XENON1T Cryogenics and Vacuum

Cameo Lance

REU via Columbia University
Located in LNGS, Italy
Summer 2015
Overview

- Dark Matter
- XENON1T
- Cryogenics
- Leak Test
- Portable Pumping Station (PPS)
- Other
Astronomical evidence

Step one in the search for dark matter: observe indirectly

Gravitational Lensing

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M33 rotation curve

Merging Galaxy Clusters

Dark Matter Project

Dark Matter 27%
Visible Matter 5%
Dark Energy 68%
The predicted sensitivity of XENON1T will be 100x lower than the current limit published for XENON100.
Located under 1,400m of rock to shield from
- Gamma Rays
- Cosmic Rays
- ~Muons
- ~Neutrons

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Detection Method

- Dual phase time projection chamber
- Measures Ionization and Scintillation
- Filled with liquid and gaseous xenon at ~ 170 K
A Leak Exists!

- Xenon was detected in the outer vessel with a residual gas analyzer (RGA)
Recuperation

- In order to reduce the loss of xenon
- Transferred xenon from cryostat into bottles on ground floor
- Used LN2 to create pressure differential to induce a flow of xenon
Characterize the Leak

- Leak monodirectional
- Leak began at a pressure of ~400mbar
- Cause: not enough torque on inner vessel bolts in cryostat

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\[
\begin{align*}
\text{Outer Pressure (bar)} & = 5.55 	imes 10^{-6} \\
\text{Inner Pressure (bar)} & = 0.1 ightarrow 0.8
\end{align*}
\]
Solution

Tighten the 54 bolts
From 65 Nm to 120 Nm
in increments

Access inner vessel
- maintain N2 purge
- remove floor
- lower outer vessel
- undress mylar

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Leak Rate Reduces

Inner Vessel Pressurization

Inner Vessel Bolt Torque
- $\tau = 120$ Nm
- $\tau = 65$ Nm
Tighten Again

- Performed load cell test
  - 30% less than torque wrench reads
- tightened in one motion
- Tightened via the head of the bolt
No More Leak!

Outer Pressure VS Inner Pressure

Outer Pressure [mbar]

8.05 x 10^-6

8.0

8.95

7.9

7.85

7.8

7.75

7.7

7.65

7.6

Inner Pressure [bar]

0

0.2

0.4

0.6

0.8

1

1.2

1.4

1.6

1.8

2

2.2

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PPS motivation

- PPS: Portable Pumping Station
- Needed for porcupine and leak testing
- Usable for other subsystems
Design

Convenient to store
Easy to maneuver

Designed using SolidWorks

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Other Tasks

- Constructed stainless steel pipes for Krypton Column
  - Orbital Welder
- Calculated Volume in Purification System
- Assembled and installed LN2 line to LN2 tower
- Simulated branching ratios of Be using geant4
Purification Volume

- Calculated volume in the inner vessel of the purification system

<table>
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<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
<th>I</th>
<th>J</th>
<th>K</th>
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<td>Component</td>
<td>Diameter (mm)</td>
<td>Radius (mm)</td>
<td>Length (mm)</td>
<td>Area (mm^2)</td>
<td>Volume (L)</td>
<td>Pressure (bar)</td>
<td>Temperature (K)</td>
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Installation of valves
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Changed cabling for Q-Drive

Anti-Bouyancy System
Learned

- Hardware
  - About cryogenics
  - Leak testing vacuum systems
  - How to use various tools (e.g. Orbital Welder, RGA, Load Cell)
- Software
  - SolidWorks
  - Programming (e.g. C++, Python)
  - ROOT
  - LaTeX
  - Spreadsheets
- Concepts
  - How photons work
  - What sound really is
- E un poco di Italiano
Conclusion

This summer let me

• In on the secret life of scientist
• Apply the information I have been learning for many years
• And appreciate that information
• Look forward to my life, as a scientist.
Thank You!

- NSF REU program
- Columbia University & Nevis Labs
- Elena Aprile
- John Parsons
- Guillaume Plante
- Patrick de Perio
- Everyone in XENON
Questions?