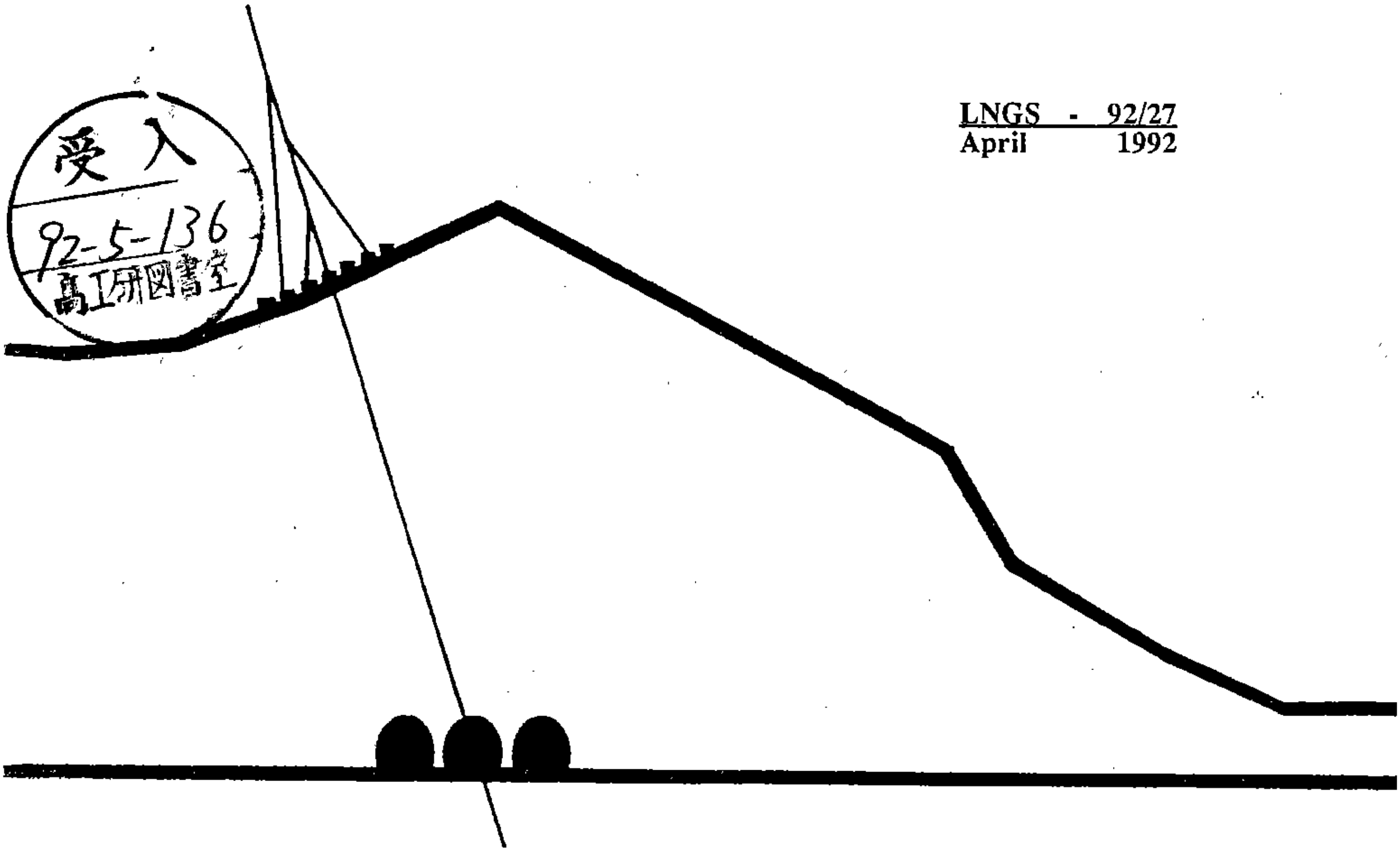
LNGS - 92/27
April 1992



SEARCH FOR AR-42 WITH A GERMANIUM DETECTOR AT GRAN SASSO LABORATORY

C. Arpesella, C. Brofferio
Laboratori Nazionali del Gran Sasso, ss. 17 bis, Assergi (Aq), Italy
P.P. Sverzellati
Dipartimento di Fisica e INFN, Universita' di Milano, via Celoria 16, Milano, Italy
M. Zhou
Department of Physics, UCLA, Los Angeles, USA
F. Cavanna
Dipartimento di Fisica e INFN, Universita' di L'Aquila, via Vetoio, Coppito (Aq), Italy

INFN - Laboratori Nazionali del Gran Sasso

LNGS - 92/27
April 1992

SEARCH FOR AR-42 WITH A GERMANIUM DETECTOR AT GRAN SASSO LABORATORY

C. Arpesella, C. Brofferio
Laboratori Nazionali del Gran Sasso, ss. 17 bis, Assergi (Aq), Italy
P.P. Sverzellati
Dipartimento di Fisica e INFN, Universita' di Milano, via Celoria 16, Milano, Italy
M. Zhou
Department of Physics, UCLA, Los Angeles, USA
F. Cavanna
Dipartimento di Fisica e INFN, Universita' di L'Aquila, via Vetoio, Coppito (Aq), Italy

INFN - Laboratori Nazionali del Gran Sasso

LNGS - 92/27
April 1992

SEARCH FOR AR-42 WITH A GERMANIUM DETECTOR AT GRAN SASSO LABORATORY

C. Arpesella, C. Brofferio
Laboratori Nazionali del Gran Sasso, ss. 17 bis, Assergi (Aq), Italy
P.P. Sverzellati
Dipartimento di Fisica e INFN, Universita' di Milano, via Celoria 16, Milano, Italy
M. Zhou
Department of Physics, UCLA, Los Angeles, USA
F. Cavanna
Dipartimento di Fisica e INFN, Universita' di L'Aquila, via Vetoio, Coppito (Aq), Italy

Intrinsic radioactivity of materials to be used in underground experiments is of extremely importance when searches for low energy rare events, like neutrino interactions, double beta decay and dark matter, are concerned.

An interesting case is the intrinsic radioactivity of natural liquid argon, which can be used in detectors for these experiments. In fact it is known that this liquid could contain ^{42}Ar [1].

At Gran Sasso Laboratory a search for ^{42}Ar in natural liquid argon has been performed by gamma spectroscopy with a Germanium detector.

^{42}Ar is a beta emitter with a half-life of 33 years and it decays to ^{42}K, which in turn β^- decays to ^{42}Ca, in 18.3% of the cases to the 1.525 MeV excited state and with lower probability to higher excited states. (Fig. 1).

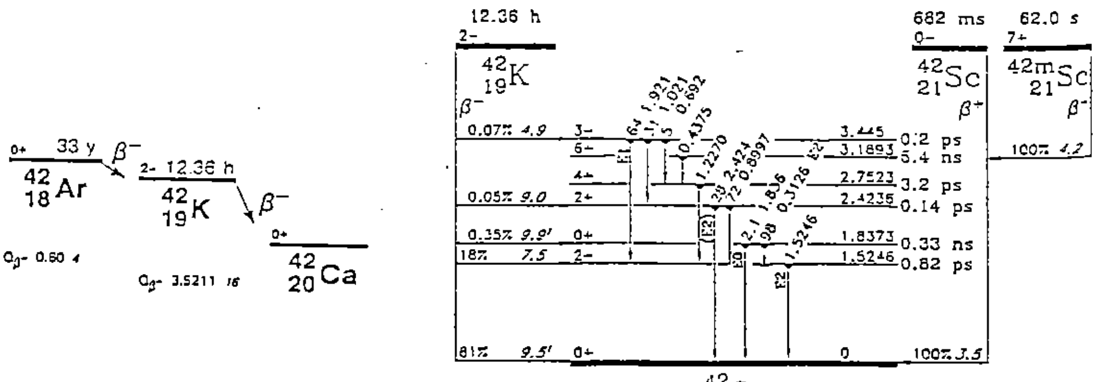


Fig. 1

Experimental setup

A 3 litre stainless steel dewar in Marinelli baker form filled with liquid argon has been placed close to a Ge(Li) diode. This detector, 169 cm^3 of total volume, 148 cm^3 of active one, has been constructed with tested low-activity materials [2]. Its energy resolution at 1.5 MeV is about 4 keV.

A shielding with 5 cm OFHC copper and 20 cm low activity lead is mounted all around the detector.

The hollow space of the dewar has always been kept, by a continuous pumping system, at a vacuum level of a few 10^{-6} mbar.

A refilling with new liquid argon was necessary each 12-15 hours, through an intermediate dewar on the top of the whole system.

A background measurement has been performed with vacuum inside the dewar (10^{-2} mbar). Data have been collected in 305.8 hours. Fig. 2 shows the energy spectrum up to 2.8 MeV. Table 1 reports the counting rate for the main radioactive nuclides:

Table 1

gamma lines	background (counts/hour)	liquid argon (counts/hour)	liquid nitrogen (counts/hour)
^{214}Bi chain			
295.2 keV	0.54 ± 0.11	25.1 ± 0.44	24.8 ± 0.5
352	0.88 ± 0.13	41.1 ± 0.57	43.5 ± 0.6
609.3	0.64 ± 0.07	33.6 ± 0.48	33.9 ± 0.6
1764.5	0.11 ± 0.03	5.7 ± 0.26	6.2 ± 0.26
^{232}Th chain			
338.7	0.54 ± 0.10	-	-
583.1	0.83 ± 0.08	0.80 ± 0.19	0.50 ± 0.2
2614.5	0.27 ± 0.05	0.20 ± 0.05	0.22 ± 0.06
^{60}Co			
1173.2	2.0 ± 0.10	1.7 ± 0.15	1.8 ± 0.12
1332.5	1.7 ± 0.09	1.6 ± 0.13	1.7 ± 0.11
^{40}K			
1460.7	0.61 ± 0.07	0.67 ± 0.13	0.70 ± 0.13
^{137}Cs			
661.6	0.94 ± 0.08	1.8 ± 0.3	2.0 ± 0.28

Data have been taken for 222 hours with liquid argon. Fig. 3 shows the energy spectrum, compared to background. In table 1, the counting rate for some lines is reported.

We attribute the increase on the rate of ^{214}Bi lines (^{222}Rn daughter) to frequent fillings with liquid argon in air: the counting rate increases during the first days of running time, then it stabilises and remains constant. The contact with air could also explain the presence of some little ice crystals at the surface of the liquid.

In order to confirm the possibility of trapping radon from the atmosphere in very cold liquid, another test has been performed by filling, every 12 hours, the "Marinelli dewar" with liquid nitrogen with the same procedure. Table 1 shows again the counting rate for the main gamma lines, after 236 hours of data taking. In fig. 4 the energy spectrum up to 2.8 MeV is compared to the one taken in vacuum. The counting rate of ^{222}Rn daughters increases in the same way and we obtained the same values (fig. 5), thus confirming that we introduce radon in the dewar from outside.

In the spectrum with liquid argon, the background continuum is also increased with respect to the spectrum obtained with vacuum in the dewar; the 338.7 keV from ^{232}Th chain is undistinguishable from Compton continuum of radon daughters. In the energy region of interest for us, which is the 1526 keV ^{42}K line search (fig. 6), Compton scattering of gamma line at 1764 keV contributes to the continuum, while the peak at 1509 keV comes from ^{214}Bi decay.

Estimation of Ar-42 concentration

Let us consider the spectrum from liquid argon. After 222 hours of data taking, no lines have been found in the energy region around 1.525 MeV.

We obtained 0.08 counts/hour upper limit counting in the region 1525 ± 5 keV (at 90% C L), by fitting the spectrum with maximum likehood method with MINUIT program on a linear background.

The intrinsic detector efficiency ε has been computed by Monte Carlo calculations with EGS4 program, thus giving 0.0026 at these energies. This program has been experimentally tested with radioactive sources.

The half-life of ^{42}K being much shorter than ^{42}Ar one, we assume equilibrium between Ar and K. From the spectrum we obtained we can deduce an upper limit on ^{42}Ar concentration in liquid argon.

This limit is 1.1×10^{-5} Bq/g at 90% CL, thus corresponding to 9.2×10^{-18} g ^{42}Ar / g ^{40}Ar.

The same technique can be improved using larger Germanium detectors, with better energy resolution and efficiency, redesigning the cryogenic system in order to avoid the presence of radon. In that way, with the detectors existing at LNGS, a factor 10 of improvement can be reached.

To get a much higher sensitivity, other techniques should be considered, like isotopic enhancement procedures.

References

[1] ICARUS Coll., LNF note 89/005, February 1989
[2] E. Bellotti et al., Il Nuovo Cimento 95A (1986), 1

Acknowledgements

We would like to thank Adriano Pepato (CERN) who designed and prepared the dewar for liquid argon in Marinelli baker form We also thank prof. E. Fiorini for fruitful discussions.

Figure captions

fig. 1 Decay scheme of ^{42}Ar
fig. 2 Energy spectrum of background measurements taken in vacuum
fig. 3 Energy spectrum of 222 hours measurements with liquid argon, compared to background shown in fig.2
fig. 4 Energy spectrum of 236 hours measurements with liquid nitrogen, compared to background shown in fig. 2
fig. 5 Energy spectrum of liquid argon compared to the one of liquid nitrogen. The two spectra are superimposed and a large binning has been chosen
fig. 6 Detail in 1.526 MeV energy region for liquid argon energy spectrum and background

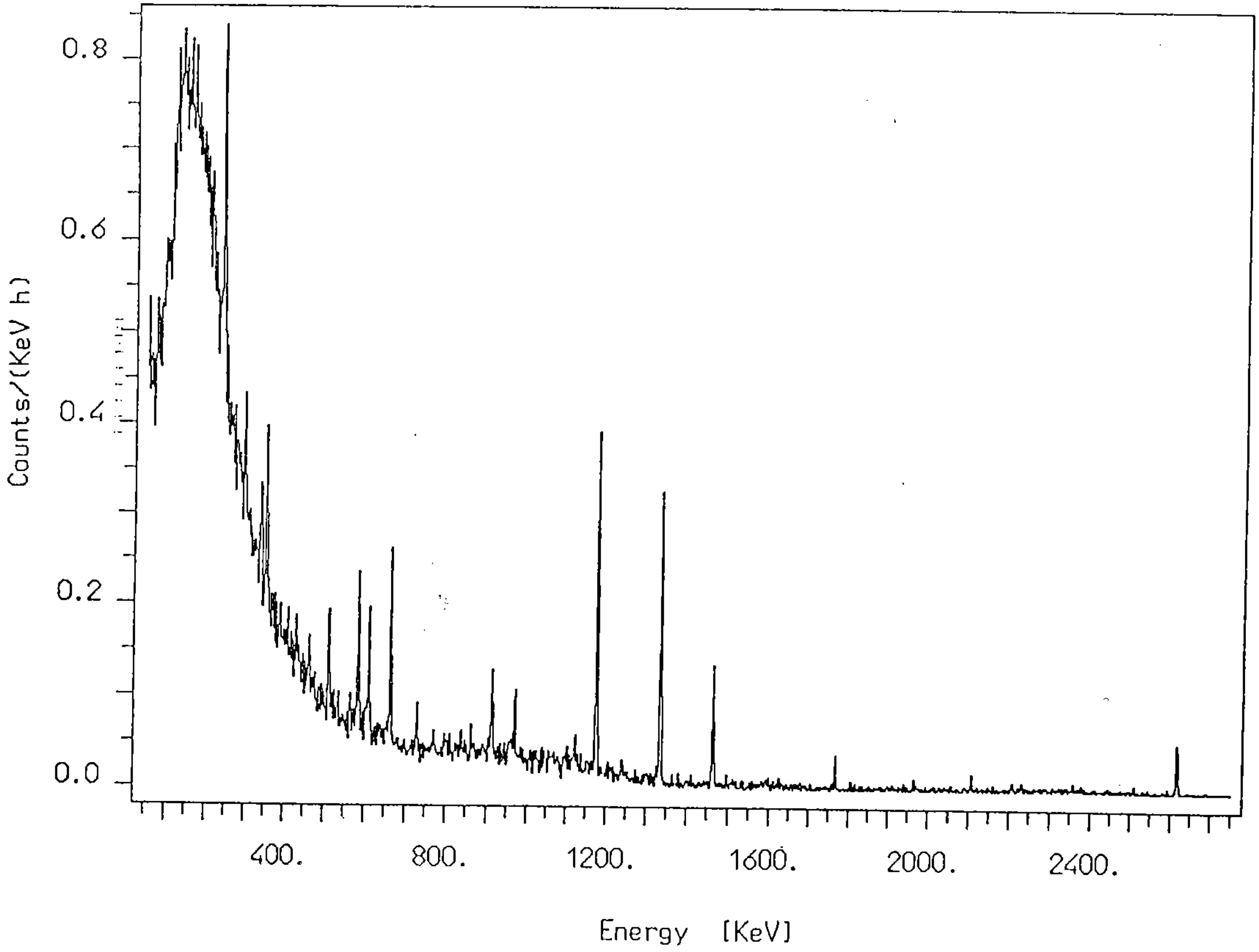


Fig. 2

24-MAR-1992 14:15:38.67

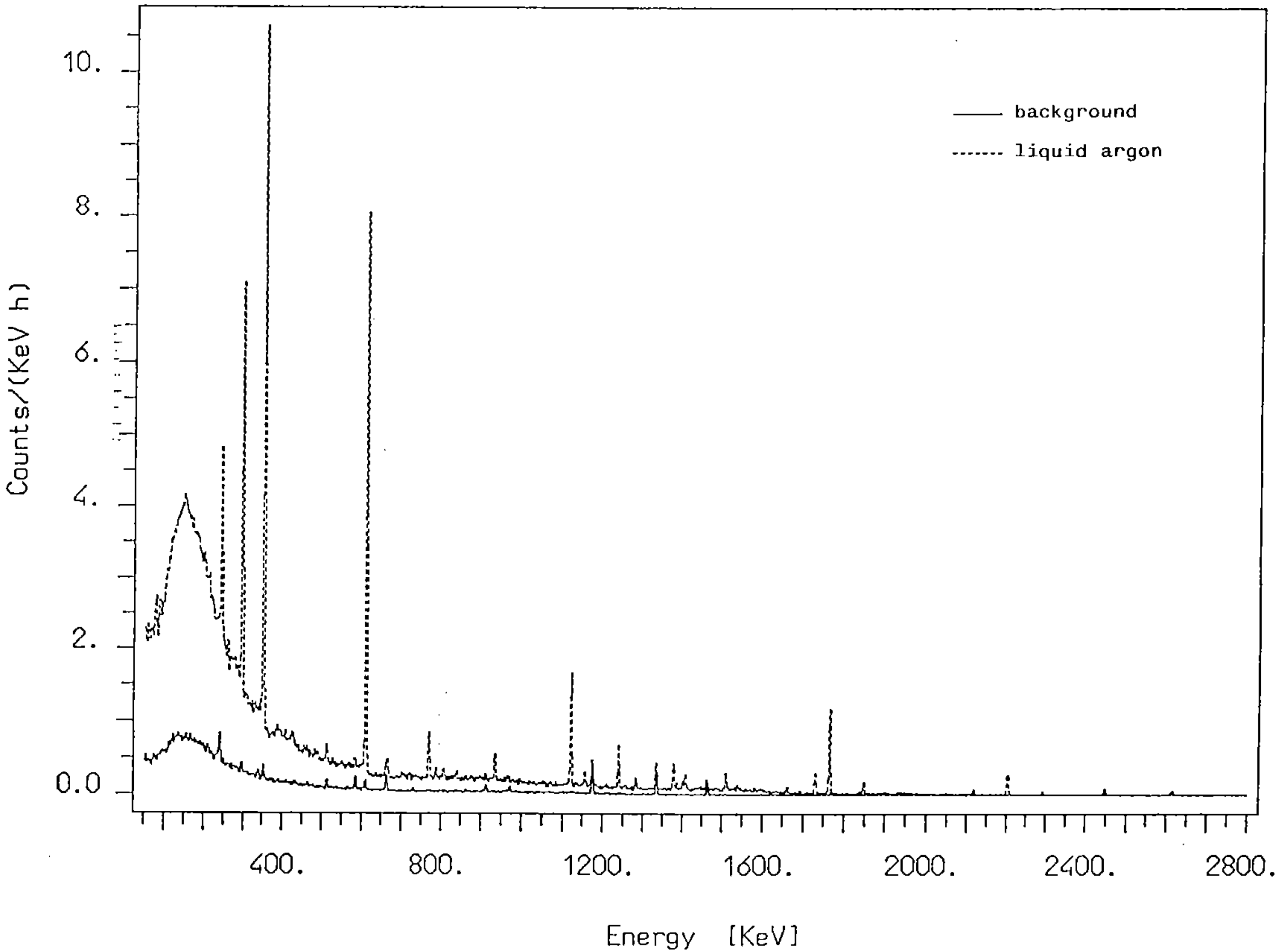


Fig. 3

24-MAR-1992 16:03:14.30

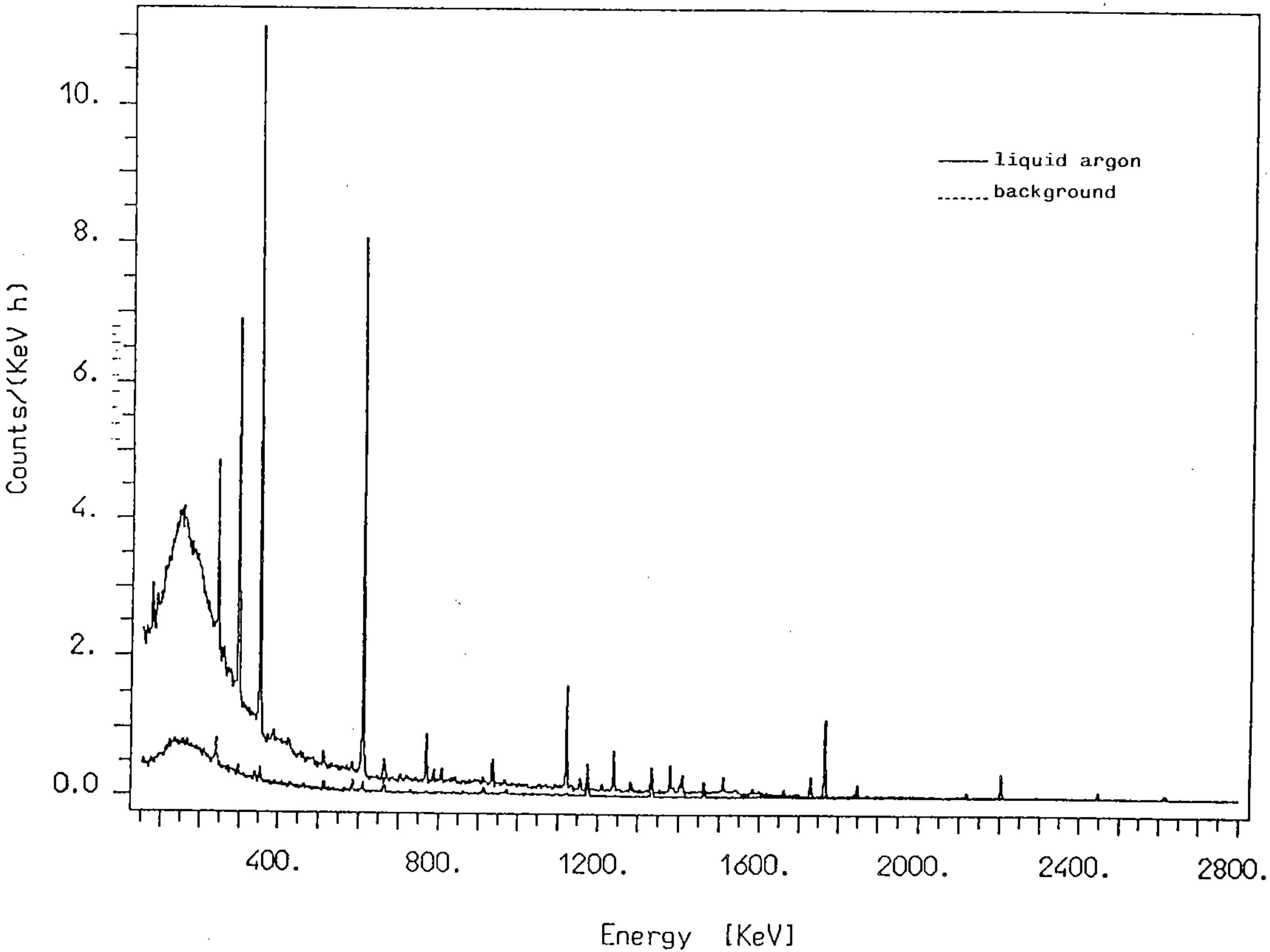


Fig. 4

24-MAR-1992 14:43:41.67

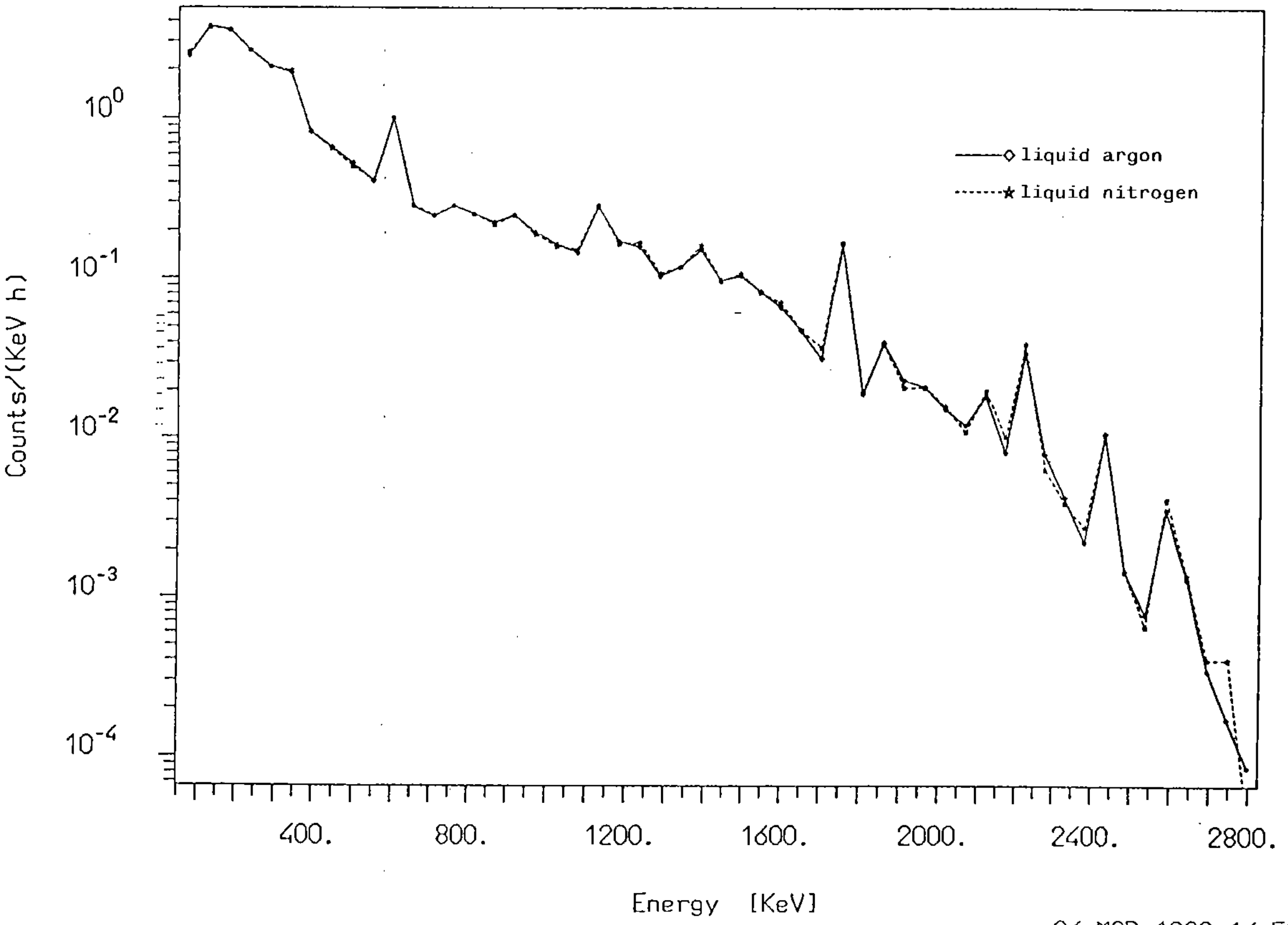
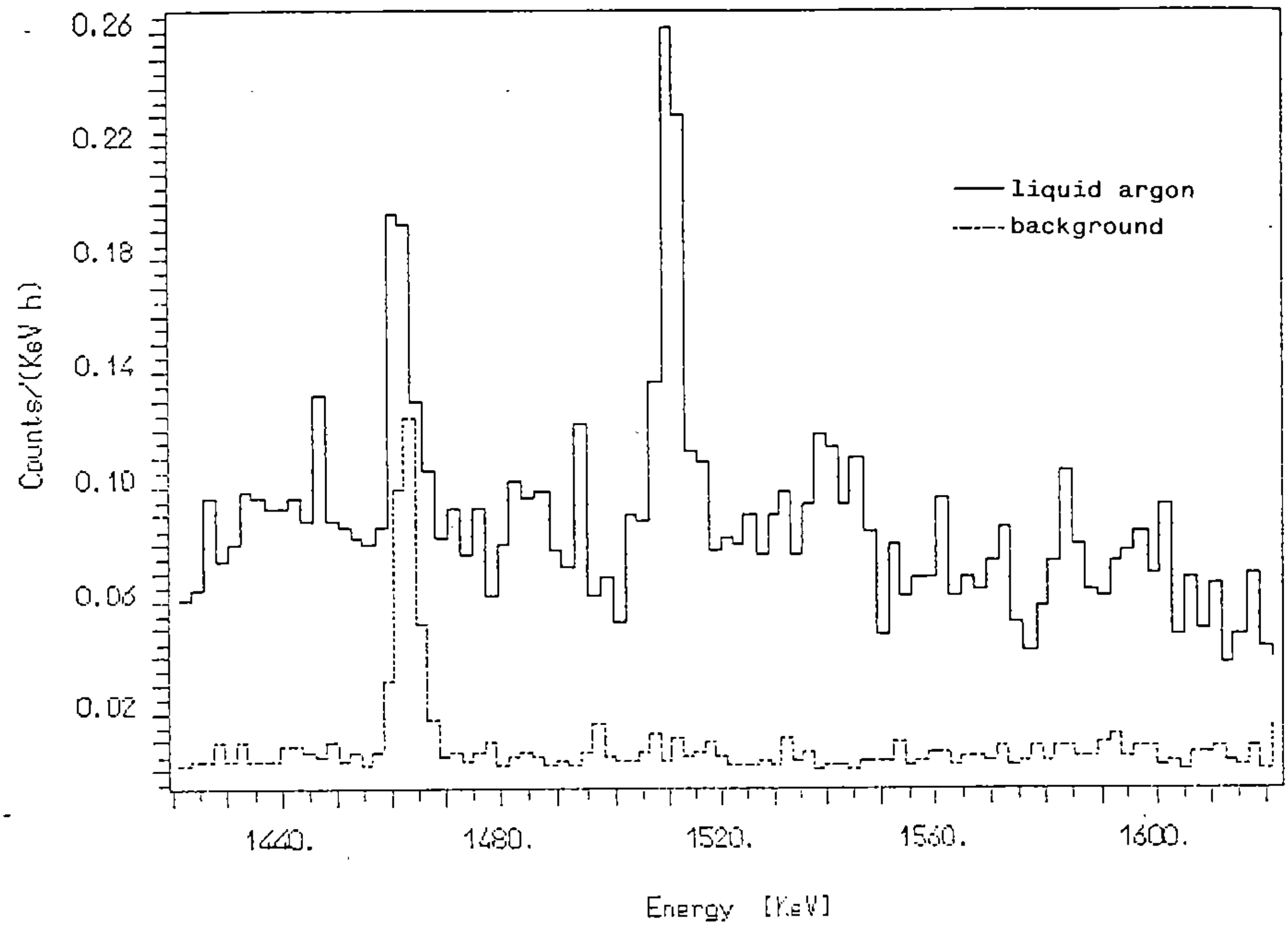


Fig. 5

24-MAR-1992 14:59:38.77



0.26
0.22
0.18
0.14
0.10
0.06
0.02
Counts/(KeV h)
liquid argon
background
1440.
1480.
1520.
1560.
1600.
Energy [KeV]

Fig. 6