

DArT in ArDM

Expression Of Interest for the LSC Scientific
committee

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The DarkSide-20k and
the Global Argon Dark Matter Collaboration

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I. CONTEXT

The DarkSide-50 Collaboration published in 2017 two world leading results for WIMP dark matter search for spin-independent interaction: the world best upper limit at low masses, between $1.8 \text{ GeV}/c^2$ and $6 \text{ GeV}/c^2$ and the best upper limit for high masses, above $30 \text{ GeV}/c^2$, for argon targets. One crucial ingredient for achieving these results was the use of argon depleted in the radioactive ^{39}Ar isotope by a factor 1400 compared to atmospheric argon (AAr) that has a radioactivity of about 1 Bq/Kg .

All collaborations pursuing first-generation liquid argon detectors, ArDM, DarkSide-50, DEAP-3600 and MiniClean, recently merged into the Global Argon Dark Matter Collaboration (GADMC), with the purpose of pursuing together the DarkSide-Low Mass (1 tonne), DarkSide-20k (20 tonnes) and DarkSide-300k (300 tonnes) experiments, aiming at investigating WIMP masses above $1 \text{ GeV}/c^2$ with cross sections down to the neutrino floor.

DarkSide-20k is an approved projects by INFN (Italy) and NSF (USA). A proposal for DarkSide-LowMass will be presented in the Fall 2019.

Two important steps of this research program are Urania, the 250 kg/day underground argon extraction plant to be deployed in Colorado, now in advanced tendering process and scheduled to start operations in 2021, and Aria, the 350 m cryogenic distillation plant in construction in Sardinia, Italy, that will achieve a factor of 10^3 ^{39}Ar suppression per pass at a rate of 10 kg/day . Aria is expected to enter operations in the second half of 2019.

For DarkSide-20k it is expected that the argon extracted in Colorado will be shipped to Sardinia where it will undergo chemical purification to be transformed into detector-grade argon at the rate of 1 ton/day , and from there shipped to LNGS.

For DarkSide-Low Mass, which requires only a ton of argon, a distillation step with Aria to suppress further the ^{39}Ar content is foreseen. Aria will enter operations before Urania and its test is a priority for the GADMC.

II. PROPOSED EXPERIMENT AND GOALS

With this EOI, we propose an experiment at LSC aiming at measuring an ^{39}Ar depletion of order 1000 with 10% precision.

The experiment *DART in ArDM* is meant to re-using the ArDM infrastructure with a minimal

modification, consisting of locating in the middle of the ArDM vessel a radio-pure copper single-phase liquid argon detector of about 1 L volume, DArT. DArT will be filled with the argon to be tested and be readout by two cryogenic SiPM 25 cm² tiles, that come, together with the readout electronics, from the DarkSide-20k production chain. The ArDM detector for this experiment is going to be operated in single phase mode, with new low-radioactivity PMT's, removing the borotron shield and the field cage, and will act as an active veto against internal and external radiation.

Extensive GEANT4-based simulations with tuned-on-data MC, inherited from the DarkSide-50 experiment at LNGS, of the setup were performed.

These simulations show that *DArT in ArDM* will achieve in this configuration a few % measurement for ³⁹Ar depletions of order 10 compared to AAr in about a week of running and a 20% measurement for depletions of order 100.

This setup will be very useful, if deployed in a timely manner, to characterize the performance of Aria, that is expected to suppress the ³⁹Ar content by a factor of 10 per pass. To achieve this, first goal we need *DArT in ArDM* to be ready by the second half of 2019.

A very important addition to the above described setup will consist of adding 6 ton lead belt of about 1.4 m height, around the ArDM vessel, at mid height position, to suppress the impact of external photons that dominate the background budget. This will allow to measure larger ³⁹Ar depletion, corresponding to those of the argon coming from deep wells underground in Colorado, from the Urania plant.

If the depletion levels are those already measured in the past (i.e. of 1400), it will be possible, according to our simulations, to measure them with a 15% uncertainty in a about a week of running.

The argon from Urania is expected to be available only at the end of 2021. However, it is planned that, after the run of DarkSide-50 at LNGS, presumably at the end of 2019, its argon will be measured in *DArT in ArDM* to cross-check the old measurement and to test the new setup.

This *DArT in ArDM* experiment is expected to become a facility for the LSC for the years to come since it will be needed to measure samples of the extracted argon from Urania over time.

The scientific relevance of depleted argon goes quite beyond its use in DarkSide-Low Mass,

DarkSide-20k and DarkSide-300k and is now being considered also by DUNE, COHERENT and LEGEND experiments.

A TDR for *DArT in ArDM* is in preparation and will be submitted to this committee in due time.

III. ORGANIZATION AND STAKEHOLDERS

The *DArT in ArDM* project is supported and backed-up by the whole DarkSide-20k and GADMC collaborations. Still, some specific groups will be more directly involved in the design, construction and operation and they are in particular: ETH Zurich (Switzerland), CIEMAT (Spain), INFN Cagliari, LNGS and Torino (Italy), Carleton University (Canada), University of Houston (USA), APC and LPNHE (France).

IV. TIMELINE AND READINESS

- Assembly and test of the DArT chamber at CIEMAT: starting Dec. 2018 ; all the material for the chamber in hand. The readout electronics is in hand in the non radio-pure version. Radio-pure version will be ready by June 2019.
- New single phase assembly design and test at CERN: starting from Feb. 2019; new low-radioactivity PMTs ordered
- Installation at LSC and run of phase 1: starting from August 2019.
- Installation at LSC of the lead belt: starting from January 2020.

V. REQUESTS TO THE LSC

- approval to install the DArT chamber in ArDM
- approval to install the lead belt
- timely support in potential safety reviews that could be needed in this context
- continue to provide support for the infrastructure as done for ArDM
- the supply of lead for the lead belt and its support structure.

VI. COST, PERSONNEL AND FUNDING

Many components of the DArT assembly come in-kind from the different participating institutions.

Personnel will be provided by the participating institutions.

VII. TOWARDS A MEMORANDUM OF UNDERSTANDING

Given the high scientific relevance of the proposed experiment and its value for the experiments to come, a MOU between the proposing Collaboration and the LSC needs to be prepared and signed in due time.

The MOU will clarify formally the ownership of the *DArT in ArDM*, the collaboration and LSC duties and its exploitation rights for the years to come.