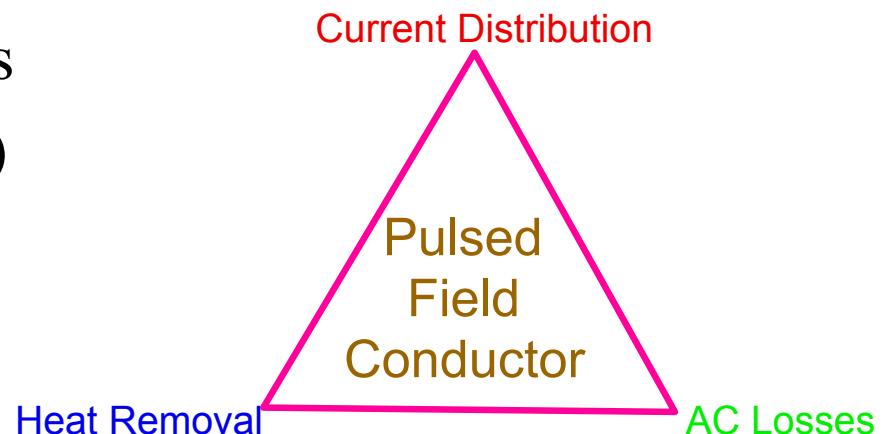
fatigue /coil restraint

SIS 100 (helium tube)

SIS 300 (collar)

bent dipole ??

HTS-leads for pulsed applications, busbars



courtesy of P. Bruzzone

wire and cable

- I_c (wire, cable)
- Magnetization (time dependent)
- Resistances (RRR , R_a , R_c)
-

magnet cold testing and magnetic measurement

Testing at CERN (or other locations):



- Development of components
 - fast integrator
 -
- supply of equipment
 - calibrated coil probes
 - full systems (polarity meters, moles for industry, stretched wire...)
- series tests
 - resistive magnets
 - instead of industry
 - superconducting magnets
 - only cryostated magnets
 - SIS 300, HESR, (SIS 100)
 - SM18 and block 4

Testing at CERN (or other locations):



Pros

- Existing facilities
- Experienced personnel (if kept)
- Experience in data quality assurance
(follow up, data storage, data reduction, EDMS, ...)

Cons

- Transporting cryostated magnets
 - successful test for arc SSS
 - failed for LSS FNAL → CERN
- CERN test facility needs many adaptions
 - feed boxes
 - helium supply: two phase flow, forced flow with 150 g /s

→ cost issue !!!
- Only prototype test facility at GSI after the project

Conclusions



- ➊ For many magnets no design work has started yet
- ➋ Many open R&D issues
- ➌ Testing scenario to be decided
- ➍ Schedule is very tight