1 Tests of Lepton-Flavor Conservation at PSI

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Various anomalies in the fluxes of solar [1], atmospheric [2] and beam dump neutrinos [3] give strong evidence that neutrino states mix, which is incompatible with the neutrino mass degeneracy assumed in the Standard Model. Consequently, charged-current weak interactions do not conserve generation number, neither in the quark nor in the lepton sector.

Many extensions of the Standard Model allow also neutral interactions between the generations. Flavor-changing neutral currents (FCNC) among leptons would yield an unambiguous signal for new physics. See [4, 5, 6] for some reviews. Theoretical study of physics beyond the Standard Model presently concentrates on supersymmetry and grand-unification. Supersymmetric models which do not conserve R-parity, i.e. those allowing transitions between the known particles and their super-partners, automatically lead to processes that do not conserve lepton and/or baryon number. Stringent constraints on various products of R-parity violating couplings have been derived from the observed upper limits on $\mu^- \to e^-$ conversion [7]. As discussed first by Hall, Kostelecky and Raby [8] flavor-violation may be introduced in grand-unified theories by loop corrections above the unification scale. Later it was realized that the flavor-violation observed in the large top-Yukawa coupling leads to measurable rates for LFC-violating processes [9], in particular for the decay $\mu \to e\gamma$, even in standard SUSY SU(5).

1.1 $\mu \to e$ conversion in muonic atoms: the SINDRUM II project (PSI proposal R-87-03)

With some three years delay, the PMC magnet reached its design field of 1.5 T early in August 1998. The PMC magnet is a 8.5 m long super-conducting solenoid which couples the new πE5 beamline to the SINDRUM II spectrometer. Ever since then stable operation at a field strength around 1.1 T could be maintained. As a result we are in the position now to increase the beam intensity by one order of magnitude and push the sensitivity for conversion on titanium into the region of a few times 10^{-14}, i.e. the goal set in the proposal. This breakthrough was achieved by improving the geometry at the far end of the PMC, where it enters the SINDRUM II spectrometer, and by lowering the temperature of the radiation shields from 70 K to 10 K. The price which had to be paid was a separation of the two magnets by 20 cm and some modifications in the SINDRUM II mirror plate and photomultiplier lightguides which took place in the beginning of 1999.

Towards the end of 1998 extensive beam studies have been performed and during three weeks data were taken on lead. The main problem that we were faced with was the heavy load of beam electrons on the spectrometer. The πE5 beam line transports about 3×10^9 s^{-1} electrons, independent of the selected beam momentum. At momenta above $\approx$ 70 MeV/c these electrons would completely saturate the SINDRUM detector systems. Fortunately, by moderating the beam at the πE5 exit and by proper selection of the resulting muon momentum in the PMC entrance collimator a significant reduction of the electron contamination can be achieved.

In 1999, after some further beam optimisation, we intend to finish the lead measurements before switching to a titanium target. It is our aim to reach a single-event sensitivity around 2×10^{-14} for titanium.

1.1.1 Search for $\mu \to e$ conversion on gold (1997 data)

In 1997 the PMC field could not yet be raised above 0.3 T and thus only a relatively low beam momentum could be selected. Data were taken on a heavy target, using a 26 MeV/c cloud-muon beam. Thanks to the low beam momentum resulting in a narrow range distribution a target with a total weight of only 18 g could be used. For reasons of mechanical stability we choose gold rather then lead. The low-momentum beam offers a number of advantages, to be balanced against the relatively low stop rate of 6×10^5 s^{-1}: negligible backgrounds induced by pions, muon decay in flight and scattered beam electrons and, as a result of the low target mass, a superb 0.7 MeV/c momentum resolution at the conversion energy.

Figure 1.1 shows preliminary results of the data analysis. The measured momentum distribution is nicely reproduced, both in shape and in number of events, by a simulation of muon decay in orbit. No events are seen in the signal region for μe conversion. At present we are still evaluating the sensitivity obtained, but the resulting upper limit will certainly improve on the best previous result on a heavy target [10].

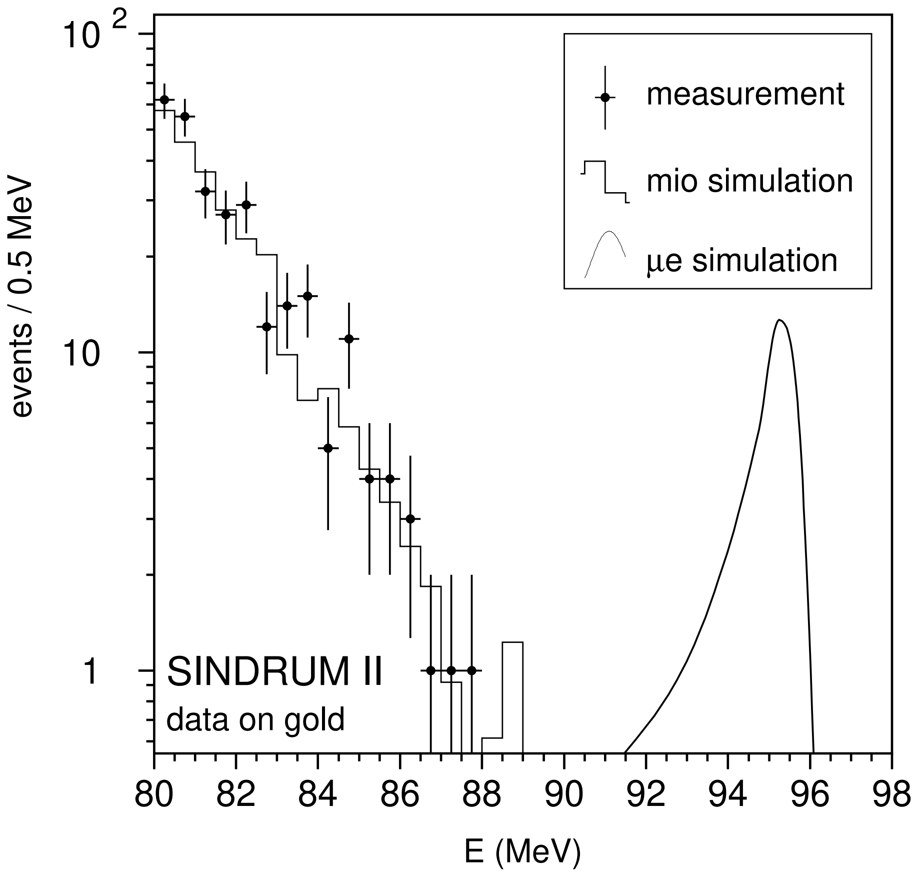

Figure 1.1: Endpoint region of the energy distribution of electrons emitted from muonic gold atoms. The measured distribution can be attributed completely to muon decay in orbit (mio). The precise normalisation is still under study.

1.1.2 Search for $\mu \to e$ conversion on lead (1998 data)

The new beamline allowed us to reach our former sensitivity for conversion on lead in less than a day so a dramatic improvement in sensitivity is anticipated. Most sources of background are enhanced compared to the case of titanium and can thus be studied more efficiently. In particular the decay-in-flight background is much more serious since the conversion energy is lowered by the binding energy of about 10 MeV.

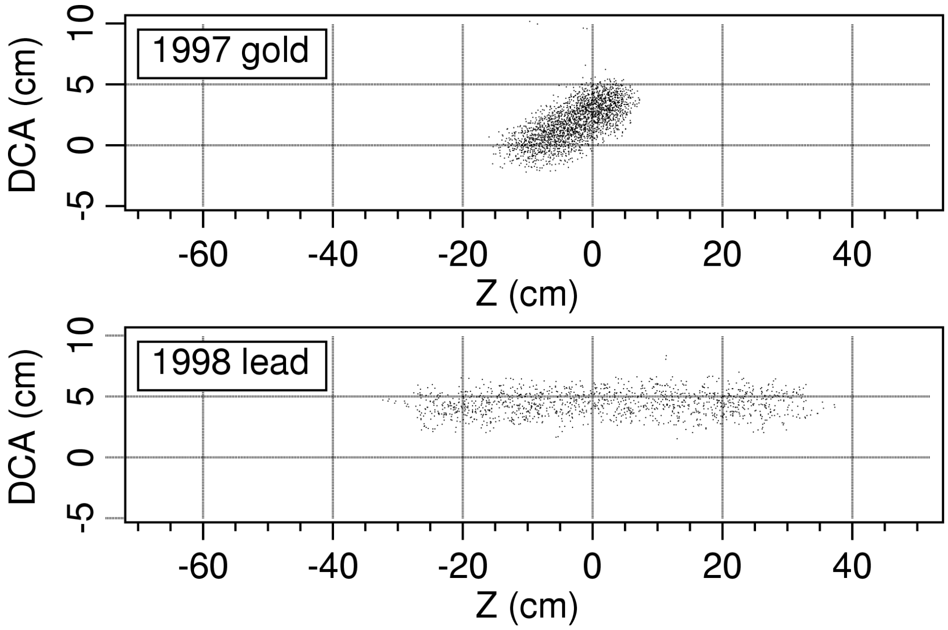

Figure 1.2: Spatial distribution of the point of closest approach to the spectrometer axis of the reconstructed trajectories for the two measuring periods. Clearly visible are the conical and tube shapes of the two targets.

Since the beam particles passing the narrow collimator at the PMC entrance periodically return to the beam axis a long narrow tube was used as a target (see Fig 1.2), resulting in a well-defined threshold on the transverse momentum selected by the spectrometer. For the first time a second-level readout trigger was installed which uses the late drift-chamber signals. At present the reduction compared to level 1 is a factor 20. Thanks to the improved trigger selectivity (the fraction of fully reconstructed muon-induced events in the on-line data-analysis increased to more than 10% of the recorded events) the readout deadtime could be kept below 15%. These data are still being analyzed as well. We should know soon whether in particular the pion background is under control which may affect the beam settings for the major six months beam period scheduled for 1999.

Spatial distribution of the point of closest approach to the spectrometer axis of the reconstructed trajectories for the two measuring periods. Clearly visible are the conical and tube shapes of the two targets.

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