GNO and its performances

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GNO (Gallium Neutrino Observatory) is monitoring the low energy solar neutrino flux at Laboratori Nazionali del Gran Sasso. I describe the main features of the experiment, the goals, and the recent results.

1. THE GALLIUM DETECTOR AT LNGS

Low energy 'pp' solar neutrinos were detected for the first time in 1991 with the radiochemical technique using a gallium target [1]. Still today gallium detectors are the only ones measuring pp ν, through the neutrino interaction is $^{71}Ga(\nu_e, e^-)^{71}Ge$, with a threshold of 233 keV. The gallium detector located at Laboratori Nazionali del Gran Sasso is made of 103 tons of a $GaCl_3$ acidic solution, containing 30 tons of natural gallium. ^{71}Ge (mean-life 16.5 days) is produced by solar neutrinos at a rate of about 0.5 atoms per day; it is chemically extracted from the target solution by nitrogen flow every four weeks, converted into germane gas (GeH_4), and inserted into miniathurized proportional counters mixed with Xe, where it is counted when it decays via EC. The number of ^{71}Ge atoms counted is proportional to the solar ν interaction rate. In each extraction ~ 5 ^{71}Ge atoms are counted, thus many 'solar runs' (extraction+counting) are required to obtain a precise determination of the ν interaction rate. For details on the experimental technique and on the apparatus see [1].

2. GALLEX

The gallium detector at LNGS was built between 1985 and 1990, and started data taking in 1991. Between 1991 and 1997 was operated by the GALLEX collaboration: 65 solar runs, corresponding to about 4.4 years of live time, were successfully performed. Results were regularely reported as shown in Table 1. The solar neutrino interaction rate on Ga was measured to be 77.5 ± 6.2 (stat) $^{+4.3}_{-4.7}$ (sys) SNU, with an overall (systematic plus statistical) error of $\sim 10\%$. This has to be compared with predictions from solar models ranging from 120 to 140 SNU [2]. The impressive deficit on the neutrino flux measured by GALLEX plays a central role in the so called 'solar neutrino problem'. For a discussion see [3]. In 1994 and 1995 the detector was exposed to an intense (~ 2 MCi) ^{51}Cr man-made electron neutrino source, producing a neutrino flux about ten times higher than the solar one. The source experiments showed that the deficit of solar neutrinos observed by GALLEX cannot be attributed to experimental problems and demonstrated the absence of unexpected systematic errors at the 10% level [4]. In 1997 the gallium detector has been spiked with $\sim 10^5$ ^{71}As atoms, decaying with half-life of 2.72 days to ^{71}Ge. A relevant amount of 'hot' ^{71}Ge atoms were produced inside the detector with a kinematics that closely mimics the solar neutrino capture. Several extractions were carryed out in different chemical conditions (with or without carrier, with or without solution mixing etc.): in all cases the recovery of ^{71}Ge from the gallium tank was 100 %, with uncertainties of only $\pm 1\%$ [5]. This rules out hot-atom chemical effects, and confirms the relyability of the gallium detector.

Table 1
Results of solar neutrino observations of GALLEX and GNO. Column 4 lists the measured solar interaction rate as from the single periods shown in column 1; in column 7 the interaction rate from all available solar runs at the end of each period is reported. The interruption of solar observations during GALLEX correspond to preparation and performance of the two source experiments; the period jan-97 → may-98 was devoted to a complete renovation of the electronics and DAQ, and to maintenance of the chemical plants. The errors quoted are statistical and systematic combined in quadrature.

Time period	Ref.	runs	partial result [SNU]	cumulative runs	live time (years)	global result [SNU]
Gallex I (may-91 → apr-92)	[1]	15	$83.4^{+18.5}_{-19.5}$	15	0.89	$83.4^{+18.5}_{-19.5}$
Gallex II (aug-92 → jun-94)	[6]	24	$75.9^{+10.5}_{-10.7}$	39	2.66	$77.1^{+9.6}_{-10.1}$
Gallex III (oct-94 → oct-95)	[7]	14	53.9 ± 11.0	53	3.63	$69.7^{+7.8}_{-8.1}$
Gallex IV (feb-96 → jan-97)	[8]	12	118.4 ± 19.0	65	4.36	$77.5^{+7.6}_{-7.8}$
GNO I (may-98 → jan-00)	[10]	19	$65.8^{+10.7}_{-10.2}$	84	5.93	$74.1^{+6.7}_{-6.8}$

Table 2
Components of the systematic error in GALLEX and GNO. All numbers are expressed in percent of the measured solar neutrino signal.

Item	GALLEX 1997	GNO-I 2000	GNO 2002 (expected)	GNO $\geq$ 2002 (expected)
Background from side reactions	1.6	1.6	1.6	1.6
Background from ^{68}Ge	1.8	1.4	≈ 0.5	≈ 0
Radon cut inefficiency	1.6	1.1	≈ 0.5	≈ 0.5
Counting efficiency	4.5	4.5	3-4	2-3
Chemical yield and target size	2.2	2.2	2.2	2.2
Tot	5.8	5.5	4-5	3-4

3. THE GNO PROJECT

Between february 1997 and april 1998 an overall maintenance of the chemical plants and of the counting system was performed [9]. This period also allowed all the ^{71}Ge activity imported in Gran Sasso for the arsenic experiments to decay completely away. Since april 1998 solar neutrino observations have been started again within the framework of the GNO project (Gallium Neutrino Observatory). 27 solar runs and 3 'blanks' were successfully performed up to august 2000. The goals of GNO are:

- Measurement of the solar neutrino interaction rate on Ga with a global error $\sim$ 4-5 % (about one half of the eror obtained at the end of GALLEX).

- Monitoring of the pp solar neutrino flux for a complete solar cycle.

In this context it is important to notice that Ga radiochemical detectors will remain the only operating experiments able to detect pp solar neutrinos for several years; next generation experiments designed for real-time detection of pp neutrinos, like LENS[11], Heron[12], or Hellaz[13] are still in a very preliminary study phase.

The GNO project should develop as follows:

- the 'minimal' program foresees a continuation of the measurements with the present 30 tons of gallium, and a reduction of the systematic uncertainties of the experiment;

- depending on fundings and on the availability of gallium, an enlargement of the target mass (to 60 tons and later to 100 tons) is expected. This would allow to signifcantly increase statistics, which is crucial especially for the study of the time behaviour of the signal.

- detectors alternative to the presently used gas proportional counters can in principle increase the counting efficiency for ^{71}Ge (which is now around 70 %), and further reduce the systematic error; a very attractive possibility under study is to employ cryogenic detectors [14].

4. RESULTS FROM GNO-I

Data from the first 19 GNO solar runs (GNO-I, from May 1998 until January 2000) have been evaluated. The ν interaction rate for GNO-I is 65.8 $^{+10.2}_{-9.6}$ (stat.) $^{+3.4}_{-3.6}$ (sys.) SNU [10]. The combined result for GALLEX and GNO-I (65+19=84 solar runs) is 74.1 $\pm$5.4 (stat.) $^{+4.0}_{-4.2}$ (sys.) SNU [10]. The overall error is 9 %. Results from the single solar runs are plotted in Figure 1 as a function of the extraction time both for GALLEX and for GNO-I.

5. R&D in GNO

R&D is ongoing to decrease the systematic uncertainty on the measured rate from the present value ($\sim$ 5.5 %), down to 3-4%. The main components of the systematic error are listed in table 2, together with the reduction expected. The most relevant improvement should come from direct precise determination of the counting efficiency and of the gain curve of all proportional counters. The uncertainty on the counting efficiency is expected to be reduced down to about 3-4 %. The developement of a new type of proportional counter could further reduce this number. For details on the other items reported in the table see [15].

6. CONCLUSIONS

The gallium detector at LNGS is monitoring low energy solar neutrinos since May 1991 with 30 tons of natural gallium. The solar neutrino interaction rate from the GALLEX data set plus the GNO I observations has been measured with an overall accuracy of $\sim$ 9%. Data taking is going on regularely with four-week-exposure runs, with the aim to reach an accuracy of the order of 5%, and to study possible time dependences of the signal at 10-15 % level.

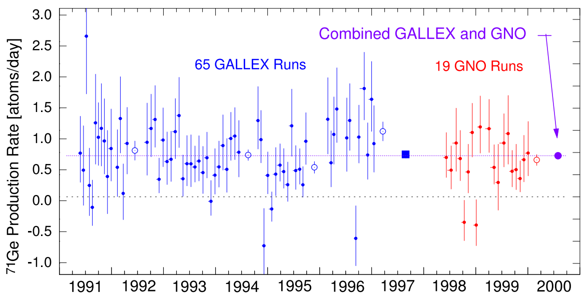

Figure 1. Measured solar neutrino capture rate (atoms/day) in the single 65 GALLEX solar runs, and in the 19 GNO solar runs. A signal of 100 SNU corresponds to a production rate of 0.90 ^{71}Ge atoms per day inside the 30 tons gallium tank.

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