The ArDM Experiment

A Double Phase Argon Calorimeter and TPC for Direct Detection of Dark Matter

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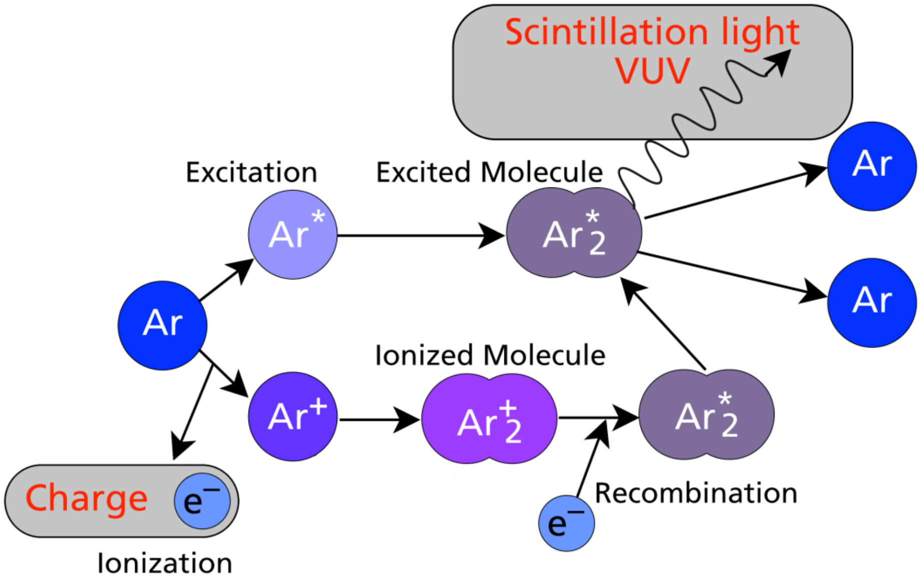
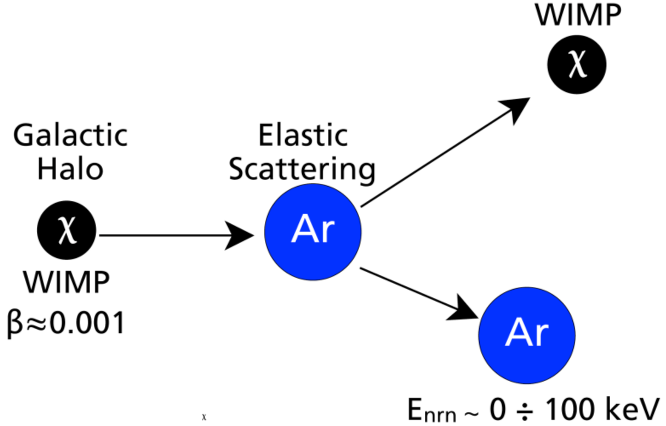
WIMP Detection

A leading Dark Matter candidate is the WIMP (weakly interacting massive particle): stable, neutral, non-relativistic.

The ArDM detection principle is based on elastic scattering of the WIMPs on argon nuclei.

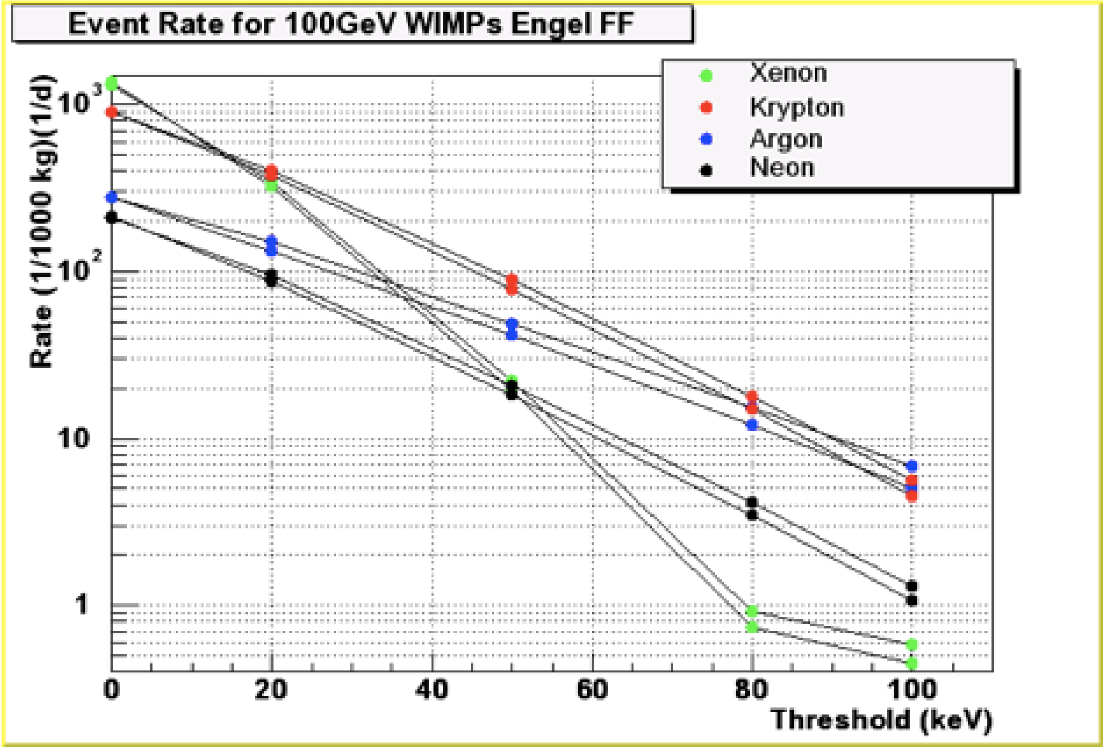
- WIMP velocity: $\beta \approx 0.001$
- Recoil energy 0 – 100 keV
- Assumed threshold for detecting a signal in ArDM: 30 keV
- Interaction similar to elastic scattering of low energetic neutrons





Both, the ionization charge and the scintillation light, are collected in the ArDM experiment.

Integrated Event Rate



Simulation of the total integrated event rate above the recoil energy threshold per day and per ton Xe/Kr/Ar/Ne

Assumptions:

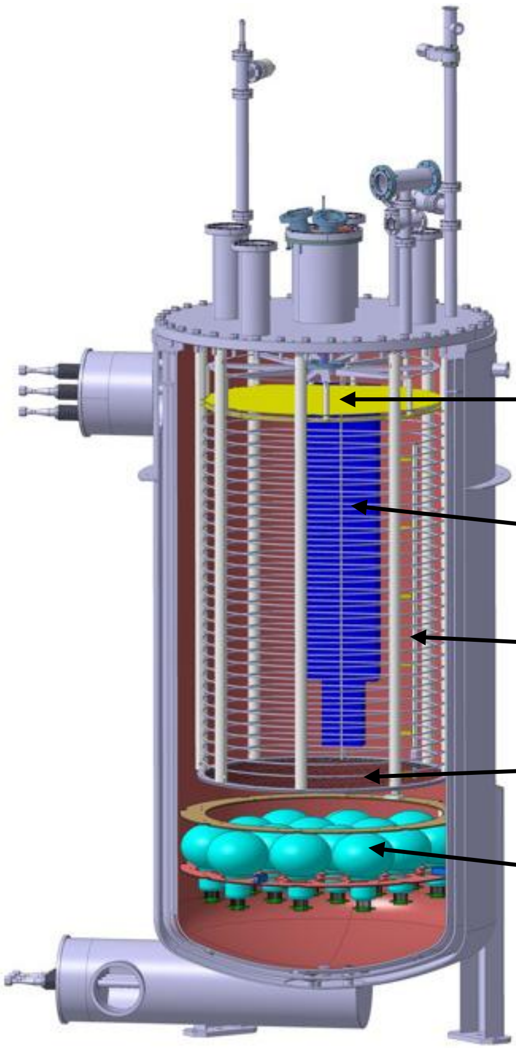
- Cross-section per nucleon $\sigma = 10^{-6}$ pb
- WIMP mass M_{WIMP} = 100 GeV
- Spin independent interaction
- Engel form factor
- WIMP density = 0.5 GeV/cm^3
- Galactic escape velocity v_{esc} = 600 km/s

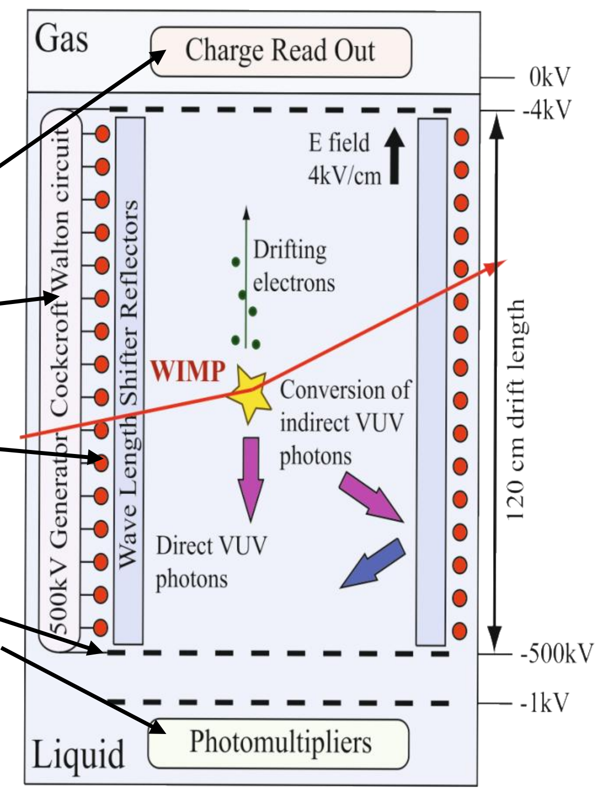
To detect this rare events the ArDM experiment will be placed in a low background underground laboratory.

Conceptual Design

Cylindrical volume:	Drift length: 120 cm
	Diameter: 80 cm
Target:	850 kg
Drift field:	1 – 4 kV/cm

Reduction of the heat input by LAr cooling jacket and vacuum insulation





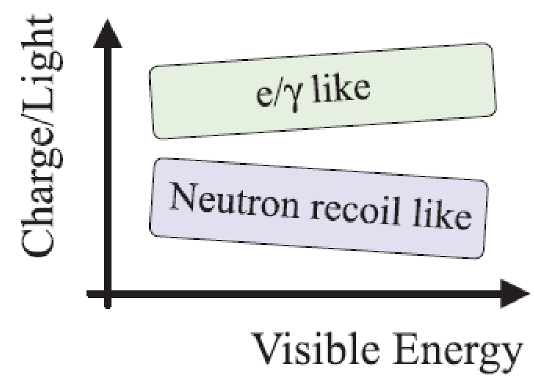
Detection principle

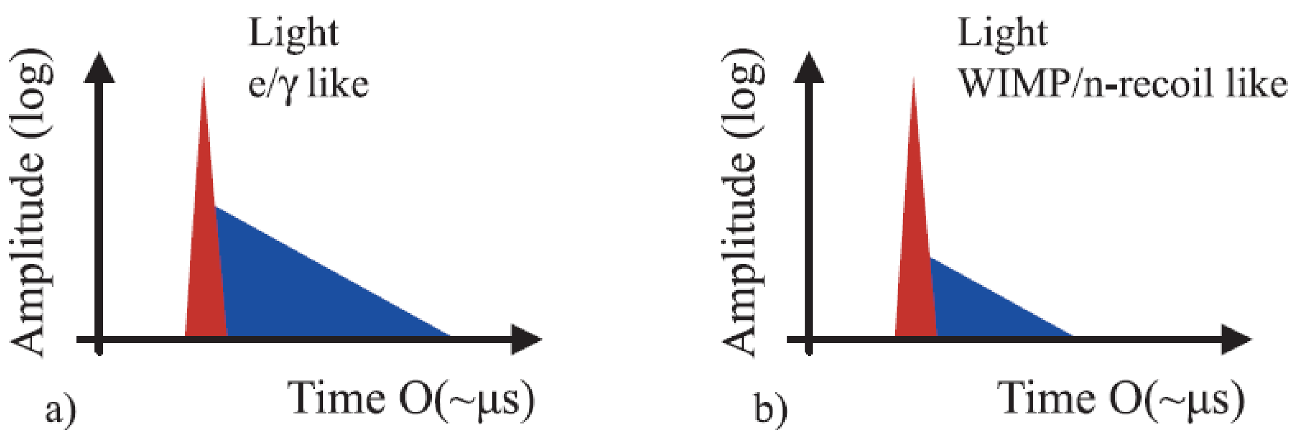
A. Rubbia, «ArDM: a ton-scale liquid Argon experiment for direct detection of Dark Matter in the Universe«, J. Phys.Conf.Ser.39:129-132, 2006

Background events

Electron and photon background:

- Originating from
  - U, Th and K contaminations of the detector material and the surrounding rock
  - Naturally occurring isotope ^{39}Ar is a β-emitter (event rate per ton Ar: ~ 1 kHz)
- Events are selected by
  - Charge/Light ratio
  - Ratio fast/slow component of the scintillation light: Two excited molecular levels emit scintillation light: singlet (fast component) and triplet (slow component)

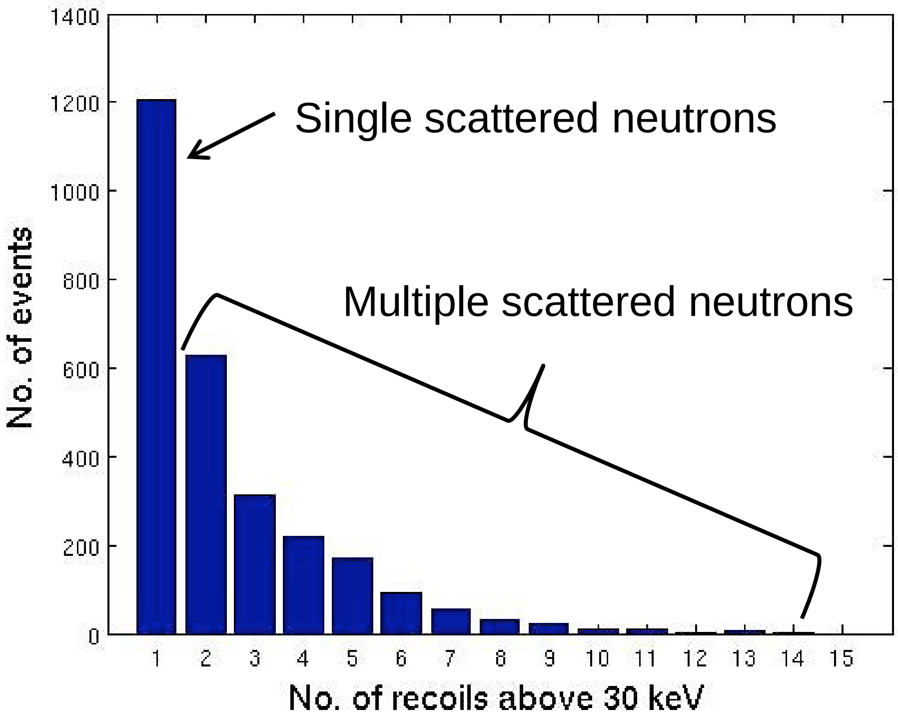




Background events

Neutron background originating from U and Th contaminations of the detector material:

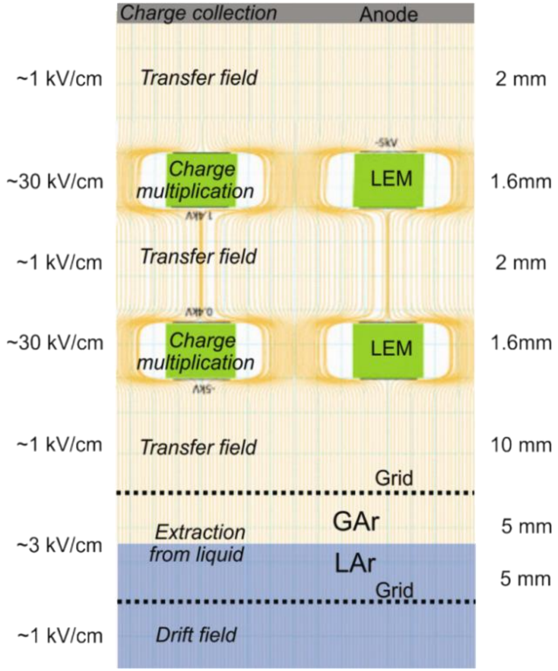
- WIMP – Ar cross-section is very low. → WIMP will not interact more than once. → Neutrons that scatter more than once can be rejected.
- MC studies:
  - More than 50% of the neutrons scatter more than once.
  - Less than 10% of the neutrons produce WIMP-like events. (single scattered, recoil energy ∈ [30,100] keV)



Muon induced neutron background:

- MC studies are in progress
- Rate depends strongly on depth of the underground laboratory

Charge Readout: LEM (Large Electron Multiplier)



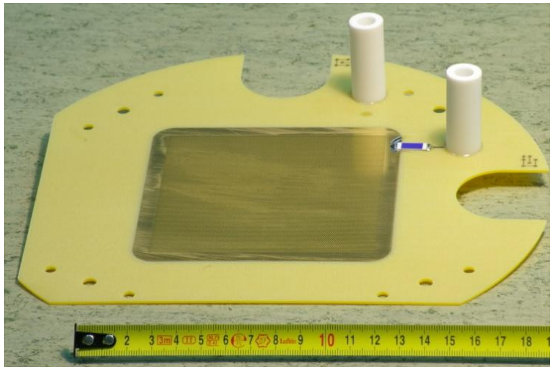
Principle of operation:

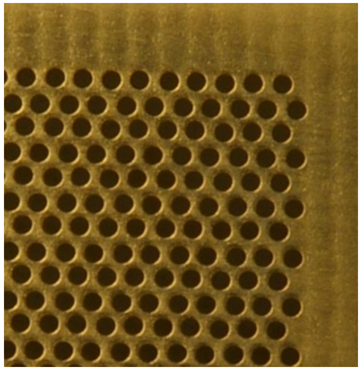
- Electrons drift up in the liquid and are extracted into the gas phase.
- Due to the high field strength in the holes of the LEM planes the electrons are multiplied. (Multiplication factor: $10^2 – 10^3$)
- The multiplied charge induces a signal in the anode.

- x- and y-position reconstruction possible due to segmentation of the anode
- z-position reconstruction using drift time of the electrons

LEM is in R&D phase:

- Test setup 10 cm x 10 cm
- Produced by standard PCB technique
- Hole diameter: 500 µm
- Hole pitch: 800 µm



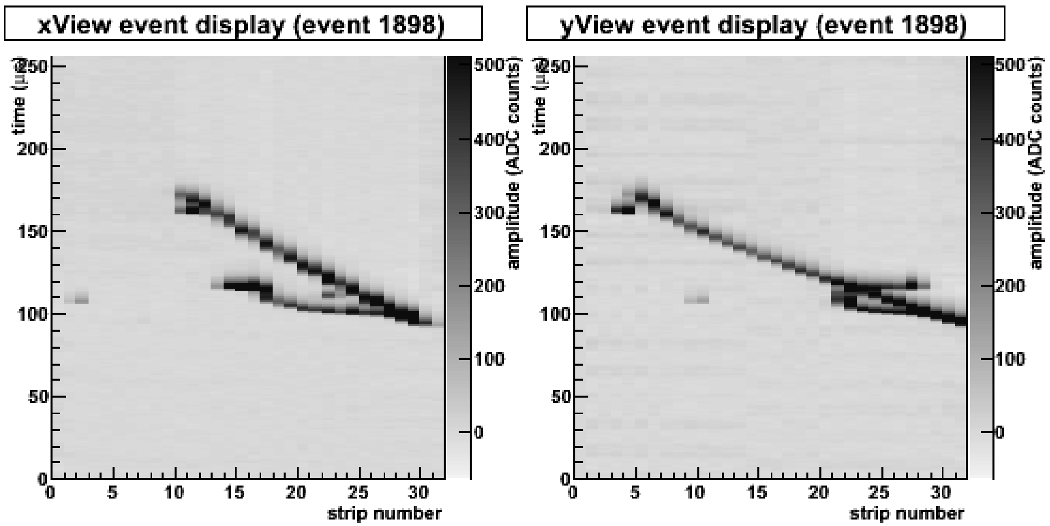


Charge Readout: LEM (Large Electron Multiplier)

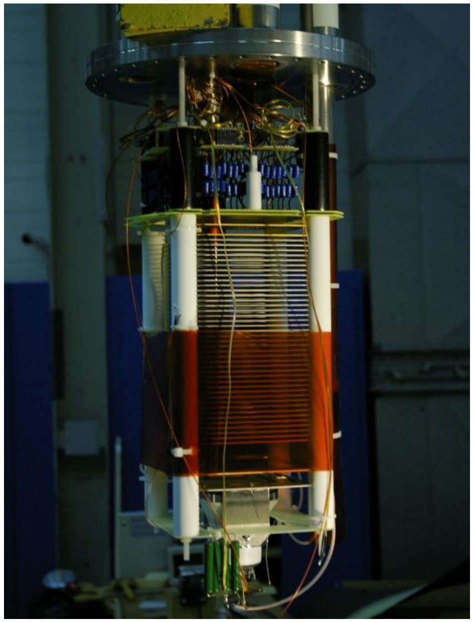
LEM R&D has two main goals:

- Reaching high gain
- Manufacture large area LEMs

Both goals are being addressed in parallel.



Track of a cosmic muon producing delta electrons in the test setup

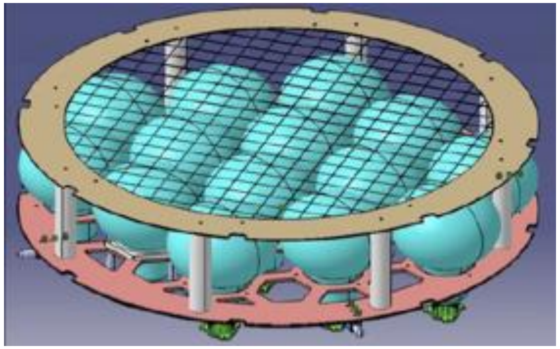


Test setup 10 cm x 10 cm

Effective gain (collected charge/ionisation charge produced in LAr) **in the test setup**:

- Effective gain of ~ 30 has been reached with one LEM stage of 1mm thickness
- Double stage (2 x 1 mm LEM) will be tested soon. Effective gain of ~ $30^2 = 900$ is expected.

Light Readout



- Wavelength of the scintillation light: 128 nm
- PMTs are not sensitive in the VUV range

→ Wavelength shifter needed: TPB (Tetraphenyl butadiene): 128 nm → 430 nm

- PMTs coated with TPB in order to detect the direct light
- Reflector foil around the fiducial volume coated with TPB in order to shift indirect light

Reflector foil under UV illumination

14 x 8 inch cryogenic low radioactivity PMT from Hamamatsu located at the bottom of the detector

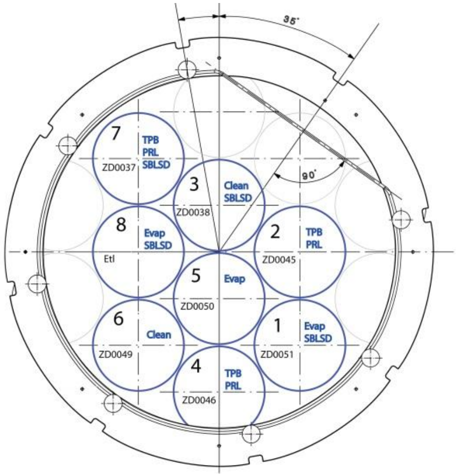
- New 3 inch PMTs (Hamamatsu R11065) ordered for 2011 to improve the light yield

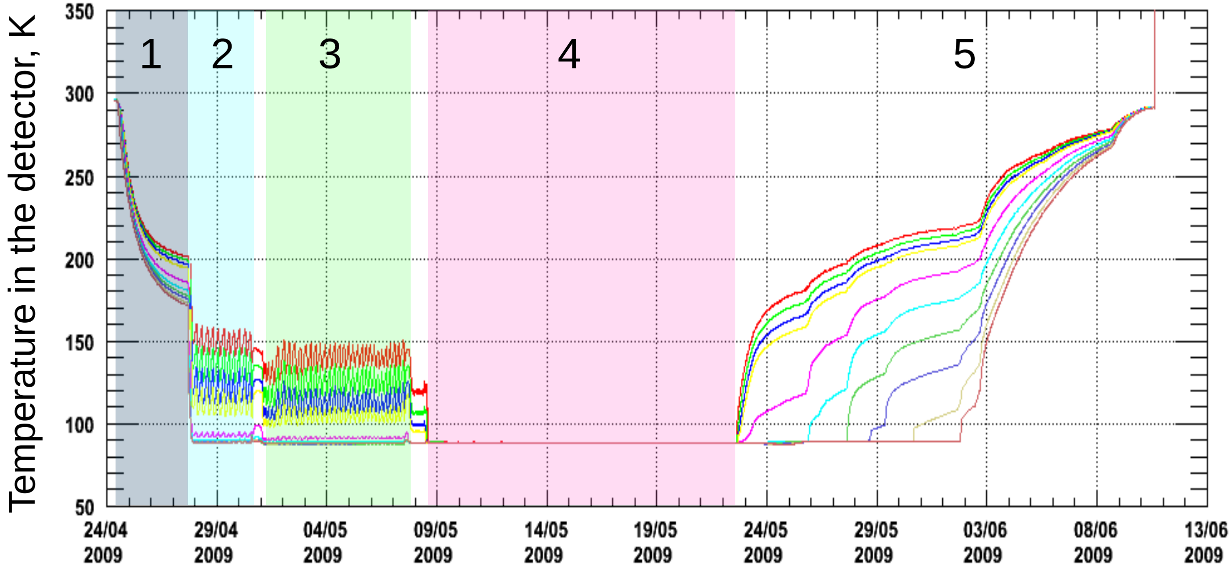
First Cool Down Test in May 2009

Test on surface at CERN

Test setup:

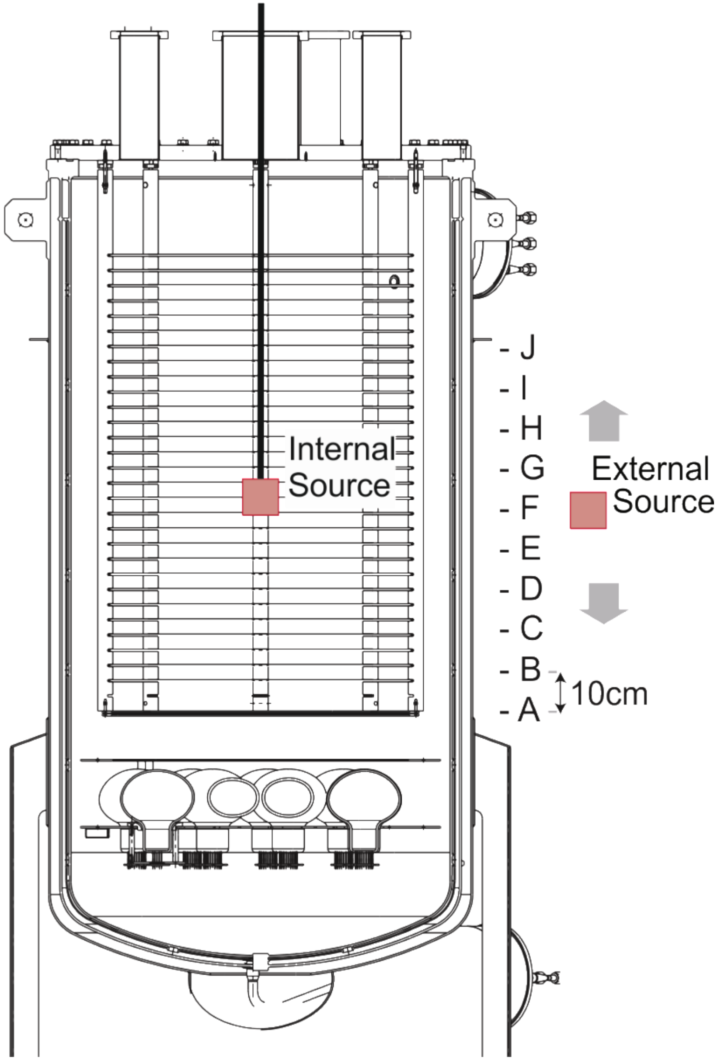
- 8 PMTs (different models and different coating)
- No electric drift field and no charge readout





1) Detector under vacuum. Cooling jacket filled with LAr.
2) Test of the light read out system in pure argon gas.
3) Detector half filled with LAr (PMTs immersed)
4) Detector fully filled with LAr. Data taking with internal and external radioactive sources
5) Warm-up phase

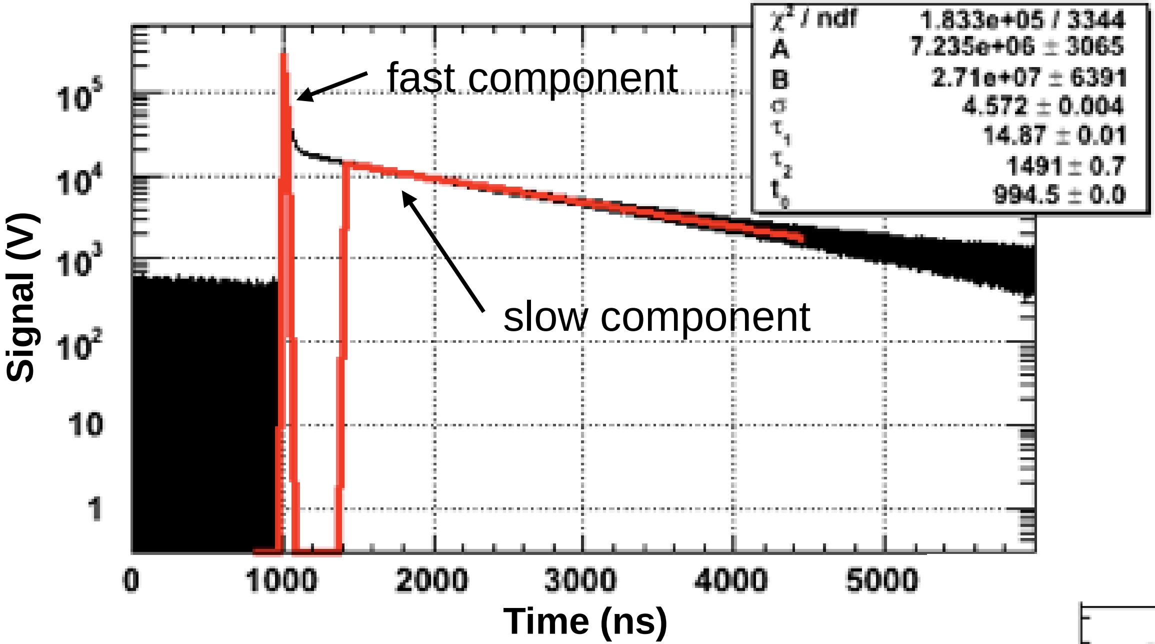
First Cool Down Test in May 2009



Measurements with internal and external sources:

- Internal source:
  - Vertically movable ^{241}Am source
- External sources:
  - ^{22}Na (511 keV gamma & 1275 keV gamma; 20kBq)
    Measurements for different lateral positions (positions A – J)
  - ^{137}Cs (661 keV gamma; 190 kBq)
    Measurements for different lateral positions
  - Am-Be source (2-8 MeV neutrons, 10 n/s)
    Measurements for different lateral positions and with the source on the top flange

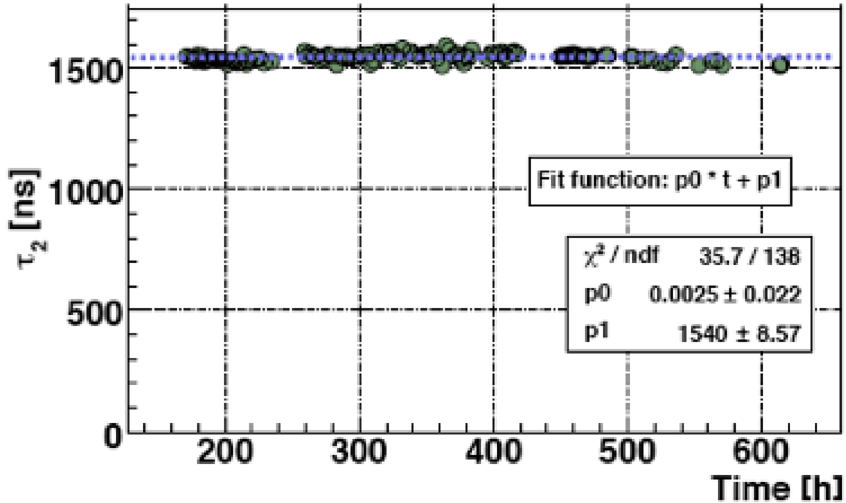
Measurements in Liquid Argon



Scintillation light signal:

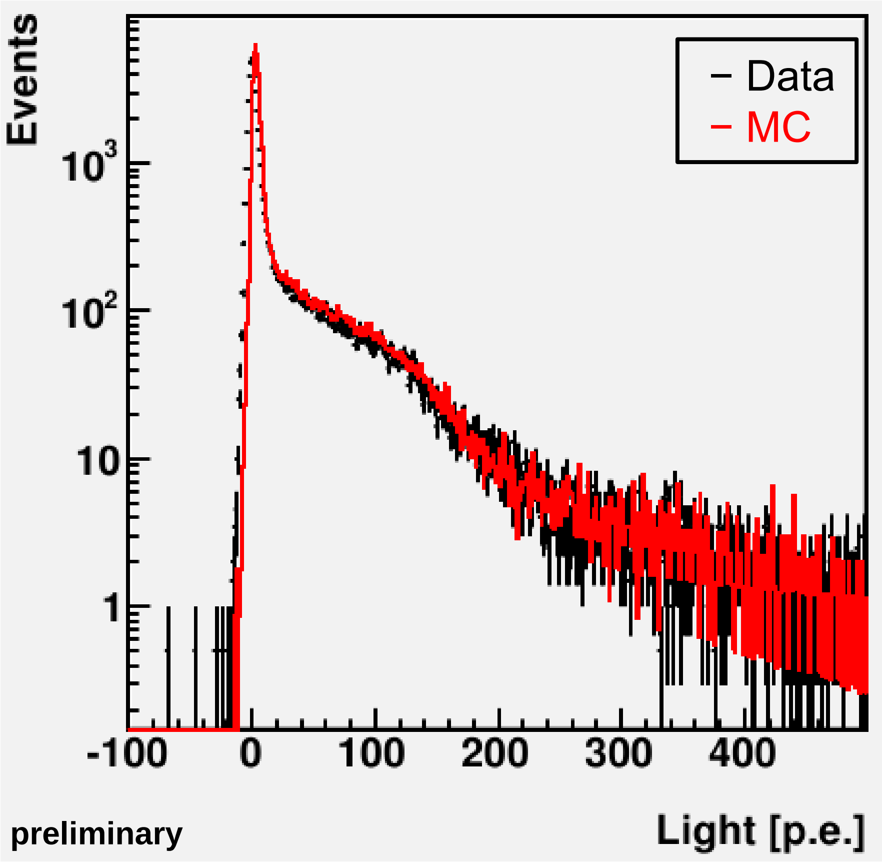
Pulse shape fitted with two exponential decay functions for the fast and the slow component

- The life time τ_2 of the slow component depends on the purity of the argon.
- τ_2 measured in ArDM: 1.5 μs.
  Literature: τ_2 = 1.2 – 1.6 μs
  → good purity
- τ_2 stays constant for more than 25 days.



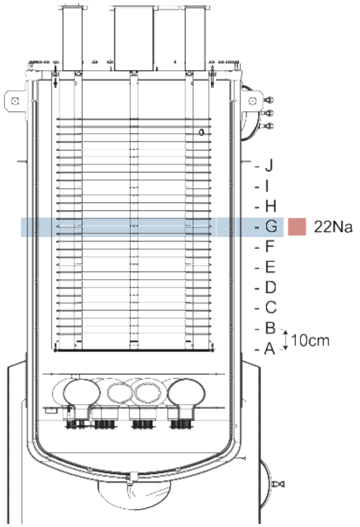
Measurements in Liquid Argon

Measurements with the ^{22}Na source in position G with external trigger

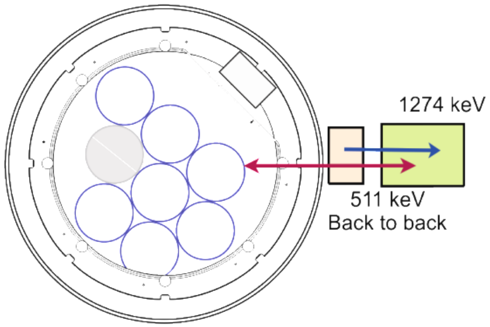


→ MC simulation describes the data very well.

Source position:



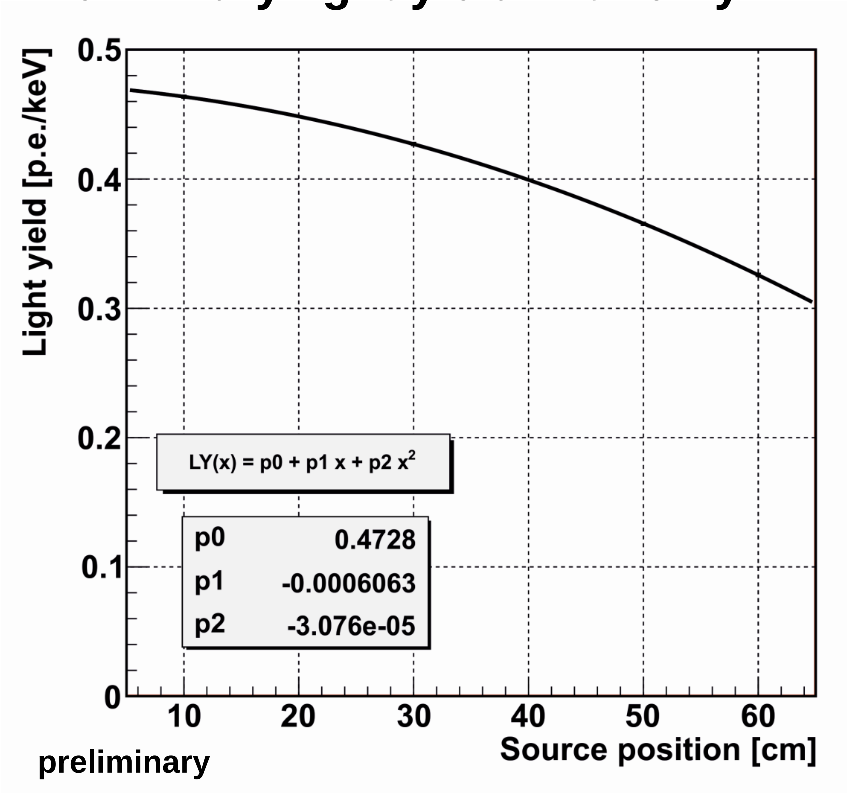
Trigger configuration:



Reconstruction of the spectrum is obtained by convoluting the MC simulation with real background data (noise, internal radioactivity, cosmic rays, signal from ^{22}Na photons which are uncorrelated to the triggered ones)

Light yield

Preliminary light yield with only 7 PMTs



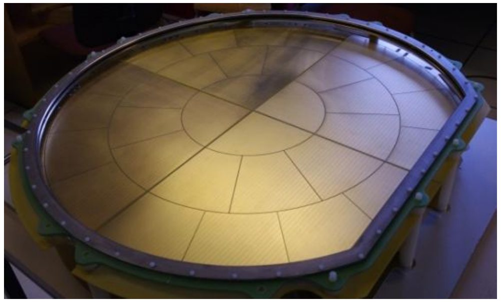
- Preliminary light yield with 7 PMTs: 0.3 – 0.5 p.e./keV depending on the position of the ^{22}Na source
- Light yield is obtained from MC simulated spectra. (MC simulation describes data very well.)
- Squared dependence of the light yield on the source position

→ Reflector foils recover most of the light that falls on them

- New test planned for August 2010 with 14 PMTs. → Improvement of the light yield
- New 3 inch PMTs (Hamamatsu R11065) ordered for 2011.

Outlook

- Next run planned for August 2010
  - First run with a drift field and a (temporary) charge readout system (segmented anode with 32 channels, no charge multiplication)
  - First measurements in LAr with the 14 new installed low background PMTs
  - Study response of the detector to gamma and neutron sources



Segmented anode

- Upgrade of the control system with a PLC (Programmable Logic Controller) is in progress
  - Safety system for underground operation
  - PLC will control the ArDM setup executing programmed processes.

ArDM control system

- Start to move the experiment to an underground laboratory before the end of 2010.

Summary

- The first cool down run in May 2009 was successful.
  - First data with gamma and neutron sources were taken.
  - Analysis of the data is in progress.
  - Good argon purity during the whole run.
- The light readout system has been tested and optimised. A new configuration with 14 PMTs is installed.
- A first charge readout system has been installed. R&D for the final charge readout is in progress. The final charge readout with LEMs will be installed for underground operation in 2011.
- Upgrade of the control system with a PLC (Programmable Logic Controller) is in progress.
- The next cool down run is planed for August 2010. This will be the first run with an electric drift field and a (temporary) charge readout.