Printed Circuit Fluxmeter to Measure the Bending Magnets of the MedAustron Synchrotron

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- Measurement requirements
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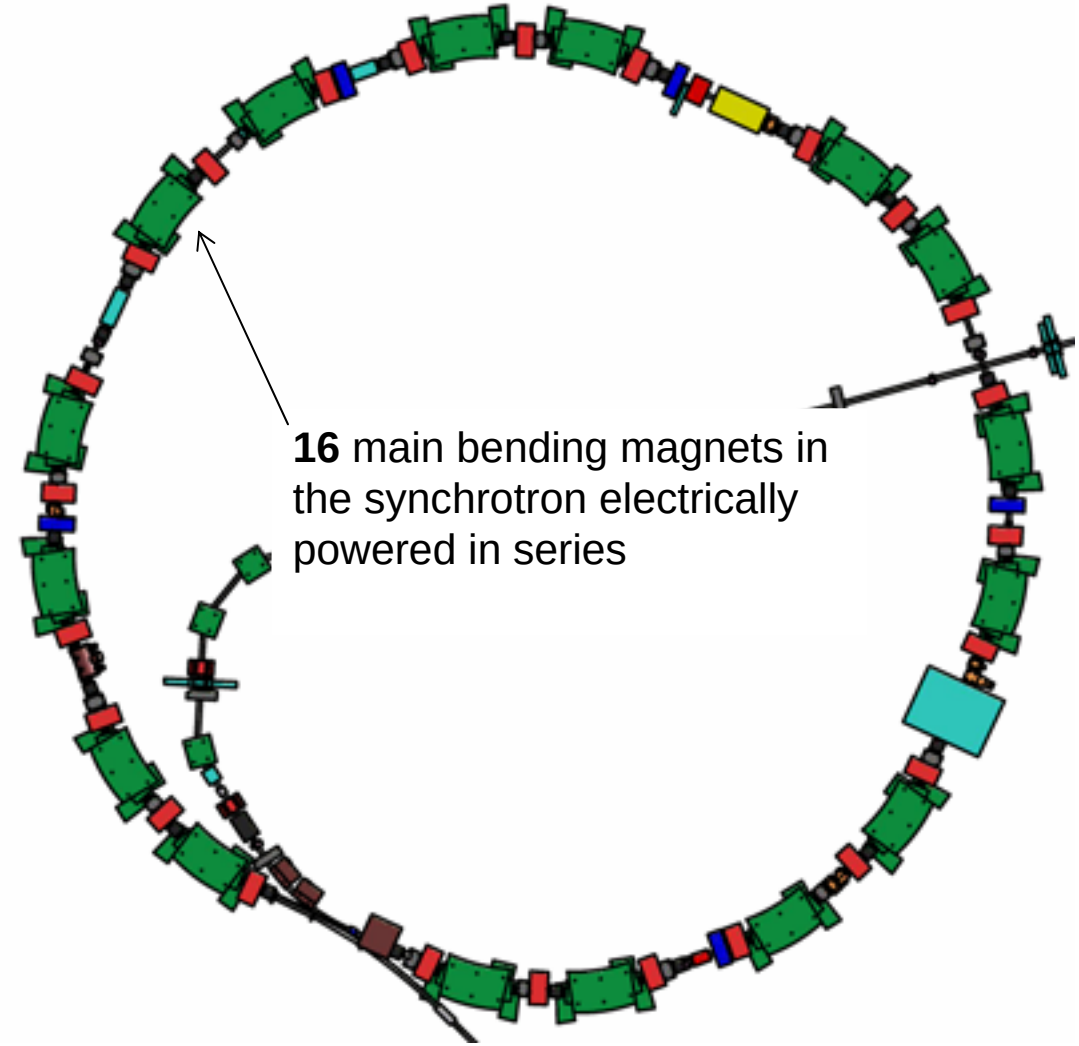
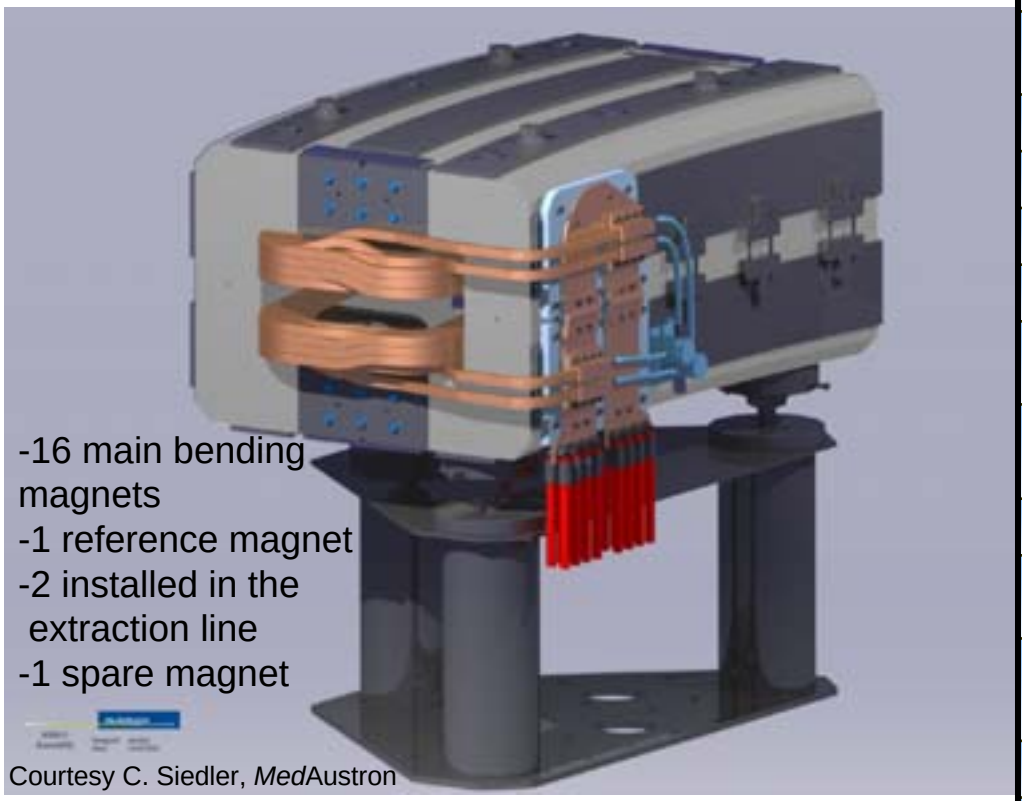
Characteristics of the synchrotron dipoles



Characteristics of the synchrotron dipoles

- In total 20 magnets will be built and measured

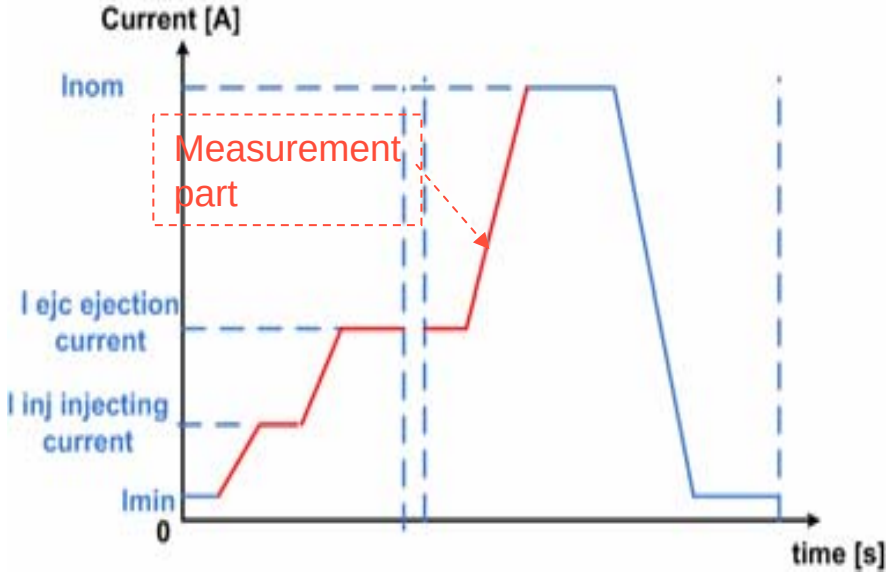


Courtesy C. Siedler, *Med*Austron

Supplier	Budker Institute of Nuclear Physics (BINP)
Dimensions	L1920 x W1444 x H750 mm
Weight	9 Tons
Bending radius	4231 mm
Magnet gap height	72 mm
Magnet pole width	220 mm
Good field region (GFR)	±60 mm(hor); ±30 mm (vert)
Field quality in the GFR at all field levels	$\pm 2.\ 10^{-4}$
Nominal field	1.5 T
Magnetic length at nominal field	1651 mm
The error of magnetic strength between magnets	$\pm 1.\ 10^{-3}$
Nominal current	2820 A
Nominal field ramp rate	3 T/s

Measurement requirements

- Issues to be considered:
  1. The field parameter constraints
  2. The magnets will be operated in pulsed mode
  3. The magnet curvature



- Magnetic properties to be measured:
  1. The integrated field strength (including magnetic length and magnetic center)
  2. The integrated field strength difference between magnets “tracking”
  3. The field quality in the good field region for all field levels
  4. Definition of pole end shims
  5. The dynamic behaviour of the magnet ”eddy current effect”

Measurement requirements

- Main measurement technique for these dipoles:
  - the measurements by search coils is the most suitable technique according to the issues mentioned above.

$$\int B(I)ds = \int_{-\frac{L_{coil}}{2}}^{\frac{L_{coil}}{2}} B(\Delta I)ds + \int_{-\frac{L_{coil}}{2}}^{\frac{L_{coil}}{2}} B(I_{\min})ds \quad with \quad \int_{-\frac{L_{coil}}{2}}^{\frac{L_{coil}}{2}} B(\Delta I)ds = \frac{1}{K_{coil}} \cdot \int_0^t V_{coil}(t)dt$$

  - An array of fixed search coils allow to reduce the alignment/position errors for the homogeneity measurement
  - Curved coils allow a better approximation of the field seen by the particles (ref :IMMW 14 "*Magnetic Measurement system for the dipoles of the Italian Therapy Centre (Centro Nazionale di Adroterapia Oncologica)"* by Didier Cornuet)

Additional measurement devices used:

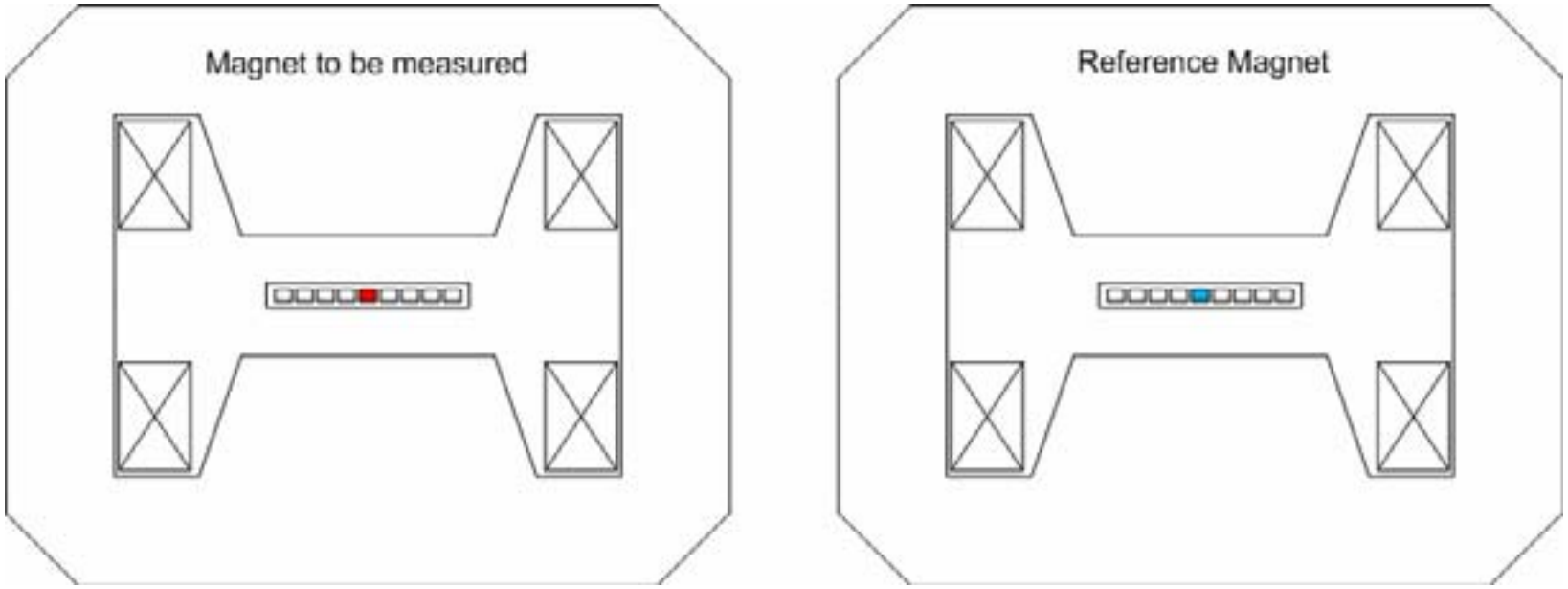
➔ This device is called "Fluxmeter"

Measurement requirements

2 fluxmeters are required: one in a magnet considered as the reference, one in the magnet to be measured.

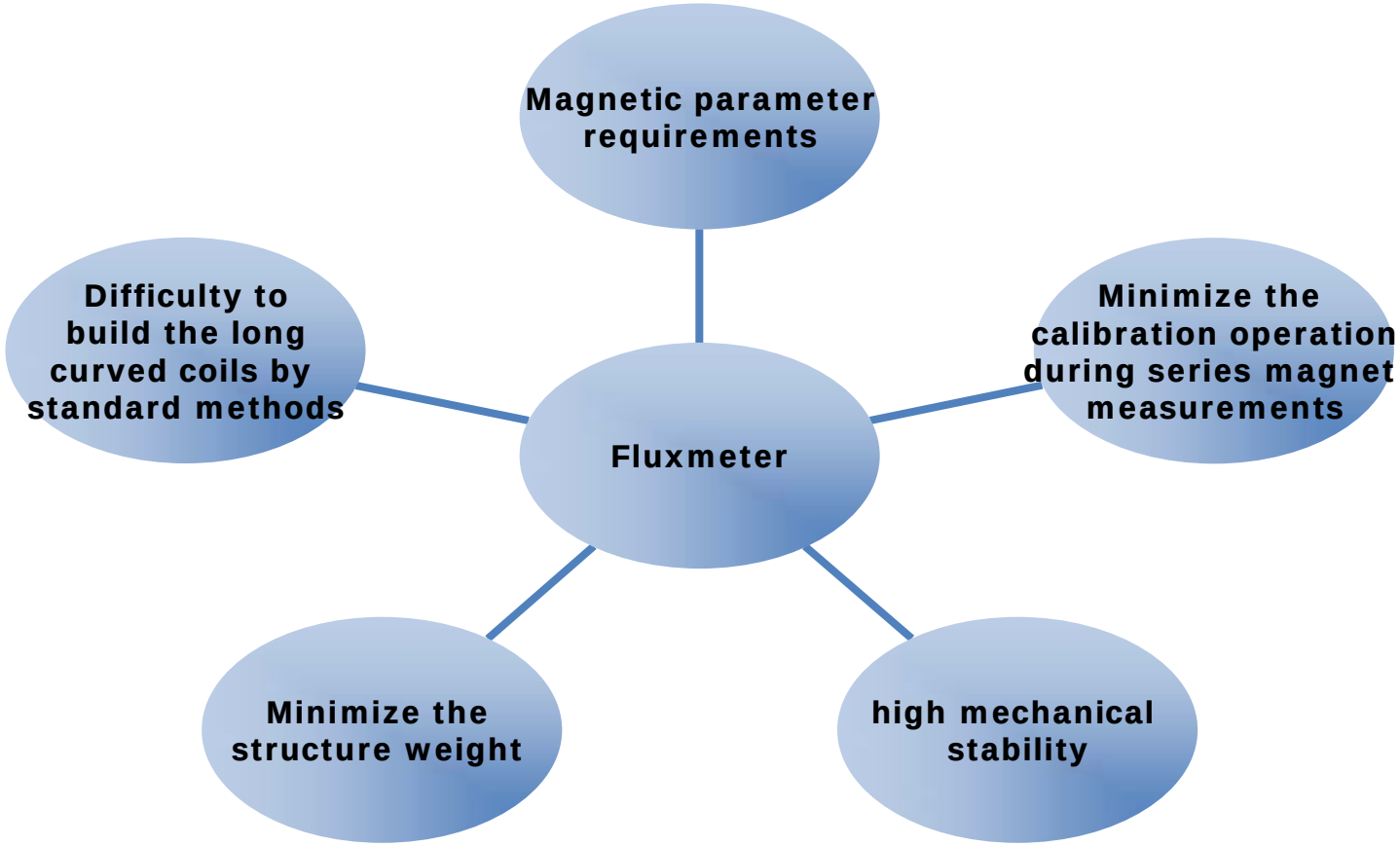
during the measurement 2 coils are connected in series in opposite sign “bucked” signal, to the integrator

Field quality measurement Field integrated strength measurement



: Positive coil signal : Negative coil signal

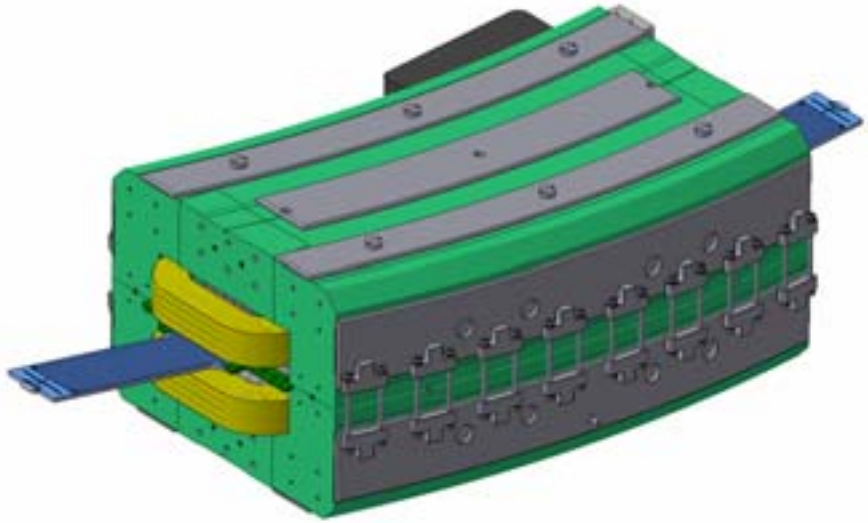
Motivation and description for the main measurement device (fluxmeter)



Motivation and description for the main measurement device (fluxmeter)

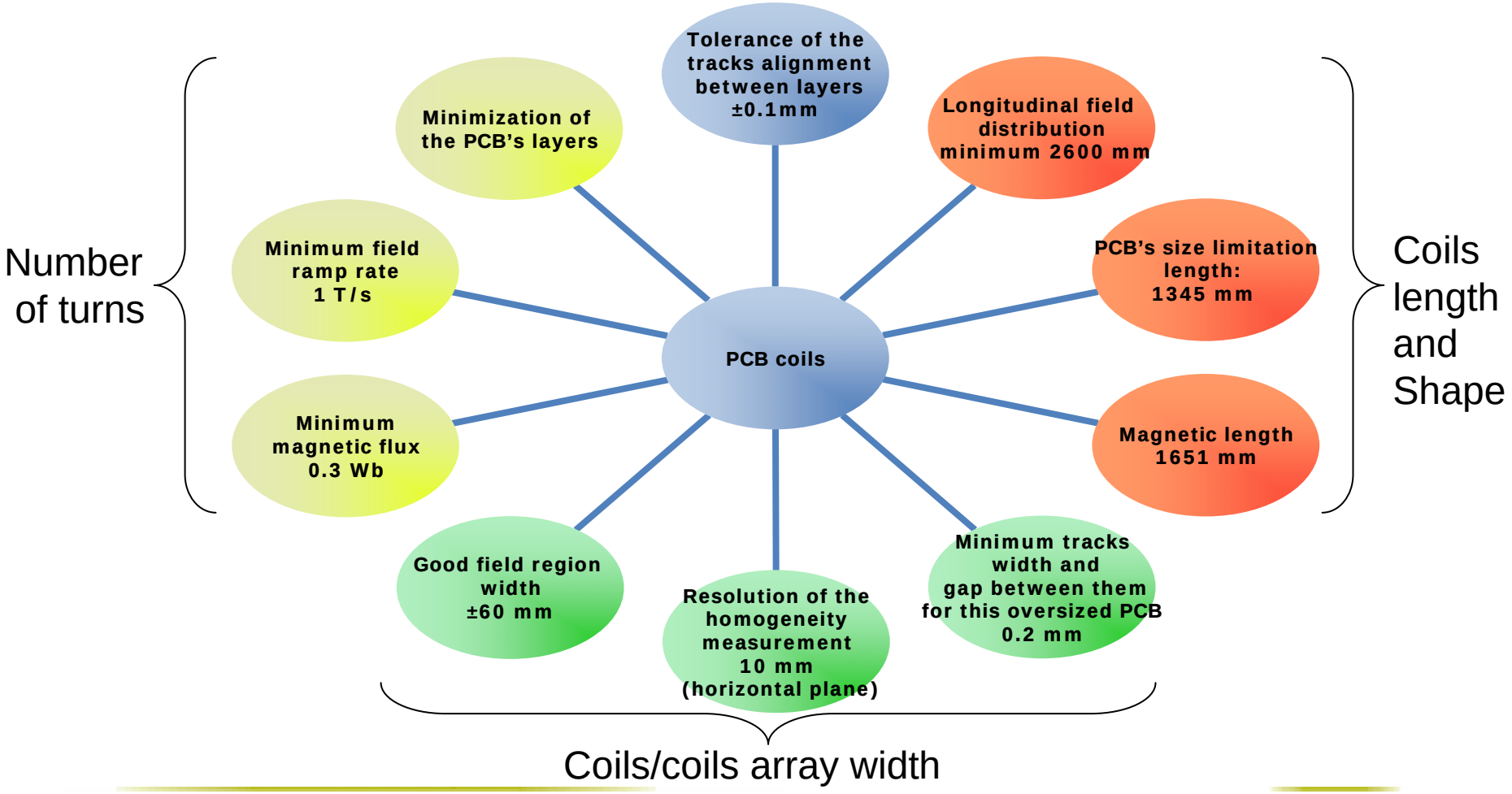
- Solution for the coils:
  - Coils array in Printed Circuit Board (PCB)
- Solution for their support:
  - Sandwich structure (fiberglass-foam)
- General characteristics:

Number of fluxmeters	2 +1 spare
Dimensions	L2800 x W210 x H12 mm
Weight	7 kg
Bending radius	4231 mm
Number of coils array	2
Gap between the coils in the beam direction	1 mm
Number of coils per coils array	17
Height position of the coils	10 mm



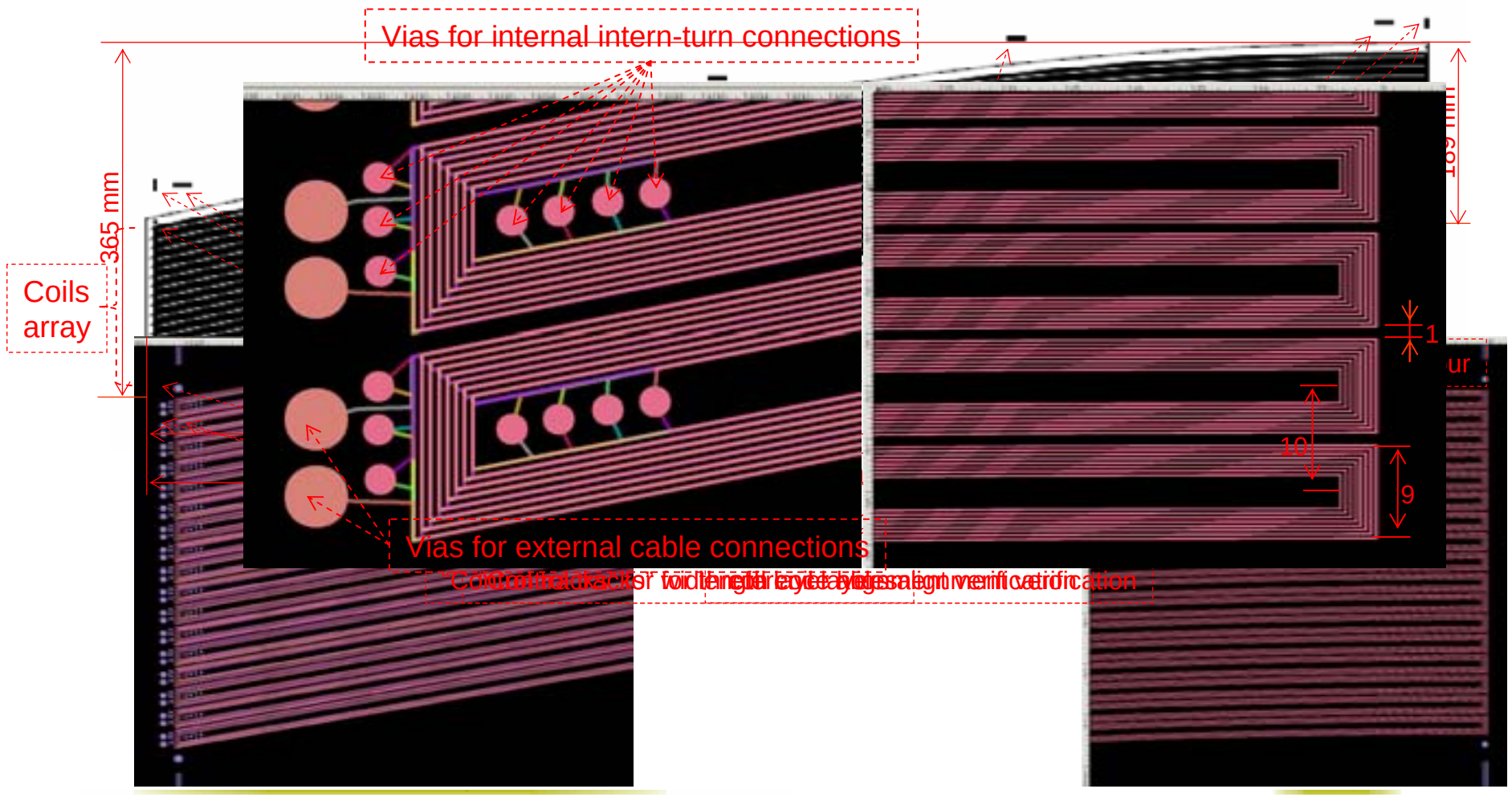
Description of the PCB coils

- Requirements for the PCB coils:



Description of the PCB coils

- Characteristics of the multilayer PCB coils:



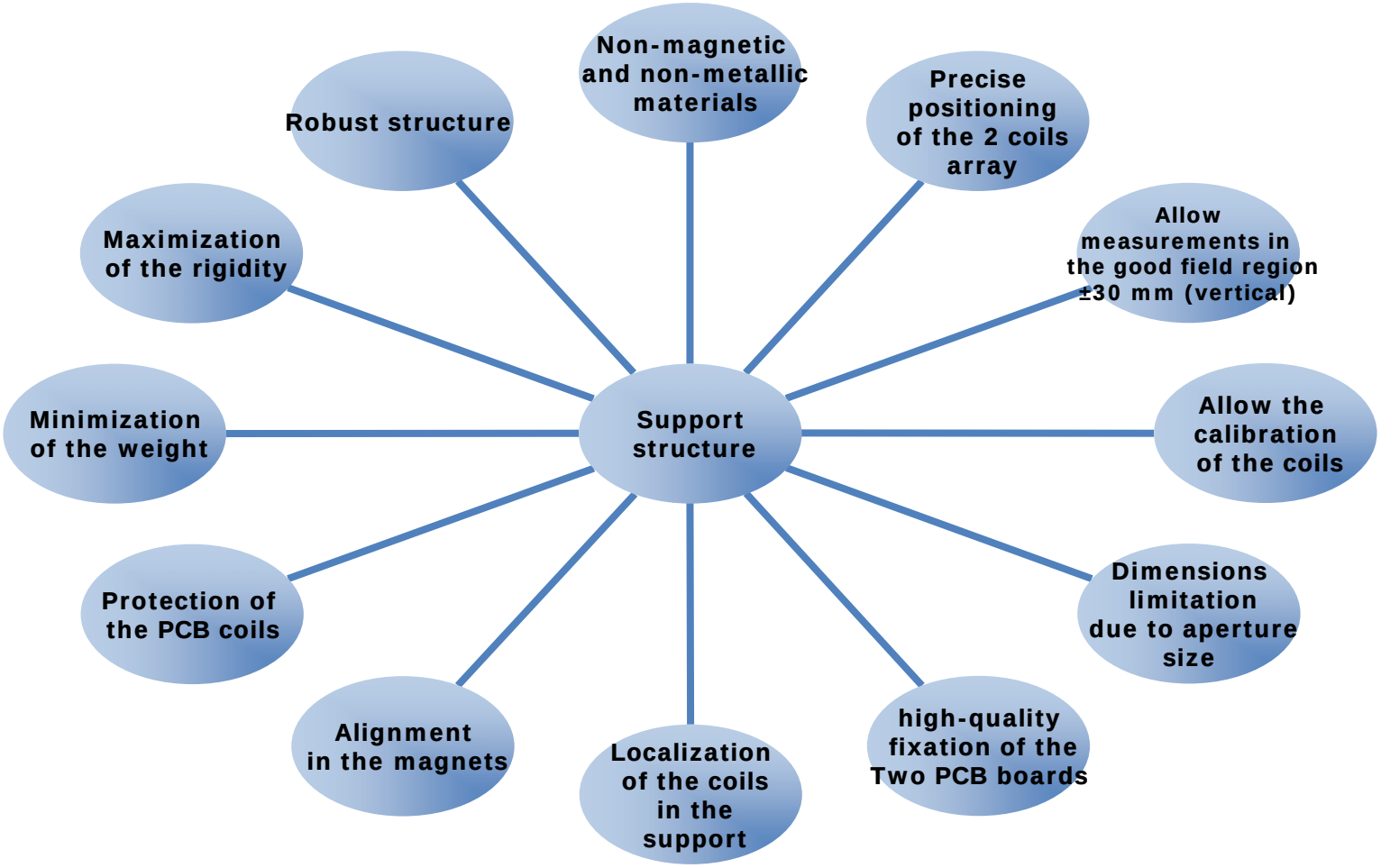
Description of the PCB coils

- Complementary characteristics:

Number of coil arrays produced	9
Number of coil arrays	6
Number of coils per array	17
Number of layers	8
Number of turns per layer	8
Number of turns	64
Coil thickness	2 mm
Equivalent width	6 mm
Equivalent length	1326 mm
Equivalent area	0.50918 m^2
Equivalent bending radius	4231 mm
Equivalent measurement width	± 80 mm

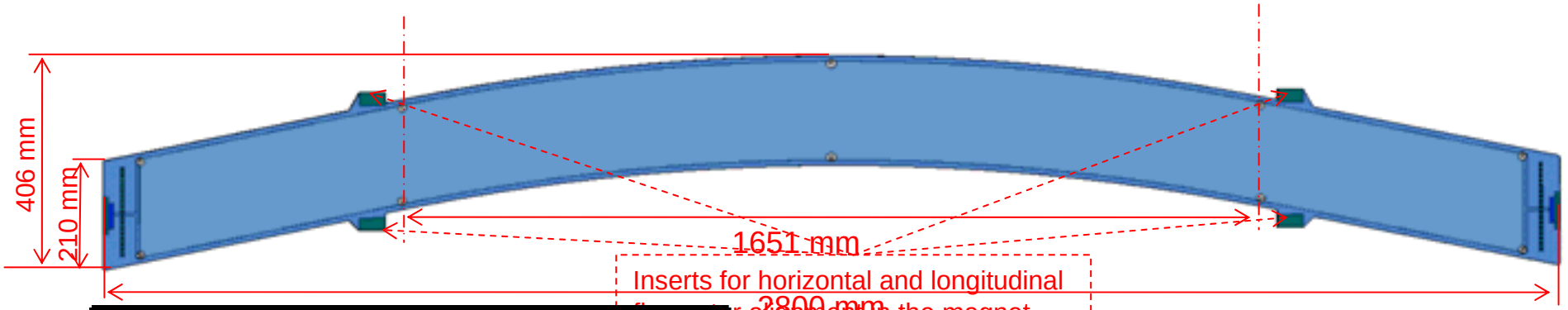
Description of the coil's support

- Requirements for the support structure:

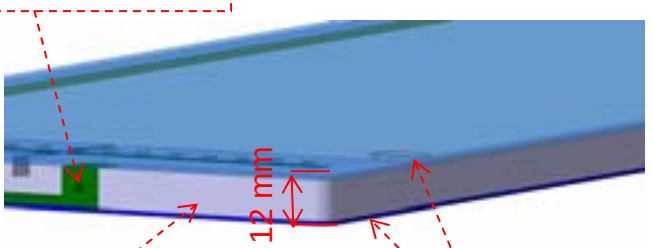


Description of the coil's support

- Characteristics of the support structure :

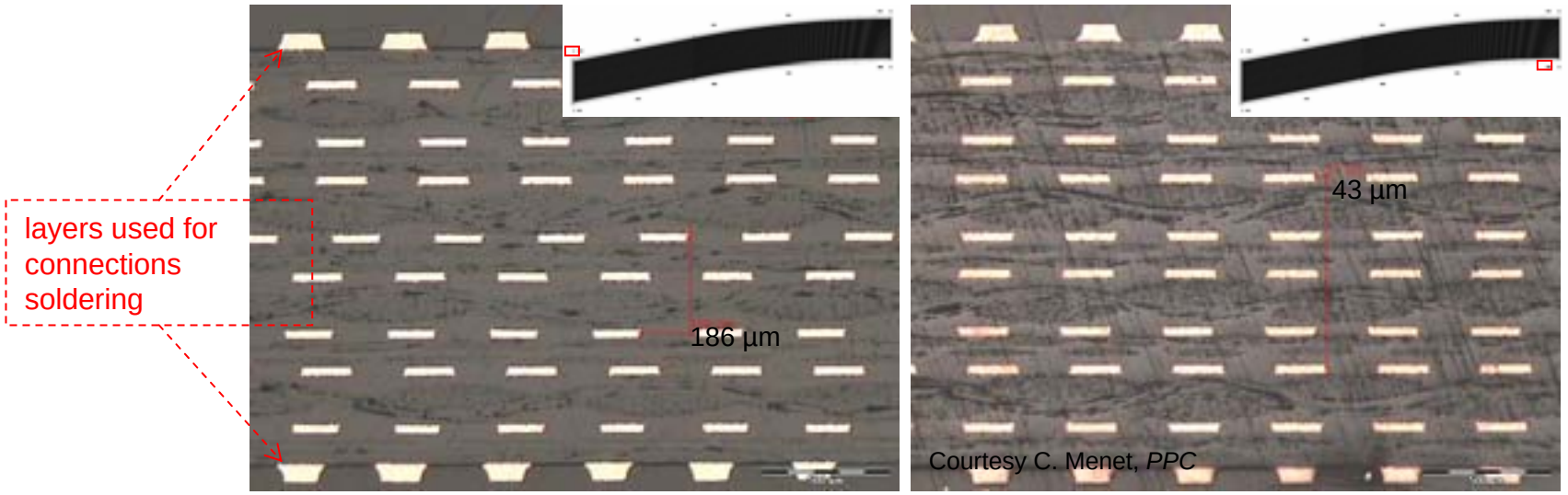


Skin material	fiberglass
Foam material	Rohacell®
Foam density	52 kg/m³
Tolerance of the calibration and alignment holes	H7
Tolerance of the calibration and alignment holes location respect to the PCB coils	±0.02 mm
Planarity of the coils groove	0.05 mm



Manufacturing and tests status

- PCB coils:
  - The PCB coils stacking have been design at the CERN's PCB section by Mr. De Oliveira
  - The "raw" PCB coils (before reference holes drilling and contour machining) have been produced by PPC Electronic AG
  - The control tracks show an maximal alignment error of 186 µm (length direction), and 100 µm (in width direction)



Maximum misalignment (longitudinal) Minimum misalignment (horizontal)

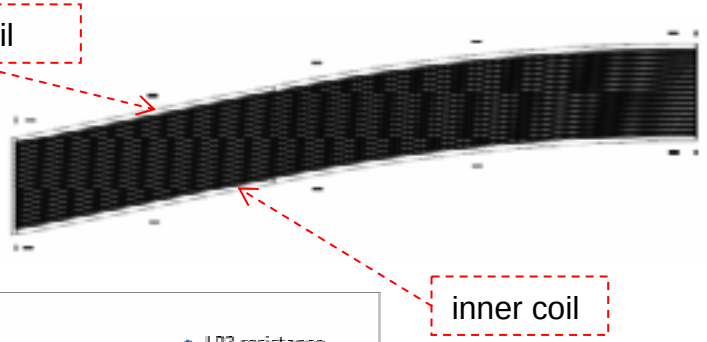
Manufacturing and tests status

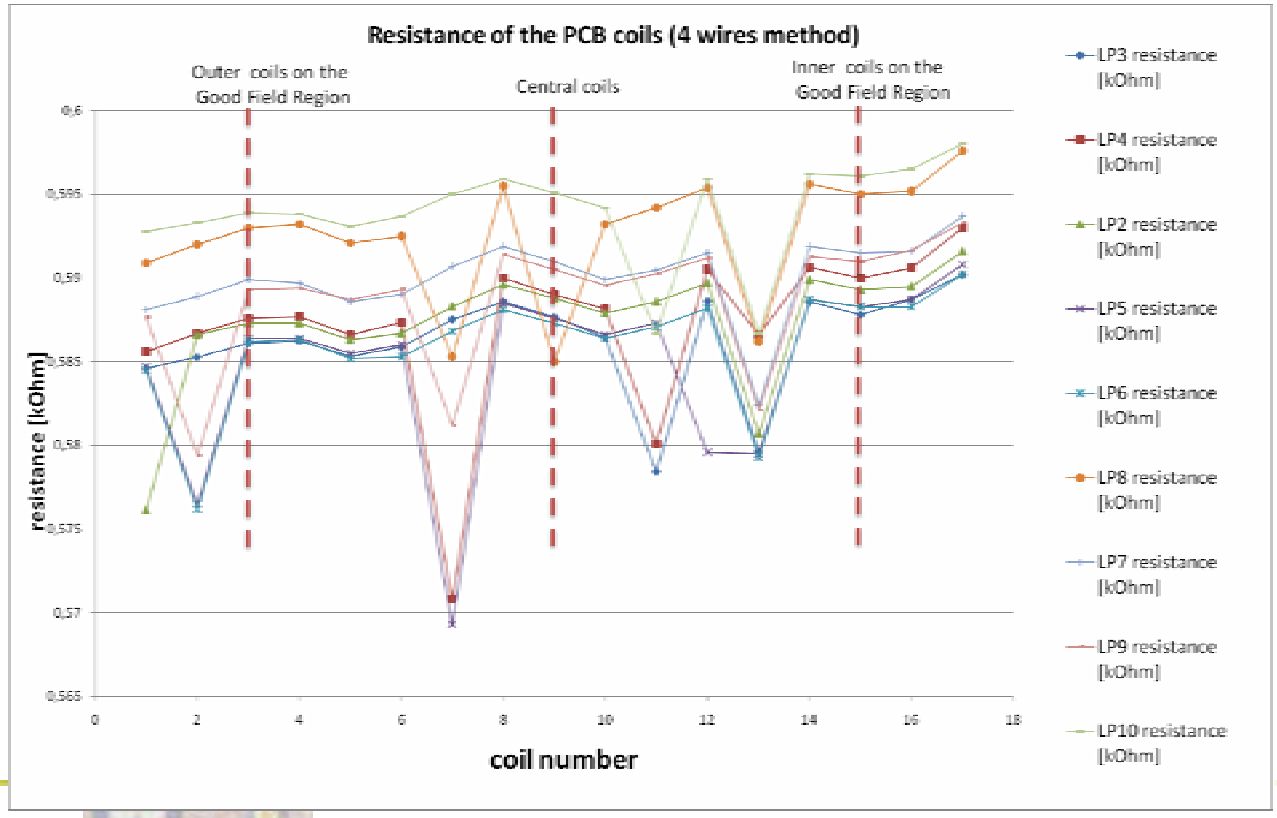
- PCB coils:
  - A preliminary calibration was done in order to verify the proper stacking of layers.

Courtesy O.Dunkel, *CERN*

Manufacturing and tests status

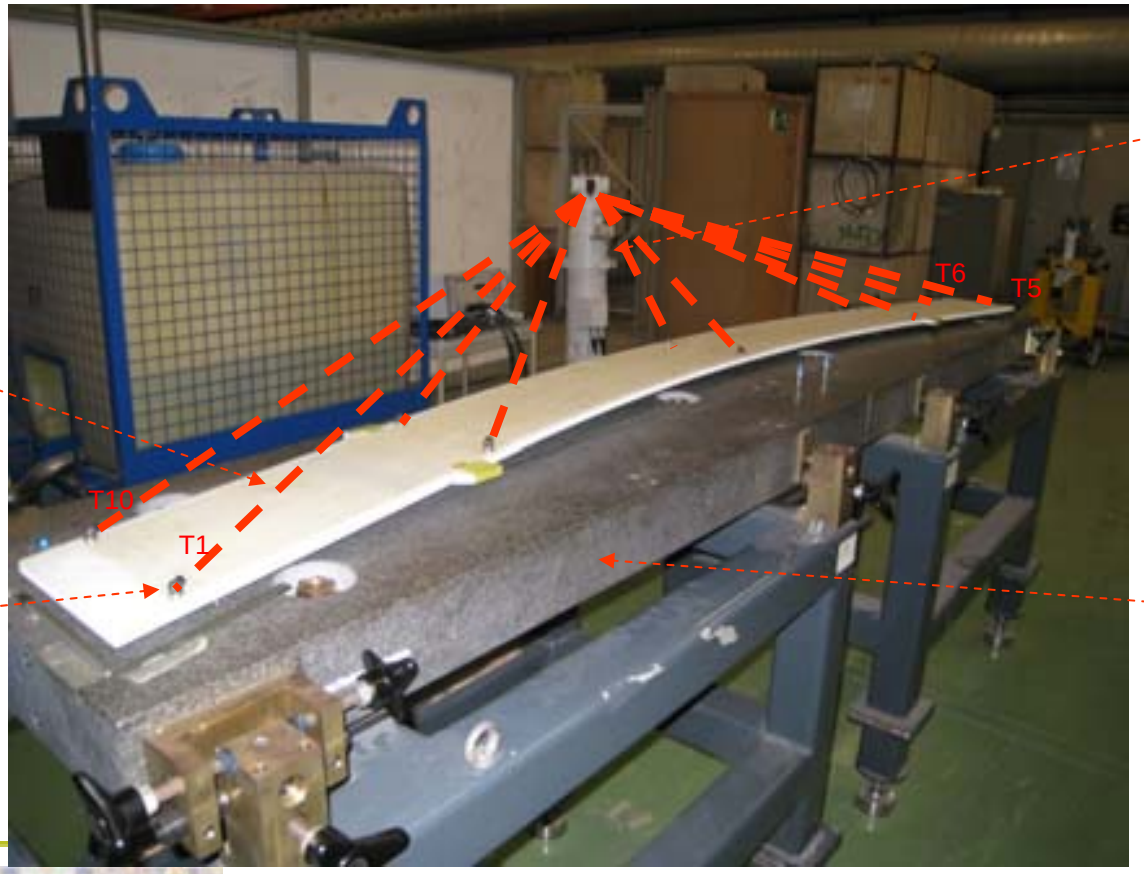
- PCB coils:
  - Calibration results (at 1T)





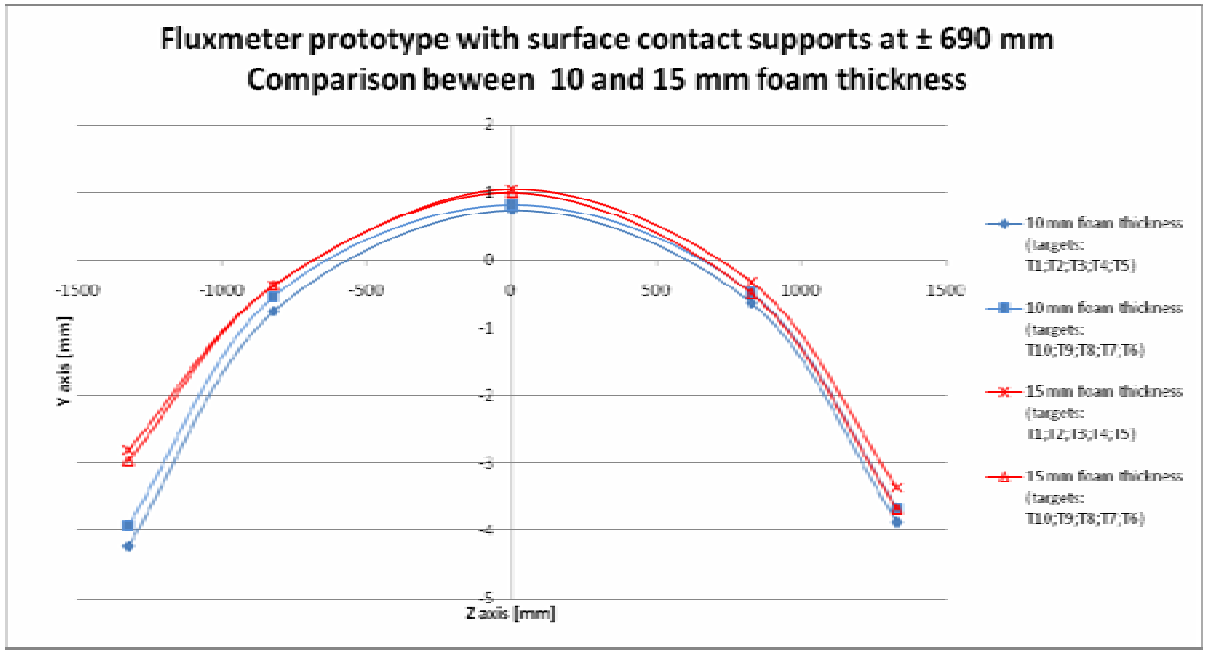
Manufacturing and tests status

- Support:
  - The coils support have been design at the CERN by Mr. Dunkel and myself
- Production of 2 prototypes with dummy PCBs by the company OCP Kunststofftechnik GmbH
  - Composed of different foam thickness: 10 mm and 15 mm



Manufacturing and tests status

- Support:
  - Prototype measurement results



- No major difference between foam's thickness in term of rigidity
  - ➔ The thinner one will be used (10 mm)
- The fluxmeter has to be supported on its full length
- Several improvements for the assembly process will be applied on the support as : machining the two skins to increase the symmetric behavior, better alignment of the two boards, increasing the skin flatness.

Conclusion

- The first fluxmeter is expected by the end of November
- The absolute calibration will be completed in a CERN dipole
- The relative calibration as well as the acceptance tests of the fluxmeter will be completed in the MedAustron magnet prototype
- In parallel, the measurement bench is currently in preparation

Acknowledgements

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Thank you for your attention.

Questions?