The Status of Super Omega Muon Beamline

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Abstract. Super Omega muon beamline is currently under construction at Experimental hall 2 of Materials and Life Science Facility at J-PARC in Tokai, Japan. The beamline has a large solid angle acceptance, and will produce the highest intensity pulsed muon beam in the world. The beamline is designed to capture both surface positive and cloud negative muons for simultaneous use in a variety of experiments. The expected rate of surface muons for this beamline is 4×10^8 μ^+/s, and that for cloud muons is 10^7 μ^-/s. The beamline consists of the normal-conducting capture solenoid, the superconducting curved transport solenoid and axial focusing solenoid. The construction of the capture solenoid has been completed and installed on March 2009, and the transport solenoid is now fabricated, and will be installed on the summer of 2011. The calculation of the beamline optics of the axial focusing solenoid is underway.

Keywords: muon, superconducting solenoid, beamline
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INTRODUCTION

Super Omega is the second muon beamline among four planning muon beamline at the Materials and Life Science Facility (MLF) at J-PARC[1], and is currently under construction for aiming the extraction of the first muon beam in the autumn of 2011. The 3GeV proton beam injected into the MLF is incident on a graphite muon production target in order to produce muons for use in various experiments. Super Omega etends at 45 degree into backward angle from the primary proton beam. Super Omega is a new type beamline for muon source, since all beamline magnets of Super Omega consist of solenoidal coils, whereas the magnets of the convensional muon beamline consist of quadropole and bend magnets[2]. This is capable of not only capturing and transporting the both positive surface muons and negative cloud muons for simaltaniously use of the various experiments, but also extracting a high intensity muon beam into the experimental hall 2 of MLF. While the beam intensities of convensional beamlines are limited, in large part, by their relatively small solid angle acceptance to capture muons, the Super Omega will have a large solid angle acceptance of 400 msr, because of solenoidal capture coils. The expected intensity of the positive surface muons for this beamline is 4×10^8 μ^+/s, and that of the negative cloud muons with the momentum up to 45 MeV/c is 10^7 μ^-/s. This means that Super Omega will be the highest pulsed muon source in the world.

DESIGN OF SUPER OMEGA BEAMLINE

Super Omega muon beamline consists of three parts, normal-conducting capture solenoid, superconducting curved transport solenoid and axial focusing solenoid. Capture solenoid captures up to 5 x 10^8 positive surface muons/s and in excess of 10^7 cloud muons/s at 30MeV/c. Curved solenoid efficiently transports captured muons through the beamline tunnel, which shields radiation from the primary proton beamline and muon production target, into the experimental hall 2 in MLF. Axial focusing solenoid further transports the muons about 6-m long in the for inserting apparatuses, such as muon beam blocker for safety operation in the experimental area and positron separator for eliminating involved positrons as impurities for muon beam, and focuses onto experimental target for individual use of the several experiments, such as ultra slow muon production and muon transfer experiment. The muon transport rate and beam trajectory are simulated using GEANT4 based Monte Carlo simulation program, called G4Beamline[3], and the magnetic field distribution and the magnetic forces onto the individual solenoids are calculated using TOSKA. Here, we report the current status of the construction and designation of Super Omega muon beamline.

Normal-conducting Capture solenoid

The front face of capture solenoid places at 0.6-m apart from the muon production target in backward angle of 45 degree from the primary proton beam. Capture solenoid can captures muons produced at the muon production target with a large solid angle acceptance of 400 msr. For avoiding radiation damage from the muon production target and the primary proton beam, the solenoid is wound using radiation-resistant mineral insulation cables (MIC), with a maximum allowable current of 2000A. Capture solenoid consist of six coils. Four coils located upstream and two downstream coils are connected in series individually. The operating current for capturing muons with momentum of 30 MeV/c is approximately 1000A for the upstream coils and 200 A for the downstream coils. The peak central field of capture solenoid is about 0.3 T for capturing the muons with momentum of 30 MeV/c. The field measurements for capture solenoid have been performed and seen to agree with TOSCA calculations up to 1500A for the upstream coils[4]. Fabrication of the capture solenoids was completed in March 2008, and has been installed on the beamline in March 2009.

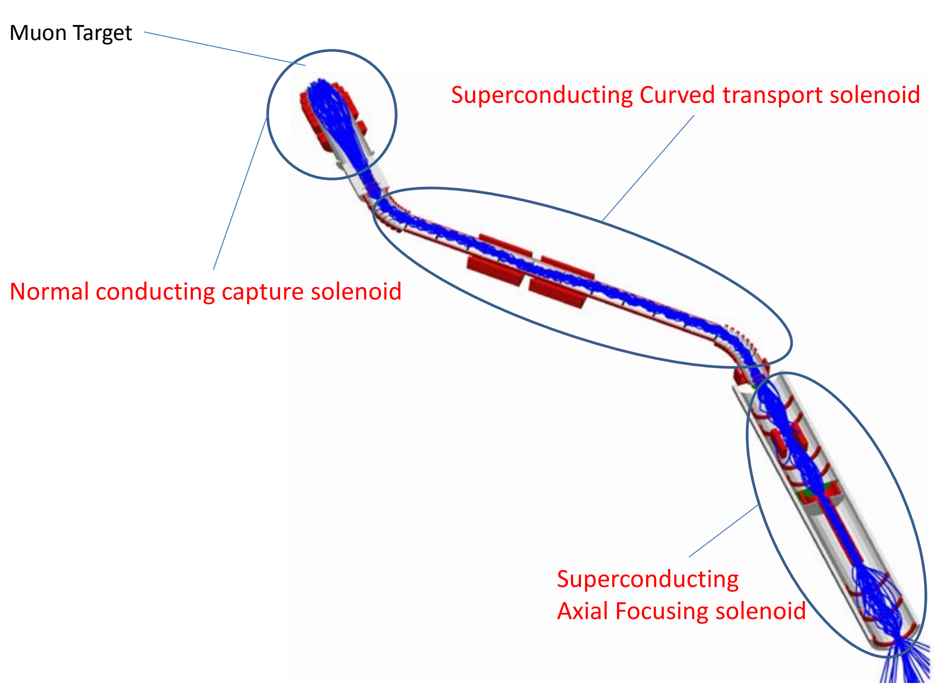

FIGURE 1. Design of Super Omega muon beamline.

Superconducting Curved Transport solenoid

Curved solenoid transports the captured muons through the secondary beamline tunnel into the experimental hall 2. The solenoid consists of a 6-m long straight section placed between two 45 degree curved sections. The curved section divided into seven segmented thin solenoids with angle between each solenoids of 5.625 degree. In order to compensate a stray field from the straight section, matching solenoids place at the entrance and exit of curved solenoid. To satisfy the feasibility of fabrication of the solenoid, the straight section divides into five 1.2-m long solenoids. These sixteen solenoids, except for exit solenoid, are connected in series, while exit solenoid can be adjusted separately for considering the matching field with axial focusing solenoid. On the straight section, two dipole coils, which produce opposite field for vertical direction each other with a integrated field of 0.2 Tm, are located near the center of the straight section for charge selection required by only use of positive muons or negative muon. For steering beam direction and position of the beam center at the exit of curved solenoid, two dipole correction coils with the fields of vertical and horizontal directions are located at center of exit solenoid.

A superconductor is commonly used for the solenoids and the dipoles. The solenoid coils are charged with current of 85 A in series and the dipoles are charged with 77 A individually. The all of the cold masses, superconducting solenoids and dipoles, are designed to be conductively cooled by five Gifford-McMahon (GM) refrigerators with capacity of 1.5 W at 4.2 K (2nd stage) and 35 W at 50 K (1st stage).

The muon transport rate of capture and transport solenoids were simulated using G4Beamline. Captured muons by capture solenoid is estimated by 5 x 10^8 muons/s when 3 GeV primary proton beam is incident on the muon production target. The simulation results show that the total transport rate of captured muons with momentum of 30 MeV/c (surface muon) is 82% at the exit of curved solenoid. This corresponds to 4 x 10^8 muons/s that are extracted into the experimental area[5]. A majority of the beam loss occurs at a gate valve located between capture and curved solenoids. This means that almost all muons incident on curved solenoid are transported to experimental hall 2.

Curved transport solenoid is currently under fabrication by Toshiba, and will be installed in summer of 2011.

Superconducting Axial Focusing solenoid

The design work of axial focusing solenoid is in progress. A muon beam blocker and positron separator are required for axial focusing solenoid system. When users work in the experimental area, the muon beam blocker must be inserted to reduce radiation exposure to the experimental area. The positron background should be eliminated for improving the muon beam quality. The latest design of axial focusing solenoid is shown in Fig.2. Upstream six thin solenoids are designed to further transport the muons and to make beam nodes for spaces of the blocker and separators. Residual three solenoids are used for focusing the muon beam onto the experimental target. Two-stage separator of Wien filter type and a beam slit are placed between thin solenoids to eliminate the positron background efficiently. The fabrication of axial focusing solenoid will start in April 2011.

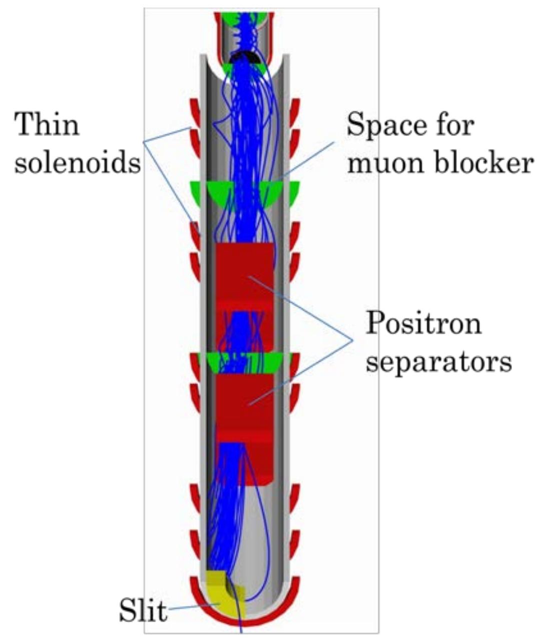

FIGURE 2. Design of axial focusing solenoid.

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