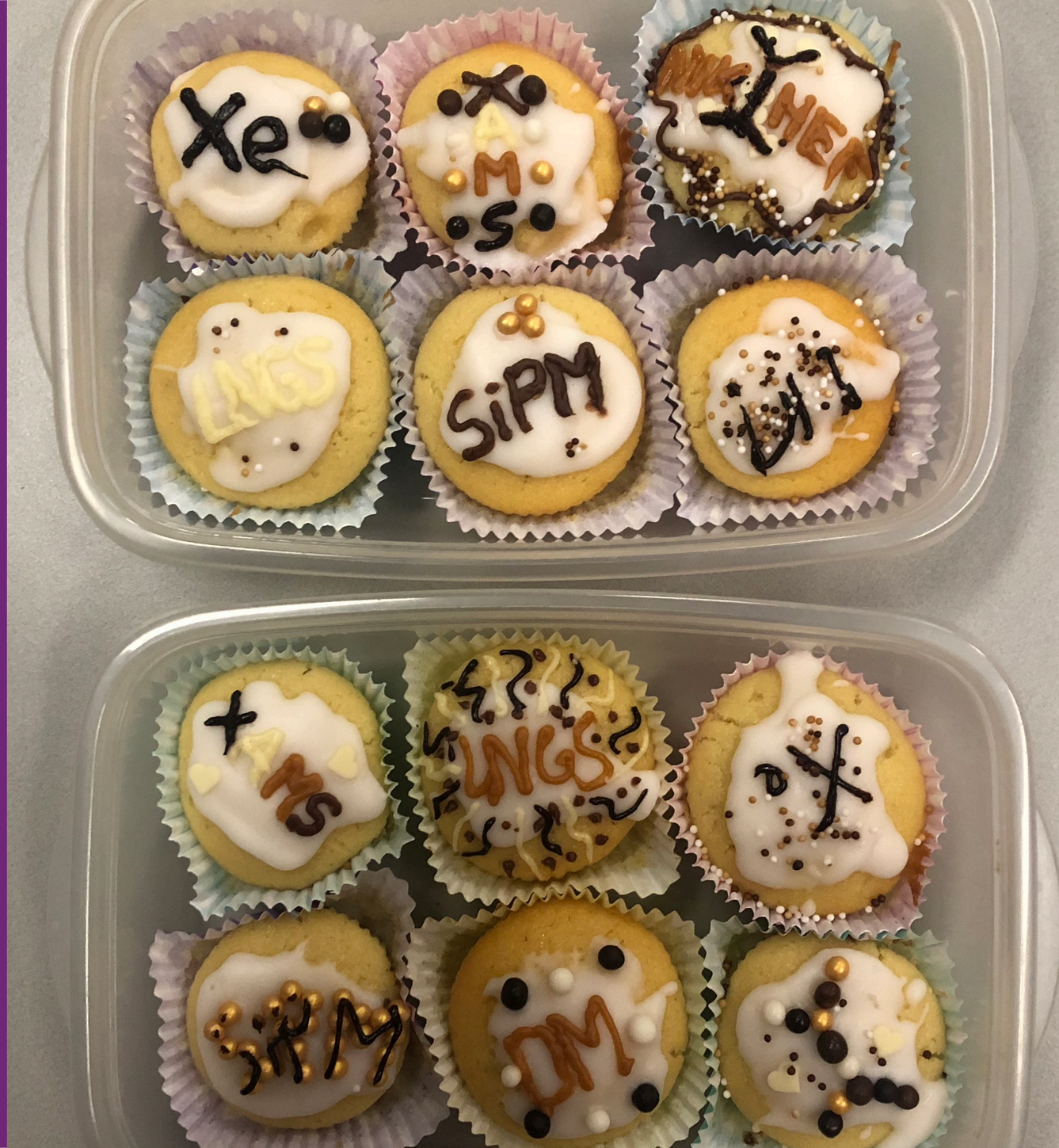
Nikhef

DARK MATTER

PATRICK DECOWSKI



DM Group Members

- **UvA Faculty Members**:
  - A.P. Colijn
  - M.P. Decowski [PL]
  - T.R. Pollmann
- **Postdocs**:
  - M. Pierre (Jan ’23)
  - J. Mead (Feb ’23)
- **PhDs**:
  - J. Angevaare (All but defense)
  - P. Gaemers
  - M. Flierman
  - C. Fuselli (Nov ’22)
  - M. van Nuland-Troost* (Aug ’22)
  - K. Weerman

*) Together with the Neutrino Program

- **MSc**:
  - Jelmer de Haan
  - Floris Jan Kamphorst
  - Saad el Morabit
- **HBO (technical) students:**
  - Danny Haringa
- **And 5 BSc students**

- Former DM PhD Jelle Aalbers will start as new faculty in Groningen in fall and will rejoin the DM group

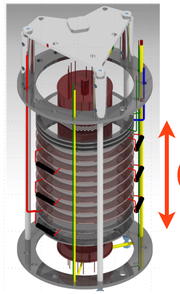
- **Goodbyes**:
  - Stefan Brünner (PD)
  - Emily Brookes (PhD)

Our Activities

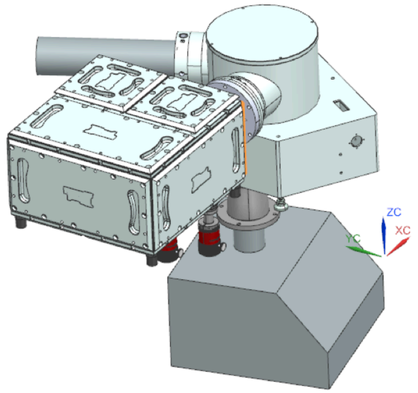
Main activity: liquid xenon based rare event experiments

XENONnT

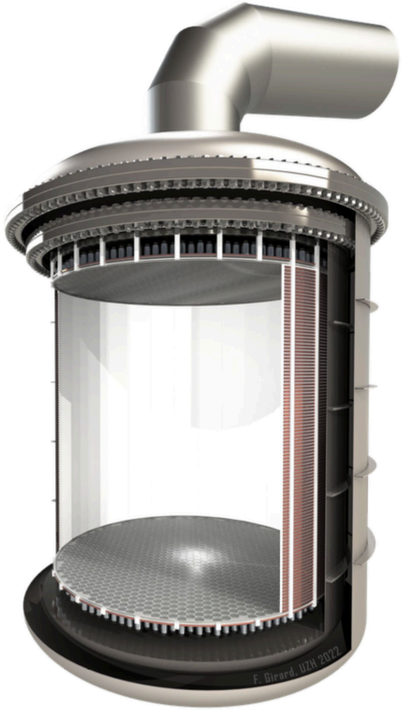
XAMS R&D



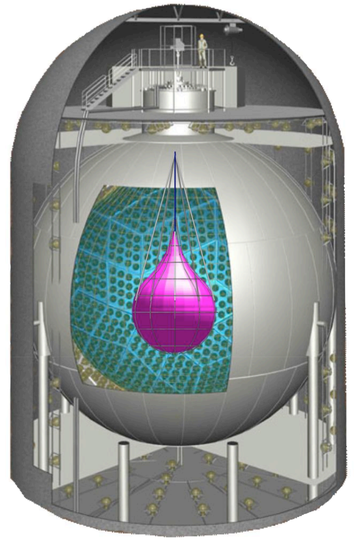
VULCAN R&D



DARWIN / XLZD



KamLAND-Zen



PTOLEMY R&D

DUNE

Columbia
KIT
Nikhef
Muenster
Stockholm
Mainz
MPIK, Heidelberg
Freiburg
Zurich
Chicago
Tsinghua
UCSD
Tokyo
Rice
Nagoya
Purdue
Kobe
Subatech
Coimbra
LPNHE
Torino
Bologna
L'Aquila
LNGS
Napoli
Weizmann
NYUAD

XENON

27 institutions
and 167 collaboration members

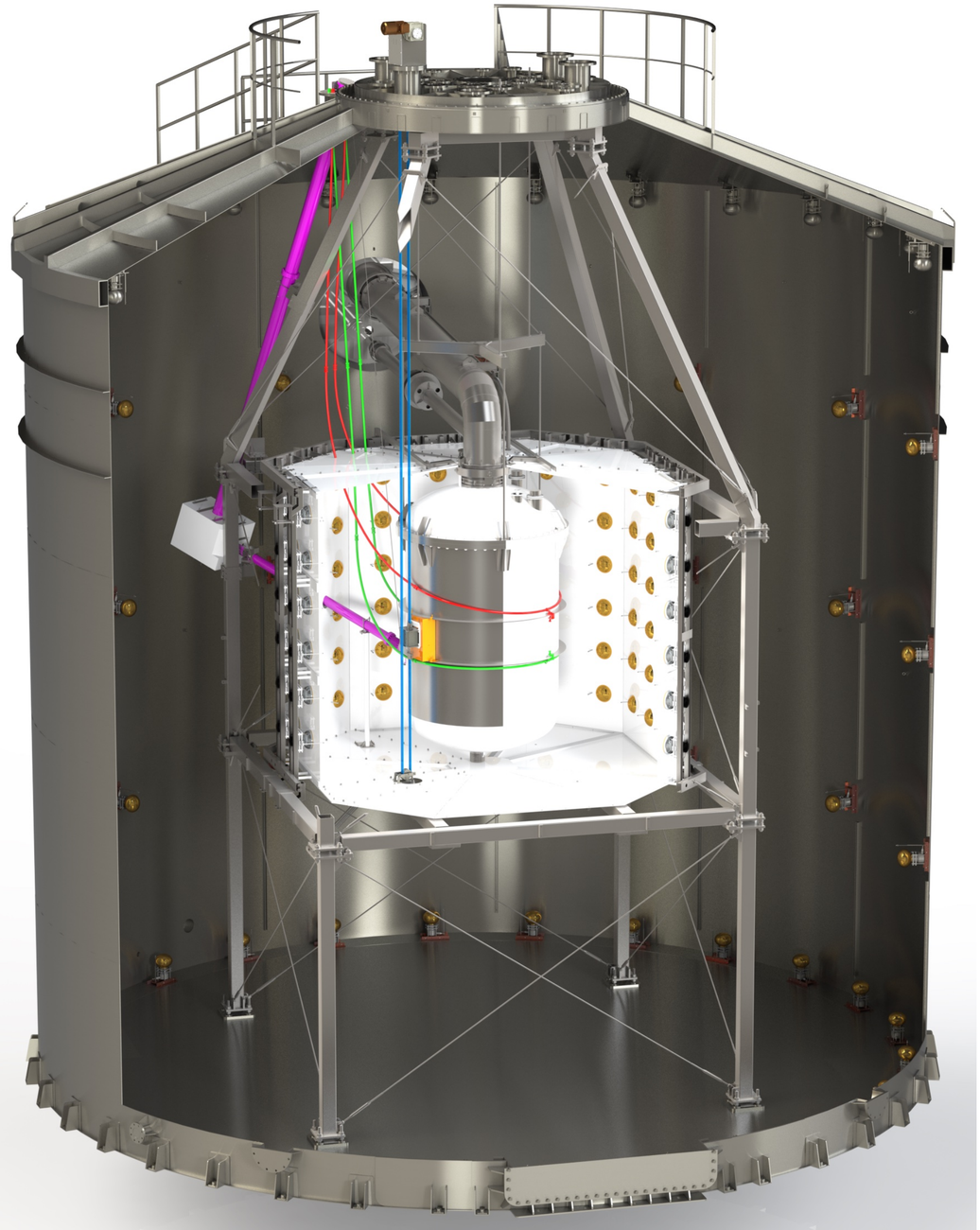
https://xenonexperiment.org

@XENONExperiment

@xenonexperiment

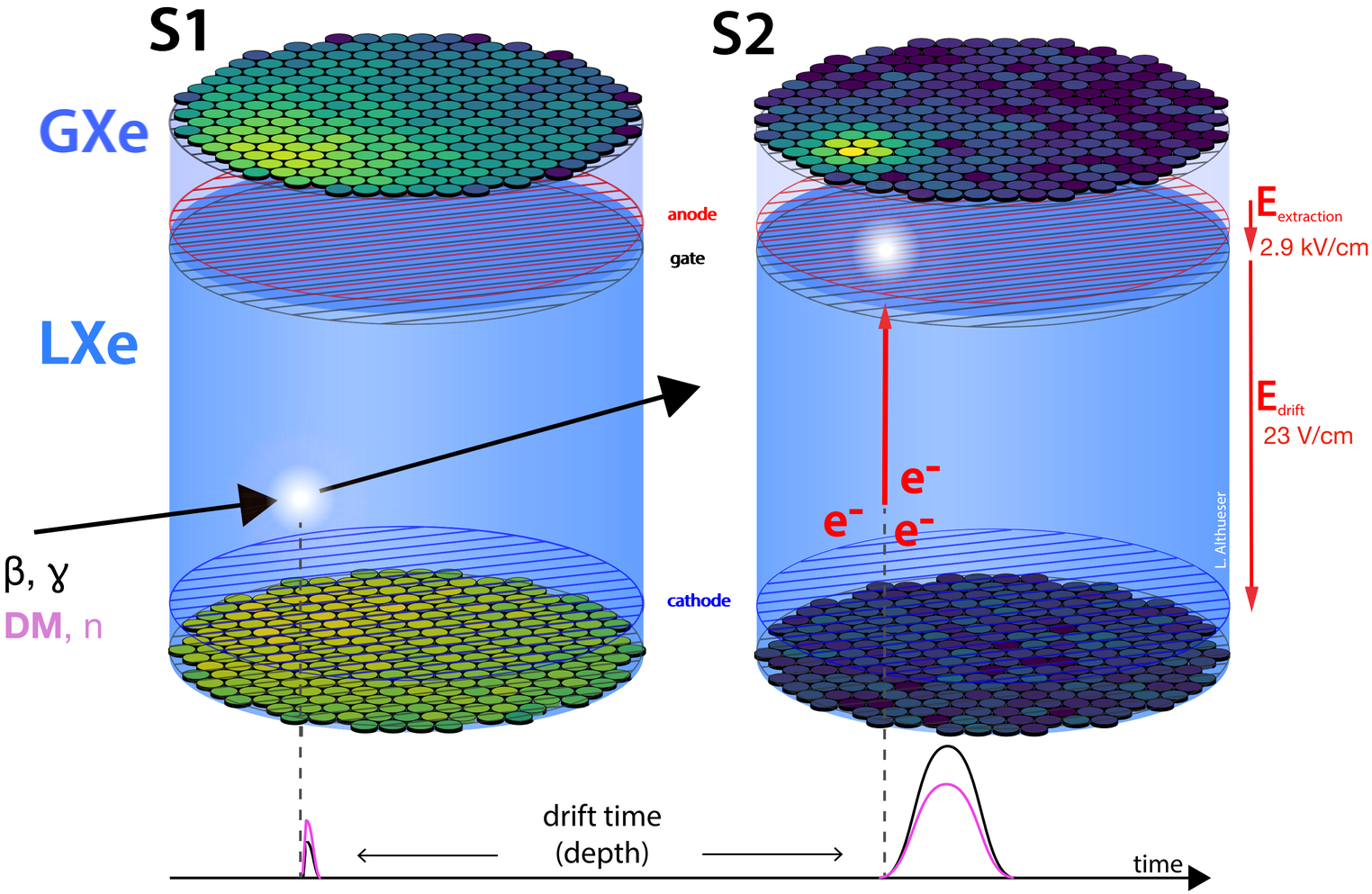
@xenon_experiment

XENON1T → XENONnT Improvements



- Reused much of the XENON1T infrastructure
- Larger TPC, more xenon: 2 t → 5.9 t LXe
- Improved cleanliness and radiopurity XENON, arXiv:2112.05629
- Liquid xenon purification system Plante et al, arXiv:2205.07336
- Radon distillation system Murra et al, arXiv:2205.11492
- Water Cherenkov neutron-veto
- New calibration systems and techniques
- Triggerless DAQ XENON, arXiv:2212.11032

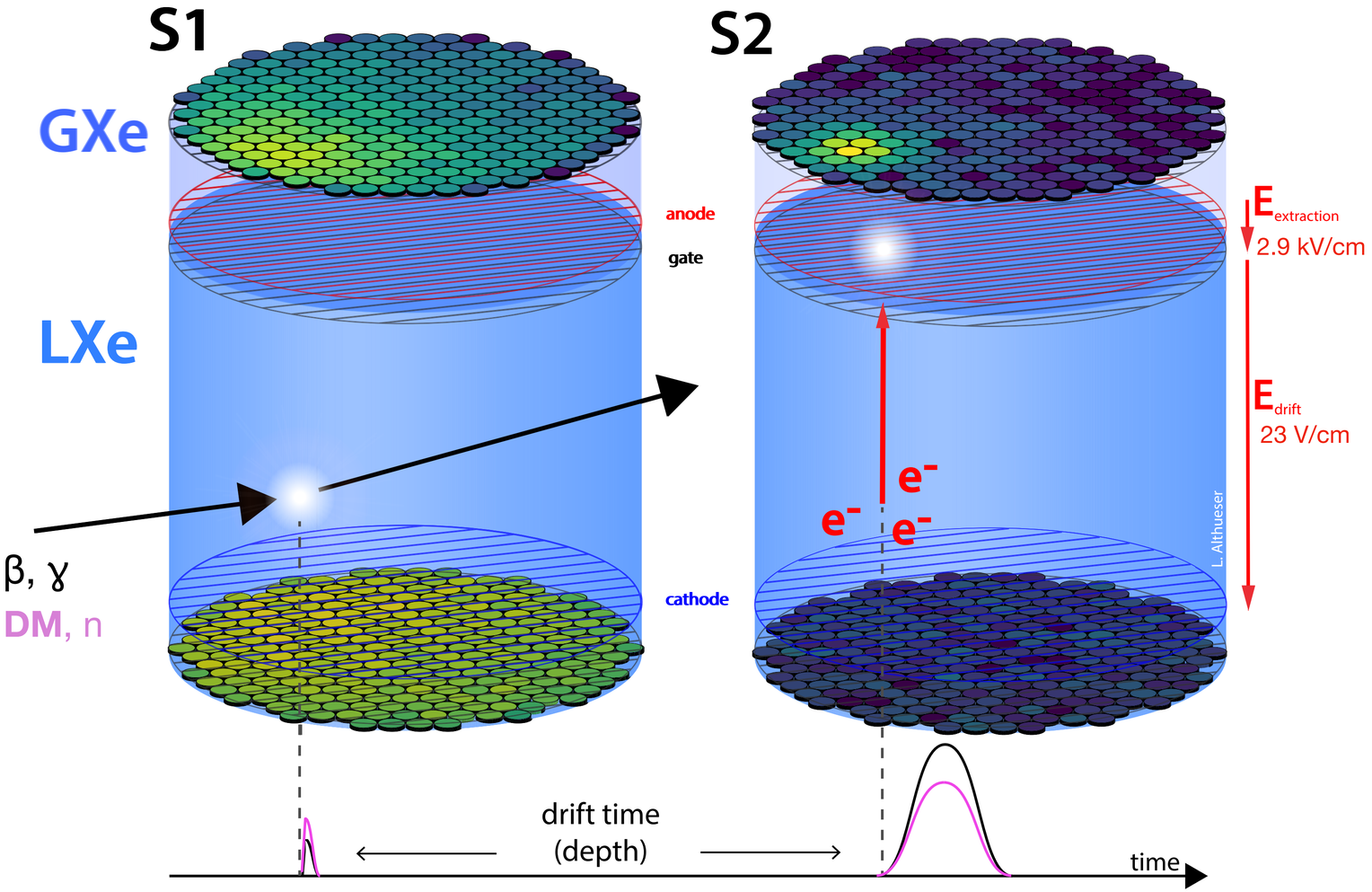
Detection Principle



- Energy range ~1 keV_{ee} to ~3 MeV_{ee}
- Discrimination of Electronic Recoils (ER) and Nuclear Recoils (NR)
- S2 light pattern and drift time give event vertex

ER / NR recoil discrimination: $\frac{S2}{S1}_{NR} < \frac{S2}{S1}_{ER}$

Detection Principle



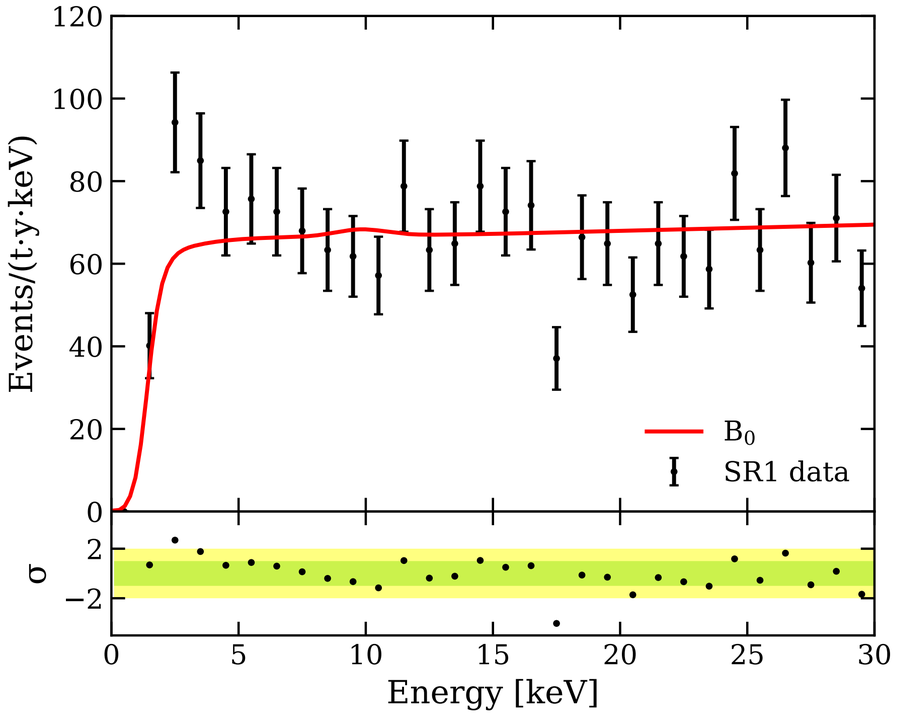
- Energy range ~1 keV_{ee} to ~3 MeV_{ee}
- Discrimination of Electronic Recoils (ER) and Nuclear Recoils (NR)
- S2 light pattern and drift time give event vertex

	Drift time [ms]	Electron lifetime [ms]
XENON1T	0.67	0.65
XENONnT	2.2	**~15**

ER / NR recoil discrimination: $\frac{S2}{S1}_{NR} < \frac{S2}{S1}_{ER}$

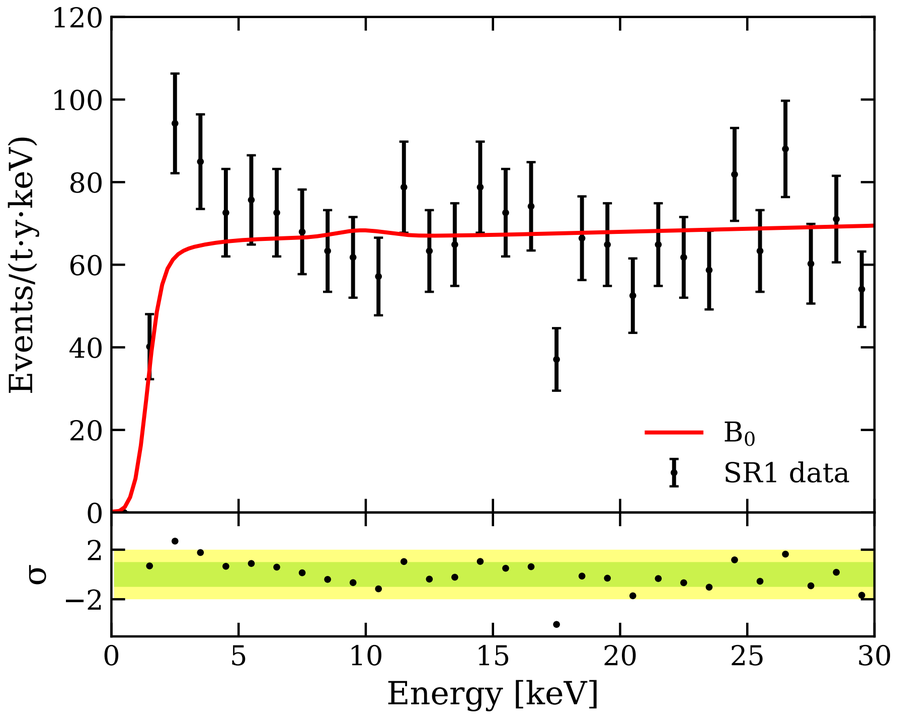
Unexpected Excess of ER events in XENON1T

Interactions with atomic electrons in LXe

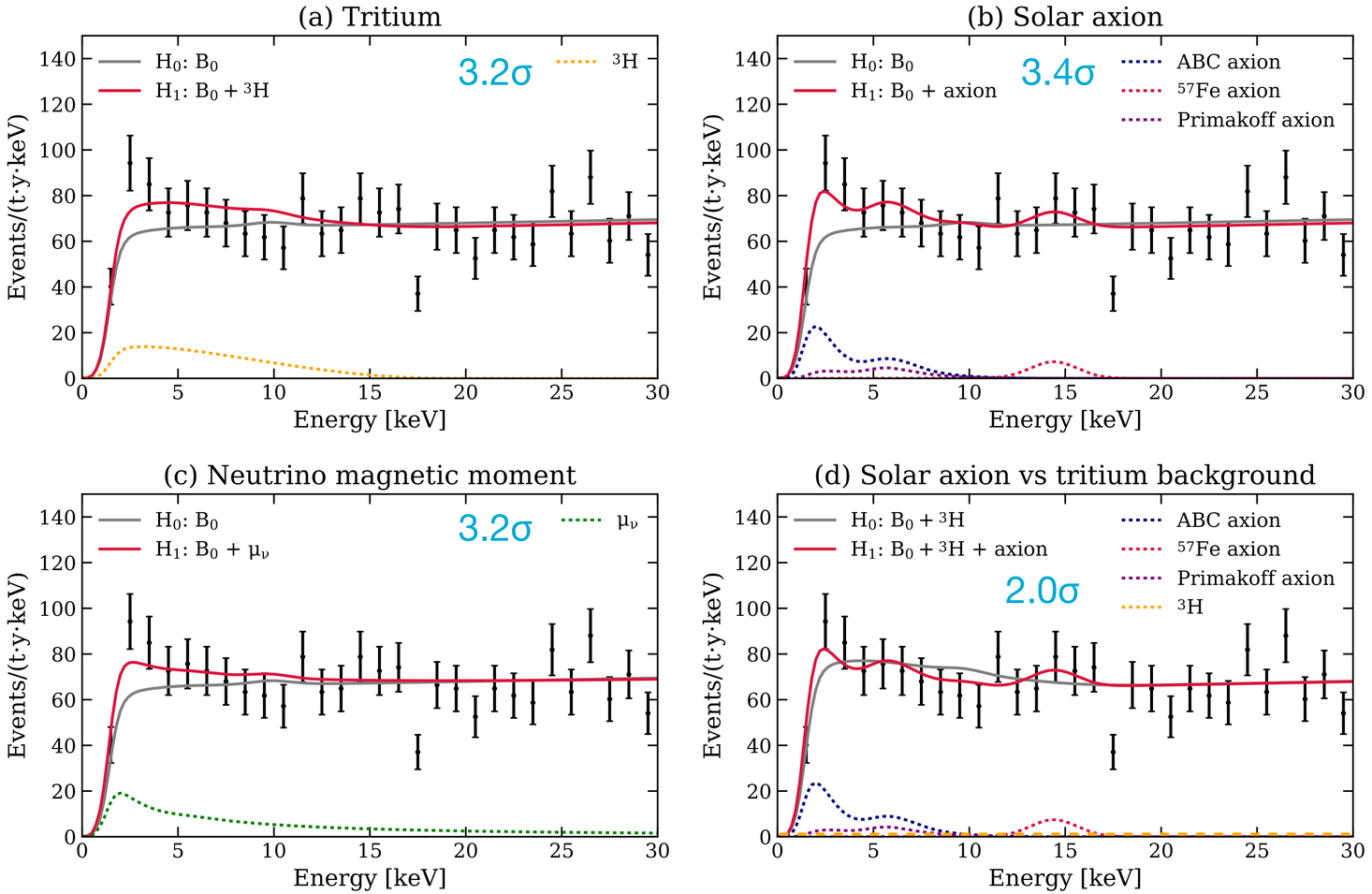


XENON, PRD 102, 072004 (2020); arXiv:2006.09721
(~550 citations)

Unexpected Excess of ER events in XENON1T



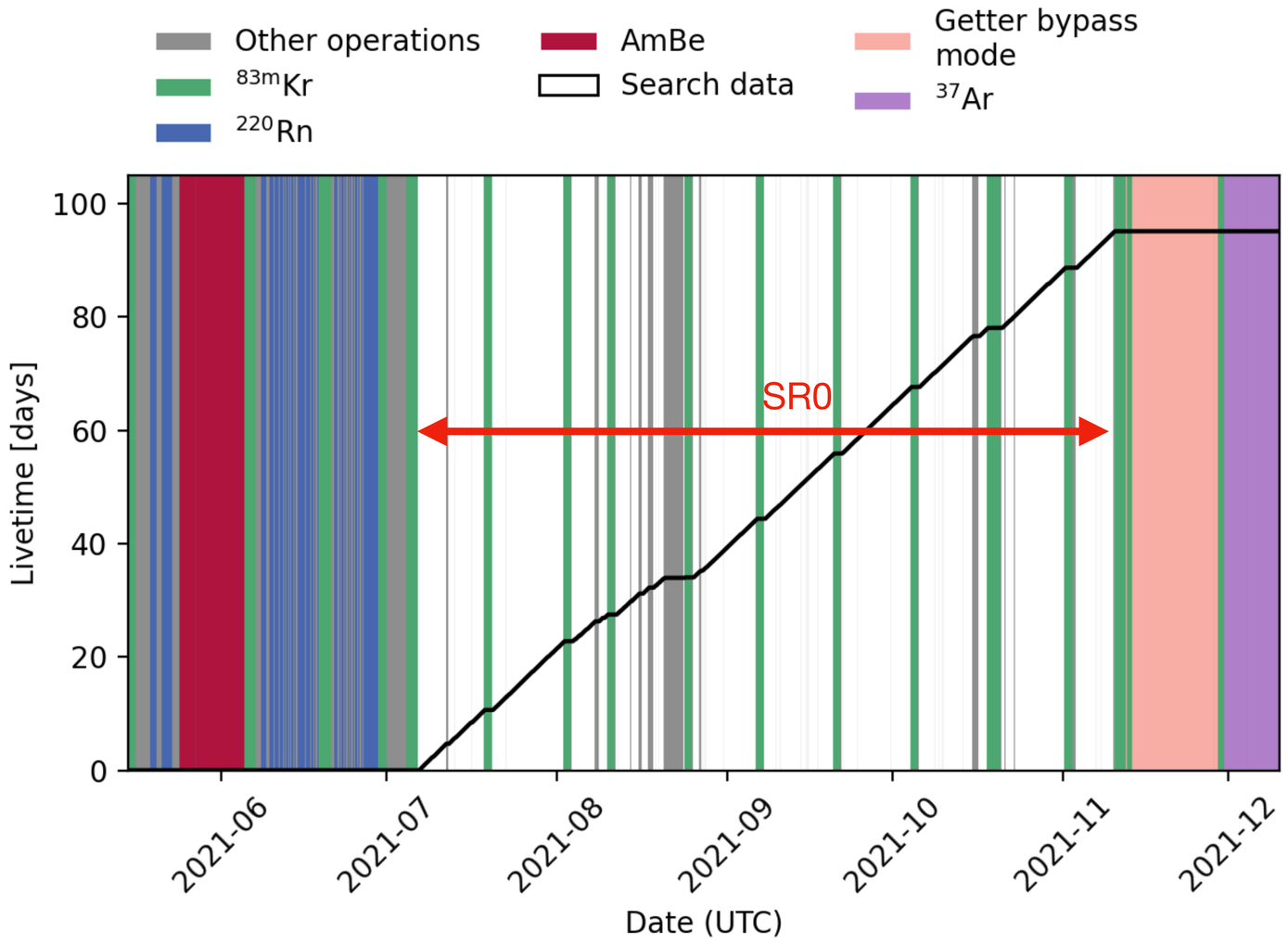
Interactions with atomic electrons in LXe



>3σ results. Unexpected Tritium BG? More Statistics? Signal?

XENON, PRD 102, 072004 (2020); arXiv:2006.09721
(~550 citations)

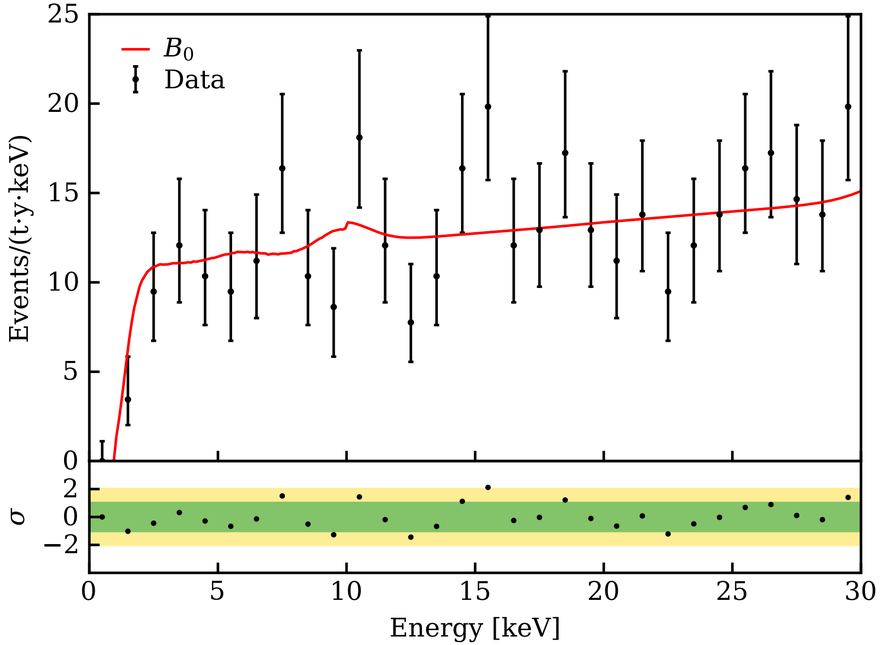
XENONnT: Science Run 0 Dataset

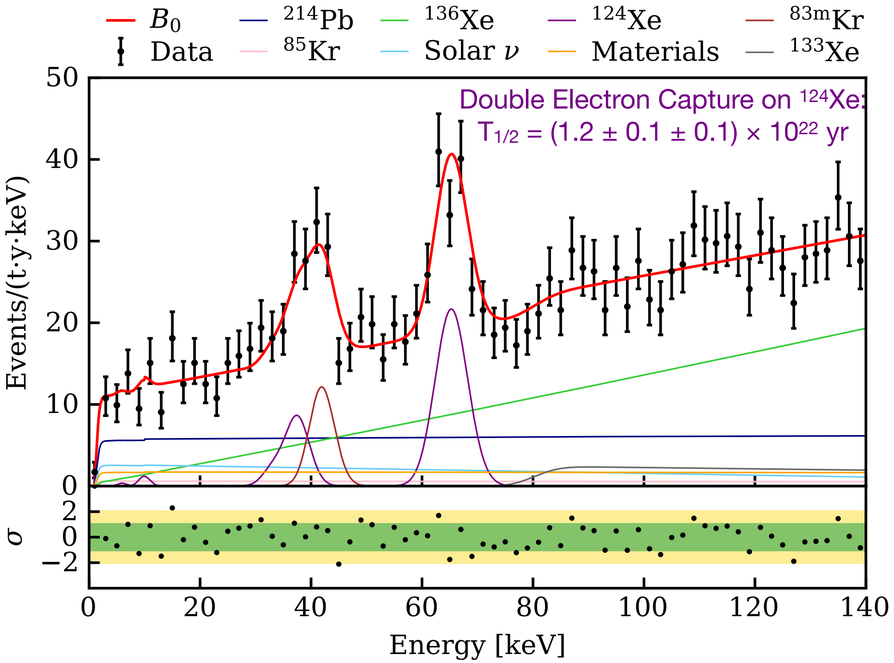


- SR0 Search Data
- July 6 to Nov 10, 2021 (97.1 days)
- 95.1 days lifetime corrected
- (4.18 ± 0.13) tonne Fiducial Volume
- Exposure: 1.1 tonne-year
- Blind analysis

Low Energy Electronic Recoil Events

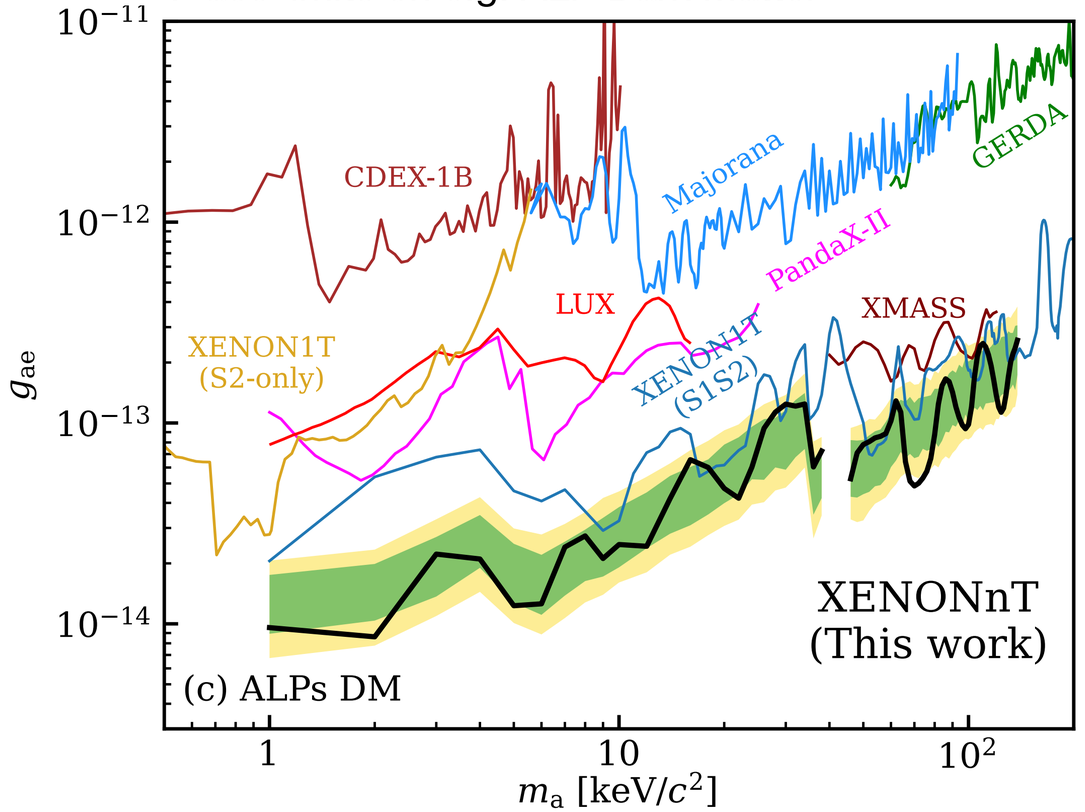
- Joran Angevaare [PhD]
- Peter Gaemers [PhD]
- Patrick Decowski (Editor)





First XENONnT paper: an investigation of the excess seen in XENON1T

Place limits on e.g. ALP Dark Matter

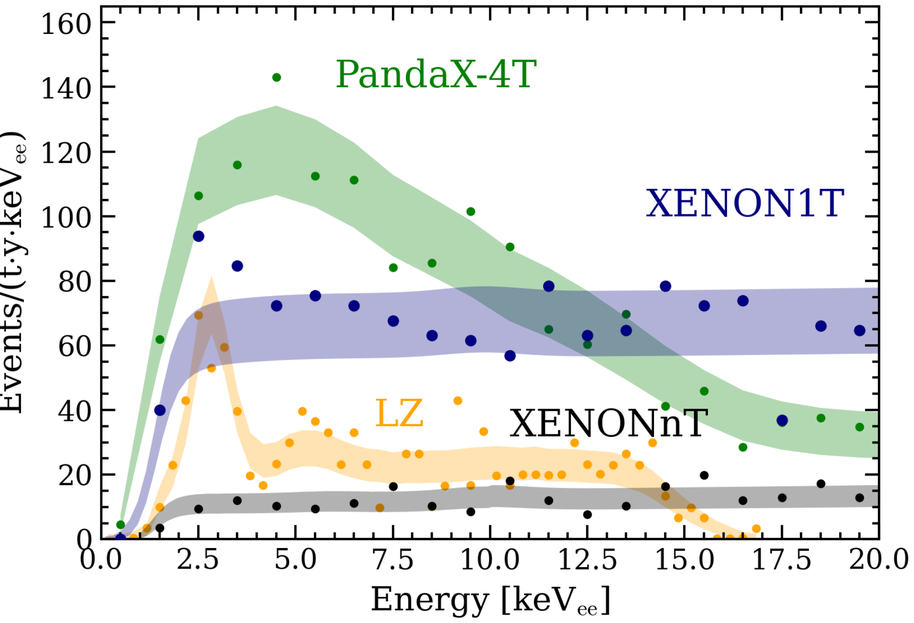


Tritium most likely explanation for XENON1T Excess

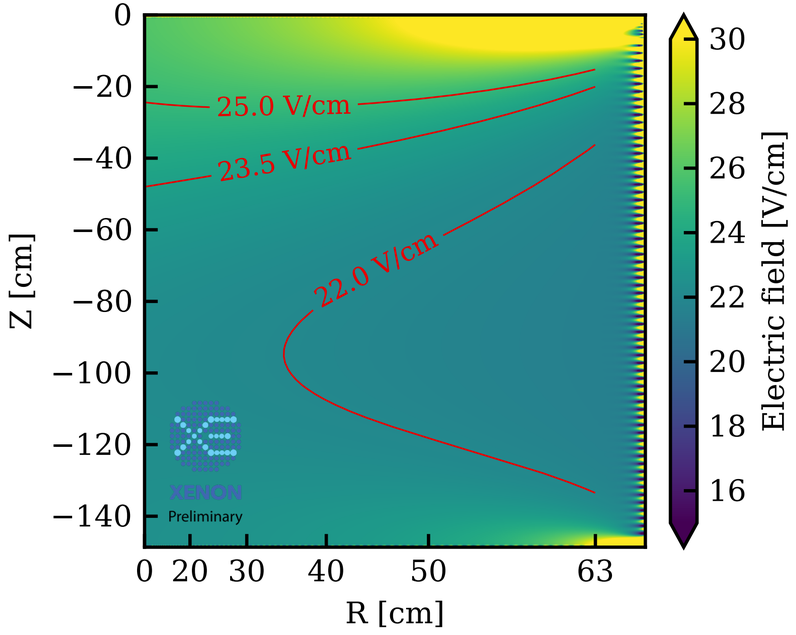
XENON, PRL 129, 161805 (2022); arXiv:2207.11330

Detector Running

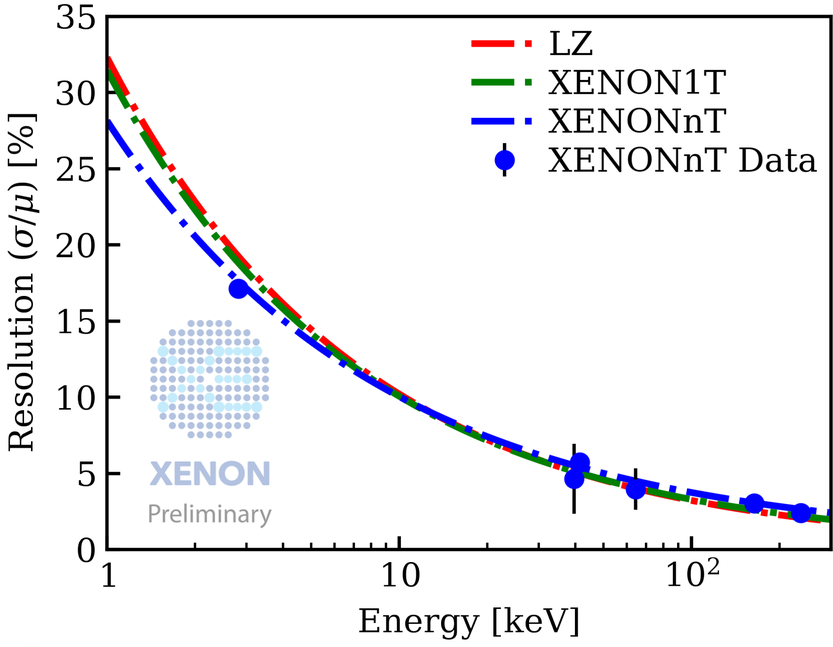
Detector running quite well, had to adopt a lot of reconstruction for lower E-field



Very low backgrounds:
5x lower than XENON1T

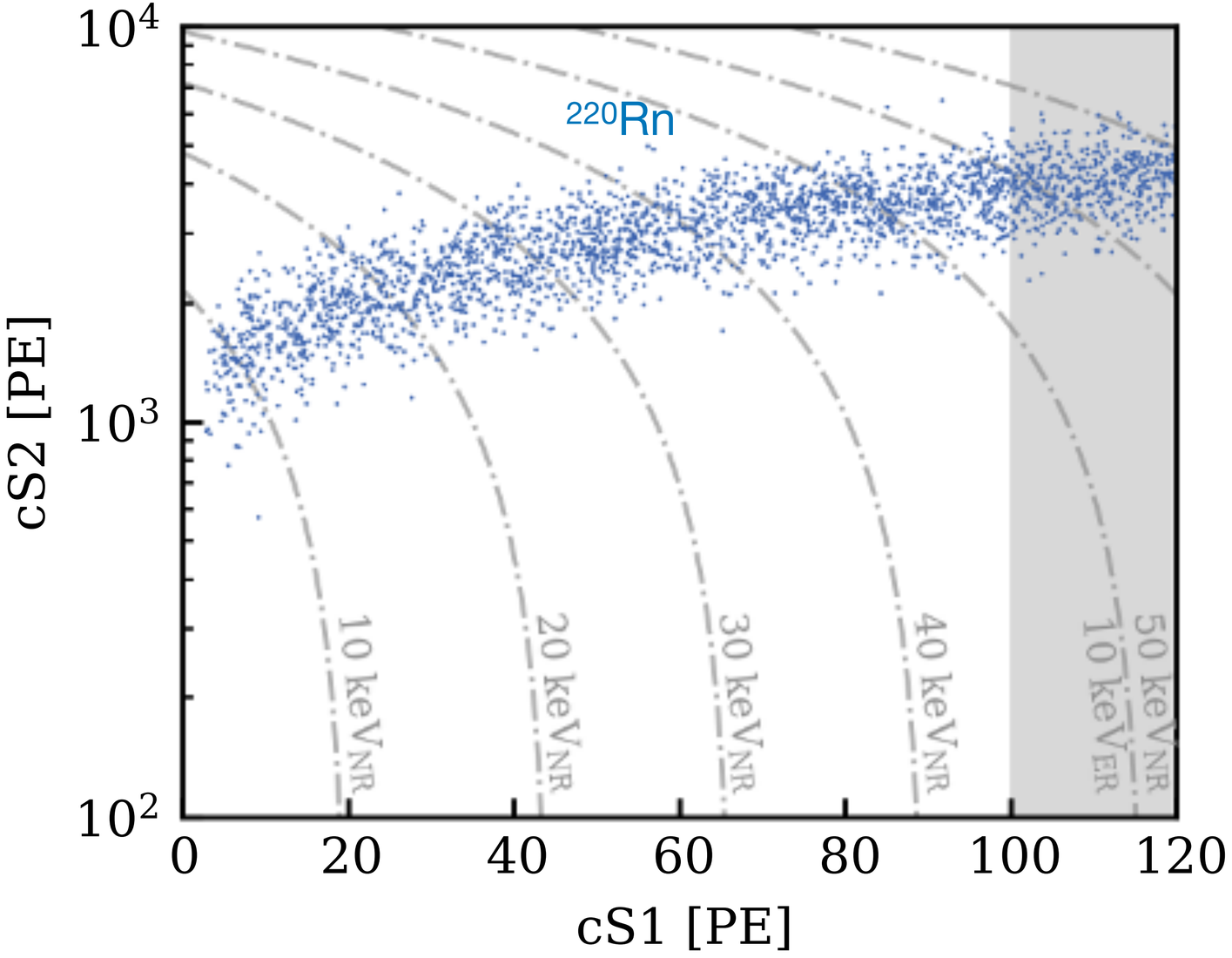


Electric Field is lower than designed (~100 V/cm)
due to short of cathode and screening mesh



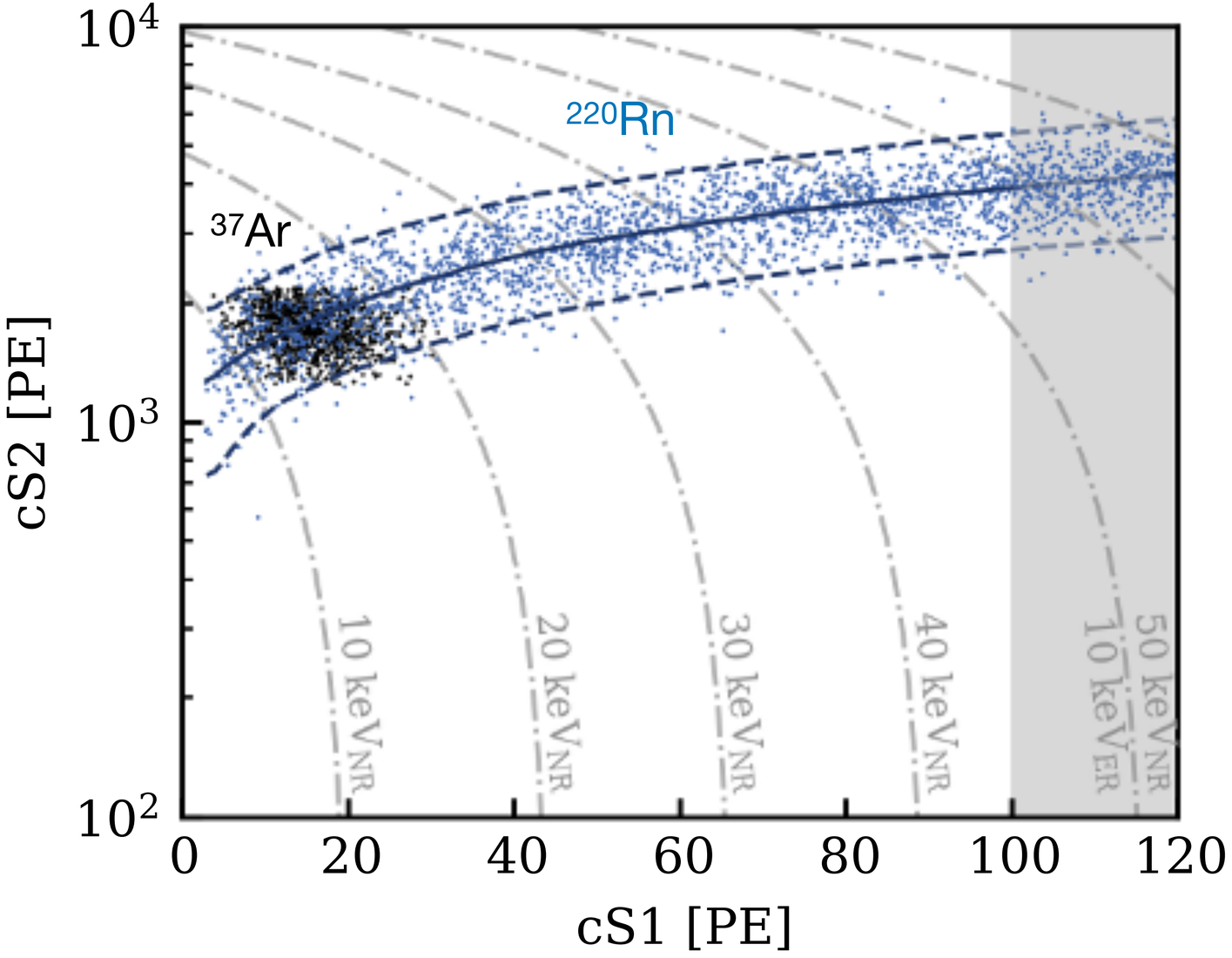
Excellent Energy Resolution

Calibration of ER / NR Response



- **Calibration of ER** response using ^{220}Rn
  - Gives approximately flat energy spectrum
  - Used to validate cut acceptance
- Detector performance at low energy with ^{37}Ar
  - Mono-energetic line at 2.8 keV
  - High statistics
  - Removed via distillation column ($T_{1/2}$ = 35 d)
- **Calibration of NR** response with AmBe
- ER model based on combined fit
- Uncertainties propagated via Principal Component Analysis

Calibration of ER / NR Response



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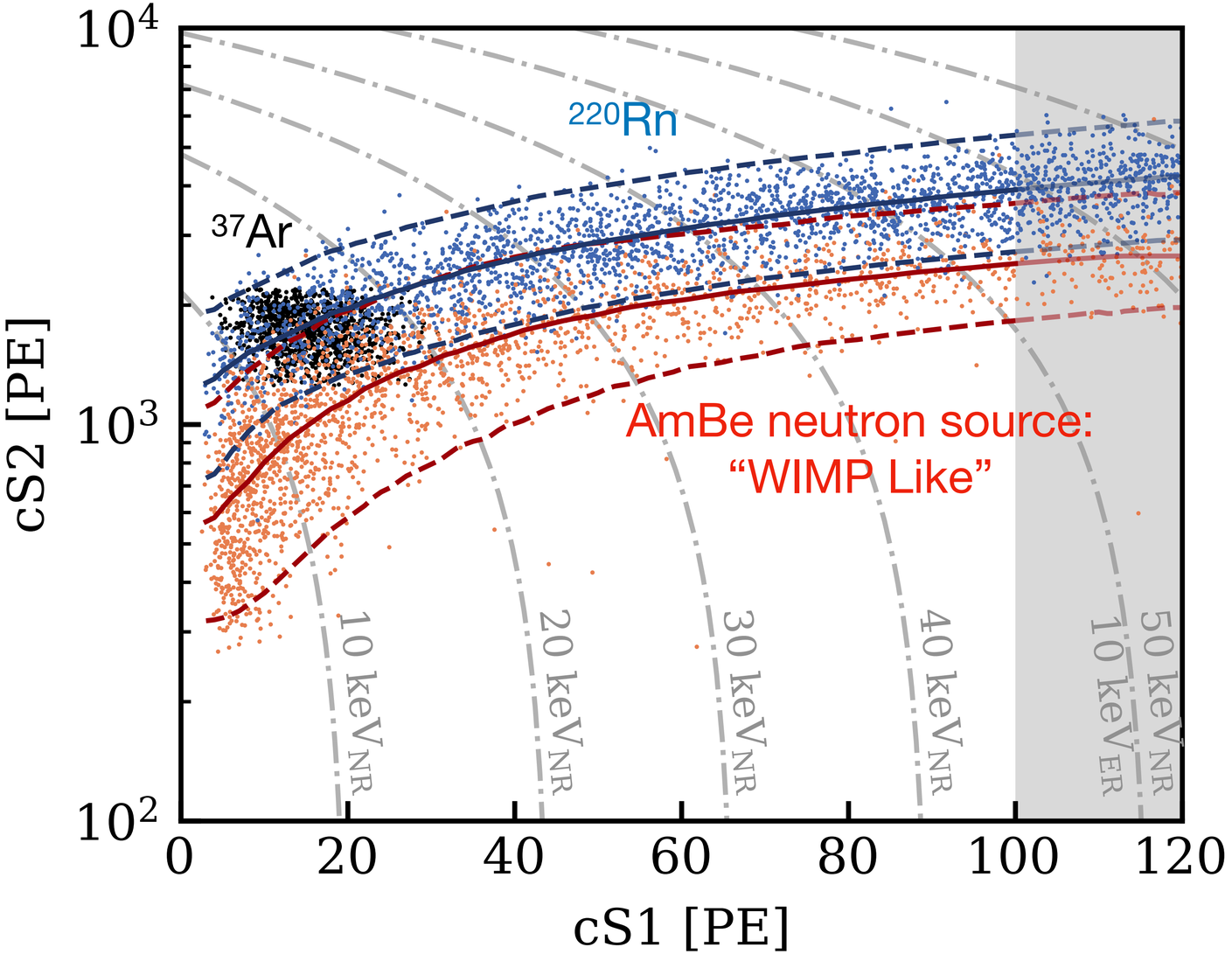
Calibration of ER / NR Response



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WIMP Results

- Joran Angevaare [PhD]

	Expectation
ER	134
Neutrons	$1.1^{+0.6}_{-0.5}$
CEvNS	0.23 ± 0.06
AC	4.3 ± 0.2
Wall	14 ± 3
Total	154
WIMP	
Observed	

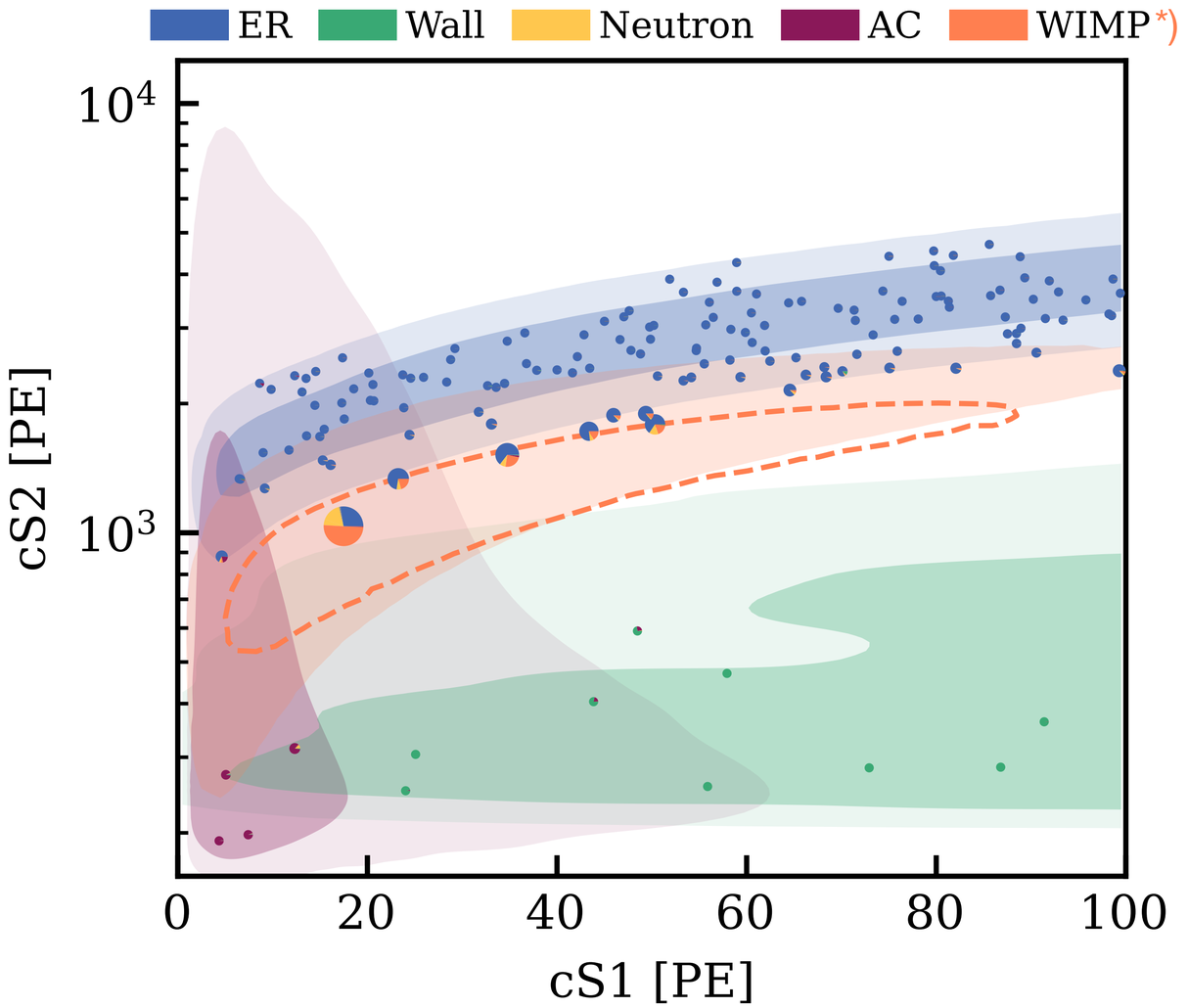
WIMP Results

• Joran Angevaare [PhD]

	Expectation	Best Fit	
	ROI		Signal-like
ER	134	135^{+12}_{-11}	0.81 ± 0.07
Neutrons	$1.1^{+0.6}_{-0.5}$	1.1 ± 0.2	0.42 ± 0.10
CEvNS	0.23 ± 0.06	0.23 ± 0.06	0.022 ± 0.011
AC	4.3 ± 0.2	4.32 ± 0.15	0.363 ± 0.013
Wall	14 ± 3	12^{+0}_{-4}	$0.34^{+0.01}_{-0.11}$
Total	154	152 ± 12	$1.95^{+0.12}_{-0.16}$
WIMP		2.4 *)	1.2 *)
Observed		152	3

152 events in ROI, 16 in blinded region

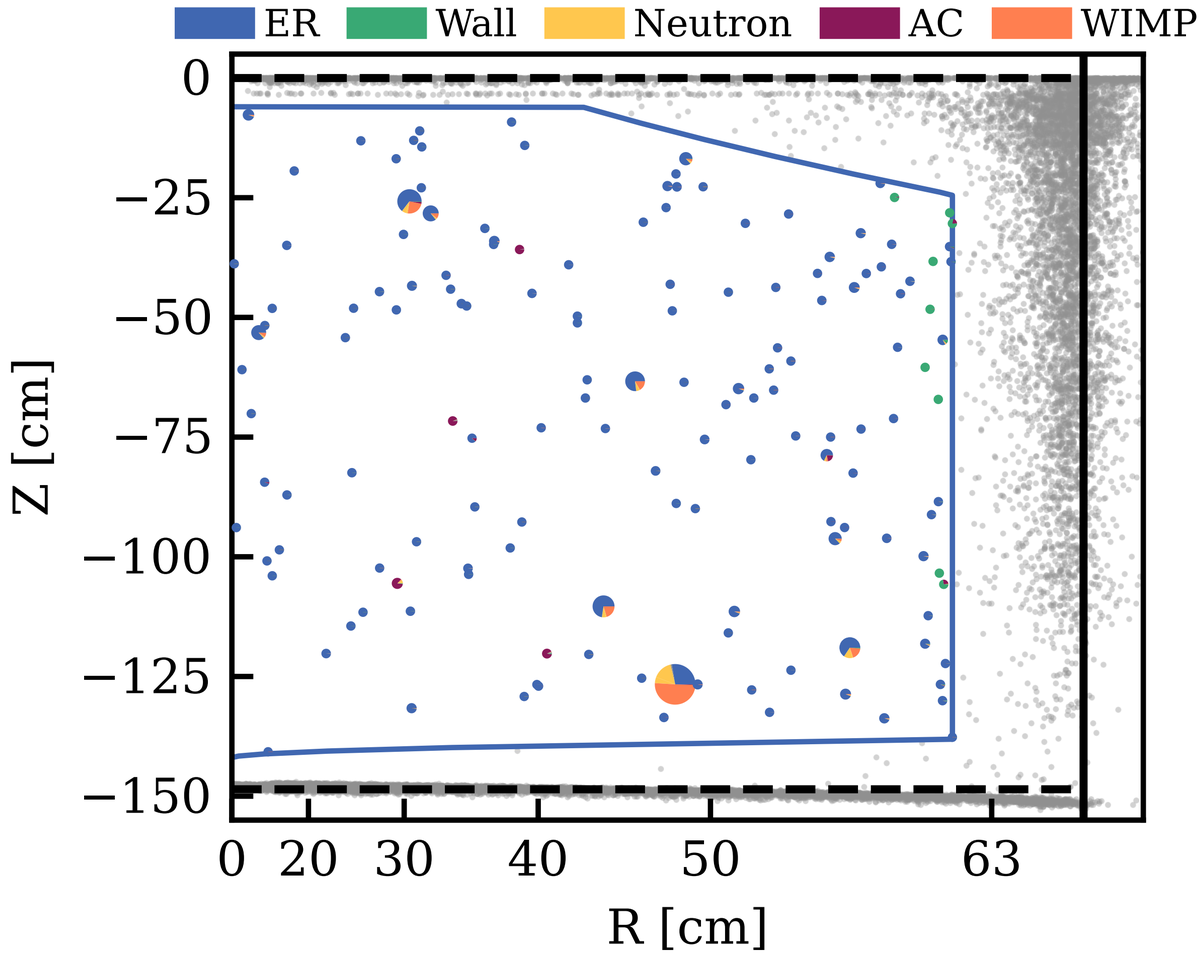
Best fit indicates no significant excess

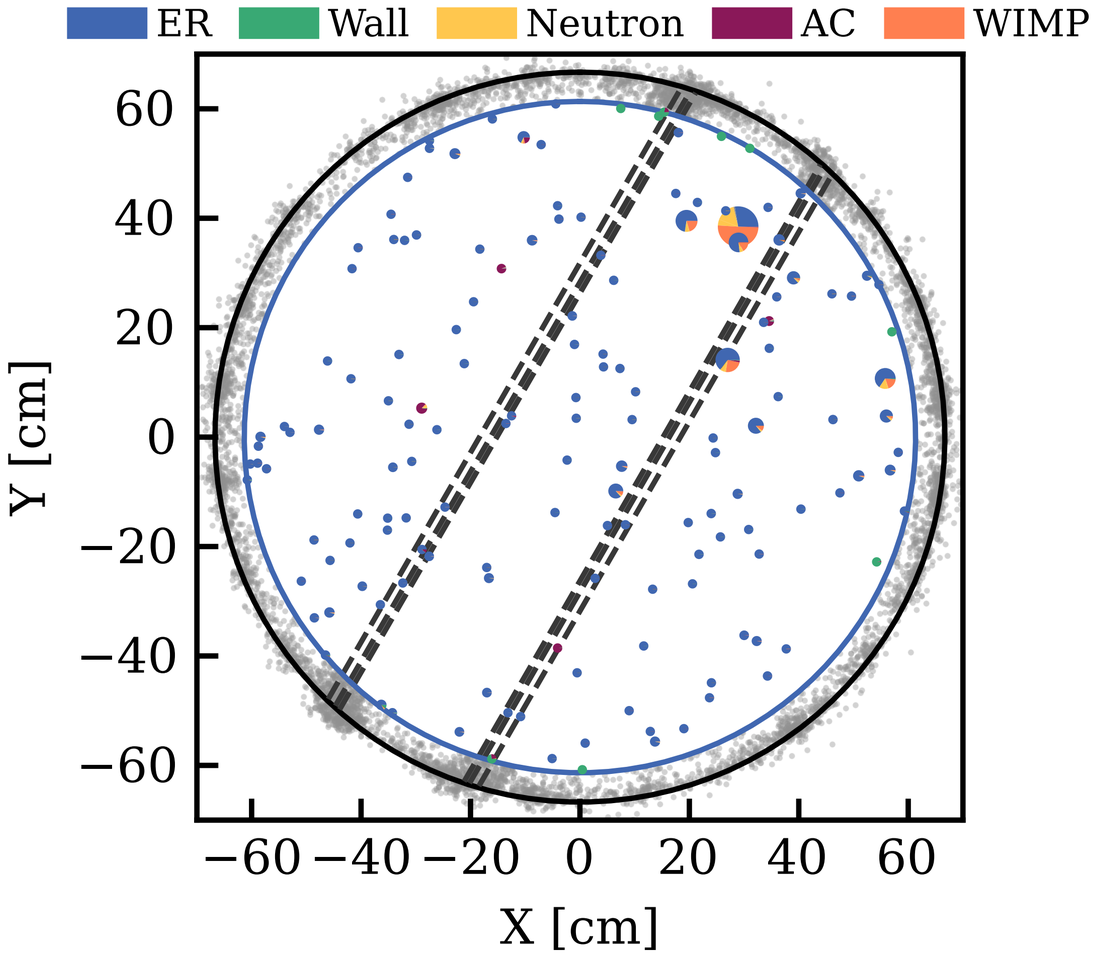


*) Assuming a 200 GeV WIMP and a best-fit $\sigma = 2.5 \times 10^{-47}$ cm^2

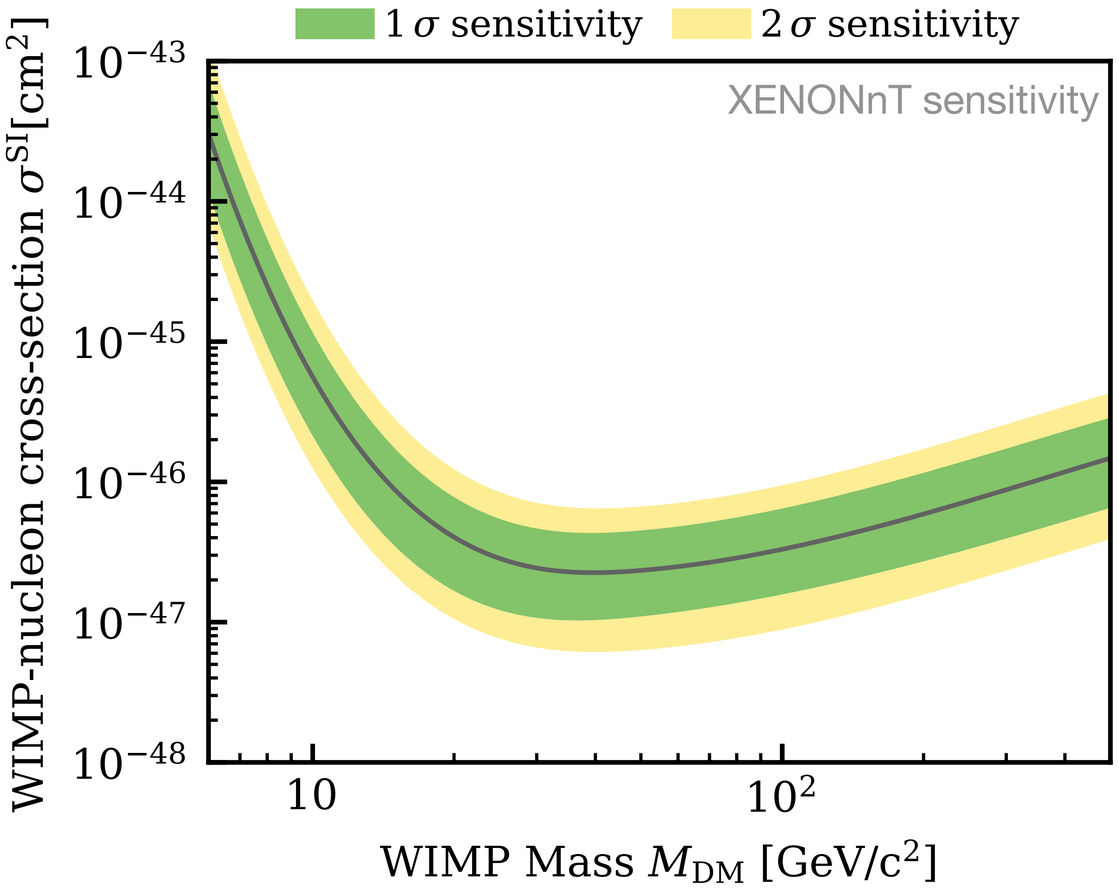
WIMP Results

- XY asymmetry in unblinded data
- Not observed in corrections, quality selection or calibration data

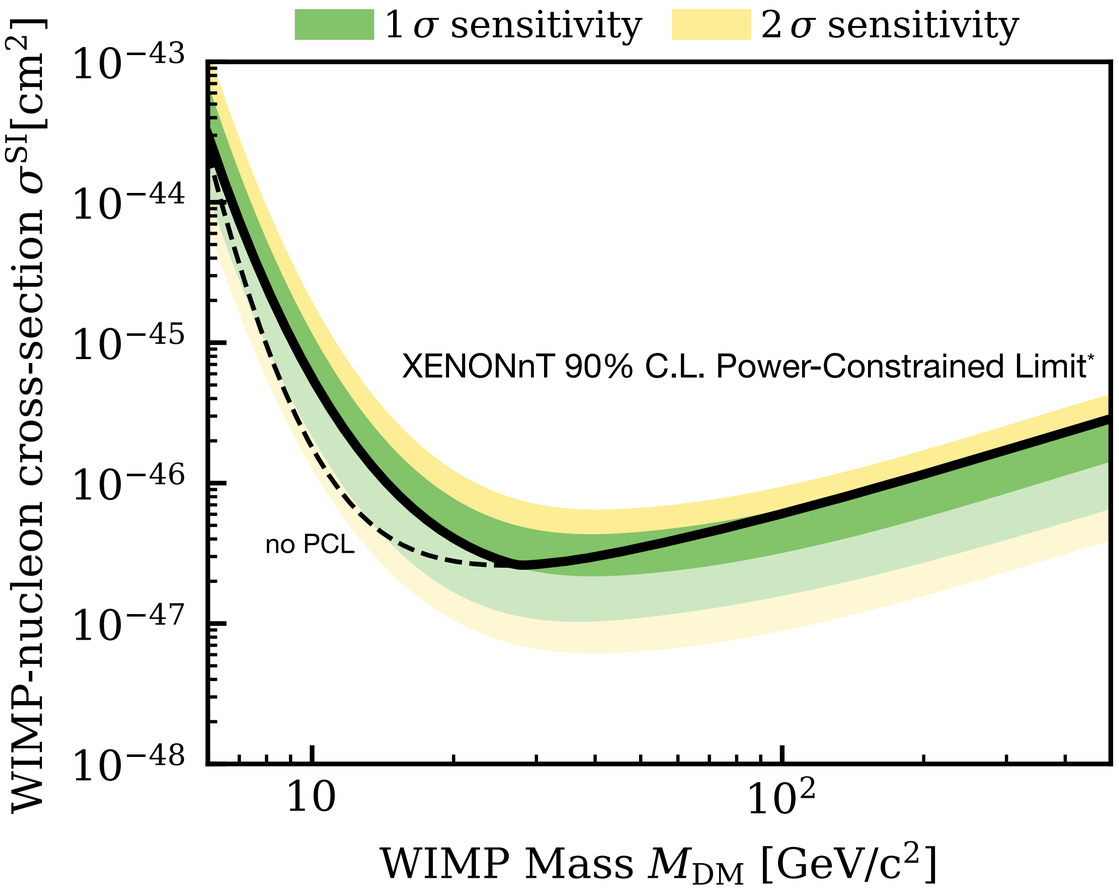




WIMP Spin-Independent Results

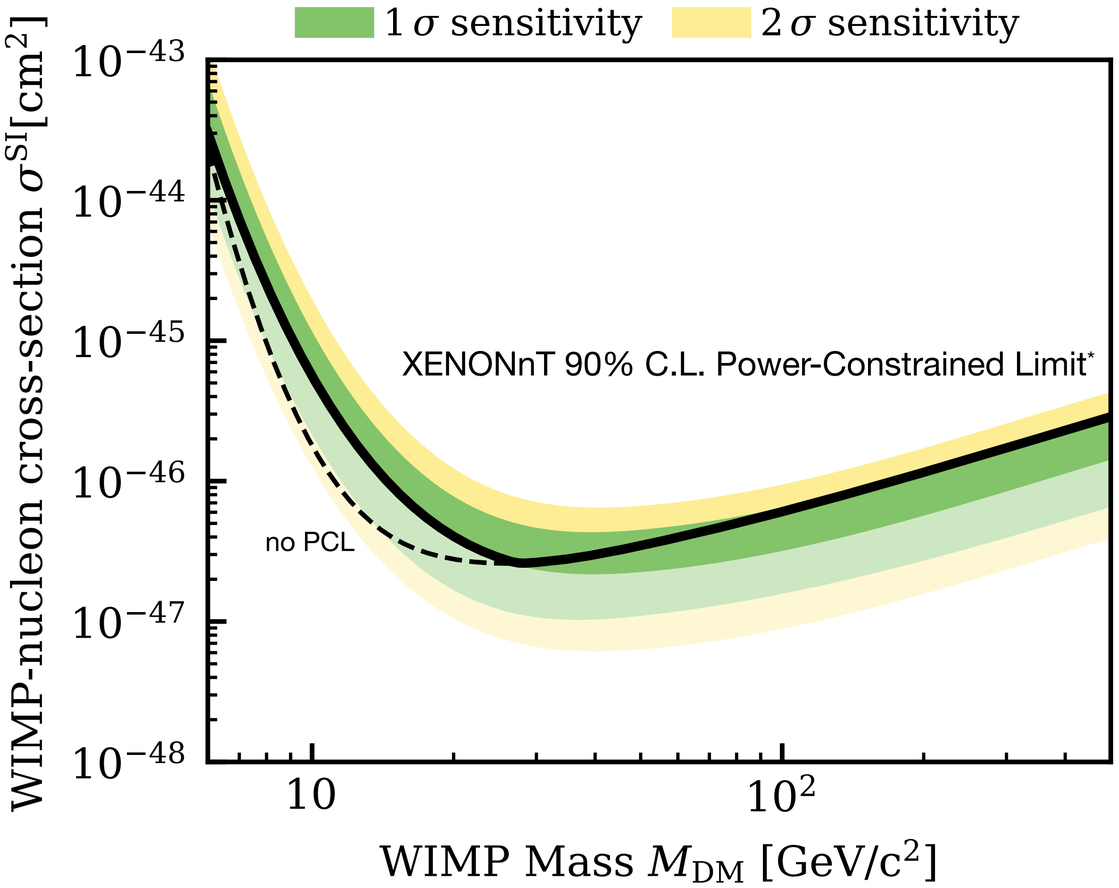


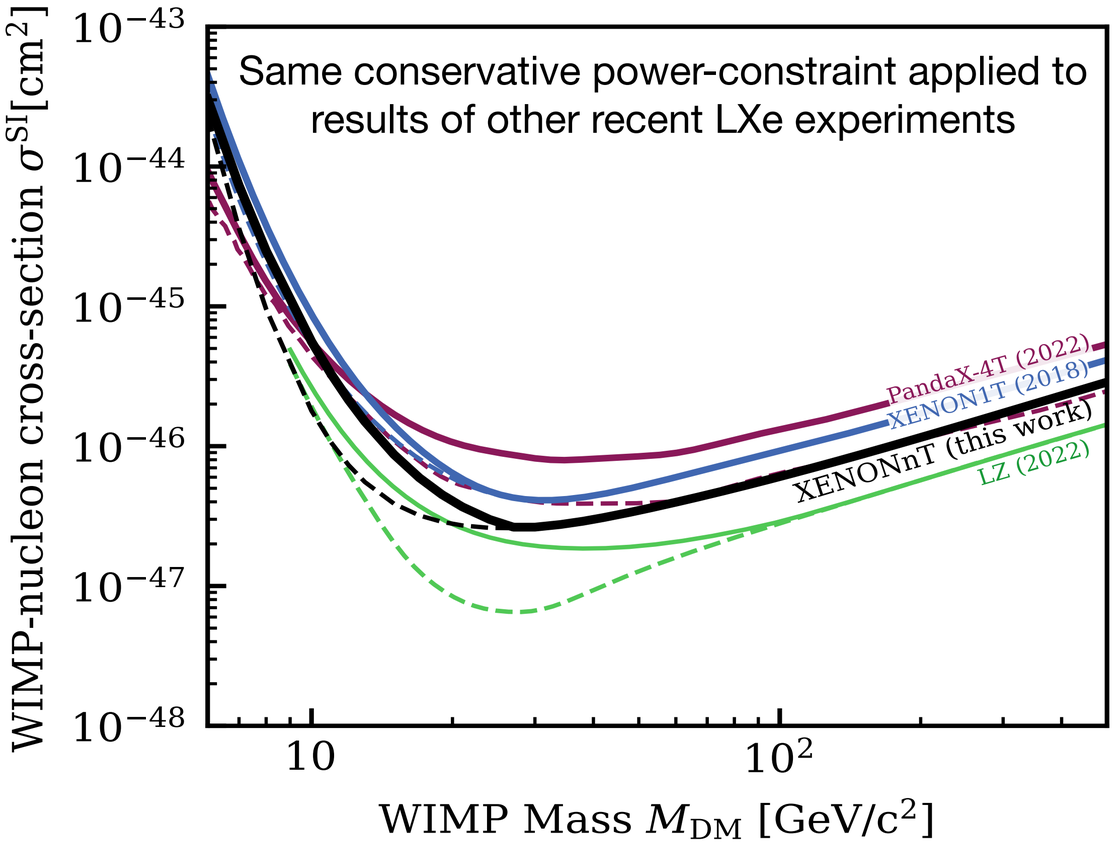
WIMP Spin-Independent Results



*) arXiv:1105.3166, arXiv:2105.00599 with 50% [median] rejection power

WIMP Spin-Independent Results





First 100 days of XENONnT already supersedes XENON1T at final exposure

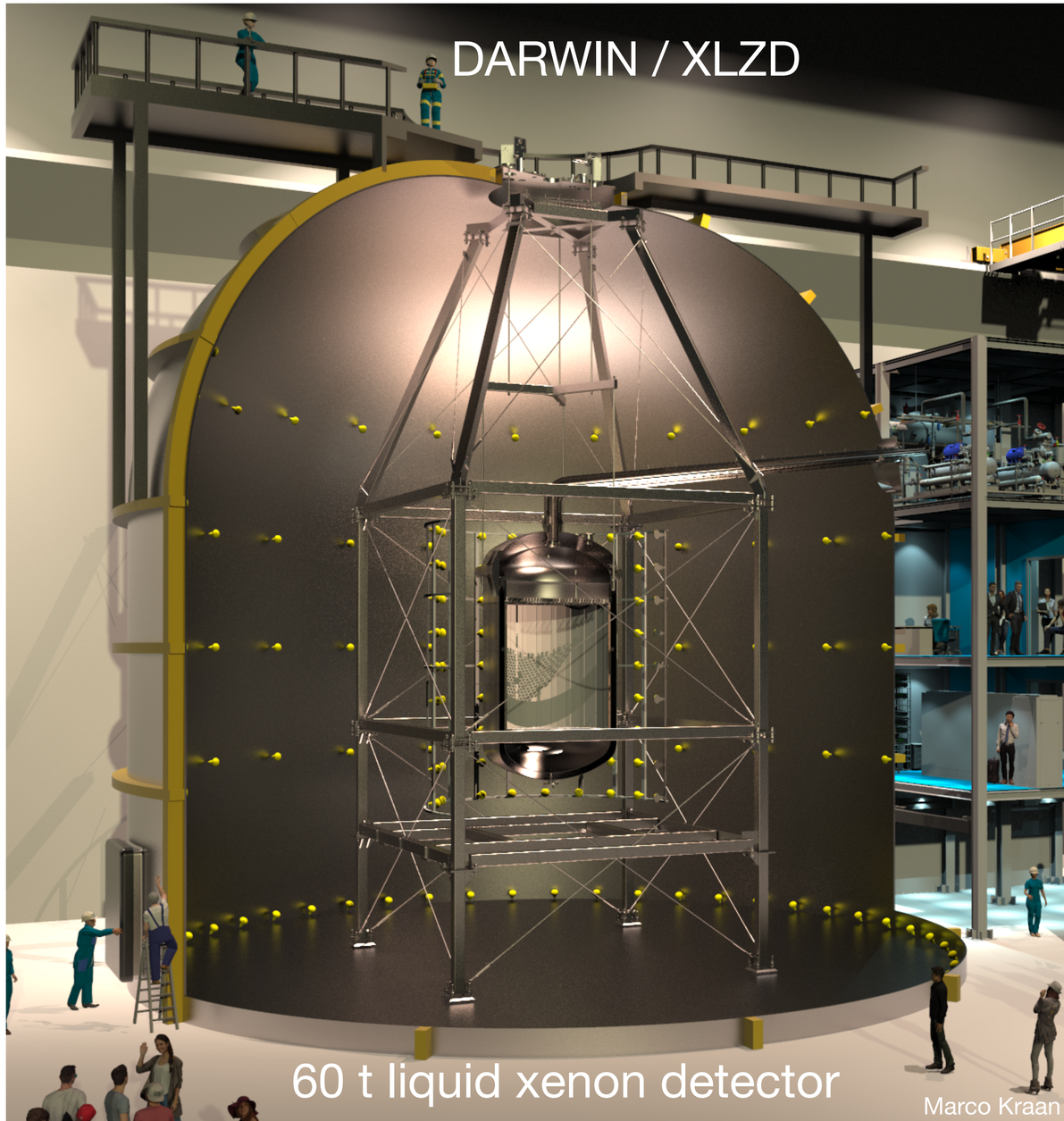
*) arXiv:1105.3166, arXiv:2105.00599 with 50% [median] rejection power

DM → Rare Event Searches & Measurements

XLZD = XENON + LZ + DARWIN

- Joined forces with competing LZ experiment
  - XLZD Consortium
- Ultra-sensitive liquid xenon rare event observatory
- On roadmaps in NL, Germany, Switzerland, US SNOWMASS / P5 process
- 60t LXe mass
- Preparing a Design Book

White Paper: J. Phys. G: Nucl. Part. Phys. 50 (2023) 013001, arXiv:2203.02309

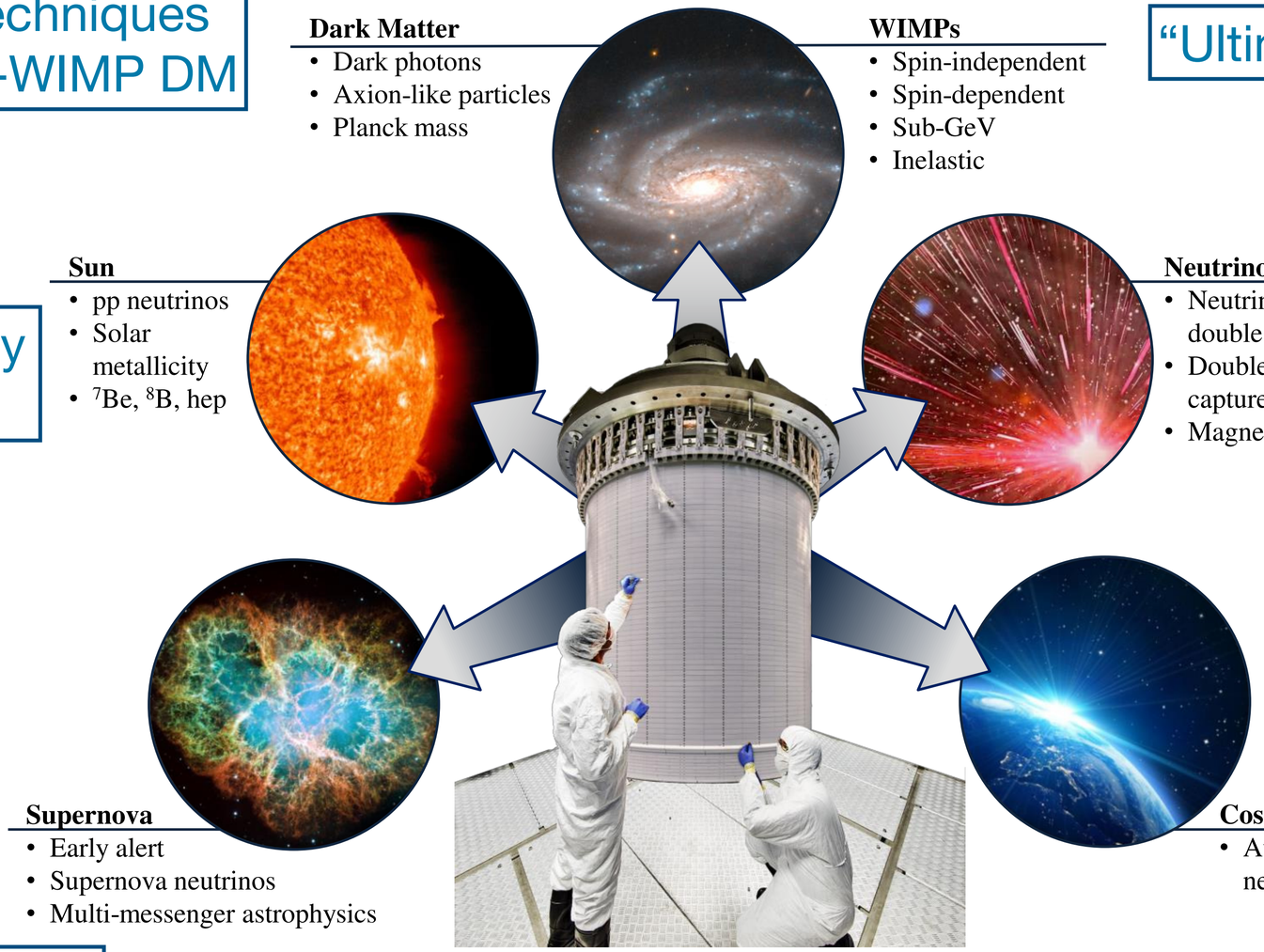


- Tina Pollmann (Science & Sensitivity WG Leader)

Ultra-low BG + new techniques allow to search for non-WIMP DM

Low-E complementarity with DUNE

Detailed measurements if/when galactic SN occurs



"Ultimate" WIMP DM detector

Competitive with dedicated 0v2b exp

Atmospheric E_ν < 100 MeV

Large liquid xenon mass and ultra-low backgrounds expand number of available physics channels

White Paper: J. Phys. G: Nucl. Part. Phys. 50 (2023) 013001, arXiv:2203.02309

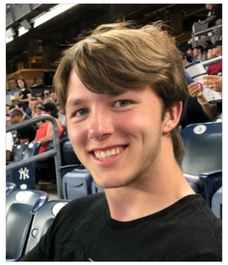
XAMS: Xenon r&d in AMSterdam

Auke-Pieter Colijn

Maricke Flierman

Danny Haringa (THUAS)

Jelmer de Haan (UvA)

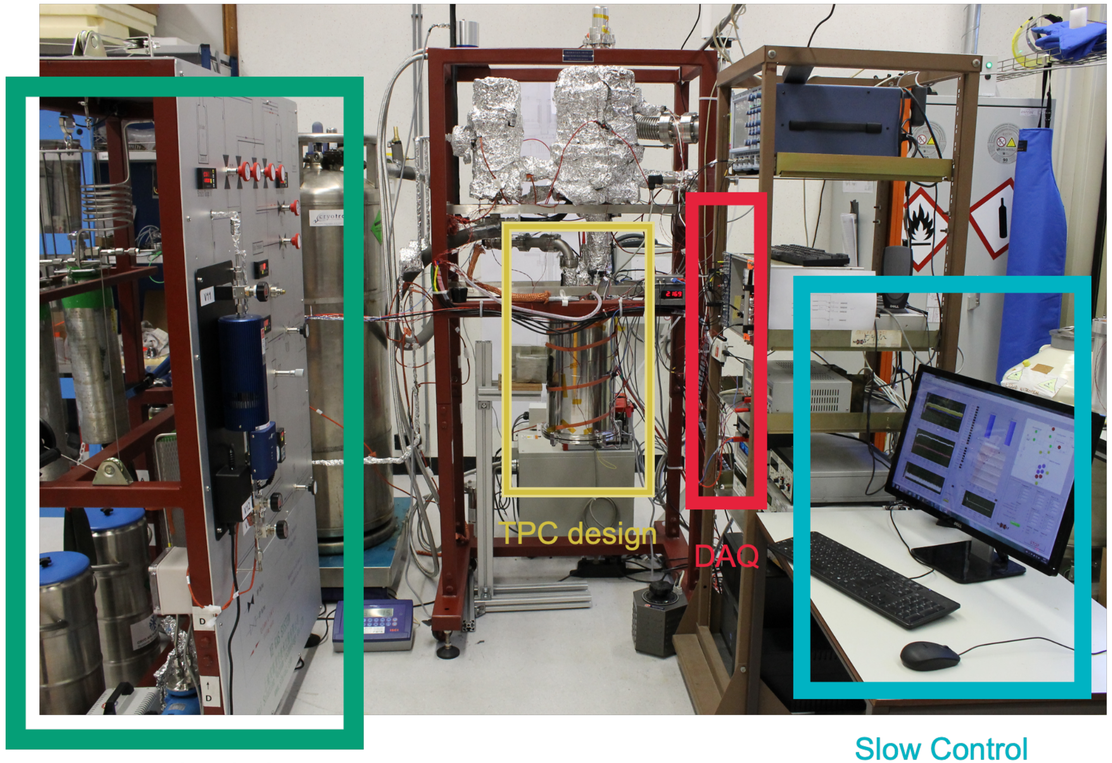


Floris Jan Kamphorst (UvA)

Joost van Dijk (UvA)

Cas Bader (voorheen LIS, nu Nikhef)

Voorheen: Robbert van Duijn (THU



Major update ongoing of different subsystems:

Xenon gas recirculation system (new pump, new gas flow meter)

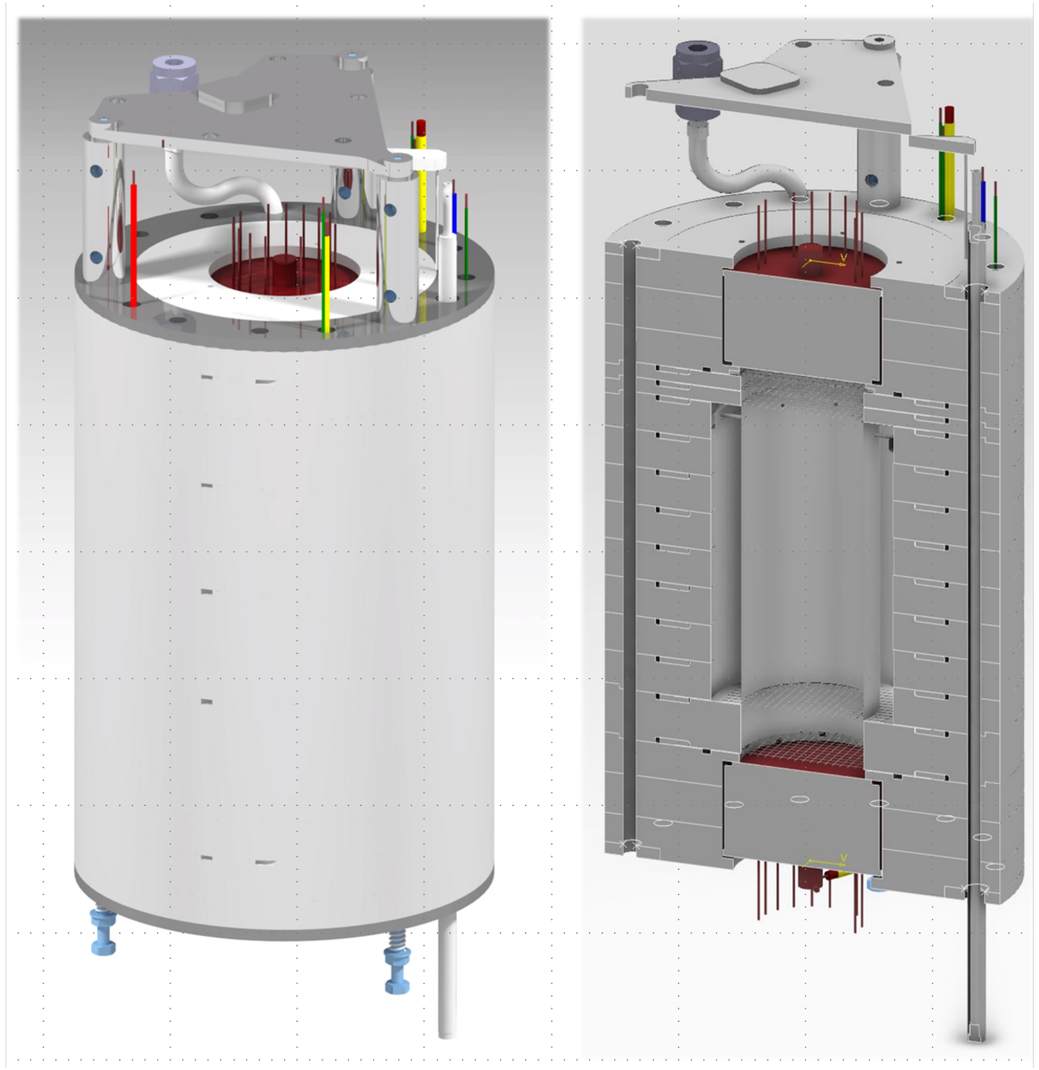
Completely new TPC design + new PMT!

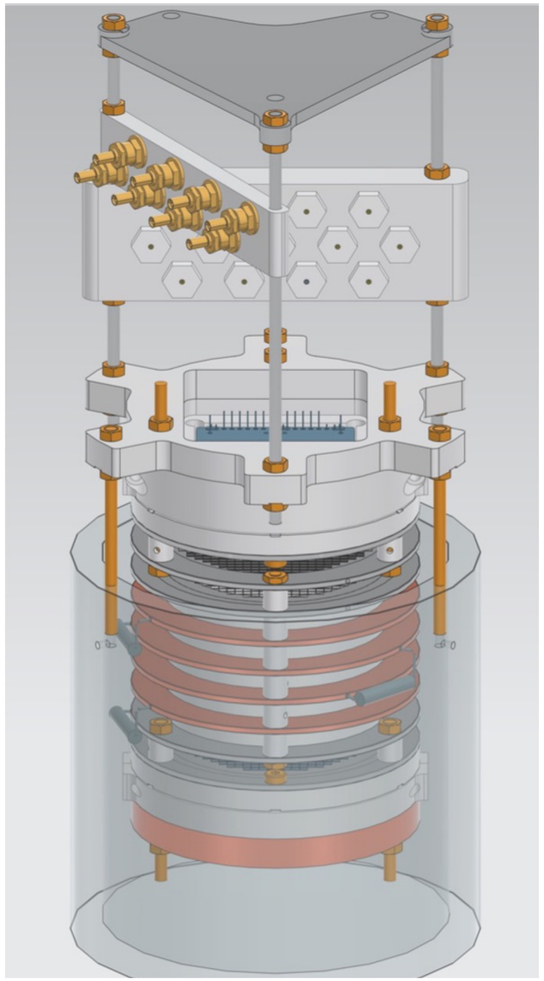
Data acquisition

Slow Control (NI compact DAQ modules)

New Modular TPC

New TPC will allow for better adaptability to new sensors, single phase operation and liquid level control





VULCAN: Vacuum UV Light Characterization at Nikhef

Vikas Gupta

Thomas v.d. Lee (UvA)

Marjolein v. Nuland-Troost

Tina Pollmann

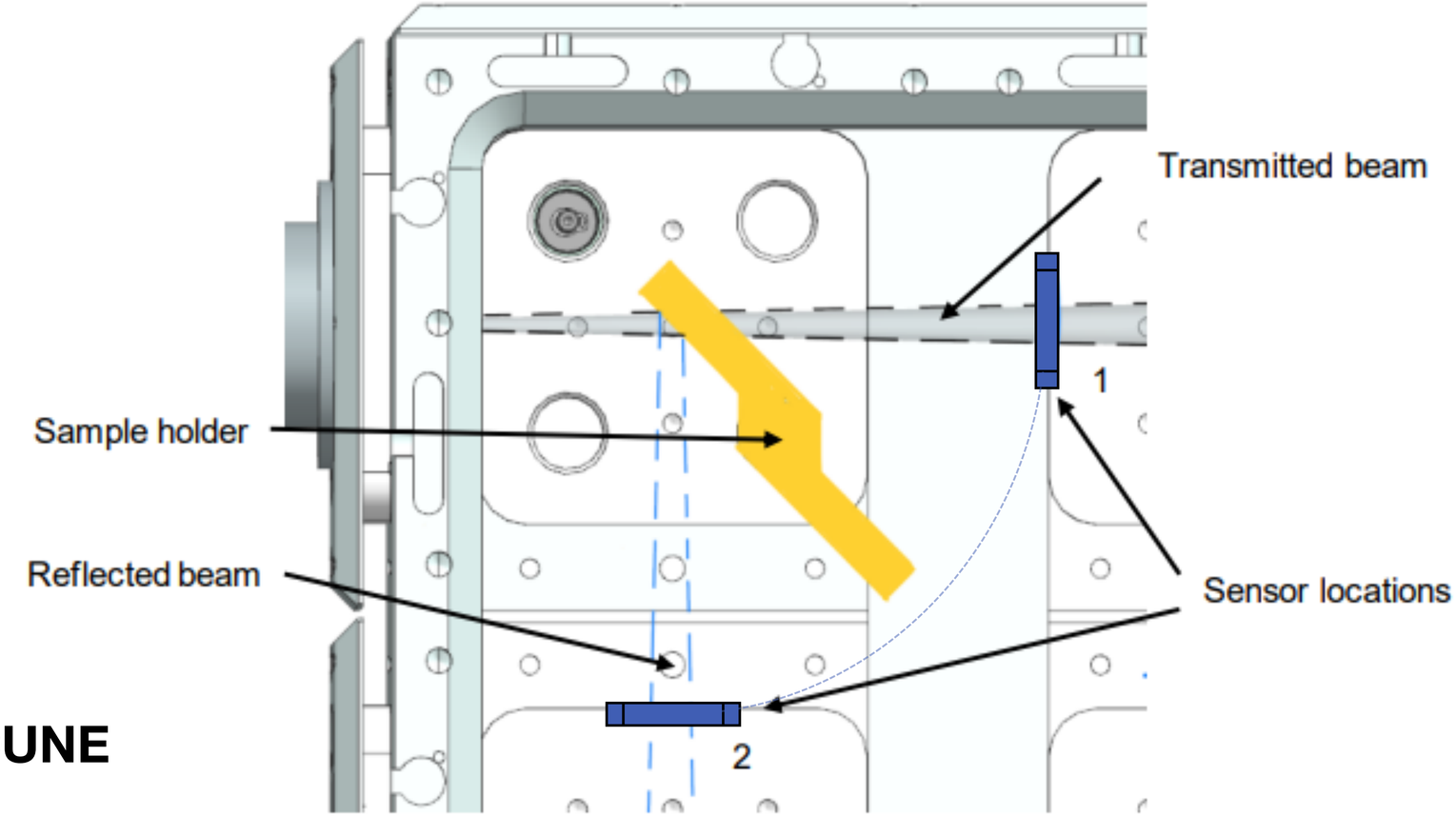
Yannick Wishaupt (UvA)

For measuring

- Reflection
- Transmission
- Fluorescence

of materials used in detectors like

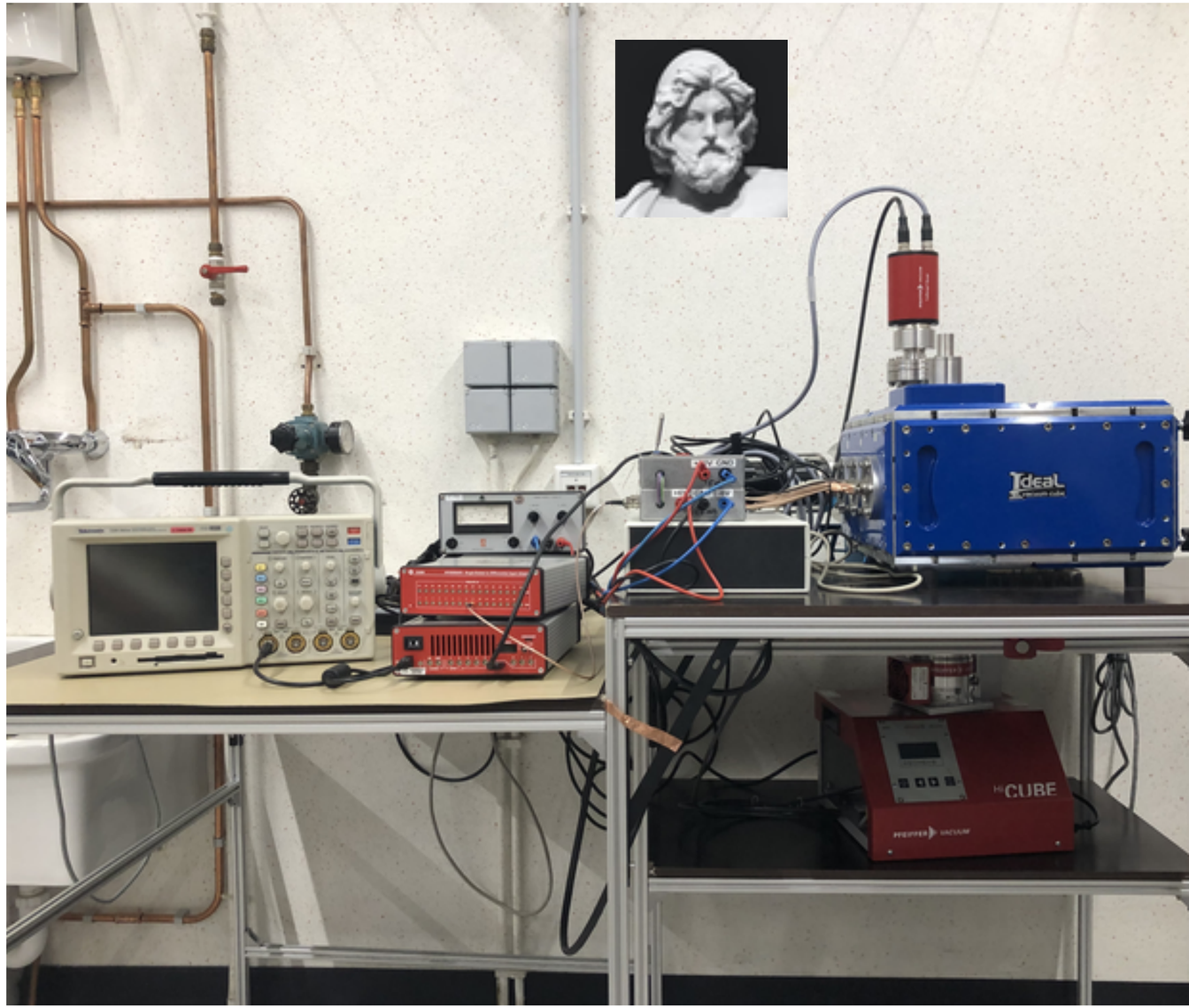
- PTFE
- Aluminium
- Wavelength shifting foils



R&D for XENON, DARWIN/XLZD and DUNE

VULCAN Fun Facts

- Lamp wavelengths from 115 nm up to 400 nm
- Sensor sensitivity from 120 nm up to 900 nm
- Pressure of 10^{-5} mbar
- Possibilities for future cooling



Summary

- XENONnT producing first science output
  - XENON1T low energy electronic recoil excess not observed
  - First 100 days of science running already better WIMP sensitivity than final XENON1T result
  - SR1 ongoing, expect more XENONnT results soon!
- LZ, XENON and DARWIN joining forces will allow to build the ultimate LXe detector combining the technical expertise of the different experiments
- R&D setups in Amsterdam being built or renewed
- Not discussed: work on neutrinoless double beta decay and other (doubly) weak processes
- We thank the Nikhef ET, MT and CT/PDP for all their help in making our scientific work possible!