MUONIUM TO ANTIMUONIUM CONVERSION EXPERIMENT AT DUBNA PHASOTRON

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Muonium / $M \equiv \mu^+ e^-$ / to antimuonium / $\overline{M} \equiv \mu^- e^+$ / transition is of interest in connection with a leptonic number nonconservation problem. $M - \overline{M}$ conversion requires nonconservation of the leptonic numbers: $\Delta L_e = -2$; $\Delta L_\mu = 2$. An existence of interaction H, transferring M into $\overline{M}$, to be supposed the true energy eigenstates will be the superpositions of M and $\overline{M}$: $M_{1,2} = (M \pm \overline{M})/\sqrt{2}$. If at $t = t_0$ the system was pure muonium, then at time t it becomes:

$$[\, M_1 e^{-im_1 t - \Gamma_\mu t/2} + M_2 e^{-im_2 t - \Gamma_\mu t/2} \,]/\sqrt{2},$$

where Γ_μ is a muon probablity; $m_{1,2}$ - masses of $M_{1,2}$ respectively. Therefore, ostillations $M - \overline{M}$ occur with a period $T = 2\pi/|\delta|$, ($\delta = 2 < \overline{M} \mid H \mid M >$), and the probability for muonium to disintegrate as antimuonium (conversion probability) [1]: $W_{\overline{M}} = |\delta|^2/2\Gamma_\mu^2$. Assuming that H has an ordinary V—A structure with a constant $G_{M\overline{M}} = G_F \cdot f$, we obtain $W_{\overline{M}} = 2.5 \cdot 10^{-5} f^2$.

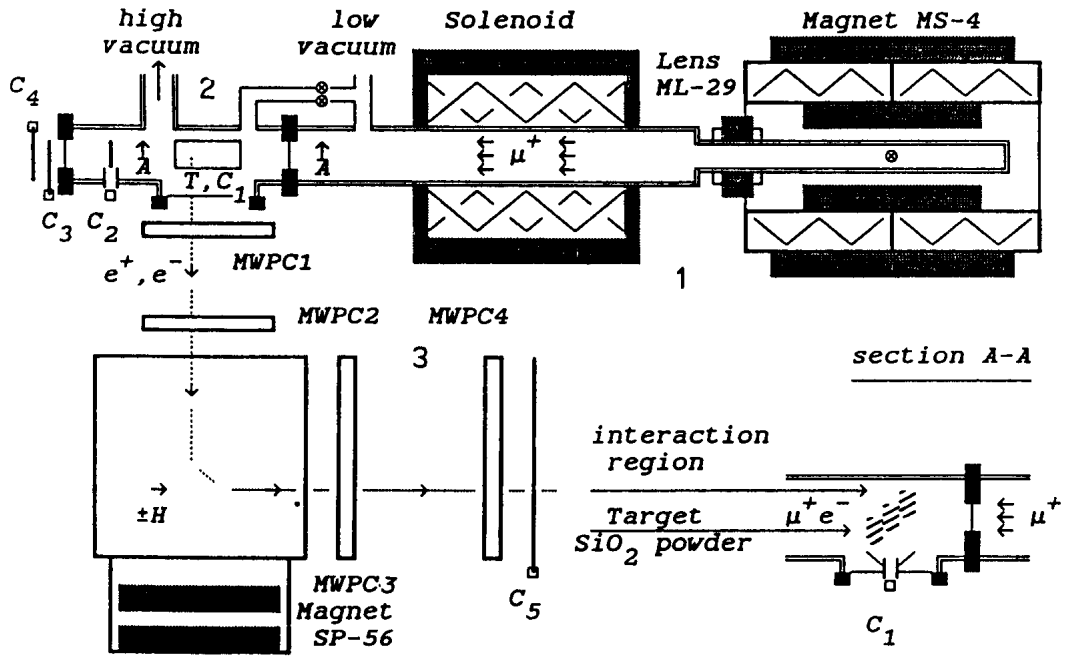

Fig. Scheme of experimental set-up

The experimental investigations at TRIUMF [2,3] and LAMPF [4], give the following restriction on $G_M\overline{M}$: $G_{M\overline{M}} < 0.29\, G_F$ [3] and $G_{M\overline{M}} < 0.16\, G_F$ [4]. While the interval $G_{M\overline{M}}$ (10^{-2}–10^{-6}) is the most interesting one from the theoretical point of view [5].

Evidently the further progress in the experimental study of the M–$\overline{M}$ conversion requires the use of the low background methods. In the paper [6] we proposed the technique which enables one to indentify the

$M-\overline{M}$ conversion by single acts. The idea is to record the high energy electrons from the decay $\mu_- \to e^- \tilde{\nu}_e \nu_\mu$ by magnetic spectrometer. The peculiarity of this technique is that the background processes' probability is essentially lower than the existing estimation for $W_{\overline{M}}$, and besides that, we have an instrument to suppress these processes by cutting a registered interval of electron energy in the high - energy end of the spectrum.

To control the results of [6] and to choose a cutting threshold for electron energy spectrum experimental arrangement in 1989—1990 at muon beam of the LNPI synchrocyclotron is proposed. We have performed an investigation of positron and electron energy spectra for particles, flying out from the target after positively charged muons (energy ~80 *MeV*) have stopped in it. The magnetic spectrometer, consisting of a magnet SP-56 and wire proportional chambers with delay line readout [7] was used.

The probability estimations for a background electron emission as a function of E_{th}, deduced from the presented data, and the calculated values for $e^+ \to e^-$ scattering processes (which dominate in the conditions of the experiment) are shown in the table. As it is seen from the table, the measured values of $e^+ \to e^-$ scattering on the set-up elements are in a good agreement with the calculated ones.

The preparation and the first run of this experiment was carried by the LNPI and the JINR groups together in 1991 at Dubna phasotron.

The scheme of the experimental set-up is shown in fig.1. It consists of road surface muons (*1*), zone of interaction with the possibility to analyze the μSR-signal of muonium (*2*), magnetic spectrometer (*3*). A collimated 22 MeV/c subsurface μ^+ beam [8] with a momentum bite of $\Delta P/P \approx 6\%$ and a duty factor of 75% were used. The incoming muons were moderated and stopped in a fine SiO_2 powder target of 10 mg/cm^2 thickness where they formed M which diffused into the vacuum region (region of the $M-\overline{M}$ transition).

After passing through a 100 μm Al vacuum window, the decay positrons or electrons, with energies 30—52.8 *MeV* were observed in an array of four MWPCs. A wide-gap dipole magnet with a central field of 2.23 *kG* deflected decay e^+ and e^- in opposite directions. The plastic scintillator behind MWPC4 provided the timing signal on the candidate track.

The production of thermal muonium was studied by the method [9]. The incoming muons were counted in a 60 μm plastic scintillator and then stopped in a SiO_2 powder. For each track the time of flight between a pulse in the muon beam counter and a decay e^+ treck in the spectrometer were measured, and the point near the target, where muonium or free muon was before the decay was reconstructed. The production of thermal muonium in vacuum region was determined from the analysis of the time distribution of the $\mu-e$ decay positrons for the different vacuum regions near the target.

Throughout the 1991 at the subsurface μ^+ beam of the Dubna phasotron the following work has been carried out: 1) investigations of the parameters of the subsurface muon beam; 2) study of the background conditions in the experiment; 3) study of the production of thermal muonium from the SiO_2 powder in vacuum; 4) the first run of the muoniom to antimuonium conversion experiment was carried.

The preliminary result of analyses for the quantities $W_{\overline{M}}$ gave the value of $M_{\overline{M}} < 3.6 \cdot 10^{-6}$ ($G_{M\overline{M}} < 0.38\ G_F$). As one can see from the data mentioned above, this result equals to that obtained at muon factories.

The second run of the muonium to antimuonium conversion experiment is planned to be carried out in April-May 1992. Its fulfilment requires a modification of the road surface muons, the read-out system of the magnetic spectrometer, an improvement of the background conditions in the experiment. There is a hope that the second run of the experiment may improve the existing estimates of $W_{\overline{m}}$ at least by 10 times.

Table

Positron and background electron emission from the target

E_{th}, MeV	N_{st}	N_{e^+}	N_{e^-}	$W^{exp} = N_{e^-}/N_{e^+}$	W_{ex}^{exp}	W^{cal}
34	$7 \cdot 10^8$	14820	19	$1.3 \cdot 10^{-3}$	$2.5 \cdot 10^{-6}$	$6.6 \cdot 10^{-6}$
40	$1 \cdot 10^9$	10380	5	$4.8 \cdot 10^{-4}$	$9.3 \cdot 10^{-7}$	$4.6 \cdot 10^{-6}$

E_{th} — energy cutting threshold of $\mu - e$ decay spectra

N_{st} — number of muons stopped in target (Cu 6.3 g/cm^2)

N_{e^+} (N_{e^-}) — number of positrons (electrons) which were registrated in spectrometer

$W_{ex}^{exp}(W^{cal})$ — expected (calculated) value of ratio N_{e^-}/N_{e^+} for thin target (Al 0.027 g/cm^2)

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