9 Neutrino Masses and Mixing

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The masses of the neutrinos are known to be small when compared with the masses of their charged partners. How small is unknown, however. If the neutrino masses are nonzero, it is considered likely that there is also neutrino mixing. In our project we are using β–spectroscopy to investigate these questions. Mixing would mean in this case that the electron neutrino, emitted in β–decay, is described by a superposition of states with two or more different masses m_i. The signature would be a characteristic 'kink' in an otherwise smooth β–spectrum at an energy $E_0 - m_i$, where E_0 is the endpoint energy for zero neutrino mass.

The objective of the project is a systematic search with high sensitivity in the β–decay of the isotopes ^{63}Ni and ^{35}S for neutrino masses up to 100 keV. The project is now nearly completed. The last measurements were performed in spring 1998. Thereafter we had to disassemble the experiment for the reason that on this location at the Paul-Scherrer-Institute the new Swiss-Light-Source is being built.

A detailed description of the β–spectrometer, some auxiliary experiments and simulations of electron scattering in the spectrometer have been published [1]. The measurements with ^{63}Ni formed the basis of P. Wenk's dissertation [2] and the final results have been published [3]. A new method for preparing thin ^{35}S–sources [4], the measurements with ^{35}S, and preliminary results are described in the dissertation of L. Palermo [5]. The final results should be ready for publication shortly.

9.1 Calibration

The ^{63}Ni–source contained a small contamination with ^{109}Cd and the K conversion line showed up as a small peak in the measured ^{63}Ni spectrum at $E = 62.25$ keV, that is below the endpoint $E_0 = 67$ keV. The peak could be corrected in the analysis and was not a serious problem. As the L conversion lines are well above E_0, the ^{109}Cd contamination could be used to test the calibration and the computed resolution of the spectrometer. Figure 9.1

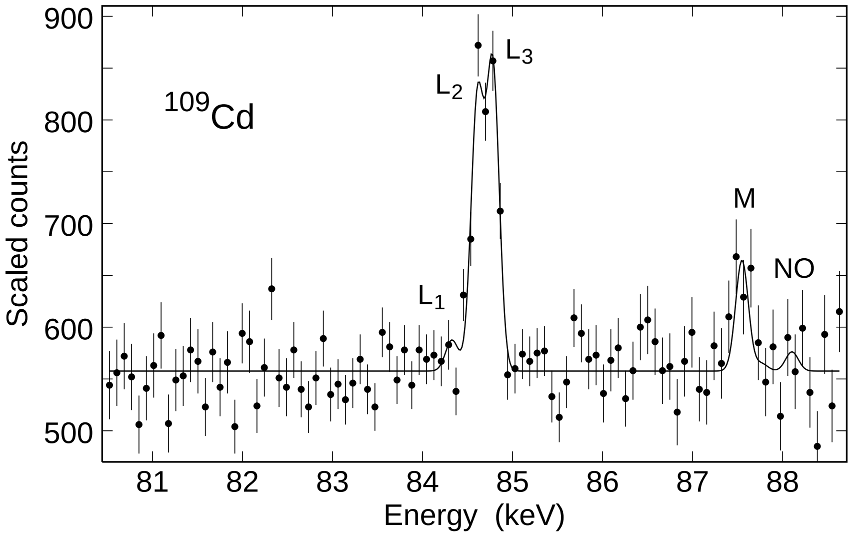

Figure 9.1: *Measured conversion line spectrum of ^{109}Cd contamination (points) and best fit (line).*

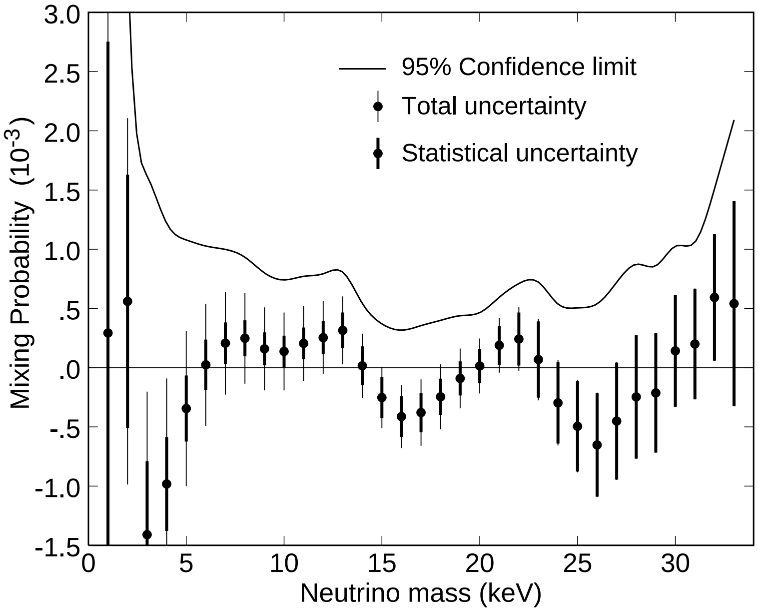

Figure 9.2: *Best fit (points) of the mixing probability as a function of assumed neutrino mass, from the ^{63}Ni data. The error bars combine statistical and systematic errors. The solid line is an upper limit at 95 % confidence.*

shows the data of a measurement over an energy range containing the L and M lines. The L_2 and L_3 lines are clearly seen. The M lines are also significant but not resolved. The data were fitted assuming the line shapes to be given by the computed spectrometer resolution function for this setting. The relative line intensities and the energy differences of the lines were taken from the literature [6]. A good fit was obtained, showed the reliability of the computed spectrometer resolution.

9.2 Results for ^{63}Ni

The ^{63}Ni β–spectrum was measured over an energy range from about 33 to 68 keV. The total number of counts in the data set was 5.2×10^9. Neutrino mixing was search for assuming the mass of a heavy neutrino in the range up to 33 keV. The fitted mixing probability is plotted in figure 9.2. The error bars combine statistical and systematic errors. As can be seen, there is no indication for neutrino mixing. The solid line in figure 9.2 is an upper limit at 95 % confidence.

9.3 Results for ^{35}S

The ^{35}S source, prepared as described in Ref. [4], had an initial activity of 5.3 mCi and was supported by a thin (2000 Å) foil of Kapton. The β–spectrum of ^{35}S was measured from 45 keV to 170 keV (endpoint of ^{35}S is $E_0 = 167$ keV). This range was divided in five overlaping regions which were measured separately, starting at high energy to avoid too large counting rates. The total number of counts is 3×10^{10} in the complete data set.

Preliminary results from about half of the available ^{35}S data is shown in figure 9.3. The analysis is not complete, however, for the following reason. During the measurements, the thin support foil of the ^{35}S source broke and had to be repaired as there was no time available to make a new source. The repair parts had necessarily a mass large compared with the thin

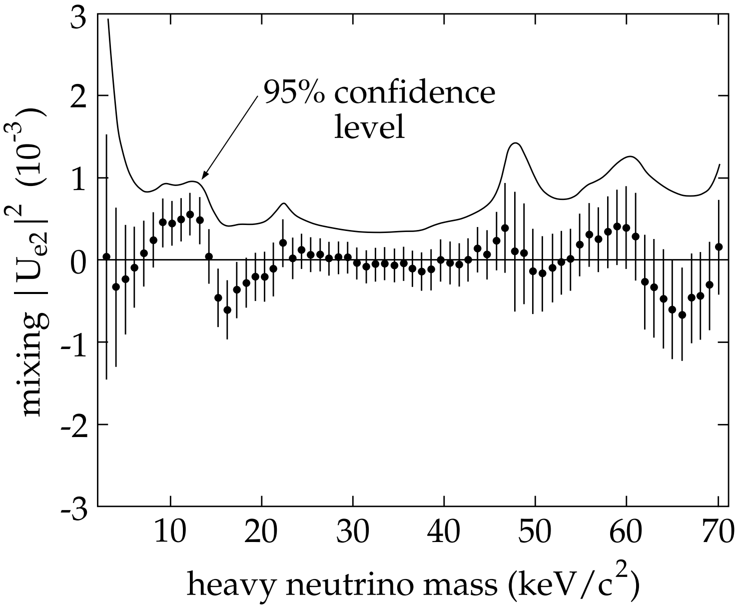

Figure 9.3: *Preliminary results from a part of the* ^{35}S *data. Plotted is the best fit (points) of the mixing probability as a function of assumed neutrino mass. The error bars combine statistical and systematic errors. The solid line is an upper limit at* 95 % *confidence.*

foil and thus scattered a significant number of electrons into the acceptance angle of the spectrometer. We are confident that an appropriate correction can be computed by Monte Carlo simulation.

9.4 Conclusion

The measurements have been successfully completed. The remaining results will be published shortly.

References

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