

High Voltage Delivery in LUX-ZEPLIN

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on behalf of the LZ Collaboration

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LUX-ZEPLIN (LZ)

Next generation Dark Matter search at Sanford Lab (Homestake, USA)

WIMP Target: 7 tonne LXe

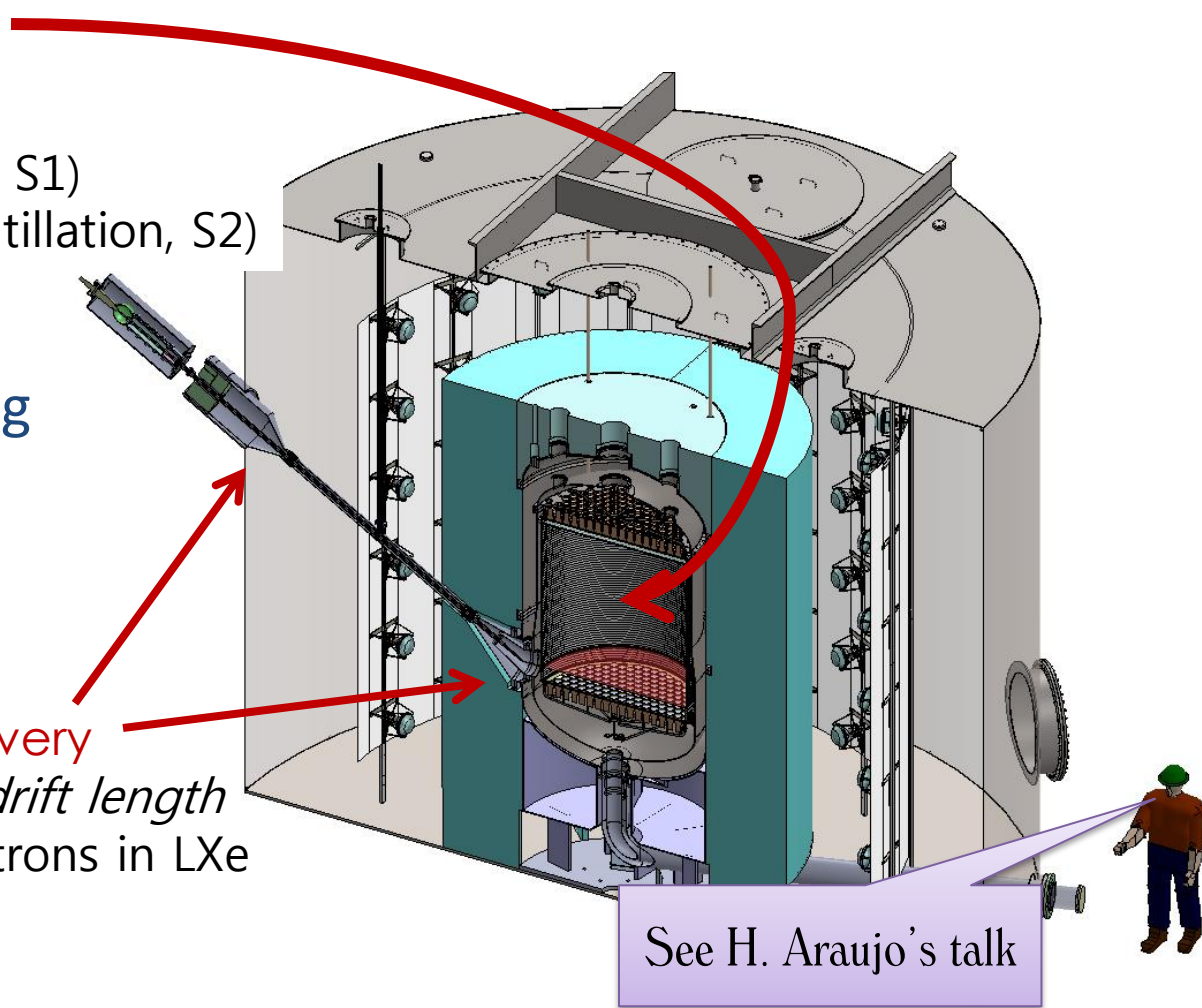
Double-phase TPC, reading

- *Light* (primary scintillation, S1)
- *Charge* (via secondary scintillation, S2)

target size ↔ self-shielding

- **Dominant background**
(in 6-tonne fiducial):
astrophysical neutrinos.

Cathode HV delivery
1.5 m maximum *drift length*
for ionization electrons in LXe



Cathode HV (≥ 100 kV) is a key parameter with direct impact on detector performance (**electron/nuclear recoil discrimination**)

Testing actual delivery of HV into chamber

Including large scale system test (Yale, SLAC)

- Engineering solutions on: feedthroughs, cable, connections, wire grids, etc.

Study of associated phenomena inside liquid xenon (wires)

Complementary set-ups (LLNL/LBNL, IC) for exploration of the physics.

- Breakdown mechanisms
 - Phenomena limiting operation and performance
- Inform engineering solutions and define procedures.

Dedicated *wire* test chamber at Imperial College

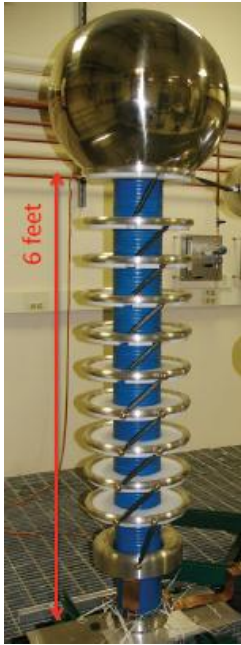
HV Feedthroughs.

All subsystems *designed* for -200 kV cathode voltage to ensure -100 kV *operational* voltage

3 different approaches under development:

1) Warm FT (Yale)

Gaseous Xe → Air



- Already 200 kV tested in G/LAr
- Further away from detector → lower radioactivity constrains
- Seals at room temperature

2) Cold FT (UCL)

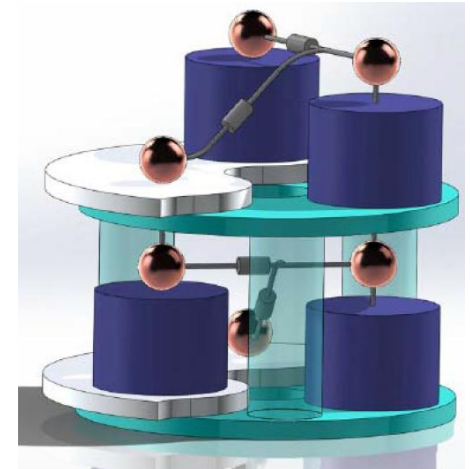
Liquid Xe → Vacuum



- Xe circulation not affected.
- Lower outgassing and contamination concerns.

3) Cockcroft-Walton generator (Yale)

In Liquid Xe



- Splits sealing and high voltage challenges.

R & D on High Electric Fields on Liquid Noble Gases

The CONTEXT

Indication of **unidentified physics processes** in most of the experiments and prototypes when increasing HV in liquid argon and xenon. Spontaneous **emission** and even **breakdown** occurring well before expected from theory (e.g. electroluminescence threshold ~ 400 kV/cm).

Diverse hypotheses suggested (from practical, mundane problems to noble liquid dynamics). Complex parameter space.

Concerns Dark Matter, Double Beta Decay and Neutrino communities:

Fermilab Workshop, Nov 2013 –

High Voltage in Noble Liquids for High Energy Physics [arXiv:1403.3613](https://arxiv.org/abs/1403.3613)


In LZ (wires) \rightarrow **practical limit** for a maximum allowable field for stable operation on metal surfaces immersed in LXe $\sim 50\text{-}60$ kV/cm

\rightarrow Impact **on detector design and performance**

- *discrimination*
- *threshold*

R & D on High Electric Fields on Liquid Xenon

AIM and REQUIREMENTS of LZ R&D programme

- *Deliver* solutions and procedures for LZ engineering.
- 
- *Understand* the HV breakdown mechanisms and previous high field phenomena (involving processes at microscopic level).
 - Development of a **xenon double-phase TPC**
 - with a **single wire** working as **cathode** sample.
 - with **single electron sensitivity**.

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→ Development of a **xenon double-phase TPC**

- with a **single wire** working as **cathode** as sample.
- with **single electron sensitivity**.

Convenient **Geometry**:
high Efield at wire surface
with modest HV

Study **single-e emission**

(often observed
prior to breakdown)

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➤ Ultrahigh purity ↔ Gas system

➤ Fast and high resolution DAQ + Analysis

➤ Slow Control

ZEPLIN-III



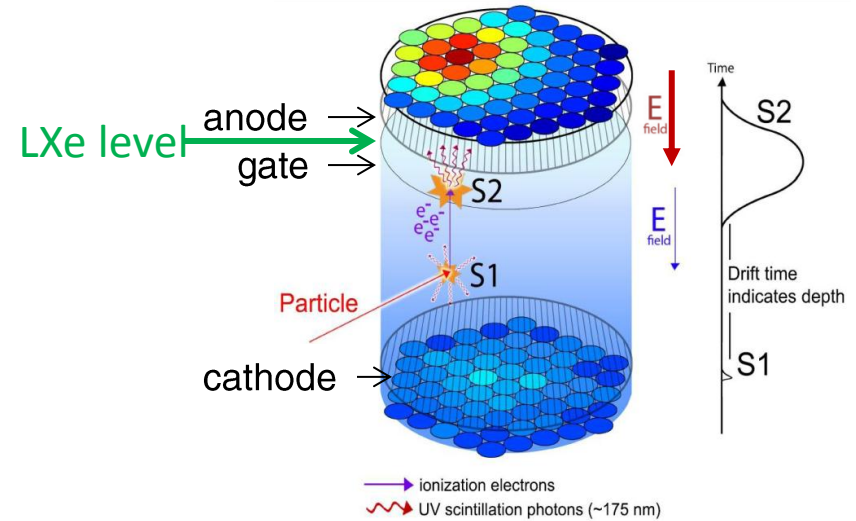
ZEPLIN-III Gas System.
Recommissioned at Imperial College

LUX-ZEPLIN R & D on High Electric Fields on Liquid Noble Gases

AIM and REQUIREMENTS: Two-phase Xenon emission detector

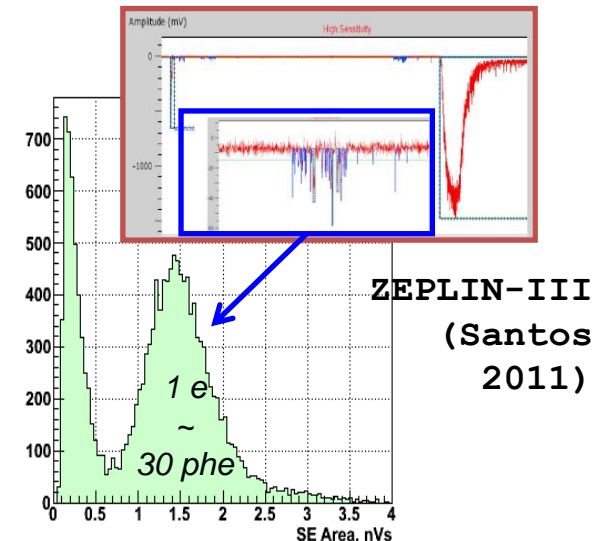
Scintillation & ionisation both measured via optical signatures

- Absolute z position from S1-S2 time;
- **Discrimination** from S2/S1 ratio
 E_{field} (cathode-gate)
improves discrimination



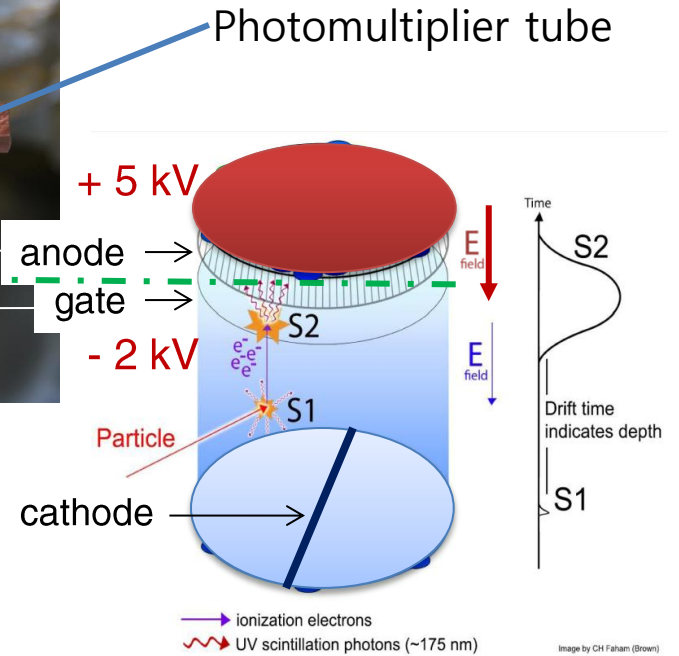
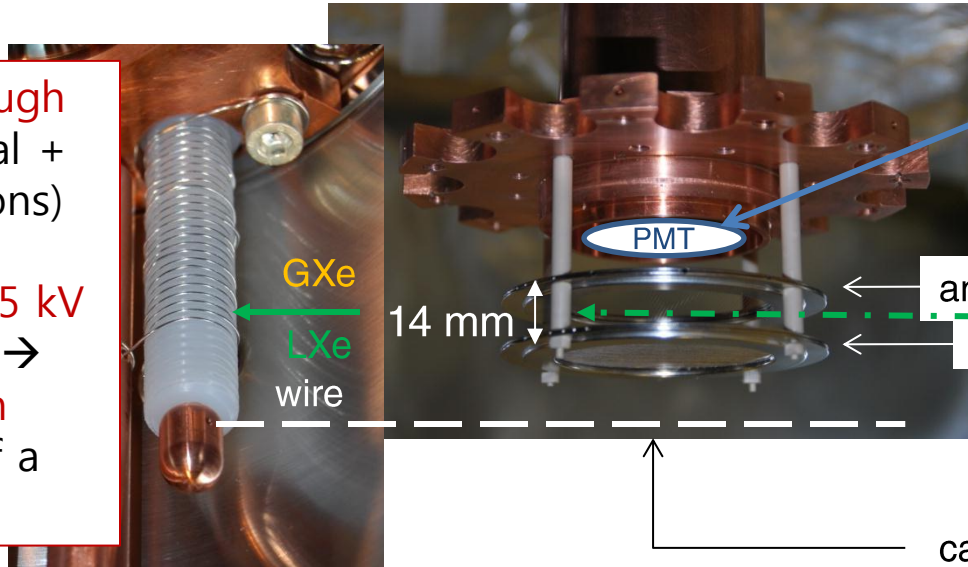
- Single-electron sensitivity from *cathode* emissions

- ultraclean Xenon
- few-photons sensitivity



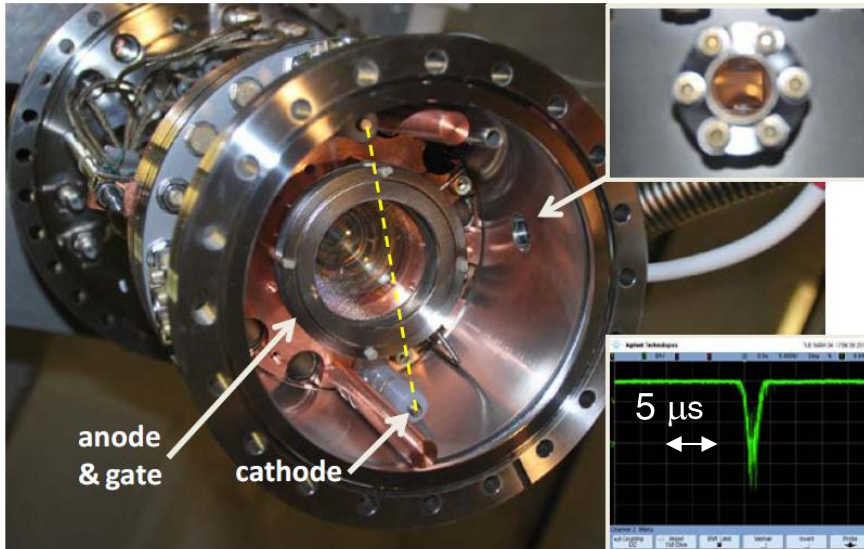
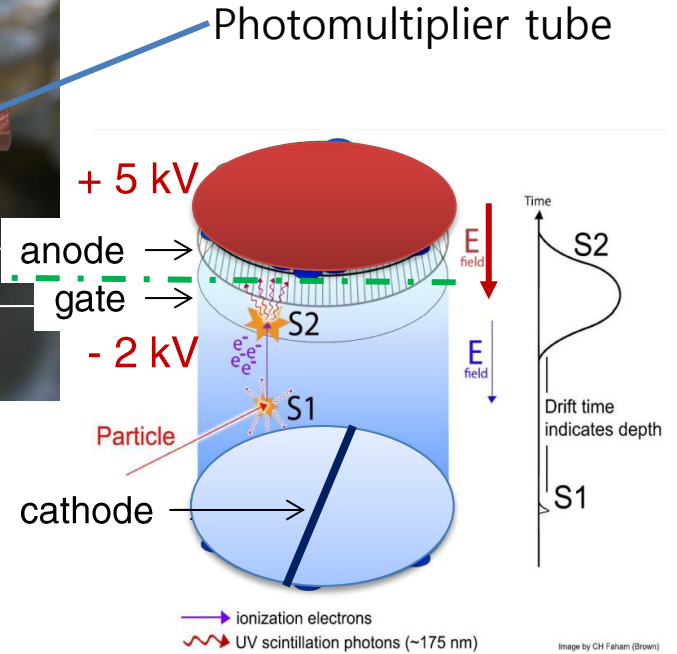
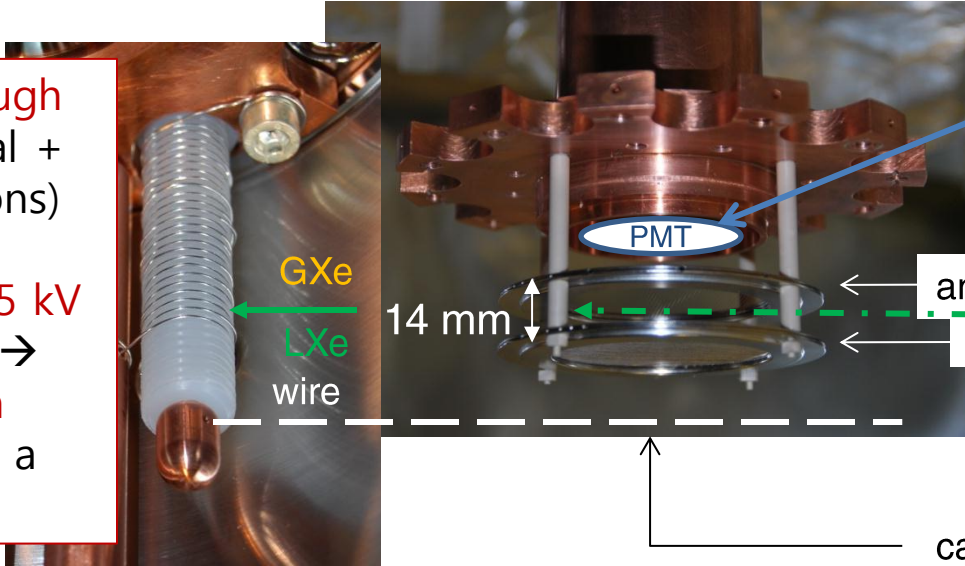
HV feedthrough
(commercial +
modifications)

Tested to -9.5 kV
in Liquid Xe \rightarrow
 ~ 250 kV/cm
@ surface of a
 $100 \mu\text{m}$ wire



HV feedthrough
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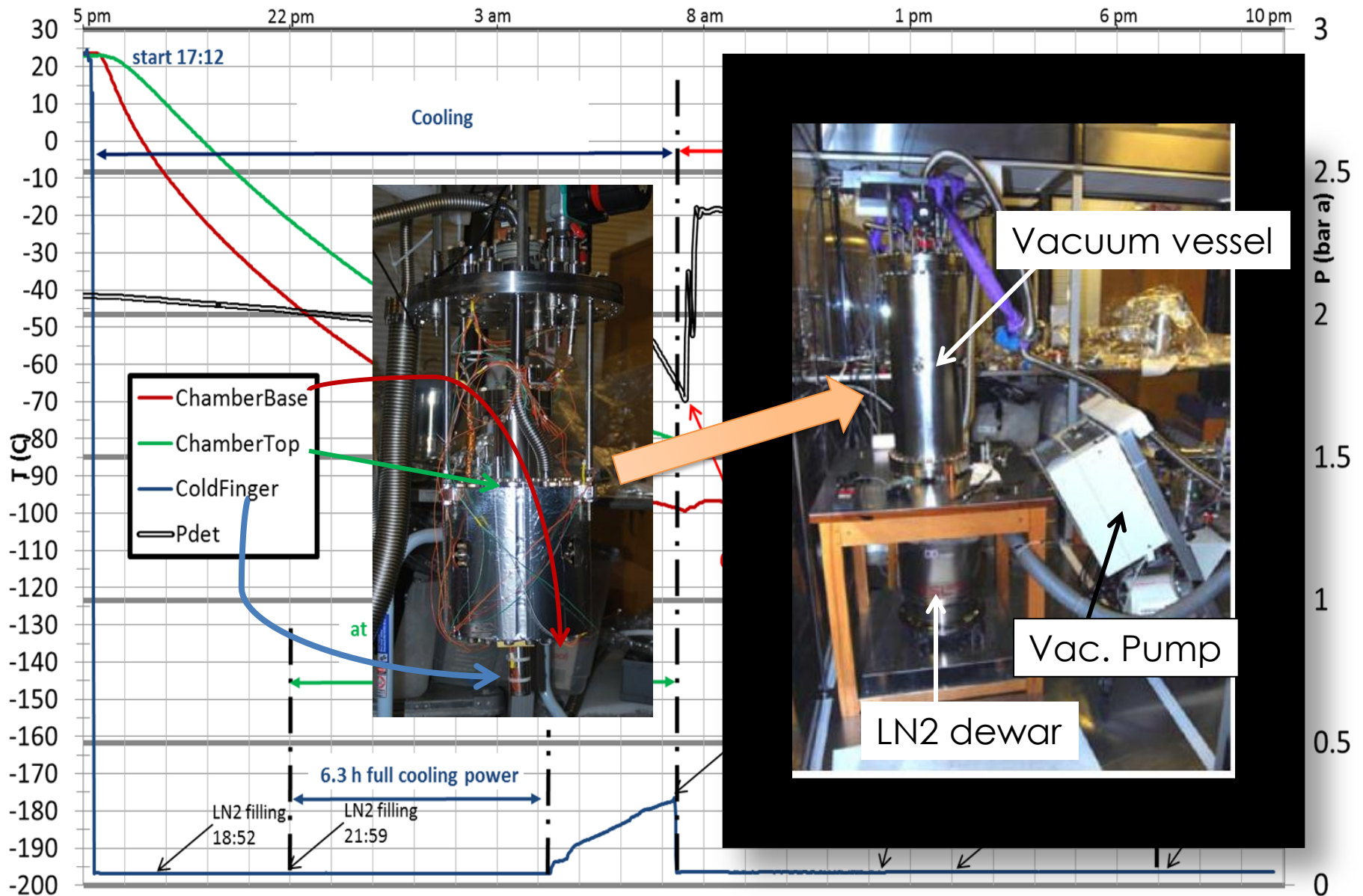


✓ Two-phase operation achieved;
first wire test successful (Mar 2014)

✓ Starting R&D programme:

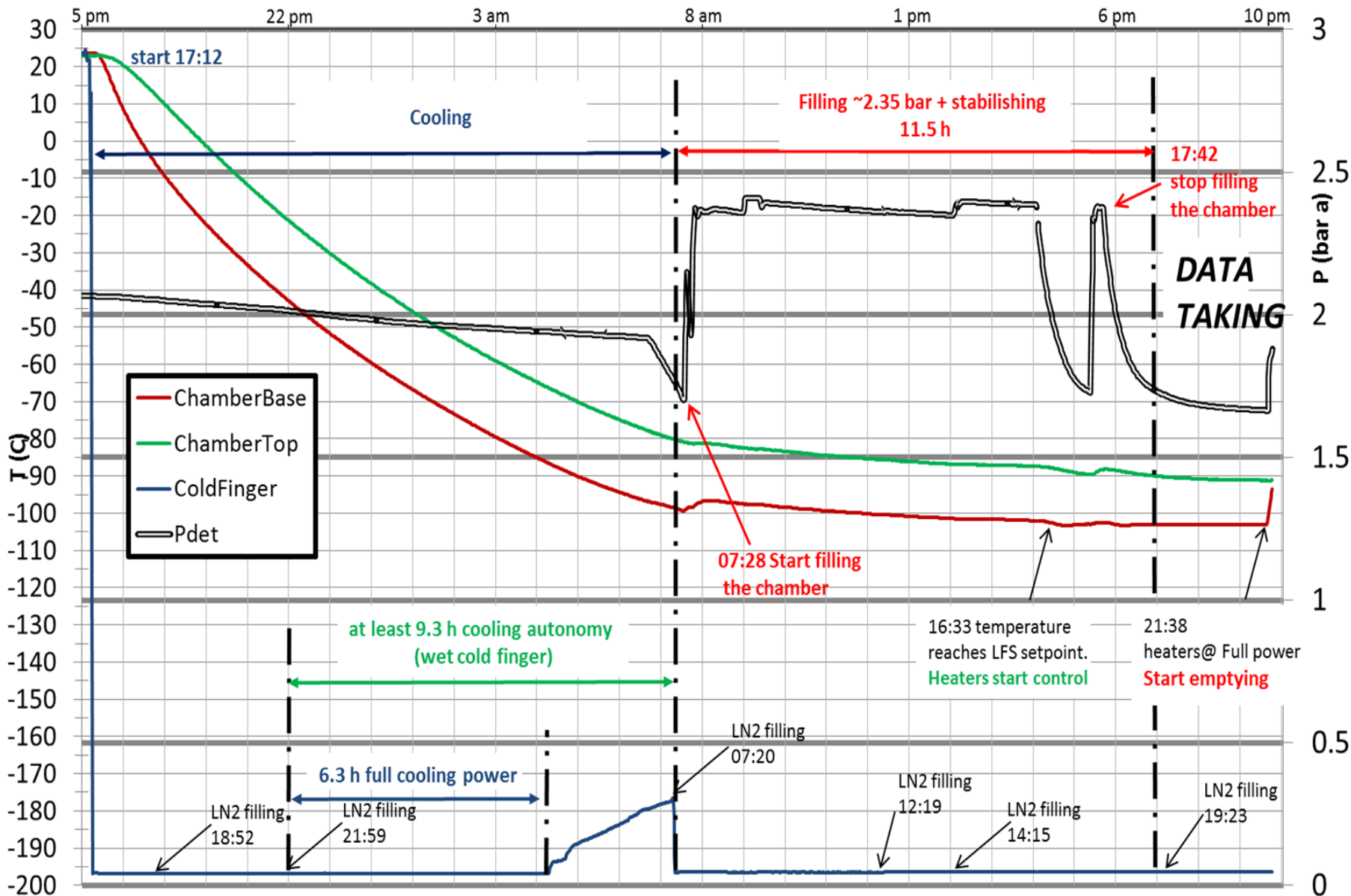
- Different wire materials, diameters, finishes, conditioning...
- Different environmental conditions: purity, etc
- Other tests. **LZ sensors**.

See
P. Scovell's
talk



Imperial College Test Chamber: typical Run

Run #8 (28/04/2014)

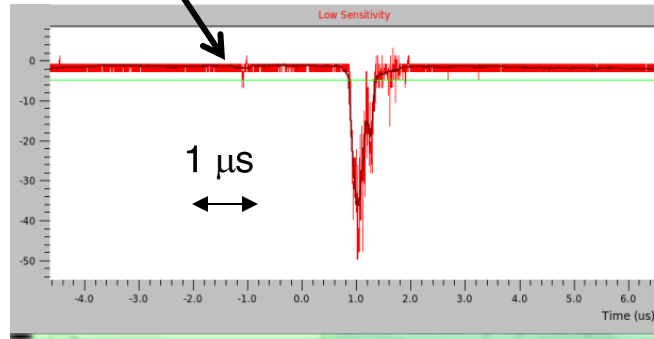


Imperial College Test Chamber: First data from wire test.

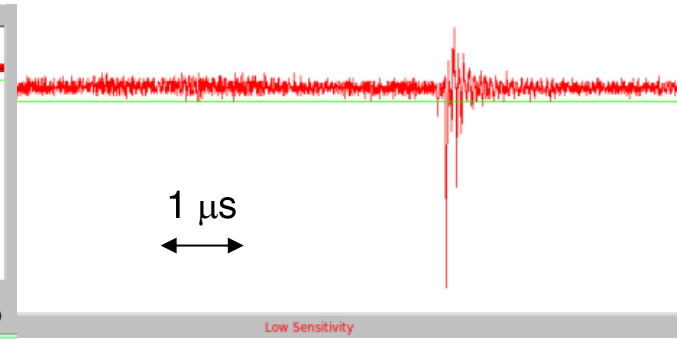
Run #8 (28/04/2014)

- ✓ Stable operation achieved
- ✓ S1 and S2 signals observed
- ✓ Single electrons recorded

S1 – S2 operation



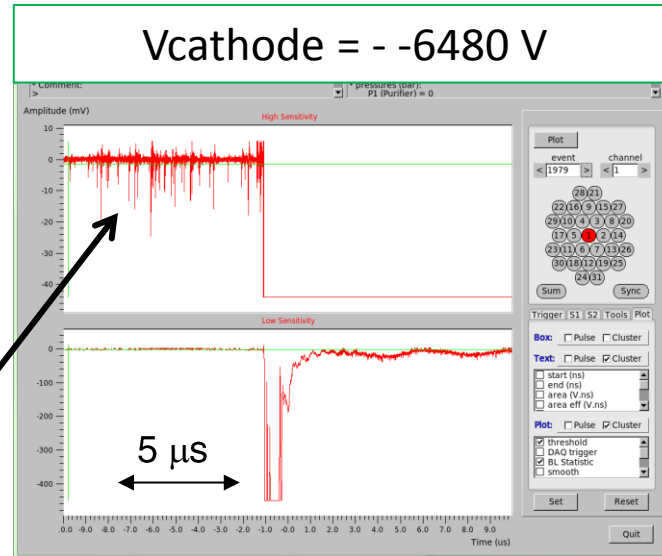
Single e- cluster (~4 phe/e)



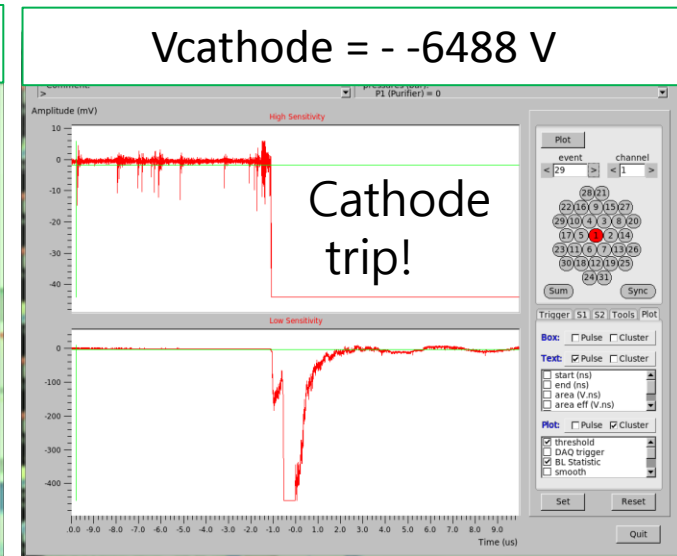
Events recorded while ramping up the voltage to the cathode wire (8 V/s)

- ✓ Wire measurement viable
- ✓ First phenomena prior to breakdown recorded:
emission of e-'s and photons from the wire.

V_{cathode} = - -6480 V



V_{cathode} = - -6488 V



Conclusions

As a much larger version of LUX and ZEPLIN, LZ requires very high voltage on the cathode (100 kV) to maximize the background rejection.

HV delivery is a serious challenge, LZ is treating it very seriously.

Understanding of phenomenology which arises on metal surfaces immersed in liquid xenon around 50 kV/cm is essential to optimize electrode grids.

In addition to other efforts undertaken by the LZ collaboration, a double-phase chamber with single electron sensitivity is already operational at Imperial College to test wires as cathode electrodes.