Dark Matter Search with DARWIN

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Dark Matter Experiments

CNNS sensitivity limit
Liquid Xenon TPCs

- 3D position reconstruction → fiducialization
- ER/NR discrimination
- Removal of double scatters
DARWIN Setup

- Water Cherenkov shield (14m diameter)
- Liquid scintillator shield under study
- LXe TPC (2.6m diameter/height)
- Possible location LNGS
DARWIN TPC

- SS/Ti/Cu cryostat (2.6m height/diameter)
- 40 tons LXe target
- ~1800x 3“ PMTs (1000x 4“)
- PTFE reflectors
- OFHC Cu field shaping rings
DARWIN Sensitivity: WIMPs

> 99.98% ER rejection, 30% NR acceptance

Spin independent

Spin dependent
WIMP Spectroscopy

> Substantial uncertainty on WIMP properties for large masses and small cross sections

$\rho_0 = (0.3 \pm 0.1) \text{ GeV cm}^{-3}$
$\nu_0 = (220 \pm 20) \text{ km s}^{-1}$
$\nu_{esc} = (544 \pm 40) \text{ km s}^{-1}$

exposure 200 ton yr
DARWIN Backgrounds: Neutrons

- Radiogenic neutrons
  - $3.8 \times 10^{-5}$ events/t/yr/keV$_{nr}$
  - Radiopurity of materials has to be improved by factor 2-5

![Graph showing neutron rate vs. energy](image.png)
DARWIN Backgrounds: Electron Recoils

> Electron recoil background

<table>
<thead>
<tr>
<th>Source</th>
<th>Goal</th>
<th>Achieved</th>
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</thead>
<tbody>
<tr>
<td>$^{85}$Kr</td>
<td>0.1 ppt $^{nat}$Kr</td>
<td>0.03 ppt (XENON1T)</td>
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<tr>
<td>$^{222}$Rn</td>
<td>0.1 $\mu$Bq/kg</td>
<td>$3.65 \pm 0.37$ $\mu$Bq/kg (EXO)</td>
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</tbody>
</table>

$pp + ^7$Be neutrinos

$2\nu\beta\beta$

$^{85}$Kr

$^{222}$Rn

Materials

Energy [keVee]

Rate [$(t \times y \times \text{keVee})^{-1}$]

arXiv: 1506.08309
DARWIN Backgrounds: CNNS

> Coherent Neutrino Nucleus Scattering

![Graph showing neutrino scattering rates with different energy scales and labels for solar and atmospheric neutrinos, along with WIMP interactions.](image)

arXiv: 1506.08309
DARWIN Sensitivity: Axions

Sensitivity to solar axions and galactic ALPs via axio-electric effect

arXiv: 1209.3810
DARWIN Sensitivity: $^{136}\text{Xe} \ 0\nu\beta\beta$

- Natural abundance 8.9%
- $T_{1/2} > 5.6 \times 10^{26}$ y for 30 ton yr ($> 8.5 \times 10^{27}$ y for 140 ton yr)

$T_{1/2} = 1.6 \times 10^{25}$ y for 6 ton fiducial volume

only $^{8}\text{B}$ background

arXiv: 1309.7024
DARWIN Sensitivity: Solar Neutrinos

- Realtime measurement of pp-neutrino flux
- < 1% precision after 5 years

BOREXINO (Nature 512, 2014)
DARWIN Sensitivity: Supernova Neutrinos

- ~100 events from galactic SN
- Detection of all flavors via CNNS
- Negligible background due to short burst (~sec.)

SN spectrum for XMASS-I

arXiv: 1604.01218
DARWIN Technical Challenge: HV

- Drift field 0.5-1kV/cm requires cathode voltage of 130-260kV
- Cathode: 100 μm thin wires for good optical transparency
- Anode: constant gap, parallel to liquid surface over 2.6m
- 3D field simulations based on BEM
DARWIN R&D: LHM

- Baseline design PMTs, alternatives: SiPM, SiGHT, GPM
- Single Phase TPC with Liquid Hole Multipliers (LHM)
  - No liquid-gas interface
  - No anode grids
DARWIN Consortium

> 25 groups from 11 countries
Conclusions

> DARWIN: multi-purpose rare event search

- **WIMPs**: $\sigma_{SI} < 2.5 \times 10^{-49} \text{cm}^2$ @ 40 GeV/c$^2$
- **solar axions**: $g_{Ae} < 10^{-12}$ for $10^{-5} < m_A < 1$ keV/c$^2$
- **ALPs**: $g_{Ae} < 10^{-14}$ for $1 < m_A < 40$ keV/c$^2$
- **pp-neutrino flux**: <1% precision after 5 years
- **0v2\beta^{136}\text{Xe]**: $T_{1/2} > 8.5 \times 10^{27}$ y after 140 ton yr
- **CNNS**: ~20 events/ton/yr from $^8\text{B}$
- **Supernova neutrinos**: ~10-20 events/ton for 10kpc
## DARWIN Timescale

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<th>Year</th>
<th>2016</th>
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<th>2018</th>
<th>2019</th>
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<td>construction</td>
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<td>comissioning</td>
<td>science run</td>
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DM Complementary
DARWIN Light Yield

Light yield for 122 keV, E = 0

PDE = photon detection efficiency  
(for photons hitting the GPM window)

- PTFE reflectivity = 95%
- Rayleigh scattering length = 30 cm
- XENON1T PMTs and meshes
- 90% transparent field cage