Precision Measurement of Nuclear μ Capture by ^{3}He

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

[a] Austrian Academy of Sciences, Institute for Medium Energy Physics, A-1090 Vienna
[b] Petersburg Nuclear Physics Institute, Gatchina 188350
[c] University of Victoria, Victoria B.C. VW8 2Y2
[d] University of California and Lawrence Berkeley Laboratory, Berkeley CA, 94720
[e] Universite Catholique de Louvain, B-1348 Louvain-La-Neuve
[f] Paul Scherrer Institut, CH-5232 Villigen PSI
[g] Russian Research Center, Kurchatov Institute, Moscow 123182

In 1994 we described [1] a new experiment at PSI with the goal to determine the spin-averaged rate Λ^{stat} of the nuclear muon capture reaction

$$\mu^- + {}^3\text{He} \longrightarrow \nu_\mu + {}^3\text{H} \qquad (1)$$

at high precision. This reaction probes the elementary semi-leptonic weak interaction process $\mu^- + \text{p} \rightarrow \text{n} + \nu_\mu$ and due to its simplicity (superallowed transition in the $A = 3$ nuclear system) it is directly sensitive to the induced pseudo-scalar coupling constant g_P.

The data from a run of four weeks in 1993 were independently analyzed by two subgroups of our collaboration, and consistency was found. Based on $3.75 \cdot 10^8$ muon stops registered in a well defined fiducial volume, we have identified $1.14 \cdot 10^6$ tritons of 1.9 MeV from reaction (1) which led after a number of small corrections to the preliminary result [2]

$$\Lambda^{\rm stat}(\text{exp}) = [1496 \pm 3(\text{stat}) \pm 3(\text{syst})]\,\text{s}^{-1}. \qquad (2)$$

This result is by more than an order of magnitude more precise than any previous measurement. At present, we are further investigating and discussing the systematic accuracy of the experiment.

Our experimental result can be analyzed in the framework of the elementary particle model (EPM) following the work of Congleton and Fearing [3]: $\Lambda^{\rm stat}$ defines a correlation between the form factors F_A and F_P shown in fig. 1. Using $F_A(-0.954 m_\mu^2) = 1.052 \pm 0.011$ extrapolated from tritium beta decay, a value of $F_P = 21 \pm 3$ can be extracted. The EPM approach yields $\Lambda^{\rm stat}(\text{EPM}) = [1497 \pm 21]\,\text{s}^{-1}$, in very close agreement with our experiment. Our result coincides thus exactly with the prediction from the partially conserved axial-vector current hypotesis (PCAC) which was the basis of calculation [3].

During 1995 Congleton and Truhlik [4] performed a microscopic calculation of reaction (1) by explicitely calculating the contribution from meson exchange currents (MEC) to the vector and axial parts of the weak nuclear current. Their new prediction is $\Lambda^{\rm stat}(\text{MEC}) = [1502 \pm 32]\,\text{s}^{-1}$, again in excellent agreement with our experiment and the EPM approach.

This experiment has produced additional results of general interest, namely a very detailed measurement of the breakup channels [5] and an upper limit for the admixture of heavy neutrinos [6]. Limits on capture from the 2s mesic-atom level as well as the transition rate between the mesic-atom hyperfine levels were also obtained.

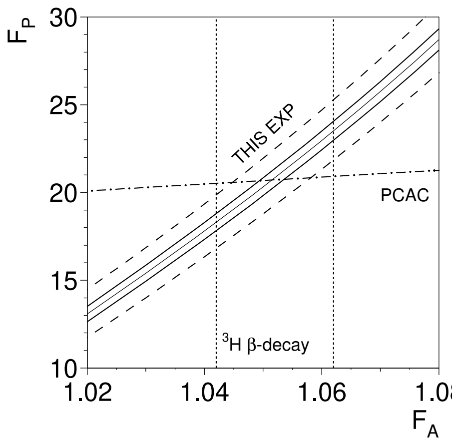

Fig. 1: Plot of pseudo-scalar F_P vs. axial F_A form factors showing the constraints by our experiment (solid lines; dashed lines with errors in F_V and F_M added). The vertical dotted lines show the constraints on F_A extrapolated from tritium β decay; the dash-dotted line is from the PCAC relation.

References

[1] PSI Annual Report 1994 / Annex I, p. 38.
[2] D.V. Balin et al., in Few-Body Systems Suppl. 8,ed. R. Guardiola, Springer (1995) 248; A.A. Vorobyov et al., Proc. μCF-95, to be publ. in Hyp. Int.
[3] J.G. Congleton and W.H. Fearing, Nucl. Phys. **A552** (1993) 534.
[4] J.G. Congleton and E. Truhlik, Proc. μCF-95, Dubna; and to be published in Phys. Rev. C (1996).
[5] E.M. Maev et al., Proc. μCF-95, Dubna.
[6] W. Schott et al., Proc. μCF-95, Dubna.