Status of the CLIC decelerator

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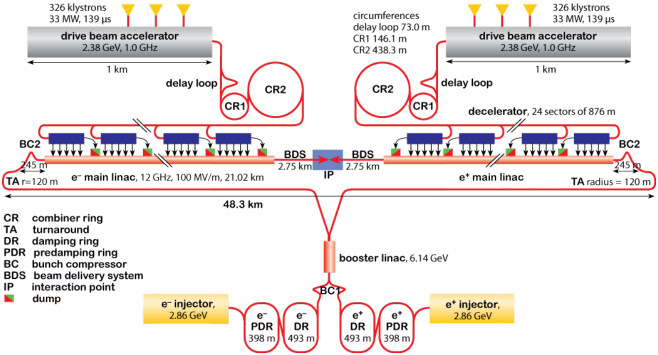
LCWS11, Granada, Spain
28 September, 2011

Acknowledgments to **E. Adli** and D. Schulte

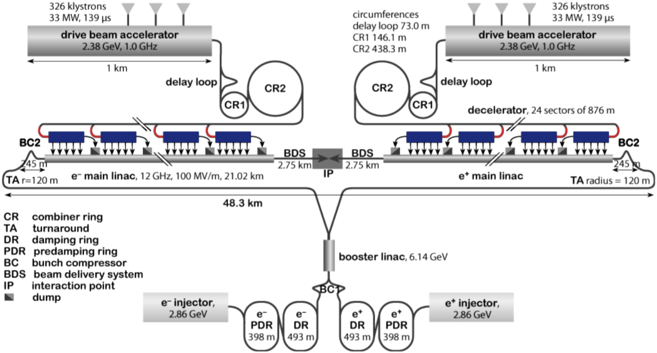


Fundamental requirements for the DB complex

Each PETS has to feed two AS's with 12 GHz frequency. They has to provide:

1. $\approx$ 135 MW power
2. $\approx$ 170 ns long at 50 Hz repetition
3. in a efficient and robust way.

Each of the 2×24 decelerators has 1492 ± 1 PETS and variable length ($\approx$ 1 km).



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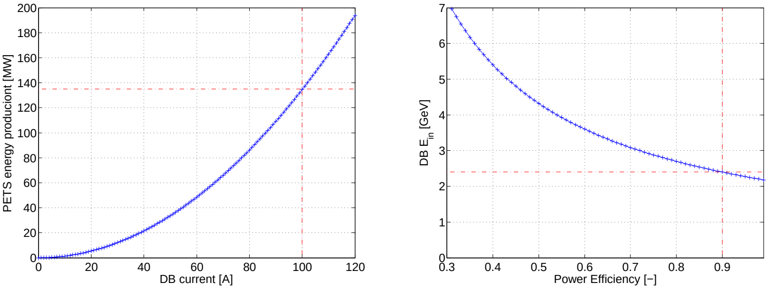
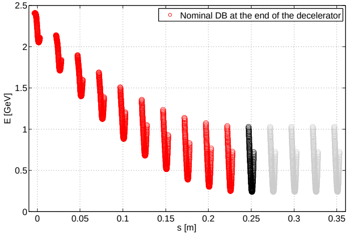
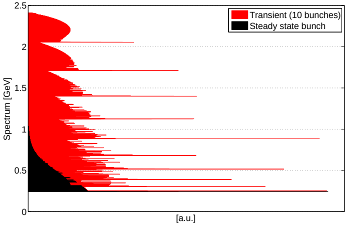


Regarding efficiency

The DB current is given by the 135 MW requirement on the PETS.
Before dumping the spent 2×24 DB pulse we have to extract 90% of the DB energy $\rightarrow$ it sets the $E_{in} = 2.4$ GeV ($E_{out} = 0.24$ GeV).





The 90% efficiency requirements induces a significant energy spread in the DB

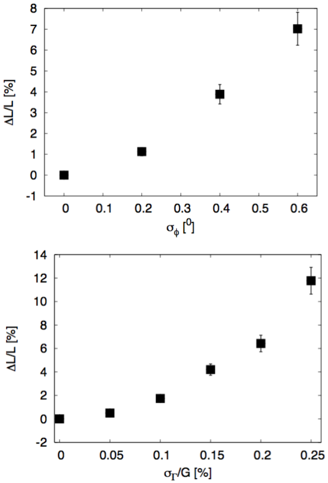
- The filling time of the PETS produces a transient in the first 10 bunches.
- The intra-bunch wake produces an important intra-bunch energy spread.

Transport such a beam for 1 km is a challenge.

Regarding stability (from D. Schulte et al.)

The gradient and phase stability required from the colliding beam determines the required DB stability.

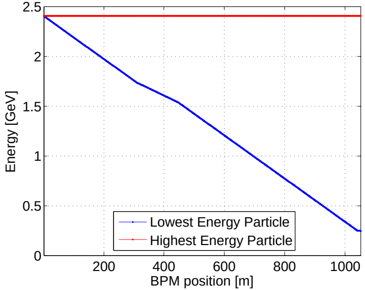
1. DB Phase stability
$$\frac{\Delta L}{L} \approx 1\% \left[\left(\frac{\sigma_{\phi,coh}}{0.2^\circ} \right)^2 + \left(\frac{\sigma_{\phi,inc}}{0.8^\circ} \right)^2 \right]$$
2. DB current stability
$$\frac{\Delta L}{L} \approx 1\% \left[\left(\frac{\sigma_{I,coh}}{0.75\times10^{-3}\ I} \right)^2 + \left(\frac{\sigma_{I,inc}}{2.2\times10^{-3}\ I} \right)^2 \right]$$
3. DB factor form stability
$$\frac{\Delta L}{L} \approx 1\% \left[\left(\frac{\sigma_{\sigma_z,coh}}{1.1\times10^{-2}\ \sigma_z} \right)^2 + \left(\frac{\sigma_{\sigma_z,inc}}{3.3\times10^{-2}\ \sigma_z} \right)^2 \right]$$

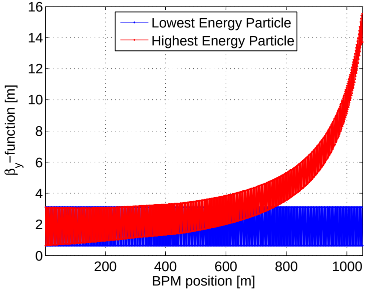


The decelerator cannot improve but has to preserve the stability of the incoming beam.

Decelerators have to transport the beam

- efficiency: minimizing the static beam losses.
  $\longrightarrow$ HOW? Maximize the energy acceptance.
  1. FODO lattice
- stability: preserving the incoming beam stability of $\Delta I/I, \sigma_z$, and ϕ
  $\longrightarrow$ HOW? Minimizing sensitivity to non idealities.
  1. minimize dipole wake instability (strong focusing + PETS design)
  2. correct parasitic dispersion due to quad's misalignments (pre-aligment+BBA steering)

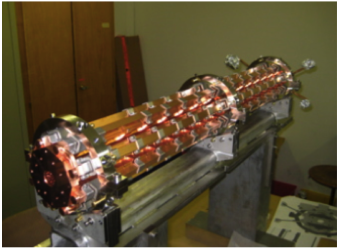


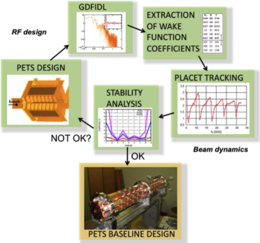


FODO lattice choice (from E. Adli et al.)

The FODO lattice has a large energy acceptance.

If we adjust the phase quad strength for having a constant focusing for the most decelerated particle the higher energy envelope is smaller than the the lower energy one due to a compensation between the different β-function and adiabatic undamping.



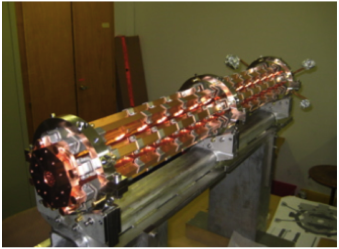


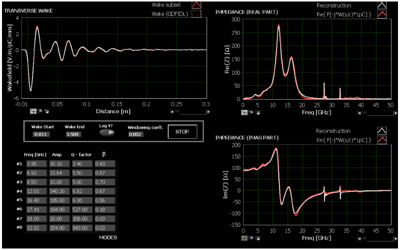
Dipole wake instability (E. Adli, A. Cappelletti et al.)

Assuming and ideal-aligned machine but a DB entering with an offset in the decelerator this can potentially produce a resonant amplification of the transverse oscillation of the beam: resonance between the natural transverse modes of the beam and PETS.

1. iterative design between PETS and lattice
2. driven by optimization of the PETS transverse mode effect
3. and by increasing the strength of the focusing

→ 2 m long FODO cell, $\Delta\mu = 90^\circ$ (number of quad's and their $\int Gdl$).





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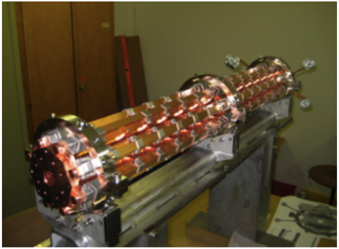

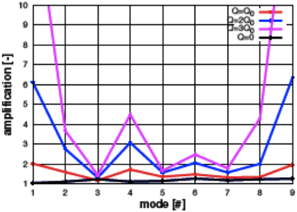

(a) Dipole mode amplification

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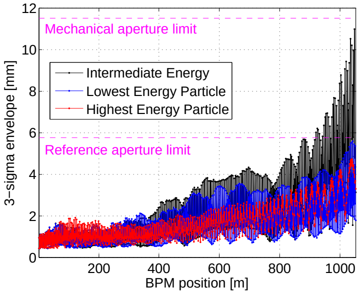
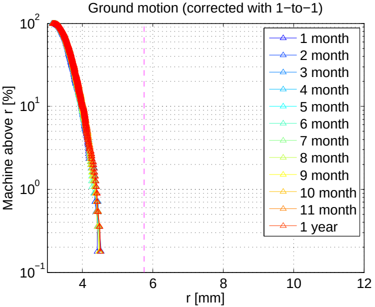




BBA alignment is needed

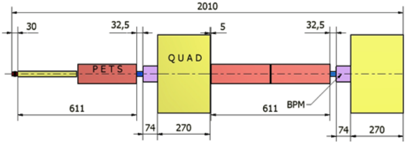
Even the advance pre-alignment techniques used for CLIC are not expect to be sufficient for the required beam current stability.
→ BBA alignment is needed: we need movers to correct the H/V positions of the decelerator quad's and we need a high precision BPM to compute the needed correction.

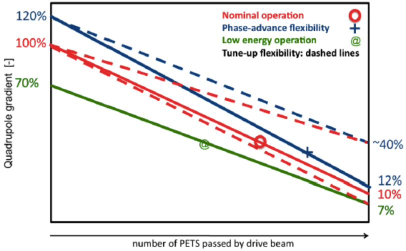
See G. Sterbini, "Correction methods in the CLIC drive beam", 28 Sep 2011

Decelerator quadrupole

- each FODO cell will correspond to the 2 m long girder,
- $\approx$ 42k quadrupoles for CLIC decelerators,
- the required gradient will vary linearly along the decelerator,
- powered magnet (baseline, serial trimmer powering) and PM option

Parameter	Value
# DB quad	$\approx$42k
r_{inner}	11.5 mm
$\int Gdl$ @ 100%	12.2 T
$\sigma_{\int Gdl} / \int Gdl$	10^{-3}
σ_I / I	$5\ 10^{-4}$





100% corresponds to a quadrupole gradient of 81.2 T/m (assuming a magnet active length of 0.15 m)

Thanks to E. Adli, J. Clarke, M. Modena, G. Riddone, S. Pittet, A. Samochkine, B. Shepherd, A. Vohorotzov. . .

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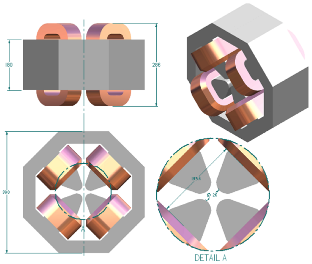

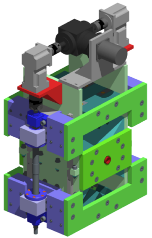

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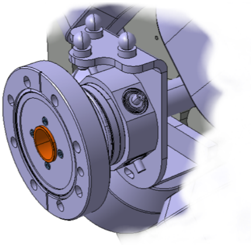
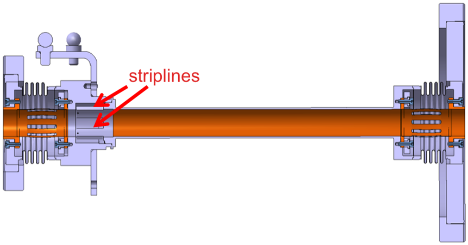
BPMs (E. Adli, S. Smith, L. Soby et al.)

Parameter	Value
Decelerator BPMs	≈28k
BPM accuracy	20 μm
BPM precision	2 μm
Time resolution	60 ns

- Simulations show we can have 2 BPM per 3 quads,
- Accuracy is driven by 1-to-1,
- Precision is driven by DFS.





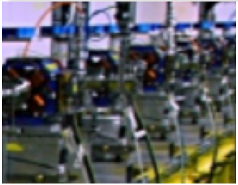
Movers

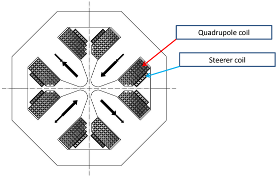
In order to correct the quadrupoles we have three solutions

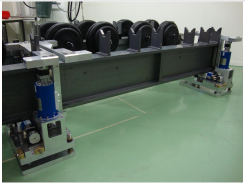
1. H/V movers for each quadrupole or dipolar coils correction → baseline
2. H/V dipole correctors combined in the quadrupole
3. H/V Girder movers (already foreseen for pre-alignment)

Parameter	Value	Unit
Girder Movers resolution	2	μm
Quad Movers resolution	2	μm
Quad Movers range[a]	$\pm 3\sigma_q$	-
Girder Movers range	± 3	mm

[a] equivalent requirements on the correctors







Specs/assumptions on the HW and pre-alignment.

Parameter	Value	Unit
BPM accuracy	20	μm
σ_{quad}	20	μm
σ_{cradle}	10	μm
σ_{PETS}	100	μm
$\sigma_{PETS-longitudinal}$	100	μm
θ_{PETS}	1	mrad
θ_{quads}	1	mrad

Important

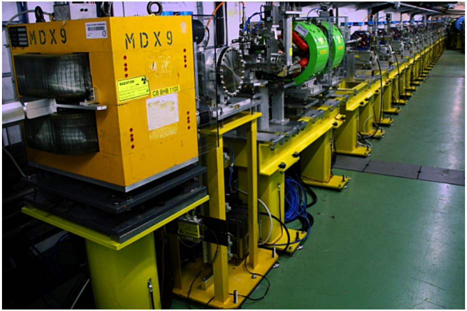
- σ_q reference to the alignment of the magnetic center of the quadrupole with respect to the perfect aligned girder.
- The BPM accuracy reference to the total accuracy (electronics, BPM mechanics and alignments)

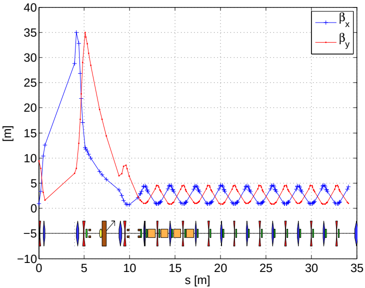
Fast-ion instability (G. Rumolo et al.)

Analytic approximations, neglecting the large energy spread, yields one fast-ion instability rise-time with p = 40 nTorr. Decelerator Spec: $p < 40$ nTorr

Resistive wall instability (B. Jeanneret et al.)

Analytic calculations yield a significant (unacceptable) amplification of beam offsets for $\sigma_{res} = \sigma_{ss}$ while negligible for $\sigma_{res} = \sigma_{Cu}$.





Test Beam Line and more

1. The natural test of the decelerator concept/optics is the TBL in CTF3. First results are encouraging, but soon with the additional 5 PETS recently installed we expect to push further the total deceleration: steering algorithms and transport efficiency can be tested. Much more difficult is to test the dipole wake (in)stability. . .
2. Modules test is important for checking pre-alignments techniques.
3. Magnetic measurements on the DB quads soon at CERN.

Summary

- Based on many contributions, I gave you a snapshot of the decelerator status trying to emphasize the driving parameters of the design choices.
- The proposed optics can cope with the expected PETS transverse modes.
- Beam based alignment is essential.
- Main specification on the HW are defined (tight but feasible) for
  - quadrupole,
  - BPM,
  - movers,
  - pre-alignments tolerances,
  - vacuum and vacuum chamber impedance.
- Experimental results are crucial and are on the way in TBL (deceleration, transport, steering) and modules test (pre-alignment).

Thank you for your attention and to all those provide me these inputs!

Related talks in LCWS11

- S. Doebert, *TBL status and results*
- H. Durand, *Status on CLIC pre-alignment studies*
- M. Modena, *Status on MBQ and DBQ prototypes procurement*
- G. Riddone, *Module layout*
- G. Riddone, *Status of the CLIC module R&D*
- M. Sosin, *Qualification of an adjustment solution for CLIC active pre-alignment on test modules*
- G. Sterbini, *Correction methods for the CLIC drive beam*
- ...