FFAG lattice with insertions by global method

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10 September, 2009
http://www.astec.ac.uk/intbeams/users
/machida/doc/nufact/ffag/machida20090910.pdf

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Introduction (1)

why insertion is necessary?

- FFAG with high symmetric structure has many but short drift spaces between magnets.
- For injection/extraction, long drift space is preferable.
- When packing factor is reduced to make drift space longer keeping high symmetry, either magnetic field becomes stronger or machine circumference becomes larger.

Introduction (2)

modular and global method

- Two ways to have an insertion.
  - Modular method
    - Insert additional cells into a normal arc with a matching of betas, alphas, dispersion and its derivative.
  - Global method (only for a scaling FFAG)
    - Introduce a variety on azimuthal field distribution $F(\theta)$.

Global method (1)

idea

- As long as magnetic fields have the shape of

$$B_z = B_{z,0}(\frac{r}{r_0})^k F(\theta)$$

$F(\theta)$ can be arbitrary. k should be constant.

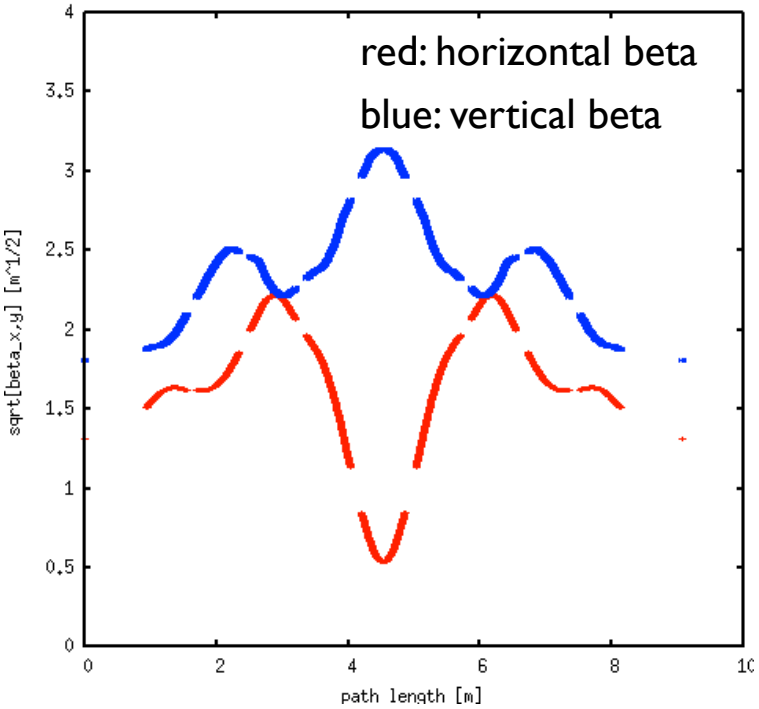
- FFAG with long drift space can be designed with more complex function of $F(\theta)$.
  - FD, FDF are the simplest case.
  - In principle, all F and D can be different.
  - Amplitude of F_1, D_1, ... is determined by minimizing beta maximum and/or optimizing phase advance.

Global method (2)

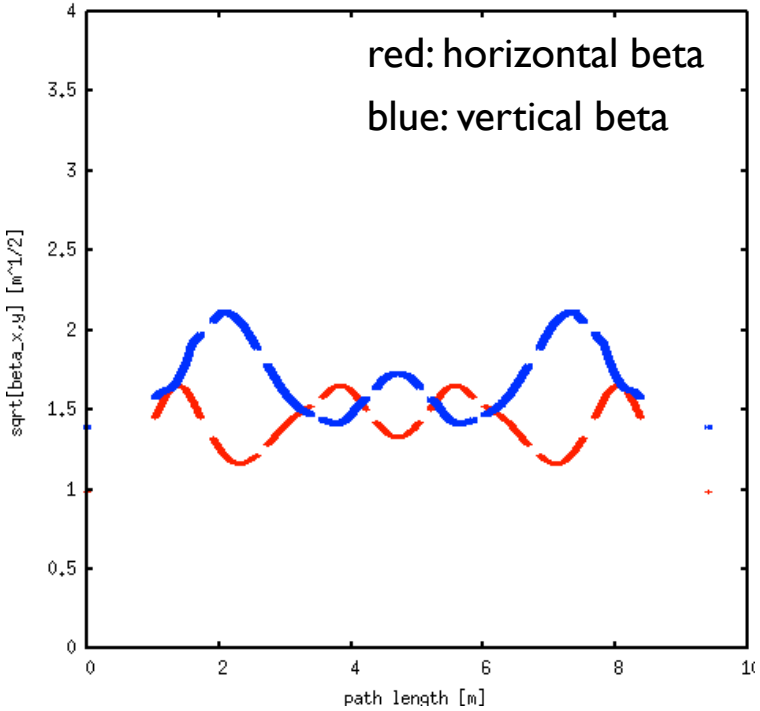
fitting example

- $O(F_3D_2F_2)(F_1D_1F_1)(F_2D_2F_3)O$ as one quadrant of a ring.
  - Three different F and two different D to minimize beta.

before fitting



after fitting



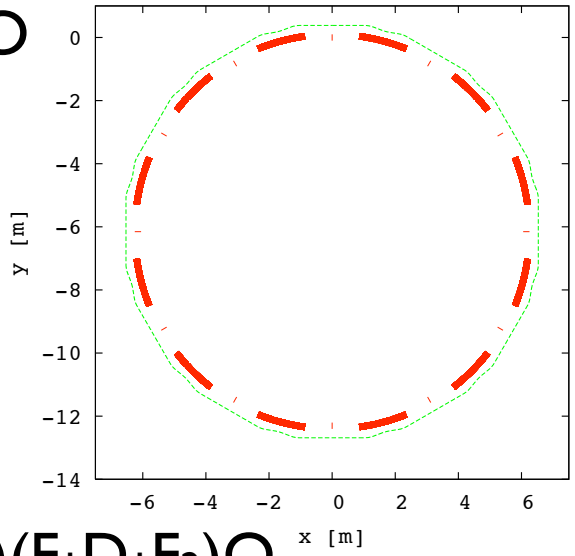
Global method (3)

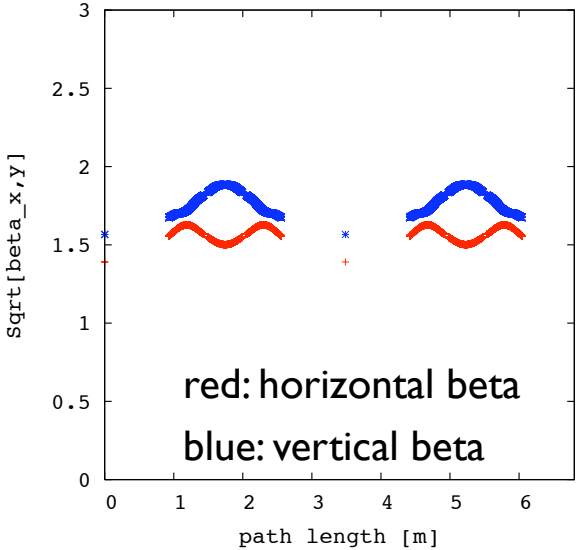
start from PAMELA like lattice

- 12*O(FDF)O

red: magnet

green: orbit

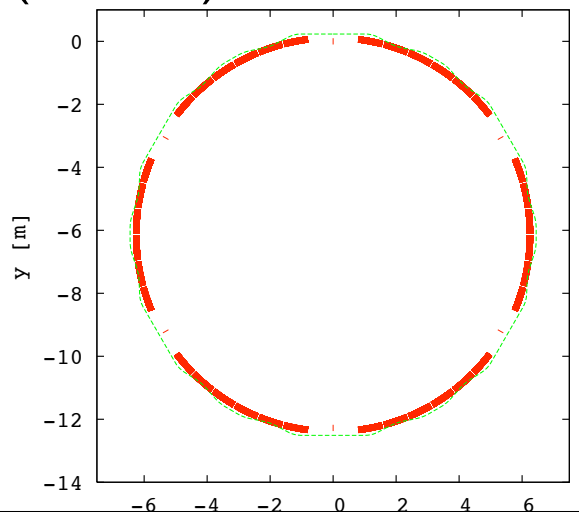


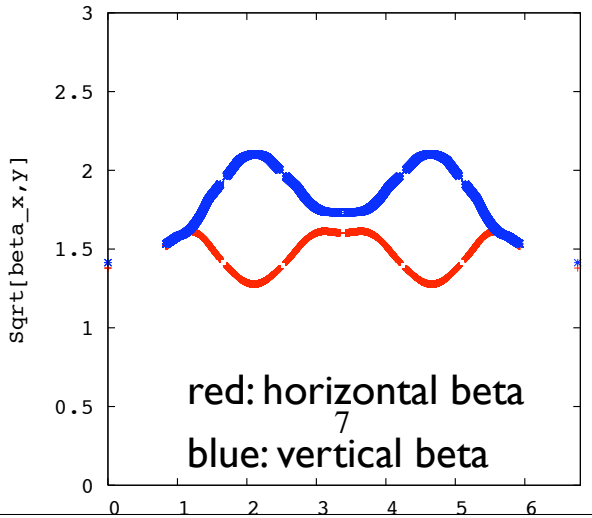


- 6*O($F_2D_1F_1$)($F_1D_1F_2$)O

red: magnet

green: orbit





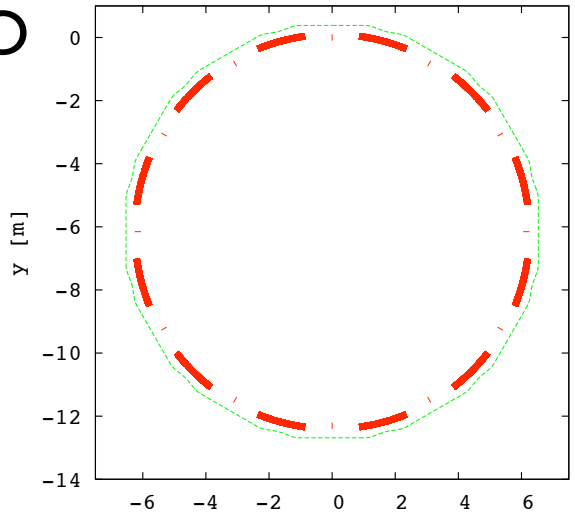
Global method (4)

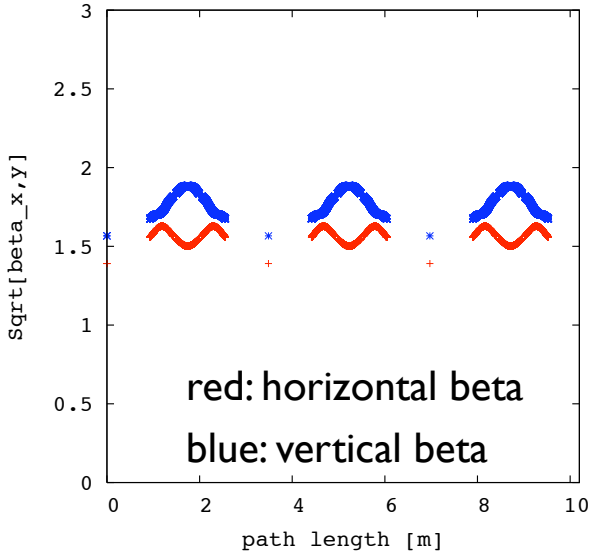
4 fold symmetry

- 12*O(FDF)O

red: magnet

green: orbit

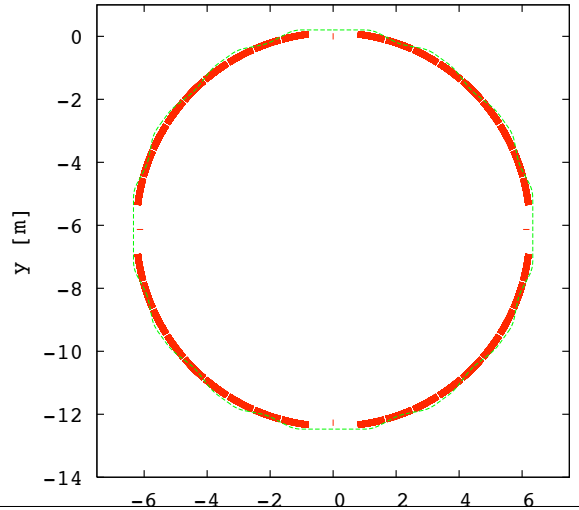


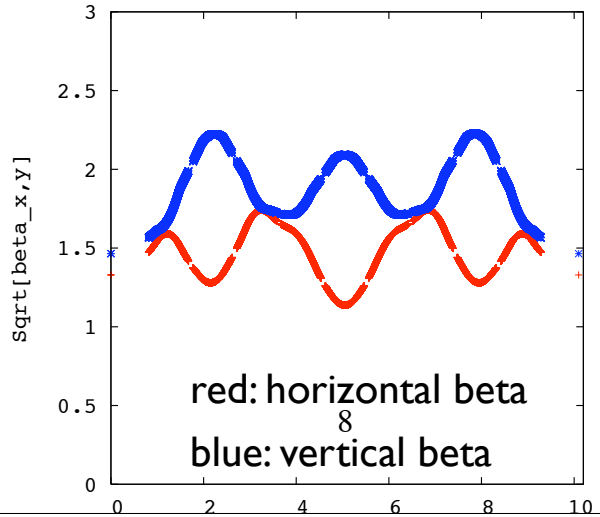


- 4*O($F_3D_2F_2$)($F_1D_1F_1$)($F_2D_2F_3$)O

red: magnet

green: orbit





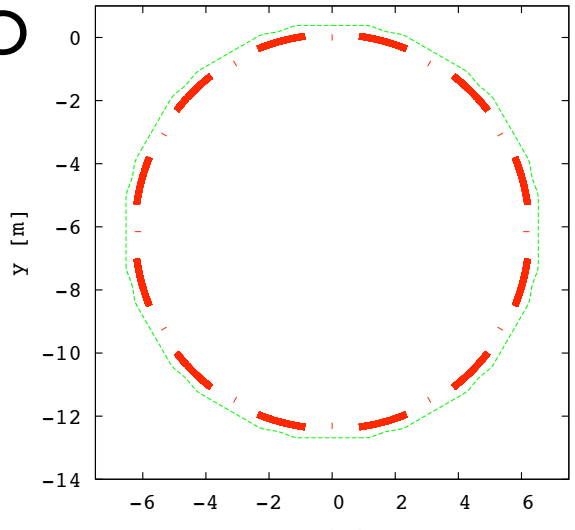
Global method (5)

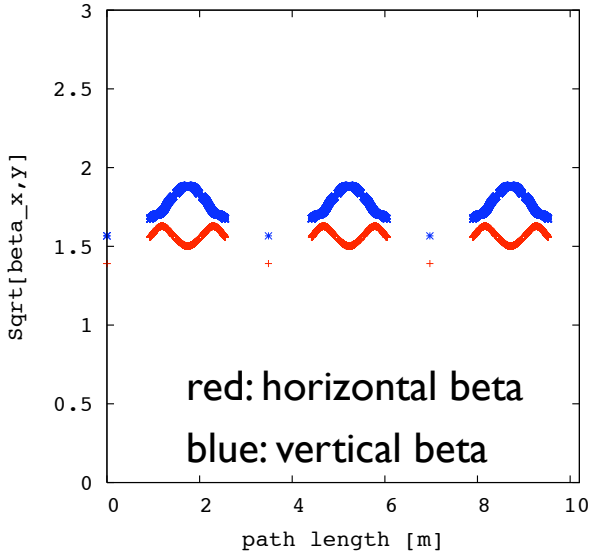
4 fold symmetry with shorter drift space

- 12*O(FDF)O

red: magnet

green: orbit

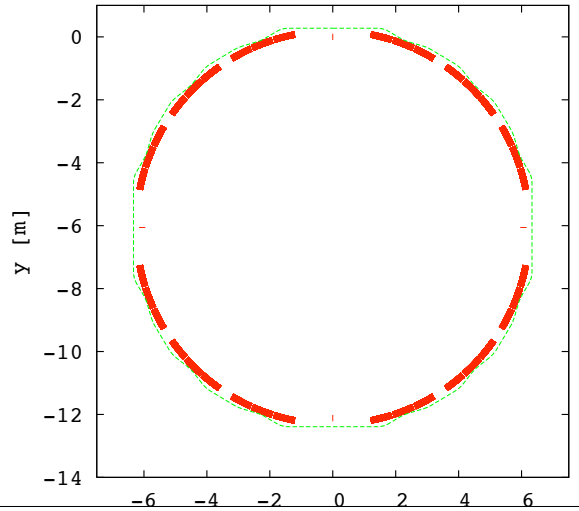


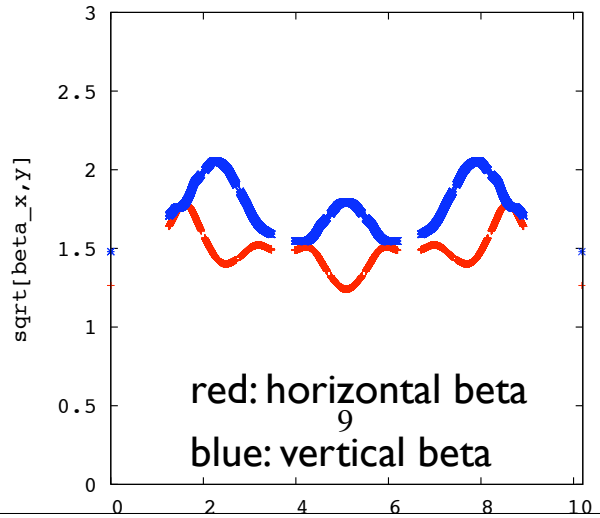


- 4*O(F3D2F2)o(F1D1F1)o(F2D2F3)O

red: magnet

green: orbit





Global method (6)

reduction of maximum fields

- Maximum field strength

superperiod	Bf_max [T]	Bd_max [T]	drift_max [m]
12 (original)	3.2	-2.2	1.96
6	2.7	-1.6	1.96
4	2.5	-1.5	1.96
4	3.4	-1.7	2.40

- Same drift length with lower magnetic field strength or longer drift length with same magnetic field strength.

Summary

- Global approach ensures scaling optics.
- Method here gives us much more flexibility with designing FFAG lattice.
  - different kinds of magnets.
  - different kinds of drift space.
- Compared with modular approach, less number of magnets is needed.
  - preferable for a small machine like PRISM and particle therapy accelerator.
  - but also works for muon (scaling) FFAG.