106° CONGRESSO NAZIONALE SIF

14-18 Settembre 2020

THE XENON DARK MATTER PROJECT

LATEST XENON1T RESULTS AND XENONnT PROJECTIONS

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THE XENON COLLABORATION

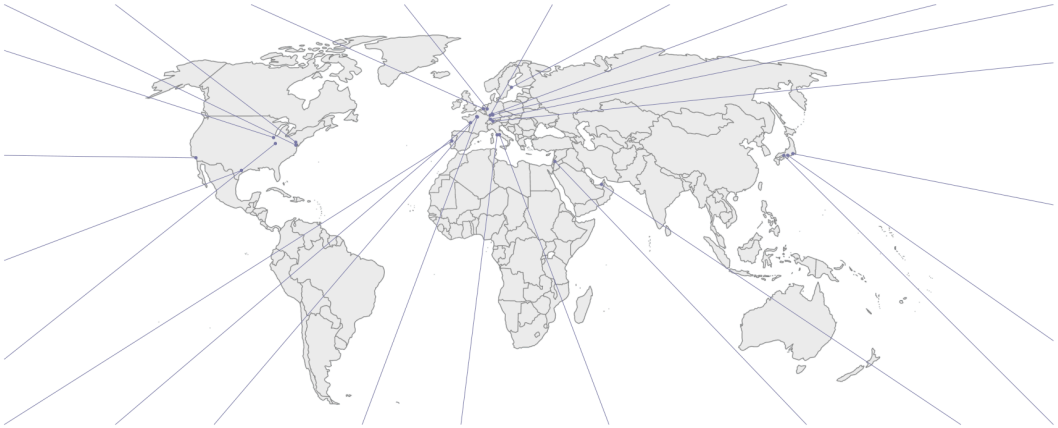
160 SCIENTISTS

28 INSTITUTIONS

11 COUNTRIES

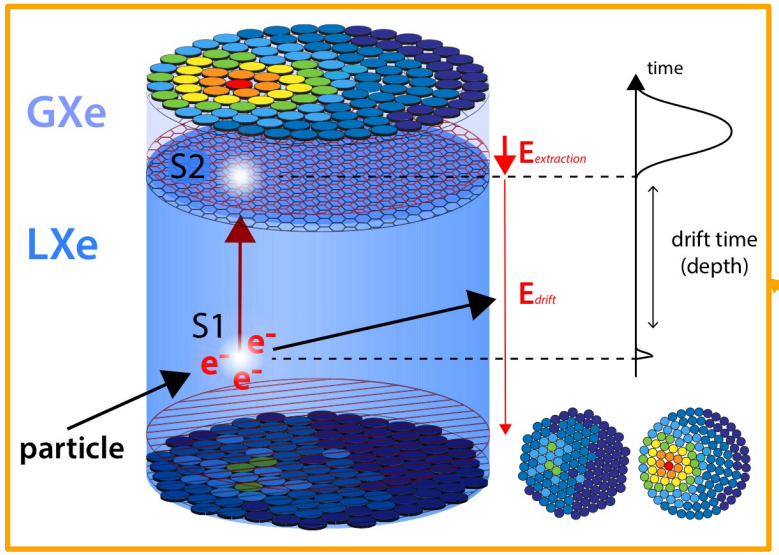
Columbia · RPI · Nikhef · Muenster · KIT · Stockholm · Mainz · MPIK, Heidelberg · Freiburg

Chicago · UCSD · Rice · Purdue · Zurich · Tokyo · Nagoya



Coimbra · Subatech · LPNHE · IJCLab · L'Aquila · Bologna · LNGS · Torino · Napoli · Weizmann · NYUAD · Kobe

THE XENON EXPERIMENT



ENERGY RECONSTRUCTION
from combined S1 and S2 signals

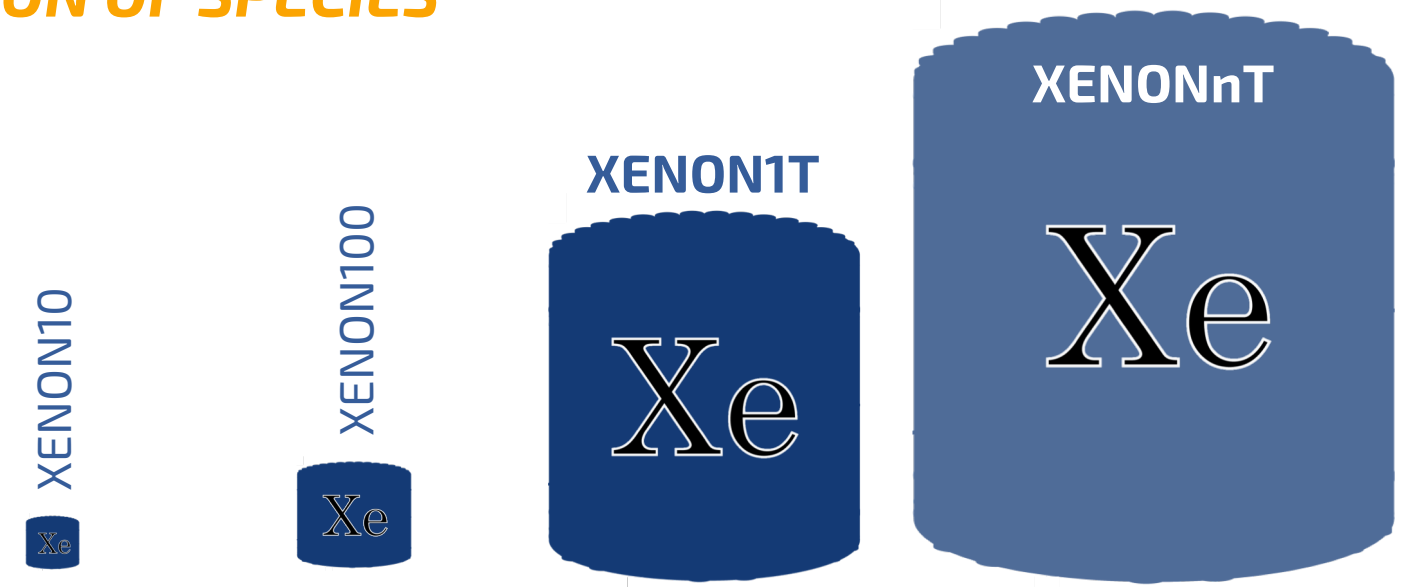
3D VERTEX RECONSTRUCTION
X,Y from S2 pattern in top PMT array
Z from drift time

👍 Volume fiducialization
👍 Single/multiple scatters discrimination

RECOIL TYPE IDENTIFICATION (ER vs NR)
S2/S1 ratio is much larger for ER than NR

THE XENON PROJECT

EVOLUTION OF SPECIES



	2005	2008	2016	2020
ACTIVE LIQUID XENON TARGET MASS	22 kg	105 kg	2000 kg	6000 kg
LOW ENERGY ER BACKGROUND $[t \cdot d \cdot keV]^{-1}$	~1000	5.3	0.2	0.04 (Projection)

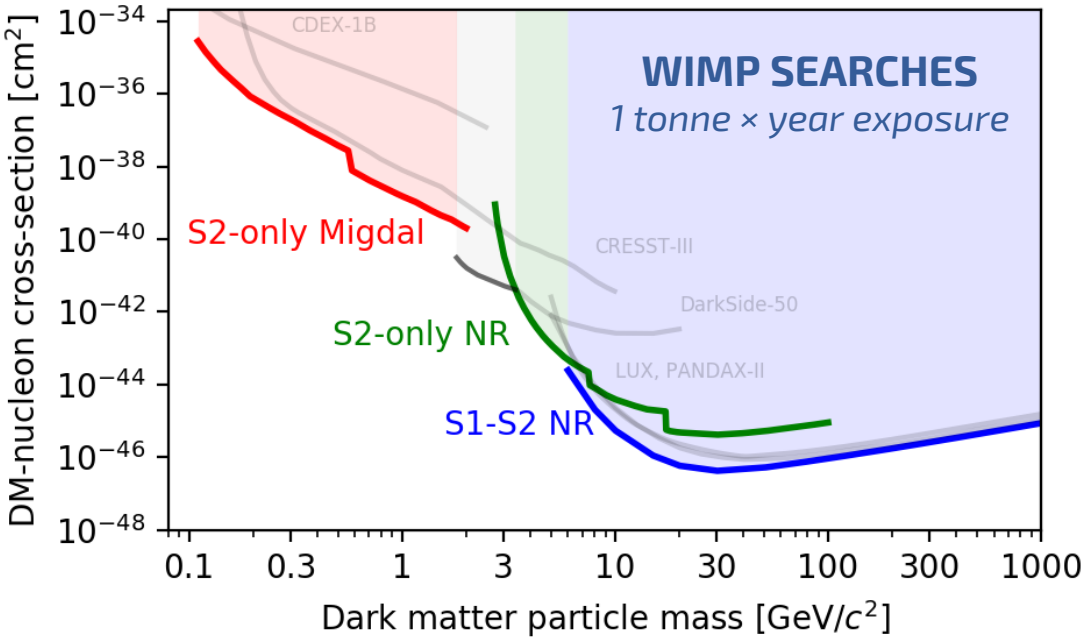
XENON1T RESULTS

2018 | PRL 119, 181301
SR0+SR1 Main WIMP search

2019 | PRL 123, 251801
Light dark matter

2019 | PRL 123, 241803
Migdal effect

WORLD'S STRONGEST LIMITS ABOVE WIMP MASSES OF 100 MeV/c^2 (but 2-3 GeV/c^2)



2019 | PRL 122, 141301 Spin-dependent WIMPs
BEST LIMITS ON WIMP-NEUTRON COUPLING FOR WIMP MASSES ABOVE 3 GeV/c^2

2019 | PRL 122, 141301 *WIMP-pion interaction*
FIRST EVER RESULT ON WIMP-PION COUPLING

2019 | Nature 568, 532-535 *^{124}Xe double e$^-$ capture discovery*
THE RAREST PROCESS EVER DIRECTLY OBSERVED IN HUMAN HISTORY

2020 | PRD (Submitted) *Observation of excess electronic recoil events*
NEW PHYSICS HINT OR NEW BACKGROUND?

ELECTRONIC RECOILS IN XENON1T

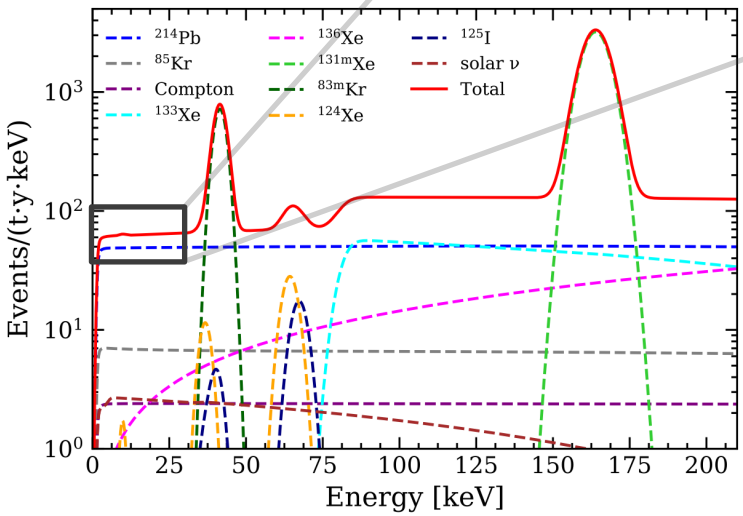
LOW-ENERGY EXCESS BETWEEN 1-7 keV

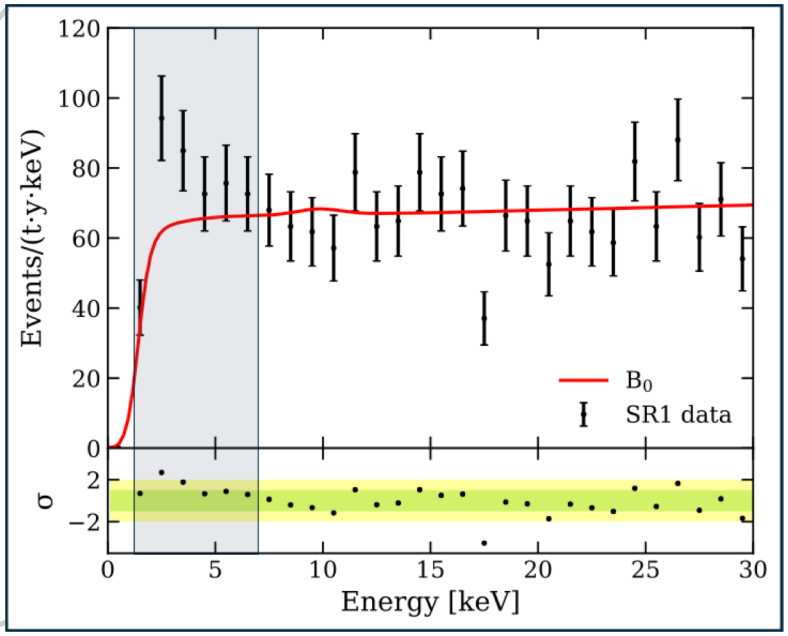
https://arxiv.org/abs/2006.09721

BACKGROUND MODEL
from GEANT4 MC simulations

Good match between data and expectations in [1, 200] keV range

FITTED BACKGROUND LEVEL:
76 ± 2 events/(t·y·keV)
LOWEST EVER IN [1, 30] keV





OBSERVED EVENTS IN [1, 7] keV
285

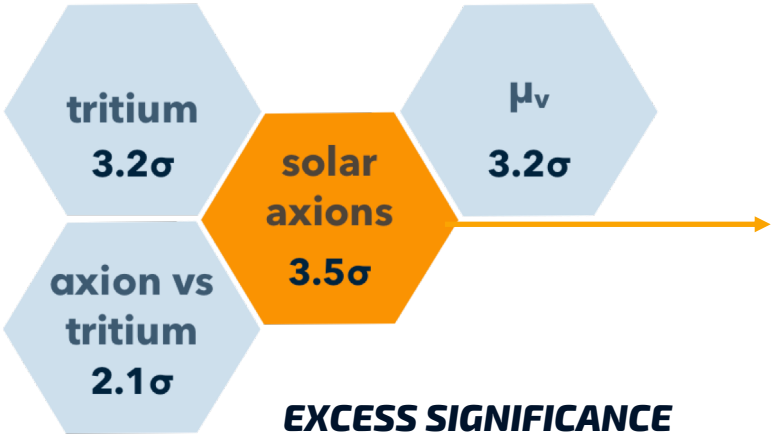
EXPECTED
232 ± 15

226.9 live-days
1 tonne fiducial mass
ER single-scatters
Standard data quality cuts

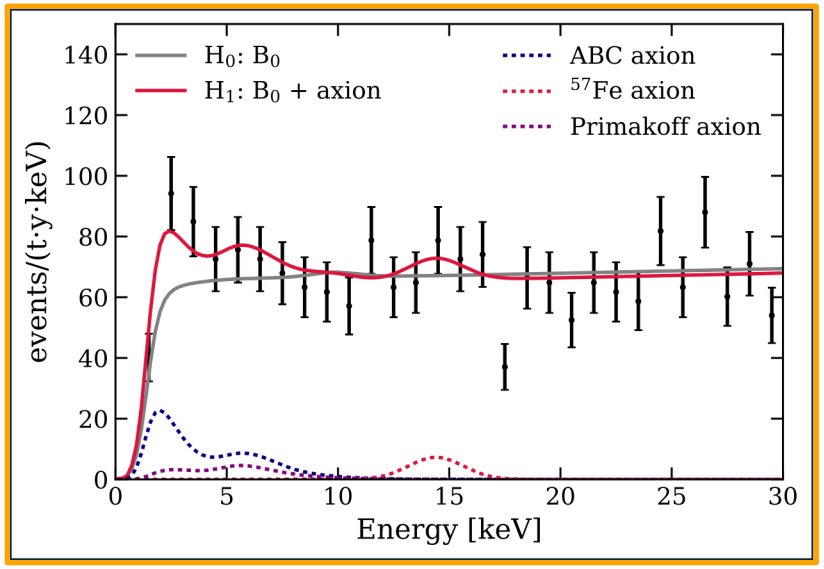
ER EXCESS INTERPRETATION

AXIONS, ν MAGNETIC MOMENT OR ^{3}H BACKGROUND?

https://arxiv.org/abs/2006.09721



EXCESS SIGNIFICANCE OVER BACKGROUND-ONLY



- **TRITIUM ^{3}H** | Fitted $(6.2\pm2.0)\times10^{-25}$ mol/mol ^{3}H/Xe concentration
  POSSIBLE ATMOSPHERIC ^{3}H IN MATERIALS BUT DIFFICULT TO CONFIRM/EXCLUDE SUCH A TINY CONCENTRATION
- **SOLAR AXIONS** | Non-null coupling for either ABC or Primakoff axions
  AXIONS ARE A LIGHT DARK MATTER CANDIDATE. SOLAR AXIONS CAN BE DETECTED (KINETIC ENERGY ~keV)
- **SOLAR AXIONS + TRITIUM** | Favoured at 2.1 σ over the ^{3}H hypothesis
  WHEN BOTH AXIONS AND TRITIUM ARE INCLUDED, THE BEST-FIT OF TRITIUM IS ZERO
- **ANOMALOUS NEUTRINO MAGNETIC MOMENT** | $\mu_\nu=[1.4, 2.9]\times10^{-11}\ \mu_B$
  THIS WOULD IMPLY THAT NEUTRINO IS A MAJORANA FERMION.
  WHEN 3H IS INCLUDED, THE SIGNIFICANCE LOWERS TO 0.9 σ.

THE XENONnT EXPERIMENT

ALMOST READY FOR THE NEXT PHASE!

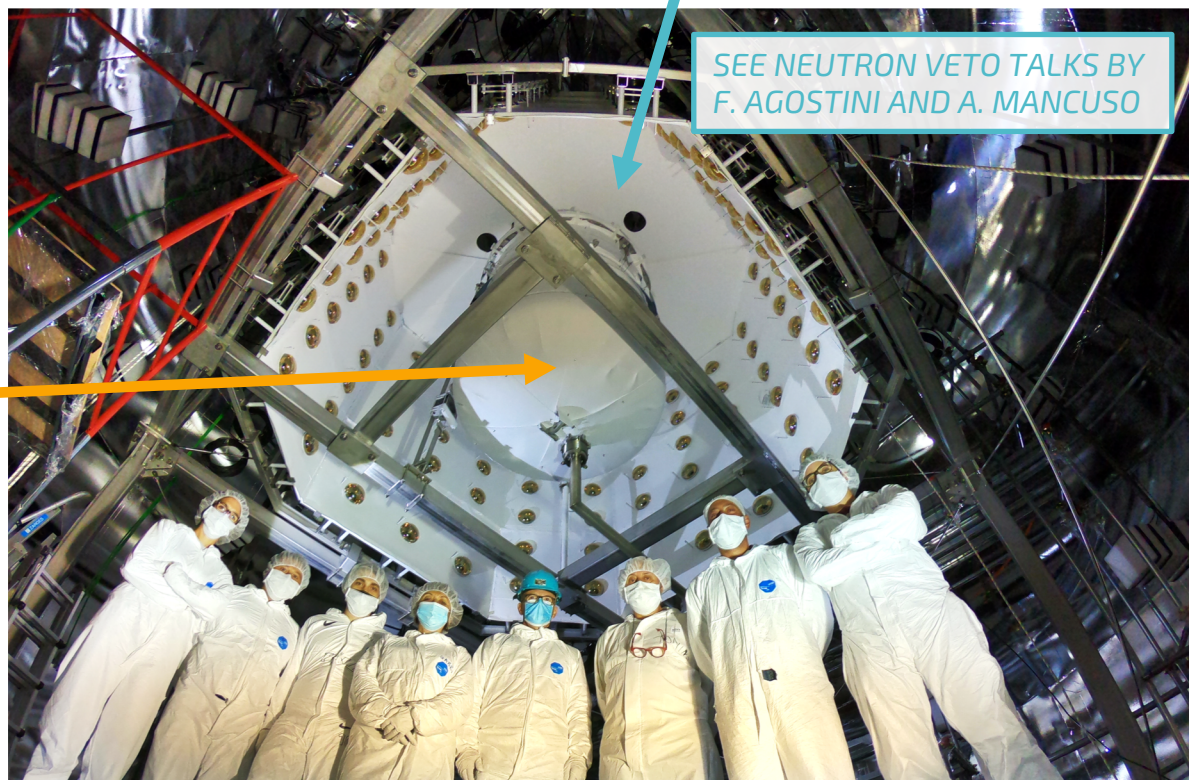
×3
ACTIVE LXe MASS
2 → 6 t

×2
LARGER TPC
248 → 494 PMTs

1/6
ER BACKGROUND
Improved LXe purification
Radon distillation

NV
NR BACKGROUND
Gd-loaded water
Neutron Veto detector

2020
EXPECTED COMMISSIONING



SEE NEUTRON VETO TALKS BY F. AGOSTINI AND A. MANCUSO

XENONnT PROJECTIONS

EXPECTED BACKGROUND

https://arxiv.org/abs/2007.08796

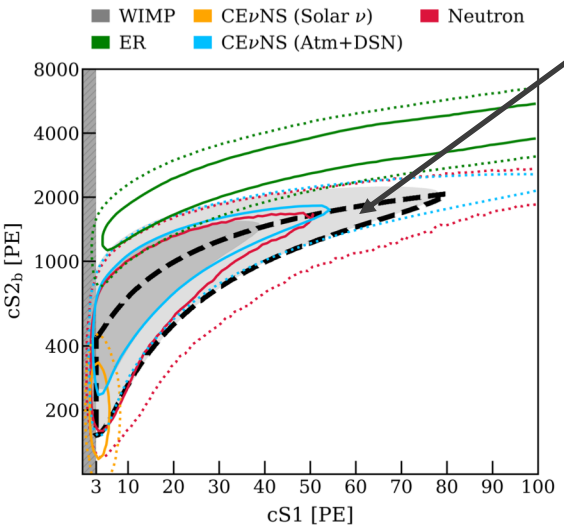
XENONnT SIMULATIONS

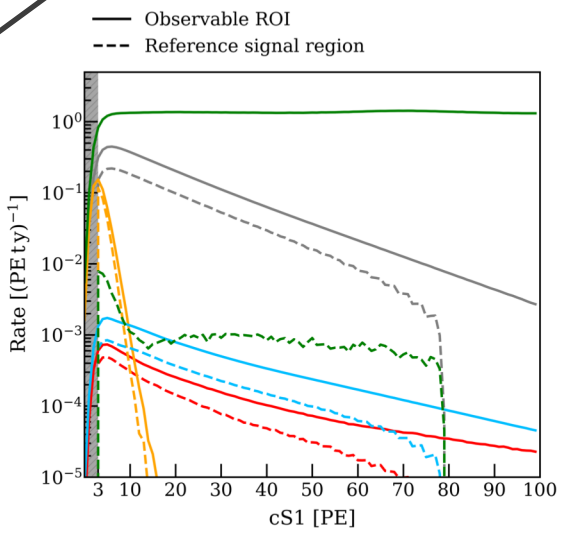
- *G4 DETECTOR MODELISATION*
- *TPC OPTICAL SIMULATIONS*
- *G4 PARTICLE GENERATION AND PROPAGATION*
- *"XENON1T" LXe RESPONSE MODEL*

BACKGROUND EXPECTATIONS

- *RADIOASSAY OF NEW DETECTOR COMPONENTS*
- *UPDATED β-SPECTRA OF INTRINSIC CONTAMINANTS*
- *UPDATED SOLAR ν SPECTRUM*
- *87% NEUTRON VETO EFFICIENCY*

Model component	Expectation value (μ) in 20 t y		Rate uncertainty (ξ)
	Observable ROI	Reference signal region	
Background			
ER	2610	1.69	
Neutrons	0.29	0.15	50%
CEνNS (Solar ν)	7.61	5.41	4%
CEνNS (Atm+DSN)	0.82	0.36	20%
WIMP signal			
6 GeV/c^2 ($\sigma_{\mathrm{DM}} = 3 \times 10^{-44}$ cm^2)	25	19	
50 GeV/c^2 ($\sigma_{\mathrm{DM}} = 5 \times 10^{-47}$ cm^2)	186	88	
1 TeV/c^2 ($\sigma_{\mathrm{DM}} = 8 \times 10^{-46}$ cm^2)	286	118	

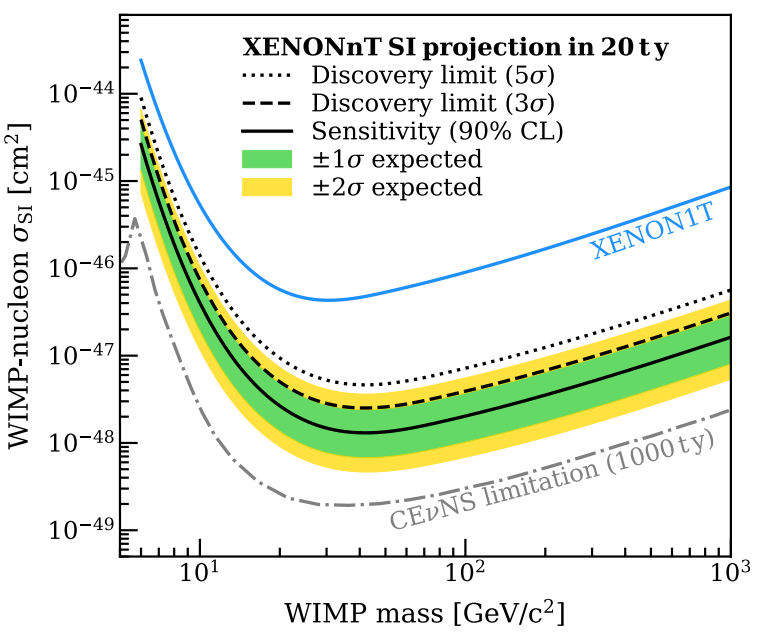


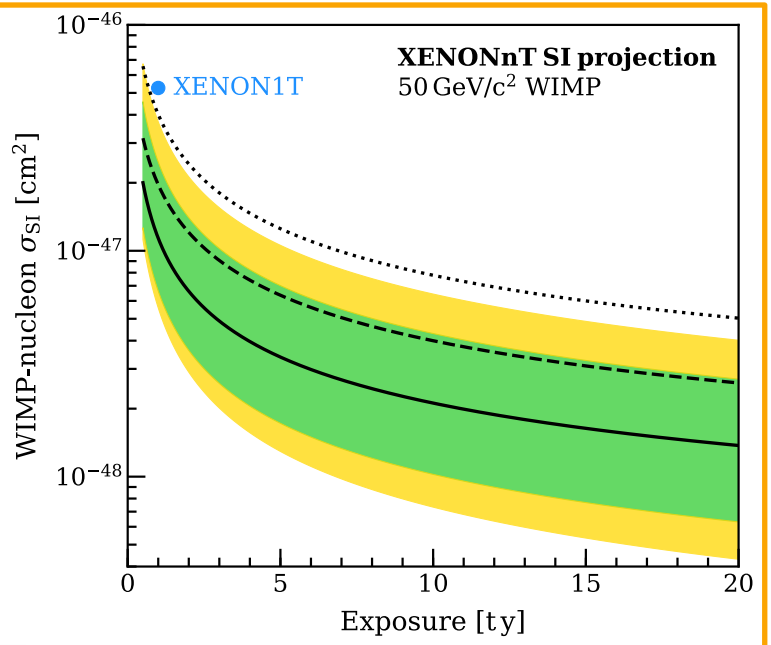


XENONnT PROJECTIONS

SENSITIVITY

https://arxiv.org/abs/2007.08796

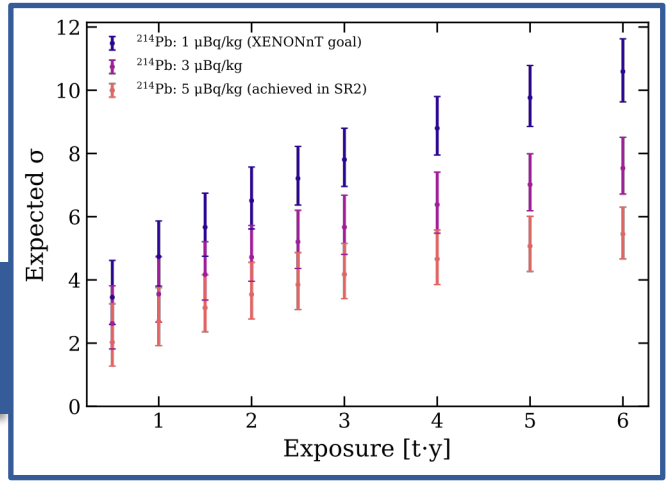




Goal exposure: 20 t·y

1.4×10^{-48} cm^2 at 50 GeV/c^2 WIMP mass

MORE THAN 1 ORDER OF MAGNITUDE IMPROVEMENT



Assuming the ER excess persists…

*XENONnT WILL DISCRIMINATE **AXIONS FROM TRITIUM** WITH FEW MONTHS OF DATA*

XENONnT IS RIGHT BEHIND THE CORNER

STAY TUNED...

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