Imperial College London

Status of Direct Dark Matter Searches

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Imperial College London

DMUK Meeting – Edinburgh University – 28th July, 2017

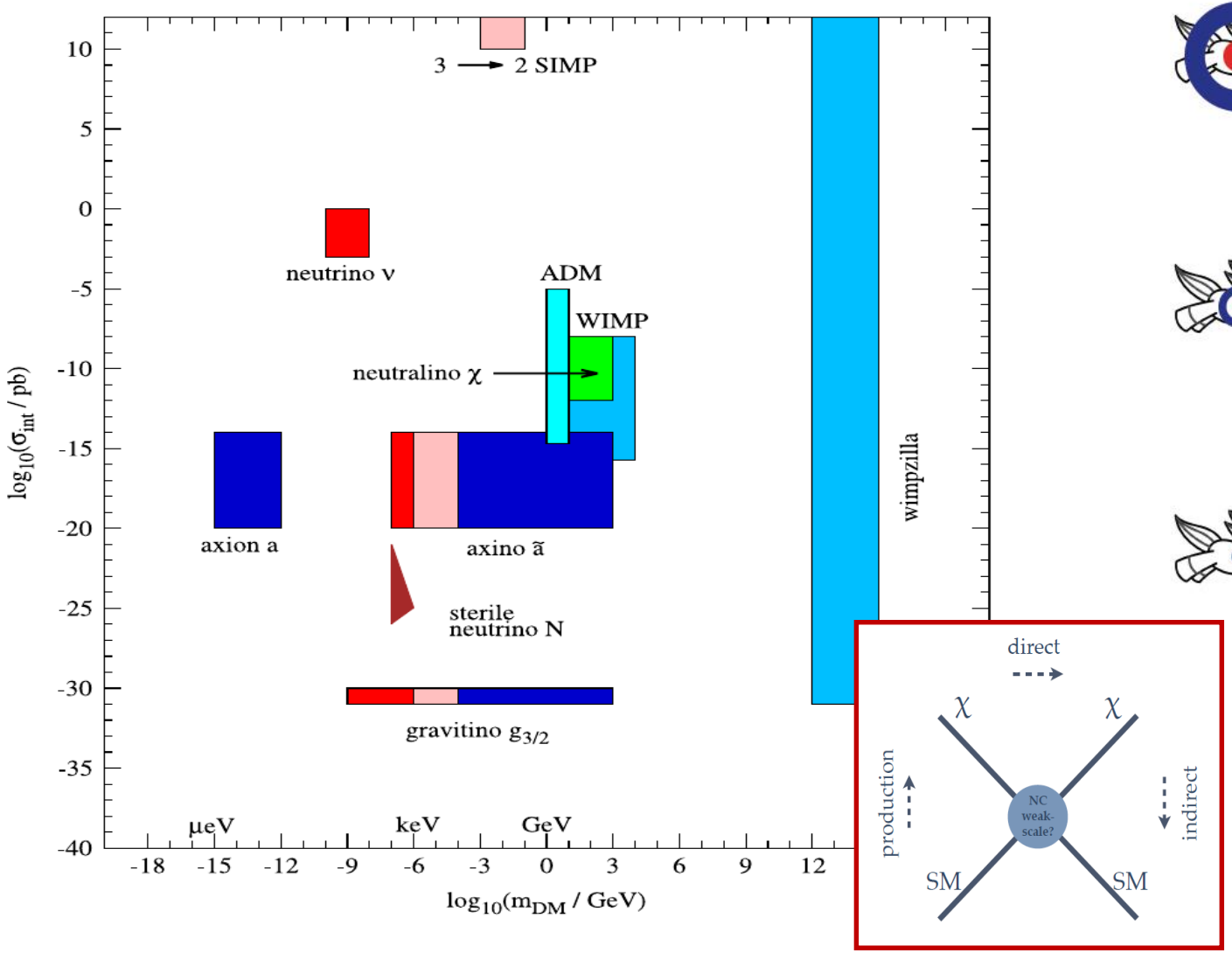
Outline

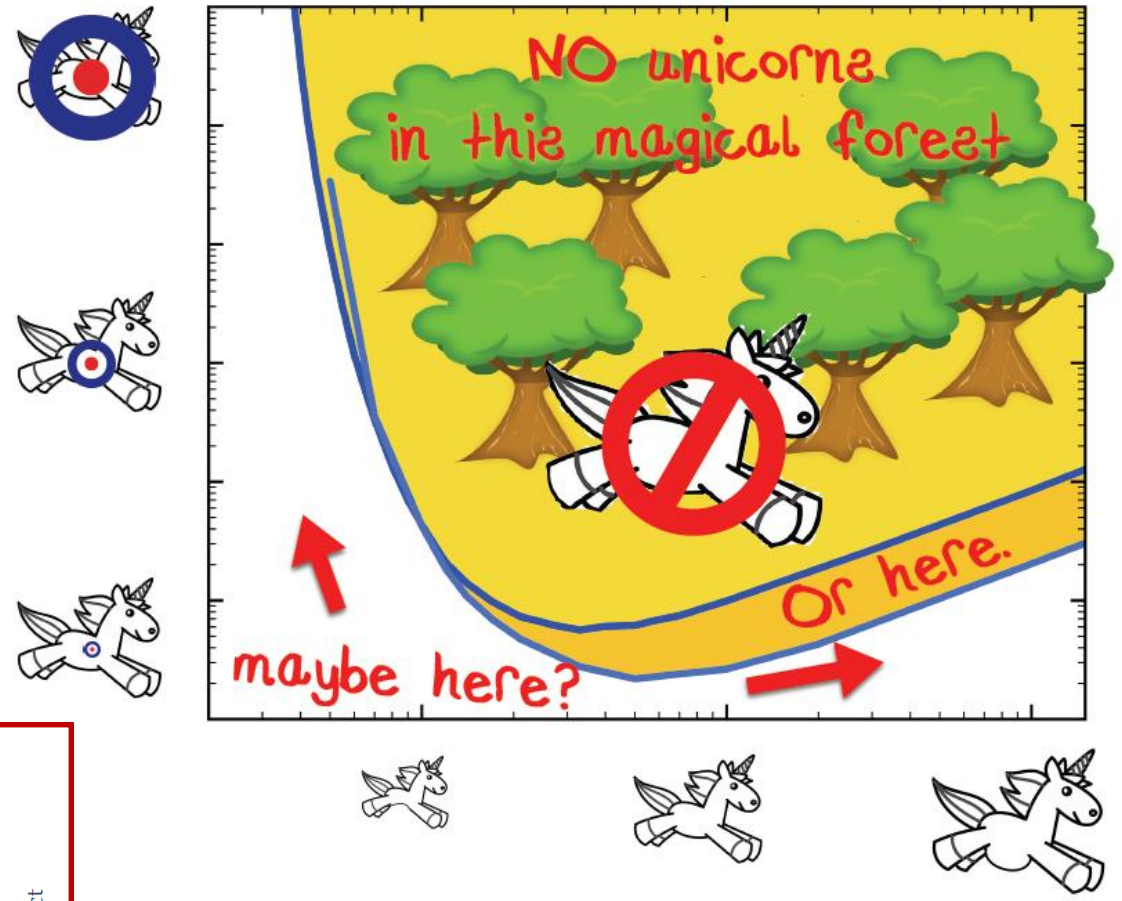
- WIMPs
- General Landscape
- Direct Detection
- Experimental Status*
  - Spin-Dependent
  - Spin-Independent
  - Annual Modulation
- LUX-ZEPLIN Status

** Mostly from TAUP'17*

Searches for Weakly Interacting Massive Particles

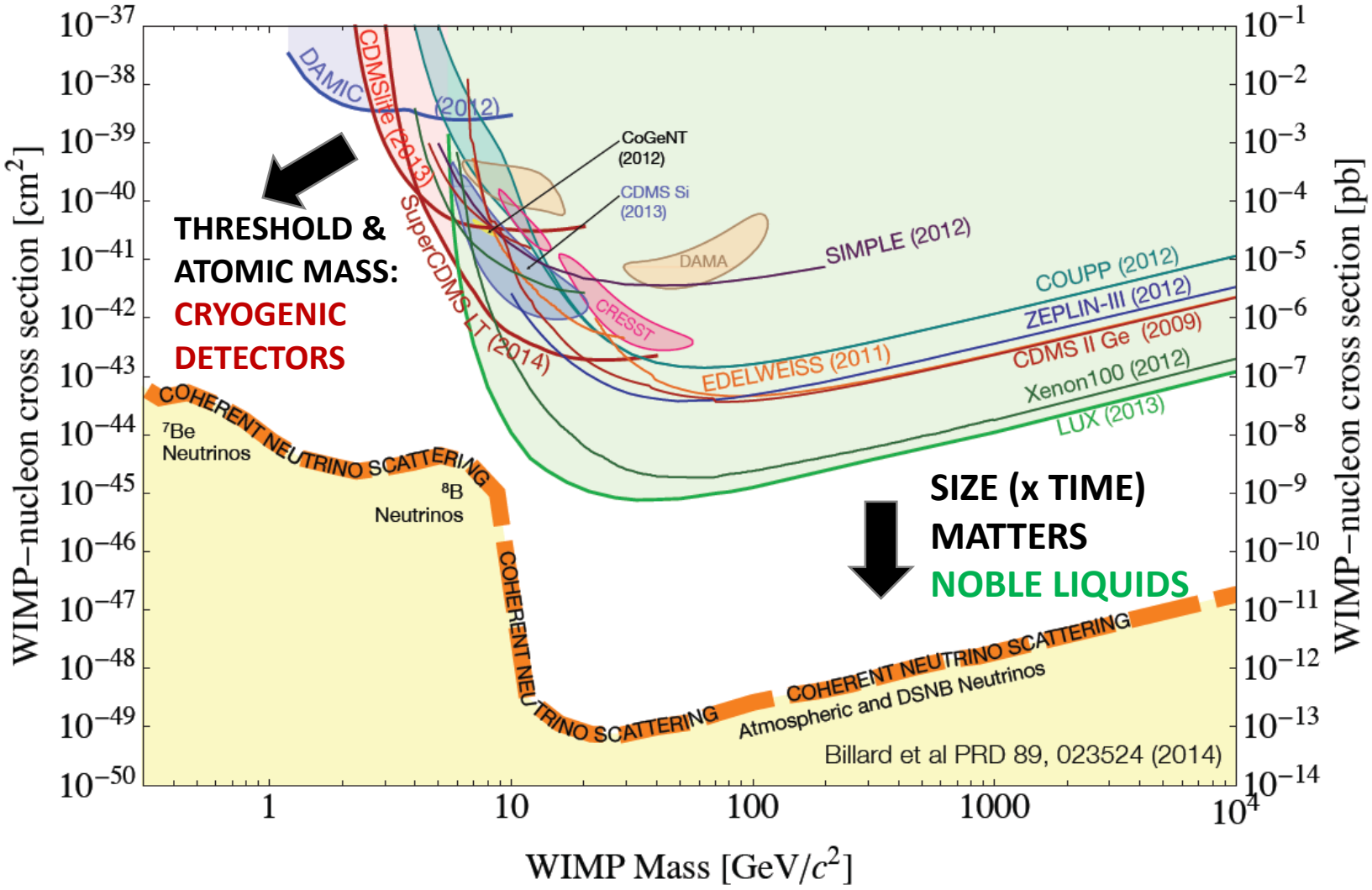
M. Horn, SURF



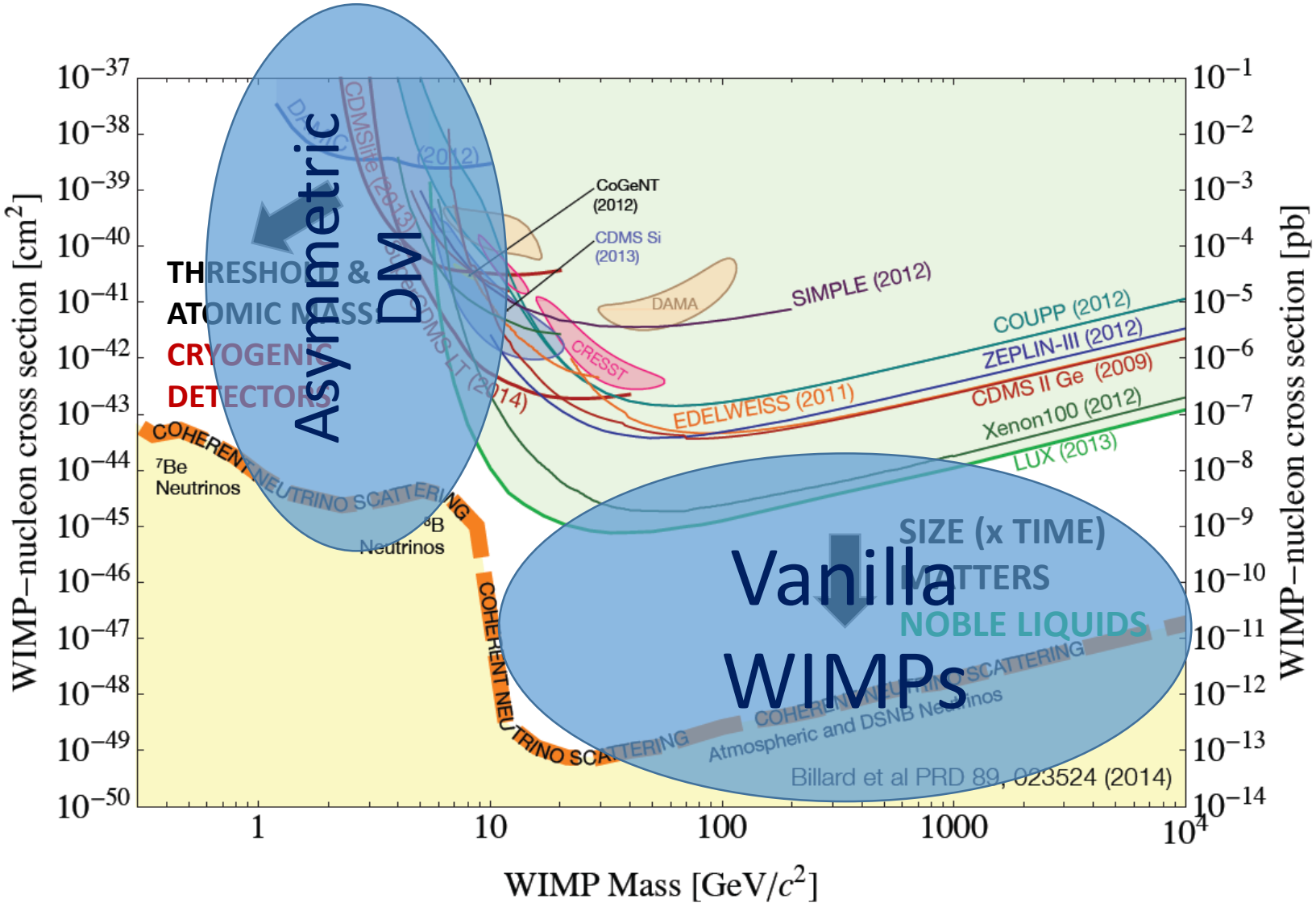


WIMP-nucleon scattering creates very low energy (~keV) recoiling nuclei which may be detected in low-background experiments.

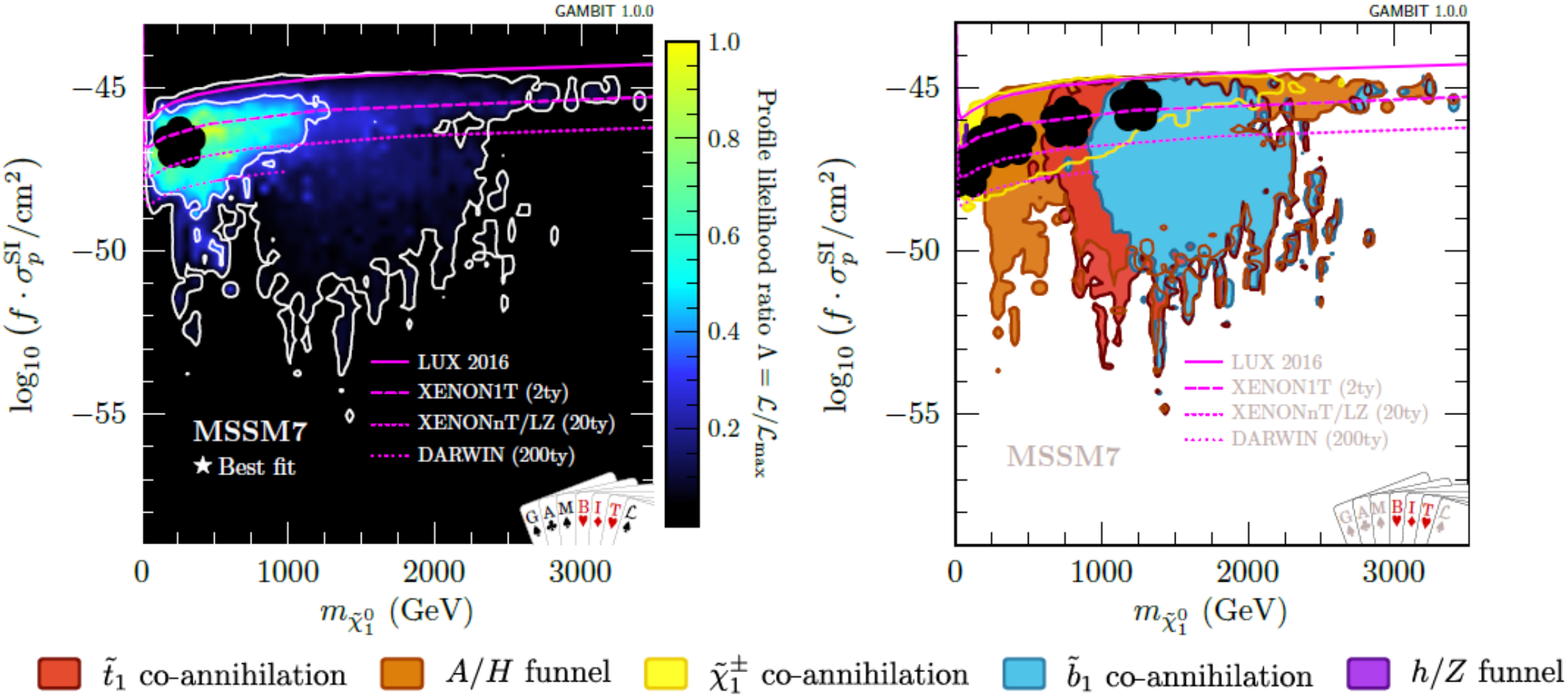
WIMP Detection Landscape



WIMP Detection Landscape

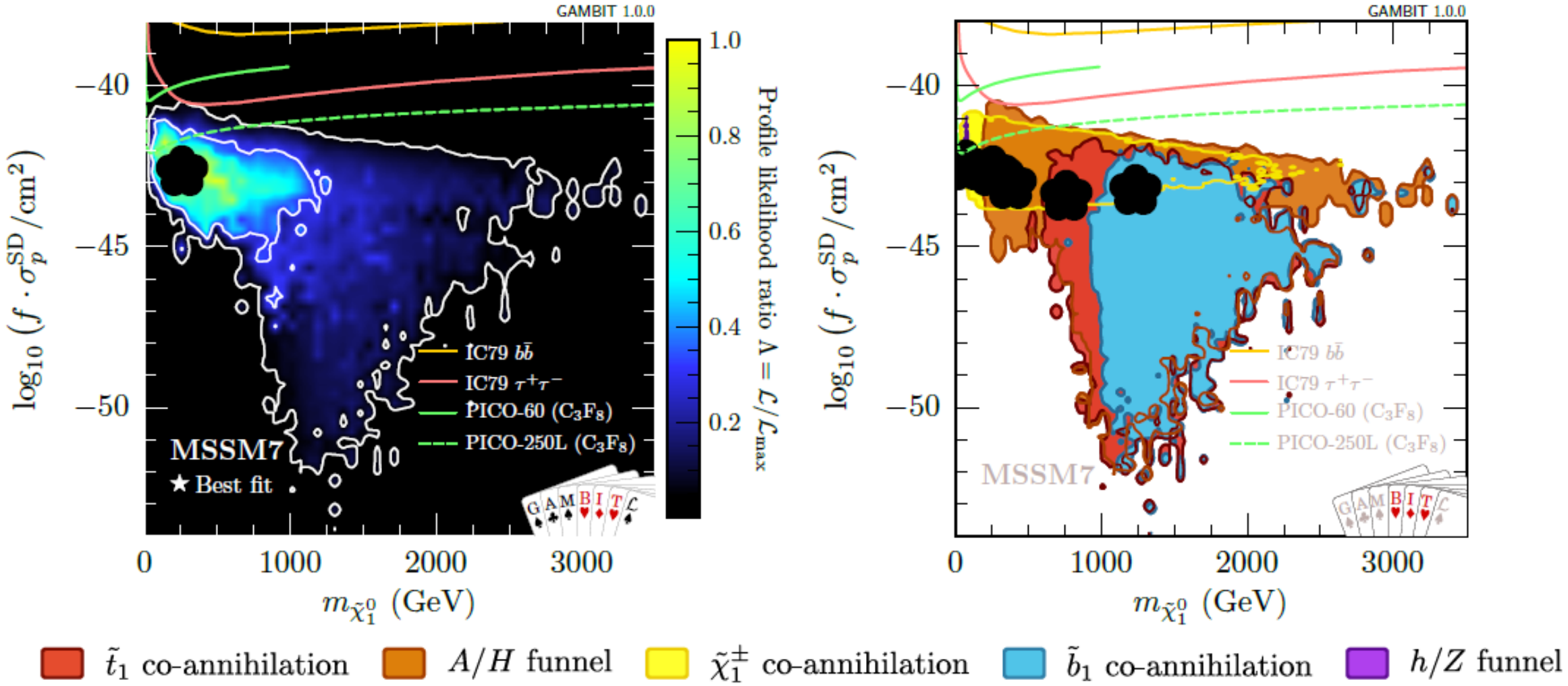


WIMP searches – MSSM7 Neutralinos (SI)



GAMBIT: 1705.07917 (J. McKay's talk)

WIMP searches – MSSM7 Neutralinos (SD)



GAMBIT: 1705.07917

Summary, before we go on….

- The combination of direct, indirect and collider searches is pushing SUSY into retreat – and the WIMP paradigm with it:

  Gambit: "In much of the parameter space of the MSSM7 (and indeed the MSSM more generally), the annihilation cross-section of heavy neutralino DM is so small that the thermal relic density greatly exceeds the value measured by Planck. Such models are robustly ruled out. The only way for a model to respect this upper limit is to exhibit one or more specific mechanisms for depleting the thermal abundance, typically associated with coannihilation with another supersymmetric species, or resonant annihilation via a neutral boson 'funnel'."

- However, plenty of well-motivated parameter space remains to be probed, we must continue to do this in a systematic way through scattering experiments as a (relatively) model independent way to look for new particles and new interactions.
- (and it's not like we have a better place to look for now!)

WIMP SEARCH TECHNOLOGY ZOO

Not even complete;
It is a vibrant field!

Ionisation Detectors

Targets: Ge, Si, CS_2, CdTe

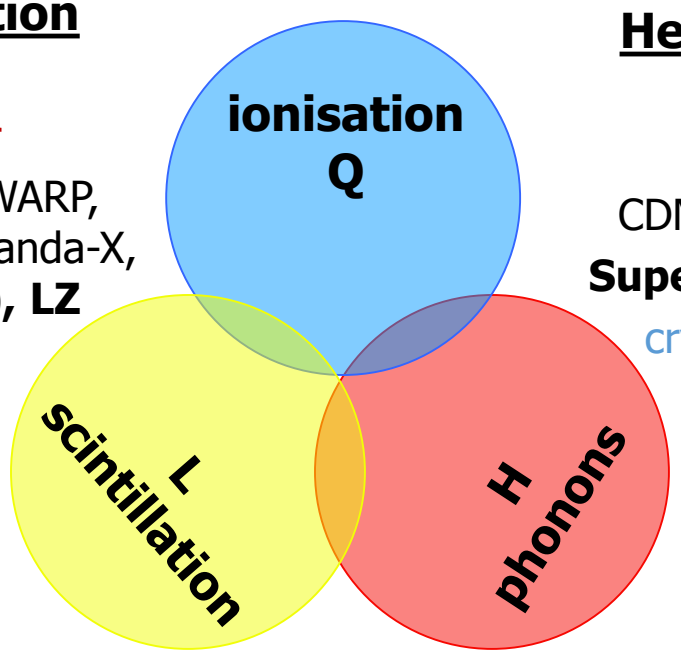
CoGeNT, CDEX, D3, DAMIC, **DRIFT**, **DM-TPC**, GENIUS, IGEX, MIMAC, NEWAGE, NEWS, TREX

Light & Ionisation Detectors

Targets: Xe, Ar

ArDM, Argo, **LUX**, WARP, DarkSide, DARWIN, Panda-X, XENON, **(ZEPLIN), LZ**

cold (LN_2)



Heat & Ionisation Bolometers

Targets: Ge,Si

CDMS, **(EDELWEISS)**
SuperCDMS, **(EURECA)**

cryogenic (<50 mK)

Scintillators

Targets: NaI, Xe, Ar

ANAIS, MiniCLEAN, DAMA, **DEAP-3600**, **DM-ICE**, KIMS, LIBRA, PICOLON, **(NAIAD)**, **SABRE**, XMASS, **(ZEPLIN-I)**

Bolometers

Targets: Ge, Si, Al_2O_3, TeO_2

CRESST-I, CUORE, CUORICINO

Light & Heat Bolometers

Targets: $CaWO_4$, BGO, Al_2O_3

(CRESST), ROSEBUD

cryogenic (<50 mK)

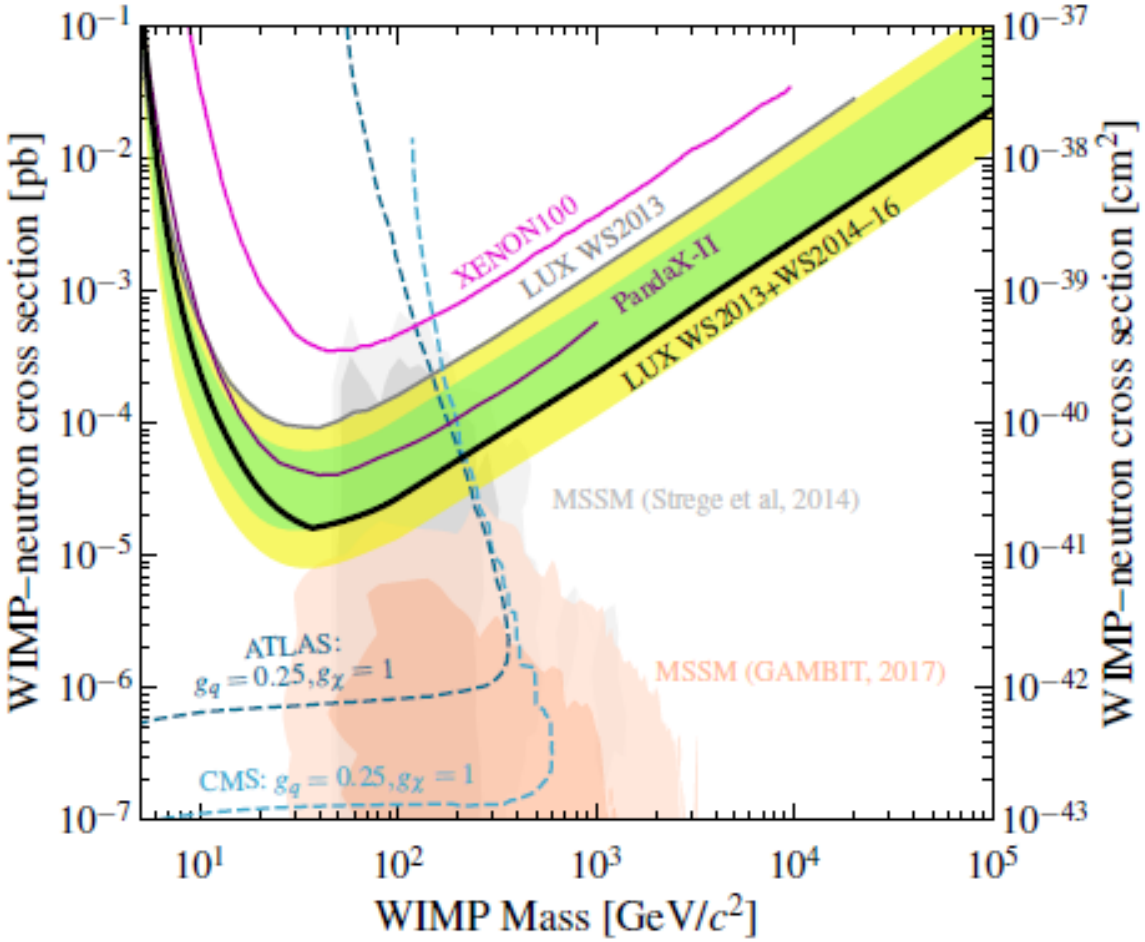
Bubbles & Droplets

CF_3Br, CF_3I, C_3F_8, C_4F_{10}

COUPP, PICASSO, PICO, SIMPLE

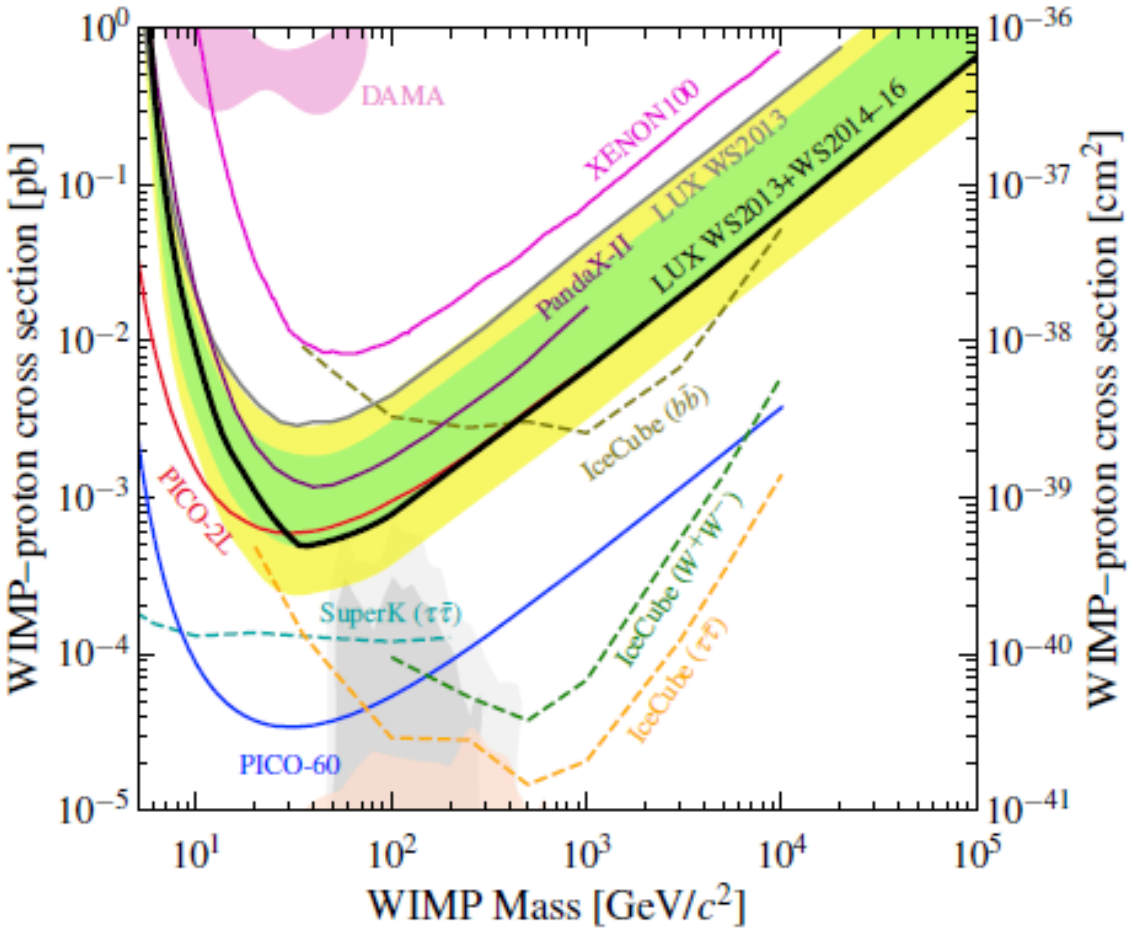
WIMP searches – SD status

WIMP-NEUTRON



LUX: 1705.03380

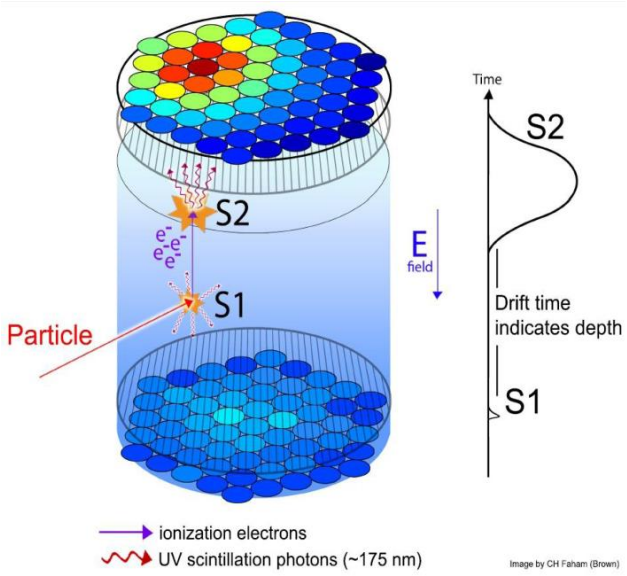
WIMP-PROTON

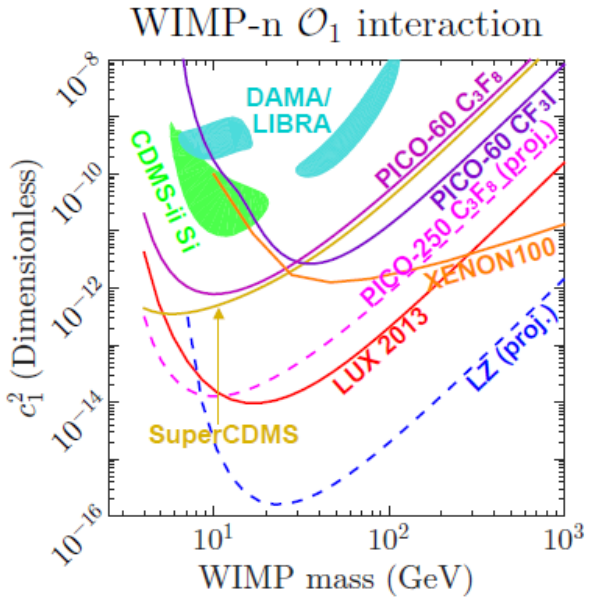


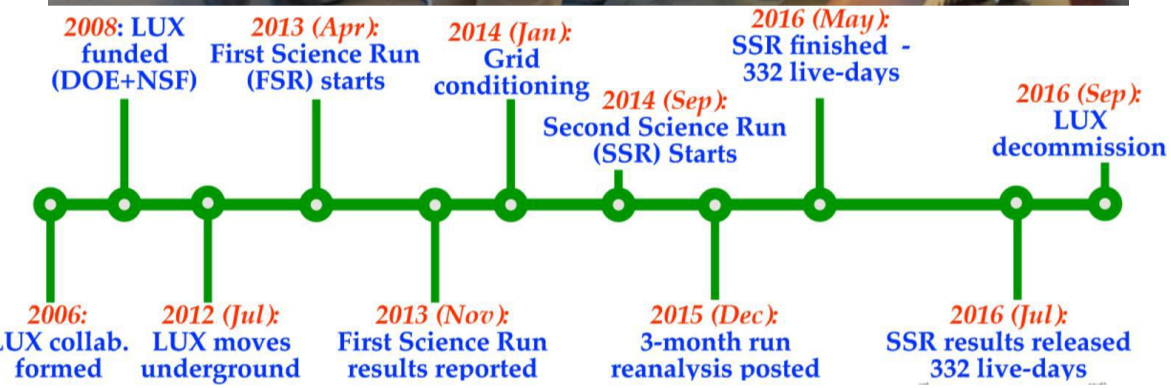
PICO-60: 1702.07666

Large Underground Xenon experiment

- Completed science operations, decommissioned from Sanford Lab to give way to LUX-ZEPLIN (LZ)
- Several world-leading results, exceeded stated sensitivity!
- More physics & technical results soon

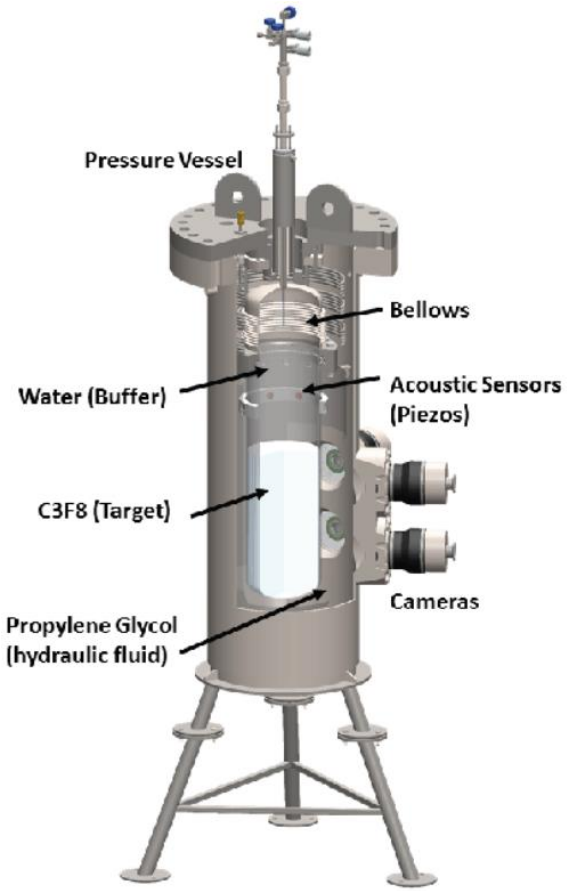


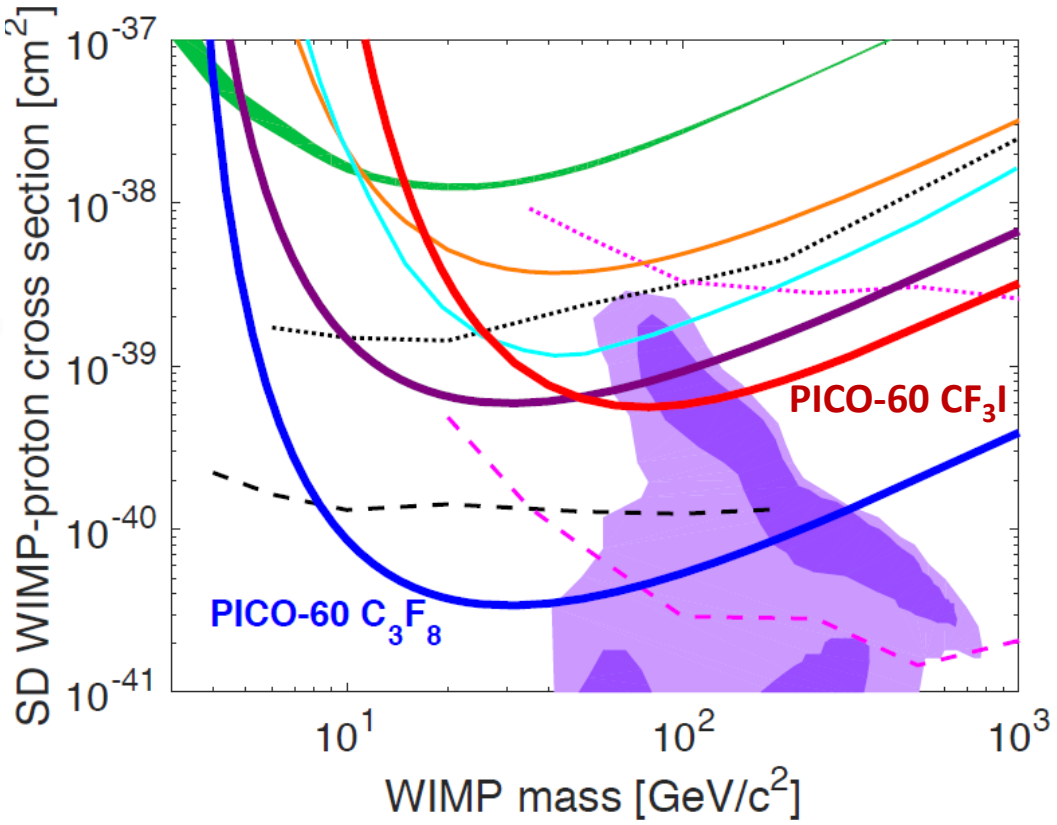




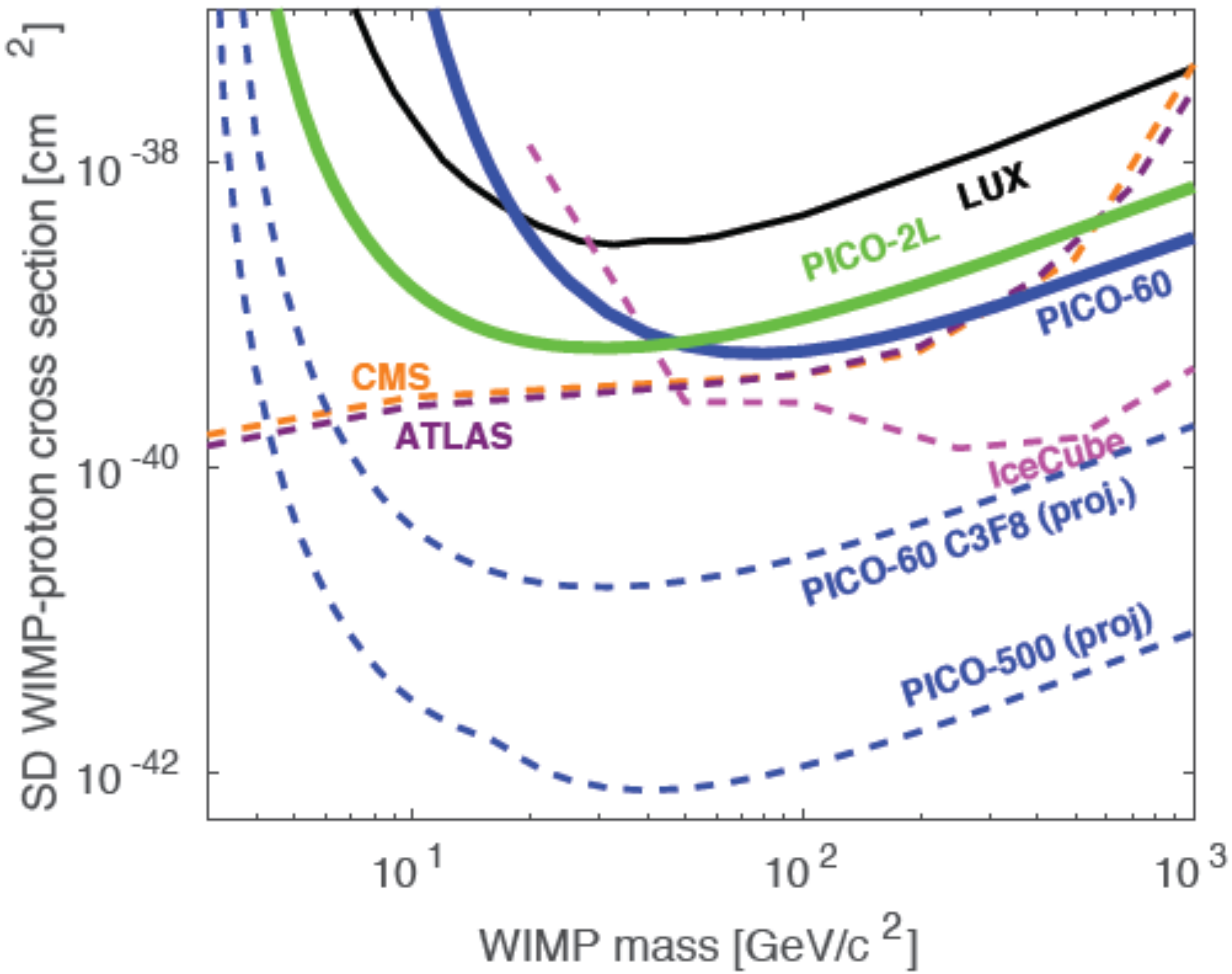
PICO-60

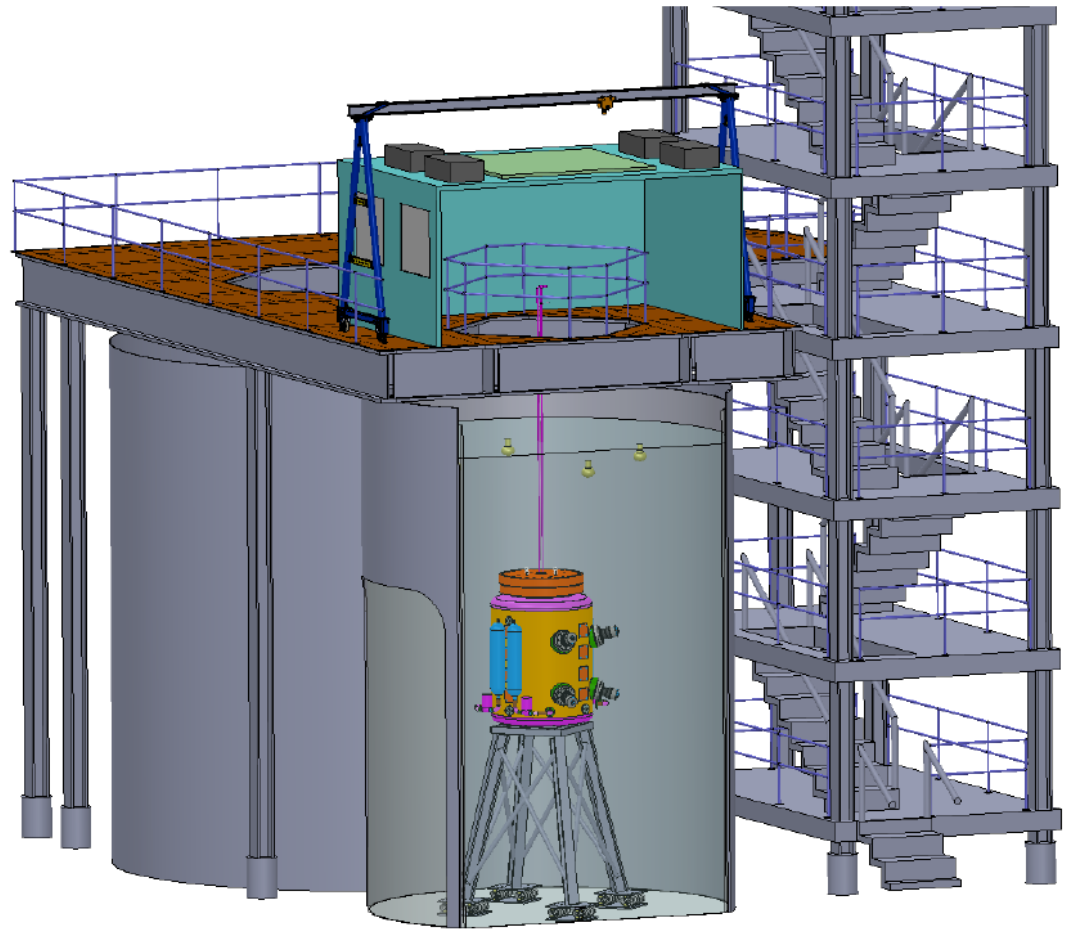
- 60-litre bubble chamber ($CF_3I \rightarrow C_3F_8$)
- Operating at SNOLAB





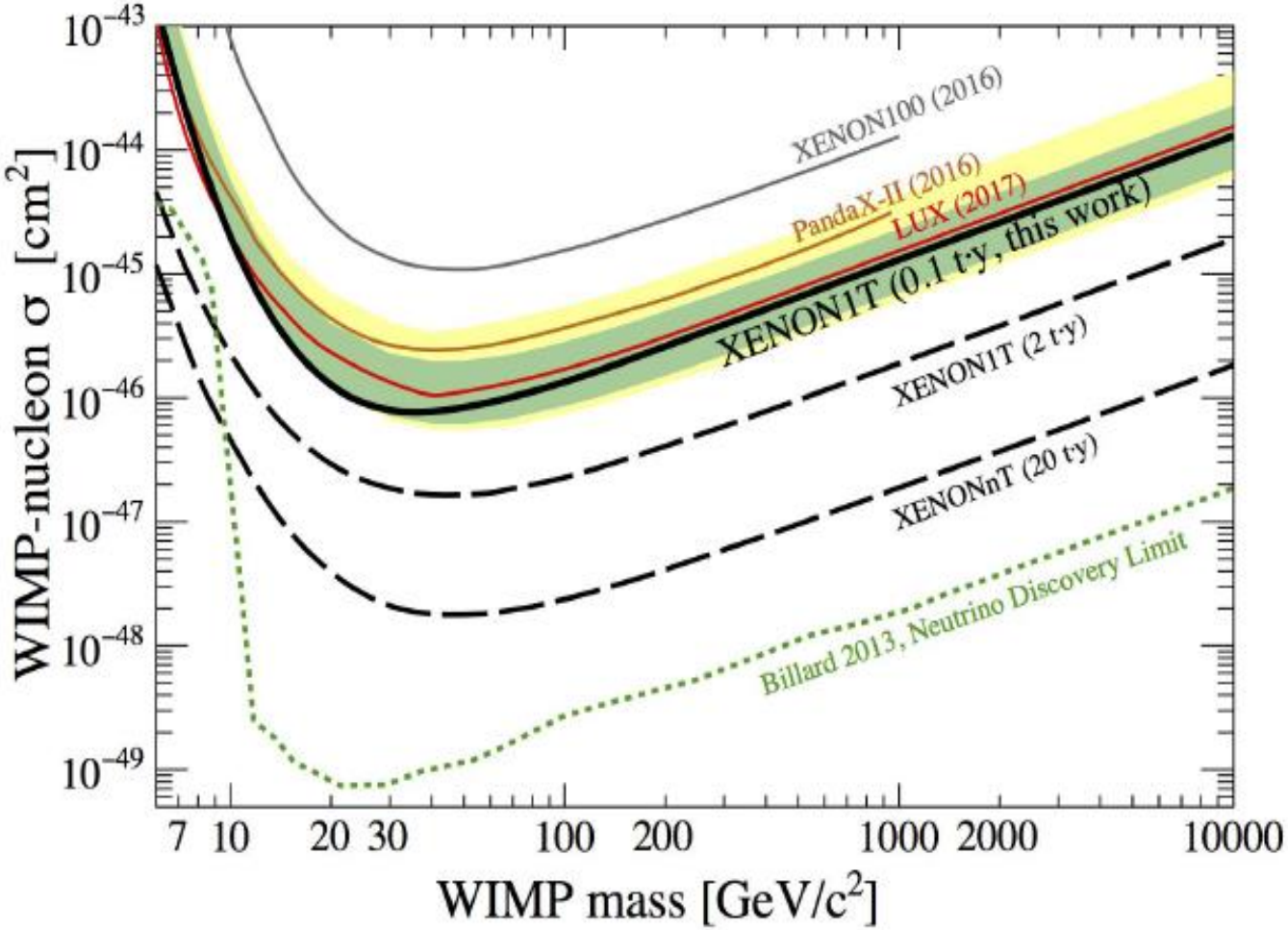
PICO-500


SD WIMP-proton cross section [cm 2]
10 -38
10 -40
10 -42
10 1
10 2
10 3
WIMP mass [GeV/c 2]
LUX
PICO-2L
PICO-60
CMS
ATLAS
IceCube
PICO-60 C3F8 (proj.)
PICO-500 (proj)

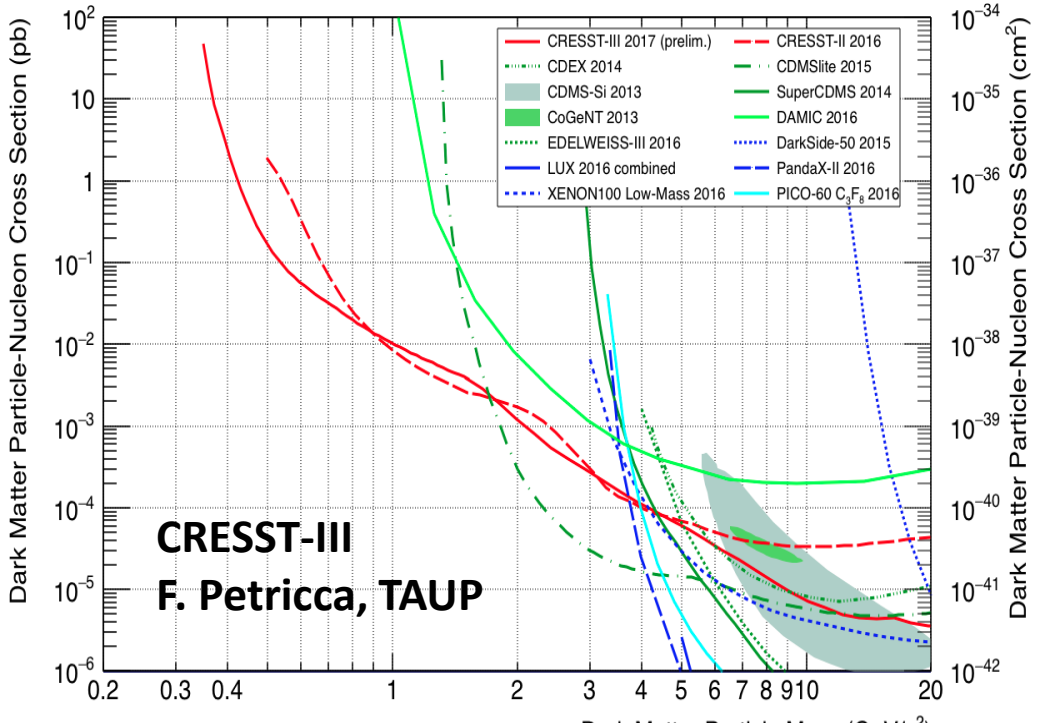


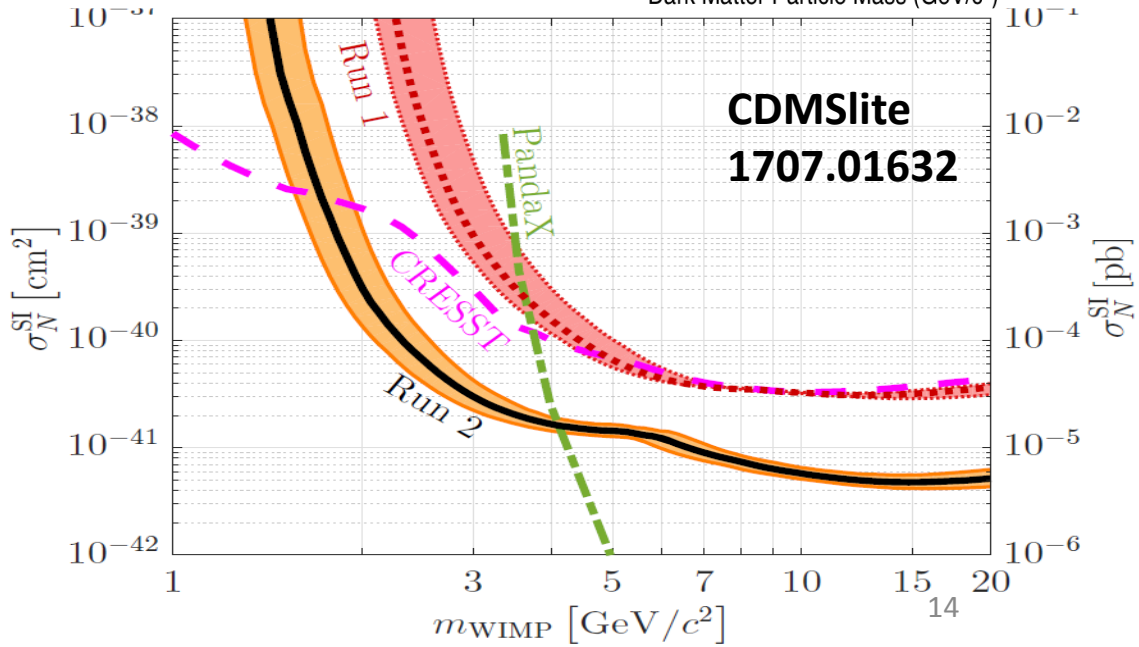
WIMP searches – SI status

STANDARD/HEAVY WIMPS **LIGHT WIMPS>**



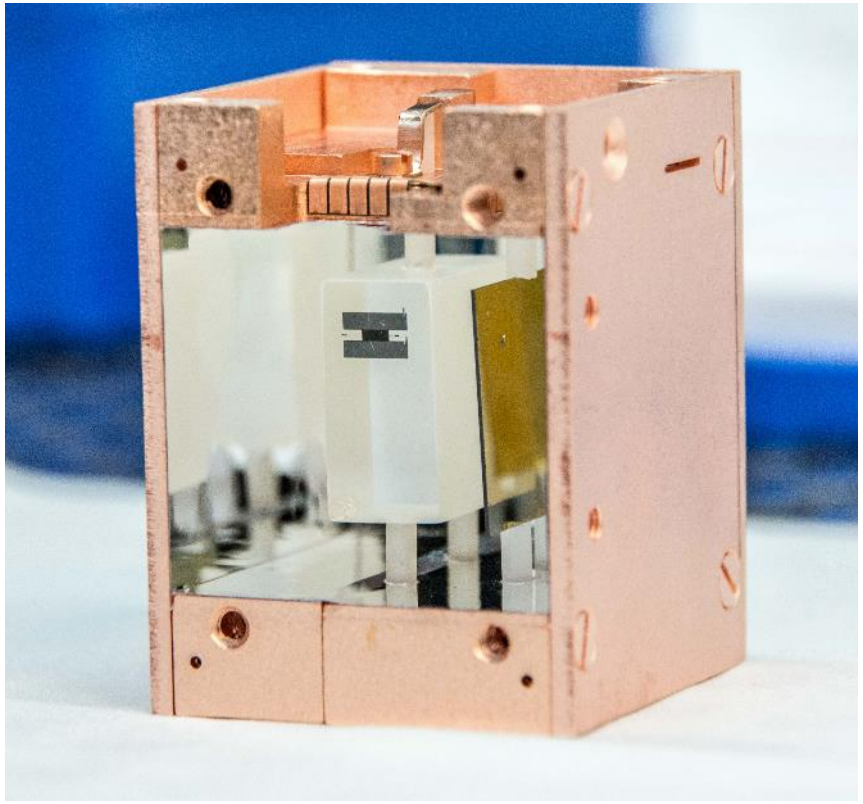
XENON1T: 1705.06655



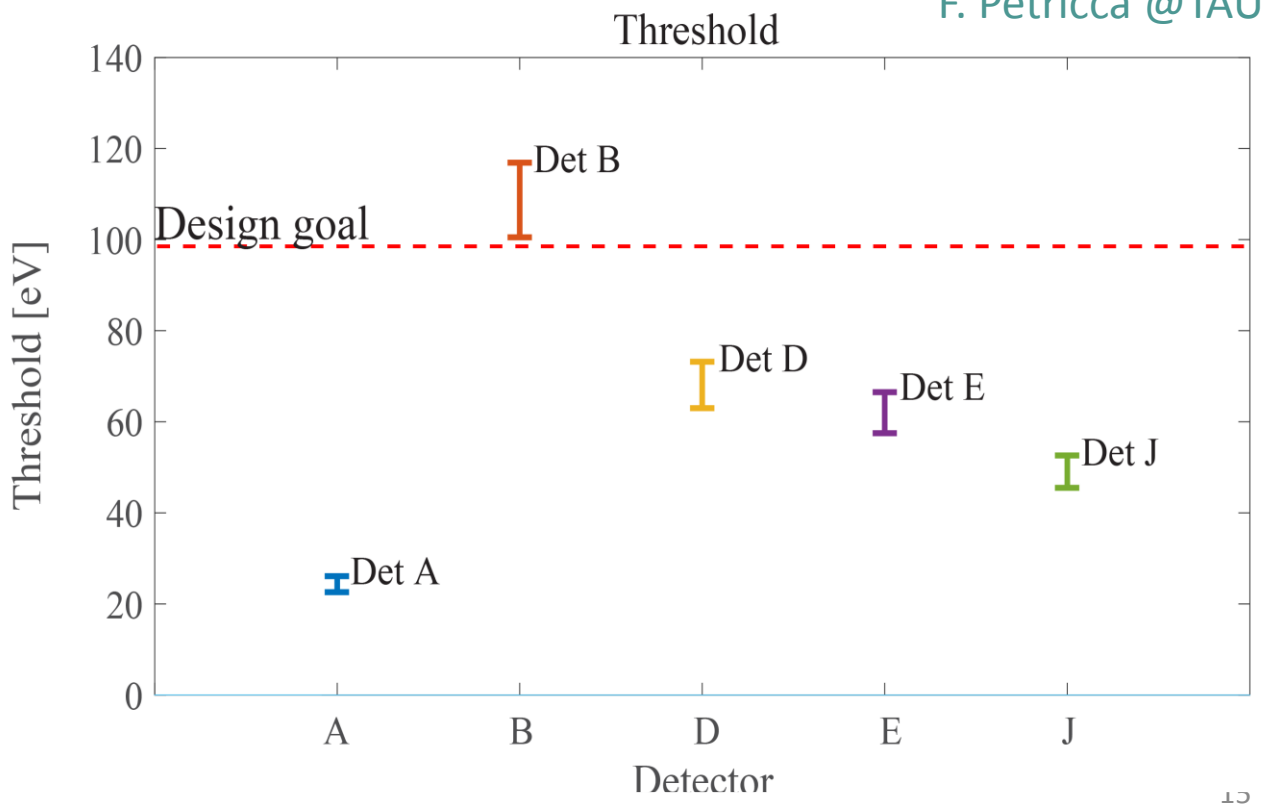


CRESST-III

- Targeting light WIMPs with ultra-low threshold (& very small) detectors
- CRESST-III: 24-g $CaWO_4$ crystals (light and phonon readout)

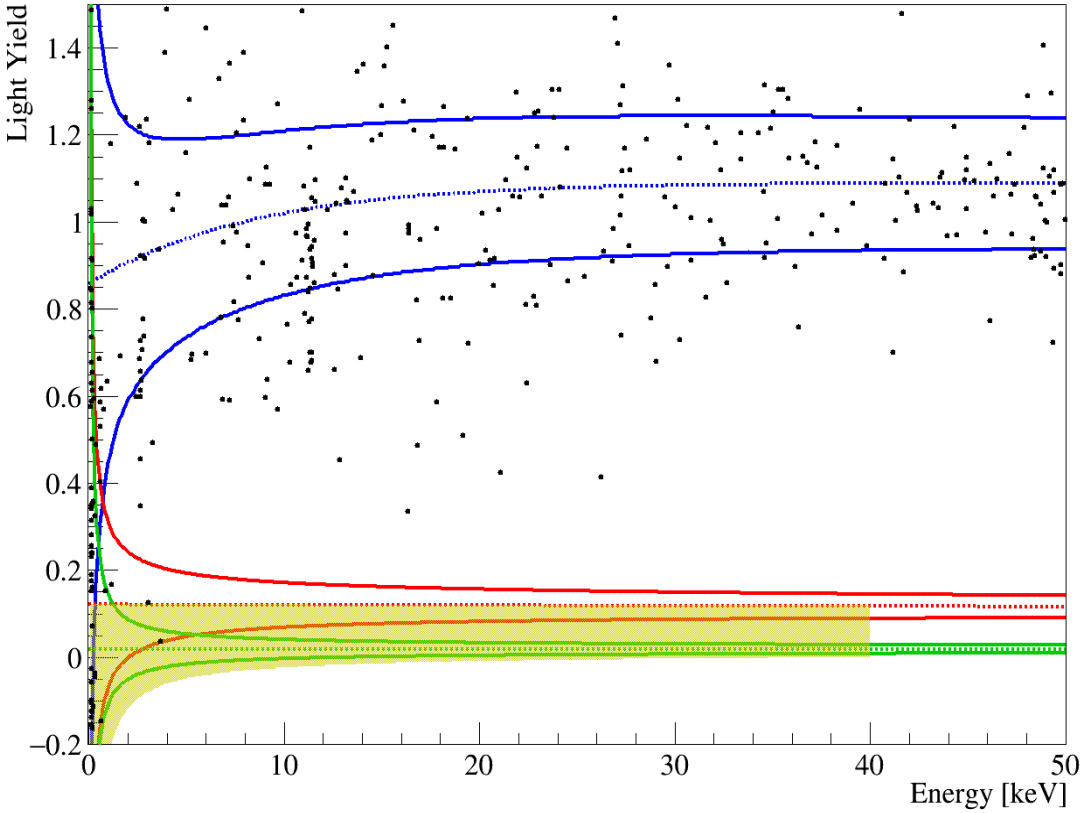


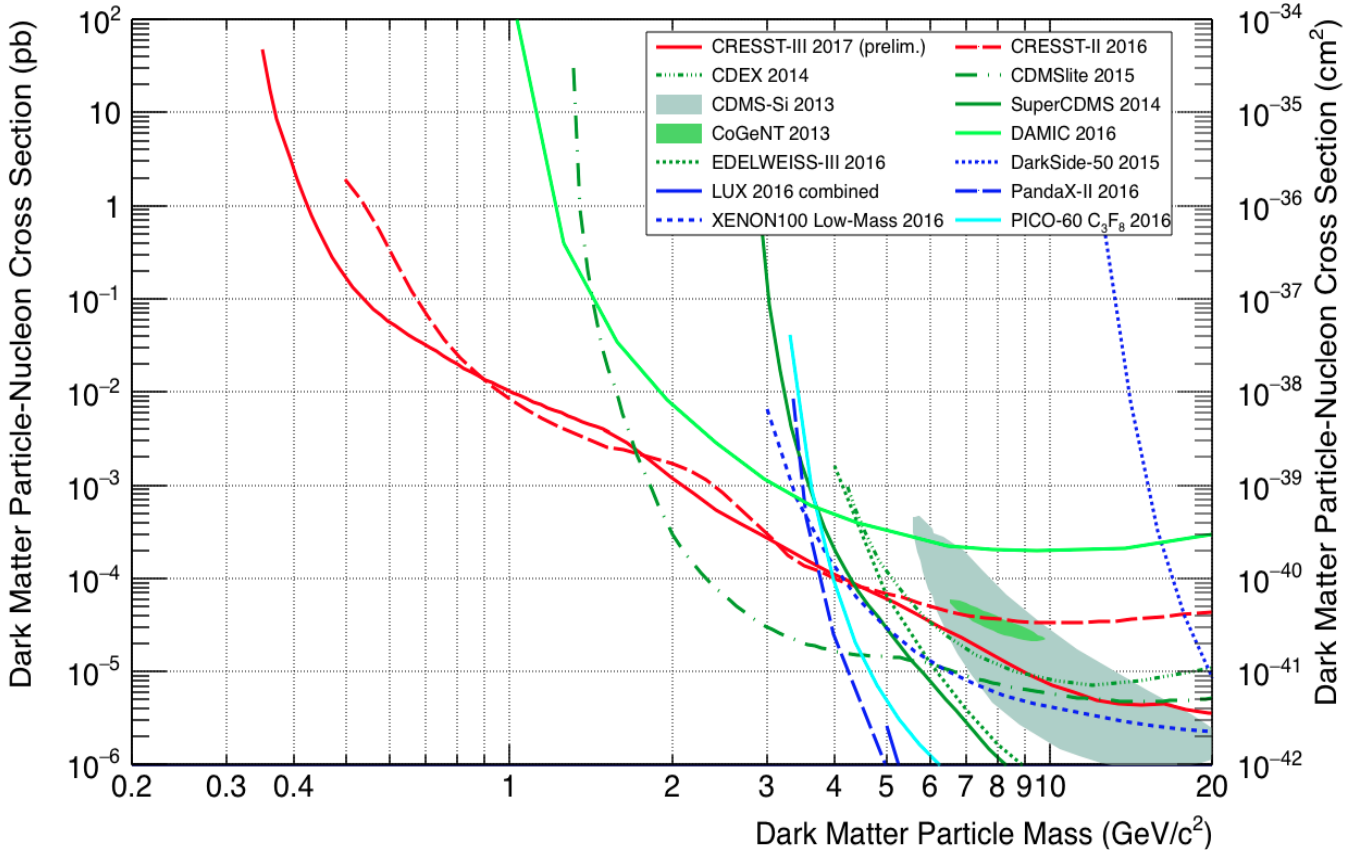
F. Petricca @TAUP2017



CRESST-III

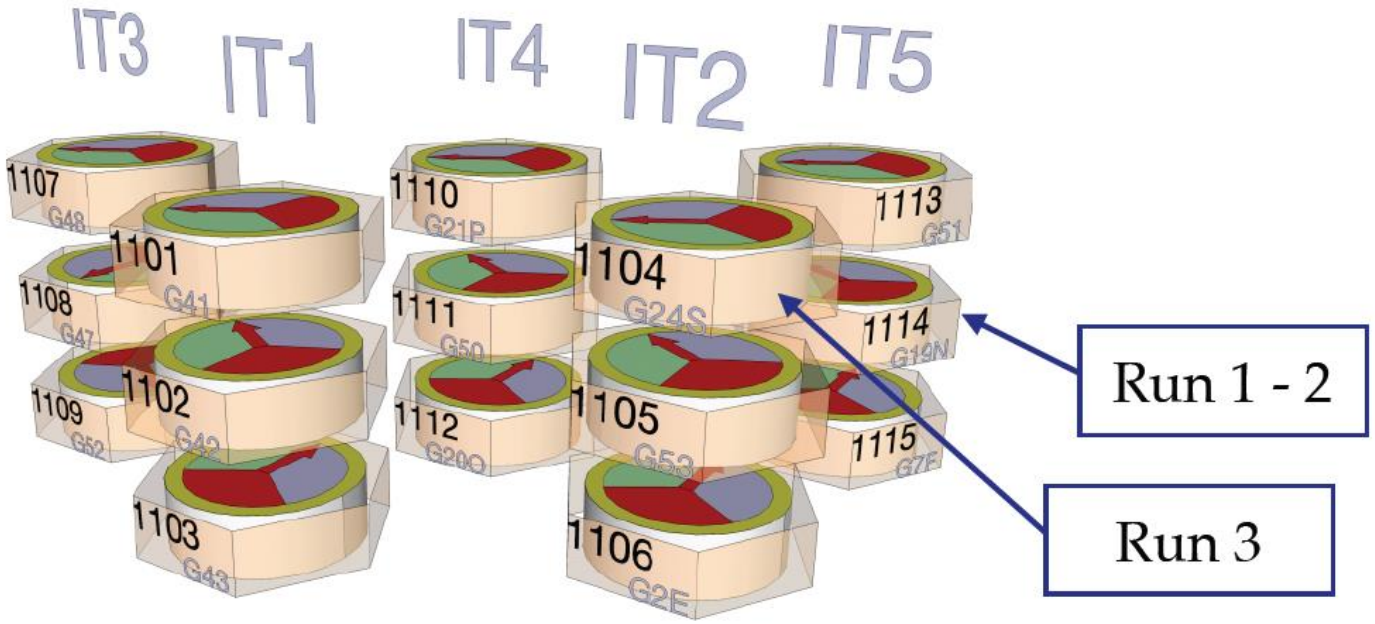
- Results from 2.21 kg*days, 100 eV threshold: minimum WIMP mass 0.35 GeV
- But with new thresholds come new backgrounds….

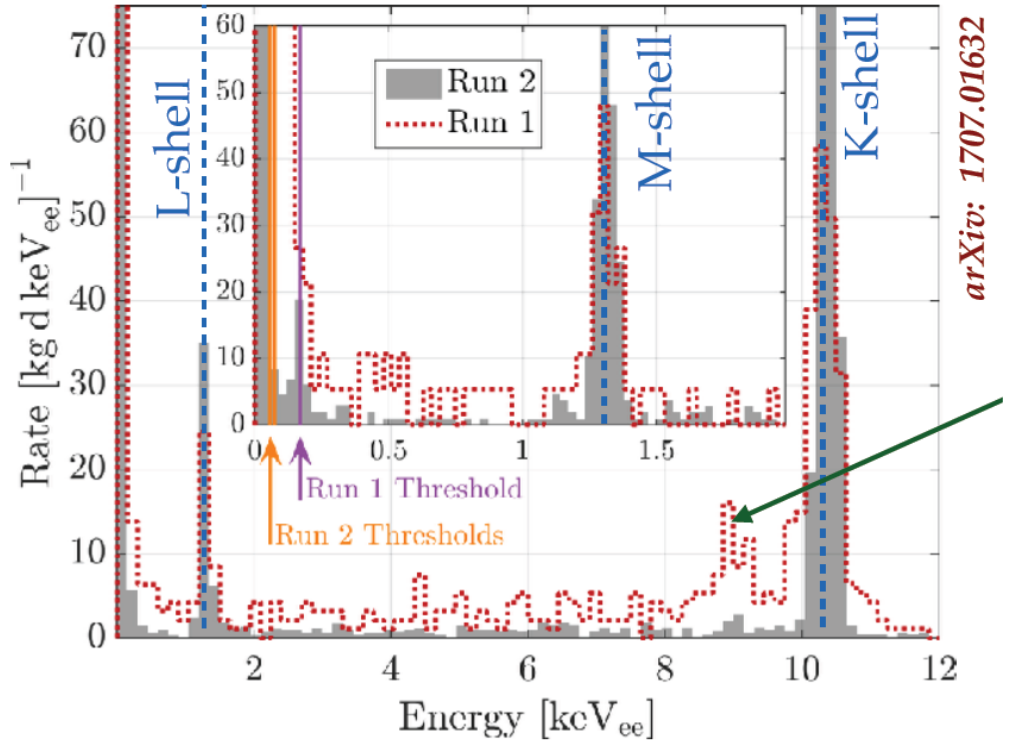


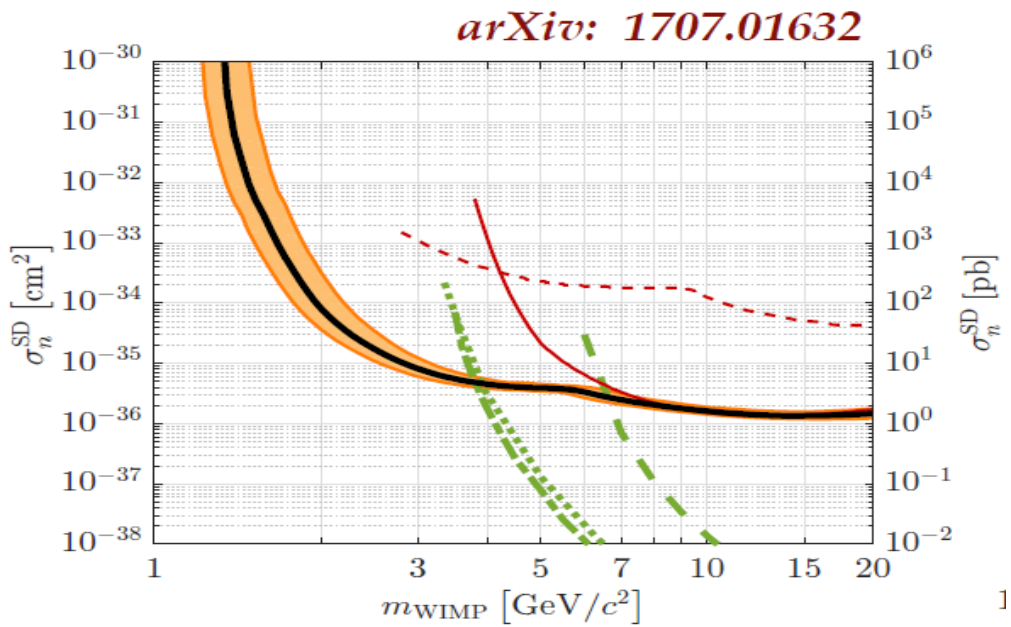


SuperCDMS & CDMSlite

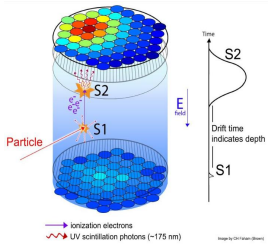
- Data collected at Soudan (2012-2015)
- SI & SD results from Run 2 with CDMSlite (HV mode, Luke phonons – no discrimination)
- Standard SuperCDMS analysis expected soon



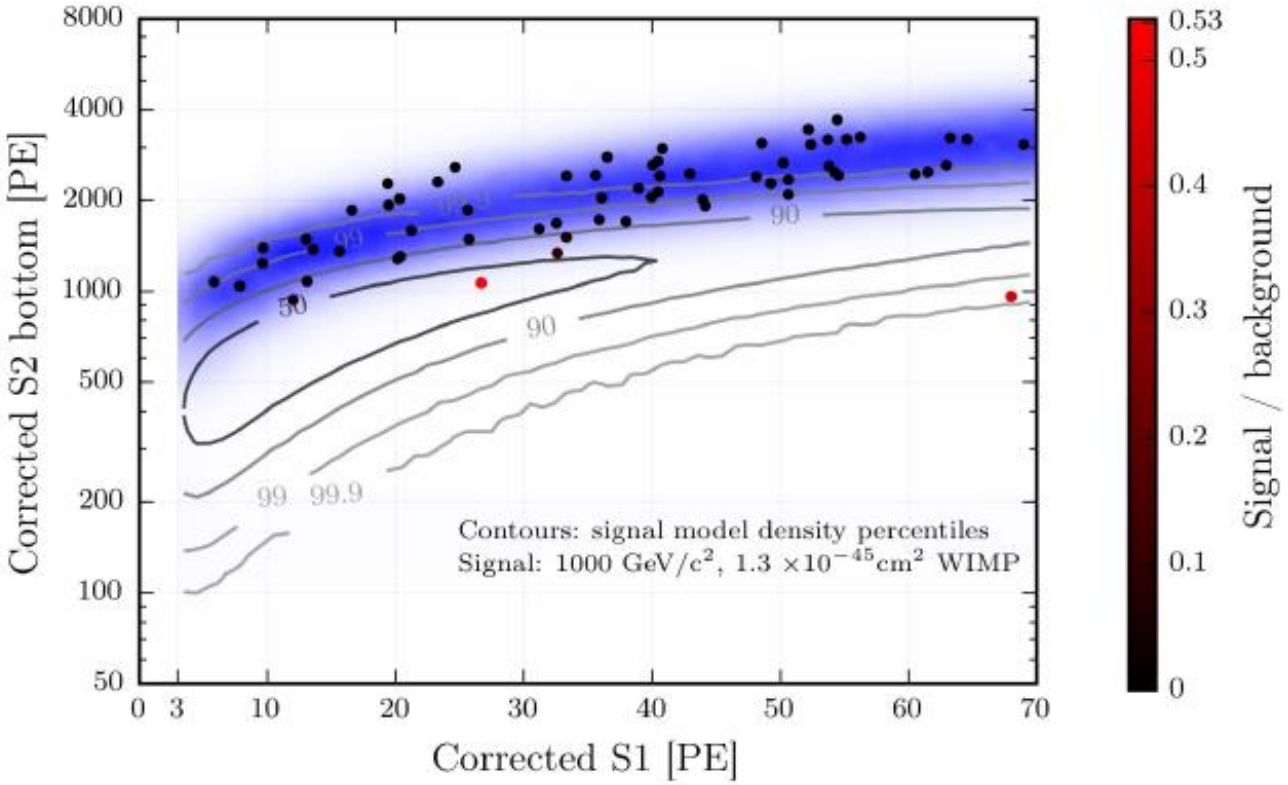




XENON1T

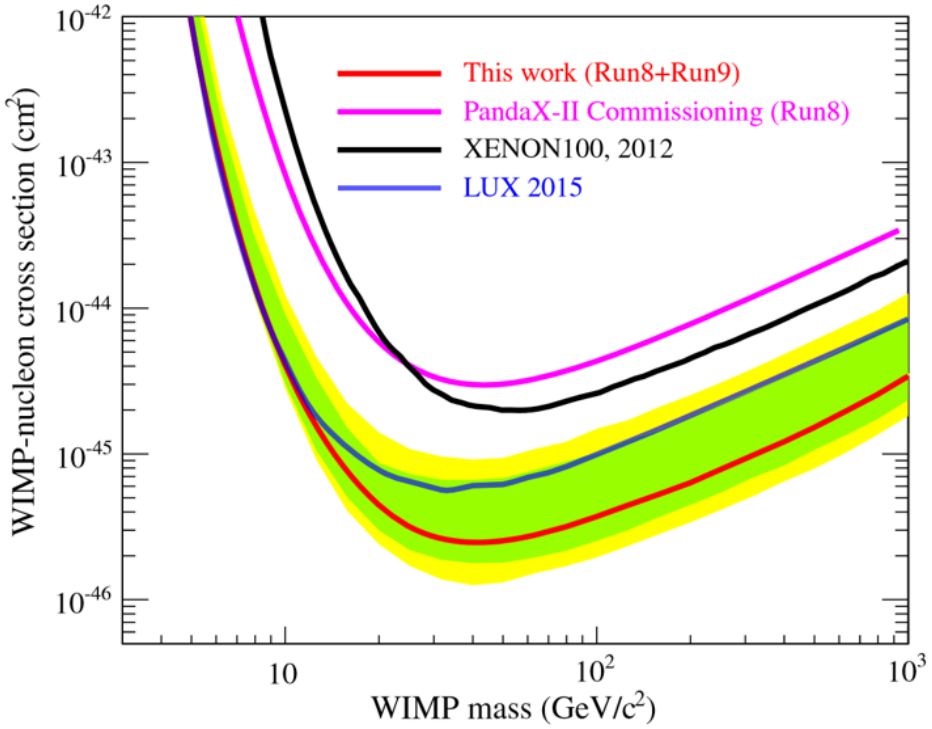


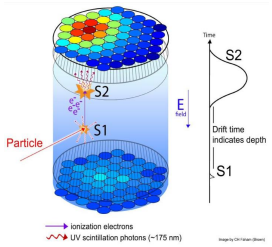
- First run in 2016/17, interrupted by quake
- Good “good” backgrounds, others less clear
- Running again, at (even) lower electric field



PandaX-II

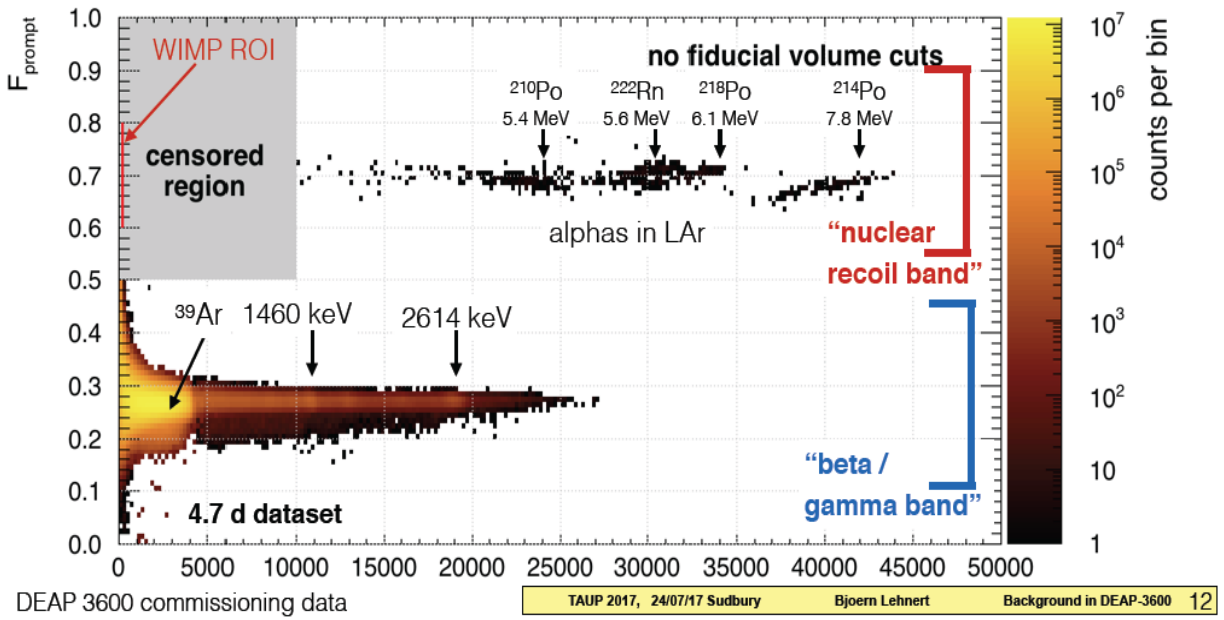
- First results in 2016, similar to LUX Run 4
- Experienced “difficulties in background control”, extended downtime
  - No result at TAUP2017

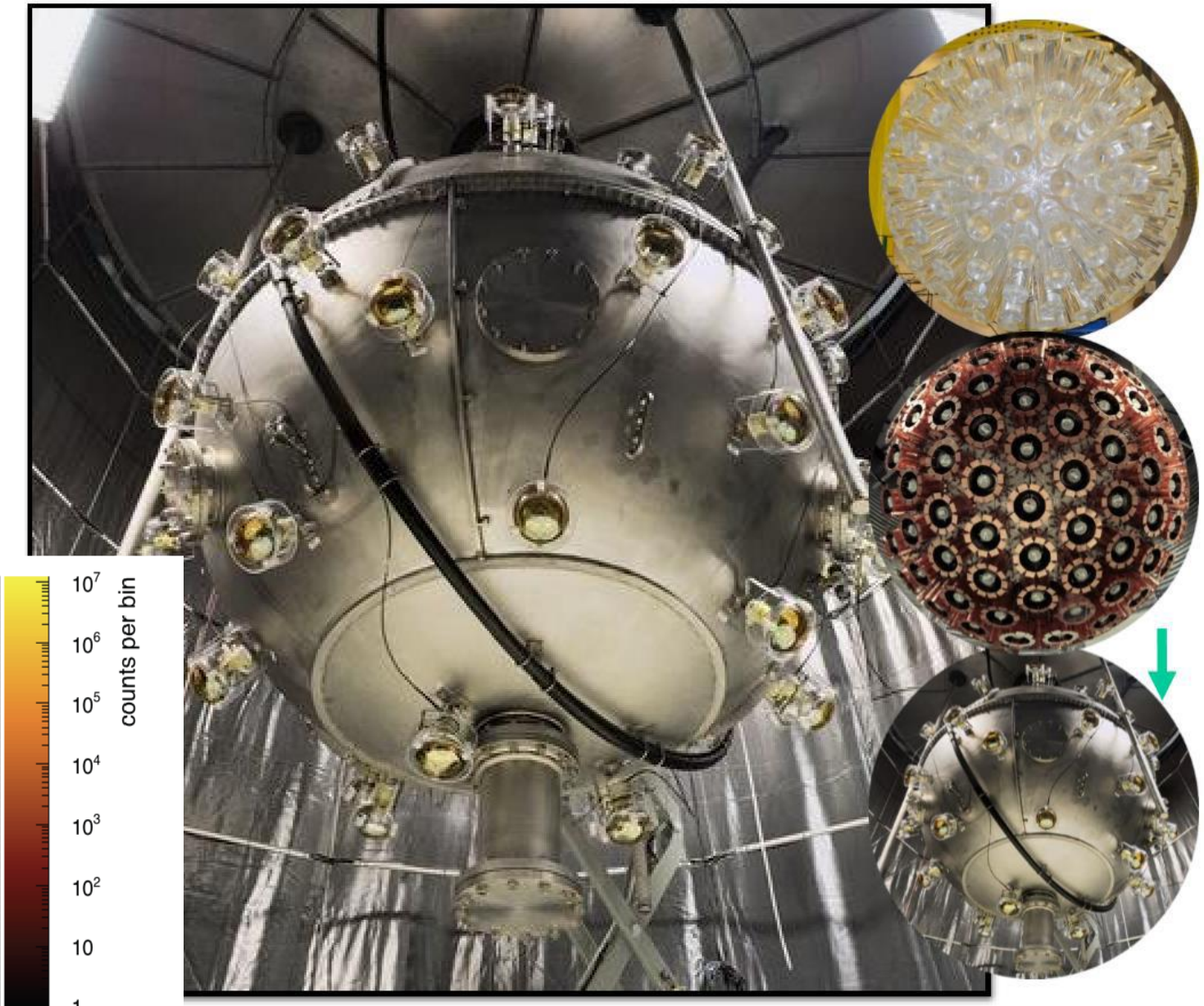




DEAP-3600

- Commissioning run completed at SNOLAB
- 220 days collected with full detector (3,322 kg)
- See J. Walding next!

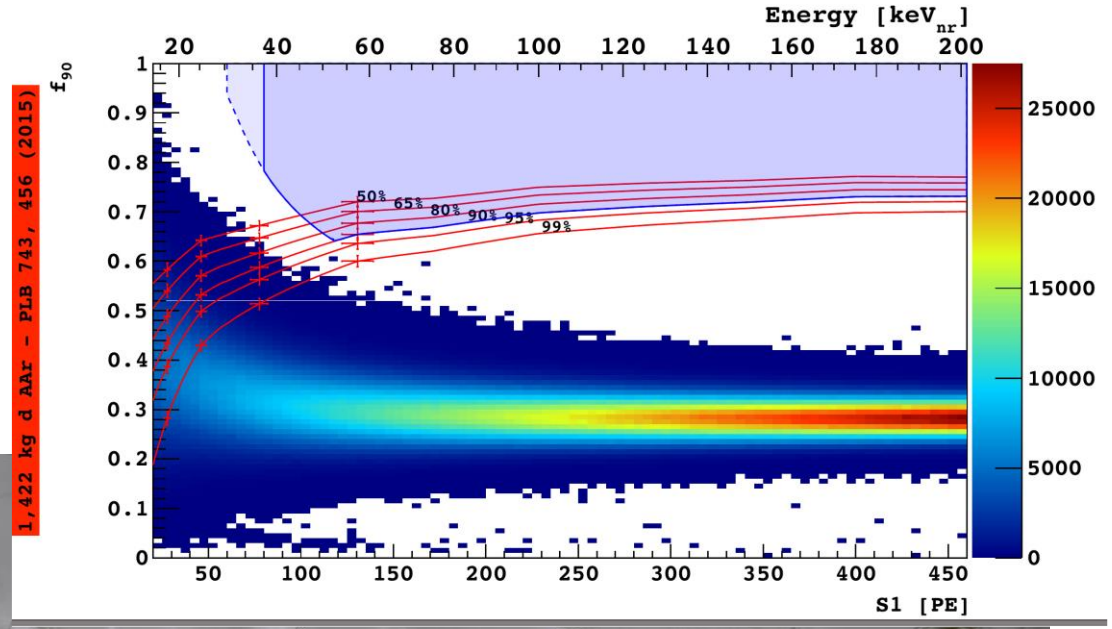


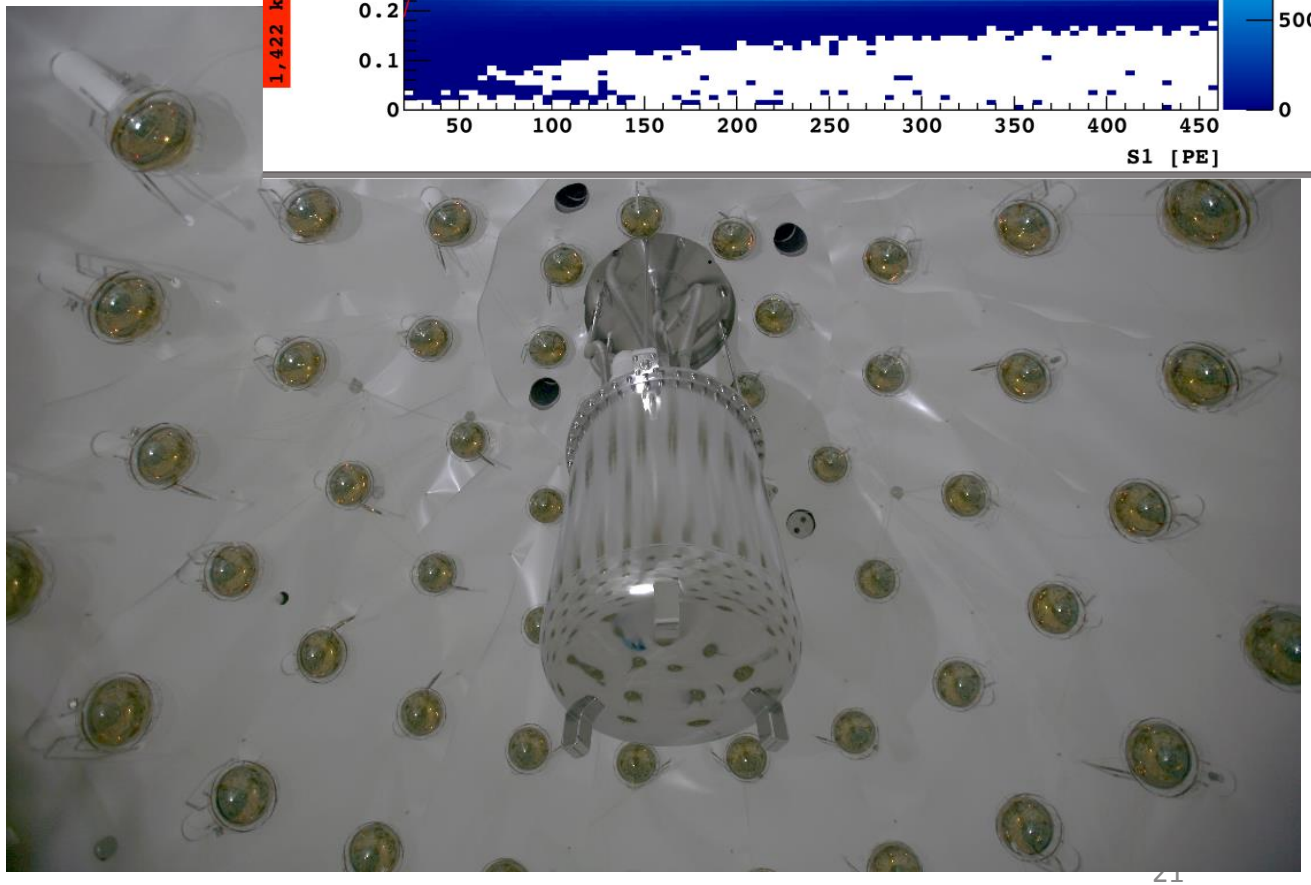


1707.08042

DARKSIDE-50

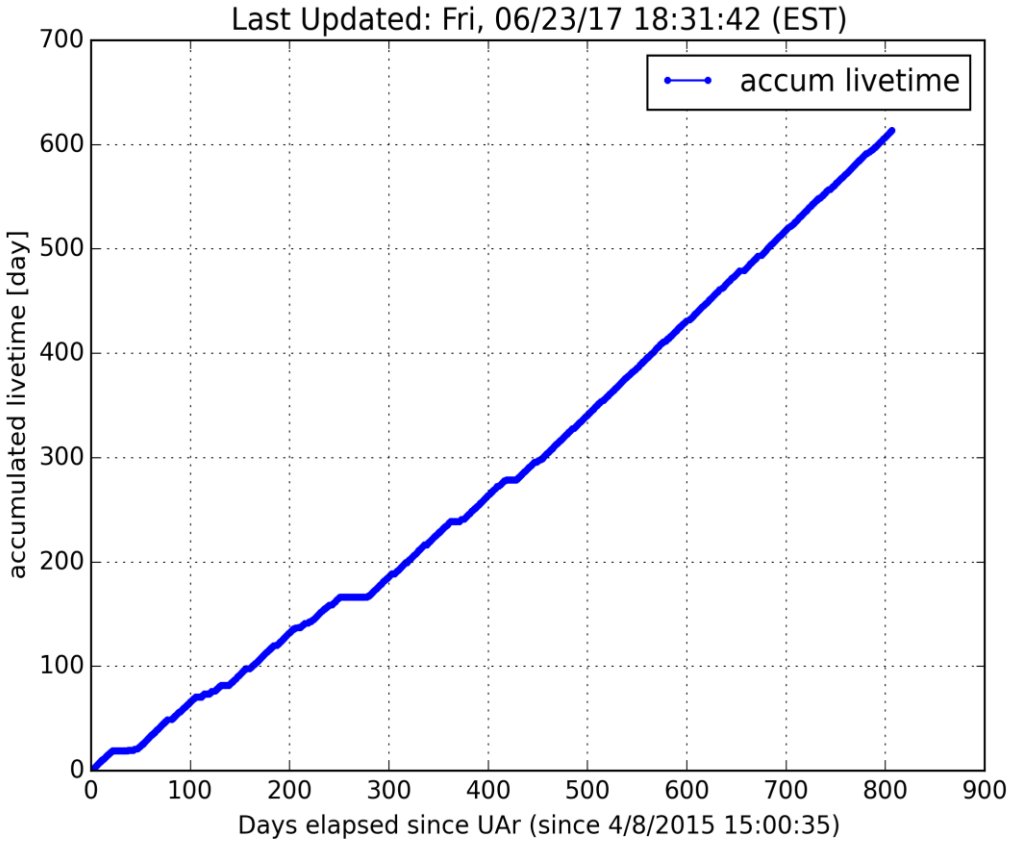
- Two-phase argon, now running on u/g Ar depleted in Ar-39

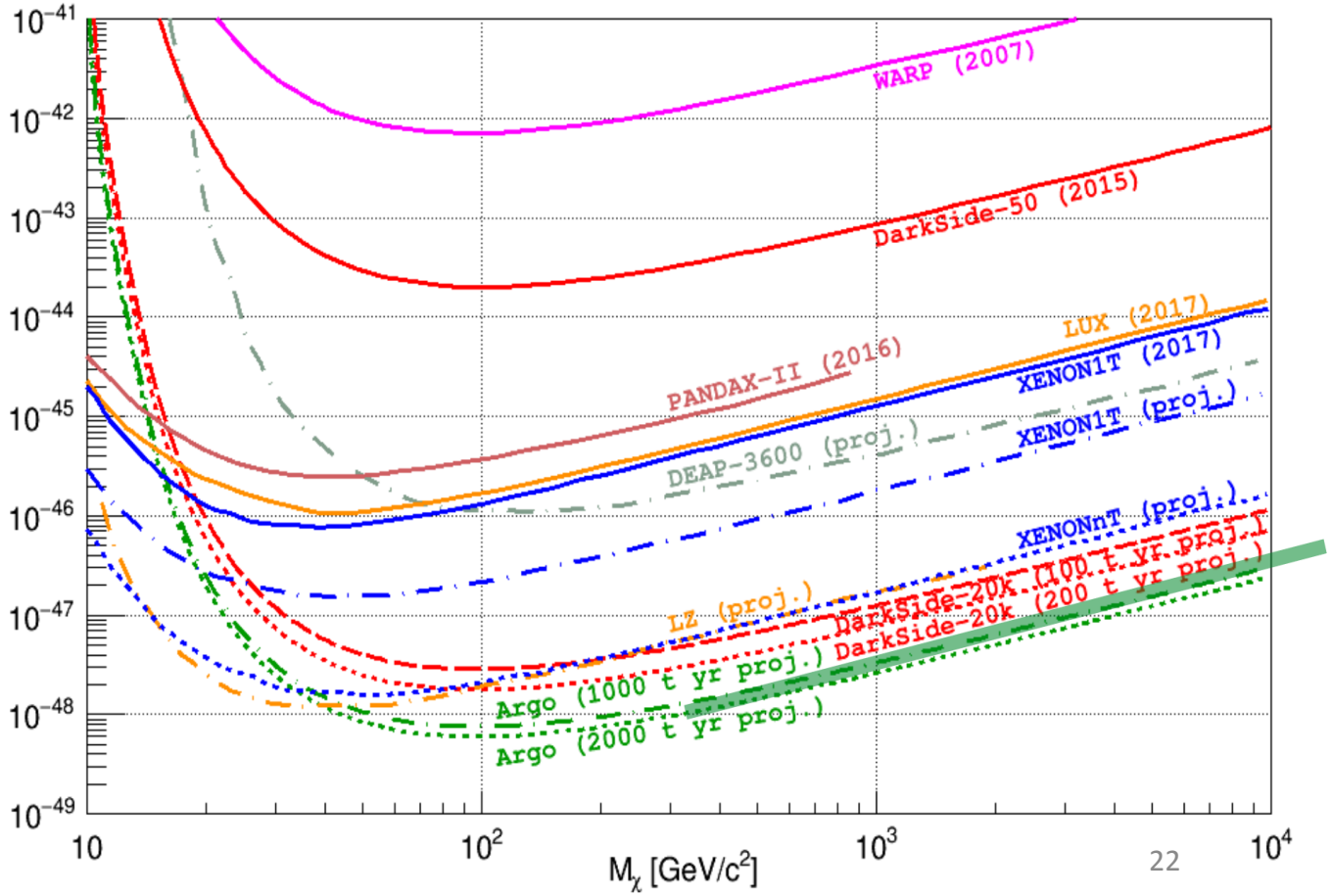




DARKSIDE-50 & 20k & Argo

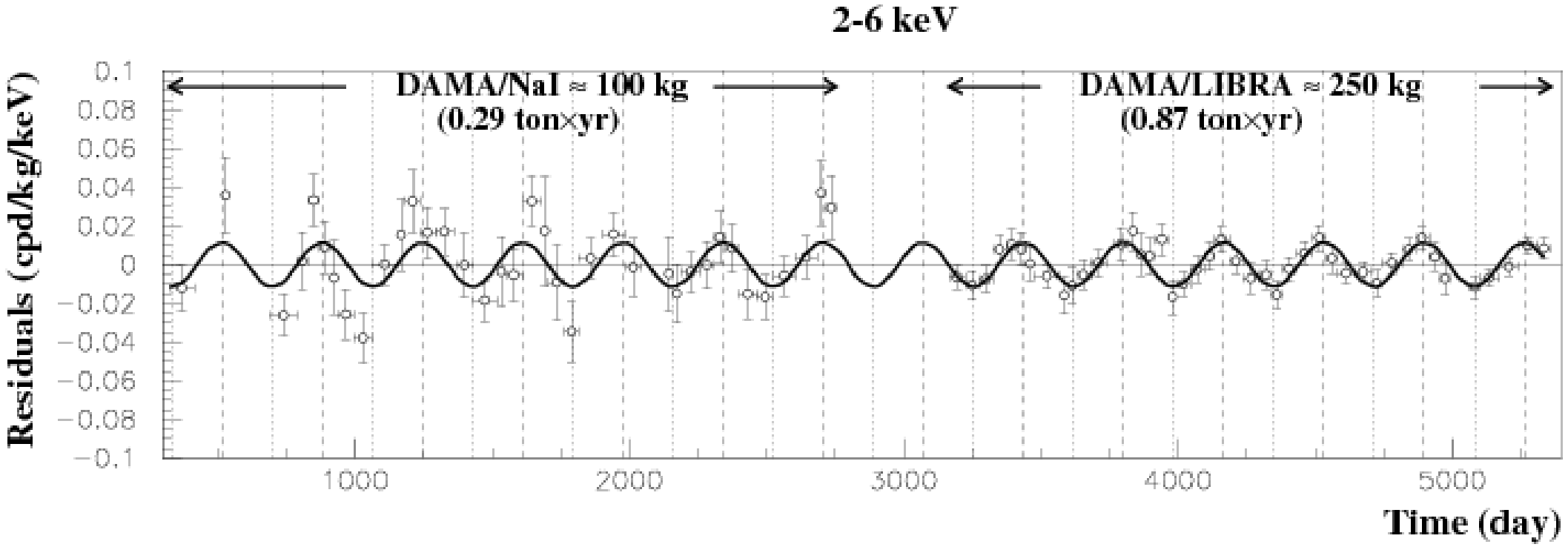
- DS-50 accrued 600 live days of data (cf. 71 live days in 1510.00702 using u/g Ar)
- Ambitious upgrade programme being planned





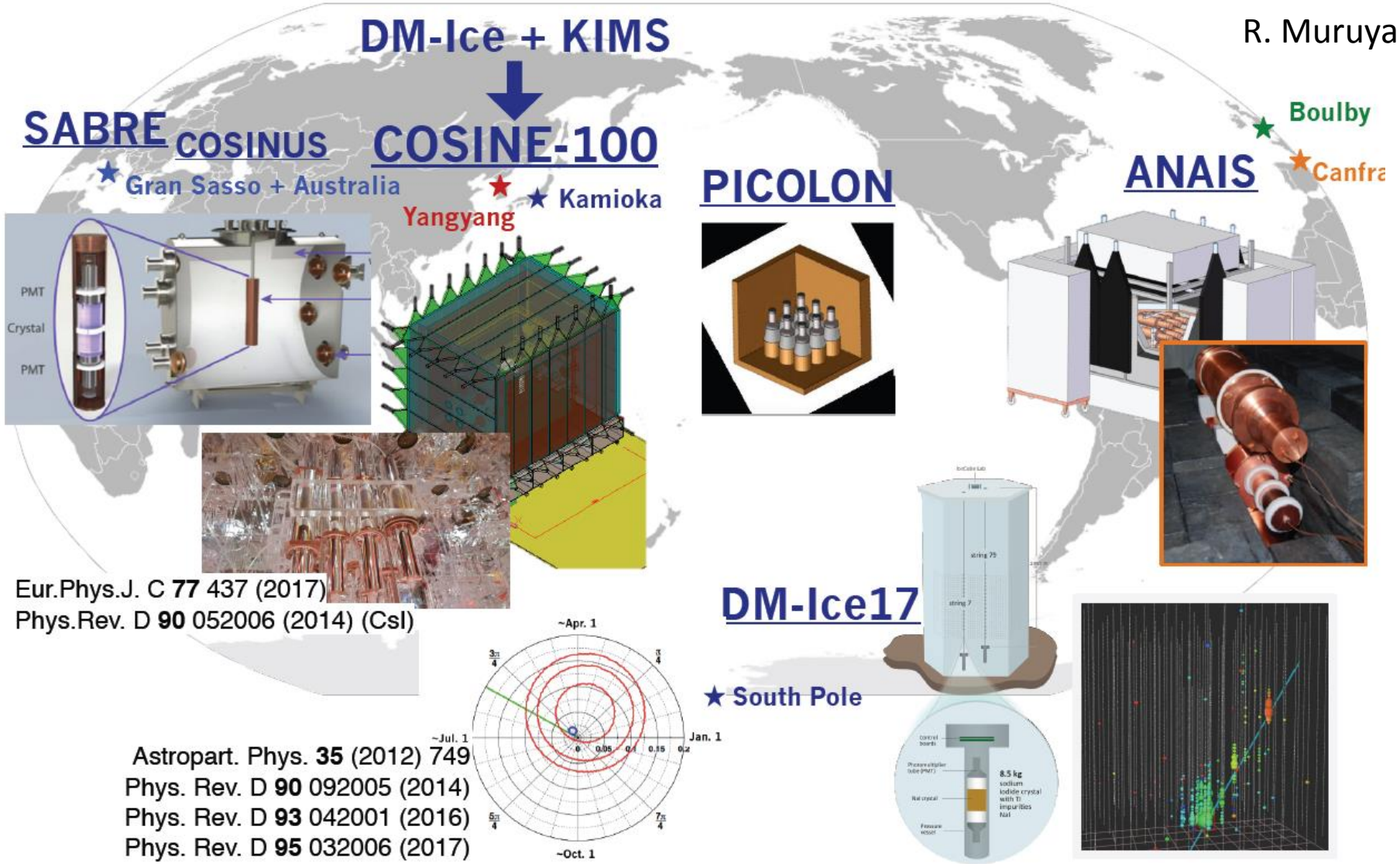
What about DAMA?

- New NaI experiments: ANAIS, SABRE, DM-Ice, COSINE, COSINUS, PICOLON
- But also xenon experiments: XMASS, XENON100, PandaX, LUX



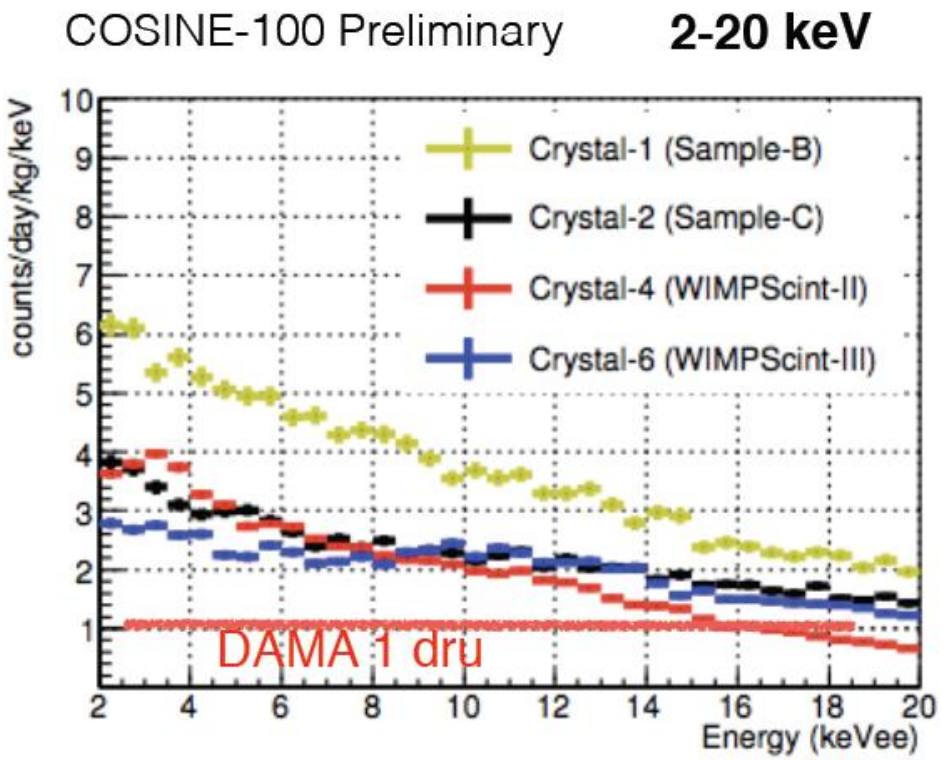
Current & Planned NaI(Tl) Experiments

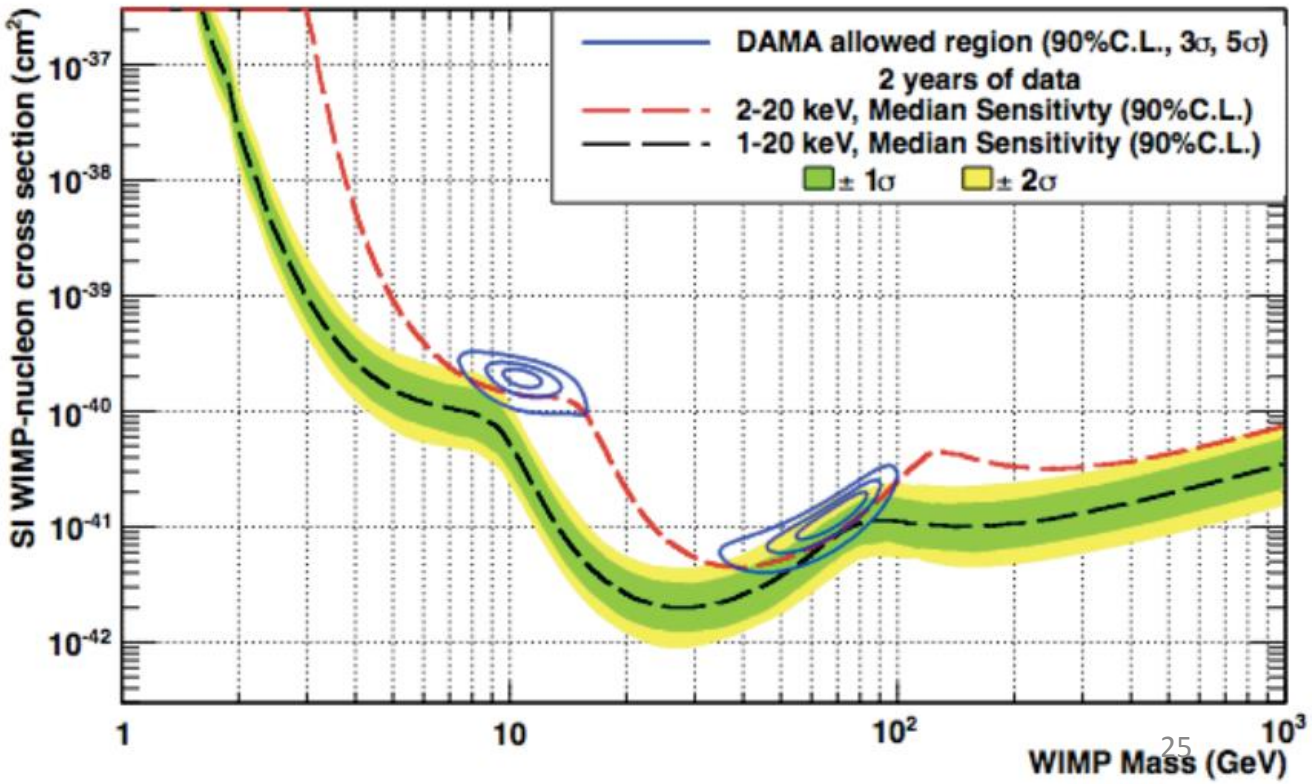
R. Muruyama



COSINE-100

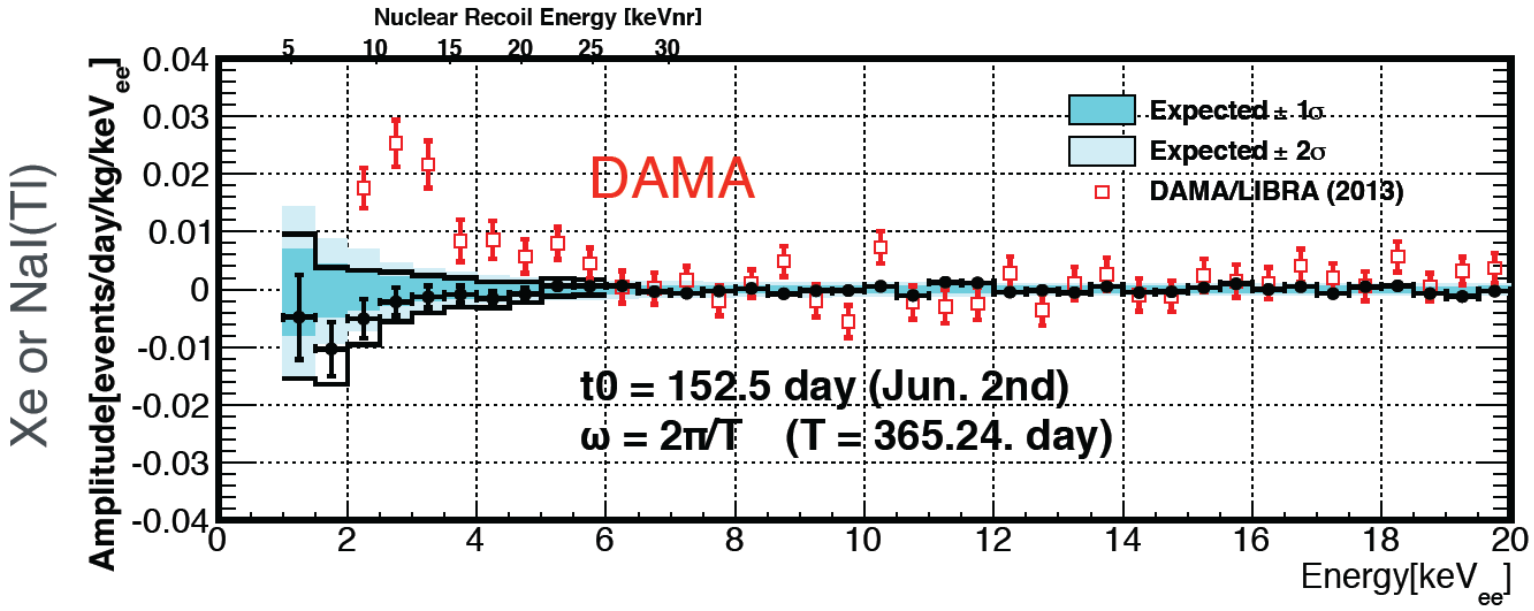
- COSINE-100 = DM-Ice + KIMS to test DAMA claim – expect DAMA sensitivity in 2 years
- Physics run started in Sep. 2016 (8 crystals, 106 kg + LS veto + muon panels)
- Continuing R&D for higher purity crystals for COSINE-200 (Phase-II)



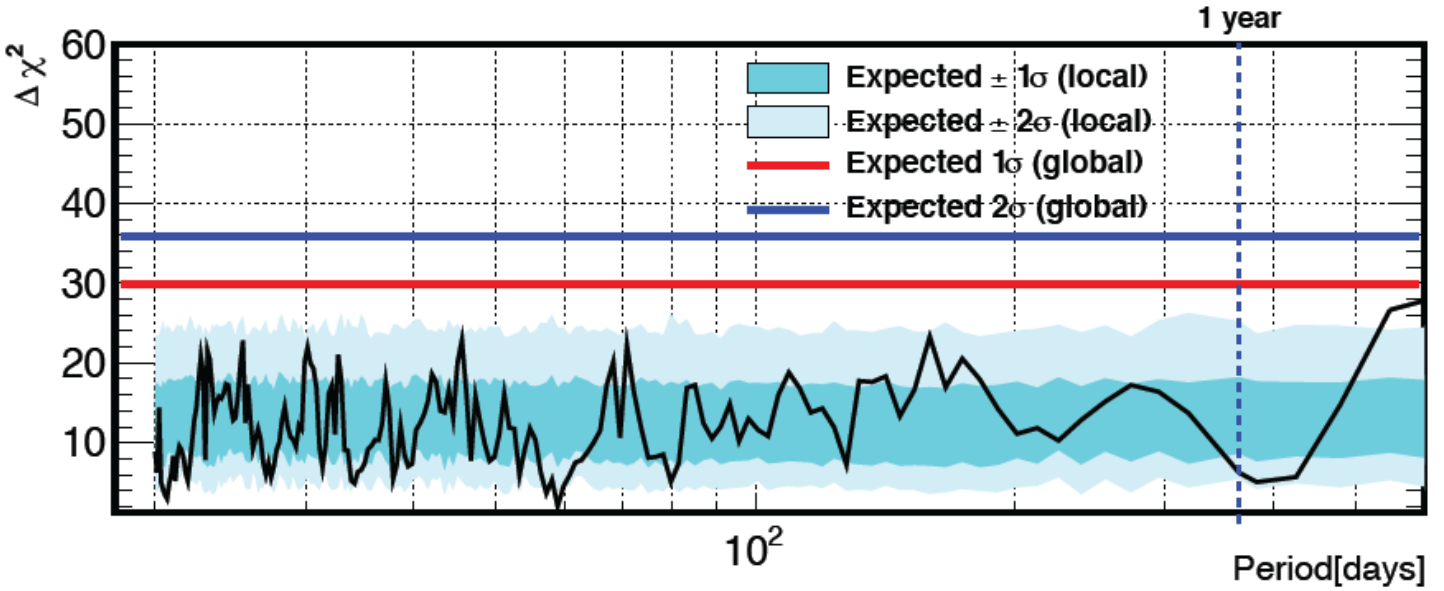


XMASS

- 832 kg LXe scintillation
- Modulation search in 2.7 years (800 live days)
- No significant period found between 20 and 600 days

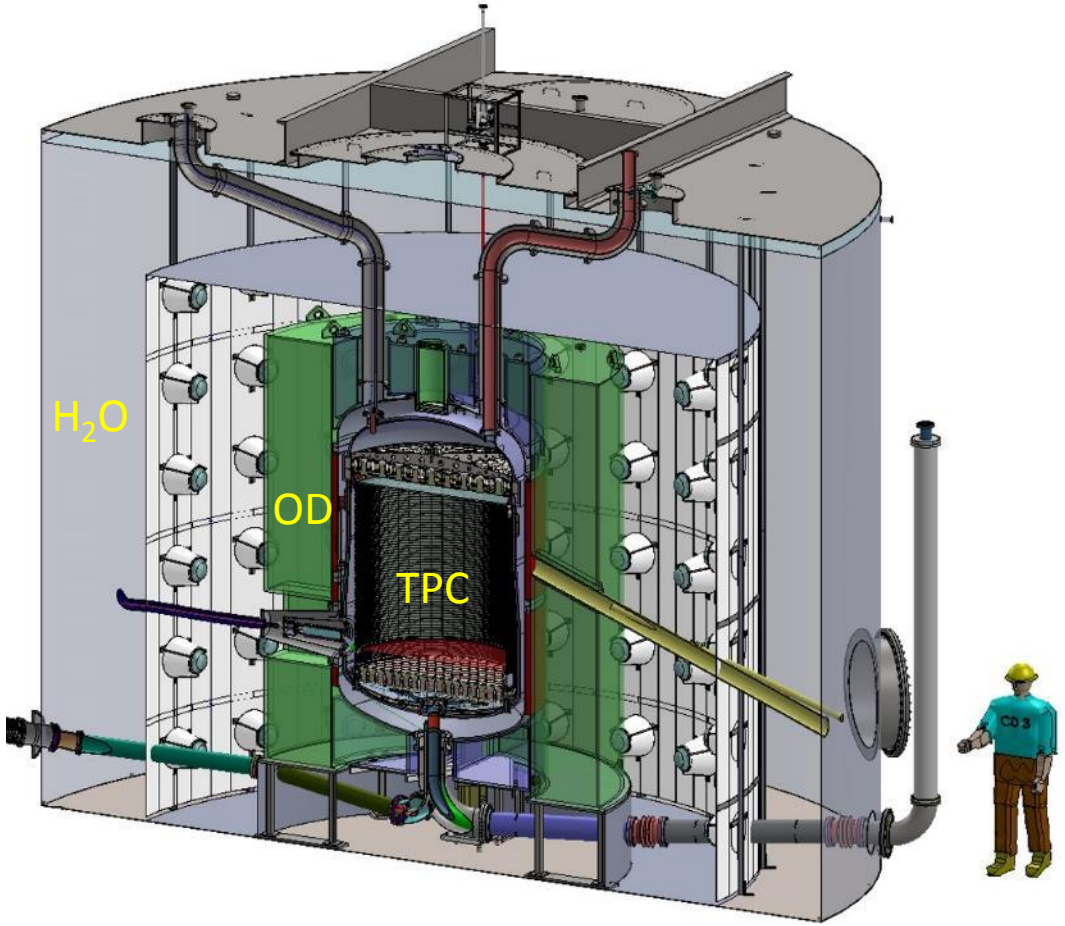


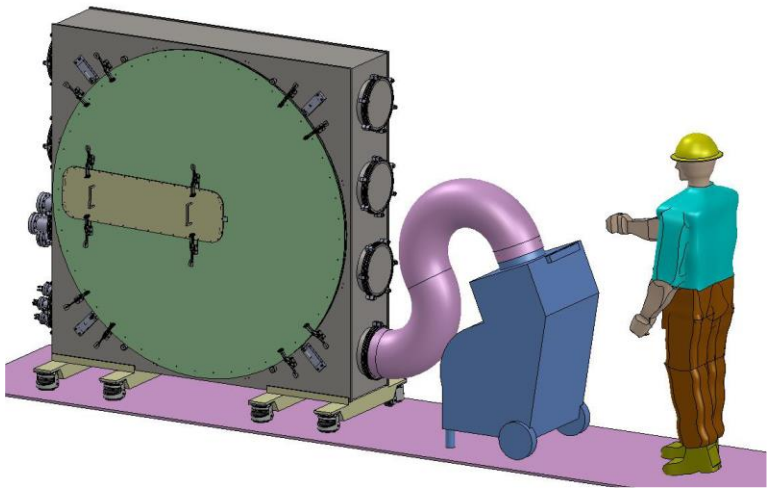
Experiment	Amplitude 10^{-3} (counts/day/kg/keVee)
DAMA/LIBRA(2013)	25@2.75 keVee
XENON100(2017)	1.67±0.73 (2.0-5.8 keVee), <3.1 90CL
XMASS-I (2017)	< 1.3-3.2 (2-6 keVee) 90CL

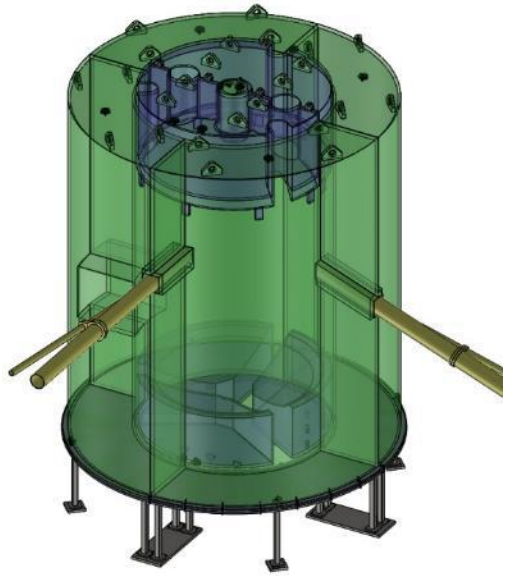


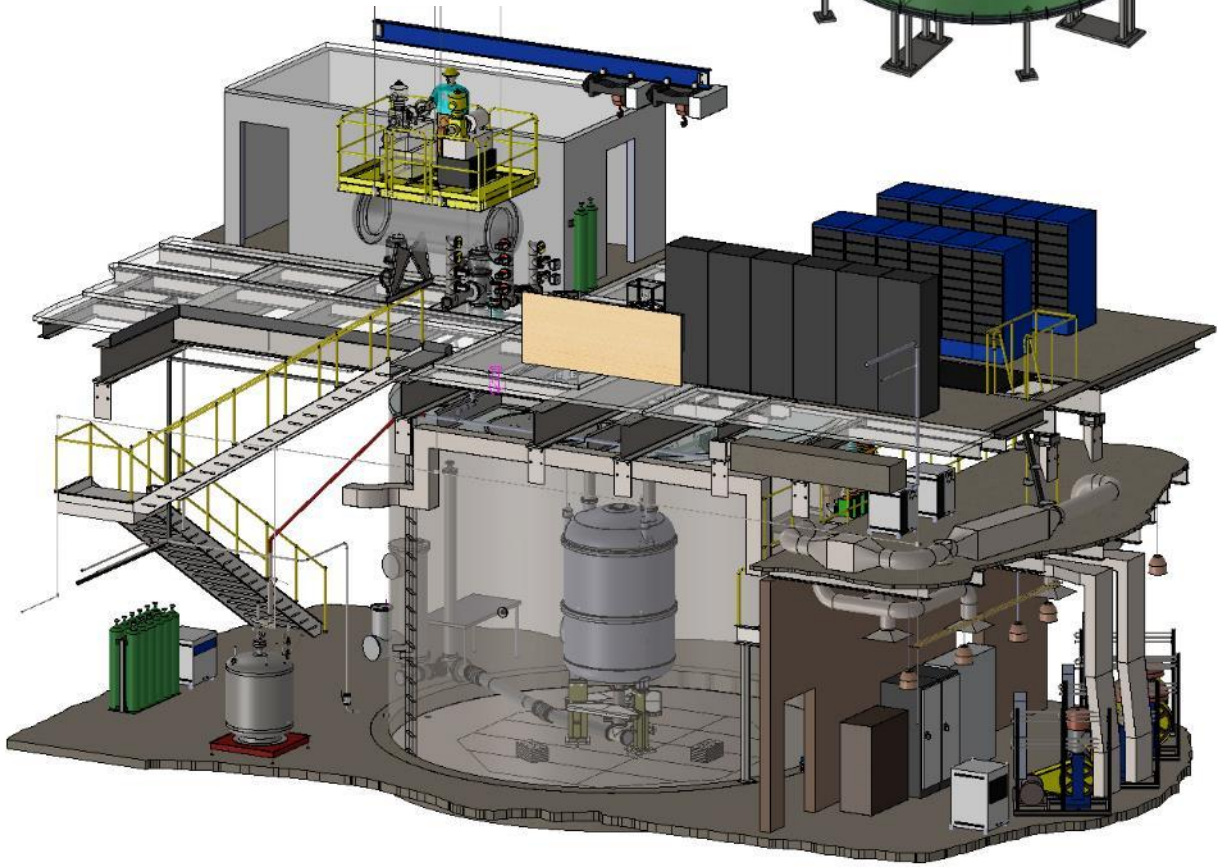
LUX-ZEPLIN (LZ)

- 7-tonne (active) Liquid Xenon TPC
- LXe Skin & Outer Detector vetoes









LUX-ZEPLIN (LZ)

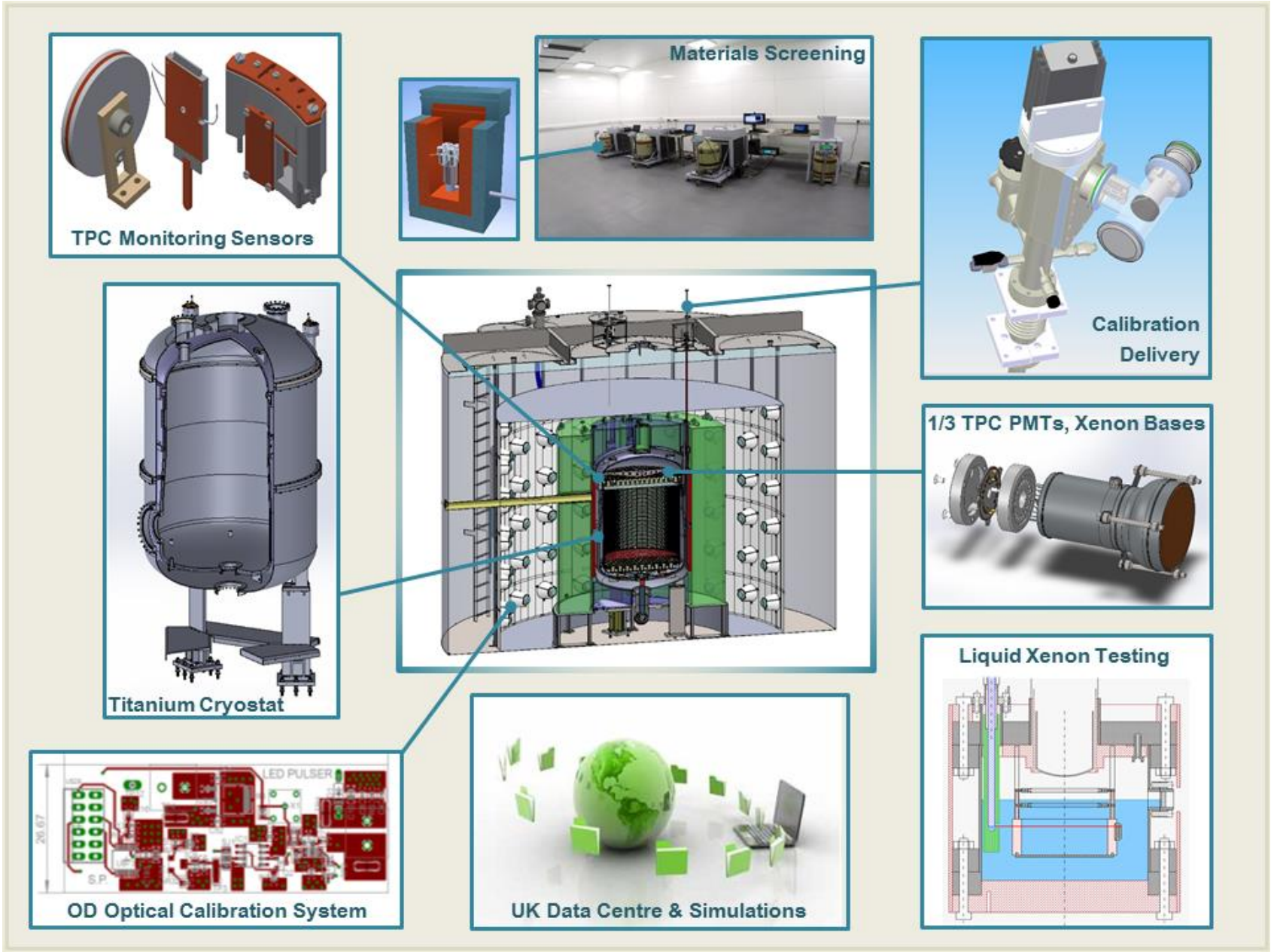
- Technical Design Report (1703.09144): hardware & sensitivity baselines
  - Sensitivity update later this year
- Final designs completed & reviewed
- Major procurements in progress

  Xenon, cryostat, photomultipliers,
  Outer Detector scintillator & vessels,
  Titanium and PTFE materials,
  DAQ/electronics coming soon
- Significant programmes to control
  - Kr-85 removal (req: 0.015 ppt)
  - External backgrounds (subdominant in FV)
  - Radon emanation (req//goal: 20//1 mBq)
  - Cleanliness/dust (500//5 ng/cm^2)

Date	Activity
March 2012	LZ collaboration formed
July 2014	Project selected in the US and UK
April 2015	DOE CD-1/3a approval, UK project kick-off *Conceptual Design Report* arXiv:1509.02910
April 2016	DOE CD-2/3b review
January 2017	DOE CD-3 review *Technical Design Report* arXiv:1703.09144
August 2017	Surface Assembly Lab @ SURF completed
January 2018	Begin surface assembly @ SURF
October 2019	Begin underground installation of detector
April 2020	DOE CD-4 review Detector commissioning
2020-2025	5+ years of operation

UK SCOPE

- LZUK: ~50 people in 9 institutes
- UK hardware fabricated by March 2018
- UK screening at >80% capacity, ~200 assays
- UK Data Centre already operational (GridPP)
- Major contributions also to simulations, sensitivity studies, and other software



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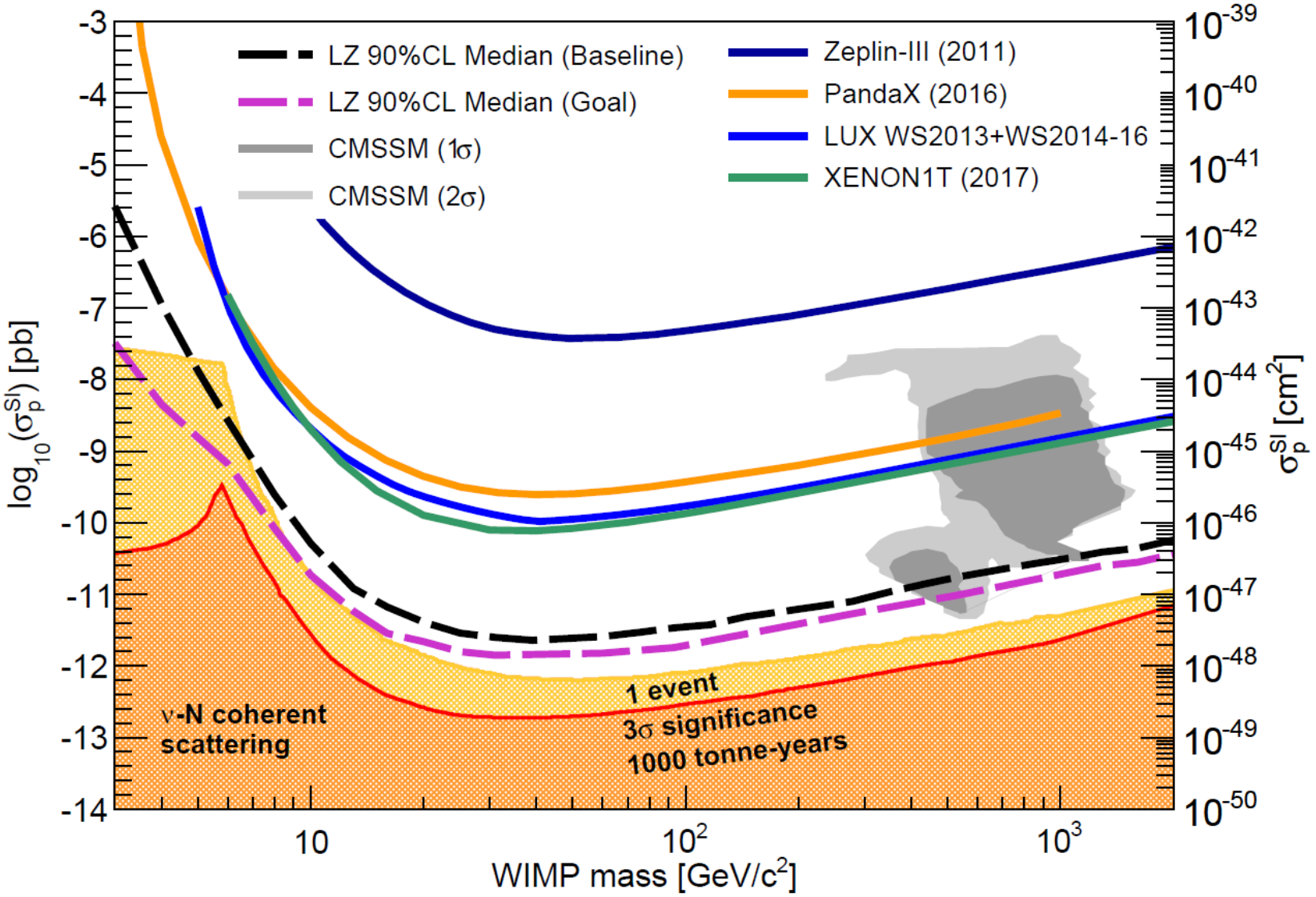
LUX-ZEPLIN (LZ)



Summary

- Several tonne-scale noble liquid experiments operating now, until ~2020, rapid progress in spin-independent sensitivity for vanilla WIMPs
- Bubble chambers leading WIMP-proton SD searches, set to continue
- Light WIMP sensitivity with cryogenic detectors also progressing, but more slowly
- DAMA claim likely probed on this same timescale with a NaI(Tl) target

- G2 experiments from ~2020 (LZ, XnT) to probe most of accessible parameter space

- G3 experiments being planned already – R&D efforts starting