Two-Beam module layout and optics.

J. Esberg,G. Sterbini, W. Farabolini

CERN, Geneva Switzerland.

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Introduction

Motivation

- In the previously proposed design of the Two beam module line, the beam would only narrowly fit within the required aperture.
- Particularly the PETS were problematic.
- Question: Can we do better without too much effort? Quick answer: YES ☺.
- Let us look closer.

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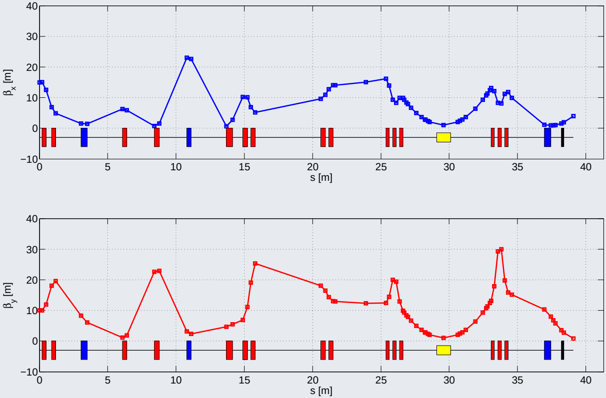
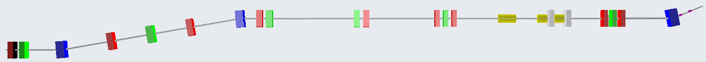
Current optics conditions

- Beta functions in drift regions are parabolas.
- The envelope has to be large at the triplets due to drift length of $\sim$ 5 m.

Current layout



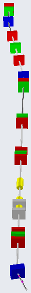
Previously proposed geometry in simulation



Properties of lattice

- The lattice consists of:
  - A horizontal dogleg.
  - Straight section with two beam stand. + 1 old PETS.
  - Momentum determination at the end.
- The needed functionalities are:

1. Zero dispersion in straight (TBTS) section.
2. Ensure small envelope throughought lattice. Particularly in PETS section.
3. Narrow horizontal beam on MTV screen for accurate momentum determination.
4. These requirements must be fulfilled in new design as well.



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Working hypotheses

PETS

- The most decelerated particles experience the voltage $V = \frac{(R'/Q)\omega F(\lambda)\eta_\Omega}{4v_g} L^2 I$ (linac convention).
- $\rightarrow$ Scale deceleration according to $V = 1.4\text{MV}\left(\frac{L}{0.23m}\right)^2 \frac{I}{101A}$.
- For primed PETS, we assume energy conservation - means that the primed PETS decelerate an additional half the decelerating voltage of the first PETS (since the first PETS signal is split into both the final PETS.).
- Assume that the PETS wake behaves as in an RF cavity (on phase).

Assumptions

- Length of PETS 1=1.00 m, Length of PETS 2,3 = 0.52 m.
- Emittance 150 μm. CAUTION - this is smaller than measured.
- Initial twiss parameters $\beta_x = 15$ m, $\beta_y = 10$ m, $\alpha_x = 0$, $\alpha_y = 0$.
- The exact longitudinal positioning of PETS not a criticical.
- The triplet quadrupoles are independently powered.

Neglected contributions

- Envelope size due to spurious dispersion.
- Envelope growth due to spurious orbit.

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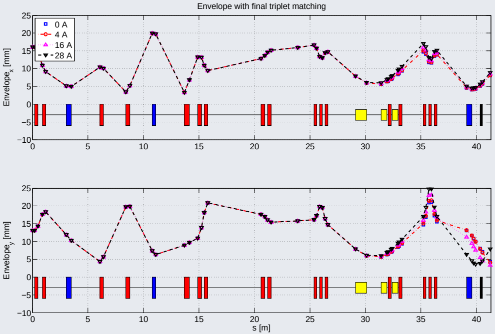
Aperture constraints

- Shown apertures defined as the 3σ envelope of the beam.
- Assume 3 times nominal emittance. Envelope will scale with the square root of emittance.
- In summary: $\text{envelope}_{x,y} = 3\sqrt{3\beta_{x,y}\epsilon_{x,y}\frac{mc^2}{E}}$ (ultrarelativistic)
- A decent choice is $\beta_{x,y} = 1.7$ m at the minimum $\rightarrow$ the 3σ envelope (for 3 times nominal emittance) is smaller than 8.5 mm in the entire PETS region.

Envelope



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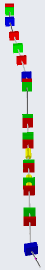
New lattice in simulation

Properties of the new lattice

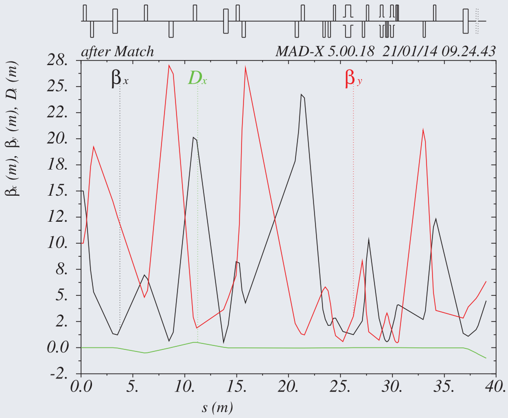
- Changes with respect to current beamline layout:
    - First triplet moved (as a single unit) upstream to give space for setup.
    - Old PETS moved upstream - will require longer waveguide.
    - Doublet introduced in space after old pets. It consists of:
        - The central quad moved from final triplet.
        - One quad found elsewhere.
        - Both are scanditronix QL3 type quads.
- The matching conditions are:

1. Small dispersion in straight (TBTS) section.
2. Ensure small envelope throughought lattice. Particularly in PETS sections, the PETS aperture is 23mm.
3. Periodic solution seen in the module PETS - 93 degree phase advance chosen.
4. Narrow horizontal beam on MTV screen for accurate momentum determination.
5. Last module quad used for matching into MTV.



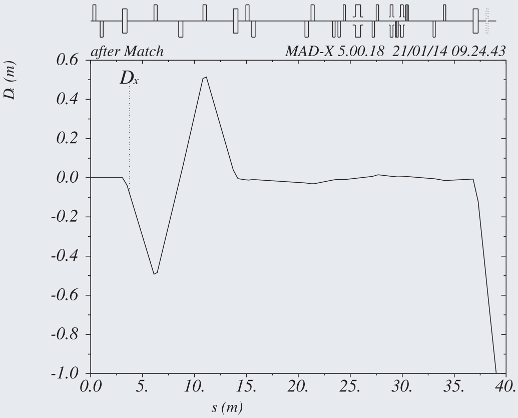
Optics functions

Beta functions



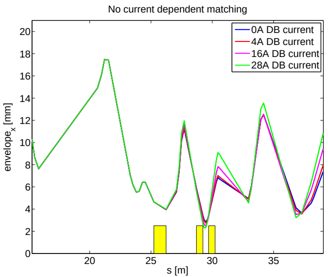
Optics functions

Dispersion

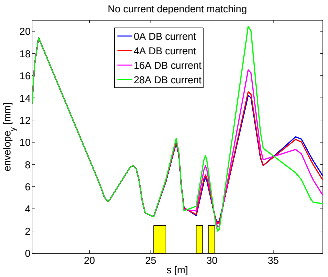


Optics with realistic PETS currents

New optics, without current dependent matching

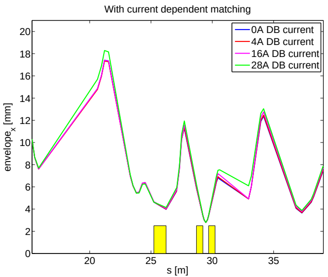


New optics, without current dependent matching

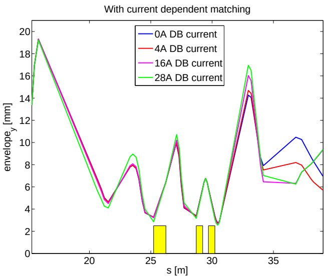


Optics with realistic PETS currents

New optics, with current dependent matching



New optics, with current dependent matching



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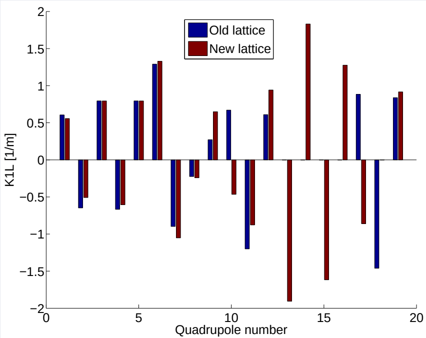
Quadrupole powering

- The diagram shows the integrated quadrupole strengths in the new design (zero beam current) compared to the currenty simulated one.
- Some polarities have changed.
- The new doublet magnets require currents of around 75A.
- 2 quads now have opposite polarity.

Old powering vs. new one



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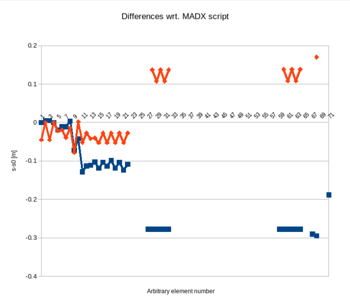
Longitudinal measurements at CLEX

Measurements to gain confidence in model

- Two sets of measurements of the longitudinal positions of elements were performed.
- They both differ from the original MADX implementation by up to ∼30cm.

Possible model errors

- Half the *magnetic* lengths were subtracted from (presumably) measured distances. Should it be half the *physical* length instead?
- The dipoles are defined as pure rbends (rectangular dipoles), this has been confirmed by inspection of the real beamline. Edge focussing is a non negligible effect.



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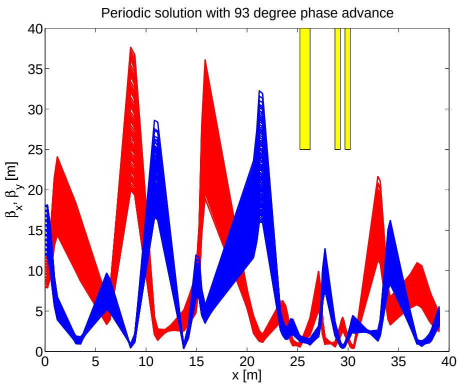
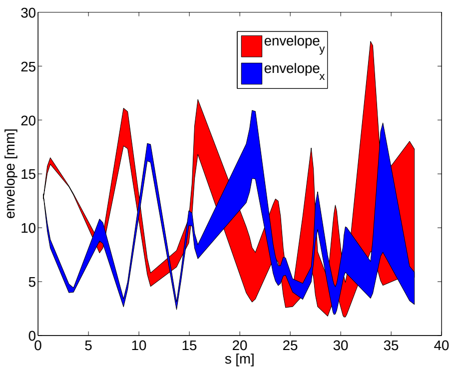
Varying twiss parameters

- Simulate effects of unknown incoming twiss parameters.
- Nominal: β_x=15m and β_y=10m, $\alpha_x = \alpha_y = 0$.
- Vary $\beta_{x,y}$ by $\pm$20% and $\alpha_{x,y}$ in the interval [-0.3;0.3] in a square grid.
- Observe effect on beta beating.

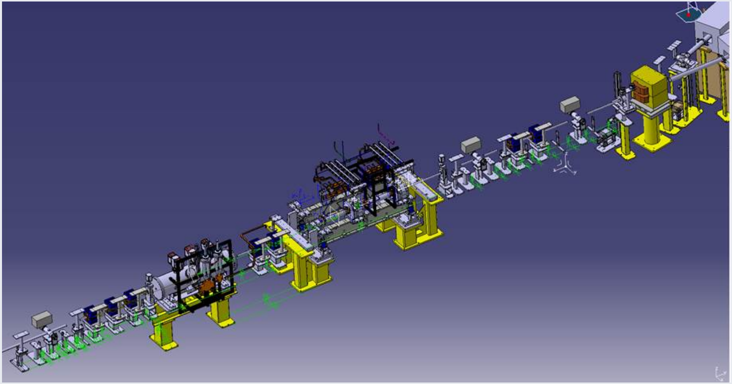


Longitudinal positioning errors.

- Try to estimate the impact of uncertainty of longitudinal positions of elements.
- A “longitudinal response matrix” is not sufficient since the problem is not linear.
- Here shown: A Monte Carlo simulation (PLACET) with 5cm uniformly distributed displacements of the elements.
- 10000 machines - display the maximum and minimum beam envelopes (not sizes).



Real-world design (D. Gudkov)



- Real-world design on the way.
- Additional components soon to be ordered.
- So feel free to comment critically. It is not yet set completely in stone.

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Conclusions

- The new layout decreases the aperture - particularly in the PETS. The PETS aperture is very close to what is currently achieved ☺
- It is quite stable with respect to large imperfections. ☺
- This setup requires: ☹
  - Moving the first triplet (3 quads).
  - Moving the old PETS tank.
  - Moving one magnet from the final triplet.
  - Installing a new quadrupole.
- Quadrupole currents and polarities change with respect to old setup.
- Powering of several quadrupoles should be made beam current dependent for optimum spectrometer performance.
- Powering of the DB quads can be done using a periodic solution of the FODO cell. ☺
- The module quads can not be powered symmetrically. ☹
- We need to gain a little more confidence in the MADX model.
- We need some iterations to ensure that the design can become a physical reality.
- Still simulations of transient effects in existence.
- Still a few more computational checks to do (energy acceptance, transverse response, performance of spectrometer...)
- Beam instrumentation still to be agreed upon.