WIMP SEARCHES WITH LIQUID XENON: LUX AND LZ

Henrique Araújo
Imperial College London

IOP HEPP/APP MEETING, LIVERPOOL, APRIL 2013
ZEPLIN → LUX → LUX-ZEPLIN (LZ)

• UK-led ZEPLIN programme at Boulby completed (2001-2011)
  – Pioneering xenon technology, world class results from 3 experiments

• MOU between ZEPLIN-III and LUX groups signed in 2008

• LUX tested on the surface at Sanford Lab (Homestake), now including UK

• Underground commissioning under way, first physics in 2013

• LZ project following ‘G2 down-selection’ process in the US (and similar in UK)
  – One of 4 WIMP experiments selected by DOE to progress to R&D/Design
  – Coordinated proposals to DOE/NSF – and hopefully STFC – in late 2013
  – Construction planned to start late 2014, commissioning from 2016/7
COLLABORATING INSTITUTES (US-UK-PT)

ZEPLIN-III

= LUX + University of Alabama ▲ Daresbury Laboratory ▲ Rutherford Appleton Laboratory ▲ SLAC National Accelerator Laboratory ▲ University of Wisconsin

Brown University ▲ University of California, Berkeley ▲ University of California, Davis ▲ University of California, Santa Barbara ▲ Case Western Reserve University ▲ Imperial College London ▲ Edinburgh University ▲ Imperial College London ▲ Lawrence Berkeley National Laboratory ▲ Lawrence Livermore National Laboratory ▲ LIP-Coimbra, Portugal ▲ University of Maryland ▲ University of Rochester ▲ South Dakota School of Mines & Technology ▲ University of South Dakota ▲ Texas A&M University ▲ University College London ▲ Yale University
TWO-PHASE XENON DETECTORS

• S1: LXe is an excellent scintillator
  – Density: 3 g/cm³
  – Light yield: >60 ph/keV (0 field)
  – Scintillation light: 178 nm (VUV)
  – Nuclear recoil threshold ∼5-10 keV

• S2: Even better ionisation detector
  – S1+S2 allows mm vertex reconstruction
  – Sensitive to single ionisation electrons
  – Nuclear recoil threshold ∼1 keV

• And a great WIMP target too
  – Scalar WIMP-nucleon scattering rate dR/dE∼A²
  – Odd-neutron isotopes (¹²⁹Xe, ¹³¹Xe) enable spin-dependent sensitivity
  – Excellent ionisation threshold: ‘light WIMP’ searches using S2 only
  – No intrinsic backgrounds (⁸⁵Kr can be removed, low rate from ¹³⁶Xe 2νββ)
ENGINEERING RUN IN SURFACE LAB

- Operation in purpose-build water tank
- Demonstrated performance of most sub-systems
- Excellent light yield: 2.5x that of XENON100
- 3D position reconstruction: mm resolution (x,y)

STATUS

- Successful move u/g
- Installed in water tank
- All systems commissioned
- Xenon gas run
- Condensing & purification
- Calibration
- Short 60-day run in 2013
- 300-day run by 2015

LUX detector in shielding water tank, 1.5 km underground at Sanford Lab (Homestake)
LUX-ZEPLIN (LZ)

Next-generation LXe experiment building on LUX and ZEPLIN programmes

• **Route to detection & study: a progressive programme**
  – UK-led ZEPLIN programme pioneered liquid xenon for WIMP searches
  – LUX (now with UK) about to turn on – expect leading sensitivity in 2013
  – LZ could discover at $10^{-11}$ pb or exclude at $10^{-12}$ pb with 3 year run

• **Experimental approach: a low risk and aggressive programme**
  – Internal bk-free strategy (self-shielding, modest discrimination assumed)
  – Two-phase Xe technology: high readiness level (ZEPLIN, XENON, LUX)
  – Team with huge track record in DM searches
  – Much infrastructure inherited from LUX350

• **LXe provides exciting physics for light & heavy WIMPs (GeV-TeV)**
  – Since we do not yet know what BSM physics looks like!
SANFORD LAB, DAVIS COMPLEX (4850-ft)
LZ INFRASTRUCTURE

- 7 tonne LXe TPC (~9t total LXe)
- Only 20-fold scale-up from LUX
- But >100x increase in sensitivity
- Layered veto strategy
  - Instrumented LXe Skin detector
  - Liquid scintillator Veto detector
  - Instrumented water shield (same as LUX)
**IMPORTANT LZ BACKGROUNDS**

- **Internal radioactivity neutrons, gamma-rays:** sub-dominant in >6-tonne fiducial
  - Self-shielding and accurate 3D position reconstruction are extremely effective
- **Intrinsic electron backgrounds:** controlled with modest discrimination (99.5%)
  - $^{85}$Kr: require $\sim$0.02 ppt Kr, but could live with $\sim$0.2 ppt (best LUX production batch)
  - Radon: require 0.6 mBq ($^{214}$Pb) in full active volume (cf. $\sim$μBq in Borexino, SNO)
  - $2\nu\beta\beta$ decay from $^{136}$Xe dominates only above $\sim$20 keVee (signal acceptance <10 keVee)
DOMINANT LZ BACKGROUNDS

- **Solar pp ν-e elastic scattering is dominant electron recoil background**
  - Requires 99.5% discrimination (achieved in XENON10; ZEPLIN-III reached 99.99% at high field)

- **Coherent neutrino-nucleus scattering is dominant nuclear recoil background**
  - From $^8$B solar neutrinos: significant number of events, but ~0 above 5 keVr
  - Small background from Atmospheric and Diffuse Supernova neutrinos (<0.5 evts in ROI)

- **LZ will push WIMP sensitivity down to the astrophysical neutrino window**
CONCLUSION

Here lie many other experiments (and theories) going back 25 years!

- **ZEPLIN-III, CDMS-II, EDELWEISS-II**
  Technology development
  Competitive experiments at 10 kg scale

- **XENON100 – present world’s best**
  62 kg active two-phase xenon

- **LUX**
  300 kg fully active LXe, 370 kg total
  Operations underway, through to 2015

- **LZ**
  7 tonnes fully active, 9 tonnes total
  Start 2017
  To boldly go where nobody’s been... (and faster!)