XENON

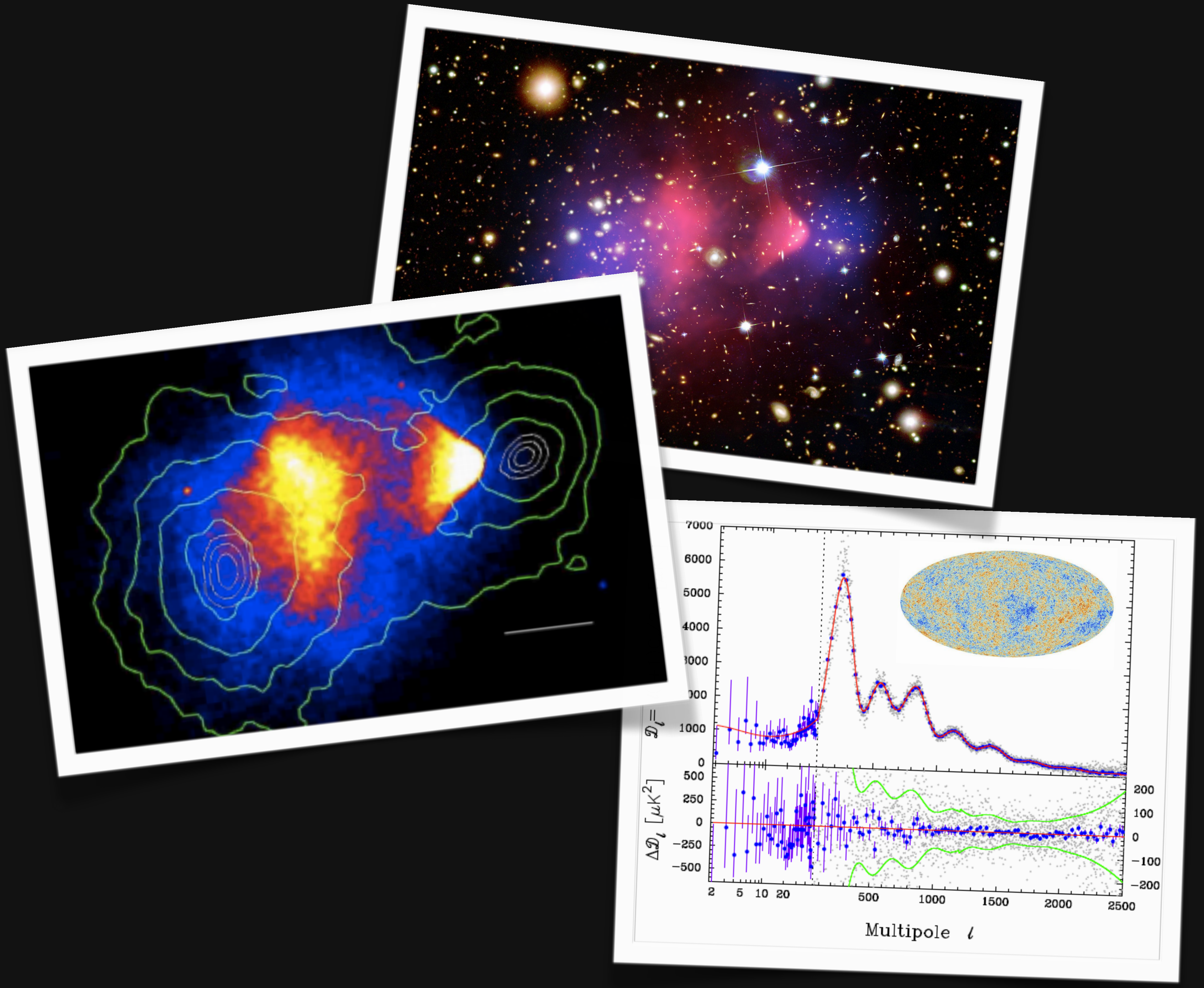
Testing the WIMP paradigm (and many others) with ultra-low background, massive xenon detectors

LUCA GRANDI

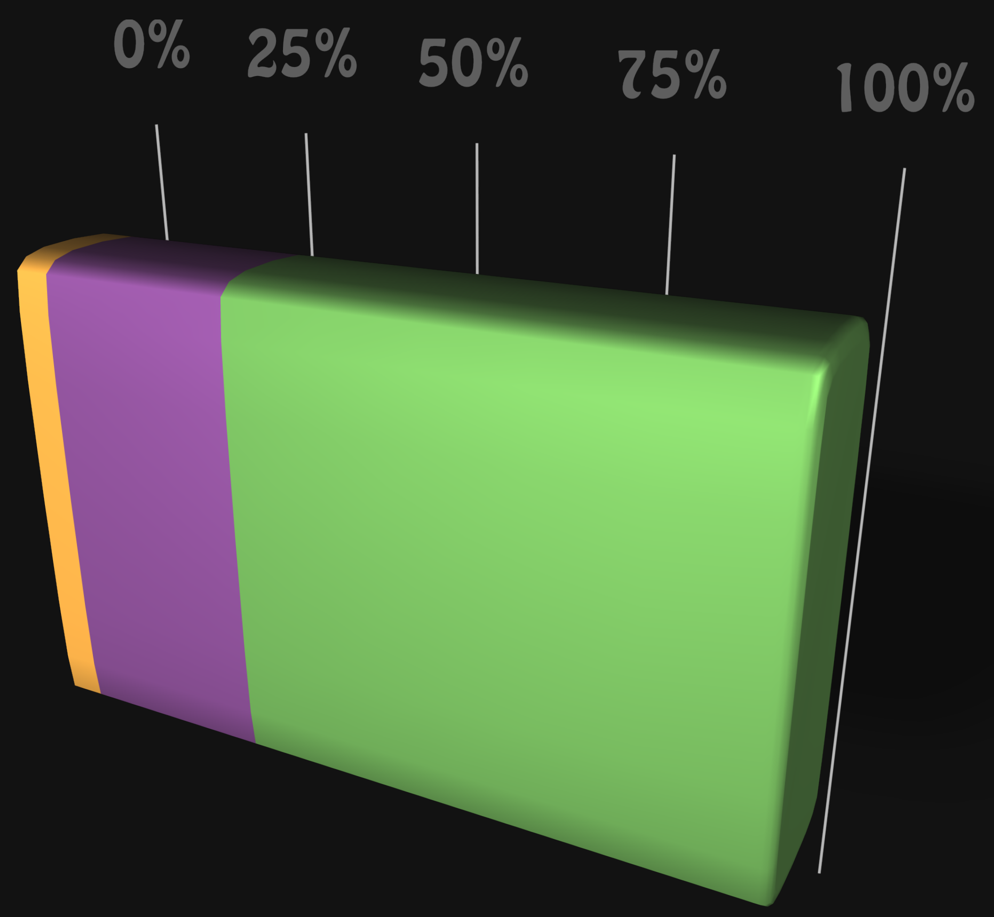
THE UNIVERSITY OF CHICAGO
ENRICO FERMI INSTITUTE
KAVLI INSTITUTE FOR COSMOLOGICAL PHYSICS

Dark Matter exists, we see its gravitational effects when we look at the sky...

... but what is its Nature?



The universe contains about 5 times more matter than what we can account for!



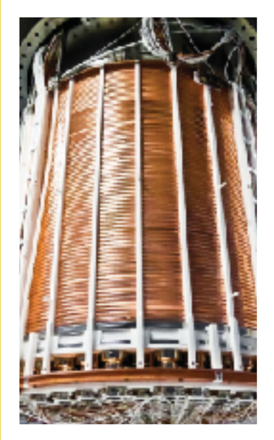

2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
XENON10
(15kg)
XENON100
(61kg)
XENON1T
(2 TONNES)
XENONNT
(5.9 TONNES)
ZEPLIN-II
(31kg)
ZEPLIN-III
(12kg)
LUX
(250kg)
LUX-ZEPLIN
(7 TONNES)
PANDAX-I
(120kg)
PANDAX-II
(500kg)
PANDAX-4T
(4 TONNES)
PandaX-4T

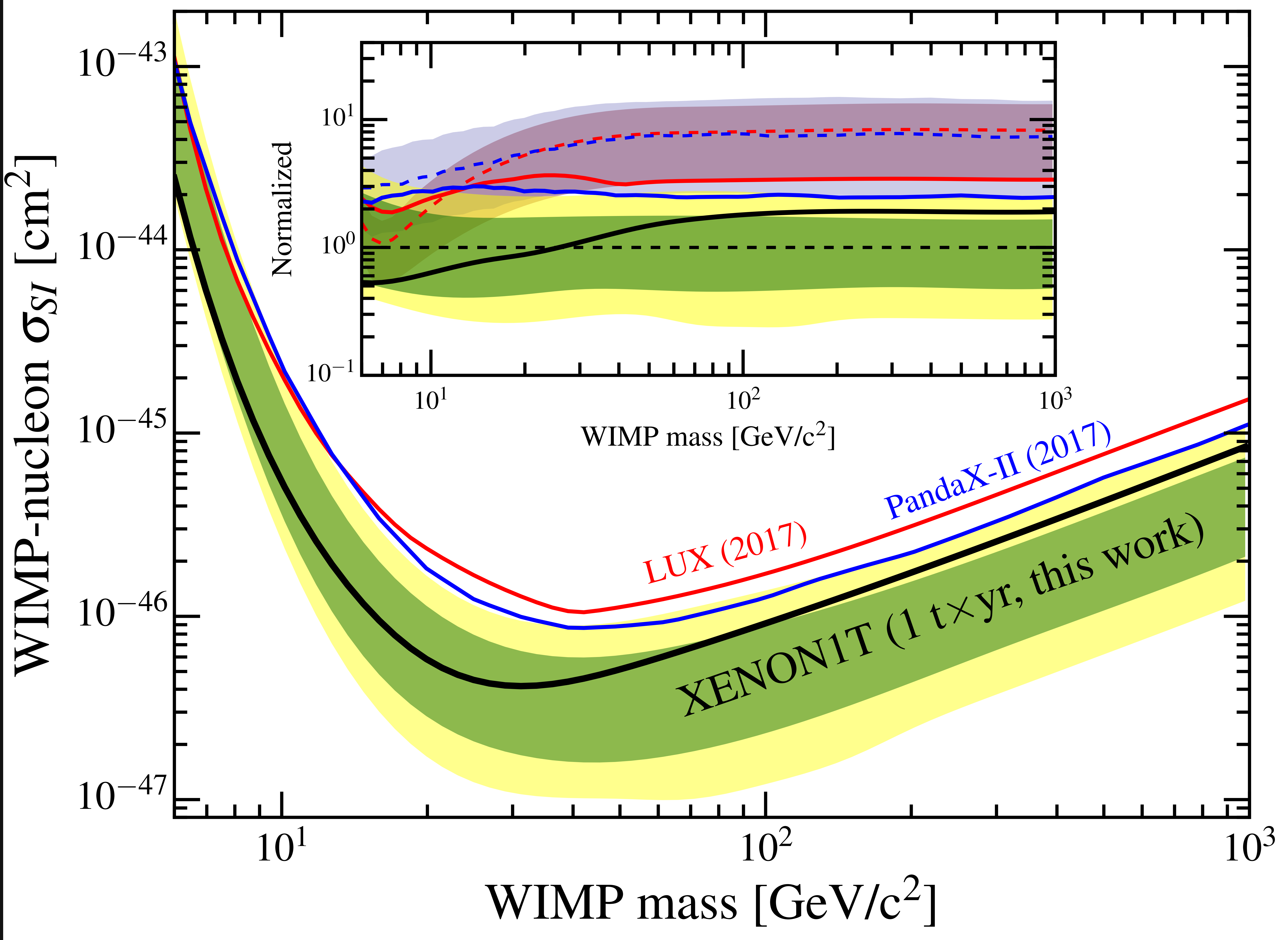
MOST CONSTRAINING LIMITS ON HEAVY WIMP DIRECT DETECTION

LUX
(250kg)

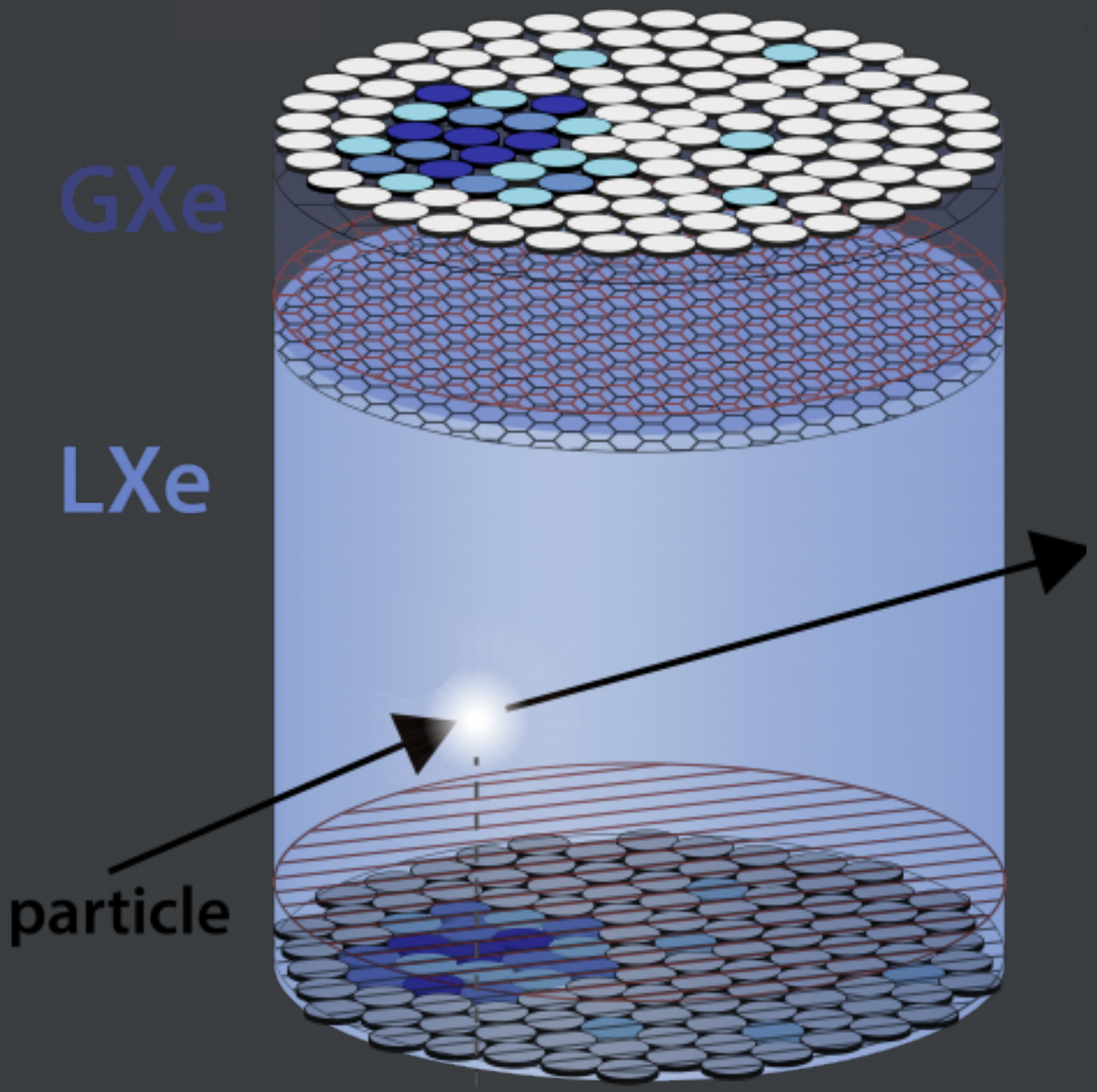
PANDAX-II
(500kg)

XENON1T
(2 TONNES)





XENON TWO-PHASE TIME PROJECTION CHAMBERS

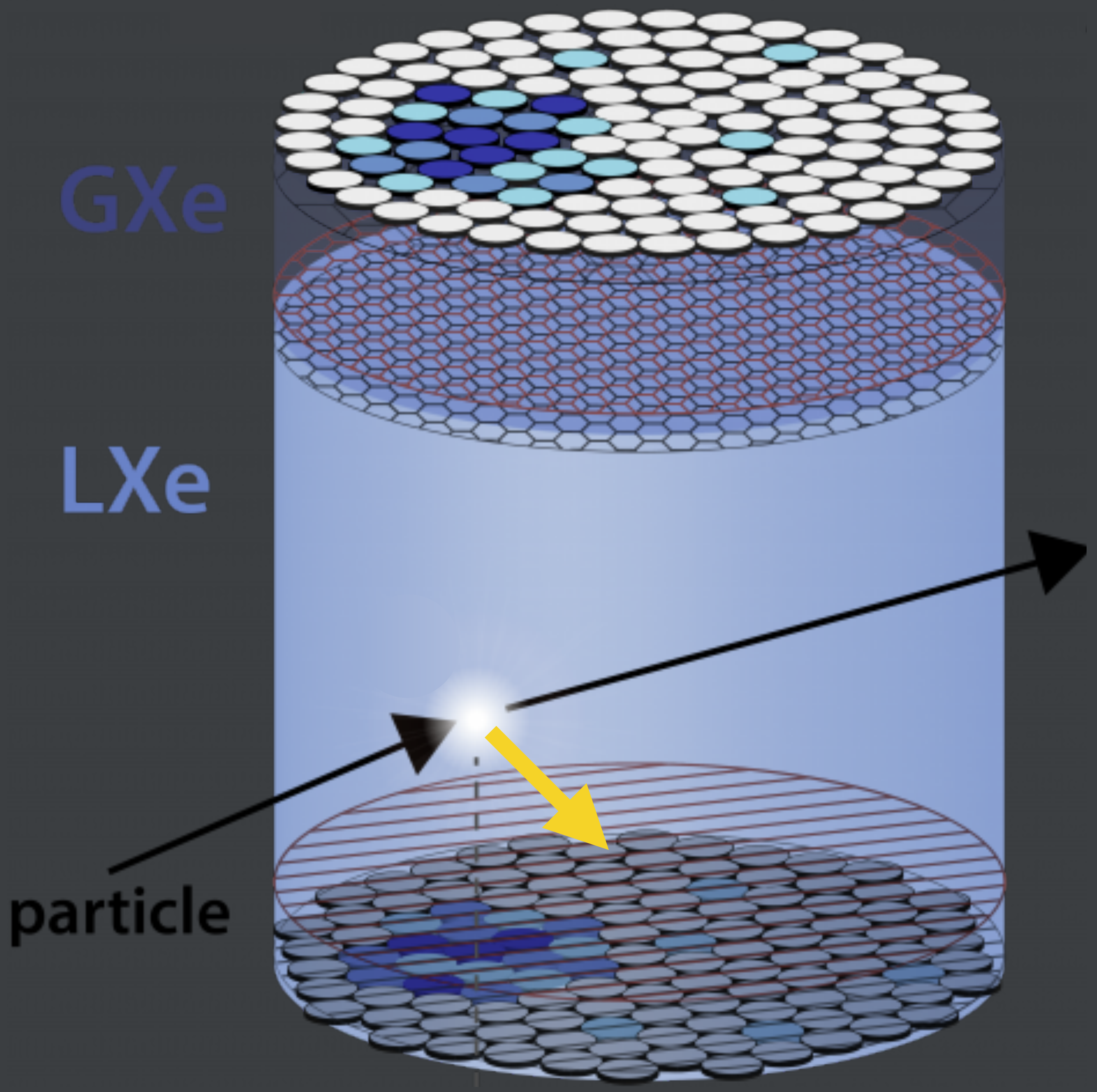


THE PRINCIPLE

XENON TWO-PHASE TIME PROJECTION CHAMBERS

TIME

S1+S2 MODE

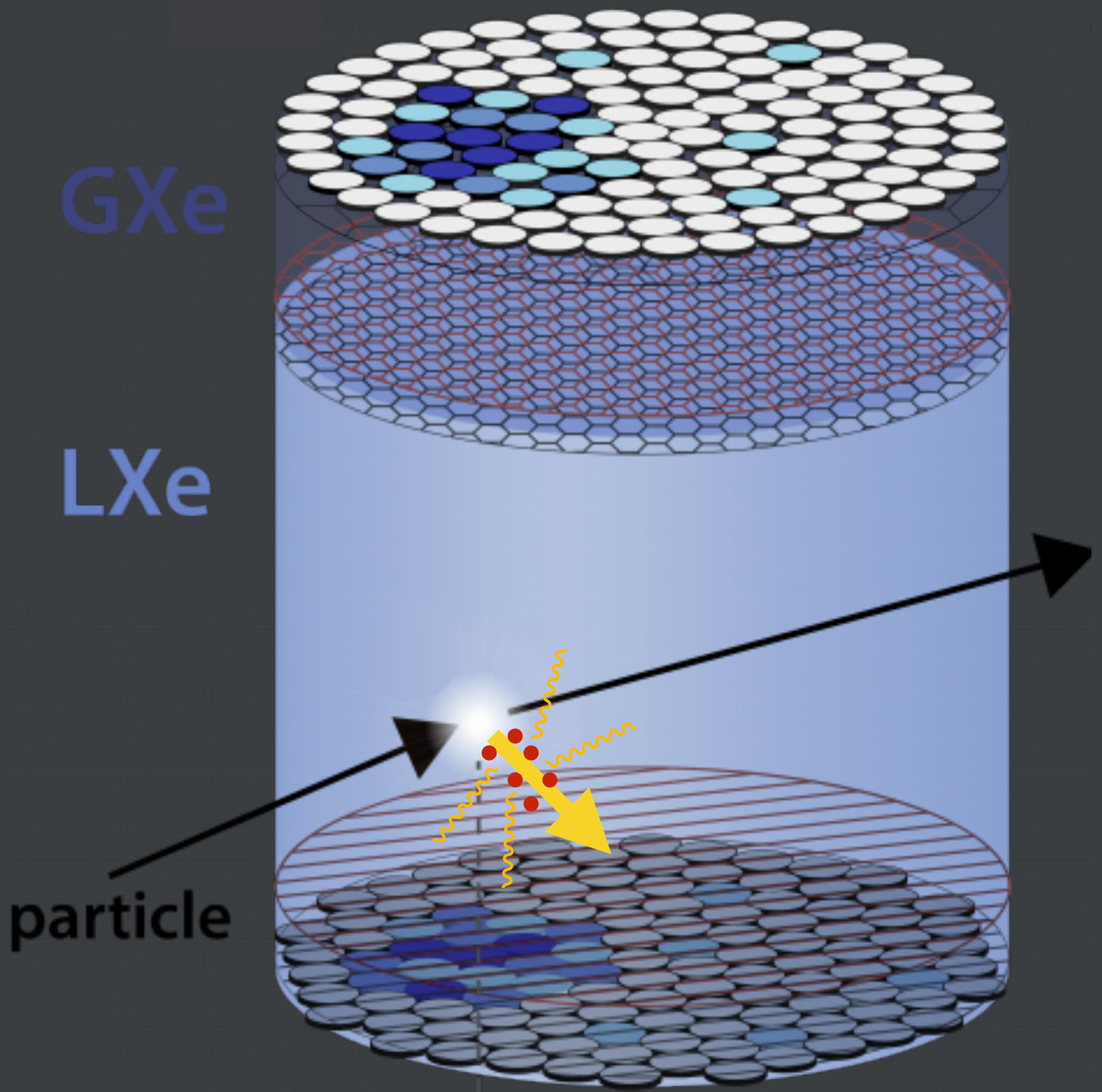


THE PRINCIPLE

XENON TWO-PHASE TIME PROJECTION CHAMBERS

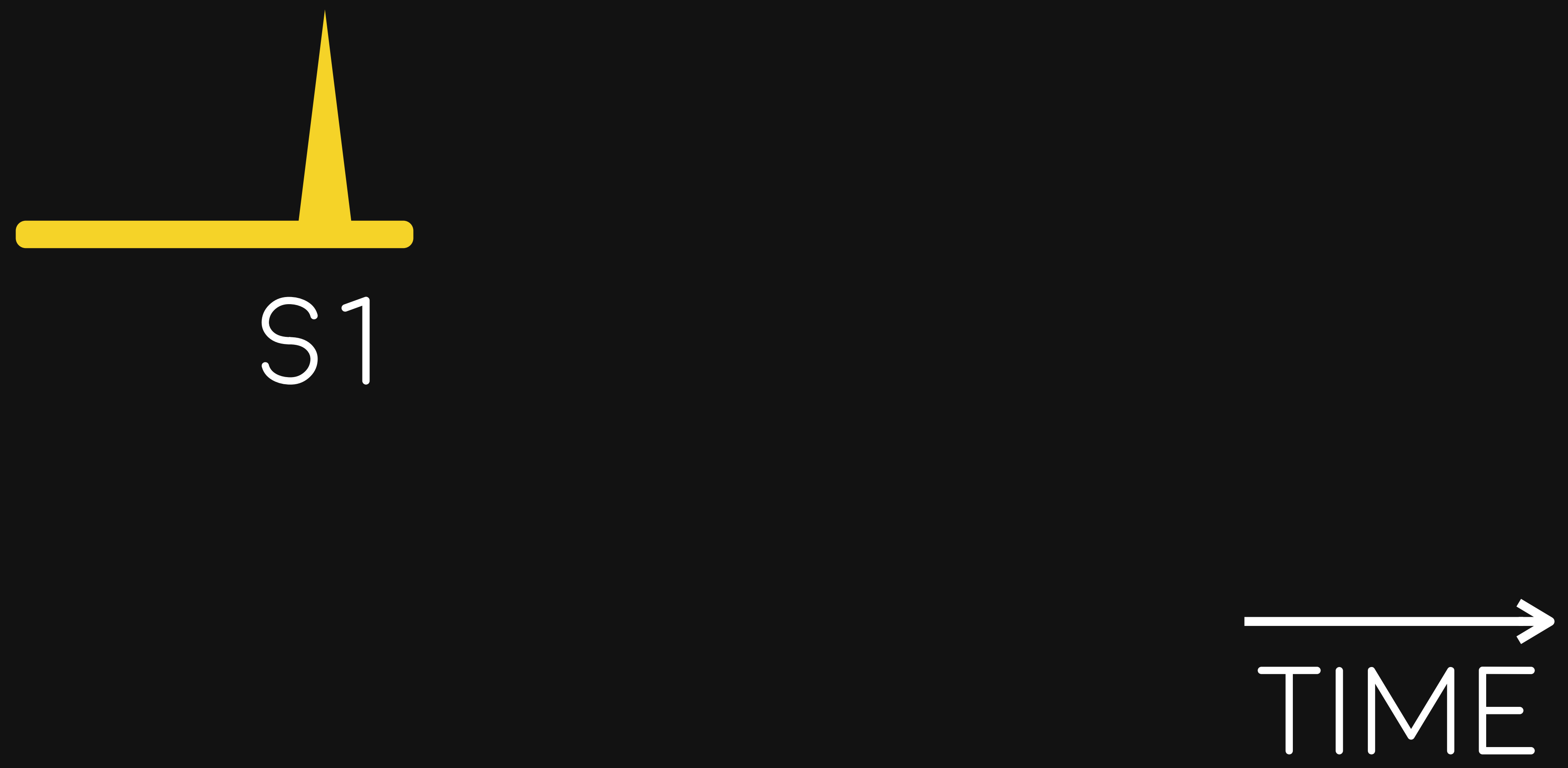
TIME

S1+S2 MODE

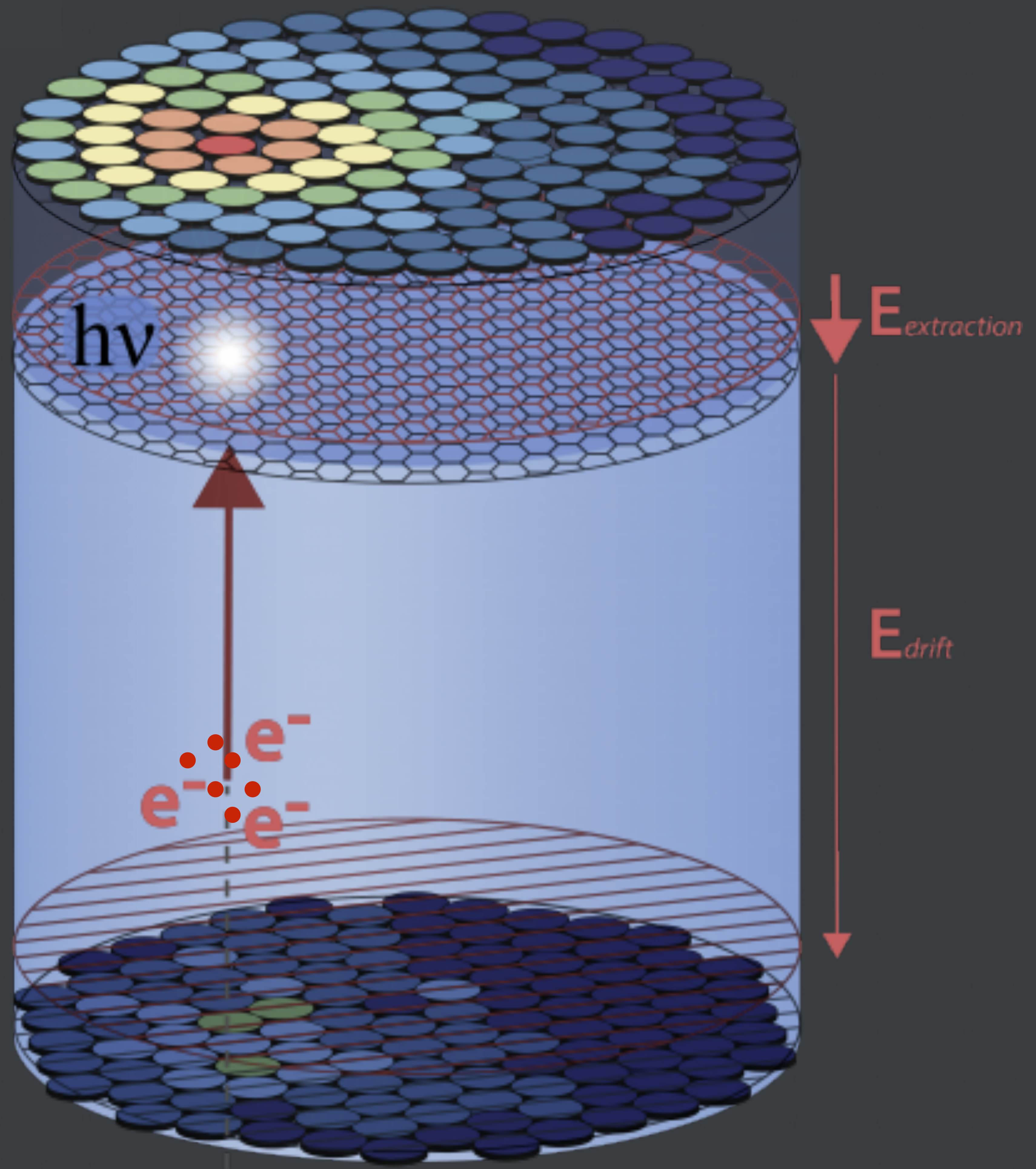


THE PRINCIPLE

XENON TWO-PHASE TIME PROJECTION CHAMBERS



S1+S2 MODE

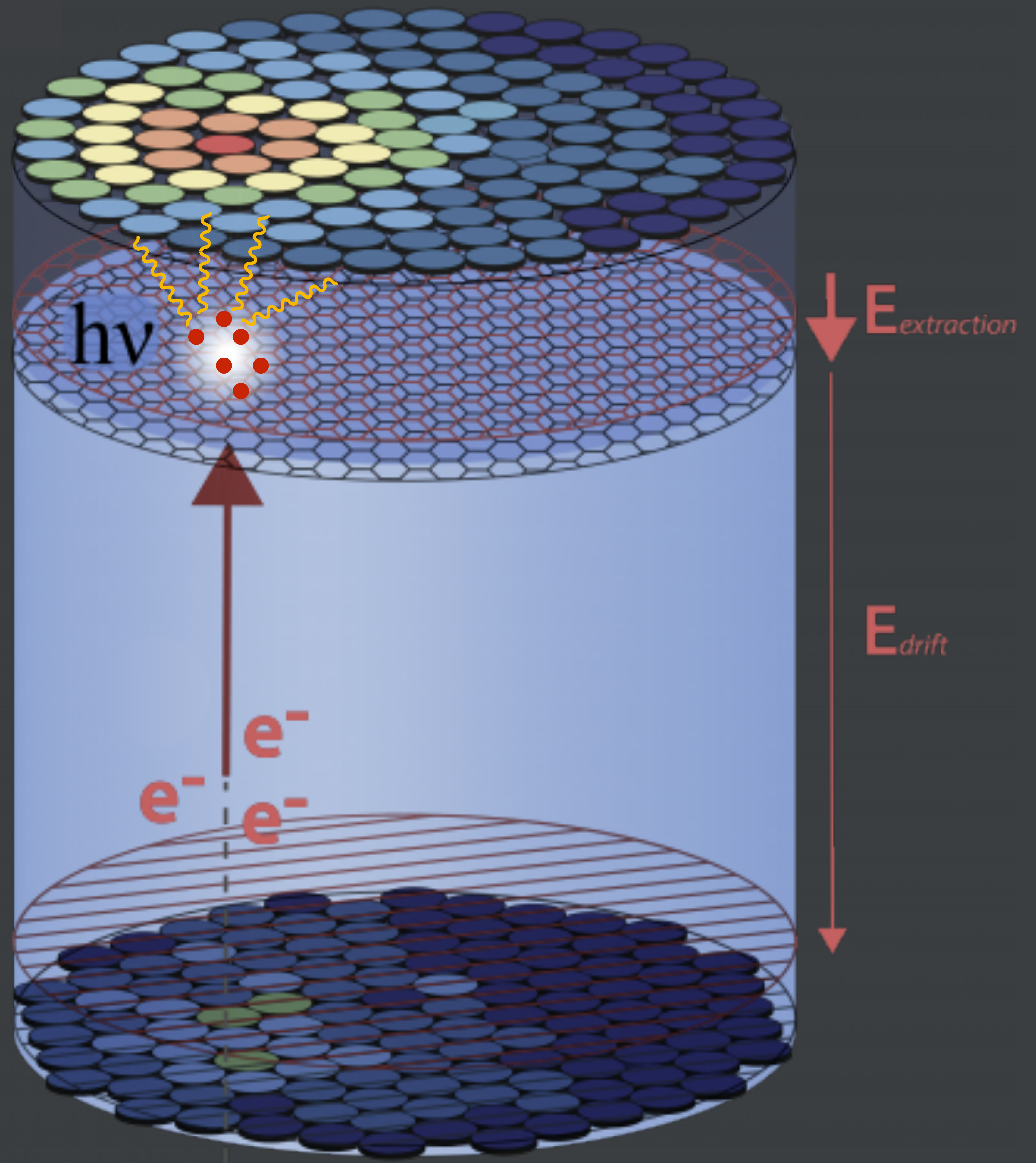


THE PRINCIPLE

XENON TWO-PHASE TIME PROJECTION CHAMBERS

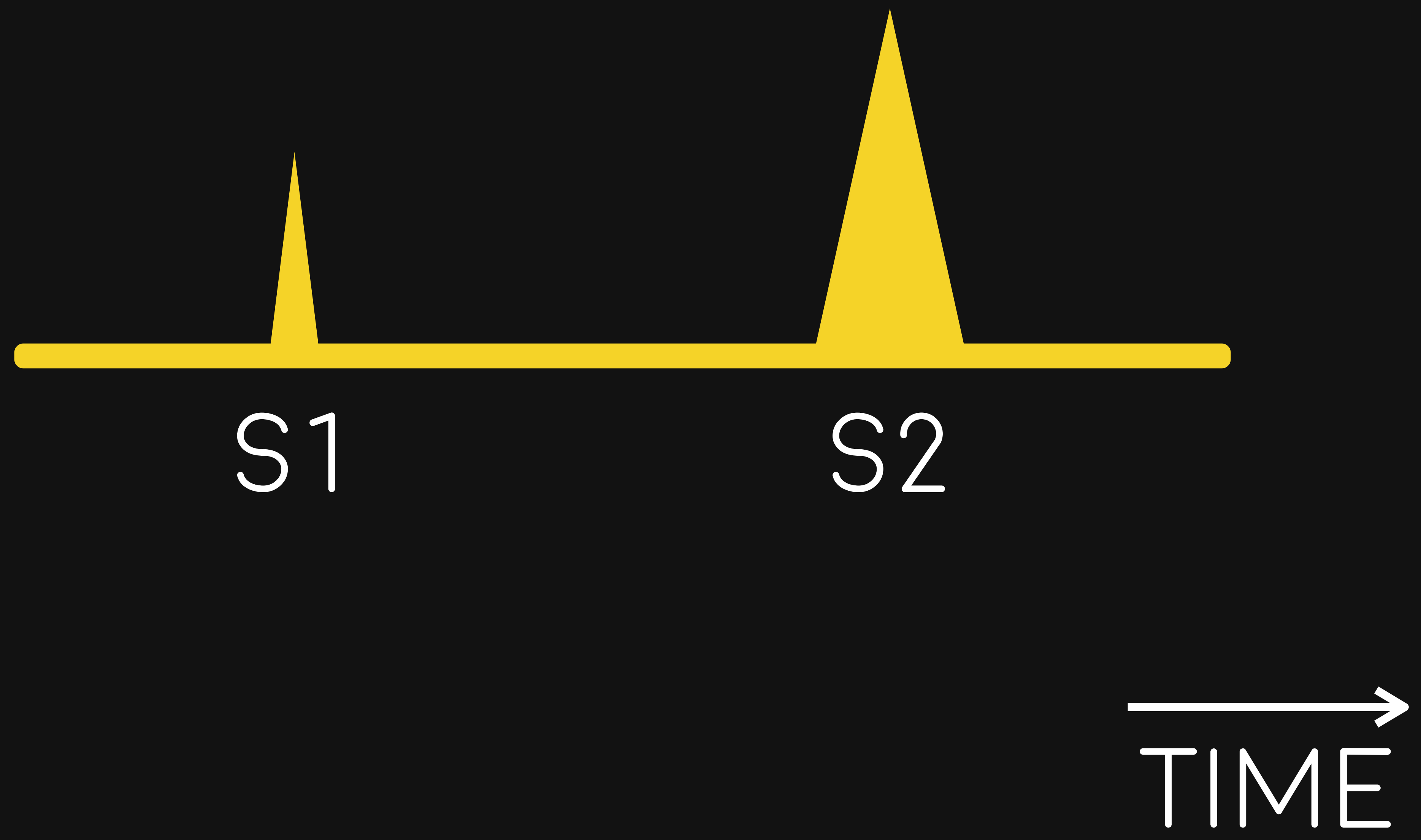
TIME

S1+S2 MODE

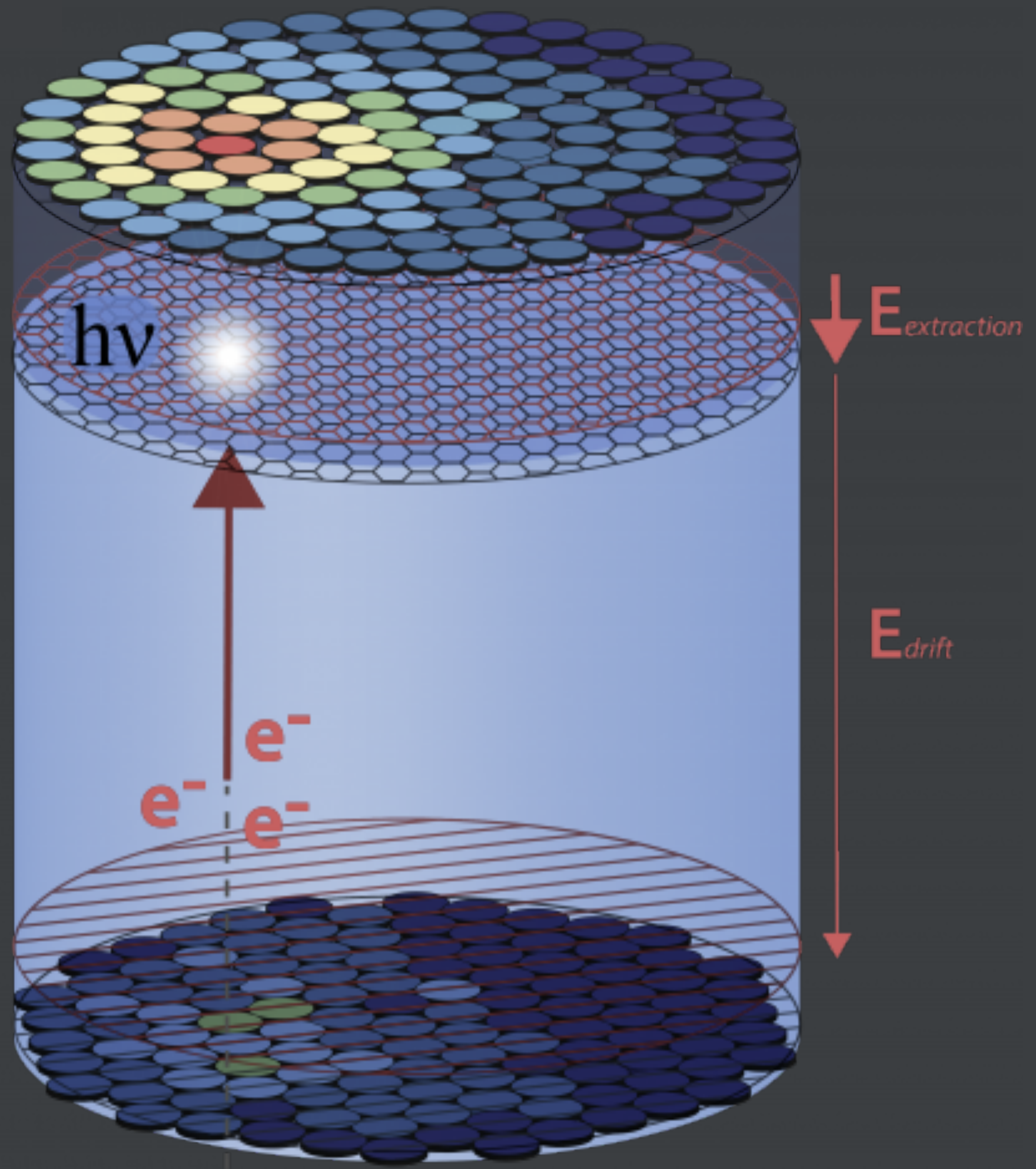


THE PRINCIPLE

XENON TWO-PHASE TIME PROJECTION CHAMBERS



S1+S2 MODE

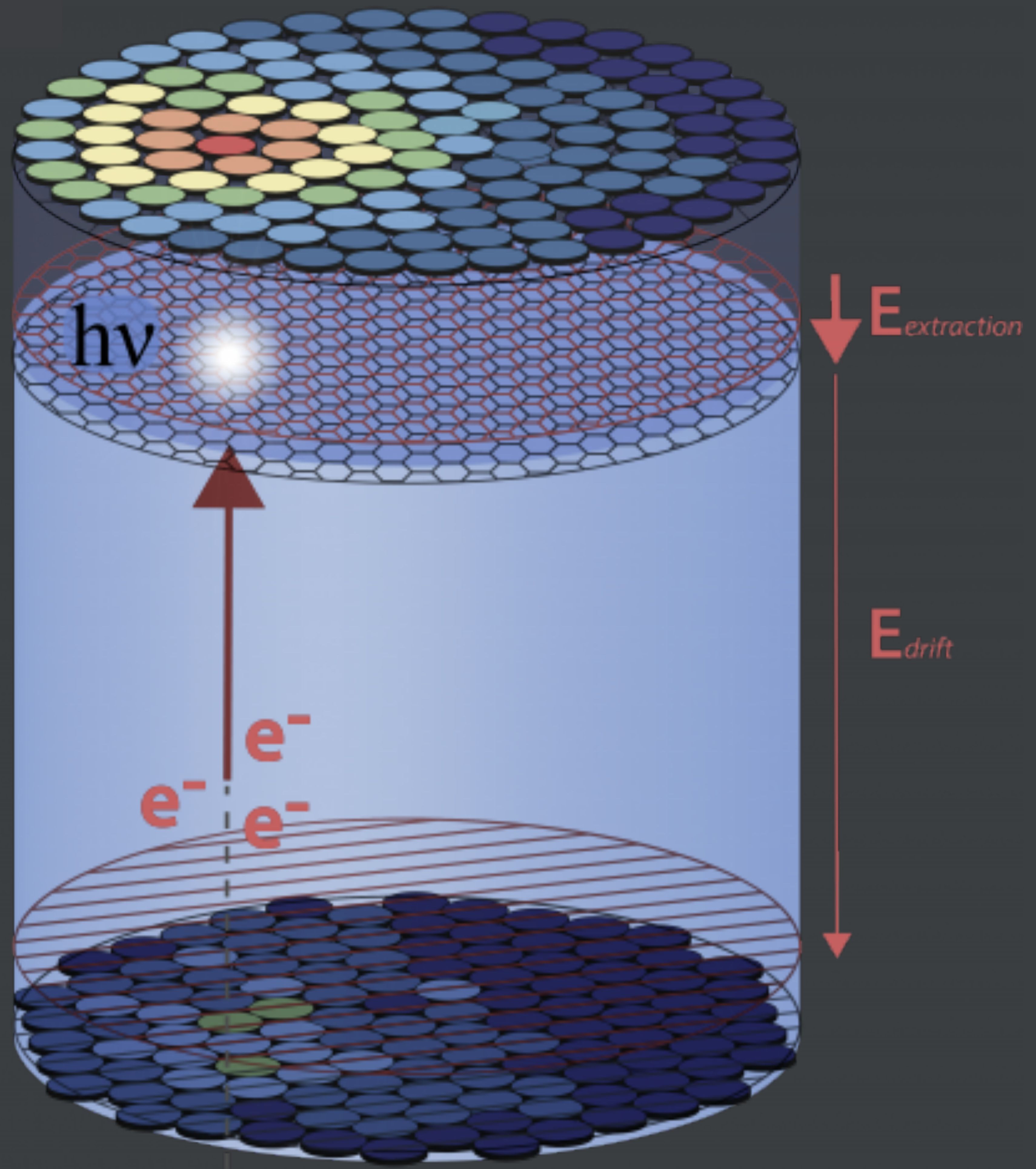


THE PRINCIPLE

SIMULTANEOUS MEASUREMENT OF IONIZATION & EXCITATION CHANNELS

FULL 3D POSITION RECONSTRUCTION

S1+S2 MODE



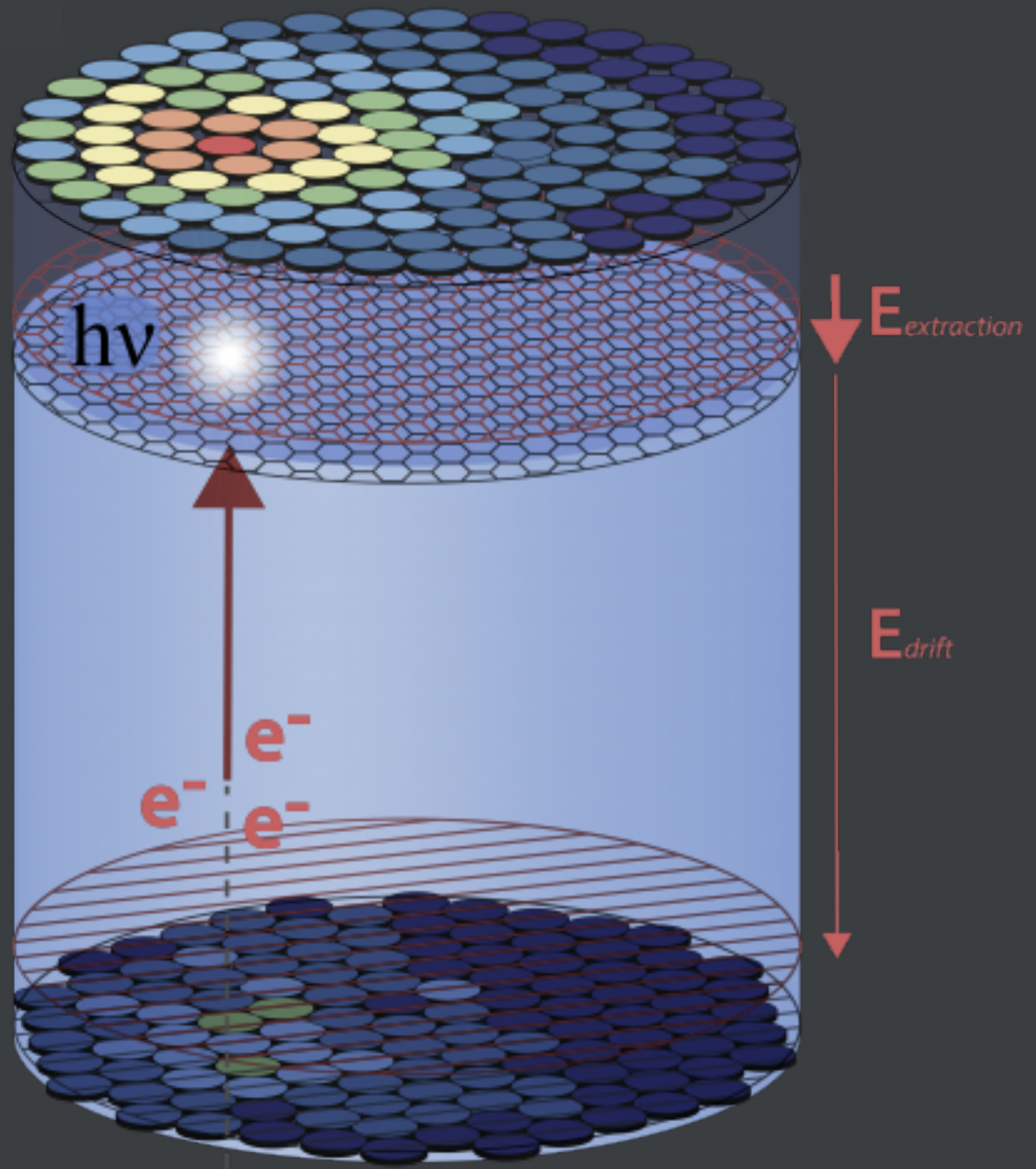
THE PRINCIPLE

SIMULTANEOUS MEASUREMENT OF IONIZATION & EXCITATION CHANNELS

FULL 3D POSITION RECONSTRUCTION

SPECTROSCOPIC CAPABILITIES DOWN TO KEV SCALE

S1+S2 MODE



THE PRINCIPLE

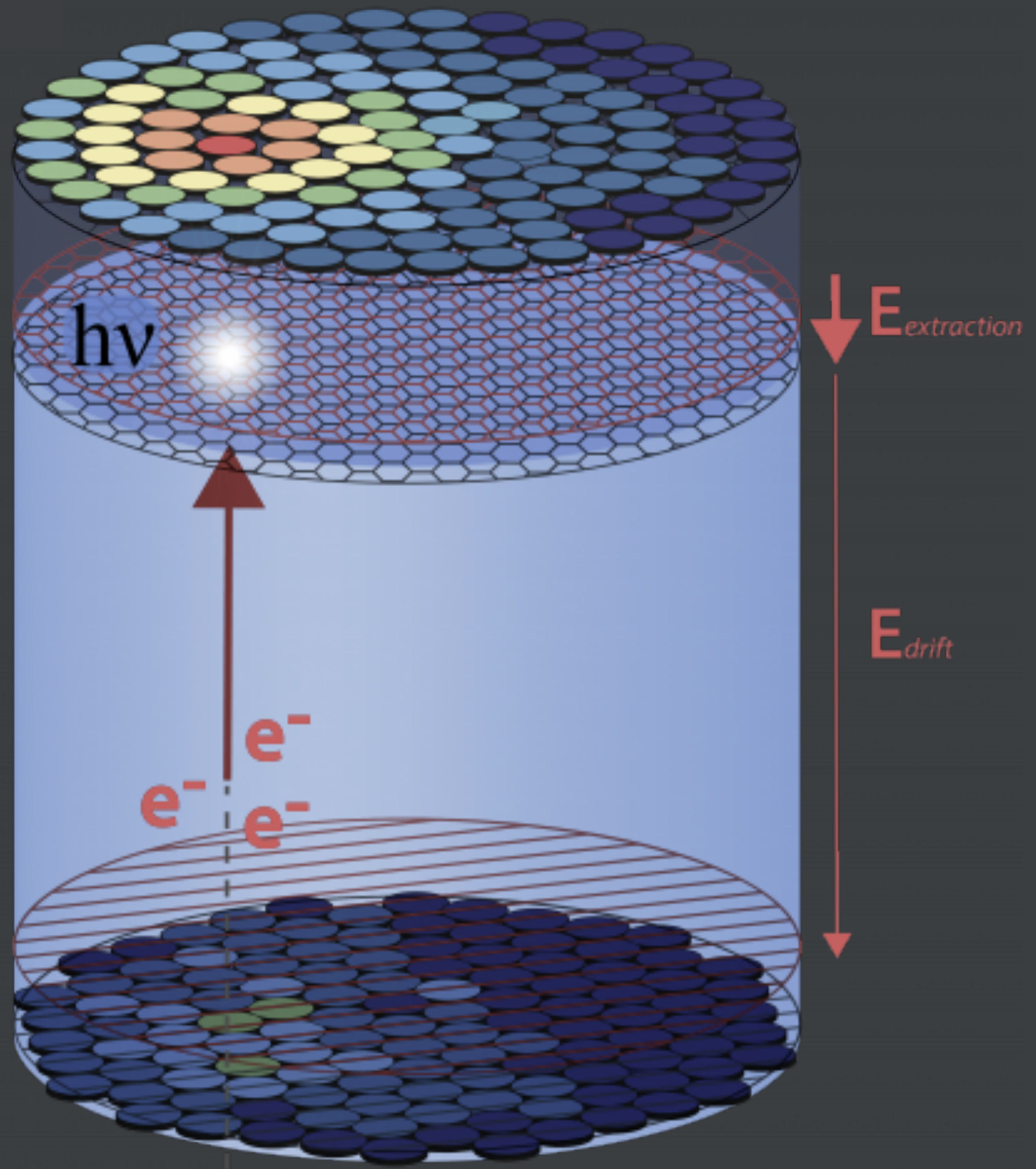
SIMULTANEOUS MEASUREMENT OF IONIZATION & EXCITATION CHANNELS

FULL 3D POSITION RECONSTRUCTION

SPECTROSCOPIC CAPABILITIES DOWN TO KEV SCALE

EFFICIENT IDENTIFICATION OF NR VS ER

S1+S2 MODE



THE PRINCIPLE

SIMULTANEOUS MEASUREMENT OF IONIZATION & EXCITATION CHANNELS

FULL 3D POSITION RECONSTRUCTION

SPECTROSCOPIC CAPABILITIES DOWN TO KEV SCALE

EFFICIENT IDENTIFICATION OF NR VS ER

+ CAN BE IMPLEMENTED IN **MULTI-TON** & **"EASY" TO PURIFY** XENON TARGETS

S1+S2 MODE

IDEAL FOR WIMP SEARCHES

(WITH MASS DOWN TO FEW GEV/C^2)

(VIA NUCLEUS SCATTERING)

SIMULTANEOUS MEASUREMENT OF IONIZATION & EXCITATION CHANNELS

- FULL 3D POSITION RECONSTRUCTION
- SPECTROSCOPIC CAPABILITIES DOWN TO KEV SCALE
- EFFICIENT IDENTIFICATION OF NR VS ER

+ CAN BE IMPLEMENTED IN MULTI-TON & "EASY" TO PURIFY XENON TARGETS

S1+S2 MODE

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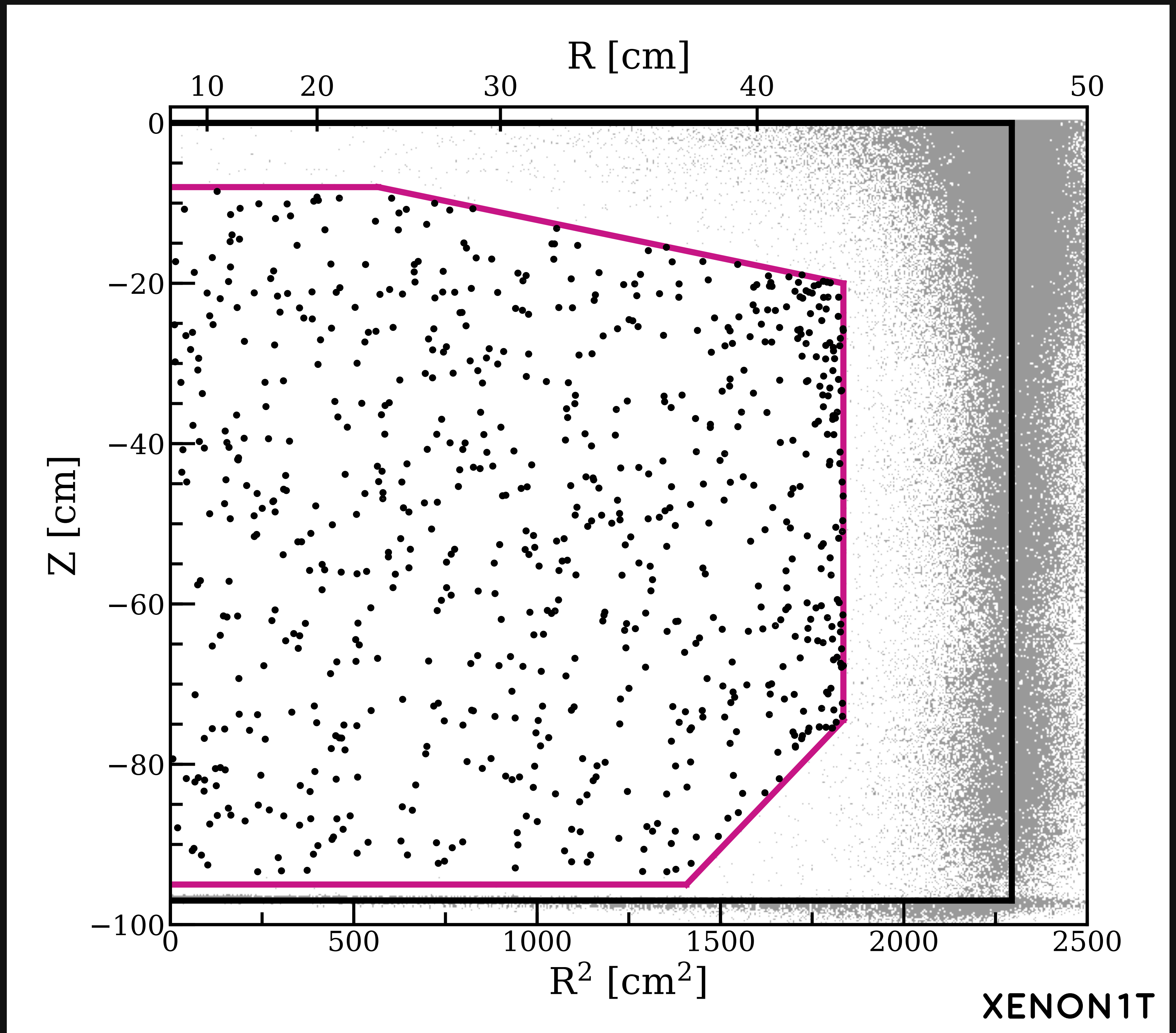

FIDUCIALIZATION

FULL 3D POSITION RECONSTRUCTION

SPECTROSCOPIC CAPABILITIES DOWN TO KEV SCALE

EFFICIENT IDENTIFICATION OF NR VS ER

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& "EASY" TO PURIFY XENON TARGETS

S1+S2 MODE

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(WITH MASS DOWN TO FEW GEV/C²)

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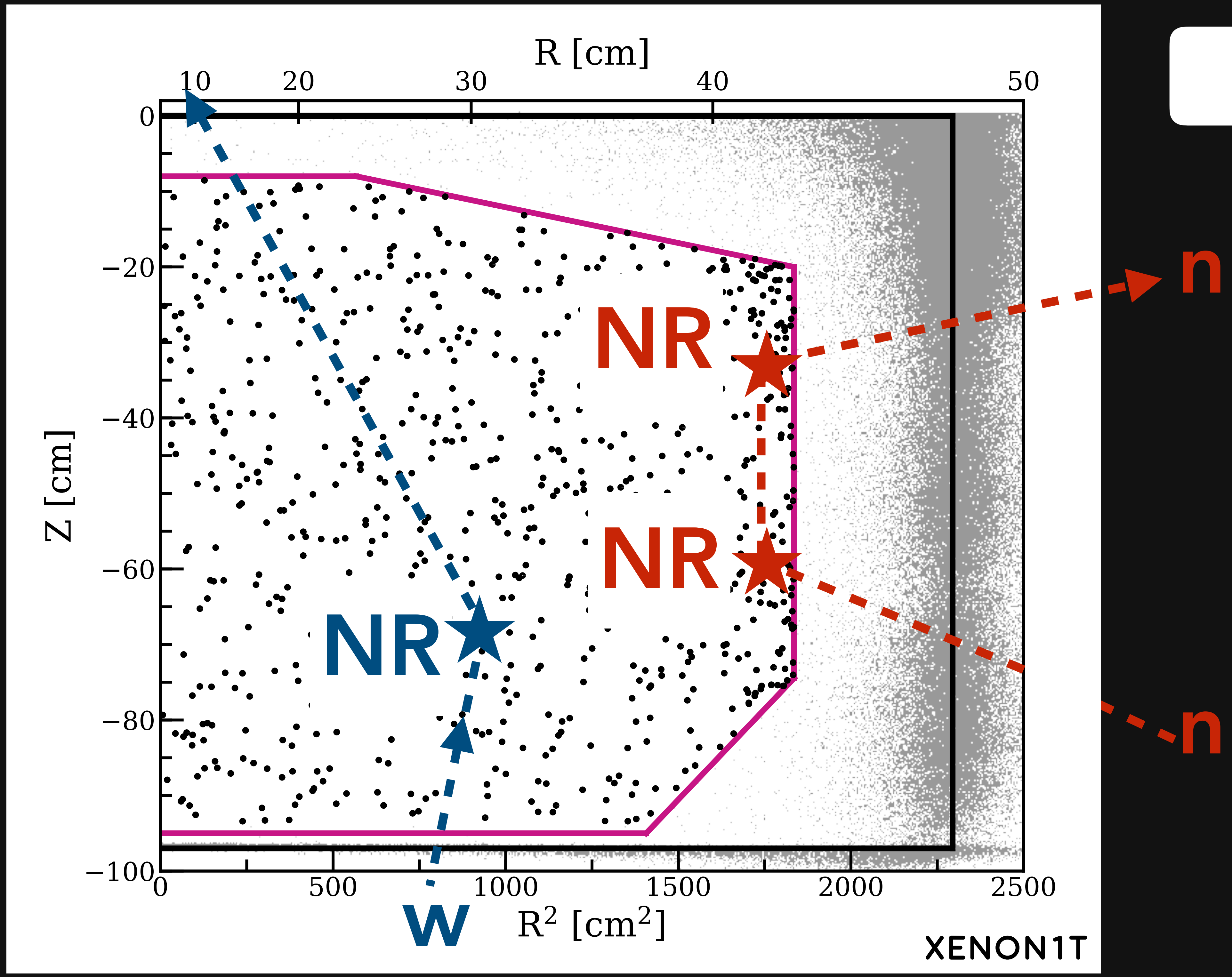
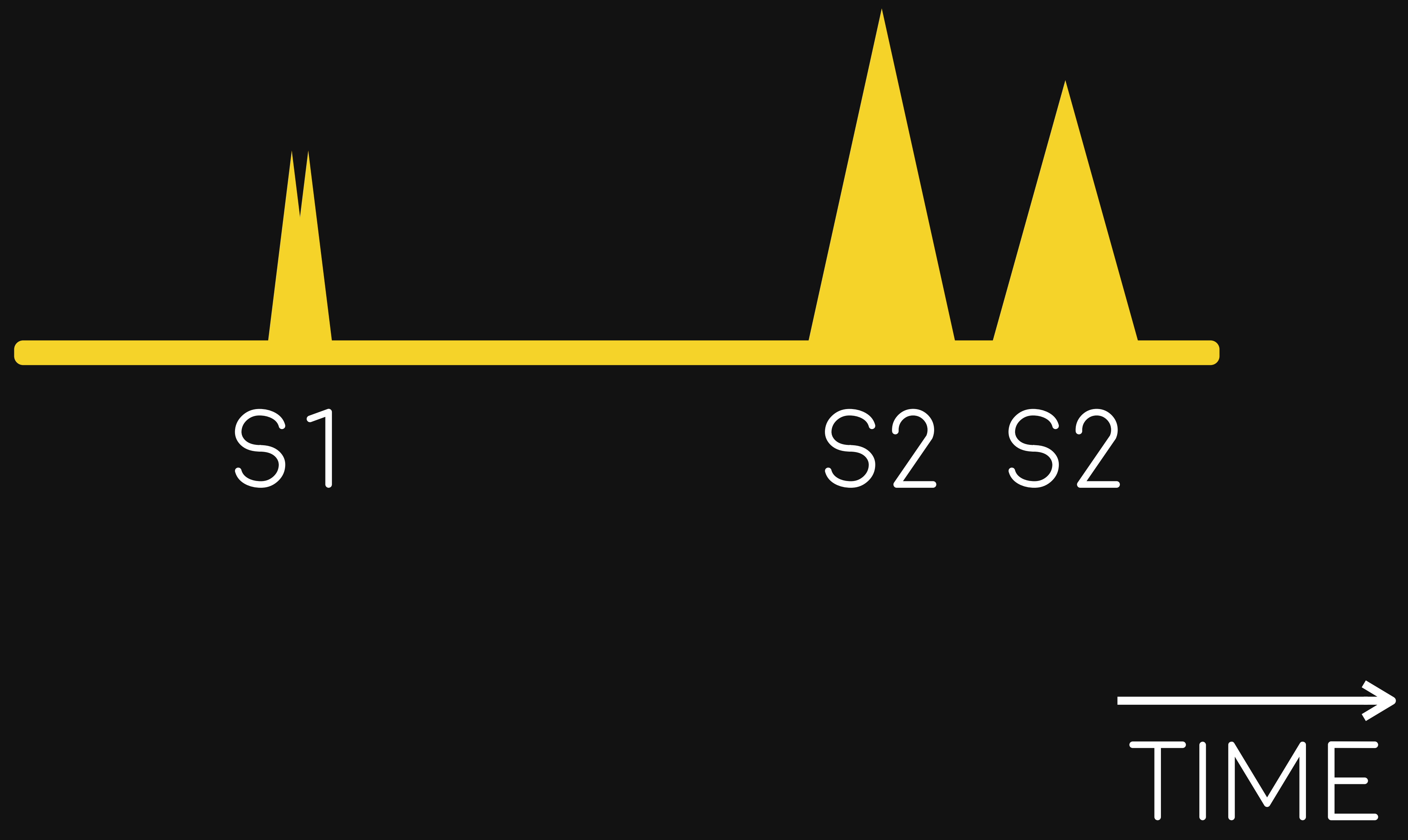


FIDUCIALIZATION & MULTI-HIT IDENTIFICATION



S1+S2 MODE

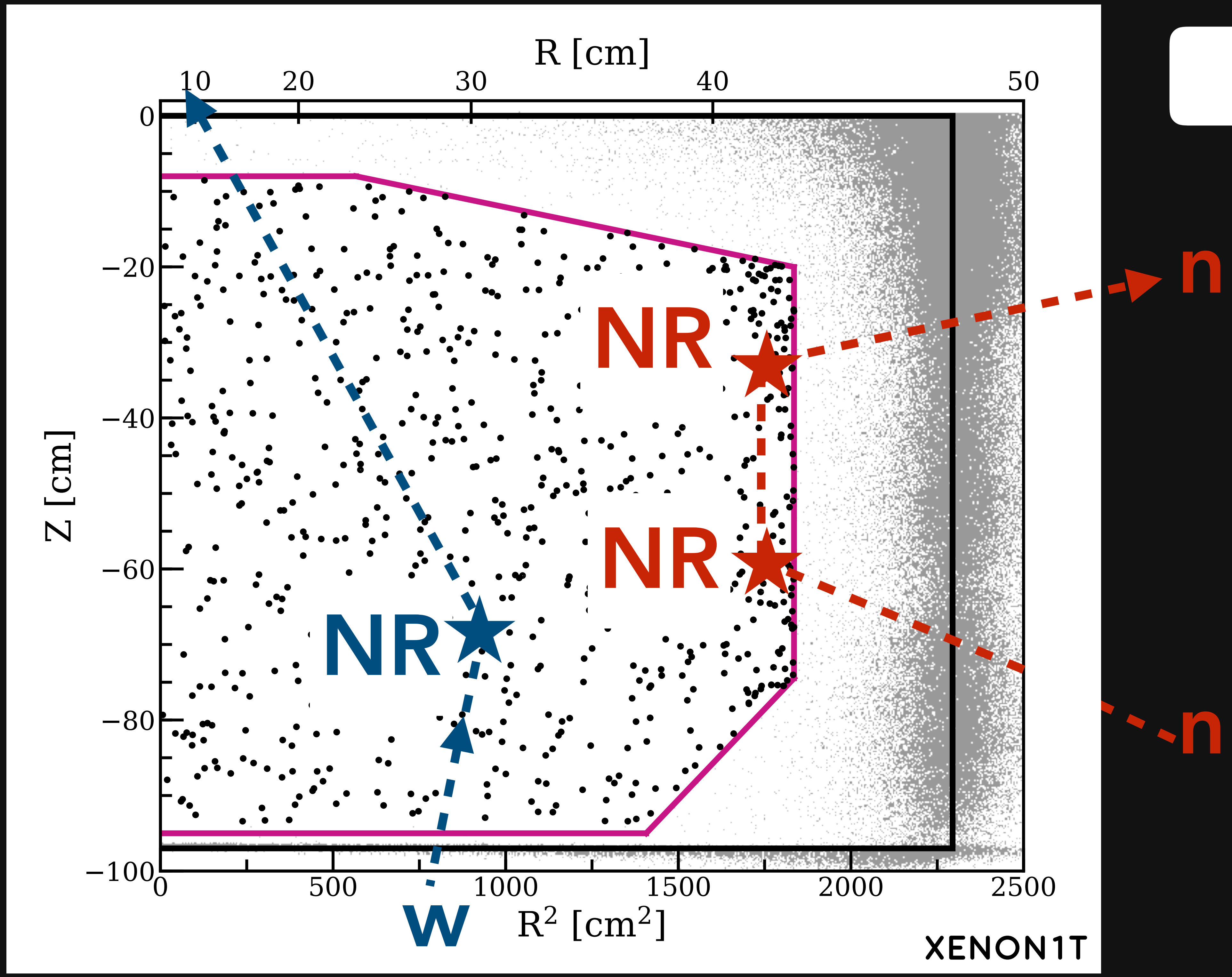
IDEAL FOR WIMP SEARCHES

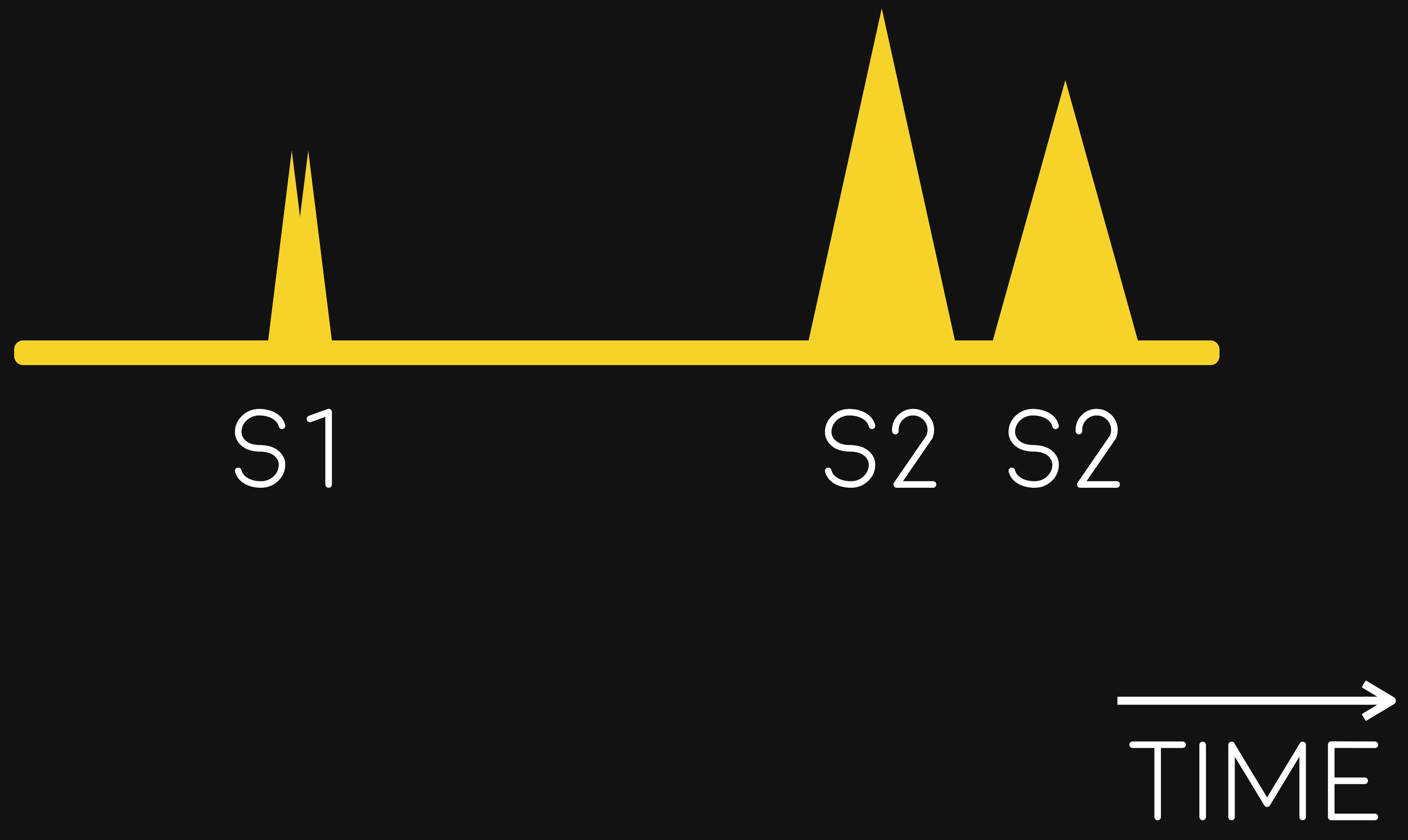
(WITH MASS DOWN TO FEW GEV/C²)

(VIA NUCLEUS SCATTERING)

FIDUCIALIZATION → BACKGROUND SUPPRESSION

- GAMMA- AND BETA-INDUCED EVENTS FROM DETECTOR MATERIALS (ER)
- NEUTRON-INDUCED EVENTS FROM DETECTOR MATERIALS (NR)



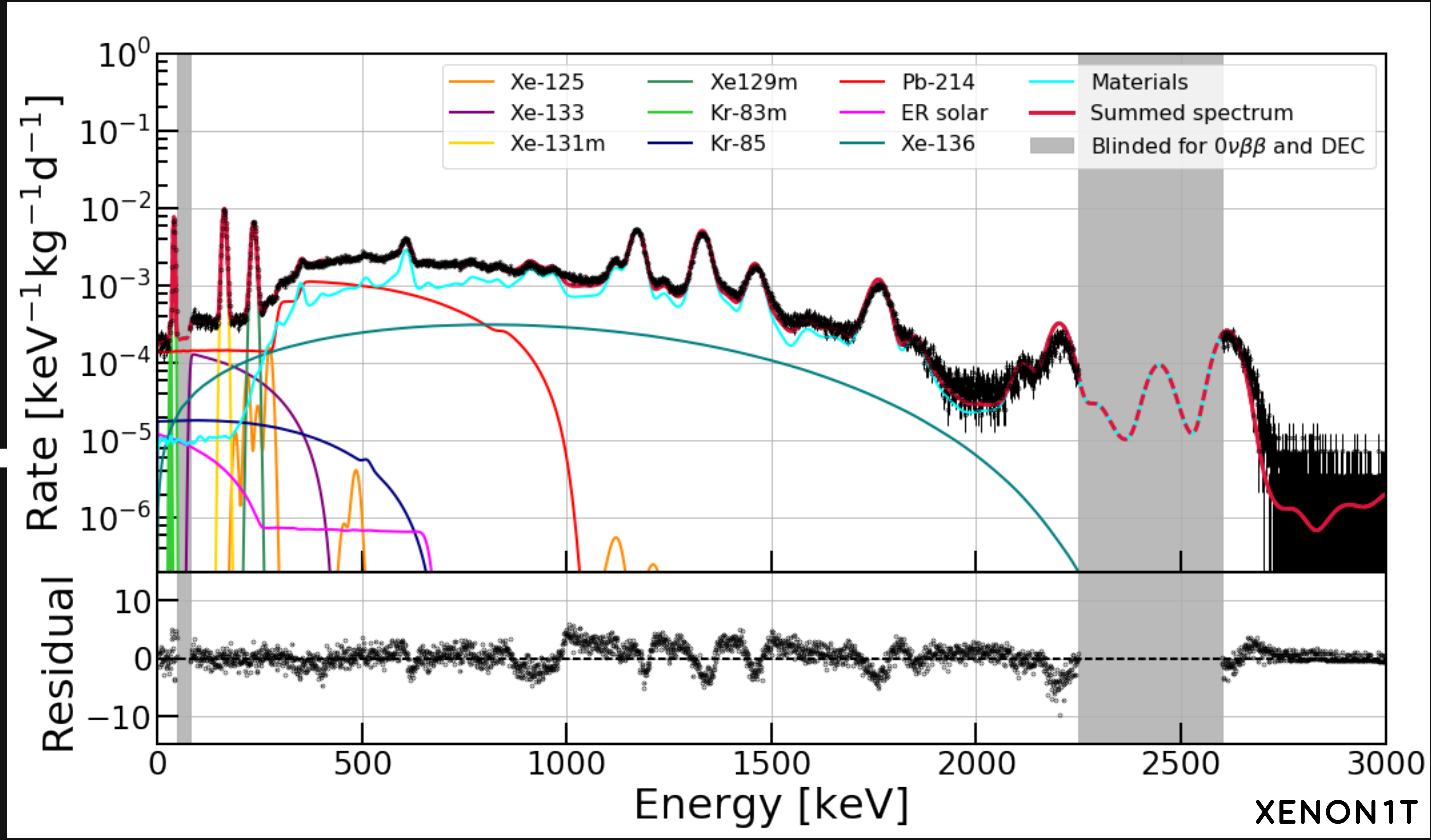


S1+S2 MODE

IDEAL FOR WIMP SEARCHES

(WITH MASS DOWN TO FEW GEV/C²)

(VIA NUCLEUS SCATTERING)



FIDUCIALIZATION → BACKGROUND SUPPRESSION

FULL 3D POSITION RECONSTRUCTION

SPECTROSCOPIC CAPABILITIES DOWN TO KEV SCALE

EFFICIENT IDENTIFICATION OF NR VS ER

+ CAN BE IMPLEMENTED IN MULTI-TON & "EASY" TO PURIFY XENON TARGETS

S1+S2 MODE

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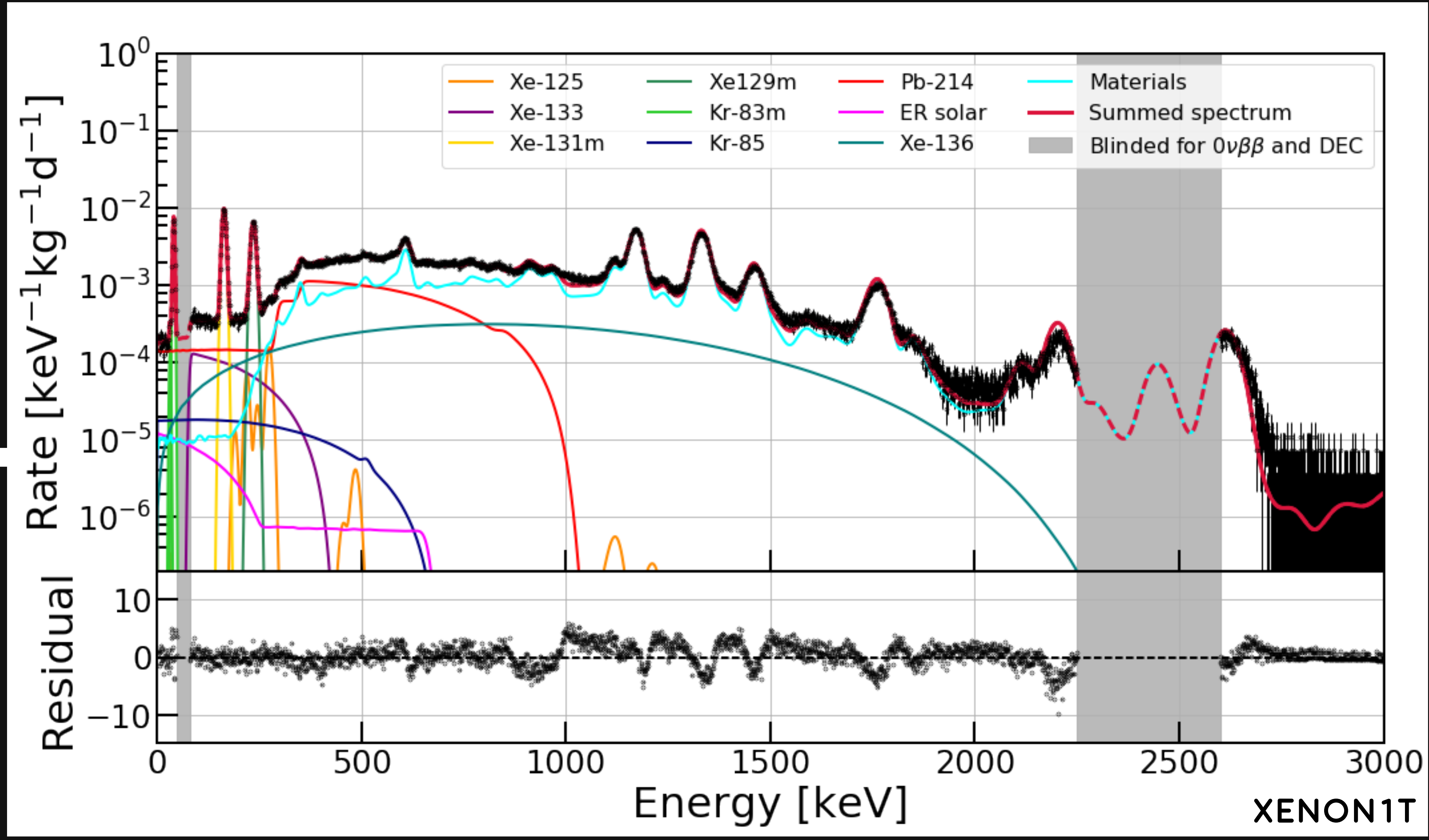
(WITH MASS DOWN TO FEW GEV/C²)

(VIA NUCLEUS SCATTERING)



FIDUCIALIZATION → BACKGROUND SUPPRESSION

FULL 3D POSITION RECONSTRUCTION

LOW ENERGY THRESHOLD

- 2 OR 3-FOLD-COINCIDENCE ON S1
- SENSITIVITY TO 1 e^- ON S2

THRESHOLD OF ABOUT 2 keV_{ee}

SPECTROSCOPIC CAPABILITIES DOWN TO KEV SCALE

EFFICIENT IDENTIFICATION OF NR VS ER

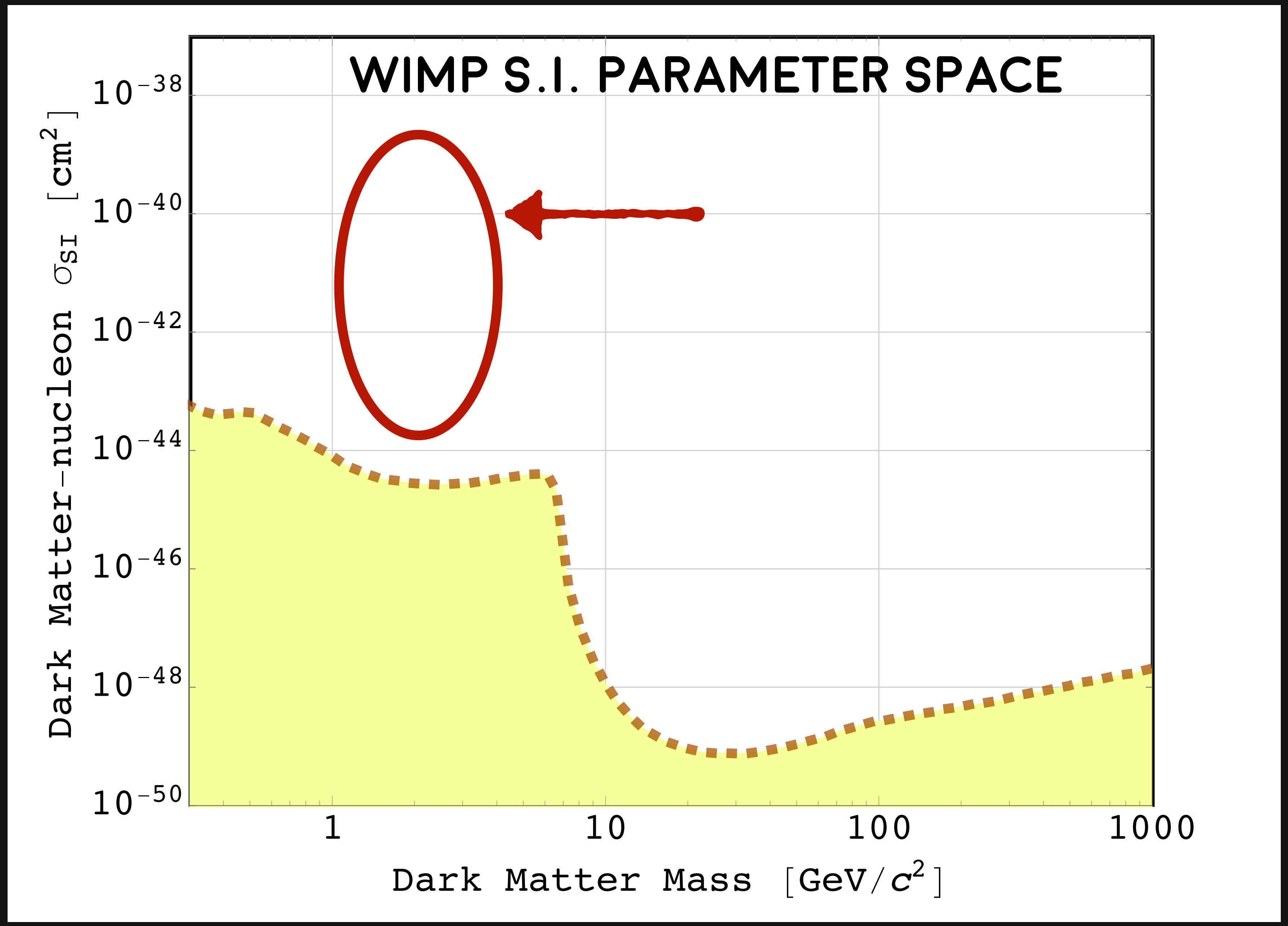
+ CAN BE IMPLEMENTED IN MULTI-TON & "EASY" TO PURIFY XENON TARGETS

S1+S2 MODE

IDEAL FOR WIMP SEARCHES

(WITH MASS DOWN TO FEW GEV/C²)

(VIA NUCLEUS SCATTERING)



FIDUCIALIZATION → BACKGROUND SUPPRESSION

FULL 3D POSITION RECONSTRUCTION

LOW ENERGY THRESHOLD → SENSITIVITY ↑

- 2 OR 3-FOLD-COINCIDENCE ON S1
- SENSITIVITY TO 1 e^- ON S2

THRESHOLD OF ABOUT 2 keV_{ee}

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EFFICIENT IDENTIFICATION OF NR VS ER

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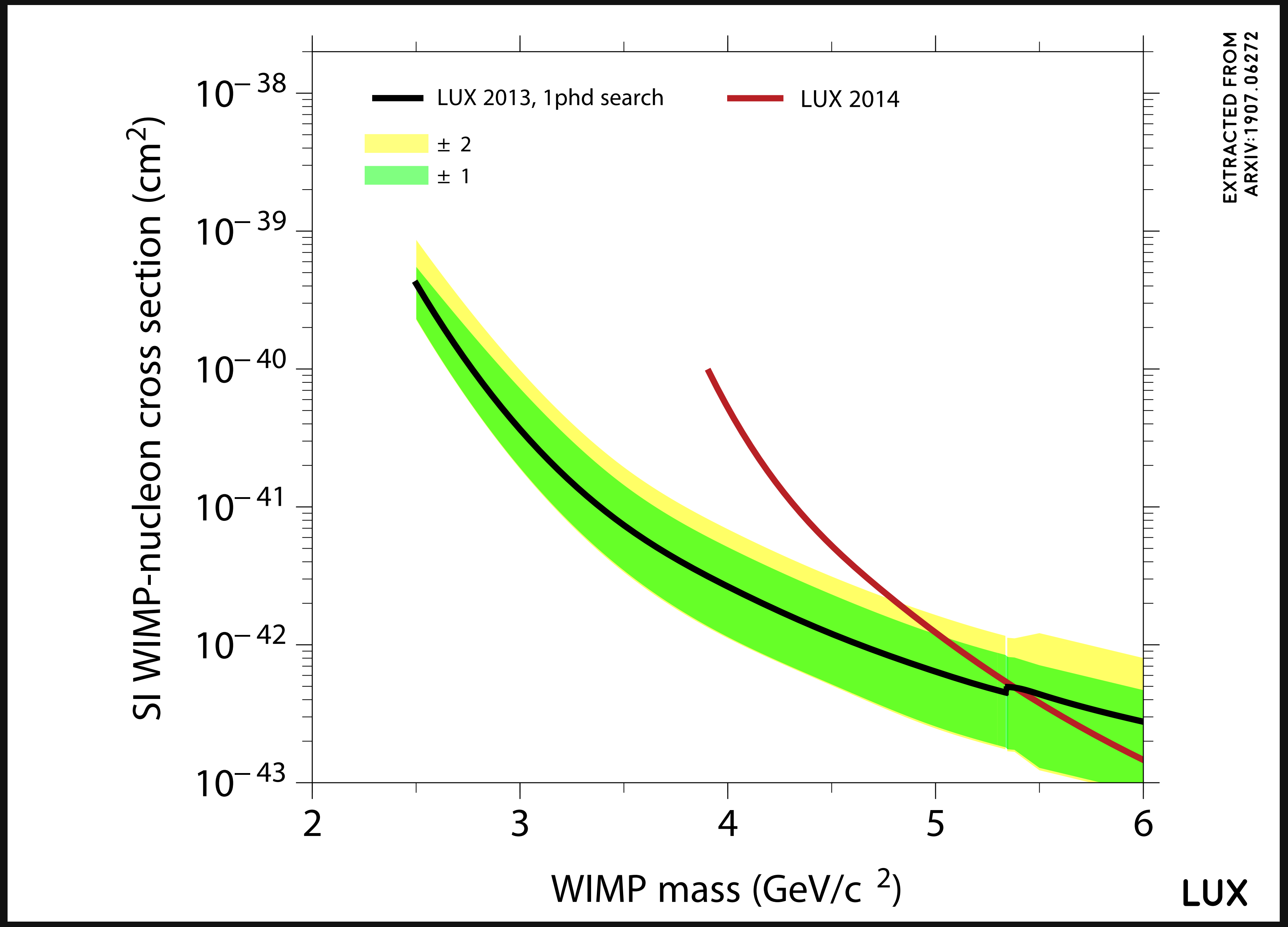
S1+S2 MODE

IDEAL FOR WIMP SEARCHES

(WITH MASS DOWN TO FEW GEV/c^2)

(VIA NUCLEUS SCATTERING)



FIDUCIALIZATION → BACKGROUND SUPPRESSION

FULL 3D POSITION RECONSTRUCTION

LOW ENERGY THRESHOLD → SENSITIVITY ↑

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S1+S2 MODE

IDEAL FOR WIMP SEARCHES

(WITH MASS DOWN TO FEW GEV/C²)

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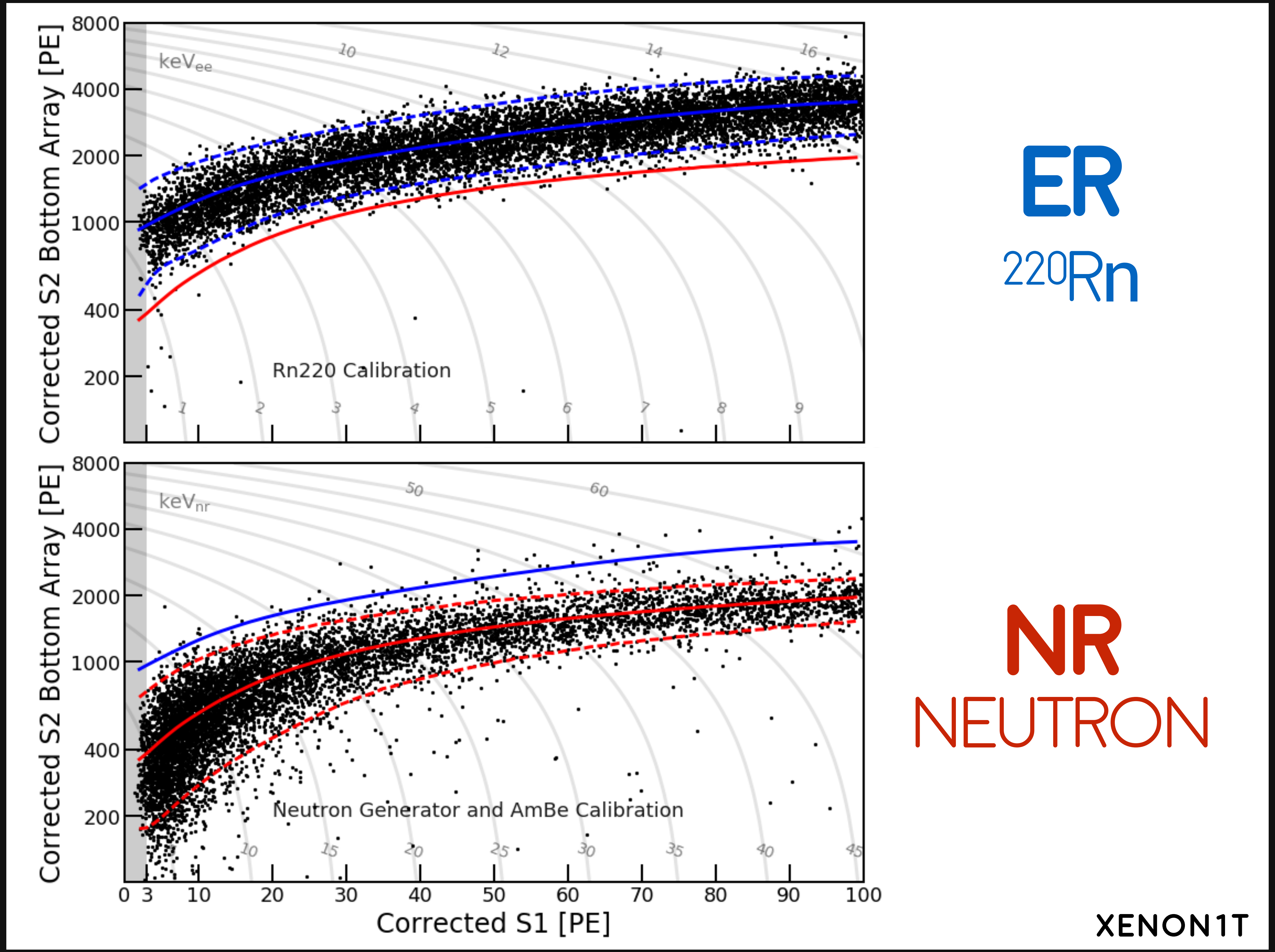


FIDUCIALIZATION → BACKGROUND SUPPRESSION

FULL 3D POSITION RECONSTRUCTION

LOW ENERGY THRESHOLD → SENSITIVITY ↑

SPECTROSCOPIC CAPABILITIES DOWN TO KEV SCALE

BACKGROUND SUPPRESSION

EFFICIENT IDENTIFICATION OF NR VS ER

+ CAN BE IMPLEMENTED IN MULTI-TON & "EASY" TO PURIFY XENON TARGETS

S1+S2 MODE

IDEAL FOR WIMP SEARCHES

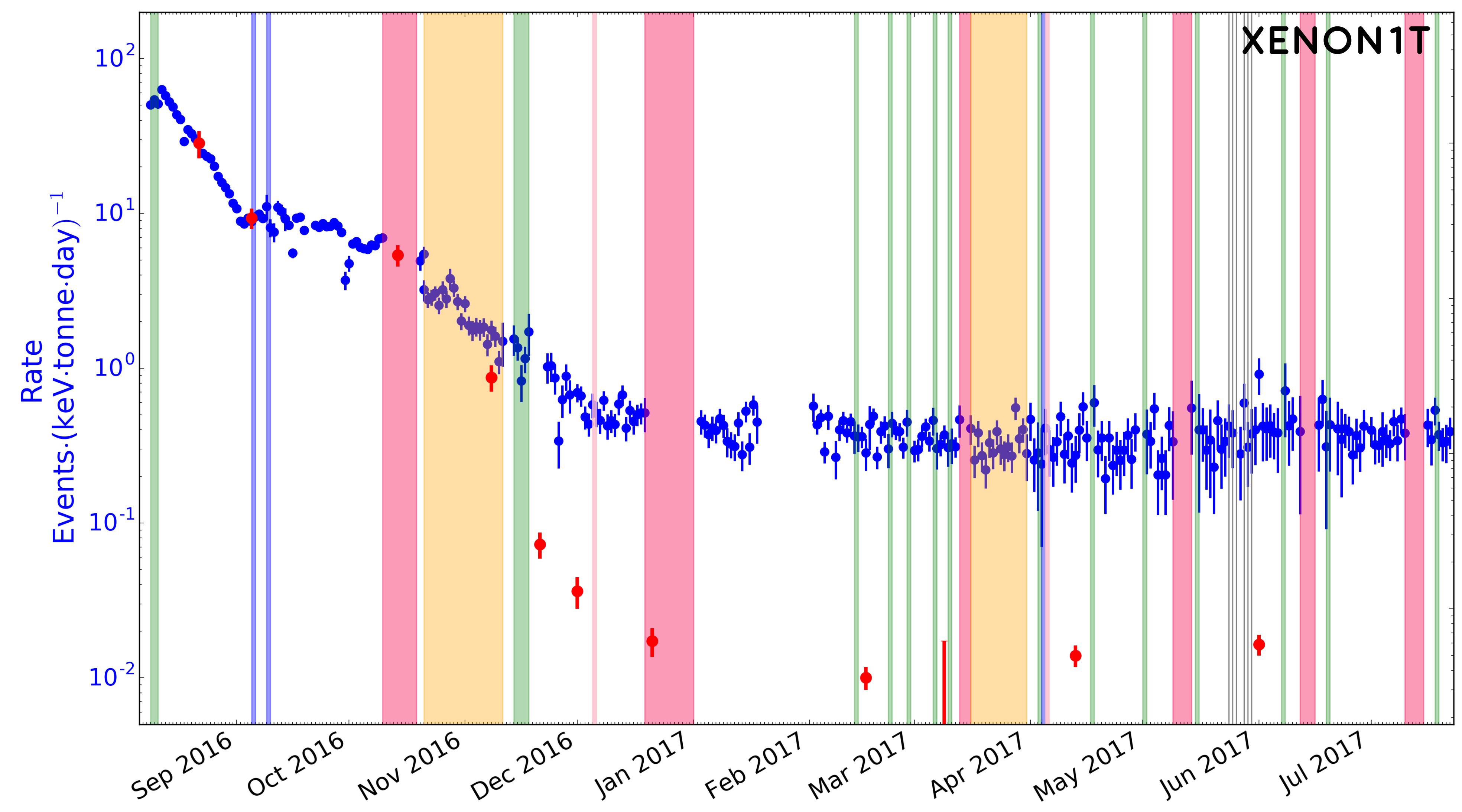
(WITH MASS DOWN TO FEW GEV/C^2)

(VIA NUCLEUS SCATTERING)

FIDUCIALIZATION → BACKGROUND SUPPRESSION

LOW ENERGY THRESHOLD → SENSITIVITY ↑

BACKGROUND SUPPRESSION



ONCE FIDUCIALIZATION IS APPLIED, THE SURVIVING BACKGROUND IS DOMINATED BY RADIOACTIVE CONTAMINANTS DIFFUSED IN THE XE GAS:

- ^{214}Pb (RADON EMANATED BY MATERIALS INTO THE GAS)
- ^{85}Kr (CONTAINED IN THE XENON GAS)

+ CAN BE IMPLEMENTED IN MULTI-TON & "EASY" TO PURIFY XENON TARGETS

S1+S2 MODE

IDEAL FOR WIMP SEARCHES

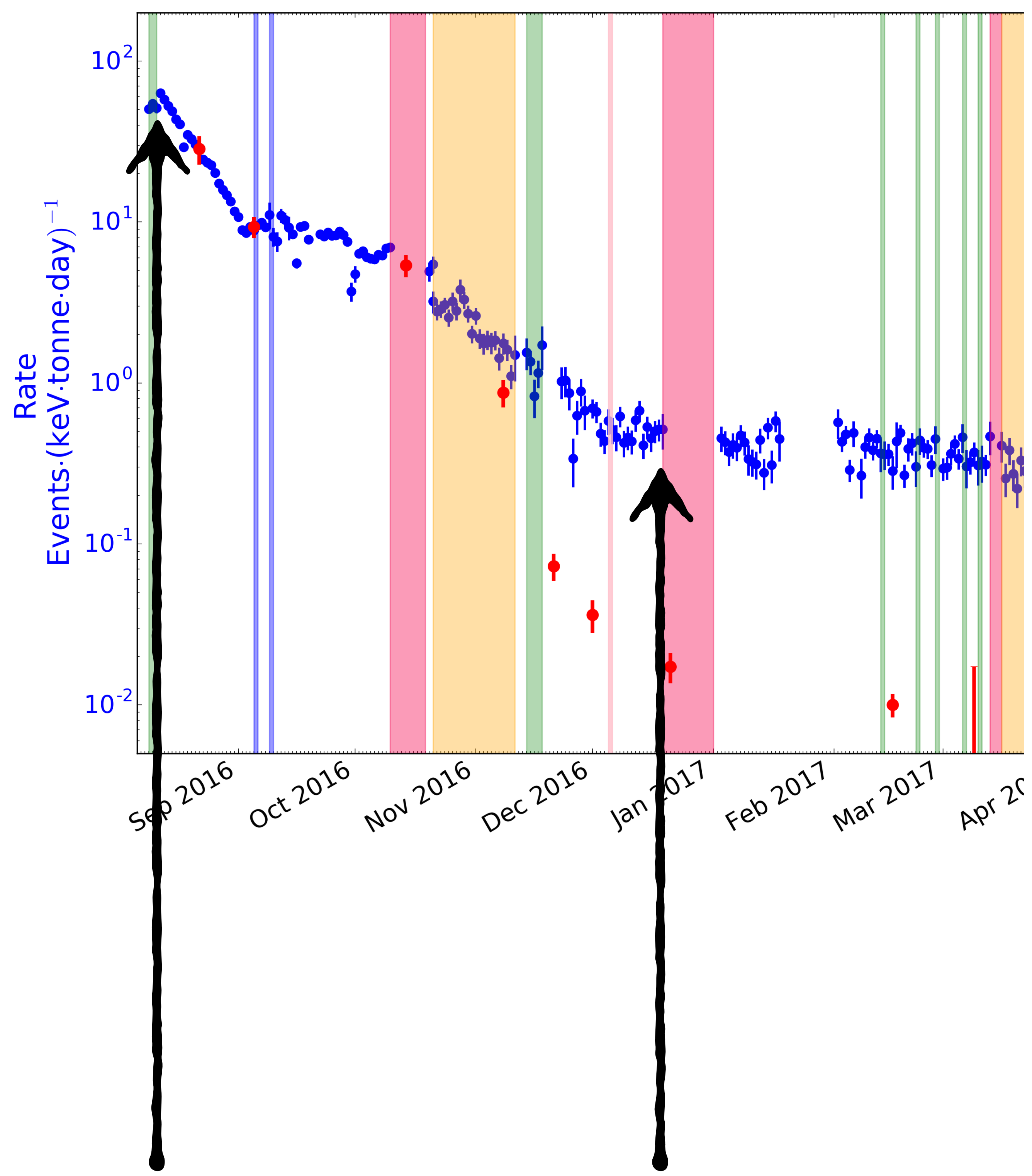
(WITH MASS DOWN TO FEW GEV/C²)

(VIA NUCLEUS SCATTERING)

FIDUCIALIZATION → BACKGROUND SUPPRESSION

LOW ENERGY THRESHOLD → SENSITIVITY ↑

BACKGROUND SUPPRESSION



ONLINE CRYOGENIC DISTILLATION COLUMN

FROM ^{nat}Kr/Xe=1ppb TO 0.66 ppt!

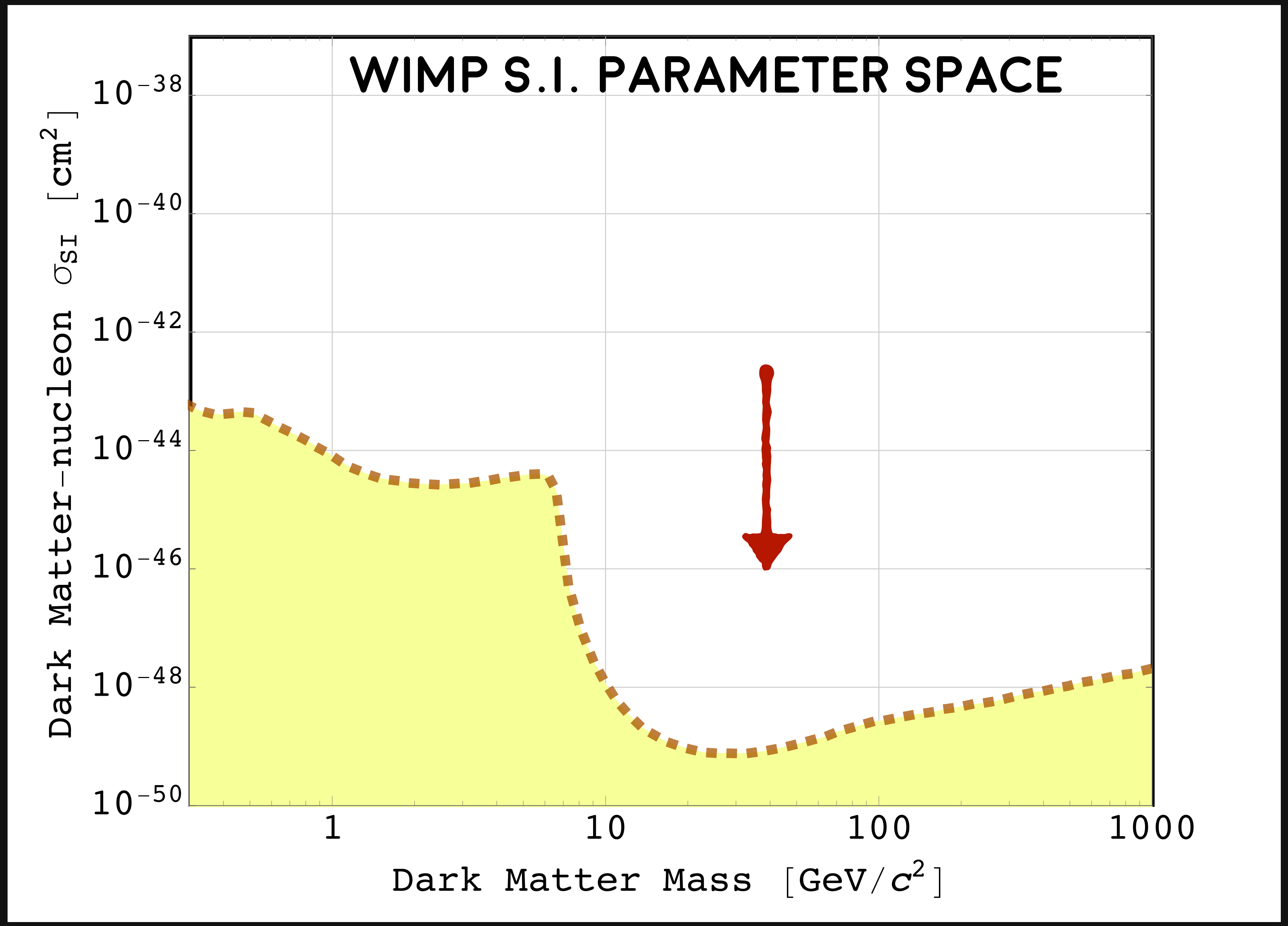
+ CAN BE IMPLEMENTED IN MULTI-TON & "EASY" TO PURIFY XENON TARGETS

S1+S2 MODE

IDEAL FOR WIMP SEARCHES

(WITH MASS DOWN TO FEW GEV/C²)

(VIA NUCLEUS SCATTERING)



FIDUCIALIZATION → BACKGROUND SUPPRESSION

FULL 3D POSITION RECONSTRUCTION

LOW ENERGY THRESHOLD → SENSITIVITY ↑

SPECTROSCOPIC CAPABILITIES DOWN TO KEV SCALE

BACKGROUND SUPPRESSION

EFFICIENT IDENTIFICATION OF NR VS ER

LARGE EXPOSURES & LOW BCK → SENSITIVITY ↑

+ CAN BE IMPLEMENTED IN MULTI-TON & "EASY" TO PURIFY XENON TARGETS

2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022

LOW-ENERGY ELECTRON RECOIL BACKGROUND IN FIDUCIAL VOLUME

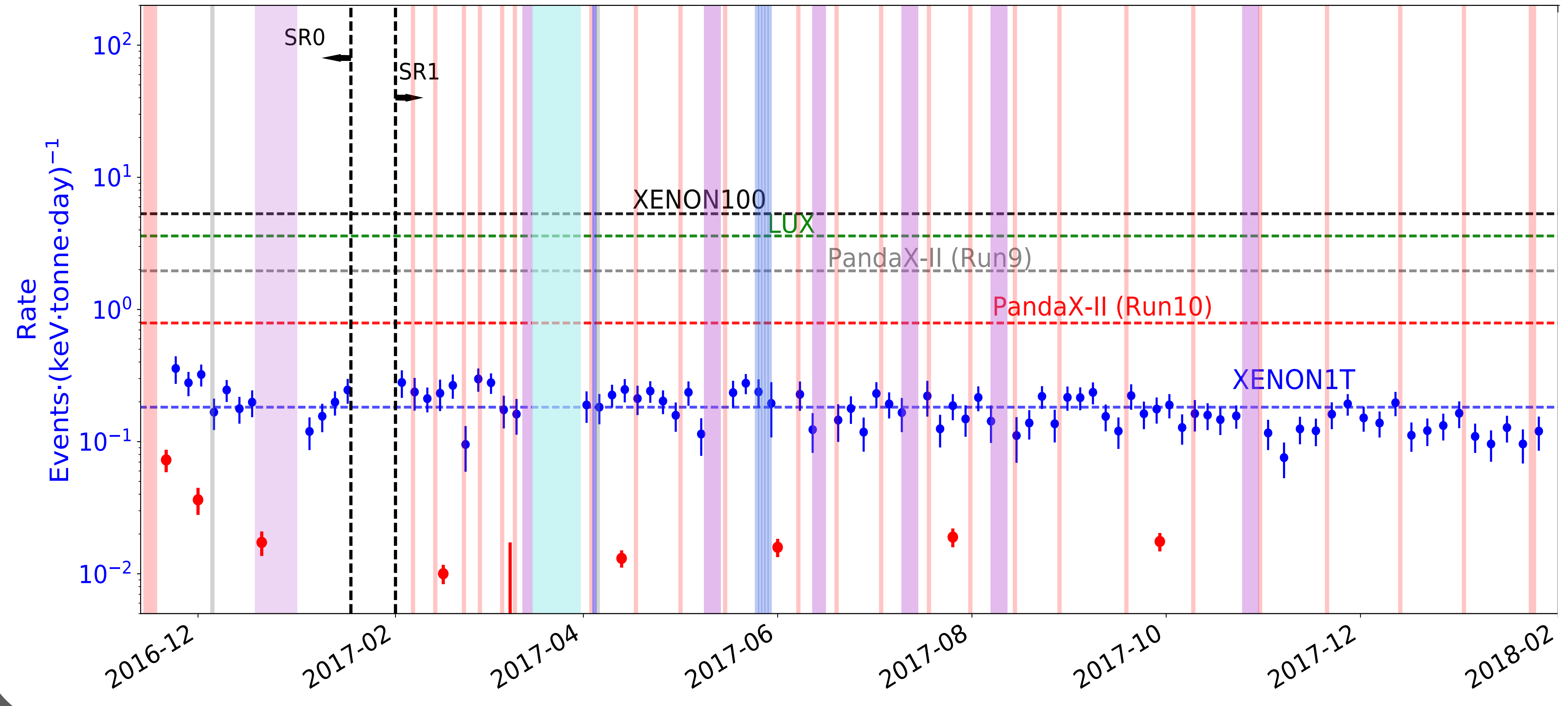
~1000

[events/(tonne*keV*day)]

LOW-ENERGY ELECTRON RECOIL BACKGROUND IN FIDUCIAL VOLUME

~0.2

[events/(tonne*keV*day)]



LOWEST BACKGROUND TO DATE

Below 25 keV dominated by **internal contamination**

91% from ^{214}Pb (10uBq/kg of Rn)

9% from ^{85}Kr

S1+S2 MODE

IDEAL FOR ~~WIMP~~ OTHER DM SEARCHES

(THROUGH ~~NUCLEAR~~ ELECTRON RECOIL)

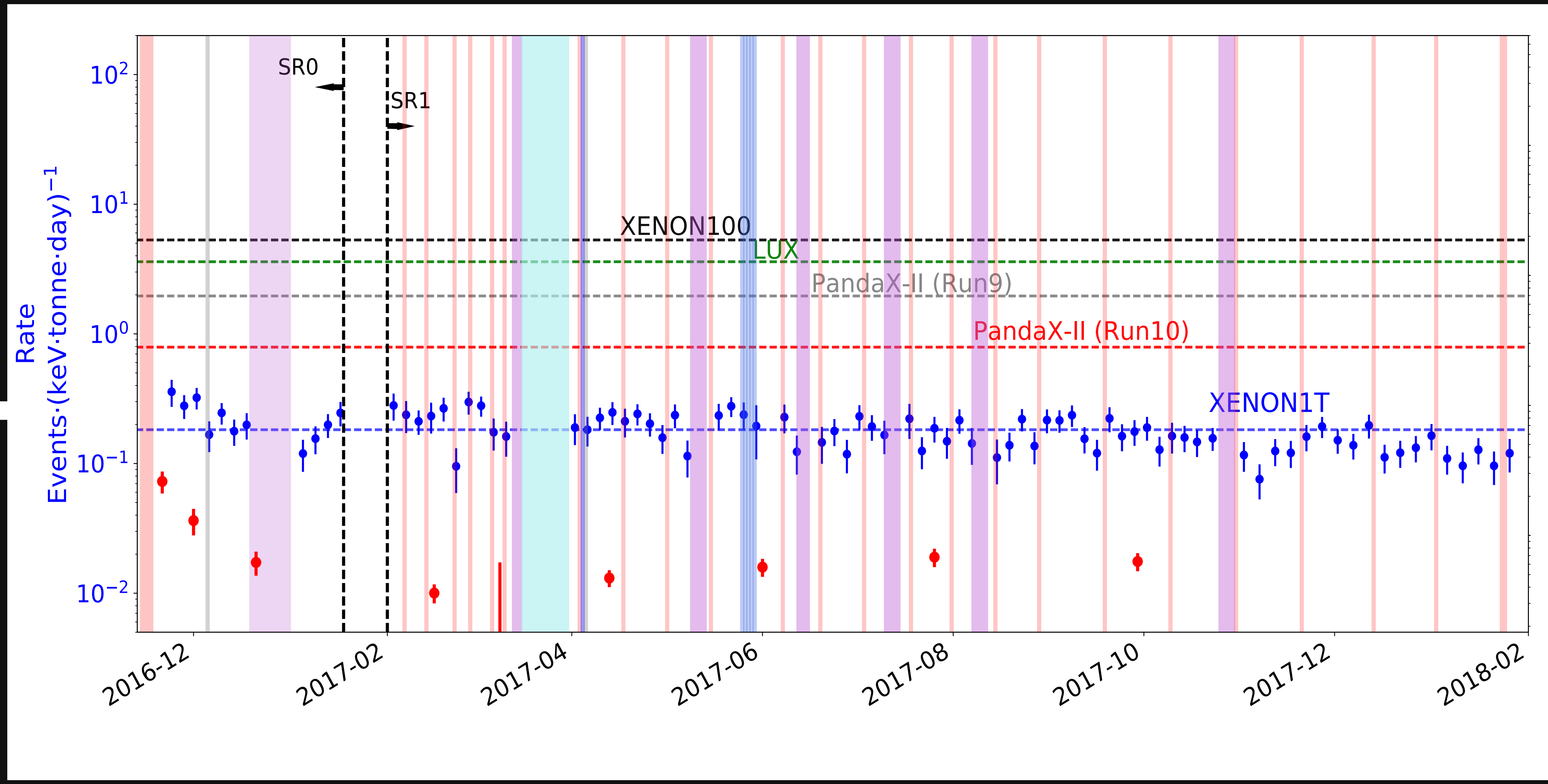
FIDUCIALIZATION → BACKGROUND SUPPRESSION

LOW ENERGY THRESHOLD → SENSITIVITY ↑

~~BACKGROUND SUPPRESSION~~

LARGE EXPOSURES & LOW BCK → SENSITIVITY ↑

WIMP S.I. PARAMETER SPACE



FULL 3D POSITION RECONSTRUCTION

SPECTROSCOPIC CAPABILITIES DOWN TO KEV SCALE

~~EFFICIENT IDENTIFICATION OF NR VS ER~~

+ CAN BE IMPLEMENTED IN MULTI-TON & "EASY" TO PURIFY XENON TARGETS

S1+S2 MODE

PRIMORDIAL ALPS

IDEAL FOR ~~WIMP~~ SEARCHES

OTHER DM

(THROUGH ~~NUCLEAR~~ RECOIL)

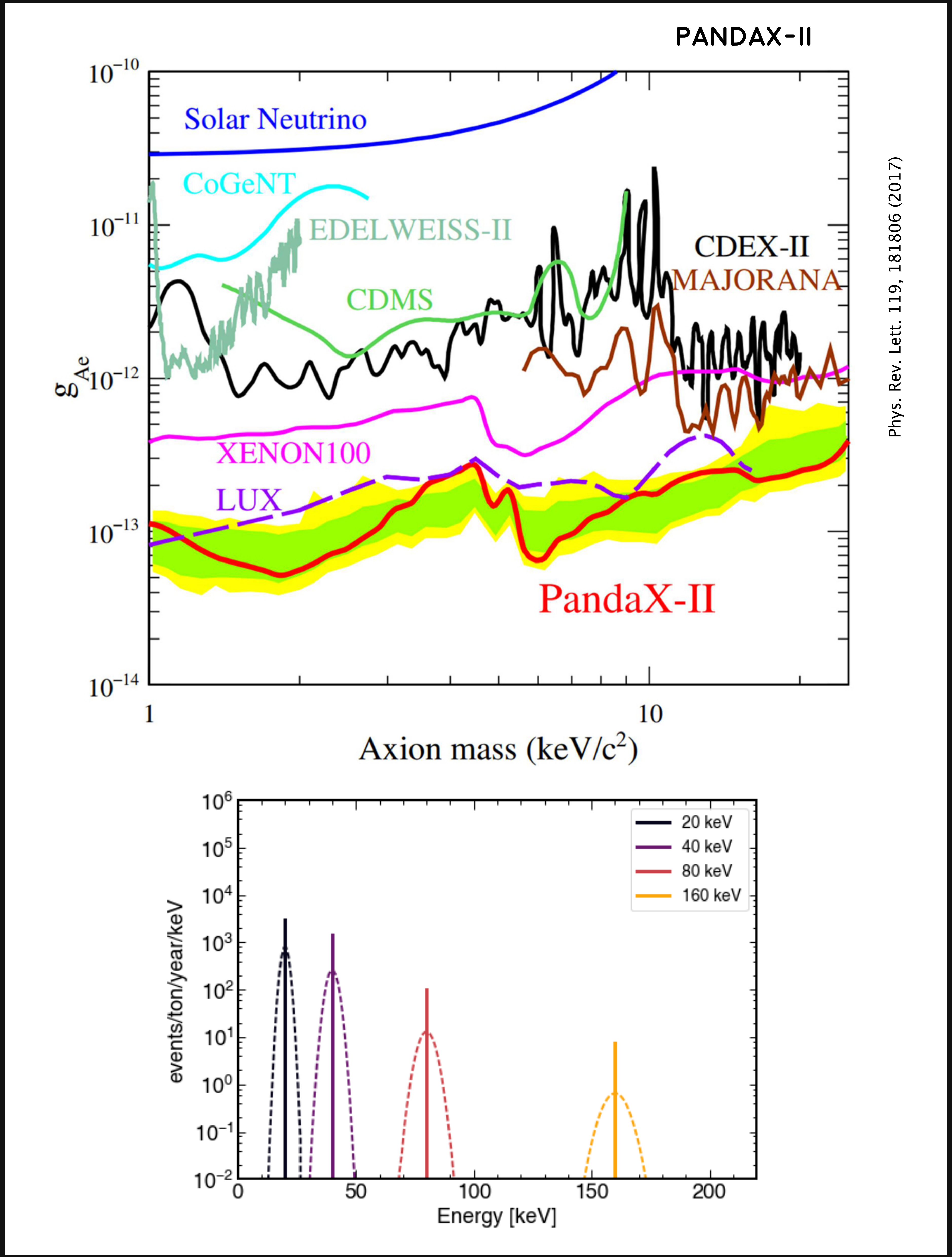
ELECTRON

FIDUCIALIZATION → BACKGROUND SUPPRESSION

LOW ENERGY THRESHOLD → SENSITIVITY ↑

~~BACKGROUND SUPPRESSION~~

LARGE EXPOSURES & LOW BCK → SENSITIVITY ↑



Phys. Rev. Lett. 119, 181806 (2017)

S1+S2 MODE

DARK PHOTONS

IDEAL FOR OTHER DM ~~WIMP~~ SEARCHES

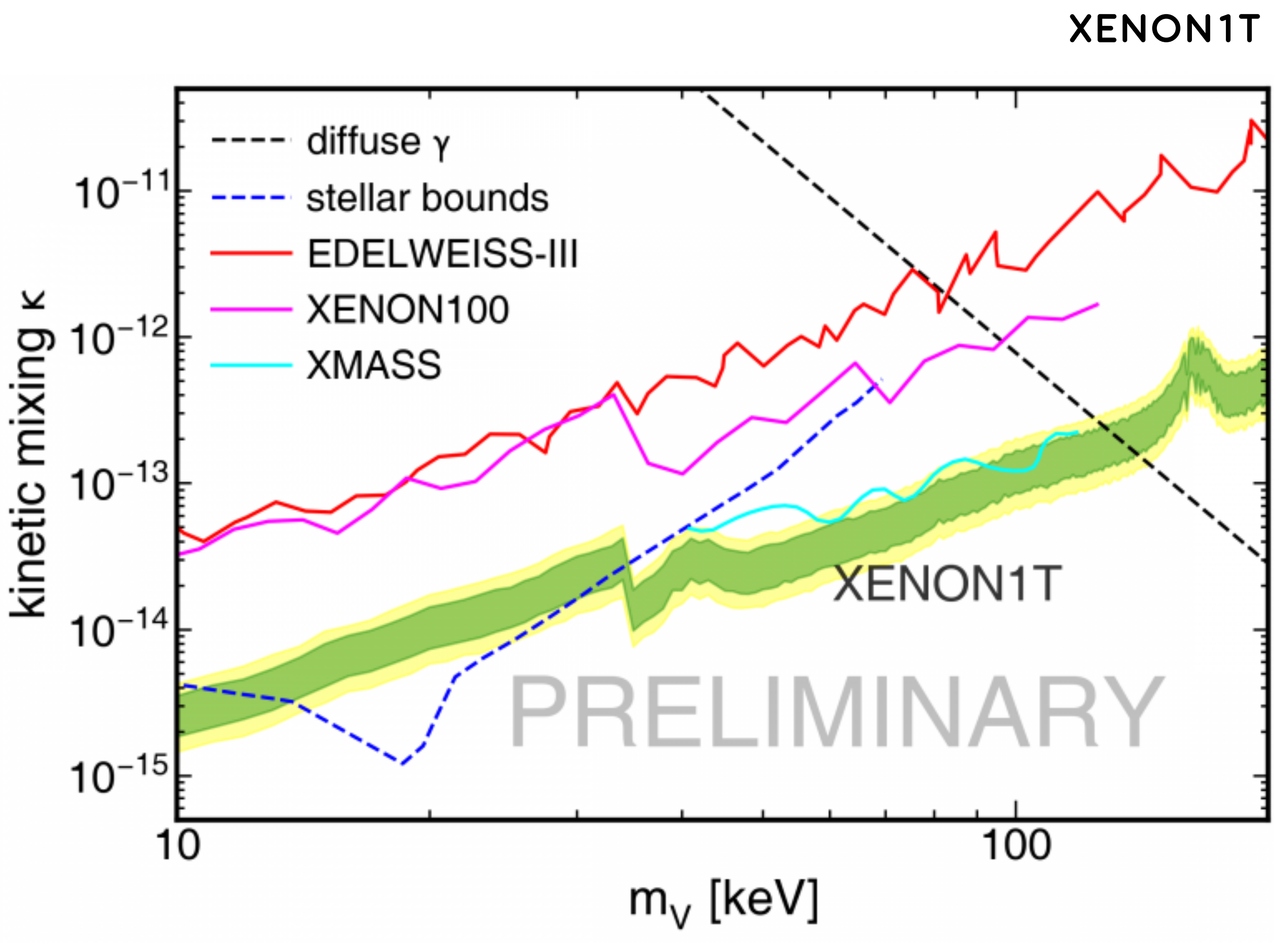
(THROUGH ~~NUCLEAR~~ ELECTRON RECOIL)

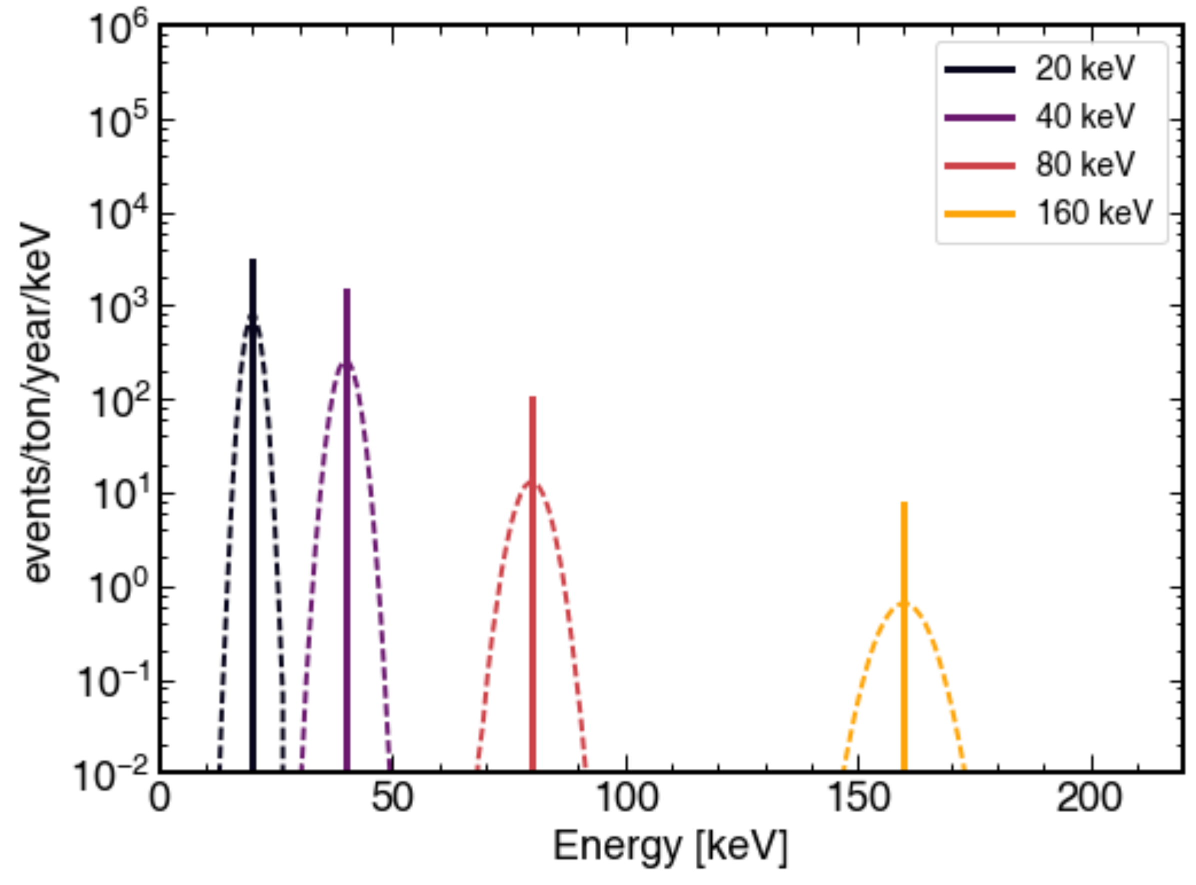
FIDUCIALIZATION → BACKGROUND SUPPRESSION

LOW ENERGY THRESHOLD → SENSITIVITY ↑

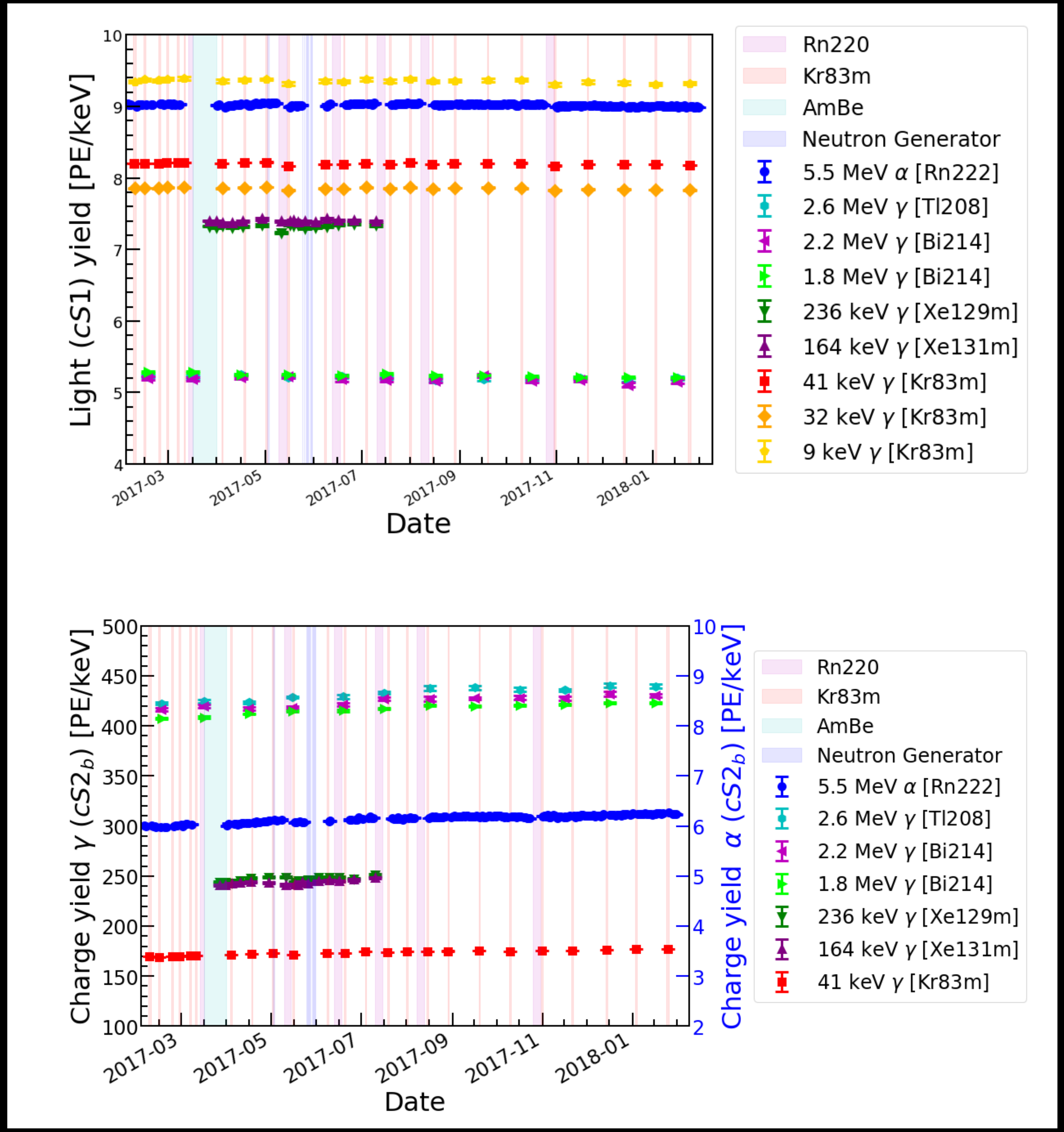
~~BACKGROUND SUPPRESSION~~

LARGE EXPOSURES & LOW BCK → SENSITIVITY ↑





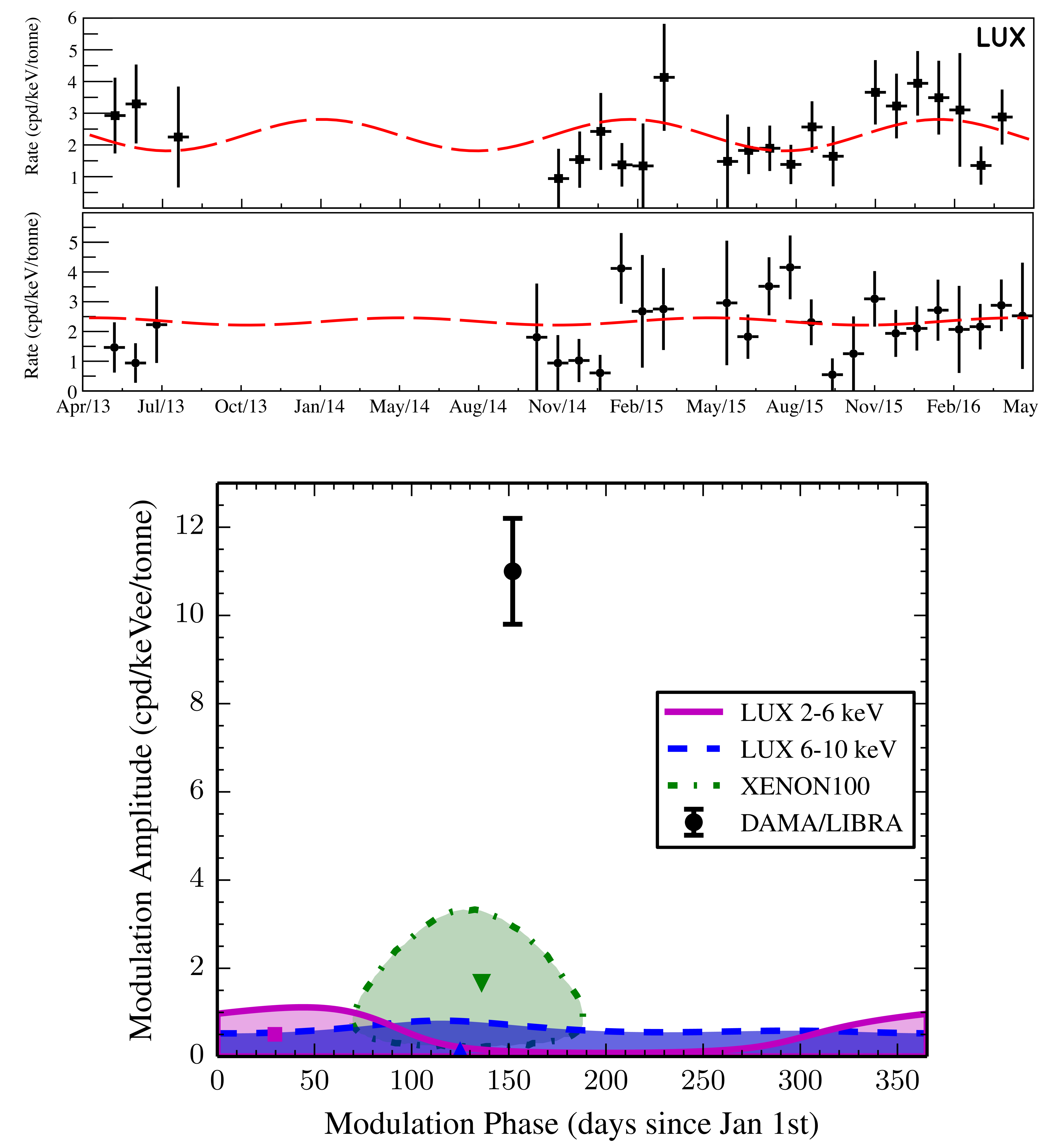
S1+S2 MODE



R
S
L)
ON
Y ↑
ON
Y ↑

DM-INDUCED ANNUAL RATE MODULATIONS

WIMPS: PARAMETER SPACE



Phys. Rev. D 98, 062005 (2018)

S1+S2 MODE

SOLAR AXIONS

IDEAL FOR RARE PROCESS SEARCHES

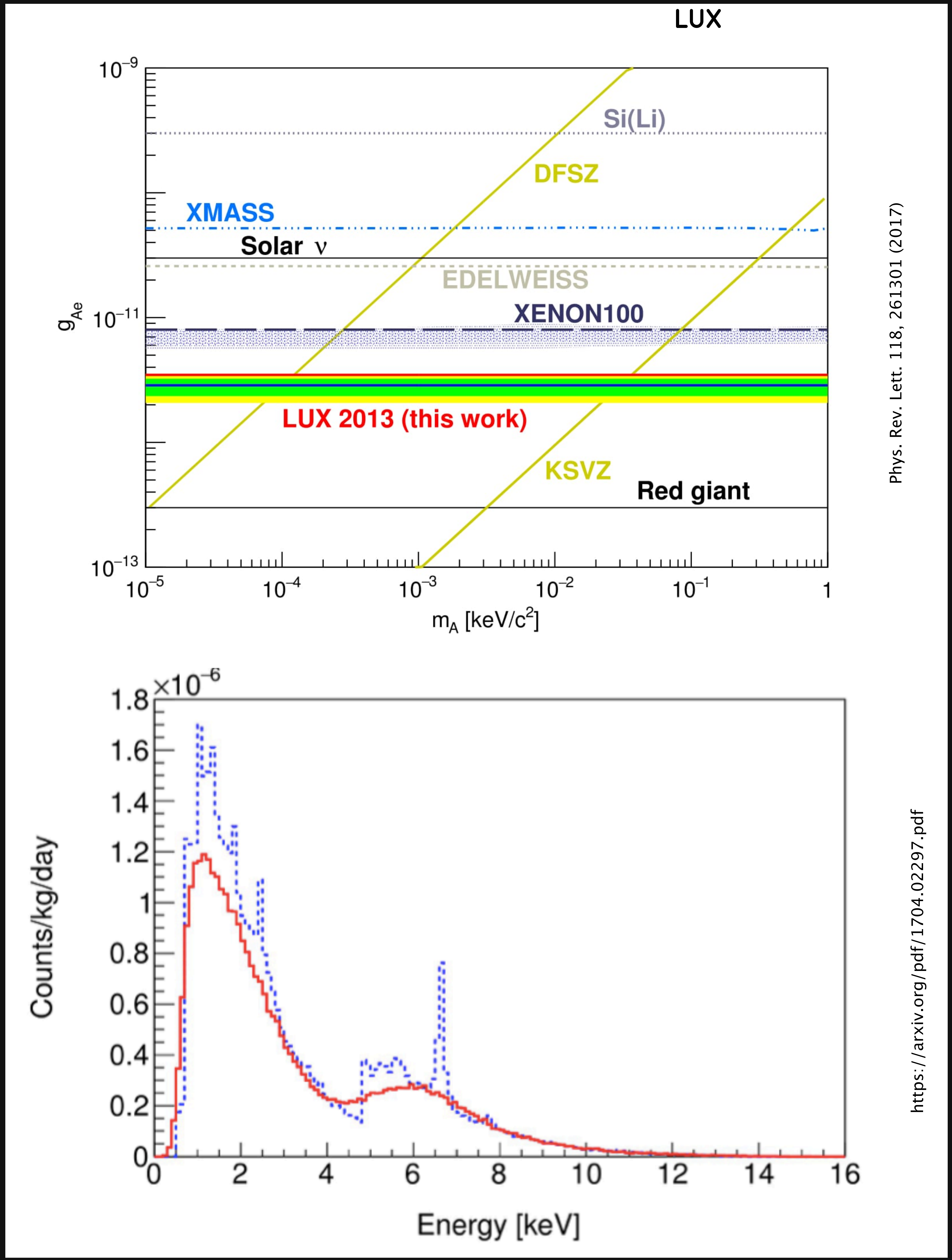
(THROUGH ELECTRON RECOIL)

FIDUCIALIZATION → BACKGROUND SUPPRESSION

LOW ENERGY THRESHOLD → SENSITIVITY ↑

~~BACKGROUND SUPPRESSION~~

LARGE EXPOSURES & LOW BCK → SENSITIVITY ↑



Phys. Rev. Lett. 118, 261301 (2017)

https://arxiv.org/pdf/1704.02297.pdf

S1+S2 MODE

IDEAL FOR RARE PROCESS SEARCHES

(THROUGH ELECTRON RECOIL)

FIDUCIALIZATION → BACKGROUND SUPPRESSION

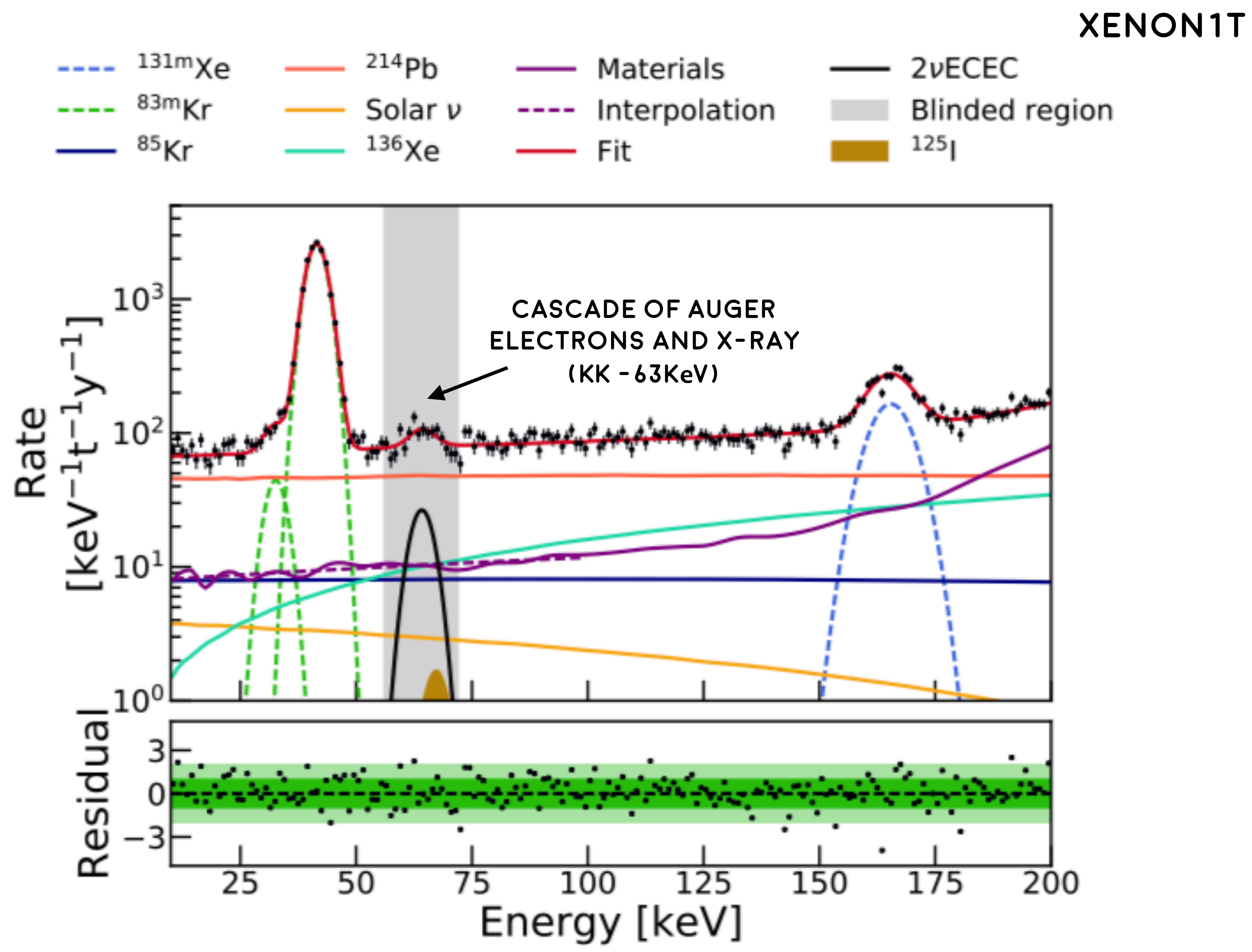
LOW ENERGY THRESHOLD → SENSITIVITY ↑

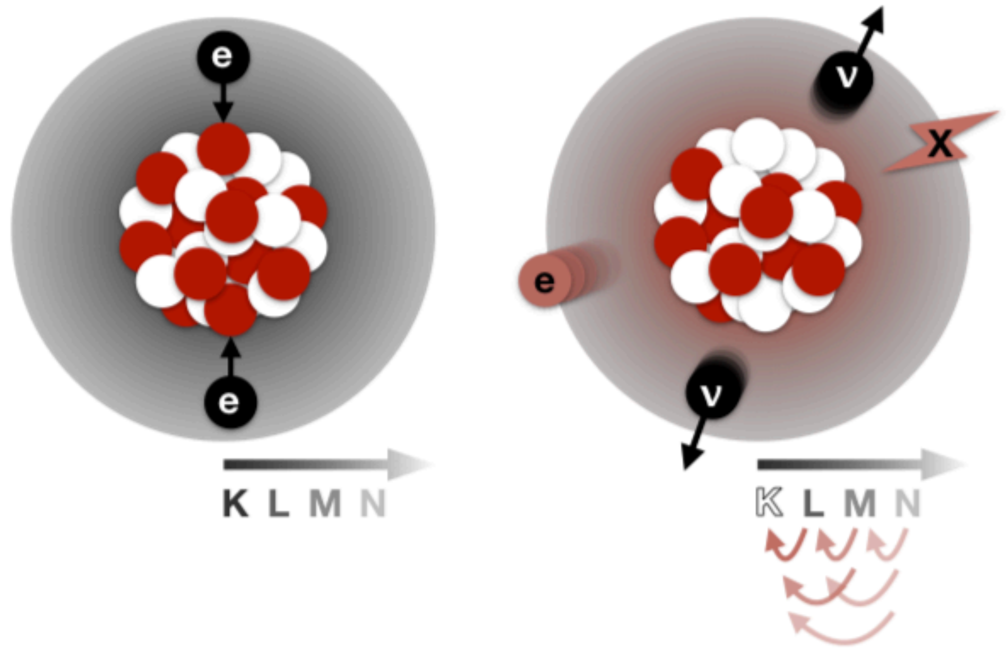
~~BACKGROUND SUPPRESSION~~

LARGE EXPOSURES & LOW BCK → SENSITIVITY ↑

2νECEC IN ^{124}XE

XENON1T





NUCLEUS CAPTURES 2 ATOMIC SHELL ELECTRONS

CONVERTS 2 PROTONS TO NEUTRONS

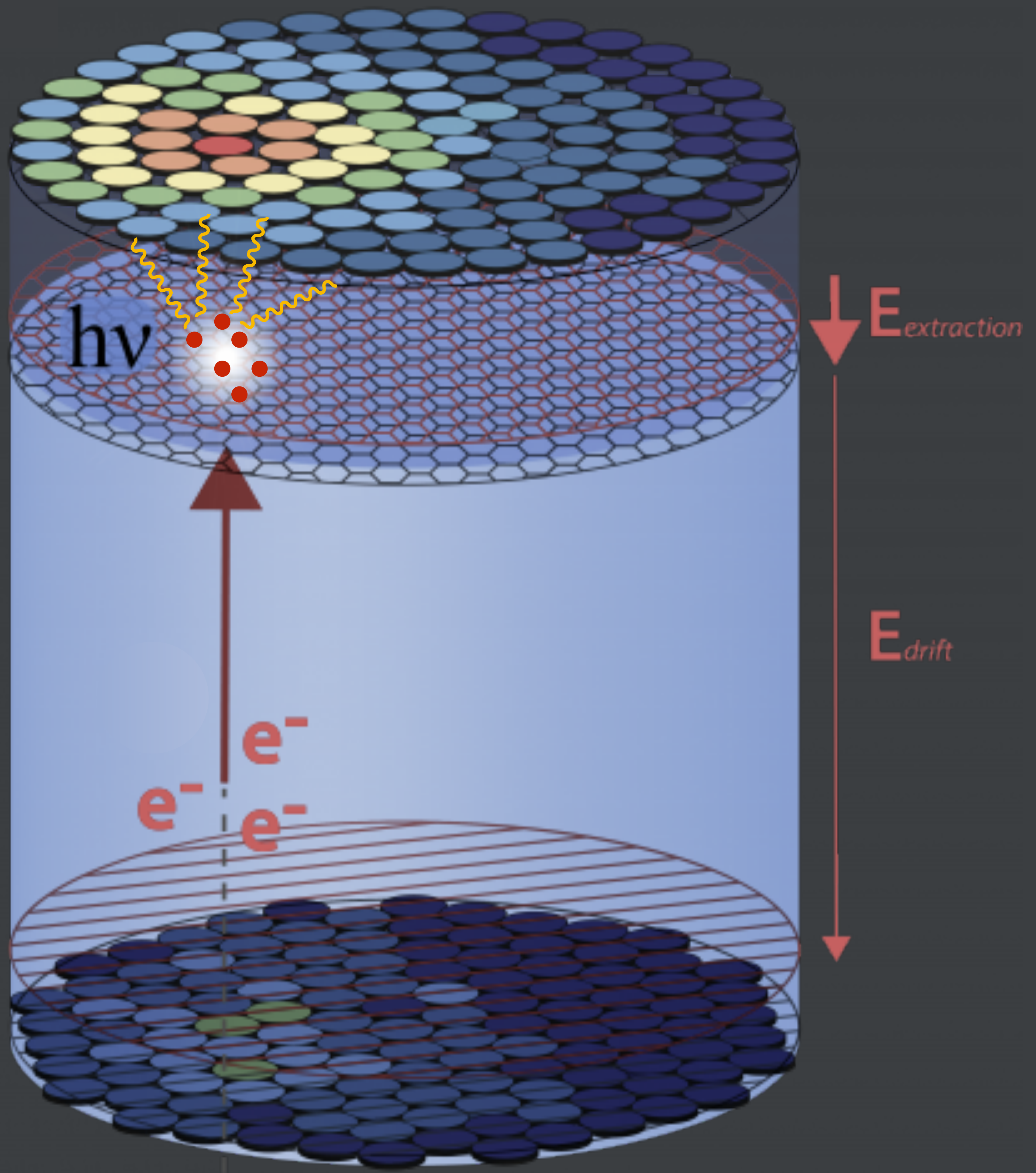
2 NEUTRINOS ARE EMITTED AND ATOMIC SHELL LEFT EXCITED.

EXTREMELY RARE PROCESS

ESTIMATED HALF-LIFE ~ 10^{22} YEAR

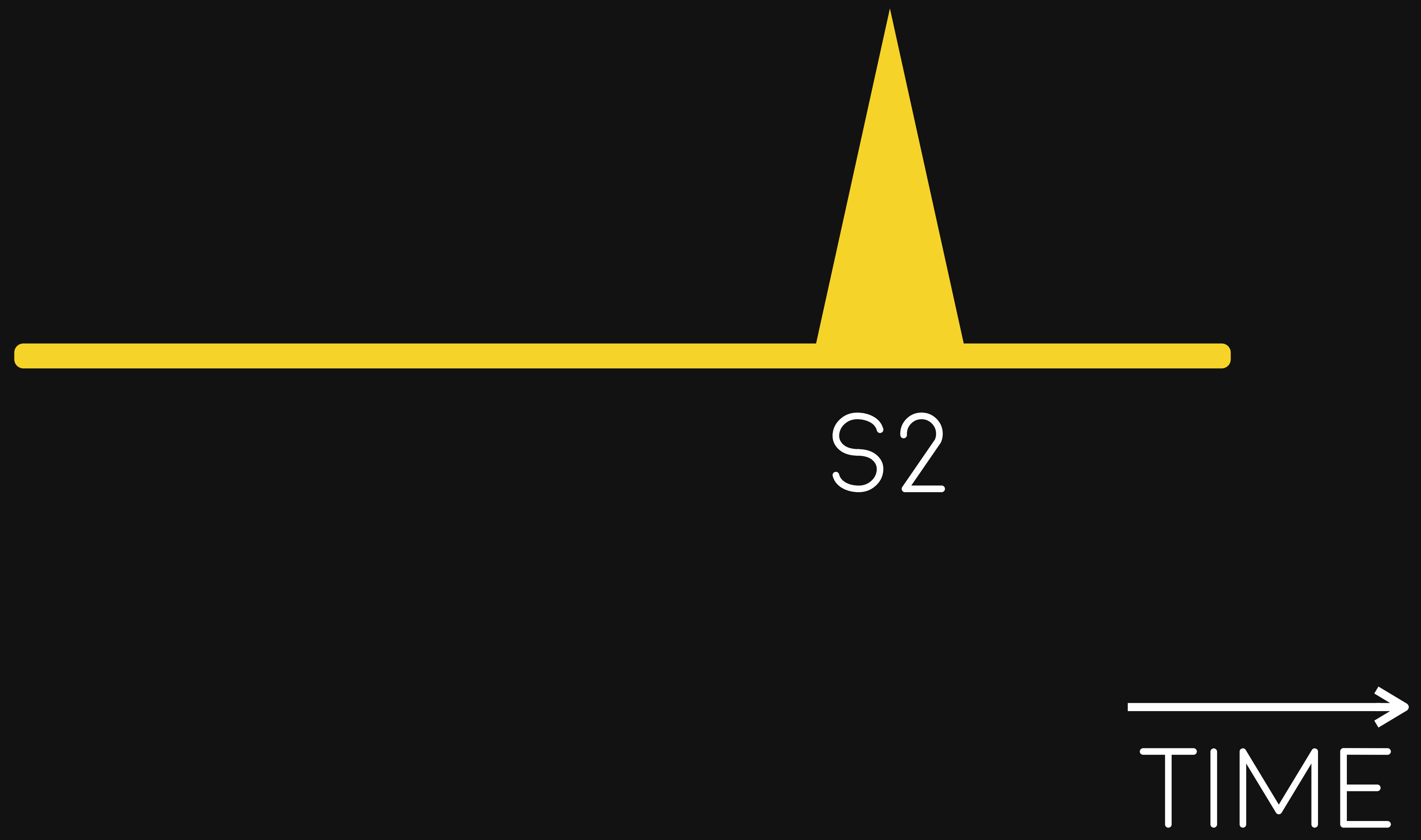
~1KG OF ^{124}XE PER TONNE

S2-ONLY MODE



THE PRINCIPLE

ONLY IONIZATION CHANNEL
(SCINTILLATION BELOW THRESHOLD)



S2-ONLY MODE

ONLY IONIZATION CHANNEL

(SCINTILLATION BELOW THRESHOLD)

~~FULL 3D POSITION RECONSTRUCTION~~ X.Y POSITION

SPECTROSCOPIC CAPABILITIES DOWN TO SUB KEV

~~EFFICIENT IDENTIFICATION OF NR VS ER~~

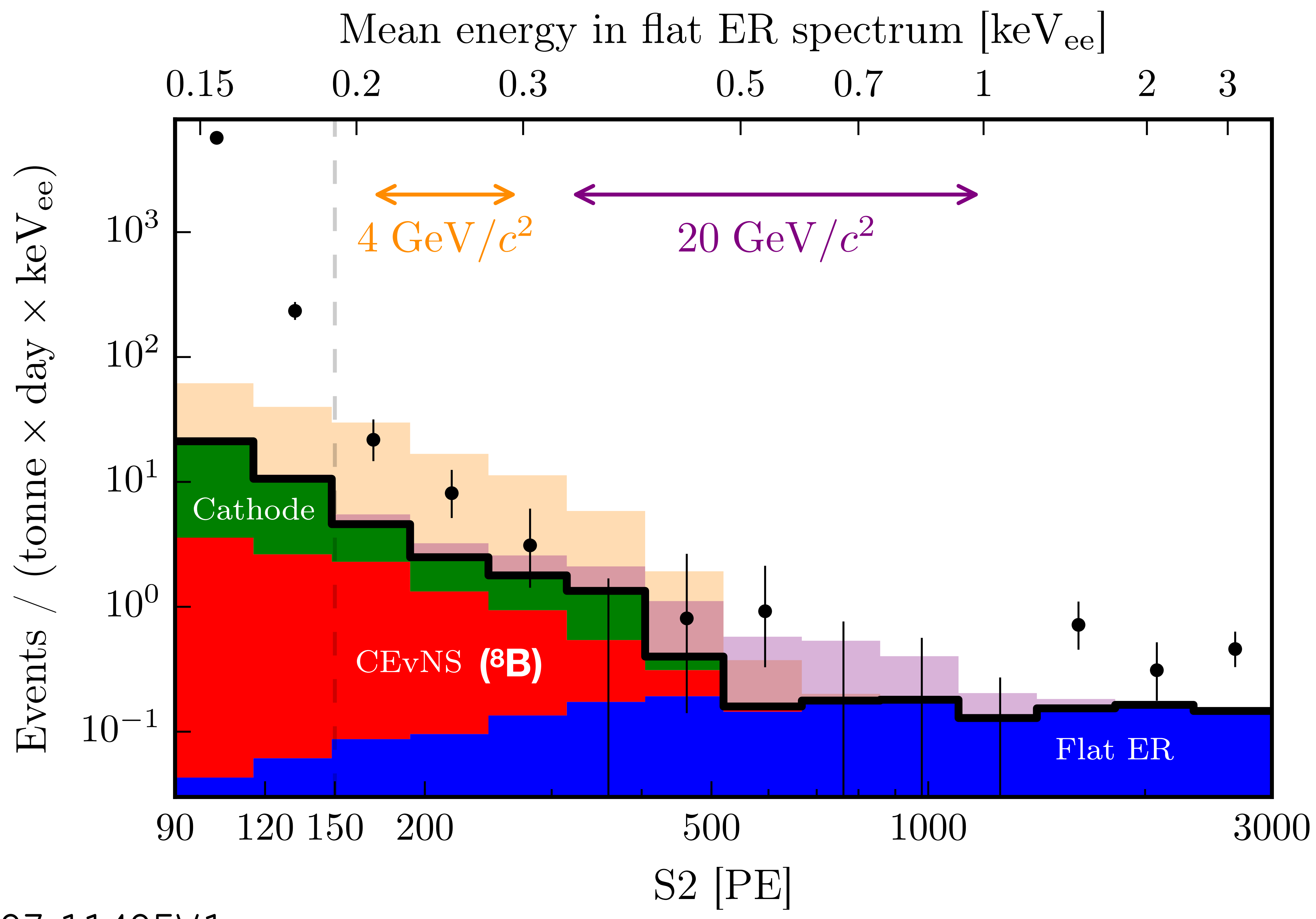
+ CAN BE IMPLEMENTED IN MULTI-TON & "EASY" TO PURIFY XENON TARGETS

S2-ONLY MODE

THRESHOLD OF ABOUT 4-5 e^- → 0.2 keV_{ee}

BACKGROUND CONTROL IS MORE CHALLENGING AND FULL BACKGROUND MODELING IS STILL MISSING

CAN BE USED TO EXCLUDE DM PARAMETER SPACE



ARXIV:1907.11485V1

ONLY IONIZATION CHANNEL

(SCINTILLATION BELOW THRESHOLD)

~~FULL 3D POSITION RECONSTRUCTION~~ X,Y POSITION

SPECTROSCOPIC CAPABILITIES DOWN TO SUB KEV

~~EFFICIENT IDENTIFICATION OF NR VS ER~~

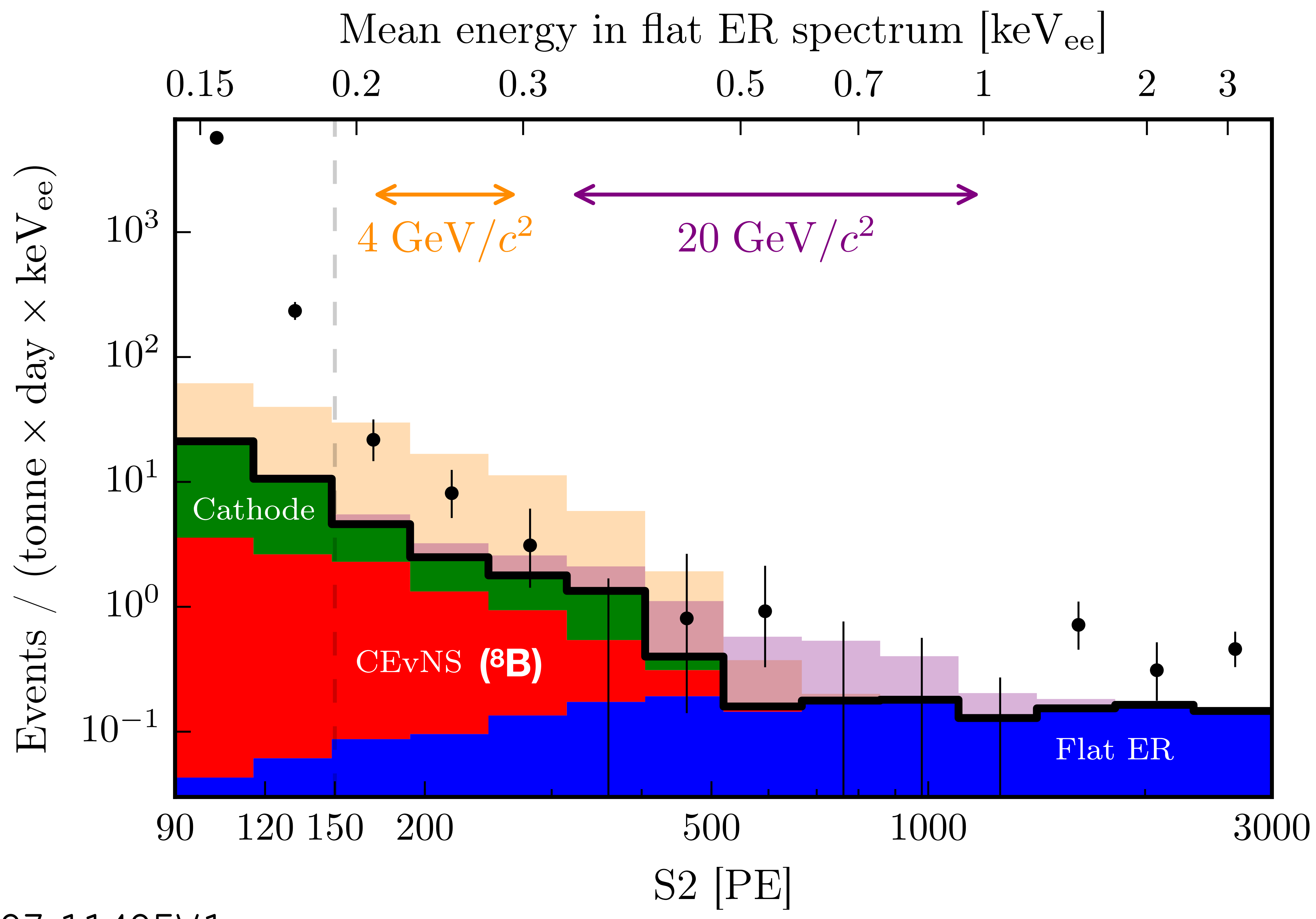
+ CAN BE IMPLEMENTED IN MULTI-TON & "EASY" TO PURIFY XENON TARGETS

S2-ONLY MODE

THRESHOLD OF ABOUT 4-5 e^- → 0.2 keV_{ee}

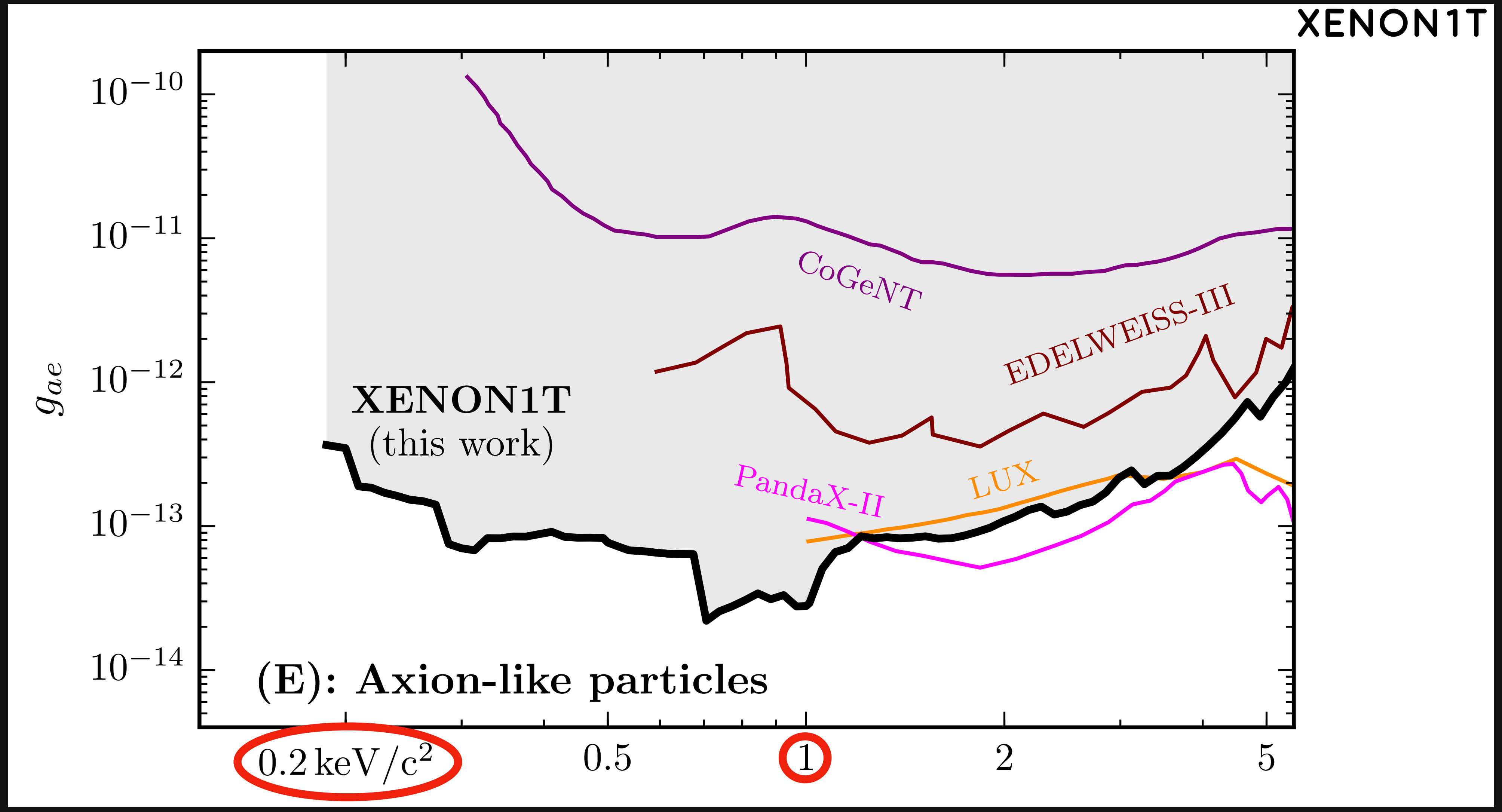
BACKGROUND CONTROL IS MORE CHALLENGING AND FULL BACKGROUND MODELING IS STILL MISSING

CAN BE USED TO EXCLUDE DM PARAMETER SPACE

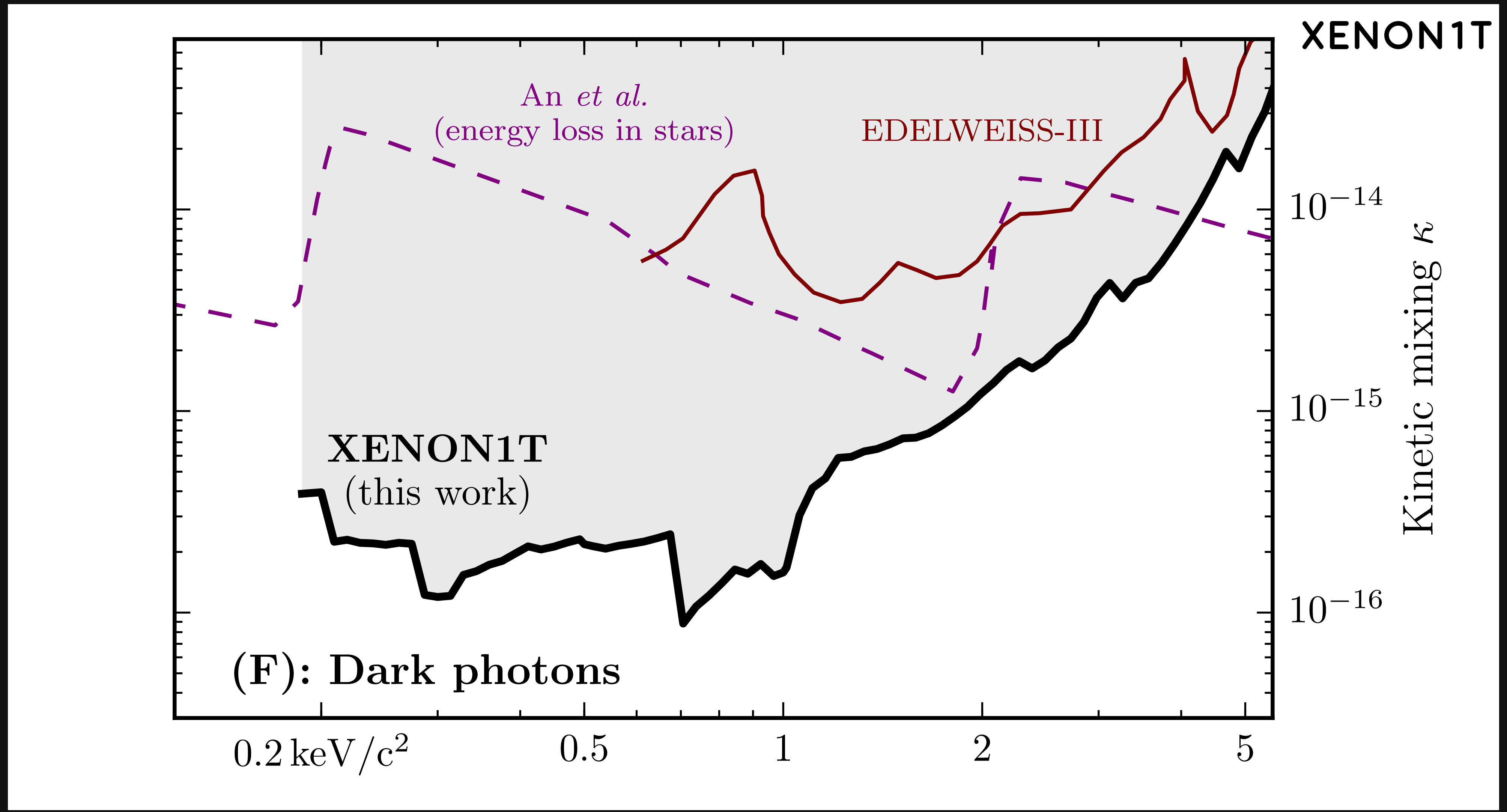


ARXIV:1907.11485V1

AXION-LIKE PARTICLES



DARK PHOTONS



S2-ONLY MODE

THRESHOLD OF ABOUT 4-5 e^- → 0.2 keV_{ee}

BACKGROUND CONTROL IS MORE CHALLENGING AND FULL BACKGROUND MODELING IS STILL MISSING

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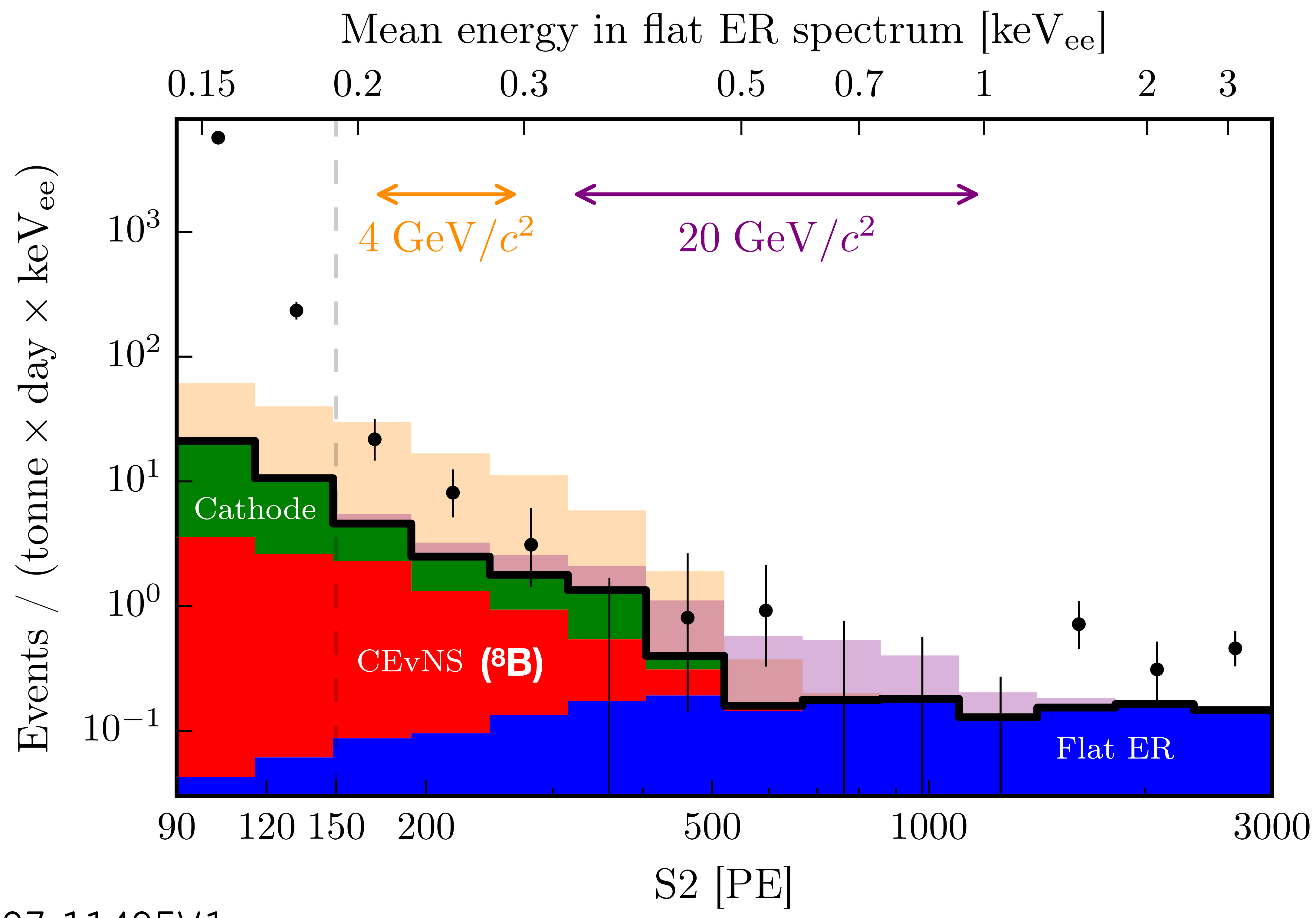
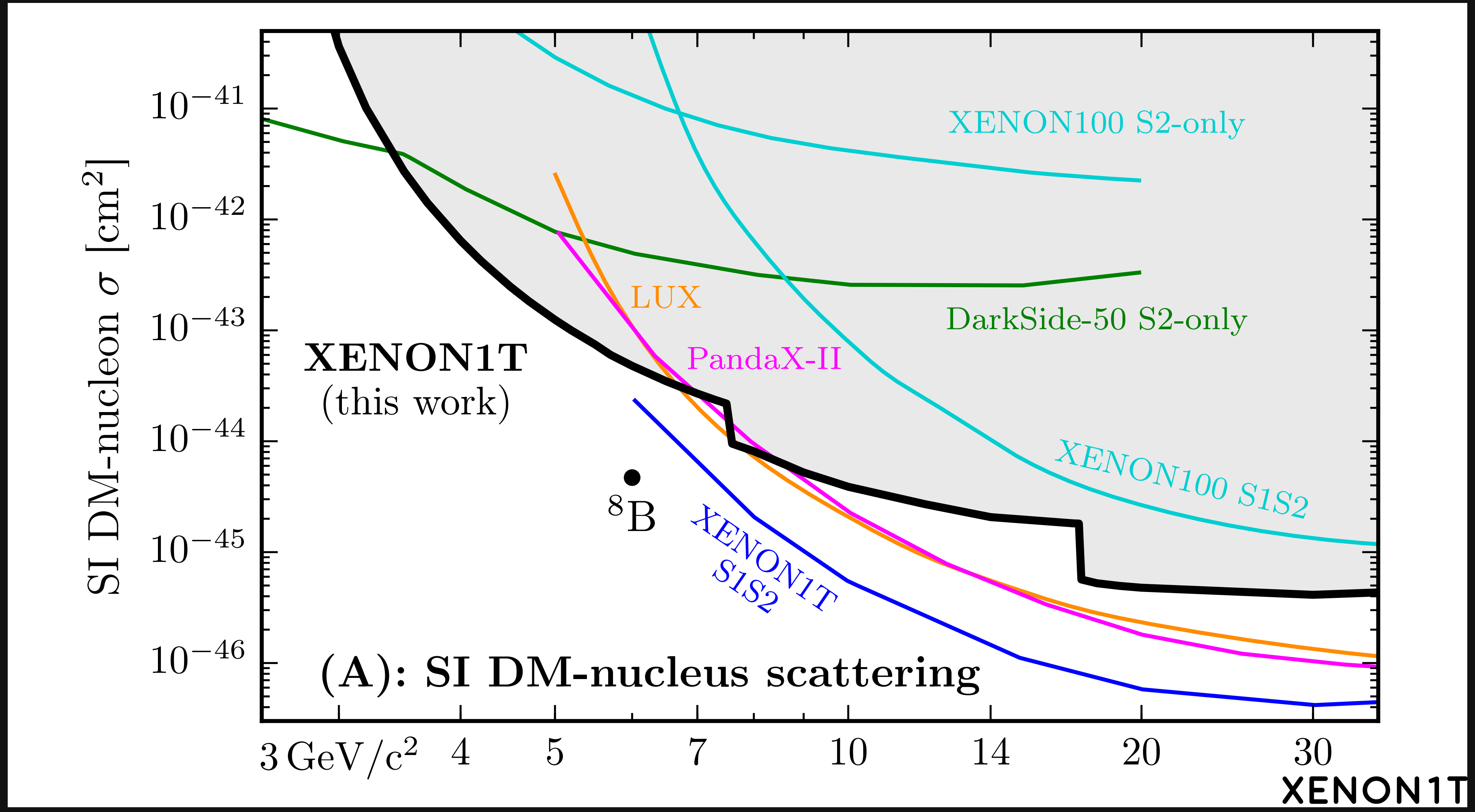
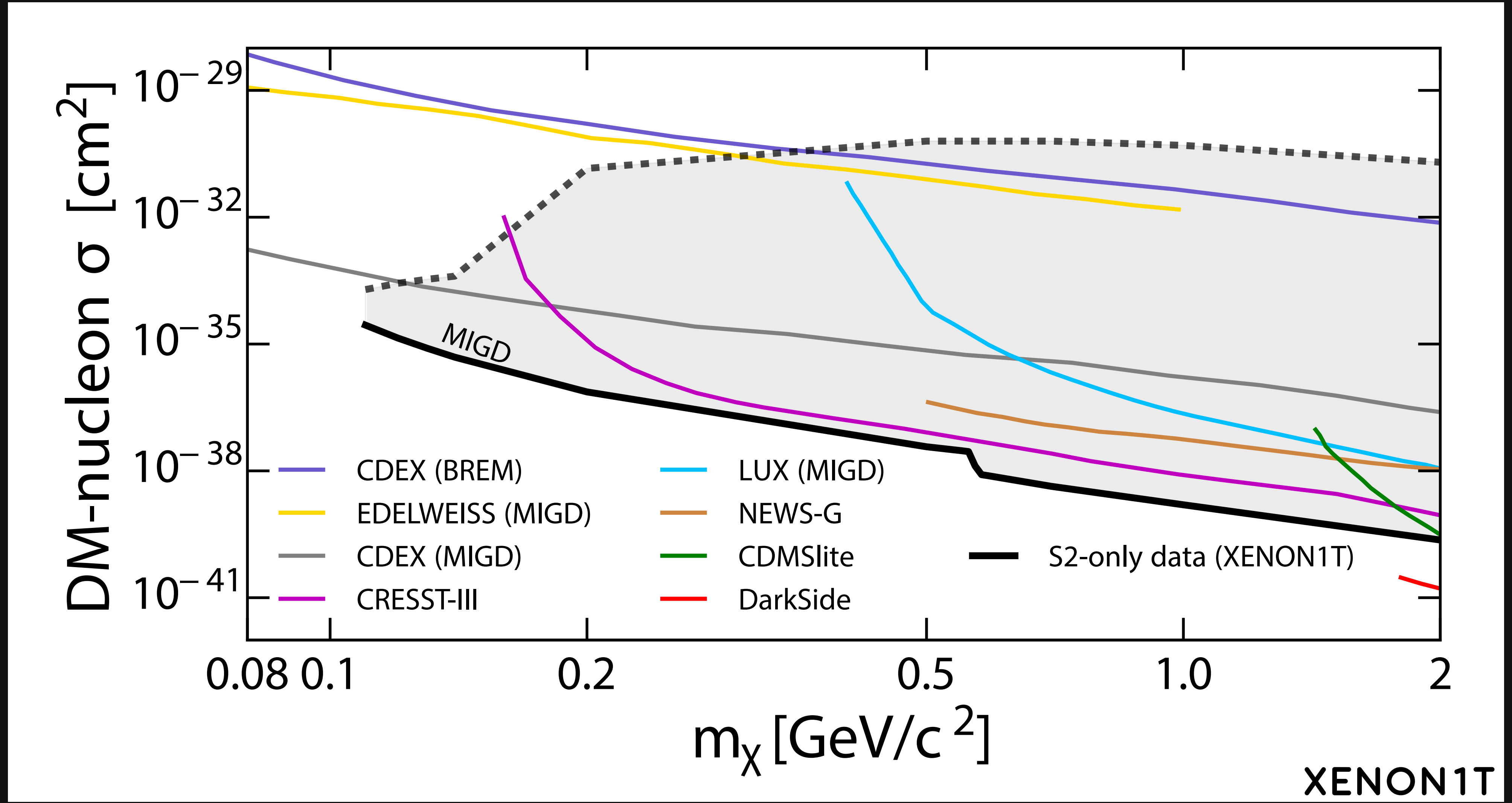


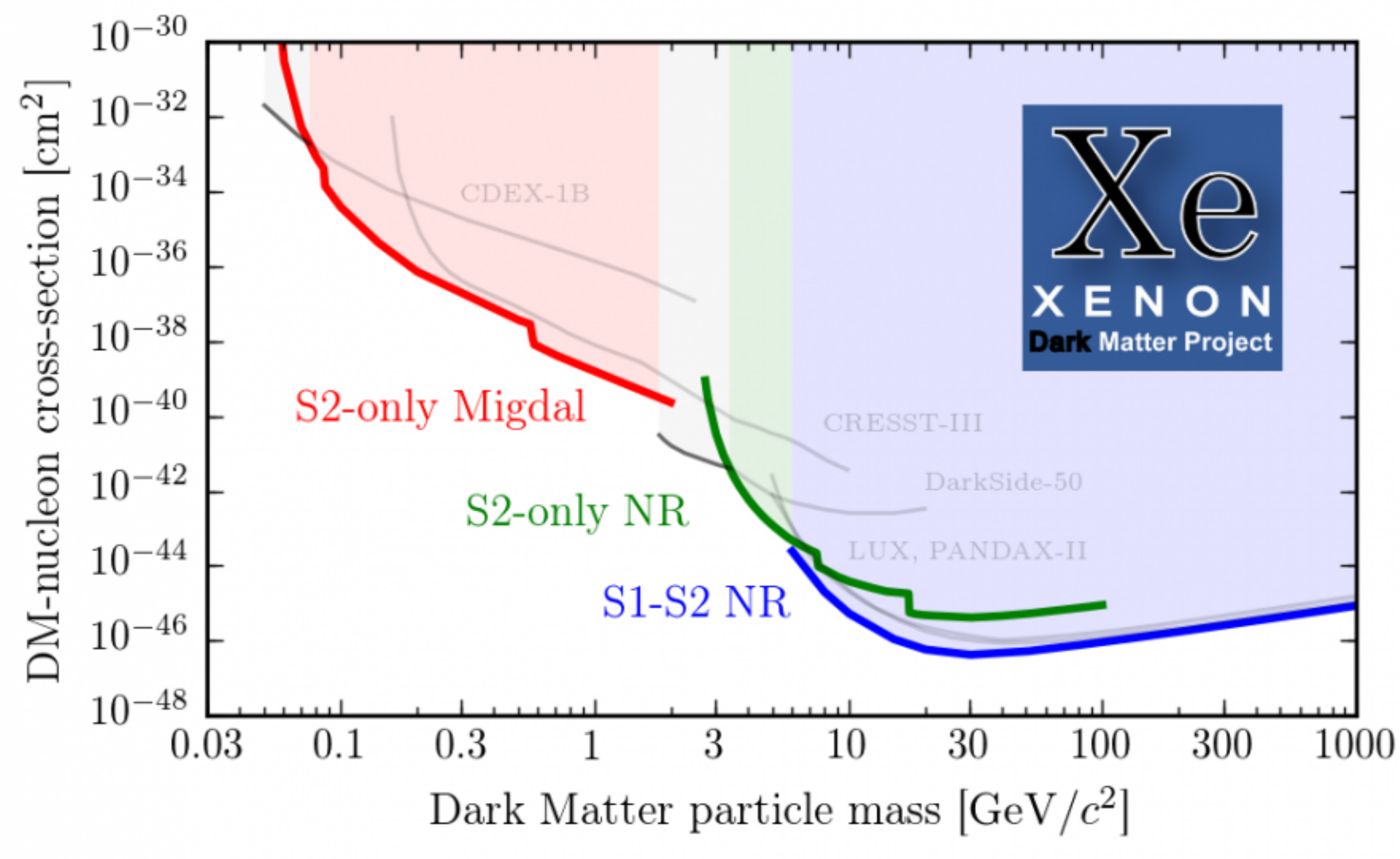
ARXIV:1907.11485V1

S.I. LIGHT WIMP



+ MIGDAL EFFECT





XENON TWO-PHASE TIME PROJECTION CHAMBERS

WHAT'S NEXT?

Xe
XENON
Matter Project
PURDUE
Stockholm University
UC San Diego
NYU | ABU DHABI
Rensselaer
CHICAGO
CAEN


2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
XENON10
(15kg)
XENON100
(61kg)
XENON1T
(2 TONNES)
XENONNT
(5.9 TONNES)
ZEPLIN-II
(31kg)
ZEPLIN-III
(12kg)
LUX
(250kg)
LUX-ZEPLIN
(7 TONNES)
PANDAX-I
(120kg)
PANDAX-II
(500kg)
PANDAX-4T
(4 TONNES)
PandaX-4T

XENONnT

Columbia RPI Nikhef Muenster KIT Stockholm Mainz MPIK, Heidelberg Freiburg

Chicago

UCSD

Rice

Purdue

Zurich

Tokyo

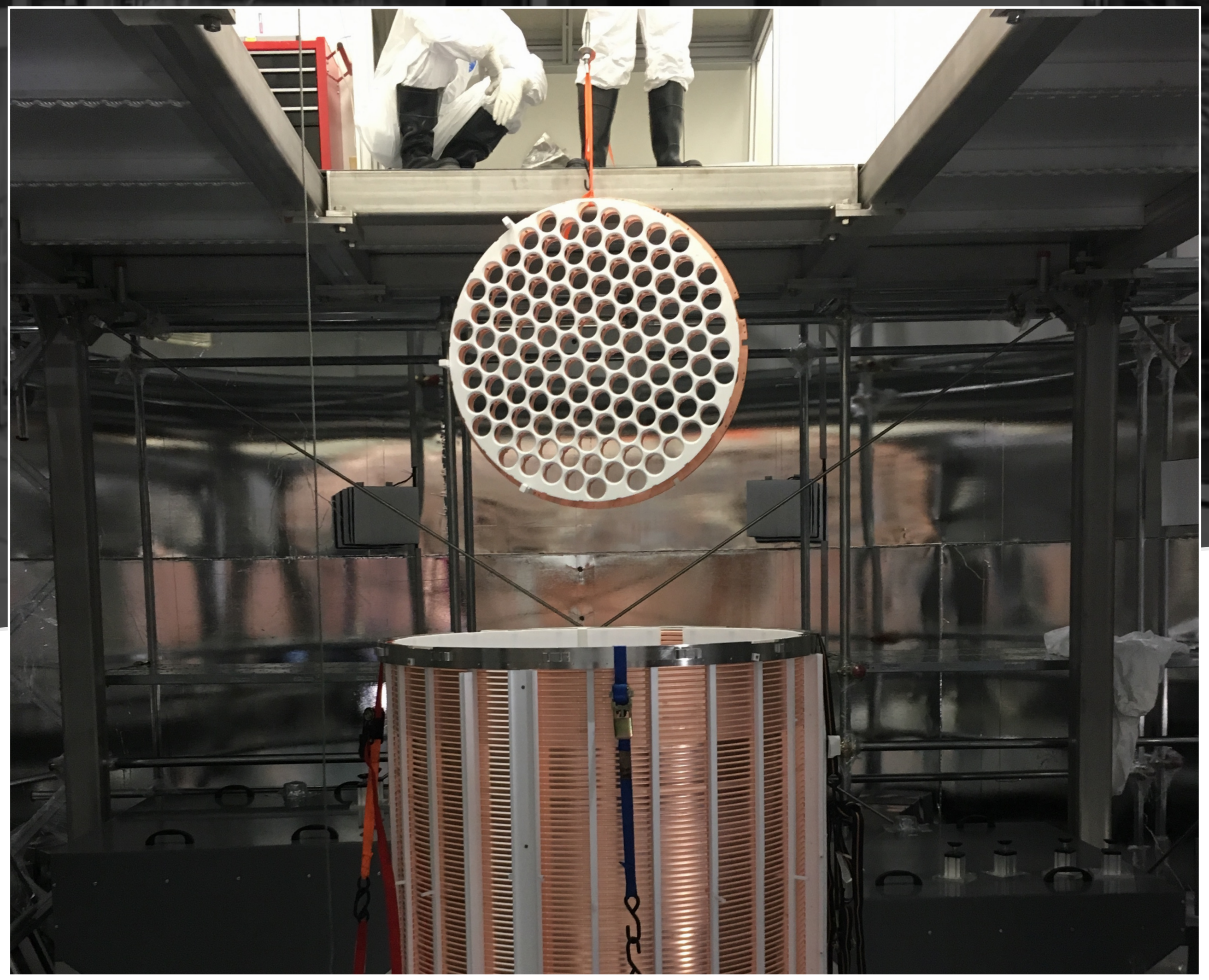
Nagoya

Coimbra Subatech LPNHE LAL Bologna LNGS Torino Napoli Weizmann NYUAD Kobe

XENONnT

X4

1/10



XENONnT

TPC

XENON1T DESIGNED TO ALLOW **FAST UPGRADE** OF ITS CENTRAL DETECTOR WITH A **NEWER AND LARGER TPC**

SENSITIVITY BOOST

FV

8.3 TONNE TOTAL
5.9 TONNE ACTIVE
~4 TONNE FIDUCIAL (X4)

IDENTIFIED AND TESTED SUCCESSFULLY STRATEGIES TO **FURTHER SUPPRESS THE DOMINANT BACKGROUND (1/10TH)**

FAST UPGRADE

FAST

XENON1T TURNED **OFF IN DEC 2018** AND **DISASSEMBLED IN FEB 2019**

XENONNT INSTALLATION STARTED IN THE SUMMER 2019

FIRST DATA IN 2020

XENON1T INFRASTRUCTURE AND SUB-SYSTEMS (ALREADY OPERATIVE)

Aprile et al., Eur. Phys. J. C (2017) 77: 881

Xenon Gas

DAQ System

Cryogenic Plant

Computing System

Recirculation System

Slow Control

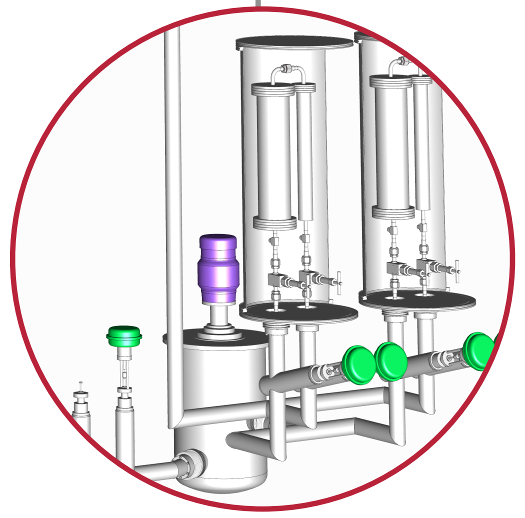
Kr Distillation Column

Infrastructure (WT and building)

Calibration System

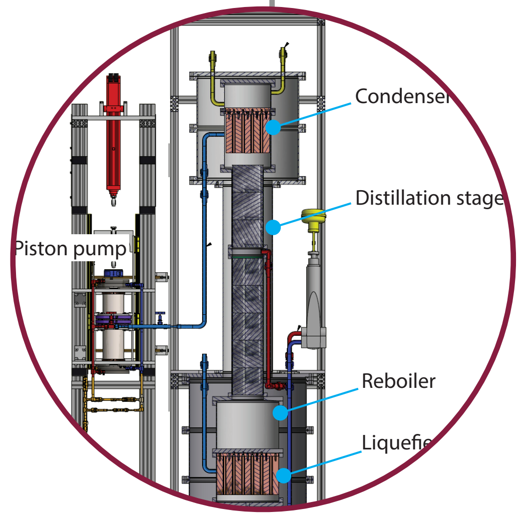
NEW TPC

5.9-TON TIME PROJECTION CHAMBER



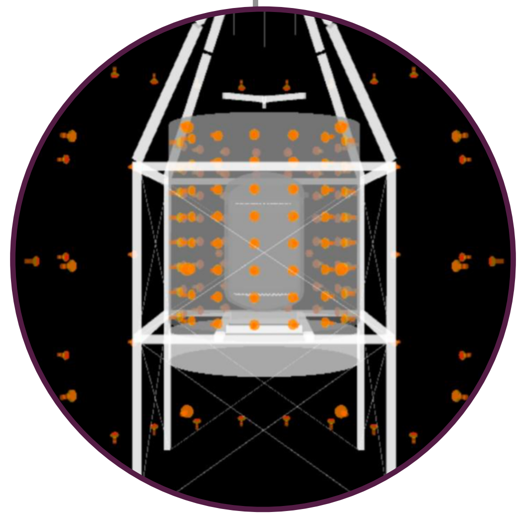
LXE RECIRCULATION PURIFICATION

TO ACHIEVE FAST CLEANING OF THE LARGE LXE VOLUME (5000 SLPM)



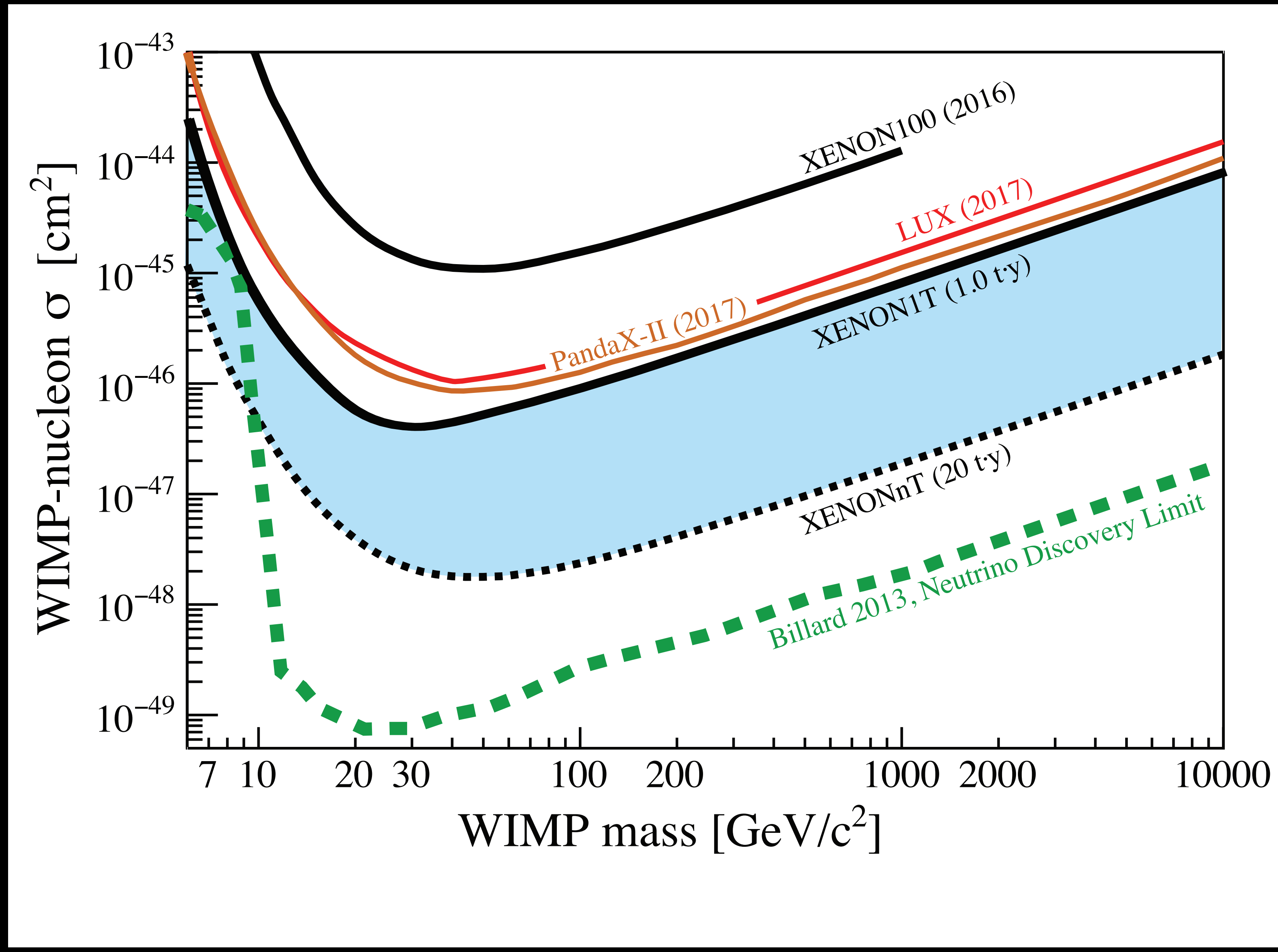
ONLINE RADON REMOVAL

TO ONLINE REMOVE THE ^{222}RN EMANATED INSIDE THE DETECTOR



NEUTRON VETO

TO TAG AND MEASURE IN SITU NEUTRON-INDUCED BACKGROUND

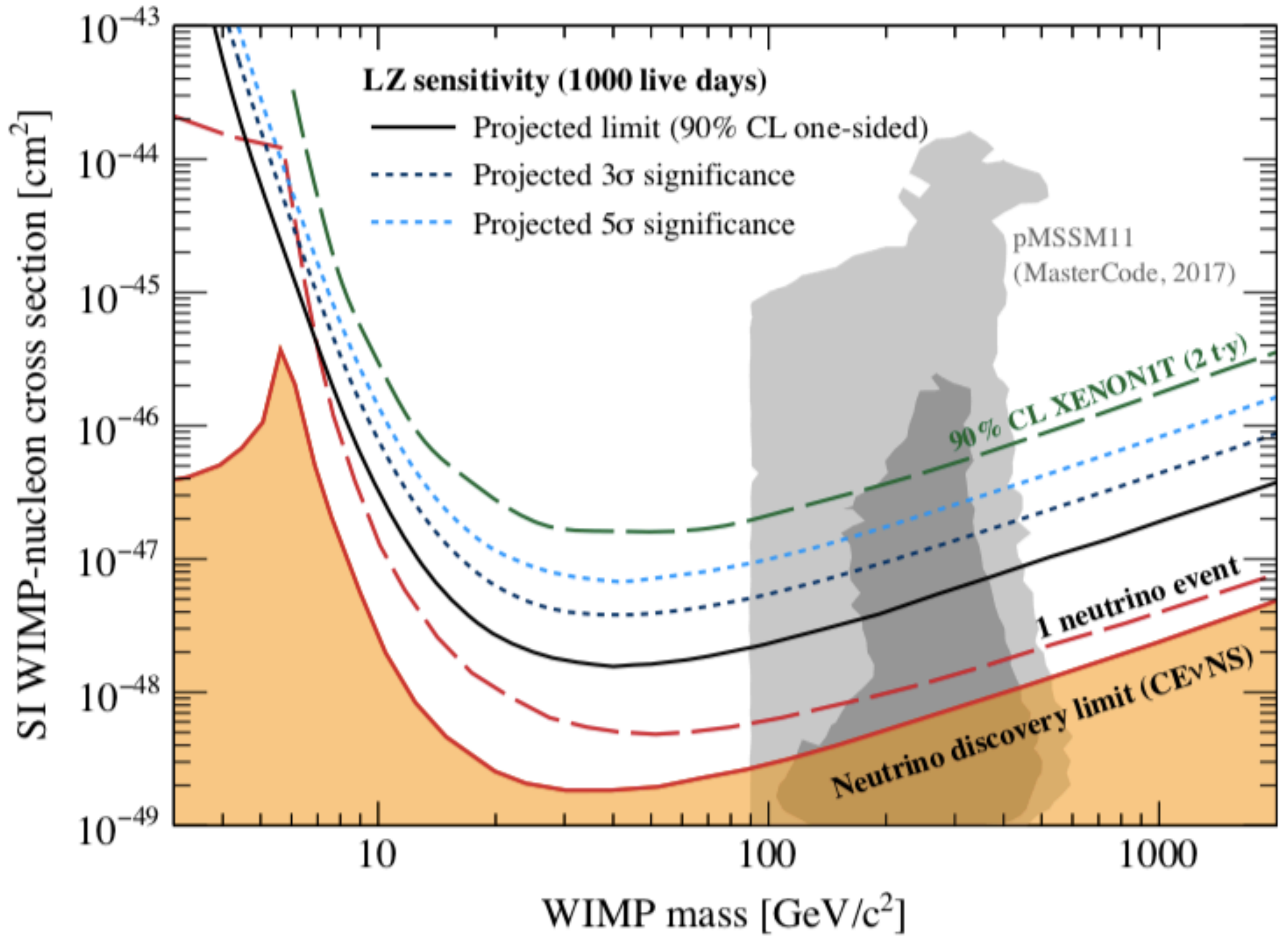


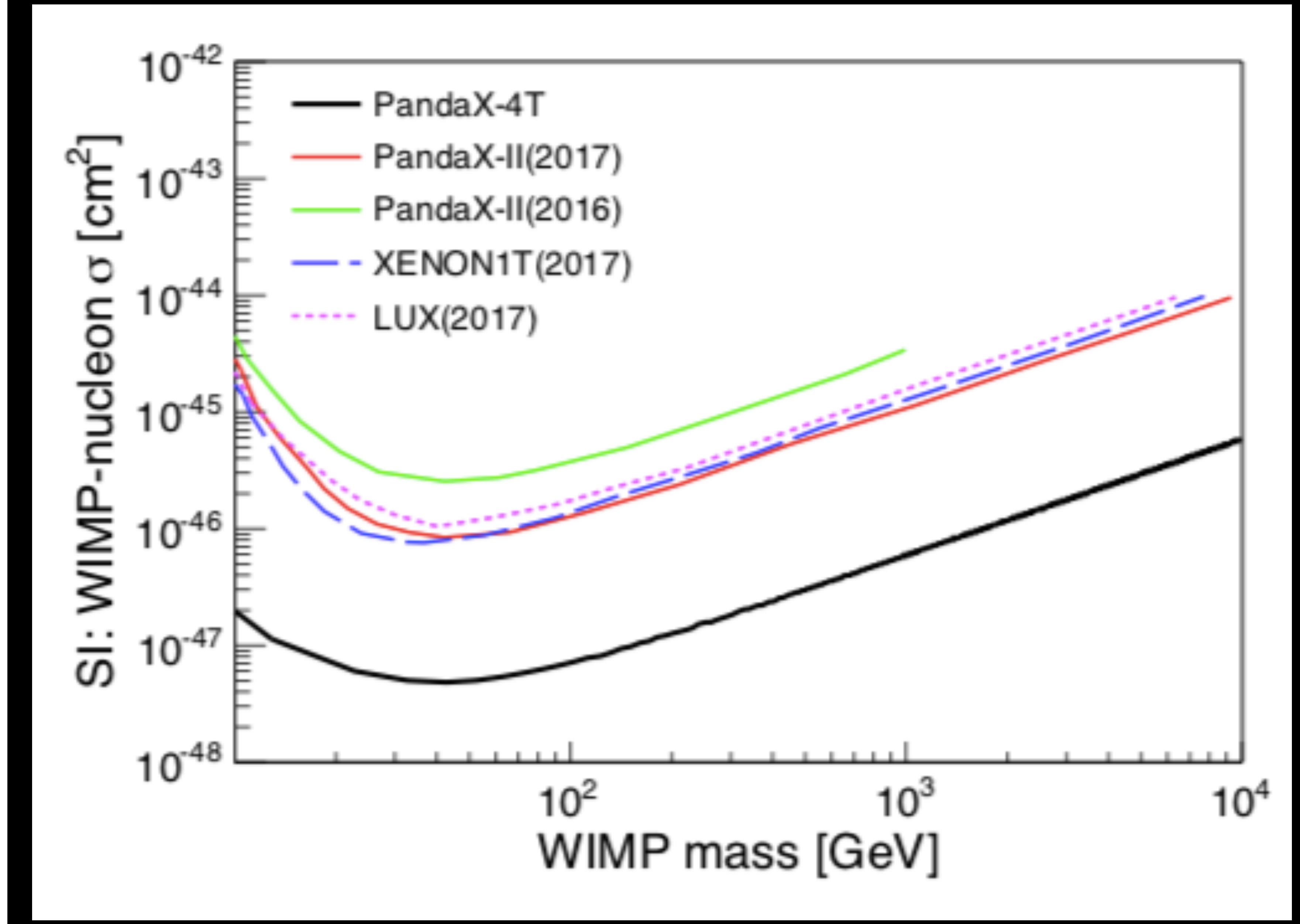
XENONnT

STARTING COMMISSIONING IN 2020

STARTING COMMISSIONING IN 2020

LUX/ZEPLIN



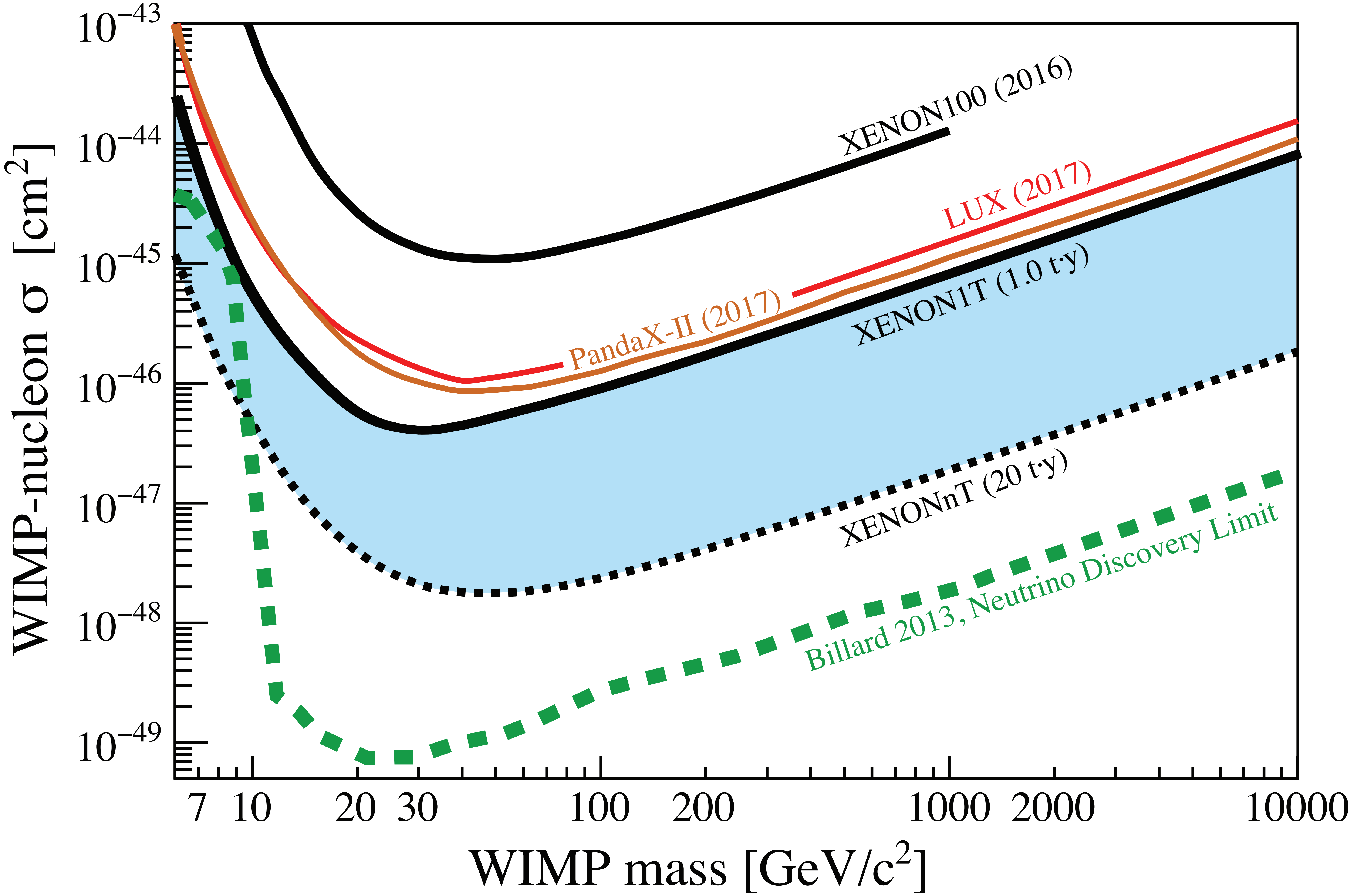


PANDAX-4T

STARTING COMMISSIONING IN 2021

BACKUP


Xe
XENON
Matter Project
PURDUE
Stockholm University
UC San Diego
NYU ABU DHABI
INFN
Rensselaer



XENONnT PROJECTED SENSITIVITY

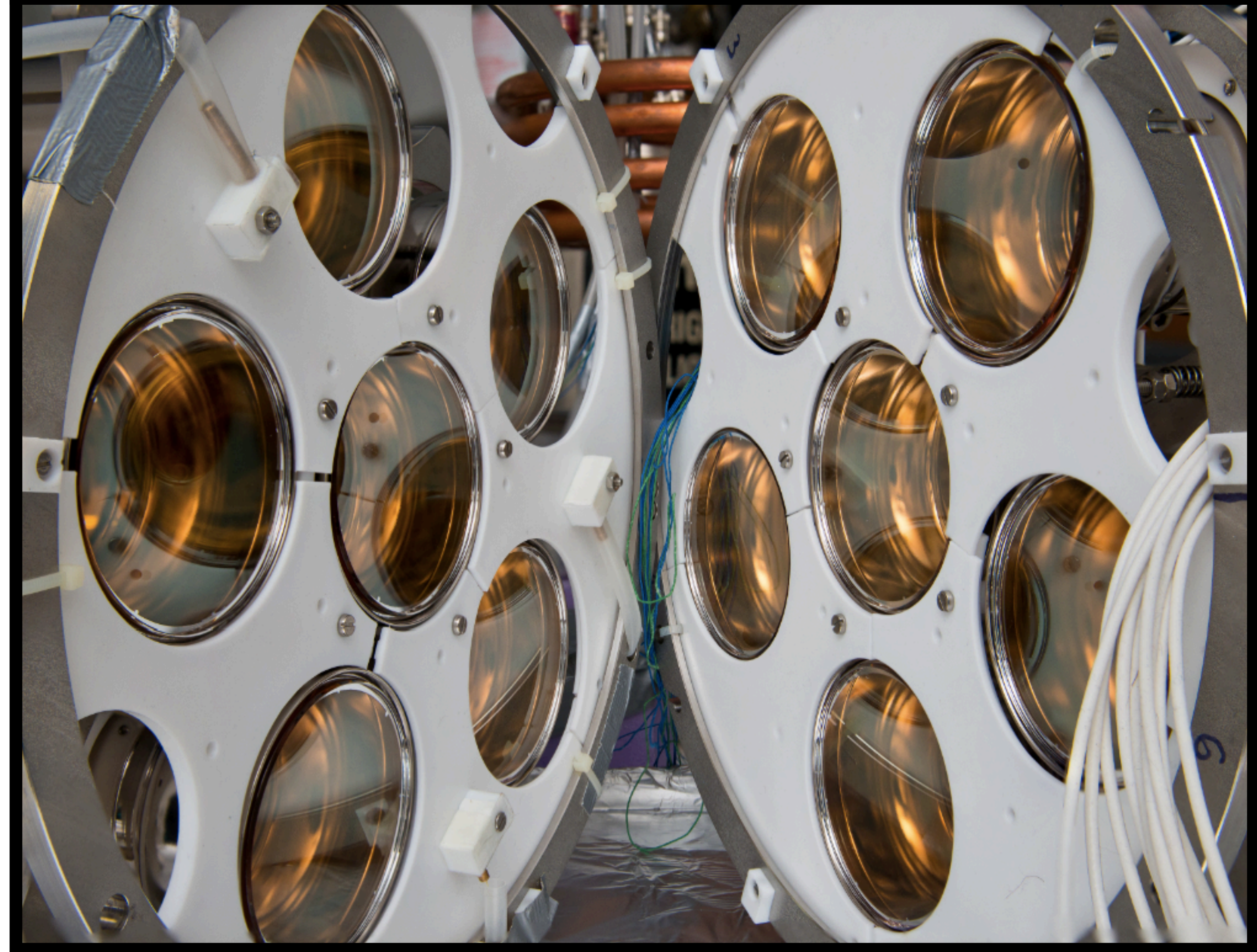
4TON- FIDUCIAL

5 YEARS

TIME PROJECTION CHAMBER

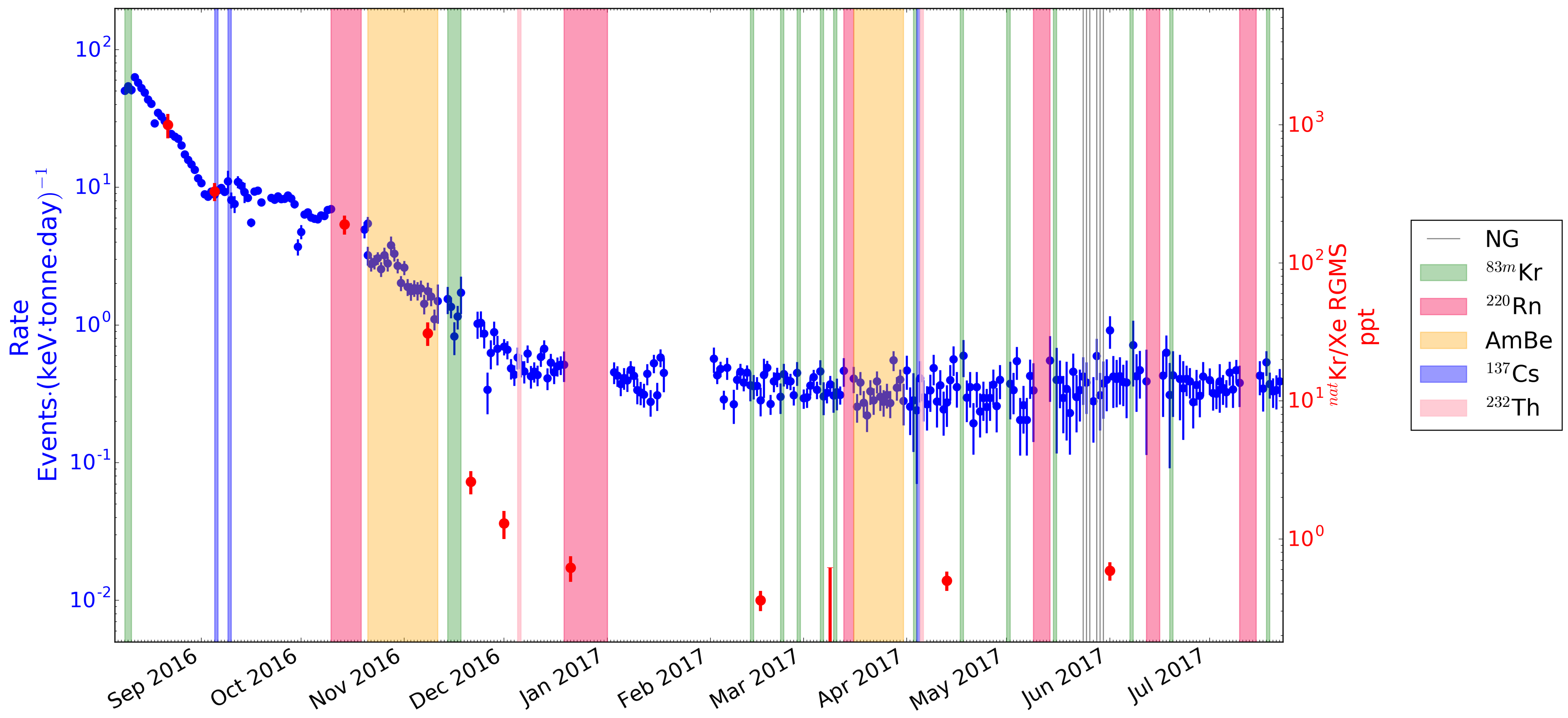
LARGEST TPC **FITTING** IN THE XENON1T **OUTER VESSEL:**

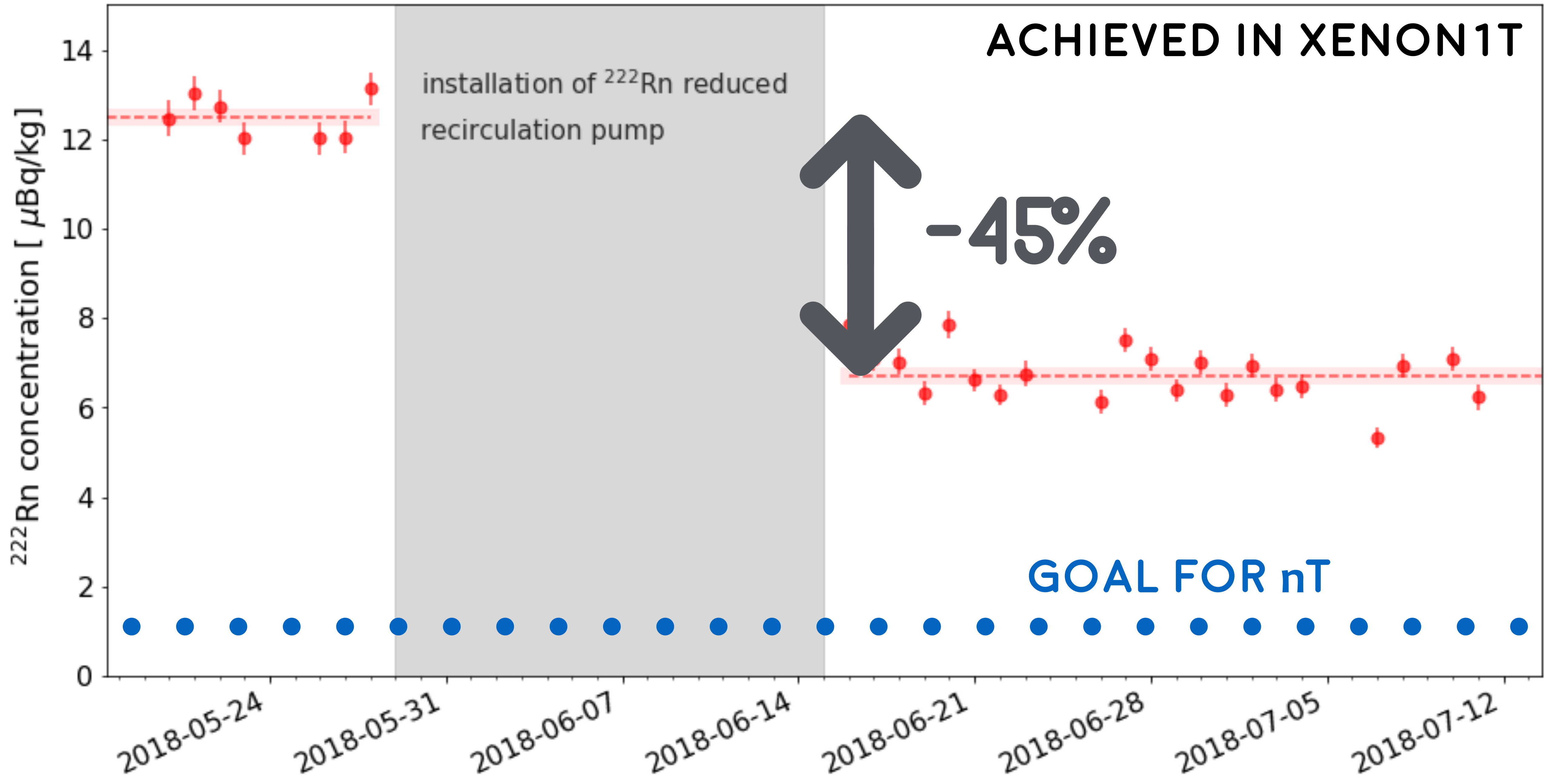
DIMENSIONS (⌀, HEIGHT)	**1340MM, 1578MM** (COLD)
TARGET MASS	**5.9 T** (COLD)
# OF PMT IN TOP ARRAY	**253**
# OF PMT IN BOTTOM ARRAY	**241**



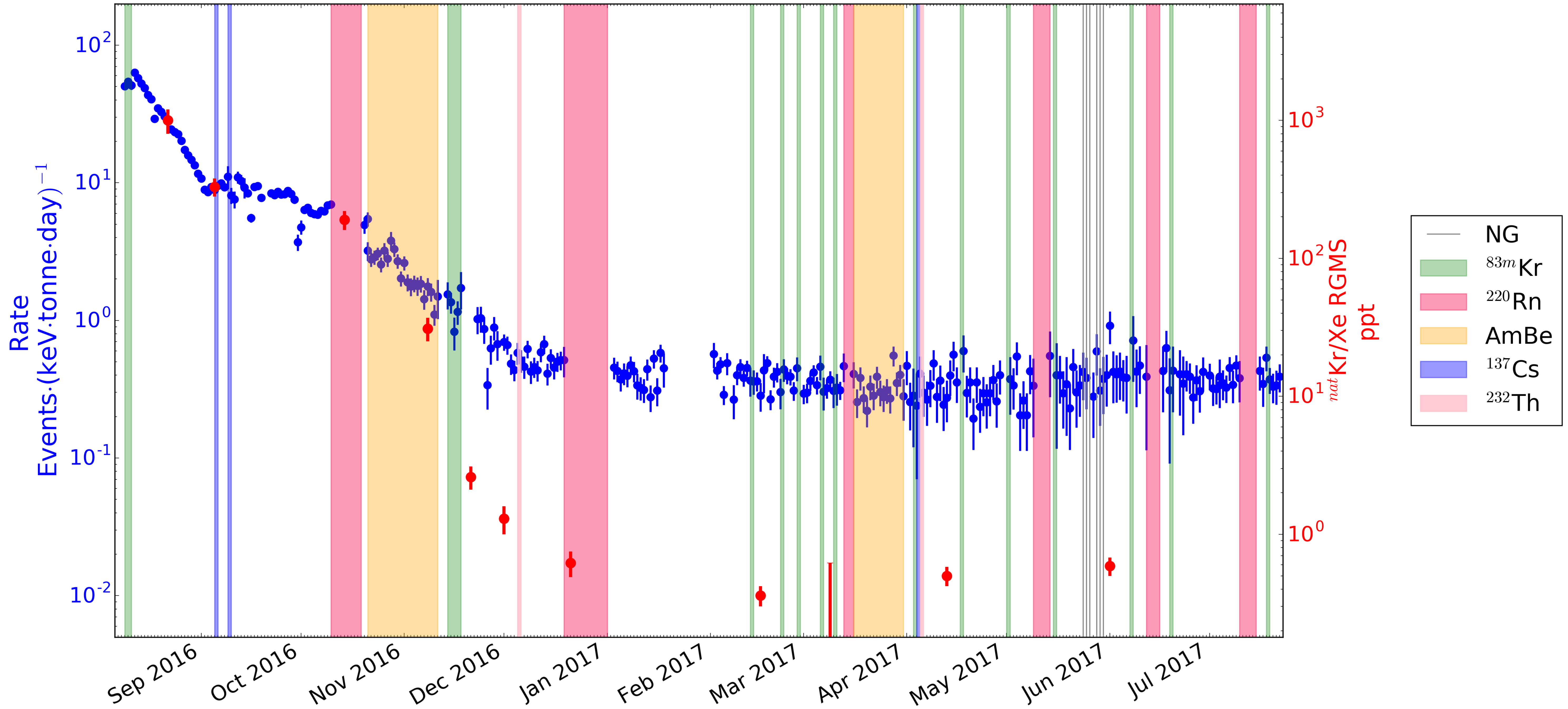
REDUCE RADON BKG?

REDUCE RADON SOURCES



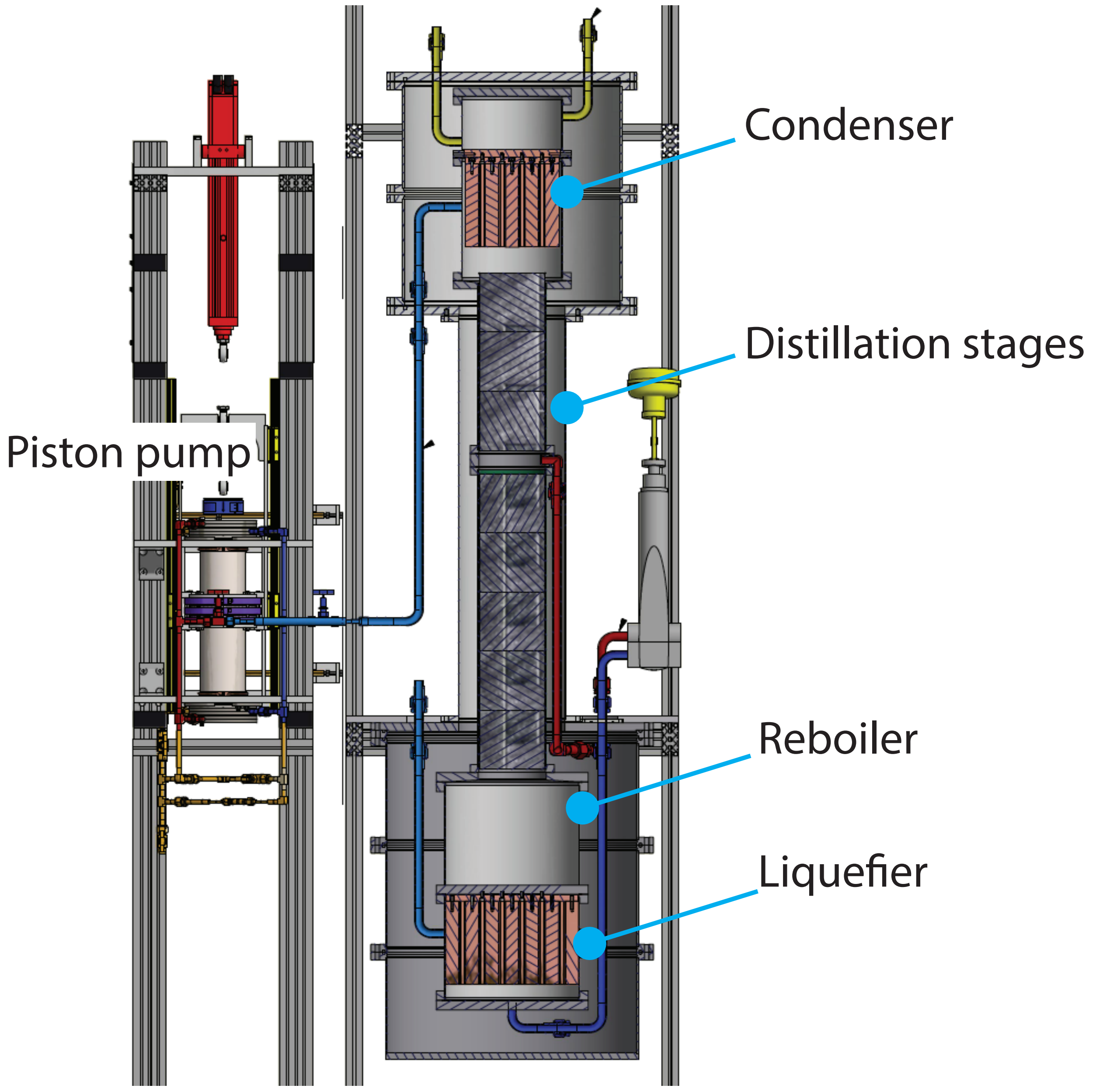


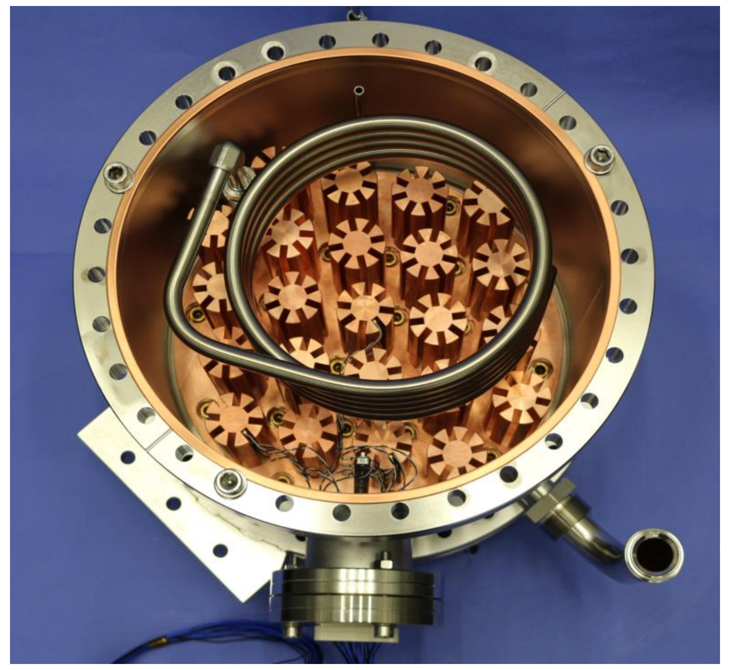
REDUCE RADON BKG?

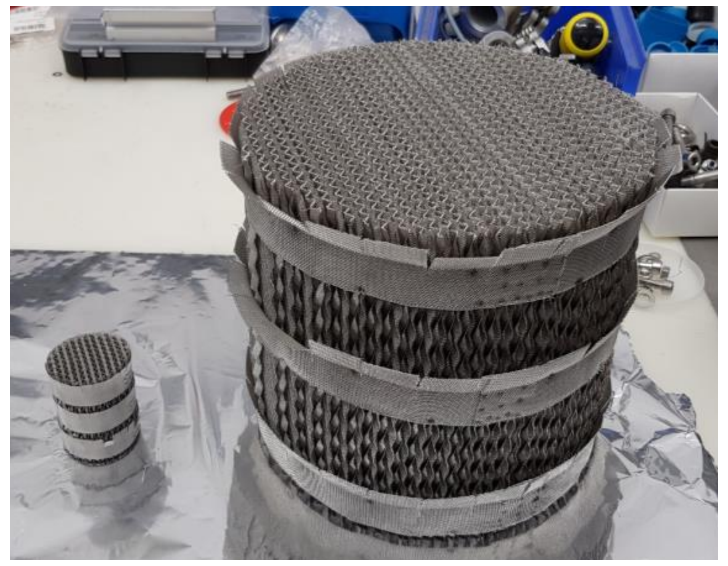


ONLINE RADON REMOVAL

A SINGLE DEDICATED COLUMN TO REMOVE RN EMANATED BOTH IN GAS AND LIQUID PHASES.





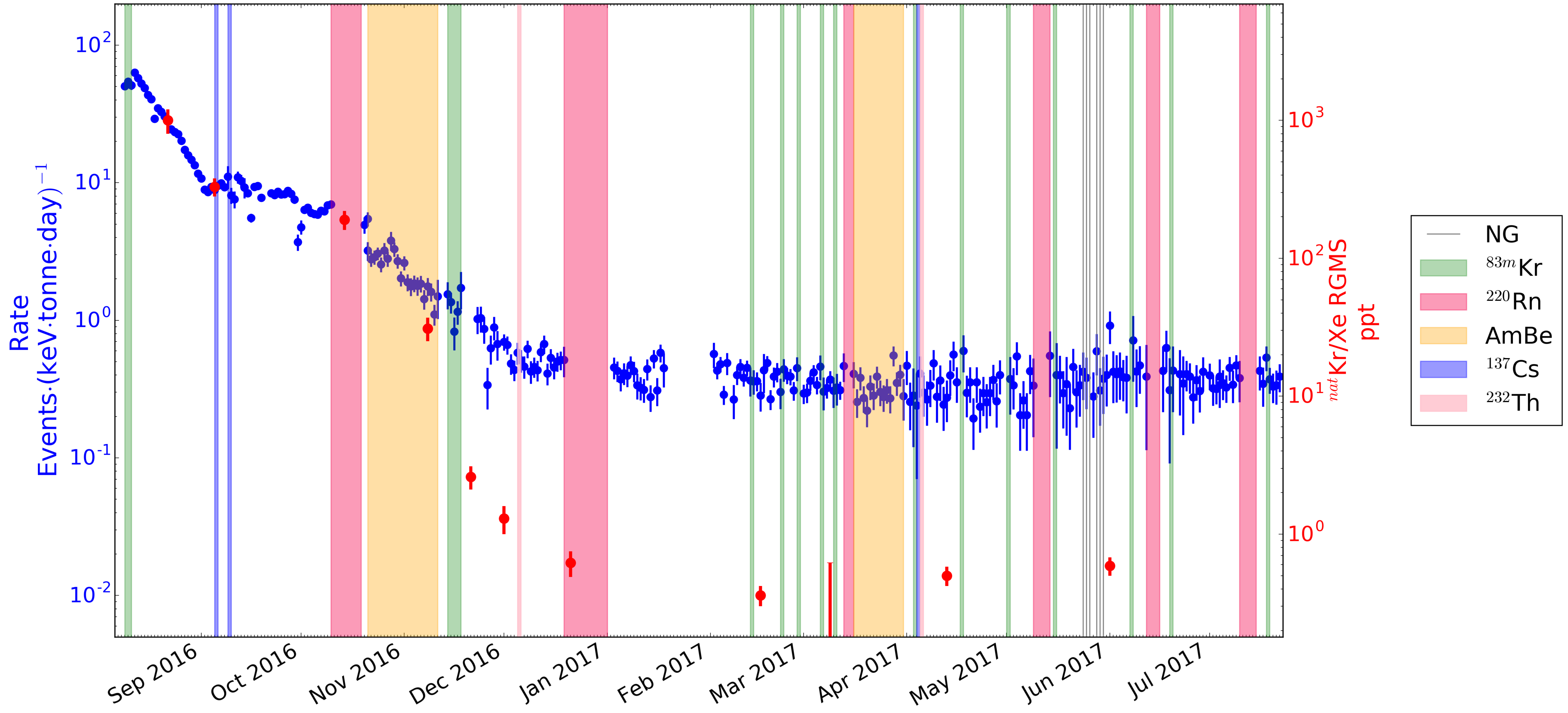


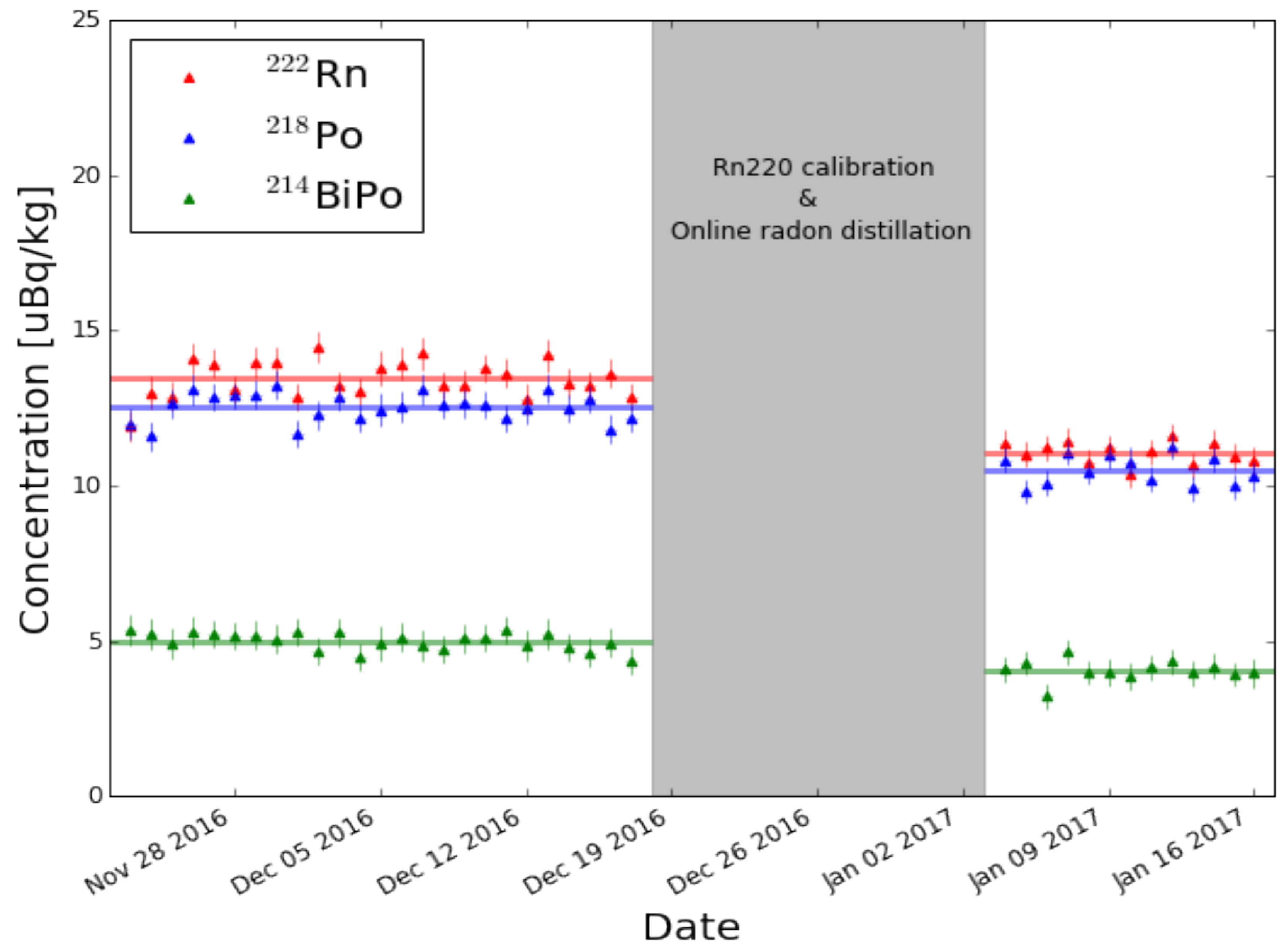
E.Aprile et al., *Online ^{222}Rn removal by cryogenic distillation in the XENON100 experiment*, Eur. Phys. J. C 77 (2017)

REDUCE RADON BKG?

ONLINE RADON REMOVAL

CONCEPT ALREADY SUCCESSFULLY TESTED IN XENON1T & XENON100. THIS FEATURES A FASTER FLOW!



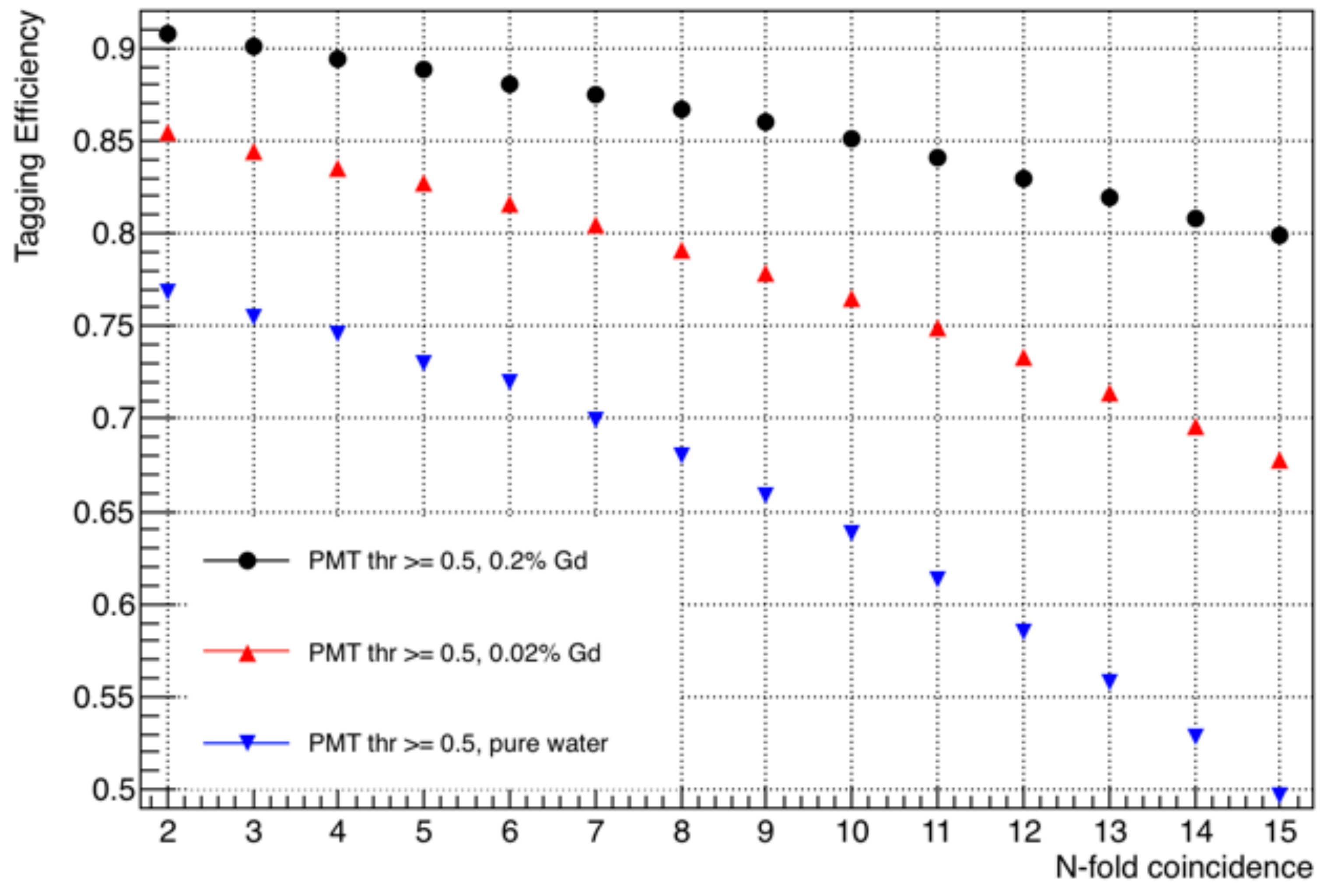


TESTED IN OBSERVED **20%** REDUCTION WHEN OPERATING THE Kr-COLUMN

INVERTED AS TEST ONLINE RADON REMOVAL PLANT!

E.Aprile et al., *Online ²²²Rn removal by cryogenic distillation in the XENON100 experiment*, Eur. Phys. J. C 77 (2017)

REDUCE NEUTRON BKG?



TAGGING EFFICIENCY > 85%

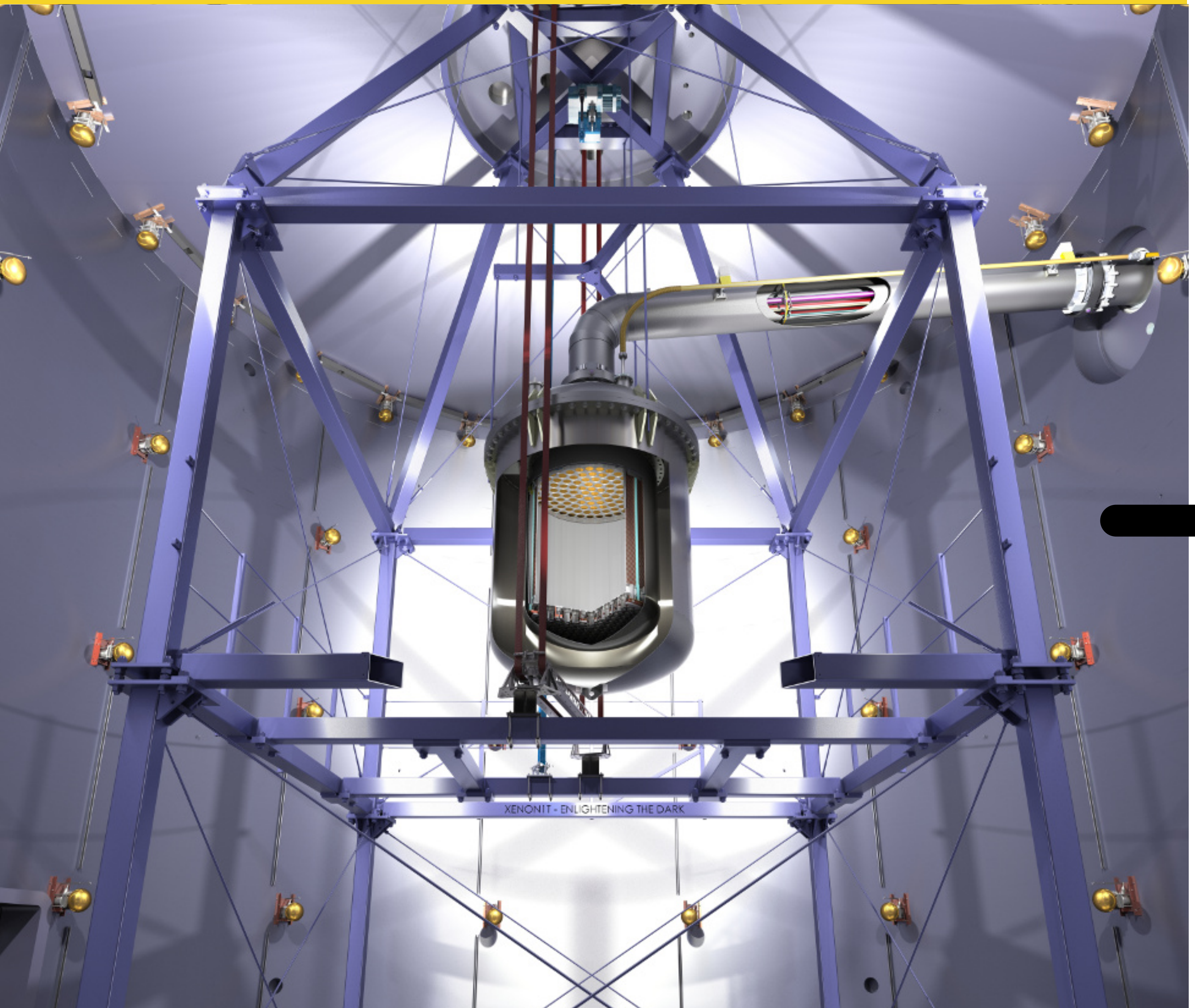
<1EVENT IN 20 TONNE×YR

Gd-DOPED WATER

ADD 0.5% OF $Gd_2(SO_4)_3$ TO ULTRAPURE WATER

TECHNOLOGY ESTABLISHED BY EGADS FOR S-K-Gd

N-capture on Gd leads to 8MeV γ's → Compton electrons → Cherenkov light



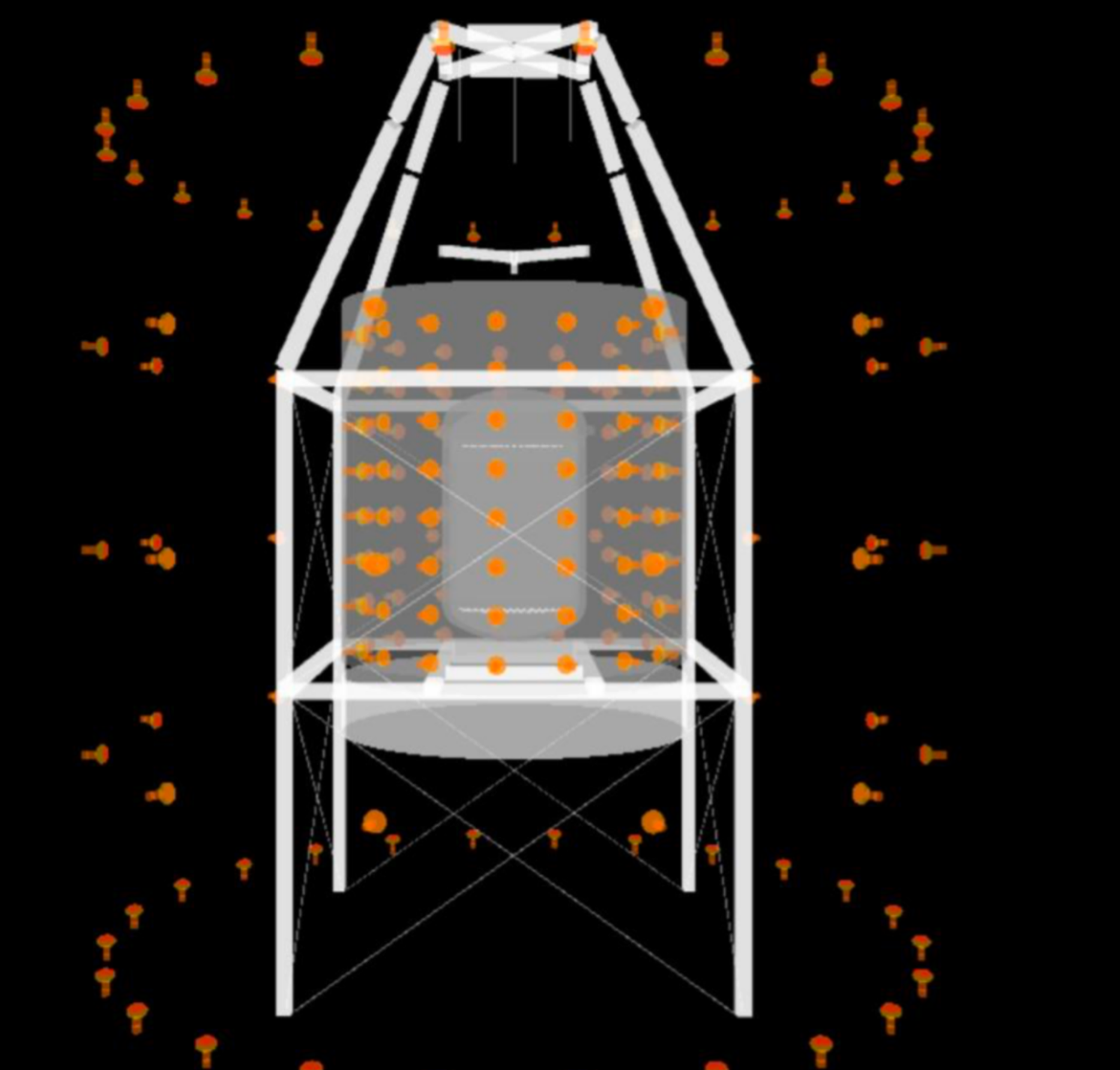
→

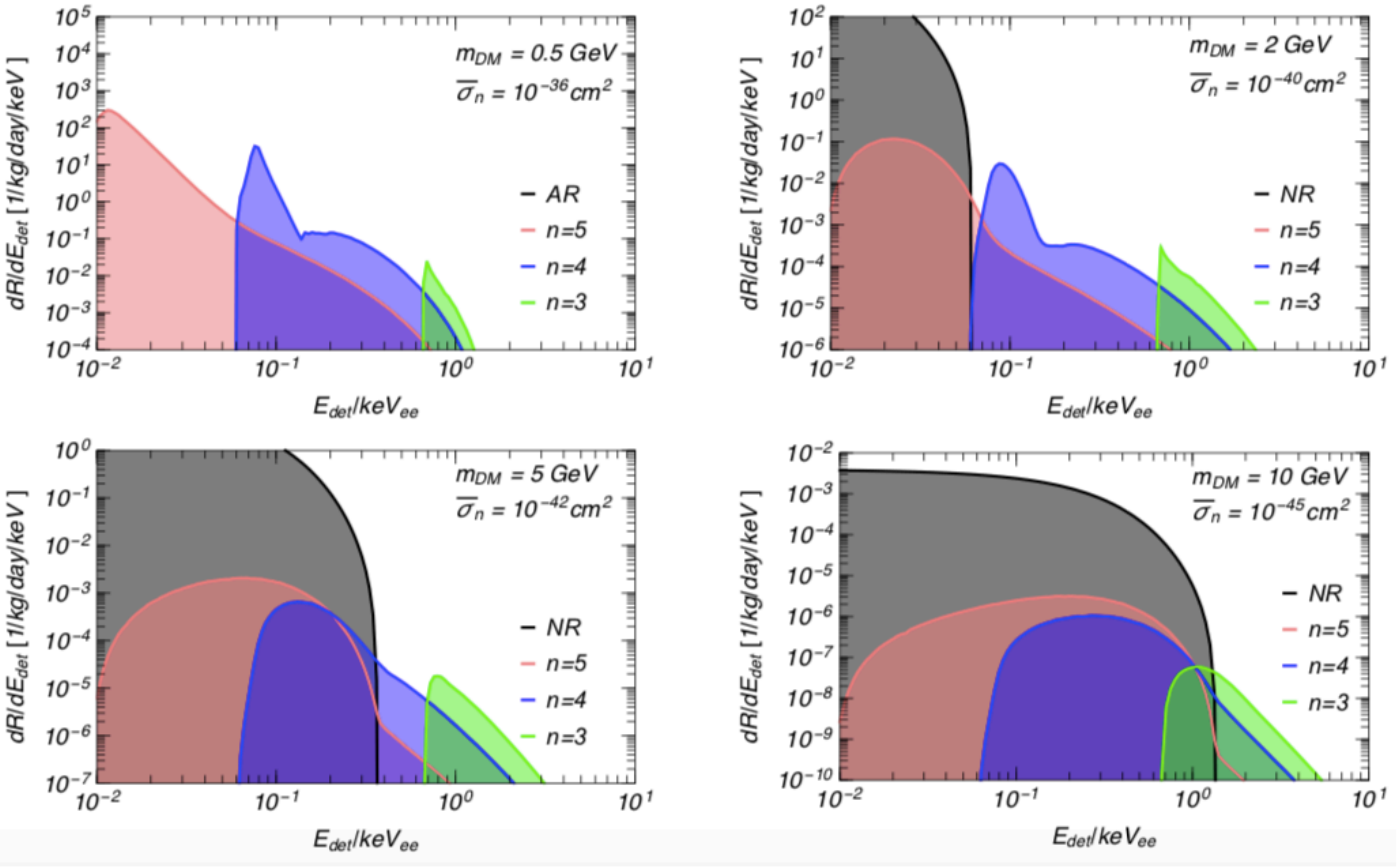
XENON1T MUON VETO

WILL BE REFURBISHED

TO ACT BOTH AS MUON AND NEUTRON VETO

→





arXiv:1707.07258

Background Source	Mass (kg)	$^{238}U_e$	$^{238}U_l$	$^{232}Th_e$	$^{232}Th_l$	^{60}Co	^{40}K	n/yr	ER (cts)	NR (cts)
		mBq/kg								
Detector Components										
PMT systems	308	31.2	5.20	2.32	2.29	1.46	18.6	248	2.82	0.027
TPC systems	373	3.28	1.01	0.84	0.76	2.58	7.80	79.9	4.33	0.022
Cryostat	2778	2.88	0.63	0.48	0.51	0.31	2.62	323	1.27	0.018
Outer detector (OD)	22950	6.13	4.74	3.78	3.71	0.33	13.8	8061	0.62	0.001
All else	358	3.61	1.25	0.55	0.65	1.31	2.64	39.1	0.11	0.003
								subtotal	**9**	**0.07**
Surface Contamination										
Dust (intrinsic activity, 500 ng/cm^2)									0.2	0.05
Plate-out (PTFE panels, 50 nBq/cm^2)									-	0.05
^{210}Bi mobility (0.1 µBq/kg LXe)									40.0	-
Ion misreconstruction (50 nBq/cm^2)									-	0.16
^{210}Pb (in bulk PTFE, 10 mBq/kg PTFE)									-	0.12
								subtotal	**40**	**0.39**
Xenon contaminants										
^{222}Rn (1.81 µBq/kg)									681	-
^{220}Rn (0.09 µBq/kg)									111	-
^{nat}Kr (0.015 ppt g/g)									24.5	-
^{nat}Ar (0.45 ppb g/g)									2.5	-
								subtotal	**819**	**0**
Laboratory and Cosmogenics										
Laboratory rock walls									4.6	0.00
Muon induced neutrons									-	0.06
Cosmogenic activation									0.2	-
								subtotal	**5**	**0.06**
Physics										
^{136}Xe $2\nu\beta\beta$									67	-
Solar neutrinos: pp+^{7}Be+^{13}N									255	-
Diffuse supernova neutrinos (DSN)									-	0.05
Atmospheric neutrinos (Atm)									-	0.46
								subtotal	**322**	**0.51**
Total									1195	1.03
Total (with 99.5% ER discrimination, 50% NR efficiency)									5.97	0.52
Sum of ER and NR in LZ for 1000 days, 5.6 tonne FV, with all analysis cuts									**6.49**	

LZ expectation for 1000 days, 5.6 tonne FV, 99.5% rejection, 50% NR acceptance

DETECTION EFFICIENCY

FOR **WIMP SEARCH** WE CONSIDERED THE REGION OF INTEREST

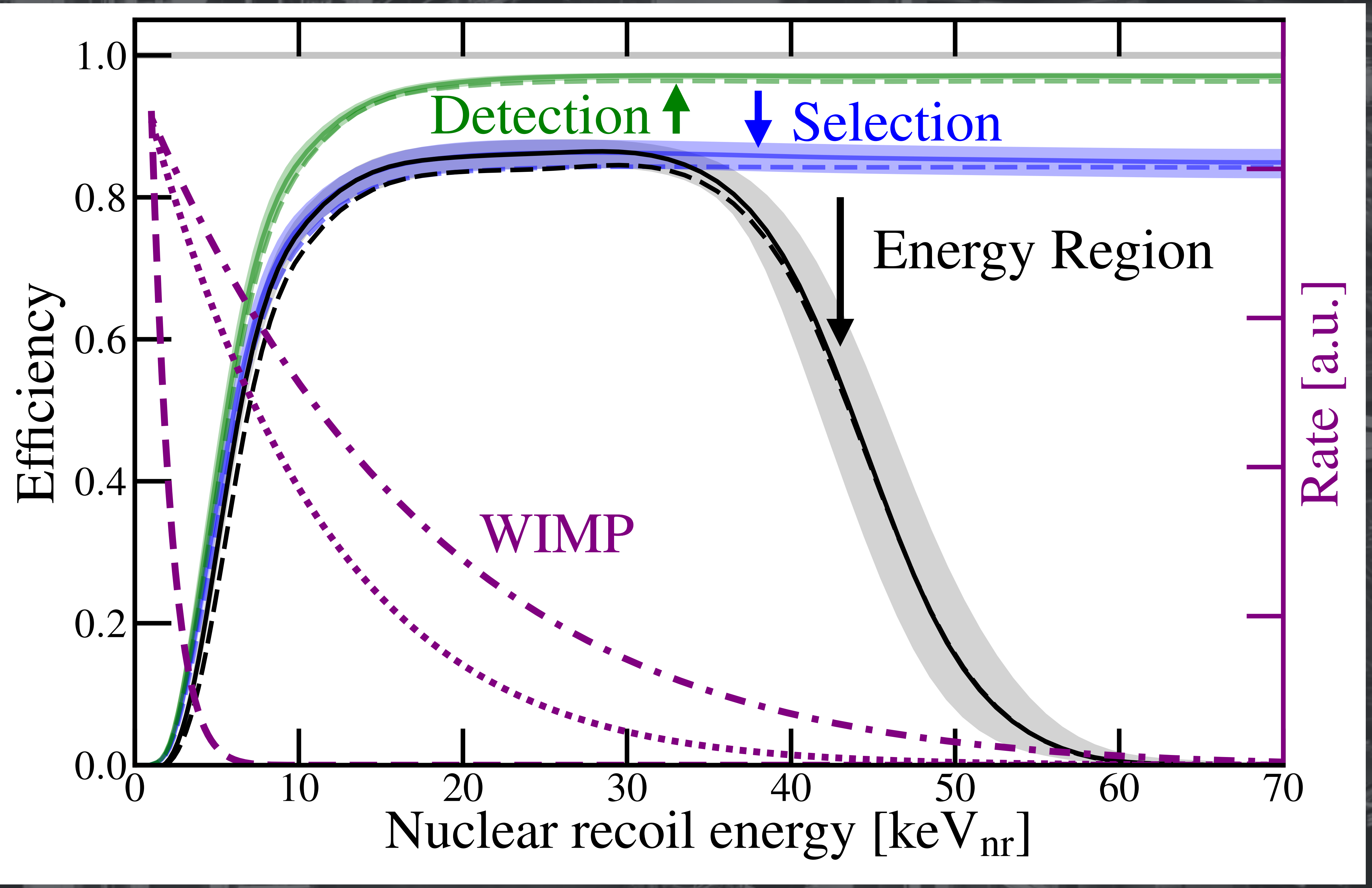
S1 → 3-70 PE

~[5-41 KEV_R]

~[1.4-10.6 KEV_{EE}]

Efficiency @ low energy dominated by statistical fluctuations in the PE production and by signal reconstruction algorithms

Artificial loss of efficiency @ high energy caused by end of ROI [70 PE]

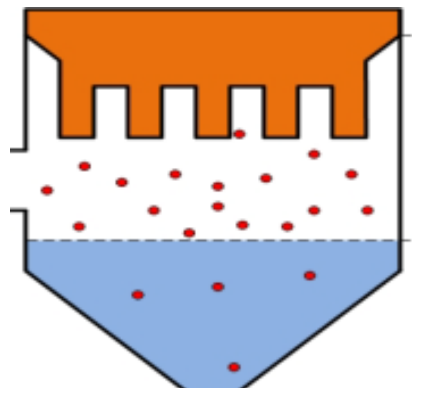


Principle and Design

Difference in vapor pressure:

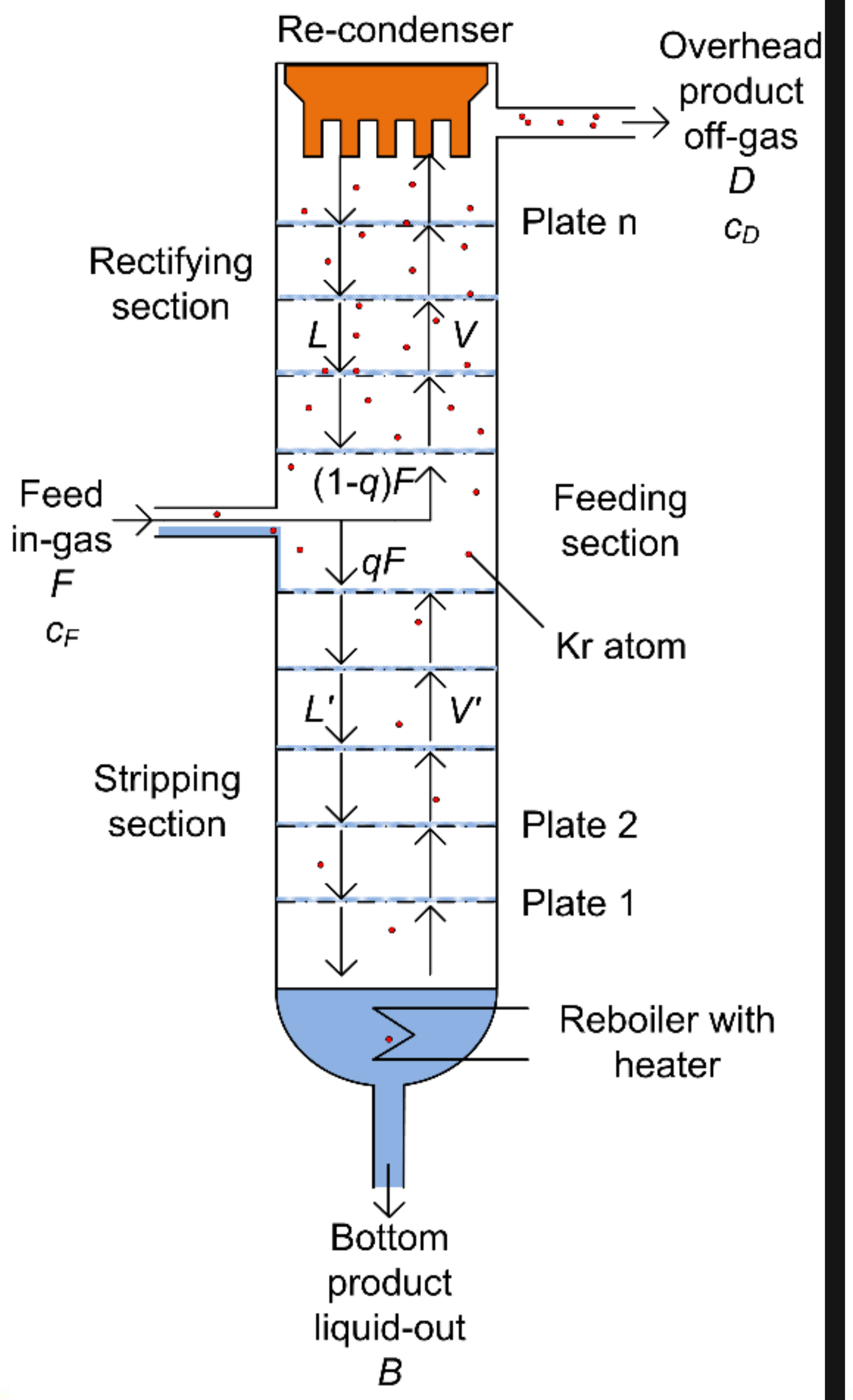
relative volatility: $\alpha = {}^{p_{Kr}}/_{p_{Xe}} \approx 10.5$ at 178 K

Single Stage DST:

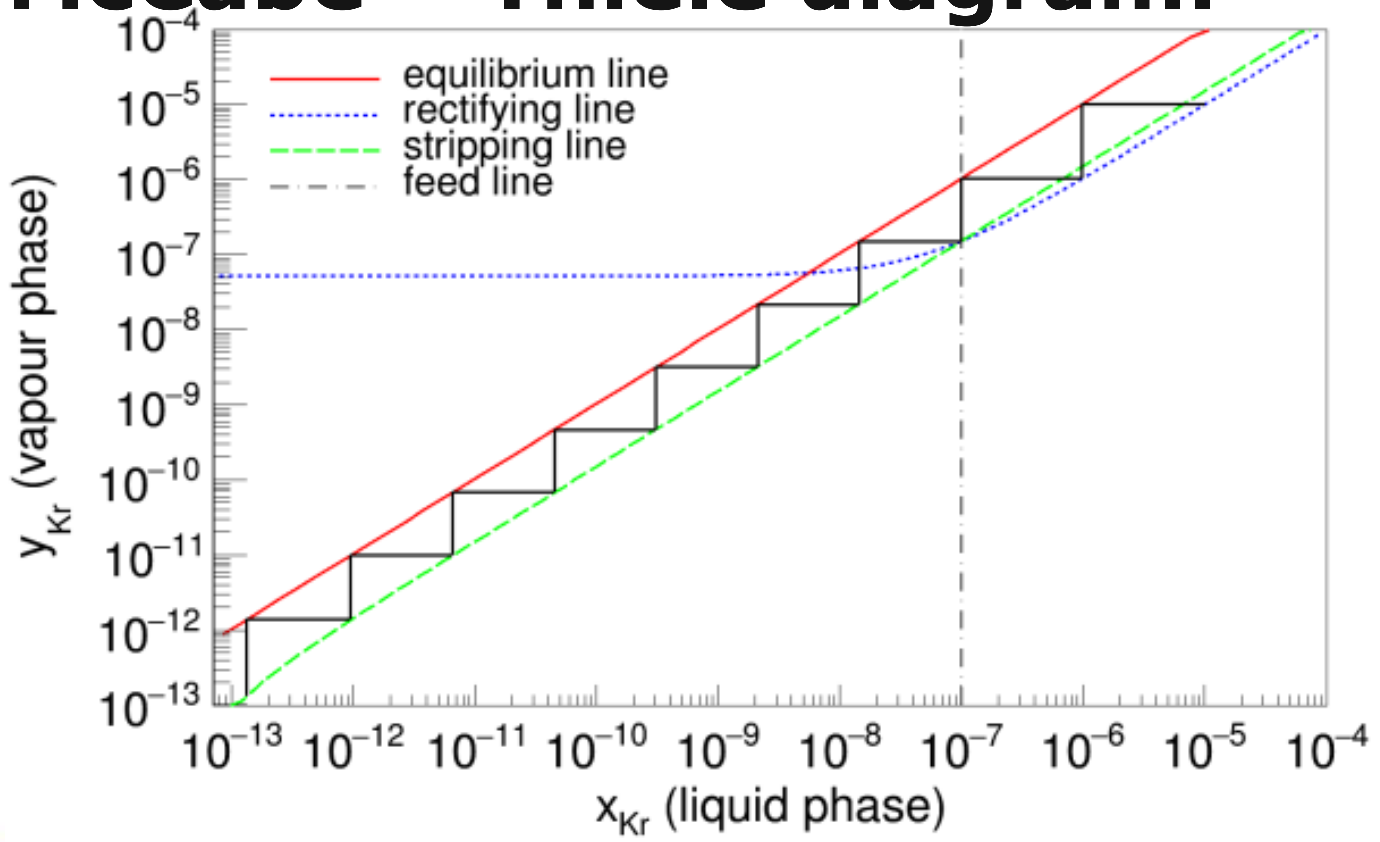


Krypton as the more volatile gas is collected at the top

Multi-stage DST with partial reflux:



McCabe – Thiele diagram:



Package column: