ArDM - LAr on the ton scale

ETHZ led collaboration with CIEMAT, LSC, CERN and others

First ton scale LAr detector in operation

Exploring the low energy frontier of the LAr technology at the ton scale
Experimental program and time line

- Developments done at CERN — synergetic with large LAr facilities (ν-programs)
- Installation at the Spanish underground site Canfranc (LSC)
- Design and commissioning for full remotely controlled operation
- ArDM reconfirmed as a CERN Recognized Experiment (RE18)
- Collaborating with DS group (e.g. Princeton, APC Paris, LNGS)
- Common developments towards G2 (DS20k) and G3, depleted argon research

• End 2014: ArDM fully embedded in safety environment of LSC — filling started
• Summer 2015: ArDM completed first physics run (single phase)
  ~ 6 months of stable data taking (Run I)
• Analysis tools and MC framework developed by means of exploiting this data
• First fundamental analyses have been performed focussing on backgrounds
• 2016: Preparation of double phase running ongoing — Run II
• 2017 and beyond — long term data taking — exp. upgrades (light read out)
• Extended program: $^{39}$Ar studies, prototype tests, BG studies….

ArDM is a R&D facility for future large LAr projects (DS20k)
ArDM in a nutshell

Total LAr mass: ~2t

- LAr mass: ~2t total, 850kg active, ~500kg fiducial
- Double phase, vertical TPC (0.1 – 1 kV/cm drift field)
- Cryogenic low radioactive 8” PMTs 12 + 12 (liquid and gas)
- Projected LY ~2pe / keV (@ LAr operation)
- Passive external neutron shield (~20t)
- Trigger rate / DAQ capability ~ kHz

Background recognition strategies:
- PSD and Ionization / scintillation ratio
- Localization: (fiducial volume, 3D imaging)
- Topology: (e.g. multiple elastic scatters from neutrons)


Status of ArDM-1t: arXiv:1505.02443
A ton scale LAr DM experiment

Expectations!

- Serious contribution to searches of higher mass WIMPs!
- Design parameters for LAr G2 and G3 future facilities!

In the research focus:

- DUV properties of large LAr targets
- Neutron interactions
- $^{39}$Ar PSD studies
- Classification of depAr batches

1st task — verifying these points

Projected sensitivity for BG expectation of $(0.22 \pm 0.08)$ n/d (MC)

Experimental upgrades foreseen
Operation of ArDM — Run I in single-phase LAr mode

Stable data taking over ~6 months — $3 \times 10^9$ triggers recorded to disk

Experiment at LSC (Canfranc / Spain)

Fully remotely controlled, e.g. from CERN

ArDM Control Center CERN

Safety: sophisticated PLC SC system

Trigger rate: 1.3–2.1 kHz, event size: 66 kB

DAQ rate: 85–138 MB/s

3.3 billion triggers — 215 TB raw data
- main calibration tool
- well matched to ROI
- many features emerge

\[ ^{83}\text{Kr} \text{ signals} \]

Injected into vapor phase — diffusion time!

LY comparison [pe/keV]

GAr

LY, width, uniformity OK

LAr:

LY lower
uniformity OK
width larger

\[ ^{39}\text{Ar} \text{ BG subtracted} \]

\[ L\text{Ar}: \text{Expected 2 pe/keV} \]

LY and shapes: evidence for DUV absorption — under study

O\textsubscript{2} - N\textsubscript{2} - trace measurements — negative result

ICP mass spectrometer analysis under way

However: question of purity only —> filters, distillation....
The full LAr target (850kg active)

Looking into one of the main features of LAr — PSD

48 hours data taking — ~30M events — no fiducial cuts

\[ 39\text{Ar} \]

\[ 252\text{Cf} \] neutron data

\[ \text{polluted with } \gamma \text{ absorptions} \]

\[ \text{preliminary} \]

separation power (gaussian assumption)

Need double phase data to proceed

Good fiducialization is important

Very high if LY good
Exploring external $\gamma$ backgrounds

Data from open - close top cover

Spectrum well described by $^{238}$U, $^{232}$Th and $^{40}$K contributions

Large target feature:
Selfshielding
Spectrum extends into higher energy range
(mult. $\gamma$ absorption)

Estimate comparable with LSC parameters (Ge measurement)


**MC efforts**

Detector simulation developed and tuned with data of Run I

- Full optical photon ray tracing for DUV (scintillation) and visible (wave shifted) light

- Optical parameters tuned to data
  (scatt. length, absorption, refl. coefficients)

- MC data fully digitized
- Same reconstruction and analysis framework
- MC is in a good agreement with data, typically to better 10%
- Main features are reproduced

Screening results used for e-like and n-like MC to estimate backgrounds
e-like spectra

Based on MC response from screening

Data well described by normalized MC spectra based on the material screening results + external BG

850 kg LAr target (~610L) — no fiducial cuts

validates our low BG goals
Projected $^{39}\text{Ar}$ sensitivity of ArDM for a $3\sigma$ measurement

Characterization of depleted argon

Measurement time for a given sensitivity

- Measurement time for a given sensitivity on $10^{-5}$ level feasible — improvements, e.g. more sophisticated analysis (spectral fit)
Hardware preparations/upgrades for Run II

- New TPC drift cage, HV system
- Replace TPB coated surfaces
- Implement ITO coated windows
- Introduce cold charcoal trap
- Add cryo link (liquid storage)

Activities ongoing at CERN and CIEMAT

Large ITO + TPB coated PMMA plates

ITO layer + TPB coating

Charge signal

Light yield

α background

Cold charcoal trap

R&D program
Light detection system upgrade — under study

- Present system based on 24 8” PMT good, but:
  low PDE (17%), large amount of glass
- Upgrade not trivial — m², cryog., PDE, fast, power
- Option Hamamatsu R11065 (30%) still under discussion (stability?, fill factor)
- SiPM solution tempting — still need some time

SiPM: digital device with analogue read out

SiPMs love low temperatures

Demonstration for PID by PSD in SiPM LAr test

Towards large surfaces - first array tests

- Large capacitance
- Light concentration possibilities ?
Conclusions and outlook

- **ArDM successfully completed first physics data taking (Run I) in single phase mode**
  3×10^9 triggers recorded to disk during ~6 months of stable data taking. Preliminary analyses based on the first data sample (<5%) confirm the expected performance of the ArDM detector — full statistics analyses ongoing

- **A detailed MC model was developed**, describing the detector from first principles. Tuning of parameters indicate a relatively short DUV absorption length in the LAr (ongoing)

- **A fully satisfactory description of e-like background in the LAr target was obtained**
  - $^{39}$Ar β-decays quantified in agreement with the expected value of ~1 Bq/kg
  - The second most dominant BG due to external sources, internal contribution ~6%

- **PSD promising (need double phase data to proceed)**

- **Presently preparing double phase Run II — scheduled for 2016**

- **2017 and beyond**
  - Accumulate statistics — further hardware upgrades planned
  - Facility available for sensitive depleted argon studies (sensitivity level down to 10^{-5})
  - Full scale demonstration at the ton-scale is a necessary step towards 10-ton scale and beyond