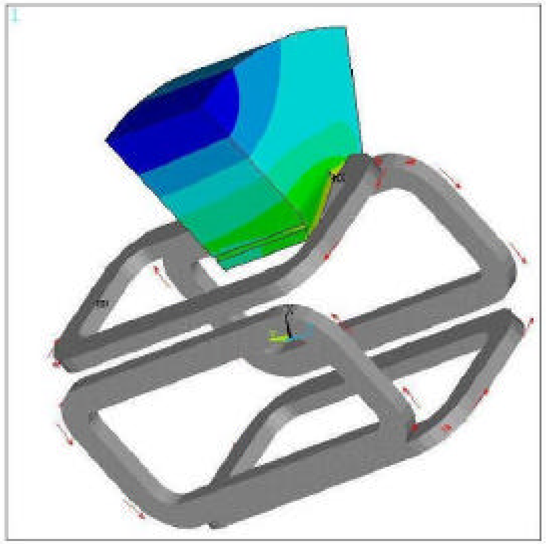
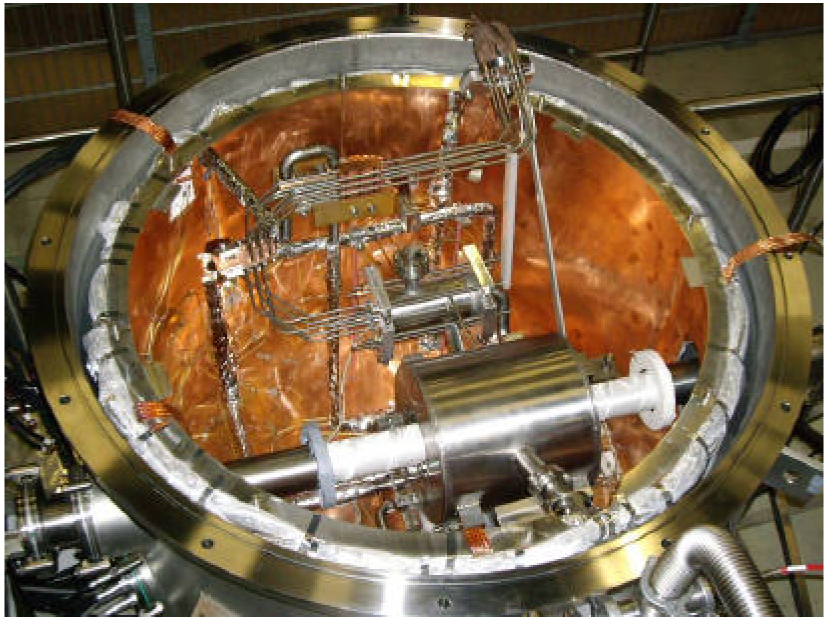
Superconducting Quadrupole Development for XFEL





MINISTERIO DE EDUCACIÓN Y CIENCIA

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Outline

- Calculation, design and fabrication
- First prototype measurements
- Second prototype measurements
- Future plans & conclusions

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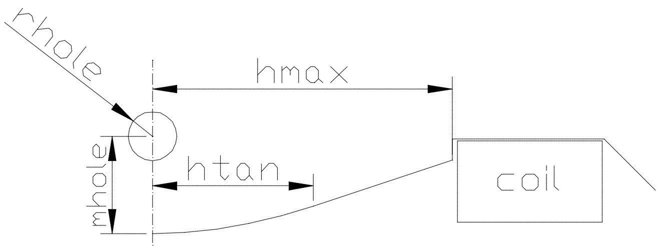
Calculations (I)

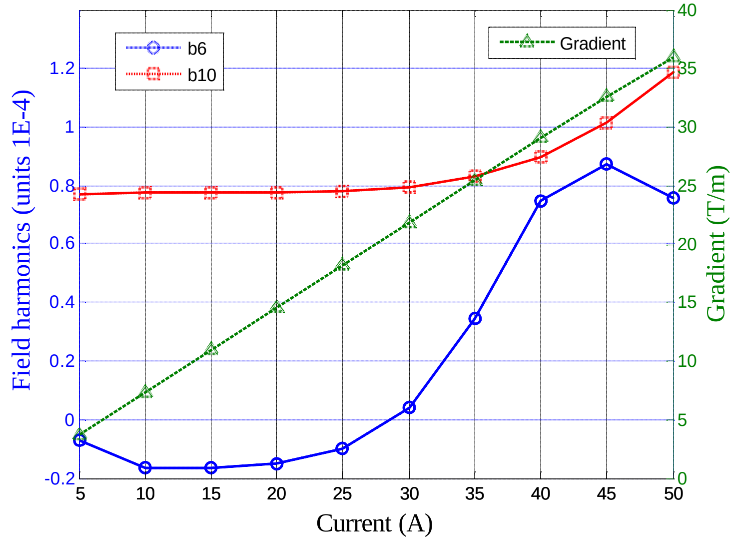
Initial specifications

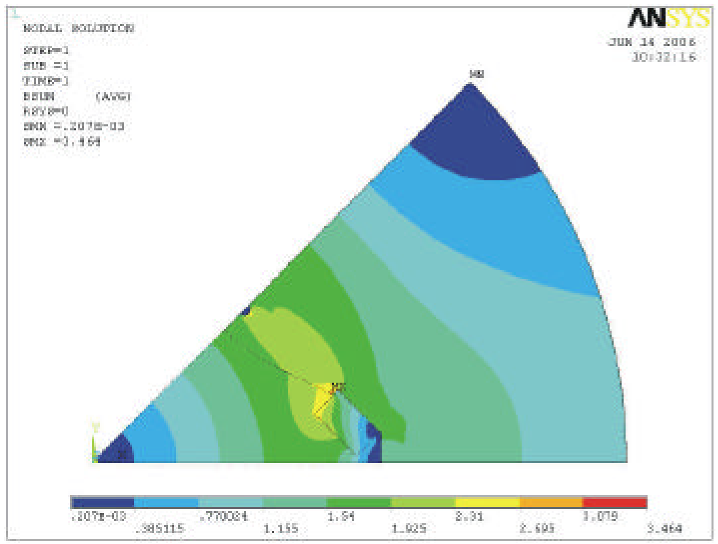
Quadrupole strength	5.6	T
Inner dipole integrated field	0.006	Tm
Outer dipole integrated field	0.006	Tm
Quadrupole field quality	<10	units
Transfer function saturation	<5	%
Operating current	50	A
Operating temperature	2	K
Beam tube aperture	78	mm
Helium vessel length	300	mm
Number of magnets	120	



Iron pole parameters for 2-d magnetic optimization

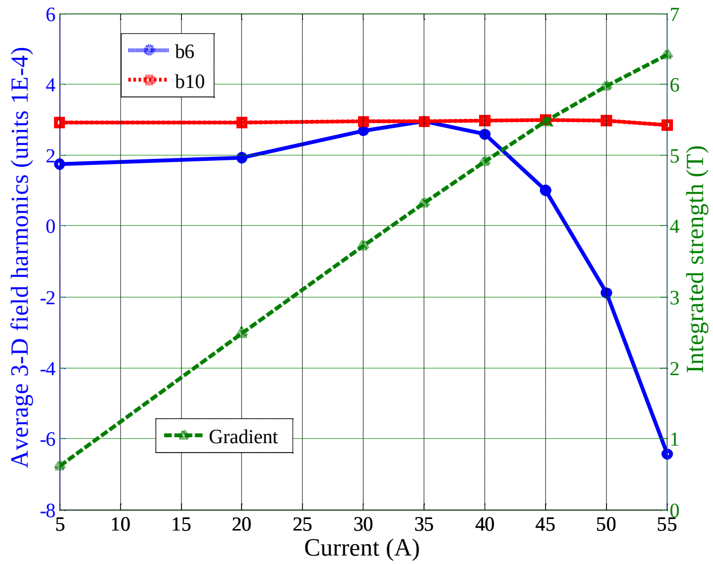
2-D magnetic calculations

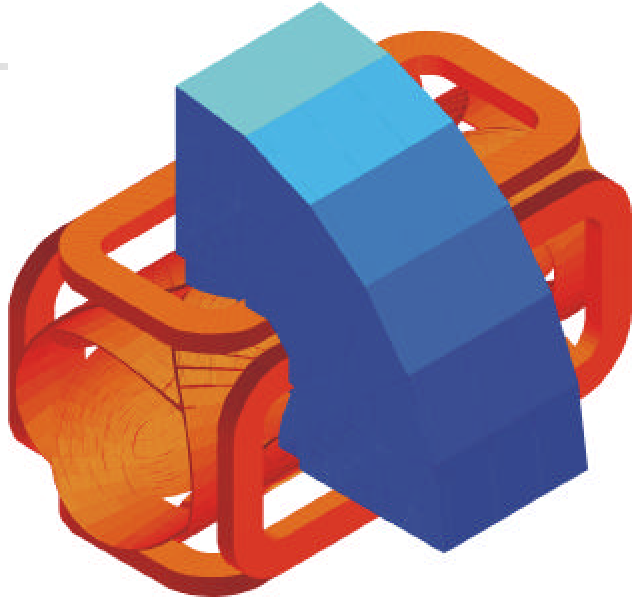


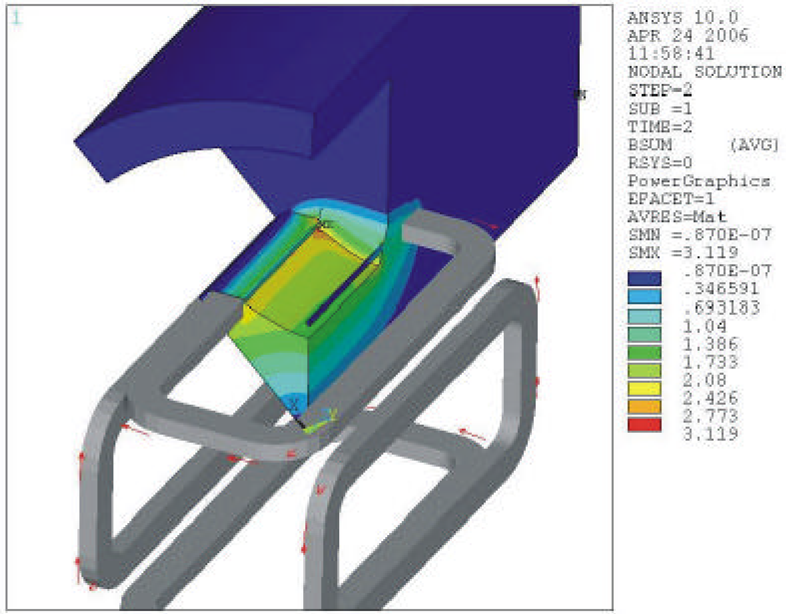


Calculations (II)

3-D magnetic calculations



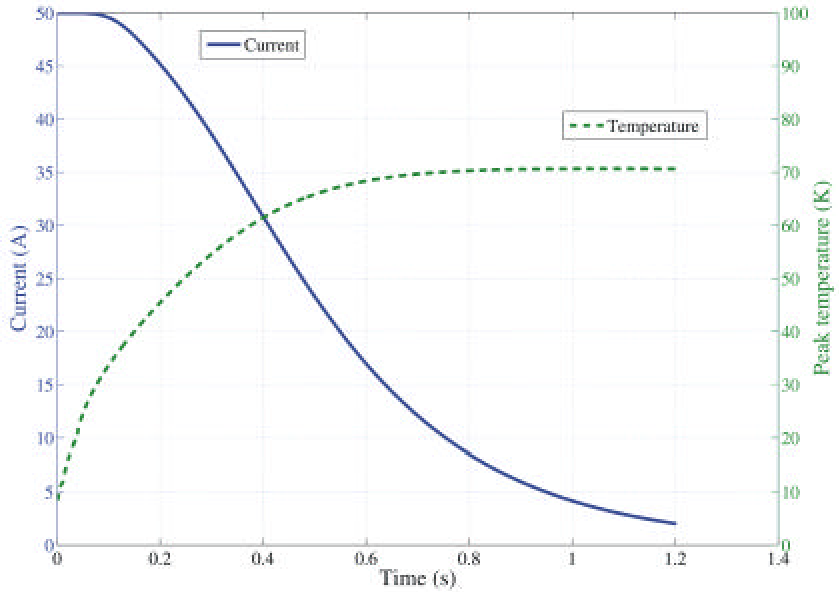




- Drilled hole on iron to compensate b6 variation on load line
- Chamfers on iron pole ends to compensate saturation
- Magnetic shielding to decrease fringe field around the SC cavities

Calculations (III)

Quench propagation simulation

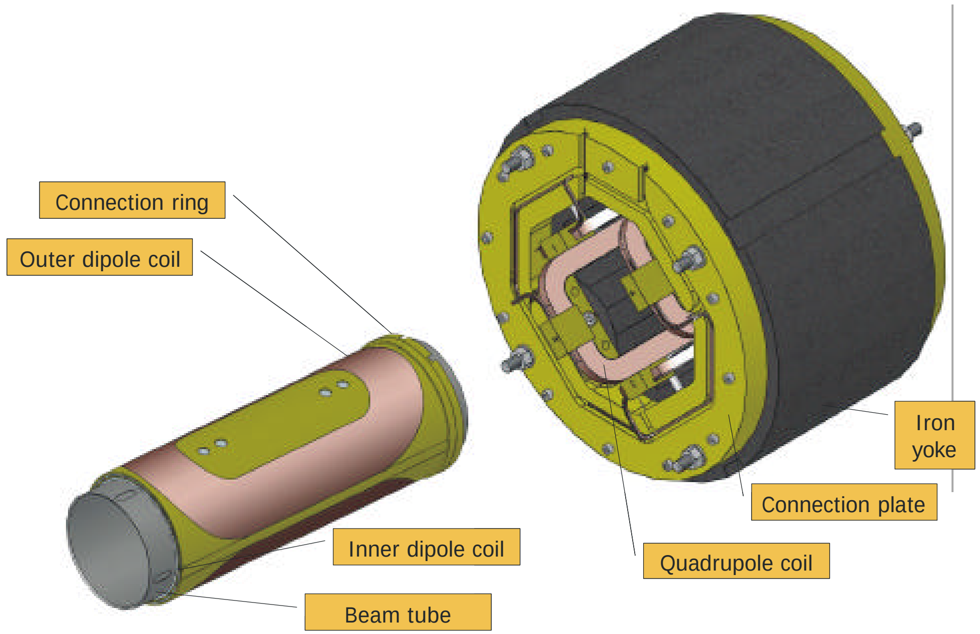


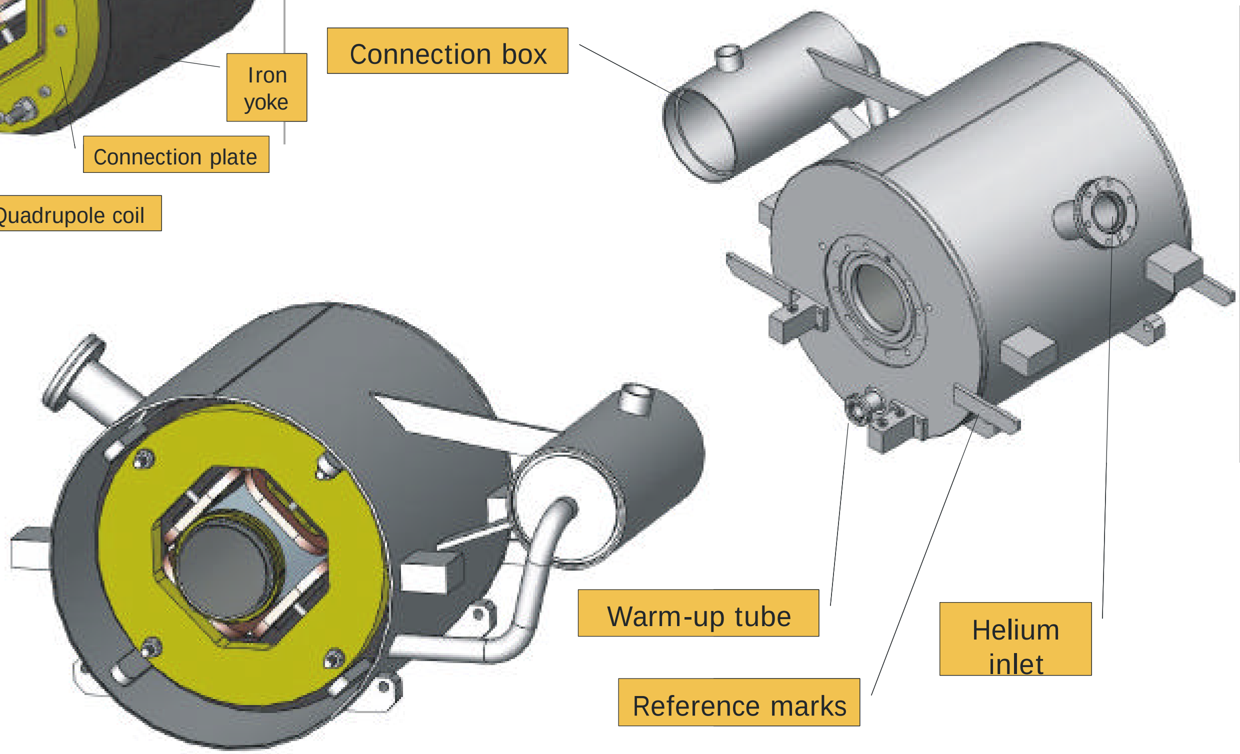
Magnet parameters

Coil	Quadru-pole	Inner dipole	Outer dipole	Units
Inner diameter	94.4	83.6	88.5	mm
Nominal current	50	50	50	A
Number of turns	648	35	36	
Integrated strength	5.976	7.92E-3	7.98E-3	T--Tm
Field relative multipoles	<10	No request	No request	1E-4
Bare wire diameter	0.4	0.7	0.7	mm
Insulated wire diameter	0.438	1.03	1.03	mm
Cu/Sc ratio	1.35	1.8	1.8	
Filament diameter	35	12	12	µm
Twist pitch	50	25	25	mm
Coil length	200.6	230	230	mm
Self inductance	1.17	0.93E-3	1.04E-3	H
Coil peak field	2.48	1.59	1.68	T
Working point at 4.3K	40	11	11	%
Working point at 2K	27	7.9	7.9	%

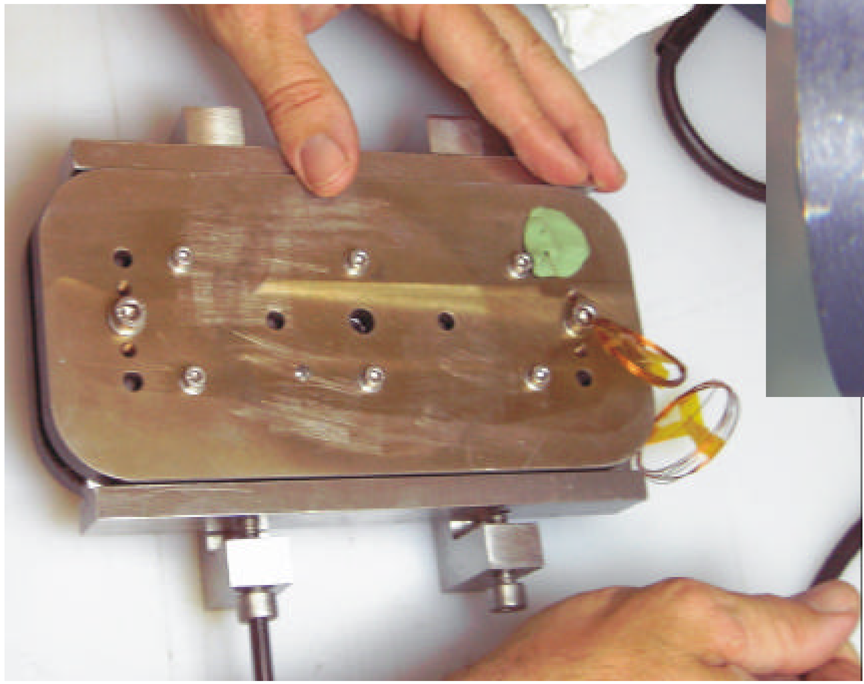
Mechanical design

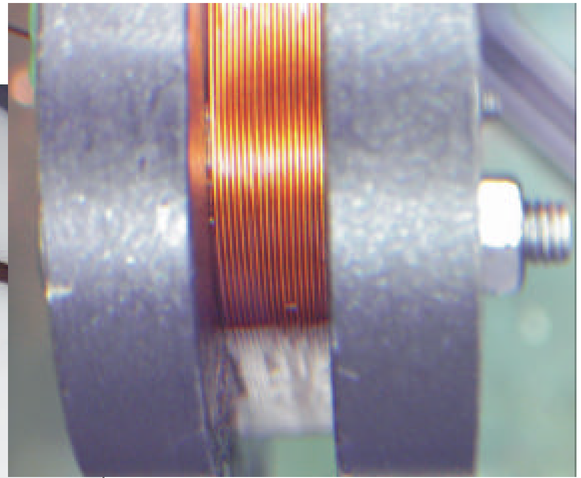
- Design according to TUEV pressure vessel rules
- Copperized beam tube
- Sliding supports on linear bearings
- BPM attached on endplate

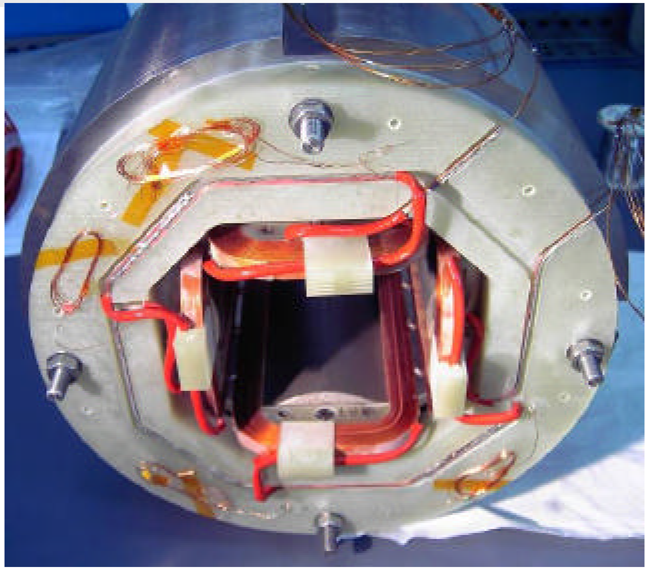


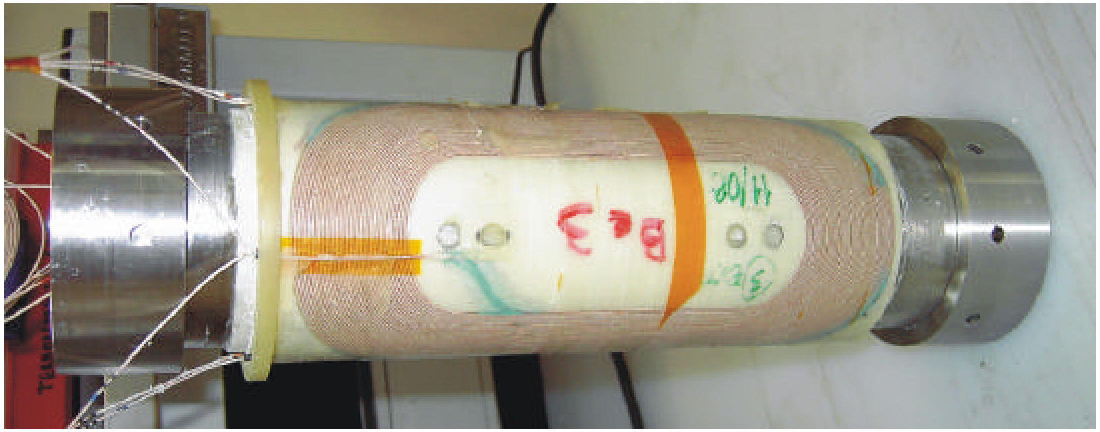


Fabrication









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First prototype measurements

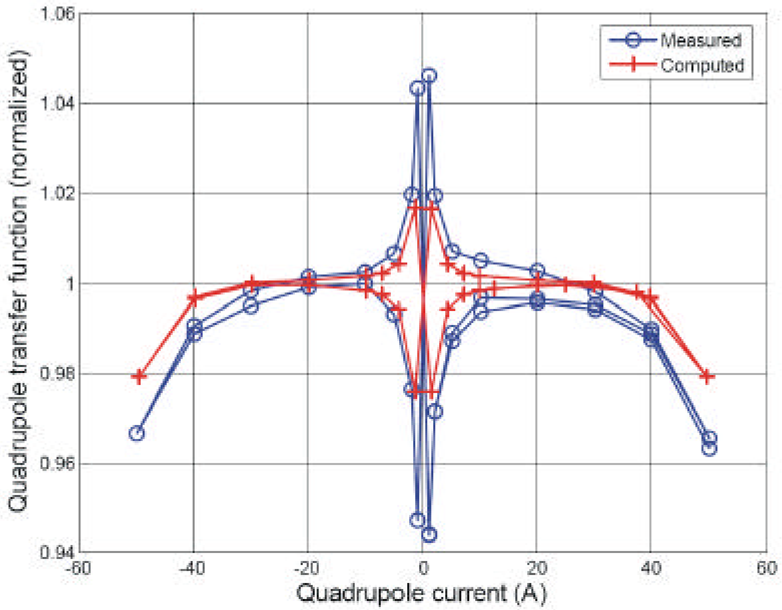
Field quality measurements

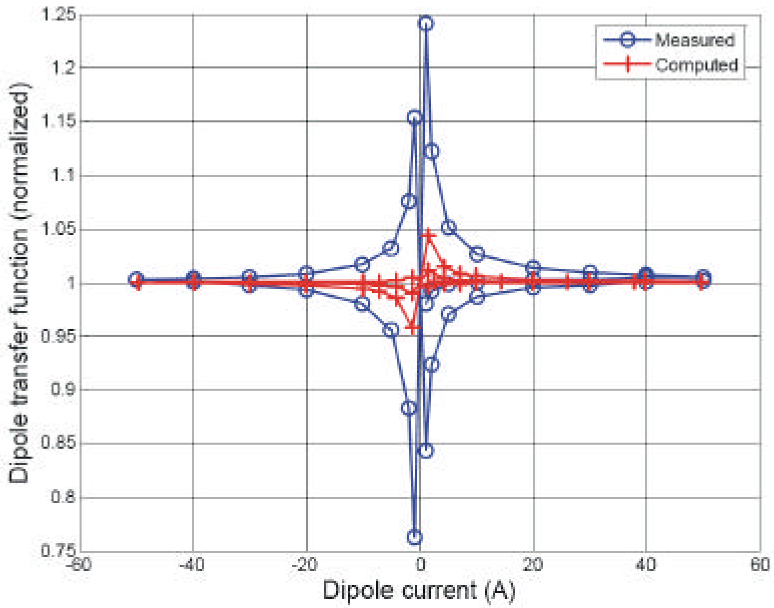
Parameter	Computed	Warm	Cold	Units
Quadrupole at 5A				
Integrated strength	6.25	6.02	6.12	T
Integrated b6	13.2	-7	-14.4	1E-4
Integrated b10	-2.0	-2.5	noise	1E-4
Quadrupole at 50A				
Integrated strength	5.98	--	5.97	T
Integrated b6	2.24	--	-5.7	1E-4
Integrated b10	-2.18	--	-1.58	1E-4
Inner dipole at 50 A				
Integrated field	7.92E-3	7.80E-3	7.75E-3	Tm
Integrated b3	194	140	149	1E-4
Integrated b5	-834	-828	-830	1E-4
Outer dipole at 50 A				
Integrated field	7.98E-3	7.85E-3	7.80E-3	Tm
Integrated b3	-131	78	92	1E-4
Integrated b5	-829	-814	-813	1E-4

- Computed and measured values agreement is quite good.
- Transfer of magnetic axis position to the external side of the helium vessel has been done within tolerances.

First prototype measurements

Magnetization measurements (individual coil powering)

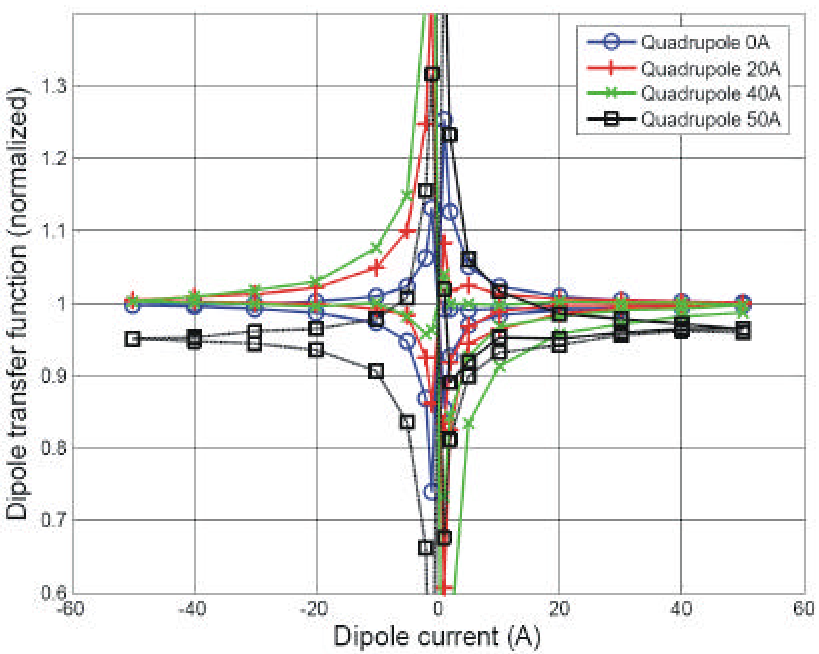


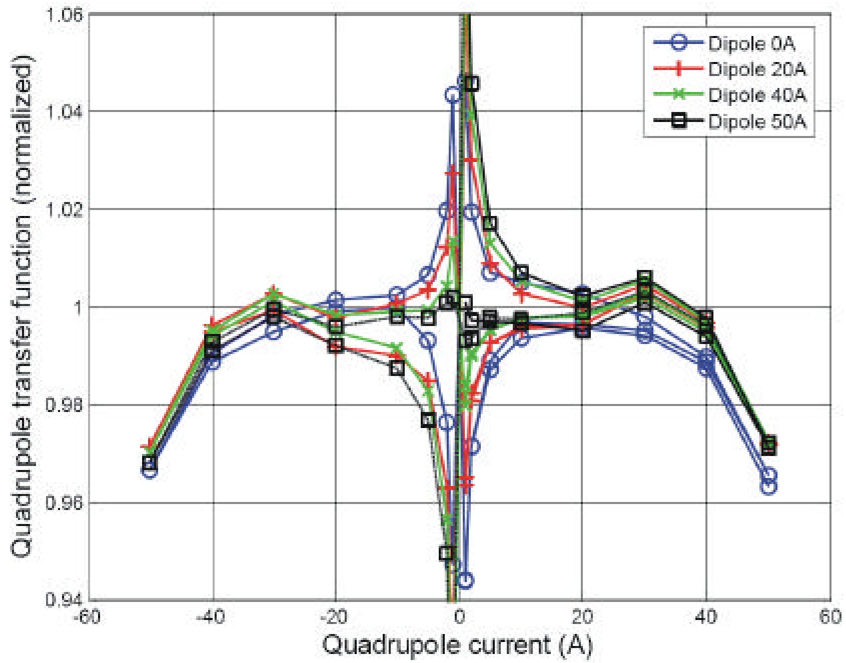


- ➢ Magnetization effects are significant at low currents, above all in dipole coils.
- ➢ Computed values are systematically lower than measured.

First prototype measurements

Magnetization measurements (combined coil powering)





- Asymmetric magnetization effects when both coils are powered at the same time.
- For the time being, simulations are not able to reproduce this effect.

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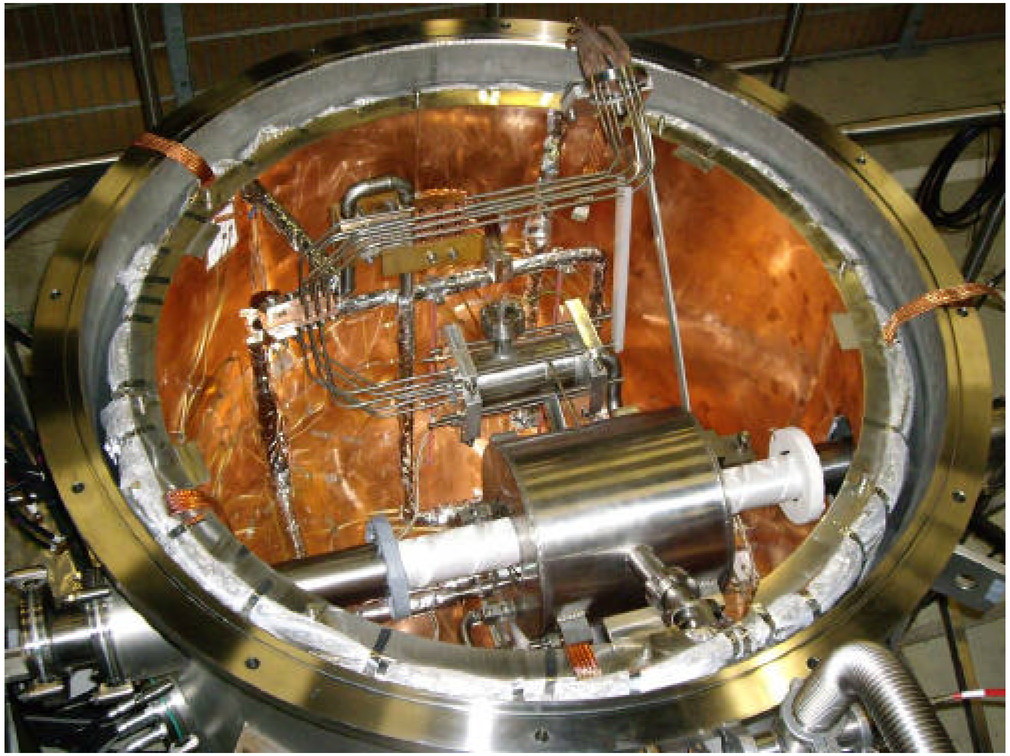
Second prototype measurements

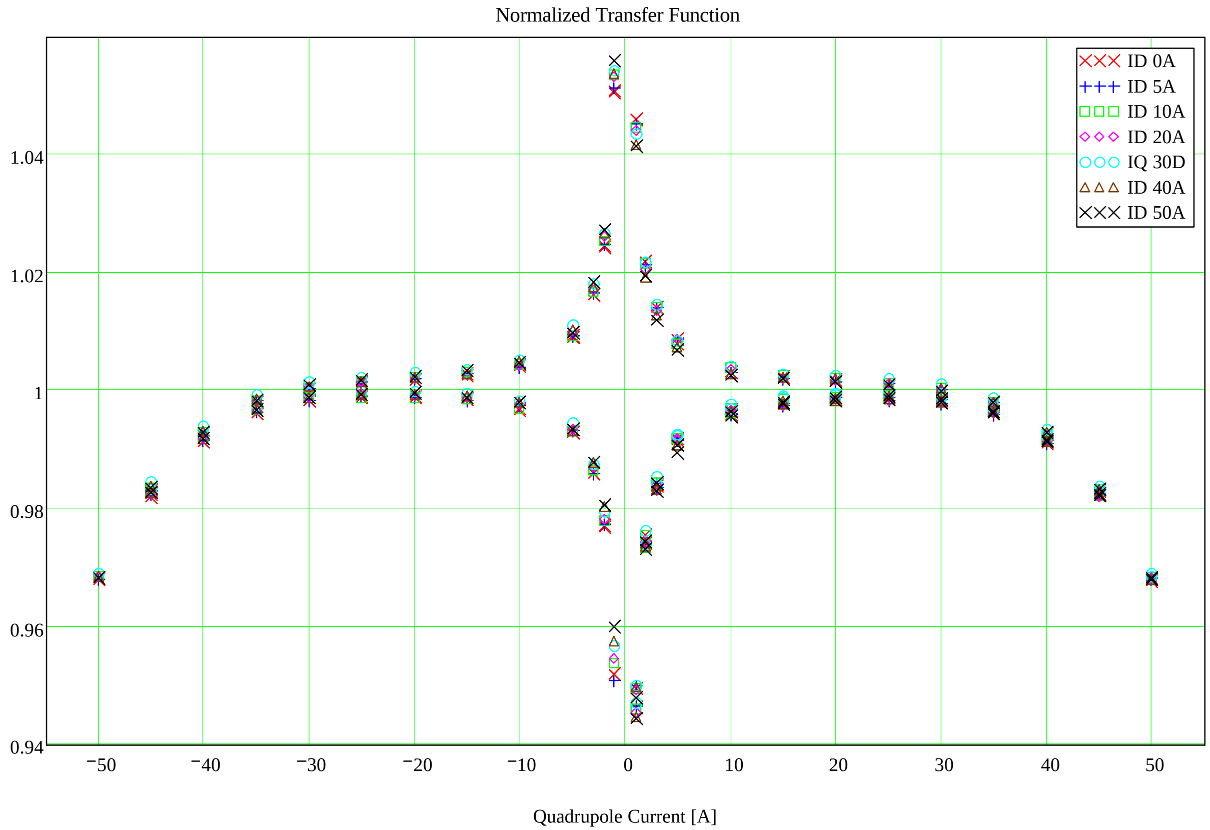
New horizontal cryostat with warm bore



- Copper current leads, conduction cooled.
- Three preseries magnets have been fabricated, with smaller filament diameter in the quadrupole coils (12 micron vs 35).

Second prototype measurements

Magnetic field measurements (PRELIMINARY)



- Measurements have been just made. Analysis is ongoing.
- Stability of the magnetic axis will be measured in the next days.

Future plans & conclusions

- First XFEL prototype was successfully tested. Magnetization effects were large.
- Three preseries magnets have been manufactured in 2008. Smaller filament diameter in the quadrupole coils.
- First preseries magnet has been measured. Analysis is ongoing.
- Stability of the magnetic axis will be measured in the next days.
- Next step is to freeze the series design:
  - A decision is necessary on the size of the dipole filament.
  - Some problems arise to fit the helium vessel design to TUEV pressure vessel rules, which must be solved.
  - The quadrupole winding process is challenging because of the small size of the conductor.