9 June 2000

Report on the Progress for the $\mu \to e\gamma$ Experiment at PSI

Collaboration for $\mu \to e\gamma$ Experiment at PSI

The progress made in preparation for the $\mu \to e\gamma$ experiment at PSI is reported. The status of preparation for the superconducting solenoid and the large prototype of the liquid xenon photon detector is described as well as the development on the positron tracker.

1 Superconducting Solenoid

We have developed a high-strength aluminum stabilized superconductor to be used in the thin-wall solenoid for the final detector. The superconductor consists of NbTi multifilament embedded in copper matrix and aluminum stabilizer. Fig. 1 shows the cross-sectional view of the superconductor. For comparison the conductor used in the BESS experiment[2] is also shown.

The aluminum stabilizer is mechanically reinforced by "micro-alloying" technology. The additive metals such as Mg and Cu in the Al stabilizer provide the mechanical reinforcement while keeping electrical resistivity as low as possible[1]. The high-strength superconductor serves to minimize the amount of materials of the coil support structure. Taking account of the materials in the coil, support structure and cryostat, the material thickness at central part of the solenoid which the photons traverse is estimated to be 2.7–3.0 g/cm^2, much smaller than the BESS solenoid which is 4 g/cm^2.

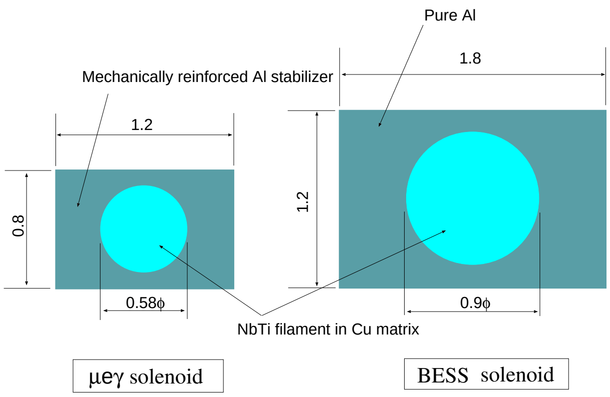

Figure 1: Cross-sectional view of the superconductor.

Fig. 2 shows the layout of the solenoid as described in the proposal. The number of layers and operating current are common to each region of the solenoid. The grading magnetic field is realized by varying the winding density. The operating current is 255 A for a single wire, corresponding to the field of 1.1 T in the central region of the solenoid. Considering the maximum magnetic filed of about 1.5 T in the vicinity of the coil, it is safely below the critical current (350 A at 5 T and 4.2 K).

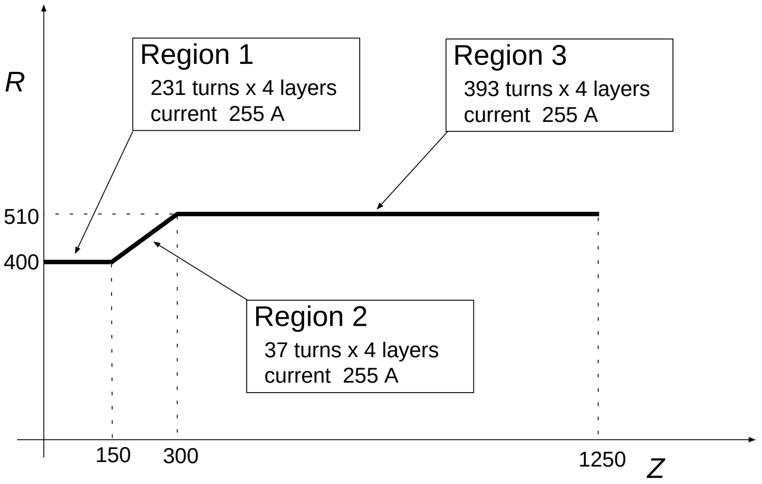

Figure 2: Winding density and operating current along the axis of the solenoid.

The mechanical analysis for the solenoid is under way using a finite element analysis method, ANSYS, for optimizing the coil configuration to reduce the stress acting on the coil. We have been also investigating the realistic design of the iron return yoke to reduce stray field in the region of the photon detector. We are studying with GEANT simulation photon backgrounds due to the positron interaction in the materials near the end of the solenoid including the iron yoke, the beam transport solenoid and the beam collimator.

2 Photon Detector

2.1 Large Prototype Detector

The large prototype will be used to examine the performance for high energy photons. Design work for the large prototype detector is under way and test measurements using high energy photon beam (~ 40 MeV) at the TERAS electron storage ring of Electrotechnical Laboratory (ETL) in Tsukuba, Japan is planned to start at the beginning of 2001.

Fig. 3 shows the current design of the large prototype. A sample of R6041Q PMTs of modified version[4] where the transmission probability is improved by 23% are being assembled. We have also done the design work in collaboration with HAMAMATSU for the glass tube PMT with higher quantum efficiency and transmission probability at low temperature which may possibly be used on side and back walls. The number of photoelectrons is expected to be gained by a factor of 2.3–2.8 compared with R6041Q. Both PMTs are now being delivered and tests in liquid xenon will start soon.

Liquid xenon of 150 liters is required for the large prototype detector. Gas xenon filtered by Oxisorb is liquefied via heat exchanger cooled by liquid nitrogen. After liquefaction a pulse tube refrigerator will be turned on to maintain stable temperature and pressure. A possible

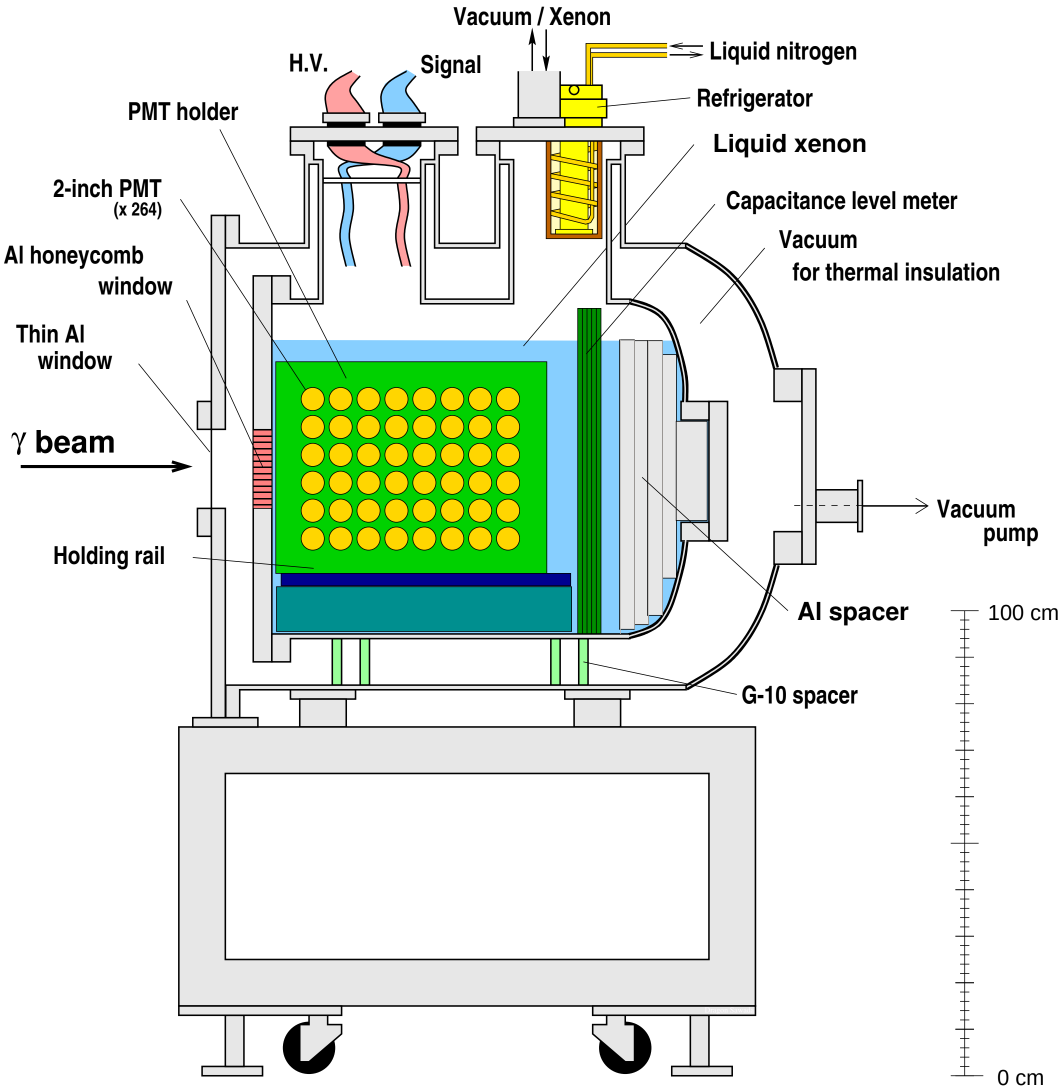

Figure 3: Design of the large prototype detector.

candidate for the refrigerator is the one provided by AIR WATER INC. which has a cooling power of 160 W at 165 K. We have estimated the heat load based on the realistic design of the vessel. The heat leak through the inner walls of the two ports made of SUS at the top of the vessel is relatively large and estimated as 20 W. The thermal radiation between the inner and outer vessels will be suppressed down to 6 W by using superinsulation layers. The heat leak through the G10 supports underneath the inner vessel is estimated as 8 W. The heat leak via cables is estimated as 1 W. The heat generated in the bleeder circuits of the PMTs will be 14 W. Consequently the total heat load is estimated to be 49 W, which is well below the cooling power of the refrigerator. For the final detector two refrigerators of the same type will be sufficient to cover the heat load.

The spatial distribution of the temperature of liquid xenon is monitored using several platinum thermistors (PT100) arranged along the vertical direction to study the effect of convection of liquid xenon caused by the heat dissipated by the PMTs and the external heat leak. The temperature measurement also gives us information on the local density of the liquid from which a possible inhomogeneity of refractive indices will be studied.

The surface level of liquid xenon is monitored by a capacitance level meter. The meter senses the surface level by measuring the capacitance between electrodes placed with a thin gap. We have constructed the capacitance level meter and successfully measured the surface level of liquid xenon in a small chamber. Fig. 4 shows the change of the measured capacitance as a function of the elapsed time from the beginning of the liquefaction of xenon. The resolution of this level meter is estimated to be 3 mm or less.

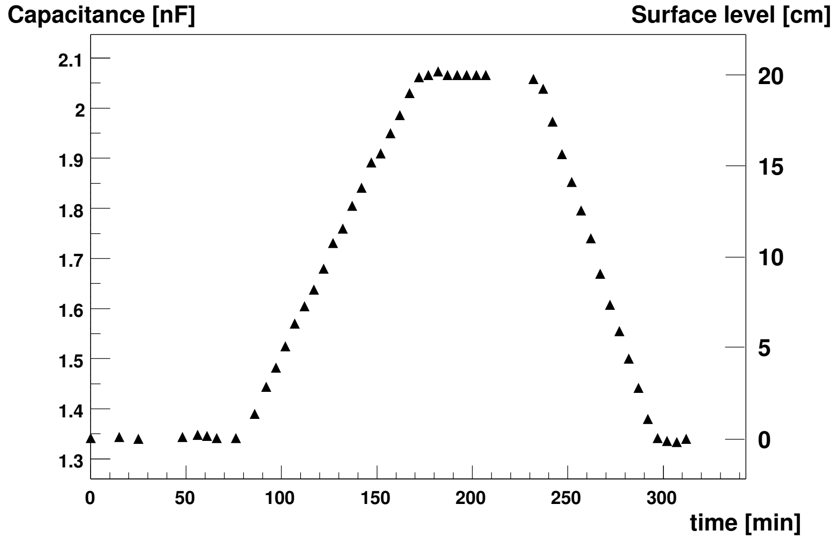

Figure 4: Change of the capacitance as a function of the elapsed time from the beginning of the liquefaction of xenon.

2.2 Light Attenuation Length in Liquid Xenon

If the light attenuation length in liquid xenon would be about 1 meter or shorter, it could affect the energy resolution of the photon detector. The Russian group is designing an experiment to measure the attenuation length in which the effect of Rayleigh scattering can be separated. The design of the setup is schematically shown in Fig. 5. X-rays are used to produce scintillation light in liquid xenon. The PMT1 can be moved vertically and used to measure the light attenuation length, while the PMT2 detects the light deflected by Rayleigh scattering. Reflection on the wall of the inner vessel is suppressed by collimators. The performance of the collimator is checked using light with a longer wavelength for which the effect of the Rayleigh scattering can be neglected. For this purpose measurements will be repeated with a BGO scintillator placed on the bottom of the vessel immediately after the aluminum X-ray entrance window as shown in the figure. The results from this experiment will appear by the end of this year.

3 Positron Tracker

Construction of two prototypes of the positron tracker has been started. The one, which is described in [4], has been constructed to optimize vernier patterns and gas mixtures with a realistic cell configuration. The setup of the tests is shown in Fig. 6 and we are starting the systematic studies with different vernier patterns and various gas mixtures.

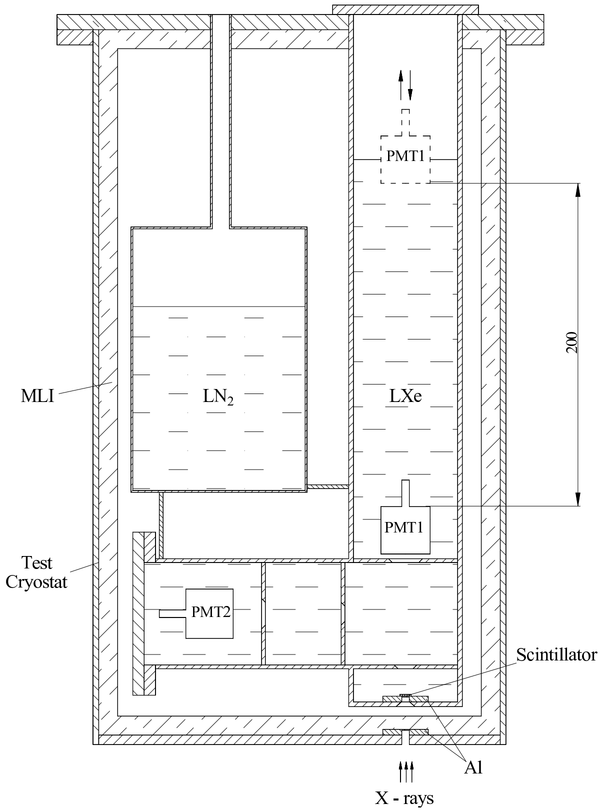

Figure 5: Experimental setup for the measurements of the light attenuation length in liquid xenon.

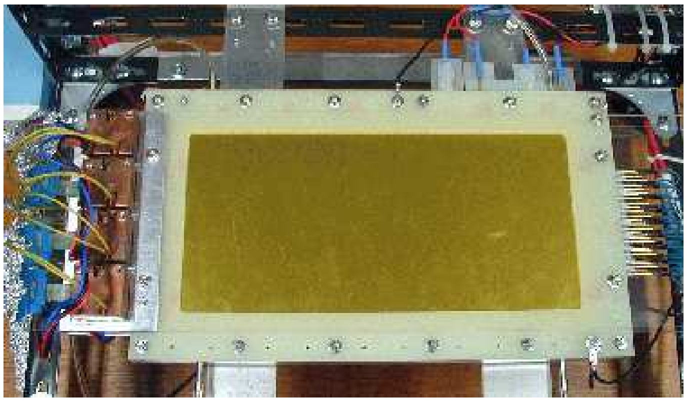

Figure 6: The first prototype drift chamber.

In order to study both the engineering problems involved in the construction of a drift chamber assembly and the chamber characteristics in a magnetic field environment, the construction of another prototype chamber has started at PSI (Fig. 7). Although the sensitive area of 150×60 mm^2 is small, being constrained by the pole-gap of the test magnet, the cell geometry is equivalent to that of the proposed final chamber design.

The prototype will have two layers of each five sense-wires, staggered by a half-pitch, with the sense-wires being read-out at either end to determine the coarse hit-coordinate along the wire. The outer cathodes will comprise of one continuous stretched foil of aluminized Kapton, supported only at its extremities, in order to significantly reduce the amount of material available to low momentum positrons to interact in. The aluminum will be in the form of a vernier pattern [4], and the charge from which, together with the charge from the corresponding wire will yield a higher resolution coordinate along the hit wire.

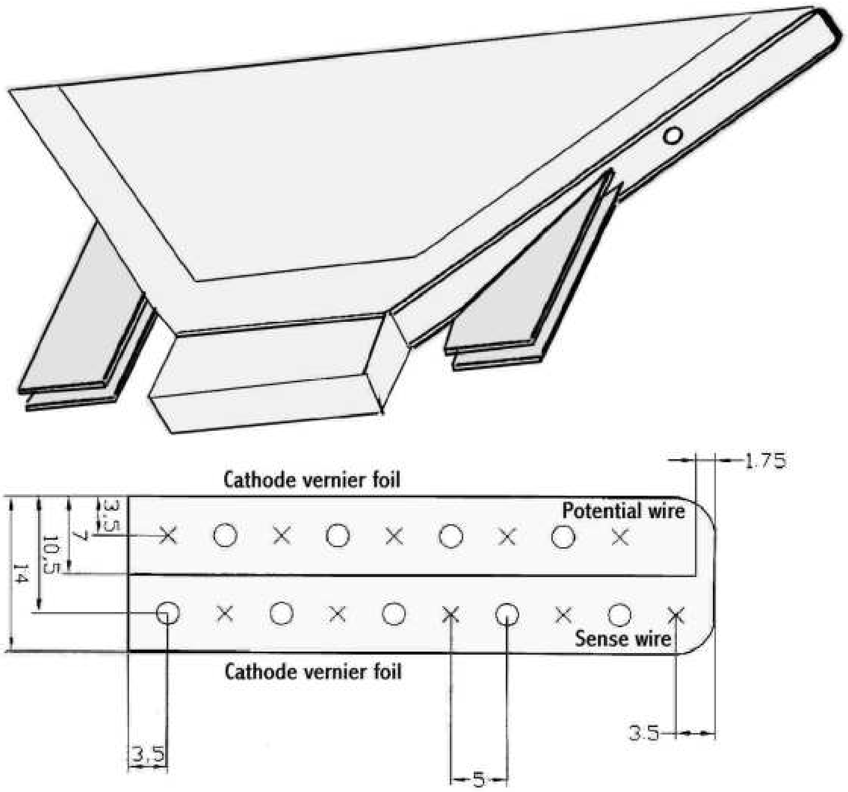

Figure 7: Schematic of prototype drift chamber together with the electrode configuration.

In parallel simulation studies are being conducted to select candidate gas mixtures that will be tested for their suitability of operation in a magnetic field environment of approximately 1 T. The measurements of the chamber response and characteristics are planned during a test beam period in October 2000, in the πM1 area at PSI. It is also planned to employ a 16-channel, 500MHz waveform sampling system, based on the 'Domino Sampling Chip' (DSC) developed at PSI [5], to digitize some of the wire and cathode signals, as a feasibility test for future use in the experiment.

4 πE5 Beam-line Studies

New beam-line studies have also started to see whether other optics solutions exist that can produce the required surface muon transmittance with a better positron suppression, using e.g. a Wien filter. It is also planned to make a study of the πE5 channel, soon after the shutdown in 2001, in order to measure the beam phase-space, particle rates, muon stopping density and contamination suppression possibilities. Optimization of the simulation code for the experimental layout and detector response is also progressing.

5 Summary and Prospects

The design works are in progress for the solenoidal magnet of the positron spectrometer. Production of the superconducting cables will start soon so that we can proceed to winding of the coils in 2001.

Construction of the large prototype of the photon detector is currently a major activity in Japan. Measurements with the photon beam at the TERAS storage ring are planned to start at the beginning of 2001. To build the final photon detector the prototype will play an important role as a test bed for various elements such as PMTs, the vessel and cryogenics.

A new prototype of the drift chamber of the positron tracker is being constructed to study engineering problems. The chamber characteristics in a magnetic field will be examined with the beam of the πM1 area at PSI in October 2000.

References

[1] A. Yamamoto et al., Nucl. Phys. **B78** (1999) 565–570.

[2] Y. Ajima et al., Nucl. Instr. and Meth. **A443** (2000) 71–100.

[3] "Search for $\mu^+ \rightarrow e^+\gamma$ down to 10^{-14} branching ratio", Research Proposal to Paul Scherrer Institut, May 1999 (PSI Proposal R-99-05.1).

[4] "Report on the Progress for the $\mu \rightarrow e\gamma$ Experiment at PSI", submitted to the PSI Programme Committee, January 2000.

[5] C. Brönnimann, R. Horisberger and R. Schynder, Nucl. Instr. and Meth. **A420** (1999) 264–269; http://pibeta.psi.ch/∼ pibeta/subprojects/dsc/dsc_sum.html.