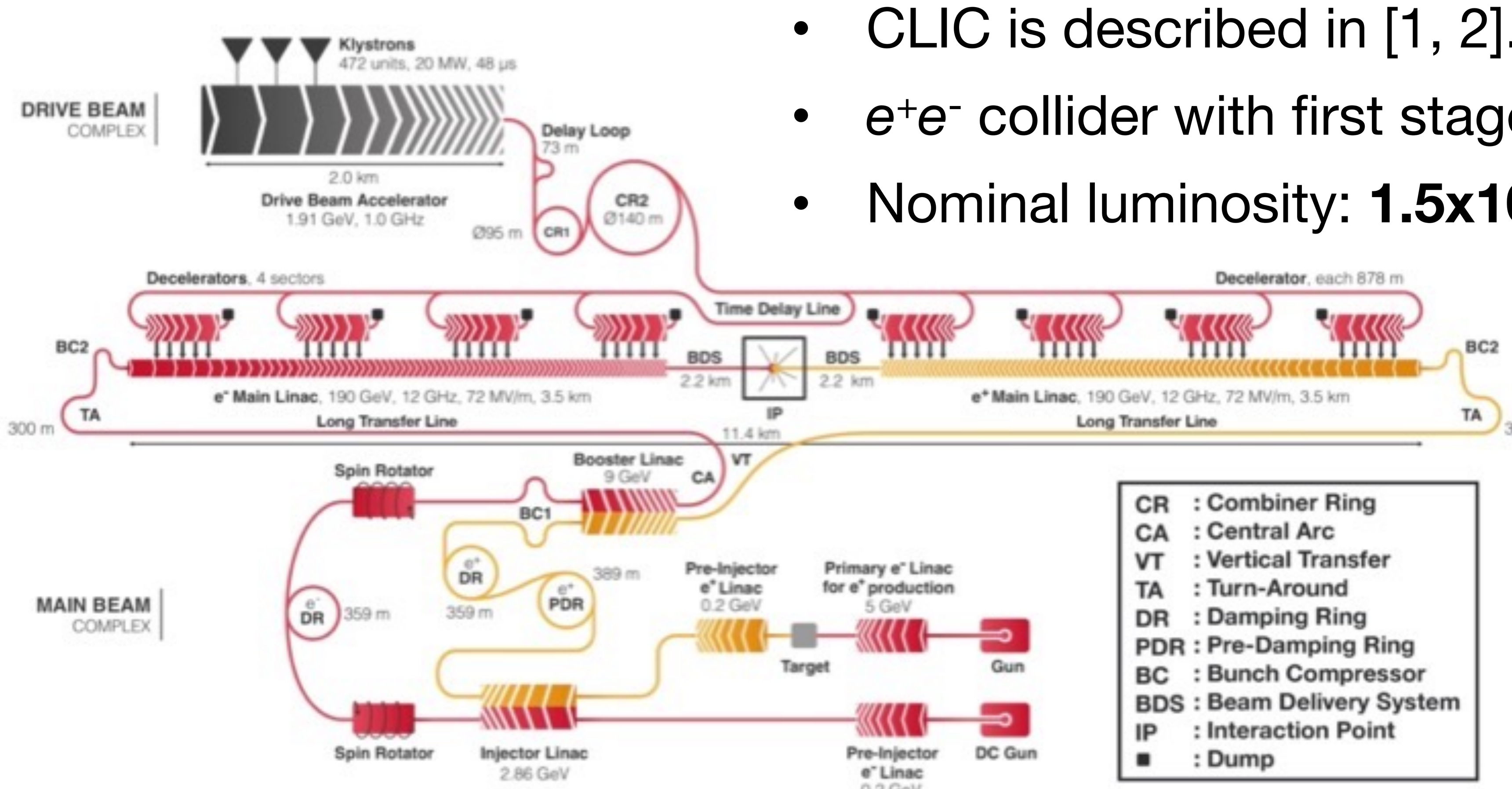
Studies Towards High Luminosity at CLIC

C. Gohil[1,2], P. N. Burrows[1], D. Schulte[2], A. Latina[2], J. Ögren[2], N. Blaskovic Kraljevic[2]

[1]*John Adams Institute (JAI), University of Oxford, OX1 3RH, United Kingdom*

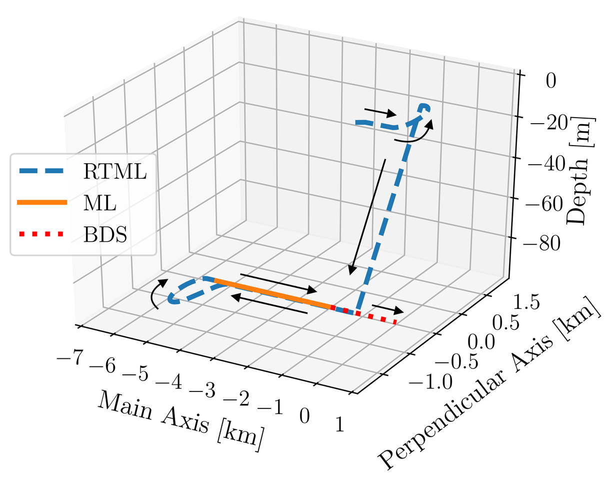
[2]*European Organization for Nuclear Research (CERN), Geneva 23, CH-1211, Switzerland*

COMPACT LINEAR COLLIDER (CLIC)



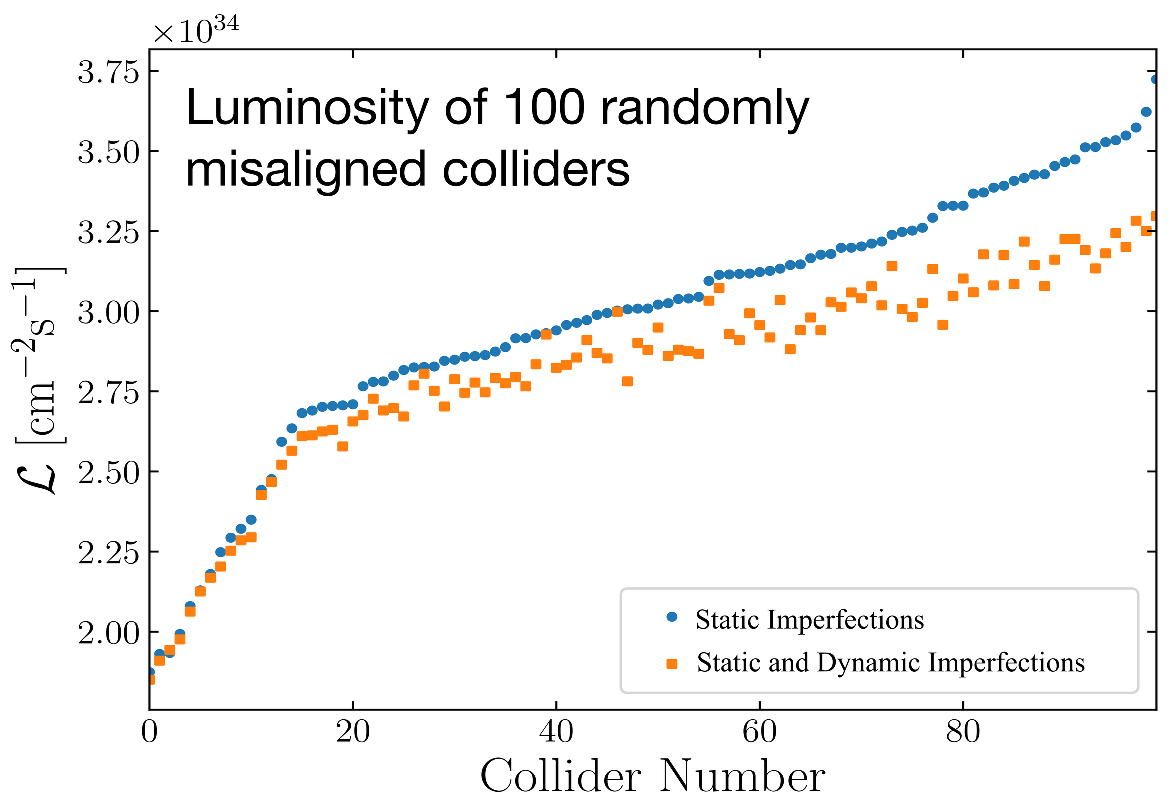
- CLIC is described in [1, 2].
- e^+e^- collider with first stage at E_{CM}=380 GeV.
- Nominal luminosity: **1.5x10^{34} cm^{-2}s^{-1}**.

e^- beam trajectory:



LUMINOSITY WITH STATIC AND DYNAMIC IMPERFECTIONS

- Start-to-end beam tracking simulations were used to realistically predict luminosity [3].
- Simulations included a comprehensive set of static imperfections (table below) and tuning procedures: one-to-one steering; dispersion free steering; RF realignment and sextupole tuning.
- The most important dynamic imperfection, ground motion (model D), was also simulated including the effect of mitigation systems: beam-based orbit feedback and quadrupole stabilisation.
- Expected luminosity: **2.8x10^{34} cm^{-2}s^{-1}**, almost twice the nominal target.



Section	Imperfection	Value
RTML		
	Magnet and BPM offset	30 μm
	Magnet and BPM roll	100 μrad
	BPM resolution	1 μm
	CA and TA quadrupole strength errors	0.01%
	All other magnet strength errors	0.1%
ML		
	Magnet and BPM offset	14 μm
	Magnet and BPM roll	100 μrad
	BPM resolution	0.1 μm
	Magnet strength errors	0.01%
	Girder end point with respect to reference wire	12 μm
	Girder end point with respect to articulation point	5 μm
	Accelerating structure offset	14 μm
	Accelerating structure tilt	141 μrad
	Wakefield monitor offset	3.5 μm
BDS		
	Magnet and BPM offset	10 μm
	Magnet and BPM roll	100 μrad
	BPM resolution	20 nm
	Magnet strength errors	0.01%

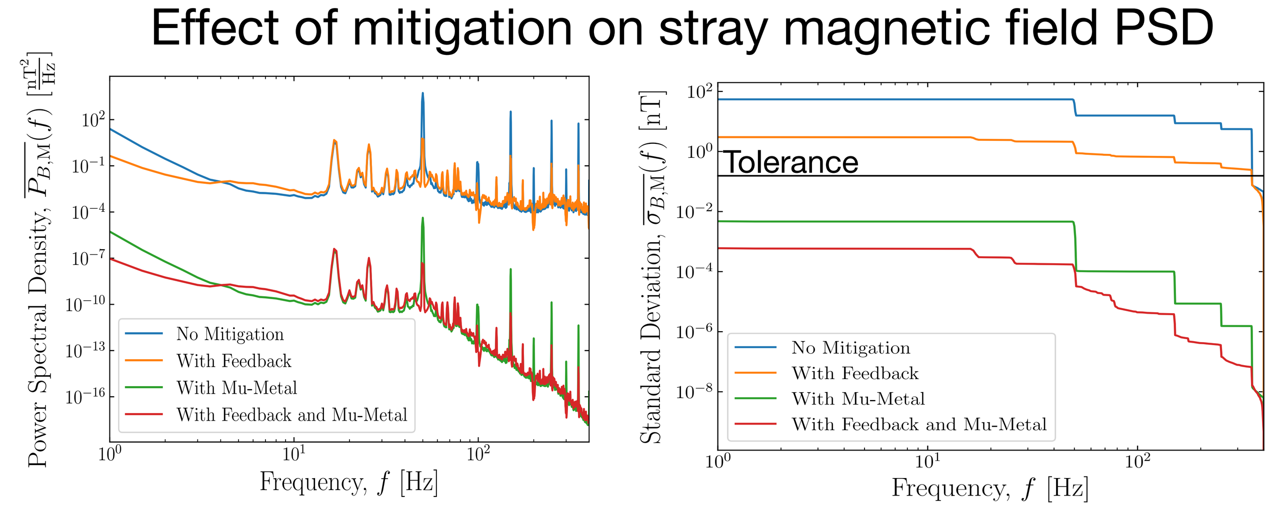
HIGH-LUMINOSITY CLIC

- Options for increasing the luminosity of CLIC are discussed in [4].
- Most factors that determine the luminosity are fixed by various considerations:
  - N/σ_x is limited to ensure a luminosity spectrum such that 60% of collisions are within 1% of E_{CM}.
  - Nn_b is limited to mitigate wakefields to ensure beam stability.
  - f_r=50 Hz is determined by the electrical network and beam stability considerations and is limited by RF power consumption.
  - β_y=100 µm is limited by the bunch length.
  - ϵ_y=30 nm is a free parameter limited by our ability to preserve emittance.

$$\mathscr{L} = \frac{1}{4\pi}\frac{N}{\sigma_x} N n_b f_r \frac{1}{\sqrt{\beta_y \epsilon_y}} H_D$$

- There are two main options for increasing the luminosity of CLIC:
  - **Lower the target vertical IP emittance ϵ_y to less than 30 nm.**
    - Integrated simulations show static tuning procedures and mitigation for dynamic imperfections can surpass the current design requirements (lower left box).
  - **Double luminosity by doubling the repetition frequency f_r to 100 Hz.**
    - The power consumption of most components is independent of the repetition frequency so this leads to a marginal increase in cost/power, expect to be ~5/30%.
    - We need to make sure we mitigate the 50 Hz stray magnetic field to less than 0.1 nT with a mu-metal shield to do this.
    - Other considerations: modulators and klystrons should be fine; ML cooling needs to be improved and detectors must be designed for the higher rate.

Effect of mitigation on stray magnetic field PSD



CONCLUSIONS

- Integrated simulations with static and dynamic imperfections show almost twice the nominal luminosity could be achieved, which leaves a large margin for unforeseen issues.
- A high-luminosity design at double the repetition frequency is possible if stray magnetic fields are mitigated with a mu-metal shield.

REFERENCES

1. M. Aicheler, et al., The compact linear collider (CLIC)—Project implementation plan, Report No. CERN-2018-010-M, 2018.
2. M. Aicheler, et al., A multi-TeV linear collider based on CLIC technology: CLIC conceptual design report, Report No. CERN-2012-007, 2012.
3. C. Gohil, et al., Luminosity performance of the compact linear collider at 380 GeV with static and dynamic imperfections, Phys. Rev. Accel. Beams 23, 101001 (2020).
4. C. Gohil, et al., High-Luminosity CLIC Studies, Report No. CERN-ACC-2019-0051, 2020.