Measurement of fringe fields (of MQXF triplet quadrupoles)

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Outline

- Introduction
- Available measurements
- Expected field profile from calculations
- What we plan to do for the series magnets
Fringe fields

- The fringe field is the field across the magnet end-regions where a large variation in the longitudinal direction is present.
The fringe fields are not affected by changes of
- Longitudinal center
- Magnetic length
The rotating-coil probe gives the integral of the field harmonics over the sensor length.
Field harmonics and fringe fields

- Harmonic measurements are done with rotating coils of a given length – they give integral values over that length
  - If the rotating coil extremes are in a region where the field does not vary with $z$, one can use the 2d harmonic expansion for the integral
  - If the rotating coil extremes are in a region where the field vary with $z$, one cannot use the 2d harmonic expansion for the integral
    - One has to use a more complicated expansion

E. Todesco, Multipolar expansion of magnetic field, https://indico.cern.ch/event/915748/
Available measurements

- Probes with different lengths are used in the different laboratories and for different conditions

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<th>At ambient temperature</th>
<th>At cryogenic temperature</th>
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<tr>
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<td>scanning 110 mm</td>
<td>scanning 110 mm</td>
</tr>
</tbody>
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*not available yet
Short models

- We take as example the magnets tested at CERN
  - MQXFS3c
  - MQXFS4a
  - MQXFS6a
- Z-scanning (130-mm step) only at ambient temperature (low field level)
Short models

- b2

Graph showing the measurements of fringe fields for different model calculations, including MQXFS3c, MQXFS4a, and MQXFS6a.
Short models

- b6

![Graph showing calculations for MQXFS3c, MQXFS4a, and MQXFS6a.](image)
Short models

- b10

![Graph showing field vs. z length for b10 models MQXFS3c, MQXFS4a, and Series4, with field values in units and z in meters.](image-url)
Full-length magnets

- We take as example one of the magnets tested in USA
  - MQXFAP2
- Z-scanning (110-mm step) at ambient temperature and cryogenic temperature (high field)
Long magnets

Calculations

- Ambient temperature
- Cryogenic temperature 10 kA

b2 [units]

z [mm]
Long magnets

Calculations

- Ambient temperature
- Cryogenic temperature 10 kA

b6 [units]

-3000 -2000 -1000 0 1000 2000 3000

z [mm]

-3000 -2000 -1500 -1000 -500 0 500 1000 1500

-3000 -2000 -1000 0 1000 2000 3000

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Full-length magnets

- We take as example the only magnet tested at CERN
  - MQXFBP1
- Only data at ambient temperature (600 mm)
- We check the other multipoles across the ends (normalized to central field)
Full-length magnets

- MQXF1P01
Full-length magnets

MQXFBP1

![Graph showing measurement data for MQXFBP1](image-url)
Strategy for measurements of series magnets

- At ambient temperature
  - Probe length 600 mm
  - 13 positions (2 end-regions, 11 straight section)
Strategy for measurements of series magnets

- At cryogenic temperature
  - Probe length of 1300 mm
  - 6 positions (2 end-regions, 4 straight section)
Conclusions

- Accurate measurement of the field profile across the magnet ends is difficult
  - Systematic errors when using rotating coils
  - Very sensitive to positioning
- Knowing the magnet geometry and properties, calculations can give reliable results
  - Cross-check with measurement on one of the magnet
- We will provide measurements of the fringe fields integrated over the ends regions
Thank you!