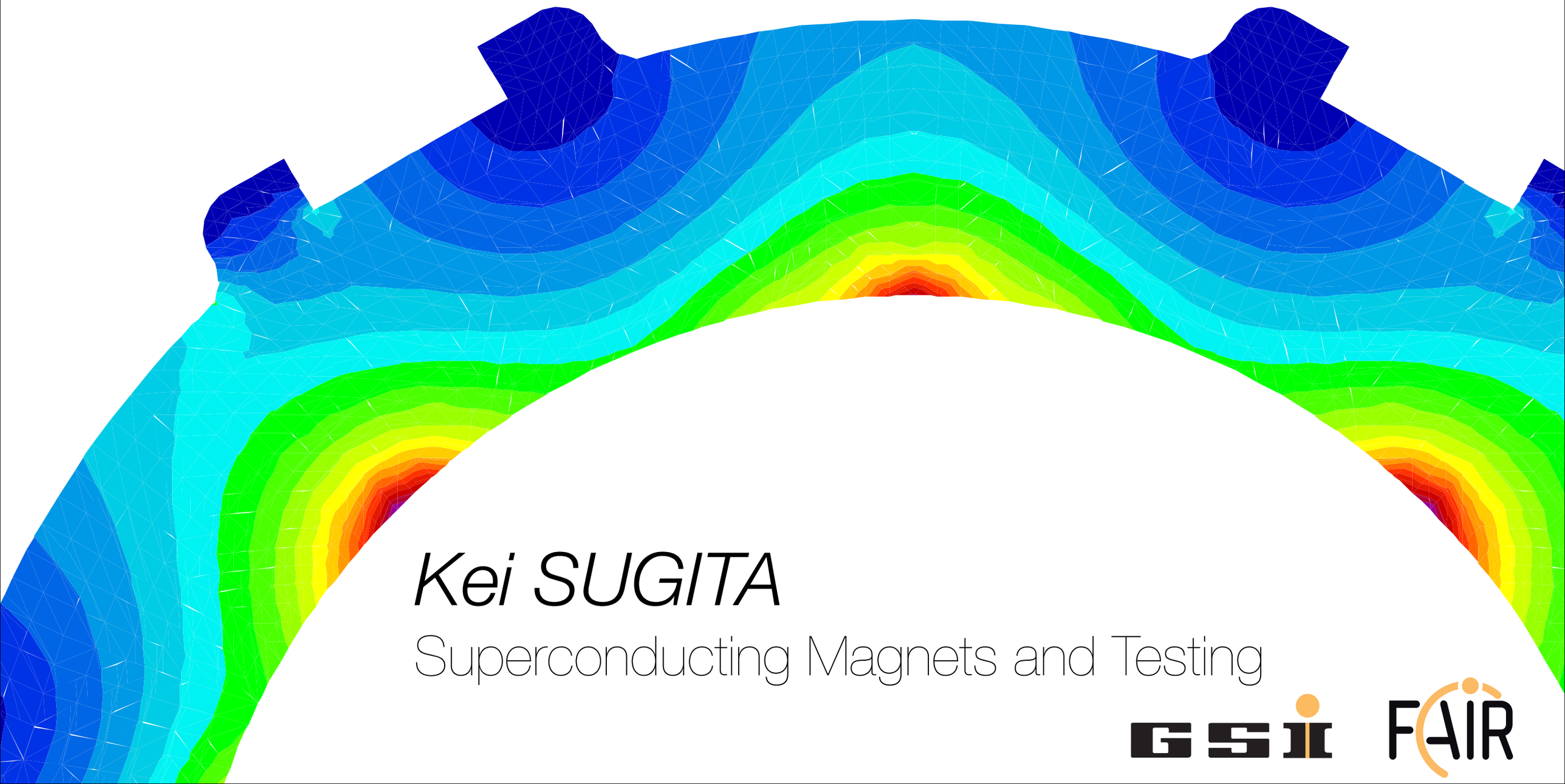
Special Design Aspects of Superconducting Corrector Magnets for SIS100



Kei SUGITA

Superconducting Magnets and Testing

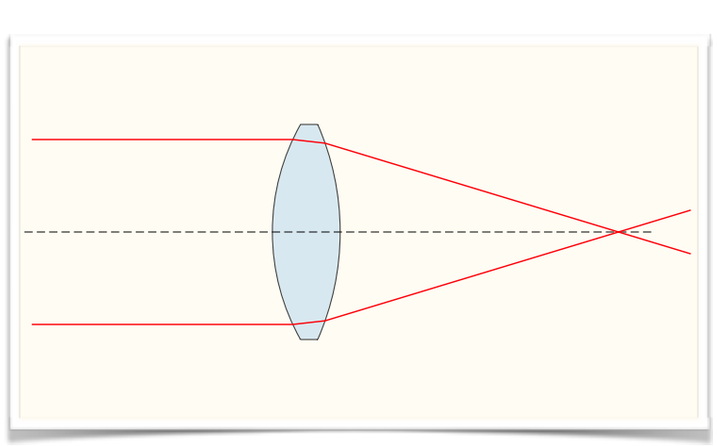
I have designed
the superconducting
corrector magnets
for SIS100.

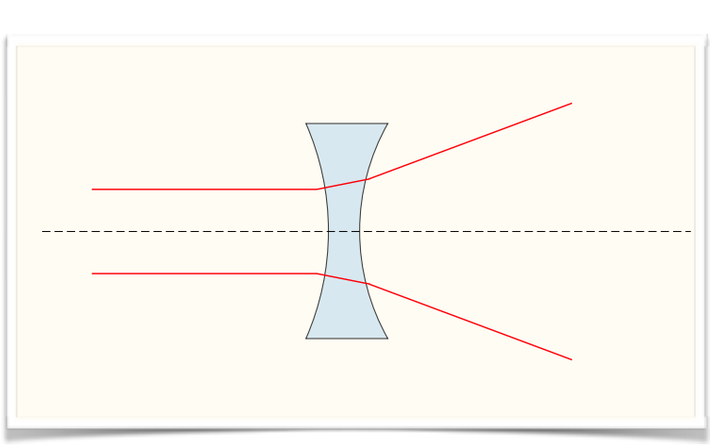
What pitiful magnets!

Everybody knows about

Dipoles and *Quadrupoles*.

The function is obvious.

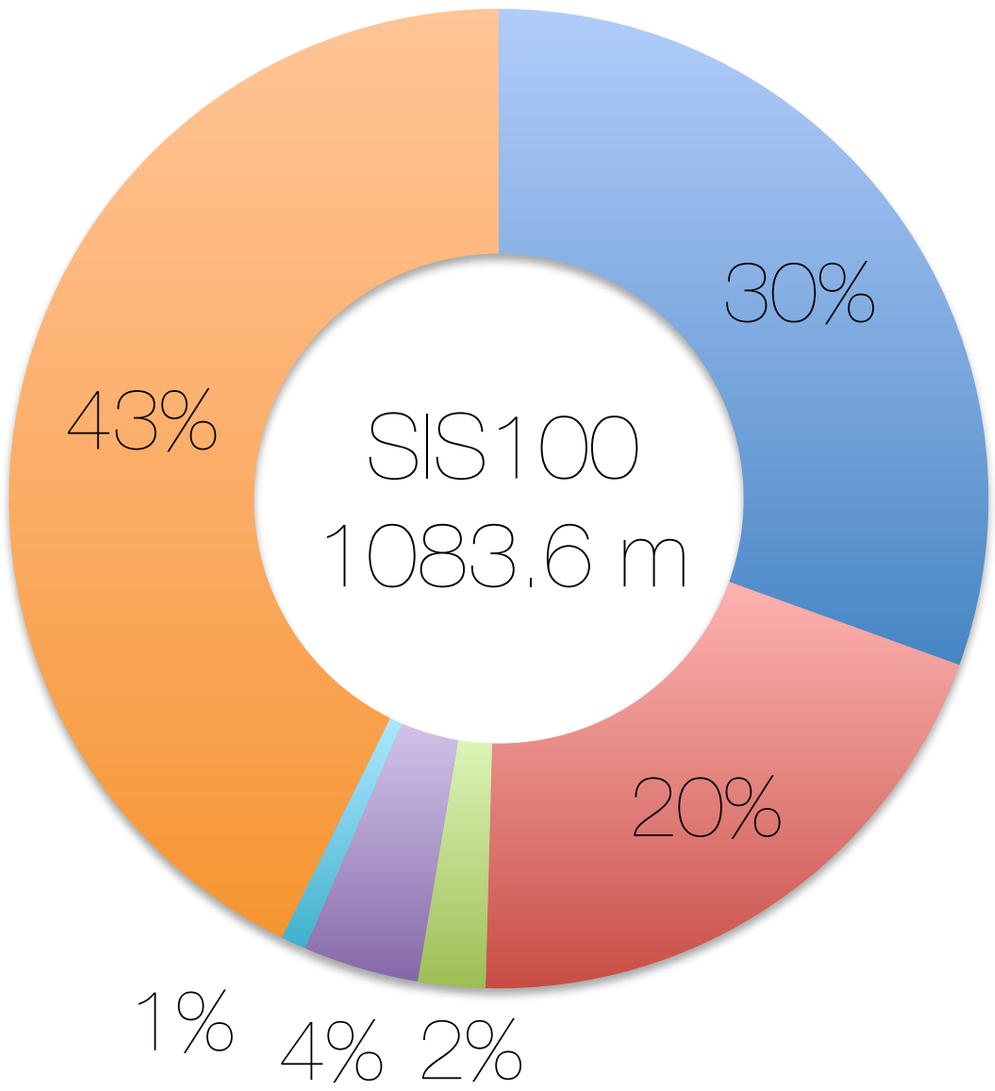




Correctors: well, correct something wrong....

Dipoles and Quadrupoles *major actors* in SIS100

RF scientists may have a different opinion…



*Effective length × Number of Magnets

Corrector Magnets: 7%

Do we really need the correctors?

Beam Dynamics

Yes...

We have requirements from *“rule-of-thumb”*.
We don’t know exactly how much we really need...

Can we design the correctors freely?

Dipole/Quadrupole Designer

No!
Design should be match to the dipoles and quadrupoles.
...as short as possible.

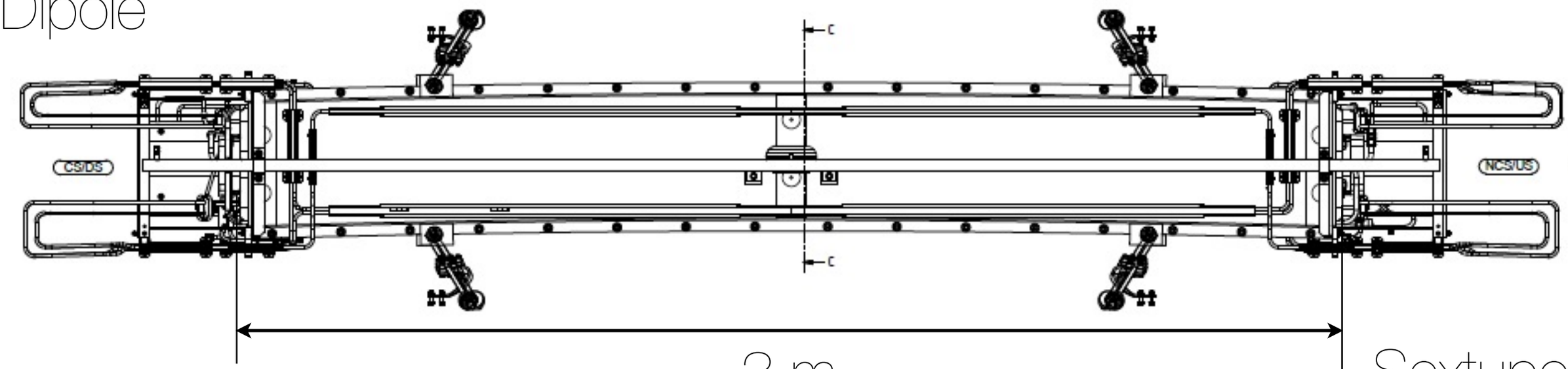
But keep the integral of the magnetic gradient!

Do we need less design effort than the dipoles and quadrupoles?

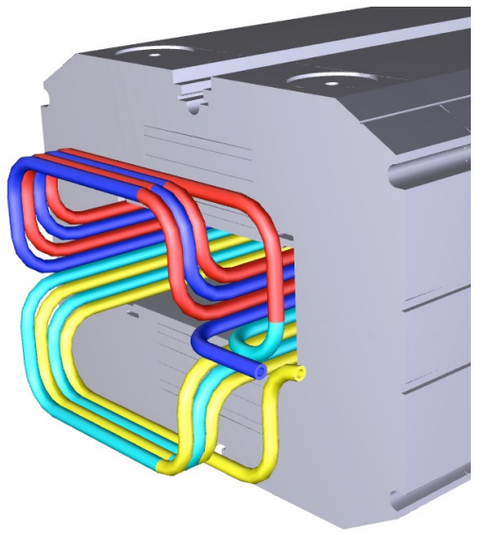
Absolutely No.
Compact, many poles, nested, design constrains...

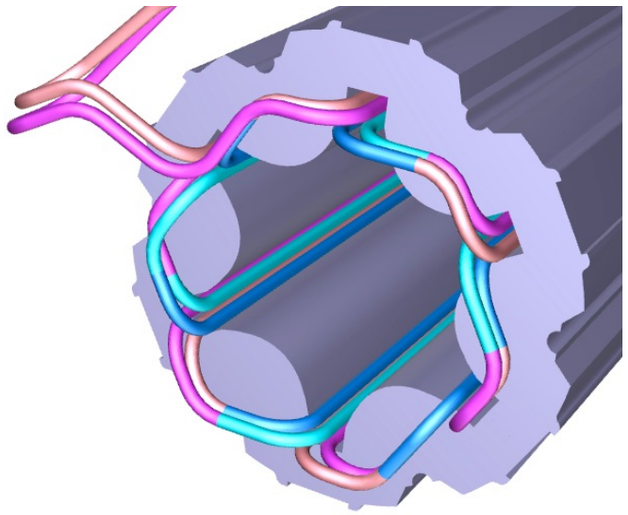
Corrector Magnet Designer

Dipole

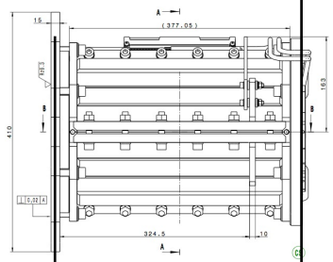


3 m





Sextupole



0.43 m

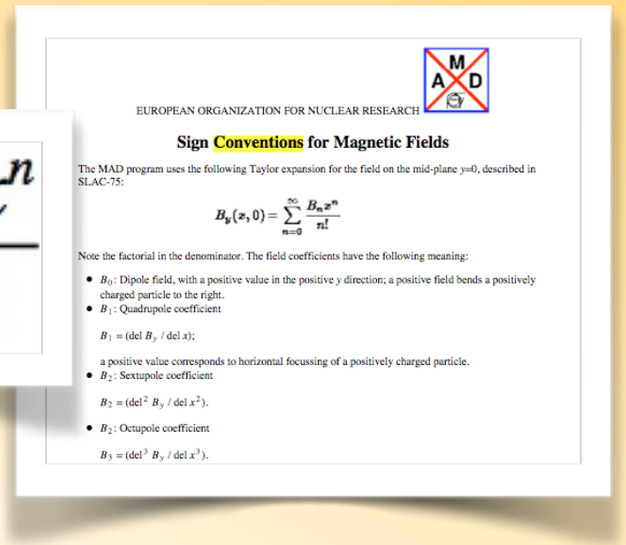
		Steering Magnet	Chromaticity Sextupole Magnet	Multipole Corrector Magnet		
				Quad.	Sext.	Octu.
Effective Length	m	0.5	0.5	0.75		
Maximum Field	T/m^{n-1}	0.3	350	0.75	50	2000
Minimum Field	T/m^{n-1}	-0.3	-350	-0.75	-50	-2000
Max. Ramp rate	$(T/m^{n-1})/s$	1.5	2000	5	210	8500

Field strength, Effective length,
Ramp rate, bi-/uni-polar.

Do you know the difference of
magnetic multipole representation?

$$\mathbf{B} = B_y + iB_x = \sum_{n=1}^{\infty}(B_n + iA_n)\left(\frac{x+iy}{r_0}\right)^{n-1}$$

$$B_y(x,0) = \sum_{n=0}^{\infty}\frac{B_n x^n}{n!}$$



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Sign Conventions for Magnetic Fields

The MAD program uses the following Taylor expansion for the field on the mid-plane y=0, described in SLAC-75:

$$B_y(x,0) = \sum_{n=0}^{\infty}\frac{B_n x^n}{n!}$$

Note the factorial in the denominator. The field coefficients have the following meaning:

- B_0: Dipole field, with a positive value in the positive y direction; a positive field bends a positively charged particle to the right.
- B_1: Quadrupole coefficient

  $B_1 = (\text{del } B_y \text{ / del } x)$;

  a positive value corresponds to horizontal focussing of a positively charged particle.
- B_2: Sextupole coefficient

  $B_2 = (\text{del}^2 B_y \text{ / del } x^2)$.
- B_2: Octupole coefficient

  $B_3 = (\text{del}^3 B_y \text{ / del } x^3)$.

Magnet design: dipole n=1
Beam dynamics: dipole n=0
Exclude "n!" from Bn in beam dynamics definition
Both units T/m^n (T/m^{n-1}) is same!

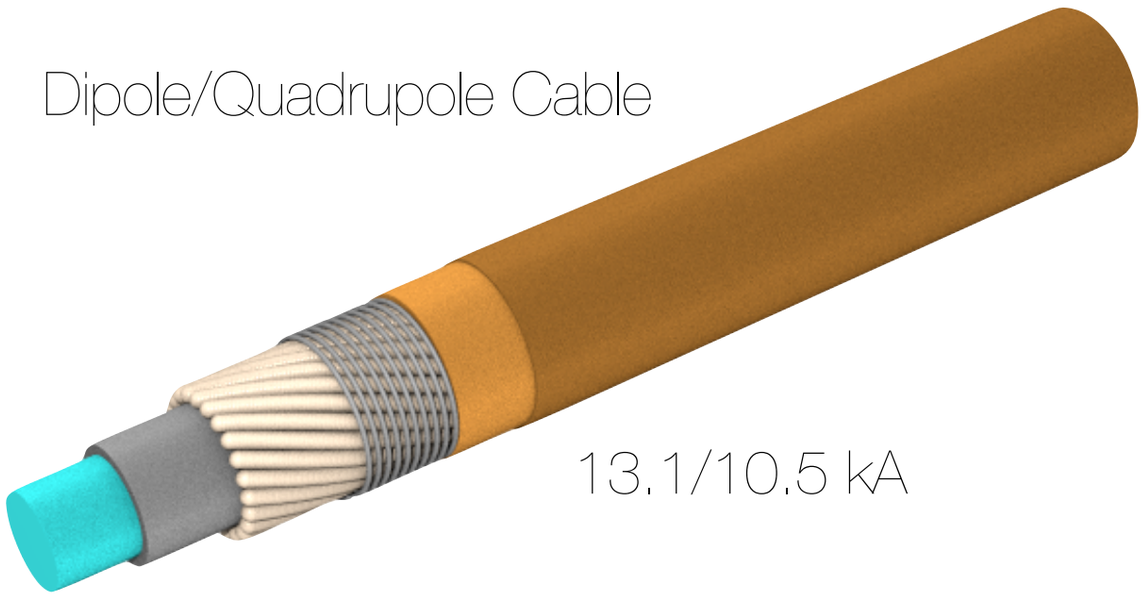
n!
Dipole 0!=1
Quadrupole 1!=1
Sextupole 2! = 2
Octupole 3! = 6

We should respect each other!
The definition should be described in the docs, specs.

Individual operation

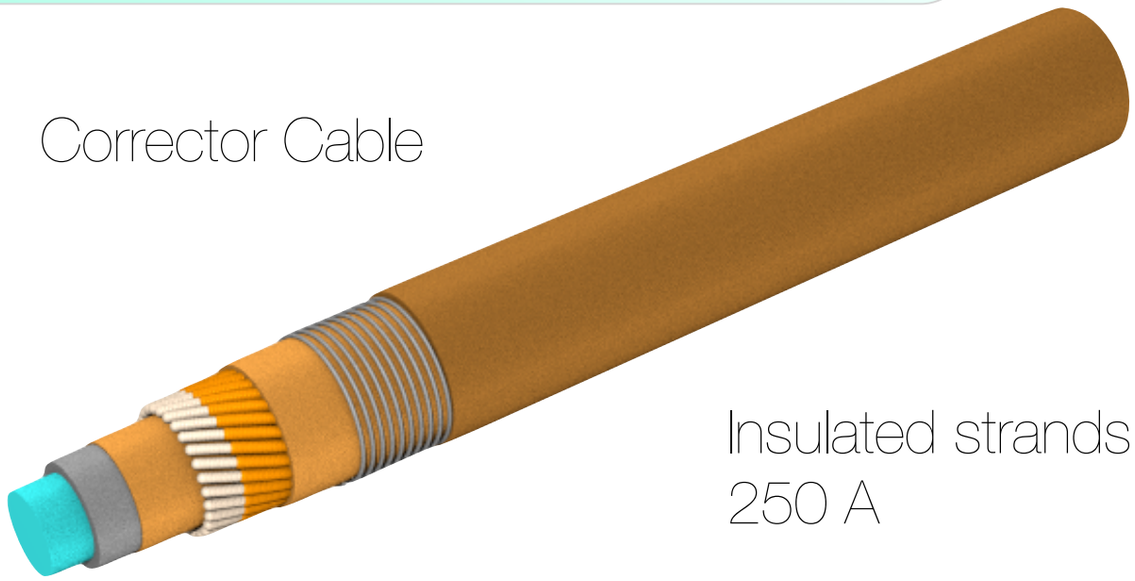
Local power converter, Low current, Nuclotron cable

Dipole/Quadrupole Cable

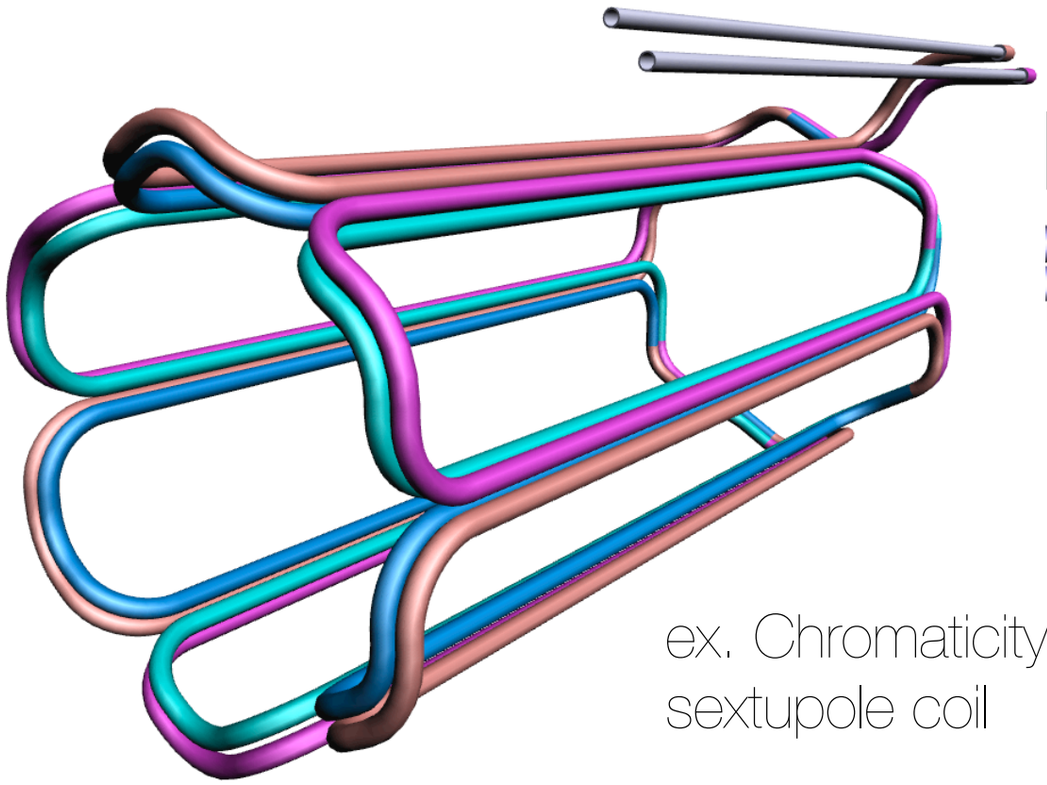


13.1/10.5 kA

Corrector Cable

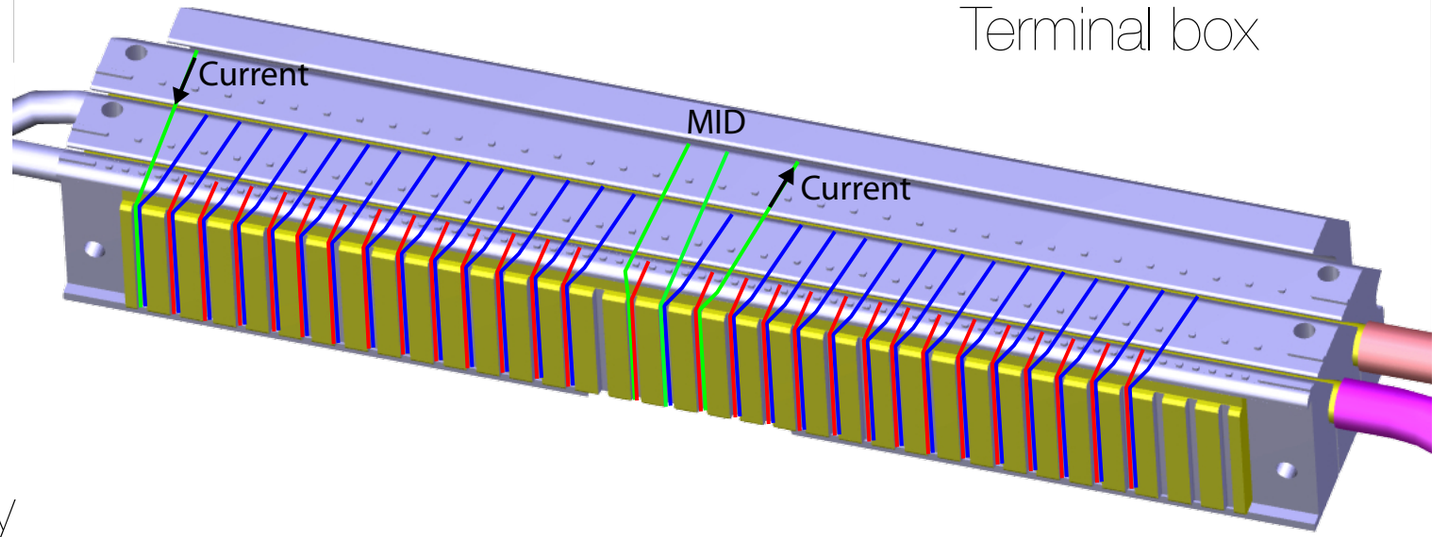


Insulated strands
250 A

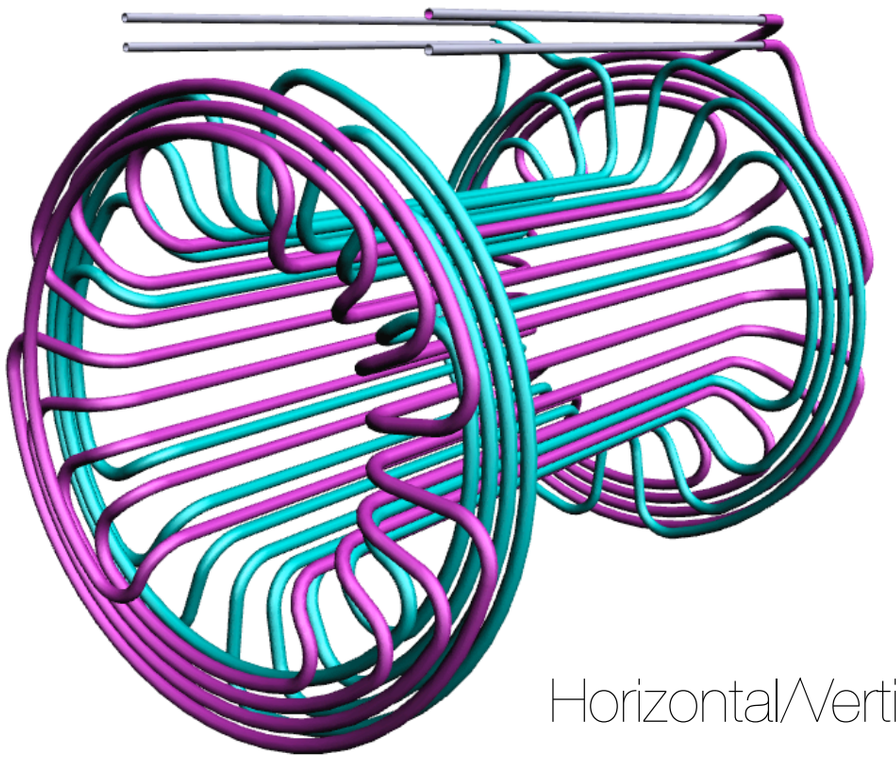


ex. Chromaticity
sextupole coil

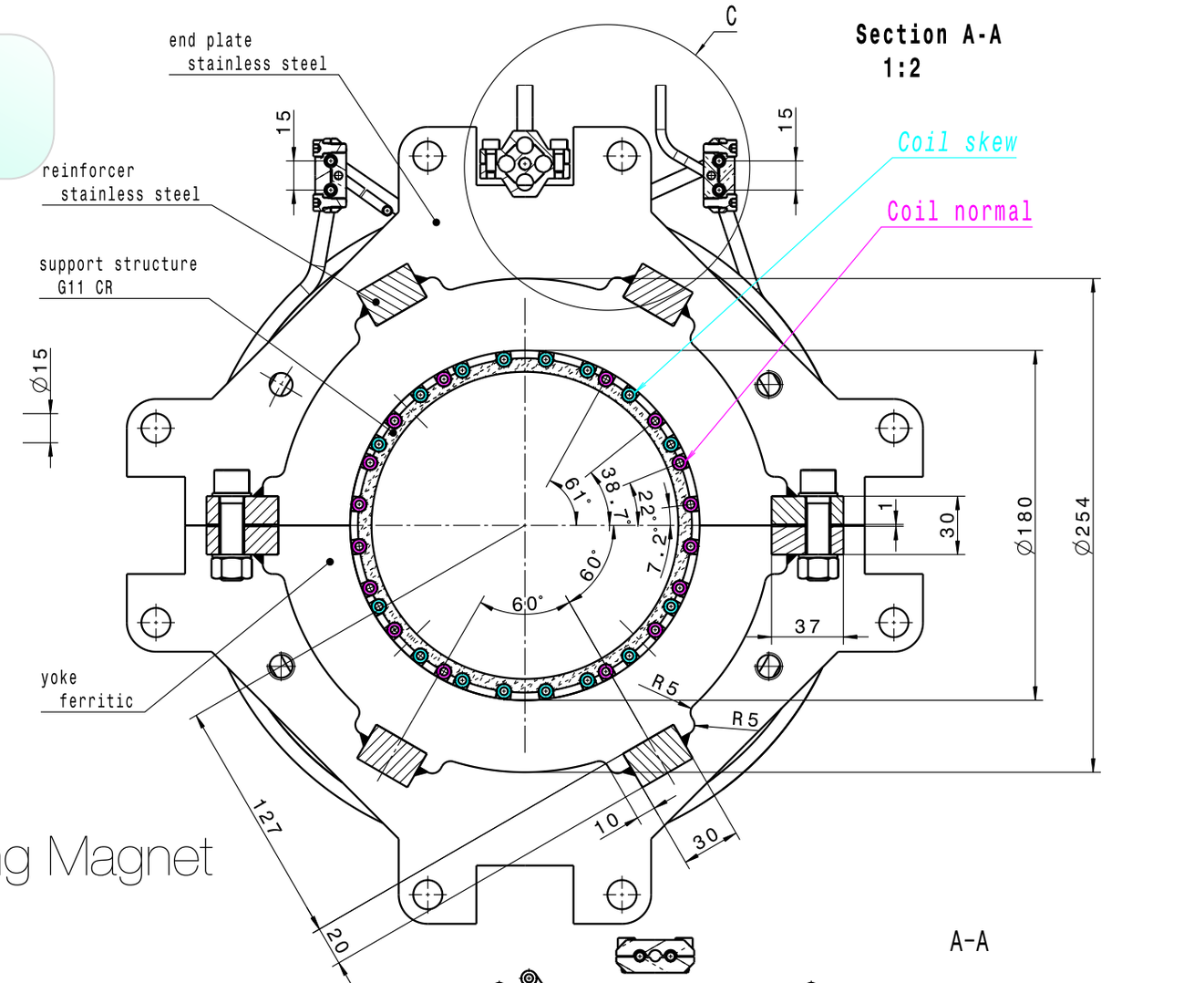
Terminal box

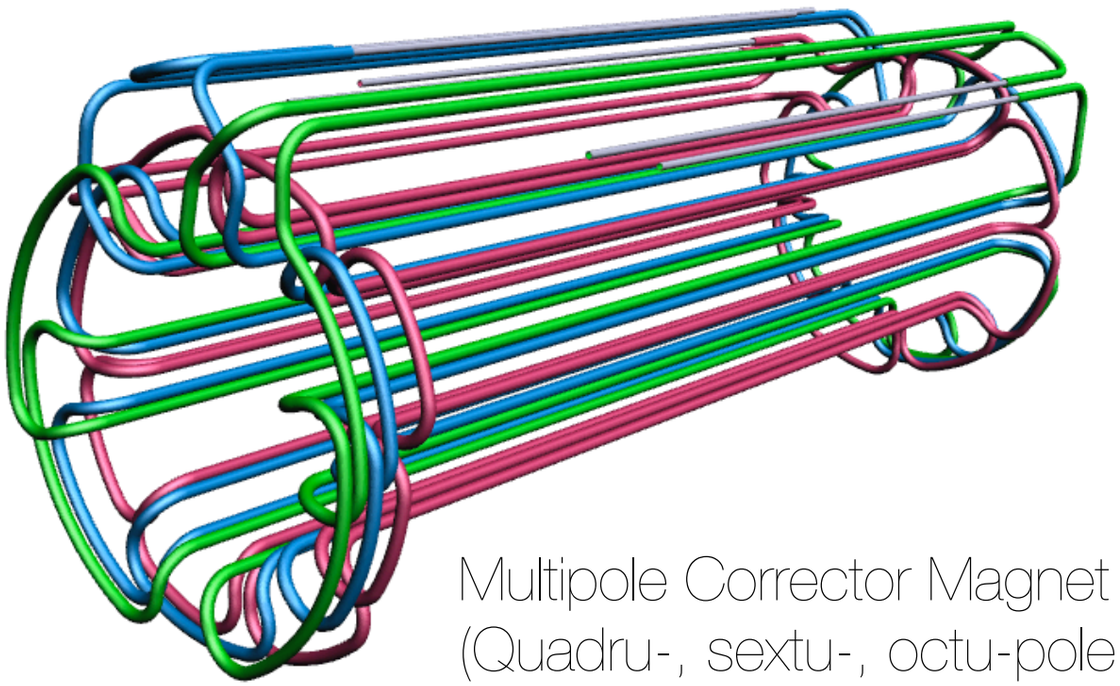


No space... nested magnets!

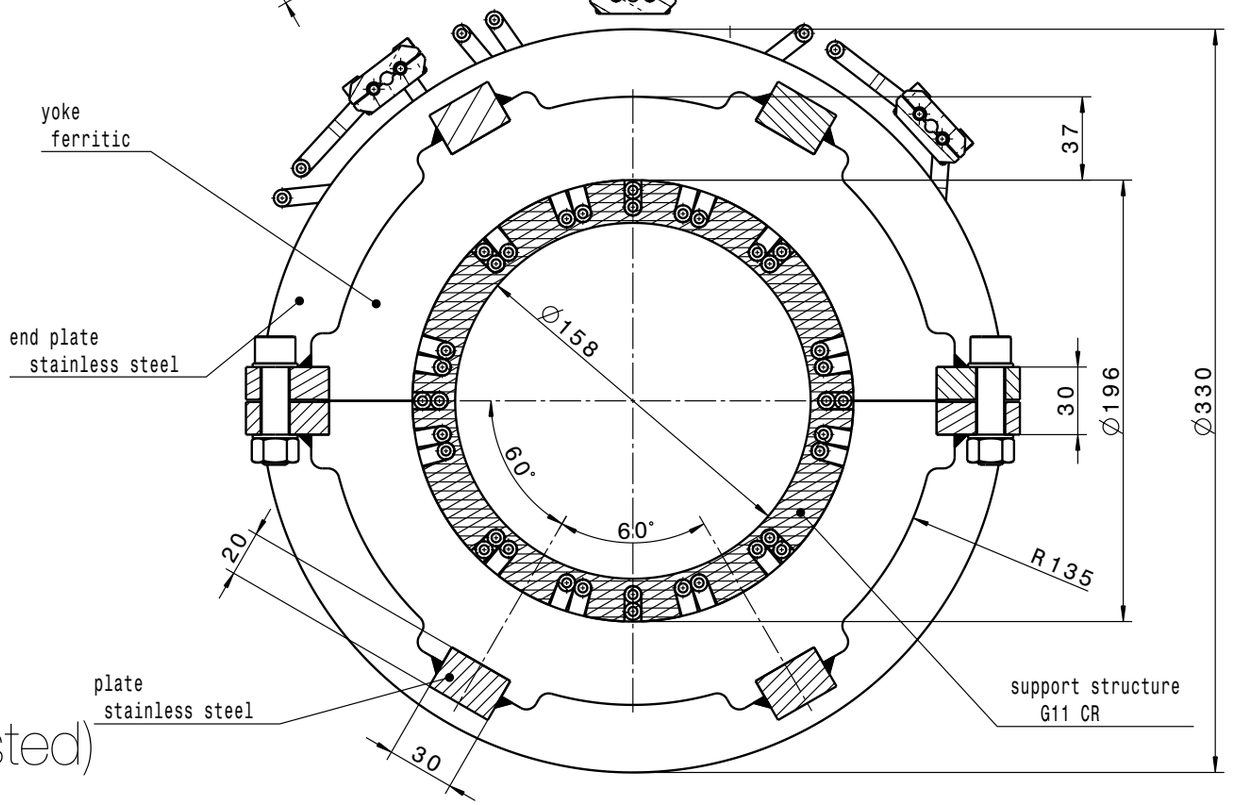


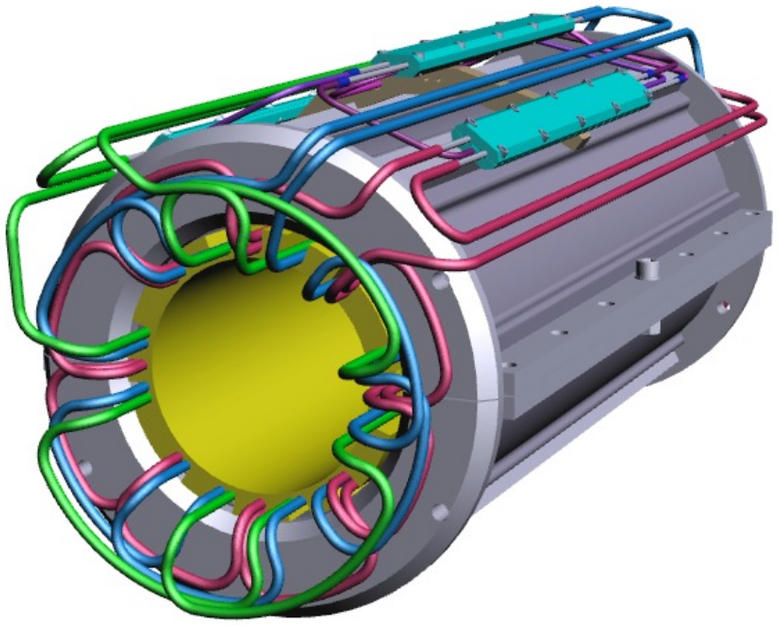
Horizontal/Vertical Steering Magnet

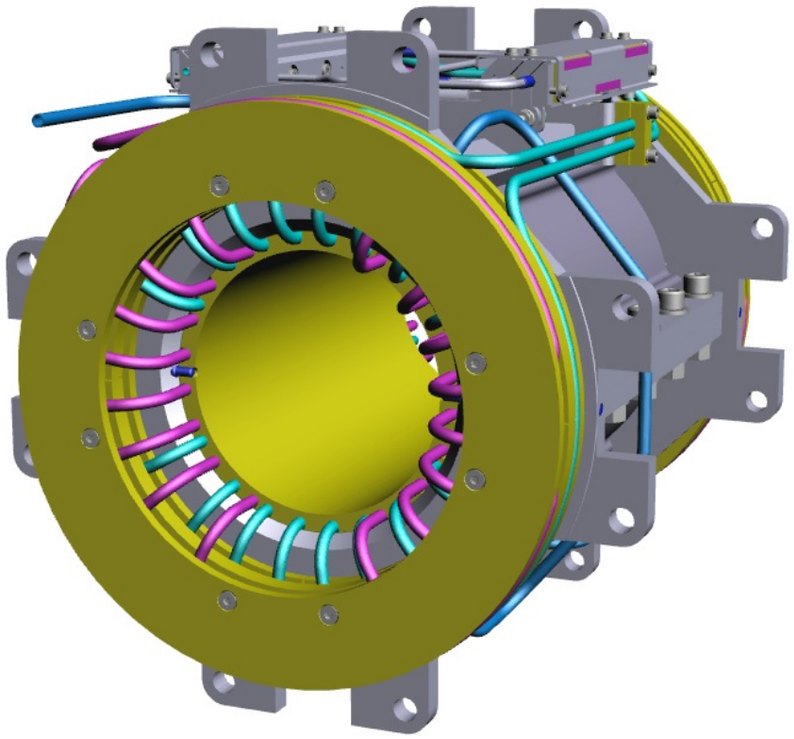


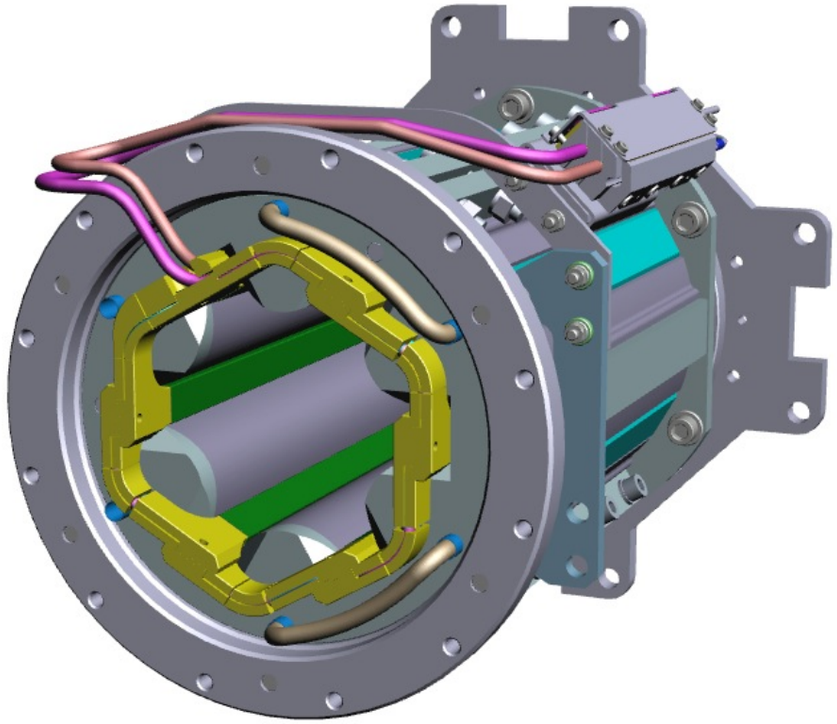


Multipole Corrector Magnet
(Quadru-, sextu-, octu-pole nested)







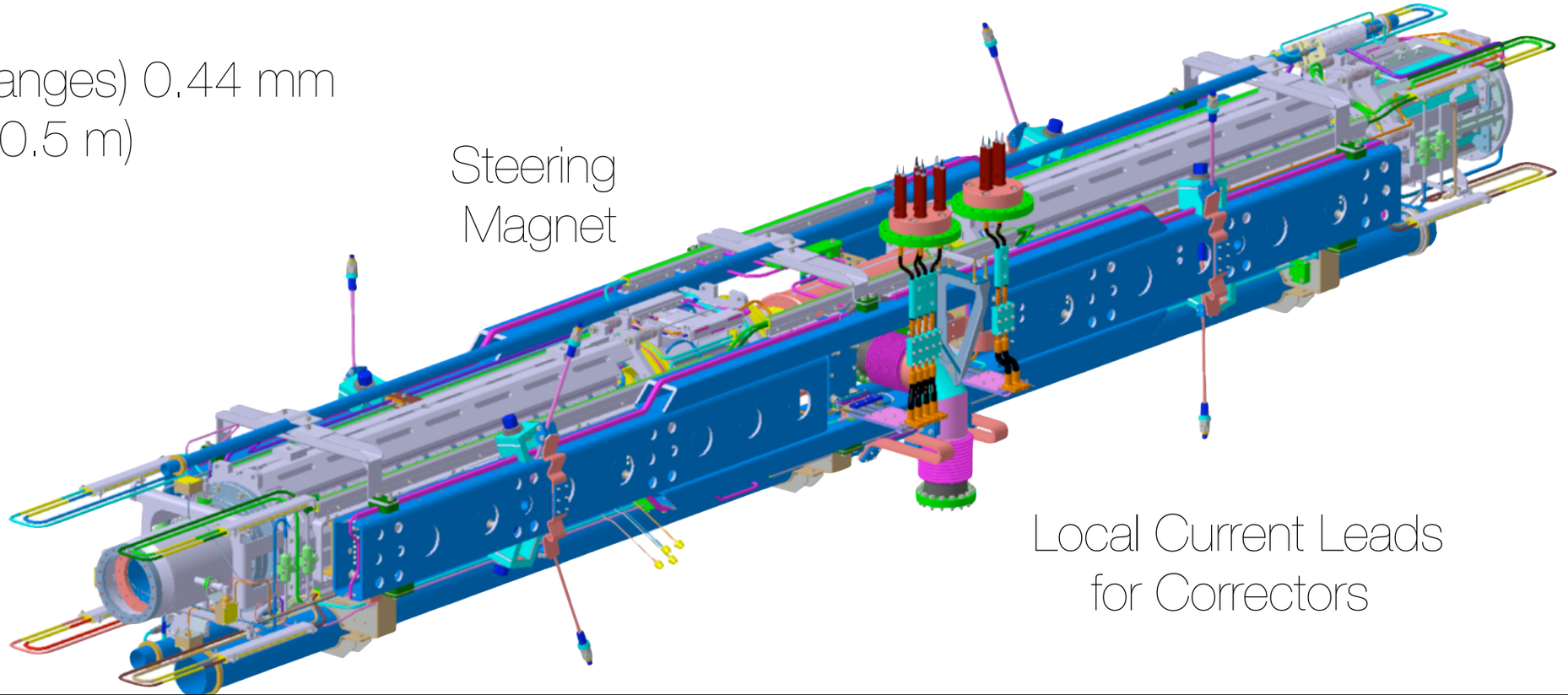


Chrom.
Sextupole
Magnet

Integrate into the slot in the quadrupole module!

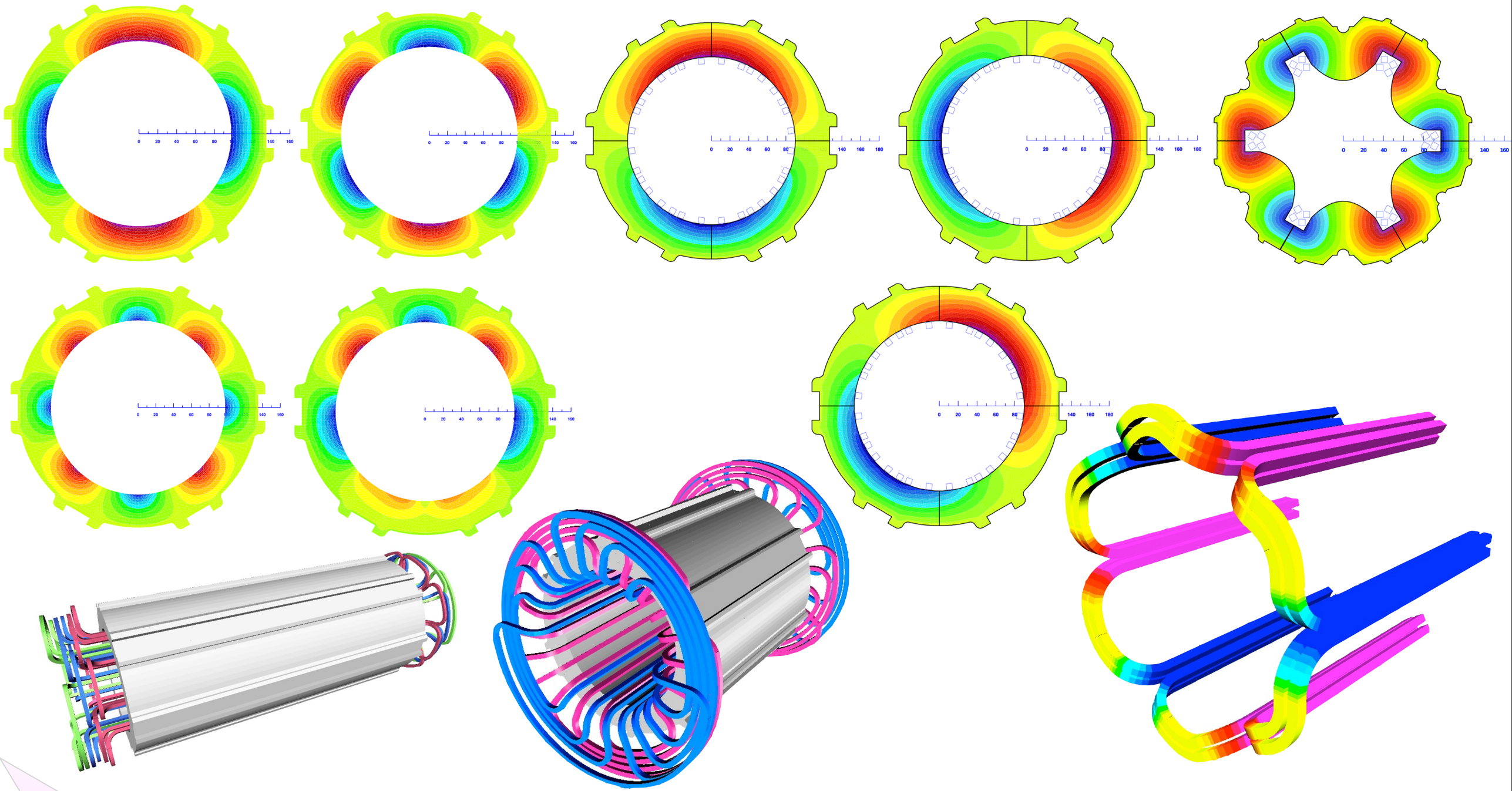
Length (incl. connection flanges) 0.44 mm
(Required effective length 0.5 m)

Steering
Magnet



Local Current Leads
for Correctors

Magnetic field computation 2D and 3D



How about the requirements on field quality?

Well... good enough… Please don’t disturb the beam!

Summary

- Correctors occupy only a ***small*** part of SIS100.
- But it is ***necessary***.
- ***Design efforts*** for the corrector is equivalent or ***more*** than that of the dipole and quadrupole.
- Corrector magnets ***destined*** (have to be designed) to absorb/undertake mechanical/magnetic issues.
- In the later stage of the developments, there is ***less+less freedom*** of the design.
- So if you have any requests, please ***inform*** corrector designers immediately!

Don't forget Correctors!