DarkSide-50 and DarkSide-20k experiments: computing model and evolution of infrastructure

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Outlook

- The DarkSide project:
  - DarkSide-50 first results;
  - Future perspectives;
- DarkSide-50 computing scheme;
- DarkSide-20k computing scheme;
- Final remarks and conclusions.
The DarkSide Project

- **Aim**: direct dark matter detection looking for nuclear recoils possibly induced by WIMPs;

- **How**: usage of liquid argon (LAr) as detector media in a dual-phase TPC which:
  - has very low background thanks to being housed in the underground laboratory at LNGS and usage of low background material, including the target itself,
  - has powerful background rejection thanks to effective PSD, ionization to scintillation ratio and 3D position reconstruction,
  - has an active neutron and muon veto, allowing in situ background measurement.
DarkSide: a multi-stage program

DarkSide-10
Prototype Detector

DarkSide-50
First physics detector
$\sim 10^{-45} \text{ cm}^2 @ 100 \text{ GeV}$

DarkSide-20k
Future multi-ton detector
$\sim 10^{-47} \text{ cm}^2 @ 100 \text{ GeV}$
DarkSide: the timetable

DarkSide-10
Operating from Dec. 2010 to Jan. 2013

DarkSide-50
Still ongoing from Apr. 2015

DarkSide-20k
Will be operational from ~ 2020
Corno Grande of the Gran Sasso massif (pictured) provides 3800 m.w.e. passive shielding against cosmic rays

11m-diameter, 10m-tall, 1 kt Water Čerenkov Detector (WCD) instrumented with 80 8”-PMTs provides active shielding against μ’s

4m-diameter 30 t borated Liquid Scintillator Veto (LSV) instrumented with 110 8”-PMTs provides additional active shielding against γ’s, n’s and μ’s

…these all surround the inner detector, the Time Projection Chamber (TPC)
A recoil excites and ionizes the liquid argon, producing scintillation light (S1) that is detected by the photomultipliers.

The electrons are extracted into the gas region, where they induce electroluminescence (S2).

The time between the S1 and S2 signals gives the vertical position.

x-y position of events are reconstructed from fraction of S2 in each PMT.

Electron drift lifetime > 5 ms, compared to max. drift time of ~ 375 µs.
Electron drift speed = 0.93 mm/µs
DarkSide-50 Results

Best limit to date, with argon target, third best limit behind LUX & Xenon100 at high mass WIMP range.
Future perspectives

- Collaboration planned to build big volume detectors [DS-20k (20t), Argo (200t)];
- R&D on going to produce radio pure SiPM;
- Plans for massive UAr production (Urania project: ~100 kg/d) and purification (Aria project: ~300 m tall column for isotope separation).
DarkSide-20k projected limits

The DarkSide-20k Yellow Book / Technical Proposal (2016).
Global Trigger logic provides mechanism to synchronize TPC DAQ and Veto DAQ events;
- Common 50 MHz high accuracy clock allows GPS based timing synchronization of the events;
- Both systems can run independently with their own triggers in local mode.

- Caen V1720 module:
  - 8 channel 12bit 250 MS/s ADC;
  - Pulse Shape Discrimination;
  - Memory buffer: 1.25 or MS/ch, up to 1024 events.

- Caen V1724 module:
  - 8 channel 14bit 100 MS/s ADC;
  - Pulse Height Analysis
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In the stable data acquisition phase, the raw’s data throughput is 10 TB/month at a rate of few Hz
DarkSide-50 computing model

- DarkSide-50 has two main offline sites: CNAF and Fermilab (FNAL);
- DAQ transfers (temporary) data to LNGS Offline Farm via a 2 Gbit optical link;
- Raw data are automatically (men supervised) copied to CNAF Farm via a 10 Gbit optical link (almost with approx. 7 hours delay);
- Raw data are semi-automatically copied from CNAF to FNAL via a 100 Gbit optical link;
  - Part of them are processed at CNAF, stored in it (SLAD files), and copied to FNAL;
- FNAL processes data and send them back to CNAF via the same link as before with a rate of 0.5 TB/month (RECO files);
- LNGS, CNAF and FNAL provide infrastructures to store and process data;
- Major effort in order to let collaborators use the same environment and tools on the two sides of the Ocean.
DarkSide-50 data distribution scheme

- Under mountain laboratory, LNGS
  - DSFRs
  - DAQ
  - DSAG
  - 7 TB

- Above ground laboratory, LNGS
  - DS50Login
  - Production: Laser, TPC, Veto, DSTs
  - DS50FS
  - Metadata
  - 720 TB

- Raw data first processed at LNGS, raw data sent to CNAF

- Raw & Processed data
  - FNAL receives processed data from LNGS, raw data from CNAF
  - Reprocessing at CNAF & FNAL

- Long-term Storage, Analysis & Reprocessing
  - CNAF
  - Bologna, It
  - Chicago, U.S.
  - FNAL
  - Long-term Storage, Analysis & Reprocessing

- Reco data
  - Raw data
DarkSide-50 @ CNAF

- CNAF officially support 30 High Energy Physics experiments (HEP): 4 LHC and 27 non-LHC (i.e. DarkSide);

- **INFN-Tier 1** provide more than 120 racks and several tape libraries:
  - 1300 server with about 10000 cores available;
  - about 10 PBytes of disk space;
  - 80 KHS06;
  - about 14 PBytes on tapes;

- **DarkSide-50** in this moment is using:
  - 1 PByte of disk space;
  - 1 KHS06;
  - about 0.3 PBytes on tapes.
Software for DS-50 @ CNAF

- DarkSide software area is located @ bastion.cnaf.infn.it in the ui-darks.cr.cnaf.infn.it machine;

- Depending on your job it is possible to configure the working environment in three possible ways:
  - **Data analysis:**
    - `source /opt/expソフトware/darkside/ds50/app/ds50/setup_highlevel`
  - **Montecarlo codes:**
    - `source /opt/expソフトware/darkside/ds50/app/ds50/setup_g4ds`
  - **To use DarkArt:**
    - `/opt/expソフトware/darkside/ds50/app/ds50/setup_ds50`

- All of the recorded data are converted in ROOT format in order to be easily analyzed by the collaborators.
DarkSide-50 @ CNAF: conclusions

- High professionalism and performances from the CNAF staff members;
- Very good technical support up to the needs of the DarkSide Collaboration;
- DarkSide-50 is a “drop” in the ocean of the computing needs of the CNAF:
  - in almost 3 years of data taking in wimp search mode we used “only”:
    - 1 PByte of disk space;
    - 1 KHS06;
    - about 0.3 PBytes on tapes;
- Plans for future: DarkSide-50 will be online until 2020.
DarkSide-20k: Computing Strategy

build on knowledge acquired in the construction and operations of the DS-50 system

+ take advantage of competences, infrastructures, resources, manpower developed and used for LHC computing

(DarkSide-20k computing: a first attempt to optimise resources connecting competences in csn2 and csn1)

- hierarchical computing model to optimise use of resources and access to data
- exploit DS-20k software trigger farm that allows to perform online part of the reconstruction and data compression that today is done offline in DS-50
- raw/pre-processed data from trigger farm will be sent to a T1 computing center (CNAF or RM1 T2) for processing, re-processing, permanent storage and automatic/on-demand distribution of analysis-format data to other centers (EU and non-EU)
- MC simulation done in the same T1 computing center exploiting grid/cloud/HPC resources
- we are evaluating possible advantages in designing the software for multi-threading/parallel processing to exploit HPC resources
- batch&interactive analysis: analysers expected to analyse small reduced samples (mini-ntuples) both in local computers and on grid
DarkSide-20k DAQ Scheme

- raw data rate from High Level Software Trigger: 3.8 (S2/Veto waveforms) to 16.5 (+S1 waveform) TB/day
- waveform compression algorithms expected to reduce the data rate on disk to: 1 to 2 TB/day
DarkSide-20k Computing Requirements

**Inputs:**
- physics events rate: 50 Hz sustained $\Rightarrow$ 4.32 Mevents/day
- raw-data event size (after online compression): 0.5 to 1 MB/ev
- simulation event size: 2.5 MB/ev to 0.7 MB/ev (compressed)

**CPU processing time (std INFN grid CPU core):**
- raw-event reconstruction: 1.2 sec/ev
- re-processing of a reconstructed event: 0.1 sec/ev
- simulation+rec. of a DS20k event: 2.5 s/ev

**Assumptions:**
- 5 years DS-20k data-taking: 2021-2026
- offline reconstruction in real-time at the T1/T2 computing center of all the events logged by the high level software trigger
- re-process two times per year in 1/2 month all physics events collected in one year
- simulation samples $\geq$10x the physics data events
DarkSide-20k Computing Requirements

- **CPU processing power needed at T1/T2:**
  - raw-data reconstruction: 4.3 Mevents / day can be processed in real time with $\geq 60$ std INFN grid cores
  - raw-data re-processing: 1.6 Gevents / year can be processed in 1/2 month with $\geq 1460$ cores (to be done 2 x year)
  - MC simulation: 10x 1.6 Gevents / year can be produced in one year with $\geq 1250$ cores
- **Summary:** a system with O(1500) cores would cover the DarkSide-20k needs in terms of CPU processing power

- **Network bandwidth needed between LNGS and T1/T2:** 2 TB / day $\Rightarrow$ 250 Mbit $\Rightarrow$ already available both at CNAF and RM1 T2

- **Storage needed at T1/T2:**
  - raw-data (after online compression): 1-2 TB / day x 5 years: 2-4 PB
  - reconstructed data: 10% of raw-data: 0.2-0.4 PB
  - calibration data: $\sim10\%$ of raw-data: 0.2-0.4 PB
  - simulation (after compression and saving only reconstructed samples): 2-4 PB
- **Summary:** total storage 4.4 PB to 8.8 PB in 5 years

- With current systems the whole needed system: ~1500 CPUs cores with ~4 PB storage should fit in 1/1.5 full-size rack for a cost of the order of 500-700 kEuro
DarkSide-20k Computing Timeline

- **Q3 2018**: Pilot farm 10% of the whole system in the CNAF T1 or RM1 T2 site
  - for development of offline/grid code&tools
  - test system reliability & performances
  - start production and storage of MC samples

- **Q1 2020**: Production farm for first 2-years of data-taking
  - 50% of cpu cores / 50% of disk/tape storage
  - full dress rehearsal planned in 2020

- **Q1 2023**: Complete farm
  - staged integration to maximise cpu&storage per Euro
ENJOY THE DARK SIDE!
Backup
Dual-phase LAr Time Projection Chamber

- Cylindrical shape of 35.6 cm radius x 35.6 cm height x 2.54 cm thick with PTFE reflector walls;
- TetraPhenyl Butadiene (TPB) wavelength shifter on the walls;
- 19 3”-PMTs in the top and 19 on the bottom with cold amplifiers;
- Drift Field: 0.2 kV/cm
- Extraction Field: 2.8 kV/cm
The DarkSide-50 signal

X, Y position through S2 light on top PMTs

Z position through S1-S2 drift time

Discrimination through:
- S1 pulse shape (F90)
- S2/S1 ratio
DarkSide-50: signal processing
DarkSide-50 Results (1/2)

Agnes et al., Phys. Rev. D 93, 081101 (R) (2016)
Direct Detection State-of-the-Art
Ionization and Scintillation branches

- Recoil
  - Ionization
    - Electrons
      - S2
    - Recombination
  - Ar$^+$
  - Ar$_2^+$
  - Ar$^{**}$
    - Ar$^*$
      - Ar$_2^*$
        - Singlet
        - Triplet
      - S1
    - Triplet
  - Excitation
    - Ar$^*$
    - Ar$_2^*$
      - Singlet
      - Triplet
Nuclear vs Electron recoil

- **Nuclear Recoil**
  - S1
  - S2

- **Electron Recoil**
  - S1
  - S2
Underground Ar vs Atmospheric Ar

Phys. Rev. D 93, 081101(R) (2016)