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Search for $\mu^+ \rightarrow e^+\gamma$ down to 10^{-14} branching ratio

Research Proposal to Paul Scherrer Institut

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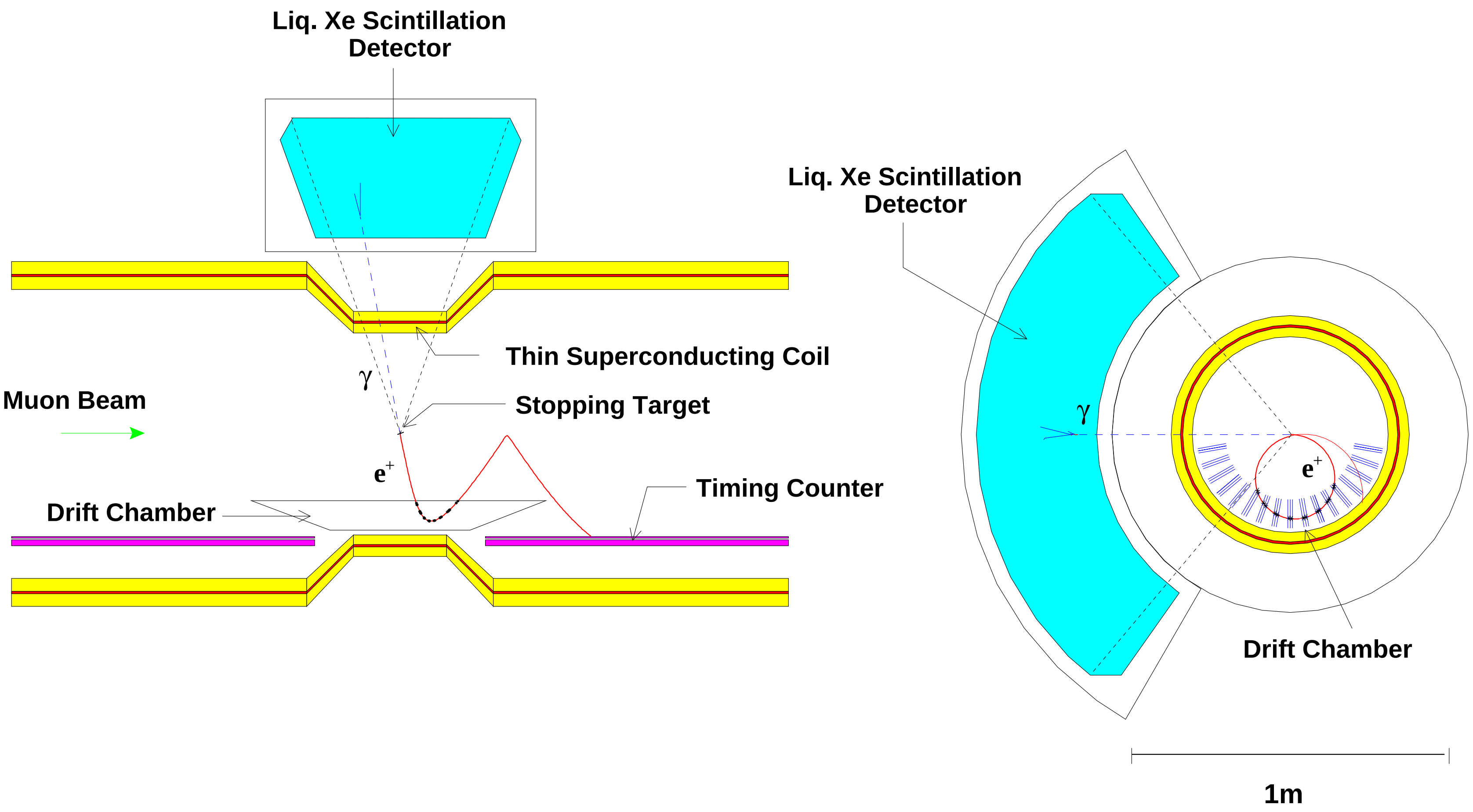

Figure 1: Schematic view of the detector

Summary of the Proposal

We propose to search for the lepton-flavor-violating decay $\mu^+ \to e^+\gamma$ with a sensitivity of 10^{-14}. The experiment will be conducted at PSI by using the πE5 beam, the most intense DC muon beam presently available in the world. Our intension is to utilize detector elements with best possible resolutions both on the e^+- and γ-sides, so that a background-free identification of the signal down to this small branching ratio can be obtained hopefully with a good margin.

Fundamental theories such as supersymmetric unification seem to generically predict that $\mu^+ \to e^+\gamma$ occurs with a decay branching ratio somewhere above 10^{-14}. We therefore consider that this experiment has a real chance of making a discovery, which will provide a stunning evidence for new physics beyond the standard model.

Even the non-observation of the decay at this sensitivity will provide a stringent constraint on the fundamental theories and on the general natures of the new physics, and thus will be of crucial importance in pointing future direction of the particle physics.

Recent discovery of the neutrino oscillation by Super Kamiokande increases the importance of this search perhaps tremendously. The see-saw mechanism induced by superheavy (10^{12} – 10^{15}GeV) right-handed Gauge singlets ($\nu_{\mathrm{R_i}}$) is considered to be a most promising candidate to explain the origin of the extremely small neutrino masses, measured by Super Kamiokande. It is pointed out that the off-diagonal slepton mass-matrices, also induced by the same right-handed singlets, will significantly contribute to the $\tau \to \mu\gamma$ and $\mu \to e\gamma$ decay rates.

It is further shown that $\mu^+ \to e^+\gamma$ branching ratio will determine or severely constrain the mass scale of the right-handed singlet $\nu_{\mathrm{R_2}}$, when combined with the Δm^2 and the mixing angle between ν_μ and ν_e, to be measured by the solar neutrino experiments. Therefore, $\mu^+ \to e^+\gamma$ decay can be the unique window to observe the isolated world of the right-handed Gauge singlets, postulated to exist at ultra high energies.

The sensitivity (1×10^{-14}) we aim is three orders of magnitudes below the limit recently set by MEGA experiment. In the frame work of the theories mentioned above, our sensitivity on $\mu^+ \to e^+\gamma$ corresponds to a sensitivity of 2.5×10^{-17} on the μ−e conversion process with the aluminum target, very similar to the sensitivity MECO proposal aims to reach.

A schematic view of the detector we propose is shown in Fig. 1.

A muon beam of intensity 1×10^8/sec with small emittances is created from the πE5 beam by a combination of collimaters, degraders and a beam transport solenoid, and is brought to stop in a thin target.

The momentum and the direction of the emerging e^+ are measured precisely by a "COnstant-Bending-RAdius (COBRA) spectrometer," composed of a solenoidal magnetic field with a field gradient. The field is arranged such that monochromatic e^+s from the target follow trajectories with constant projected bending radius, independent of the emission angle over a wide angular range. This allows us to sharply define the absolute momentum window of e^+ to be detected by drift chamber cells placed at outer most radii, thereby reducing the accidental pile-up of the Michel e^+ much more effectively than is possible with a simple solenoidal configuration

employed by MEGA. This new feature, together with the special arrangement of the drift chamber cells, make the pattern-recognition secure against the pile-up, specially with our beam rate, which is a factor 2.5 below the instantaneous beam rate (2.5×10^8/sec) MEGA had taken. Simulation shows the expected FWHM resolutions of 0.7% for the positron momentum and 9 mrad for the angle.

A hodoscope array of plastic scintillators is placed on each side of the spectrometer to measure the impact point and the timing of the e^+ with resolution (FWHM) of 2 cm and 0.1 nsec, respectively.

While all e^+ are confined inside the magnet by the bending, the gamma rays penetrate through the thin superconducting coil of the spectrometer with 95% transmission probability, and are detected by a liquid Xenon scintillation detector of "Mini-Kamiokande" type, which is a 0.8 m^3 volume of liquid Xe viewed by arrays of total 800 photomultipliers from all sides. We use only the scintillation light, and do <u>not</u> attempt to collect the ionization. Thus our photon detector is very simple. The scintillation pulse from the Xe is very fast and has a short tail, thereby minimizing the pile-up problem, which can further be reduced by off-line analyses of the image-pattern and the pulse-shapes. Construction and long-term operation of a prototype have been very successful. Tests on the prototype and a full simulation show that one can expect, for 52.8 MeV γ rays, FWHM resolutions of 1.4% for the energy-, 4 mm for the position- and better than 0.1 nsec for the timing-measurements.

Detailed studies and simulations indicate that we can reduce the background well below our sensitivity, with all these features of the detector. We fully realize that the experiment is a difficult one. At the same time, we are confident that we can conduct the experiment and arrive at the sensitivity. This confidence is based on our past experiences of performing various projects ranging from collider to balloon-borne experiments, in which most of the detector elements we propose were actually used.

We request a total of 6,000 hours of beam time starting in year 2003 with a proton intensity above 1 mA. Tests and engineering runs with πE5 will be requested in years 2000 to 2002. A dedicated in-house group of physicists and engineers at PSI will be a necessity.

The collaboration invites scientists who share common physics interests and detector strategies to join this project.