Status and Results of DarkSide-50

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(for the DarkSide collaboration)
The DarkSide Program

• WIMP dark matter search using **direct detection**
• Dual-phase **Liquid Argon** Time Projection Chamber (LArTPC)
• Multi-stage approach
• Ultra **low background**
  • Deep underground at LNGS
  • Low-background materials, including Ar target
• Powerful **background rejection**
  • Pulse Shape Discrimination (PSD)
  • Ionization/Scintillation ratio (S2/S1)
  • Surface rejection using 3D position reconstruction
• Active neutron and muon **veto**es
  • In situ background measurement
Why Argon?

• Relatively **dense**

• Easy to **purify**

• High **ionization**
  • High electron mobility
  • Low diffusion

• High **scintillation yield**
  • ~40k photons/MeV
  • Transparent to its own scintillation light

• Exceptional **discrimination power**
  • PSD
  • S2/S1

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Main challenge: 
$^{39}$Ar contamination
Underground Argon

- **Atmospheric argon:**
  - high concentration of $^{39}$Ar
  - beta decay (269 yr half life)
  - cosmogenically activated
  - 565 keV endpoint

- **Underground argon:**
  - significantly reduced $^{39}$Ar activity
  - allows to scale to large detectors

First limit on UAr activity measured in small TPC underground at KURF in 2009

<table>
<thead>
<tr>
<th></th>
<th>Total rate (mBq/100keV)</th>
<th>Background rate (mBq/100keV)</th>
<th>BG-subtracted rate (mBq/100keV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atmospheric Ar</td>
<td>108.8 +/- 0.4</td>
<td>1.54 +/- 0.22</td>
<td>107.2 +/- 1.9</td>
</tr>
<tr>
<td>Underground Ar</td>
<td>1.87 +/- 0.06</td>
<td></td>
<td>0.32 +/- 0.23</td>
</tr>
<tr>
<td>Overall reduction</td>
<td>1.71 +/- 0.05 %</td>
<td></td>
<td>&lt;0.65% (95% CL)</td>
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</tbody>
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Multi-stage DarkSide program

DarkSide-10
2011-2013

DarkSide-50
2013-201x

DarkSide multi-ton
201?-20??

(A). Fan
(UCLA Qualifying Oral Exam)

Electron drift length: 2.4 meters
Segmented S2 region

Cold point (heat sink) on both top and bottom for electronic heat load

Preliminary

H. Wang @ Cagliari DS GM, DS20K

06/29/15

Vessel (OD): 358 cm
Cryostat (ID): 338 cm
Dual-phase LArTPC

PSD parameter: \( F_{90} = \) fraction of light in first 90 ns
Dual-phase LArTPC

![Diagram of Dual-phase LArTPC with labels S1, S2, E_{drift}, and E_{extr}]

- **S1**
- **S2**
- **E_{drift}**
- **E_{extr}**

**Graphs:**
- NR: No signal
- ER: Event-related signal

![Graphs showing amplitude vs. sample time for NR and ER signals]
TPC

• **46 kg active** volume
• 36 cm diameter, 36 cm height
• 38 R11065 3” PMTs
• **Cold pre-amps**
• High **reflectivity** PTFE walls
• Fused silica anode and cathode windows
  • Coated with **ITO**
• All inner surfaces coated with **TPB**
• 0.2 kV/cm drift, 2.8 kV/cm extraction
Vetoes

**Liquid Scintillator Veto**
- 4 m diameter sphere
- Boron-loaded: PC + TMB
- 110 8” PMTs
- Active neutron veto
  - tag neutrons in TPC
  - in situ measurement of neutron BG
- Neutron and gamma shielding

**Water Tank**
- 11 m diameter x 10 m high
- Existing Borexino CTF tank
- 80 PMTs
- Active muon veto
  - tag cosmogenic neutrons
- Neutron and gamma shielding
DarkSide-50
Atmospheric argon campaign

- 47.1 live-days with AAr
- ~1 Bq/kg of $^{39}$Ar
  1.5 x $10^7$ events
- Light yield:
  ~7.9 PE/keV at null field,
  ~7.0 PE/keV at 200 V/cm
- Electron drift lifetime >5000 μs
  Compare to 375 μs max. drift time
- Reduced veto performance due to high $^{14}$C content in TMB
  Have since replaced with far cleaner TMB
Nuclear recoil calibration

**SCENE**
Scintillation Efficiency of Nuclear Recoils in Noble Elements

LArTPC exposed to bunched low energy neutron beam
Extremely pure sample of single nuclear recoils
Extrapolate NR energy scale and F90 response from SCENE to DS50
First results (using atmospheric argon)

$1422 \pm 67$ kg-day exposure

Expected $^{39}\text{Ar}$ leakage: $<0.1$ evt

Corresponds to $> \sim 20$ yr exposure of DS50 with UAr
Limit @ 100 GeV/c²: $6.1 \times 10^{-44}$ cm²

Calibrations

- CALIS deployed Sept 2014
- Calibration campaigns
  Oct - Dec 2014 and Jan - Feb 2015
- **Validate NR band** extrapolated from SCENE for first paper
- Tuned MC

**DATA-MC comparison: $^{57}$Co source next to the cryostat**
Underground argon

atmospheric and underground argon at 200 V/cm

Events/[50 PE × kg × s]

Normalized by live time
Underground argon

Atmospheric and underground argon at 200 V/cm

Normalized by live time
Underground argon

atmospheric and underground argon at 200 V/cm

Normalized by live time
Underground argon

atmospheric and underground argon at 200 V/cm

Normalized by live time
Underground argon

atmospheric and underground argon at 200 V/cm

- AAr (200 V/cm, 44 kg)
- UAr (200 V/cm, 44 kg)
- UAr (200 V/cm, 44 kg, LSVeto)
- AAr (200 V/cm, 4 kg core)
- UAr (200 V/cm, 4 kg core)
- UAr (200 V/cm, 4 kg core, LSVeto)

$^{37}$Ar is cosmogenically activated
- 35 day half life
- very low energy calibration point

Normalized by live time
Future

DS-20k

- Large TPC
- SIPMs (no PMTs)
- 30 ton detector (20 ton fiducial)
- 100 t-yr BG-free exposure
- Projected sensitivity: $9 \times 10^{-48} \text{ cm}^2 @ 1 \text{ TeV/c}^2$
Summary

• **First results published** with atmospheric argon in DS-50

• **Calibration campaigns** with gammas and neutrons

• Running with **underground argon** since Apr 2015

• **$^{39}\text{Ar depletion factor} \geq 300** in underground argon

• DS-20k development underway
Backup
3D position reconstruction

![Graph showing 3D position reconstruction with a red box marking the 4kg core area and labels for Top and Bottom.]