Xenon nT REU
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About me

• Student at Harvey Mudd College

• Interested in Dark Matter detection/signal isolation
• Wanted to learn many necessary considerations that go into the detector
• See a little bit of what it is like to work on such a large scale project
Introduction to Xenon

- Designed to detect dark matter
- Xe 1T just decommissioned
- Ramping up to start Xenon nT
  - 3->8.5 Tons of Xenon
  - New liquid phase xenon purification system
  - Neutron Veto
Main Projects

• Ensuring cold-test PMT’s work
  • 1” PMTs originally designed for Xenon 10

• Modelling Xenon Purification System
  • New liquid purification system for Xenon nT
Motivation/Background

- Particles are detected and identified by analyzing two signals
- Second signal from ionized electrons
- Two (of many) co-dependent factors influence resolution of this signal:
  - TPC electric field strength
  - Liquid xenon purity

Taken from Xe 1T paper
Cold Test

• Cold test in August
• Place electrodes in cryostat with xenon, cool everything down
• Test liquid purification system
• Apply high voltage to the cathode
  • See how high of a voltage we can apply without seeing any emission/hot spots
  • Need PMTs to find this emission
PMTs

- First task: determining if the old Xenon PMT’s take positive or negative high voltage

Photo-cathode

Anode
Test System

- Pulse Generator
- 30 ns delay
- Trigger Signal
- Light Tight Box
  - PMT
  - PMT Signal
- 900 V Power Supply
- Digitizer
- Computer
Configuring the equipment

- Current offset of high voltage module
- Trouble finding the signal with the digitizer
  - Unalterable latency in digitizer
  - Added a 30 ns delay on trigger signal relative to LED pulse
Ensuring all of the PMT’s work

• Once everything was configured, the process was fairly simple
• Lots of soldering help from Amanda
Complications

• PMT 6
  • Current increases by 8 uA at 160 V!

• Discharge
  • Boards that were previously working had started malfunctioning
  • Found discharge on the board at high voltages
  • At 900 V electric field ~ 2.3 kV/mm

• HV-supply
  • Earlier this week we realized the HV supply was having problems
  • Voltage value changed dramatically while running
  • After words, the peak amplitude on the oscilloscope changed significantly
Data analysis? Looking at gain

First week: no HV supply problems, 100 MS/s digitizer

Next week

Maybe a 1 GS/s digitizer will show the peak more clearly

2*10^6 electrons

High voltage supply problems

10*10^6 electrons

Changed the HV supply
PMT Conclusion

• 7 working PMT’s (enough for the cold test)
  • Additional PMT’s from columbia

• Analysis:
  • Will be finalized with new high voltage supply
  • Gain values are more reasonable again
Xenon Purification

- New liquid phase purification system for nT
- Project: Model the whole system
Introduction to Xenon Purification

• Electronegative impurities reduce WIMP resolution
  • Initial Impurities
  • Outgassing

• Necessary to reach a sufficient purity quickly: 2 ms electron lifetime

• Previous system
  • Gas phase purification only
  • Not sufficient for nT

• New Liquid system
  • Higher Purity faster

Previous study by Nobu based on 1T SR1
Simplified Purification System

New System for nT

Liquid phase filter

TPC

Purification method for 1T

Gas phase filter

Heat Exchanger

Evaporation

LXe out

GXe out

LXe out

LXe out

LXe return
Including Liquid and Gas Phase Xenon in the Model

- Exchange between phases in the TPC

- Two filtration systems
  - New liquid only system
    - Expected flow rate: 5 LPM
    - May not be achievable
  - Gas phase filtration system

- Previous outgassing data shows ~100 times larger outgassing rate into the gas phase xenon
  - Expected to be about 3 times Xe 1T outgassing rate
LXe Purification Modelling

\[
M_L \frac{dn_L}{dt} = -F_c \epsilon \nu n_L - F_L n_L + \Lambda_L + F_{G \rightarrow L} n_G P_{\text{cond}} - F_{L \rightarrow G} n_L P_{\text{evap}}
\]

\[
M_G \frac{dn_G}{dt} = -F_G n_G + \Lambda_G - F_{G \rightarrow L} n_G P_{\text{cond}} + F_{L \rightarrow G} n_L P_{\text{evap}}
\]

Time evolution of outgassing rate

\[
\Lambda(t) = \frac{\Lambda_0}{1 + t/t_{1/2}}
\]

\[
t_{1/2} = 180 \text{ days}
\]
Determining the significance of poorly-known Parameters

- Less well known parameters: Phase exchange rates, Evaporation and Condensation Probability
- These parameters were varied to determine their significance
- Example: Varying Evaporation Probability
Goals of project

- Desired Characteristics
  - 2 ms purity
  - Fast rise time

- Uncertain Parameters:
  - Liquid filter flow rate
  - Outgassing rate

Goal: Determine what flow and outgassing conditions allow us to achieve our goal
Ultimate Question: What is a sufficient flow rate for the liquid phase filter?

- Flow rate that satisfies requirements as a function of outgassing rate
- Requirements:
  - 2 ms electron lifetime
  - Rise time lower than a range of thresholds

- Flow rate determined algebraically
- Increased to meet rise time threshold
Effect of time dependence examined in the region of higher outgassing rates

- Similar plot made incorporating time dependence for higher outgassing rates
- Slightly more wiggle room for the flow rate

\[ \Lambda(t) = \frac{\Lambda_0}{1 + t/t_{1/2}} \]

\[ t_{1/2} = 180 \text{ days} \]
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