Jagiellonian University

for the GERDA-LARGE Team

Krzysztof Pelczar

in Large

Modeling of 42K behavior

GERDA

INTERNAȚIONAL PHD PROJECTS IN APPLIED NUCLEAR PHYSICS AND INNOVATIVE TECHNOLOGIES
Outline

- Experimental results for $^{42}\text{Ar}$ spike
- Electric configuration of the detector and its encapsulation
- The model of ionic drift
- Hypothesis on LAr self-purification
- Conclusions
Recent measurements with PMTs off:
- encapsulation bias wire (from 3000 V to +1500 V)
- permanently biased wire (detector bias +3200 V)
- grounded surfaces (cross, cables, string)

Improved to account for all the details:
- Detailed 3D model of the large geometry was enhanced compared to "real" field-free environment towards the 0 V encapsulation (2 -- 3 times signal)
- Positive bias potential drags positive charges (quasi field-free)
- Presence of unshielded wires always results in non-field-free configuration close to the detector

Electric configuration of the detector and its encapsulation
Encapsulation at 0 V (quasi field-free, 3D model)
\[ \frac{\frac{L}{2}}{\frac{1}{2} + L} = \mathcal{Z} \]

Minority (\(\mathcal{Z}\)) of \(4\mathcal{Z}\) K is charged due to short ionic life time. \(4\mathcal{Z}\) K is consistently produced in ionized state.

\[ 0^{0}_n = (1 - \mathcal{Z})^{0}_{\text{neutral}} \]

\[ 0^{0}_{\text{charged}} = \mathcal{Z}^{0}_{\text{charged}} \]

Flux of \(4\mathcal{Z}\) K+ at \( t = 0' \) is \( 0 \).
Decay

Part of neutral decayed

Charged part moved by $E$ field

$\text{Flux of } 4\pi K^+, \ t = \forall t, \ E < 0$
Part or neutral decayed
Charged part moved by $E$ field

Decay

Flux of $4_2K^+, t = 2\Delta t, E < 0$
Part of neutral decayed

Charged part moved by $E$ field

Decay

$\text{Flux of } \frac{4}{2} K^+, t = 3 \forall t, E < 0$
As an effective distribution of $K$ is shifted with respect to $AR$ distribution to $\mathcal{A}_2K$.

Flux of $\mathcal{A}_2K^+$, $t = nt^{1/2}$, $E < 0$. 

$\Delta V$
The model of ionic drift.
\[
\frac{\frac{L}{\pm L}}{+N} \approx \frac{\frac{L}{\pm L} + \frac{L}{\pm L}}{+L} = \frac{N}{+N} = 3
\]

\[+N - N = 0, N\]

\[
(r - 1) \frac{v}{V} = (1) + N
\]

\[+v + v = v\]

\[
(r - 1) \frac{v}{V} = (1) N
\]

How much of \(42K^+\) do we have?
A study of the factors affecting the electron life time in ultra-pure liquid argon,

A. Bettini et al. NIMA

Time (min)

Lifetime (μs)

CO₂ concentration (ppb)

22.0

E = 100 V/cm

Purified LAR doped with 50 ppb CO₂

ICARUS results on self-purification of LAR and its impact on e⁻ life time
where $M$ is order of 10 m ppm.

\[
\frac{\frac{z}{O}}{N} = 2
\]

concentration

Ionic life time depends on the impurity equivalent of all electronegative impurities (e.g. oxygen).

Let's assume we have $[O^-] = 2$ ppm (oxygen). LAR purity better than 5 ppm (measured > 5 ppm) particular HV at encapsulation. 1525 Key count rate enhances in time for hypotheses on LAR self-purification.
Hypotheses on LAR self-purification
\[ A = 2.3 \text{ ppm} \]

\[ B = 1.7 \]

\[ \frac{1}{k} = 74 \text{ days} \]

\[ A/B = 1.4 \text{ ppm equilibrium purity} \]

\[ A(\text{B-1}) = 3.3 \text{ ppm at t = 0} \]

\[ \mu = 6 \times 10^{-4} \text{ cm}^2 \text{ V}^{-1} \text{ s}^{-1} \]

\[ \mathrm{HV} = -3000 \text{ V} \]

\[ [Q] = \frac{M}{A} \left( B - e^{-\alpha t} \right) \]

\[ [Q] = \frac{A}{B-e^{-\alpha t}} \]

\[ A \]

- Assuming positive ion mobility

The ionic life time was obtained in the model for LAr self-purification.
Hypothesis on LAR self-purification
around the detectors

\( V/m \text{m} \) on a few cm distance appropriately distributed

GERDA: ion sweepers should produce \( E \text{ field} \approx 10 - 100 \)

lower mobility value is assumed

Effective 42-K ion lifetime estimated to be 5 m or 15 m if

and the short ion lifetime time

The observed transient is linked to the nuclear buildup up

(\+1500 V - comparable (factor 0.9) -

\(-0 \text{ V - factor 3 higher}\)

\(-3000 \text{ V - factor 30 higher signal}\)

(field-free, based on simulation only!

encapsulation), with respect to homogeneous distribution

close to the detector (negative potential on

\( 42 \text{K} \) ions are subject to \( E \text{ field} \), causing buildup of activity

Conclusions