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

Next generation of pressure cells: Delivering hardware and improved design of µSR spectrometers

Leading beneficiary: EU Researchers

Partners: PSI and to be confirmed

PDRAs requested at PSI (24 person months).
50 kEuros for material.

Abstract of your innovative activity:

This project is focused on the improvement and further development of the pressure capabilities for the µSR technique. There are a number of different designs of pressure cells for µSR but practically all of them are of type “piston cylinder”. Due to the sample space requirement, presently only a maximum pressure of 2.4 GPa can be reached. Our goal is to improve the so-called “double layers” pressure cells and in addition to design and develop an “anvil-type” pressure cell. These novel cells will be used with different sample environments (temperature and fields).

1. State of the Art

µSR is a powerful technique for gaining an insight into magnetic and superconducting properties of materials at the microscopic level. High-pressure allows scientists to control in a reversible manner the volume of the sample and consequently the properties of a system. The application of high pressure can produce magnetic, electronic, or many other phase transitions. The requirements for the success of µSR experiments under pressure are numerous, as the possibility to have large samples, hydrostatic pressure conditions, low temperatures, and the possibility of achieving high pressures. The usual “piston cylinder” pressure cells, which were used for the µSR up to now, provide a reasonable sized sample cavity. However, the highest pressure is rather limited. In order to increase the pressure limit, a design with double-wall layer has been already introduced. However, the maximum possible pressure is still limited to 3.4 GPa at room temperature and 2.4 GPar at low temperatures. The main source for the observed pressure drop between room temperature and low temperature is a huge amount of friction, developing between the sliding parts of the sealing system and the walls of the pressure cell. An important restriction in pressure experiments is the fact that (as no material is transparent to muons) a substantial fraction of the μSR signal originates from muons stopping in the pressure cell surrounding the sample. Nowadays, typical fraction of muons stopped in the sample is about 40-45 %, which could be reached after recent developments.

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

We plan to improve the pressure cell scheme in two aspects: improving the mechanical properties of pressure cell materials and modifying the design in order to reduce the friction substantially, which will allow increasing the pressure at the sample at low temperature by about 30 %. In addition, it is intended to increase the fraction of muons stopping in the sample, which will allow low background measurements. Regarding pressure cells of type “anvil”, they allow a variety of optical, X-ray, and other studies over a wide range of the electromagnetic spectrum to be carried out at low and high temperatures and high magnetic fields. Using diamond anvil cell one can generate pressures above 400 GPa, depending on the cullet size of the diamond. For μSR, we plan to use Boron-Nitride anvils which are cheaper as compared to diamond anvils and exhibit low background for μSR. The use of anvil cells in µSR studies will significantly increase the pressure range, providing technical challenges for a conventional instrument. µSR requires relatively large sample volumes of typically several cubic millimetres. To be able to apply high pressures on such samples will require rather bulky anvil pressure cells. However, the available space is limited by the necessary detector system and the sample environment. Hence, the use of novel anvil cells will require also the design of novel detectors geometry. We foresee that such development will also be applied for a pulsed muon source as ISIS (UK).

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

The μSR user community will benefit directly, as these developments will open new research directions in condensed matter physics research, since many exciting behaviours in magnetic and superconducting materials and strongly-correlated systems were observed using solely bulk techniques as transport measurements. μSR will allow studying these systems at the microscopic level, which is important to understand their fundamental properties.