RESULTS FROM THE 1 T X YEAR DM SEARCH WITH XENON1T

Sara Diglio on behalf of the XENON Collaboration

Subatech – Nantes

IRN Terascale: 30th May – 1st June 2018, IPHC Strasbourg

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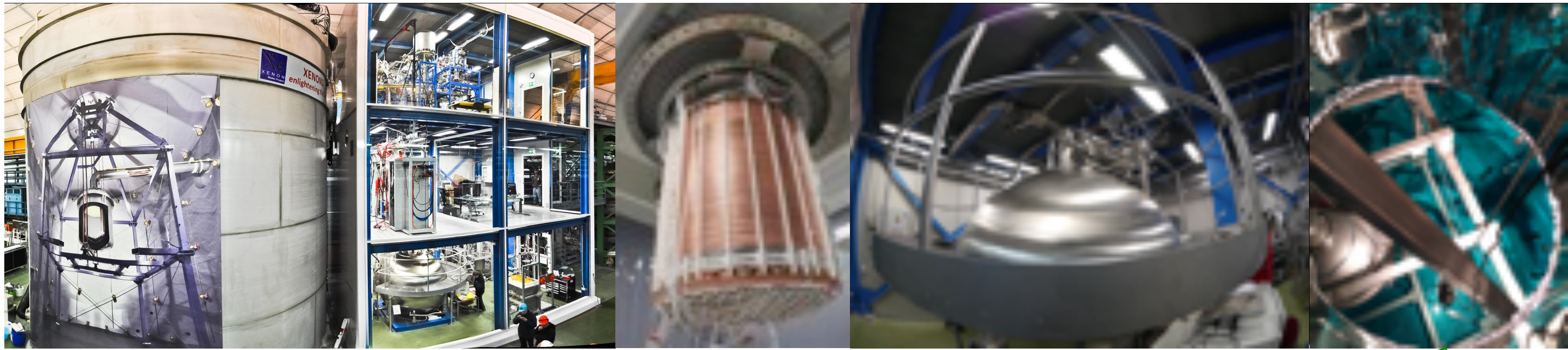

RESULTS FROM THE 1 … SEARCH

Sa… …aboration

…es

…1 June 2018, IPHC Strasbourg

Disclaimer: VERY recent results!

Presented for the 1st time Monday the 28th of May by E.Aprile (@LNGS) and M.Lindner (@CERN)

Not published yet!

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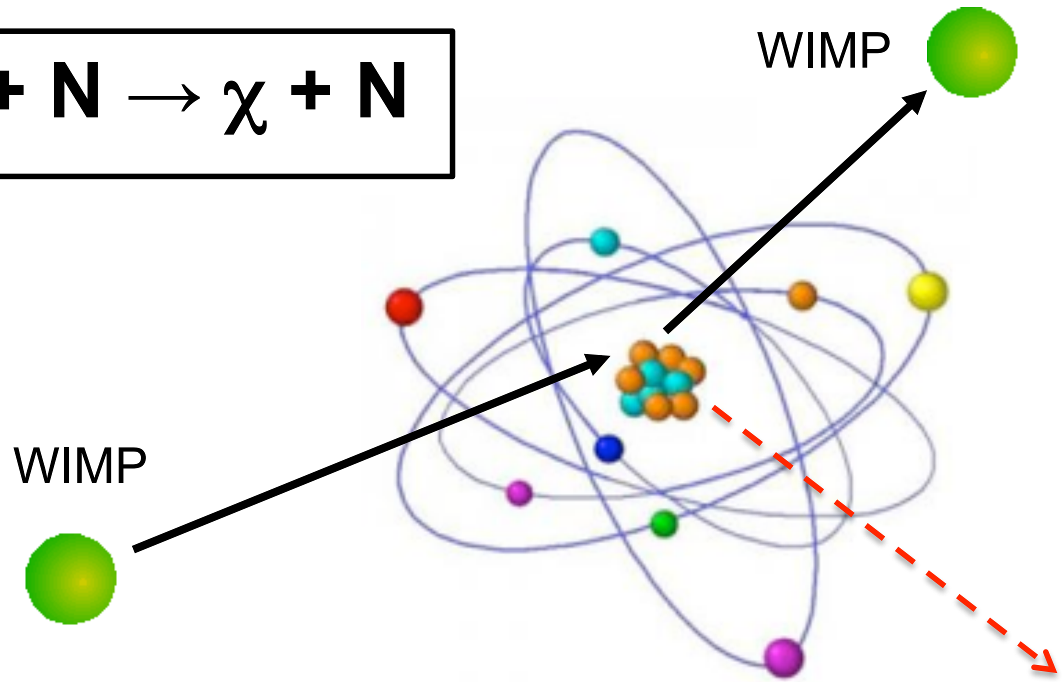
THE DIRECT DETECTION PRINCIPLE

WIMPs elastically scatter off nuclei in targets, producing Nuclear Recoils (NR)

$$\chi + N \rightarrow \chi + N$$



NR: Detectable Signal

$$E_{recoil} \leq 50\,keV$$

For example, by assuming

- WIMP mass: M_χ = 100 GeV/c^2
- WIMP velocity: v_0 = 220 km/s

we have the average recoil energy: $E_0 = \frac{1}{2} M_X v_0^2 \sim 30$ keV

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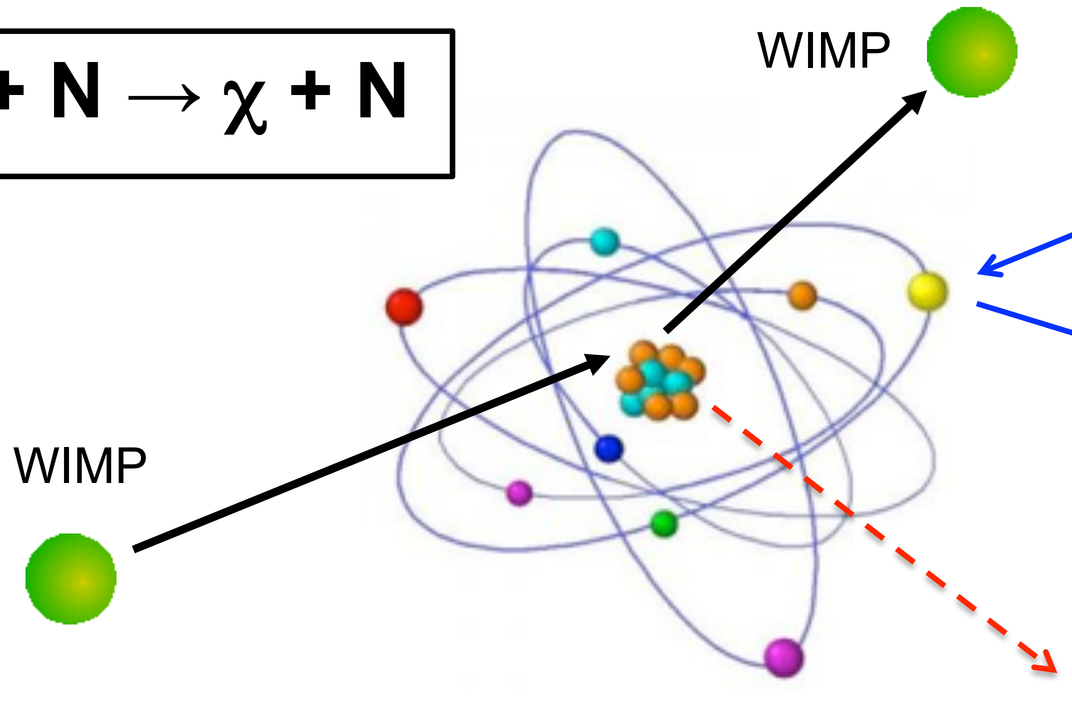

γ- and β-particles (**bkg**) interact with the atomic electrons
→ **electronic recoil (ER)**

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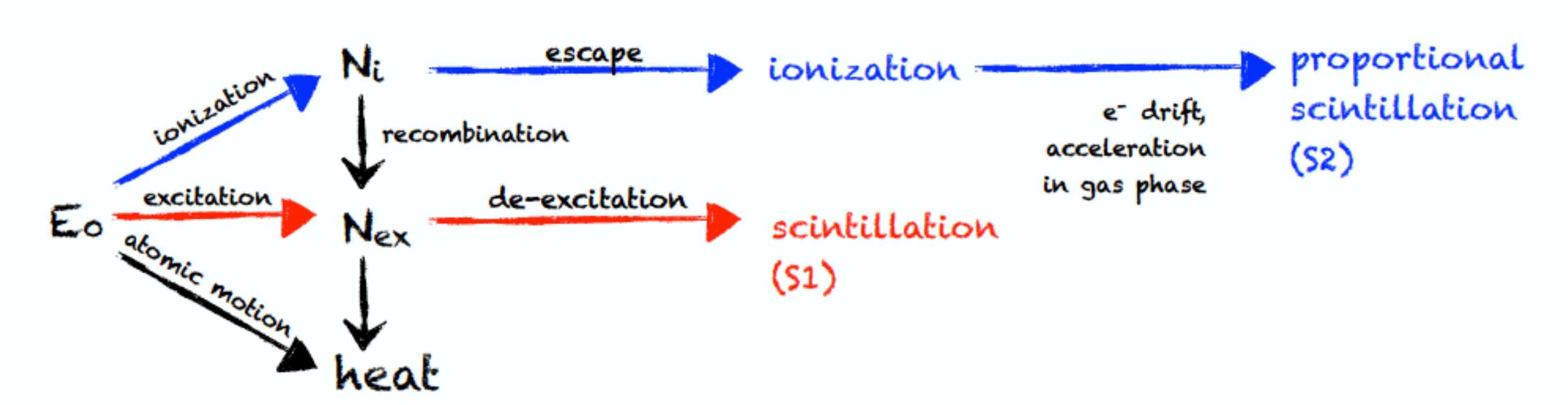
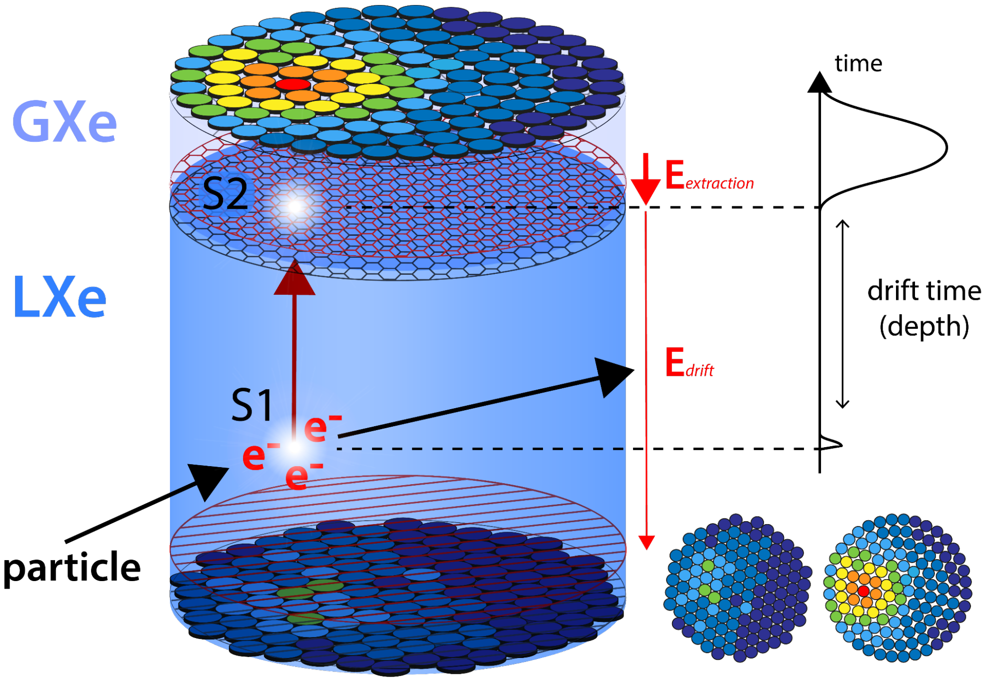
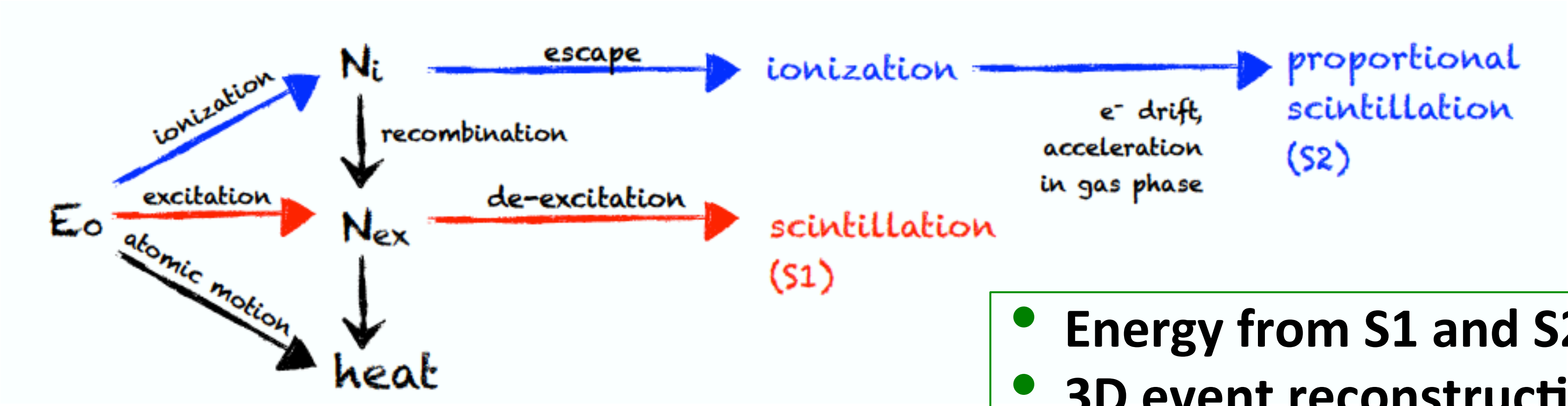
DUAL PHASE TIME PROJECTION CHAMBER

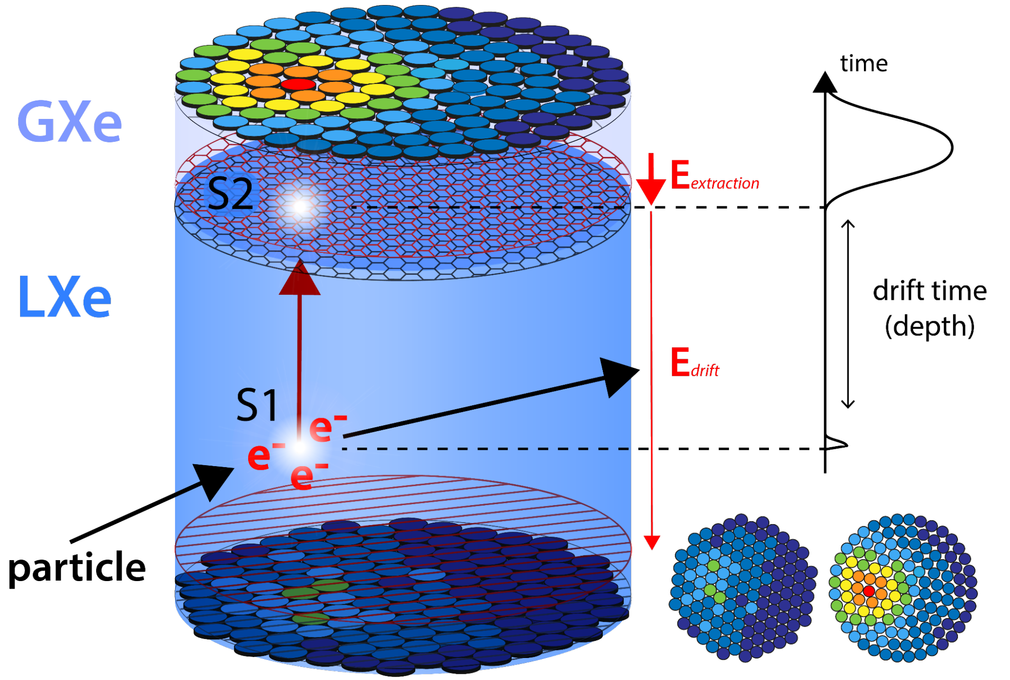


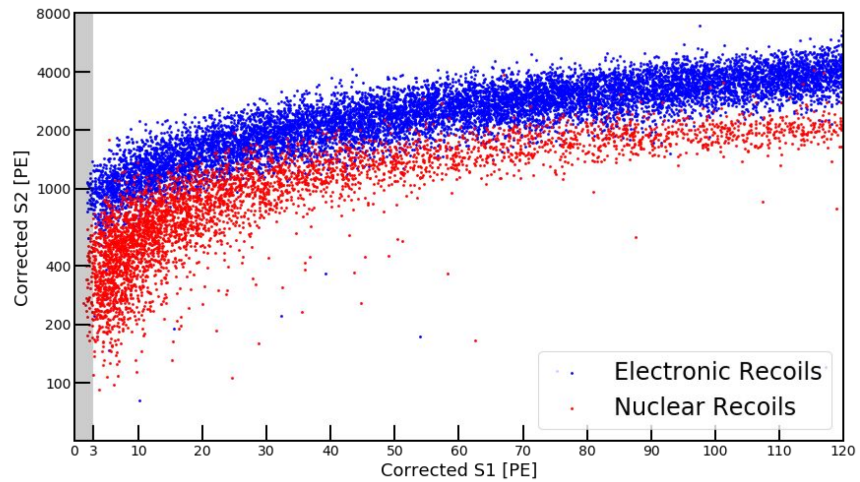


Dual Phase Time Projection Chamber



- **Energy from S1 and S2 area**
- **3D event reconstruction:**
  - X , Y from S2 hit pattern on top PMTs
  - Z from electrons drift time
- **ER - NR discrimination**
  $(S2/S1)_{WIMP,n} < (S2/S1)_{\gamma,\beta}$





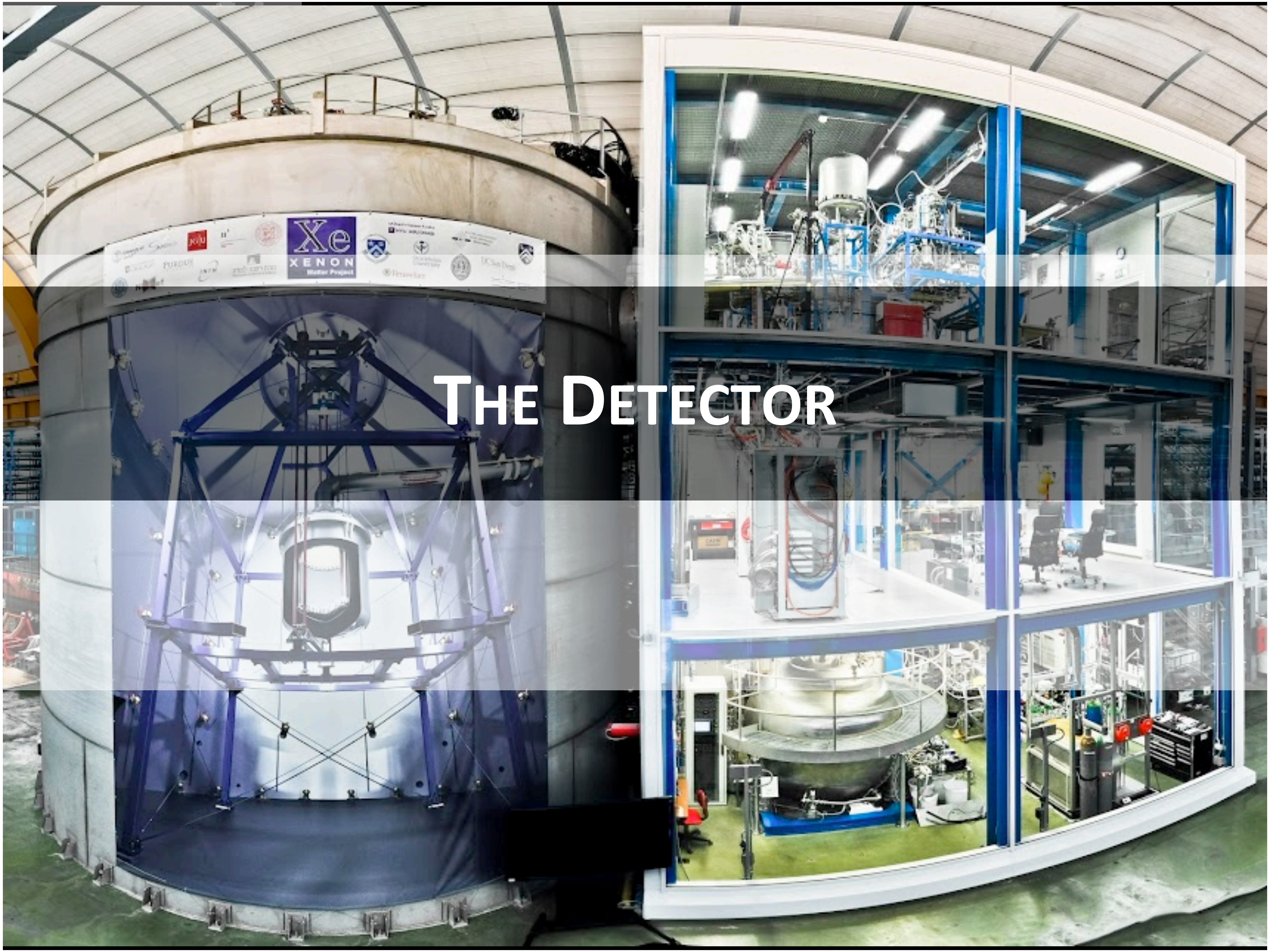
THE XENON COLLABORATION

27 Institutions

11 Countries

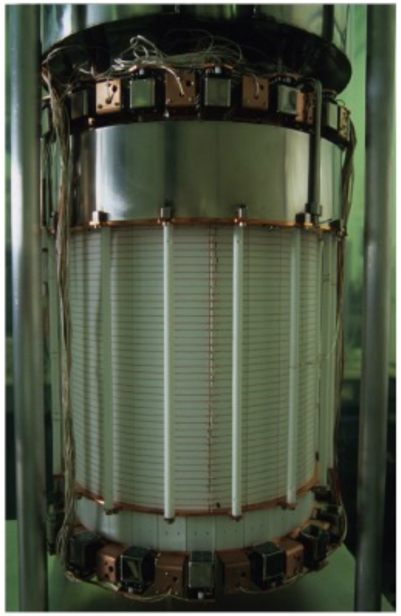
~ 160 Scientists

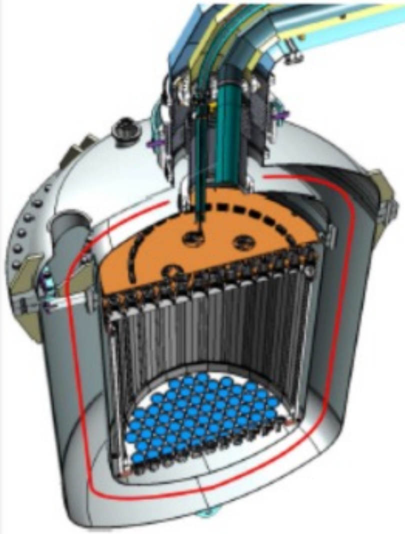
THE DETECTOR



THE XENON PROJECT

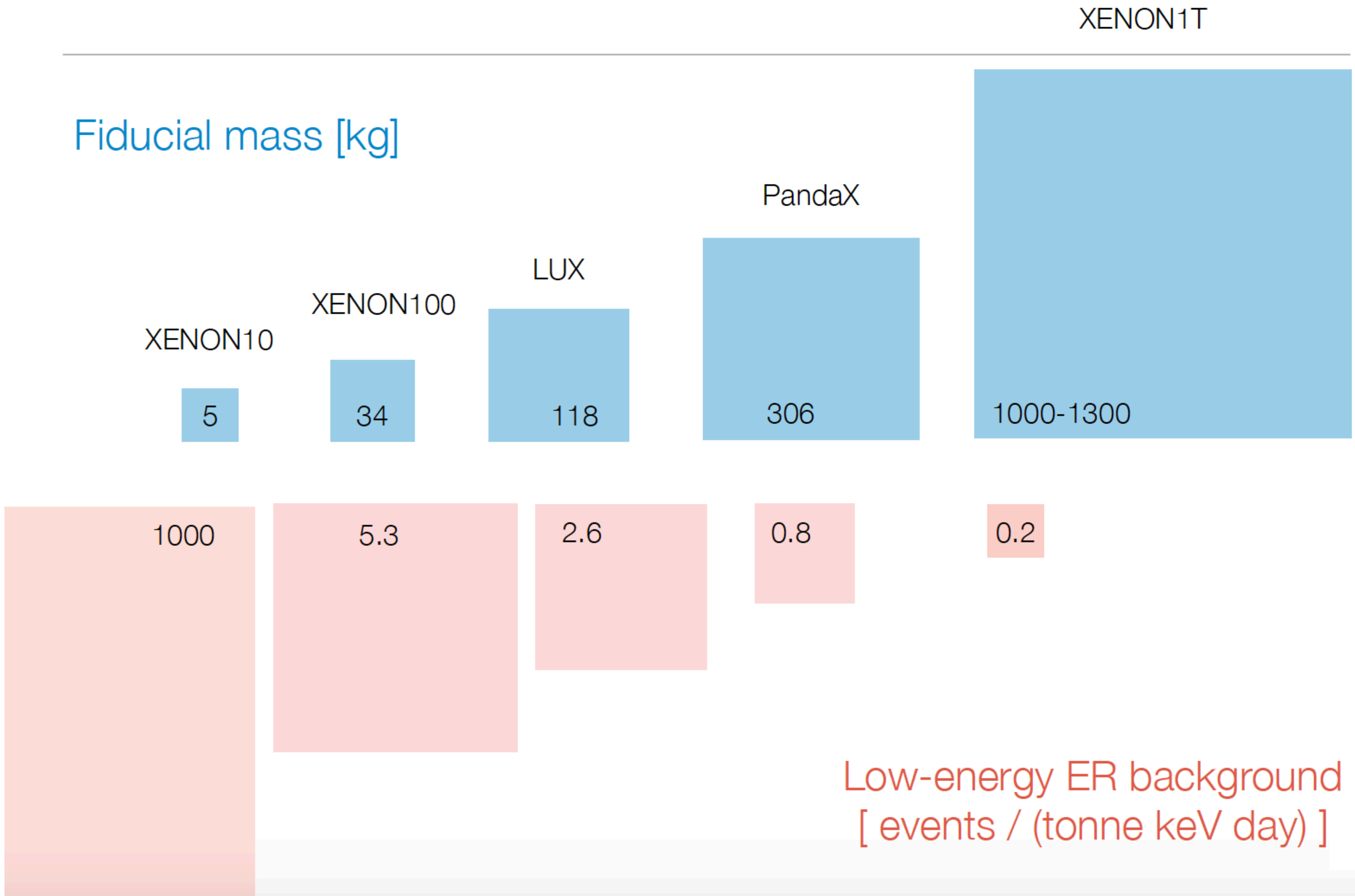
Time



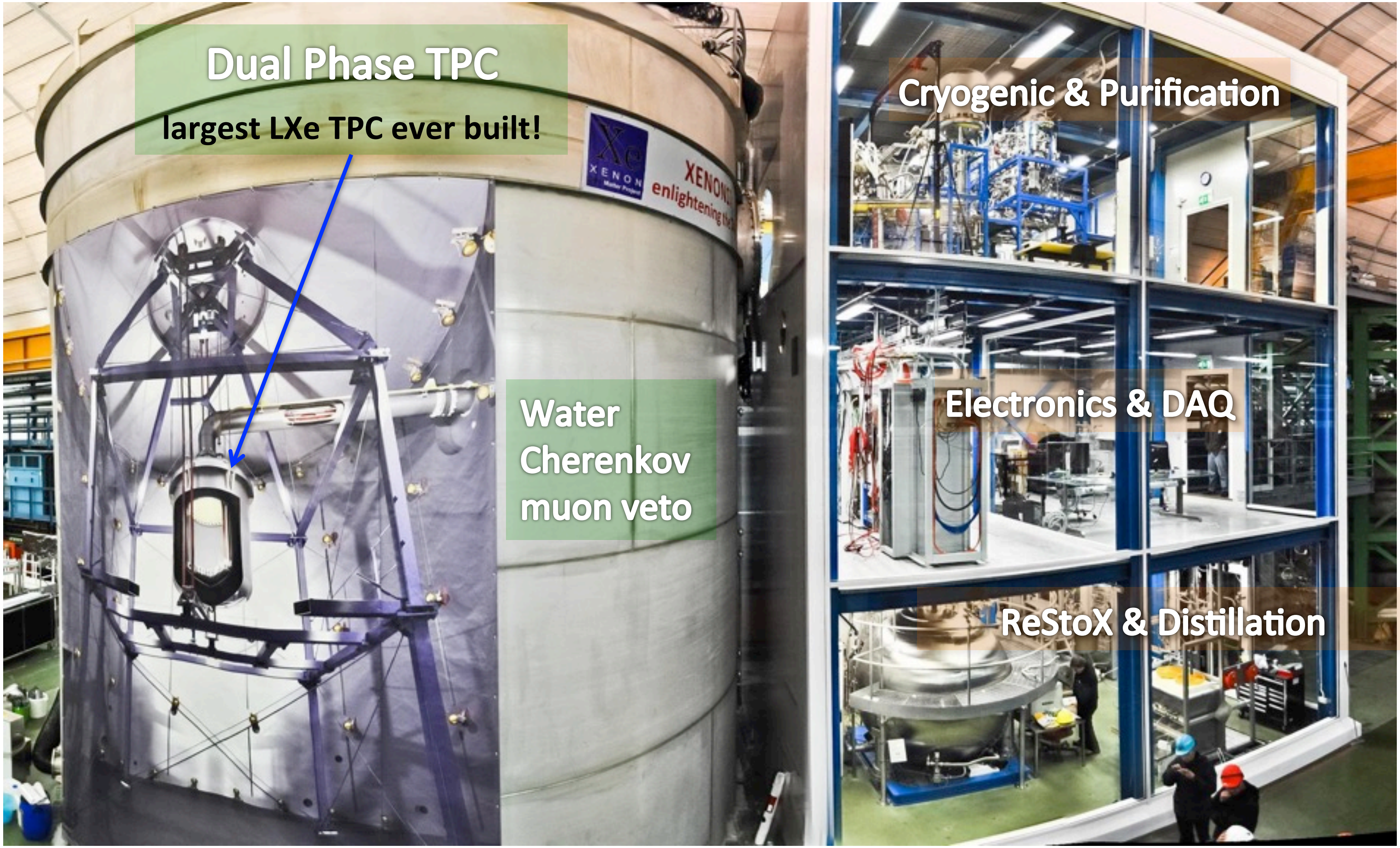


XENON10	XENON100	XENON1T	XENONnT
2005-2007	2008-2016	2012-2018	2019-2023
25 kg - 15cm drift	161 kg - 30 cm drift	3.2 ton - 1 m drift	8 ton - 1.5 m drift
~10^{-43} cm^2	~10^{-45} cm^2	~10^{-47} cm^2	~10^{-48} cm^2

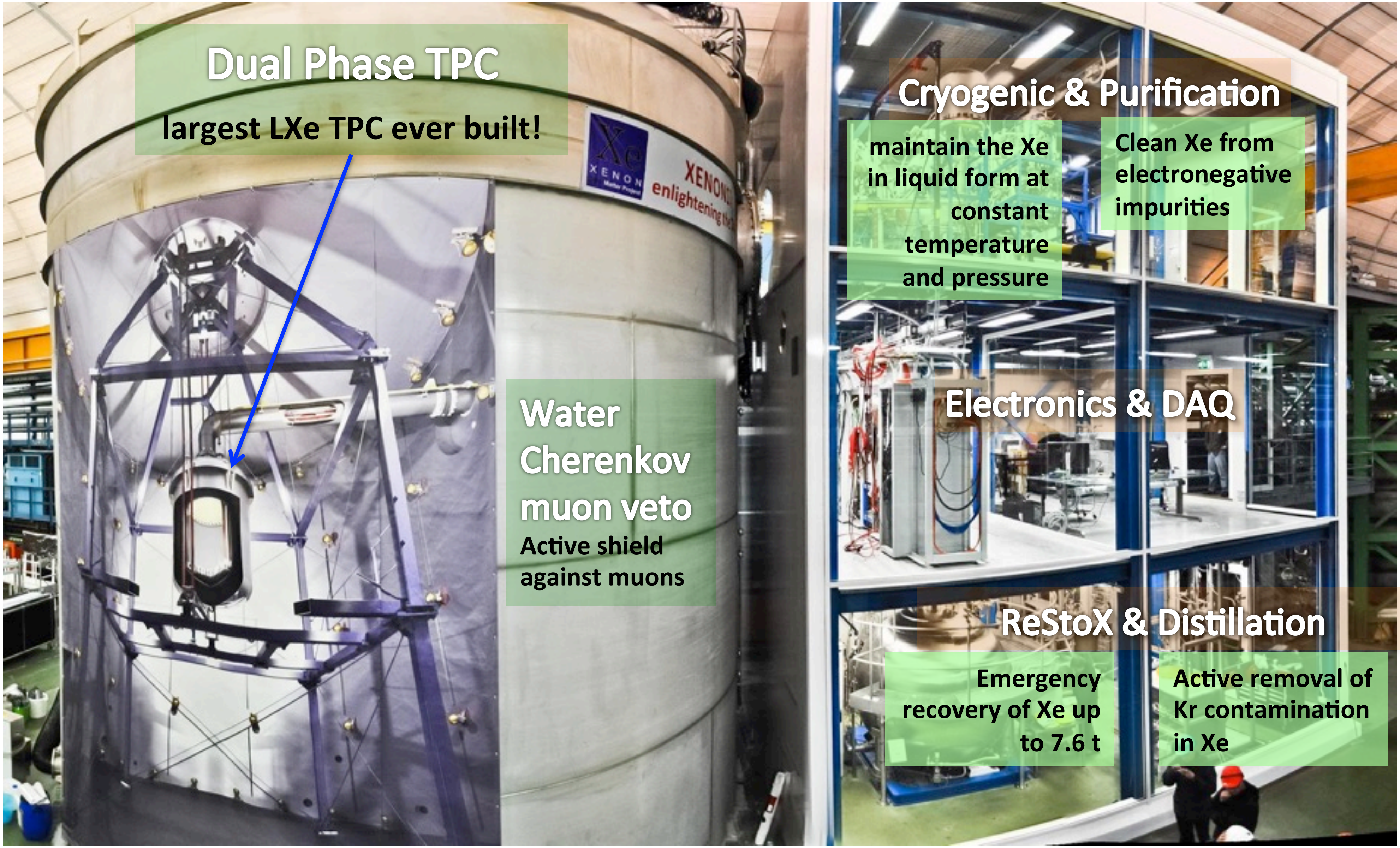
LXeTPCs as WIMP detectors Scaling



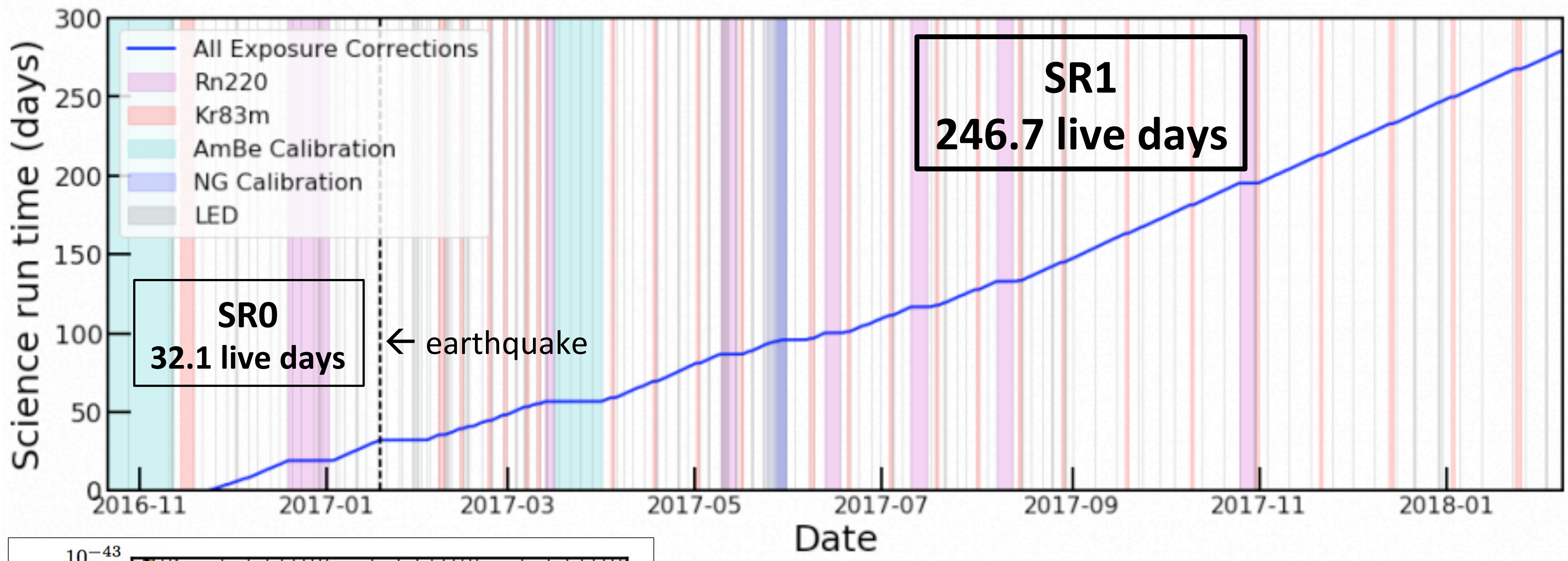
THE XENON1T EXPERIMENT

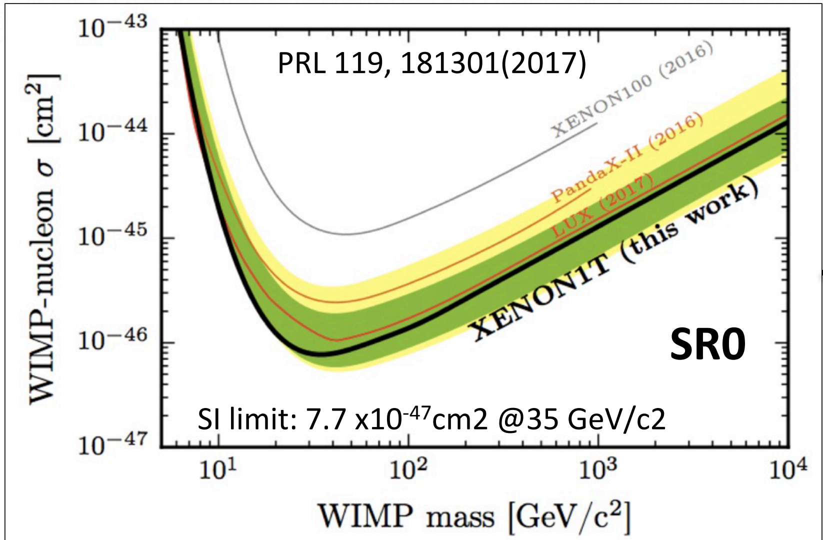


The XENON1T Experiment



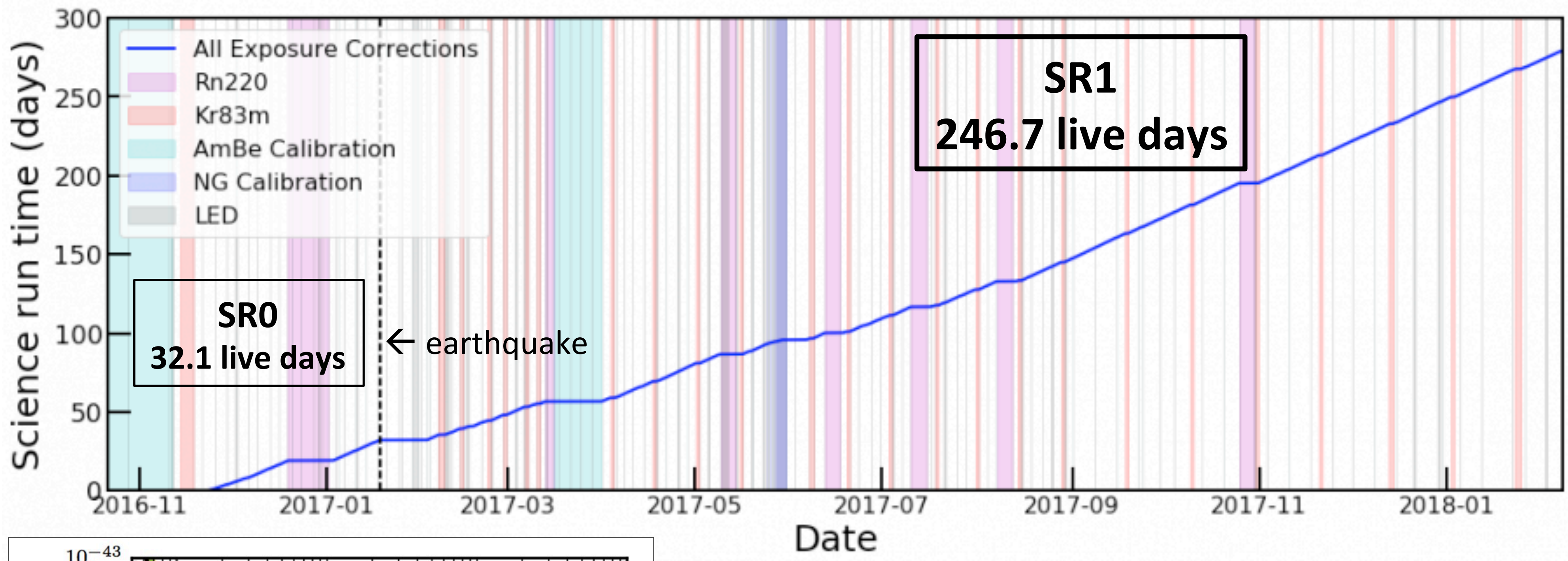
XENON1T DATA TAKING

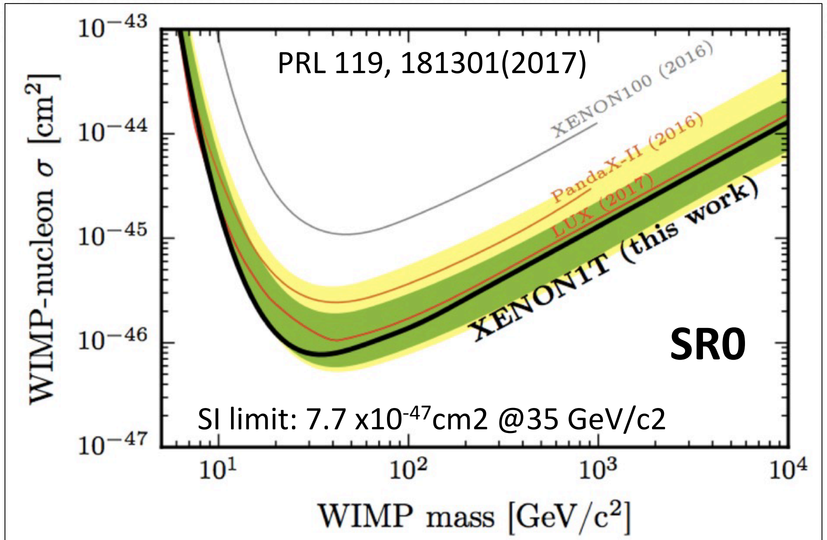




[Presentation of First results by XENON1T (SR0) by Julien Masbou at GDR Terascale 2017 in Montpellier](#)

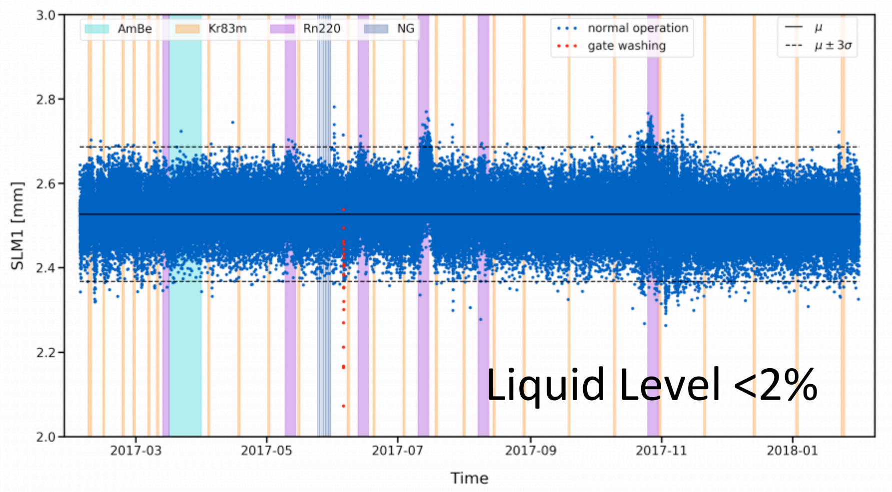
XENON1T DATA TAKING

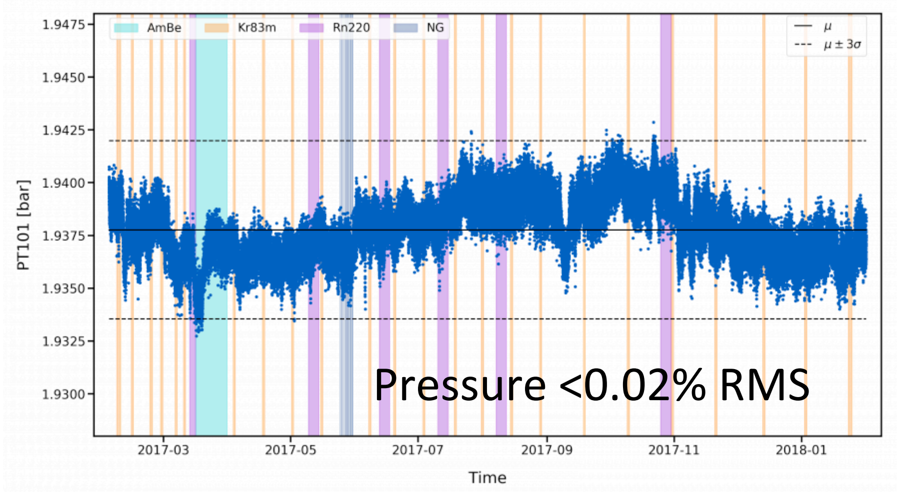




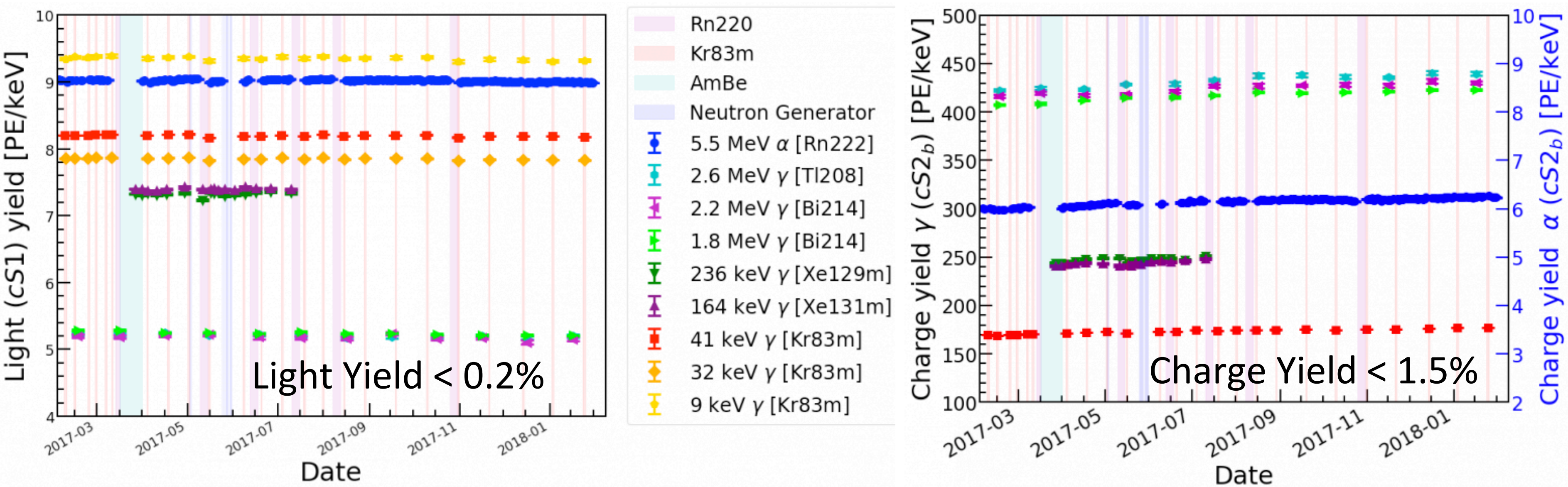
- DM total exposure SR0+SR1: 278.8 Live days
- Calibration:
  - LED → PMT gain monitoring
  - ^{83m}Kr → Position corrections, stability monitoring
  - ^{220}Rn → Low energy electronic recoils: **ER-bands**
  - ^{241}AmBe and NG → Signal response: **NR-bands**

DETECTOR STABILITY



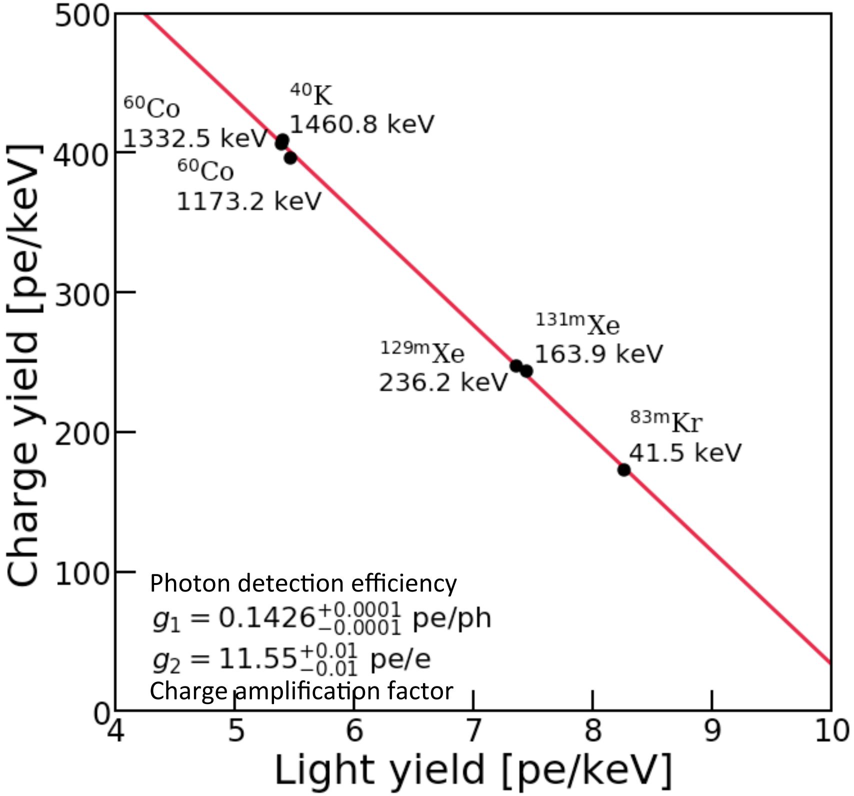


All relevant parameters look stable throughout science runs



ENERGY RECONSTRUCTION

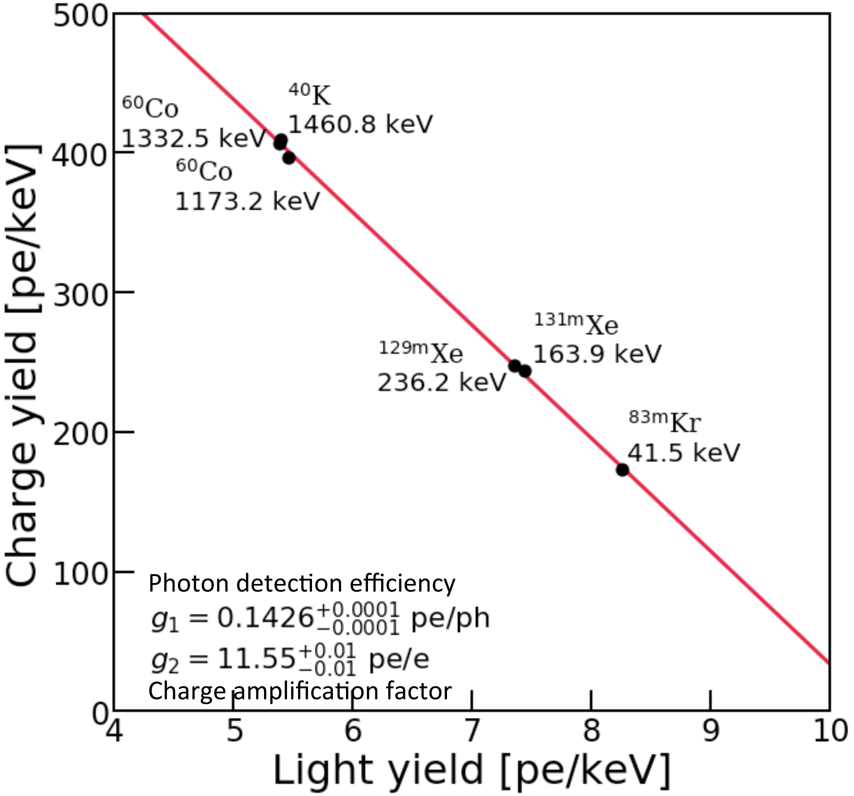
$$E = (n_{ph} + n_e) \cdot W = (\frac{S1}{g1} + \frac{S2}{g2}) \cdot W$$



- Energy loss to either light or charge channel → S1/S2 anticorrelation
- γ-lines from known sources
  - Internal source: ^{83m}Kr
  - Activated lines in NG: ^{129m}Xe, ^{131m}Xe
  - Detector material: ^{60}Co, ^{40}K
- Linear from keV to MeV

Energy Reconstruction & Resolution

$$E = (n_{ph} + n_e) \cdot W = (\frac{S1}{g1} + \frac{S2}{g2}) \cdot W$$



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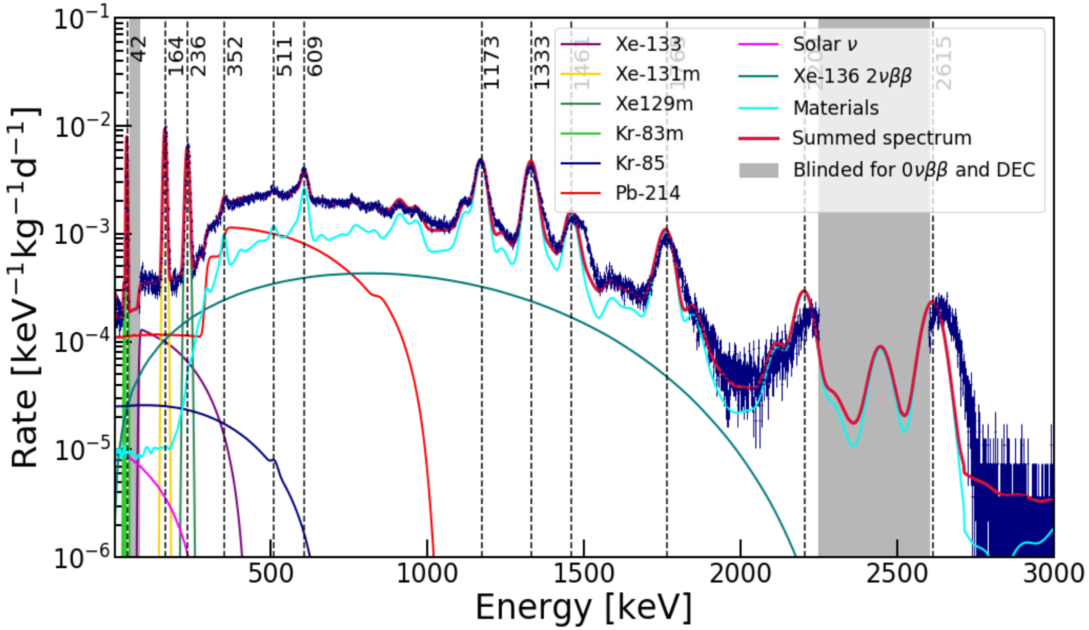
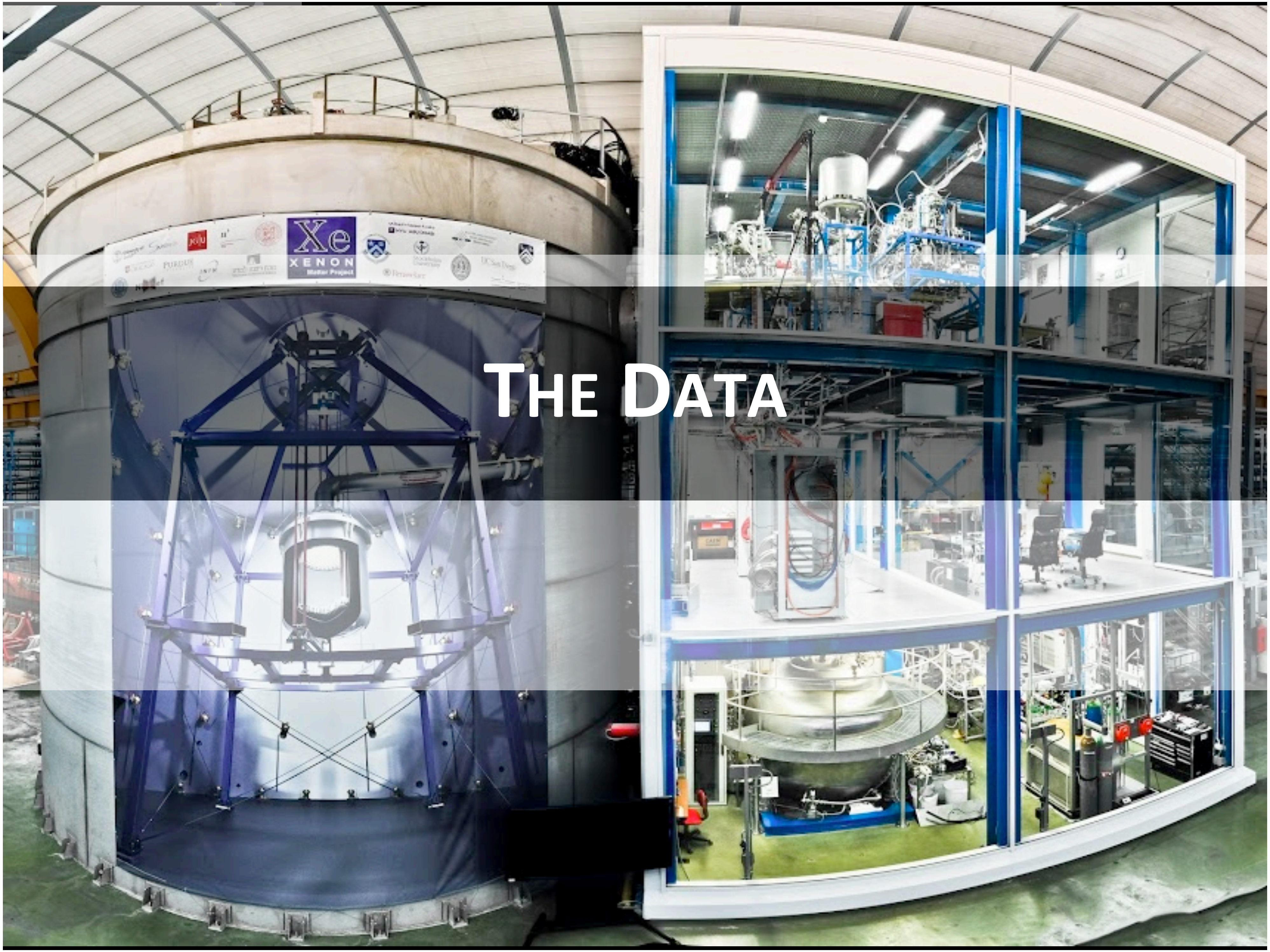
- Good agreement between predicted and measured background spectrum

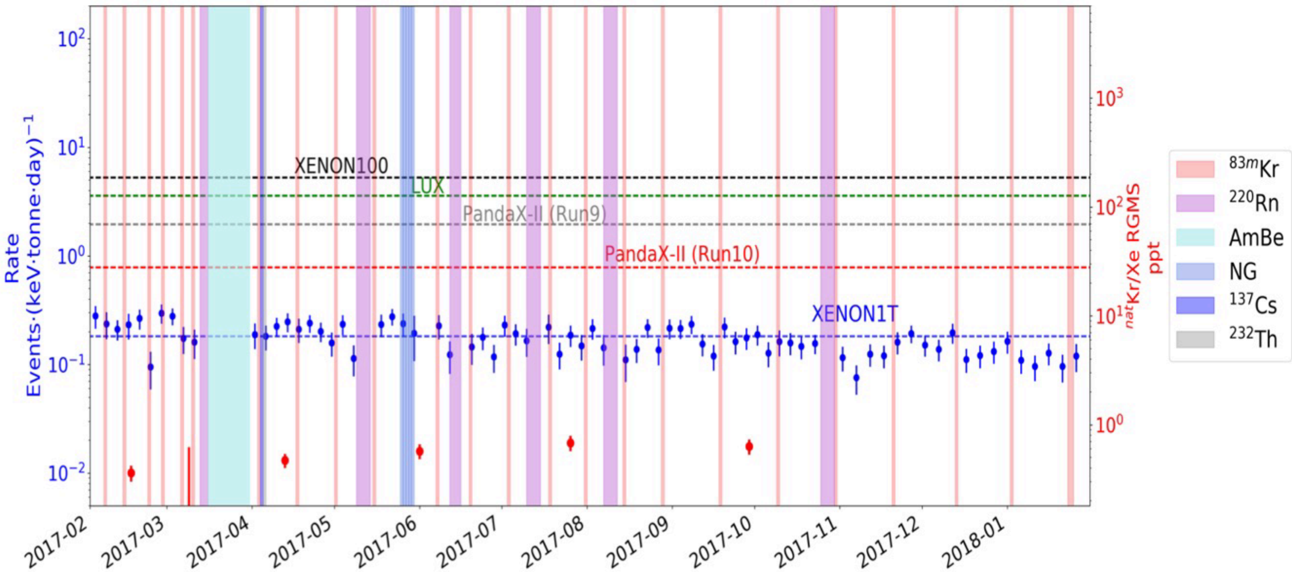


THE DATA



ELECTRONIC RECOIL BACKGROUND

- ^{222}Rn : 10 µBq/kg
  - Achieved with careful surface emanation control and measurements
  - Further reduction with online cryogenic distillation
- ^{85}Kr: sub ppt Kr/Xe
  - Achieved with online cryogenic distillation



lowest ER background ever in DM detectors
< 0.2 evt /(ton·year·keV)

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- ^{85}Kr: sub ppt Kr/Xe
  - Achieved with online cryogenic distillation
- Material radioactivity is subdominant
- Select fiducial volume in the TPC

lowest ER background ever in DM detectors
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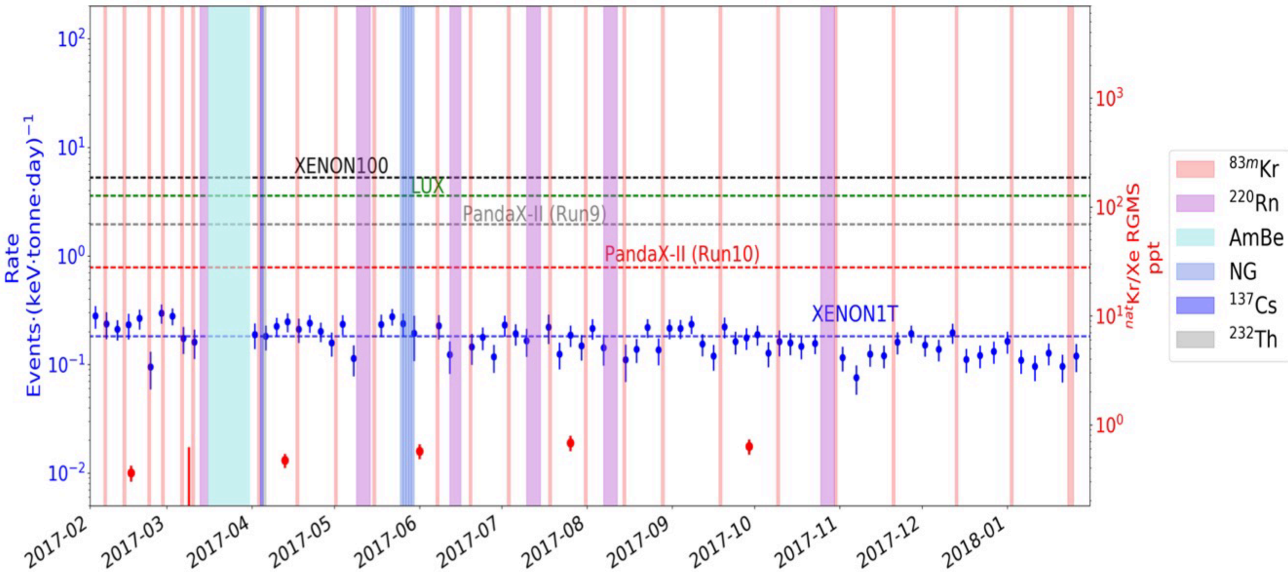


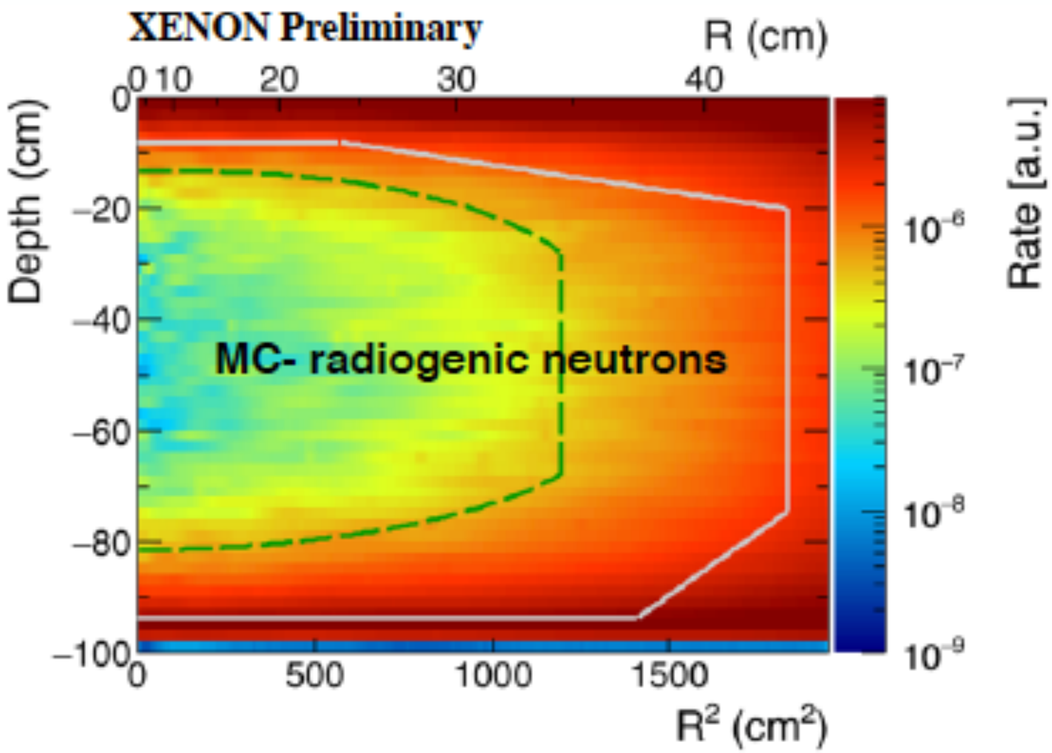
Source	Rate [t^{-1} yr^{-1}]	Fraction [%]
^{222}Rn	620 ± 60	84.5
^{85}Kr	31 ± 6	4.3
^{136}Xe	9 ± 1	4.9
materials	30 ± 3	4.2
solar ν	36 ± 1	1.4
Total	**720 ± 60**	**100**

Expectations in 1-12 keV search window, 1t FV,single scatters, before ER/NR discrimination

JCAP04 (2016) 027

NUCLEAR RECOIL BACKGROUND

- Radiogenic neutrons from (α, n) reactions and fission from ^{238}U and ^{232}Th: reduced via careful materials selection, event multiplicity and fiducialization



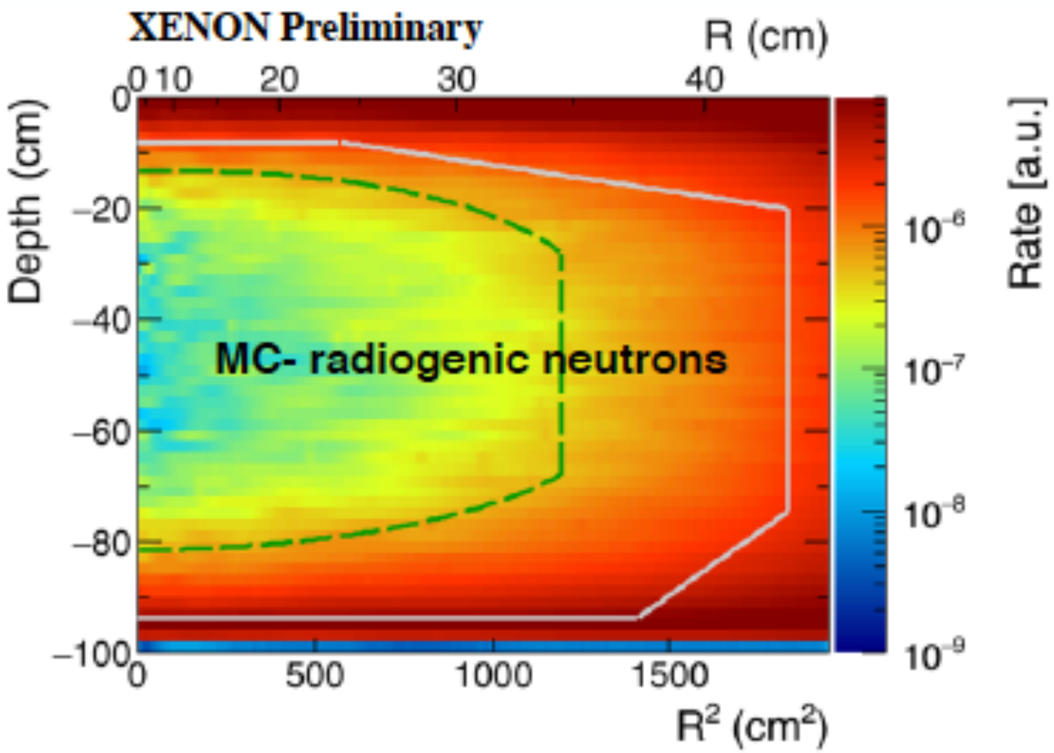
Source	Rate [t^{-1} yr^{-1}]	Fraction [%]
Radiogenic	0.6 ± 0.1	96.5

Expectations in 4-50 keV search window, 1t FV, single scatters

JCAP04 (2016) 027

NUCLEAR RECOIL BACKGROUND

- Radiogenic neutrons from (α, n) reactions and fission from ^{238}U and ^{232}Th: reduced via careful materials selection, event multiplicity and fiducialization
- Cosmogenic μ-induced neutrons significantly reduced by rock overburden and muon veto
- Coherent elastic ν-nucleus scattering, constrained by ^{8}B neutrino flux and measurements, is an irreducible background at very low energy (1 keV)



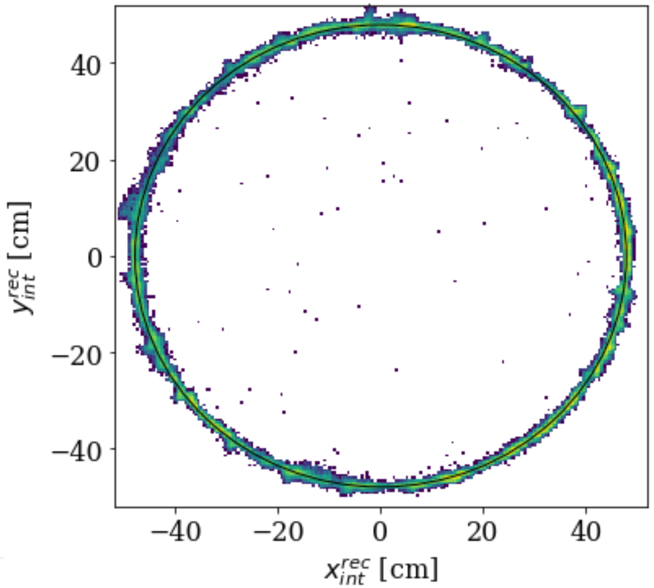
Source	Rate [t^{-1} yr^{-1}]	Fraction [%]
Radiogenic	0.6 ± 0.1	96.5
Cosmogenic	< 0.01	<2.0
Coherent ν scattering	0.012	2.0

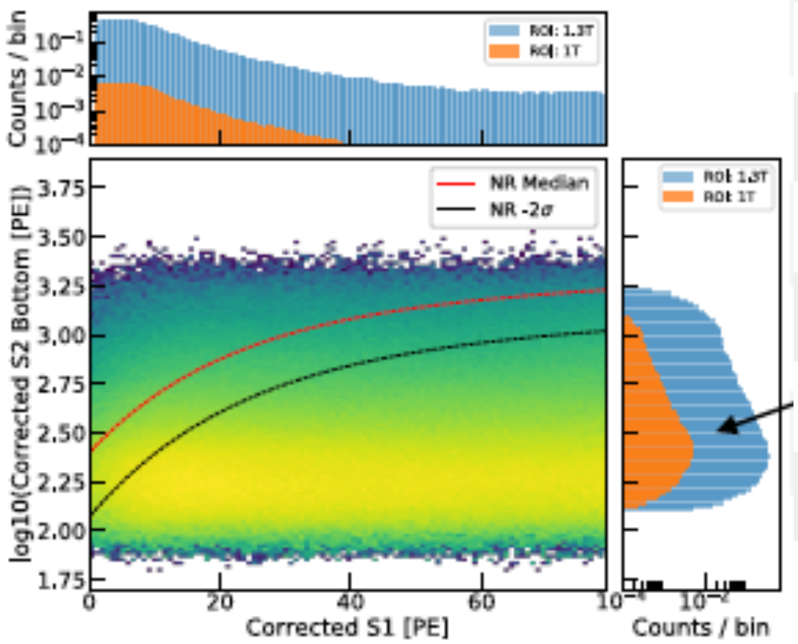
Expectations in 4-50 keV search window, 1t FV, single scatters

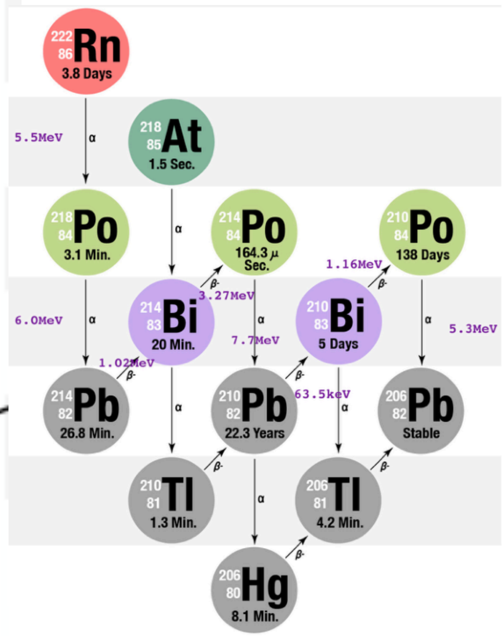
JCAP04 (2016) 027

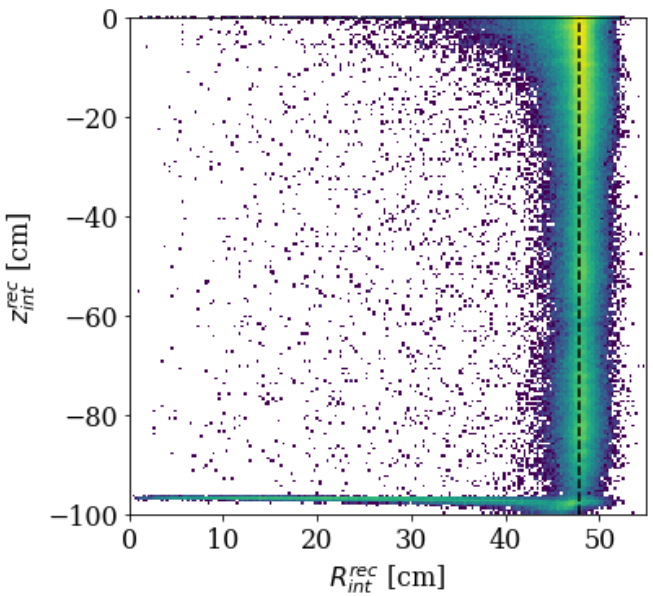
SURFACE BACKGROUND

- Charge accumulation on the PTFE surfaces
  → ^{222}Rn progeny (Pb210 and Po210) plate-out on PTFE surface produce events with reduced S2
  → S2 can be mis-reconstructed into NR signal region
- Suppressed by fiducialization of volume
- Data-driven model derived from surface event control samples



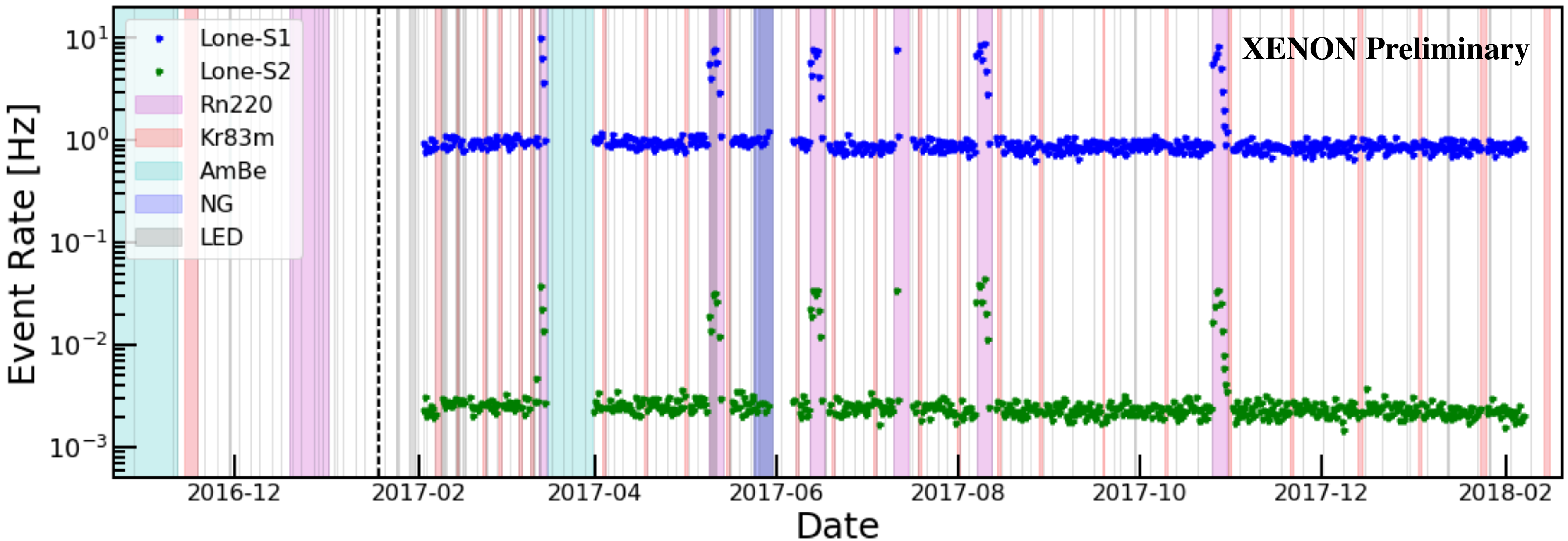






ACCIDENTAL COINCIDENCES

- Lone S1 and lone S2 signals
  - from interactions in regions with poor light/charge collection
  - lone signals close in time get paired to fake events
- Background modeled by searching for randomly paired lone S1/S2



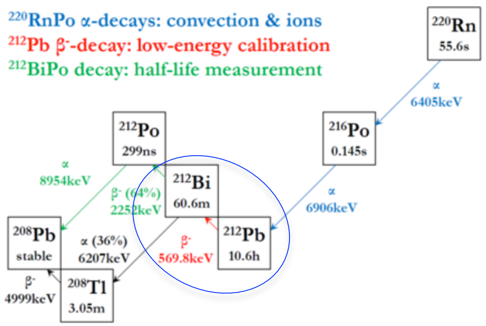
Apply selection conditions to suppress ACs

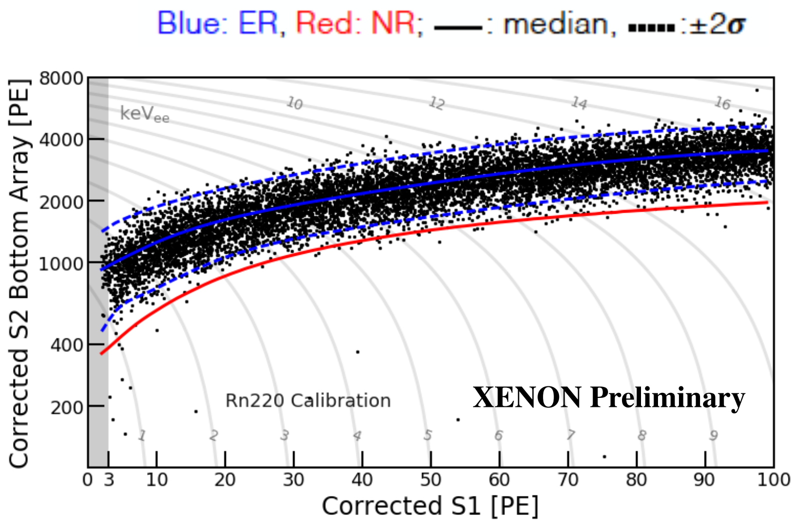
Electronic and Nuclear Recoil Calibrations

Electronic Recoils

- ^{228}Th source emanates ^{220}Rn into LXe
- **β-decay** of ^{212}Pb to ^{212}Bi → **low energy** events (2-20 keV)
- Decay of activity dominated by ^{212}Pb half-life (10.6 h)

Internal source





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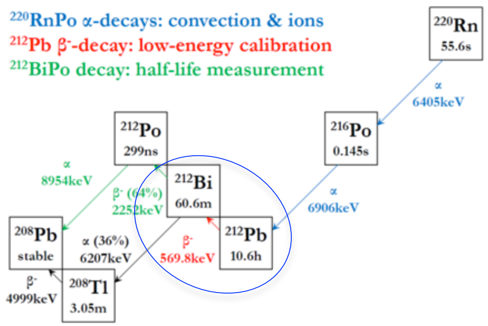
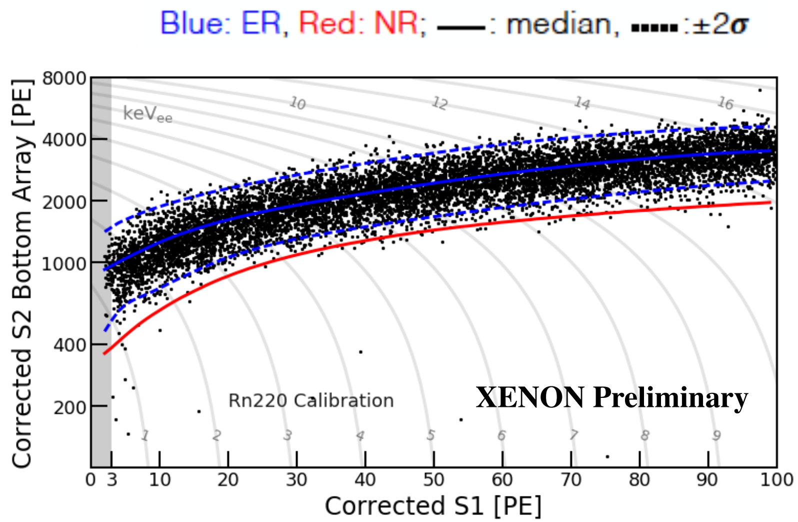
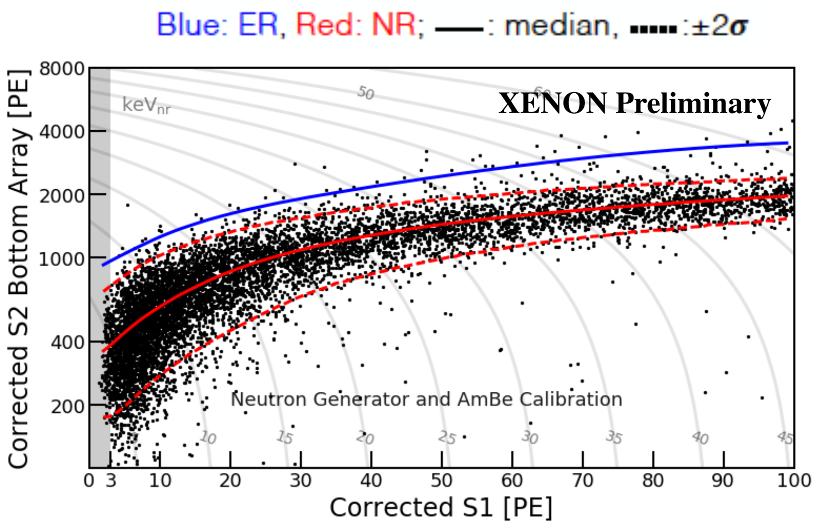
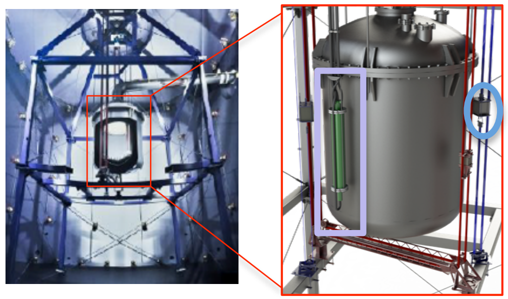






External source

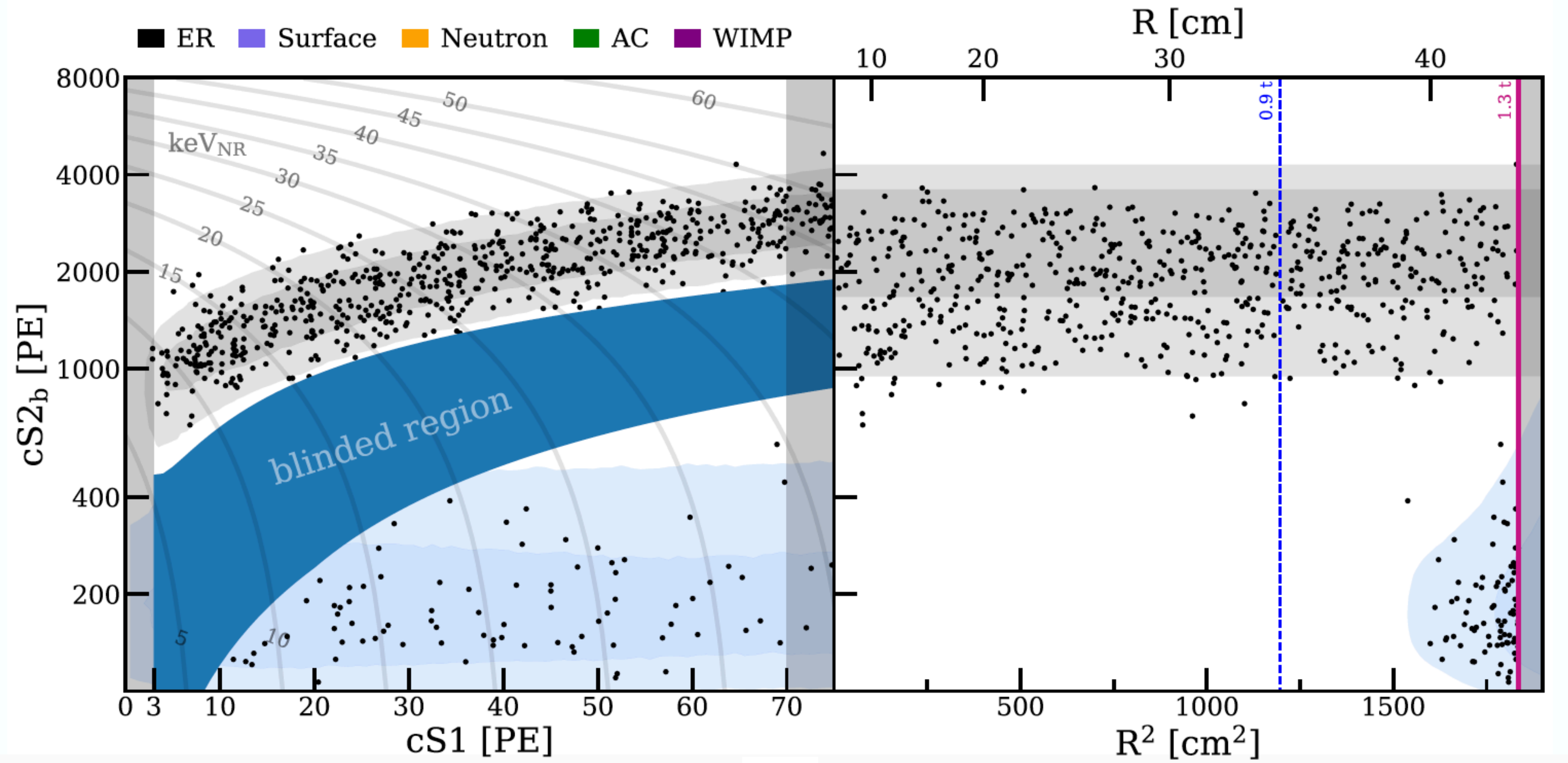


Nuclear Recoils

- External ^{241}AmBe source mounted on a belt
  - The α particles emitted by the decay of the Am collide with the light Be nuclei producing fast neutrons
- Neutron Generator

DARK MATTER SEARCH DATA

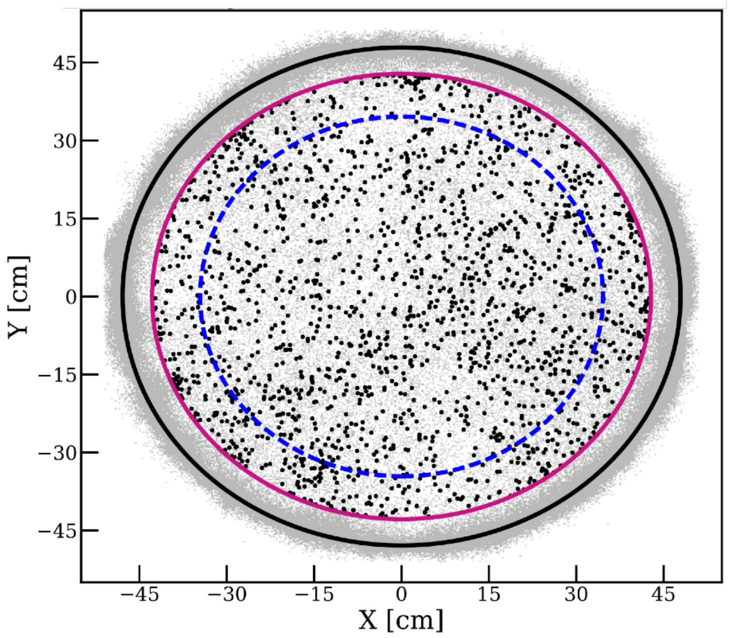
- **Blinding** → to avoid biases in event selection and signal/background modeling
- **Salting** (addition of fake events) → to protect against post-unblinding tuning of the cuts and background models

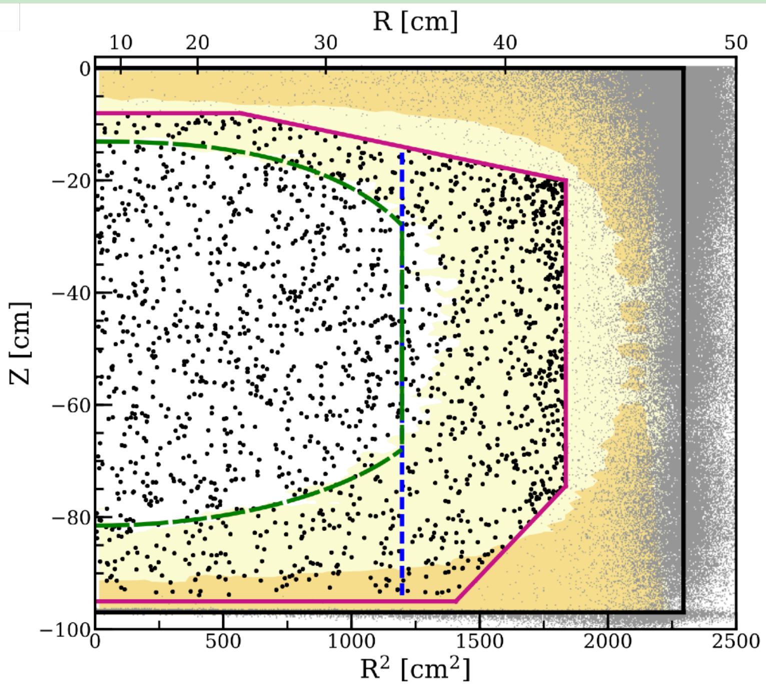


FIDUCIAL VOLUME OPTIMIZATION

Optimize fiducial volume before unblinding by using improved understanding

- position reconstruction
- detector response
- correlations between spectral and spacial distribution
- include knowledge on background distributions in statistical framework
- MC simulations



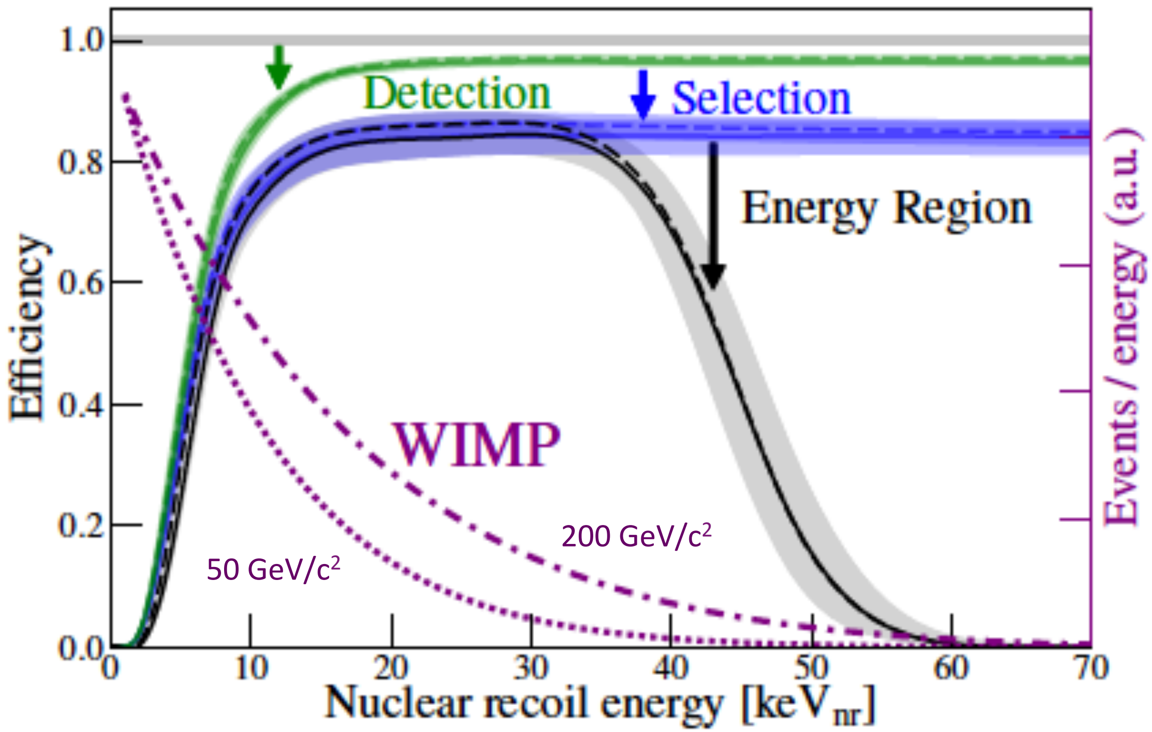


Aim at optimal S/B

larger FV

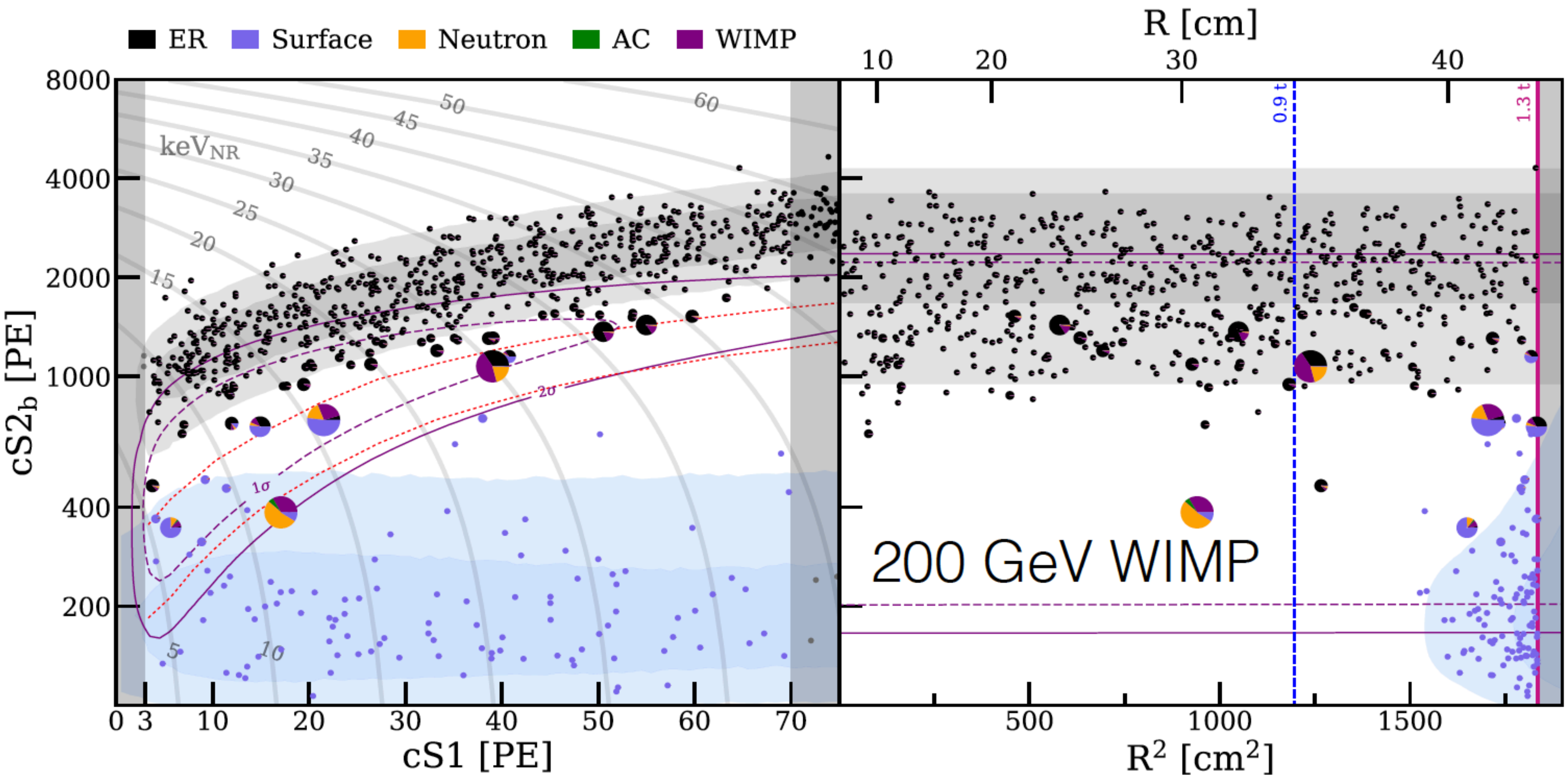
1 t → 1.3 t

EVENT SELECTION & DETECTION EFFICIENCY



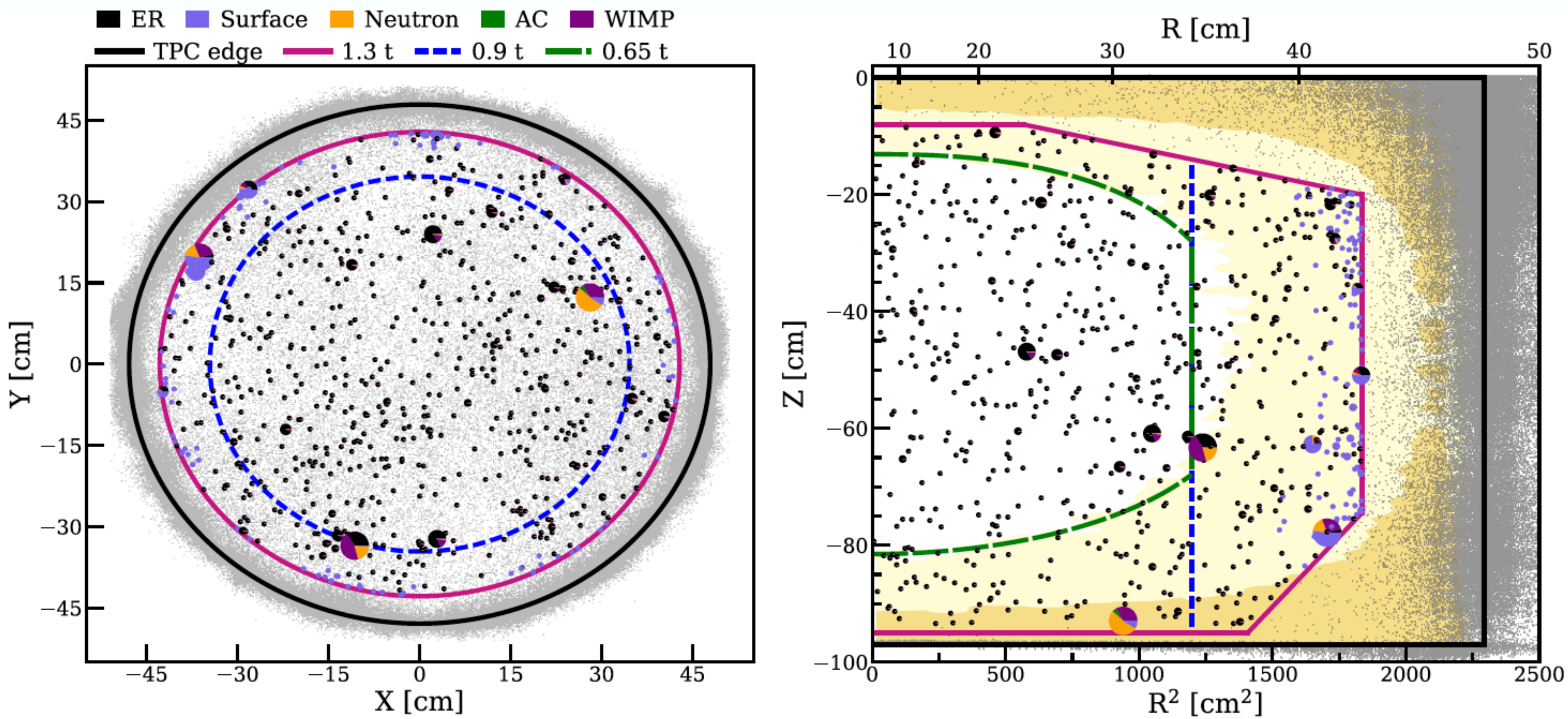
- **Detection Efficiency** from MC: dominated by 3-fold coincidence
- **Event Selection**: estimated from control samples or simulations
- **Energy Region**: defined within corrected S1 range 3-70 PE

Dark Matter Search Results



- Results interpreted with unbinned profile likelihood analysis in cs1, cs2, R space
- Piechart indicate the relative probabilities of this event to be of a certain class for a best fit to a 200 GeV/c^2 WIMPs with a cross-section of 4.6 x 10^{-47} cm2

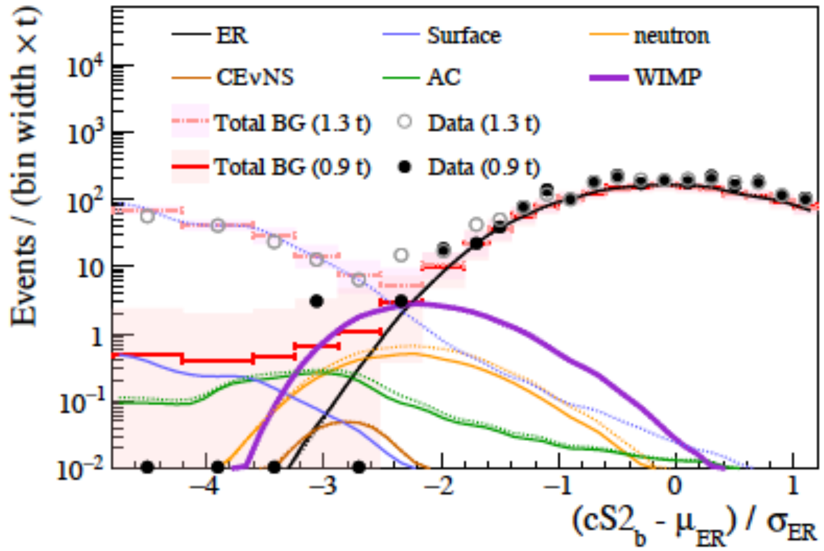
SPATIAL DISTRIBUTION OF DARK MATTER SEARCH RESULTS



- Core volume to distinguish WIMPs over neutron background
- Yellow shaded regions display the 1σ (dark), and 2σ (light) probability density percentiles of the radiogenic neutron background component

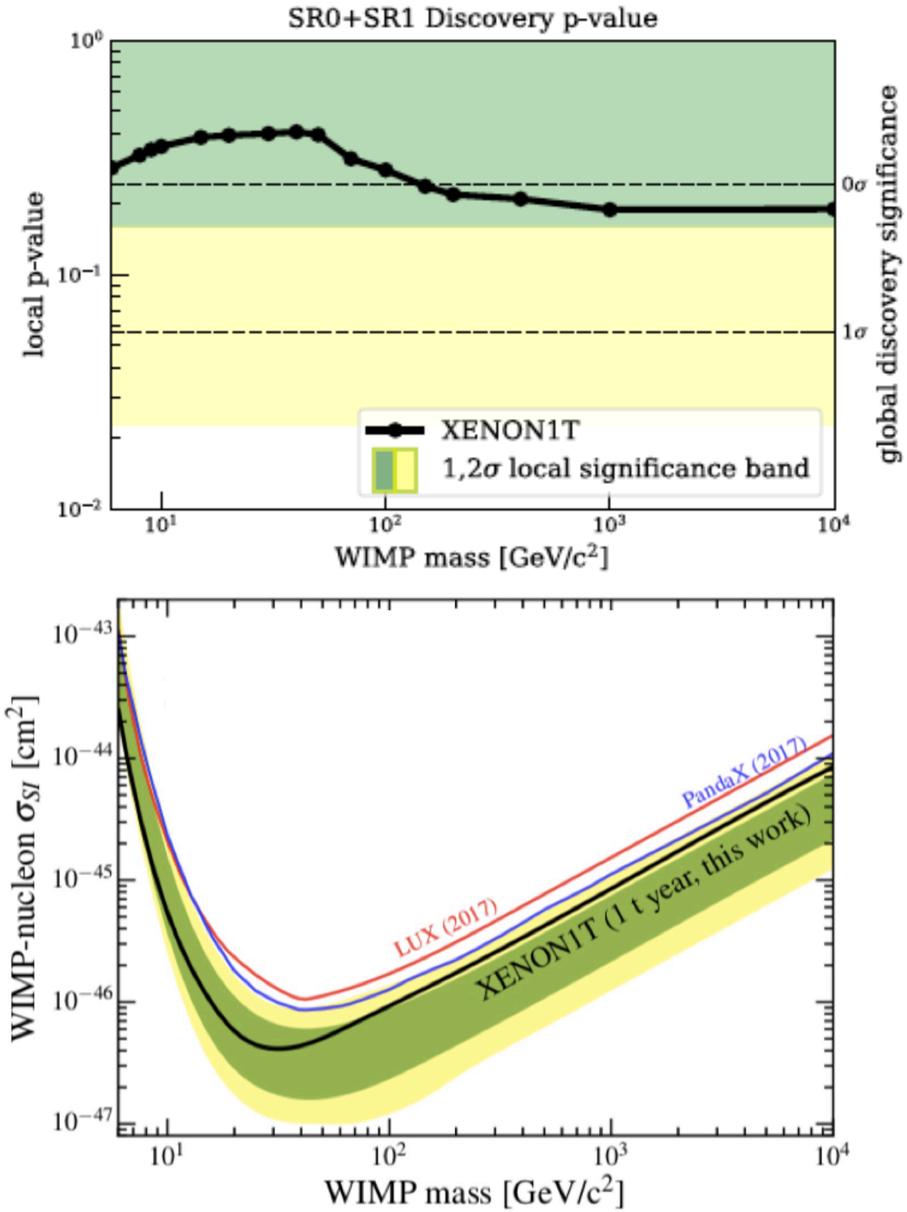
OBSERVATIONS VS EXPECTATIONS

- Reference region between NR median and -2σ quantile in $cS2_b$
- **ER** is the most significant background and uniformly distributed in the volume
- **Surface** background contributes most in reference region, but radius will reduce its impact to be subdominant
- **Neutron** background is less than one event, and effect will be further suppressed by position information
- Other background components are completely sub-dominate



Event Rates	Full 1.3t	Reference 1.3t
Electronic recoils (ER)	627 ± 26	2.2 ± 0.1
neutrons	1.4 ± 0.6	0.8 ± 0.3
CEνNS	0.05 ± 0.02	0.02 ± 0.01
Accidental coincidences	0.47 ± 0.15	0.10 ± 0.03
Surface	106 ± 11	5.4 ± 0.5
Total background	**736 ± 28**	**8.4 ± 0.6**
Data	**739**	**11**
WIMP @200 GeV/c^2, σ_{SI} =4.6 X 10^{-47} cm^2	**3.36**	**1.55**

SR0+SR1 XENON1T Results



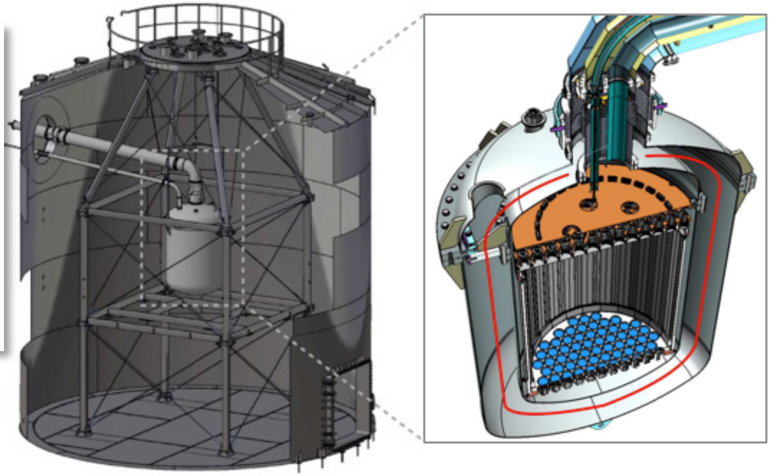
- Most stringent 90% upper limit on WIMP-nucleon cross section at all masses above 6 GeV
  - Minimum at σ_{SI} = 4.1 x 10^{-47} cm^2 for a WIMP of 30 GeV/c^2
- A factor of 7 more sensitivity compared to previous experiments (LUX, PandaX-II)
- ~ 1 sigma upper fluctuation at high WIMP masses, could be due to background or signal

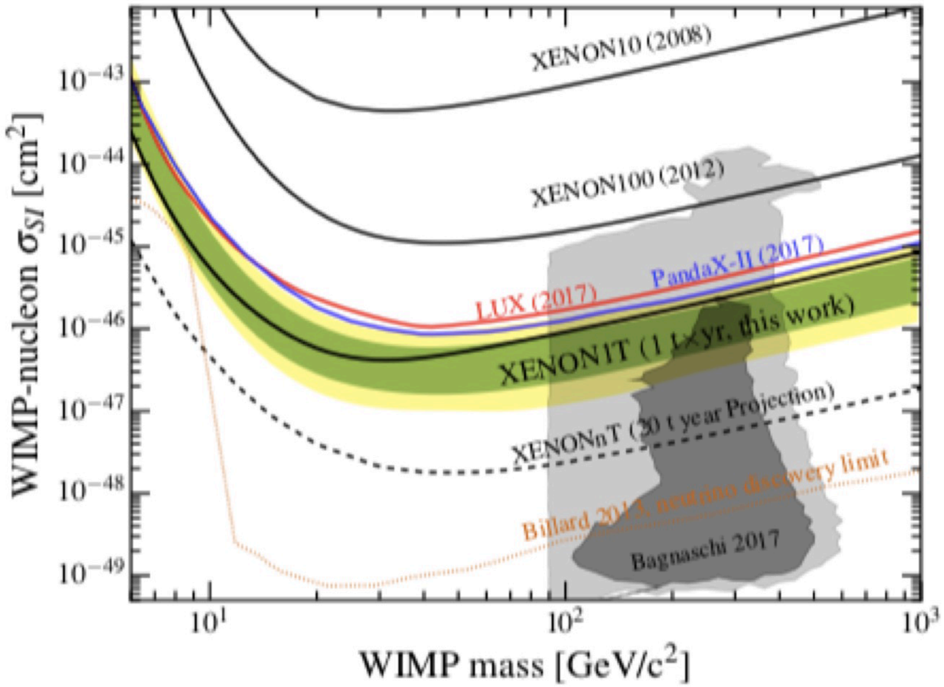
SUMMARY

- Demonstrated >1 year stable operation with the 1st multi-ton scale LXe TPC
- Achieved lowest background in a DM detector
- Surpassed the original XENON1T sensitivity goal, but found no statistically significant sign of WIMPs
- The search with XENON1T continues until an even larger detector, **XENONnT**, will allow another boost in sensitivity

XENONnT

- Total LXe mass ~8 t
- Projected to start in 2019





Thank you !