The XENON1T Water Cherenkov Muon System for the Next Generation of XENON Dark Matter Searches

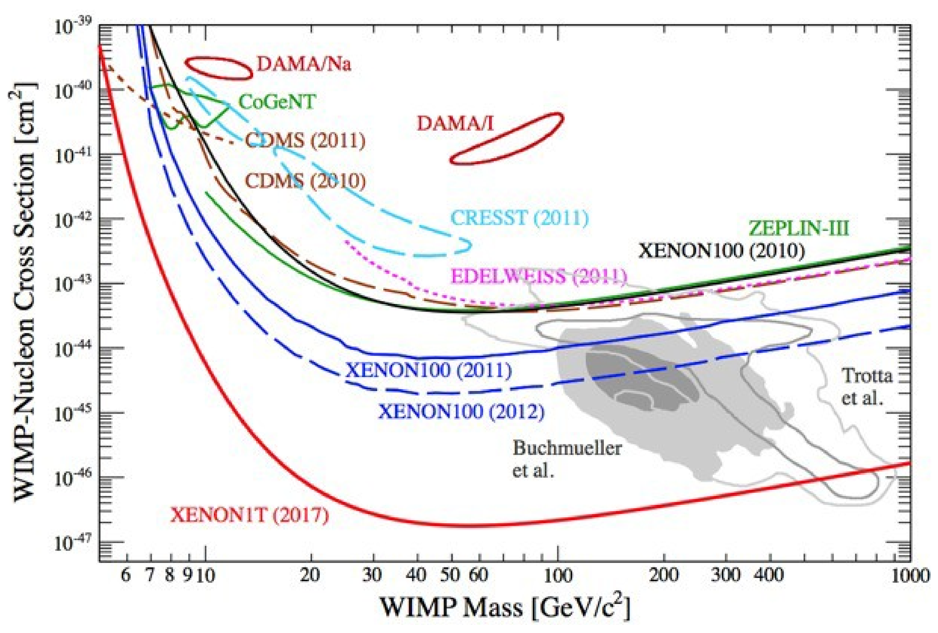
Serena Fattori, Christopher Geis, Cyril Grignon, Uwe Oberlack, Rainer Othegraven, Daniel Paetzold
(On behalf of the XENON Collaboration)

Columbia Rice UCLA Zurich Coimbra LNGS Mainz Purdue INFN Bologna Subatech Münster Nikhef Heidelberg Weizmann

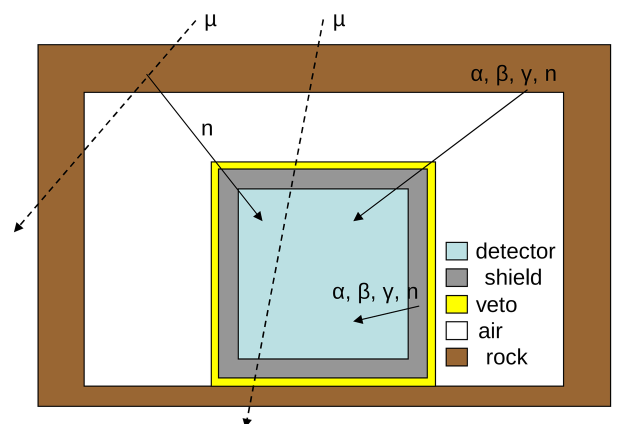
Introduction

Following the Xenon10 and Xenon100 experiments , **XENON1T** is planned to become the 3rd stage of a series of experiments performed by the XENON collaboration for the direct detection of WIMPs[1]. As for the previous two experiments, the XENON1T detector will be placed in the Gran Sasso underground laboratory (LNGS) in Italy. The system design phase is now completed, final tests are ongoing and the construction of the detector will begin by the end of 2012. First analysis of Dark Matter data is expected in 2014.

The goal of this third XENON experiment is to achieve a sensitivity for the spin-independent WIMP-nucleon cross section in the order of 10^{-47} cm2. This sensitivity improvement of two orders of magnitude requires, beside a fiducial mass of the detector of about 1 ton liquid Xenon (LXe), a similar reduction in background.



Background is caused by radioactive contaminatioins in the detector materials and surroundings as well as from high energy neutrons induced by cosmic ray muons penetrating the rock.



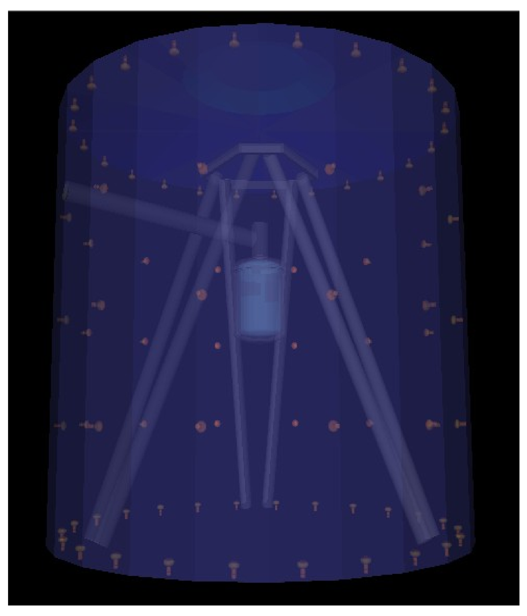
This last contribution is the most dangerous since it cannot be stopped with passive shielding and produces a WIMP-like signal in the detector. Residual muons reaching the LNGS under-ground halls have a flux in the order of 10^{-8} μ/cm^2s[3] and an average energy of 320 GeV[4]. The consequent neutrons hitting the detector can be vetoed if the passage of their parent muon or its secondary charged particles are detected through the Cherenkow light they produce in a mass of pure water surround the XENON detector.

The XENON1T Water Cherenkov Muon Veto system was developed to absorb environmental natural radioactivity and tag energic neutrons from muon interactions. The system is composed of a stainless steel tank 10.5m high and 9.6m in diameter, with the internal surface covered with a reflector film and filled with high pure water. To exploit the water as a Cherenkov medium the system is equipped with Photomultiplier tubes (PMTs). The LXe detector is placed in the center of the tank sustained by its support structure.

MC Simulation

An intenseive Monte Carlo (MC) study has been performed in order to optimize the shape of the tank, the type of reflector foil and the number, type and position of the PMTs. Results of this study led to the choice of DF2000MA reflector foil, together with 84 high quantum efficiency (~30%) Hamamatsu 8" PMTs located in 3 arrays:

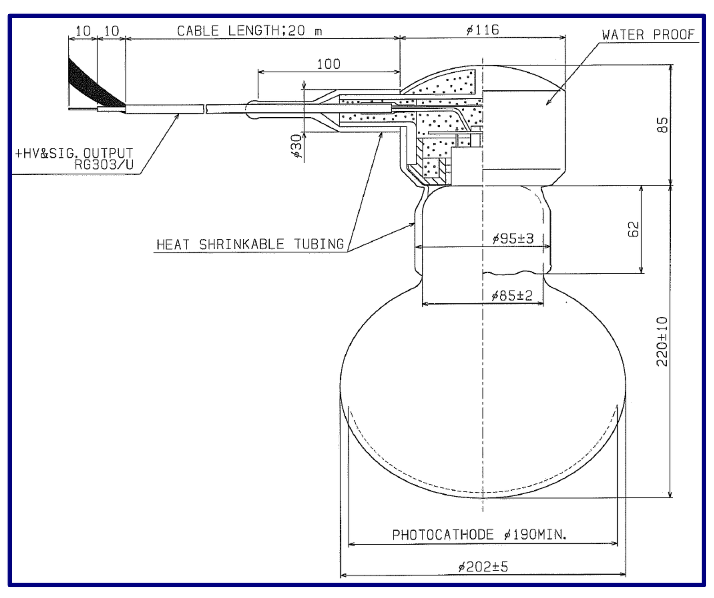
TOP: composed of a ring of 24 PMTs at 4.5m radius looking down-wards;
LATERAL: composed of 3 times 12 PMTs in equally spaced rings attached to the tank surface, looking inwards;
BOTTOM: composed of 24 PMTs at 4.5m radius looking upwards.

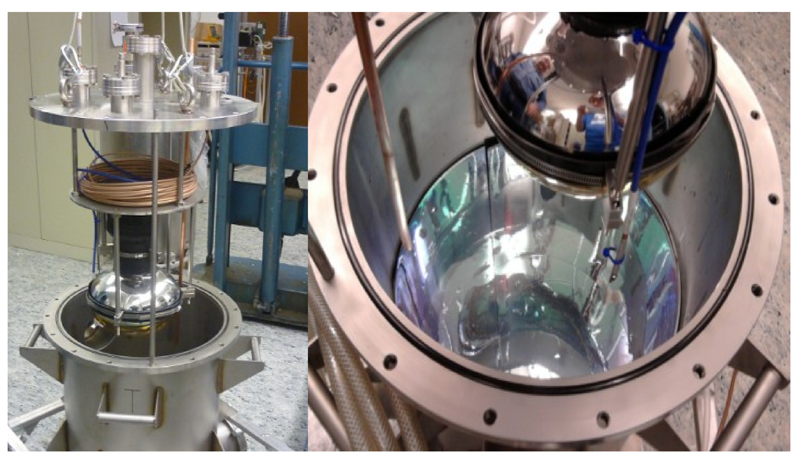


The efficiency in tagging muon induced neutrons hitting the water tank, obtained simulating this set-up is: >99.5% (this happens in 1/3 of the cases) when also the parent muon is hitting the water tank, (70.7 +/- 0.5)% otherwise (this happens in 2/3 of the cases).
These results are conservative since they do not take into account the wavelength shifting power of the reflector foil, which increase the amount of Cherenkov photons in the visible region of the PMTs. This property of DF2000MA is at present under study.

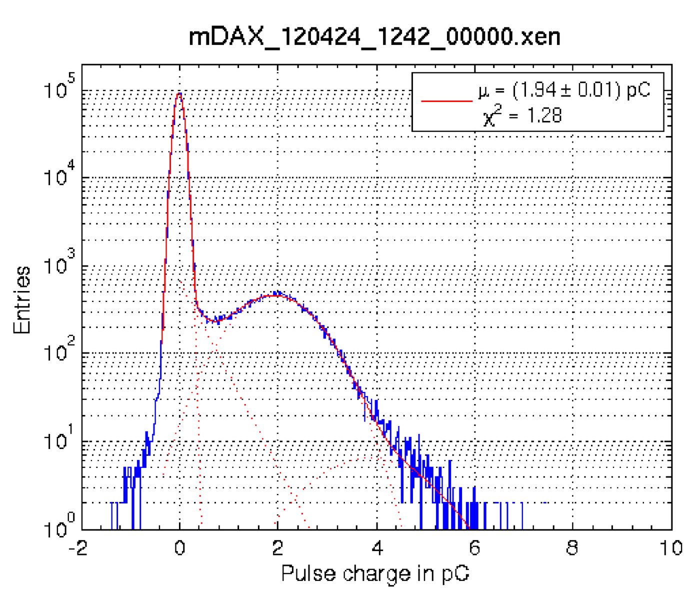
PMT tests

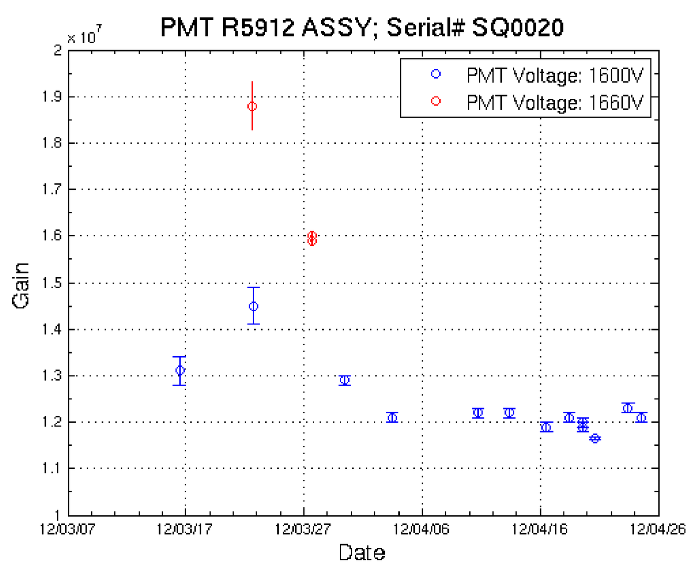
The **PMT model**, that will be used for the muon veto, is the 8-inch R5912 ASSY from Hamamatsu[6].
84 of this PMTs will be placed inside the XENON1T tank and will run in water. Tests have been performed in order to verify their waterproof capability, to measure their gain and to check their long term stability.



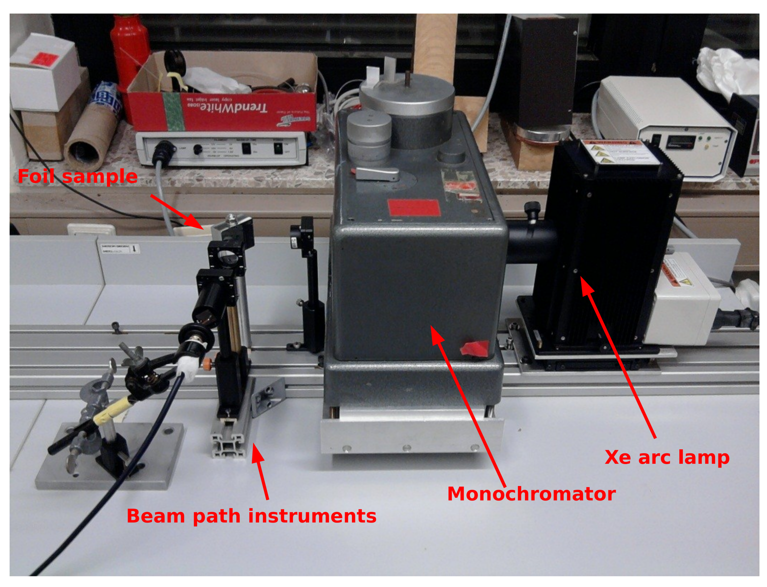


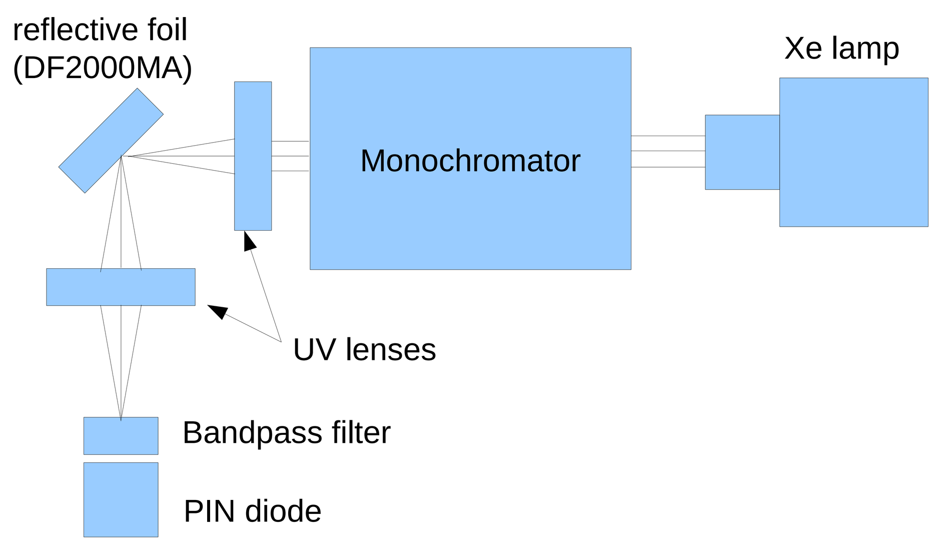
The measurements under water have been realized in a small water tank with and without pressure (2 bar to simulate the pressure of the water column in the Muon Veto Water Tank)





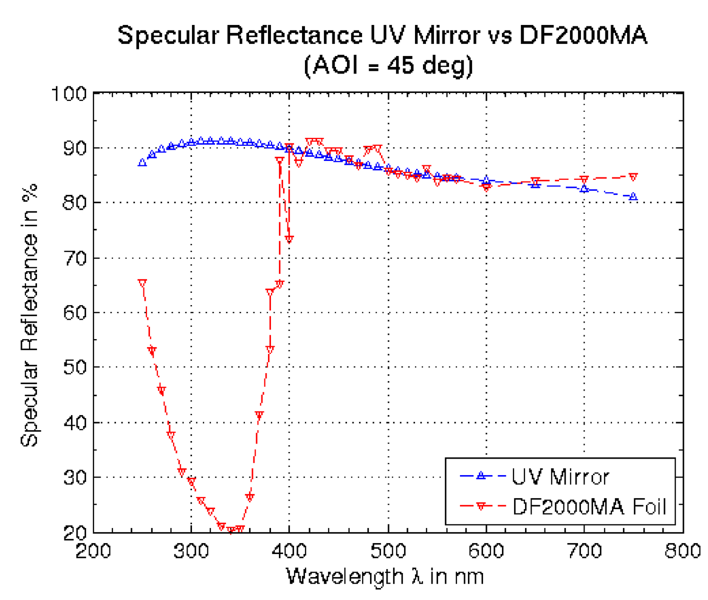
Reflective foil tests

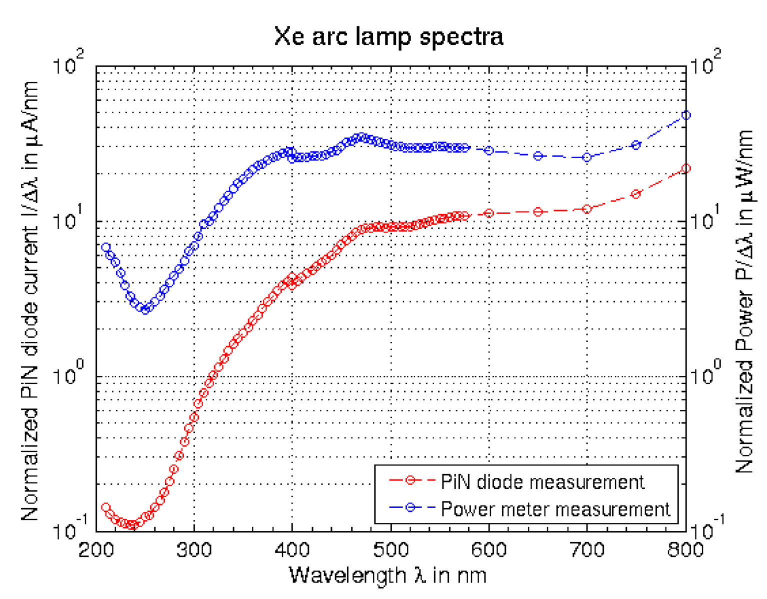




The foil selected through the MC study is DF2000MA by 3M[7]. It is a polymeric film with a total luminous reflectivity of 99% for wavelengths higher than 400nm. In order to verify this property and to know a detailed reflectivity curve, an optical setup has been build

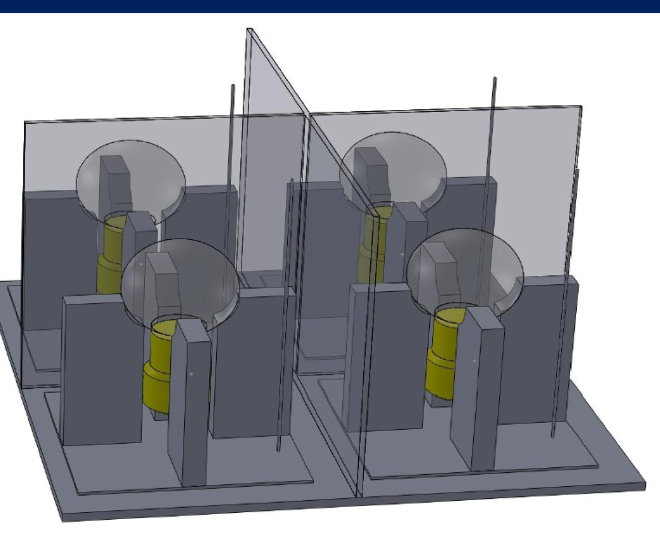
The reflectivity has been measured with the use of a Xe arc lamp coupled to a monochromator in order to scan small wavelength intervals. Comparison to a certificated reflection standard leads to the specular reflectance curve of the foil.





What next

Before to install the 84 PMTs in the Muon Veto they will be tested inside a black box (in bunch of 4) in order to verify their functioning and to measure their gain and dark rate. These systematic tests will start in July 2012.
In parallel measurements devoted to verify the wavelength shifting power of the reflector foil DF2000MA will be realized.



References

[1] M. W. Goodman, E. Witten, Phys. Rev. D31, 1985
[3] M.Selvi et al, Proceedings of the 31st ICRC 2009
[4] M. Ambrosio et al., Astroparticle Physics 10 (1999) 11-20
[5] Serena Fattori, DPG spring meeting 2012 in Mainz, talk session HK 63.8
[6] Hamamatsu Photonics K.K., Electron Tube Division
[7] 3M Company, Graphic Solutions Divison
[8] http://xenon.physik.uni-mainz.de