Status of the MEG Experiment

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for the MEG collaboration
Outline

- Physics motivations for the MEG experiment
- MEG detector
- Status of the sub-detectors
  - Beam line
  - Photon detector
  - Positron spectrometer
    - Magnet
    - Drift chamber
    - Timing counter
  - Trigger, DAQ, and slow control
- Summary
MEG Collaboration

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$\mu \rightarrow e \gamma$

- Event signature
  - Back to back
  - Time coincident
  - $E_\mu = E_\gamma = 52.8$ MeV
- Lepton-family-number nonconserving process
- Extremely small branching ratio in the standard model with finite neutrino mass
  
  \[ \text{ex.) BR}(\mu \rightarrow e \gamma) \sim 10^{-52} \text{ for } m_\nu \sim 0.05 \text{eV} \]
- Sensitive to physics beyond the standard model
  \[ \text{SUSY-GUT, SUSY+ } \right \uparrow \, \cdots \]
- Present experimental bound
  \[ \text{BR}(\mu^+ e^- \gamma) < 1.2 \times 10^{-11} \text{ (MEGA experiment, 1999)} \]
- New experiment with a sensitivity of BR$\sim 10^{-14}$ planned at PSI
Physics Motivations

- SU(5) SUSY-GUT predicts BR \( \mu \rightarrow e \gamma \) = \(10^{-15} - 10^{-13}\)  
  (SO(10) SUSY-GUT: even larger value \(10^{-13} - 10^{-11}\))
- Small \(\tan\beta\) excluded by LEP SUSY search

J. Hisano et al.,  
Physics Motivations, cont’d

After the recent SNO measurements...

SNO collaboration, Q.R.Ahamd et al., PRL89(2002)010302

Our goal

- Solar $\nu$ meas. strongly favor the LMA.
- Large $\tan\beta \rightarrow$ large $\mu e\gamma$ rate
MEG Detector

- Liquid xenon photon detector
- Positron spectrometer with gradient magnetic field (COBRA spectrometer)
- World’s most intense DC muon beam at PSI
- Sensitivity down to BR~$10^{-14}$
- Engineering/physics run will start in 2004
Sensitivity and Background

• Single event sensitivity

\[ N_\mu = 1 \times 10^8 \text{sec}, \quad T = 2.2 \times 10^7 \text{sec}, \quad \Omega/4\pi = 0.09, \quad \varepsilon_{\gamma} = 0.7, \varepsilon_e = 0.95 \]

\[ \Rightarrow \quad \text{BR}(\mu^+ \rightarrow e^+\gamma) \sim 0.94 \times 10^{-14} \]

• Major backgrounds

  • Accidental Coincidence
    Michel decay(\(\mu^+ \rightarrow e^+\bar{\nu}_e\nu_e\)) + random \(\nu\)
    \[ B_{\text{accidental}} \sim 5 \times 10^{-15} \]

  • Radiative muon decays
    \(\mu^+ \rightarrow e^+\bar{\nu}_e\nu_e\)
    \[ B_{\text{prompt}} \sim 10^{-17} \]

These values could be changed according to the actually achieved performance of the detector.
Beam Line

- DC muon beam rate above $10^8 \mu/s$ at $\pi E5$ beam line
- Two beam branches ("U" and "Z")
- Comparative study of the branches is in progress.
- Positron contamination can be reduced by:
  1. Combination of an energy degrader and a magnetic selection
  2. Wien filter

<table>
<thead>
<tr>
<th>Condition</th>
<th>&quot;Z&quot;-branch</th>
<th>&quot;U&quot;-branch</th>
</tr>
</thead>
<tbody>
<tr>
<td>No degrader, transmitted to zone</td>
<td>$3.6 \times 10^8 \mu+/s$</td>
<td>$3.5 \times 10^8 \mu+/s$</td>
</tr>
<tr>
<td></td>
<td>$6.0 \times 10^6 e+/s$</td>
<td>$1.6 \times 10^9 e+/s$</td>
</tr>
<tr>
<td>Degrader at final focus</td>
<td>$2.0 \times 10^8 \mu+/s$</td>
<td>$3.2 \times 10^7 \mu+/s$</td>
</tr>
<tr>
<td>m/e ratio at Muon Peak</td>
<td>9</td>
<td>16.5</td>
</tr>
</tbody>
</table>

Decision on the choice of the beam branch will be made after the beam tests with "U"-branch in Aug.2002 and with "Z"-branch in Nov.2002.
Liquid Xenon Photon Detector

- High light yield (75% of NaI(Tl))
- Fast signals
  → avoid accidental pileups
- Spatially uniform response
  → no need for segmentation

**Current design**

- Active volume of LXe: ~800 liter
- Scintillation light is collected by ~800 PMTs immersed in LXe
- Compact PMT with metal channel dynode structure and quartz window
  (Hamamatsu R6041Q)
Photon Detector Prototype

- A total of 120 liter liquid xenon (active volume of 69 liter)
- Viewed by 240 PMTs
- Large enough to test with ~50MeV $\gamma$
- LEDs and $\alpha$ sources ($^{241}$Am) implemented for calibration
Gamma Beam Tests

- Performance test of large prototype using high-energy gamma rays
- Laser Compton backscattering facility at TERAS electron storage ring of AIST, Tsukuba, Japan
- Gamma-ray beam with energy up to 40MeV
- Energy resolution evaluated by spread of Compton edge
- Position reconstructed by PMT output distribution with proper collimator
- Timing reconstructed by averaging arrival time
- Beam test in Feb. 2002

Energy spectrum of gamma beam with 1mmφ collimator (simulation)
Beam test in Feb. 2002

- Observed amount of light from 40MeV $\gamma$ is smaller than expected. (~10%)
- Strong correlation between the conversion depth and $N_{pe}$
- Worse position resolution than expected

$\sigma^2$: conversion depth parameter

→ can be explained by strong light absorption in LXe
MC Predictions with Absorption

**Energy resolution**

- Feb02 beam test
- MC: monochromatic 40MeV

**Position resolution**

- MC predictions indicate $\lambda_{\text{abs}} < 10\text{cm}$ in gamma beam test in Feb. 2002
- We need $\lambda_{\text{abs}} > 100\text{cm}$ at least for an energy resolution of a few % order
Light Absorption in LXe

H$_2$O, C$_2$H$_4$, NH$_3$, O$_2$ can strongly absorb 175nm scintillation light from LXe → Contaminations in LXe?

Mass spectrum for the remaining gas in the detector vessel
Purification

- New circulatory purification system is installed after the beam test in Feb. 2002.
- Xenon vapor is purified in Zr-V-Fe getter and Oxisorb filter and recondensed by the refrigerator and LN$_2$ during the operation of the detector.
- Circulation speed 10-12 cc liq./minute
Improvement of Light Yield

- Alpha event
- Cosmic ray event
Absorption Length Estimation

Absorption length is estimated by seeing the absorption of the light from the alpha source event and cosmic ray event.

4 x alpha source inside  
Cosmic ray trigger setup
Absorption Length Estimation, cont’d

Both measurements (CR and \(\alpha\)) indicate \(\lambda_{\text{abs}} \approx 100\text{cm}\) after the purification.
Positron Spectrometer

COBRA spectrometer

- Thin superconducting magnet designed to form gradient magnetic field
- Drift chamber for positron tracking
- Scintillation counters for timing measurement
Concept of COBRA Spectrometer

COBRA : COnstant Bending RAdius

- Constant bending radius independent of emission angles
- Low energy positrons quickly swept out
Magnet

- Five coils with three different diameter to form gradient field
- \( B_z = 1.26 \text{T}, B_{zz} = 0.49 \text{T} \) at operating current = 359A
- Compensation coils to suppress the residual field around the LXe detector down to \(~50 \text{ Gauss}\)
- High-strength aluminum stabilized superconductor
  \( \Rightarrow \) thin superconducting coil: \( 0.2X_0 \)
Construction of the Magnet

- Magnet design was finalized after detailed mechanical calculations and related experimental tests.
- Winding of the cable is in progress @ Toshiba.
- Excitation test for the central part of the magnet will be performed in October 2002.
Positron Tracker

- 17 chamber sectors aligned radially with 10° intervals
- Two staggered arrays of drift cells
- Chamber gas: He-C$_2$H$_6$ mixture
- Vernier pattern on the cathode foil to determine z-position
First Prototype of the Chamber

Sr-90

<table>
<thead>
<tr>
<th>Resolution(σ)</th>
<th></th>
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<tbody>
<tr>
<td>Drift time measurement</td>
<td>100-150μm</td>
</tr>
<tr>
<td>Vernier cathod measurement</td>
<td>425μm</td>
</tr>
<tr>
<td>Charge division measurement</td>
<td>2cm</td>
</tr>
<tr>
<td>Drift velocity and drift time</td>
<td>4-12ns</td>
</tr>
</tbody>
</table>
Chambers System R&D in PSI

- Two prototypes are under construction at PSI.
  - "Double cathode" test chamber
    - Two separated double-strip cathodes for each chamber layer
      → homogeneous position sensitivity
    - Test in 1 Tesla magnetic field
  - "Charge division" test chamber
    - Charge division test
    - 1m-long W(330W/m) or Steel(1200W/m)
- Supporting system is also under development.
Timing Counter

- Two layers of scintillator hodoscopes placed at right angles with each other
  - Outer: timing measurement
  - Inner: additional trigger information
- Goal $\sigma_{\text{time}} \approx 50\,\text{psec}$
Timing Counter Prototype

CORTES: Timing counter test facility with cosmic rays at INFN-Pisa

- Scintillator bar (5cm x 11cm x 100cm long)
- Telescope of 8 x MSGC
- Measured resolutions
  \( \sigma_{\text{time}} \approx 60 \text{psec} \) independent of incident position
- \( \sigma_{\text{time}} \) improves as \( \sim 1/\sqrt{N_{pe}} \) → use thicker counter \( \sim 12 \text{cm} \)
**Trigger Electronics**

- Beam rate: \(10^8\) s\(^{-1}\)
- Fast LXe energy sum: \(>45\) MeV, \(2 \times 10^3\) s\(^{-1}\)
- Interaction point
- \(e^+\) hit point in timing counter
- Time correlation \(\gamma-e^+\): \(200\) s\(^{-1}\)
- Angular correlation: \(20\) s\(^{-1}\)

- Design and simulation of type1 board completed
- Prototype board delivered in Pisa by this fall
Slow Control

- New field bus system under development for a reliable control of cryogenics of LXe detector, superconducting magnet, high voltage supply
- Low cost (typ. 20 US$ per node)
- Several prototypes have been built and tested at PSI
- See http://midas.psi.ch/mscb
Summary

• R&D work on the sub-detectors for the MEG experiment are going well.
• Performance of the LXe photon detector prototype is improving thanks to the improvement of the light yield.
• A beam test of the photon detector prototype with the purified xenon will be performed in Oct. 2002.
• Beam line tuning with the COBRA magnet and assembly of the sub-detectors will start in 2003.
• Engineering run will start in 2004.

Updated status can be seen at three mirrored sites:

http://meg.icepp.s.u-tokyo.ac.jp/
http://meg.psi.ch/
http://meg.pi.infn.it/