Non-scaling FFAG Issues

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http://hadron.kek.jp/~machida/doc/nufact/

ffag/machida_20060123.ppt & pdf

Issues

- Lattice and optics
  - Doublet or triplet
  - Injection and extraction
- **Beam dynamics**
  - Longitudinal: acceleration out of bucket
  - Transverse: resonance crossing
  - Large acceptance in both planes
- Hardware
  - 200 MHz superconducting cavity
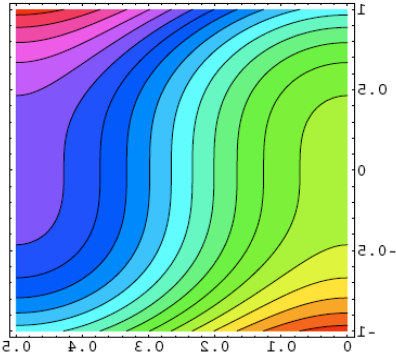 - End fields of a magnet
- Cost

Beam dynamics issues

- Acceleration out of RF bucket. "Gutter" acceleration.
    - Mismatch in longitudinal and transverse .
    - With finite initial transverse amplitude.

- Crossing of many resonances during acceleration.
    - Structure resonance has some effects.
    - With alignment errors, integer resonances have to be considered.

- Huge acceptance (30,000 π mm-mrad) for muons.
    - Dynamic aperture without acceleration at injection energy.

"Gutter" acceleration

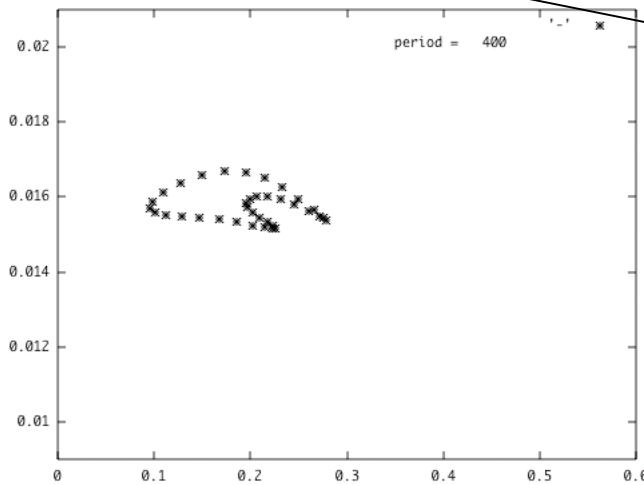## Distortion of longitudinal emittance due to initial "mismatch"

dp/p (normalized)

Phase (1/2 pi)

Kinetic energy [GeV]

Matched

Less tilted (-50%).

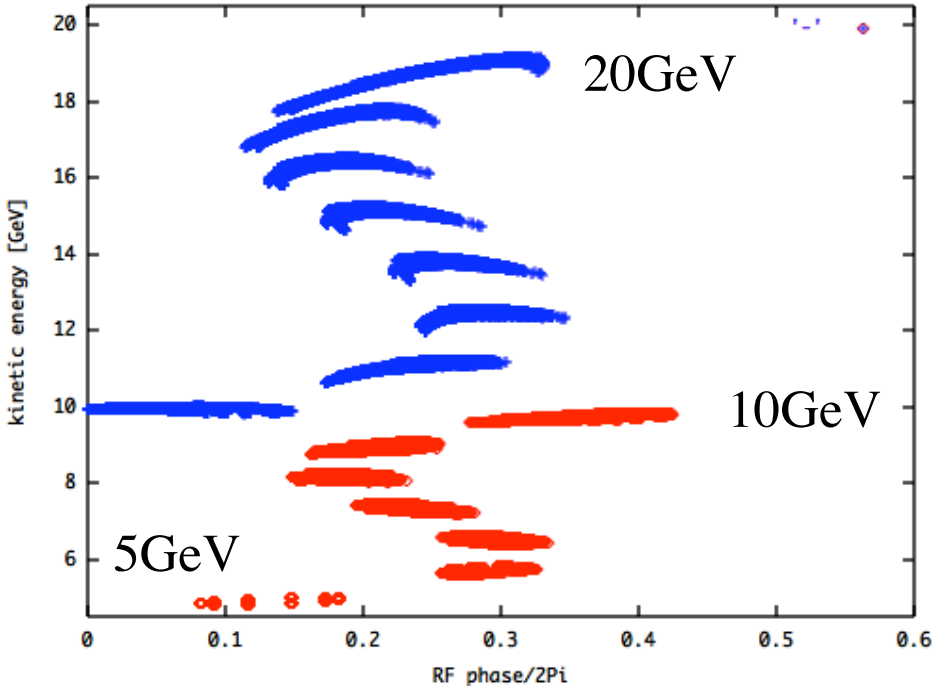tail is developed.

More tilted (+50%).

tail is developed.

RF phase/2Pi

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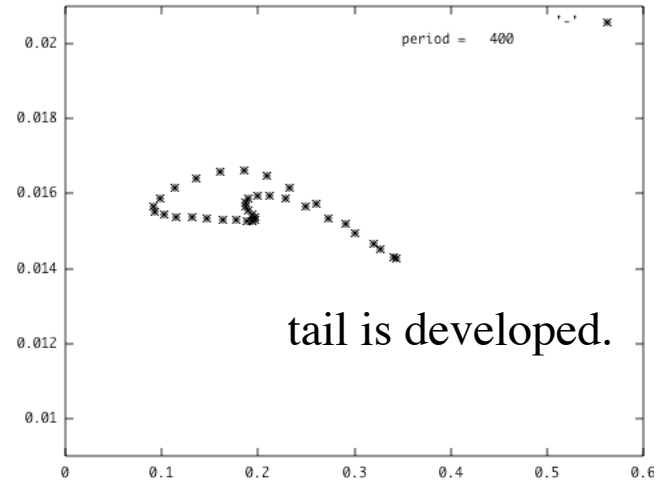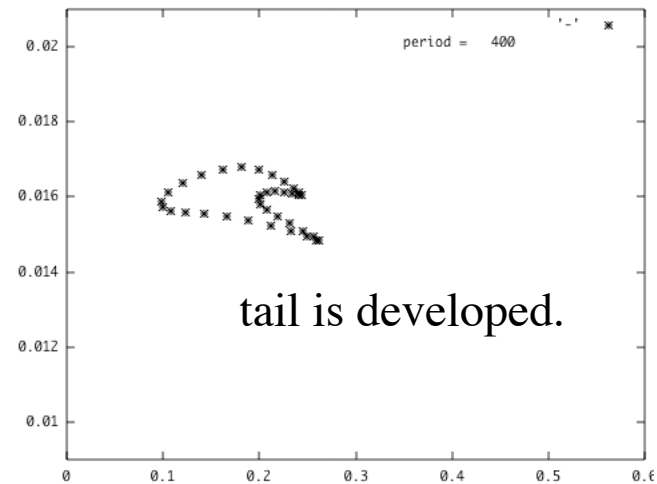
"Gutter" acceleration
Longitudinal matching with two rings.

- Over all optimization is necessary.

- What is the criterion?

Tracking results

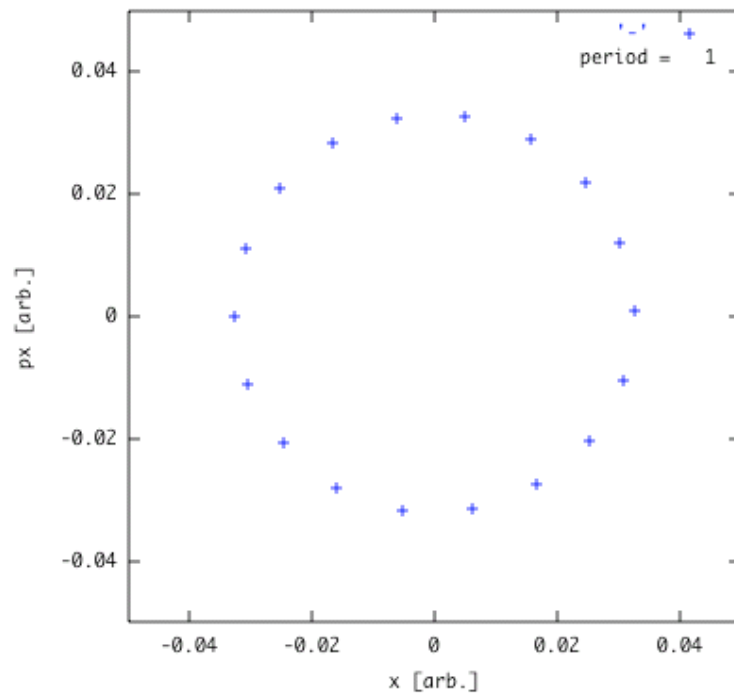# "Gutter" acceleration
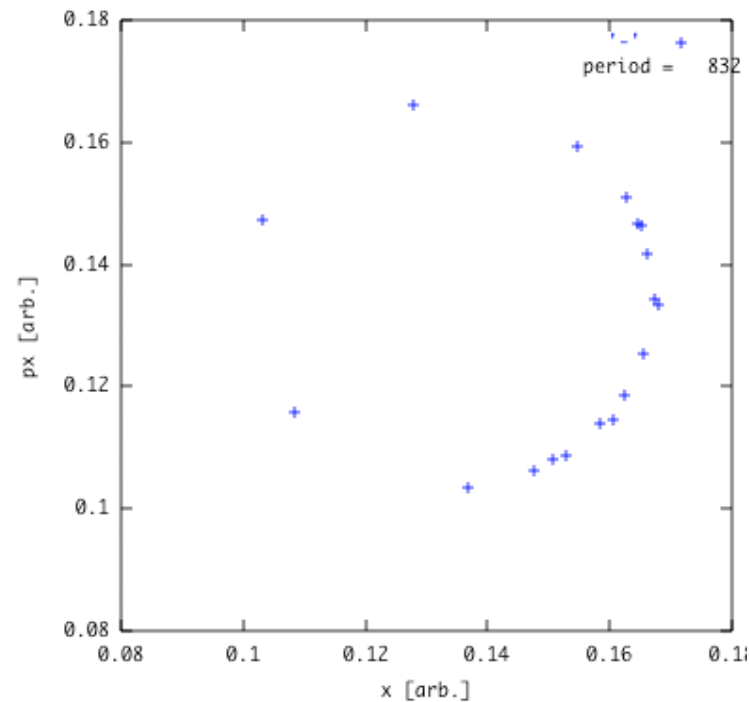## Effects on betatron oscillations

- Starting with a circle of 10 pi mm (equally spaced).

- Accumulated betatron phase depends on initial betatron phase.

- Distribution becomes non-uniform after acceleration.
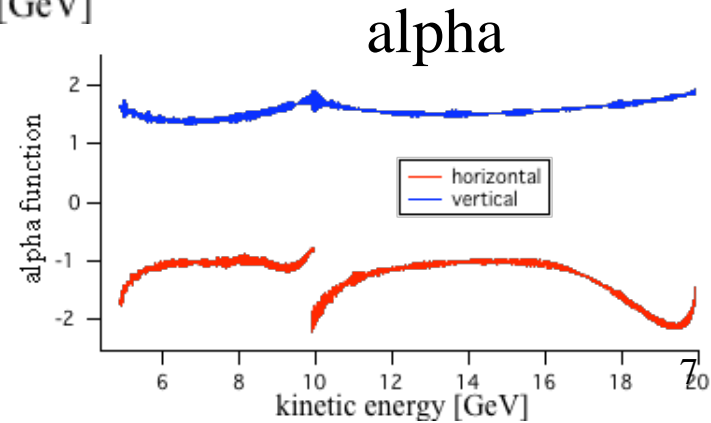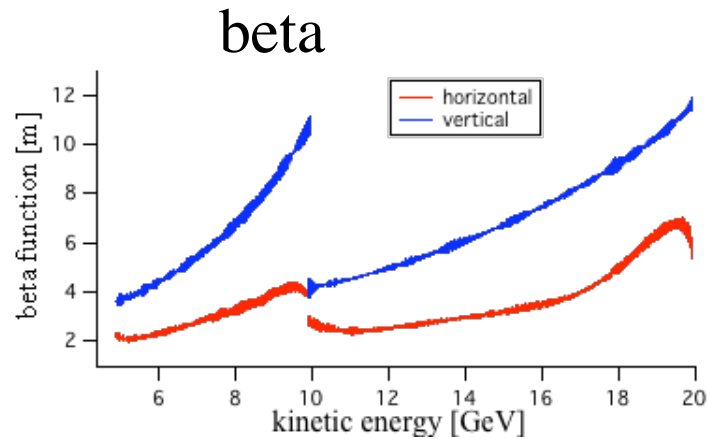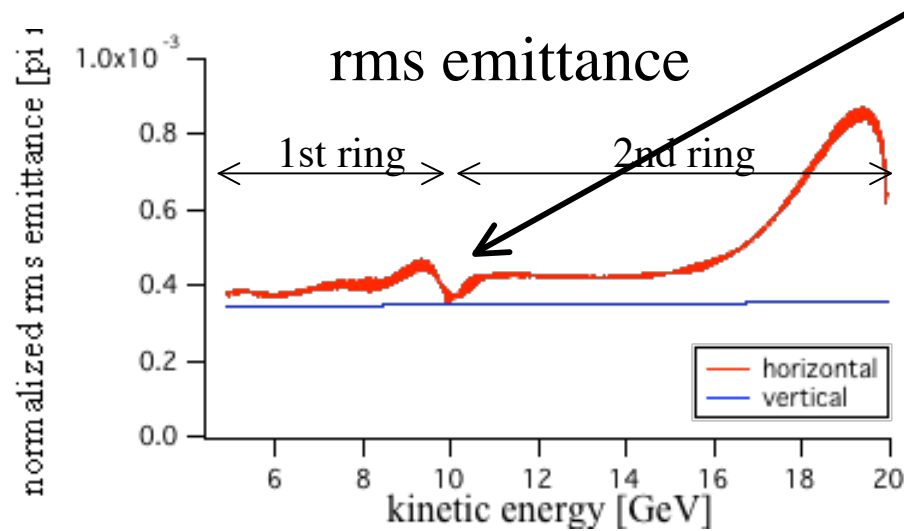

at 5 GeV (injection)   at 10 GeV (extraction)   6

"Gutter" acceleration

Transverse matching between two rings

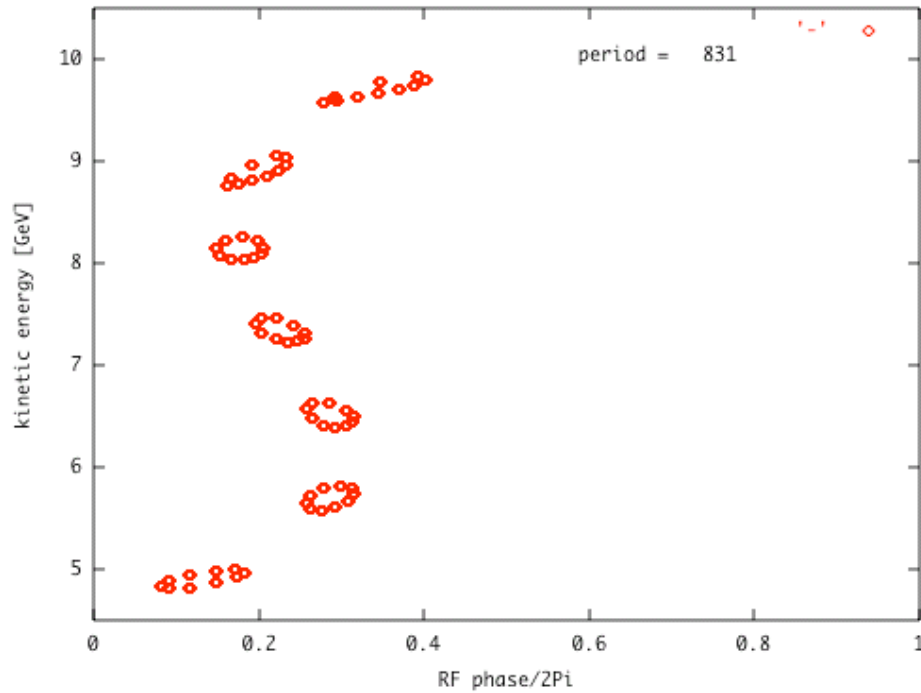- Does distribution mismatching make any problem?
- Optical matching can be done.

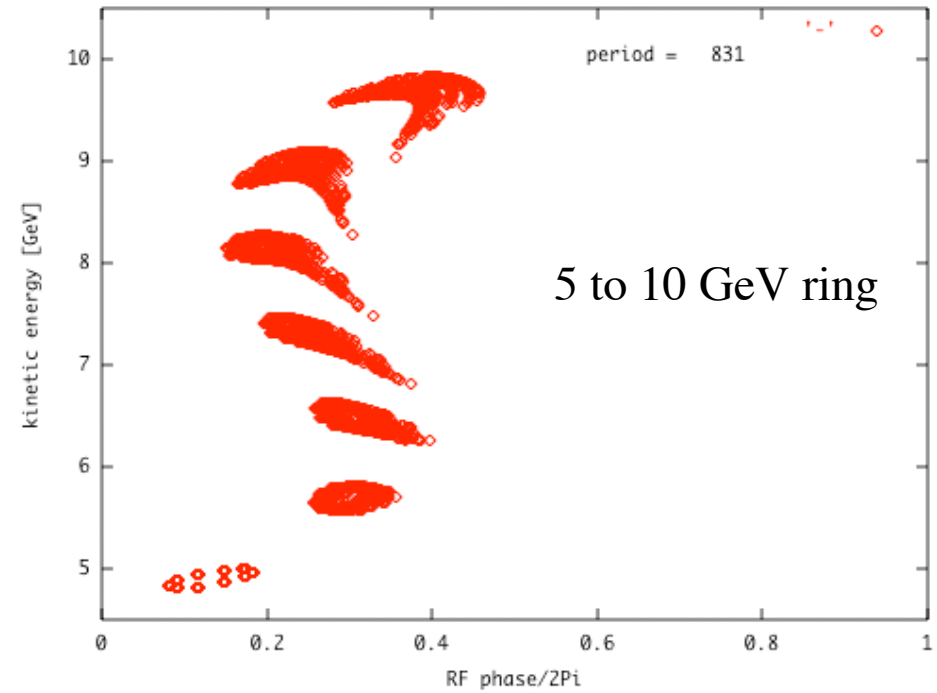Mismatch is small maybe because of small emittace (0.5 pi mm).

rms emittance

1st ring   2nd ring

beta

alpha

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"Gutter" acceleration
Finite transverse amplitude

Longitudinal phase space (phi, momentum)

5 to 10 GeV ring

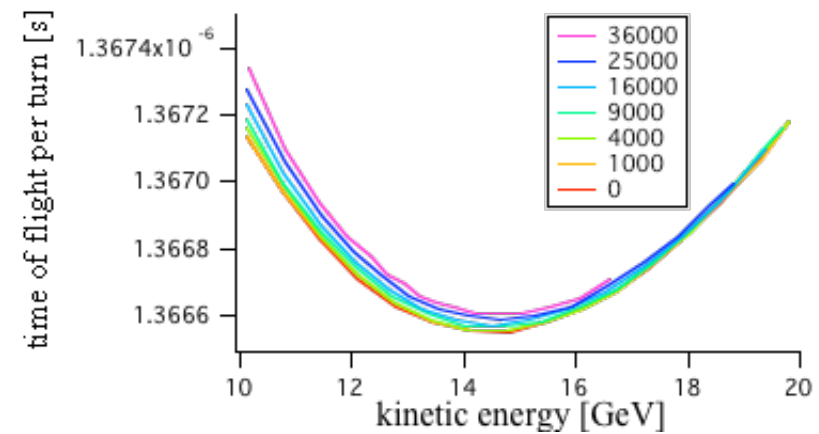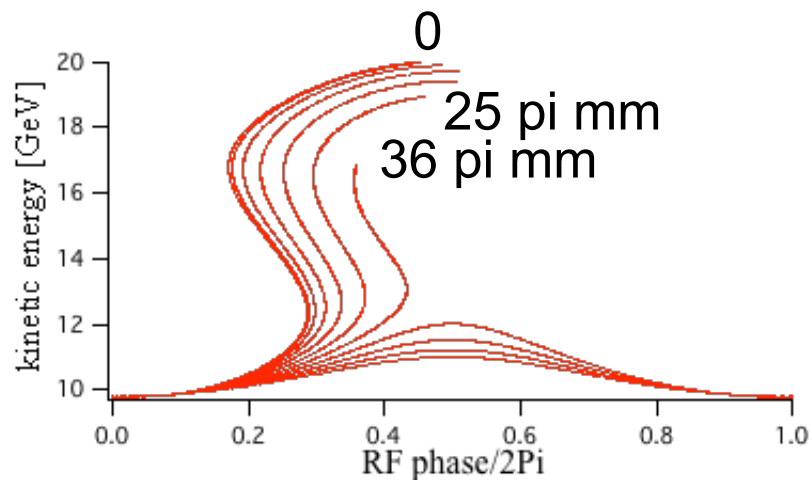without transverse amplitude   with finite transverse amplitude

Horizontal is <u>5 pi mm</u>
Vertical is zero

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"Gutter" acceleration
Finite transverse amplitude

- Horizontal amplitude are
  (0, 1, 4, 9, 16, 25, 36, 49, 64, 81, 100 π mm, normalized.)
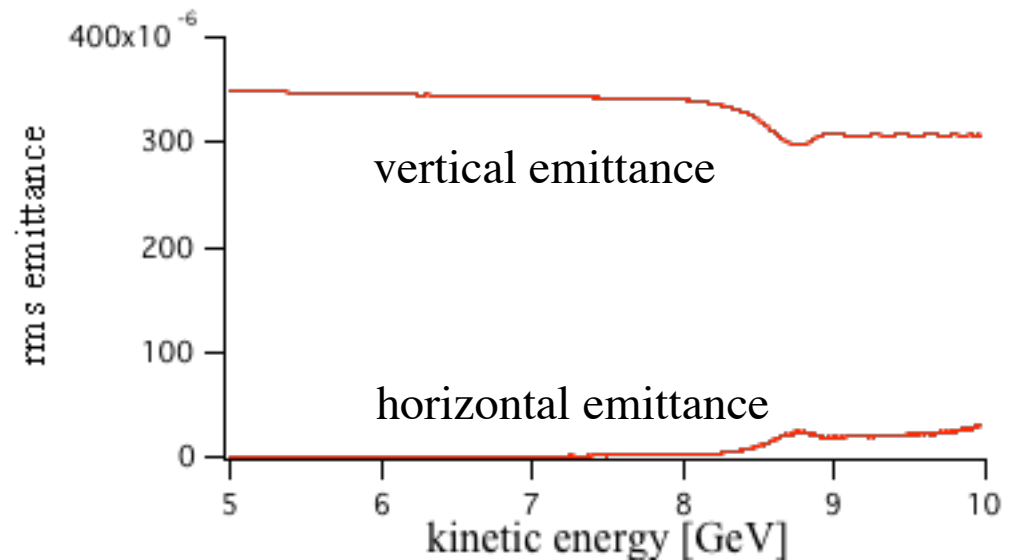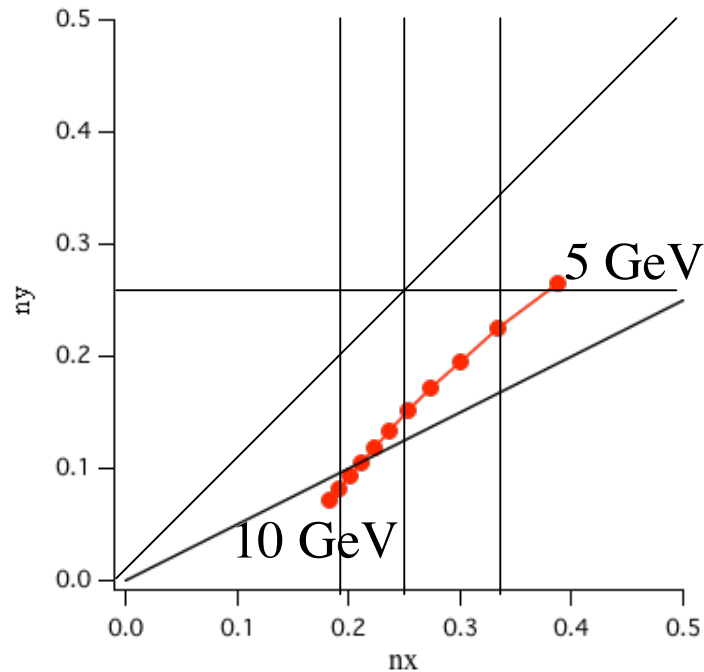
- Vertical amplitude is zero.

- Difference of ToF becomes smaller as accelerated.
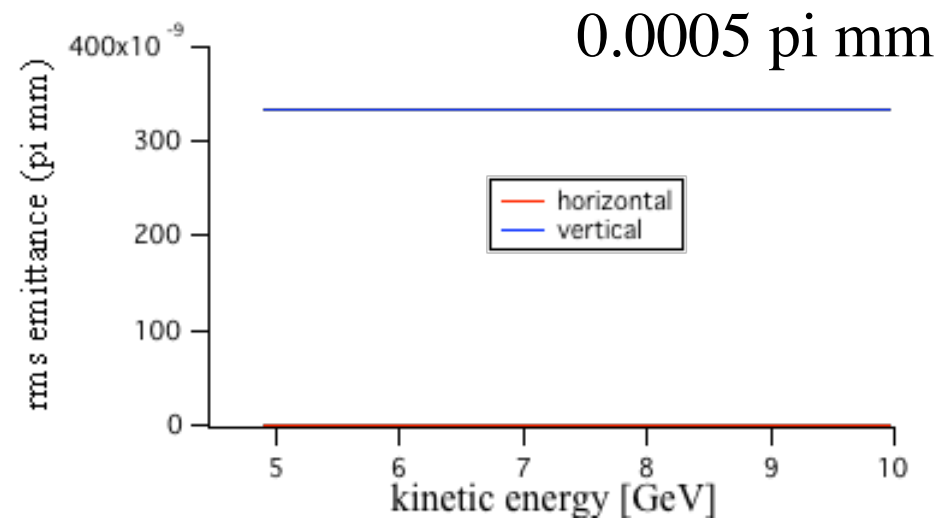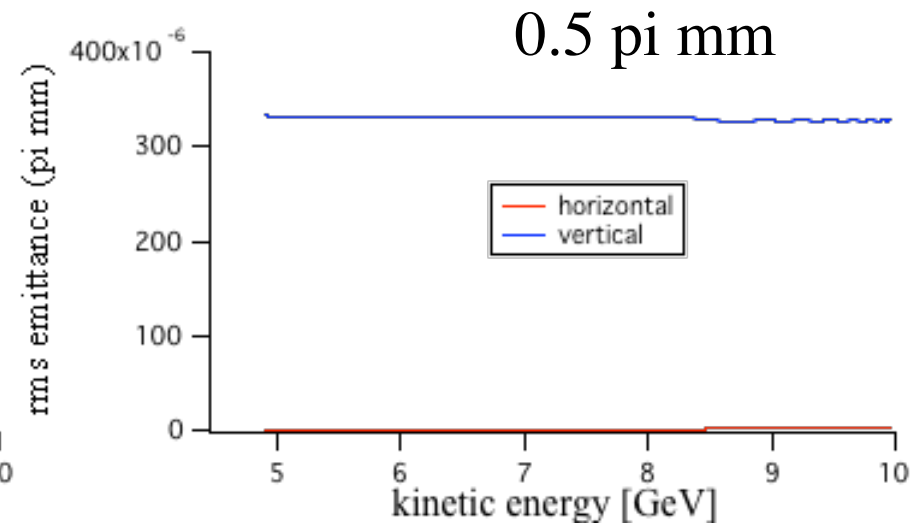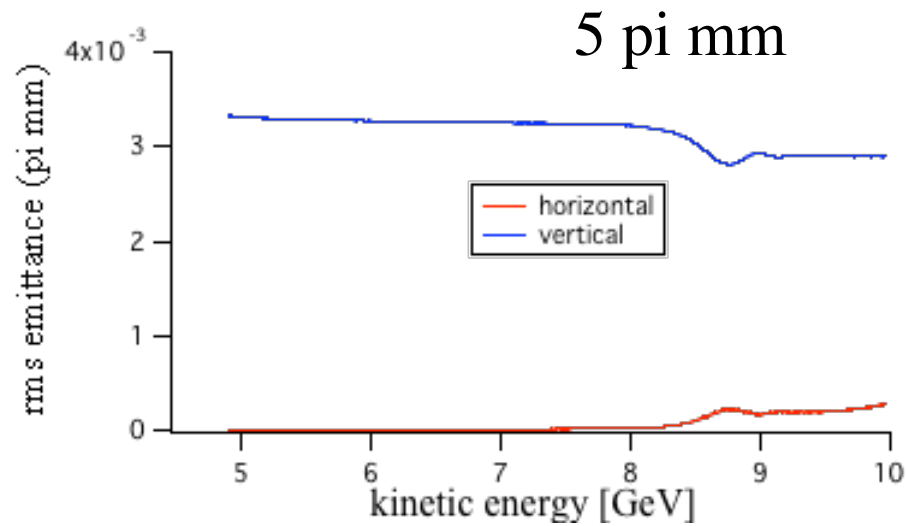
Resonance crossing
without errors

- Vertical is 5 π mm, normalized, zero horizontal emittance.

- Shows the coupling due to nx-2ny=0 (structure) resonance.
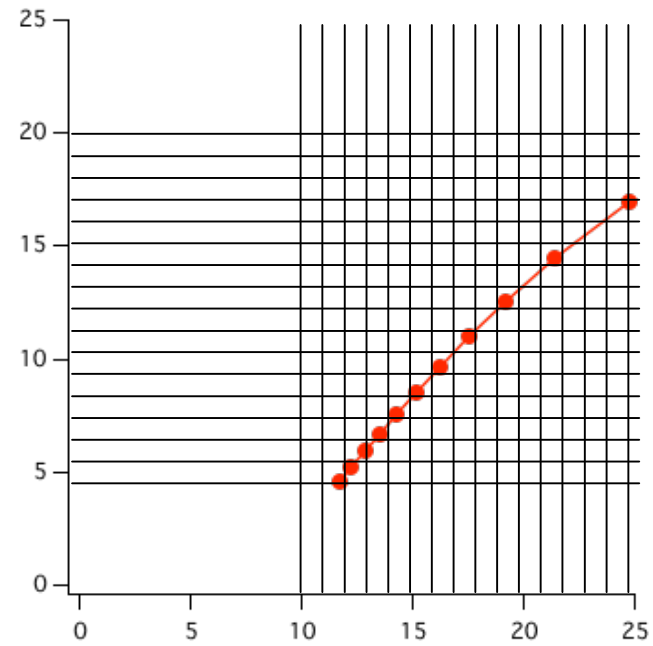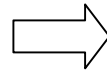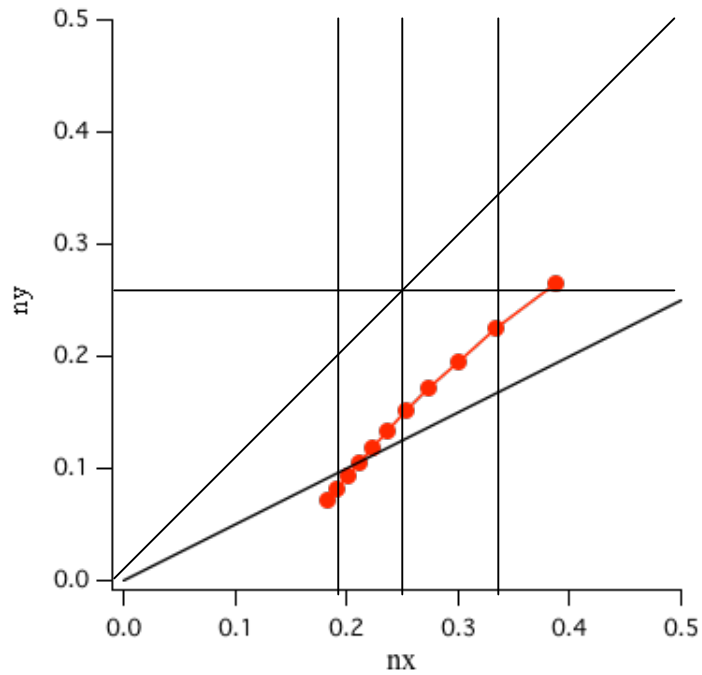- If we start finite horizontal and zero vertical emittance, no exchange of emittance.

Resonance crossing
without errors, amplitude dependence

Resonance crossing
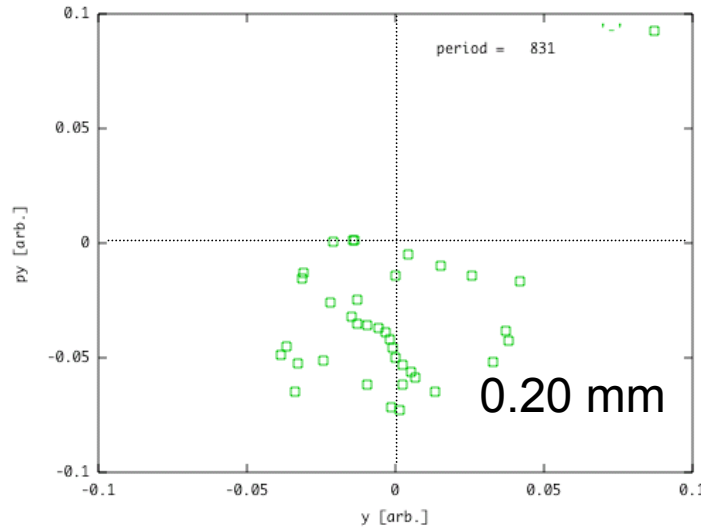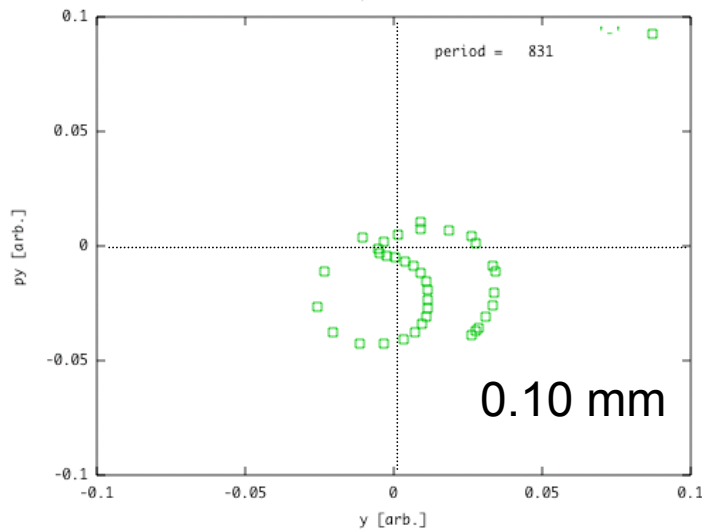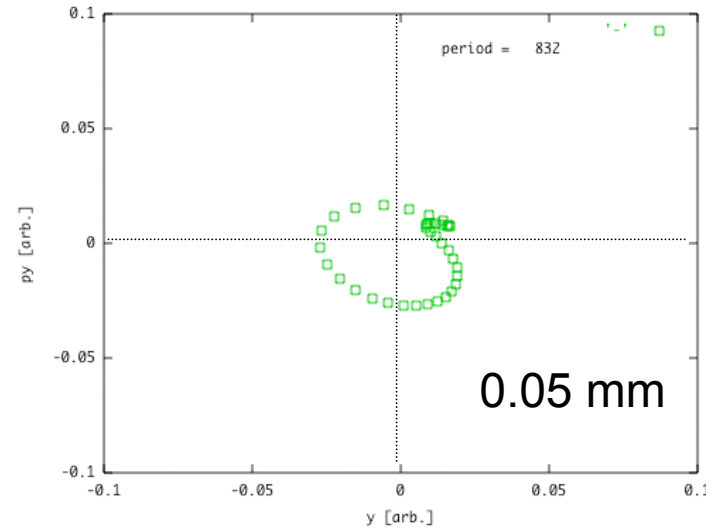## with alignment errors
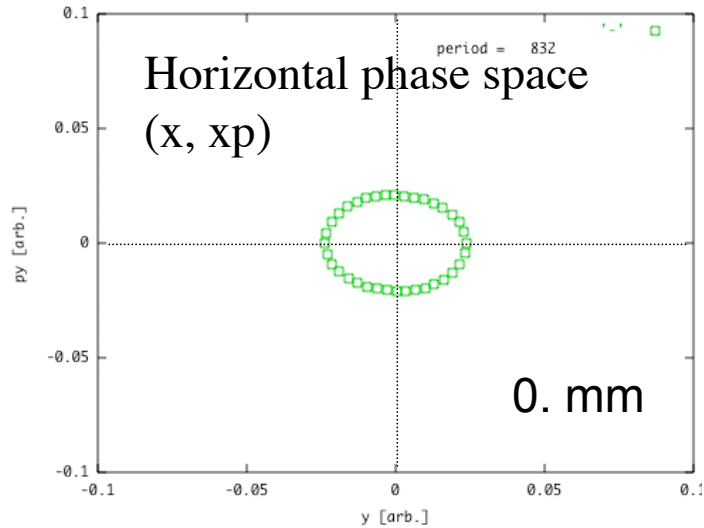
Beam has to face many integer tunes.

tune per cell

tune per ring

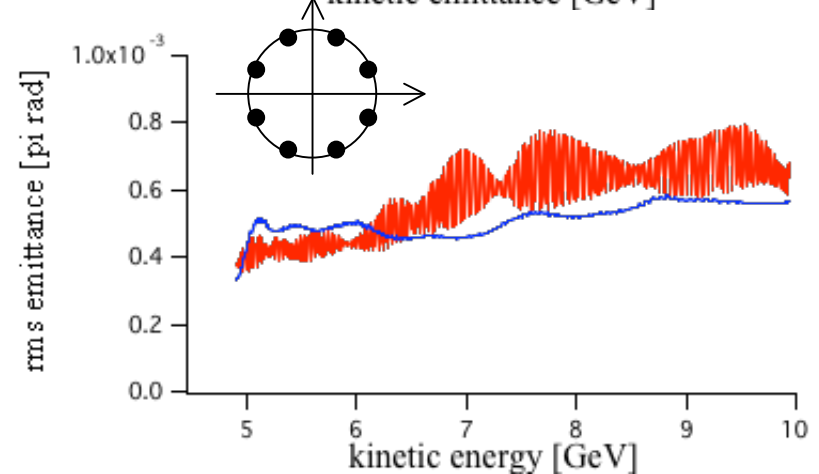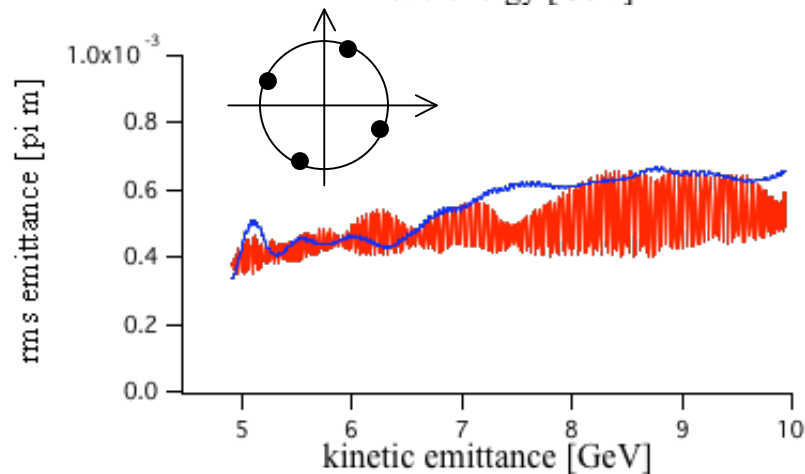# Resonance crossing

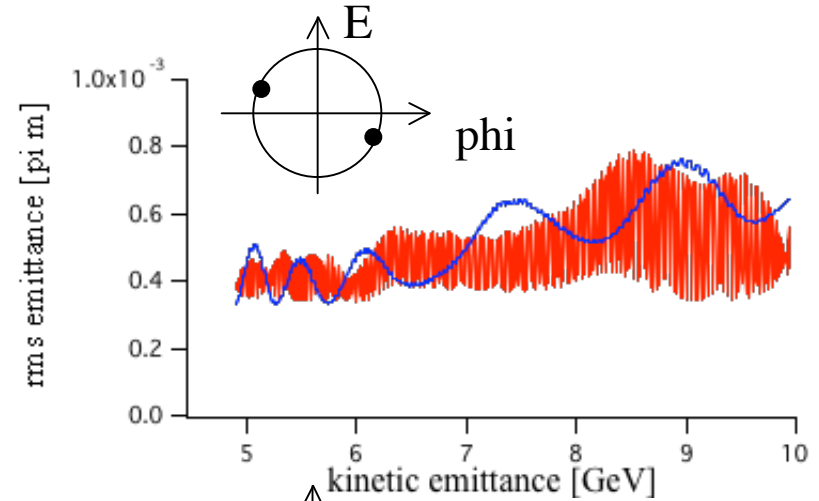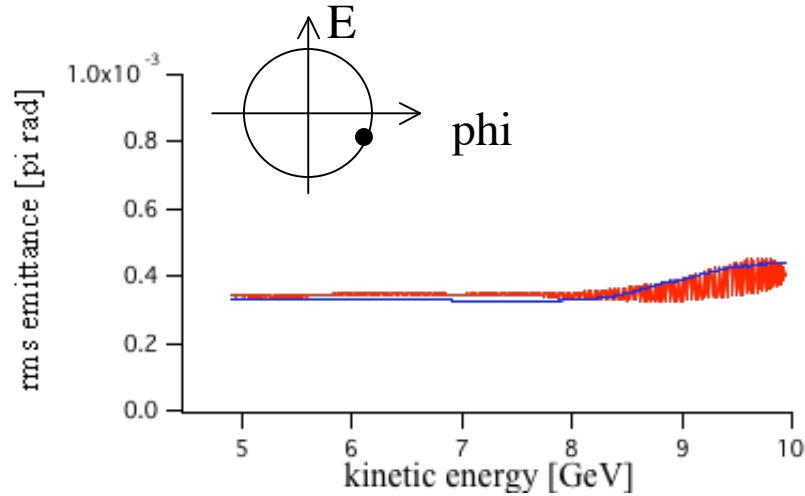## with alignment errors, envelope

- Horizontal is 10 π mm, normalized, zero vertical emittance.

- Errors of 0, 0.05, 0.10, 0.20 mm (rms).

Resonance crossing

with alignment errors (0.1mm), rms emittance

rms emittance: red(Hor.), blue(Ver.)

- ~16 turns are not enough to make decoherence.

- Each particle cross the resonance at difference time. That is another source of decoherence.

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Summary

- Gutter acceleration is a scheme that introduces strong longitudinal and transverse coupling

  (due to finite chromaticity, small dispersion, and no synchrotron oscillations).

  – Matching between 2 rings (both longitudinal and transverse).

  – Finite transverse amplitude makes longitudinal distortion.

- Resonance crossing

  – Tune should avoid structure resonances if possible.

  – Distribution of longitudinal amplitude makes tune spread of transverse tune. That is a source of decoherence in transverse motion.