DarkSide-20k
and the Darkside Program
for Dark Matter Searches

Cristiano Galbiati
Princeton University
Physics Beyond Colliders
CERN
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Coherent neutrino-nucleus scattering floor
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 $^{39}$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:
• $v$-induced coherent scattering of atm neutrinos [$\sim 1/(100 \text{ tonne } \times \text{yr})$]
Elastic Scatters of $pp$ Solar Neutrinos on Electrons

- 200 events/tonne×yr in ROI
- 200,000 background events @neutrino floor
- Defeated in argon thanks to $β/γ$ 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)
Urania to Aria to LNGS
Aria

- 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
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.
SiPM Status

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

• Dark Count Rate (DCR): 0.1 Hz/mm$^2$ requirement met and surpassed

• Challenge in tiling due to 50 pf/mm$^2$ capacity. Signal-to-Noise Ratio (SNR) rapidly decreases with increasing surface. The steps:
  
  • 2×2 cm$^2$ tile: fully demonstrated
  
  • 3.5×3.5 cm$^2$ tile: on the way, success projected on the basis of available data
  
  • 5×5 cm$^2$ tile: in 2017, some R&D necessary to improve SNR due to the increase in capacity
Baseline: mean = -2 pVs, $\sigma = 67$ pVs
SPE peak: mean = 801 pVs, $\sigma = 76$ pVs
SNR: 12.0
### DarkSide-20k

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

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### Argo

- 300-tonnes depleted argon detector
- Start of operations at LNGS within 2027
- 100 tonne/year search for dark matter free of instrumental background
- Precision measurement of solar neutrinos
The End