Status of the XENON Experiment

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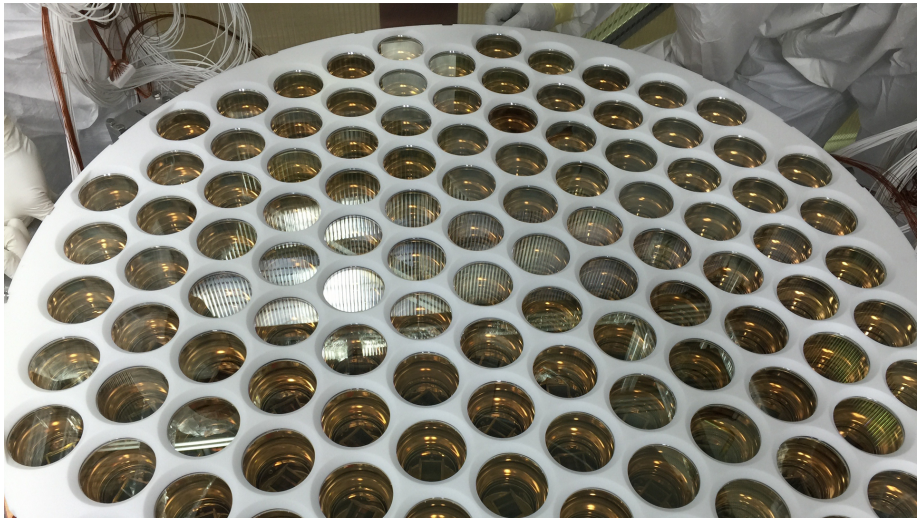
on behalf of the XENON collaboration

XLVIII LNGS SC meeting
October 2, 2017



XENON1T Overview

XENON collaboration, arXiv:1708.07051

Water tank and
Cherenkov muon veto

Cryostat and support
structure for TPC

Time projection
chamber

Cryogenics pipe
(cables, xenon)

Cryogenics and
purification

Data acquisition and
slow control

Xenon storage,
handling and
Kr removal via
cryogenic
distillation

The XENON collaboration

144 scientists

25 institutions

10 countries

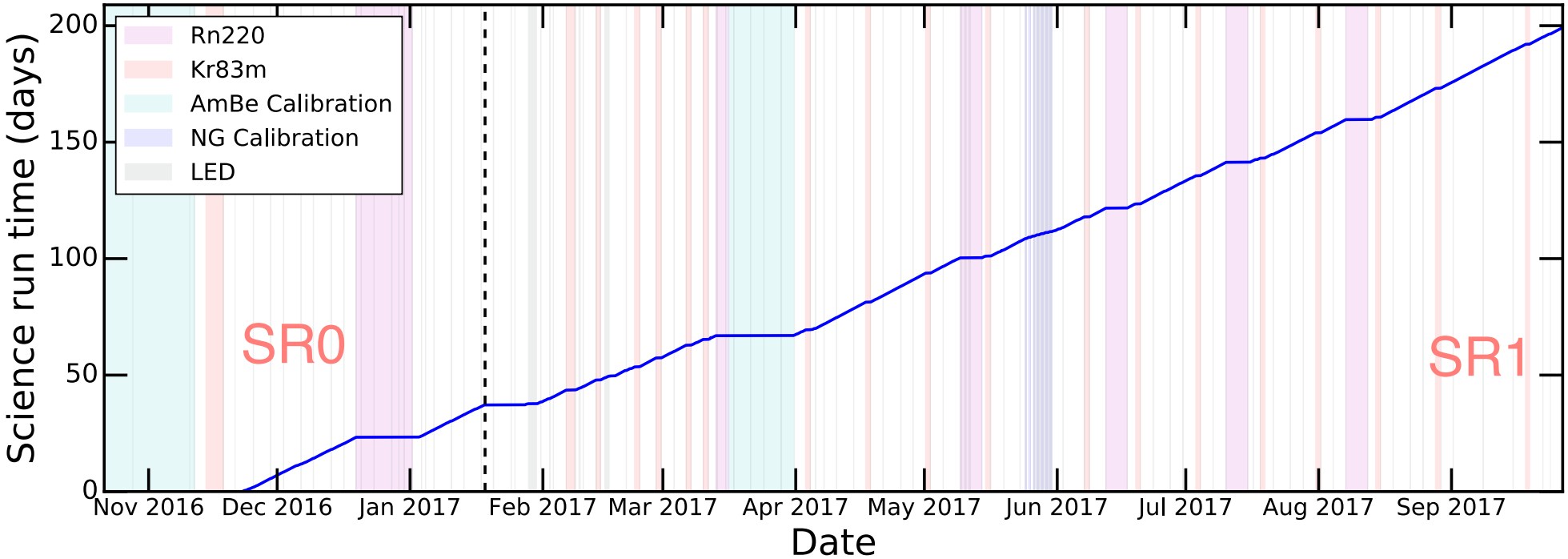
Columbia, RPI, Nikhef, Stockholm, Muenster, Mainz, MPIK, Chicago, Freiburg, UCLA, Zurich, UCSD, NYUAD, Rice, Weizmann, Purdue, Coimbra, Subatech, LPNHE, LAL, Bologna, LNGS, Torino, Napoli

XENON publications since last SC meeting

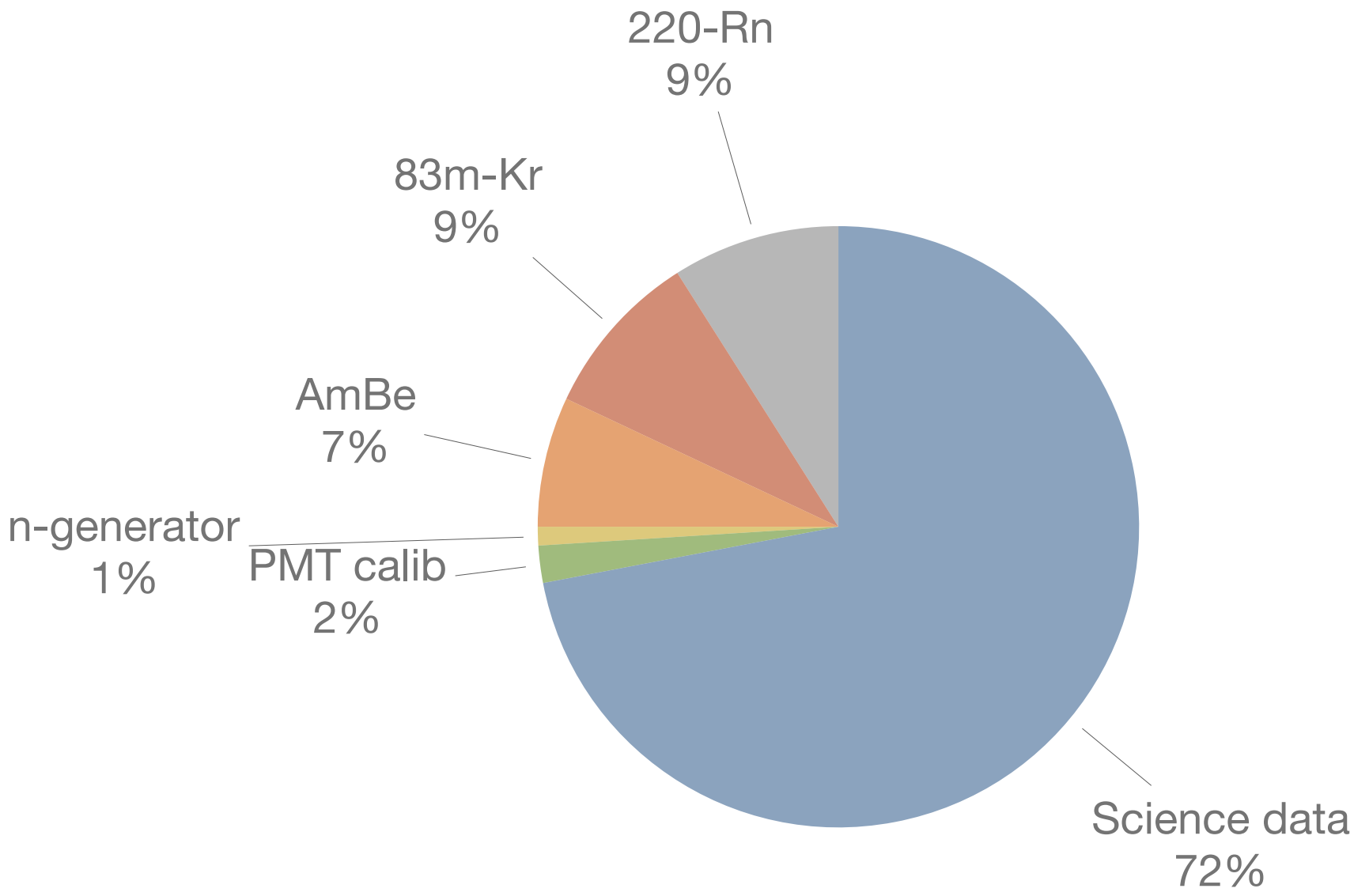
1. **First Dark Matter Search Results from the XENON1T Experiment (accepted in PRL)**
2. **The XENON1T Dark Matter Experiment (submitted to EPJC, arXiv:1708.07051)**
3. **Material radio-assay and selection for the XENON1T dark matter experiment (submitted to EPJC, 1705.01828)**
4. Intrinsic backgrounds from Rn and Kr in the XENON100 experiment (submitted to EPJC, arXiv:1708.03617)
5. Online ^{222}Rn removal by cryogenic distillation in the XENON100 experiment (published in EPJ C (2017) 77:358)
6. Search for Bosonic Super-WIMP Interactions with the XENON100 Experiment (submitted to PRD, arXiv:1709.02222)
7. Search for magnetic inelastic dark matter with XENON100 (accepted in JCAP, arXiv:1704.05804)
8. Effective field theory search for high-energy nuclear recoils using the XENON100 dark matter detector (published in PRD 96, 042004, 2017)
9. Search for WIMP Inelastic Scattering off Xenon Nuclei with XENON100 (published in PRD 96, 022008, 2017)
10. Search for Electronic Recoil Event Rate Modulation with 4 Years of XENON100 Data (published in PRL 118, 101101, 2017)

Data taking in 2017

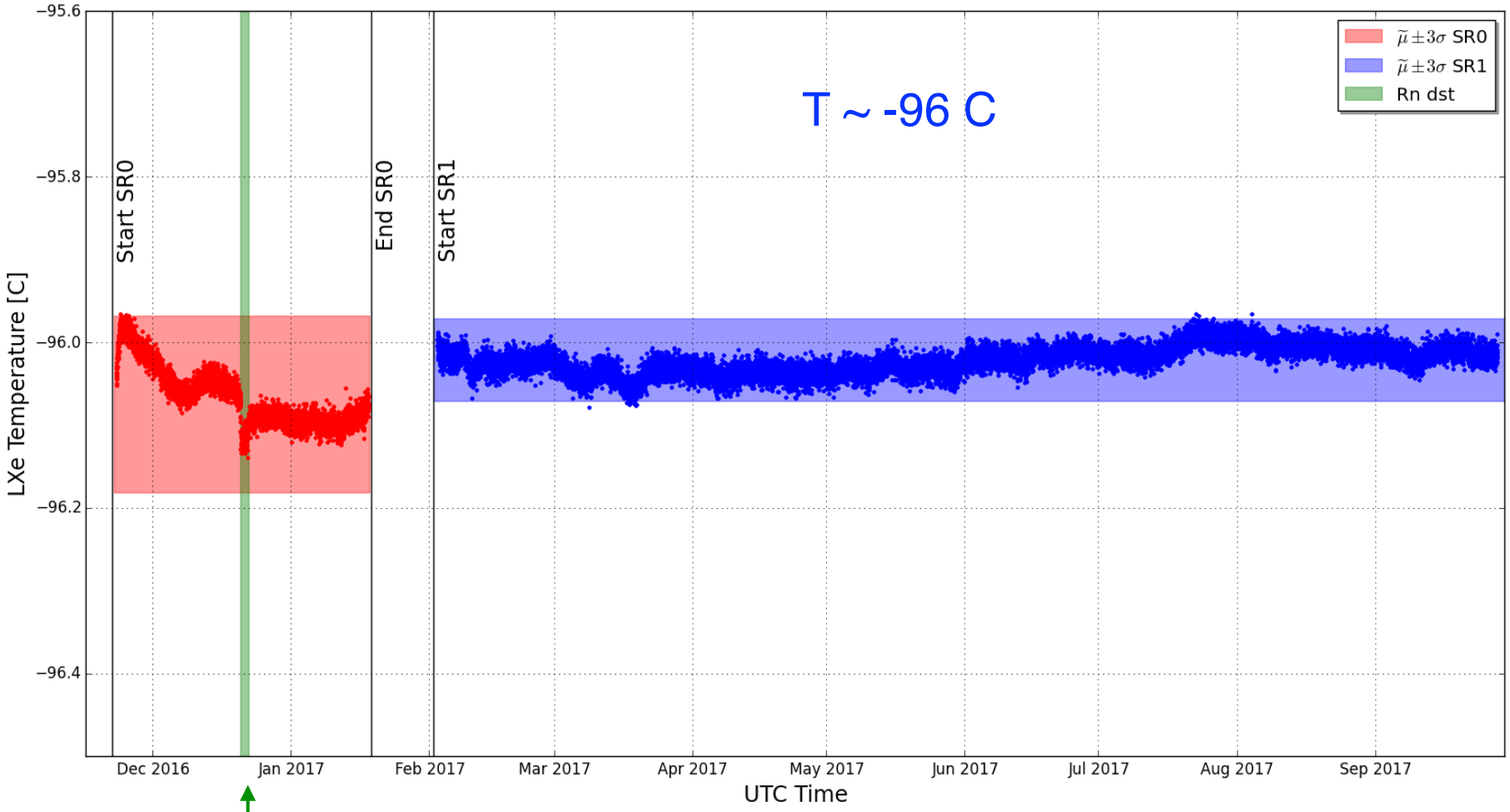
- Detector running smoothly
- **DAQ efficiency: ~ 99%**
- Accumulated live days: SR0 (34.2 d), SR1 (~159 d of blinded dark matter data)



Data overview: science and calibration

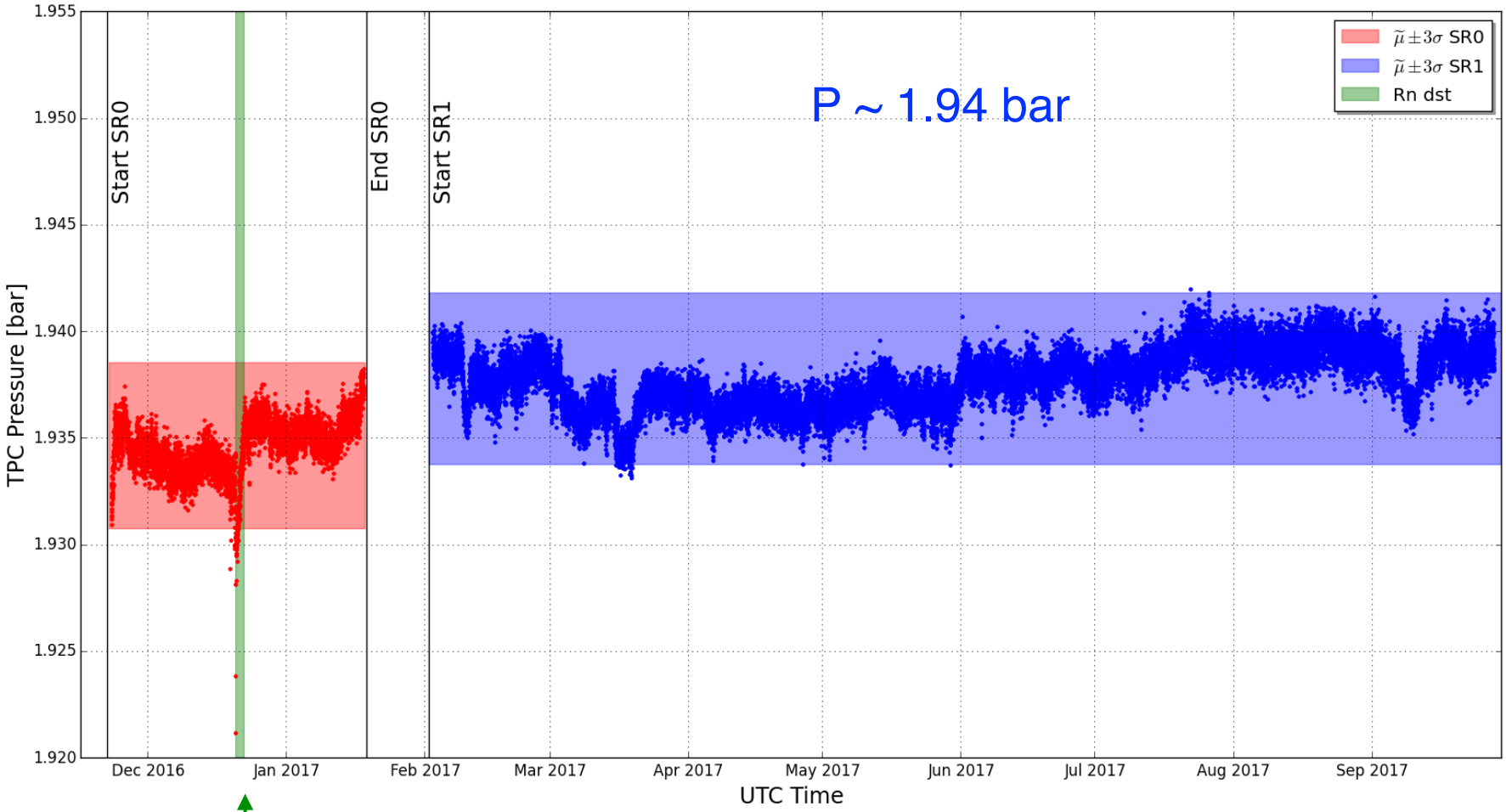


Slow control parameters: temperature of LXe



Rn distillation, Rn level reduced by ~20%

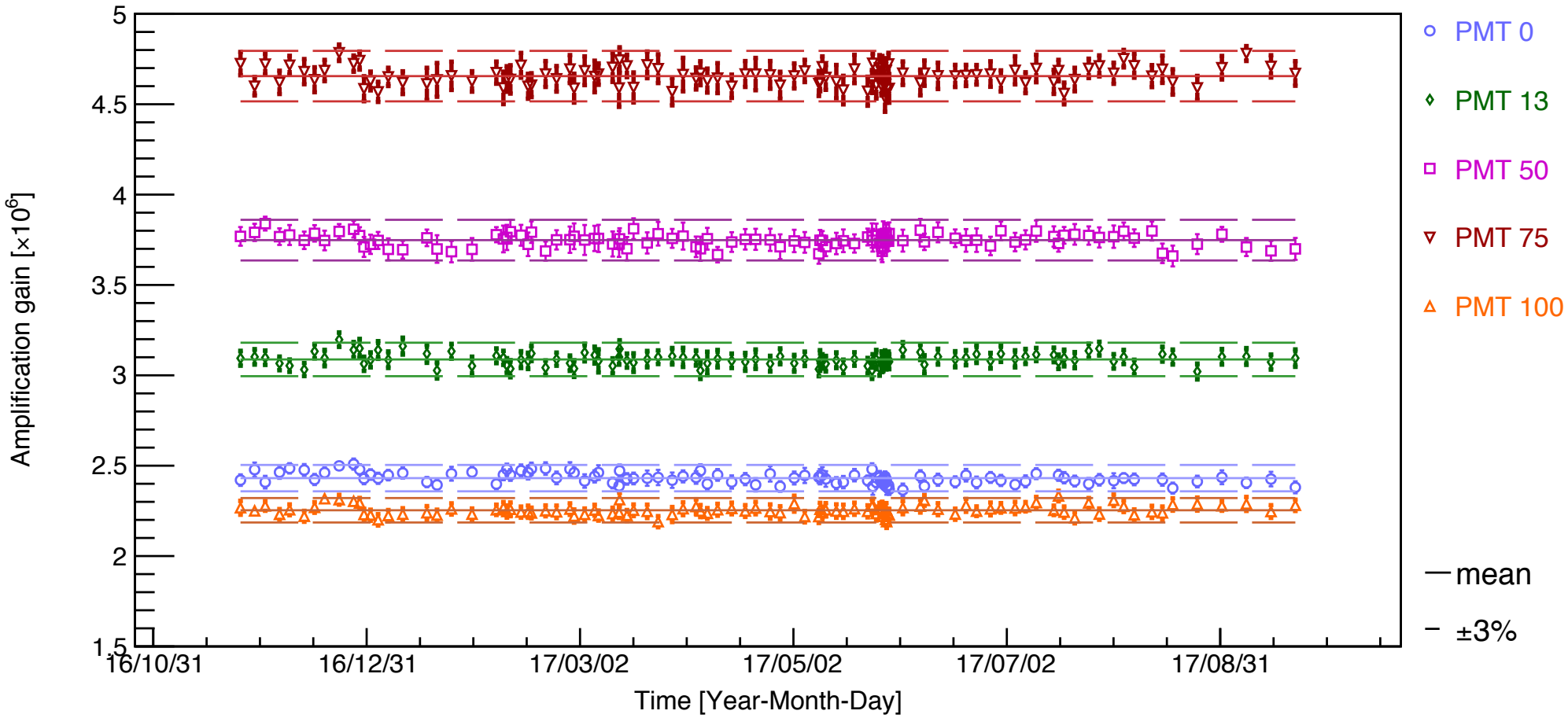
Slow control parameters: pressure in the TPC



Rn distillation, Rn level reduced by ~20%

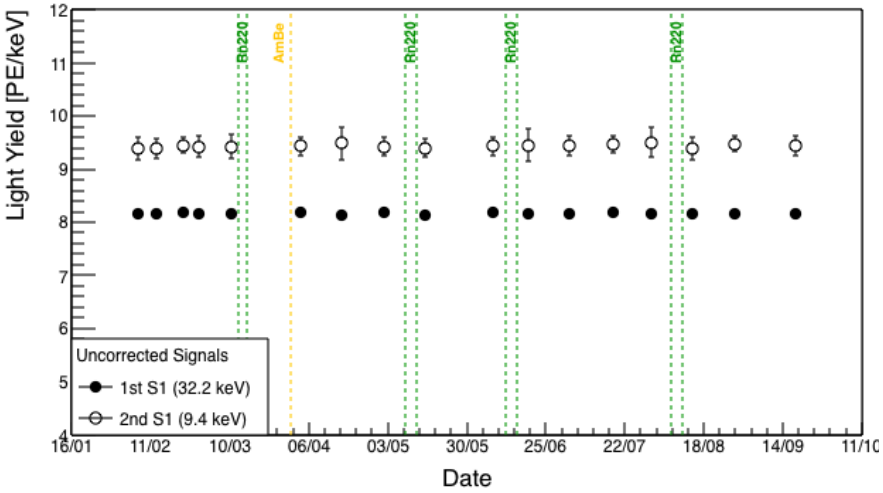
PMT calibration stability

- Monitored: gains, dark count rates, after-pulse rates

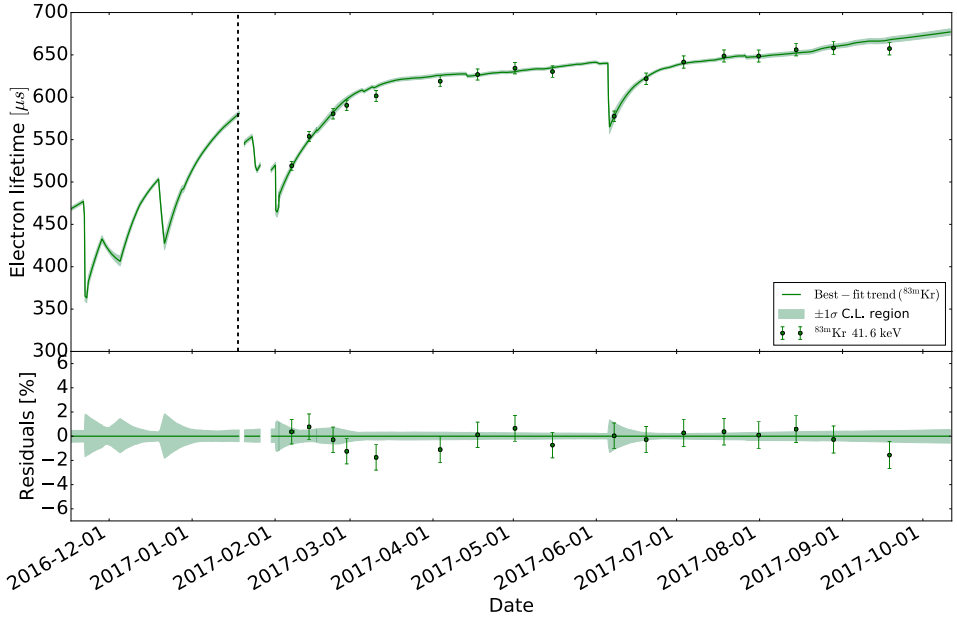


Light yield and electron lifetime evolution

- From regular calibrations with a ^{83m}Kr source: $S_2(t) = S_2(t_0)e^{(-t/\tau_e)}$



Light yield versus time, using the 9.4 keV and 32.2 keV transitions of the ^{83m}Kr source

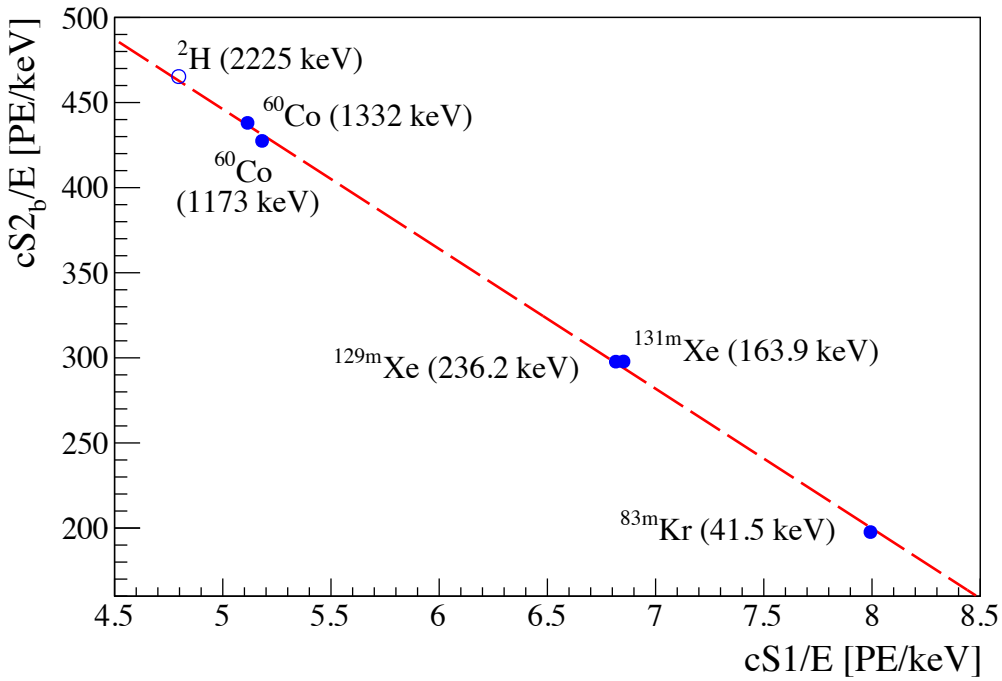


$$t_{\mathrm{d,TPC}} = 673\,\mu s$$

Energy response

at 125 V/cm drift field

- L_y = (8.02±0.06) pe/keV at 41.5 keV
- Q_y = (198.3±2.3) pe/keV at 41.5 keV



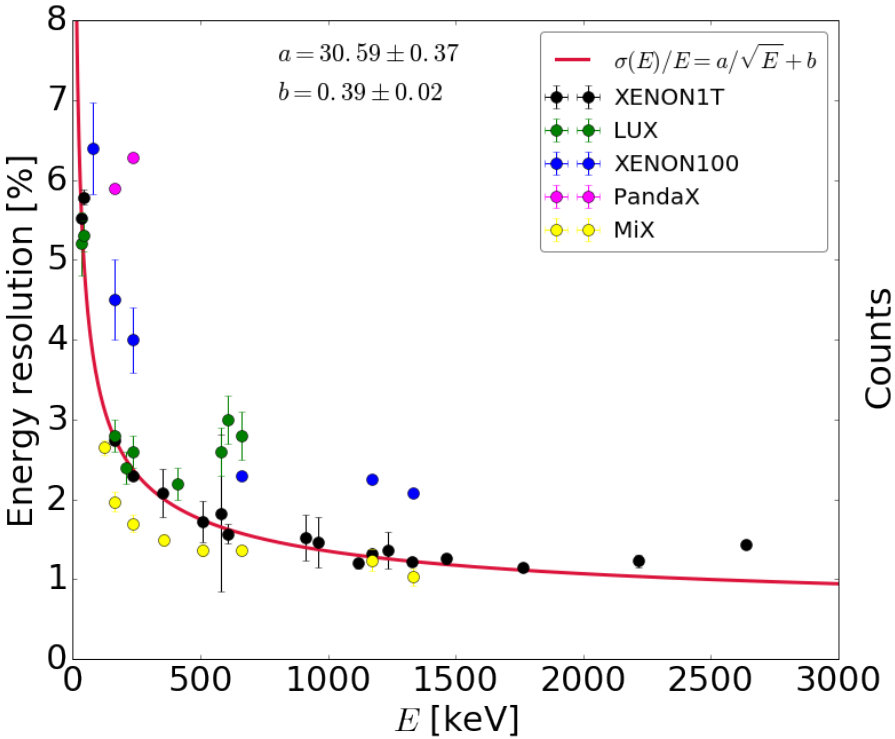
$$E = (n_{ph} + n_e) \cdot W = \left(\frac{S_1}{g_1} + \frac{S_2}{g_2}\right) \cdot W$$

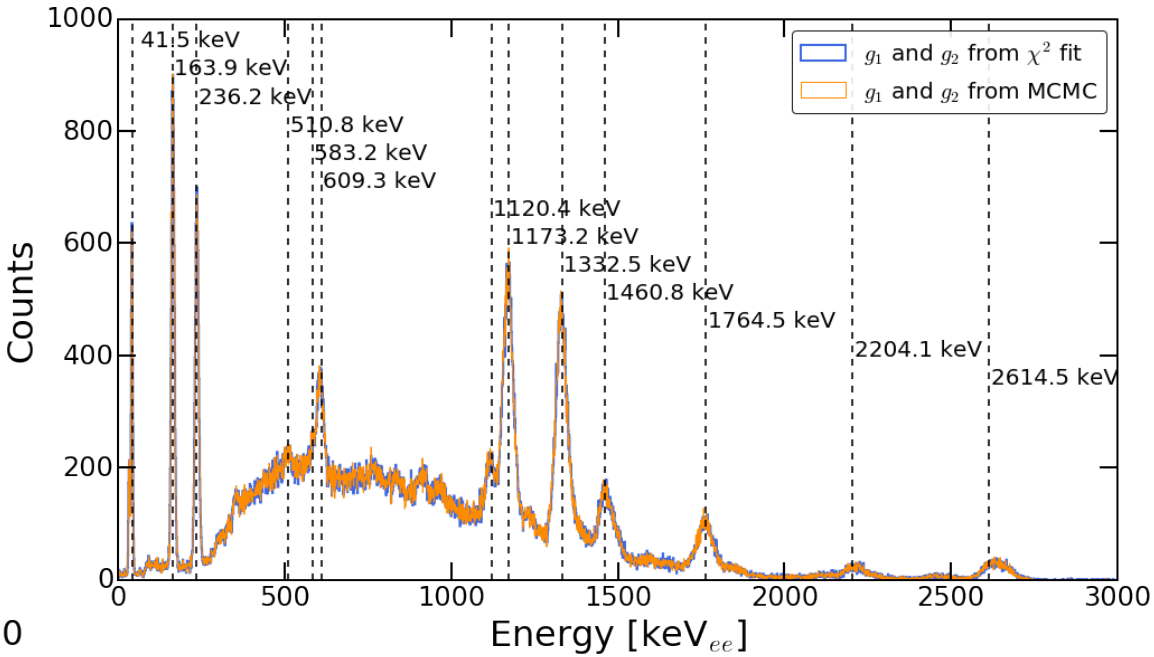
- Excellent linearity with electronic recoil energy from 40 keV to 2.2 MeV
  - g_1 = photon gains
  - g_2 = electron gain
  - W-value = 13.7 eV

- g_1 = (0.144 ± 0.007) pe/photon
- g_2 = (11.5 ± 0.8) pe/electron

Energy resolution

- One of the best energy resolutions among all liquid xenon TPCs
- Covers large energy range





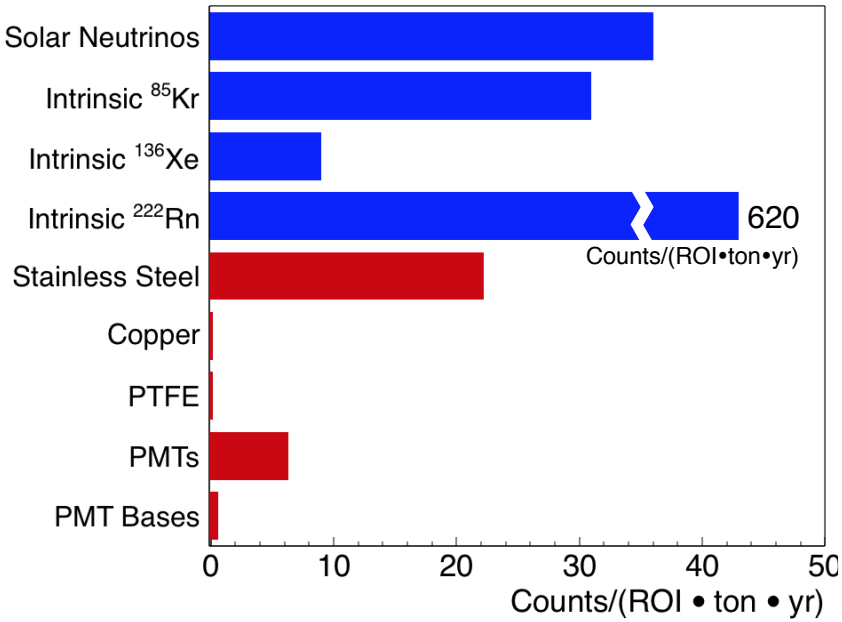
Relative energy resolution (σ(E)/E) versus energy

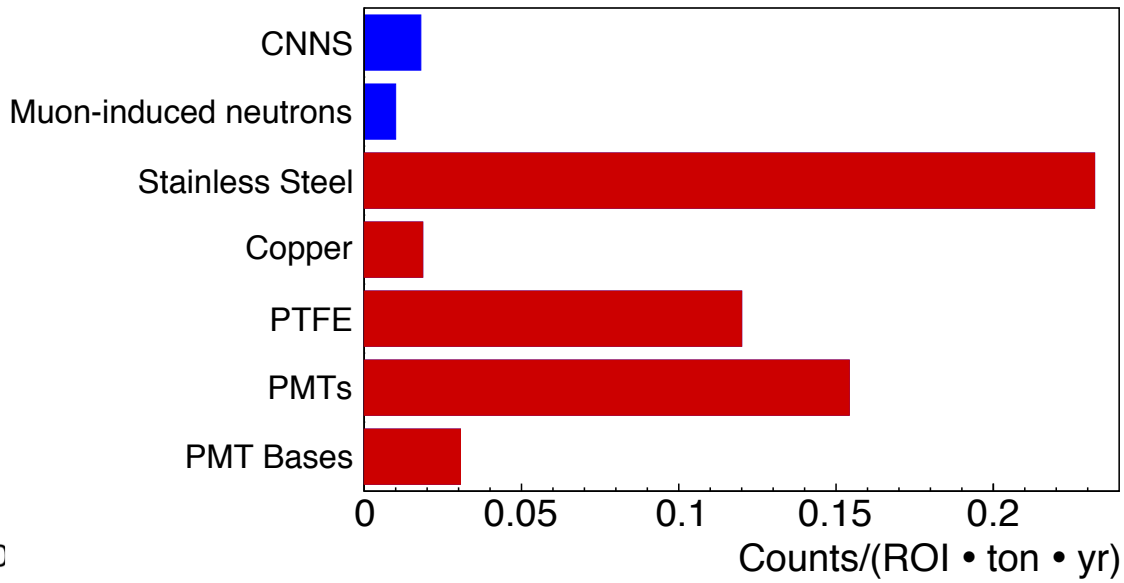
Energy spectrum of electronic recoils

Background predictions

XENON collaboration: JCAP 1604 (2016) no.04, 027, and arXiv: 1705.01828 , submitted to EPJC.

Intrinsic and neutrinos + materials*





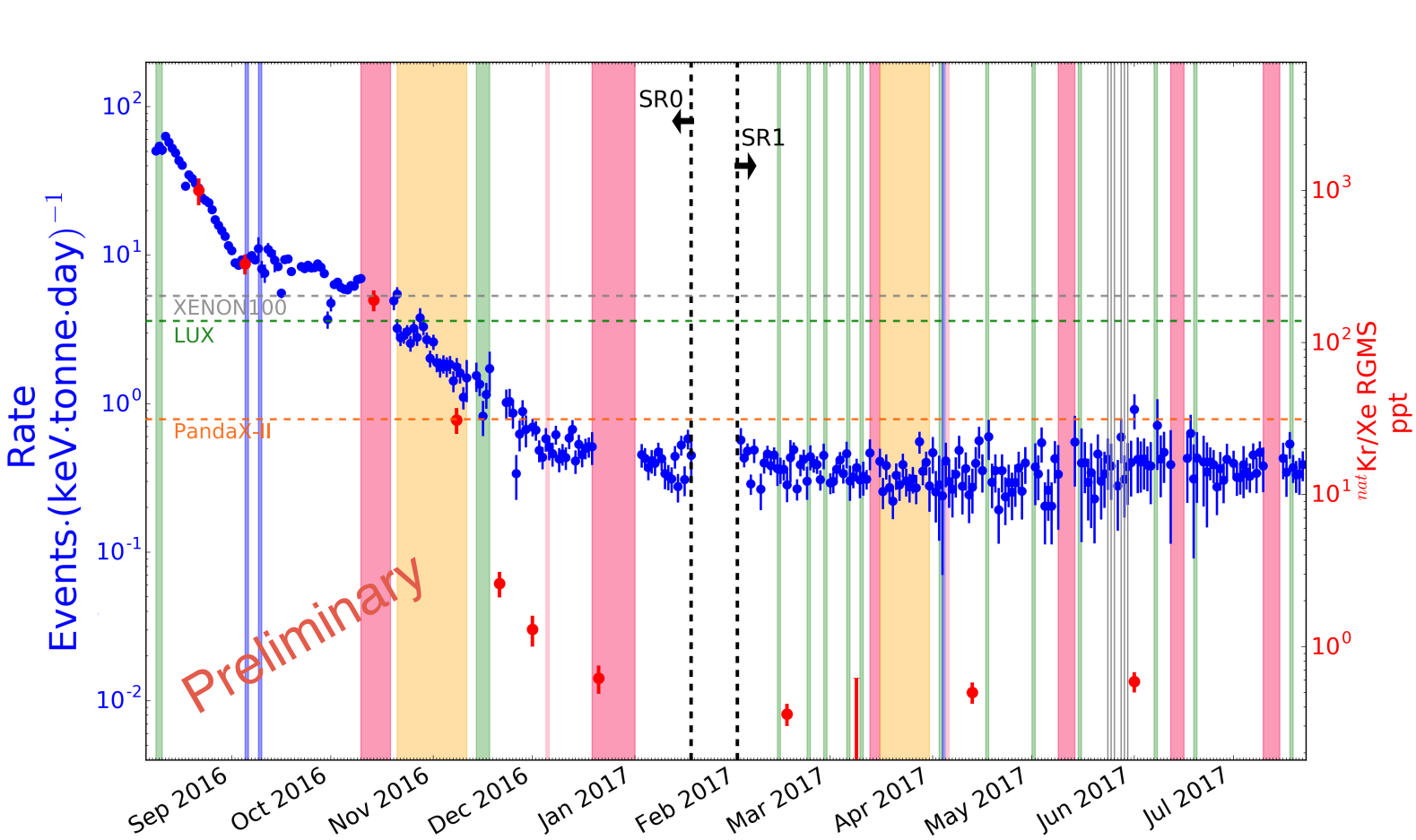
Electronic recoils in 1 t fiducial, energy region: 1-12 keV_{ee}

Nuclear recoils in 1 t fiducial, energy region: 4-50 keV_{nr}

*based on screening with HPGe detectors (Gator, GeMPI etc) and ICP-MS

Backgrounds: prediction versus data

- Prediction for ER rate: ~0.2 events/(keV t d) below 10 keV; NR: subdominant
- Background reduced to ~ the predicted level



NG
^{83m}Kr
^{220}Rn
AmBe
^{137}Cs
^{232}Th

- ^{nat}Kr concentration in LXe
- reduced from:

~1 ppb to 0.36 ppt

SR0 results

Accepted Paper

First dark matter search results from the XENON1T experiment

Phys. Rev. Lett.

E. Aprile et al.

Accepted 15 September 2017

ABSTRACT

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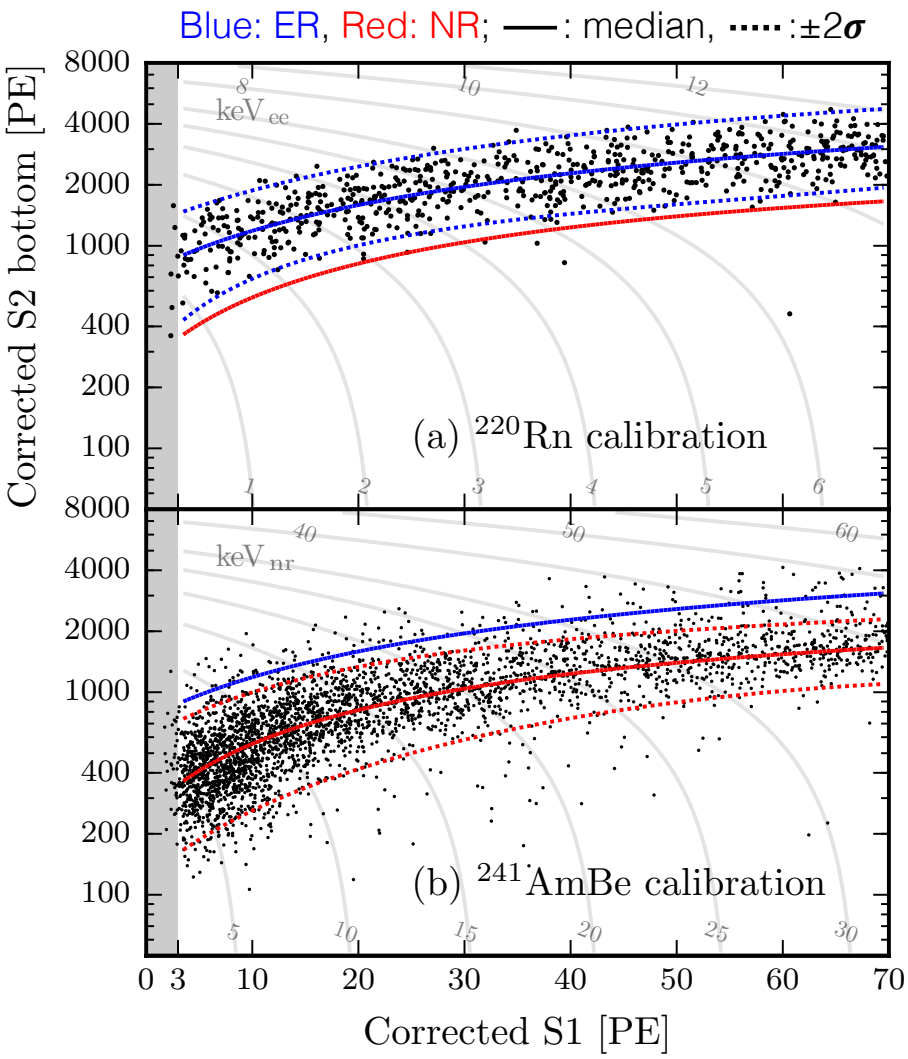
We report the first dark matter search results from XENON1T, a \sim2000-kg-target-mass dual-phase (liquid-gas) xenon time projection chamber in operation at the Laboratori Nazionali del Gran Sasso in Italy and the first ton-scale detector of this kind. The blinded search used \num{34.2} live days of data acquired between November 2016 and January 2017. Inside the \num{(1042\pm12)}~kg fiducial mass and in the [5, 40] keV$_{nr}$ energy range of interest for WIMP dark matter searches, the electronic recoil background was (1.93 \pm 0.25) \times 10^{-4} \dru, the lowest ever achieved in such a dark matter detector. A profile likelihood analysis shows that the data is consistent with the background-only hypothesis. We derive the most stringent exclusion limits on the spin-independent WIMP-nucleon interaction cross section for WIMP masses above 10~\gevcsq, with a minimum of 7.7~\num{\times 10^{-47}}~cm^2 for 35-\gevcsq~WIMPs at 90\% confidence level.

Calibrations: ER and NR bands

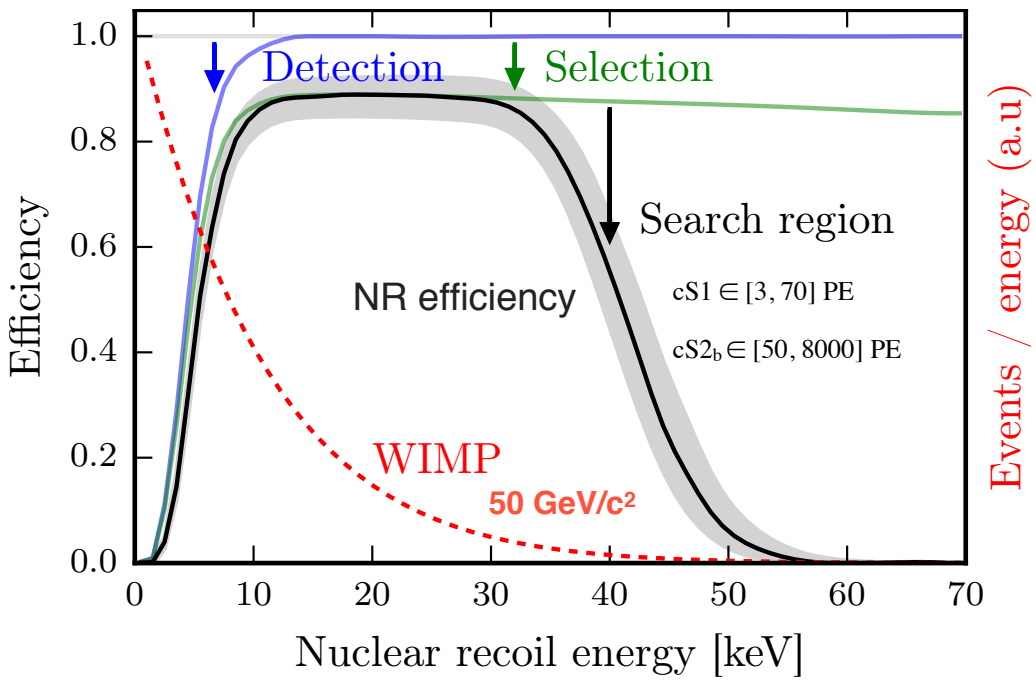


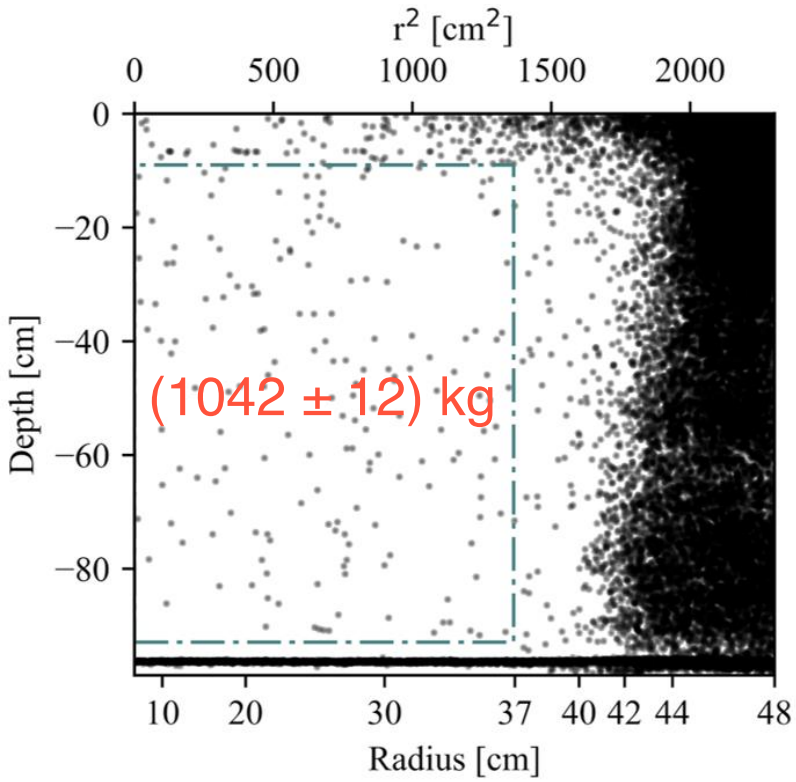
- **Electronic recoils**
  - ^{220}Rn ($T_{1/2}$ = 65 s), emanated by ^{228}Th source, directly into LXe
  - ^{212}Pb ($T_{1/2}$ = 10.6 h) buildup, decays to ^{212}Bi => low-energy ER events
- **Nuclear recoil**
  - external AmBe source
  - upgraded to D-D fusion n-generator
  - time required to calibrate: weeks -> days

Data selection

- Signal region blinded until selection fixed
- Single-scatter, event quality, peak quality, fiducial volume

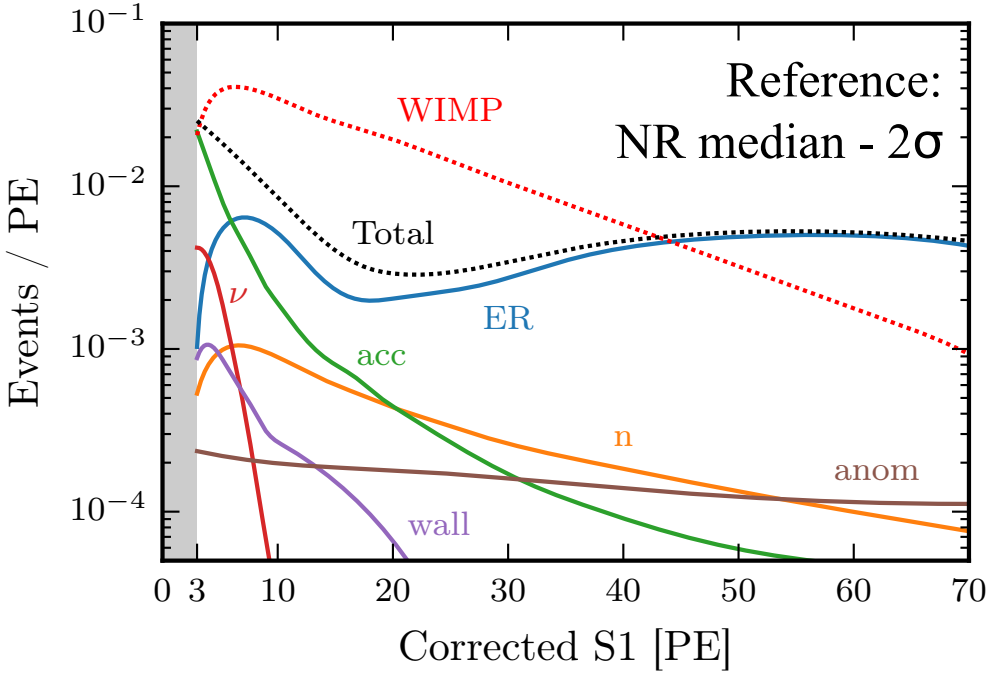
Selection criterium	Events remaining
All events (cS1<200 PE)	128144
Data quality, selection	48955
Fiducial volume	180
S1 range (3-70) PE	63





Total background

- ER rate is dominated by radon (emanation from detector materials)
- Target concentration of 10 μBq/kg reached
- Further reduction by Rn distillation (see EPJ C (2017) 77:358, arXiv:1702.06942)

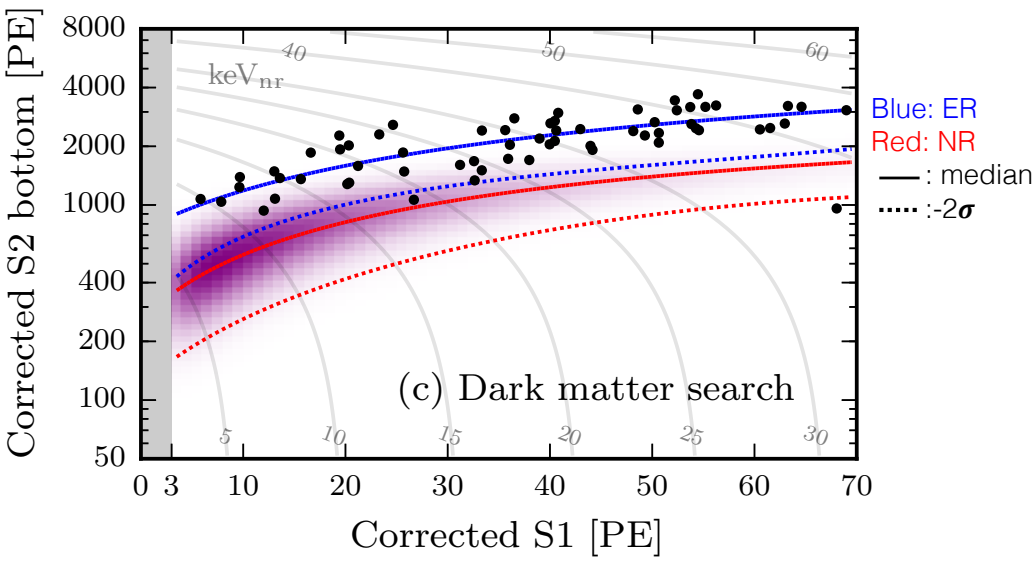


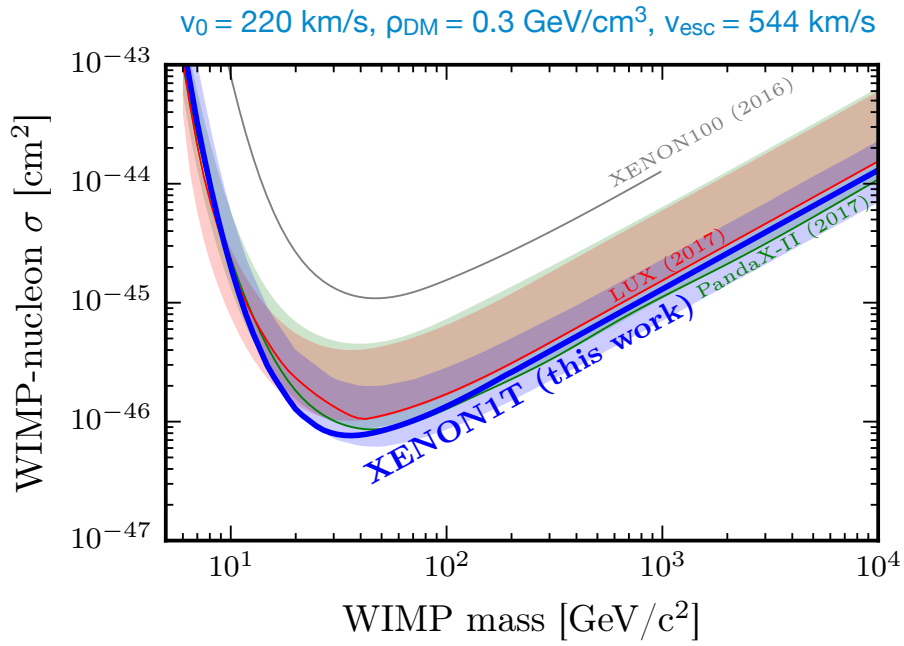
	Full	Reference
Electronic recoils (ER)	(62 ± 8)	$(0.26^{+0.11}_{-0.07})$
Radiogenic neutrons (n)	0.05 ± 0.01	0.02
CNNS (ν)	0.02	0.01
Accidental coincidences (acc)	0.22 ± 0.01	0.06
Wall leakage ($wall$)	0.5 ± 0.3	0.01
Anomalous ($anom$)	$0.10^{+0.10}_{-0.07}$	0.01 ± 0.01
Total background	63 ± 8	$0.36^{+0.11}_{-0.07}$

Observed ER rate: $(1.93 \pm 0.25) \times 10^{-4}$ events/(kg × d × keV)

Dark matter search results

- No post-unblinding changes to event selection
- Unbinned profile likelihood analysis, data consistent with background-only hypothesis
- ER/NR shape largely determined from calibration fits



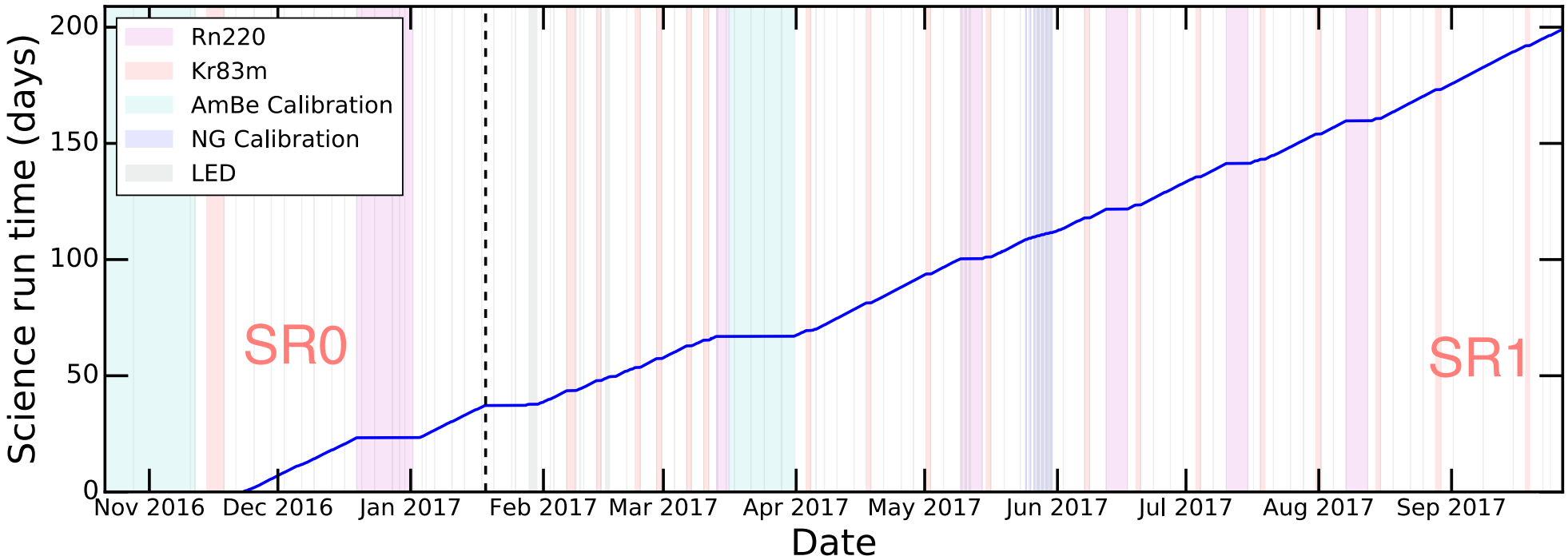


Accepted in PRL, September 15, 2017

$\sigma_{\min} = 7.7 \times 10^{-47}\,\mathrm{cm}^2$ at $35\,\mathrm{GeV/c}^2$

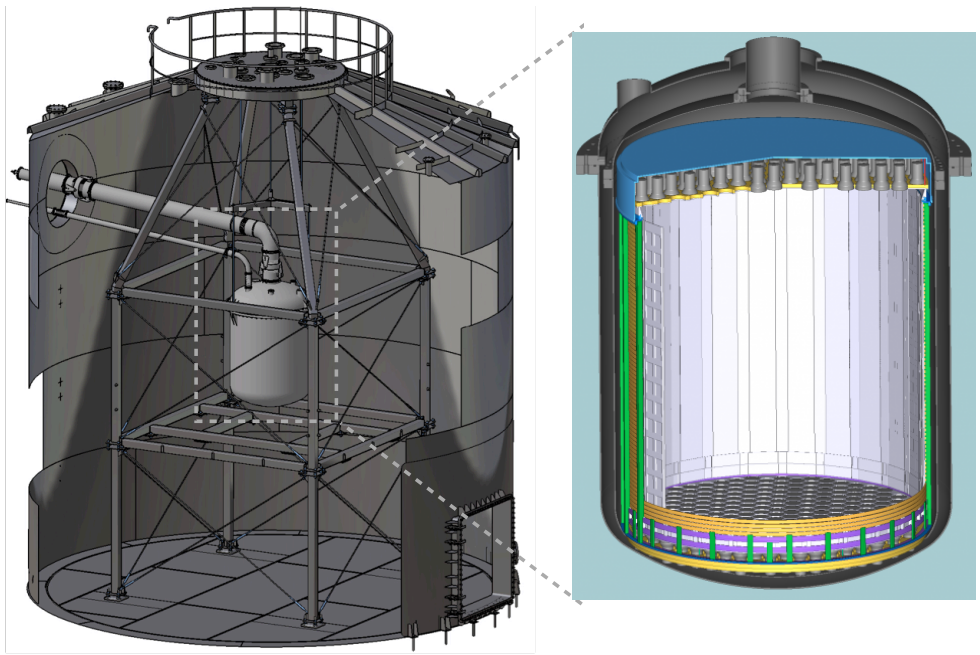
SR1 analysis: in progress

- Several improvements with respect to SR0 analysis
- Expect new results early next year



The XENONnT Experiment

- A rapid upgrade to XENON1T, with: 8 t total LXe mass, 6 t active (x3 compared to 1T)
- Most sub-systems can handle a larger detector with up to 10 t of LXe:



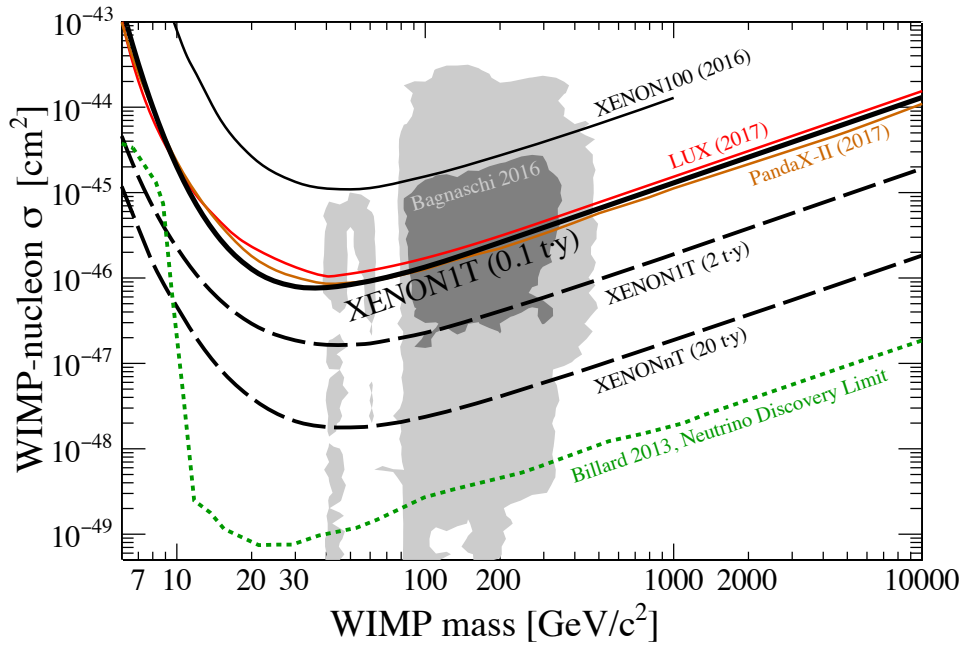
- Water tank + muon veto
- Outer cryostat and support structure
- Cryogenics and purification system
- LXe storage system
- Cables installed for XENONnT as well
- New inner cryostat, new TPC, 476 PMTs
- Neutron veto, Rn removal tower, additional LXe storage system

- PMTs ordered & under tests; TPC materials ordered, first batches under screening & outgassing measurements

XENON1T and XENONnT science reach

- XENON1T: 1.6 x 10^{-47} cm^2 with an exposure of 2 tonnes x year
- XENONnT: to start in mid 2019, aiming for 20 tonnes x year exposure

	XENON1T	XENONnT	LZ
Fiducial Volume [tons]	1	4	5.6
Livetime Fraction	80%	80%	80%
WIMP Energy Range [keV_{nr}]	4-50	4-50	6-30
NR Acceptance	40%	40%	50%
ER Rejection	99.75%	99.75%	99.5%
Bkg rate [evt/year]	2.08	1.15	2.35



Conclusions and Outlook

- The XENON1T experiment operates in stable mode and shows very good data taking performance in 2017
- **First physics results accepted in PRL, from 34.2 live days of data**
- Lowest background in a dark matter detector (~0.2 events/(t d keV))
- More than 155 additional live days of (blinded) science data on disk, new results expected for early next year
- Upgrade on critical path, with XENONnT proposal to LNGS submitted. Upgrade work on site at LNGS to start in late 2018
- **Stay tuned for a wealth of interesting physics results from Science Run 1 and beyond!**