

Stray Magnetic Field Measurements for CLIC

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Acknowledgements:

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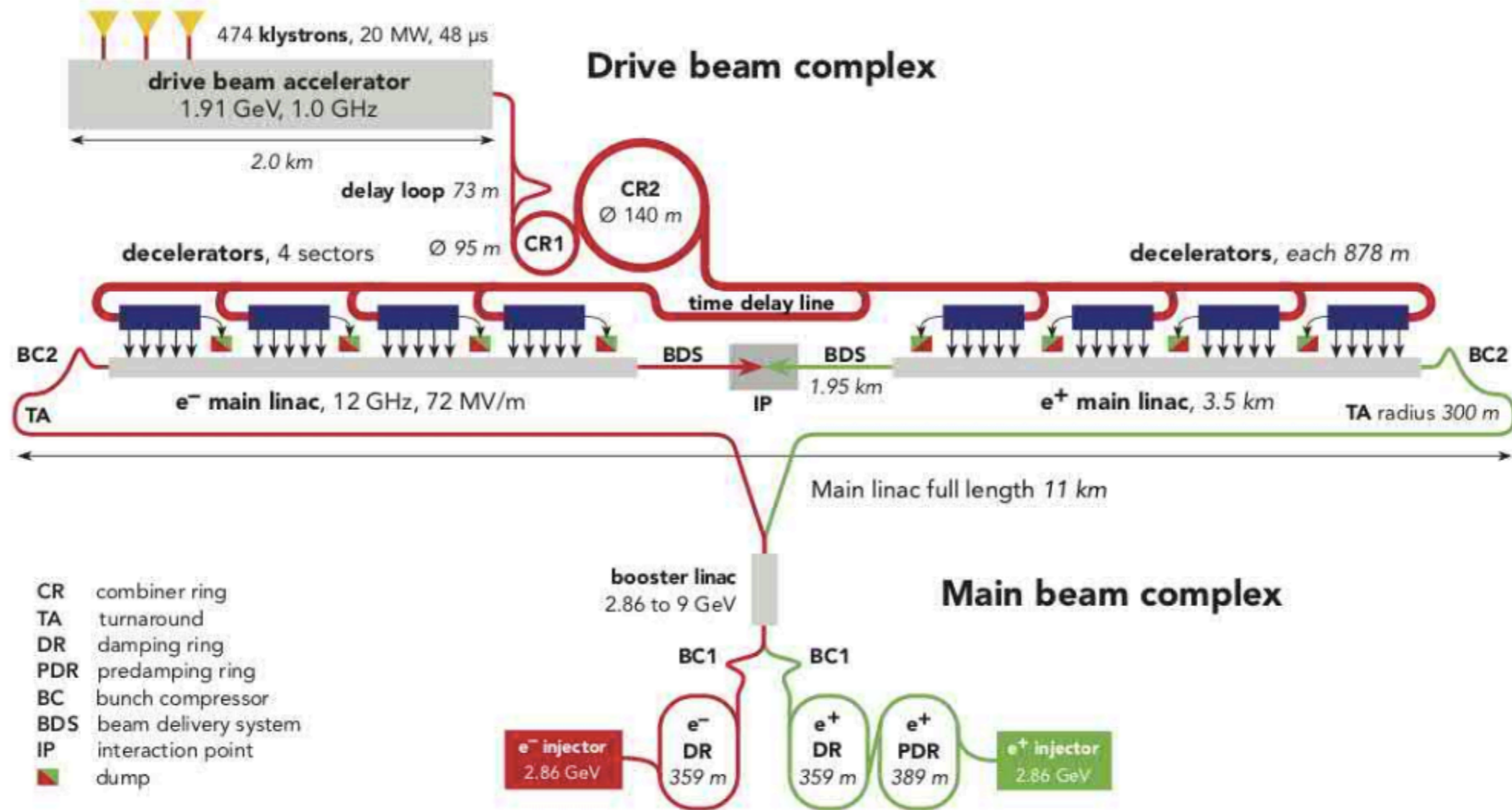
Contents

- Stray Magnetic Fields
- 380 GeV CLIC Tolerances
- Sources:
 - Natural: geomagnetic storms, lightning.
 - Environmental: electrical grid, other accelerators.
 - Technical: CLIC elements.
- Outlook

Stray Magnetic Fields

- External (stray) magnetic fields kick the beam.
- Leads to luminosity loss via:
 - A beam-beam offset at the IP.
 - Emittance growth.
- Only dynamic stray fields matter.
 - Static fields are removed by tuning.

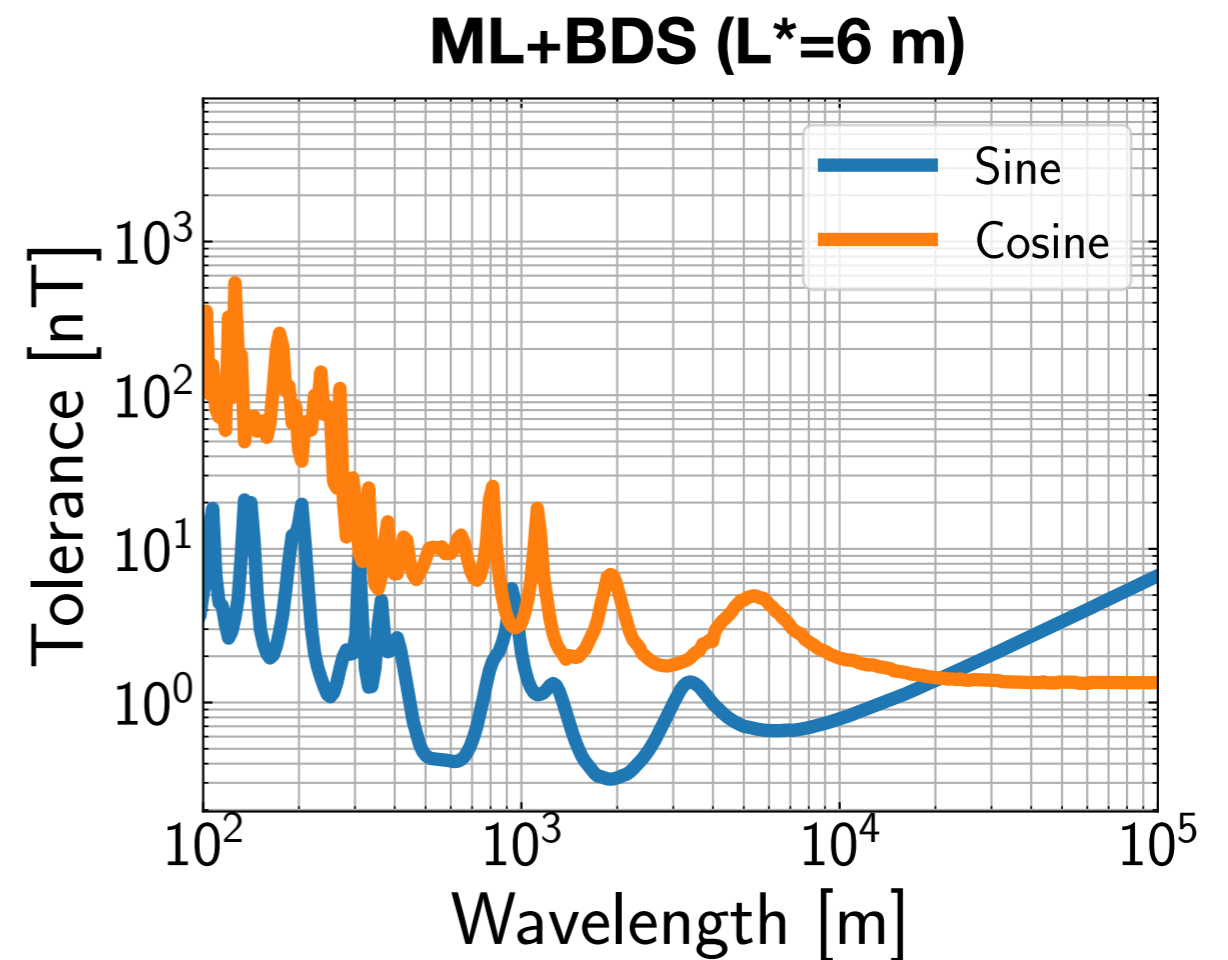
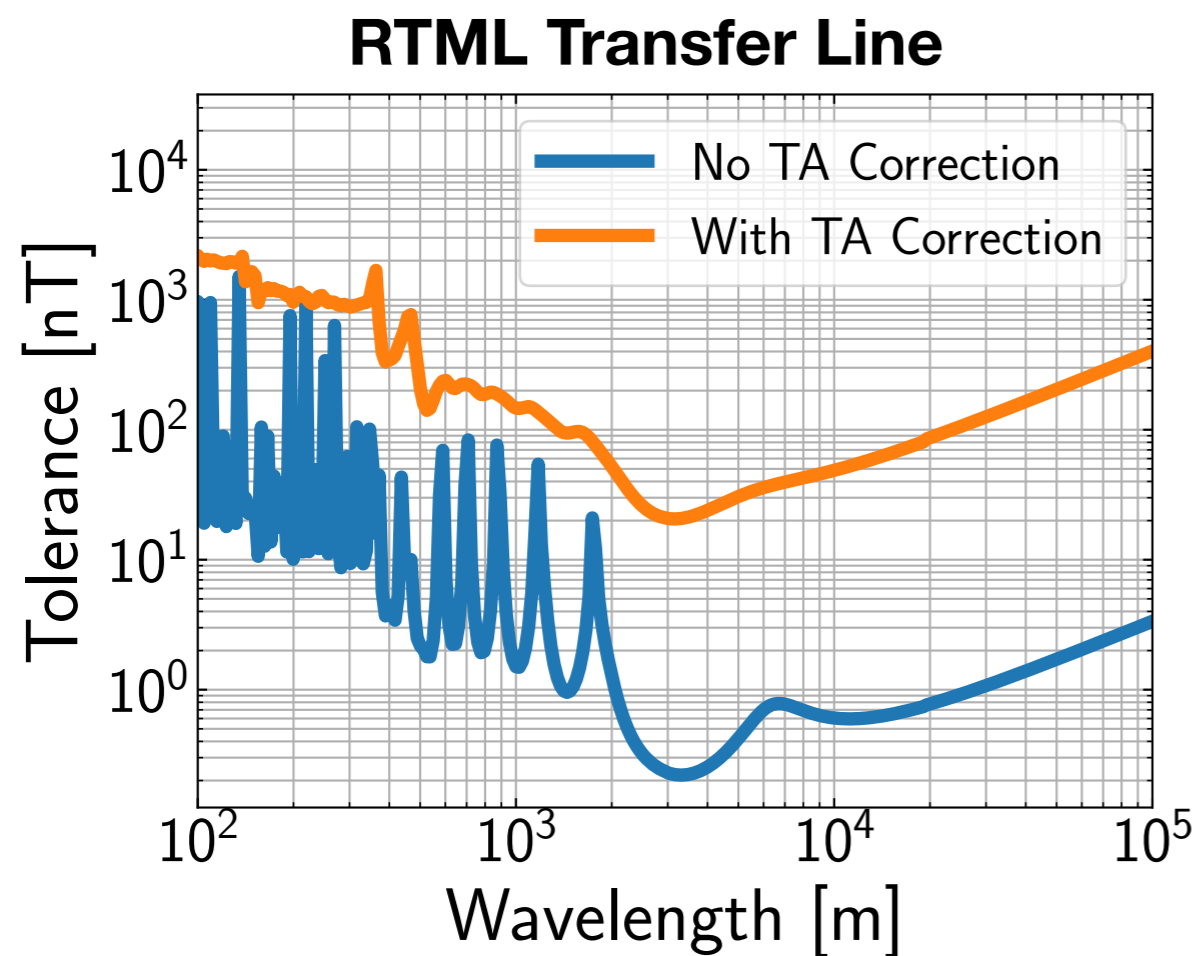
CLIC 380 GeV



- Targets $\sigma_x=150$ nm, $\sigma_y=3$ nm.
- Leads to a sensitivity to stray fields.

CLIC 380 GeV

- Sinusoidal stray field tolerances for 2% luminosity loss:



- nT level tolerances emerge.

Stray Field Sources

- Natural sources:
 - Stray fields from non-man-made objects.
- Stray fields from man-made objects:
 - Environmental sources:
 - Equipment in the vicinity of CLIC, but not an element of CLIC.
 - Technical sources:
 - Elements of CLIC.

Natural Sources

- E.g. geomagnetic storms, lightning, etc.
 - B. Heilig, et al, “Natural sources of geomagnetic field variations”. <http://cds.cern.ch/record/2643499>.
- Typically have low frequencies (< 1 Hz).
 - Mitigated effectively with a beam-based feedback.
- Natural sources above 1 Hz:

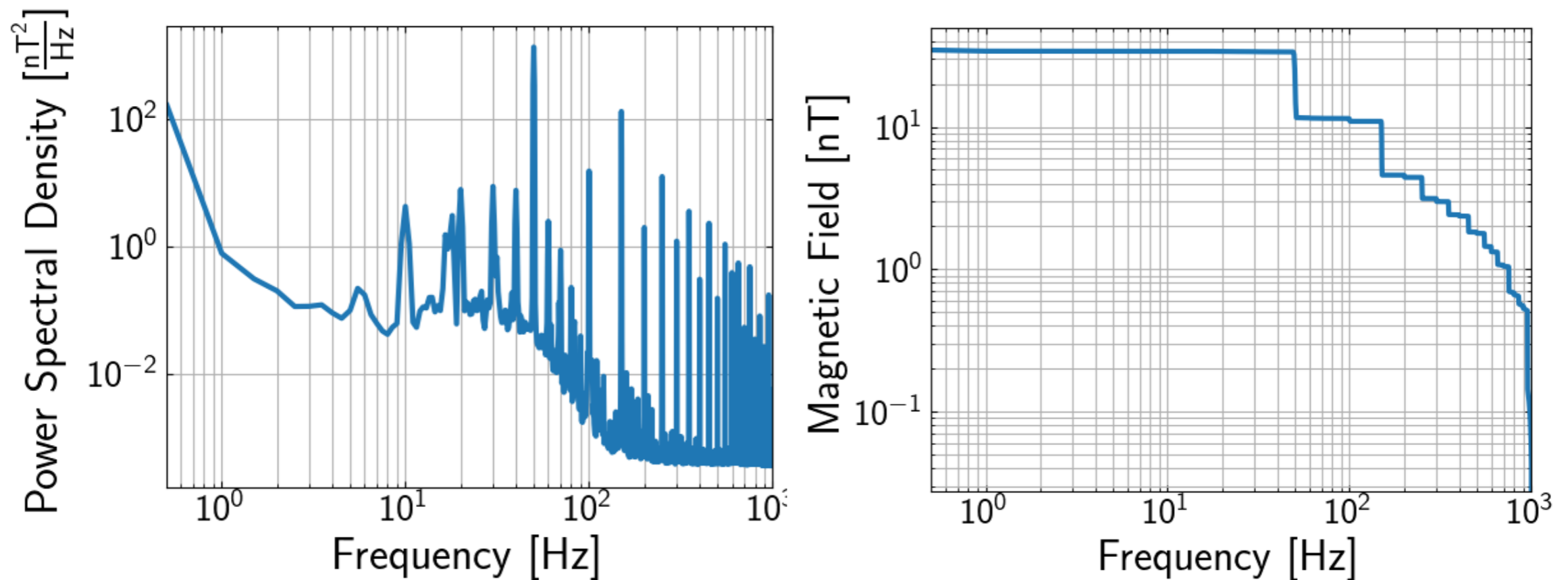
Phenomenon	Typical Amplitude	Frequency Range	Typical Occurrence
Schumann Resonances	3 pT	Hz	Continuous
Ionospheric Alfvén Resonator	1 pT	Hz	> 1 per week
Pc1 Pulsations	0.1 nT	Hz	< 1 per year
‘Regional’ Lightning (< 1000 km)	0.25 nT	Hz-MHz	Daily
‘Local’ Lightning (< 10 km)	1 nT	Hz-MHz	> 1 per month

Environmental and Technical Sources

- Environmental sources:
 - E.g. electrical grid.
 - Largest contribution in most measurements.
 - Electrical grid is at 50 Hz
 - Looks static.
- Technical sources:
 - Could have a wide frequency range, above tolerance.
 - There is an on-going campaign to characterise technical sources.

CLEAR Facility

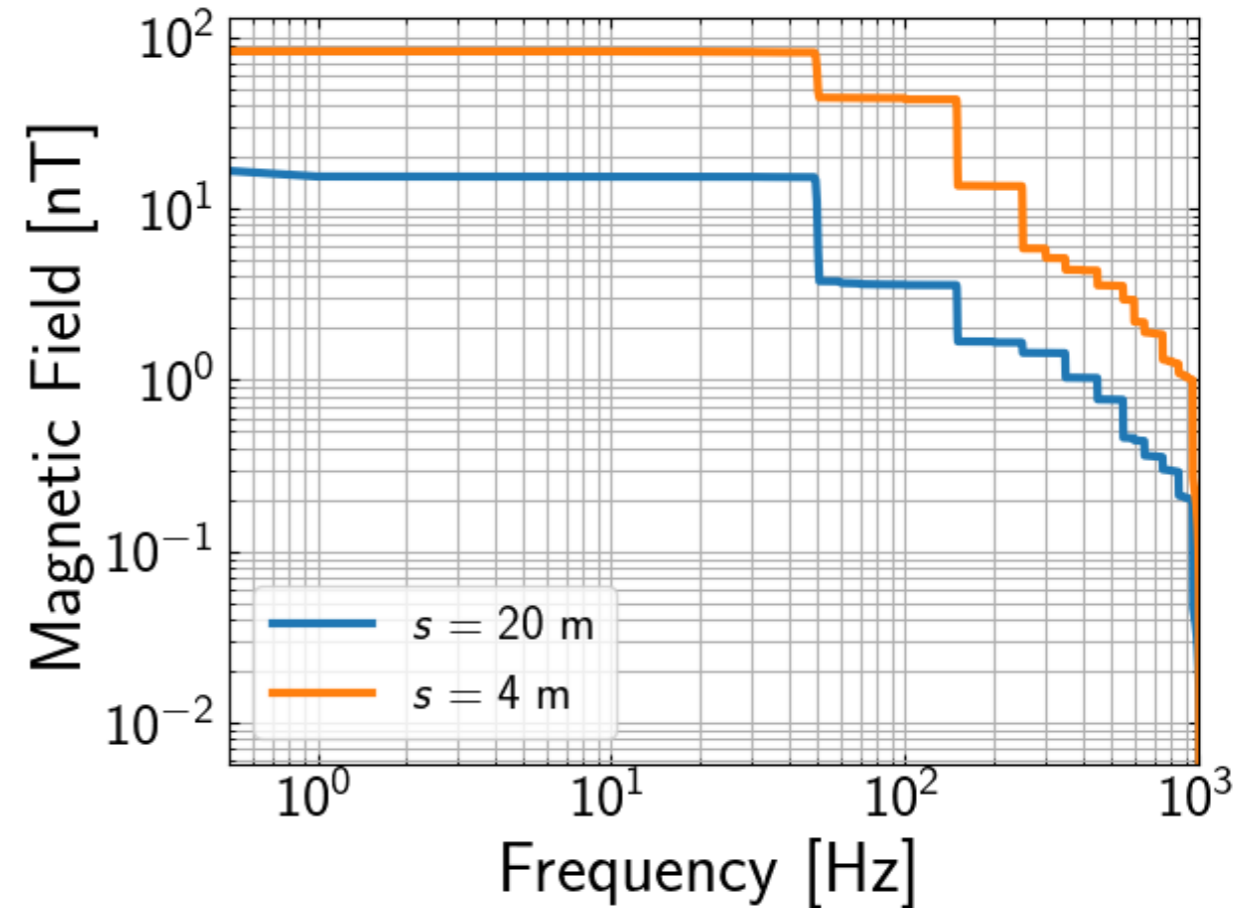
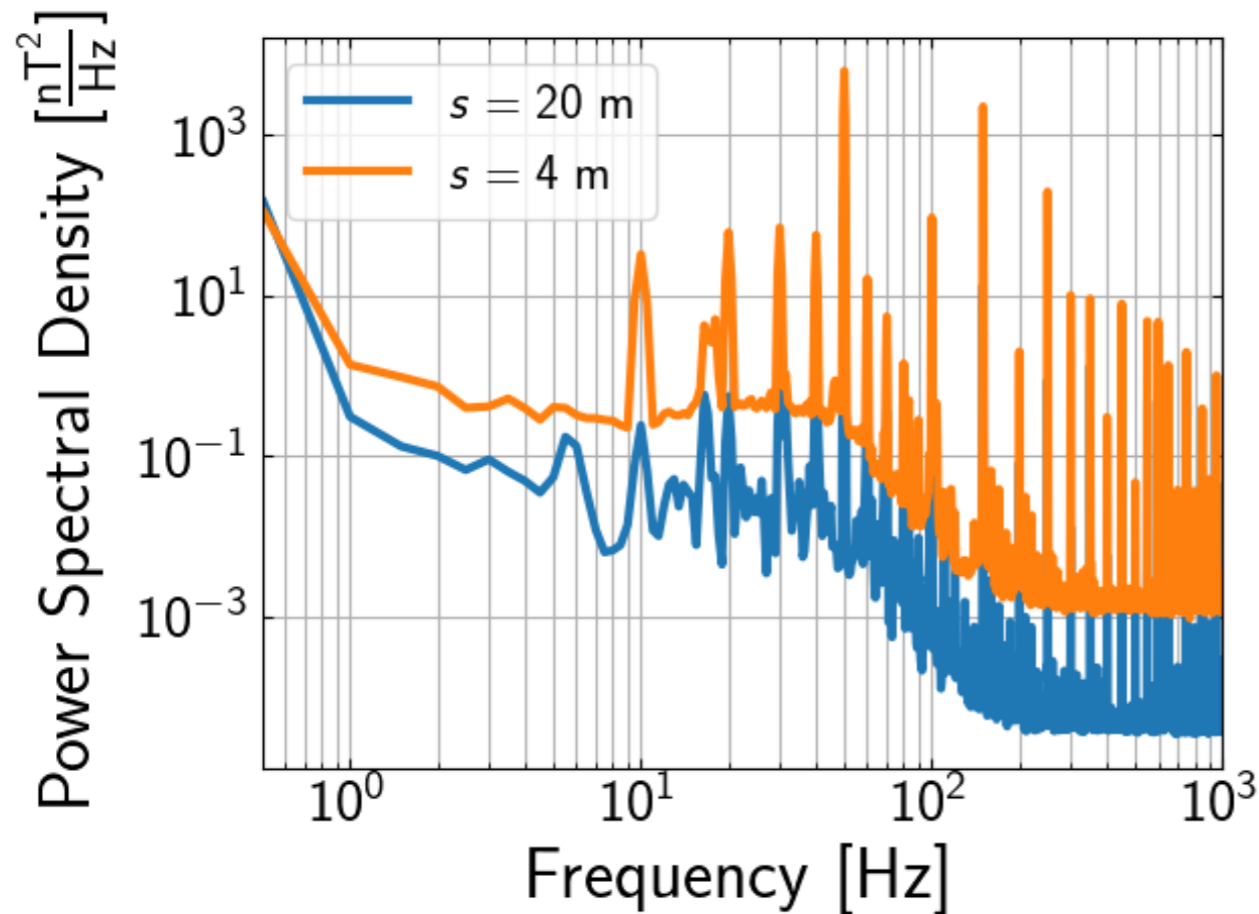
- The CLEAR facility at CERN is the closest representation of a CLIC beamline.
- Average total PSD measured along the beamline (10/12/18):



- Everything apart from RF was powered. No beam.

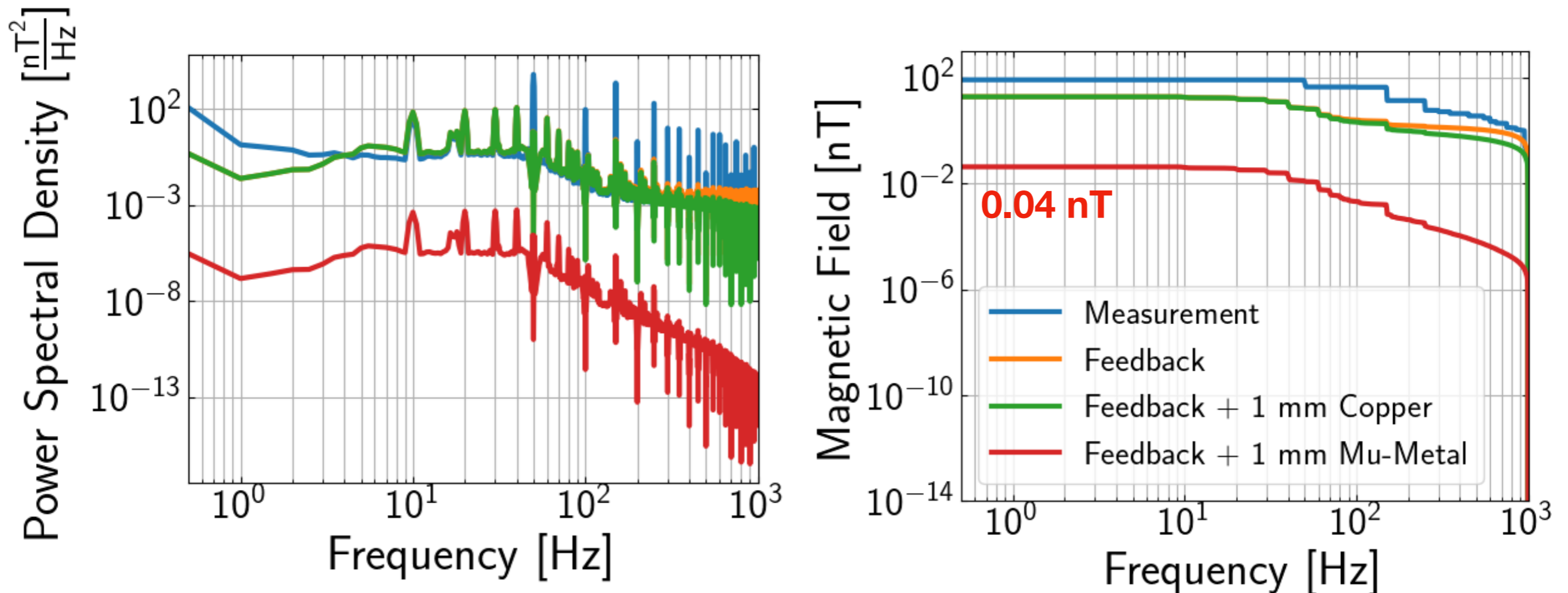
CLEAR Facility

- Smallest and largest total PSD measured:



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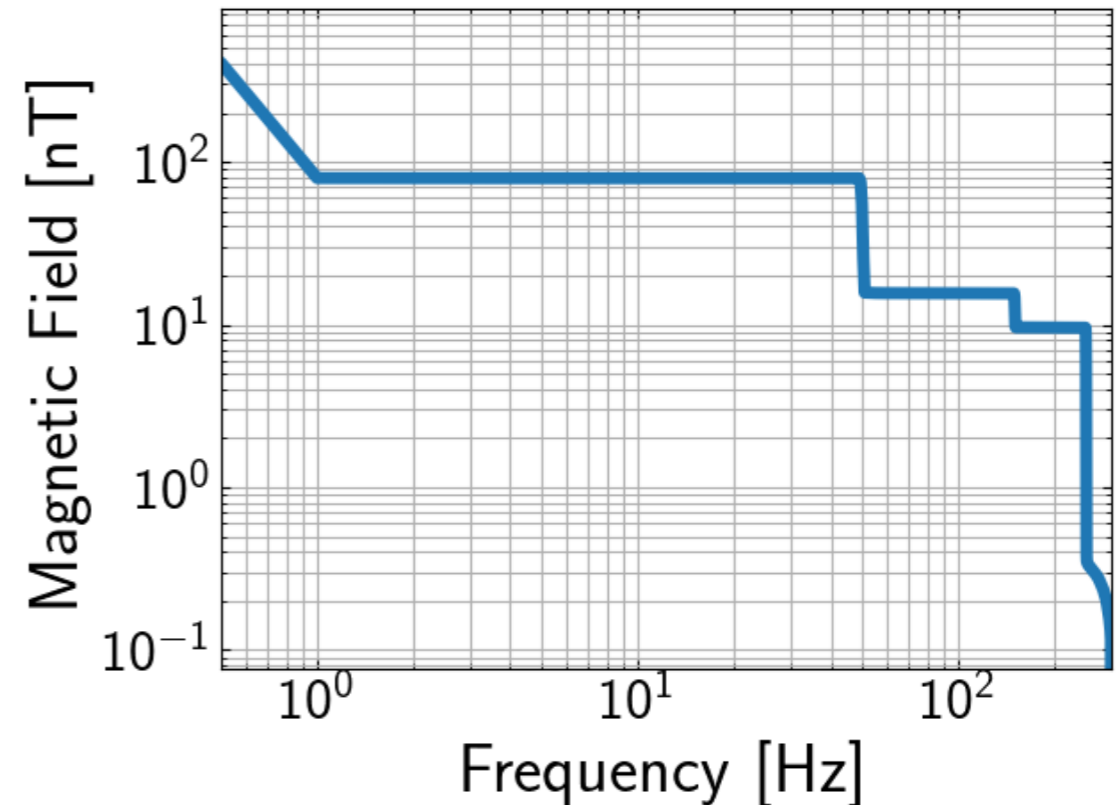
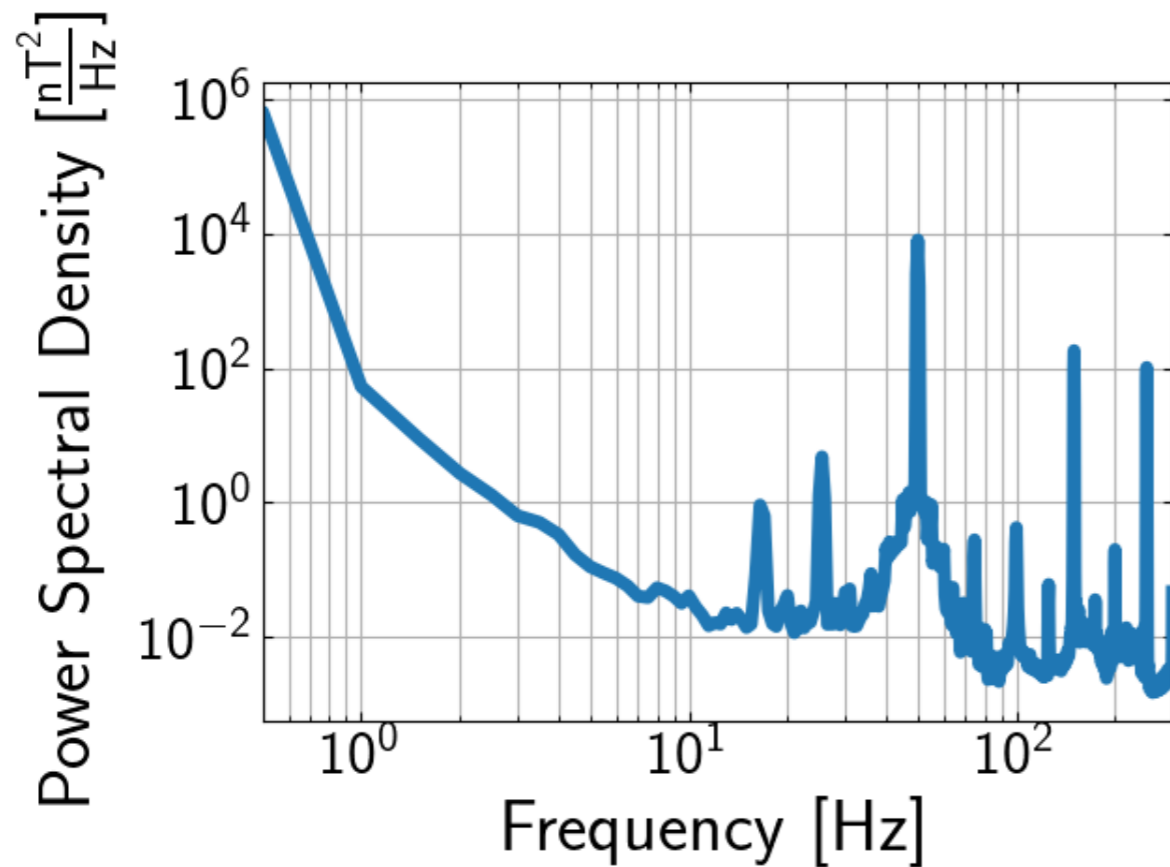
- Looking at effect of mitigation on the maximum PSD measured:



- The feedback system isn't enough alone.
- Can bring the field within tolerance with a mu-metal shield.

LHC Tunnel

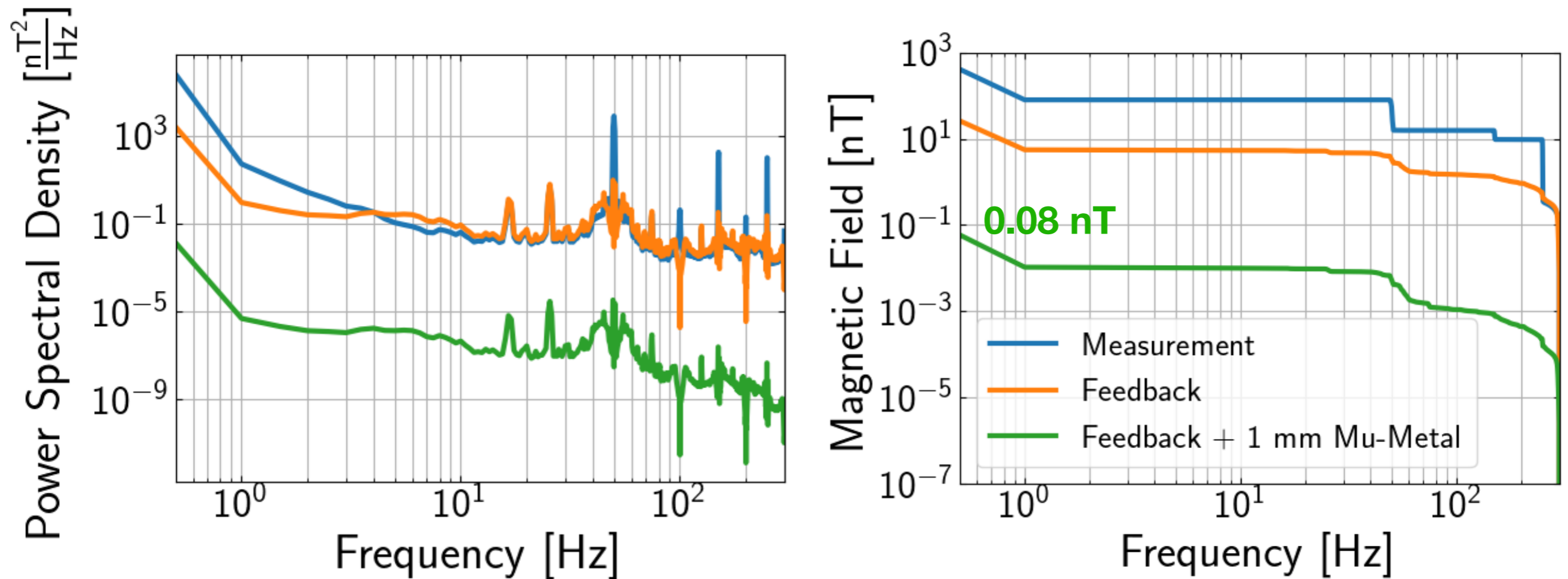
- Average background magnetic field (Point 2, 31/01/18):



- In presence of environmental and some technical sources.
 - No magnets.

LHC Tunnel

- Looking at the effect of mitigation:



- A 1 mm mu-metal shield brings field within tolerance.

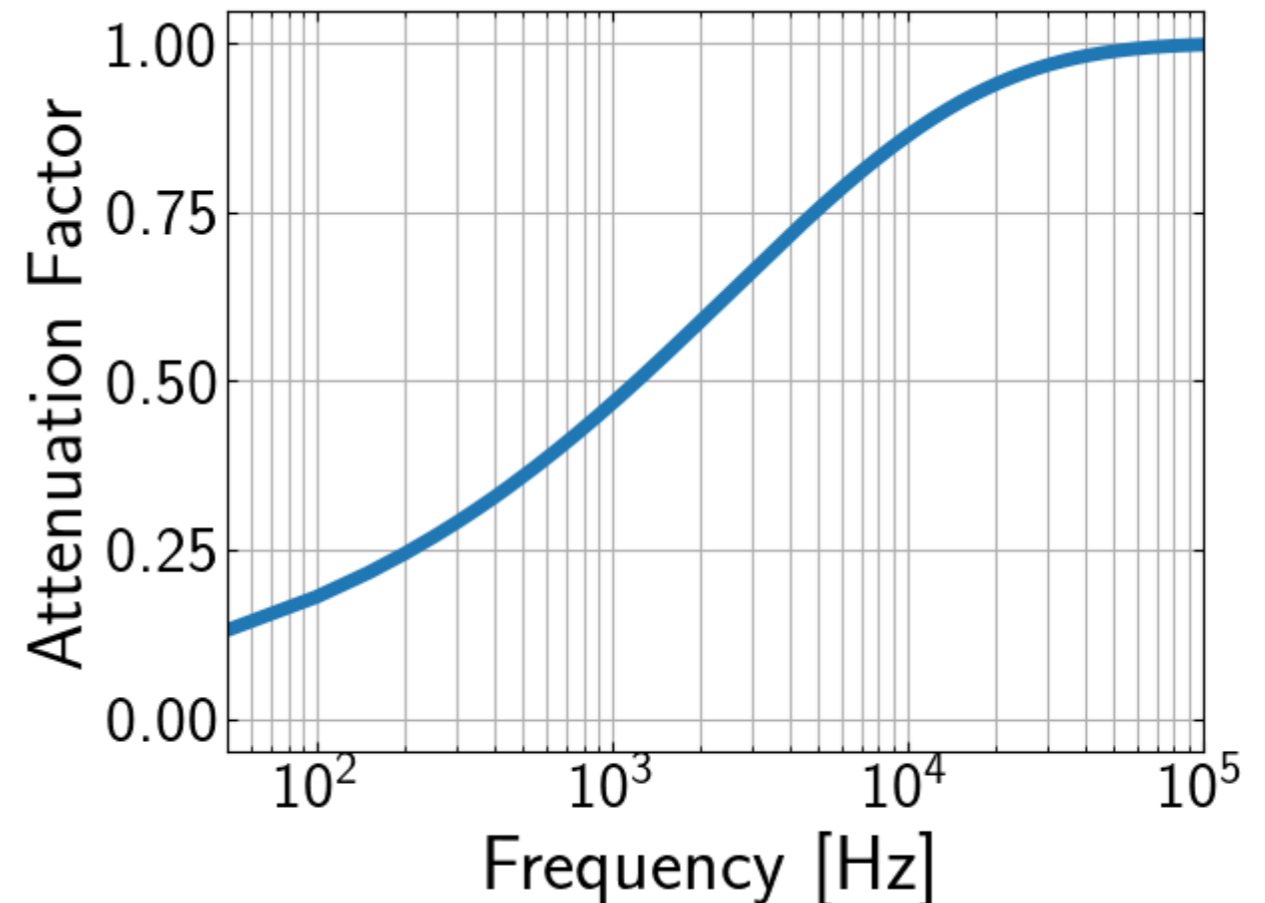
Outlook

- CLIC is sensitive to stray fields to the nT level.
- A measurement campaign is on-going to characterise technical sources in a realistic environment.
- A combination of beam-based feedback and passive shield is being considered as mitigation.

Back Up Slides

Attenuation from the Earth

- Earth conductivity is 1-50 mS/m.
 - Use 10 mS/m.
- Non-magnetic Earth:
 - Rel. permeability is 1.
- Skin depth for 50 Hz is ~710 m.
- Attenuation of 50 Hz at 100 m is 13%.



$$B(d) = B_0 \exp\left(-\frac{d}{\delta}\right) \quad \delta = \sqrt{\frac{2}{\omega\mu\sigma}}$$