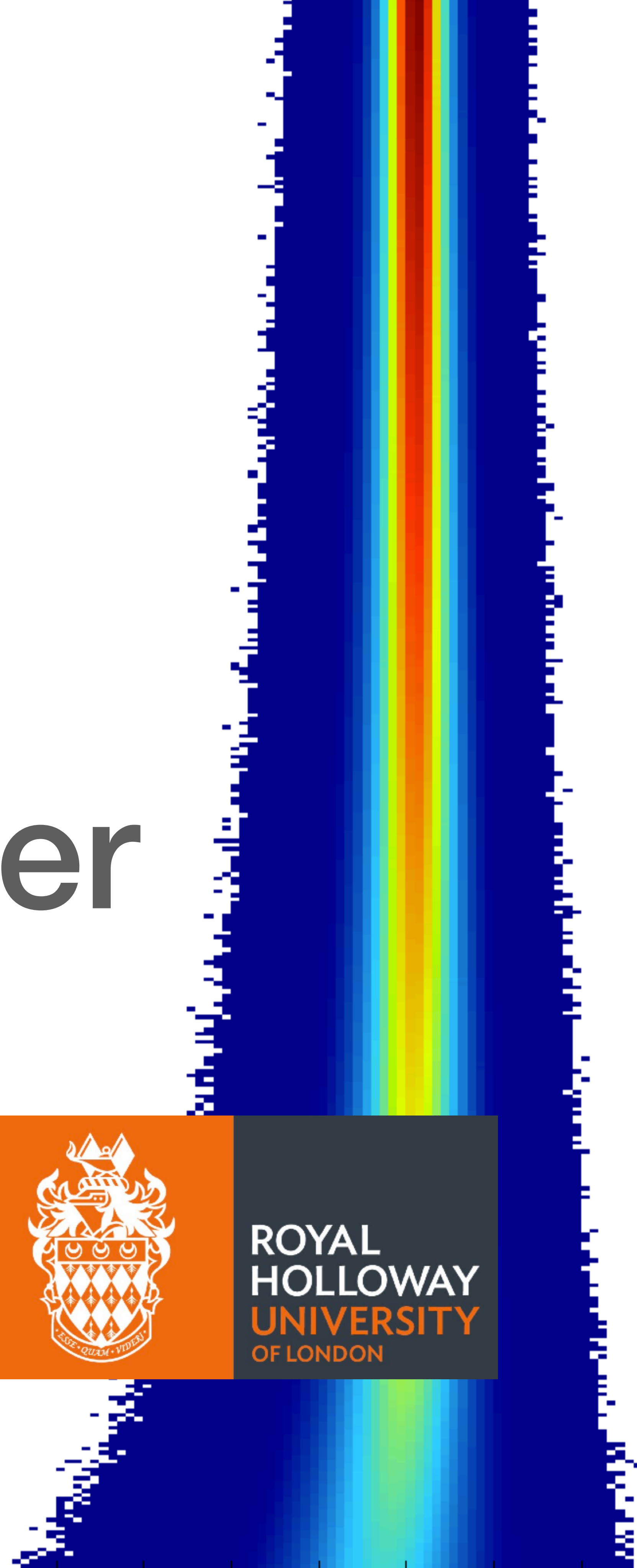
Detection of *Light* Particle Dark Matter

with *noble liquids*

Paolo Agnes, RHUL
QSFP school
9th Sept 2021



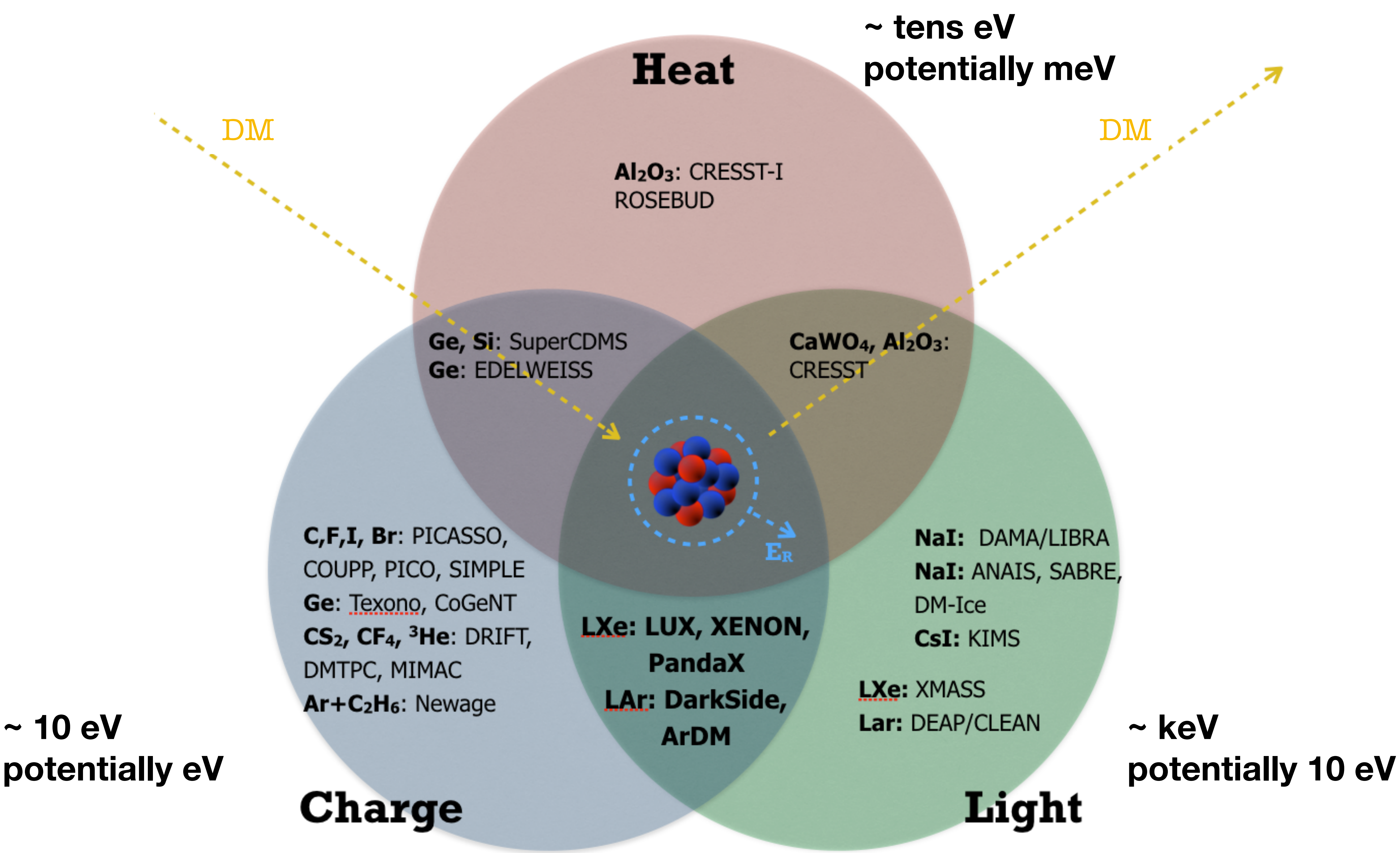
Summary of the first lecture - and overview

Short review of Evidence for DM
WIMPs and alternative candidates
Principles of Direct Detection of DM
Formalism of sub-GeV DM DD in matter

Plan for Today:
  Experiments point of view
  Common Challenges
  Noble liquids: dual-phase TPCs
  Outlook

Readings:
- DarkSide-50, DEAP-3600 papers
- Xenon1t, LZ, Xenon100 papers

DM direct detection: observables



DM direct detection

Number of Events = (Flux) x (Cross Section) x (Exposure)

(how much dark matter)

(how likely it is to interact)

(how long you look)

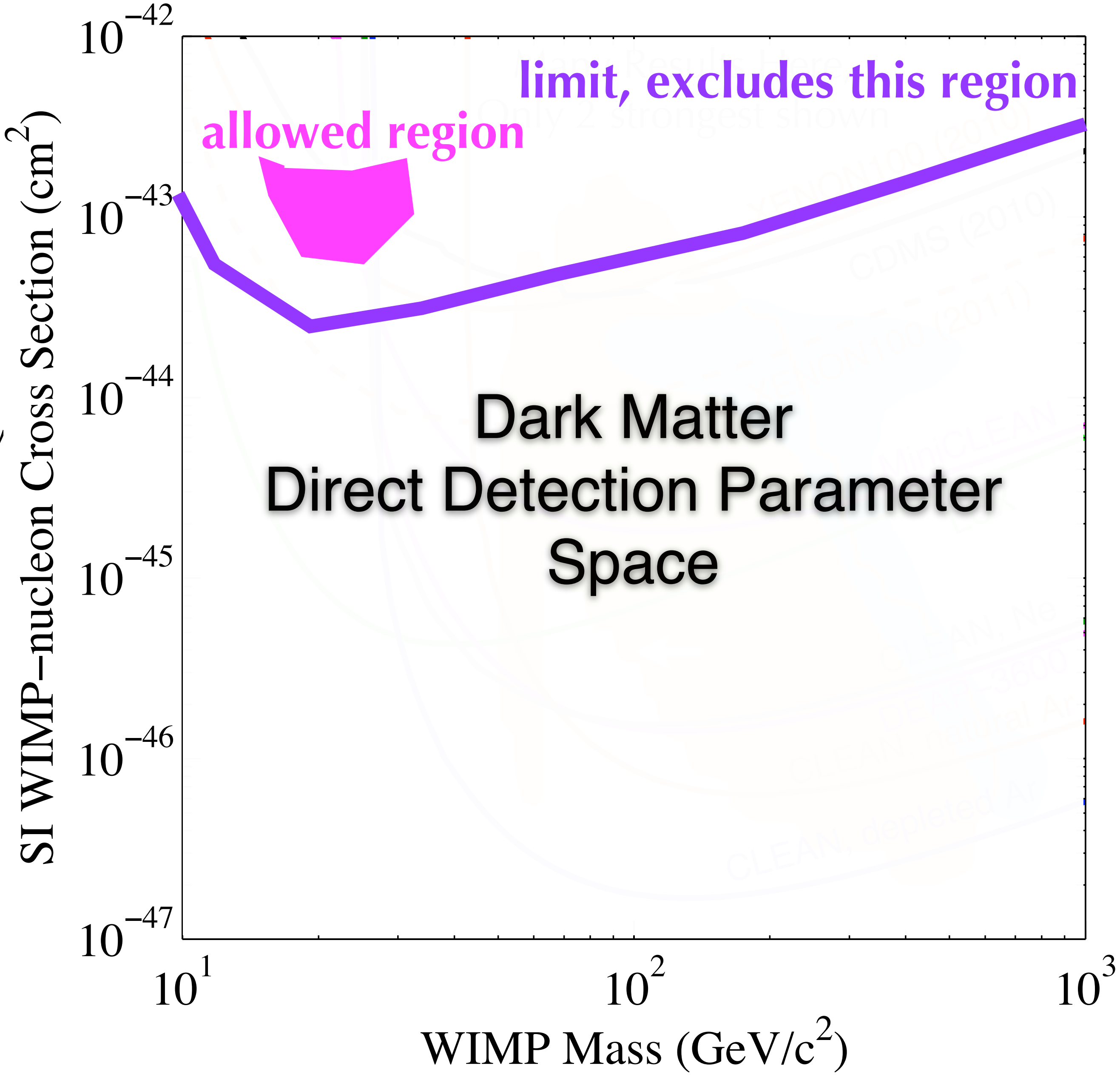
The LUX experiment

Setting limits

1 event/ kg/day

1 event/ 100 kg/day

1 event/ 100 kg/ 100 days



Observe a signal (tens of ev): Estimate mass from best fit

Observe nothing (null result): Can set upper limit on σ

For a counting experiment:

$$Pois(n|\mu) = \mu^n \frac{e^{-\mu}}{n!}$$

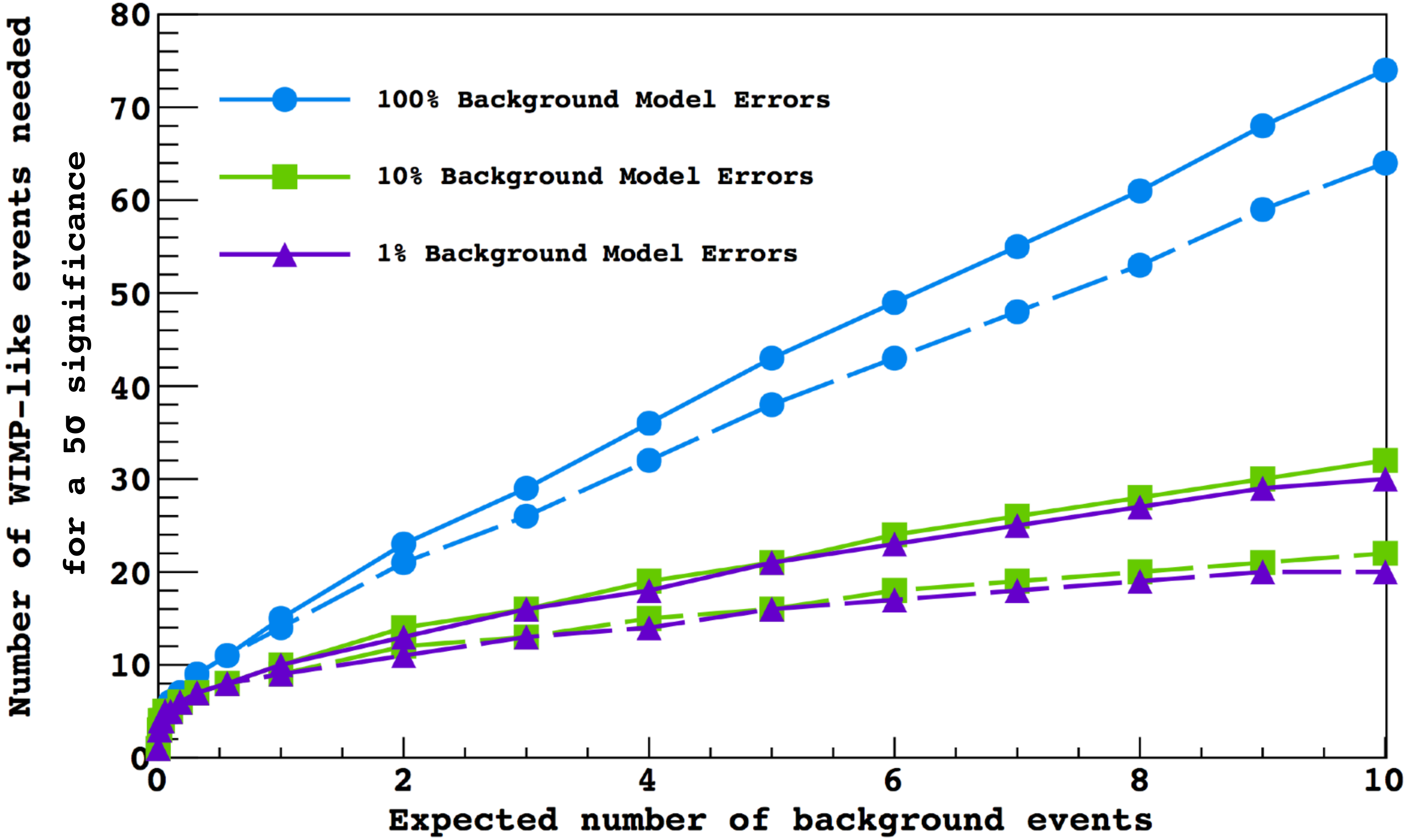
Find μ for which P(n=0) < 0.1 set a 90% CL upper lim on σ

—> Tutorial 2

$$\frac{dR^{NR}}{dE_R} = \boxed{\sigma_n} \frac{\rho_\chi}{M_\chi} \frac{m_A}{2\mu_{n\chi}^2} A^2 F_A(q)^2 \int_{v_{min}(E_R)}^{v_{esc}} d^3v \frac{f(v, v_E)}{v}$$

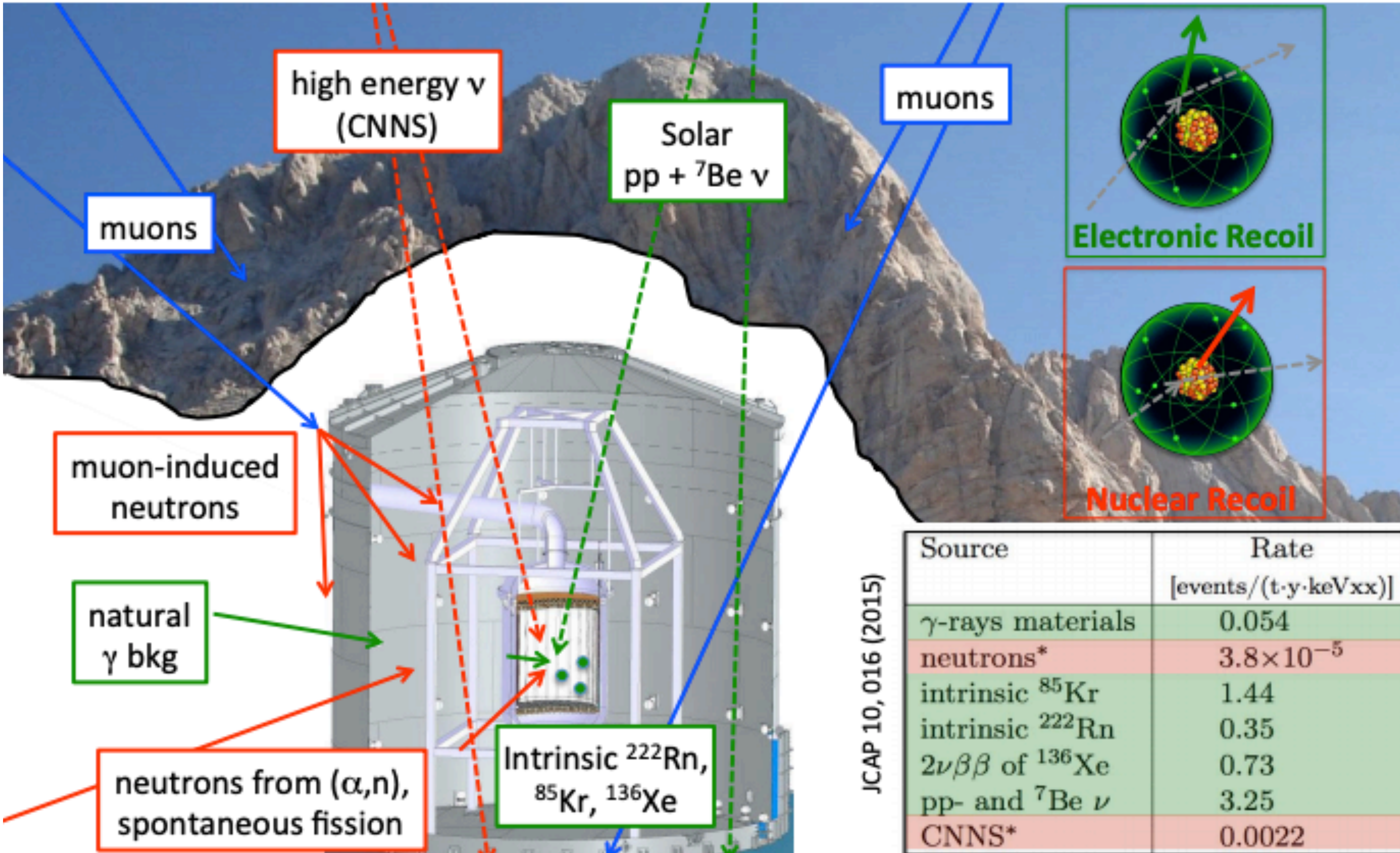
Backgrounds under control!

$$P(n|s,b) = \frac{(s+b)^n}{n!} e^{-(s+b)}$$



G Cowan: https://www.pp.rhul.ac.uk/~cowan/stat/medsig/medsigNote.pdf

Backgrounds in a typical WIMP experiment

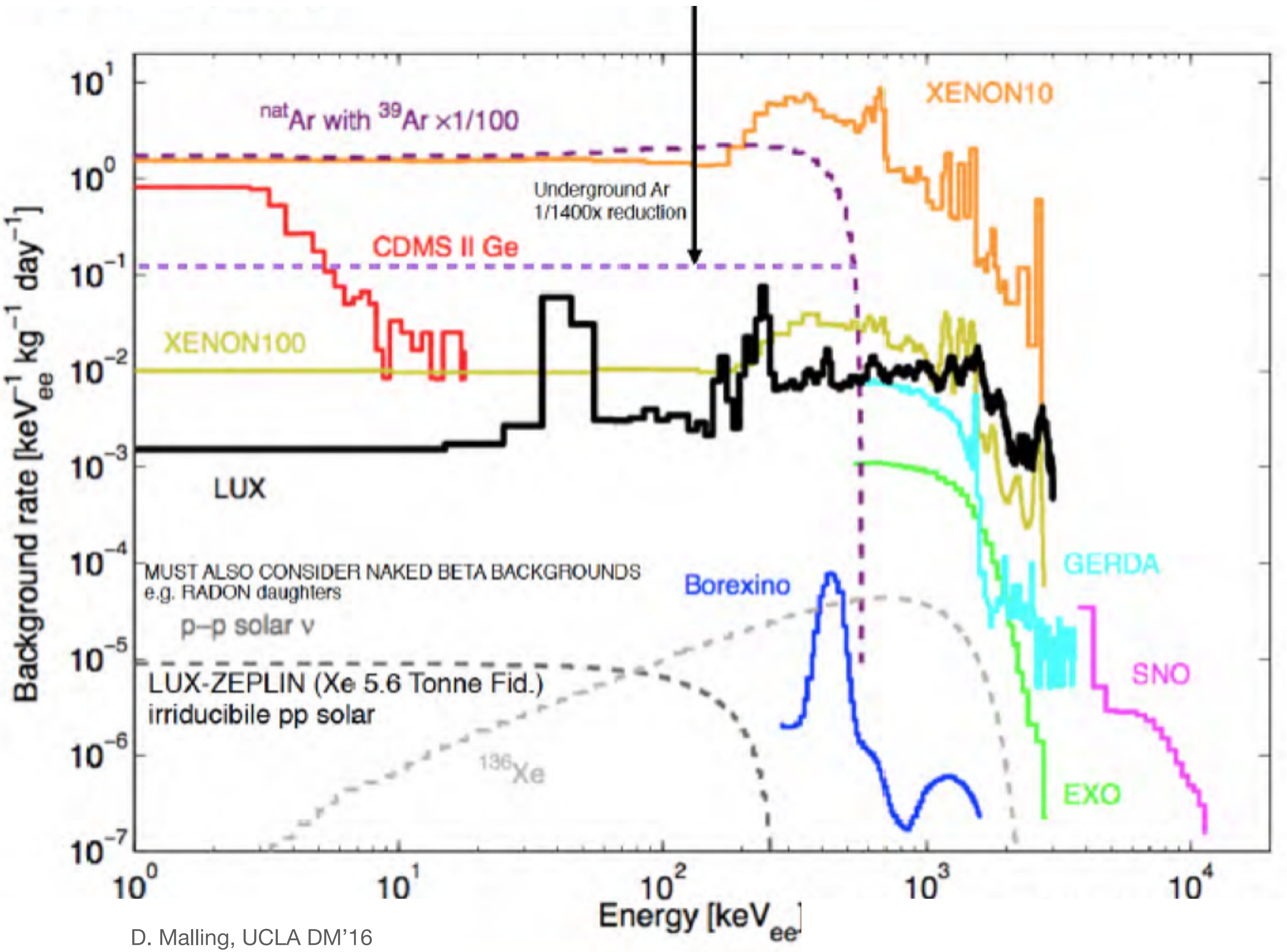


Source	Rate [events/(t·y·keVxx)]
γ-rays materials	0.054
neutrons*	3.8×10^{-5}
intrinsic ^{85}Kr	1.44
intrinsic ^{222}Rn	0.35
$2\nu\beta\beta$ of ^{136}Xe	0.73
pp- and ^{7}Be ν	3.25
CNNS*	0.0022

Carla Macolino, TAUP 2019 - DARWIN

estimates here are for a specific energy region and assume some discrimination

The main Challenge: backgrounds



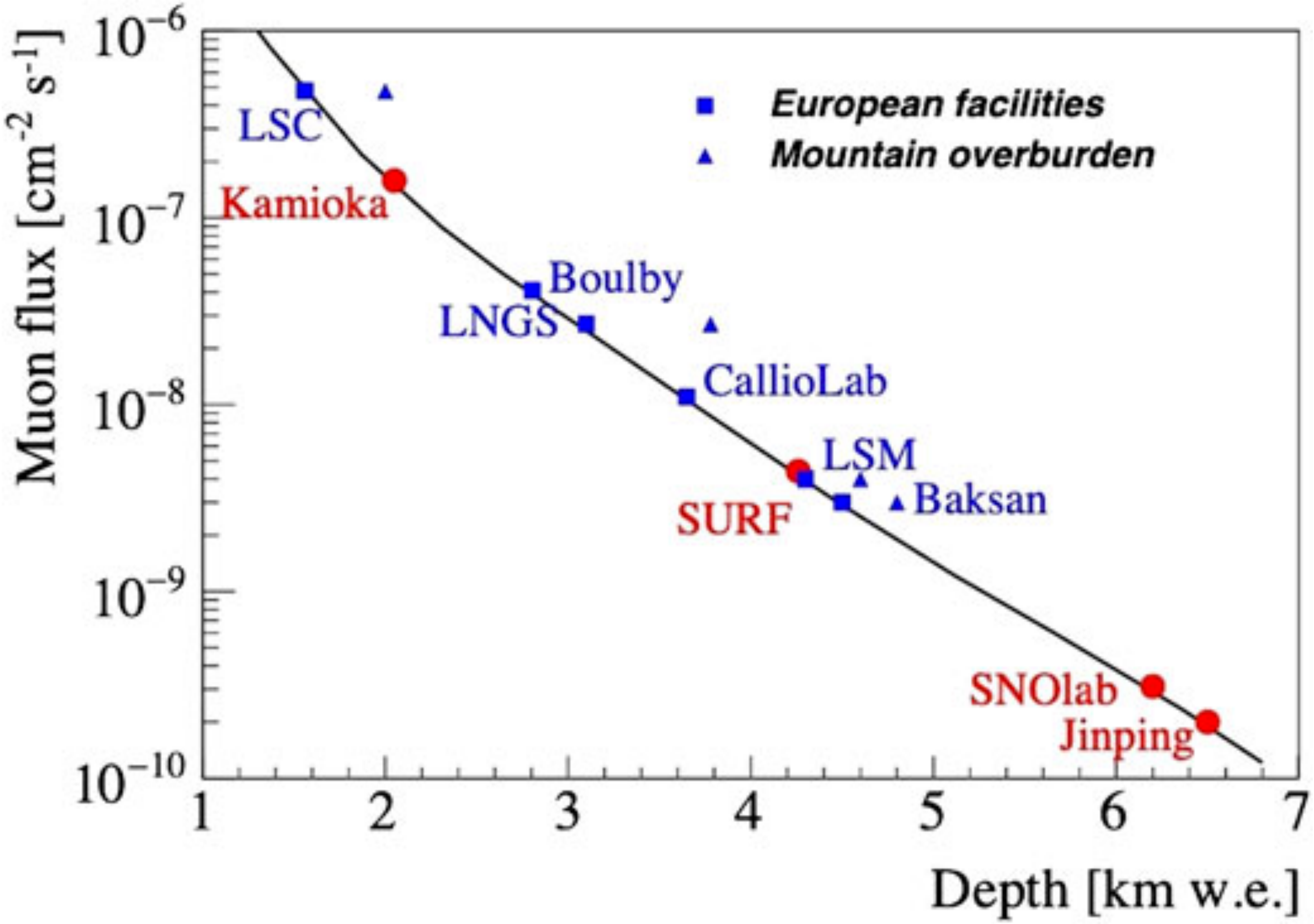
D. Malling, UCLA DM'16

Recipe for building a low-background experiment

Recipe for building a low-background experiment

1) go underground

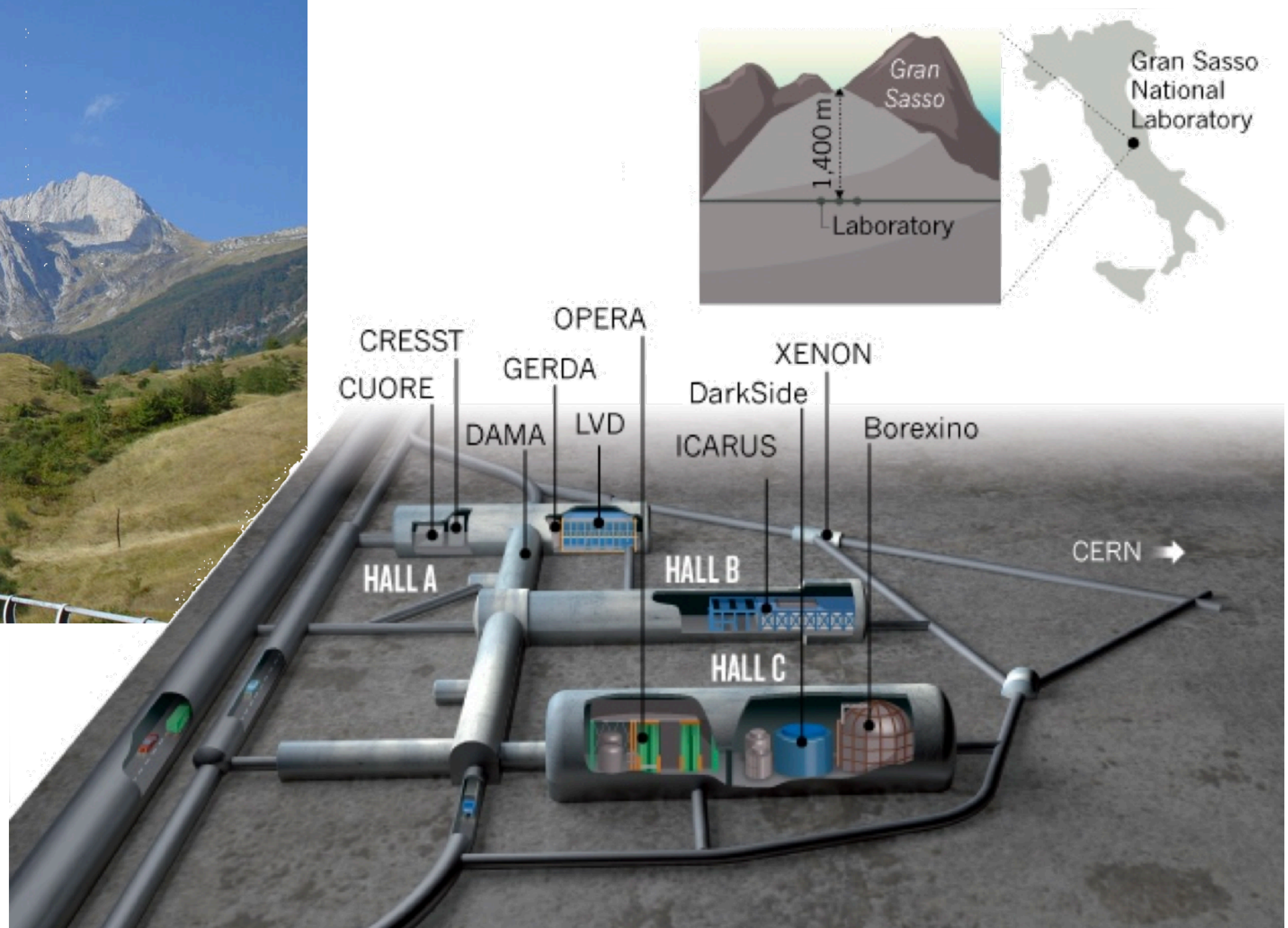
deep in mines or underneath mountains are both OK



cosmogenic neutrons and cosmogenic activation are proportional to muon flux

LNGS

cosmic μ flux underground ~ 1 / m² / hr

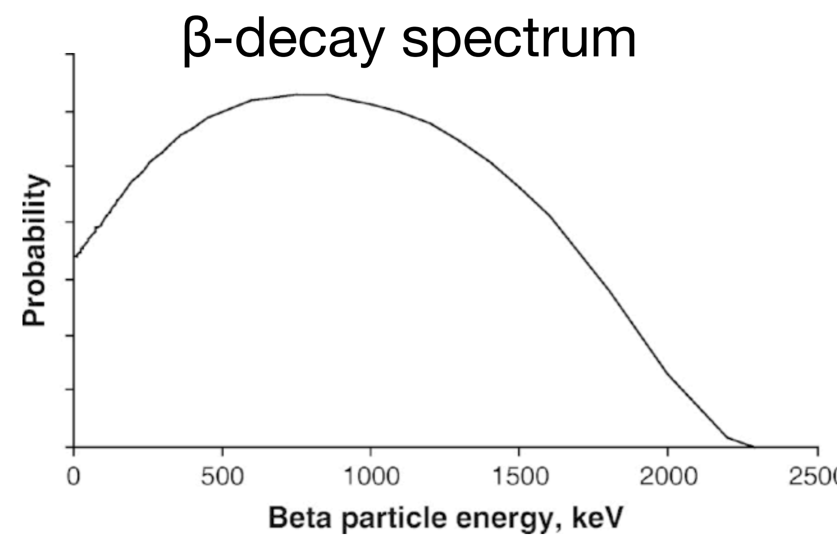


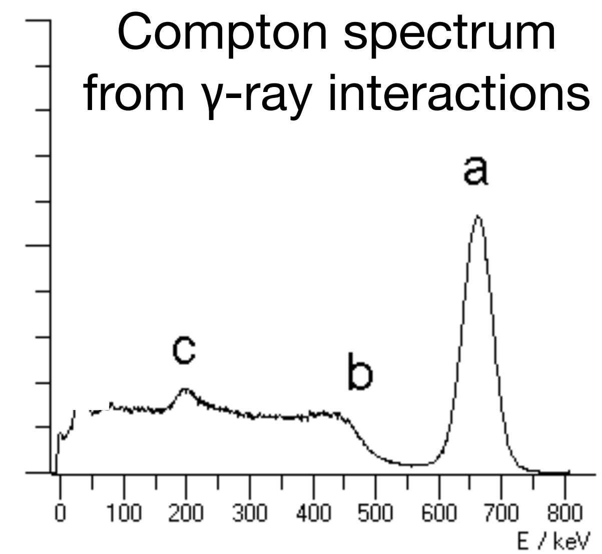
Recipe for building a low-background experiment

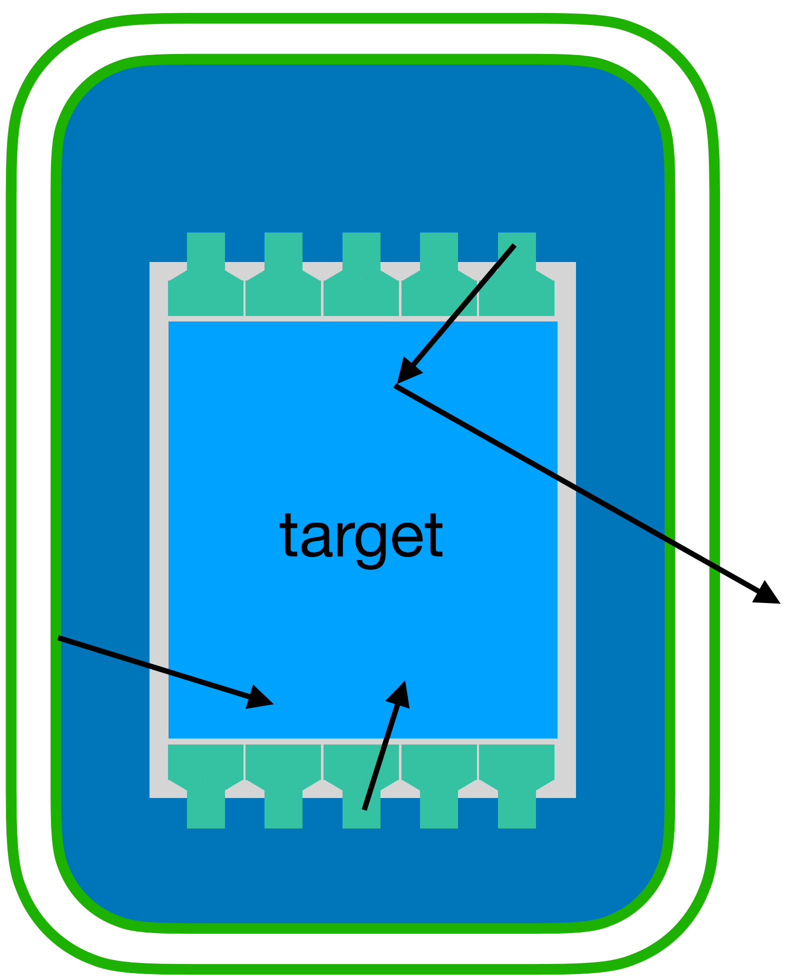
1) go underground

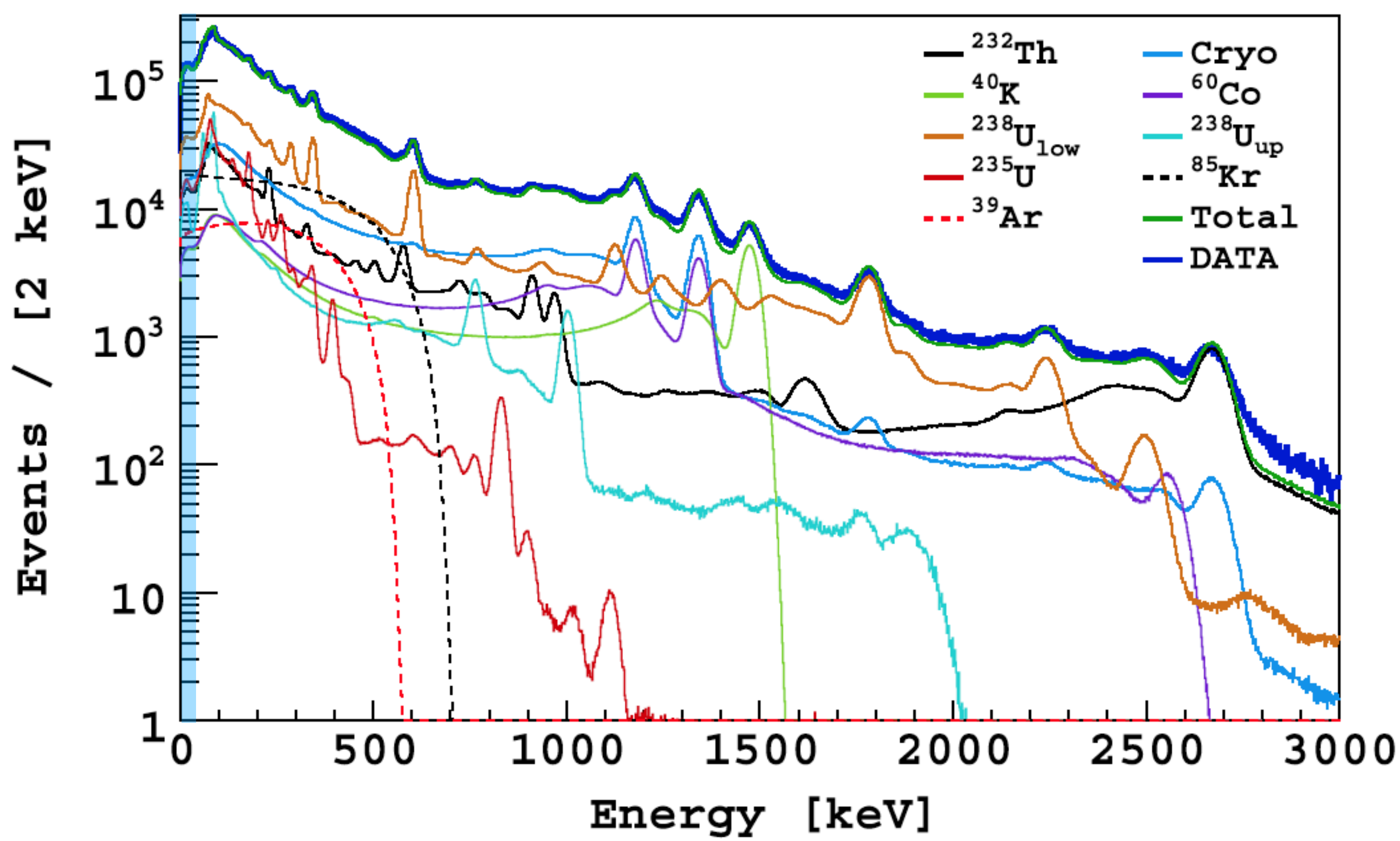
2) use radio-pure materials

not only for the target, but for all the construction materials









DarkSide-50

Material Assay and Selection

Is an essential part of design/construction of the experiment.

- ^{40}K in humans → primary source of radiation from our body (practically constant)
  - K content of the body is 0.2 %
  - Natural abundance of 0.0117 % of K_{Nat}
  - K-40 specific activity 2.6e5 Bq g^{-1} (using the half-life 1.28×10^9 y from raconv).

  For a 70-kg person, the amount of ^{40}K will be about 4.26 kBq (≈ 60 Bq/kg)
- ^{14}C for a 70-kg person would be about 3.08 kBq.

Table 7: Gamma assay results for tooling used during construction and manufacture of detector components. Activities are reported with 1-sigma uncertainties. A 90% confidence limit is placed when the measurement is below the background sensitivity of the detector. It is assumed that secular equilibrium is broken between ^{230}Th and ^{226}Ra in the ^{238}U decay chain.

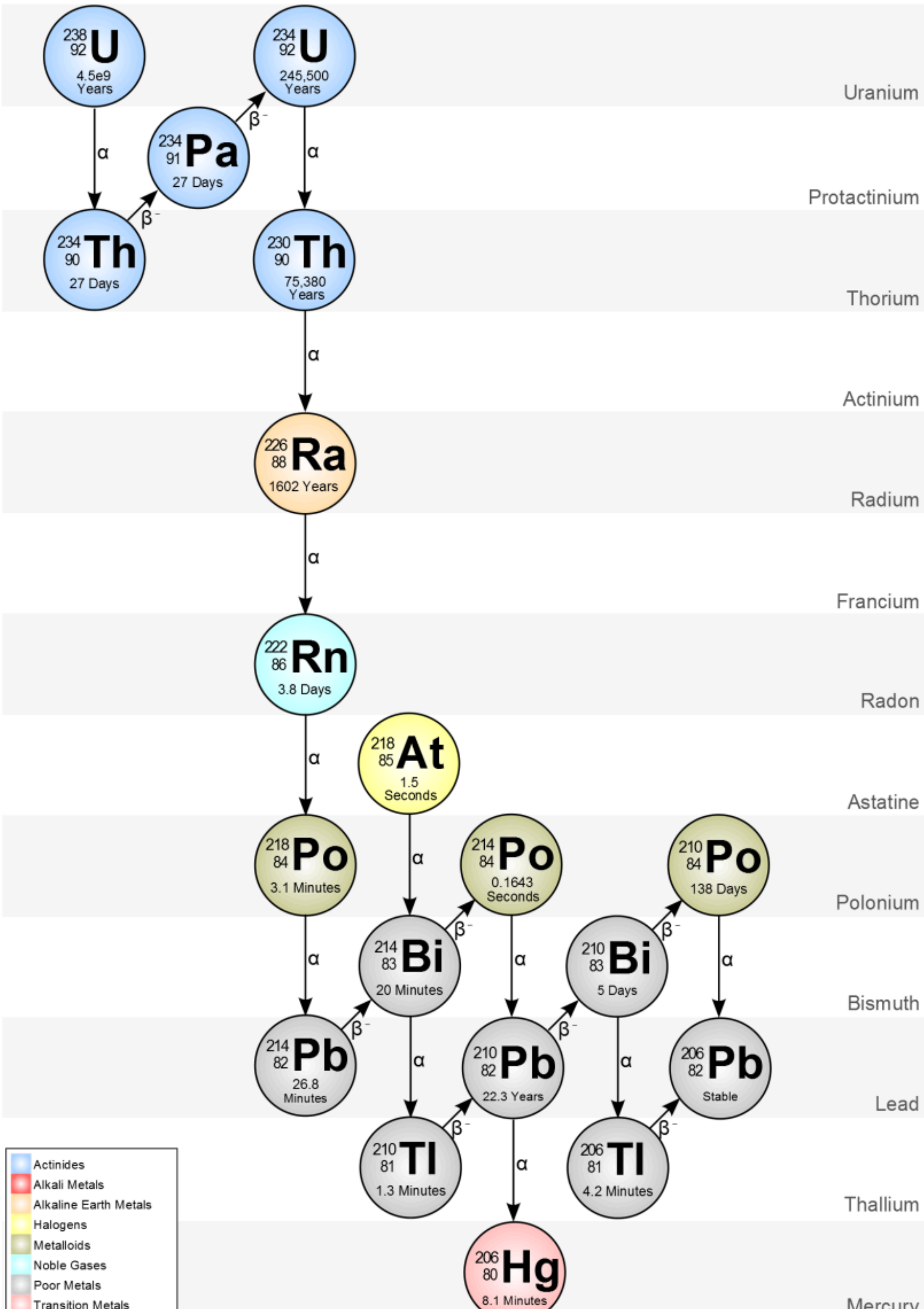
Component	$^{238}U^{lower}$	$^{238}U^{upper}$	^{232}Th	^{235}U
		[mBq/kg]		
Purification System Welding				
TIG weld sample	7.7 ± 5.7	< 27	25.2 ± 7.8	< 16
SMAW weld sample	< 23	< 1255	51.9 ± 12.2	< 13
Welding electrodes A (Blue Demon TE2C-116-10T)	221 ± 65	< 493	1890 ± 184	< 56
Welding electrodes B (Blue Demon TE2C-116-10T)	66.6 ± 42.6	< 1300	710 ± 103	< 138
Welding electrodes C (Blue Demon TE2C-116-10T)	86.1 ± 21.8	< 642	911 ± 73	< 108
Weld filler rods	< 4.8	< 157	3.0 ± 2.5	< 1.8
Inner AV Sanding				
Brazed diamond sanding pad (Superabrasives)	141 ± 24	< 845	49.8 ± 17.9	31 ± 19
Plated diamond sanding pad (Superabrasives)	4680 ± 283	< 4130	6180 ± 300	218 ± 64
3M 6002J flexible diamond pads	25.1 ± 15.4	< 785	< 10.8	< 33
Diamond sandpaper (Diamante Italia)	3120 ± 136	< 2300	3370 ± 125	157 ± 22
Red sandpaper (RPT)	48.7 ± 19.7	< 335	< 10.1	< 32
LG Acrylic Polishing				
Diamond lapping film (3M 661X)	142 ± 38	< 882	93.6 ± 35.0	< 31
Diamond lapping film (3M 661X)	94.0 ± 16.5	< 276	105. ± 18.1	< 33

Table 6: Gamma assay results for major detector materials. A description of the components can be found in Section 4. Activities are reported with 1-sigma uncertainties. A 90% confidence limit is placed when the measurement is below the background sensitivity of the detector. It is assumed that secular equilibrium is broken between ^{230}Th and ^{226}Ra in the ^{238}U decay chain.

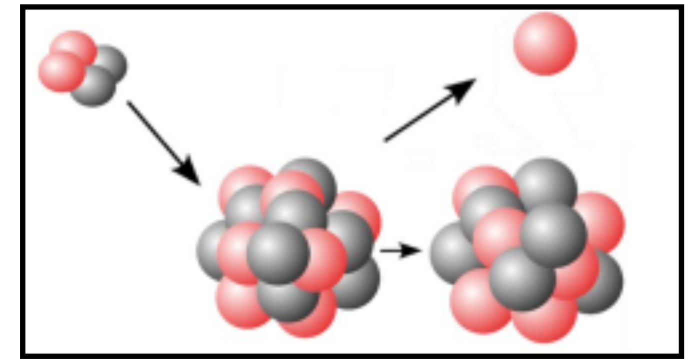
Component	$^{238}U^{lower}$	$^{238}U^{upper}$	^{232}Th	^{235}U
		[mBq/kg]		
Methyl methacrylate monomer (LG bonding)	1.4 ± 1.0	< 15	< 0.9	< 1.8
AV acrylic	< 0.1	< 2.2	< 0.5	< 0.2
Acrylic beads (RPT)	< 3.1	16 ± 15	0.8 ± 0.3	0.6 ± 0.5
LG acrylic	< 0.1	< 9.0	< 0.3	< 0.6
304 welded stainless steel (steel shell)	1.4 ± 1.1	< 5.0	4.7 ± 1.5	< 3.3
304 stainless steel stock (steel shell)	2.1 ± 1.1	40 ± 56	1.9 ± 1.1	< 5.4
316 stainless steel bolts (steel shell)	< 6.1	< 315	94 ± 9	< 17
Carbon steel (stock)	2.0 ± 0.7	111 ± 43	10.0 ± 1.0	8.6 ± 1.9
R5912 HQE PMT glass	921 ± 34	225 ± 114	139 ± 7	25 ± 3
R5912 HQE PMT ceramic	978 ± 56	15500 ± 2800	245 ± 28	503 ± 51
R5912 HQE PMT feedthrough pieces	1140 ± 60	2350 ± 1460	430 ± 32	38 ± 9
R5912 HQE PMT metal components	< 5.5	–	< 3.3	–
RG59 PMT cable (Belden E82241)	4.5 ± 1.3	91 ± 46	1.2 ± 0.9	3.4 ± 1.4
PMT mount PVC (Harvel)	72 ± 5	232 ± 130	18.6 ± 2.5	5.6 ± 1.5
PMT mount copper	< 0.5	< 10	< 0.8	< 1.3
Filler block polyethylene	0.4 ± 0.3	< 14	< 0.1	< 0.15
Filler block Styrofoam [39]	33.5 ± 3.4	115 ± 64	< 1.5	< 1.4
White Tyvek paper (diffuse reflector)	< 0.3	50 ± 37	1.3 ± 0.8	< 2.2
Black Tyvek paper (LG wrapping)	< 1.8	< 127	5.6 ± 2.3	< 3.8
Black polyethylene tube (upper neck)	13.7 ± 1.8	< 60	3.2 ± 1.1	2.6 ± 1.4
TPB (Sigma Aldrich)	< 3.9	–	< 8.7	–

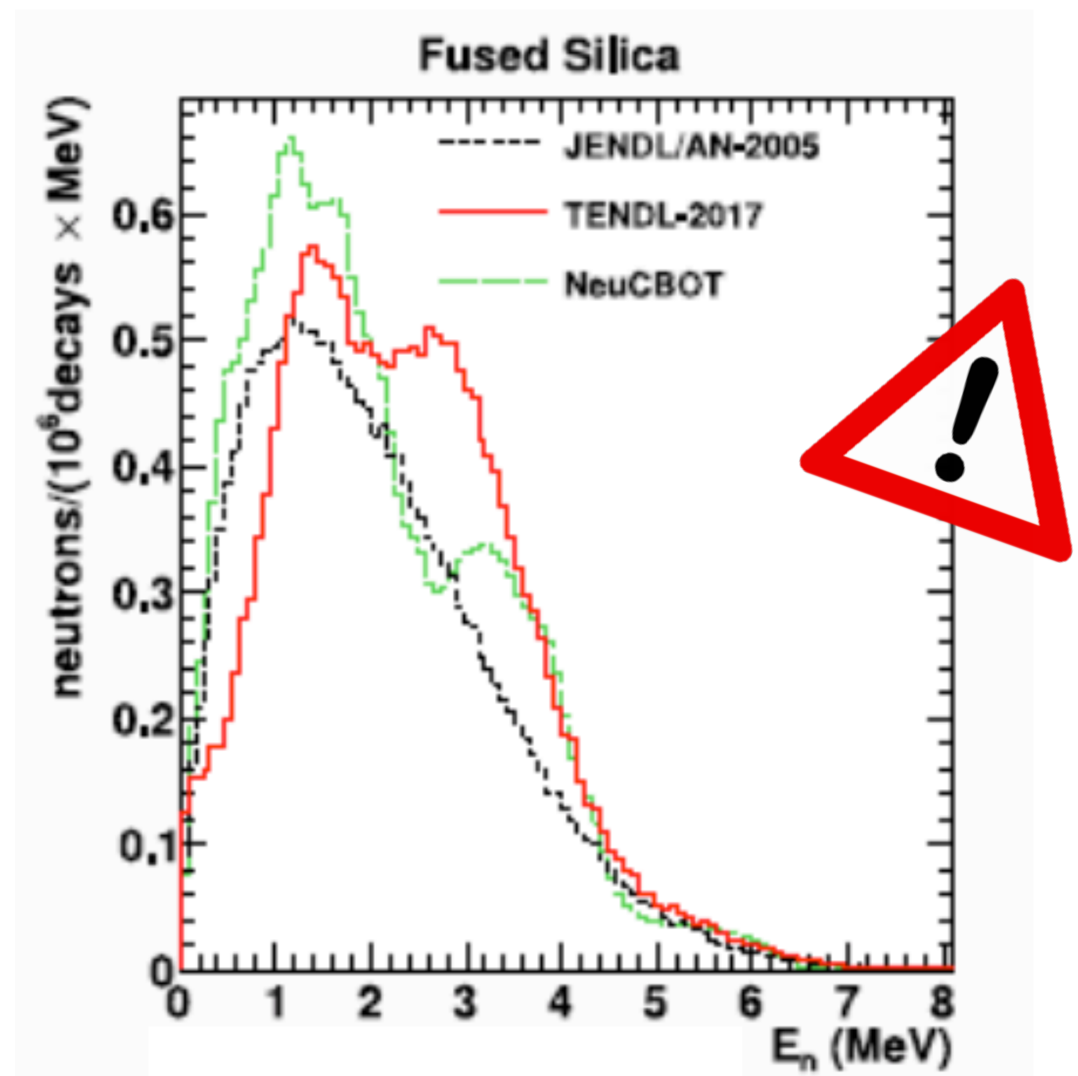
Not only gamma rays!

U and Th decay chains are particularly relevant for neutrons too, via (a,n) reactions



XS: $10^{-9} \div 10^{-5}$
n / decay





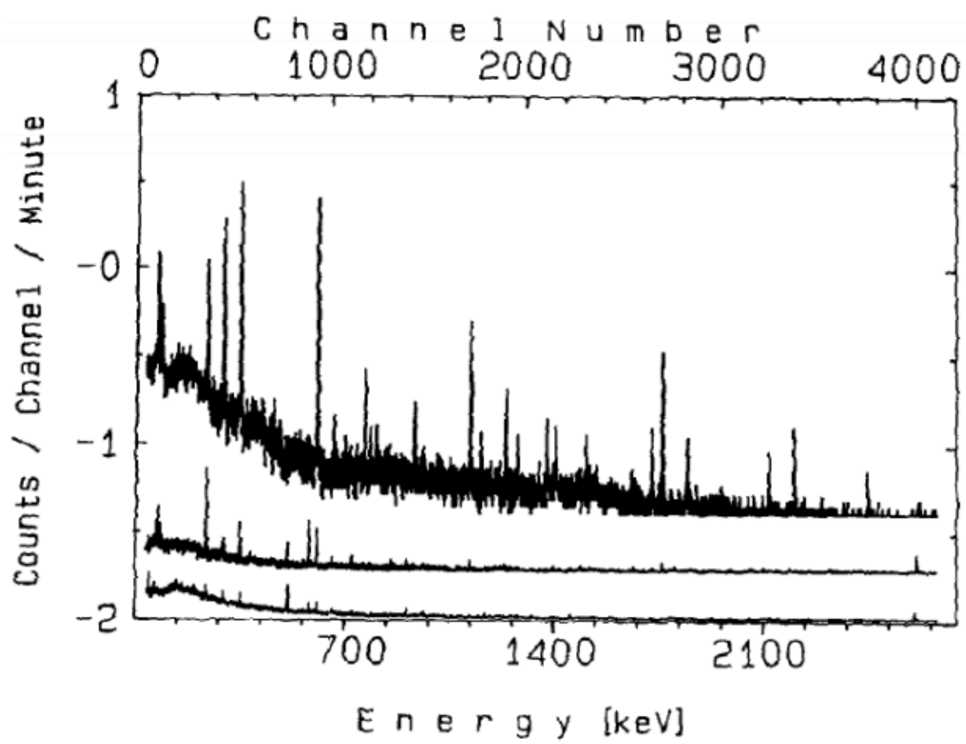
The Radon contamination

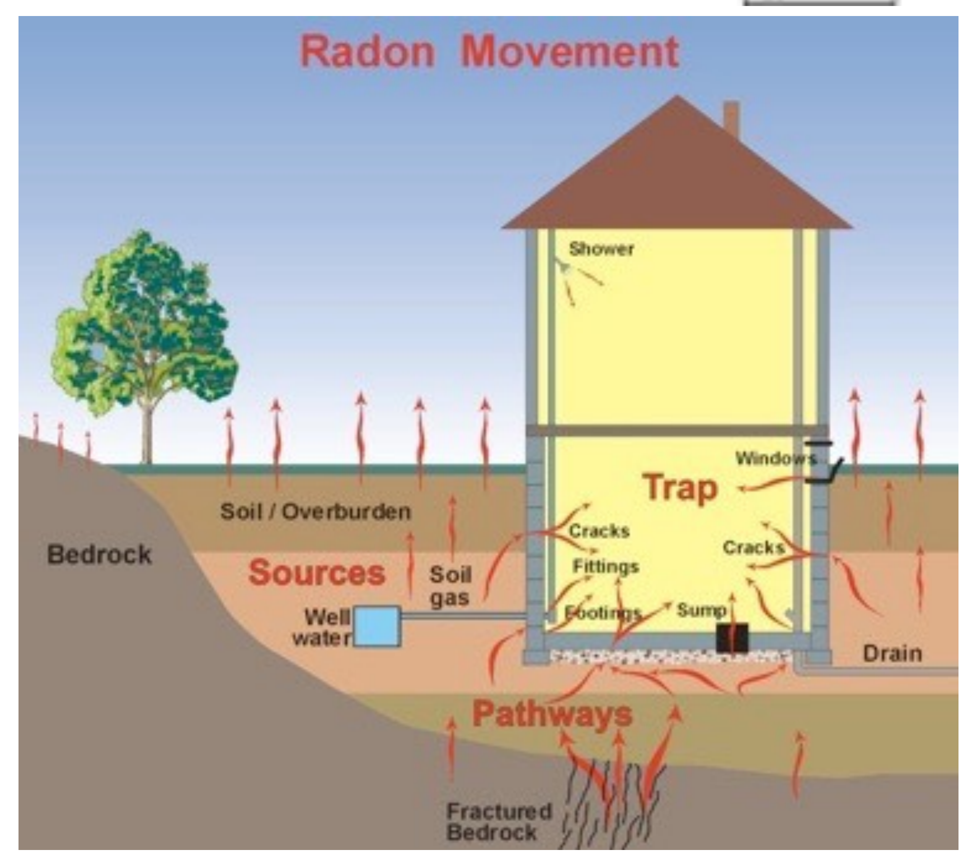
Radon escapes both solids and liquids

^{220}Rn, ^{219}Rn, and especially ^{222}Rn and their daughters release several high-energy γ's and α's

— underground Rn contamination is larger than surface (~10 vs ~100 Bq/m^3)
— Rn daughters plate-out on surfaces

==> Techniques based on charcoal adsorption suppress Rn ~ by 10^4 -10^5
==> Rn-free clean rooms





Recipe for building a low-background

1) go underground
2) use radio-pure materials
3) plan for shield(s), better if active

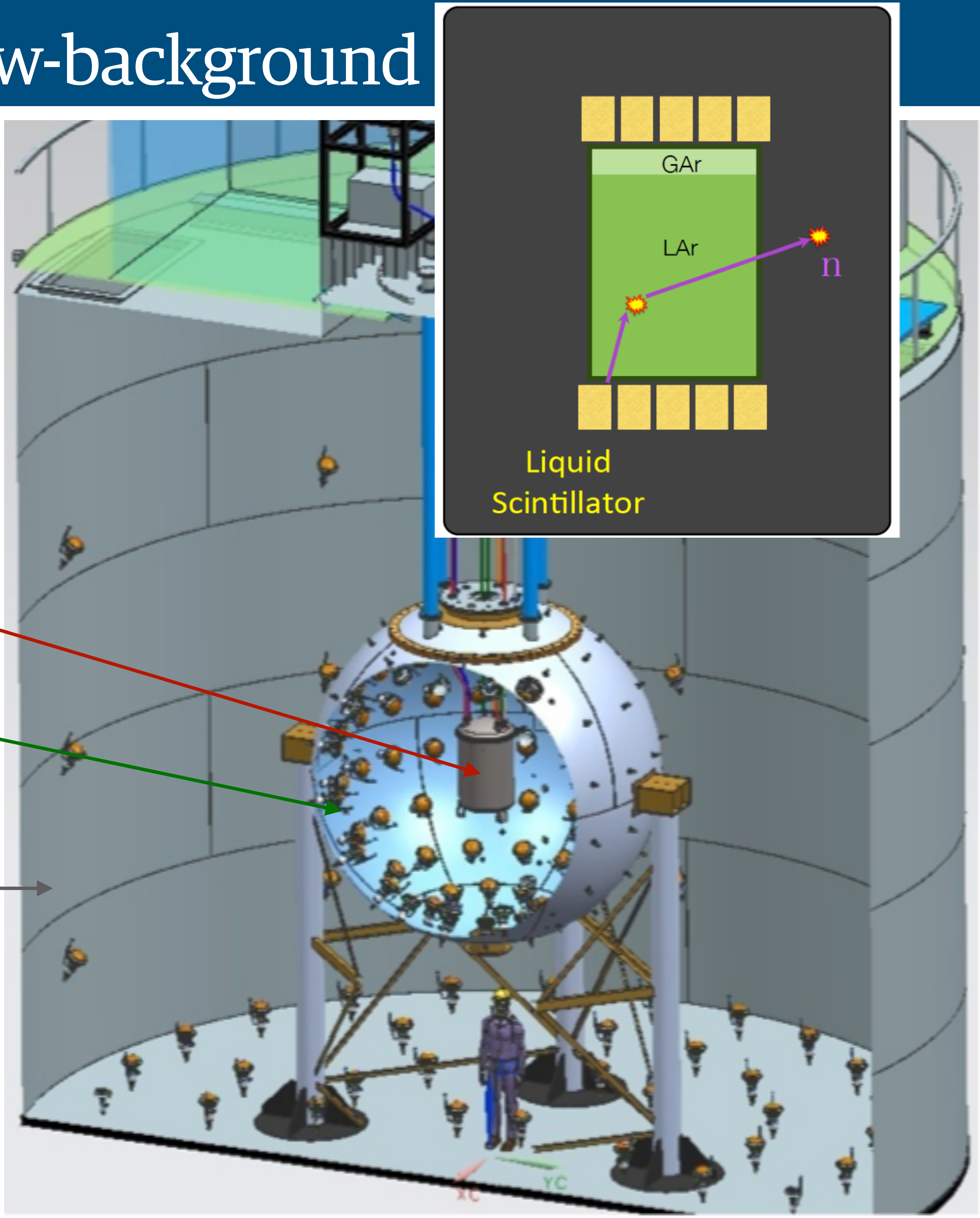
The DarkSide-50 case:

Liquid argon TPC
50 kg LAr

Liquid Scintillator Veto (LSV)
30 tons, 2 m radius
110 PMTs (LY = 0.5 pe/keV)

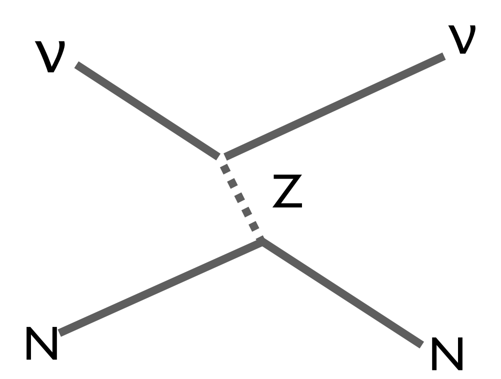
Water Cherenkov Detector (WCD)
1 kt water, 5.5 m radius
80 PMTs

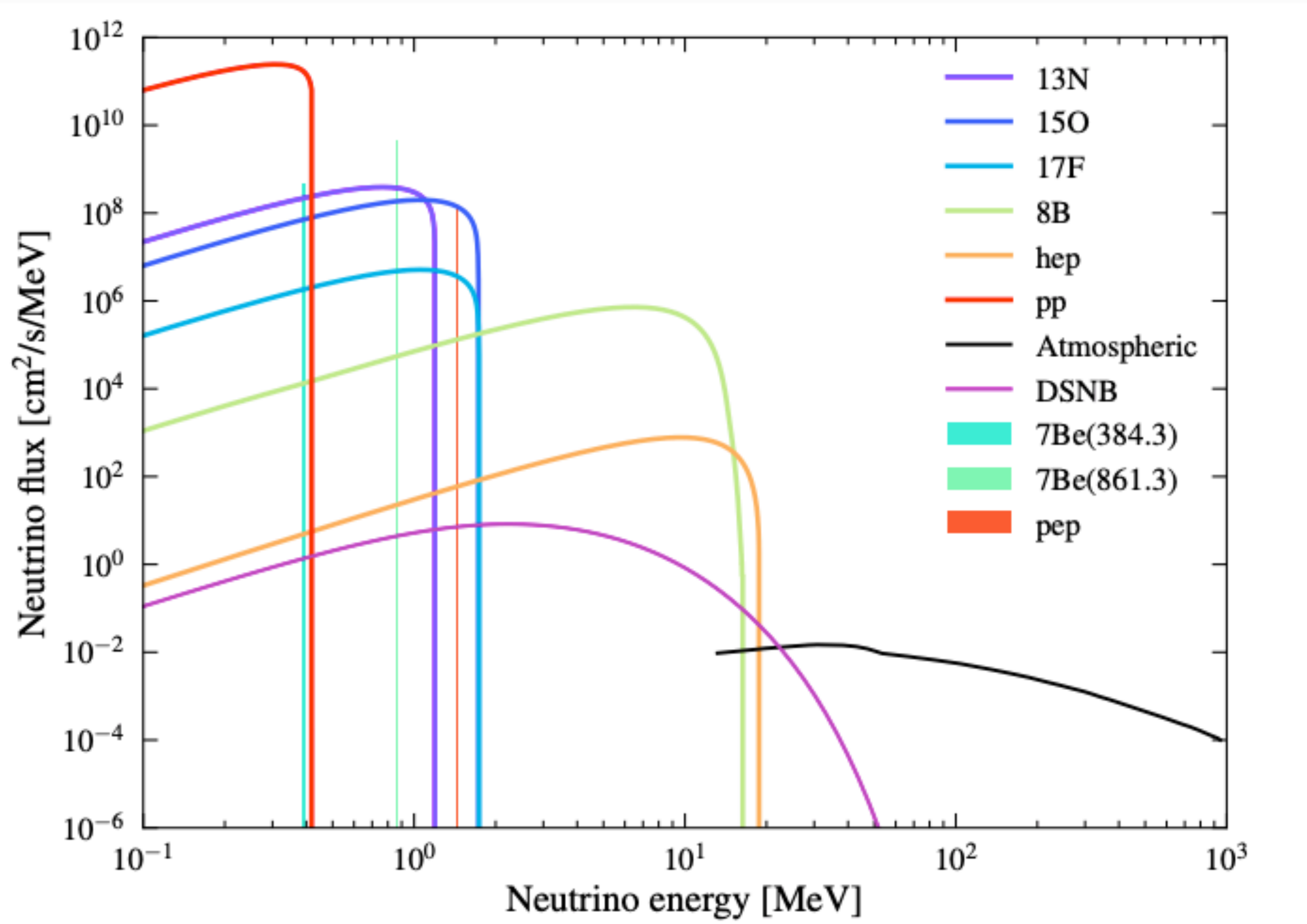
Active Veto:
- suppresses bg rates from outside
- measures bg rate *in-situ*! and reduce systematics

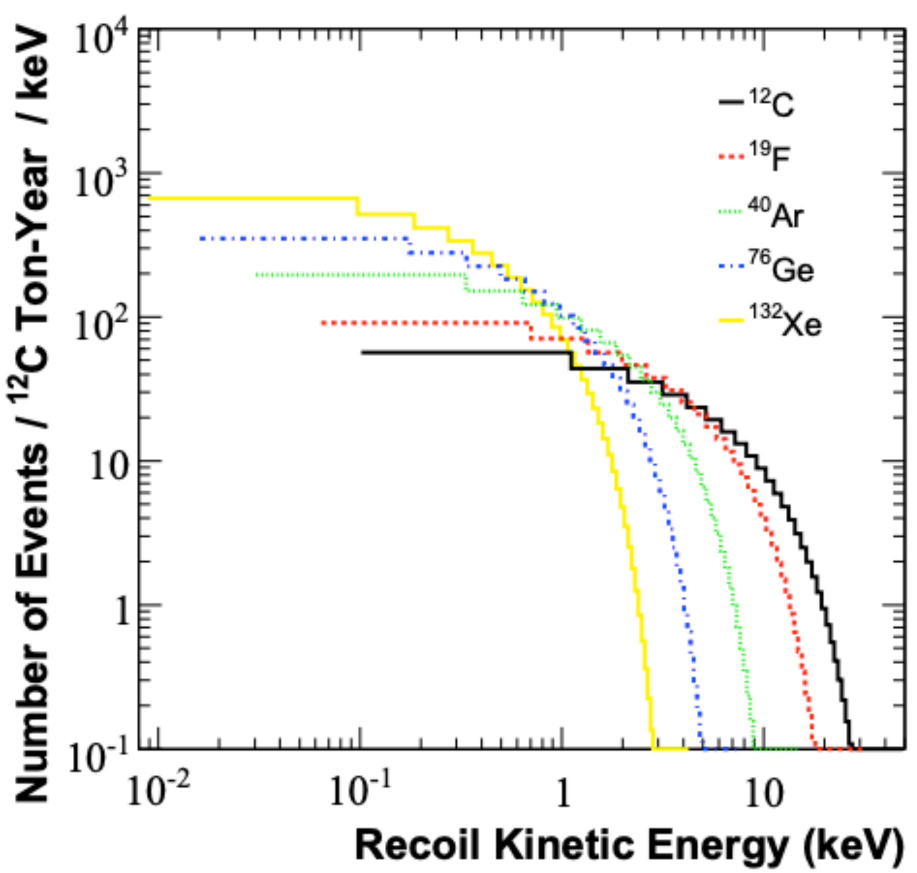


Recipe for building a low-background experiment

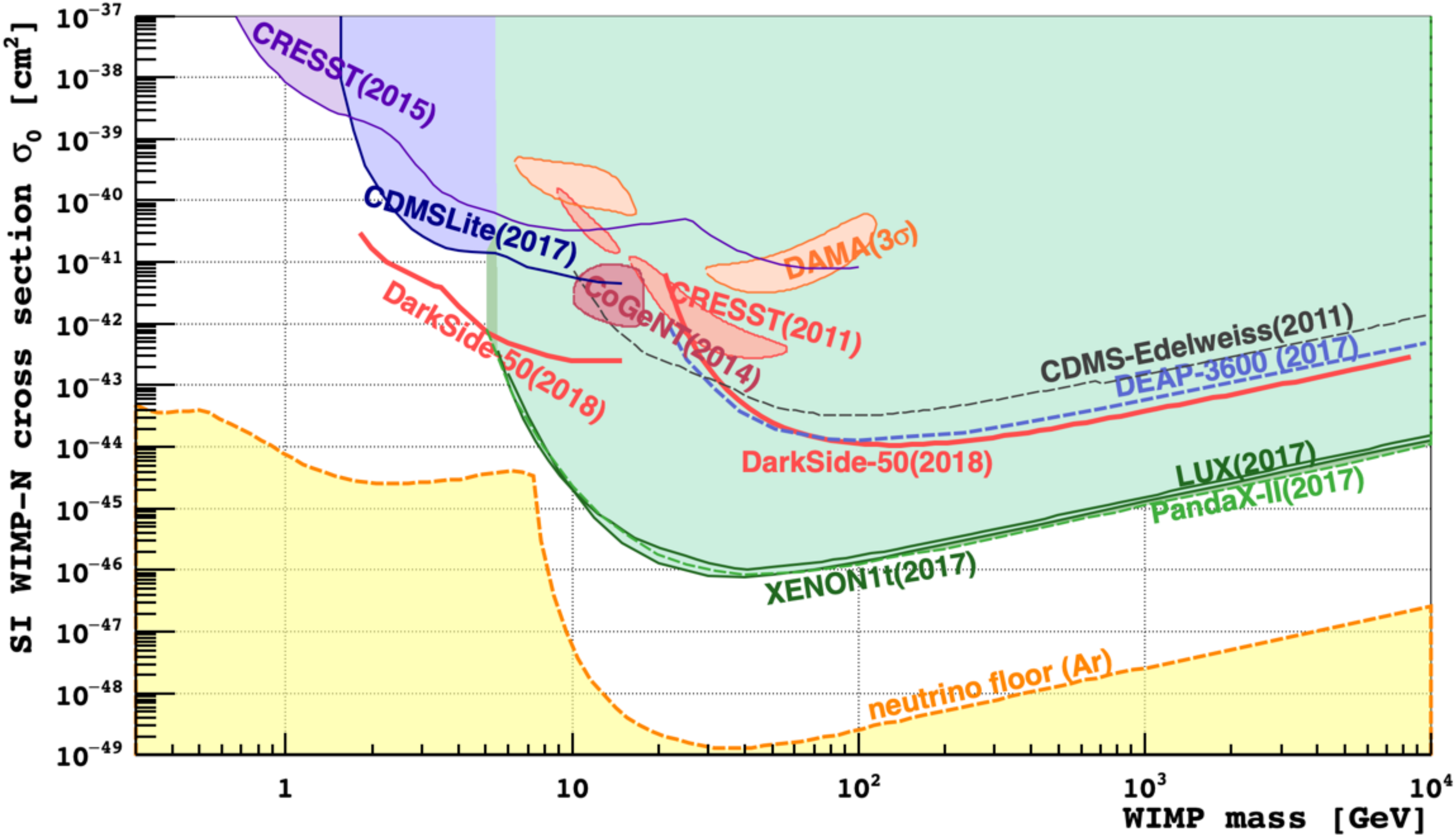
1) go underground
2) use radio-pure materials
3) plan for shield(s), better if active
4) learn to deal with irreducible backgrounds
neutrinos from Sun, SNae, atmosphere







“Neutrino Floor”



Recipe for building a low-background experiment

1) go underground
2) use radio-pure materials
3) plan for shield(s), better if active
4) learn to deal with irreducible backgrounds
5) not immune from detector-specific backgrounds, usually not easily predictable

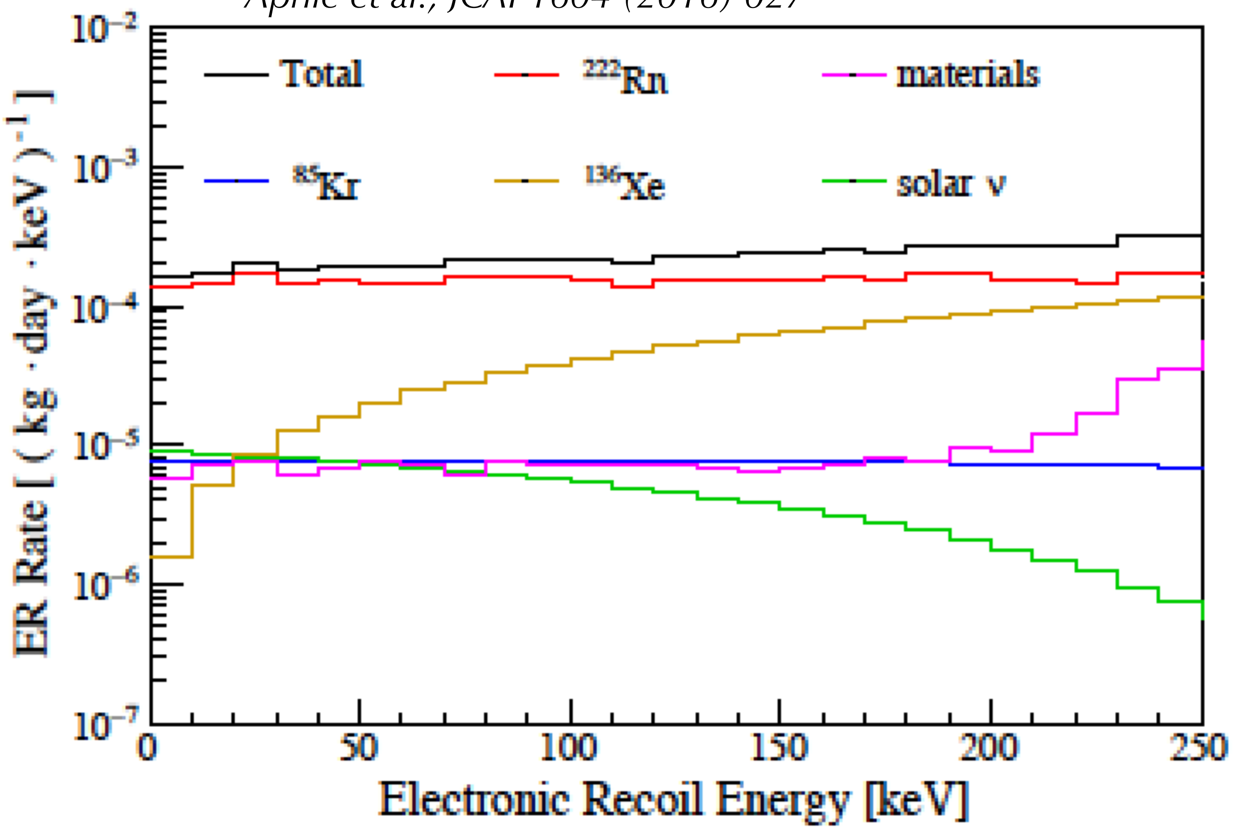
Examples:

- single electrons emission from photo-ionisation of metal surfaces in the detector
  https://iopscience.iop.org/article/10.1088/1748-0221/13/02/P02032
- dust in the detector or construction materials shadowing the signal
  https://pos.sissa.it/395/527/pdf
- Cerenkov radiation from gamma rays NOT reaching the active volume
  https://arxiv.org/abs/1802.07198
- …

Recipe for building a low-background experiment

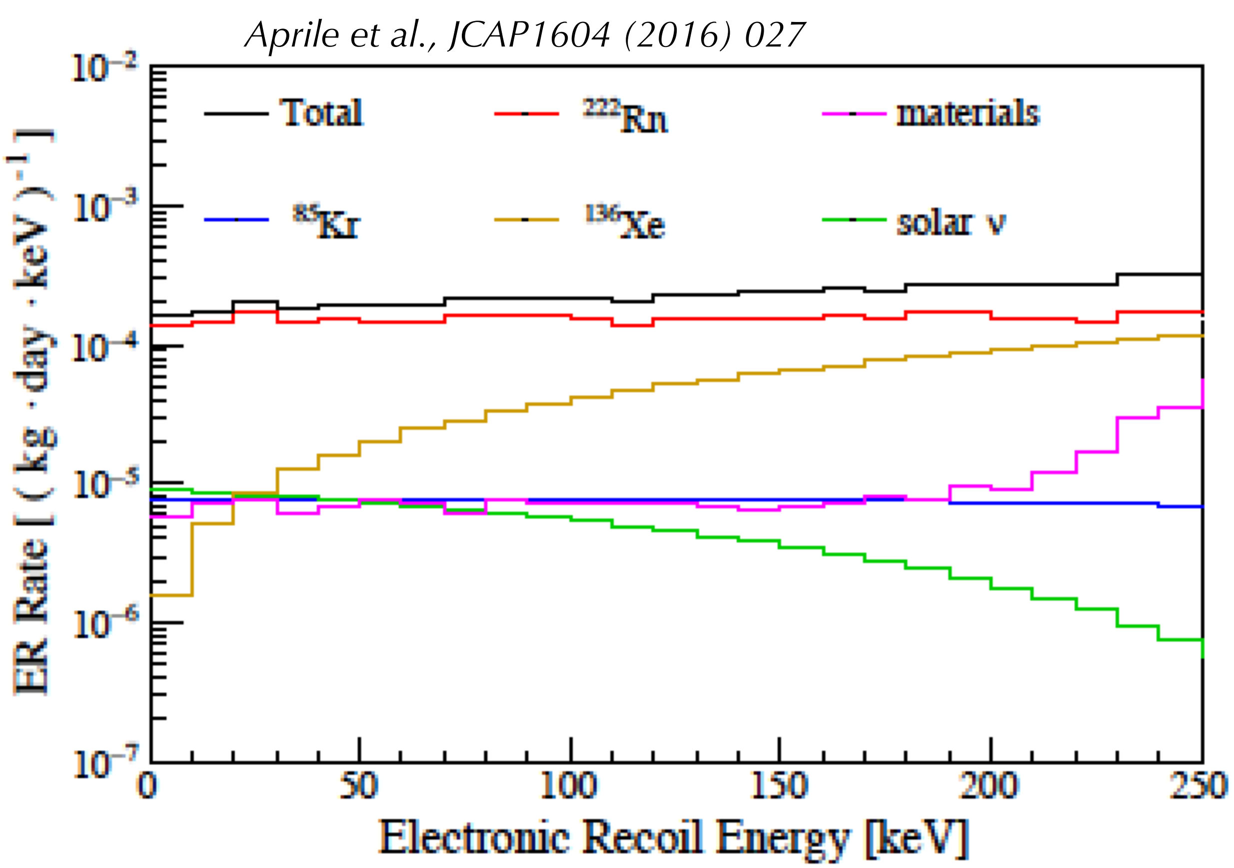
Example: Xenon-1t projections vs real data

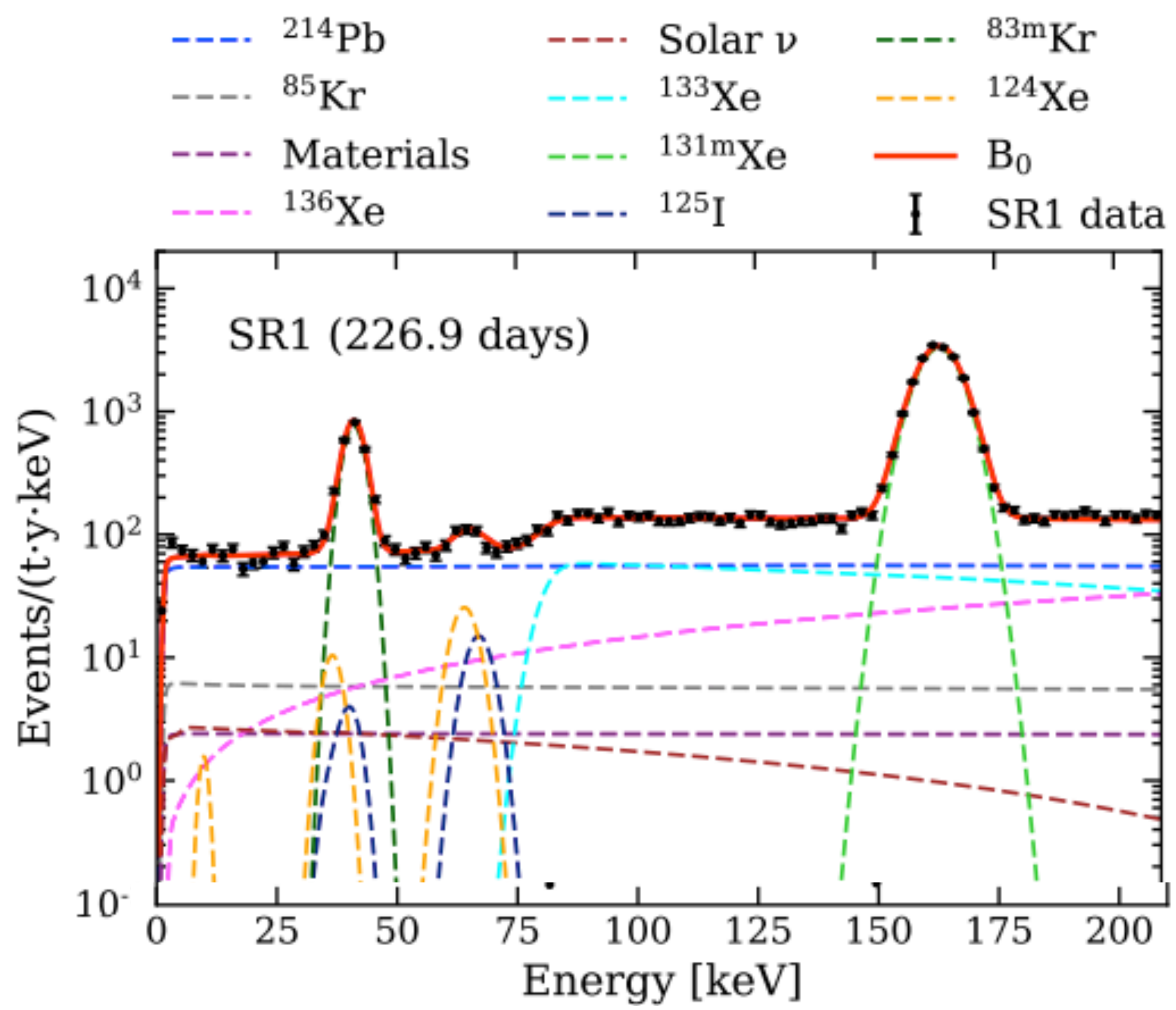
Aprile et al., JCAP1604 (2016) 027



Recipe for building a low-background experiment

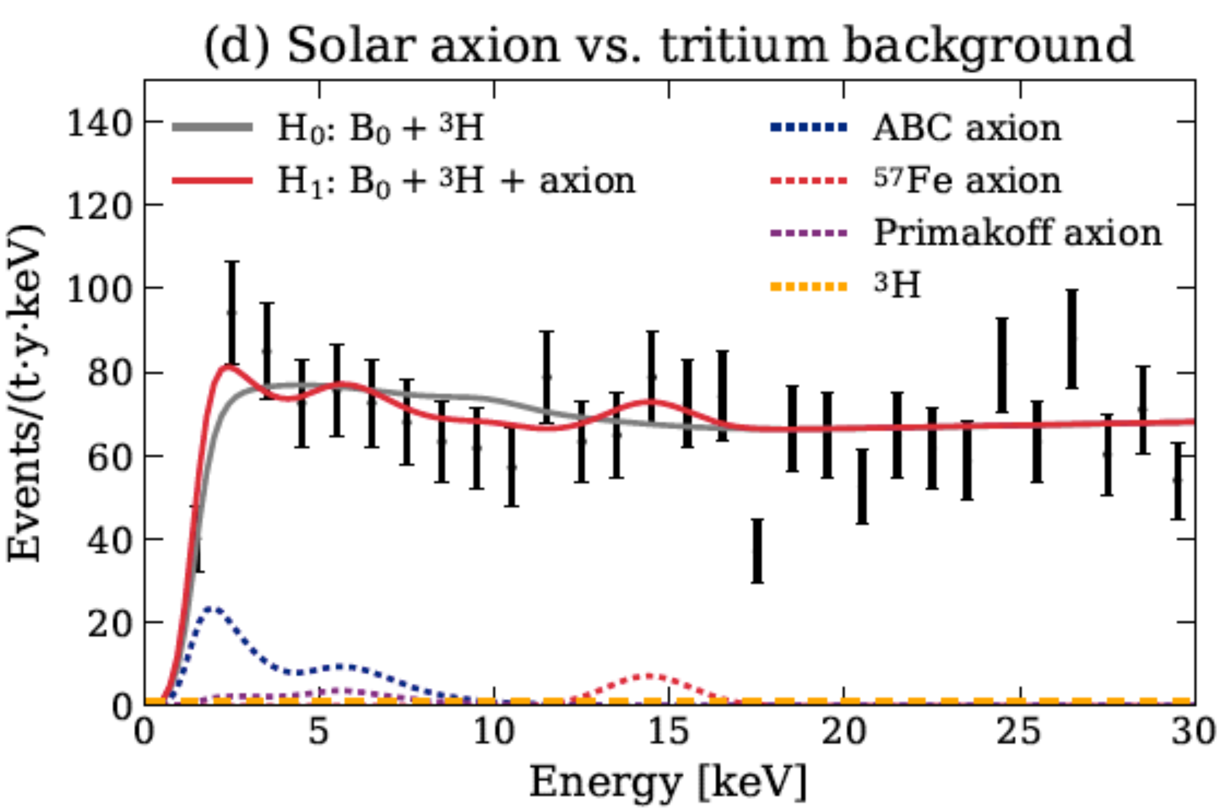
Example: Xenon-1t projections vs real data

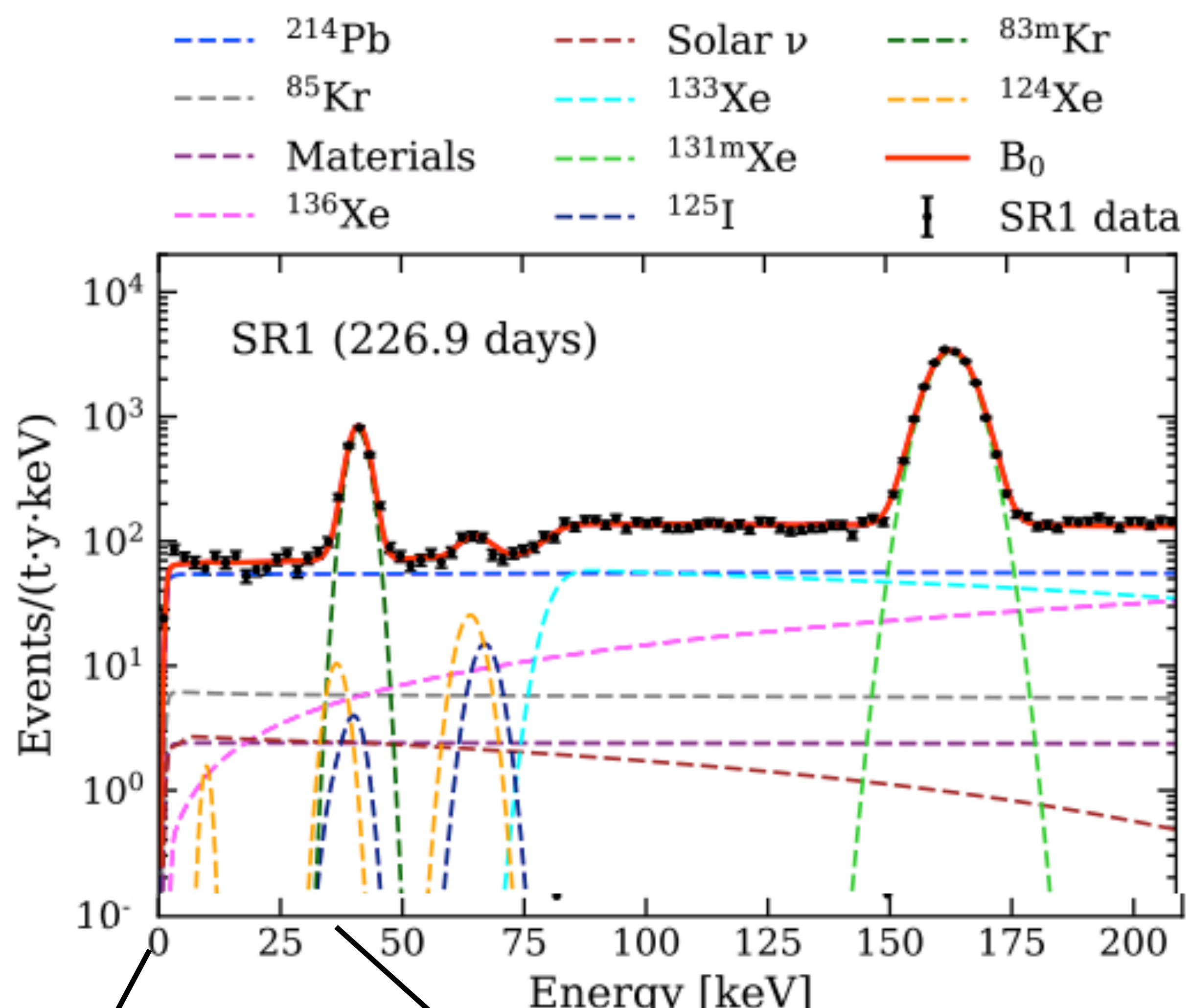


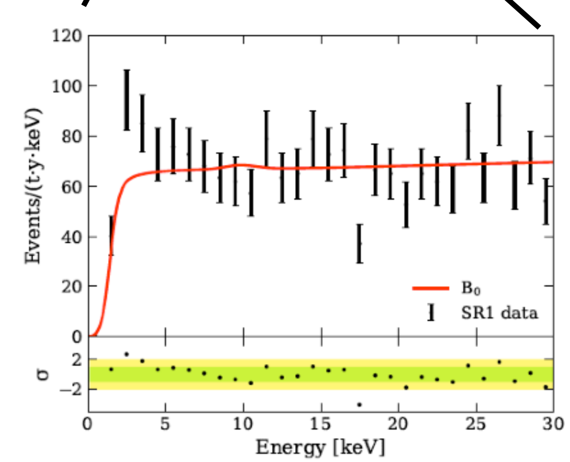


Recipe for building a low-background experiment

Example: Xenon-1t projections vs real data







https://arxiv.org/pdf/2006.09721.pdf

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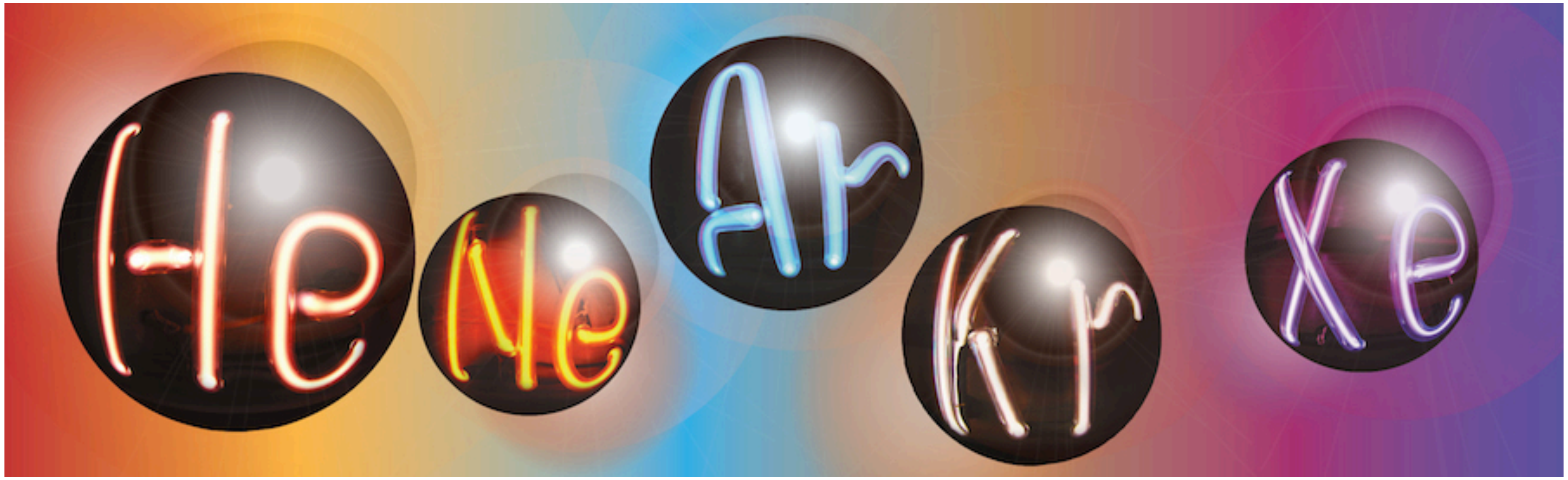
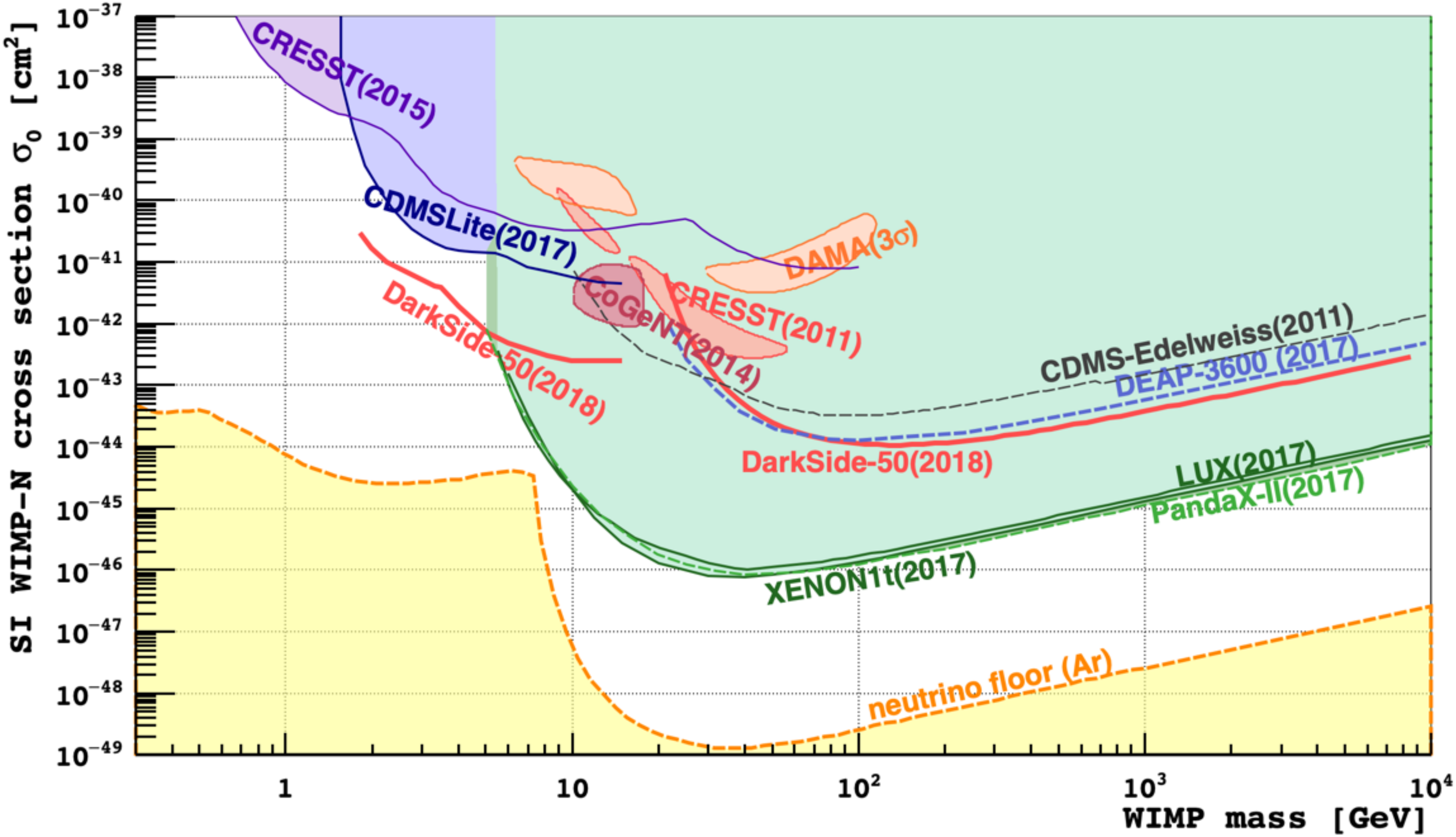

He
Ne
Ar
Kr
Xe

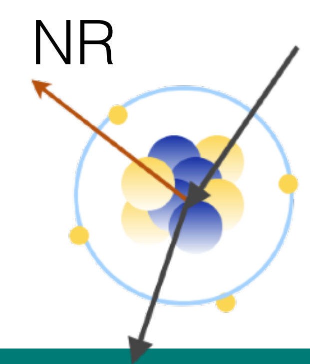
Noble liquids

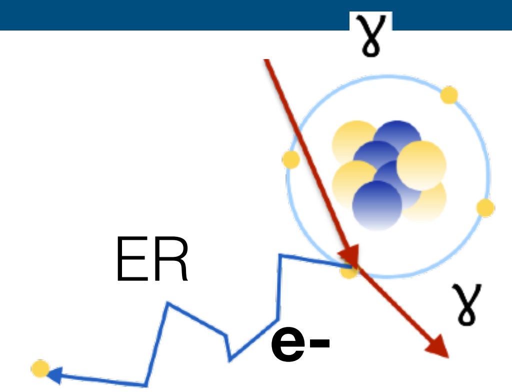


Why noble liquids?

Noble liquids are suitable targets:

- ☑ dense, inexpensive, easy to purify
- ☑ large ionization/scintillation yields (W~10 eV)
- ☑ ER recoil background discrimination

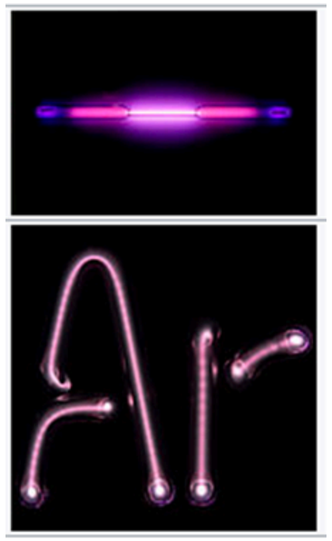


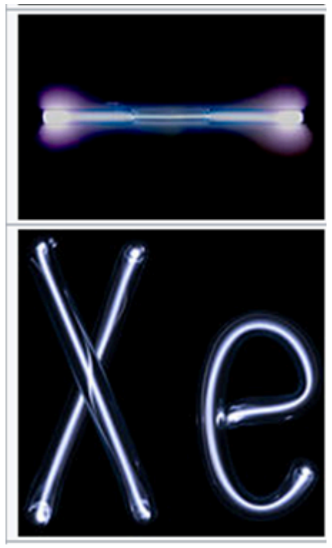


NR backgrounds	ER backgrounds
neutrons α's, ν's	internal and external β's, γ's

	Ar	Xe
density	1.4 g/cm^3	~3 g/cm^3
cost	1 $/kg (AAr) 100 $/kg (UAr)	1 k$/kg
internal radioactivity	1 Bq/kg (AAr) < 1 mBq/kg (UAr)	~ uBq/kg
Rn purification	0.2 uBq/kg	~ uBq/kg
Ionisation yield	40 e- / keV	70 e- / keV
Scintillation yield	50 ph / keV	80 ph / keV
ER discrimination	1E+08	1E+03

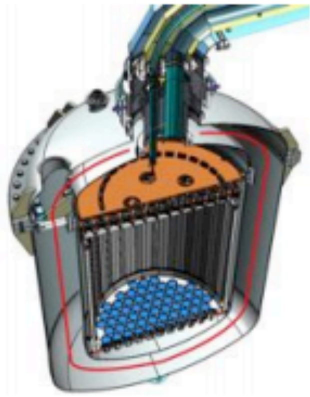
AAr: Atmospheric Argon UAr: Underground Argon





Complementarity: great value in case of an excess

The Xenon Programme

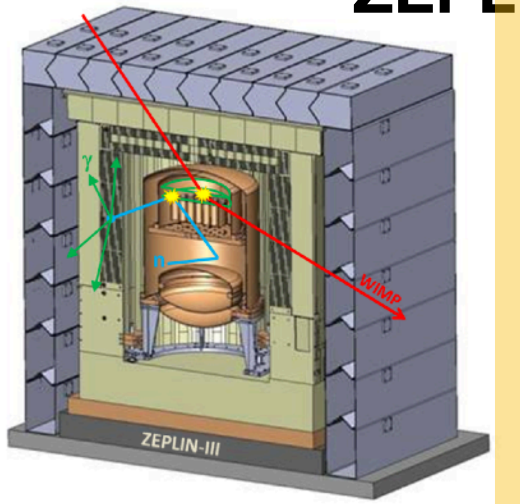
XENON10	XENON100	XENON1T	XENONnT	DARWIN
2005—2007	2008—2016	2012 – 2019	2017 – 2023	**~2023 –**
				
Past	**Past**	**Present**	**Near future**	
Total mass : 25 kg	Total mass : 161 kg	Total mass : 3.2 t	Total mass : ~8 t	**Total mass : ~50 t**
Target mass: 14 kg	Target mass: 62 kg	Target mass: 2 t	Target mass: ~6 t	**Target mass: ~40 t**
Drift TPC: 15 cm	Drift TPC: 30 cm	Drift TPC: 96 cm	Drift TPC: 144 cm	**Drift TPC: 260 cm**
Limit ~ 10^{-43} cm^2	Limit ~ 10^{-45} cm^2	Limit ~ 10^{-47}cm^2	Sensitivity ~ 10^{-48}cm^2	**Sensitivity ~ 10^{-49}cm^2**
				Future

PandaX-I:
120kg Liquid xenon
(2009-2014)

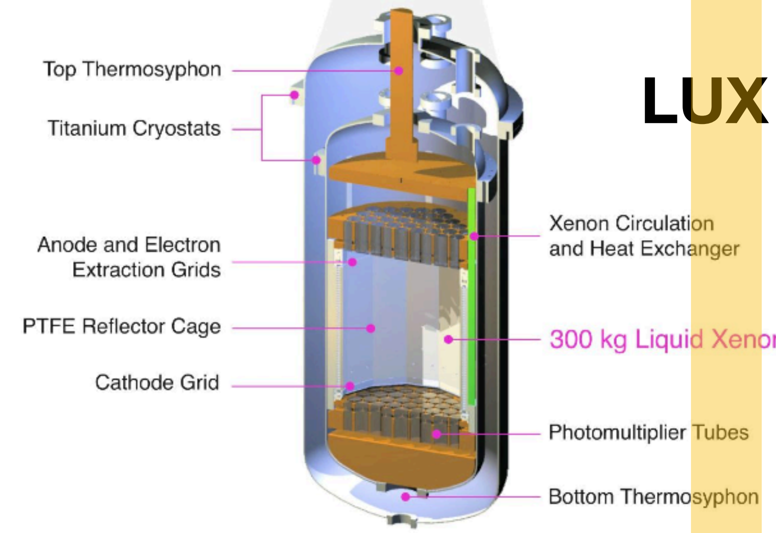
PandaX-II:
580kg LXe
(2014-2019.6)

PandaX-xT:
Next step,
4ton LXe
(future)

ZEPLIN-III



LUX



LZ

The DarkSide programme

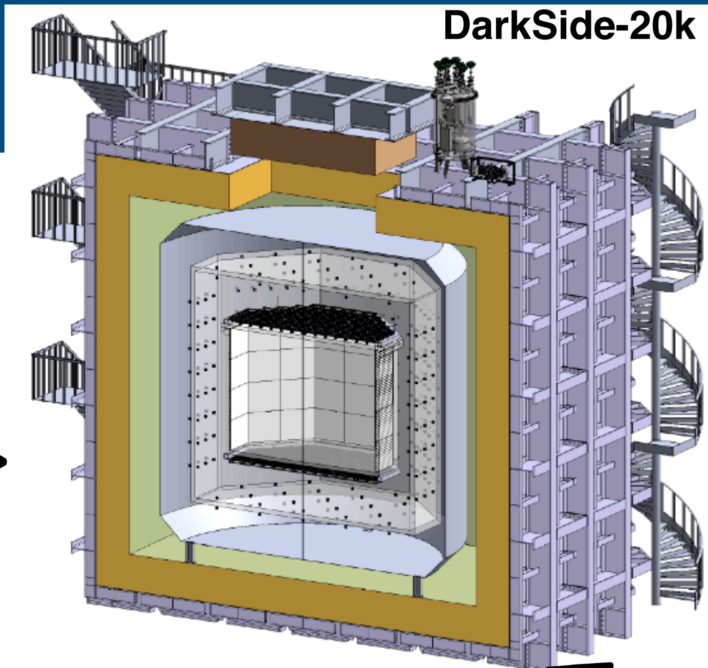
GDAMC Global Dark Matter Argon Collaboration, merges **ArDM**, **DEAP-3600**, **DarkSide-50**, **MiniCLEAN** for a dual-phase LAr TPC, through a **staged** approach:

Background suppression
- Ultra-low background materials
- **Depleted Liquid Argon**
- Low background photo-detectors
- Low background material components

Background identification
- **Pulse Shape Discrimination** (PSD)
- Ionization/scintillation ratio
- Position reconstruction (surface events)
- Multiple scatters within the TPC

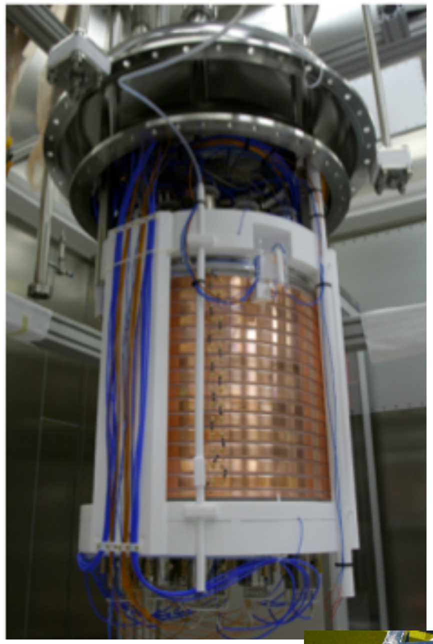
Active Shielding
- **Active Neutron Veto**
- Water Cherenkov against muons (WCD)

Main goal: collect 200 t yr bg-free exposure



x 1000

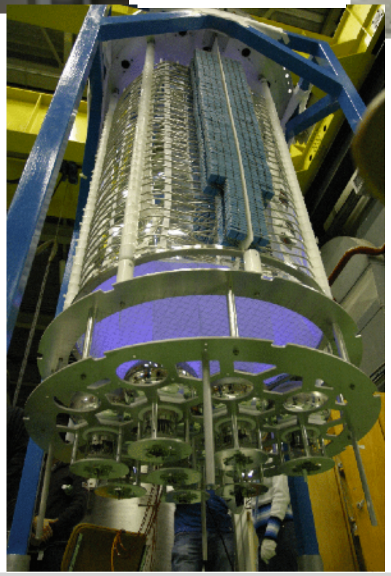
DarkSide-50



x 20

DEAP-3600

ArDM



2024
2022
2020
2018
2016
2014
2012
2010

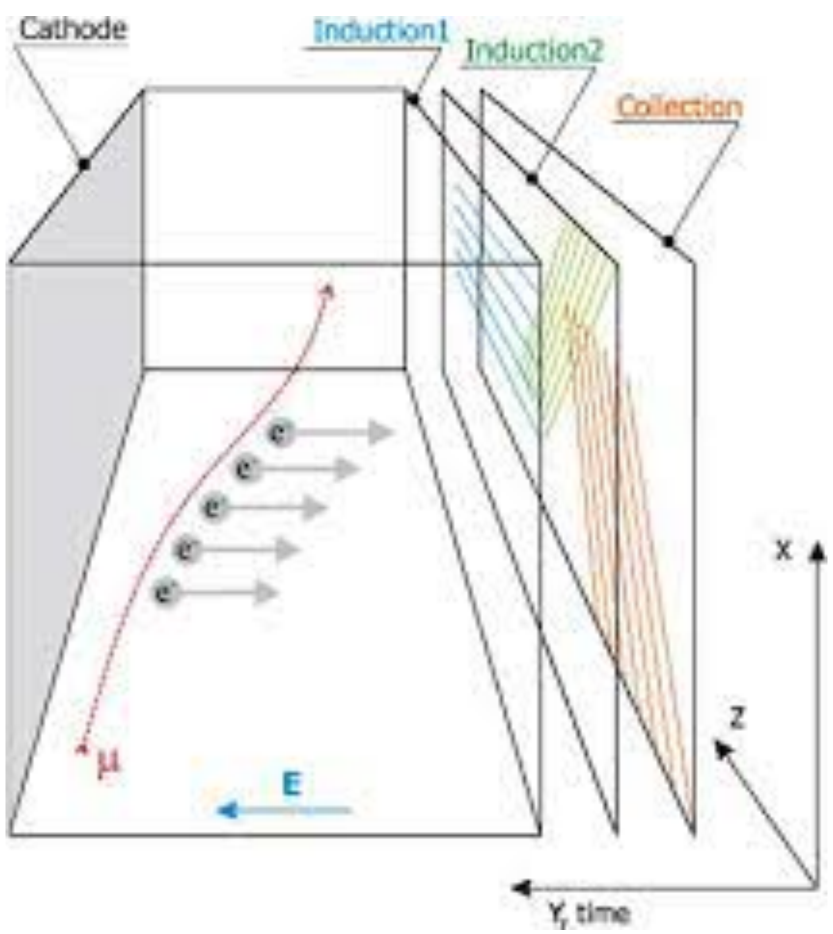
Energy loss in LAr (LXe)

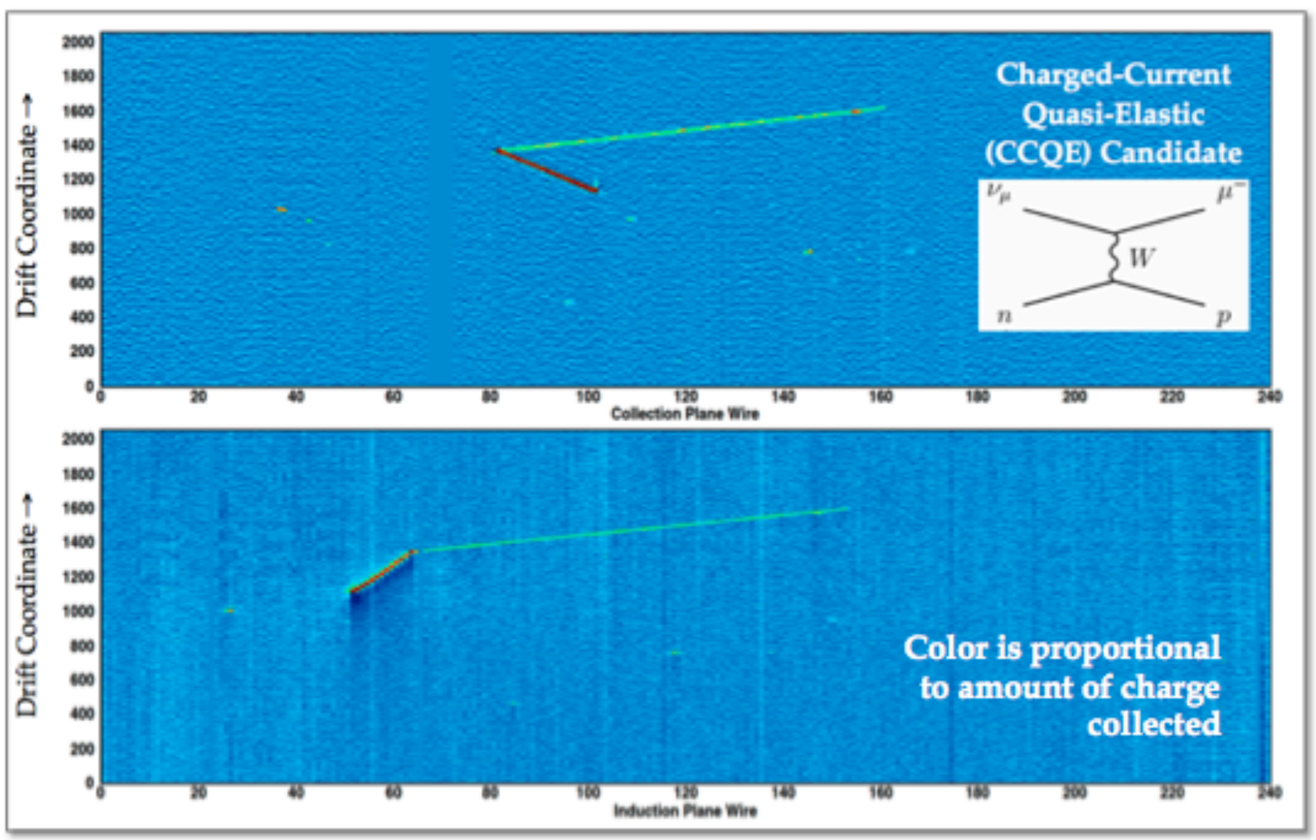
Energy deposition → ~~Heat~~

Excitation — Ionization

$\langle W_{Ar} \rangle_{ER} = 20$ eV
$\langle W_{Xe} \rangle_{ER} = 13$ eV

typical drift fields: 200 - 500 V/cm



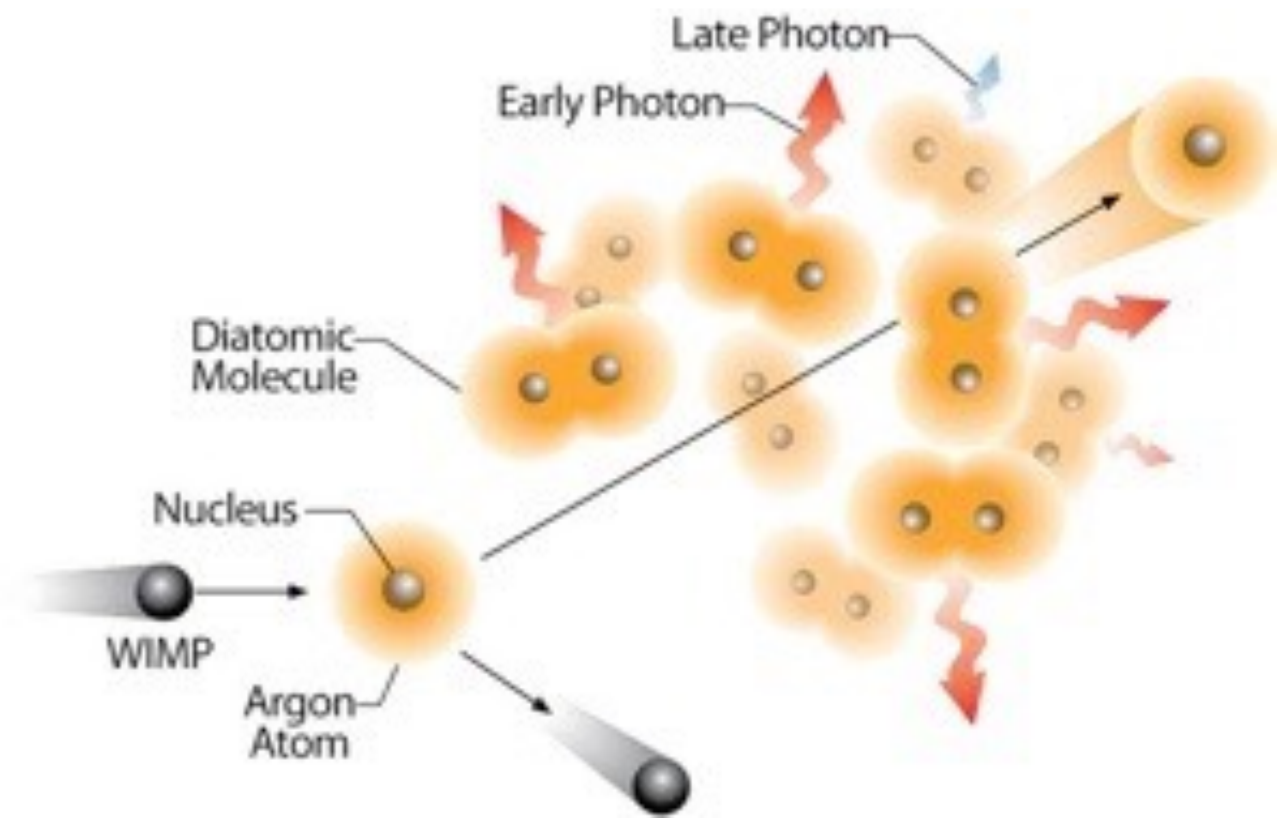


The Liquid Argon Time Projection Chamber: A New Concept For Neutrino Detector
C. Rubbia, CERN-EP/77-07 (1977)

Energy loss in LAr (LXe)

Energy deposition → ~~Heat~~

Excitation | Ionization



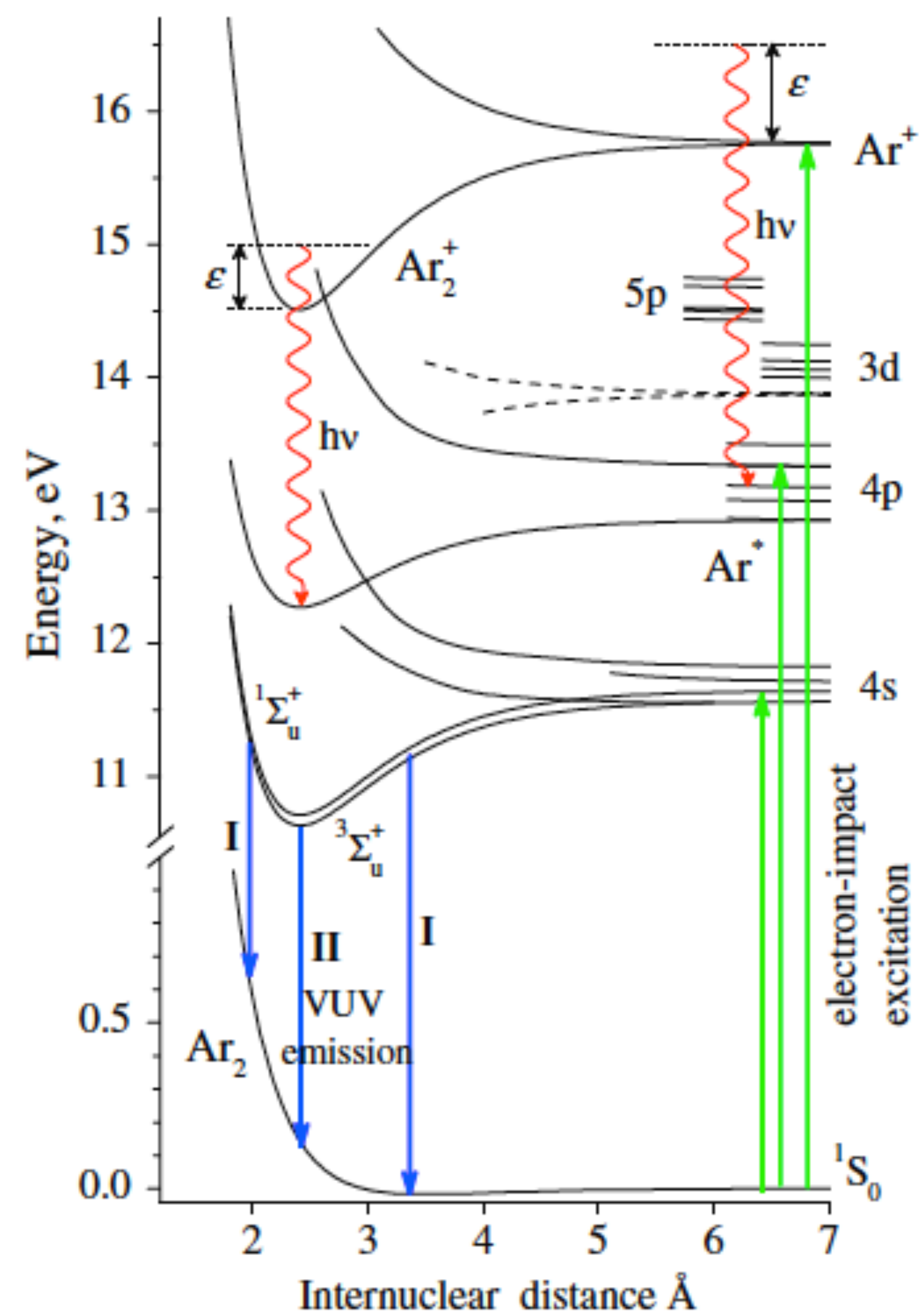
singlet or triplet state
for the dimers

$$\mathrm{Ar}^* + \mathrm{Ar} \rightarrow \mathrm{Ar}_2^*$$

$$\mathrm{Ar}_2^* \rightarrow 2\mathrm{Ar} + \gamma$$

liquids are transparent to their own scintillation

10.1070/QE2010v040n03ABEH014243

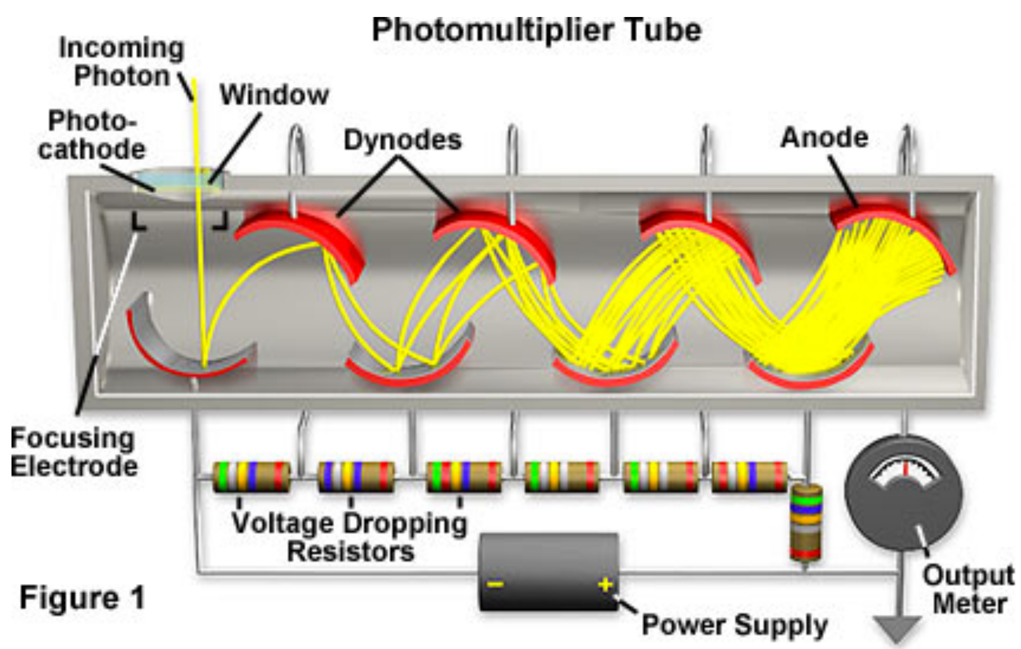


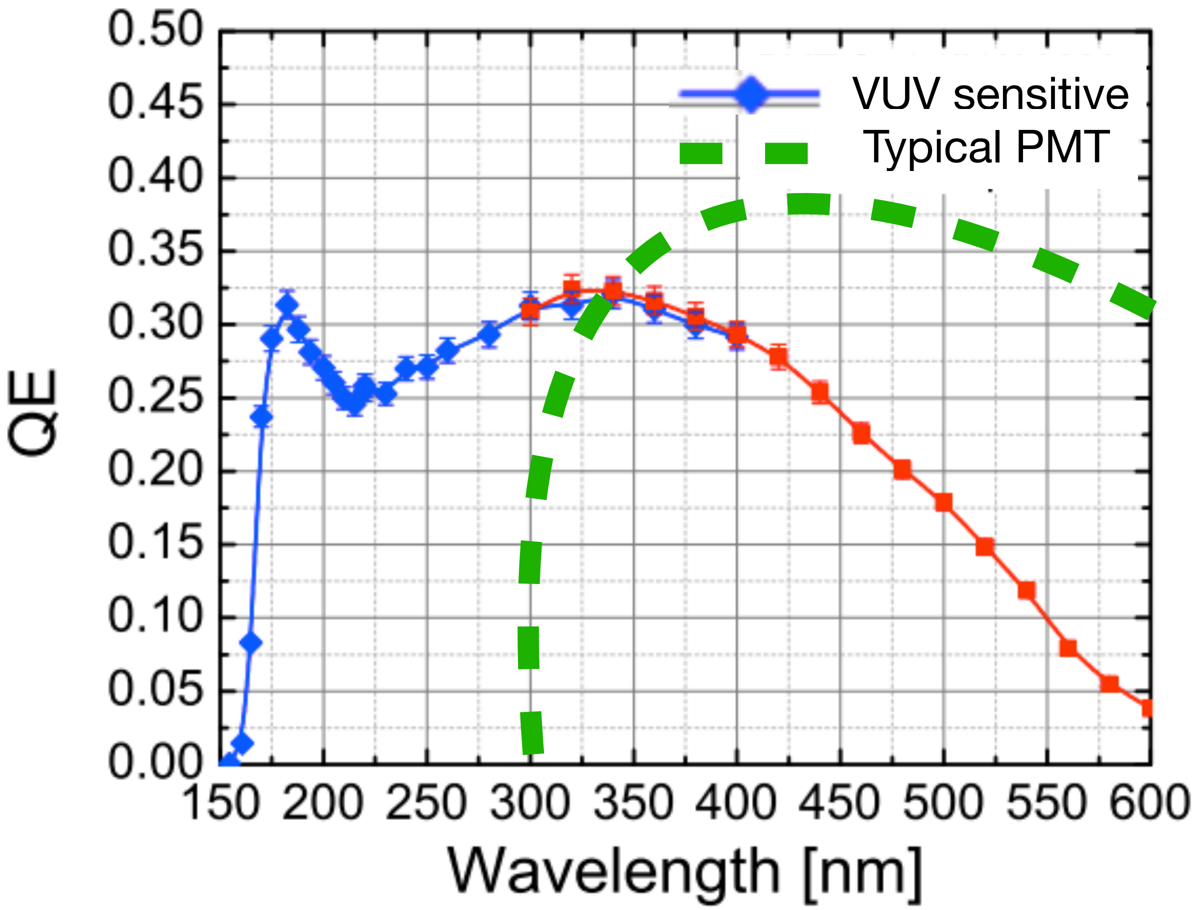
$\lambda_{Ar} = 128\ nm$

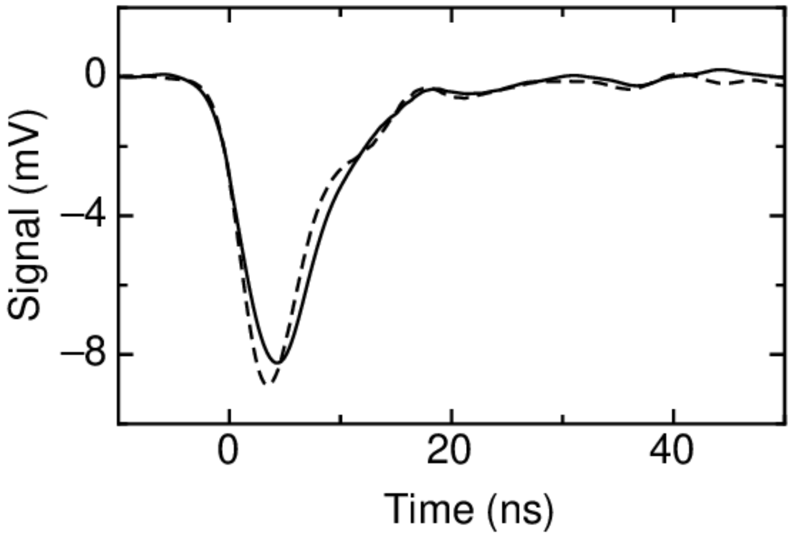
$\lambda_{Xe} = 178\ nm$

Observables: PMT signals

Light signals from Photo-Multipliers (PMTs)
1 incident photon -> QE x 1. (~1.15 for VUV sensitive PTMs) reconstructed Photo-electron
VUV (> 150 nm) sensitive photo sensors exist, typical efficiency ~30%
Below 150 nm, need to rely on WaveLengthShifters (WLS) to convert VUV light to visible

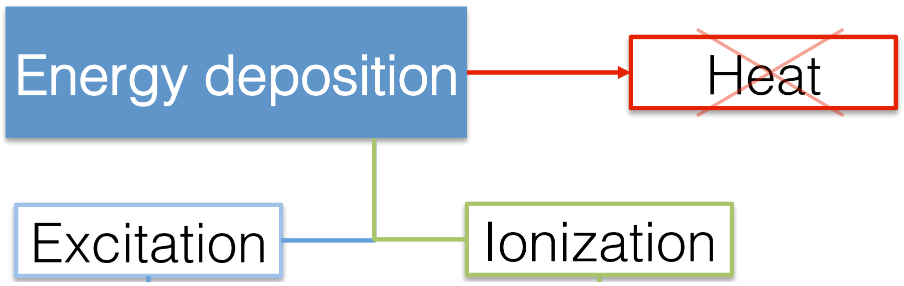




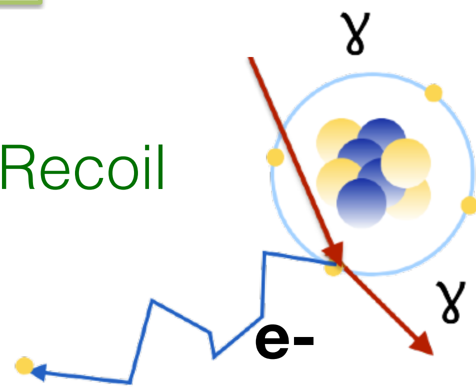


Typically, avg detection efficiency ~ 10-15 % in DM DD experiments

Nuclear Recoil quenching

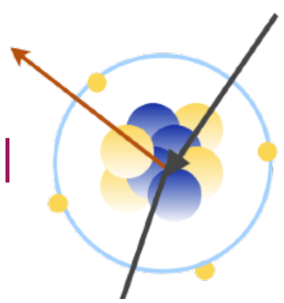


Electron Recoil



$$E_R = \eta(E_R) + \nu(E_R)$$

Nuclear Recoil



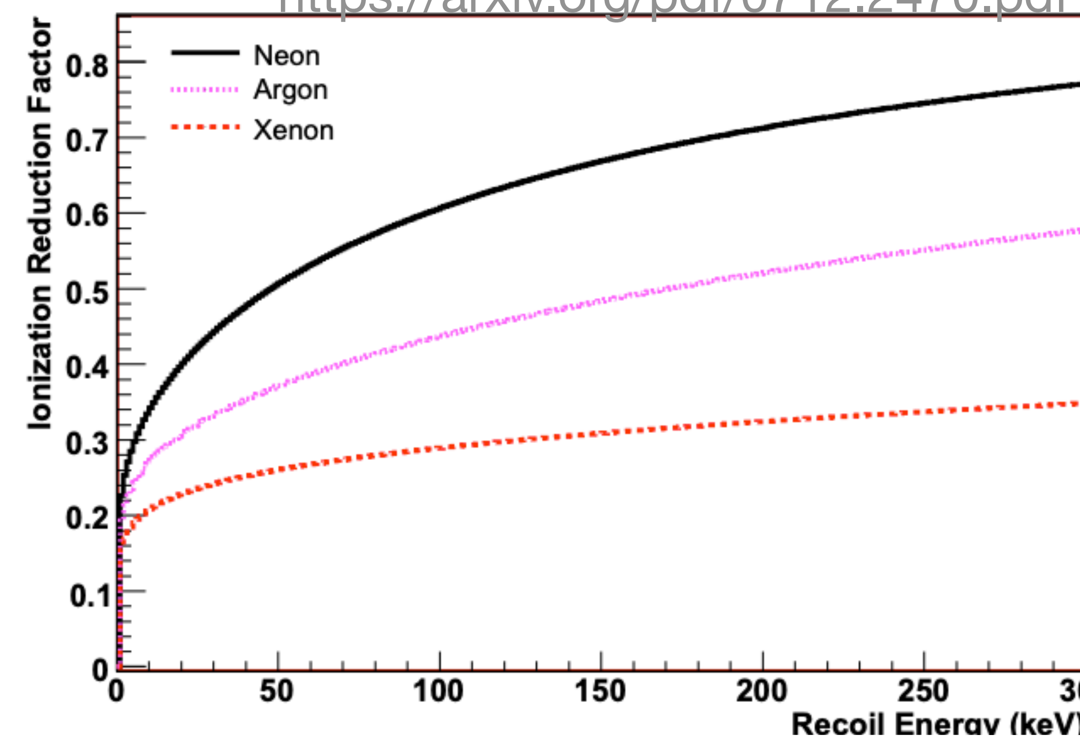
$$f_n(E_R) \equiv \frac{\eta(E_R)}{E_R} = \frac{\eta(E_R)}{\eta(E_R) + \nu(E_R)}.$$

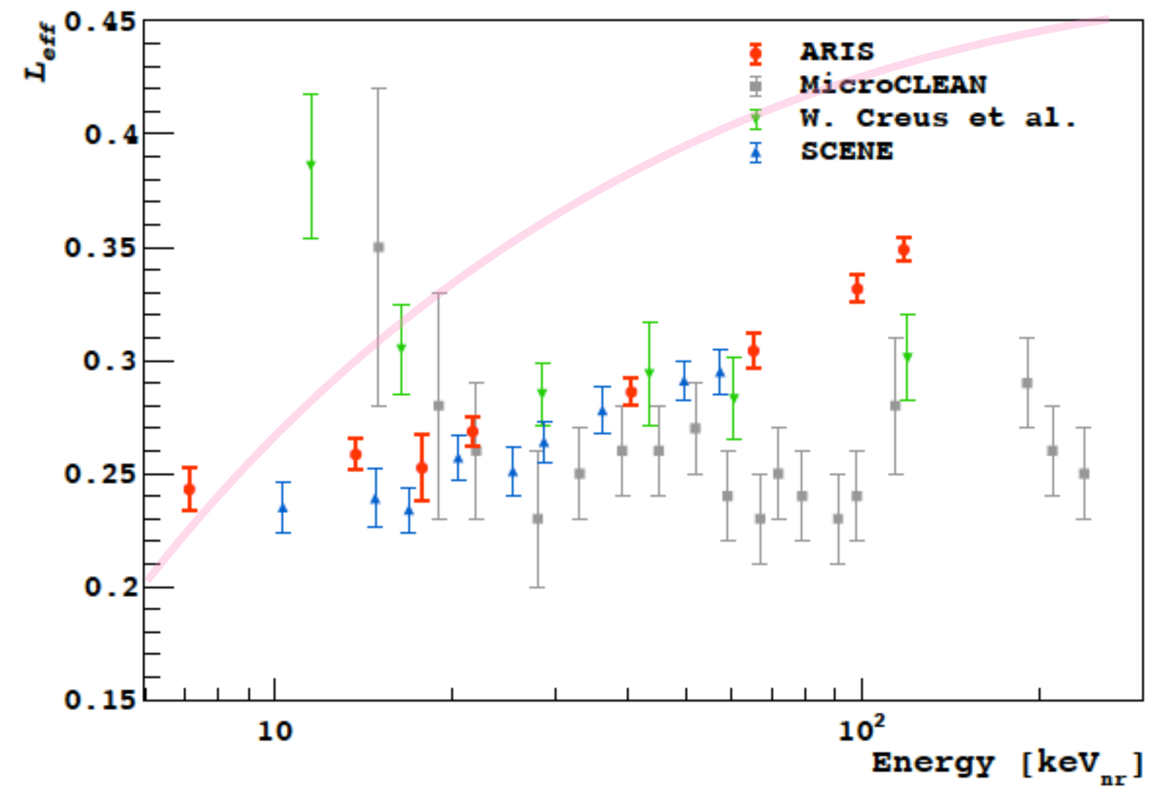
$$f_n = \frac{kg(\varepsilon)}{1 + kg(\varepsilon)}$$

bi-excitonic quenching?

$$\mathrm{Ar}^* + \mathrm{Ar}^* \rightarrow \mathrm{Ar}^+ + \mathrm{Ar} + \gamma.$$

https://arxiv.org/pdf/0712.2470.pdf

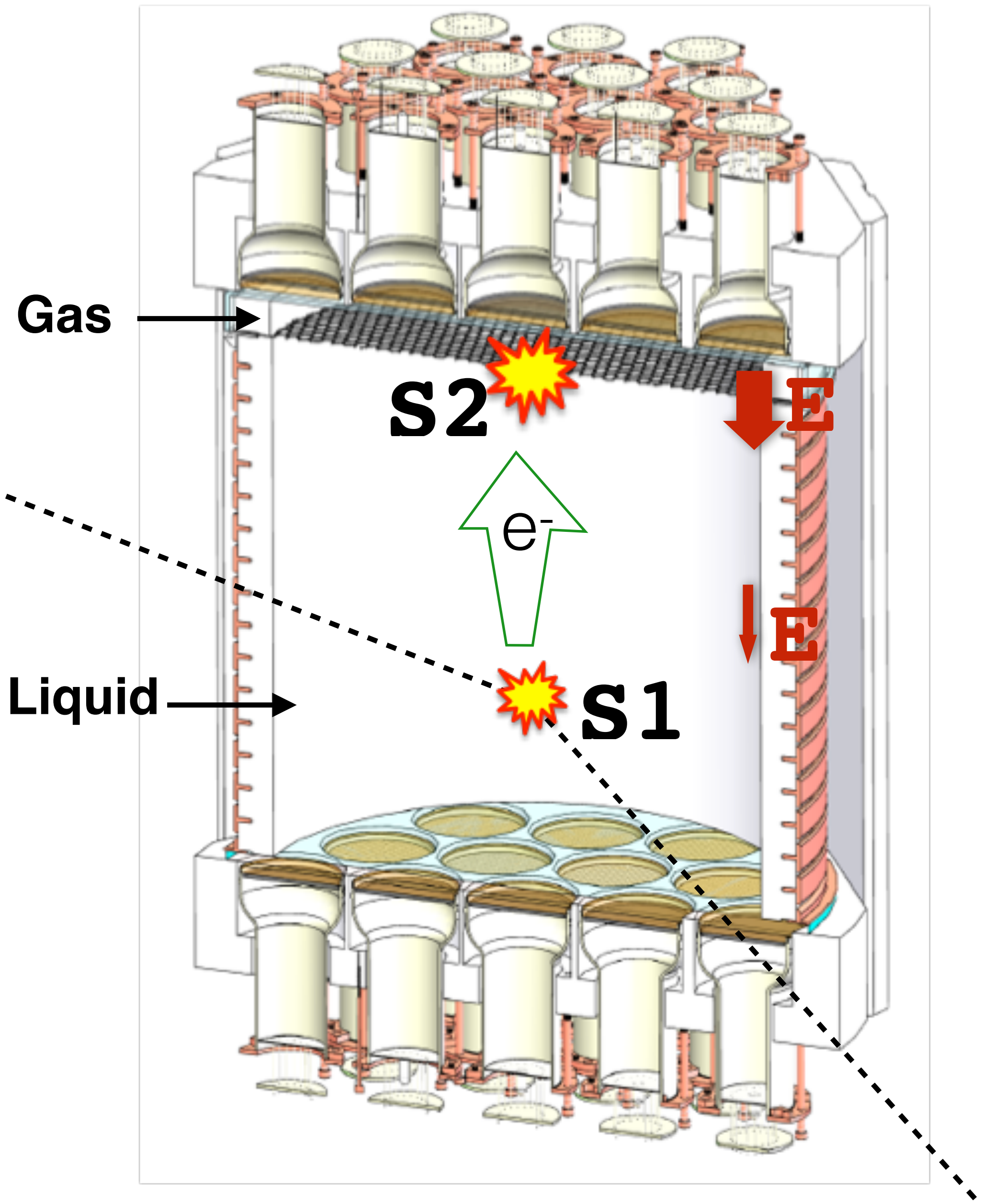


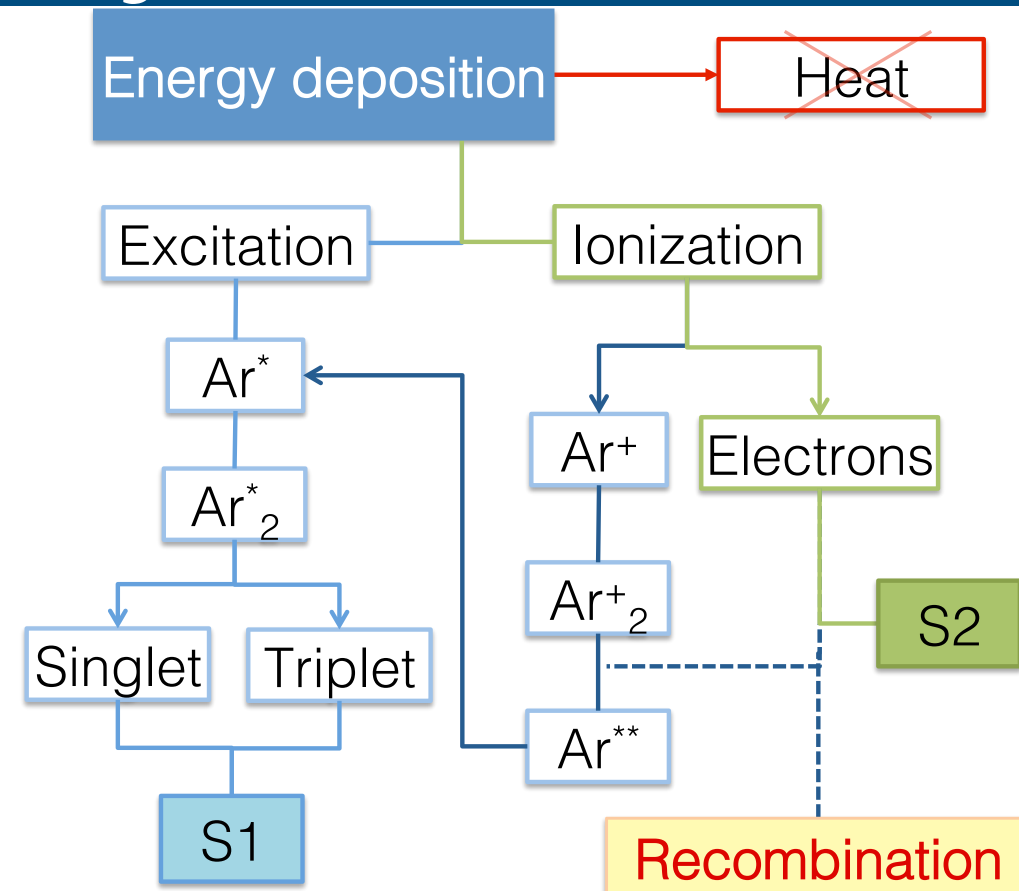


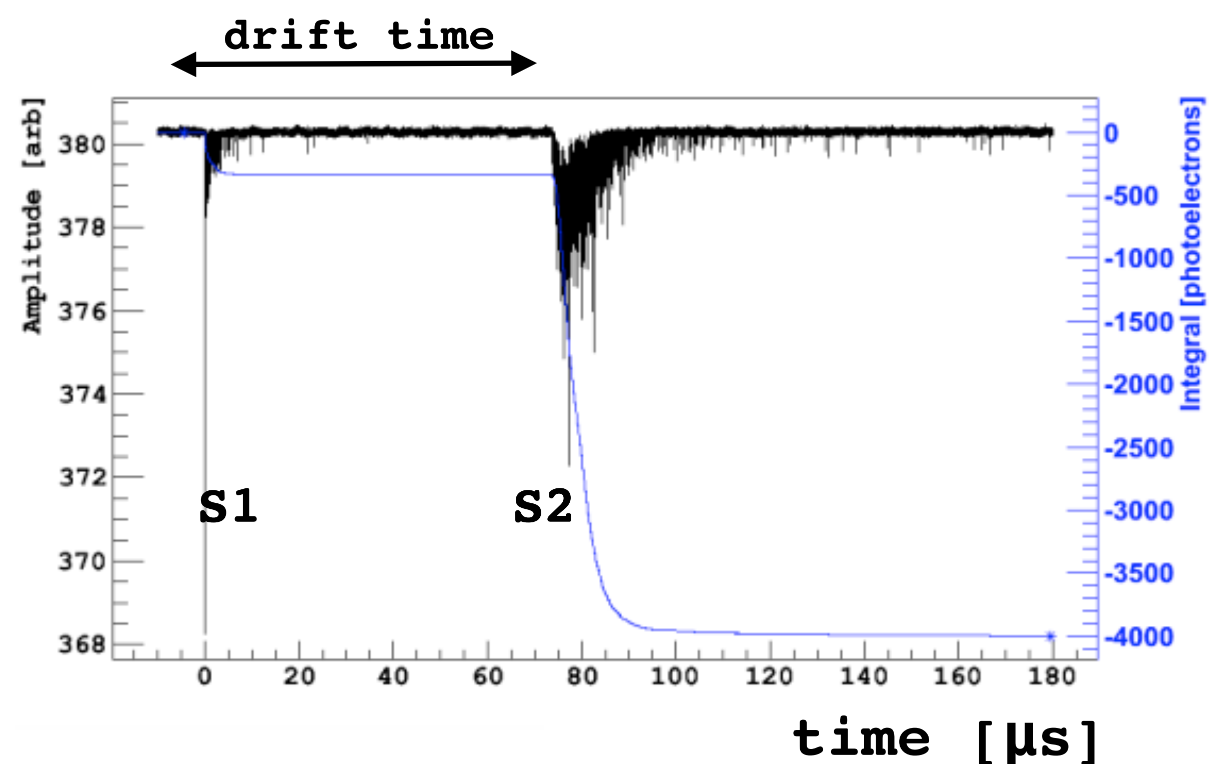
Largest systematics for WIMP-nucleon searches

Implementation & Results

Dual-phase TPC (time projection chamber)

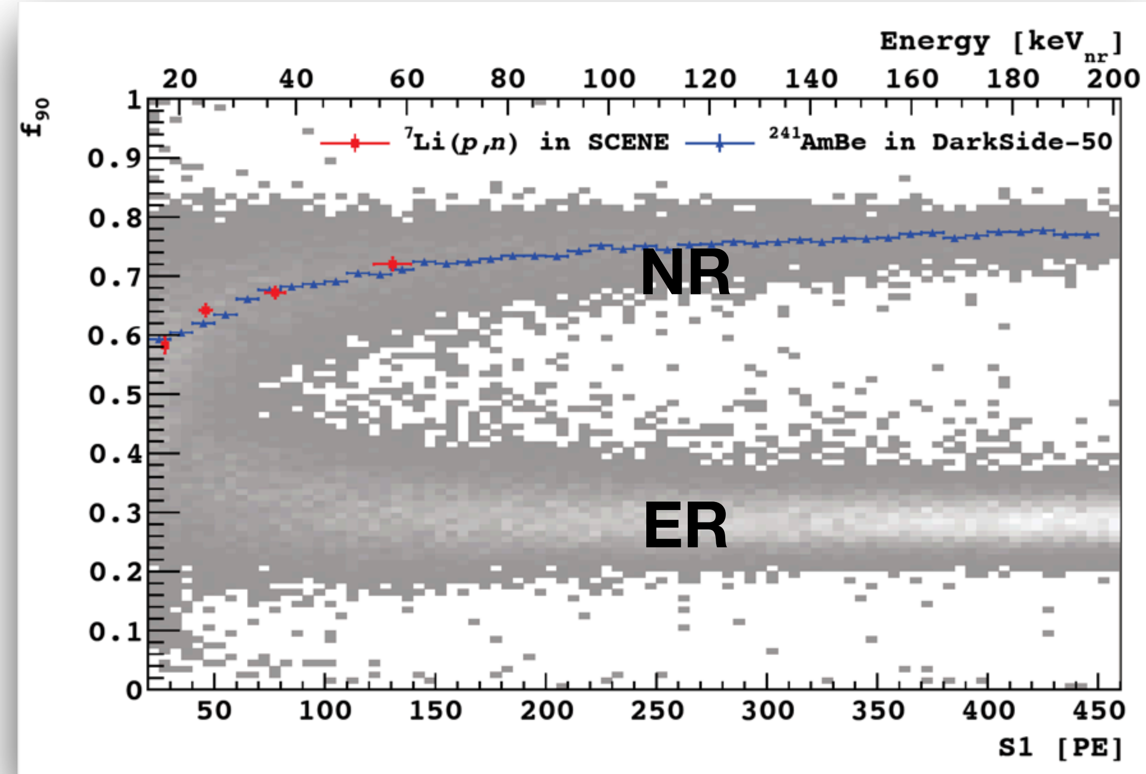






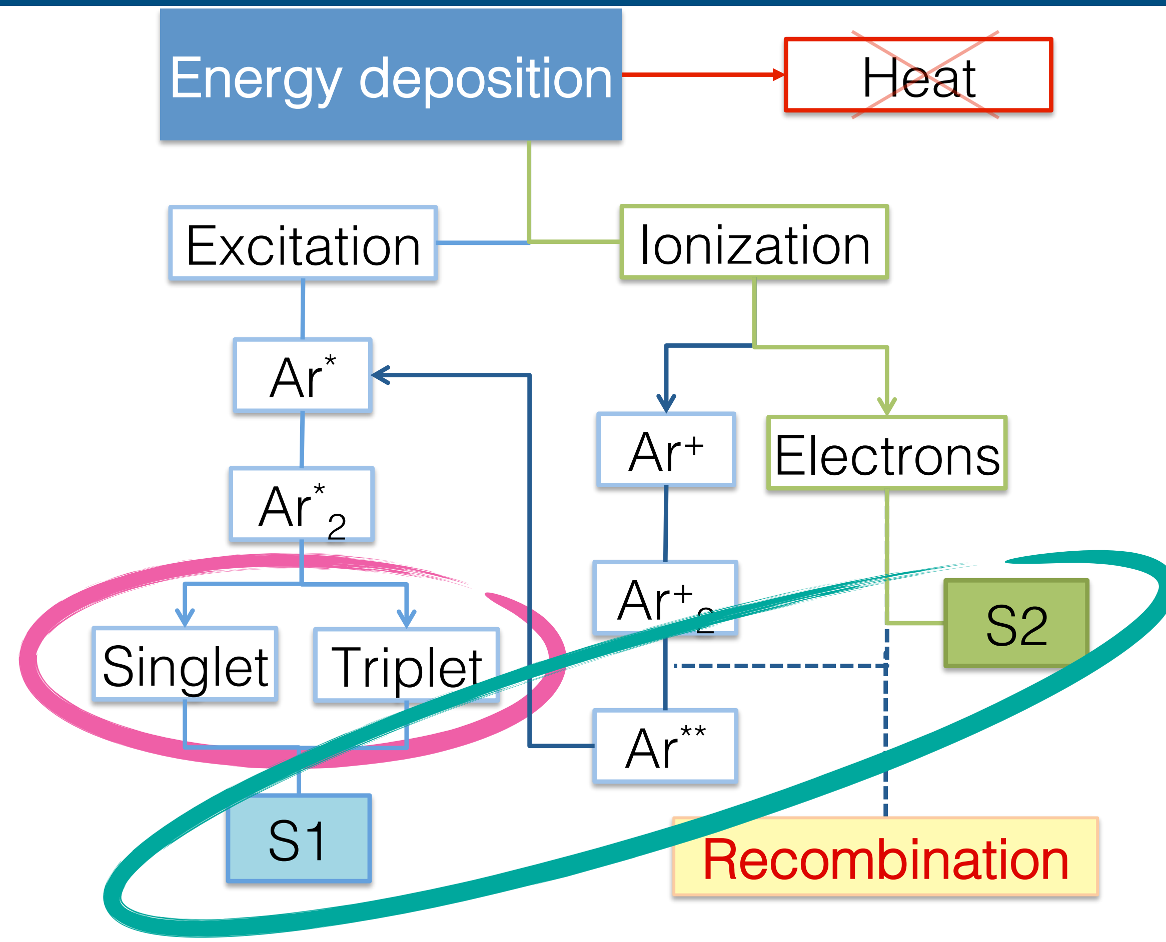
==> 3D vertex reconstruction
(surface events, multi-sited events) !

Discrimination



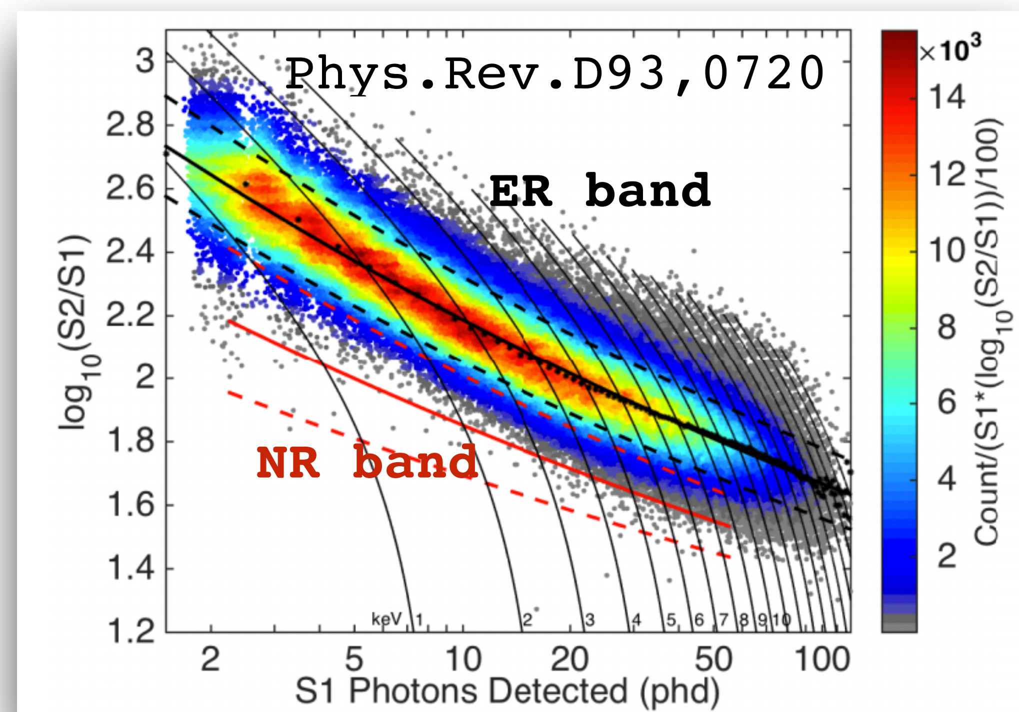
DEAP-3600: Phys. Rev. D 100, 022004

S1 PSD in LAr:
ER Rejection factor: ~ 10^8



Charge/Light in LAr/LXe:
ER Rejection factor: 10^2 - 10^3

XENON-1t: PRL 121, 111302 (2018)



Detector Calibration

Energy deposit $\Longleftrightarrow$ Observable

photon detection efficiency ~ 0.1 - 0.15

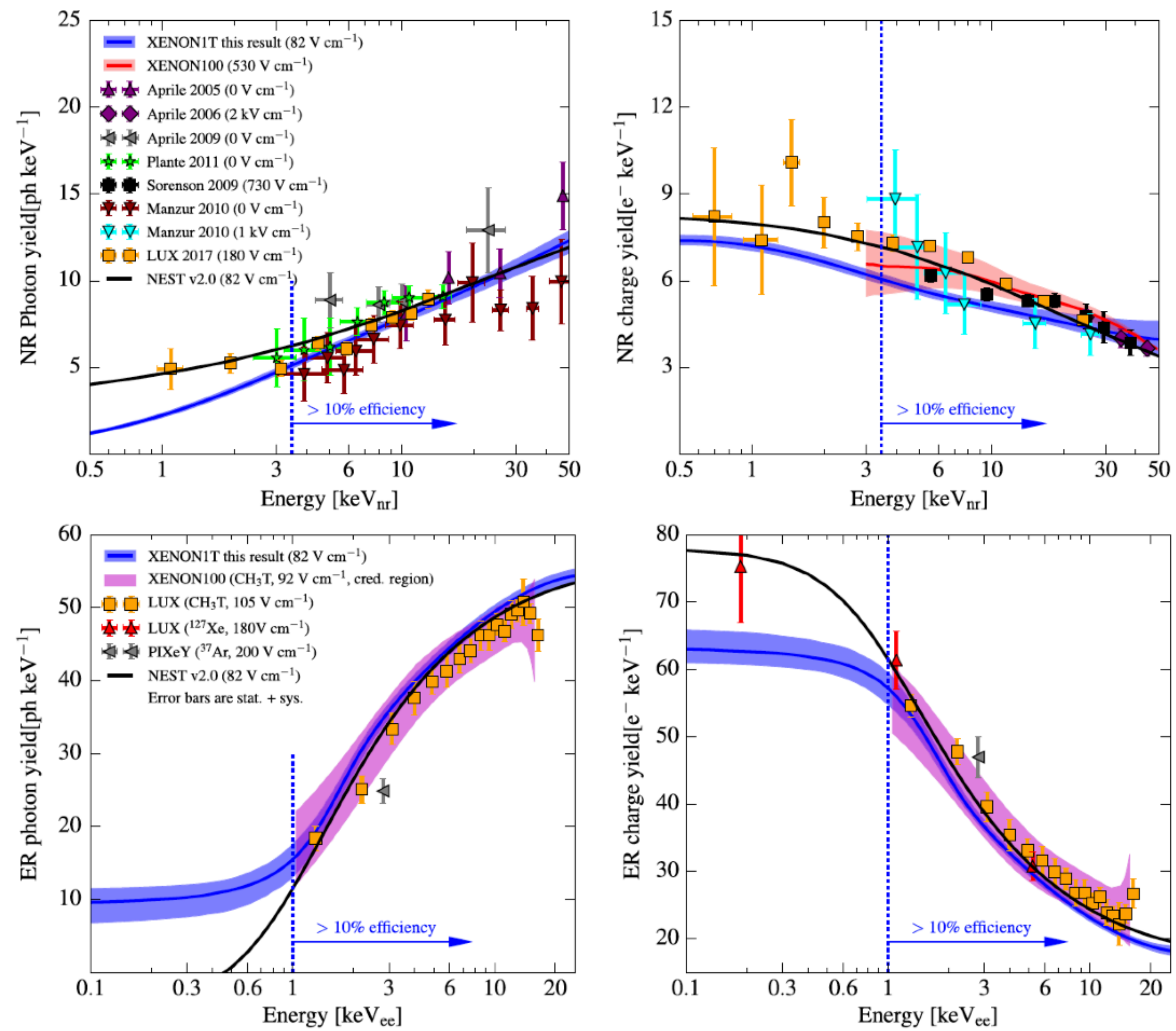
LY_{ER} ~ 7 PE / keV_{ee}

LY_{NR} ~ 2.5 PE/keV_{NR}

(high energy)

charge is multiplied in the gas, with typical gain of 10-20

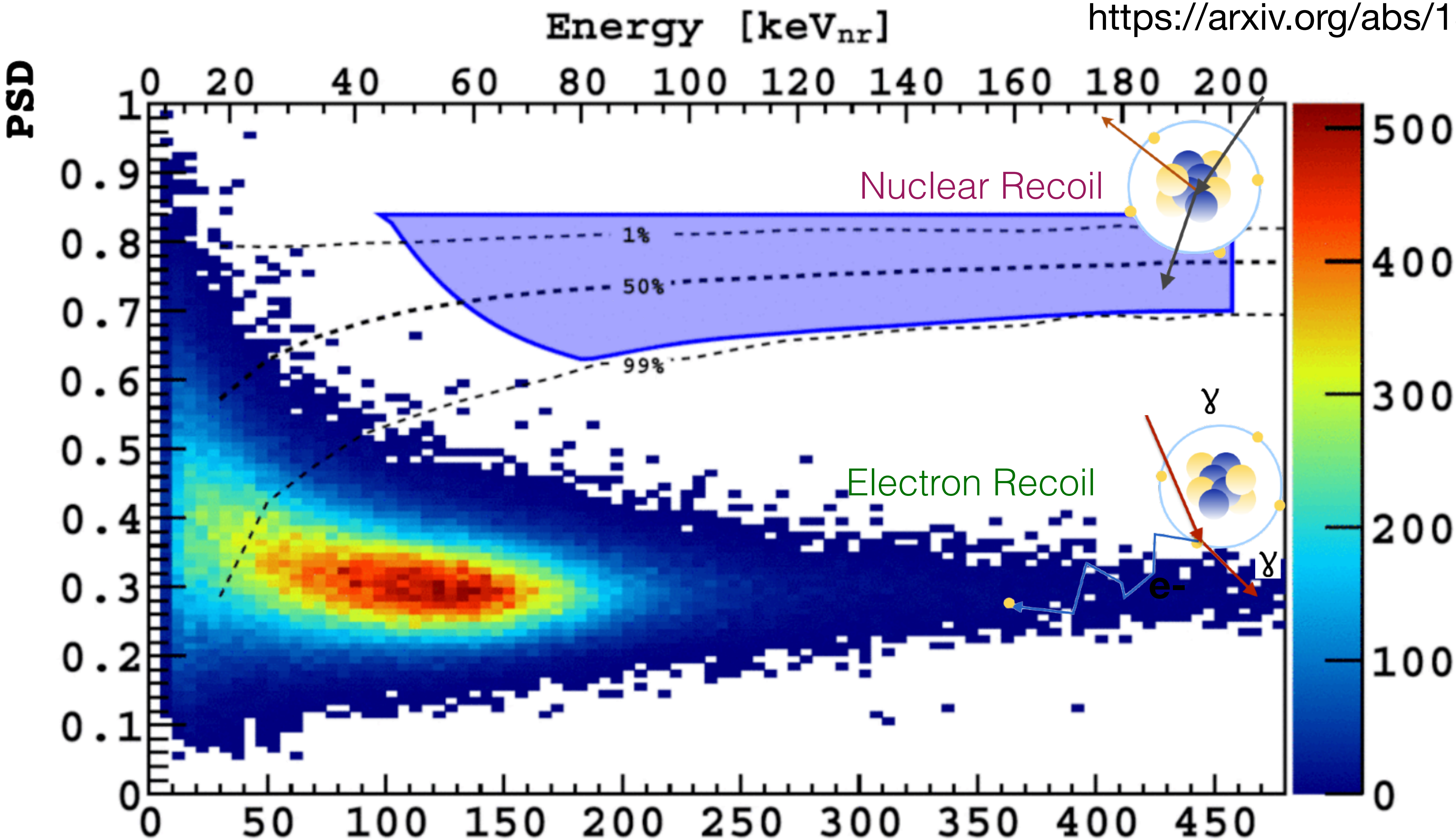
g2 ~ 10-20 PE/e-



PHYSICAL REVIEW D 99, 112009 (2019)

High-mass WIMP search - DS50

https://arxiv.org/abs/1802.07198

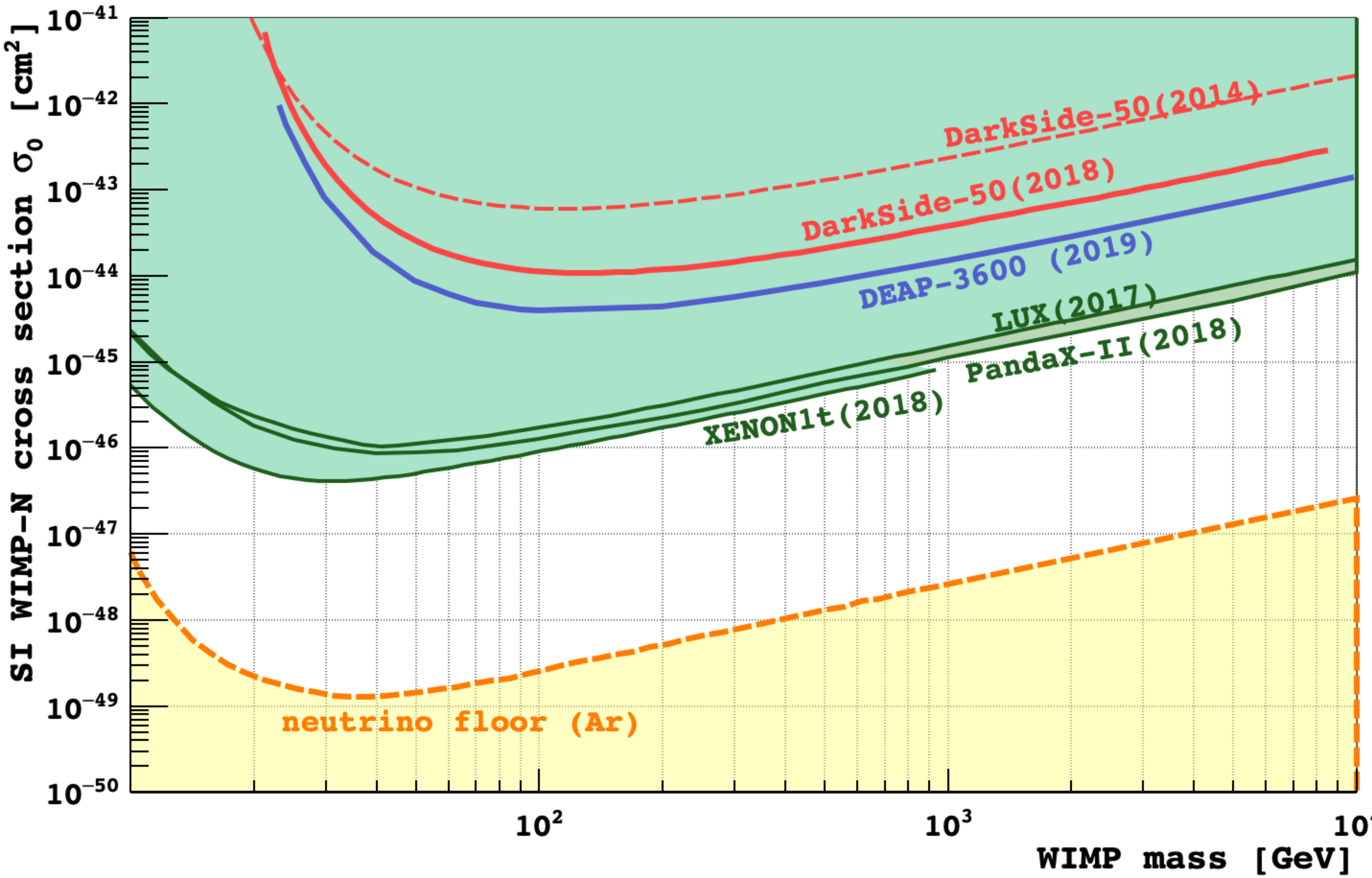


500 days dataset with a 50 kg target ***Background-free***

However, the PSD sets a HIGH-ENERGY threshold ~ 50 keV$_{NR}$

High-mass WIMP search

90% CL upper limits on spin-independent WIMP-nucleon coupling



DS-50: Phys. Rev. D 98, 102006 (2018)
DEAP-3600: Phys. Rev. D 100, 022004

PandaX-II: Phys Lett B 792, 193 (2018)
XENON-1t: PRL 121, 111302 (2018)

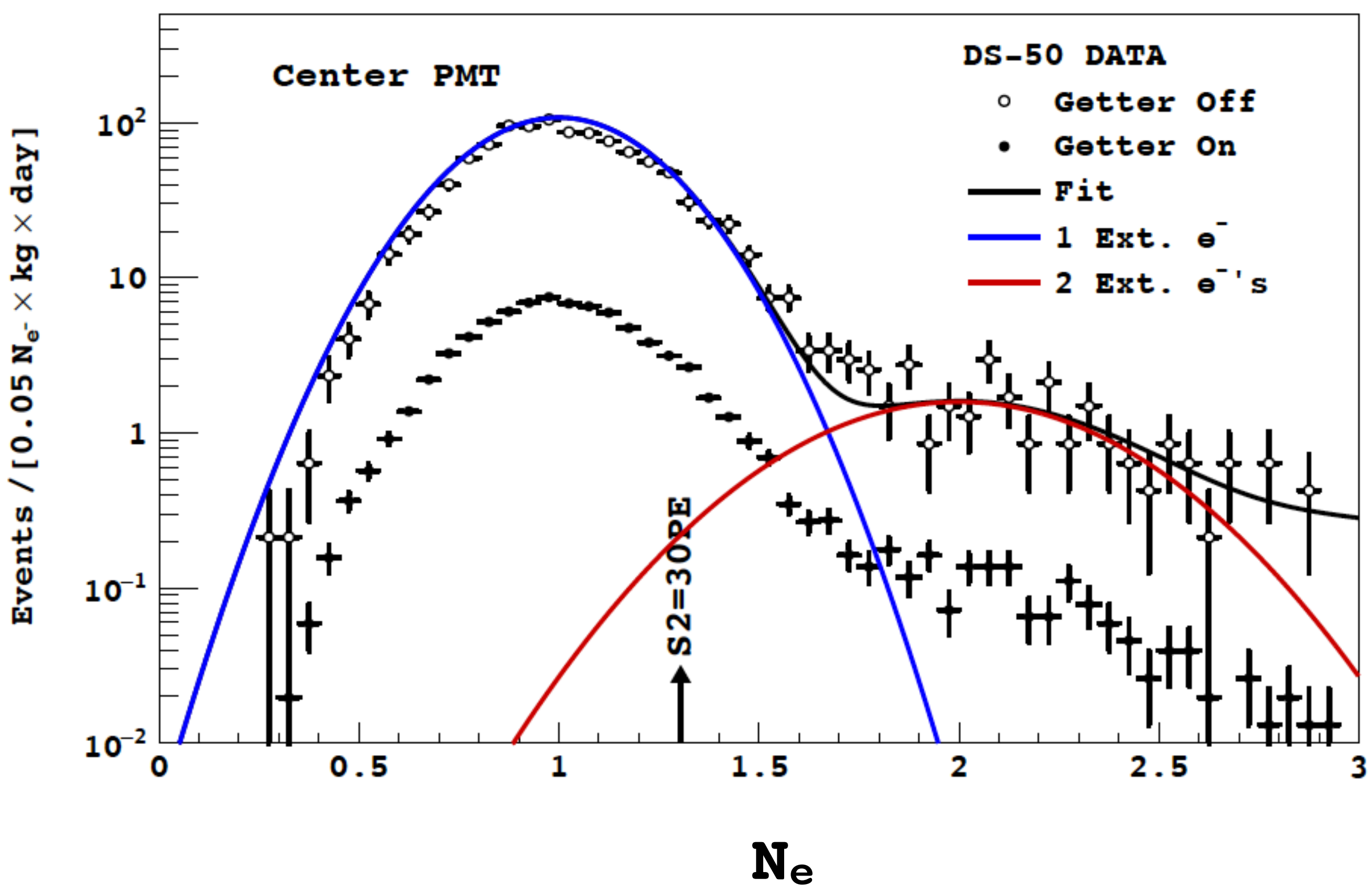
Low-mass searches

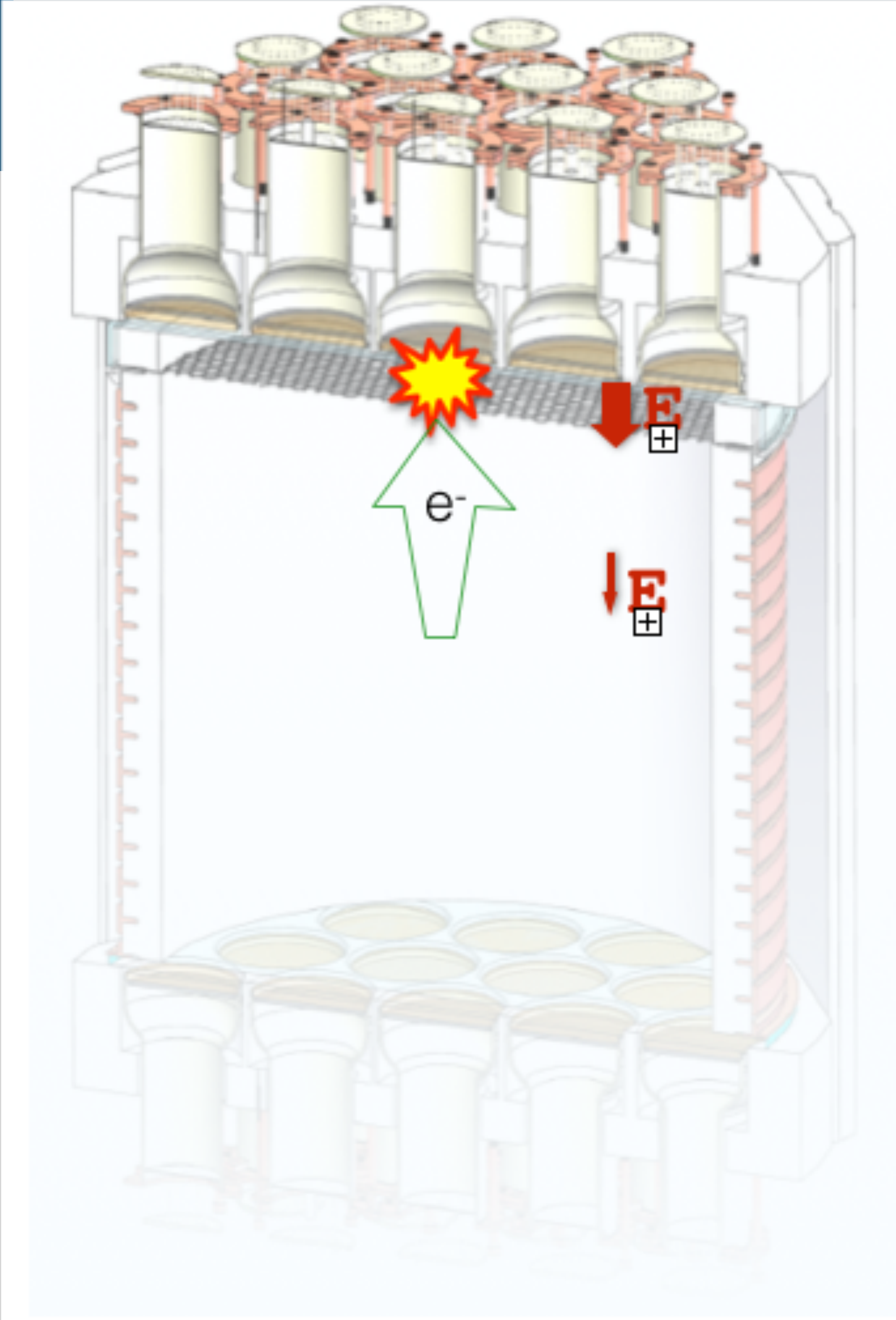
S2only analyses

Look at the **ionization only** spectrum (W_{ion} = 23.5 eV, multiplication in the gas: 23 PE/e^-)

Below 3 keV_{ee}: give up the scintillation signal (too small to trigger the detector), and thus

- **minimal fiducialization** (only radial)
- **no PSD**

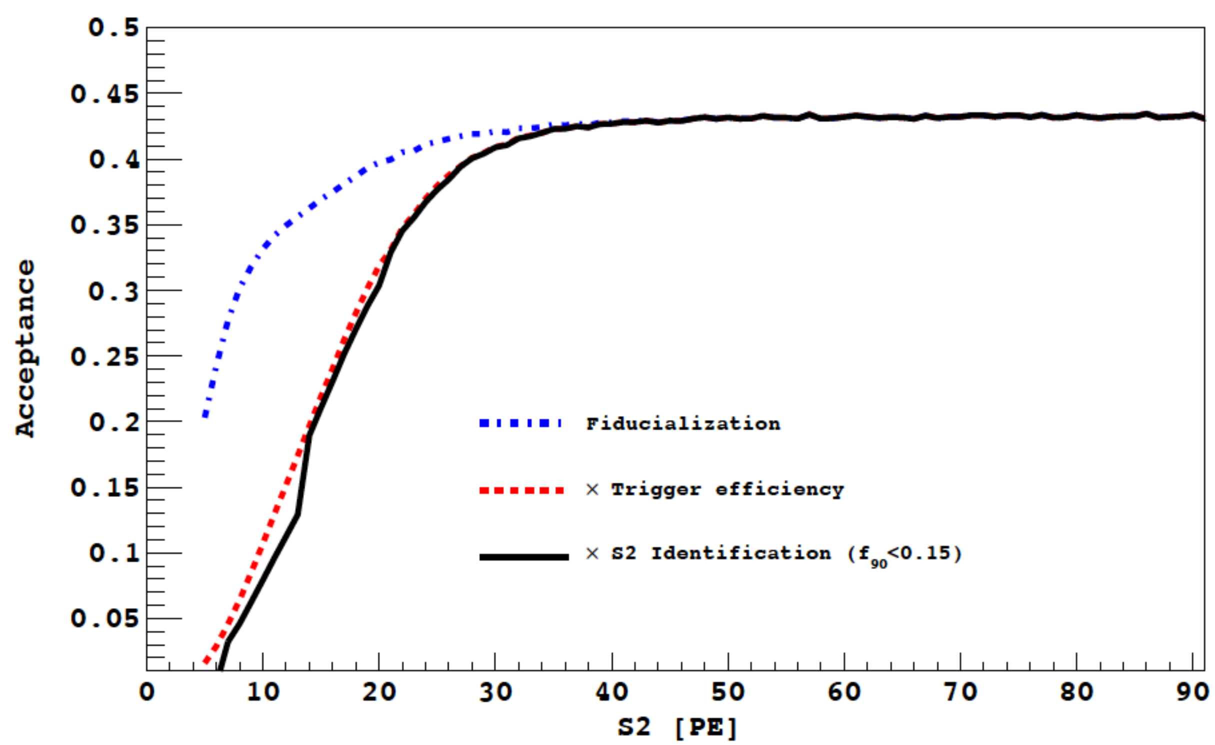


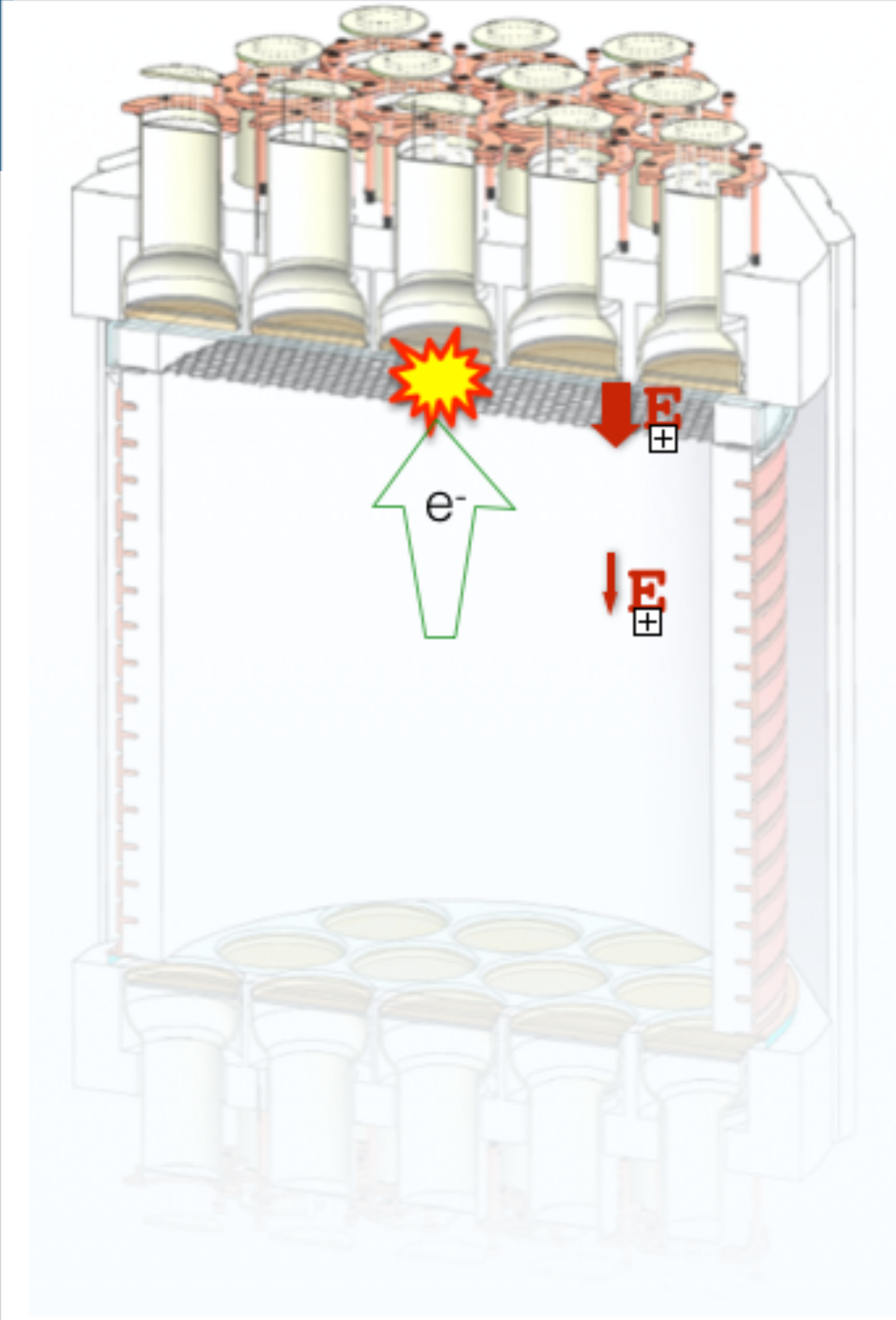


S2only analyses

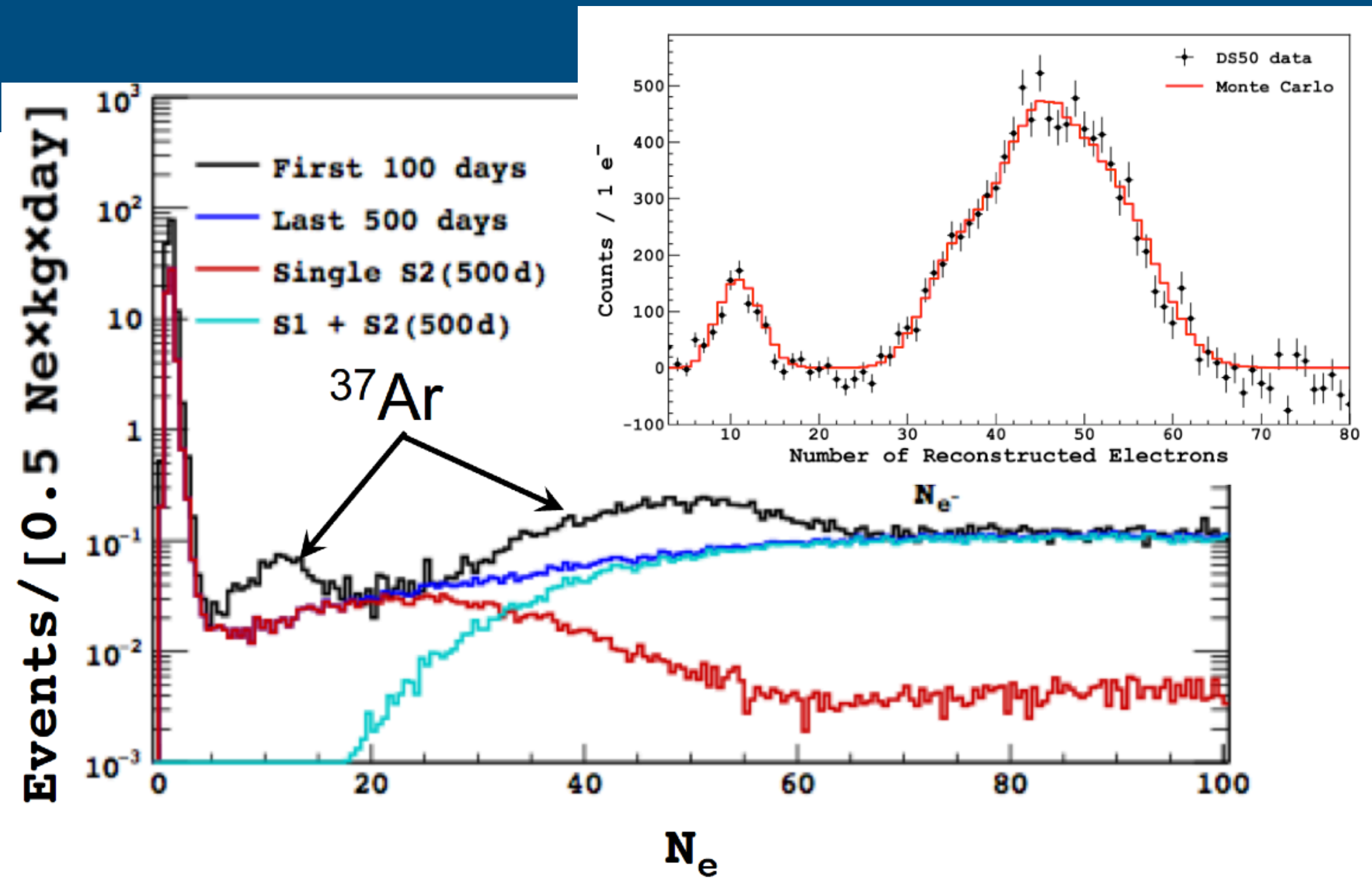
Look at the **ionization only** spectrum (W_{ion} = 23.5 eV, multiplication in the gas: 23 PE/e^-)
Below 3 keV$_{ee}$: give up the scintillation signal (too small to trigger the detector), and thus
- **minimal fiducialization** (only radial)
- **no PSD**

Trigger efficiency is 100% at 1.5 N_{e-}





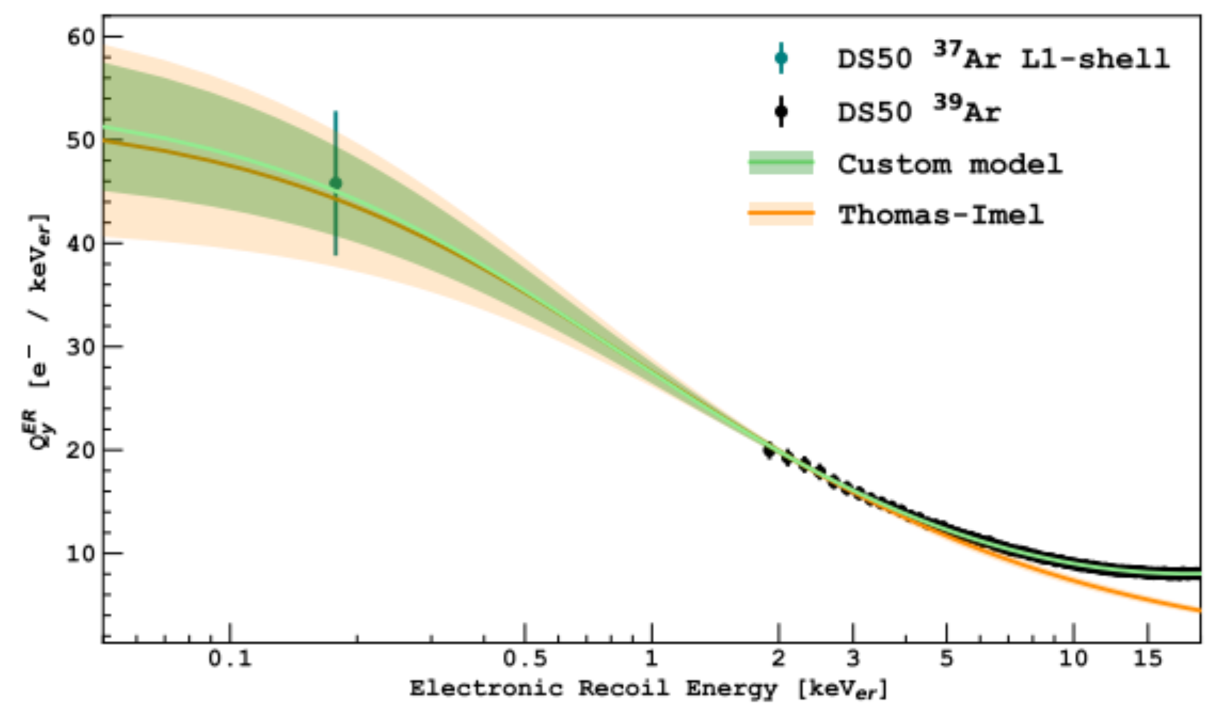
^{37}Ar



arXiv:2107.08087

	K–shell EC		L1–shell EC	
Branching Ratio	90.4%		8.4%	
Total Released Energy	2829		277	
Mean number of primaries[a]	3.9		2.8	
	⟨N⟩	⟨E⟩	⟨N⟩	⟨E⟩
K Auger electrons	0.905	2414		
K X-rays	0.095	2634		
L Auger electrons	1.77	179	0.9995	179
L X-rays	8E-4	188	0.0005	207
M Auger electrons	0.35	51	0.96	51
UV photons (E>16 eV)	0.77	25	0.86	25
Undetectable via ionization	3.26	13	2.10	13

[a] Excluding undetectable via ionization

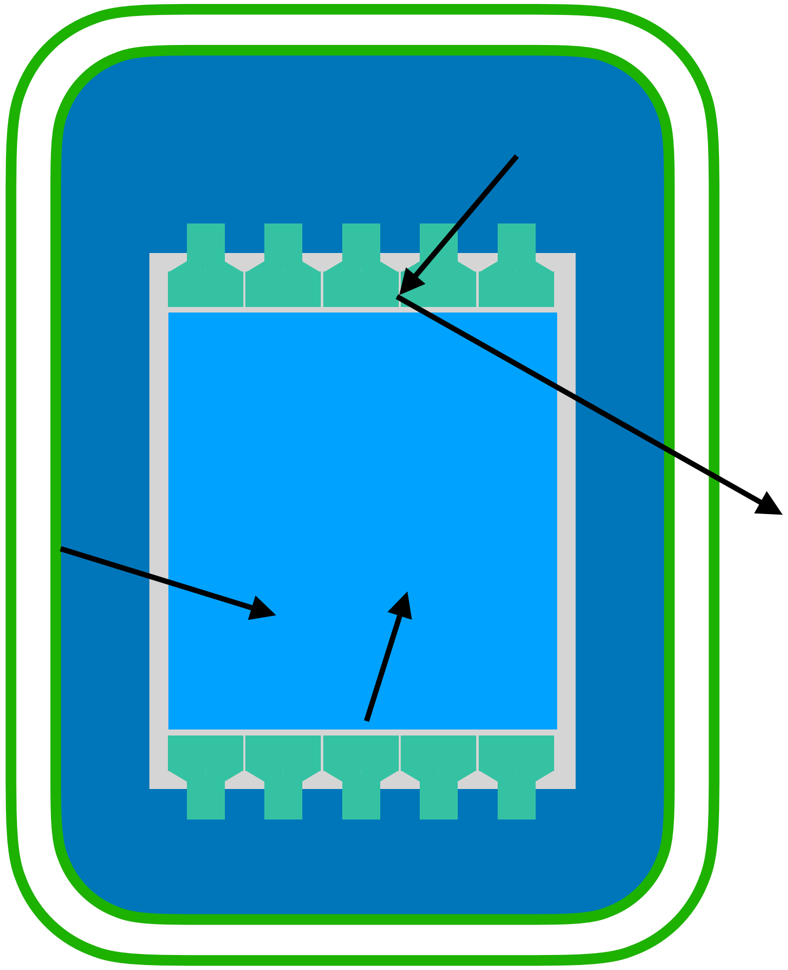


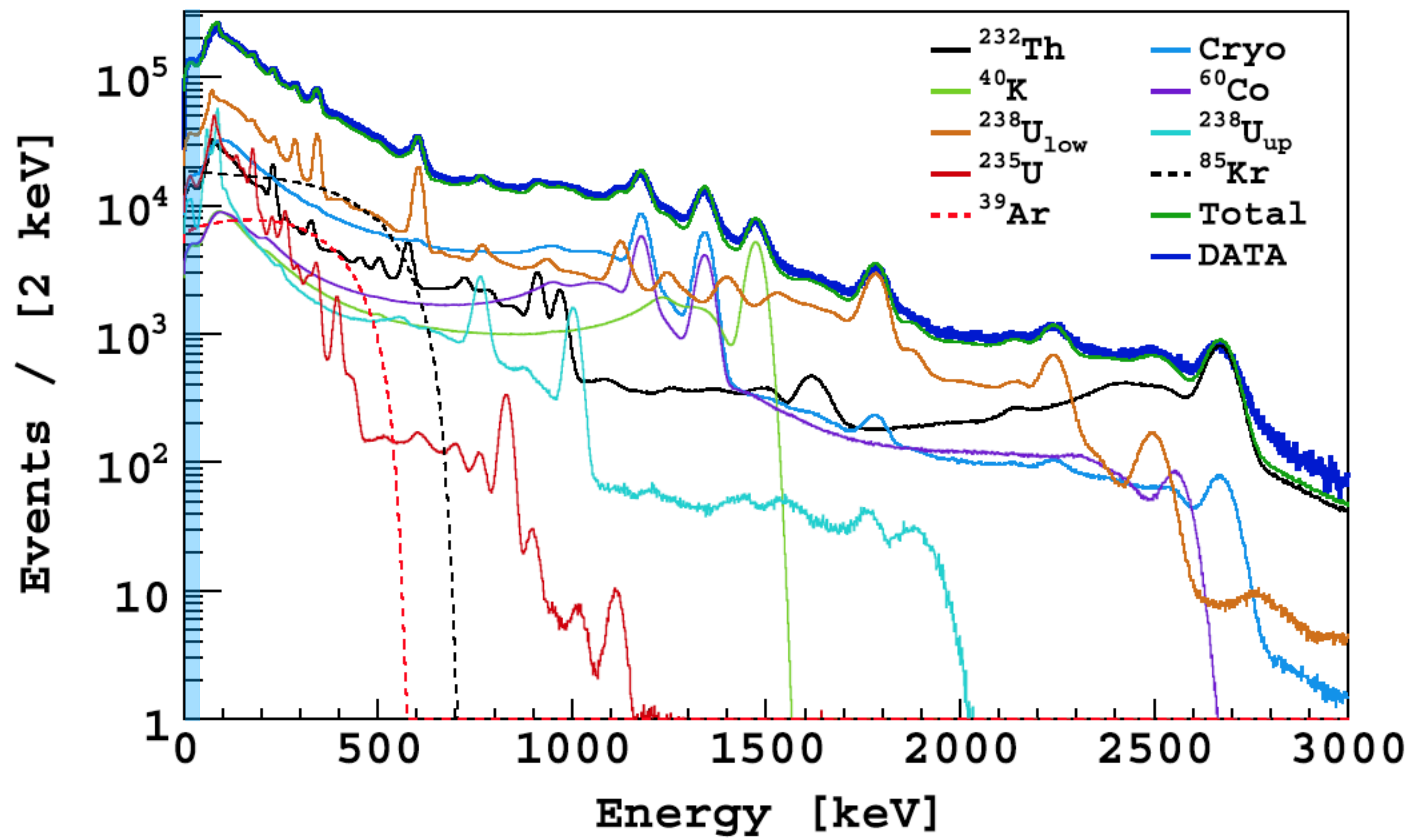
arXiv:2107.08087

Background model

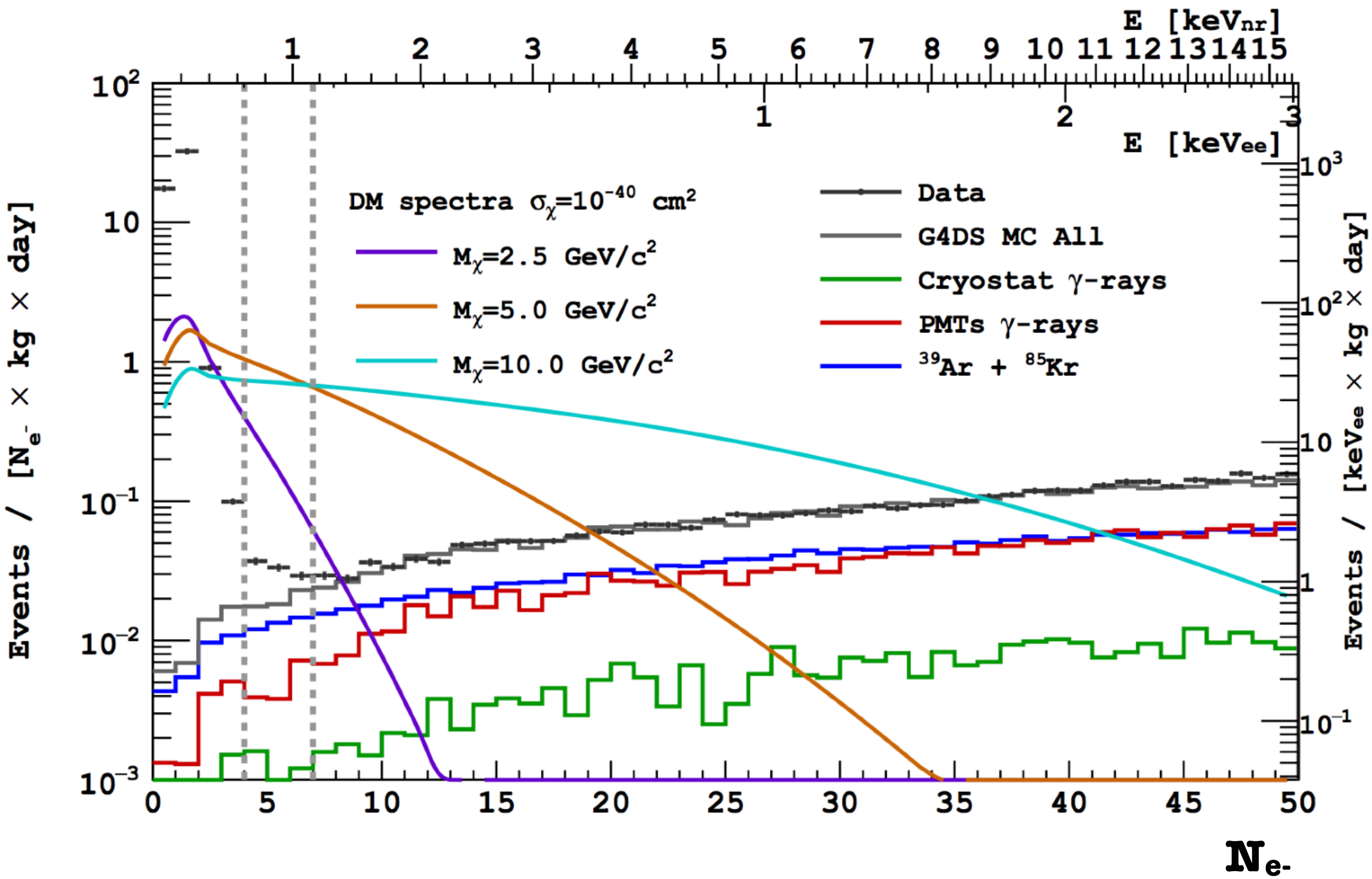
Background model for DarkSide-50

- Full simulation of **each radioactive component** (^{238}U, ^{232}Th, ^{40}K, ^{60}Co) from detector materials and intrinsic to the target (^{39}Ar and ^{85}Kr).
- **Multivariate fit** based on S1 single scatter, S1 multiple scatter, and drift time
- Covers a wide energy range





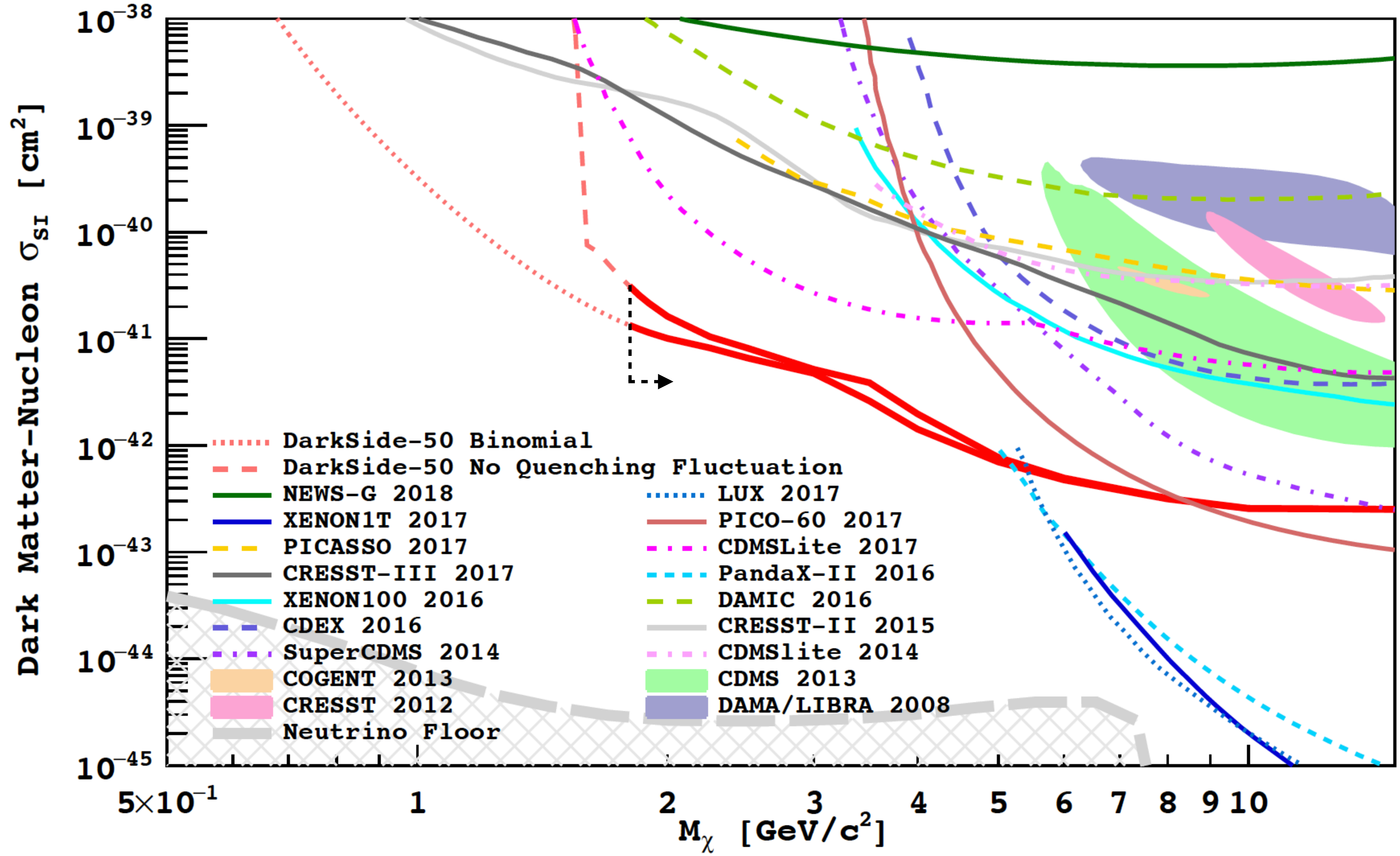
Dataset



MC spectra in the low energy region, converted in N_{e-} (ER). **Activities constrained to the results of fit at high energy**.
WIMP induced spectra in N_{e-} (NR); **PLL** analysis.

Un-modeled component(s) below 7 e^-: impurities (+ radiogenic neutrons?)

Exclusion limits



Additional searches

New models!

Existing dataset

Background model

Exclusion limits

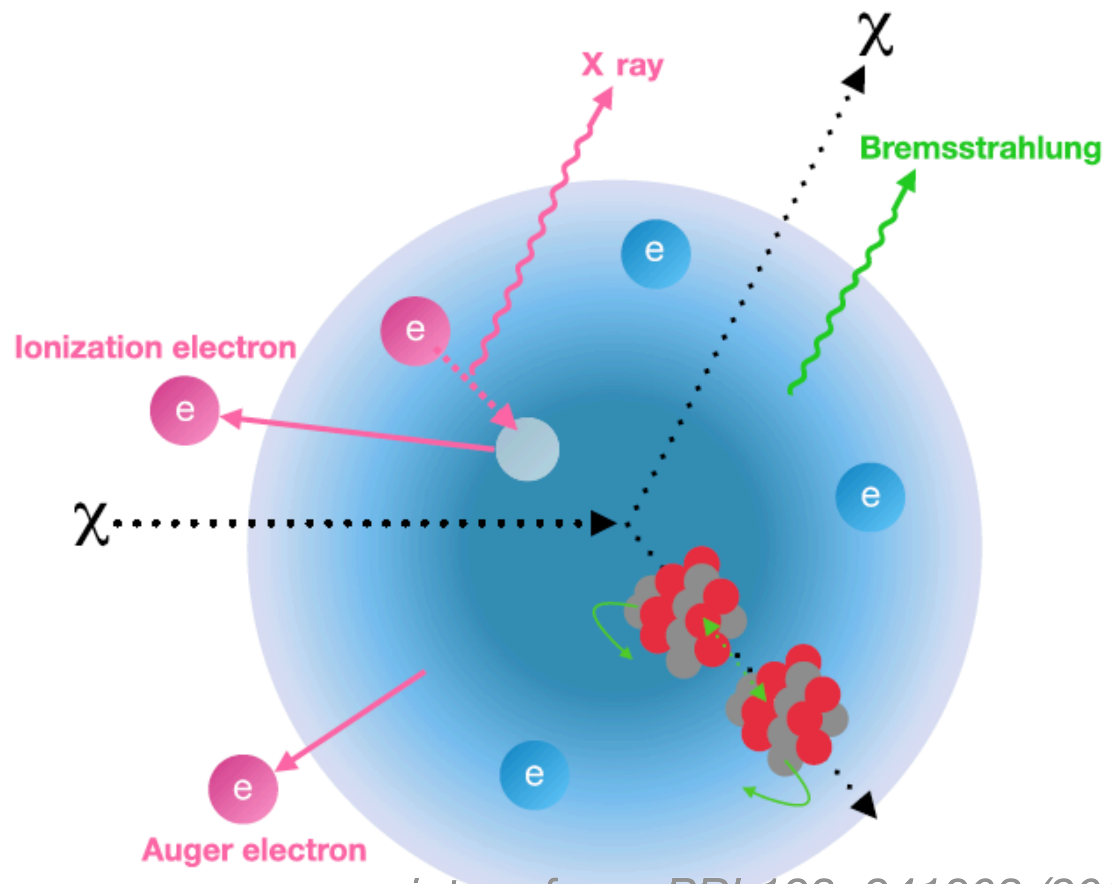
The Migdal Effect

Due to sudden acceleration, the struck atom may **release electron(s)**, total released energies up to keV

Predicted probability is << 10^{-3} and a function of ***q***, thus:

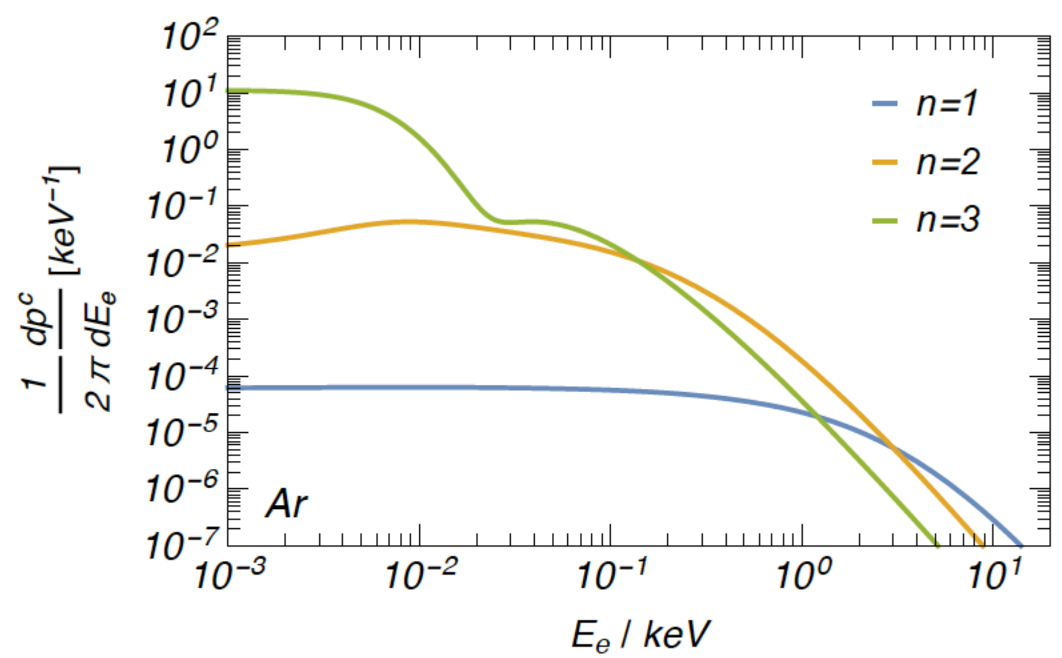
- only small correction for high-mass WIMPs
- decreases for light DM particles

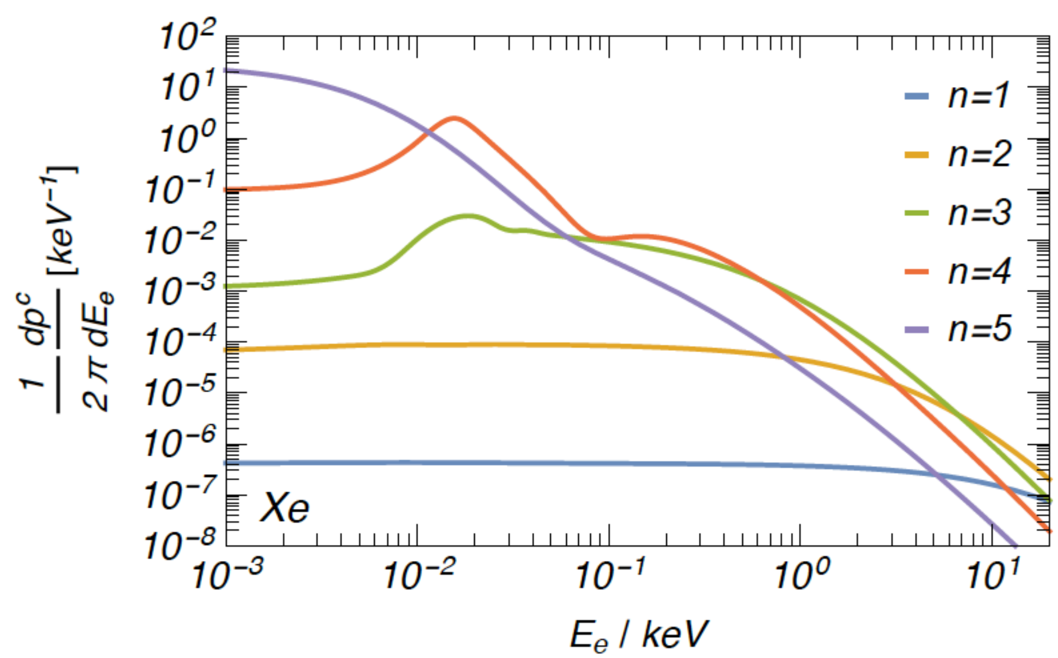
However, the ER channel, as opposed to NR one, is **not quenched** and may **enhance** sensitivity to low-mass candidates



picture from PRL123, 241803 (2019)

Contributions of different shells:





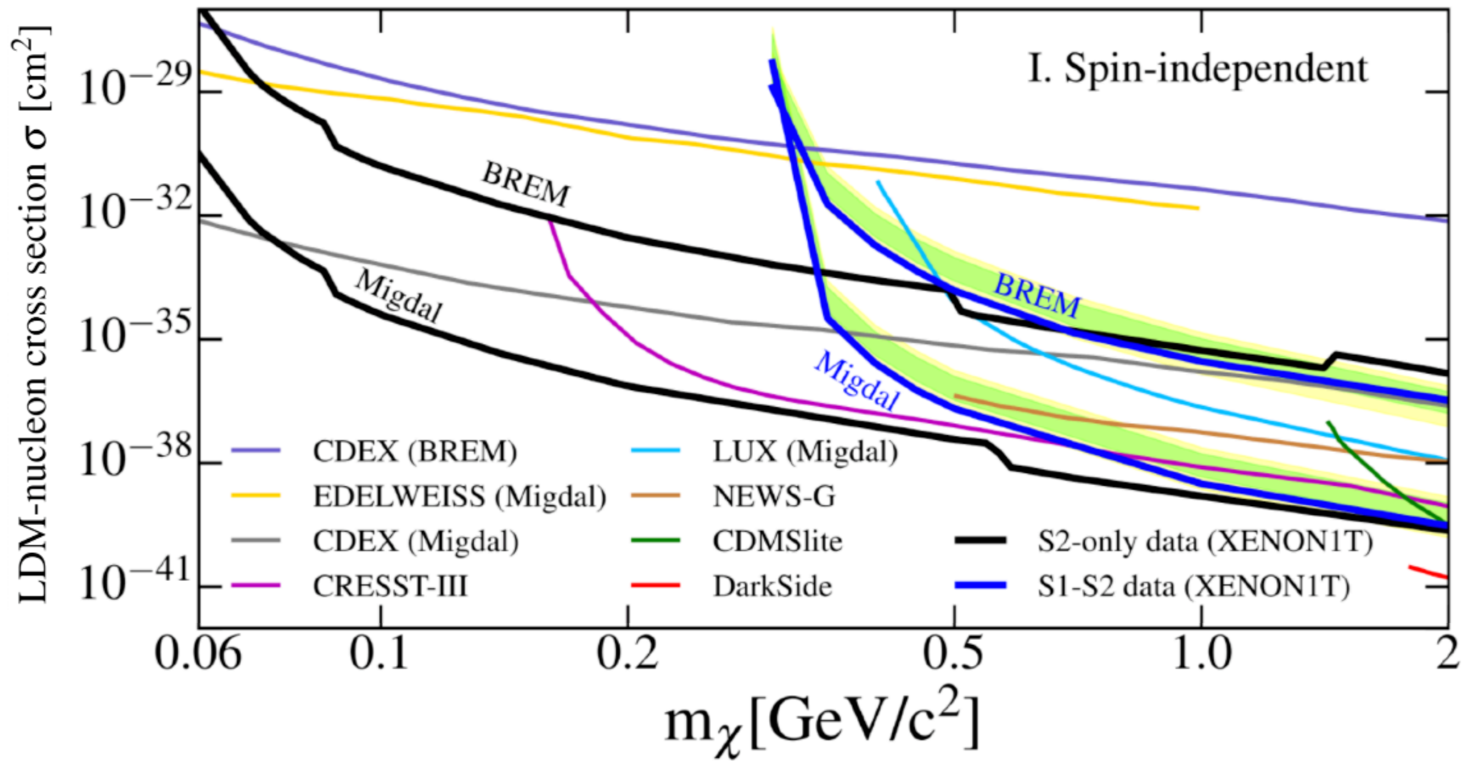
arXiv:1707.07258v2

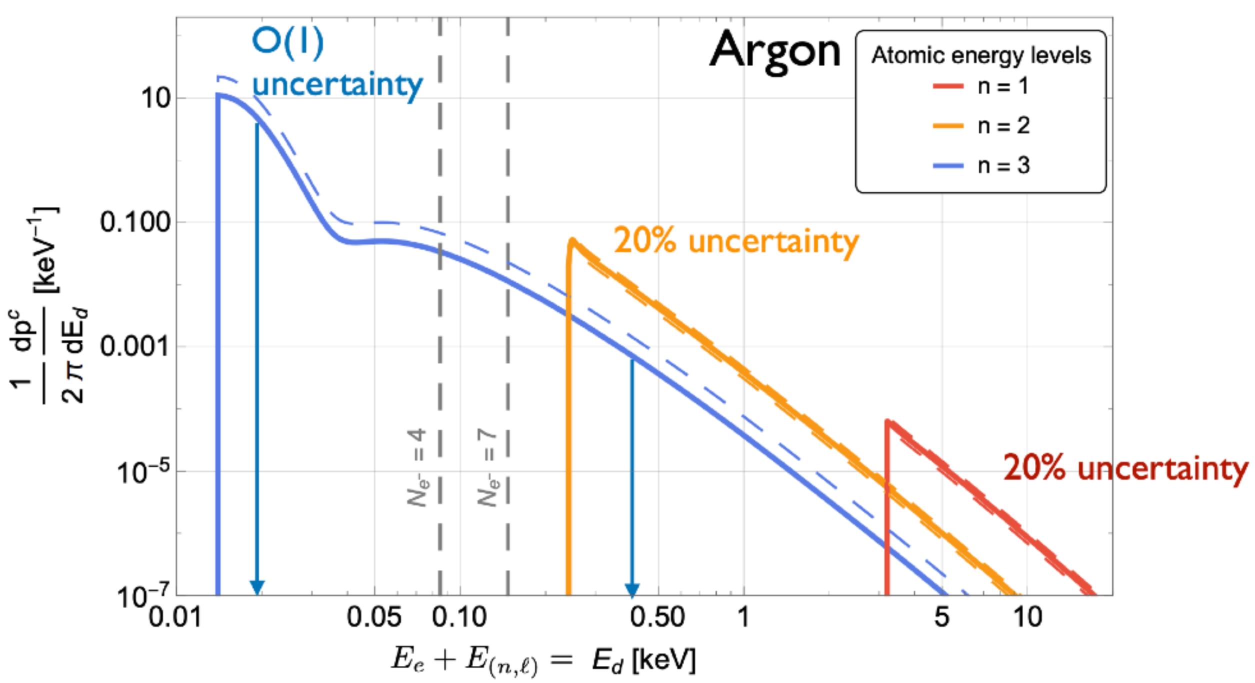
The Migdal Effect

Results with Xenon are leading exclusion. Allow to explore sub-GeV range!

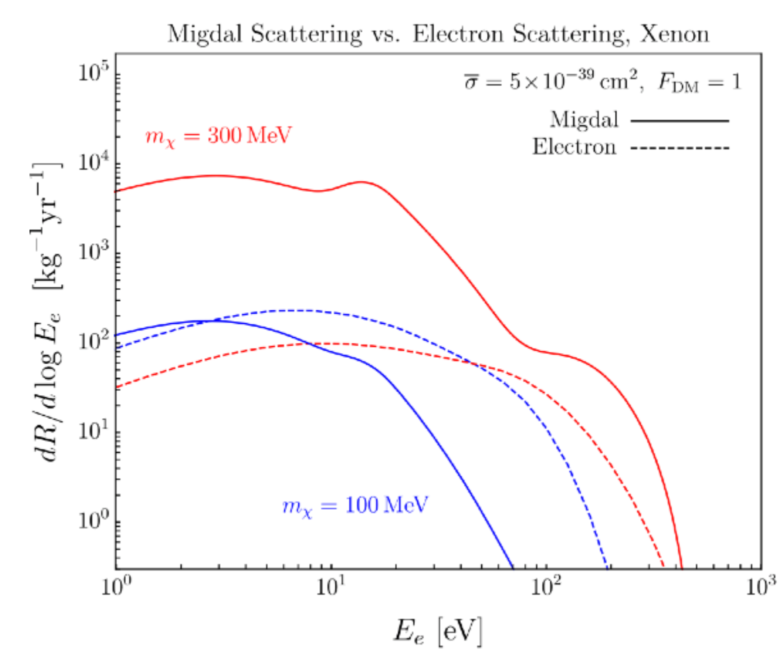
Assume the ER component only

Significant uncertainties in the calculations, yet to be fully characterised experimentally





Suggested that experimentally should be even more significant than WIMP-e-
[arXiv:1908.00012]



DM-electron

Cross section

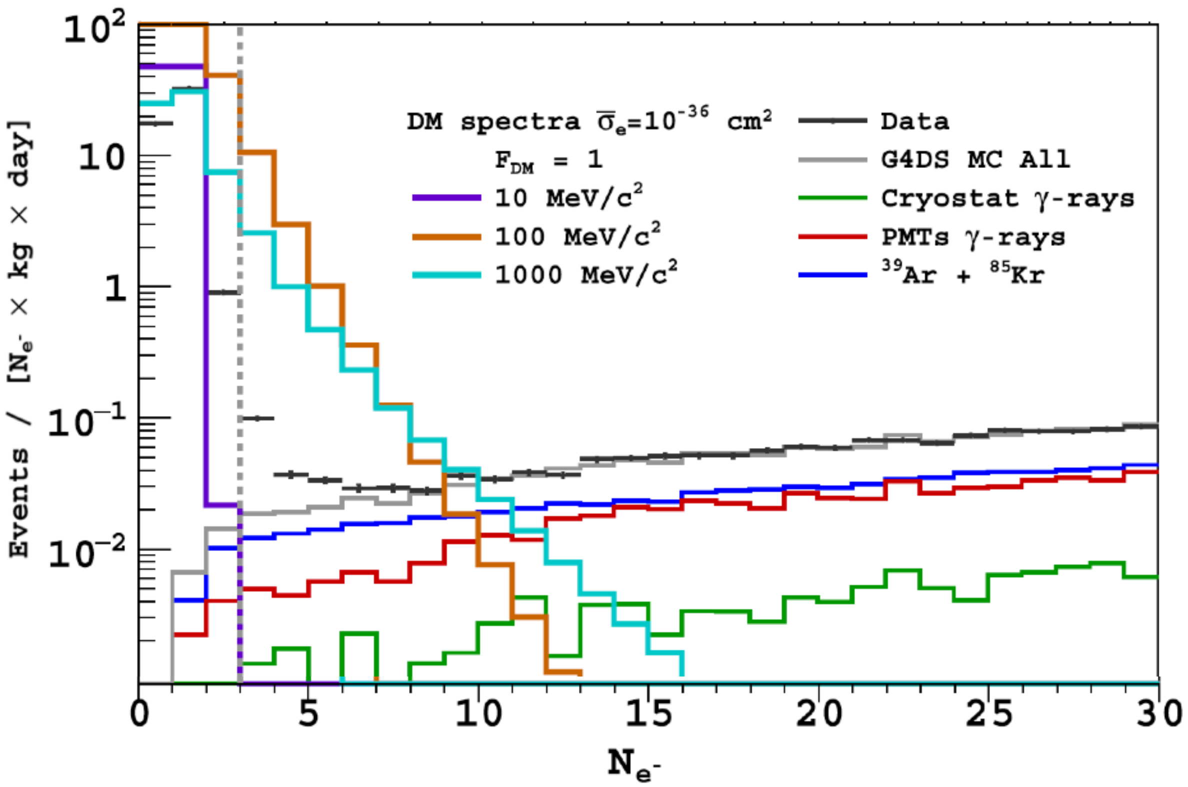
Form Factor (interaction)

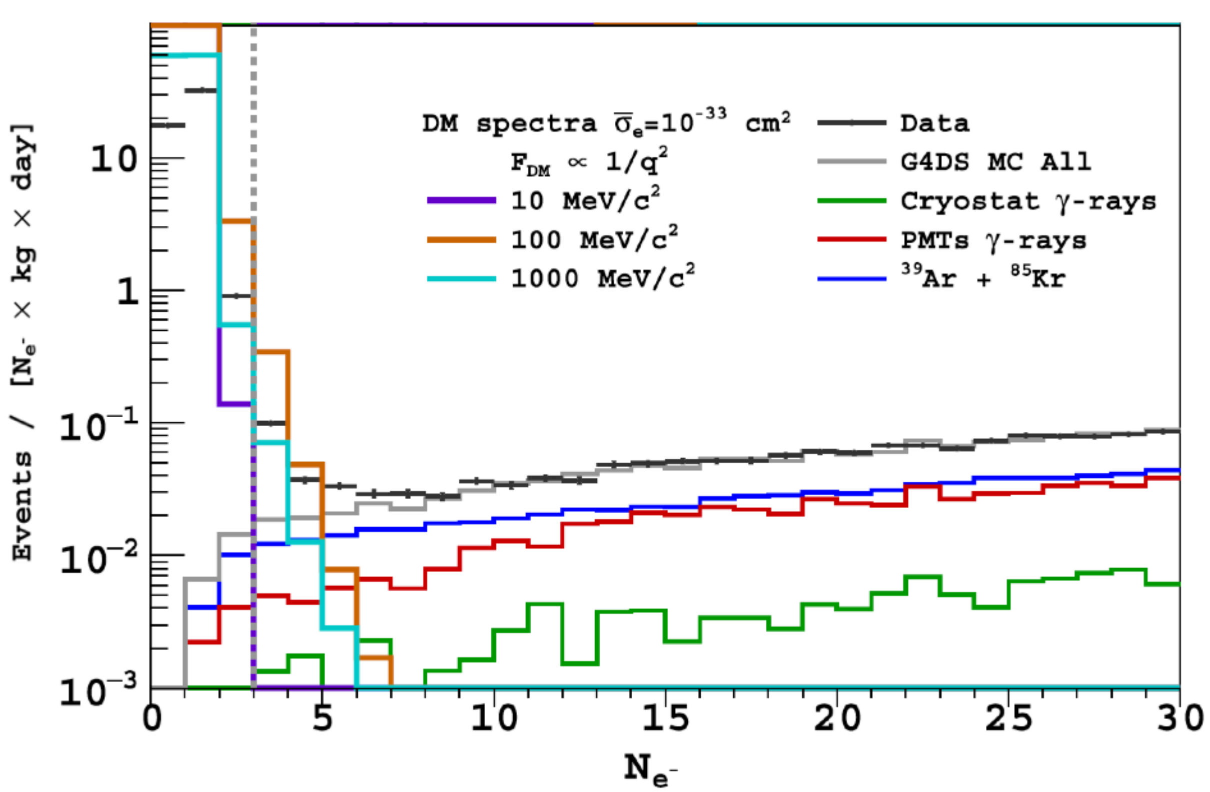
Astrophysics

$$\frac{dR^{ER}}{dE_e} = \boxed{\bar{\sigma}_e} \boxed{\frac{\rho_\chi}{M_\chi}} \frac{1}{8\mu_{e\chi}^2} \int q dq \boxed{|F_{DM}(q)|^2} \boxed{|f_{n,l}^{ion}(q, E_e)|^2} \boxed{\eta(v_{min})}$$

Electron wave-functions

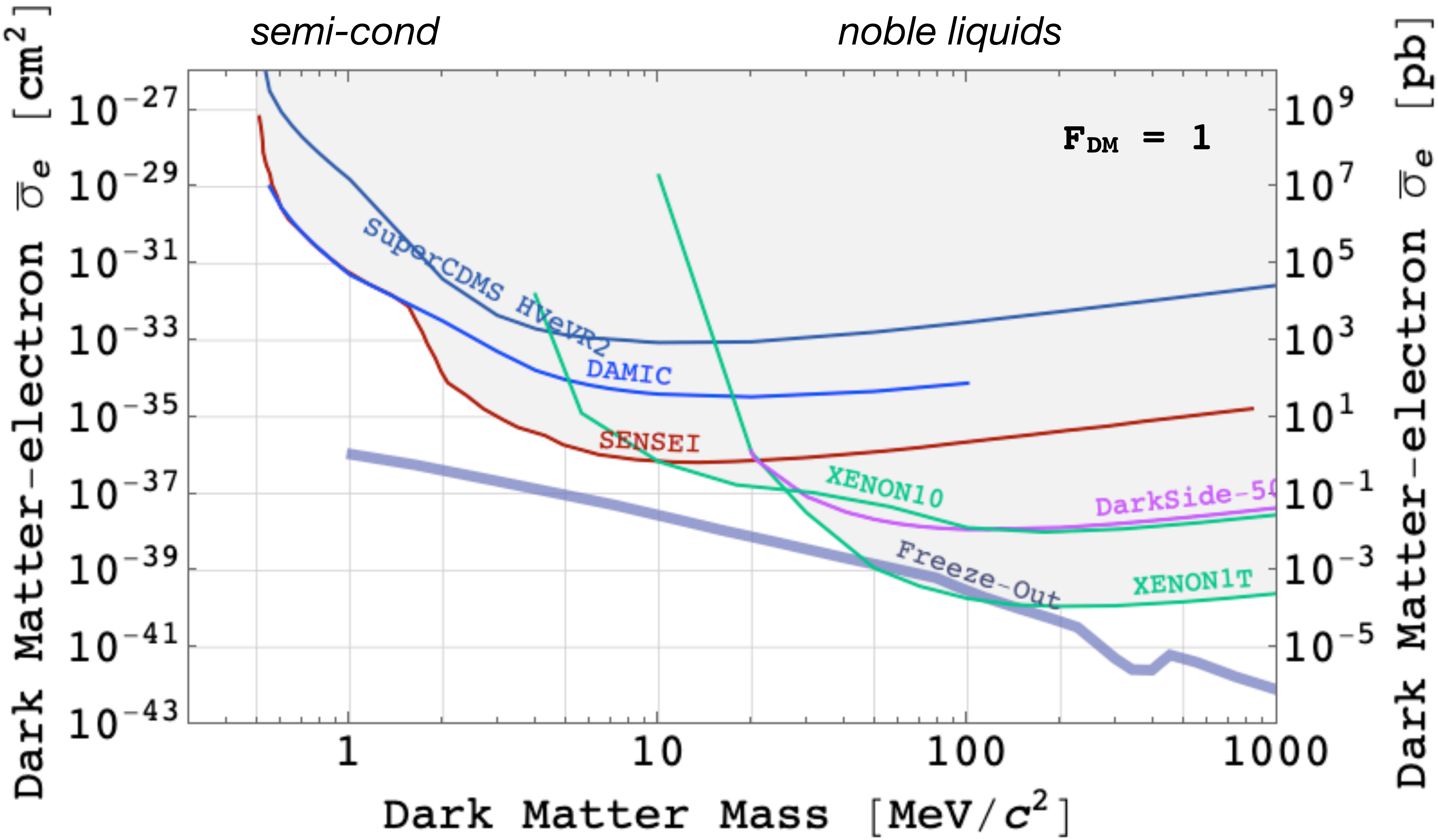
Dark Matter Properties





Exclusion limits

https://supercdms.slac.stanford.edu/dark-matter-limit-plotter



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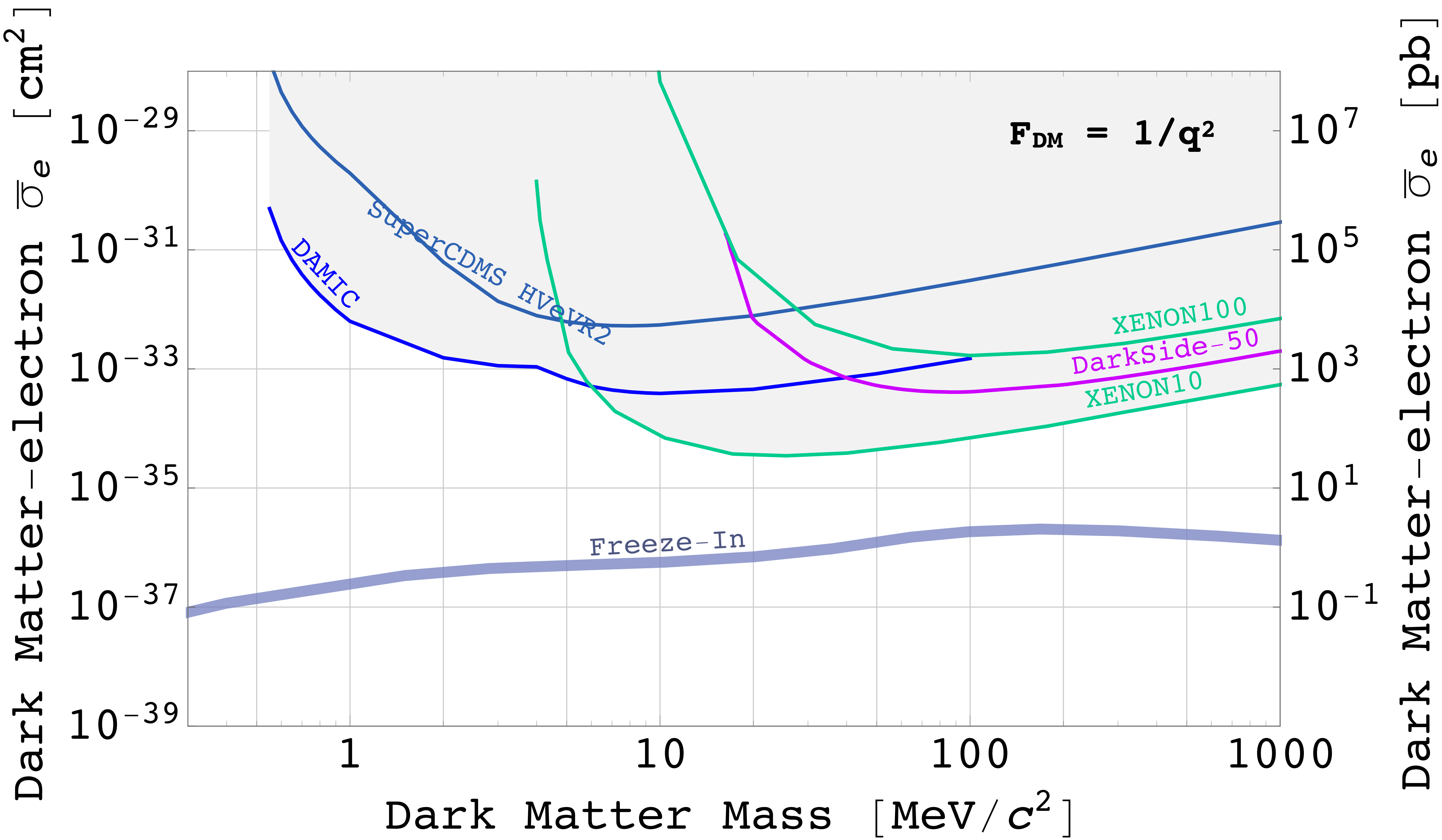

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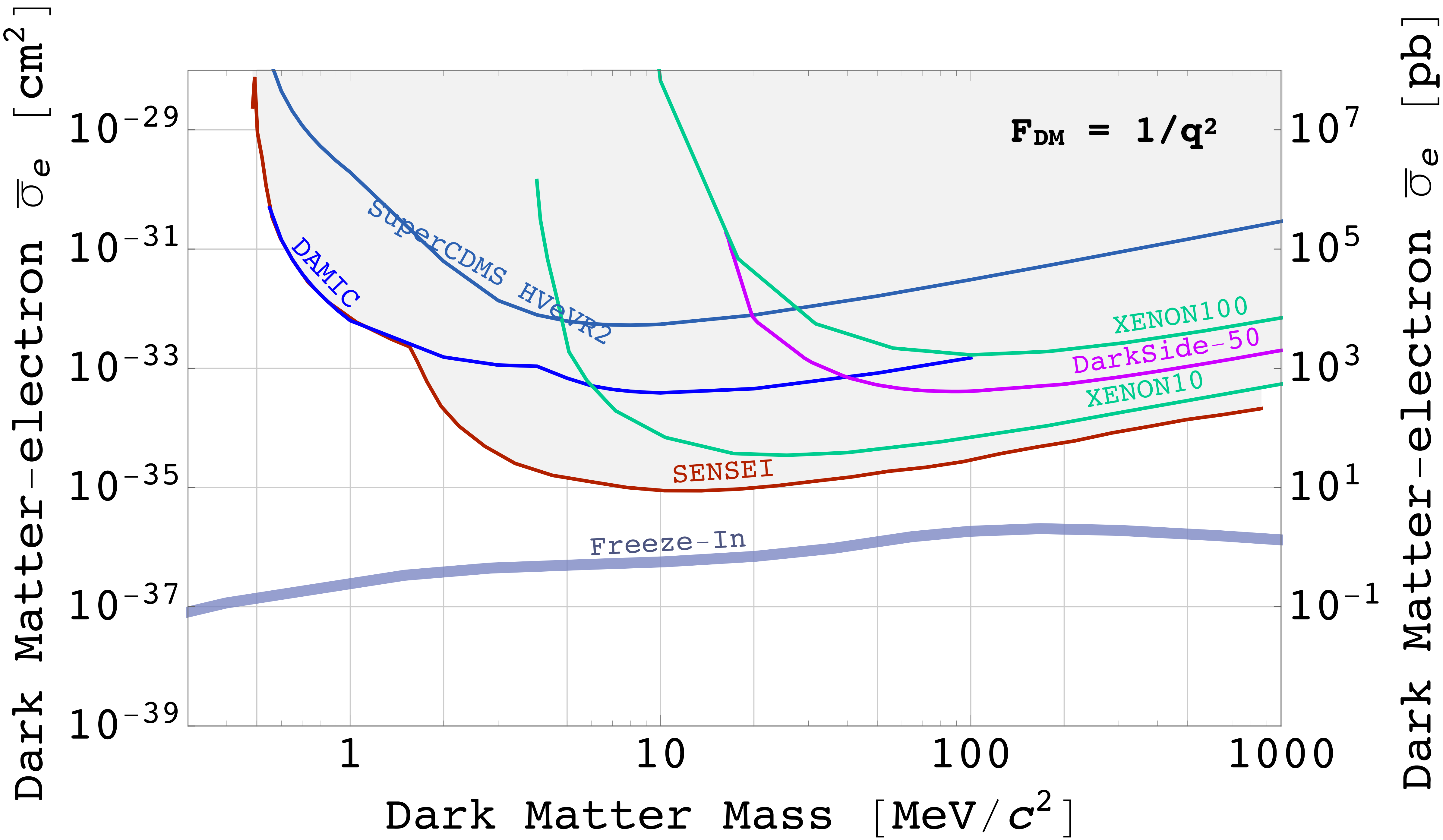
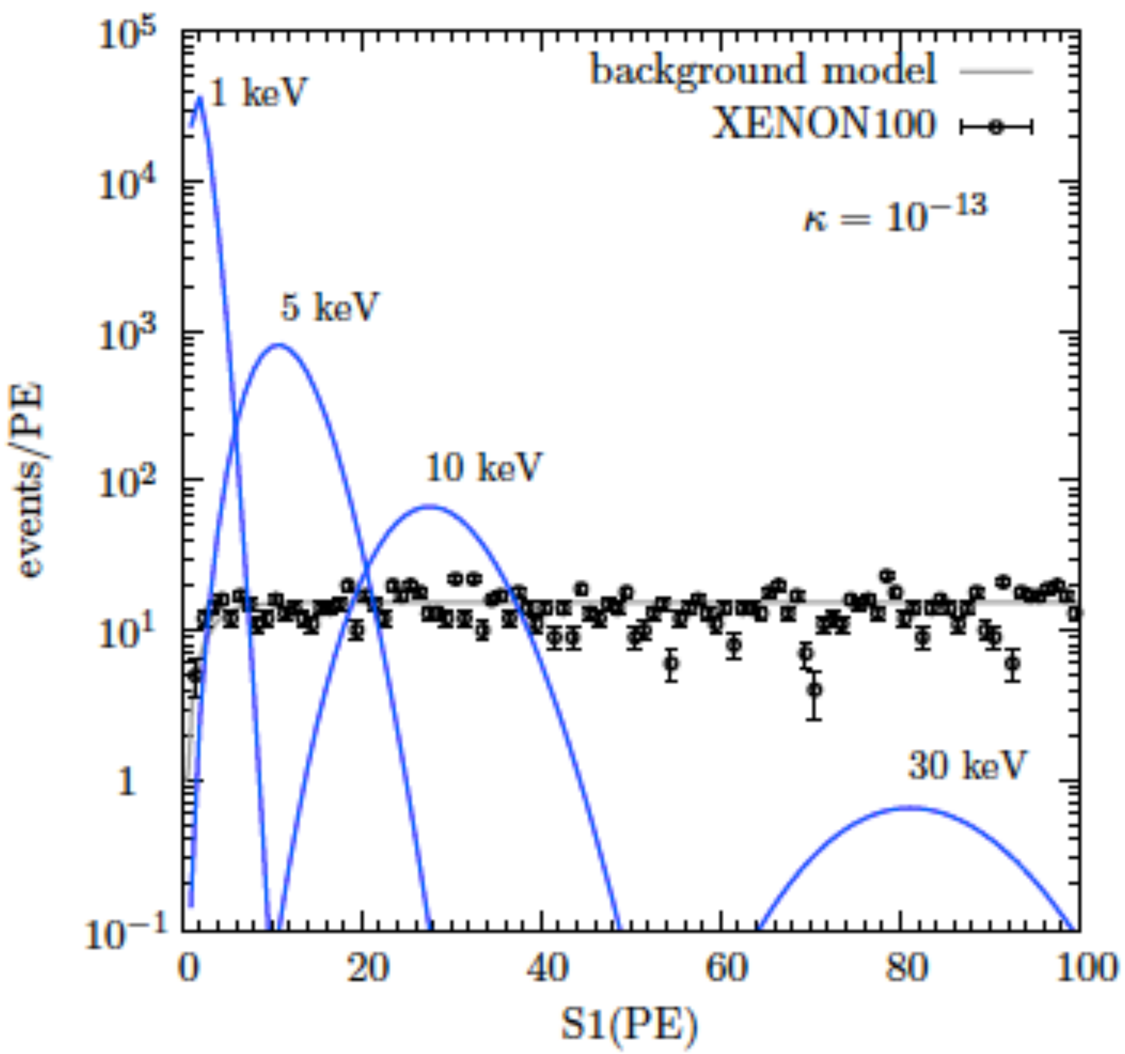
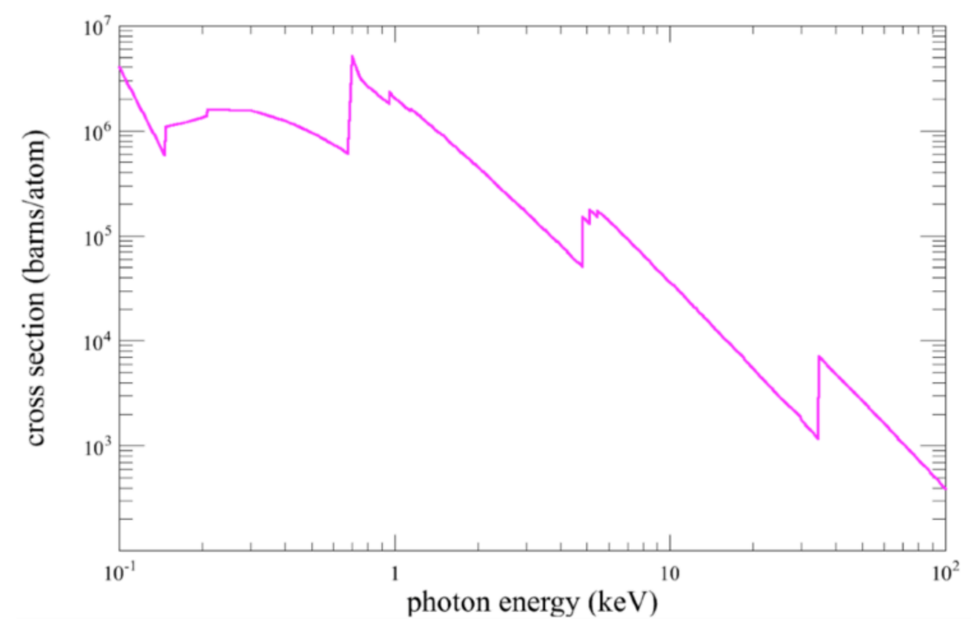


Dark Photon Absorption

Non-thermal candidate! Need a different production mechanism

$$\sigma_V(E_V = m_V)v_V \simeq \kappa^2 \sigma_\gamma(\omega = m_V)c,$$





$$\text{Rate per atom} \simeq \frac{\rho_{\mathrm{DM}}}{m_V c^2} \times \kappa^2 \sigma_\gamma(\omega = m_V)c,$$

$$R \simeq \frac{4 \times 10^{23}}{A} \frac{\alpha'}{\alpha} \left(\frac{\mathrm{keV}}{m_V}\right)\left(\frac{\sigma_{\mathrm{photo}}}{\mathrm{bn}}\right) \mathrm{kg}^{-1}\,\mathrm{day}^{-1}.$$

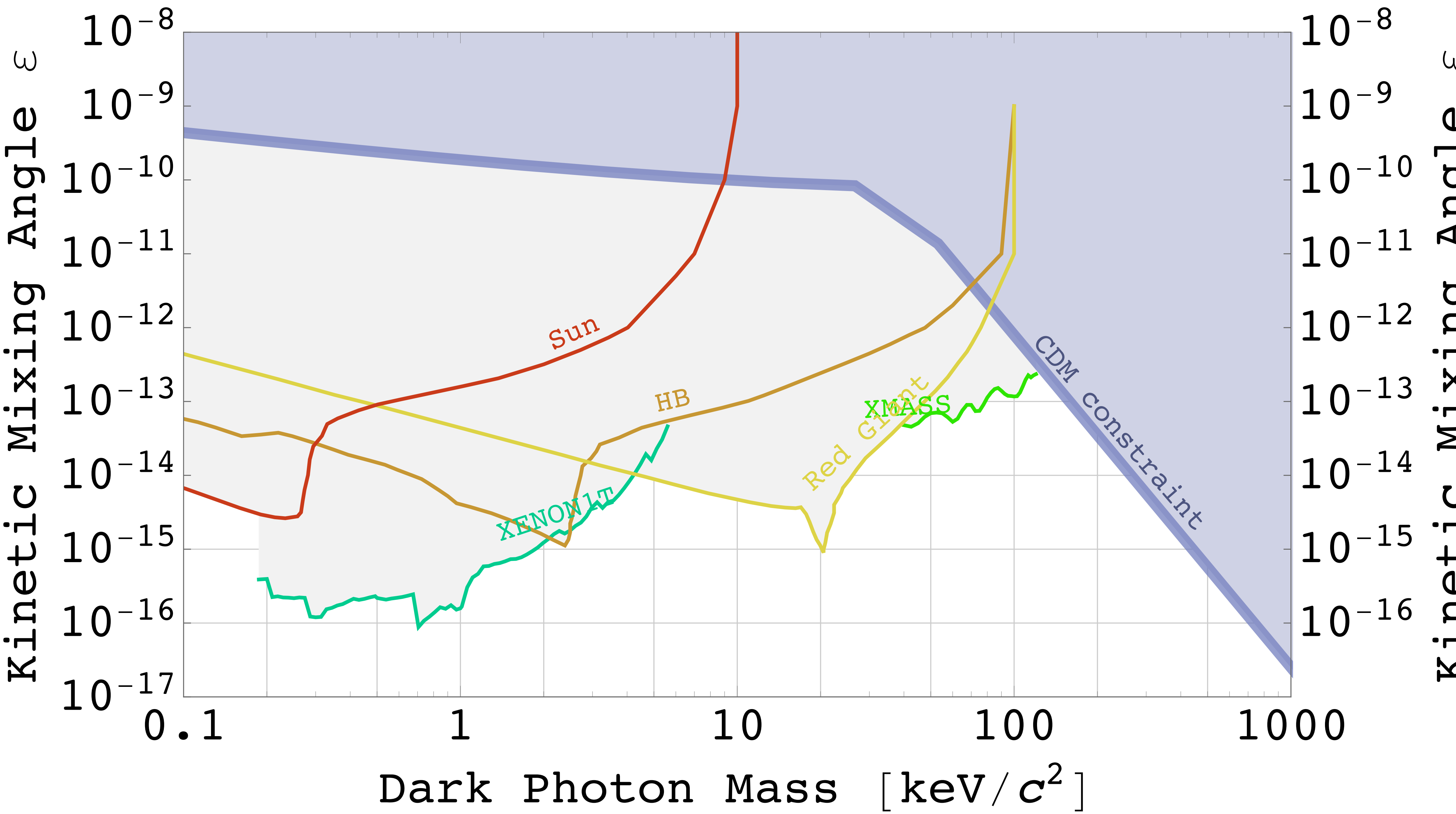
($\alpha' / \alpha = \kappa$)

https://arxiv.org/pdf/1412.8378.pdf

Dark Photon Absorption

https://supercdms.slac.stanford.edu/dark-matter-limit-plotter

doi:10.1088/1475-7516/2012/06/013



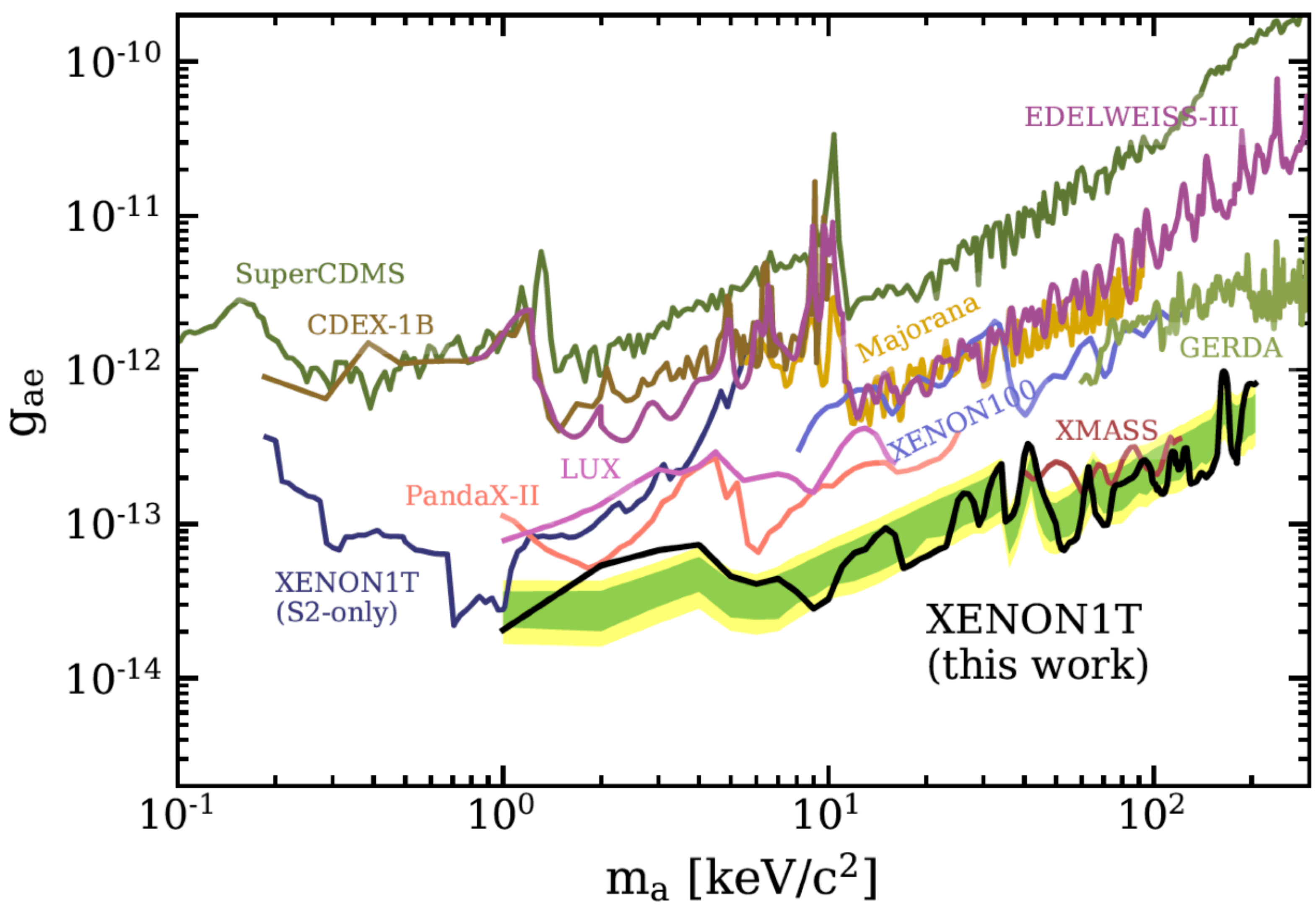
Axion-Like Particles

Non-thermal candidate! Need a different production mechanism

$$\mathcal{L}_{\rm int} = -\frac{\partial_\mu a}{f_a}\,\bar{\psi}\gamma^\mu\gamma^5\psi$$

$$\frac{\sigma_{\rm abs} v}{\sigma_{\rm photo}(\omega = m_a)c} \simeq \frac{3m_a^2}{4\pi\alpha f_a^2}.$$

$$R \simeq \frac{1.2\times 10^{19}}{A} g_{aee}^2 \left(\frac{m_a}{\rm keV}\right)\left(\frac{\sigma_{\rm photo}}{\rm bn}\right)\,{\rm kg}^{-1}\,{\rm day}^{-1},$$

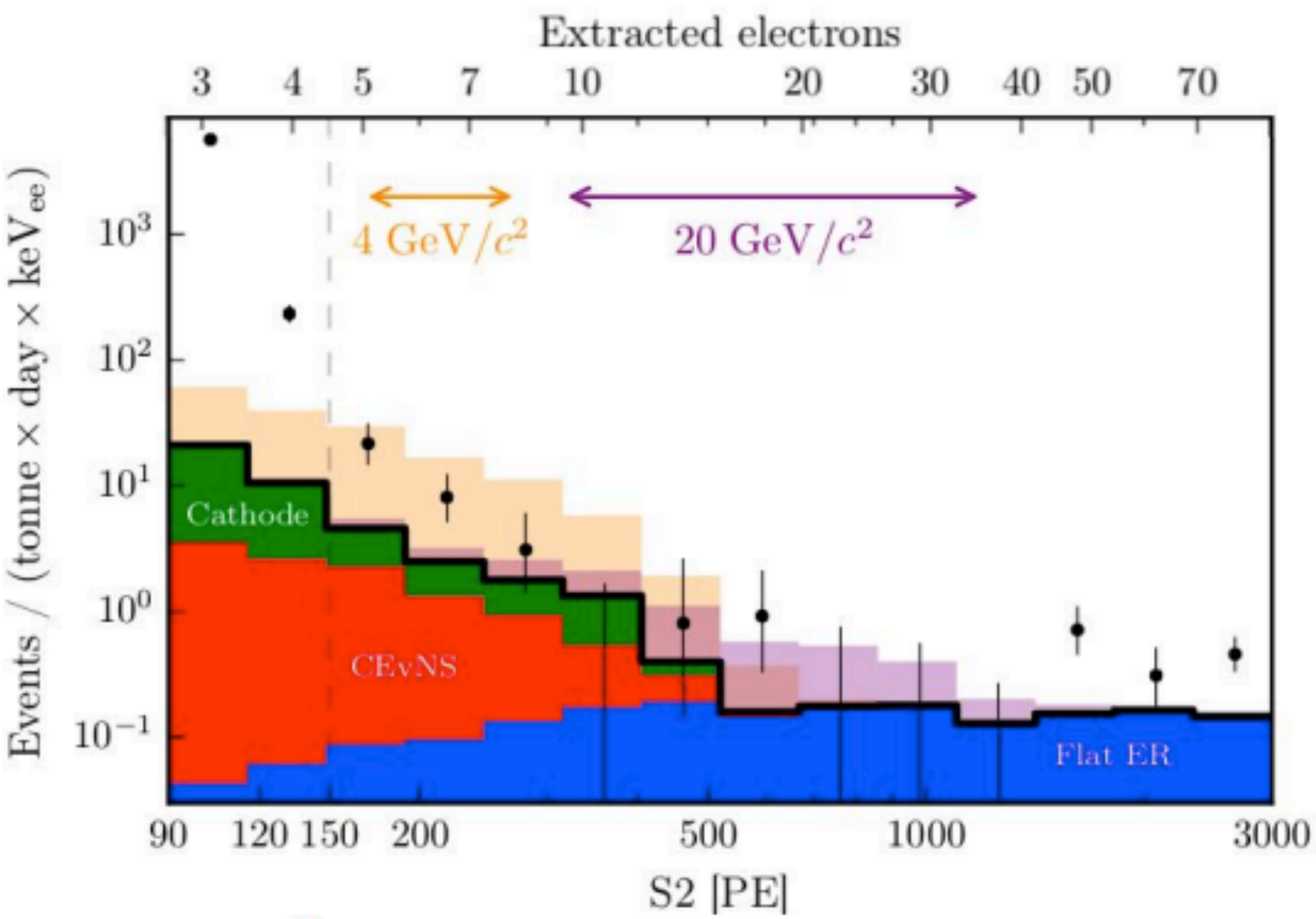


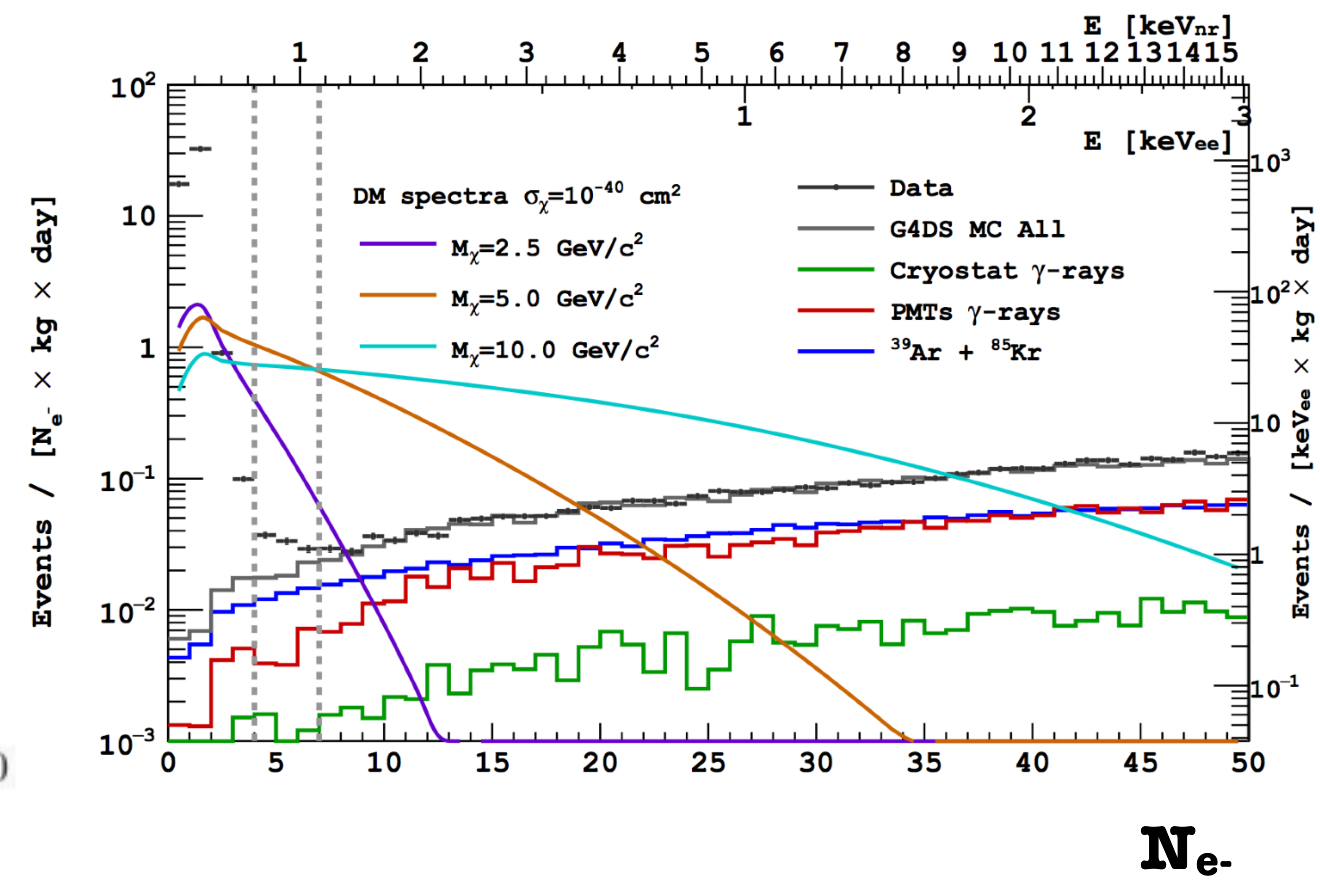
https://arxiv.org/abs/1002.2979

Future projects

Spurious events at low energy

Existing datasets: Xenon-1t (LXe) / DarkSide-50 (LAr)

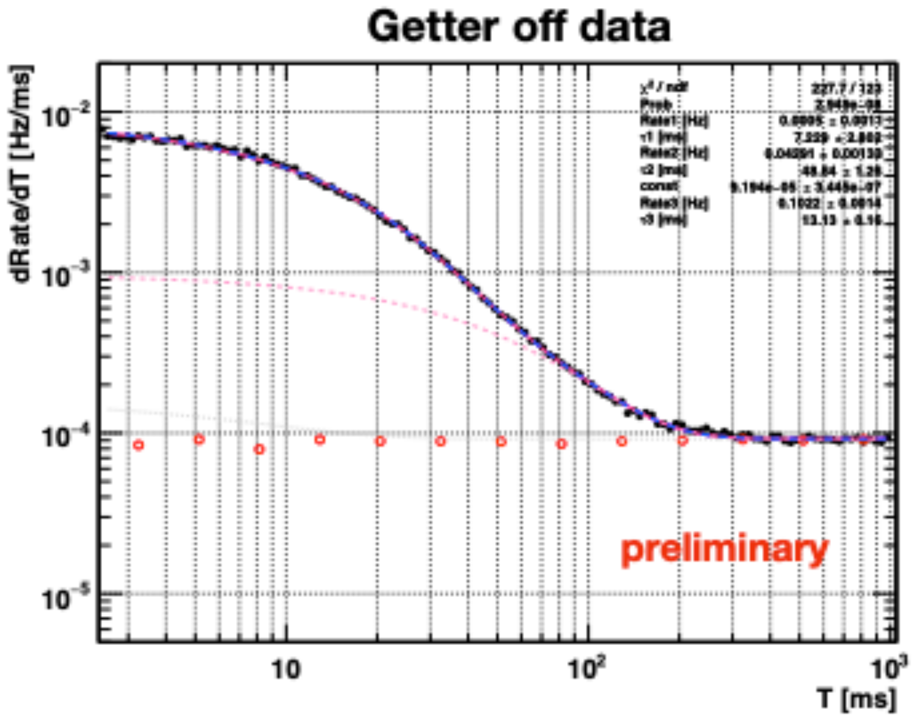




- Different exposure and detector size
- Same detector design and principles
- Same backgrounds!

Spurious events at low energy

Time correlation with preceding event



Spatial correlation with preceding event

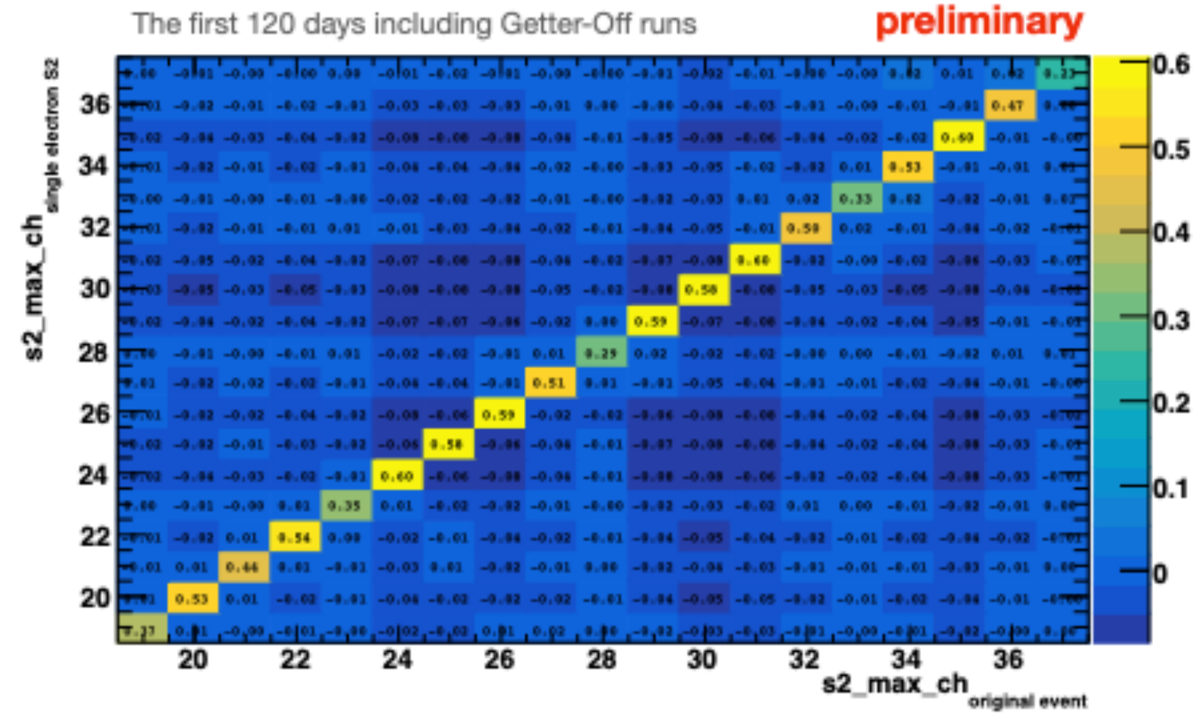
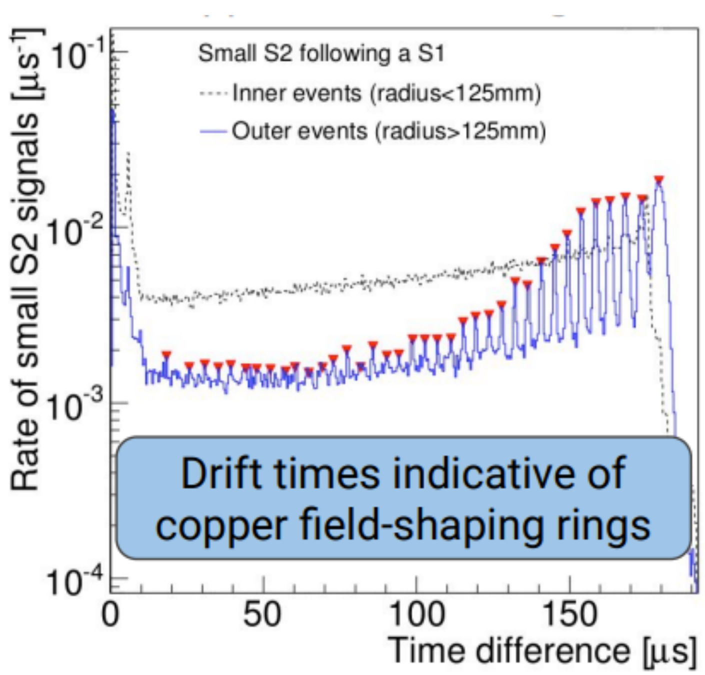
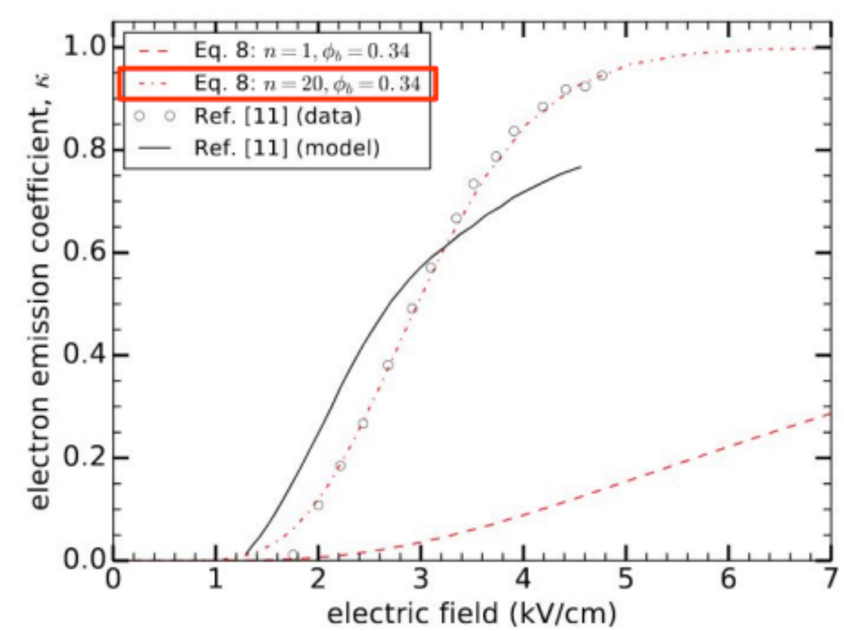


Photo-ionisation on metal components

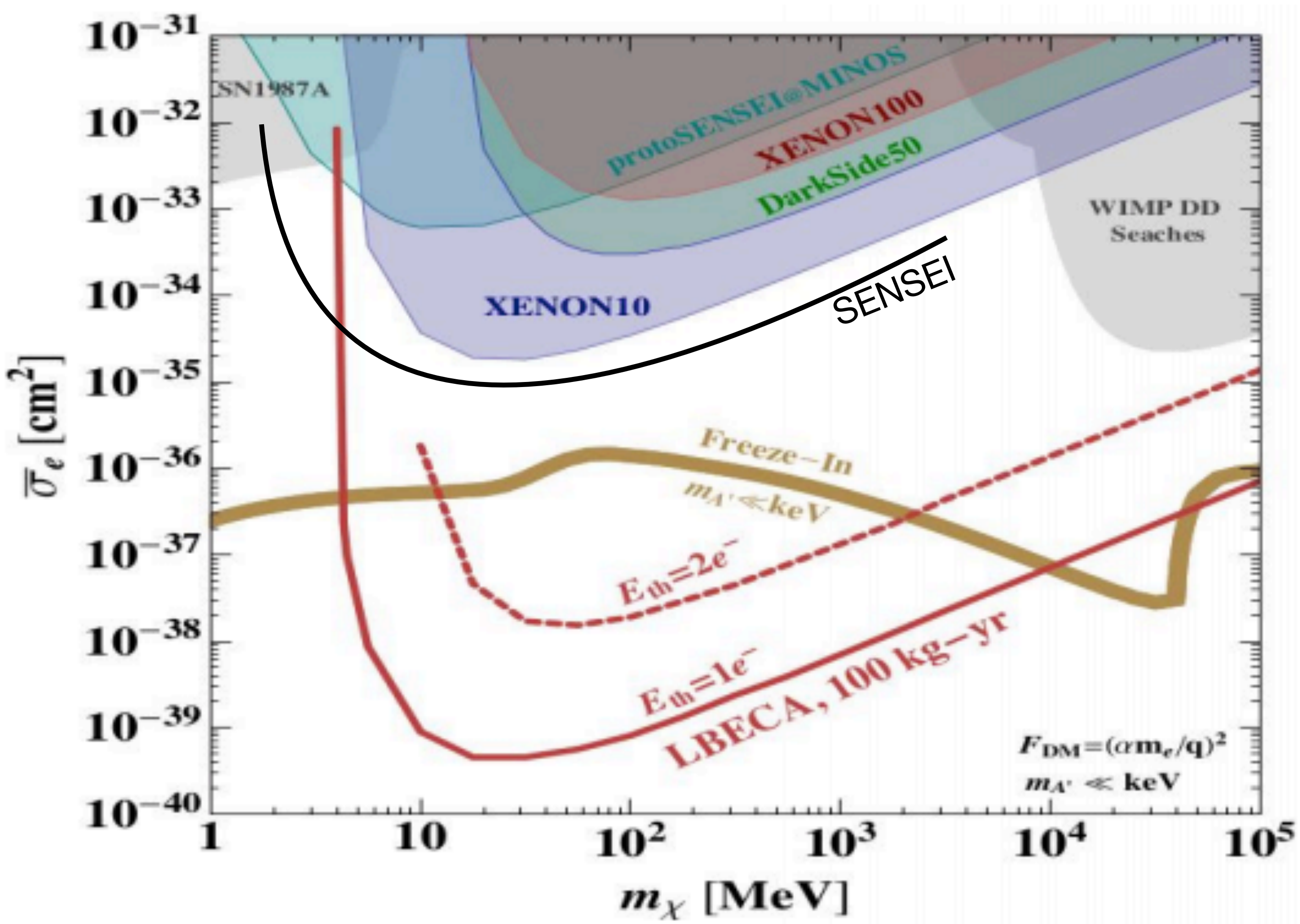


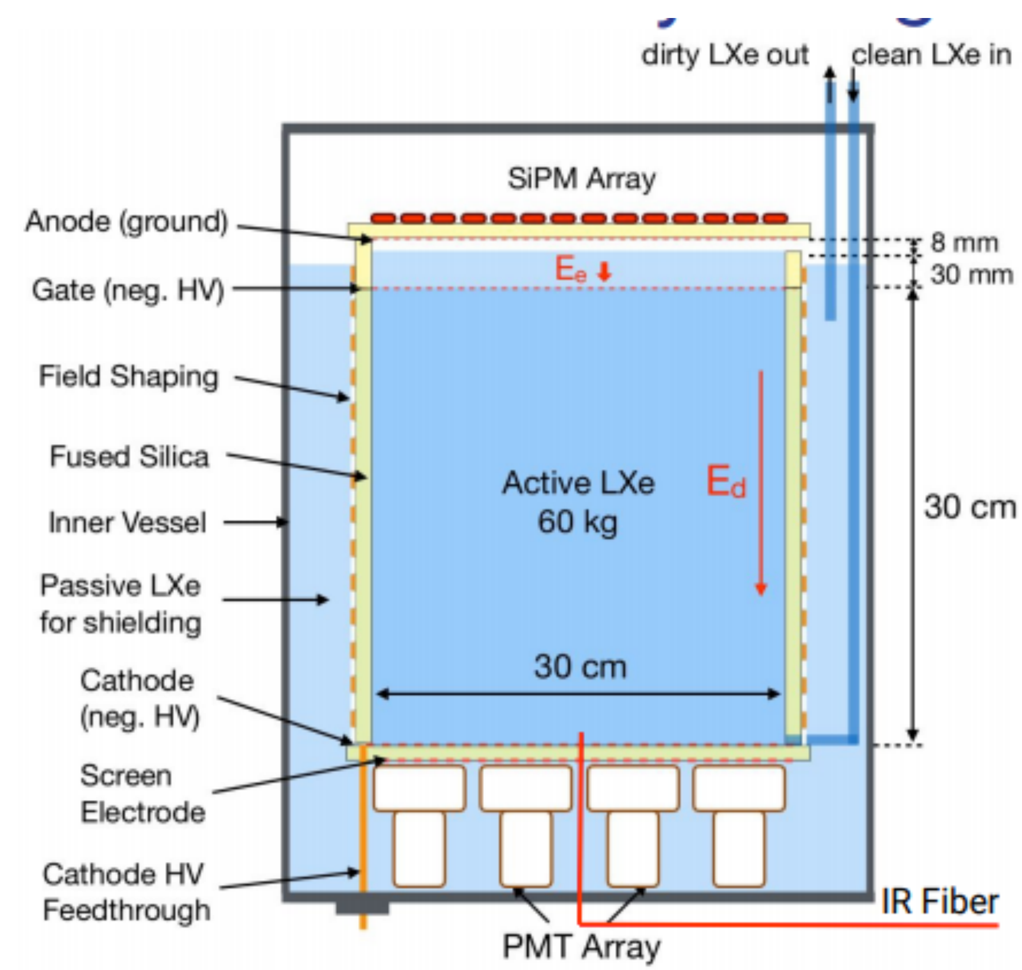
Delayed extraction of ionization electrons… ○ trapped on electronegative impurities

○ at the liquid-gas interface



LBECA



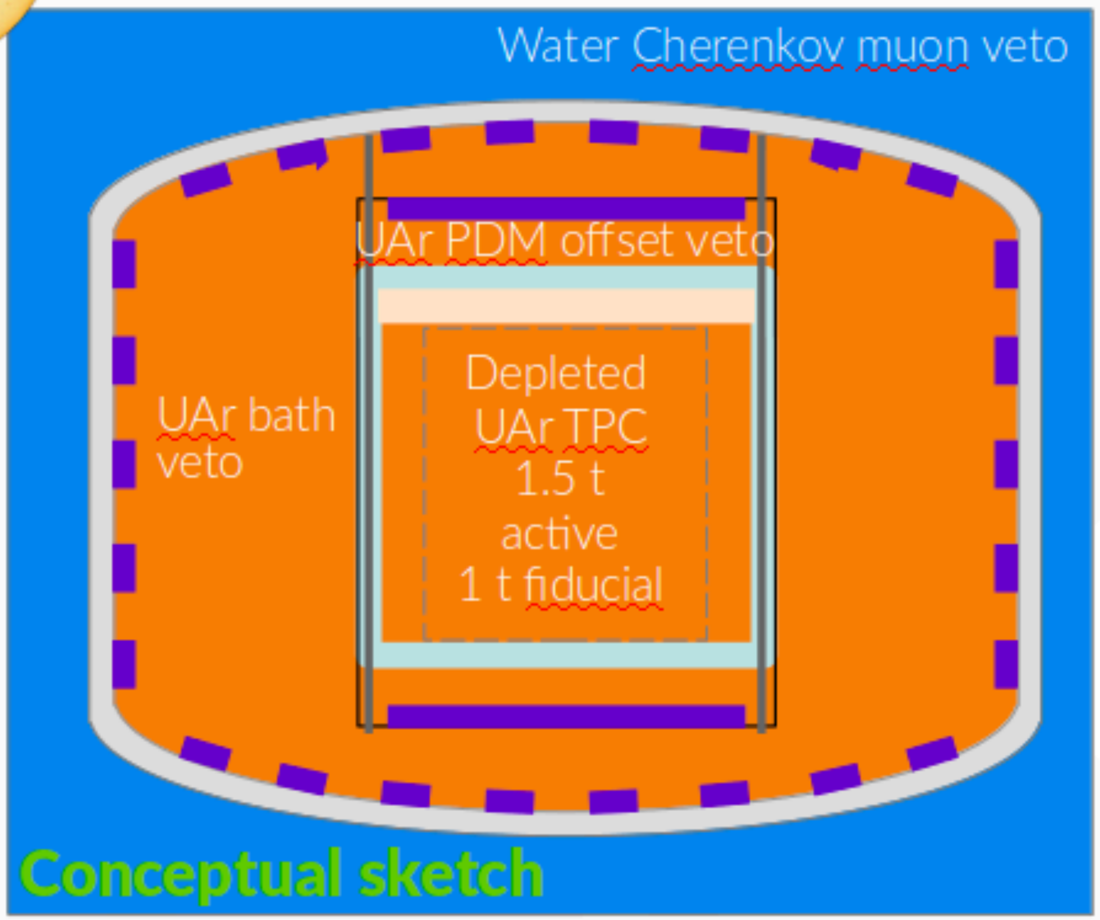


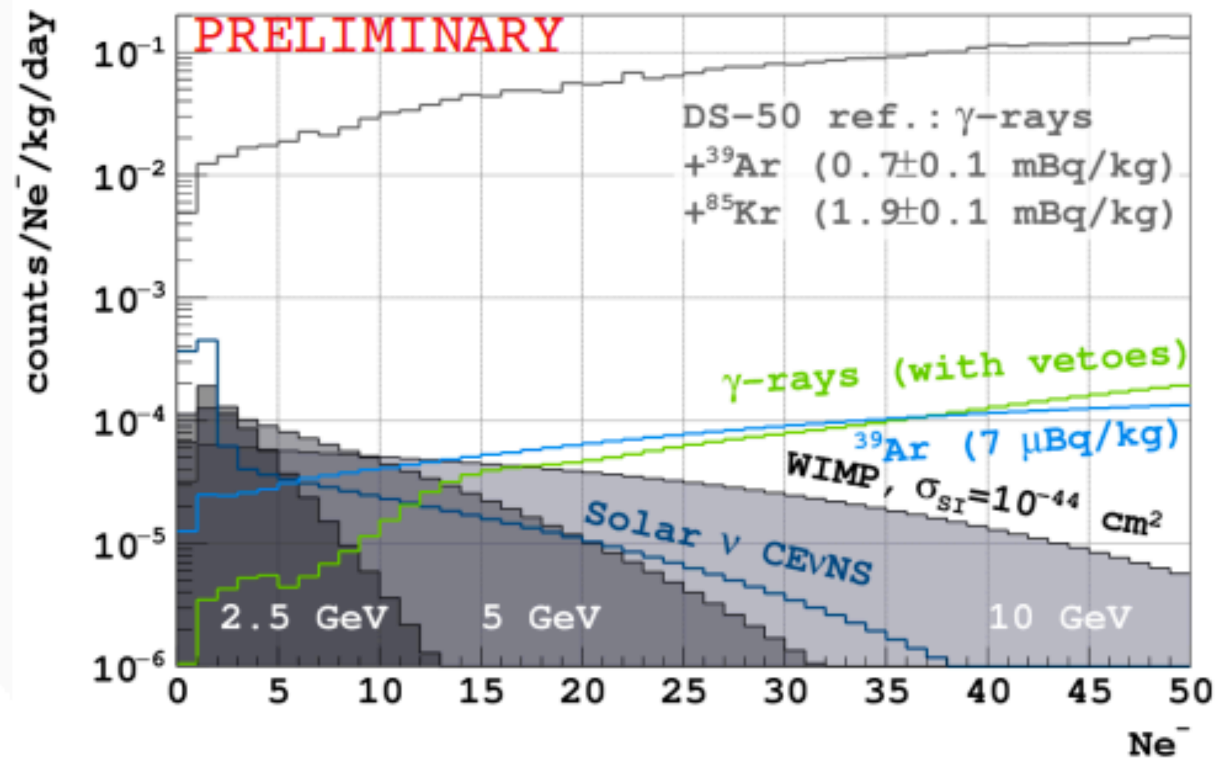
Implement technological solutions to reduce those bgs:
- avoid metal surfaces
- target cleanliness (less impurities)
- SiPM readout to improve spatial resolution (tag correlated events)
- low-background materials
- higher extraction field for higher efficiency
- IR light source to shorten lifetime of trapped e- at surface

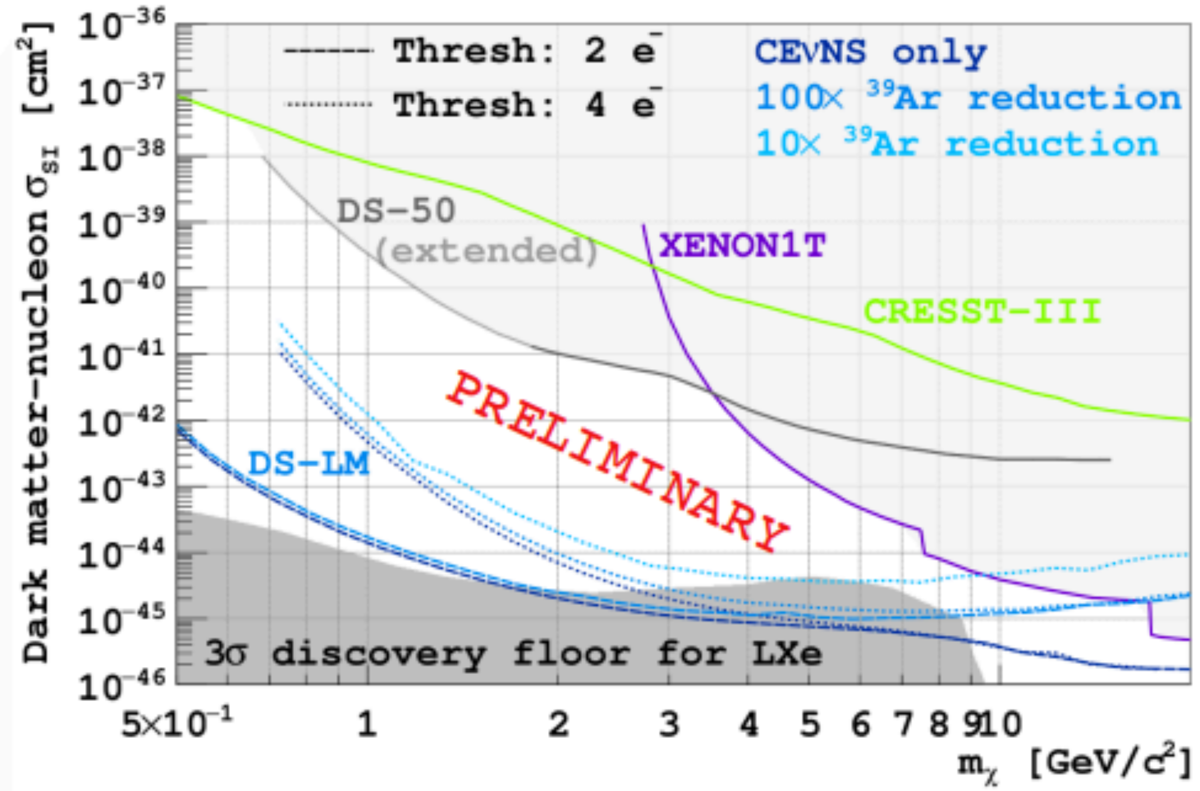
https://arxiv.org/pdf/2001.09311.pdf

DarkSide-LM

DarkSide-LowMass







- Dual-phase LAr TPC based on DarkSide-50
- Aiming for solar ν-floor with 1 t·yr exposure
- Lower backgrounds thanks to low-γ materials, γ-vetoes, and ^{39}Ar reduction with Urania and Aria
- Ongoing R&D to lower threshold, understand and decrease spurious electron backgrounds, and measure low-energy ionization response of LAr

Additional Searches: low-energy Xe-1t excess

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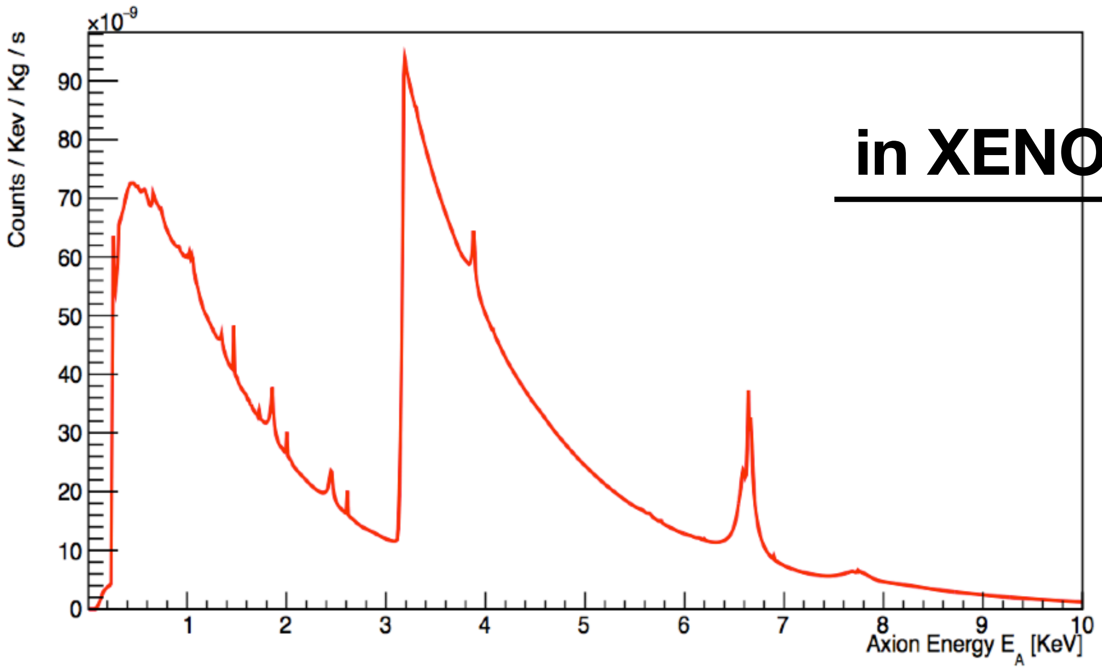
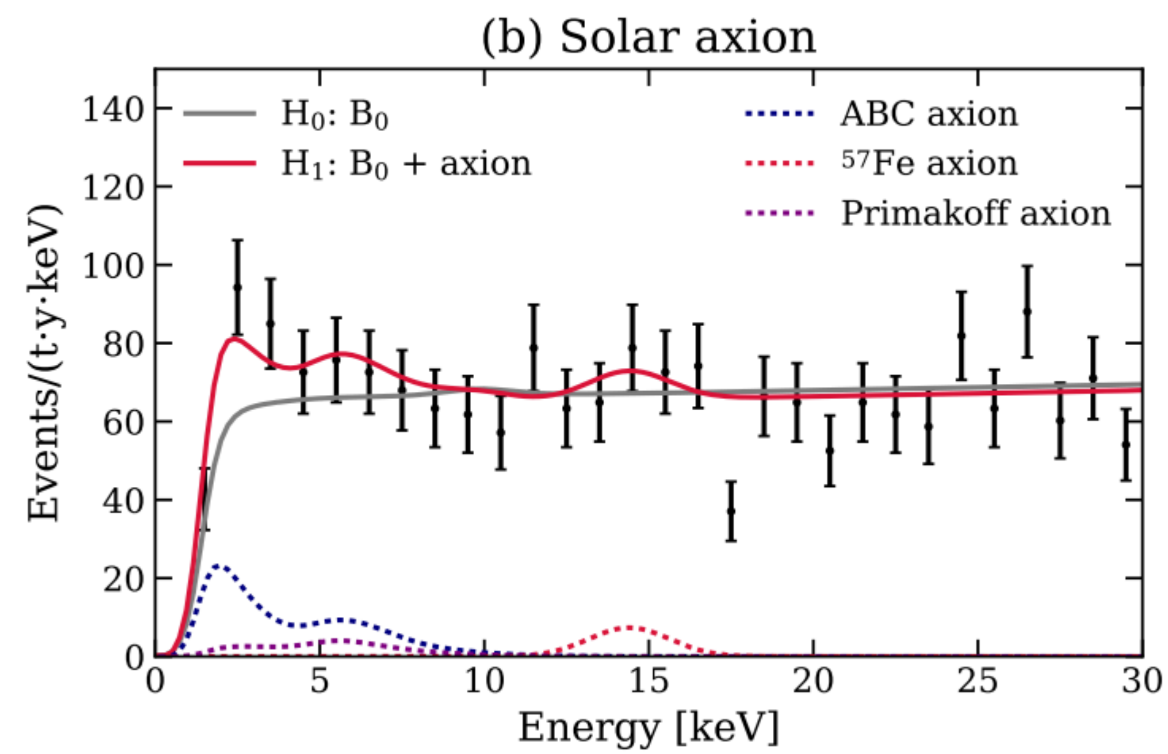


in XENON1t

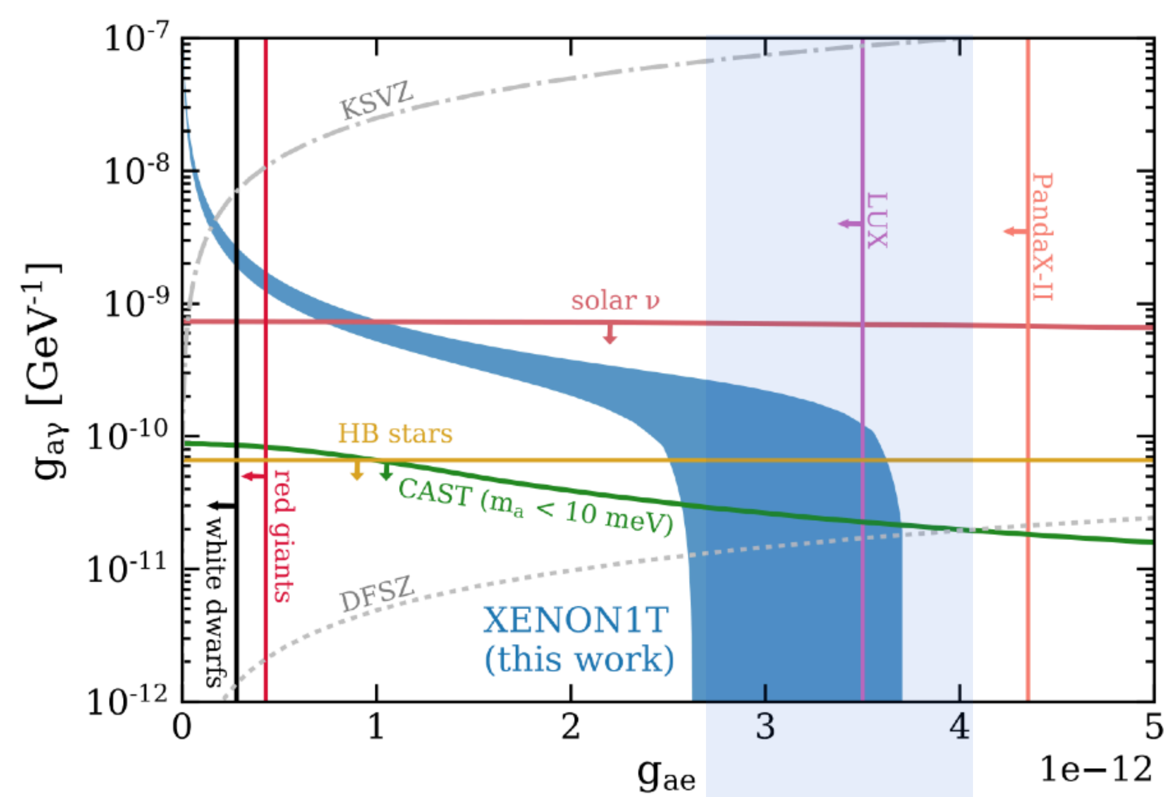


Axions were introduced to solve the strong CP problem

The Sun could be a source of Axion-like Particles via 3 production mechanisms

Detection via axio-electric effect (photo-electric), constrain coupling strength g_{ae}.

Tritium hypothesis



partial picture only

Backup