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Addendum to NA54

**Determination of cross sections of fast muon induced background reactions
for
the low-level experiments LENS, BOREXINO and CRESST**

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Abstract

In continuation of NA54 we propose to measure cross sections of fast muon induced reactions which contribute as background in the low-level experiments LENS (Low Energy Neutrino Spectroscopy), BOREXINO and CRESST (Cryogenic Rare Event Search with Superconducting Thermometers). LENS and BOREXINO are solar neutrino experiments, CRESST is a dark matter search. The background reactions to be studied are caused by showers produced by fast muons. The targets to be investigated are Gd and Yb (LENS), pseudocumol C_9H_{12} (BOREXINO), and sapphire Al_2O_3 and calcium tungstate $CaWO_4$ (CRESST). The energy dependences of the cross sections are studied using muon beam energies between 60 and 280 GeV.



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Beam requirements

Experimental area: barrack BX 82 behind experimental hall EHN 2
Particles: μ
Energy: 60 - 280 GeV

Duration of the Experiment at CERN

Beam time: 6 weeks, starting from end of 1999. The beam time can be parasitary.

Requirements from CERN

No requirements from CERN concerning scintillators, electronics or data handling. Equipment consisting of targets, detectors, scintillators, electronics, data handling and mechanical set-up is provided by Technical University of Munich. Installations of a few concrete blocks in the barrack for the generation of showers is required by CERN.

Experiment

The experiment consists of two parts:

- irradiation of targets by fast muon induced showers at CERN
- measurements of the produced short-lived radionuclides at CERN and of the long-lived radionuclides at Technical University of Munich

Safety risks

No safety risks

1 Introduction

The cosmic ray induced in-situ production of radionuclides consists of three contributions: spallation and nuclear reactions with the nucleonic component of the cosmic radiation, reactions with stopped negative muons and reactions with showers produced by fast muons. In the lithosphere, the spallation reactions with the nucleonic component are dominant in the upper first few meters, reactions with stopped negative muons are dominant in depths around 10 m, and fast muon induced reactions are dominant below tenths of meters.

In the framework of NA54, fast muon induced reactions to long-lived radionuclides were studied mainly for geophysical applications. Some preliminary experiments were performed for determinations of background contributions in low-level experiments.

The aim of the addendum of NA54 are investigations of background contributions due to fast muon induced reactions for the solar neutrino experiments LENS (Low Energy Neutrino Spectroscopy) and BOREXINO and for the dark matter experiment CRESST (Cryogenic Rare Event Search with Superconducting Thermometers). For LENS, a letter of intent has been submitted to the scientific committee of LNGS.

2 LENS

The LENS solar neutrino detectors contain as targets the elements Gd or Yb. The isotopes which are used for the detection of solar neutrinos are ^{160}Gd and ^{176}Yb , respectively. The studied reactions are ${}^A Z(\nu_e, e^-) {}^A Z+1^*$ with a subsequent delayed γ emission of the isomeric state ${}^A Z+1^*$ with the lifetime τ . The signature of the signal is a delayed coincidence $e - \gamma$.

In the case of ^{160}Gd , the signal from the first excited state at 63.7 keV in ^{160}Tb with a lifetime of 86.6 ns is a delayed coincidence $e - \gamma$ with this lifetime and the γ energy of 63.7 keV. For ^{176}Yb , the signal is a delayed γ emission of 71 keV from the 194.5 keV isomeric state in ^{176}Lu which has a lifetime of 50.5 ns. Disturbing background contributions are β decays of radionuclides to excited states which have similar lifetimes in the range of 100 ns and emit γ radiation of similar energy, or delayed $\gamma - \gamma$ coincidences with lifetimes of the intermediate state in the 100 ns range.

For the Gd target, disturbing cosmic ray produced radioactivities to be investigated are $^{152}, ^{154}, ^{155}, ^{157}, ^{159}\text{Eu}$ and $^{151}, ^{153}\text{Gd}$. For the Yb target, radioactivities to be studied are $^{168}, ^{170}, ^{171}\text{Tm}$.

Within the addendum, cross sections of fast muon induced reactions to these disturbing radionuclides shall be measured. These cross section measurements are crucial whether LENS can be performed at LNGS depths or whether deeper sites have to be taken.

3 BOREXINO

The aim of the solar neutrino experiment BOREXINO at the LNGS is to detect in a first real time experiment the ${}^7\text{Be}$ solar neutrino flux. The target is the liquid scintillator pseudocumol C_9H_{12} with a fiducial mass of about 100 t. Within NA54, cross sections to disturbing muon produced radioactivities of ${}^7\text{Be}$ and ${}^{11}\text{C}$ were measured. It was found that ${}^{11}\text{C}$ contributes with 13 events per day in the energy window 1 to 2 MeV compared to about 10 events per day for the SSM pep neutrino signal.

Within the addendum, cross sections to other disturbing radioactivities ${}^6\text{He}$, ${}^8\text{He}$, ${}^8\text{Li}$, ${}^9\text{Li}$, ${}^{11}\text{Be}$, ${}^8\text{B}$, ${}^{12}\text{B}$, ${}^9\text{C}$ and ${}^{10}\text{C}$ shall be measured on-line.

4 CRESST

The dark matter experiment CRESST in LNGS uses two different absorbers, sapphire Al_2O_3 and calcium tungstate CaWO_4 , and a superconducting thermometer. The phonon signal induced by collisions of WIMPs (Weakly Interacting Massive Particle) with the nuclei of the absorber crystal is detected by the superconducting thermometer. In the case of the sapphire crystal, nuclear recoil events and electron recoil events cannot be distinguished, in the case of CaWO_4 they can be distinguished. The primary background is projected to be lower than 1 event/(kg d keV). The in-situ production of radionuclides by fast muons in LNGS is estimated to be negligible. Disturbing radioactivities can be those produced by cosmic radiation in the crystals during storage at shallow depths before installation in LNGS.

Within the addendum, cross sections of fast muon induced reactions from Al_2O_3 to ^7Be and ^{22}Na and from CaWO_4 to ^{22}Na , ^{35}S , ^{151}Gd , ^{159}Dy , ^{175}Hf , $^{179, 182}\text{Ta}$ and $^{181, 185}\text{W}$ shall be measured.

5 Energy dependence of the cross sections

The cross sections for fast muon induced reactions were obtained to scale with E^α with the mean muon energy E in GeV and $\alpha \approx 0.7$ (Zatsepin et al., Sov. J. Nucl. Phys. 33 (1981) 200; Wolfendale and Young, Nature Phys. Sci. 238 (1972) 130). At LNGS depths, the mean muon energy is about 300 GeV, at shallow depths it is about 3 GeV. For the targets to be investigated, the energy dependences of the cross sections shall be measured in the energy range 60 to 280 GeV in order to determine the exponent α .

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