

Search for Dark Matter with the XENONnT experiment

Physikerinnentagung – German Conference of Women in Physics
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The XENON collaboration

More than 170
members from 27
institutes



XENON

AMERICA


San Diego 

Houston 

Chicago 

New York City 

Lafayette 

EUROPE

							
Zurich 	Karlsruhe 	Münster 	Freiburg 	Mainz 	Heidelberg 	Amsterdam 	Stockholm 
							
Coimbra 	Nantes 	Paris 	Torino 	Bologna 	L'Aquila 	Assergi 	Napoli 

MIDDLE EAST


Rehovot 

Abu Dhabi 

ASIA


Beijing 

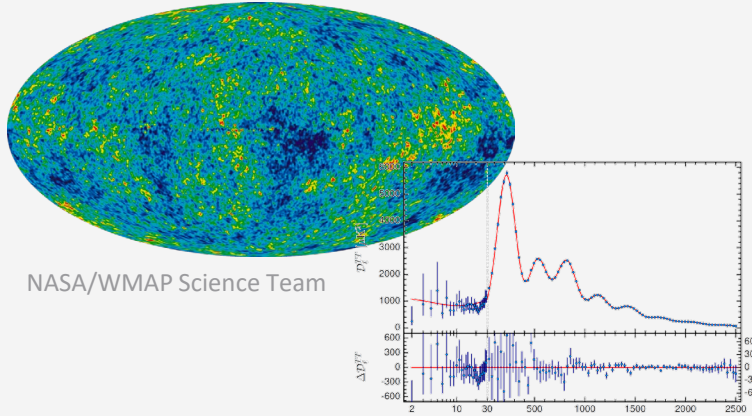
Tokyo 

Nagoya 

Kobe 

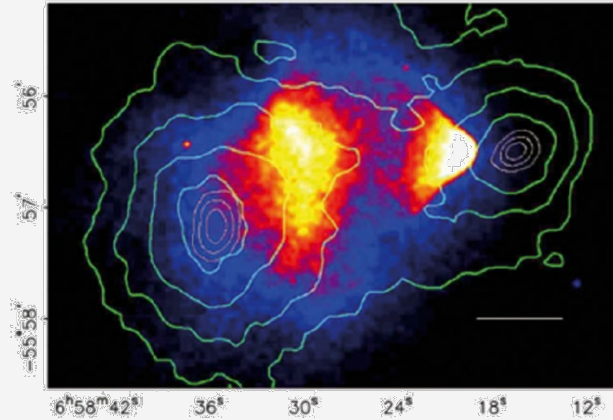
Dark Matter Evidence

Cosmic Microwave Background



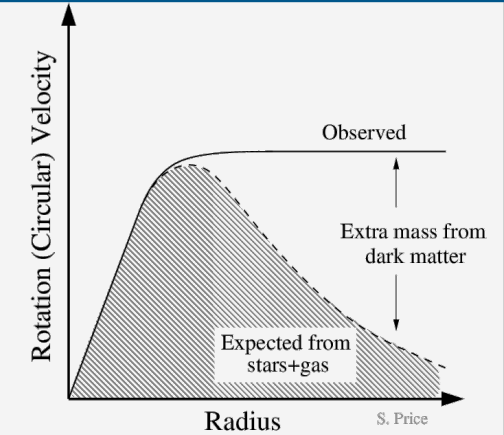
Planck 2015 results, arXiv:1502.01589

Gravitational Lensing (Bullet Cluster)



Douglas Clowe *et al* 2006 *ApJ* **648** L109 DOI 10.1086/508162

Galaxy Rotation Velocity



<https://mosdef.astro.berkeley.edu/for-the-public/public/galaxy-masses/>

... non-luminous – stable – neutral – massive – non-relativistic ...

Axions / ALPs
~meV

Sterile ν
~keV

WIMPs
~GeV

Primordial Black Holes

mass

Detection principle: dual-phase time projection chamber (TPC)

- Prompt light signal (S1)
- Secondary light in xenon gas phase from drifted charges (S2)
- Energy reconstruction** using the combined S1 and S2 signal
- 3D position reconstruction**
 - z from S1-S2-delay time
 - x-y from S2 light distribution
- Event discrimination**
 - Electronic recoil (ER)
 - Nuclear recoil (NR)

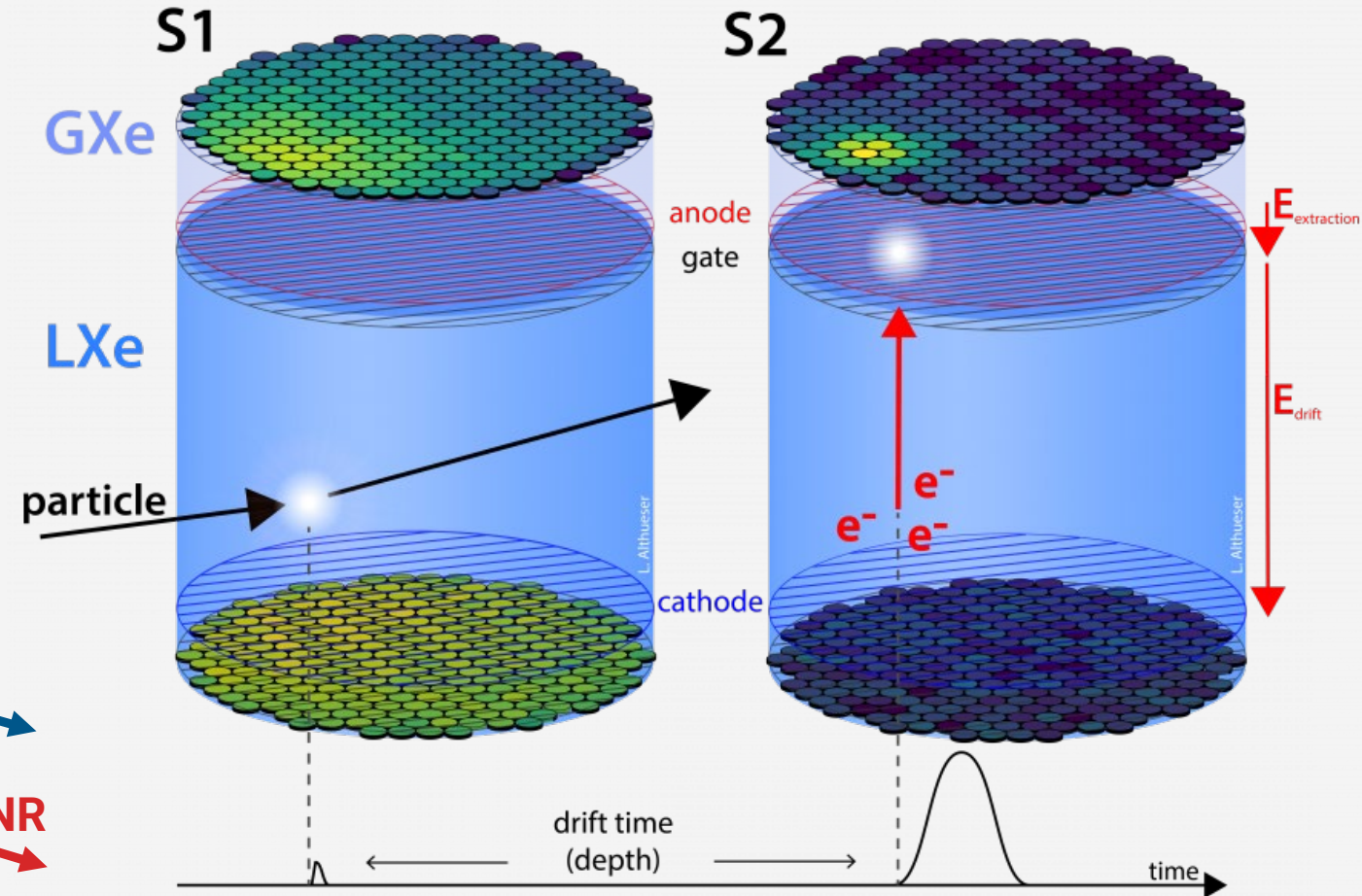
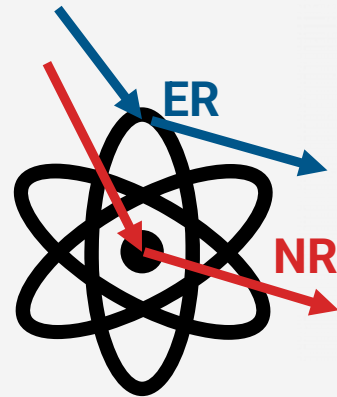


Illustration: Lutz Althueser

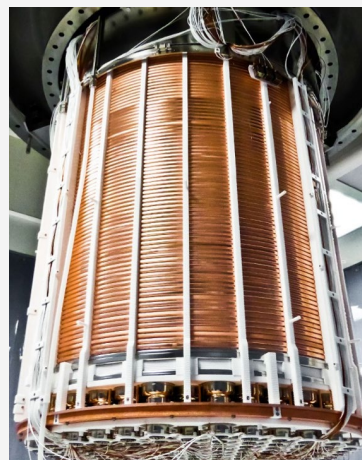
The XENON experiments



XENON Collaboration



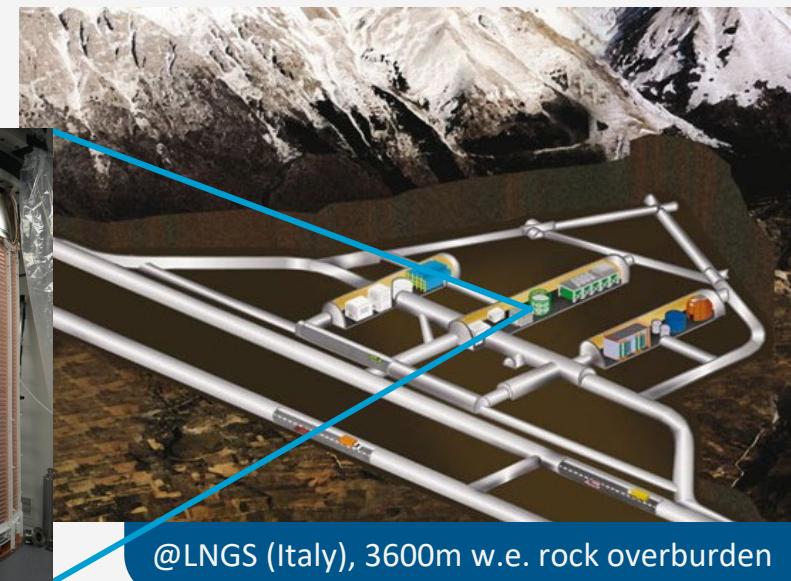
XENON Collaboration



XENON Collaboration



XENON Collaboration



@LNGS (Italy), 3600m w.e. rock overburden

INFN LNGS

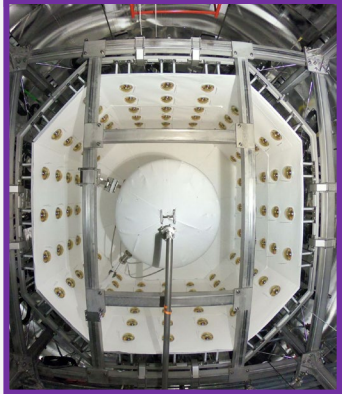
XENON10	XENON100	XENON1T	XENONnT
2005 – 2007	2008 – 2016	2012 – 2019	2020 – 2026
14kg Xe target	62kg Xe target	2t Xe target	~6t Xe target, 8.6t total
$\sim 10^{-43} \text{cm}^2$	$\sim 10^{-45} \text{cm}^2$	$4 \cdot 10^{-47} \text{cm}^2$	Projection: $1.4 \cdot 10^{-48} \text{cm}^2$ for 20 t·yr
~2,000,000 background ER events/(keV·t·yr)	1800 background ER events/(keV·t·yr)	82 background ER events/(keV·t·yr)	16.1 background ER events/(keV·t·yr)

XENONnT

TPC



Neutron veto

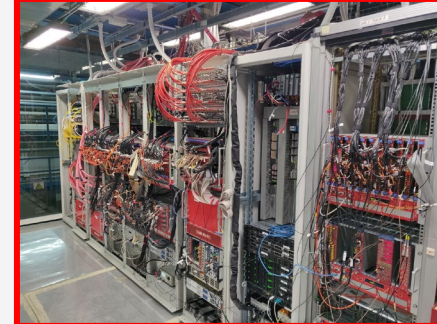


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Radon column



Data acquisition

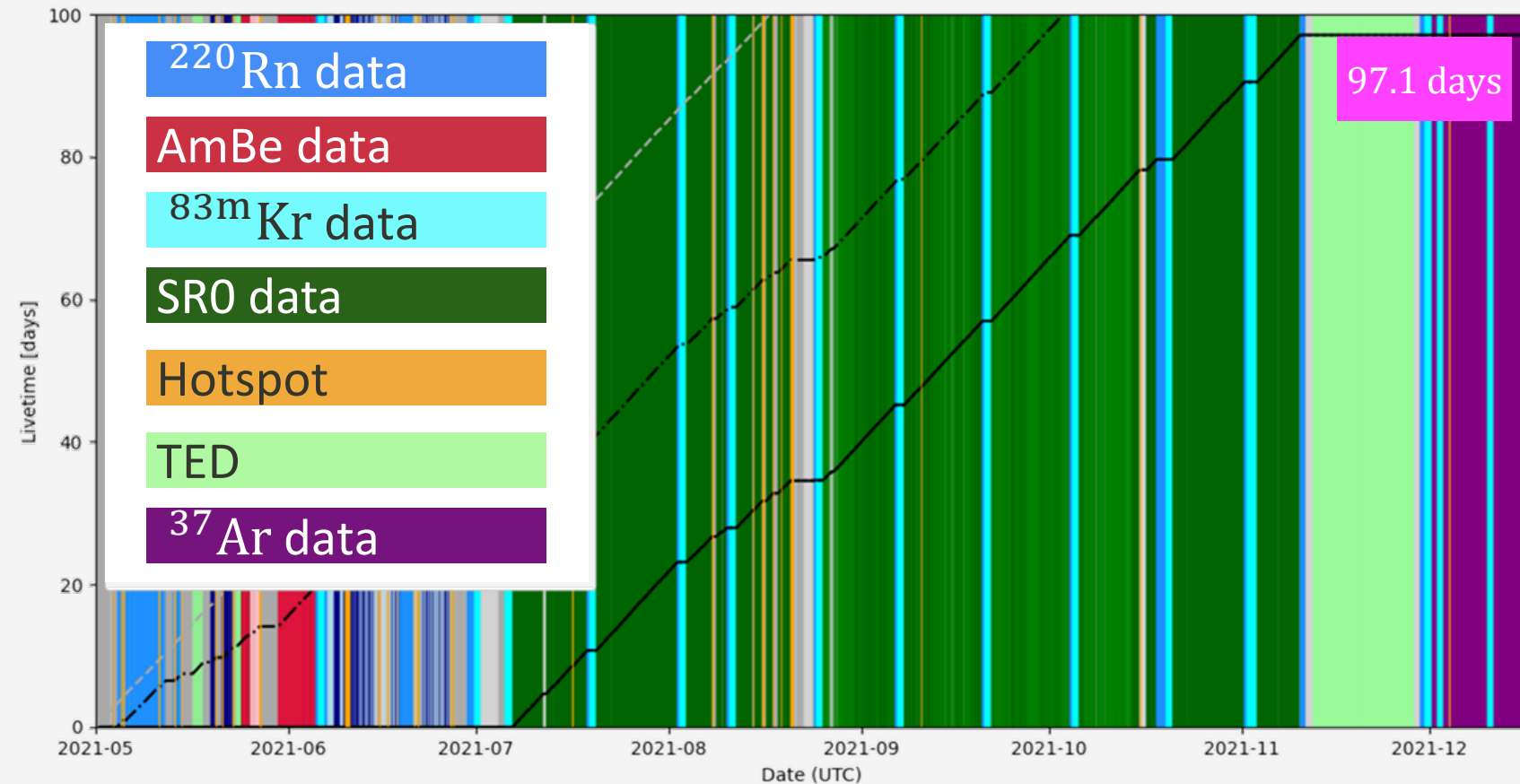


LXe purification system



First XENONnT Science Run (SR0)

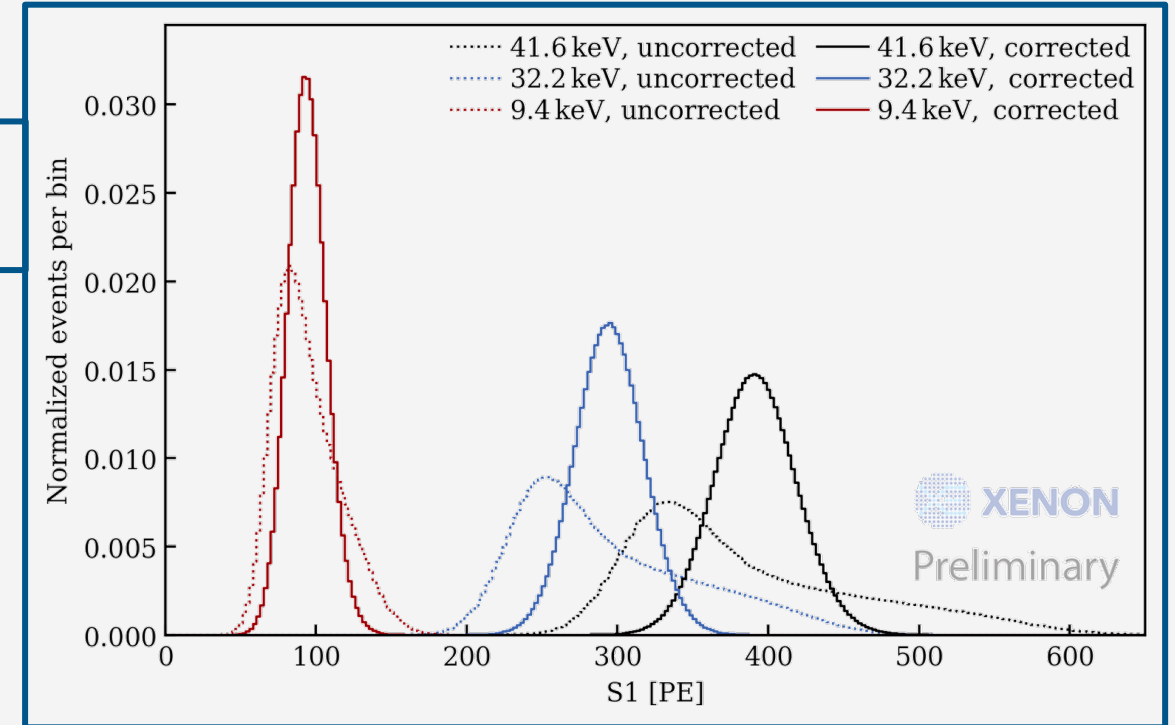
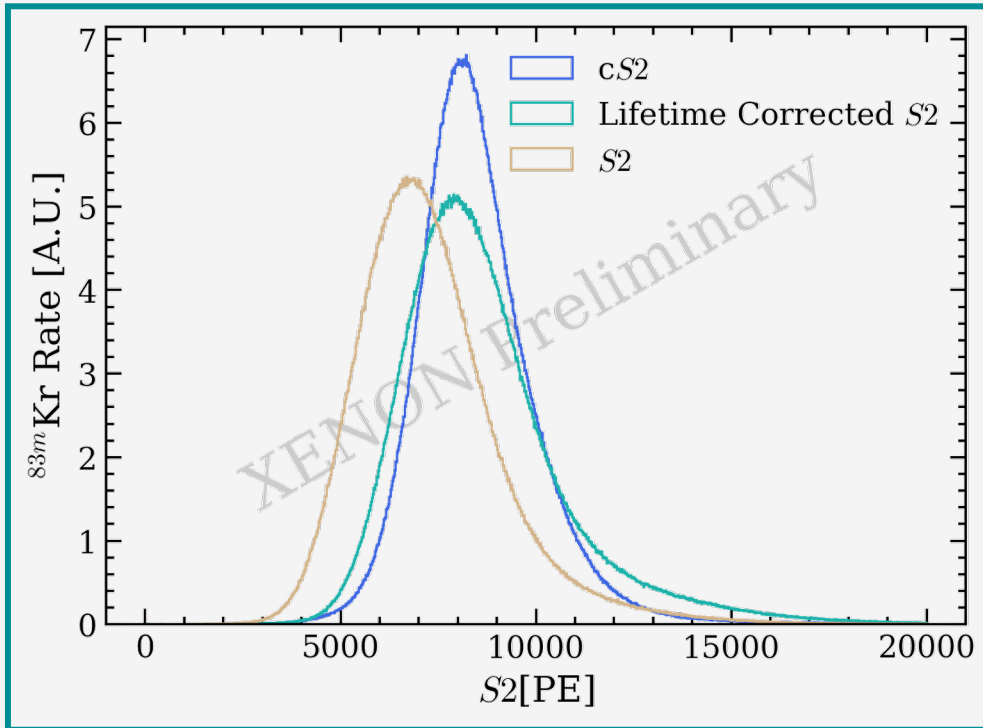
- Exposure of $\sim 1.16 \text{ t}\cdot\text{y}$
- Radon column in gas only mode
- Drift field at 23 V/cm
- 477 PMTs out of 494 operating
- Hotspot: localized bursts of single electron emission
- Various calibration sources for detector characterization



Signal Corrections with ^{83m}Kr

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S1 correction: S1 light collection efficiency as function of position



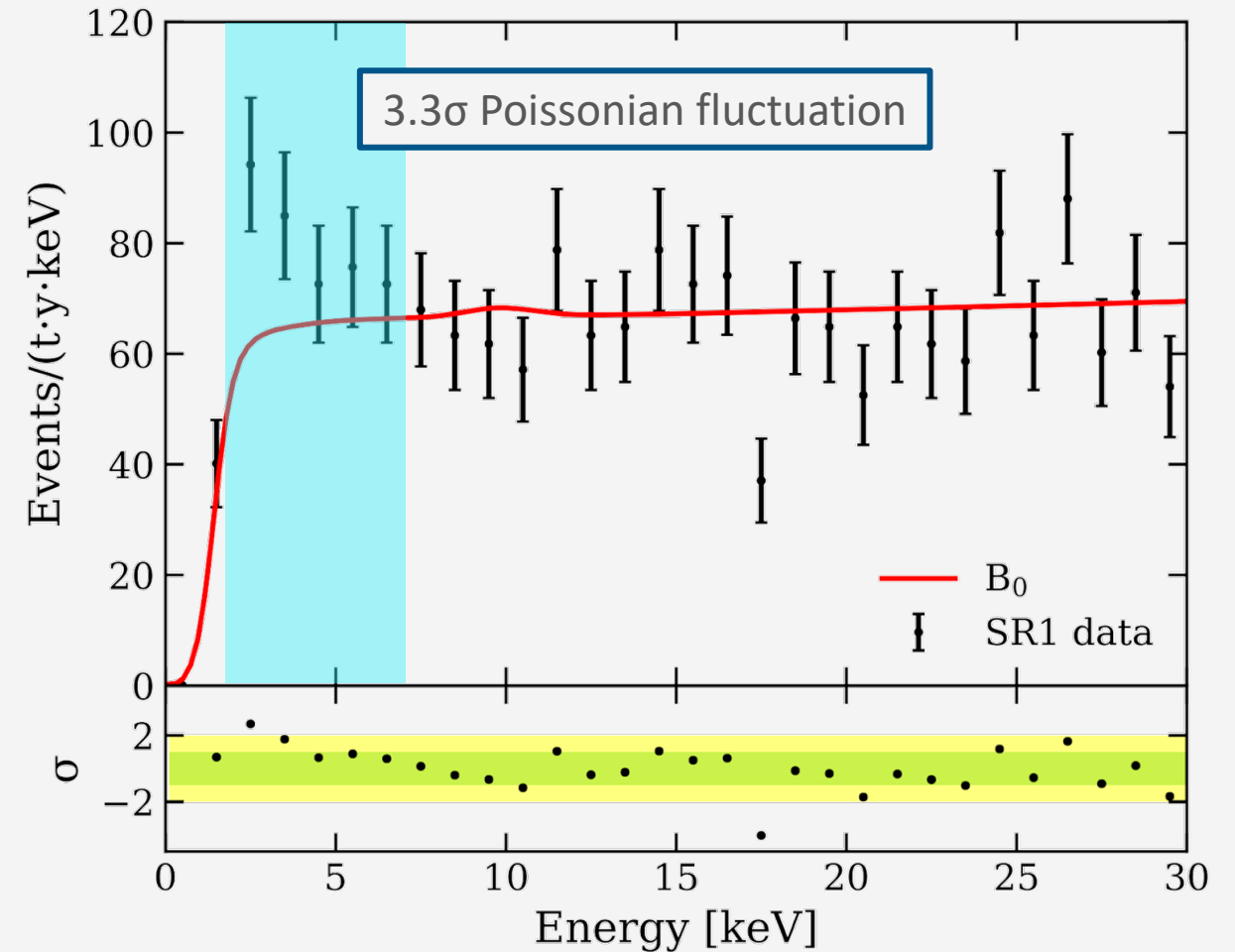
S2 correction: electron lifetime, S2 light collection efficiency as function of horizontal position

Position reconstruction:
distortion induced by drift field

Low-energy ER excess in XENON1T

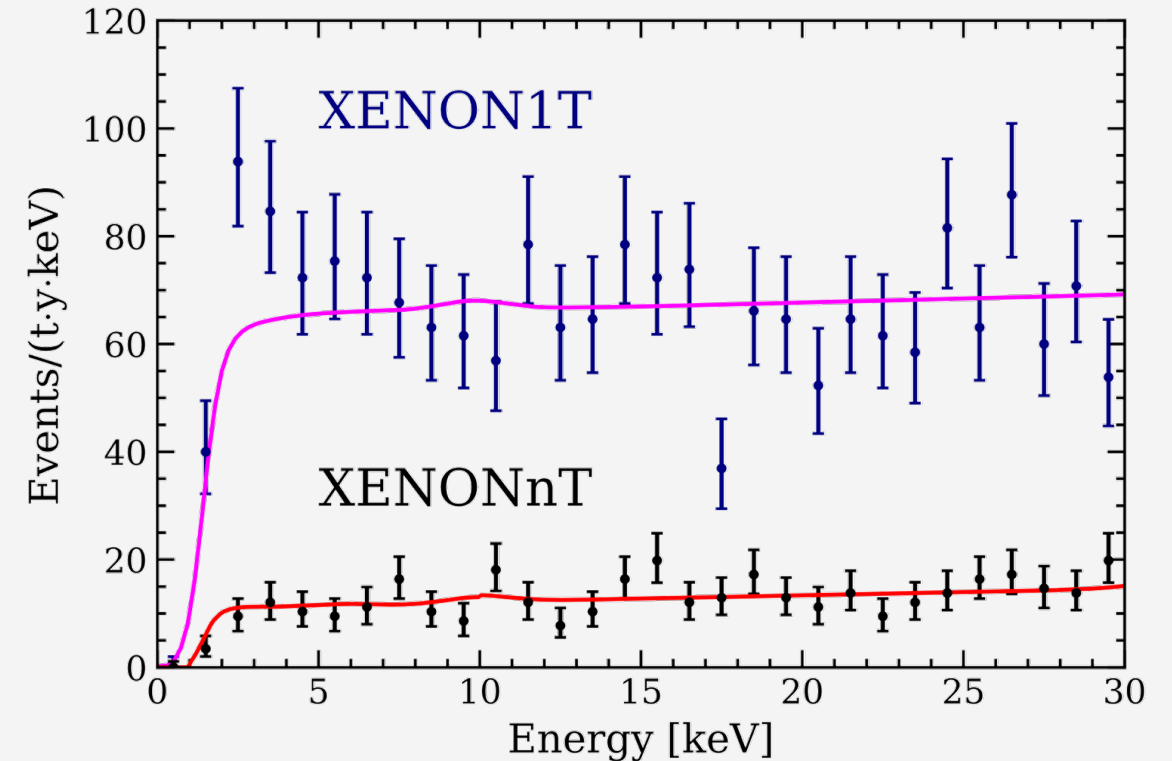
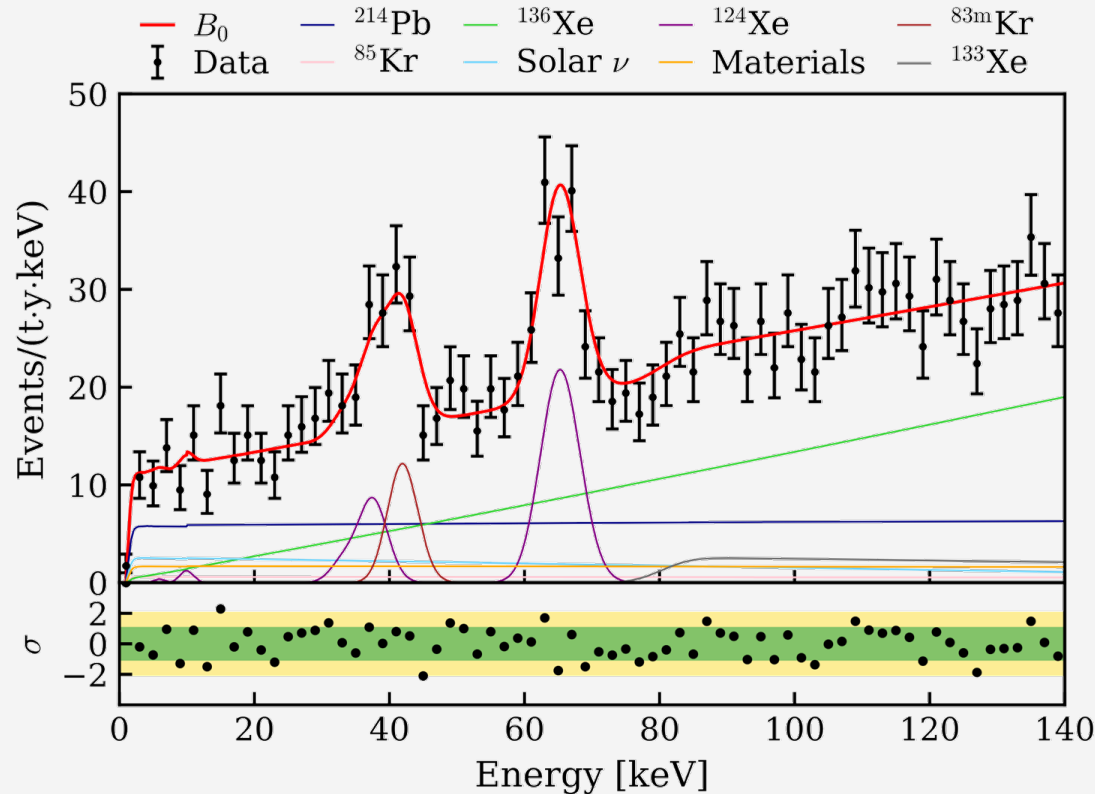
- XENON1T: **excess of events** in low-energy ER spectrum
- Compatible with various **BSM signatures** (solar axions, ALPs, dark photons, enhanced neutrino magnetic moment, ...)
- Also consistent with potential **tritium (^3H) background**, required rate would conflict with observed target purity and transparency
- ^{37}Ar removed by krypton distillation

➔ XENONnT SR0 addressing this question first



Phys. Rev. D 102, 072004 (2020)

Low-energy ER spectrum in XENONnT

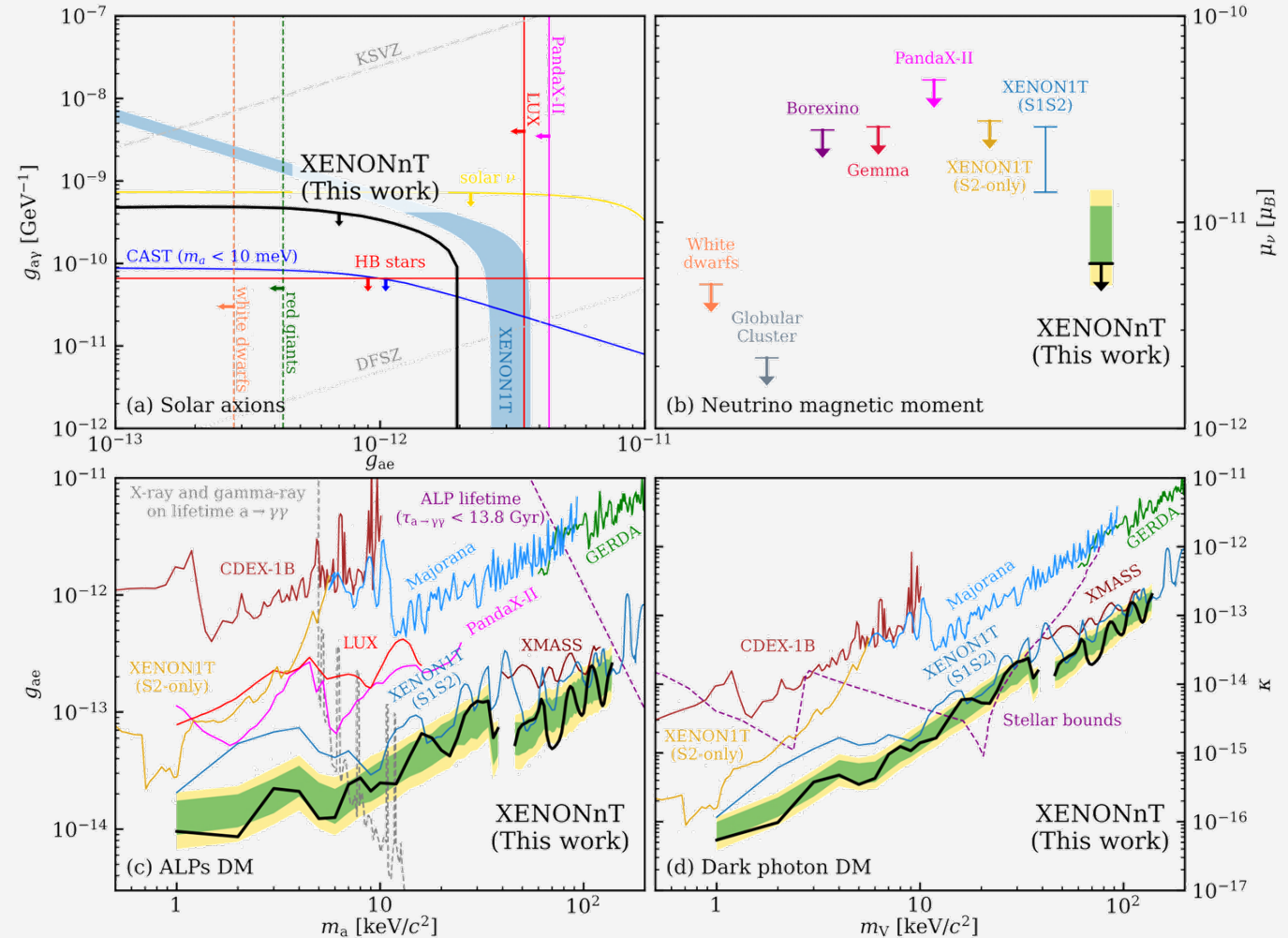


After low-ER unblinding: extraordinary background reduction, **no excess observed** (PRL 129, 161805 (2022))
NR analysis in preparation, expected to set new limit on WIMP nucleus scattering

Further BSM Physics Constraints

- **Axion signal** search assumes axio-electric and inverse Primakoff effect
- Improved constraints on axion-gamma, axion-electron and axion-nucleon coupling
- Constraint on solar **neutrino magnetic moment** $\mu_\nu < 6.3 \times 10^{-12} \mu_B$
- Most stringent limit in any direct detection experiment
- Peak search for **axion-like particles** or **dark photons** sees no significant excess
- New limits between 1 keV and 140 keV

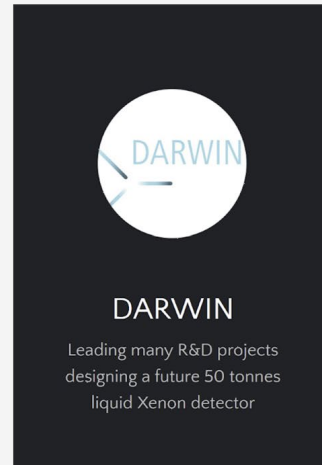
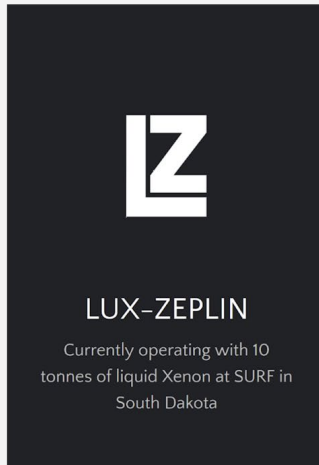
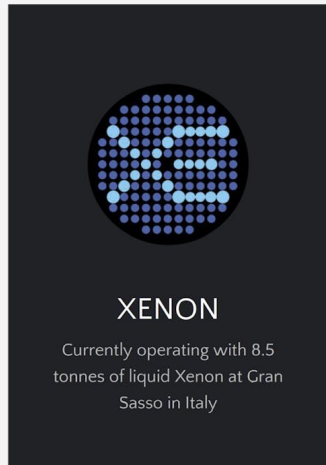
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PRL 129, 161805 (2022)

Summary

- New XENONnT subsystems successfully commissioned
- Lowest ER background level ever achieved by dark matter experiment: 16.1 ± 0.3 events/(t·y·keV)
- SRO ER analysis observed no excess, new limits on BSM physics
- NR WIMP analysis in preparation

xenonexperiment.org[xenon_experiment](https://www.instagram.com/xenon_experiment)[Xenonexperiment](https://twitter.com/Xenonexperiment)

- More analysis channels to be explored (S2only, Migdal effect, CEvNS, double-weak decays)
- Joining forces towards a next-generation dark matter experiment: **XLZD consortium**, still in planning phase

White paper: [arXiv:2203.02309](https://arxiv.org/abs/2203.02309)