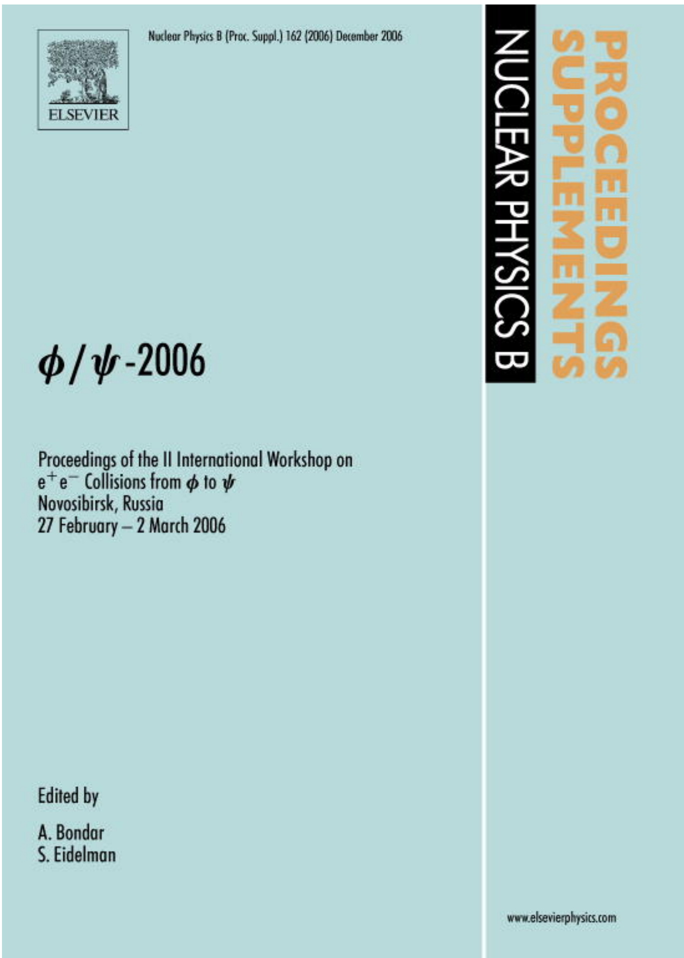
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Status of the MEG expriment $\mu \to e\gamma$

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The MEG experiment searches for the Lepton Flavor Violating (LFV) decay $\mu \to e\gamma$ down to a branching ratio of 10^{-13}. It is currently being built at the Paul Scherrer Institute in Switzerland, and in 2006 will go into commissioning and in 2007 into data taking. The goal is to achieve a significant result before the start of the LHC experiments.

1. Introduction

In the Standard Model (SM), quark mixing through the CKM matrix and neutrino oscillations are now well established. The question may be asked why no mixing in the charged lepton section has been observed. In fact lepton flavor can even change in the SM, mediated through a virtual W boson. But since the branching ratio scales with the neutrino mass over the W mass by the fourth power, the result is in the order of 10^{-60} and thus immeasurably small. In the framework of Supersymmetric (SUSY) models, however, a branching ratio for the $\mu \to e\gamma$ decay is predicted in the order of 10^{-12}, which is just below the current experimental limit of 1.2×10^{-11}. Due to the extremely high suppression of the SM contribution to this decay, it is a very clean signature of physics beyond the SM.

The experimental search for LFV in the $\mu \to e\gamma$ decay or in the $(\mu - e)$ conversion has a long history dating back to 1947. The upper limits of the branching ratios were constantly lowered down to 1.2×10^{-11}, 1.7×10^{-12} and to 1.0×10^{-12} for the $\mu \to e\gamma$ decay[1], the $(\mu - e)$ conversion in Titan[2], and to the $\mu^+ \to e^+e^+e^-$ decay[3], respectively. It should be noted that in the framework of SUSY, the $\mu \to e\gamma$ branching ratio is enhanced by a factor of approximately 200 over the $(\mu - e)$ conversion, and thus the current experimental limits probe SUSY at about the same level. The most recent measurements on $(\mu - e)$ conversion have been performed with the SINDRUM II detector at PSI, Switzerland. The data analysis is still going on for $(\mu - e)$ conversion on titan and gold, and it is expected that a result slightly better than the current values will be published within 2006. The SINDRUM II experiments were limited by background from pion decay in flight, and thus new experiments are planned which suppress the pion background considerably. The MECO experiment was unfortunately terminated in 2005, which leaves the PRISM/PRIME[4] project at J-

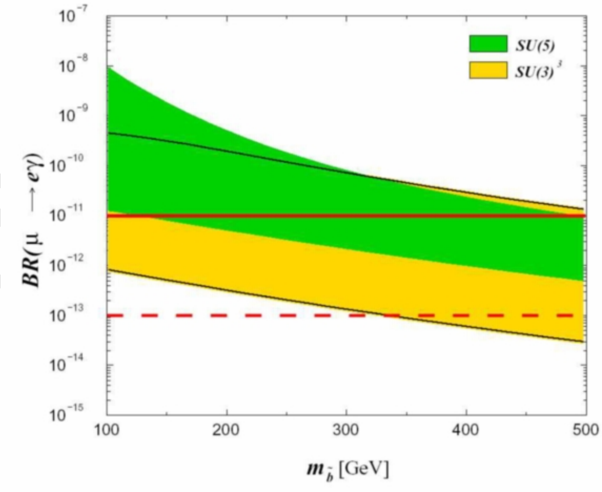

Figure 1. Prediction for the $\mu \to e\gamma$ branching ratio in SU(3) and SU(5) theories. The dashed line corresponds to the current experimental limit, while the dotted line corresponds to the aimed sensitivity of the MEG experiment.

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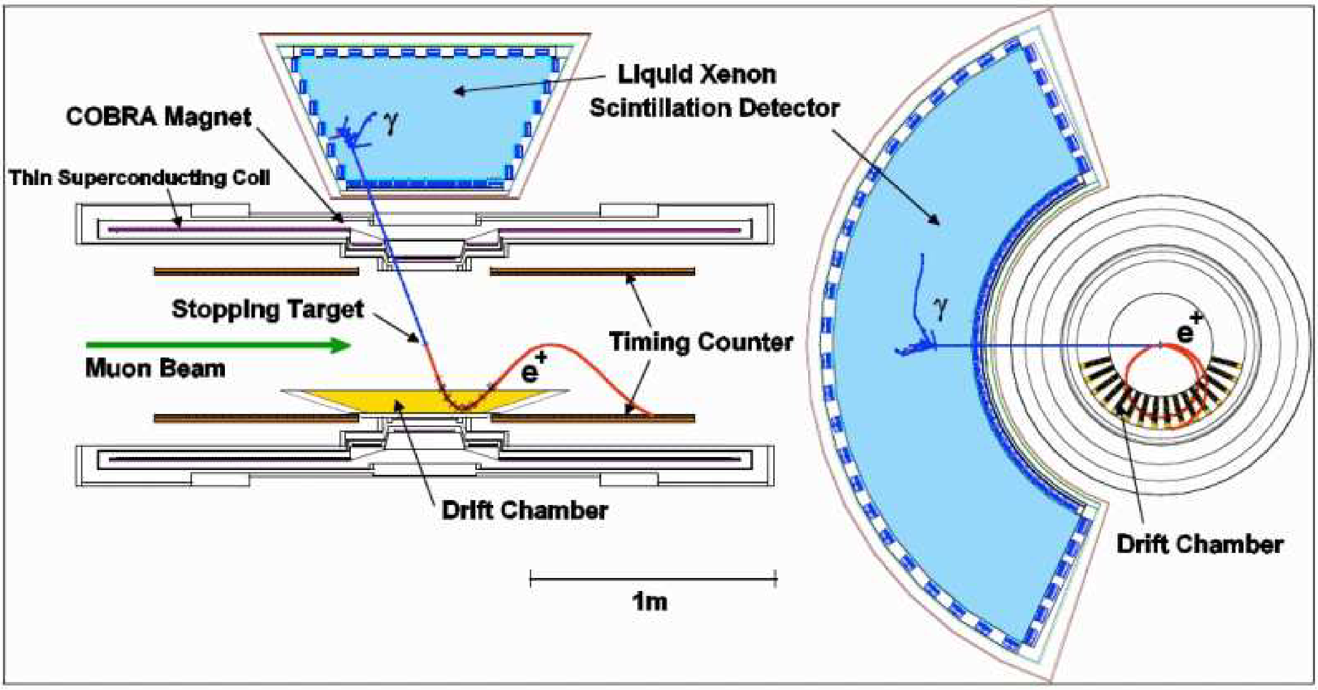

Figure 2. Schematic cross section of the MEG detector. A muon beam entering from the left stops in a thin target. The $\mu \rightarrow e\gamma$ decay is detected in a liquid xenon calorimeter, a set of radial drift chambers and a set of timing counters.

PARC, Japan, as the only successor. Using a $10^{11} - 10^{12}\mu/s$ pulsed muon beam and novel techniques for pion background suppression down to $10^{-18}\pi/\mu$, the experiment aims to measure $(\mu - e)$ conversion rate with a sensitivity of 10^{-18}. While the magnet construction for the PRISM facility will be finished in 2008, the PRIME detector is currently in the design phase and will be completed in a few years from now.

In the case of the $\mu \rightarrow e\gamma$ decay, many predictions for the branching ratio were made in the last years. Figure 1 shows a prediction in the framework of SUSY SU(3) and SU(5) theories. Since the supersymmetric parameters are not known, some reasonable ranges must be assumed, leading to entire bands of possible values for the branching ratio. The parameter range in this particular prediction has been chosen such that it corresponds to the observable parameter space visible to the LHC experiments.

While a significant fraction of the predicted range can already be excluded by the current experimental limit, an improved measurement down to a branching ratio of 10^{-13} would cover almost the complete parameter space, thus bearing a big potential for discovery.

2. The MEG Experiment

To perform such an improved experiment, the MEG collaboration has been gathered in 1999. It now consists of about 80 people from five countries. The key to the experiment is the clean topology of the $\mu \rightarrow e\gamma$ decay. Both decay products have an energy of 52.8 MeV and span an angle of 180^o. The main background for this decay is an accidental pile-up of two $\mu \rightarrow e\nu\nu\gamma$ decays, where one positron undergoes annihilation in flight. In order to distinguish the signal from the background, good energy, spatial and timing resolutions are required together with excellent pile-up rejection. The MEG detector consists therefore of different subdetectors which are designed for the best currently possible performance.

A positive muon beam with up to $10^8 \mu/s$ is stopped in a thin target. The γ from the $\mu \rightarrow e\gamma$ decay gets detected in a liquid Xenon (LXe) calorimeter. 850 photomultiplier tubes are immersed in the LXe observing the light from the γ-induced showers. The positron from the $\mu \rightarrow e\gamma$ decay spirals in the solenoidal magnetic spectrometer "COBRA", where it traverses a set of radial drift chambers for momentum and position measurements and ends up in timing counters consisting of scintillator staves. Since the detector pushes the performance to its limits, prototypes of all subdetectors have been built and thoroughly tested and optimized. It turned out that one of the most crucial points was the purity of xenon gas. A contamination of the liquid xenon with water or oxygen in the 10^{-6} range is enough to reduce its light output by more than one order of magnitude. Techniques had to be developed which allow a continuous purification of the xenon both in gas and in liquid phase.

The beam line delivering 10^8 stopped muons per second has been built and commissioned. It uses an electrostatic separator and a beam transport solenoid to suppress the positron background in the muon beam below 10^{-3}. The beam is focused on a thin tilted CH_2 target with a spot size of 30 mm FWHM. The interior of the COBRA spectrometer is filled with He gas to minimize multiple scattering. Detailed studies are currently underway to optimize the position and layout of cable ducts and drift chamber support structures to minimize the background from annihilating positrons.

In order to detect and suppress pile-up effectively, fast waveform digitizing is required in all detector channels. For this purpose, a new Domino Ring Sampling (DRS) chip has been developed at PSI. The chip contains eight channels which are digitized at up to 4 GHz with a resolution of 12 bits. A VME board with 32 channels at a cost of $\sim$ 100 Euros per channel has been produced. First measurements indicate that pile-up can be recognized if two events are apart in time by approximately the rise-time of the signals, which is about 10 ns for the LXe calorimeter and a few ns for the timing counters. Since the cost of this technology is relatively low, it has been decided to use only waveform digitizing on all 3000 detector channels. Traditional techniques like constant fraction discrimination or ADC and TDC functions are then performed in software on the acquired waveforms. The radiation hard DRS chip will be licensed to industry to become available for other experiments.

The achievable sensitivity of the MEG experiments depends linearly on the timing resolution and momentum resolution for the positron and quadratically on the energy resolution for the γ and the relative angle between the e^+ and the γ. The current values for the resolutions are shown in Table 1.

Item	MC	Measured
μ stopping rate		1×10^8 /s
Measurement time		4×10^7 s
Solid angle		0.09
e^+ detection efficiency	0.9	
γ detection efficiency		0.4
Event selection eff.	0.7	
γ energy		5 %
γ timing		150 ps
γ position		9 mm
e^+ energy	0.8 %	
e^+ timing		100 ps
e^+ angular	10.5 mrad	
μ decay position	2.1 mm	
Single event sens.		3.7×10^{-14}
90% C.L. sensitivity		1.2×10^{-13}

Table 1
Current resolutions and experiment parameters with the resulting single event and 90% C.L. sensitivity. All resolutions are given in FWHM at 52.8 MeV.

Most of the critical values have been measured in prototypes of the subdetectors. The resolution for the LXe detector strongly depends on the method for data analysis. Unlike a crystal calorimeter, this detector is non-segmented, so the scintillation light from a shower is distributed to almost every photomultiplier. A careful analysis of all signals together with an accurate modeling of the γ-induced shower might yield an improved resolution for the LXe detector, but this can only be done after the full detector is operational.

The R & D phase of the MEG experiment took considerably longer than anticipated due to the mentioned technical difficulties, but the collaboration is confident that the engineering runs can be finished in 2006, so data taking can start from 2007 for several years. Since the LHC experiments will probe SUSY already in the first years of their running, the primary goal of the MEG experiment is to obtain a "significant" result before the LHC experiments produce data.

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