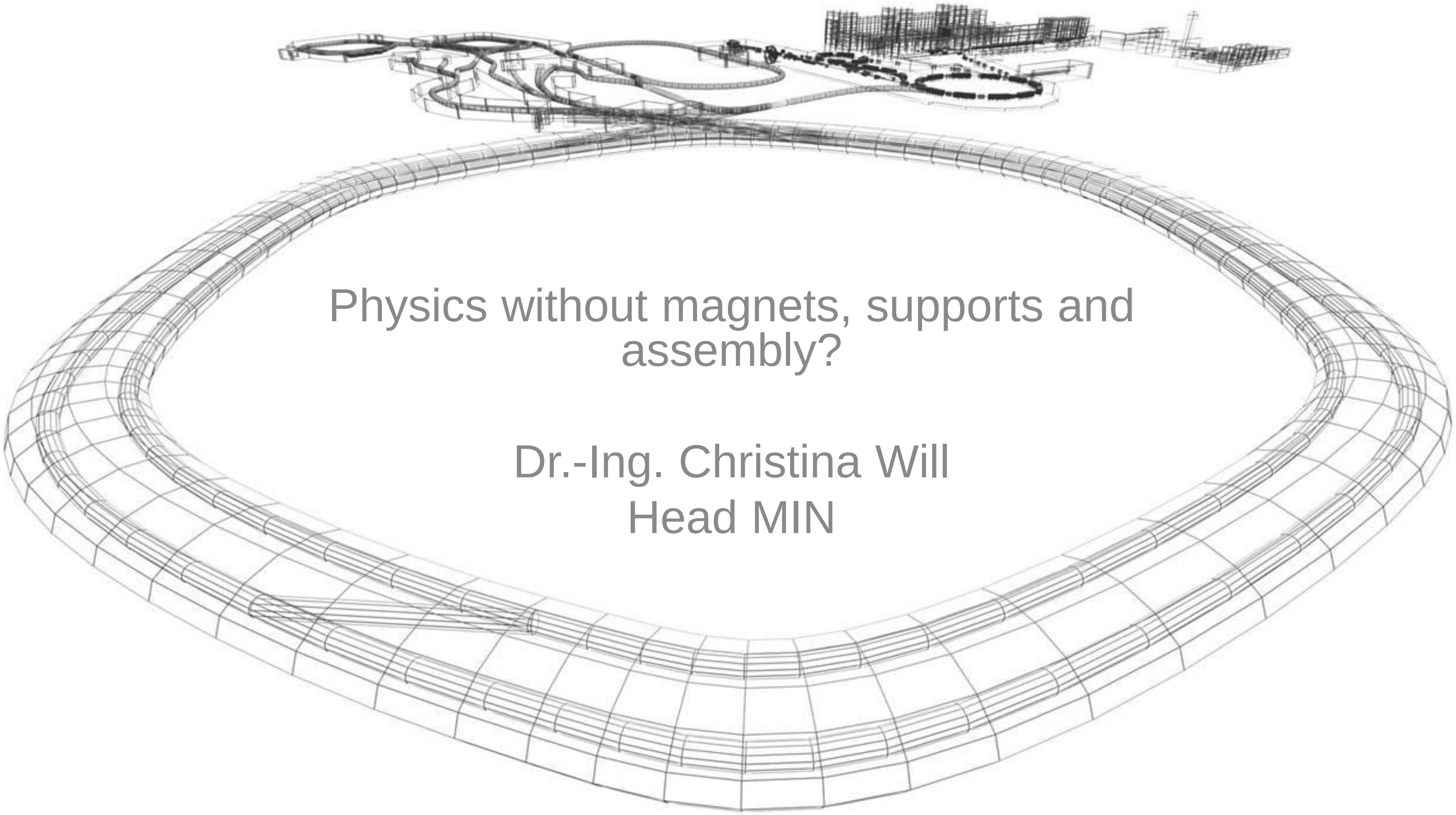
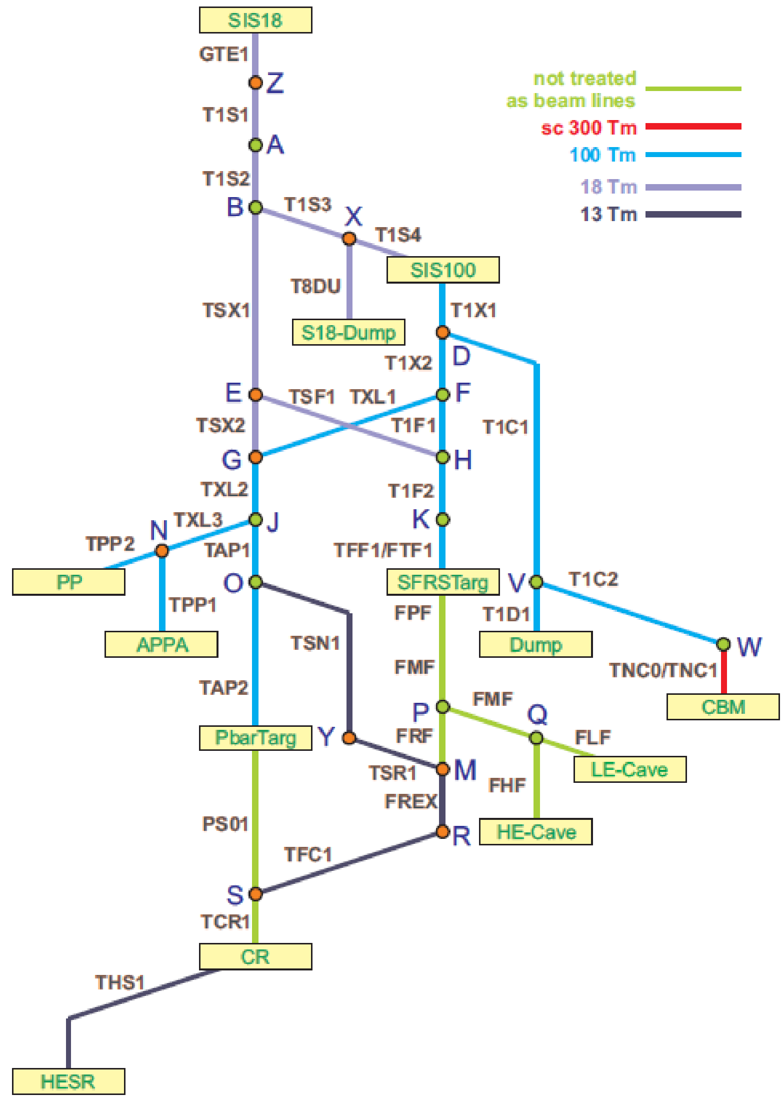


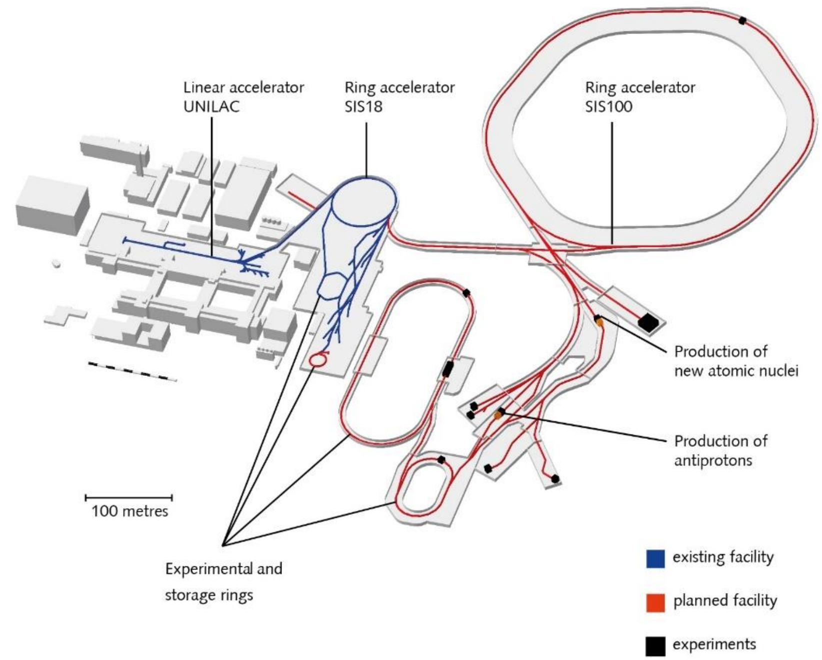
Physics without magnets, supports and assembly?

Dr.-Ing. Christina Will
Head MIN

NO!

HEBT – High Energy Beam Transport





- 29 sections (13 connections/beam lines)
- total length (HEBT) ca. 1.5 km
- all beam lines normalconducting
- nominal magnetic rigidity 100Tm, 18Tm, 13Tm
- parallel operation

Requirements for stands

- 3 active alignment elements per component (f.i. alignment feet)
- Active alignment as close as possible to the components
- Accessibility to the active alignment components from all directions
- Pay attention to product life cycle
- Each component needs its own stand, exceptions are defined individually
- Interface for transportation

- No crane in the tunnels
- Transportation on floor
- No damage of reinforcement steel in the concrete
- Partially 1.5 km beam line -> long transportation distances

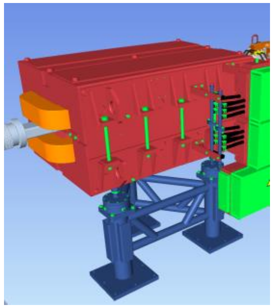
Materials

Primarily:

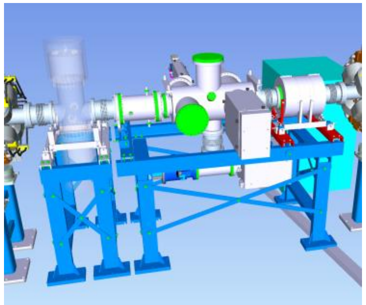
- Structural steel
- Basic profiles U100, flat steel 50x10, angle 60x60x5, sheets, threaded rods, standard parts
- Direct contact of the beam pipes, if necessary aluminium
- Capton foil or rubber

In a very few cases, stainless steel instead of structural steel.

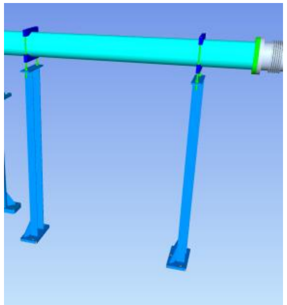
Basic Definition, Standards



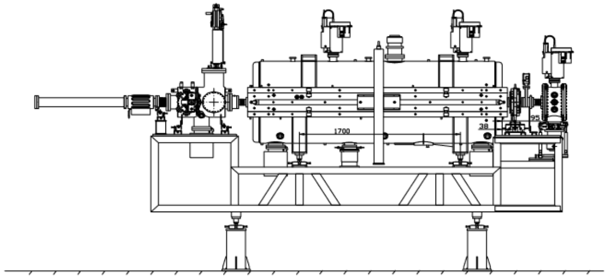
Individual Stand
Dipole



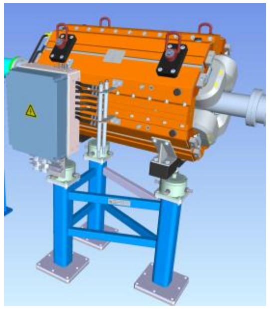
Modular collecting stand
with alignment



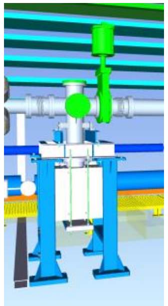
Single foot



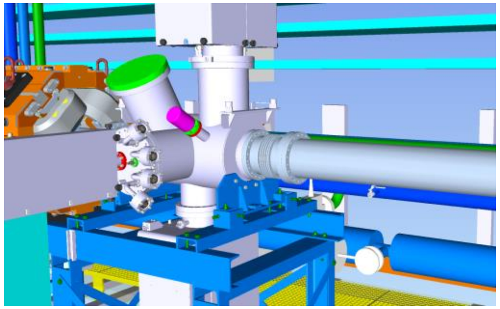
Non modular collecting stand



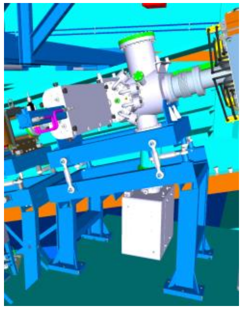
Individual Stand
Quadrupole



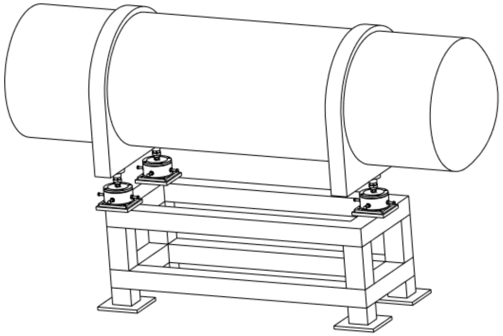
Modular
collecting
stand
without
alignment



Modular collecting stand
alignment bridges

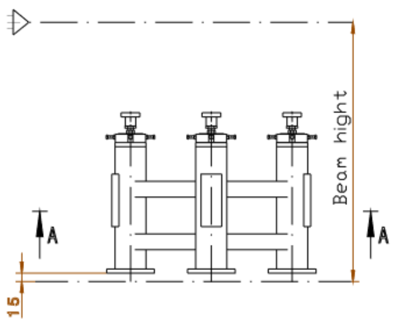


Modular
collecting stand
with alignment,
Six-Strut

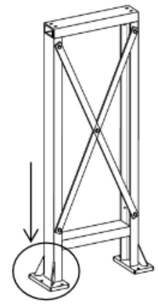


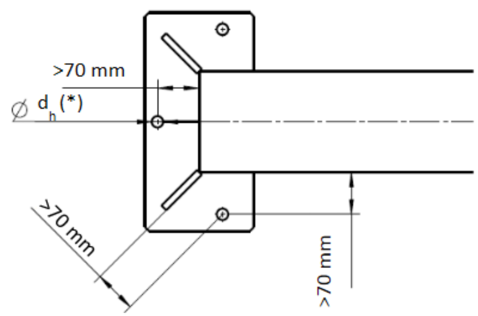
Non modular stand

Basic Definition, Standards



Shimming plates are to be used to compensate for the unevenness of the floor. The thicknesses are 2, 5 and 10 mm. During assembly , these shimming plates are to be inserted under the base plate of the stand.





The minium space for drilling holes into floor is defined.

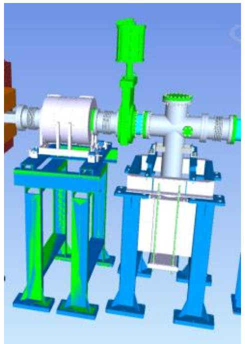
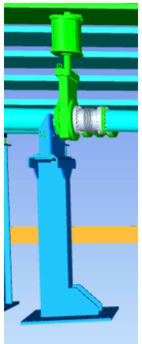
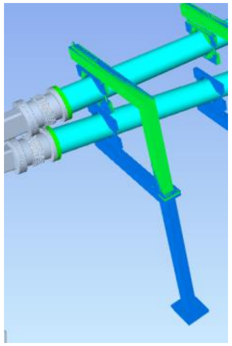
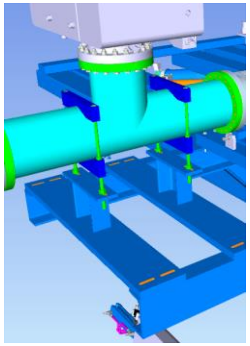

Source: Schwerlastanker HSL-3 - Spreizanker - Hilti Deutschland


Source: Schraubanker HUS3-H 6 - Schraubanker - Hilti Deutschland


Source: Bolzenanker HST3 - Spreizanker - Hilti Deutschland

The preferred anchor screws are defined.

Type of stands which are needed for Early Science

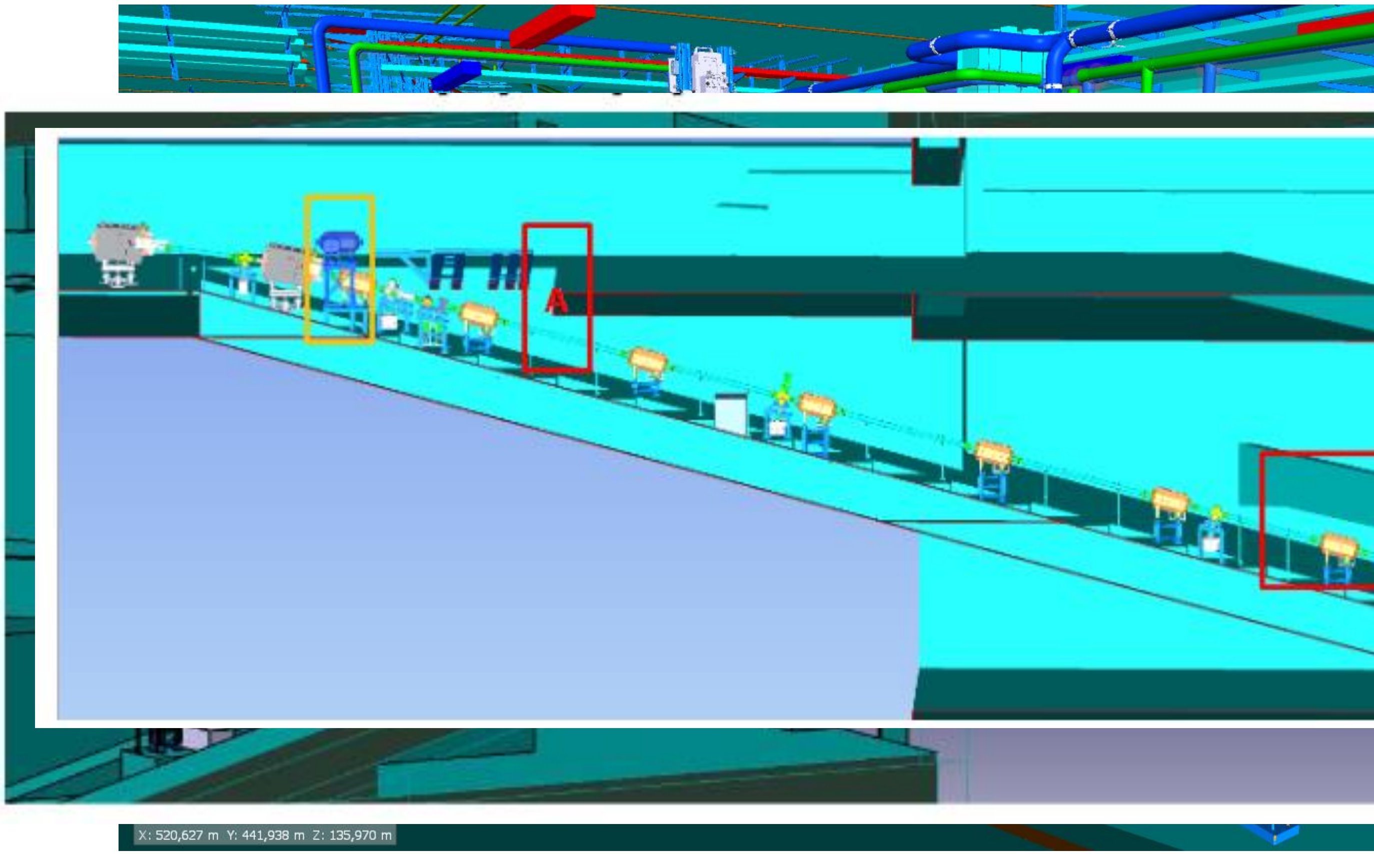
     

Category I	Category II	Category III	Category IV	Category V	Category VI
Ca. 81	Ca. 13	Ca. 1	Ca. 3	Ca. 1	Ca. 4

Development and production procedure

Specification	Design		Production	FAT	SAT
	CDR	FDR			
Description of procedure, draft models and drawings of the stands with interfaces and delivery sequence	Check of 3D-model (data hygiene) Check of solution Check of inerfaces Calculations Risk analysis Draft of Manuals Draft of QR plan Draft of production plan	Check of drawings (data hygiene) Check of content manuals QR plan Production plan	Progress reports NCR	Acceptance test measurement protocolls NCRs Documentation	Test installation of selected components

Assembly tasks

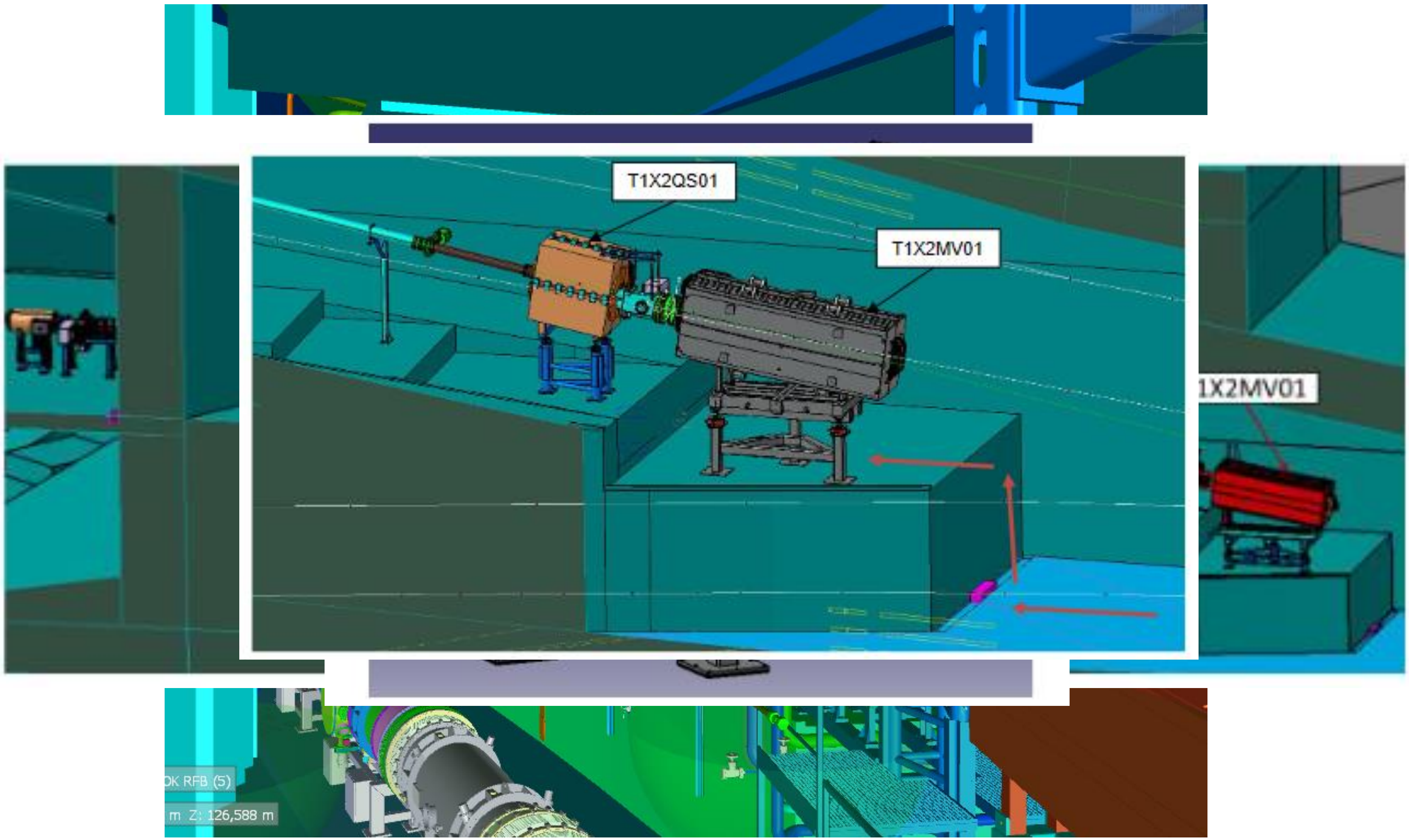


Injection line to SIS100 (15°)

Assembly tasks, components 15° ramp

	nomenclature	type	2D/3D drawing no.	weight with support [kg]	height with support [mm]	2D/3D drawing no. supplier	Currently from supplier only 3D Data available
TSX1	TSX1QS01	quadrupole	FT-BEQS-ZU-0000212	2888	2468	FHTQS212AS	
T1S3 No.							
01	T1S3VKA	chamber	FT-BEVA-ZU-0001025	325	1908	N/A	
02	T1S3MV02	dipole	FT-BEMV-ZU-0000022	10180	2209	1A.519.833AD	
03	T1S3QS01	quadrupole	FT-BEQS-ZU-0000035	3000	2100	FHTQS035AS	X
04	T1S3DK1	diagnostics	FT-BEDI-ZU-0000127	ca. 750 (not uniform)	1720	N/A	
05	T1S3KH01/KV01	steerer	FT-BEKH-ZU-0000012	800	1903	FHTKH012AS	
06	T1S3QS02	quadrupole	FT-BEQS-ZU-0000181	2800	1700	FHTQS181AS	X
07	T1S3QS03	quadrupole	FT-BEQS-ZU-0000183	2800	1600	FHTQS183AS	X
08	**T1S3VKB**	**vacuum**	**FT-BEVA-ZU-0000886**	**302**	**2000**	N/A	
09	**T1S3QS04**	**quadrupole**	**FT-BEQS-ZU-0000185**	**2900**	**2170**	**FHTQS185AS**	X
10	**T1S3QS05**	**quadrupole**	**FT-BEQS-ZU-0000195**	**2900**	**2010**	**FHTQS195AS**	X
11	T1S3QS06	quadrupole	FT-BEQS-ZU-0000187	2800	1850	FHTQS187AS	X
12	T1S3VKC	vacuum	FT-BEVA-ZU-0000887	400	1900	N/A	
13	T1S3QS07	quadrupole	FT-BEQS-ZU-0000189	2800	1750	FHTQS189AS	X
14	T1S3DT1C	resonant transformer	FT-BEVA-ZU-0000695	238	1700	N/A	
15	T1S3QS08	quadrupole	FT-BEQS-ZU-0000191	2800	1650	FHTQS191AS	X
16	**T1S3KH02/KV02**	**steerer**	**FT-BEKH-ZU-0000014**	**800**	**1800**	**FHTKH014AS**	
17	**T1S3DK2**	**diagnostics**	**FT-BEDI-ZU-0000117**	**750 (not uniform)**	**2480**	N/A	
18	**T1S3QS09**	**quadrupole**	**FT-BEQS-ZU-0000193**	**2800**	**1950**	**FHTQS193AS**	**X**

Assembly tasks



Extraction line to SIS100 (6,67°)

Assembly tasks, components 6,67° ramp

T1C1 no.	nomenclature	type	2D/3D drawing no.	weight with support [kg]	height with support [mm]	2D/3D drawing no. supplier	Currently from supplier only 3D Data available
01	**T1C1QS01**	**quadrupole**	**FT-BEQS-ZU-0000096**	**10400**	**2500**	**FHTQS096AS**	
02	T1C1VV1T/VKA	vacuum	FT-BEVA-ZU-0000937	377	1700	N/A	
03	T1C1DK1	diagnostics	FT-BEDI-ZU-0000149	400(not uniform)	1530	N/A	
04	**T1C1MH01**	**dipole**	**FT-BEMH-ZU-0000048**	**15250**	**2036**	**1A.519.365AD**	
05	T1C1KV01	steerer	FT-BEKV-ZU-0000030	830	2050	FHTKV030AS	
06	T1C1DS1H	halo collimation	FT-BEDI-ZU-0000468	no support	no support	N/A	
07	T1C1QS02	quadrupole	FT-BEQS-ZU-0000137	4000	1860	FHTQS137AS	X
08	T1C1DS2V	halo collimation	FT-BEDI-ZU-0000469	no support	no support	N/A	
09	T1C1DK2	diagnostics	FT-BEDI-ZU-0000153	750(not uniform)	1750	N/A	
10	T1C1KH01	steerer	FT-BEKH-ZU-0000026	710	1848	FHTKH026AS	
11	**T1C1MV01**	**dipole**	**FT-BEMV-ZU-0000038**	**16300**	**2154**	**1A.519.779AD**	
T1X2 No.							
01	**T1X2QS01**	**quadrupole**	**FT-BEQS-ZU-0000092**	**10400**	**2520**	**FHTQS092AS**	
02	T1X2QS02	quadrupole	FT-BEQS-ZU-0000155	4000	2560	FHTQS155AS	X
03	T1X2SB01	chamber	FT-BEDI-ZU-0000172	618	2780	N/A	
04	T1X2VKA	vacuum	FT-BEDI-ZU-0000190	360	3000	N/A	
05	T1X2QS03	quadrupole	FT-BEQS-ZU-0000120	4000	2900	FHTQS120AS	X
T1X2 02	**T1X2DK1**	**diagnostics**	**FT-BEDI-ZU-0000175**	**1000(not uniform)**	**4175**	**N/A**	
T1X2 01	**T1X2QS04**	**quadrupole**	**FT-BEQS-ZU-0000157**	4000	**3550**	**FHTQS157AS**	**X**

Content of delivery for assembly tasks

The first task is to install accelerator components on ramps with 15 and 6.67 degree inclination. The second task is to transport dipole T1X2MV01 to and lift it onto the platform at the lower end of the 6.67 degree angle for final the installation.

Following items belong to the scope of delivery:

Development:

- concepts to transport the accelerator components and the dipole to their designated installation places (for transport routes see [17], [19], [19.1], [19.2], [25] p. 18-23)
- concepts for mounting on final position
  - accelerator components of the beam lines T1C1, T1X2 (6.67 degree) and T1S3 + TSX1QS01 (15 degree) on the inclined plains
  - dipole T1X2MV01 on the platform
- concepts for positioning and fixing of all components to be installed with bolts (see [30]) to the floor (the bolts will be provided by the Company, also the geodetic measuring network with reference points)
- concepts for disassembly and removing single components of the beam lines (in case of maintenance and repair) – if possible without disassembly the surrounding components
- development of necessary supporting equipment (e.g. supports, tools, lifting units)
- design of necessary supporting equipment
- development of a concept for a safe movement of persons on both ramps
- if necessary: structural analysis of supporting equipment with regard to the loads (up to 26 tons)
- risk analyses and final risk evaluation
- certification by independent authorized body like TÜV (if necessary)

In all buildings of FAIR non-abrasive tires that are soil-friendly and light in color have to be used, e.g. light plastic rolls. The structural constraints of the building have to be taken into account.

Production:

- production of necessary supporting equipment (e.g. supports, tools, lifting units)
- transport and delivery (see [6])

All supporting equipment for later disassembly and/or exchange of components (e.g. in case of maintenance and repair) passes into ownership of the Company.

Source: Specification F-DS-MIN-en-T_002

Normal conducting Magnets HEBT

65 magnets (normal conducting, not radiation-hard), may be divided into batches

Total weight of iron: 205 tons

Total weight of copper: 31 tons

Magnet type	# variants	# magnets	Iron weight per magnet /kg	Copper weight per magnet /kg	conductor shape (width x height; cooling channel diameter) /all in mm
dip13_3	1	2	11254	1843	32 x 13.5; Ø6 26 x 26; Ø13
dip17_0	1	1	19130	1974	15 x 21 Ø9
dip10_0	1	2	21560	1725	23.8 x 23.8; Ø8
Quadrupole 12 (Figure of Eight)	2	4	8066	495	12x 12; Ø6
Quadrupole 2	3	3	1746	307	9 x 9; Ø6
Quadrupole 2 long	1	4	2096	367	9 x 9; Ø6
Quadrupole 11 (elliptic beam profile)	4	33	2163	485	12 x 12; Ø6
Steering Magnet HEBT100	2	6	297	184	9 x 9; Ø5
Steering Magnet HEBT18	2	10	87	36	5 x 5; Ø3

We provide:

- Models and drawings with few exceptions:
  - Quadrupole 11 modification for elliptic beam
  - Quadrupole 2 long drawings
  - Drawings of several stands for Quadrupoles
- No models or drawings of tooling

Scope of delivery

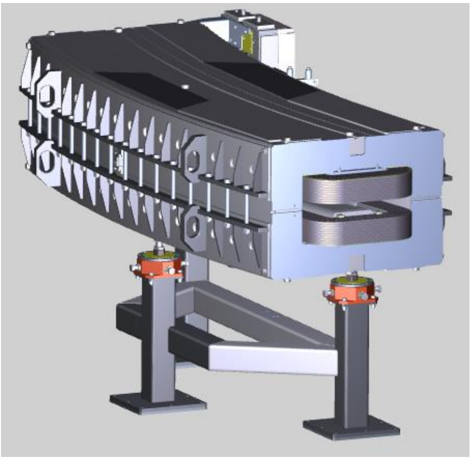
- Magnets (normal conducting, not radiation-hard)
  - connection box
  - lifting connections
  - magnetic measurements
- Stands
- Alignment feet
- documentation
- declaration of CE conformity

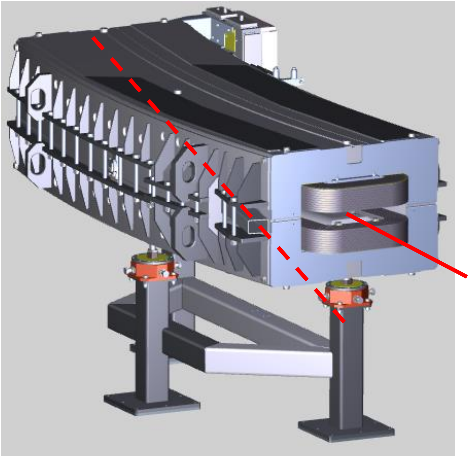
HEBT – Dipole Magnets (1)

dip4_0, dip17_0 – H-type, 1.6T, laminated, curved stack, same lamina

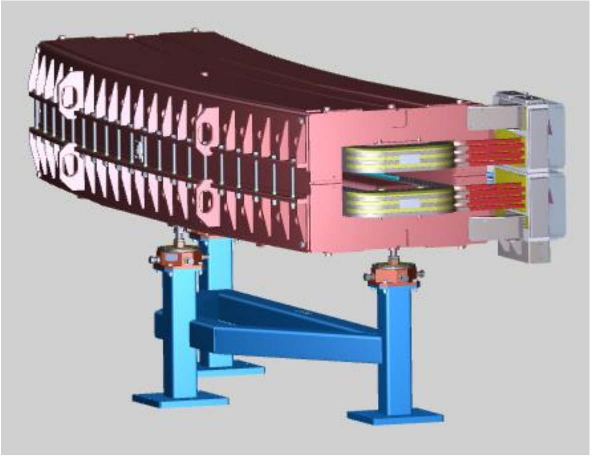
Magnet type	Bending angle	Bending radius [m]	B max. [T]	Gap height [mm]	Yoke length/ width/ height [mm]	Iron weight per magnet [kg]	Copper weight per magnet [kg]	Conductor shape (width x height; cooling channel diameter) [mm]	Quantity magnets needed	Quantity variants
dip4_0	22.34°	8.125	1.6	80	3148/ 1035/760	15505	1277	12 x 12; Ø8	**2**	2
dip17_0	20°	11.250	1.6	80	3907/ 1035/760	19130	1974	15 x 21; Ø9	**1**	1

dip4_0
2 magnets (2 variants) needed





dip17_0
1 magnet needed

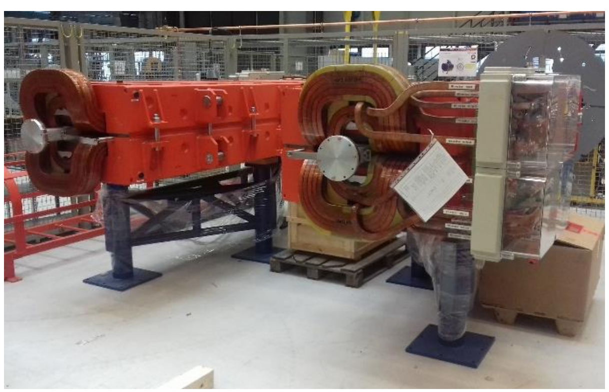


HEBT – Dipole Magnets (2)

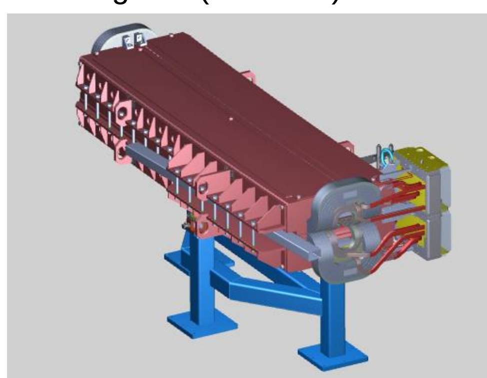
dip13_0, dip13_3, dip19_0 – H/WF-type (Hybrid), 1.8T, laminated, curved stack

Magnet type	Bending angle	Bending radius [m]	B max. [T]	Gap height [mm]	Yoke length/ width/ height [mm]	Iron weight per magnet [kg]	Copper weight per magnet [kg]	Conductor shape (width x height; cooling channel diameter) [mm]	Quantity magnets needed	Quantity variants
dip13_0	3.333°	55.556	1.8	73	3231/ 937/589	11254	1843	32 x 13.5; Ø6 26 x 26; Ø13	**1**	1
dip13_3	3.333°	55.556	1.8	73	3231/ 937/589	11254	1843	32 x 13.5; Ø6 26 x 26; Ø13	**3**	1
dip19_0	3.333°	55.556	1.8	93	3231/ 1150/700	16662	2308	15 x 15; Ø7.5 18 x 14; Ø19	**4**	4

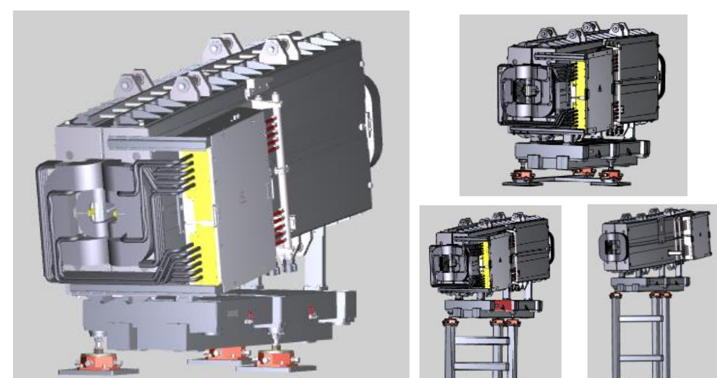
dip13_0
27 dip13_0 at GSI/FAIR;
1 magnet of the same variant needed



dip13_3
cut out for adjacent beam line
3 magnets (1 variant) needed



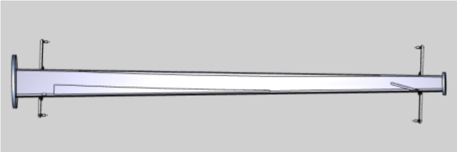
dip19_0
4 magnets (4 variants) needed



HEBT – Dipole Magnets (3)

dip10_0 – H-type, 1.8T, laminated, curved stack,

branching dipole, must accomodate trapezoidal chamber

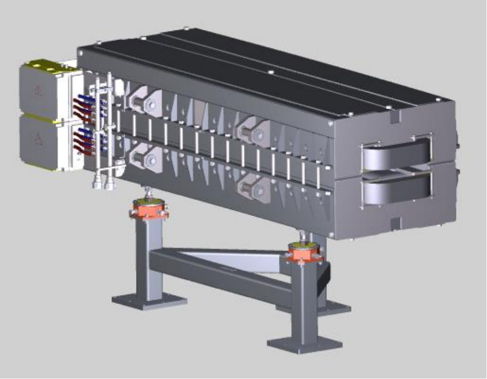


Magnet type	Bending angle	Bending radius [m]	B max. [T]	Gap height [mm]	Yoke length/ width/ height [mm]	Iron weight per magnet [kg]	Copper weight per magnet [kg]	Conductor shape (width x height; cooling channel diameter) [mm]	Quantity magnets needed	Quantity variants
dip10_0	3.333°	55.556	1.8	73	3210/ 1100/910	21560	1725	23.8 x 23.8; Ø8	**3**	1

dip10_0

during FAT; 3 magnets at GSI/FAIR

3 magnets (1 variant) needed



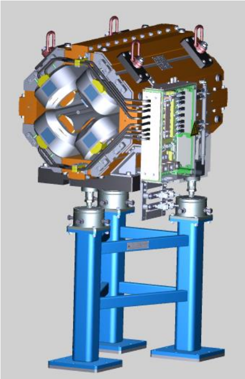
HEBT – Quadrupole Magnets (1)

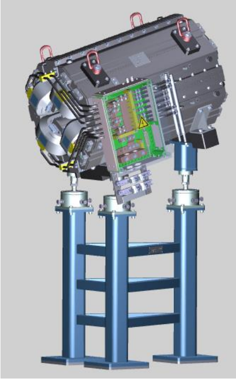
Magnet type	Field Gradient max. [T/m]	Aperture radius [mm]	Yoke length [mm]	Iron weight per magnet [kg]	Copper weight per magnet [kg]	Conductor shape (width x height; cooling channel diameter) [mm]	Quantity magnets needed	Quantity variants
Quadrupole 2	9.5	65	1000	1746	307	9 x 9; Ø6	**44**	10
Quadrupole 2 long	9.5	65	1200	2096	367	9 x 9; Ø6	**4**	1

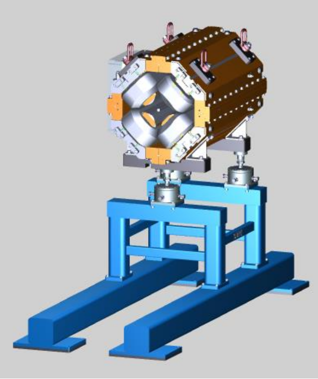
Quadrupole 2

during FAT; 47 magnets at GSI/FAIR

44 magnets (10 variants) needed







examples of Quadrupole 2 variants

Quadrupole 2 long

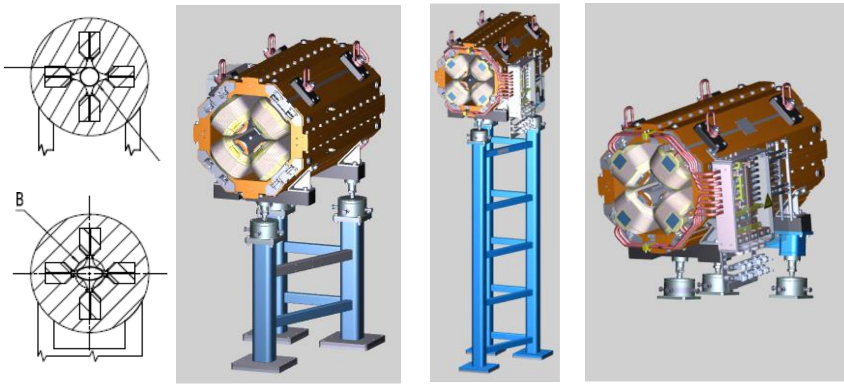
4 magnets (1 variant) needed

HEBT – Quadrupole Magnets (2)

Magnet type	Field Gradient max. [T/m]	Aperture radius [mm]	Yoke length [mm]	Iron weight per magnet [kg]	Copper weight per magnet [kg]	Conductor shape (width x height; cooling channel diameter) [mm]	Quantity magnets needed	Quantity variants
Quadrupole 11	14.8	52.5	1200	2163	485	12 x 12; Ø6	**65**	24
Quadrupole 12 (Figure of Eight)	15	52.5	1200	8066	495	12 x 12; Ø6	**12**	5

Quadrupole 11
must accomodate round and elliptic chamber

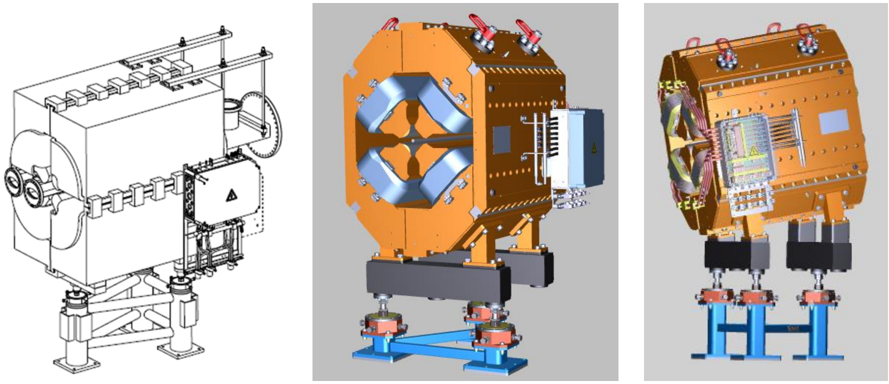
65 magnets (24 variants) needed



examples of Quadrupole 11 variants

Quadrupole 12 (divider quadrupole)
must accomodate elliptic vacuum chamber and vacuum chamber between coils

12 magnets (5 variants) needed



examples of Quadrupole 12 variants

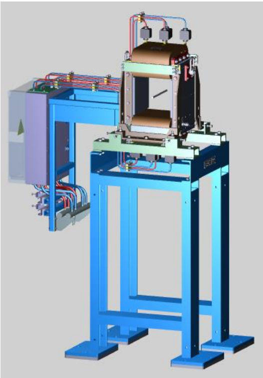
HEBT – Steering Magnets

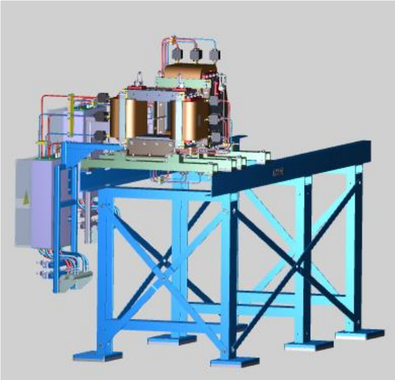
Magnet type	Bending angle	Bending radius [m]	B max. [T]	Gap height/ width [mm]	Yoke length [mm]	Iron weight per magnet [kg]	Copper weight per magnet [kg]	Conductor shape (width x height; cooling channel diameter) [mm]	Quantity magnets needed	Quantity variants
Steering Magnet HEBT18	2mrad	194	0.093	205/ 205	200	87	36	5 x 5; Ø3	**19**	8
Steering Magnet HEBT100	2mrad	290	0.35	170/ 170	380	297	184	9 x 9; Ø5	**19**	10

Steering Magnet HEBT18

during FAT;
29 magnets at GSI/FAIR

19 magnets (8 variants) needed



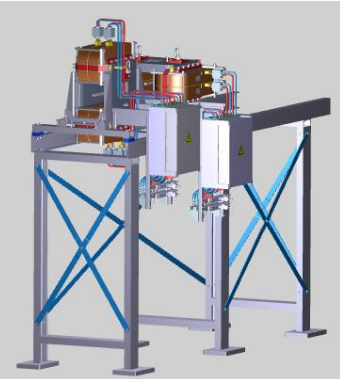


examples of Steering Magnet HEBT18 variants

Steering Magnet HEBT100

during SAT;
26 magnets at GSI/FAIR

19 magnets
(10 variants) needed



example of Steering Magnet HEBT100 variants

HEBT – Magnets

We provide

- Models and drawings with few exceptions:
  - Quadrupole 11 modification for elliptic beam
  - Quadrupole 2 long drawings
  - Drawings of several stands for Quadrupoles
- No models or drawings of tooling

Scope of delivery

- Magnets (normal conducting, not radiation-hard)
  - connection box
  - lifting connections
  - magnetic measurements
- Stands
- Alignment feet
- documentation
- declaration of CE conformity

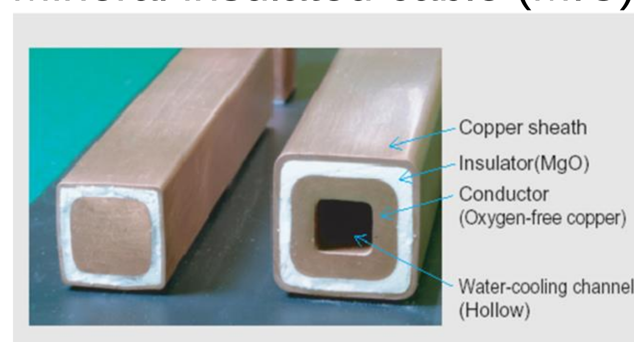
Radiation hard dipoles for Super-FRS

Status

- 1st of kind dipole already built and at GSI
- 2 further dipoles required
- MIC cable will be purchased be GSI/FAIR

Bending radius R	m	12.50
Bending angle	deg	11.0
Effective magnetic length L	m	2.400
Yoke length	m	2.864
Total magnet length (coil)	m	3.084
Total magnet width	m	2.8
Maximum magn. induction B_{max}	T	1.6
Minimum magn. induction B_{min}	T	0.15
Integrated field quality in the range $B_{min} \leq B \leq B_{max}$		$\pm 3 \cdot 10^{-4}$
Good field region (horizontal)	mm	±195
Good field region (vertical)	mm	±70
Estimated free horizontal aperture	mm	±520
Inner height of vacuum chamber	mm	±70
Vertical pole gap height	mm	±90
Ramp rate dB/dt		(Dt_{rise} = 120 sec)
Yoke weight	to	78
Coil weight	to	11
Number of turns (per pole)		192
Maximum current	A	640
Resistance	W	0.34
DC losses	kW	140
Inductance	H	2.1
Cooling water requirements	l/min	72
For temperature rise	K	25
Pressure difference (only dipole without water lances)	bar	0.8

Mineral insulated cable (MIC)

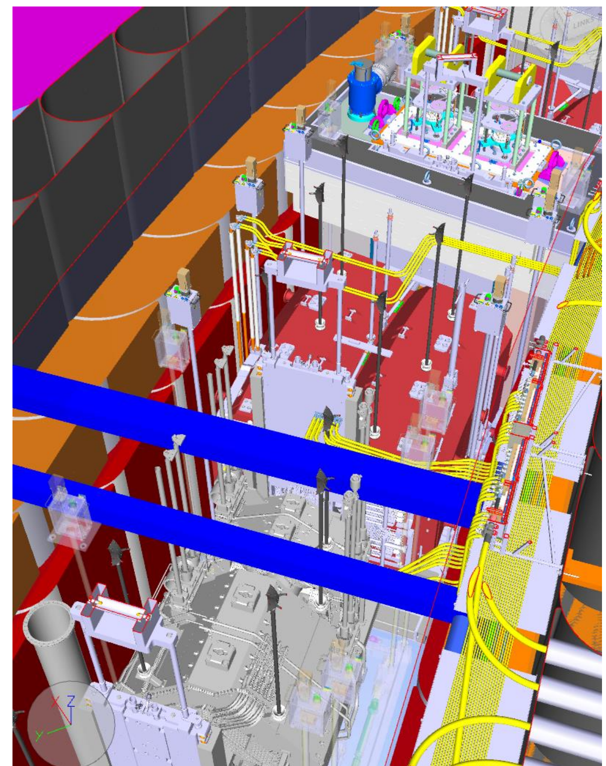


Radiation hard dipoles for Super-FRS

Design for Supports made by GSI

Draft for power interface and water interface made by GSI has to be adapted

- Complete anorganic design
- Installation from top
- Maximum weight for crane incl. transportation units ca. 70 to



Thank you for your attention!

Questions?