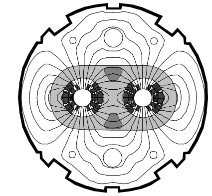
MSD beam dump septum magnets: overview and fault scenarios



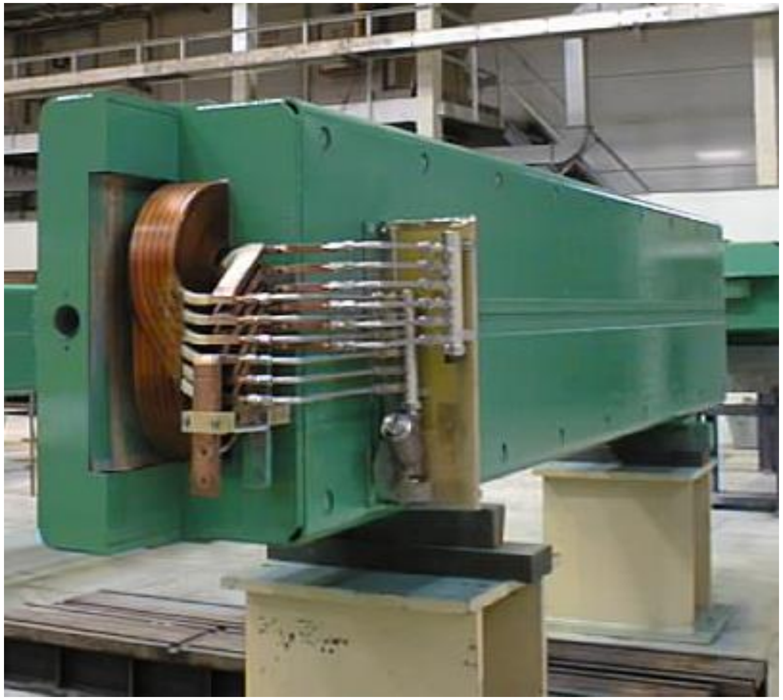
M. Sassowsky (SL/MS)

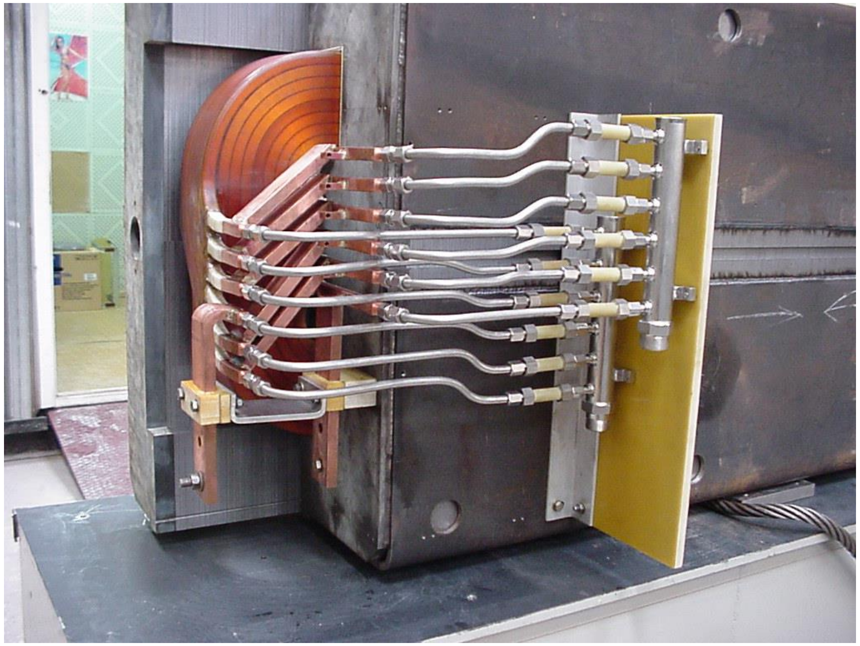
CERN: M. Gyr, E. Weisse, R. Guinand, W. Weterings, S. Bidon, D. Gerard, M. Sassowsky
IHEP: E. Ludmirsky, N. Tyurin, A. Kleshchov, P. Korobchuk, A. Ivanenko, N. Yarygin, V. Noskov, E. Gudkova, V. Komarova

- **Status**
- **Calibration curve**
- **Cooling and thermal protection**
- **Coil design**
- **Interturn short-circuits**

Status

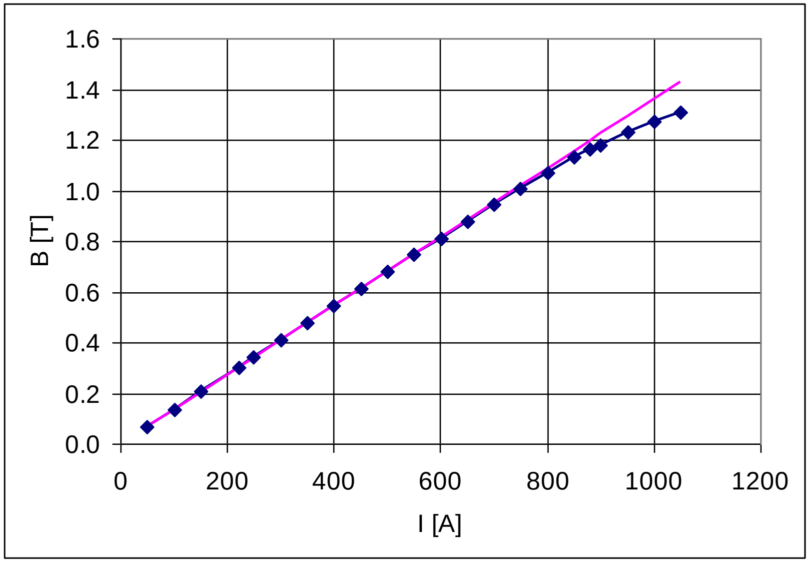
- 1 MSDC prototype built by IHEP
- Mechanical, electrical and magnetic measurements OK
- Shipment of prototype foreseen end of May 2001



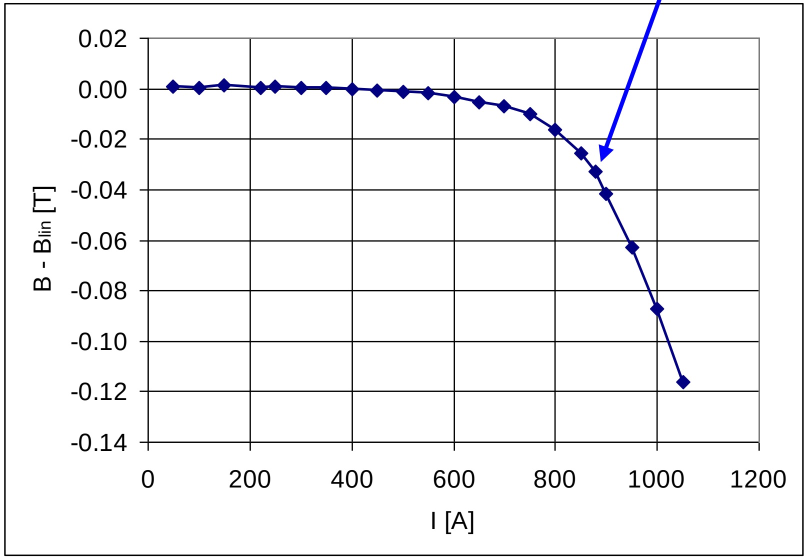


Calibration curve (1)

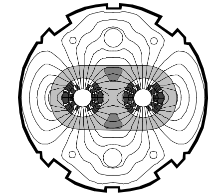
- **B vs. I using NMR probe**



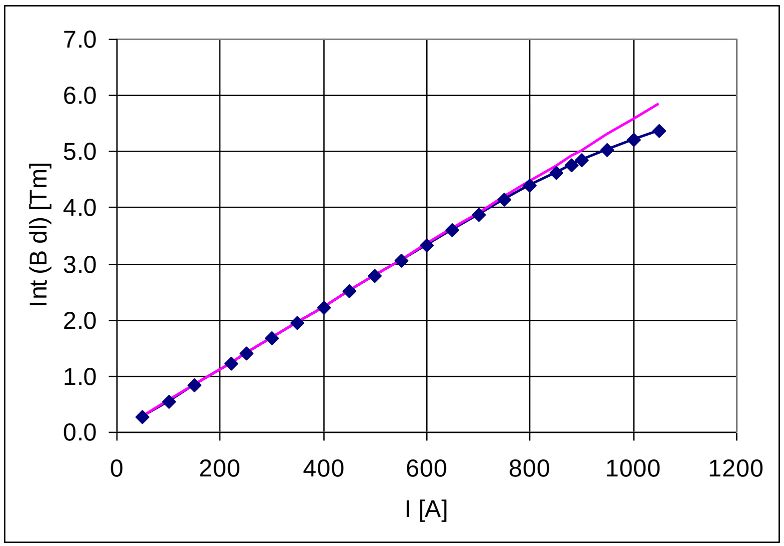
At nominal current (880 A) for top energy: Non-linearity ~2.8 percent



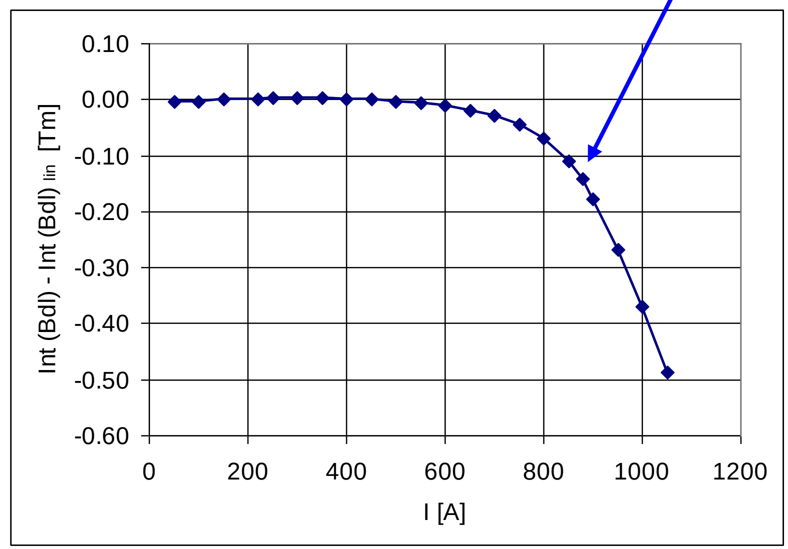
Calibration curve (2)



- ∫ Bdl vs. I using stretched wire technique

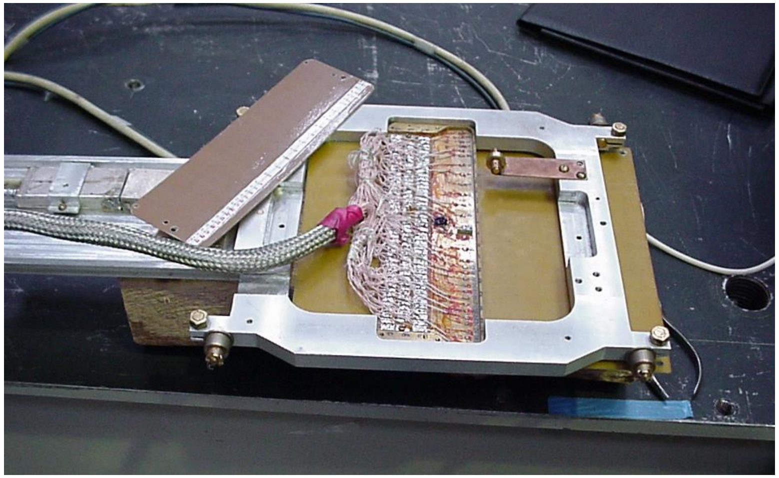


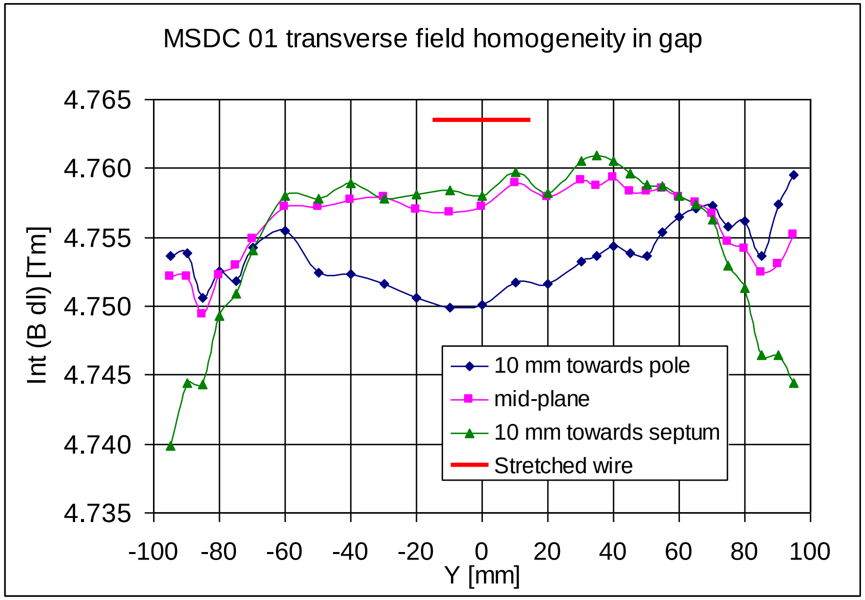
At nominal current (880 A) for top energy: Non-linearity ~3.0 percent

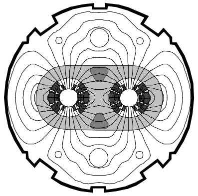


Calibration curve (3)

- **Cross-check: ∫ Bdl at I = 880 from field map with Hall probe array**







Cooling

- **Basic formulae:**

$$RI^2 = cQ(T_{out} - T_{in})$$

$$\frac{\Delta p}{l} = k\frac{Q^{1.75}}{d^{4.75}}$$

- **Temperature dependence of Resistance:**

$$R(T) = R(T_0)\cdot\left(1+\alpha(T - T_0)\right)$$

$$\alpha = 3.8\cdot 10^{-3}/K$$ **(for Copper)**

- **Average coil temperature:**

$$T \approx \frac{1}{2}\left(T_{out} + T_{in}\right)$$

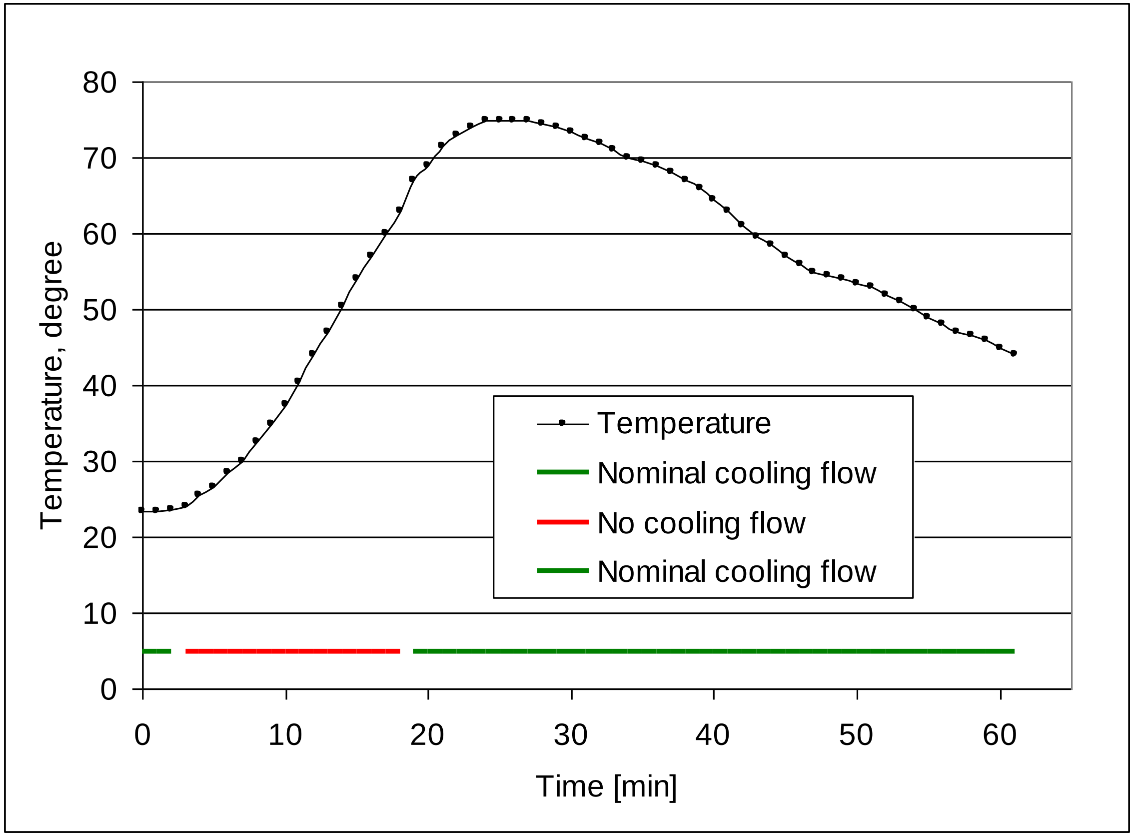
- **Actual average coil temperature depends on T_{in} and I_{RMS}**

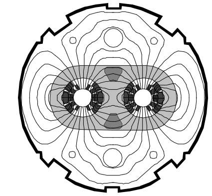
- **For continued operation at 880 A:** $(T_{out} - T_{in}) \approx 20^{o}C$

$$\Rightarrow \Delta R/R \approx 4\%$$

Thermal protection

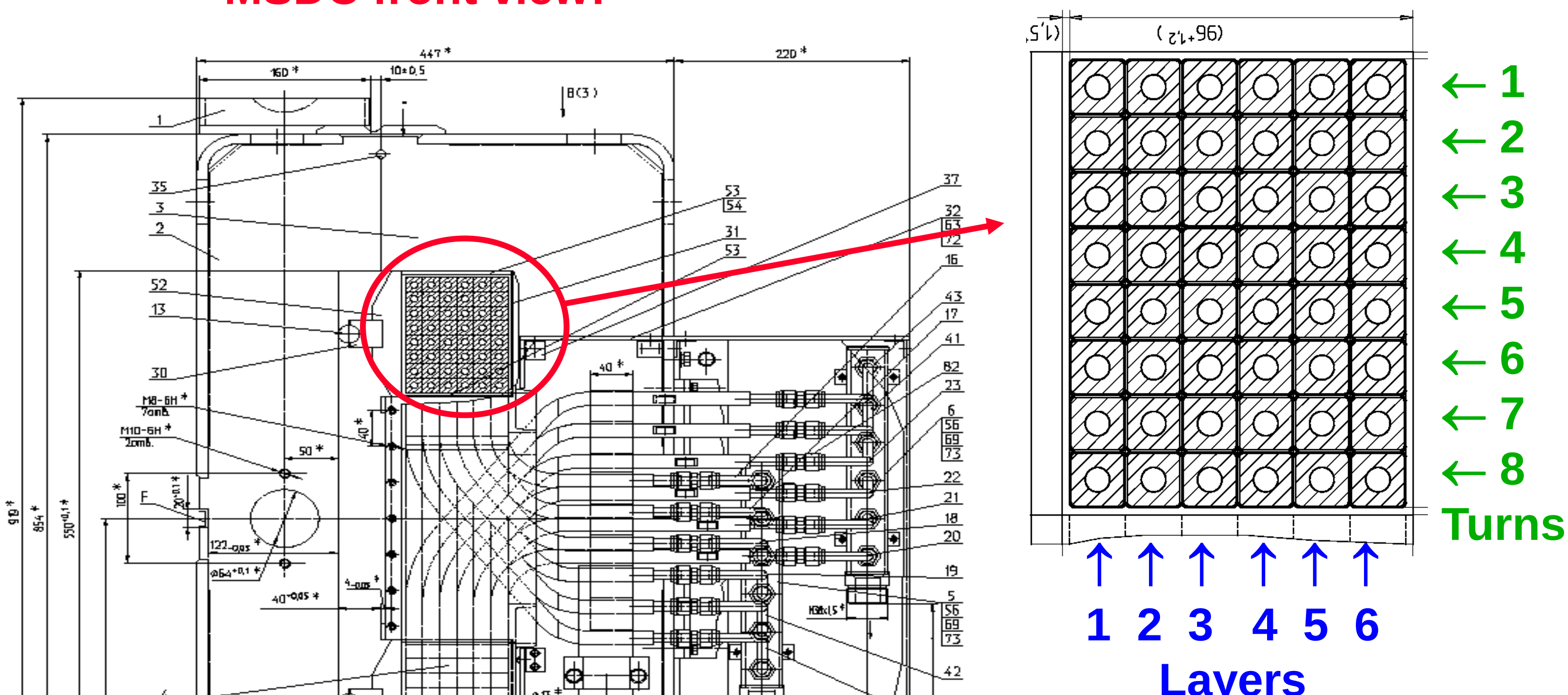
- Each layer: thermoswitch
- Test of thermoswitches by stopping cooling water:





Coil design (1)

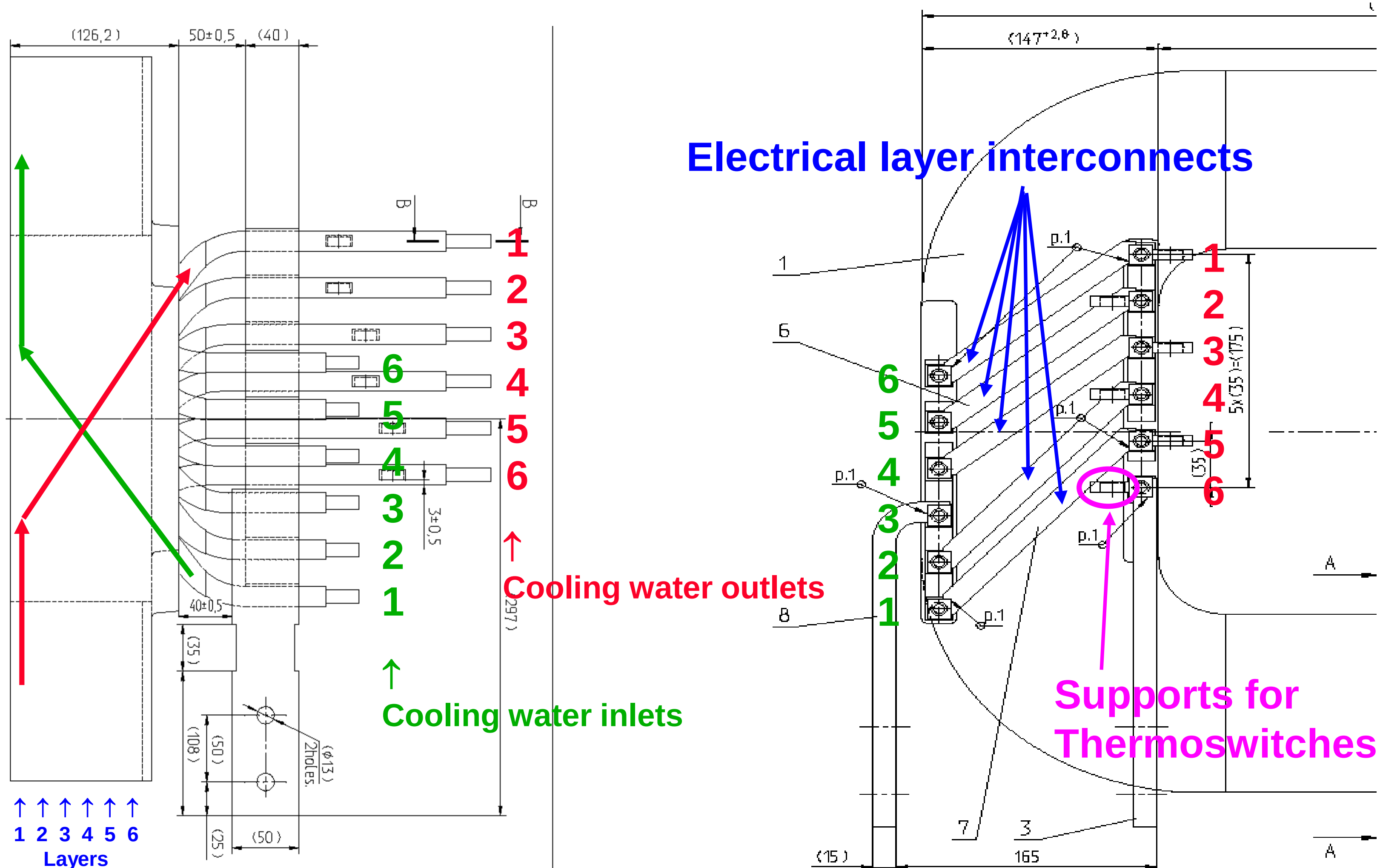
MSDC front view:



Electrically: in series
Hydraulically: in parallel

MSDB: 5 layers
MSDA: 4 layers

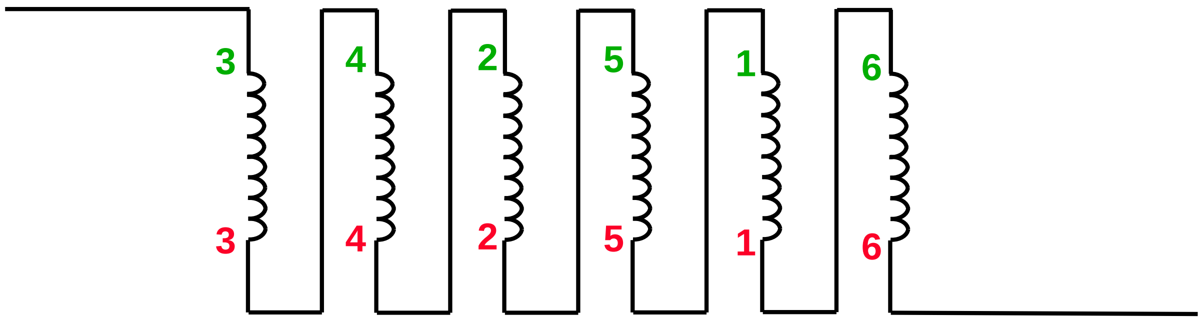
Coil design (2)



Coil design (3)

Electrical series connection of layers:

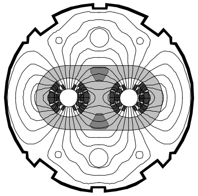
Layer: 3 4 2 5 1 6



$I_{nom} = 880\,A$ **(at top energy)**

$R_{layer} = 6.76 m\Omega$ **(at T=20°C)**

$U_{layer} = 5.95 V$ **(at T=20°C)**



Interturn short-circuits (1)

- **Integrated field of a dipole magnet:**

$$\int B dl = \frac{\mu_0 nI}{g + \frac{d}{\mu}}(l + k \cdot g)$$

$nI =$ **Ampere-turns**

$g =$ **Gap height**

$d =$ **Path length in return yoke**

$\mu =$ **Steel permeability**

$l =$ **Yoke length**

- **Interturn short-circuit**

  => reduction of nI

  => reduction of $\int B dl$

  => wrong deflection angle θ

Interturn short-circuits (2)

- **For one beam:** **5 MSDA**
  5 MSDB
  5 MSDC

- **Total number of turns:**

$$n_{tot} = 5 \cdot (4 \cdot 8 + 5 \cdot 8 + 6 \cdot 8) = 600$$

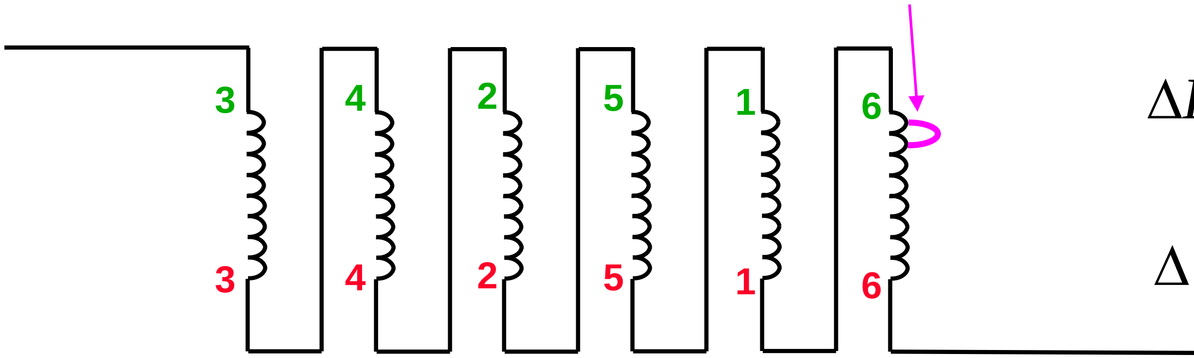
- **Worst case for one interturn short-circuit:**

$$\Delta n = 2 \cdot 8 = 16$$

$$\frac{\Delta n}{n} = \frac{\Delta \int B dl}{\int B dl} = \frac{\Delta \theta}{\theta} = 2.7\%$$

Interturn short-circuits (3)

- **Between two turns within one layer:**

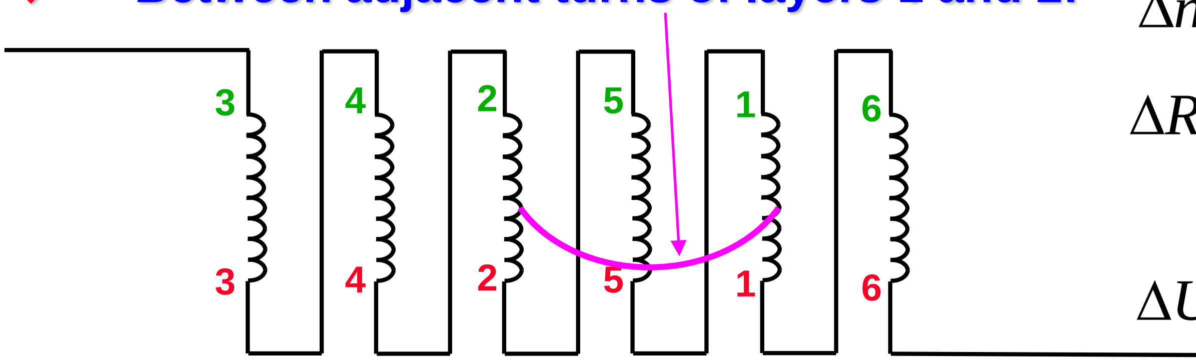


$$\Delta n = 1$$

$$\Delta R = -\frac{1}{8} R_{layer}$$

$$\Delta U_i = \begin{cases} \Delta R \cdot I & i = 6 \\ 0 & i = 1 \ldots 5 \end{cases}$$

- **Between adjacent turns of layers 1 and 2:**



$$\Delta n = 16$$

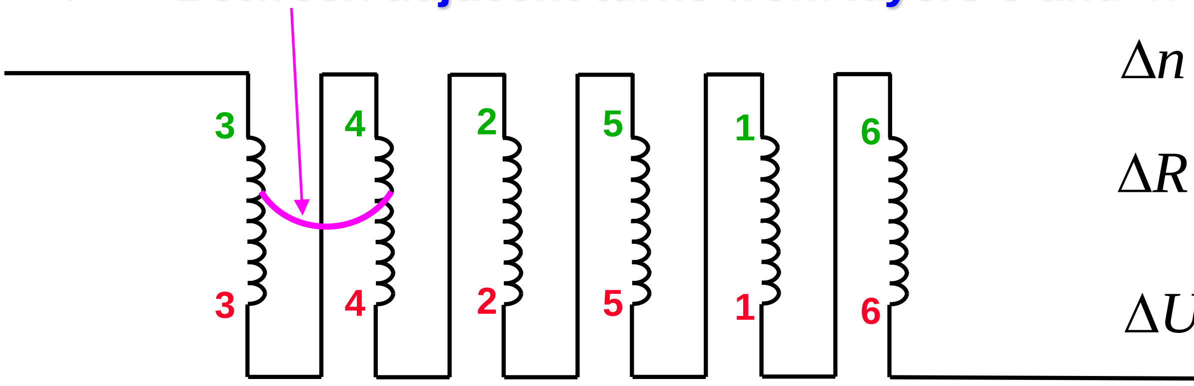
$$\Delta R = 2 \cdot R_{layer}$$

$$\Delta U_i = \begin{cases} -R_{layer} \cdot I & i = 5 \\ \neq 0 & i = 1,2 \\ = 0 & else \end{cases}$$

(similar: 2-3, 4-5, 5-6)

Interturn short-circuits (4)

- **Between adjacent turns from layers 3 and 4:**



$$\Delta n = 8$$

$$\Delta R = R_{layer}$$

$$\Delta U_i = \begin{cases} \neq 0 & i = 3,4 \\ = 0 & else \end{cases}$$

- **etc. for MSDB coil (5 layers) and MSDA coil (4 layers)**

- **Worst case:** $\Delta n = 16$

- **To detect interturn short circuits:**
  Absolute value of layer voltage is not useful
  (depends on coil temperature and current)
  => Compare the voltage of the different layers

Summary

- Non-linearity of $\int B\,dl$ vs. I
- Thermoswitches as protection against overheating
- To detect interturn short circuits:
  Compare the voltage of the different layers

To be studied in detail:

- “Matrix” for comparison of layer voltages
- Threshold values
- Residual temperature dependence
- Systematic differences from layer to layer
- Long term stability
- Calibration
- ….