A liquid hydrogen target for the calibration of the MEG and MEGII liquid xenon calorimeter

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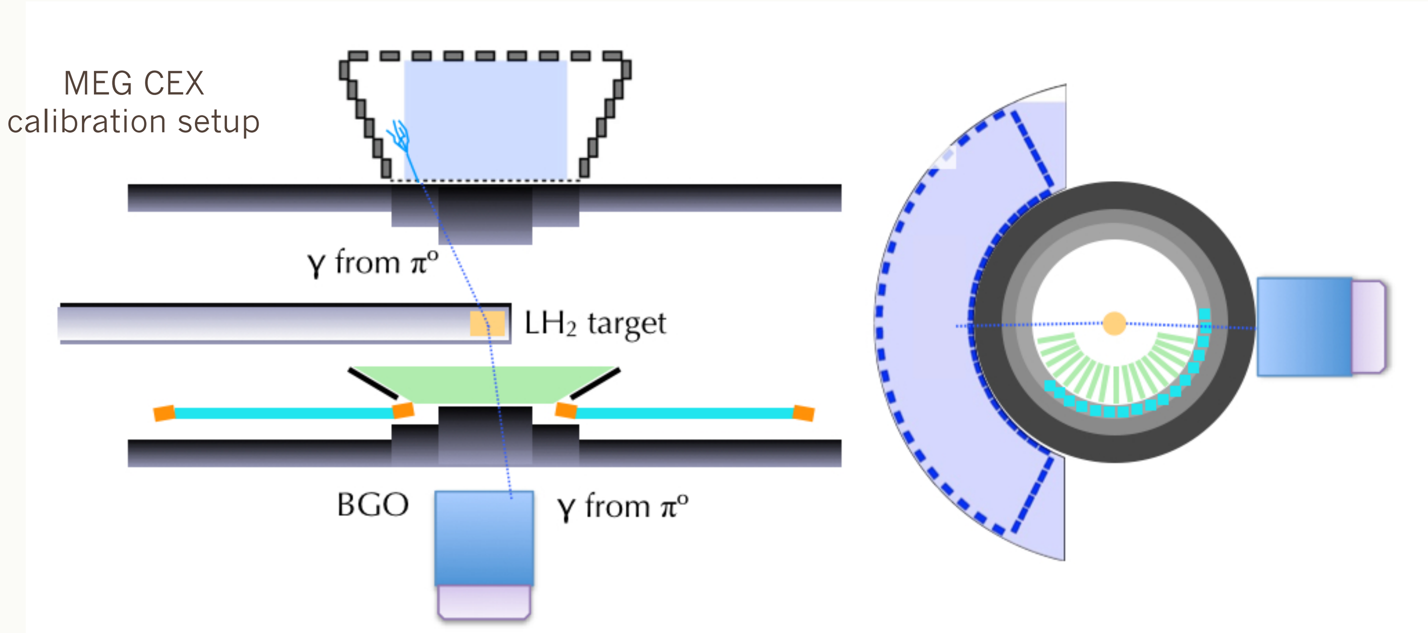
Summary We designed, constructed and operated a liquid hydrogen target for the calibration of the liquid xenon calorimeter of the MEG experiment. The target was used throughout the entire data taking period, from 2008 to 2013 and it's being refurbished and partly re-designed to be integrated and used in the MEG-II experiment.

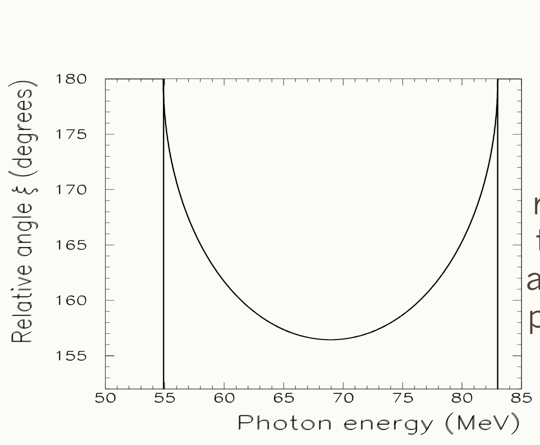
The MEG and MEG-II experiments at PSI

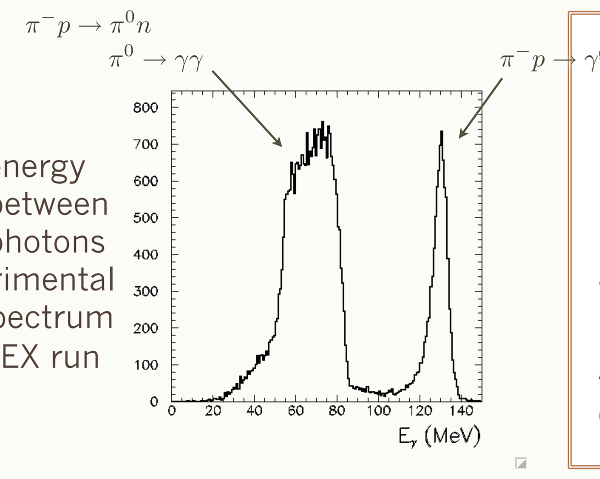
The MEG experiment at the Paul Scherrer Institut (PSI, Switzerland) is searching for the decay $\mu^+ \rightarrow e^+\gamma$ with unprecedented sensitivity [1]. This decay is forbidden in the Standard Model of elementary particles (SM), nevertheless all viable extensions of the theory predict a branching ratio for this process that could be in the reach of present or future experiments.

The observation of such a decay would be certain signature of charged lepton flavor violation (cLFV) and therefore of new physics beyond the SM. The non observation of the process at the foreseen sensitivity, on the other hand, would constrain the class of possible extensions of the present theory.

The candidate 52.8 MeV γ–rays are measured by a liquid xenon homogeneous detector, in which xenon scintillation light is measured by 848 photo-multiplier tubes (PMTs) submerged in the liquid at cryogenic temperature [2]. This will be improved in the MEG-II upgrade, where the inner face PMTs will be replaced by 12x12 mm^2 VUV-sensitive silicon photomultipliers [3]







Angle/energy relation between the two photons and experimental photon spectrum from a CEX run

The Charge Exchange Reaction

In the charge exchange (CEX) calibration a beam of π^- is stopped in a proton-rich target. Neutral pions (π^0) are produced via the reaction $\pi^- p \rightarrow \pi^0 n$ and immediately decay in two photons in the energy range 55 MeV < E_γ < 83 MeV. When the two photons are detected in a back-to-back topology their energies are 55 MeV and 83 MeV within 0.5%.

These photons, when detected by the xenon detector allow a precise determination of its energy and timing resolutions.

A proton-rich target is needed to maximize the event rate. The natural choice is a liquid hydrogen target, since both LiH and $(CH_2)_n$ targets suffer from pion capture on the elements other than hydrogen which goes like Z^4.

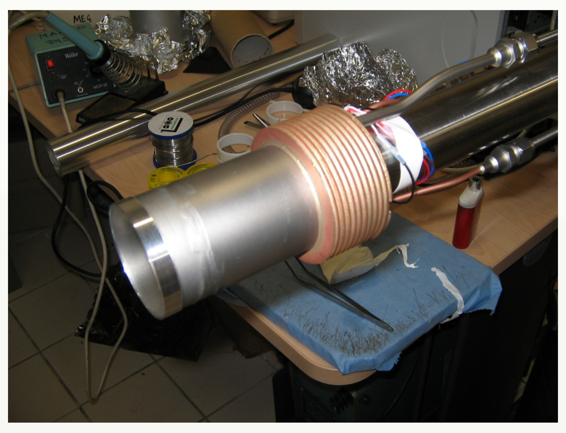
Peculiarities of the MEG/MEGII liquid hydrogen target

The liquid hydrogen target for the calibration of the MEG experiment is subject to several constraints imposed both by the geometry of the experiment and by the need to perform calibrations in a limited time during normal data taking. In particular:

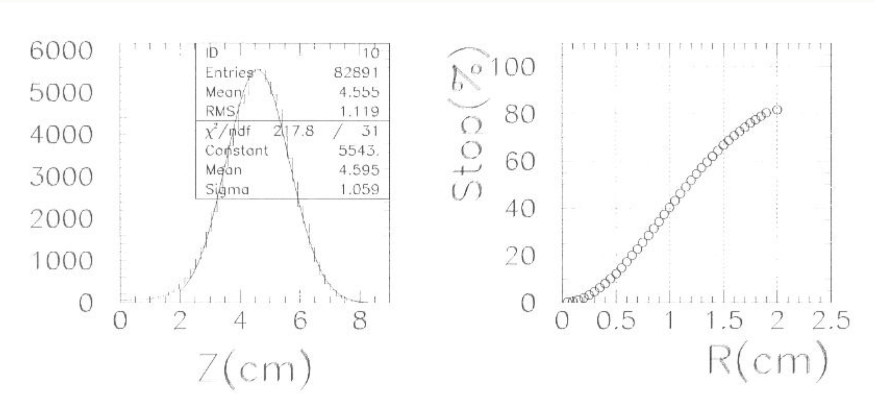
- Cell at the center of a solenoid magnet with high magnetic field (1.4 T)
- Thin windows
- Accessibility to the operating position
- Minimal material towards the calorimeter
- short data taking interruption (max beam time)
- Quick preparation: mounting, liquefaction, evaporation.

The liquid hydrogen is contained in a 500 um thick stainless steel cell 75 mm long and 50 cm diameter (150 cc liquid). This is sufficient to contain the impinging 56 MeV/c negative pions. The cell is cooled by a copper coil by a continuous flux of liquid helium. The entrance window is made of a 135 μm mylar foil glued to the target cylinder by a two components fast setting epoxy resin. The target cell is suspended by a 2 m long non-magnetic stainless steel pipe to be placed at the nominal center of the MEG-MEGII detector. A superinsulation layer is used for radiation shield. The target is enclosed in a 1 mm thick aluminum pipe 90 mm diameter, with a 135 μm mylar window glued the same way as the target. Temperature sensors, liquid helium inlet and outlet and gas hydrogen inlet/outlet ports are available at the rear of the target

Thin window pressure test at 8 bar

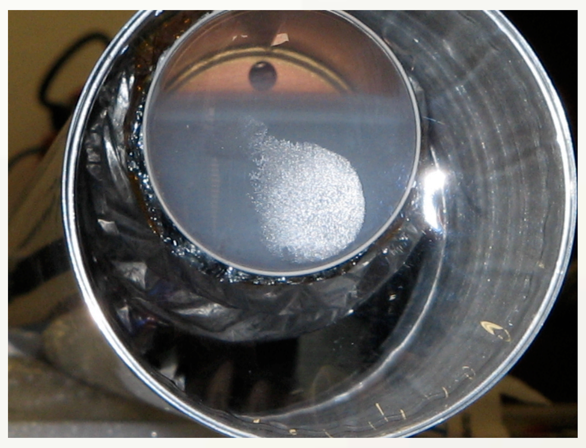


The liquid hydrogen cell



Longitudinal and radial containment of the impinging negative pions

Empty cell before liquefaction. The hydrogen gas inlet is visible

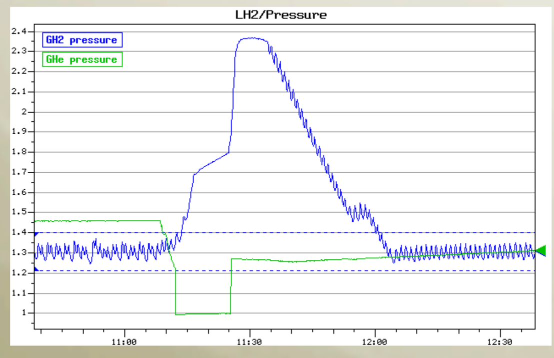


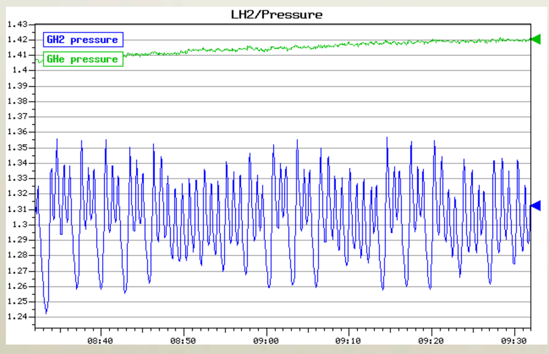
The cell in operating conditions is full of liquid hydrogen

Target operation

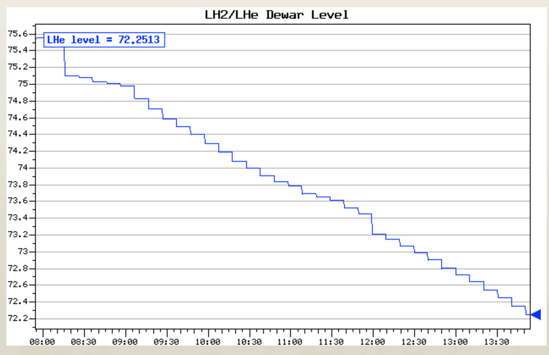
Hydrogen is kept liquid by a liquid helium flow, whose magnitude is controlled in order to keep the liquid volume stable. The working principle of the target is the following: a fixed amount of hydrogen is kept in a constant large volume (H_2 buffer) constantly connected to the cell. During normal operation the cell is cooled down to 20K and therefore fills up with hydrogen lowering the buffer pressure. When the helium flux ends the hydrogen is left free to expand back to the 94 liters buffer volume. The maximum buffer pressure is 2.5 bar when the target is warm, and 1.2 bar when the target is operating. In this way we guarantee a safe operation in case of liquid helium shortage.

The target does not need precooling and liquefaction takes place in about 50 minutes from the start of the LHe flow. Helium exits the cooling circuit in gas phase. To keep the hydrogen level stable a sensor monitors the cell pressure and activates a PID feedback on a proportional valve that controls the helium exhaust flux. In this way a level stability of 2% is reached.

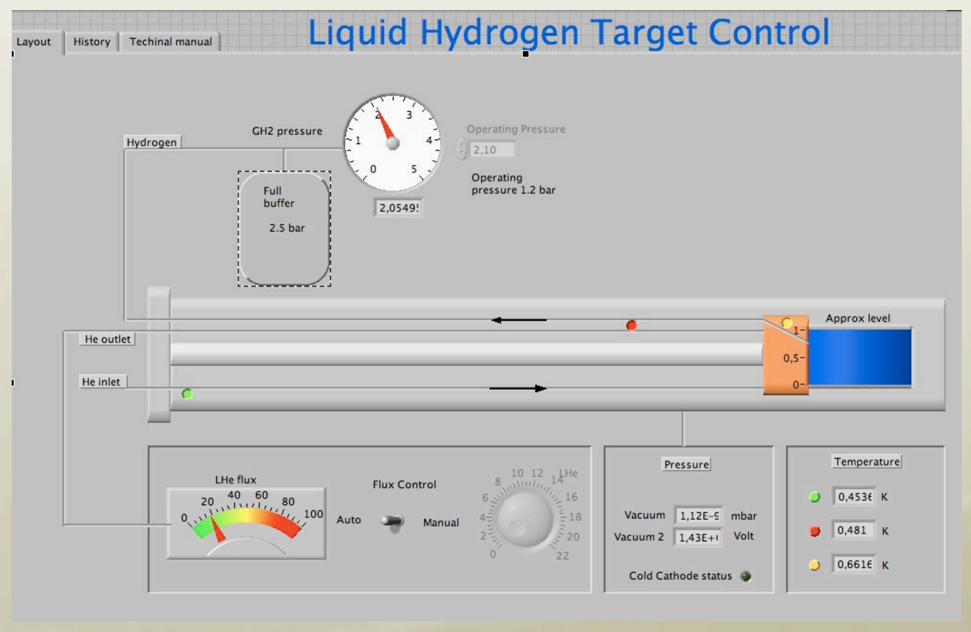




In 50 minutes the target is ready for operation and its pressure/volume is stable at the percent level

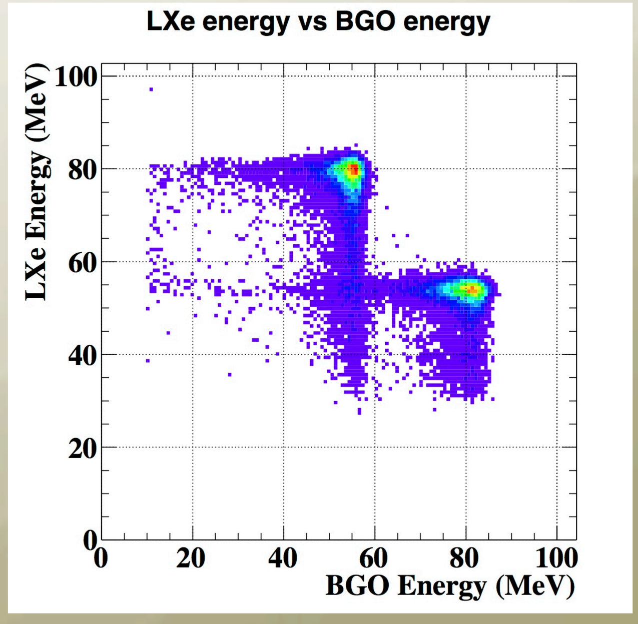


Liquid He consumption is roughly 3 liters per hour



The control panel of the hydrogen target allows an easy operation and tuning of the stability

Plot of the energy of back-to-back photons as observed by the MEG liquid xenon detector against a calibration BGO detector, as depicted in the picture above right



Results

The liquid hydrogen target described here was operated for the calibrations of the MEG experiment during years 2008-2013 and allowed the precise determination of the energy and timing response of the liquid xenon detector.

It is presently being re-adapted, both from a mechanical and a cooling point of view to be used in for the MEGII detector calibrations.

References:

[1] J. Adam *et al.* [MEG Collaboration], *Phys. Rev. Lett.* **110** (2013) 201801

[2] J. Adam *et al.* [MEG Collaboration], *Eur. Phys. J.* **4** (2013) 2365

[3] K. Ieki, Oral presentation at this conference

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