Search for a Heavy Neutrino by Measuring Muon Capture by ^{3}He

W. Schott, S. Müller, H. Daniel, J.Deutsch [a], P. Ackerbauer [b], D.V. Balin [c], V.N. Baturin [c], G.A. Beer [d], W.H. Breunlich [b], T. Case [e], K.M. Crowe [e], J.-P. Egger [f], J. Govaerts [a], Yu.S. Grigoriev [c], F.J. Hartmann, P. Kammel [b], B. Lauss [b], E.M. Maev [c], V. Markushin [g], J. Marton [b], M. Mühlbauer, C. Petitjean [f], T. Petitjean [f], G.E. Petrov [c], R. Prieels [a], W. Prymas [b], G.G. Semenchuk [c], Yu.V. Smirenin [c], B. van den Brandt [f], A.A. Vorobyov [c], N.I. Voropaev [c], and P. Wojciechowski

[a] Université Catholique de Louvain, B-1348 Louvain-la-Neuve, Belgium
[b] Austrian Academy of Sciences, A-1090 Vienna, Austria
[c] St. Petersburg Nuclear Physics Institute, Gatchina 188350, Russia
[d] University of Victoria, Victoria B.C. V8W 2Y2, Canada
[e] University of California Berkeley and Lawrence Berkeley Laboratory, Berkeley, CA 94720, USA
[f] Paul Scherrer Institut, CH-5232 Villigen PSI, Switzerland
[g] Russian National Center I.V. Kurchatov Institute, Moscow 123182, Russia

The residuum of the triton energy spectrum dN/dT of the muon capture reaction $\mu^3\text{He} \to \text{t} + \nu_\mu$, where μ^3He is the ground state of muonic ^{3}He, was processed through a filter. The filtered spectrum was analyzed searching for massive neutrinos.

dN/dT has been measured by means of a high pressure ionization chamber (IC) in order to determine the nuclear muon capture by ^{3}He with high precission [1] and to investigate a possible heavy ν admixture into the μ flavor with high sensitivity. Using $1.28\,\sigma$ as statistical error of the measured counts/channel, where σ means the standard deviation, the 90 % C.L. upper limit of the μ-heavy ν_i mixing matrix element squared was obtained to be $|\text{U}_{\mu i}|^2 \leq 10^{-3}$ for heavy neutrino masses in the range of $25\,\text{MeV} \leq E_{o\nu} \leq 75$ MeV [2]. Figure 1 shows the measured t lines in the collected charge spectra. The spectrum a contains 38,800 t events measured at the first anode (B1), whereas in spectrum b 220,000 t events of the B1 and the further downstream anodes (B3, B4, B5) are added. In fig. 2a the residuum spectrum $B'(x) = (y - f)/t_a$ is plotted vs charge channels x. y is the measured data using anode B1 (cf. fig. 1a). f is an analytical function fitted to the spectrum being the addition of a Gaussian and an exponential function with a second order polynomial in the exponent. The energy T is given by $T(keV) = 19.96645 \cdot x$. According to the fit the t peak is at $x = 94.859$ with a width $p_w = 4.128$ (FWHM) and an amplitude $t_a = 8834.98$.

In fig. 2b the filtered spectrum $s(x)$ of B'(x) is plotted vs x. $s(x)$ is the folding of the residuum B' with the detector response function with opposite argument. This procedure enhances any response function shaped hidden signal from the background [3]. In our case $s(x)$ is given by

$$s(x) = \sum_{x_i} B'(x_i) \frac{2}{p_w} \sqrt{\frac{\ln 2}{\pi}} \exp\left(-4\ln 2 \cdot \left(\frac{x - x_i}{p_w}\right)^2\right)$$

Since $s(x)$ is smaller than the 1.28 σ points in the whole x range, for the given B'(x) no claim can be made at 90 % C.L. for the observation of statistically significant positive values of the amplitude, i.e., for the existence of massive neutrinos. In fig. 2 the position of the weak interacting particle with $E_{o\nu} = 33.9$ MeV corresponding to $T = 1.70$ MeV is drawn which was reported to have been observed with the KARMEN detector [4].

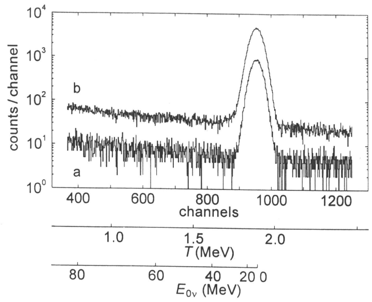

Fig. 1: Charge spectra showing triton events after μ^- capture in ^{3}He. The charge channel width is 43.3e. T means triton energy, $E_{o\nu}$ ν rest energy. a. Charge collected on anode B1. b. Charge collected on B1, B3, B4, B5.

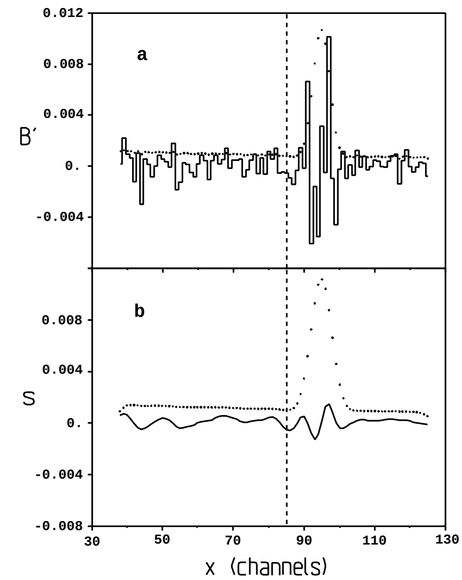

Fig. 2: Quantities derived from the data of fig. 1a vs charge channels x. The charge channel width is 433 e. The dashed line corresponds to $T = 1.70$ MeV and $E_{o\nu} = 33.9$ MeV. a. Residuum B'. The dots indicate the statistical standard deviation σ. b. Filtered spectrum s of B'. The dots indicate 1.28 σ.

References

[1] A. A. Vorobyov *et al.*, Hyperfine Int. **101/102** (1996) 413
[2] W. Schott *et al.*, ibid., p. 445.
[3] N. De. Leener-Rosier *et al.*, Phys. Rev. **D43** (1991) 3611
[4] B. Armbruster *et al.*, Phys. Lett. **B348** (1995) 19