XENON
Dark Matter Project

The 26th International Workshop on
Weak Interactions and Neutrinos (WIN2017)
19th – 24th June 2017, University of California, Irvine

FIRST RESULTS FROM THE XENON1T EXPERIMENT

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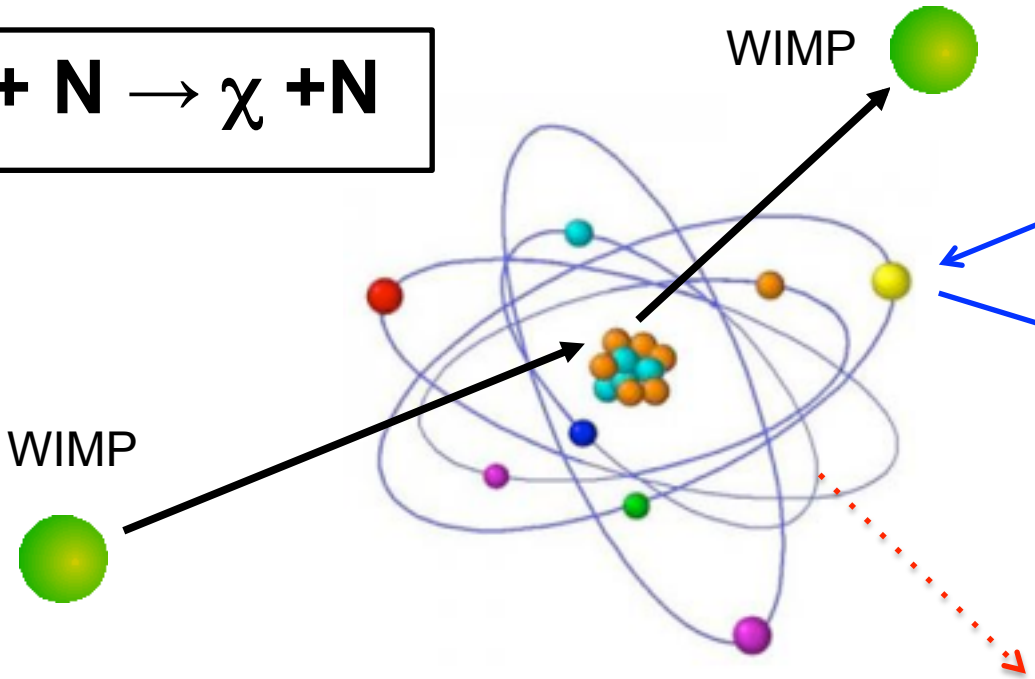
THE DIRECT DETECTION PRINCIPLE

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

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



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

NR: Detectable Signal

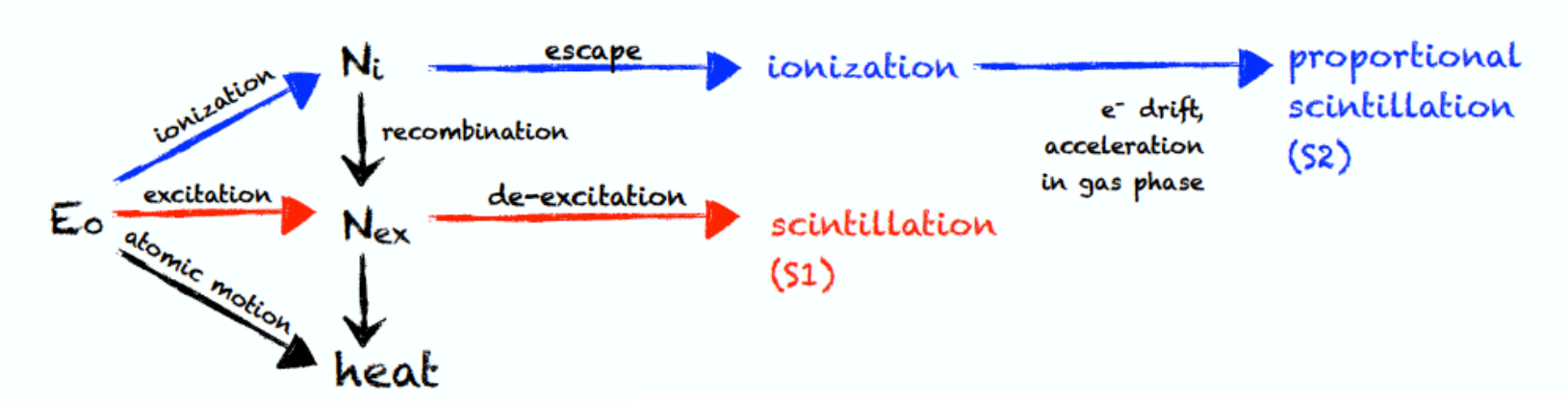
$$E_{recoil} \leq 50\, keV$$

For example, by assuming

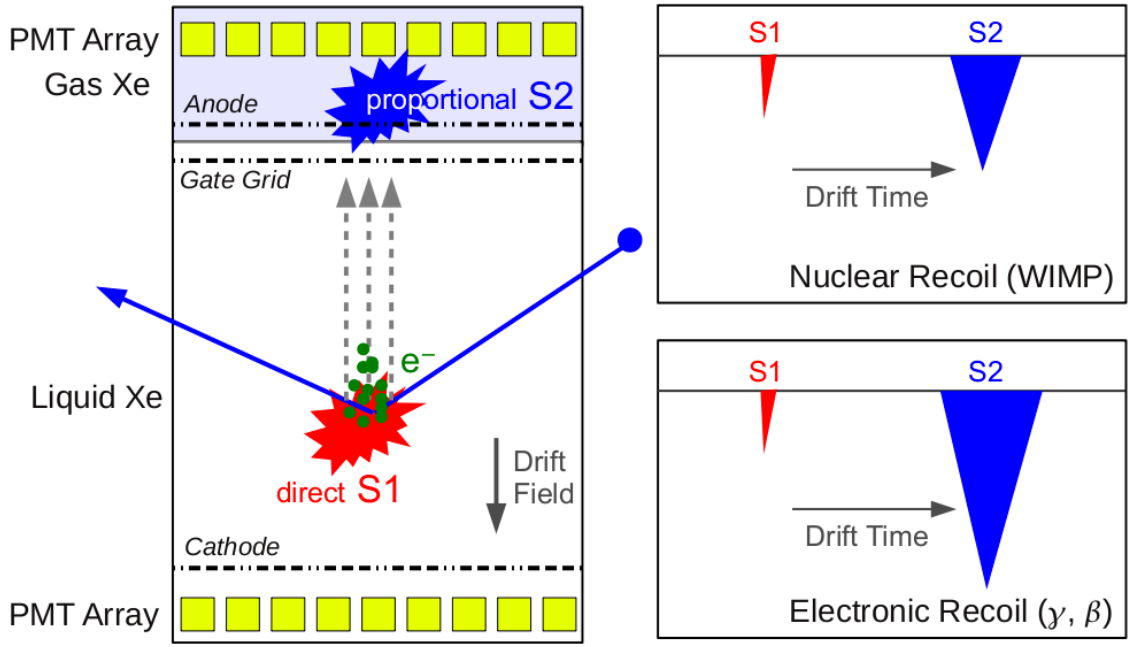
- WIMP mass: M_χ = 100 GeV/c^2
- WIMP velocity: v_0 = 220 km/s

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

DUAL PHASE TIME PROJECTION CHAMBER



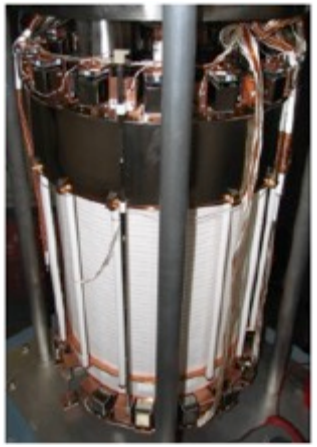
- **Interaction vertex reconstruction**
  - X , Y position from S2 hit pattern on top PMTs
  - Z position from electron drift time
- **ER - NR discrimination**
  $(S2/S1)_{WIMP,n} < (S2/S1)_{\gamma,\beta}$

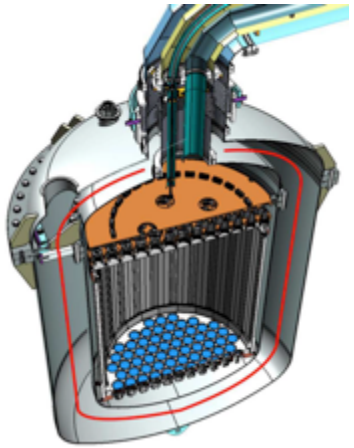


THE XENON (TO DARWIN) PROJECT

Time

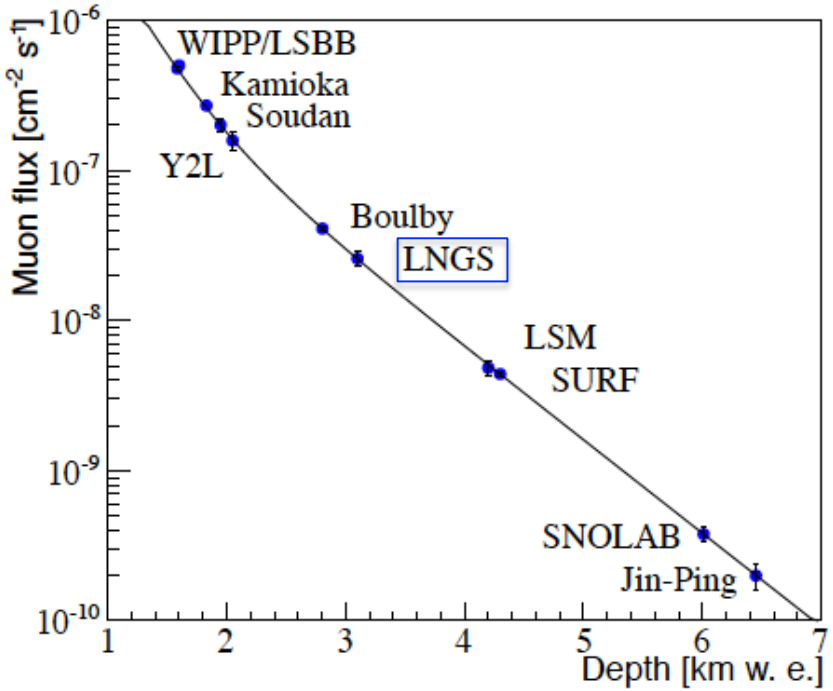
XENON10	XENON100	**XENON1T**	XENONnT	DARWIN
2005—2007	2008—2016	**2012 – 2019**	2017 – 2023	~2023 –





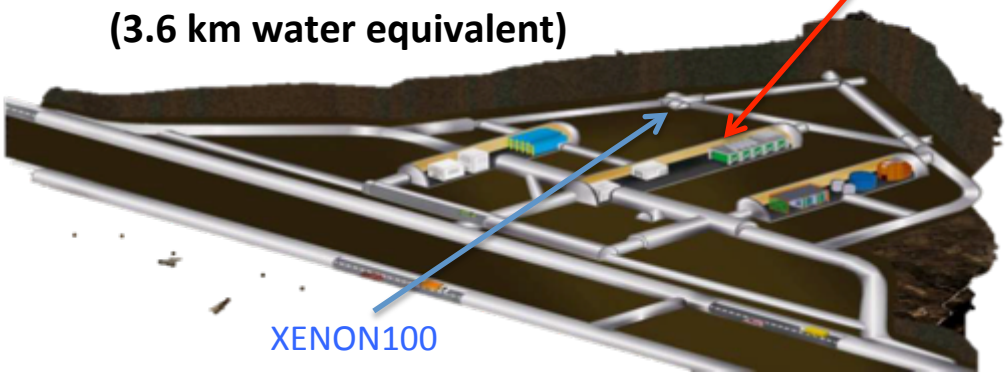
Total mass : 25 kg	Total mass : 161 kg	**Total mass : 3.2 t**	Total mass : ~8 t	Total mass : ~50 t
Target mass: 14 kg	Target mass: 62 kg	**Target mass: 2 t**	Target mass: ~6 t	Target mass: ~40 t
Drift TPC: 15 cm	Drift TPC: 30 cm	**Drift TPC: 96 cm**	Drift TPC: 144 cm	Drift TPC: 260 cm
Limit ~ 10^{-43} cm^2	Limit ~ 10^{-45} cm^2	**Sensitivity ~ 10^{-47}cm^2**	Sensitivity ~ 10^{-48}cm^2	Sensitivity ~ 10^{-49}cm^2

LABORATORI NAZIONALI DEL GRAN SASSO



Below 1400 m of rock

(3.6 km water equivalent)



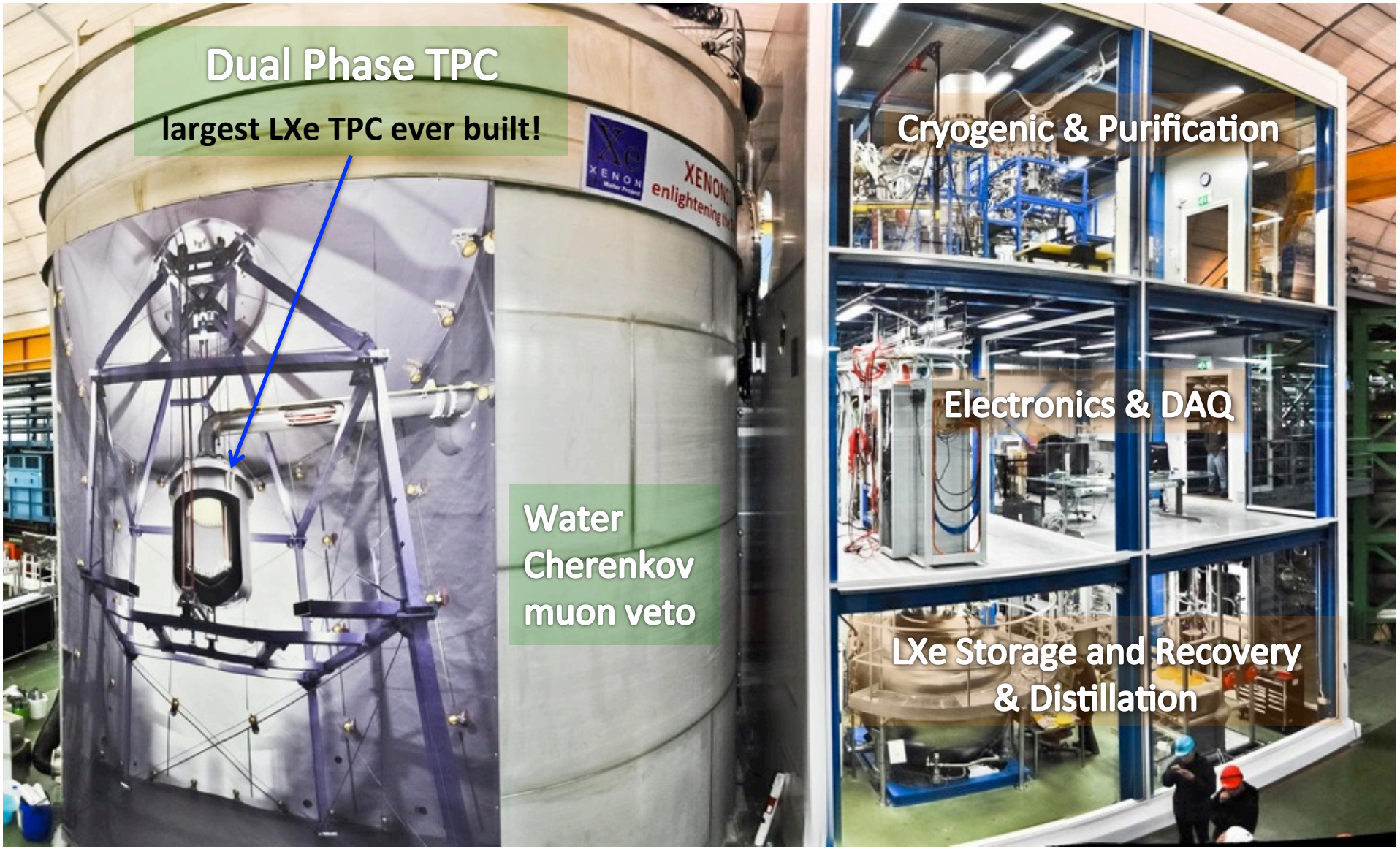
THE XENON COLLABORATION

23 Institutions

10 Countries

~ 135 Scientists

THE XENON1T EXPERIMENT

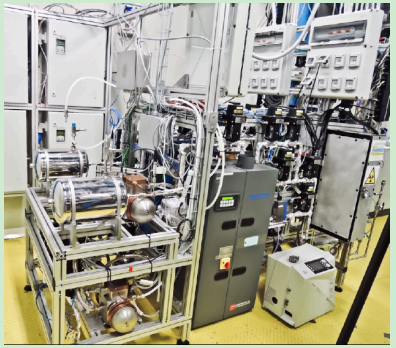


CRYOGENIC & PURIFICATION SYSTEMS

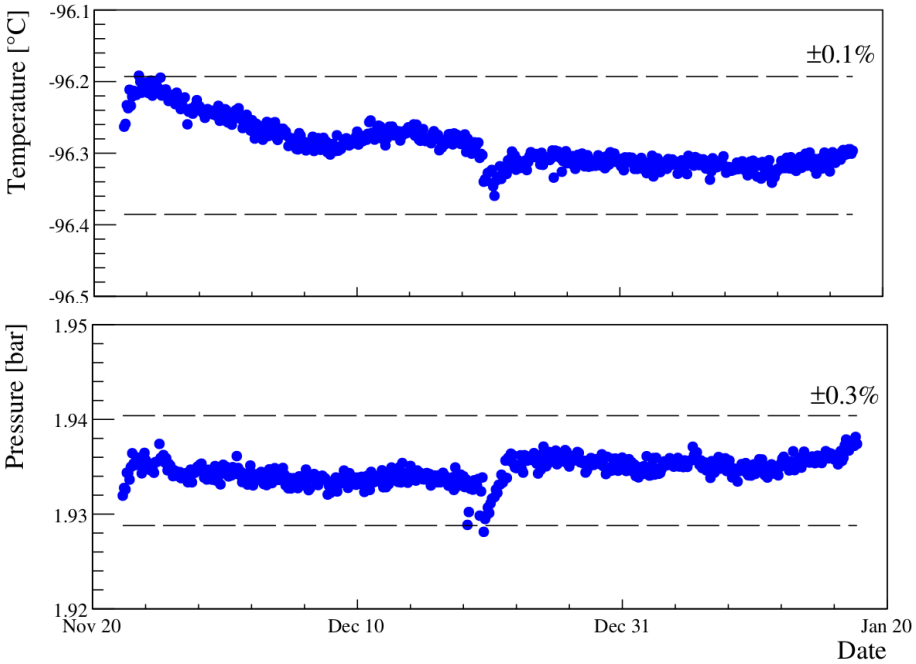
Cryogenic system

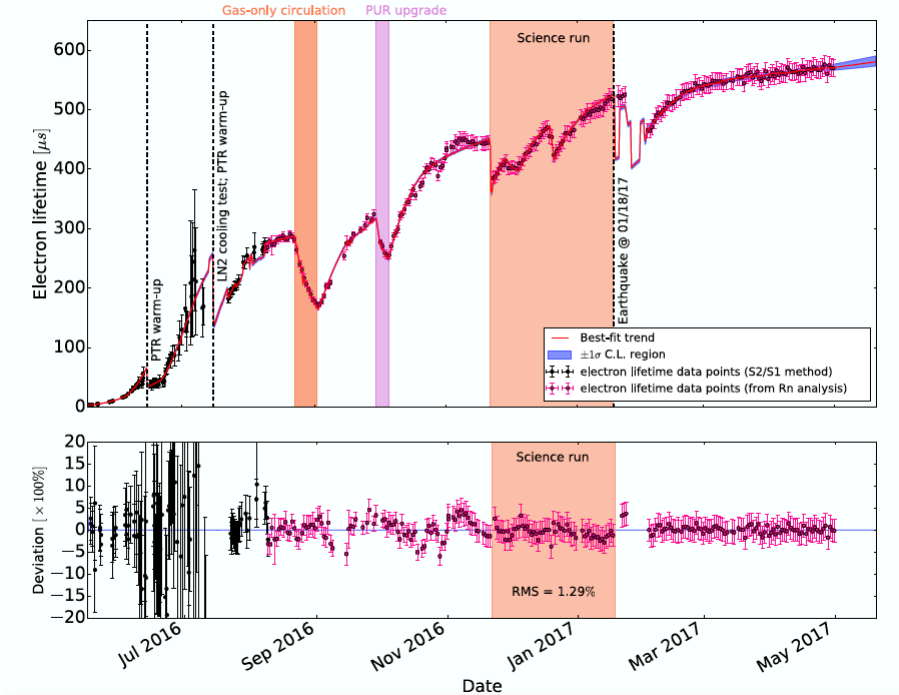
- liquefy the 3.2 t Xe
- maintain the Xe in the cryostat in liquid form at a constant temperature and pressure

Purification system



- clean Xe from electronegative impurities below 1 ppb with continuous circulation of gas through heated getters



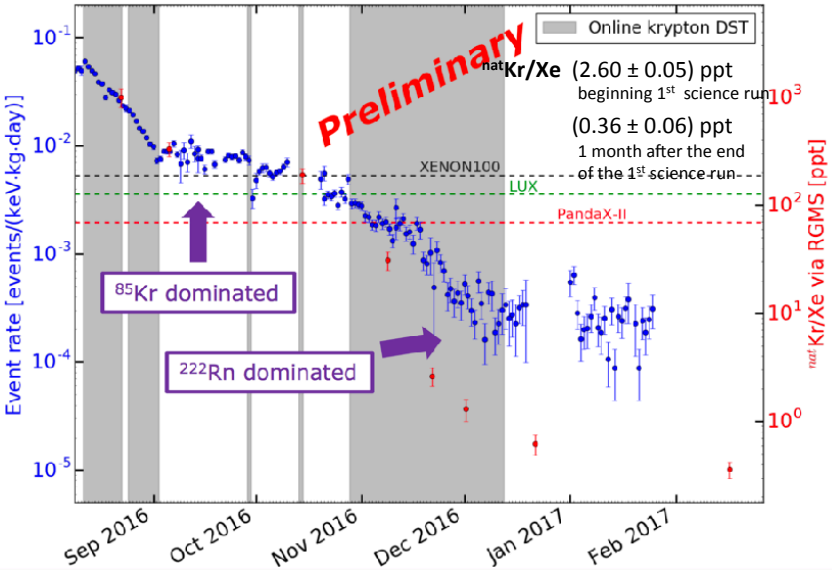


RECOVERY AND STORAGE & DISTILLATION

Kr Distillation Column

- Active removal of Kr contamination in Xe

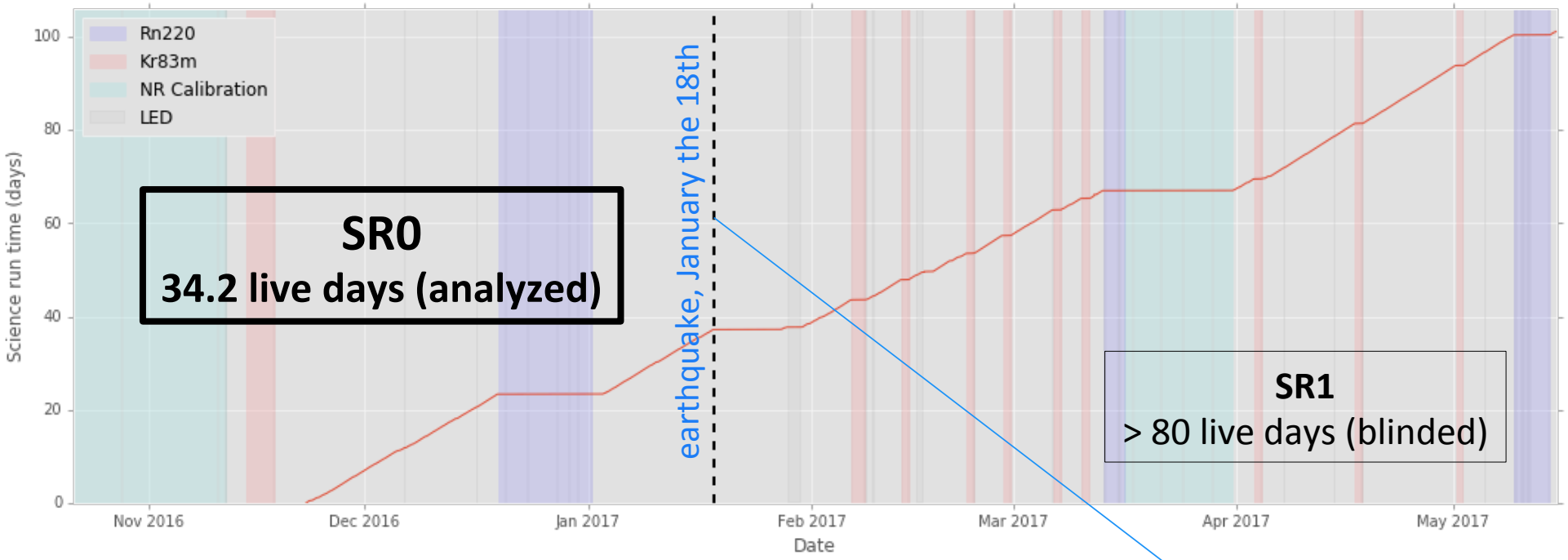
arXiv:1702.06942
Eur. Phys. J. C77 (2017) no.5, 275



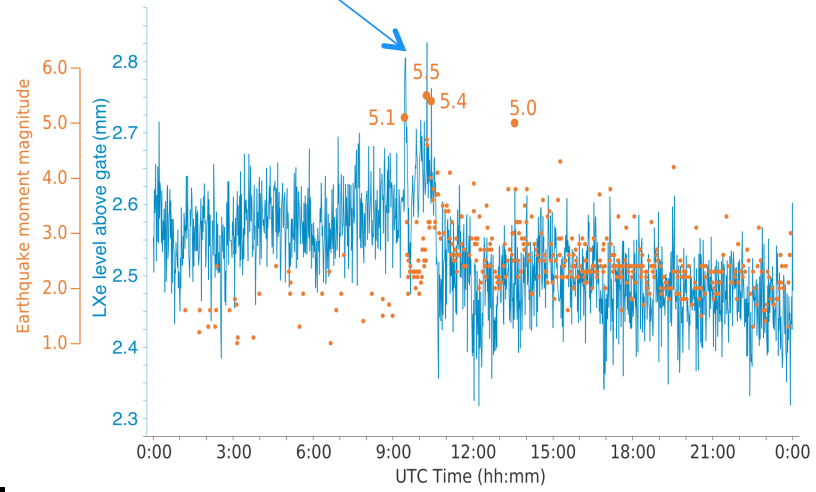
Recovery and Storage of the Xenon: ReStoX

- Store up to 7.6 t of Xe either in gas or liquid phase under high purity conditions
- Fill Xe into detector vessel in ultra-high-purity conditions
- Recover all Xe from the detector in case of emergency in a few hours

SCIENCE RUN EXPOSURE

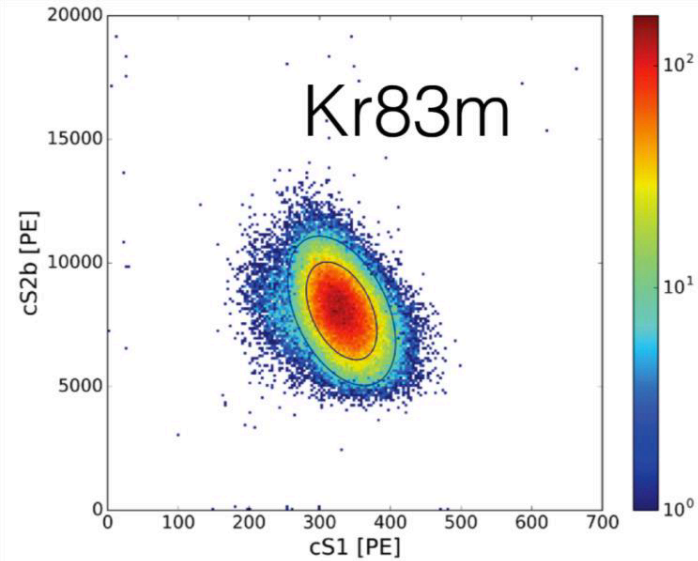


- Dark matter exposure : 34.2 Live days
- Calibration data:
  - ^{83m}Kr →Spatial Response
  - ^{220}Rn→ ER-bands
  - ^{241}AmBe →NR-bands
- Interrupted by a 5.5 magnitude earthquake

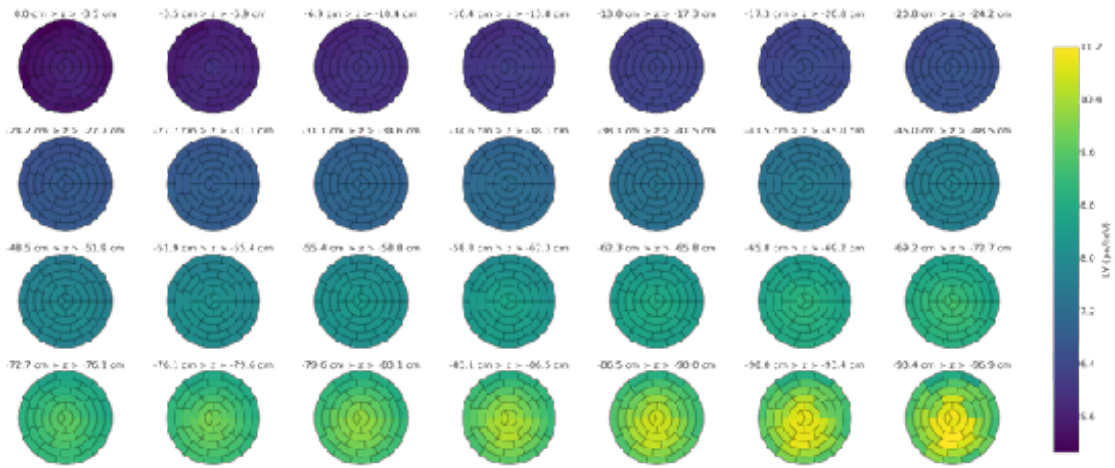


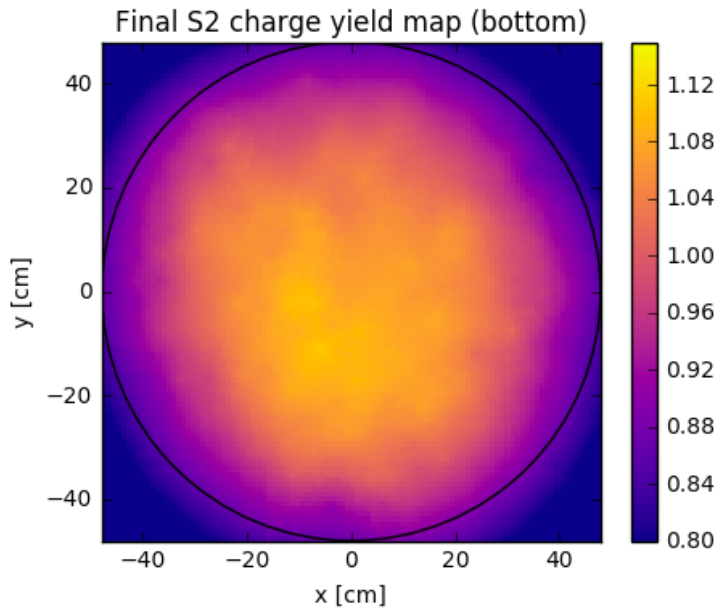
^{83M}Kr Calibration

- **Signal corrections**
  - position-dependent light collection efficiency
  - position-dependent S2 amplification
  - electric field non-uniformity
- electron lifetime cross-check
- light/charge yield stability



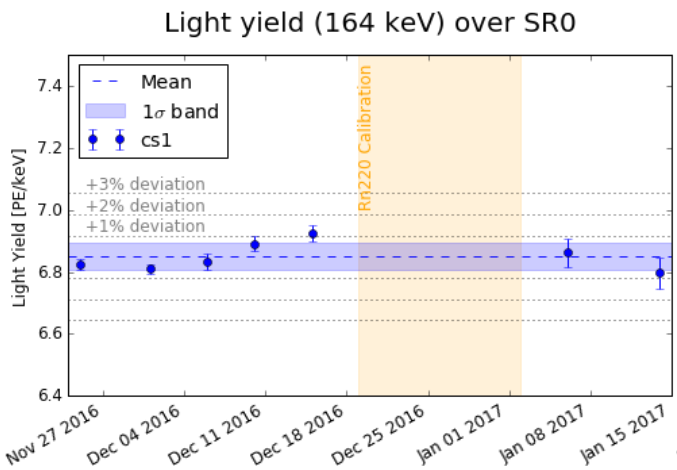
Light collection efficiency maps

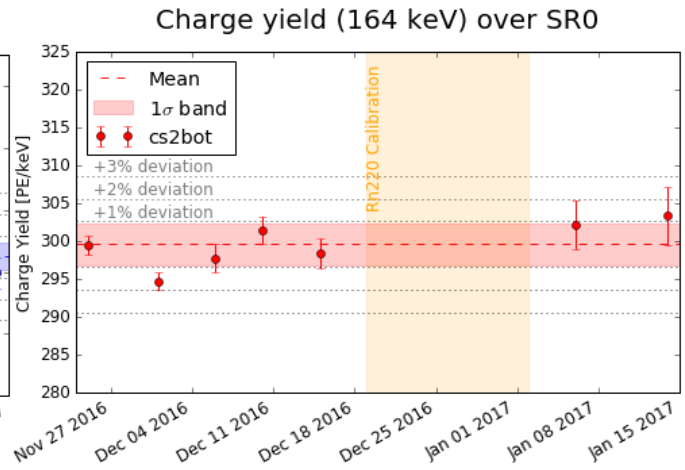


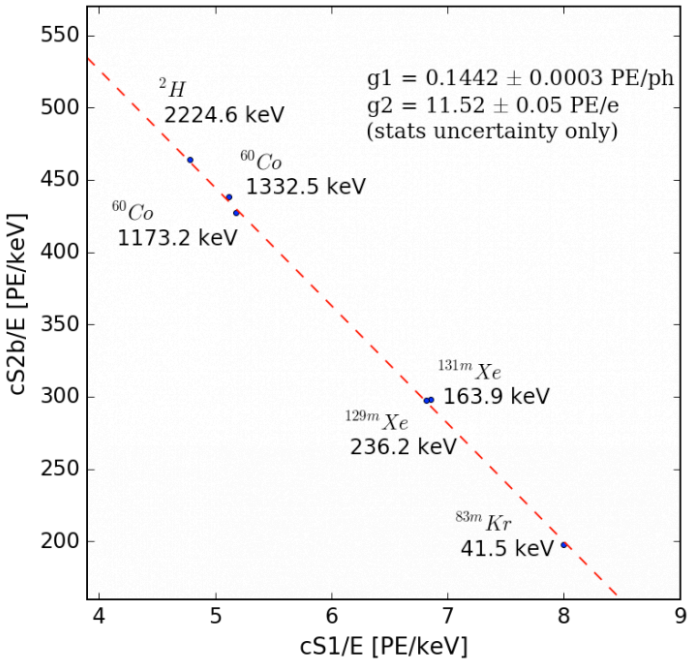


ENERGY RESPONSE

- Activated ^{131m}**Xe** (shown) and ^{83m}**Kr** used for monitoring
- Light Yield and Charge Yield variations at ~1%







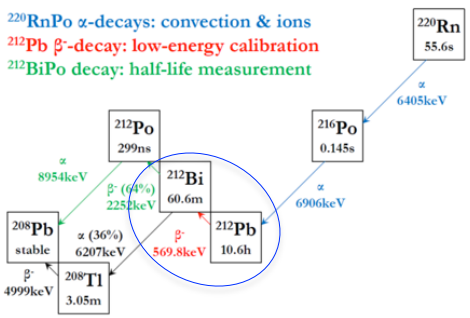
- Using known calibration sources
  - ^{83m}Kr
  - ^{241}AmBe (^{129m}Xe, ^{131m}Xe, ^{2}H)
  - detector material (^{60}Co)
- Linear from keV to MeV
- **Photon gain** g1 = 0.144 ± 0.007 (sys) PE/ph
  - light detection efficiency (12.5±0.6)%
  - MC prediction 12.1%
- **Electron gain** g2 = 11.5 ± 0. 8 (sys) PE/e-
  - corresponds to ~100% extraction of ionization charges from the liquid

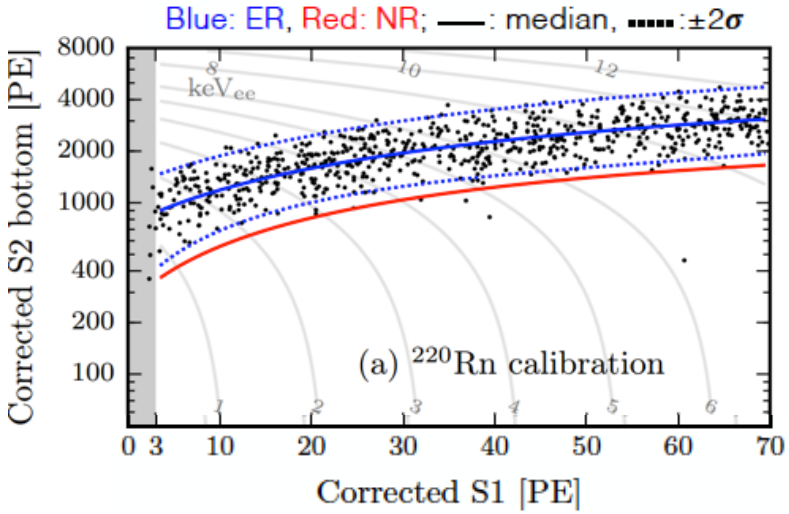
ELECTRONIC AND NUCLEAR RECOIL CALIBRATIONS

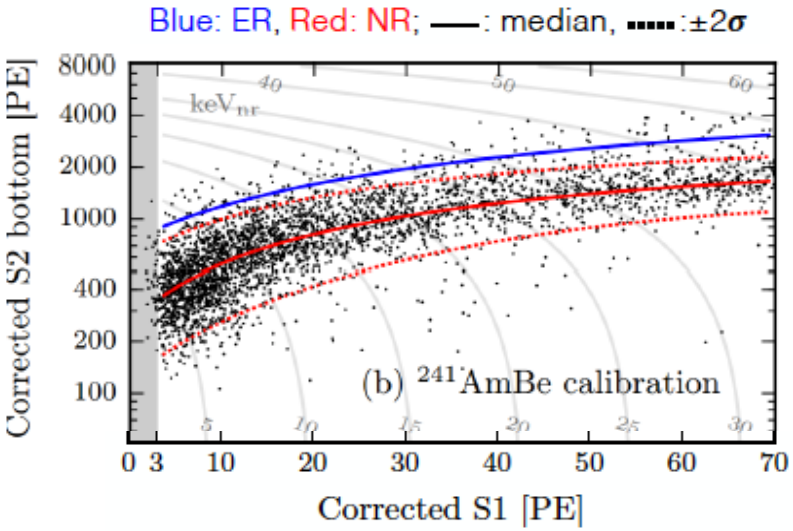
Electronic Recoils

- ^{228}Th source emanates **^{220}Rn** into LXe
- **β-decay** of ^{212}Pb to ^{212}Bi → **low energy** events (2-20 keV)

Phys. Rev. D 95, 072008 (2017)







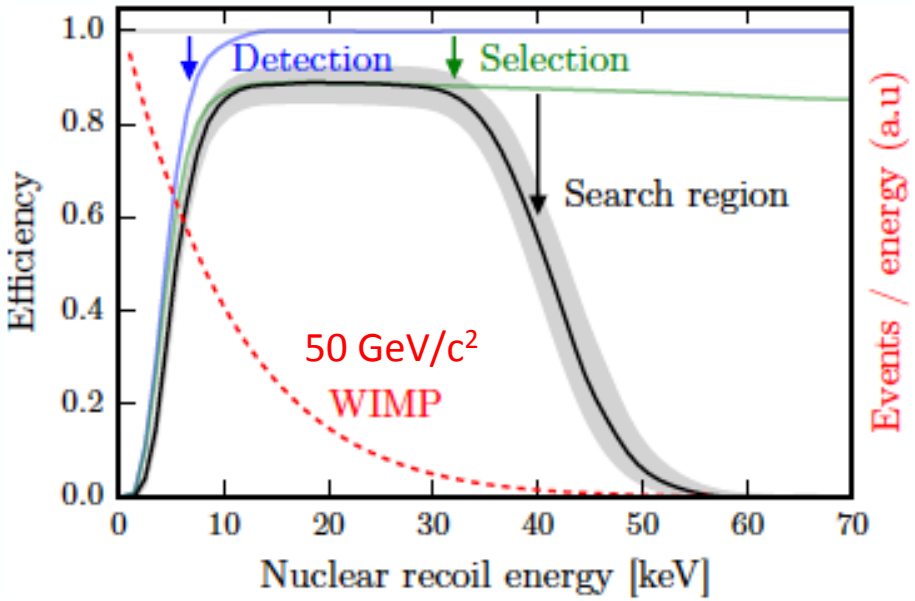
Nuclear Recoils

- 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

DATA SELECTION

Signal region **blinded** until selection fixed

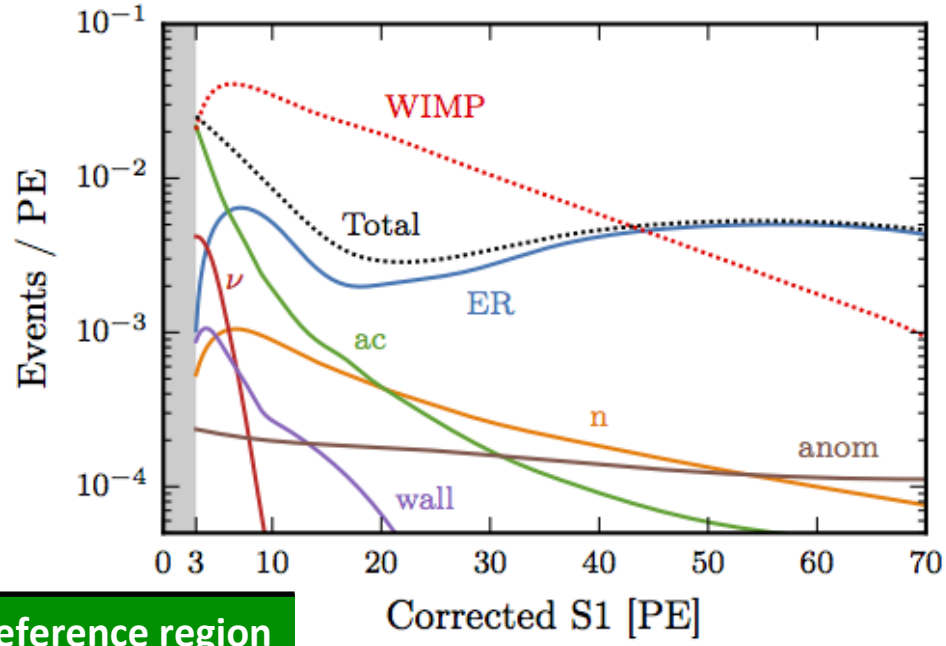
- **Detection Efficiency from MC**
  - Dominated by 3-fold PMTs coincidence requirement
- **Event Selection from control samples or simulations**
  - Data quality and selection cuts tuned to calibration data
  - single scatter (WIMP-like) events
- **Search Region**
  - corrected S1 range 3-70 PE



Cuts	Events remaining
All events (cS1<200 PE)	128144
Data Quality & Selection	48955
Fiducial Volume	180
3 PE < cS1 < 70 PE	**63**

BACKGROUNDS

- ER and NR spectral shapes derived from model fitted to calibration data
- Use control samples in data to derive other backgrounds



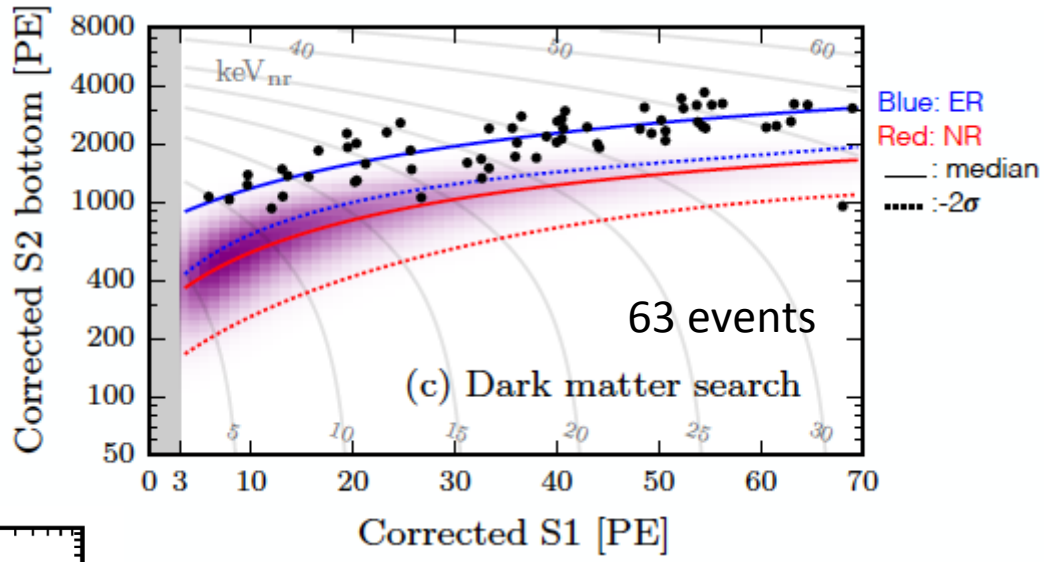
Background & Signal Rates	Full search region	Reference region
Electronic recoils (ER)	62 ± 8	0.26 (-0.07)(+0.11)
Radiogenic neutrons (n)	0.05 ± 0.01	0.02
CNNS (ν)	0.02	0.01
Accidental coincidences (ac)	0.022 ± 0.01	0.06
Wall leakage (wall)	0.52 ± 0.3	0.01
Anomalous (anom)	0.09 (-0.06)(+0.12)	0.01 ± 0.01
Total background	**63 ± 8**	**0.36 (-0.07)(+0.11)**
50 GeV/c^2, 10^{-46} cm^2 WIMP (NR)	1.66 ± 0.01	0.82 ± 0.06

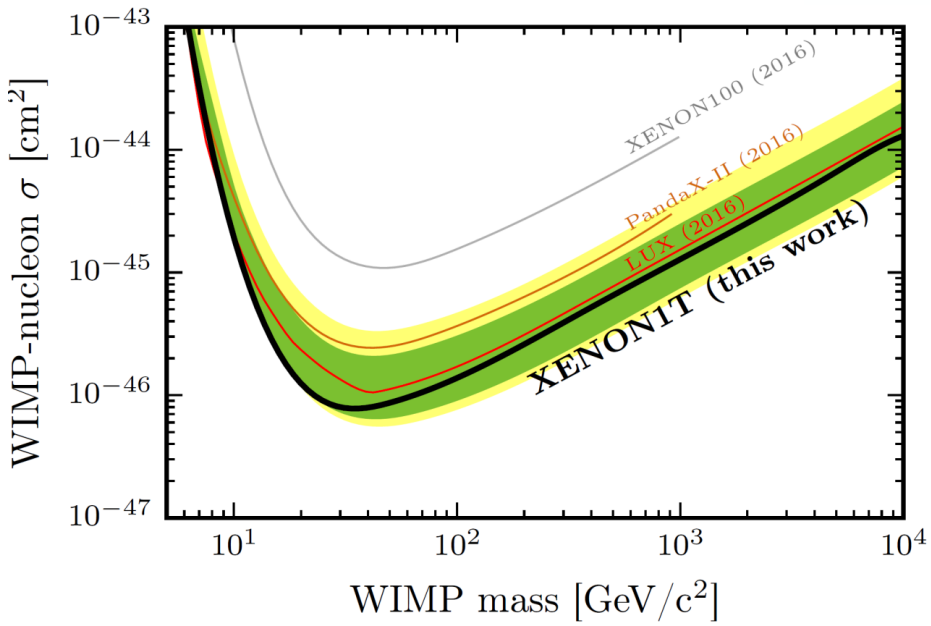
Full search region
see previous slide

Reference region
between NR median and -2σ quantile in $cS2_b$

DARK MATTER SEARCHES

- ER and NR shape largely determined from calibration fits
- Unbinned profile likelihood analysis
- Uncertainties from background components included





Strongest exclusion limit :
7.7×10^{-47} cm^2 @ 35 GeV/c^2

arXiv:1705.06655 (May 18)

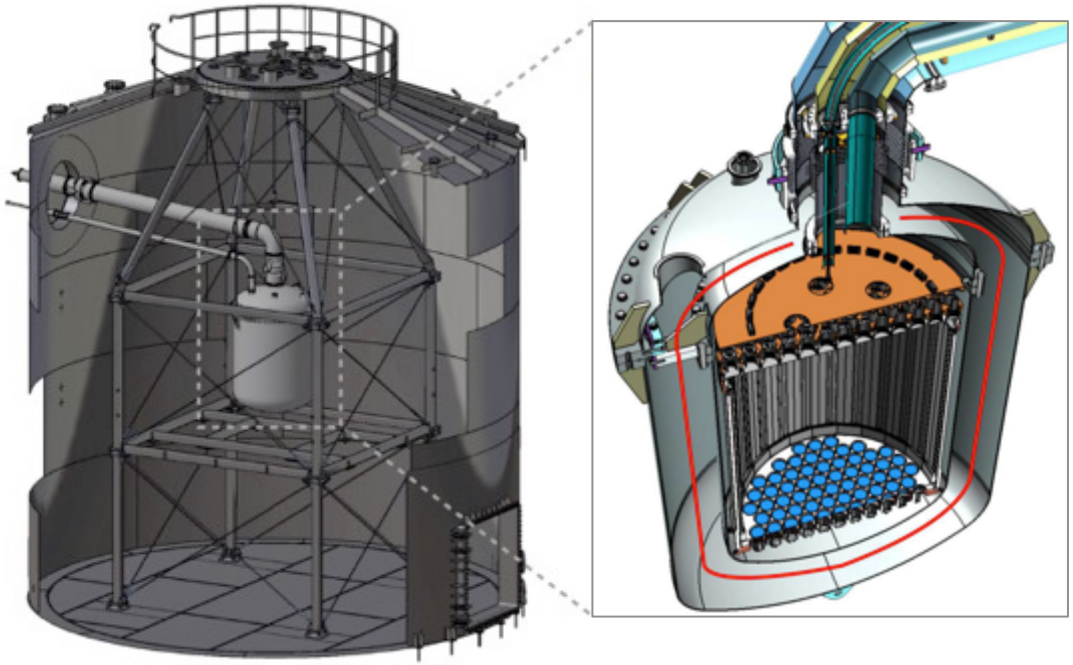
XENON1T → XENONnT

XENON1T infrastructure already designed to host XENONnT

Projected to start in 2019

Fast upgrade of XENON1T

- **Total LXe mass ~8 t**
- **Active LXe mass** increases x3: 2.0 t → **6.0 t**
- **Additional PMTs** (and electronics): 248 → **476**
- **New TPC and Inner Cryostat**
- **Additional recovery system**



All the other systems already sized to host and run XENONnT:
Outer Cryostat, Cryogenics, DAQ, Purification, Support structure, Muon veto, DAQ, Calibration system, screening facilities

CONCLUSIONS

- **XENON1T** first results demonstrate that the detector is performing very well
- The measured background is the lowest ever achieved in a DM detector: (1.93 ± 0.25) 10^{-4} events /(kg day keV)
- With only 34.2 days of exposure we have already obtained the best exclusion limit in the world: 7.7 x 10^{-47} cm^2 @ 35 GeV/c^2
- Up to now, >80 days additional days of science run have been acquired (and detector still running) and are currently under analysis
- The foreseen sensitivity of **XENON1T** in 2 t y is 1.6 x 10^{-47} cm^2
- Planning a fast upgrade to **XENONnT** for another order of magnitude in sensitivity

Xe
XENON
Dark Matter Project
THANK YOU !
Subatech