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Felsenkeller shallow-underground accelerator laboratory for nuclear astrophysics

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Abstract. Favored by the low background in underground laboratories, low-background accelerator-based experiments are an important tool to study nuclear reactions involving stable charged particles. This technique has been used for many years with great success at the 0.4 MV LUNA accelerator in the Gran Sasso laboratory in Italy, proteced from cosmic rays by 1400 m of rock. However, the nuclear reactions of helium and carbon burning and the neutron source reactions for the astrophysical s-process require higher beam energies than those available at LUNA. Also the study of solar fusion reactions necessitates new data at higher energies. As a result, in the present NuPECC long range plan for nuclear physics in Europe, the installation of one or more higher-energy underground accelerators is strongly recommended.

An intercomparison exercise has been carried out using the same HPGe detector in a typical nuclear astrophysics setup at several sites, including the Dresden Felsenkeller underground laboratory. It was found that its rock overburden of 45 m rock, together with an active veto against the remaining muon flux, reduces the background to a level that is similar to the deep underground scenario.

Based on this finding, a used 5 MV pelletron tandem with 250 μA upcharge current and external sputter ion source has been obtained and transported to Dresden. Work on an additional radio-frequency ion source on the high voltage terminal is underway. The project is now fully funded. The installation of the accelerator in the Felsenkeller is expected for the near future. The status of the project and the planned access possibilities for external users will be reported.

1 Introduction

Nuclear astrophysics has benefited enormously from data obtained in recent years at the world's only underground ion accelerator, LUNA (Laboratory for Underground Astrophysics) [1]. This 0.4 MV accelerator addressed key reactions of solar fusion, improving the standard solar model [2], and several reactions of Big Bang nucleosynthesis [3, 4]. Recent LUNA work has been presented at this conference (talks by A. Formicola and F. Cavanna). The reason for this success story is the very low no-beam background. A rock overburden of 1400 m thickness suppresses the muon flux by six orders of magnitude and the neutron flux by three orders of magnitude [1].

However, the beam energy range is limited, preventing a study of the nuclear reactions of helium and carbon burning and the neutron sources of the astrophysical s-process. Due to this fact, a project for an additional, 3.5 MV accelerator is underway at LUNA (talk by M. Junker), and a high-current 5 MV underground accelerator is being developed at the Dresden Felsenkeller (this contribution).

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2 Status

Inside the city limits of Dresden, there is a system of nine tunnels shielded by 45 m of hornblende monzonite rock. Since 1982, one tunnel hosts an underground laboratory for low-radioactivity measurements [5]. Two additional tunnels will be readied in 2015 for the installation of an ion accelerator (fig. 1).

For nuclear astrophysics radiative capture experiments, the background in the 4-10 MeV γ-energy region is of decisive importance. In order to address this point, a background intercomparison was carried out using one and the same Compton-suppressed high-purity germanium (HPGe) detector system. This system was moved successively to several sites. The data show that with Compton suppression, the background in the 6-8 MeV energy region is only a factor of 2-4 higher in Felsenkeller (tunnel IV) than deep underground at LUNA, enabling highly sensitive experiments [6].

Recently, a muon background study and geodetic measurements were carried out by the REGARD group. It was estimated that the rock overburden at the place of the future ion accelerator is equivalent to 130 m of water. The

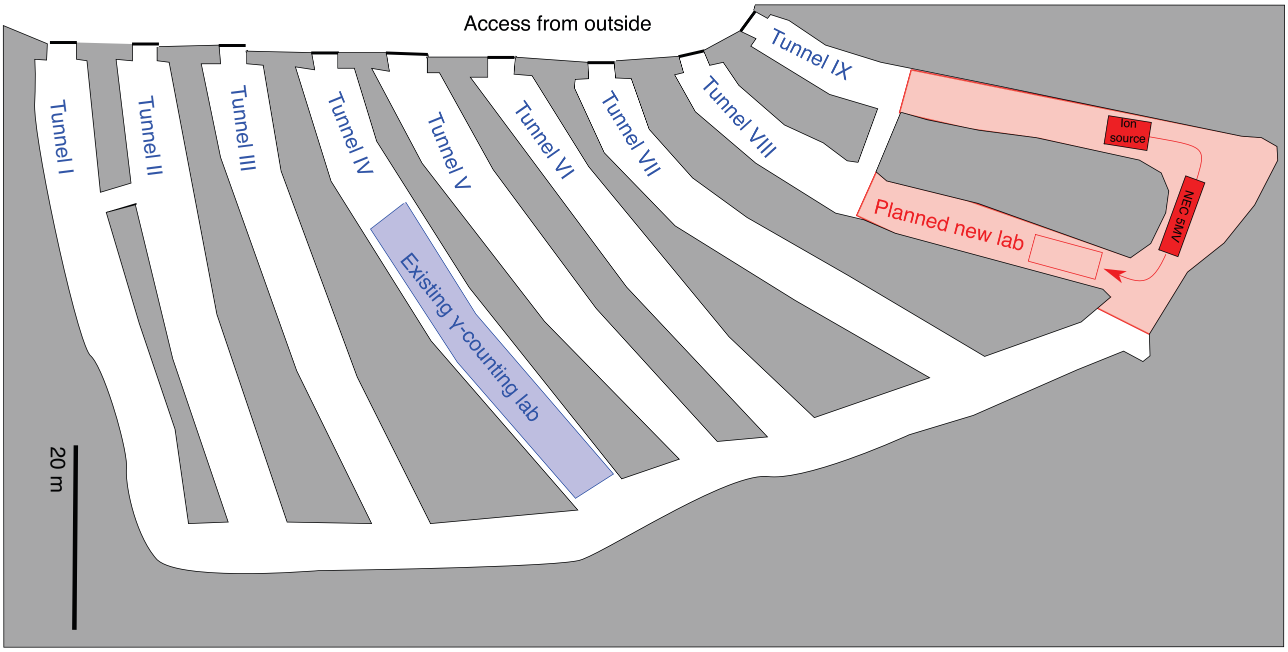

Figure 1. Layout of the Felsenkeller underground facility with the existing [5] and the planned new laboratory.

maximal muon flux measured was 2.5 $m^{-2}sr^{-1}s^{-1}$, in the direction of the tunnel entrance [7].

For the purpose of the project, a used accelerator mass spectrometry system consisting of a 5 MV Pelletron with double charging chains (250 μA upcharge current, high-current MC-SNICS sputter ion source for hydrogen and carbon beams) was recently bought and transported to Dresden. The accelerator is currently undergoing refurbishment, and a radio frequency ion source is projected to be added to the high voltage terminal in order to enable intensive helium beams.

As a result, intensive beams of ^{1}H, ^{4}He (from the terminal ion source), and ^{12}C will be provided at astrophysically relevant energies. Additional beams available in tandem mode include ^{14,15}N. The accelerator will thus be a versatile tool able to address solar fusion reactions at higher energies [2], as well as the nuclear reactions of carbon and helium burning. In addition, also a large, well-shielded HPGe detector for offline counting will be installed in Felsenkeller, enabling activation experiments as well as material selection for dark matter studies.

The fact that an existing, immediately available accelerator is used means that at Felsenkeller important hands-on experience may soon be collected, aiding the preparation of deeper-underground projects such as LUNA-MV with their longer time horizons. In addition, the proximity of the laboratory to the TU Dresden campus will facilitate its use as an educational and outreach tool.

3 Outlook

The planned accelerator laboratory will be used in part by in-house research by HZDR and TU Dresden, aiming for complementarity with the LUNA-MV project. In addition, external users from any field of science will be highly welcome. Users are to be selected based on the recommendations of an independent group of outside advisers judging the scientific merits of the proposals.

The project (accelerator purchase, tunnel refurbishment) is fully funded. Existing preliminary plans for the tunnel renovation are being updated now. An optimistic opening date of late 2015 is foreseen.

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