Status of Super Omega Muon Beamline at J-PARC

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Outline

1. Super Omega Muon Beamline
2. Muon Facility in J-PARC
3. Status of Super Omega
    - Capture section - Installed
    - Transport section - Under construction
    - Focusing section - Design work in progress
4. Summary and Future plan

Introduction

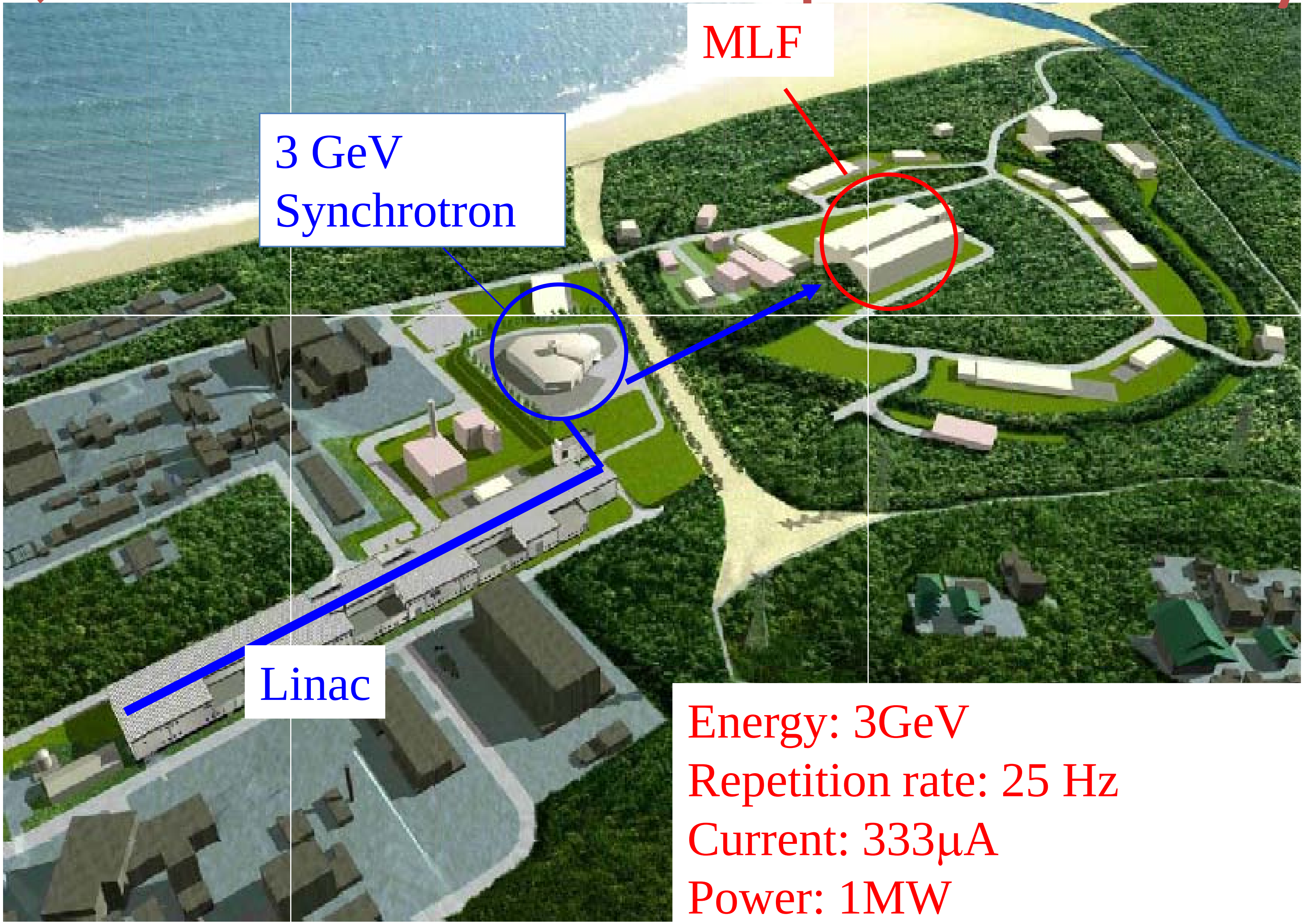
What is Super Omega?

- New and the second muon beamline under construction at MLF/J-PARC.
- New type beamline for muon
  - All beamline magnets consist of solenoids.
- Simultaneously capture and transport both μ^+ and μ^-.
  - The experiments using μ^+ and μ^- can be conducted at the same time. (possibly produces μ^+-μ^- atom)
- Large solid angle acceptance
  - Produce the highest intensity pulsed muon beam in the world.

First goal of Super Omega:
Surface muon source that produce Ultra Slow muon (E= 0.3 eV – 30 keV) with high intensity and high luminosity.

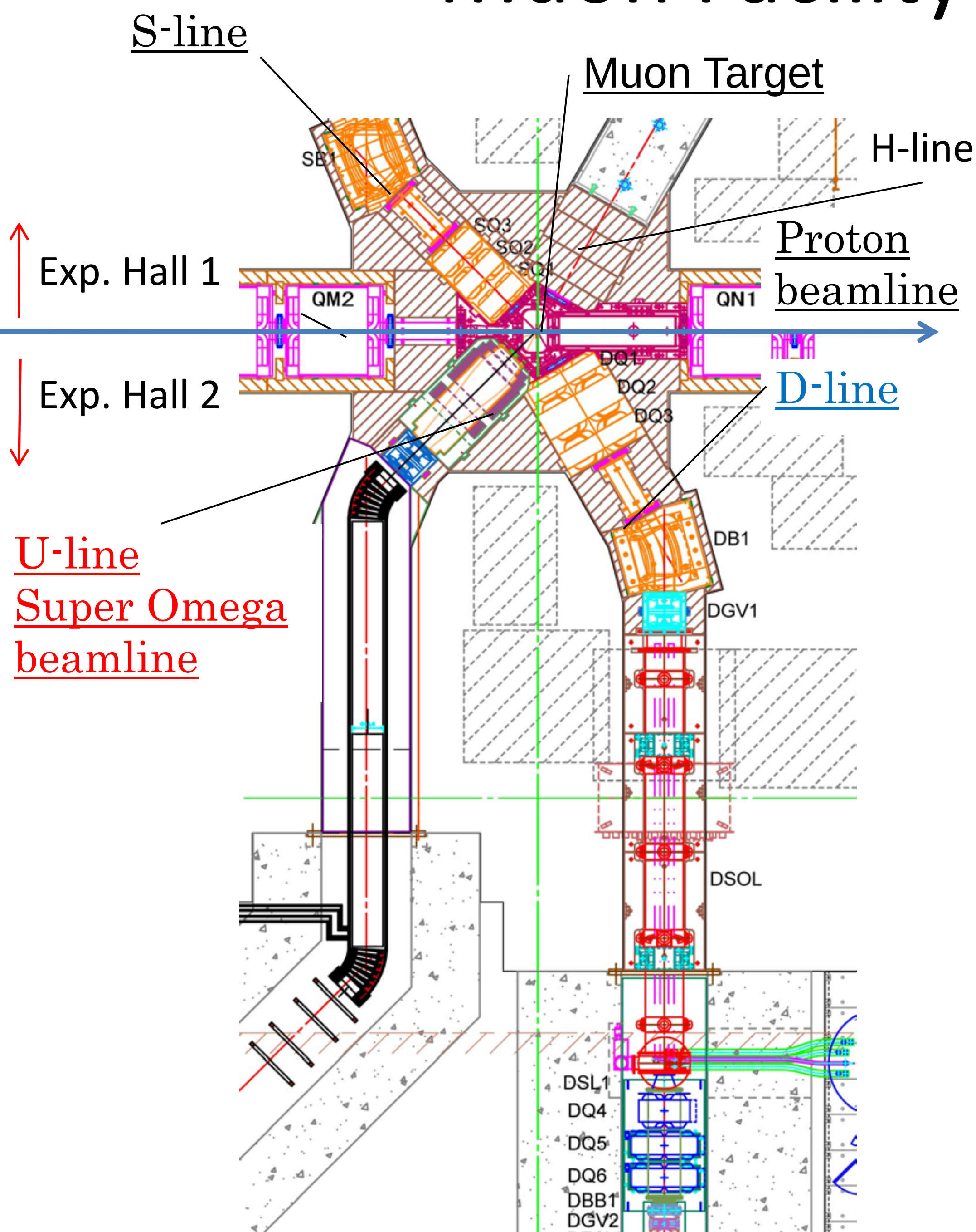
Future → G-2 experiment, muon transfer etc…

Primary Proton Beam at MLF
(Material and Life Science Experimental Facility)



Energy: 3GeV
Repetition rate: 25 Hz
Current: 333μA
Power: 1MW

Muon Facility in MLF



- Muon target: Graphite (20 mm thickness)
- Four secondary beamlines extend from the muon target.
  - D-line: Decay muon
    In operation with two experiment area.
  - U-line: Ultra slow muon
    Super Omega is under construction

In the future

- H-line: High momentum muon
- S-line: Surface muon

Experimental Hall 2 at MLF

The exit of
U-line tunnel

Super Omega
will be installed.

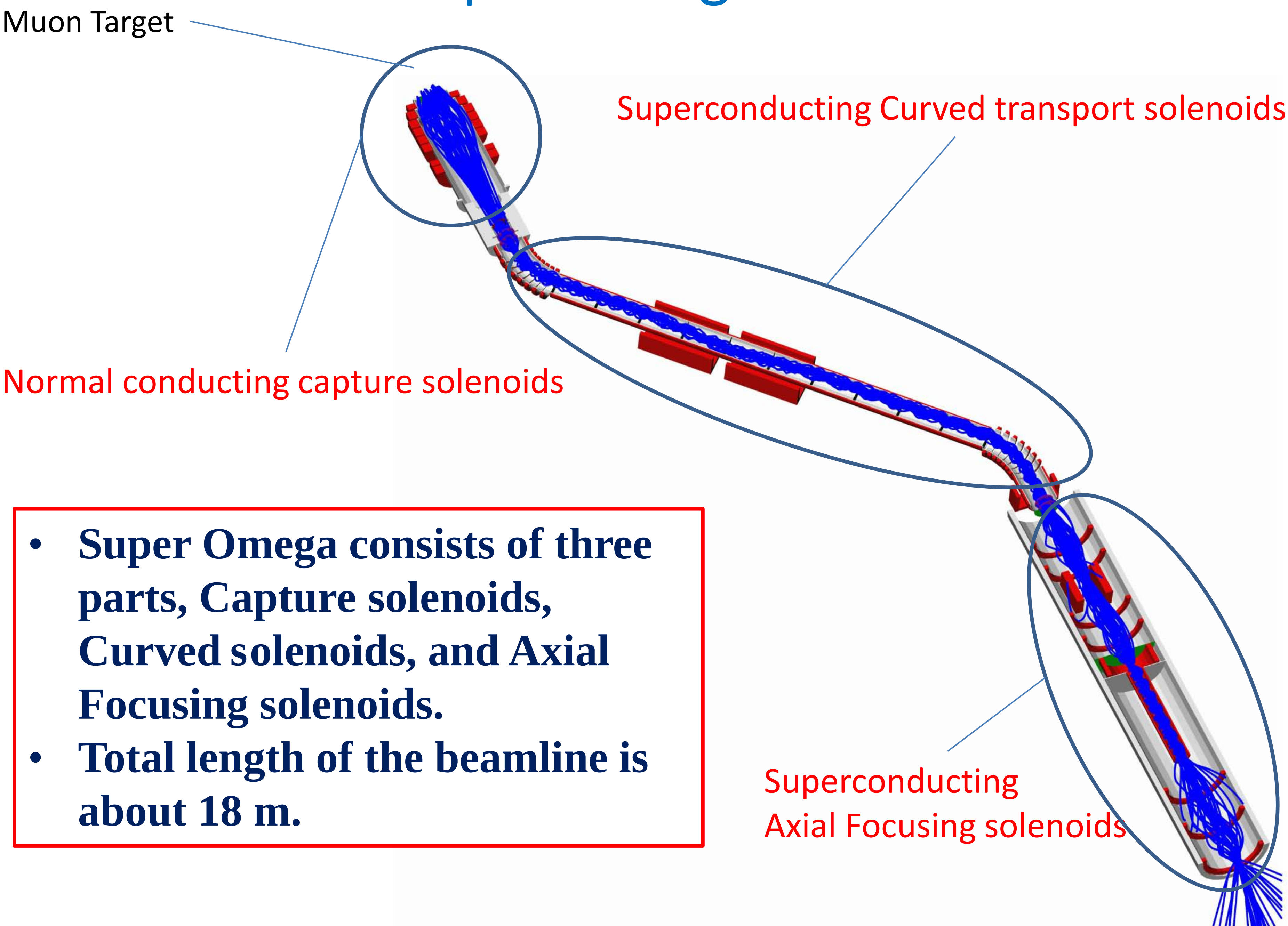
D-line

D2 port

Cabin
(Control and
Counting room)

D1 port

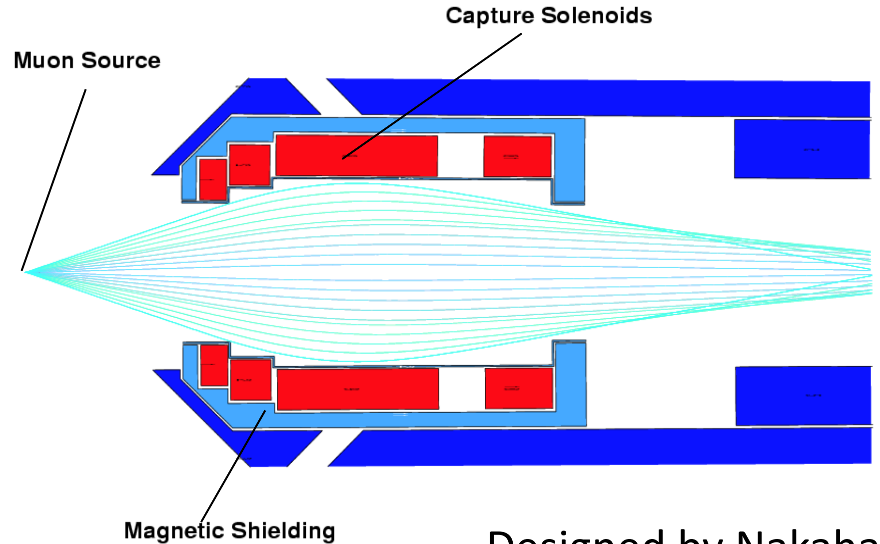
Status of Super Omega Muon Beamline



- **Super Omega consists of three parts, Capture solenoids, Curved solenoids, and Axial Focusing solenoids.**
- **Total length of the beamline is about 18 m.**

Normal Conducting Capture Solenoids

- The capture solenoids consist of eight normal- conducting solenoids designed to capture the muons produced in muon target with a solid angle acceptance of 400msr.
- Due to the high level of exposure to radiation, the solenoids are wound with radiation-resistant mineral insulation cables(MIC).
- The solenoids can be simultaneously captured μ^+ and μ^- with the momentum up to 50 MeV/c.



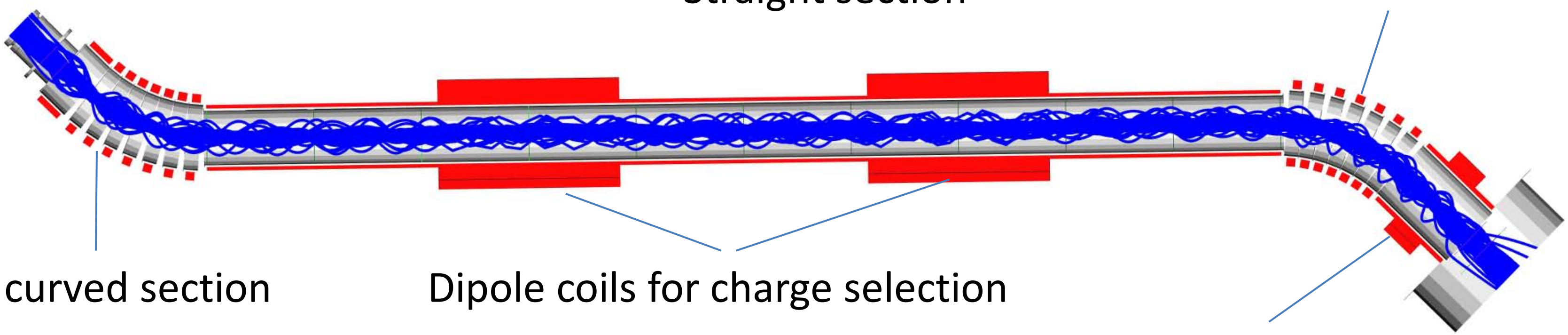
Designed by Nakahara

Maximum current	1500A
Peak central field	0.3T
Coolant	130 l/s
Muon capture rate	$5x10^8$ μ^+/s @ 30 MeV/c
Solid angle acceptance	400 mSr ($\pm 20^o$ initial angle)

Normal Conducting Capture Solenoids

- Beamline is 1.6m above floor level
- All maintenance to be performed at FL+4m above floor level
- All water and power cables are connected at FL+4m
- To keep radiation levels low, multiple layers of shielding are necessary to maintain
- Installation on beamline has been completed on March 2009.

Superconducting Curved Transport Solenoids

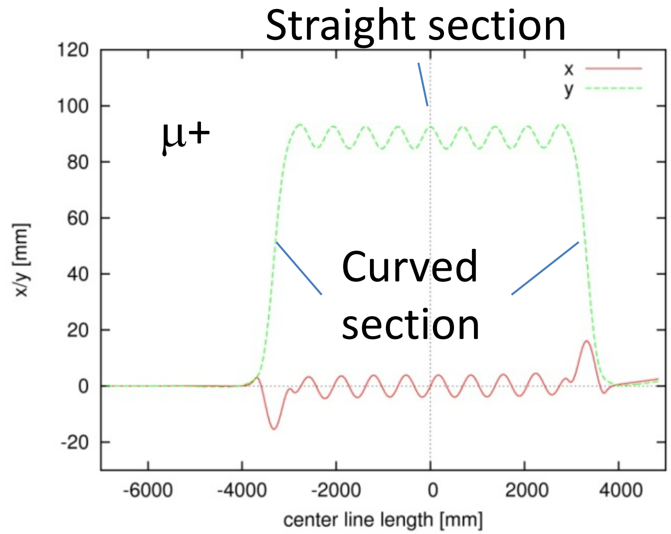


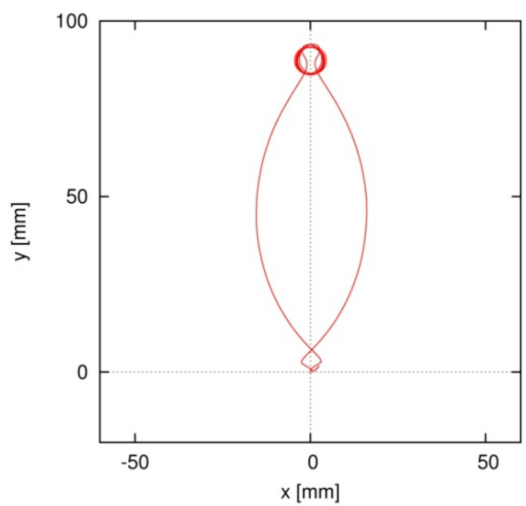
- The transport solenoids are designed to transport the captured muons to experimental hall 2.
- The solenoids have two 45 degree curved sections (7-segment) for reduction of radiation from neutral particle, and one 6-m-long straight section.
- A set of correction dipole coils for the charge selection and for steering beam direction, are mounted onto the solenoid structure.
- Cryogenics – Extensive collaboration with the KEK cryogenic group.
- A series of five Gifford–McMahon (GM) refrigerators are used to cool down the superconducting coils.

Beam trajectory simulation

G4Beamline :

Geant4 based Monte Carlo beam simulation program



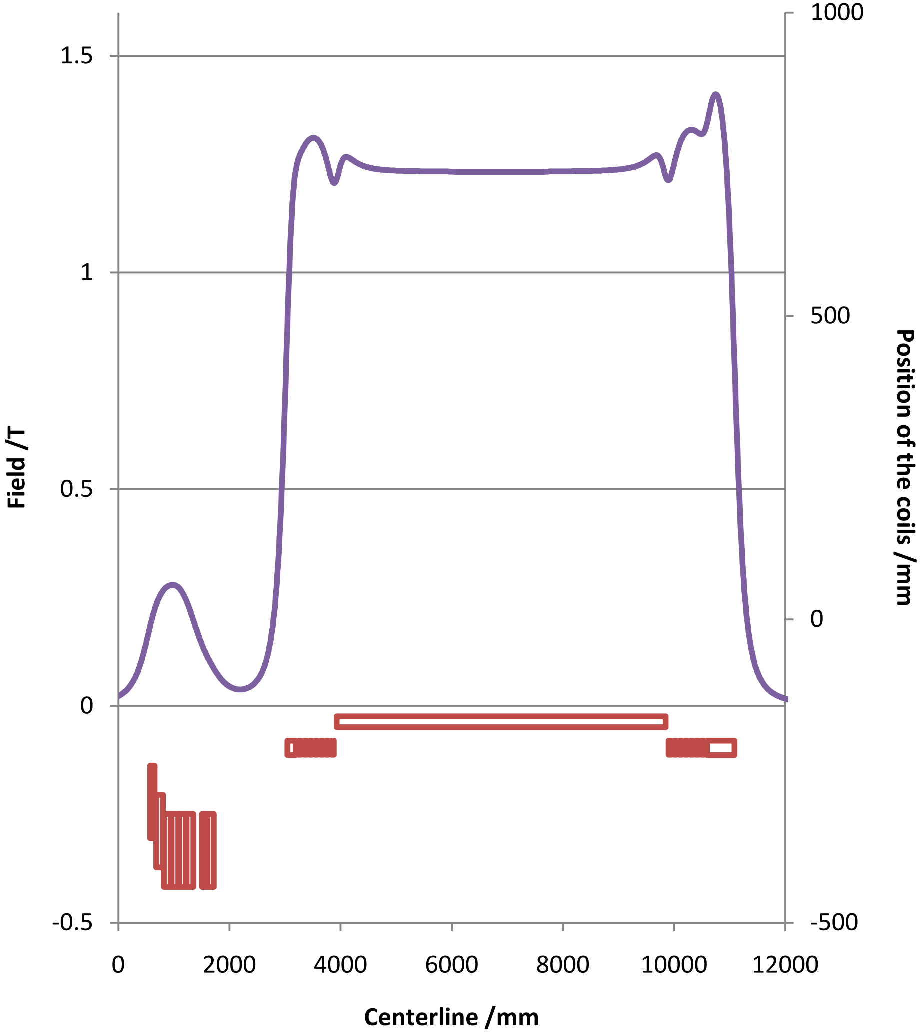


Projection on to the normal plane of solenoid center axis

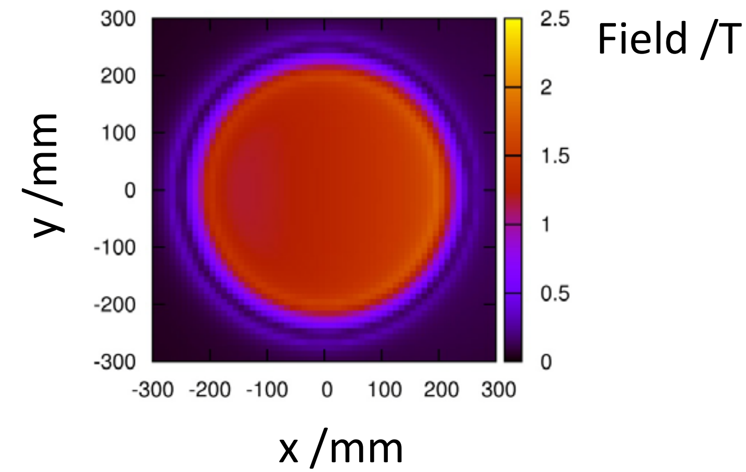
- The trajectory of muon which injected from the center of the muon target along the solenoid center axis are calculated.
- At the curved section, trajectory of positive (negative) muon drift up (down) due to the field flux effect.
- In the straight section, muons move in a spiral along with solenoid field.
- Optimize the beam trajectory
  - ➢To minimize the horizontal shift of the Lamour rotation center at straight section. The shift occurred by stray field from straight section at curved section. (Entrance matching solenoid)
  - ➢To achieve the symmetric trajectory about the center point of the straight section. (Straight section)
  - ➢To minimize the radius of the Lamour rotation in the straight section. (Curved section)

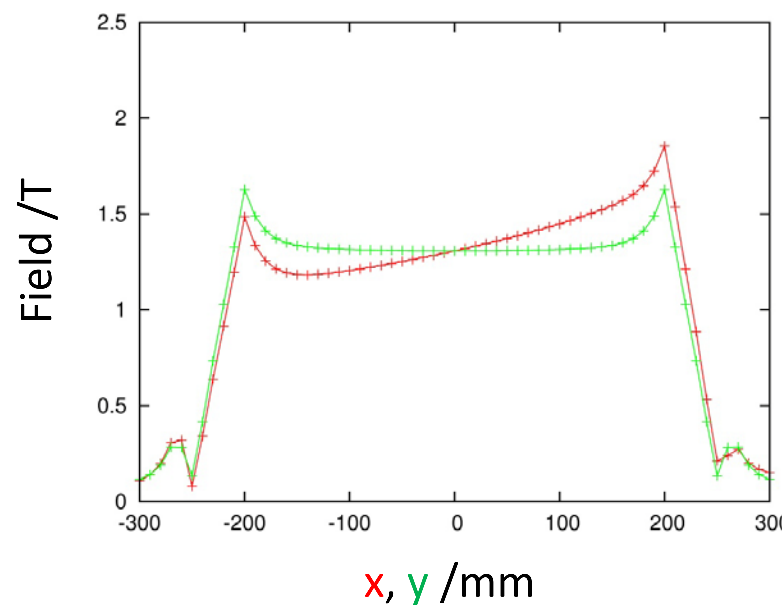
Field Distribution

The optimized field distribution along the centerline axis of the capture solenoids and the curved solenoid



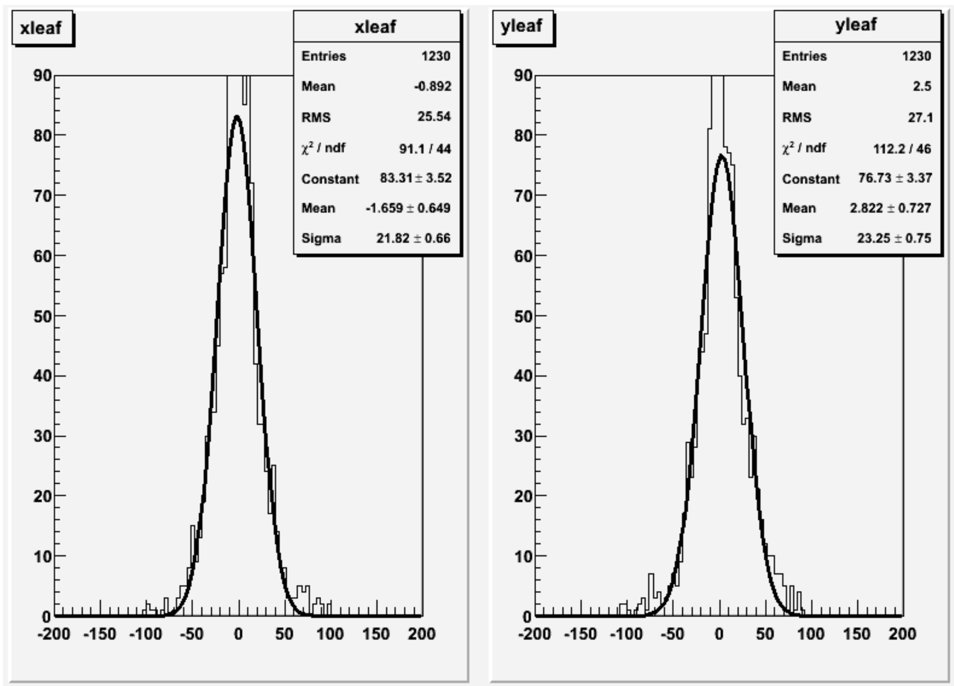
The cross section of the field at curved section



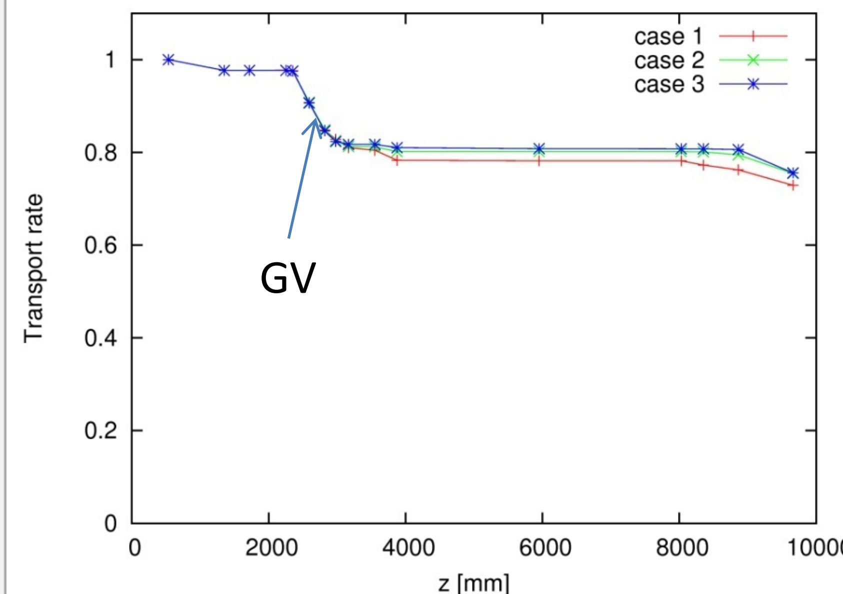


Beam Transport Simulation

Beam profile at the exit of the curved solenoid

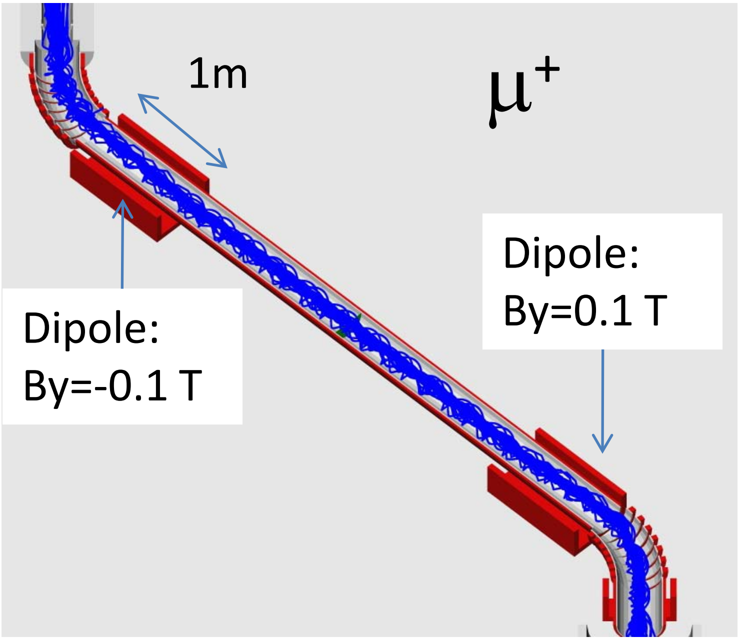


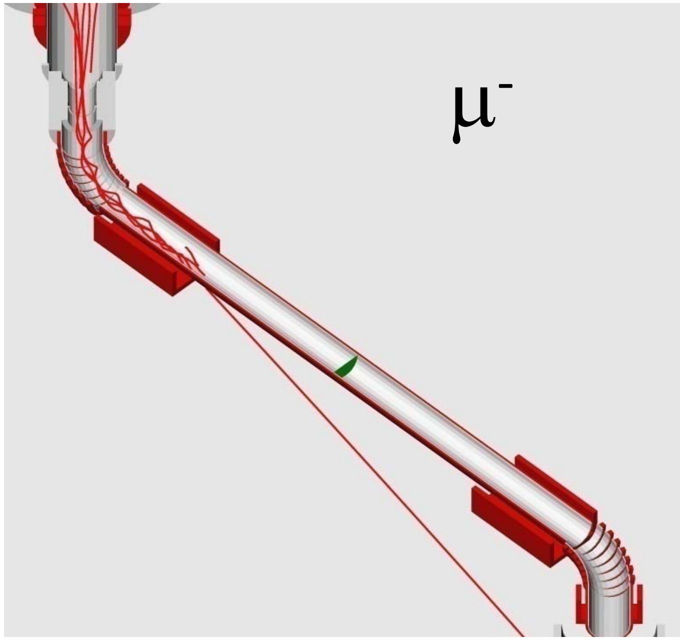
Transport rate



- The beam center at the exit of curved solenoid is almost identical to that of the solenoid axis. The beam full width is about 44 mm (one σ).
- Total beam loss is approximately 20% for 30 MeV/c muons.
- The almost all beam loss appears at gate valve pillow seal which located between capture and curved solenoid (minimum aperture: 220 mm).
- The injected beam of the curved solenoid can be transported with rate of ~100%.
- Total beam extraction at 1 MW is 4 x 10^8 μ^+/s for surface muon, and 1 x 10^7 μ^-/s for cloud muon. They are ten times larger than the currently available pulsed muon source.

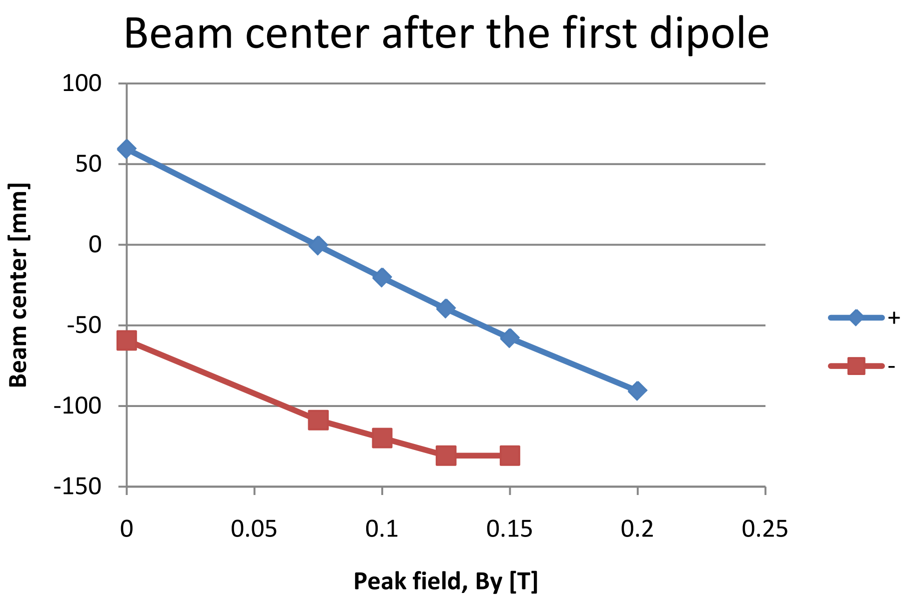
Dipole correction coils on straight section





- Although the simultaneously transport of the both μ+ and μ- is an advantage of the Super Omega beamline, it is necessary to equip a charge selecting system in the case of the experiments that require only one side charged particle, and also that make serious BG signals from the other charged particle.
- Superimposing dipole field on solenoid field, it is enable to decline beam trajectory of the both charged particle to the same direction.
- Add a set of dipole coil with opposite field direction at the straight section of the curved solenoid.

Transport rate with charge selection

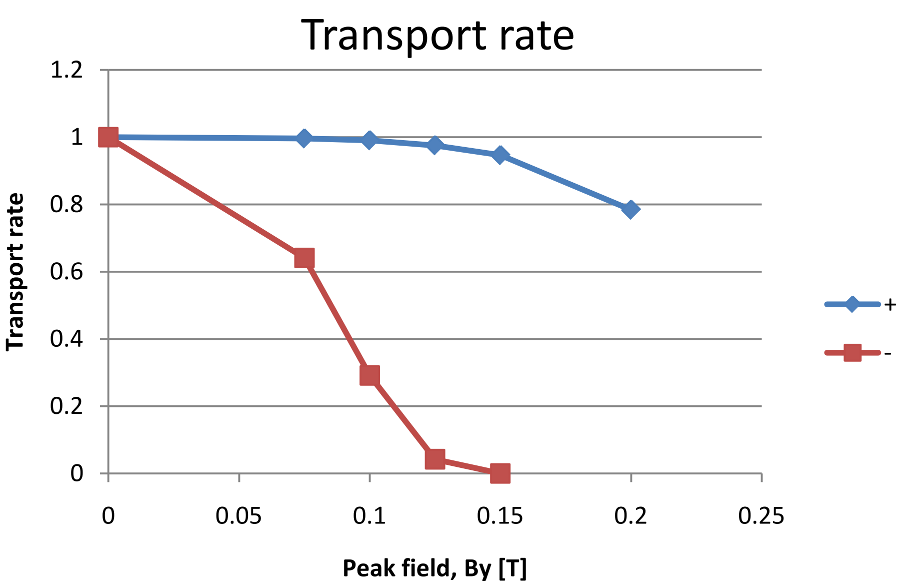


- The beam center of the both μ+ and μ- beam is lowered with increasing the field.
- The beam center positions are proportional to the peak field:

  -75 mm @ 0.1 T

- Transport rate for μ- reduces with lower field than that of μ+.
- Transport rate at the exit of the curved solenoid is not changed by applying a set of the dipole field.
- Transport rates of the both μ+ and μ- with applying field of 0.15 T are:

  μ^+ : 0.95, μ^-: 0.00 @ 0.15 T

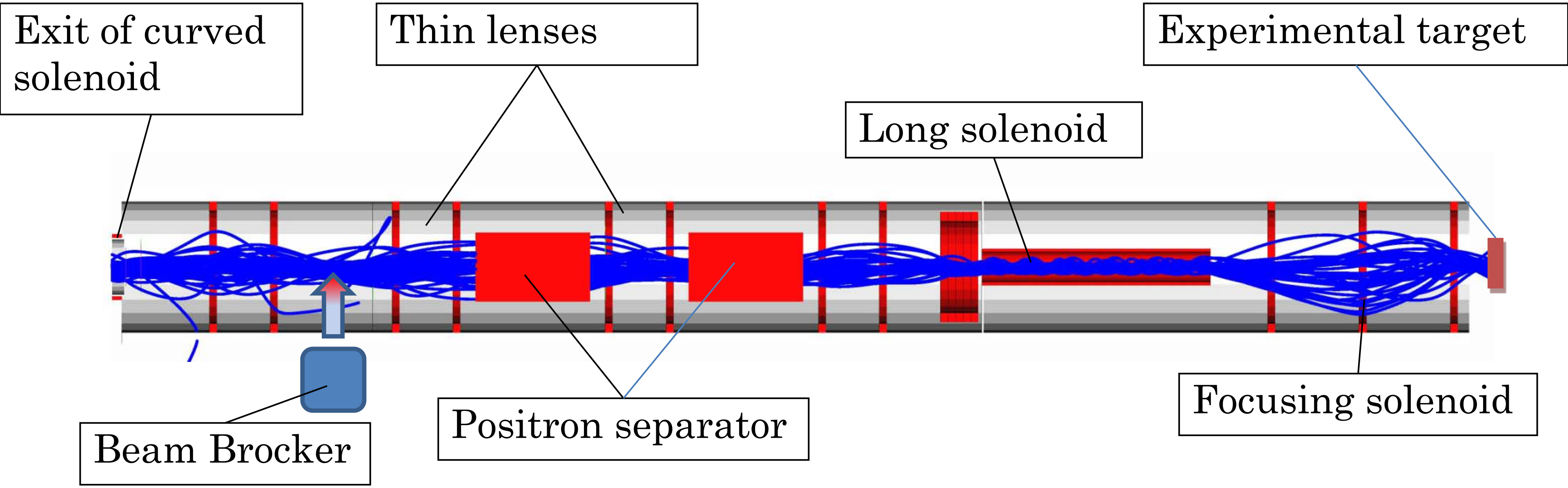


Superconducting Axial Focusing solenoids

Required function of the Axial Focusing solenoids

- The transported muon beam through the curved solenoid must be further transported about 7-m long (restriction from configuration of the experimental hall 2 and reduction of radiation exposure) and will be focused on the experimental target efficiently.
- Transported positron (electron) with muon beam estimated more than ten time larger than muon beam. Positron background should be eliminated from the muon beam for improving the muon beam quality.
- Beam brocker is needed to insert into the upstream of the beamline for reducing radiation exposure, when users will enter a experimental area for setting up apparatus etc.
- The axial focusing solenoids, used to focus the muon beam on the experimental target, is under consideration with particular emphasis on its compatibility with the positron separator.

Preliminary design of Axial Focusing solenoids

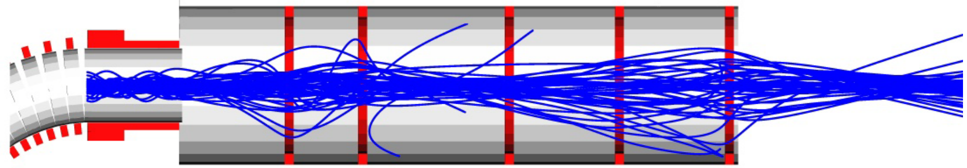


- Thin lens: Transport and make beam nodes to create spaces for inserting the brocker and the separators.
- Long solenoid: Further reducing the radiation exposure on experimental area.
- Beam Brocker: Cupper brock with at least 30-cm thickness for stopping neutron and gamma ray.
- Positron separator: Two-stage Wien filter type separator.
- Focusing solenoids: Focus on the experimental target using three thin lenses.

Axial Focusing System

Current densities of the solenoids

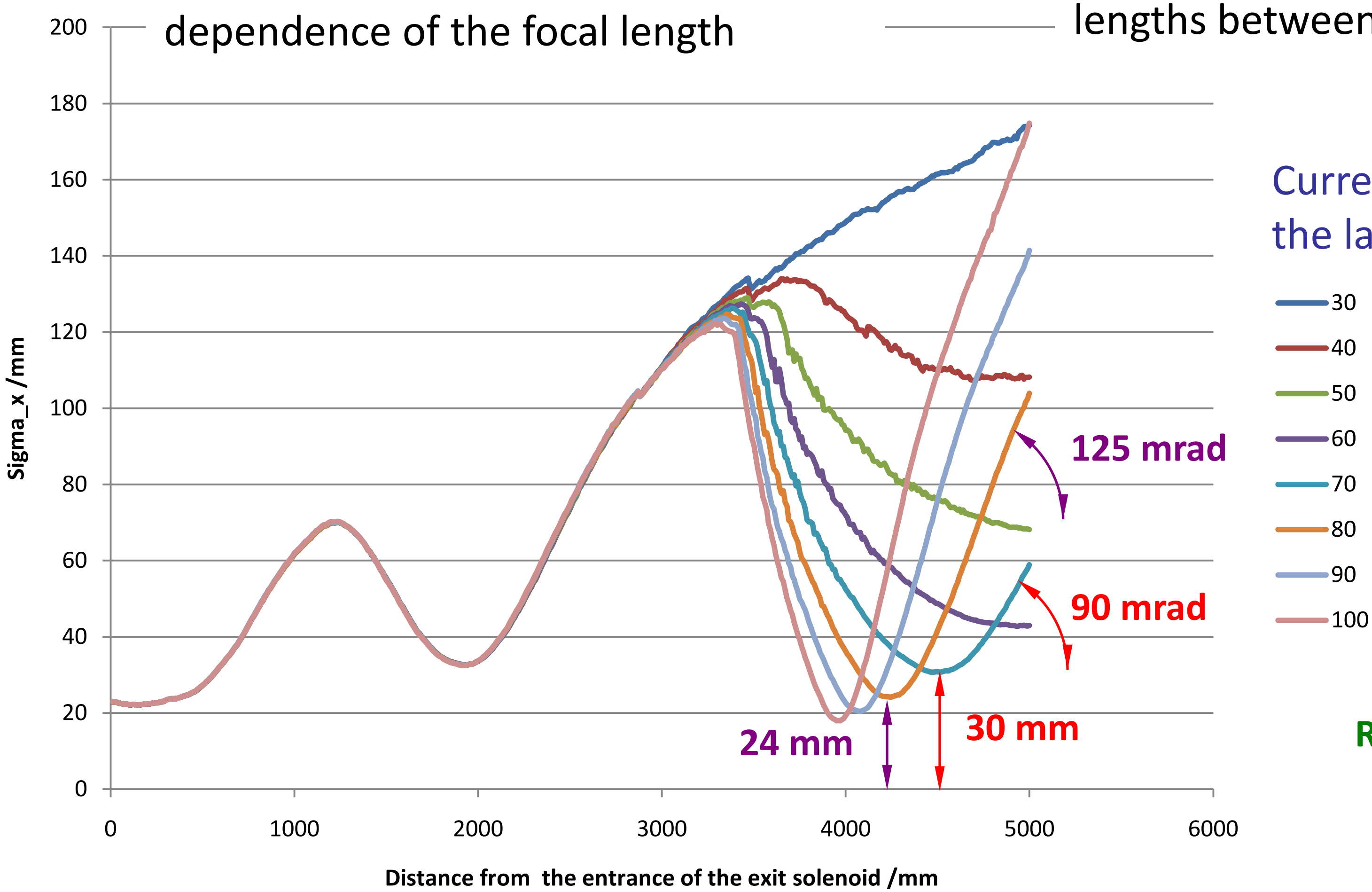
60 60 10 20 A/mm²



600 400 800 600 600 mm

lengths between solenoids

The current density of the last coil dependence of the focal length



RMS Emittance ~ 3 mm•rad

σ = 18 mm, Focal length 460 mm

σ = 30 mm, Focal length 1000 mm

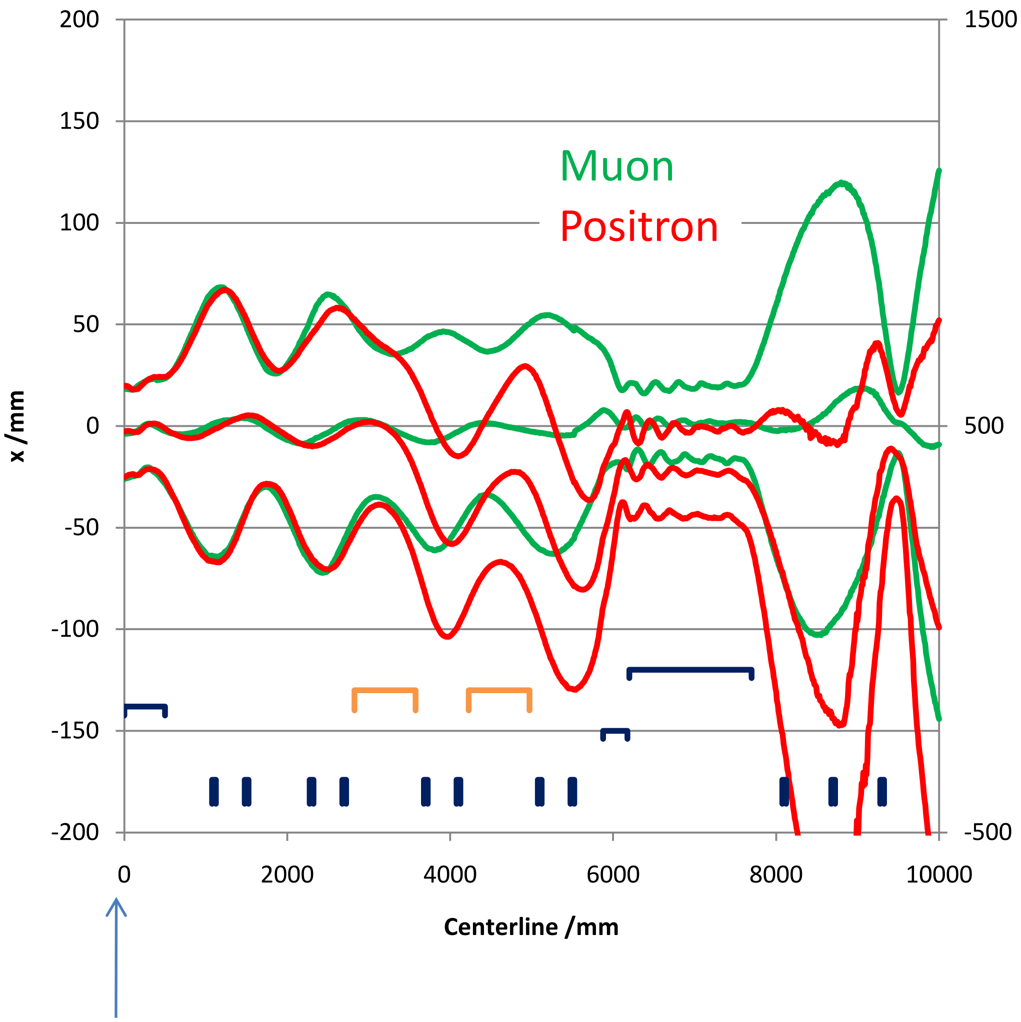
Positron Separator

Parameters of Separator:

- Two stages
- width 450, length 750, gap 300 mm
- Ey field +1.33 MV/m (±200 kV)
- Bx field -0.0173 T

- Maximum separation in beam center is about two σ at entrance of the long solenoid.
- Optimize parameters of the separator in progress.
- To eliminate positrons efficiently, it is necessary to insert slit in the space of the beamline.
- The position and the shape of the slit is under consideration.

Beam envelopes (σ) in Axial Focusing solenoids



Summary and Future plan

- Super Omega beamline, the second muon beamline of MLF/J-PARC , is under construction.
- Normal conducting capture solenoids

  → installed on March 2009
- Superconducting curved transport solenoids

  → start fabrication by Toshiba in this summer, will be installed on September 2011.
- The first beam extraction experiment of Super Omega (without axial focusing solenoids) will be conducted on October 2011.
- Superconducting axial focusing solenoids

  → conceptual design must be completed until the end of 2010, and hopefully will be fabricated on March 2012