T2K proton beam handling and failure analysis

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For T2K collaboration

Introduction

- Proton beam power at J-PARC
  →~100 times larger than K2K (750kW)
- The primary proton beam line is designed to bend the beam ~85º in ~250m due to space limitation.
- We like to make sure
  1. Can we handle beams well?
  2. Is the beam line robust against accidents?

Contents of this talk

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- Beam handling
  - Preparation section
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  - Preparation section
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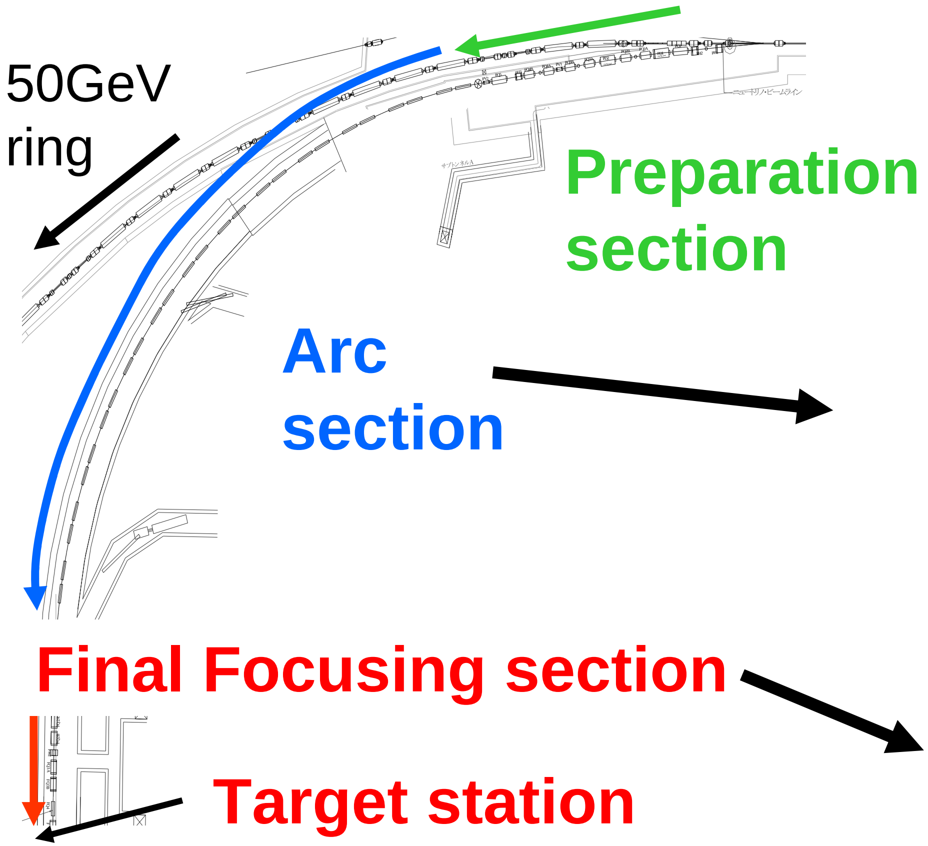
- Summary

T2K primary beam line



~250m

To match the beam with the suitable condition to pass through the arc section

To bend the proton beam towards SK with super conducting Combined Function magnets (CF)

To focus (and bend) the beam to fit the target

Beam handling

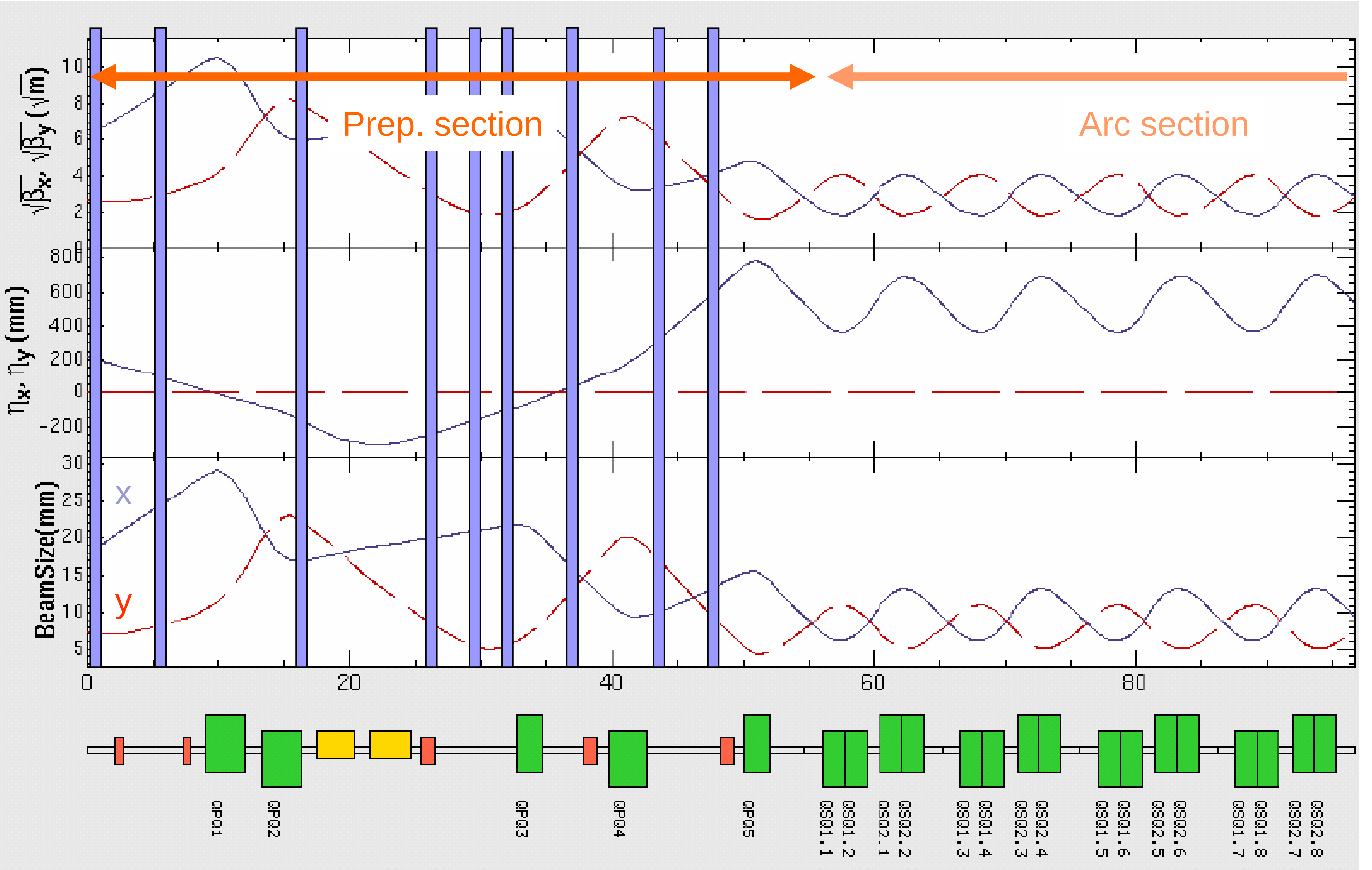
- Objective:

  Is the current monitor configuration is enough to handle proton beam?

1. For preparation section, expected emittance and Q-magnet values are estimated.
2. For final focus section, expected position and profile resolutions at the target are estimated.

Tuning of the Prep. section

There are 9 position/profile monitors and 5 Q-magnets



Twiss parameter measurement at the Prep. section

Using the 9 monitors, we measure the Twiss parameters because of large beam sizes (5~25mm)

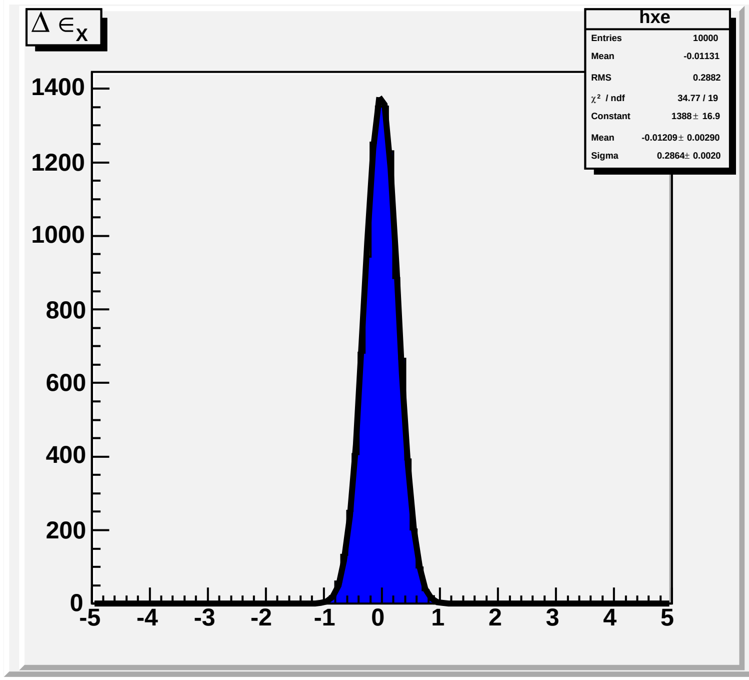
Here we assume the profile monitor (SSEM) resolution of ~3.5% of the beam width, determined by the beam test (0.18mm – 0.60mm)

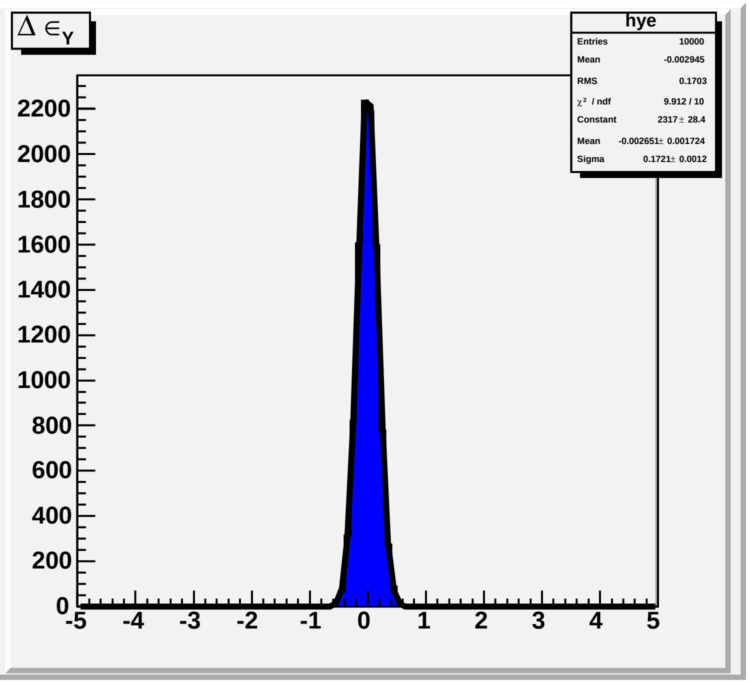
1. Twiss parameter measurement (Q-values are fixed)

2. Simultaneous fit of the twiss parameters and Q-values to check the Q-values
(Here we can fit 1st , 2nd, and 4th magnets)

Emittance resolution (monitor resolution 0.18 – 0.60 mm)

Magnet Values are fixed





$\Delta\varepsilon(x) \sim 4\%$ $\Delta\varepsilon(y) \sim 2\%$

Simultaneous fit of the Twiss parameters and Q values

We can perform the simultaneous fit of twiss parameters and Q values (PQ1 or PQ2 and PQ4)

→ Can check the Q values and measured emittance values

1. Q-values are all fixed

   $\Delta\varepsilon$(x) 4% $\Delta\varepsilon$(y) 2%

2. Simultaneous fit of twiss parameter + PQ2 + PQ4

   $\Delta\varepsilon$(x) 5% $\Delta\varepsilon$(y) 2% ΔPQ2 0.6% ΔPQ4 1.0%

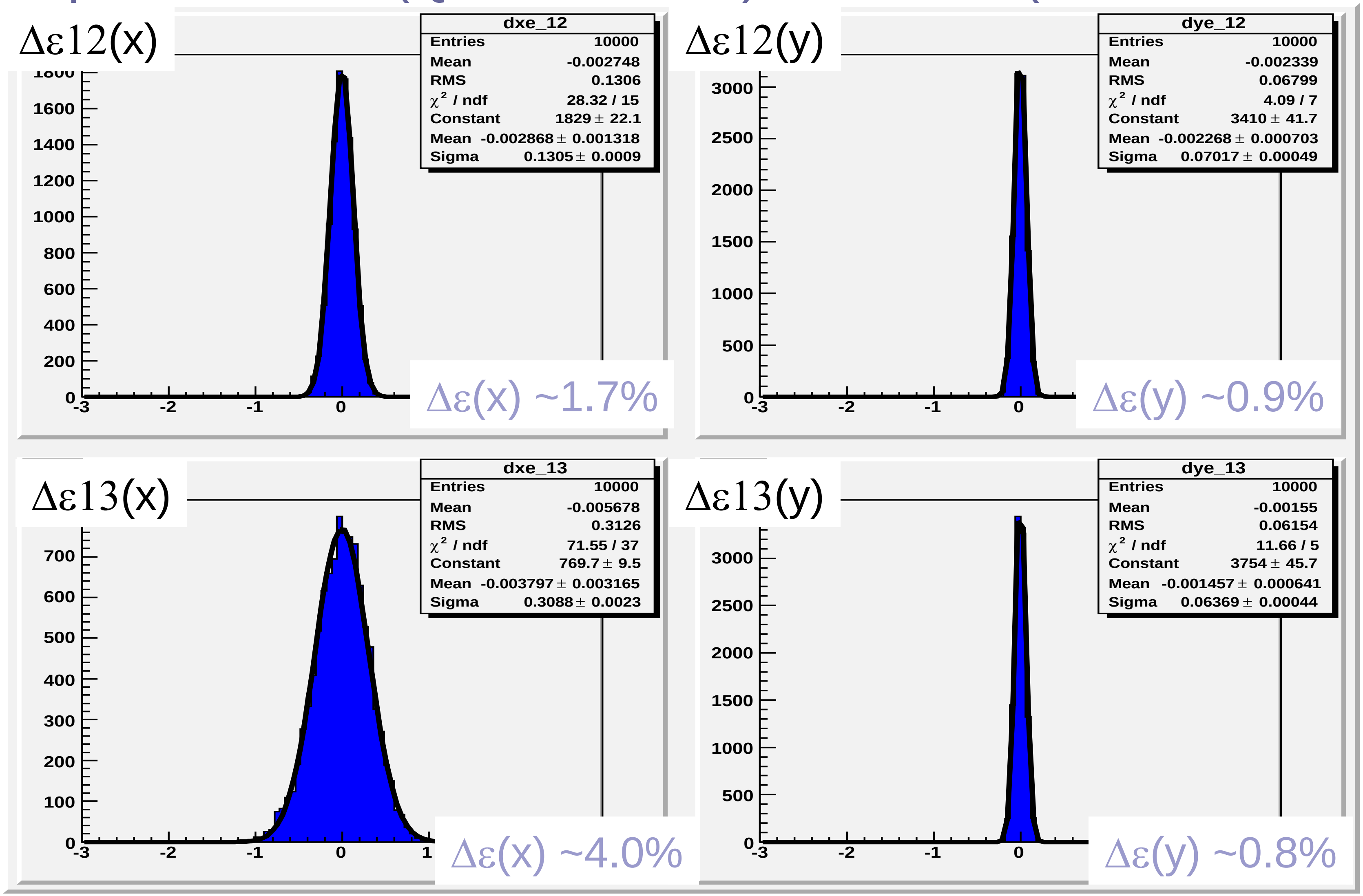
3. Simultaneous fit of twiss parameter + PQ1 + PQ4

   $\Delta\varepsilon$(x) 6% $\Delta\varepsilon$(y) 2% ΔPQ1 1.6% ΔPQ4 1.0%

Using the simultaneous fit, we can check the Q values with 0.6 – 1.6% accuracy

Stability of the emittance measurements:

Comparison btw 1 (Q values fixed) and 2 or 3 (Simultaneous fit)

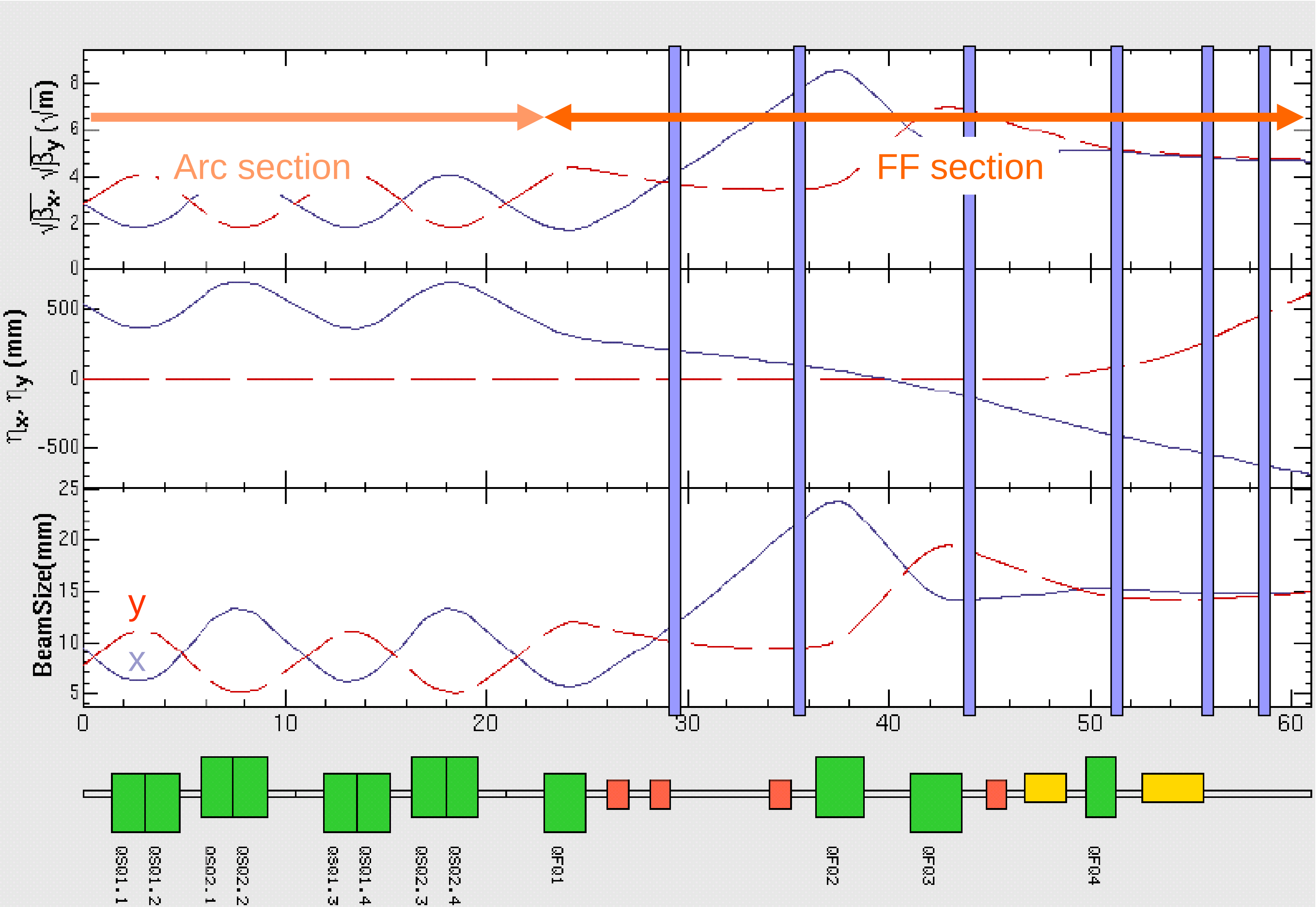


Measured ε difference 1. vs 2. : Δε(x) ~1.7% Δε(y) ~0.9%

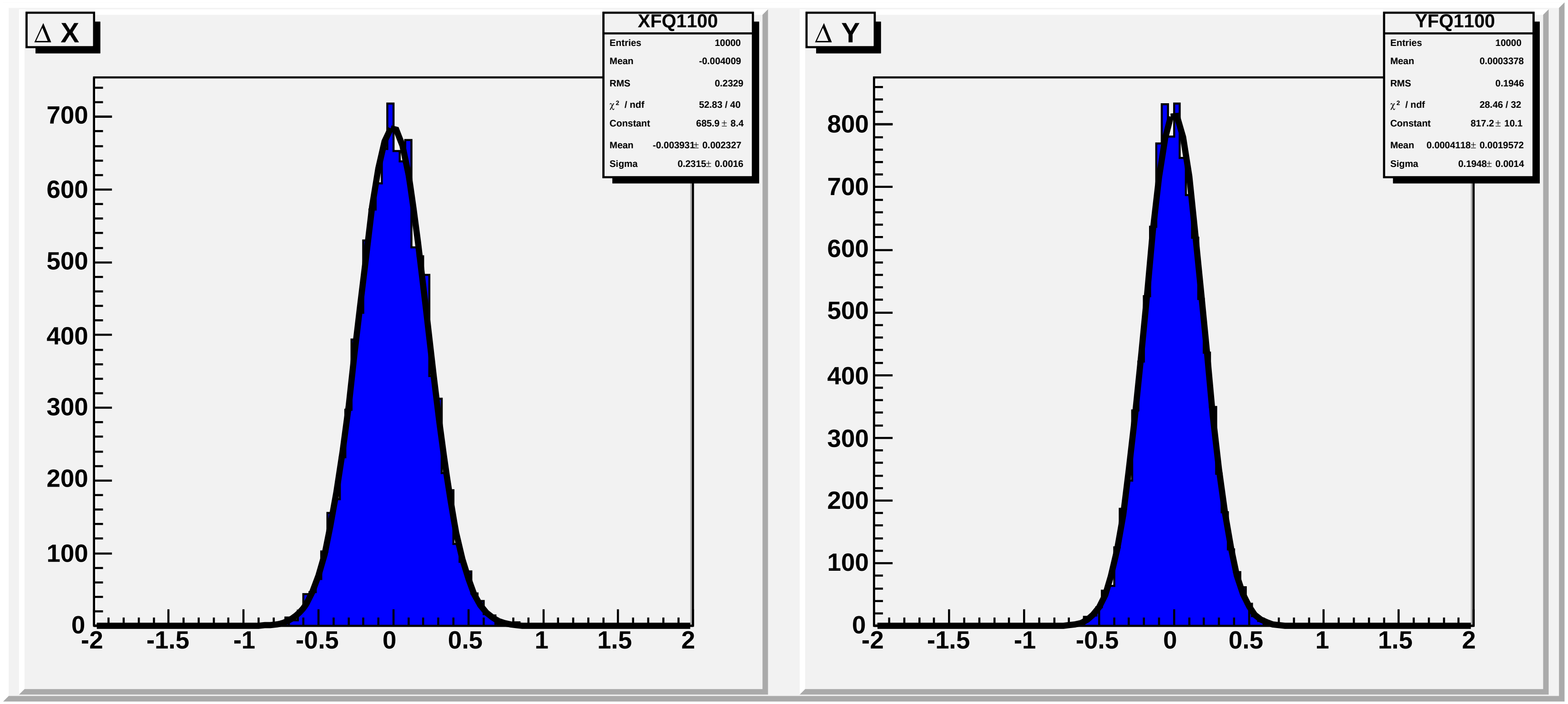
1. vs 3. : Δε(x) ~4.0% Δε(y) ~0.8%

Beam position/width extraction at the Target

Using 6 position/profile monitors at the FF section and the measured ε, we extract the beam position and width at the Target



Beam position extraction resolution (assumed BPM resolution .. 0.25mm)

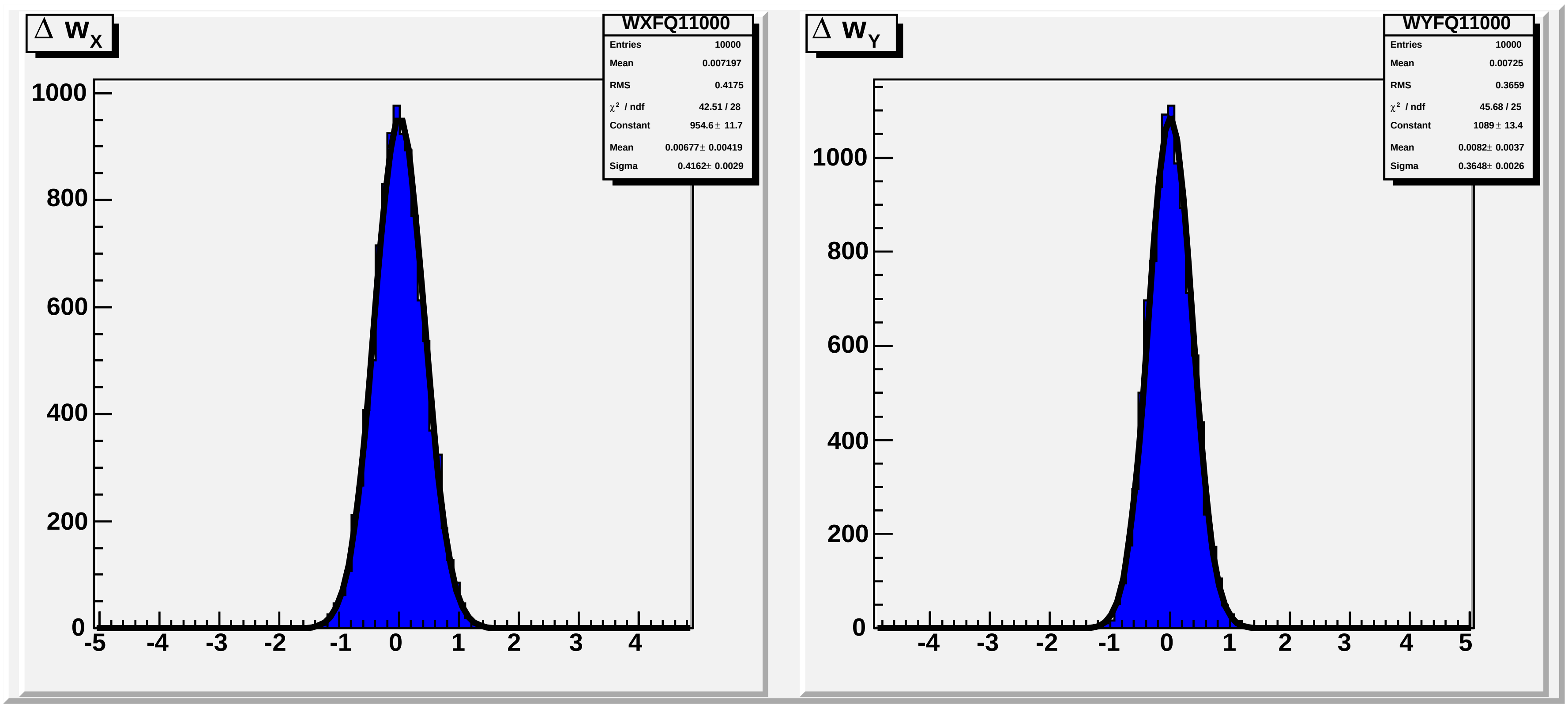


$\Delta x \sim 0.2$mm

$\Delta y \sim 0.2$mm

Required position resolution is 1mm.

Beam width extraction resolution
(assumed SSEM resolution .. 3.5% of the width)



$\Delta x \sim 0.4$mm

$\Delta y \sim 0.4$mm

Compared to the beam width of 15.0mm at the target

Failure analysis

- Objectives:

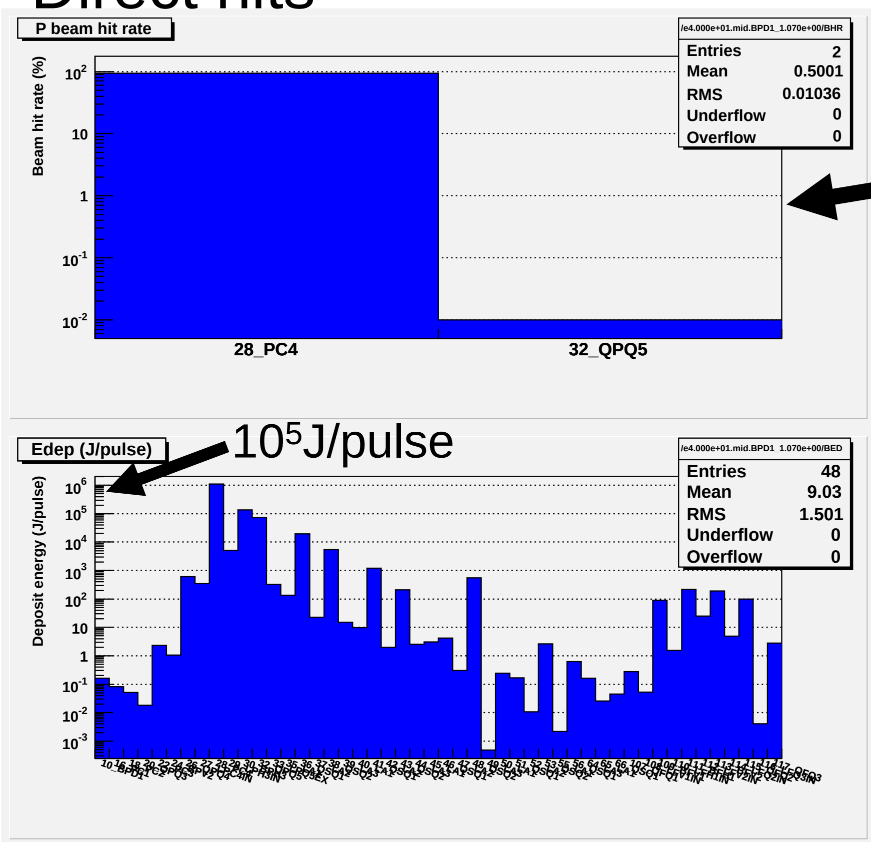
  Is the primary beam line well designed to prevent failure problems?

  1. Is the current configuration of prepare section enough to protect Arc section from failures?
  2. How about final focus?
  3. Arc?
- Use full simulation code (LCBDS) based on GEANT4 (E_{beam}=40GeV ε=7.625π).

Prep. section

PD1 1.07

Direct hits



10^5J/pulse

- The collimators works well to protect magnets from kicker, bending magnets (PD1, PD2) failures.
- There are significant energy deposits in magnets due to showers.

Including hits by secondary particles

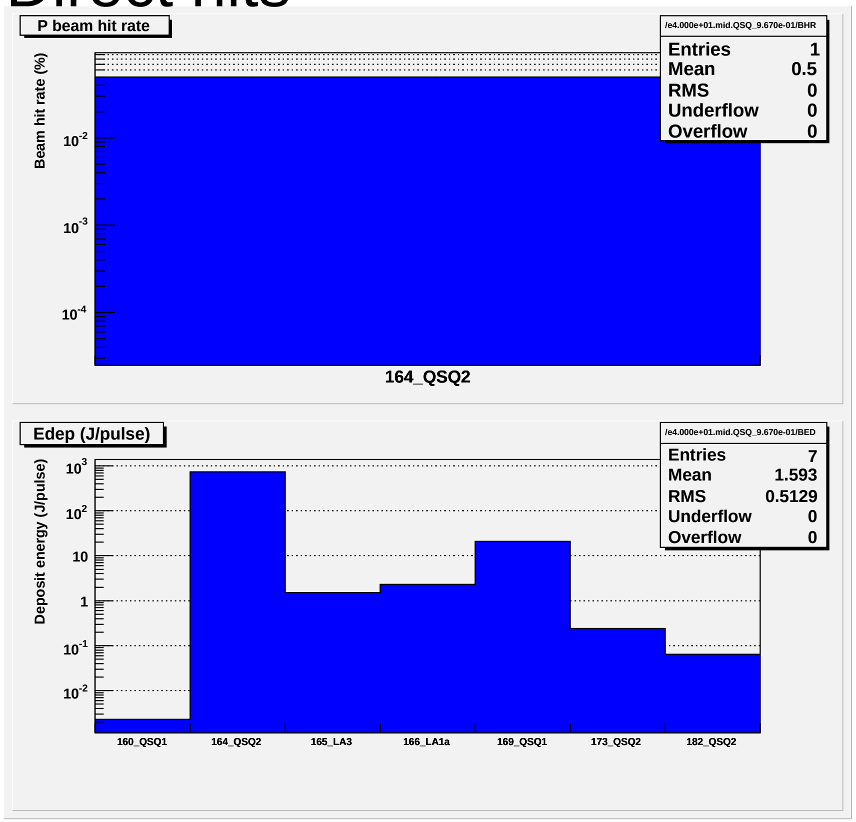
Final Focus section

- OK if
  - |BFH1|<1.0T
  - |BFH2|<1.8T
  - |BFV1|<1.0T
  - |BFV2|<0.7T
  - 0.7<BFVD1(failure)/BFVD1<1.25

Arc

QSQ 0.967

Direct hits



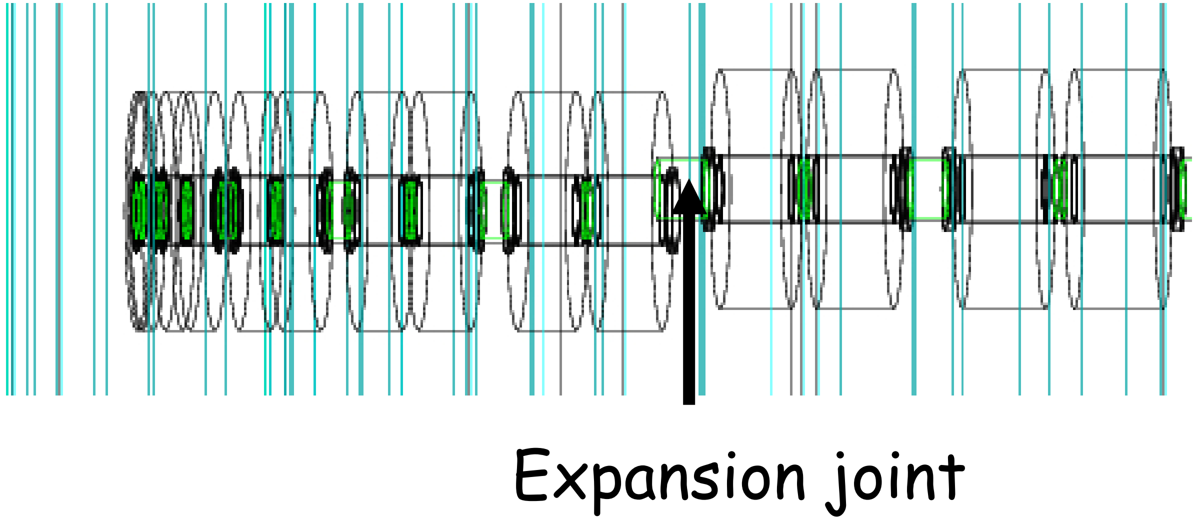
- OK if 0.967<CF(failure)/CF <1.045,

  otherwise breaks CF magnets.

Including hits by secondary particles

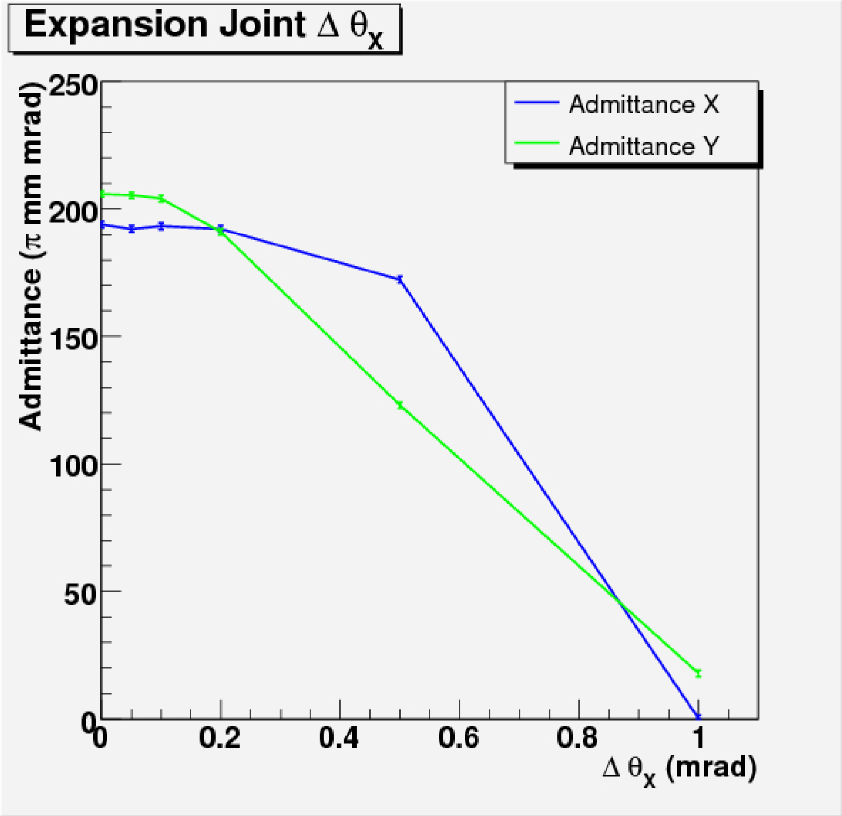
Expansion joint in Arc

- Beam line components stand on concrete blocks. And there is an expansion joint between #10 and #11 magnets in Arc.



Expansion joint in Arc (cont.)

admittance



- We need careful procedure in alignment at the beginning.
- But how about time dependent effect? Because the equipments on SAND!

Summary

- Several simulation studies has been done for the T2K proton beam line
- With the current monitor configuration
  1. $\sigma_{position}$(target)=0.2mm (x) and 0.2mm(y)
     σ_{width}(target)= 0.4mm (x) and 0.4mm(y)
  2. ΔQ = 1.6%(PQ1) 0.6%(PQ2) 1.0%(PQ4)
- Collimators works well to prevent direct hits by failures, but showers?
- Time dependent expansion joint effect?