

Low- β^* Insertion

CERN Accelerator School 2017

September 14, 2017

Motivation

- ▶ Collision experiments require small beam sizes for high instantaneuos lumi
- ▶ $\mathcal{L} \propto \frac{1}{\sigma_x \sigma_y} \propto \frac{1}{\sqrt{\epsilon_x \epsilon_y \beta_x \beta_y}}$
- ▶ Special optics needed to achieve low β^* at the interaction point
- ▶ ... while keeping the periodicity in the rest of the ring!

Plan of Attack

1. Start with a FODO-Ring that ...
 - ▶ has a dispersion-free straight section
 - ▶ is chromaticity corrected
 - ▶ → see Exercise 4
2. *Cut out* the FODO-quads in the straight section
3. Design insertion
 - ▶ MATCH insertion to optical functions of the old FODO-lattice
 - ▶ low β in the center ($\approx 1\text{ m}$)
4. Splice insertion into the ring
5. Correct chromaticity again

Cutting the lattice

1. Set up FODO-ring
2. Decide where to cut and put markers

```
! *snip*
! START straight section
    START_EXP:                                MARKER, AT=n*lcell;
        qf: qf,      at=n*lcell;
        qd: qd,      at=n*lcell + 0.50*lcell;
        n = n + 1;

        qf: qf,      at=n*lcell;
        qd: qd,      at=n*lcell + 0.50*lcell;
        n = n + 1;
    ! END straight section

! ****
! START dispersion suppressor
    END_EXP:                                MARKER, AT=n*lcell;
        qf: qf,      at=n*lcell;
        mb: mb,      at=n*lcell + 0.15*lcell;
        mb: mb,      at=n*lcell + 0.35*lcell;
    ! *snip*
```

3. Store optical functions at the “seams” for later

```
SAVEBETA,sequence=cas4,PLACE=START_EXP,LABEL=BEXPSTART;
SAVEBETA,sequence=cas4,PLACE=END_EXP,LABEL=BEXPEND;
```

Designing the Insertion

- ▶ Create new SEQUENCE for the insertion
- ▶ Several options:
 - ▶ How many quads? Where to put them?
 - ▶ Force symmetry?
 - ▶ End of FODO → Start of FODO
 - ▶ End of FODO → IP
- ▶ For example:

```
lexp := lcell;
insertion: sequence,refer=centre,l=lexp;
    ! START straight section

        START_INS:                      MARKER, AT=0;

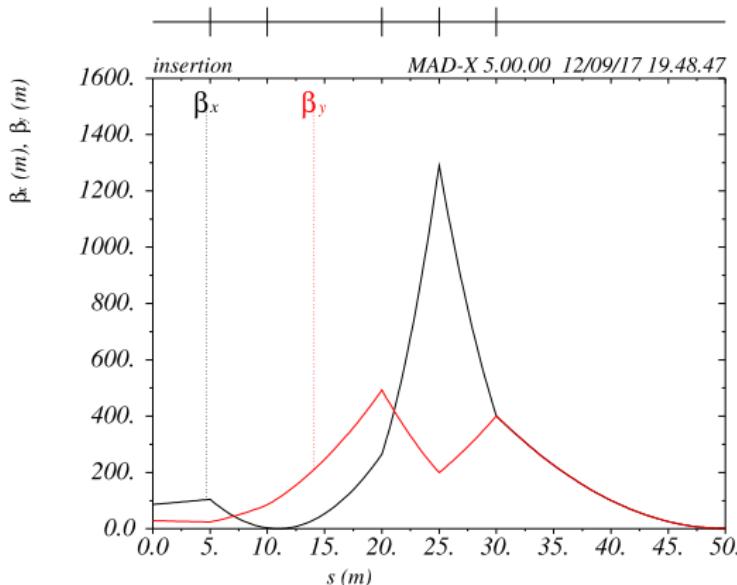
        qins3: qins3,at= 0.1*lexp;
        qins2: qins2,at= 0.2*lexp;
        qins1: qins1,at= 0.4*lexp;
        qins0: qins0,at= 0.5*lexp;
        qinsA: qinsA,at= 0.6*lexp;

        IP_INS: MARKER,                  AT= lexp;

    ! END straight section
endsequence;
```

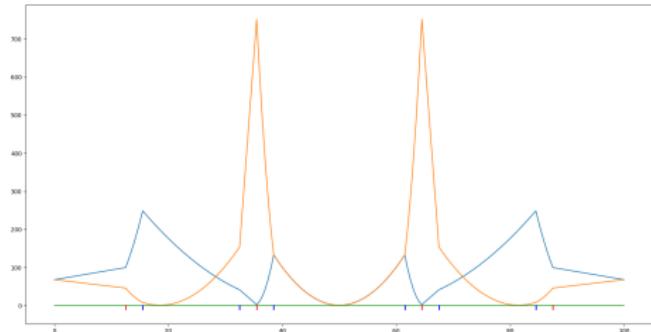
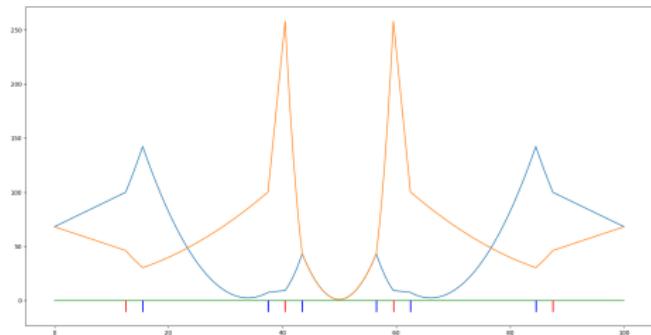
Matching the Insertion

```
match, sequence=insertion,BETA0=BEXPSTART;
    CONSTRAINT,SEQUENCE=insertion,RANGE=IP_INS ,BETX=1,ALFX=0,BETY=1,ALFY=0;
    vary, name=kins0, step=0.00001;
    vary, name=kins1, step=0.00001;
    vary, name=kins2, step=0.00001;
    vary, name=kins3, step=0.00001;
    vary, name=kinsA, step=0.00001;
    jacobian, calls=100, tolerance=1.0e-21;
endmatch;
```

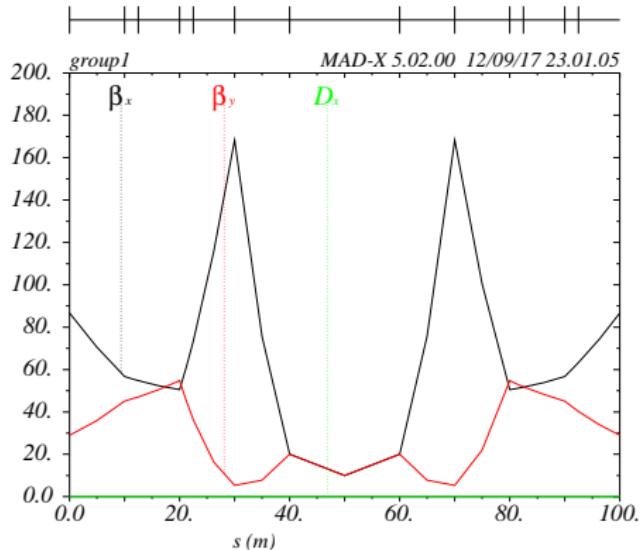


Many possible Layouts

- Generally:
Shorter
experimental
region allows
for lower β_{\max}



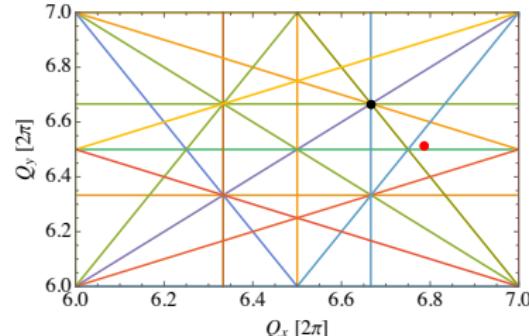
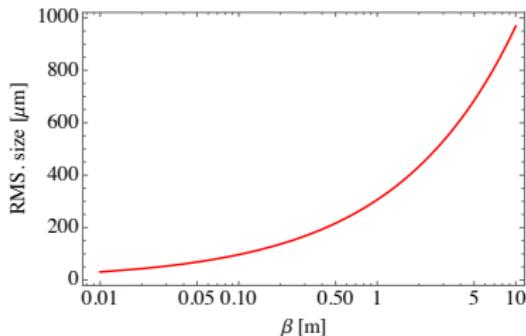
Many possible Layouts



- With a larger β^* much smaller β_{\max} can be achieved

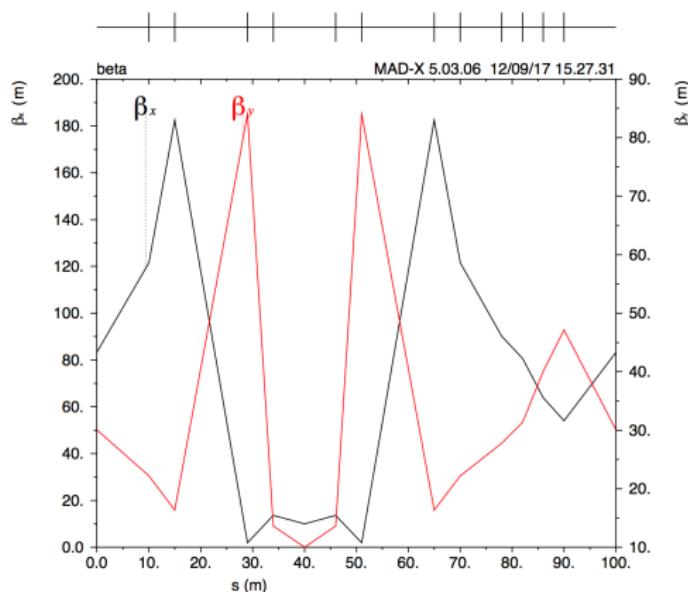
Consideration of FF design (round beam)

- ▶ Small beam size at IP: $\beta_{x,y} = 1 \sim 10\text{m}$
- ▶ Transverse acceptance: Max. of β_x and β_y at FF to avoid beam loss
- ▶ L^* of FF \rightarrow IP-QD0: 5 m (space of insertion)
- ▶ Doublet or triplet
- ▶ Strength of FF magnets, Chromaticity, tuning shift ...



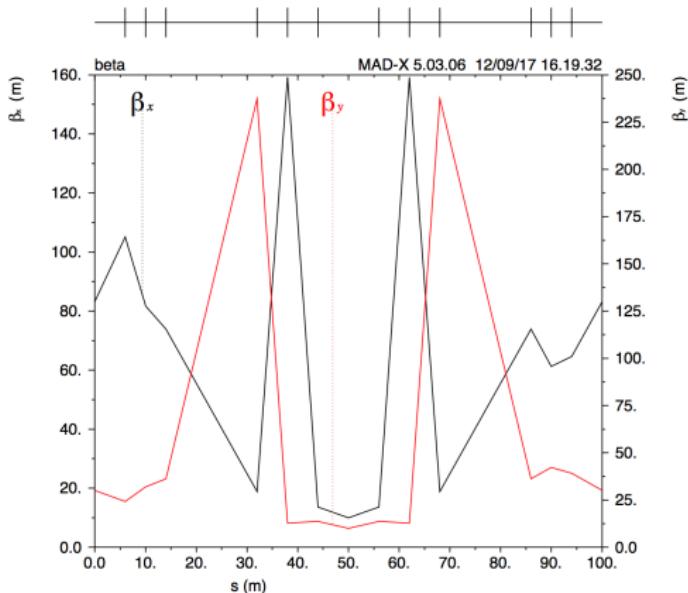
Asymmetric FF

- ▶ Configuration of IR: 4+4 quads to focus beam at IP, 2 quads on one side to match periodic Twiss parameters
- ▶ Parameters: round beam $\beta_x^* = \beta_y^* = 10$ m, Max. $\beta_x/\beta_y < 200$ m
- ▶ Disadvantage: Asymmetric IR for real machine with 2 rings



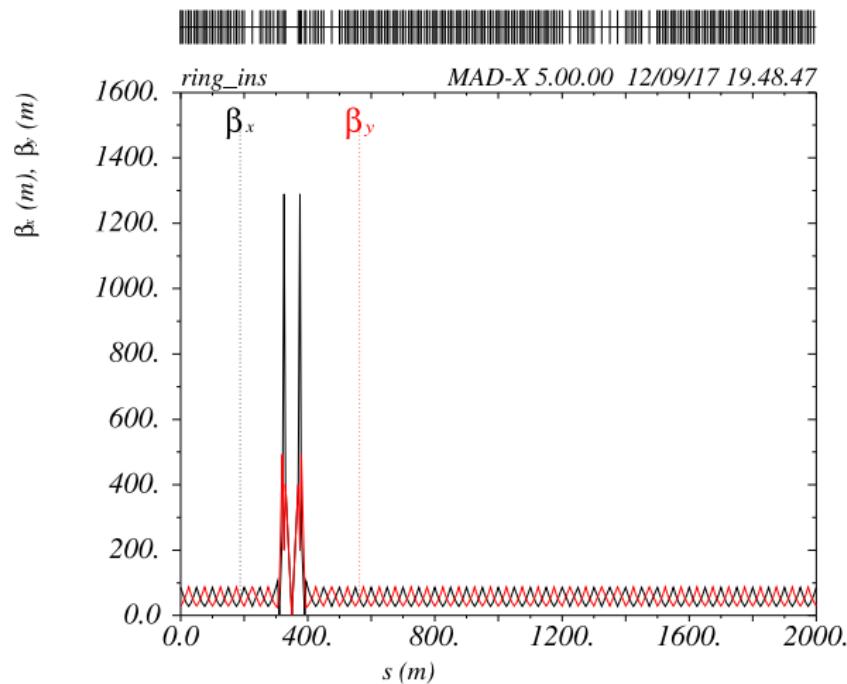
low β insertion

- ▶ Triplet focusing Quads and two group matching quads configuration
- ▶ Parameters: round beam $\beta_x^* = \beta_y^* = 10$ m, Max. $\beta_x/\beta_y < 250$ m



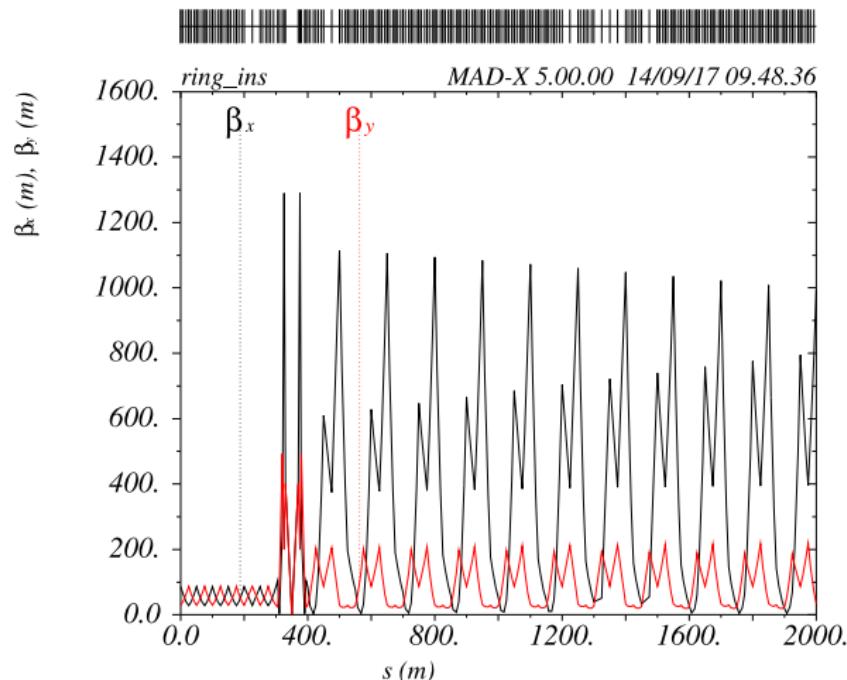
Putting it together

- ▶ Put matched insertion in the straight section
- ▶ If correctly matched the periodicity is not disturbed



Putting it together?

- If not correctly matched the periodicity is disturbed

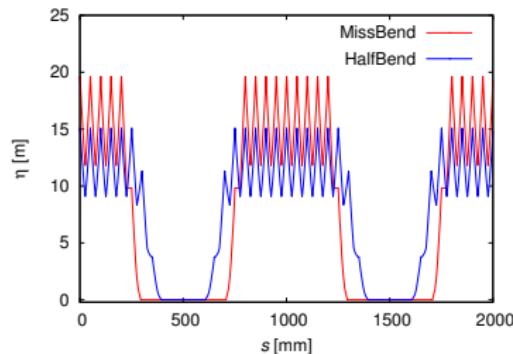
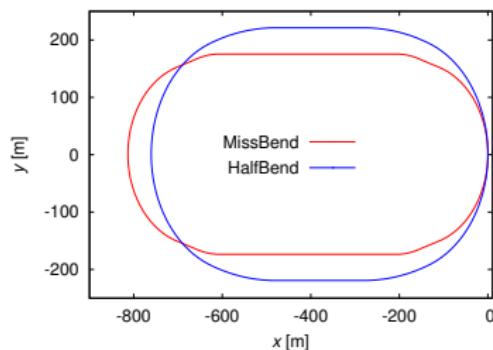


Finishing up

- ▶ Insertion introduces additional chromaticity
 - ▶ $Q'_x : 0 \rightarrow -30.6$
 - ▶ $Q'_y : 0 \rightarrow -9.3$
 - ▶ → reMATCH
- ▶ Because of low β^* tune changes drastically
 - ▶ $Q_x : 6.7 \rightarrow 7.84$
 - ▶ $Q_y : 6.65 \rightarrow 6.92$

Global view of machine

- ▶ Arc-Dispersor suppressor-Transport line (injection/diagnostics)-FF-IP
- ▶ Two dispersion suppressor methods: missing bend and half bend
- ▶ Half bend method is applied: smaller bending angle ($\eta_x \downarrow$) and 3+3 Cells in straight section



Thank you
for your attention!