Simulation study of the J-PARC primary proton beamline

Outline

- Introduction
- Simulation setup
- Estimation of beam loss and design parameters
  - Collimators
  - Radiation shield
- Summary

Introduction - J-PARC Neutrino beamline -

Proton Beam Power at J-PARC → ~100 times larger than K2K (750 kW)

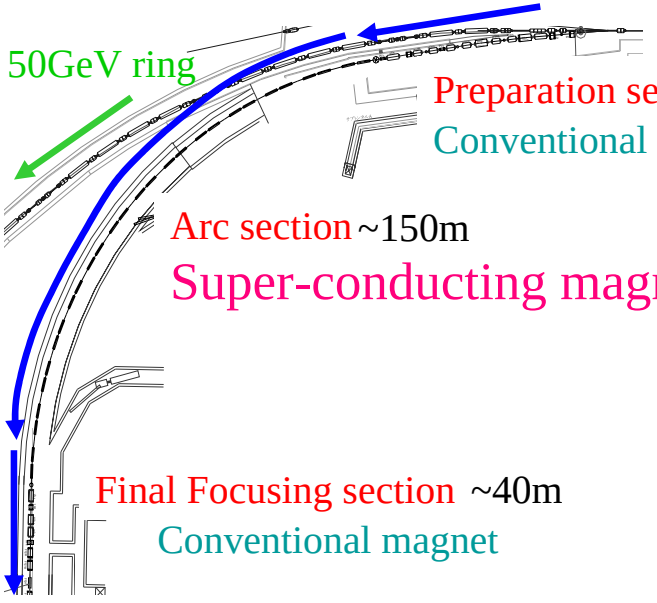
- Beam loss induces large radiation dose.

(Total Beam loss limit : 1W/m in Arc)

The Arc Section consists of super-conducting magnets.

- Protect the super-conducting magnets from quenching

(Line loss limit : 10W/1magnet)



It is very important to reduce the beam loss in the arc section in designing the proton beam line.

Collimators and Shield in Preparation Section

Beam core: ε =6 [π*mm*mrad] , dP/P = 0.3%

Acceptance

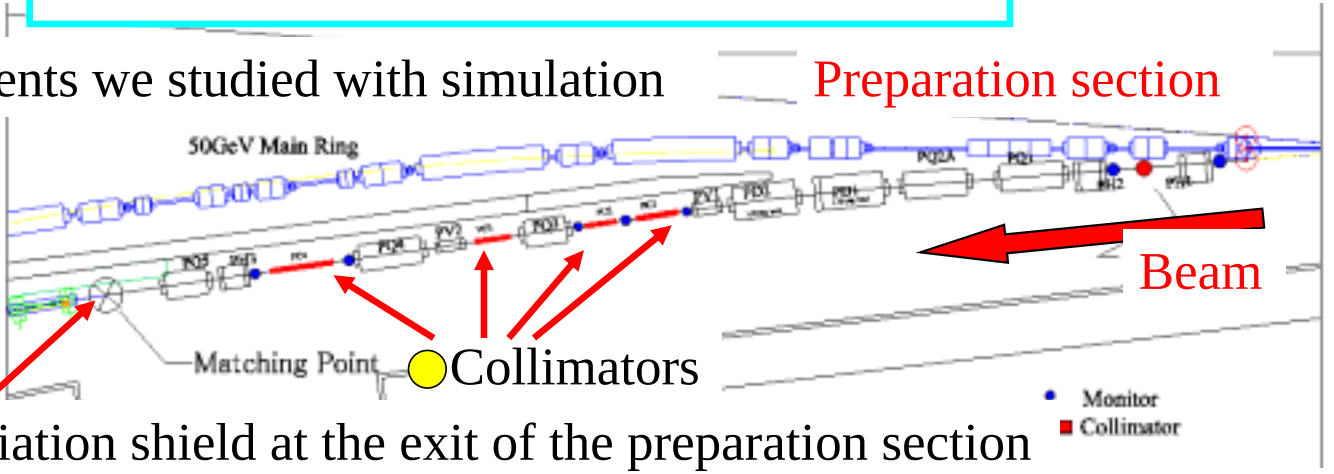
Preparation section : ε =60 [π*mm*mrad]

Arc section : larger than preparation section

To controll the energy deposit in the arc section, the design of the preparation section is important.

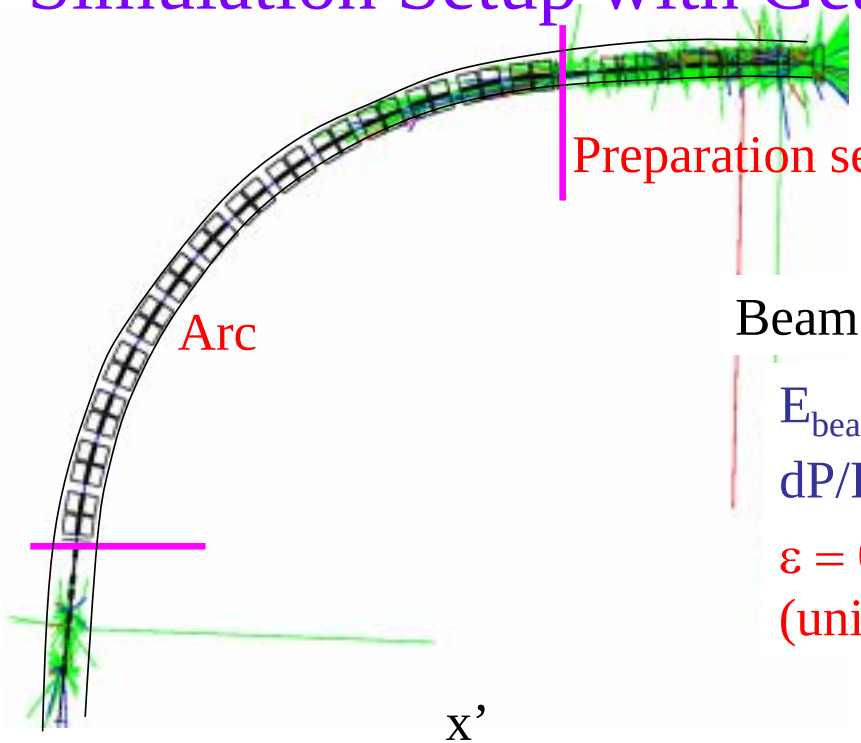
We have varied the design parameters, and estimated the beam loss in the arc section.

Components we studied with simulation



Radiation shield at the exit of the preparation section

Simulation Setup with Geant4



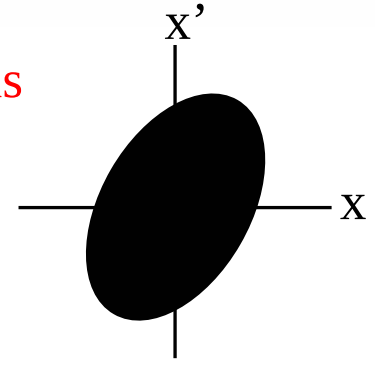
Beam halo parameter

E_{beam} = 50 GeV

dP/P = 2.0%

ε = 0~200 [π*mm*mrad]

(uniform distribution in phase space)



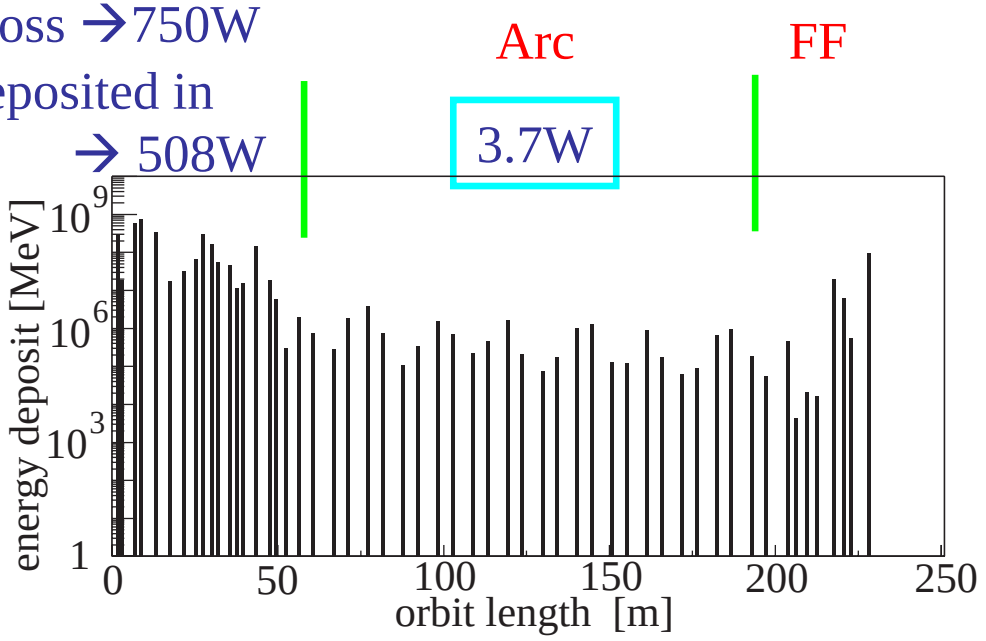
Inject beam halo, estimate beam loss in the arc section.

Simulated beam loss at each component

Preparation section

Total beam loss →750W

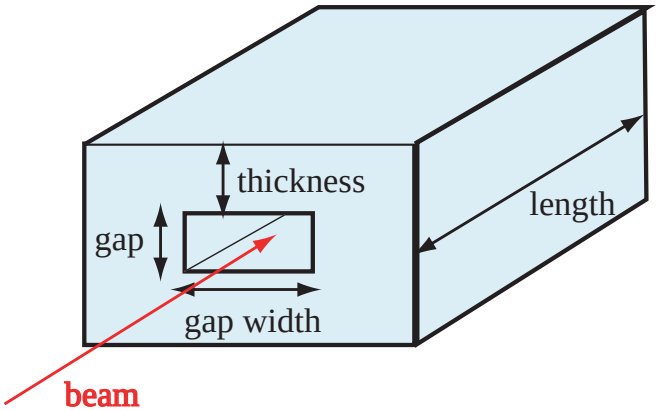
Total loss deposited in components → 508W



Total beam loss in preparation section is assumed 750W (0.1%).

On this assumption, energy deposit in each component were normalized.

Collimator design



To protect the Arc magnets from beam loss, collimators in preparation section scrape off the beam halo.

Current design

- Thickness : 50 cm
- Length : 1.45 ~ 3.0 m
- Gap height : 3.1 ~ 9.5 cm
- Gap width : 6.4 ~ 12.1 cm

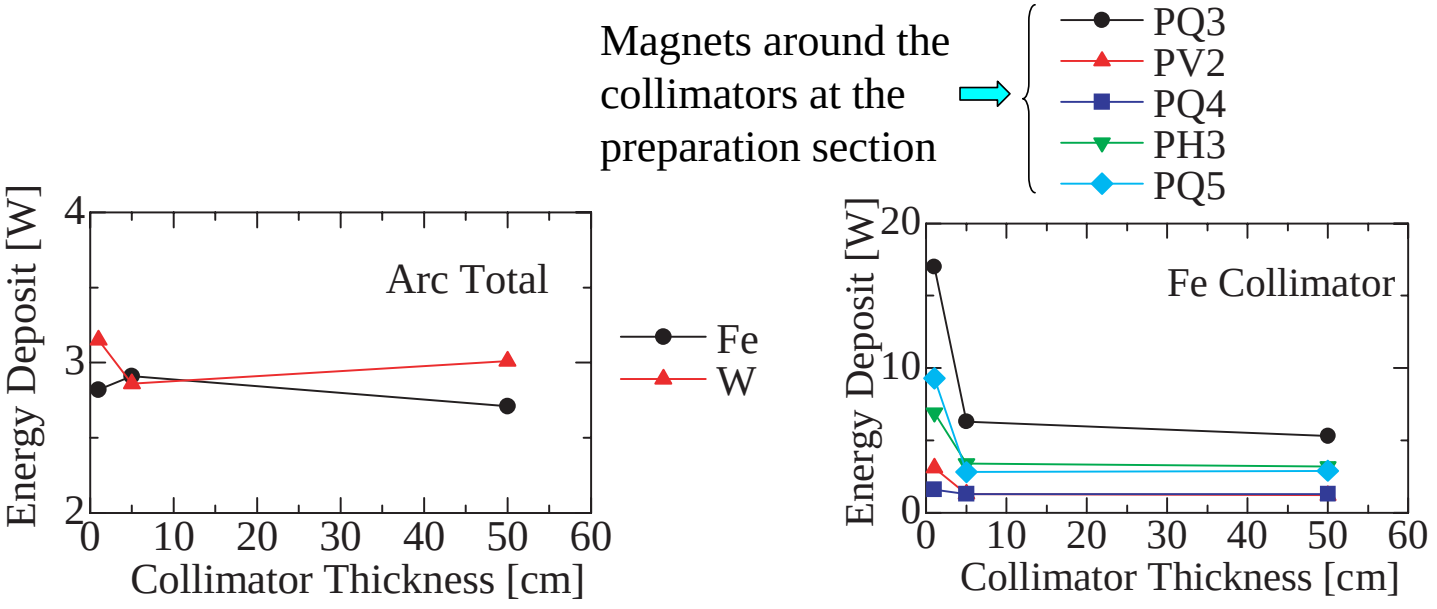
→ Fills up as much drift space as possible.

→ These gap sizes are designed to accept particles in $\varepsilon = 60$ [π * mm * mrad] .

→ Very large collimators (very conservative)

Collimator design - Thickness of collimators -

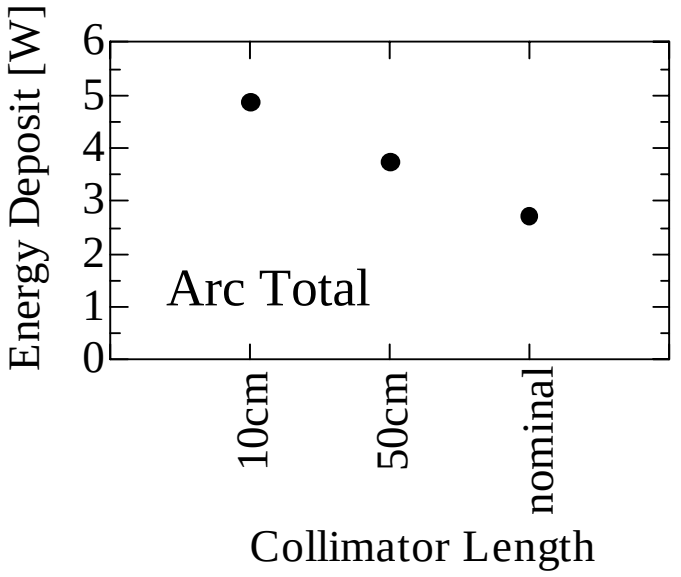
We checked whether we can make collimators smaller without increase of the beam loss in super-conducting magnets in arc section and conventional magnets in preparation section.



Calculation result indicates that 5cm is thick enough.

Collimator design - Length -

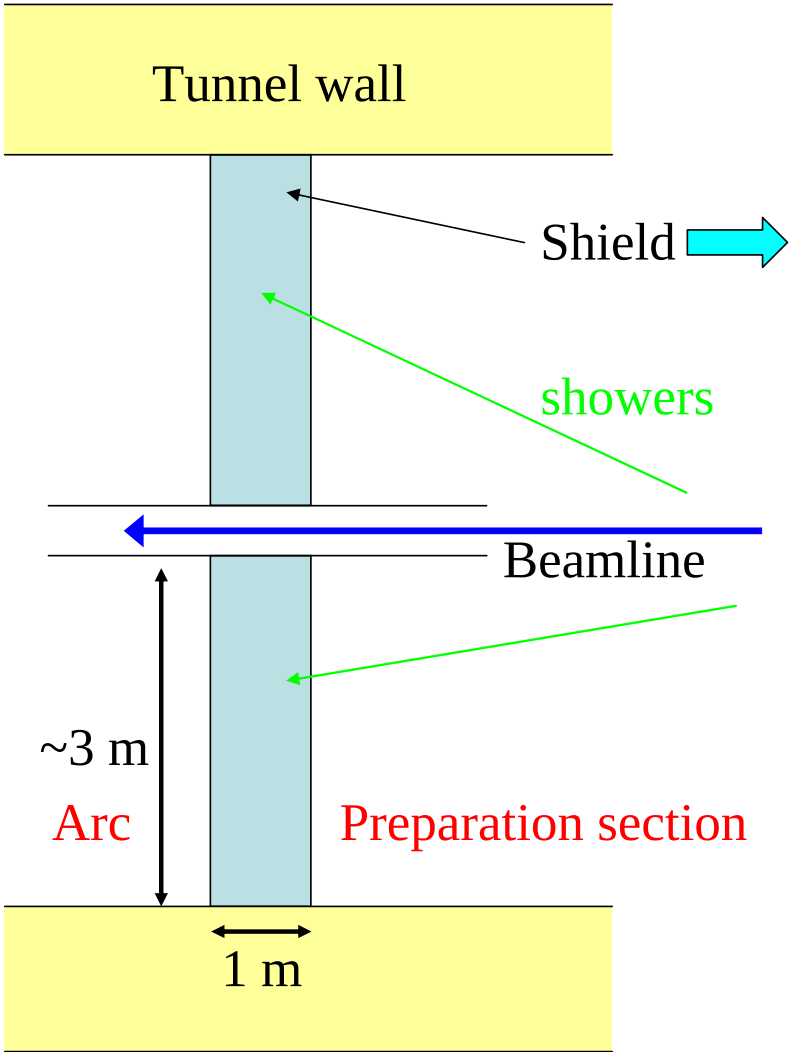
We changed the length of collimators.



Making collimators shorter increases energy deposit in the arc section.

Length of the collimators must be long.

Radiation Shield at the exit of preparation section



In order to protect the super-conducting magnets from shower particles generated in preparation section, radiation shield can be placed at the exit of the preparation section.

Assumed shield size :

1m thick, 3m wide (tunnel filler like illustrated in the left figure)

material of shield :

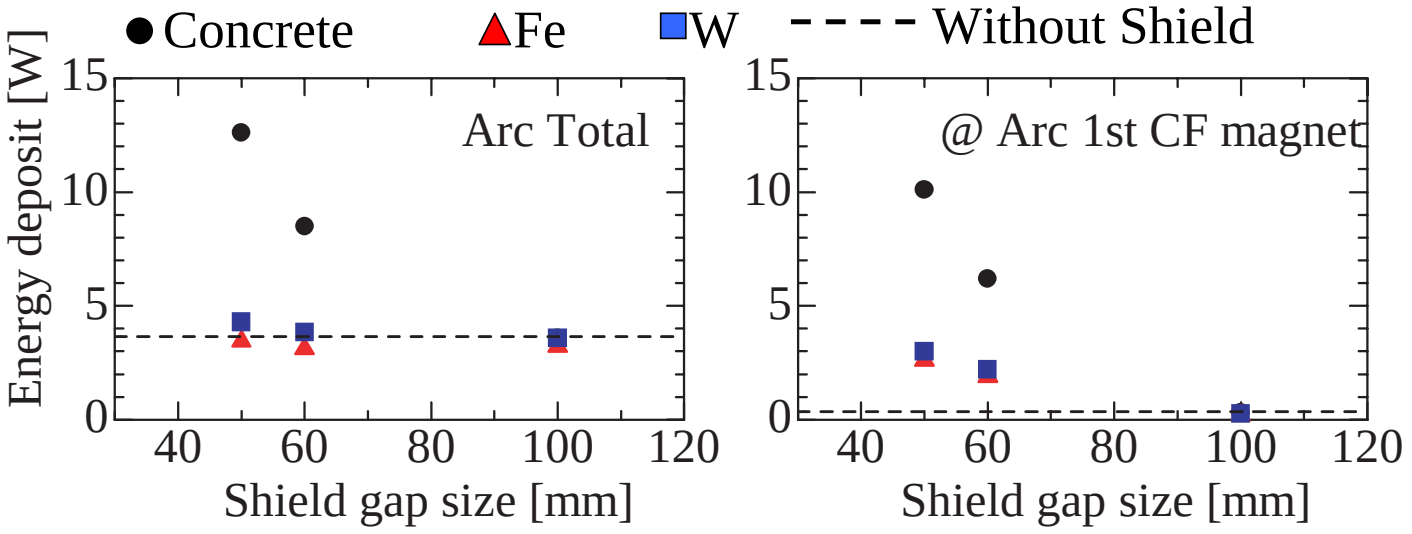
concrete, iron or tungsten

Radiation Shield at the exit of preparation section

The inner diameter of the shield :

100mm ⇒ result is nearly identical with those without shield.

smaller (50 or 60mm) ⇒ the energy deposit in the arc section increased, due to the shower particles generated at the shield.



The current simulation result does not favor the radiation shield at the exit of preparation section.

Summary

We have carried out the J-PARC proton beamline simulation studies.

We estimated the beam loss, and studied the design for collimators and radiation shield.

- Collimator

  Thickness : 5cm is good enough.

  length : > 1m needed.

- Radiation shield at the exit of preparation section

  The current simulation study does not favor.