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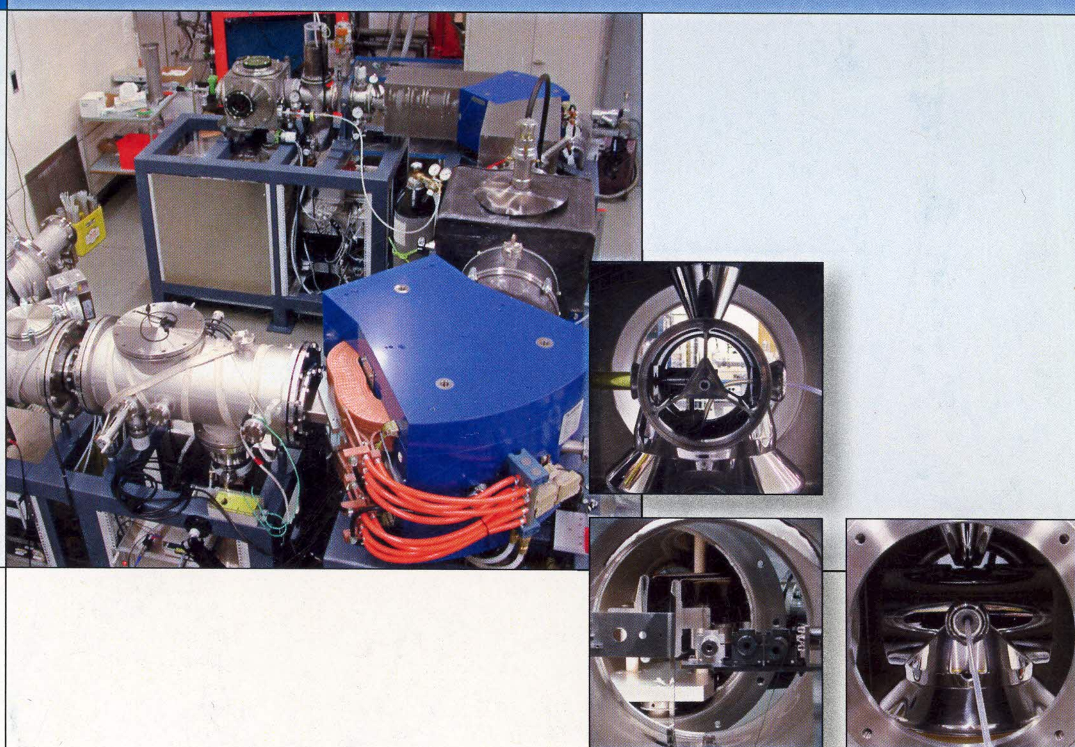

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Particles and Matter

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ed. by: H.W. Gäggeler, M. Güdel, P.W. Kubik, R. Lorenzen,
A. Pichlmaier, R. Rosenfelder

Paul Scherrer Institut
5232 Villigen PSI
Switzerland
Tel. +41 (0)56 310 21 11
Fax +41 (0)56 310 21 99
www.psi.ch

TABLE OF CONTENTS

THE MEG EXPERIMENT

R-99-05, MEG Collaboration: BINP Novosibirsk - INFN & Univs. Genova, Lecce, Pavia, Pisa - KEK - Osaka Univ. - PSI - ICEPP Univ. Tokyo - Waseda Univ.

The year 2004 marked the start of the commissioning phase of the MEG experiment, which will search for the so-called 'forbidden decay' $\mu \rightarrow e\gamma$, with a sensitivity of more than two-orders of magnitude lower than the current best limit [1]. This start was symbolized by the "moving in" of the first major piece of the detector to the refurbished πE5 Area. Figure 1 shows the superconducting COBRA magnet some time after this move, together with the Large Prototype liquid Xenon photon detector.

Significant progress was made on several aspects of the experiment, as well as the completion of the design phase of some of the major components. The πE5 beam was utilized extensively during the year for both beam line commissioning and various background and calibration studies and also detector performance tests. Some notable examples are given below:

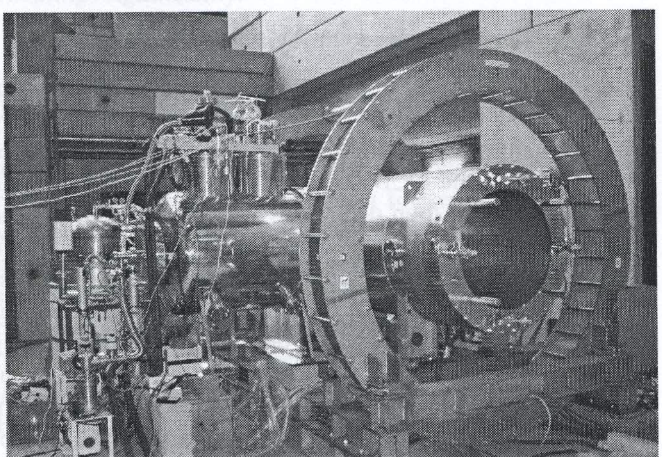

Figure 1: The COBRA Magnet, soon after its installation in the πE5 Area, seen with one of its compensation coils in the foreground, together with the the Large Prototype liquid Xenon photon calorimeter placed at its side.

Beam related

With the construction of the final extraction element, triplet 1 [2] and the placing into the shielding of the πE5 'Z-branch', the beam line commissioning could be completed up to the location of the injection into the beam transport solenoid BTS. An improved beam transmission efficiency of more than 86% through the 200 kV WIEN filter ($\vec{E} \times \vec{B}$ separator) and the following triplet 2 could be achieved. The results enabled the parameters for the final MEG separator and the superconducting BTS solenoid to be fixed. This allowed the technical design for both elements to be completed and the procurement phase to start by the end of the year.

First MEG pion-beam studies were also undertaken i preparation for the Large Prototype liquid Xenon calorimete test, employing both the charge-exchange reaction (CEX) produce 55 and 83 MeV photons and the radiative pion ca ture reaction (RPC) for the 129 MeV photons, all used as energy calibration source.

Extensive neutron background studies, necessary for th shielding concept of the final liquid Xenon calorimeter we also undertaken using a set of Bonner Spheres and vario detectors to determine both the thermal and non-thermal a bient backgrounds with and without beam present.

Detector related

The COBRA magnet was also successfully tested in com bination with its large compensation coils, for the first tim since arriving at PSI. A study of the stray magnetic field the neighbouring areas, originating from the COBRA a core solenoid was also made, allowing compensation me sures to be undertaken by most of the experiments affected

The liquid Xenon calorimeter, incorporating a number improved photomultipliers (PMTs), was also studied exhau tively in a dedicated $\pi^- H_2$ run using CEX and RPC photo as a source of high energy calibration events. Significa improvement to both the timing and energy resolutions w found due to the increased quantum efficiency of the ne PMTs.

Another highlight, also in conjunction with the run, w the implementation of the MEG prototype fast waveform di itizing chip DRS2. A total of 16 channels were successful employed for the reading-out of the waveforms from the ph ton calorimeter PMTs and so demonstrating the power of t method in clearly distinguishing the waveform of high e ergy photons from those of calibration α-events. This eff was also supported by the use of a new MEG software fram work incorporated into the MIDAS online system.

Significant progress was also made on the tracking cha ber side, with the complex mechanical design problems the frame pre-tensioning and the foil low-mass support str ture being solved. A solution to the signal matching betwe the wires and the prints was also found. Finally, the detail chamber construction procedure could be defined and the quired geometrical precision (0.1-0.2 mm over 800 mm) the manufactured cathode foils confirmed.

More detailed contributions on some of the above me tioned aspects of the experiment are presented on the follo ing pages.

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RECENT DEVELOPMENTS OF THE MEG LIQUID XENON PHOTON DETECTOR

R-99-05, MEG Collaboration: BINP Novosibirsk - INFN & Univs. Genova, Lecce, Pavia, Pisa - KEK - Osaka Univ. - PSI - ICEPP Univ. Tokyo - Waseda Univ.

The Large Prototype liquid xenon photon detector has been extensively tested to evaluate its performance. Two different beam tests were performed in 2003, using a γ-beam as well as γ's from π^0-decays produced in the charge exchange process (CEX) as previously reported [1]. Detailed analysis of these data shows that an excellent improvement of the energy resolution as a function of energy is obtained as shown in Figure 1. This result indicates that we can improve the

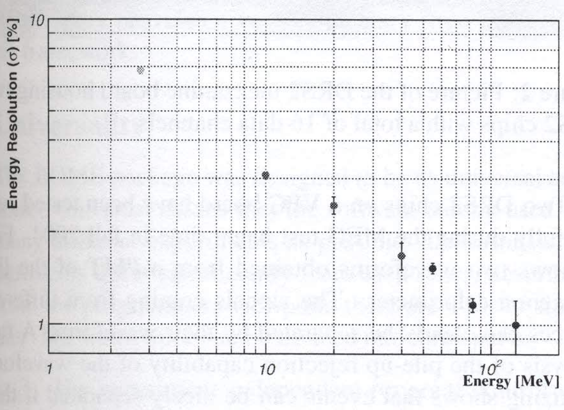

Figure 1: Energy resolution obtained with the Large Prototype. The leftmost point is for an α event, the next three are obtained in the γ-beam test, and right three points are from the CEX test in 2003.

resolution even further by adopting photomultipliers (PMTs) with a higher light detection efficiency, i.e. quantum efficiency. An intensive effort has been made to improve the quantum efficiency, in collaboration with the PMT manufacturer Hamamatsu Photonics, by modifying the photocathode configuration and its material. The development succeeded in producing a new PMT with an, on average, three times higher quantum efficiency.

A farther CEX beam test was conducted in 2004 in the πE5 area itself, employing the new PMTs in the Large Prototype. The πE5 area was chosen as this is where the MEG experiment will be carried out, thus allowing experience to be gained in the operation of the detector as well as the control of the beam. Prior to the test an upgrade to the detector calibration system was undertaken, by installing thin wires (Ø 50 μm) with tiny radioactive spots into the active volume. Note that such calibration methods are only possible in liquid detectors such as ours. Waveform digitizers were also introduced in addition to the original data acquisition system. Details of the waveform digitizer and data analysis are reported in a separate article in this report.

A picture of the setup is shown in Figure 2. A π^- beam from the πE5 beam line was stopped in a liquid-hydrogen target located at the centre of the setup. Neutral pions (π^0) produced from the charge exchange process, $\pi^- + p \rightarrow \pi^0 + n$, decay predominantly to $\gamma\gamma$. One of the γ's was tagged by a NaI array located opposite to the Large Prototype. A LYSO crystal counter was placed in front of the NaI detector to measure the reference timing of the π^0 decay. A series of collimators of lead and paraffin blocks was located around the target in order to suppress an induced background from electrons and neutrons. PMT calibration was done using LEDs and the polonium α-sources electrodeposited on thin wires, mentioned previously.

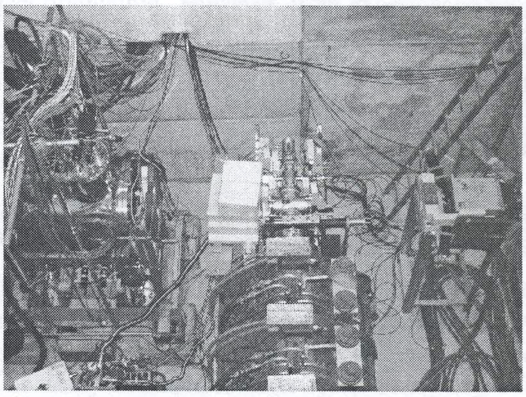

Figure 2: CEX test setup at πE5. The NaI detector is shown on the right and the Large Prototype opposite.

Data analysis is currenly still in progress with several methods under evaluation. For example for the energy reconstruction two independent methods are being studied. One is the simplest method in which all PMT outputs are summed up after the PMT calibration. In this analysis we obtained a preliminary energy resolution of (1.2±0.1)% in sigma on the right side of the distribution for the 55MeV γ's, which is a significant improvement from the previous result. The other method is a more sophisticated one using the linear-fit algorithm [2], which is expected to improve the resolution. However, in order to achieve this, detailed calibration data for the new PMTs has to be included in the Monte Carlo simulation and the parameters for fitting need to be tuned.

In parallel with prototype studies, construction of the final detector cryostat was started in 2004. Preparation of other equipment such as the xenon storage and supply system is in progress and should be ready for initial detector tests around the end of 2005. Further development programmes are also ongoing. A new purification system will be tested in the early part of 2005. The system is dedicated to remove water contamination from liquefied xenon in the detector with a purification rate of 100 liters/hour. Another calibration method using 9 MeV γ's from excited nickel nuclei by thermal neutron capture is also under investigation. Such a γ-source with a monochromatic energy above a few MeV is indispensable to monitor and calibrate the detector constantly.

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THE DRS2 CHIP - A 4.5 GHZ WAVEFORM DIGITIZING CHIP FOR THE MEG EXPERIMENT

R-99-05, MEG Collaboration: BINP Novosibirsk - INFN & Univs. Genova, Lecce, Pavia, Pisa - KEK - Osaka Univ. - PSI - ICEPP Univ. Tokyo - Waseda Univ.

A switched-capacitor array (SCA) chip is currently under development for fast waveform digitizing of photomultiplier (PMT) and drift chamber signals for the MEG Experiment. This development is based on an earlier system at PSI [1]. After a first prototype (DRS1), the second prototype chip (DRS2) was fabricated in the UMC 0.25 μm 1P5M MMC CMOS process in spring 2004. It contains 10 channels, each with 1024 capacitative sampling cells. Waveform digitizing takes place with an on-chip generated frequency ranging from 0.5 GHz to 4.5 GHz. This frequency is generated on-chip by a series of inverters, through which the sampling signal is propagating (domino principle, see Fig. 1).

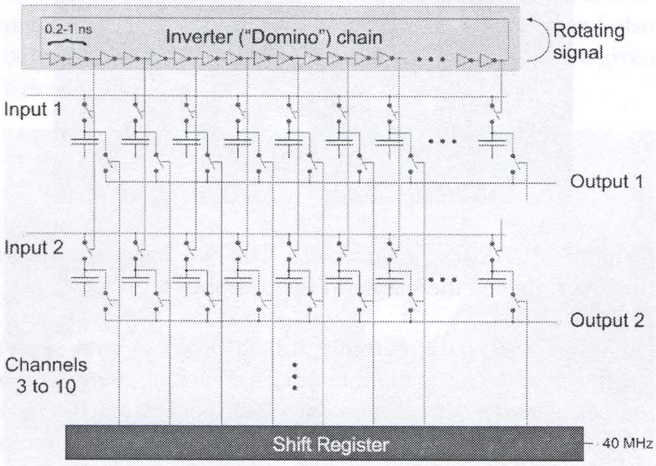

Figure 1: Simplified schematic of the DRS2 chip.

The domino wave runs continuously in a circular fashion and is stopped by a trigger signal. Since the storage depth is larger than a typical PMT signal width, the storage chain acts like an analog pipeline and makes delay cables unnecessary. An external stabilization keeps the domino wave speed stable over a wide temperature range. Each chip contains eight data channels plus two additional channels for timing and amplitude calibration, making the chip suitable to replace both ADCs and TDCs in an experiment with a timing resolution below 100ps and an ADC resolution equivalent of 13-14 bit for typical PMT pulses.

The stored analog waveform is read out via a shift register and externally digitized with a commercial flash ADC with 12 bit at 40 MHz. Two DRS2 chips fit together with the flash ADC on a common mezzanine card (CMC) as shown in Fig. 2. This board can be used together with the PSI VPC board [2], which fits two CMC boards, into a single width VME slot for a total of 32 channels.

The onboard field programmable gate arrays (FPGA) can be used for fast waveform processing such as zero suppression or baseline subtraction. Alternatively, a USB interface is available, such that the CMC board can be directly connected to a PC or laptop without the need of a crate or an additional power supply.

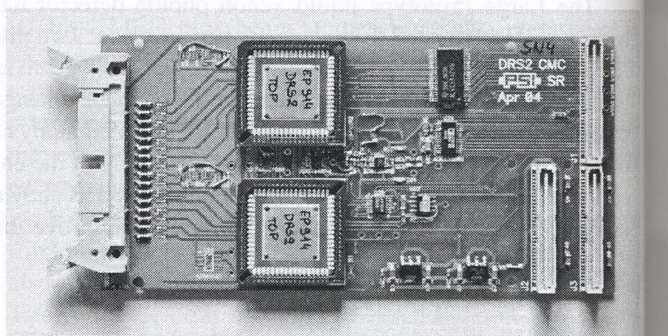

Figure 2: Picture of the DRS2 mezzanine board housing two DRS2 chips with a total of 16 data channels

Two DRS2 chips on a VPC board have been tested successfully during the MEG test beam time in fall 2004. Fig. 3 shows two waveforms obtained from a PMT of the liquid xenon calorimeter. The signals coming from different sources can clearly be separated by their waveform. A first analysis of the pile-up rejection capability of the waveform digitizing shows that events can be nicely separated if they are more than 10 ns apart in time. While the MEG experiment will finally use about 3000 channels, the DRS2 chip will also be used in several other projects both inside and outside of PSI.

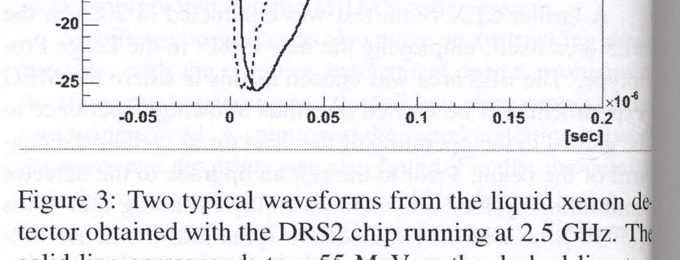

Figure 3: Two typical waveforms from the liquid xenon detector obtained with the DRS2 chip running at 2.5 GHz. The solid line corresponds to a 55 MeV γ, the dashed line to a signal from a built in 5.3 MeV α source used for calibration purposes. The signals are shown normalized to the same amplitude.

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ROME - A UNIVERSALLY APPLICABLE ANALYSIS FRAMEWORK GENERATOR

R-99-05, MEG Collaboration: BINP Novosibirsk - INFN & Univs. Genova, Lecce, Pavia, Pisa - KEK - Osaka Univ. - PSI - ICEPP Univ. Tokyo - Waseda Univ.

During the course of developing an online analysis software for the MEG experiment a generally applicable data analysis framework generator has been written. The Root based Object oriented Midas Extension (ROME) [1] is a user-friendly tool, that both helps and guides the experimenter in writing a data analysis software package. ROME can be connected to the midas system [2], which is widely used in and outside PSI. The software is based on the ROOT libraries [3] and acts as a natural extension of ROOT. At present ROOT only provides a very elementary (tree based) analysis framework.

Universality

The ROME package was designed to be as universal as possible. Universal means that the software can be used for as many different experiments as possible. Unfortunately, experiments differ significantly from each other, nevertheless, from the programmers viewpoint there are a lot of similarities. The framework can be divided into three parts:

1. The experiment independent program control code, which contains the event loop, handles part of the input and output and provides basic functionality. This code can be truly universal, i.e. it can be used for any experiment. However, this code normally covers only a small part of an analysis software package.

2. The experiment dependent framework code, which extends the program control code to cover all control codes of the final software, contains everything but the calculations. This code is not universal but it can be summarized to a very compact description of the experiment. From such a summarization, all codes can be generated. By contrast the translation program is however universal.

3. The calculation code contains all calculations which are performed on the data. This code is different in each experiment and can in no way be simplified.

The universality of ROME is assured by the fact that it is not a framework itself but a framework generator. The experimenter defines the structure of the desired analysis software in an XML file, out of which ROME builds the whole framework, i.e. everything but the calculation code, see Figure 1. The calculations are then added by the experimenter.

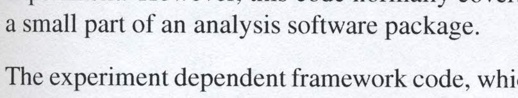

Figure 1: The translation program generates all codes of the framework from an experiment description. The framework is also linked and documented.

Programming inside ROME

The generated framework is written in c++ and is completely object oriented. However, since all code except the calculations is generated, the experimenter has only to add code to predefined functions. Therefore, he does not need to write classes himself and hence does not need to know the concept of object orientation. However, if an experienced programmer wishes to extend the framework beyond the capability of ROME he will benefit from the object orientated structure. Accordingly ROME is designed to be very easy to use for less experienced programmers and also easy to extend for experienced users.

Features

ROME can be used in every event-based experiment for on-line and off-line analysis. So far, only a connection to the midas data acquisition (DAQ) system has been implemented but it can be easily extended to other systems. Having a framework, which is capable of doing on-line and off-line analysis brings consistency, saves manpower and instruction time.

The generated program can be connected to a database. The access to the database is completely covered by the framework, i.e. no database calls have to be implemented by the experimenter. So far the access to a MySQL database [4] as well as for small amounts of data, to a XML database, has been implemented. Implementing access to any other database system is also very straitforward and can be done without changing the translation program.

ROME generated analysis software packages are highly modular. The calculation code is split up into tasks, which contain one or several calculation steps. Tasks can be exchanged arbitrarily as long as they access the same data. In this way two different types of analysis can be performed with the same program by rearranging the tasks. This can be done simply by configuring the program over a XML configuration file before startup and without relinking of the program.

The software runs under Windows, Linux and Macintosh and can be downloaded from a CVS repository.

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