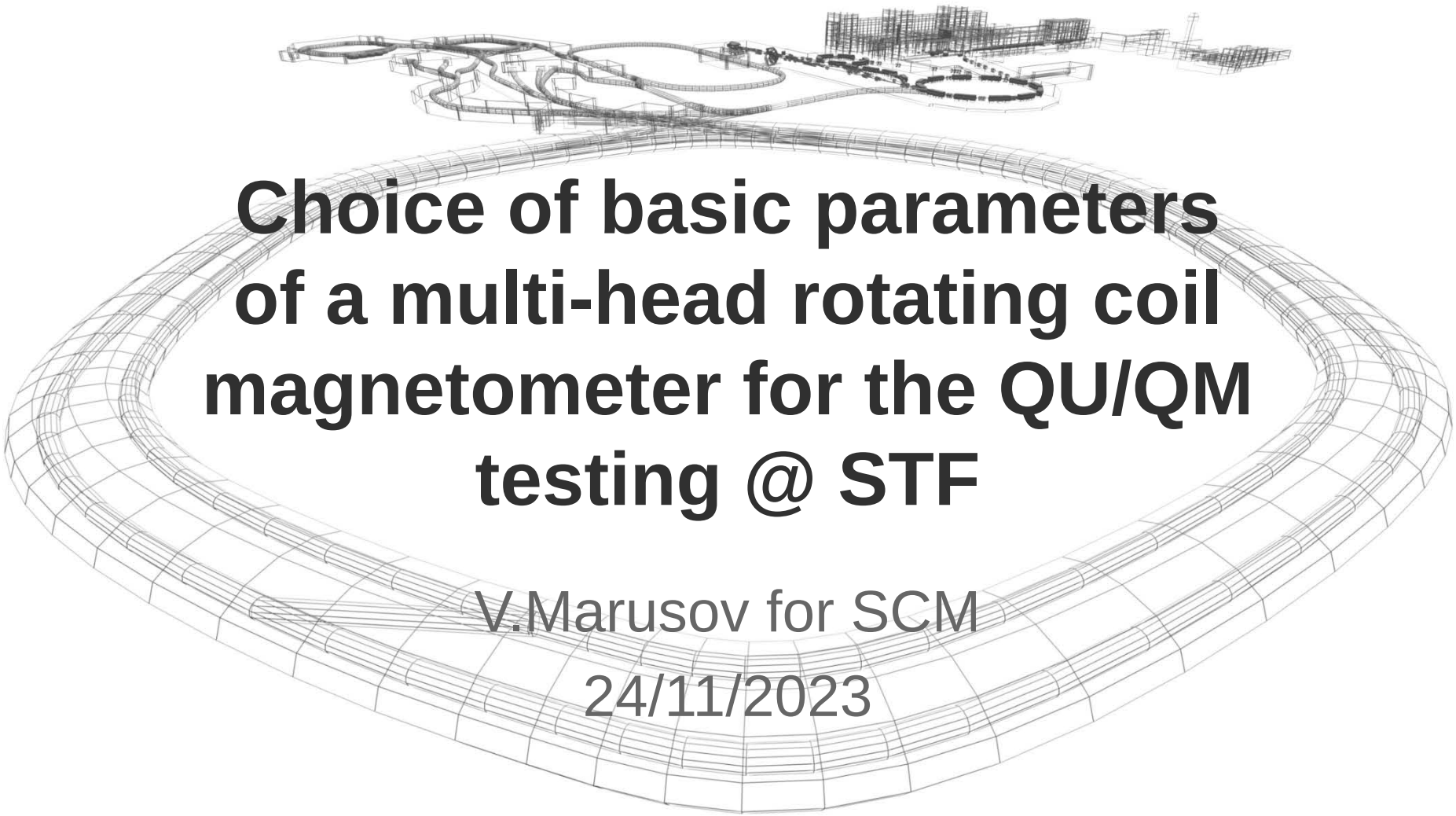
GSI Helmholtzzentrum für Schwerionenforschung GmbH



Choice of basic parameters of a multi-head rotating coil magnetometer for the QU/QM testing @ STF

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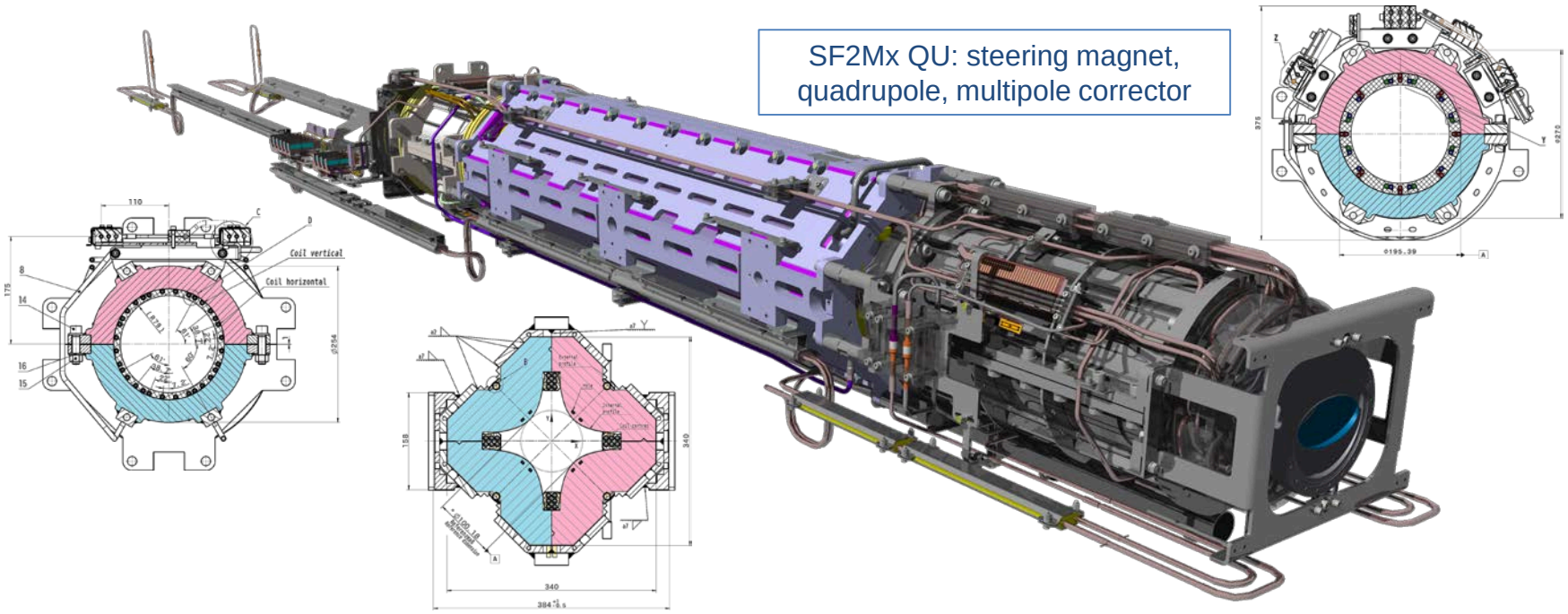
24/11/2023

Magnetic measurement subjects - Quadrupole Units

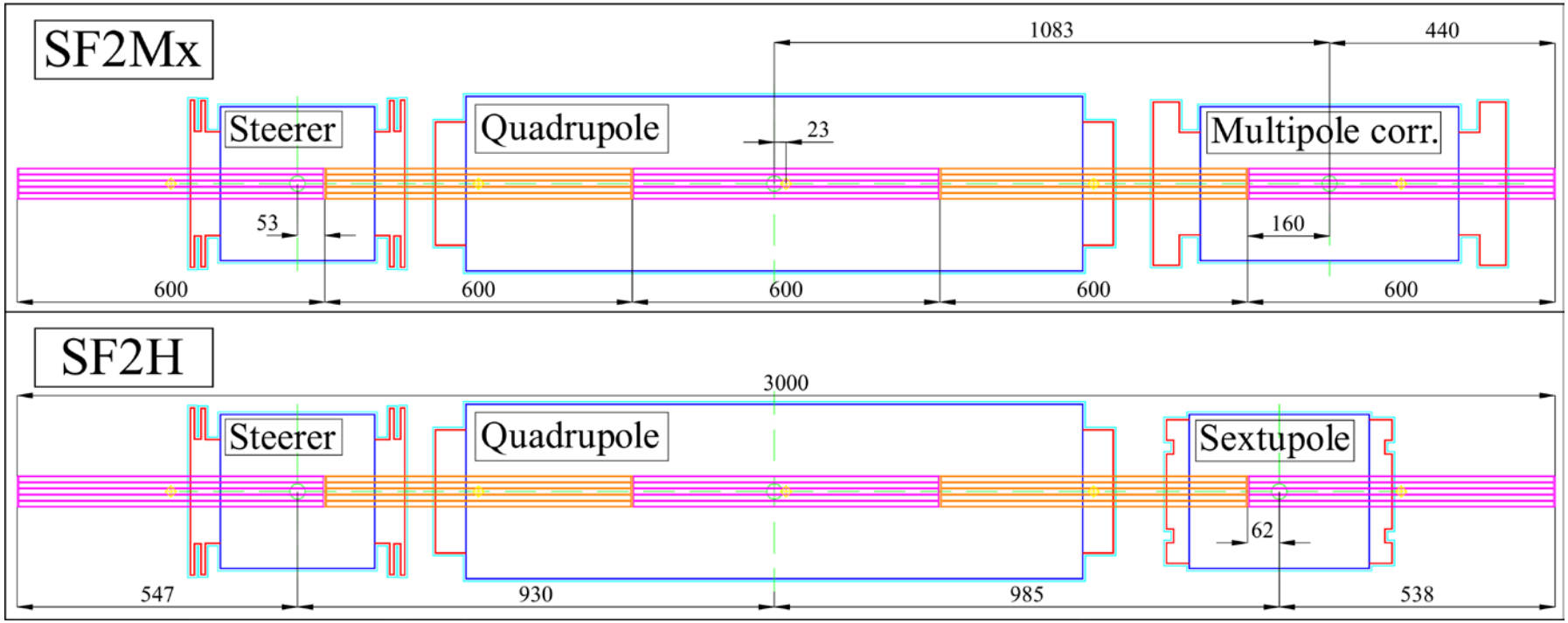
SIS100 ring contains 166 QU of 18 different types. QU consist of a main quadrupole magnet, together with up to two corrector magnets or a beam position monitor.



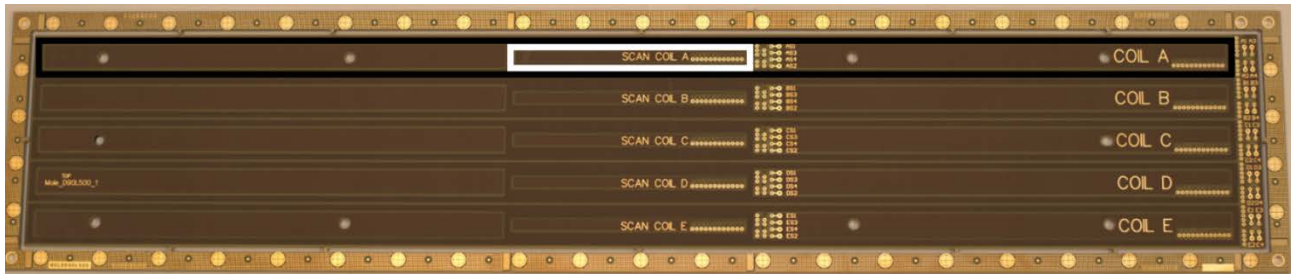
Quadrupole unit length measured at edges of the magnet coils reaches 2.6 *m* (for SF2Mb and SF2Mx, shown above). Magnetometer must cover the field of all magnets.

Below we consider options for a multi-head magnetometer that allows measurements without longitudinal scanning.

Longitudinal magnetometer segmentation - version #1

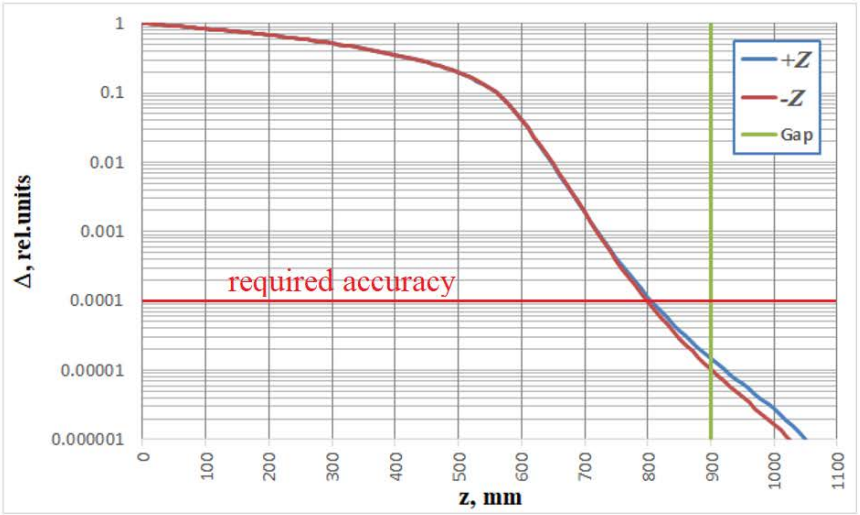


Five identical 600 *mm* long PCBs. Additional short coils on PCB, like done at CERN:

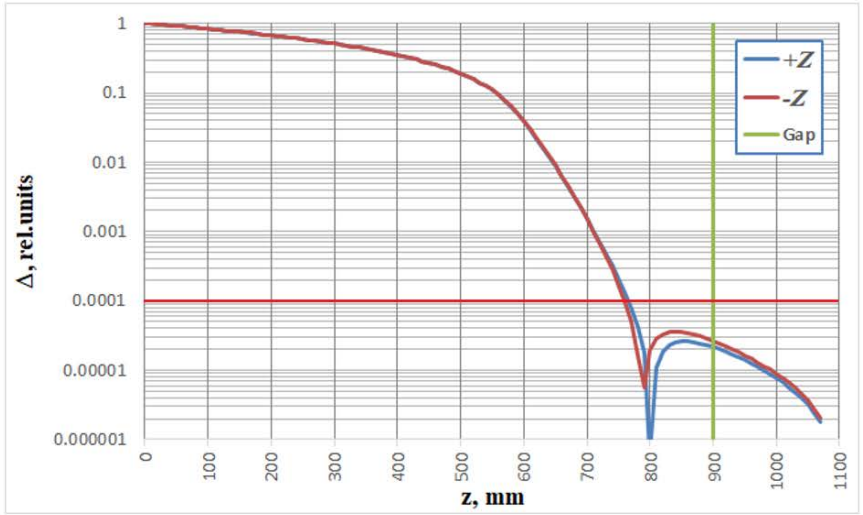


Quadrupole field coverage

"Missing integral fraction": how much of integral from $z = 0$ to $z = \infty$ is missing if to integrate to a finite z value.



Missing integral fraction of the quadrupole field vs. distance from center @ 1.2 *kA*

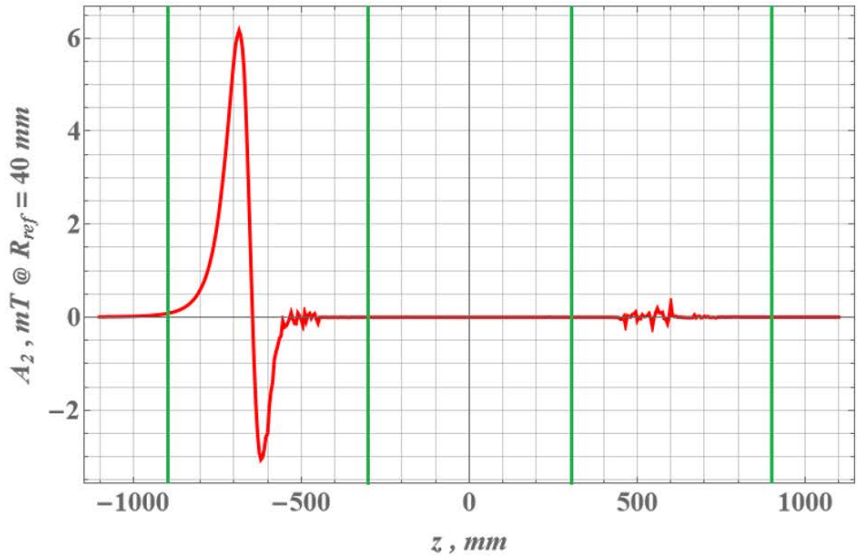


Missing integral fraction of the quadrupole field vs. distance from center @ 10.5 *kA*

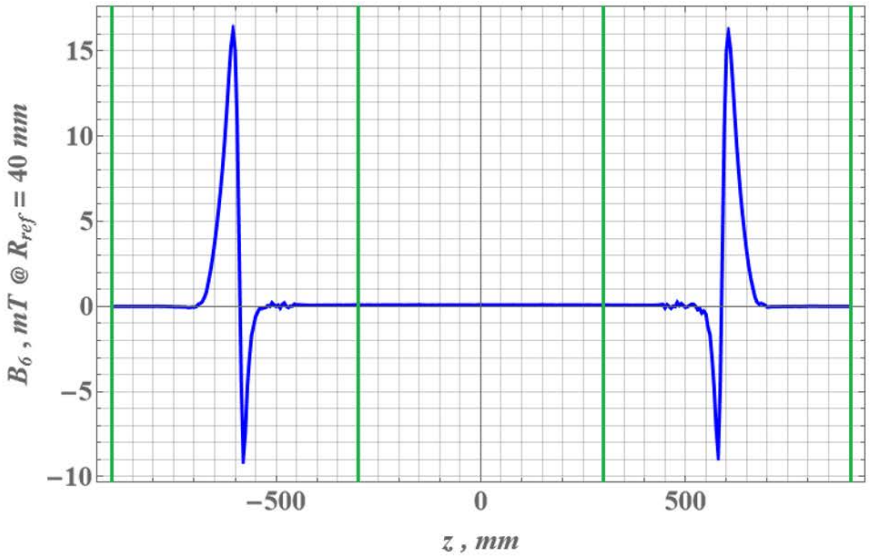
Green vertical line shows position of the gap between PCBs outside the quadrupole magnet. **Missing integral fraction is well below 1 "unit".**

Quadrupole magnet multipoles coverage

The most “long-tailed” multipoles of the quadrupole magnet are A_2 and B_6:



Local A_2 in the quadrupole @ 10.5 kA



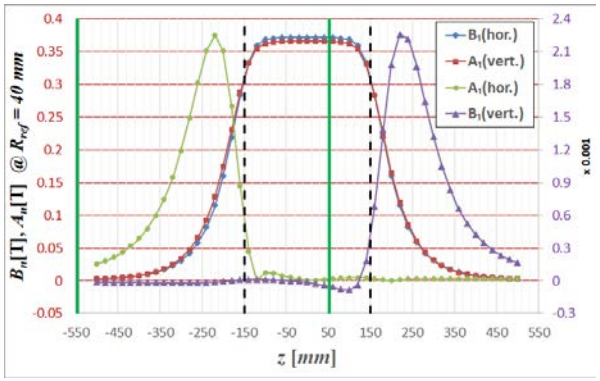
Local B_6 in the quadrupole @ 10.5 kA

Green vertical line shows position of the gap between PCBs.

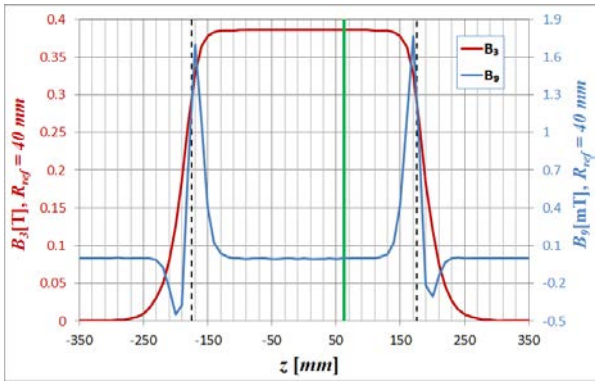
The most “long-tailed” multipoles of the quadrupole magnet are well covered. None of the gaps between PCBs fall into a region with a rapidly varying field.

Correctors‘ field coverage

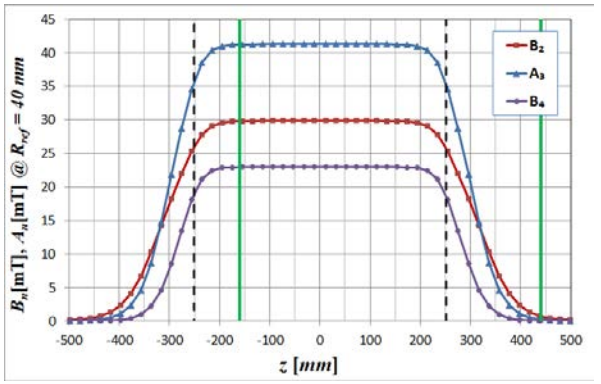
Steering magnet



Sextupole corrector



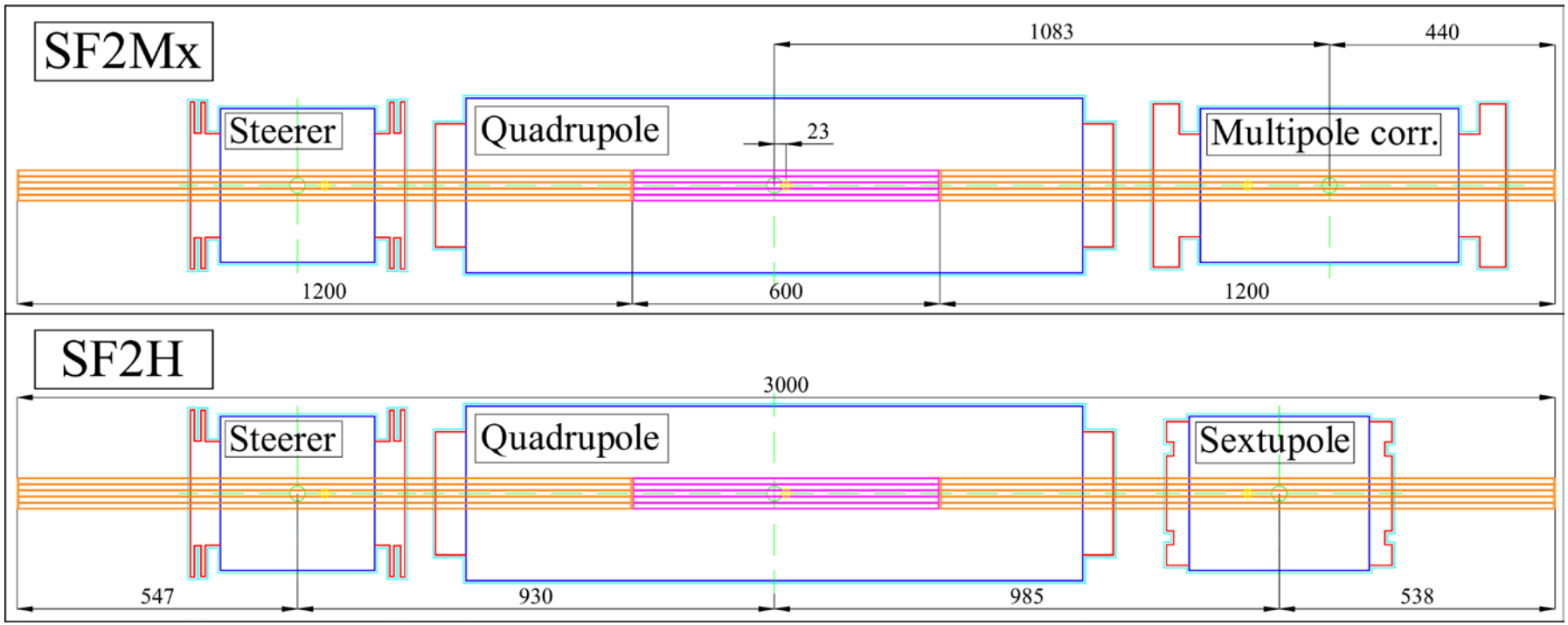
Multipole corrector



Field of the corrector magnets is well covered, provided that additional short coils are included in the PCB design to recover field in gaps.

If to merge pairs of end segments (one PCB of 1200 *mm* length instead of two PCBs of 600 *mm* length), then additional short coils in end segments will not be required. But the technological feasibility of production of 1200 *mm* long PCBs should be discussed with CERN.

Longitudinal magnetometer segmentation - version #2

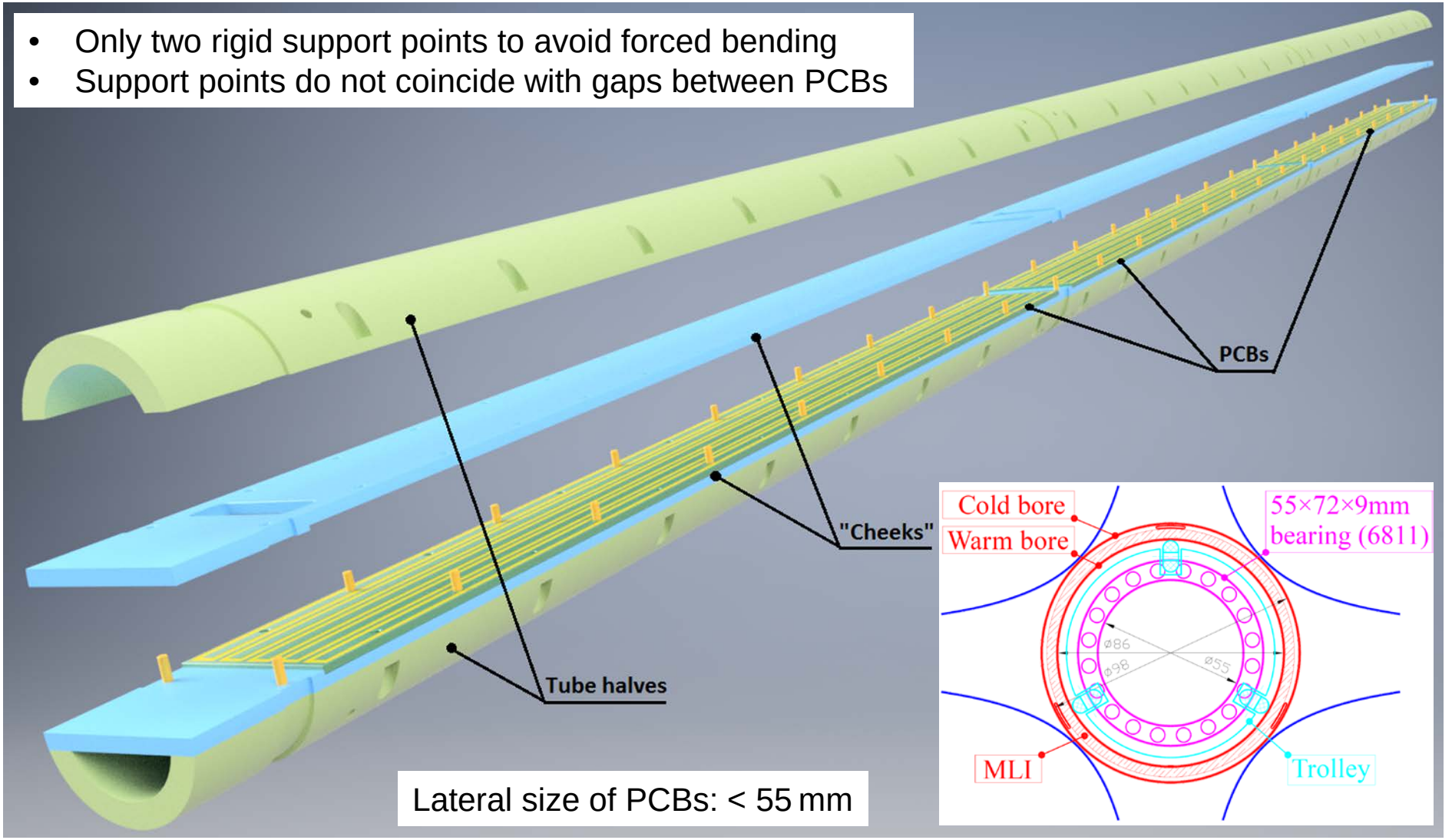


1×600 *mm* long central PCB, 2×1200 *mm* long side PCBs. Long PCBs do not require additional short coils.

The technological feasibility of producing 1200 *mm* long PCBs should be discussed with CERN

Maximum lateral dimension of PCBs

- Only two rigid support points to avoid forced bending
- Support points do not coincide with gaps between PCBs

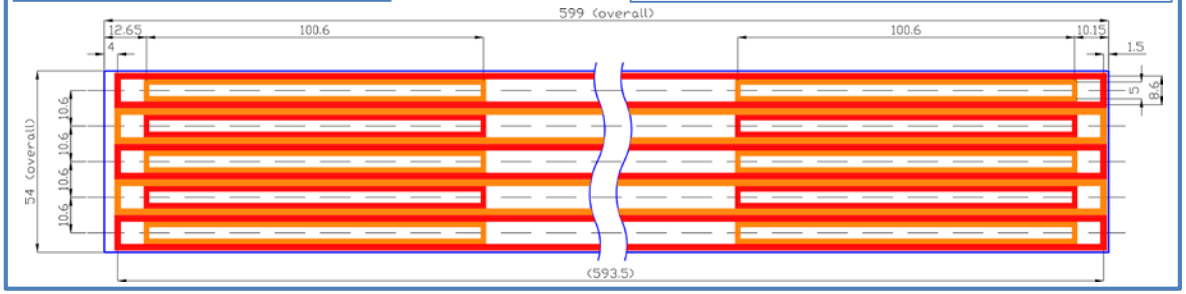


Lateral size of PCBs: < 55 mm

Preliminary PCBs design & measurement sequence

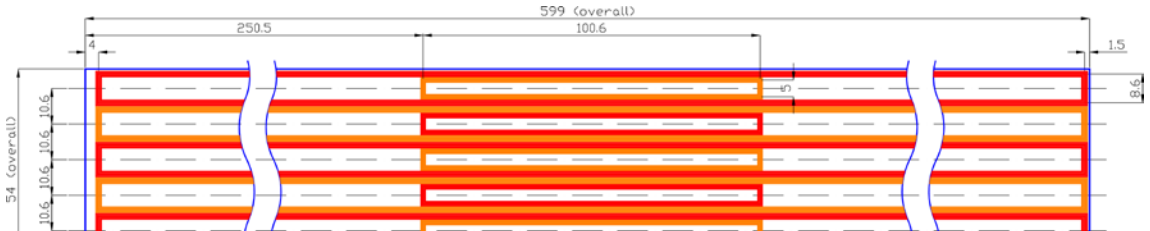
5-PCB version

same PCB in all positions

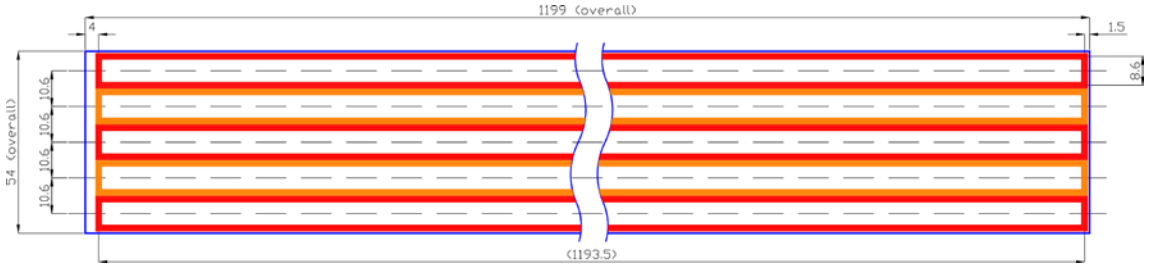


3-PCB version

central PCB



side PCBs



20 layer PCB, track pitch 150 *µm*.
Main coils: 13 turns per layer.
Short coils: 11 turns per layer.
Coils dimensions in the drafts are given for the middle turn.

Min. # of measurement channels:
5-PCB: 16+1 ch.; 3-PCB: 7+1 ch.

Measurement sequence:
rotating coil DC at injection plateau (~5 *s*); step-wise AC from the injection plateau to the max. (~5 *s* ×64 *poz.* = 320 *s*); add DC measurement results to the AC.

To estimate the statistical error, measurements should be repeated ~10 times → total measurement time **~1 hour per QU**.

Conclusion & Discussion

- With the proposed 5-PCB magnetometer layout with identical 600 *mm* PCBs, field of a quadrupole unit of any type can be well covered, provided that additional short coils are included in the PCB design (they are needed to restore the field in the gaps).
- 3-PCB magnetometer layout can be considered: 600 *mm* long PCB at center and 1200 *mm* PCBs at ends. Then the additional short coils aren't required in the long PCBs, and the number of measurement channels can be substantially reduced. But the technological feasibility of production of 1200 *mm* long PCBs should be discussed with CERN.
- Transverse PCB size can be specified only after the anti-cryostat is designed and the bearings are chosen for the magnetometer. Preliminary, maximal PCB transverse size is < 55 *mm*.

Conclusion & Discussion (cont.)

- The assessment of the maximum transverse size of PCBs is made with an optimistic assumption that the cold bore of the anti-cryostat is a smooth 1 *mm* thick cylindrical tube lying directly on the magnet poles. Highly likely, in a real design it will be necessary to introduce stiffening ribs on the outer surface of the tube, as was done for the existing vacuum chamber. **Why not use a one-to-one vacuum chamber design for the anti-cryostat cold bore?**
- For a multi-head rotating magnetometer, the maximum PCB lateral dimension is limited by bearings, which cannot be placed in gaps between the PCBs. This limitation does not apply to a single head scanning magnetometer, where the bearings may be mounted behind the PCB ends. The only drawback of a single head magnetometer is the multiple increase in measurement time. Depending on the QU type, measurements take three to five times longer than with a multi-head magnetometer. In all other respects, a scanning magnetometer is better. **Is a fivefold increase in measurement time acceptable?**