The LUX-ZEPLIN Dark Matter Search

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for the LZ collaboration

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Dark Side of the Universe
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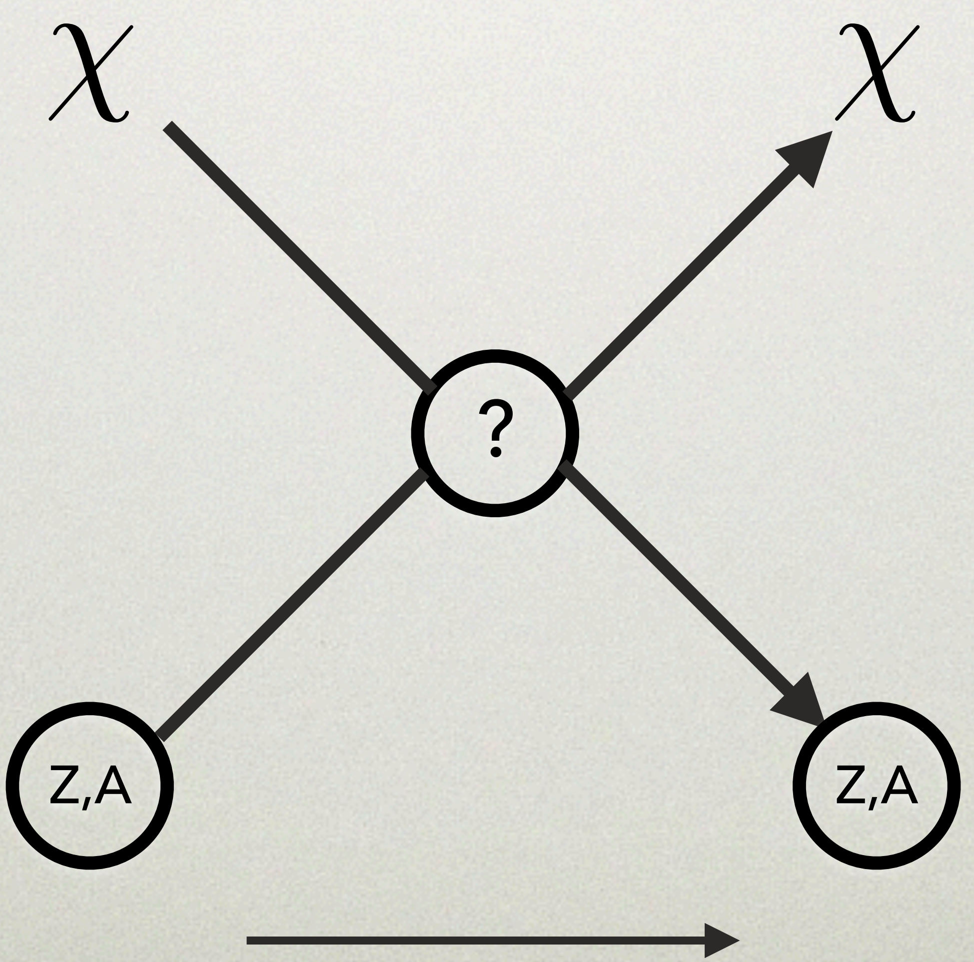
LUX-ZEPLIN

A direct-detection search, looking primarily (but not only) for WIMP dark matter with liquid xenon



LZ collaboration, March 2017

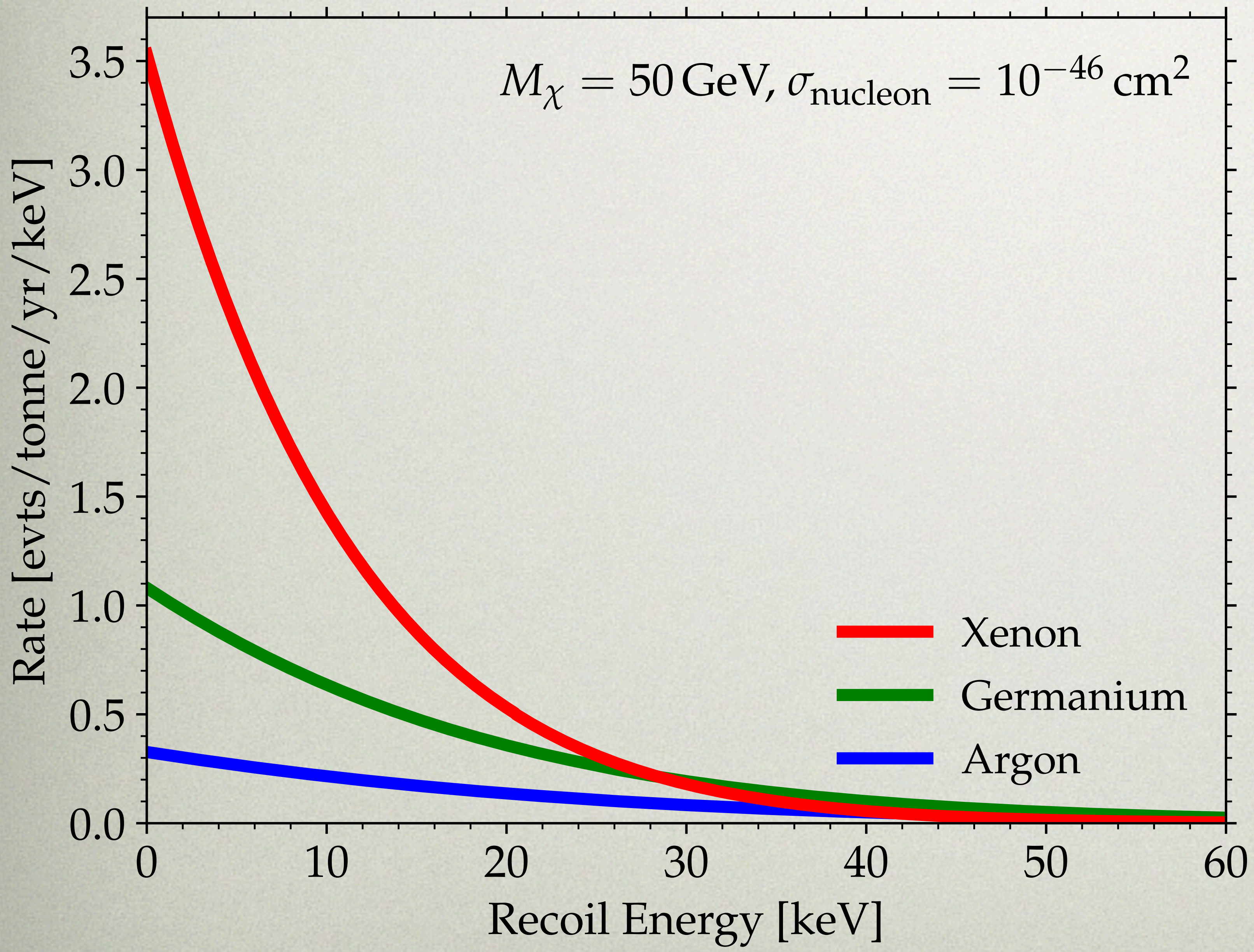
36 institutions
250 scientists, engineers, and technicians

1) **IBS Center for Underground Physics (South Korea)**
2) LIP Coimbra (Portugal)
3) MEPhI (Russia)
4) Imperial College London (UK)
5) STFC Rutherford Appleton Lab (UK)
6) University College London (UK)
7) University of Bristol (UK)
8) University of Edinburgh (UK)
9) University of Liverpool (UK)
10) University of Oxford (UK)
11) University of Sheffield (UK)
12) Black Hill State University (US)
13) Brookhaven National Lab (US)
14) Brown University (US)
15) Fermi National Accelerator Lab (US)
16) Lawrence Berkeley National Lab (US)
17) Lawrence Livermore National Lab (US)
18) Northwestern University (US)
19) Pennsylvania State University (US)
20) SLAC National Accelerator Lab (US)
21) South Dakota School of Mines and Technology (US)
22) South Dakota Science and Technology Authority (US)
23) Texas A&M University (US)
24) University at Albany (US)
25) University of Alabama (US)
26) University of California, Berkeley (US)
27) University of California, Davis (US)
28) University of California, Santa Barbara (US)
29) University of Maryland (US)
30) University of Massachusetts (US)
31) University of Michigan (US)
32) University of Rochester (US)
33) University of South Dakota (US)
34) University of Wisconsin - Madison (US)
35) Washington University in St. Louis (US)
36) Yale University (US)

Why use liquid xenon?

Why use liquid xenon?

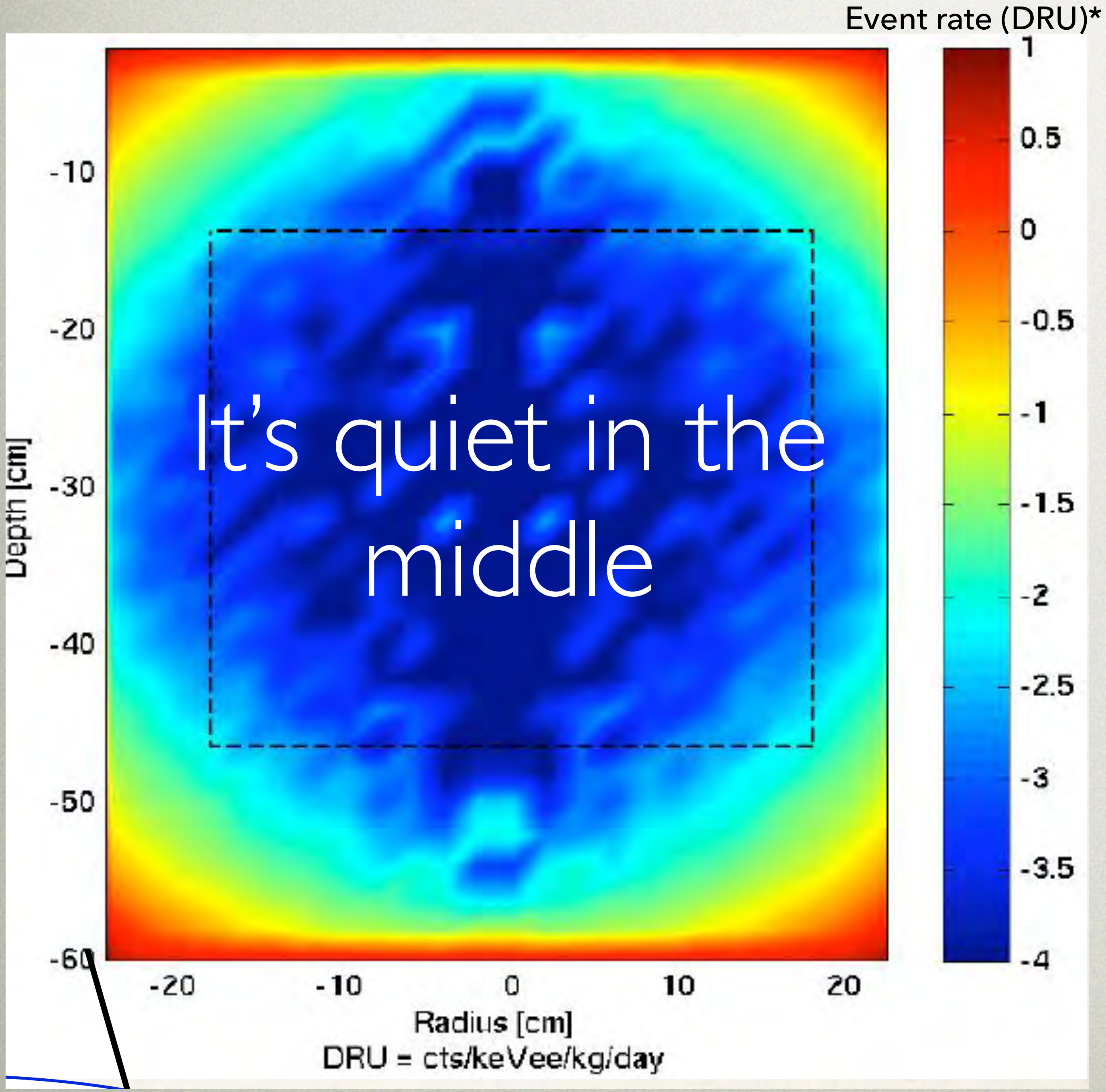
Large signal



- Scalar WIMP-nucleus interactions feature an A^2 dependence on the scattering rate.
- Natural xenon contains ~50% odd isotopes, giving high sensitivity to spin-coupled interactions

Why use liquid xenon?

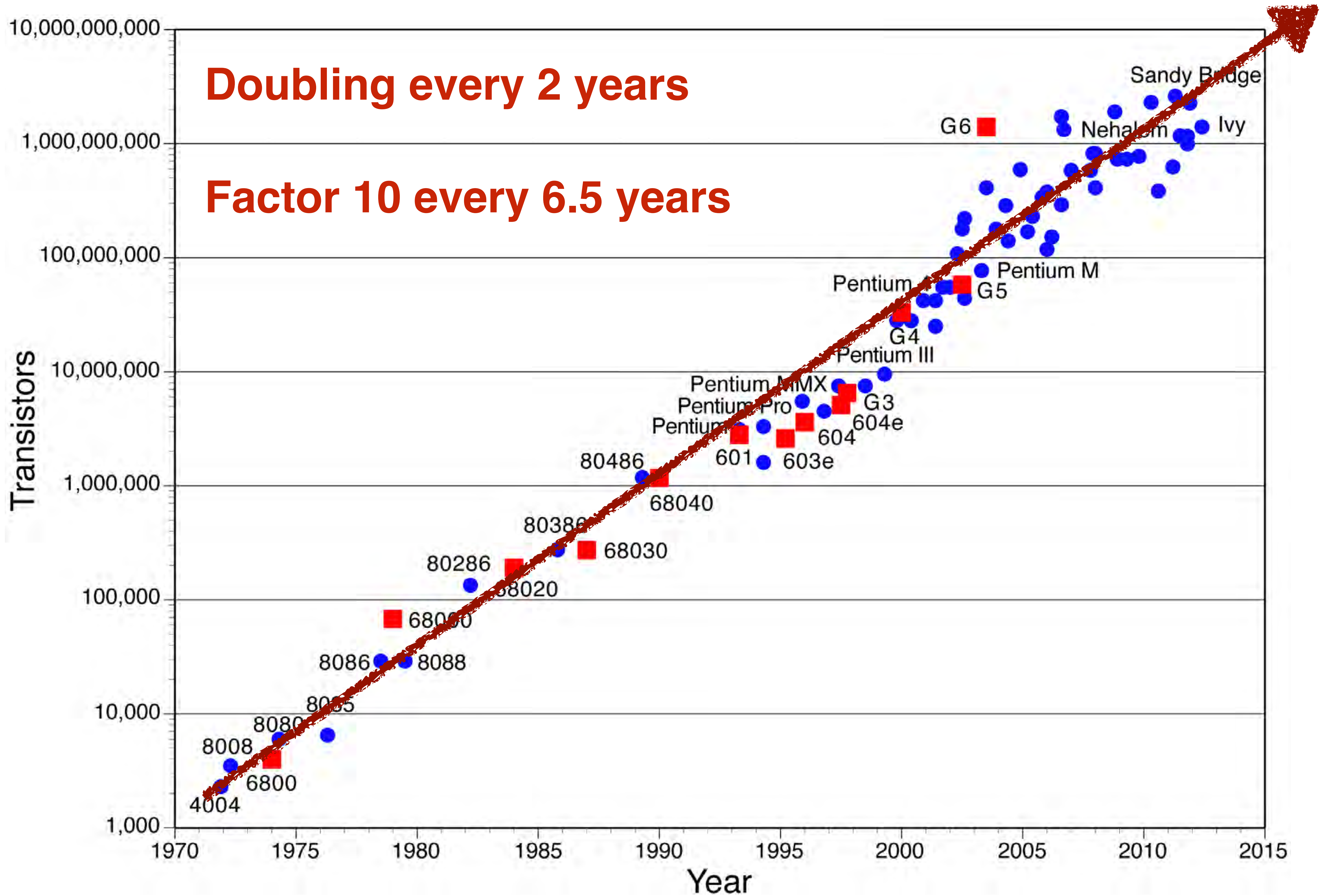
Low background

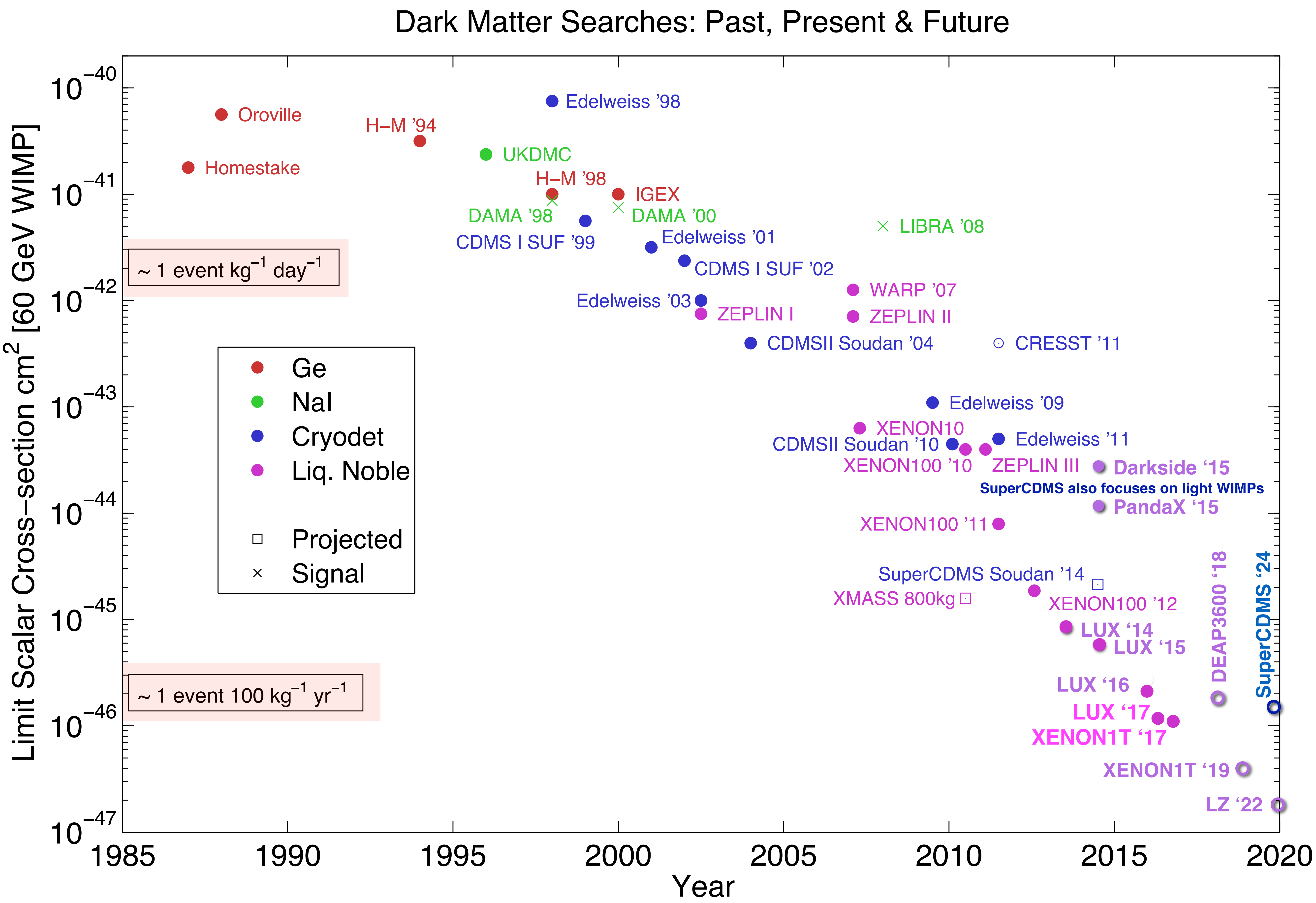


1. Easily scalable to large size
2. 3-D localization of events
3. 1 and 2 permit an ultra-low-background inner region to be defined.

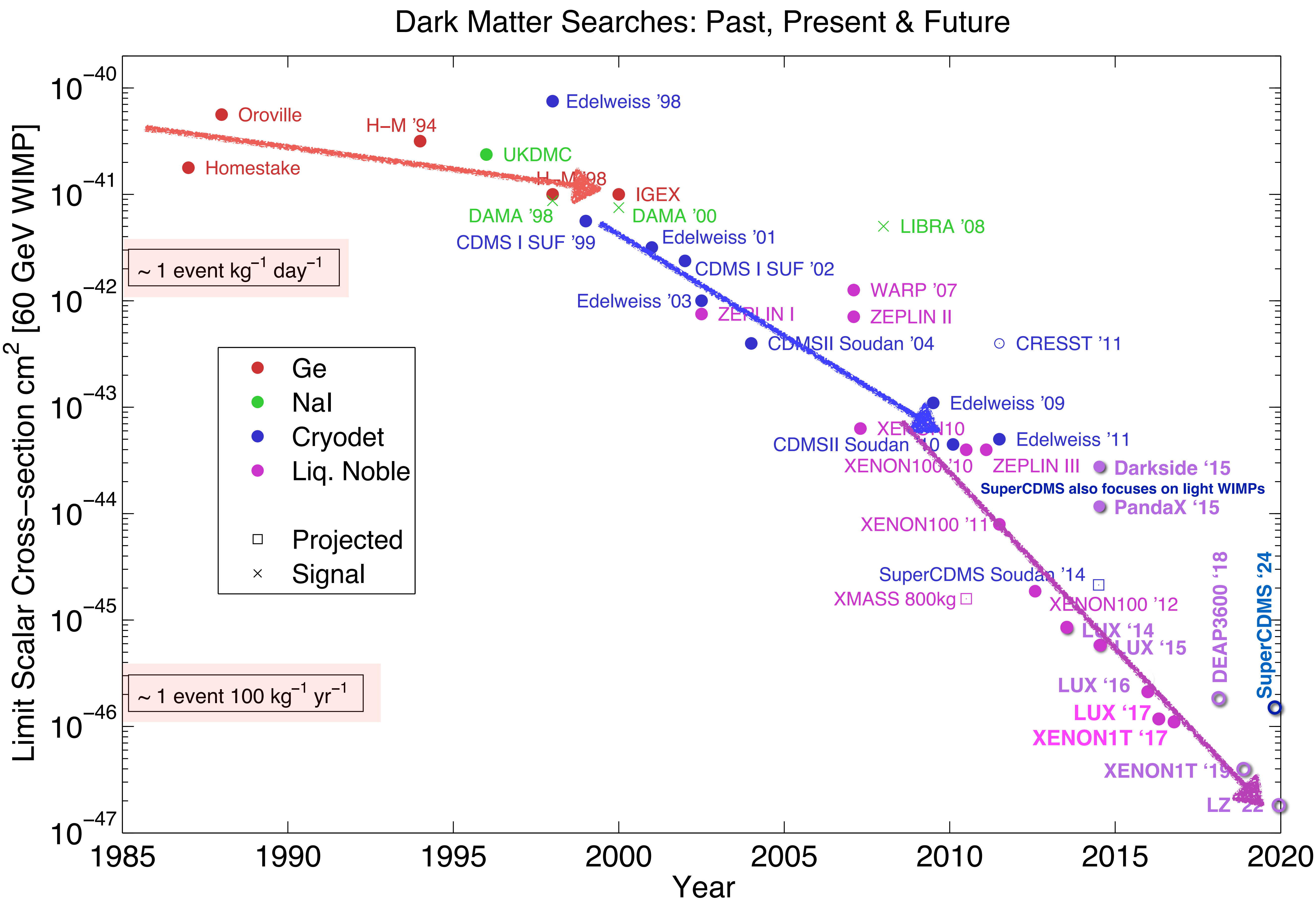
* "DRU" = evt/kg/day/keV

Moore's Law

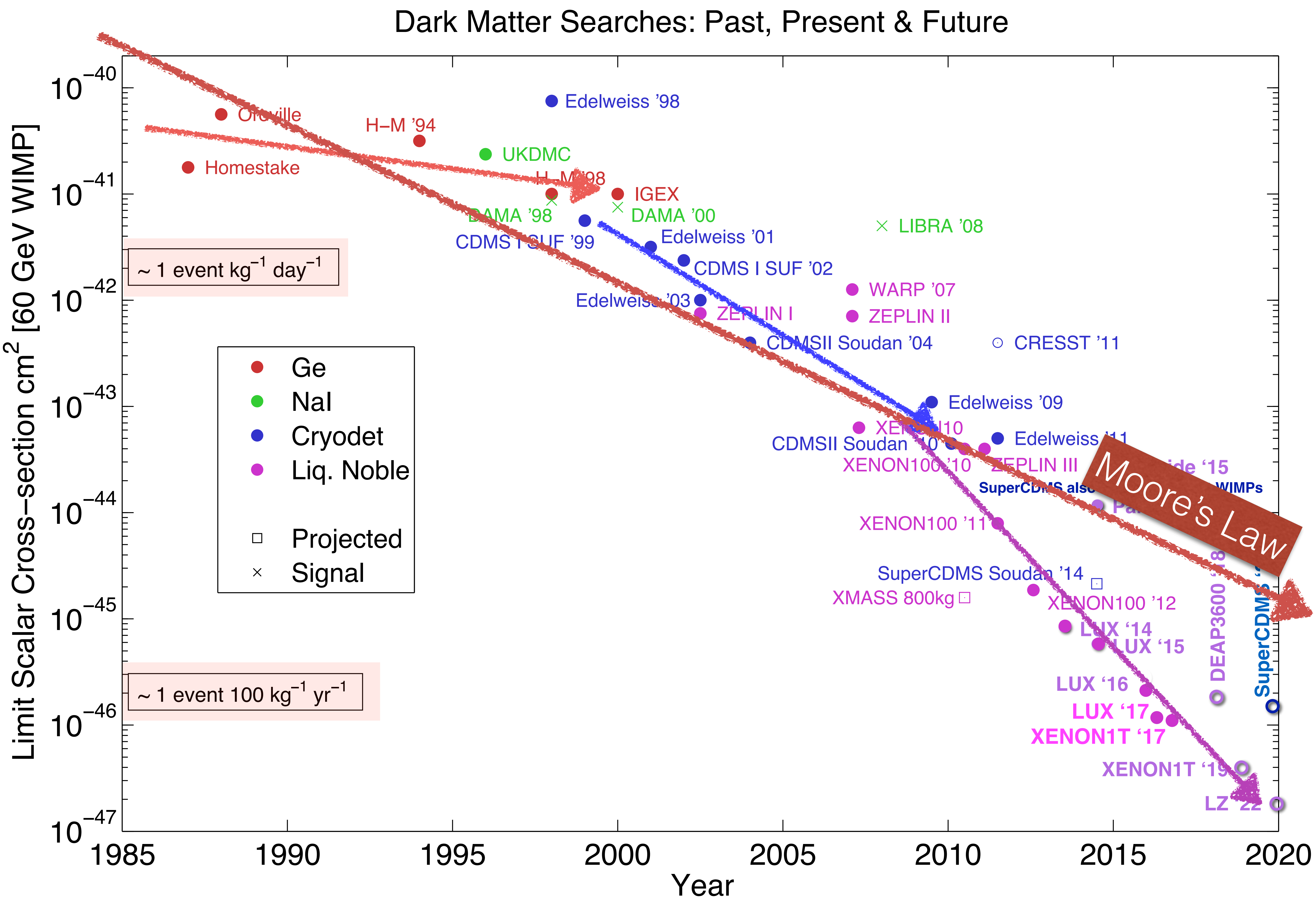

Doubling every 2 years
Factor 10 every 6.5 years
Transistors
Year
10,000,000,000
1,000,000,000
100,000,000
10,000,000
1,000,000
100,000
10,000
1,000
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
4004
8008
8080
6800
8085
8086
8088
68000
80286
68020
80386
68030
80486
68040
Pentium
601
603e
604
604e
Pentium Pro
Pentium MMX
G3
Pentium III
G4
Pentium 4
G5
Pentium M
G6
Nehalem
Sandy Bridge
Ivy



Courtesy R. Gaitskell



Courtesy R. Gaitskell

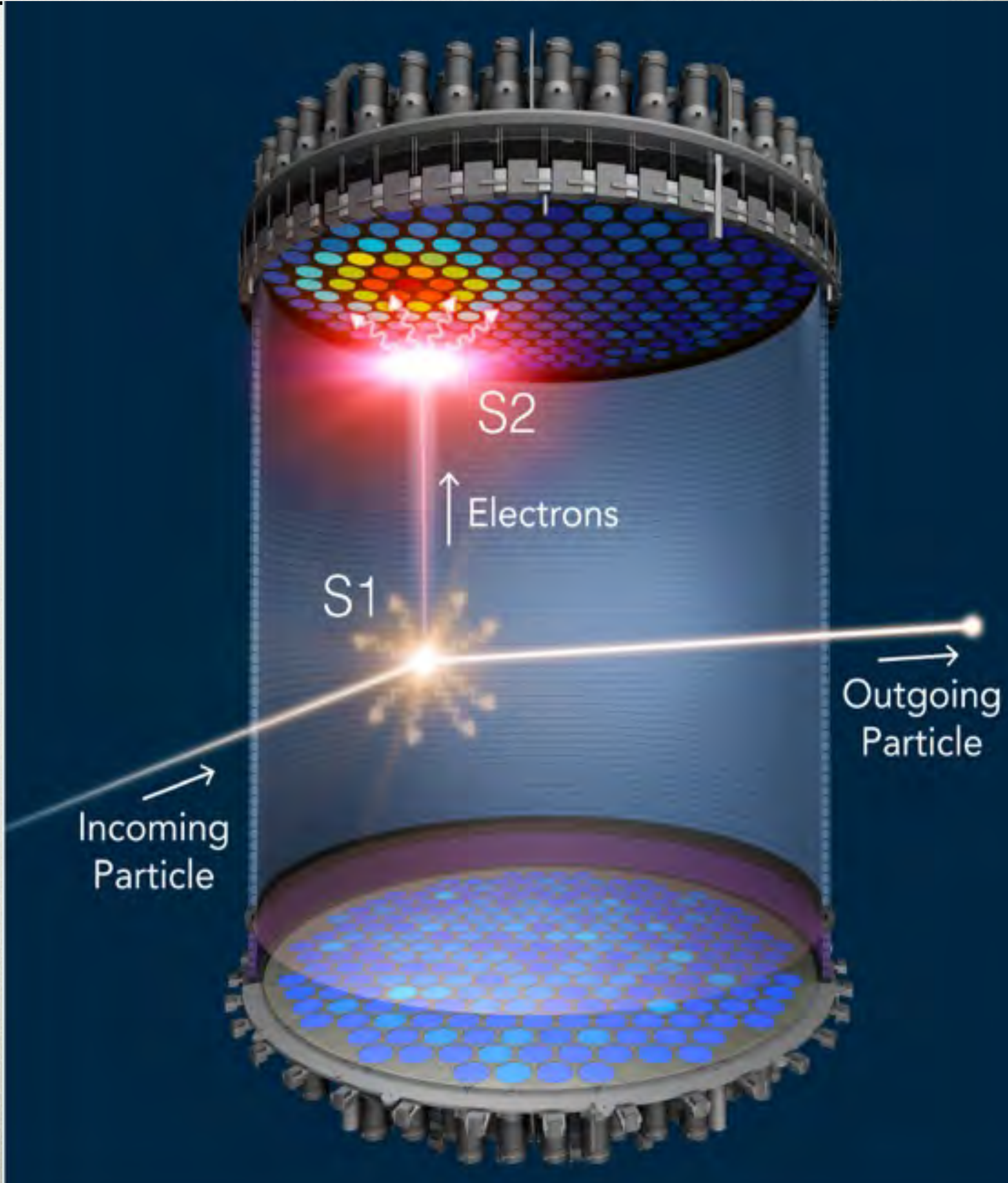


Dark Matter Searches: Past, Present & Future
Limit Scalar Cross–section cm^2 [60 GeV WIMP]
10^{-40}
10^{-41}
10^{-42}
10^{-43}
10^{-44}
10^{-45}
10^{-46}
10^{-47}
1985
1990
1995
2000
2005
2010
2015
2020
Year
~ 1 event kg^{-1} day^{-1}
~ 1 event 100 kg^{-1} yr^{-1}
Ge
NaI
Cryodet
Liq. Noble
Projected
Signal
Homestake
H–M '94
Edelweiss '98
UKDMC
IGEX
DAMA '00
LIBRA '08
Edelweiss '01
CDMS I SUF '02
WARP '07
ZEPLIN II
CDMSII Soudan '04
CRESST '11
Edelweiss '09
ZEPLIN III
XENON100 '11
SuperCDMS Soudan '14
XMASS 800kg
XENON100 '12
LUX '14
LUX '15
LUX '16
LUX '17
XENON1T '17
Moore's Law

Dual-phase time projection chamber (TPC)

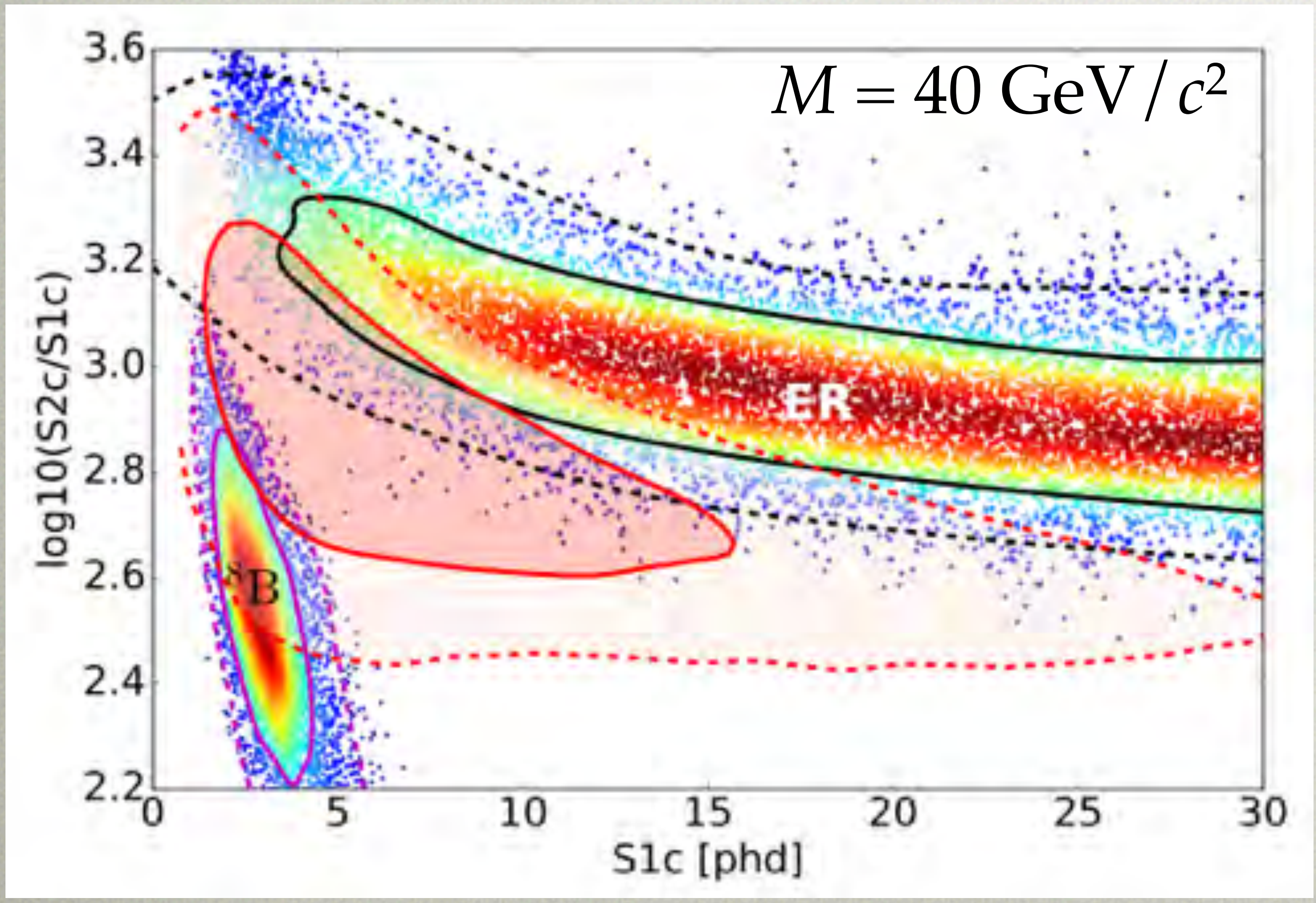
- Main target is liquid xenon (180 K).
- Primary scintillation light (S1) emitted from interaction vertex
- Ionized e^- drift to the liq. surface; produce prop. light as they travel through gas (S2).
- S1 and S2 permit:
  - Energy reconstruction
  - 3-D position reconstruction
  - Background rejection

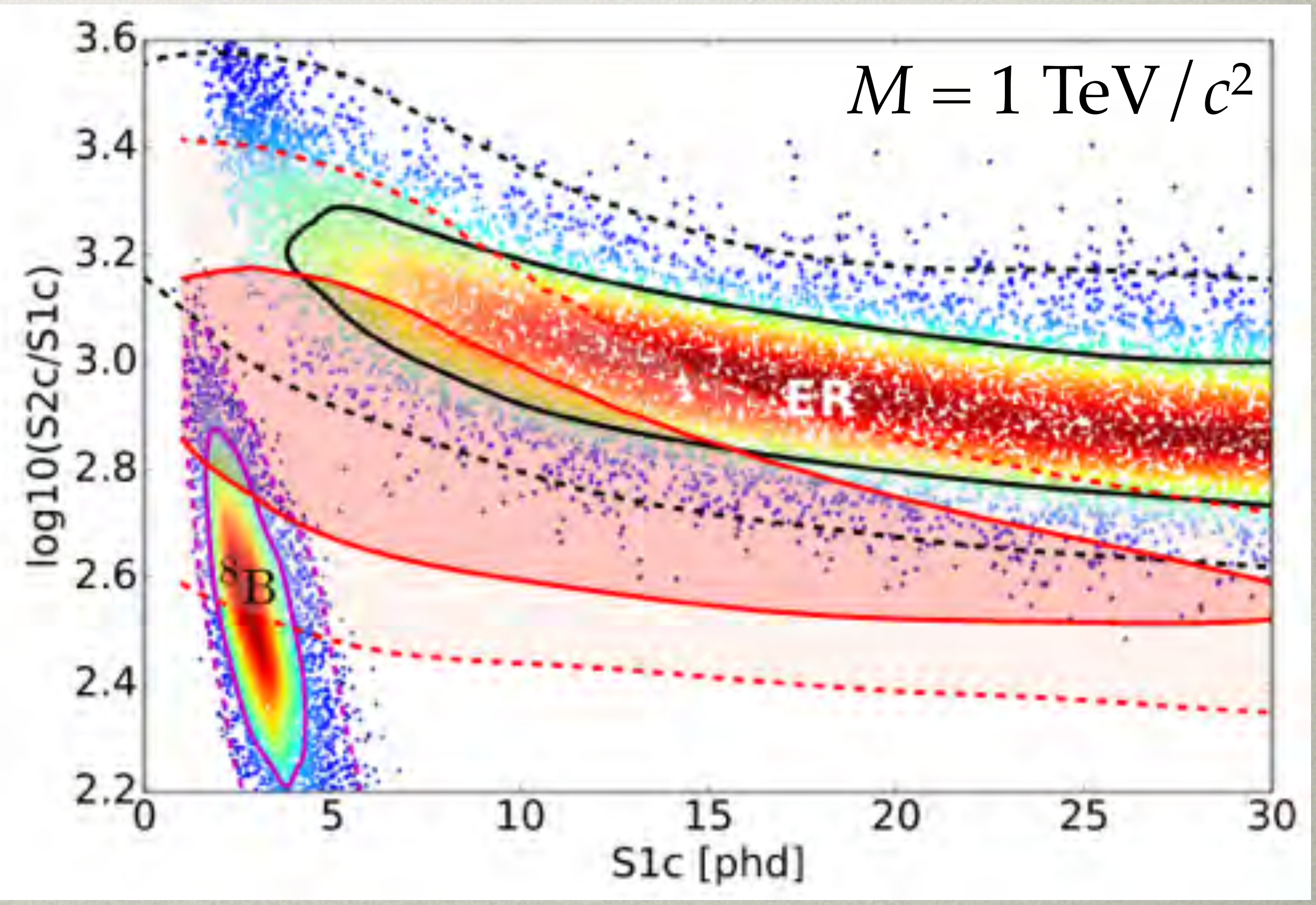
Details in our Technical Design Report: arXiv/1703.09144



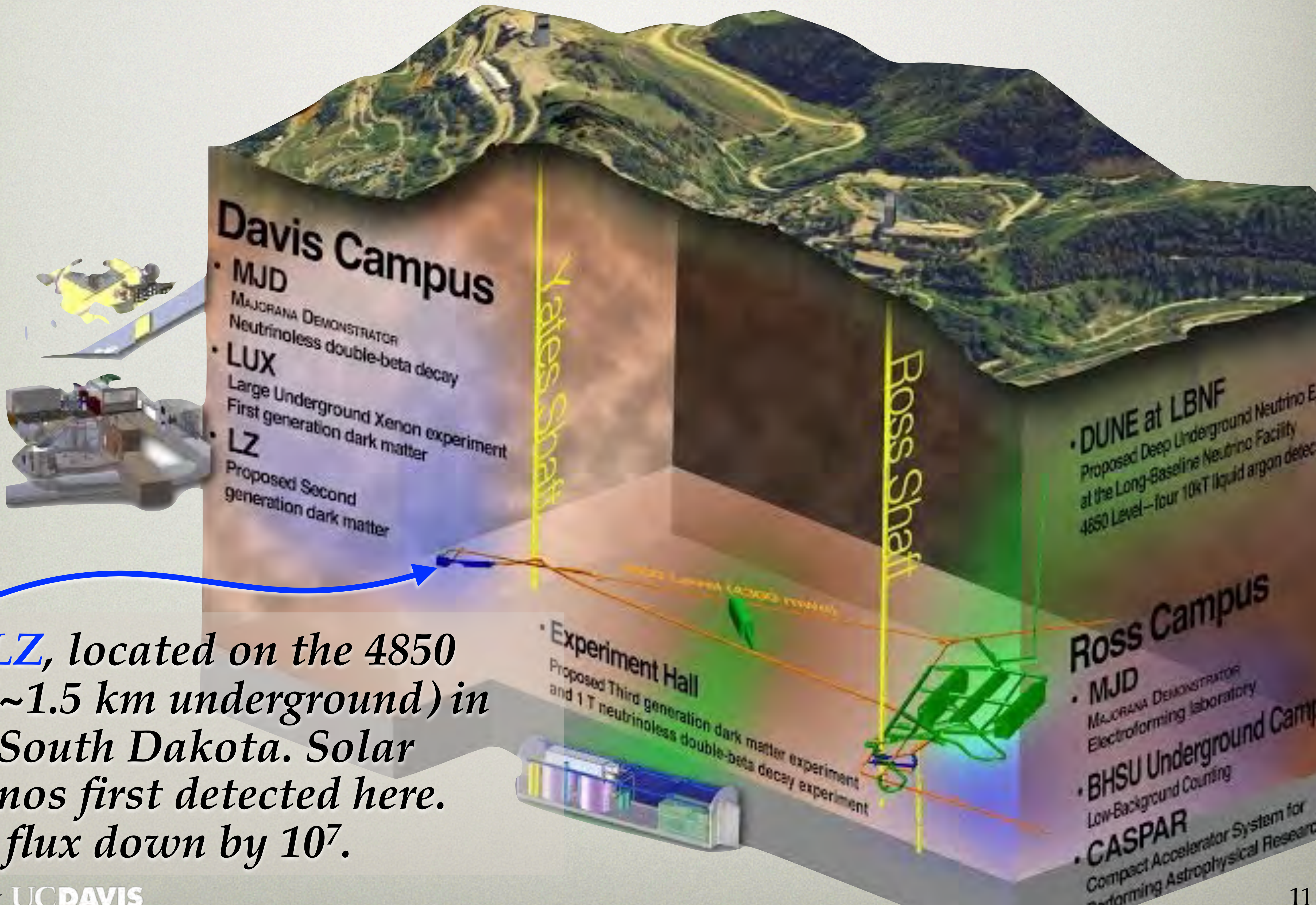
WIMPs: expected signal

- Majority of BG is from electronic recoils (ER).
- WIMPs detected via nuclear recoils (NR).
- ER and NR have different S1/S2 ratio.
- Shape of observed spectrum gives info on WIMP mass.
- Low mass sensitivity affected by NR from ^{8}B solar neutrinos (7±3 events in 1000d).





Sanford Underground Research Facility



***LUX/LZ**, located on the 4850 level (~1.5 km underground) in Lead, South Dakota. Solar neutrinos first detected here. Muon flux down by 10^7.*

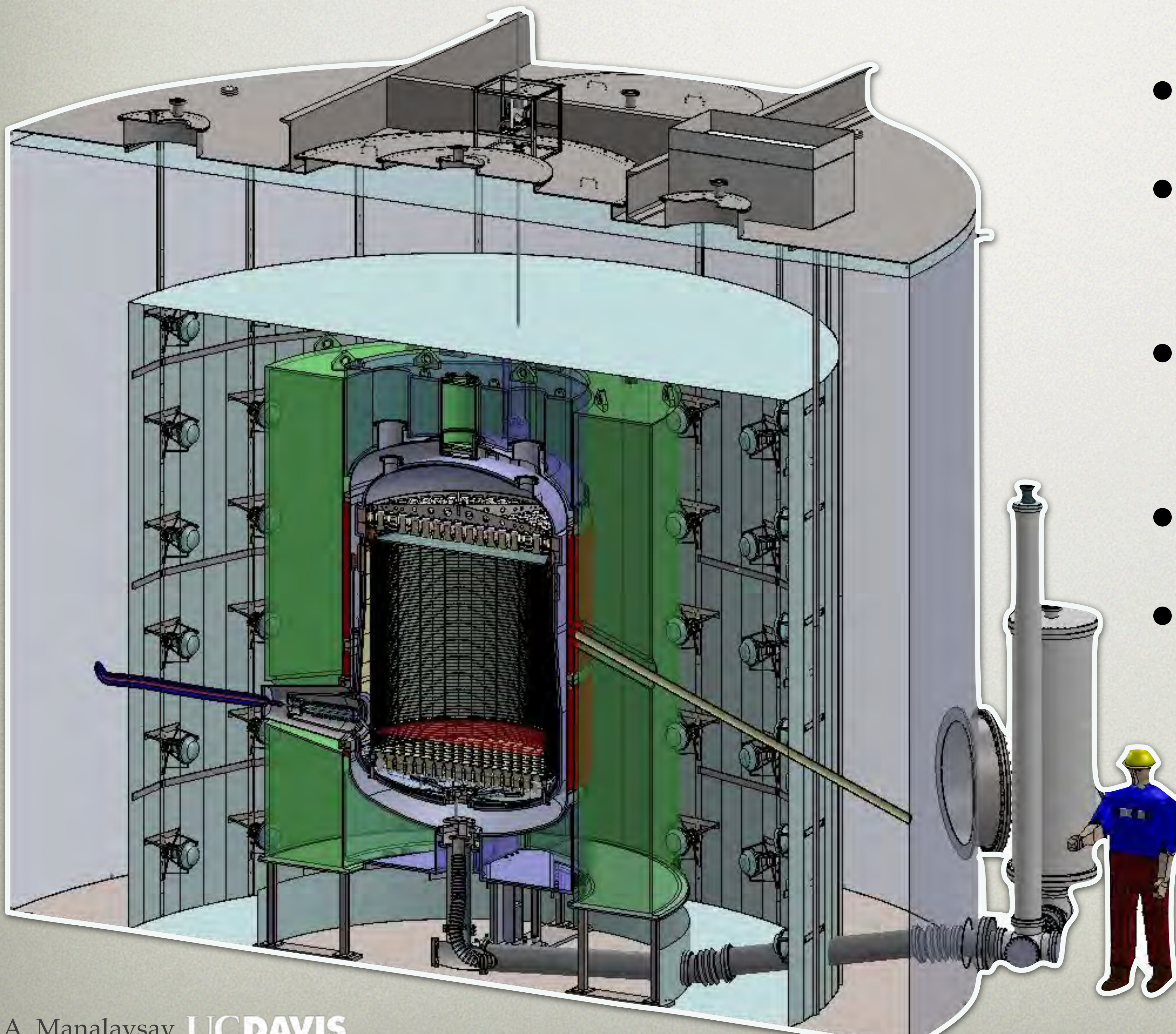
- LZ: factor of ~50 larger fiducial than LUX
- Lower backgrounds

LZ
(inner can)

LUX
(inner can)

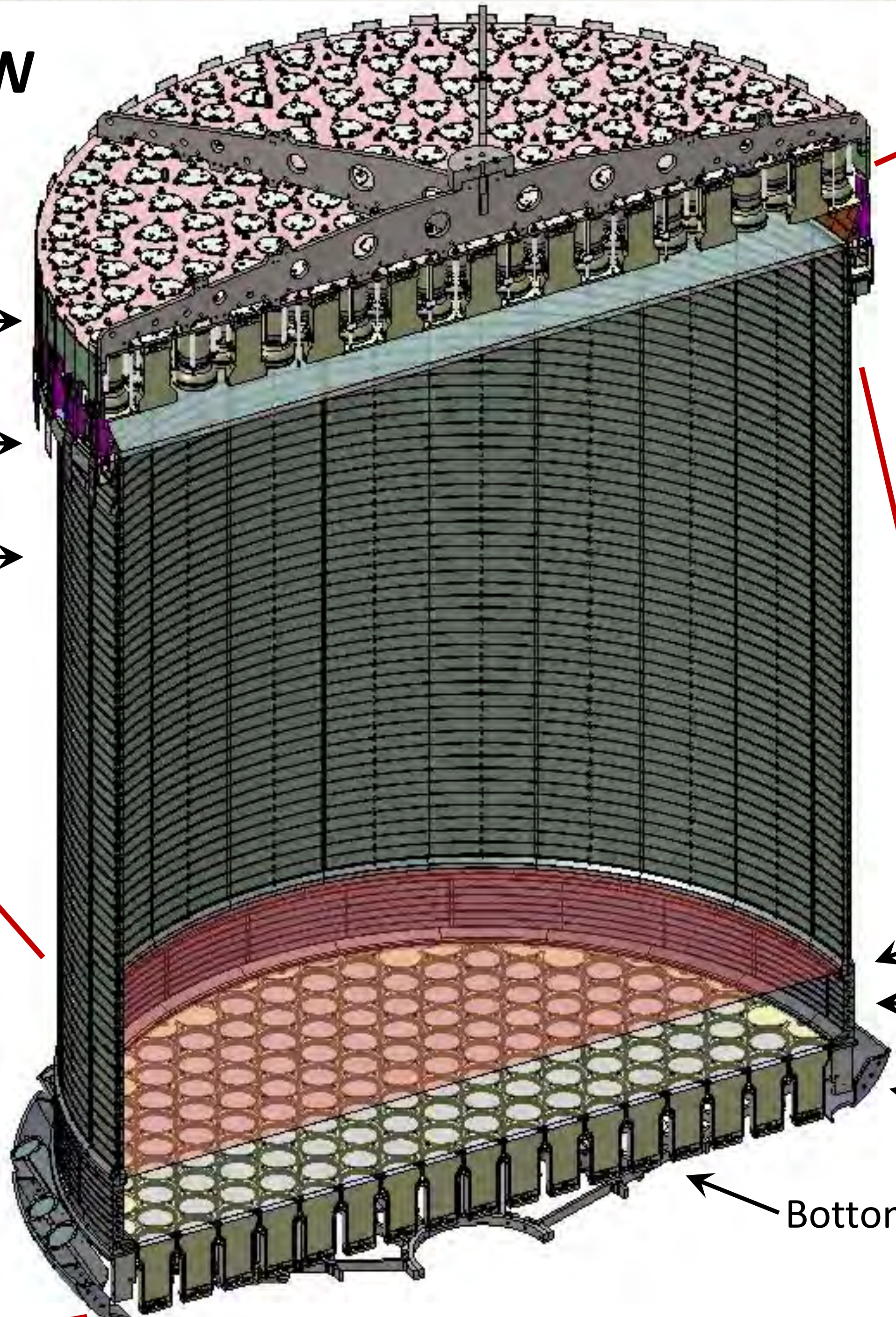
(See talk by L. Tvrznikova)

LZ

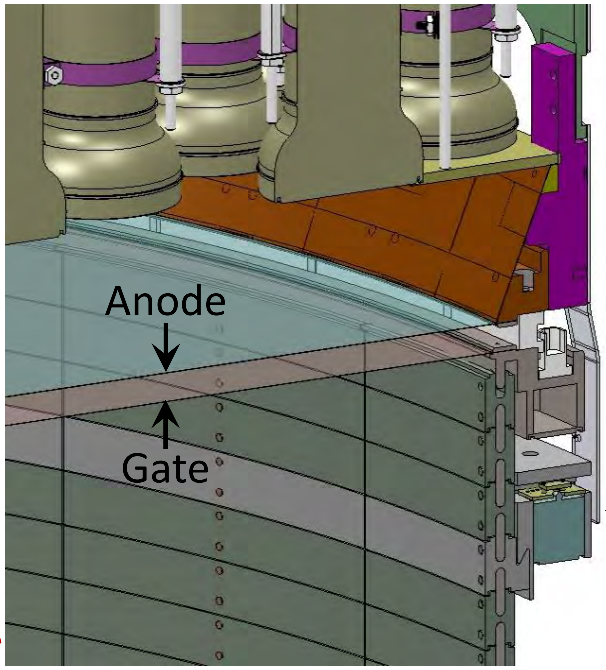


- 7 tonnes active mass.
- Active LXe “skin” veto (outside of TPC)
- Gd-loaded LAB scintillator veto
- LUX’s water shield
- External liquefaction/ purification tower

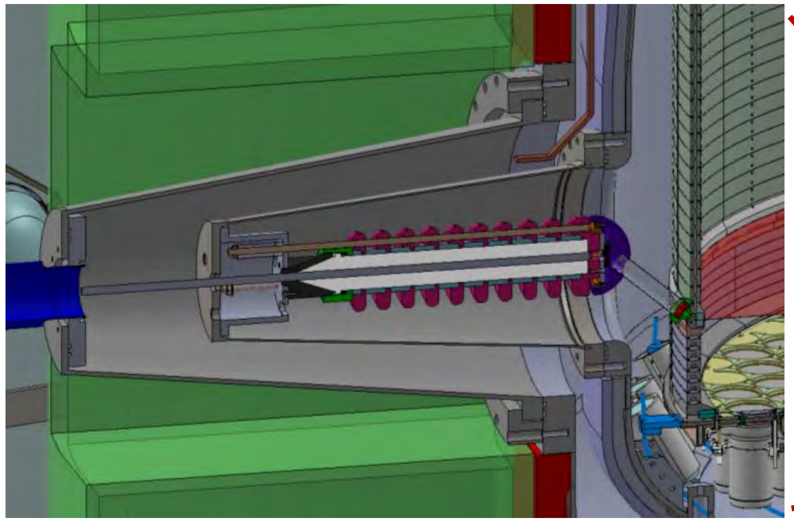
TPC



SECTION VIEW OF LXE TPC
Top PMT array
Side Skin PMTs
TPC field cage
Cathode grid
Reverse-field region
Side skin PMT mounting plate
Bottom PMT array



GAS PHASE AND ELECTROLUMINESCENCE REGION
Anode
Gate
LXe surface
Weir trough
Skin PMT



HV CONNECTION TO CATHODE

Photomultiplier Tubes

Hamamatsu

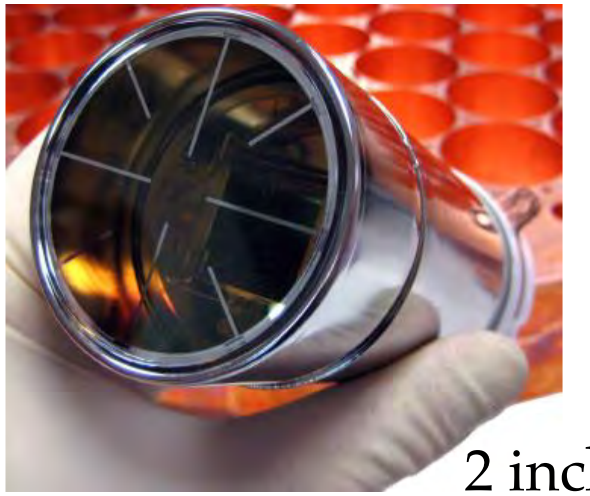
R11410

3 inch

R8520

1 inch

R8778 (recycled from LUX)



2 inch

Main TPC

Xe "skin" veto

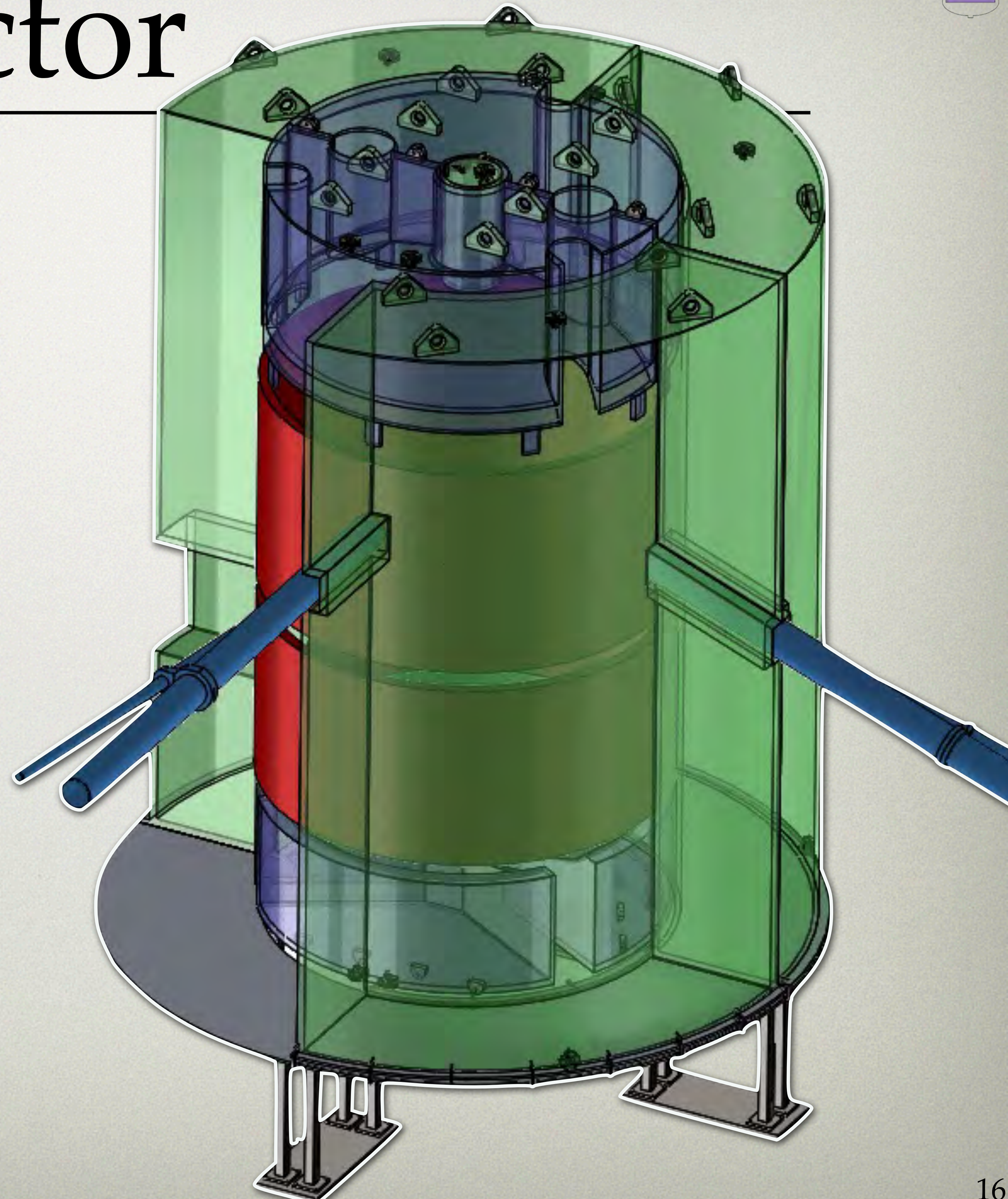
R5912

8 inch

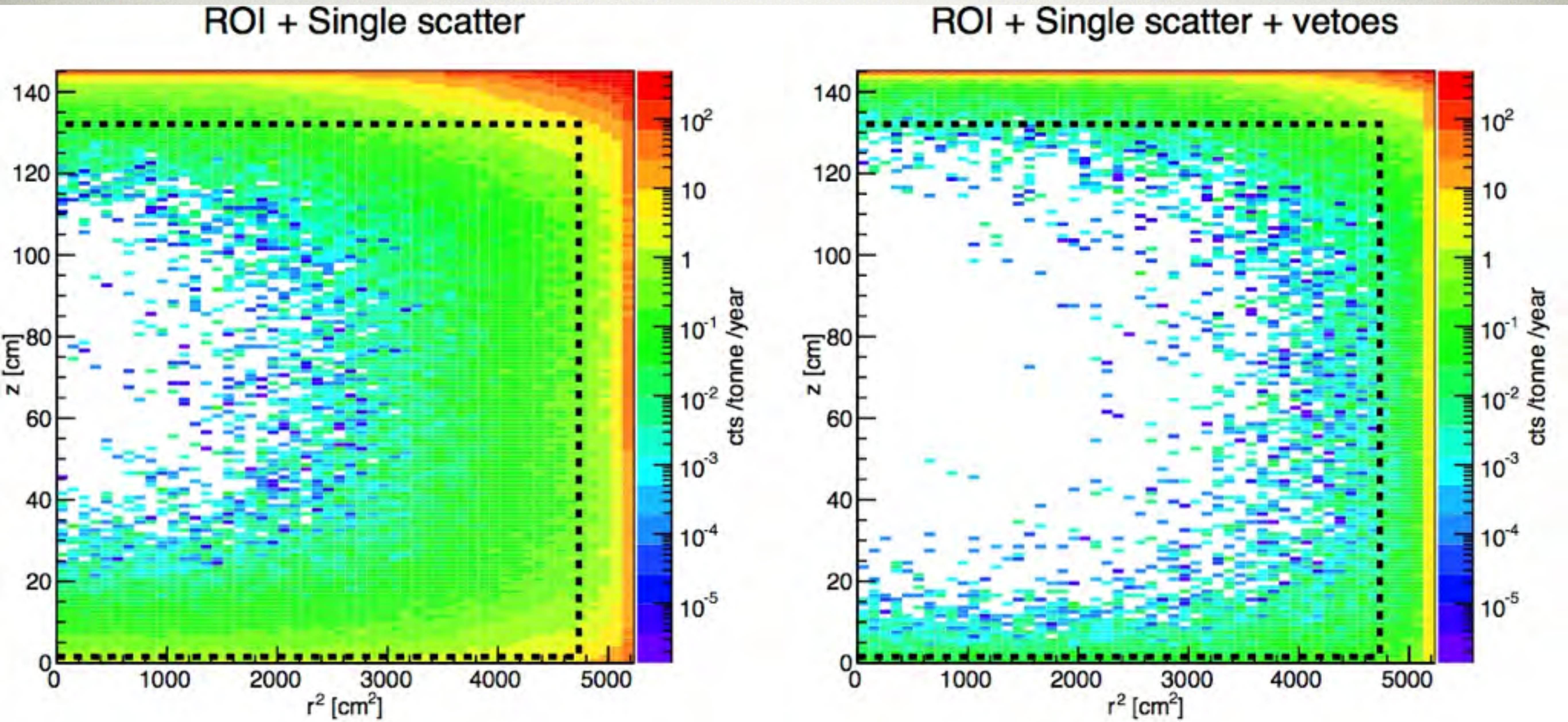
Scintillator veto

Outer detector

- Gd-doped LAB liquid scintillator.
- Neutron and gamma veto.
- 4π coverage
- Cutouts for cryogenics, electronics, neutron tubes, HV
- Screener vessel already deployed in LUX water shield, good results.



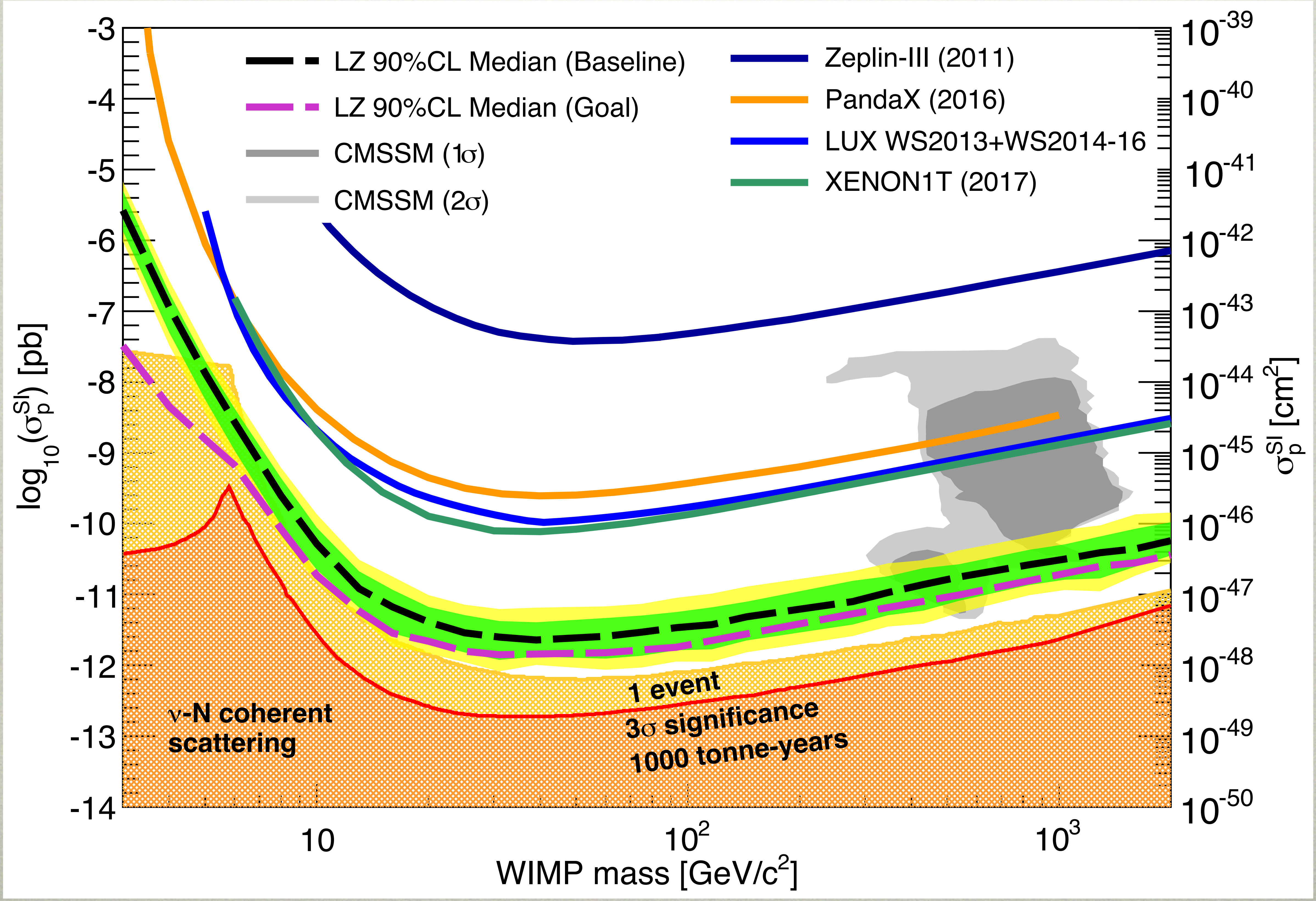
Backgrounds



No vetoes

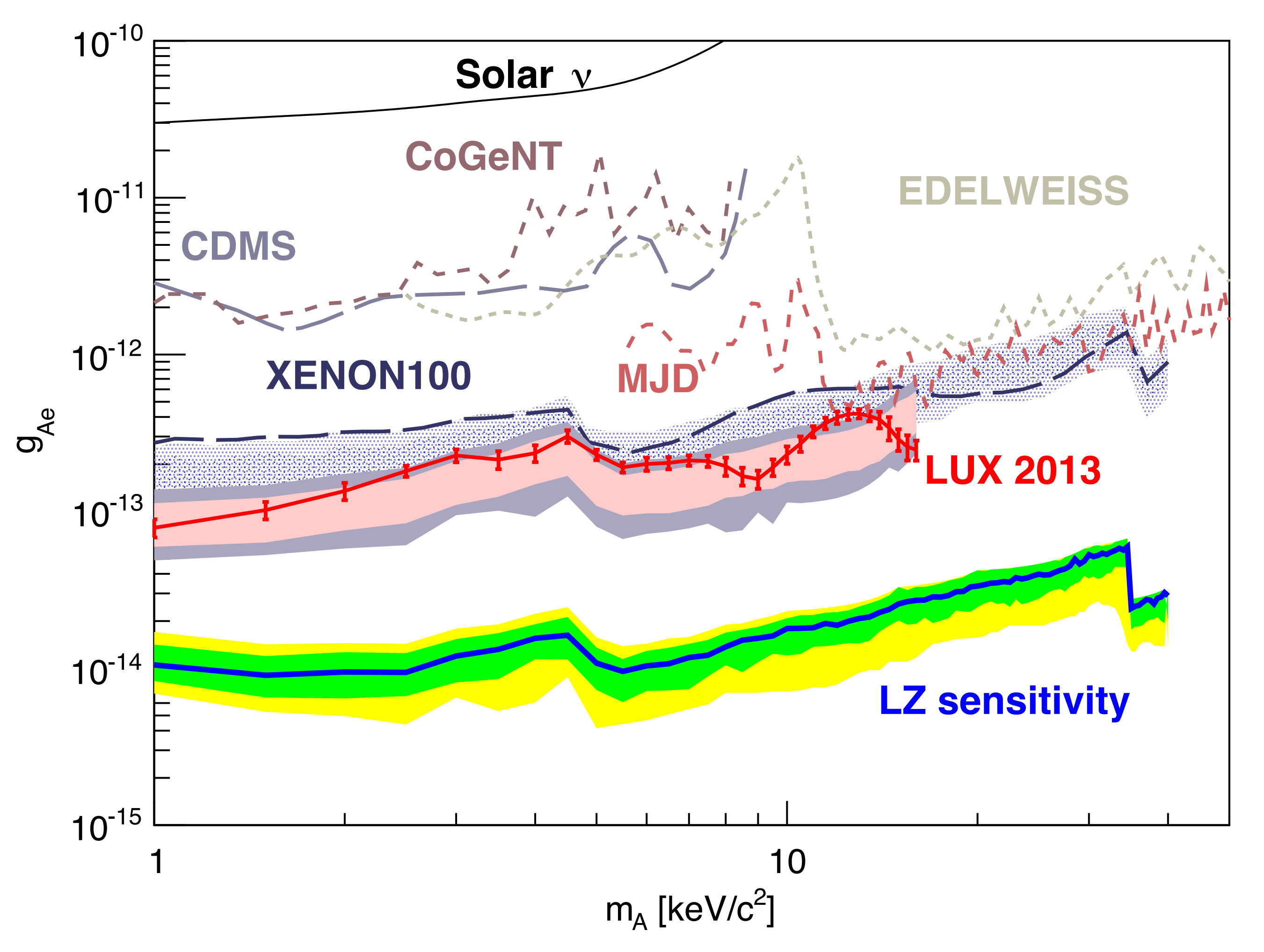
With vetoes (LXe skin and liquid scint.)

Scientific Reach — Standard WIMPs

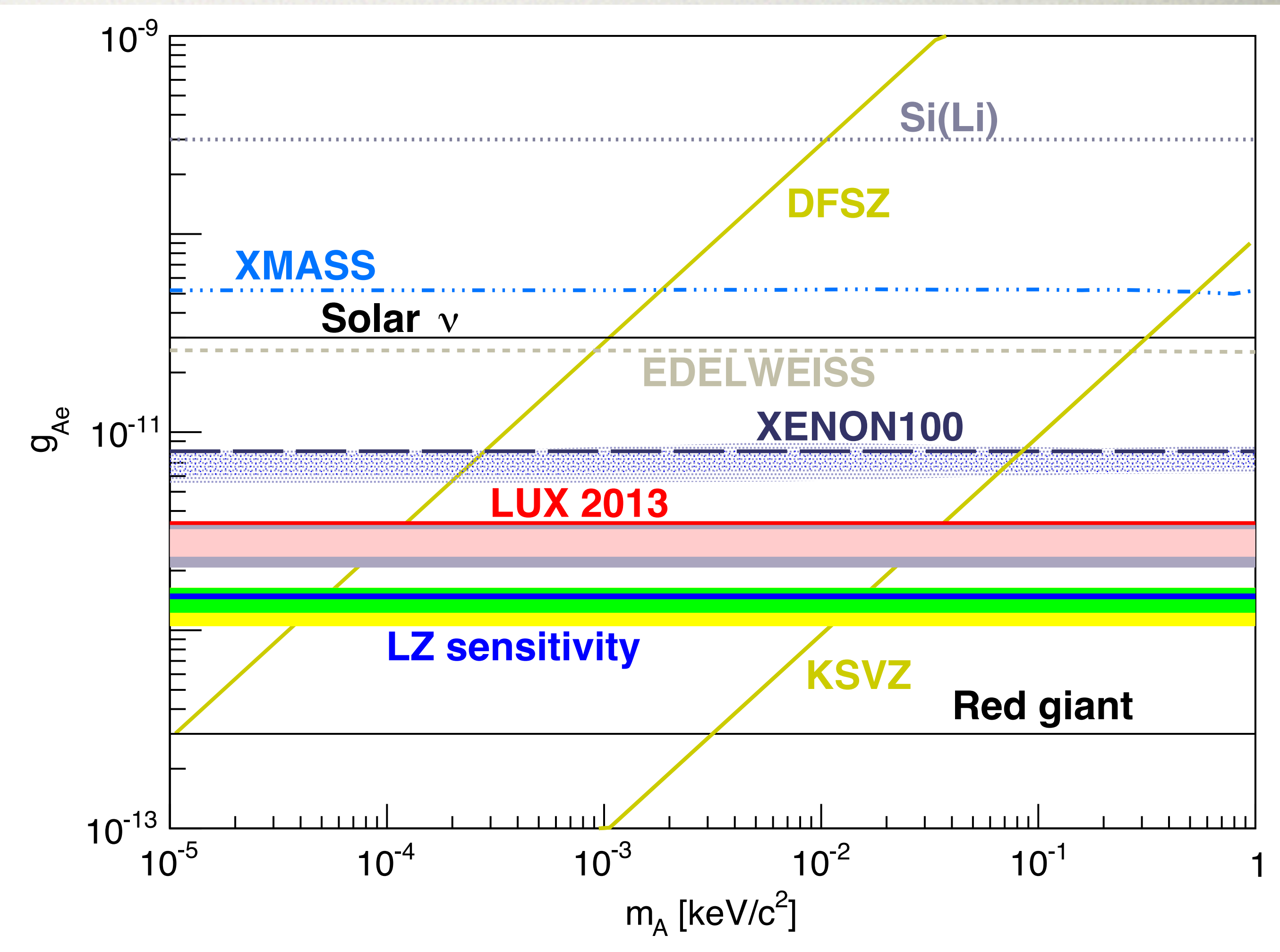


Scientific Reach — Axions and ALPs

DM ALPs



Solar axions



Summary

- Noble-liquid TPCs leading the field in WIMP sensitivity
- LZ is the successor to ZEPLIN and LUX. 7 tonnes LXe (5.6 tonnes fiducial)
- LZ will reach sensitivity of 2.3×10^{-48} cm^2 for SI WIMP-nucleon interactions. Other dark-matter results expected as well.
- LZ is at an advanced stage. Construction already begun, planning for first signals in 2019.

Backup

Backgrounds

	Projected counts in 1000d	
Source	**ER**	**NR**
Material contamination	6.22	0.07
Contam. in LXe*	916	0.43
Physics backgrounds**	322	0.72
Total (raw)	1240	1.22
Total (99.5% ER rej., 50% NR acc.)	**6.2**	**0.61**

* Mostly radon

** Astrophysical neutrinos, $2\nu\beta\beta$ from ^{136}Xe