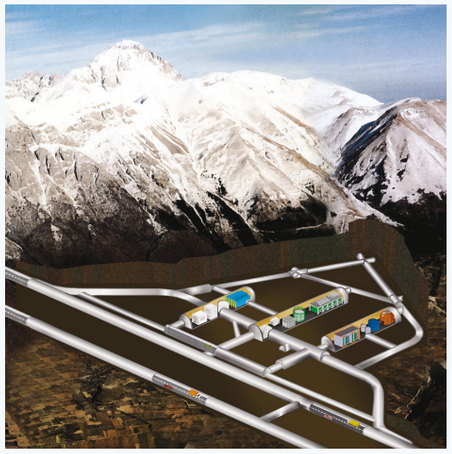
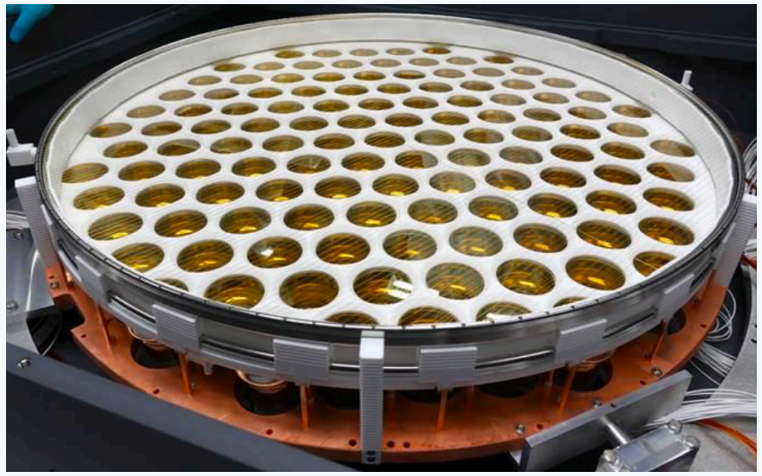
First Results

from the

XENON1T Dark Matter Experiment





Michelle Galloway

on behalf of the

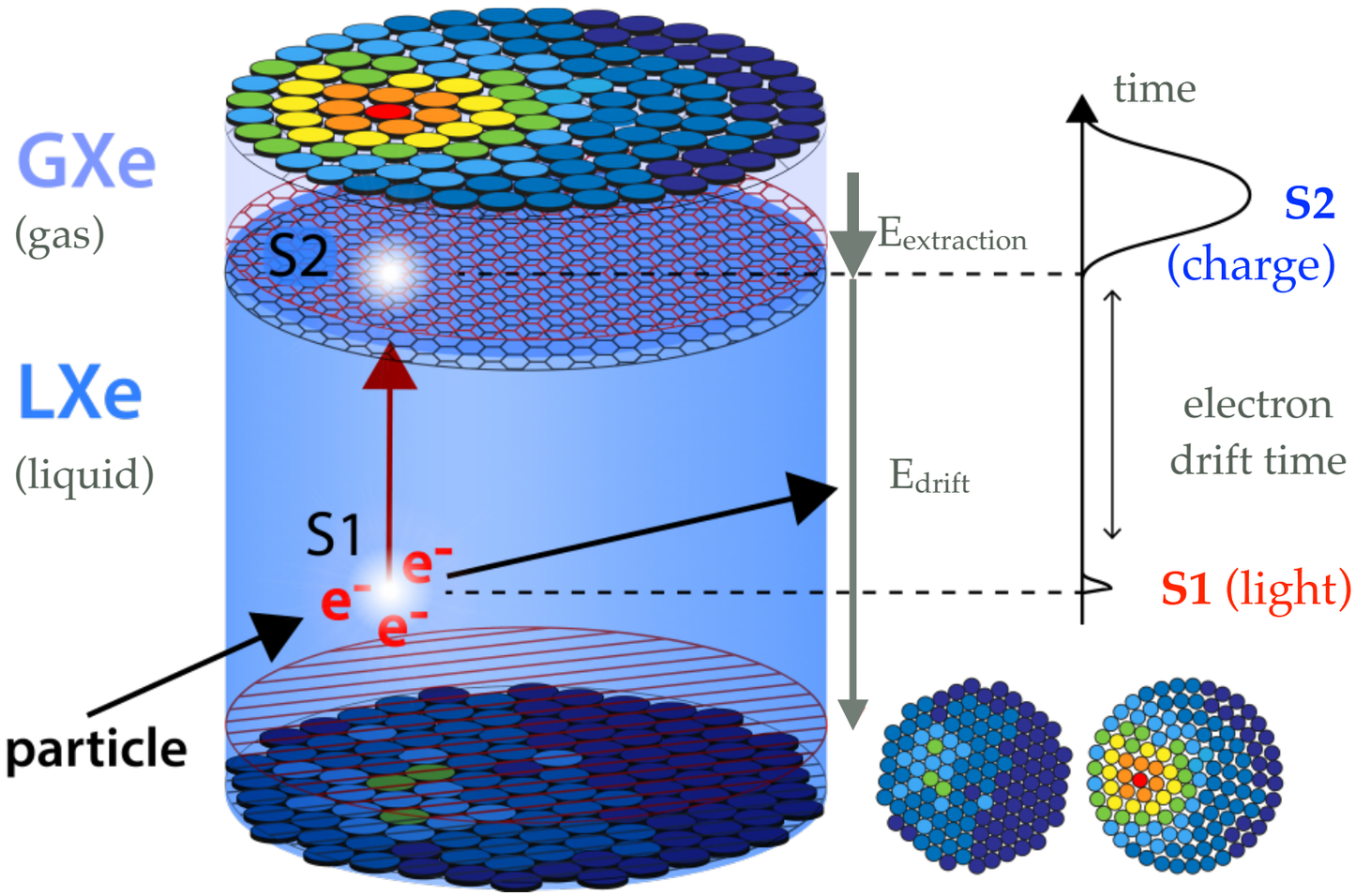
XENON Collaboration

European Physical Society Conference on High Energy Physics

Venezia, July 6-12, 2017

Direct Detection with Liquid Xenon TPCs

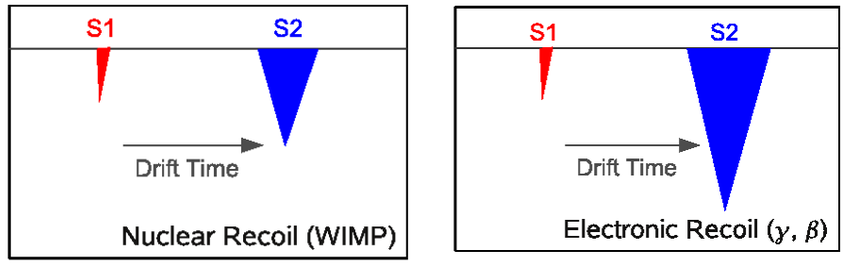
Dual-phase Time Projection Chamber (TPC)



Event Type Discrimination

- nuclear recoils (WIMPs, neutrons) have higher-density tracks than electronic recoils (gamma, beta): more recombination, less charge
- charge and light signals are anti-correlated:

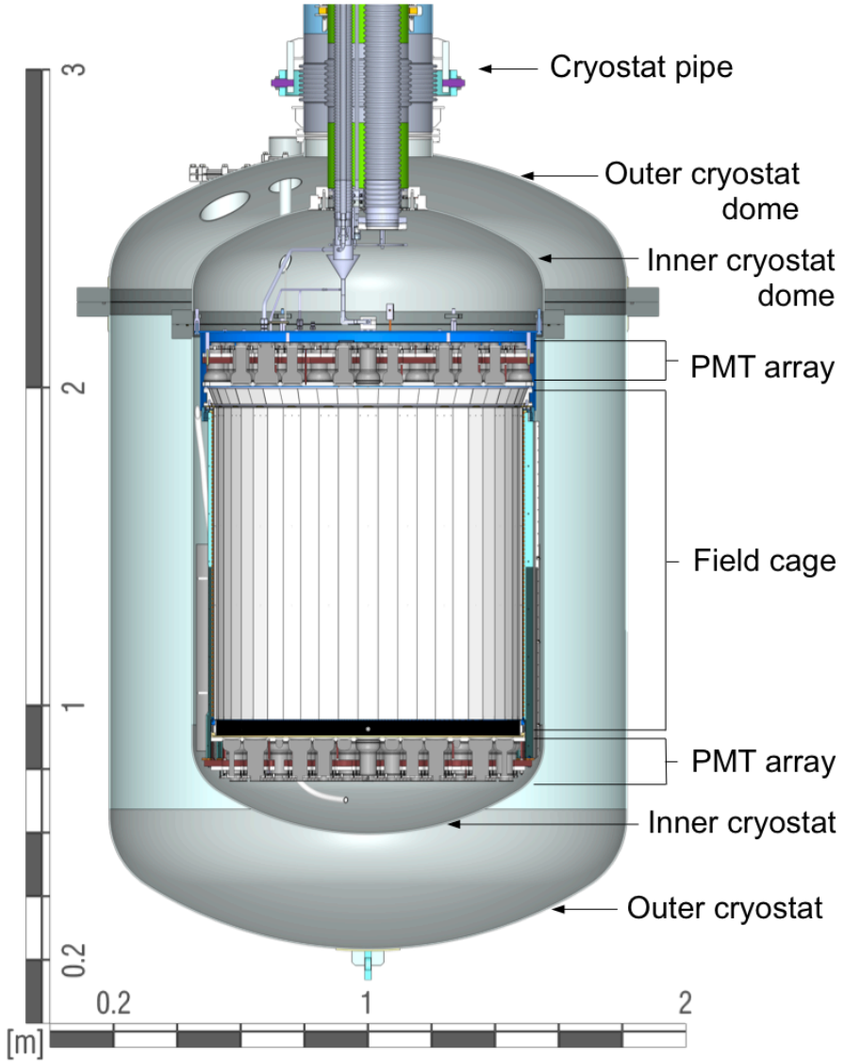
$$\frac{S2}{S1_{NR}} < \frac{S2}{S1_{ER}}$$



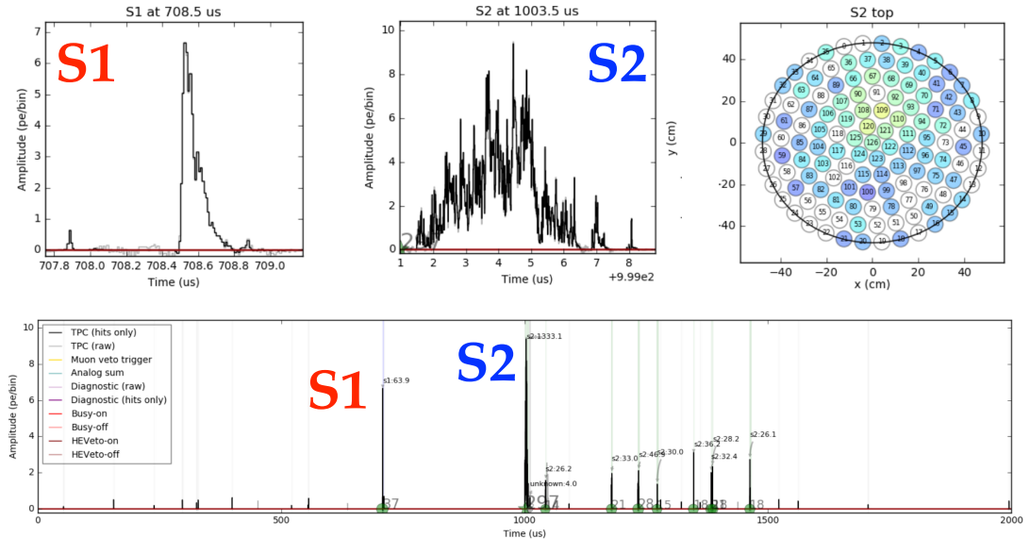
Vertex Reconstruction: Fiducialization

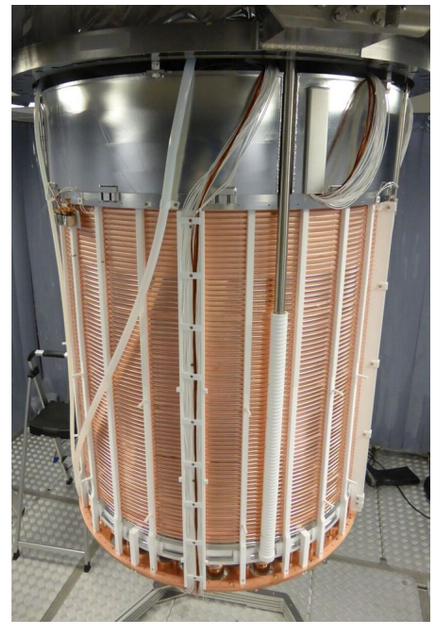
- depth (z) from electron drift time
- x-y from S2 hit pattern

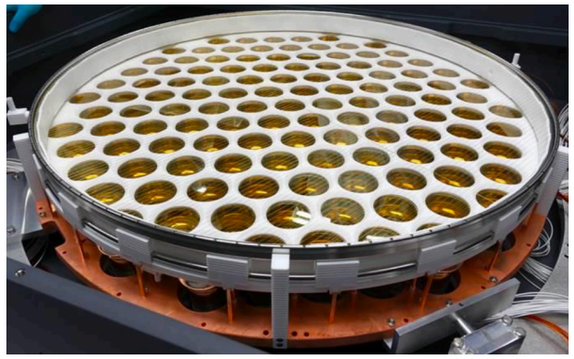
The XENON1T TPC



Example Waveform







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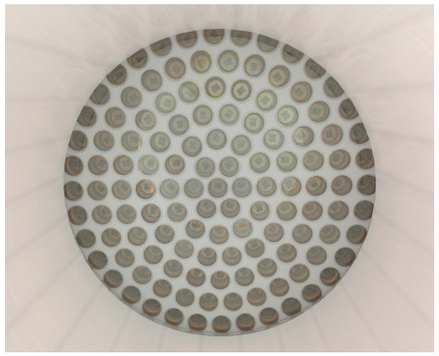

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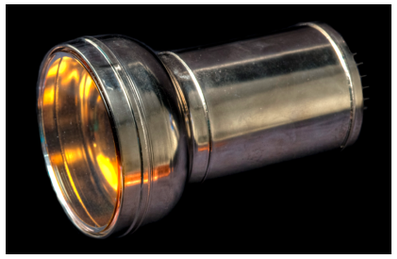


Hamamatsu R11410

TPC

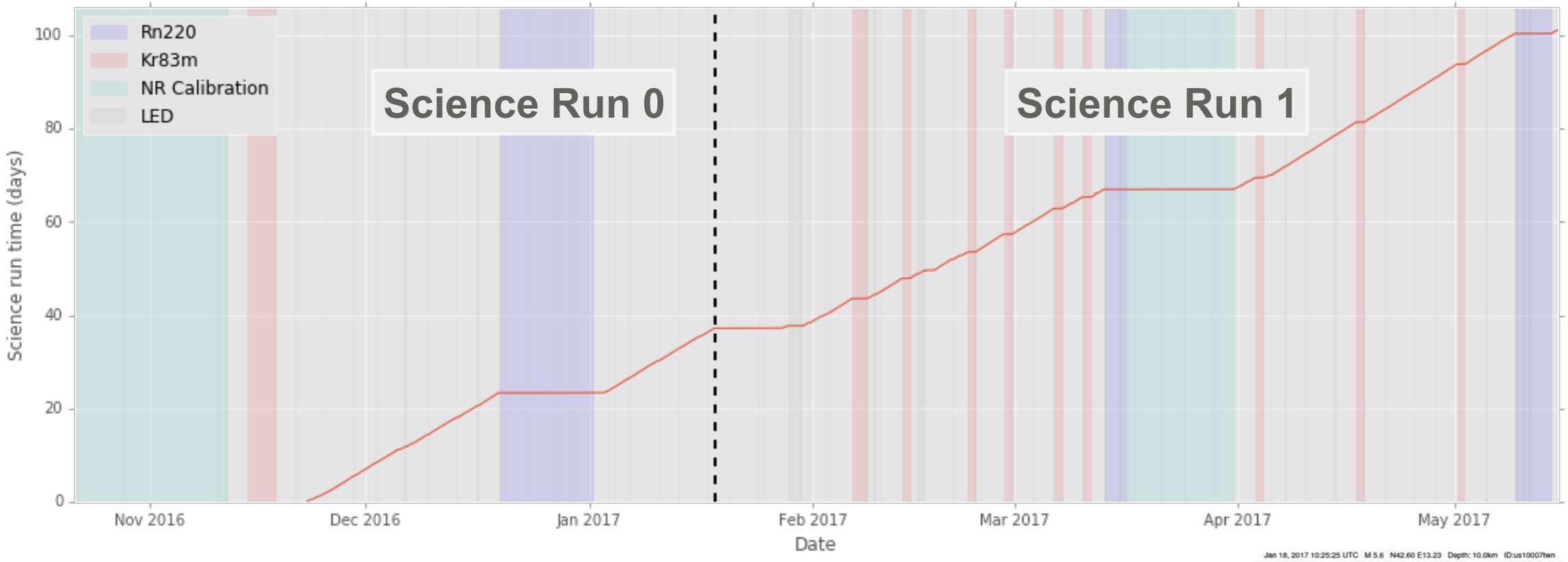
- 1x1 m volume: 2 tons LXe (3.2 t total)
- high reflectivity PTFE inner surfaces
- E_{drift} 120 V/cm, $E_{extraction}$ >10 kV/cm

PMTs

- High QE ~34% @175 nm
- average gain ~5×10^6 @ 1500 V
- cryogenic, low-radioactivity

Eur. Phys. J. C75, 11, 546 (2015)
JINST 8, P04026 (2013)
JINST 12, P01024 (2017)

First Science Run



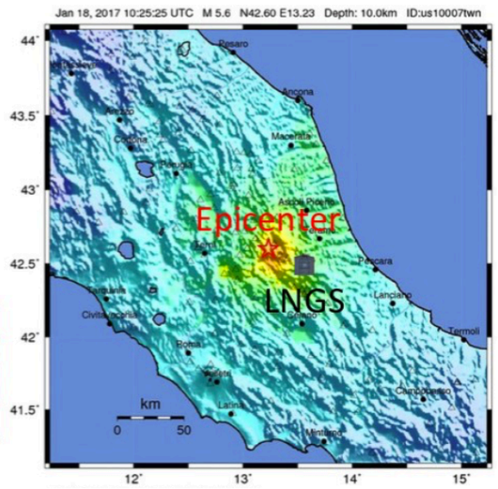
34.2 live days dark matter exposure

3.0 days ^{220}Rn for low-energy electronic recoil band calibration

16.3 days ^{241}AmBe for low-energy nuclear recoil calibration

3.3 days ^{83m}Kr: for spatial response correction

Geological interruption defined first science run;
Still running with more than 130 days exposure.

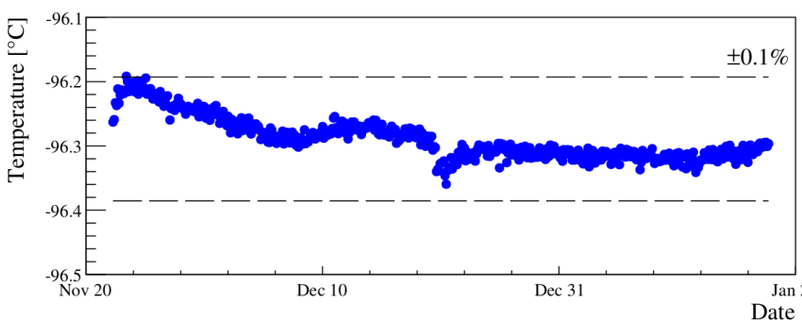


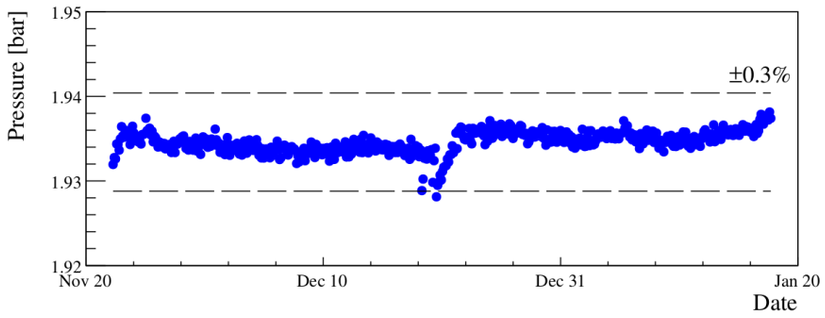
Earthquake magnitude 5.5
Jan. 18, 2017

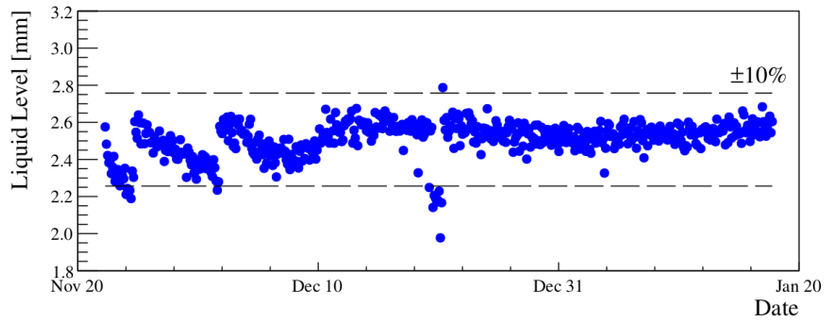
Detector Stability

All critical detector parameters were stable throughout run:

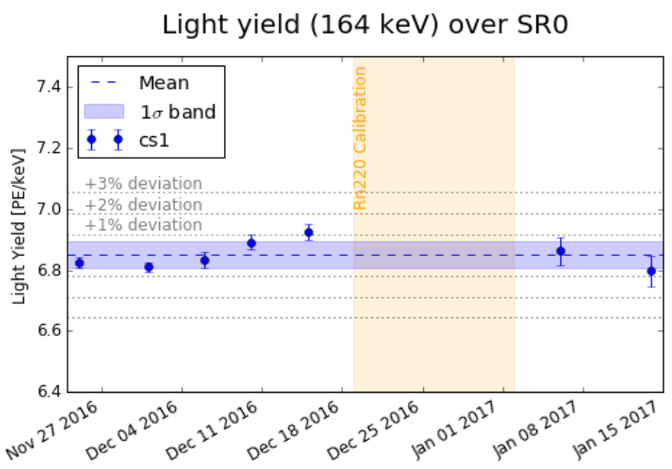
- LXe temp: (177.08 ± 0.04) K
- GXe pressure:(1.934 ± 0.001) bar
- LXe level: (2.5 ± 0.2) mm

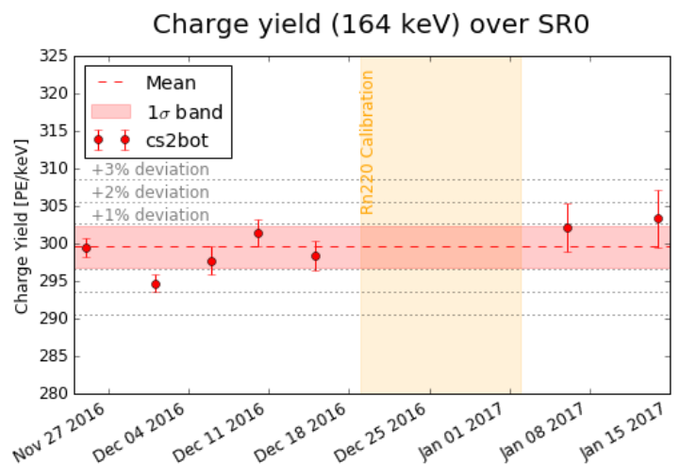


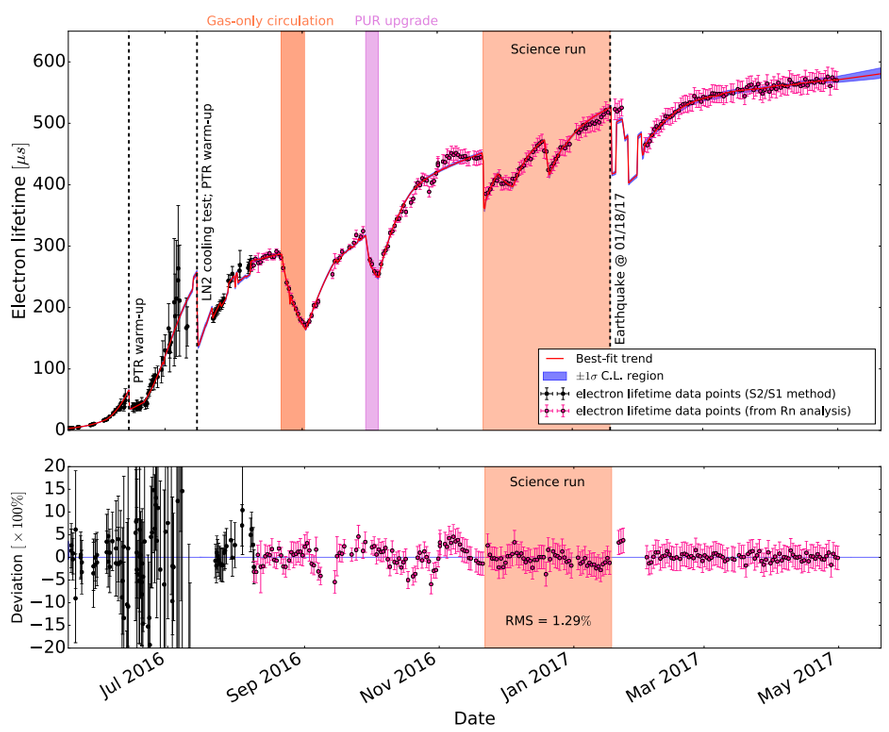




Light and Charge Yield stable within 1%
monitored using internal sources (^{131m}Xe, ^{83m}Kr)





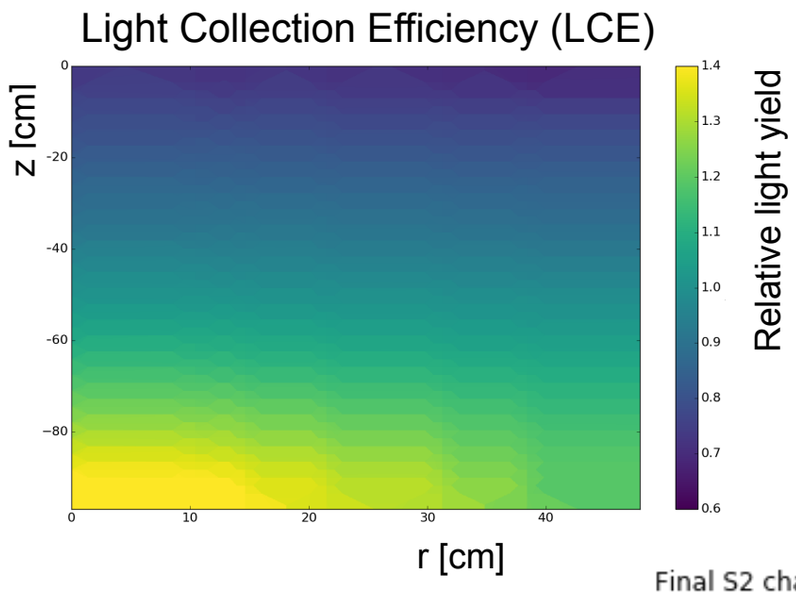


Electron Lifetime

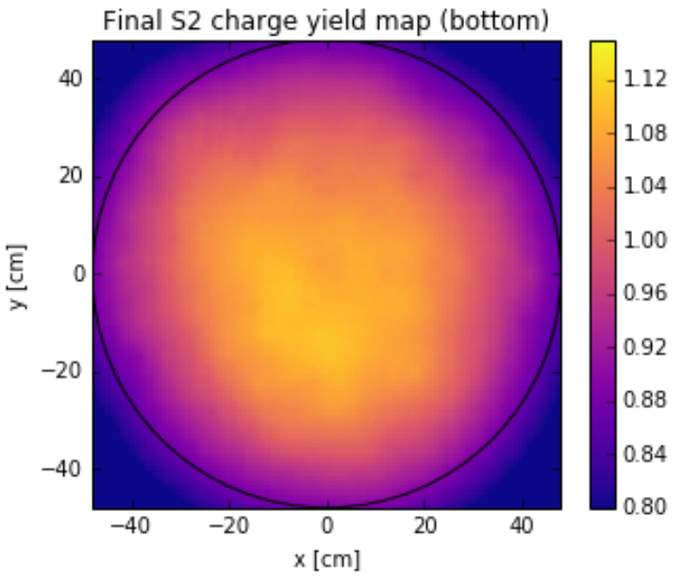
- increased from 350 μs to 500 μs (average 452 μs, max. drift 673 μs)
- continuous recirculation and purification with hot metal getters

Calibrations

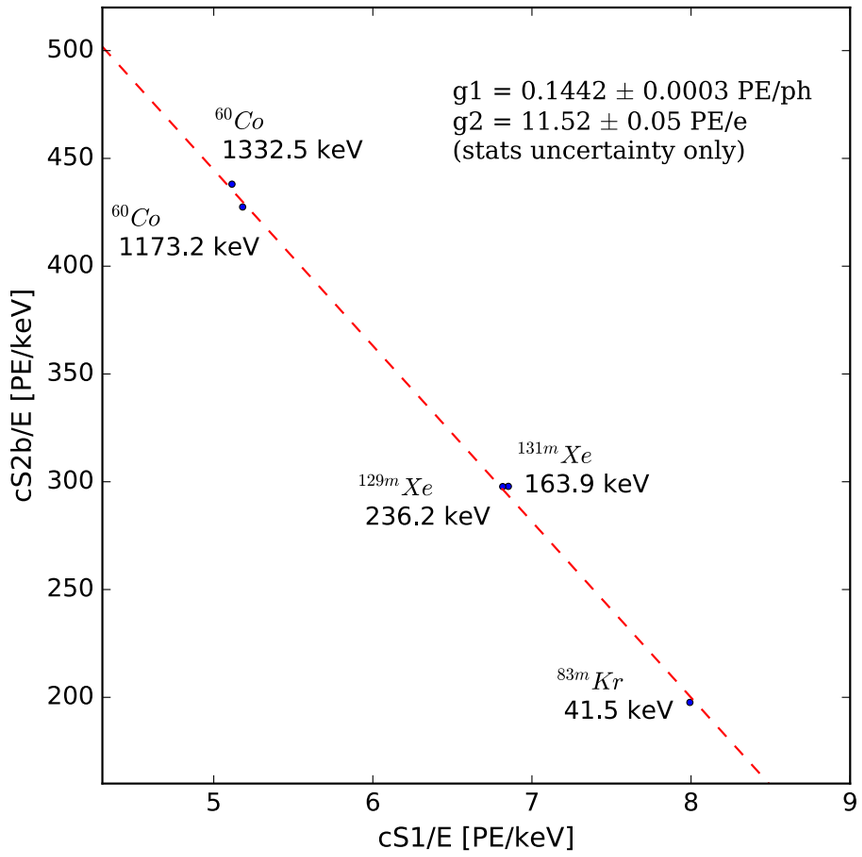
Signal corrections for electron lifetime and spatial response (^{83m}Kr)



Spatial calibration for
- electric field non-uniformities
- interaction position dependent LCE
- position dependent S2 amplification



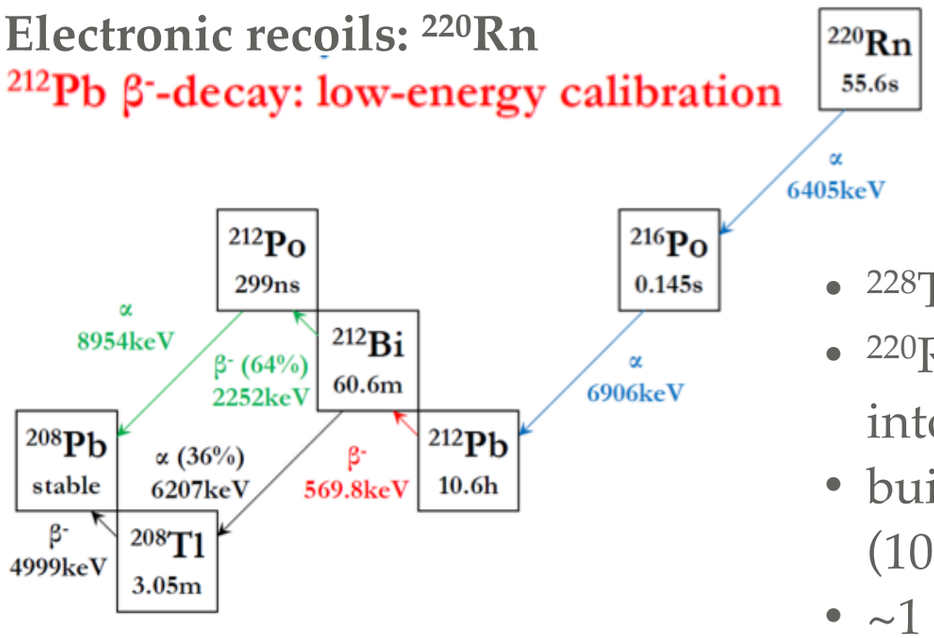
Energy scale
- linear from keV to MeV using known calibration sources (^{83m}Kr, ^{129m,131m}Xe, ^{60}Co)
- **g1** = 0.1442 ± 0.0068 (sys) PE/photon
- light detection efficiency (12.5 ± 0.6)%, Monte Carlo prediction 12.1%
- **g2**= ~100% charge extraction



Calibrations

Electronic recoils: ^{220}Rn

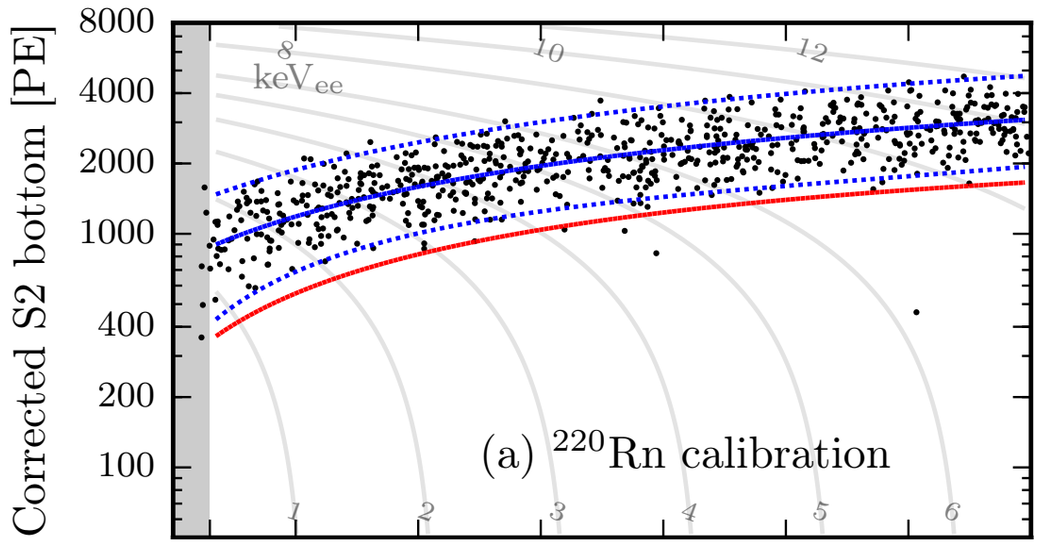
^{212}Pb β$^-$-decay: low-energy calibration



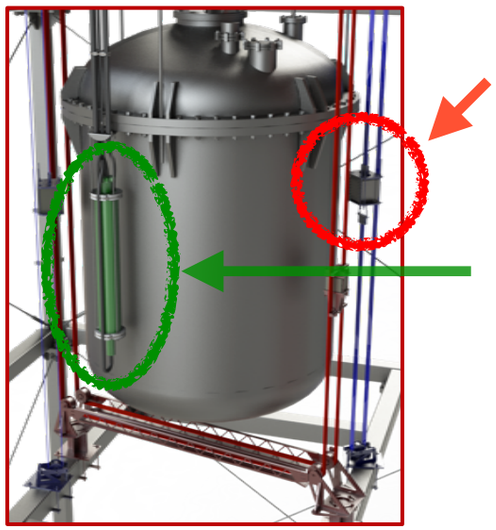
Phys. Rev. D 95, 72008 (2017)

- ^{228}Th source
- ^{220}Rn emanates into xenon gas
- builds to ^{212}Pb (10.6 h): 2-30 keV
- ~1 week decay

Blue: ER
Red: NR

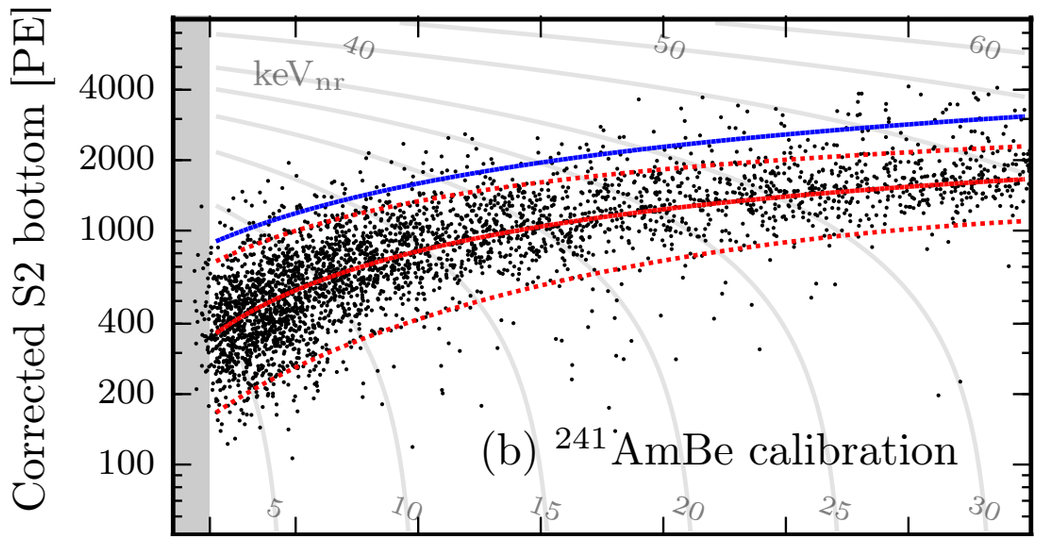


Nuclear recoils: AmBe

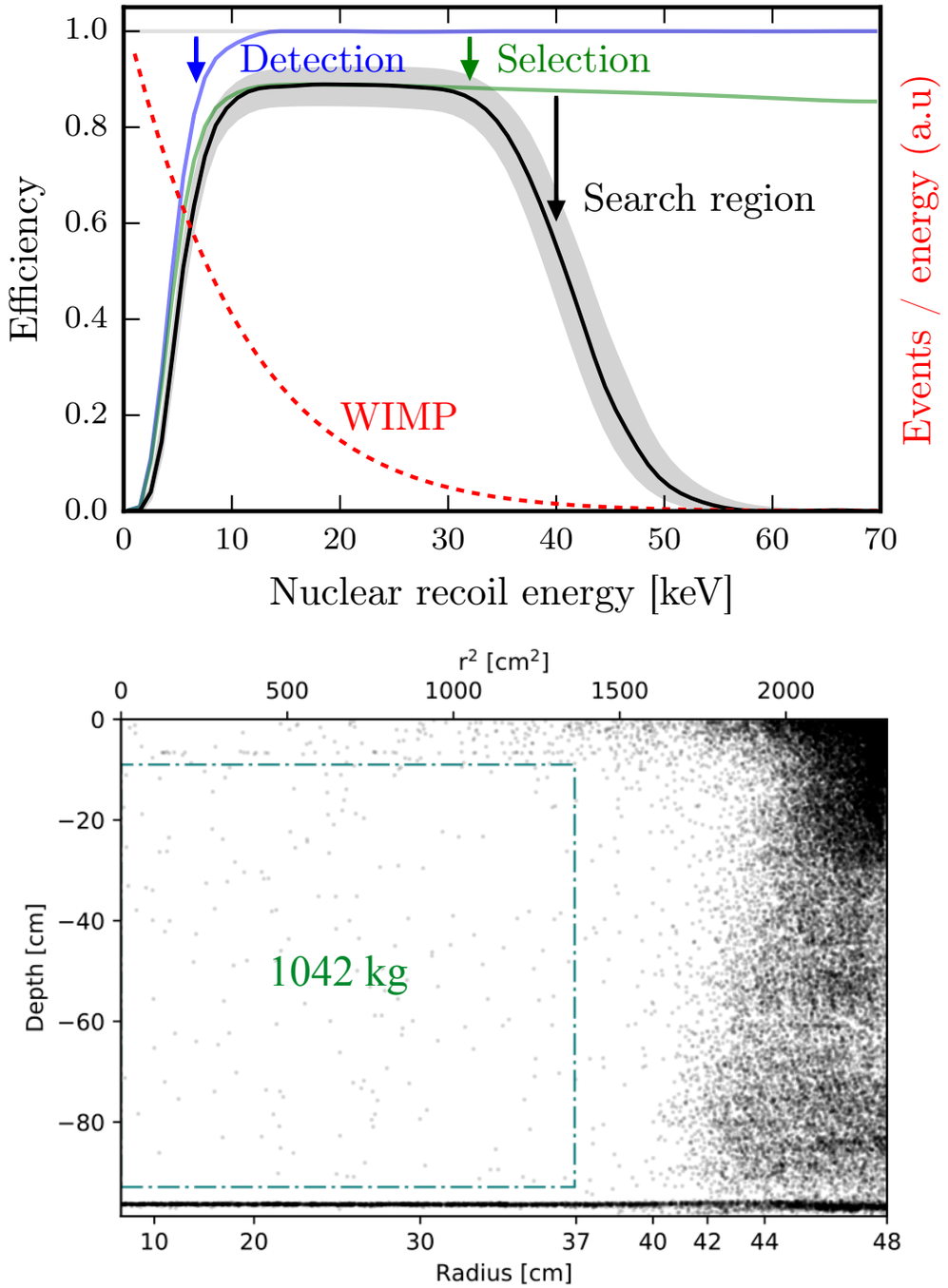


arXiv: 1705.04741

- ^{241}AmBe external source (belt system) emits 1-10 MeV neutrons
- neutron generator commissioned May 2017, peaks 2.2 and 2.7 MeV
- reduced calibration time from weeks to ~days



Event Selection



Nuclear recoil detection efficiency

Signal reconstruction algorithms tuned with MC

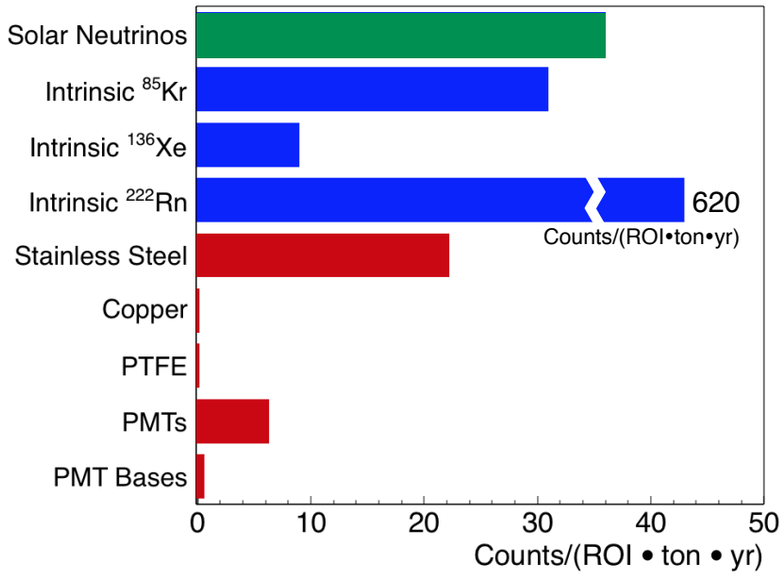
- modeled light propagation and detector electronics (noise)
- validated S1/S2 waveforms

Selections

- WIMPs are expected as low-energy, single scatters
- reject events with uncorrelated signals before main S2 & events after a high-energy event
- S2 width and PMT hit patterns must be consistent with reconstructed vertex

Cut	Events remaining
All (cS1 < 200 PE)	128144
Selections	48955
1 t Fiducial volume	180
S1 range (3 < cS1 < 70)	63

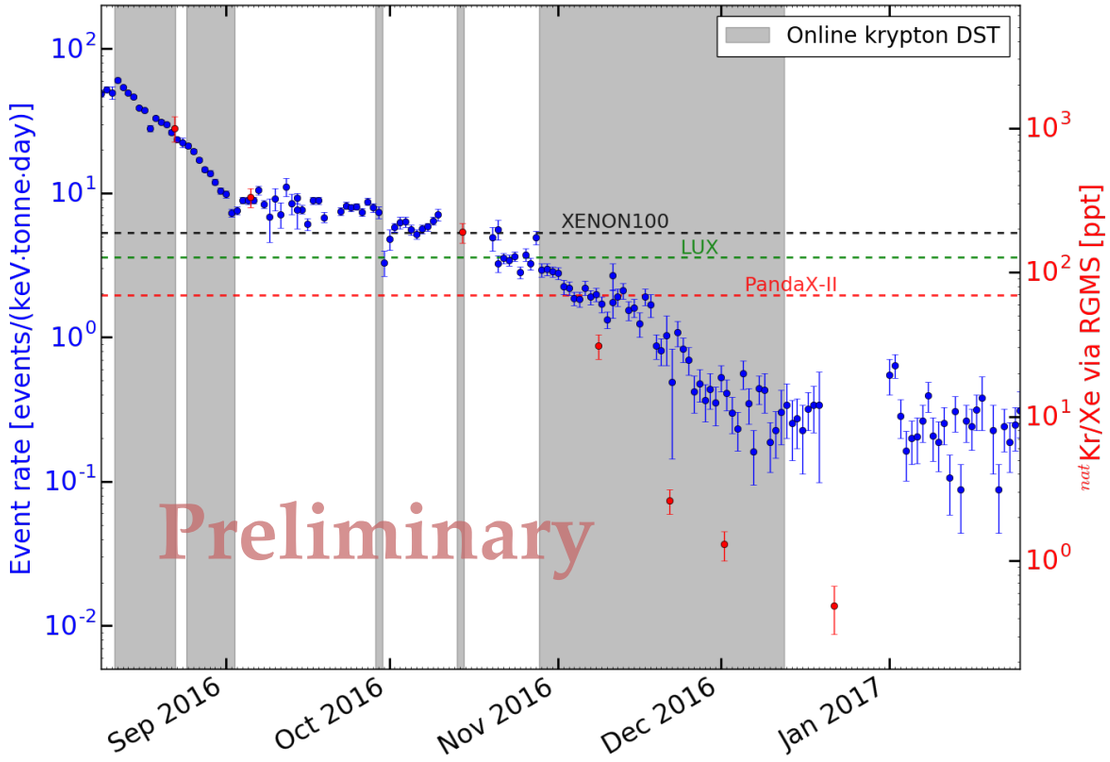
Electronic Recoil Backgrounds



Reduction Methods:

- materials radioassay & selection
- cryogenic distillation to remove Kr
- Rn distillation (in-situ: 20% lower tests: >27x decrease in Xe100)

***Materials**: arXiv:1705.01828 (2017)*
***Kr**: Eur. Phys. J. C77, 275 (2017)*
***Rn:** arxiv:1702.06942 (2017)*

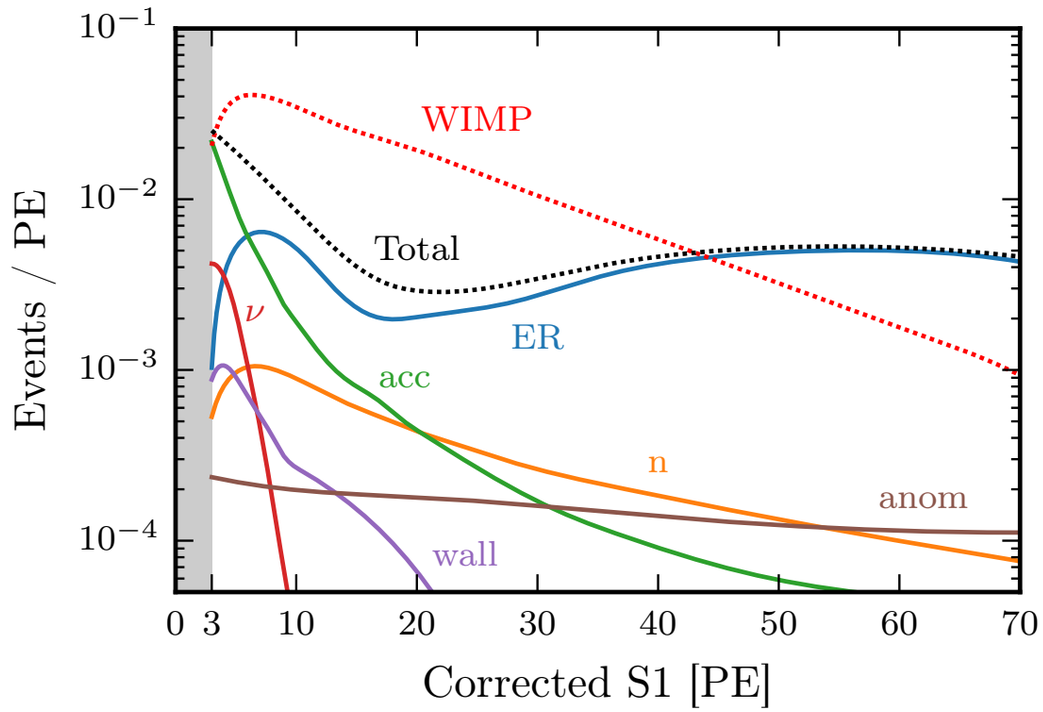


- ^{nat}**Kr/Xe < 0.048·10^{-12} (<48 ppq)**
- ^{222}Rn 10 μBq/kg target concentration

MC predictions	**Measured**
(2.3±0.2) ×10^{-4} events/kg/day/keV$_{ee}$	**(1.93±0.25) ×10^{-4} events/kg/day/keV$_{ee}$**

Lowest background ever achieved in a dark matter detector!

Total Background

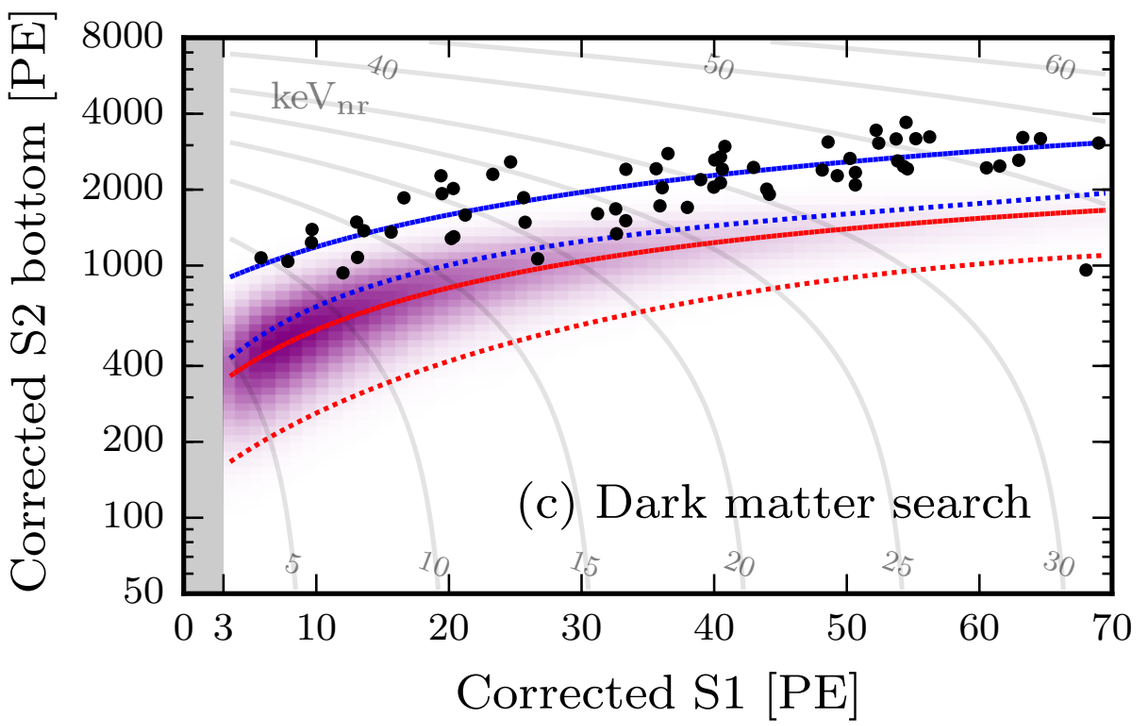


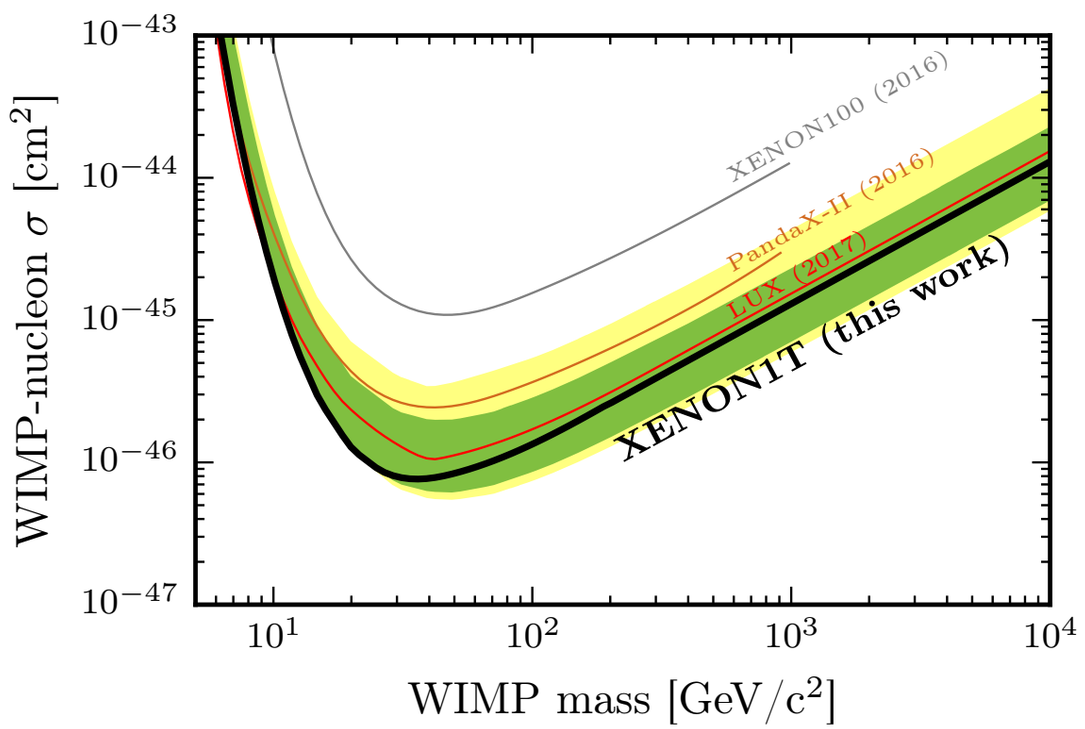
Background Model

- ER and NR spectral shapes derived from models fitted to calibration data
- NR energy conversion is based on the model and parametrisation from NEST
- background expectations are data-driven, derived from control samples

Background & Signal Rates	Total	NR median -2σ
Electronic recoils *(ER)*	62 ± 8	0.26 (+0.11)(-0.07)
Radiogenic neutrons *(n)*	0.05 ± 0.01	0.02
CNNS (?)	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 (+0.11)(-0.07)**
50 GeV/c^2, 10^{-46} cm^2 WIMP *(NR)*	**1.66 ± 0.01**	**0.82 ± 0.06**

First Results





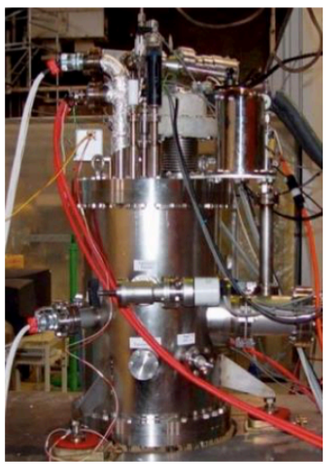
Results consistent with null hypothesis

- WIMP region blinded until fiducial mass and event selections were finalized
- Extended unbinned profile likelihood analysis for statistical interpretation
  - ER/NR shape parameters from calibration fits
  - Normalization uncertainties for all background components
- Standard isothermal WIMP halo model + Helm form factor
- No significant excess was observed above the expected background

Strongest exclusion limit for spin-independent WIMPs of 7.7×10^{-47} cm^2 @ 35 GeV/c^2

arXiv:1705.06655

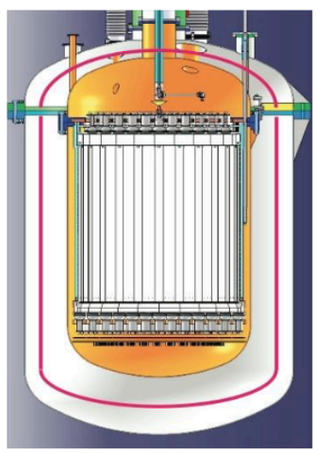
The XENON (to DARWIN) Project



XENON10
Total Xe: 25 kg
Target: 14 kg
Fiducial: 5.4 kg
Limit: ~10^{-43} [cm^2]

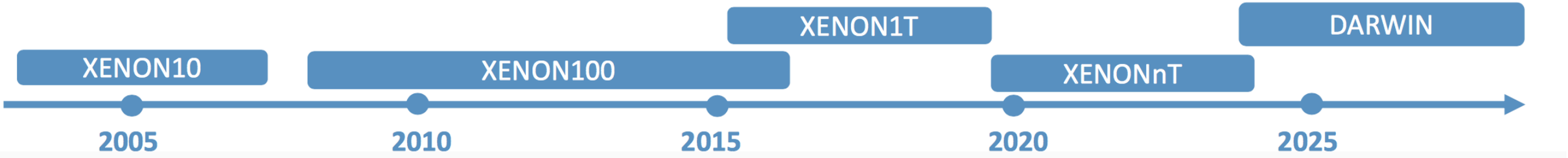
XENON100
Total Xe: 162 kg
Target: 62 kg
Fiducial: 34/48 kg
Limit: ~10^{-45} [cm^2]

XENON1T
Total Xe: 3.2 ton
Target: 2 ton
Fiducial: 1 ton
Limit: ~10^{-47} [cm^2]



XENONnT
Total Xe: ~8 ton
Target: ~6.5 ton
Fiducial: ~5 ton
Limit: ~10^{-48} [cm^2]

DARWIN
Total Xe: ~50 ton
Target: ~40 ton
Fiducial: ~30 ton
Limit: ~10^{-49} [cm^2]

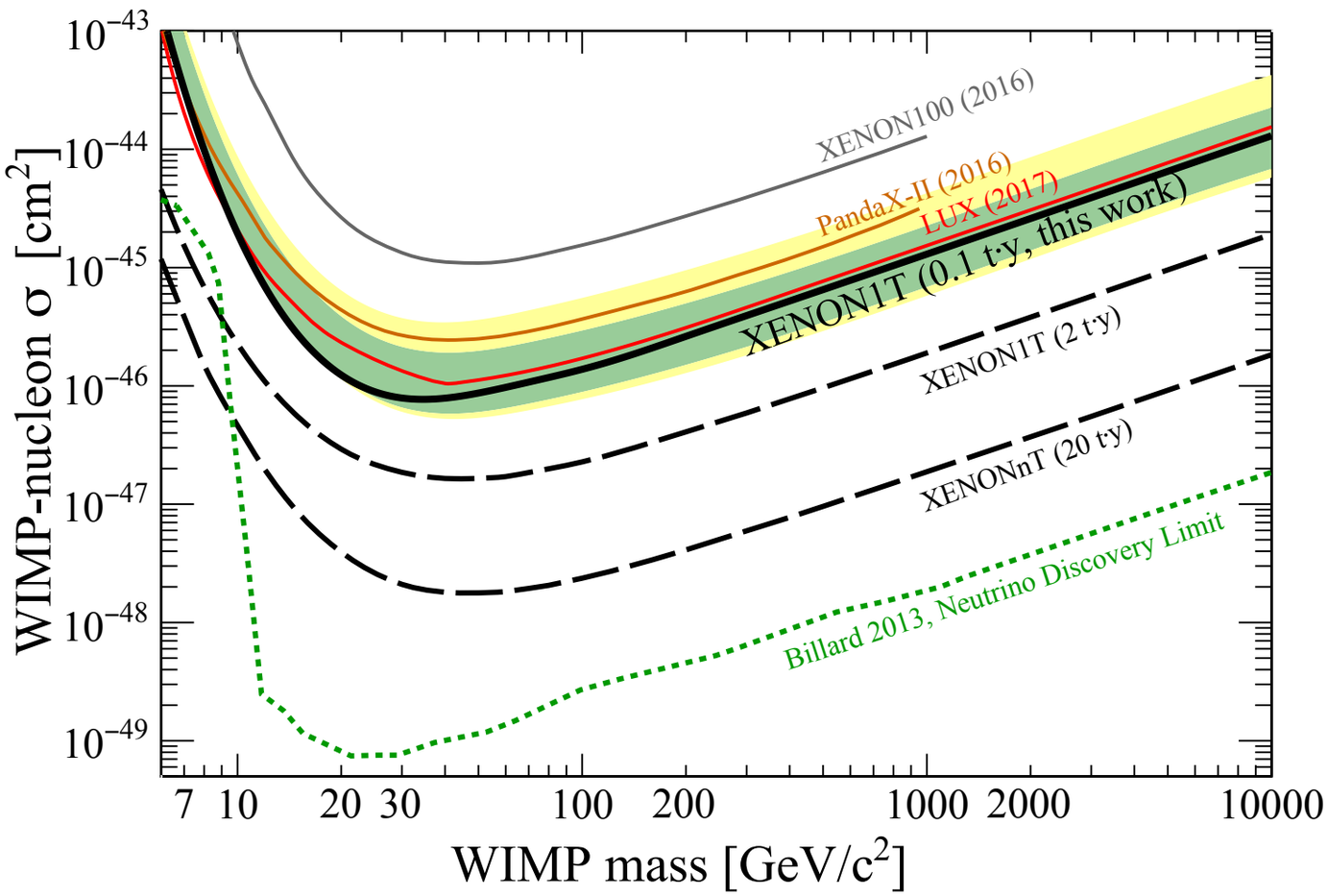


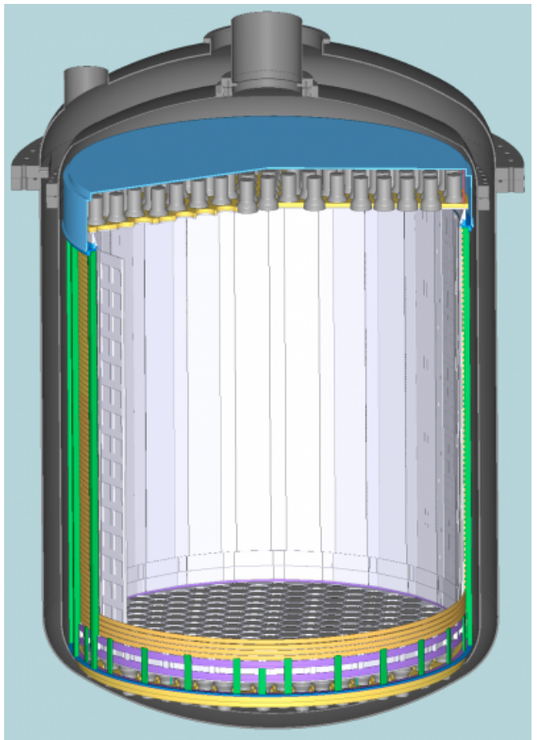
See DARWIN talk by F. Arneodo, Thursday 12:00

Summary and Outlook

XENON1T is currently the most sensitive direct dark matter search experiment

- The detector has the lowest background ever achieved
- Results with 34.2 live days are now published
- An additional > 85 days of data already acquired
- A fast upgrade to XENONnT is planned, using most of the existing infrastructure.





XENONnT: 2019-2023
144 cm drift TPC
~8000 kg
Projected (2023)
$\sigma_{SI} = 1.6 \times 10^{-48}$ cm^2