Status of the B-field studies for the pEDM experiment

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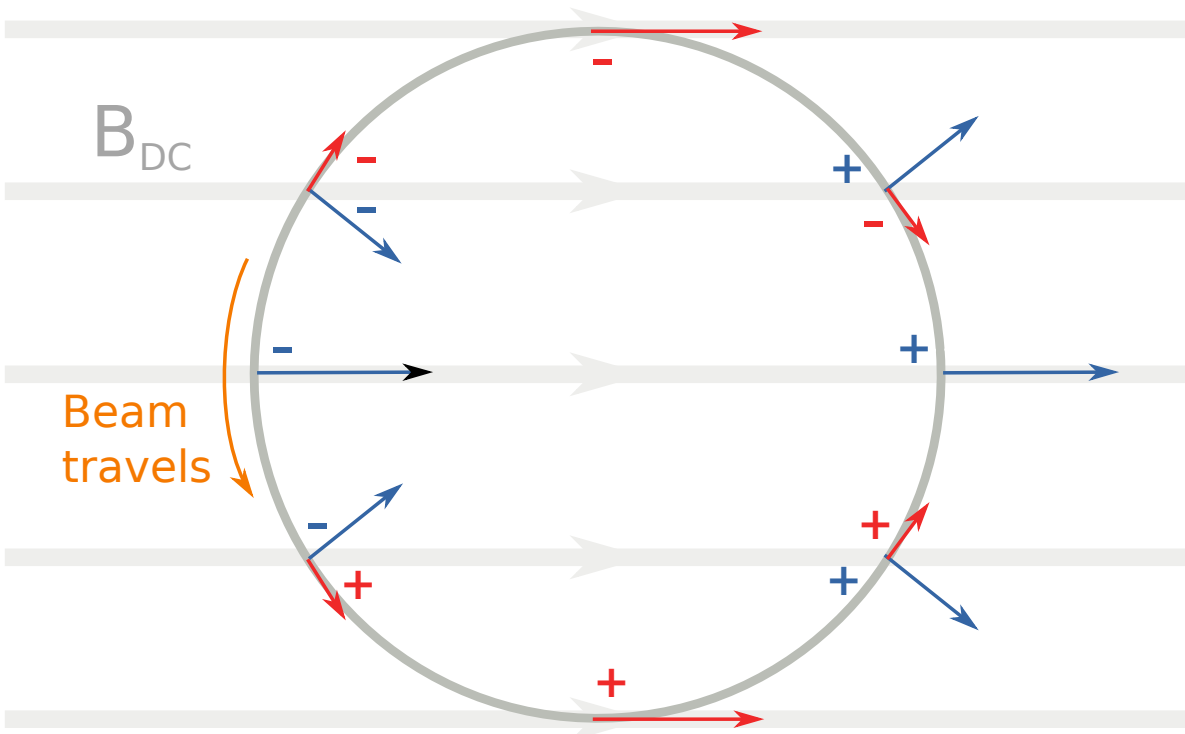
Overview of the SQUID-based BPM measurement

- We are mostly interested in radial DC B-field. The effect of others are either negligible or easier to control. Vertical DC B-field is the second important, but several orders of magnitude more flexible.
- SQUIDs are insensitive to DC. But our SQUID-based BPMs will measure the average (DC) B-field along the ring and will not be sensitive to spatial variations.
- The measurements will be insensitive to small pickup misalignments.
- Distortions originating from E-field cause negligible effects
- We assume equal intensities to 10 ppm of counter rotating beams.

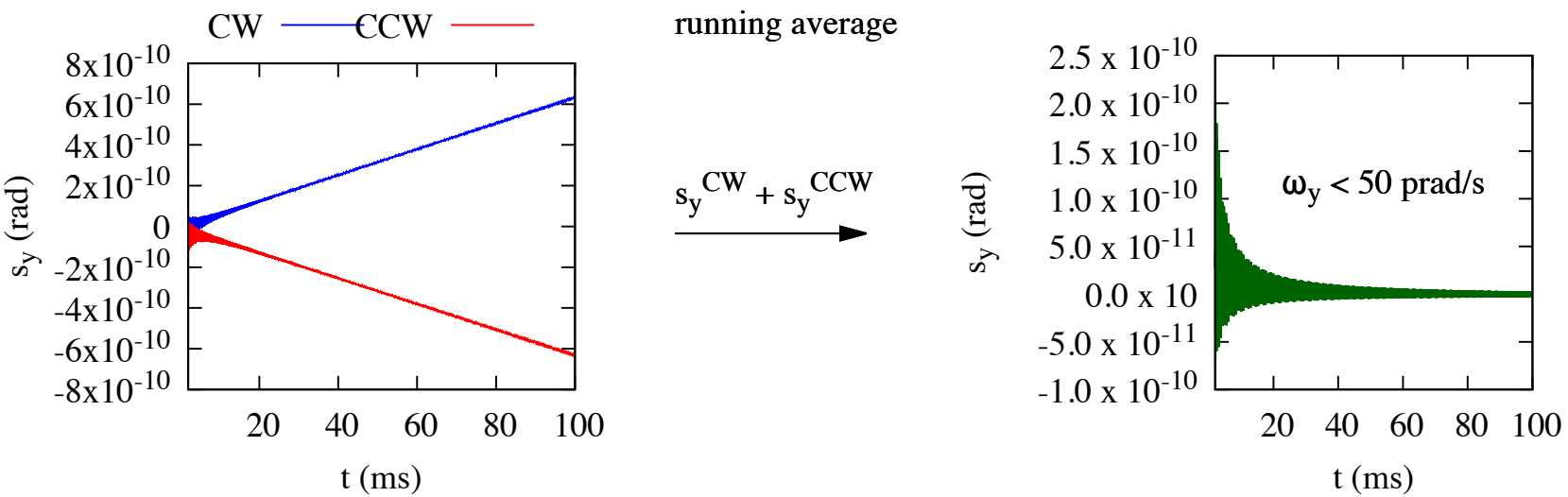
Alternating fields - 1

- DC field in lab coordinate is alternating in particle's rest frame
- Therefore the DC field along the ring is dominated by the residual field of shielding.
- Earth's field turns out to be AC in the rest frame.
- Distortions along the ring have negligible contribution to the DC field.



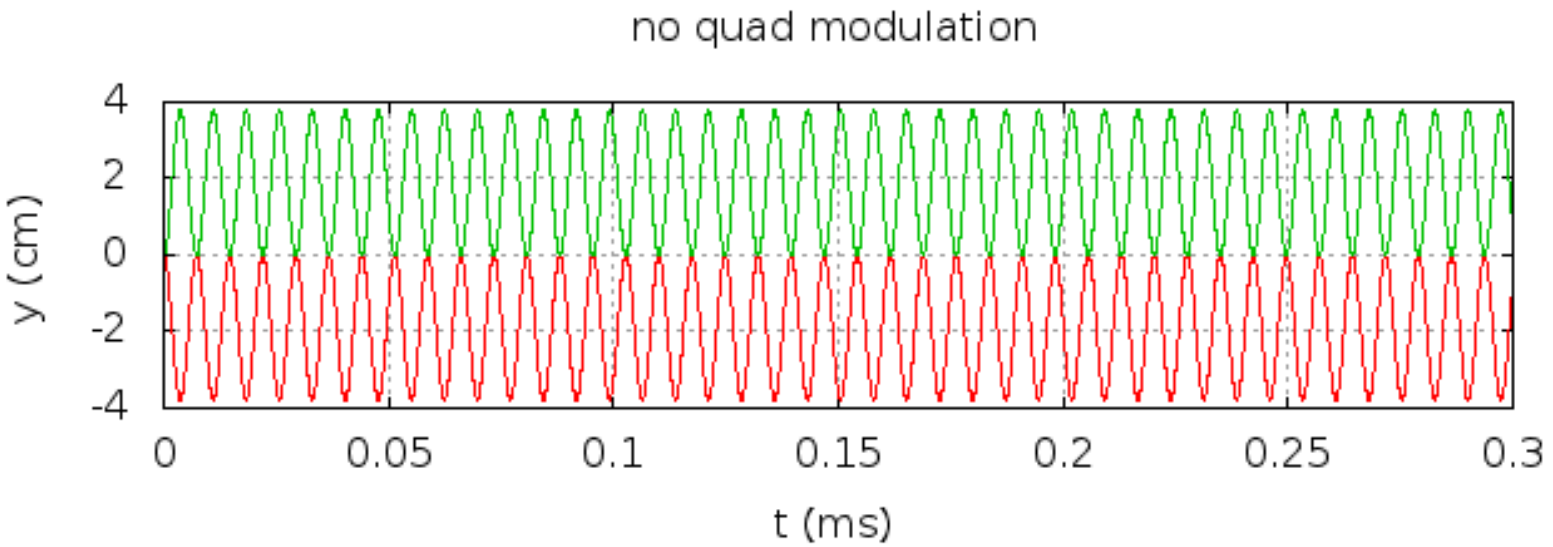
Alternating field - 2

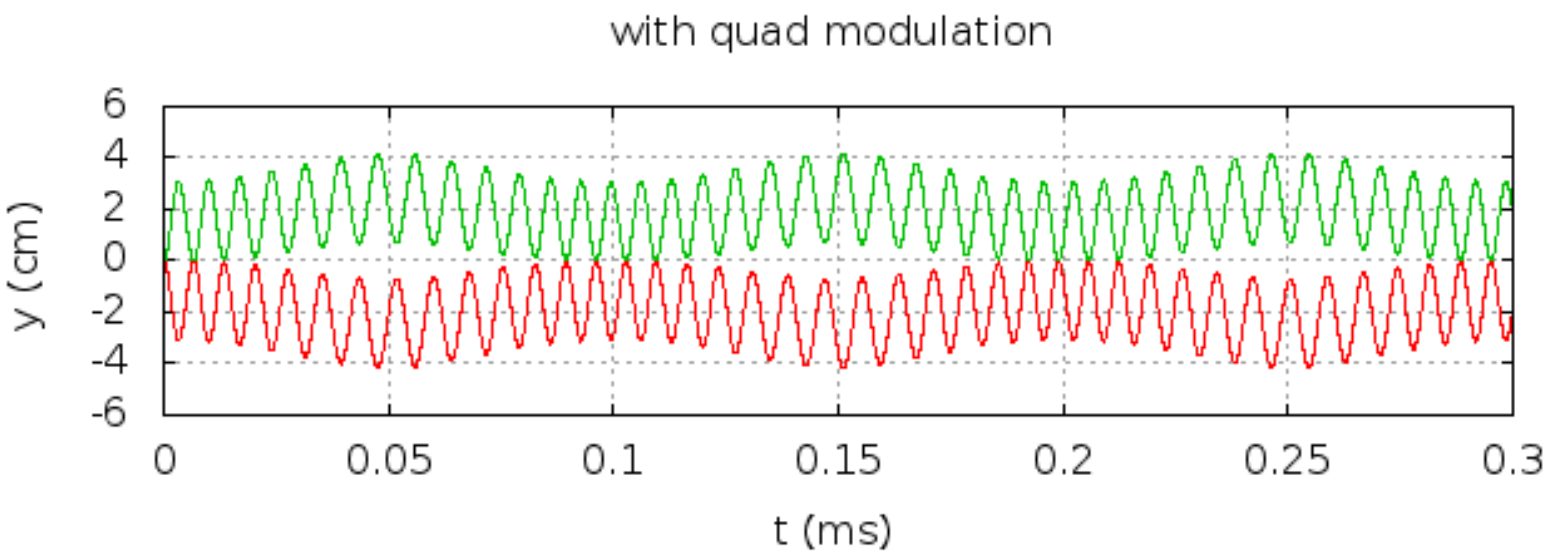
- It is trivial to achieve ≈ 1 nT residual field with two-layer shielding.
- Our previous work shows that all kinds of alternating field configurations (geometric phase) cancels or averages out if the residual field is 1-10 nT level.



Beam modulation

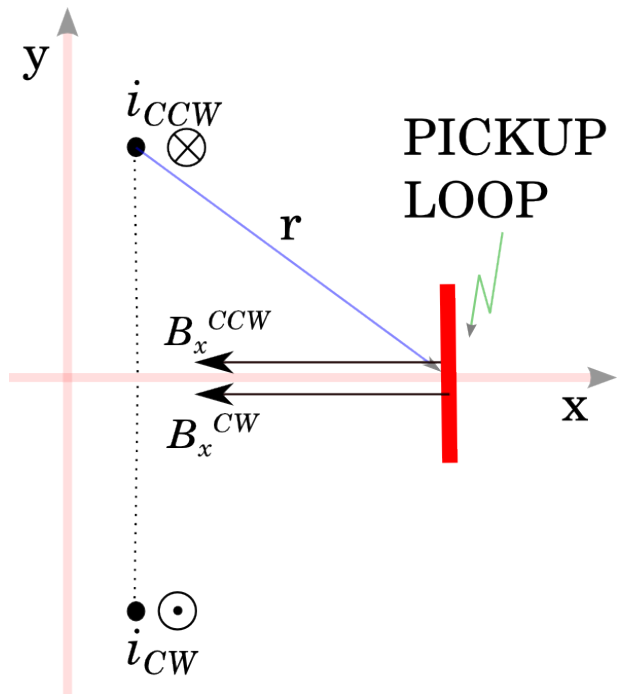
$B_r = 1$ nT





SQUIDs and beam motion

- SQUIDs will measure the beam separation.
- 10 aT radial B-field splits them by 10 pm.
- Beam separation and the pickup misalignment will be much smaller than distance from pickup loop.
- If the two beams together move up or down a bit, this does not affect the BPM measurement
- E-field has no effect on beam separation, if not at the modulation frequency
- E-field originated motions will be fixed by means of button BPMs. Then it will be harmless for SQUID measurements.

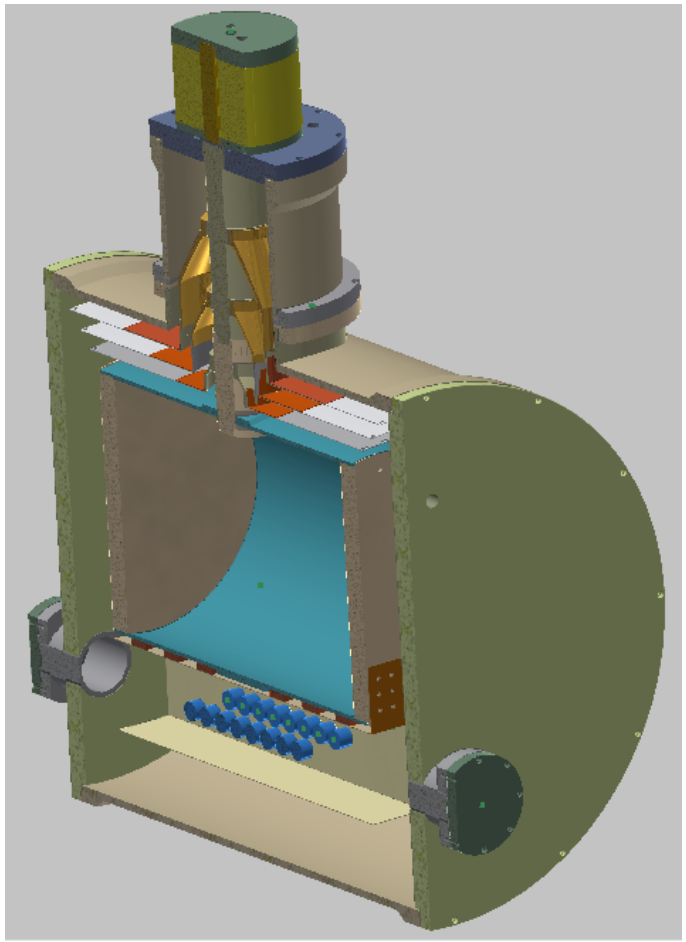


Intensity of the counter-rotating beams

- We will measure the difference of the intensity using a beam current monitor.
- We will have a scraper (let's say above the beams)
- If one beam has more intensity, we will apply B-field to move it up and get scraped

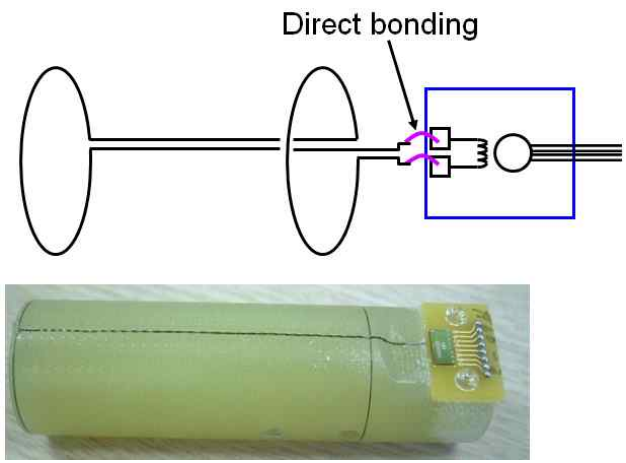
Design of the BPMs

- Custom-made dewar, SQUIDs and electronics
- Array of SQUIDs aligned along the beam
- The frame of the SQUIDs will be possible to actuate (current design does not have it)
- The length is around 50 cm
- Expected to require L-He refill every 2 weeks

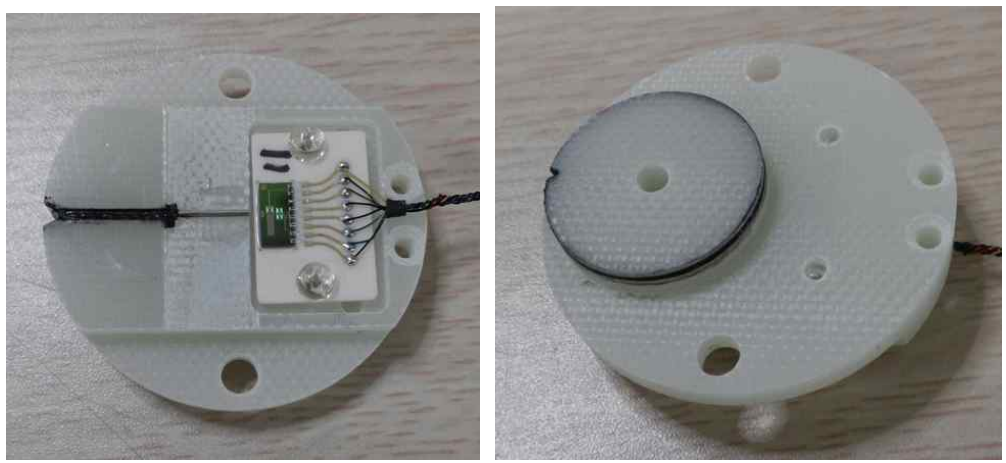


SQUID Hardware - SQUIDs

Axial gradiometer



Planar gradiometer



SQUID Hardware - Signal acquisition

Optical receiver

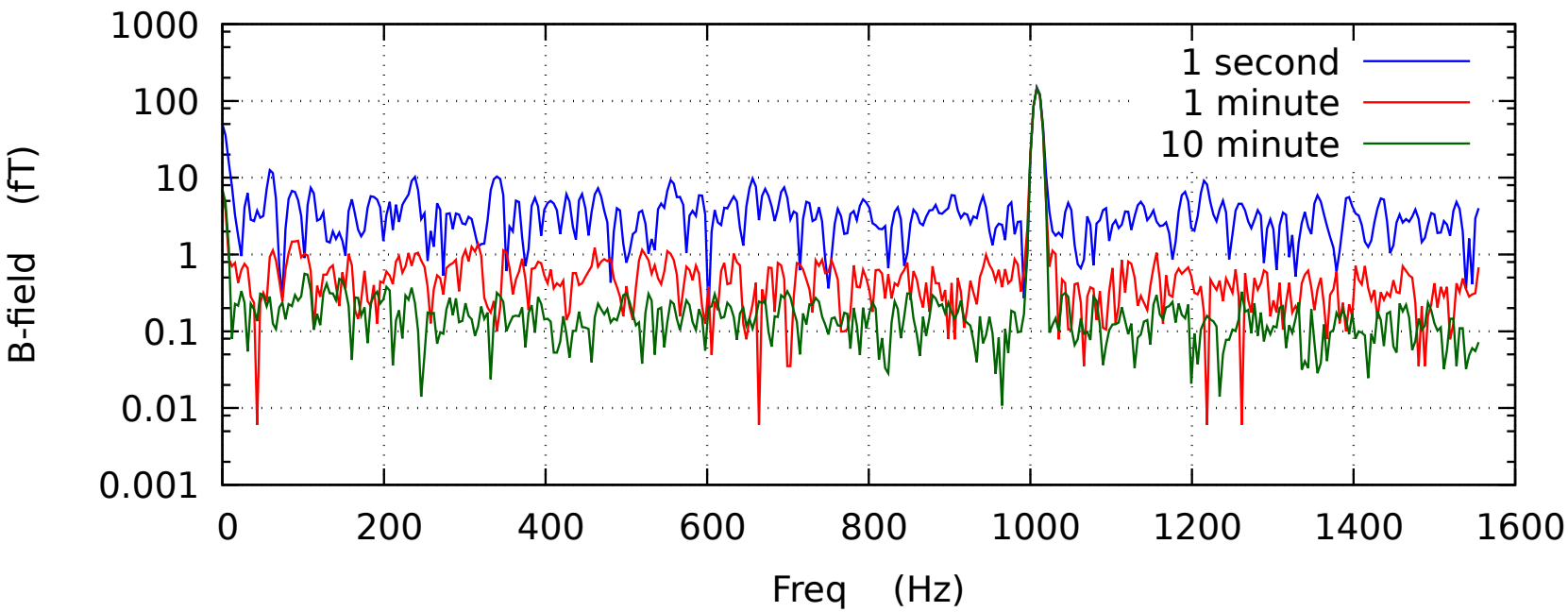
Optical transmitter

16 channel readout

Signal acquisition PCB

Preliminary setup

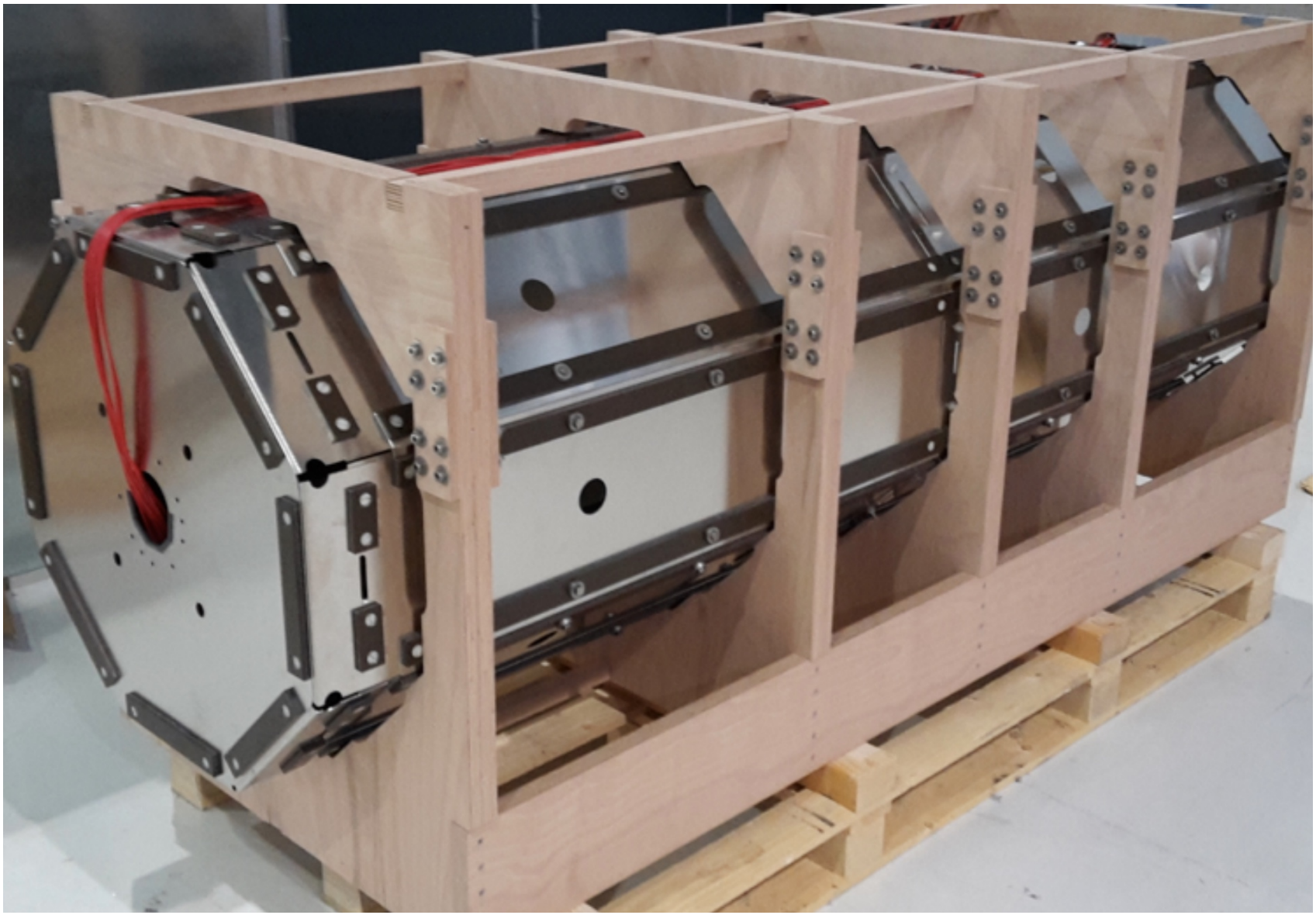
- We currently have a preliminary setup to play with
- 3 fT/$\sqrt{\text{Hz}}$ sensitivity
- Currently we are making wire tests.
- We will use the same electronics in the next design



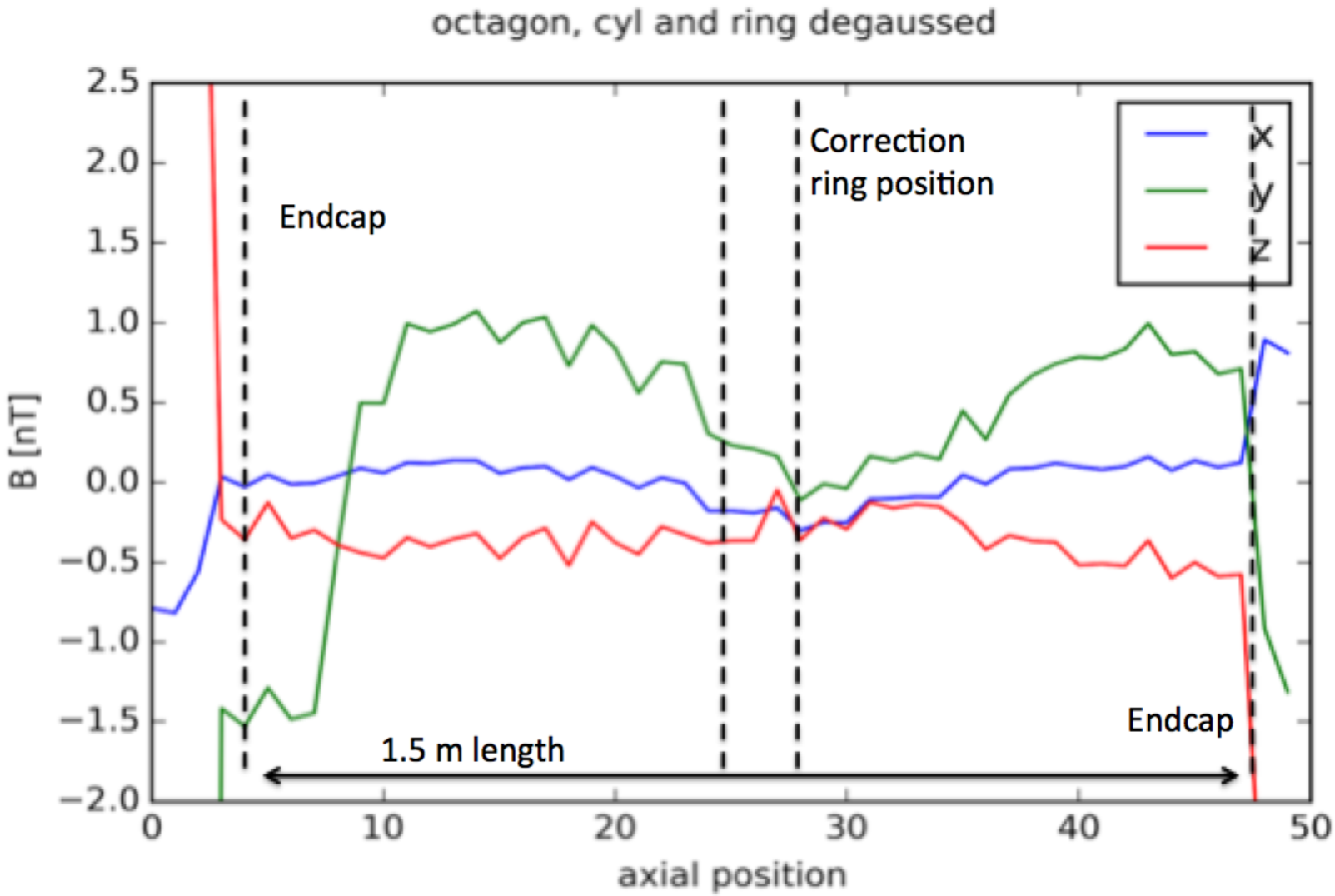
Prototype

- The new design is to be delivered by summer
- Will be 2fT$\sqrt{\text{Hz}}$
- We will make wire tests in Korea
- Would be good to test here at COSY

Shielding - Prototype



Shielding - Preliminary measurements



MSR - 1

Dimensions are around 3m.

MSR - 2

- 3-layer permalloy and 1-layer aluminium
- SF $\approx$ 1000, depending on frequency
- Residual field $\approx$ 1 nT after degaussing
- We make the SQUID measurements inside it

Upgrading MSR

- We aim to upgrade it to get the best residual field in Korea: $\approx 100pT$
- We recently got a field mapping system to monitor field inside
- Currently designing an additional inner layer.

Summary

- SQUID-based BPMs measure the DC radial B-field by means of beam dynamics
- The motion of the particle picks the average field very efficiently
- We can avoid most of the systematics thanks to the counter-rotating beam design and modulation of the focusing.
- We already got a preliminary setup to work with.
- The prototype will be delivered by summer
- We would like make some tests in COSY
- We achieved < 1 nT with two-layer magnetic shielding