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Study on Neutron-induced Background in the CRESST Experiment

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Abstract. CRESST II is an experiment for direct WIMP search, using cryogenic detectors. The ratio of the two signals (temperature rise and scintillation light) measured for each interaction is an excellent parameter for discrimination of the radioactive background. The main remaining background is the neutron flux present at the experimental site, since neutrons produce the same signals as WIMPs do. Based on Monte Carlo simulations the present work shows how neutrons from different origins affect CRESST and which measures have to be taken into account to reach the sensitivity goal.

1. Sources of Neutron Background

The flux of neutrons in the vicinity of CRESST (Jagemann et al. 2004) is dominated by low energy neutrons induced by radioactivity in the surrounding rock/concrete. In addition, a very small remaining impurity in the material used in the setup can induce significant background if higher sensitivity is to be aimed for.

Although the flux of high energy neutrons induced by muons in the rock is small compared to the total flux at the experimental site, this component can penetrate a neutron moderator, reach the setup and produce additional neutrons through spallations. Moreover, neutrons can be produced by muons in the experimental setup, particularly in the lead shield.

To investigate the contribution of each neutron source to the expected background rate in CRESST II, a study based on Monte Carlo simulations has been performed. For this purpose different Monte Carlo codes have been employed, namely MCNP4B (Briesmeister 1997), MCNPX (Waters 1999), FLUKA (Fasso 2001a) and MUSIC (Antonioli 1999).

2. Neutron Background Rates Expected in CRESST II

The contributions of different neutron sources to the count rate in the 15–25 keV interval in a $CaWO_4$ detector are shown in Table 1. In CRESST II, 60 GeV WIMPs with a cross section as claimed by the DAMA experiment (Bernabei et al. 2000) would give 55 cts/kg/y in the same energy range. This makes

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it difficult for CRESST II to check the DAMA evidence without a neutron moderator. The flux of low energy neutrons from the surrounding rock/concrete can be reduced effectively by a hydrogen-rich material like polyethylene. For the CRESST II setup a polyethylene shield (35–50 cm thick) is advisable. This will reduce the background count rate in the $CaWO_4$ detector by up to three orders of magnitude. Then the background will be dominated by neutrons from other origins (see Table 1) and the sensitivity of the experiment for the WIMP-nucleon cross section would be limited to about 10^{-7} pb.

Table 1. Contributions of different neutron sources to the count rate at 15–25 keV in a $CaWO_4$ detector inside the CRESST setup.

Neutron origin	Count Rate (cts/kg/y)
Low energy neutrons from the rock: (i) no moderator	50
(ii) Pb/Cu + 50 cm PE	0.04
Low energy neutrons from fission of 0.1 ppb ^{238}U in the lead	0.2
High energy neutrons produced by muons in the rock	0.3
High energy neutrons produced by muons in the shields	1

The remaining neutron flux with the neutron moderator installed is dominated by neutrons induced by muons in the lead shield. It is possible to suppress this neutron background by detecting the muons and rejecting muon coincident events. For CRESST II a muon veto system is planned in addition to a neutron moderator. This will enable CRESST II to reach the projected sensitivity of below 10^{-7} pb. The muon veto will be placed inside the polyethylene shield and will have an efficiency of more than 90%.

However, the muon veto will reduce the neutron background only by a factor of three, unless high energy neutrons from the rock can be overcome. Neutrons scattered in more than one detector can be rejected as background, because WIMPs do not multiply-scatter. Therefore the neutron background will be further reduced and multiple scattering can also be engaged to determine the remaining single scatter neutron background. Such a simulation with an array of detectors will be done in the near future to investigate which sensitivity level can be reached by this technique.

References

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