Cryogenic Detectors for the Solar Neutrino Experiment GNO ◇

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Radiochemical solar neutrino experiments have played an important role in establishing neutrino properties beyond the standard model, namely neutrino oscillations, and thus neutrino masses. For a detection process that is sensitive to electron neutrinos only, the phenomenon of neutrino oscillations leads to a reduction of the measured neutrino flux from a pure ν_e source like the sun. The charged-current reaction $^{71}\mathrm{Ga}(\nu_e, e^-)^{71}\mathrm{Ge}$ used by GALLEX, SAGE and GNO [1] is of this type. Its unique feature is the low neutrino energy threshold, which makes it sensitive to the dominant flux of neutrinos originating in the solar fusion reaction $\mathrm{p} + \mathrm{p} \rightarrow \mathrm{d} + \mathrm{e}^+ + \nu_e$. With the results of recent solar, reactor, atmospheric and accelerator neutrino experiments [2], neutrino mixing is established and most of the neutrino mixing parameters are determined. As a consequence, the importance of sub-MeV solar neutrino experiments has moved towards open astrophysical questions. To make use of the full potential of radiochemical Gallium experiments in respect to solar physics, a reduction of the total experimental uncertainty consisting of statistical and systematic contribution is necessary.

A favorable way to achieve both could be the use of cryogenic detectors instead of the presently used miniaturized proportional counters. In GNO, neutrino-produced ^{71}Ge-atoms are extracted in a monthly cycle from the Gallium target tank and introduced after a synthesis process as Germane gas ($\mathrm{GeH_4}$) in low-background proportional counters. Important prerequisite for a new detector concept for application in GNO is that the 1.3 keV, 10.4 keV and possibly also the 0.16 keV X-rays and Auger electrons associated with the ^{71}Ge EC decay are detected with high efficiency and low systematic uncertainty. During the last years, a R&D project was installed which focuses on meeting the technical requirements for implementation of a detection concept based on low-temperature detectors into the large-scale experiment at Gran Sasso [3,4]. As a first step to realize a cryogenic detection concept for GNO, a 4π-detector was developed and tested successfully. Its efficiency was determined by MC calculations to be 98%. Results obtained with 2π and 4π test detectors did already serve to demonstrate an improvemtent by a factor of 6 in energy resolution. A chemical method to deposit ~1mg Germanium onto the detector's absorber with ~95% efficiency in 3h was realized with $\mathrm{GeH_4}$ as an interface to GNO's existing synthesis chemistry. The achieved energy resolution was not negatively affected by a new production process which allows for decoupling detector fabrication and $\mathrm{GeH_4}$ deposition, which was necessary to minimze the time window between extraction and measurement.

The detection setup has to exhibit extreme intrinsic radiopurity and must operate stable for a counting period of several months. In this context, experiences in longterm operation of the cryostat and the detection system are of great importance. Typical activities to be measured are in the order of 5 decaying ^{71}Ge nuclei. A shielded dilution cryostat was set up and tested in the Underground Laboratory Garching (15 m.w.e.) to allow studies of intrinsic and external background sources and the background-rejection potential of the detector setup. After first background measurements the shielding of the cryostat was modified and now consists of a lead belt of 15cm thickness around which a muon-veto, using 16 plastic scintillator panels, was installed for anti-coincidence measurements.

Furthermore, an ongoing effort is being made concerning the investigation and selection of suitable low-background materials inside and outside the cryostat essential to low-level counting. In order to guarantee an effective shielding e.g. against muon-induced copper-fluorescence and low energy gamma lines an inner shielding mainly consisting of ultrapure copper and antique lead is presently being designed to be operated at mixing chamber temperature of 10 mK.

References

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