Transverse Dynamics
&
Lattice Design

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FFAG WORKSHOP @ LBL

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Reference Parameter

(FODO Lattice)	Type1	Type2
Momentum Range(GeV/c)	10 to 20	10 to 20
Num. of Cell	180	120
k Value	670	330
Machine Radius(m)	200	120
Orbit Excursion(m)	0.206	0.251
Max. Beta Func.(m)	9.43(H)/21.4(V)	8.28(H)/21.3(V)
Max. Beam Size(mm)	106(H)/160(V)	99.7(H)/160(V)
Opening Angle(deg.)	0.562(F)/0.438(D)	0.87(F)/0.63(D)
Packing Factor	0.5	0.5
Max. B Field on Orbit(T)	5.86	7.73
Betatron Tune	41.3(H)/15.7(V)	28.1(H)/9.38(V)
Phase Adv. per Cell(deg.)	82.2(H)/31.4(V)	84.3(H)/28.1(V)
Revolution Frequancy(MHz)	0.24	0.4
RF Voltage (MV/m average)	0.75	0.75
RF Frequancy (MHz)	24	12－18
harmonic number	100	30-45
number of turn	15	20-30

Procedure of Design

1.Linear Approximation

Composing a lattice only of combined function magnet,
Evaluating focusing force of the linear lattice

2.Tracking Simulation with Model Magnetic Field

Numerical integration (Runge-Kutta)
with Hard Edge Model or Soft Edge Model

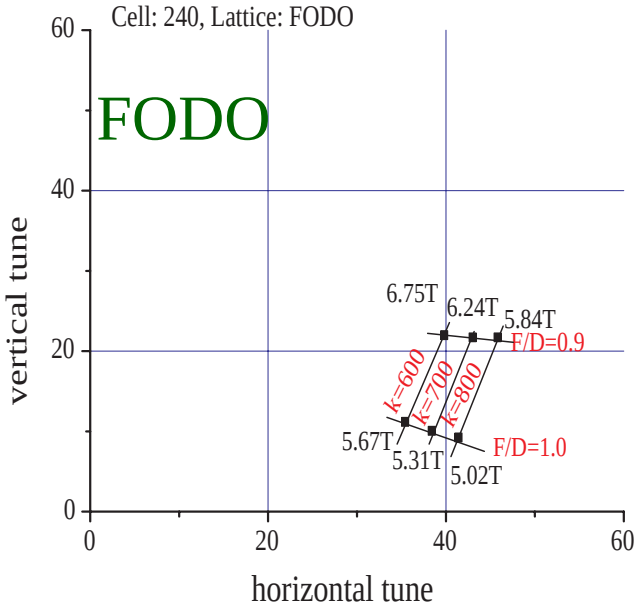
(Finally, with calculated or measured field)

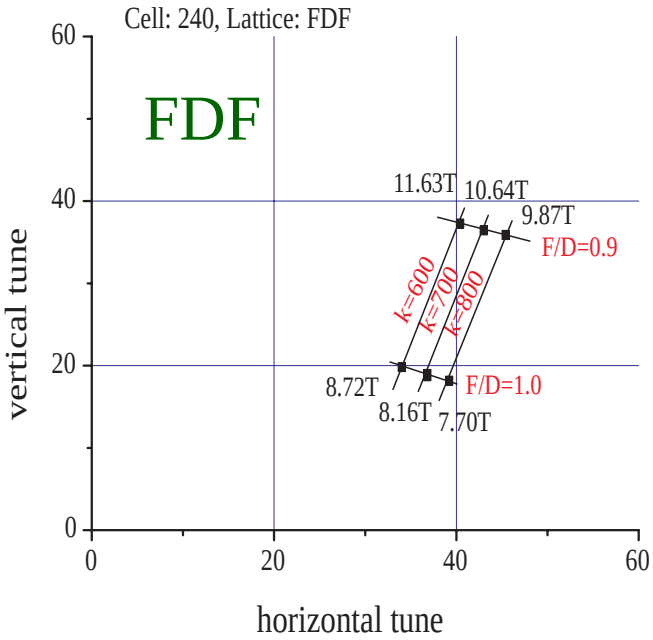
Trimming parameters and calculating
closed orbit, betatron tune, acceptance etc...

Especially, it is important to carry out 6D-tracking,
because the muon acceleration is very rapid.

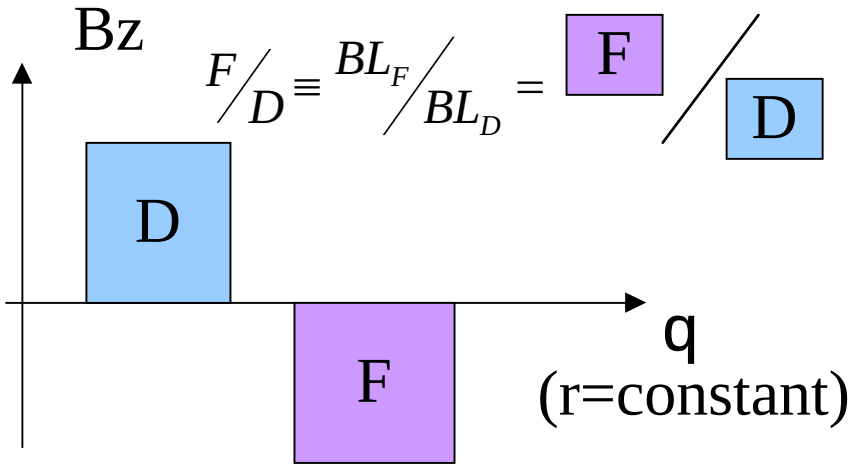
Maximum Magnetic Field

(1) Comparison of FODO and Triplet FDF





Definition of FD ratio (ex. FODO)



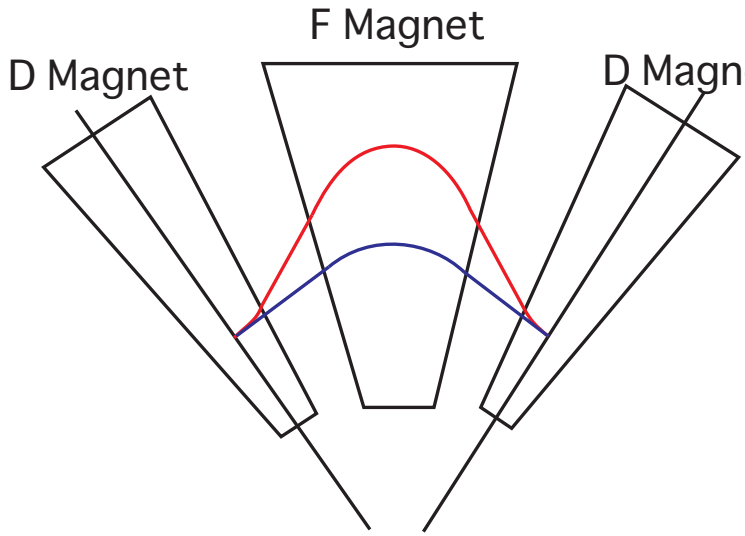
From the viewpoint of higher k value, FDF lattice is better.

From the viewpoint of lower magnetic field, FODO lattice is better.

Maximum Magnetic Field

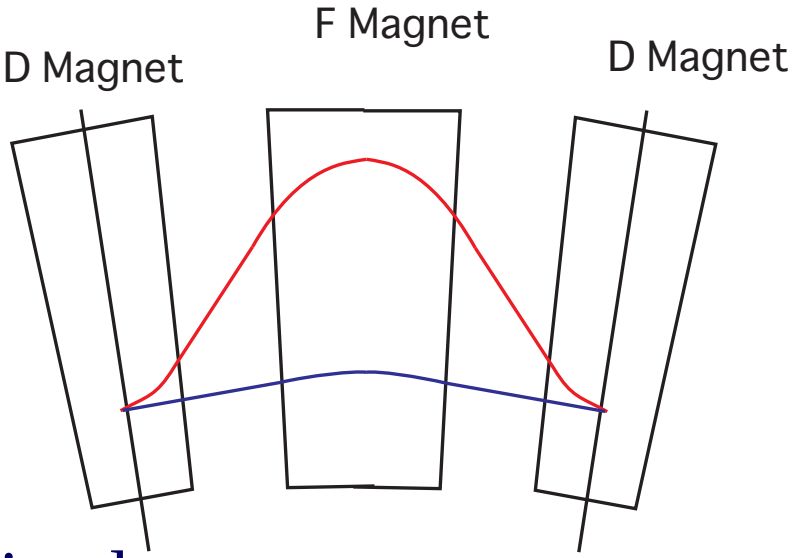
(2) Cell Number Dependence

Small number of cell



Enough edge angle can be obtained even if D mag. does not exist.

Large number of cell



D mag. is essential to vertical focusing.

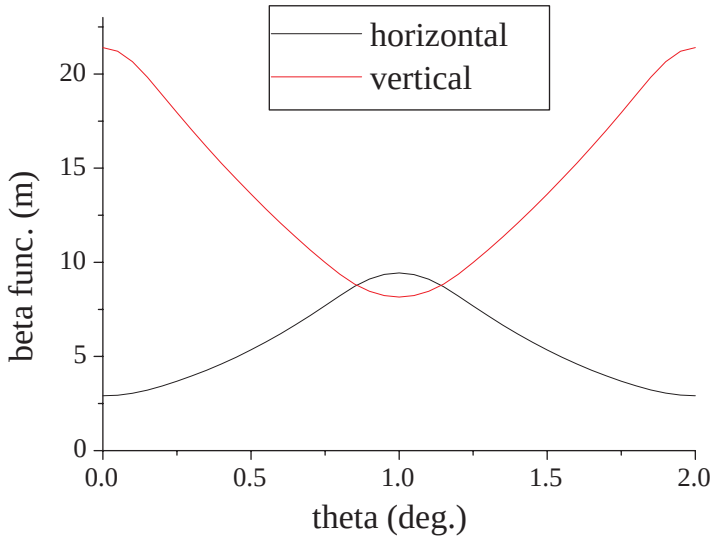
Small number of cell ⟺ Low magnetic field

Large number of cell ⟺ Large k value

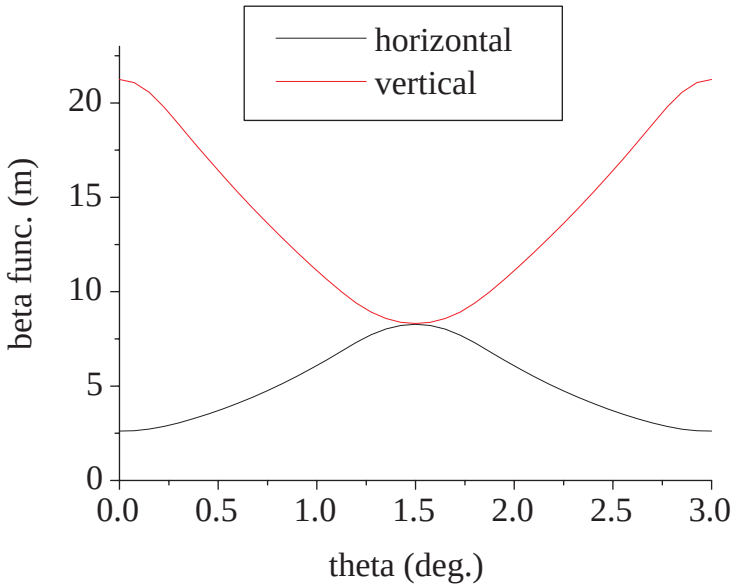
Cell number can be optimized with the limitation of magnetic field.

Phase Advance per Cell & Beta Function

Type1



Type2



82.2deg.(H)/31.4deg.(V)

84.3deg.(H)/28.1deg.(V)

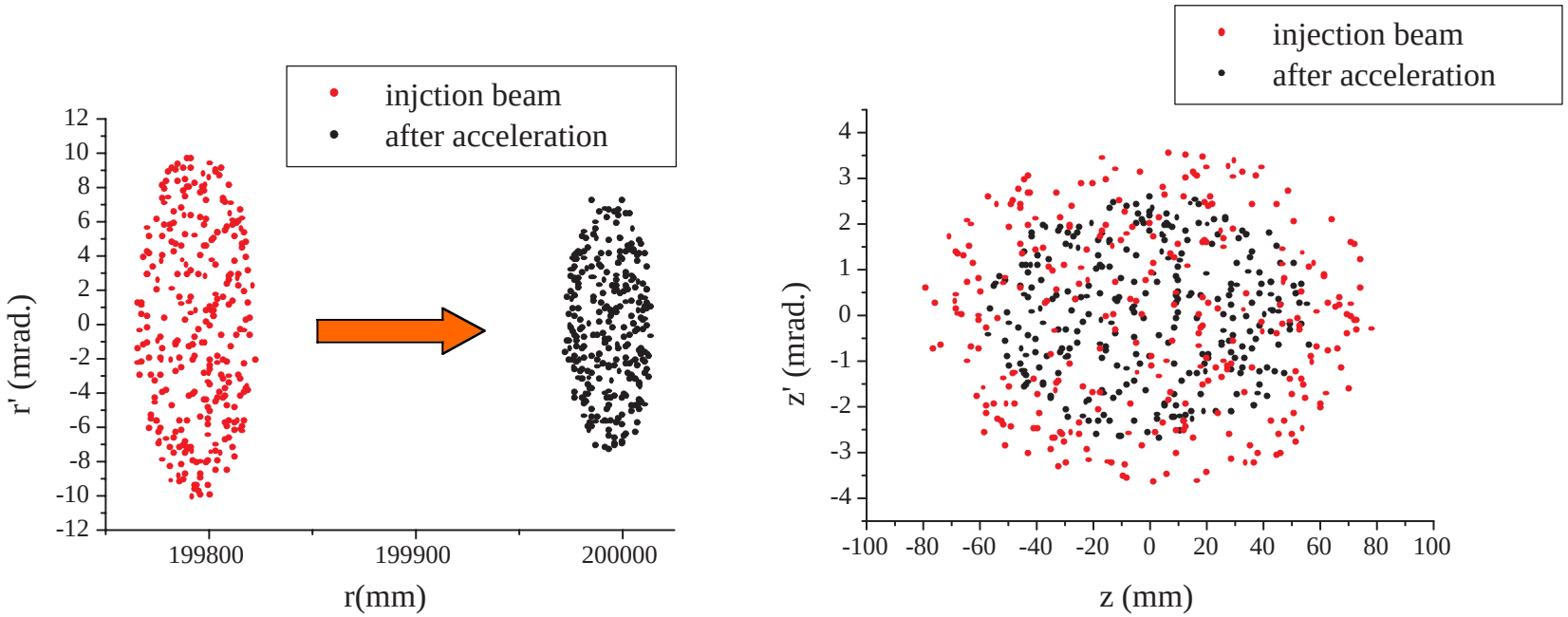
$4n_x = N(90\,\mathrm{deg.})$

$5n_x = N(72\,\mathrm{deg.})$

Horizontal: Avoiding the structure resonances

Vertical: Low phase advance as long as a beam size is acceptable

Acceleration



RF Voltage: 0.75MV/m average
RF Frequency: 23.8MHz
Number of Turn: 13

Muon beam (300πmm-mrad.@injection) is successfully accelerated from 10 to 20 GeV/c.