

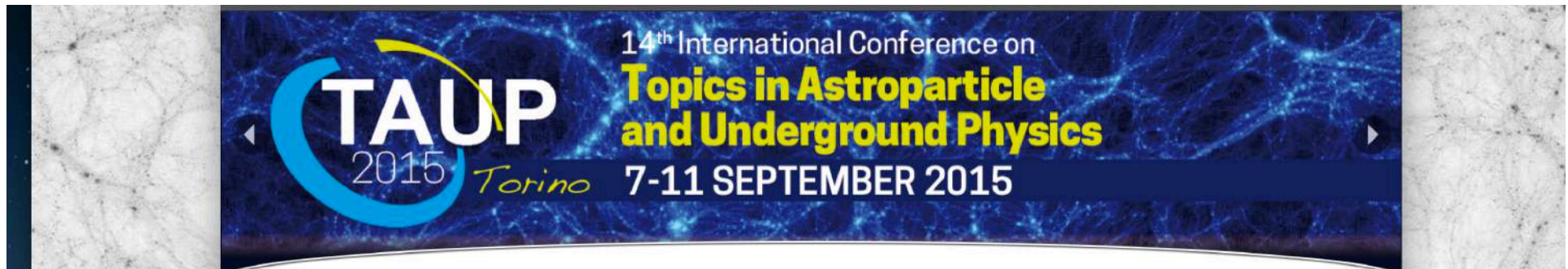


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Status of the XENON Project

Dott. Marco Garbini
Bologna University
On behalf of the XENON Collaboration



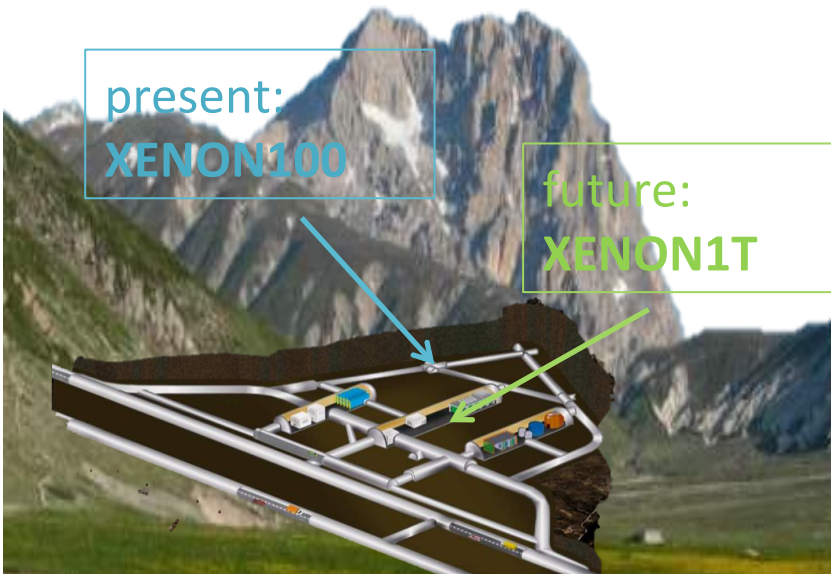
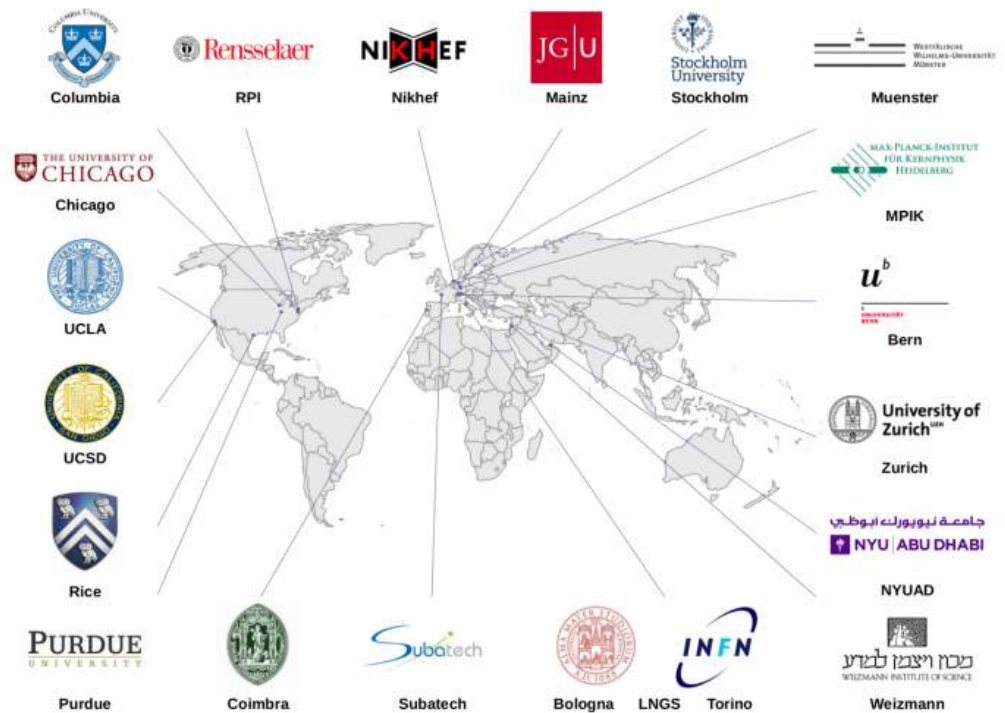


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The XENON Collaboration



More than
100 scientists
from 20 Institutions



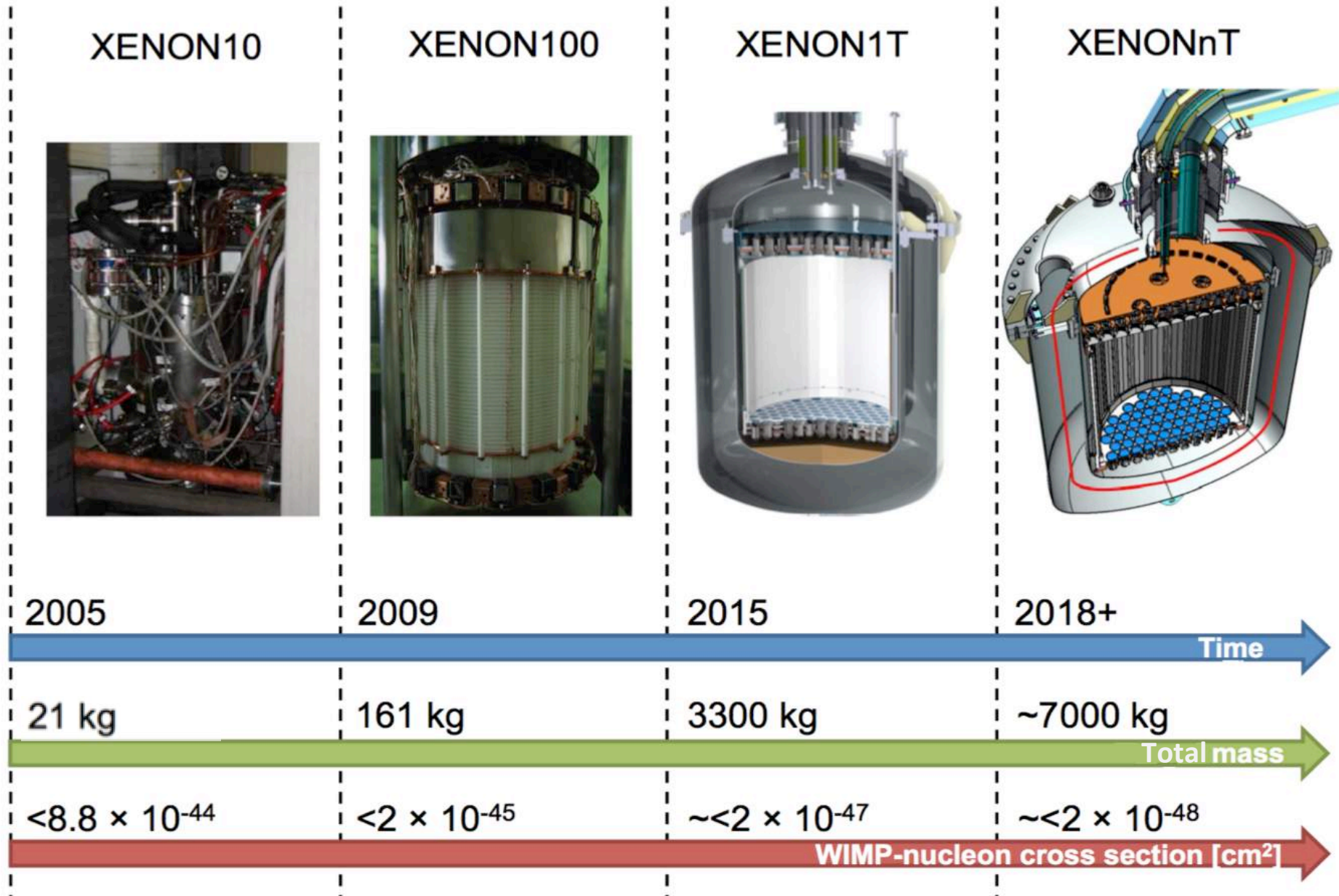
TAUP 2015, Torino, 7th Sept. 2015

M. Garbini, Bologna University



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The XENON Program

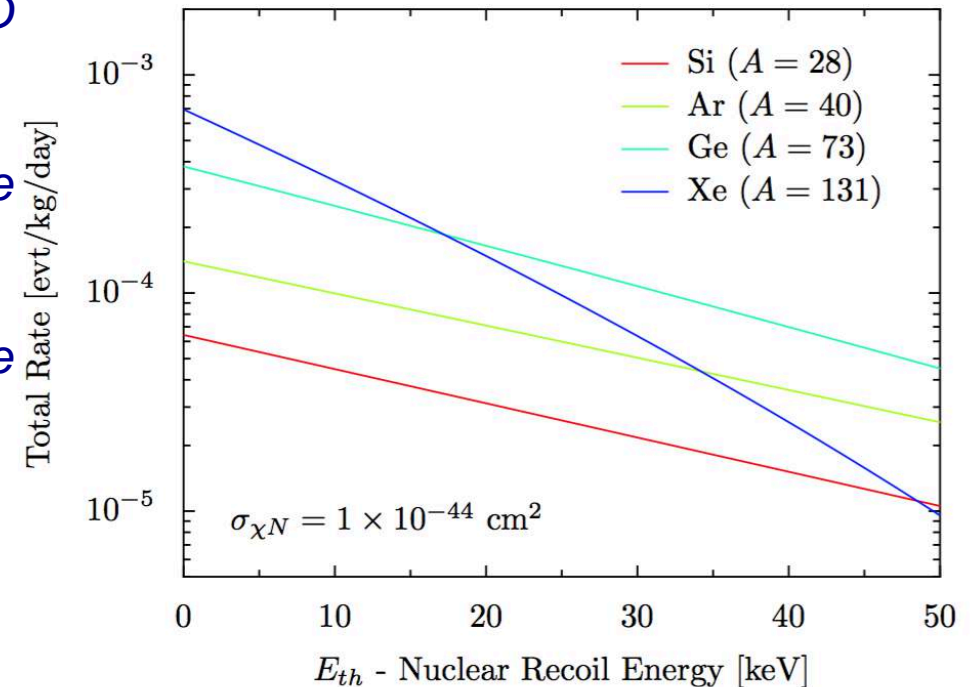




First of all, why we use Xenon



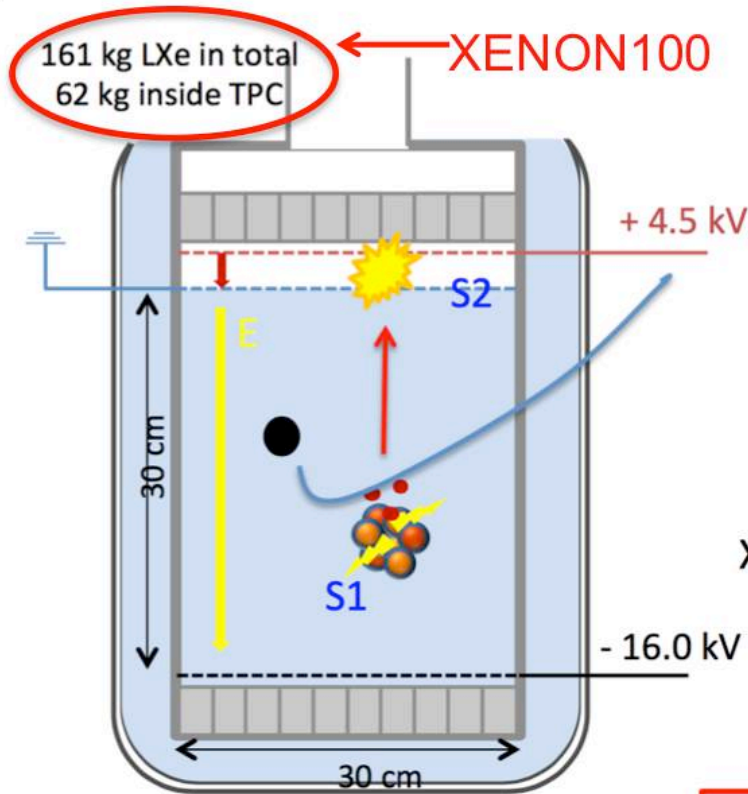
- Large mass number A (131)
- 50% odd isotopes (^{129}Xe , ^{131}Xe) for SD interactions
- No long-lived radioisotopes, Kr can be reduced to ppt levels
- High stopping power, i.e. active volume is self-shielding
- Efficient scintillator (178 nm)
- Scalable to large target masses
- Electronic recoil discrimination with simultaneous measurement of scintillation and ionization



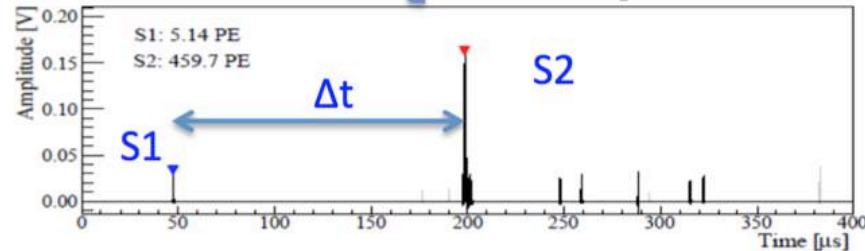


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Second...How we use it!

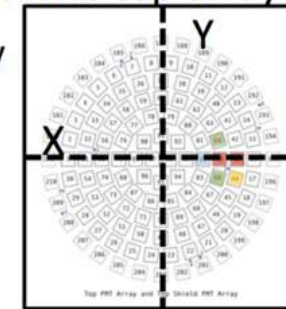


$$z \begin{cases} z(dt) = v_{\text{drift}} \times dt ; & v_{\text{drift}} \approx 1.74 \text{ mm}/\mu\text{s} \\ \text{Resolution } \sigma_z < 0.3 \text{ mm} \end{cases}$$

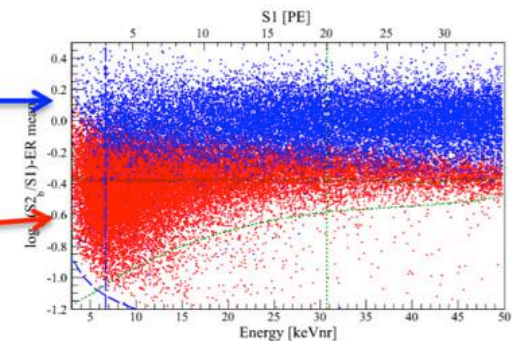
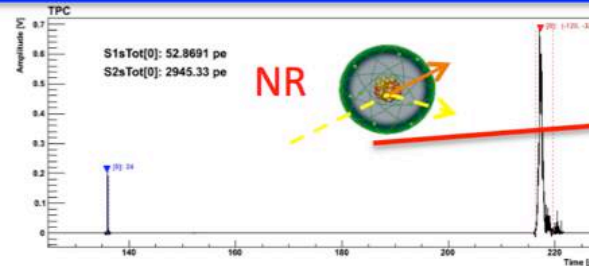
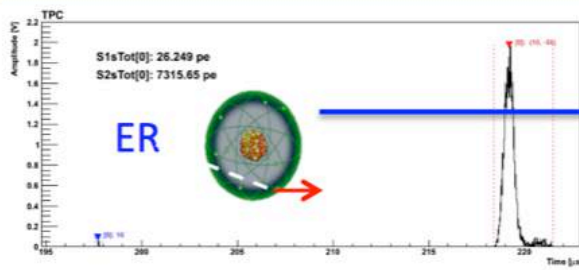


- X-Y
- Computed and cross-checked by
 - Neural network algorithm
 - χ^2 minimization
 - Support Vector Machine
- Resolution $\sigma_{x,y} < 3 \text{ mm}$

PMTs top array



PARTICLE IDENTIFICATION





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Still Running XENON100



present: XENON100



- 161 kg LXe TPC
(62 kg target + 99 kg active veto)
- 30 cm height and 30 cm x 30 cm diameter
- 242 1" square PMTs
Hamamatsu R8520 (low radioactivity
< 1mBq/PMT for U/Th)
Low radioactive materials
Multilayer passive shield
(H₂O, Pb, Poly, Cu)

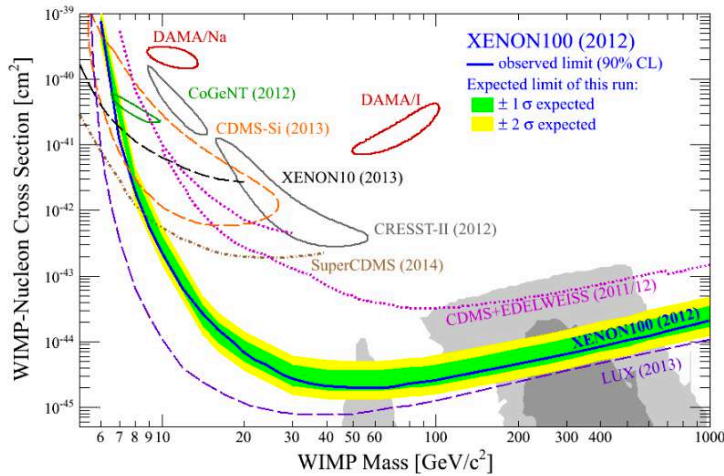


XENON100 Results on 225 live days



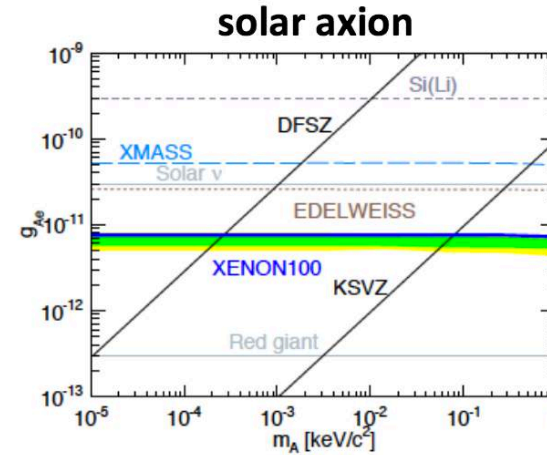
SI WIMP-nucleon Xsec limit

[Phys.Rev.Lett.109.181301 \(2012\)](#)



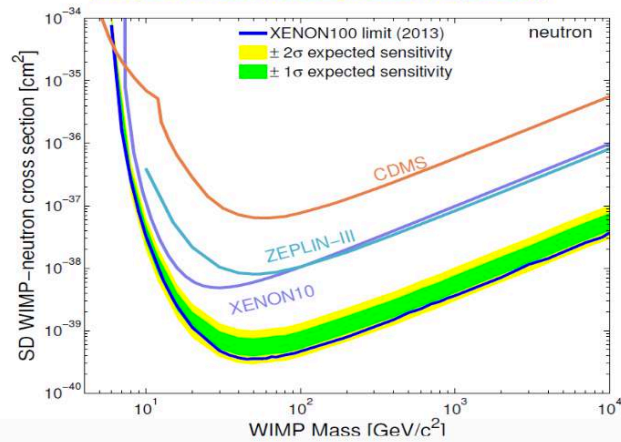
Axion-electron coupling limits

[Phys.Rev.D90, 062009 \(2014\)](#)

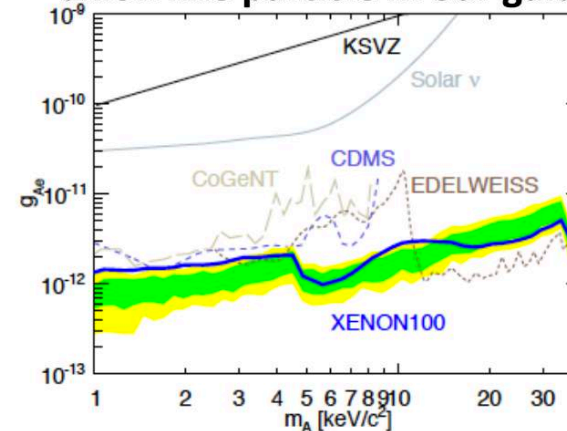


SD WIMP-neutron Xsec limit

[Phys.Rev.Lett.111,021301 \(2013\)](#)



axion-like particle in our galaxy

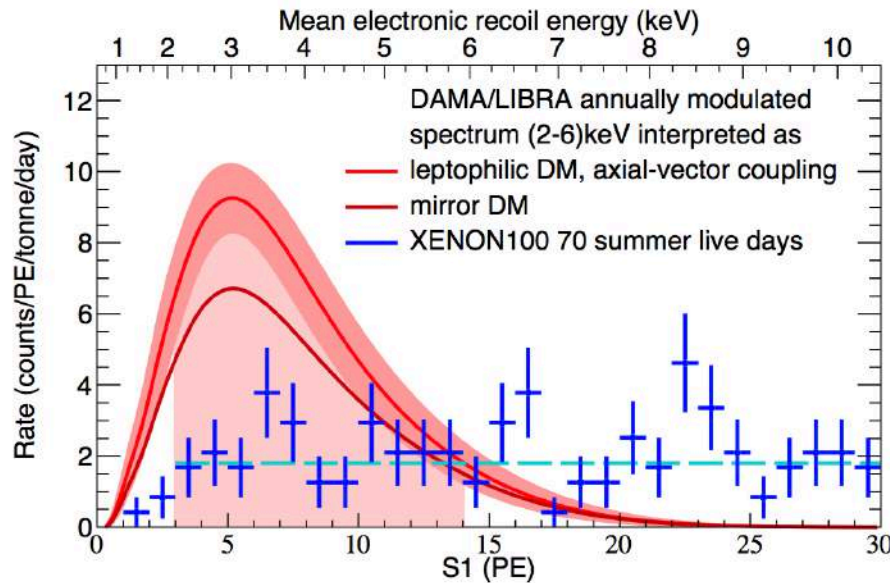




Latest Analysis on Leptophilic DM



Use XENON100 225 live days Data to search for DM interacting with electrons
Reconcile the DAMA vs Null-results situation in case of Nuclear Recoils

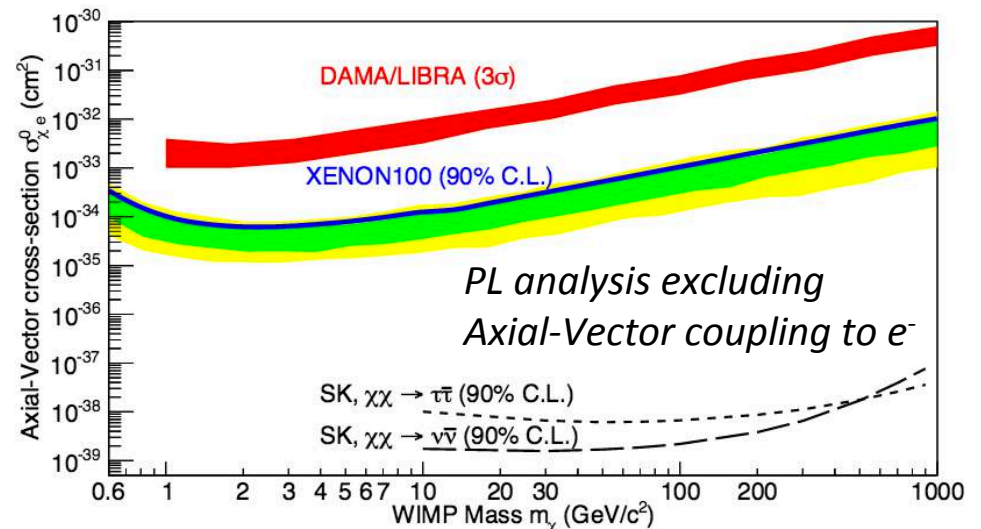


E. Aprile et al. (XENON Coll.),
Science 349, 851 (2015)

We selected ER events around (70 days) the expected peak of modulation.
Then, assuming 3 models on WIMP coupling to e^- , we estimated the expected signal and derived exclusion curves.

We exclude the DAMA signal as being induced by WIMPs interacting with e^- according to

- Axial-Vector Coupling at 4.4σ
- Mirror DM at 3.6σ
- Luminous DM excluded at 4.6σ

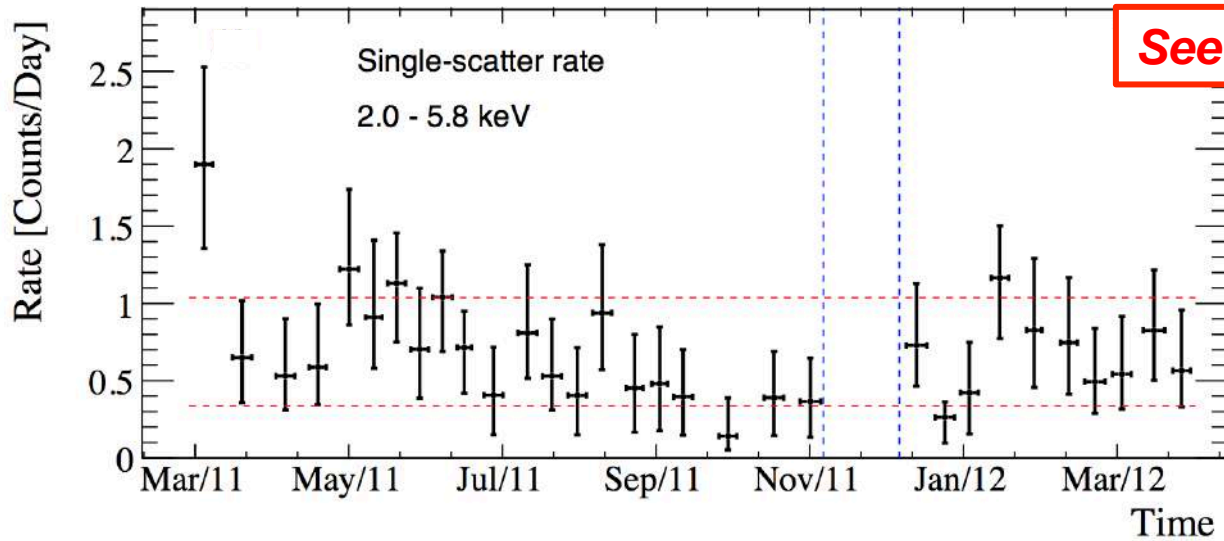




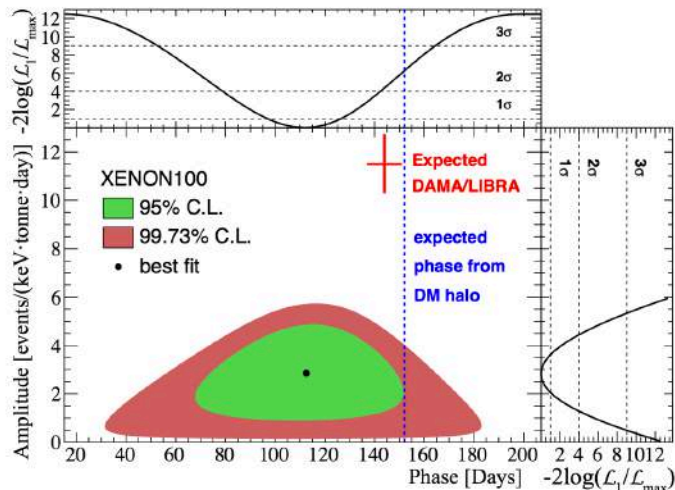
Latest Analysis on Annual Modulation



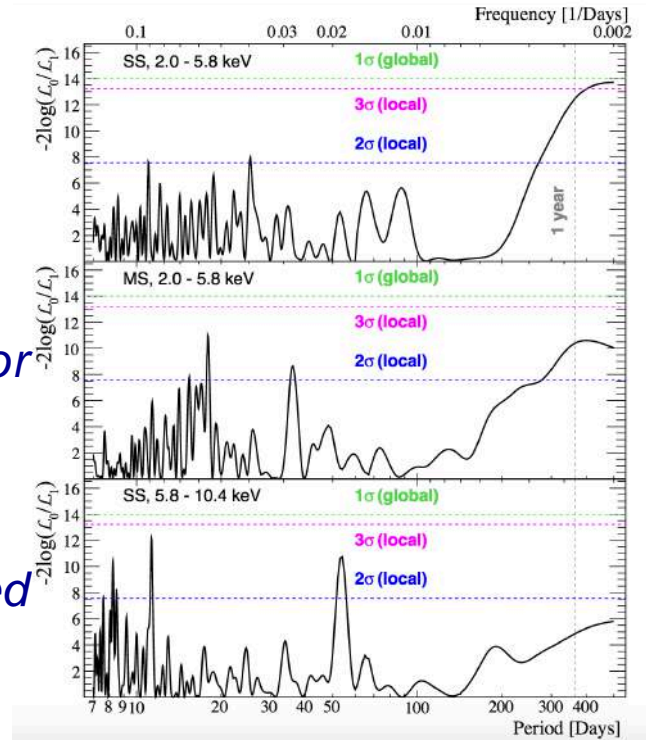
Use XENON100 225 live days Data to search for periodic variations of electronic recoil event rate → E. Aprile et al. (XENON Collaboration), Phys. Rev. Lett. 115, 091302 (2015)



Compare periodic signal hypothesis to null hypothesis (no periodic signal)



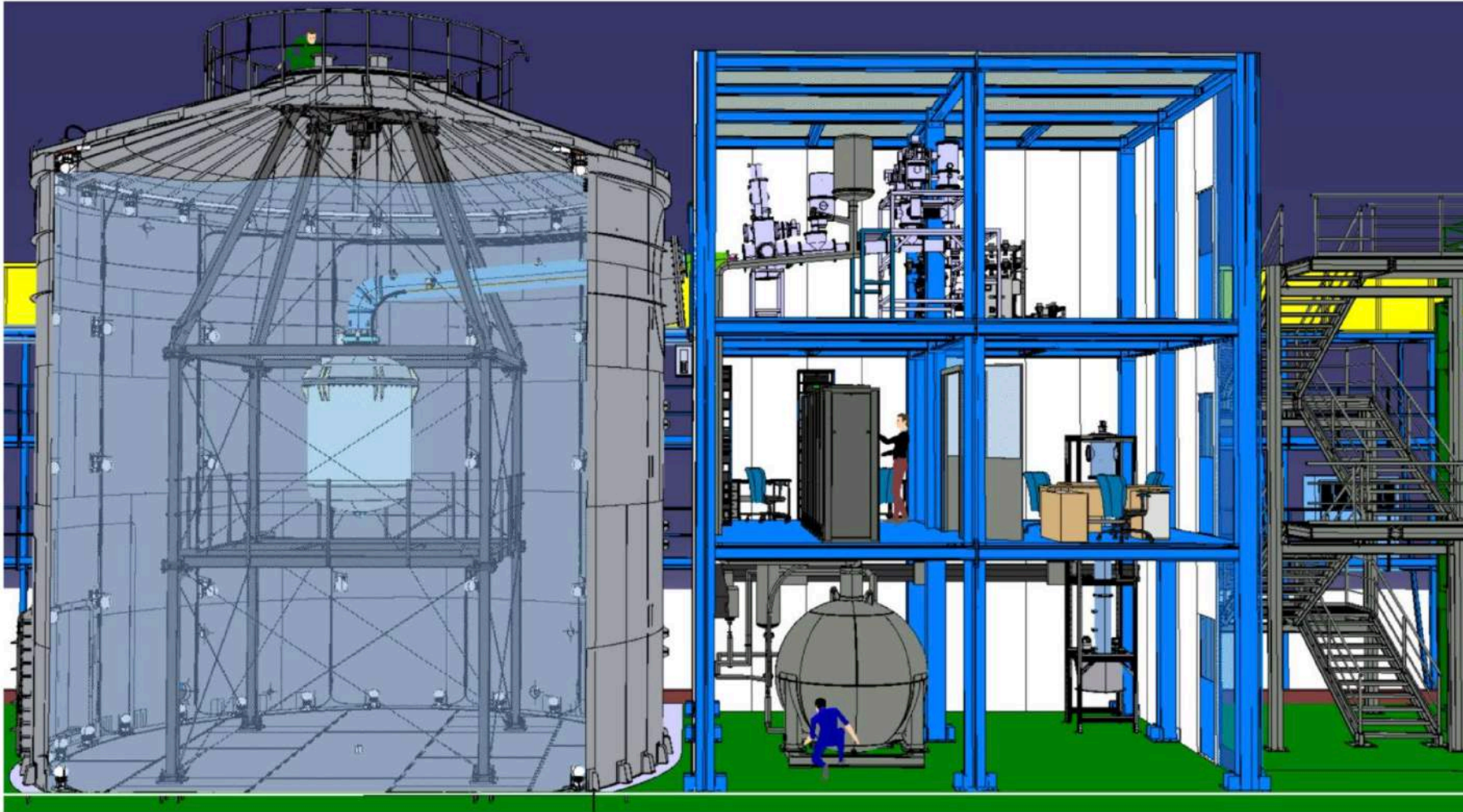
Assuming Axial-Vector coupling of WIMPs to electrons, DAMA/LIBRA annual modulation is excluded at 4.8σ





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XENON1T...Coming soon





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XENON1T...Coming soon

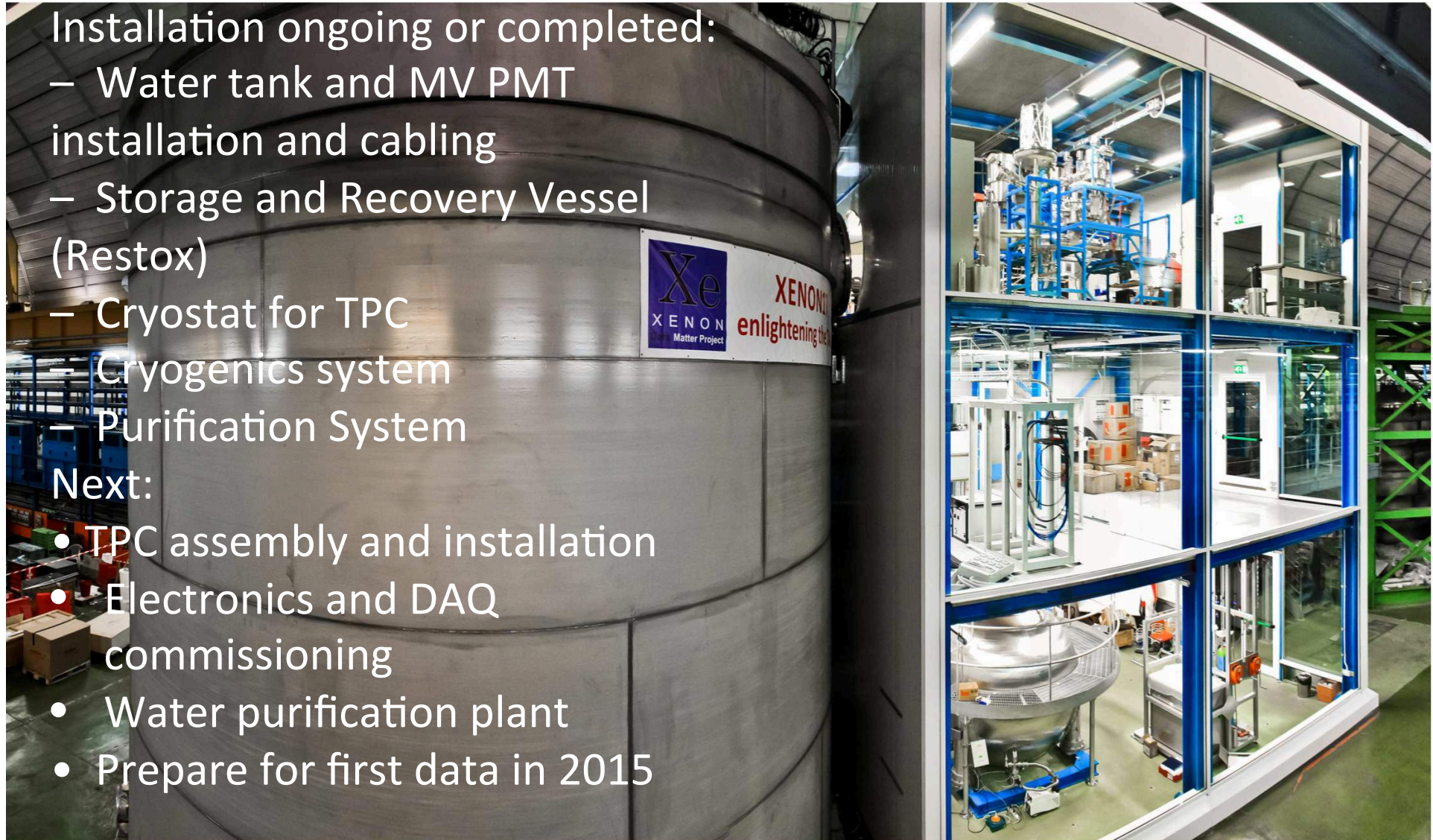


Installation ongoing or completed:

- Water tank and MV PMT installation and cabling
- Storage and Recovery Vessel (Restox)
- Cryostat for TPC
- Cryogenics system
- Purification System

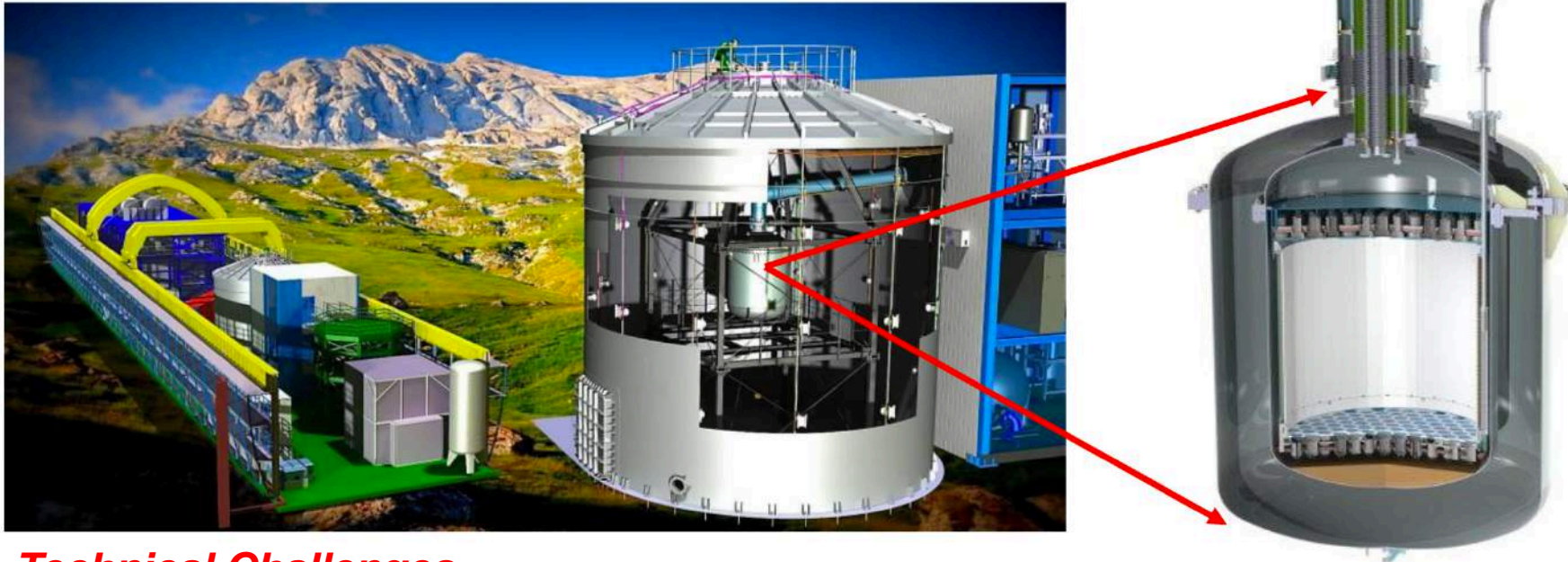
Next:

- TPC assembly and installation
- Electronics and DAQ commissioning
- Water purification plant
- Prepare for first data in 2015





The Detector



Technical Challenges

Low Background

- Material selections
- Muon Veto
- Kr Removal

Handling of >3 tons of Xe

- Storage system
- Cryogenic System
- Purification system

- Total LXe mass: ~3.3 tonnes
- Total LXe active volume: ~ 2 tonnes
- Fiducial volume: ~1 tonne
- 248 3" PMTs Hamamatsu R11410-21

Screening campaign was conducted to select materials with lowest radionuclide contamination level

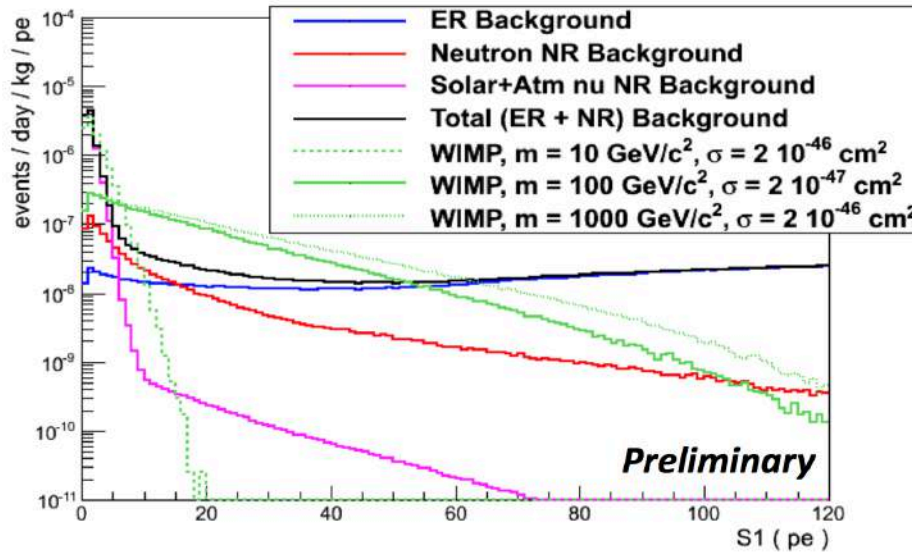
Reduce background of a factor 100 with respect to XENON100



Expected Background and Sensitivity

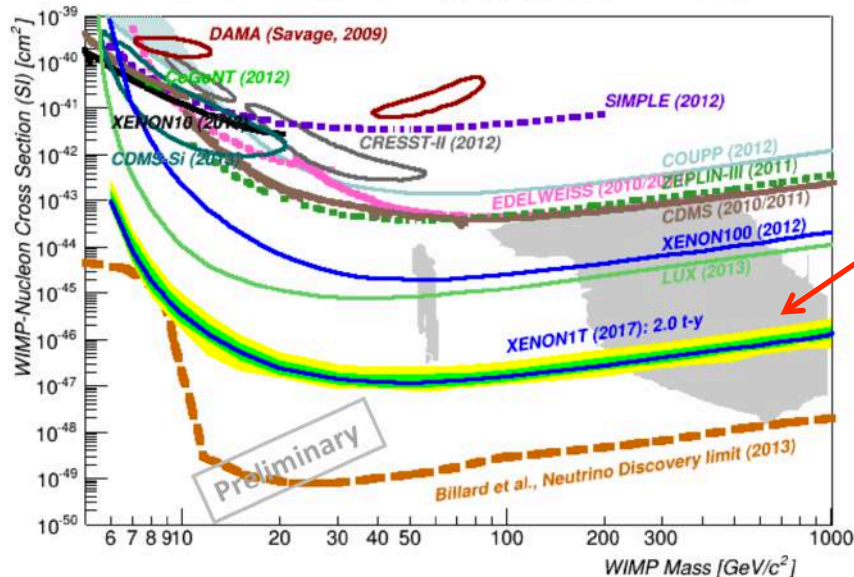


Total Background in XENON1T

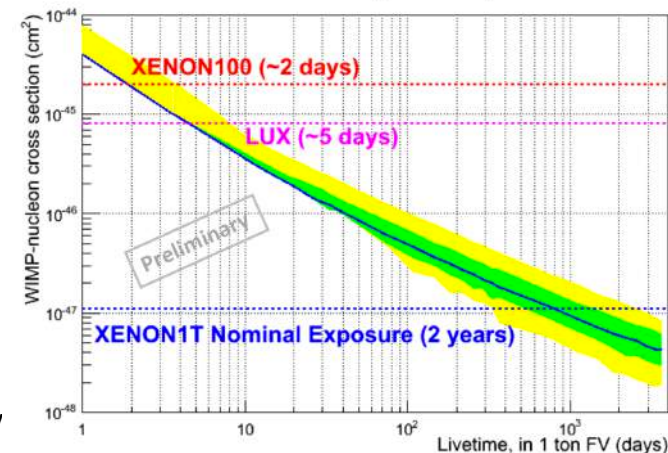


1 tonne fiducial volume, S1 in [3, 70] pe ([2, 12] keVee, [5, 50] keVr), ER discrimination 99.75%, NR Acceptance 40%.

Source	Background (ev/y)
ER (Material+ Intrinsic +solar ν)	0.32
NR from radiogenic neutrons	0.22
NR form neutrino Coherent Scattering	0.21
TOTAL	0.75



XENON1T design sensitivity after 2 years data taking





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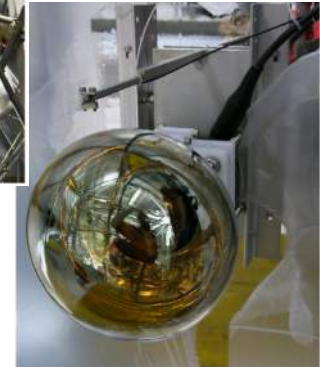
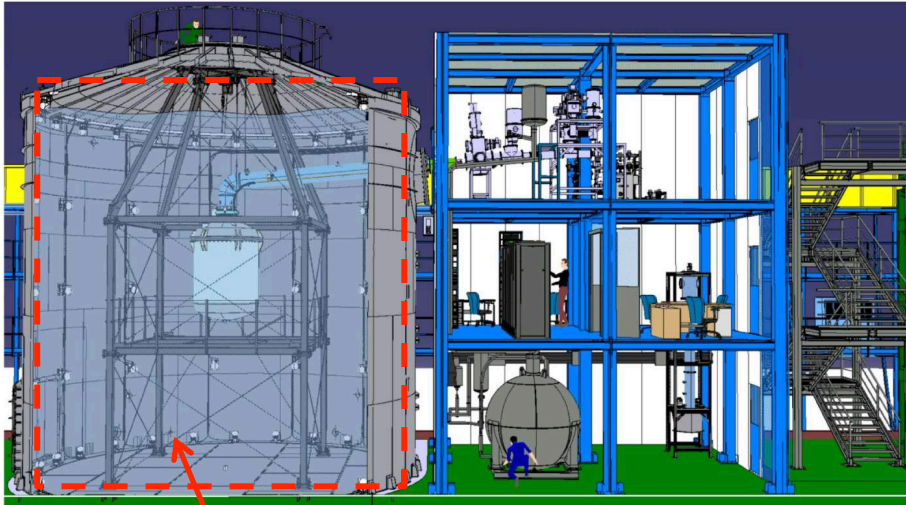


XENON1T: Systems Status



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Muon Veto



- 10 m height, 9.6 m diameter
- 84 high QE 8" PMTs (Hamamatsu R5912)
- Internal surface covered with reflective film foil
- Reject >99.5% of neutron with muon in water tank
- Reject >70% of neutron with muon outside water tank
- μ -induced neutron background < 0.01/(ton year)



Details in Aprile et al., JINST 9, P11006, 2014



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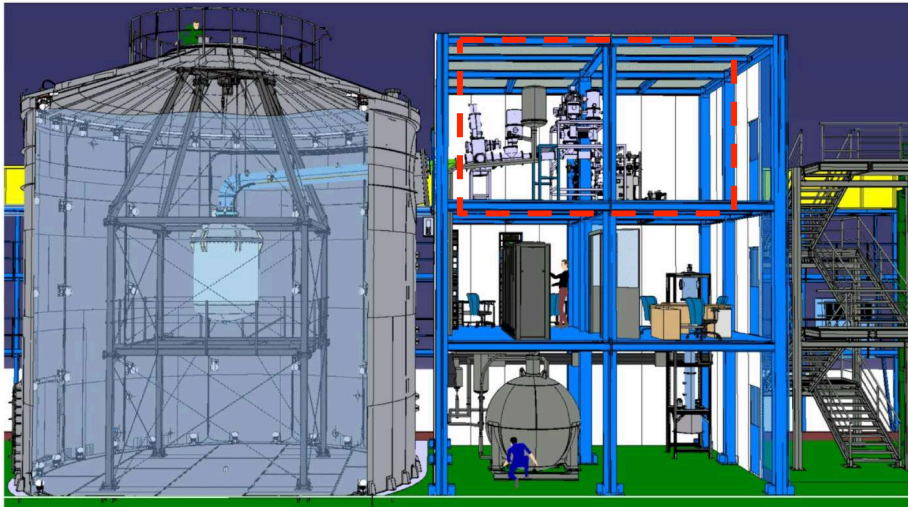
Cryogenic System



The design of the Cryogenic System is based on experience acquired by operating XENON10, XENON100, and XENON1T Demonstrator.

Purpose: keeping LXe temperature (~ -100 °C) in reliable way

E Aprile et al. 2012 JINST 7 P10001, arXiv:1208.2001



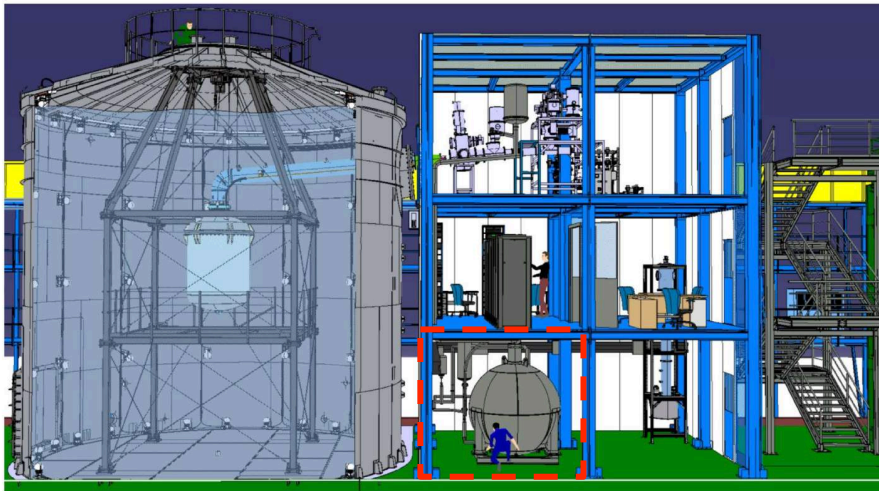
- 2 Redundant 200 W pulse tube Refrigerators
- One PTR can be serviced while the other is in operation
- Backup liquid nitrogen cooling
- Circulation at ~ 100 slpm through heat exchanger

The System has been fully validated and works as designed

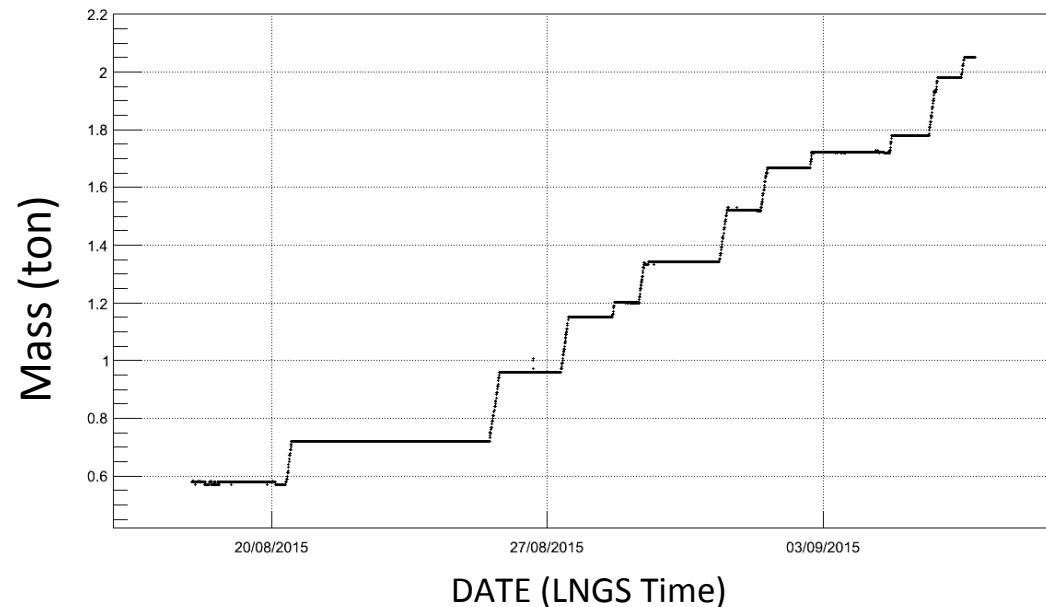


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Xenon Storage → RESTOX



- Double-wall, high-pressure (70 atm), vacuum insulated, LN2 cooled sphere
- Designed to store ~7.6 tons of xenon, in liquid form at -100°C or in gaseous form at room temperature
- Detector can be filled with liquid xenon directly instead of condensing xenon gas
- In case of emergency, liquid xenon from the detector can be recovered in a few hours

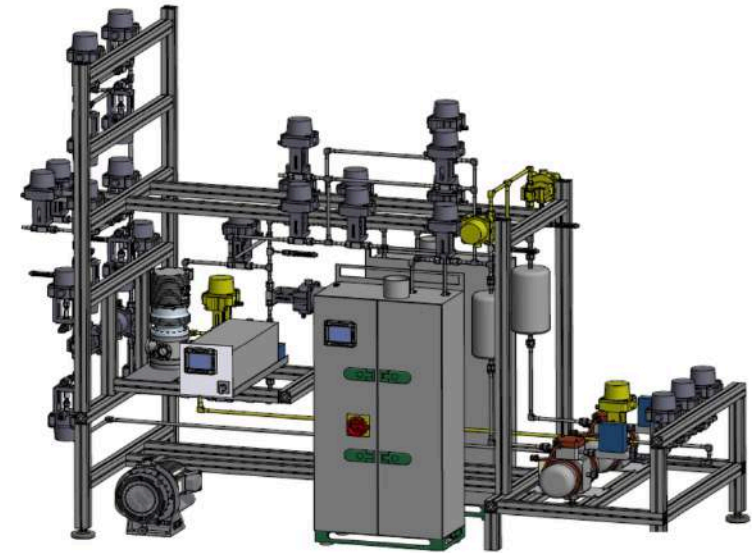
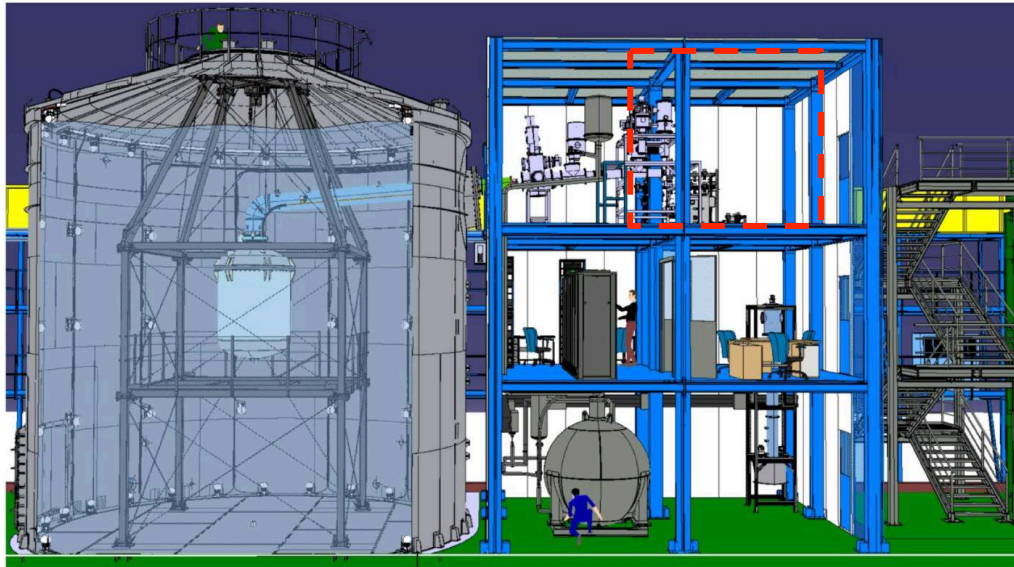


Currently being filled with Xenon and works as expected



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Purification System

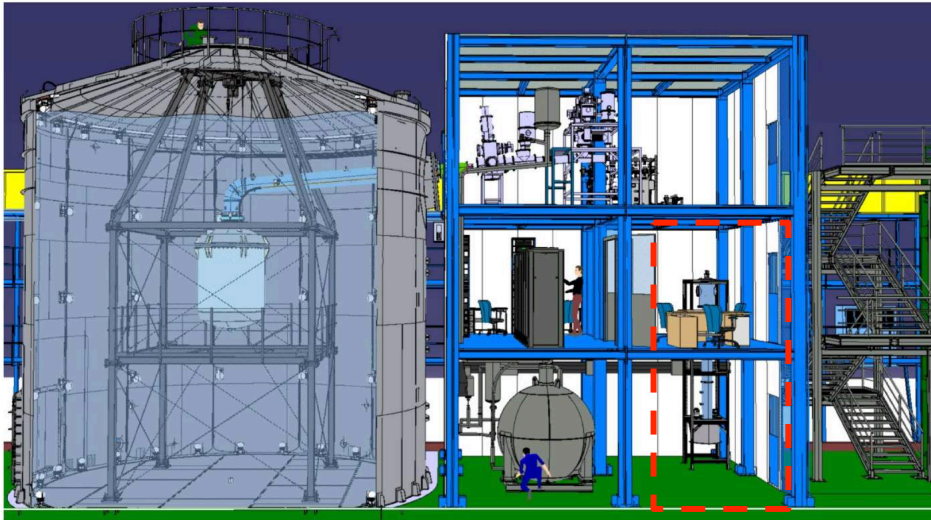


- **Continuous GXe circulation at ~100 slpm**
- **Purification using high-flow heated getters**
- **Two parallel circulation pumps (QDrive) and purification circuits**
- **Continuous monitoring of impurity concentrations (e.g. H₂O)**



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Distillation Column → Kr Removal



Custom designed cryogenic distillation column for Kr removal with *the purpose of reducing ^{85}Kr internal beta-background.*

- XENON1T Kr/Xe concentration requirement is $< 0.2\text{ppt}$, aim at $< 0.1\text{ppt}$ with the column
- High throughput, 3 kg/hr
- 3.5 tons in ~ 1.8 months (single pass)
- Custom gas purity diagnostics (online, 83m Kr tracer, and offline, ATTA, RGMS, RGA+ cold trap)
- Very efficient purification: column between RESTOX and Cryostat



More Details in the poster by Alex Fieguth

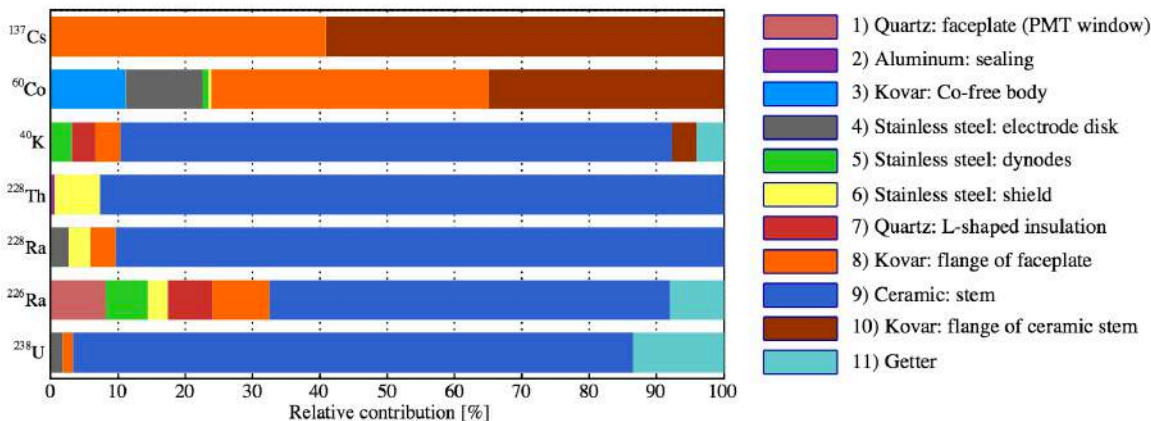
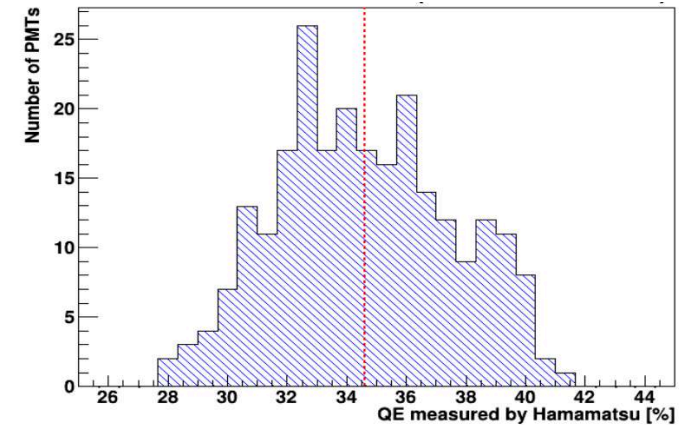


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The PMTs



- 248 3" PMTs (Hamamatsu R11410-21)
- Quartz window, bialkali photocathode, 12 dynode, Kovar enclosure
- Average QE ~35%
- Gain $\sim 3.5 \times 10^6$ @ -1.5 kV
- All PMTs were screened before they get into the detector
- Test in cold (-100°C in N₂)
- Test in LXe



Component	Radioactivity
²³⁸ U	< 10 mBq/PMT
²²⁸ Th	~ 0.5 mBq/PMT
²²⁶ Ra	~ 0.6 mBq/PMT
²³⁵ U	~ 0.3 mBq/PMT
⁶⁰ Co	~ 0.8 mBq/PMT
⁴⁰ K	~ 12 mBq/PMT

Lowering the radioactivity of the photomultiplier tubes for the XENON1T dark matter experiment → arXiv:1503.07698

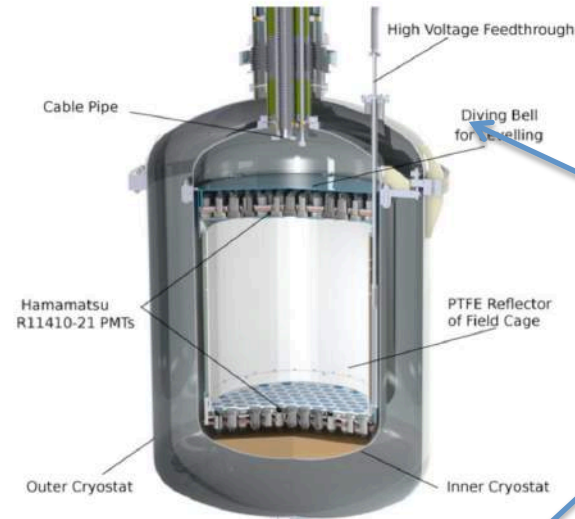


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The TPC



Under Construction

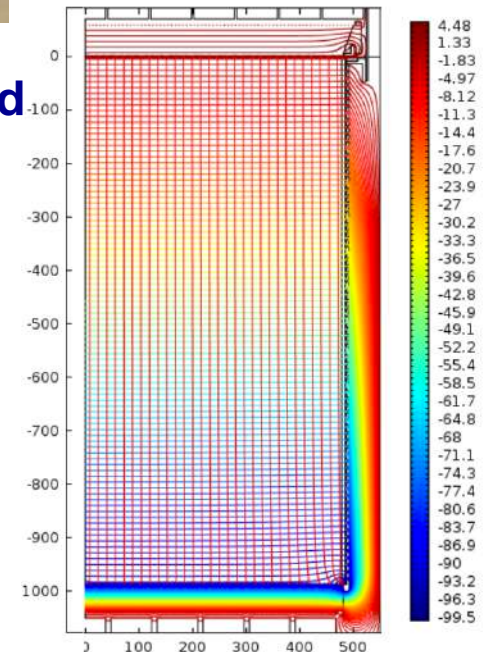


Custom cathode HV feedthrough tested up to -110 kV in LXe

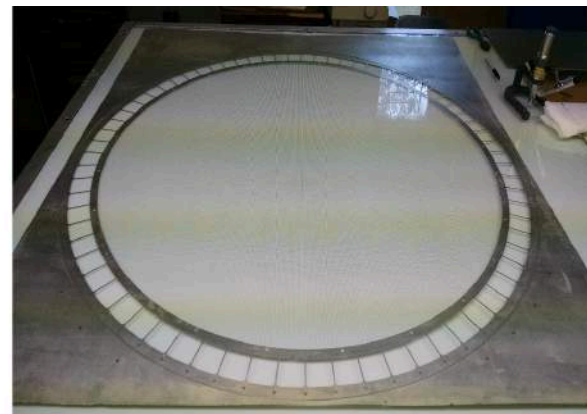
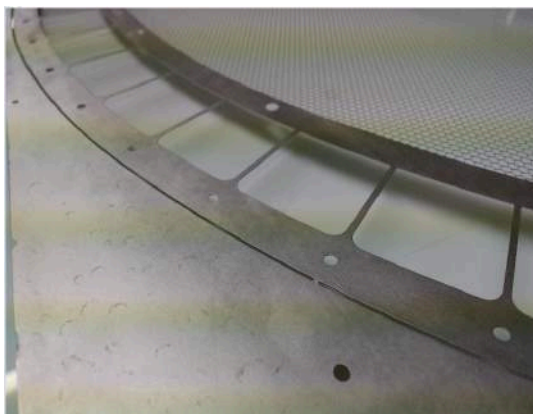


**Height ~ 96 cm
Diameter ~ 96 cm
Active target mass
2 tonnes**

**Uniform Electric field
(variation ~ 1%)**



Anode Mesh

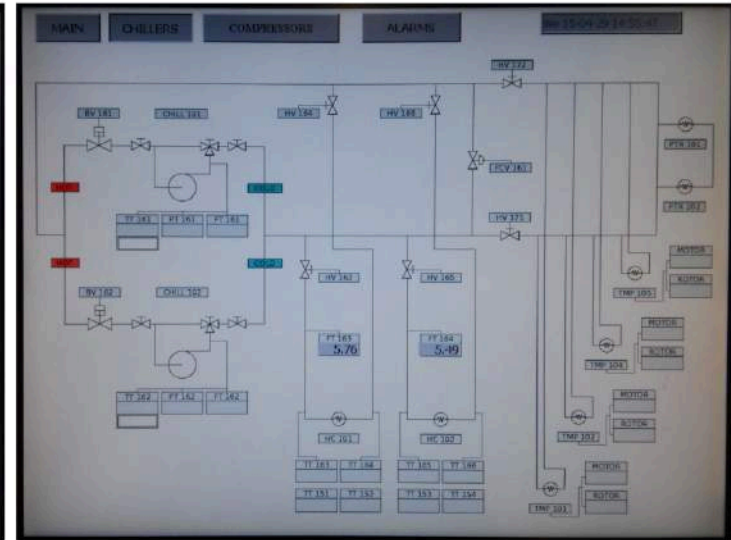
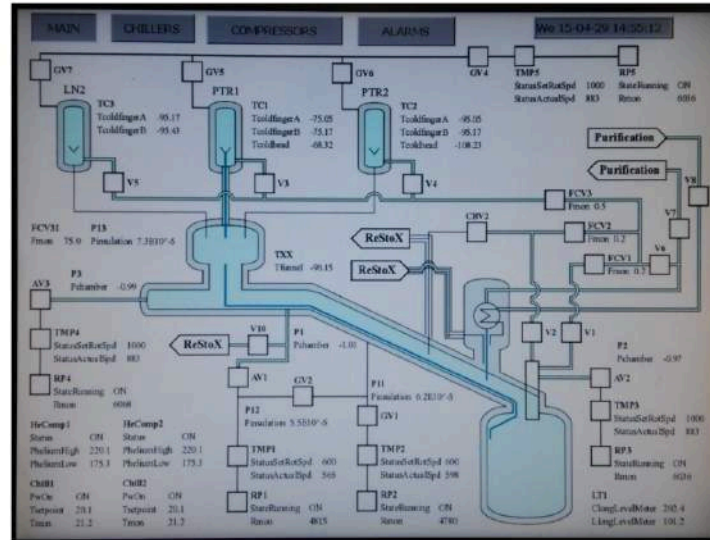




More Subsystems



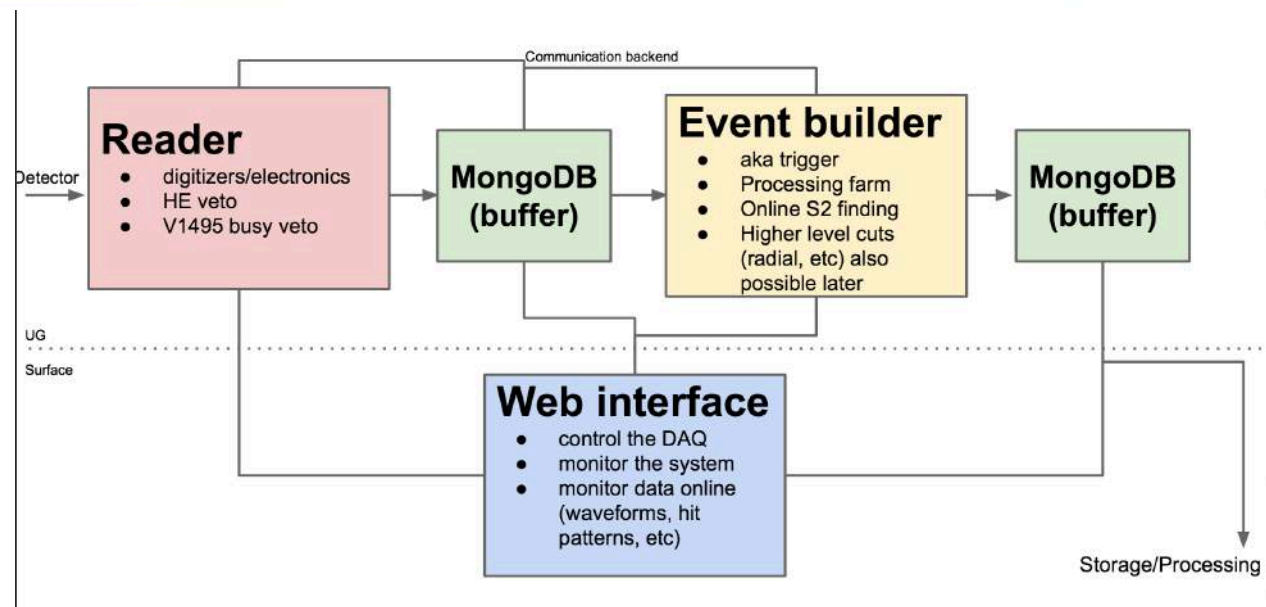
Slow Control:
-The Slow control system is under commissioning and already in use for ongoing LXe commissioning



DAQ:
New DAQ Scheme Developed.
It consists of two parts:

- **Reader:** raw data readout from digitizer
- **Event Builder:** online software trigger

Tested and easily scalable
We aim to use the GRID





Summary



- *The XENON Program is continuing the search for the DM signal*
- *XENON100 still in operation is providing physics results and data analysis is still ongoing*
- *XENON1T is under construction/commissioning. Cryogenic system /Restox/purification systems have been validated and work as expected*
- *Detector Assembly starts this month*
- *First data are expected by the end of the year*

So... We will strongly try to enlighten the DARK



What Next?

XENONnT:2018-2022

The total mass of Xenon will be ~ 7000 kg.

The systems developed for XENON1T can be used to operate XENONnT:

Underground infrastructure, Cleanrooms, DAQ, Slow Control, Computing Infrastructure, Water Tank, Muon Veto, Outer Cryostat, Support Structure, Cryogenics and Purification systems, LXe storage and recovery system.

Only the inner cryostat, the number of PMTs (~ 200 more) and TPC will be upgraded.

