BILFINGER

Babcock Noell GmbH

Mad Max Workshop @ DESY 18-19 October 2017

Design of the Magnet System

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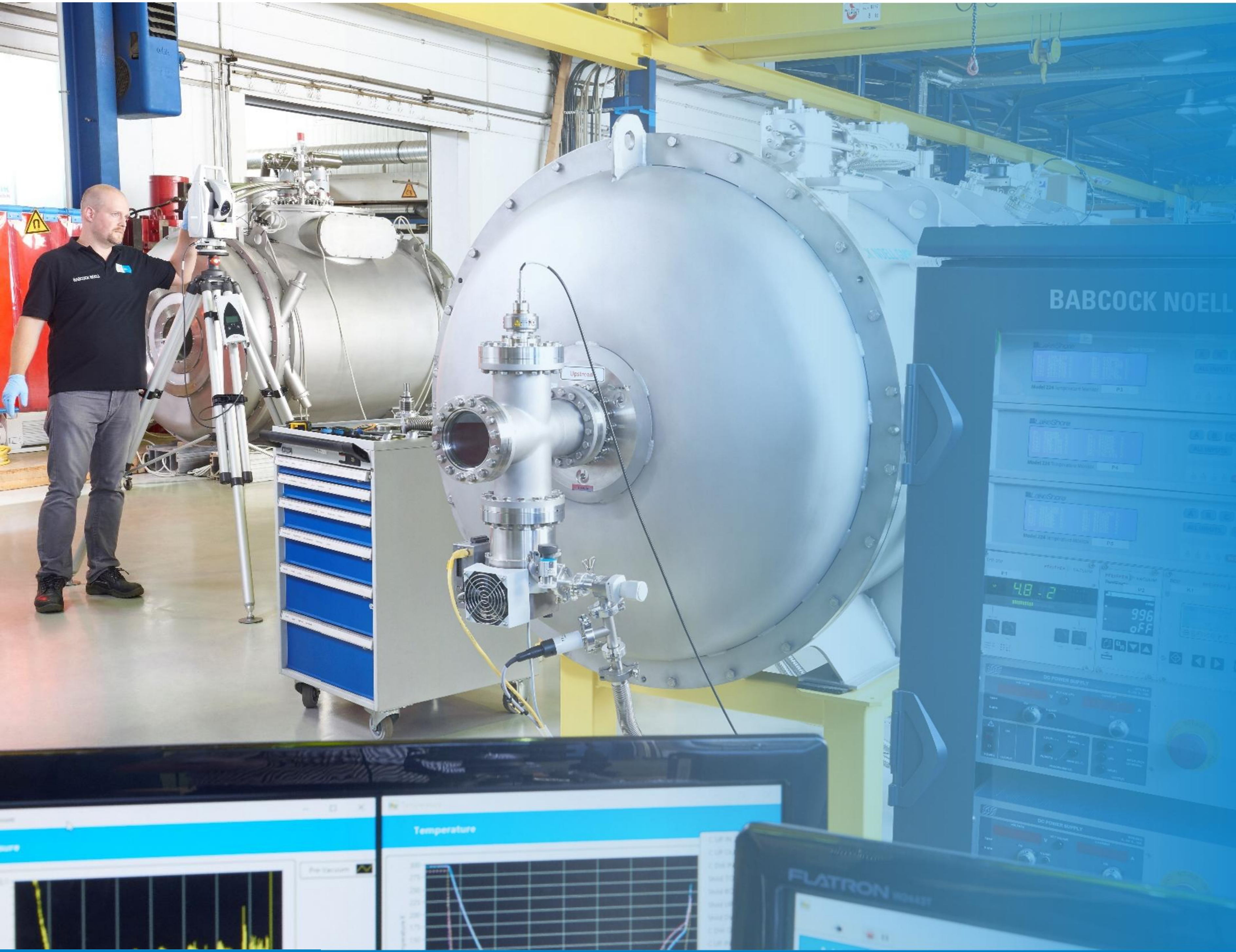


Outline

Introduction

Framework of the study

Magnetic designs

Comparison

Conclusion

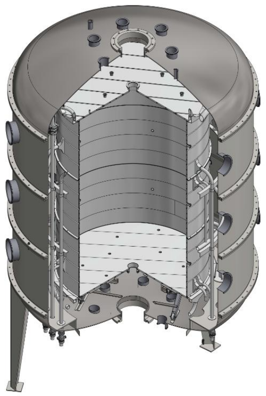
Babcock Noell GmbH

Varian
(Troisdorf)

DFG
(Bonn)

DESY
(Hamburg)

IPP
(Greifswald)



FZJ
(Jülich)

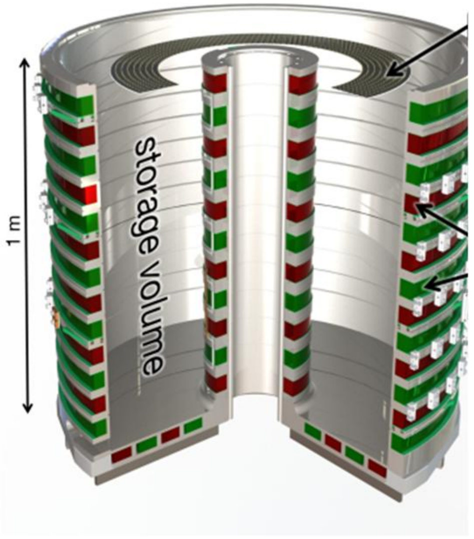
GSI
(Darmstadt)

EURATOM
(Brüssel)

Siemens
(Erlangen)

KIT
(Karlsruhe)

TUM
(München)

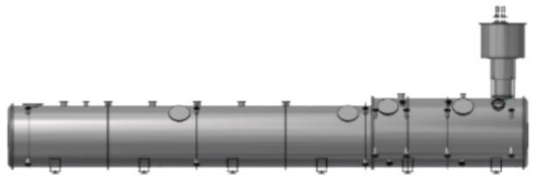


CERN
(Genf)

Voith
(Heidenheim)

MPI/MPG
(München)

Siemens
(Taufkirchen)



The Framework of the study

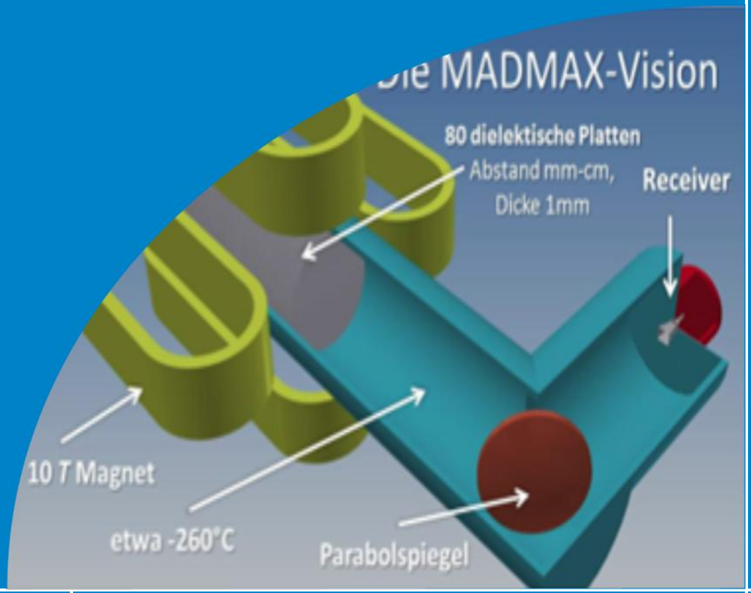


Figure of Merit

100 T^2m^2

Nb_3Sn 15 T @ 0.75 m
NbTi 9 T @ 1.25 m

Homogeneity

Better than 5 % on the disk surface assuming negligible distribution along length.

10^{-3} on mirror disk

Fringe Field

Fringe field should be within 5 gauss in a range between 4 to 10 m.

Length

Evaluation of length impact (0.5 to 2.0 m) on cost and performance

Bore

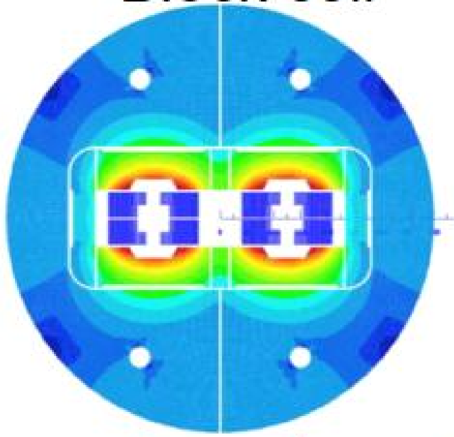
Warm bore for maximum flexibility of the system. At the moment Noell fixed the coils inner diameter at >1.0 m with 0.75 m disks.

Cooling

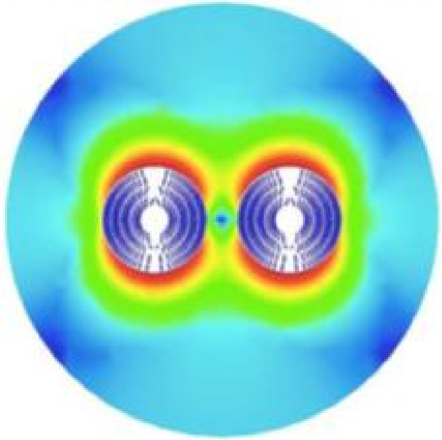
Different options based on level of heat losses in operation and during ramping (15 minutes to max current).

Preliminary designs as of Nov. 16'

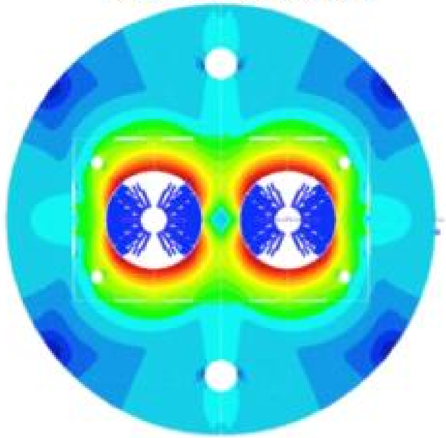
Block coil



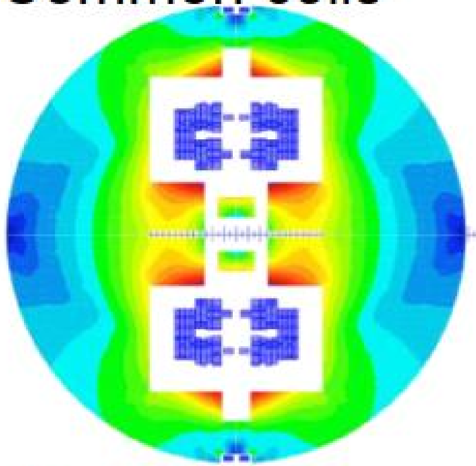
Canted Cosine Theta



Cos-theta



Common coils

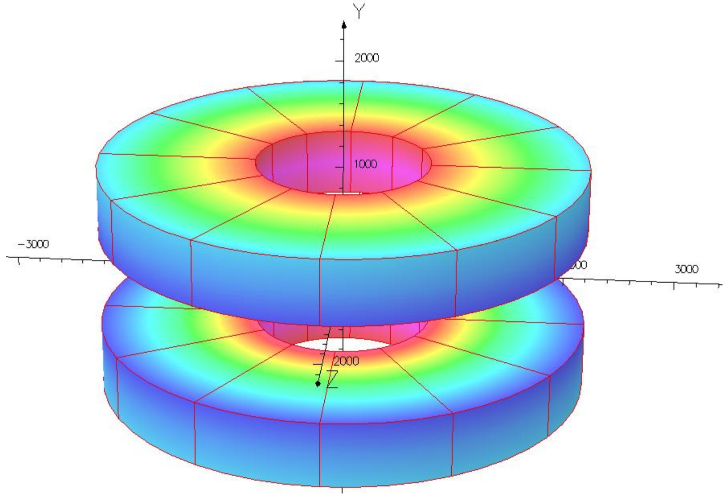


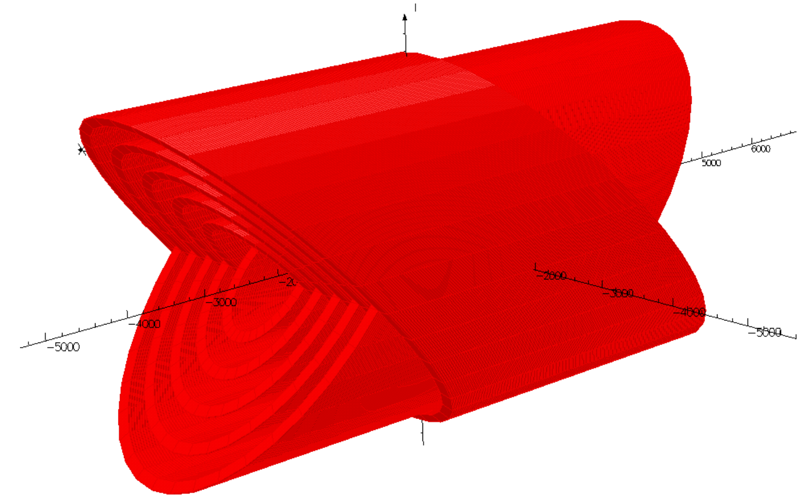
16 T dipoles for FCC

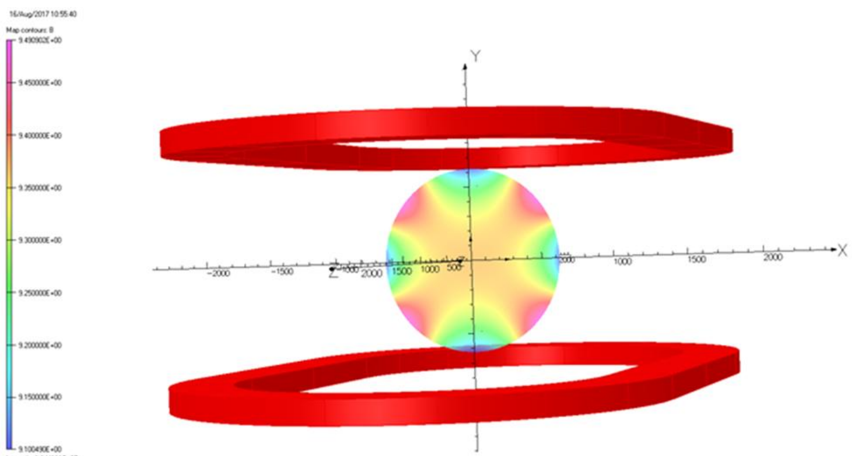
<100 mm cold bore

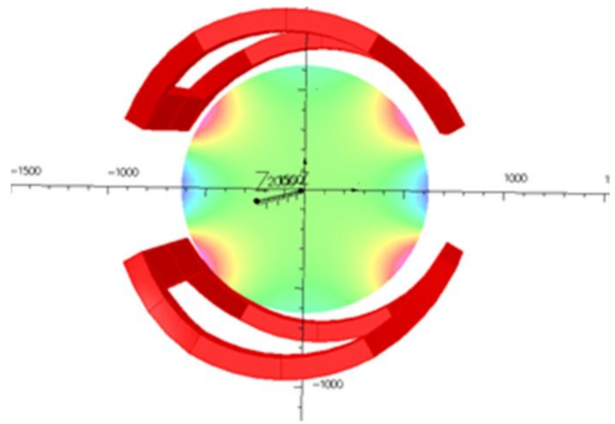
Courtesy B. Auchmann, PSI

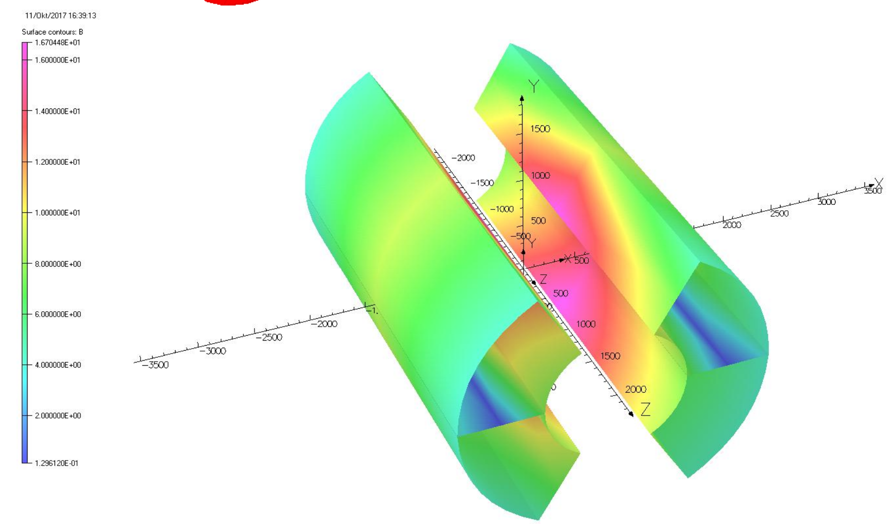
The Dipole Zoo

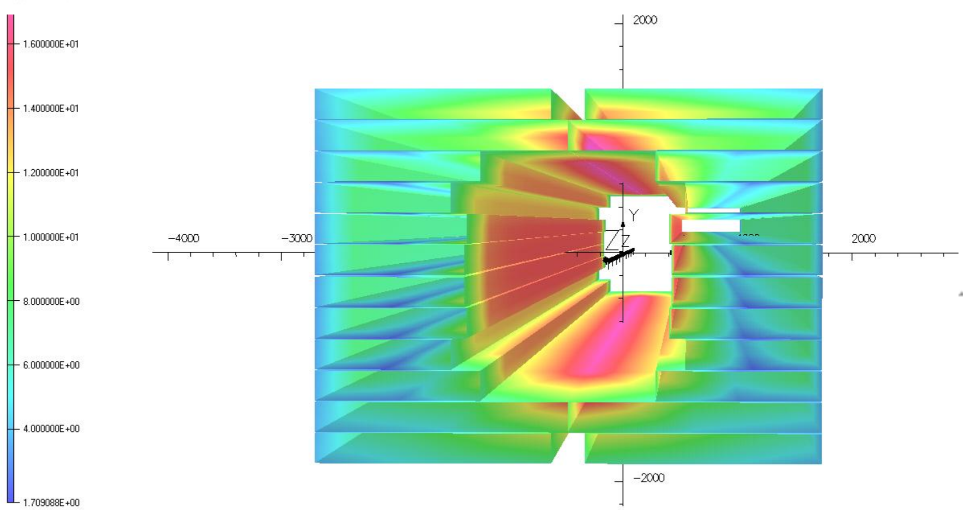


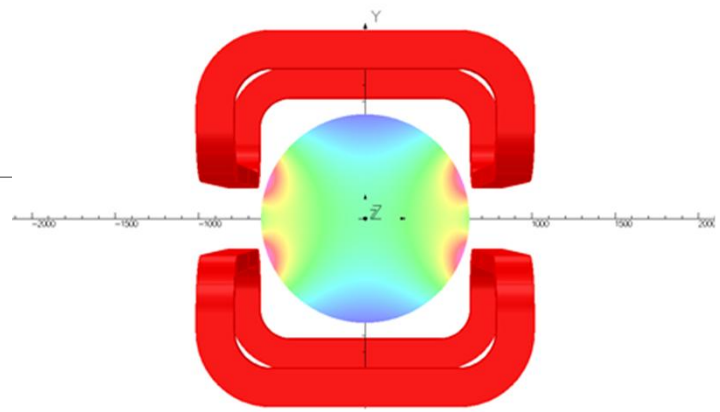


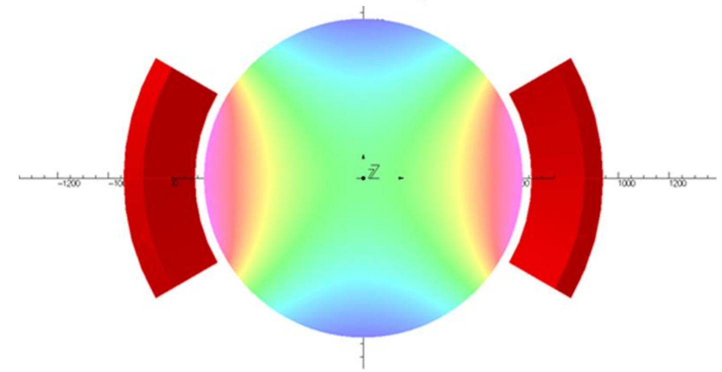












Systematic Study

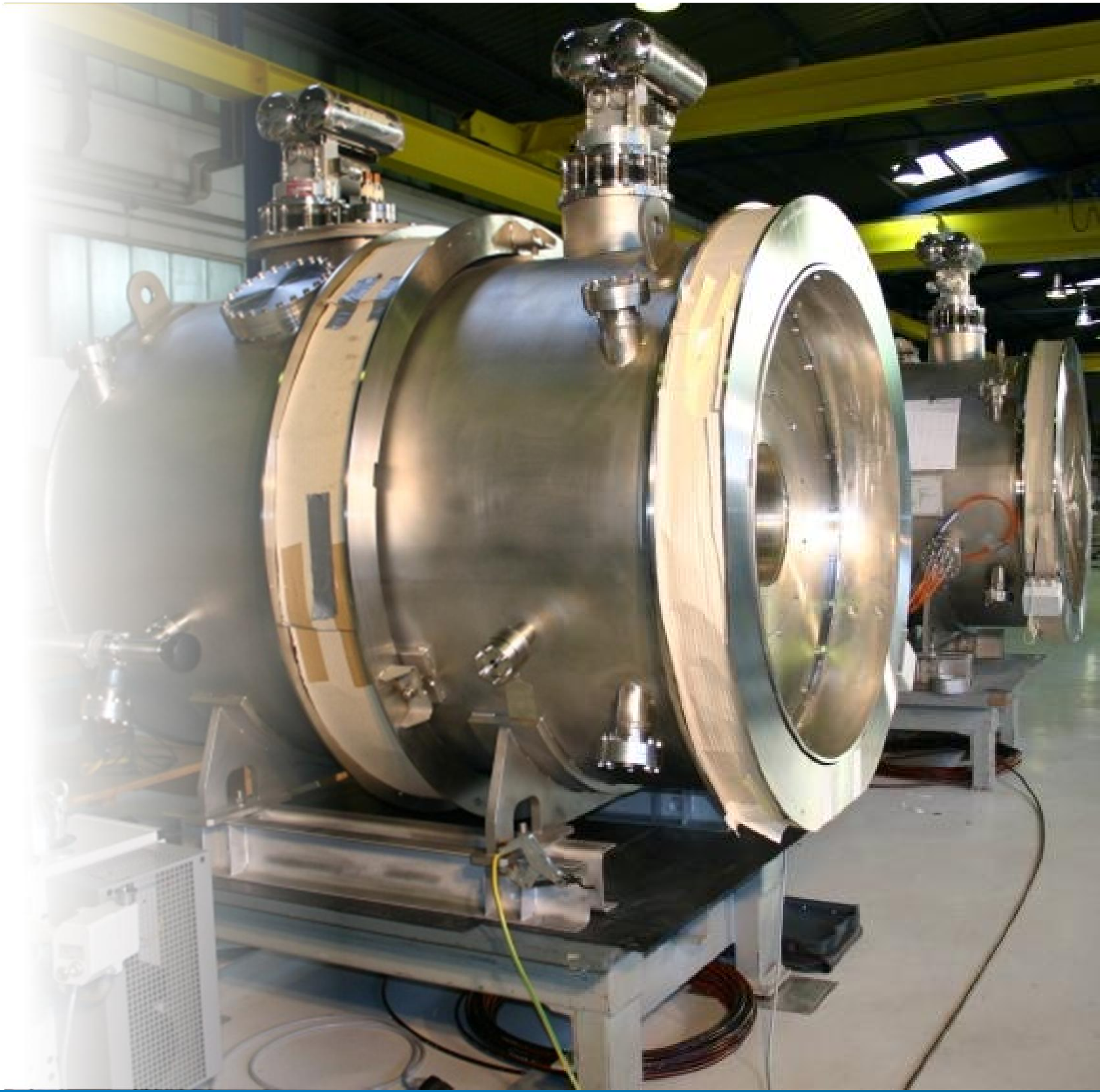
Toward a fair comparison

INPUT:

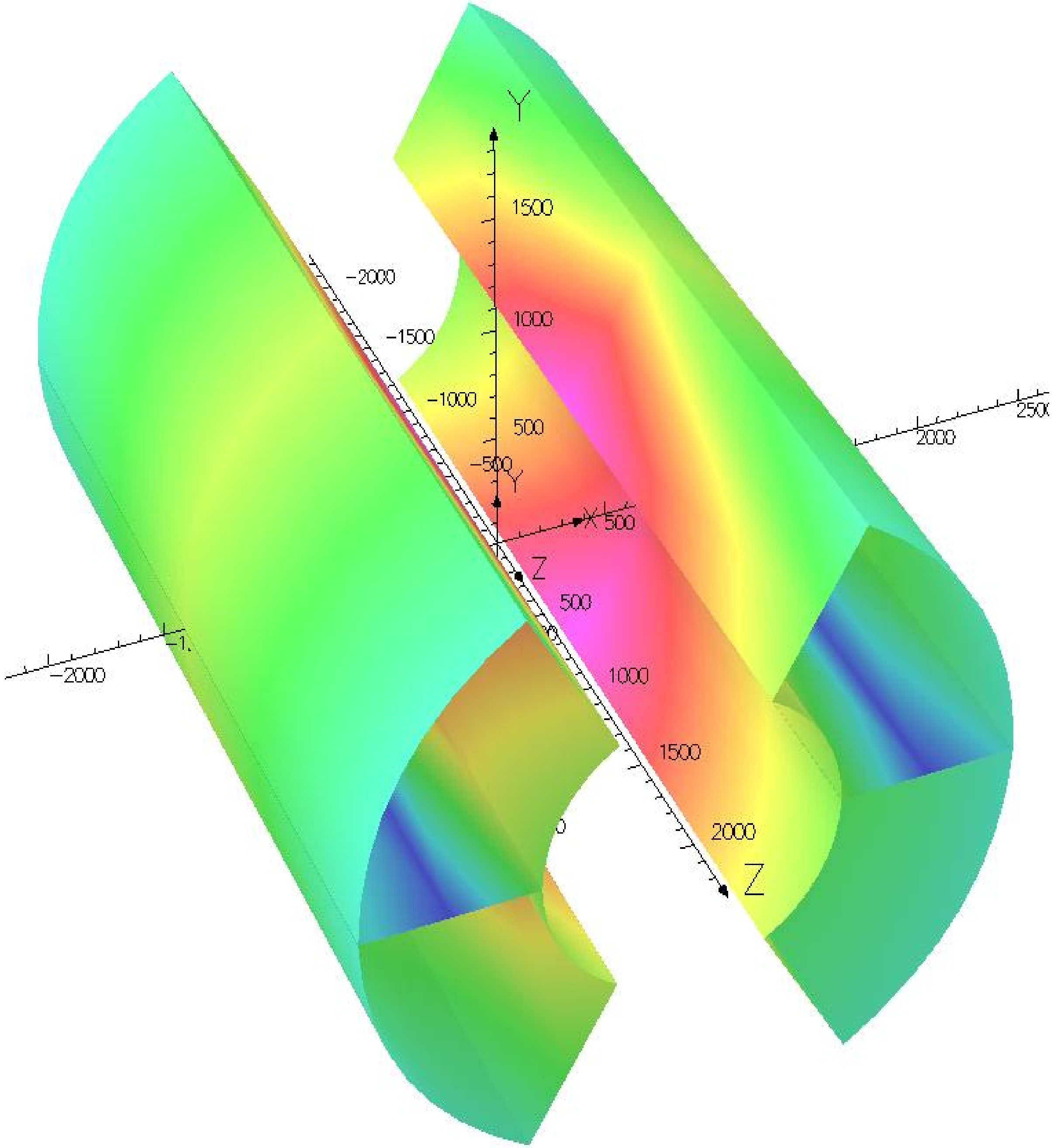
- Nb_3Sn solution with 0.75 m disks
- Magnetic field on disks 15 T
- Engineering current density 30 and 100 A/mm^2
- Minimum ID of coils 1 m
- Magnetic field deviation on disk < 2%

OUTPUT:

- Magnetic field map on disk
- Fringe field
- Volume SC per meter



Cosine Theta Design



Standard for accelerator magnets

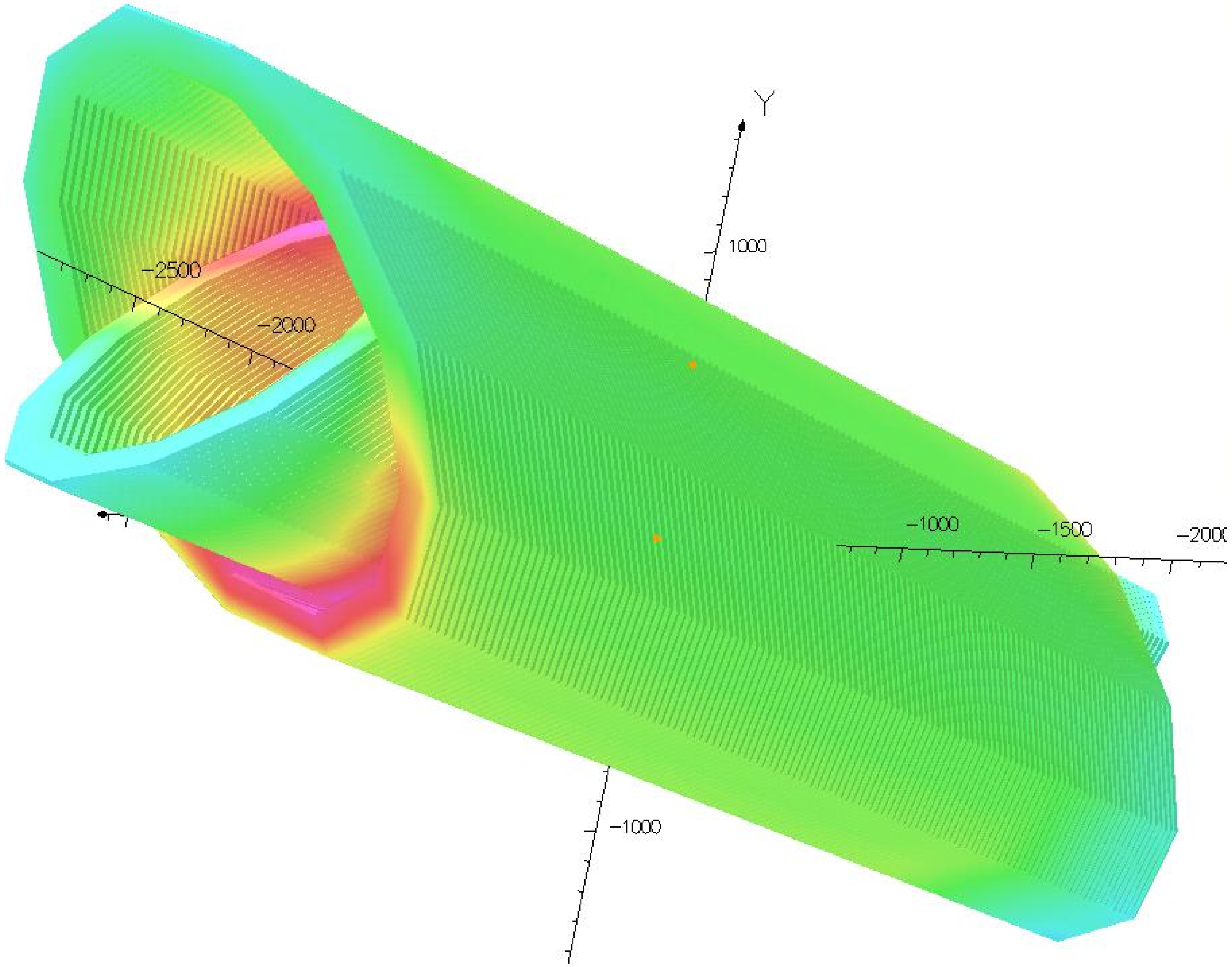
Self supporting coils

Keystones Rutherford cable

Field above Nb_3Sn @ 4.5 K

Parameter	30 A/mm²	100 A/mm²
Homogeneity on disk	1.99 %	2.00 %
Coil outer diameter	2.8 m	2.0 m
Cross section SC	3.3 m²	0.86 m²
B max at conductor	16.7 T	19.0 T
Fringe field at 6 m	286 mT	211 mT

Canted Cosine Theta Design



New trend for accelerator magnets

Higher current densities possible

Flat Rutherford cable

Field above Nb_3Sn @ 4.5 K

Parameter	30 A/mm^2	100 A/mm^2
Homogeneity on disk	0.52 %	1.14 %
Coil outer diameter	4.0 m	2.0 m
Cross section SC	5.2 m^2	2.6 m^2
B max at conductor	20 T	20 T
Fringe field at 6 m	240 mT	40 mT

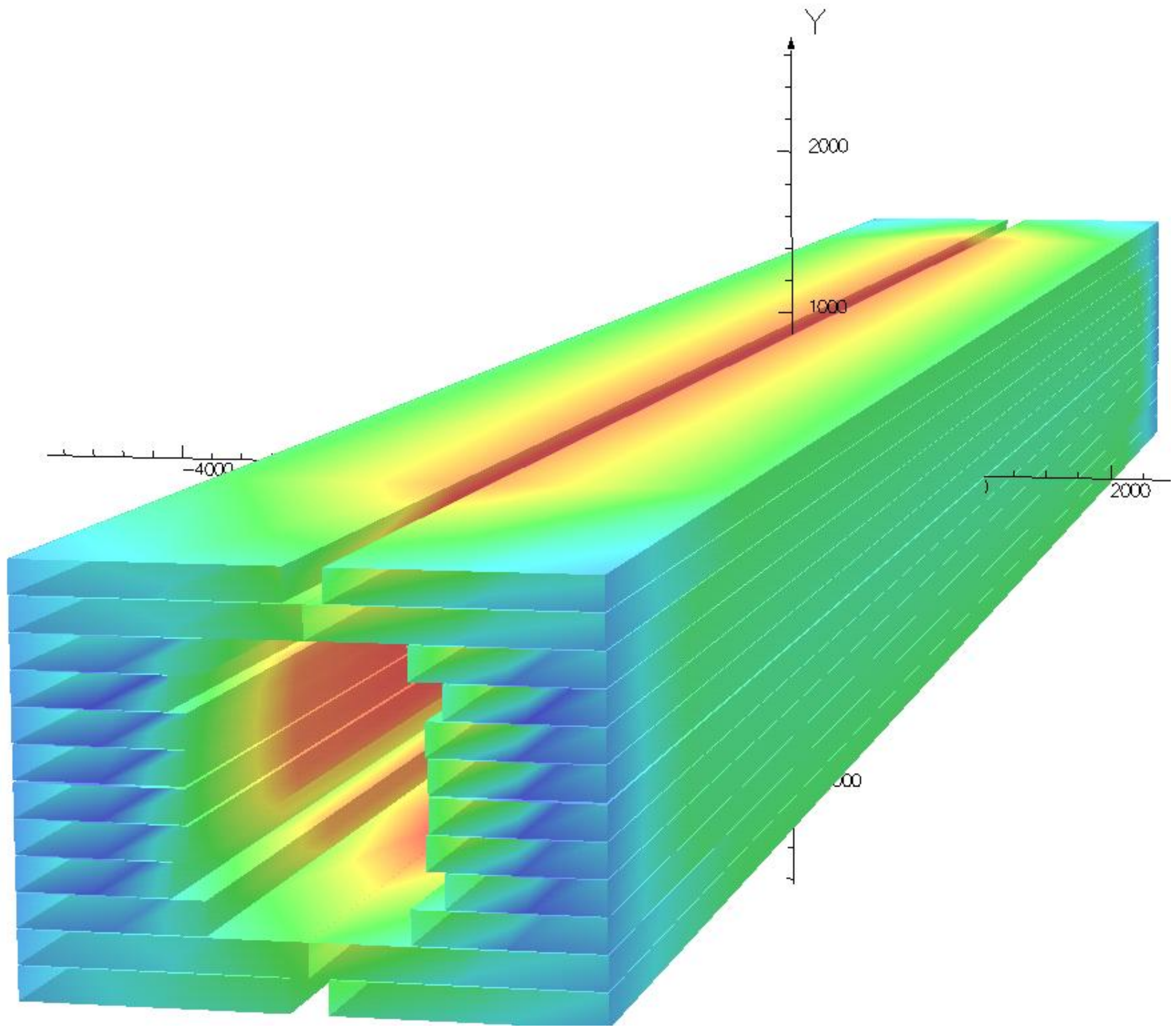
Block coil Design

Prototype magnets built

Simple design

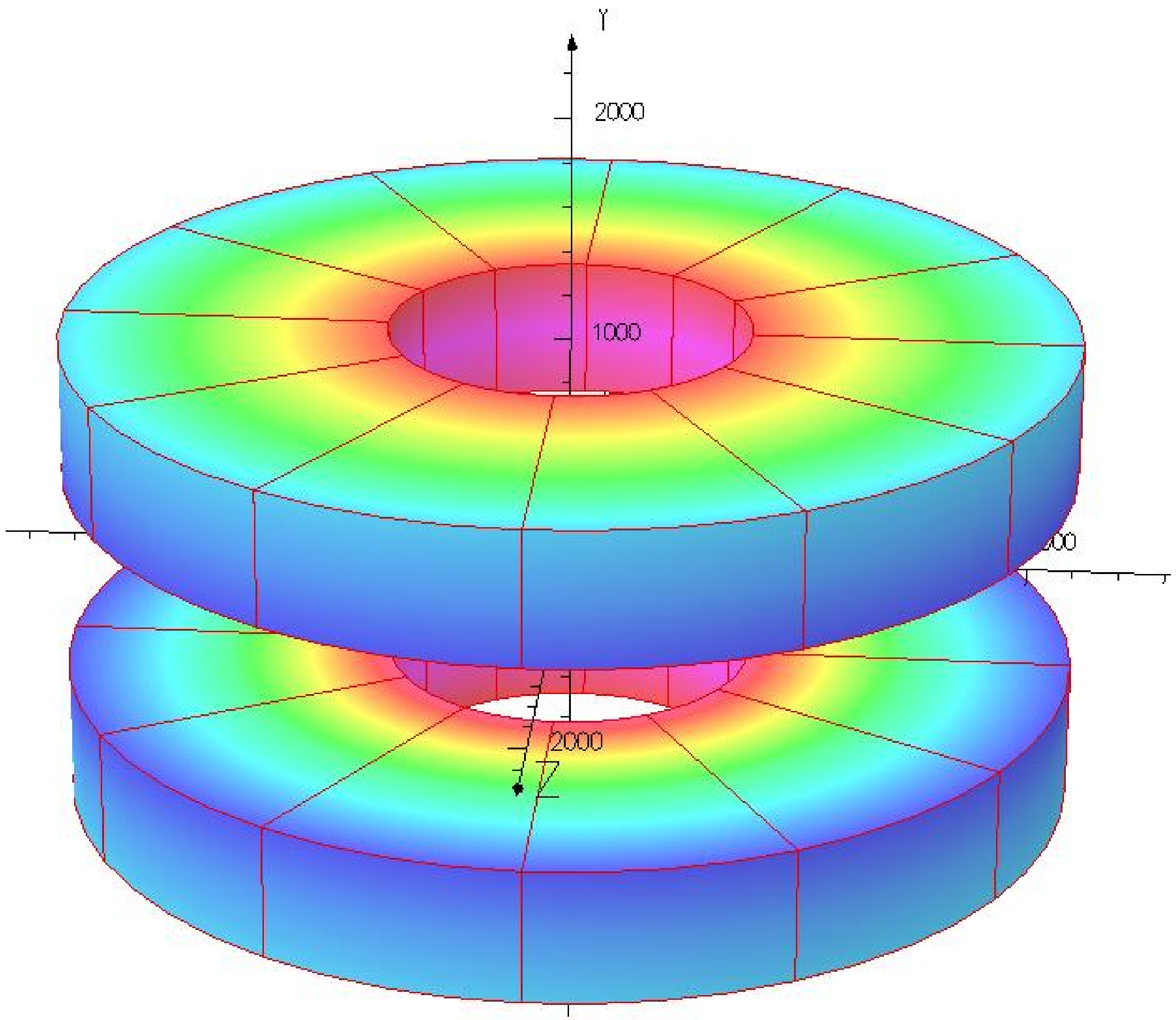
Flat cable

Field above Nb_3Sn @ 4.5 K



Parameter	30 A/mm²	100 A/mm²
Homogeneity on disk	2.22 %	1.01 %
Coil outer diameter	2.4 m	1.9 m
Cross section SC	3.1 m^2	0.94 m^2
B max at conductor	18.6 T	20.4 T
Fringe field at 6 m	415 mT	425 mT

Helmholtz pair Design



Short experiment configuration

Simple solenoids

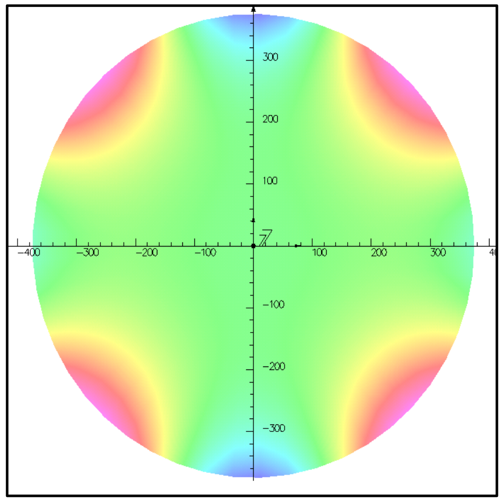
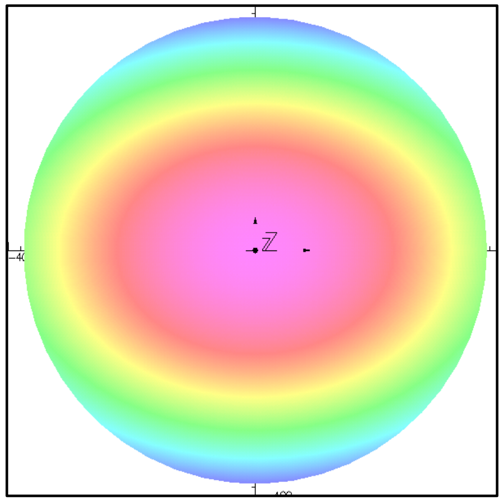
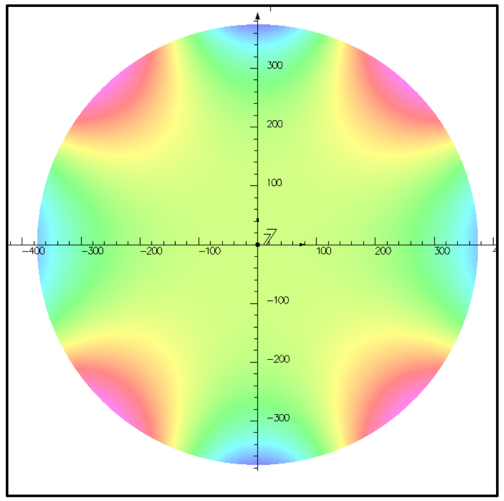
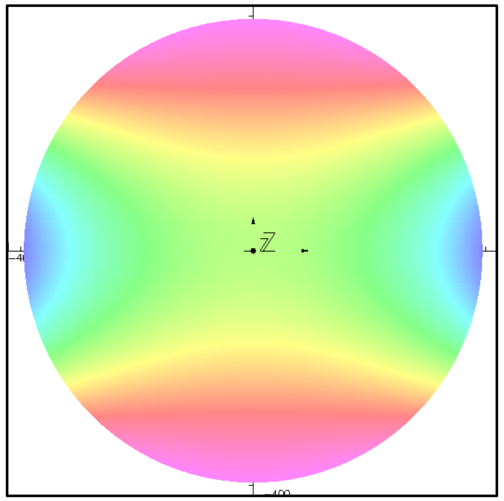
Large open space

Field above Nb_3Sn @ 4.5 K

Parameter	30 A/mm^2	100 A/mm^2
Homogeneity on disk	4.53 %	4.84 %
Coil outer diameter	4.2 m	3.1 m
Cross section SC	-	-
B max at conductor	18.9 T	24.0 T
Fringe field at 6 m	182 mT	80 mT

Comparison

Preparing for the next step

Cosine Theta	CCT	Block design	Racetrack	Helmholtz pair
				
Traditional design Extensive exp. Good homogeneity Small cross section	Easy to optimize High potential Easy to produce Good homogeneity	Easier to manufacture than cos theta Flat or cc cable Harder to optimize		Short setup solution Lots of space Low homogeneity

Discussion Topics

Compromises between magnet and test setup

Magnetic field shall be reduced -> disks of 1 m would be preferred

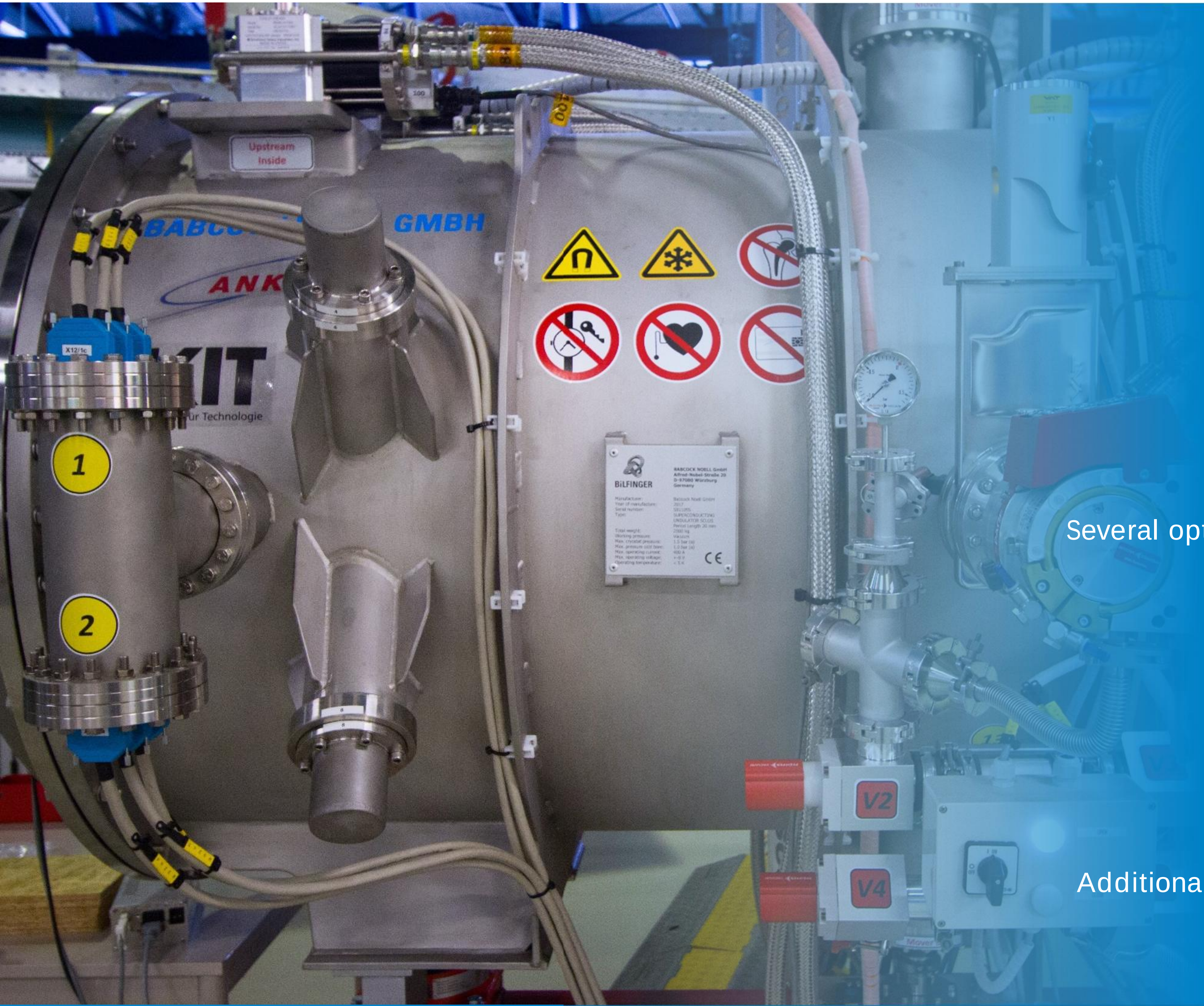
NbTi solution is difficult to achieve due to field limits

Graded coils (NbTi + Nb_3Sn) could work

Homogeneity 10^{-3} on mirror disk is hard to achieve

Each solution requires specific optimization

12 T dipole CIC Magnet, 2008



Conclusions

EXTREME DESIGN

Increase disk diameter to reduce field

DIPOLE ZOO

Several options, costs and manufacturability must get in the picture

EDUCATED DECISION

Systematic study to appreciate differences

IN DEPTH ANALYSIS

Additional step to push each solution toward its sweet spot

Thank you for your attention