Cryogenic Detectors for the Solar Neutrino Experiment GNO

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The Gallium-Neutrino-Experiment GNO (Gallium Neutrino Observatory, successor of GALLEX) which is located at the Laboratori Nazionali del Gran Sasso (Italy), measures neutrinos radiochemically via the reaction ^{71}Ga(ν,e)^{71}Ge. Due to the low energy threshold of 233keV the experiment is mainly sensitive to the pp-neutrinos that constitute about 53% of the overall signal theoretically predicted for Gallium experiments. Further contributions are: ^{7}Be neutrinos (27%), ^{8}B neutrinos (12%) and CNO neutrinos (8%). The GNO target consists of 101 tons of acid $GaCl_3$ solution, containing 30.3 tons of natural Gallium. The neutrino-produced ^{71}Ge-atoms are extracted in a monthly cycle from the Gallium tank and introduced after a synthesis process as Germane gas (GeH_4) in low-background proportional counters.

When combining the published data of GALLEX and GNO, the observed neutrino flux is:

$$\Phi_{\nu_e} = (73.9 \pm 4.7(\mathrm{stat}) \pm (4.0(\mathrm{syst}))\ \mathrm{SNU}$$

The statistical error within GNO is presently of ± 7.2 SNU, the systematic error of ± 3.2 SNU.

In order to reduce statistical and systematic uncertainties in detecting the decay of ^{71}Ge to ^{71}Ga, a favourable way could be the use of high-resolution cryogenic detectors instead of the presently integrated miniaturized proportional counters. An important prerequisite is that the established and highly efficient chemical extraction procedure, in which a few atoms of ^{71}Ge are 'filtered out' of 101 tons of $GaCl_3$, must not be altered under any circumstances.

As a first step to realize a cryogenic detection concept for GNO, a highly efficient (98%) 4π-detector was developed and tested successfully. Due to the short half-life of ^{71}Ge ($T_{1/2}$ = 11.43d), the time window between extraction and measurement is very small. Therefore, a detection concept was realized in which the fabrication and testing of the transition edge sensor of the cryodetector can be performed independently from the chemical deposition of ^{71}Ge via CVD (= chemical vapour deposition) onto the detector's substrate. After the CVD the transition edge sensor and the substrate are coupled to each other with a special cryo-resin. Later the two glued parts are integrated into the existing 4π geometry. This concept has proved to be very reliable and is presently becoming a state-of-the-art technique. The energy spectrum resulting from an ^{55}Fe source demonstrates that the glueing process does in no way negatively affect the energy resolution (187eV @ 6keV). Furthermore the energy threshold of this detector lying in the region of ∼100eV is low enough not only to detect the electron capture from the K- and L-shells but also opens the detection range down to the energy deposition of the M-capture with 160eV.

In order to prepare a cryogenic prototype experiment at the Gran Sasso Underground Laboratory (3600 mwe), a new dilution cryostat was set up and tested in the Underground Laboratory of the 'Beschleuniger-Laboratorium / Maier-Leibnitz Laboratorium' (15 mwe) in Garching. The cryostat is shielded by a muon-veto consisting of several panels of plastic-scintillator and a low-activity lead belt. First long-term measurements (∼6 weeks) and several temperature cycles between room temperature and ∼20mK were performed. These measurements showed as a result the excellent stability of both the cryogenic detector and the entire SQUID read-out system. The now following steps will focus on recording the decay curve of artificially activated ^{71}Ge with a 4π efficient detector, while also intense care will be given to the low-background analysis and optimization of all the detector and cryostat components concerning their intrinsic radioactive impurities.

References

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