AUGUST 7-11 COLUMBUS, OHIO

TeVPA 2017

Center for Cosmology and AstroParticle Physics
The Ohio State University

The Next Generation Dark Matter Project

LUX-ZEPLIN

Matthew Szydagis, on behalf of the LZ Collaboration

(a merger of 2 collaborations, separate from LUX)

UNIVERSITY AT ALBANY
State University of New York

THE OHIO STATE UNIVERSITY

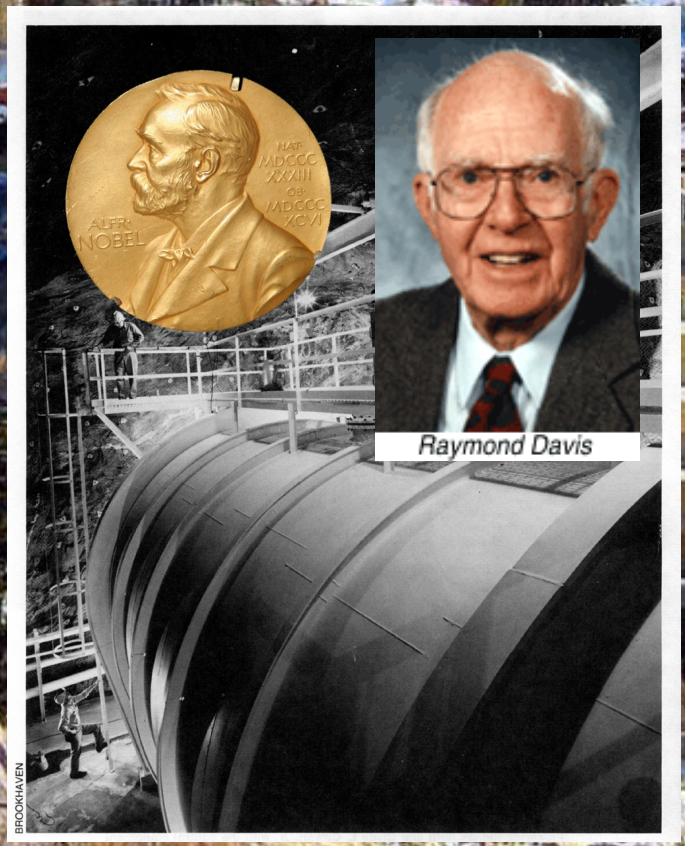
TeVPA OSU August 8, 2017

adapted from slides by M.E. Monzani, SLAC

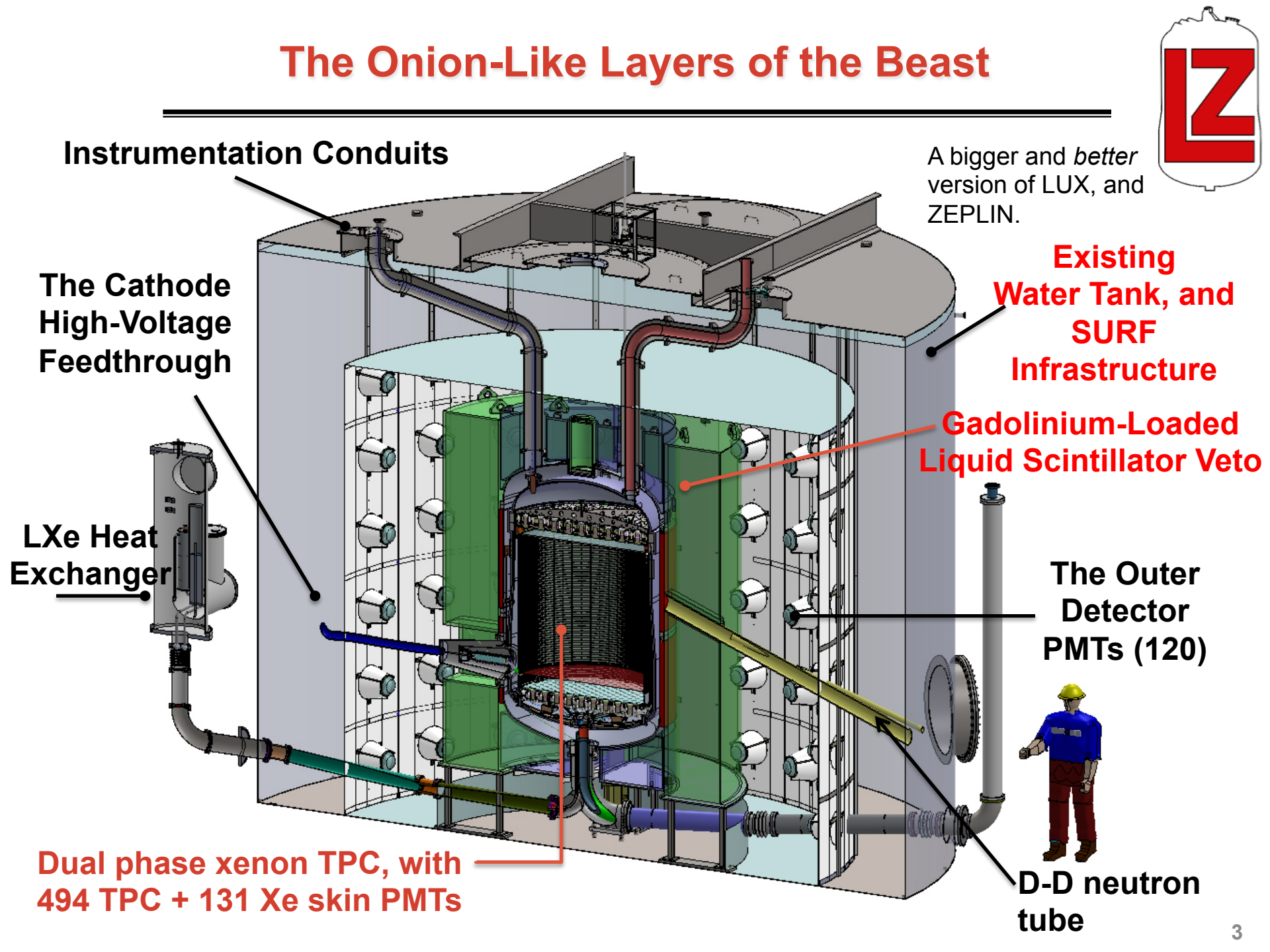
Sanford Underground Research Facility SURF

4,850 feet below Lead, SD: the former site of the Homestake gold mine

LZ, like LUX, will be installed in the Davis Cavern, once home to the Nobel prize-winning Ray Davis solar neutrino experiment

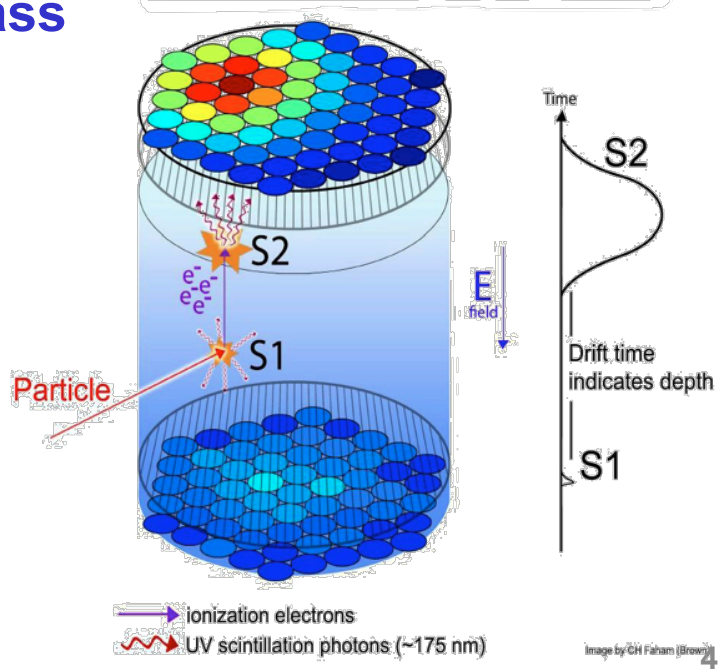


The Onion-Like Layers of the Beast



A Big Liquid Noble Time Projection Chamber

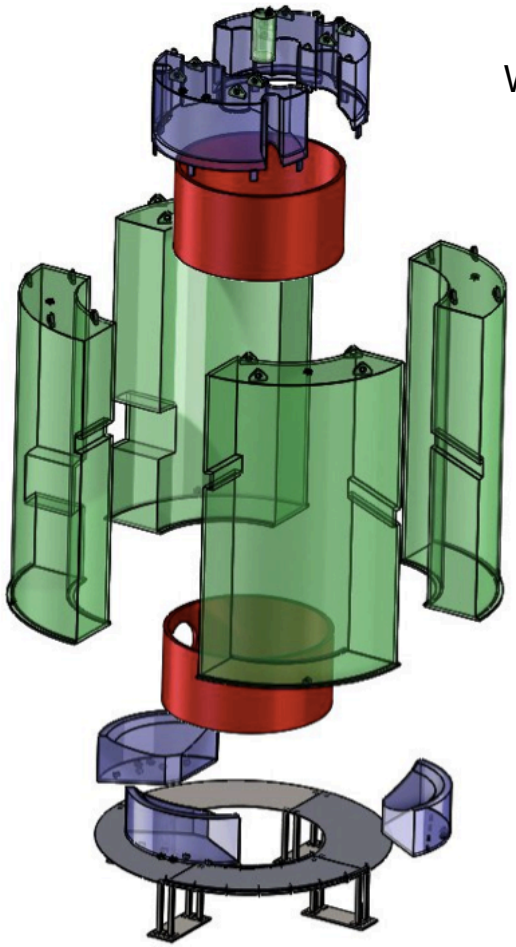
- 10 tons, to find WIMP nuclear recoil (NR)
  - 7 tons in the active volume (drift E-field)
- 5.6 ton total fiducial mass nominally
  - Thanks to unique *triple* veto system
- Spin-independent WIMP search sensitivity goal of <= 2.3 x 10^-48 cm^2 interaction cross-section for a mass-energy of 40 GeV
  - Clip the neutrino "shoulder" at low mass
- Turning on by 2020, with 1,000 initial live-days: get within order mag. high-m ν floor
- 6 keVnr threshold with at least 99.5% discrimination are baseline assumptions
  - Threshold means energy at which efficiency (sigmoid-like) is 50%
  - Electron recoil (ER) leakage of 0.5% below NR band Gaussian centroid



Discovery Machine

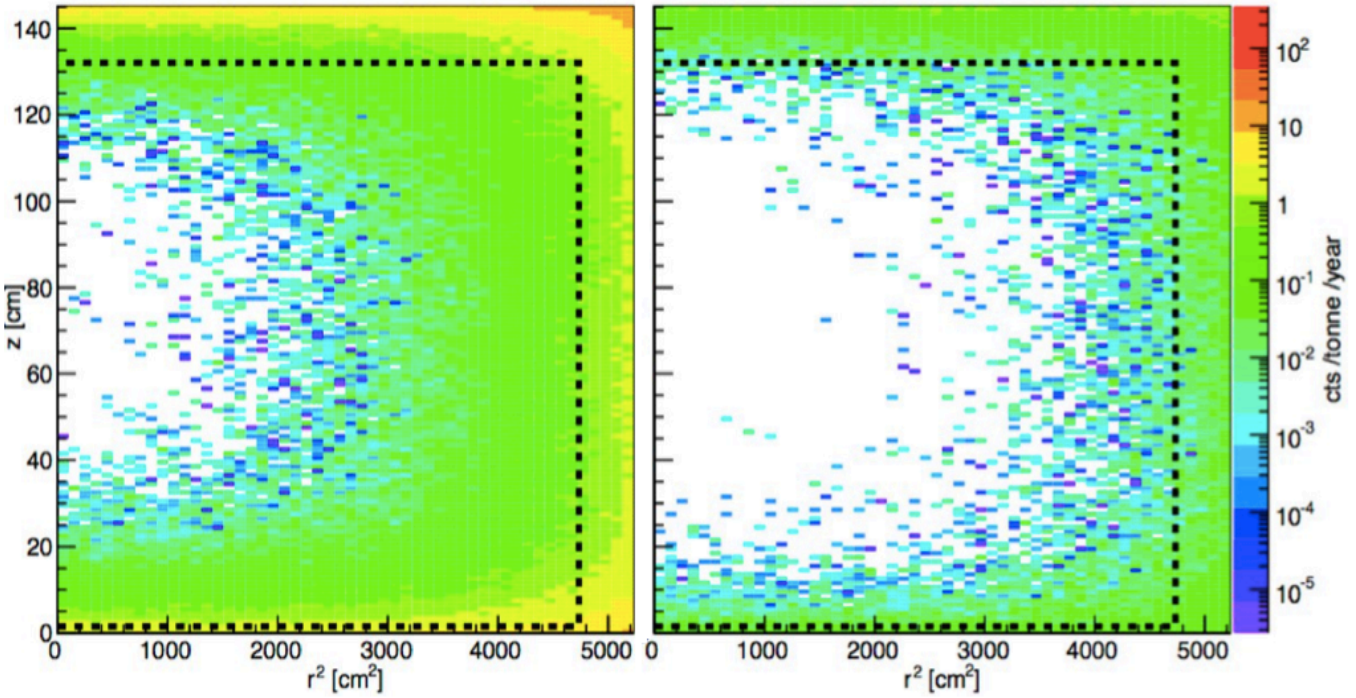
- 61-cm thick Gd-loaded scintillator
- instrumented xenon “skin” layer
- water shield, an active muon veto

} **in-situ monitoring of residual backgrounds**



We will be able to tag both neutrons (muon-induced and other) & gammas

Energy RoI + Single Scatter **RoI + SS Cut + All Vetoes**



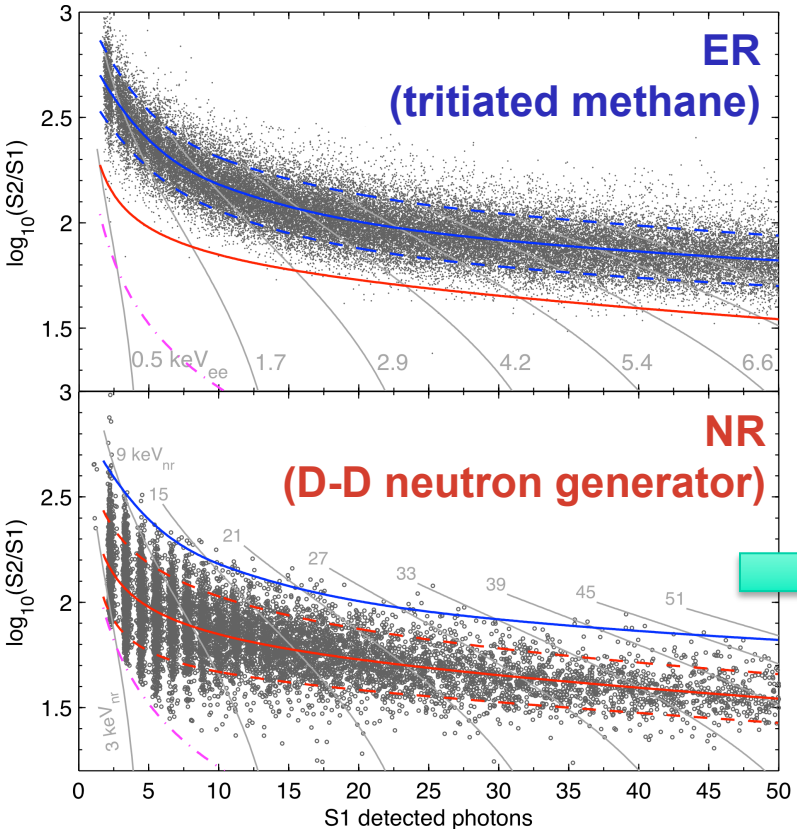
Screening and Simulations: Background Table

Expected counts in 1,000 live days in an indicative 5.6-ton fiducial mass in (1.5-6.5 keV_{ee}) and (6-30 keV_{nr}) energy ranges:

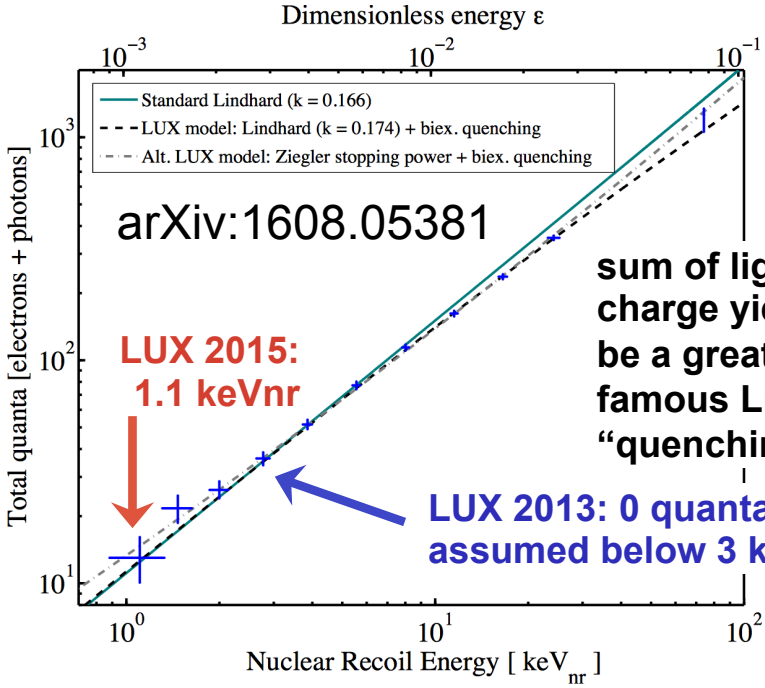
Item	ER cts	NR cts
Detector Componenents	6.2	0.07
Dispersed radionuclides (Rn, Kr, Ar)	911	-
Laboratory and cosmogenic	4.3	0.06
Fixed surface contamination	0.19	0.37
^{136}Xe $2\nu\beta\beta$	67	-
Neutrinos (ν-e, ν-A)	255	0.72
Total	1244	1.22
Total (with 99.5% ER discrimination, 50% NR efficiency)	6.22	0.61
Total ER+NR background events	6.83	

- **ER vs. NR discrimination is critical to success of experiment**
- **PLR analysis: very powerful at rejecting residual ER events**

High-stat LUX Calibrations + NEST



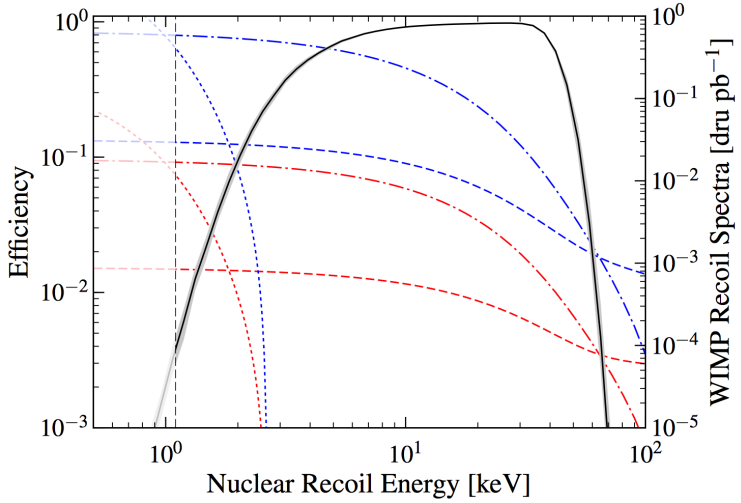
Phys. Rev. Lett. 116, 161301 (2016)



sum of light and charge yields, found to be a great match to the famous Lindhard "quenching" factor

Efficiency

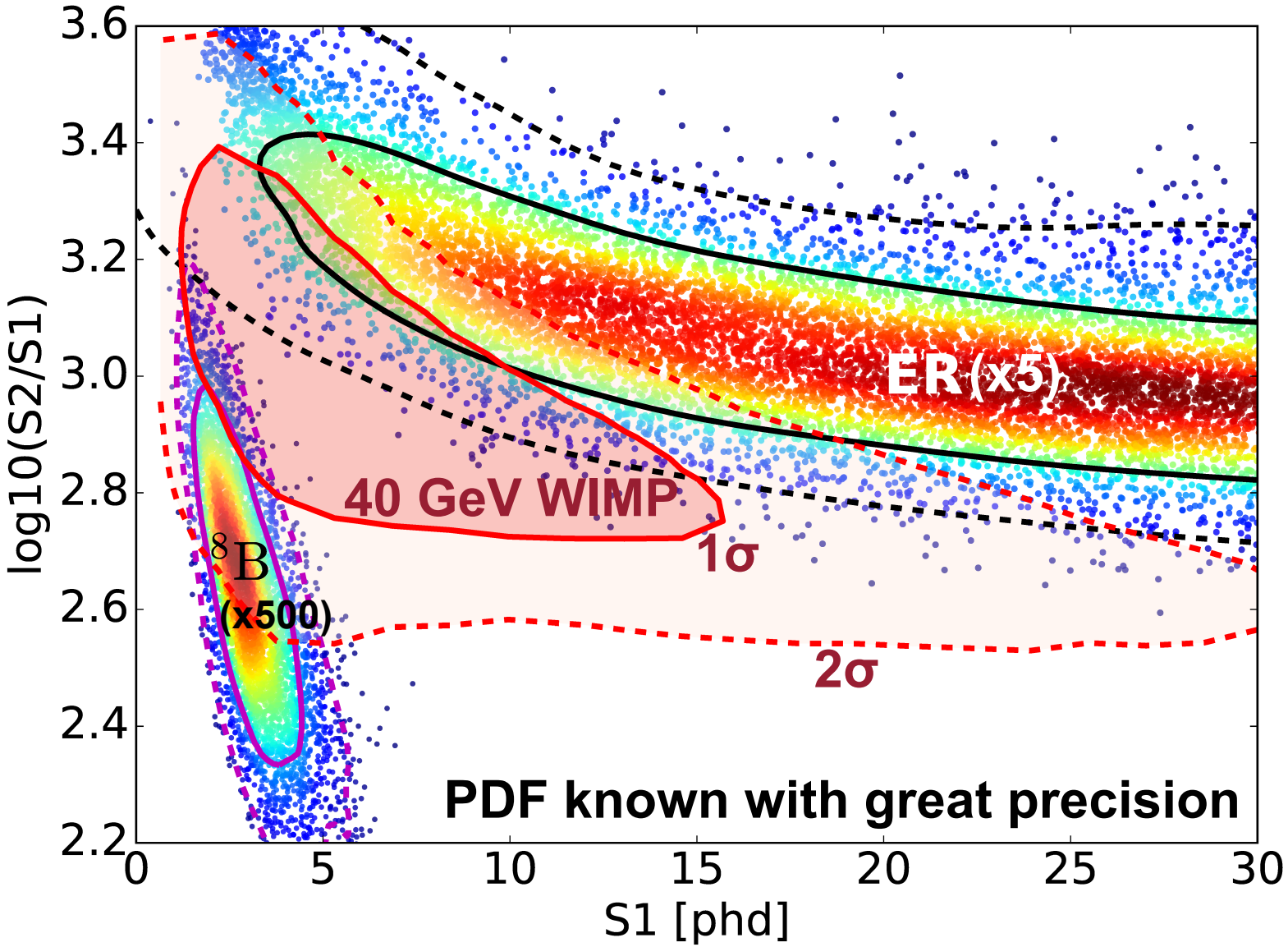
Phys. Rev. Lett. 118, 251302 (2017)



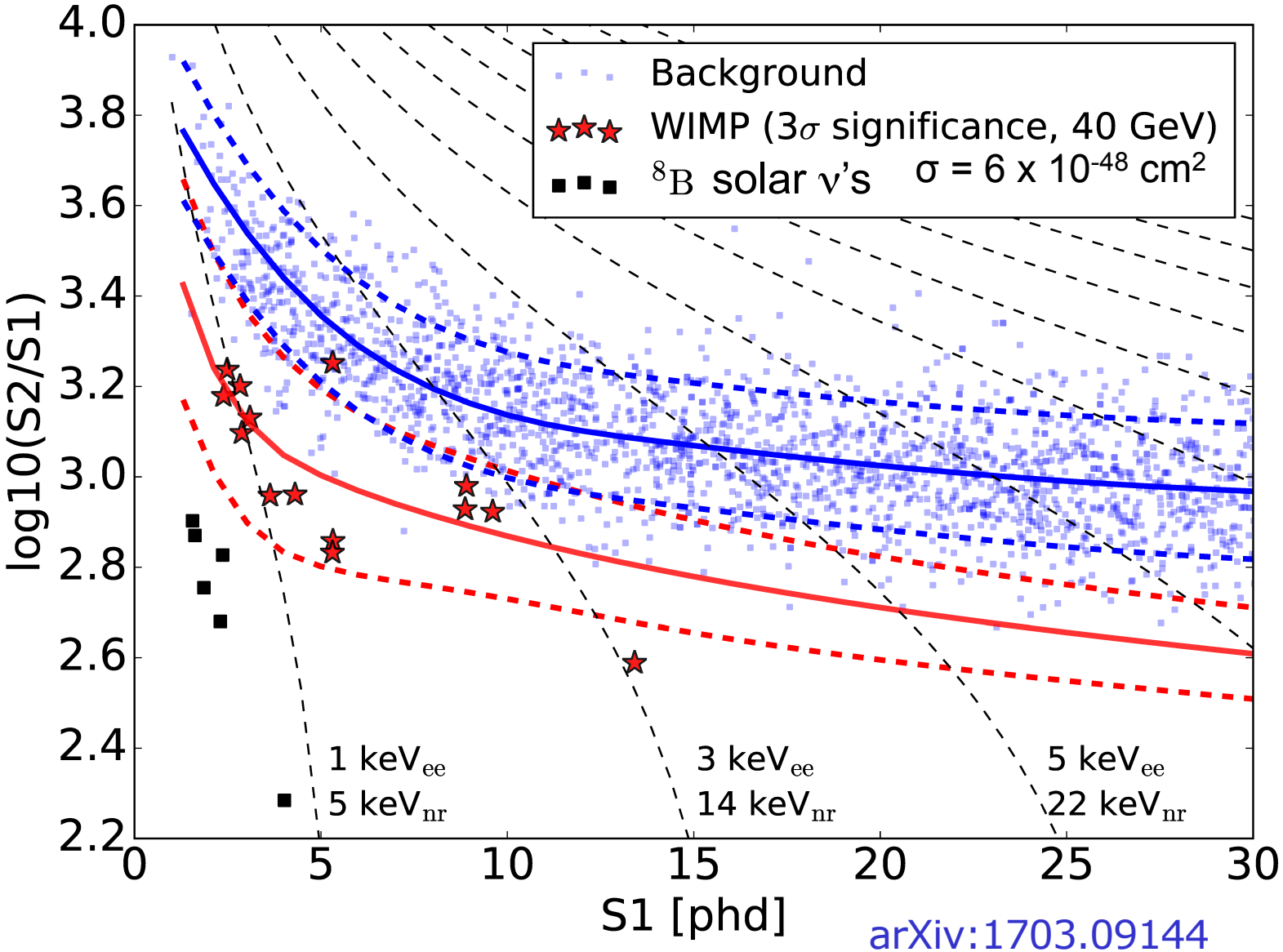
2nd science run (~1 live-year)

An Example WIMP Signal Region

Technical Design Report (TDR) arXiv:1703.09144

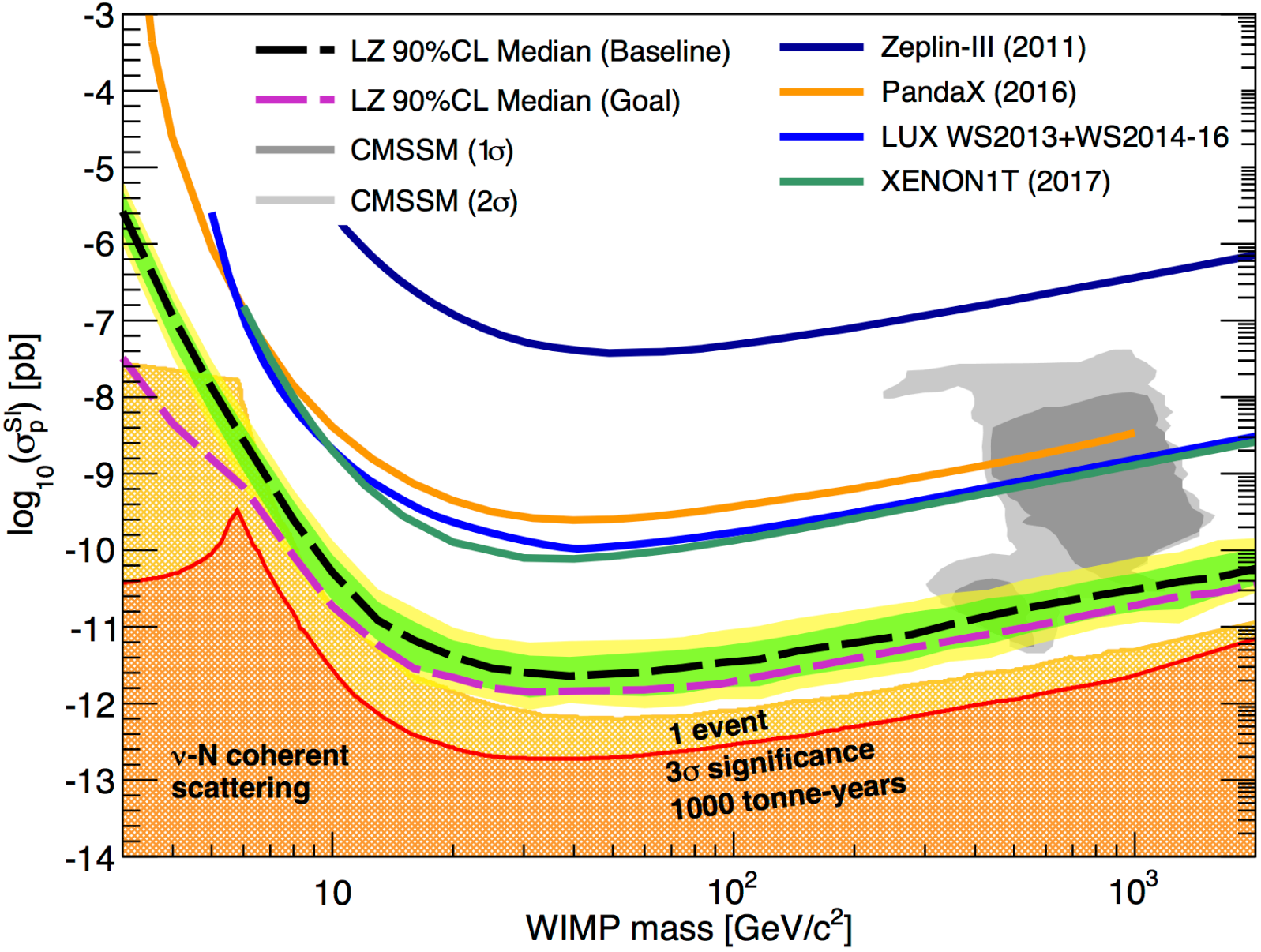


Simulation of LZ's Full Initial Exposure

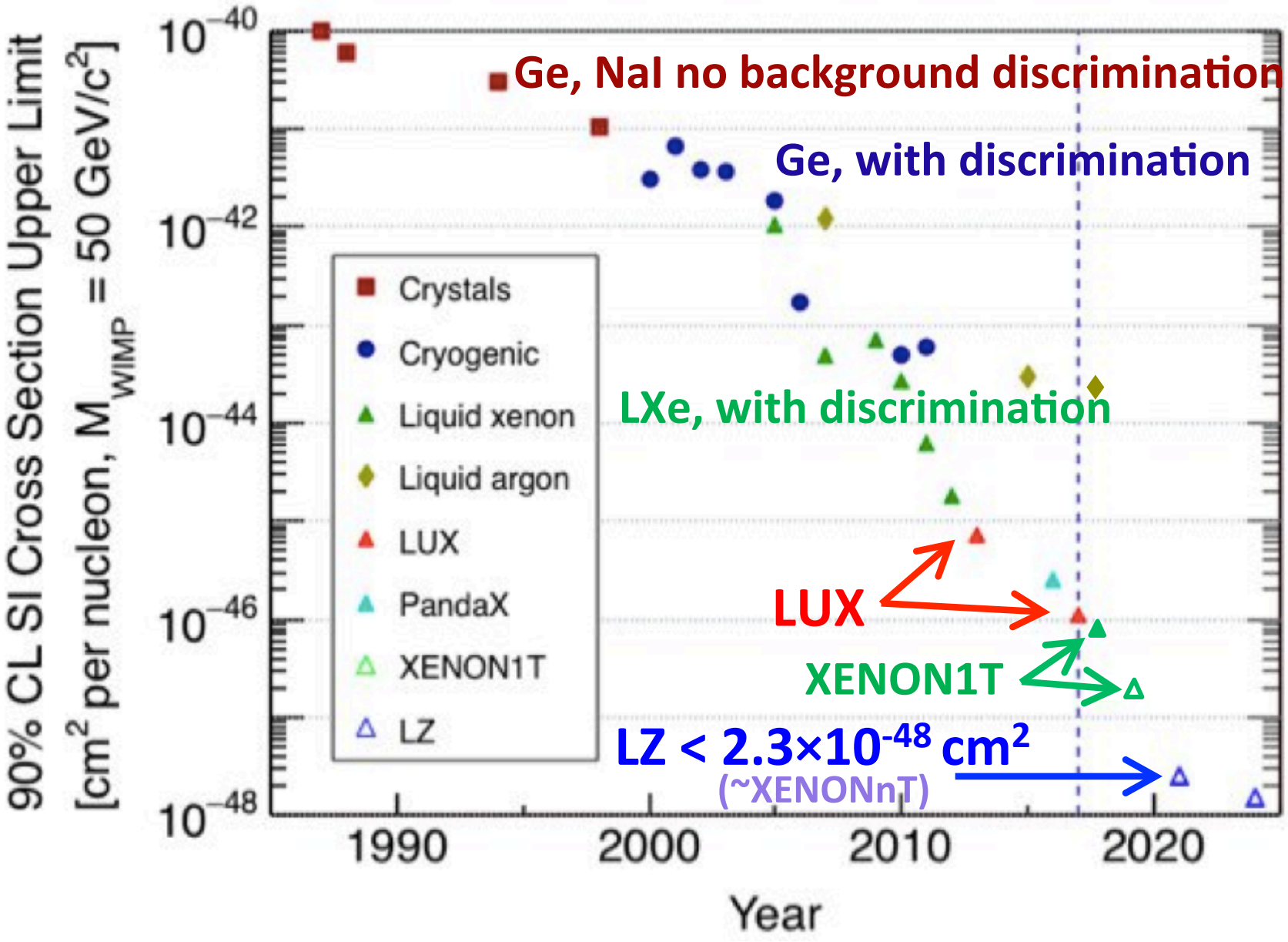


arXiv:1703.09144

Latest Sensitivity Projections: Spin-Independent

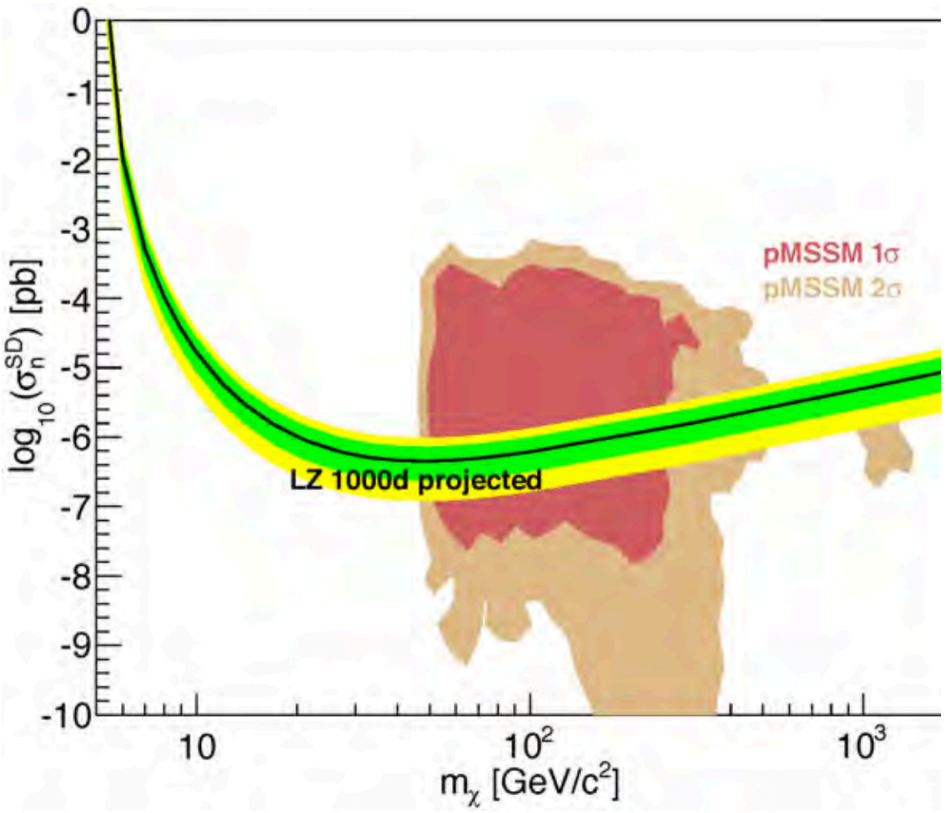


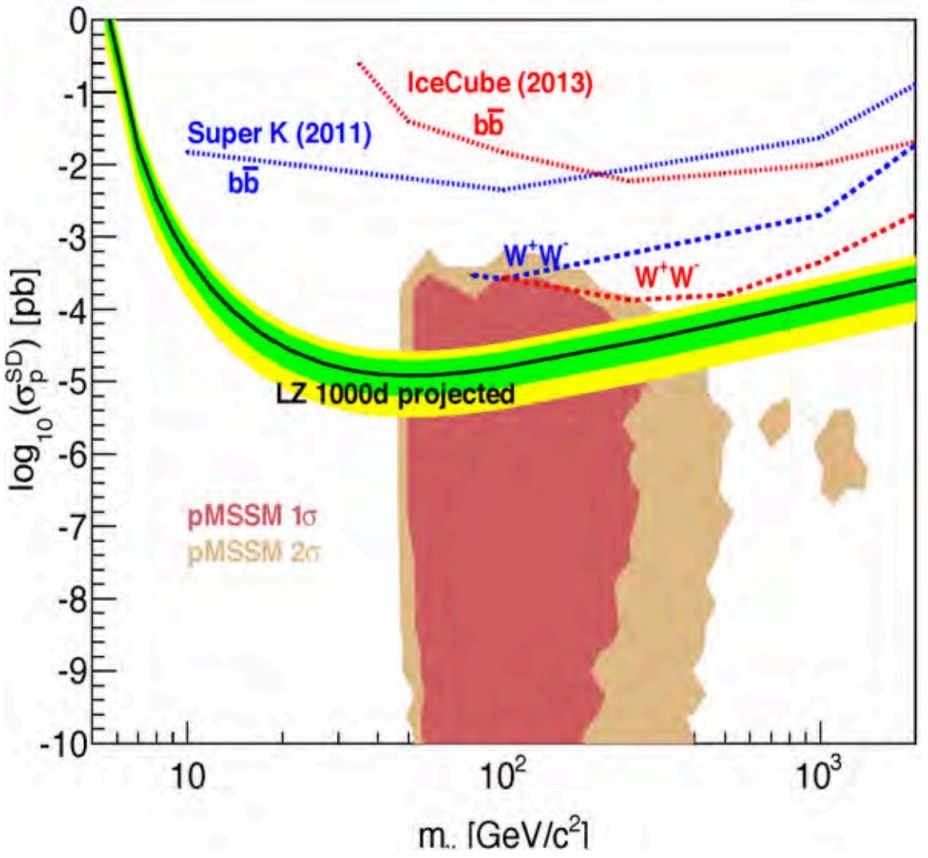
Moore's-like Law for WIMP SI Direct Detection



Spin-Dependent Neutron and Proton

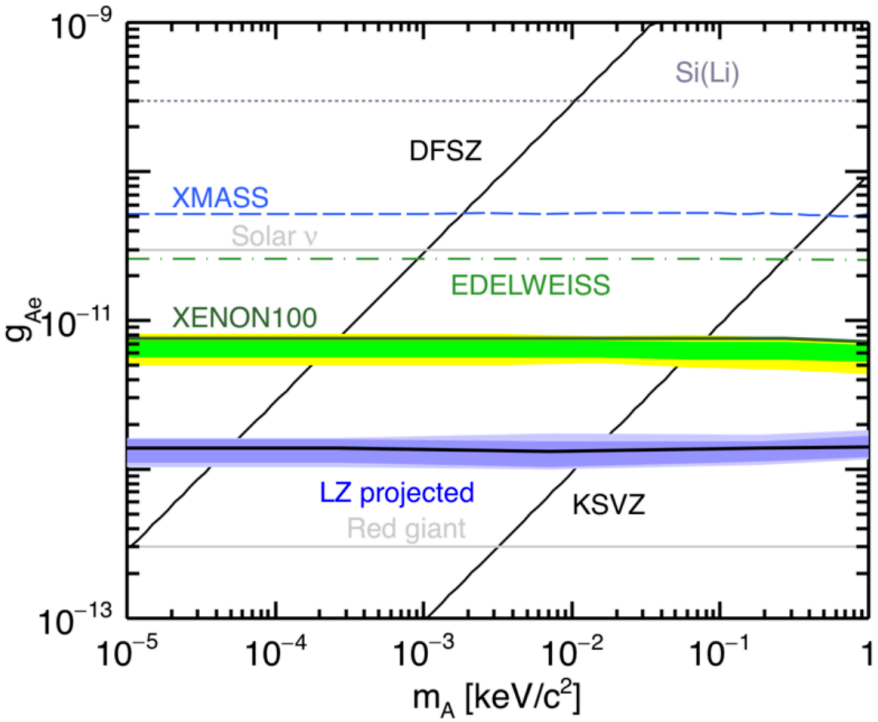
Conceptual Design Report (CDR) arXiv:1509.02910

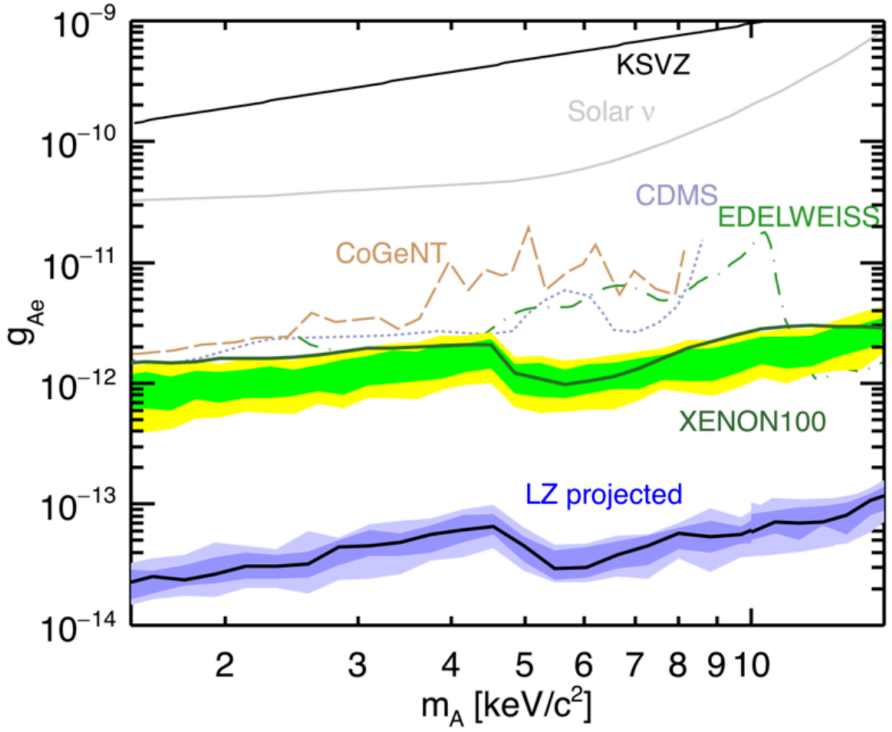




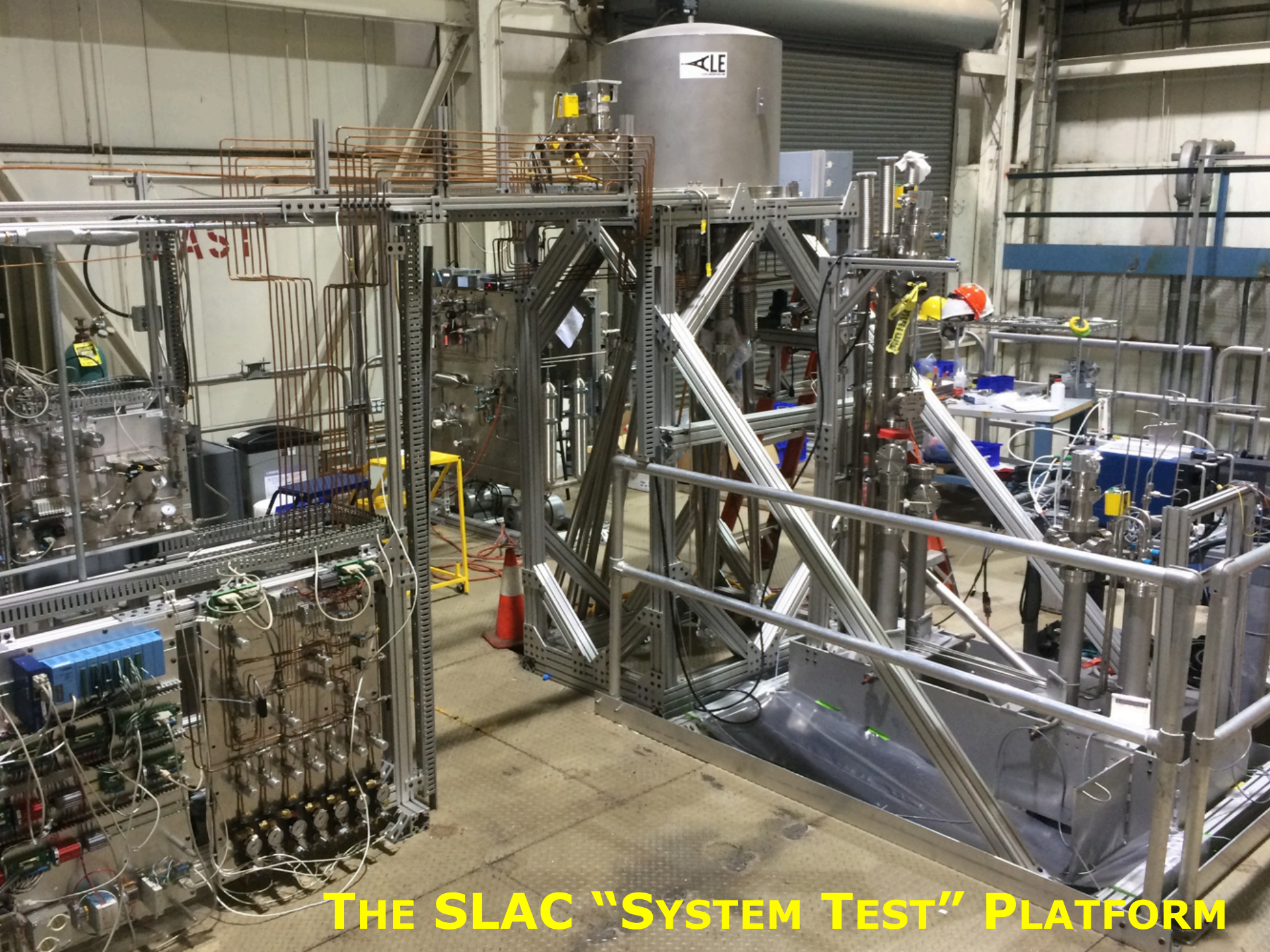
(apologies that slightly outdated: latest PICO SD-p results missing for instance)

Solar Axions, and Galactic ALPs

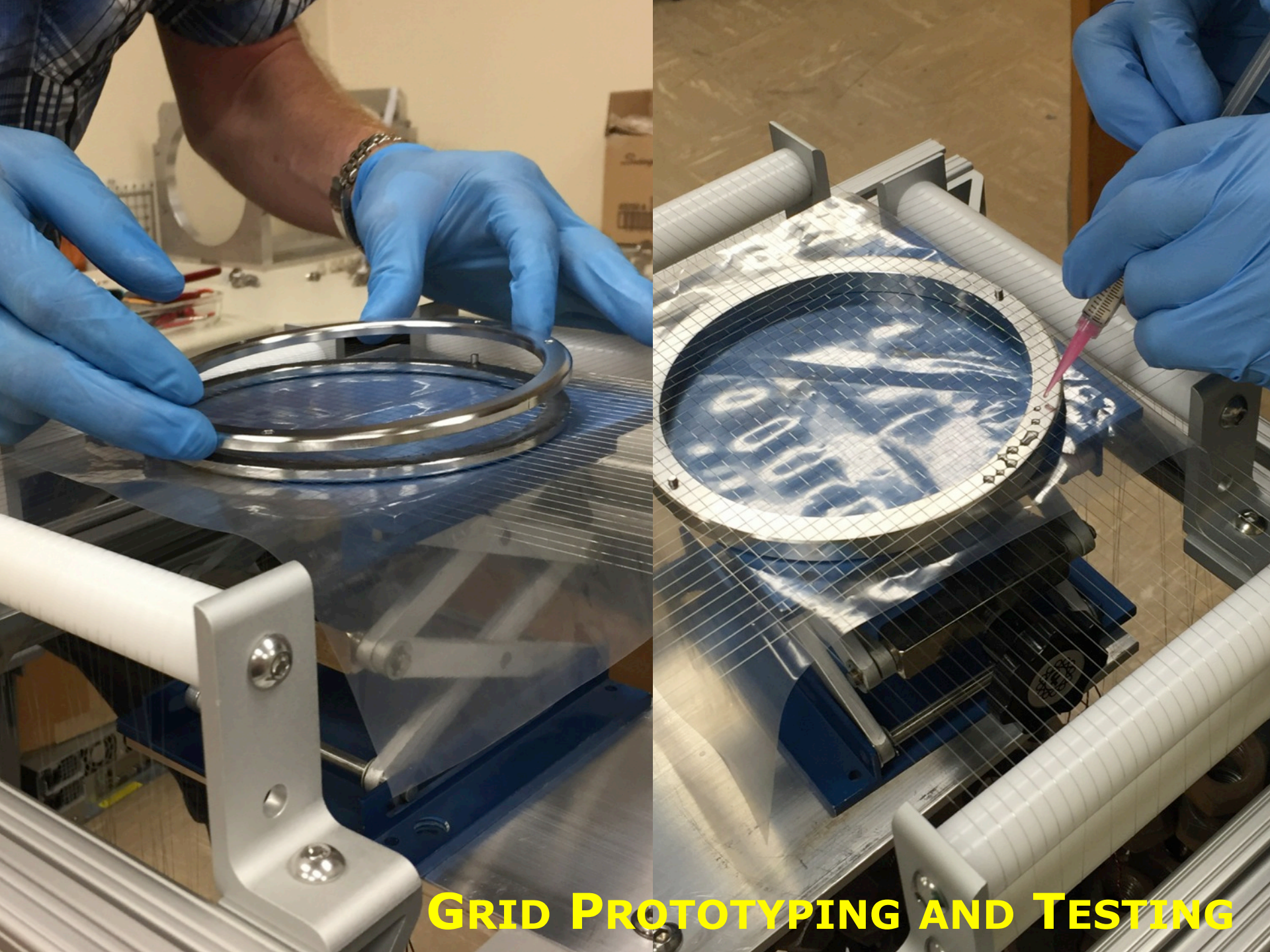




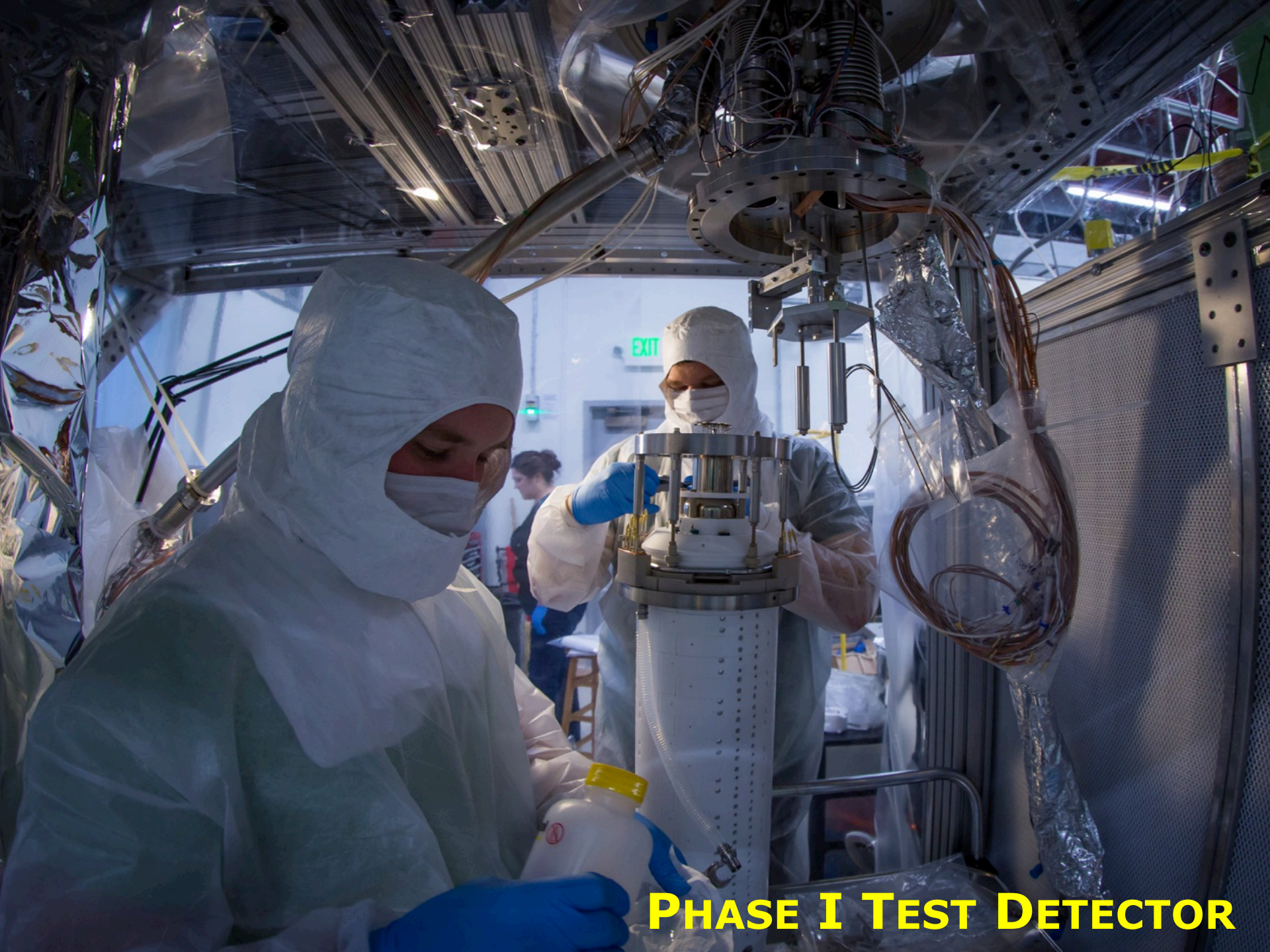
Note LUX not here because plots predate that work. See LUX talk for recent results



The SLAC "System Test" Platform



Grid Prototyping and Testing


EXIT
PHASE I TEST DETECTOR

Full-Scale Grid Loom at SLAC

LZ = LUX + ZEPLIN

A large collaboration, for the field of dark matter:

- 38 institutions (US, UK, Portugal, Russia, + South Korea)
- >250 laboratory staff scientists, university faculty, postdocs, graduate students, engineers, & technicians

The most recent LZ collaboration meeting, at SURF, July 2017

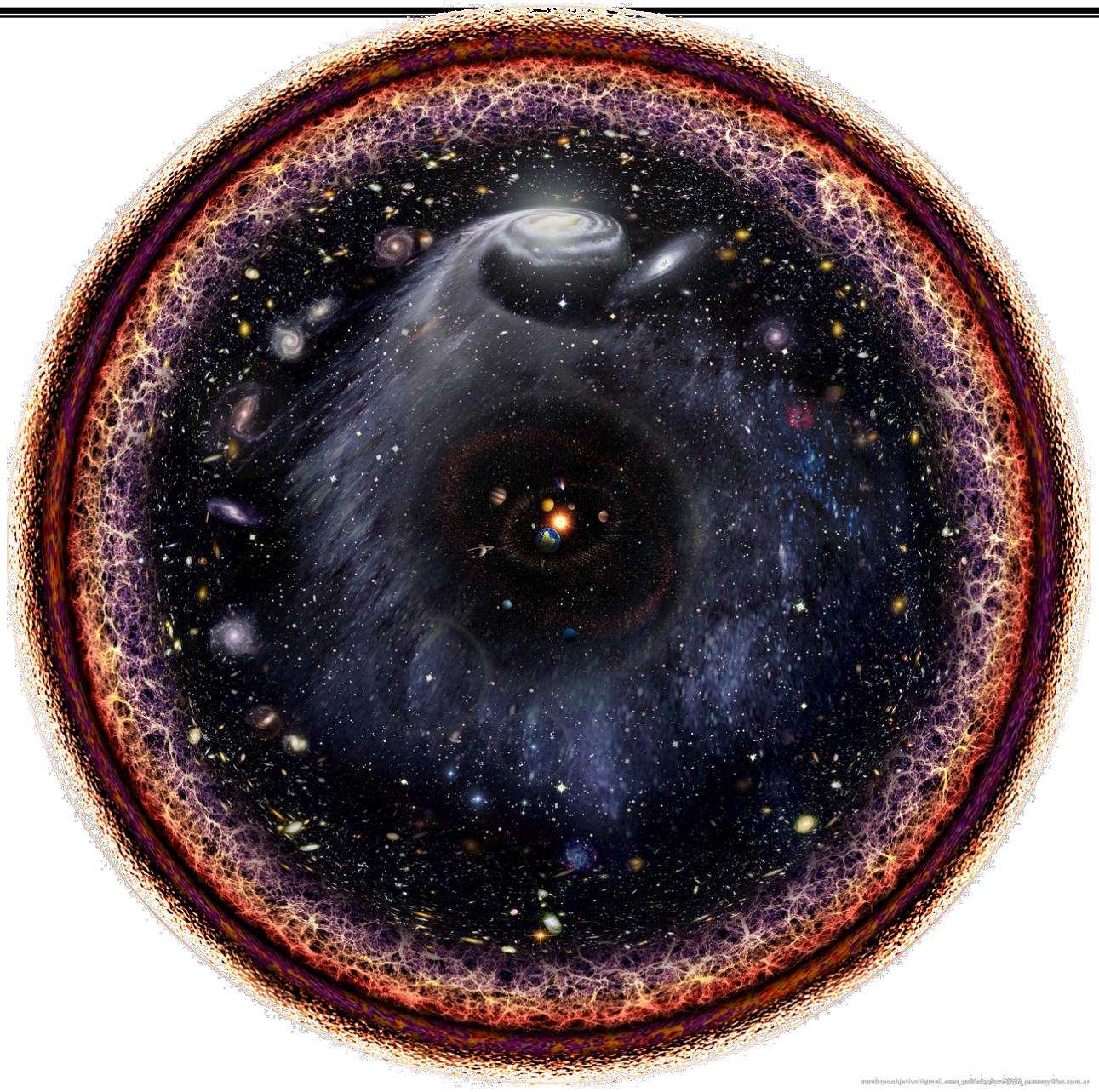
Summary and Outlook

- **LZ achieved CD-3 milestone on 02.09.17**
  - **March 2016: LUX removed from Davis**
  - **July 2017 (NOW): surface assembly prep**
  - **July 2018: underground installation**
  - **2020: beginning of LZ commissioning**

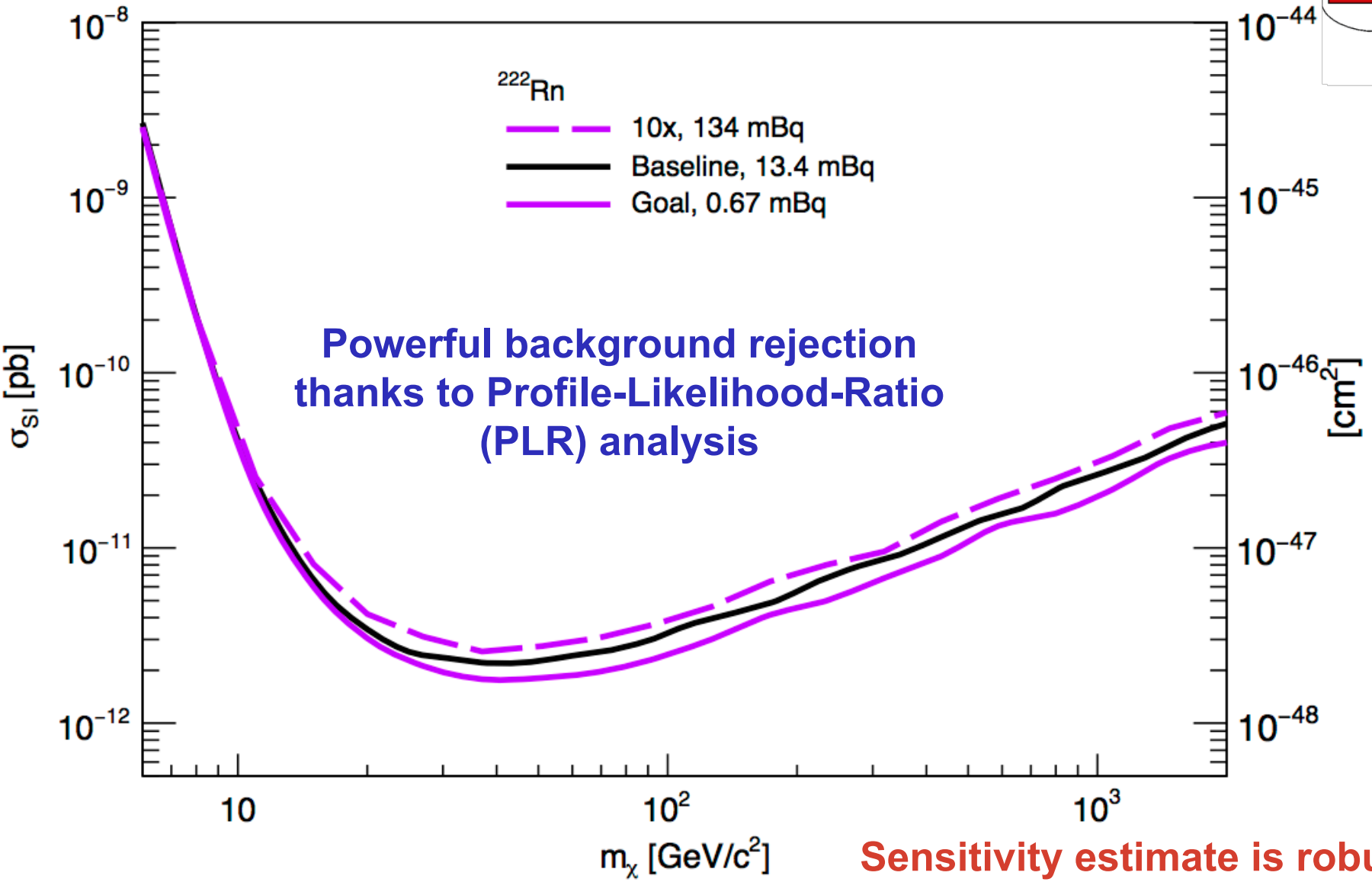
- **Long lead-time procurements are underway**
- **Quality assurance and testing for hardware underway; material screening program busy**
- **LZ benefits from excellent LUX calibrations plus understanding of BGs, and from NEST**

- **LZ science run planned to start in 2021:**
  - **1,000 live-days and 5.6T fiducial mass**
  - **Baseline SI sensitivity of 2.3×10^{-48} cm^2**
  - **Start probing the ν floor at <10 GeV/c^2**

Backup Slides



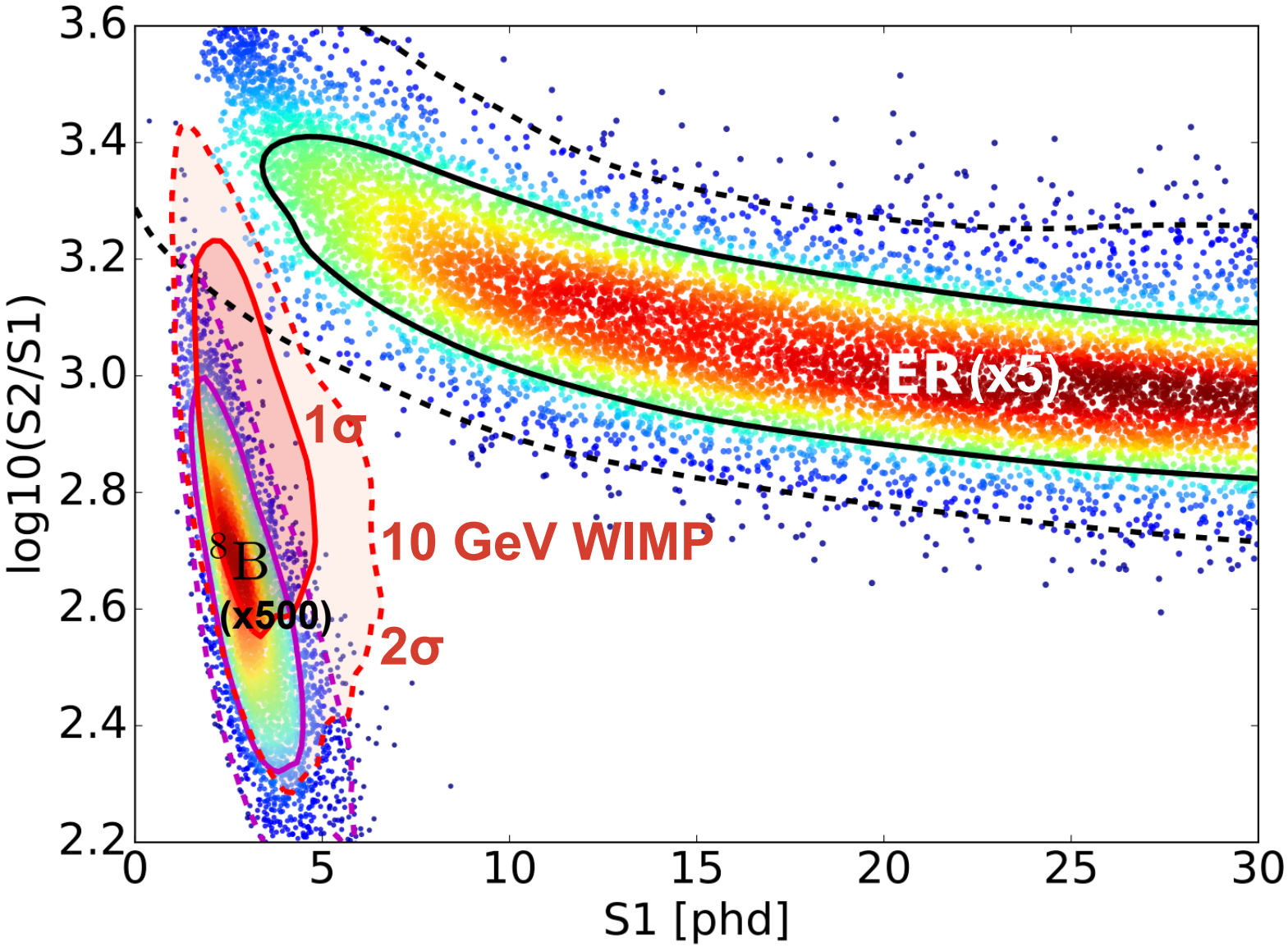
Hypothetical ^{222}Rn Scenarios



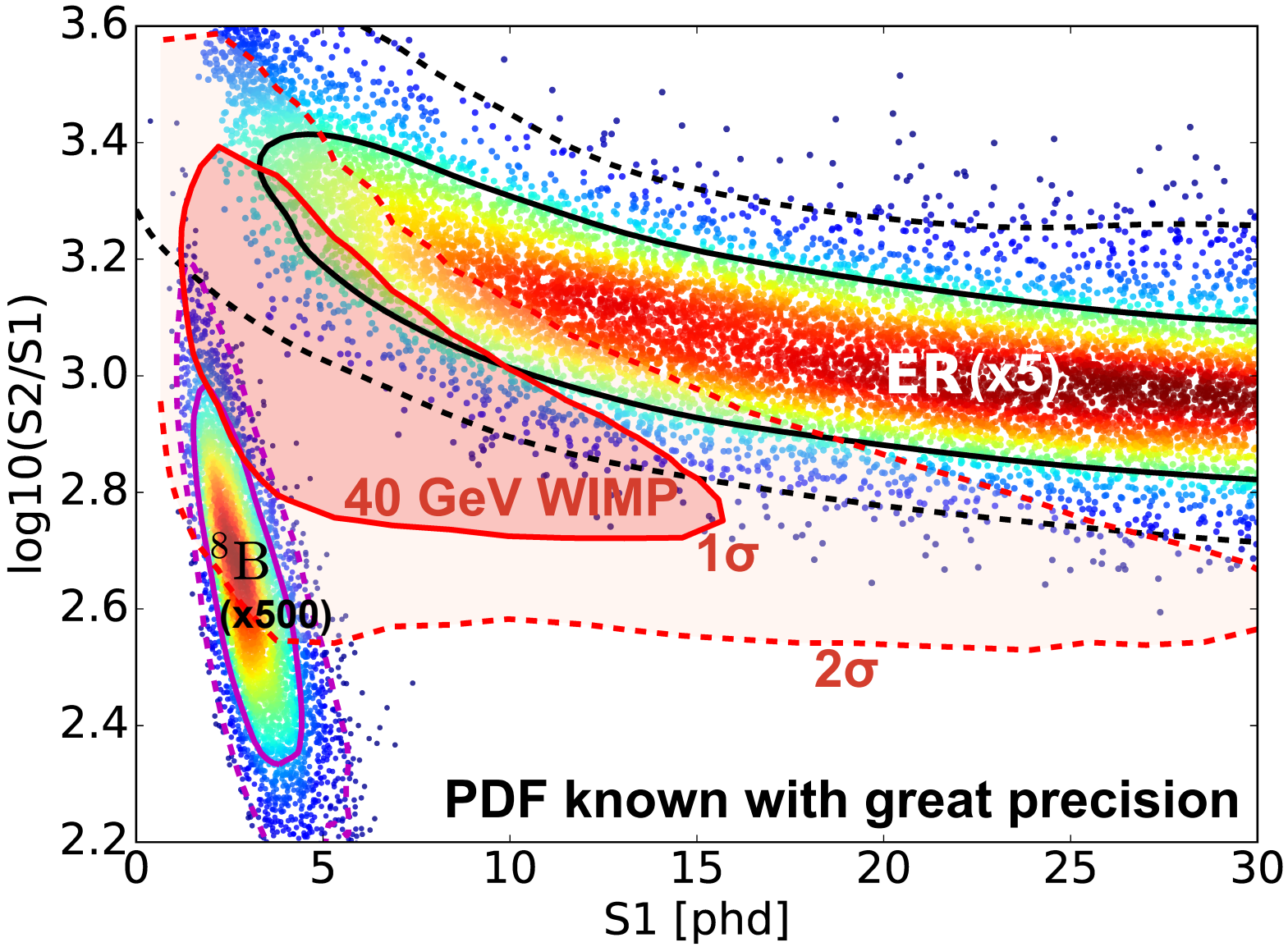
Powerful background rejection thanks to Profile-Likelihood-Ratio (PLR) analysis

Sensitivity estimate is robust!

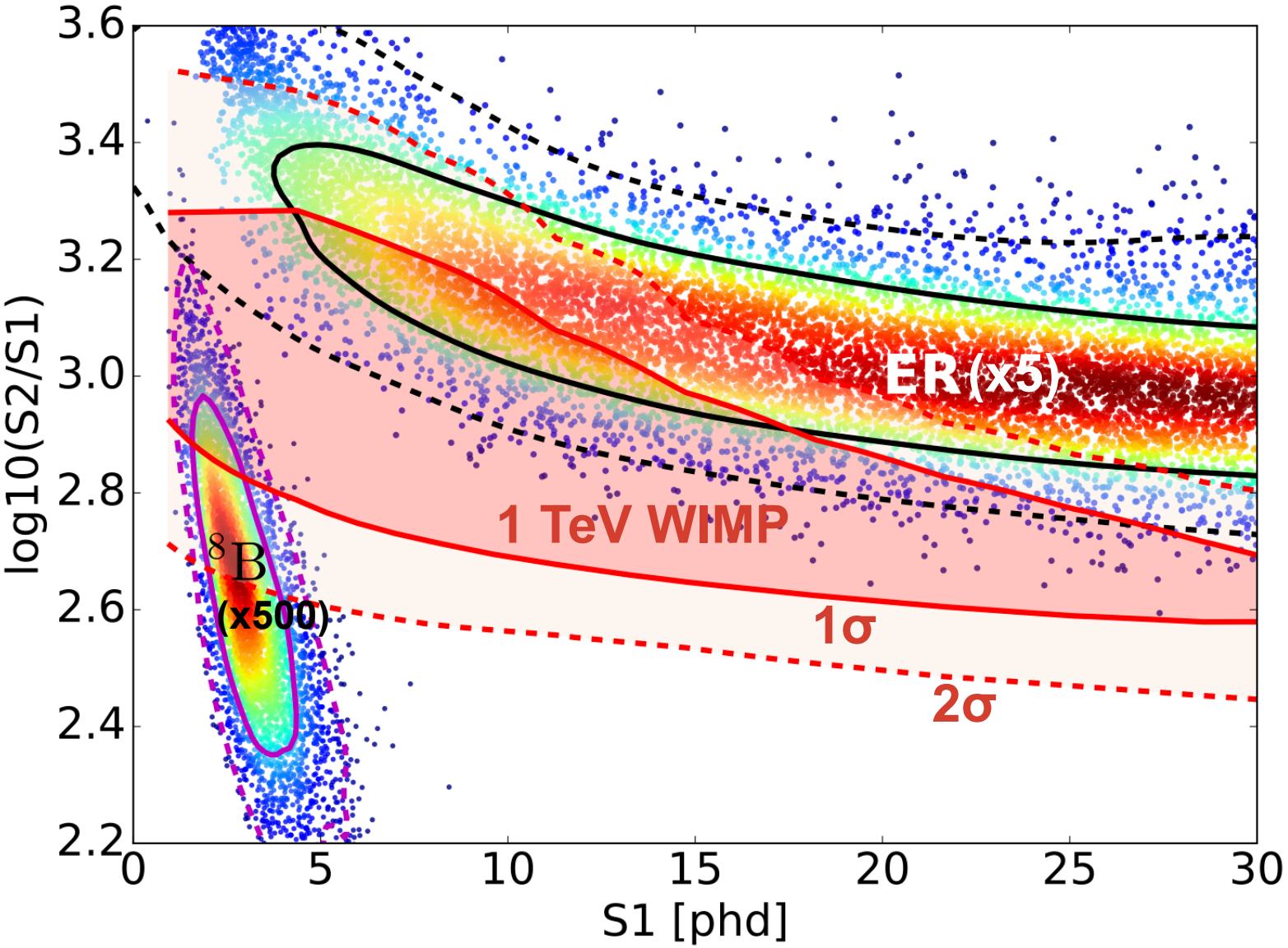
WIMP Signal Region in LZ



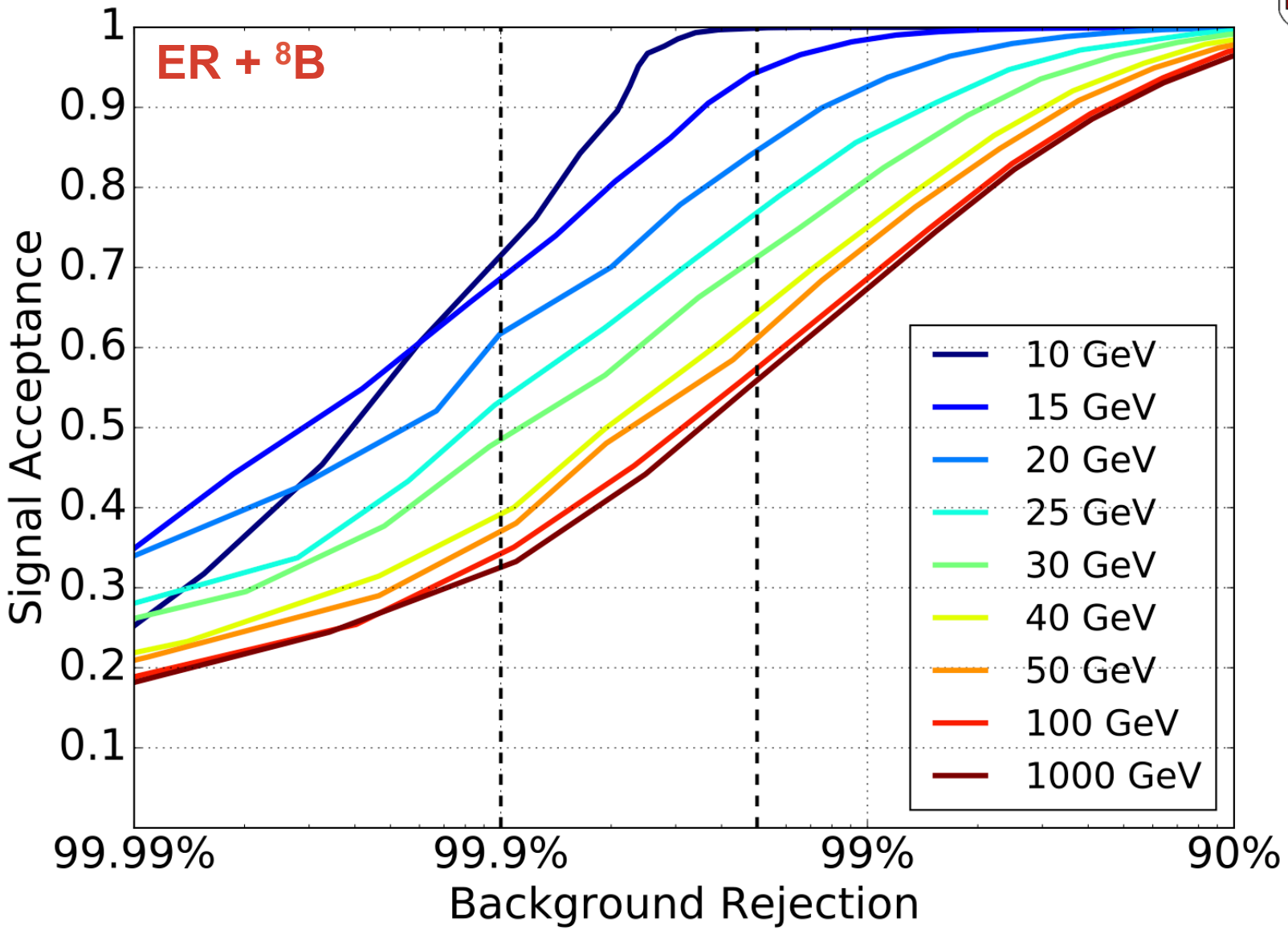
WIMP Signal Region in LZ



WIMP Signal Region in LZ



Effective background rejection with PLR



What is NEST?

- **Noble Element Simulation Technique**
- **Simulates excitation, ionization, and elastic scattering processes**
- **Simulates electron recombination and escape/drift**
- **Pulse shapes: S1 triplet and singlet decay times, and photon travel times**
- **http://nest.physics.ucdavis.edu/site/**
  - **See website for publications list**
- **Used by LUX, LZ, XENON100, XENON1T/nT, PandaX**