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GNO

Gallium Neutrino Observatory

Aim:

measurement of low energy solar neutrino interaction rate

Collaboration:

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Location : Laboratori Nazionali del Gran Sasso

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The Gallium -Germanium system for solar neutrinos

Gallium is a metal of the III group
ρ = 5.91 g/cm3
melting point 29.8 C evaporation point 2237 C

^{nat}Ga contains two isotopes: ^{69}Ga (60%) and ^{71}Ga (40%)

$^{69}Ga\ (\nu_e, e^-)\ ^{69}Ge$
En_{th}= 2.23 MeV $T_{1/2}$ (^{69}Ge) = 39 h

$^{71}Ga\ (\nu_e, e^-)\ ^{71}Ge$
En_{th} = 233 keV $T_{1/2}$ (^{71}Ge) = 11.4 days

Expected rate (SNU) according SSM

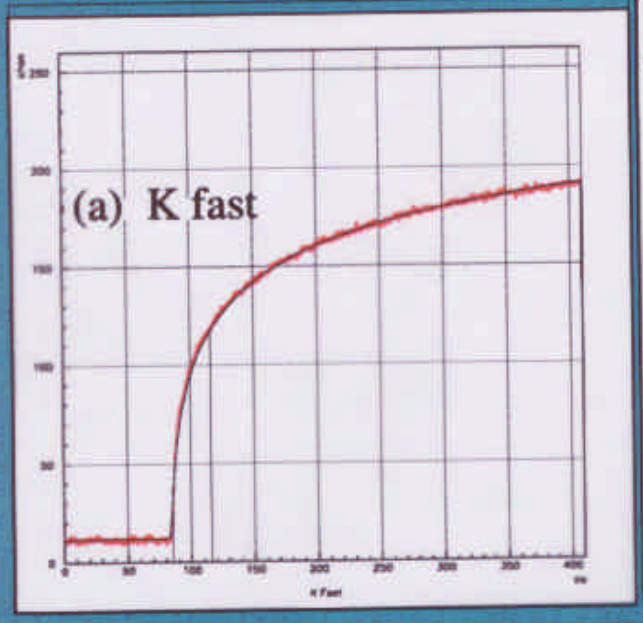
pp	70
^{7}Be	34
pep	3
^{8}B	12
CNO	10
TOTAL	$129\ ^{+8}_{-6}$

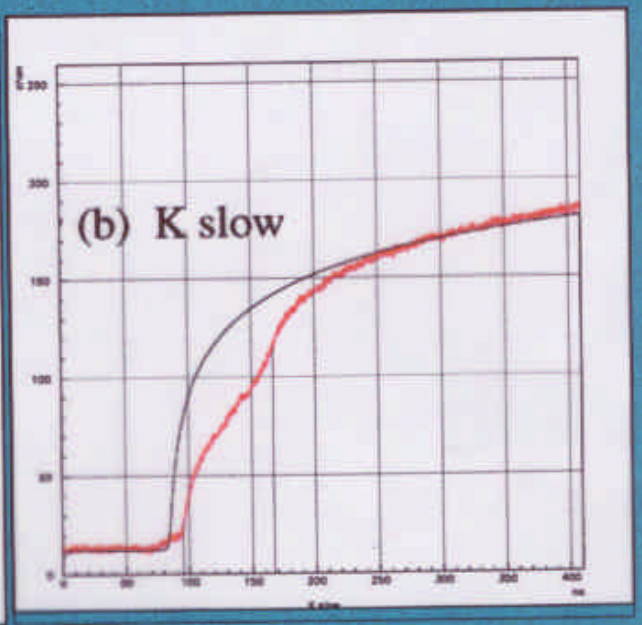
^{71}Ge electronic capture

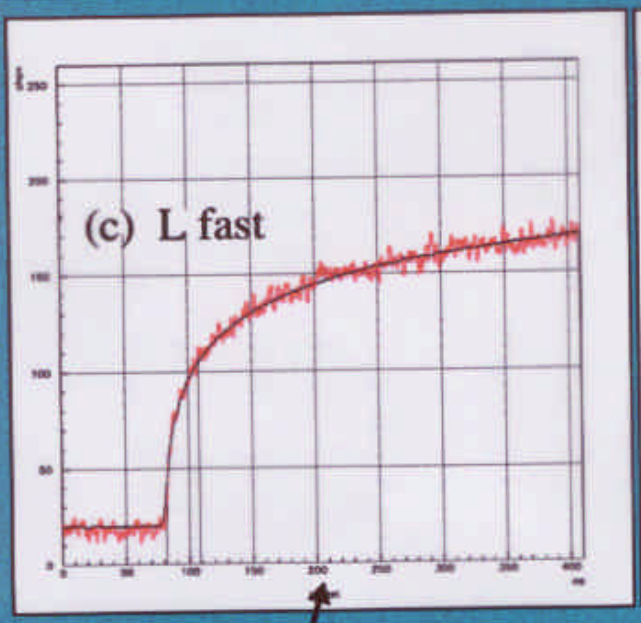
K capture	10.4 keV	88.2%	Auger 48% X 52%
L capture	1.2 keV	10.1%	Auger 98.5% X 1.5%
M capture	0.1-0.6 keV	1.7%	Auger 100%

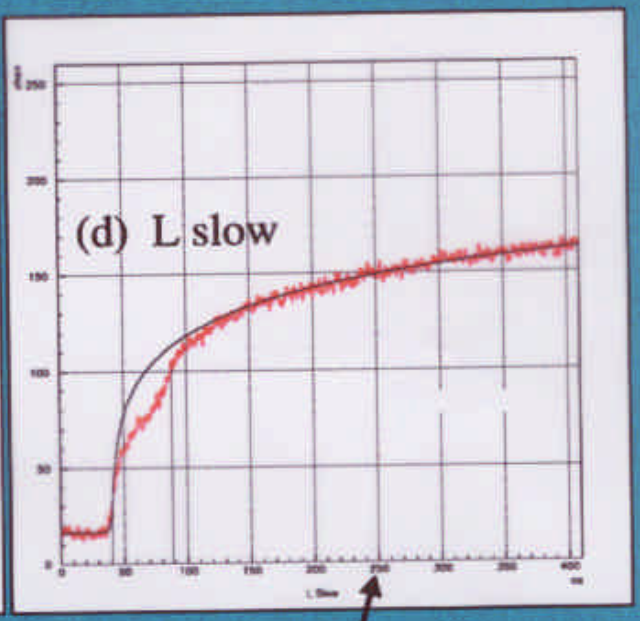
Germanium has many stable isotopes = useful as carrier

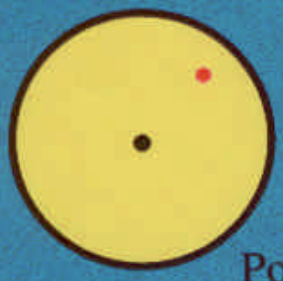
Pulse shape discrimination











Point-like ionization

Diffuse ionization

GNO30 is the continuation of GALLEX and (we hope) the first step of a long term program

target

30.3 tons of Gallium (12 tons of ^{71}Ga) in hydrochloric solution are contained in a single tank

sequence of the measurement

- every 4 weeks ^{71}Ge in form of $GeCl_4$ plus ~1mg of carrier (^{70}Ge, ^{72}Ge..) is extracted from the solution
- $GeCl_4 \rightarrow GeH_4$
- GeH_4 + Xe filling gas of proportional counters
- Counters are inserted in a heavy shielding
- Counting last about six month

Chronology

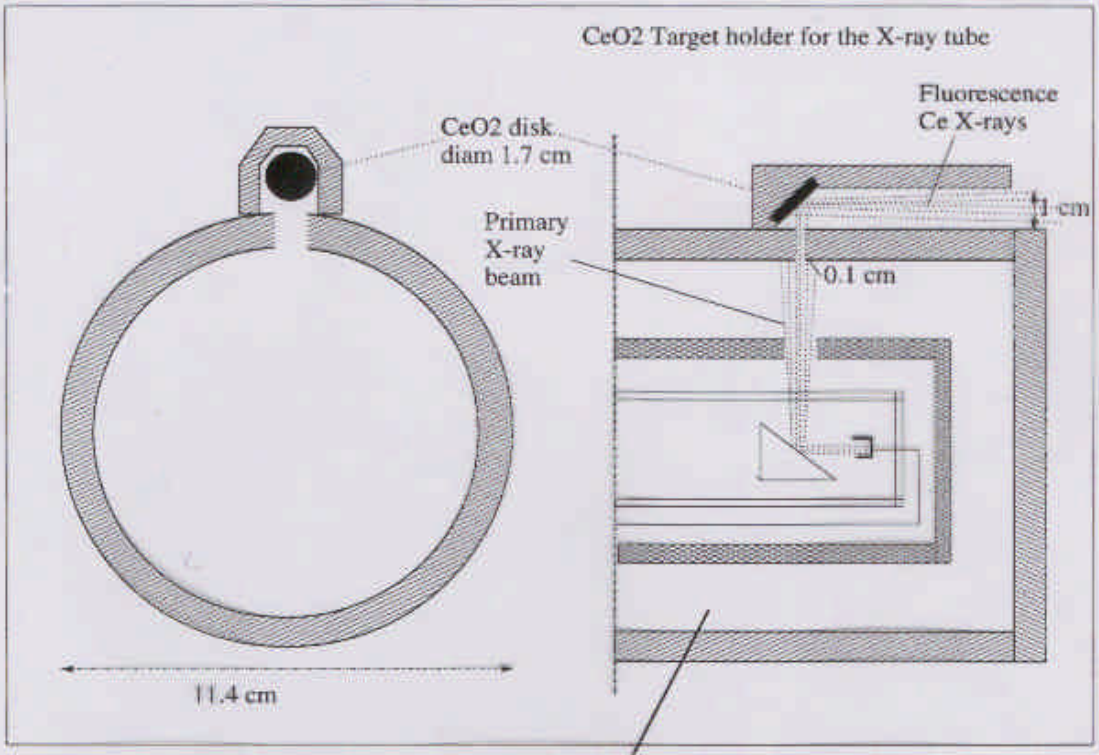
Fall 1997 last experiment of GALLEX (Arsenic test)

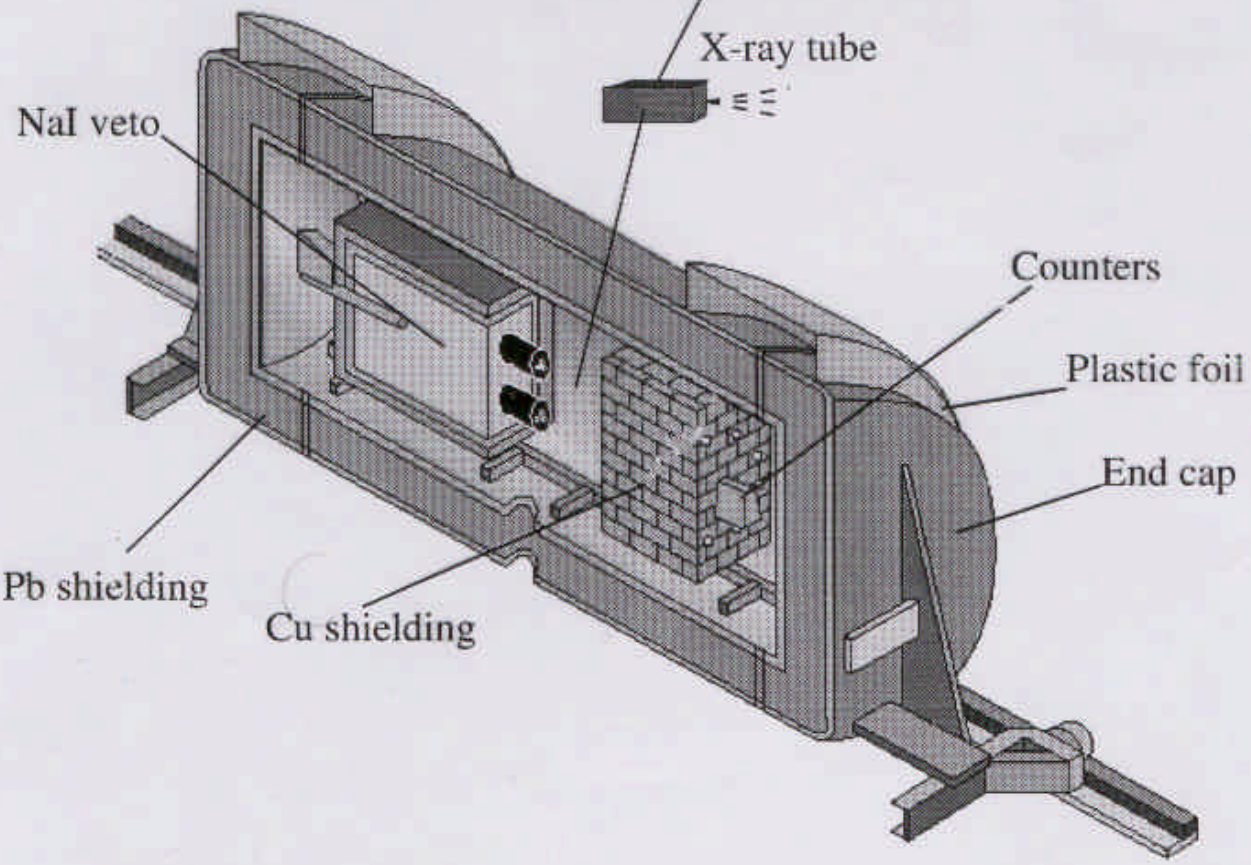
Fall 1997- summer 1998
general maintenance
new (partly) electronics
pre and amplifiers 300MHz band width
fast transient digitizer for each line (counter)
no multiplexing
new DAQ system

April 1998 data taking starts

July 1999 X ray tube in the shielding for calibration purposes

The GNO X-ray source for the calibration of counters





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DATA

2 extractions: debugging of the system

20 May '98 14 Dec '99
19 runs (+1 lost) used for the present analysis

14 Jan '00 30 May '00
5 runs still counting

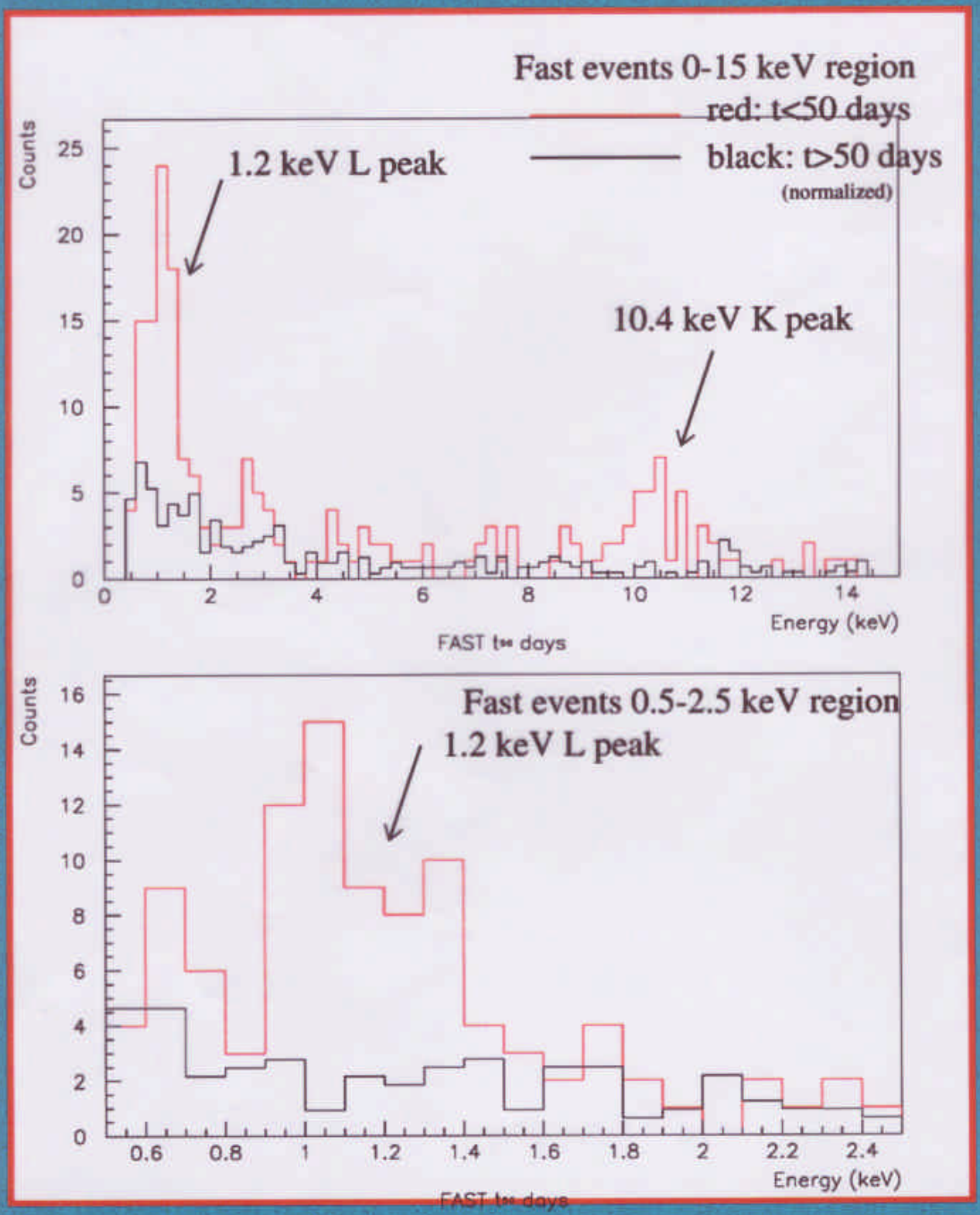
data analysis: energy and rise time

	run number	Period	Result (SNU) (K + L)	
	A001 - A002	Debugging		
	A003 SR1	20/05 - 17/06 1998	71 + 45 - 36	
	A004 SR2	17/06 - 22/07 1998	48 + 44 - 34	
	A005 SR3	22/07 - 26/08 1998	97 + 63 - 51	
	A006 SR4	26/08 - 23/09 1998	69 + 51 - 40	
	A007 SR5	23/09 - 21/10 1998	-46 + 40 - 33	
	A008 SR6	21/10 - 18/11 1998	45 + 50 - 33	
	A009 SR7	18/11 - 16/12 1998	116 + 53 - 44	
	A010 SR8	16/12 - 13/01 1999	-51 + 46 - 37	
	A011 SR9	13/01 - 10/02 1999	126 + 56 - 47	
	A012	Lost		
	A013 SR10	10/03 - 14/04 1999	123 + 53 - 43	
	A014 SR11	14/04 - 19/05 1999	53 + 41 - 30	
	A015 SR12	19/05 - 16/06 1999	26 + 69 - 50	
	A016 SR13	16/06 - 28/07 1999	97 + 53 - 43	
	A017 SR14	28/07 - 25/08 1999	114 + 69 - 55	
	A018 SR15	25/08 - 22/09 1999	46 + 38 - 28	
	A019 SR16	22/09 - 10/10 1999	49 + 46 - 36	
	A020 SR17	20/10 - 17/11 1999	33 + 32 - 34	
	A021 SR18	17/11 - 14/12 1999	67 + 44 - 40	
	A022 SR 19	14/12 - 12/01 1999	79 + 57 -41	
	A023 - A027	12/01 - 2000	Still counting	

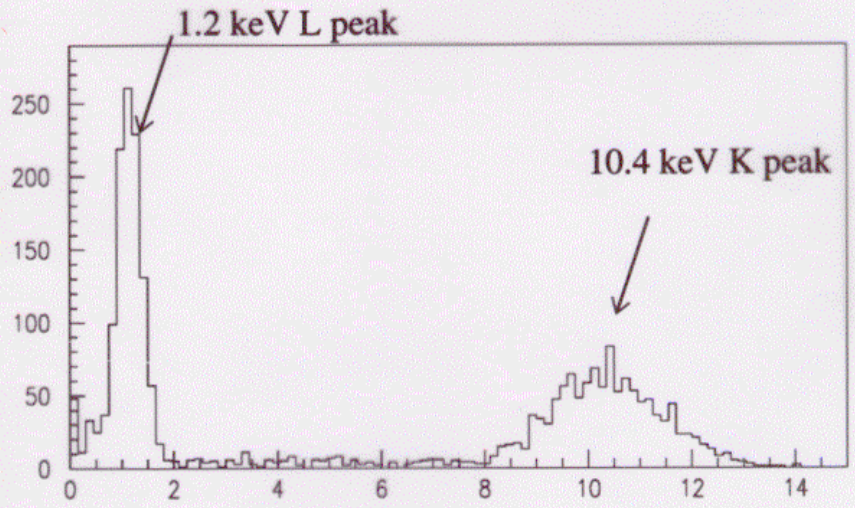
5.2 ± 1.0 SNU due to side reactions subtracted

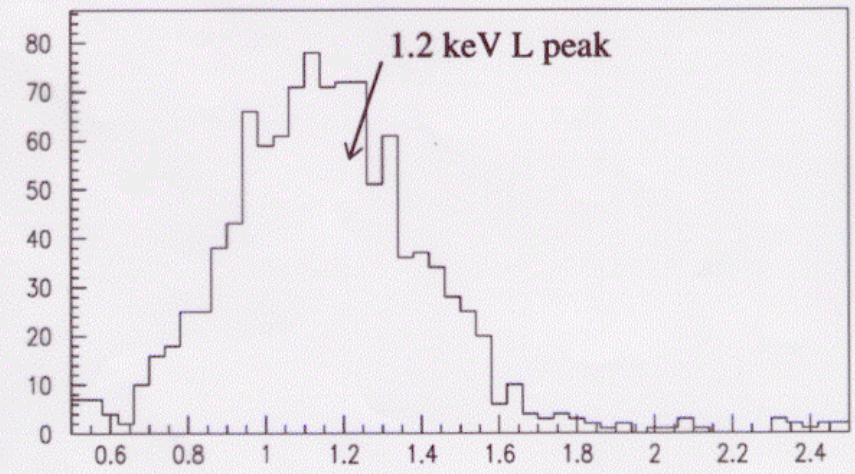
background (mean) rate
L 0.046 cpd (range 0.02 -015)
K 0.025 cpd (range 0.00 -0.09)

GNO 1 - 19 SR - energy spectrum

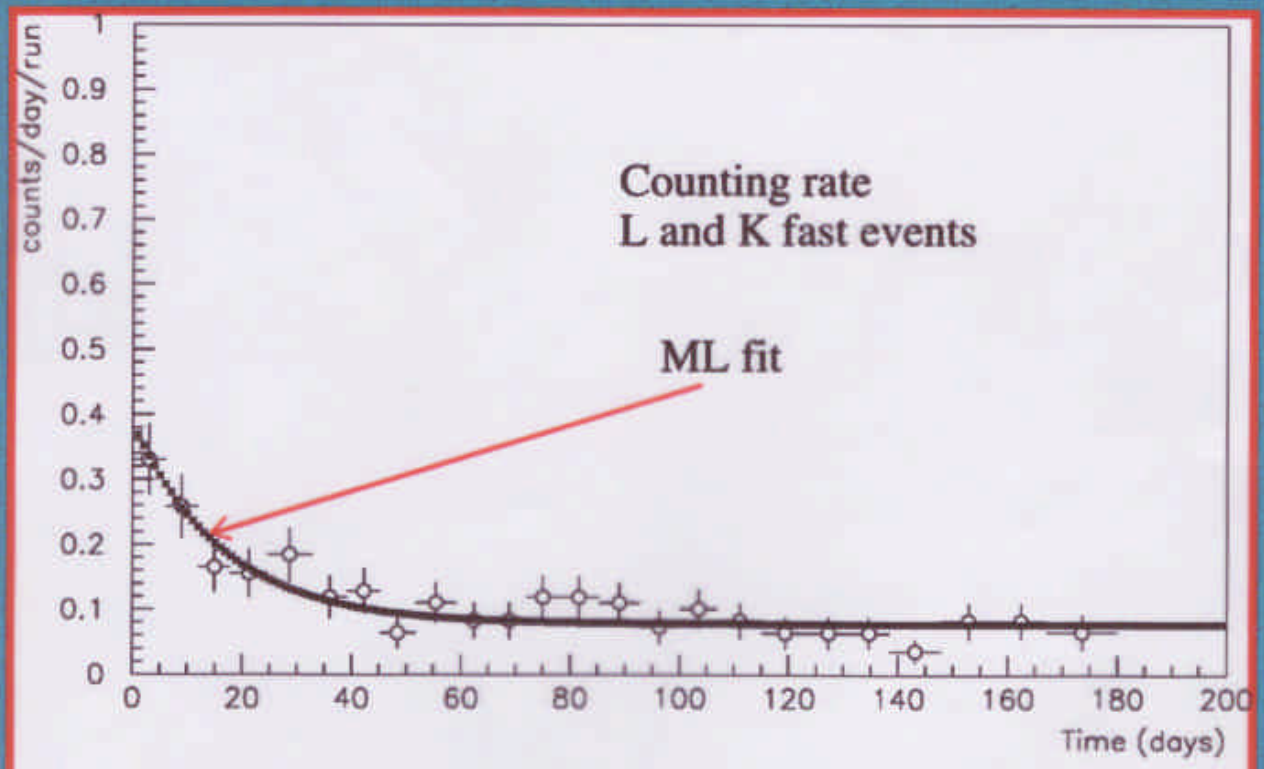


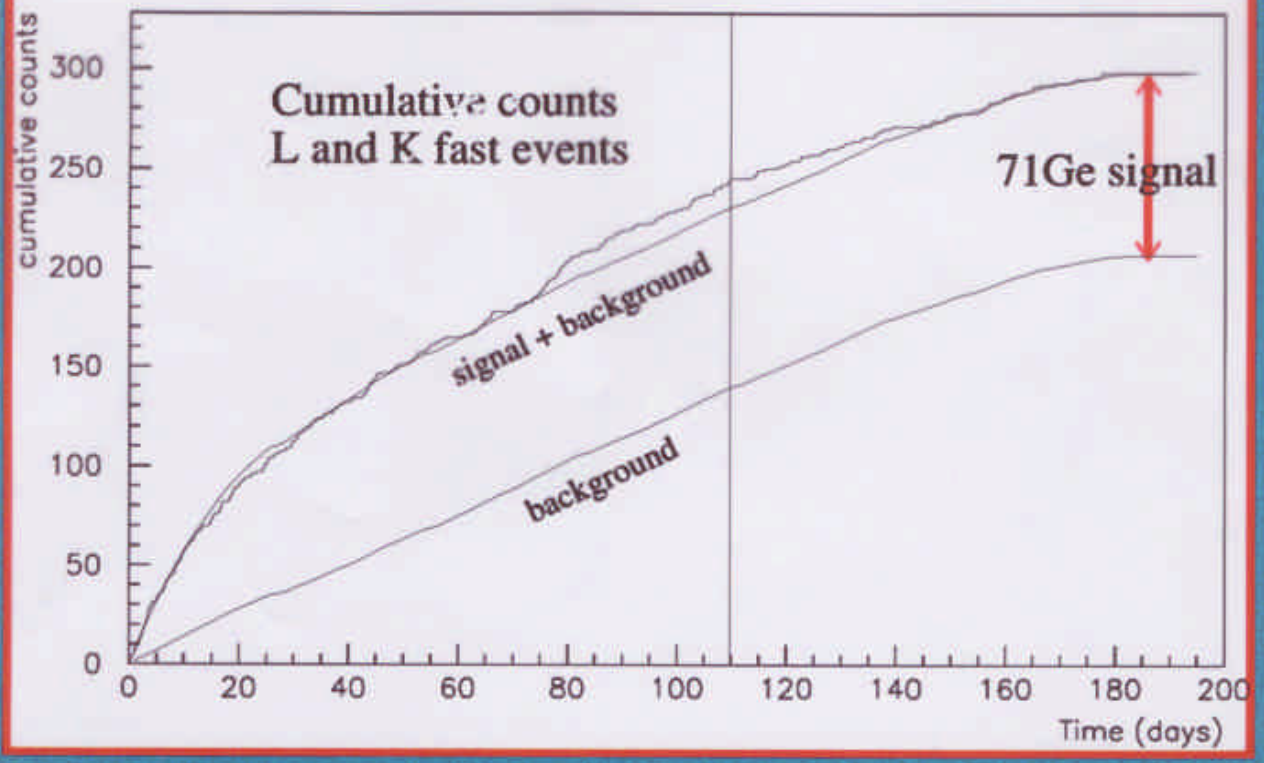
GNO 1 - 71Ge calibration

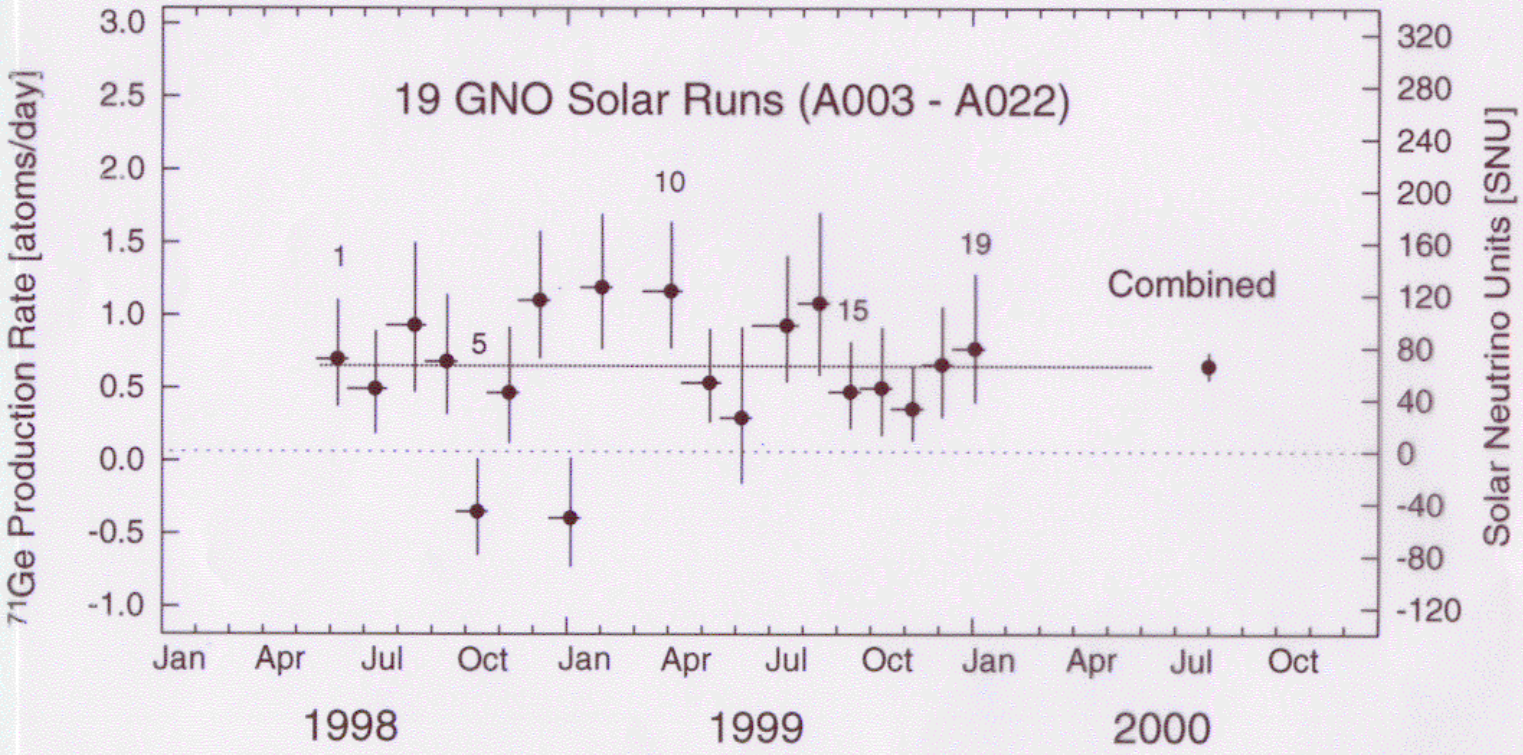




GNO 1 - counting






19 GNO Solar Runs (A003 - A022)
^{71}Ge Production Rate [atoms/day]
Solar Neutrino Units [SNU]
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
320
280
240
200
160
120
80
40
0
-40
-80
-120
1
5
10
15
19
Combined
Jan
Apr
Jul
Oct
Jan
Apr
Jul
Oct
Jan
Apr
Jul
Oct
1998
1999
2000

Side reactions

Muon induced background	3.1 ± 0.6
Fast neutrons	0.15±0.1
^{69}Ge	1.0 ± 0.5
Radon cut inefficiency	1.0 ± 0.5
TOTAL	5.2 ± 1.0

Systematic errors

Energy and rise-time cuts	± 3.0
Target size- chemical yield	± 1.5
Side reactions	± 1.0
TOTAL	± 3.5

GLOBAL FIT

total L only $80\ ^{+17.5}_{-16.2}$ K only $57.2\ ^{+12.4}_{-11.4}$

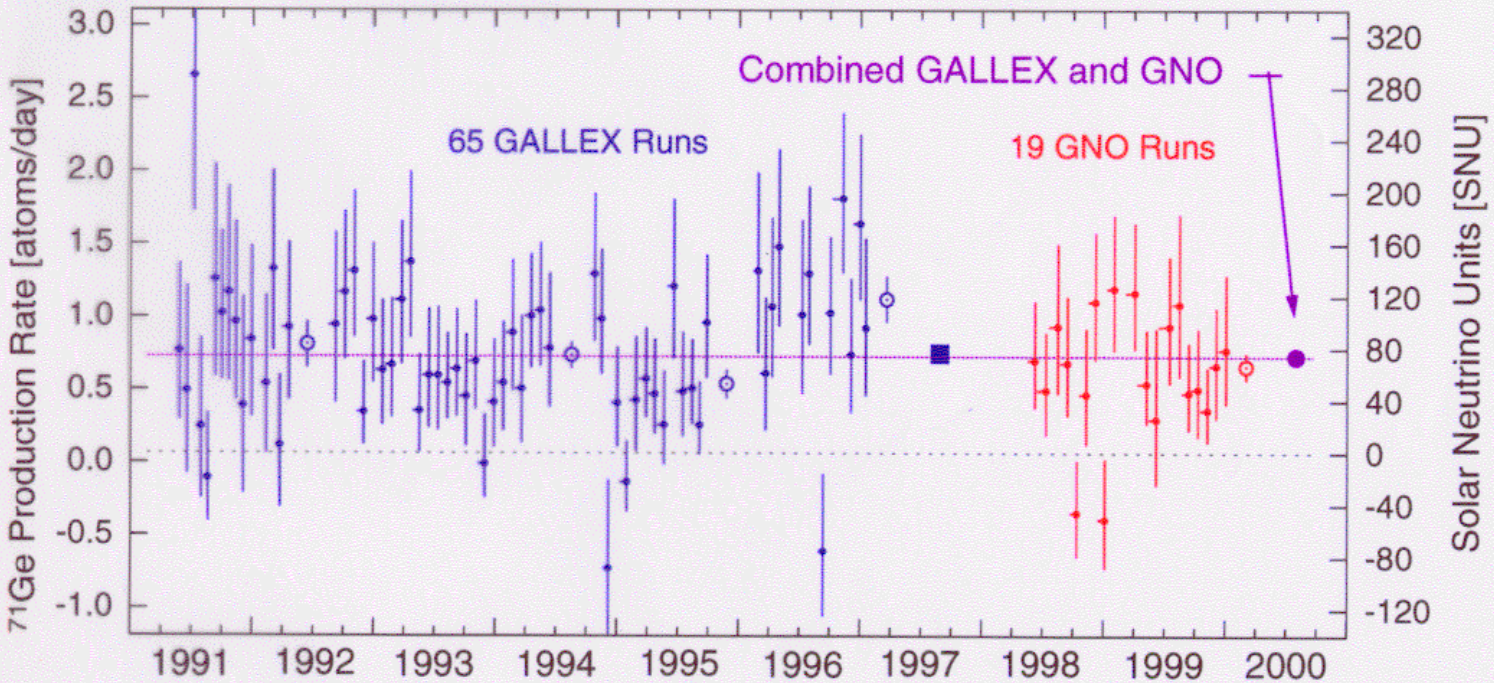
GNO

L+ K $65.8\ ^{+10.2}_{-9.6} \pm 3.5$ SNU

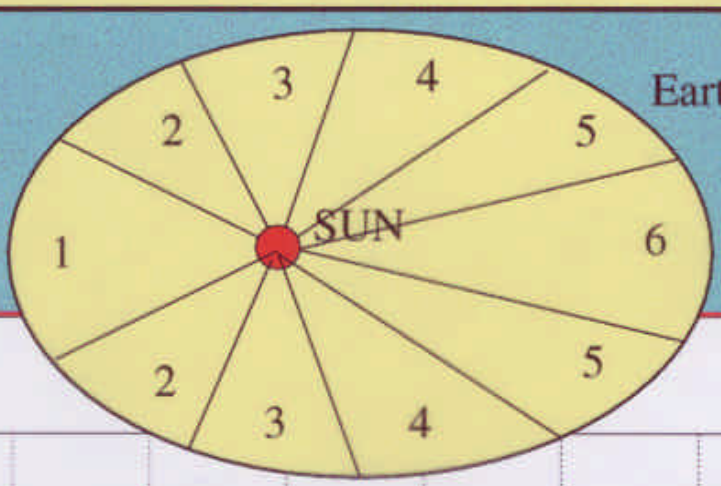
background (5.2 ± 1.0 SNU) subtracted

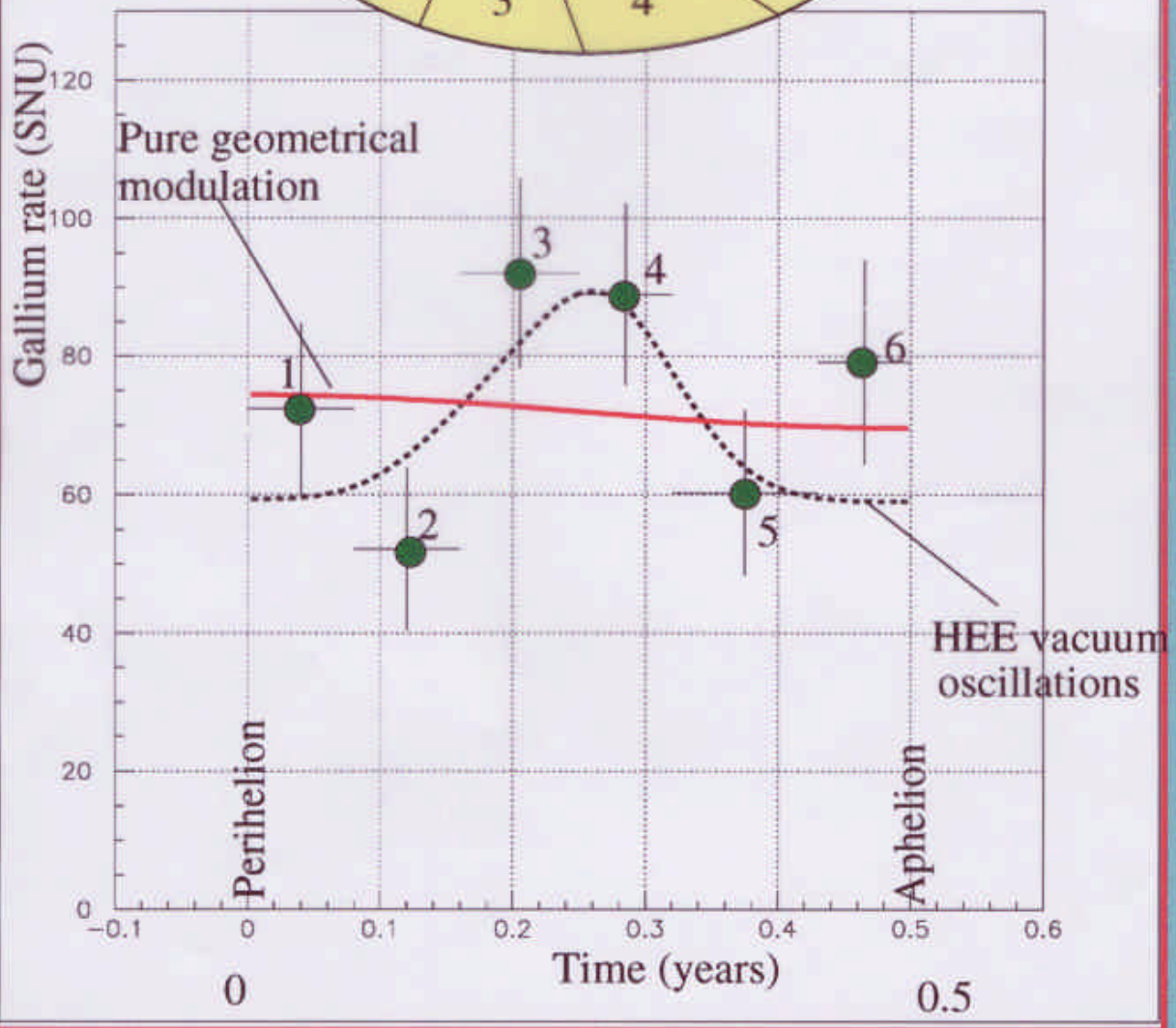
GALLEX I -IV $77.5 \pm 6.2\ ^{+4.3}_{-4.7}$

GALLEX+GNO $74.1\ ^{+6.7}_{-6.8}$ SNU


Combined GALLEX and GNO
65 GALLEX Runs
19 GNO Runs
^{71}Ge Production Rate [atoms/day]
Solar Neutrino Units [SNU]
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
320
280
240
200
160
120
80
40
0
-40
-80
-120
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000

GALLEX/GNO data binned with distance from the Sun





Geometrical : chi2 = 8.3 / 5 DOF C.L. = 14%

HEE VO : chi2 = 4.4 / 5 DOF C.L. = 49%

Future plans

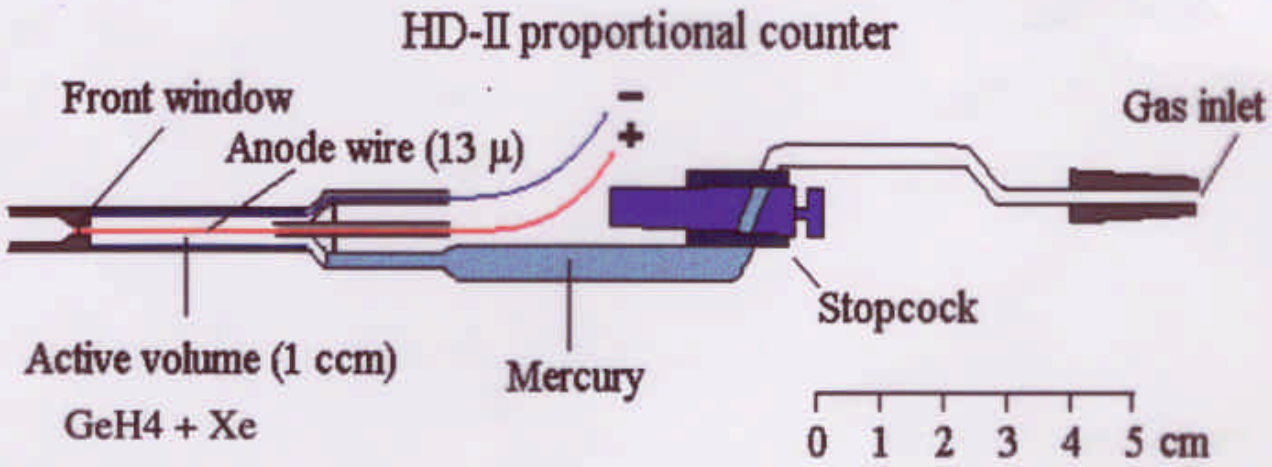
Developments of new counters:
machined proportional counters
to improve uniformity of counters and lower systematic errors
cryogenic detectors
to improve K to L ratio, energy resolution and background

Analysis
Radon rejection
More elaborated pulse shape analysis
Quantitative verification of Ge extraction by mass spectroscopy

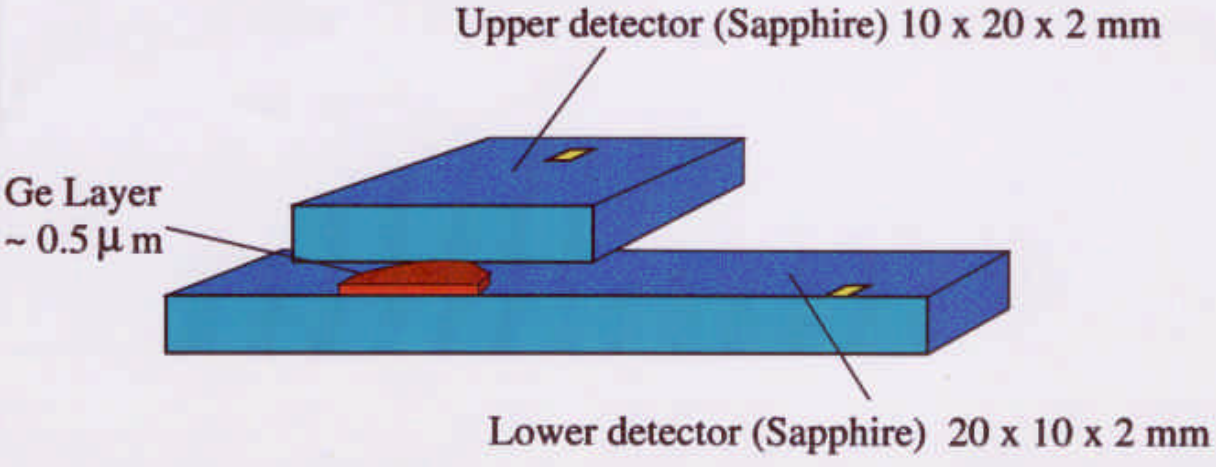
More solar runs

Detection of the 71Ge decay

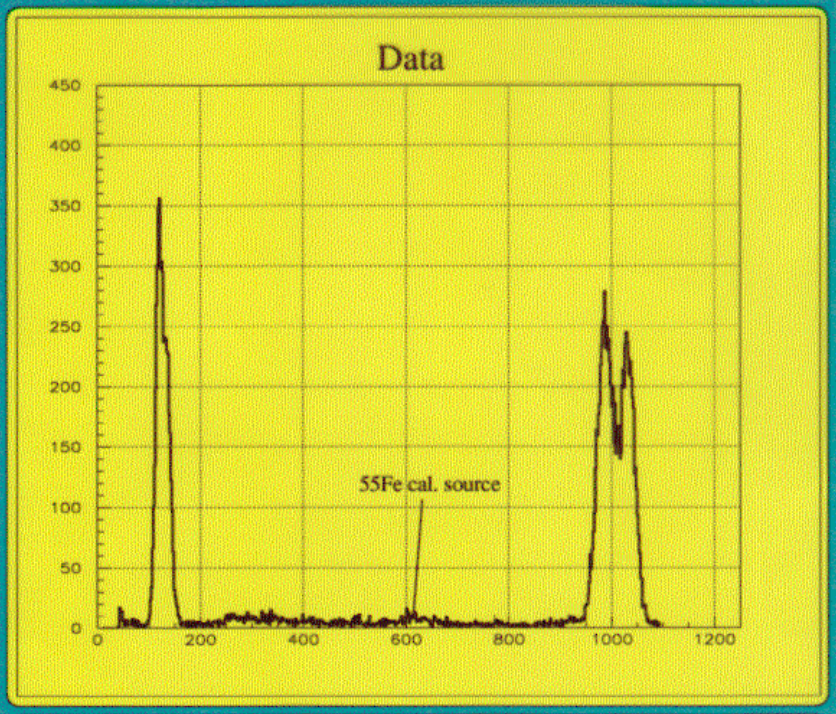
GALLEX / GNO Gas proportional counters

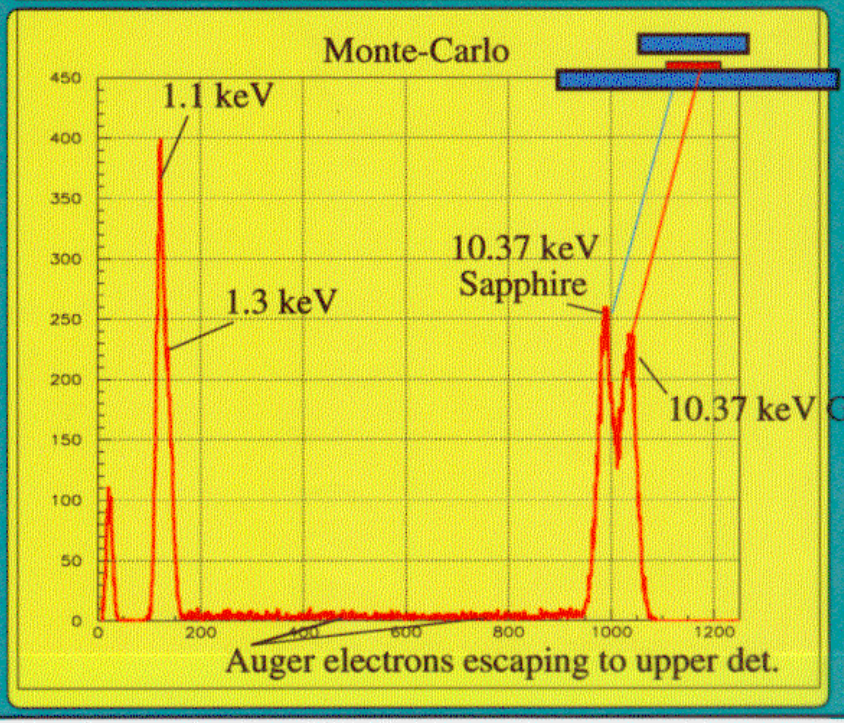


'Cryo' GNO : 4π cryogenic detectors

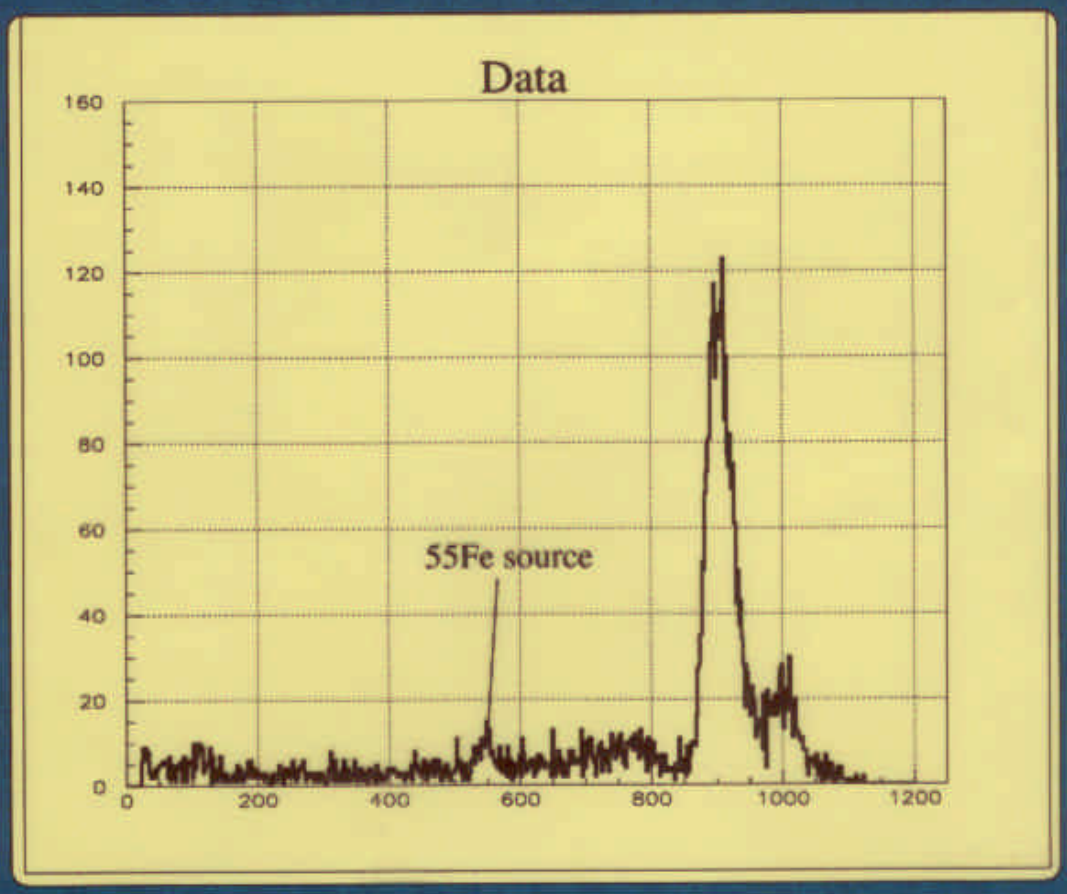


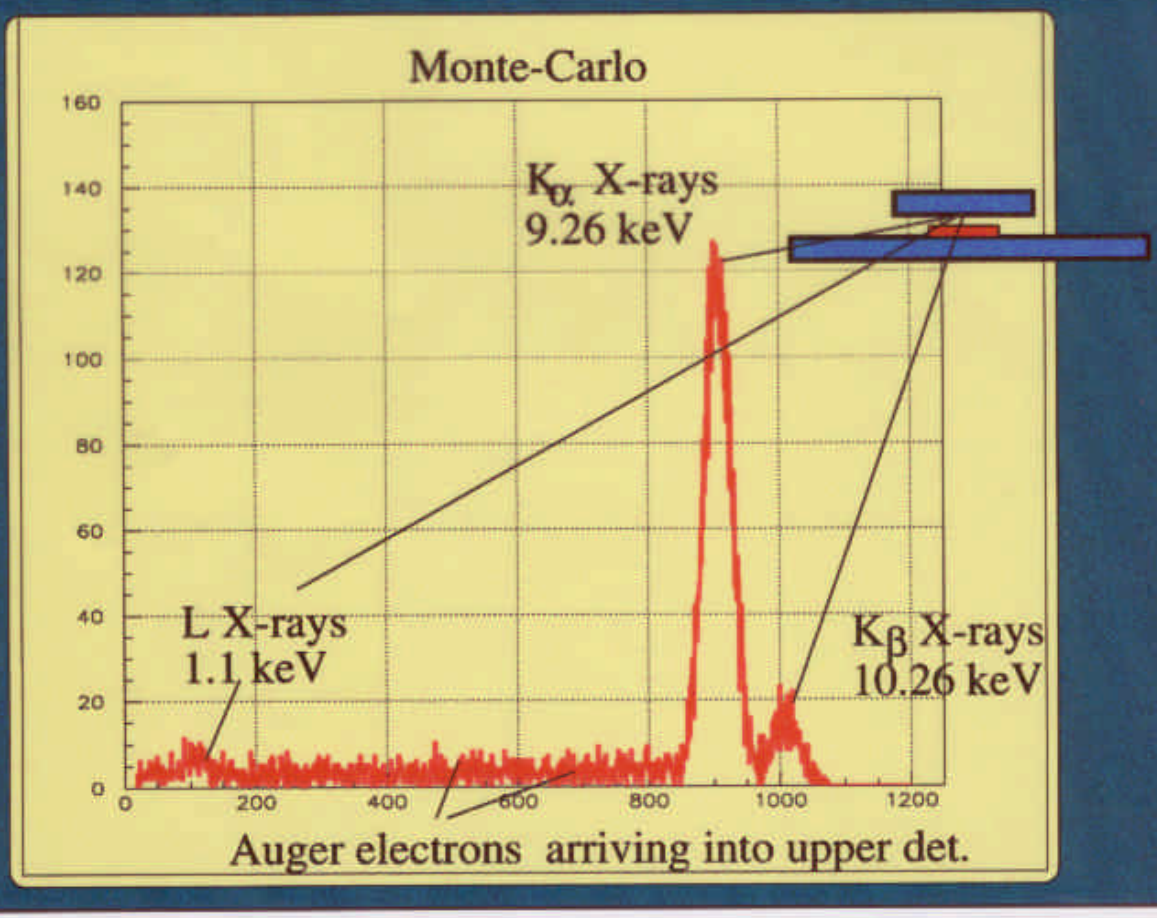
Lower detector





Upper detector





Conclusion

The result of GNO first period of data taking confirms the results of GALLEX and SAGE:
the deficit of solar neutrino and an interaction rate below (central value) the minimal predictions of solar models;

Improvements in statistics as well in systematic will allow to reject any standard solution of the solar neutrino problem by the Gallium data alone with high confidence level;

for many years gallium based detectors will be the only capable of measuring the pp neutrinos; they will complete the set of data on solar neutrinos collected at higher energy (^{7}Be and ^{8}B ν's) by Homestake, Superkamiokande, SNO, and Borexino and Kamland in a near future;

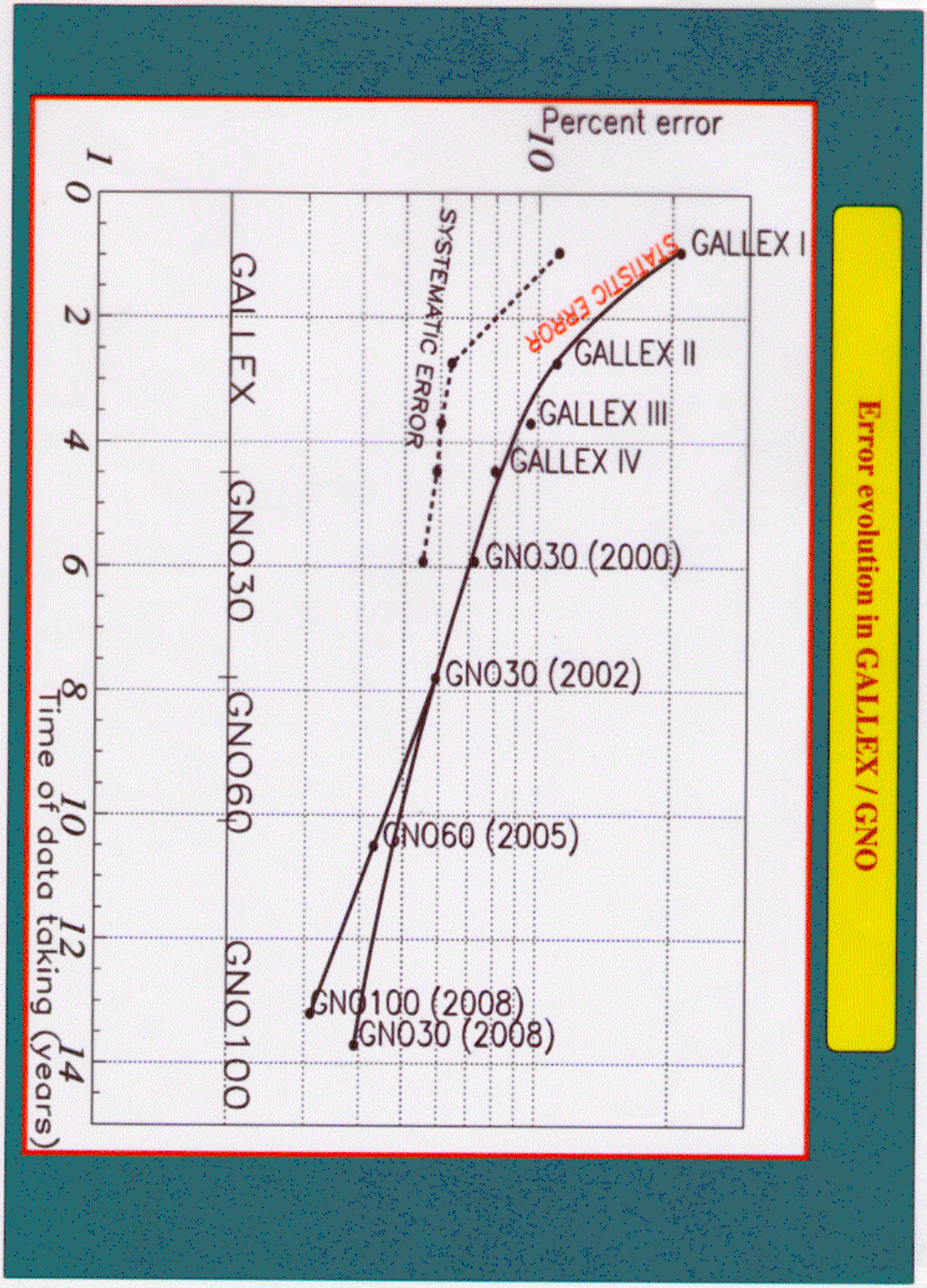
they will be essential for a complete understanding of results of planned experiments like LENS

they allow a better study of time variations (e.g. vacuum oscillations) and will contribute in any case to a more accurate definition of the electron neutrino oscillation parameters.

For that reasons we have asked for an increase of gallium mass from the presently available 30 tons to GNO60 and finally GNO100 with 100 tons of gallium as target.

http://www.lngs.infn.it/site/exppro/gno/GNO_home.htm

http://www.mpi-hd.mpg.de/kirsten/



Error evolution in GALLEX / GNO