# LEM - LOW ENERGY MUONS THE RECONSTRUCTION OF THE SECONDARY BEAMLINE AT THE PSI µE4 AREA

*R. Kobler*

*PSI is constructing a new beam line for the LEM facility which will replace the present µE4 beam line. The design and production of new components is fully controlled and supervised by PSI. The disassembly and the disposal of partly activated sections of µE4 create many problems and needs careful preparation.*

## INTRODUCTION

To explore the full potential of solid-state physics based on very low energy muons, a dedicated beam line with a high flux of muons is needed. The new beam line at µE4 is designed to achieve fluxes of about $5 \times 10^8$ $\mu^+$/s. This line will start with a solenoid lens system, installed directly at the main production target E, followed by transport elements made of conventional large acceptance quadrupoles and dipoles. Design and construction of the beam line had to fulfil different constraints. The new beam line has to fit into the existing channel in the primary shielding around the production target. The reconstruction work can only be done during a shutdown period with a minimum duration of 10 weeks and the assembly of new components and the disassembly of old elements has to be done in a radioactive environment. In addition, the waste disposal of activated material needs a very careful organisation in order to minimize the dose collected by personnel during the handling and to guarantee correct and professional storage.

## THE RECONSTRUCTION OF THE µE4 BEAM LINE

The design of the new beam line commenced during 2001. We had to design a total of about twenty meters of beam line with all its components. There are twelve quadrupoles, three bending magnets, three collimating slit systems, two beam blockers and several vacuum chambers, bellows, shielding and systems to connect the active components to cooling water and power supplies. In addition, an electrostatic separator is foreseen at the end of the beam line. The LEM apparatus, which will be installed at the end of the new beam line, also needs a major upgrade to adjust to the modified beam conditions and to achieve a more user-friendly and stable operation. For the production of the magnets, we had to use industrial partners. The solenoid and the first bending magnet have to be made out of radiation hard material. For example, the first bending magnet is exposed to a neutron dose of about $10^6$ Gray per year which made it necessary to use mineral insulated coils. All other beam line components are produced by our mechanical workshop. Our ambitious goal was to install the first part of the beam line fitting into the proton shielding during the shutdown 2003.

Fig. 1 shows the first part of the old µE4 beam line. The elements are mounted on a wagon, which also carries the huge shielding blocks. This wagon forms part of the primary shielding of target E. The very first quadrupole triplet is also embedded in this shielding. The presently installed magnets are activated and have dose rates up to 30 mSv/h. These elements can only be replaced during a shutdown. We scheduled to do only this replacement during the 2003 shutdown and to finalize the beam line in the subsequent two months.

Such a project for installation of new and complicated components in the environment of the primary and secondary beam line is normally split in phases: design, production and assembly. Here, this is not sufficient because the work has to be done during time-limited shutdowns and partly in a radioactive environment. Therefore, a serious test assembly is essential for a successful installation. This allows mechanical parameters to be checked early enough for contingent correction.

During spring 2002, we were already behind schedule. This was basically caused by a lack of manpower in mechanical design. After discussions with the PSI management, the project was given higher priority for the design and in the production workshop. There was still the risk that some components, in particular the radiation hard magnets, would not arrive in time.

**Fig. 1:** The photo shows the old insertion wagon with its shielding made of iron-concrete. On the left, the first bending magnet ASK61 is visible. This magnet will be replaced by a magnet with radiation hard coils because of its exposure to target E. On the right, it is possible to recognise a part of the superconducting µ-channel. The µE4 wagon will be reused for the new components.

In order to maintain the original schedule we were forced to omit the test assembly. Our workshop was faced with the task of delivering a large number of components before the end of November 2002. Some orders were placed with industrial companies, but not all of them were fully aware of our demanding requirements. They could not meet the technical specifications. For example, a few vacuum chambers had to be returned to the supplier for modification. For future projects, it is important to build up co-operation with experienced specialised companies.

The delivery of the quadrupoles was subject of a world wide tender. The Efremov Institute in St. Petersburg, Russia, delivered thirteen quadrupole magnets on schedule and of very good quality. Three of these magnets are combined to a triplet as shown in Fig. 2.

**Fig. 2:** The picture shows a new QSM quadrupole magnet (mirror plates removed) during assembly of the cooling water connections. The triplet on the wagon will be supplied with cooling water and current using insulated copper tubes to avoid the use of nylon or rubber tubes which would need regular replacement in an inaccessible region.

To have good and compact shielding on the wagon, low quality cast iron was chosen. The short time for delivery was another problem we had to solve. As a welcome surprise, the lowest price for the 100 tons of cast iron was offered by a Swiss company.

It was more difficult to find a company which could produce radiation hard coils for the solenoid and the first bending magnet. Nevertheless, we could benefit from the opening of new markets in Eastern Europe, where excellent facilities are available at competitive prices. Unfortunately, the company we found for the supply and manufacture of the specified radiation hard coils underestimated the technical difficulties involved. Last autumn, we were faced with a delayed delivery of these coils and other components, so that we were forced to postpone the planned reconstruction.

The project has a budget of about 2.5 million Swiss Francs 30 % has been spent for magnets; an additional 30 % went into the vacuum systems. The rest is used for mechanical components; infrastructure and correct and professional storage of activated components.

## OUTLOOK

The delay for the reconstruction will almost certainly be an entire year. Some technical groups at PSI are relieved to have more time for serious preparation. We will use the time until next summer for a detailed pre-assembly of the whole beam line in the experimental hall. Simultaneously, the experiment currently installed can be continued. Next summer or autumn the modification of the area's shielding walls and platforms can be made in advance of the work we have to do during shutdown 2004.

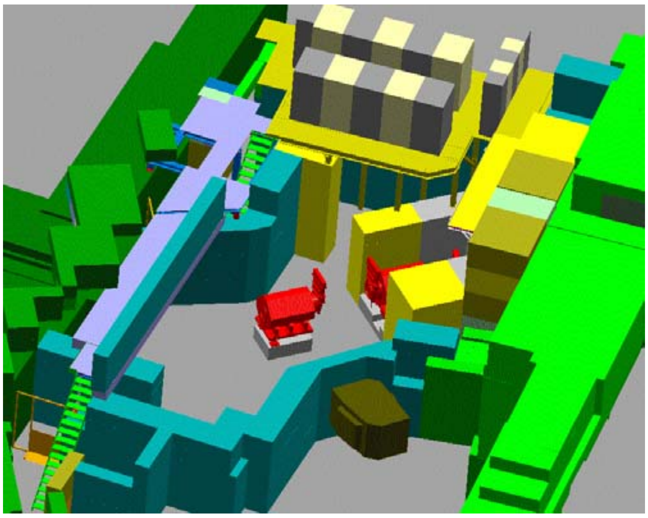

**Fig. 3:** The CAD graphic shows the µE4 area as it should appear after the 2004 shutdown. In the centre, it is possible to recognise a quadrupole triplet. The extended platform for the electrical cabinets can be seen in the background.

As a general guideline for the disassembly of the old beam line, we try to avoid waste disposal of radioactive components. In this case, most of the material is only slightly activated. Magnets, slit systems and the so-called µ-channel can be reused by other experiments. The µ-channel is a superconducting solenoid, which helps to improve the muon rate. It will be available for another European research institute during spring 2004. Material with stronger activation will be stored in special storage areas and disposed of later.

## REFERENCES

[1] PSI FUN newsletter 2002.

[2] http://lmu.web.psi.ch/lem/index.html