XENON1T WATER CHERENKOV MUON VETO

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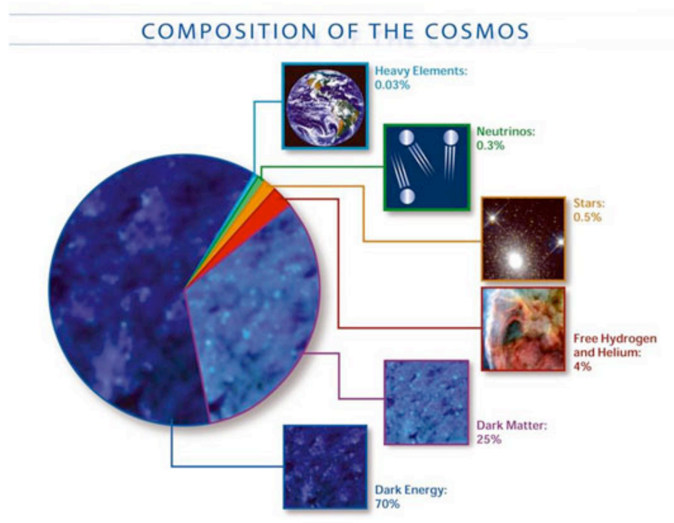
XENON Dark Matter Project

Dark Matter & the XENON Project

Astronomical observations [1],[2],[3] indicate that the universe is mostly composed of unknown ingredients, so called Dark Matter and Dark Energy, rather than the familiar types already integrated in the Standard Model.

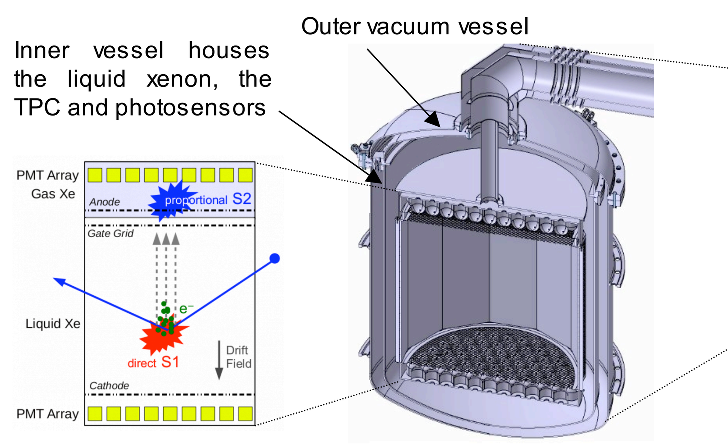
The dark matter favorite candidate, arising from SUperSimmetrY (SUSY) theories [4] , is the Weakly Interactive Massive Particle (WIMP).

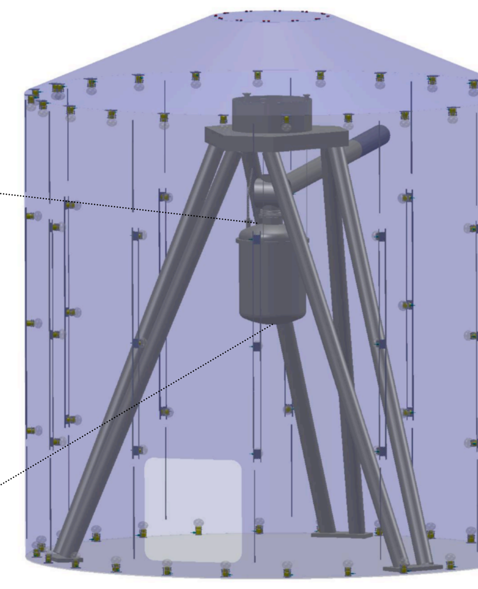


XENON is a dark matter search experiment based on the direct detection of WIMPs interacting in the target nuclei.

The detector is a double-phase (gas/liquid) Time Projection Chamber (TPC) with liquid xenon being the target material for the WIMP scattering.

A particle interaction produces direct scintillation light and ionization electrons. After the electrons have been extracted into the gas phase they cause proportional scintillation.





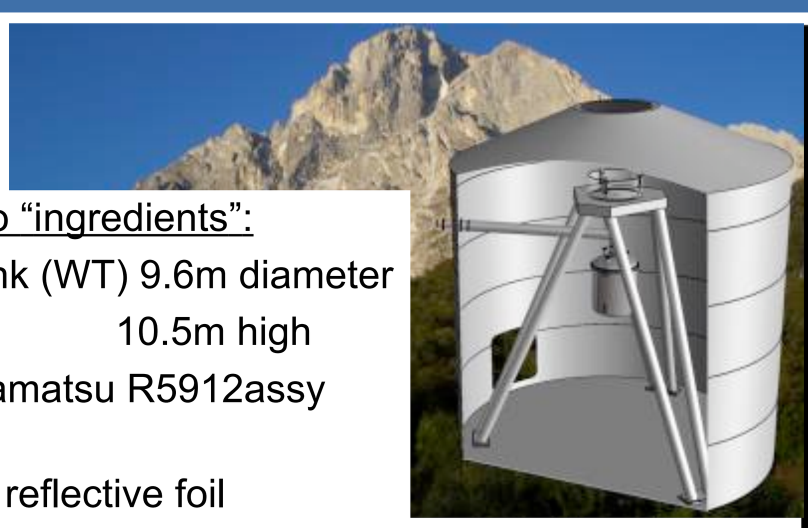
The detection principle is based on a simultaneous measurement of both scintillation signals by using two arrays of photomultipliers (PMTs) on top and bottom of the TPC

❑ **XENON10** (of 5.6 kg fiducial mass), operated in 2006-2007 at the Gran Sasso National Laboratory (LNGS) - Italy, published the world's best limits, in 2008, on elastic WIMP-nucleon interactions [5],[6] : in particular **$4.5 \cdot 10^{-44}$ cm²** for Spin Independent (SI) case and WIMP mass of 30 GeV/c² at 90% C.L..

❑ **XENON100** (of 48 kg fiducial mass) is currently taking dark matter data at LNGS, with the goal to explore the SI elastic cross section at a sensitivity of $2 \cdot 10^{-45}$ cm², and has completed a dark matter run with 100.9 live-days of data last year, setting the world best limit on the SI cross section of **$7.0 \cdot 10^{-45}$ cm²** for a WIMP mass of 50 GeV/c² at 90% C.L.[7]. XENON100 has also ruled out the explanation for the observed DAMA/LIBRA modulation as being due to inelastic dark matter [8].

❑ The next generation experiment **XENON1T**, with construction at LNGS starting this fall, aims at a further sensitivity improvement by two orders of magnitude to about **$2 \cdot 10^{-47}$ cm²**. This requires a similar reduction in background and a fiducial mass of about 1 ton liquid Xenon. Backgrounds result from natural radioactivity in the detector materials and surroundings as well as from high-energy neutrons from cosmic ray muons penetrating the rock. Looking inside out, backgrounds are reduced by the self-shielding properties of high Z and high density liquid xenon, enabled by the 3D position reconstruction ability of the TPC, and by discrimination of electronic and nuclear recoils. Materials are screened and selected for radiopurity. Here we present the water Cherenkov muon veto system, which will attenuate all backgrounds from environmental natural radioactivity and tag energetic neutrons from muon interactions. Muons reaching the LNGS underground halls have a residual flux of **$(3.31\pm0.03)\cdot10^{-8}$ μ/cm²s** [9] and an average energy of **320 GeV** [10]. Through electro-magnetic and hadronic cascades, muons produce energetic neutrons that may elastically scatter off xenon nuclei, leaving a WIMP-like signal. Such background can be vetoed if the passage of a muon or secondary charged particles are detected through their Cherenkov light in pure water.

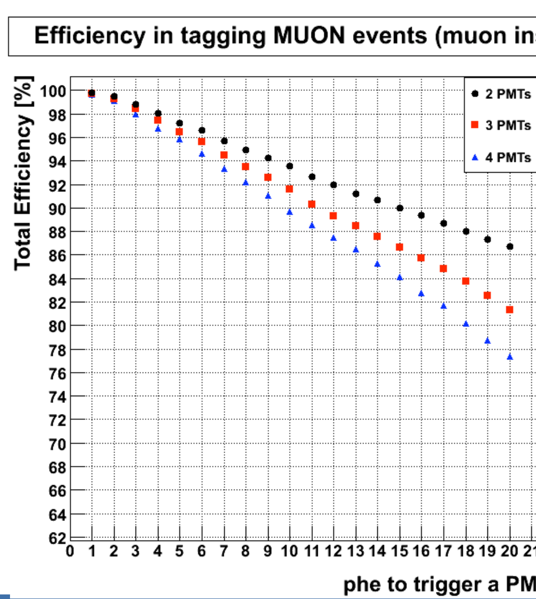
GEANT4 MC Simulations

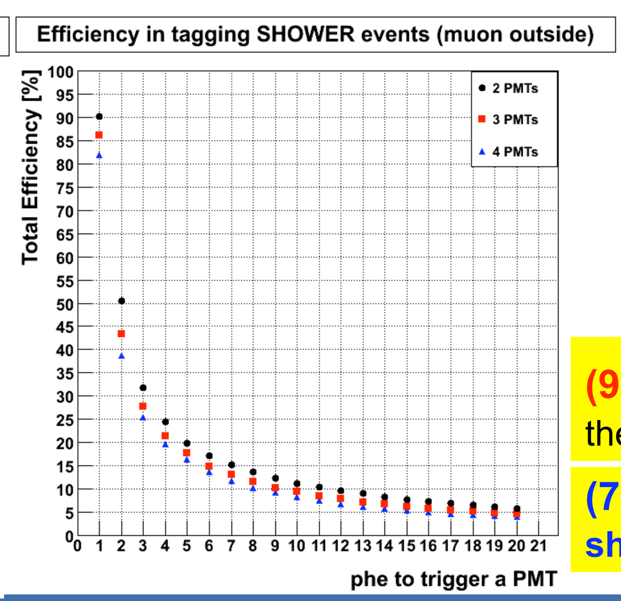


Muon Veto "ingredients":

- water tank (WT) 9.6m diameter 10.5m high
- 84 Hamamatsu R5912assy PMTs
- VM2000 reflective foil

A detailed MC study has been performed with GEANT4 simulations in order to optimized the choice of the reflective foil, the shape of the water tank and the PMTs type, number and positioning.



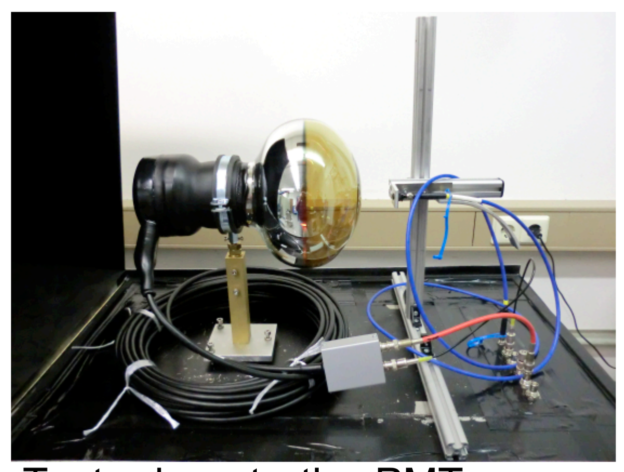


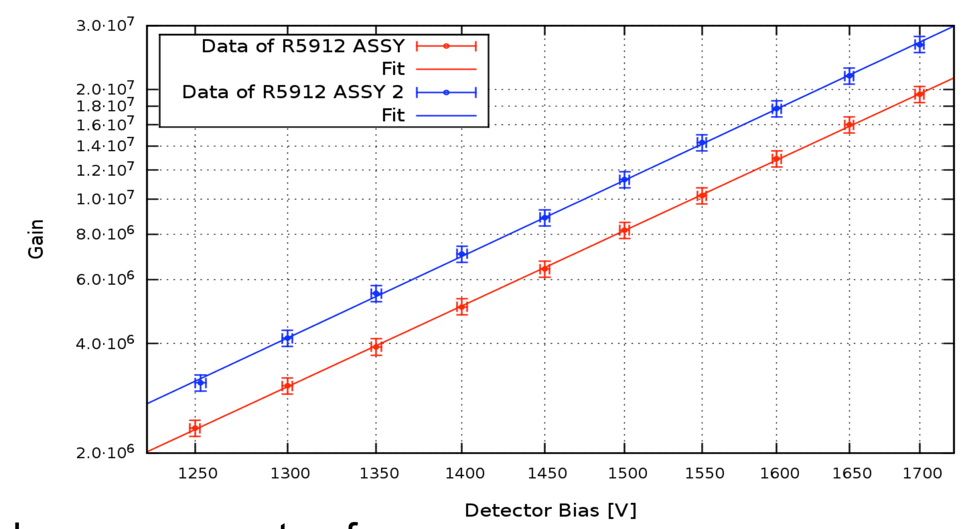
Triggering at 1 photoelectron/PMT, 4-fold coincidence in 300 ns (verified with measurements), we have the efficiency values of:

(99.73 ± 0.05)% μ-event the muon hits the WT

(78.3 ± 0.4)% shower-event only the μ secondaries hit the WT

HAMAMATSU PMTs Tests





Tests done to the PMTs in different institutions:

- Bologna,
- Mainz,
- Torino

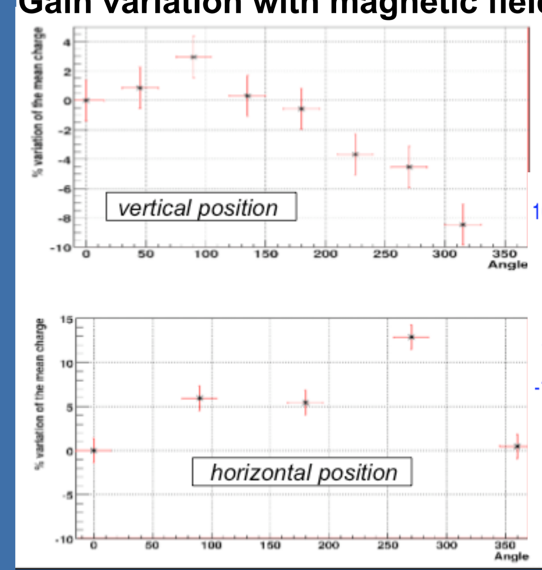
We had measurements of:

- dark rate vs. threshold;
- gain vs. high voltage;
- gain vs. magnetic field;
- gain stability vs. time;
- response vs light position

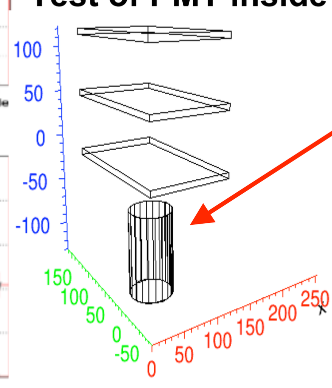
PMTs were tested:

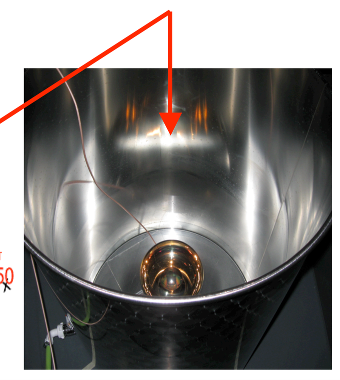
- in air;
- in water;
- above ground
- underground

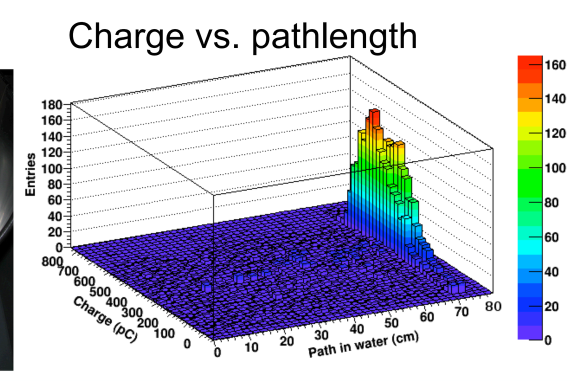
Gain variation with magnetic field



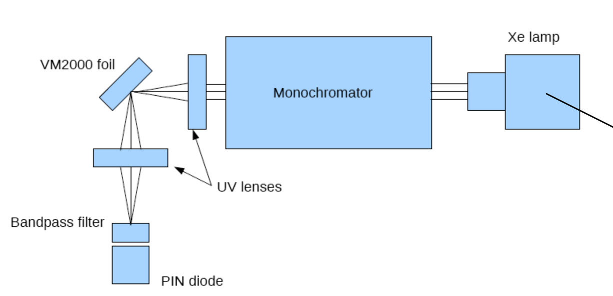
Test of PMT inside small water tank with cosmic muons (SQE PMT)

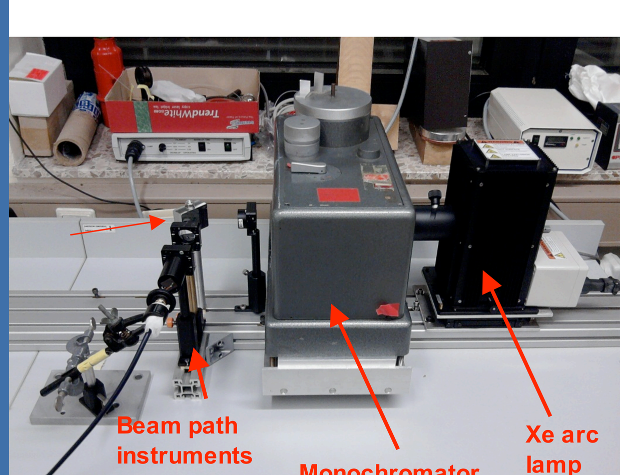


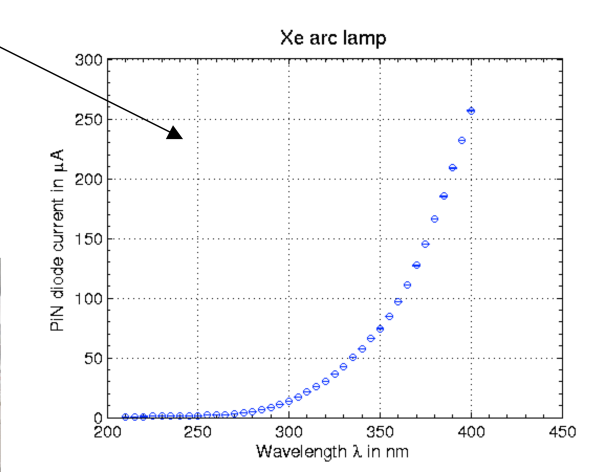




VM2000 foil Tests







Measurements are ongoing to test the wavelength shifting power and the reflective properties of foil VM2000

Ideas for Calibration

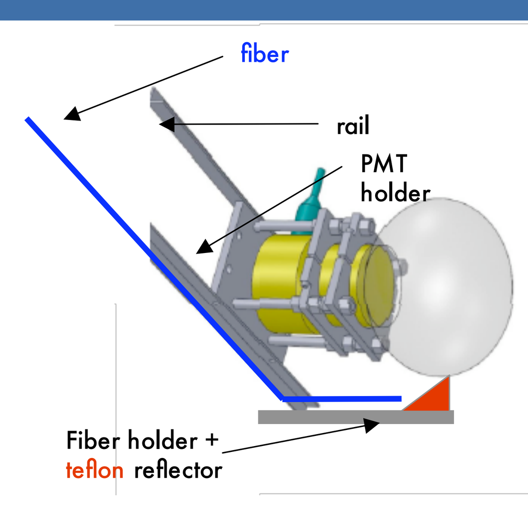
Studies for a calibration system are ongoing.

We are considering to use:

-1 blue LED + PMMA fiber (1 mm diameter core) for each PMT to allow a s.p.e calibration

- diffuser balls (silicon + glass bubbles [11]) for homogeneous illumination.

Simulations will be realized to decide how many diffuser balls to use and where to put them.



References

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http://xenon.astro.columbia.edu/

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