Optics Misalignment and Correction

PERLE Collaboration Meeting

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Supervisors

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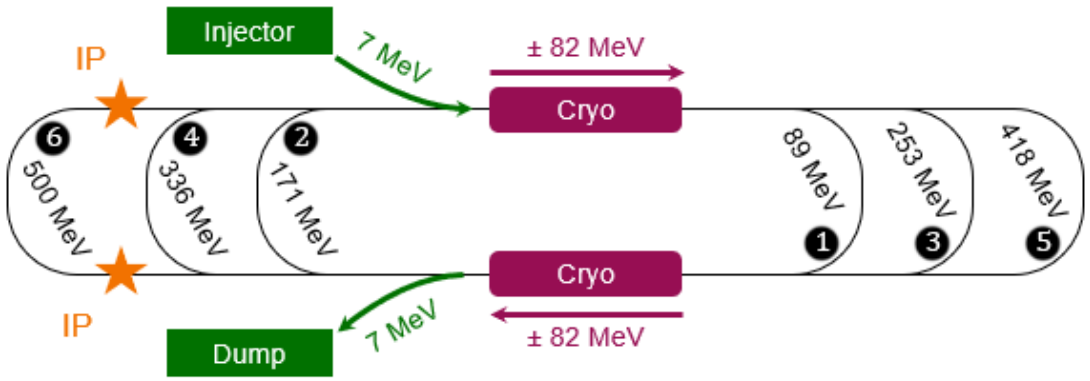
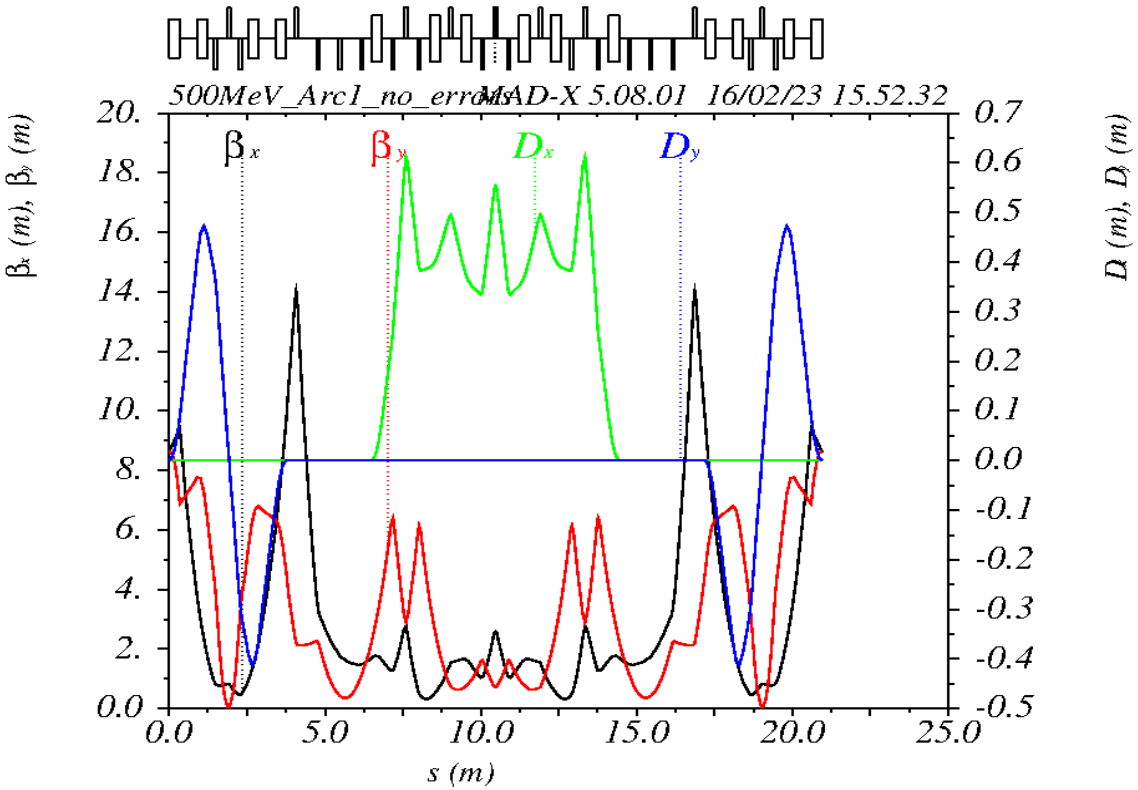
Outline

- Introducing errors to the PERLE lattice
- Misalignment errors:
  - Dispersion function
  - Beta function
  - Alfa function
- Field errors
  - B-com magnet

500 MeV PERLE Lattice

Reproduction of the PERLE 500 MeV machine using MADX.



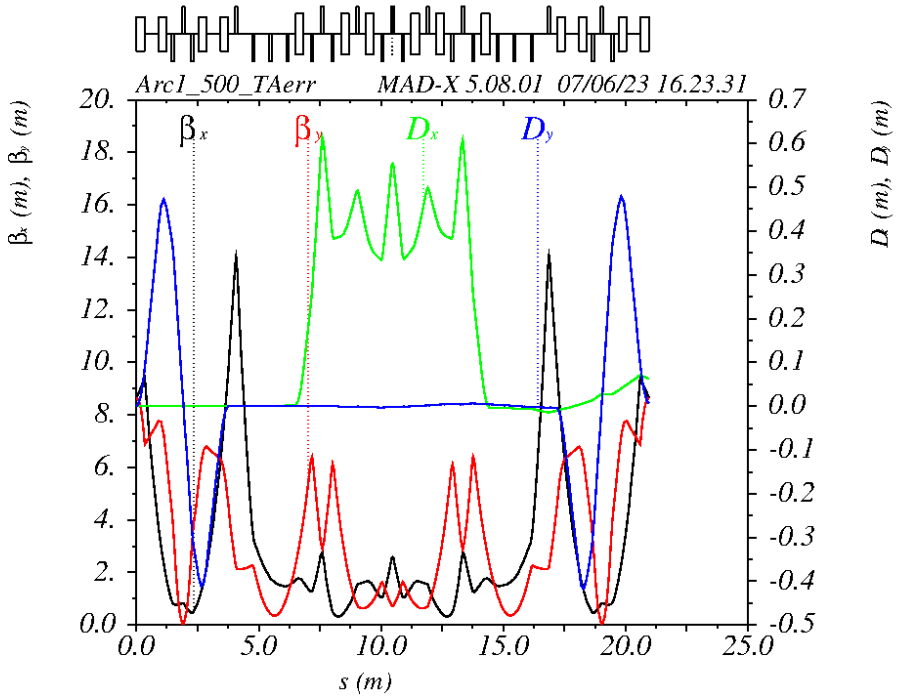


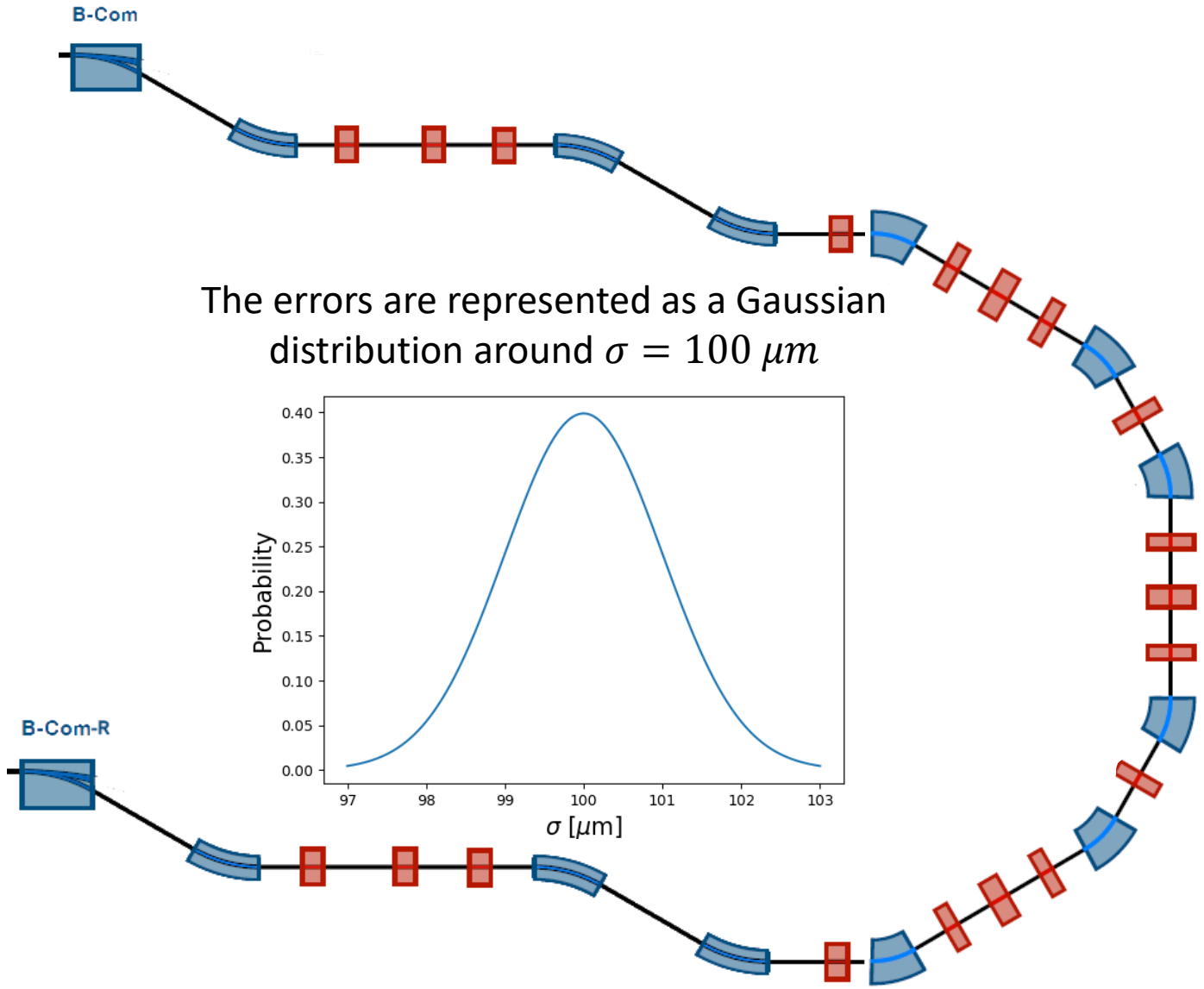
- The optics are perfect elements.
- The dipoles (bends) are defined by an angle and tilt.
-
- The quadrupoles are defined by K1.

- Arc1 refers to the spreader section after the first LINAC, the circulating arc, and the merger section before the second LINAC

Introducing Misalignments

- Misalignments were introduced to all the quadrupoles in Arc1.
- Transverse errors in the position of the quads the xy-plane: $\Delta x, \Delta y$ are only considered.

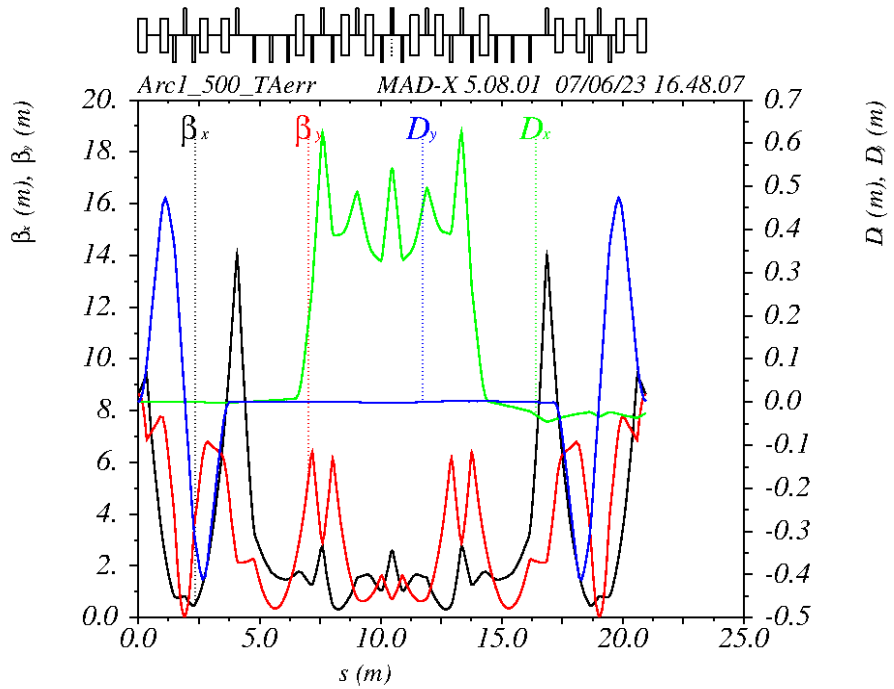




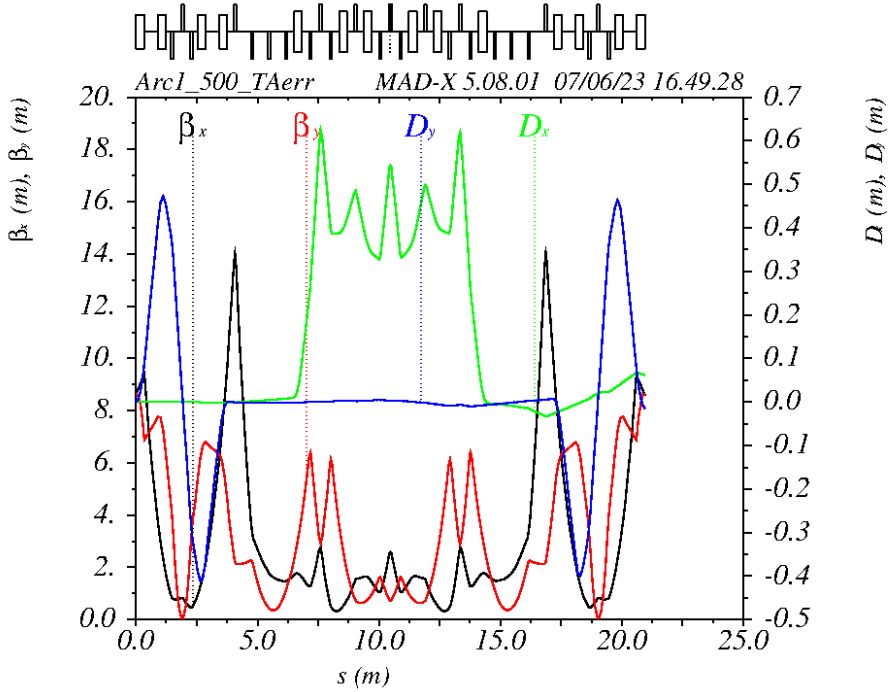
Different Possibilities

Since the distribution is Gaussian → different seeds generate different values to each element.

D_x is negative at Arc1 end



D_x is positive at Arc1 end



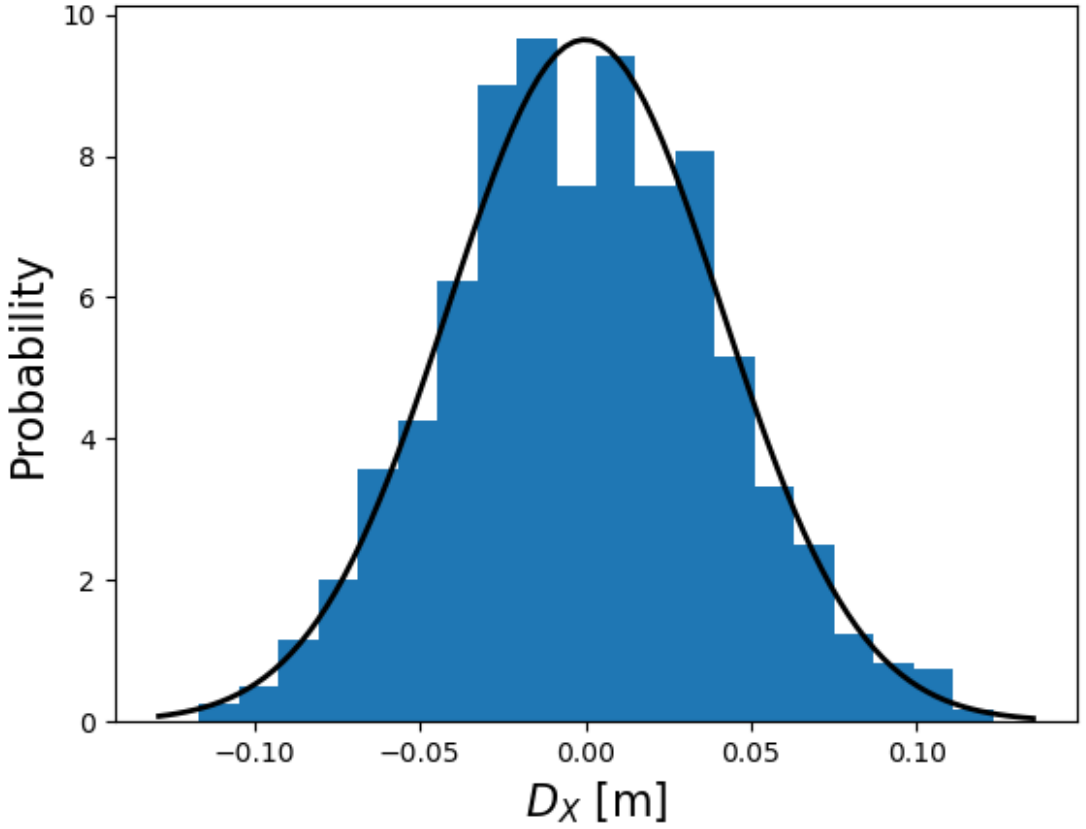
1000 simulations were performed to deduce:

- Dispersion DX, DY at the **exit** of the Arc.
- The difference in BETX, BETY between the arc's entrance and exit.
- The difference in the ALFX, ALFY between the arc's entrance and exit.

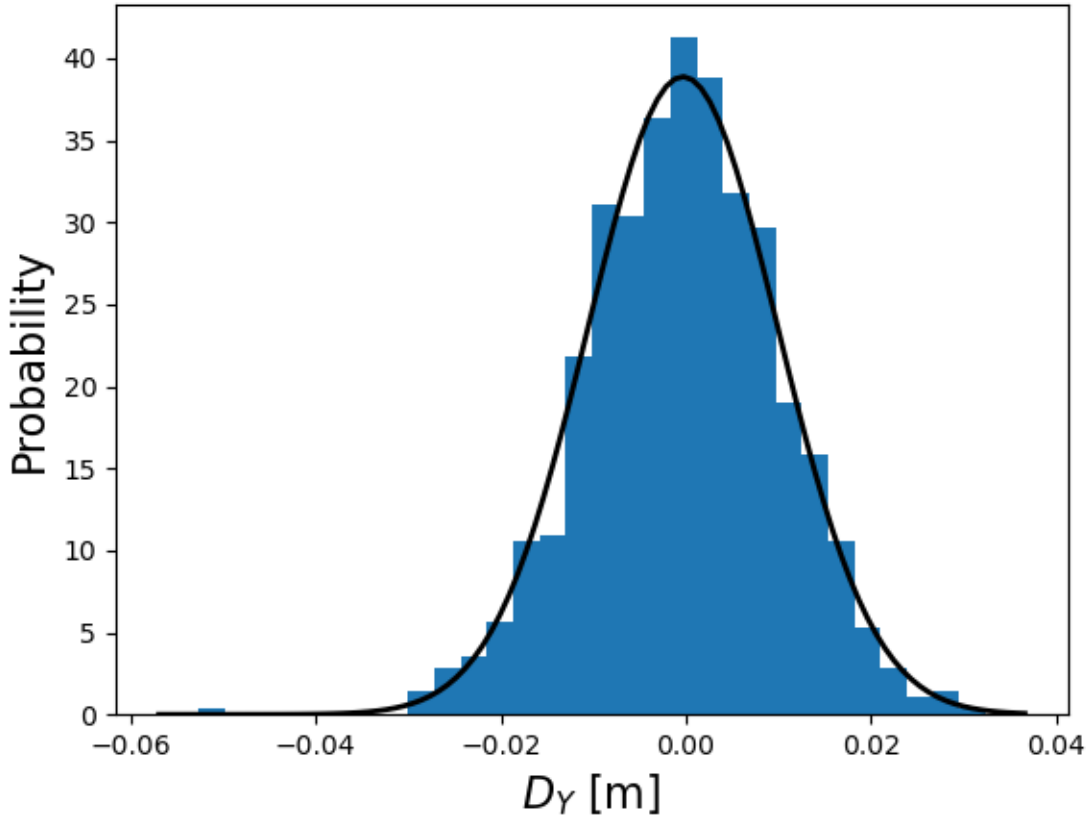
Dispersion DX and DY

The lattice is tuned so that the Dispersion function is Zero at the exit of each arc

Mean value $= 0.00$
Standard deviation $\sigma \sim 40\ mm$



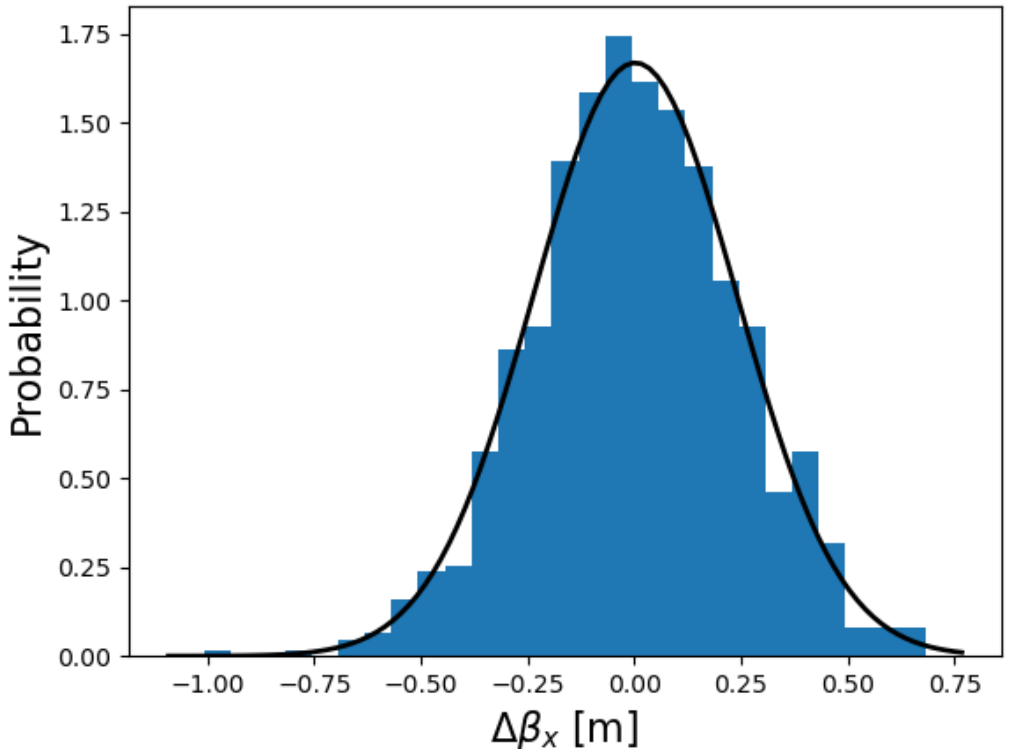
Mean value $= 0.00$
Standard deviation $\sigma \sim 10\ mm$



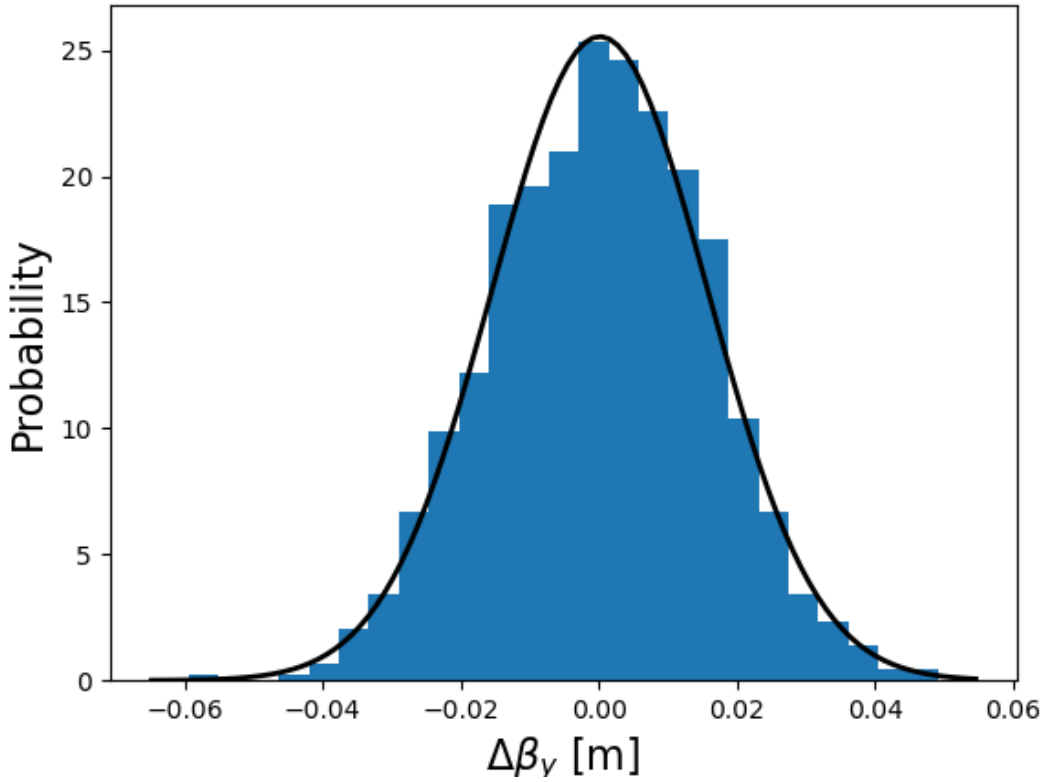
Difference in BETX and BETY

The lattice is tuned so that the Beta function is the same at the entrance and exit of each arc

Mean value $= 0.00$
Standard deviation $\sigma \sim 24\ mm$



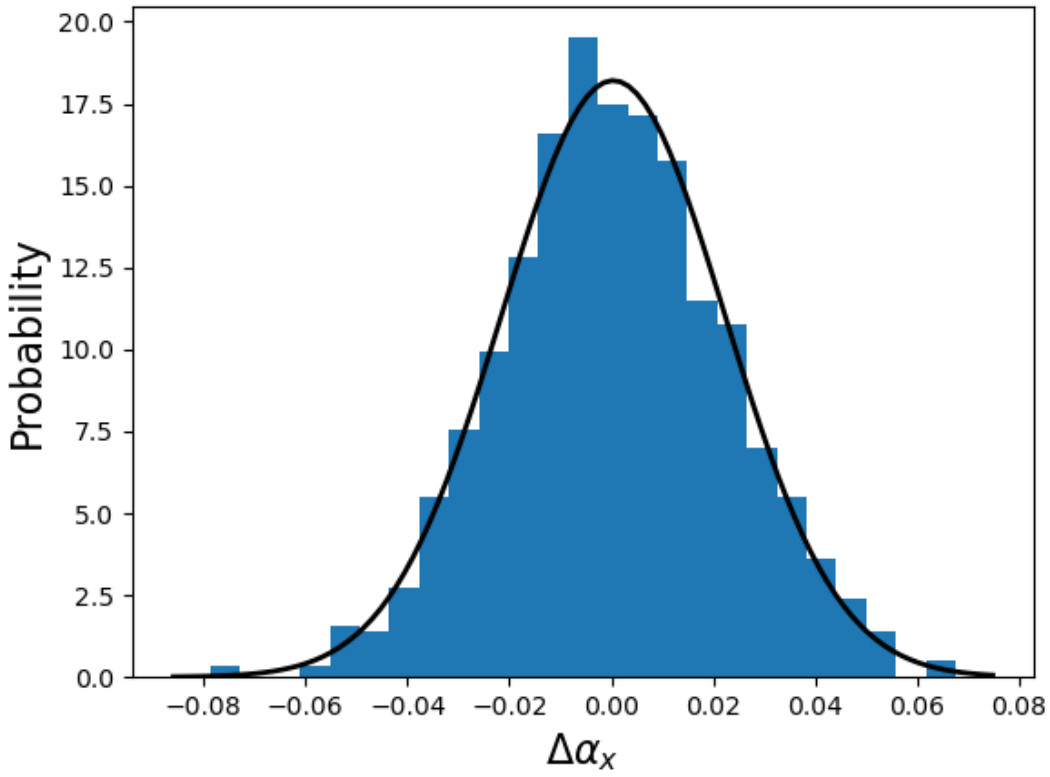
Mean value $= 0.00$
Standard deviation $\sigma \sim 15\ mm$



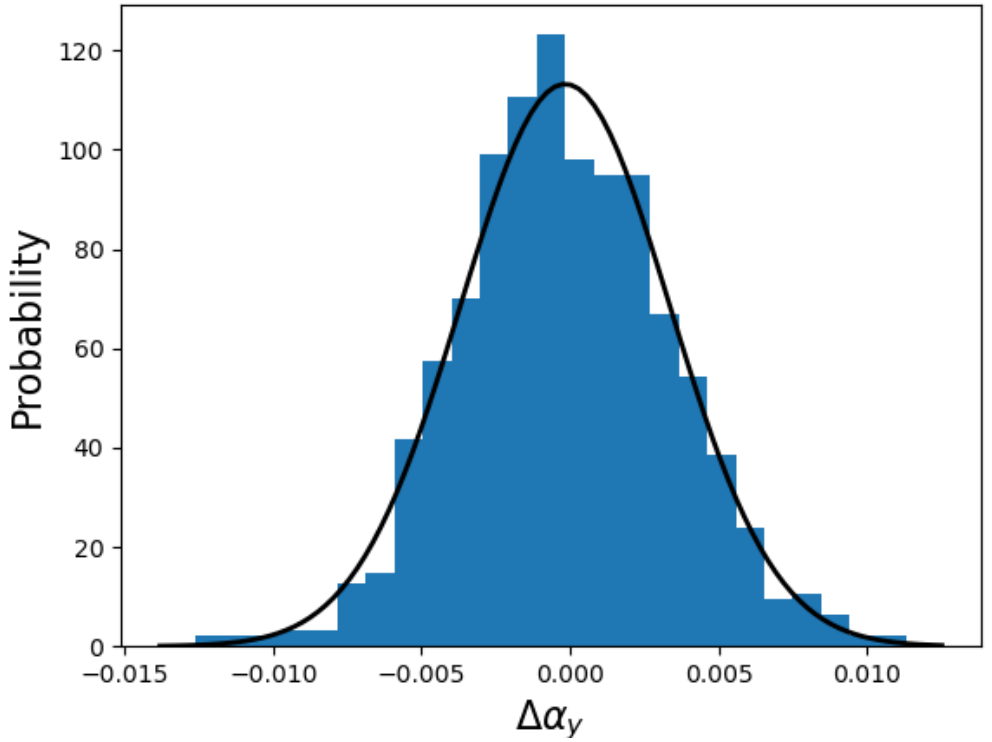
Difference in ALFX and ALFY

The lattice is tuned so that the ALFA function changes sign between the entrance and exit of each arc

Mean value $= 0.00$
Standard deviation $\sigma \sim 22\ mm$

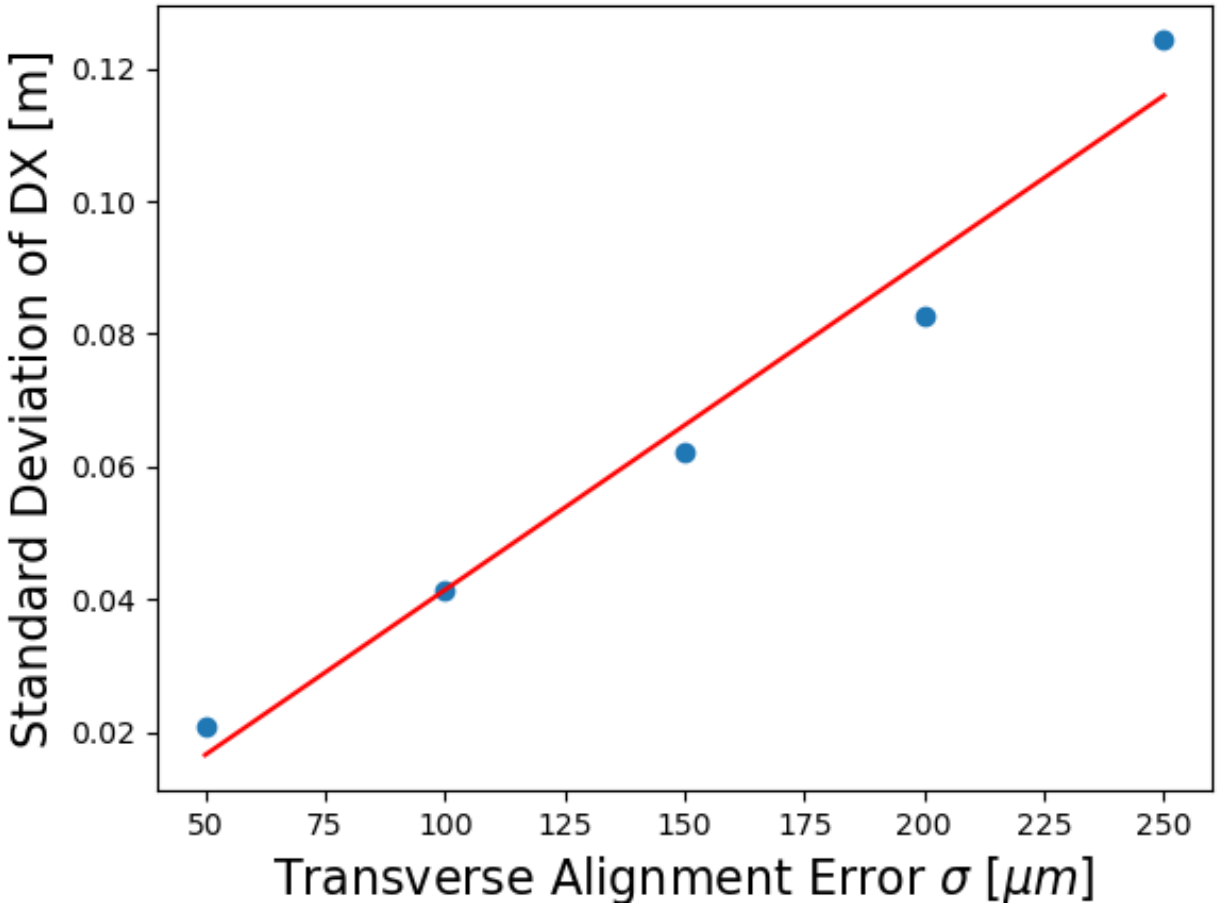


Mean value $= 0.00$
Standard deviation $\sigma \sim 3.5\ mm$



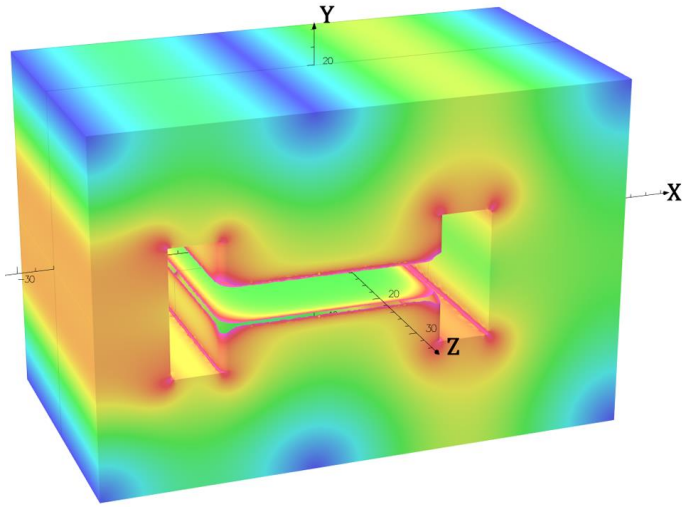
Introducing Different Values of Errors

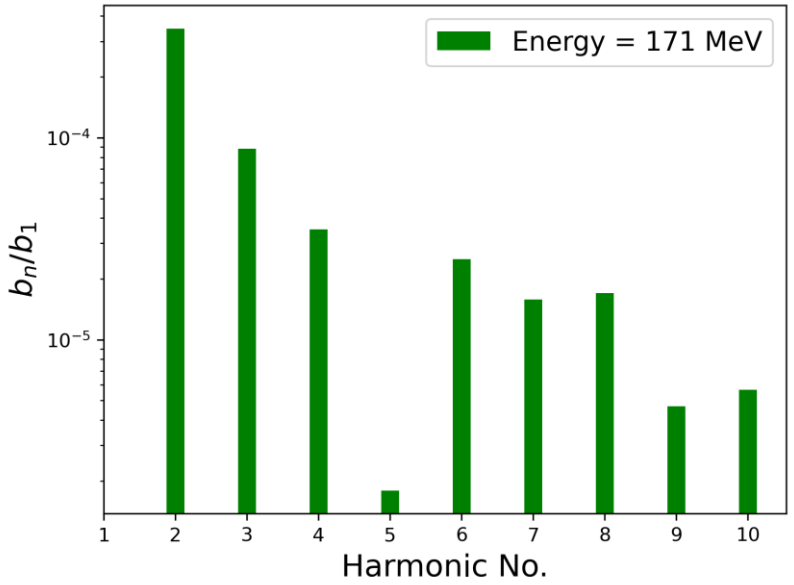
- Different values of the transverse alignment errors were introduced.
- Each time, the standard deviation of DX at the exit of the Arc is extracted.



Introducing Field Errors to B-com Magnet

- The B-com magnet was designed using Opera 3D.





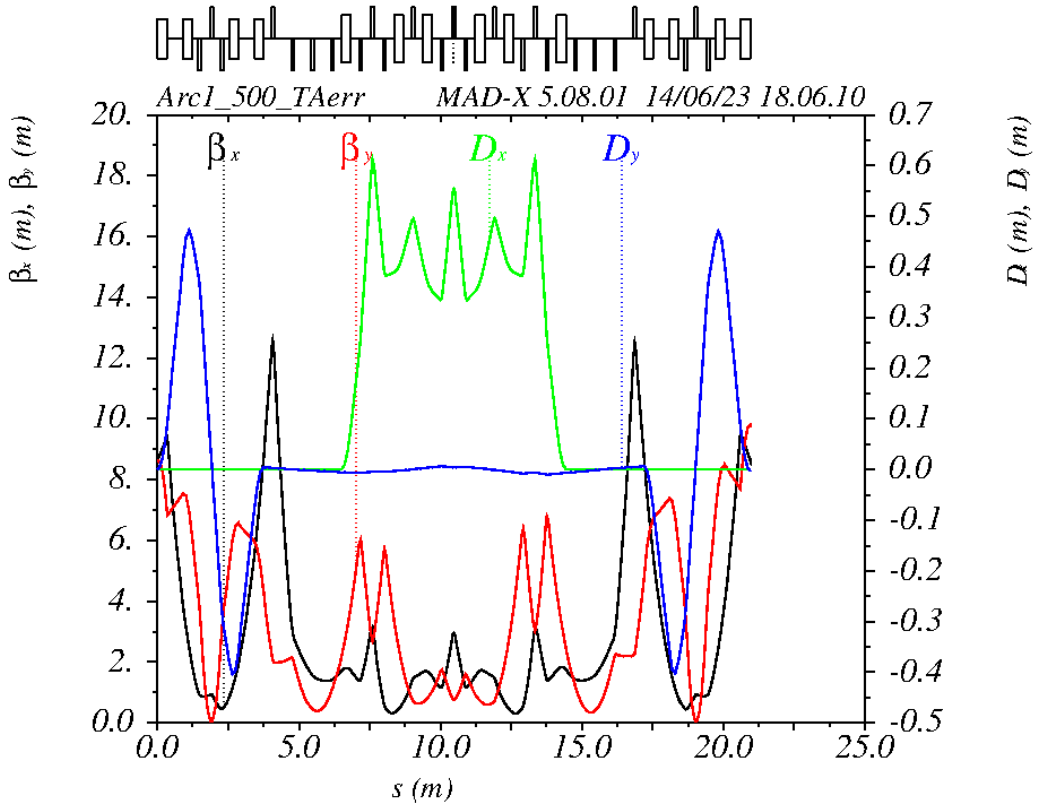
Harmonic No.	b_n/b_1
2	3.47×10^{-4}
3	8.80×10^{-5}
4	3.52×10^{-5}
5	1.79×10^{-6}
6	2.51×10^{-5}
7	1.58×10^{-5}
8	1.70×10^{-5}
9	4.67×10^{-6}
10	5.64×10^{-6}

- The values of the first relative four higher harmonics were considered to introduce field errors

(see tomorrow's talk: Magnet Specifications, Design and Prototyping)

Introducing Field Errors

- Relative field errors were introduced to the first B-com in the spreader and the B-com-R in the merger section.
- Increase in the BETY function is noticed at the exit.



Twiss functions at the **exit** of Arc1

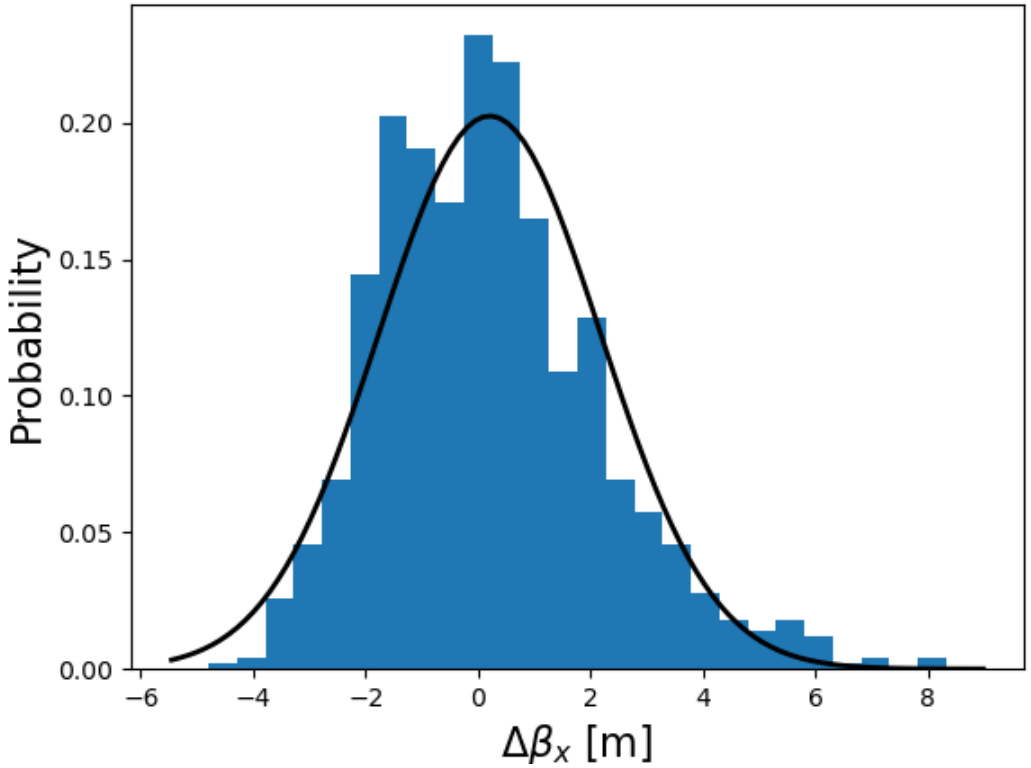
Twiss	With Field errors	Without Field errors
D_x [m]	0.00	0.00
D_y [m]	-0.00301	0.00
DP_x	0.00	0.00
DP_y	0.00059	0.00
β_x [m]	8.70493	8.63544
β_y [m]	9.73175	8.63478
α_x	0.68527	0.67145
α_y	0.76694	0.67294

Further investigation is to be done

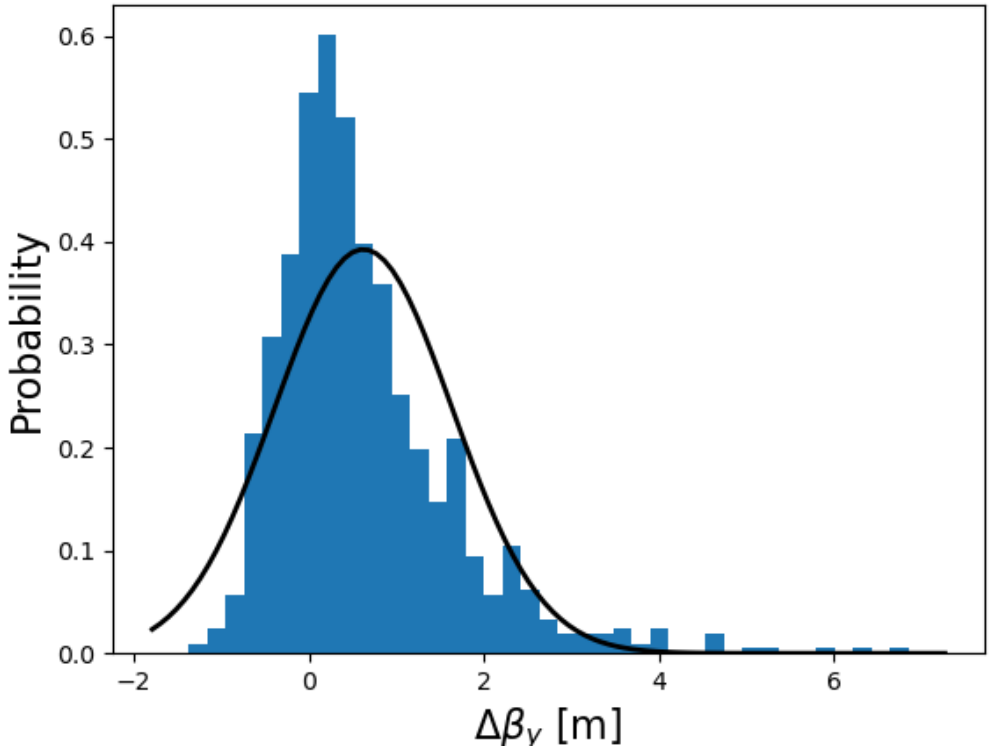
Difference in BETX and BETY

The lattice is tuned so that the Beta function is the same at the entrance and exit of each arc

Mean value = 0.2055 m
Standard deviation $\sigma = 1.971\ m$



Mean value = 0.622 m
Standard deviation $\sigma = 1.016\ m$



- Truncated Gaussian to limit the value of field errors.

Conclusion and Outlook

- The effect of misalignments on the Twiss functions (D_x, D_y, β_x, β_y, α_x, α_x) was studied for a $\sigma = 10^{-4}m$
- The misalignment of quadrupoles affects mostly the dispersion function D_x with 40 mm standard deviation at the end of the arc.
- The error value affects linearly the Twiss functions as seen for D_x.
- The harmonic content of the B-com magnet affects mostly β_y but it is still acceptable.

What type of errors?

I. Alignment error:

- ✓ Δx and Δy.
- Δs.
- Tilt (angular direction): $\Delta\phi, \Delta\theta, \Delta\psi$.

II. Field errors:

- ✓ B-com magnet.
- Other dipoles and quadrupoles

Next Steps:

- ➢ Perform the errors study to the full PERLE machine (500 MeV and 250 MeV)
- ➢ Check if corrections are needed and where.

Thank You!

The MADX code for introducing Errors

Alignment Errors
In xy plane only

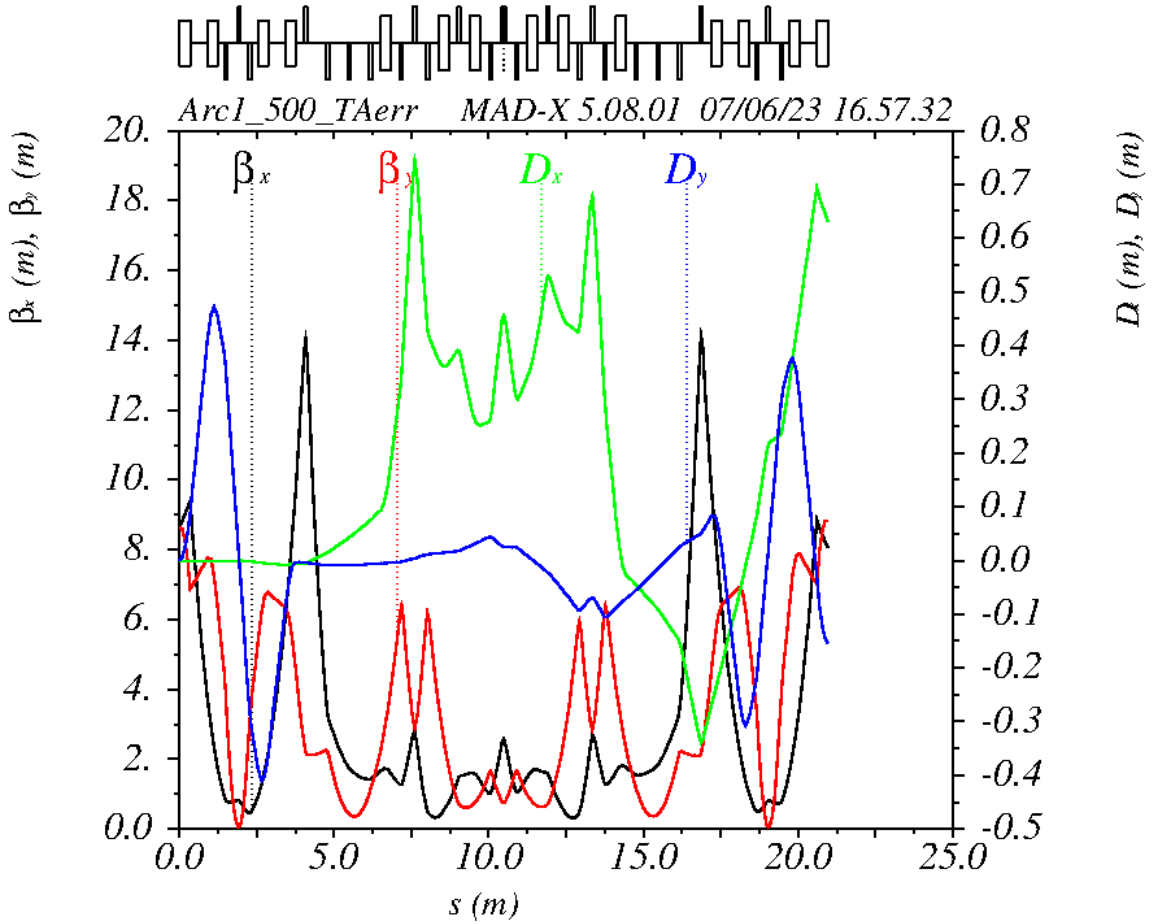
```
!Introducing errors
    i=0;
    while(i<10){
    use sequence = Arc1 ;
    select flag = error, pattern = "qQ*" ; ! transverse alignment errors to all quads of the arc
    eoption, seed=i;
    q_aerr := GAUSS()*1e-4 ;
    ealign dx := q_aerr, dy := q_aerr ;
    !eprint;
    savebeta, label=istart, place=Arc1$start, sequence=Arc1;
    savebeta, label=iend, place=Arc1$end, sequence=Arc1;
    TWISS ENERGY=E0,BETA0=B_Arc1 ;
    assign echo = "Twiss/iend_twiss.txt";
    printf text="%9.5f %9.5f %9.5f %9.5f %9.5f %9.5f %9.5f %9.5f", value =iend->DX,iend->DY,iend-
    assign echo=terminal;
    i=i+1;}
```

Field Errors

```
!introducing field errors to the Bcom: b1S01, b1S01r
use sequence = Arc1 ;
SELECT, FLAG=ERROR, PATTERN="b1S01*";
EFCOMP, ORDER=0, RADIUS=0.01, dknr := { 0, 3.47E-04, -8.80E-05, 3.52E-05, -1.79E-06};
eprint;
```

Different possibilities

- 10^{-3} errors cause a significant increase in the dispersion.
- The Beta functions are “almost” unaffected.



MADX code problem solved

The USE command in MADX destroys the assigned errors to the lattice.

- The code is modified and the assignment of errors is now correct.
- The errors are Gaussian distribution around σ.
- 10^{-4} [m] alignment error is taken in the transverse plane xy for all quadrupoles in Arc1.