3 Search for μ-e Conversion with SINDRUM II

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SINDRUM II

Observations on solar and atmospheric neutrinos indicate that neutrinos mix so lepton flavor would not be conserved. SINDRUM II tests lepton-flavor conservation by a search for μe conversion in muonic atoms. The process would result in electrons at fixed momentum (depending on atomic number) around 100 MeV/c.

In recent years a dedicated beamline was brought into operation in the πE5 area at PSI. The major element is a 9 m long superconducting magnet. In spring 2000, after a long series of modifications, reliable operation of this PMC magnet was obtained. In the following months data were taken on gold. Conversion on a heavy nucleus might be enhanced relative to a medium Z target, such as titanium [1].

See Fig. 3.1 and Fig. 3.2 for a description of the experimental setup.

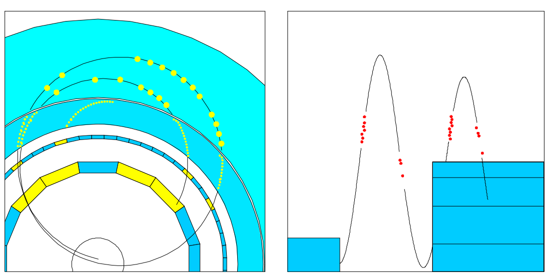

Figure 3.1: *Traces left by a 100 MeV/c electron. The particle made two full turns before reaching an endcap detector. Fits to the particle trajectory are indicated.*

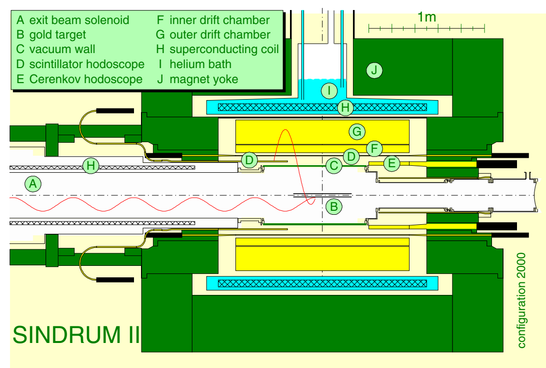

Figure 3.2: *The* SINDRUM II *spectrometer during the year 2000 measurements. Muons are transported to the gold target with the help of a 9 m long superconducting solenoid coupled directly to the spectrometer magnet.*

Radiative pion capture (RPC), followed by e^+e^- pair production, can be a major source of background. A pion reaching the gold target has a chance of order 10^{-5} to produce an electron in the energy region of interest, so the pion stop rate must be below one every ten minutes. At the PMC entrance the beam contains similar amounts of muons and pions. Since the pion range in matter is about half as large as the corresponding muon range the pion contamination can be reduced strongly with the help of a moderator at the PMC entrance. Only one out of 10^6 pions may cross this moderator. Typically 99.9% of them would decay before reaching the target. The requirement puts strong constraints on the high-momentum tail transported by the beam line which could be met after a careful optimization of the beam settings. Figure 3.3 shows muon range distributions before and after the optimization procedures. The dramatic reduction of the tails in the range distribution was achieved at the cost of $\approx$ 30% loss in beam intensity.

The target (see Fig. 3.4) was produced in a galvanic process to ensure the high purity required to suppress background from μ decay in orbit in low- and medium-Z contaminations.

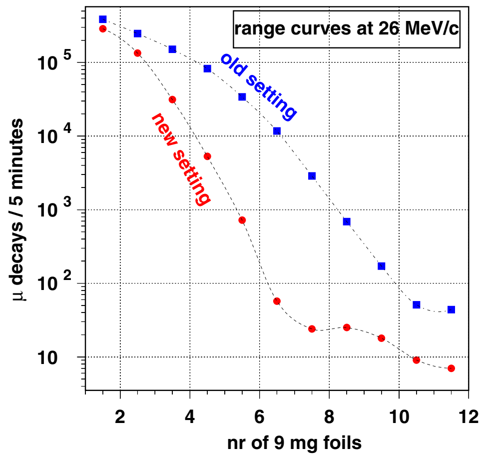

Figure 3.3: *Muon range curves at 26 MeV/c nominal beam momentum. Stopped muons were monitored through their decay electrons. Note a dramatic improvement in the slope obtained with the new beam setting.*

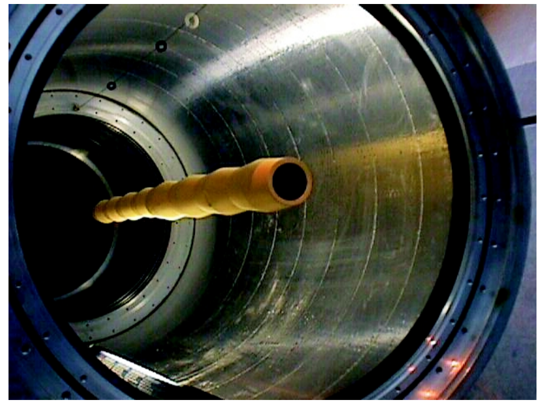

Figure 3.4: *The hollow gold target (wall thickness 30 microns only).*

Due to the lower muon binding energy such background reaches beyound the energy of the hypothetical μe conversion electrons in gold (95.6 MeV).

During an effective measuring period of 75 days about 4×10^{13} muons stopped in the gold target. Figure 3.5 shows as a preliminary result various momentum distributions. The main spectrum, taken at 53 MeV/c, shows the steeply falling distribution expected from muon

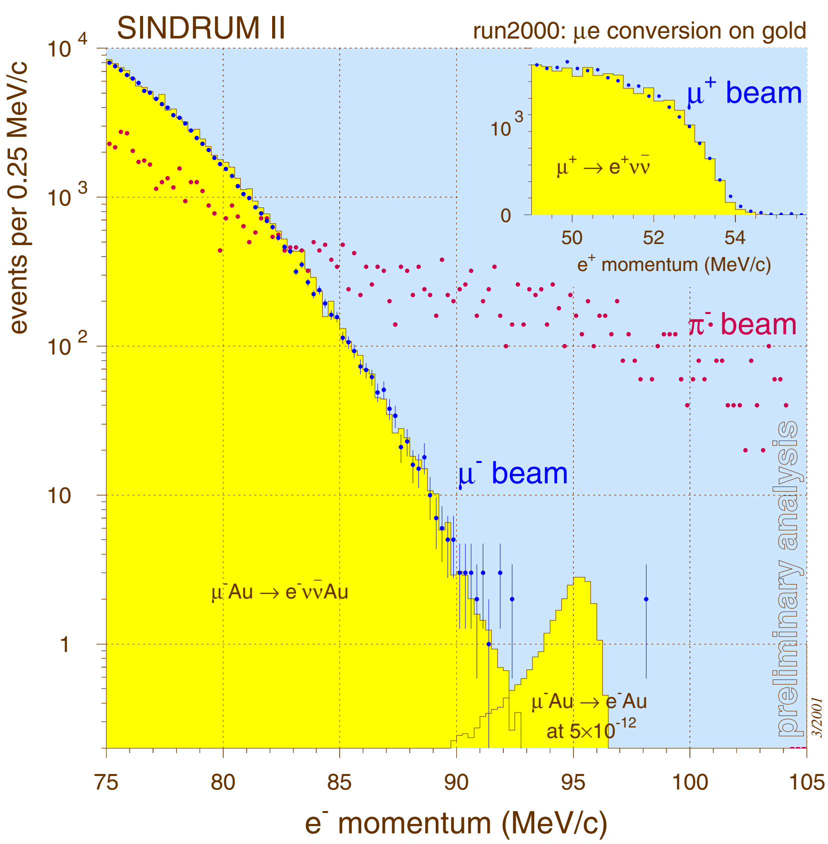

Figure 3.5: *Momentum distributions for three different beam momenta and polarities:*

(i) 53 MeV/c negative, optimized for μ^- stops

(ii) 63 MeV/c negative, optimized for π^- stops

(iii) 48 MeV/c positive, for μ^+ stops.

The 63 MeV/c data were scaled to the different measuring times. The μ^+ data were taken at reduced spectrometer field.

decay in orbit. Two events were found at higher momenta, but just outside the region of interest. The agreement between measured and simulated positron distributions from μ^+ decay gives us confidence in the momentum calibration. At present we have no hints about the nature of the two high-momentum events: they might be induced by cosmic rays or RPC, for example. Both processes result in flat momentum distributions such as shown by the data taken at 63 MeV/c (see Fig.3.5).

Presently we are still studying the various rates and efficiencies that enter the calculation of the new limit on the branching ratio. As a preliminary result we obtain a single-event sensitivity slightly below 2×10^{-13} which corresponds to a 90% C.L. upper limit below 5×10^{-13}. This constitutes an improvement by two orders of magnitude of the previous best result on a heavy target [2].

References

[1] T.S. Kosmas, Z. Ren and A. Faessler, Nucl.Phys. **A**665 (2000) 183, and references therein.

[2] SINDRUM II Collaboration, W. Honecker *et al.*, Phys.Rev.Lett. **76** (1996), 200.