The first results of the XENON1T

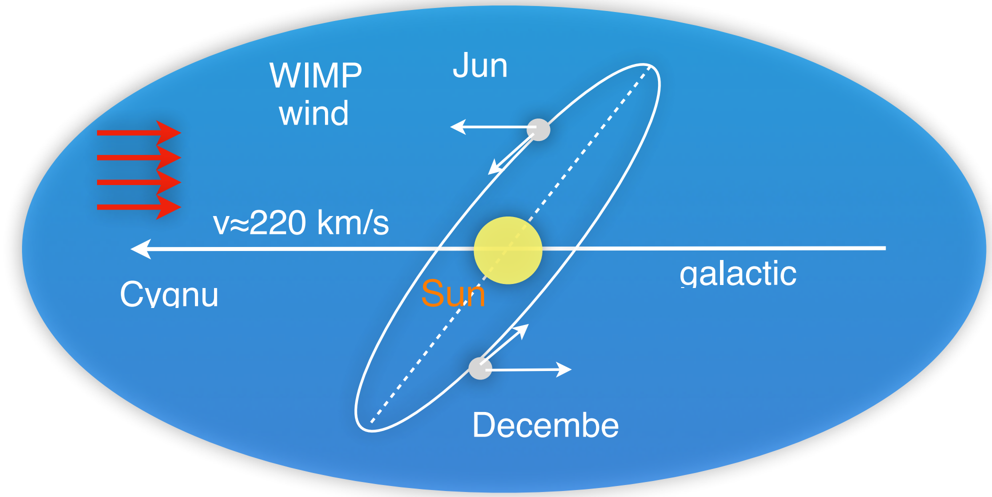
on behalf of the XENON collaboration

M. Messina NYU-Abu Dhabi,
Cosmo17, 28-31 August, Paris, 2017

Dark Matter detection with LXe TPC

Some information about physics aspects

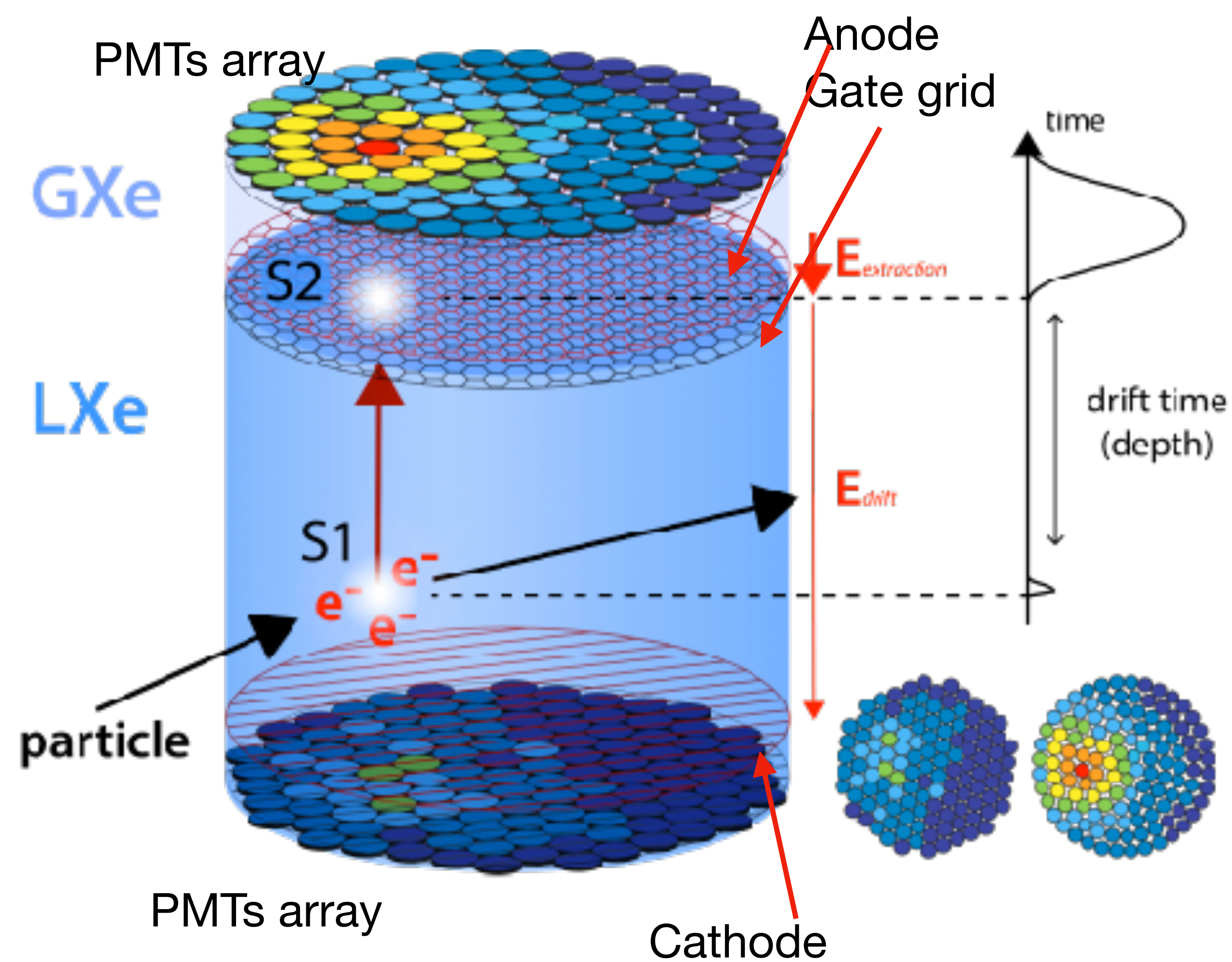
XENON1T is and Earth-based detector that realizes a Dark Matter direct search by measuring scattering between possible remnant particles foreseen in many theoretical framework, like WIMPs, and detector target



Most relevant measurable variables:

- low energy release in the target
- rate modulation because of the WIMP wind (expected to be
- few % above background).

- **Prompt** scintillation light S1
- Ionization electron drift to the top of the TPC
- Strong field extracts electrons to gaseous phase
  Linear light amplification → proportional
  to charge signal S2
  - **X, Y** position → S2 hit pattern
  - **Z** position → electron drift time
  - Energy → S1, S2 integral
  - **Electron/Nuclear recoil discrimination** → S2/S1
    - **WIMP** (NR), **background** (mostly ER)



Historical path of the XENON collaboration

XENON10

2005-2007
15 cm drift TPC -25 kg
14 kg instrumented
5.4 fiducial
Achieved 2007
Limit σ_{SI}=8.8 x 10^{-44} cm^2

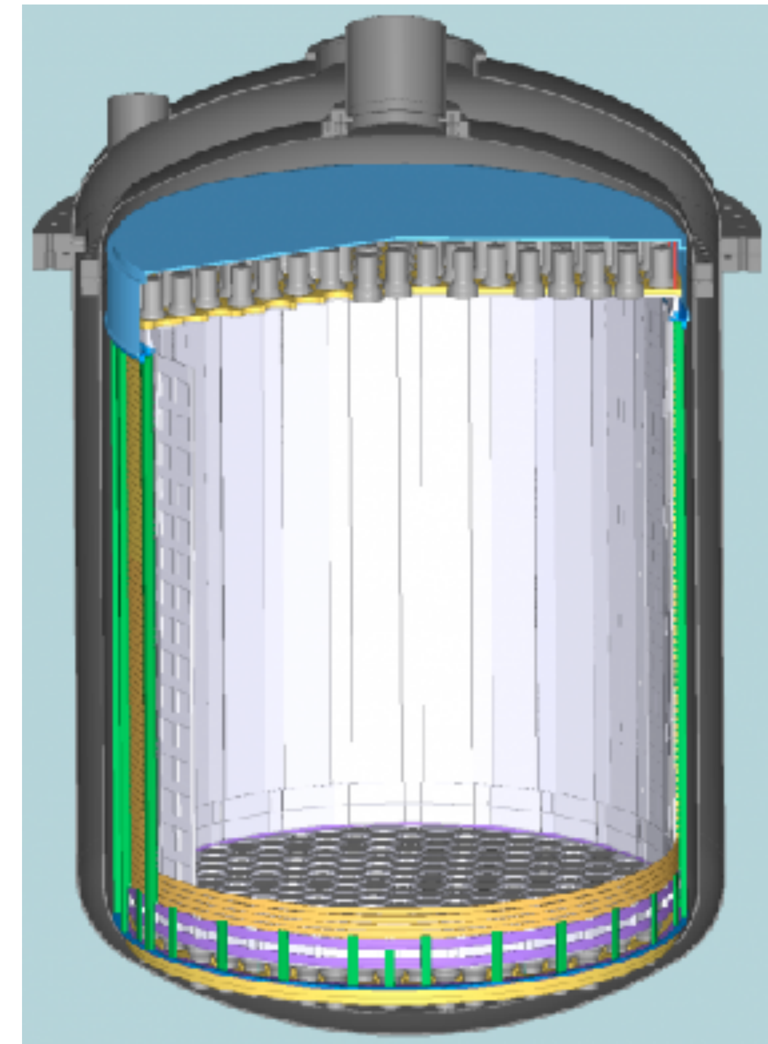
XENON100

2008-2016
30 cm drift TPC -161 kg
62 kg instrumented
34/48 kg fiducial
Achieved 2016
Limit σ_{SI}=1.1 x 10^{-45} cm^2

XENON1T

2015-2018
97 cm drift TPC 3200 kg
2000 kg instrumented
1000 kg fiducial
Projected 2018
Limit σ_{SI}=1.6 x 10^{-47} cm^2

XENONnT

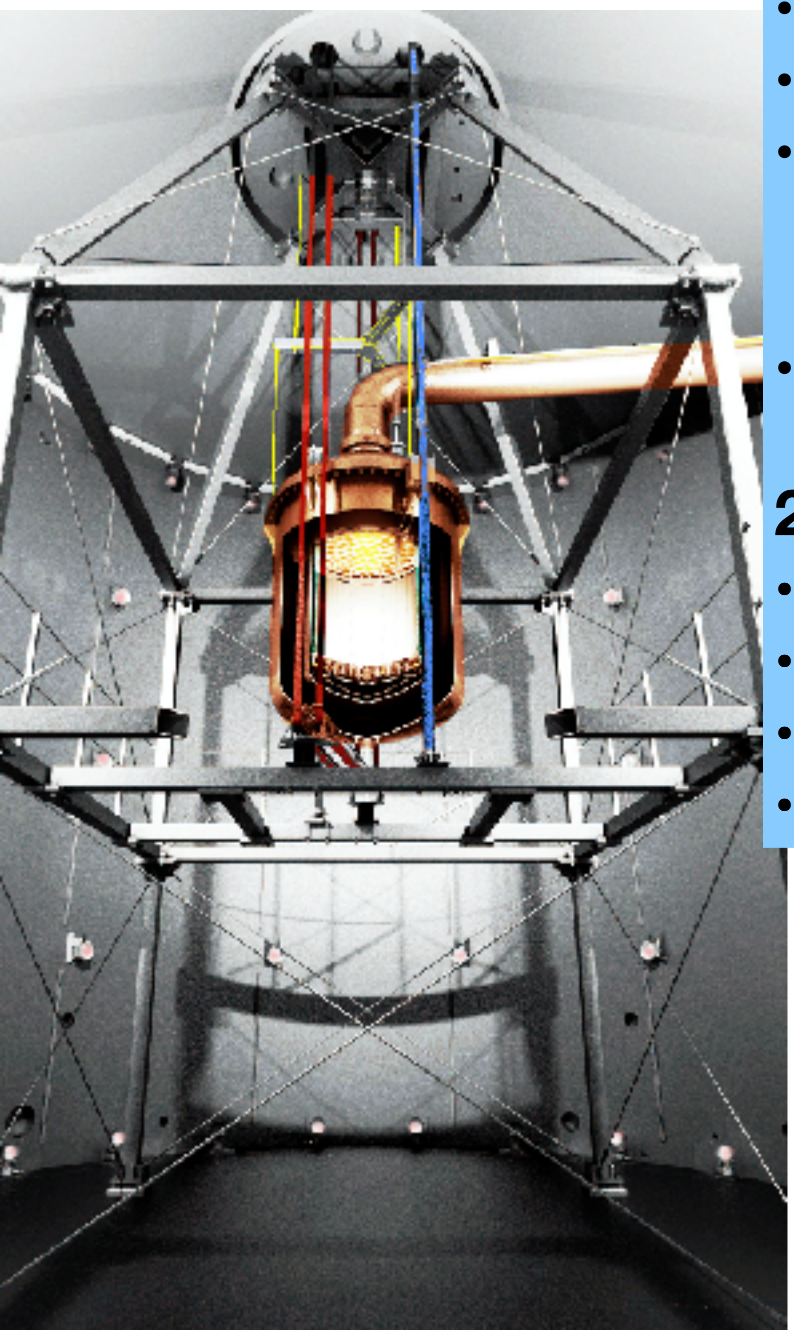


2019-2023
144 cm drift TPC 8000 kg
6500 kg instrumented
5000 kg fiducial
Projected 2018 /2023
Limit σ_{SI}=1.6 x 10^{-48} cm^2

2005 **2010** **2015** **2020**

XENON1T TPC

installed in its cryostat which is hosted in the Muon Veto detector



TPC Design

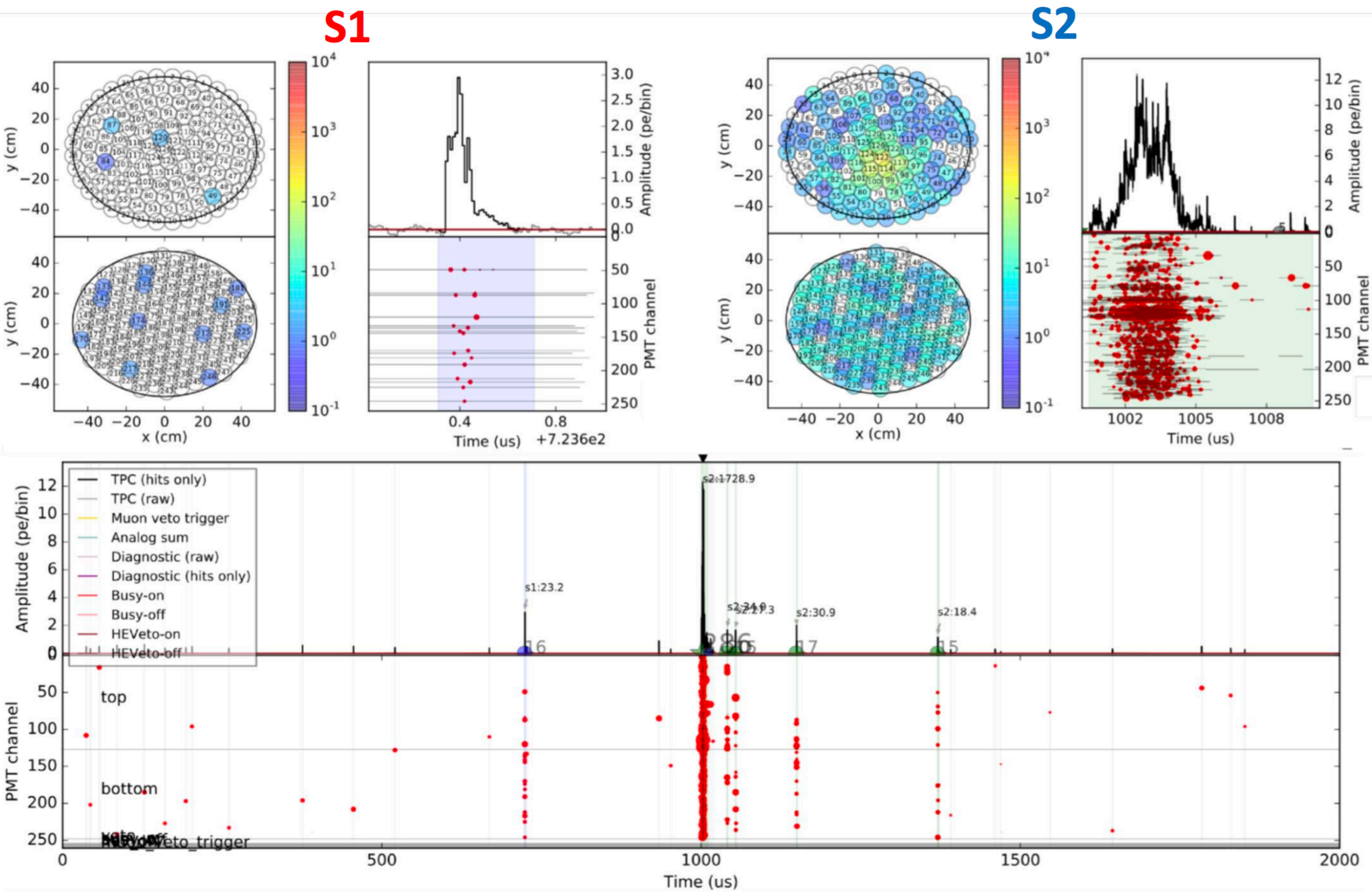
- Located at LNGS Italy, (3600 m.w.e)
- 3.2 t (total) 2.0 t (target) mass
- Inner side of the field cage(except PMTs) covered by high-reflectivity PTFE
- Field cage 1 x 1 meters

248 Hamamatsu R11410, PMTs

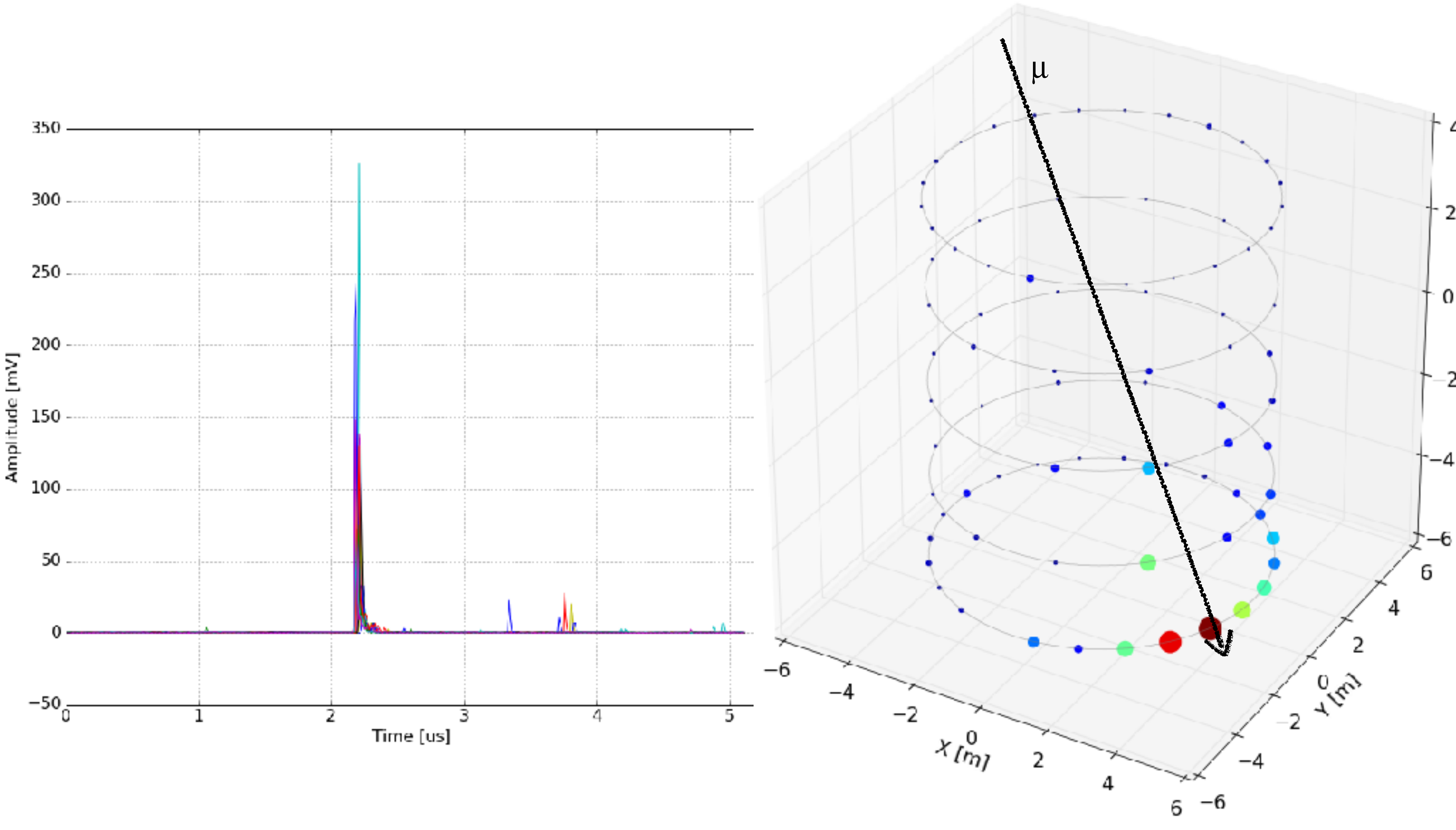
- Low radioactive background
- Developed with Hamamatsu
- QE 34% @ 178 nm
- Average gain 5 x 10^6 @ 1500 V

See XENON Collaboration (E. Aprile et al.,) Eur. Phys J. C75 (2015) 11, 546

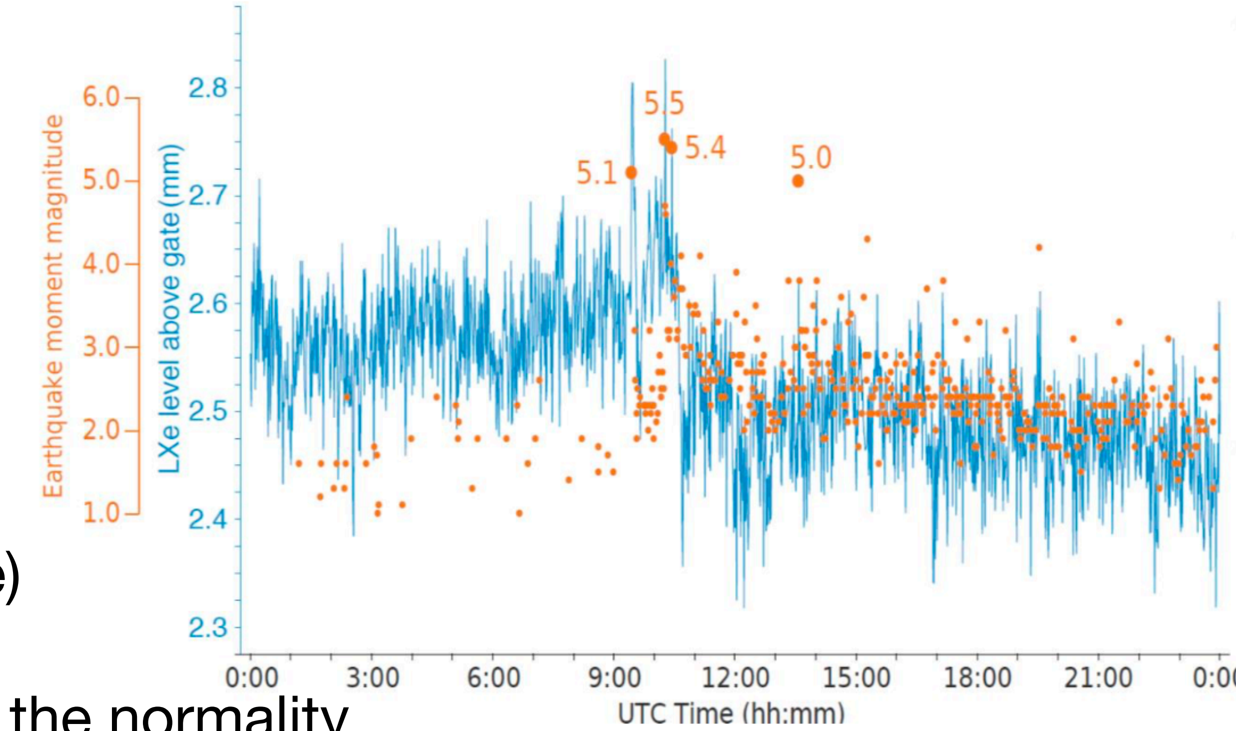
Typical event in XENON1T TPC



Typical event in the Muon Veto



First Dark Matter search campaign

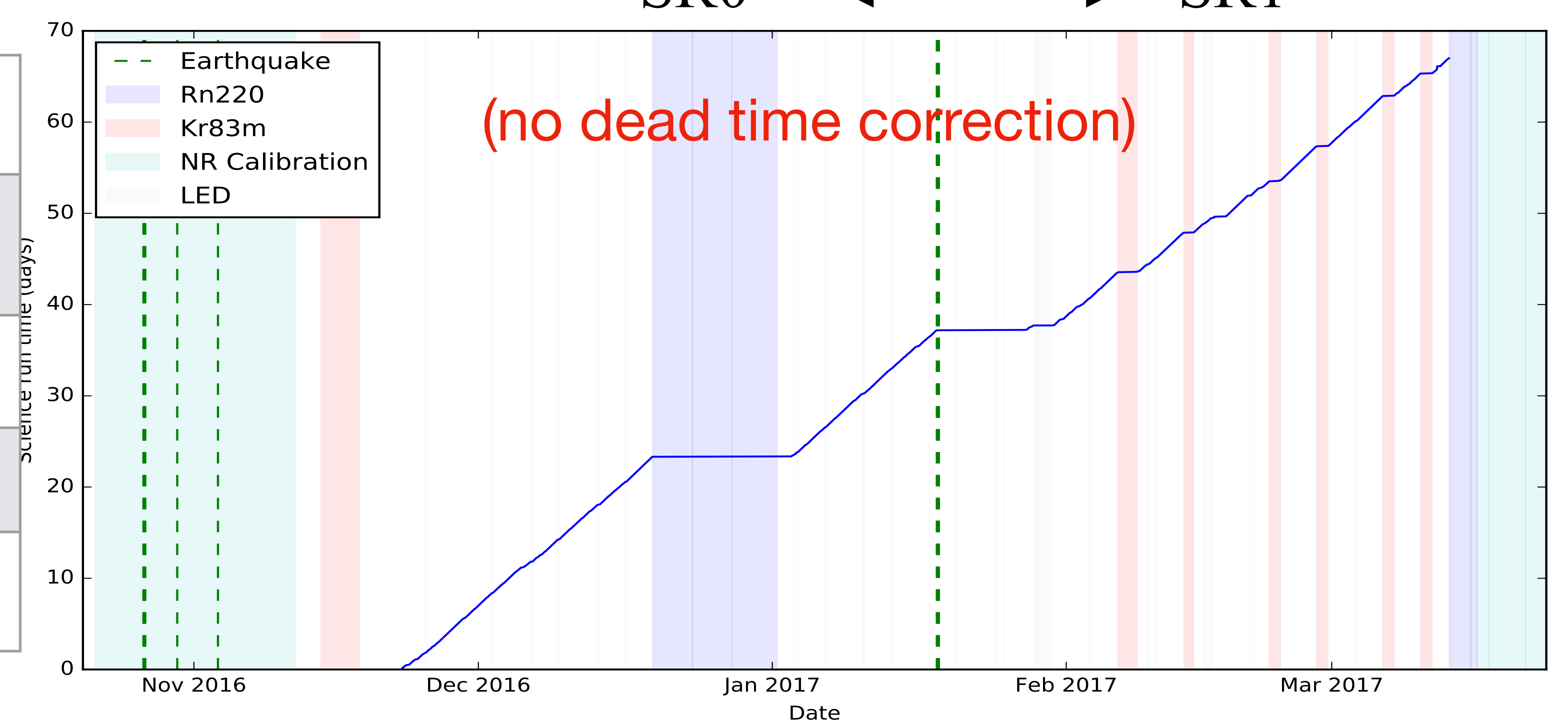


- **34 days** dark matter exposure (dead time corrected)
- NR and ER recoil calibration data
- Interrupted by earthquake of magnitude 5.5
  - Plus one meter snow. (Problems never come alone)
- Access to lab restricted
  - Detector survived. Operations restarted soon after the normality came back.
  - Now over 120 days exposure and counting!

SR0 data

Calendar	56 days
Search data	34.2 days
AmBe	16.3 days
Kr83m	3.3 days
Rn220	3.0 days

SR0 ⟷ SR1



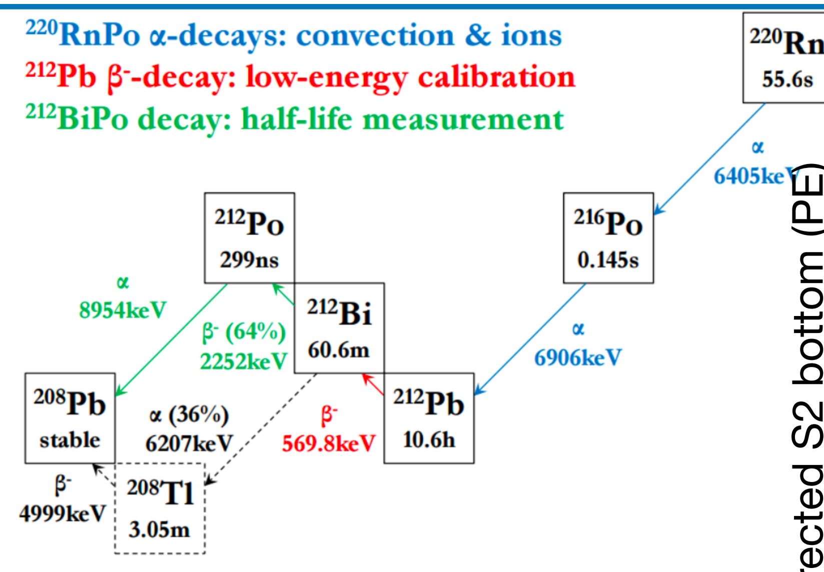
Deadtime since run0 ~ 12%

Deadtime since run1 ~ 1%

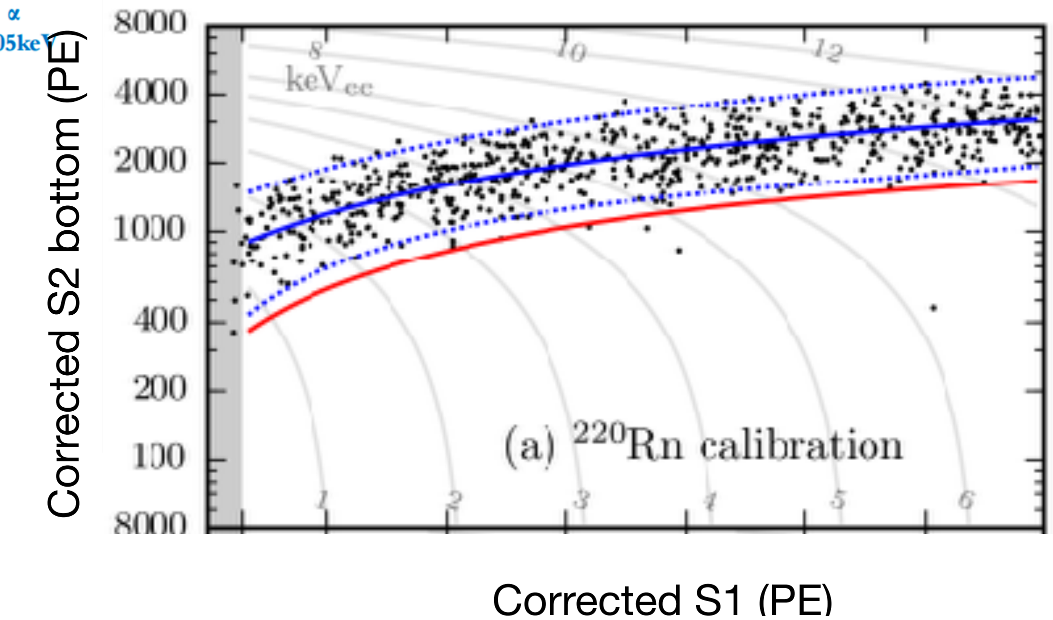
Calibrations I

Electronic Recoil ^{220}Rn

- ^{228}Th source emanates ^{220}Rn directly into LXe
- ^{212}Pb buildup → decays away to ^{221}Bi → low energy ER events

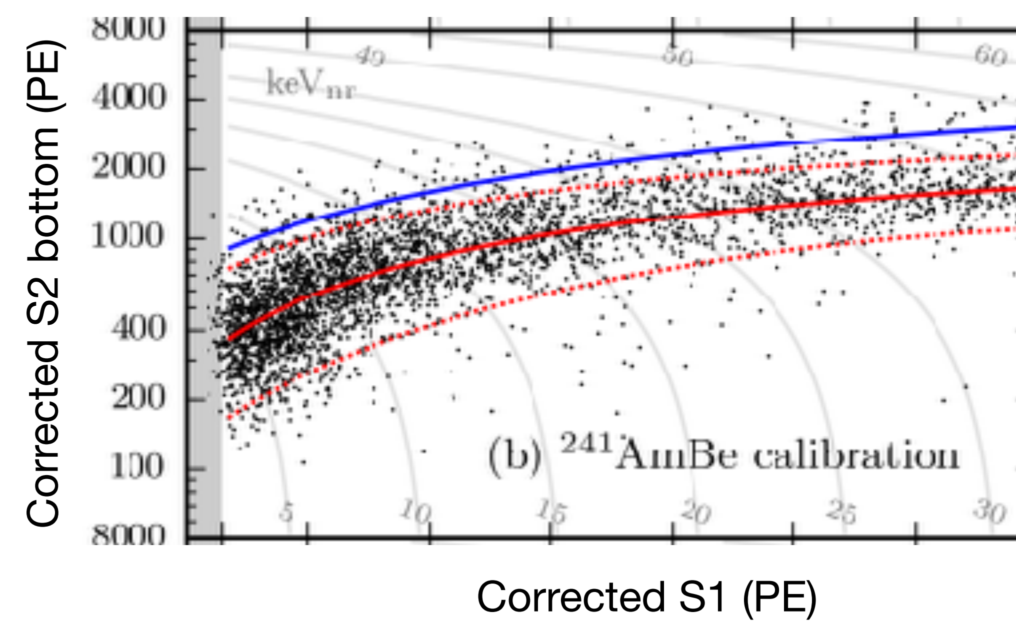


Source S. Breuer Xesat 2017
See also arxiv: 1602.01138



Nuclear Electronic AmBe

- External Source (source belt)
- low energy ER band
- Upgrade to neutron generator
  - Commissioned in May 2017
  - Time needed to calibrate was reduced from weeks to days



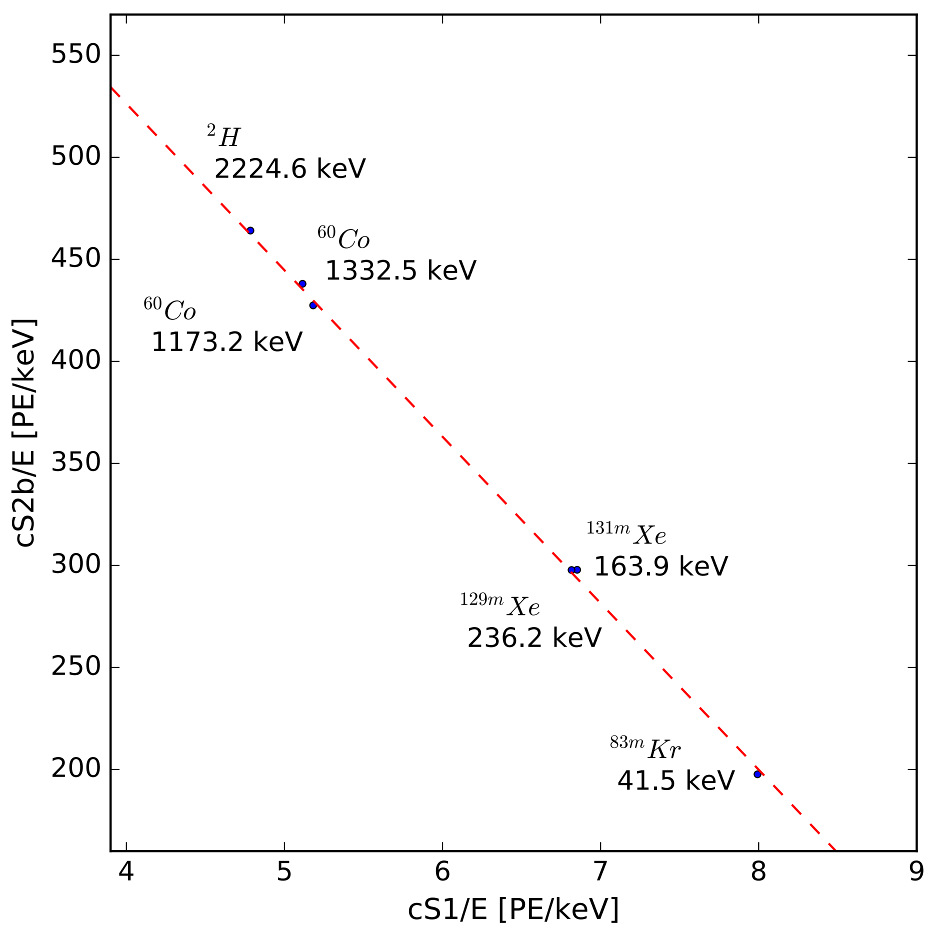
Calibrations II

Energy Response

- Linear from keV to MeV using known calibration sources (LCE~12 %)

$$E = W \cdot (n_\gamma + n_e) = W \cdot (\frac{S_1}{g_1} + \frac{S_2}{g2})$$

$$\frac{S_1}{E} = \frac{g_1}{W} - (\frac{g_2}{W}) \cdot \frac{S_2}{E}$$

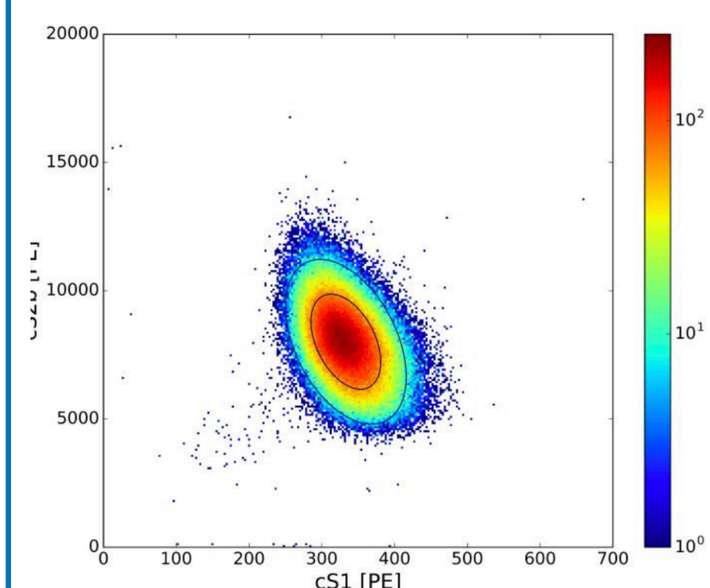


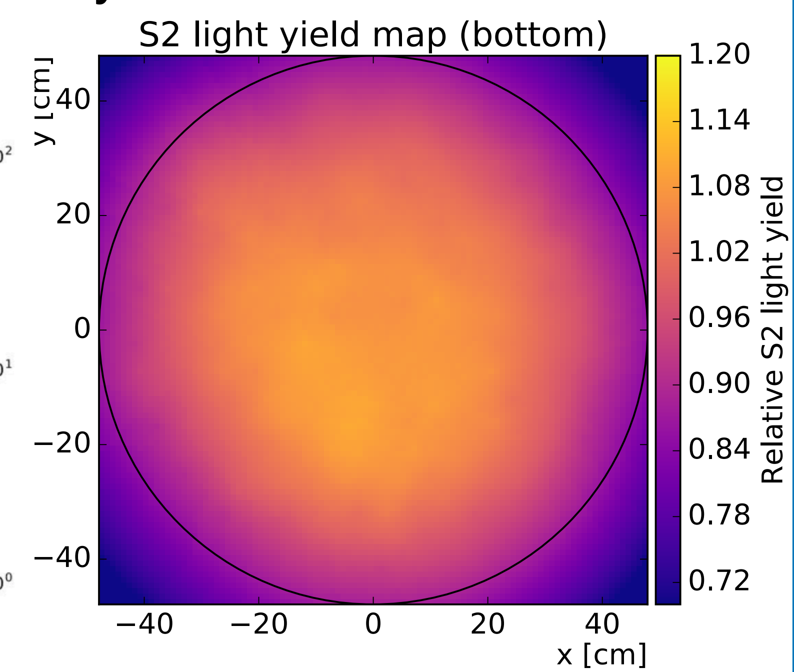
- **g1** = 0.1442 ± 0.0068 PE/photon
- **g2** = 11.5 ± 0.8 (PE/e) (with full extraction)

Calibration with ^{83m}Kr

It is generated by ^{83}Rb decaying with 86.2 days lifetime. ^{83m}Kr decays with 1.83 hours lifetime by means of two conversion electrons.

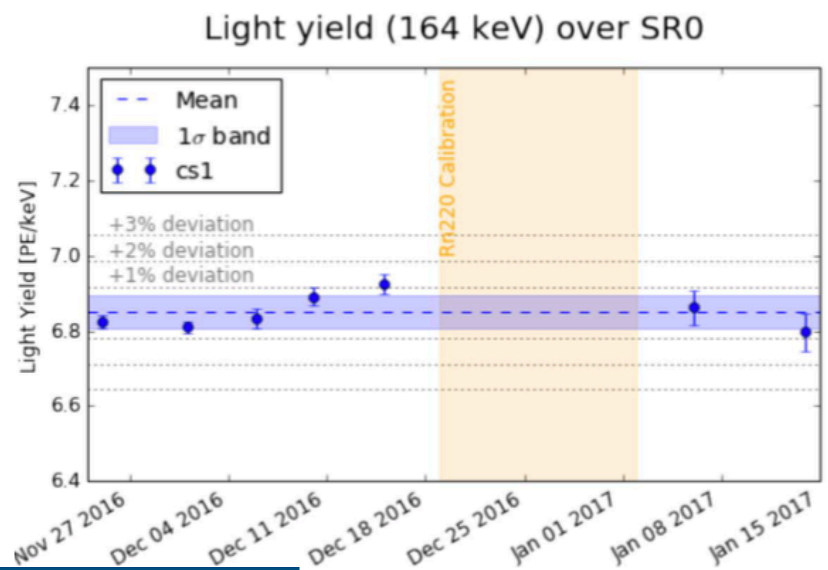
- Internal source (injected into LXe)
  - Homogeneous coverage
- 32.2 keV and 9 keV emissions separated by 152 ns
- used for several corrections
  - Position dependent light correction
  - Position dependent S2 amplification
  - Electric field distortion
  - Electron life-time cross check
  - Light/Charge yield stability

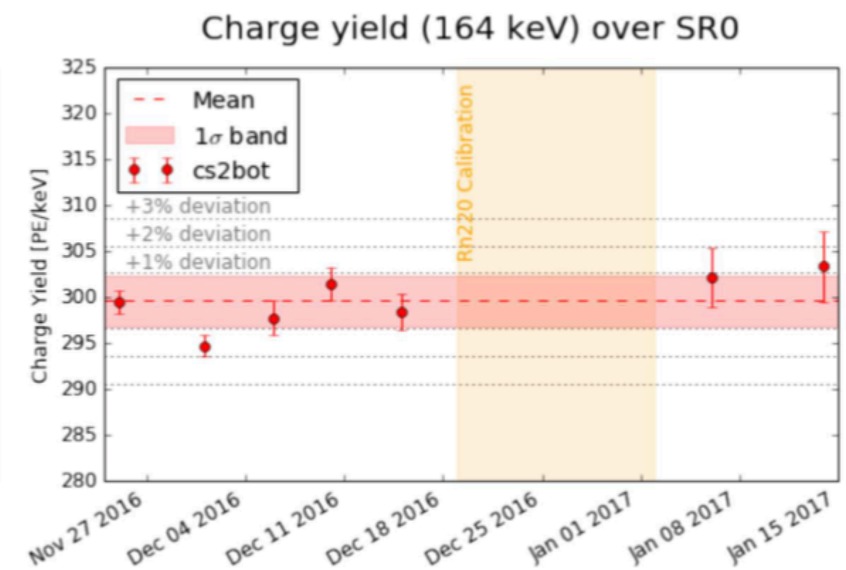




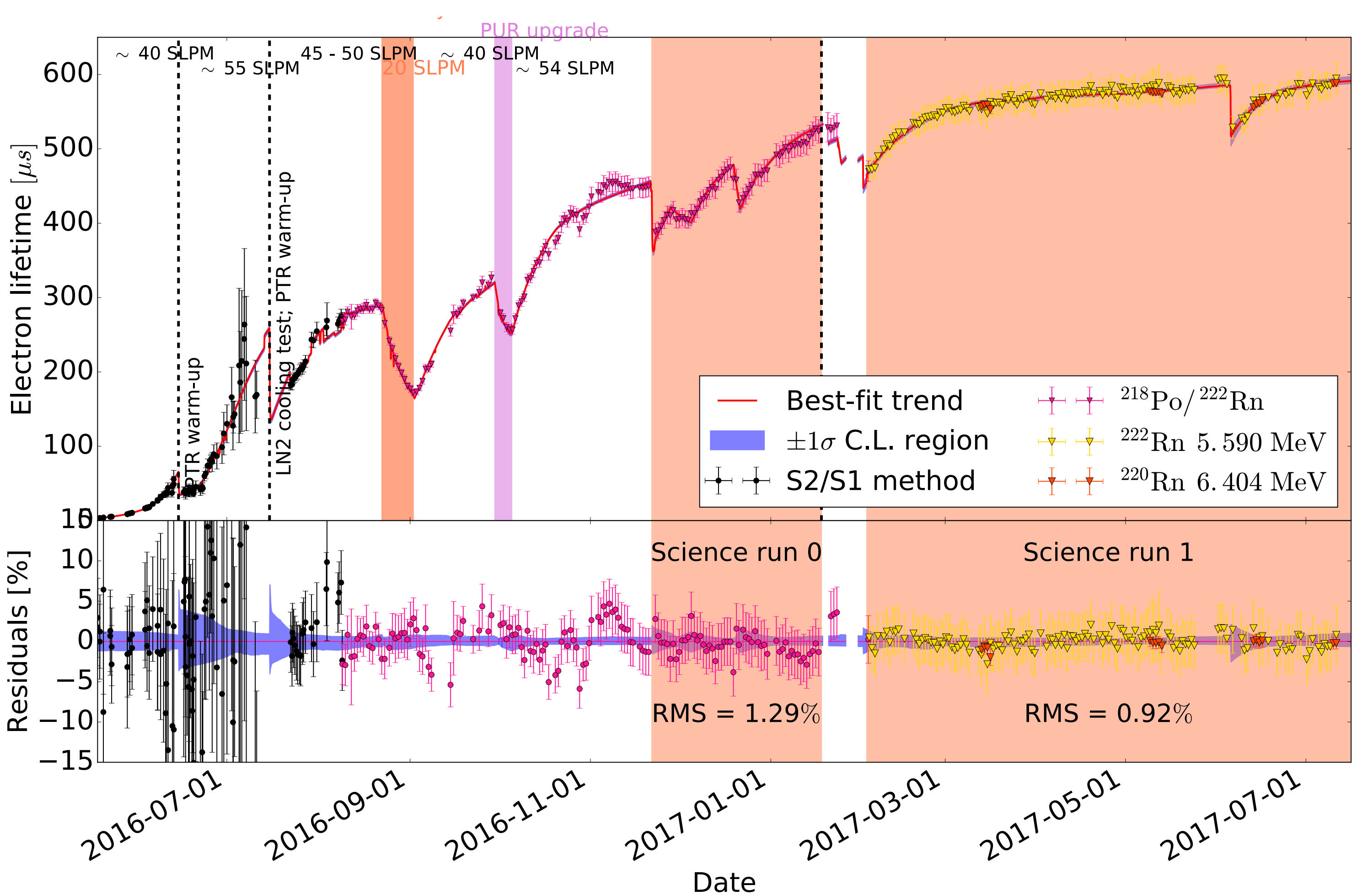
Stability
of working parameters

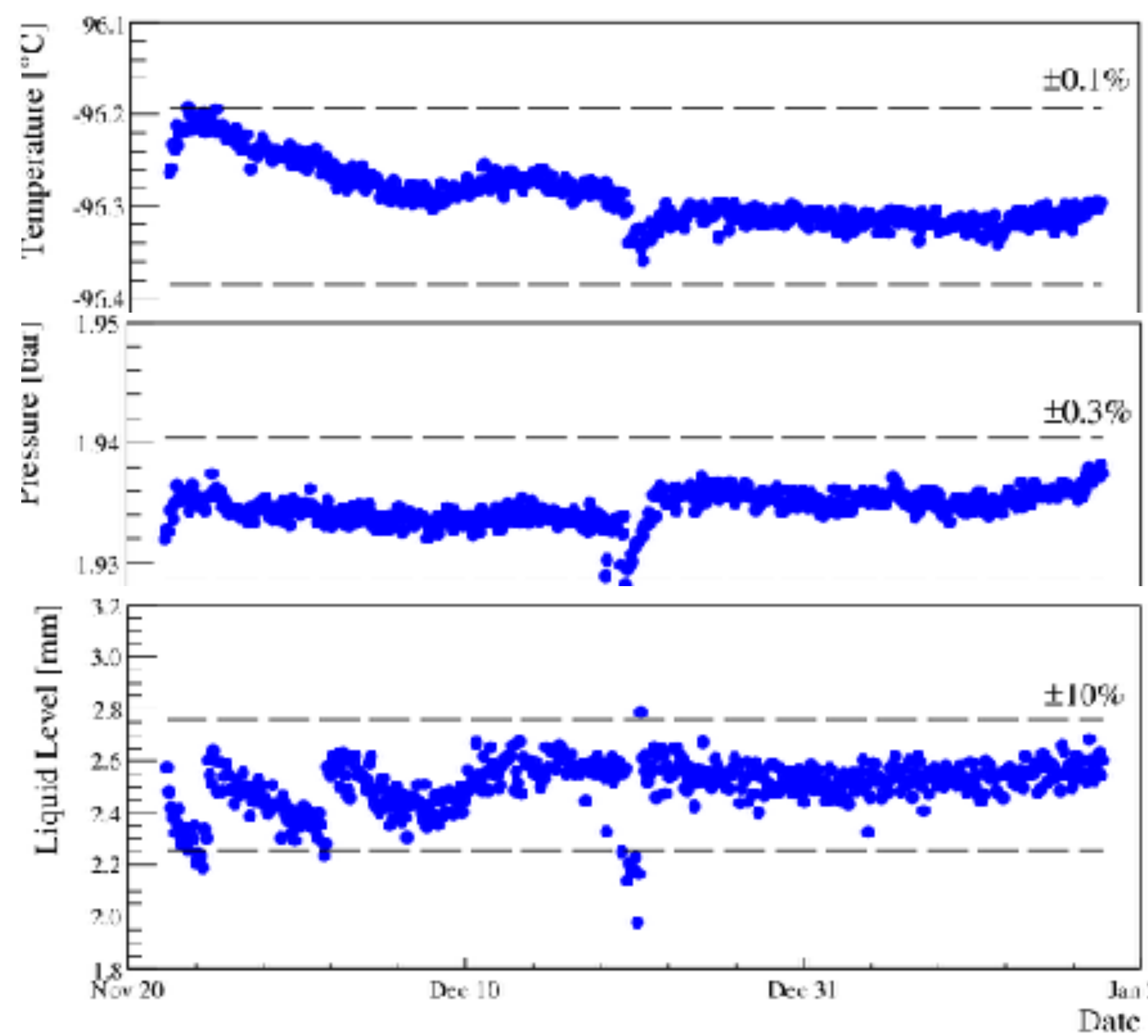
- Light/Charge yield stable within 1%
- ^{131m}Xe (shown) and ^{83m}Kr used for monitoring





- Electron lifetime increased during running time
  - Model as function of physical detector parameters



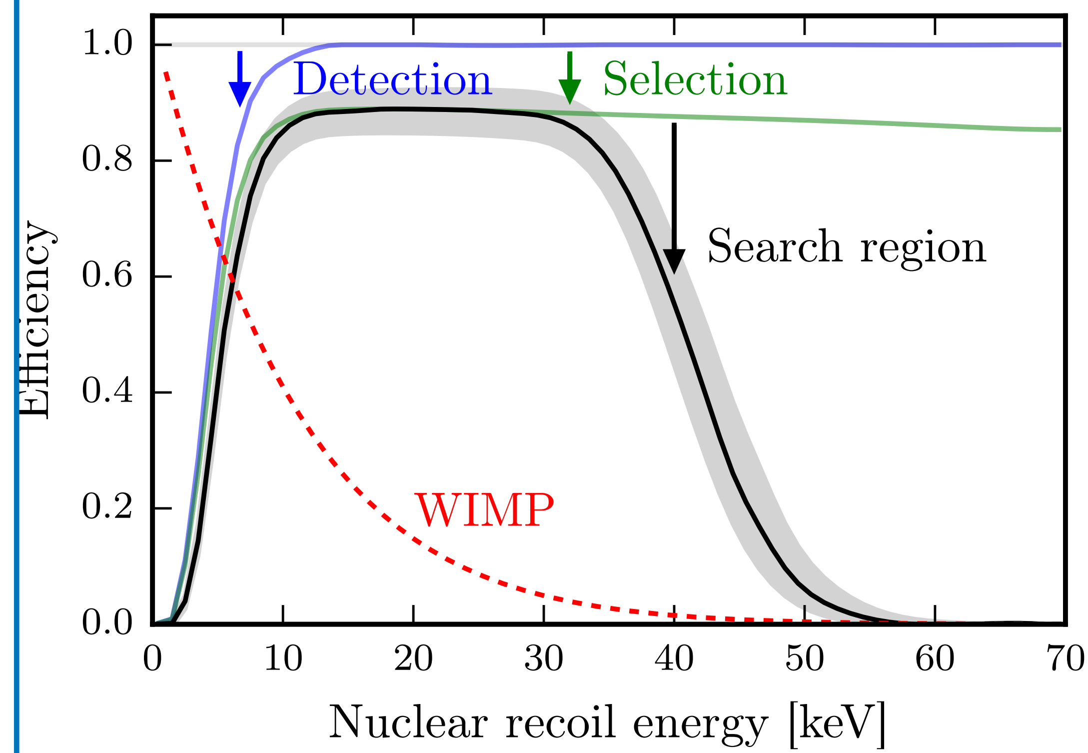


- Working parameters were stable throughout the run

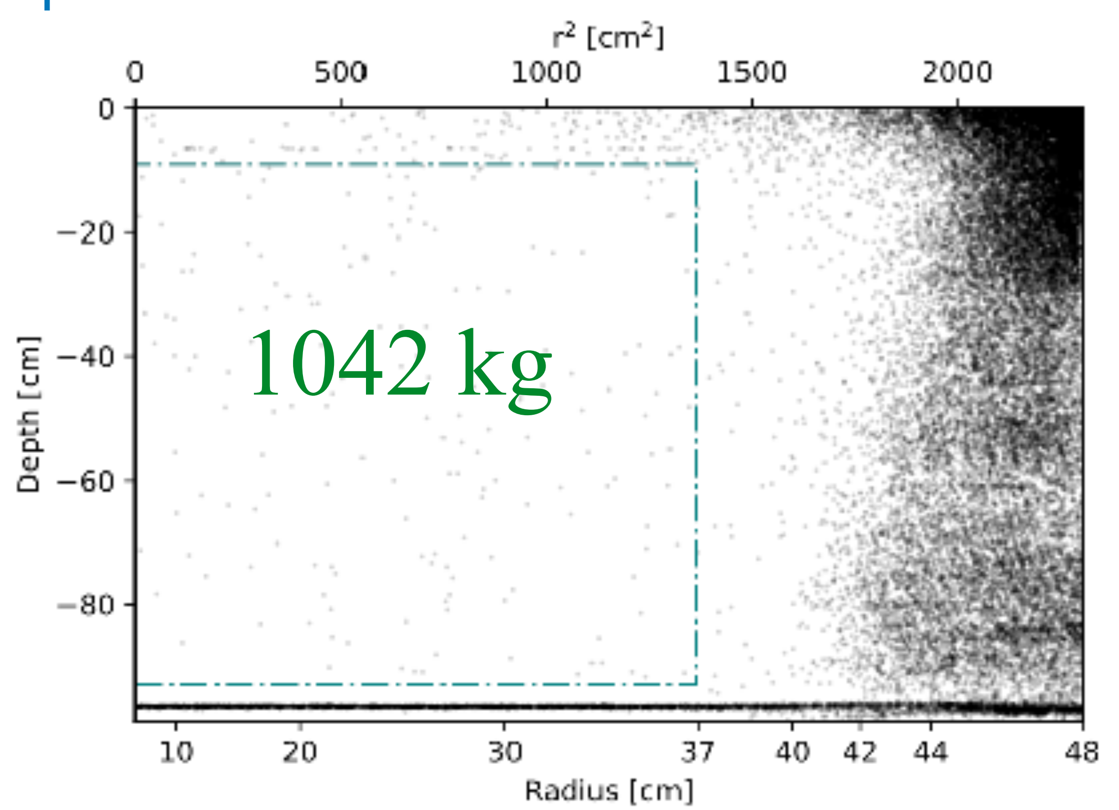
Data Selection

Note: Signal region **blinded** until selection fixed!

- Single-Scatter
  - Only one S2 (>200 pe) per event
- General event quality
  - Event can't directly follow high energy → avoid single e tails
  - Reject noise (uncorrelated signal) before main S2
- Peak Quality
  - Drift time and width of S2 must be consistent
  - S1 and S2 hit patterns must be consistent with reconstructed position
  - Ratio of light seen by top/bottom array consistent with event in liquid
- Fiducial Volume → Cylindrical, 1ton



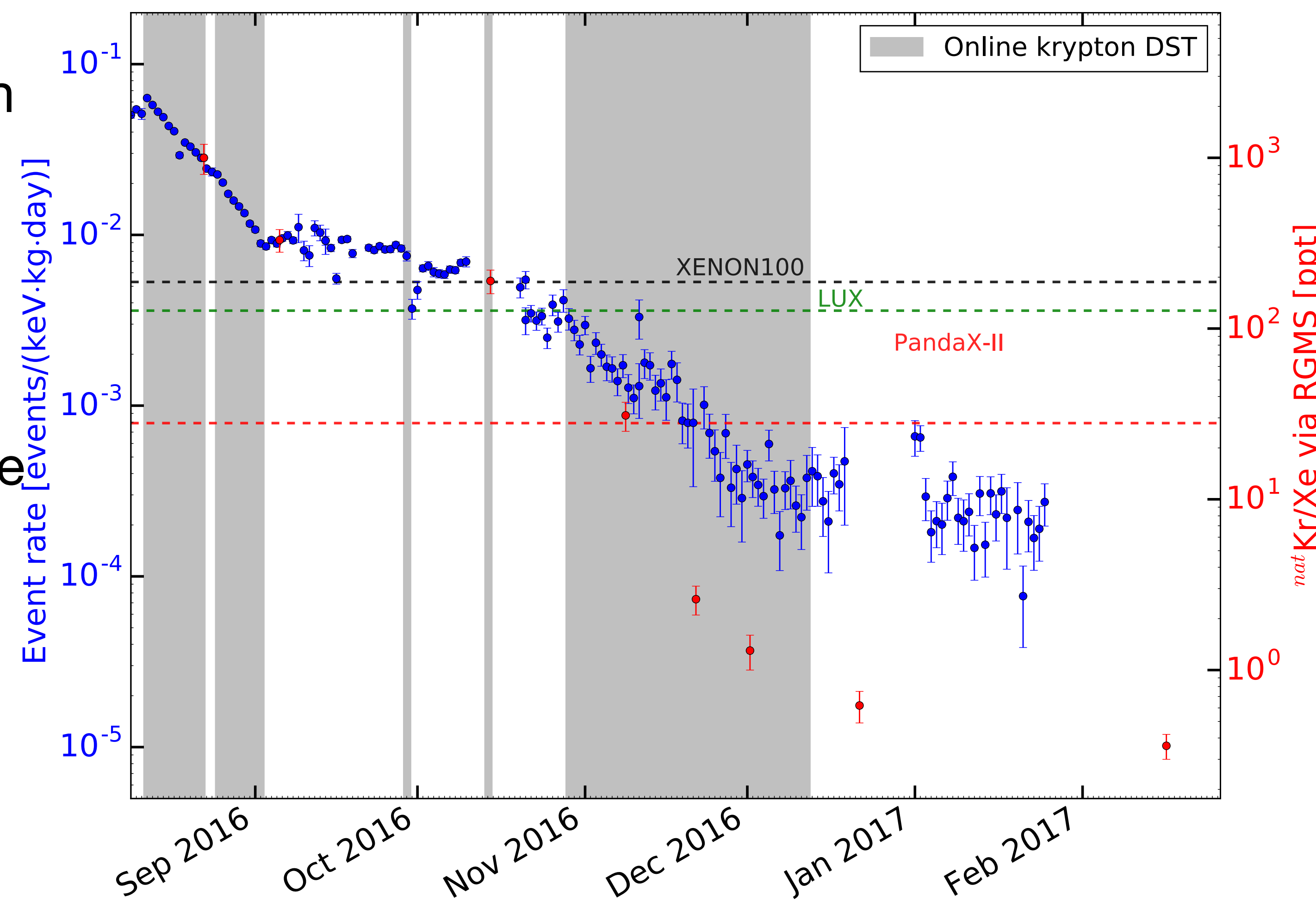
Cut	Events Remaining
All events (cS1 < 200 PE)	128144
Data quality, selection	48955
Fiducial volume	180
S1 Range (3 < cS1 < 70 PE)	63



Background in the ER channel

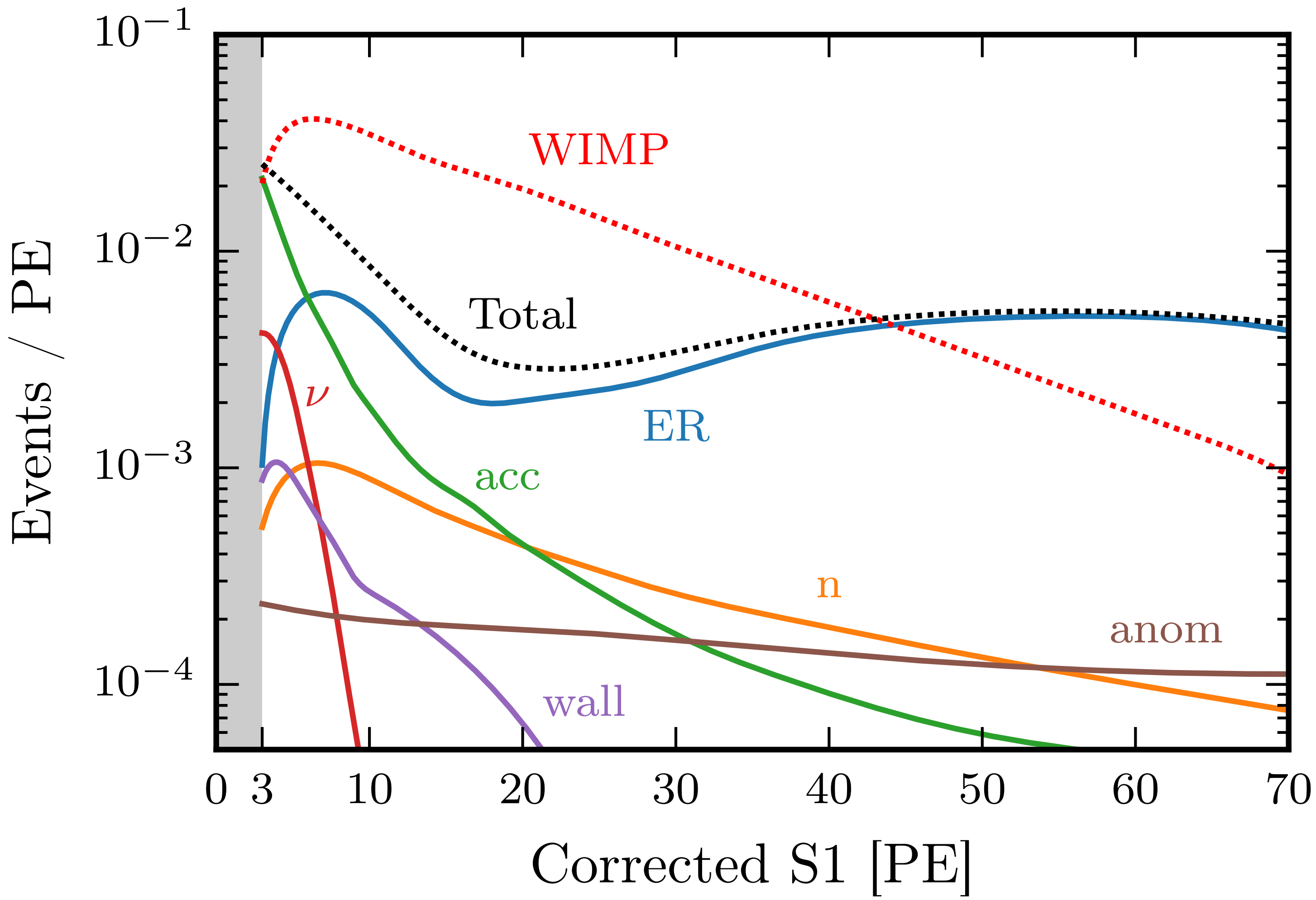
Background events are mainly generated by impurities present in any components of the detector, by surfaces emanation and by impurities present in the Xe itself.

- Online Krypton distillation
  - ^{85}Kr background ^{nat}Kr/Xe <0.048 x 10^{-12} (<48 ppq) at the output of the distillation column while in the TPC it is ^{nat}Kr/Xe = (0.36 ± 0.06) ppt
  - ER background radon dominated
- ^{222}Rn chain
  - Emanation from detector materials
    - Extensive screening program
    - Lowest possible emanation materials chosen
    - Surface treatments for internal components
  - **10 μBq/kg target concentration reached**
  - Further reduction possible (XENONnT)
    - Rn distillation in XENON100 → 27 x decrease
      - See arxiv:1702.06942
    - First tests in XENON1T promising



See arxiv: 1612.04284 and S. Lindeman, H. Simgen, Eur. Phys. J. C 74, 2746 (2014)

Background Evaluation in Run0

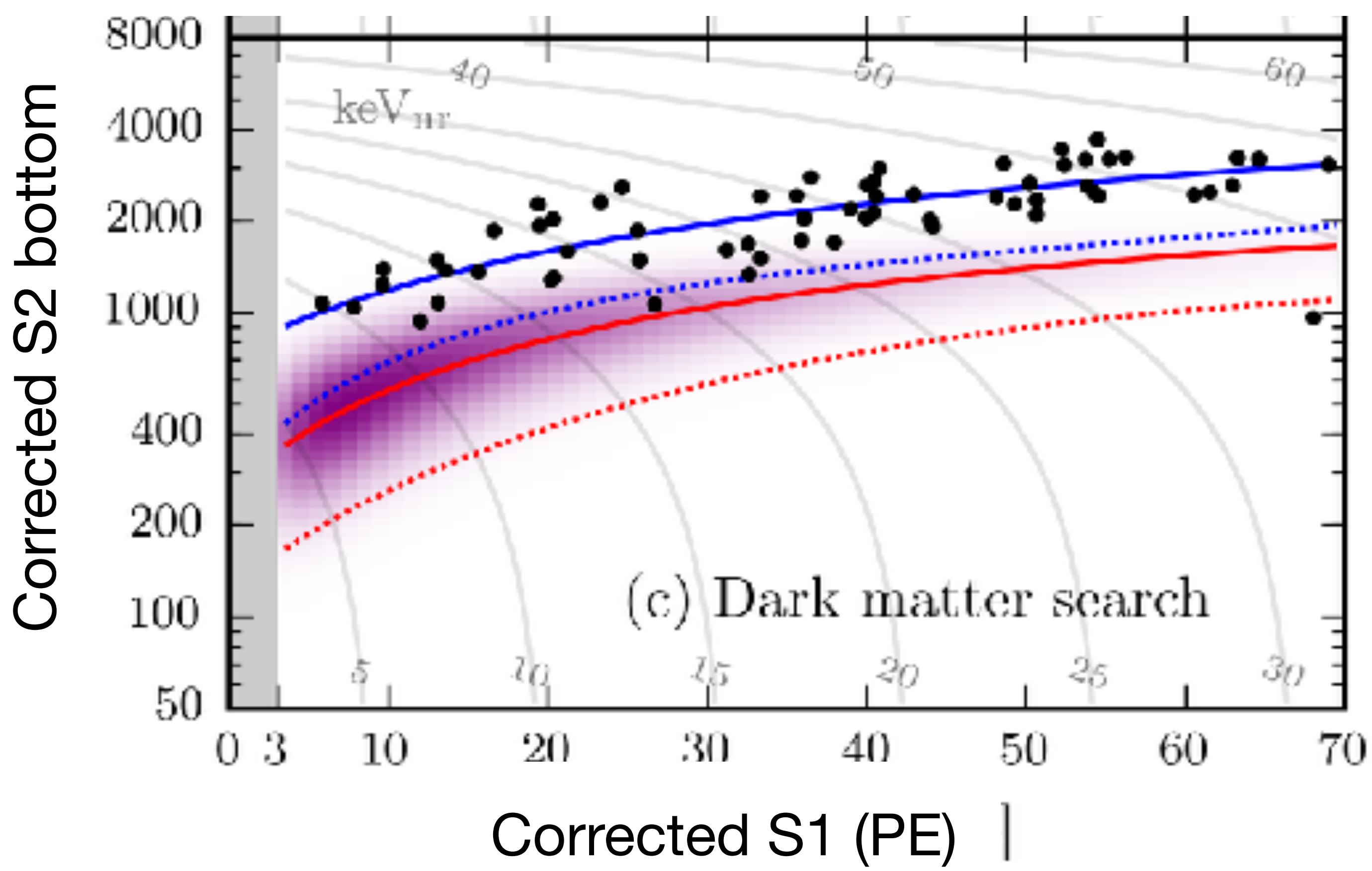


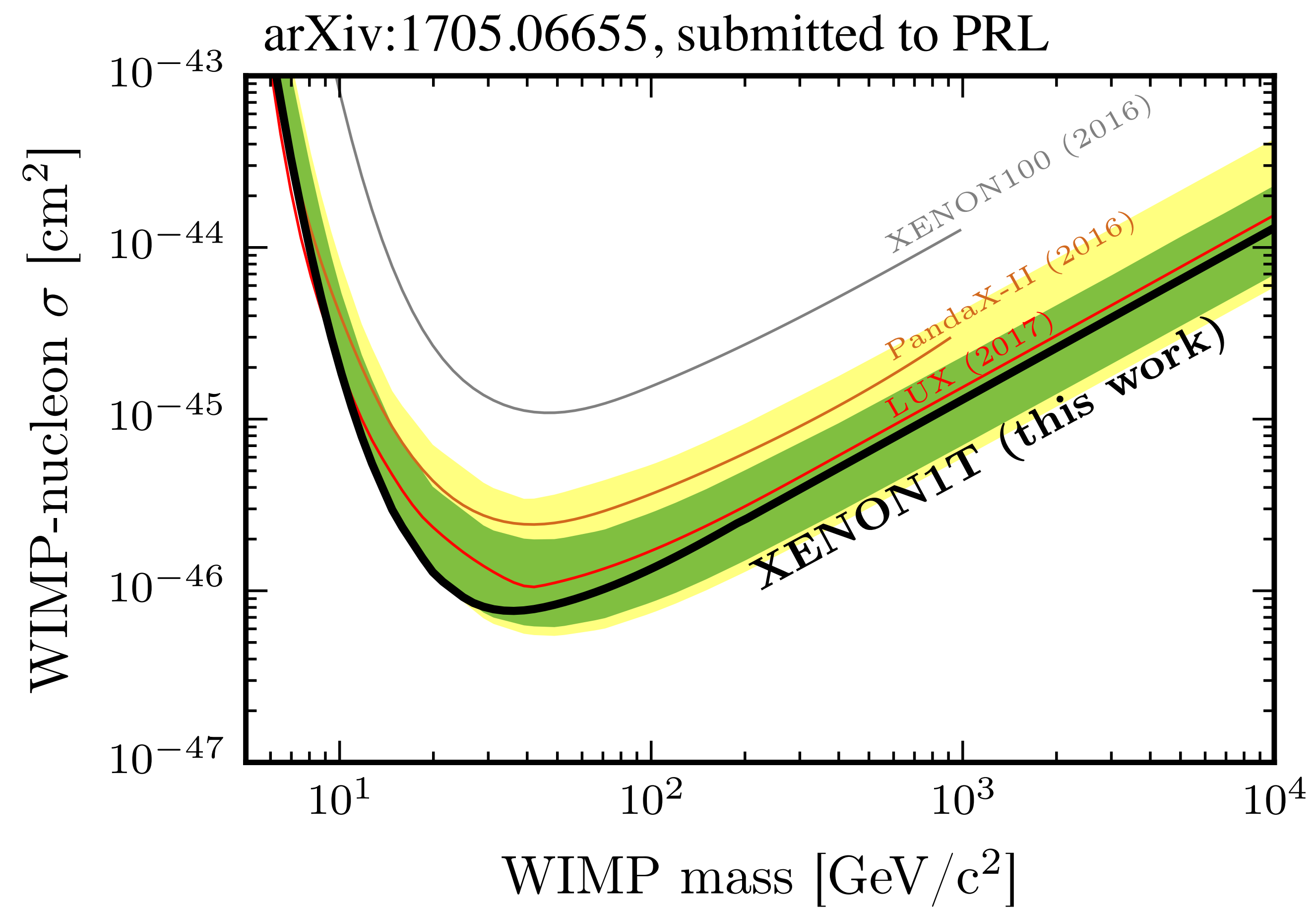
Expected WIMP rate calculated assuming $WIMP_M$=50 GeV/c^2 and σ ~$10^{-46}$$cm^2$

ER and NR spectral shapes derived from models fitted to calibration data

Background	Total	NR median -2σ, 3–70 pe
Electronic recoil	(62 ± 8)	0.25 (+0.10)(-0.07)
Rediogenic 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)	(0.52±0.32)	0.01
Anomalous (anom)	0.09 (+0.12) (-0.06)	(0.01±0.01)
Total background	(63±8)	0.36±0.09

First Result from Dark Matter Search





- Extended un-binned profile likelihood analysis
- No changes on event selection after unblinding
- Most significant ER & NR shape parameters inferred from cal. fits
- Most stringent limit on SI cross section between WIMPs and nucleons happens to be at 35 GeV of WIMP mass and it is 7.7 x 10^{-47} cm^2 @ 90 C.L

XENONnT: the next step

XENONnT is a rapid upgrade of the XENON1T detector:

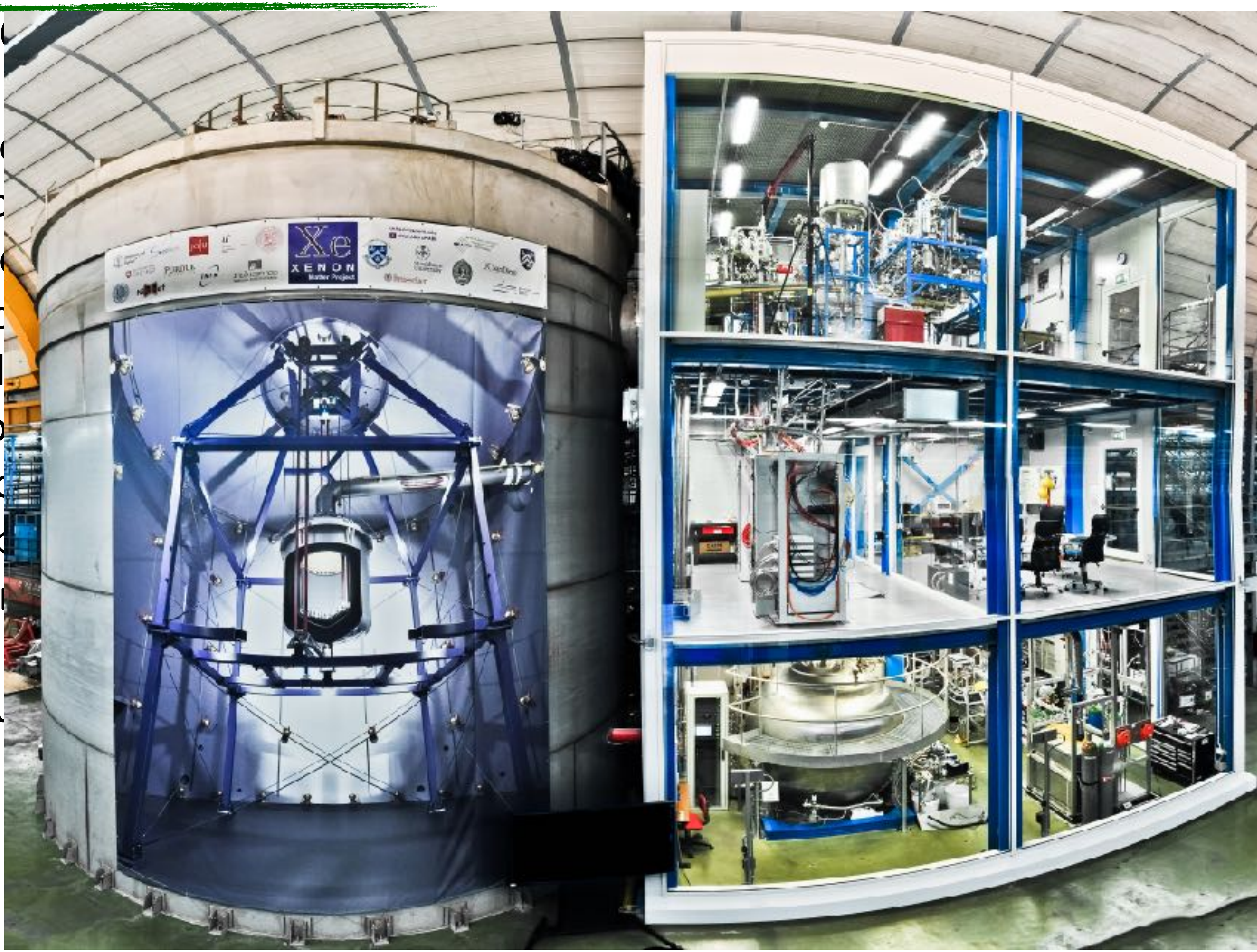
- New inner cryostat vessel inside the same outer vessel
- Total LXe mass will be ~8 t with 6 t active- x3 more than XENON1T
- New TPC structure with increased diameter and height (x1.4), additional PMTs (and electronics): 248 -> 476
- All other systems can handle a larger detector with a target mass of up to 10t: Cryogenics, Purification, Recovery, Support structure, DAQ, Slow Control, Muon veto. Their established performance will enable the operation of XENONnT on a fast timescale.
- Under study the need of a modular nVeto around the detector

- Current schedule: start XENONnT in early 2019

XENONnT: the next step

XEN

- N
- To
- Ne
  ac
- Al p
  to w
  Co
  op
- Ur
- Cu



Conclusion and Outlook

XENON1T leads the world sensitivity

- 34 live days published
- > 120 live days on disk and more are coming!

Messages

- First ton-scale LXe TPC has given results
- The detector with lower BG rate: 1.93 x10^{-3} ± 0.25 events/(kg x day x keV)
- Many more blinded data are ready to be analyzed
- XENON1T upgrade (XENOnT) is underway