TITLE and type of activity (Networking, Joint Research development):

Development of a design for a high-intensity muon beamline at ESS

Leading beneficiary: Paul Scherrer Institut (PSI); Laboratory for Particle Physics, Muon Physics Group (P.-R. Kettle, A. Knecht) in cooperation with other laboratories from PSI departments
NUM (ASQ; B. Blau, K. Geissmann, LMU; E. Morenzoni) and GFA (ABE; M. Seidel).

Partners: ESS Lund: L. Zanini, M. Lindroos; ETH Zürich, IPP: K. Kirch

Estimated budget (in person months, other direct cost) and tentative distribution per partner
4 PY – 2 postdocs for two years (PSI, PSI-ESS), 3 PY – 1 PhD student (ETHZ);

Abstract of your innovative activity:

There is a high demand for high-intensity muon beamlines both from the particle physics community with its searches for rare, lepton-flavor violating decays and from the material science community using the technique of muon spin-rotation (muSR).

The world's most powerful muon beamlines are currently located at the Paul Scherrer Institut delivering several 10^8 positive muons per second at momenta of around 28 MeV/c (so called surface muons) to muSR and particle physics experiments. However, both communities would greatly profit from increased production rates. For particle physics this would allow to go beyond the now existing limits on lepton-flavor violating processes while for material science it would substantially improve the rates achieved in low-energy muSR experiments studying thin films/heterostructures and surface phenomena and allow the possibility to perform muSR measurements on very small samples using a muon micro-beam.

To this end a feasibility study was started at PSI – termed HiMB – examining the possibility to extract a surface muon beam from the neutron spallation target SINQ. The basic idea is to use the muons stemming from the decays of pions that stopped in the entrance window of the spallation target. These surface muons can then be guided away from the spallation target using a suitable magnetic beamline. The envisaged rates achievable at SINQ are of the order of 10^{10} muons per second and would thus constitute an improvement of two orders of magnitude.

We propose here to develop a design similar to HiMB at ESS. This would foresee equipping one of the access shafts for fast neutron irradiation with a window close to the spallation target and suitable for surface muon production, as well as a solenoidal channel for transporting the muons out of the shielding monolith. Based on a first estimate, average muon rates of 10^{10} to 10^{11} muons per second seem possible at ESS. With such rates ESS would become a prime location for particle physics and material science with muons.

1. State of the Art

Currently the highest intensity muon beams, such as those at PSI, are produced by the interaction of protons with a relatively thin, transmission type of target, made of carbon. In such a setup, only a fraction of the protons are used while the remainder travels on to other target stations such as SINQ in the case of PSI. The proposed design of producing a muon beam at a spallation target has several advantages: i) All of the remaining protons are used in the production of pions. ii) The pion production volume is larger and higher energy pions can be exploited in addition. iii) The high-Z materials employed in spallation targets have higher pion production cross-sections than those of a transmission type of target made of carbon.

2. What is new? Why should it be done on a European consortium level (synergies)?

The proposed design is completely new and has never been implemented before. The feasibility study currently being conducted at PSI will answer many important open questions. Such a facility could potentially be implemented at PSI, in 2019 and so could be regarded as a prototype for the proposed muon beamline at ESS.

It is clear that the construction of such a beamline close to a multi-megawatt spallation target poses a large challenge and so can only be attempted on an international level employing suitable experts from both PSI and ESS, with the strong support of the involved communities.

3. How could your activity be connected with other methods and techniques (outside the neutrons community)?

This proposal provides a chance to bring a whole new community to ESS in the form of particle physics and material science based on muons.

4. Is there any link with national initiatives/projects (e.g. national data initiatives, but also European roadmaps etc)?

PSI is developing a similar design in the form of a feasibility study. It would be implemented at the spallation source SINQ and can be regarded as a prototype for the proposed design here.

5. How is the user community involved in your activity? Benefit for the user (evtl for any specific science community?)

There is a strong endorsement from both the particle physics and the muSR communities. For both of them, new high-intensity muon beamlines are paramount in going beyond what is currently possible. Both communities have "next generation" experiments foreseen at the intensity frontier, where the full

potential can only be exploited by such high-intensity beams. In parallel to the development of the beam line concept, the physics case would be described in a collaborative effort involving both communities.