Expected Background in the LZ Experiment

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on behalf of the LZ Collaboration

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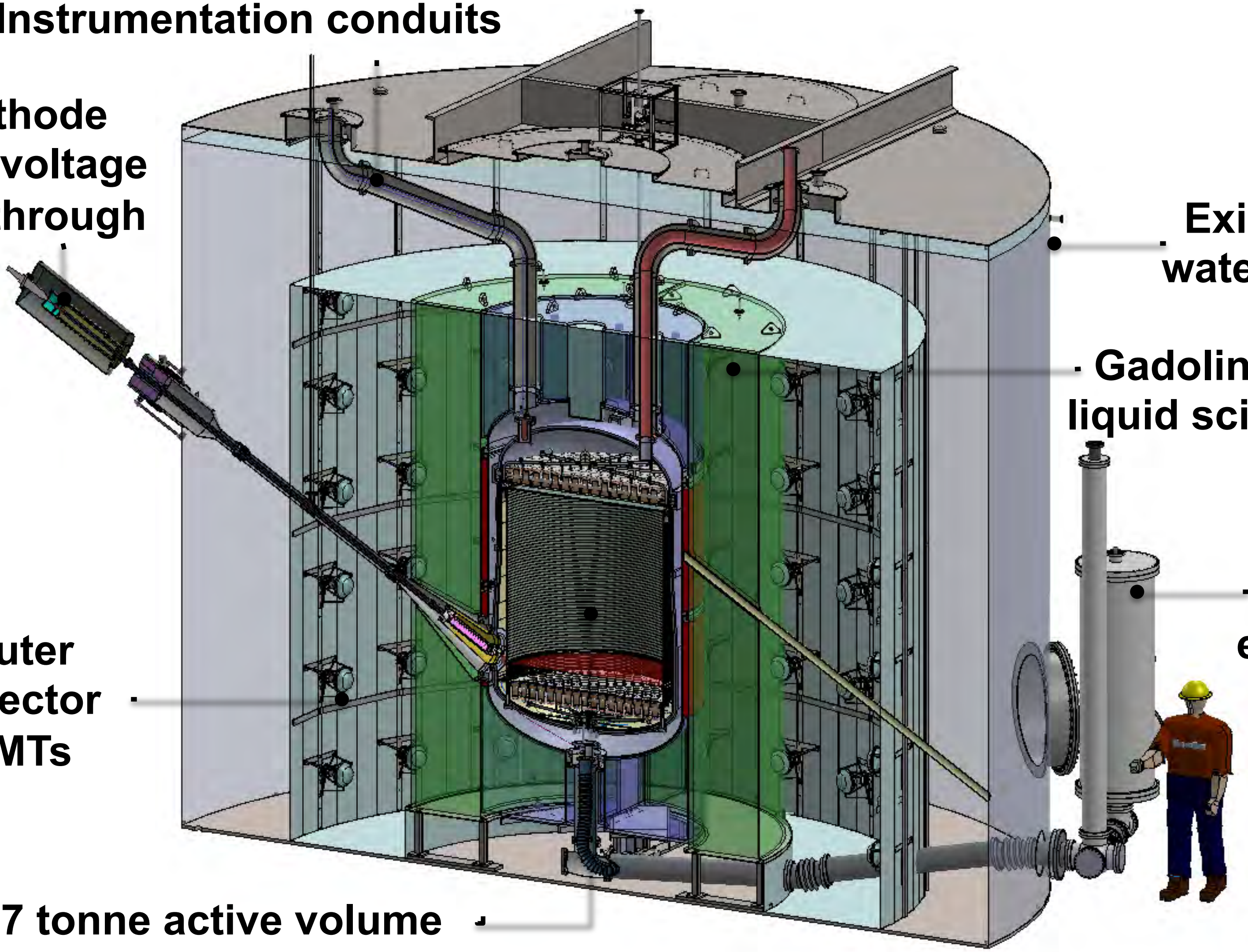
LZ Detector Overview



Selected Experimental Challenges

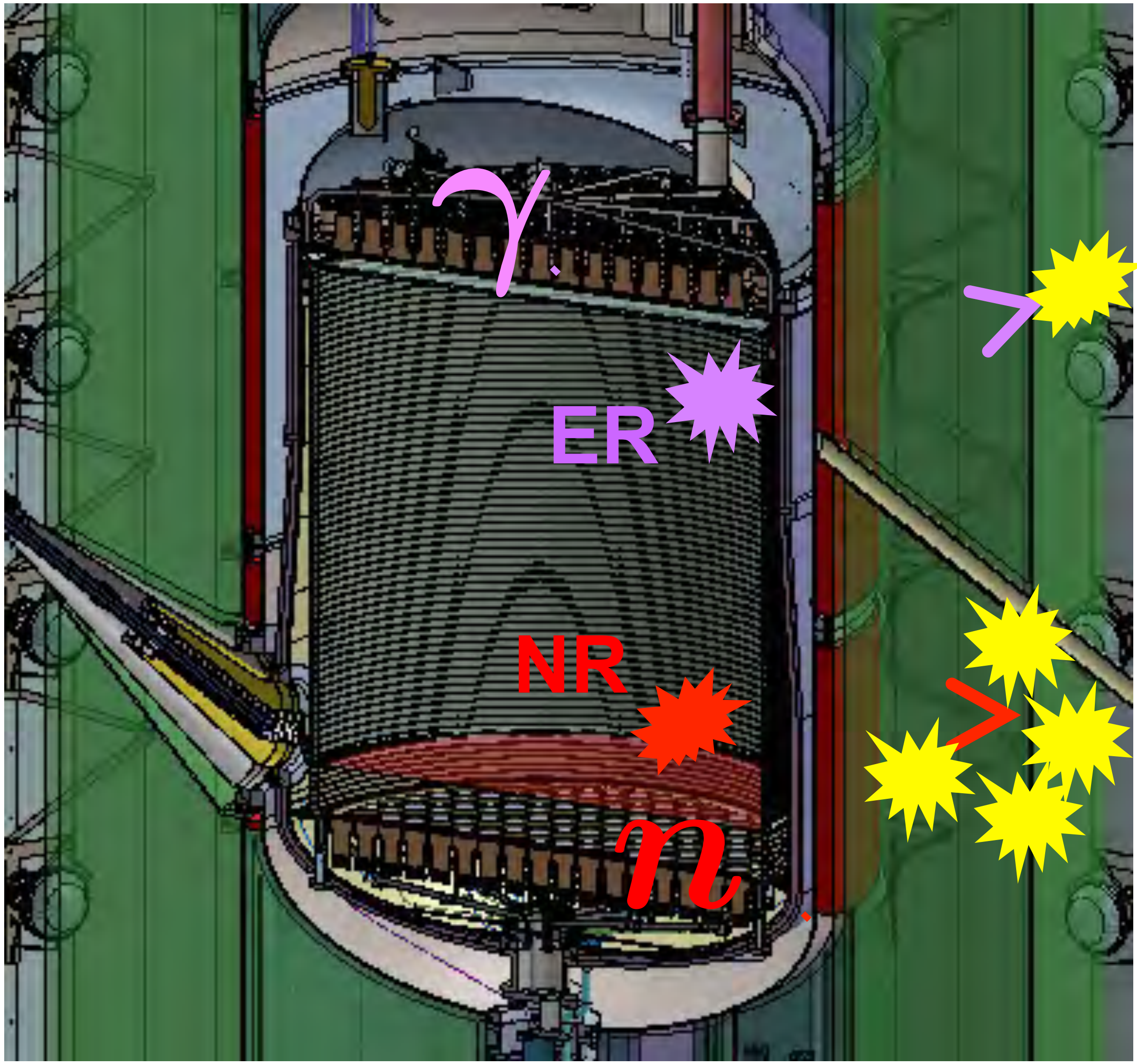
- **Backgrounds, backgrounds, backgrounds:**
  - External (PMT, Cryostat, etc.): select materials carefully
  - Internal (Kr + Rn): Kr removal by charcoal chromatography
  - Cosmogenic+Laboratory: experiment deep underground
  - Irreducible: double beta decay, solar+atm. neutrinos

- **Maximize WIMP target mass:**
  - Self-shielding necessary (Xe100-LUX: fiducial fraction ~1/2)
  - Veto and LXe skin have a role in expanding fiducial region

- **ER and NR Calibrations:**
  - Self-shielding complicates matter: source injections
  - LUX: unprecedented accuracy for ER/NR response
  - LZ sensitivity estimates based on precise calibrations

Backgrounds – Detector Materials

Populate edges: Skin and Outer detector tag



External Backgrounds

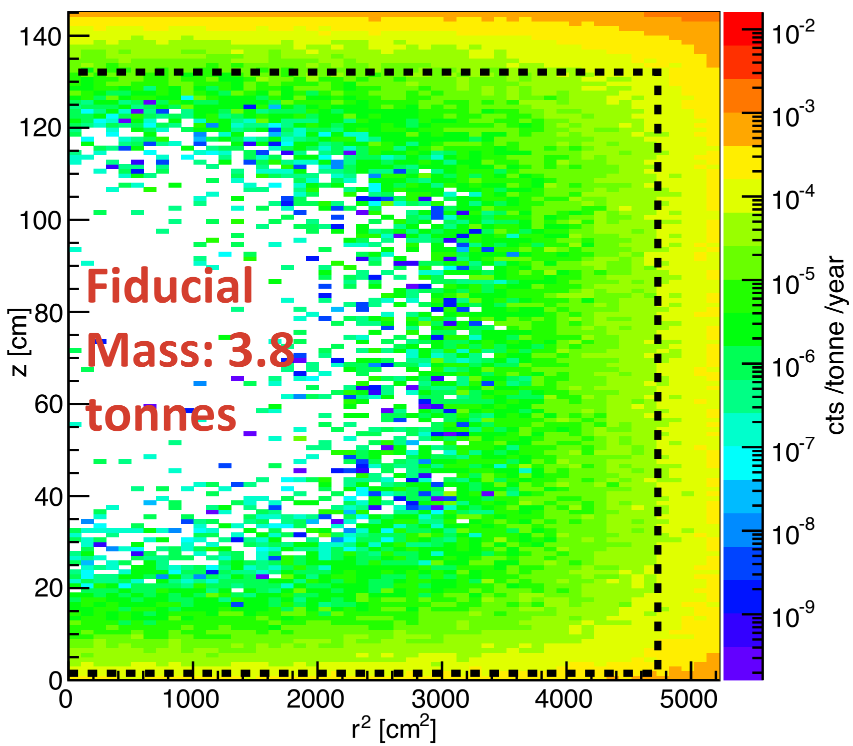
- Activity intrinsic to the detector construction materials
  - Main concerns: PMTs, PMT Bases, Cryostat, and PTFE
  - Goal: External Backgrounds <10% of Physics Backgrounds
  - Comprehensive material screening program complete: all components at or below goals (see K. Oliver-Mallory's talk)
- Complete simulations of External Backgrounds:
  - Simulation chain based on LZSim (Geant4-framework)
  - Detector geometry updated to latest engineering model
  - Each contaminant estimated from assay results
  - S1/S2 response modeled using NEST-based simulations

How to maximize the WIMP target mass?

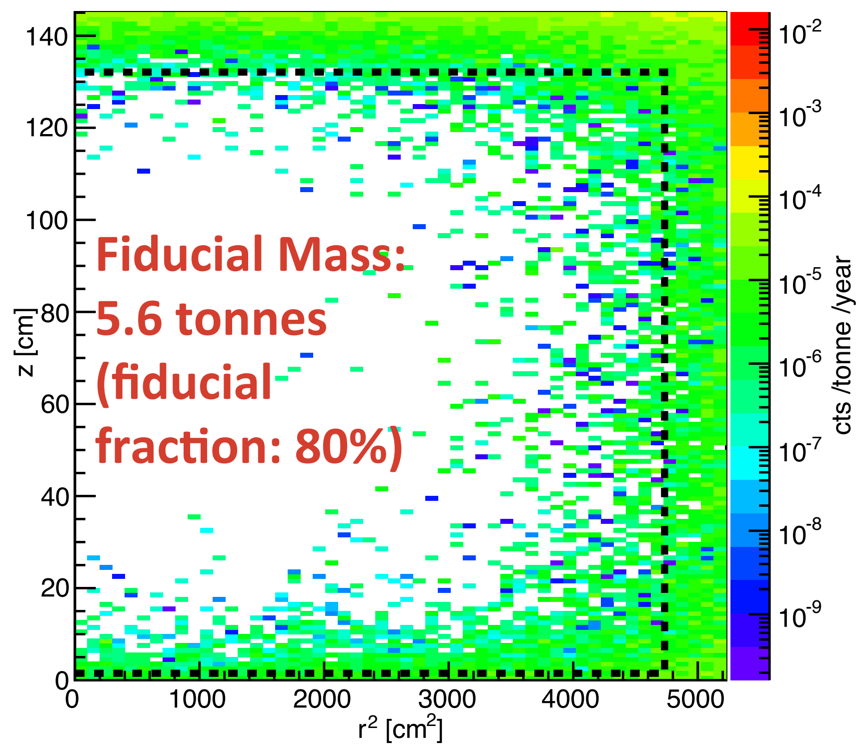
- **Two-component outer detector:**
  - **0.61 m thick Gd-loaded scintillator**
  - **instrumented Xenon “skin”**

Tag neutrons and gammas!

Single NR scatter in TPC



Vetoed by Gd-LS and Skin



External Backgrounds

- **Expected counts in 1,000 live days in an indicative 5.6-tonne fiducial mass in [1.5-6.5] keV_{ee} (ER) and [6-30] keV (NR):**

Item	Mass kg	U mBq/kg	Th mBq/kg	^{60}Co mBq/kg	^{40}K mBq/kg	n/yr	ER cts	NR cts
R11410 PMTs	90.8	3.78	3.40	2.85	17.17	79	2.11	0.010
R11410 bases	2.60	76.3	30.5	2.33	82.6	44	0.36	0.003
TPC PTFE	275	0.02	0.03	≈ 0	0.12	34	0.08	0.010
Cryostat vessels	2406	0.11	0.25	0.07	0.56	124	0.53	0.010
Other components	-	-	-	-	-	14946	9.59	0.040
Total components (Before S2/S1 discrimination)							12.7	0.073

Backgrounds – Uniform through volume

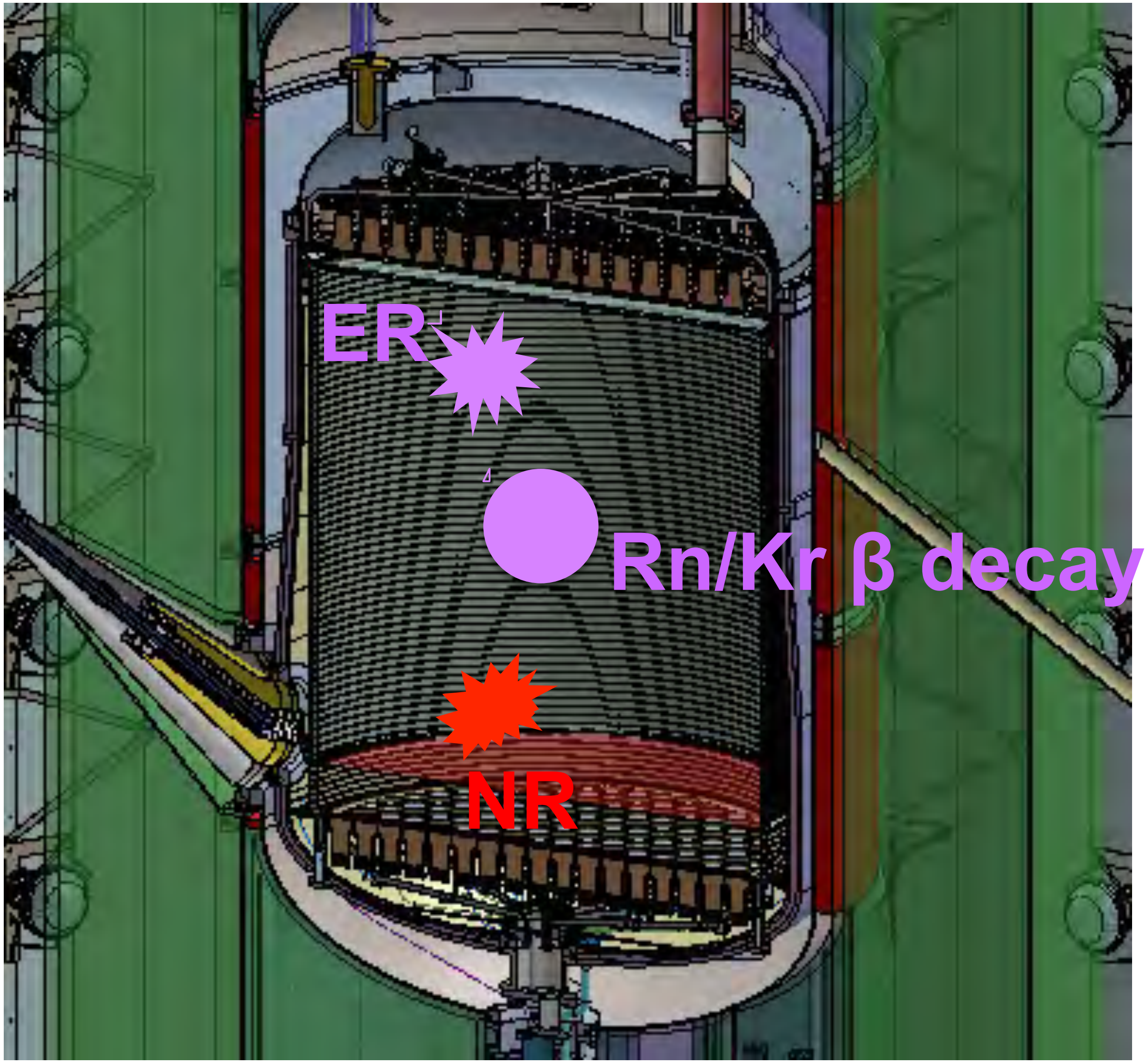
ν

Solar (pp)

ν

Solar (^{8}B)

Atmospheric, SN



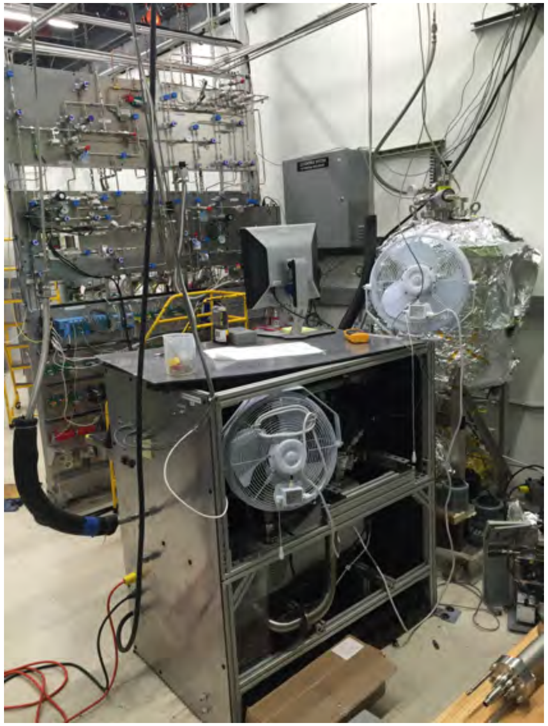
Neutrino Backgrounds

- Elastic ν-e interactions from Solar neutrinos:
  - Sources: pp, ^{7}Be, ^{13}N (signal is an ER recoil)
- Coherent elastic ν-A interactions (irreducible background):
  - Solar Neutrinos: ^{8}B (below nominal threshold) and hep
  - Atmospheric and diffuse supernova neutrinos
- Expected counts in 1,000 live days in an indicative 5.6-tonne fiducial mass in [1.5-6.5] keV$_{ee}$ (ER) and [6-30] keV (NR):

Item	Mass kg	U mBq/kg	Th mBq/kg	^{60}Co mBq/kg	^{40}K mBq/kg	n/yr	ER cts	NR cts
^{136}Xe $2\nu\beta\beta$							67	0.00
Astrophysical ν counts (pp + ^{7}Be + ^{13}N)							255	0.00
Astrophysical ν counts (^{8}B)							0.00	0.00
Astrophysical ν counts (hep)							0.00	0.21
Astrophysical ν counts (diffuse supernova)							0.00	0.05
Astrophysical ν counts (atmospheric)							0.00	0.46
Subtotal (Physics backgrounds) (Before S2/S1 discrimination)							322	0.72

Uniform ER Internal Backgrounds

- Kr, Ar requirement: 0.015 ppt (g/g) ^{nat}Kr, 0.45 ppb (g/g) ^{nat}Ar
  - Demonstrated 2-pass ^{nat}Kr reduction at 10^9 (10^7 required)
  - Kr removal process also efficient at eliminating Ar
- Gas charcoal chromatography system @ SLAC



Gas system, pumps, column

Condenser

Sampling System

Uniform ER Internal Backgrounds

- Kr, Ar requirement: 0.015 ppt (g/g) ^{nat}Kr, 0.45 ppb (g/g) ^{nat}Ar
  - Demonstrated 2-pass ^{nat}Kr reduction at 10^9 (10^7 required)
  - Kr removal process also efficient at eliminating Ar
- Radon requirement: 2.0 μBq/kg ^{222}Rn, 0.2 μBq/kg ^{220}Rn
  - Extensive Rn-assay campaign mapped out and initiated
  - Current requirement extrapolated from other experiments:
    - Total Rn [20 mBq] ≈ achieved by LUX in 380 kg
    - Rn concentration [2 μBq/kg] ≈ achieved by EXO200
- Surface Contamination: Radon Daughters (^{210}Pb) and dust
  - Concerns: ^{210}Pb on PTFE and dust on all TPC surfaces
  - LZ requirement: 500 ng/cm^2 (goal: 5 ng/cm^2)
    - Compare with other experiments: EXO 70 ng/cm^2, SNO 20 ng/cm^2, Borexino 1 ng/cm^2

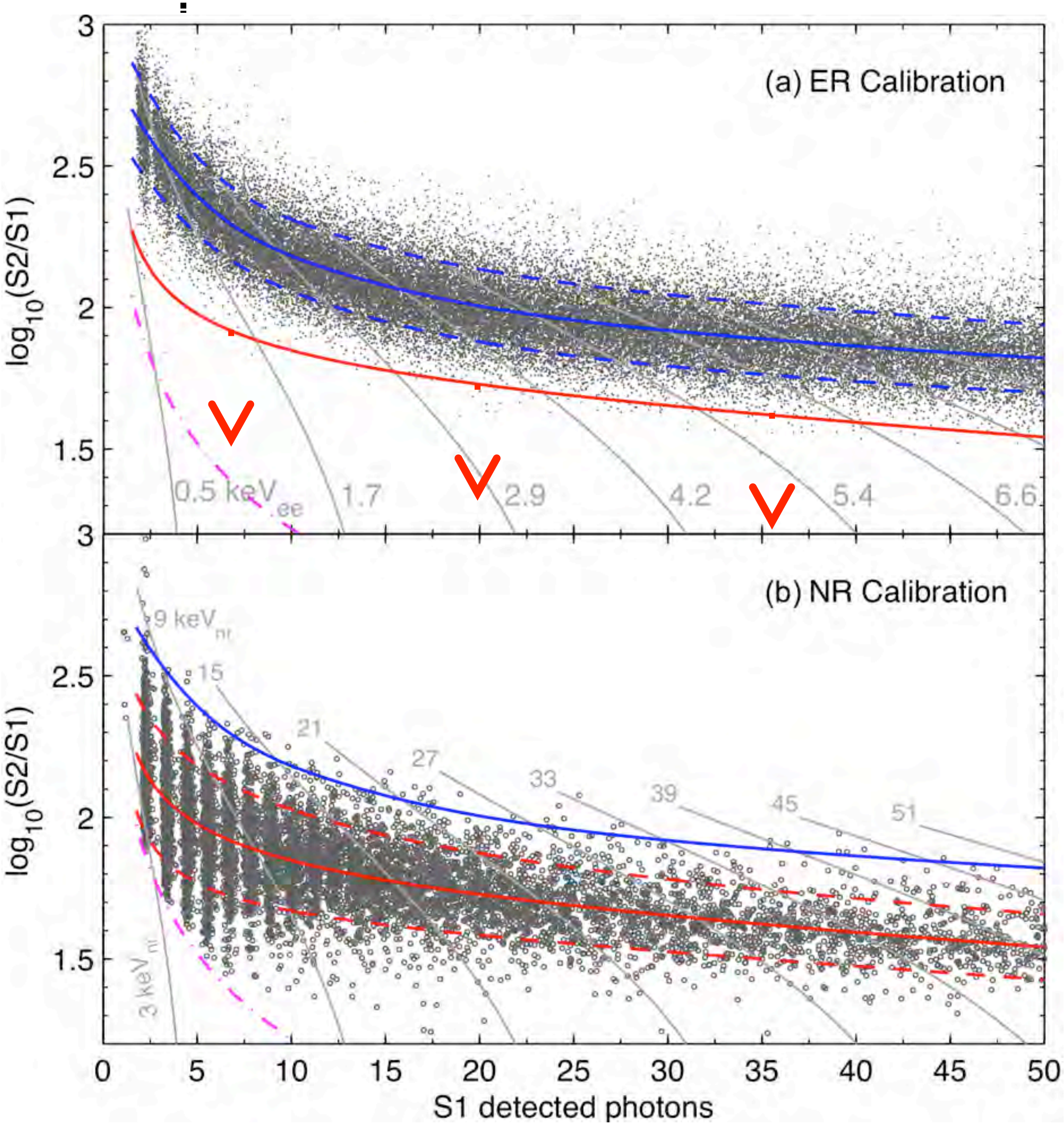
Uniform ER Internal Backgrounds

- **Expected counts in 1,000 live days in an indicative 5.6-tonne fiducial mass in [1.5-6.5] keV$_{ee}$ (ER) and [6-30] keV (NR):**

Item	Mass kg	U mBq/kg	Th mBq/kg	^{60}Co mBq/kg	^{40}K mBq/kg	n/yr	ER cts	NR cts
^{222}Rn (2.0 μBq/kg)	-	-	-	-	-	-	783	-
^{220}Rn (0.2 μBq/kg)	-	-	-	-	-	-	129	-
^{nat}Kr (0.015 ppt g/g)	-	-	-	-	-	-	24.5	-
^{nat}Ar (0.45 ppb g/g)	-	-	-	-	-	-	2.47	-
Dispersed radionuclides (Rn, Kr, Ar) (Before S2/S1 discrimination)							938	-

- **PLR analysis: very powerful at rejecting these backgrounds**

High Statistics Calibrations from LUX

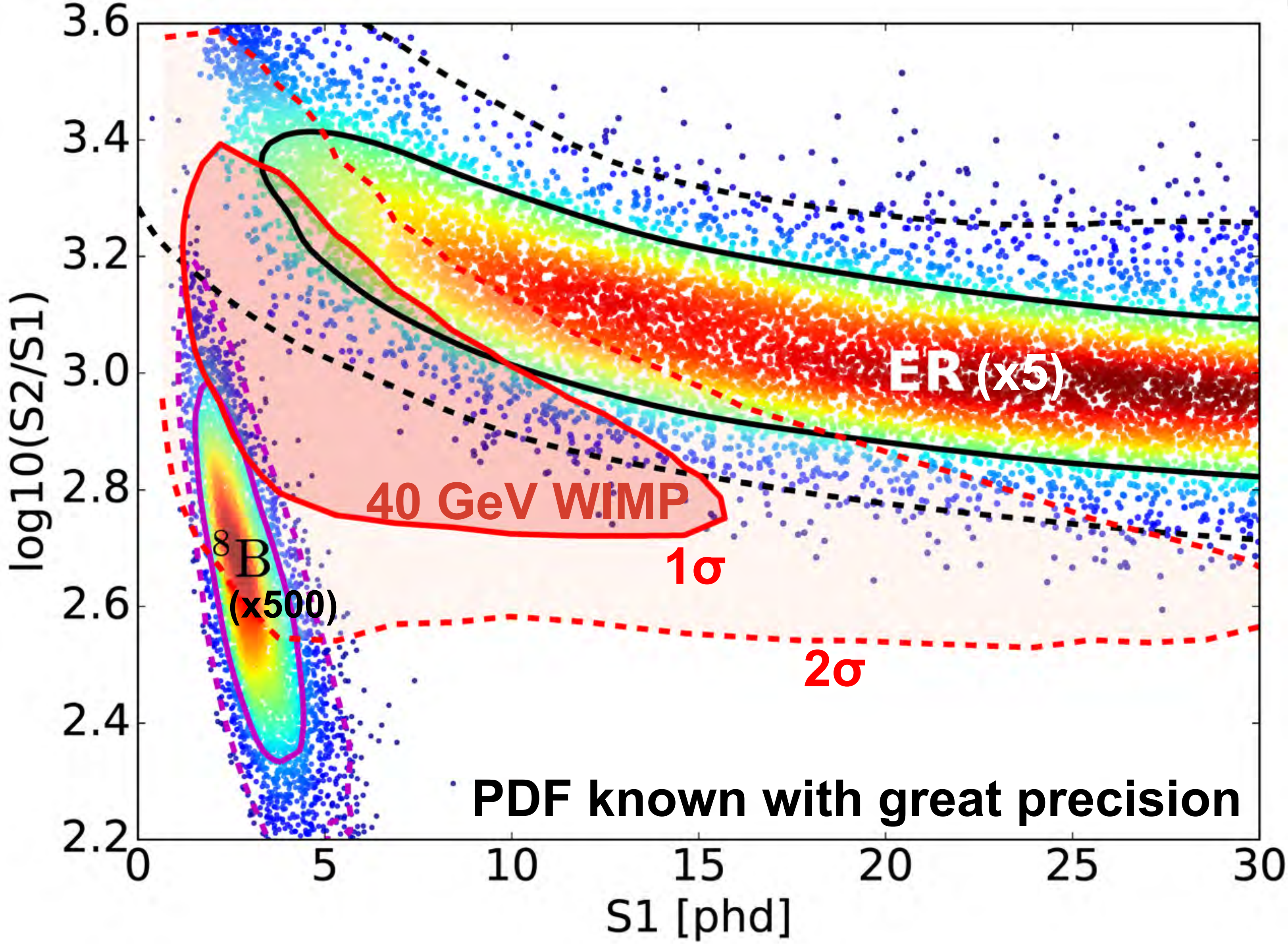


Electron Recoil (ER) (Tritiated methane)

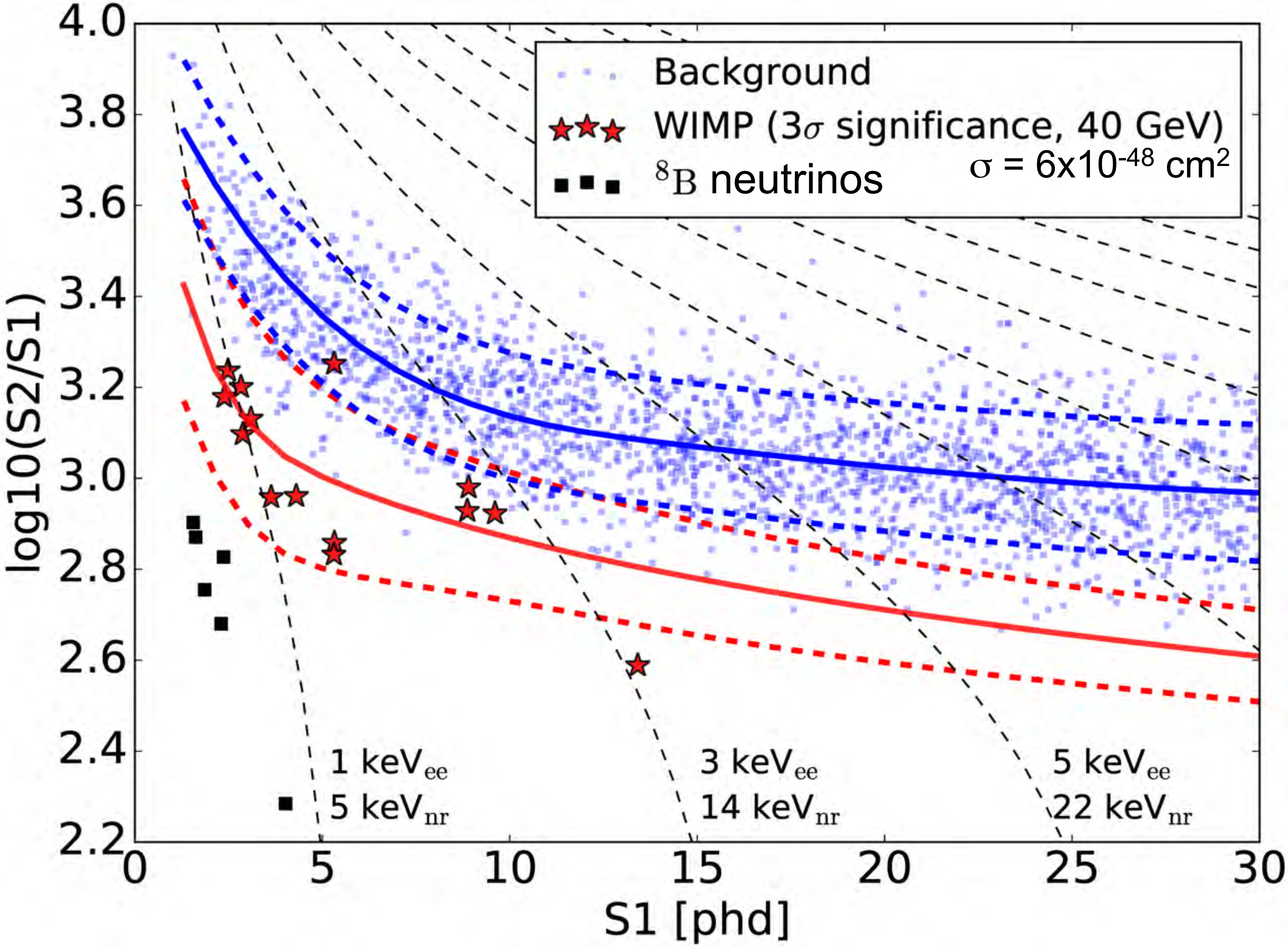
Nuclear Recoil (NR) (DD neutron gun)

Build PDF for signal & background with unpreced. precision

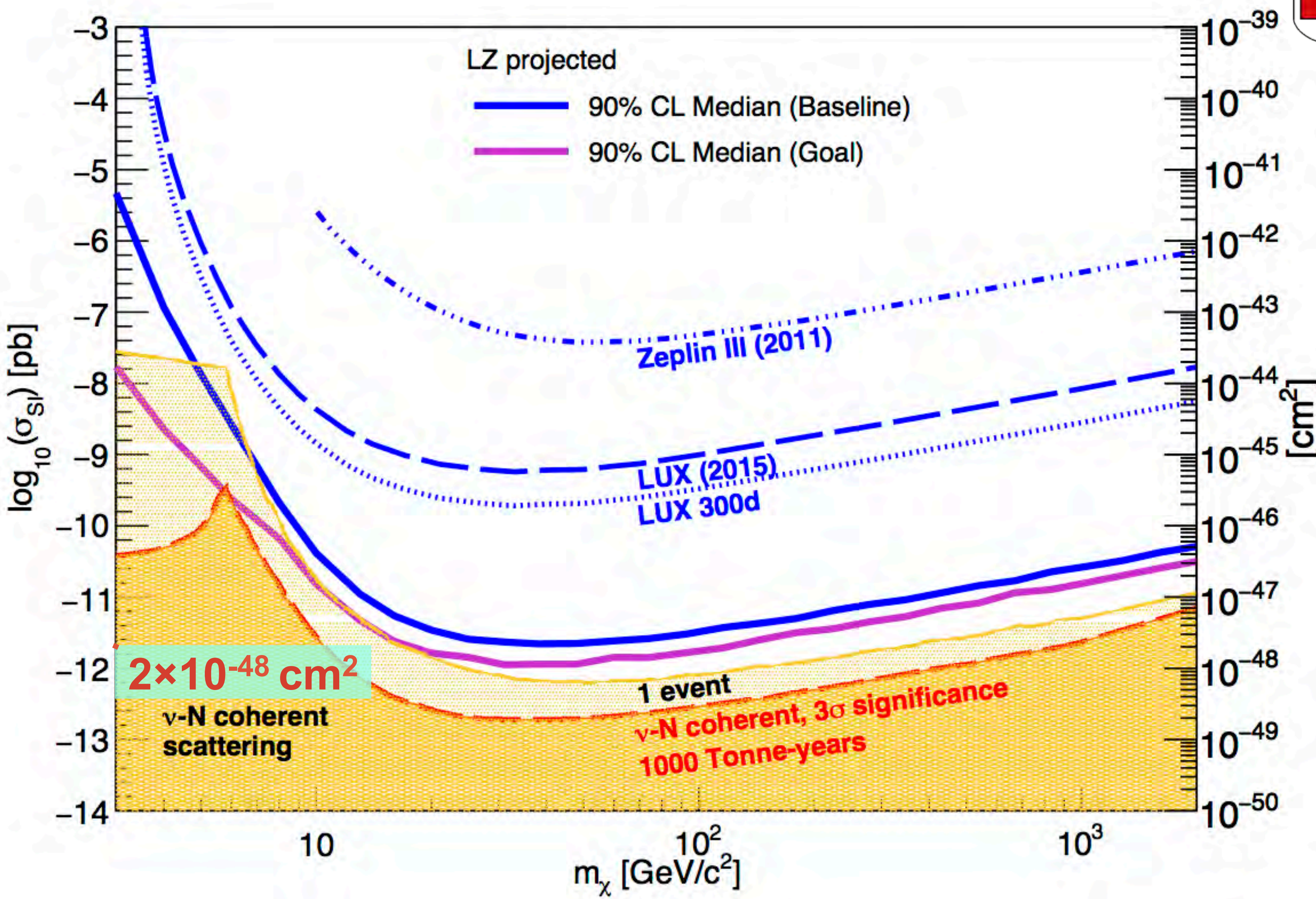
WIMP Signal Region in LZ



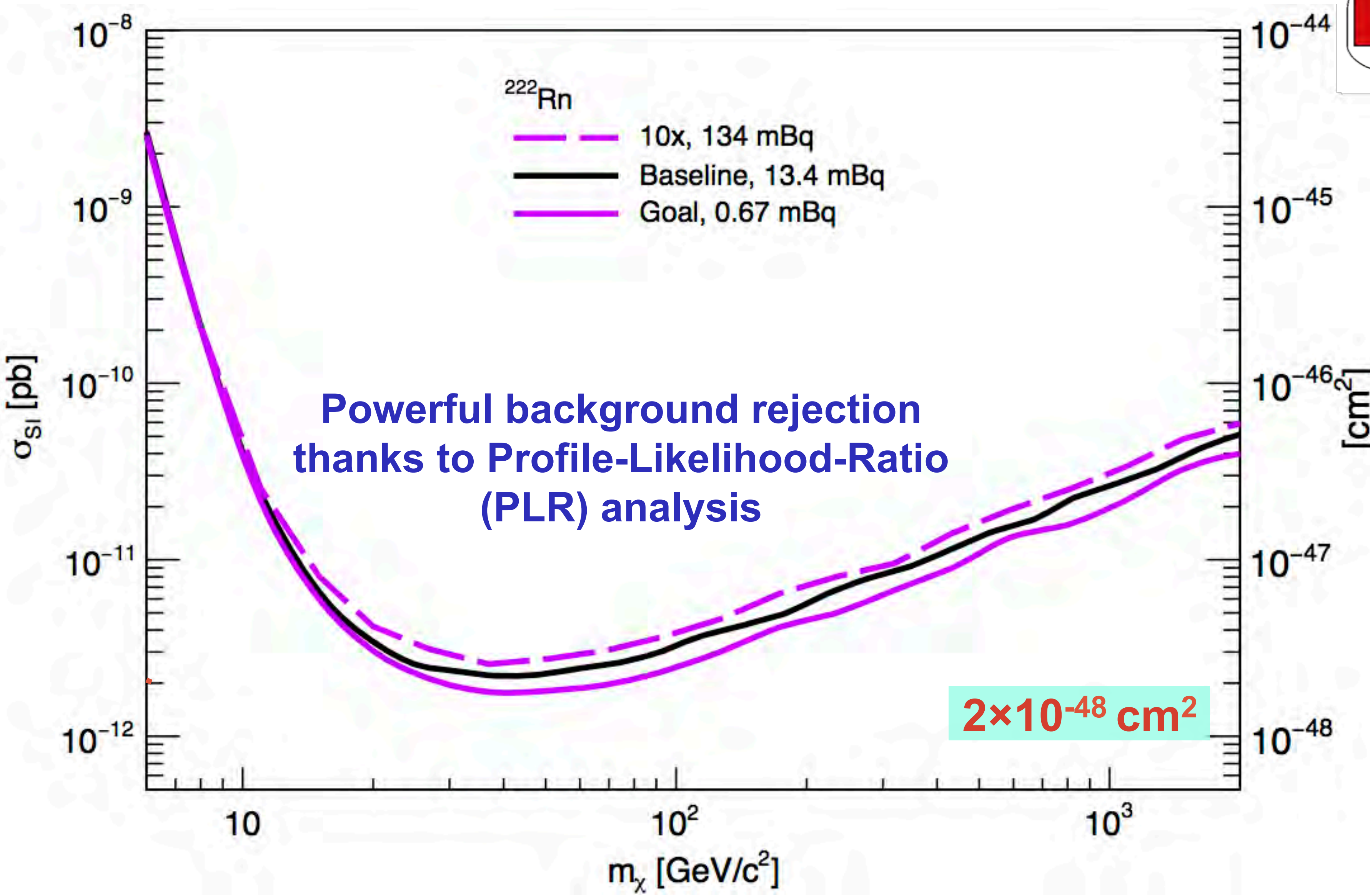
1,000 days of simulated LZ (5.6 T)



Projected Sensitivity: Spin Independent



Hypothetical ^{222}Rn Scenarios



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

2×10^{-48} cm^2

Sensitivity estimate is very robust!

Conclusions

- **LZ material screening complete:**
  - **All components are at or below goals**
- **Irreducible NR background, dominated by solar and atmospheric neutrinos**
  - **PLR can still help with ^{8}B neutrinos**
- **Background estimates dominated by Rn:**
  - **Large uncertainties on Rn emanation**
  - **Extensive Rn-assay campaign started**
  - **PLR analysis very effective at dealing with ER background: sensitivity is largely unaffected by final Rn value**
- **Very robust sensitivity estimate:**
  - **1-2×10^{-48} cm^{2} at 40 GeV**
  - **Start probing the ^{8}B neutrino floor**