UNIVERSITEIT VAN AMSTERDAM

Nikhef

Particle Dark Matter searches, the next generation

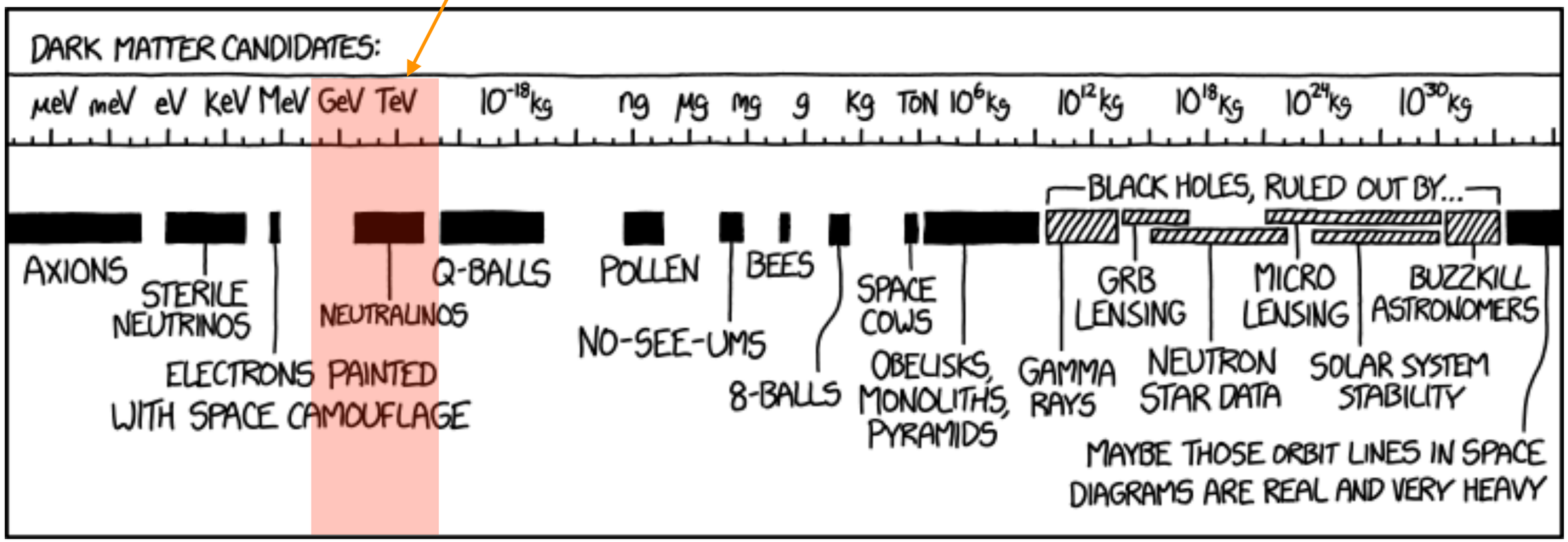
LIDINE 2022

Sept 21, 2022

Tina Pollmann

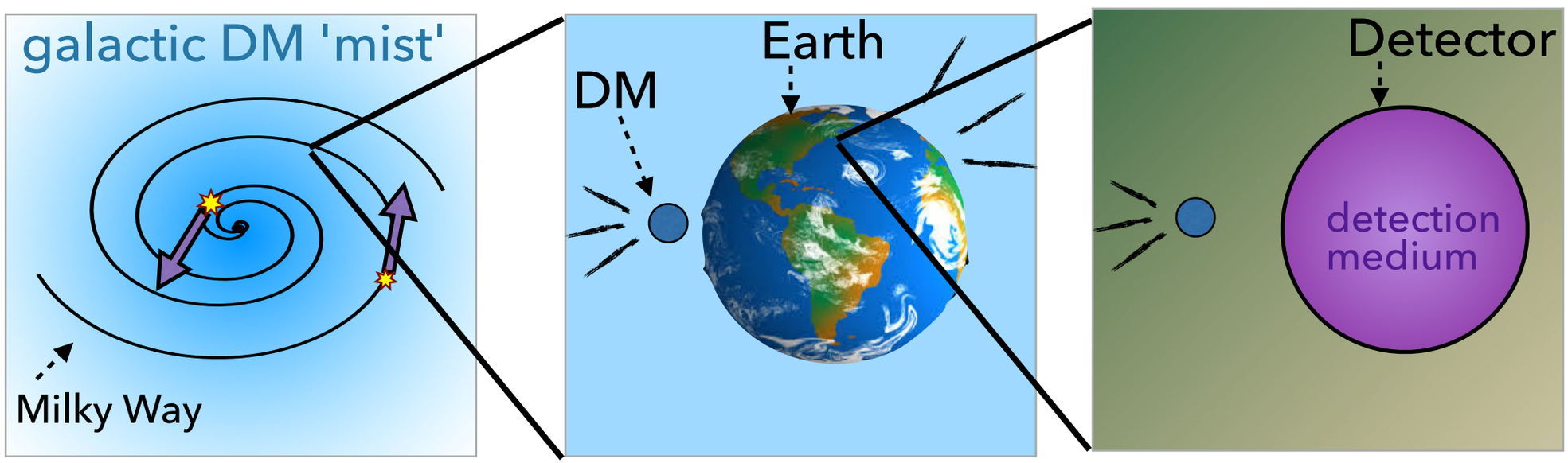
Liquid noble gas detectors are well-suited to the search for weakly interacting massive particles (WIMPs)

liquid noble gasses excel here

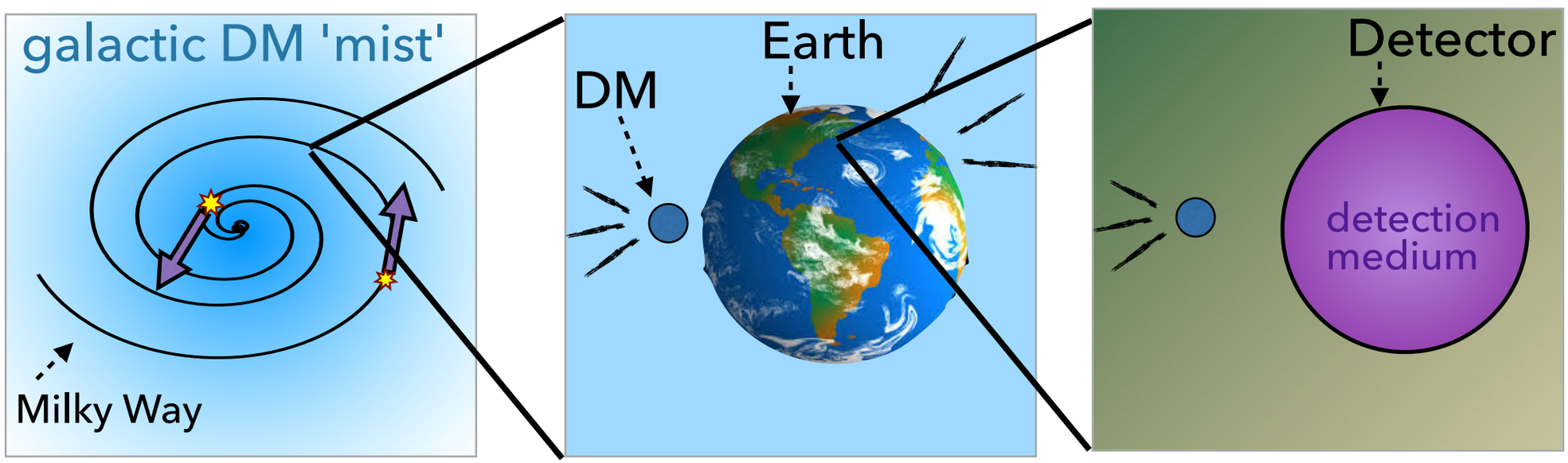


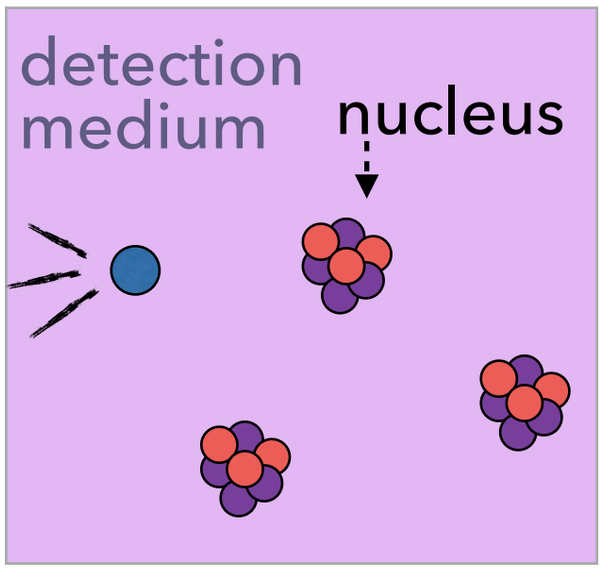
https://xkcd.com/2035/

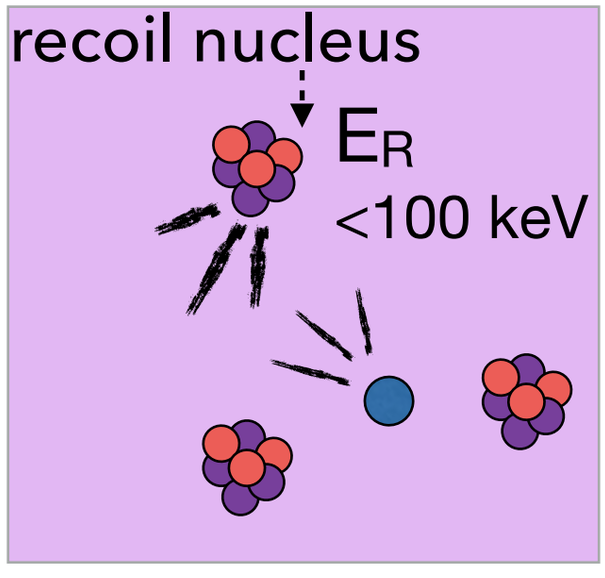
Direct detection: the basic idea is elastic scattering between galactic DM and SM particles (atomic nuclei) in our detector.

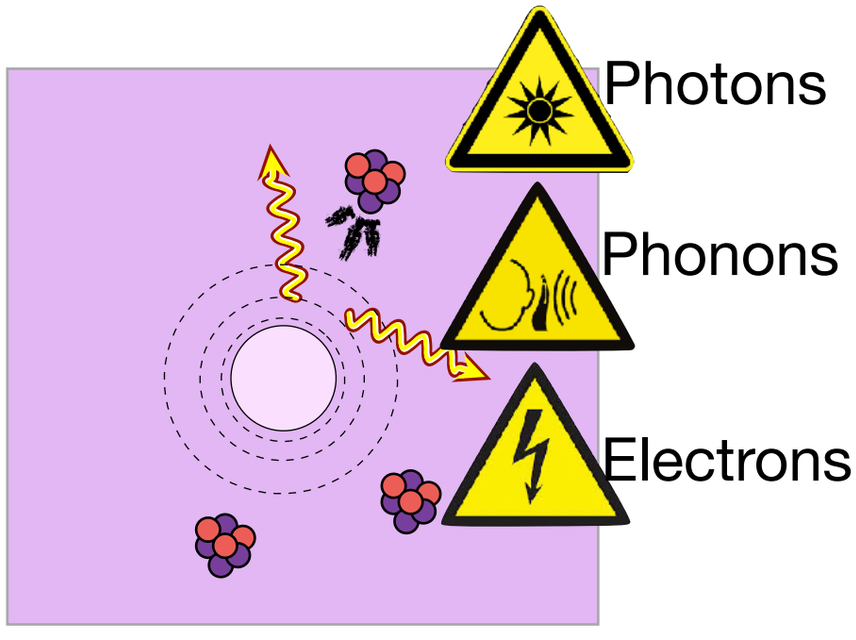


Direct detection: the basic idea is elastic scattering between galactic DM and SM particles (atomic nuclei) in our detector.



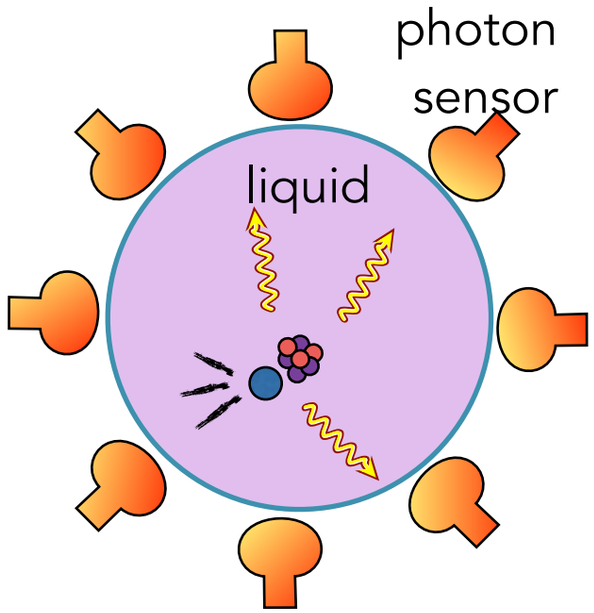






Three main detector configurations for measuring these nuclear recoils are in use:

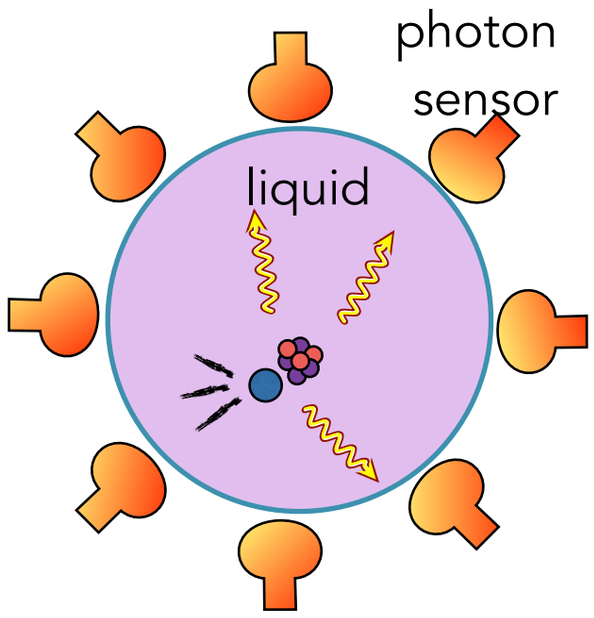
light-only



DEAP-3600

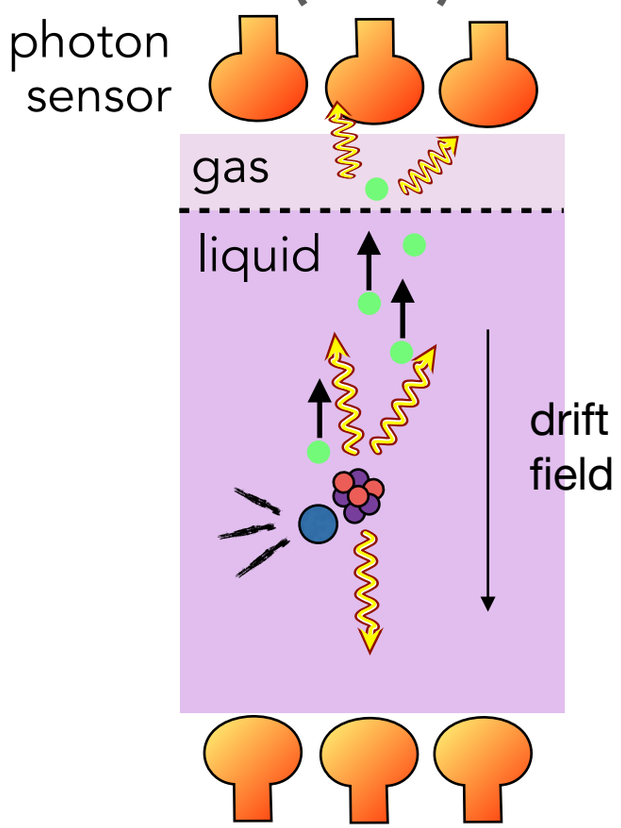
Three main detector configurations for measuring these nuclear recoils are in use:

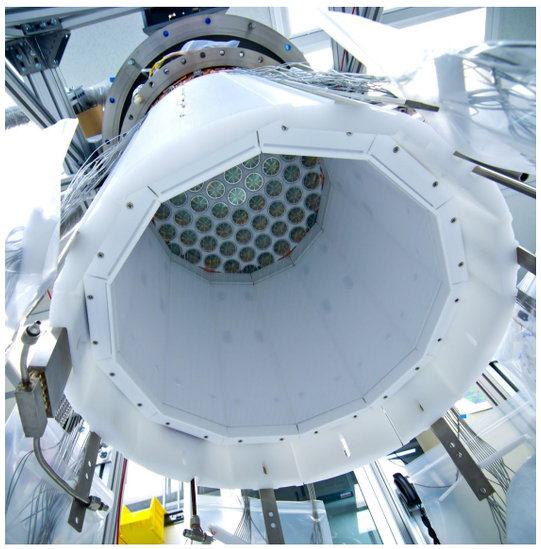
light-only



DEAP-3600

light+charge / charge-only (TPC)





LUX

Three main detector configurations for measuring these nuclear recoils are in use:

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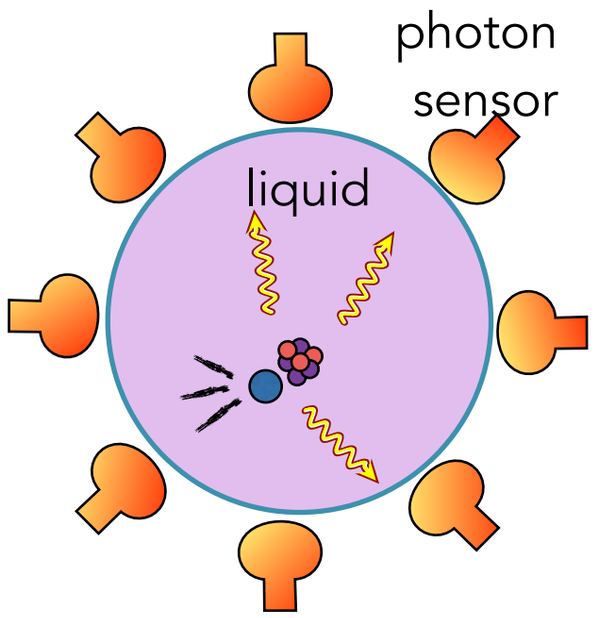
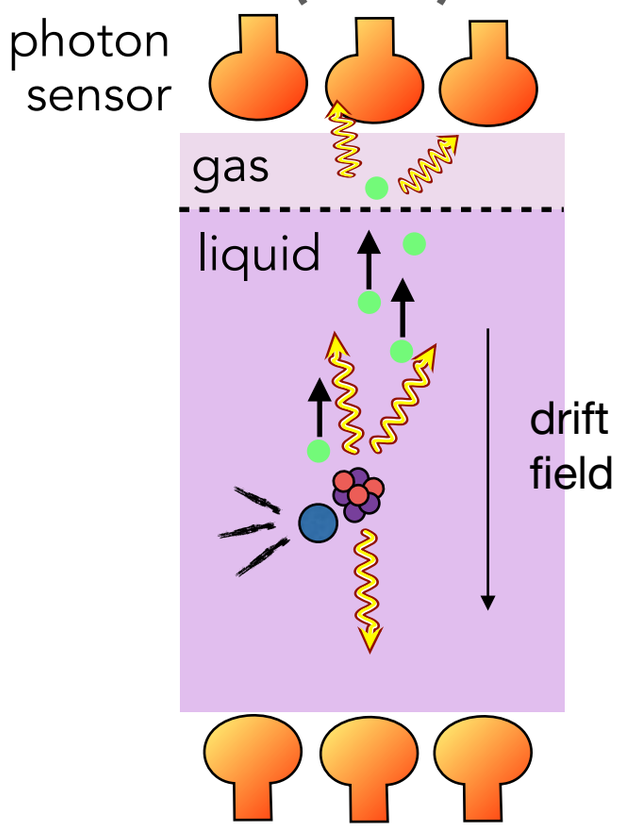
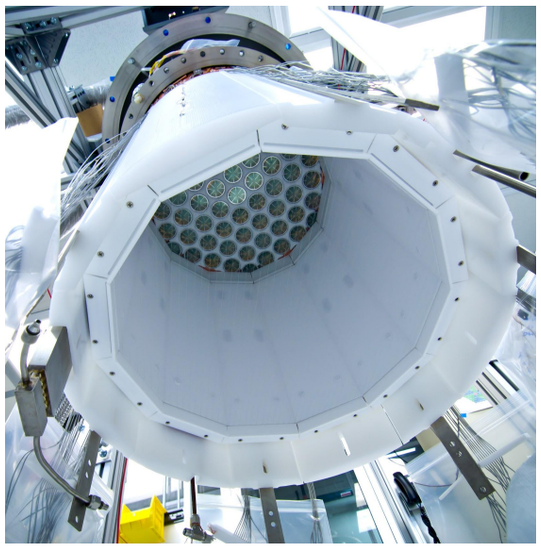


DEAP-3600

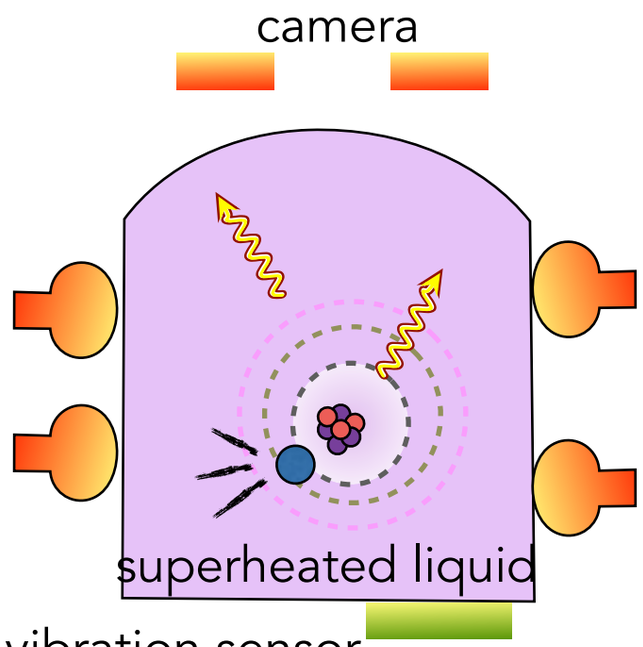
light+charge / charge-only (TPC)





LUX

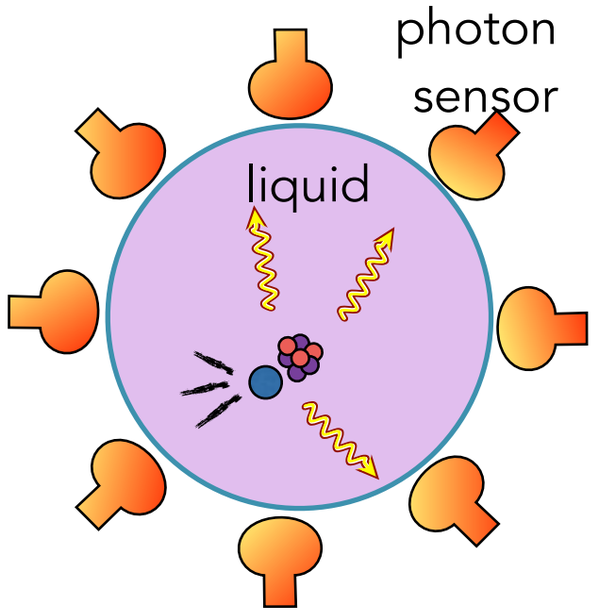
light+heat



SBC

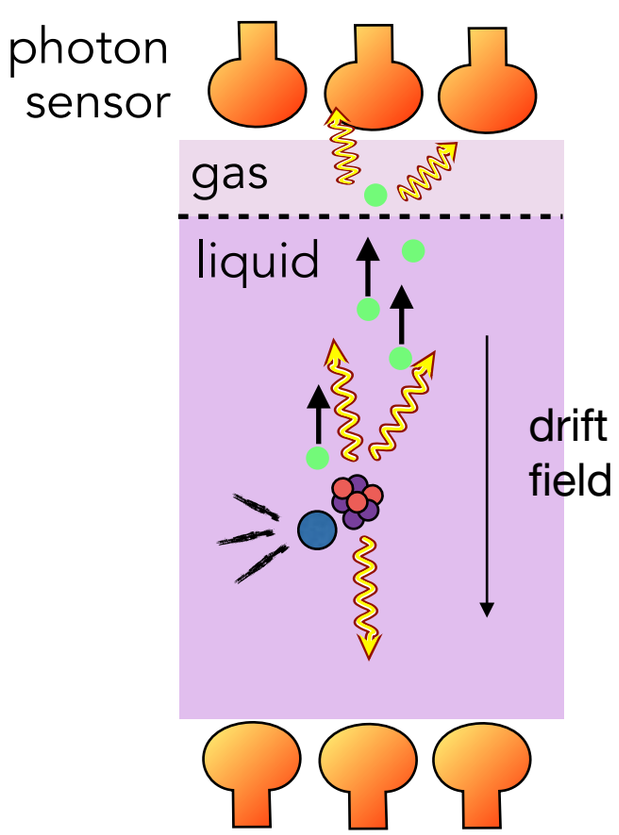
And at least one newer idea using superfluid helium.

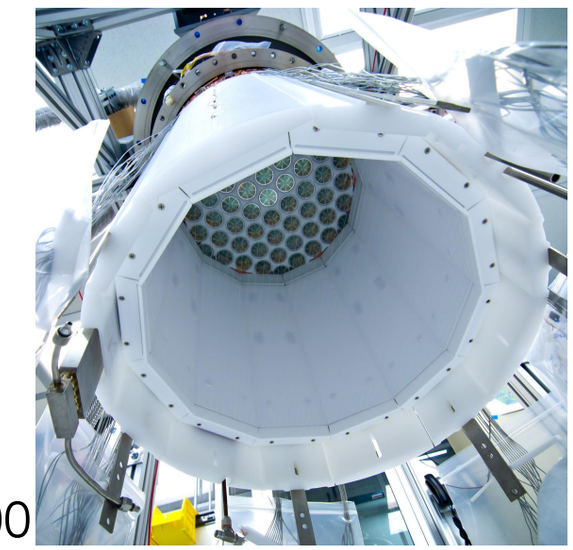
light-only



DEAP-3600

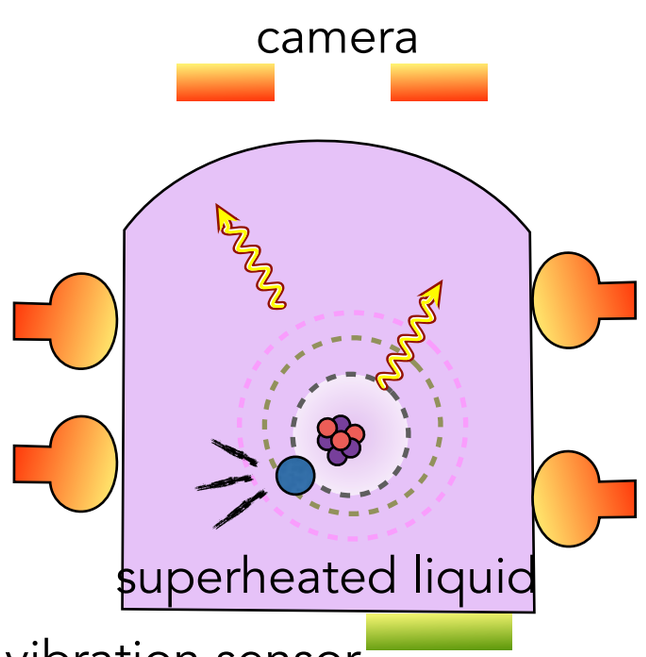
light+charge / charge-only





LUX

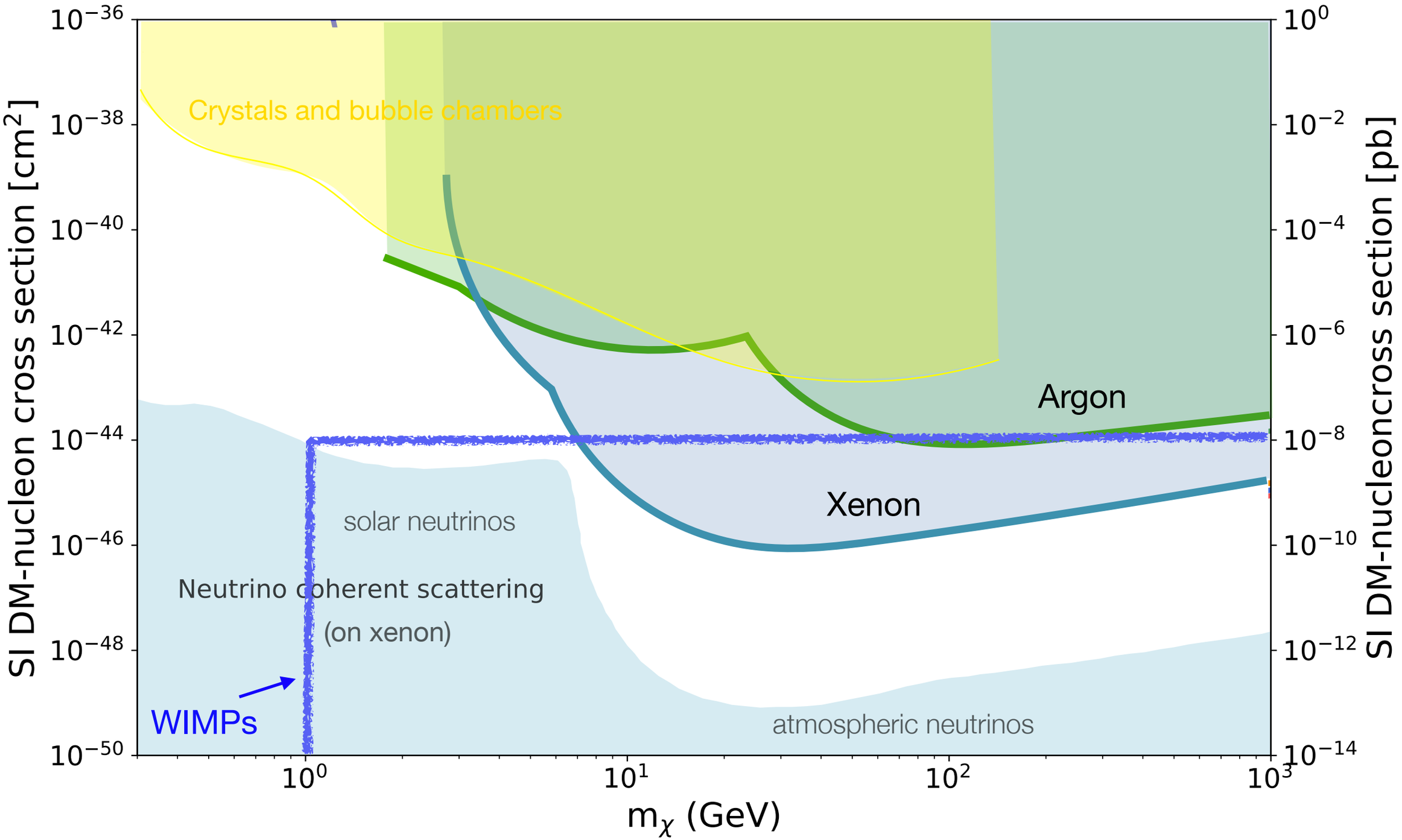
light+heat



Superfluid
He ?

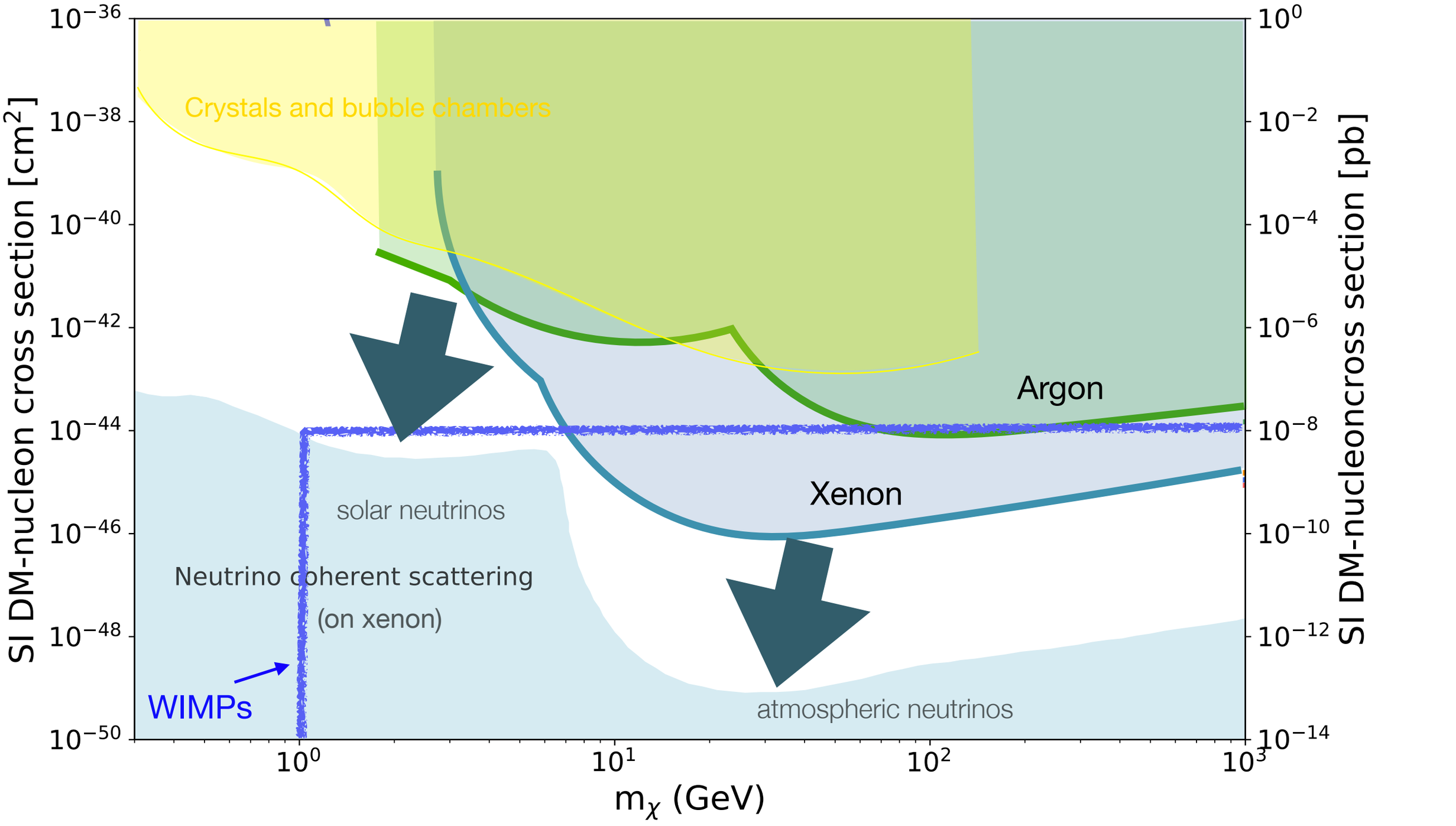
SBC

No credible WIMP signal has been found so far.



Based on: P.A. Zyla *et al.* (Particle Data Group), Prog. Theor. Exp. Phys. **2020**, 083C01 (2020)

We want to extend the sensitivity of the detectors into the neutrino fog



Based on: P.A. Zyla *et al.* (Particle Data Group), Prog. Theor. Exp. Phys. **2020**, 083C01 (2020)

Two neutrino-fog-penetrating detectors (plus SBC for lower mass WIMPs) are planned:

GADMC

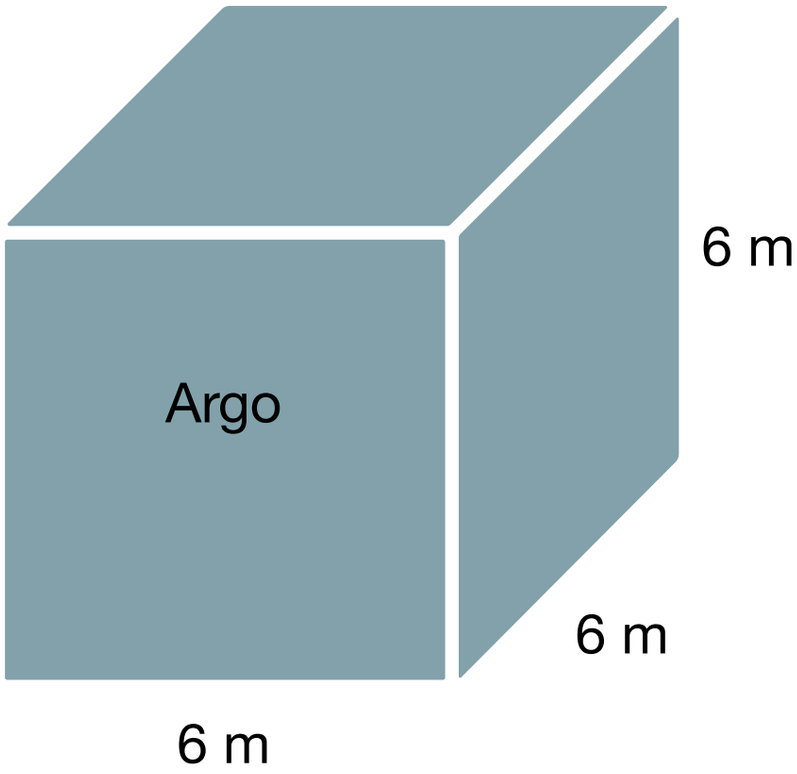
DEAP + DarkSide + ArDM + CLEAN

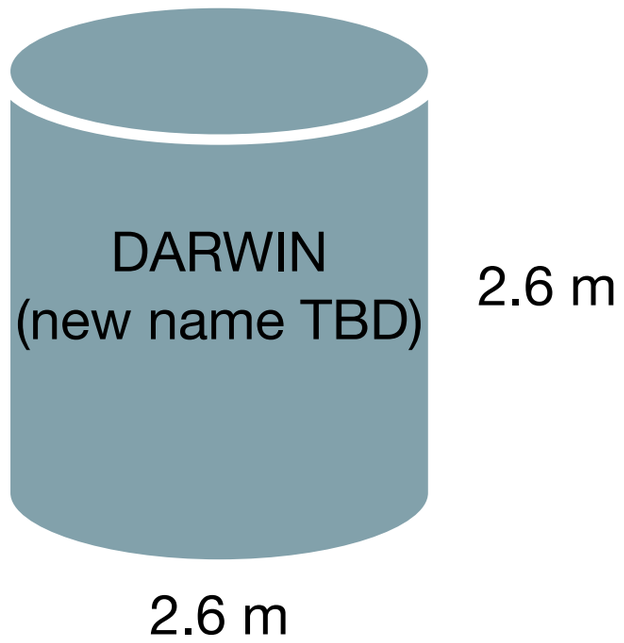
~300 tonnes liquid argon

XLZD

XENON + LZ + DARWIN

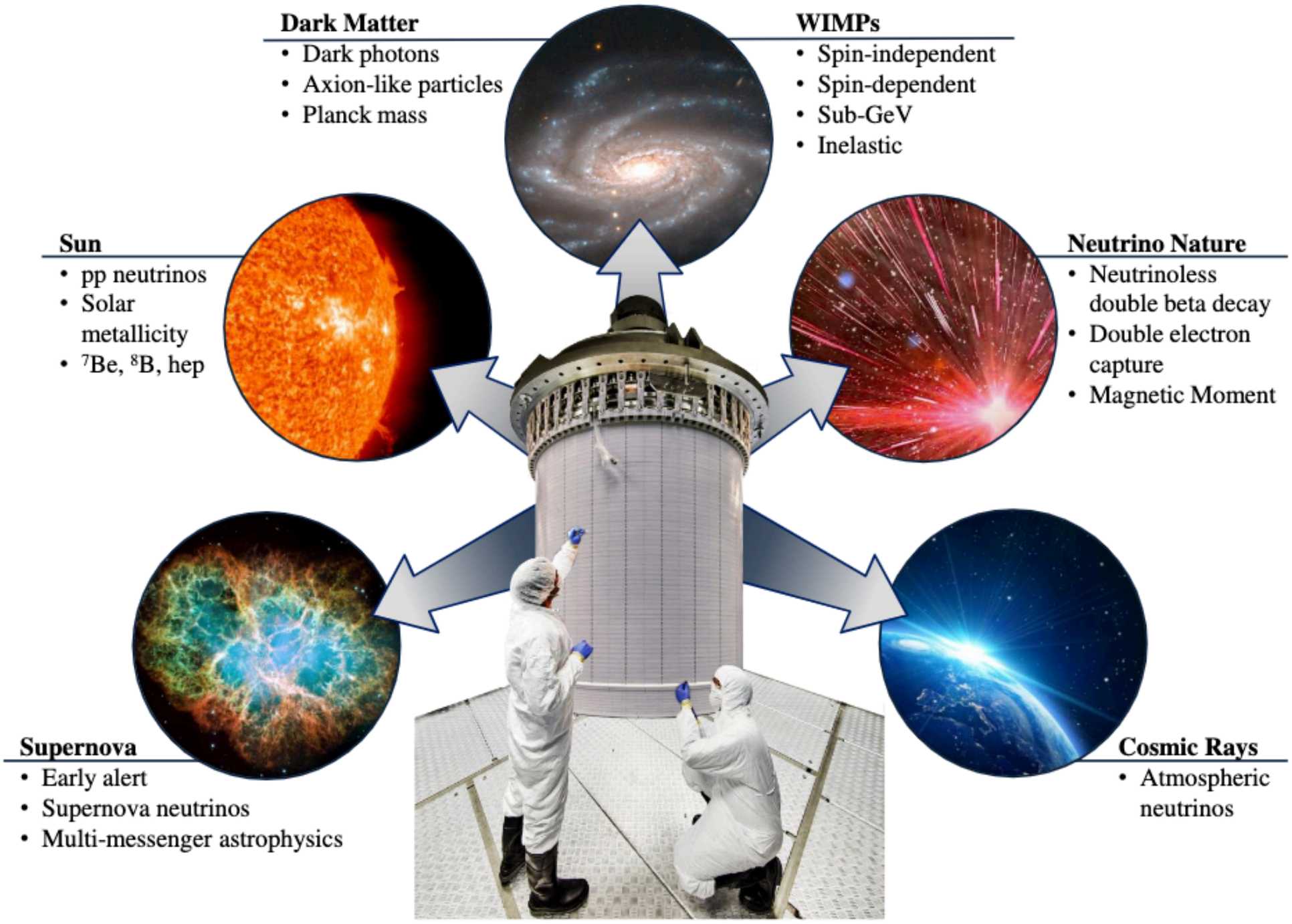
~40 tonnes liquid xenon





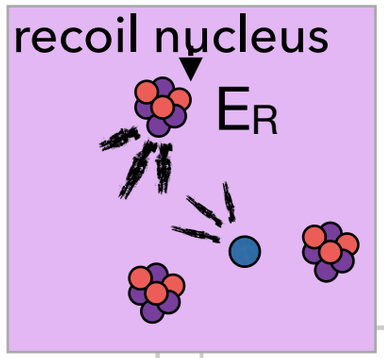
And for both detectors, a science programme beyond WIMPs is foreseen (making lemonade out of the neutrino-lemons).

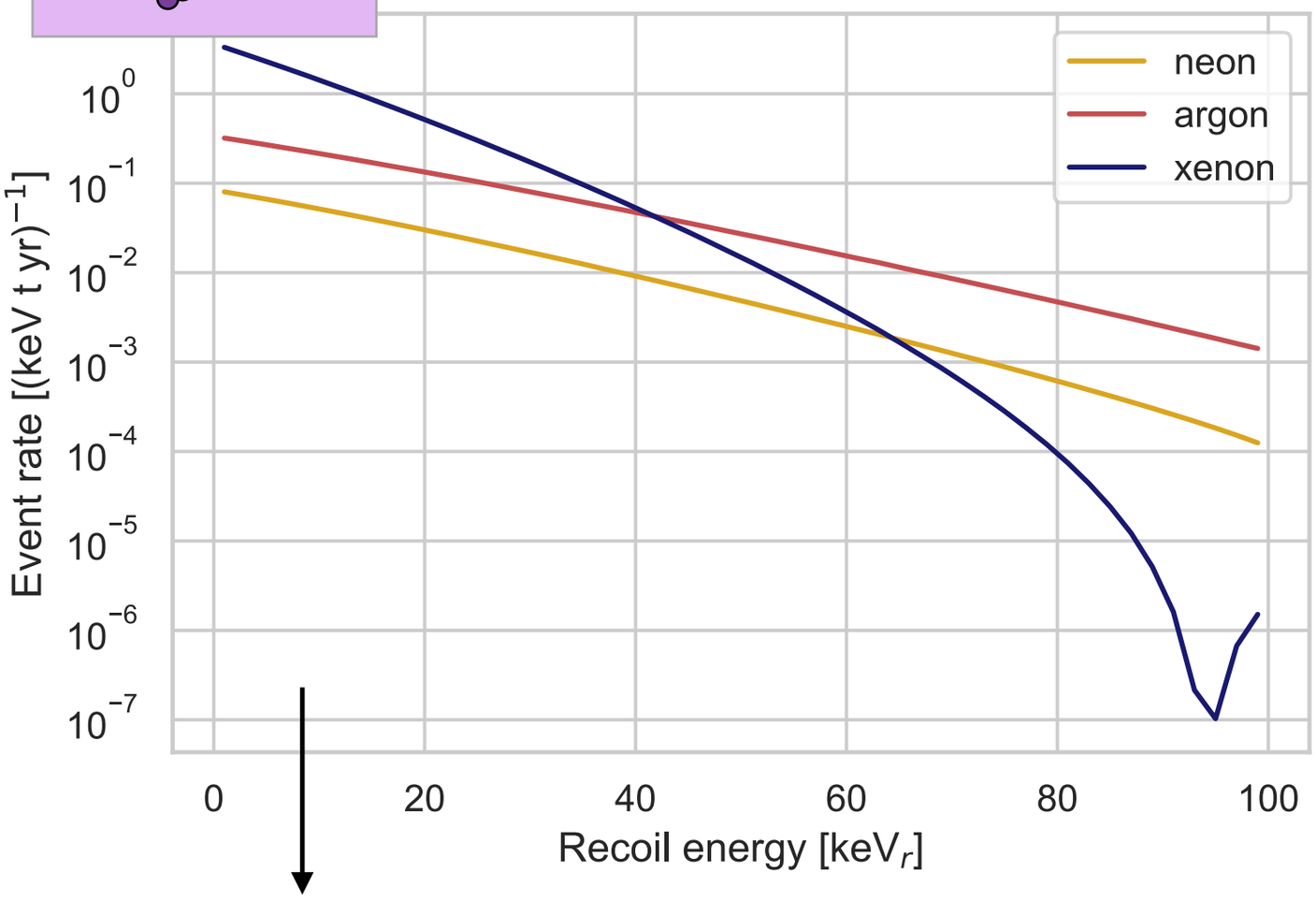
Physics reach of XLZD detector.

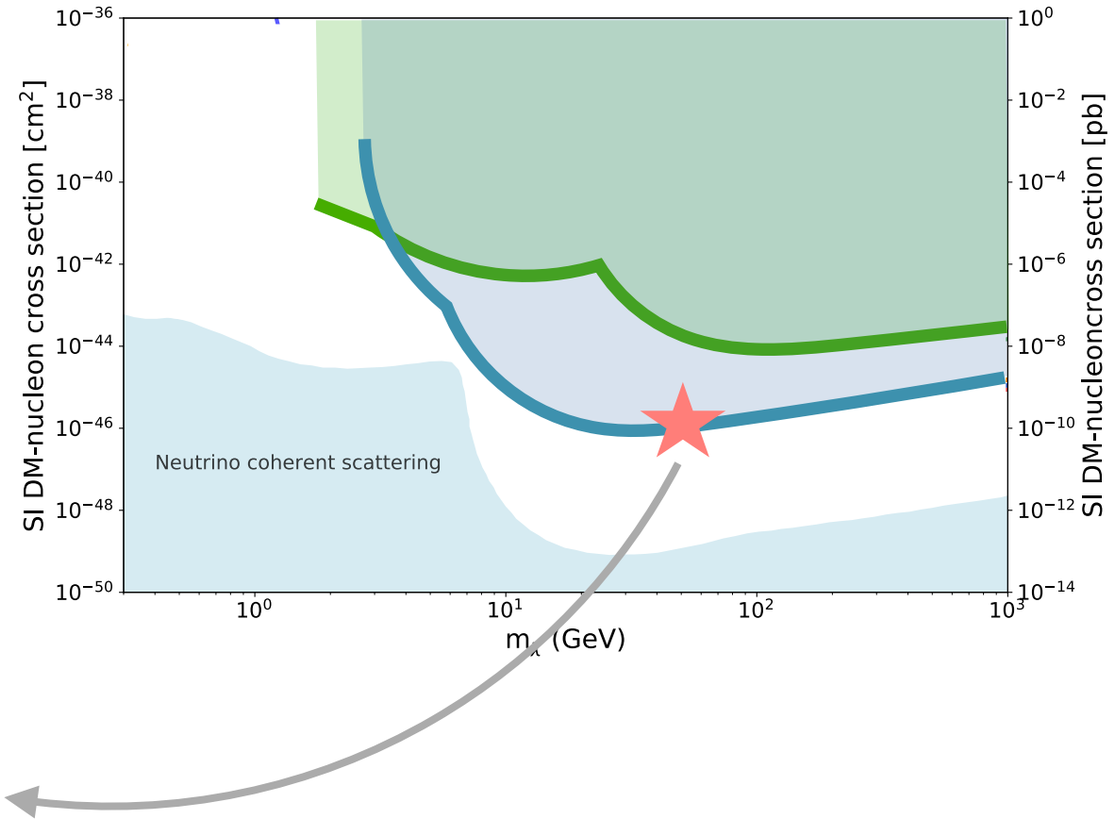


arXiv:2203.02309

For WIMPs (and some neutrino channels), the signal rate is highest at low recoil energies, where few quanta are produced.







~60 electrons and 60 photons (LXe TPC)

~100 photons (LAr light-only)

Several talks here will report on recent developments in efficient means of detecting small amounts of light, electrons, and heat coming from large detectors

Wed 21/09 | Thu 22/09 | Fri 23/09 | All days

Print | PDF | Full screen | Detailed view | Filter

13:00

Novel electron & photon sensing concepts of single-phase noble-liquid detectors
316A, University of Warsaw Library

Progress with the bubble-free Liquid Hole-Multiplier for dual-phase scintillation- &
Gonzalo Martínez Lema

Floating Hole Multiplier – a novel concept for dual-phase noble liquid detectors
316A, University of Warsaw Library

14:00

Rugged and radiopure amplification structures for large-area xenon chambers rea
Sara Leardini

Wed 21/09 | Thu 22/09 | **Fri 23/09** | All days

Print | PDF | Full screen | Detailed view | Filter

11:00

The light detection system of the ICARUS detector in the Short Baseline Neutrino program at Fermilab. *Marta Babicz*
316A, University of Warsaw Library 11:20 - 11:35

The Photon Detection System of SBND *Francisco Javier Nicolas-Arnaldos*
316A, University of Warsaw Library 11:35 - 11:50

SiPM array of Xenoscope, a full-scale DARWIN vertical demonstrator *Ricardo Peres*
316A, University of Warsaw Library 11:50 - 12:05

12:00

Production and Testing of the Large-Area Photon Detector ArCLight *Jan Kunzmann*
316A, University of Warsaw Library 12:05 - 12:20

Scintillation Light Detection Performance for the DUNE ND-LAR 2x2 Modules *Anja Gauch*
316A, University of Warsaw Library 12:20 - 12:35

Light detection with power and signal transmission over fiber. *Henrique Souza*
316A, University of Warsaw Library 12:35 - 12:50

Thu 22/09

Print | PDF | Full screen | Detailed

11:00

Correlated noises for NUV-HD-Cryo SiPMs
316A, University of Warsaw Library

Measurement of SiPM external cross-talk in a liquid xenon detector
316A, University of Warsaw Library

A large facility for photosensors test at cryogenic temperature
316A, University of Warsaw Library 11:50 - 12:05

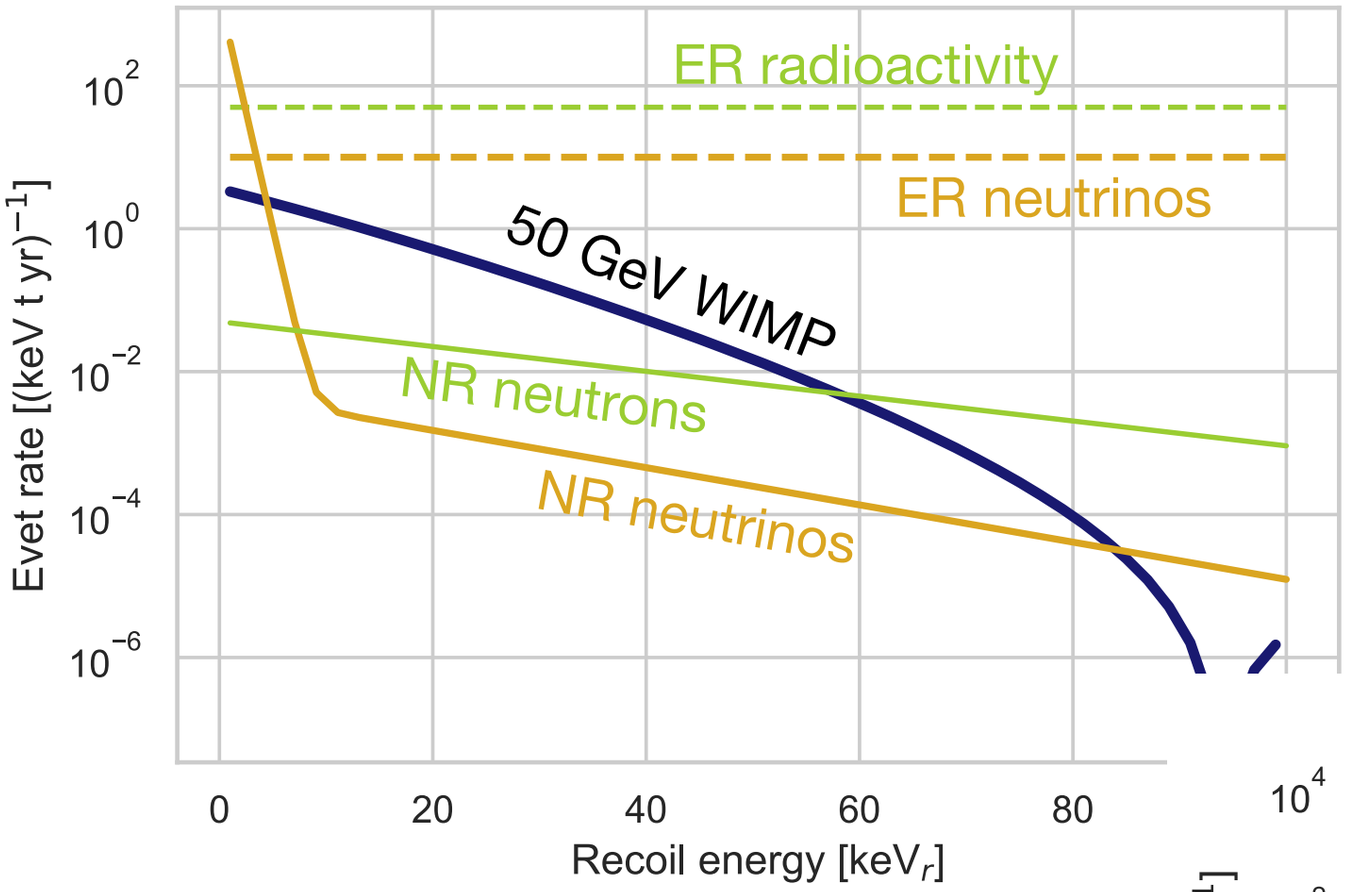
12:00

Rapid characterization of SiPMs for noble liquid experiments *Bindiya Chana*
316A, University of Warsaw Library 12:05 - 12:20

Novel VUV Light Detection in a Pixelated Liquid Argon Time Projection Chambers *Jonathan Asaadi*
316A, University of Warsaw Library 12:20 - 12:35

Studies of event burst phenomenon with SiPMs at cryogenic temperature *Thomas Tsang*
316A, University of Warsaw Library 12:35 - 12:50

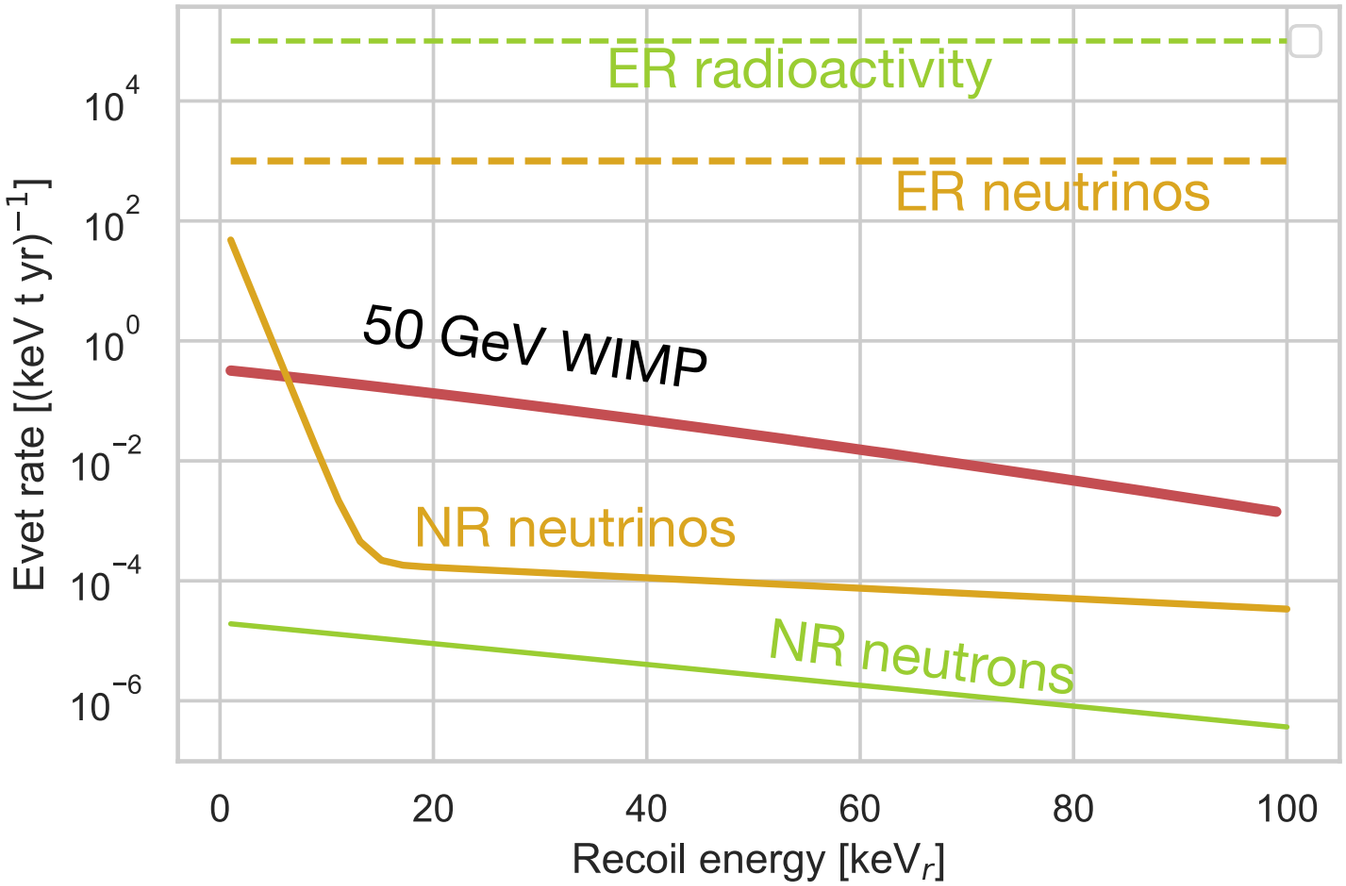
The overall event rate is small, and backgrounds render some of the parameter space inaccessible.



Background estimates roughly for XENONnT, DarkSide-20k

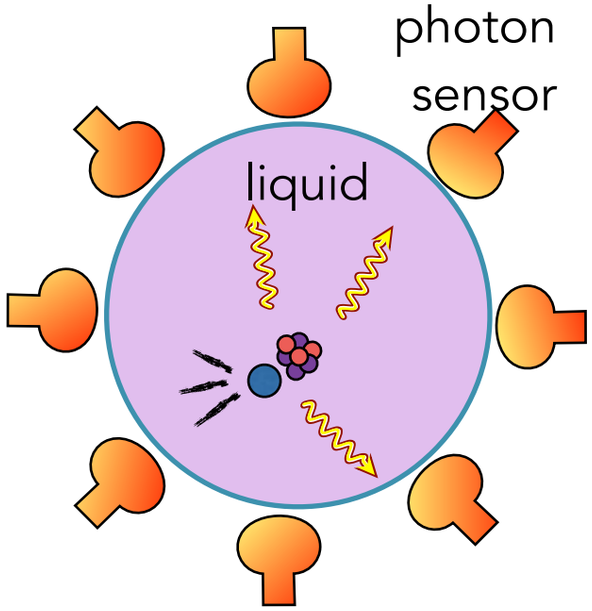
⇐ Xenon

⇓ Argon

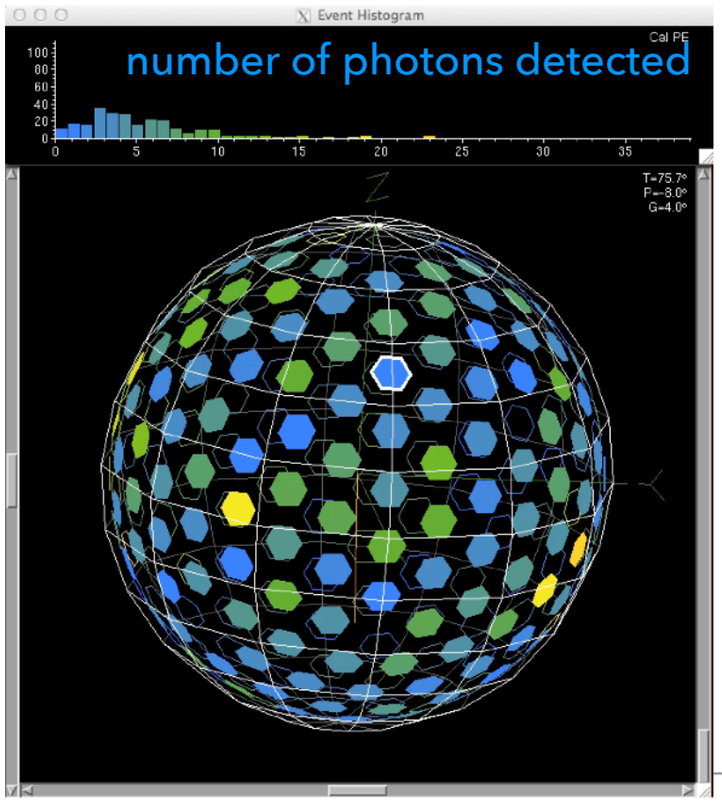


Self-shielding of the liquid noble gases + position reconstruction allows fiducialization against external backgrounds.

light-only

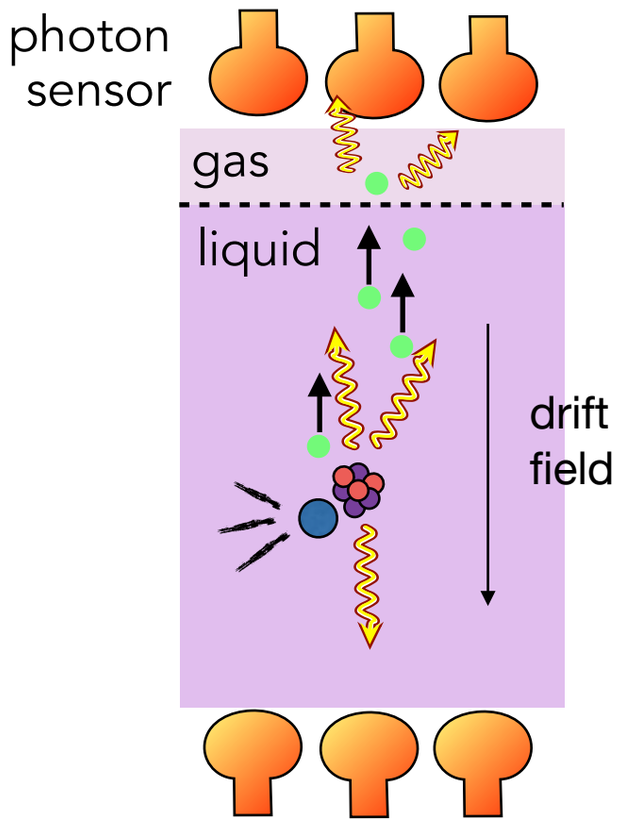


intensity pattern

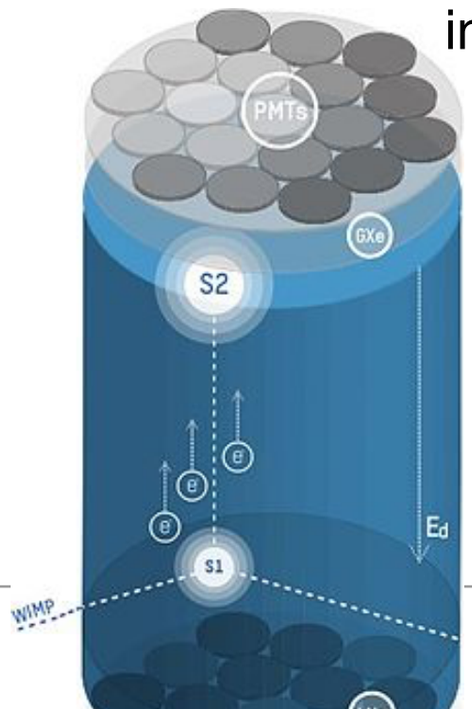


T. Pollmann, LIDINE 2022

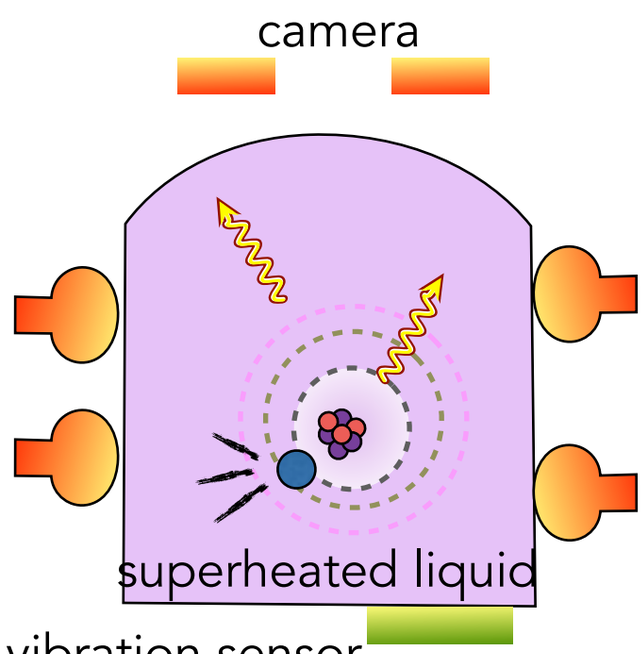
light+charge / charge-only



intensity pattern
+ drift time

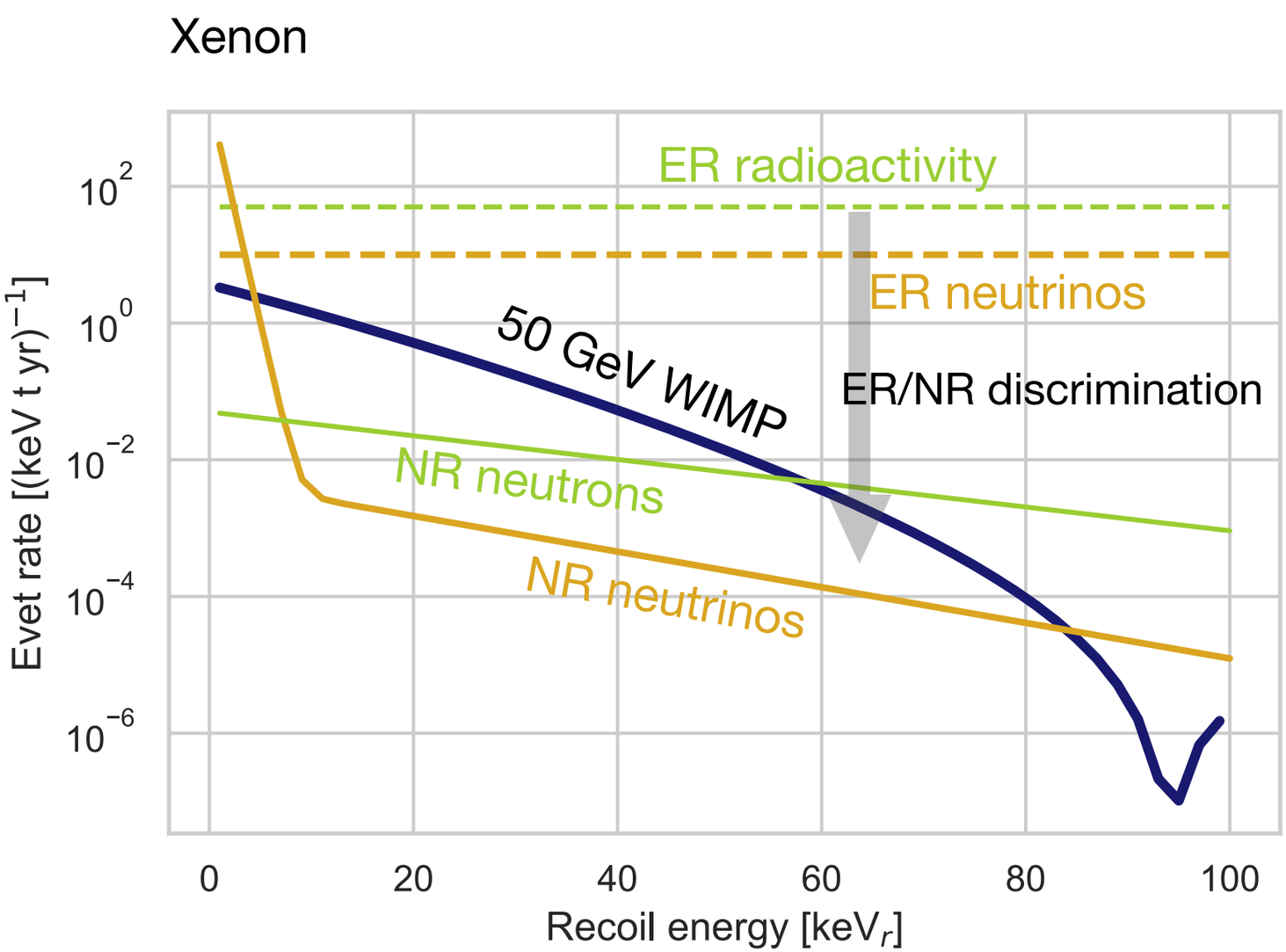


light+heat



camera image

In LXe, purification of the Xe from radioactive contaminants is crucial



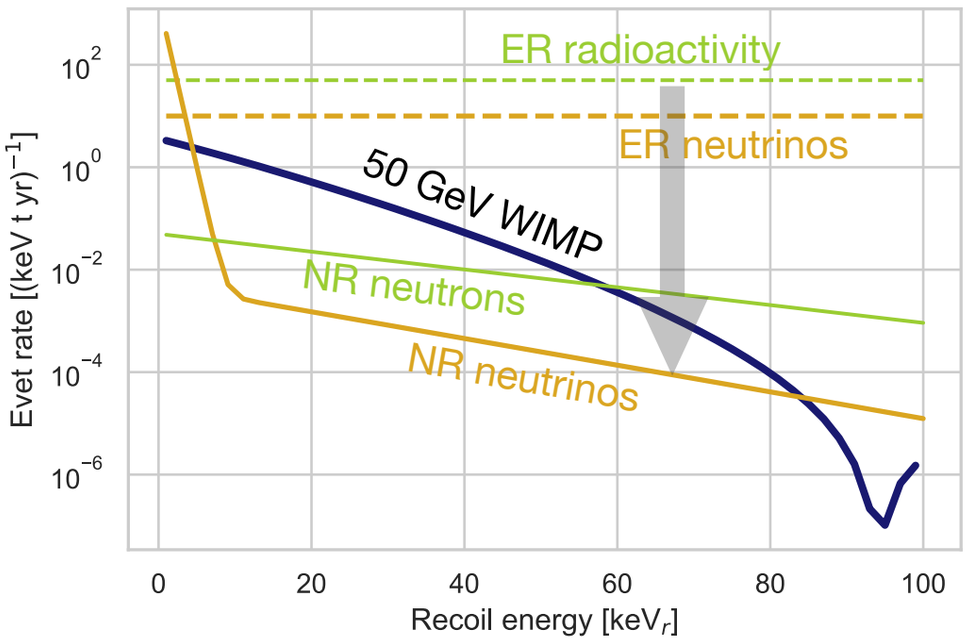
Mostly Kr-85, Rn-222 in LXe volume

cosmic rays and natural radioactivity

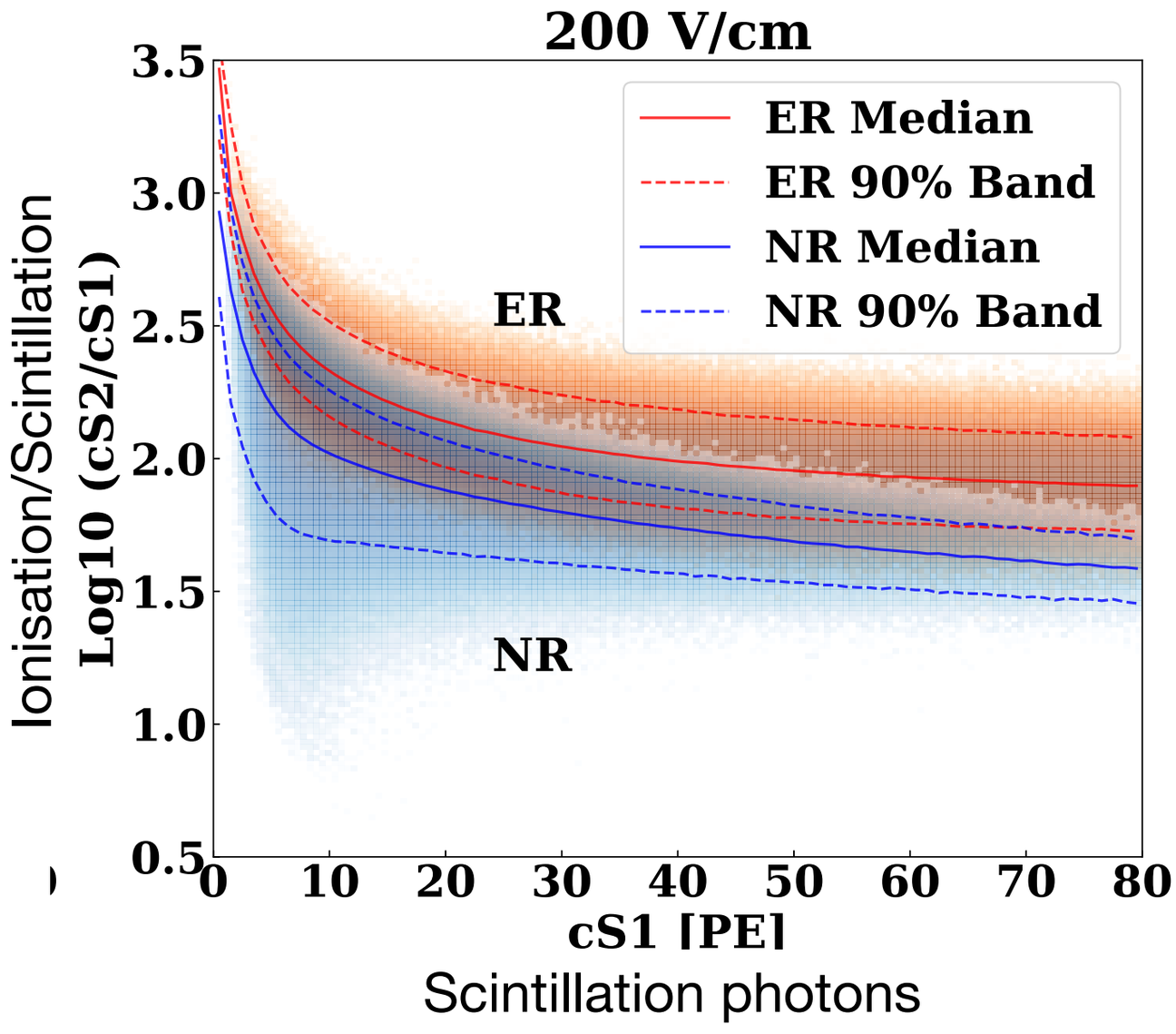
the neutrino fog

The remaining ER background can be reduced by ~4 orders of magnitude through discrimination based on the ionisation/scintillation ratio.

Xenon



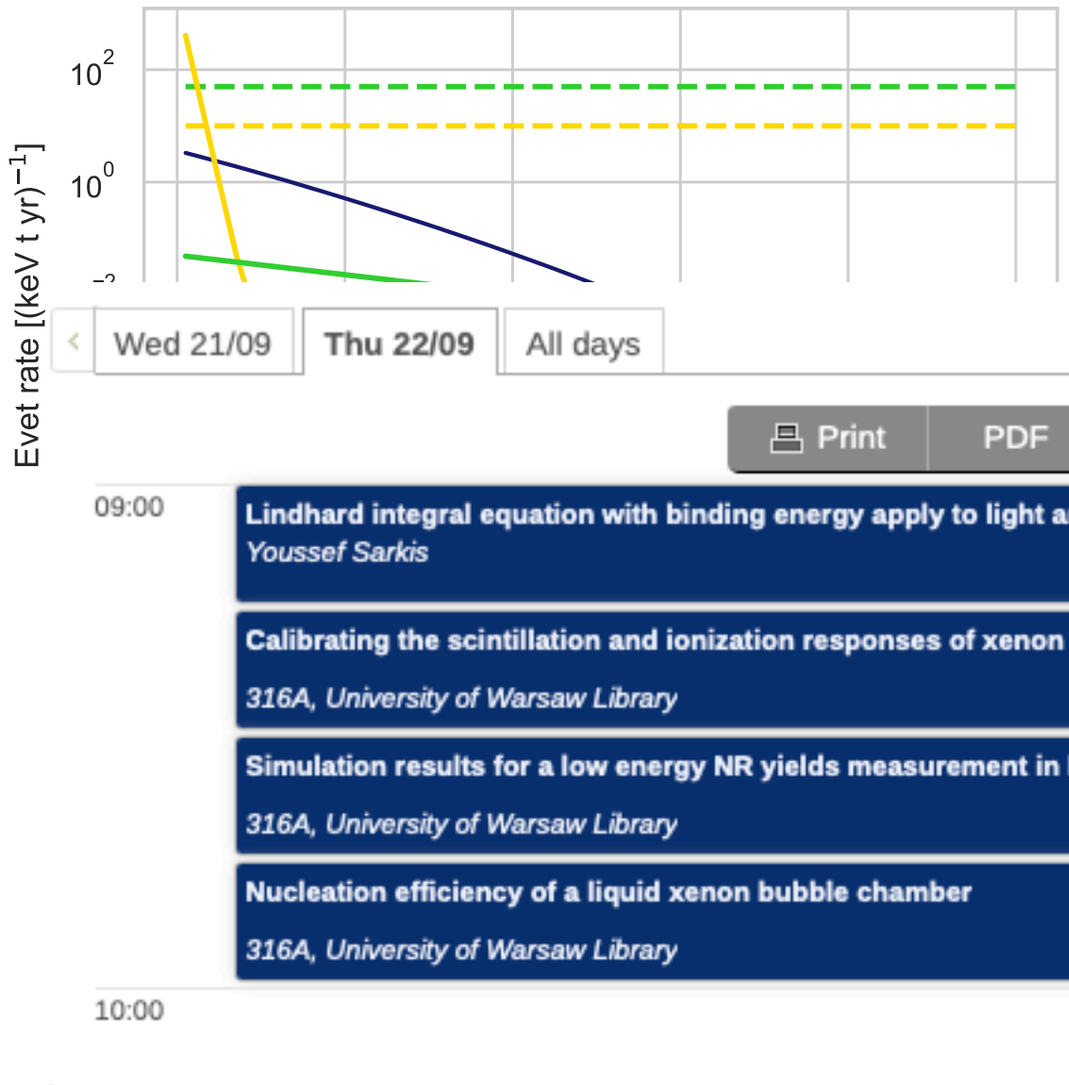
ER/NR separation



T. Pollmann, LIDINE 2022 arXiv:2203.02309

The ionization and scintillation yields as function of drift field, event energy, and event type are crucial inputs for design and analysis of the detectors

Xenon



54. Latest Development of the Noble Element Simulation Technique (NEST)

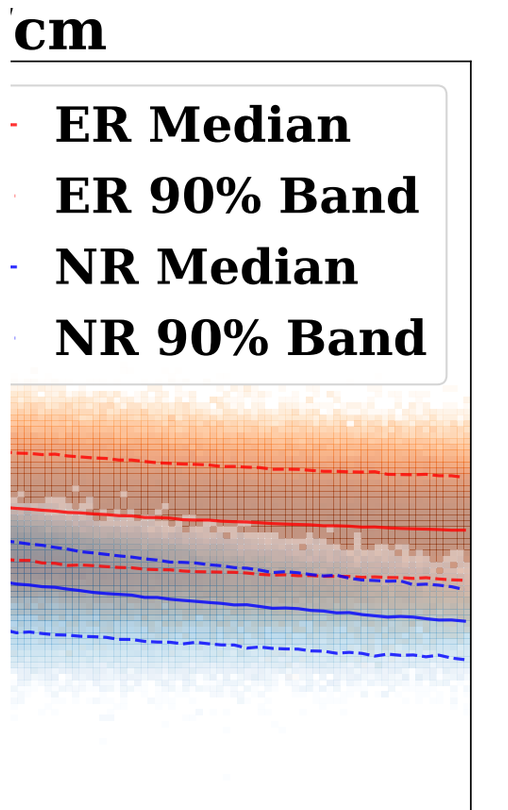
Kaixuan Ni (UC San Diego)

23/09/2022, 13:50

Signal reconstruction a... | Presentation | Signal reconstruction

We will report the latest development of NEST, a comprehensive simulation package for noble liquid experiments. It has achieved increasingly accurate predictions of energy spectrum and discrimination between electronic and nuclear recoils for a large range of drift fields in liquid xenon and is used by leading dark matter experiments such as LZ and XENONnT.

ER/NR separation

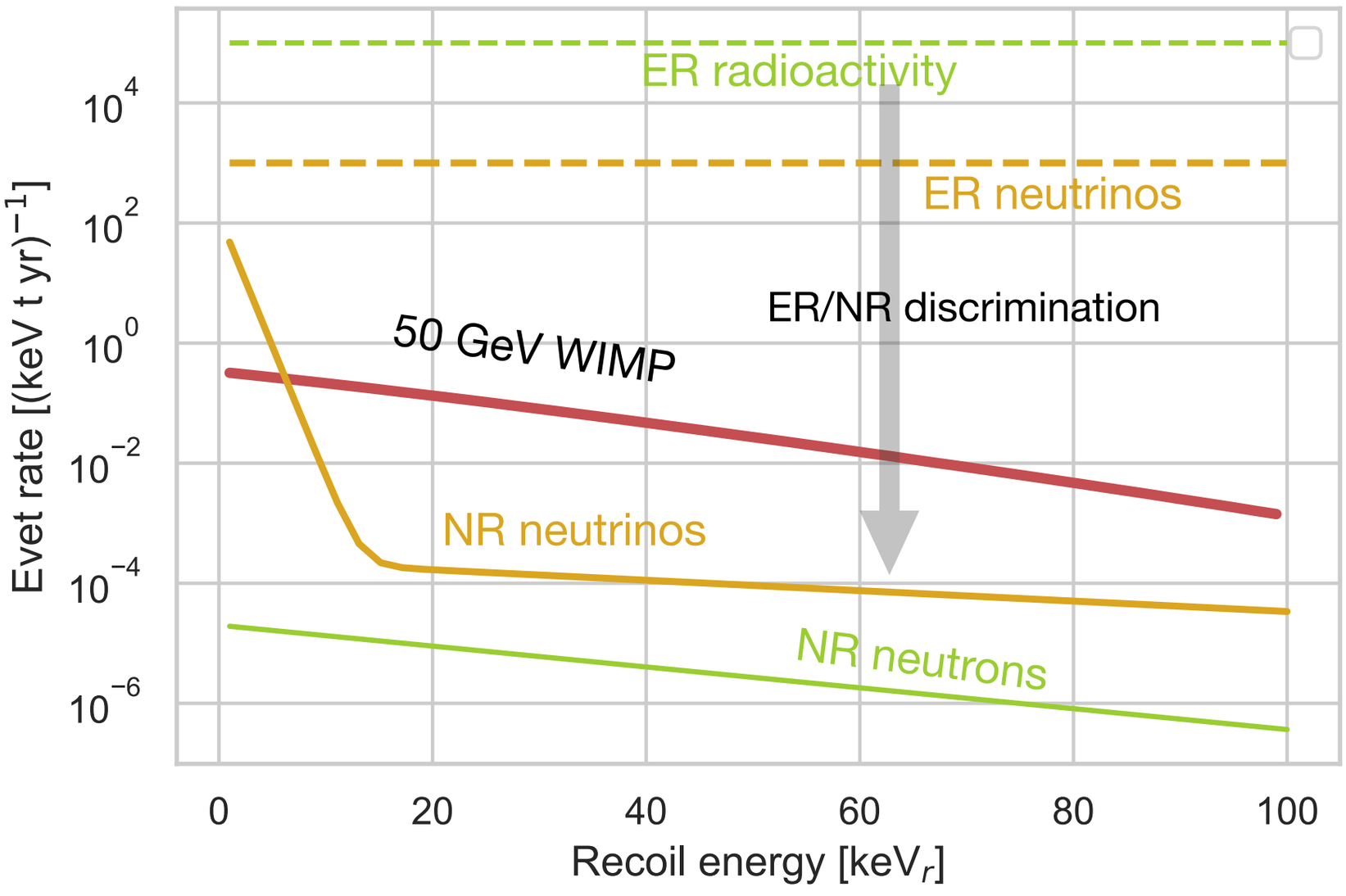


cintillation photons

T. Pollmann, LIDINE 2022 arXiv:2203.02309

In argon detectors, Ar-39 depleted argon (underground argon) is necessary.

Argon



Mostly Ar-39 in LAr volume
(underground argon)

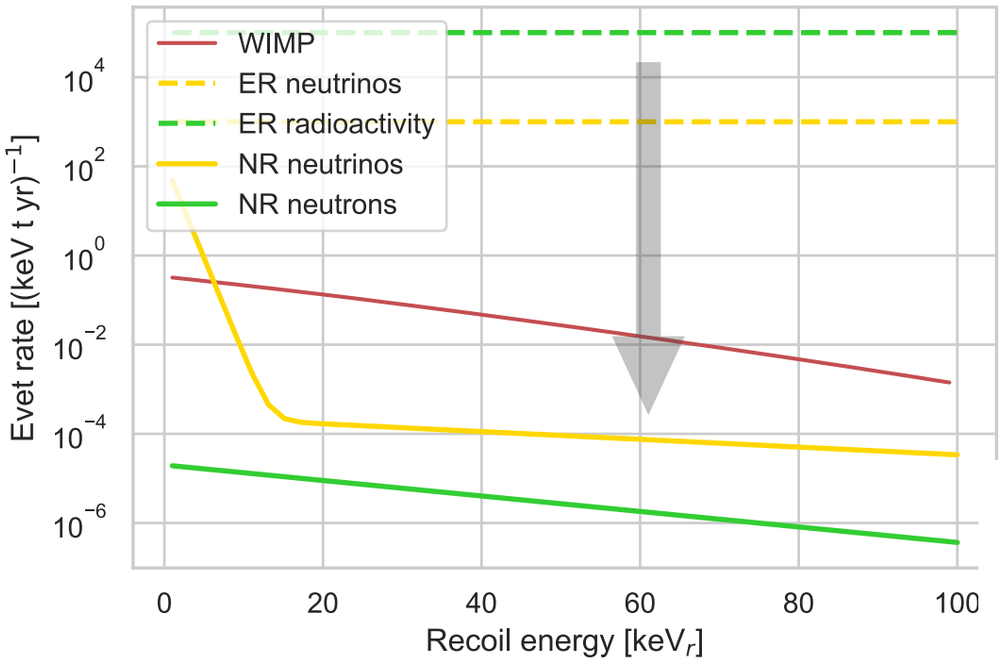
the neutrino fog

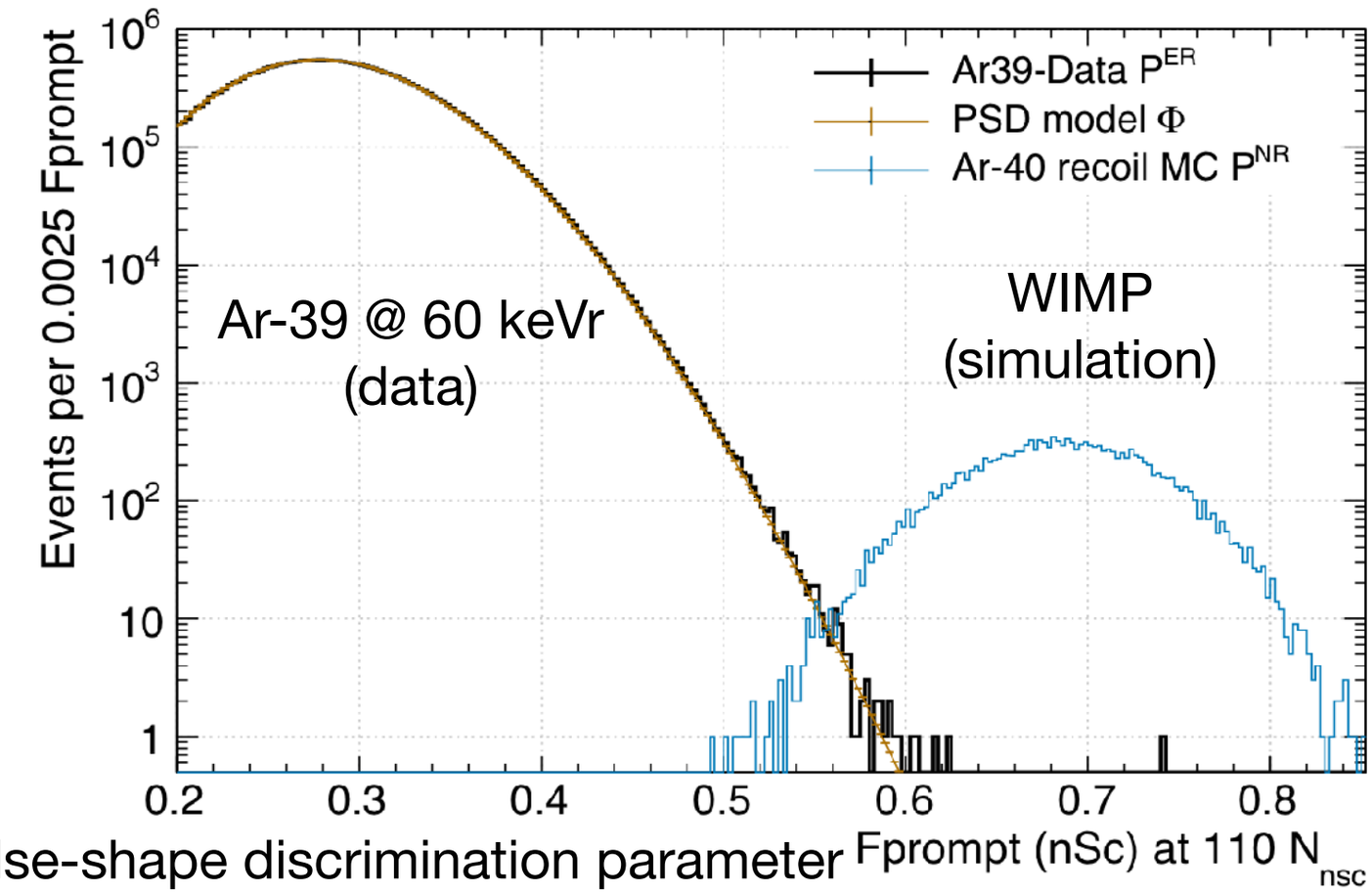
cosmic rays and natural radioactivity

T. Pollmann, LIDINE 2022 arXiv:2203.02309 http://arxiv.org/abs/2103.12202

The remaining Ar-39 ER background can be reduced by ~8 orders of magnitude (per keV) through PSD

Argon

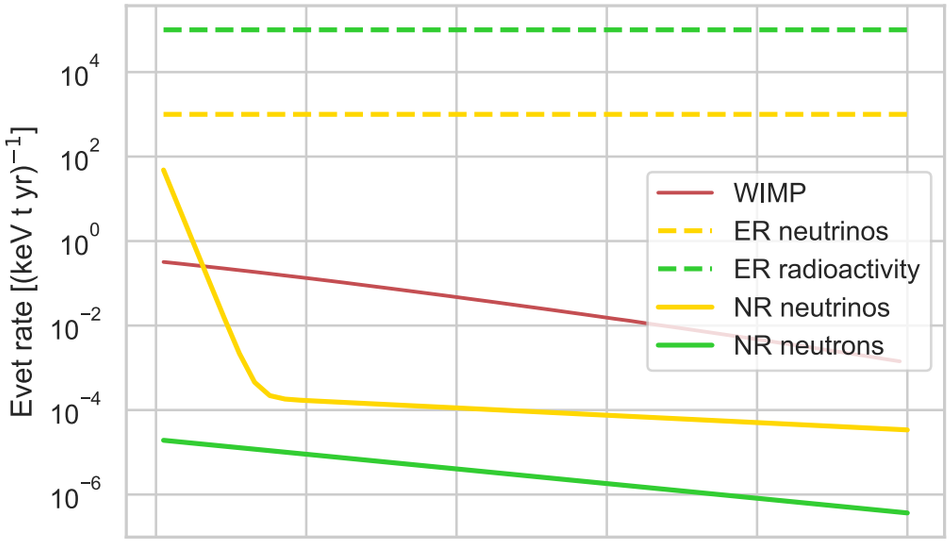


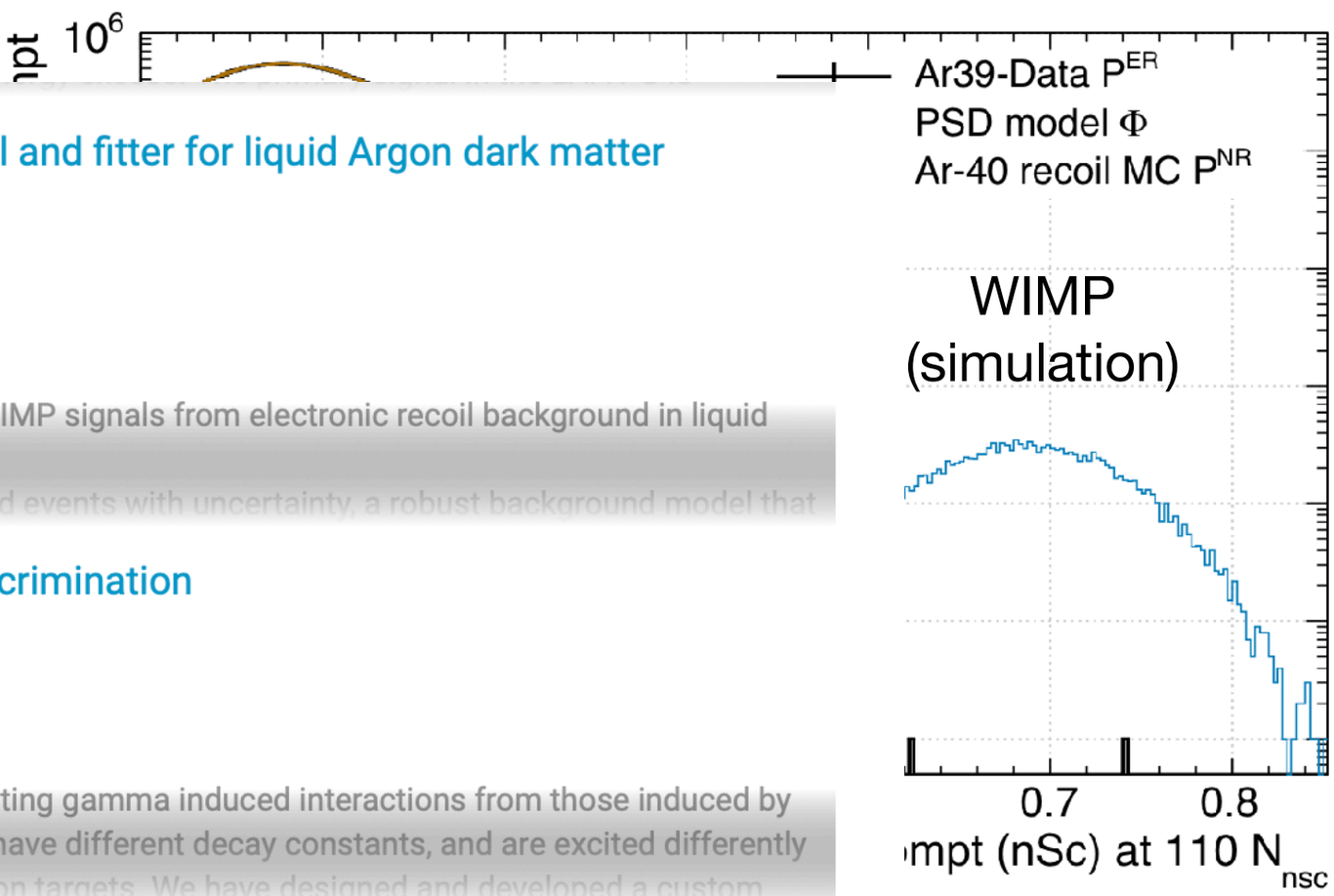


http://arxiv.org/abs/2103.12202

PSD power must be predicted/evaluated accurately over 8-9 orders of magnitude

Argon





39. Monte Carlo Pulse Shape Discrimination model and fitter for liquid Argon dark matter detectors.

Sarthak Choudhary (AstroCeNT)

23/09/2022, 14:35

Signal reconstruction a... | Presentation | Signal reconstruction

Pulse Shape Discrimination is a powerful tool to distinguish WIMP signals from electronic recoil background in liquid Argon detectors.
In order to accurately evaluate the expected rate of background events with uncertainty, a robust background model that

62. An ASIC for Real Time Analog Pulse Shape Discrimination

Mani Tripathi (UC Davis)

23/09/2022, 14:50

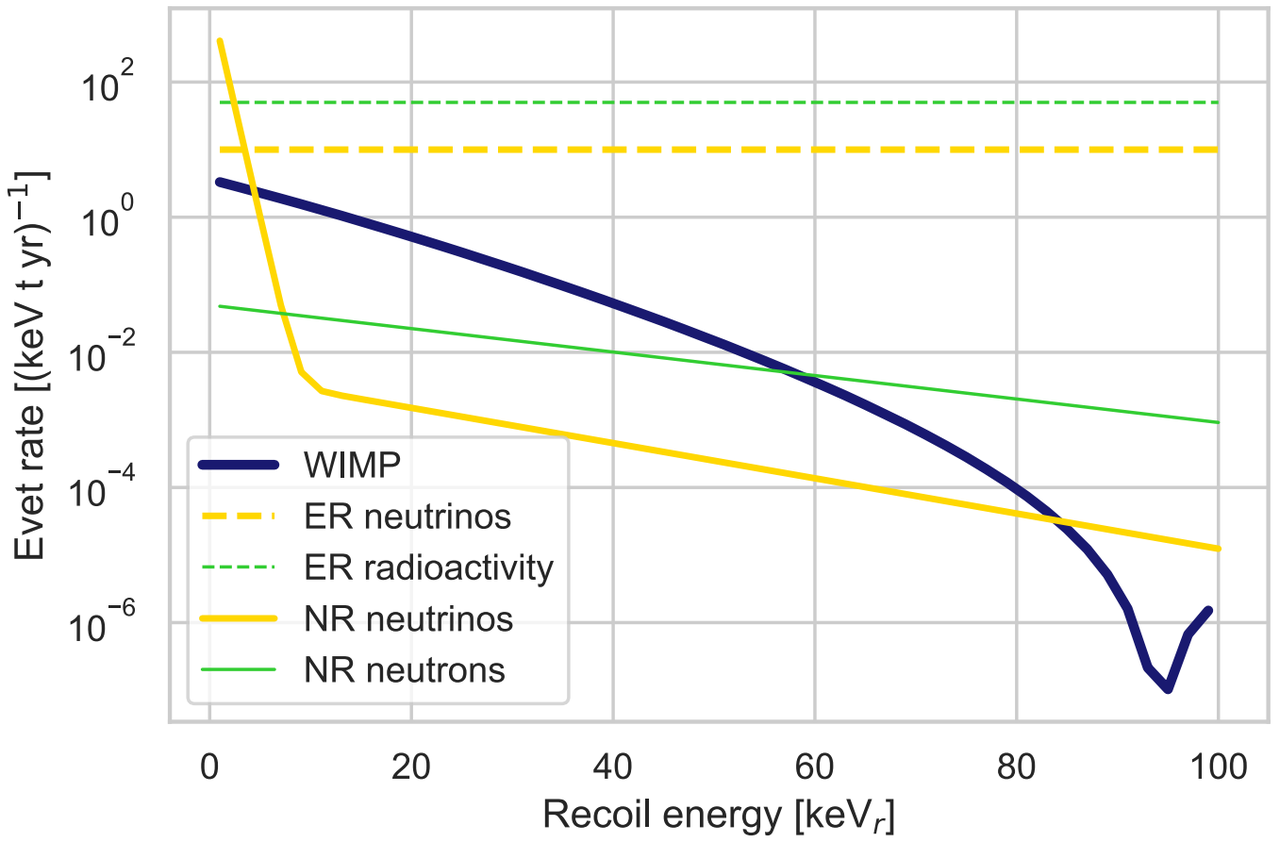
Light/charge readout (P... | Presentation | Signal reconstruction

Pulse shape discrimination (PSD) is a powerful tool for separating gamma induced interactions from those induced by fast neutrons. It relies on the fact that various excited modes have different decay constants, and are excited differently by neutrons and gammas. This is especially true for liquid argon targets. We have designed and developed a custom

T. Pollmann, LIDINE 2022

http://arxiv.org/abs/2103.12202

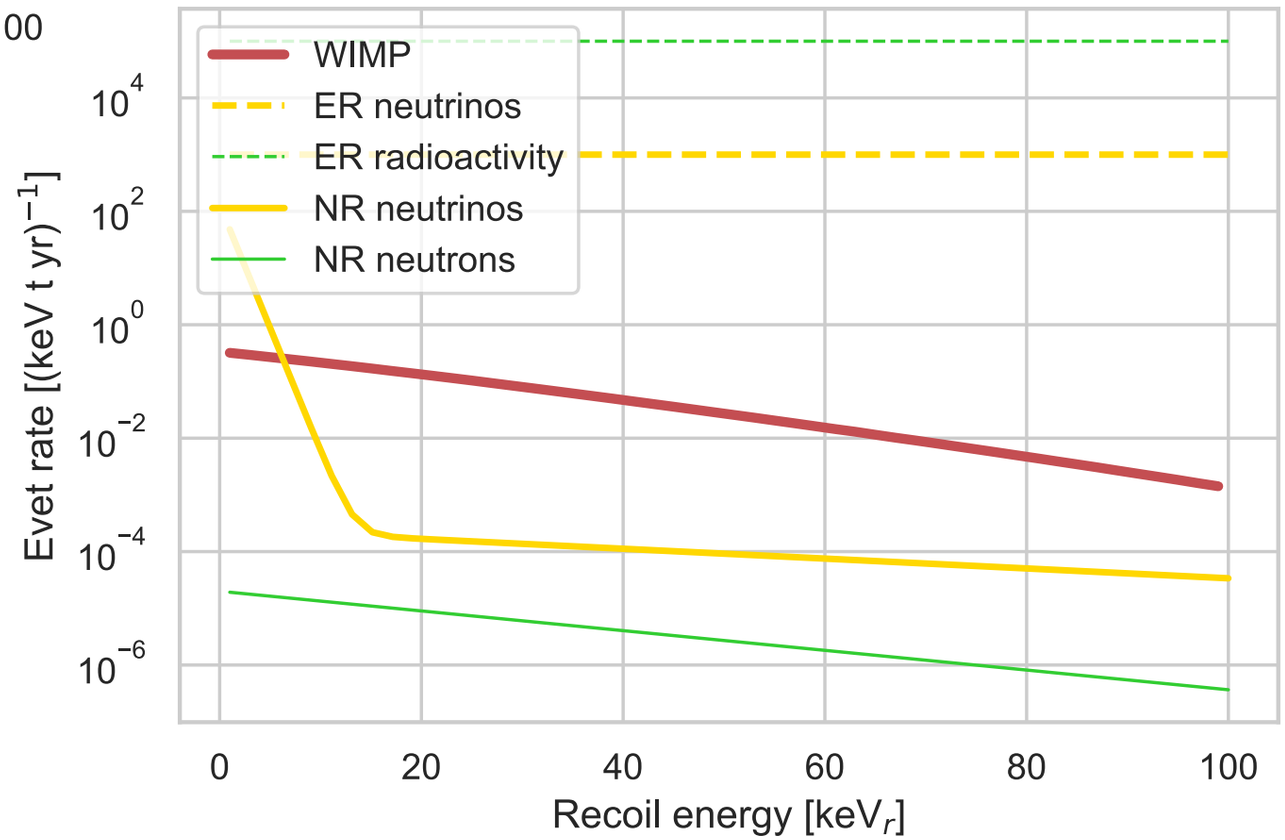
To get the expected background levels as low as shown here, extensive measures were taken.



⇐ Xenon

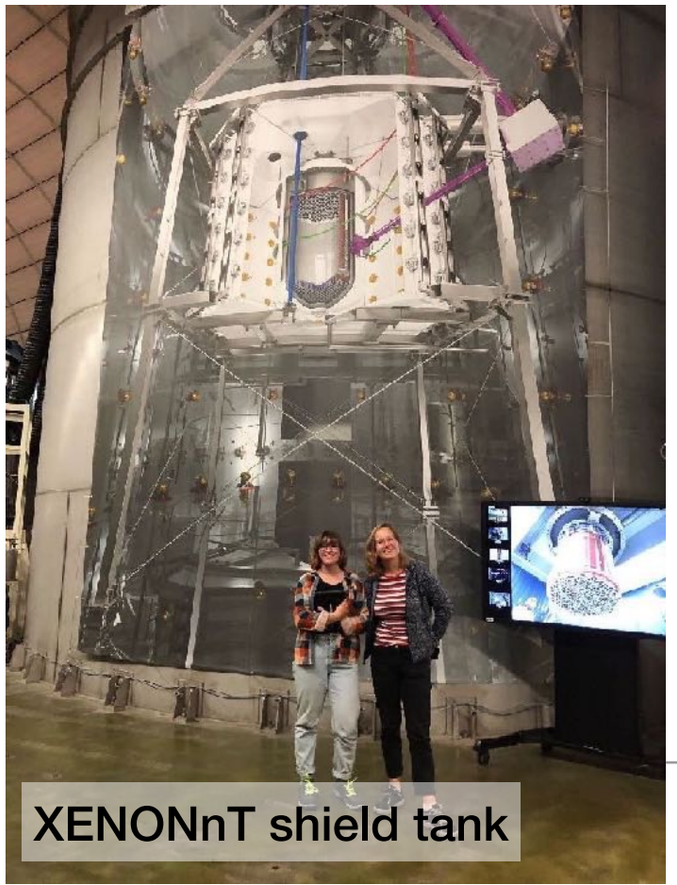
⇓ Argon

Background estimates roughly for XENONnT, DarkSide-20k

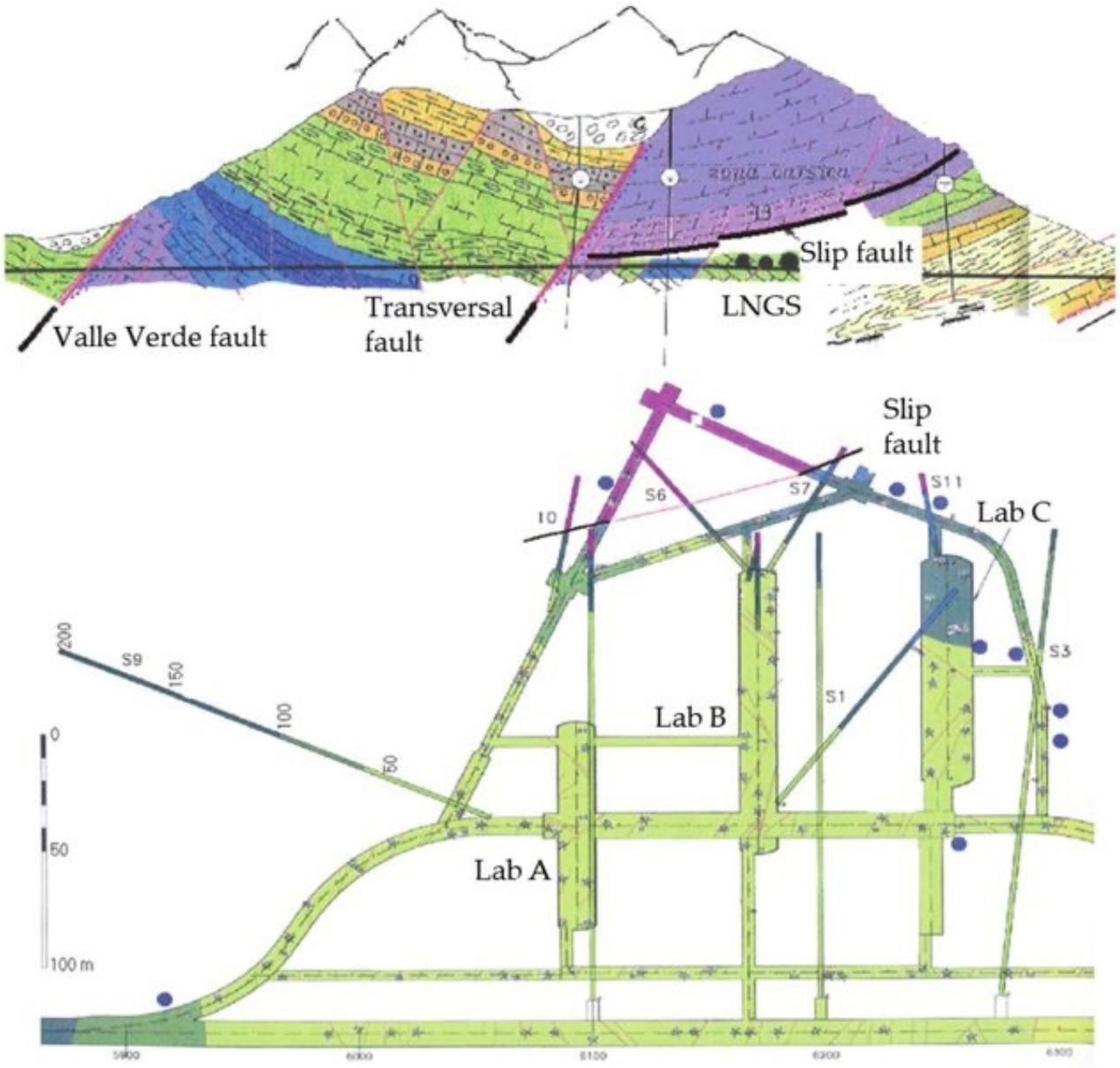


Shielding against cosmic rays includes going to deep underground laboratories and placing detectors in several layers of additional active and passive shielding.

SNOLAB access drift



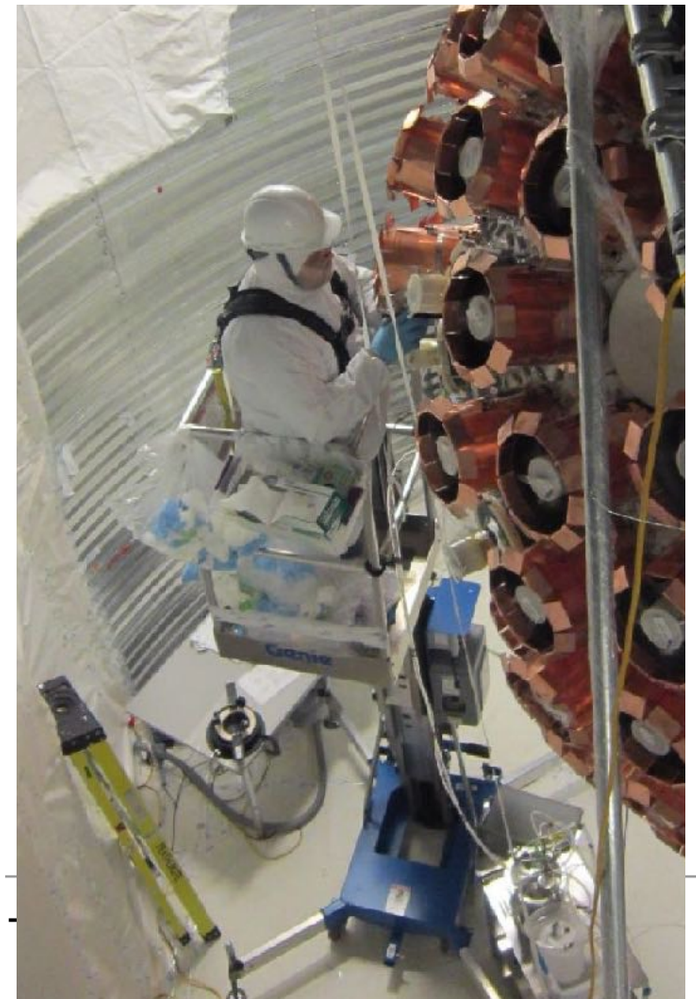
XENONnT shield tank



Gran Sasso lab schematic

DOI: 10.5772/intechopen.76853

All materials used to build the detector are screened for radioactive contaminants, and custom made if necessary. Detectors are large construction projects in clean-rooms.



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pmt

Total results: 37

ing	Name	Isotope	Amount	Isotope	Amount
000)	PMT				
100 (2011)	PMT, Hamamatsu R11410			U-238	50 mBq/unit
ILIAS UKDM	Glass, Hamamatsu PMT	Th-232	140 ppb	U-238	90 ppb
ILIAS UKDM	Glass, Hamamatsu PMT	Th-232	50 ppb	U-238	44 ppb
ILIAS UKDM	Glass, Hamamatsu PMT				
XENON100 (2011)	R8520 custom PMT base			U-238	3 mBq/unit
BOREXINO (2002)	Master Bond EP45HT for PMT sealing	Th-232	6.0E-9 g/g	U-238	3.0E-9 g/g
BOREXINO (2002)	Dynodes	Th-232	1.1E-7 g/g	U-238	2.3E-8 g/g
XENON100 (2011)	PMT, Hamamatsu R8520 - batch 7			U-238	4.7 mBq/unit
XENON100 (2011)	PMT, Hamamatsu R8520 - batch 4			U-238	2.6 mBq/unit
XENON100 (2011)	PMT, Hamamatsu R8520 - batch 3			U-238	75 mBq/unit
XENON100 (2011)	PMT, Hamamatsu R11410-MOD			U-238	95 mBq/unit
XENON100 (2011)	PMT, Hamamatsu R8520 - batch 15			U-238	22 mBq/unit
XENON100 (2011)	PMT, Hamamatsu R8520 - batch 9			U-238	2.7 mBq/unit
XENON100 (2011)	PMT, Hamamatsu R8520 - batch 13			U-238	1.5 mBq/unit
XENON100 (2011)	PMT, Hamamatsu R8520 - batch 16			U-238	21 mBq/unit
XENON100 (2011)	PMT, Hamamatsu R8520 - batch 11			U-238	2.5 mBq/unit

Noble gases are purified in systems specialized in removal of radioisotopes. Argon procurement from depleted underground sources ongoing.

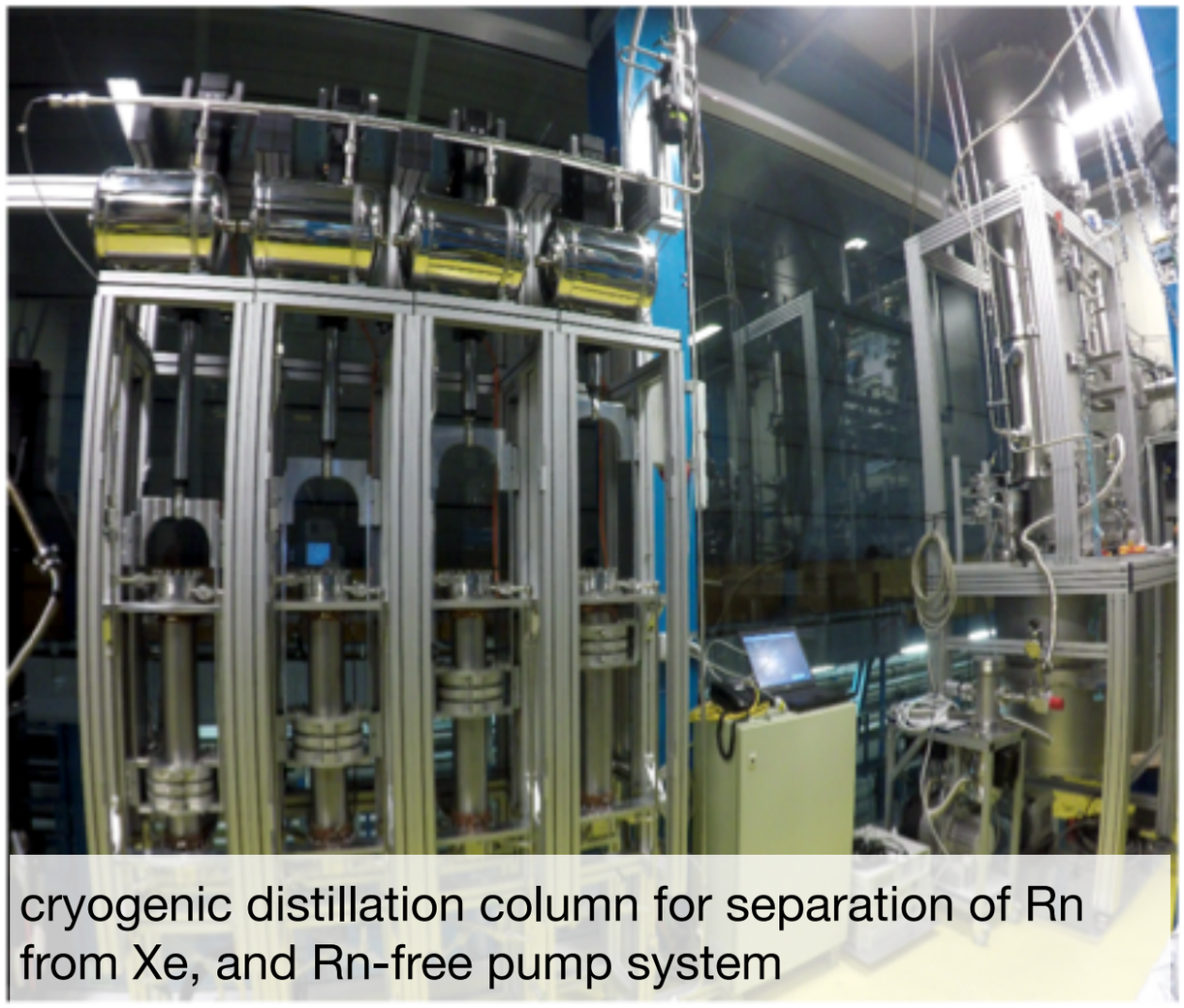
43. Monitoring 39Ar Background for DarkSide-20k with DArT in ArDM

Devidutta Gahan (University of Cagliari,...

23/09/2022, 09:15

Detector techniques (H... | Presentation | Detector techniques

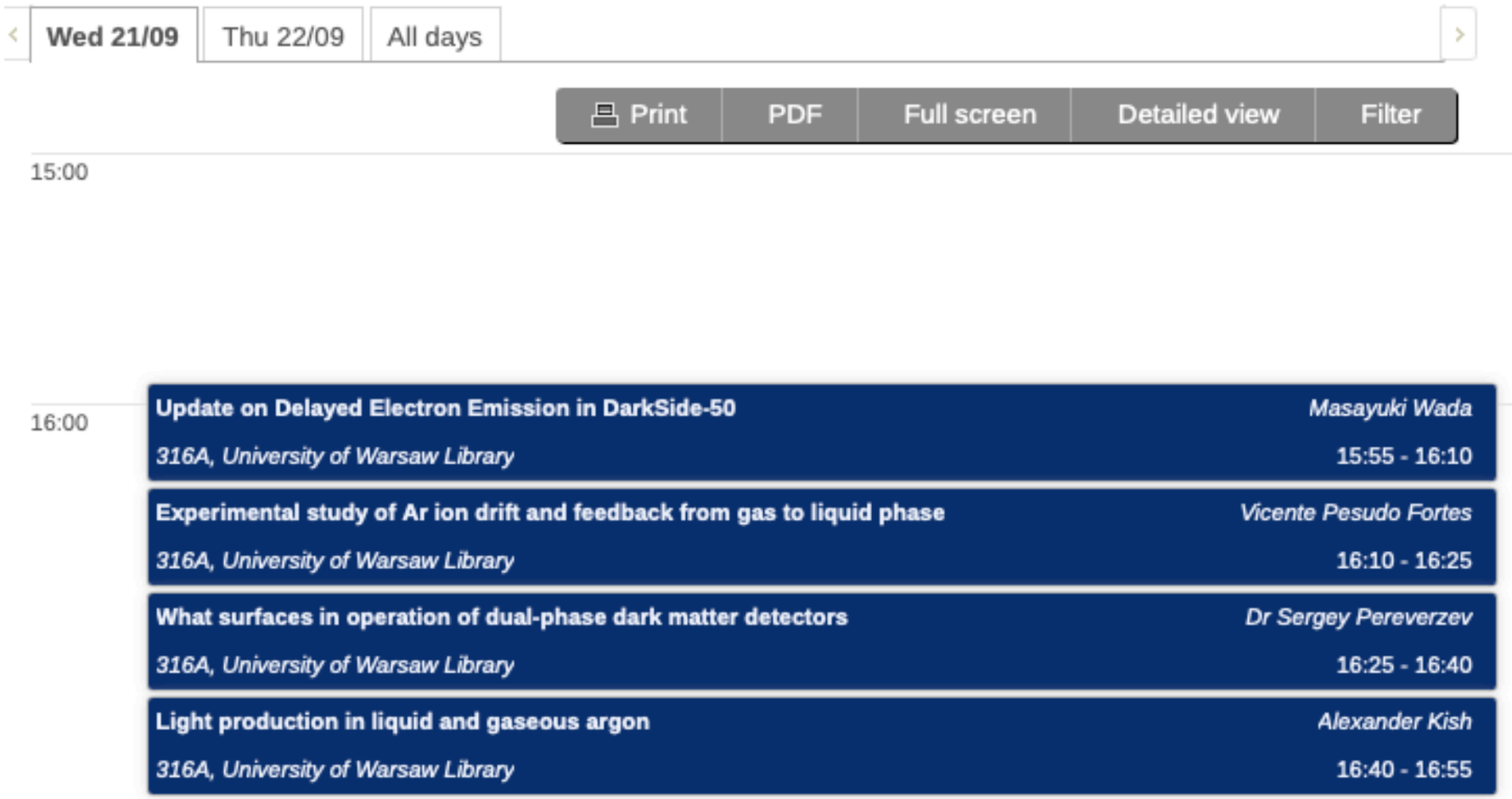
The current landscape for the hunt of particle Dark Matter (DM) requires us to achieve state of the art ability to mitigate and account for the various backgrounds. DarkSide-20k, a 20-tonn scale double phase TPC, will commission its voyage for the DM with an exclusion sensitivity to spin-independent WIMP-nucleon interaction of 6.3×10^{-48} cm^2 (90% C.L.) @



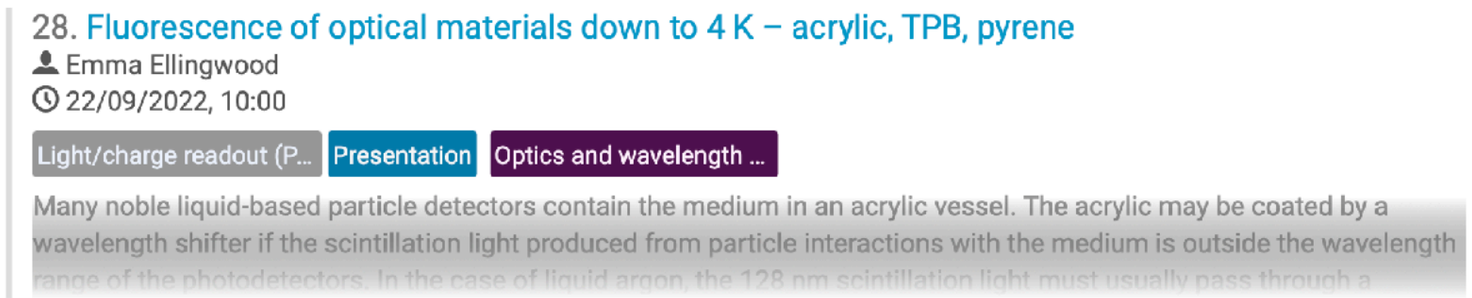
cryogenic distillation column for separation of Rn from Xe, and Rn-free pump system

underground argon distillation column

Instrumental backgrounds are not accounted for in sensitivity projections, but are important considerations in upscaling efforts.

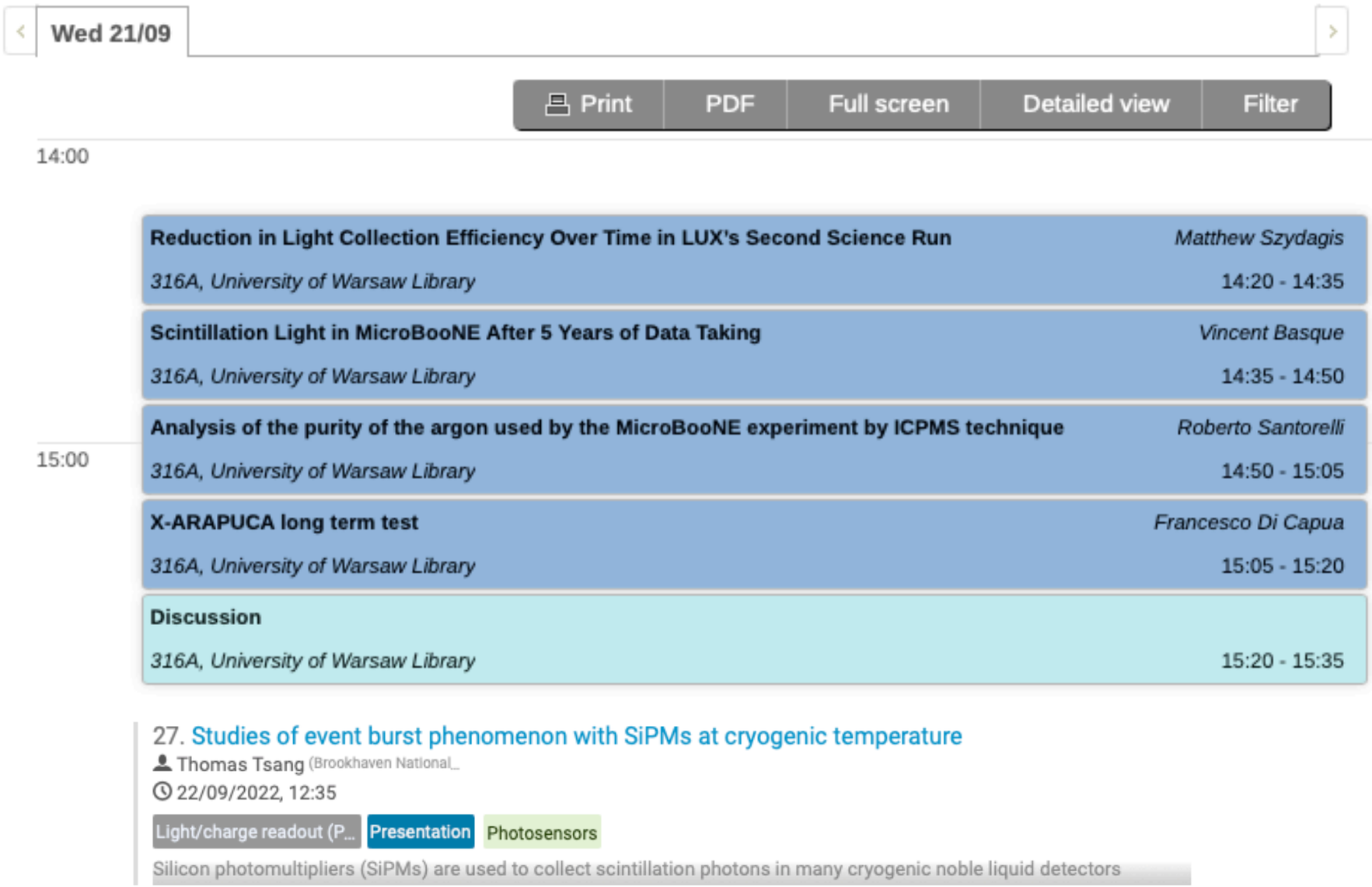


➡ "lone electron" emission



➡ nuisance fluorescence

Long-term stability is crucial to acquire enough exposure

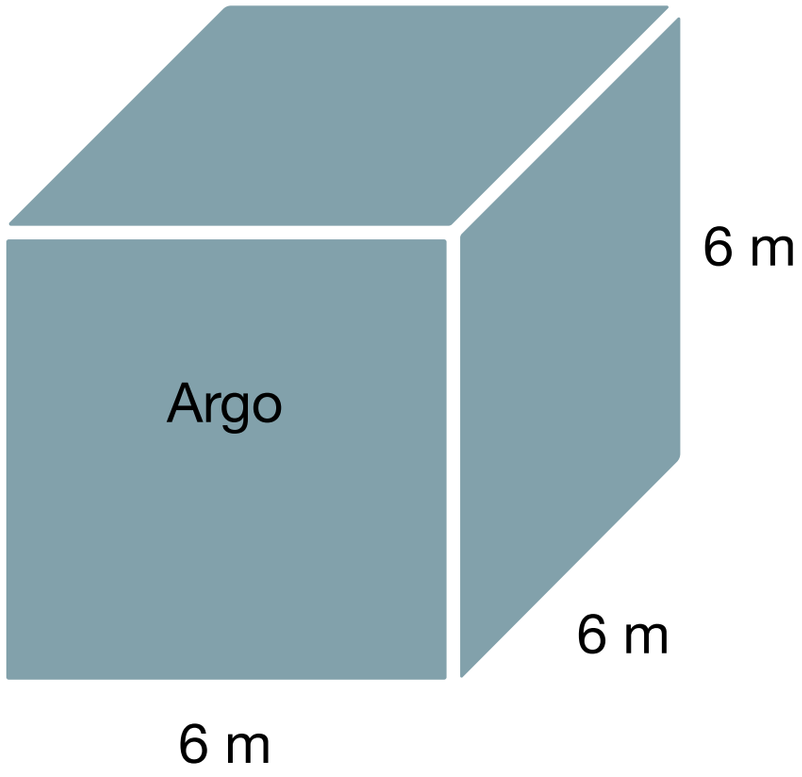


➡ photon/electron yield stability
➡ ageing of light detection system
➡ hot spots, flashes

Upscaling current detectors is conceptionally straight forward, but presents technological challenges

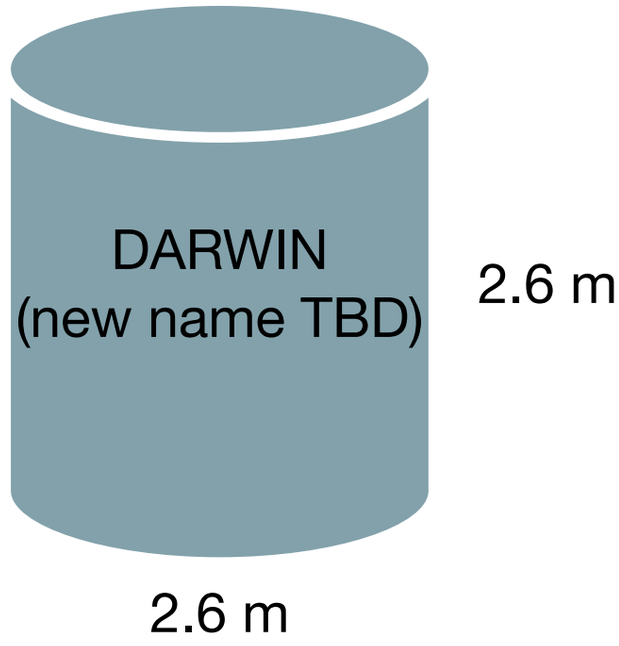
GADMC

~300 tonnes liquid argon



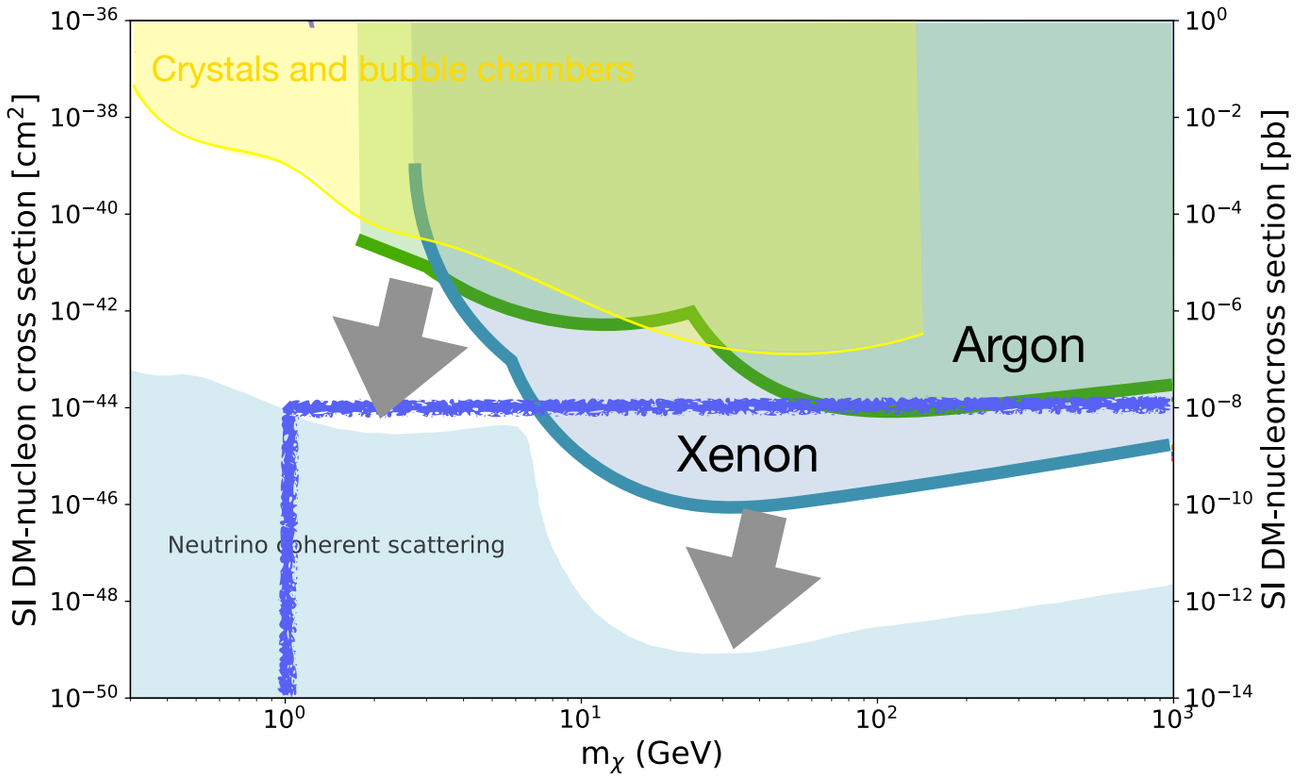
XLZD

~40 tonnes liquid xenon



- ➡ large-area photon detection while keeping dark noise low
- ➡ large-area wavelength-shifters
- ➡ drift field instrumentation and mechanical stability
- ➡ procurement/availability of underground argon
- ➡ procurement of xenon

Summary



- Upscaling LAr and LXe-based WIMP detectors is the fastest path toward the neutrino fog in a wide range of WIMP masses.
- Novel detector ideas (bubble chamber, superfluid He detector) offer further redundancy and extended reach.
- Continued R&D into read-out of low-intensity scintillation, ionisation, and heat remains crucial to enabling the upscaling.
- Improved understanding of liquid noble gas properties is likewise necessary to ensure success of the experimental program.