DarkSide

Dark Matter with Ar

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Buenos Aires
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Coherent neutrino-nucleus scattering floor
(New) Argon Collaboration

Researchers from
- DarkSide
- DEAP
- ArDM
- MiniCLEAN

planning to collaborate on future program:

- Completion of current science and R&D programs by each collaboration (DS-50, DEAP-3600, MiniCLEAN, ArDM)
- Joint collaboration on DS-20K at LNGS, including Low Radioactivity Argon (operation starting 2021) and SiPM photodetectors
- Joint collaboration on future multi-hundred-tonne LAr detector, site TBD (mid-2020’s)
Towards global argon collaboration: DarkSide, DEAP, miniCLEAN, ArDM > 350 researchers

Collaboration

• 68 institutes
• 350 researchers
• 12 nations:
  Brasil, Canada, China, France, Greece, Italy, Poland, Romania, Spain, Switzerland, UK, USA
An Ambitious Discovery Program

• Complementary to LHC

• Raising the bar: from 1 tonne × yr → 1,000 tonne × yr

• “Zero Background” necessary for a discovery program

• Two crucial technologies
  • Liquid argon target depleted in the radioactive $^{39}$Ar
  • SiPMs replacing cryogenic PMTs
Liquid Argon TPC
153 kg $^{39}$Ar-Depleted
Underground Argon Target
4 m Diameter
30 Tonnes
Liquid Scintillator
Neutron Veto
10 m Height
11 m Diameter
1,000 Tonnes
Water Cherenkov
Muon Veto
Liquid Argon TPC
153 kg $^{39}\text{Ar}$-Depleted
Underground Argon
Target

4 m Diameter
30 Tonnes
Liquid Scintillator
Neutron Veto

10 m Height
11 m Diameter
1,000 Tonnes
Water Cherenkov
Muon Veto
“Zero Background” condition (<0.1 background events) necessary to conduct discovery program
What are the instrumental backgrounds for large scale, high mass dark matter searches?
Minimum Ionizing Events:

• Scatters of $pp$ solar neutrinos on electrons
• Radioactive noble gases ($^{39}$Ar)

Nuclear Recoils:

• $\nu$-induced coherent scattering of atm neutrinos [$\sim 1/(100 \text{ tonne } \times \text{ yr})$]
Elastic Scatters of \textit{pp} Solar Neutrinos on Electrons

- 200 events/tonne\(\times\)yr in ROI
- 200,000 background events @neutrino floor
- Defeated in argon thanks to \(\beta/\gamma\) rejection better than \(1\div1.6\times10^7\)
16M $^{39}$Ar events
1,422 kg×day (@AAr)

$\div 1400$ $^{39}$Ar depletion
AAr/UAr

16M $^{39}$Ar events
5.5 tonne×yr (UAr)

additional active isotopic depletion
higher light yield

1,000 tonne×yr (DAr)
Based on what we know today, can a depleted argon experiment be free of any instrumental (other than ν-induced recoils) background at the scale of 1000 tonnes×yr?

Yes.
Urania to Aria to LNGS
Production Column
150 cm diameter
350 m height

R&D Column
30 cm diameter
350 m height

• Volatilità relative => 1.007
• Valori tipici >1.5
• Numero di stadi teorici => ordine delle migliaia
• HETP = 10 cm
• H=200-400 m
• Usuali = 20-30 m
• Fuori terra
• A sezioni separate
Nostra Signora di Bonaria, Cagliari
SiPM Status

• Photon Detection Efficiency (PDE): 45% requirement met and surpassed

• Dark Count Rate (DCR): 0.1 Hz/mm² requirement met and surpassed

• Challenge in tiling due to 50 pf/mm² capacity. Signal-to-Noise Ratio (SNR) rapidly decreases with increasing surface. The steps:

  • 2×2 cm² tile: fully demonstrated

  • 3.5×3.5 cm² tile: on the way, success projected on the basis of available data

  • 5×5 cm² tile: in 2017, some R&D necessary to improve SNR due to the increase in capacity
Entries 400149

Gain: 21.0

$\sigma_b$: 1.52

SNR: 13.8
DarkSide-20k

20-tonnes fiducial dark matter detector
start of operations at LNGS within 2021
100 tonnexyear search for dark matter free of instrumental background
INFN-NSF science review: ✓
Yellow Book to LNGS: ✓
INFN-NSF budget and schedule review: ongoing

Argo

300-tonnes depleted argon detector
start of operations at LNGS within 2027
100 tonnexyear search for dark matter free of instrumental background
precision measurement of solar neutrinos
57.2 keV

- Parallel to $\vec{E}_d$
- Perpendicular to $\vec{E}_d$

S1 yield relative to 0 field

Drift electric field [V/cm]
Why we need more Latin American Astroparticle Physicists?

Pablo Javier Mosteiro y Romero

Alvaro Eugenio Chavarria
Single/double electron

From simulation:
By identification of Bragg peak have achieved $10^{-3}$ suppression of single electron background, with 50% signal acceptance.

Strongly suppresses $\gamma$-ray and single $\beta$ backgrounds
## Radioactive backgrounds

<table>
<thead>
<tr>
<th>In ROI</th>
<th>Source</th>
<th>Raw background rate / kg(^{-1})y(^{-1})</th>
<th>After discrimination / kg(^{-1})y(^{-1})</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>β-decay (bulk)</td>
<td>&lt; 3.3 \times 10^{-1}</td>
<td>&lt; 3.7 \times 10^{-9}</td>
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<tr>
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<td>β-decay (surface)</td>
<td>&lt; 4.1 \times 10^{-1}</td>
<td>&lt; 1.2 \times 10^{-8}</td>
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<td>β-decay (cosmo.)</td>
<td>&lt; 9.9 \times 10^{-5}</td>
<td>&lt; 1.5 \times 10^{-7}</td>
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<tr>
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<td>γ-ray (photo-elec.)</td>
<td>&lt; 7.2 \times 10^{-4}</td>
<td>&lt; 7.2 \times 10^{-7}</td>
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<tr>
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<td>γ-ray (Compton)</td>
<td>&lt; 1.6 \times 10^{-3}</td>
<td>&lt; 4.1 \times 10^{-7}</td>
</tr>
<tr>
<td></td>
<td>γ-ray (pair prod.)</td>
<td>&lt; 1.9 \times 10^{-6}</td>
<td>&lt; 1.9 \times 10^{-7}</td>
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<tr>
<td></td>
<td><strong>Total</strong></td>
<td><strong>&lt; 7.4 \times 10^{-1}</strong></td>
<td><strong>&lt; 1.5 \times 10^{-6}</strong></td>
</tr>
</tbody>
</table>

Bulk backgrounds suppressed by α/β particle ID and spatial coincidences. Also applied multiple scattering cut, limited to 10\(^{-1}\) suppression of nearby scatters.
Why we need more Latin American Astroparticle Physicists?

Ivone Albuquerque

Maximo Ave Pernas
Why we need more Latin American Astroparticle Physicists?

Ana Amélia Machado

Ettore Segreto
The End