XENON1T Demonstrator

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Most of the matter in our universe is made of Dark Matter.

Dark Matter lies outside the scope of the Standard Model.

Weakly Interacting Massive Particles (WIMPS) are predicted in most Beyond-Standard-Model (BSM) theories (SUSY, KK, ...)

Their interaction is so weak that out of $10^{15}$ that pass through your body per day, only <10 interact.

How can we detect them in a lab?
Direct Detection of WIMPs

- The DM halo density is around $\rho \sim 0.3 \text{ GeV cm}^{-3}$

- WIMP flux on earth is about $10^5 \text{ cm}^{-2}\text{s}^{-1}$ (for 100 GeV WIMP). This flux is large enough to enable detection in the lab.

- Direct detection by their elastic collision with nuclei in ultra-low background detectors

- Spin Independent (SI) $\sigma \sim A^2$, SD~WIMP couples to nuclear spin $J_N$
Dark Matter Direct Detection

- Ionization
  - HPGe exp.
  - IGEX → GEDEON
  - GERDA
  - CoGeNT

- Scintillation
  - PICASSO
  - SIMPLE
  - COUPP

- WIMP
  - HEAT
  - CDMS I-II
  - superCDMS
  - EDELWEISS I-II

- Detector
  - CRESST -II
  - ROSEBUD

- WIMP
  - +time measurement

- Dark Matter Direct Detection
  - ZEPLIN I
  - CLEAN
  - DEAP
  - XMASS

- ZEPLIN II-III
  - XMASS II
  - LUX
  - XENON
  - WARP, ArDM
  - DarkSide

- DAMA / LIBRA
  - KIMS
The XENON Detector Concept

→ lots of information for each event
The XENON Program

XENON R&D
ongoing

XENON10
PRL100
PRL101
PRD 80
NIM A 601

XENON100
2008-2011
taking science data
first results: PRL105

XENON1T
1 ton fiducial
2.4 t total
@180K
2011-2015
The XENON1T collaboration
XENON sensitivity goal
The future: XENON1T

- 2.4 tons of liquid Xenon with a 1 ton fiducial volume
- 5 meter radius water shield instrumented with PMTs
- Approved to be built in Hall B in LNGS
The future: XENON1T
Highlights of technologies and concepts for XENON1T

- **XENON1T Demonstrator** for long drift and HV tests (Columbia and Rice)
- **Cryogenics system with heat exchanger high flow rate purification** (Columbia)
- Measured QE at low temperature of 3” Hamamatsu R1140 and R8520 with LT Bialkali PC (Columbia & Munster)
- Measured response of 3” QUPIDs in LXe (UCLA)
- Measured radioactivity of all above PMTs for XENON (Zurich)
- Measured low activity SS and Ti for XENON1T cryostat (Zurich)
- Designed a new system for storage of 3 ton Xe in gas and liquid phase (Subatech)
- Designing new Kr distillation column (Munster)
- Developed Atom Trap (Columbia) and Mass Spectrometry system (MPKI) for < 1ppt measurement of Kr/Xe
Challenges for 1 Meter Drift LXe TPC

- **Purification:**
  - High speed recirculation (2.4t purification must not take months...) **Cost: 11 Watt/slpm**, ~80% for latent heat
  - Long electron lifetime

- **High Voltage:**
  - Notoriously problematic
  - Feedthrough (Vacuum, size, radiopurity)
  - Meshes
  - PMTs/QUPIDs
XENON1T Demonstrator
Cooling: XENON100 cooling system

- Separating the cooling / circulation from the TPC, for the sake of low background
Cooling and heat exchange

Xe volume separated from the cooler

Heat exchanger

TPC

pump
What is wrong here?

Heater

Connection between cold finger and cooler
Gas system

½'' pipes for low resistance to flow

Large capacity pump by KNF – capable of flowing 200 slpm

Large capacity SAES getter – nominally capable of 75 slpm

Buffer volume

Heat exchanger
Fast recirculation

Pressure drop on the getter

Pressure drop on the Heat Exchanger

Violent pressure fluctuations, buffer volume required
Heat exchange efficiency

On a smaller system (28W cooler), up to 13 slpm Lxe – 96%!

With the same Heat exchanger, limited to 40 slpm – down to 85%

JINST 6 P03002 (2011)
Larger HE

High capacity (almost 4 litres) heat exchanger

Mounted correctly, ¼" pipes on the liquid side

Efficiency > 90% up to 70 slpm

Able to circulate ~90 slpm

higher flow expected after more tuning
Physics principle – liquid heat exchange

High P gas $\rightarrow$ High T(g-l) $\rightarrow$ Give heat

Low P gas $\rightarrow$ Low T(g-l) $\rightarrow$ Get heat
Movie
High voltage FT

Special Feed Through, based on design used for Xe100:
- 3/8'' tube, fits on a mini CF or CF40
- Low radioactivity
- Leak tight at operation conditions
- Tested with a grid in Lxe up to 60kV

Dedicated test setup at Columbia/Rice
TPC

TPC and vacuum jacket designed to have a net of 1m drift

Testing both 3" Hamamatsu PMT and QUPID

Being manufactured, will be ready in a few weeks.
Summary

- The first phase of the XENON1T Demonstrator has been completed.
- High circulation rate up to 90 SLPM has been achieved. Higher rate expected in the future.
- Low radioactivity HV feed-through tested with cathode mesh in LXe up to 60 KV.
- Two-phase TPC with drift gap up to 1 meter is being manufactured.
- Both 3" PMTs and QUIPIDs will be tested in this TPC.