Measurement of fringe fields (of MQXF triplet quadrupoles)

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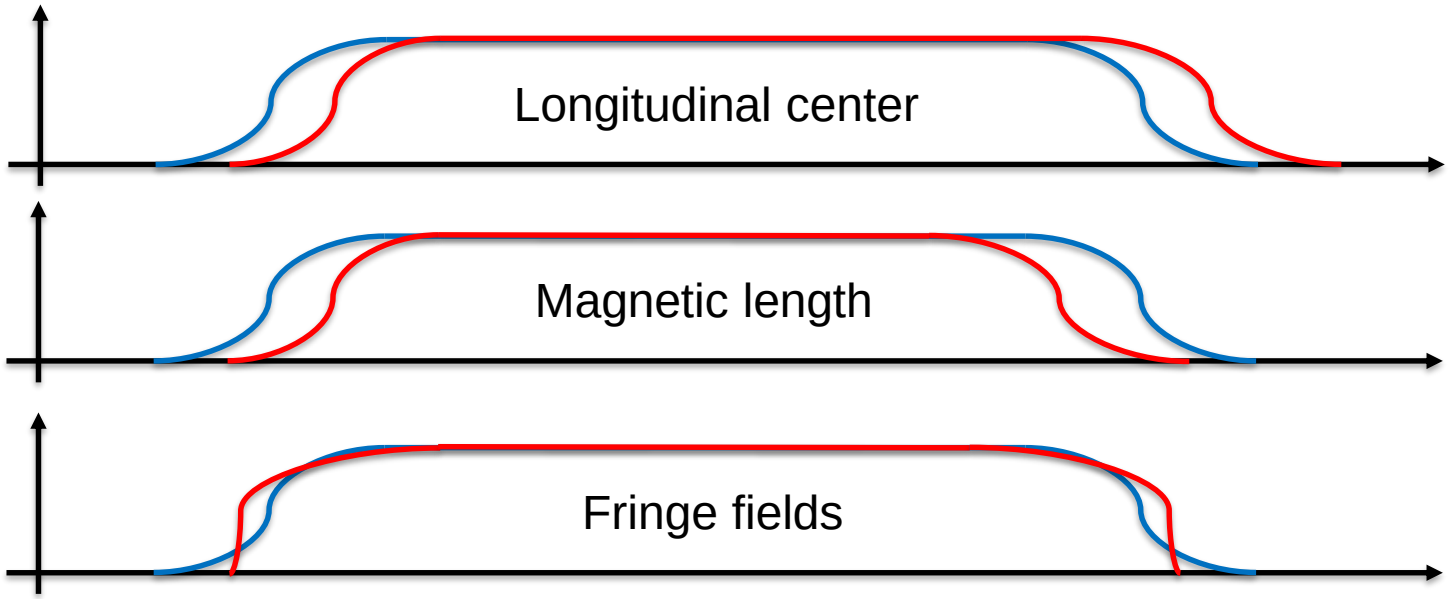
Outline

- 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

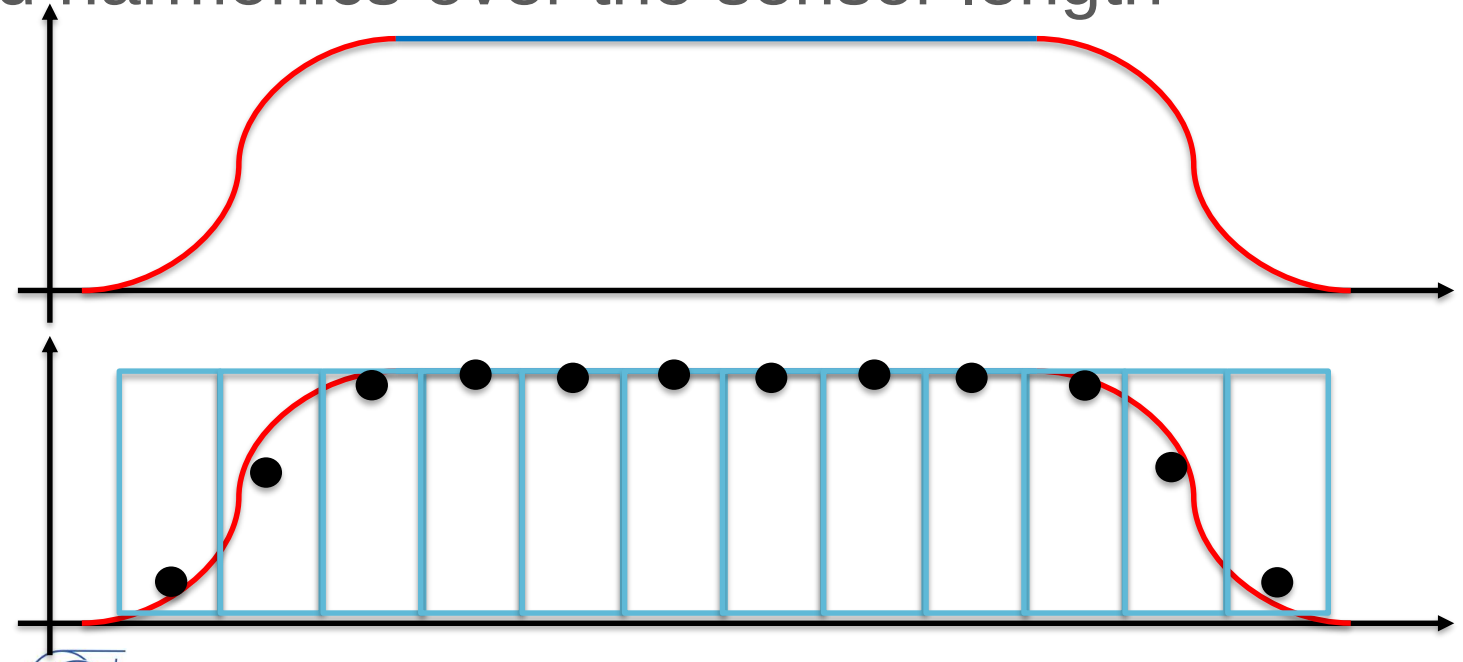
Fringe fields and other figures



- The fringe fields are not affected by changes of
  - Longitudinal center
  - Magnetic length

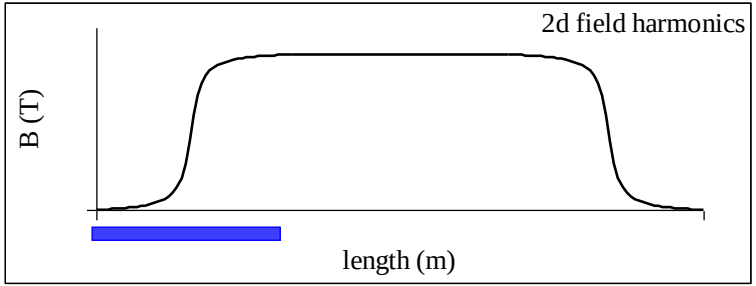
Probe length

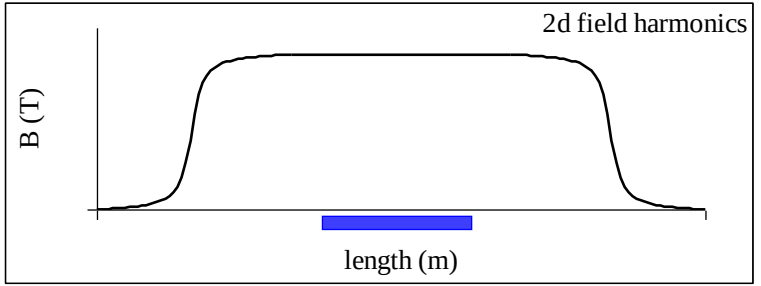
- The rotating-coil probe gives the integral of the field harmonics over the sensor length



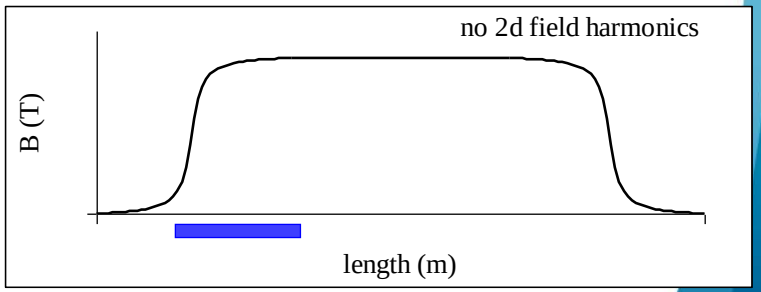
Field harmonics and fringe fields

- 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

	At ambient temperature	At cryogenic temperature
Short models		
CERN	scanning 130 mm	fixed 5 x 500 mm
USA	scanning 110 mm	scanning 110 mm
Long magnets		
CERN	scanning 600 mm	fixed 6 x1300 mm*
USA	scanning 110 mm	scanning 110 mm

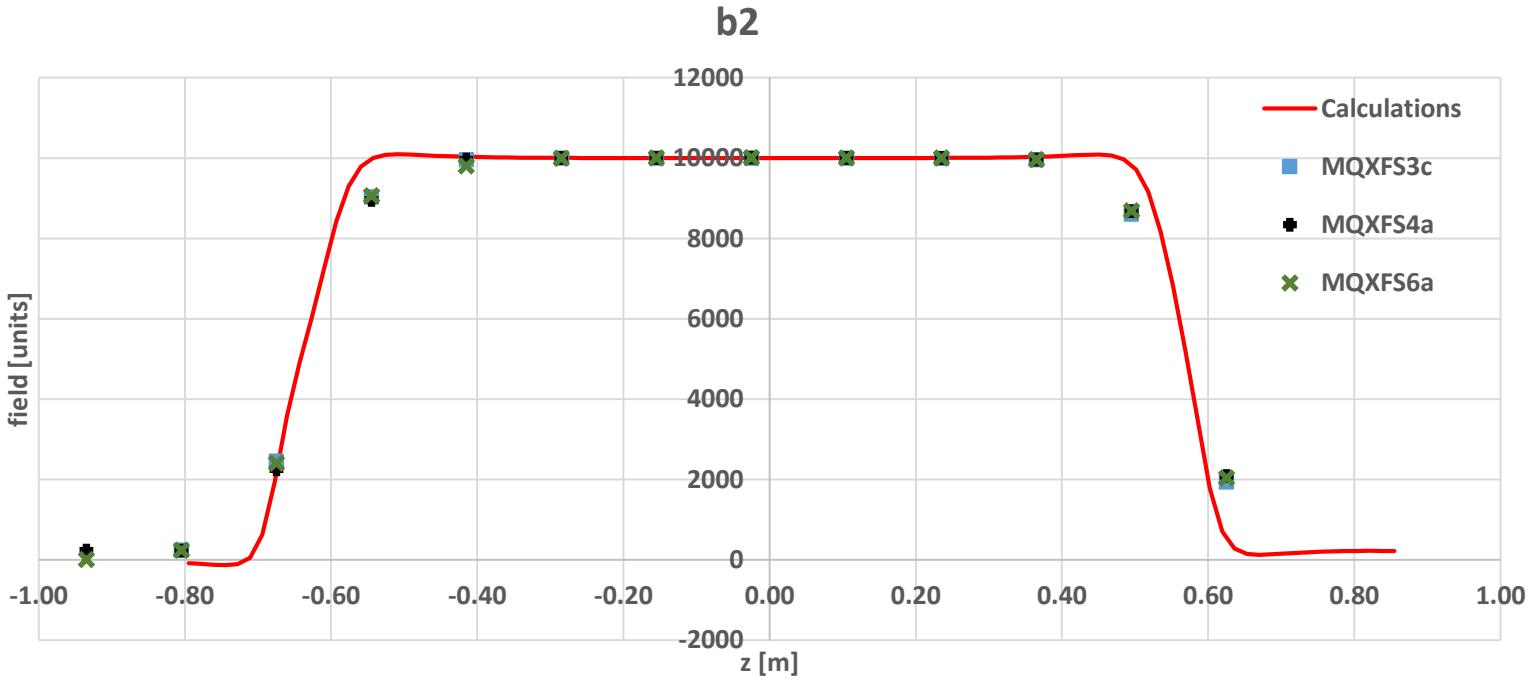
*not available yet

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)

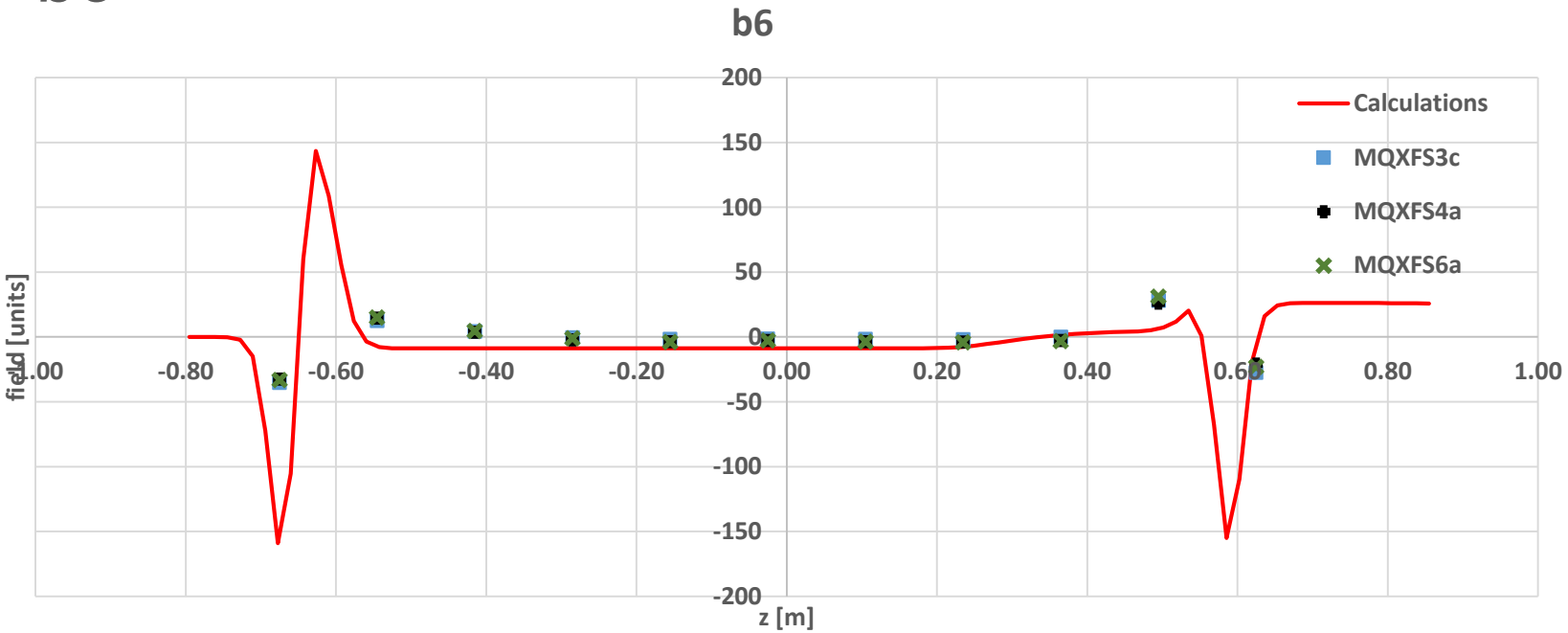
Short models

- b2



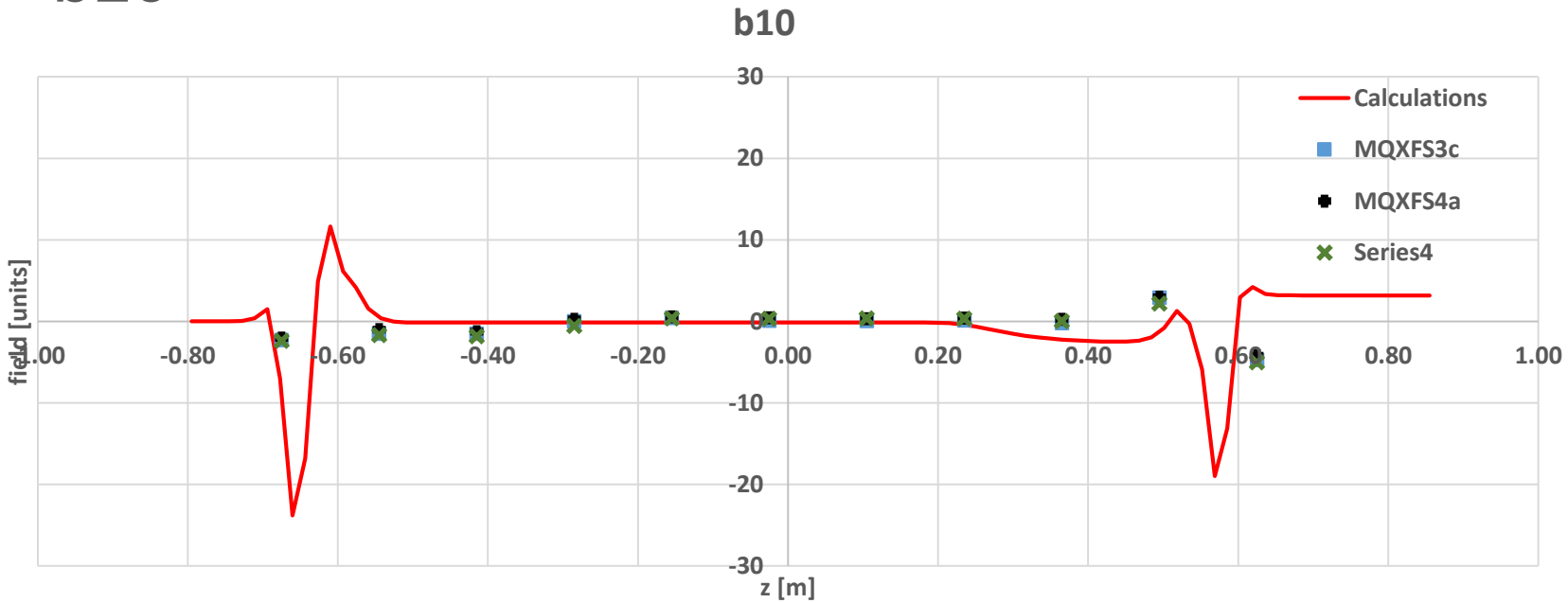
Short models

- b6



Short models

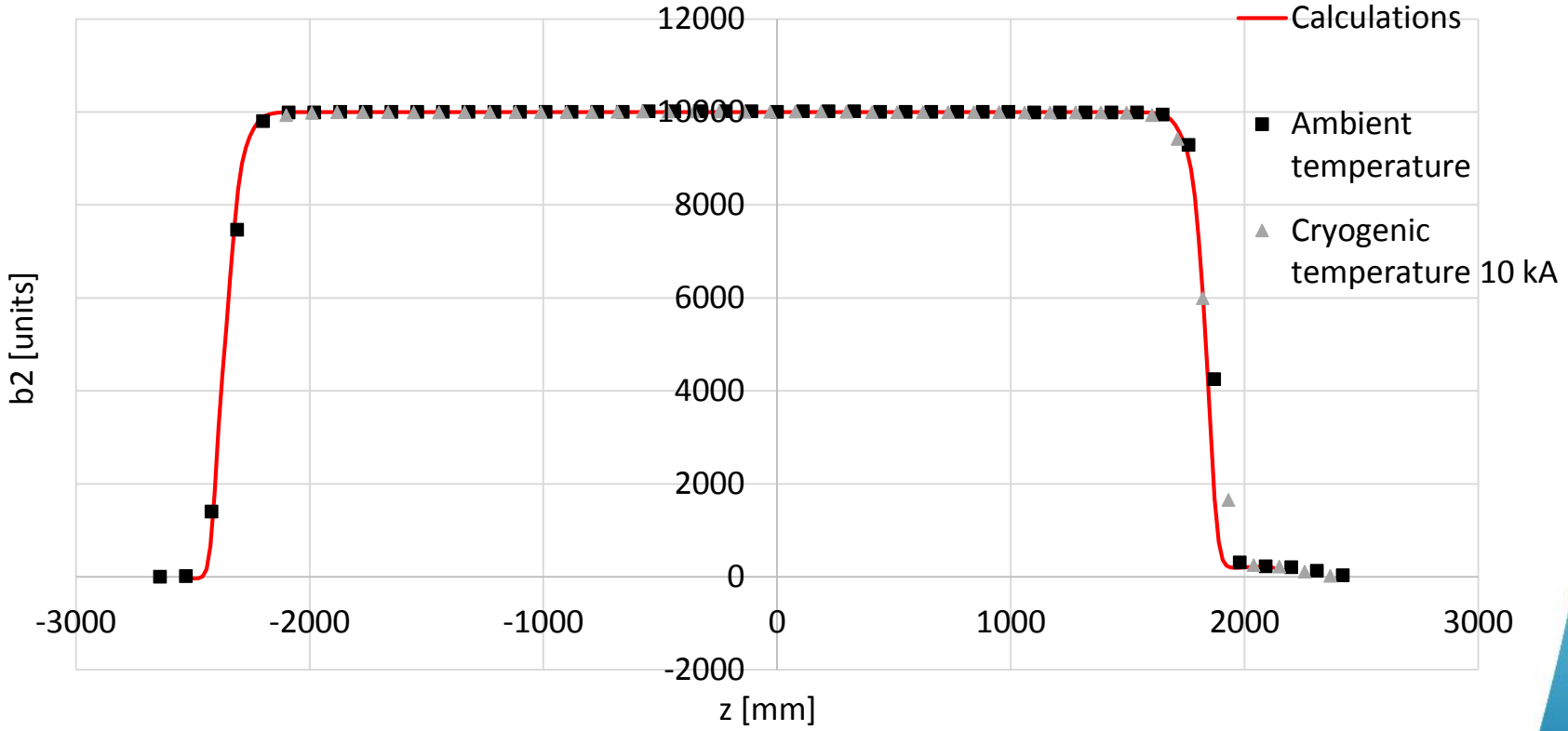
- b10



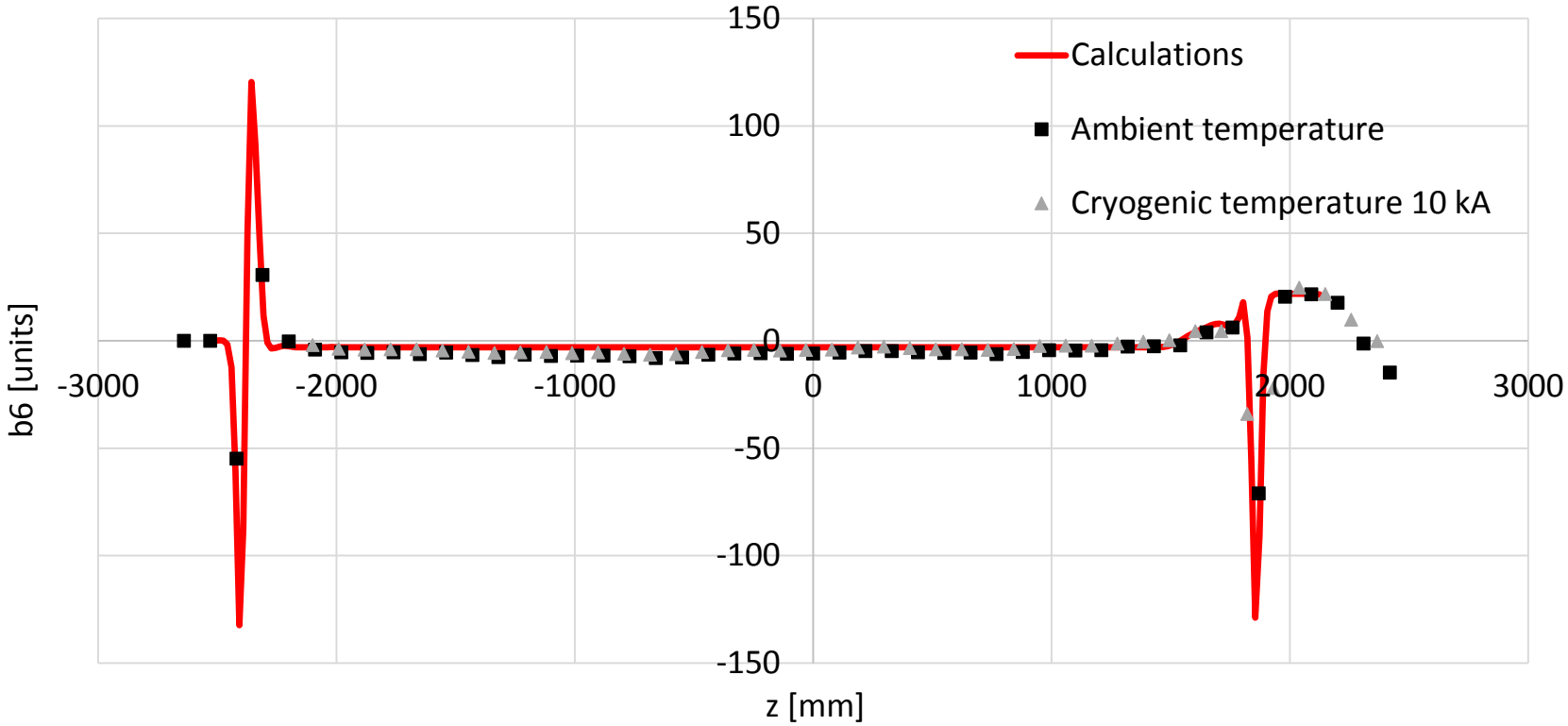
Full-length magnets

- 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



Long magnets

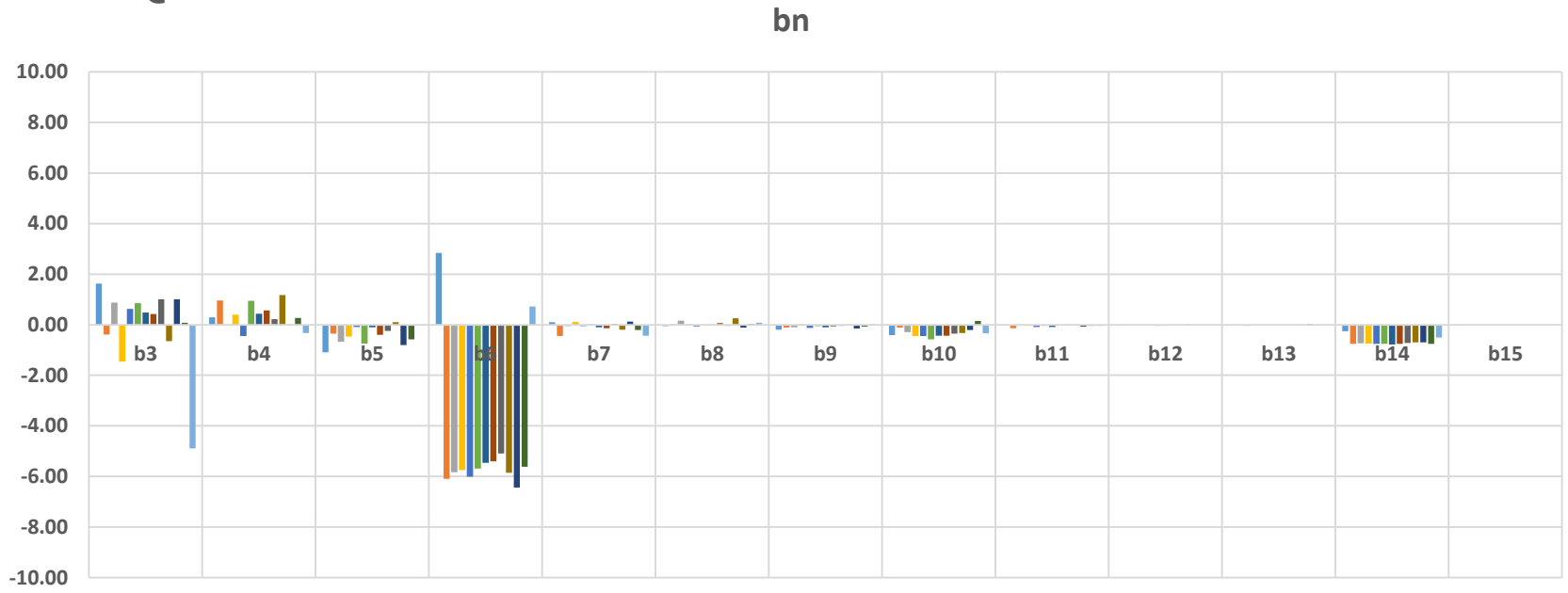


Full-length magnets

- 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)

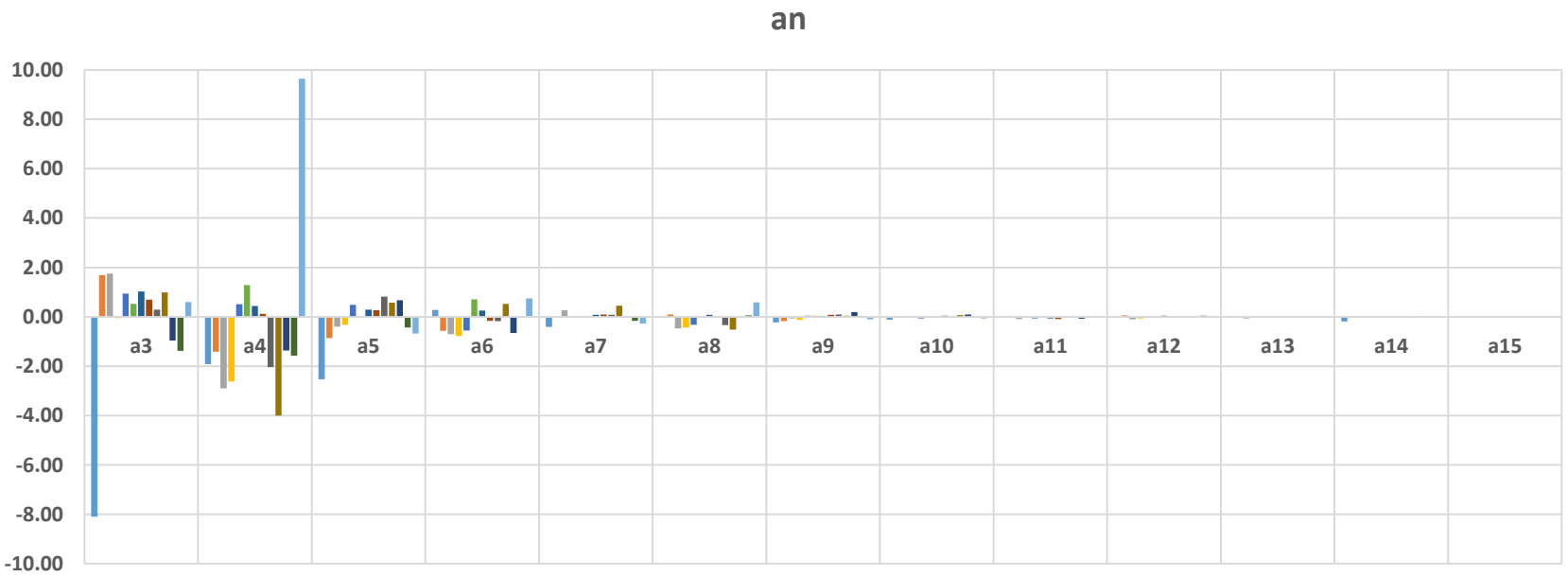
Full-length magnets

- MQXFBP1



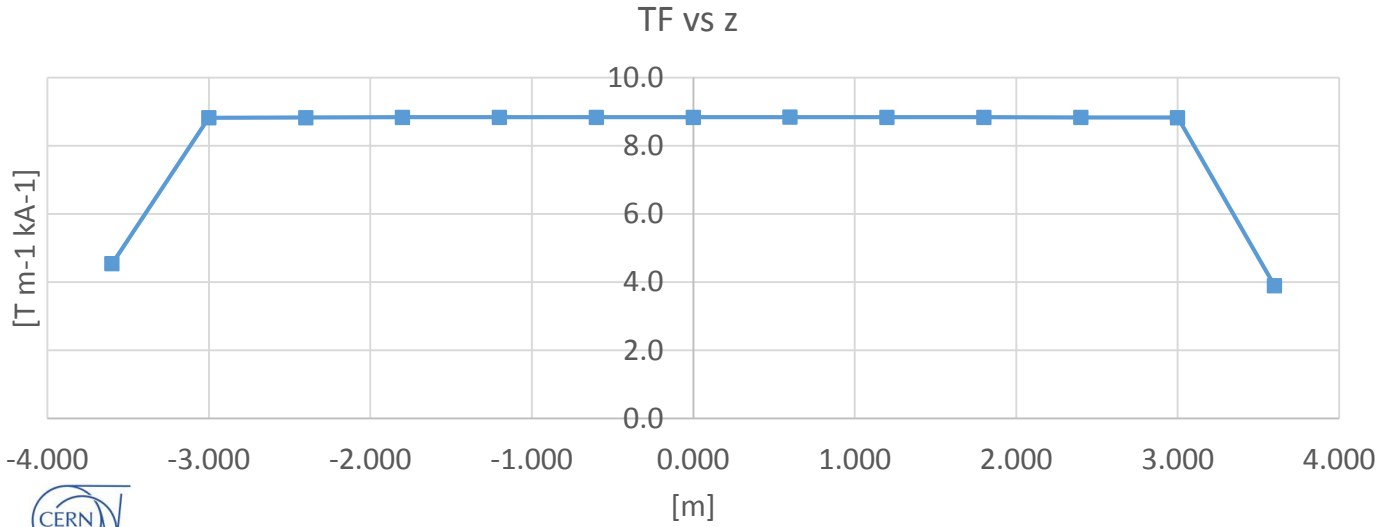
Full-length magnets

- MQXFBP1



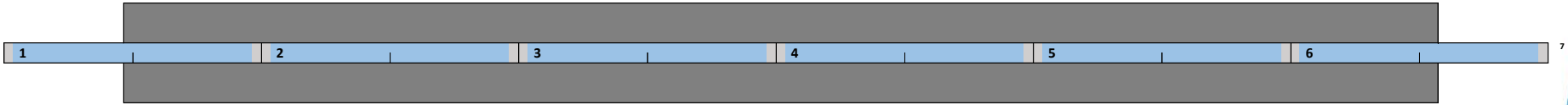
Strategy for measurements of series magnets

- 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!