On concentration of ^{42}Ar in liquid argon

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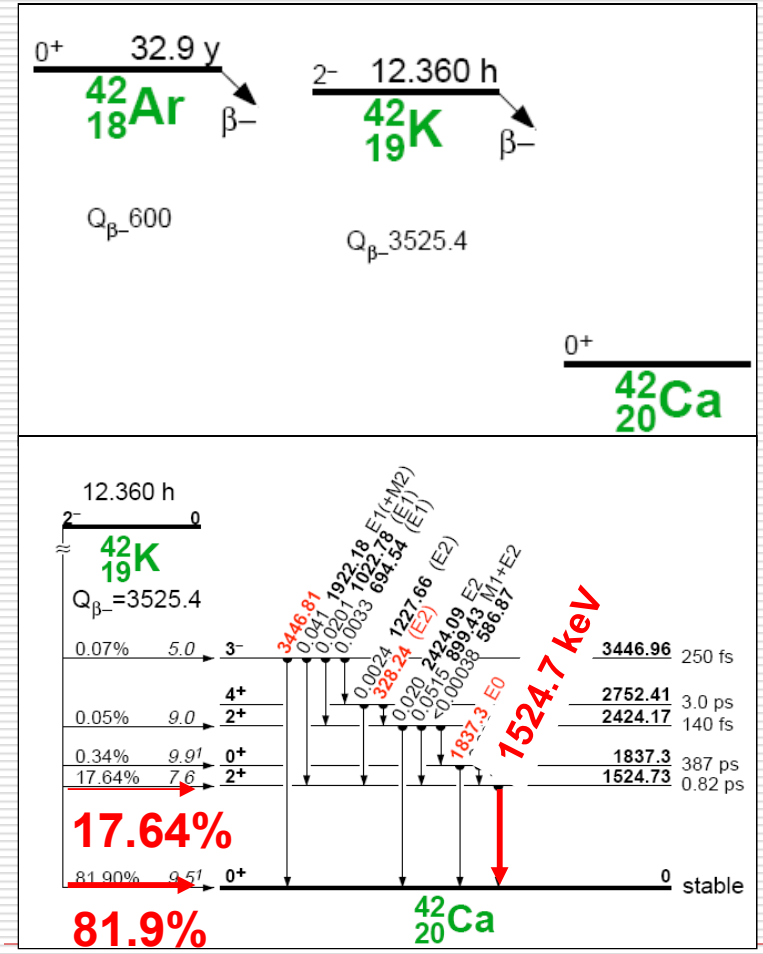
^{42}Ar is a possible background for Ar based detectors

- ICARUS (solar **ν** program)
- GERDA (**2β**)
- DBA (**2β**)
- **Dark matter** liquid Ar detectors

Decay scheme of ^{42}Ar



$T_{1/2}$ = 32.9 yr

Q(^{42}K) = 3525.4 keV

Eγ = 1524.7 keV

Short history of ^{42}Ar problem

1979 – **R. Davis** (possible background for **ICARUS**; ^{42}Ar as a result o nuclear bomb tests)

1992 – **C. Arpesella et al. [1]** (first experimental limit, **$< 10^{-18}$ ^{42}Ar/^{40}Ar**)

1995 – first estimations using information about nuclear tests in atmosphere, **$< 10^{-22}$–10^{-23} ^{42}Ar/^{40}Ar** (**P. Cennini et al. [2]** and **A.S. Barabash et al. [3]**)

1997 – **A.J. Peurrung et al. [4] -** new source of ^{42}Ar has been discussed: ^{40}Ar(α,2p)^{42}Ar (cosmic-ray interactions in the upper atmosphere; **$\sim 10^{-20}$ ^{42}Ar/^{40}Ar**)

1998 – **V.D. Ashitkov et al. [5]** – new experimental limit from **DBA** experiment, **$< 6 \cdot 10^{-21}$ ^{42}Ar/^{40}Ar**

2003 - **V.D. Ashitkov et al**. **[6]** – final experimental limit from **DBA** experiment, **$< 4.3 \cdot 10^{-21}$ ^{42}Ar/^{40}Ar (90% CL)**

2011 – **LArGe (GERDA) [7], $(2.2 \pm 1.0) \cdot 10^{-21}$ ^{42}Ar/^{40}Ar**

2014 – **GERDA-I [8], $(7\text{-}12) \cdot 10^{-21}$ ^{42}Ar/^{40}Ar**

List of references

[1] C. Arpesella et al., Preprint INFN-LNGS 92/27, 1992.

[2] P. Cennini et al., NIMA, 356 (1995) 526.

[3] A.S. Barabash et al., NIMA, 385 (1997) 530; preprint ITEP 18-95, 1995.

[4] A.J. Peurrung et al., NIMA, 396 (1997) 425.

[5] V.D. Ashitkov et al., NIMA, 416 (1998) 179.

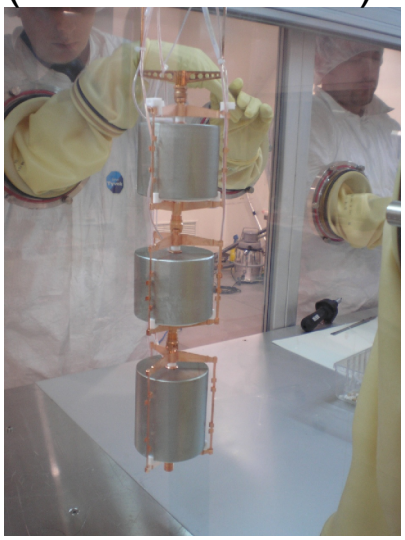
[6] V. D. Ashitkov et al., Inst. Exp. Tech. 46 (2003) 153.

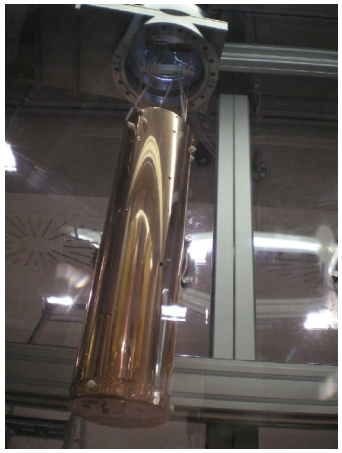
[7] M. Heisel, thesis, Heidelberg, 2011.

[8] M. Agostini et al., Eur. Phys. J. C 74 (2014) 2764.

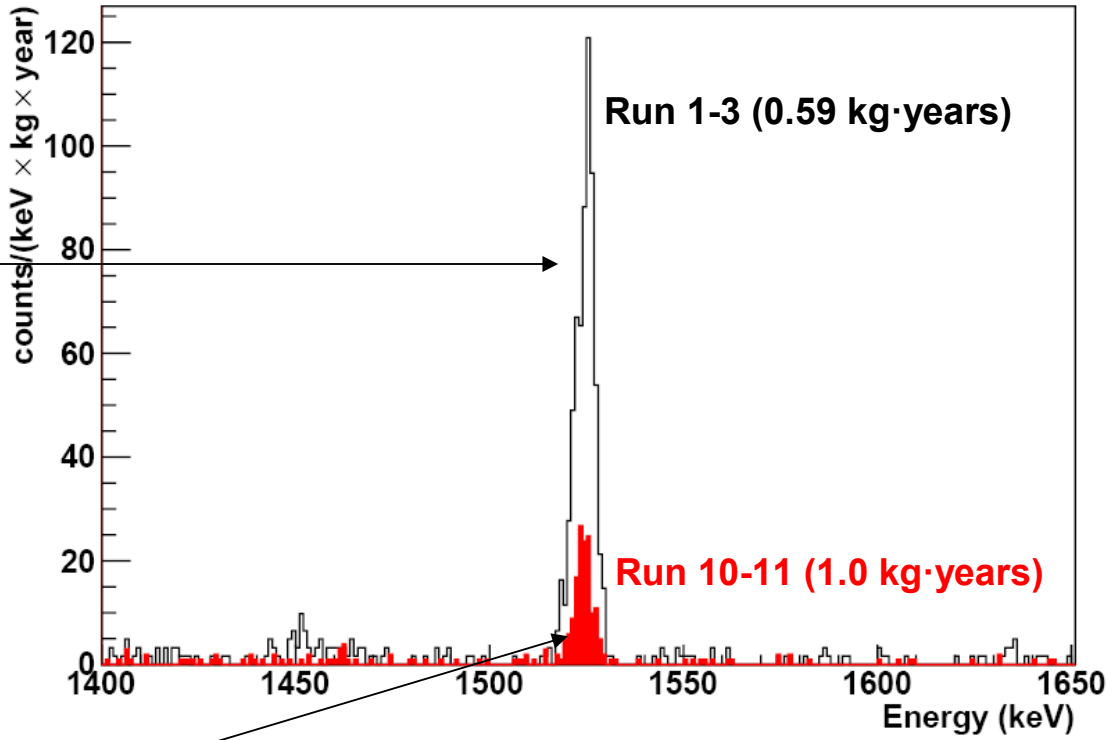
Enhancement of $^{42}K(^{42}Ar)$ count rate by E-field of detectors: 1525 keV peak

+HV on n+ contact
(w/o mini-shroud)





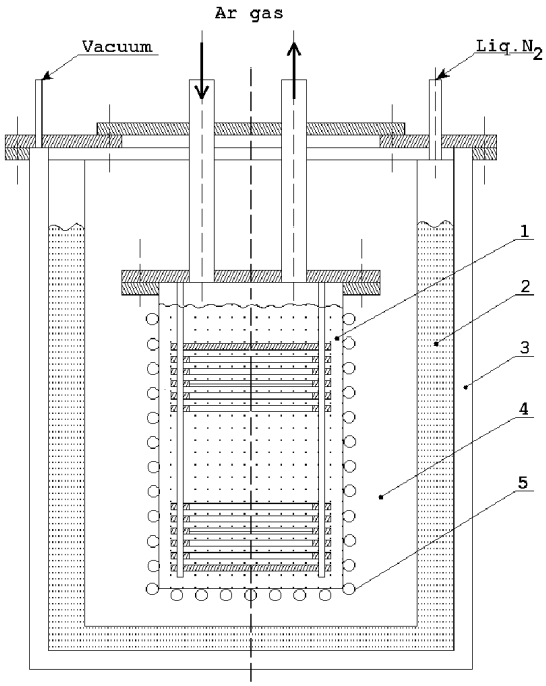
mini-shroud
shields
E-field &
possible
convections



And we've decided to reanalyze **DBA** data

- After new analysis we've discovered that **energy calibration** was not absolutely correct
- We've took into account **"age"** of used Ar (~ 10 years; ~ 20% of ^{42}Ar have been decayed)
- More correct subtraction of **possible background** was done

DBA experiment (Gran Sasso, 3500 m w.e., 1995-2000)



Liquid Ar ionization chamber with 14 identical sections

Sensitive volume:
∅30 x 56 cm (39.6 l; 55.4 kg; $8.4 \cdot 10^{26}$ Ar atoms)

Electric field:
1.9 kV/cm (cathode-grid gap; 14.5 mm)
4 kV/cm (anode-grid gap; 5.5 mm)

Energy resolution:
6% (FWHM) at 3 MeV

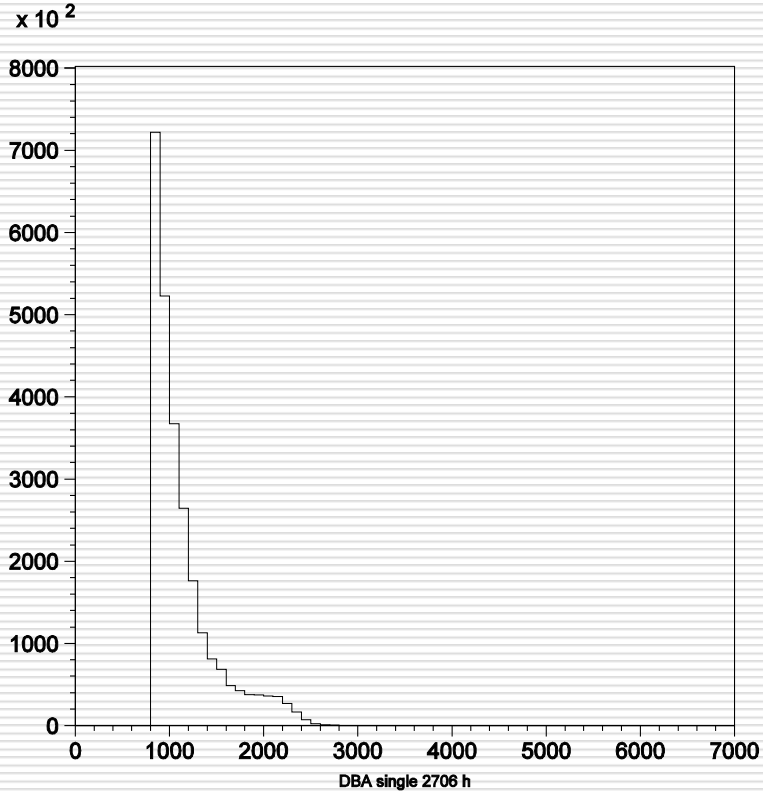
Main goal of DBA was search for double beta decay of ^{100}Mo

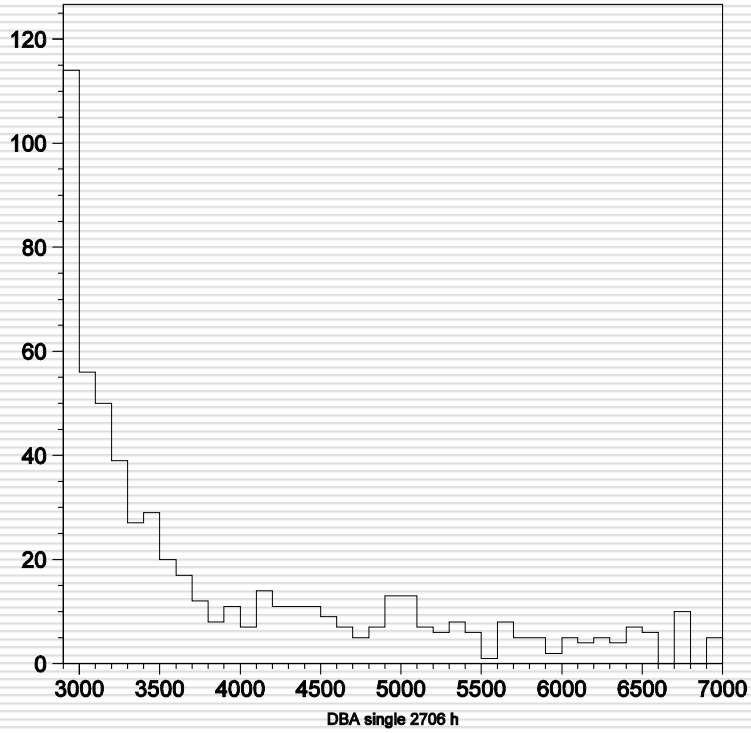
- In addition (as buy product) new limit on concentration of ^{42}Ar was obtained:

$$< 4.3 \cdot 10^{-21}\ ^{42}Ar/^{40}Ar$$

(V.D. Ashitkov et al., Inst. Exp. Tech. 46 (2003) 153)

The single electron spectrum obtained for 2706 h





Extra events in (3-3.5) MeV energy region

- **201** events detected
- Background contribution:
  - **45** from neutrons
  - **1** from ^{208}Tl (Ti)
  - **< 62** from ^{208}Tl (Mo)
  - < 0.2 from ^{214}Bi (Ti)
  - < 2 from ^{214}Bi (Mo)
- Possible contribution from **^{42}K** – **155** events*)

*) Possible scenario is **155 – 62 = 93**

Correction of calibration

- Calibration was done using **^{22}Na** (1275 keV), **^{88}Y** (1836 keV) and **2615 keV** line in the spectrum
- **Edge of Compton** spectrum was used to establish the real energy
- Using MC it was demonstrated that some correction has to be done
- This correction is **~ 100 keV** for high energy part of the spectrum **(~ 3 MeV)**

Efficiency

- In paper [6] we investigated energy interval **(3-3.5) MeV**
- It means that, in fact, this is ~ **(3.1-3.6) MeV.**
- Efficiency was calculated by MC for this new interval:
  - **0.47%** (homogeneous distribution of ^{42}**K**)
  - **0.39% (^{42}K is positive ion)**

Concentration of ^{42}Ar in the Earth atmosphere

- Positive ions case (”age” of Ar is taken into account):

$$C_i = 8^{+2}_{-4} \cdot 10^{-21}\ ^{42}Ar/^{40}Ar$$

(Activity is ~ 82^{+20}_{-41} μBq/kg)

- Homogenous case (”age” of Ar is taken into account):

$$C_h = 7^{+1.8}_{-3.5} \cdot 10^{-21}\ ^{42}Ar/^{40}Ar$$

LArGe (GERDA) [7] – $(2.2 \pm 1.0) \cdot 10^{-21}$; GERDA-I [8] – $(7\text{-}12) \cdot 10^{-21}$

Concentration of ^{42}Ar (after possible ^{208}Tl contribution subtraction)

- Positive ions case (”age” of Ar is taken into account):

$$C_i = (5 \pm 1.5) \cdot 10^{-21}\ ^{42}Ar/^{40}Ar$$

[Activity is ~ (52 ± 15) μBq/kg]

LArGe (GERDA) [7] – $(2.2 \pm 1.0) \cdot 10^{-21}$; GERDA-I [8] – $(7\text{-}12) \cdot 10^{-21}$

CONCLUSION

- Old **DBA** data were reanalyzed
- Concentration of **^{42}Ar** in the Earth atmosphere is estimated as:

  $C = (4\text{-}10)\cdot 10^{-21}\ ^{42}Ar/^{40}Ar$

  (Activity is ~ (40-100) μBq/kg)

  (preliminary result)
- This value is in agreement with **GERDA-I** estimation