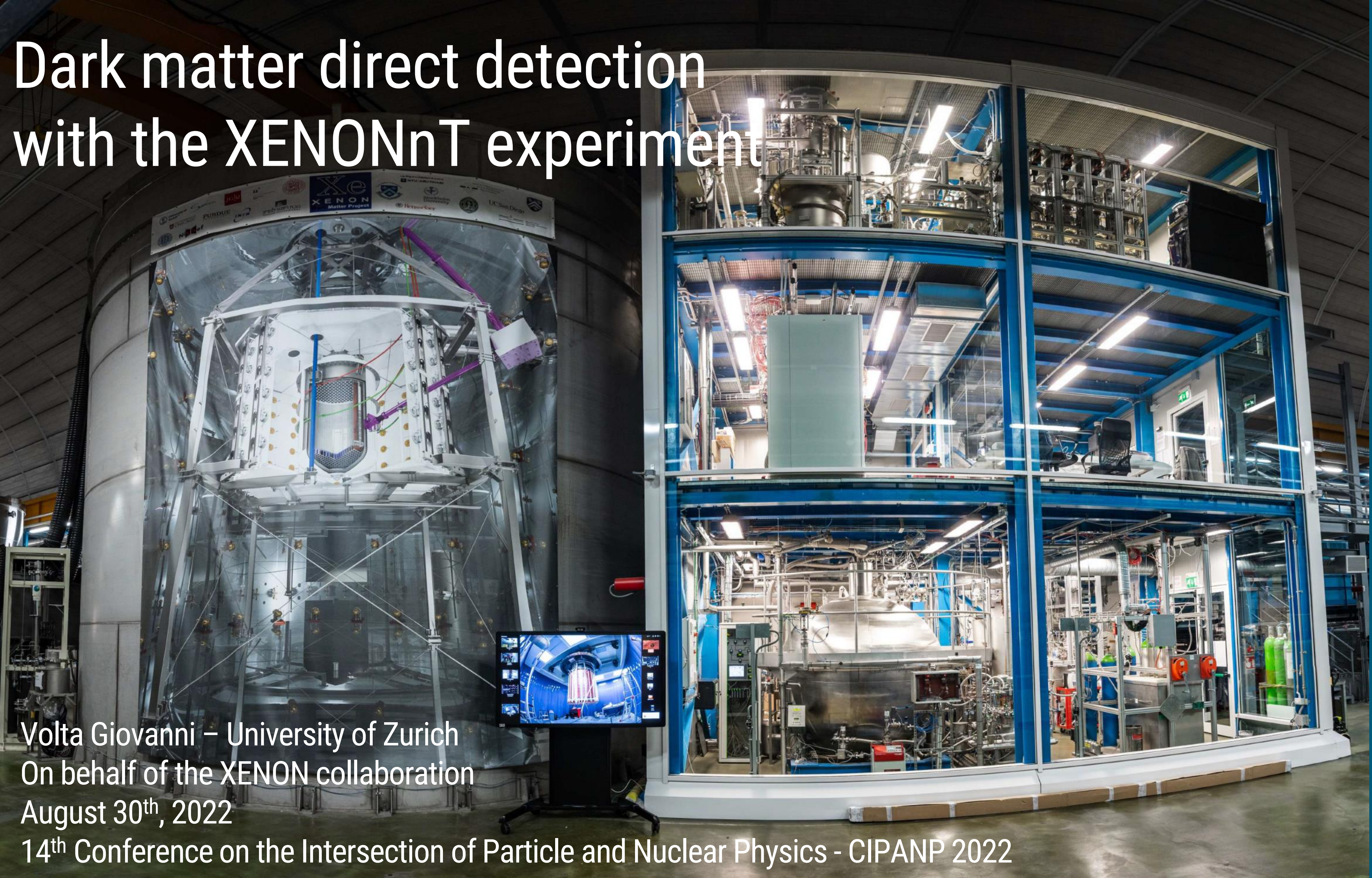
Dark matter direct detection with the XENONnT experiment



XENON

Volta Giovanni – University of Zurich
On behalf of the XENON collaboration
August 30th, 2022
14th Conference on the Intersection of Particle and Nuclear Physics - CIPANP 2022

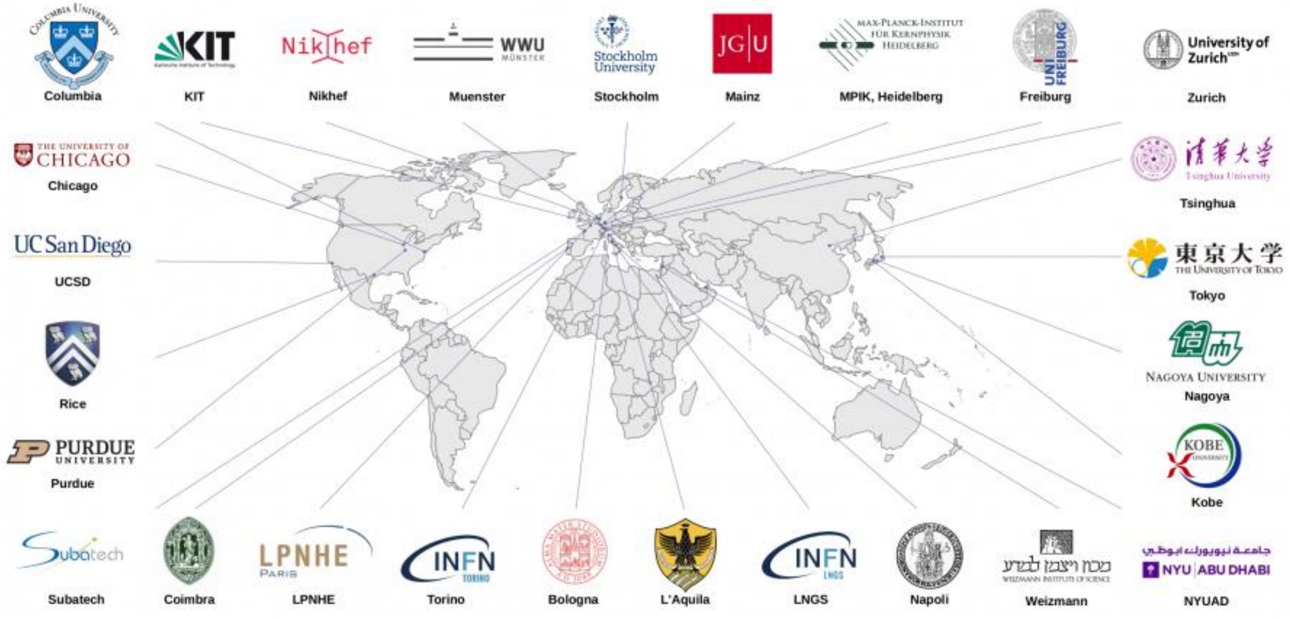
The XENON collaboration

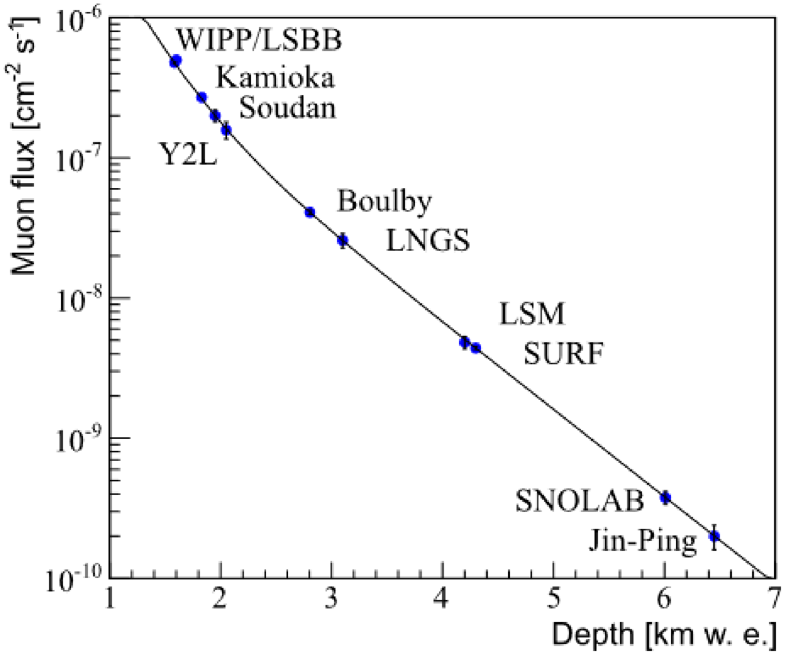
Dark matter direct detection experiment

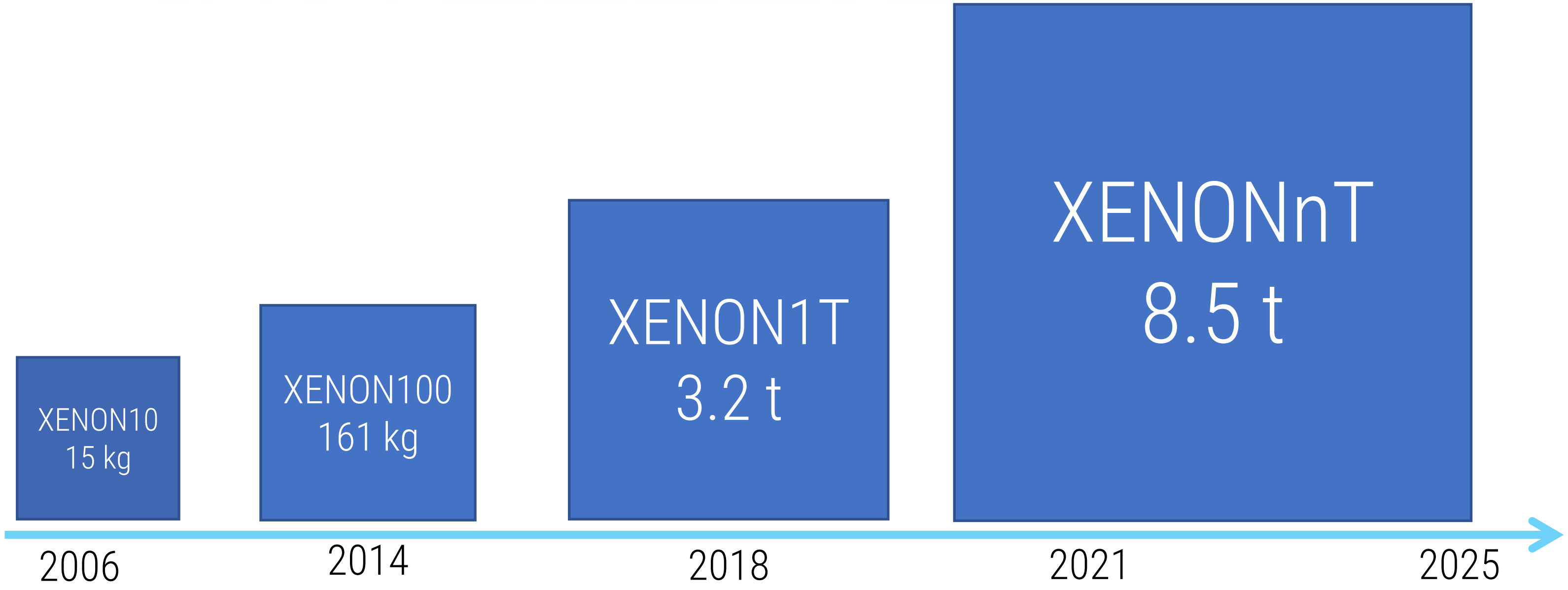
Laboratori Nazionali del Gran Sasso (LNGS)

Dual phase xenon time projection chamber

170 scientists, 27 institutions, 12 countries



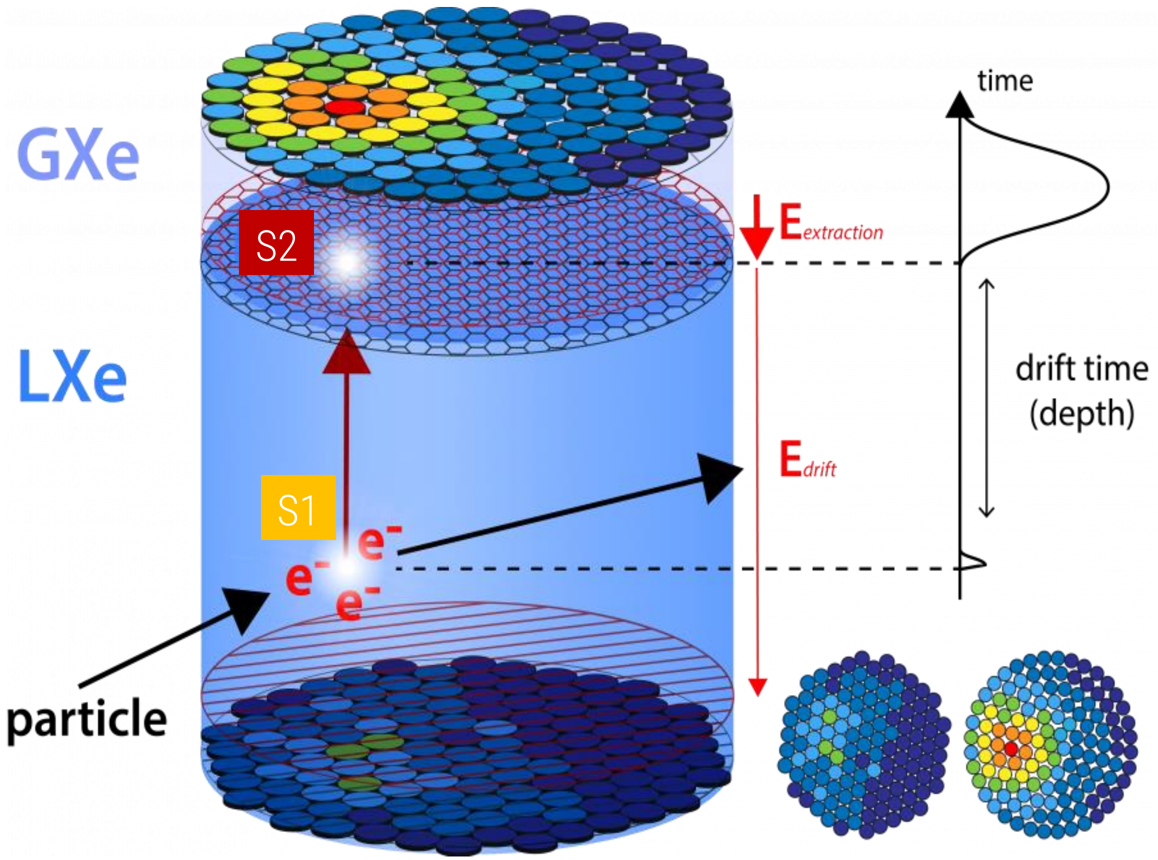




The XENON collaboration

Collaboration Meeting - Torino, July 2022

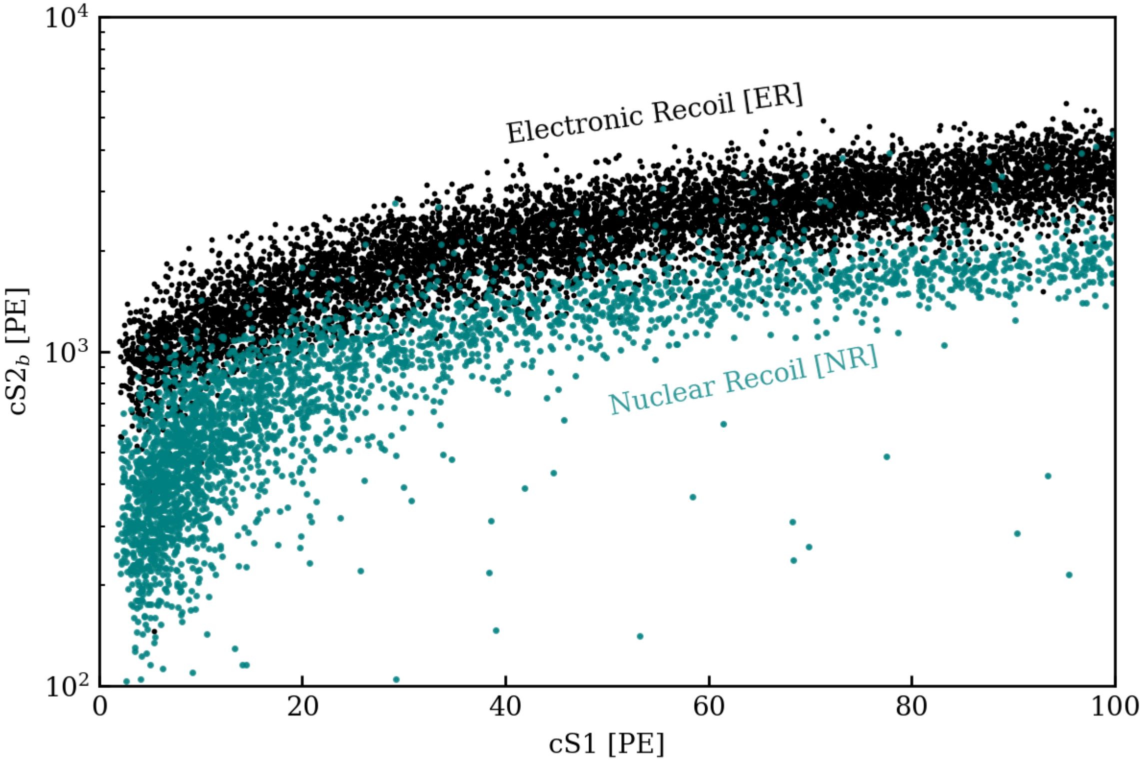
Detection principle



Scintillation photons (S1) and free electrons (∝ S2) are produced from an impinging particle.

Combination of S1 and S2 signals allows for:

- 3D Position reconstruction
- Energy reconstruction
- ER/NR discrimination

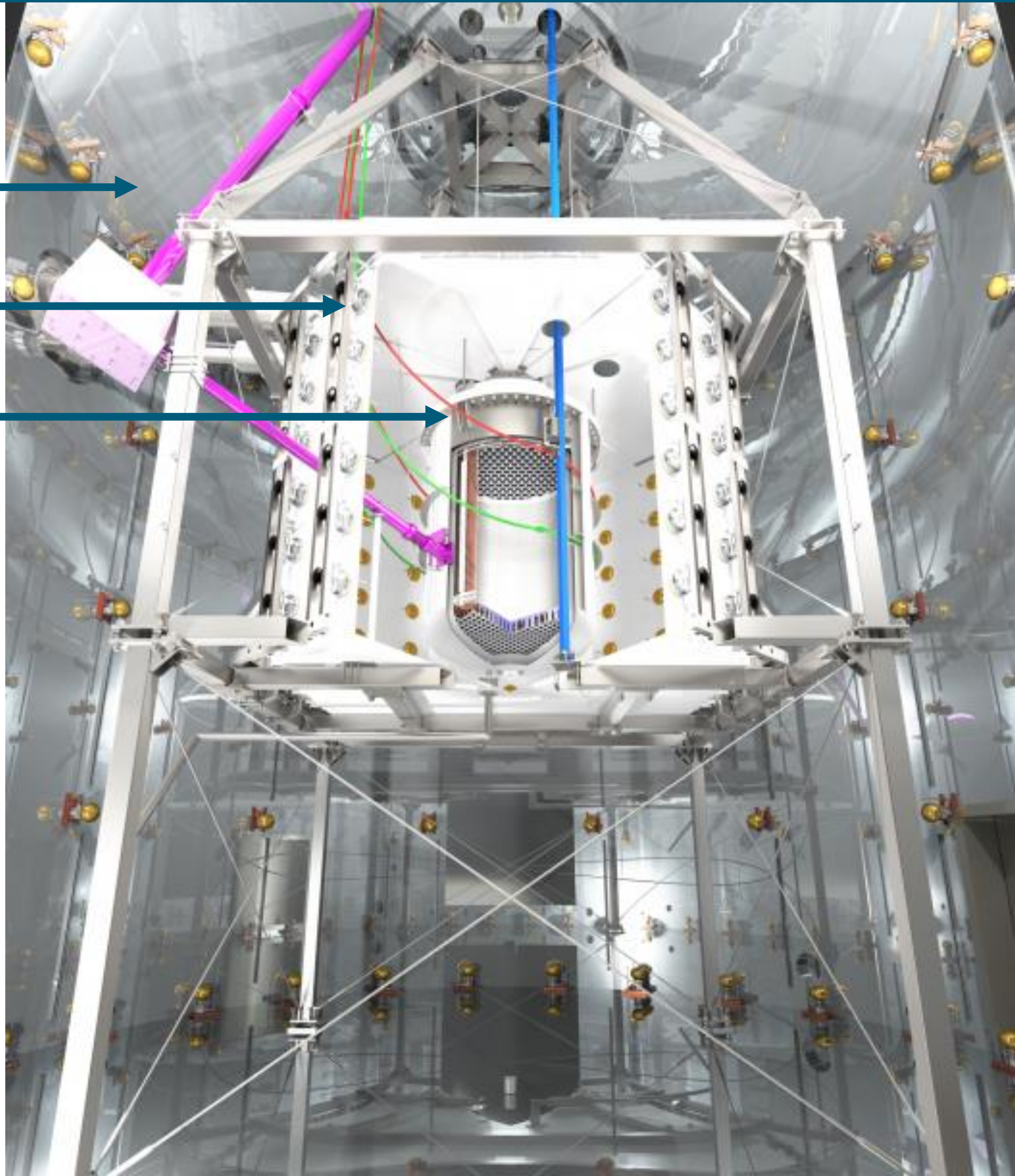


The XENONnT experiment

The XENONnT detectors

Three nested detectors:

- Cherenkov muon veto (MV)
- Neutron veto (NV)
- Dual phase time projection chamber (TPC)



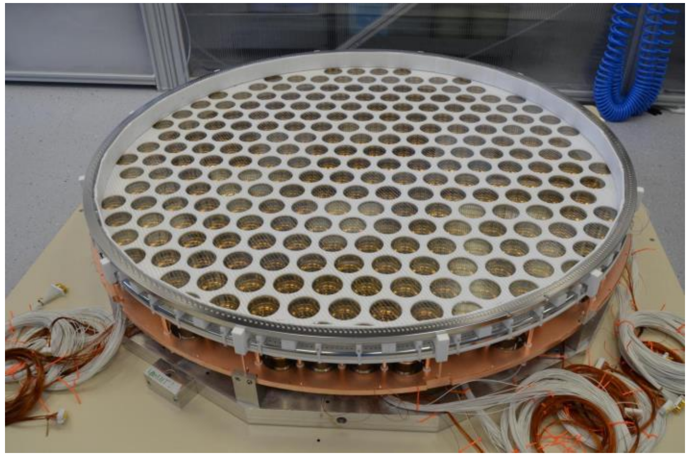
Service building facility provides the systems for the auxiliary components (distillation, recovery, cryogenics and purification, DAQ and SC, …)

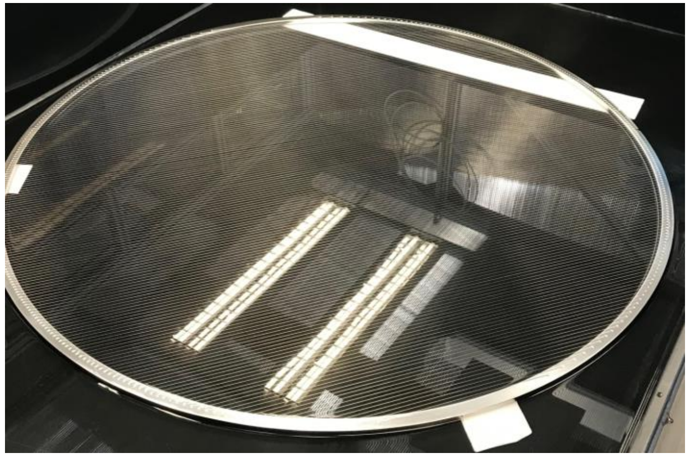
Main requirements:

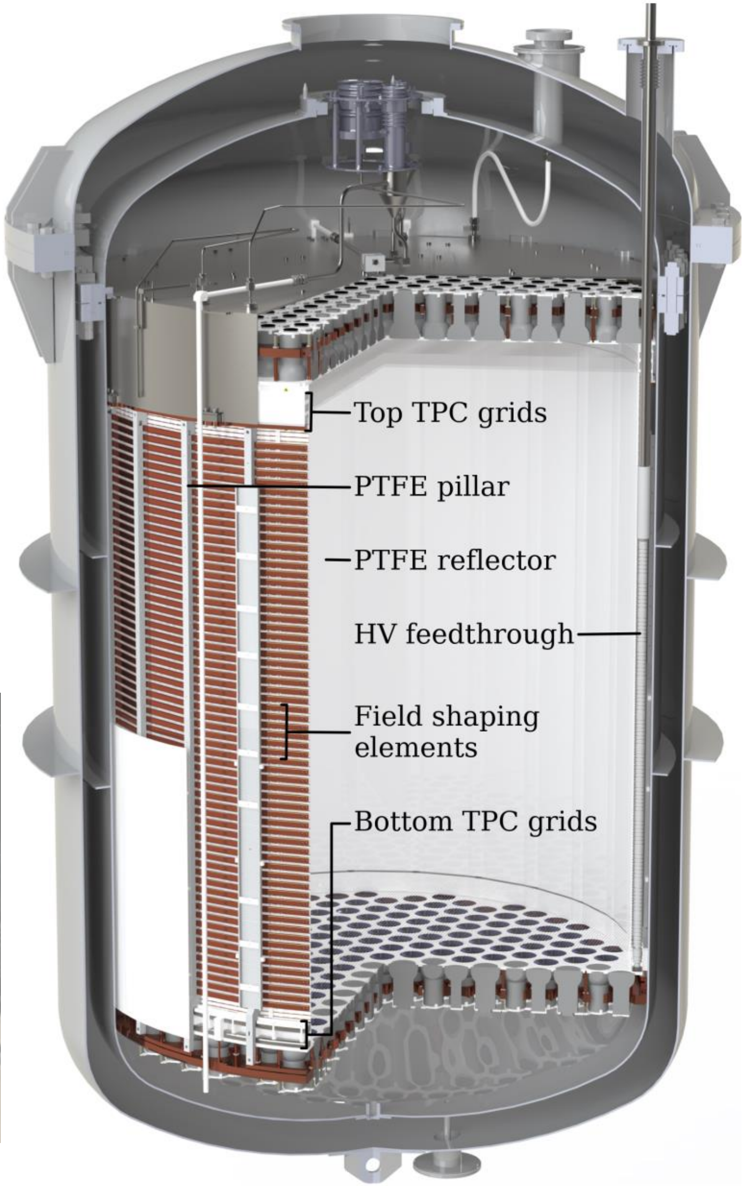
- Low electronegative impurities concentration
- ^{222}Rn mitigation (target 1 μBq/kg)
- High neutron veto tagging efficiency

The XENONnT TPC

- 1.5 m × 1.3 m
- High reflectivity PTFE panels
- 494 3'' R11410-21 PMTs
- 8.5 t of liquid xenon of which 5.9 t instrumented
- 5 electrodes
- Two sets of field shaping rings



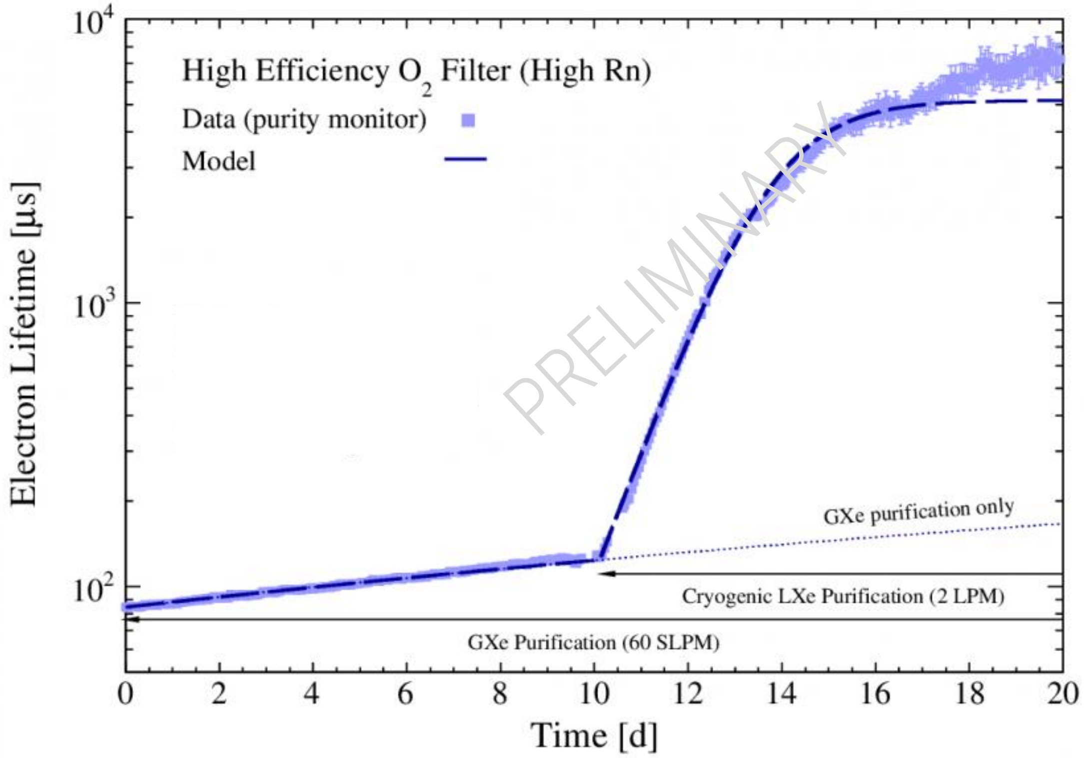




The purification system

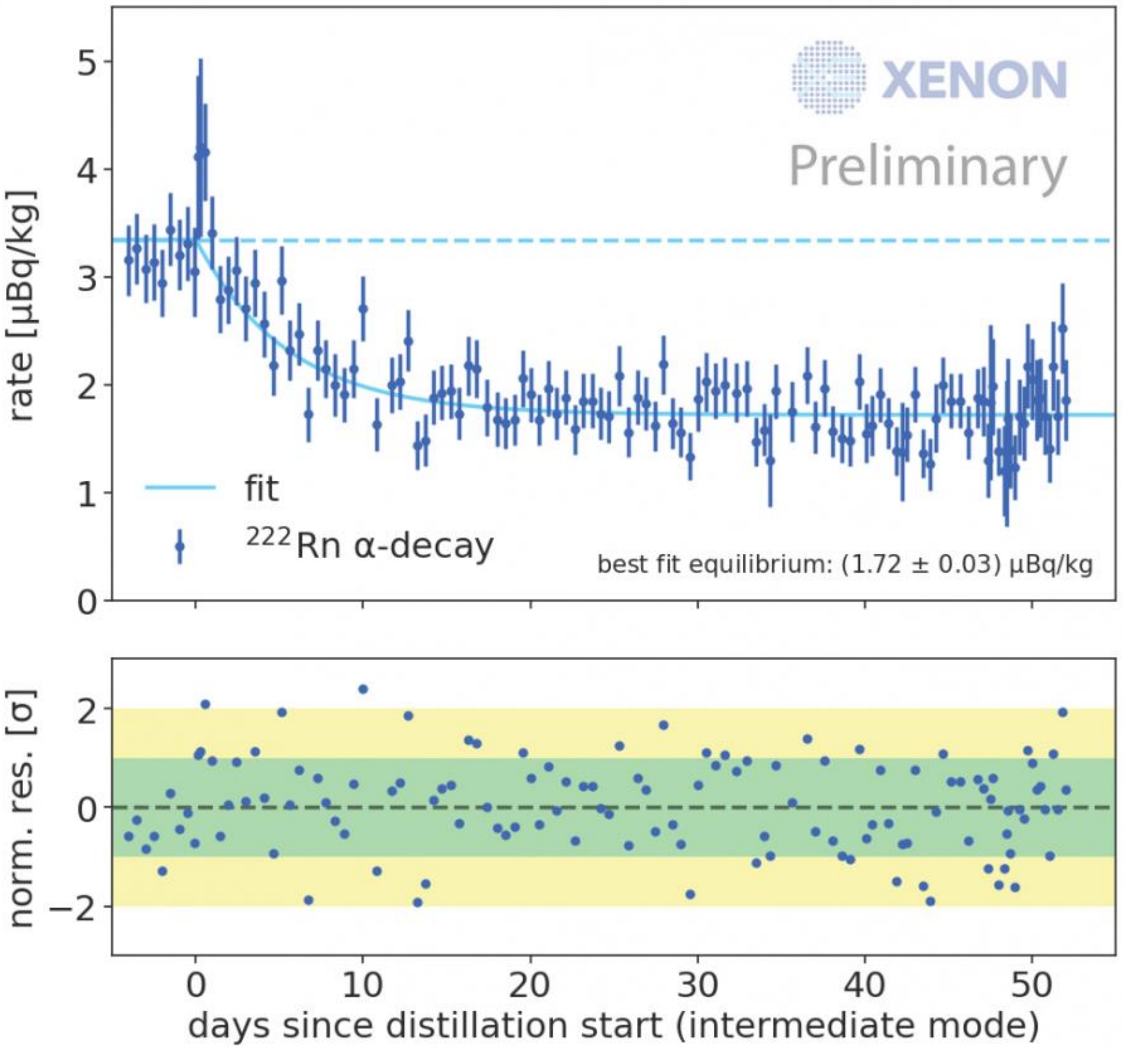
E. Brown et al Eur. Phys. J. C 78, 604 (2018)
G. Plante et al arXiv:2205.07336

- Xenon purified from electronegative impurities, e.g. O_2
- Gas purification system, partially inherited from XENON1T
- Novel liquid-phase purification system implemented
- Electron lifetime improved from ~650 μs in XENON1T to > 10 ms



Xenon distillation

- Background mitigation through distillation of the xenon
- Kr distillation performed before the science run data acquisition
- ^{nat}Kr concentration achieved: (56 ±36) ppq, ~0.66 ppt in XENON1T
- Online Radon distillation, x10 reduction with respect to XENON1T(~12 μBq/kg)
- Measured ^{222}Rn concentration: ~1.7 μBq/kg
- Recent improvements in the Radon column helped to get to XENONnT goal of 1 μBq/kg

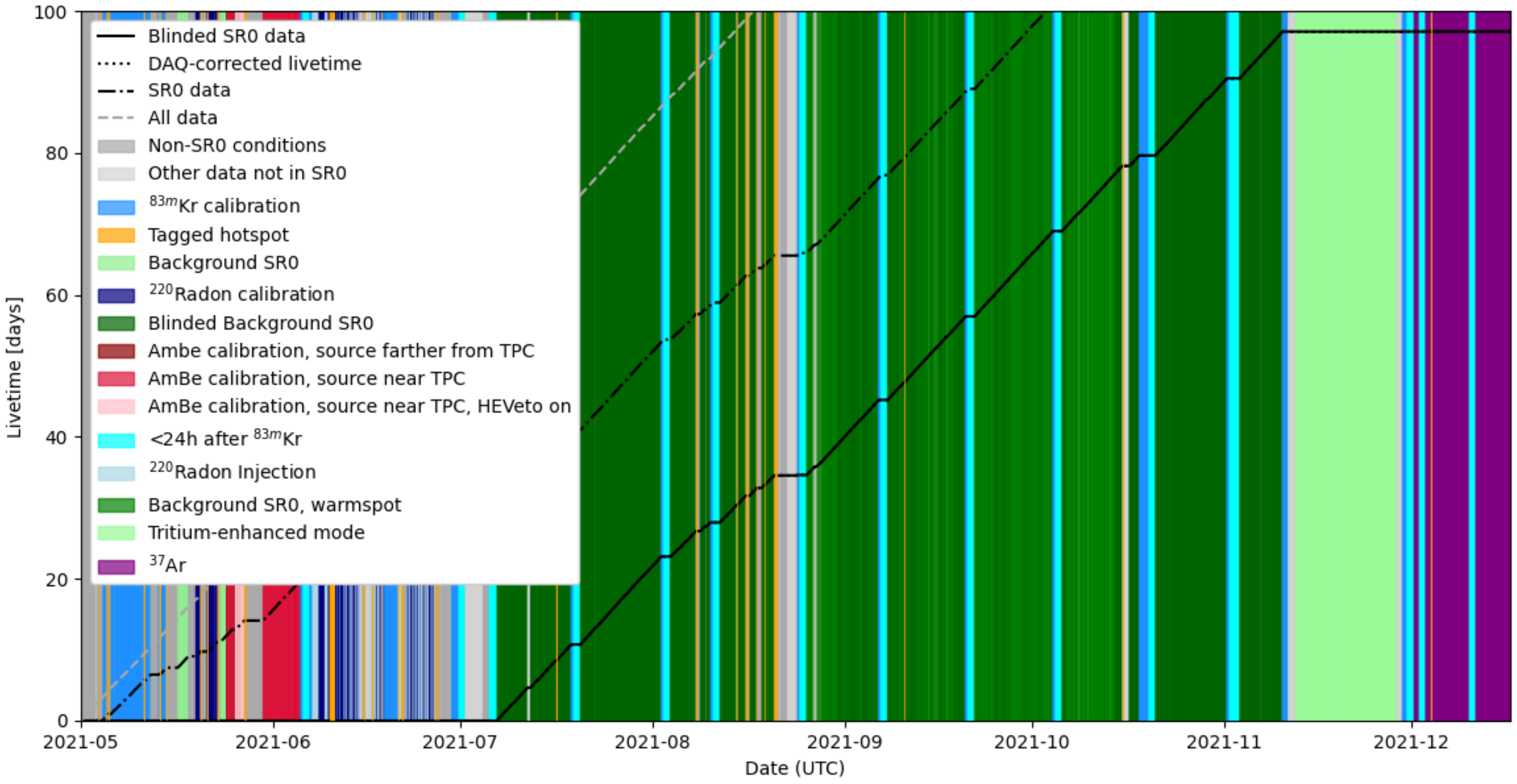


XENON collaboration, Eur. Phys. J. C 77, 275 (2017)
XENON collaboration, PTEP Vol 2022, Issue 5, May 2022
XENON collaboration, Eur. Phys. J. C 77, 358(2017)
M.Murra et al, arXiv:2205.11492

Where are we now ?

XENON Science Run 0

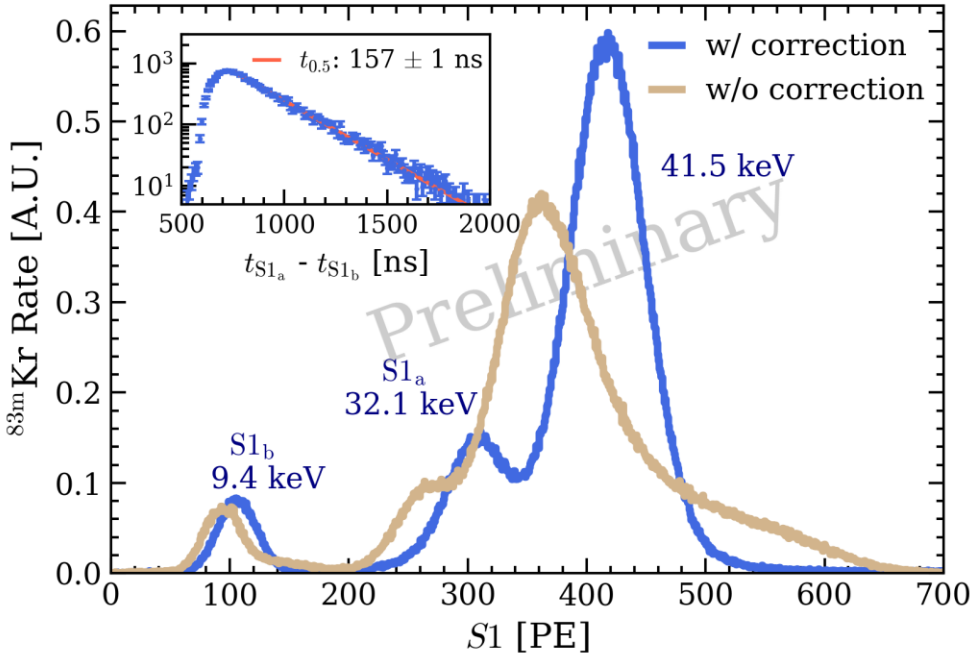
- Spring 2020: installation of the TPC underground at LNGS
- Summer/Fall 2020: nVeto installation, TPC and WT filling
- Winter/Spring 2021: detectors commissioning
- From May to December of 2021: XENONnT science run 0

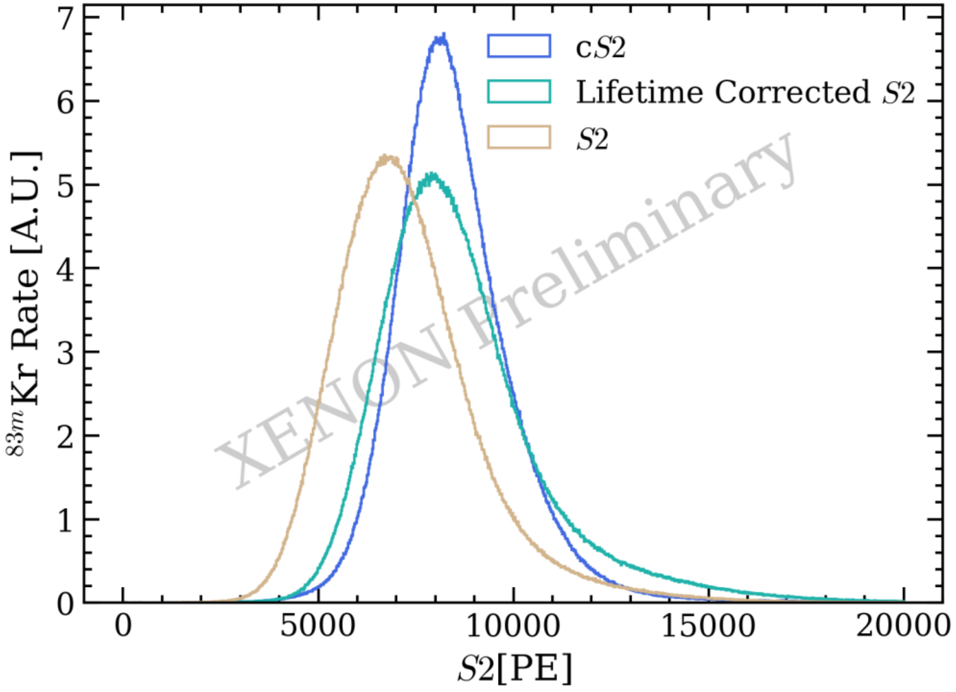


- ⟶ 97.1 days SR0 search data
- ⟶ ~23 V/cm drift field
- ⟶ ~2.9 kV/cm extraction field
- ⟶ ^{222}Rn concentration: ~1.7 μBq/kg
- ⟶ $e_{lifetime}$ > 10 ms
- ⟶ 477/494 working PMTs
- ⟶ Localised high single electron emission
- ⟶ ER and NR blinded analysis

TPC response characterization

- ^{83m}Kr calibration every 14 days
- $T_{1/2}$ (~ 1.83 h) big enough to distribute uniformly in the detector
- Essential calibration source for understanding S1 and S2 collection efficiency as a function of the position
- Useful to validate the simulation framework, e.g. photon propagation in the xenon





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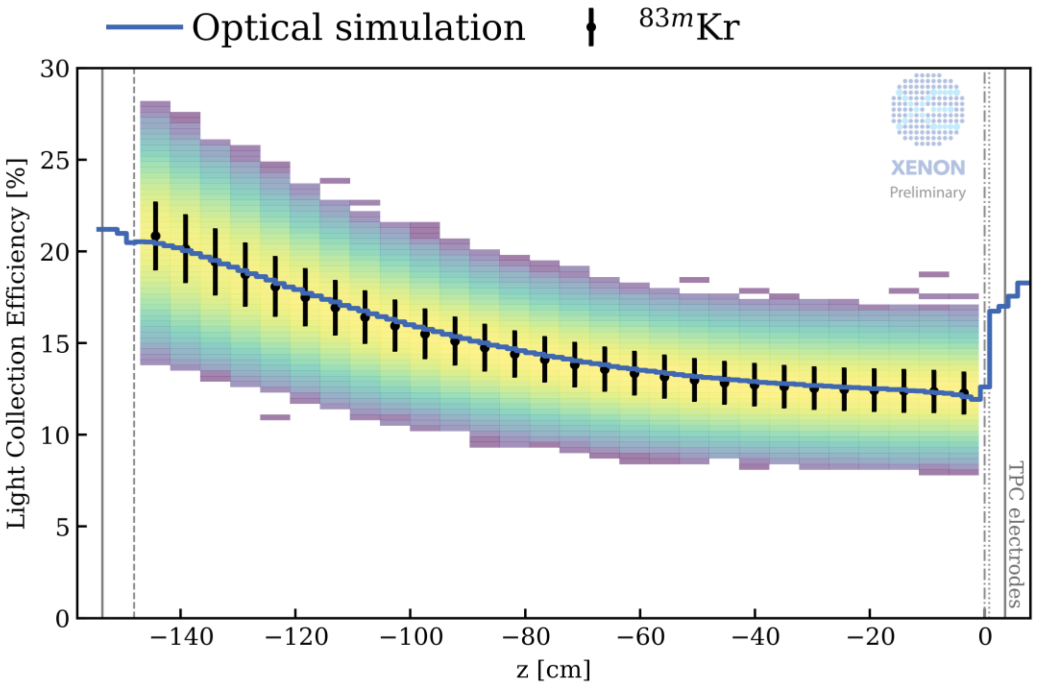
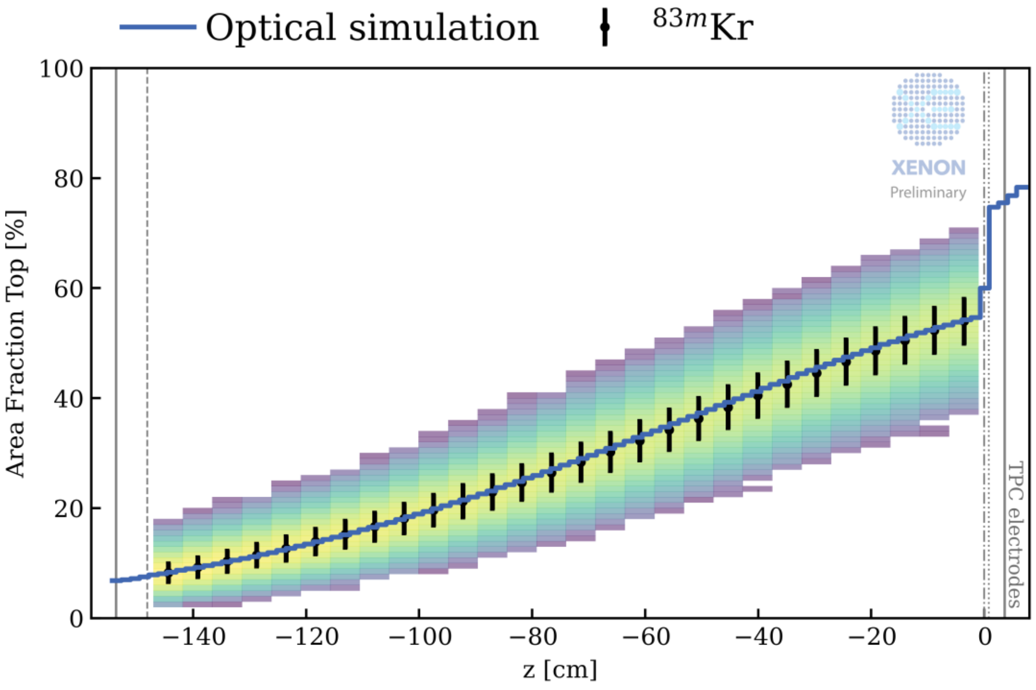
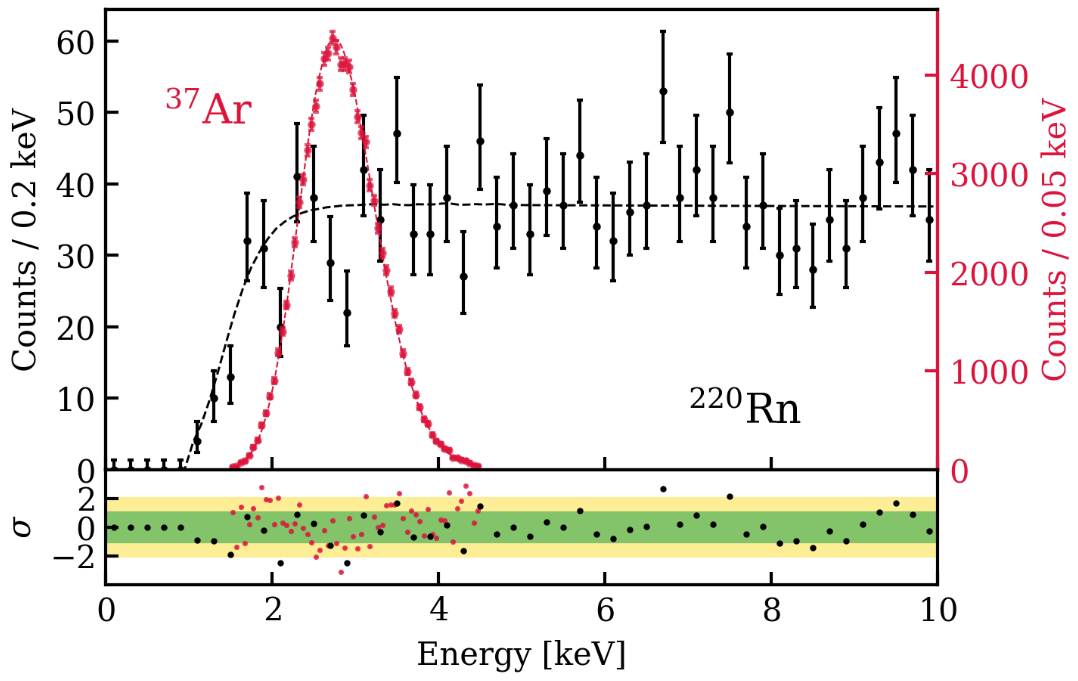
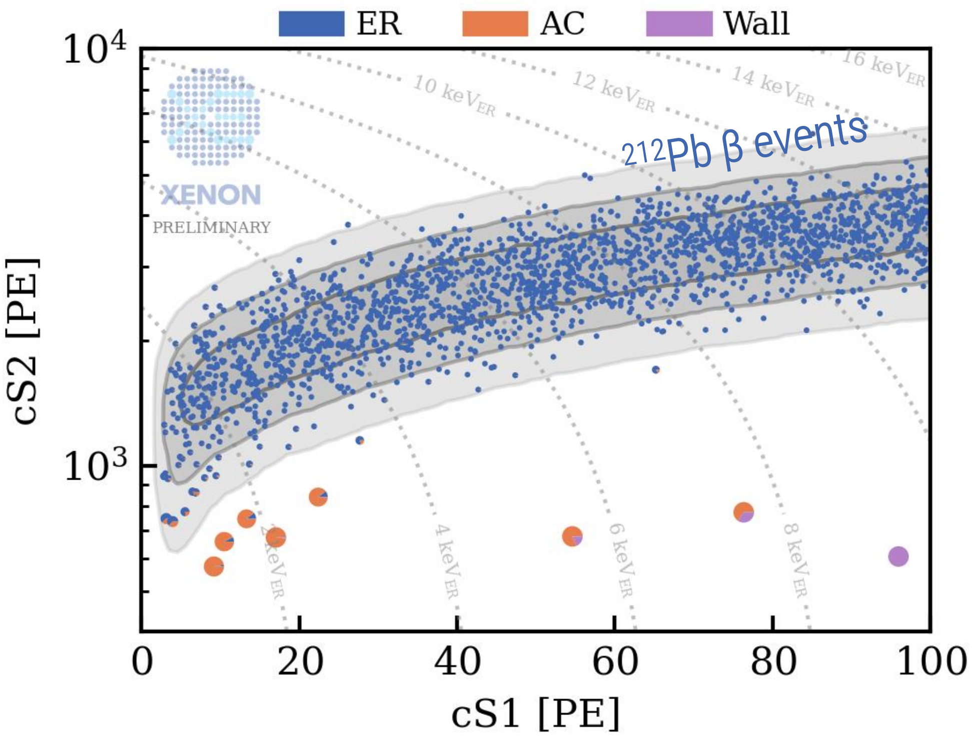




ER response characterization

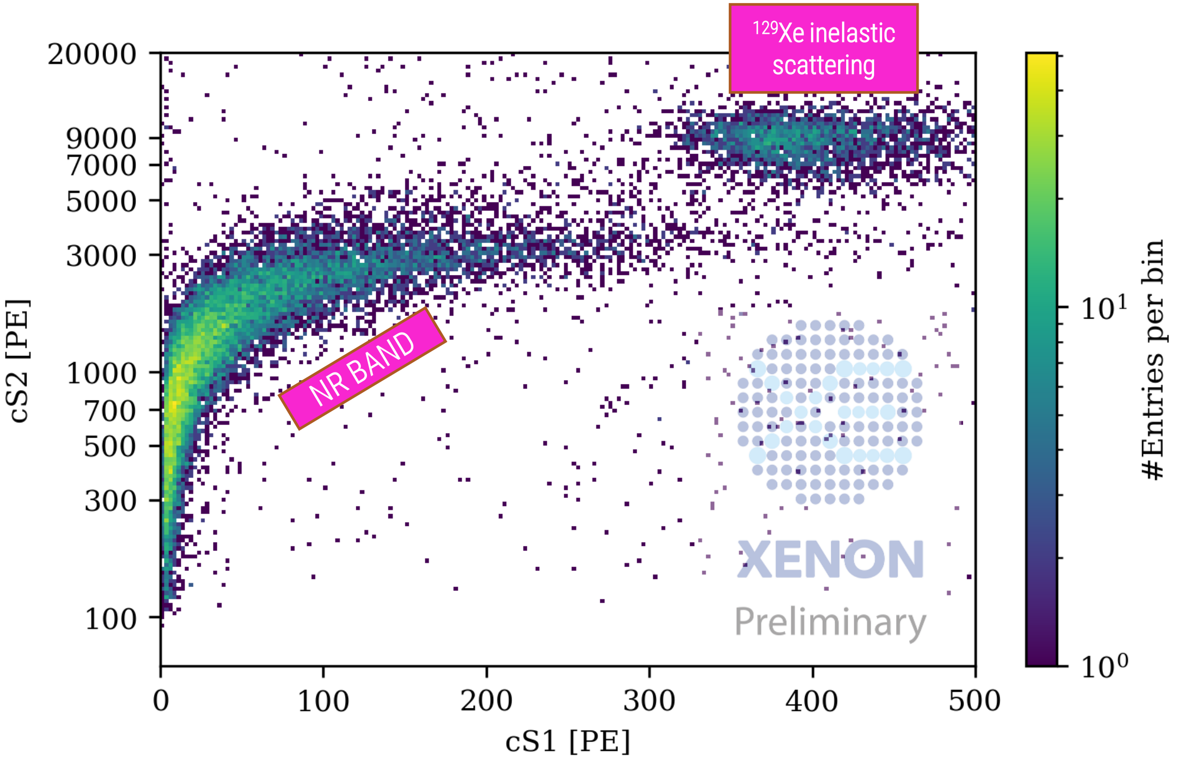
- ER calibrated at low energy with ^{37}Ar and ^{220}Rn, homogeneously distributed in the detector volume
- ^{37}Ar gives 2.82 keV peak used for understanding low energy response and resolution near the energy threshold
- ^{212}Pb, radon daughter, gives a reasonably flat β spectrum necessary to develop data quality selections and study their acceptances, as well as validate the energy threshold

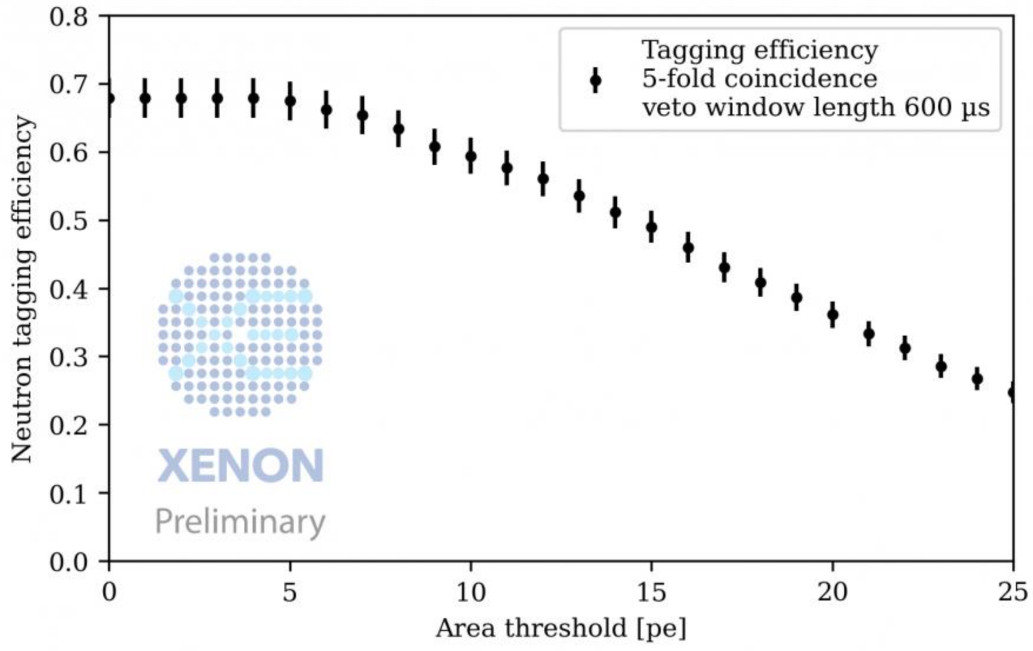




NR response characterization

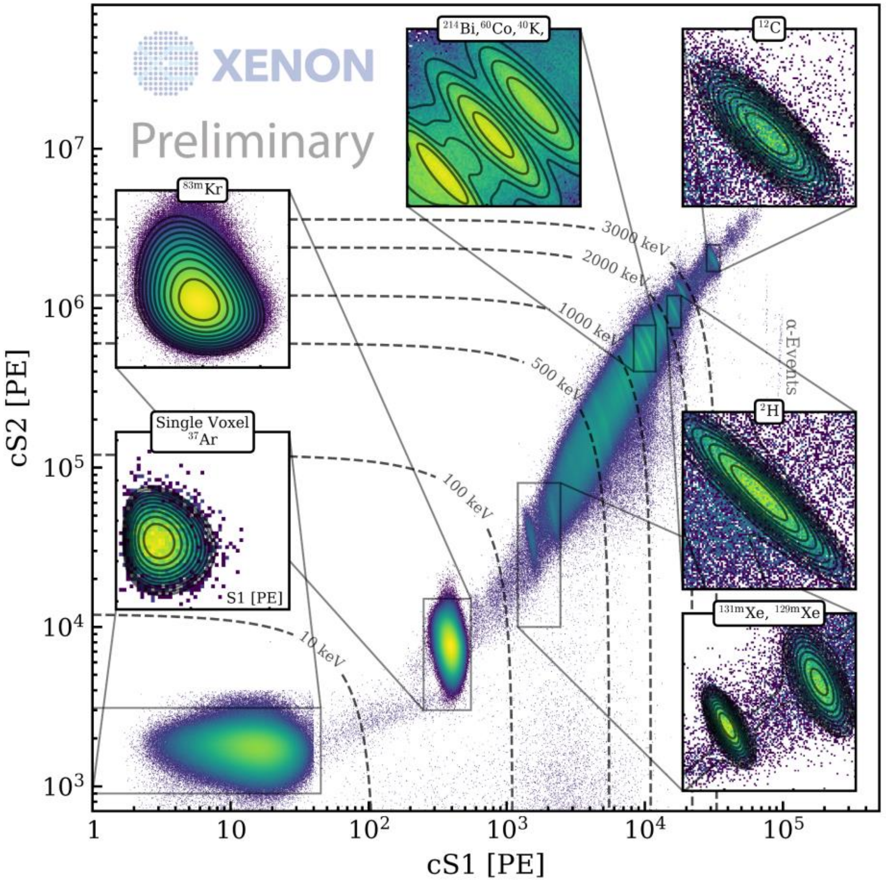
- Neutrons provided by AmBe source, deployed in the calibration tubes around the TPC
- 4.4 MeV gamma emitted 50% of the time together with AmBe neutron
- Events in coincidence have been used to validate nVeto performances as well as select pure NR events



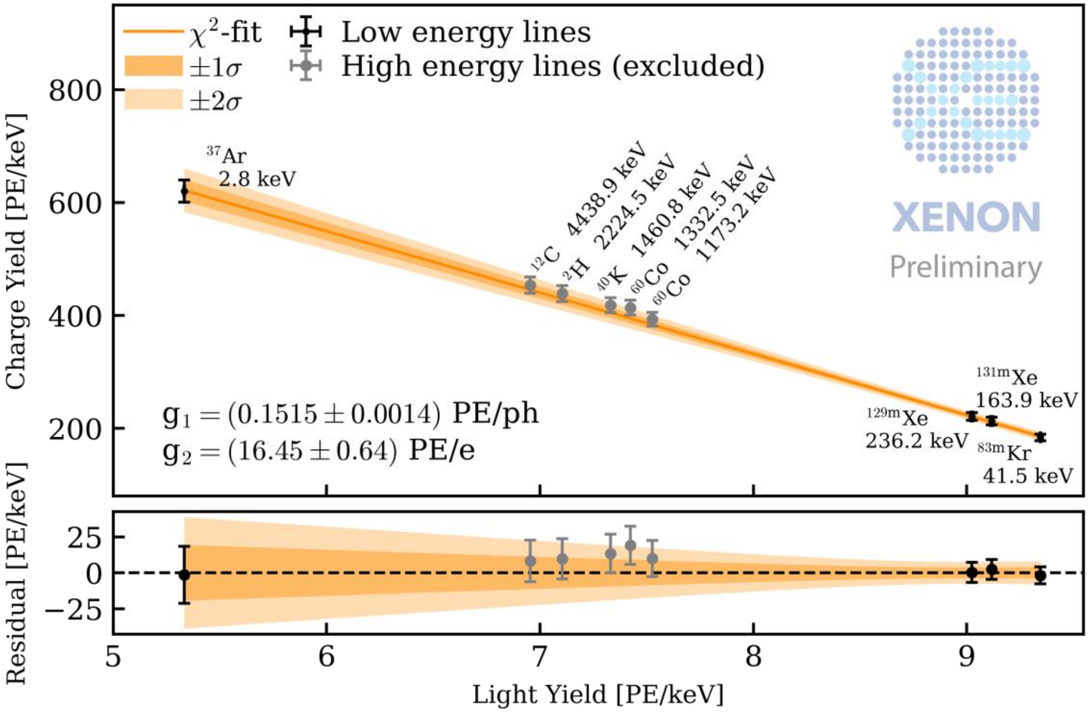


Energy calibration

- Based on ^{37}Ar, ^{83m}Kr, ^{129m}Xe, and ^{131m}Xe
- Reconstruction has not been optimized for high-energy events (~ MeV)
- Observed 1-2% bias on reconstructed energy, included as systematic uncertainty in the model

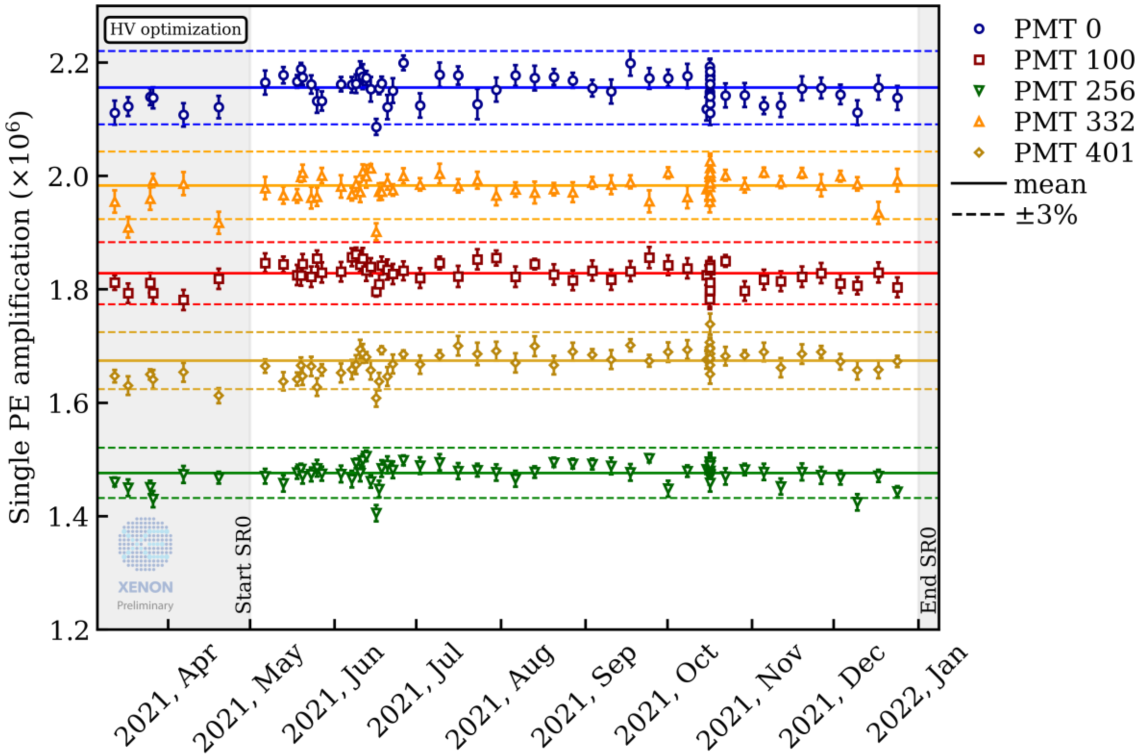


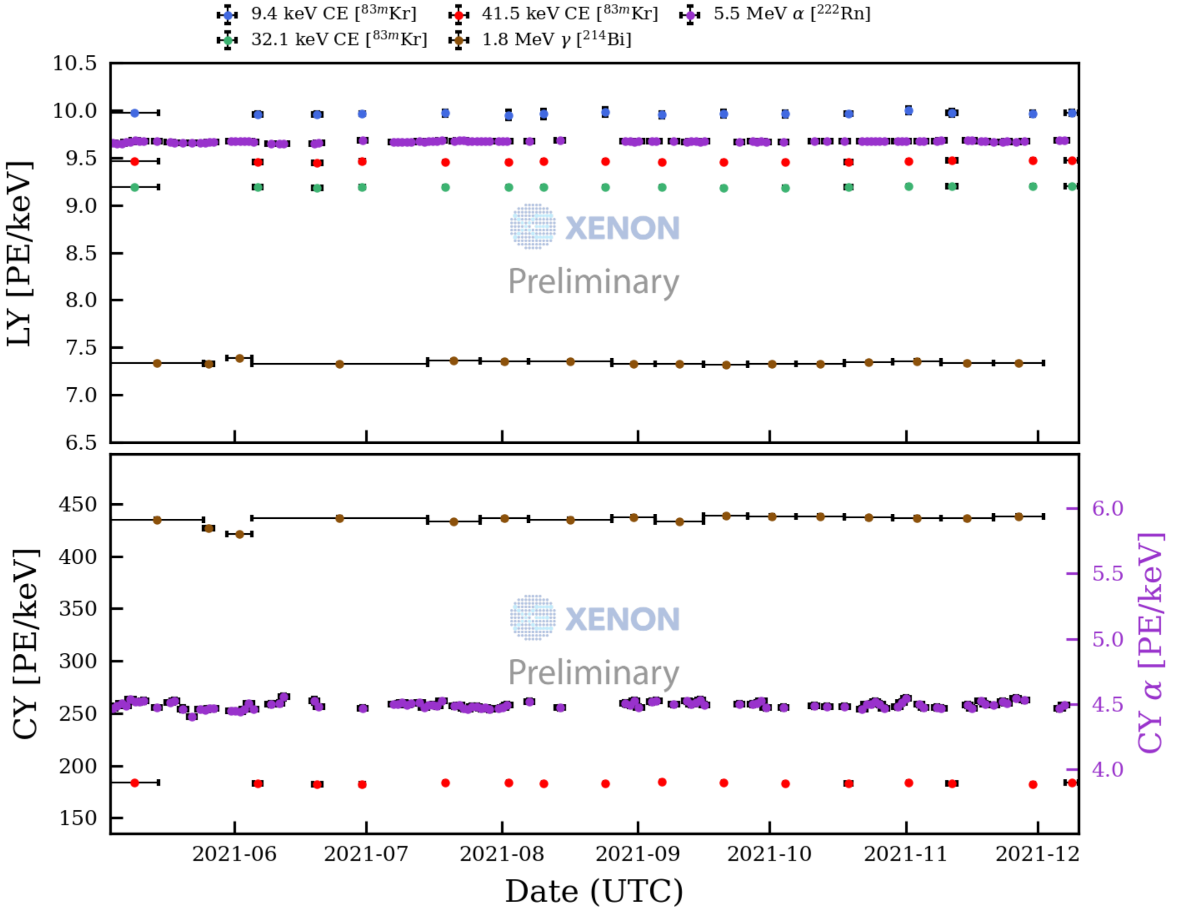
$$E = 13.7\ \text{eV}\left(\frac{cS1}{g_1} + \frac{cS2}{g_2}\right)$$



Detector response stability

- Detector performance have been monitored through all the SR0
- PMTs single PE amplification stable within 3%, averaged single PE acceptance during SR0 around 91%
- Alphas from ^{222}Rn and gammas from materials[1] used for monitoring light and charge yields. Fluctuations within 1% and 1.9% respectively





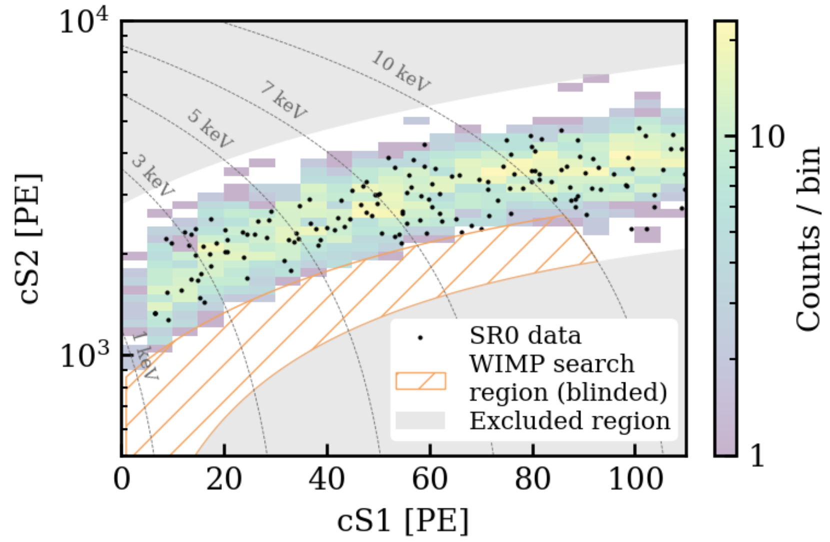
[1] Gammas from ^{214}Bi, daughter of ^{238}U

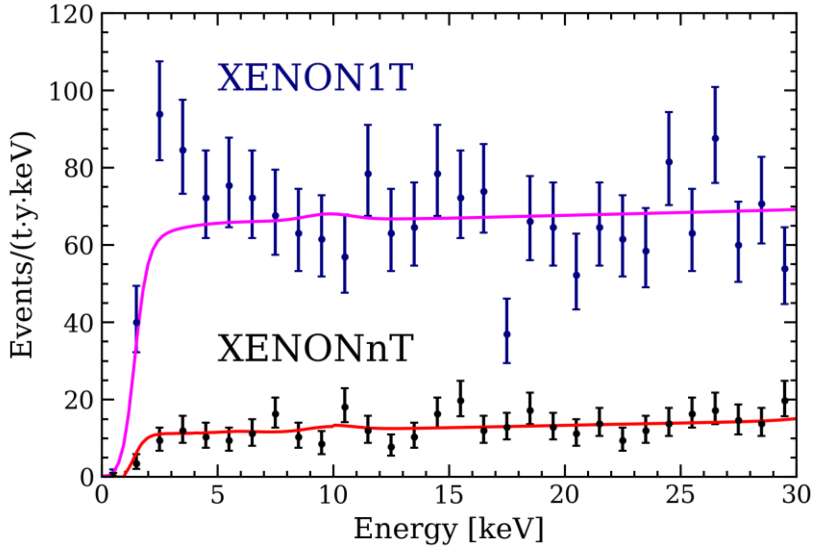
Summary and outlook

XENON collaboration, arXiv:2207.11330

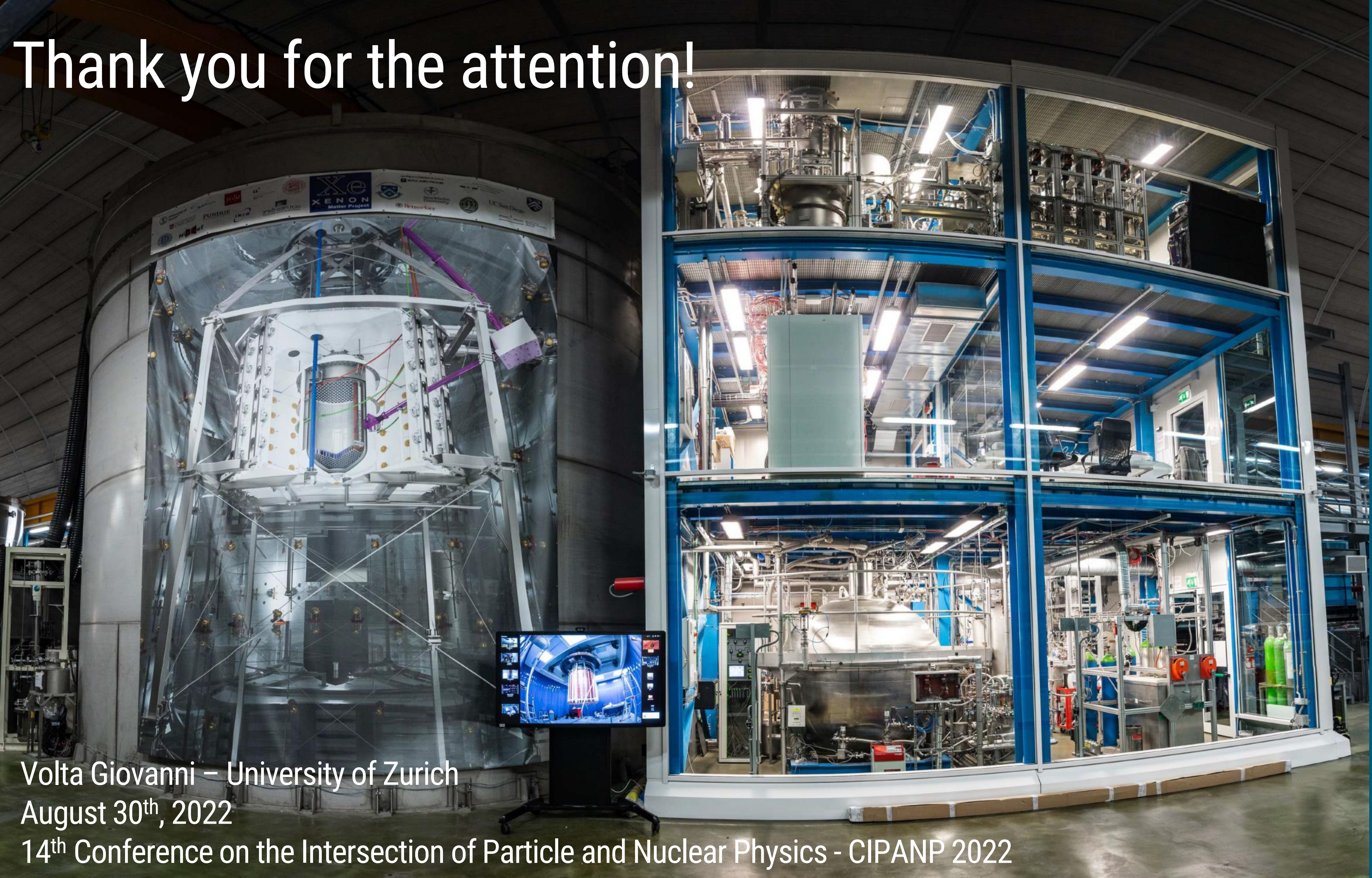
- ^{222}Radon activity concentration (1.72 ± 0.03) µBq/kg achieved
- Excellent purity of the LXe target: > 10 ms electron lifetime
- Electronic recoil response validated – July 2022 the ER band has been unblinded
- 1.16 tonne years exposure, ~×2 XENON1T ER search exposure
- (16.1 ± 0.3) events/(t × yr × keV) in [1; 30] keV energy range, ~×0,2 compared to XENON1T
- The validation of nuclear recoil response is ongoing – unblinding foreseen soon!

Check out Jingqiang Ye's talk @ 14:40 (30/08) for the unblinding results





Thank you for the attention!



XENON

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Gas purification system

Liquid purification system

Kr/Ar distillation column

Radon distillation column

Energy reconstruction