JÜLICH
FORSCHUNGSZENTRUM

Status of the Main Magnets for HESR

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EDMS 1036594

Overview

- Types of Magnets, Status of Work
  - Dipoles (44)
  - Quadrupoles (84)
  - Sextupoles (60)
  - Steerer (48)
- Work to be done (Problems and Possible Solutions)
- Personnel
  - U. Bechstedt FZJ IKP
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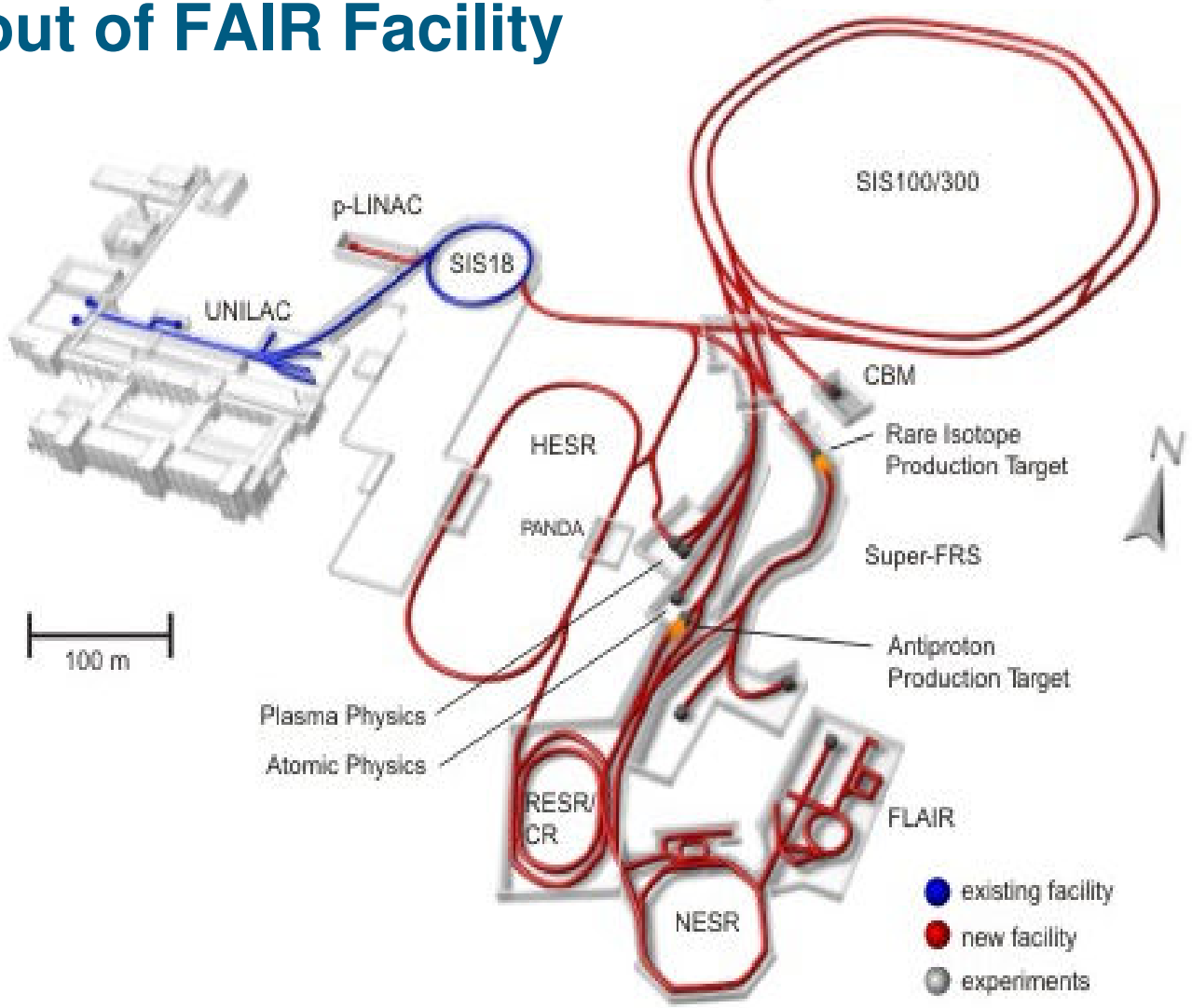
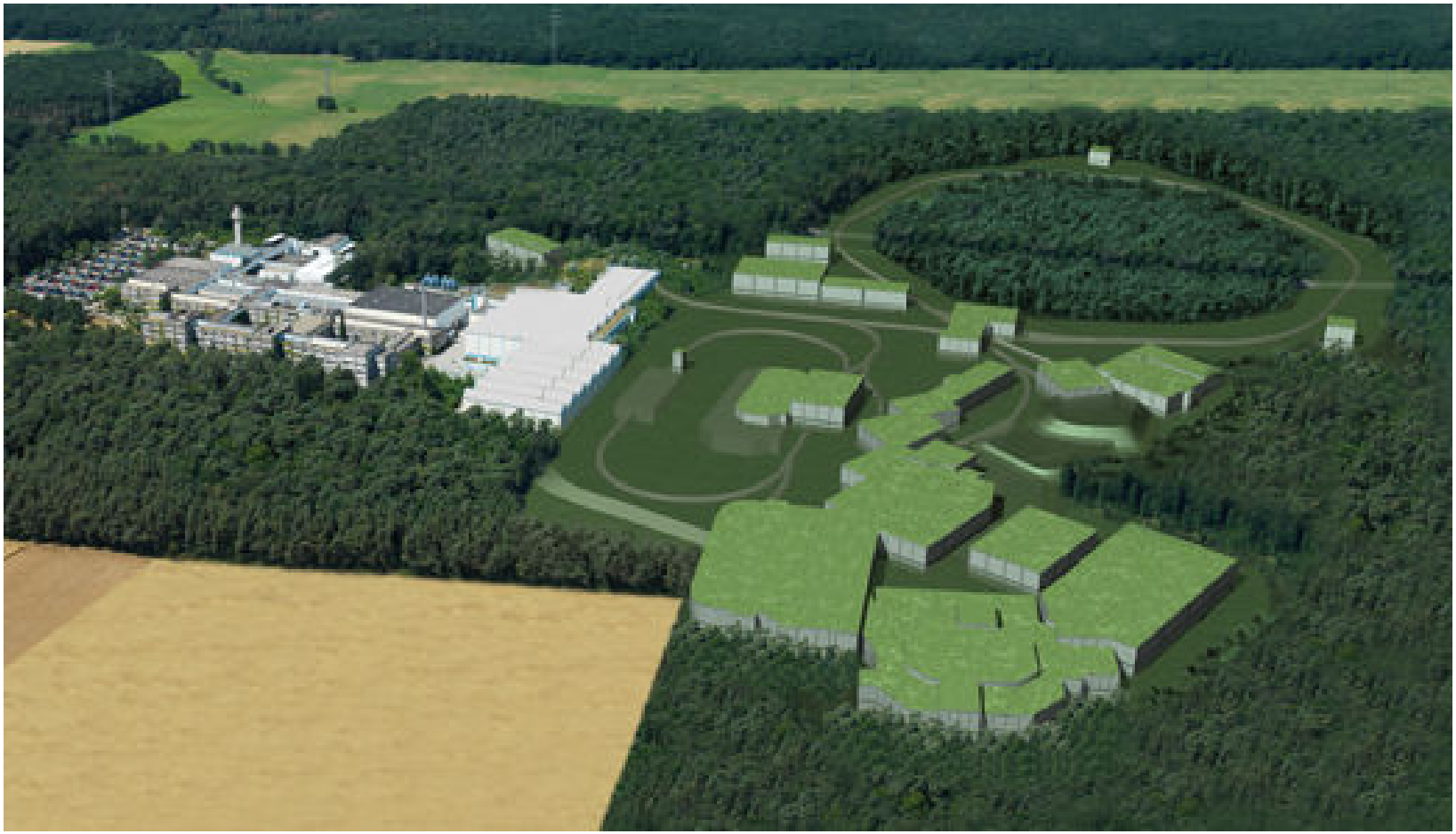
  - G. de Villiers iThemba LABS South Africa, Project code SUA 06/003

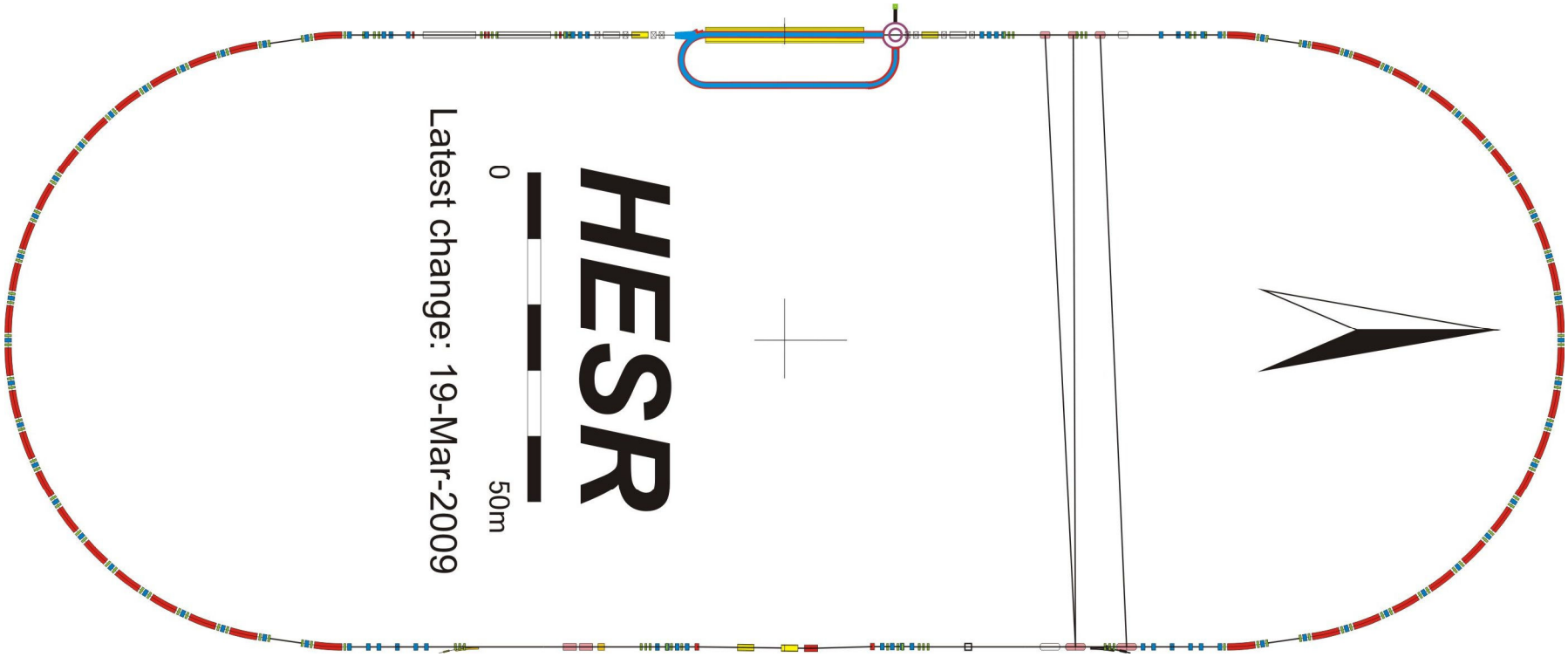
Layout of FAIR Facility



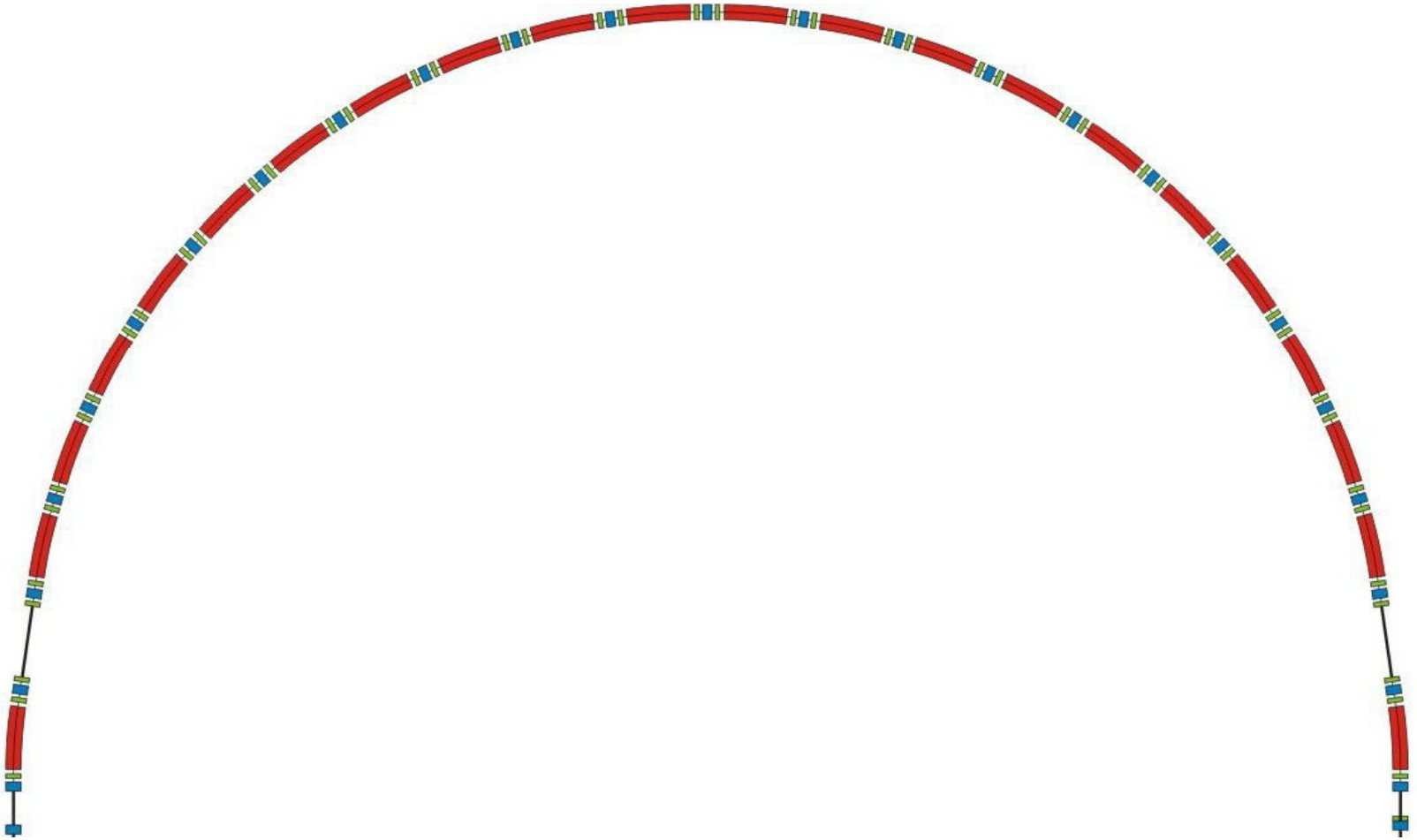
Civil Construction



Lattice of HESR



Arc of HESR



The PANDA Experiment (Proton ANtiproton DArmstadt)

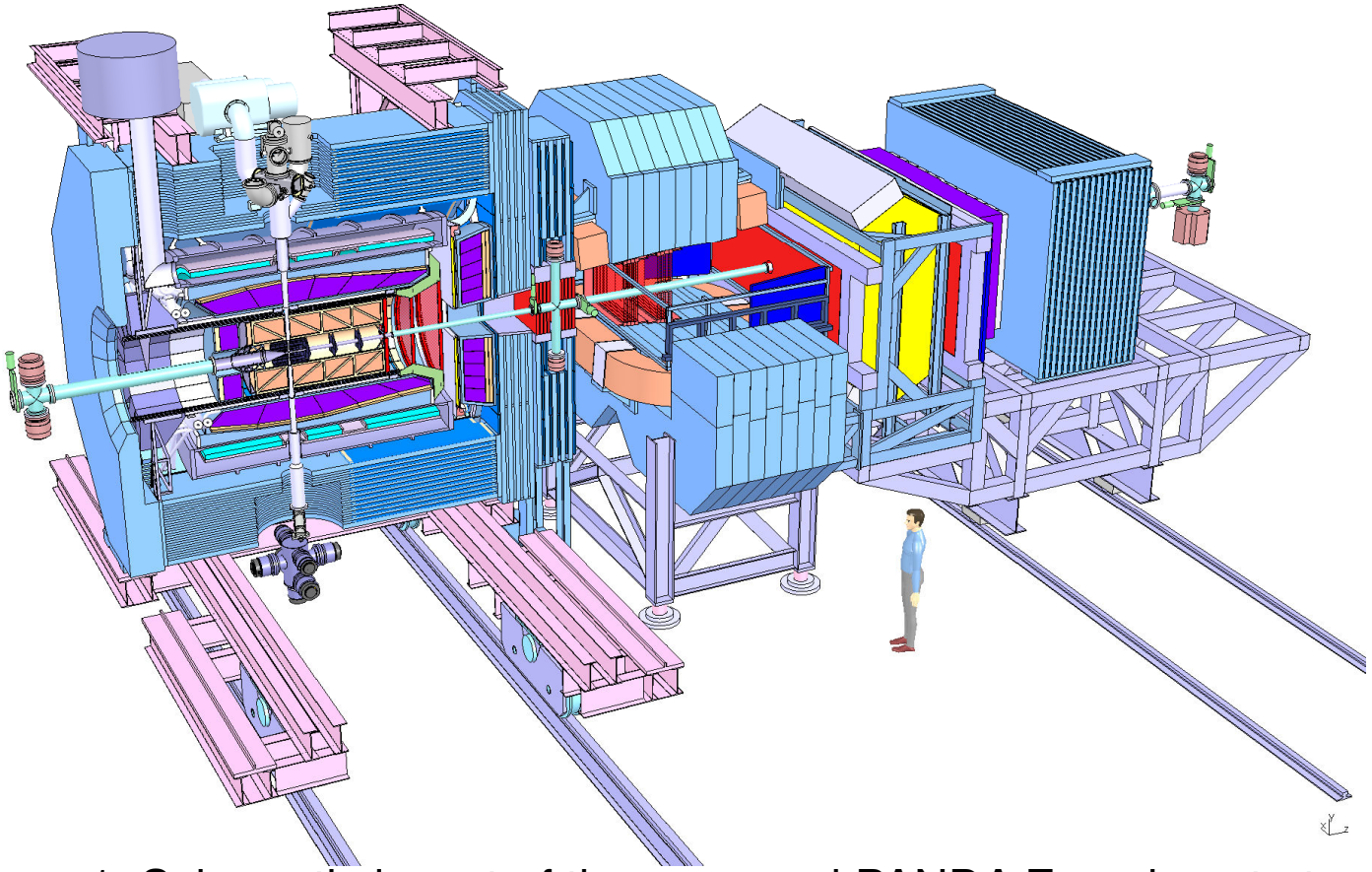


Figure 1: Schematic layout of the proposed PANDA Experiment at FAIR. The antiproton beam enters the detector from the left. The Target Spectrometer is complemented by a Forward Spectrometer to ensure full phase space coverage.

Basic Specs for Dipole Design

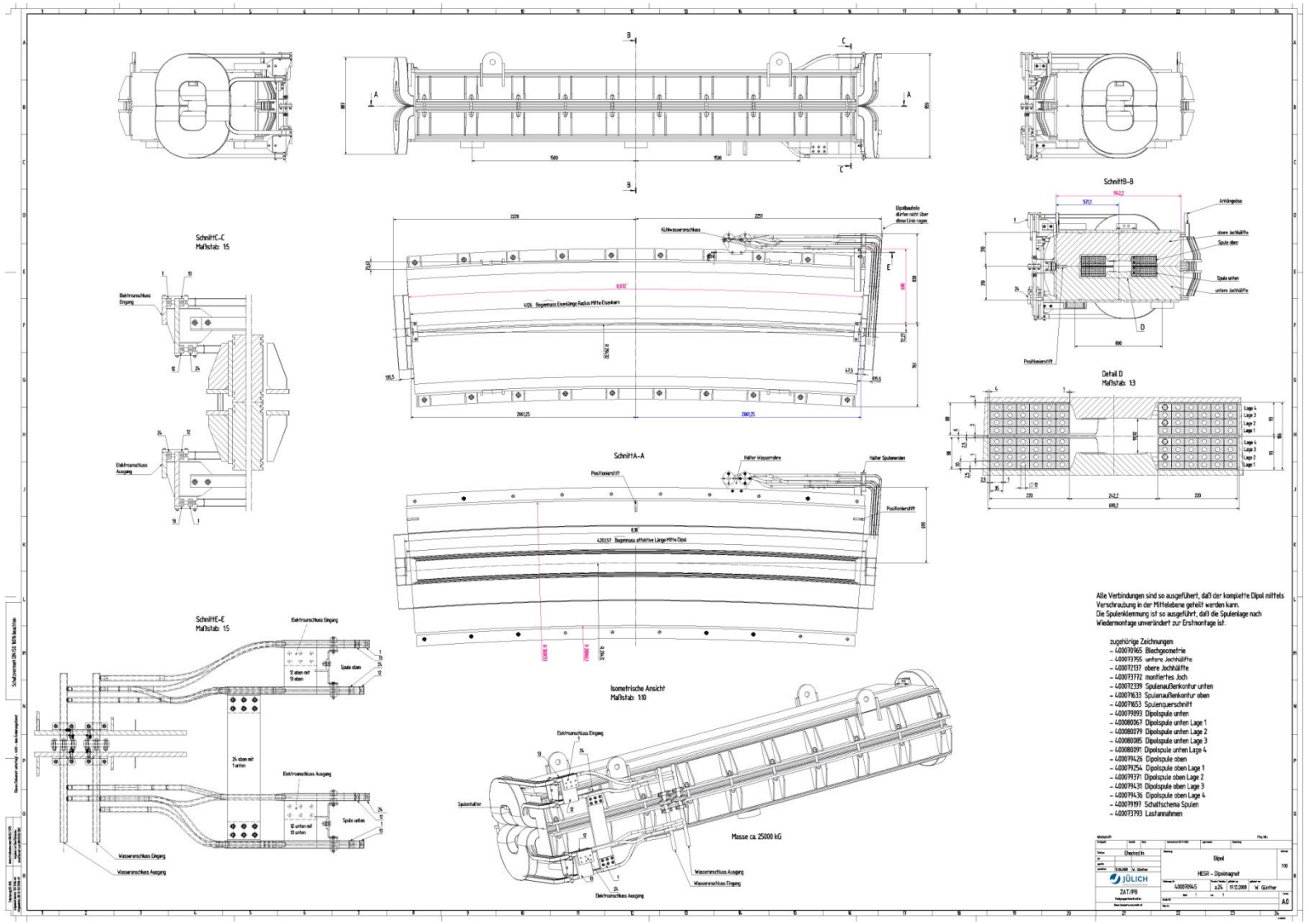
magnetic and mechanical specs		
Gapheight	100	mm
Beam radius max	45	mm
p min	1,5	GeV/c
p injection	8,9	GeV/c
p max	15	GeV/c
B rho max	50,03	Tm
B max (gap)	1,7	T
B max (iron)	1,5	T
B rho min	5,00	Tm
B min (gap)	0,17	T
B rho injection	29,69	Tm
B injection	1,01	T
good field region diam.	90	mm
Field quality dB/B	0,0001	
L eff	4,20	m
L iron	4,126	m
Bending angle	8,18181818	deg
Bending radius	29,432126	m
number of magnets	44	

Parameters of the Dipoles

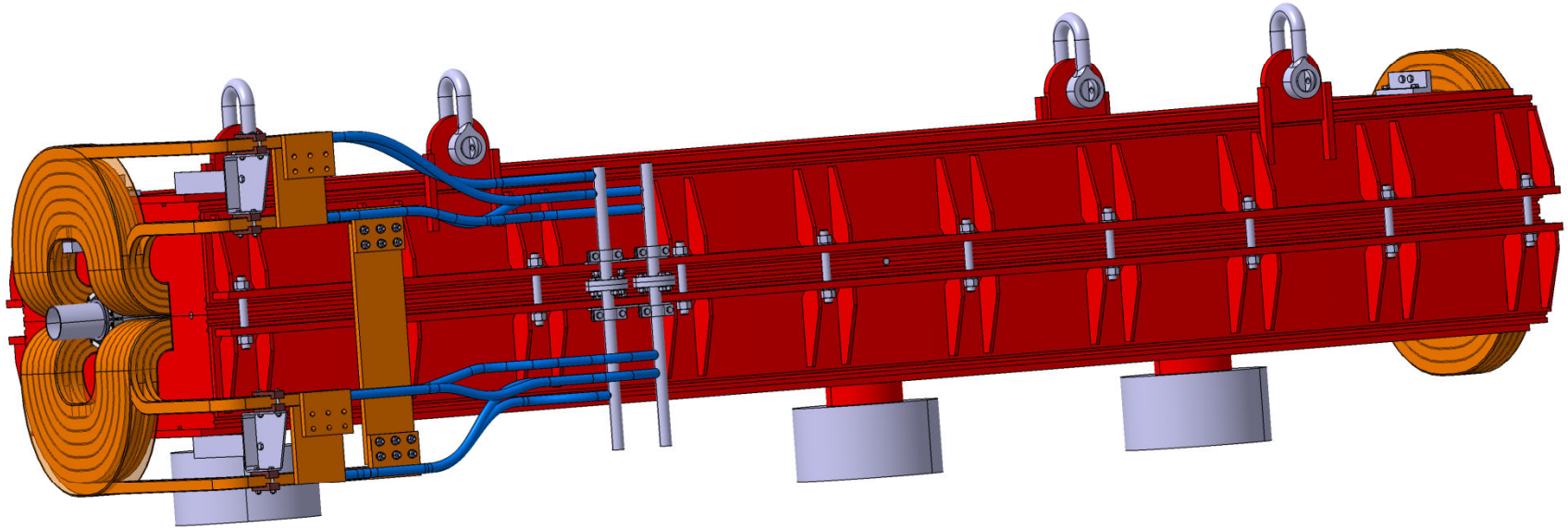
Maximum magnetic induction B	1,7 T
Deflection radius R	29,432 m
Deflection angle φ	8,182°
Iron yoke:	
Length	4,126 m
Radius of pole centerline	29,432 m
Width	1,142 m
Height	0,62 m
Mass of magnetic circuit	19,27 t
Coils:	
2 coils, number of turns/coil	24
Winding layers	4
Windings/layer	6
Dimension od conductor	35x20 mm^2
Cooling bore	12 mm
Copper crossection	583,47 mm^2
Copper mass	1,3 t

Conductor length	245 m
Resistance	7,47 mΩ
Current	2930 A
Current density	5,02 A/mm^2
Voltage (DC)	21,9 V
Power (DC)	64,17 kW
Cooling:	
Temperature rise	ΔT=30 °C
Cooling circuits/coil	2
Water flowrate	30,8 l / min.
Pressure drop Δp	6,45 bar
Data per dipole:	
Total mass	24 t
Voltage (DC)	43,8 V
Power (DC)	128,34 kW
Iductivity	37,0 mH
Water flowrate	61,6 l / min.

Dipole Drawing (overview)



Picture of Dipole

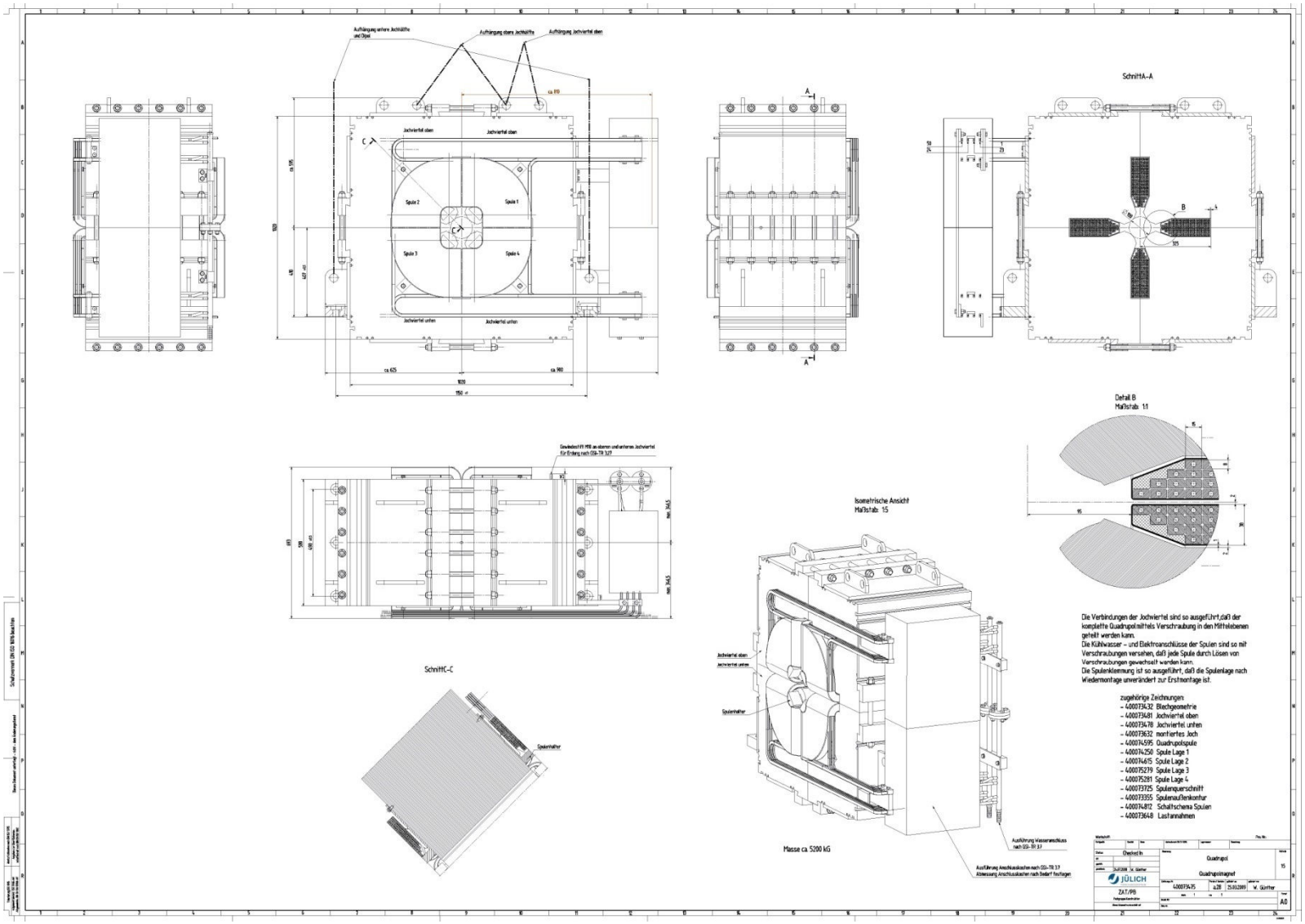


Parameters of the HESR Quadrupole

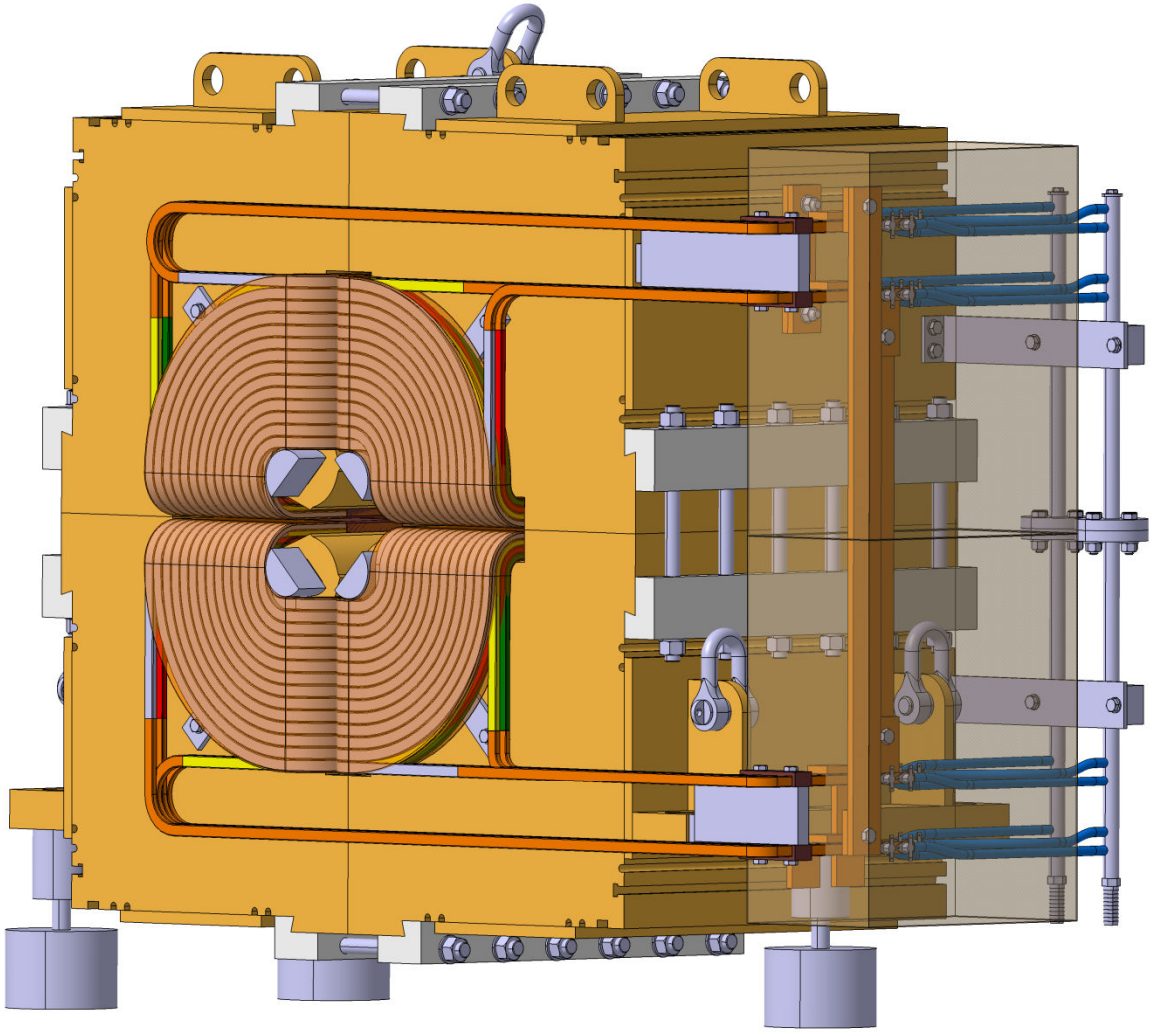
Gradient	20 T/m	25 T/m
Aperture (diameter)	100 mm	
Effective length	600 mm	
Iron yoke:		
Length	0,58 m	
Width	1,06 m	
Height	1,06 m	
Mass of iron (magnetic circuit)	~ 4,3 t	
Coils:		
Number of coils	4	
Turns / coil	50	
Layers / coil	4	
Windings / layer	14, 13, 12, 11	
Conductor dimensions	15 x 8 mm^2	
Cooling bore	4,5 mm	

Copper crossection	103,23 mm^2	
Length of conductor / coil	95,4 m	
Mass of copper / coil	87,8 kg	
Resistance / coil	16,5 mΩ	
Current	426 A	726 A
Current density	4,13 A/mm^2	7,03 A/mm^2
Voltage (DC)	7,03 V	12,0 V
Power (DC)	3 kW	8,7 kW
Cooling circuits / coil	2	
Water flowrate at ΔT=30°C	~1,6 l/Min.	~3,6 l/Min.
Pressure drop Δp	1,6 bar	7,9 bar
Data / quadrupole:		
Total mass	~ 5,2 t	
Voltage (DC)	28,12 V	47,92 V
Power (DC)	12,0 kW	34,8 kW
Inductivity	46,4 mH	
Water flowrate	~ 6,4 l/min.	~14,4 l/min.

Quadrupole Drawing (overview)



Picture of Quadrupole

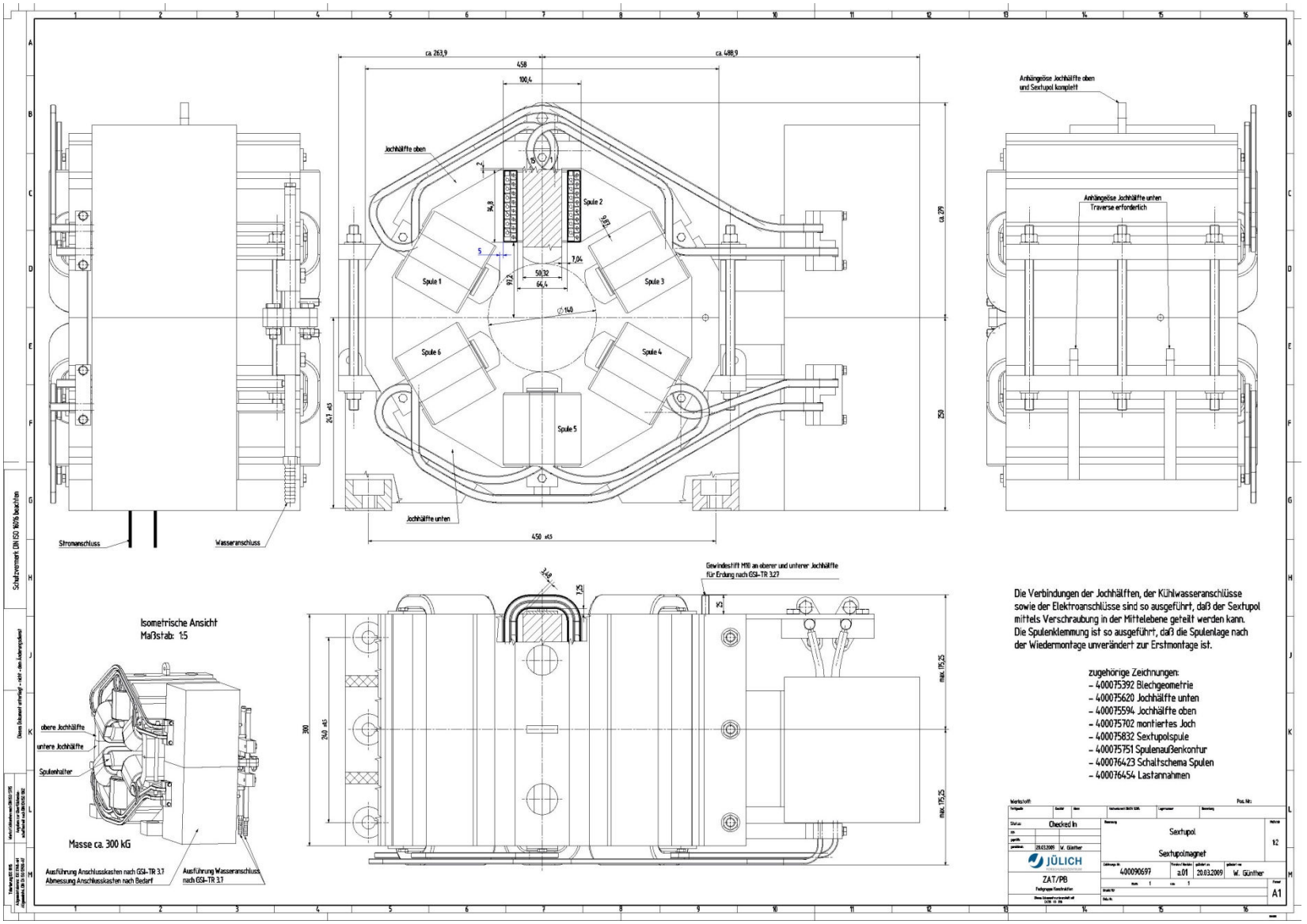


Parameters of the HESR-Sextupole

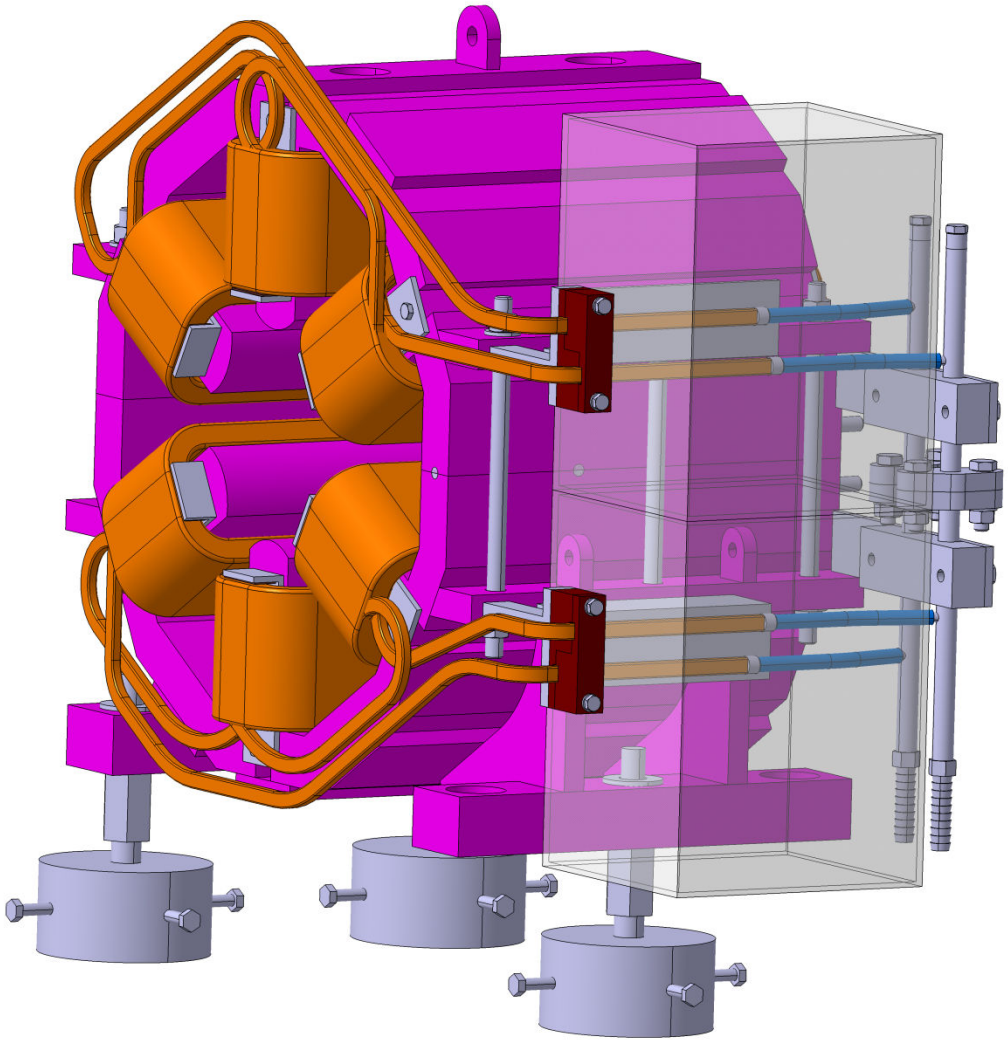
Sextupole strength	45 T/m²
Aperture (diameter)	140 mm
Effective length	300 mm
Iron yoke:	
Length	0,3 m
Width	0,45 m
Height	0,45 m
Mass of iron (magnetic circuit)	~ 160 kg
Coils:	
Number of coils	6
Windings / coil	15
Laayers / coil	2
Windings / layer	7,5
Conductor dimensions	10,6 x7 mm²
Cooling bore	4 mm
Copper crossection	60,77 mm²

Length of conductor / coil	12,02 m
Copper mass / coil	6,53 kg
Resistance / coil	3,52 mΩ
Current	290 A
Current density	4,77 A/mm²
Voltage (DC)	1,02 V
Power (DC)	0,296 kW
Cooling circuits / coil	1
Water flowrate at ΔT=30°C	~0,14 l/Min.
Pressure drop Δp	0,033 bar
Data / sextupole:	
Total mass	~ 220 kg
Voltage (DC)	6,12 V
Power (DC)	1,8 kW
Inductivity	3,4 mH
Water flowrate	~ 0,86 l/min.
Pressure drop Δp	~ 1,14 bar

Sextupole Drawing (overview)



Picture of Sextupole

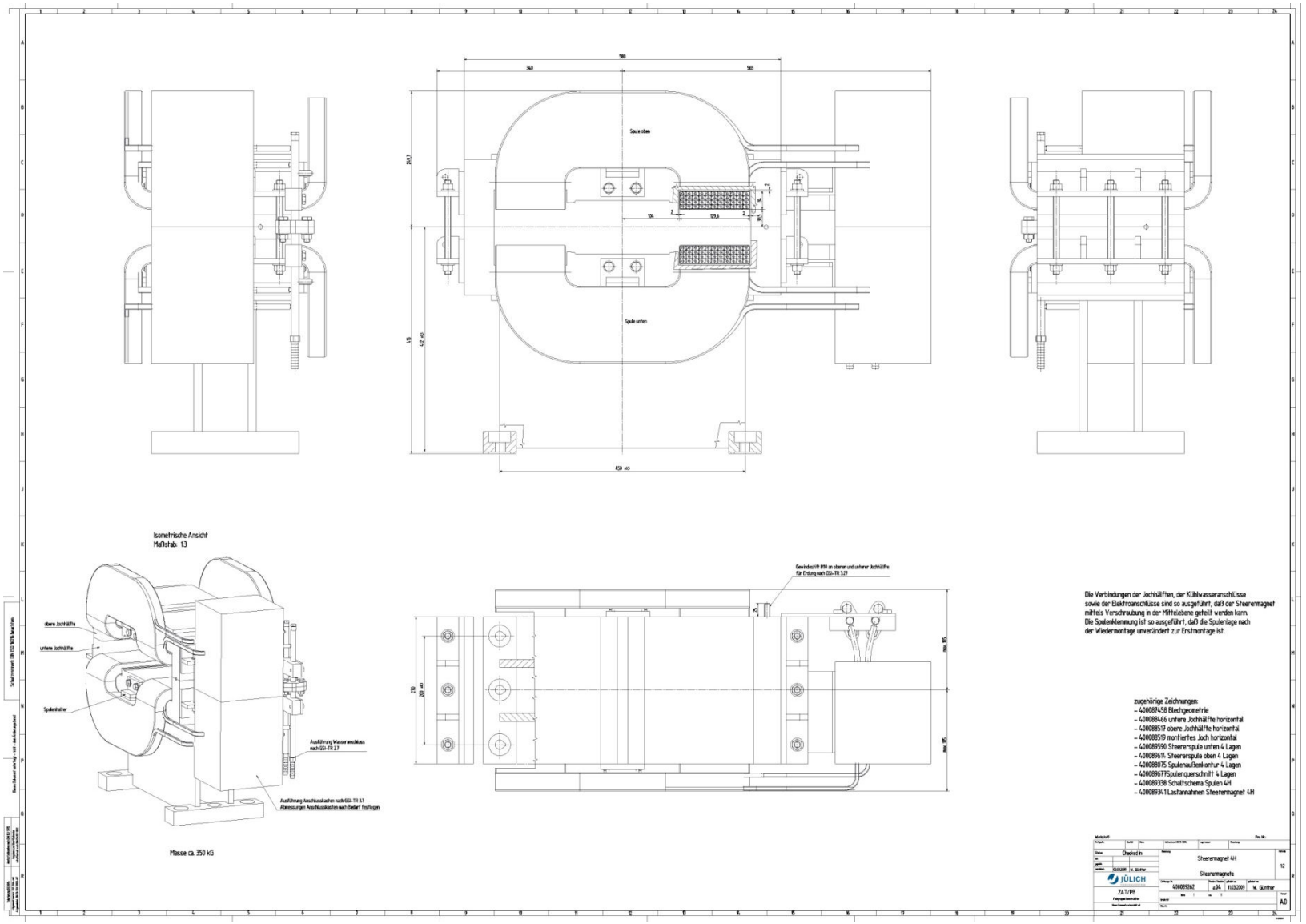


Parameters of the HESR-Steerers

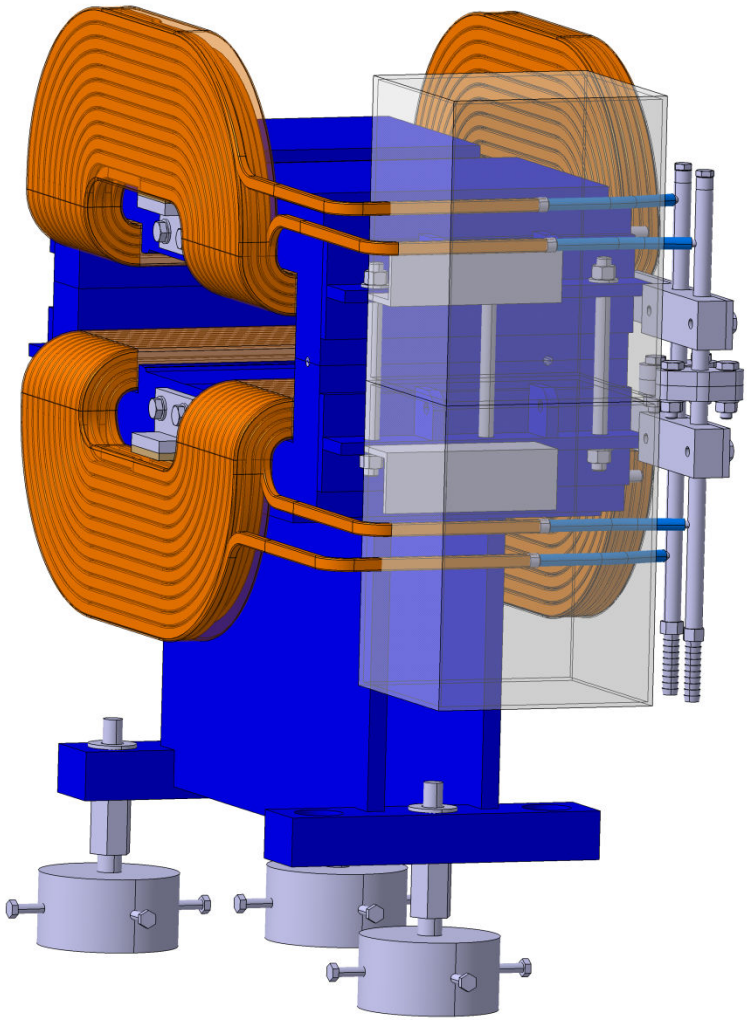
Deflection angle at p_{max}	1 mrad	2 mrad
Gapheight	100 mm	
Effective length	300 mm	
Iron yoke:		
Length	0,3 m	
Width	0,58 m	
Height	0,45 m	
Mass of iron (magnetic circuit)	~ 160 kg	
Coils:		
Number of coils	2	
Windings / coil	22	44
Layers / coil	2	4
Windings / layer	11	
Conductor dimensions	10,6 x7 mm^2	
Cooling bore	4 mm	
Copper crossection	60,77 mm^2	

Conductor length / coil	35 m	72 m
Copper mass / coil	19,0 kg	39,1 kg
Resistance / coil	10,25 mΩ	21,1 mΩ
Current	304,1 A	
Current density	5,00 A/mm^2	
Voltage (DC) / coil	3,12 V	6,42 V
Power (DC)	0,95 kW	1,95 kW
Cooling circuits / coil	1	1
Water flowrate at ΔT=30°C	~0,46 l/Min.	~0,94 l/Min.
Pressure drop Δp	0,72 bar	5,21 bar
Data / steerer:		
Total mass	~ 310 kg	~350 kg
Voltage (DC)	6,24 V	12,84 V
Power (DC)	1,9 kW	3,9 kW
Inductivity	0,072 mH	0,28 mH
Water flowrate	~ 0,92 l/min.	~1,81 l/min.
Pressure drop Δp	~ 0,72 bar	~5,21 bar

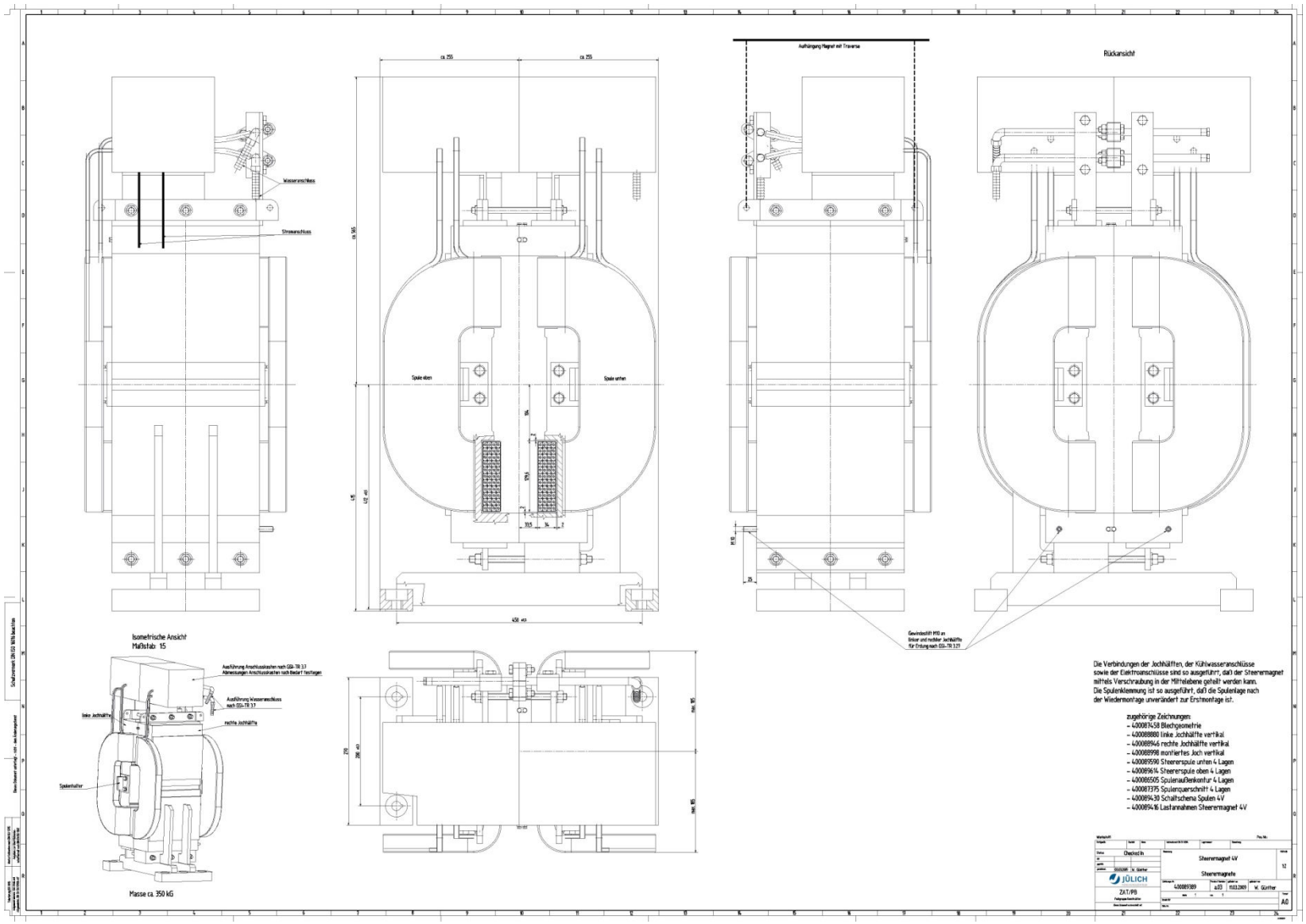
Drawing Horizontal Steerer (overview)



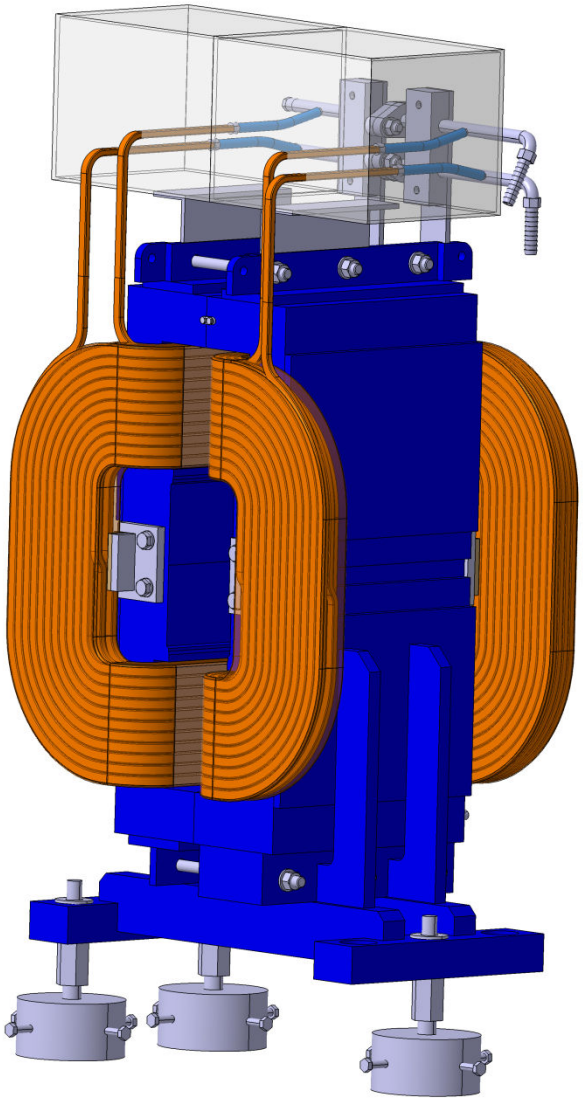
Picture of Horizontal Steerer



Drawing of Vertical Steerer (overview)



Picture of Vertical Steerer



Results of Calculations

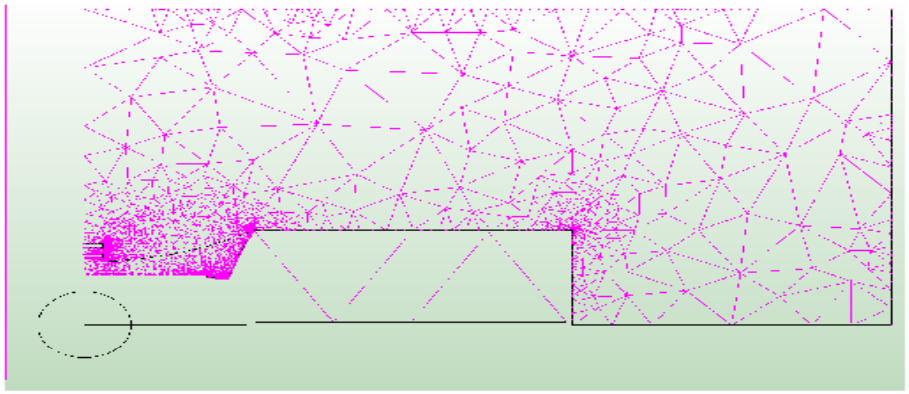
		Dipole (curved)	Dipole (straight)	Quadrupole	Sextupole
Field value		**1 T**	**1 T**	**20 T/m**	**45 T/m²**
n	Order of multipole				
1	Dipole	10000	10000		
2	Quadrupole	0,01		10000	
3	Sextupole	0,72	-1,98		10000
4	Octupole	0,06		-0,08	
5	Decapole	-0,05	-0,33		0,00
6	Duodecapole	0,01		-0,20	
7	14-Pol	0,10	-0,16		0,00
8	16-Pol	0,00		0	
9	18-Pol	0,04	-0,05		-0,70
10	20-Pol	0,00		-0,17	
	Field index n	1	1	2	3
	Reference radius [m]	0,033	0,033	0,033	0,044
	Filling factor	100%	95%	95%	95%
	Magnetic length - real [m]	4,228	4,228	0,6101	0,3373
	Magnetic length - required [m]	4,204	4,204	0,600	0,300
	Length of coil [m]		4,397	0,690	0,368
	Length of yoke [m]		4,125	0,580	0,300
	Angle of yoke chamfer	50°	50°		
	$\|B\|$ on reference circle [T]	1,000	1,002	0,6602	0,0915
	$\|B\|/ r^{n-1}$ on reference circle [T/ m^{n-1}]	1,000	1,002	20,006	47,26

Multipole Components of the Dipole

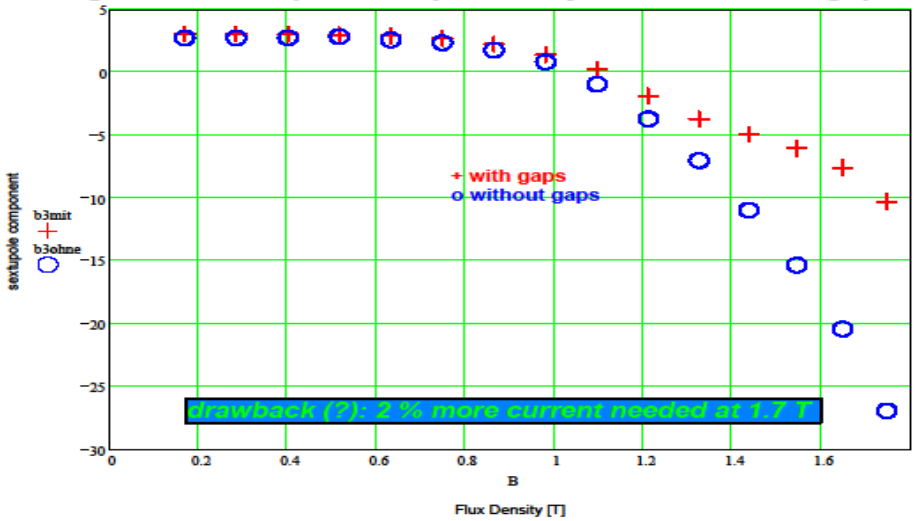
B(nominated) (T)	0.17	1.0	1.7
B(calculated) (T)	0.1700000765	0.999999846	1.6999746
Effective Length (mm)	4229.8	4228.6	4220.8
Normalized multipole field values (p.p.10^4)			
2-pole	10000	10000	10000
4-pole	-0.02985	0.01452	0.09507
6-pole	**-4.31587**	**0.72052**	**28.15974**
8-pole	0.03863	0.06330	0.08561
10-pole	**-1.62142**	-0.05189	**6.02751**
12-pole	0.00854	0.01314	0.01264
14-pole	-0.06199	0.10217	**0.42625**
18-pole	0.00060	0.00061	-0.00030
20-pole	0.06480	0.04337	-0.09899

Reduction of Sextupole Component at High Induction

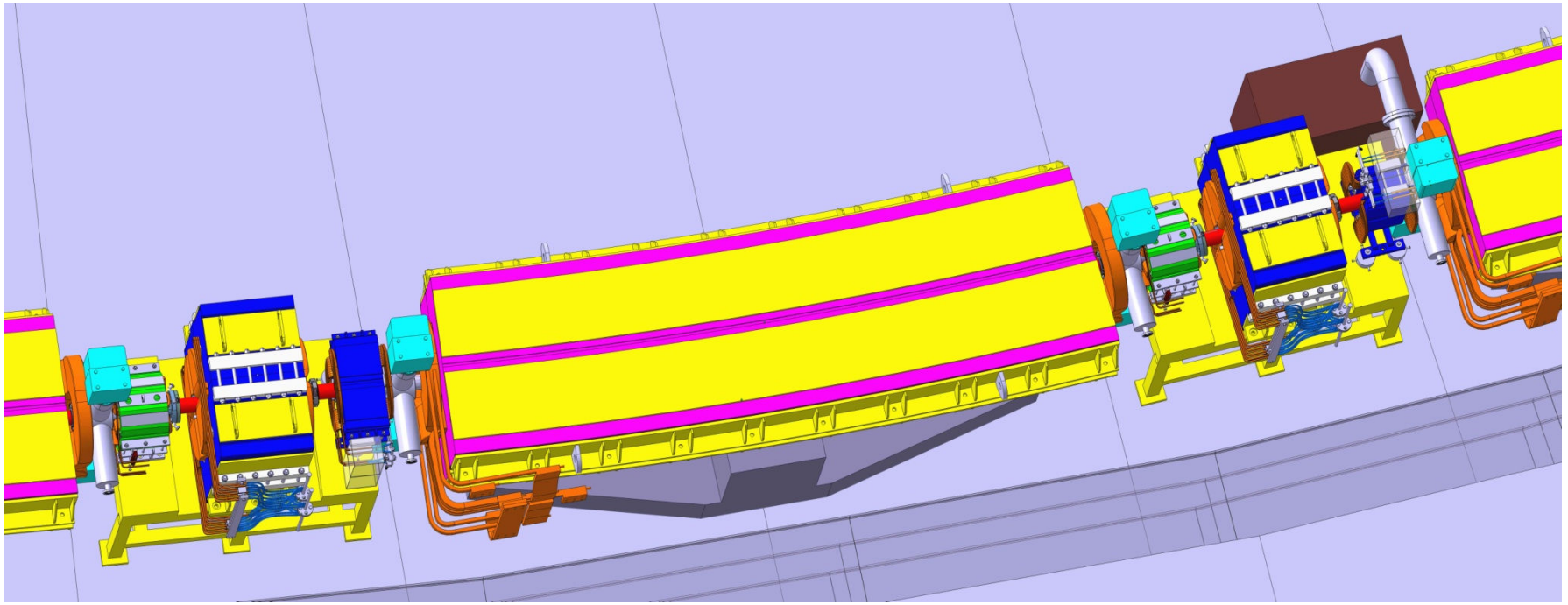
Compensation of sextupole component by the introduction of gaps in the yoke



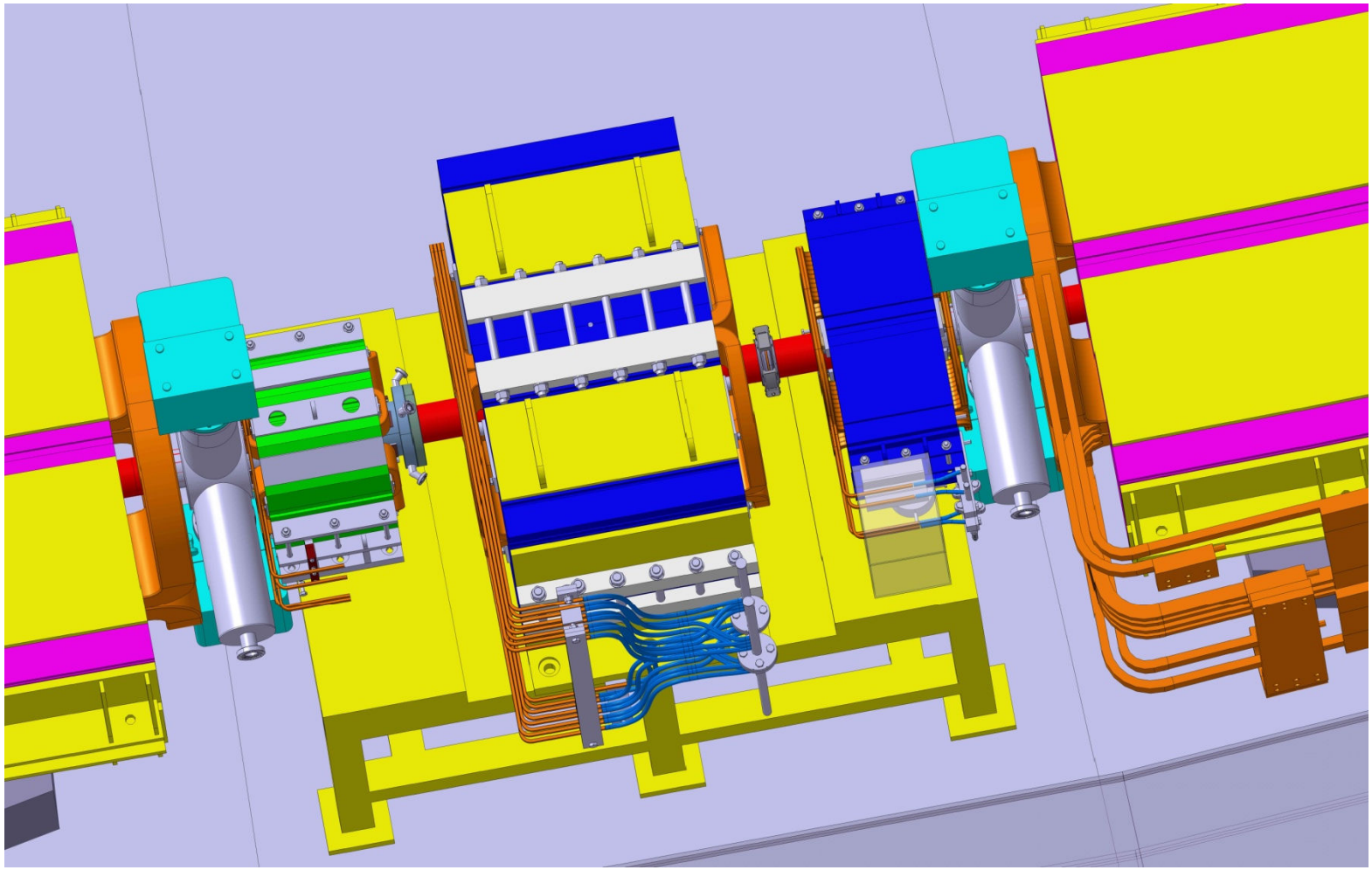
Change of of sextupole component by introduction of gaps



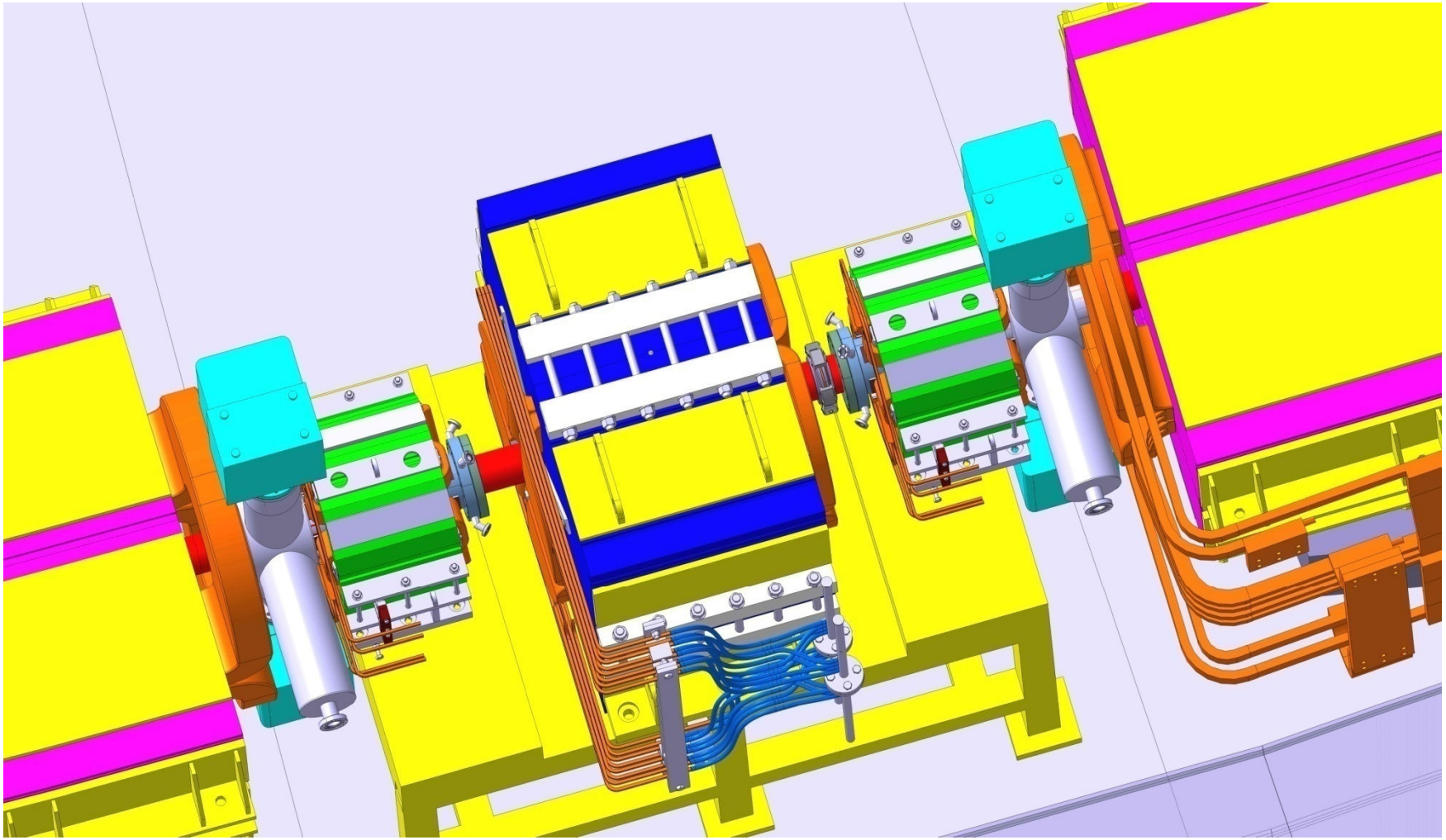
Neighborhood of Magnets in the Tunnel 1



Neighborhood of Magnets in the Tunnel 2



Neighborhood of Magnets in the Tunnel 3



Transport of Magnets Inside the Tunnel