Status of the ArDM experiment

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Collaboration

• ETH Zurich

• CIEMAT
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Outline

• Argon as a target for WIMP direct detection
• ArDM recent past
  • Pulse shape discrimination (old runs)
  • Material screening
  • Neutron background and passive shielding
• Status of the detector
  • New TPB coating performance
  • Installation of the detector in Canfranc
  • First test in warm GAr underground and expected light yield
• Conclusions and outlooks
Argon as target

- Extensive experience as detector medium (neutrino experiments).
- Cheap, easy to handle and to purify (large volumes).
- Event rate less sensitive to energy threshold than for heavier noble gasses.
- PSD and charge/light (β/γ background rejection).

\[ ^{39}\text{Ar} \text{ in atmosphere} \]  
(β-active isotope, \( T_{1/2} = 269 \text{ y} \), \( Q = 565 \text{ keV} \), \( \sim 1 \text{ Hz/kg} \)).
Direct WIMP detection
with double phase TPC

• WIMPs (elastic) scatters on Ar nuclei.
• Nuclear recoils (<200 keV) excite and ionize surrounding argon atoms.

• Detection of scintillation light:
  • VUV (~128 nm) photons + WLS + PMTs.

• Detection of ionized charge:
  • e- drift + extraction to the vapor + proportional scintillation.
  • charge can be amplified in gas and directly readout (LEM).
ArDM

- ~1 ton double phase argon TPC for direct DM searches.
- Presently installed in the Laboratorio Subterráneo de Canfranc.

- Drift length: 120 cm.
- Diameter: 80 cm.
- Target mass: 850 kg.
- Neutron shielding: passive polyethylene.
- Argon purification: LAr and GAr recirculation through getters.
- Temperature control: vacuum insulation + two cryo-coolers.
- Light readout: 12 PMTs in LAr + 12 PMT in GAr (8“ Hamamatsu R5912-02MOD-LRI).
- Charge readout: proportional scintillation in vapor (eventually Large Electron Multiplier).


30 keV_{er} threshold
0.5 ev/ton/day
Phased approach

• Surface operation:
  • Build and assemble the ArDM prototype (extensive R&D efforts).
  • Commission the detector cryogenics, purification, HV, electronics, light readout and software.

• Underground operation I:
  • Construction and installation of the passive neutron shielding.
  • Installation of ArDM and its infrastructures (finished in March 2013).
  • Warm gas argon runs (test light readout system) - ongoing.
  • Cold gas argon runs (test cryogenics, light readout, impact on the lab environment, ...).

• Underground operation II:
  • Liquid argon tests (commission HV, purification, cryogenics, ...).
  • Physics runs (beginning 2014).
Pulse shape discrimination

LAr run on surface with only 14 PMT array below the cathode

$^{241}$Am-Be source (externally triggered tagging the $\gamma$ with a NaI)

PSD parameter is the component ratio: fast/(fast+slow)

neutron -> “fast”

$\beta/\gamma$ -> “slow”
Pulse shape discrimination

$^{241}\text{Am-Be}$
- neutrons: < 11 MeV (max Ar recoil ~1 MeV)
- $\gamma$: 4.4 MeV

$1 \text{ MeV}_{\text{re}} \sim 175 \text{ p.e.}$
@ $0.7 \text{ p.e./}\text{keV}_{\text{ee}}$

$^{22}\text{Na}$

$^{241}\text{Am-Be}$
Pulse shape discrimination

Measured fraction of $^{22}$Na source events mis-identified as neutron.

Natural and cosmic induced background biases the measure -> to be evaluated underground

Light yield estimated for the present configuration: 2 p.e./keV$_{ee}$
Contamination expected: $O(10^{-3}) @ 10$ keV$_{ee}$ (statistical fluctuation only)

Additional rejection factor from charge to light ratio (measure foreseen during the underground operation)
Material screening

Cryogenic and low activity
Hamamatsu R5912-02MOD-LRI
Material screening

Measurement campaign with Ge detector supported by the LSC

Already measured:
- PMT (glass / dynodes / base)
- Drift cage resistors
Measurement foreseen:
- Stainless steel of the vessel
- Parts of the field cage

Contaminations are input to evaluate the neutron flux inside the detector (irreducible background) -> Ongoing

Simulation (SOURCES) of 1 ppb $^{238}$U in stainless steel
Neutron background in the cavern

In collaboration with Nuclear Innovation Unit (CIEMAT)

“External” sources of neutrons:
- Natural isotopes (spontaneous fissions and \((\alpha,n)\) reactions)
- Cosmic muon (spallation reactions)

Neutron flux and energy spectrum “before the shielding” are essential input parameters for the complete Monte Carlo simulation

Detector tested at CIEMAT and to be moved in LSC

liquid scintillator BC501A

252Cf

[Graph of neutron energy spectrum]
Passive shielding

- 50 cm thick polyethylene shield reduces the flux of neutron below 1 MeV by a factor of \(~10^5\)
- Evaluate neutron interaction rate in ArDM -> need of the measurement of the neutron flux in the cavern (ongoing)

- Lateral shield partially installed (allow to work on the top flange).
- Bottom shield ready to be shipped to LSC.
- Top shield assembled in CIEMAT (load test ongoing).
Evaporated TPB requires careful handling, minimize exposure to UV light and air

TPB very good WLS solution for LAr applications. R&D to chemically attach it on Makrolon (paper in preparation)

24 PMTs and reflectors re-coated. Test in warm GAr with a $^{241}$Am $\alpha$ source. Comparison of the same PMT before and after the re-coating. Detection efficiency improvement: \( \sim 5x \).
Installation (PMTs)

PMTs coated and tested at CERN mounted at ETH (Zurich).

- PMT layout
- TPB 0.1-0.2 mg/cm²
- PMT independently mounted
- Completed PMT array (Zurich)
- In the boxes ready to be shipped
Installation (reflectors)

Side reflectors prepared at CERN and coated at IFIC (Valencia).

Tetratex sewed on Vikuiti
Evaporator (Valencia)

TPB ~1 mg/cm²

Unpacking (LSC)
Mounting the detector

March 2013
First GAr test underground

Measurement of the light yield of the newly coated detector fully assembled

- 9 days of data-taking (~5 h/day)
- GAr (99.9999% pure) filling and evacuation every day.

Mylar sealed $^{241}$Am source (~500 Bq) custom made at CIEMAT installed in the active volume of ArDM.
- ~5 MeV $\alpha$ @ 100 Hz in the active volume.
- 60 keV $\gamma$ @ ~1 Hz in the active volume.
$\alpha$ events well localized:
- Z coordinate scan with the source facing downwards.
- VME based electronics.
- CAEN crate and modules including
  4x ADC V1720, 8ch, 12bit, 2Vpp, 250MS/s.

Trigger on the coincidence of the top and bottom PMT arrays with a threshold of 1.75 p.e.
- PMT response stable over 9 days: $2.5 \times 10^7$ (gain within 5%) continuously monitored.

- Dark rate (2 PMT excluded):
  top array: $\sim 9$ p.e. / 8 $\mu$s
  bottom array: $\sim 2$ p.e. / 8 $\mu$s

- $\sim 5$ keV$_{ee}$ threshold (11 p.e. @ 2 p.e/keV) from the dark counts.
Alpha events

TTR: top/(top+bottom) \sim Z \text{ position}

“short track”

source holder (PTFE)

alpha track

“long track”

source holder (PTFE)

alpha track
Source @ the cathode

dark counts (~11 p.e.)
~15 Hz (compatible with p.e. statistics)

background ~15 Hz
material in the detector,
environmental radioactivity,
$\gamma$ from the $^{241}$Am, ...

$\alpha$ from the top PMTs
< 0.1 Hz

$\alpha$ long tracks hitting the cathode grid

$\alpha$ short tracks
~40 Hz

$\alpha$ long tracks
35 Hz

~15 Hz (compatible with p.e. statistics)
Position Scan

Total light yield [p.e]

TTR

24.5 cm above cathode

45.5 cm above cathode

66.5 cm above cathode

87.5 cm above cathode
Light collection uniformity

- Top/bottom “naive” dependence on the source position.
- Uniform total collected light (10 % variations): ~3000 p.e. @ ~5 MeV α

Old tests of prototype with 14 PMTs below the cathode:
- GAr test with $^{241}$Am source: 850 p.e. (Now 3x better)
- LAr test with $^{22}$Na source at 0 kV/cm: 0.7 p.e./keV$_{ee}$

Extrapolating new light yield in LAr at 0 kV/cm: > 2 p.e./keV$_{ee}$ (compatible with Geant4 simulation)
Conclusions and outlooks

• The ArDM detector is installed underground at LSC
• First measurement of light yield of the newly coated detector:
  • uniform collection light ~3000 p.e. for ~5 MeV α in GAr
• Expected light yield in LAr at 0 kV/cm: 2 p.e./keV_{ee}
  • 850 kg of Ar, uniform light collection and 30 keV_{re} threshold

• Next steps:
  • warm gas argon tests with different sources.
  • cryogenic tests in gas argon (learn how to operate the detector underground)
  • LAr run (full commissioning)

• Beginning 2014: first ArDM physics run
Backup slides
Monte Carlo simulation
Full detector simulation of ArDM using Geant4

The ArDM Monte Carlo simulation includes:

- **Full detector geometry**: PMTs, reflectors, TPB layers, support structure, 3-layer stainless steel vessel wall
- **Ionization and scintillation processes** in argon media (gas or liquid)
- **Optical photon tracing** involving all the optical processes:
  - **wavelength shifting** (conversion of VUV photons to visible)
  - definition of all the “**optical surfaces**” (refraction, reflection ...)
- PMT response to visible photons

Simulation of the GAr data is on the way

![Graph](image)

58 cm above cathode

Light yield [arb.]