ArDM,
a 1t liquid argon detector
for dark matter searches

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Abstract (nr. 711):
We are assembling a 1t liquid argon detector at CERN using the two-phase technique to detect both charge and luminescence produced by recoil nuclei from WIMP interactions. We have investigated background suppression capabilities and impurity effects in argon using the scintillation light and its decay time. We are studying ways to efficiently collect and detect the VUV-light to reach a detection threshold of 30 keV in a large liquid argon detector, and to efficiently suppress background from neutrons and electrons. First results for the light collection efficiency in the 1t detector will be presented.
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Spin independent WIMP-N cross section currently $< \sim 4 \times 10^{-44}$ cm$^2$ at 100 GeV

Rate/day in a 1 ton liquid Ar detector
0.3 GeV/cm$^3$, if DM a spherical halo:
$v = 245$ km/s (June), 215 km (December)

$M(\text{WIMP}) = 100$ GeV, $\sigma = 10^{-42}$ cm$^2$

$\frac{d\sigma}{dq^2} = \frac{G_F^2 C F^2(q^2)}{v^2}$

Goal of ArDM $\approx 10^{-45}$ cm$^2$:
0.1 event/day @ 30 keV threshold
ArDM Experiment (CERN recognized RE18)

500 kV, 210 stages

CHARGE READ OUT

Photomultipliers

500kV Generator  Cockcroft Walton circuit

120 cm drift length

Wave Length Shifter Reectors

-500kV

-1kV

-4kV

0kV

Drifting electrons

WIMP

128nm photons

Wavelength shifter

128nm -> 430 nm

TPB on Tetratex

14 x 8"

Gas

GAr

E extract = 3 kV/cm

LE

E transf = 1 kV/cm

Anode

TPB on Tetratex

1t LAr (87K)

1t LAr (87K)

1.6mm

1cm

3mm

3mm

1.6mm

3mm

Vacuum insulation

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14 x 8”
ArDM: Strategy

1. Assemble the detector and test its performance on the surface (at CERN).
2. Study the response of the detector to γs, electrons and neutrons
3. Particle identification
4. Underground (low background) operation (2010), three optional sites

**Background rejection** is based on:
- Population ratio of $^1\Sigma$ to $^3\Sigma$ excimers are different for nuclear recoils and e/γ-events (excellent in argon).
- Different primary charge/light ratios for WIMPs and e/γ-like events (strong recombination)
- Interaction point, self-shielding of LAr

<table>
<thead>
<tr>
<th>Amplitude (log)</th>
<th>Time $O(\mu s)$</th>
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</thead>
<tbody>
<tr>
<td>e/γ</td>
<td>Nuclear recoil n, WIMPs</td>
</tr>
<tr>
<td>e.g. &lt; 656 keV</td>
<td>e from $^{39}$Ar</td>
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LAr: two decay times: **5ns ($^1\Sigma$) and 1.6µs ($^3\Sigma$)**

- 1e/1γ for e, γ ($\sim 600$ e @ 30 keV)
- 1e/100γ for WIMPs, n ($\sim 3$ e @ 30 keV)

**Goal:** 1 photoelectron / keV ee
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**Light yield at maximum gas purity vs TPB Thickness**

- **mg/cm²**
- **Top flange**
- **Detector insertion**
- **8” PMT**
- **Exp. area at CERN**
- **Large scale evaporator**
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R & D with small LAr cell

Integrated pulse height [photoelectrons]
from $^{210}$Pb -> $^{210}$Bi -> $^{210}$Po -> $^{206}$Pb source

Ratio of fast (<50ns) to total light yield

5.2 MeV α (heavily ionizing)

1.2 MeV e⁻

Polyethylene
NaI(Tl)

370 MBq Am-Be

Cooling LAr

Pure LAr
Reflector/WLS

$^{210}$Pb source

74 x 78 mm²

Purity monitor

C. Amsler et al. JINST 3 (2008) P02001

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Wednesday, 15 July, 2009
Neutrons from the rocks (spallation) can simulate WIMPs!
\[ \sigma(\text{WIMP } A) \sim 10^{-18} \sigma(\text{n } A) \]

**Am-Be source Energy distribution**

- Fast (<50ns) to total light yield

**Neutron Energy Spectrum**

- AmBe neutron energy (S.T. Park, 2003)
- 3 Gaussian fit for ToyMC

**Pb source only (low energy region)**

- with Am-Be
- polyethylene absorber
Source of monoenergetic neutrons (2.45 MeV):

- Calibration of recoil energy (quenching!)
- Determination of the multiplicity distribution for neutron interactions

Radiation level below 1 $\mu$Sv/h at places of human access

Delivery expected in August

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Wednesday, 15 July, 2009
First filling of 1t detector in May 2009

Top flange
\( \approx 200 \text{ K while filling} \)

Liquid surface

To the cartridge

\( \tau_2 \approx 1.5 \mu s \text{ for } >30 \text{ days with bulk LAr w/o purification circuit} \)

\( \tau_2 = (1.6 \pm 0.1) \mu s \)

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**Literature**

\( \tau_2 = (1.6 \pm 0.1) \mu s \)
Preliminary results 1t LAr

- Triggered on combinations of PMTs and/or external NaI crystal
- $^{22}\text{Na}$ and $^{137}\text{Cs}$ sources
- Only half (7) of the PMTs were installed

$\approx 1\text{pe/keV ee (with 14 PMTs)}$

about 0.3 p.e. / keV WIMP, hence 9 p.e. for 30 keV
400 VUV photons, hence detection efficiency is about 2%
Conclusions

• ArDM is preparing the detection of DM induced nuclear recoils with a large LAr TPC (goal $\sigma \sim 10^{-45}$ cm$^2$)

• For the first time ArDM (1t) was operated on the surface:
  - Light yield is consistent with expectations (0.5 p.e./keV ee with 7 PMTs);
  - First successful detection of 50 keV energy in 1t detector;
  - Evidence for nuclear recoils (from neutrons).

• Next test foreseen in autumn 2009, 14 PMT, drift electric field to also measure ionization.

• The detector will then be moved to an underground location.
Three possible underground sites (end of 2010?)

Canfranc underground laboratory (2450 mwe)

Unirea salt mine in the slanic mine of the Prahova region (Romania)

SUNLAB. Sieroszowice mine, Poland; (2200 mwe)

Planned for end of 2010?
Participants

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