Linear e^+e^- collider case study

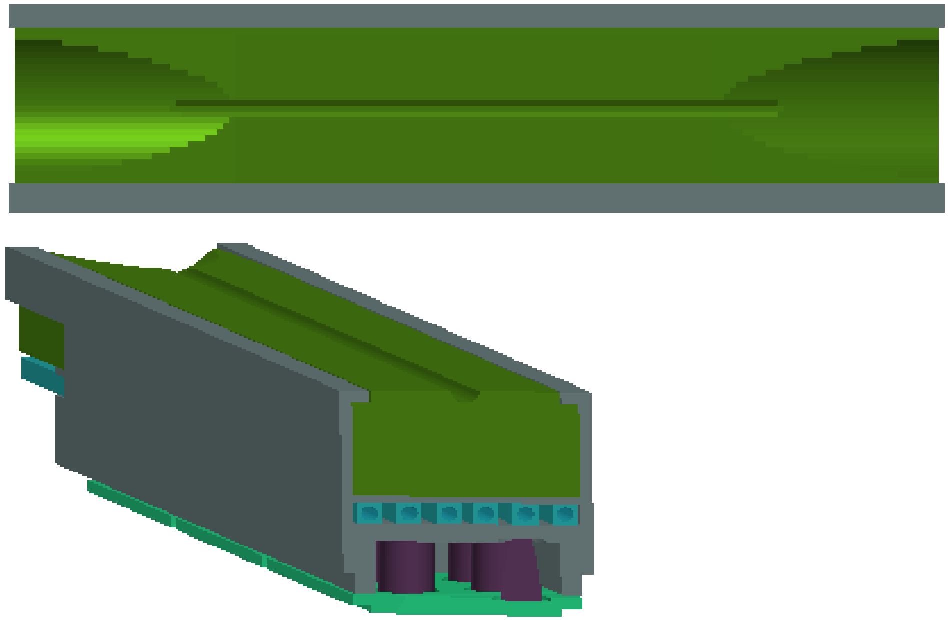
Goals of the case study

- Review the baseline 380 GeV CLIC design and propose R&D programs to:
  - Reduce the risk
  - Reduce the cost
  - Reduce the power consumption
  - Maximise luminosity
- Reliable, cheap, energy efficient super collider…

Proposal: Camel Collimator for CLIC

- **Considering cylindrical collimator:** a pipe in centre of a cube along the S coordinate (2 jaws are band together without gap)
- CLIC operation (one collision optic) might not necessarily require variation in the collimators aperture (the optic does not change in the collimators)

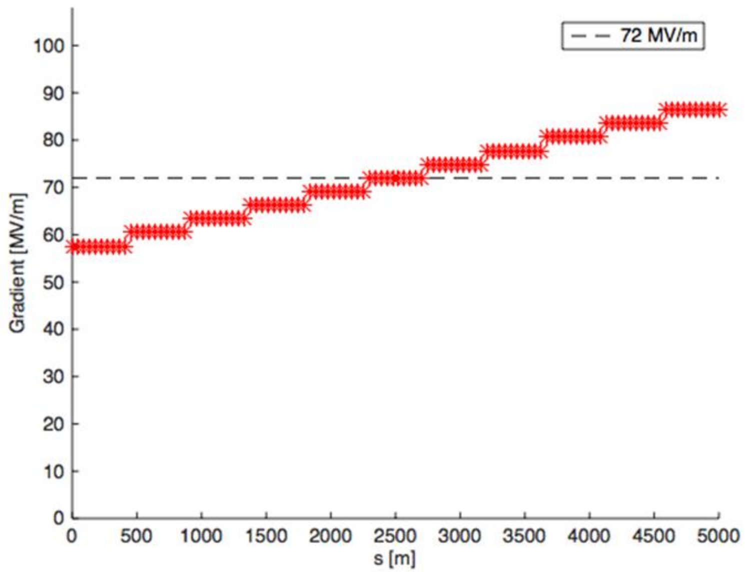
- **Lighter absorber with low Z and low density material instead of Ti-Cu:**
- Carbon-Fibre Composite (CFC) or Molybdenum-Graphite Composite



- **Reduction in cost by reducing the number of collimators (almost 1/3)**
- **Easy to handle and align along the line**
- **Potentially shortening the system length**
- **Might help in Muon reduction (in case of MoGr)**
- **Minimizing the Wakefield effect by tapering the edges**

→ Disadvantage: not necessarily but maybe increment of the total power in the collimator

RF Optimization

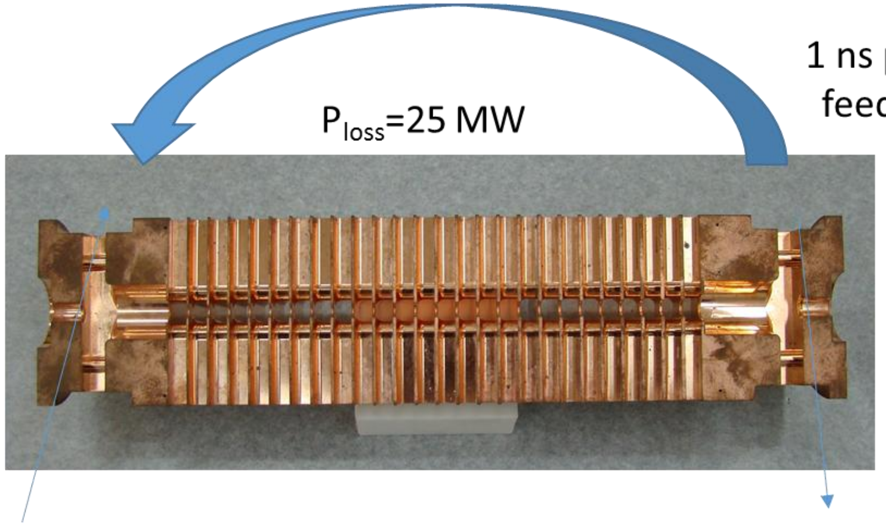


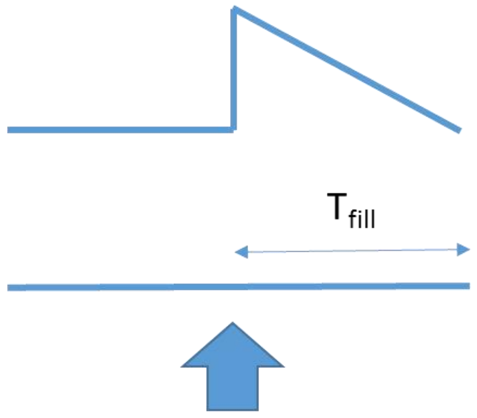
Lower gradient means larger aperture and reduced wakefields:

$$W_{\perp}(z \ll z_0) \approx 2\frac{Z_0 c}{\pi a^4} z$$

	100 MV/m	72 MV/m
a/lambda	0.11	0.13
W_transverse	2.15	1

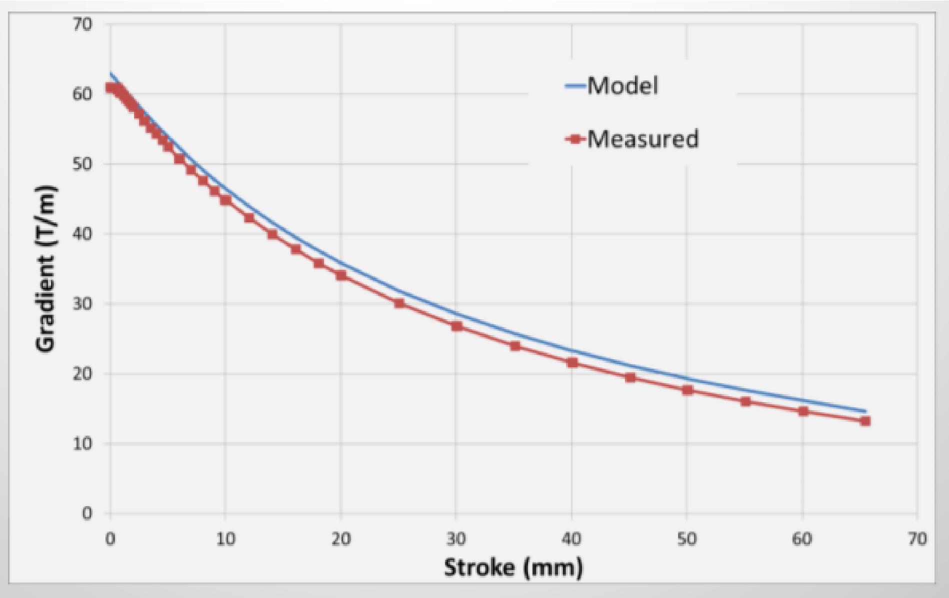
Increase gradient at higher energies when the beam is more rigid.

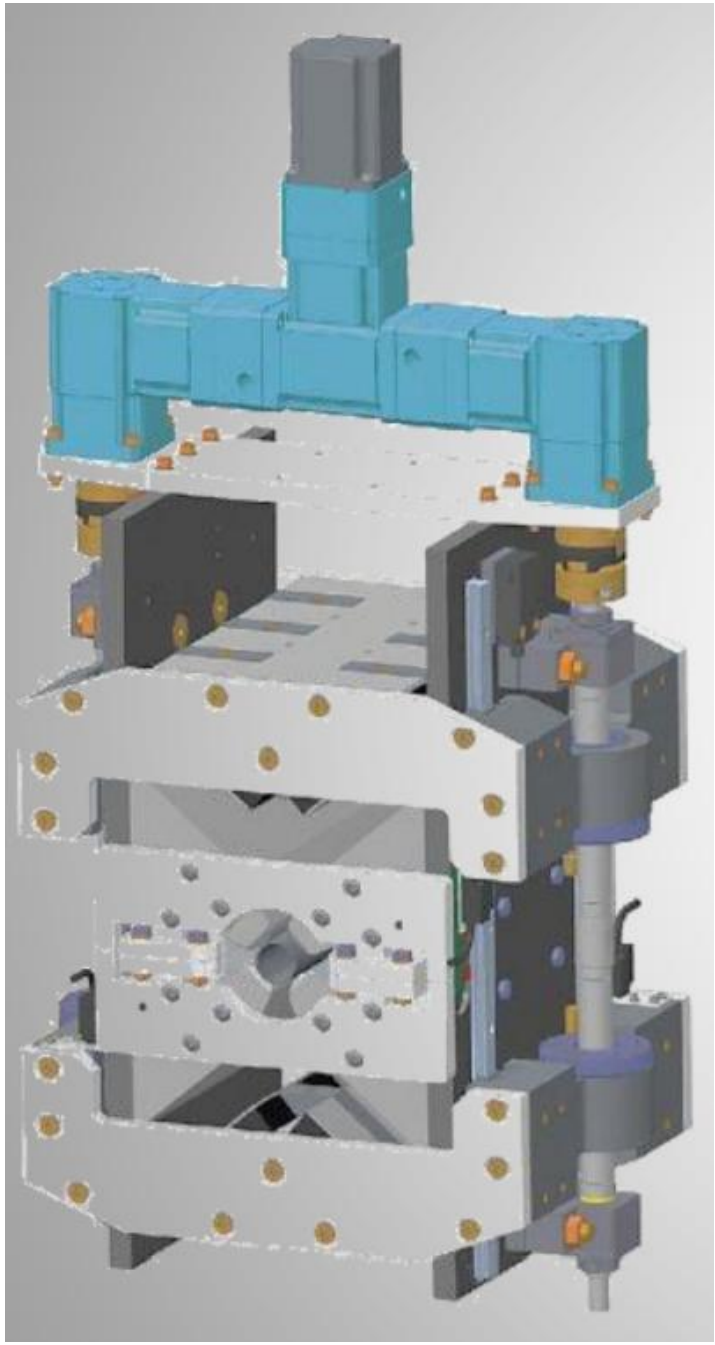




Use of Permanent Magnets

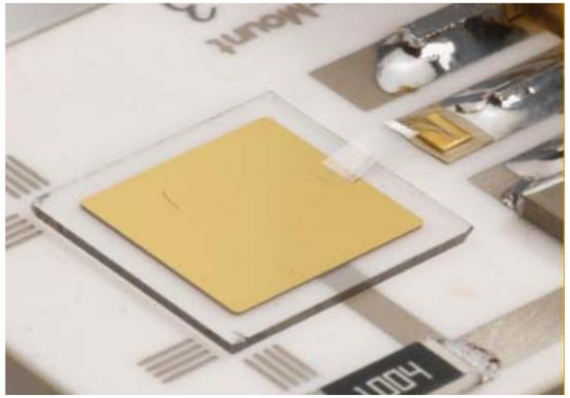
- Main beam linac 1700 quadrupoles
- Drive beam linac 7000 quadrupoles (1/m)
- Gradients comfortably within reach (23 T/m)
- Considerable operation cost savings if alternation of permanent and EM quads possible (e.g. 50 % at least for drive beam)
- Replace SC wigglers in DR with permanent magnets





Luminosity Measurement Optimization using diamond feedback systems

- R&D of CVD Diamond Detectors recommended for luminosity measurement feedback due to:
  - Radiation-hardness -> 10 MGy
  - Fast Readout signal ~ nanoseconds
    - Time resolutions ~30 ps
  - Ability to detect
    - Single particle
    - multi-particle
    - shower cascades
    - high-intensity beam losses



B. Dehning et al. CERN-BE-2011-001 BI

Luminosity Measurement Optimization using diamond feedback systems

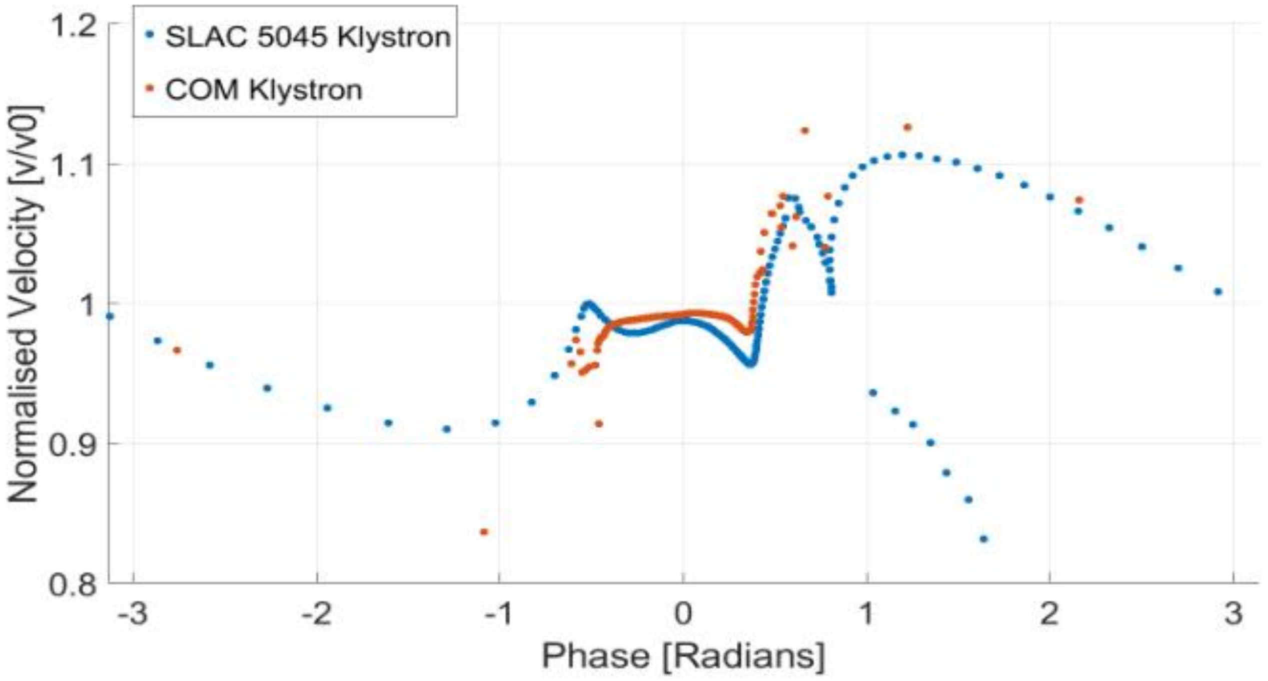
- Position CVD Detectors after the interaction point to measure outgoing beams and calculate luminosity
- Radiation-hardness makes them ideal for this region in which high losses can be expected
- Fast response times allows for real-time measurements and feedback into the steering system

R&D on Klystron Efficiency

- If investment is directed towards R&D on klystrons, efficiencies could increase →
  - L-band: $\eta = 0.7 \rightarrow \eta = 0.9$
  - X-band: $\eta = 0.5 \rightarrow \eta = 0.7$
- Traditional way: decreasing the bunch length by increasing the accelerating voltage of the Klystron
  - Limitation: Voltage
- New way: use the space charge and the Klystron cavity to stimulate a oscillation of the core of the bunch
  - Effect: periphery electrons can be connected to the bunch

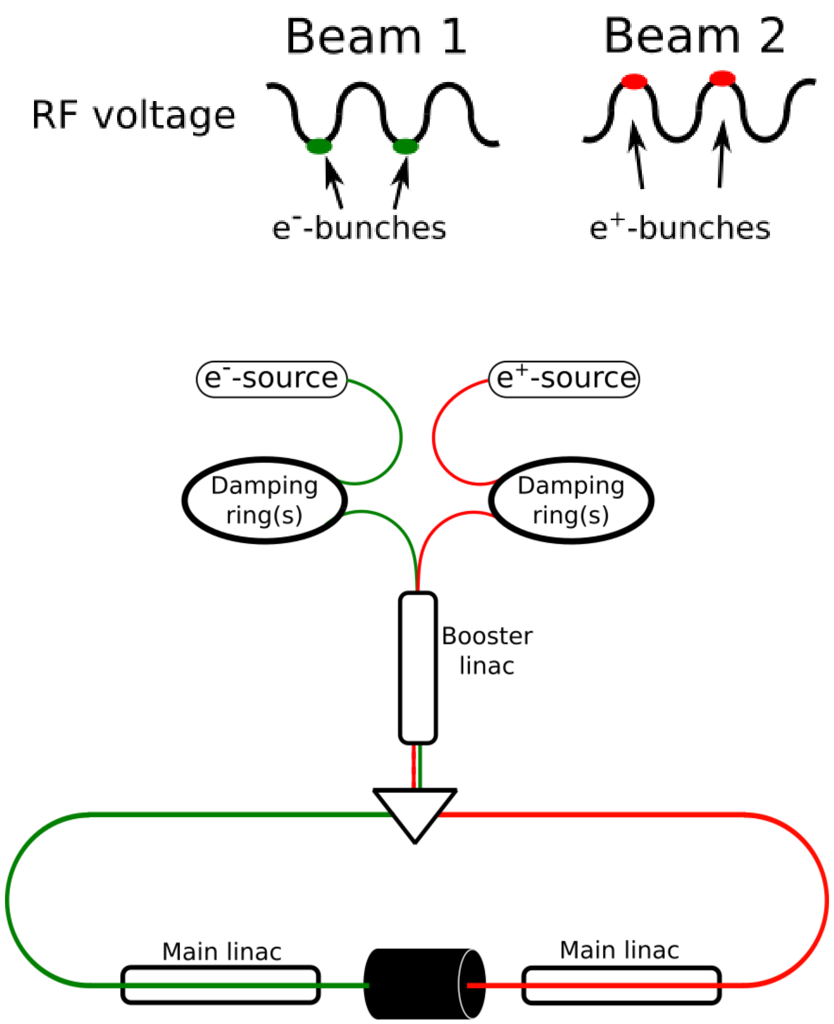
R&D on Klystron Efficiency

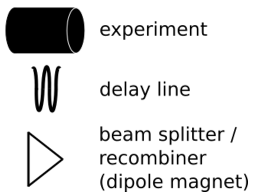
- Comparison



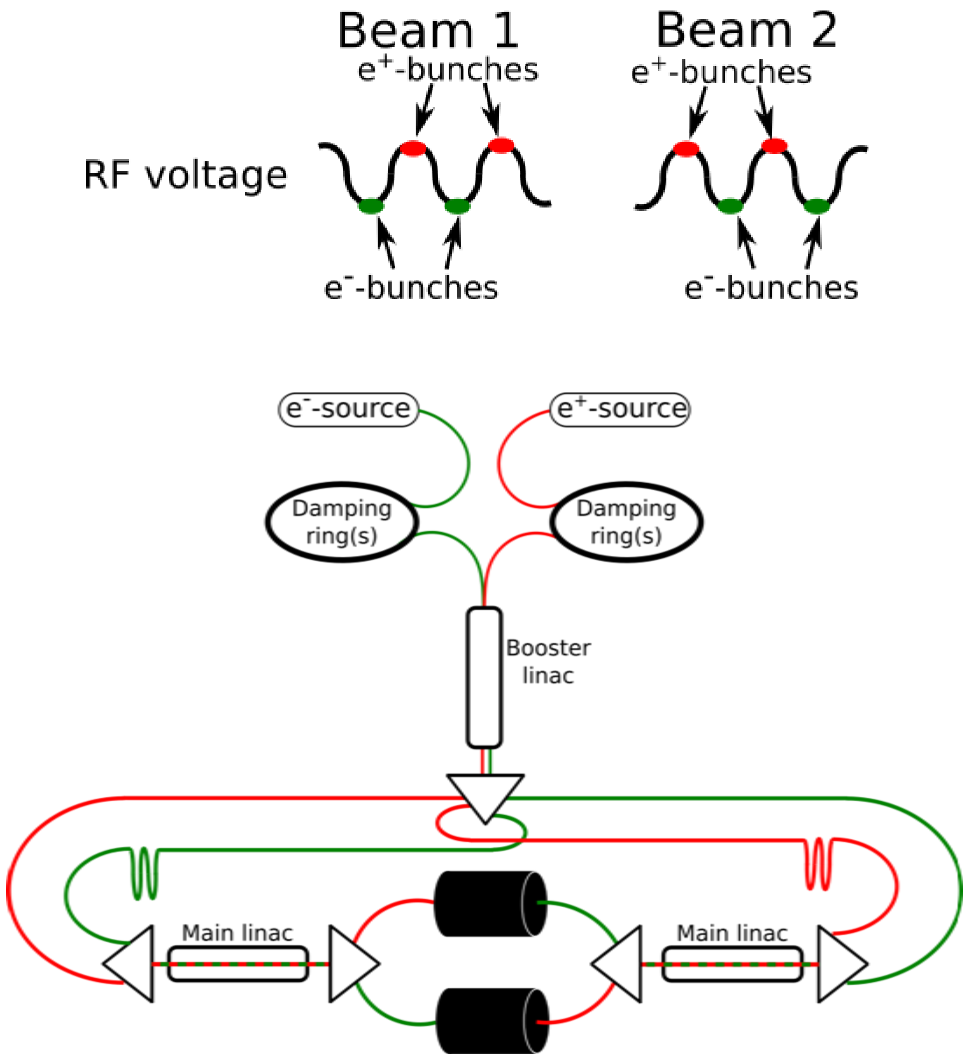
Dual experiment CLIC with combined e^+e^- beams

Original CLIC layout





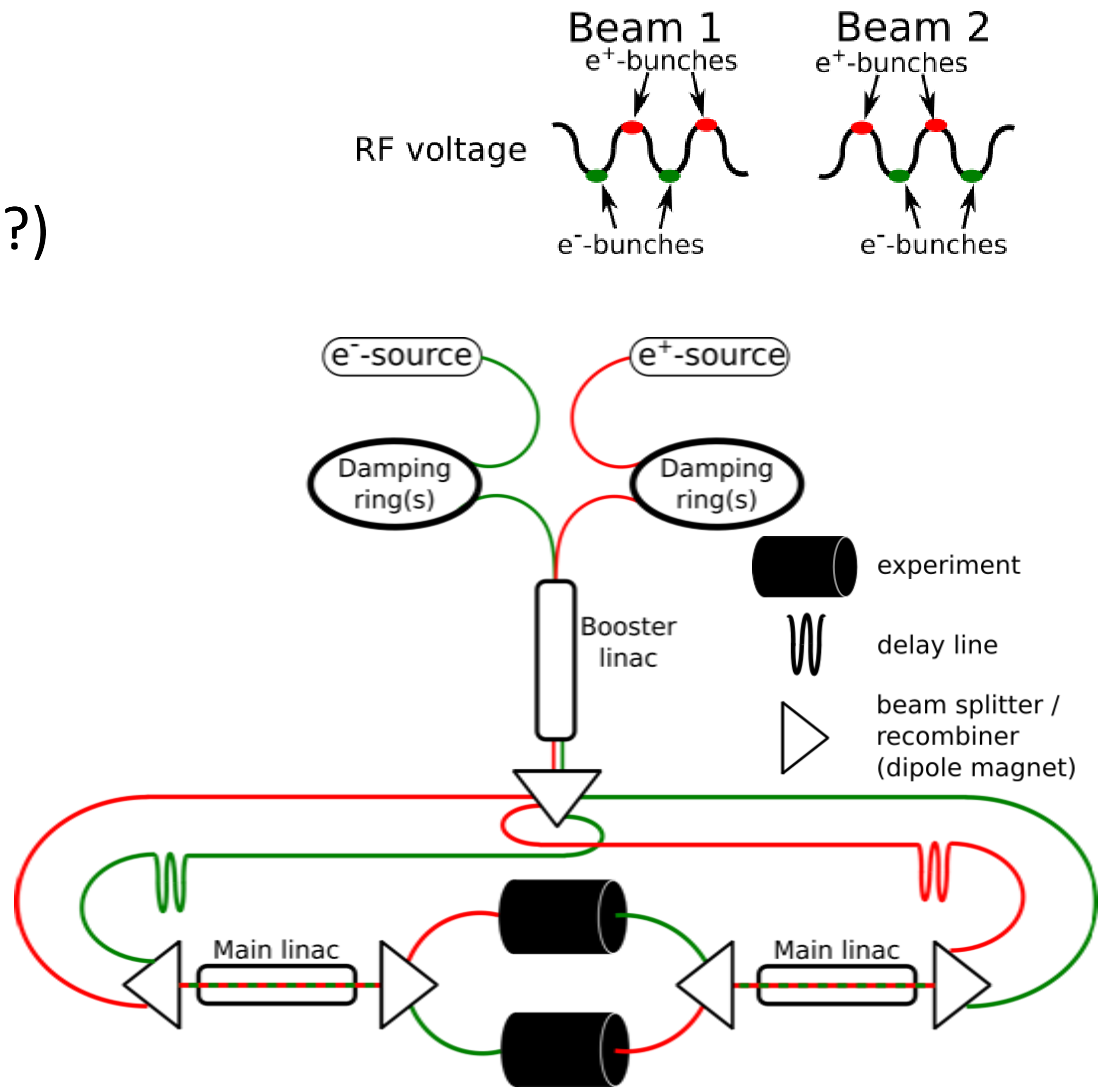
Combined-beams CLIC layout



Dual experiment CLIC with combined e^+e^- beams

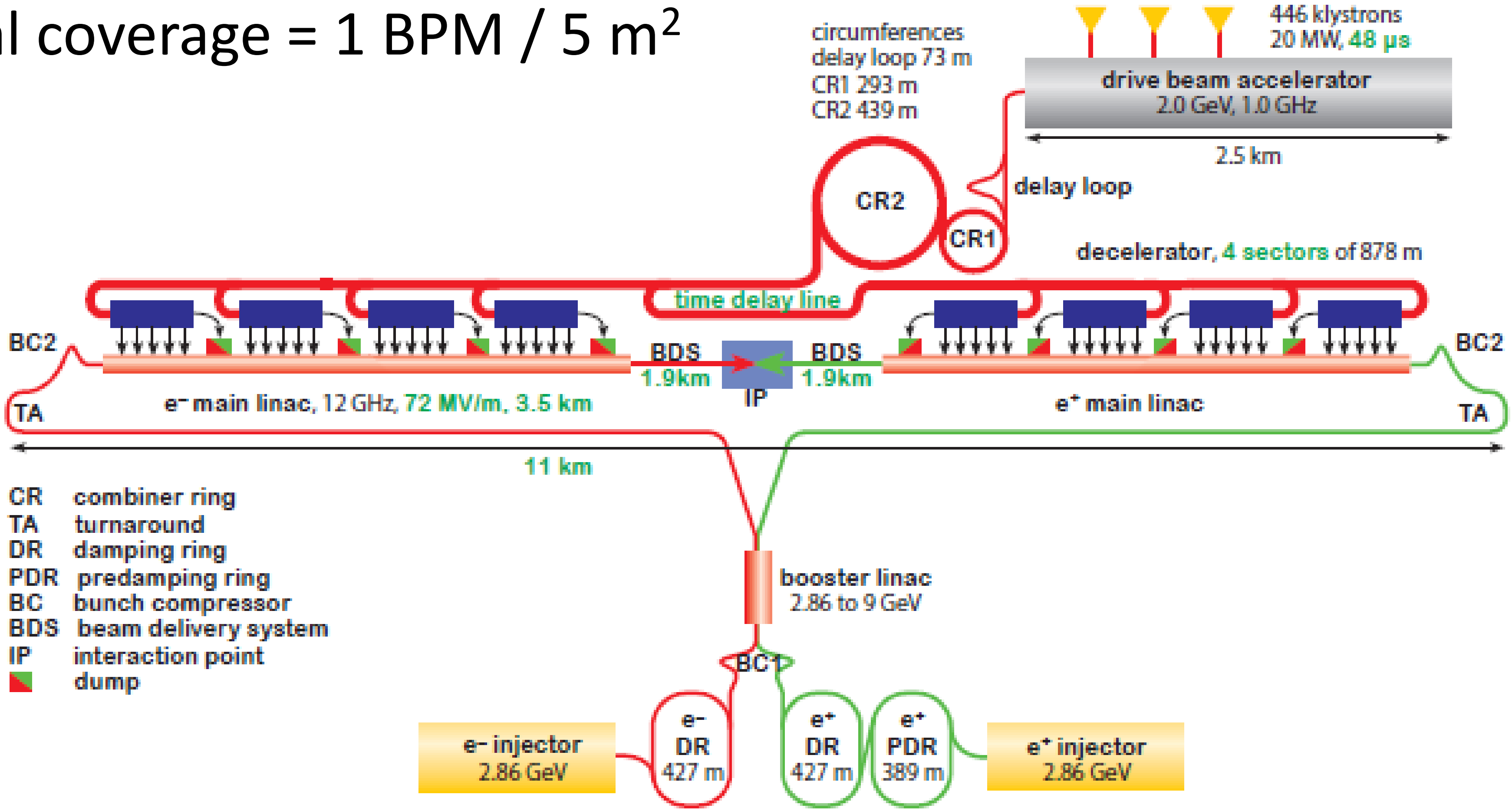
- Appealing benefits
  - Two experiments
  - More stable beams – self stabilisation (?)
  - Shorter RF pulse

- Inspiring challenges
  - Beam quality
  - 0 A beam diagnostics
  - More complex
  - Beam synchronization
  - Extra beam lines
  - Beam split into two experiments
  - Reduced luminosity or more RF power



Beam-based coherent CLIC motion monitoring

- 11 km long, 10 m wide tunnel = ~ 100 000 m^2 area
- ˜ 20 000 BPMs on “three” beamlines
- BPM spatial coverage = 1 BPM / 5 m^2

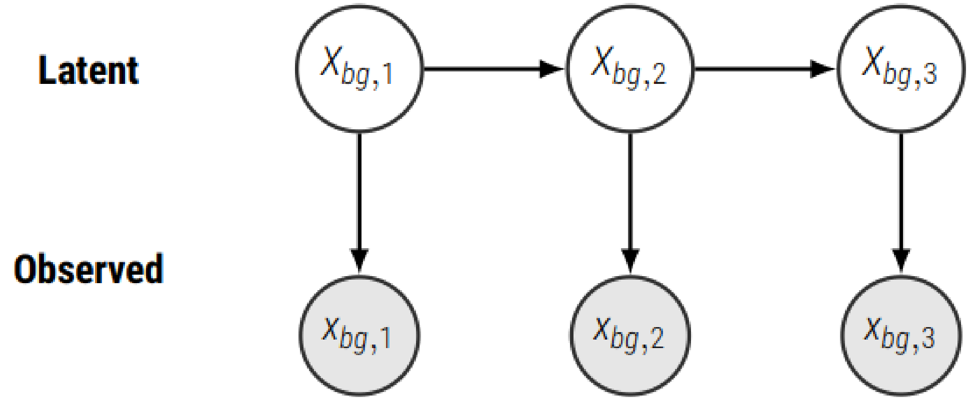


BEAM ALIGNMENT

- Improve the magnet position stability: YES
- Improve the pre-alignment of the beam components:YES
- Improve the beam-based alignment procedures:YES
- Improve the beam-based feedback system design: YES
  - An active stabilization system exists which corrects magnet motion but needs to be improved.
  - Pre-Alignement performance low (BPM, quadruple and module offset, cavity tilt) requires more efficient technics like dispersion free steering for BPM offset.
  - Dynamic imperfections: ground motion, RF amplitude and phase jitter, magnet power supply ripple lead to direct luminosity loss.
  - Displacement of final doublet (FD) causes similar displacement of the beams at the IP (L^*=6 m).
  - Stability of FD requires a fraction of nanometer accuracy.
  - Luminosity is directly related to the gain on beam stabilily (static and dynamic): gain $\propto \varepsilon_y$ and $1/\varepsilon_y \propto \mathcal{L}$.
  - The idea is to predict the beam trajectory and to correct misalignment in advance.
  - Valid for both static and dynamic imperfections.

Location	Design limits $\Delta\varepsilon_y$ [nm]	Static imperfect. $\Delta\varepsilon_y$ [nm]	Dynamic imperfect. $\Delta\varepsilon_y$ [nm]
Damping ring exit	5	0	0
End of RTML	1	2	2
End of main linac	0	5	5
Interaction point	0	5	5
Sum	6	12	12

GROUND MOVEMENT FEED FORWARD SYSTEM



- Offline Learning - slow
  - Learn the model
  - Unsupervised machine learning problem

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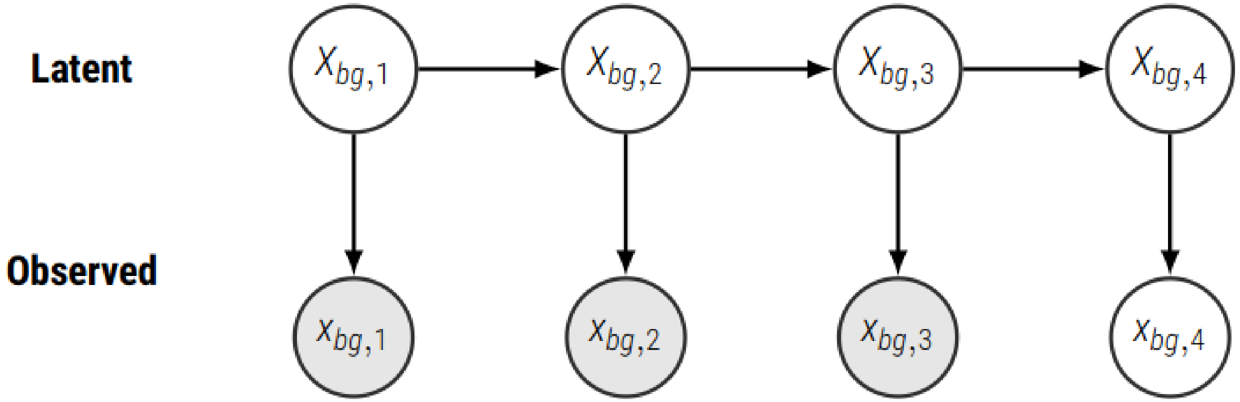

- Offline Learning - slow
  - Learn the model
  - Unsupervised machine learning problem

- Online Predictions - fast

COST SAVINGS

- **clicstarter**