The Latest from XENON100 and XENON1T

On behalf of the XENON Collaboration
Detect two signals with photomultipliers:

- Prompt scintillation (S1)
- Ionization via proportional scintillation (S2)

3D Position Reconstruction
- XENON100:
  - $\delta z < 0.3 \text{ mm}$
  - $\delta r < 3 \text{ mm}$
- Recoil Discrimination

\[ \frac{S2}{S1}_{NR} < \frac{S2}{S1}_{ER} \]
The XENON100 Detector

- Located at LNGS
- 161 kg liquid xenon (62 kg sensitive volume)
- Active liquid xenon veto
- Careful material screening and selection
- 100X lower background than XENON10

E. Aprile et al. (XENON100), Phys.Rev.D83:082001, 2011
E. Aprile et al. (XENON100), Astroparticle Physics 35, 573 (2012).
Spin Independent Search

- Blind analysis based on 225 live days data
- Two candidate events in benchmark region
- BG Expectation:
  - NR: $0.17^{+0.12}_{-0.07}$
  - ER: $0.79 \pm 0.16$
  - Total: $1.0 \pm 0.2$
- Profile likelihood analysis performed
- Results inconsistent with dark matter signal
- Set upper limit on WIMP-nucleon SI cross section

$\sigma_{SI} < 2.0 \times 10^{-45} \text{ cm}^2$ for 50 GeV/c$^2$ WIMP
Spin Dependent Search

- Same 225 days data and event selection as SI search
- Look for spin dependent coupling
  - Odd Xe isotopes (unpaired neutron)

E. Aprile et al. (XENON100), Phys. Rev. D 88, 012006 (2013)

- Set limit on pure neutron and pure proton coupling
- Most sensitive limit on pure neutron coupling above 6 GeV/c^2
  \[ \sigma_n < 3.5 \times 10^{-40} \text{ cm}^2 \]
  for 45 GeV/c^2 WIMP
Axions and ALPs

- **Solar axions**
  - Created in sun's B field
  - Kinetic energy dominant
  - Signal in XENON100

- **Axion Like Particles (ALPs)**
  - Behave like axion but don't solve CP
  - Many extensions of SM
  - Good cold dark matter candidate
  - Mass energy dominant
  - Signal in XENON100
  - Look for Line

E. Aprile et al. (XENON100), Phys. Rev. D 90, 062009
Nuclear Recoil Response

- $L_{\text{eff}}$ and $Q_y$ determined by data MC matching in XENON100
- Data/MC in excellent agreement
- Absolute matching
- Independent measurement of $L_{\text{eff}}$ down to 3 keV
- Threshold of 3 pe means sensitivity to lowest energy recoils due to $E$ resolution (Poisson fluctuations of S1)

Low E YBe Calibration

- Maximum nuclear recoil energy of 4.5 keV\(_{nr}\)
- 3 pe threshold corresponds to 6.6 keV\(_{nr}\)
- Can only observe S1 signals above threshold due to upward fluctuations

We See These Recoils!

- Implies non-zero L\(_{\text{eff}}\) below threshold
- Detailed analysis underway
  - Will reduce uncertainty of low E response
  - More robust statement on low mass WIMP sensitivity
The Next Step: XENON1T

- 2.0 ton target (~1T fiducial)
- ~1m height X ~1m diameter
- ~10 m water shield

- Reduce background 100 X from XENON100
  → Goal: ~1 background event in 2 years

- Increase sensitivity by factor 100
Projected Sensitivity

**XENON1T sensitivity:**

- $\sigma_{SI} = 2 \times 10^{-47} \text{ cm}^2$ for 50 GeV/c$^2$ WIMP
- Probe majority of SUSY-favored phase space → Strong discovery potential

Example of discovery at $10^{-45} \text{ cm}^2$

Background Reduction

- Gamma suppression comes “for free”:
  - Self shielding of Xe

- Dominant backgrounds become:
  - Neutrons (spontaneous fission, α-n, and muon induced)
  - Internal betas ($^{85}$Kr, $^{222}$Rn daughters)

**How?**

- Reject muon induced neutrons with 10 m water shield
- Select materials with low $^{222}$Rn emanation
  - Screen all detector materials
  - Investigate construction techniques (eg clean welds)
  - Ultra-clean gas purification units (pumps, getters)
- Remove internal impurities
  - Remove $^{85}$Kr via cryogenic distillation
XENON1T: Reality
Scaling it up

<table>
<thead>
<tr>
<th>XENON100</th>
<th>XENON1T</th>
</tr>
</thead>
<tbody>
<tr>
<td>LXe Mass</td>
<td>161 kg</td>
</tr>
<tr>
<td>ER Background</td>
<td>$5 \times 10^{-3}$ dru</td>
</tr>
<tr>
<td>Kr Concentration</td>
<td>$(19 \pm 4)$ ppt</td>
</tr>
<tr>
<td>Rn Concentration</td>
<td>$\sim 65 \mu$Bq/kg</td>
</tr>
<tr>
<td>Charge drift</td>
<td>30 cm</td>
</tr>
<tr>
<td>Cathode HV</td>
<td>$-16$ kV</td>
</tr>
<tr>
<td>LXe Purification</td>
<td>Several Months</td>
</tr>
<tr>
<td>Cryogenics</td>
<td>$\sim 1$ year run</td>
</tr>
<tr>
<td>Storage/Recovery</td>
<td>GXe</td>
</tr>
</tbody>
</table>
Construction started 2013

With tape on the floor!
The Water Tank

- 10 m high
- 9.6m diameter
- Interior lined with 3M specular reflector foil
- 84 high QE 8” Hamamatsu PMTs R5912
- Muon induced neutron background < 0.01evt/yr
- Trigger efficiency > 99.5% for neutrons with muons in water tank, ~78% with muons outside
- Construction done in December 2013

E. Aprile et al. (XENON Collaboration), JINST 9, P11006 (2014)
Double-wall vacuum insulated cryostat
Made of selected low-activity stainless steel
Outer vessel: 2.4m high, 1.6m diameter
Inner vessel: ~2m high, 1.1m diameter
Contains 3.3 tons Lxe
Construction done september 2014
Design based on experience from previous detectors
- Two 200W pulse tube refrigerators for liquefaction
- Circulation at ~100slpm through getters and heat exchangers
- Interruption free maintenance
- Xenon storage and recovery vessel to hold 7 t gas
- Kr removal with cryogenic distillation column on site
- Construction complete!
- Commissioning underway, first xenon gas filled this spring!
Last step: The TPC

- Fiducial mass ~ 1 ton LXe
- 248 3'' PMTs Hamamatsu R11410-21, 36% avg QE, < 1mBq/PMT in U/Th
- Background 100 x lower than XENON100
- Custom low activity high voltage feedthrough
- Design finalized
- Construction and installation this summer

First Light This Year!
XENONnT = XENON1T + a larger TPC and inner cryostat for a total of 7 tons of xenon
Everything from the outer cryostat out unchanged
Aim: 20 ton-years exposure
Thanks!