Proportional Scintillation in LXe

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Detecting Dark Matter
Detecting Dark Matter

Collisions at the LHC

Direct detection

Indirect detection

Production at colliders

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(cms.web.cern.ch/)
Detecting Dark Matter

Collisions at the LHC

Decay products detected by AMS02

Direct detection

Indirect detection

Production at colliders

P

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P

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Detecting Dark Matter

Dark matter enters the detector and deposits energy

Collisions at the LHC

(DMS.web.cern.ch/)

DARk matter WImp search with liquid xenoN (DARWIN)

Decay products detected by AMS02

(DMS.ams.nasa.gov/)
The DARWIN detector searches for WIMPs (Weakly Interacting Massive Particle)

40t LXe as detector material

Goal:
Sensitivity for spin-independent WIMP-nuclei interactions down to the neutrino floor
DARWIN Challenges

Challenges:
- Electron drift over long distance
- Scaling: e.g. electrodes \( \rightarrow \) diameter
- LXe mass (purification)
- Background reduction
  - \(^{222}\text{Rn}\)
  - \((\alpha, n)\) neutrons from PTFE
- Light sensors
  - stability
  - low radioactivity
  - high light yield
- ….
DARWIN Challenges

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  - stability
  - low radioactivity
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• ...
Signal readout in a Time Projection Chamber (TPC)

GXe

LXe

e-•

S1

S2

+HV

GRD

-E_{drift}

-E_{amp}

GXe

LXe
Signal readout in a Time Projection Chamber (TPC)
Signal readout in a Time Projection Chamber (TPC)

- Photons along drift path
- Proportional scintillation in GXe
Electronic Recoil (ER)

\[ E_0 = N_i E_i \times N_{ex} E_{ex} \times N_i \varepsilon \]
Signal readout in a Time Projection Chamber (TPC)

Electronic Recoil (ER)

\[ e^-, \gamma \]

Nuclear Recoil (NR)

\[ n, \text{WIMP} \]

\[ E_0 = N_i E_i \times N_{ex} E_{ex} \times N_i \varepsilon \]
Electronic Recoil (ER)

\[ E_0 = N_i E_i \times N_{ex} E_{ex} \times N_i \varepsilon \]

Nuclear Recoil (NR)

Signal readout in a Time Projection Chamber (TPC)

To date: Proportional Scintillation in GXe
Test this in LXe!
From dual-phase to single-phase

2.6m

GXe

GRD

d

+HV

-LXe

-HV
From dual-phase to single-phase

- anode sagging
- Amplification length changes
- impact on charge signal

\[ S2 \propto \left( \frac{E}{P} - 1 \right) Pd \]
From dual-phase to single-phase
From dual-phase to single-phase

From dual-phase to single-phase
From dual-phase to single-phase

Charge signal:
- Photons at anode
- Proportional scintillation in LXe
- Strong e-field required
From dual-phase to single-phase

**Charge signal:**
- Photons at anode
- Proportional scintillation in LXe
- Strong e-field required

**x-y-independent amplification**
From dual-phase to single-phase

- LXe
- GXe

E_\text{drift}

E_\text{amp}

S1

S2

+HV

-HV

GRD
From dual-phase to single-phase

\[ E = -\frac{\partial \phi}{\partial r} \mathbf{e}_r \approx \frac{\lambda}{2\pi \epsilon_0} \frac{1}{r} \mathbf{e}_r \]
From dual-phase to single-phase

- Strong e-field $O(10^3 \text{kV/cm})$
- Has been demonstrated with one single wire (arXiv:1408.6206)
  Wire diameter 10 μm

Build a single-phase TPC with a full wire grid!

\[
E = -\frac{\partial \phi}{\partial r} \vec{e}_r \approx \frac{\lambda}{2\pi \epsilon_0} \frac{1}{r} \vec{e}_r
\]
The XEBRA test platform

**XEnon Based Research Apparatus**

- **Cryostat:**
  - Cooling
  - LXe
  - Sensors (pressure, temperature,…)

- **Gas system:**
  - Xenon in/out
  - Purification
  - Pressure control

- **TPC in inner cryostat:**
  - Currently dual-phase
  - Inner dimensions: 7cm x Ø 7cm

- **Electronics:**
  - DAQ
  - High voltage
  - Control

Located in Freiburg
Goal:

- S2 signal independent along x-y-plane

Goal:

- Reduce $^{222}$Rn background down to 0.1 µBq/kg
Amplification with thin wires - status

Wire put under tension with weight
Stainless steal ring fixed here
Change position for additional wires
Keep wires parallel
Wire is fixed

(Bachelor thesis by Nico Strauß)
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Amplification with thin wires - status

- Full grid consisting of 19 single wires built
- Fits into the TPC

Properties:
- Gold plated tungsten
- 10 µm diameter
- 5 mm distance in between

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Tested cooling with liquid nitrogen:
- None of the wires broke

Diameter hair: 100 μm
Amplification with thin wires - status

Device for high voltage tests

- Teflon for high reflectivity
- 11.5 mm drift distance from each side
- 70mm inner reflector diameter
- 1 PMT top side (R11210)
- Bottom side is closed
Amplification with thin wires - status

Device for high voltage tests

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Goal:
- Operational stability of the grid
- Observe S1 + S2
Outlook and summary

What do we want:
• Single-phase TPC
  • S2 independent of x-y-plane
• Compare dual-phase TPC with single phase mode
  • Contestable?
• Understand statistics of amplification at thin wires

What do we have:
• Single wire grids are stable under effect of cooling
• HV test device is ready to maintain
Outlook and summary

What do we want:
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Chances:
- Reduce intrinsic background of PMTs by self shielding of LXe?
- Impact on S1 threshold?
- Impact on discrimination of electronic and nuclear recoils?