7th Nov. 2003, NBI03@KEK

J-Parc Neutrino Facility Primary Proton Beam Design

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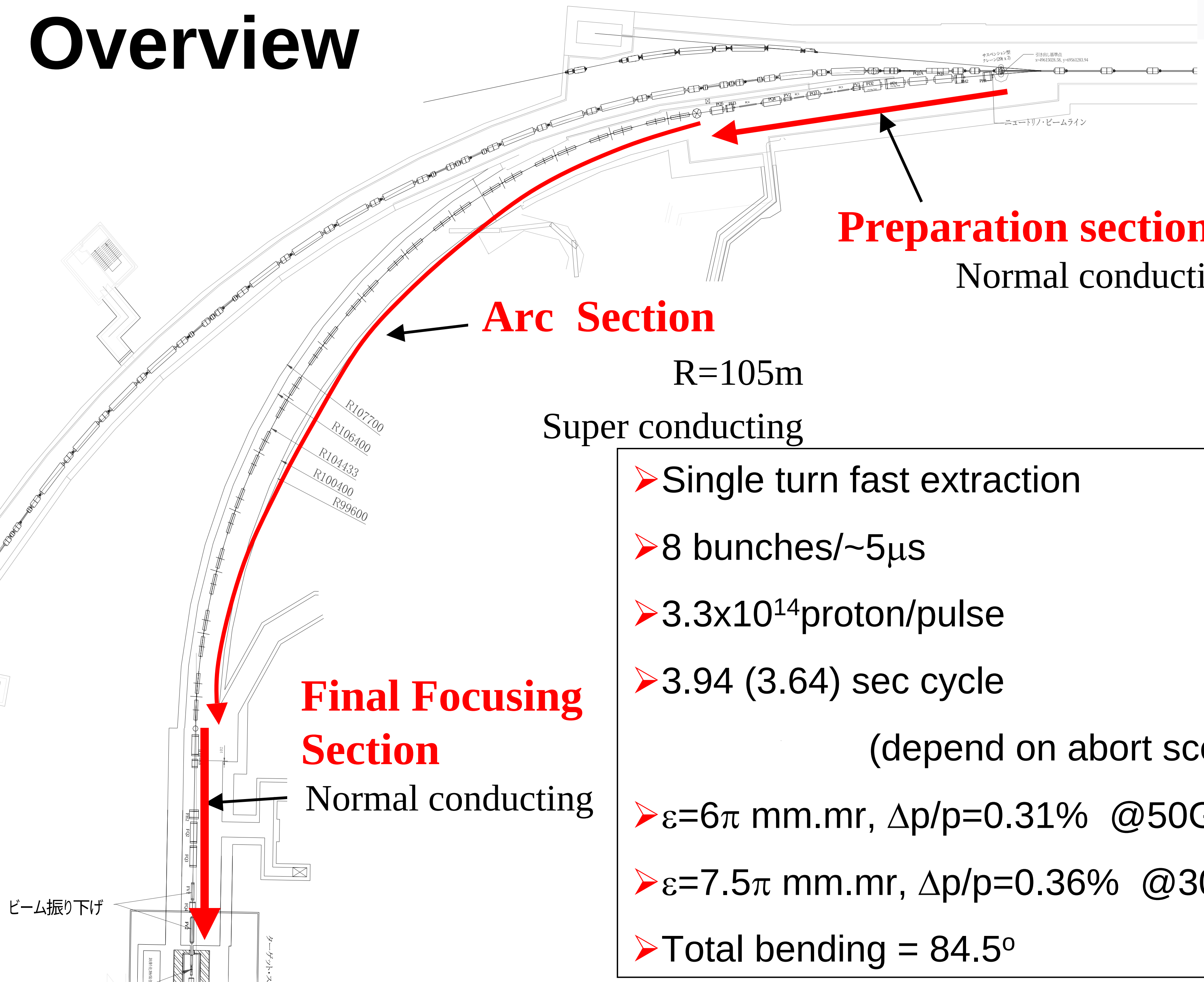
et.al.

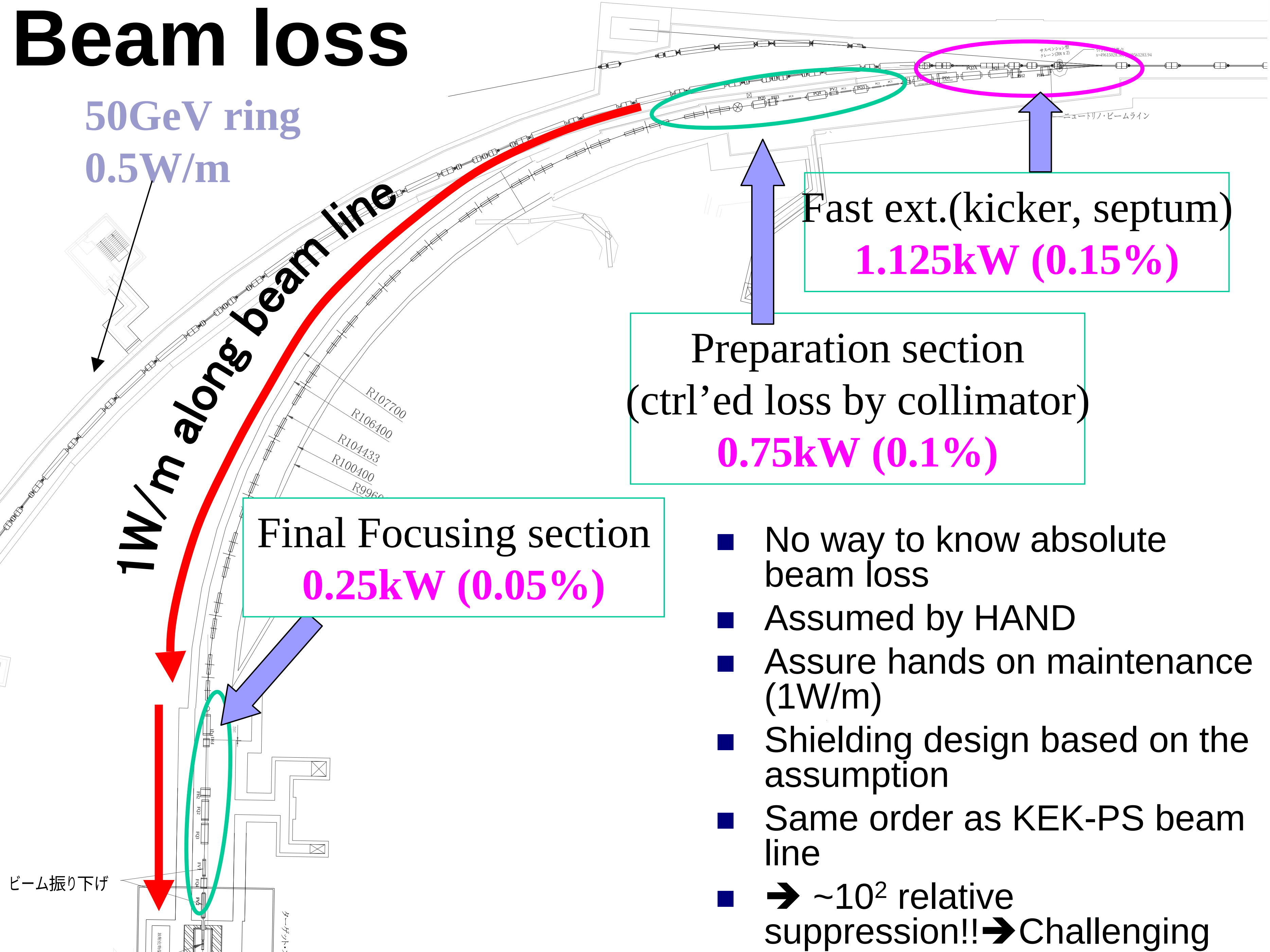
Overview



- Single turn fast extraction
- 8 bunches/~5μs
- 3.3×10^{14}proton/pulse
- 3.94 (3.64) sec cycle

  (depend on abort scenario)
- $\varepsilon = 6\pi$ mm.mr, $\Delta p/p = 0.31\%$ @50GeV
- $\varepsilon = 7.5\pi$ mm.mr, $\Delta p/p = 0.36\%$ @30GeV
- Total bending = 84.5^{o}

Beam loss



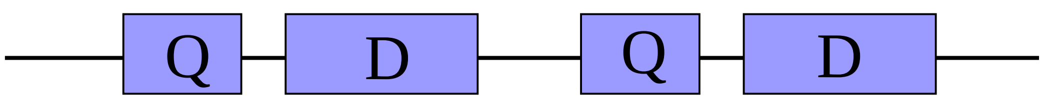
- No way to know absolute beam loss
- Assumed by HAND
- Assure hands on maintenance (1W/m)
- Shielding design based on the assumption
- Same order as KEK-PS beam line
- ➔ ~10^2 relative suppression!!➔Challenging

Boundary Condition for the design

- about 80^{o} bending
- R~105 m → Super conducting magnet
- Beam size in the arc should be as small as possible to prevent quenching
- Beam halo should be cut at Preparation section → Collimator

Two candidates for the arc section design

- ✓ (Separate Function) FODO x10 (20 D's & 20 Q's)



- ✓ Combined function FODO x14 (28 magnets)

$$B_x = Q^*y/r$$

$$B_y = D + Q^*x/r$$

Combined Function
–Merit & Demerit?-

- Merit

    Reduce # of components

    ⇩

    can increase # of (Q-)magnets. ⇨ Smaller beam size

    space btw magnets ⇨ monitor can be installed

    cost reduction

- Demerit

    No example in the world

    Tunnability is restricted

    need corrector?

We adopt combined function scheme !

Treatment of Combined function w/ SAD

$$B_y = B_D + Q_{\text{grad}} \times x$$
$$= Q_{\text{grad}}(x - \Delta x)$$

$$\Delta x = -\frac{B_D}{Q_{\text{grad}}}$$

Quadrupole magnet displaced by Δx.

Fitting parameters,

Δx (by hand), Q_{grad}, angle of magnet

Fitting condition for the cell

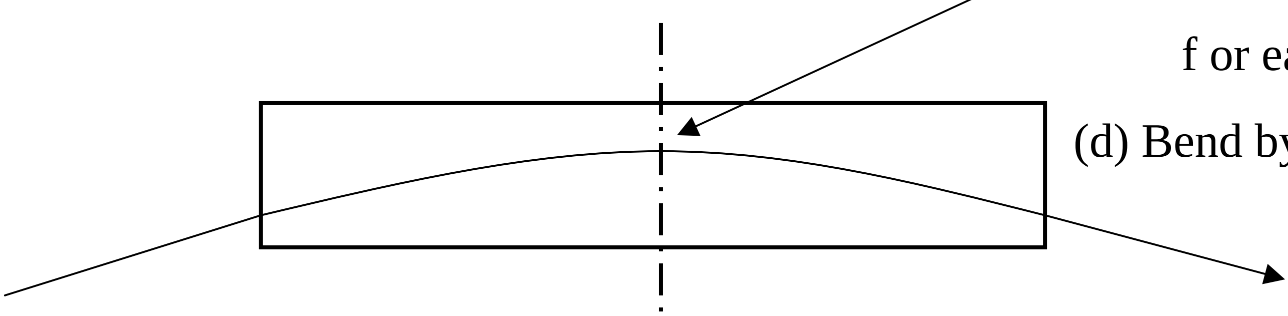
(a) Periodic

(b) 90^o phase advance

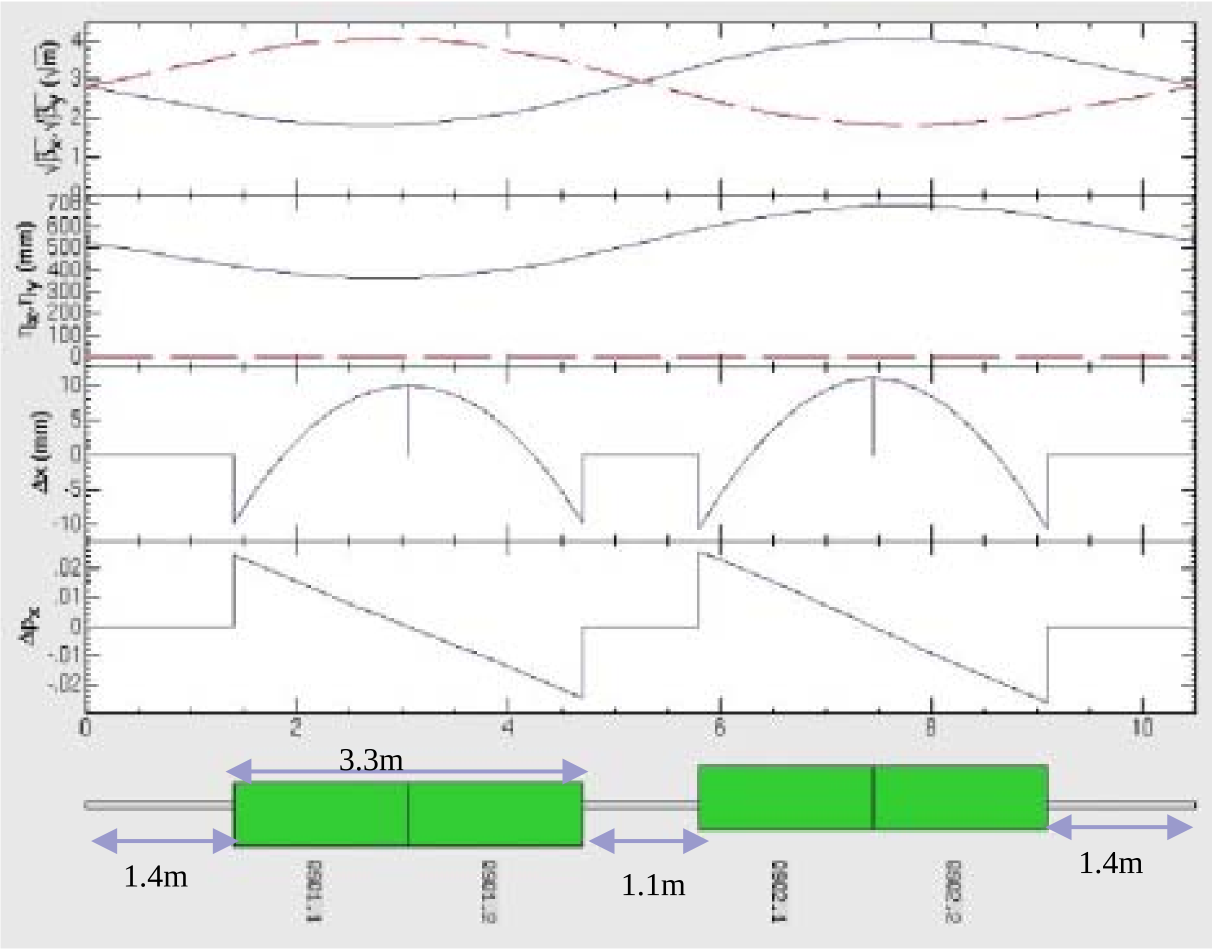
(c) Align orbit and magnet at this point

f or each of two magnets

(d) Bend by 5.76^o



Arc section optics (fitting result)



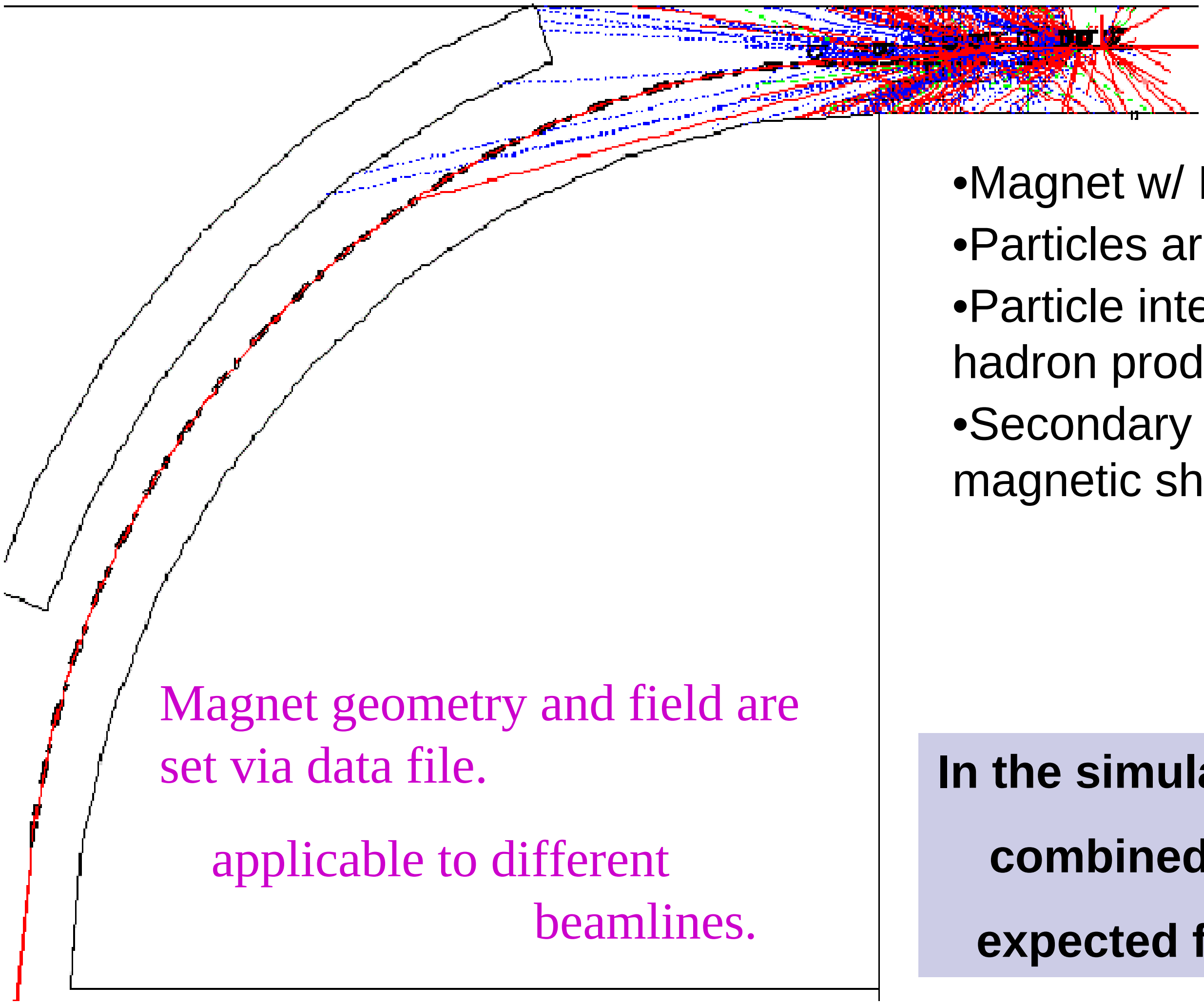
$$K1 = 0.18085$$

$$\frac{dB_y}{dx} = K1 \times \frac{B_o \rho}{L} = 18.620T/m$$

$$B_y(\text{dipole}) = \frac{dB_y}{dx} \times \Delta x = 2.5863T$$

Admittance : 205π mm.mr for horizontal,

Simulation Study (w/ GEANT3 & Geant4)



Magnet geometry and field are set via data file.

applicable to different beamlines.

•Magnet w/ Iron poles are stationed.

•Particles are tracked.

•Particle interact w/ magnet accoring to hadron production model.

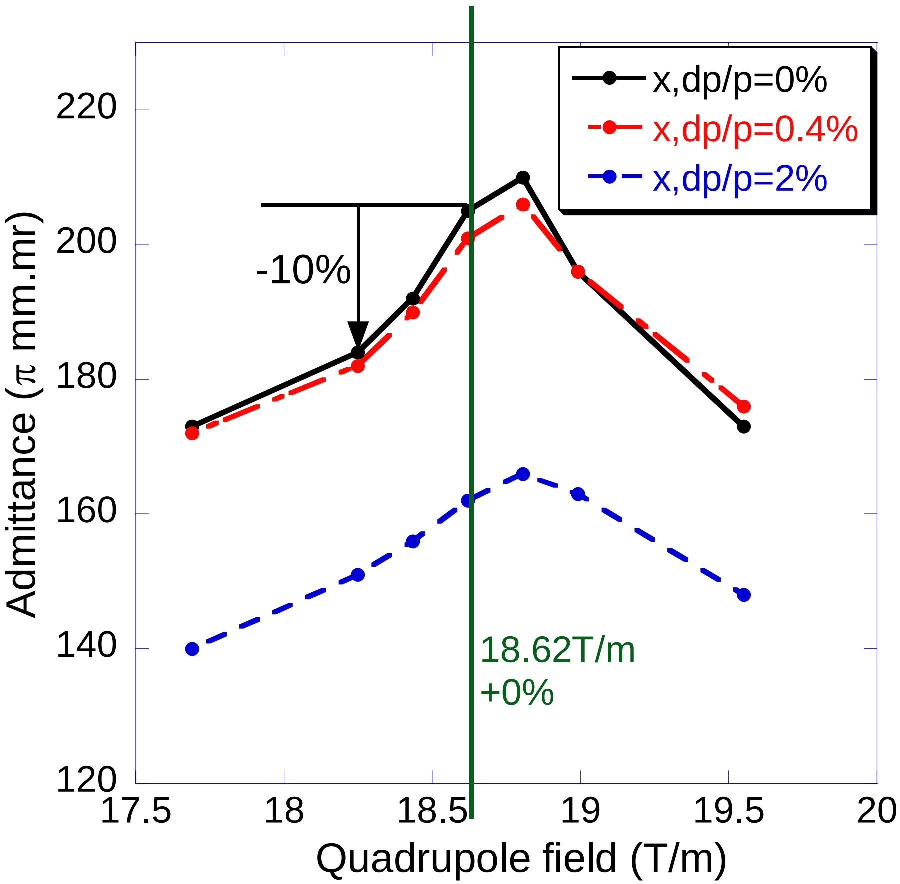
•Secondary hadrons and electro magnetic showers can be traced.

In the simulation,

combined function section works as

expected from optics calculation!

Arc section Admittance
-quadrapole field change-



Admittance calculation
with quadrupole field changed by
0, 1, 2 and 5 %.

The momentum bite was assumed
to be 0, 0.2 and 0.4%.

Admittance changes about 10 %
with quadrupole field decreased by 2 %.

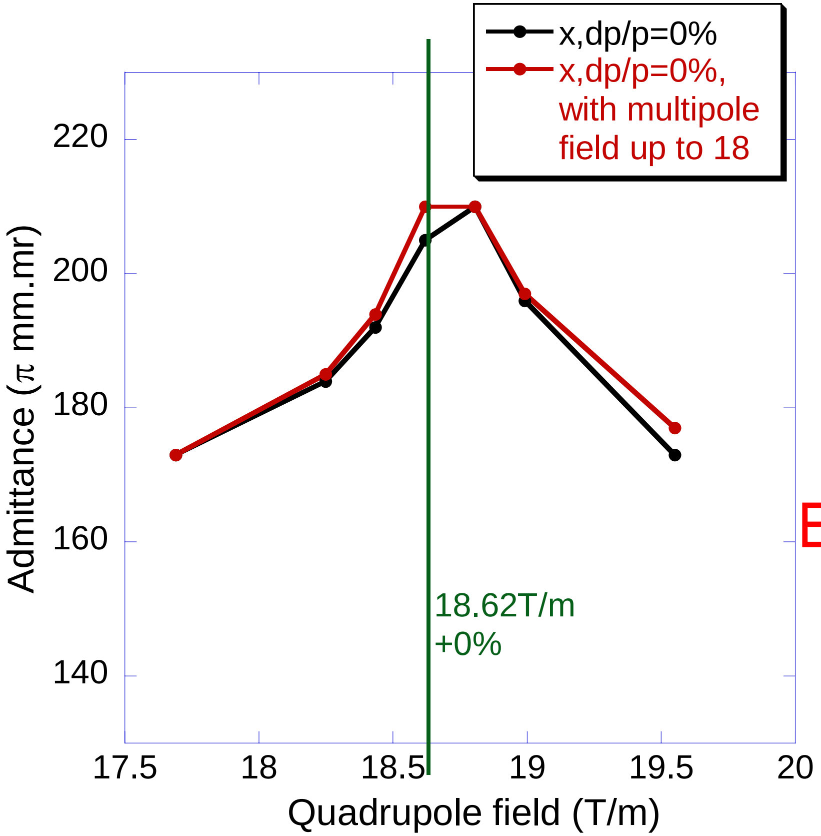
Maximum is at quadrupole field increased
by 1 %.

by Y. Iwamoto

Arc section Admittance
-higher component-

$$B = B_y + iB_x = \frac{B_{ref}}{10000}\sum_{n=1}^{\infty}(b_n + ia_n)\left(\frac{x+iy}{R_{ref}}\right)$$

b_n: dipole component
a_n: skew component
B_{ref}: reference field
R_{ref}: reference radius



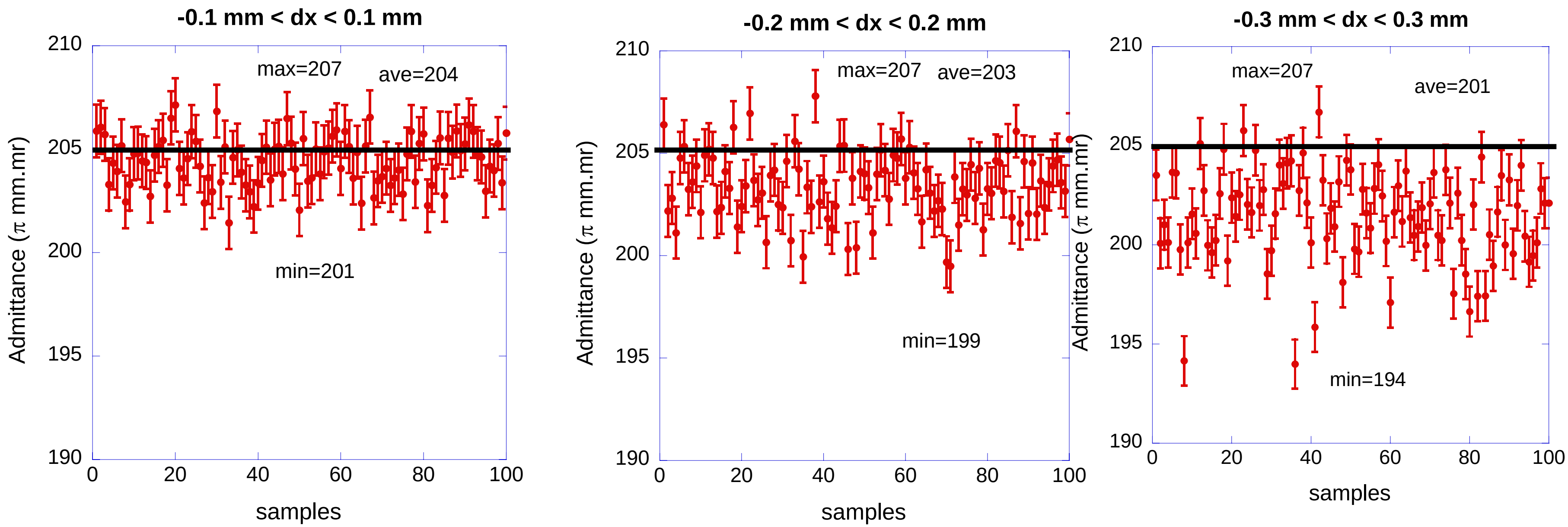
n=1, 2	dipole and quadrupole field
n=1, 2, ..., 18	multipole field

Effect of the multipole field is small.

by Y. Iwamoto

Arc Section Admittance
-Alignment error-

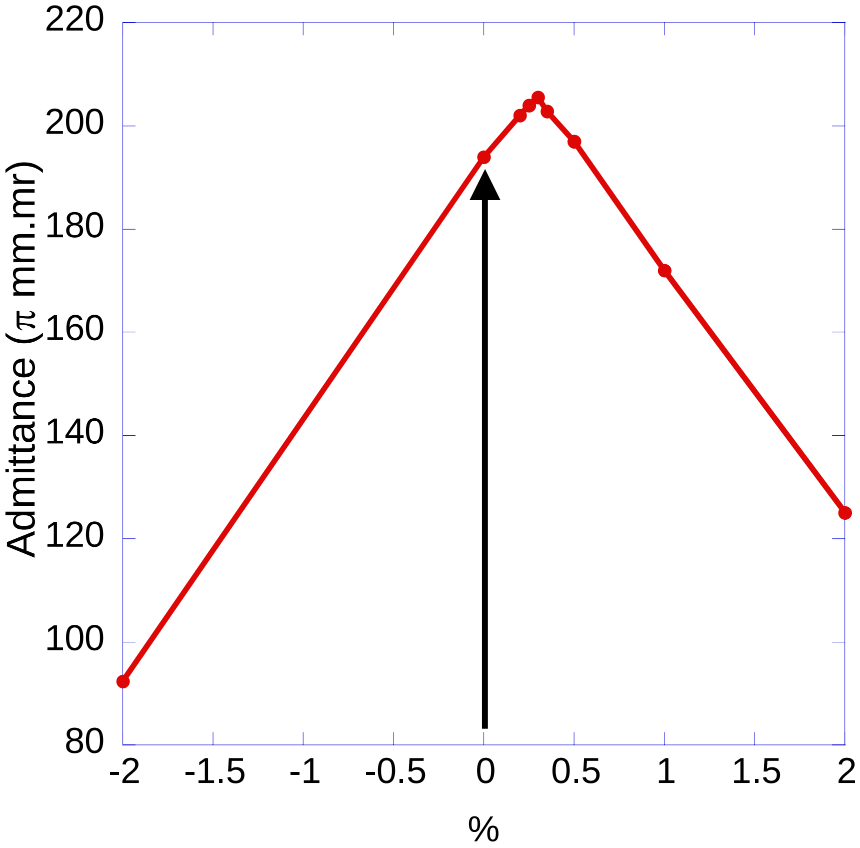
205π for no error



Acceptable alignment error of dx is ± 0.2 mm.
dy is ± 0.2 mm.
dz is ± 5.0 mm.

However, admittance can be recovered by changing the field strength to some extent

With the set up for
dx=0.3mm 、adm=194π



Do we need corrector magnet for the arc section?

The ratio of the quadrapole field and dipole field is fixed.

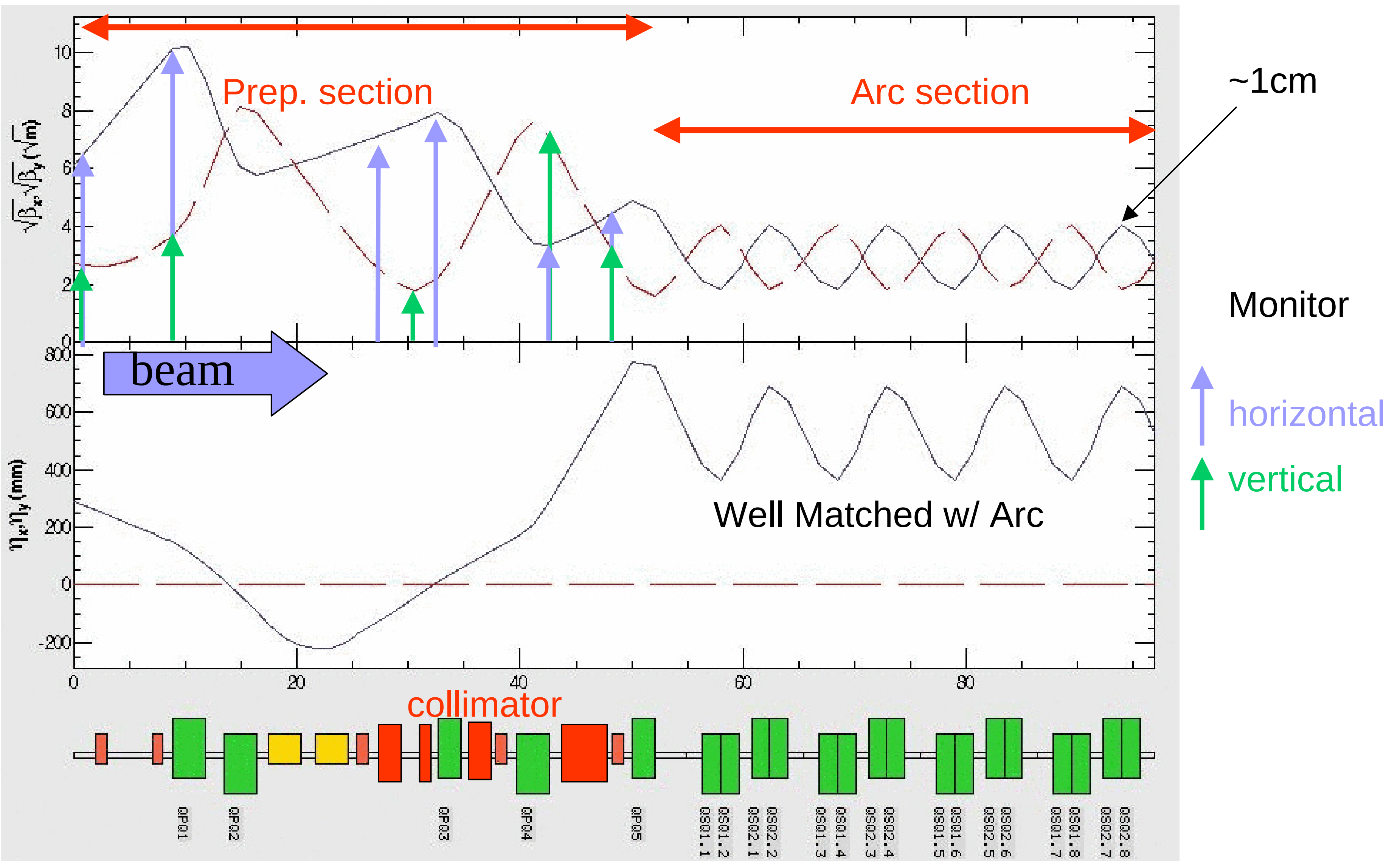
Correction scheme -> T.Ogitus's talk.

It will be decided within this year.

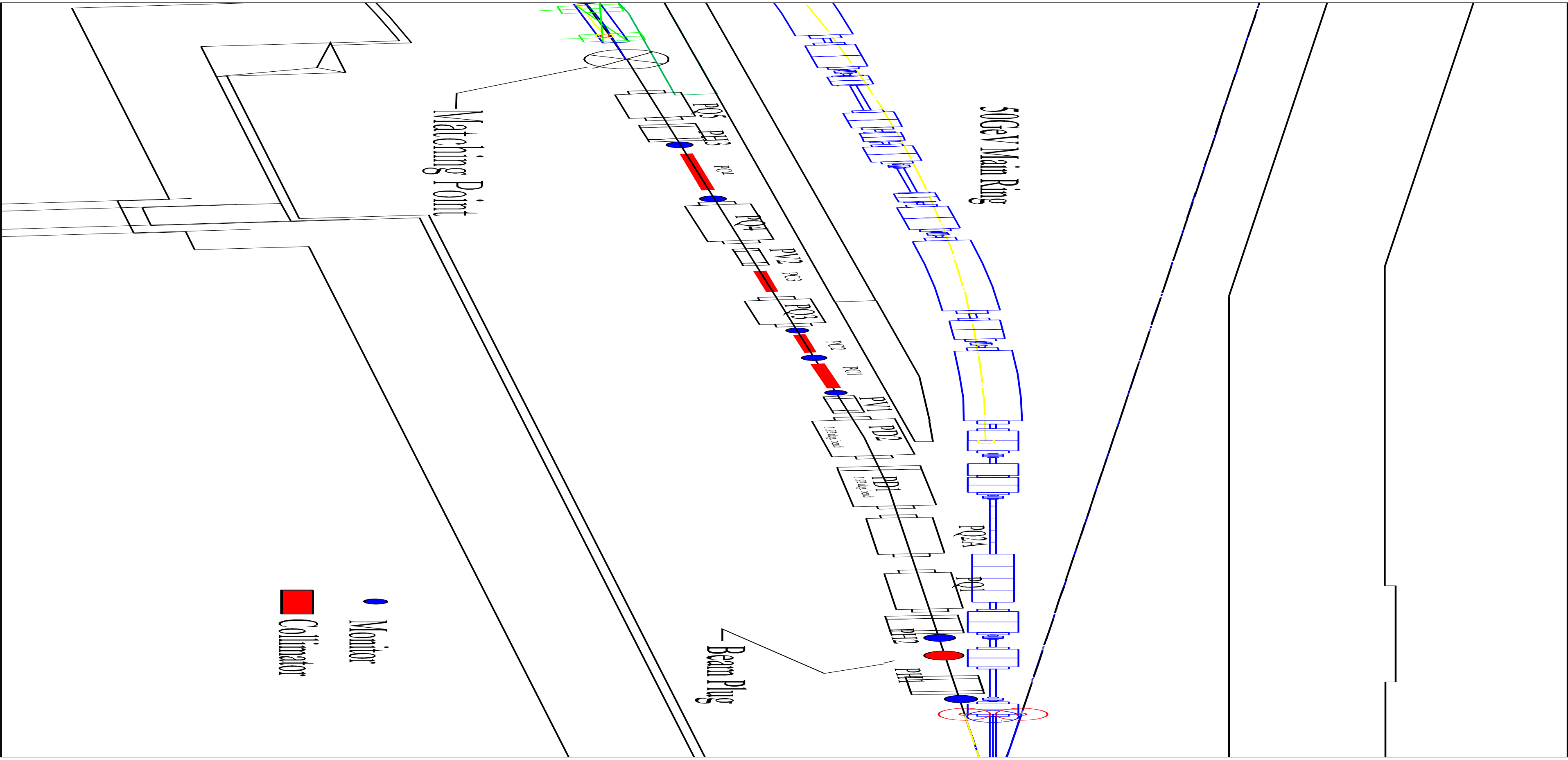
Preparation section **–Overview-**

- ✓Make matching with the Arc.
- ✓Consists of normal conducting magnets.
- ✓Almost no freedom on the **Length and angle**
- ✓Total Length : 52.3m → **Tight spacing**
- ✓3.84 degrees bending
- ✓Scrape beam halo to protect super conducting magnet in the Arc

Preparation Section –optics-



Preparation section



Acceptance : 60π mm.mr (c.f. Acc. design = 6π mm.mr)

Focusing Section

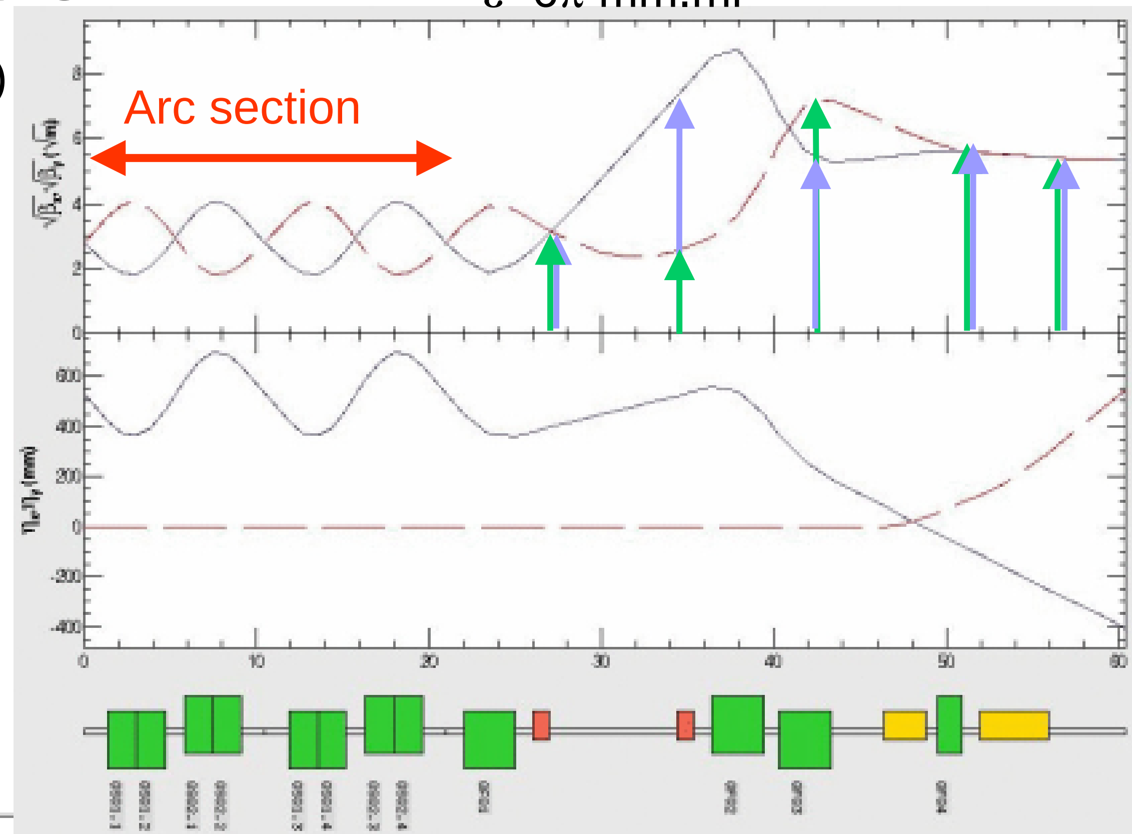
Beam should fit to target (30mmφ)

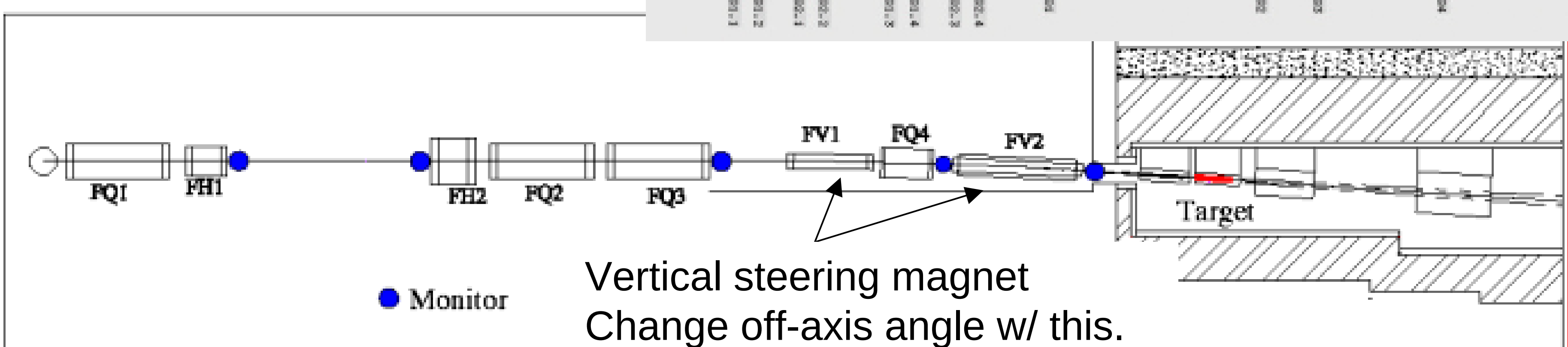
whatever the emittance is.

Focus 6~24π beam

Accept 60π beam.

ε=6π mm.mr





Vertical steering magnet
Change off-axis angle w/ this.

Summary

- J-Parc Neutrino beamline must transport high intensity(0.75 MW) proton beam with 0.01~0.1% loss.
- We adopt super-conducting combined-function magnets for the arc section.
- Simulation study for the possible beam loss sources and halo scraper (see Tanabe's talk) is on going.
- Current big subject is a decision about corrector magnet

for the combined function magnet.

Supplement

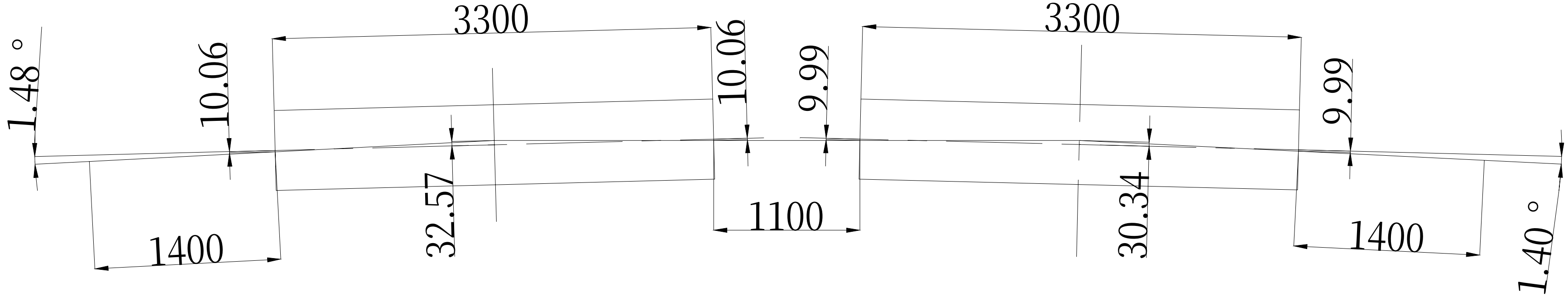
Arc section – fitting results-

$$K1 = 0.18085$$

$$\frac{dB_y}{dx} = K1 \times \frac{B_o \rho}{L} = 18.620T/m$$

$$B_y(\text{dipole}) = \frac{dB_y}{dx} \times \Delta x = 2.5863T$$

ビーム方向



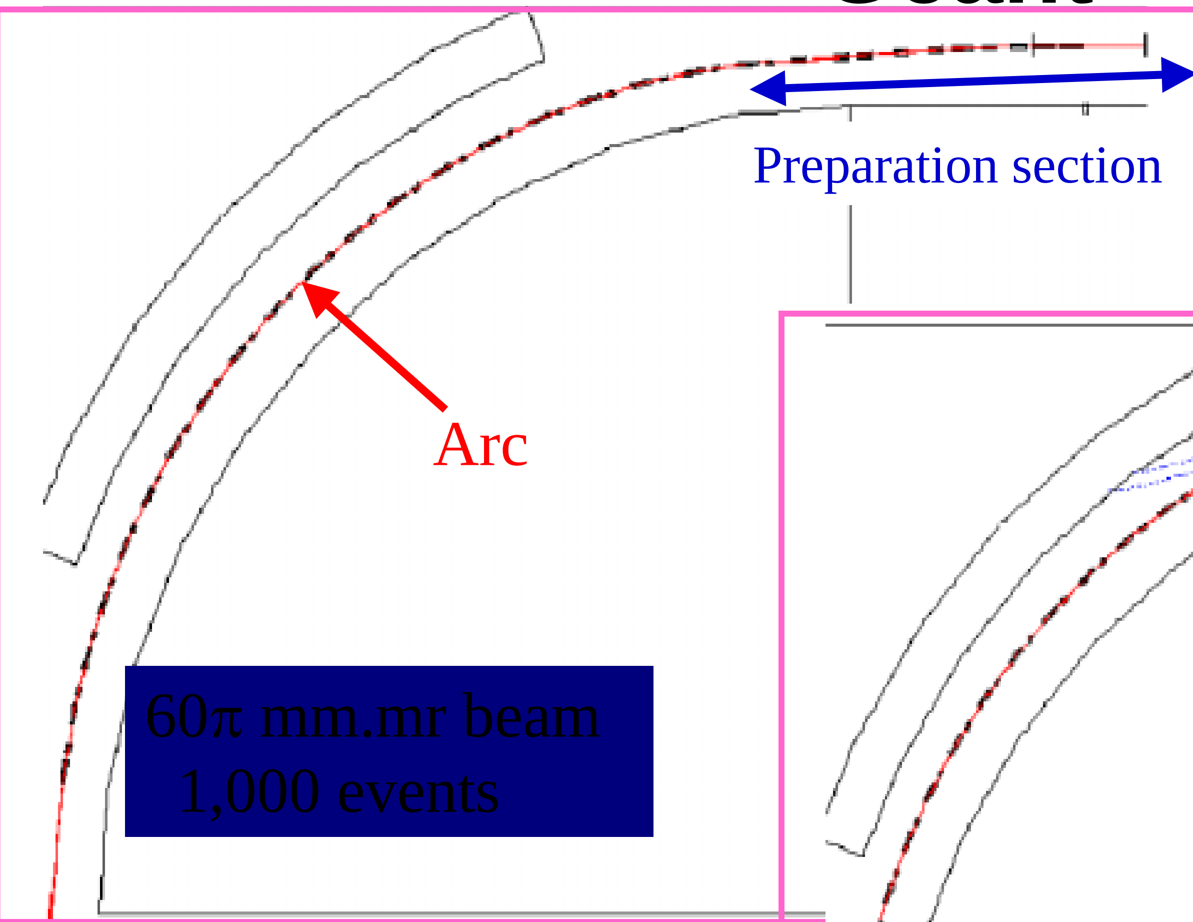
Admittance : 165π mm.mr for horizontal,

262π mm.mr for vertical

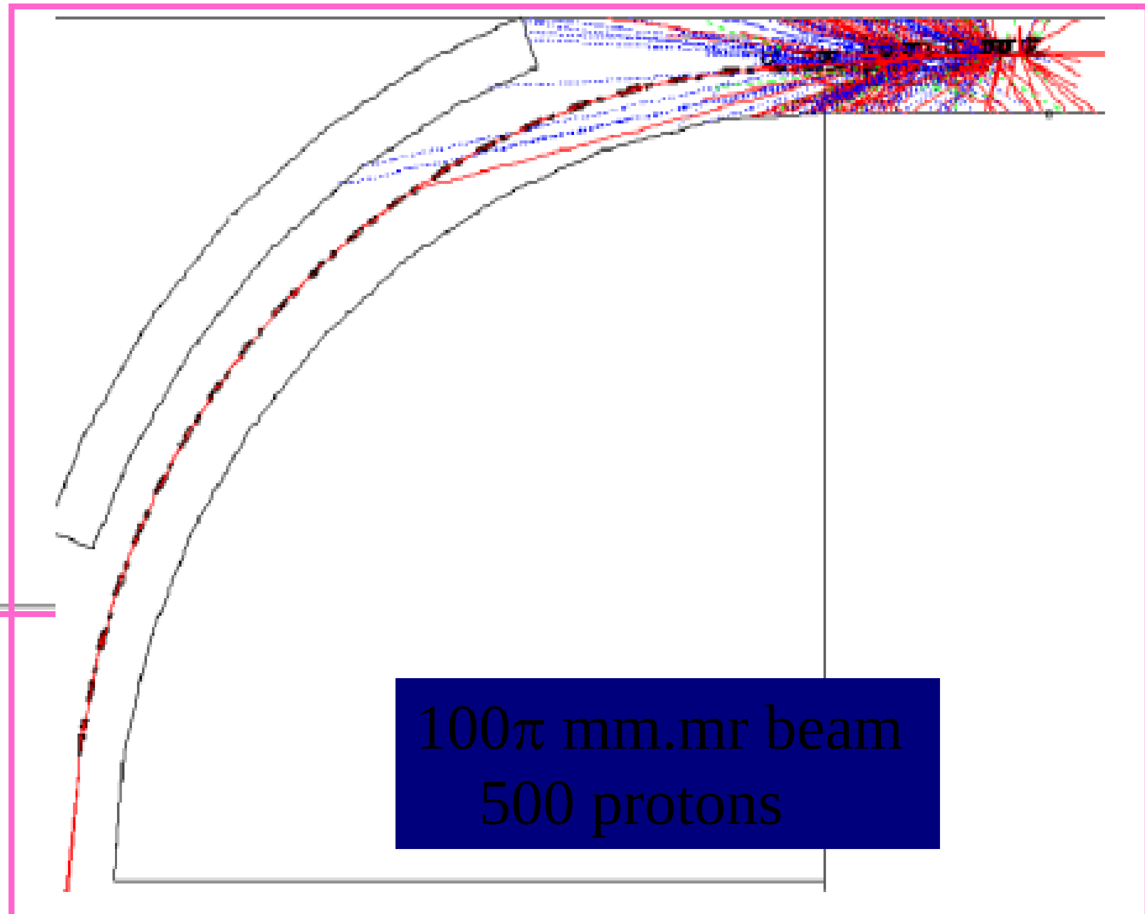
Acceptance and collimator study using Geant

Magnet geometry and field are set via data file.

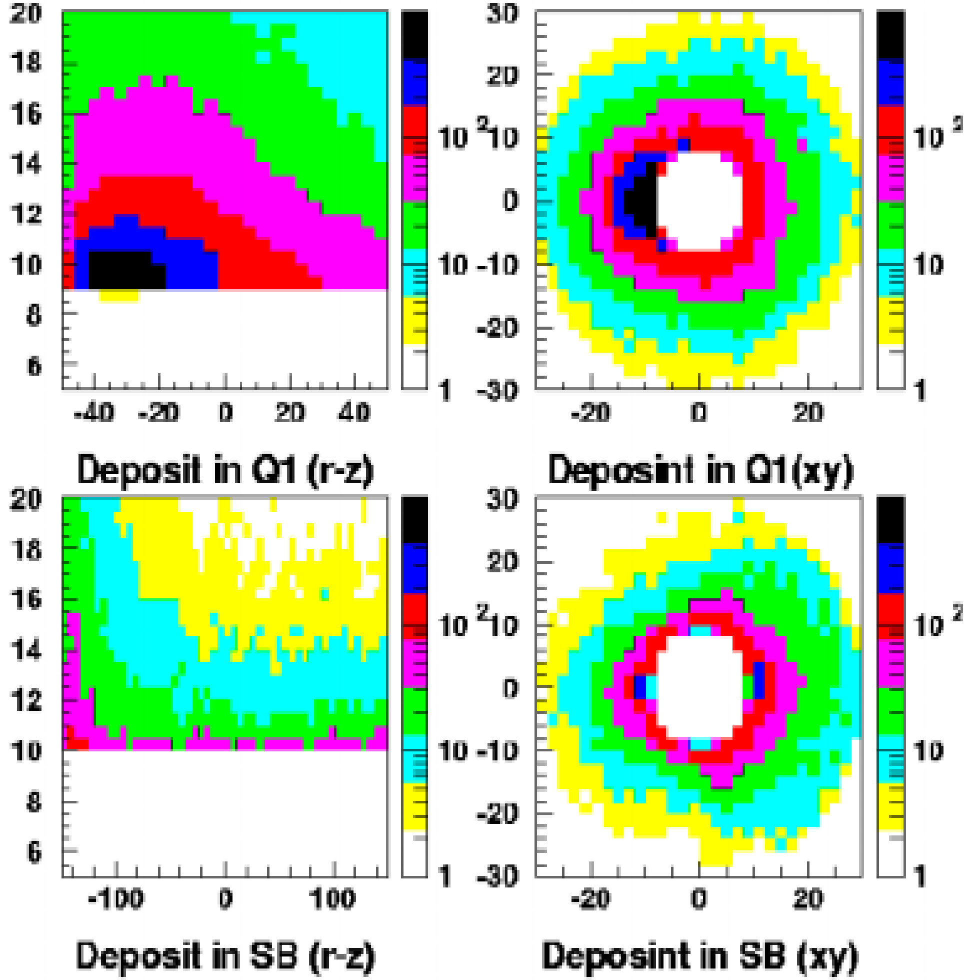
→ applicable to different beamlines.



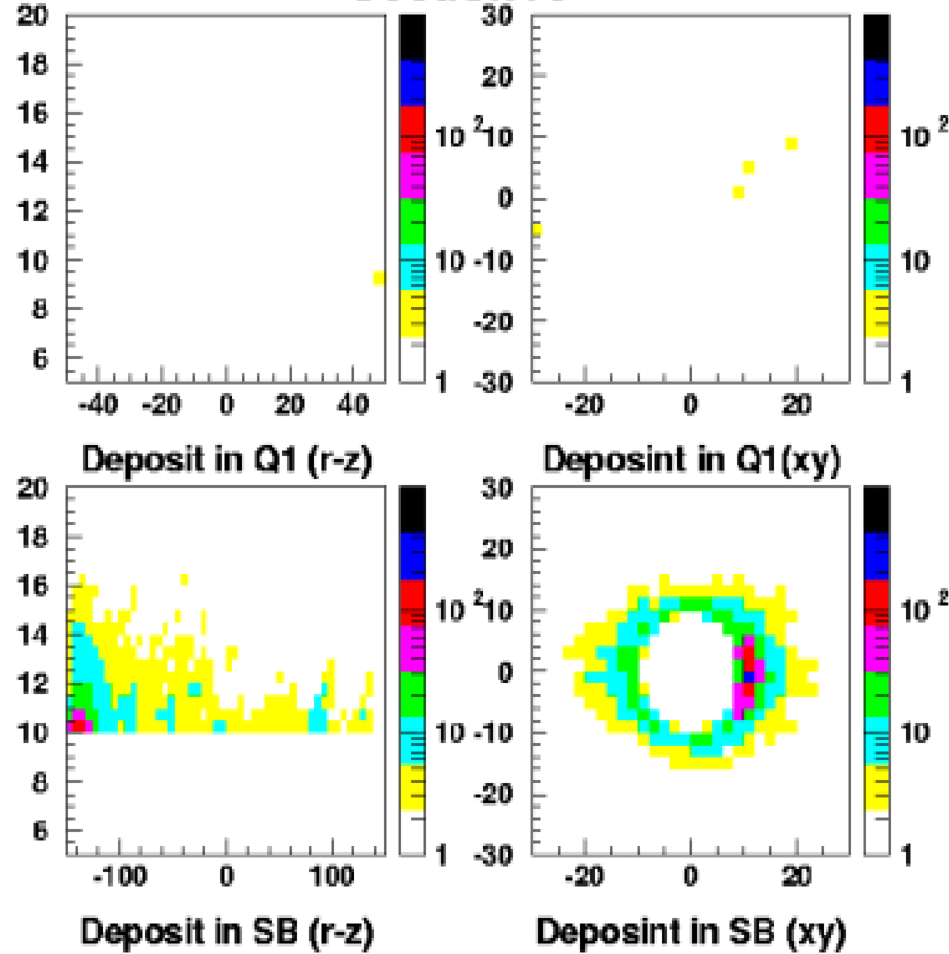
Tune collimator aperture



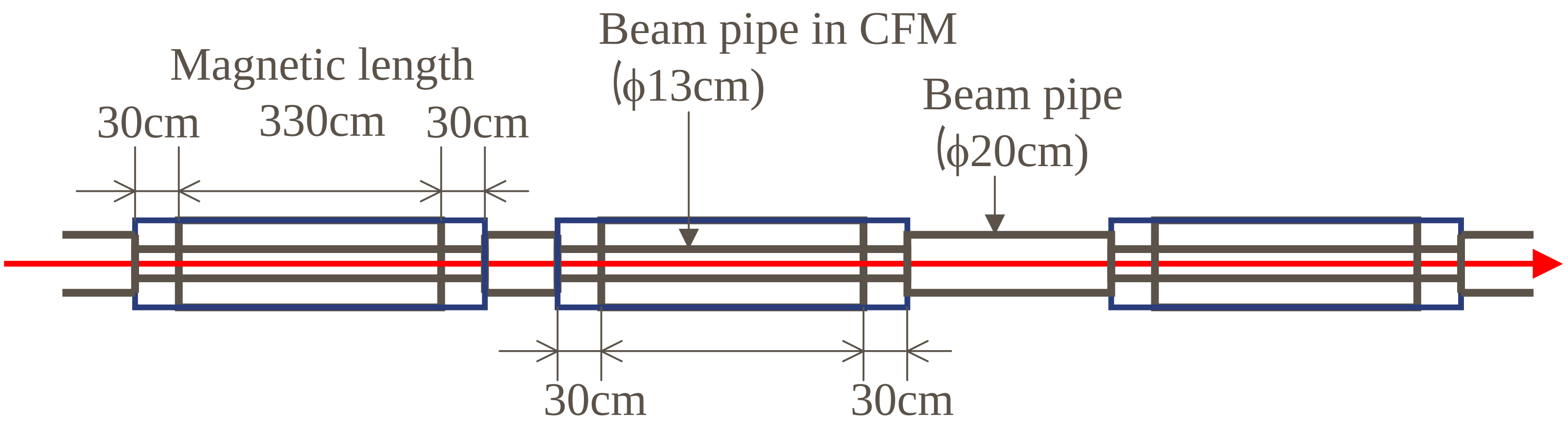
Section1



Section10

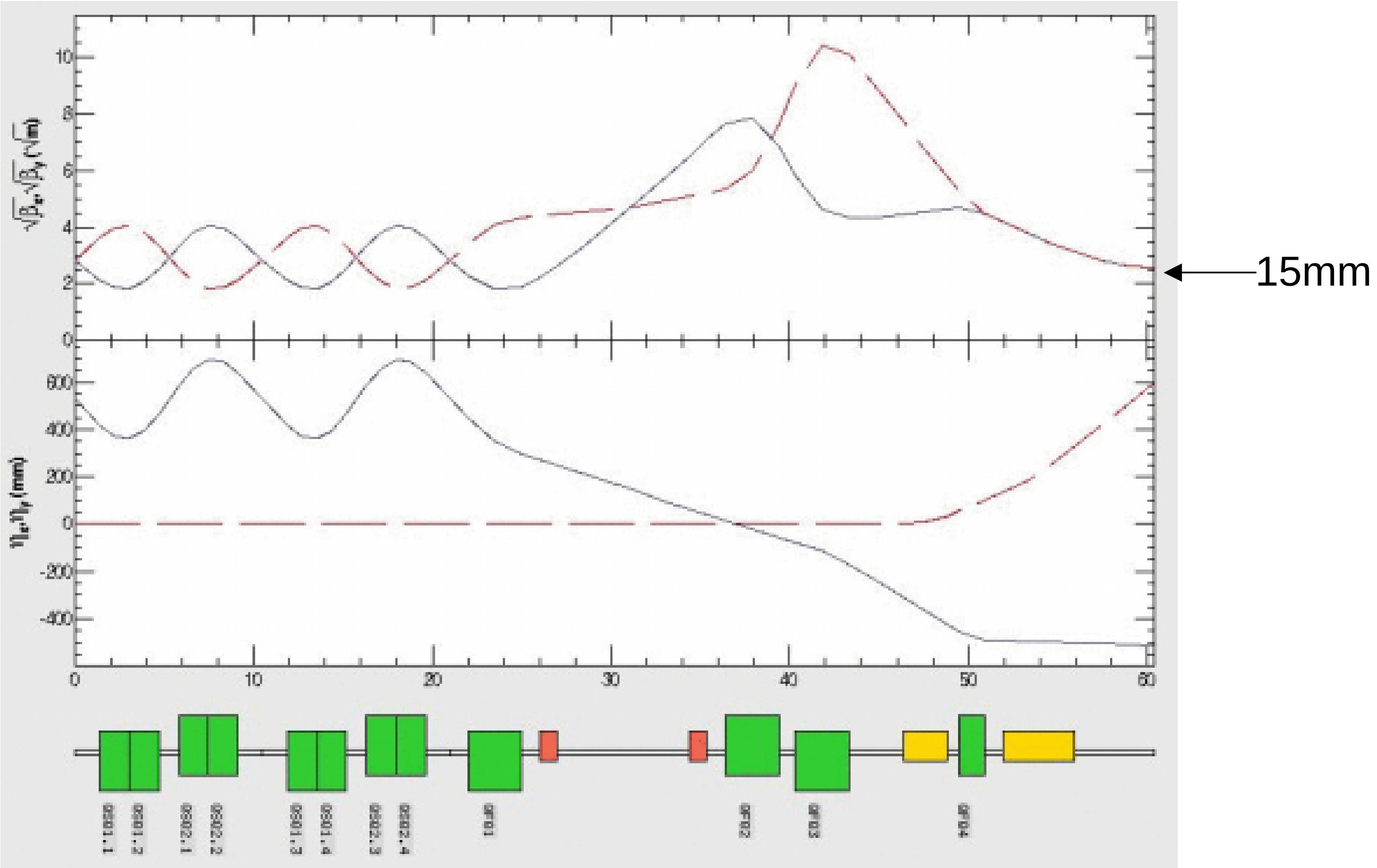


The set-up in GEANT3 calculation

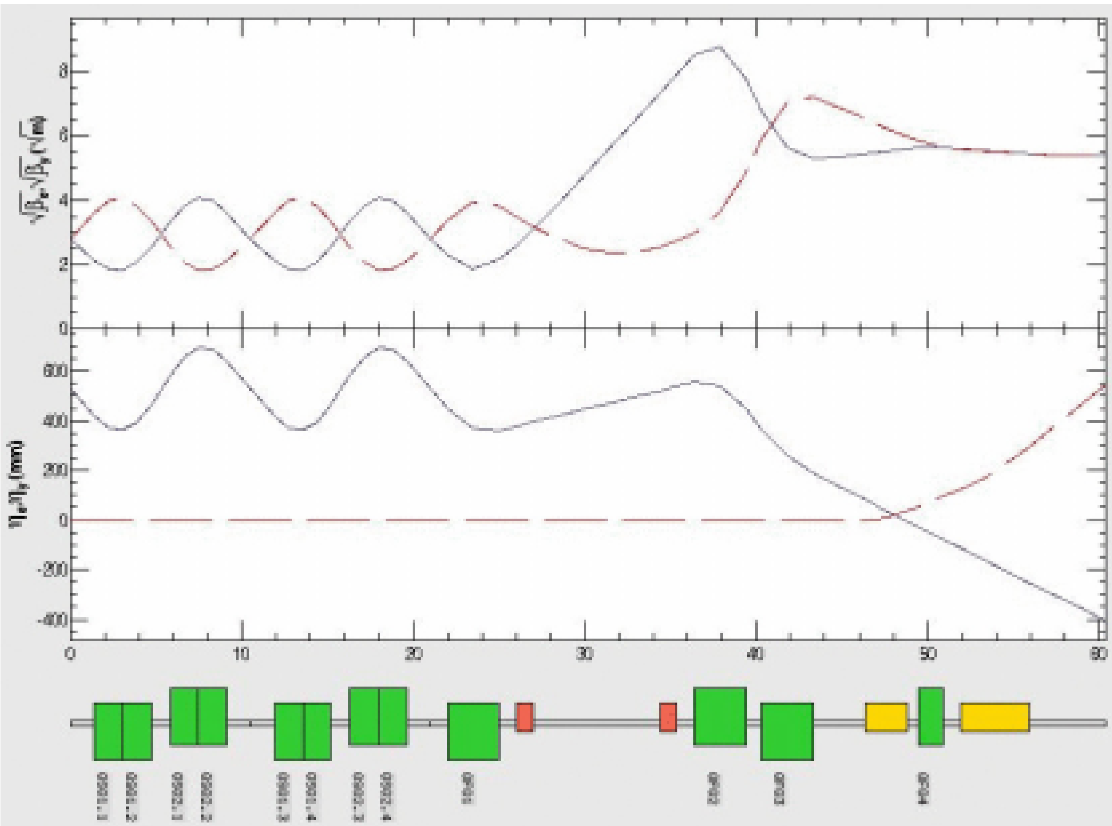


Incident beam size in x-x' phase space is 2000π.
(x: horizontal, y: vertical)

Focus 24π mm.mr beam



Momentum dispersion at target



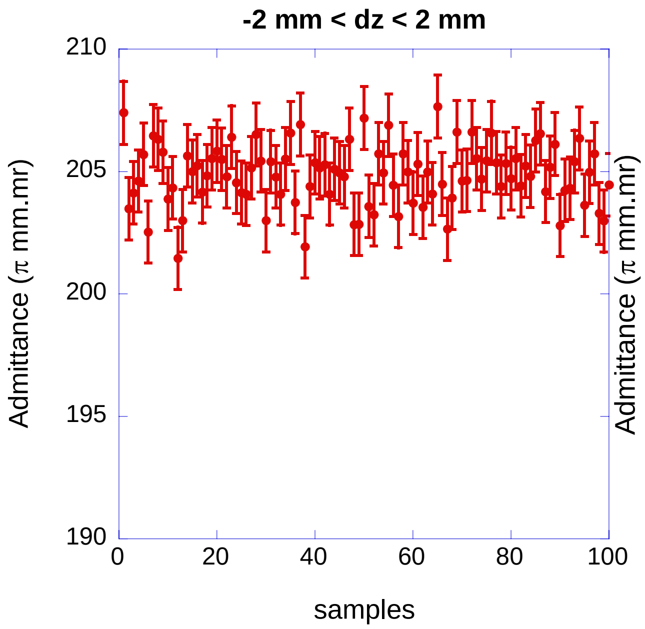
$$\approx 600mm / \frac{\Delta p}{p}$$

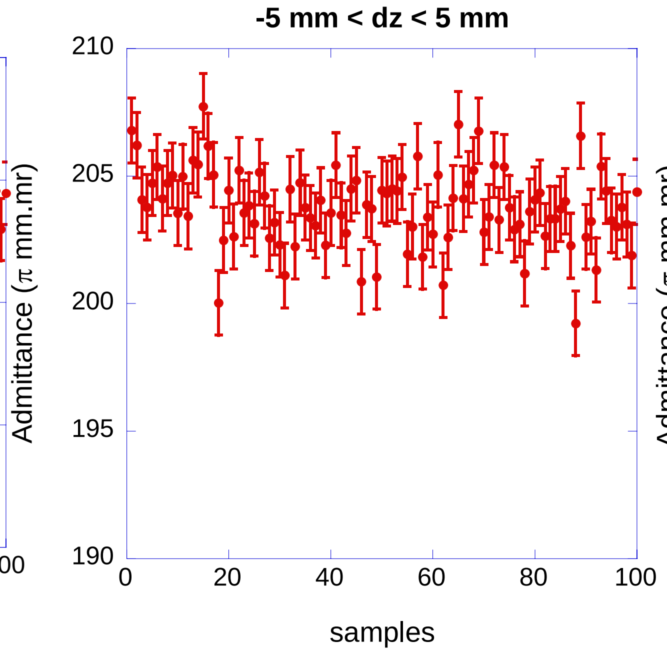
2.4mm @ Δp/p=0.4%

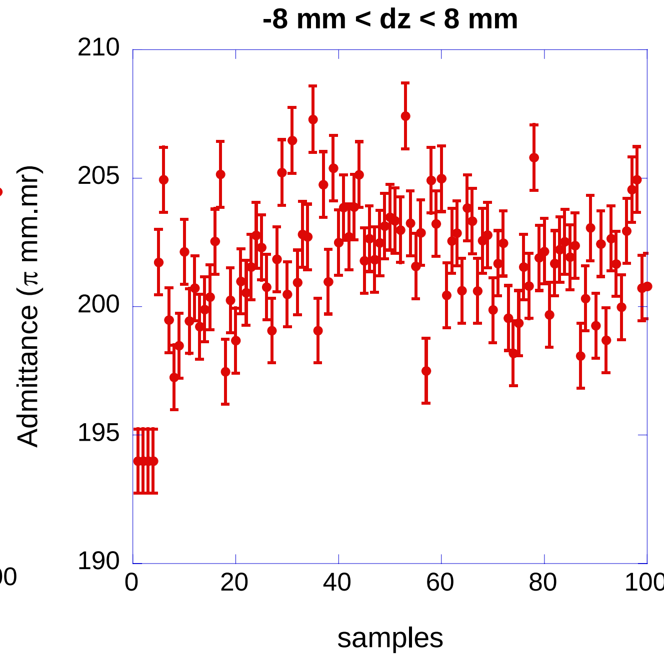
Cannot be zero due to limitation of beam line length.

Zero is preferable but this is acceptable.

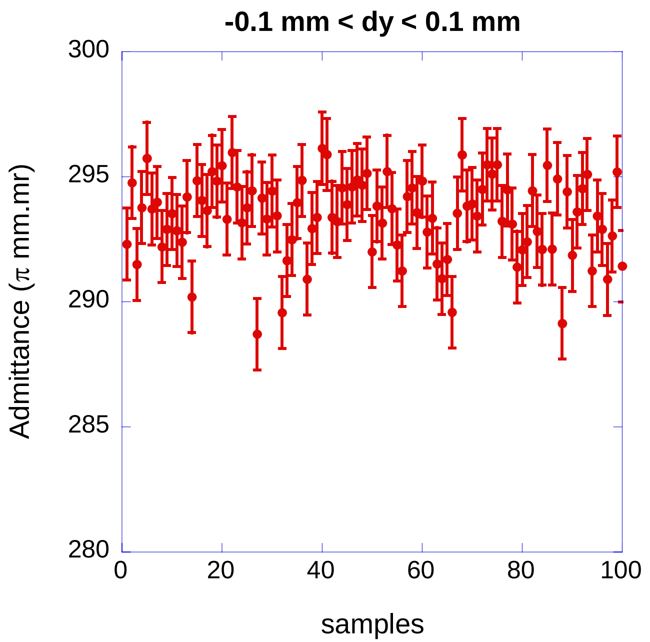
Incident beam size in x-x' phase space is 1000π.

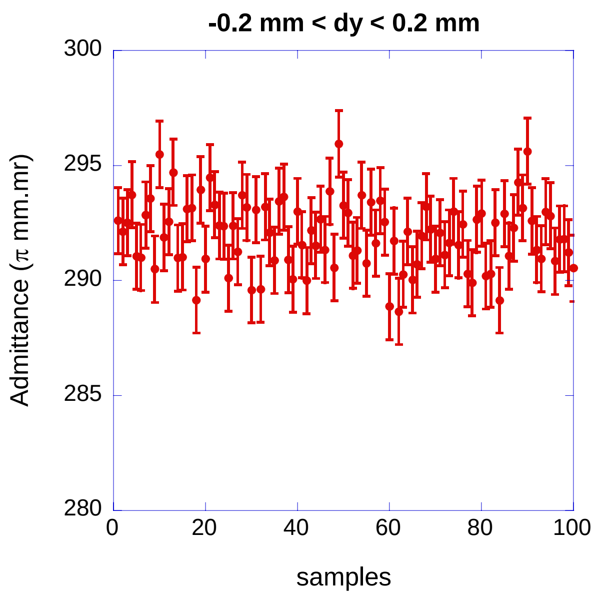


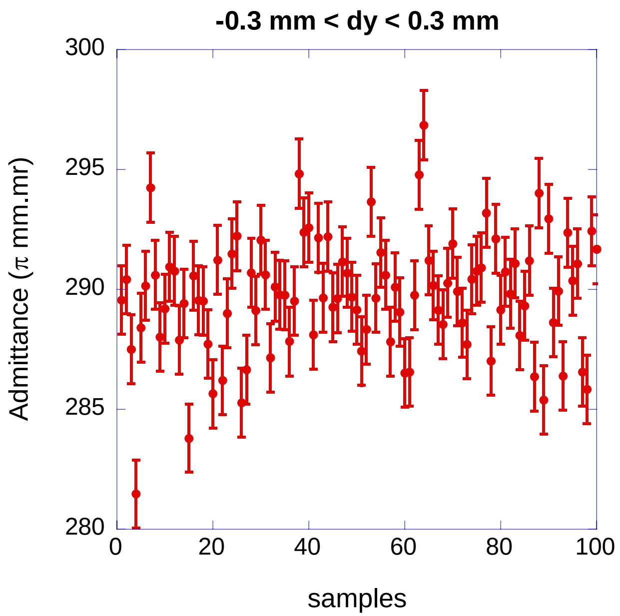




Incident beam size in y-y’ phase space is 1000π.







Beam size in x-x’ plane **はやってませんでした‥。**

Incident beam size in x-x' phase space is 1000π.