Correction methods in the CLIC Drive Beam

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Acknowledgments to E. Adli, A. Latina and D. Schulte

The Drive Beams provide the RF power to the colliding beams

It has to provide it within the required pulse-to-pulse and intra-pulse

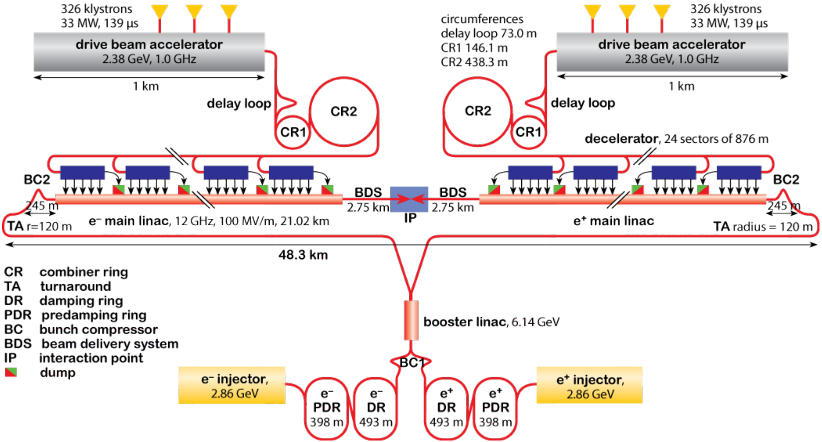
- amplitude stability,
- phase stability,

and by optimizing overall

- power efficiency
- and system complexity.

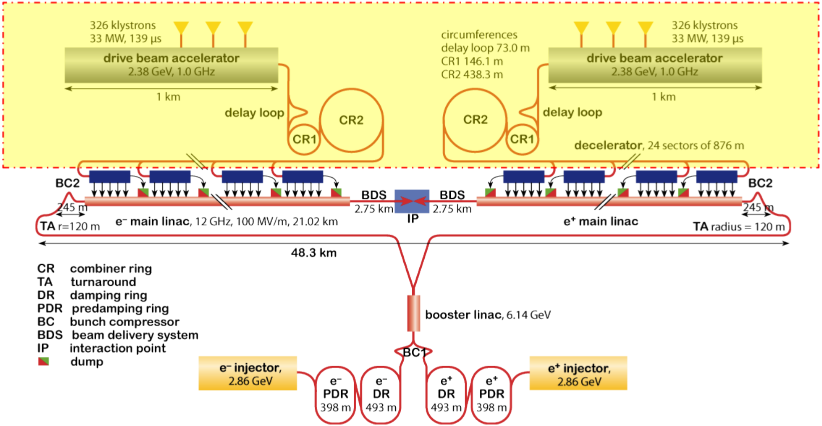
From RF to DB specs

1. beam current stability,
2. form factor stability,
3. phase stability.

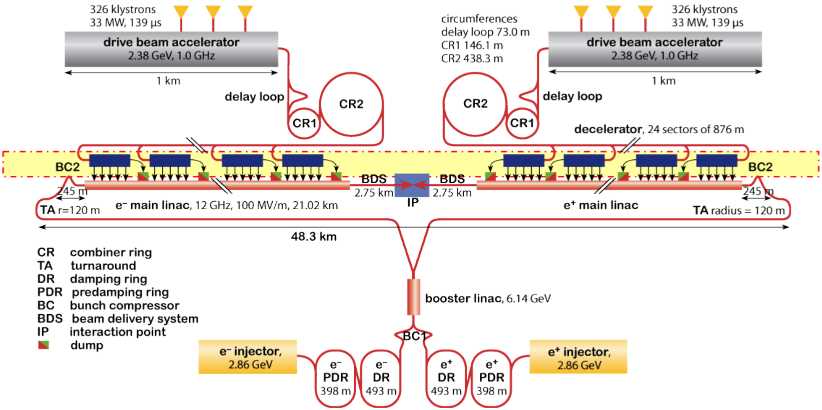


All DB systems play a role in the achieving the performance!

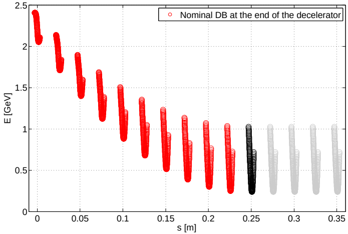
...but trying to (over)simplify it...

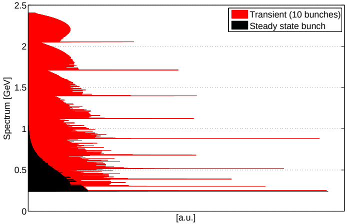


The “monochromatic” region of the DB complex (up to the turn around) will mostly cope with form factor and phase stability.



The decelerators will mostly cope with current stability. In this presentation we discuss about baseline and alternative correction methods for increasing the energy acceptance of the decelerator.



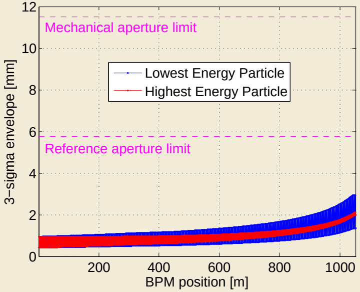


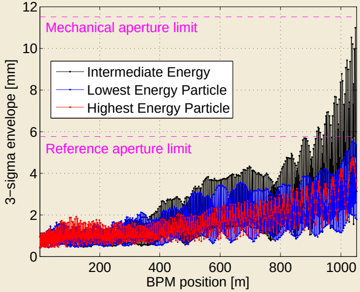
The GOAL

To meet the specified beam current stability ($\Delta I/I = 0.75\ 10^{-3}$) and power extraction efficiency (90%) we have to maximize the decelerator energy acceptance. This is done by

1. choosing a FODO lattice solution (during design phase),
2. minimizing the envelope growth produced by the transversal kicks received by misaligned HW components (during commissioning phase). Local correction is required.

The metric chosen to quantify this problem is the 3-σ beam envelope.



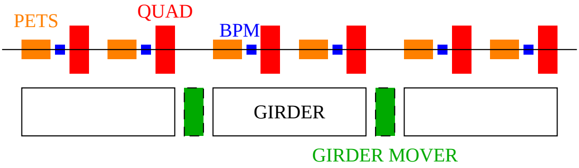


Beam based aligned is needed!

- To minimize the beam envelope we need Beam-Based Steering: we minimize the beam position (1-to-1) and after the dispersion (DFS). Non-linear $\rightarrow$ linear: the optimal solution of the linear problem minimizes the non-linear problem too.
- In theory both quad and PETS should be aligned: in practice the PETS effects is negligible...

We perform the correction only on the quads

1. H-V movers for all quadrupoles (QBBA) ← CDR BASELINE.
2. H-V correctors integrated in the quads.
3. Re-using the H-V actuators on the girder (GBBA).



The steering using the girder

- it implies a significant complexity saving in terms of HW,
- it has not all the flexibility of the previous methods: due to the "snake configuration" we ave only half of the needed degree of freedom and by moving the girder we move also the PETS and the BPMs.

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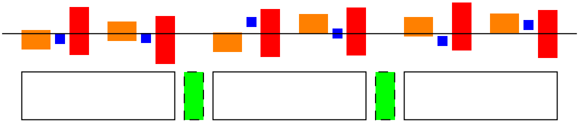

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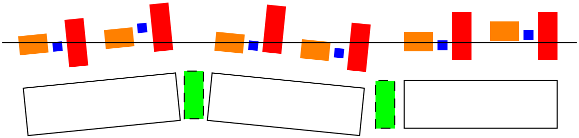

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Specs/assumptions on the HW and pre-alignment.

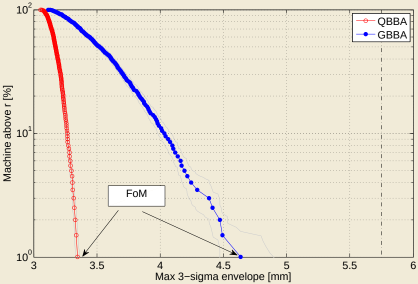
Parameter	**Value**	**Unit**
BPM accuracy	20	μm
BPM precision	2	μm
σ_{quad}	from 20[a] to 55	μm
σ_{cradle}	10	μm
Girder Movers resolution	2	μm
Quad Movers resolution	2	μm

[a] CDR specification

Important

- σ_q reference to the alignment of the magnetic center of the quadrupole with respect to the perfect aligned girder.

Figure of Merit (FoM) to compare the performance

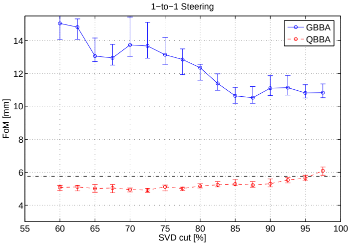


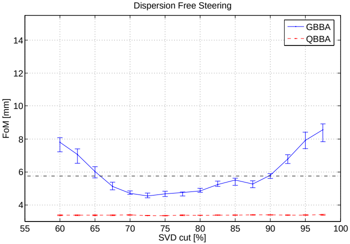
We use the survival function $f(x)$ to compare the performance of two methods and the synthetic Figure Of Merit considered it $\bar{x}$ given by $f(\bar{x}) = 1\%$. Our reference is the half PETS radius: 5.75 mm.

Optimization of the number of SV's

We assume $\sigma_Q = 50\ \mu$m

- 1-to-1 steering: the QBBA performance is clearly better than the GBBA. For the GBBA an optimal correction is reached using 85% of the SV's.
- DF steering: still QBBA is better than GBBA, moreover QBBA has a very weak dependence of the number of SV used. For the GBBA an optimal correction is reached using 75% of the SV's.



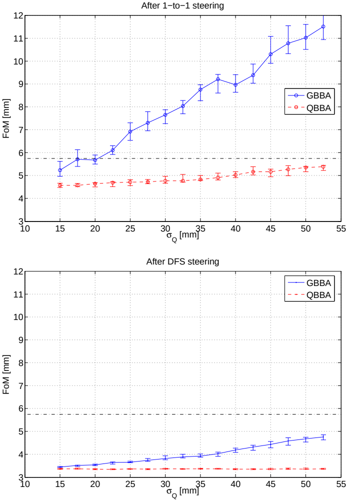


Performance of QBBA wrt σ_Q

- 1-to-1 steering: linear dependence on σ_Q.
- DF steering: while GBBA conserves its linear dependence vs σ_Q, QBBA is independent on the initial and systematically better than the GBBA. GBBA presents a linear dependence vs σ_Q.

Some scenarios...

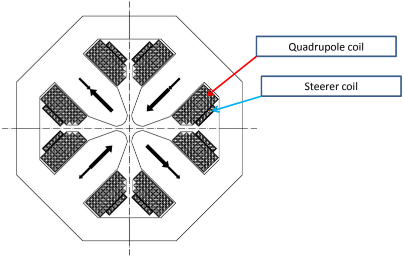
- $\sigma_q < 30\ \mu$m: the girder option is interesting
- $30 < \sigma_q < 50\ \mu$m: complexity/flexibility trade-off is not so evident.
- $\sigma_q > 50\ \mu$m: the GBBA capability is too limited.

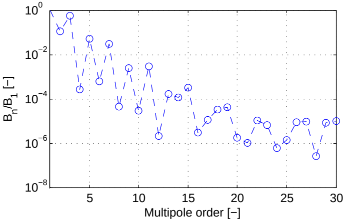


In the QBBA, instead of the quadrupole movers dipole correctors can be used.

Using dipole correctors...

- Due to the geometry constraint of the CLIC module, integration of dipole correctors in the quad's in under investigation (H/V dipole per quad): the designed $\int Bdl$ is 12 mT·m.
- A severe systematic multipolar content is obtained: saturation of quad iron shape. What it is effect on the DB? We were conservative in the multiples considered since we assumed the worse case (max gradient and max correction, i.e. deeper saturation).



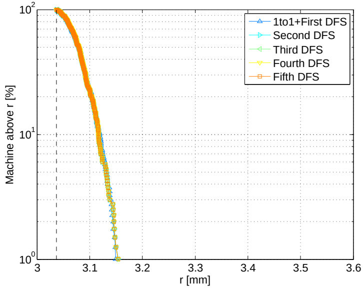


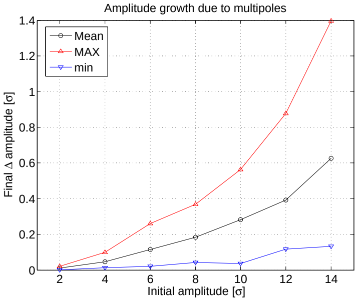
Courtesy of Alexey Vorozhtsov.

Using dipole correctors...

- The motion of the centroid it is not significantly affected by the multiples: the correction algorithm is stable.
- Halo studies were performed. In the bottom plot we show the amplitude increase at the end of the decelerator: for the interesting amplitude ($< 3 - 4\sigma$) the diffusion is visible but $< 0.1\ \sigma$.

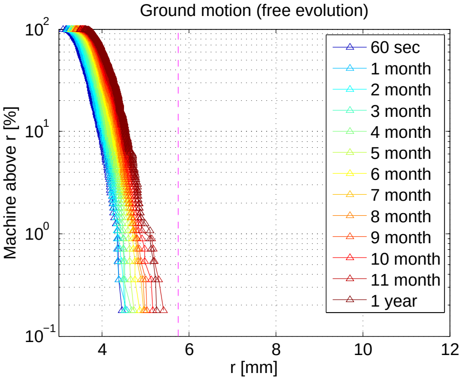
$\rightarrow$ The present multipolar content does not seem a show stopper.





How often do we need to realign the decelerator?

Assuming ATL ground motion with A=0.5 10^{-6} $\mu m^2/$ (s m) after 1-2 months we observe in simulations 100÷200 μm of envelope growth: we can correct it by 1-to-1 correction on the golden orbit.



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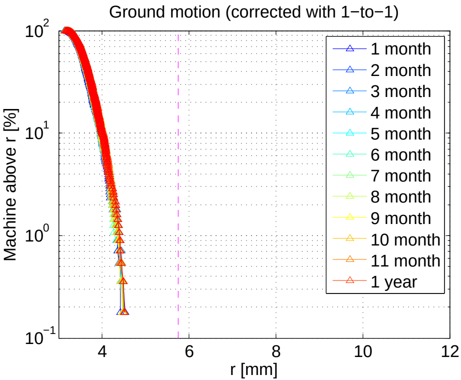

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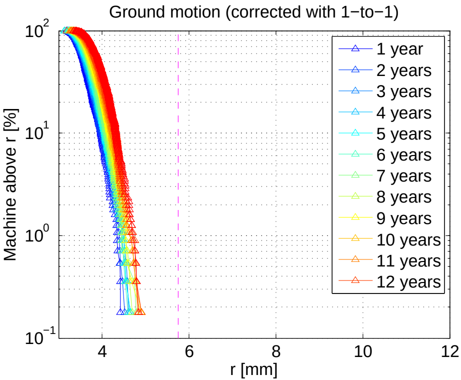
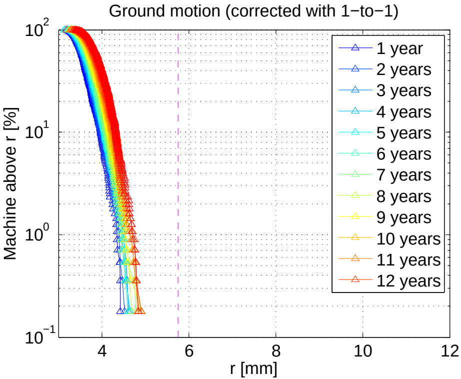


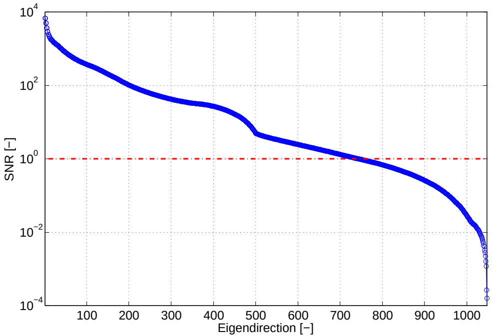


After some times the BPM motions starts to invalid the approach. . .

...but assuming a static linear response between BPM and girder position we can recover the initial performance of the DFS inverting the system

$$\mathbf{R} \times \Delta_{GIRDER}(t) = \Delta_{BPM} + \underbrace{\delta_{BPM}(t)}_{\mathbf{T} \times \Delta_{GIRDER}(t)}$$

- Minimizing the requires corrections can be beneficial in term of complexity/cost.
- In theory the rms correction requested is σ_q (typically the range requested range is $\pm 3\sigma_q$)
- Since the GM effect is slow wrt the beam pulse rate (50 Hz) one can profit of statistical averaging and correct only the eigen-directions with a limited uncertainty.



Conclusions

- To produce in a stable and efficient way the needed RF power, BBA steering has to be performed along the DB decelerator.
- Three different possibilities of HW implementation have been considered and compared. Depending on the initial σ_q, steering using the girder can be interesting and in any case we can recover full performance combining girder correction with half of quadrupole movers or dipoles.
- The expected multipolar content of dipoles is not a show stopper.
- Since the GM effect is slow wrt the beam pulse rate (50 Hz) one can profit of statistical averaging so reducing the requested correction range.
- Testing of this algorithms are on going in the the Test Beam Line of CTF3.

Thank you for your attention!

More information...

G. Sterbini, *TBL optics studies and automatic steering*, WP6

E. Lacoma and G. Sterbini, *Status of the CLIC decelerator*, WP6

E. Adli, Ph.D. Th., *A Study of the Beam Physics in the CLIC Drive Beam Decelerator*.

G. Sterbini and D. Schulte, *BBA of CLIC DB decelerator using girder movers*, IPAC2011