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ArDM (LSC EXP-08) status report and shutdown plan 24th Scientific Committee Meeting 12-13 June 2019

The ArDM Collaboration

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1 Overview

With the last SC meeting in December 2018, ArDM entered the final phase of its present experimental program, mass data taking in the dual phase (DP) operational mode. Up to date more than $20 \cdot 10^9$ events, in more than 270'000 runs were taken, transferred to CERN and are presently reconstructed and analysed. Since December 2017, when Run II was started, the detector is running in the double phase operational mode under very stable experimental conditions. Data taking is done at a charge drift field around 28 kV/m and an extraction field around 4 kV/cm at event rates around 2 kHz, which is governed by ^{39}Ar decays, each producing a S1/S2 signal pair. Figure 1 shows the number of events accumulated during this run time.

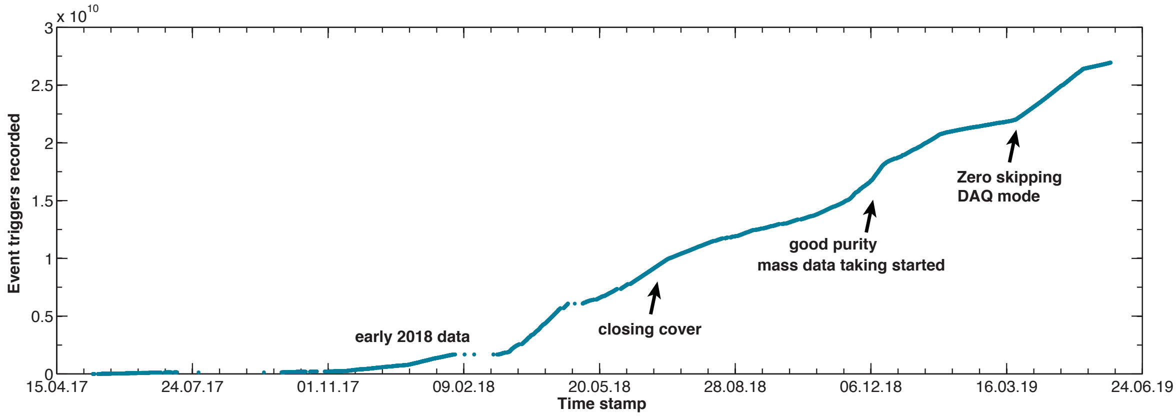

Figure 1: Number of recorded events during Run II

The constant improvement of the liquid argon (LAr) purity, and the resulting increase in the scintillation signal emission time necessitated an enlargement of the ADC sampling window to 16 μs, which required in consequence the introduction of a zero skipping DAQ mode to comply

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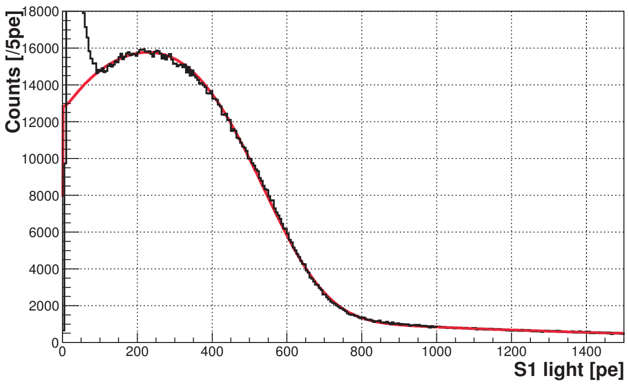
with the strongly increased data rate (factor of 4x in comparison to single phase operation) for dead-time less data taking (full reconstruction of all S1 and S2 events). Also the software framework had to be adapted, both represented major upgrades of the existing systems. In addition to DAQ improvements also the trigger thresholds and PMT gains were optimised. Since about 2 months the DAQ is running successfully in the zero skipping mode.

On May 10th a small leak developed in the gaseous argon recirculation pump which lead to a too large loss of argon to be compensated by the Ar refill system and the experiment had to be put into standby mode for some time. The faulty pump was replaced and the experiment will be restarted soon to accomplish the experimental program of Run II. We plan to complete the data set in DP (4 weeks) and also to take data with a 100 Bq ^{252}Cf neutron source (2 weeks), which was recently provided by LSC. This will be finished this summer, in accordance with the schedule presented at the last SC meeting.

In parallel to these activities we are preparing the next phase of the experiment, the transition to depleted argon studies within the DarkSide program. After the completion of Run II, we will shutdown the ArDM experiment and transfer the main LAr target of ArDM to the recovery dewar and store it by means of an independent cryogenic system (cryocooler). The ArDM installation will be warmed up and the main detector unit will be replaced with the new single phase setup, designed to host the DArT chamber. The new detector system can then be cooled down and the LAr from the recovery vessel can be restored to the ArDM vessel. The recovery dewar is in an advanced state of preparation and the last safety measures are being added. The system is planned to be operational in the next weeks.

2 Towards WIMP searches in the Run II data

Over the last months the light yield improved due to a better LAr purity as well as better PMT set points (increased gain). Figure 2 (left) shows the fit of S1 data with a β- function on an exponential background. From the fit we derive an average light yield of 1.33 $pe/$ keV extrapolated to zero electric field which gives an acceptable base for physics analyses.



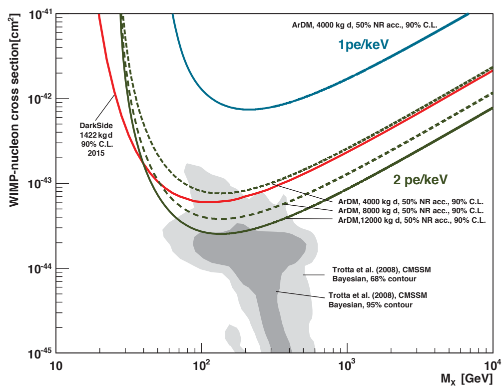


Figure 2: Left: Fit to the ^{39}Ar beta spectrum of data taken 3 weeks after starting the purification, giving a light yield of 1.33 $pe/$kev. Right: Projected sensitivity at 90% C.L for exposures of 4000, 8000 and 12000 kg×day (green lines), assuming 50% NR acceptance and an energy range of 60–160 keV$_{nr}$. A light yield of 2 $pe/$keV is assumed. The blue line shows the sensitivity for a light yield of 1 pe/keV and 120–160 keV$_{nr}$ energy range.

The sensitivity for WIMP searches in ArDM was determined earlier from the Run I results, based on the PSD discrimination between the NR and ER bands, as well as the single scatter neutron background, as described in our previous reports. The calculated numbers are based on the observed e-like events due to ^{39}Ar, internal (material contaminations from screening results) and external (Hall A) backgrounds. This allowed us to predict the number of nuclear recoils induced by neutrons emitted by those materials. Considering a 500 kg fiducial mass, about 0.045 single scattering neutron evt/day in the energy range 50–100 $\mathrm{keV_{nr}}$ are expected. Hence, we expect at least 20 days of data taking in neutron background free mode.

The projected DM sensitivity as function of the WIMP mass is shown in Fig. 2 (right) for three different short term exposures of 4000, 8000 and 12000 kg×day (resp. 8, 16 and 24 ArDM days) assuming 50% NR acceptance and an energy range of 60–160 $\mathrm{keV_{nr}}$. In this range the number for single scatter neutron evt/day is about 0.05. The expected WIMP-nucleon cross-section best sensitivity is $3 \times 10^{-44}\,\mathrm{cm}^2$.

2.1 Background rejection by PSD from the new data

We prepared a 1.2 ld (live days) data set to train the analysis tools and to check the data quality. Figure 3 shows the performance of PSD for different light yields, which is according to expectations. The spectra are well described by Gaussian profiles. This analysis will be repeated

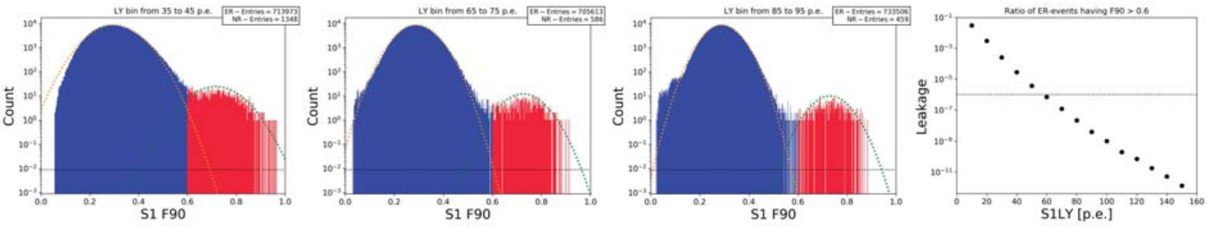


Figure 3: Spectra of the pulse shape factor F90 of unfiducialized data in several signal regions. The nuclear recoil region in this data is mainly populated by residual α-events.

as soon as neutron data will be available. For the final suppression of leakage from the electronic recoil band into the region of interest (RoI) for WIMP signals we will also use the S1 to S2 signal ratio, which is presently under development. An additional background suppression factor of >100 is expected.

2.2 Determination of the RoI from the new data

The new data set was also used to determine more precisely the sensitive region in the data for nuclear recoils, derived from a parametrisation of the electronic and nuclear recoil bands (see Fig. 4). In this first approach the RoI is delimited by the $5\,\sigma$ upper boundary of the ER band, as well as the upper and lower $3\,\sigma$ NR band envelopes. For a more stringent suppression of feedthrough from ER we also investigate the use of the centre of the NR band (instead of the lower $3\,\sigma$ NR band envelope) with the cost of the smaller signal acceptance.

To comply with the enormous amount of data (about 8 GB per live minute) the software framework is presently modified for multithreading and parallel processing. In addition a dedicated computing cluster at ETHZ was recently commissioned, working together with the main data storage of ArDM at CERN.

3 Decommissioning of ArDM and transition towards DArT

The ArDM infrastructure will be used for depleted argon studies within the Darkside program as it was presented in our previous reports (since May 2017). To increase the flexibility and to efficiently continue the experimental activities we added a 2 t LAr vessel with an independent

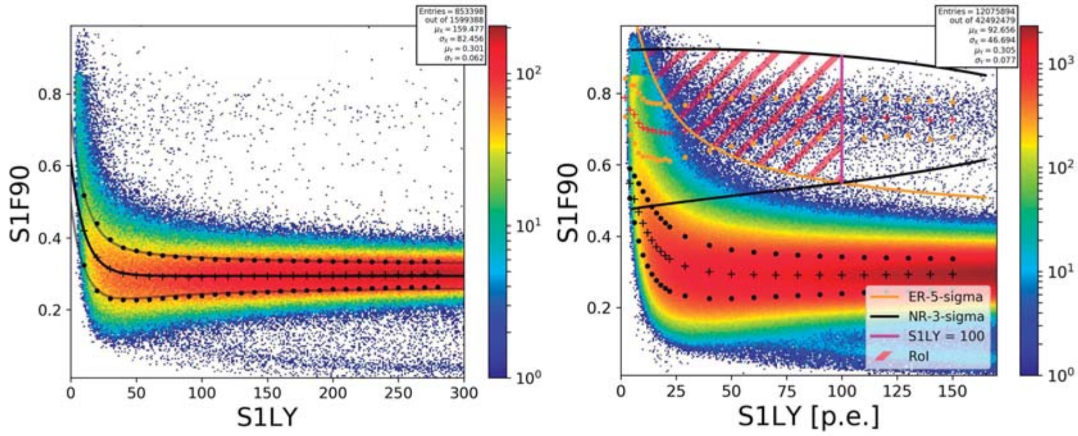


Figure 4: Parametrisation of the ER and NR bands for a precise determination of the RoI.

cryocooler to the setup, the LAr recovery vessel. On demand the LAr between the main detector vessel and the recovery vessel can be transferred in the desired direction. Presently the recovery vessel is mechanically fully installed and the last safety measures are being added. The registration of the installation with the Spanish authorities for pressure vessels is completed and the operational documents are in the last stage of approbation. One of the last missing items is the installation of a small LAr containment pool around the recovery vessel supposed to be completed in the next weeks. The shutdown of ArDM and transfer of the LAr is planned for summer 2019.

Once the ArDM experiment is stopped the LAr can be transferred to the recovery vessel and the ArDM apparatus including the cryogenic system can be warmed up. The procedure will require about 10 days. While the main argon is kept in the recovery dewar the detector inset in the main cryostat can be extracted and replaced. The new SP chamber hosting the 1 Ltr DArT chamber will be built onto a spare top flange facilitating largely the exchange of the two systems. The design was done in such a way that the DArT chamber can also be added at a later time (see our last reports) and the new SP setup could also be tested standalone. However the insertion (from the top) of the DArT chamber will require an additional warmup / cooldown cycle of the experiment.

4 Conclusions and outlook

With the dual-phase operation of the ArDM detector a major milestone was achieved in the project. A couple of hardware and software modifications were necessary to reach this final aim of the experiment, e.g. the installation of the heated getter filter, or the introduction of the zero skipping method. By those means we have now basically reached the technological limits for a ton scale detector, operating with natural argon, and are hence completing data taking, as planned, in summer 2019. The next phase of the project, depleted argon tests within the DarkSide/ArDM/DArT framework is well under preparation and will seamlessly continue with the experimental activities at LSC.

We would like to take the opportunity to sincerely thank the SC, as well as LSC and its staffs for their support and vital help for more than 10 years, without which the ArDM project would not have been possible.