CLIC Stray Magnetic Field Tolerances and Shielding Techniques

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Acknowledgements:
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Asian Linear Collider Workshop 2018
(30/05/18)

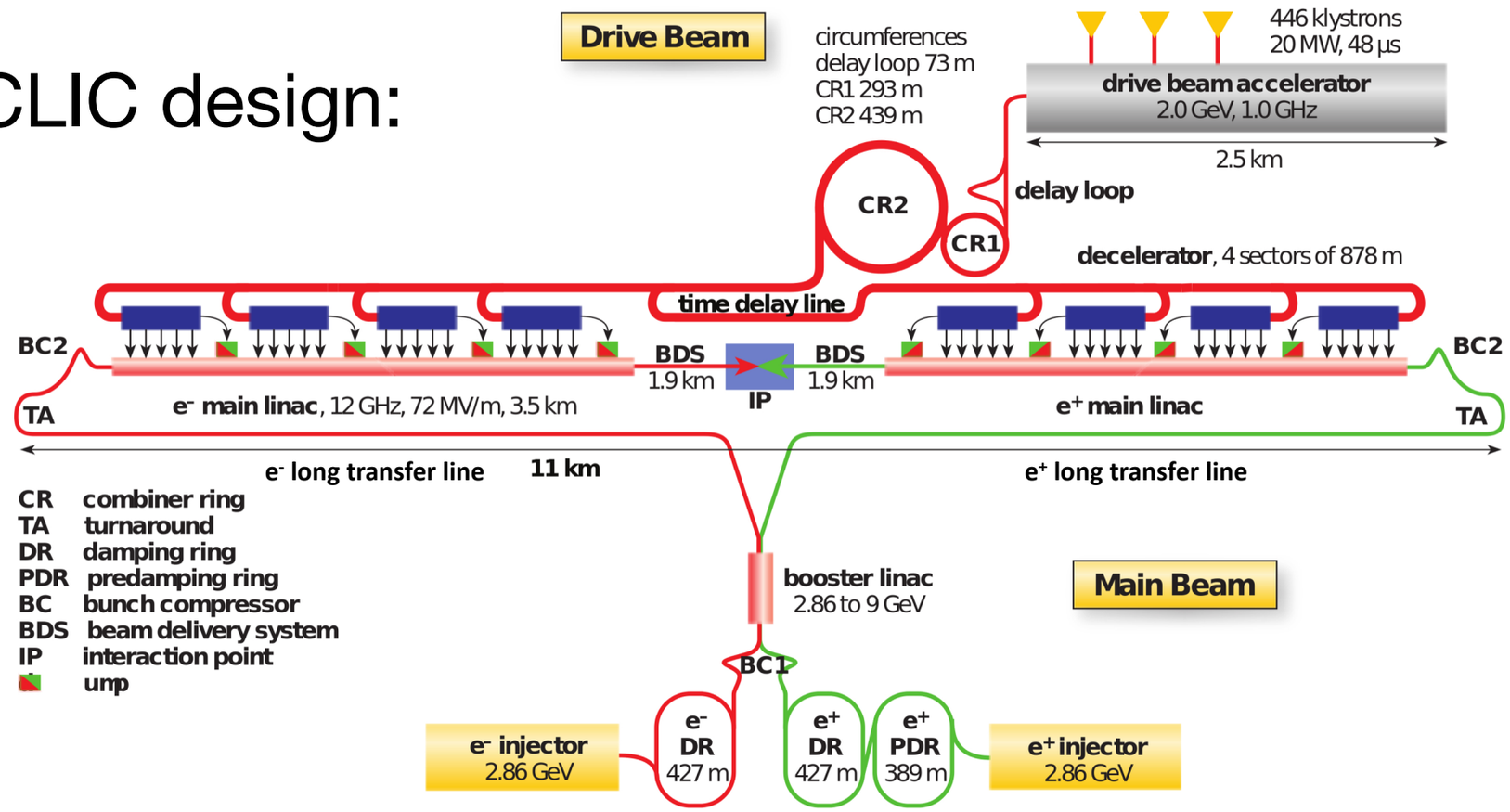
Contents

- Tolerances for the 380 GeV CLIC design
- Background magnetic field on CERN site
- Effects of mitigation
  - Beam-based feedback
  - Passive shielding
- Conclusions and Future Work

Tolerances

Tolerances

- 380 GeV CLIC design:



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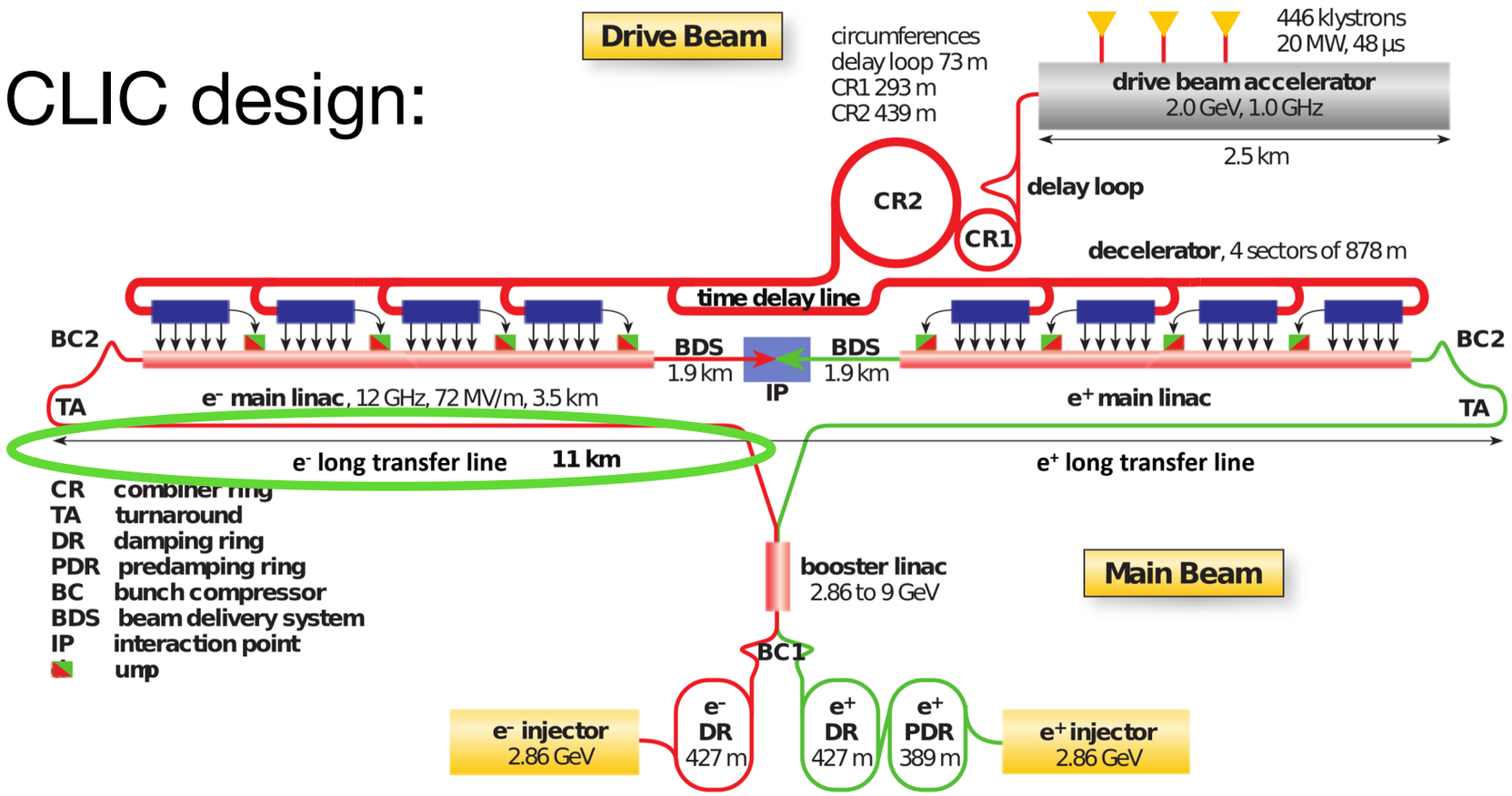

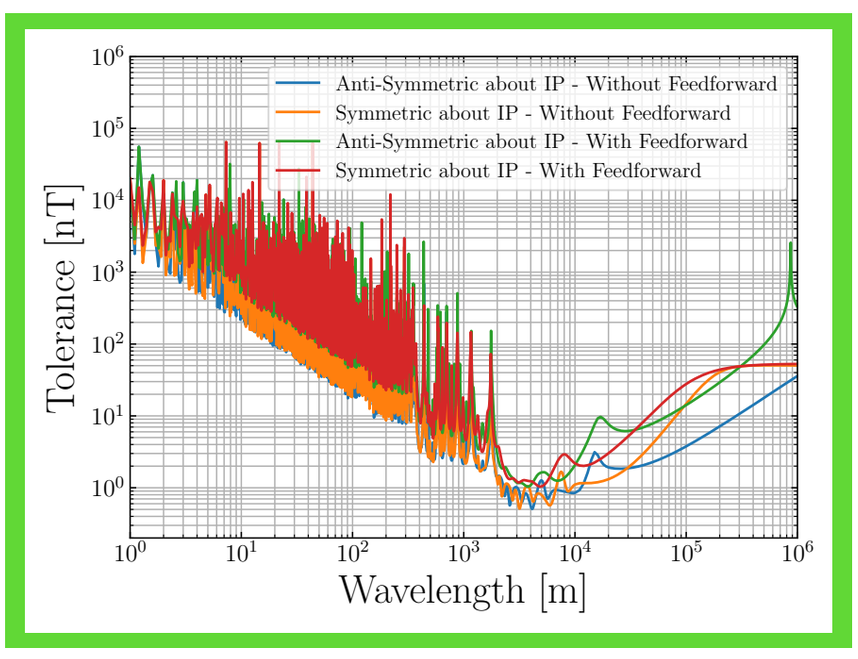

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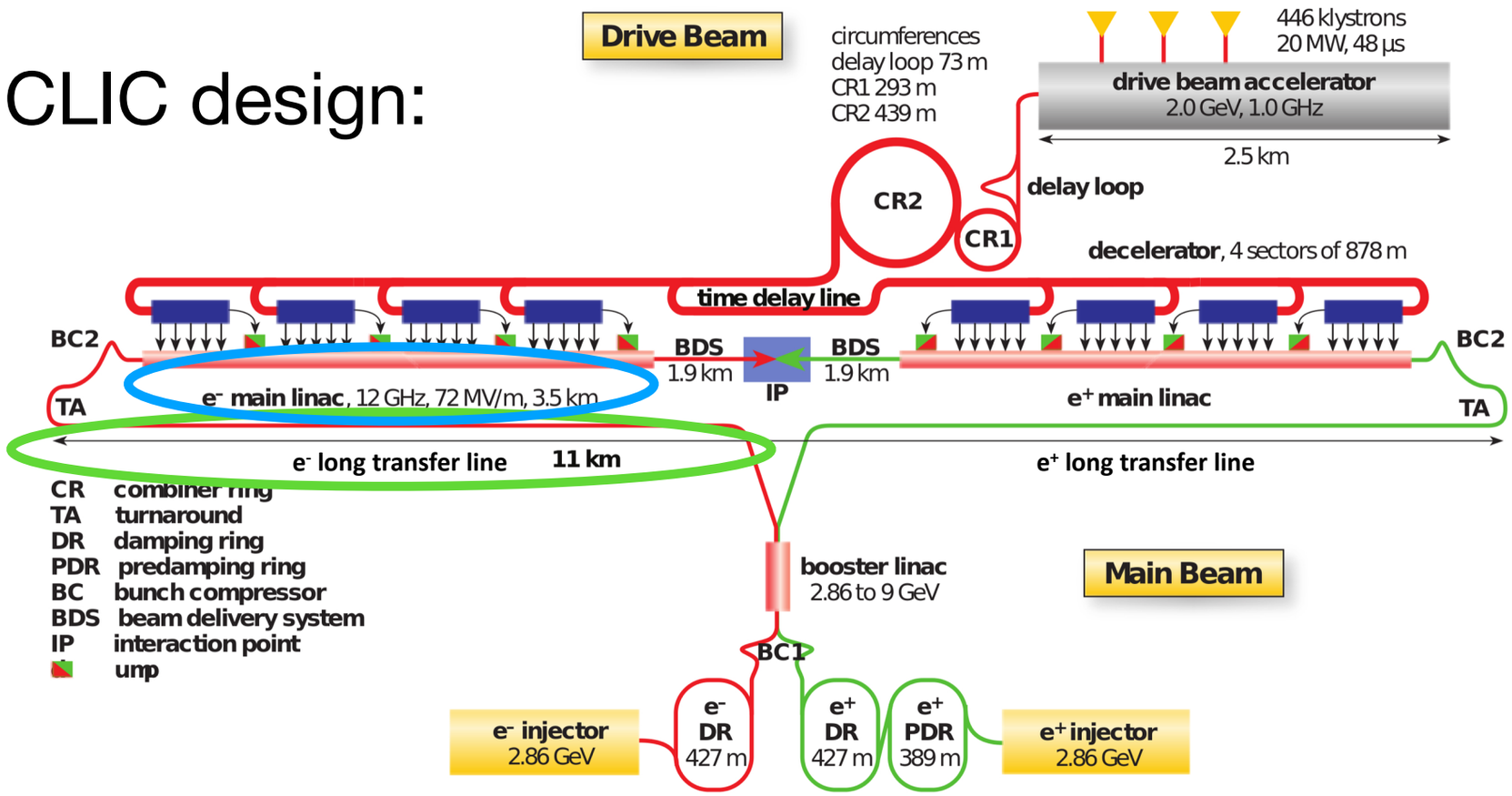

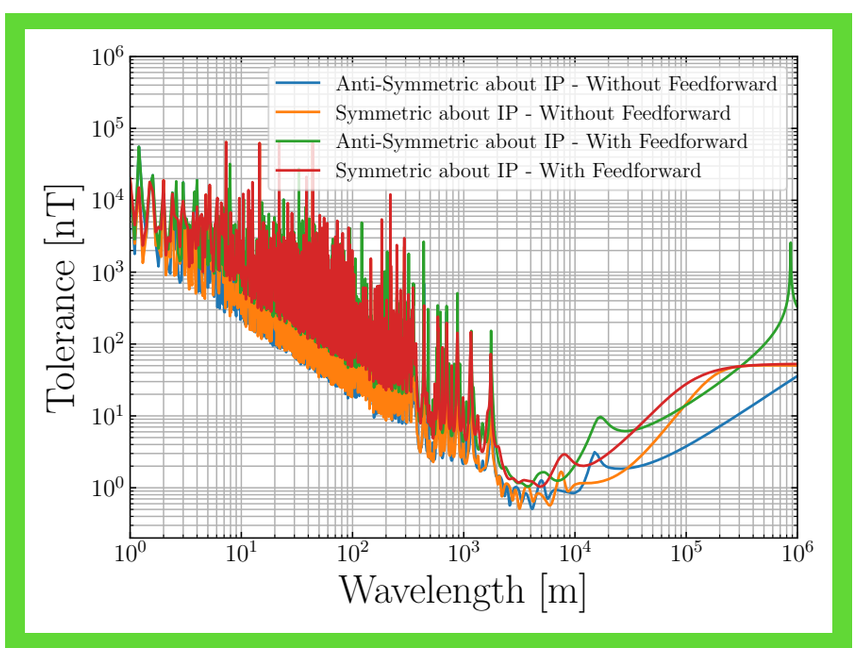

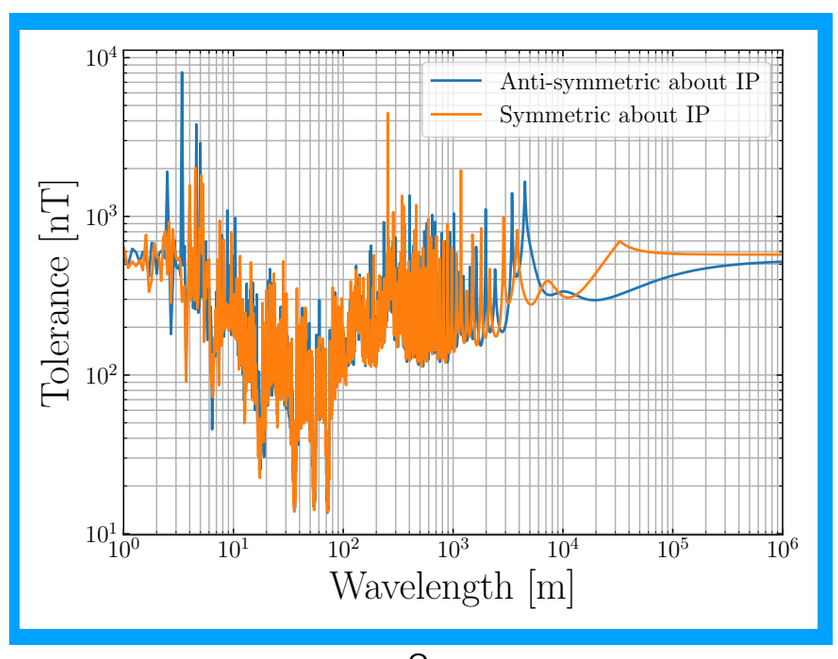

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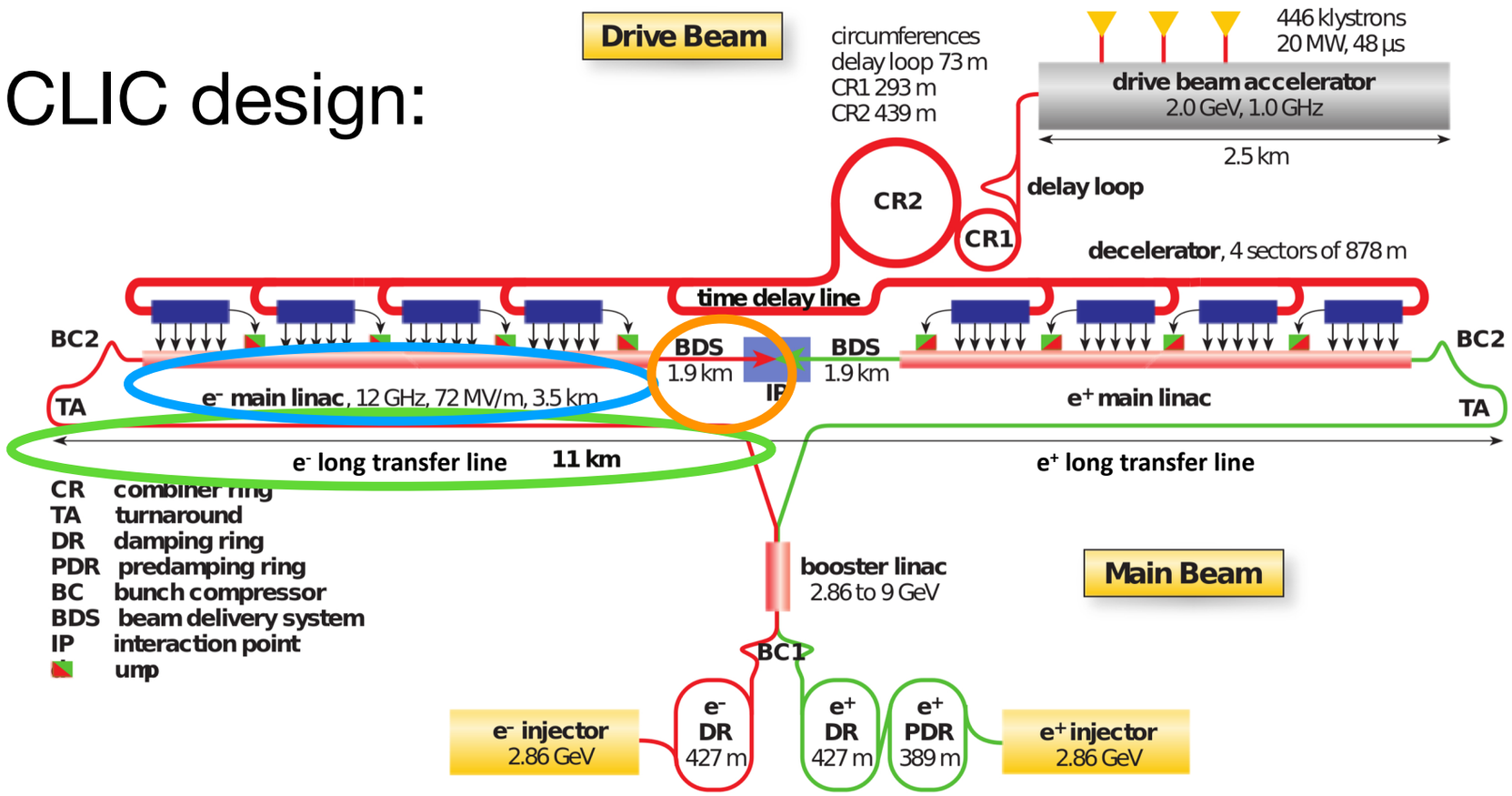
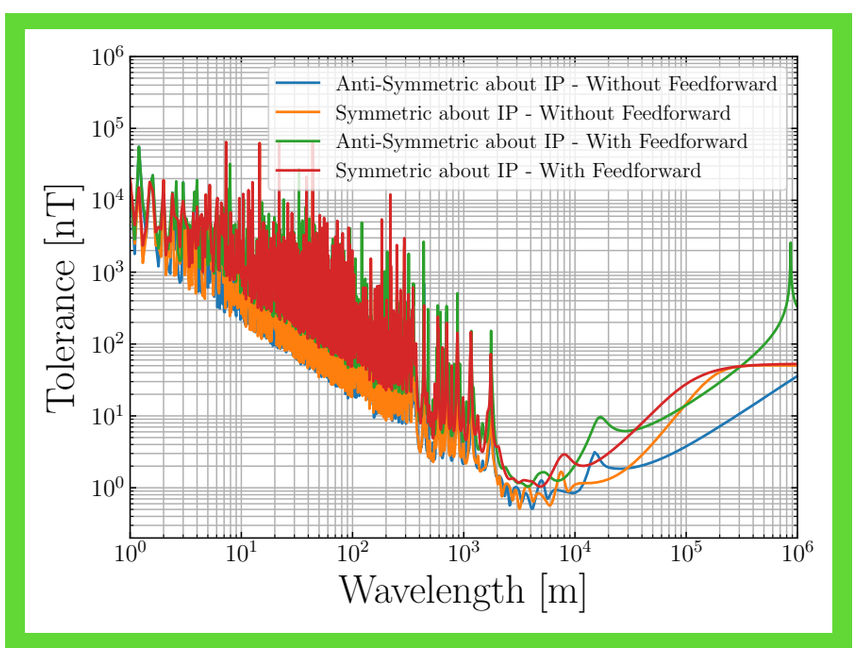
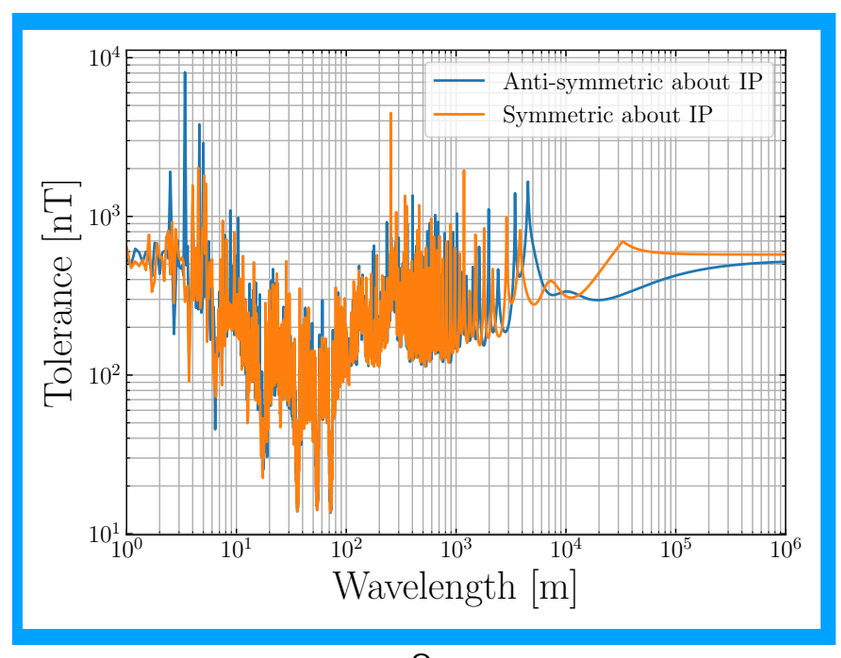
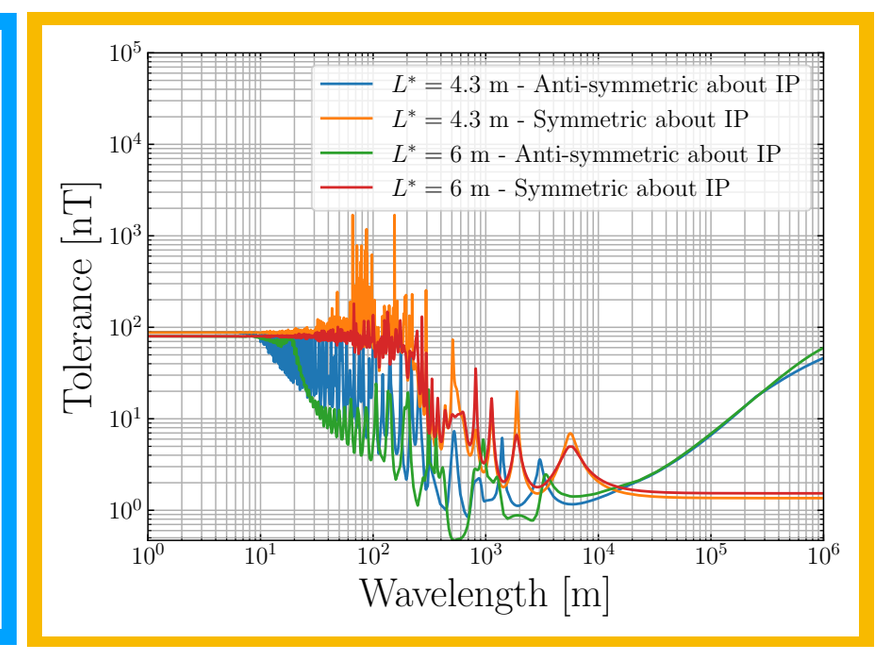


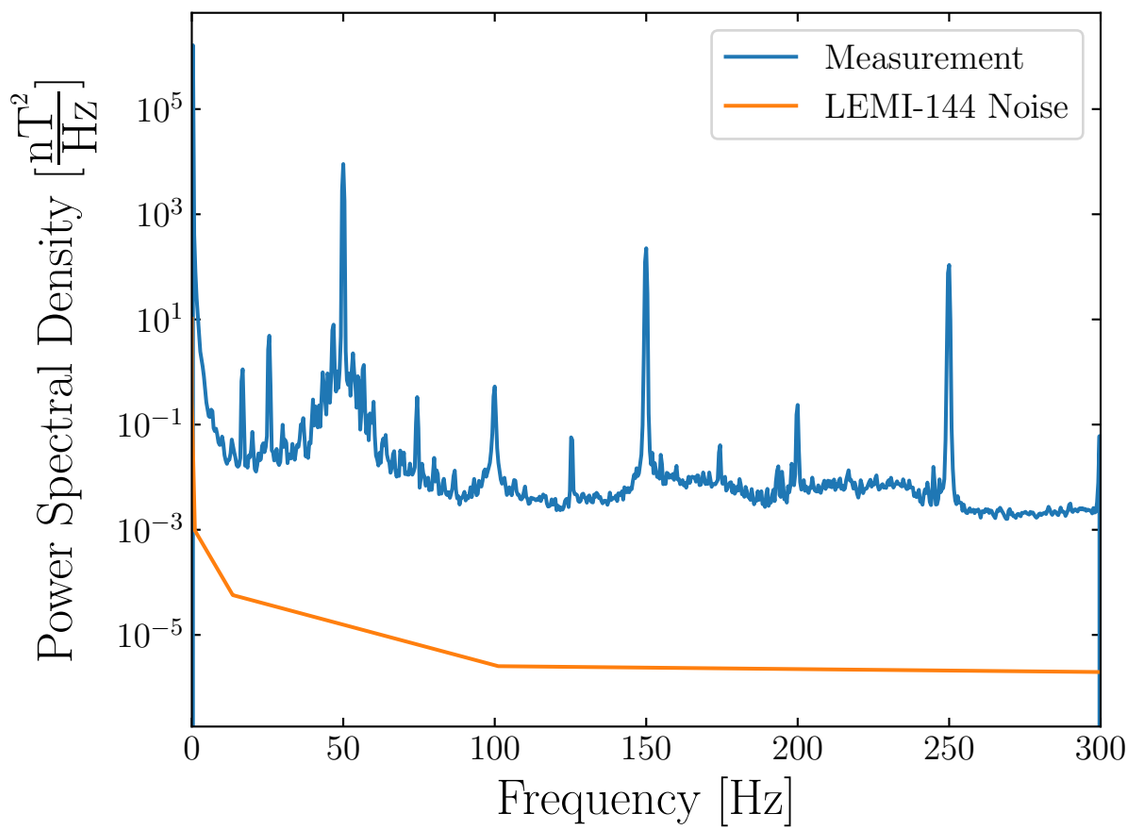


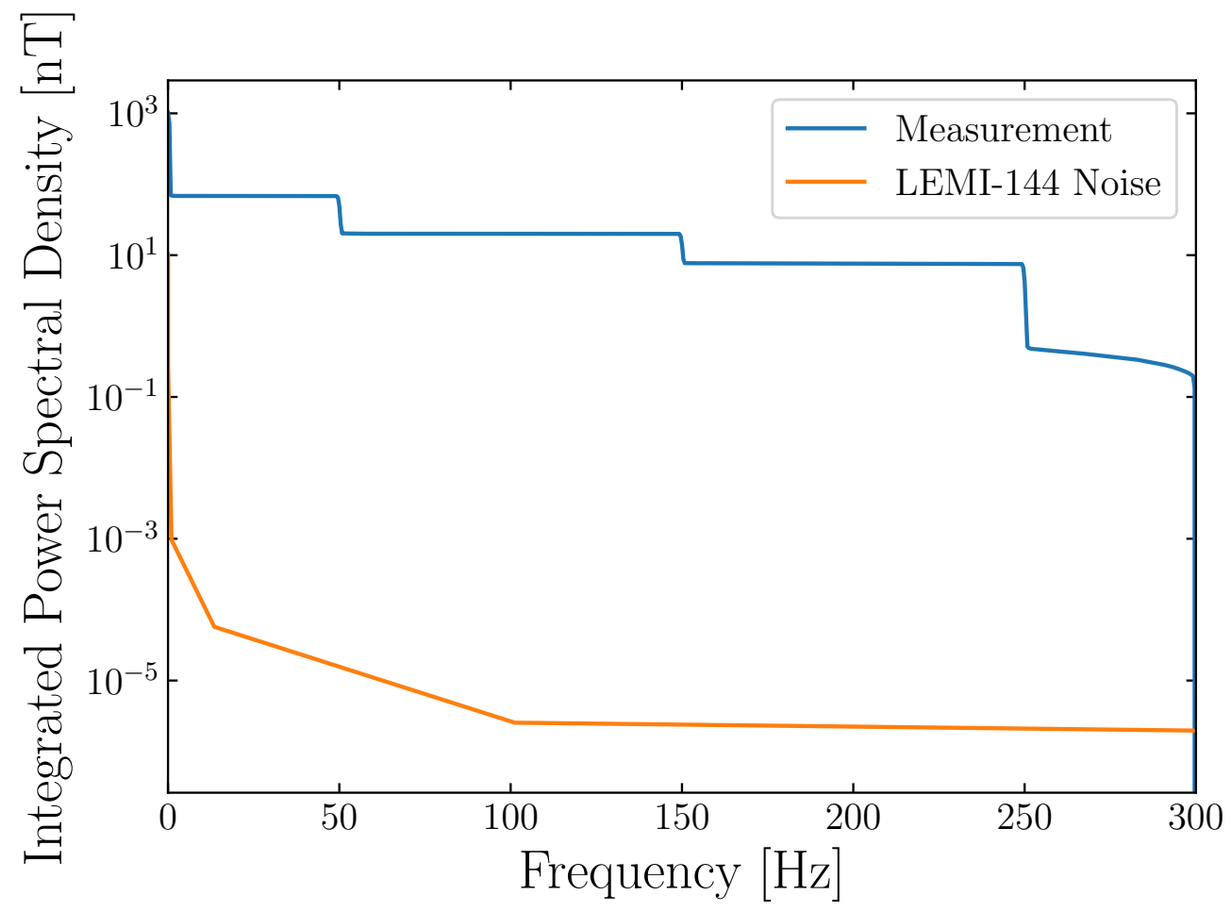




Magnetic Fields Measurement

- Background magnetic field measured in the LHC tunnel (near the ALICE detector) on the 31/01/18:





Magnetic Fields Measurement

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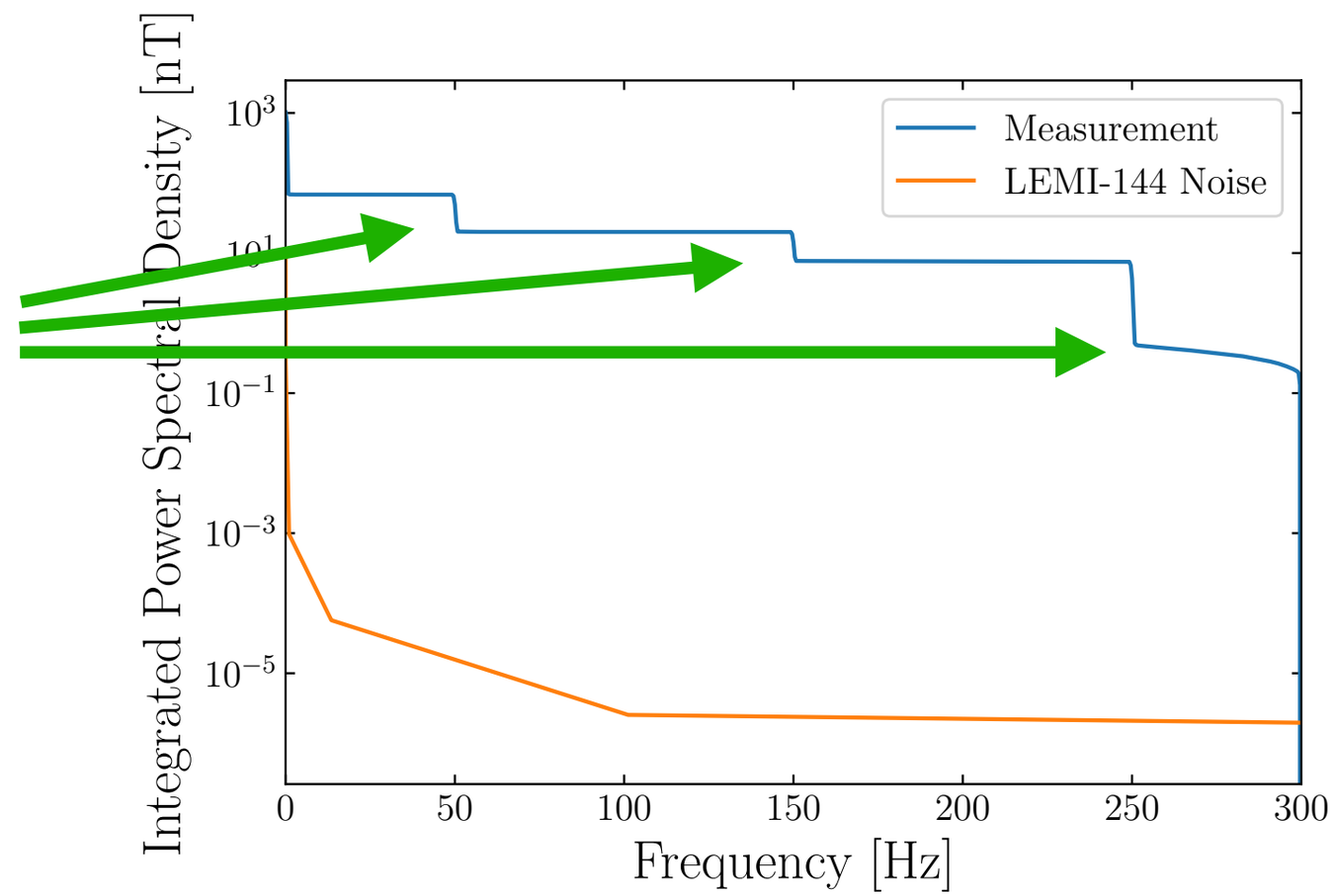
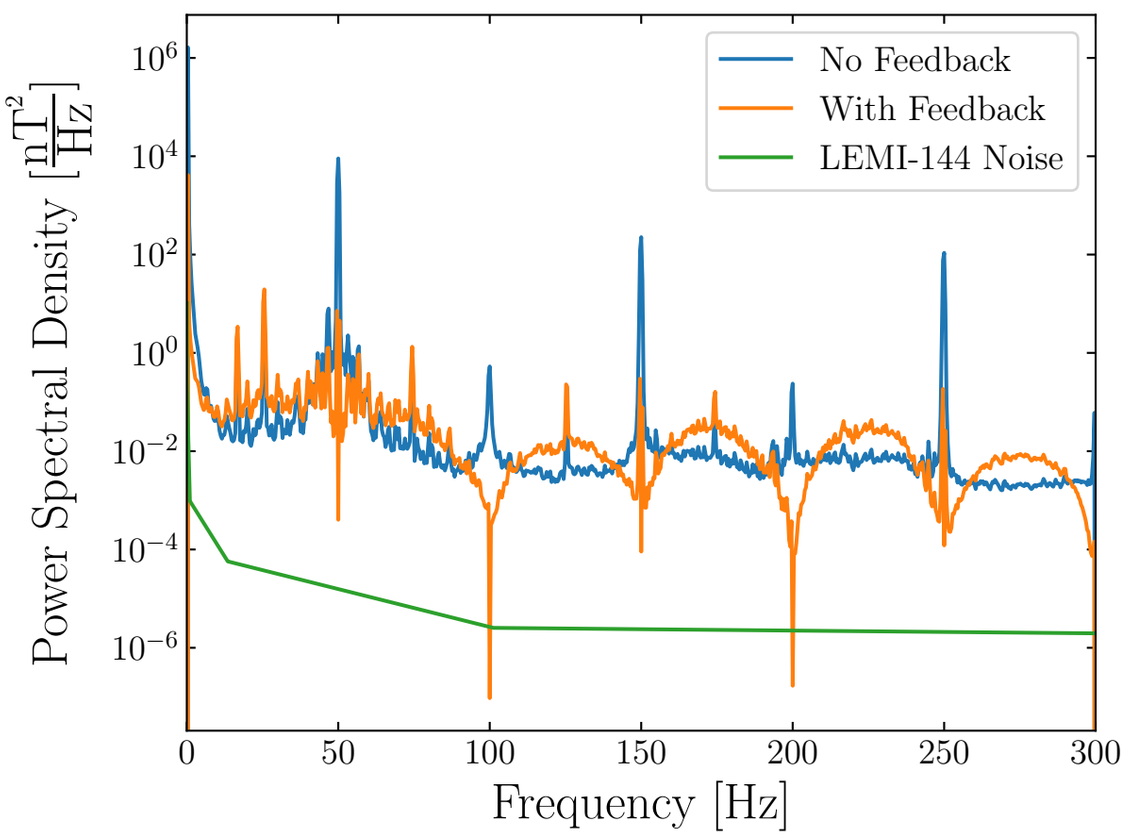
Largest contributions come from harmonics of the electrical grid

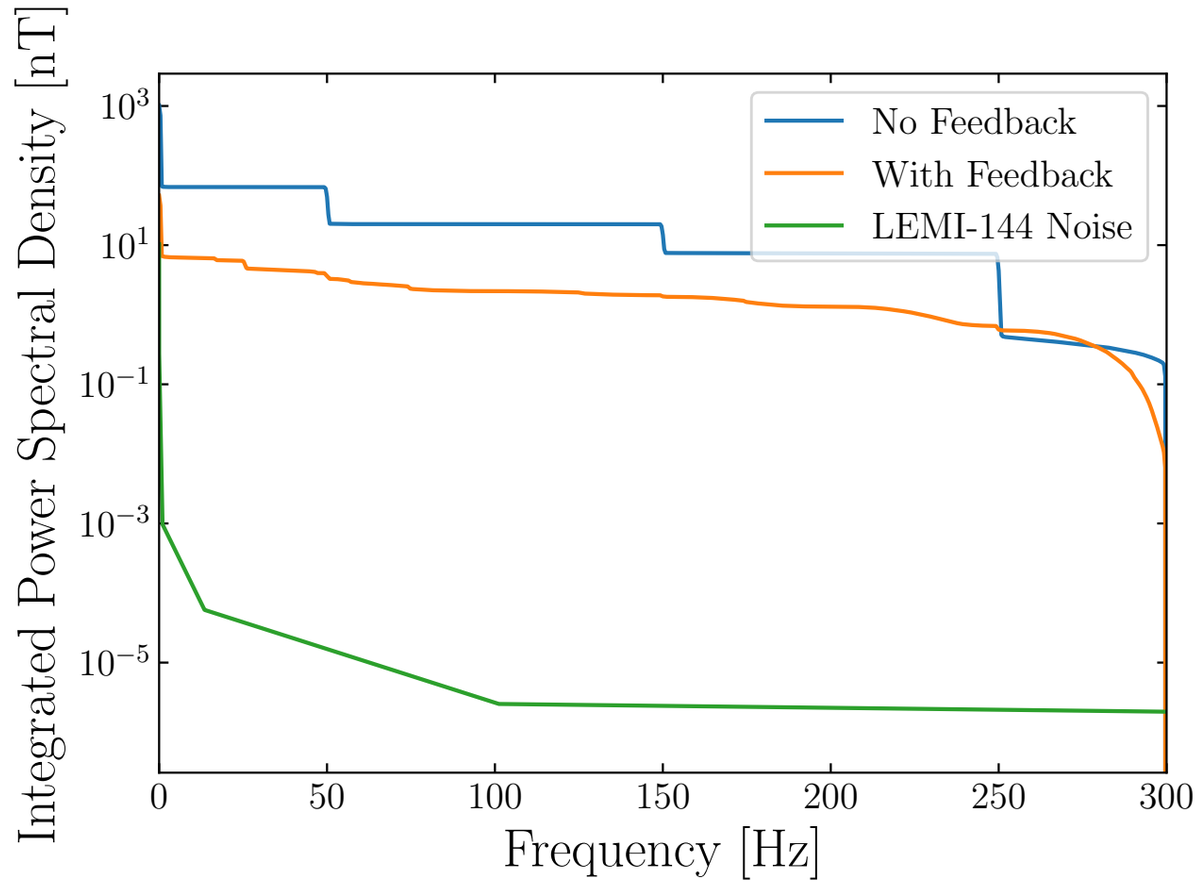


Effect of Beam-Based Feedback

- CLIC has a repetition rate of 50 Hz. This means it is insensitive to harmonics of 50 Hz.

- Effect of a dead-beat feedback of unity gain:





Effect of Shielding

Effect of Shielding

Material	Advantages	Disadvantages
Conductive materials: Copper, Silver	Effective for high frequencies	Expensive Not effective for low frequencies
Ferromagnetic materials: Mu-Metals, Permalloys	High permeability Effective for low frequencies	Weak field behaviour needs to be verified
High Temperature Superconductors	Attenuates all frequencies	Expensive Availability Temperature requirements

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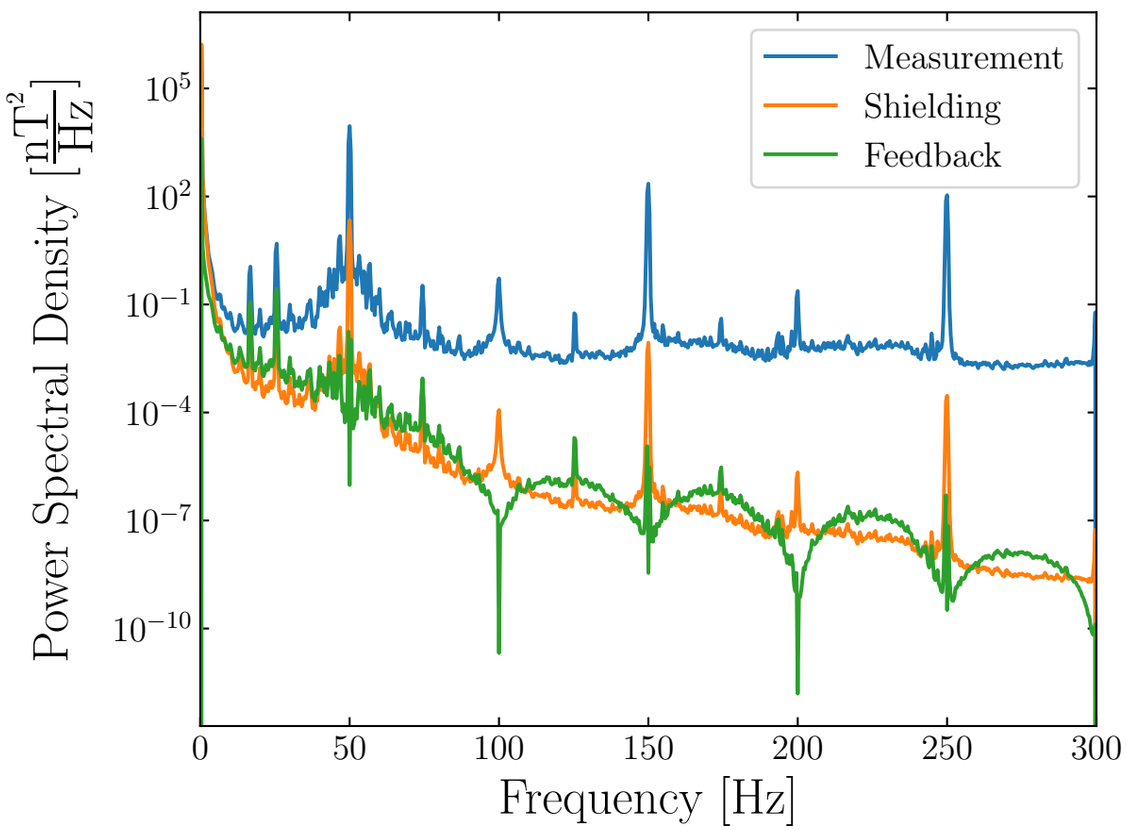
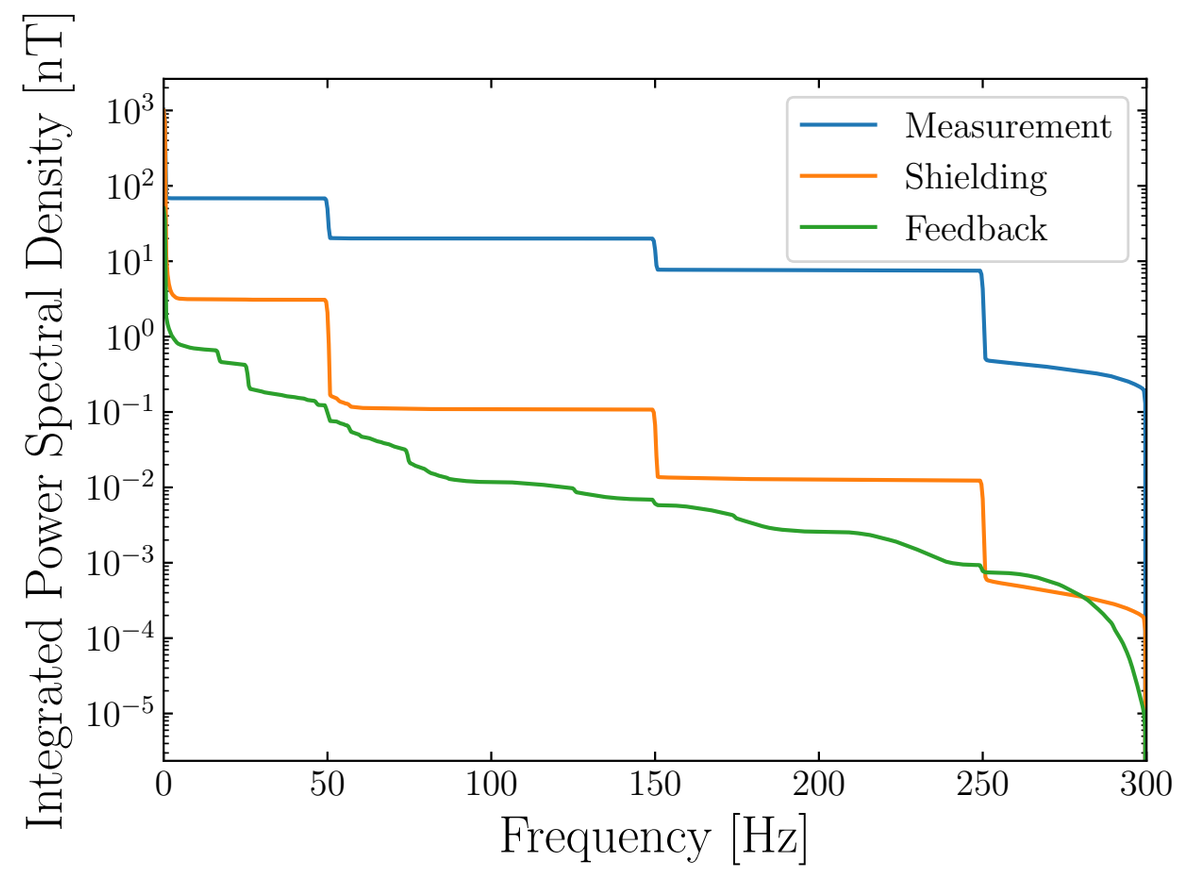
Effect of Shielding

2 cm copper beam pipe:





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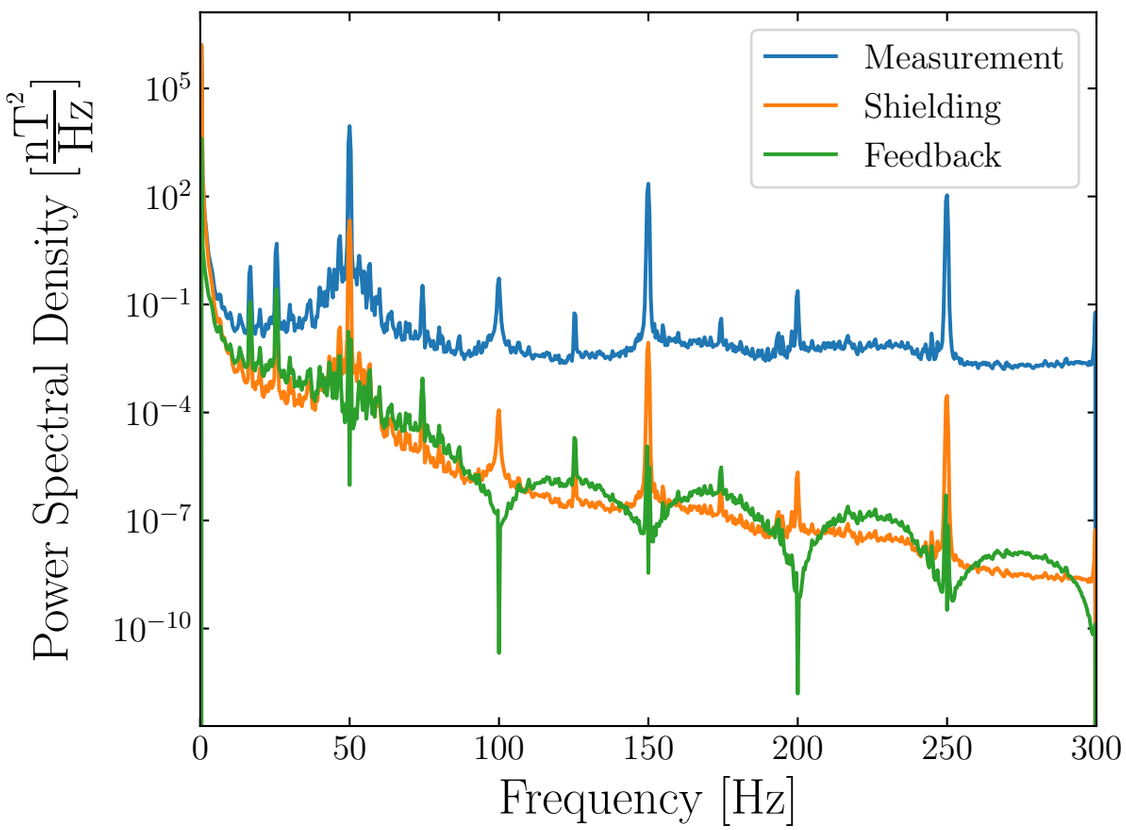
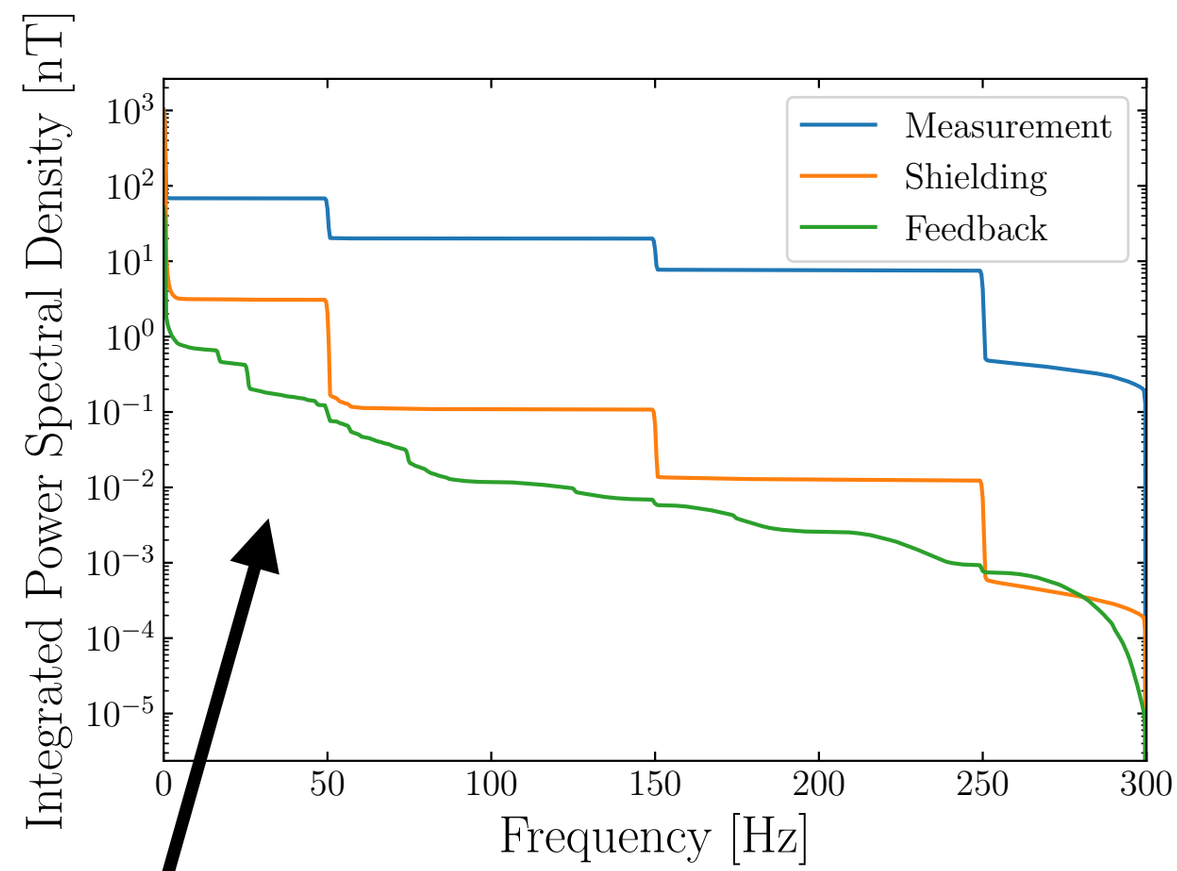
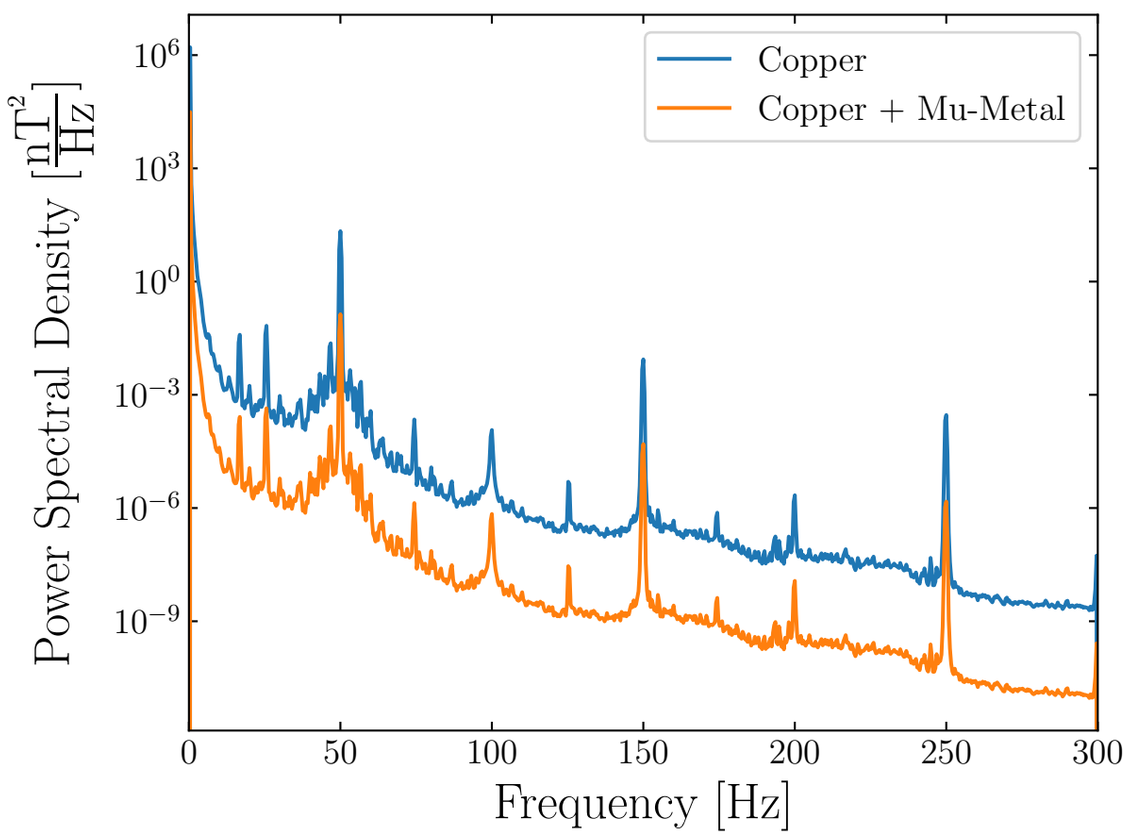


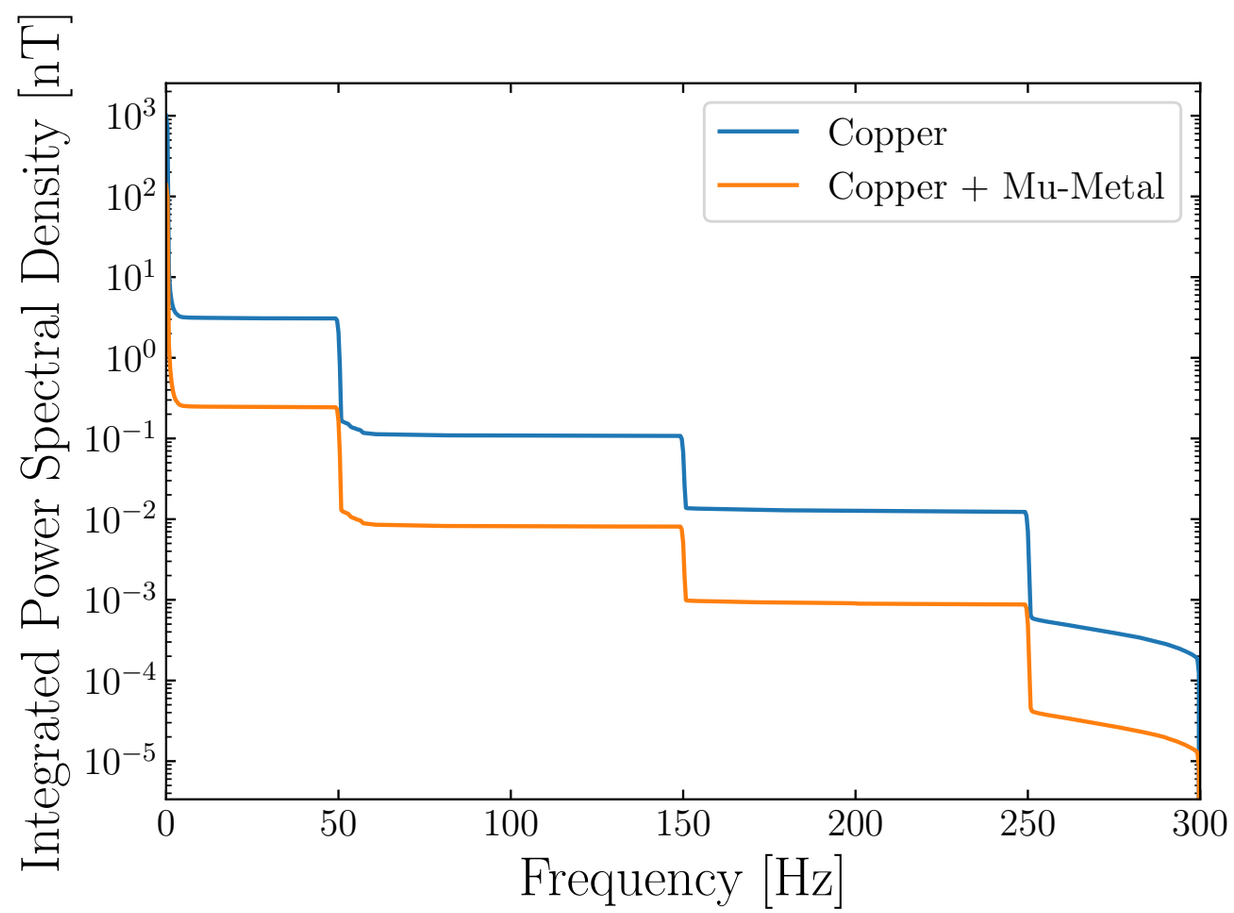


Largest contributions are low frequencies

Effect of Shielding

Effect of a 1 mm mu-metal coating around beam pipe:





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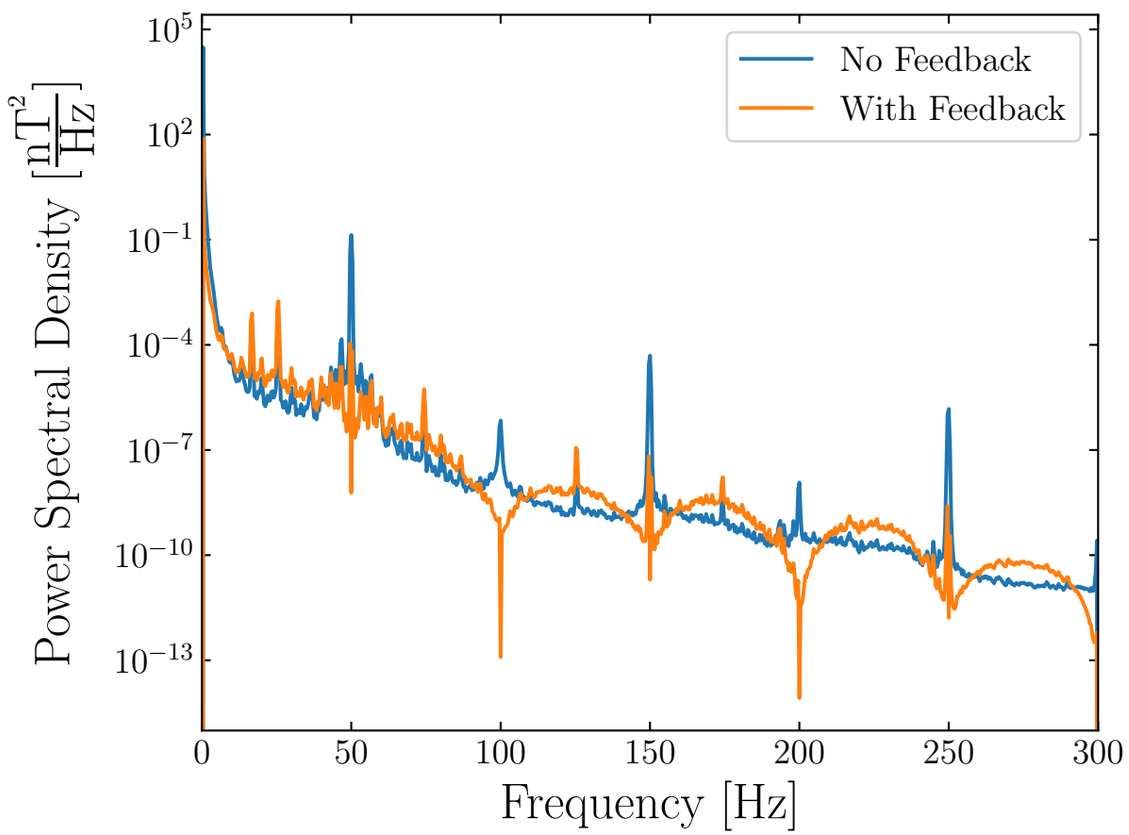

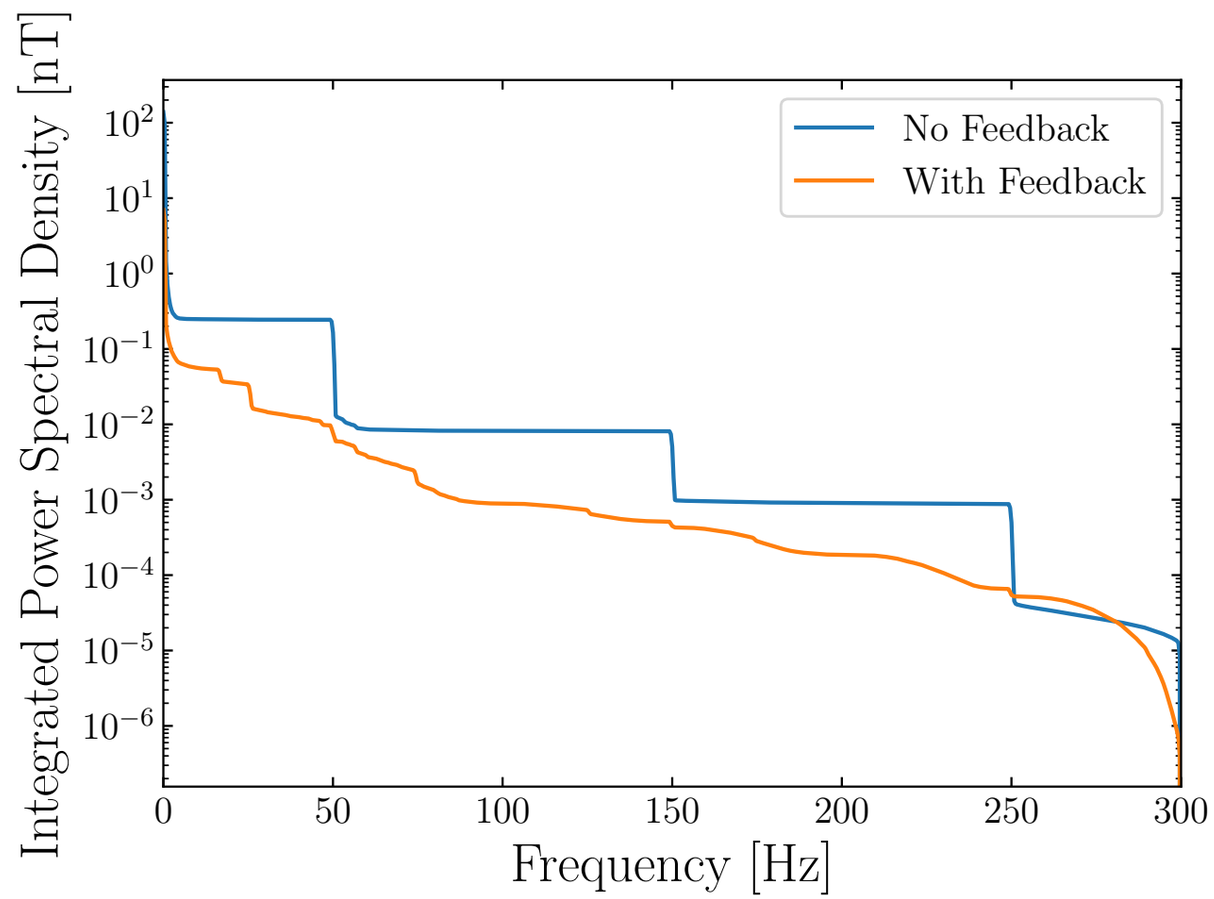

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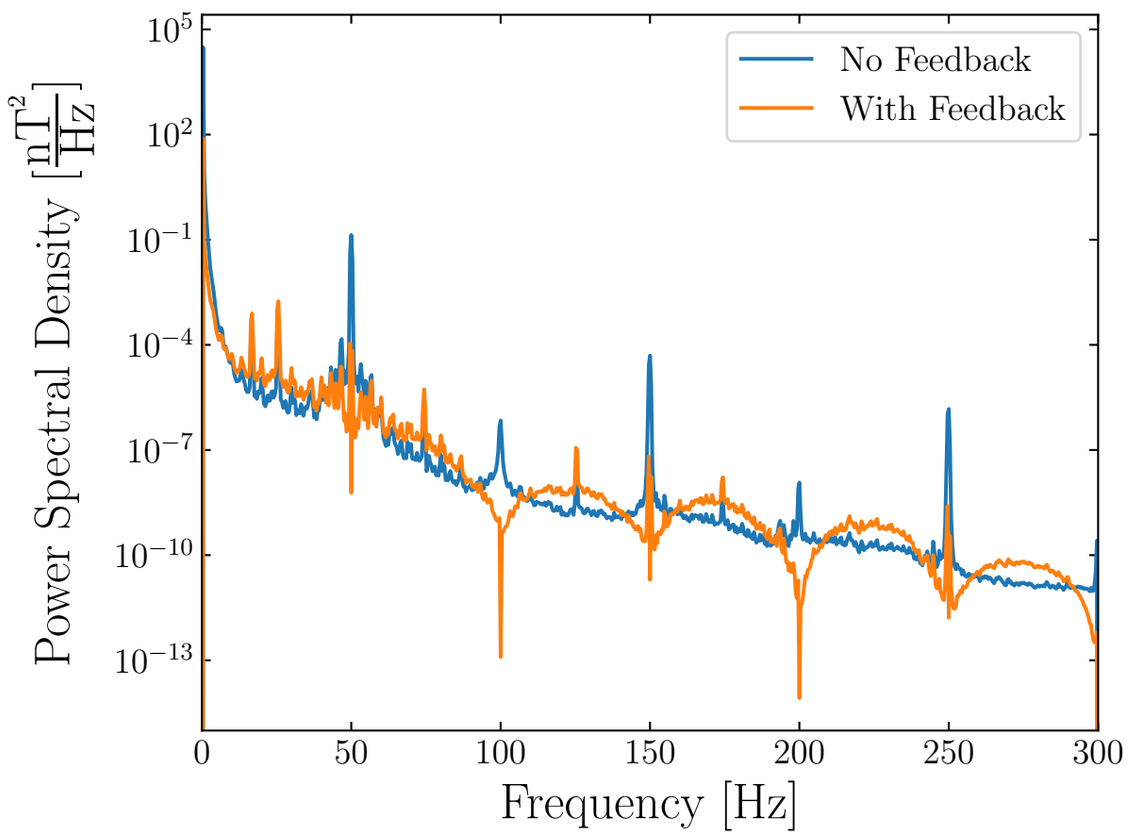
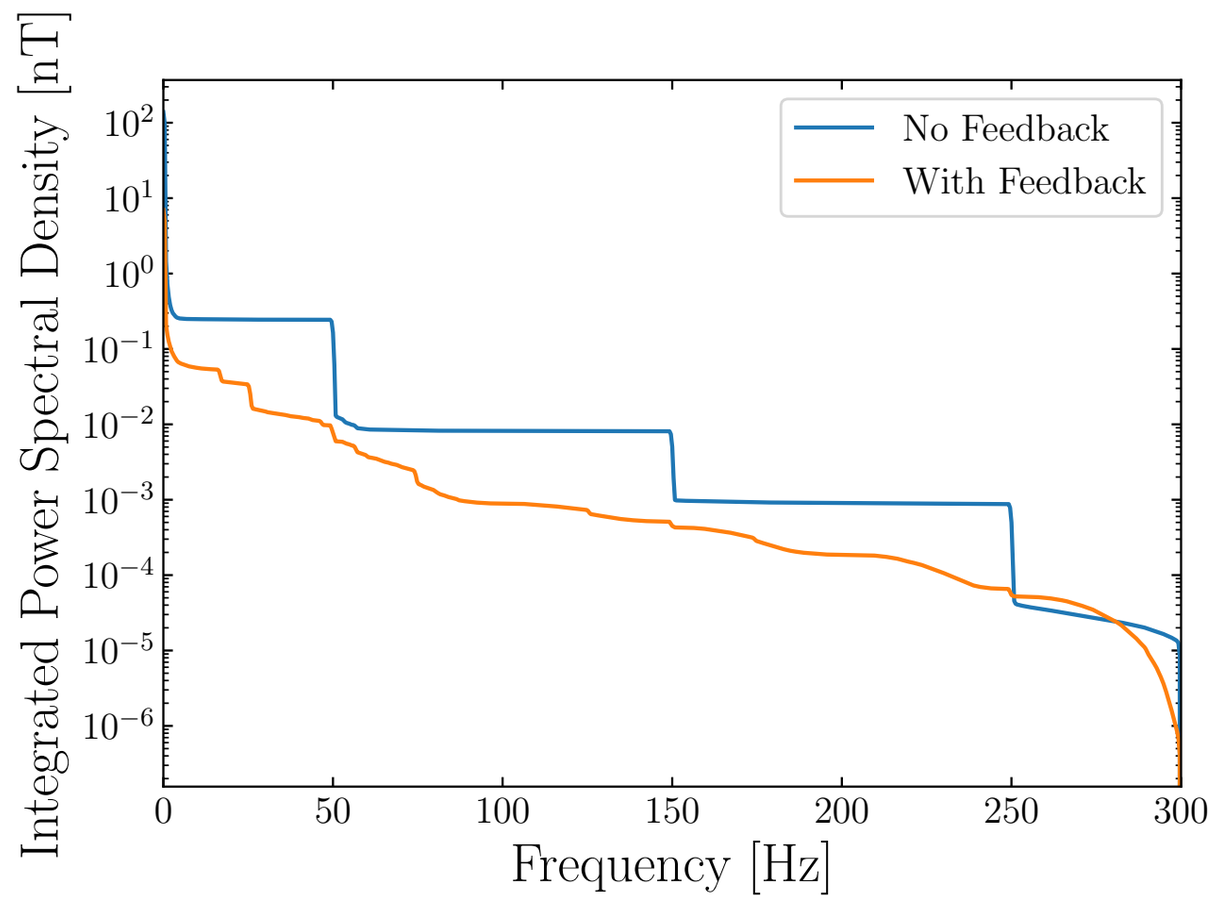




Shielding appears to be very effective

Effect of Shielding

- The calculation on the previous slide requires measurements of permeability and validation of the model.

- The model used is outlined in:

  J. F. Hoburg, "A computational methodology and results for quasistatic multilayered magnetic shielding," IEEE Trans. Electromagn. Compatibility, vol. 38, pp. 92–103, 1996.

- Valid for linear materials, where $\boldsymbol{B}(t) = \mu \boldsymbol{H}(t)$.

Effect of Shielding

- The Rayleigh region:

$$\boxed{\begin{gathered} B_0 = \mu_i H_0 + \nu H_0^2 \\ B_0 \simeq \mu_i H_0 \end{gathered}}$$

- Has been measured to be valid for $H_0 \leq 0.1\ \mathrm{mT}$.

- μ_i is usually extrapolated from measurements.

Initial Permeability

Superconducting Cavities for the ILC:

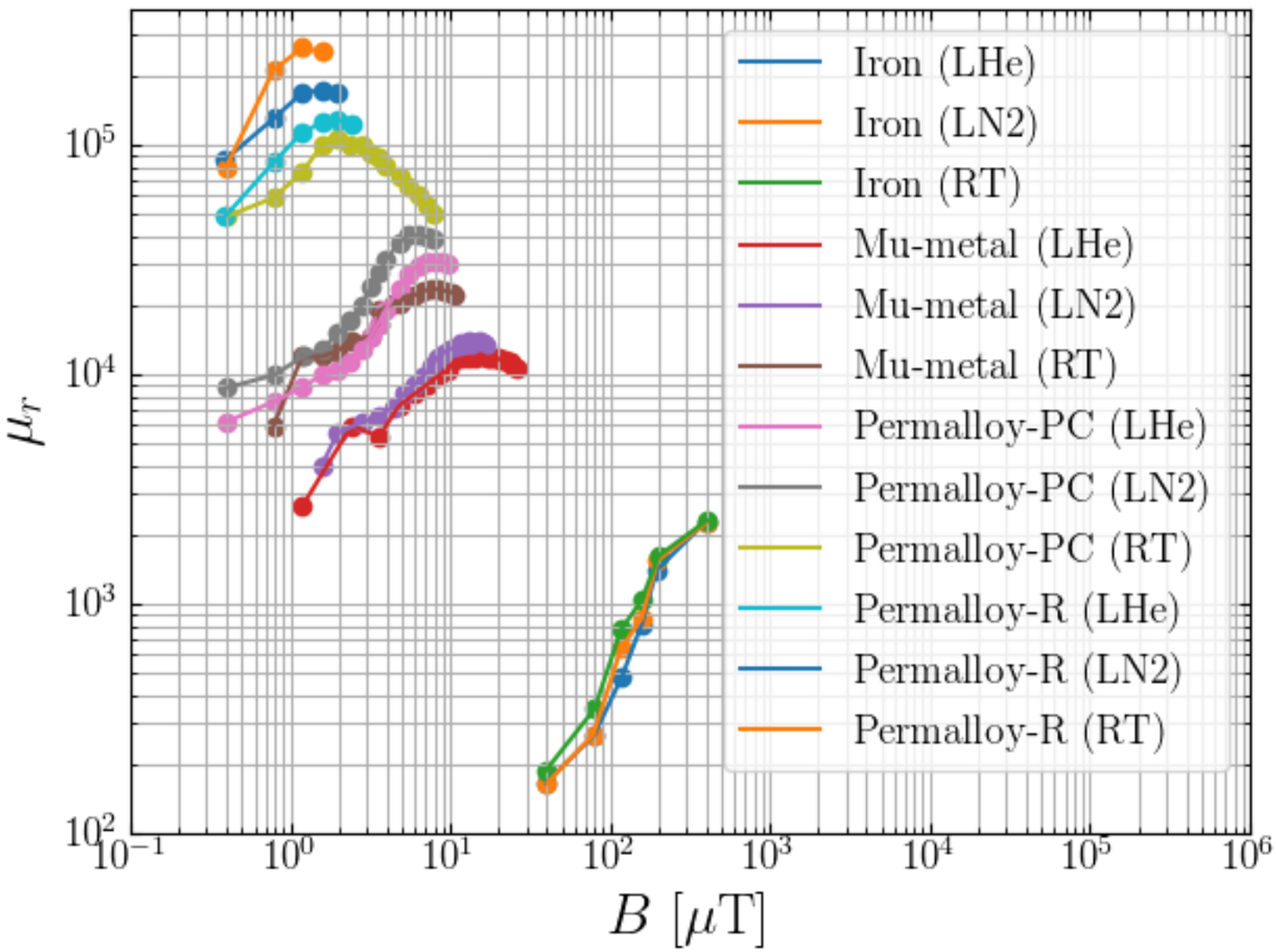
- DC magnetic fields in the vicinity of superconducting cavities leads to power losses - lowers Q-value.

- Magnetic shields to protect against the Earth's magnetic field are being investigated at KEK by:

K. Tsuchiya, *et al*., Proc. EPAC' 2006 (Edinburgh, Scotland, 2006) pp 505–507.

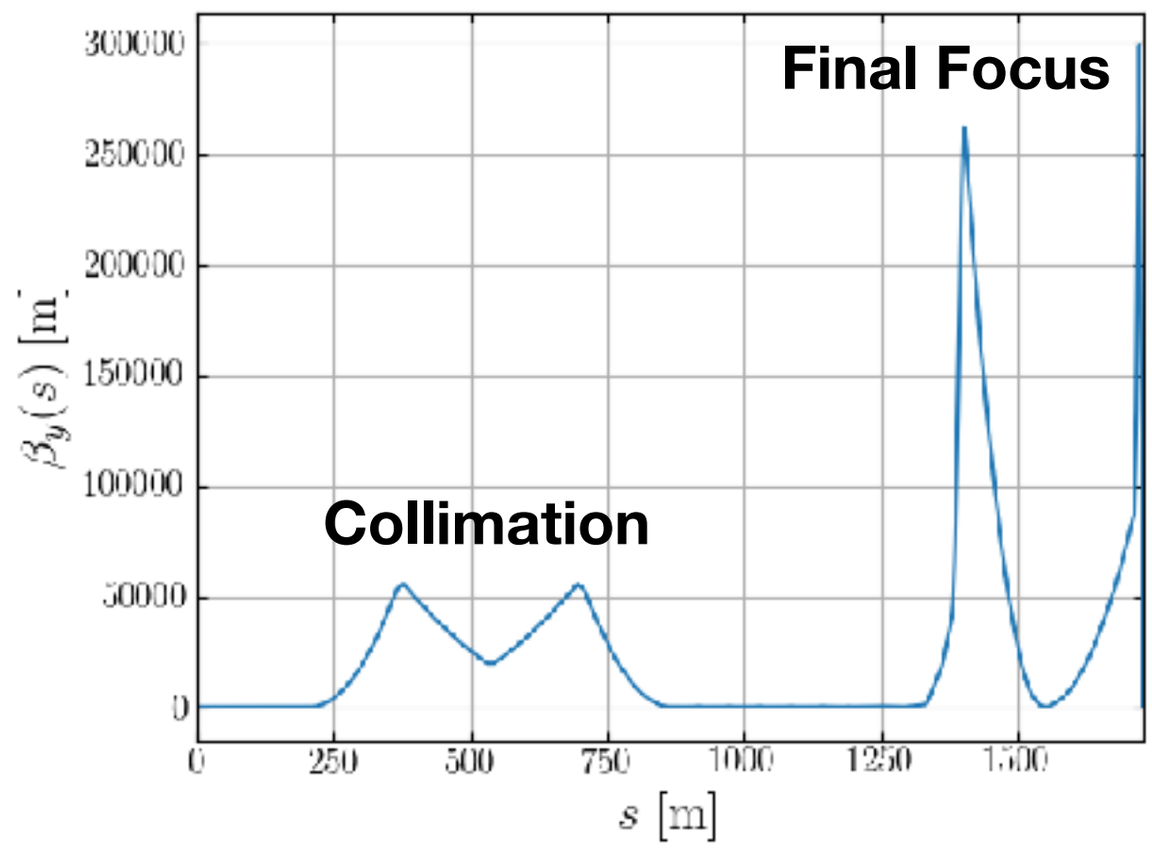
Initial Permeability

Superconducting Cavities for the ILC:



Shielding Strategy

- Two most sensitive sections are the RTML transfer line and BDS.
- The long drifts in the RTML transfer line can easily be shielded.
- The BDS contains two sensitive regions.
- It is expected that the tolerance can be greatly improved by shielding just these regions.



L*=4.3 m Vertical Beta-Function

Cost Estimate

- Assuming:
  - Outer radius of 8 cm.
  - Total length of 16.4 km after DRs.
  - Mu-metal coating for all of the beam pipe (after DRs).
  - Approximately $580 per metre squared of mu-metal (for 0.1 mm thick foil).

Total cost = $ 5.3 million

Conclusions and Future Work

- Conclusions:
  - Passive shielding looks like a promising technique to mitigate stray magnetic fields.
- Future work:
  - Measure permeability of mu-metal at low magnetic field intensities.
  - Experimentally verify models for shielding.
  - Investigate homogeneity of field inside a shield.
  - Cost optimise the shielding thickness and effectiveness.