ISBN: 978-3-95450-208-0 doi:10.18429/JACoW-IPAC2019-MOPGW046

PROTON BEAM STEERING FOR THE EXPERIMENTAL MUON SOURCE AT CSNS*

Y. K. Chen†[1], H. T. Jing[1], J. Y. Tang[1], G. Zhao, Y. P. Song[1], C. Meng,
Institute of High Energy Physics, Chinese Academy of Sciences, Beijing, China
[1]also at Dongguan Neutron Science Center, Dongguan, China

Abstract

Experimental Muon Source (EMuS) is a muon source to be built at China Spallation Neutron Source (CSNS). The EMuS baseline design adopts a stand-alone target sitting in capture superconducting solenoids, and the muon beam is extracted in the forward direction. In the same time the spent protons are also extracted from the target station and guided to an external beam dump. Because there is an angle of 15 degrees between the axis of solenoids and the proton direction, the protons will be deviated by the solenoids field. A pair of correction magnets in front of the solenoids is used to align the incoming proton beam to the target and also guide the spent protons to the beam dump. As the target station is design to work at different field level, this increases the complexity of the proton beam transport.

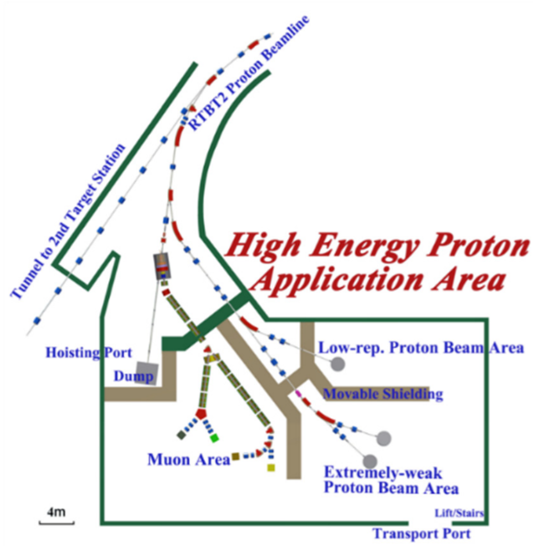

Figure 1: General layout of the High Energy Proton Application Area.

INTRODUCTION

Muon spin rotation/relaxation/resonance (μSR) is a very useful technique, complementary to NMR and neutron scattering techniques [1]. China Spallation Neutron Source (CSNS) is a newly completed multidisciplinary research facility, located in Dongguan, Guangdong [2]. The proton energy is 1.6 GeV, and the design beam power is 100 kW in Phase I, and will be upgraded to 500 kW in Phase II [3]. To take full advantage of the powerful proton beam, CSNS plans to add a muon source in Phase II [4]. The so-called Experimental Muon Source (EMuS) is located in a dedicated high energy proton application area, together with different proton beam endstations, as showed in Figure 1. And it shares 5% of the total proton beam power, with a repetition rate of 2.5 Hz. The EMuS baseline design adopts a stand-alone conical target of about 250 mm in length sitting in a capture superconducting solenoids, and the muon beam is extracted in the forward direction. With this target design and a proton beam power of 25 kW, the surface muon intensity can achieve about 5×10^5 /s at each of the three μSR spectrometers with a polarization of about 74%. And the decay muon intensity for 45 and 150 MeV/c can achieve 4×10^5 /s and 5.9×10^6 /s respectively, with polarization of 81% and 82%

PROTONS DEFLECTED BY THE SOLENOID FIELDS AND PROTON BEAM STEERING DESIGN

Influence of Solenoid Fields to the Proton Beam

The protons impacting on the muon target located in the solenoids. And there is an angle of 15 degrees between the axis of solenoids and the proton direction in horizontal plane, in order to separate the outgoing spent protons from the muon beam and also enhance the surface muon capture. The layout of the target station is showed in Figure 2.

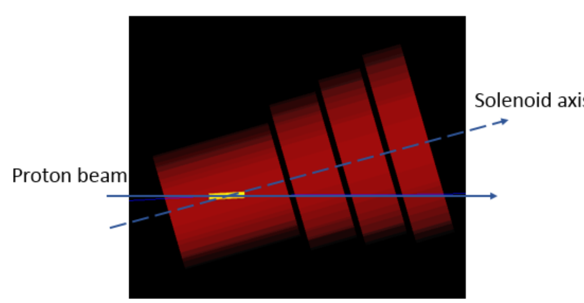

Figure 2: Layout of target station.

With the above layout, both the incoming and spent protons will be deflected by the solenoid fields. The motion of the protons can be decomposed into two parts, one is parallel and the other is perpendicular to the field line as showed in Figure 3. The motion of parallel part will not be influenced by the magnet field, but the perpendicular one will move around the field line. So the protons will make precessional motion around the field line in the solenoids. When the protons leave the solenoids, they will have vertical motion, which will make them deviating from their original direction. And the motion in horizontal direction

*Work supported by NSFC (11527811 and 11805218)
chenyk@ihep.ac.cn

ISBN: 978-3-95450-208-0 doi:10.18429/JACoW-IPAC2019-MOPGW046

will be affected too. So when the protons go to the beam dump 6 m away from the target centre, their position will have different deviations with different strength of the solenoids.

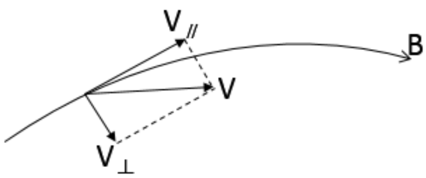

Figure 3: The protons motion decomposition in the solenoid field.

Two working modes are designed for the EMuS main target station. One is the surface muon mode with the main solenoid field of 1 T. The other one is the decay muon mode with the main solenoid field of 5 T. Another case to be considered is that the proton beam goes through the target station directly when the solenoid field is turned off during the commissioning. Considering all of the situations above, there will be three different beam spots at the beam dump as showed in Figure 4.

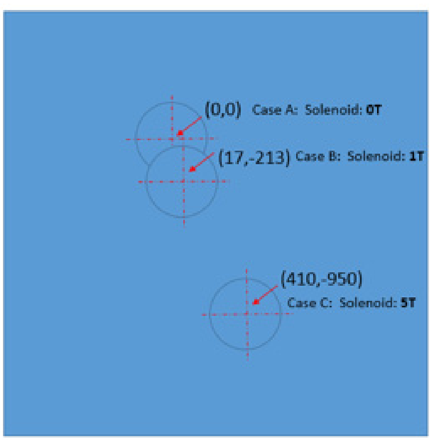

Figure 4: Three possible beam spots at beam dump.

Proton Beam Steering Design for EMuS

The different deviations of proton beam cause uncertainty of beam spot positions at the beam dump, which will make the beam dump design more complicated. Measures should be taken to reduce the deviation of proton beam and the number of beam spots at the beam dump. A steering scheme was designed, which uses a pair of steering dipole magnets in front of the solenoids to steer the incoming protons with a proper angle, which can compensate the deflection by the solenoid fields partially. The layout of the proton beam steering scheme by two dipoles is showed in Figure 5. One is horizontal bending magnet, and the other one is vertical bending magnet. For a given field pattern, the alignment of the incoming protons with the target is guaranteed and the beam spot positions at the beam dump can also be optimized both in the horizontal and the vertical directions.

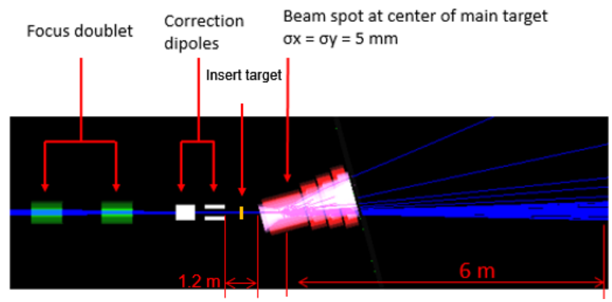

Figure 5: Proton beam steering layout for EMuS.

The relationship between the steering angles and the deviation of beam spots at the beam dump is showed in Figure 6. For the surface muon mode, the beam spot deviation can be adjusted to zero by a steering angle of 0.05 degrees in the horizontal 1.75 degrees in the vertical. Zero position at the beam dump is related to the case of solenoid fields turned off. In the decay muon mode, although the beam spot deviation cannot be adjusted to zero, but it can be reduced significantly. What's more, there are just left two spots at the beam dump, which will be helpful in the beam dump design. The two dump holes are showed in Figure 7.

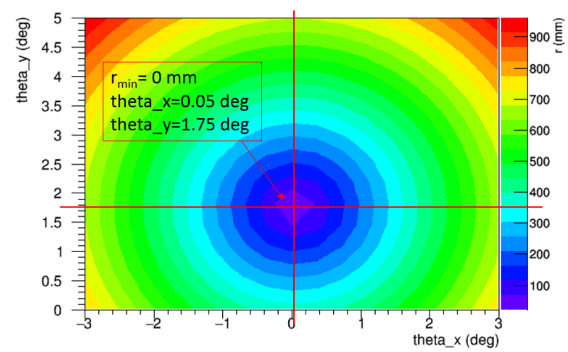

Figure 6: The relationship between steering angles and beam spot deviation.

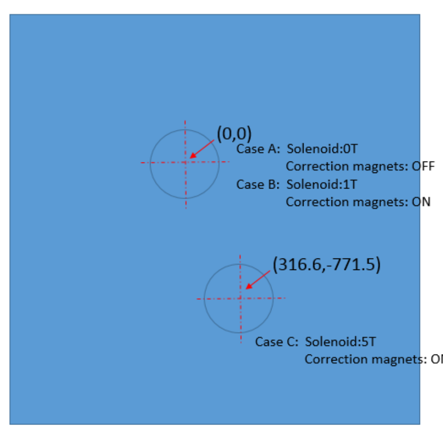

Figure 7: The two beam spots at the beam dump with proton beam steering scheme.

ISBN: 978-3-95450-208-0 doi:10.18429/JACoW-IPAC2019-MOPGW046

SPENT PROTONS EXTRACTION FROM THE TARGET STATION

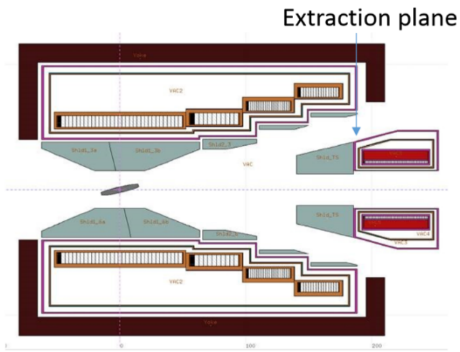

Figure 8: Layout of solenoids structure and proton extraction space.

The structure of the capture solenoids is showed in Figure 8. On the right it is a matching solenoid between the target station and the muon transport line, whose shape is like a cone that helps to provide space for the spent protons extraction. The extraction channels for different modes go through the inner shielding of the capture solenoids and the outer shielding of the matching solenoid, as showed in Figure 9. At the so-called extraction plane marked in Figure 8, the radius of the inner circle is 370 mm, and the outer one is 580 mm.

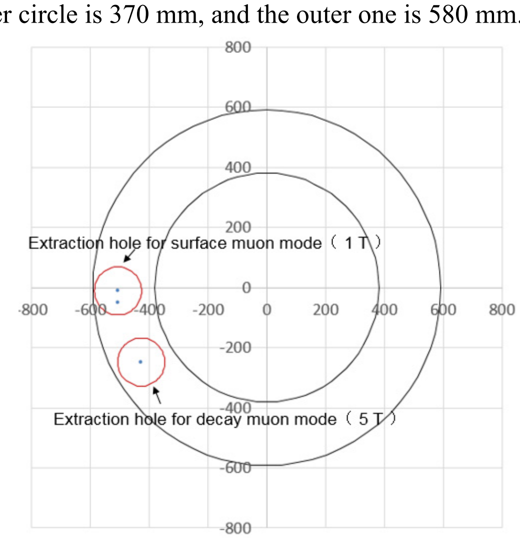

Figure 9: Extraction channels of the spent protons at the extraction plane.

CONCLUSION

This paper presents the design for the proton beam steering at the EMuS. In order to solve the problem of protons deflected by the magnet fields of the capture solenoids, a pair of steering magnets in front of the solenoids is used to align the incoming proton beam to the target and guide the spent protons to the beam dump. Based on this scheme, the angle deflected by the solenoids field can be compensated partially with proper steering angles. The beam spot deviations at the beam dump for different working modes or solenoid fields can be minimized to be consistent to different steering schemes, there are two extraction holes in the inner shielding of the target station for the spent protons extracting from the target station.

REFERENCES

[1] A Yaouanc and P D R´eotier. “Muon spin rotation, relaxation, and resonance: applications to condensed matter.” *Number 147. Oxford University Press,* 2011.

[2] Fu S N, Chen H S, Chen Y B, *et al.*, “CSNS Project Construction [C].” *Journal of Physics: Conference Series. IOP Publishing,* 2018, 1021(1): 012002.

[3] Wang S, An Y W, Fang S X, *et al.*, “An overview of design for CSNS/RCS and beam transport [J].” *Science China Physics, Mechanics and Astronomy,* 2011, 54(2): 239-244.

[4] Tang J, Ni X, Ma X, *et al.*, “EMuS muon facility and its application in the study of magnetism [J].” *Quantum Beam Science,* 2018, 2(4): 23.