# Active Neutron Detector for direct Dark Matter searches with the DarkSide-50 experiment at Gran Sasso

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*The existence of dark matter is known from gravitational effects, and although its nature remains undisclosed, there is a growing indication that the galactic halo could be permeated by WIMPs with mass on the order of 100GeV. Among diverse and complementary ongoing dark matter searches, direct observation of WIMP-nuclear collisions in a laboratory detector plays a key role in this search. However, it also poses significant challenges, as the expected signals are low in energy (below 100keV) and very rare (a few interactions per year per ton of target).*

*DarkSide is a project for direct observation of WIMPs in a liquid argon time-projection chamber that can meet these challenges. A limiting background for all dark matter detectors is the production in their active volumes of nuclear recoils from the elastic scattering of neutrons. DarkSide-50 is equipped with a high-efficiency liquid scintillator, doped with Boron, which is used as an active neutron detector. The neutron detector's tank is a 4m diameter sphere instrumented with 110 low-background 8'' PMTs deployed in a water Cherencov detector which will serve both as a passive shield and as a veto of cosmic-ray muons. In order to acquire the PMT signal we have developed custom front-end amplifiers with built-in trigger capabilities and a DAQ system based on high-resolution fast digitizers.*

## Introduction

There are many compelling pieces of evidence for the existence of **Dark** (*i.e.*, non-luminous and non-absorbing) **Matter**. Such evidences include the measurement of the galactic rotation curves and the observation of clusters of galaxies: their behaviour can only be explained supposing the presence of a large amount of invisible non-baryonic matter. Dark Matter candidates must be **stable on cosmological time scales** (otherwise they would have decayed by now), must **interact very weakly with e.m. radiation** (otherwise they wouldn't qualify as *dark* matter) and must **have the right relic density**.

The best motivated candidates are **WIMPs**, particles with mass ~100GeV and cross-section ~$10^{-47}$cm$^2$, that can be gravitationally trapped inside our galaxy and detected by their scattering on nuclei [1]. Direct observation of WIMP-nuclear collisions in a laboratory detector plays a key role in the dark matter search. However, it poses at the same time significant challenges, as the expected signals are low in energy (below 100keV) and very rare (a few interactions per year per ton of target). Large (0.1-10 ton target mass) "discovery" (underground and ultra low-background) detectors are mandatory.

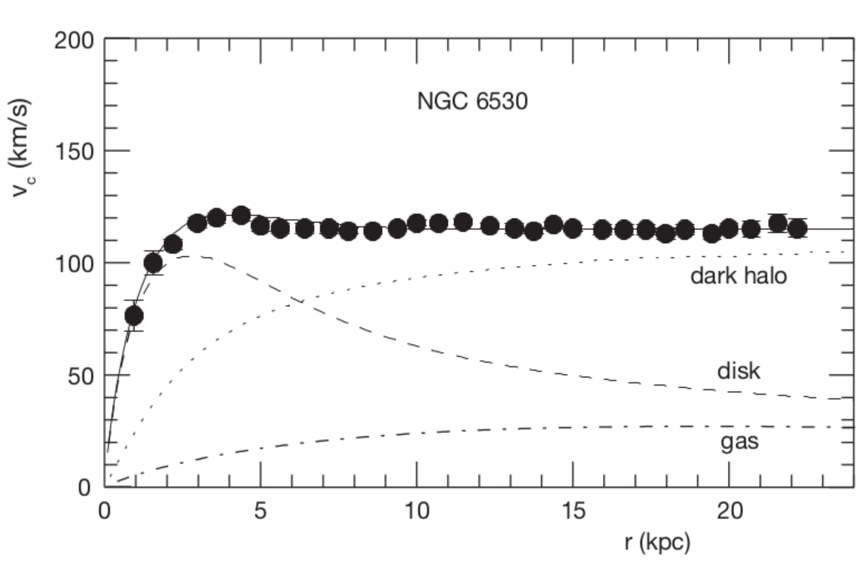


Fig. 1 Example of a galactic rotation curve

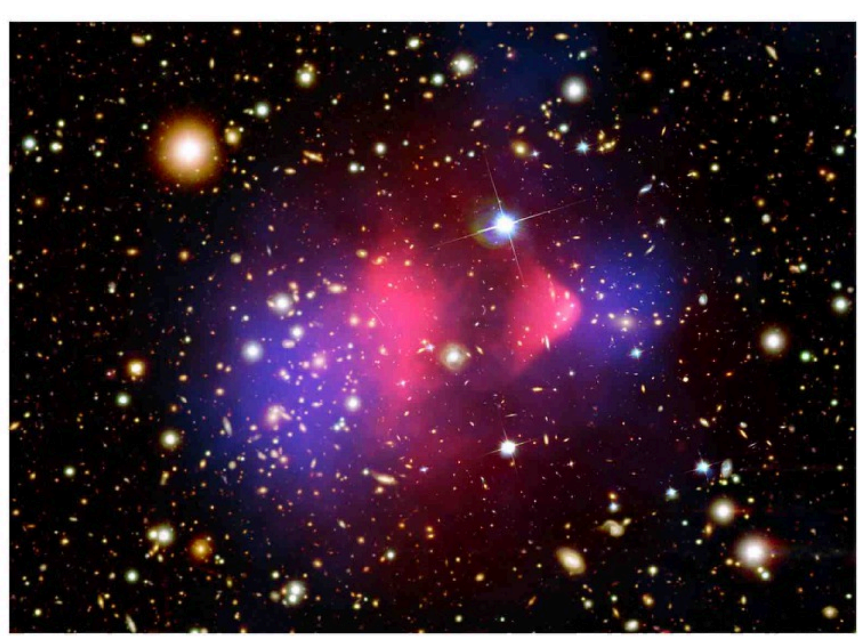

Fig. 2 Example of gravitational lensing: the galactic cluster 1E0675-56

## DarkSide-50 detector

**DarkSide** is a project for direct observation of WIMPs in a two-phase liquid argon time-projection chamber (TPC) with scalable, zero-background technology.

**DarkSide-50 (DS-50)** is the first of the DarkSide physics detectors built using low-background techniques and materials. Located underground in Hall C @ Gran Sasso National Laboratory (LNGS), DS-50 has an active mass of 50kg of low-radioactivity underground argon and a projected sensitivity of 2 × $10^{-45}$ cm$^2$ for a WIMP mass of the order of 100GeV (90% C.L.) in a 3 year run. The DS-50 TPC is surrounded by its liquid scintillator neutron detector. Both detectors are deployed in the Borexino Counting Test Facility (CTF), a 10m high, 11m diameter water tank instrumented with photomultipliers.

Fig. 3 The DS-50 TPC inside the Neutron detector.

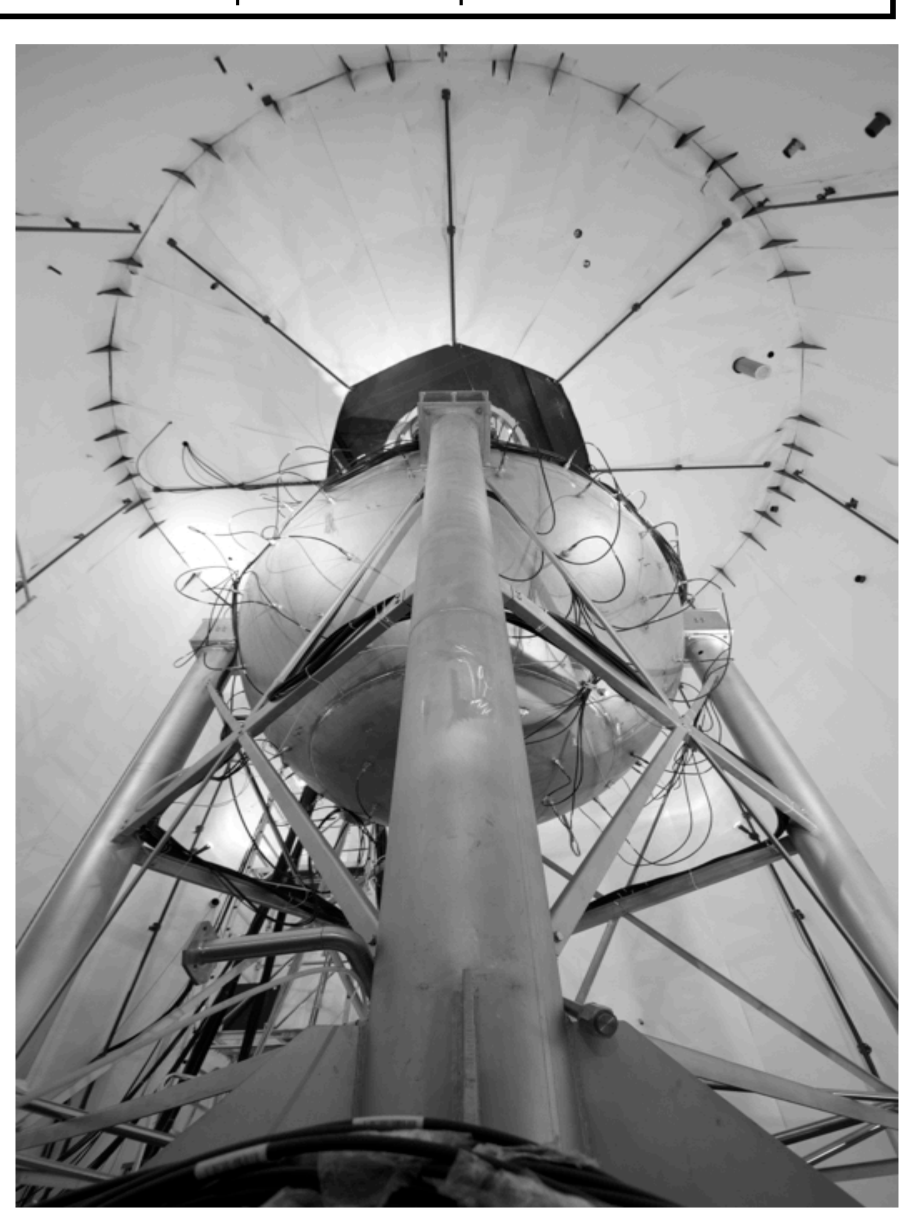

Fig. 4 The Netron detector inside the CTF.

## The Neutron detector

The **ultimate background** for any dark matter detector is **neutrons** which can elastically scatter to produce single recoil nuclei in the detector. Individually, these neutron-induced recoils are indistinguishable from WIMP interactions.

Instead of passive shielding, a **superior method** of neutron suppression is the use of an active detector in which the neutrons from both internal and external sources are detected with very high efficiency and the corresponding recoil events induced by neutrons in the argon are thus identified and rejected. Apart from the direct background suppression, an active veto also provides an *in situ* measurement of the true neutron background in the experiment.

DarkSide-50 is equipped with a high-efficiency liquid scintillator (a 1:1 mixture of PseudoCumene PC and TriMethylBorate TMB) which is used as a **Neutron detector**. The neutron detector's tank is a 4m diameter sphere instrumented with 110 low-background 8'' PMTs and it is covered with diffuse reflectors to recycle the light not hitting the PMTs directly [2].

## The Neutron detector electronics

Neutron veto PMT signals are fed to custom low noise (~220μV), high-bandwidth (200MHz) x10-amplifiers with compensated low-drift offset.

Such **Front-End Modules** (FEM) also feature built-in discrimination with scaler and coincidence trigger functionality.

Amplified signals are acquired by National Instruments high-resolution (10bit) fast (1.25GSample/s) **digitizers**. The necessary high data throughput is guaranteed by an *ad-hoc* designed LabVIEW based data acquisition system.

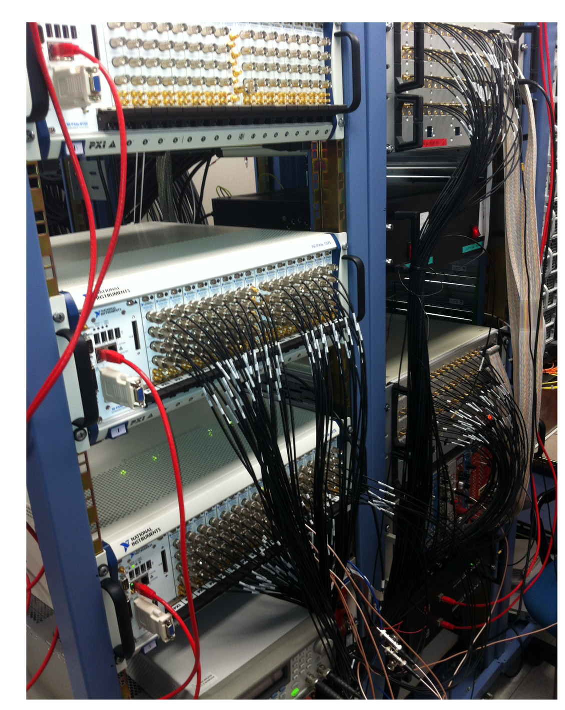

Fig. 5 The Neutron detector electronics.

## Current Status

The system is under **commissionig**. We are performing a full test of the Neutron Detector using laser and sources. Currently we are **taking data** with an $^{241}$Am source and a glass cell filled with the scintillator mixture and suspended in the detector in different positions in order to evaluate light collection uniformity.

The neutron detector will be filled in September 2013. The first DarkSide-50 **physics run** is expected to start **before the end of 2013**.

Fig. 6 The PC cell and the $^{241}$Am before the insertion.

Fig. 7 The PC cell and the $^{241}$Am inside the neutron detector.

## References

[1] J. Beringer et al. (Particle Data Group), Phys. Rev. D86, 010001 (2012)

[2] A. Wright et al. "*A Highly Efficient Neutron Veto for Dark Matter Experiments*", Nuclear Instruments and Methods A 644, 18 (2011).