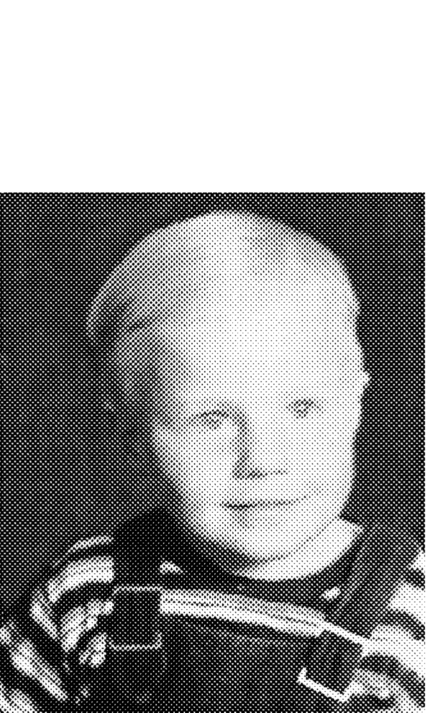

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Limit on the Muon Neutrino Mass from $K^0\mu3$ Decay Spectra

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Recent upgrades to the BNL-AGS have made it possible to make many high statistics measurements. Here we will consider the statistics and the resolution needed to improve the limit on the muon neutrino mass using $k_L{}^o \to \pi^\pm\mu^\mp\,\nu_\mu$ decays. The method relies on the shape of the invariant mass distribution of the pion and the muon, $m_{\pi\mu}$, near the end point where the neutrino energy is low in the center of mass[1]. The use of simultaneously detected $k_L{}^o \to \pi^+\pi^-$ events to calibrate the mass scale and understand the resolution of the spectrometer reduces the sensitivity of this method to previously measured particle masses and to the magnetic field in the spectrometer. An additional check on the experimental method can be obtained by measuring the endpoint of $k_L{}^o \to \pi^\pm e^\mp\,\nu_e$ decays in which one does not expect to observe a non-zero neutrino mass at the sensitivity level of this experiment. Finally, by comparing the end point spectra for neutrinos and antineutrinos one can obtain the most stringent limit on a neutrino-antineutrino mass difference, a non-zero value of which would violate CPT invariance. The only other method that limits a neutrino-antineutrino mass difference is the measurement of π^+ and π^- lifetimes, if one attributes the difference in the lifetimes to the dependence of the decay amplitude on neutrino mass[2,3].

The V-A theory of weak interactions predicts little dependence of the k_{l3} matrix element on the neutrino mass. The boundary of the Dalitz plot does, however, depend on the neutrino mass. In the case of zero neutrino mass the $m_{\pi\mu}$ distribution approaches m_k with the first derivative zero, and in the case of non-zero neutrino mass the same distribution terminates before approaching m_k. The measured quantity, $m_{\pi\mu}$, at the endpoint is simply related to the neutrino energy in the kaon center of mass by the following formula:

$$E_\nu = \frac{m_k^2 - m_{\pi\mu}^2 + m_\nu^2}{2m_k} \approx \frac{(m_k + m_{\pi\mu})}{2m_k}(m_k - m_{\pi\mu}) \approx m_k - m_{\pi\mu}.$$

Since m_k is effectively measured in the same experiment by using $k_L{}^o \to \pi^+\pi^-$ decays, the neutrino energy measurement is independent of the kaon mass. Furthermore, the

approaches the kaon mass with zero slope so that in the case of zero neutrino mass there are no events at the end point. Most possible systematic errors, such as variation in the spectrometer acceptance over the fitted mass range or background contamination, will either change the shape smoothly or cause the overall normalization to shift. A non-zero neutrino mass should cause a relatively abrupt change in the shape only at the endpoint, therefore the systematic errors should not be a major difficulty. This, of course, will have to be studied with actual data. I have used the geometric dimensions of the E871 spectrometer, the appropriate kaon spectrum, and the requested intensity to compute the rate of $k_L{}^o \to \pi^\pm\mu^\mp\,\nu_\mu$ events with $m_{\pi\mu} > 493.5$ MeV to be about 300 per hour. E871 should be able to collect more than enough events in a 4000 hour run for this measurement.

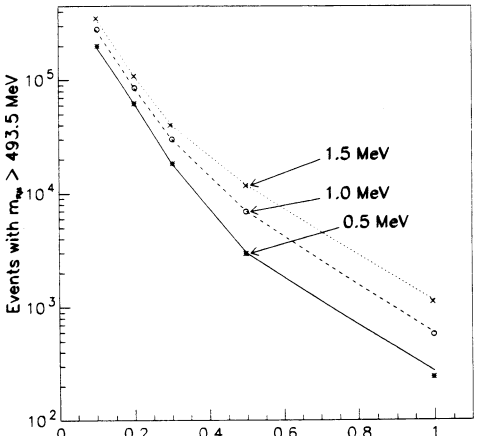

Figure 1. Number of $k_L{}^o \to \pi^\pm\mu^\mp\,\nu_\mu$ events needed with $m_{\pi\mu} > 493.5$ MeV versus the muon neutrino mass sensitivity for various mass resolutions. This was calculated assuming that the data will be binned with a binsize equal to or smaller than the mass sensitivity. A maximum likelihood method using the small event statistics at the endpoint should yield somewhat better sensitivity.