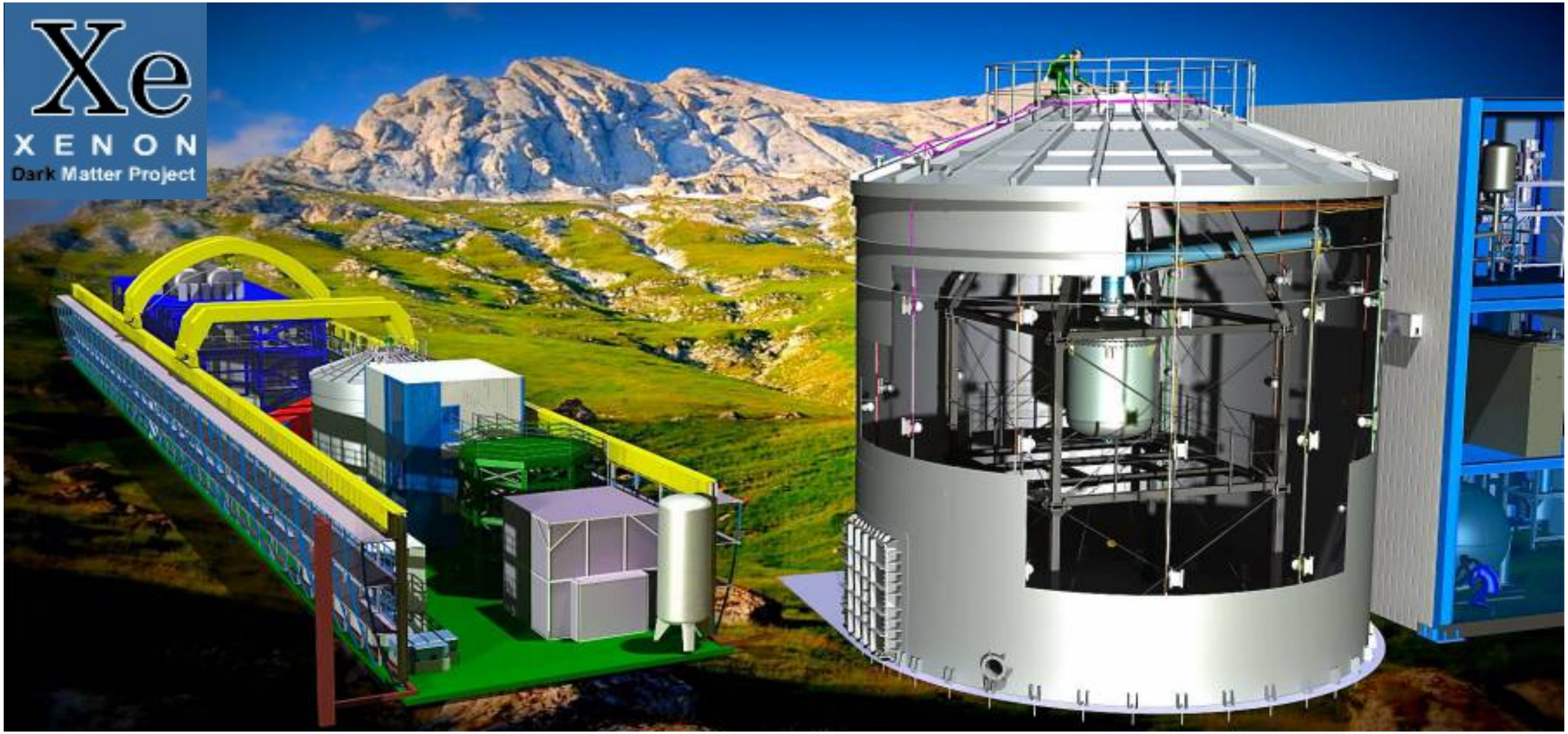
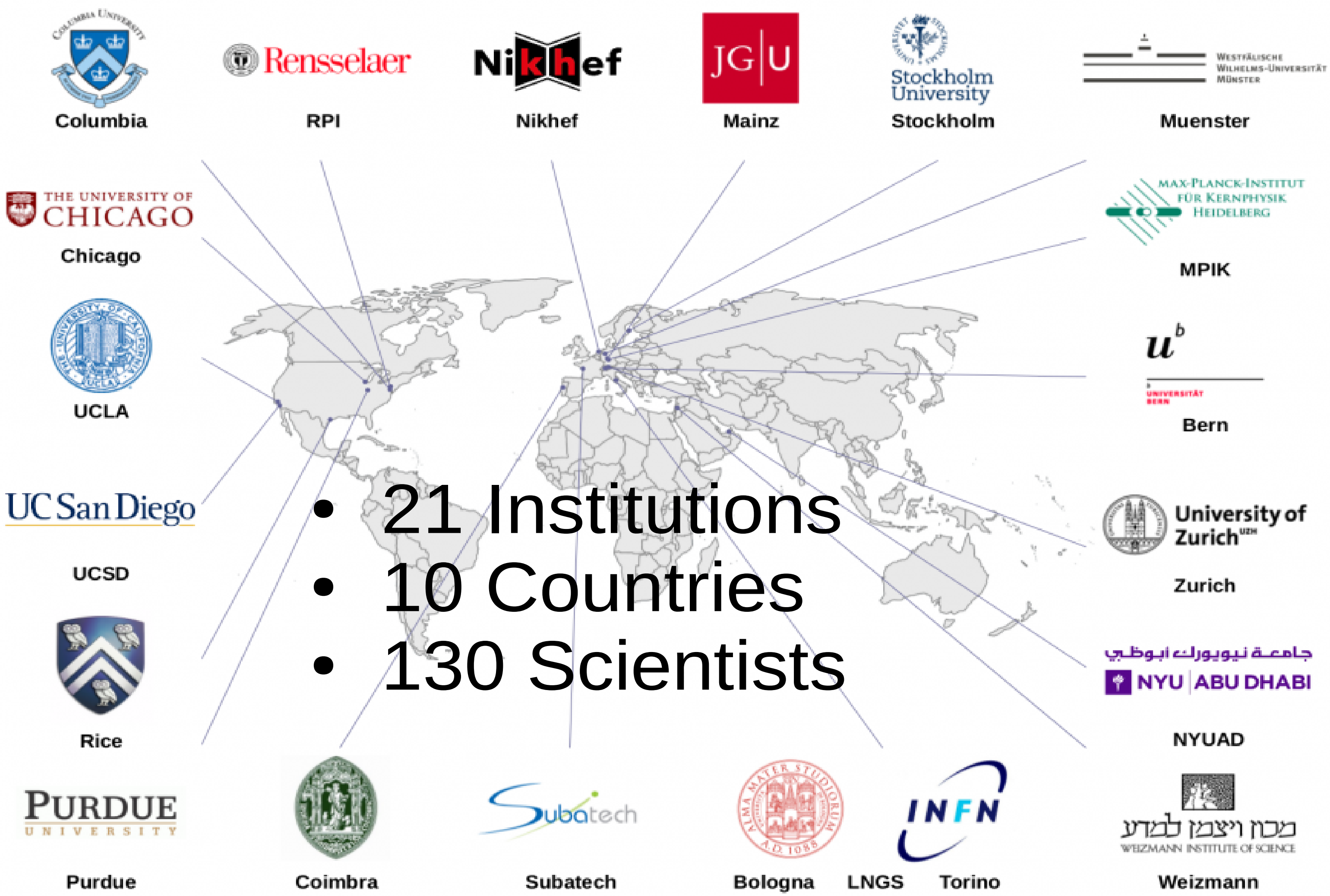


Status of the XENON Project

M. Selvi – INFN Bologna
on behalf of the XENON collaboration

LNGS Scientific Committee meeting – 17th October 2016

The XENON Collaboration



- 21 Institutions
- 10 Countries
- 130 Scientists

The XENON program

XENON10

2005-2007
15 cm drift TPC – 25 kg

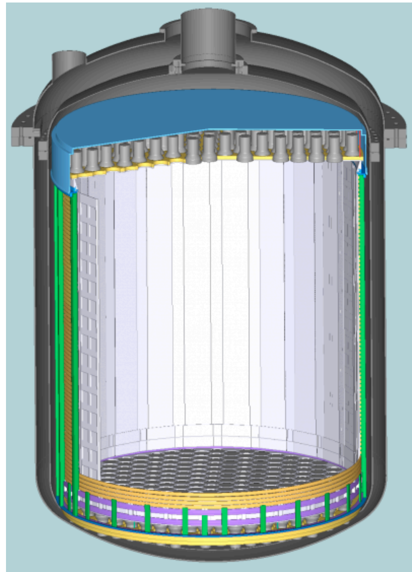
Achieved (2007)
$\sigma_{SI} = 8.8 \times 10^{-44}$ cm^2

XENON100

2008-2016
30 cm drift TPC – 161 kg

Achieved (2016)
$\sigma_{SI} = 1.1 \times 10^{-45}$ cm^2

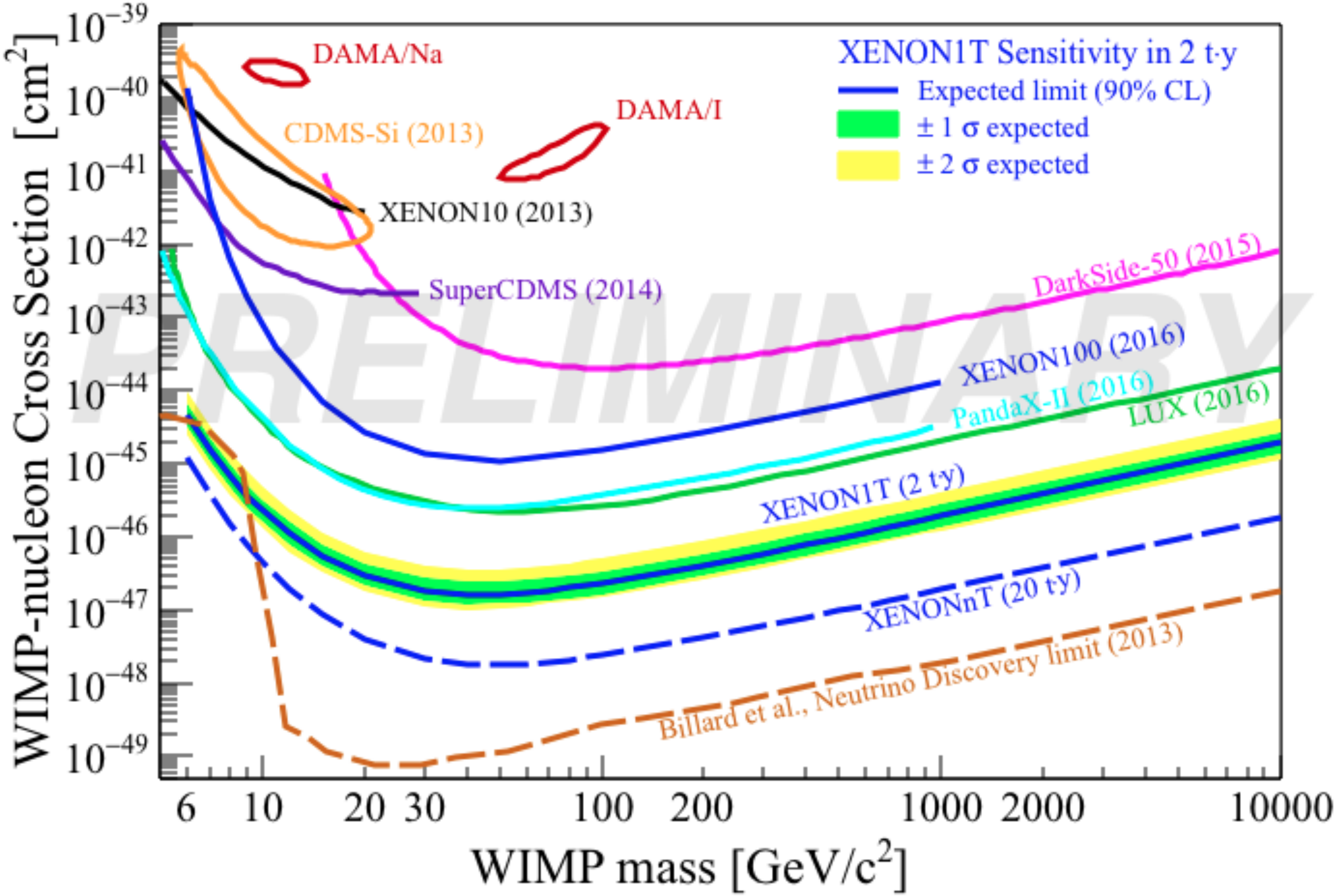
XENON1T / XENONnT



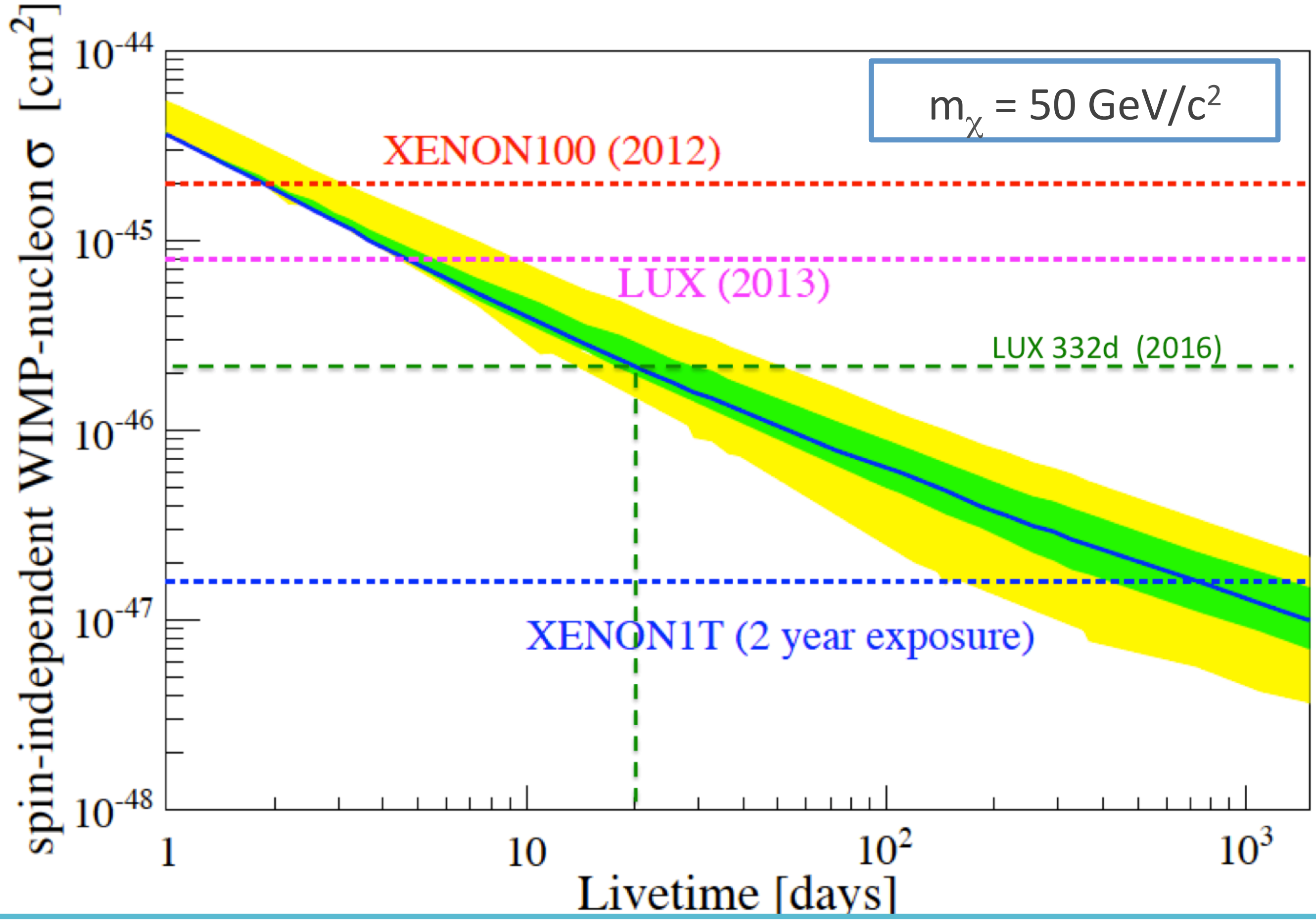
2012-2018 / 2019-2023
100 cm / 144 cm drift TPC - 3200 kg / ~8000 kg

Projected (2018) / Projected (2023)
$\sigma_{SI} = 1.6 \times 10^{-47}$ cm^2 / $\sigma_{SI} = 1.6 \times 10^{-48}$ cm^2

Sensitivity Plot (summer 2016)



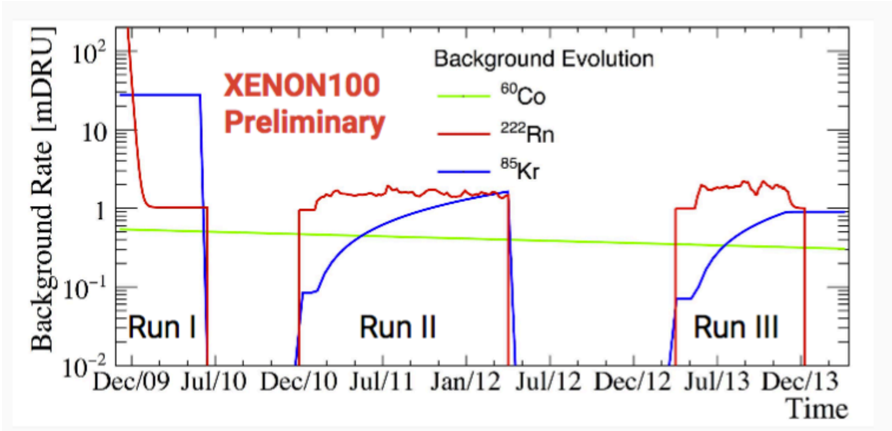
XENON1T Sensitivity VS time



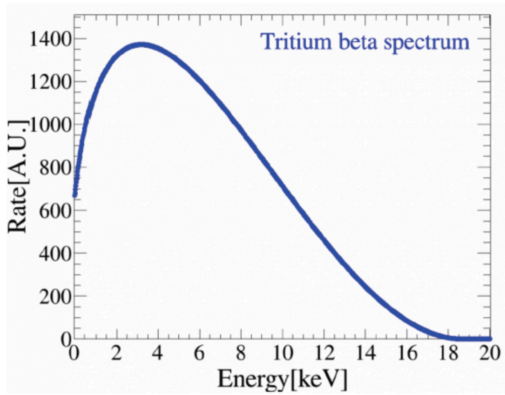
In about 20 days we can reach the sensitivity
of the current best limits (LUX, PANDAX-II)

XENON100 status

- Run Combination analysis: 477 live-days in total. New Spin-dependent and -independent limit. $\sigma_{SI} = 1.1 \times 10^{-45}$ cm^2
  arXiv:1609.06154
- "A low-mass dark matter search using ionization signals in XENON100"
  arXiv: 1605.06262, accepted by PRD
- Search for Two-Neutrino Double Electron Capture of ^{124}Xe with XENON100
  arXiv: 1609.03354
- Ongoing analysis of data modulation in the whole sample: 477 days along about 4 years

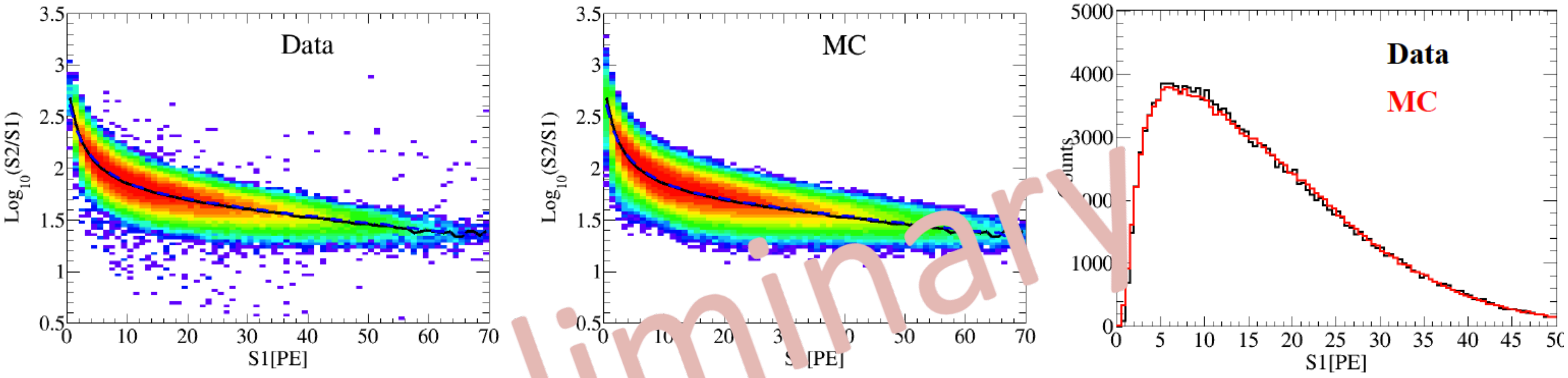


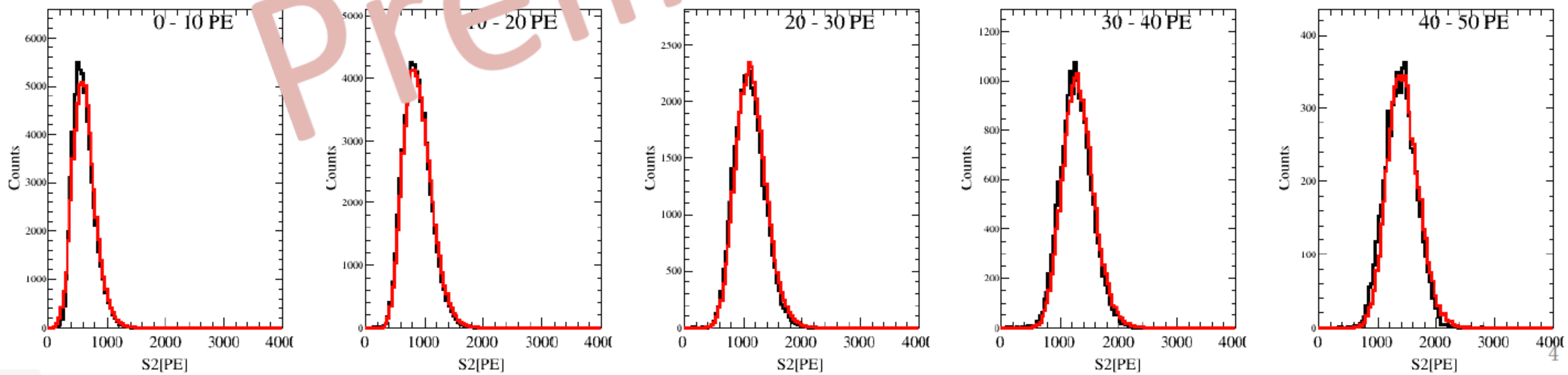
- XENON100 is also an important tool to test new internal calibration sources towards XENON1T:
  - ^{83m}Kr (ER light yield, electron lifetime),
  - Tritiated Methane (ER band, ER acceptance),
  - ^{220}Rn (ER band, Rn flow inside the detector).



XENON100: Tritiated Methane ER calibration

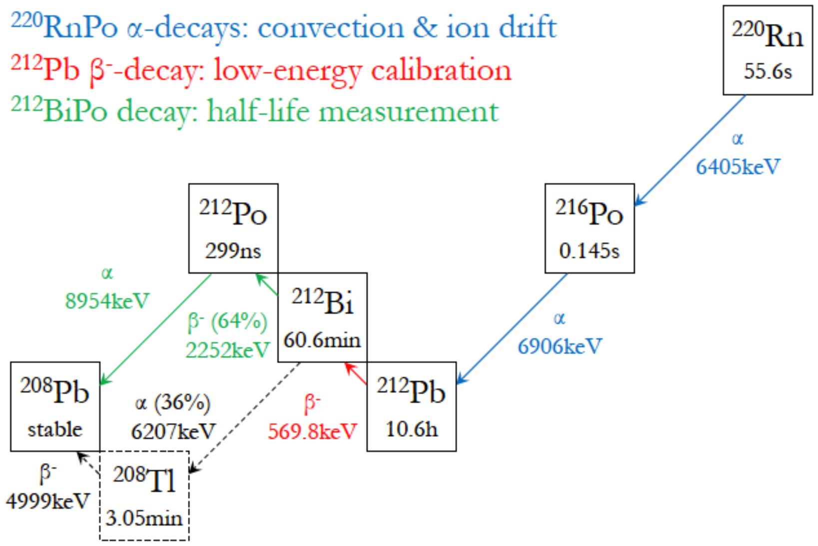
Precise measurement of the characteristics of the low energy ER band





XENON100: ^{220}Rn ER calibration

- Radon is injected from a ^{228}Th source
- ^{212}Pb has 12% b.r. decay to the Bi ground state -> efficient low energy ER calibration
- No long lived isotopes in ^{220}Rn chain -> no need to purify LXe, sample cleaned in one week



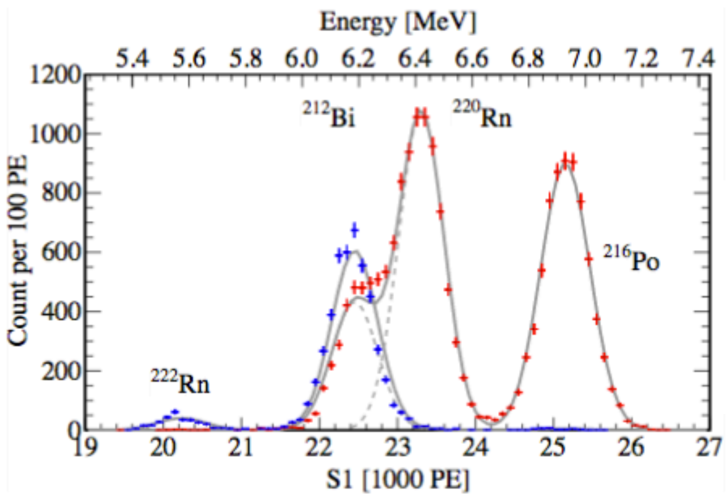


FIG. 4. The alpha spectrum of the ^{220}Rn ... chain is shown integrated over times during which the source is open (40.3 hours, red) and after (148.7 hours, blue) the source is closed. The constant background of ^{222}Rn (cp. Figure 2) is visible only over the longer time period.

Results from a Calibration of XENON100 Using a Dissolved Radon-220 Source Version 1.0

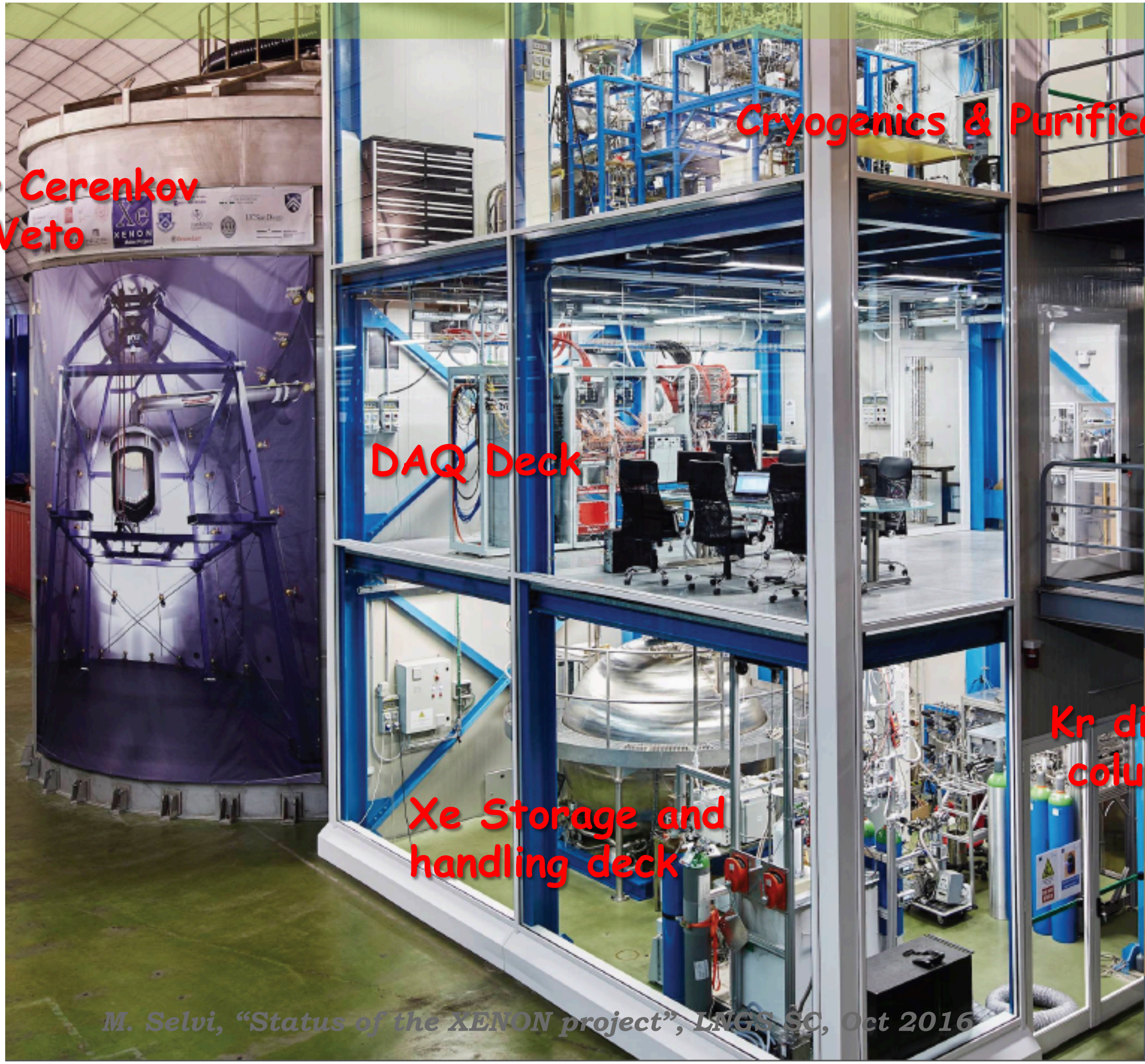
The XENON Collaboration

A ^{220}Rn source is deployed in the XENON... dark matter detector in order to address the challenges in calibration of tonne-scale li... noble element detectors. We show that the ^{212}Pb beta emission can be used for low-energy electronic recoil calibration in searches for dark matter.

XENON1T

- **Science goal:** 100 times more sensitive than XENON100.
- **Detector:** Total 3.2 t of LXe/ 2.0 t in the dual-phase TPC, readout by 248 PMTs.
- **Shielding:** Water Cherenkov muon veto.
- **Cryogenic Plants:** Xe cooling/ purification/distillation/storage systems designed to handle up to ~8 tonne of Xe. Upgrade to a larger detector (XENONnT) planned for the end of 2018.
- **Status:** All systems successfully tested. Calibrations of detector ongoing. First Dark Matter run in a few weeks.

XENON1T overview



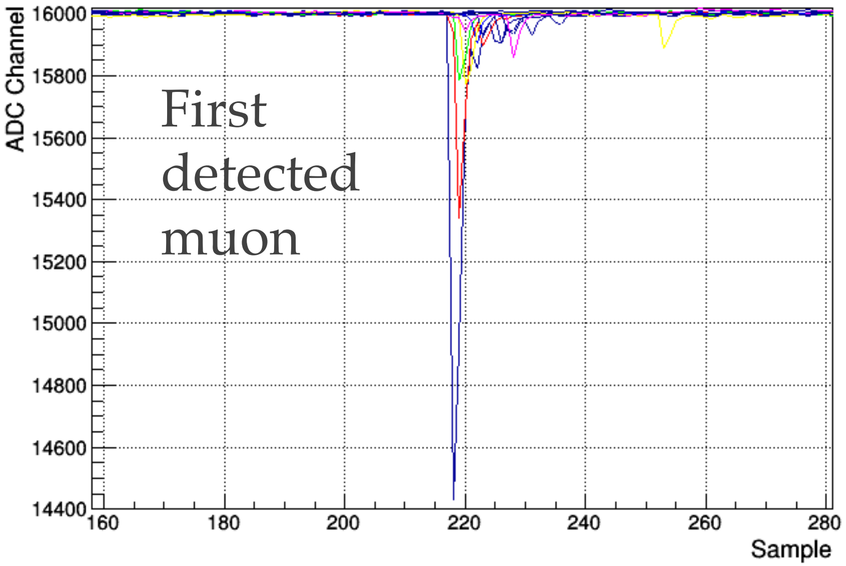
Inside the Water Tank

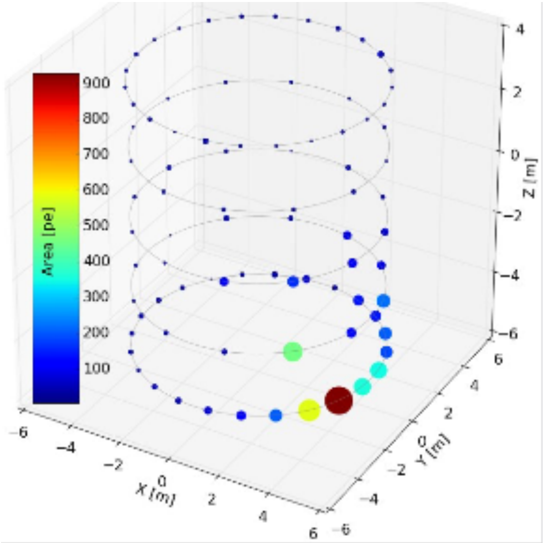
Reflector foil attached to all the internal surfaces (June 2016)

XENON1T Muon Veto

E. Aprile et al., JINST 9 P11006 (2014)

- The XENON1T cryostat is immersed in a tank filled with 700 tonnes of pure water.
- The tank is instrumented with 84 high-QE, 8″ photomultipliers in order to be used as a Water Cherenkov detector and tag cosmogenic-induced background (< 0.01 ev/y).
- The muon veto serves also as passive shield against external radioactivity.
- The muon veto in its final design has been commissioned.
- Currently installing the GPS timing unit.





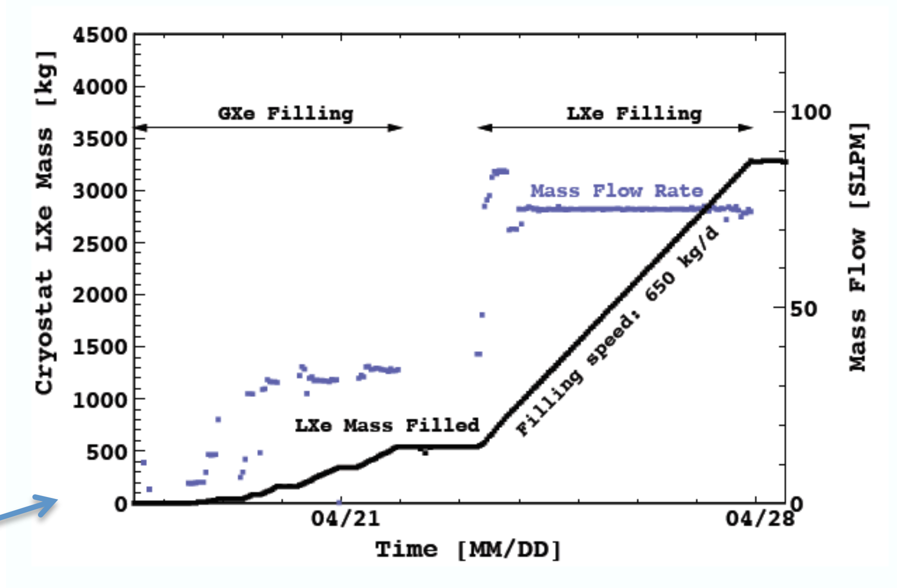
XENON1T TPC

The largest Xe double-phase TPC ever built !

- Deployed inside the inner cryostat in November 2015.
- Active Xe mass: 2 tonnes.
- Light sensors: 127+121 low-background 3” PMTs with average QE = 35% (R11410-21).
- Fully covered with high reflectivity PTFE to maximize light collection.
- Drift region: 1m height , 1m diameter.
- Highly transparent electrodes (meshes, wires).
- Electric field: up to 1 kV/cm.

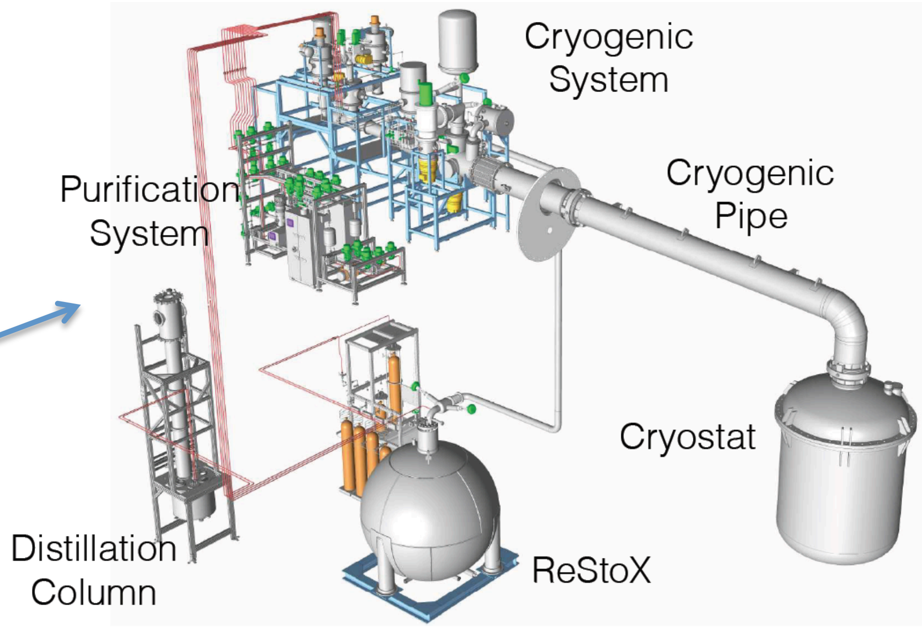
XENON1T Status (Spring 2016)

- March 2016: small leak in the water tank found. Solved with additional soldering in the "feet" of the support structure. Delays in filling the water tank.



- Detector is **filled with 3.2 tonnes** of Xe since end of April

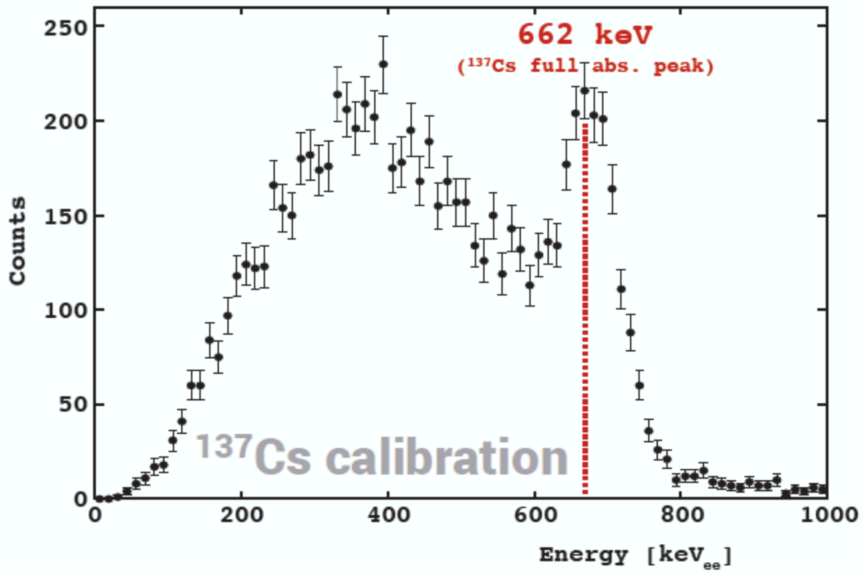
- **completed early** (un-shielded) **commissioning**:
  - the impressive cryogenic system/infrastructure is behaving extremely well



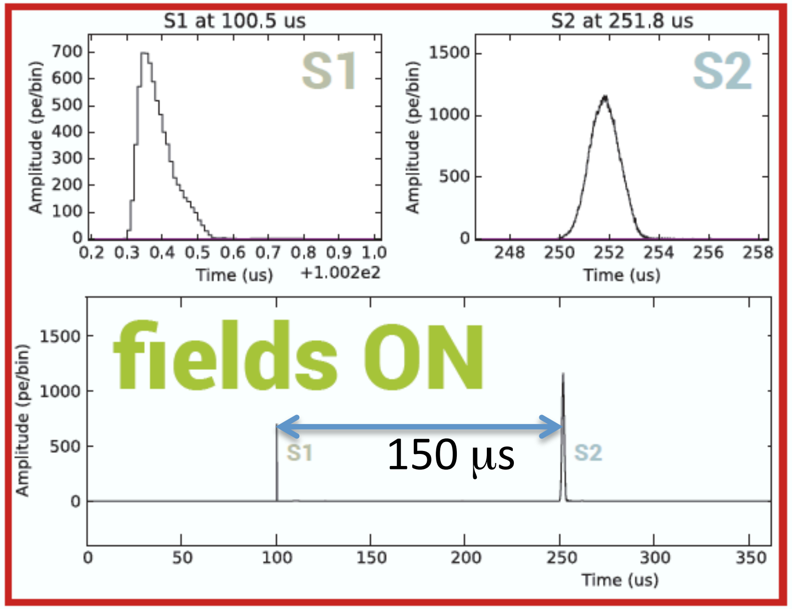
M. Selvi, "Status of the XENO

XENON1T Commissioning

fields ON



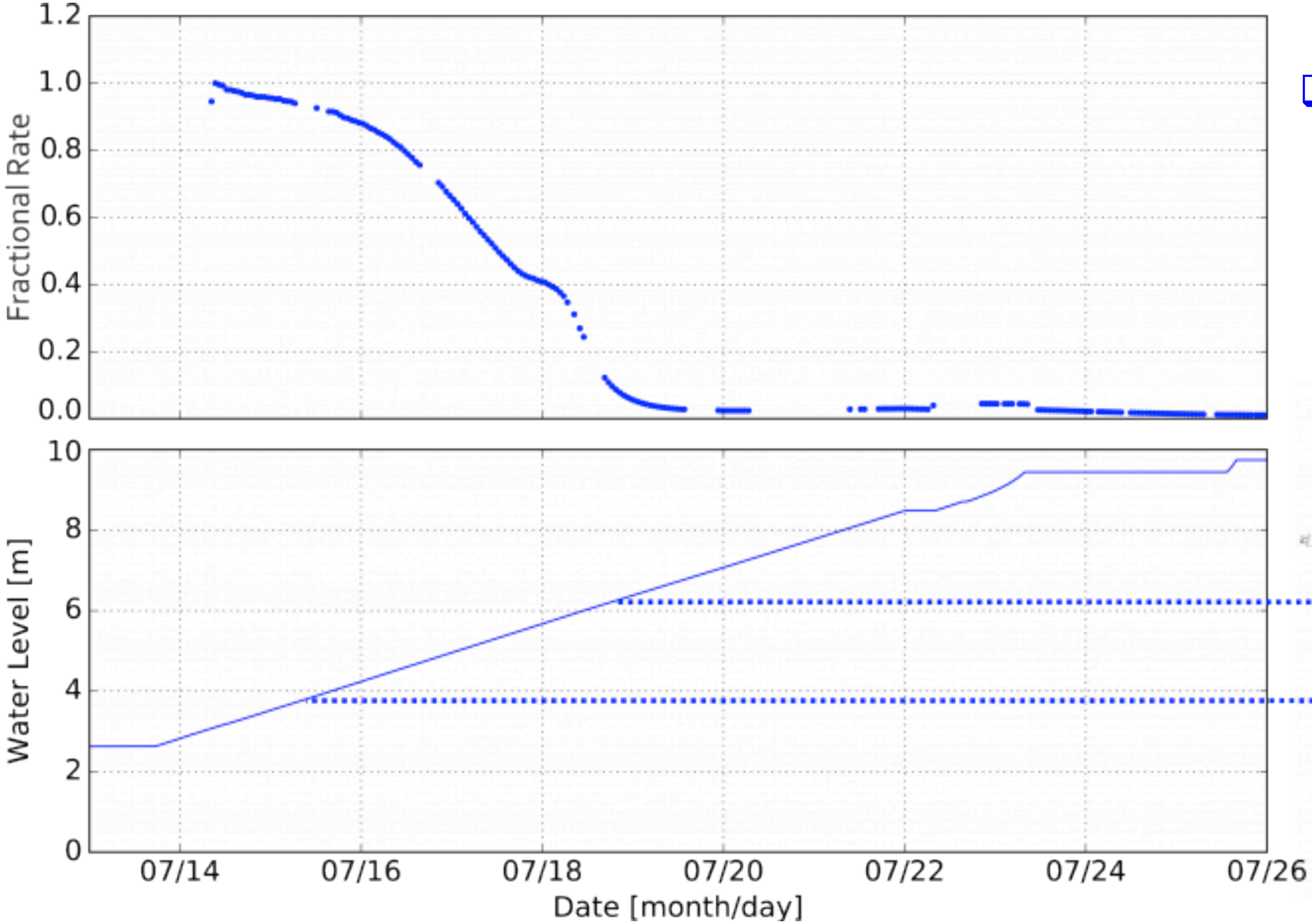
- early (and rudimentary!) **combined energy variable** spectrum (S1&S2)
- ^{137}Cs external source calibration
- corrected for **light collection efficiency** as function of z and **electron lifetime**
- already an impressive result given the unshielded conditions (several kHz rate!). Not indicative of final resolution!

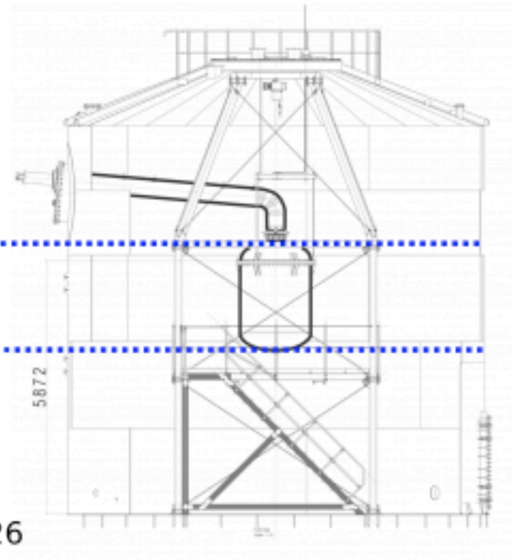


- 3.2 tonnes of LXe are being **continuously purified** (while commissioning the cryogenic system) to reach the desired charge yield at the applied field.
- Electron lifetime presently at *few-hundred μs* and still exponentially improving.
  - unexplored territory (huge LXe detector!)

Water Tank Filling

- In middle July we got the OK from LNGS to fill the water tank
- Started the "low-background" commissioning phase





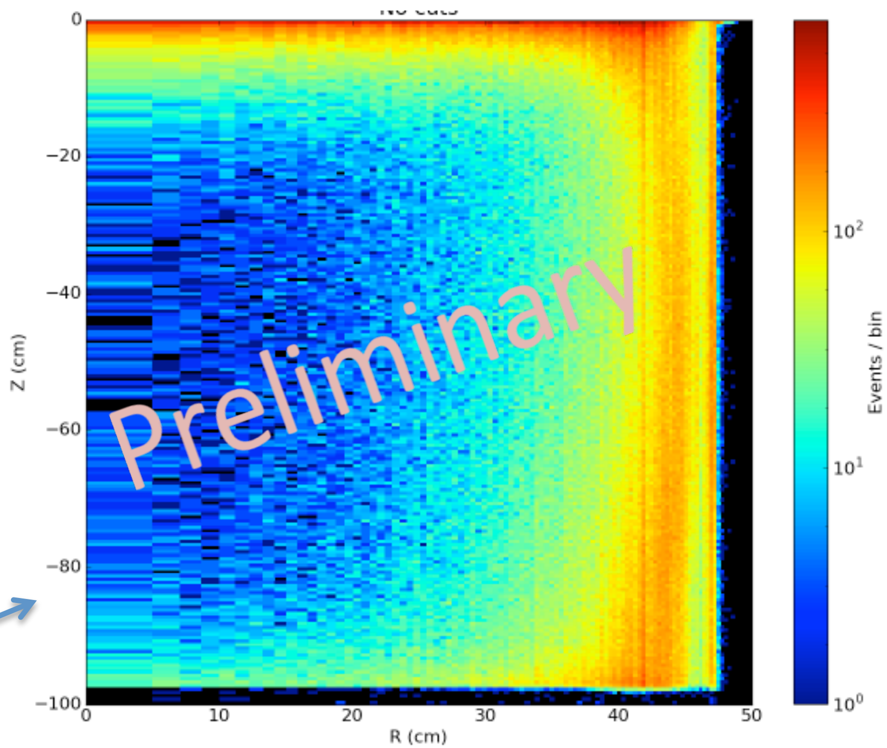
XENON1T: TPC performances

The XENON1T experiment is operational:

- ❑ **In August we performed the first calibration with ^{83m}Kr**:
  - 32 and 9 keV line in the whole TPC -> Validation of the optical model in the MC and measurement of the electron lifetime.

- ❑ The TPC performance is very promising:
  - o Light yield, preliminary results confirm a factor 2 improvement with respect to XENON100, as predicted by the optical MC simulation;
  - o Electron lifetime is currently close to 500 μs, still increasing.

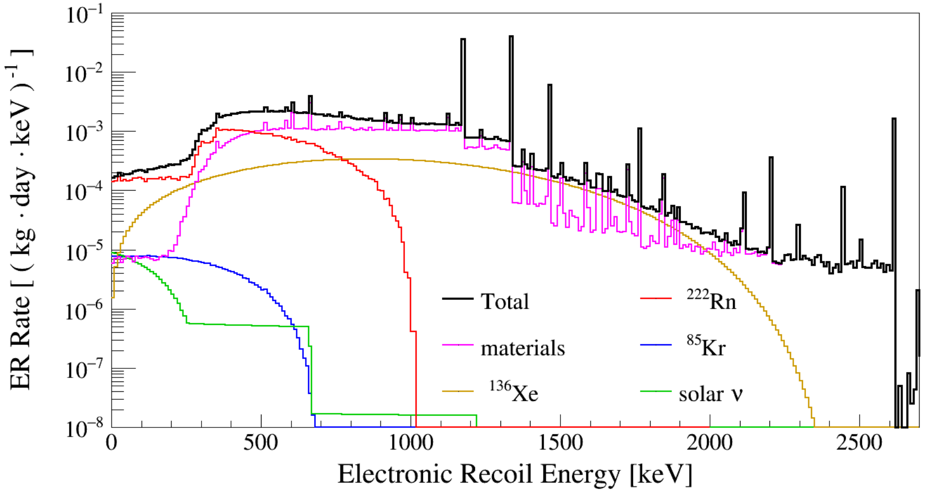
  <u>The whole TPC is "visible".</u>

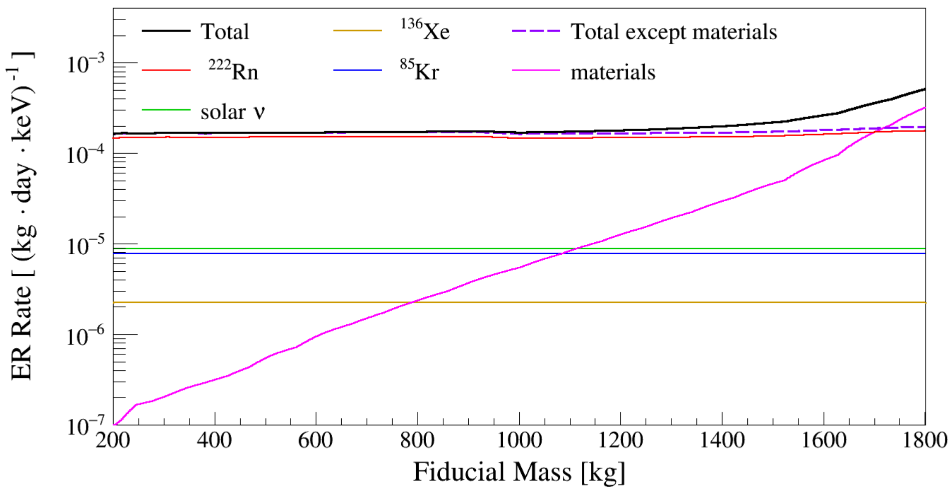


XENON1T Background: Rn

- **Started the background studies**: ^{222}Rn
  - from the alpha and BiPo analysis we can estimate the amount of ^{222}Rn in the TPC (the most relevant ER background). Preliminary results confirm the assumptions based on Rn emanation from materials used in the sensitivity study (~10 μBq/kg of ^{222}Rn).

ER background MC prediction in 1t FV (0.2ppt of Kr and 10 μBq/kg of ^{222}Rn).

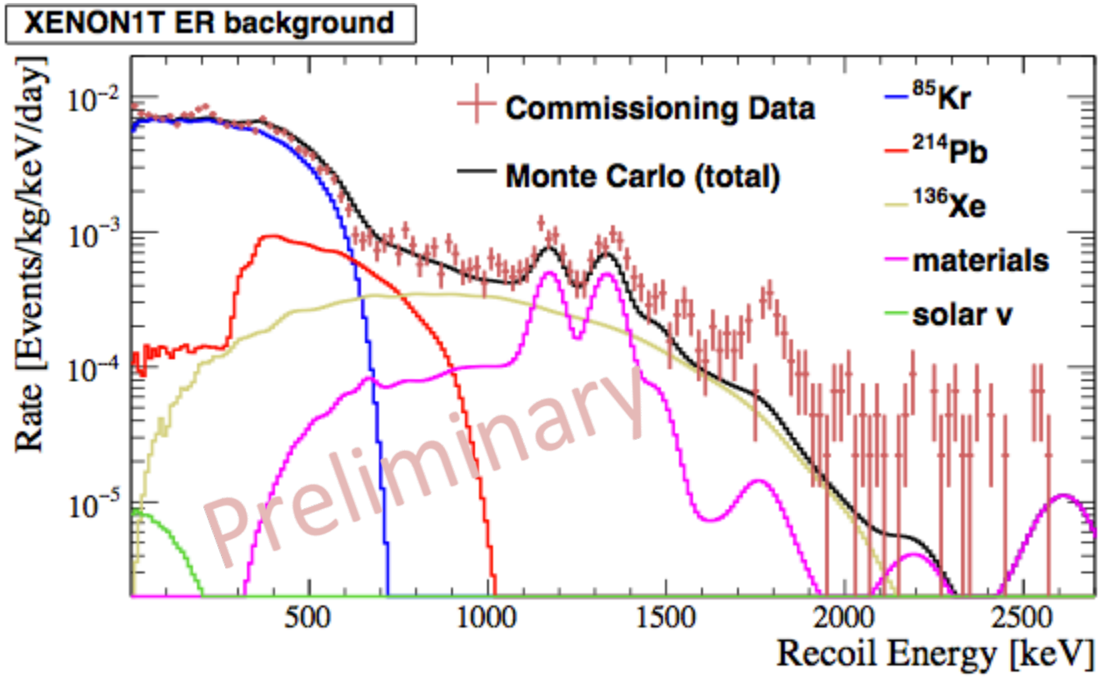




E. Aprile et al., “Physics reach of the XENON1T dark matter experiment”, JCAP 1604 (2016) 027. arXiv:1512.07501

XENON1T Background: Kr

- Next step before the Dark Matter run: ^{85}Kr removal via online distillation.



Initial Kr content in LXe: ~10 ppb.

Current data in agreement with 180 ppt of Kr.

It can be removed in a few weeks via online distillation through the column (no need to empty the detector)

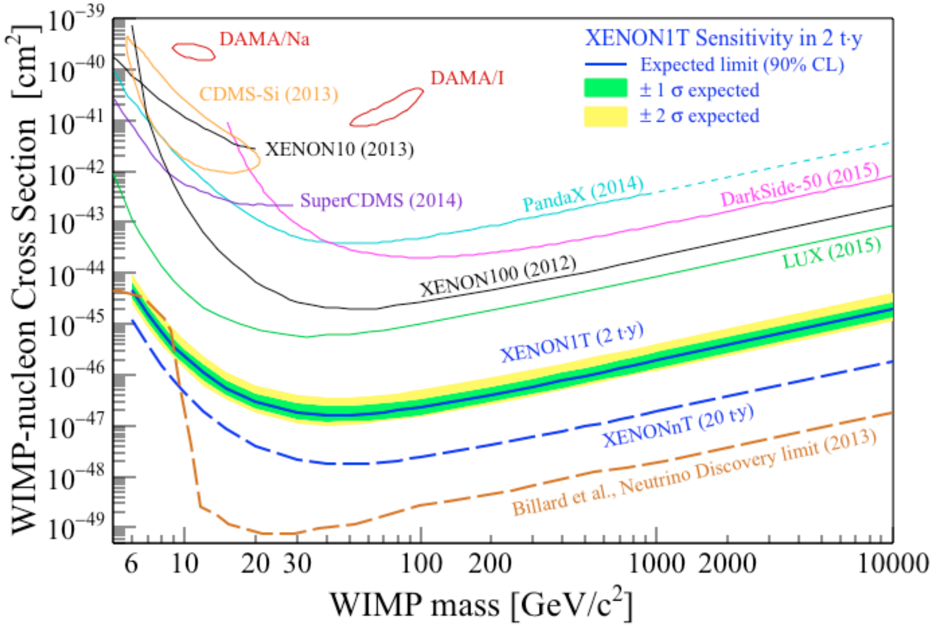
Goal for the first DM run: few ppt.

We are currently in regular operation phase:

- We are performing the ER band calibration flushing ^{220}Rn in the TPC.
- Last week: first deployment of the neutron generator in the water.
  In a few weeks first NR calibration.

XENON1T Sensitivity Goal

Assuming the LXe emission model measured in LUX arXiv:1608.05381



Expectation values of events in XENON1T, in 2 t·y exposure	*XENON100* model	*LUX2015* model
Signal (μ_s)		
6 GeV/c^2 WIMP ($\sigma = 2 \cdot 10^{-45}$ cm^2)	0.68	2.72
10 GeV/c^2 WIMP ($\sigma = 2 \cdot 10^{-46}$ cm^2)	4.65	5.96
100 GeV/c^2 WIMP ($\sigma = 2 \cdot 10^{-47}$ cm^2)	7.13	7.13
1 TeV/c^2 WIMP ($\sigma = 2 \cdot 10^{-46}$ cm^2)	8.85	8.85
Background		
Total ER (μ_{bER})	1300	1300
NR from neutrons	1.10	1.13
NR from CNNS	1.18	5.36
Total NR (μ_{bNR})	2.28	6.49

Potential to detect CNNS from solar neutrinos.

Significant improvement in sensitivity to WIMPs at low masses, below 10 GeV/c².

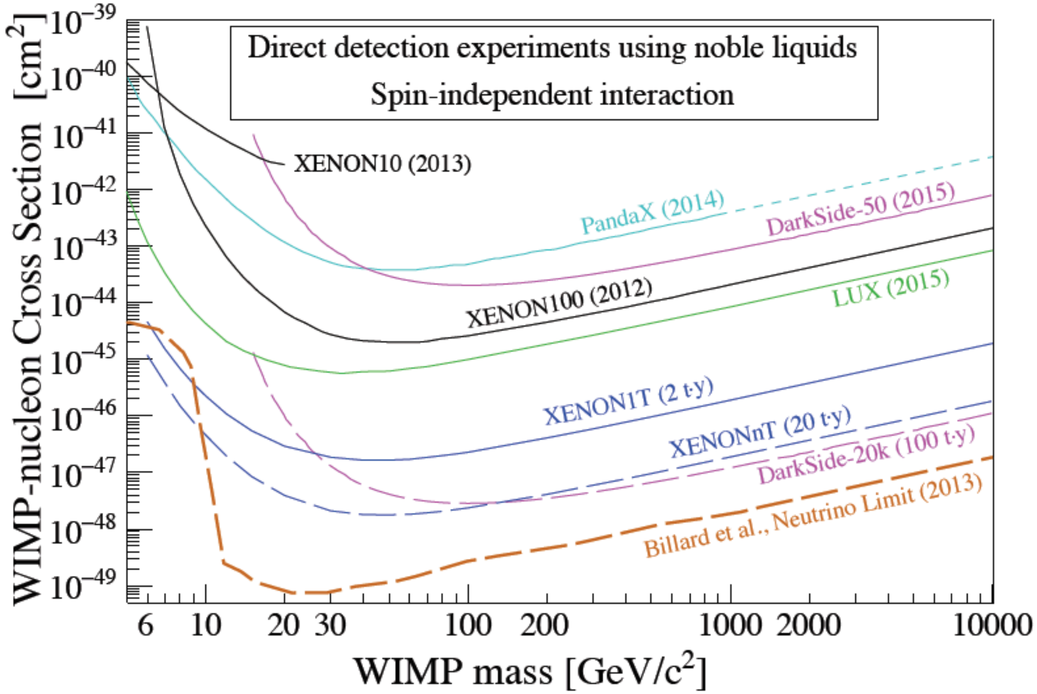
With a 2 t y exposure, with XENON1T we'll reach a sensitivity to spin-independent WIMP-nucleon interactions of $1.6\ 10^{-47}$ cm² for a 50 GeV/c² WIMP.

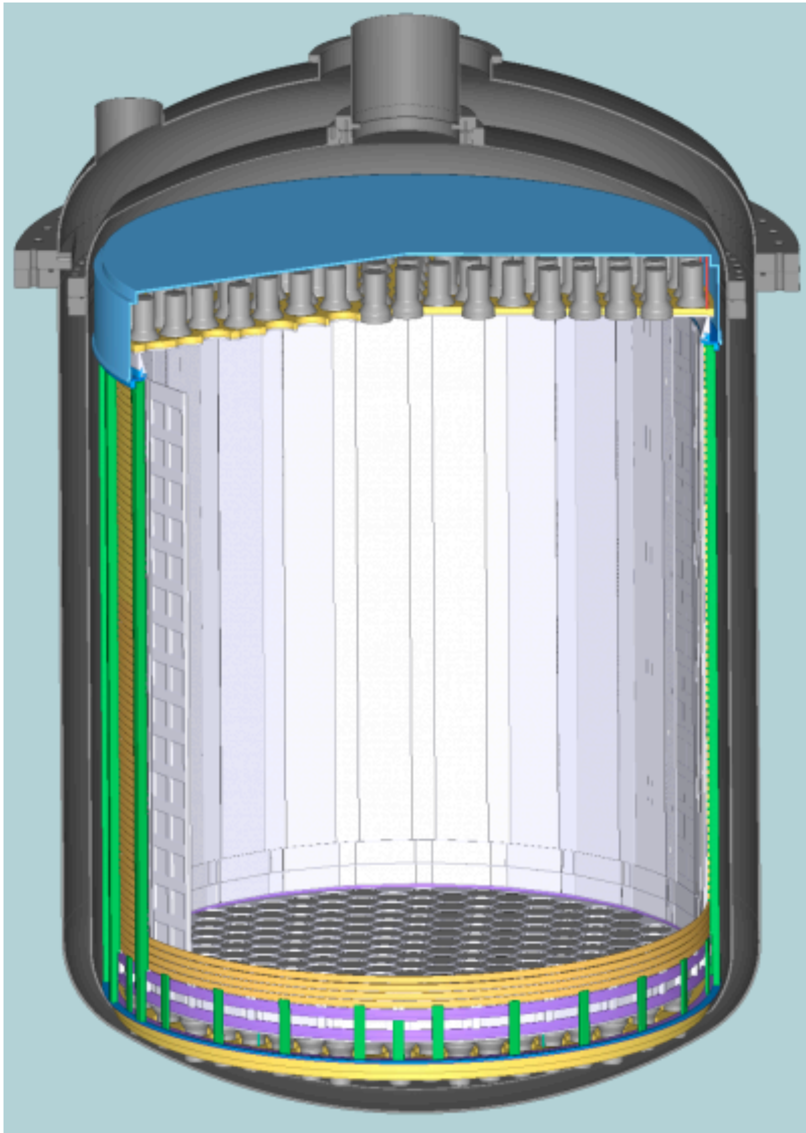
XENONnT

XENONnT is not a new experiment,
but rather a fast upgrade of the XENON1T detector:

- The total LXe mass will be ~8 t
- The active LXe mass increases x3 (2.0t -> 6.0 t)
- Additional PMTs (and electronics): 248 -> 476
- New Inner Cryostat Vessel

- All the other systems are already sized to host and run up to 8 t of LXe: Outer Cryostat, Cryogenics, DAQ, Purification, Recovery, Support structure, Muon veto.



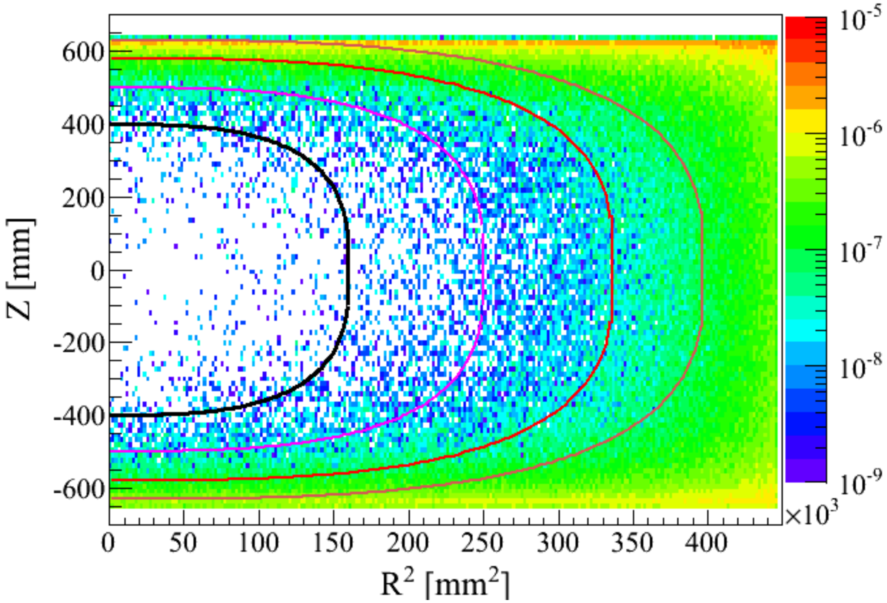


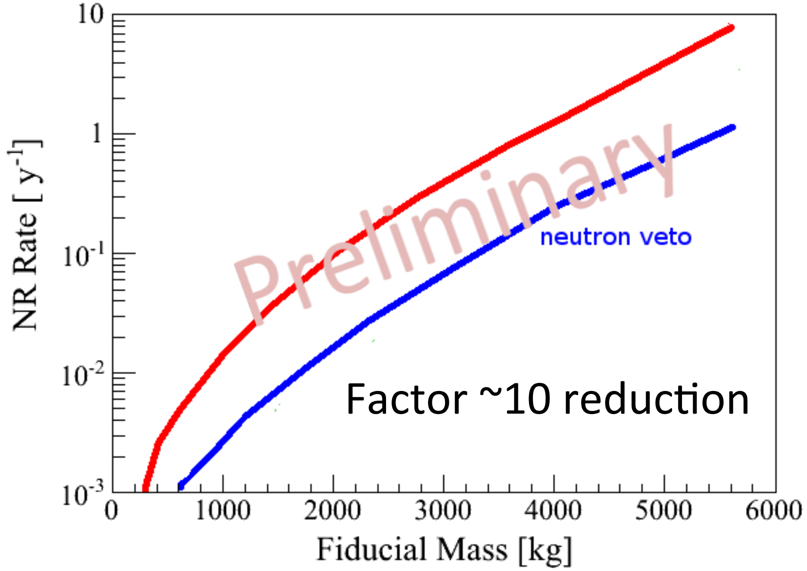
XENONnT Backgrounds

To reach the claimed XENONnT sensitivity the assumptions on the background are:

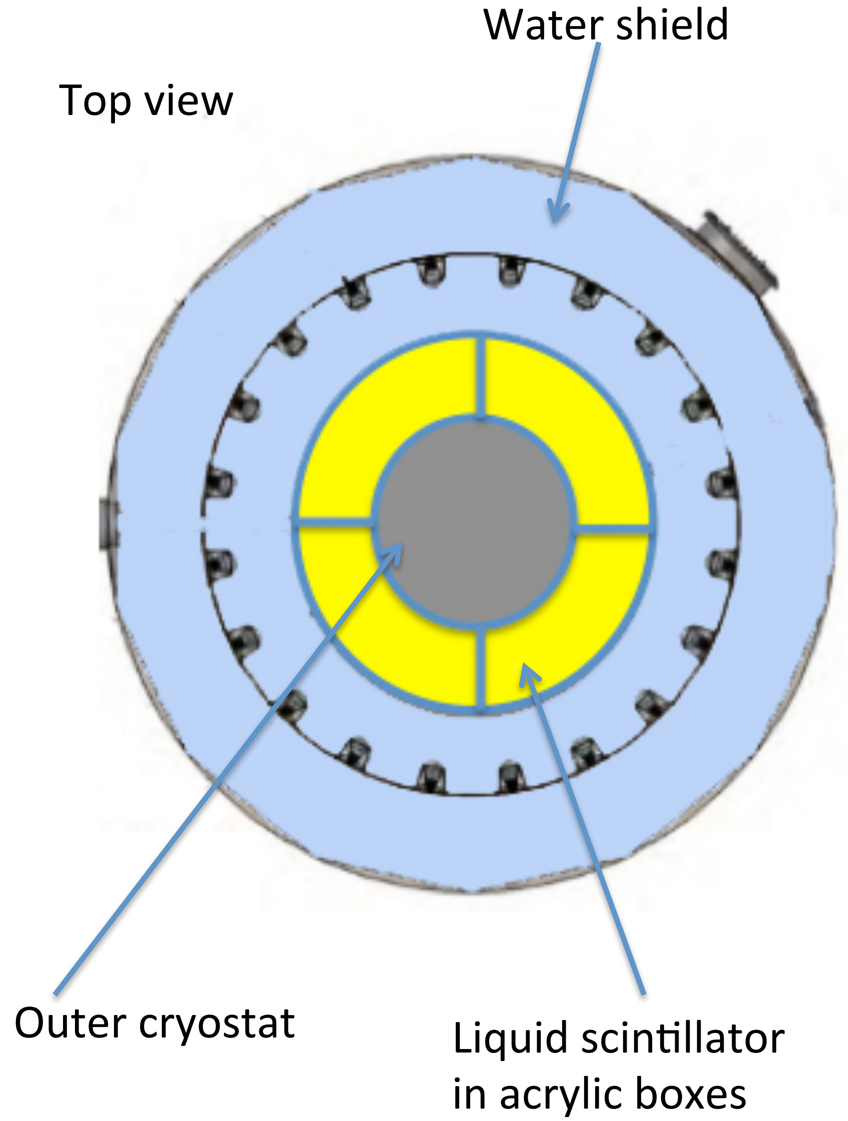
- reduction in the intrinsic contamination (x10 in ^{85}Kr, x100 in ^{222}Rn) -> ongoing R&D
- select a fiducial volume where the ER and NR background from the materials is negligible -> neutron veto

Background from radiogenic neutrons





XENONnT nVeto R&D



We plan to install around the outer cryostat a liquid scintillator layer (Gd-doped LAB) with a modular structure, contained inside transparent acrylic boxes.
Total LS thickness: 50 cm.
Total LS mass: ~20 ton

The scintillation light will be viewed by the muon veto PMTs (increasing their number and coverage) or if needed with additional PMTs installed closer to the LS boxes.

MonteCarlo studies to determine the neutron capture efficiency in the various configurations are ongoing.

INFN and German groups are interested to study and build the nVeto.

Summary

XENON100:

- Important analyses still ongoing (e.g. study of periodic modulations with the full data taking).
- Crucial tool to test new calibration sources for XENON1T.

XENON1T:

- We are in regular operation phase.
- The detector and all the subsystems are performing well:
  High light yield; charge yield continues to improve with purification,
  Kr/Xe concentration continues to decrease with on-line distillation,
  Rn consistent with expectation from measured emanation from materials.
- ER calibration ongoing; NR calibration will start this week.
- First Science Run will start before the end of October.
- With ~1 month of data XENON1T will test SI WIMP-n cross section at the current best limit.
- Sensitivity goal: $\sigma=1.6\ 10^{-47}\ cm^2$ in 2 t y.

XENONnT:

- Fast upgrade of the XENON1T detector.
- Design studies for new detector started.
- Procurement of additional Xe and PMTs ongoing.
- Expect the new detector to be operational in 2019. Aggressive schedule enabled by reusing all major systems.
- Sensitivity goal: $\sigma=1.6\ 10^{-48}\ cm^2$ in 20 t y.