

## Direct search for WIMP Dark Matter particles with the LUX-ZEPLIN (LZ) detector







Kirill Pushkin University of Michigan on behalf of the LZ collaboration

14<sup>th</sup> Pisa meeting on Advanced Detectors, May 27 – June 2, 2018





### The LZ collaboration April, 2018

(250 scientists, engineers and technicians; 37 institutions)





## LZ = LUX + ZEPLIN

#### ZEPLIN-III (UK, Boulby)



LUX (USA, SURF)



ZEPLIN pioneered WIMP-search with two-phase Xe 3.9×10<sup>-44</sup> cm<sup>2</sup>

6 kg fiducial volume (FV)

LZ 5,600 kg FV



 $1.1 \times 10^{-46} \text{ cm}^2$ at 50 GeV/c<sup>2</sup> (decommissioned in early 2017)

> Scale-up using demonstrated technology and experience for low-risk but aggressive program:

- Very low internal background strategy
- Infrastructure inherited from LUX
- LZ expected sensitivity: 1.6×10<sup>-48</sup> cm<sup>2</sup> in 1000 days

D. Akerib et al., "Projected WIMP sensitivity of the LUX-ZEPLIN (LZ) dark matter experiment", <sub>3</sub> arXiv:1802.06039v1 [astro-ph.IM]



## Sanford Underground Research Facility (Lead, South Dakota)

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MAJORAMA DEMONSTRATOR Neutrinoless double-beta decay Large Underground Xenon experiment

· Experiment Hall

Proposed Third generation dars matter experiment and 1 T neutrinoless double-bels decay experiment

Proposed Second generation dark matter Proposed Deep Underground Neutrino Experiment at the Long Baseline Neutrino Facisty

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Ross Campus

MALCRIMA DEscusmence Electronoming laboratory

Low Background Counting

CASPAR

BHSU Underground Campus

Compact Accelerator System for

Performing Astrophysical Pe



# Why LXe is suitable for Dark Matter search

## **Properties of Xenon**

54

131.30

5.894 g/L

161.4 K

165.1 K

161.405 K

Atomic Number (Z):
Mass number (A):
Number of electrons
per energy level:
Density STP:
Melting point:
Boiling point:
Triple point:

Xenon Noble gas Symbol Neutrons Xe Atomic number 2, 8, 18, 18, 8 54 108 54

- Dense liquid (3 g/cm<sup>3</sup>) for a massive WIMP target at modest cost (~2000 USD/kg) and scale.
- No intrinsic radioactivity other than <sup>85</sup>Kr and <sup>222</sup>Rn which both can be significantly removed using certain techniques (cryogenic distillation and radon reduction using gas chromatography).
- High sensitivity to spin-independent (SI) WIMP interactions due to its high atomic mass (acts coherently on the entire nucleus and scales as  $A^2$ ).
- For spin-dependent coupling, the cross-section depends on the nuclear spin factor. Does not scale with nuclear size (<sup>129</sup>Xe and <sup>131</sup>Xe). 5



# Two phase time-projection chamber





# LZ (LUX-ZEPLIN)

- LXe TPC: 50 times larger than LUX
- 1.6 km underground (4300 m.w.e.), SURF, Davis Campus
- Underground installation will start in fall 2018
- Physics data taking will start in 2020

LZ Total mass: 10 T WIMP active mass: 7 T WIMP fiducial mass: 5.6 T





# **Engineering model of the LZ detector**

- 494 Hamamatsu PMTs, R11410-22, 3" (low radioactive)
- TPC walls are covered with highly VUV light reflective PTFE
- Nominal cathode operating voltage ≈50 kV, E≈310 V/cm
- ~2 T of LXe in the skin veto region (93 Hamamatsu, R8520 PMTs and further 38 Hamamatsu R8778 PMTs)
- The second veto system contains liquid scintillator – Gadolinium (17.3 T) to tag neutrons.
- 120 Hamamatsu R5912 PMTs mounted in water tank





# **Radioactive background strategy**

#### Xenon purification from <sup>85</sup>Kr and <sup>39</sup>Ar

- Distillation system at SLAC based on LUX R&D
- Final <sup>84</sup>Kr/Xe ~ 0.015 ppt (g/g)

#### Extensive radioactive assay of detector materials

- Gamma screening with inductively coupled plasma mass-spectrometry (ICP-MS), neutron activation analysis (NAA)
- Comprehensive radon emanation measurements

#### Strict surface cleanliness protocols

- Detector assembly in <sup>222</sup>Rn reduced clean rooms
- Dust control, < 500 ng/cm<sup>2</sup> on all LXe wetted surfaces
- Rn-daughters plate on TPC walls <0.5 mBq/m<sup>2</sup>

## <sup>222</sup>Rn reduction system for LZ (designed and constructed at the University of Michigan)



Vacuum-jacketed cryostat with 11 kg of HNO<sub>3</sub> etched Saratech adsorbent

#### <sup>222</sup>Rn emanation from some charcoals (the list is not complete, read the article)

- Carboact: (0.23±0.19) mBq/kg
- Regular Saratech: (1.71±0.20) mBq/kg
- HNO<sub>3</sub> etched Saratech: (0.51±0.09) mBq/kg



Total <sup>222</sup>Rn concentration reduction output from the LZ detector vs mass of adsorbent (Xe flow rate 0.5 SLPM)

K. Pushkin et al., "Study of radon reduction in gases for rare event search experiments", 10 submitted to NIM A and arXiv:1805.11306v1 [physics.ins-det].



## **Veto system performance**

- WIMP-like nuclear recoil backgrounds in 6-30 keV region of interest
- Before and after application of outer detector plus skin veto



#### **Before veto**

After veto



# **Projected background rates**

- Counts/kg/day/keV in 5.6 ton fiducial volume
- Signal scatter events with no veto signal





# Counts/1000 days: WIMP search region-of-interest (ROI)

LZ 1000 day exposure; Counts for a 40 GeV/c<sup>2</sup> WIMP ROI

Background Source	ERs	NRs
Detector Components	9	0.07
Dispersed Radionuclides — Rn, Kr, Ar	816	
Laboratory and Cosmogenics	5	0.06
Surface Contamination and Dust	40	0.39
Physics Backgrounds — 2β decay, neutrinos*	322	0.51

Total sum of ER and NR with 99.5% ER discrimination and 50% NR efficiency: 6.49 events



## Projected LZ sensitivity, spin-independent, (5.6 ton FV, 1000 live-days)





## LZ schedule

- Critical decision, step 1 (CD1) Review March 2015
- CD2 Review April 2016
- CD3 Review February 2017 construction can start in earnest
- Cryostat fabrication has recently been completed
- PMT array assembly began in March of 2018
- Xenon handling installation and commissioning starts this fall
- TPC installation will start in Spring-Summer of 2019
- Xe liquefaction will start in winter of 2019
- First physics data are expected in Spring of 2020





- The LZ detector will be the largest dual-phase Xe detector in the world with an active mass of 7 tons optimized for a potential discovery of WIMPs.
- The detector's components are carefully selected and meticulously assayed for the presence of radioactive background.
- The active veto system will help to suppress NR background.
- The LZ detector will have an order of magnitude sensitivity improvement compared to the currently running LXe experiments.
- The underground installation will begin this fall and data taking will start in 2020.



## **Backups**

## LZ sensitivity vs <sup>222</sup>Rn level









