
# Inner Triplet Correctors for Phase I: First Ideas

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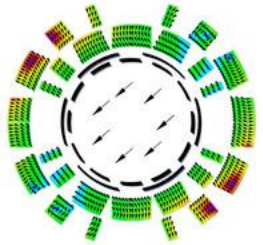
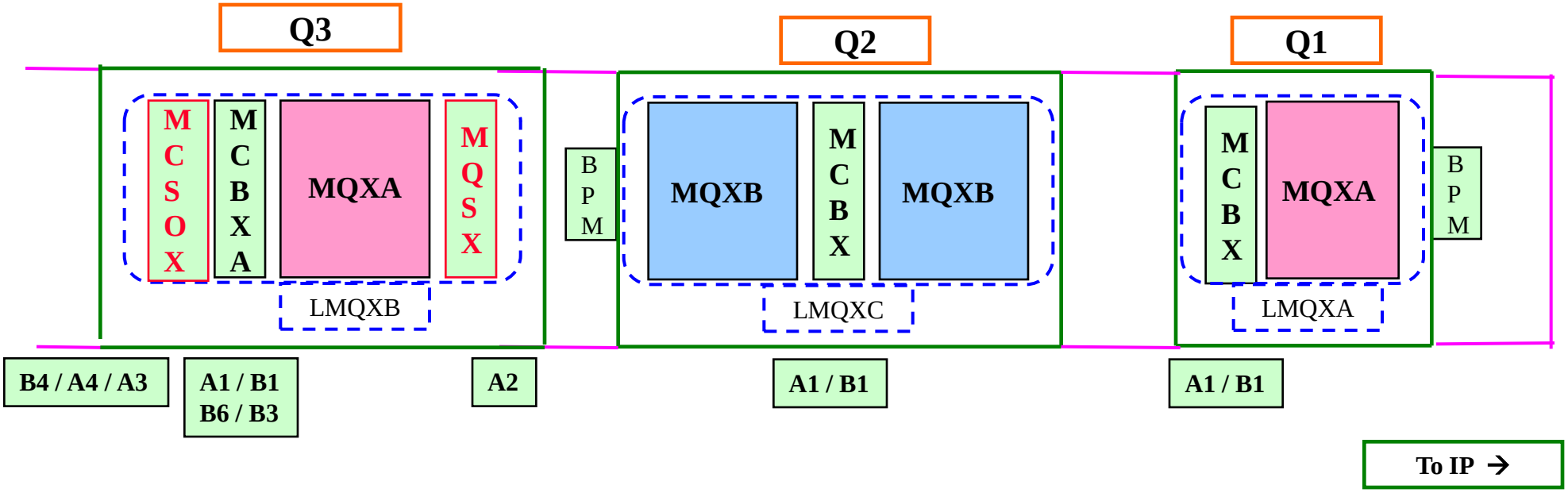
# Main topics

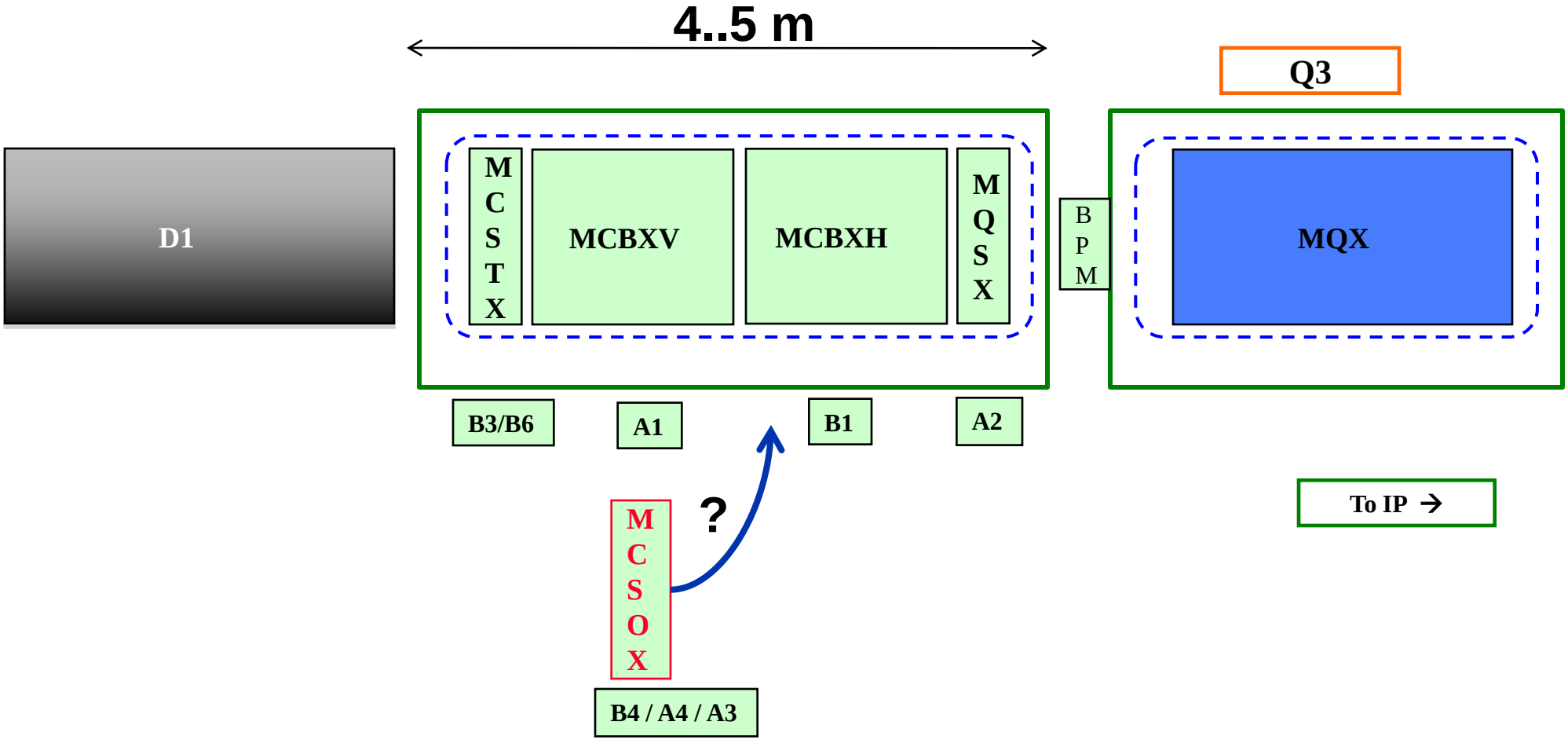


- **Layout**
- **Corrector requirements V0.1**
- **Scale-up of present Inner triplet correctors**
  - **MCBXH/V: Horizontal and Vertical Dipole-corrector**
  - **MQXA: Skew Quadrupole**
  - **MCSTX: Sextupole-Dodecapole**
  - ***(MCSOX: A4-B4-A3-package)***
- **Some fabrication aspects**
- **To Do**

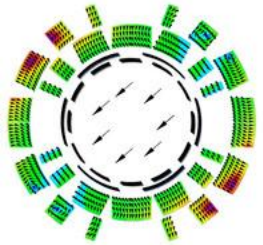
# Inner Triplet Correctors: Present



# Inner Triplet Correctors: Phase I

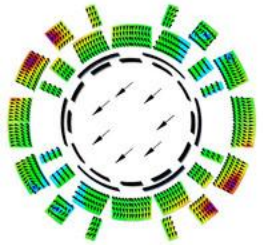


# Requirements V0.1
## (by S. Fartoukh)



- **Fit all correctors in 4..5 m between Q3 and D1**
- **Aperture ø130 mm (ø115 mm)**
- **MCBX**
  - **correct for a triplet misalignment of 1mm**
  - **1-1.5 Tm for generation of X-angle, parallel separation, and transverse adjustment of the IP**
    - **6 Tm in H- and V-plane (presently 3 x 1.51/1.56 Tm)**
- **MQSX**
  - **Compensate for triplet roll of 4 mrad**
    - **20 Tm/m or 80 T/m x 0.25 m (80 T/m x 0.223 m)**

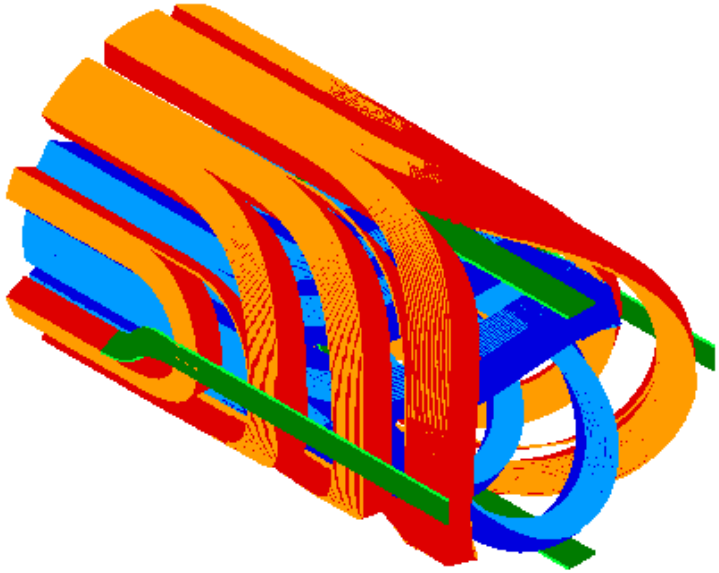
# Requirements (cont)

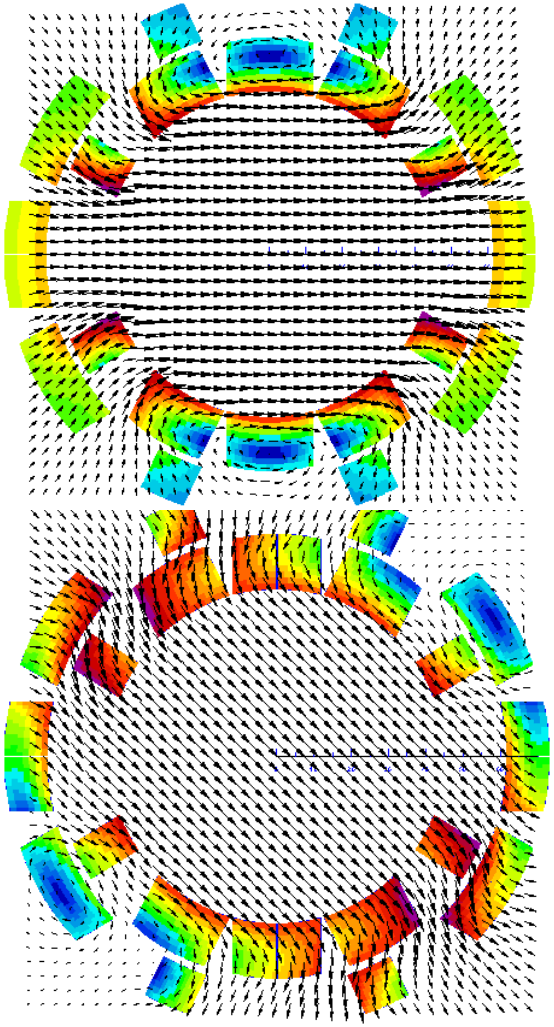


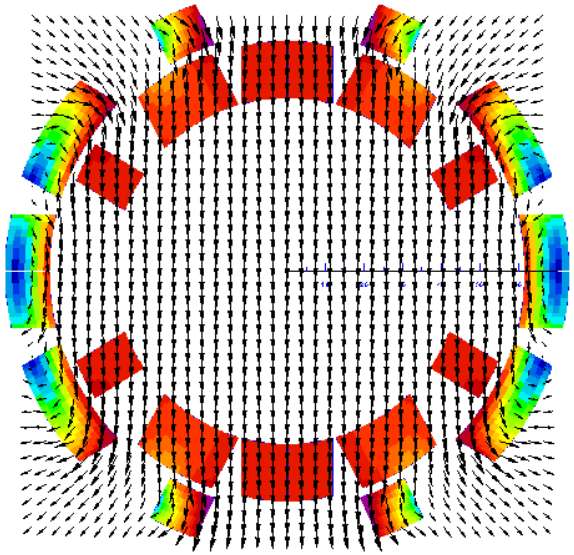
- **MCSX**
  - **correct for b3 (6 units) of D1 (29 Tm)**
    - **0.02 Tm @R40 mm or 25 T/m$^2$ x 0.5 m**
- **MCTX**
  - **MQX systematic b6 (1 unit) correction**
    - **0.02 Tm @R40mm**
- **MCSOX**
  - **Not yet clear if required…**

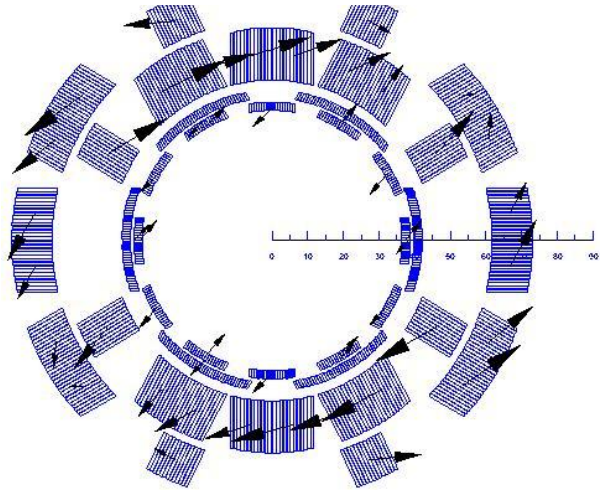

MCBX

# Present MCBX(A)

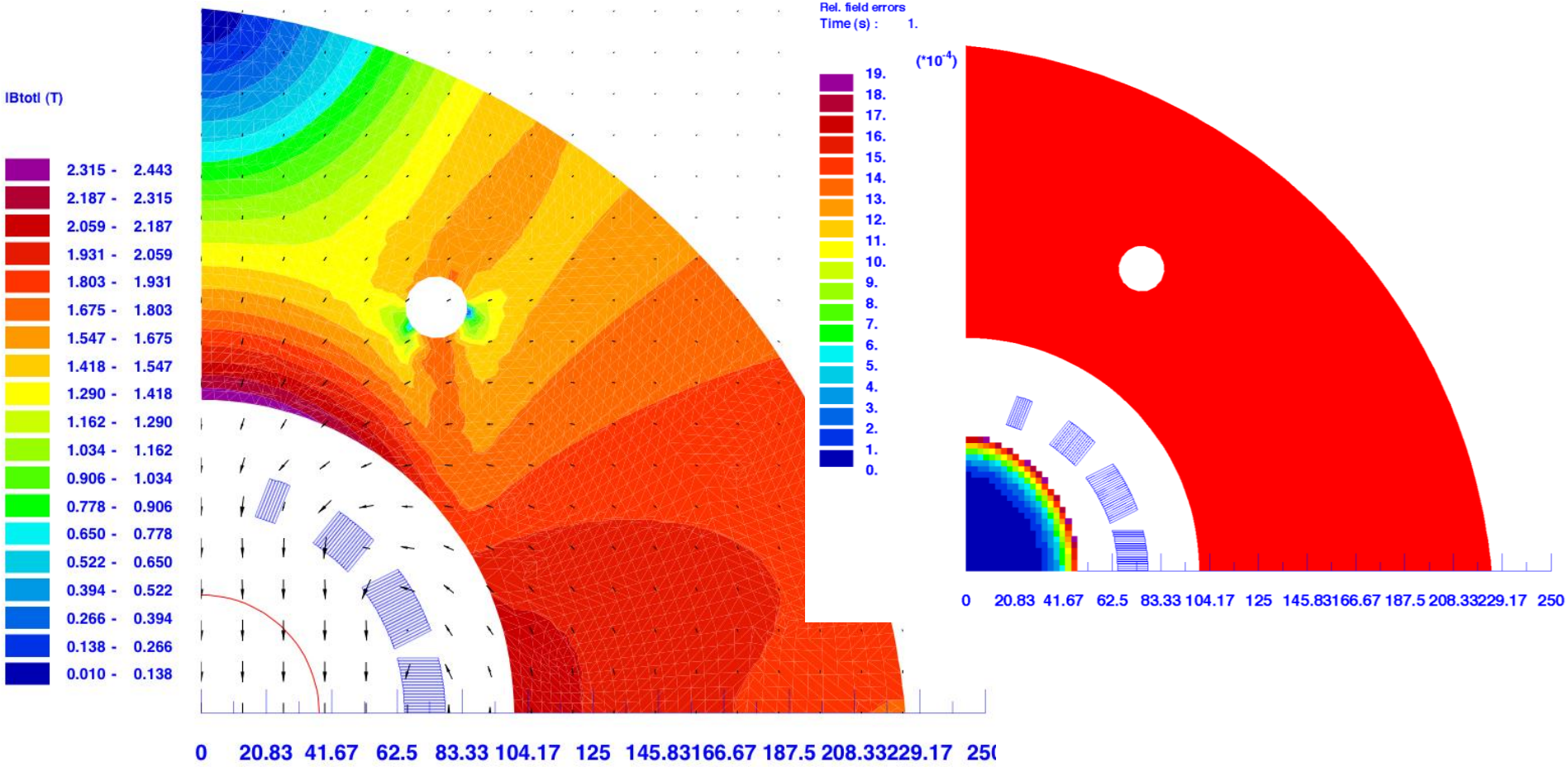




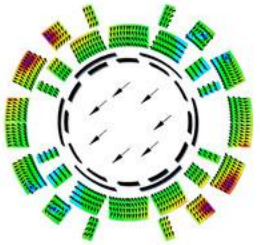




# Phase I MCBXH



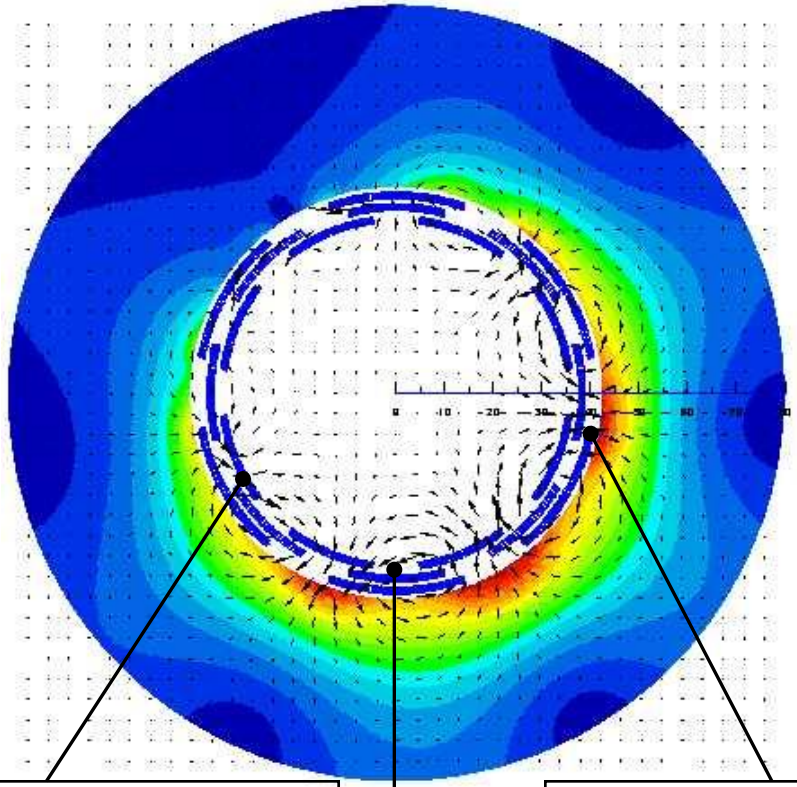
# MCBX: Parameters



| | Unit | MCBXV | MCBXH | PHASE I |
|---|---|---|---|---|
| **Integrated field** | Tm | 1.56 | 1.51 | **6.1** |
| **Nominal field** | T | 3.26 | 3.35 | **3.78** |
| **Mag. length** | m | 0.48 | 0.45 | **1.61** |
| **Nominal current** | A | 550 | 550 | **550** |
| **Stored energy** | kJ | 26.5 | 43.4 | **~176** |
| **Self inductance** | mH | 175.2 | 287.2 | **~1200** |
| **Wire section (metal)** | mm | 1.53 x 0.85 | 1.53 x 0.85 | **1.53 x 0.85** |
| **Cu/Sc** | | 1.71 | 1.71 | **1.71** |
| **Total length** | m | 0.72 | | **~1.9** |
| **Aperture** | mm | ø90 | | **ø130** |
| **Total mass** | kg | 465 | | **~2450** |


MQSX & MSCOX

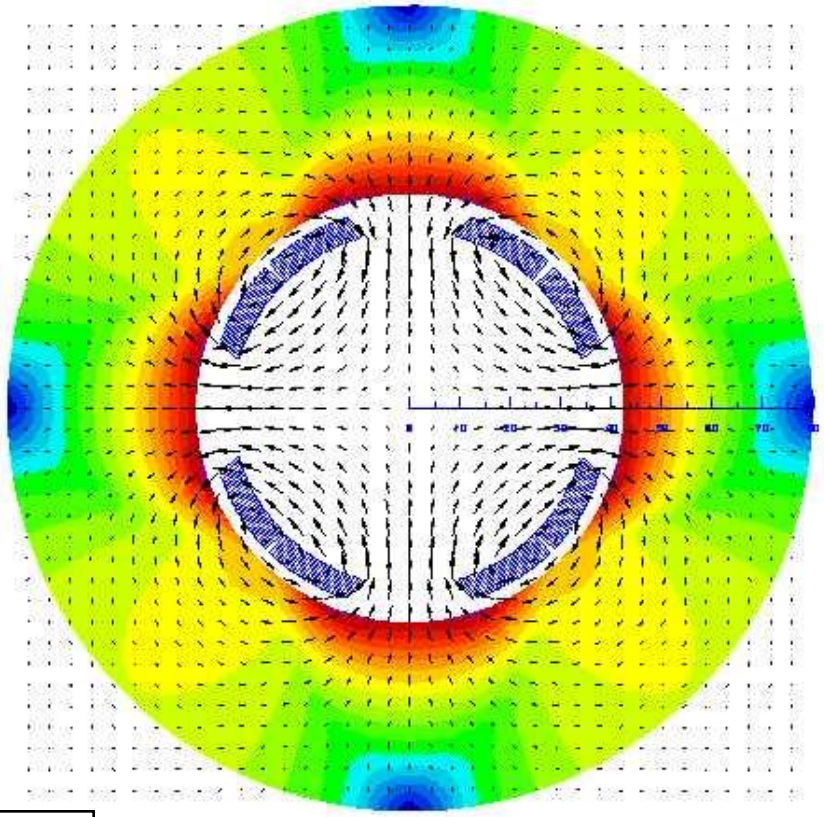
# Present MQSX & MCSOX



Skew octupole (MCSOX)

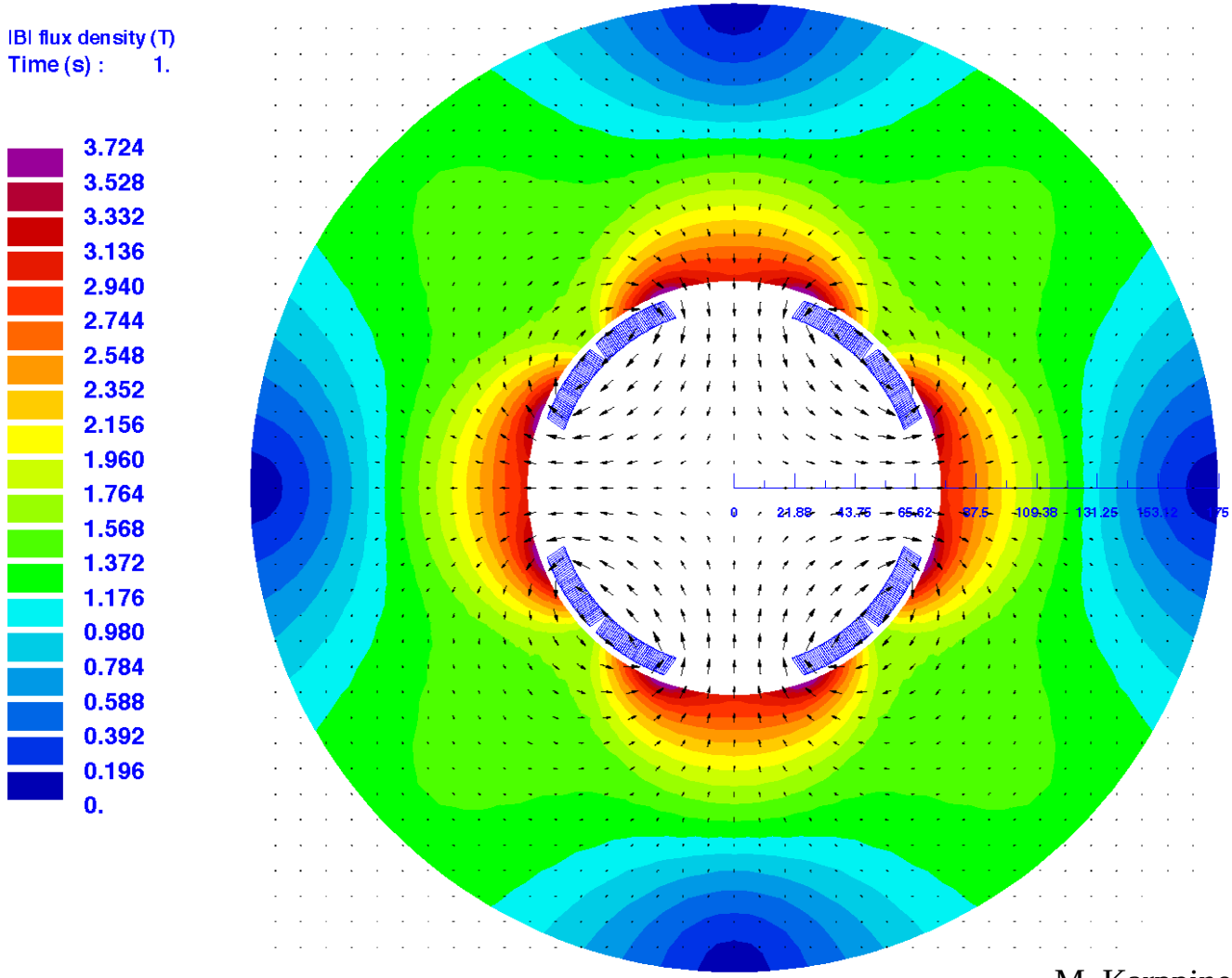
Octupole (MCOX)

Skew sextupole (MCSSX)

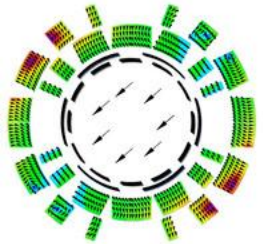


Skew quadrupole (MQSX)

# Phase I MQSX


|B| flux density (T)
Time (s) : 1.
3.724
3.528
3.332
3.136
2.940
2.744
2.548
2.352
2.156
1.960
1.764
1.568
1.372
1.176
0.980
0.784
0.588
0.392
0.196
0.
0
21.88
43.75
65.62
87.5
109.38
131.25

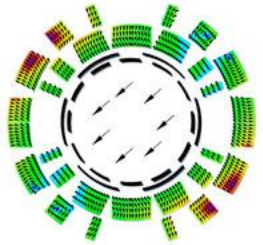
# MQSX & MCSOX: Present Parameters



| | Unit | MQSX | MCOSX | MCOX | MCSSX |
|---|---|---|---|---|---|
| Nominal field at 17 mm radius | T | 1.36 | 0.0475 | 0.0453 | 0.1089 |
| Magnetic length | m | 0.223 | 0.138 | 0.137 | 0.132 |
| Nominal operation current | A | 550 | 100 | 100 | 100 |
| Working temperature | K | 1.9 | 1.9 | 1.9 | 1.9 |
| Theoretical quench current at 1.9 K | A | 926 | 267 [1)] | 262 [1)] | 257 [1)] |
| Theoretical quench current at 4.3 K | A | 673 | 181 [1)] | 179 [1)] | 176 [1)] |
| Self inductance | mH | 14.0 | 3.2 | 4.4 | 7.8 |
| **SC-wire** | | | | | |
| Cu/Sc-ratio | | 1.6 | 4 | 4 | 4 |
| **Main dimensions** | | | | | |
| Overall length | mm | 300 | | 175 | |
| Overall diameter (Support Flange) | mm | 380 | | 380 | |
| Aperture | mm | 70 | | 70 | |
| Total mass (approx.) | kg | 51 | | 30 | |

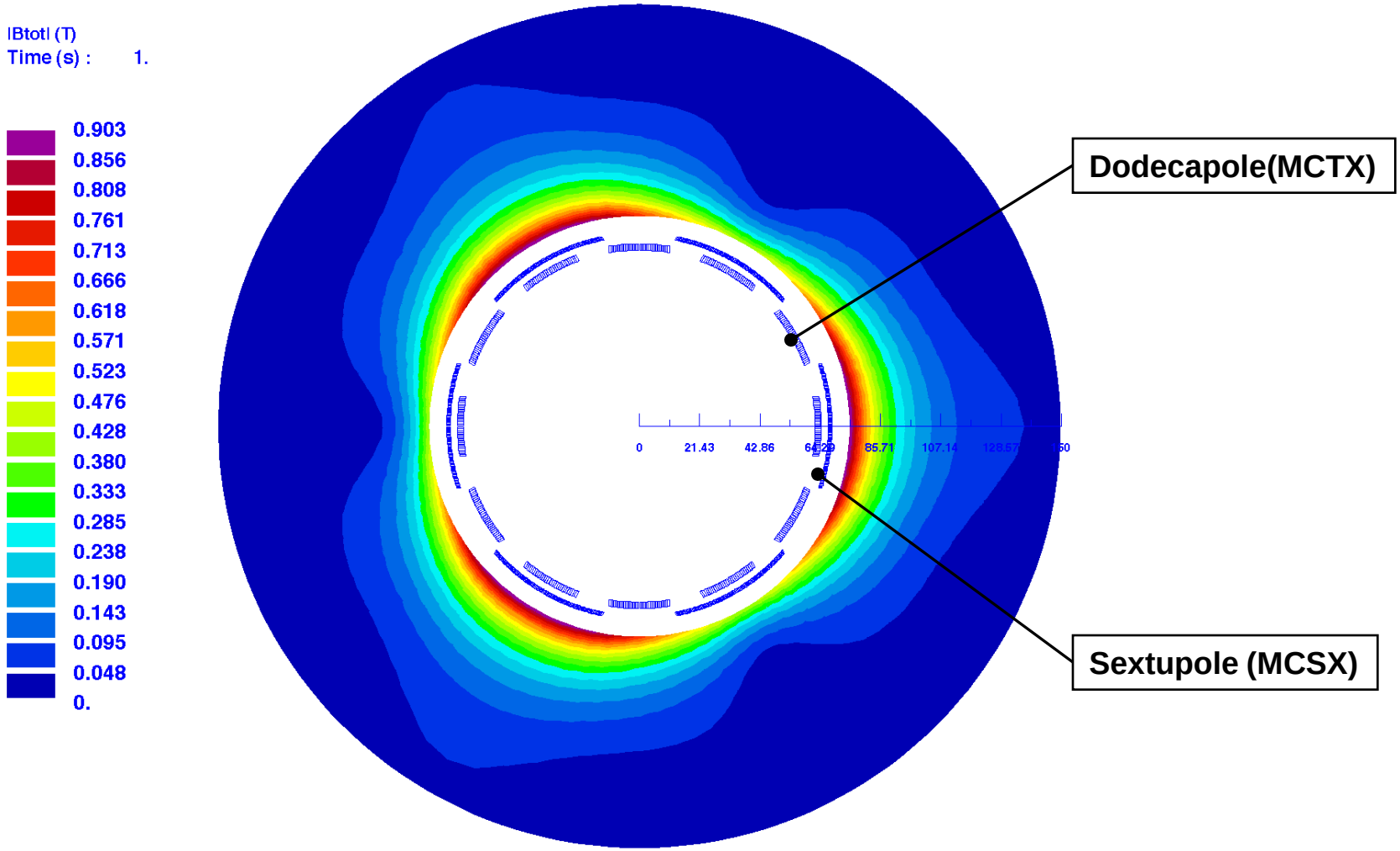
1) With two other layers powered at the nominal current

# MQSX: Parameters

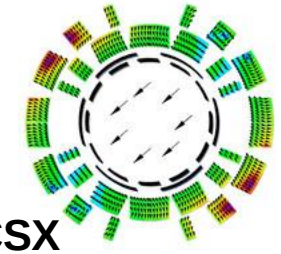


| | Unit | Present | PHASE I |
|---|---|---|---|
| **Nominal gradient** | T/m | 80 | **64.6** |
| **Mag. length** | m | 0.223 | **0.31** |
| **Nominal current** | A | 550 | **550** |
| **Stored energy** | kJ | 4.2 | **22** |
| **Self inductance** | mH | 14 | **145** |
| **Wire section (metal)** | mm | 1.13 x 0.61 | **1.13 x 0.61** |
| **Cu/Sc** | | 1.71 | **1.71** |
| **Total length** | m | 0.3 | **~0.4** |
| **Aperture** | mm | ø70 | **ø130** |
| **Total mass** | kg | 51 | **~250** |

# Phase I MCSTX



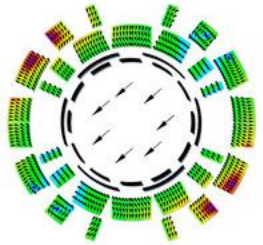
# MCSTX: Present Parameters



| | Unit | MCTX | MCSX |
|---|---|---|---|
| Nominal field at 17 mm radius | T | 0.0103 | 0.015 |
| Magnetic length | m | 0.615 | 0.576 |
| Nominal operation current | A | 80 | ~~50~~ 120 A |
| Working temperature | K | 1.9 | 1.9 |
| Theoretical quench current at 1.9 K | A | 208 [1)] | 220 [1)] |
| Theoretical quench current at 4.3 K | A | 128 [1)] | 131 [1)] |
| Self inductance | mH | 29.2 | 4.7 |
| **SC-wire** | | | |
| Cu/Sc-ratio | | 4 | 4 |
| **Main dimensions** | | | |
| Overall length | mm | 700 | |
| Overall diameter | mm | 380 | |
| Aperture | mm | 70 | |
| Total mass (approx.) | kg | 4 | |

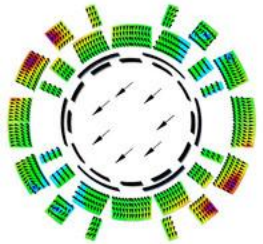
1) With other layer powered at the nominal current and in backround field of 3.9 T from the MCBX

# MCSTX : Phase I Parameters



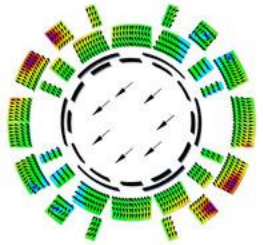
| | Unit | MCTX | MCSX |
|---|---|---|---|
| Integrated field (r = 40 mm) | Tm | 0.030 | 0.025 |
| Mag. length | m | 0.27 | 0.28 |
| Nominal current | A | 550 | 50 |
| Stored energy | kJ | 4.4 | 0.11 |
| Self inductance | mH | 29 | 90 |
| Wire section (metal) | mm | 1.13 x 0.61 | 0.67 x 0.32 |
| Cu/Sc | | 1.71 | 4 |
| Total length | m | ~0.35 | |
| Aperture | mm | ø130 | |
| Total mass | kg | ~150 | |

# Some Fabrication Aspects



- **Flat cable**
  - Purpose built machine to bond 2-25 enamel insulated wires together
  - Tolerance +0.02/-0.01 mm, unit length up to 160 m
  - Wires are connected in series on connection plate
  - Sometimes problems with cable splitting during winding
- **Coil winding**
  - Dipole coils with standard rock 'n roll winding machine
  - Counter-winding technique used for single winding block coils
  - All coils epoxy impregnated in vacuum or by wet-laying
- **Assembly**
  - Epoxy-glass around the coils by vacuum impregnation or pre-preg
  - Pre-stress from shrink-fitted Alu/St.steel cylinders
  - Off-center laminations

# Superconducting wire



| | Wire No 1 | Wire No 2 | Wire No 3 | Wire No 4 |
|---|---|---|---|---|
| Overall dimensions (mm) (insulated wire) | ϕ 0.435 | 0.38×0.73 | 0.73×1.25 | 0.97×1.65 |
| Ic (A) at 4.222 K and 5 T<br>// | >55A | >100<br>>110 | >630<br>>700 | >1190<br>>1320 |
| Cu/Sc volume ratio | ≥4.0-4.8 | ≥ 4.0-4.8 | ≥1.6-1.9 | ≥1.6-1.9 |
| Approx. length (km) | 5685 | 1556 | 1211 | 27 |
| Approx. total weight (kg) | 5200 | 3100 | 6700 | 260 |

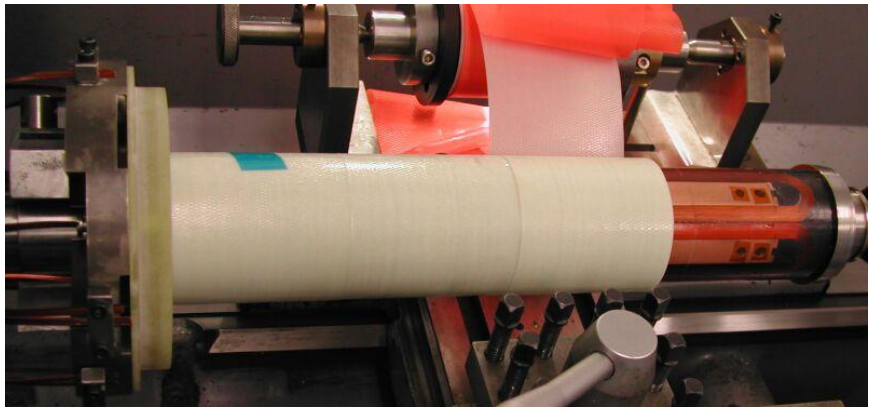
- **Nb47%Ti**
- **PVA insulation**
- **RRR >100**
- **Filament diameter 6-7 micrometer.**
- **Limited quantity available for model magnets**

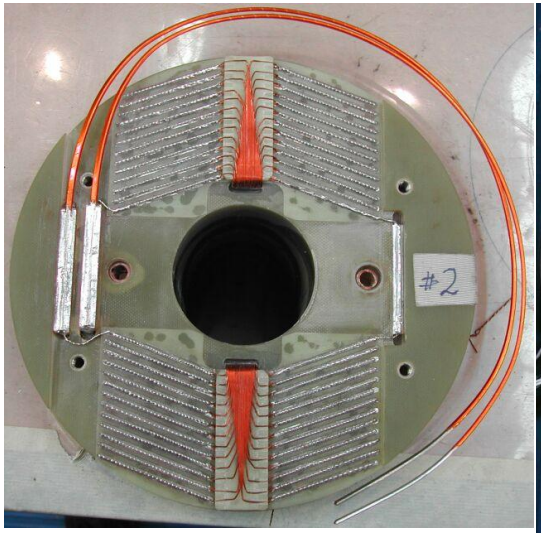
# Flat cable

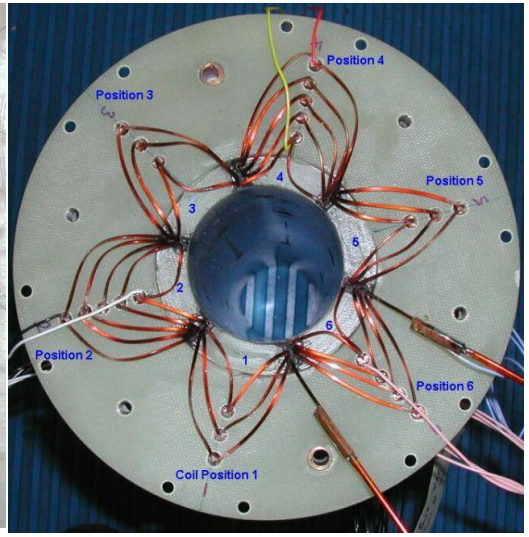
# Coil winding

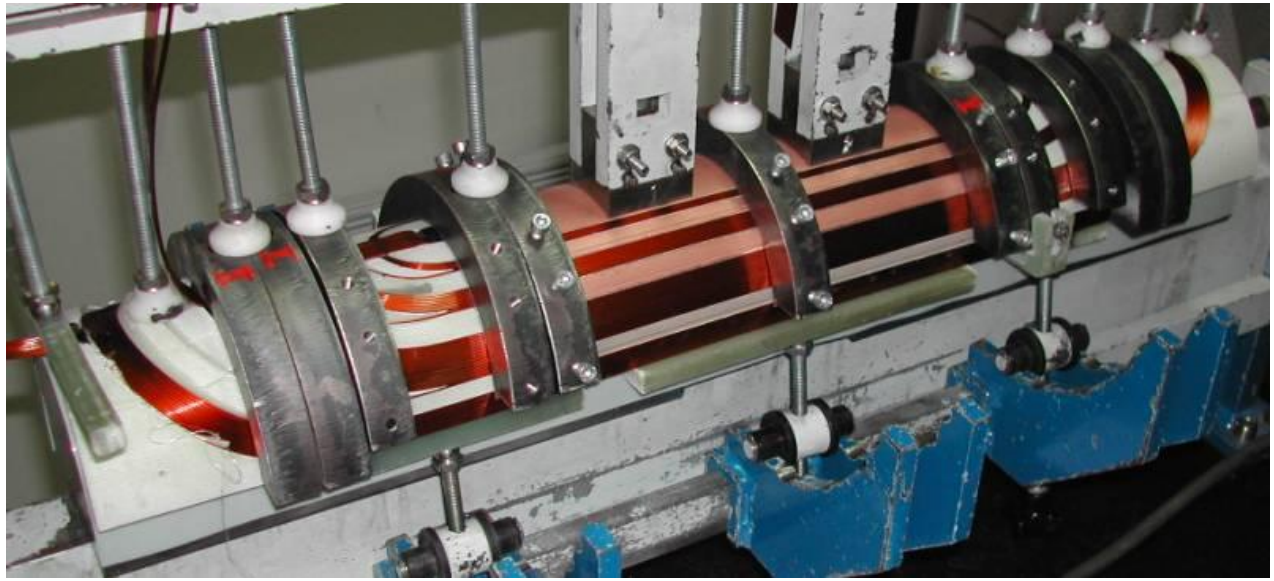
**Counter-winding (MQSX)** **Dipole winding (MCBM)**

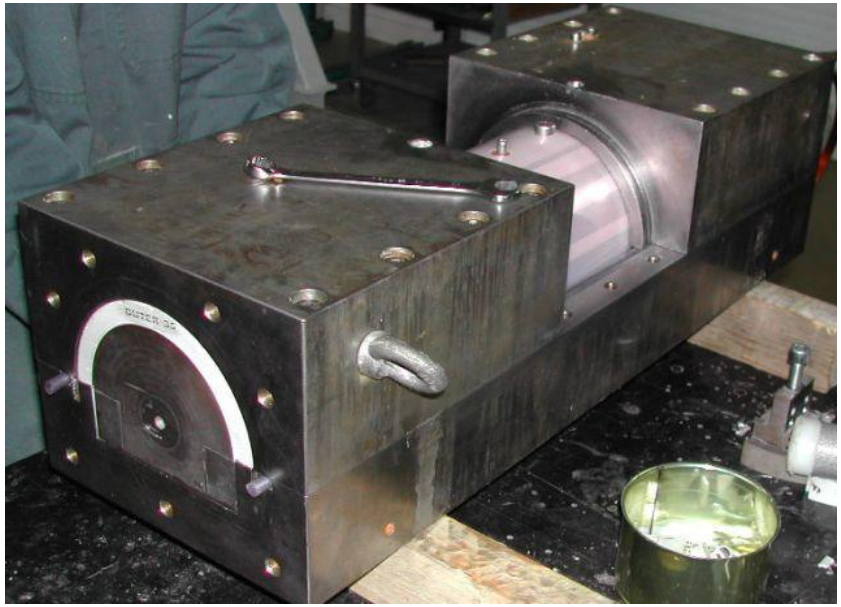
# Coil assembly

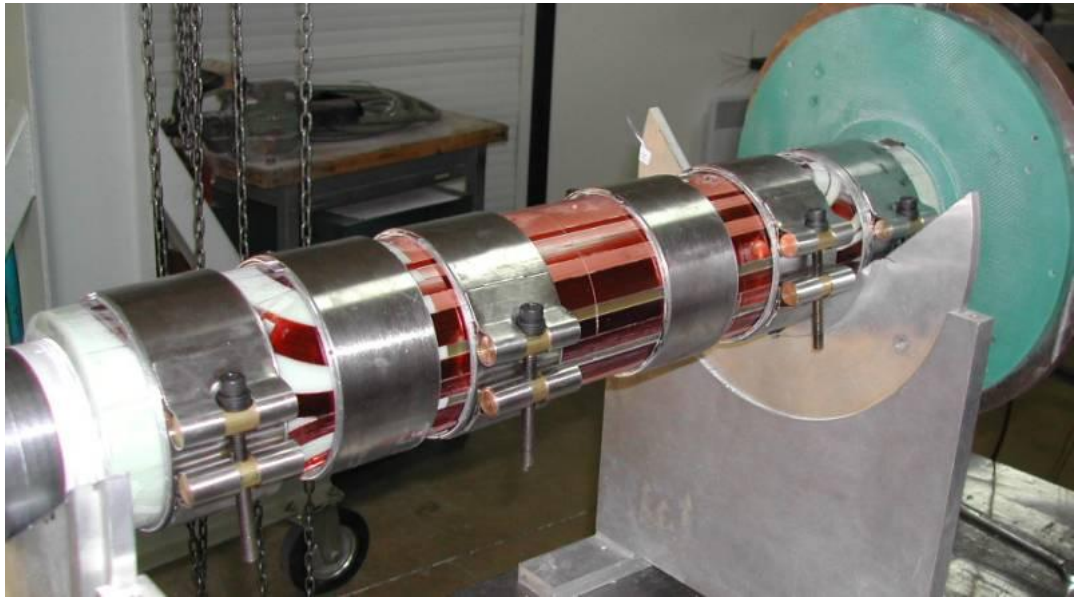


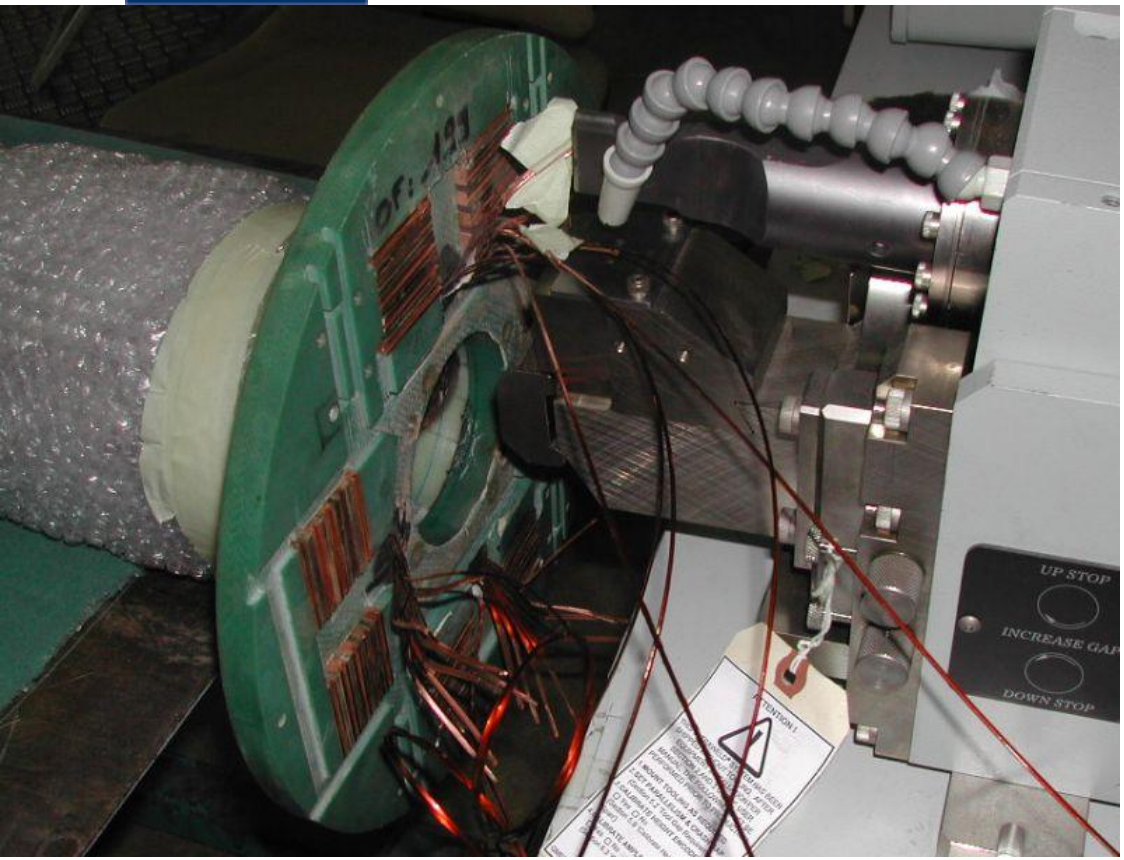


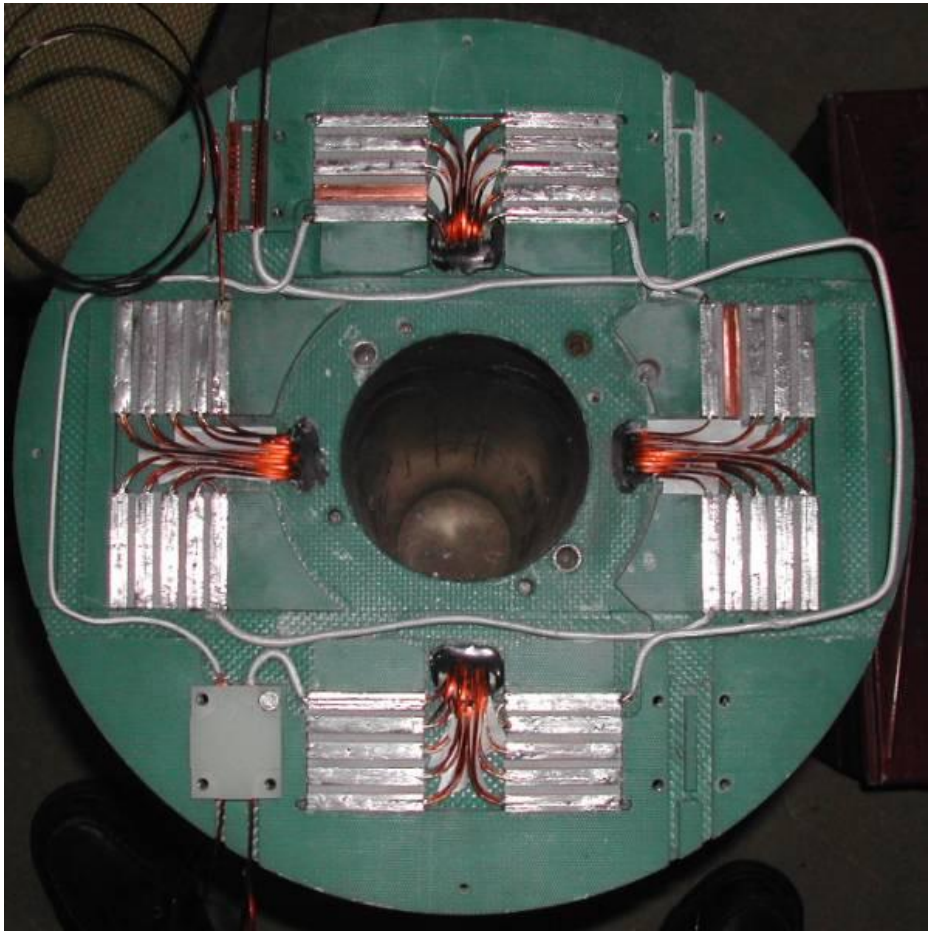





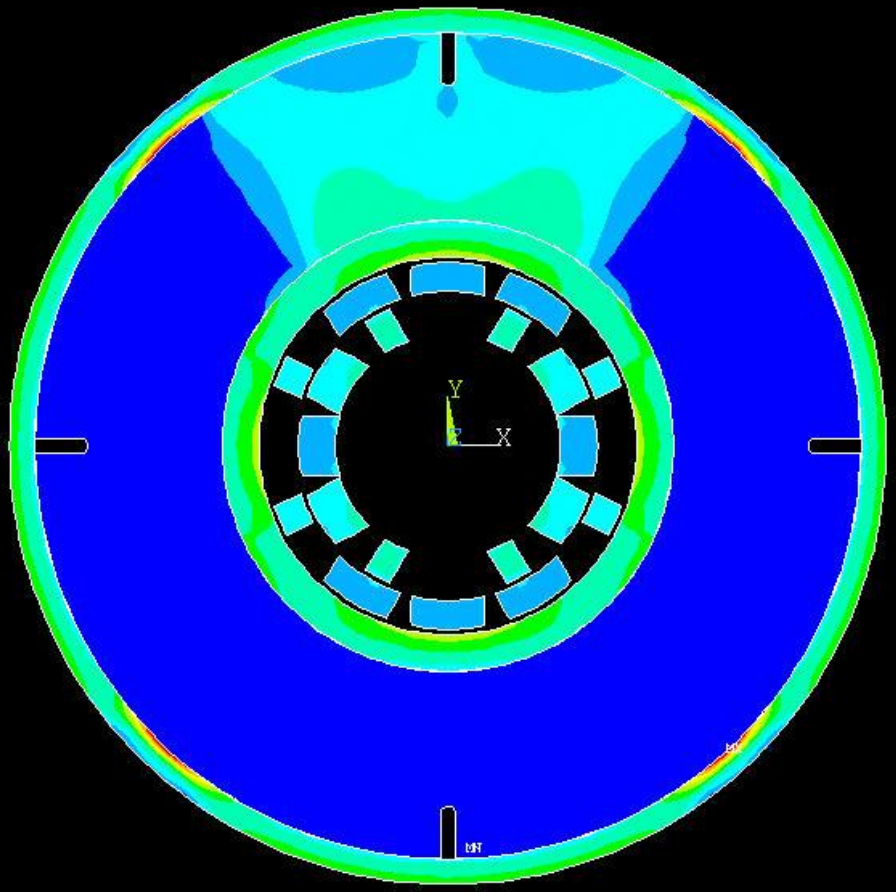





UP STOP
INCREASE GAP
DOWN STOP



# Coil Pre-stress




MCBX at 293K Interf: Inner=0.100mm Outer=0.050mm Keys=0.50

+ Field enhancement, less superconductor

+ Pre-stress increases during cooldown

+ Auto centering

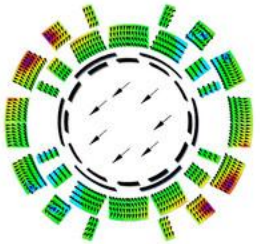
+ Cheap

- Non-uniform loading

- Saturation effects

- Non-static structure

# To Do..



- Conceptual magnetic design (underway)
- Conceptual mechanical design (underway)
- Quench protection study (MCBX, MQSX)
- Detailed magnetic and mechanical design
- Conductor procurement
- Model magnet(s)
- Prototype magnet(s)
- “Series” magnets