Beam dynamic specifications for CLIC WFM

CLIC towards Readiness Report 2025-26 - Wakefield Monitors

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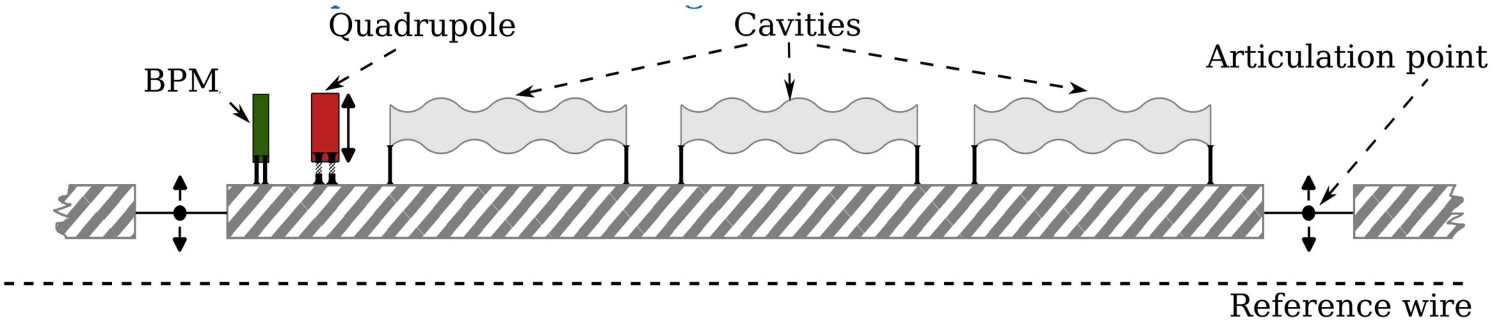
BBA in the CLIC ML



- **Prealignment:**

RMS Element Misalignments:

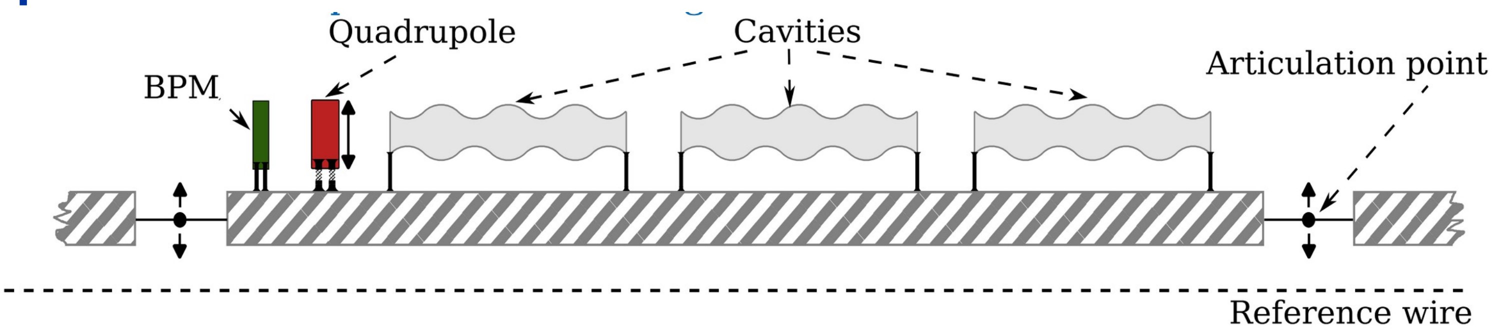
	With respect to	Error value	$\Delta\epsilon_y$ [nm] 1-2-1	DFS	RF
Girder end point	Wire reference	12 μm	12.38	12.27	0.07
Girder end point	Articulation point	5 μm	1.22	1.21	0.02
Quadrupole roll	Longitudinal axis	100 μrad	0.05	0.05	0.05
BPM offset	Wire reference	14 μm	208.82	7.05	0.18
Cavity offset	Girder axis	14 μm	5.01	4.98	0.04
Cavity tilt	Girder axis	141 μrad	0.14	0.41	0.29
BPM resolution		0.1 μm	0.03	0.75	0.05
Wake monitor	RF structure center	3.5 μm	0.02	0.77	0.41

- **Beam Based Alignment**

1) One-to-one correction (**1-2-1**)
2) Dispersion free steering (**DFS**)
3) Accelerating structures realignment with the wake monitors (**RF alignment**)

Budget for the static errors – **5 nm.**

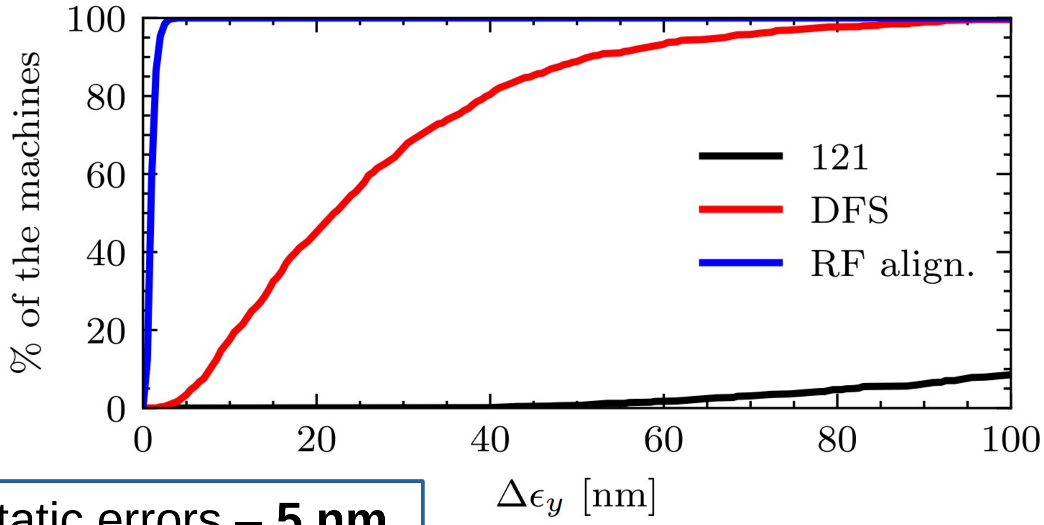
BBA performance



Current performance:

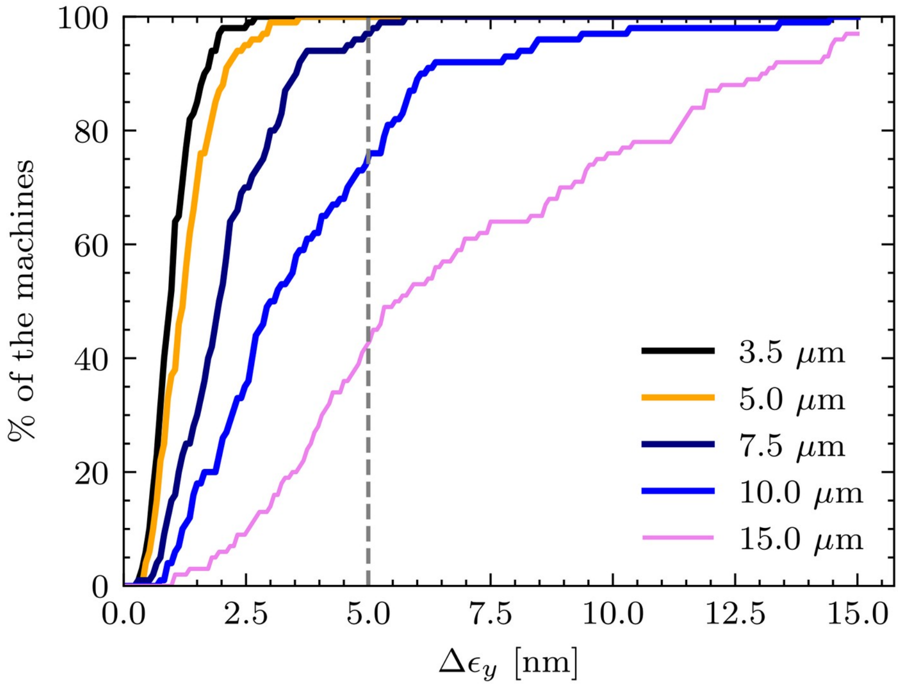
- **100 %** of the machines respect the budget.
- **95 %** of the machines end up with emittance growth below 2 nm

!! For the ideal WFMs' accuracy of <u>3.5μm</u>.



Budget for the static errors – **5 nm.**

RF alignment performance vs WFMs accuracy



We set different accuracy for the WFMs in the BBA simulations:

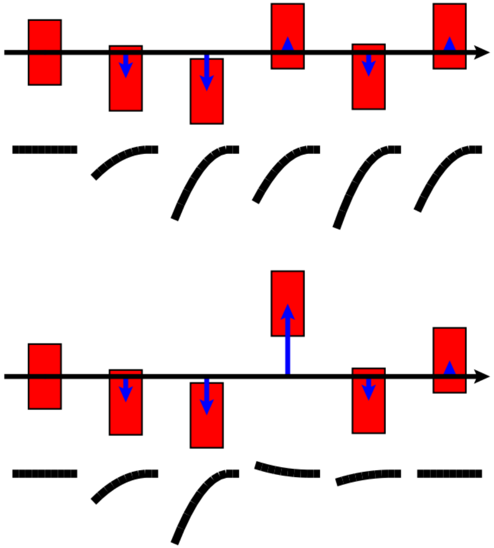
- **For <= 7.5 µm budget is reachable.**
- **For > 7.5 µm budget not respected.**
- **For 10 µm, ~75% of the machines reach the budget**

Budget for the static errors – **5 nm**.

Back-up solution (alternative)

As a back-up solution to the RF alignment, it is possible to use emittance tuning knobs[1].

- **Knob** is a set of redefined lattice modifications to fine-tune the emittance.
- The key idea is to **add the vertical displacement to the cavities** to compensate the unwanted wakefield kicks and **reduce the emittance**.

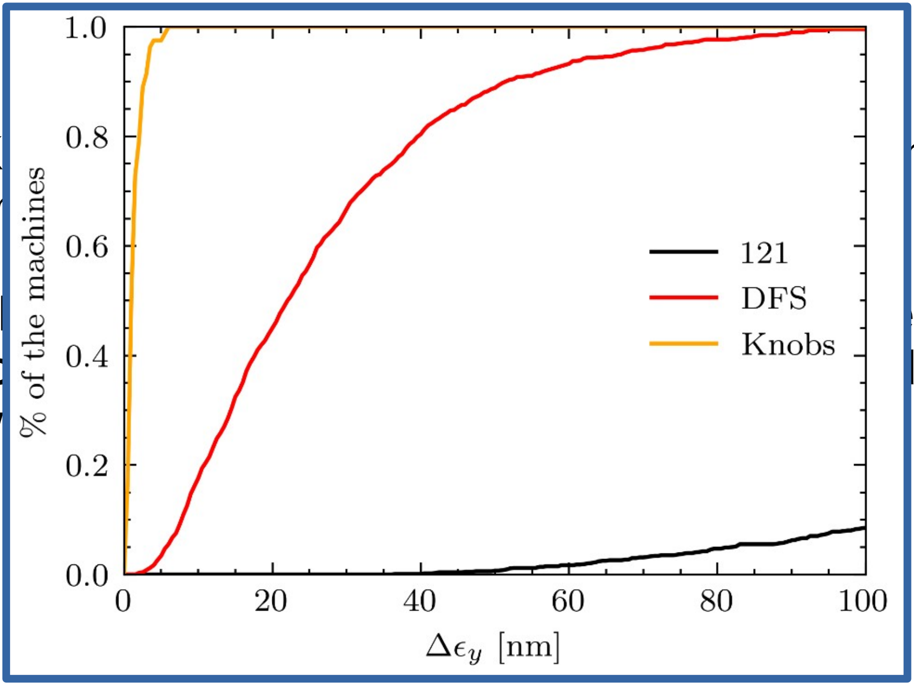


[1] A. Pastushenko, D. Schulte, "*Emittance tuning bumps for the Main Linac of CLIC 380 GeV*", IPAC 2023, THPL087

Back-up solution (alternative)

As a back-up solution to the RF alignment, it is possible to use emittance tuning knobs[1].

- **K** ... ns to fi...
- T... **ement to**... W...



It shows great potential, but there are few things to consider:

- **Number of elements involved.**
- **Elements' offsets.**

the final performance to be explored!

[1] A. Pastushenko, D. Schulte, "*Emittance tuning bumps for the Main Linac of CLIC 380 GeV*", IPAC 2023, THPL087

Summary

- **3.5μm WFMs’ accuracy** provides sufficient margin to fit within the budget for static errors.

- **3.5μm WFMs’ accuracy + emittance tuning knobs** allows to tighten the emittance budget to **~1 nm** and maximize luminosity.

- For the accuracy **> 7.5μm**, the budget is no longer respected.

- It is possible to use the emittance tuning knobs as a backup solution for the WFMs (potential to be explored).

Thank you for your attention!

Back-up

Luminosity performance

- The vertical budgets are the similar to the 3 TeV design. Typically, it is easier to meet the budget for 380 GeV.
- Integrated simulations starting from the exit of the DR to the IP including static errors give the average luminosity of [1]:

$$\mathcal{L} = (3.0 \pm 0.4) \times 10^{34} \mathrm{cm}^{-2} \mathrm{s}^{-1}$$

- With ground motion included:

$$\mathcal{L} = (2.8 \pm 0.3) \times 10^{34} \mathrm{cm}^{-2} \mathrm{s}^{-1}$$

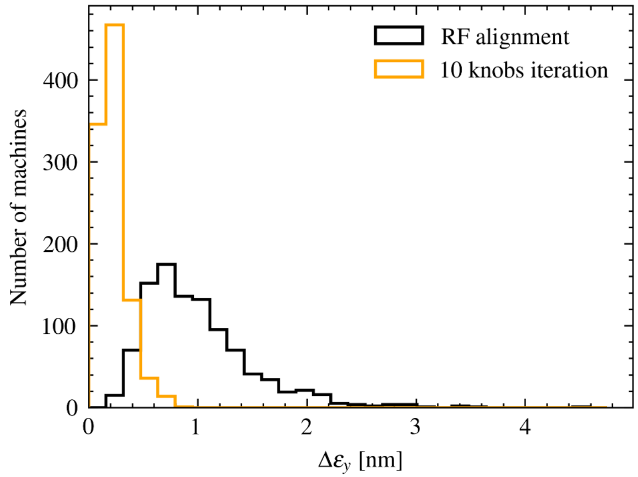
90% of the machines reach the lumi of:

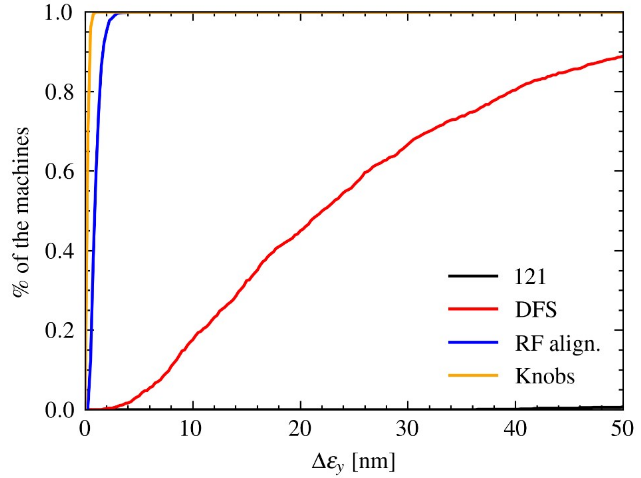
$$\mathcal{L} = 2.35 \times 10^{34} \mathrm{cm}^{-2} \mathrm{s}^{-1}$$

[1] C. Gohil, et. al. "*Luminosity performance of the Compact Linear Collider at 380 GeV with static and dynamic imperfections*", 2020,PhysRevAccelBeams.23.101001

BBA + knobs

- We perform the knob scans after the RF alignment
- Each knob is scanned once.
- **After the knobs tuning:**
  100% of the machines - < 0.8 nm
  95% of the machines - < 0.5 nm





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