Status of the XENON1T experiment

Dott. Marco Garbini,
Bologna University
on behalf of the XENON Collaboration

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The XENON Collaboration

10 countries, 21 institutions, 130 scientists
The XENON Program @ LNGS

Direct Dark Matter Search using a dual phase Xenon TPC

XENON10 (2005~2007)

- Total: 25 kg
- Target: 14 kg
- Limit ~ $10^{-43}$ cm$^2$

XENON100 (2008~2016)

- Total: 161 kg
- Target: 62 kg
- Limit ~ $10^{-45}$ cm$^2$

XENON1T (2015-)

- Total: 3.2 t
- Target: 2 t
- Sensitivity ~ $10^{-47}$ cm$^2$

XENONnT (2018+)

- Total: ~ 8 t?
- Target: ~ 6 t?
- Sensitivity ~ $10^{-48}$ cm$^2$
Why Xenon?

- Large mass number A (131) (Interaction cross section $\propto A^2$)
- 50% odd isotopes ($^{129}$Xe, $^{131}$Xe) for Spin-Dependent interactions
- No long-lived radioisotopes, Kr can be reduced to ppt levels
- High stopping power, i.e. active volume is self-shielding
- Efficient scintillator (178 nm)
- Scalable to large target masses
- Electronic recoil discrimination with simultaneous measurement of scintillation and ionization
**How we use Xenon**

**Interaction in the Liquid Xenon**

- **Scintillation signals** \( S_1 \)
- **Ionisation signals** \( S_2 \)
- **The time between them** → \( z \) coordinate
- **Pattern on PMTs array** → \( x-y \) coordinates

**Particle Identification**

\[
\frac{S_2}{S_1}_{\text{wimp}} < \frac{S_2}{S_1}_{\text{ER}}
\]

**Vertex identification**
XENON1T

First ton scale Xe dual phase TPC for direct dark matter search

✦ Total Xe mass: 3.2 t
✦ Active Xe in the TPC: 2 t, readout by 248 PMTs
✦ Water Cherenkov muon veto
✦ Cooling/purification/distillation/storage systems designed to handle up to 10 tonne of Xe. Upgrade to a larger detector (XENONnT) planned for 2018
✦ Expected sensitivity $1.6 \times 10^{-47} \text{ cm}^2$ @ 50 GeV WIMP 2ty (100 times more sensitive than XENON100)
The XENON1T

Water Tank with Muon Veto & XENON1T Detector

Cryogenic & Purification

DAQ

Xe Storage & Purification
Water Shield & Muon Veto

- The XENON1T cryostat is immersed in a tank filled with 700 tonnes of pure water
- Reflective film foil on inner surface
- Instrumented with 84 high-QE, 8” PMTs to detect Cherenkov light
- Cosmogenic-induced background <0.01 events/y
- The muon veto has been commissioned in March 2016.

E. Aprile et al., JINST 9 (2014) 11006
Cryo/Storage/Purification

Xenon Handling System commissioned
Both for XENON1T & XENONnT
PMTs

✧ 248 PMTs: 3” Hamamatsu R11410

✧ Custom designed for low radioactivity
34.5% average QE @ 175 nm

✧ Low T tests and characterisation prior to installation

✧ In situ calibration

The TPC

- 96 cm drift x 96 cm diameter TPC
- Filled with 2 t of high-purity Xenon (active liquid target)
- 248 low radioactivity PMTs
The XENON1T Time Projection Chamber and associated cryogenic system are currently under commissioning.

Detector is responding to radiation as expected, with both charge and light being detected. The LXe is being continuously purified to reach the desired charge yield at the applied field.
Calibrations

First gamma ray spectrum (Cs-137 external)

- Spectrum obtained with detector unshielded.
- Full absorption peak clearly separable

Preliminary
Entering Low Background mode

Rate decrease with increasing Water level
**MC: Expected Electronic Recoil background**

**From Materials**

- Extensive screening campaign

**Intrinsic**

- 0.2 ppt of $^{nat}Kr$ (achieved in distillation column tests)
- 10 $\mu$Bq/kg $^{222}Rn$ (estimation based on Rn emanation measurements)

1 – 12 keVee, 1t fiducial, before ER discrimination

<table>
<thead>
<tr>
<th>Source</th>
<th>Background (evts/y)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Materials</td>
<td>0.07</td>
</tr>
<tr>
<td>$^{85}Kr$</td>
<td>0.05</td>
</tr>
<tr>
<td>$^{222}Rn$</td>
<td>1.4</td>
</tr>
<tr>
<td>$^{136}Xe$</td>
<td>0.02</td>
</tr>
<tr>
<td>pp+$^7$Be neutrinos</td>
<td>0.08</td>
</tr>
</tbody>
</table>

$^{222}Rn$ (mainly from $^{214}Pb$ $\beta$-decay) is the most relevant source of ER background in most of the TPC.

~ 1.62 evts/t/y after discrimination

**MC: Expected Nuclear Recoil background**


<table>
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<th>Source</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Radiogenic</td>
<td>0.22</td>
</tr>
<tr>
<td>Muon-induced neutrons</td>
<td>&lt;0.01 (Muon Veto ON)</td>
</tr>
<tr>
<td>Neutrinos</td>
<td>0.23</td>
</tr>
</tbody>
</table>

~ 0.45 evts/t/y after Discrimination

**Total expected background (ER+NR) ~ 2 evts/t/y**

**Total expected for WIMP mass ~100 GeV (σ~ 10^{-47} cm^2) ~ 2-3 evts/1t/yr**
**Expected Sensitivity**

**Expected Sensitivity**

![Graph showing WIMP-nucleon cross section vs. WIMP mass](image)

- DAMA/Na
- CDMS-Si (2013)
- DAMA/I
- XENON10 (2013)
- SuperCDMS (2014)
- DarkSide-50 (2015)
- XENON100 (2016)
- PandaX-II (2016)
- LUX (2016)
- XENONnT (2019)

**XENON1T Sensitivity in 2 ty**

- Expected limit (90% CL)
- $\pm 1 \sigma$ expected
- $\pm 2 \sigma$ expected

**1.6 \times 10^{-47} \text{ cm}^2 @ 50 \text{ GeV WIMP}**

**Only need 20 days to reach LUX/PandaX sensitivity**
Conclusions

✧ XENON1T, the largest two phase Xenon TPC ever built, is starting operations

✧ The Detector is filled with 3.2 tonnes of Xenon

✧ The commissioning demonstrated that all the systems are behaving as expected.

✧ First studies are promising

✧ Now in "low-background" commissioning

✧ First DM data expected in fall 2016
The total mass of Xenon will be $> 7 \text{ t}$.

The systems developed for XENON1T can be used to operate XENONnT: Water Tank, Muon Veto, support structure, Cryogenics and Purification systems, LXe storage and recovery system.

The inner cryostat number of PMTs (~ 200 more) and TPC will be modified.
First look at Background

Background studies started

- Detector filled with LXe
- No Electric field applied
- No shielding
**Systems: Some Details**

**Purification**
- Continually clean Xe
- ~100 SLPM
- Parallel circuits for optimization and maintenance
- Custom xenon pump
  - Chart QDrive

**Cryogenics**
- Externally cool and liquefy Xe
- ~10 tons Xe @ 170K
- Redundant systems and LN₂ for safety

**Feedthrough Pipe**
- Liquid and gaseous Xe
- Cables
- Connections through water tank

**Distillation**
- Custom Kr filtration system
- \(Kr_{nat}/Xe \sim 10^{-14}\)
- Process Xe inventory in ~1 month

**Xe Storage ReStoX**
- Store up to 7.6 T tons
- Liquid or gas phase
- Safety recovery system

**Cryostat**
- Double walled SS vessel
- Houses TPC (for 1T and nT!)

All designed for XENON1T and XENONnT!