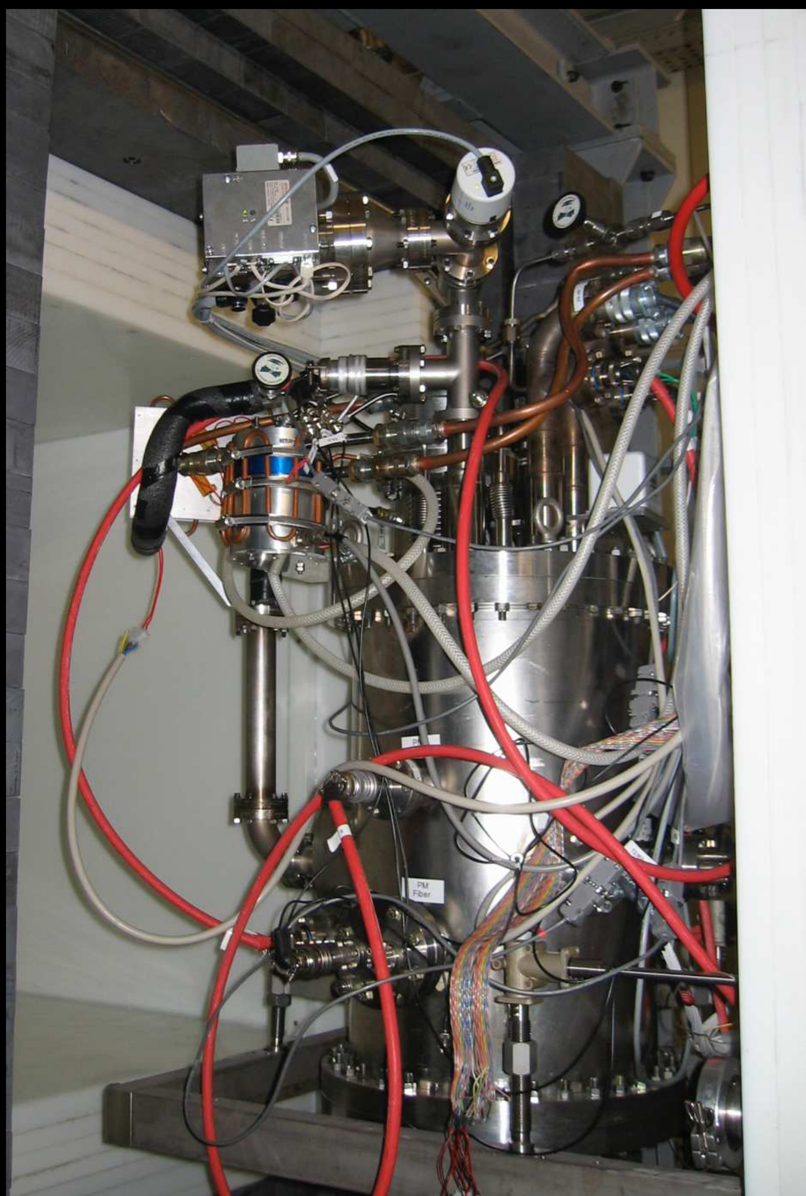
The XENON1T Dark Matter Experiment

Elena Aprile, Columbia University
on behalf of the Collaboration, Vulcano Workshop, May 26, 2016

The XENON Dark Matter Program

2005-2007



XENON10

15 cm drift TPC - 25 kg

~10^{-43} cm^2

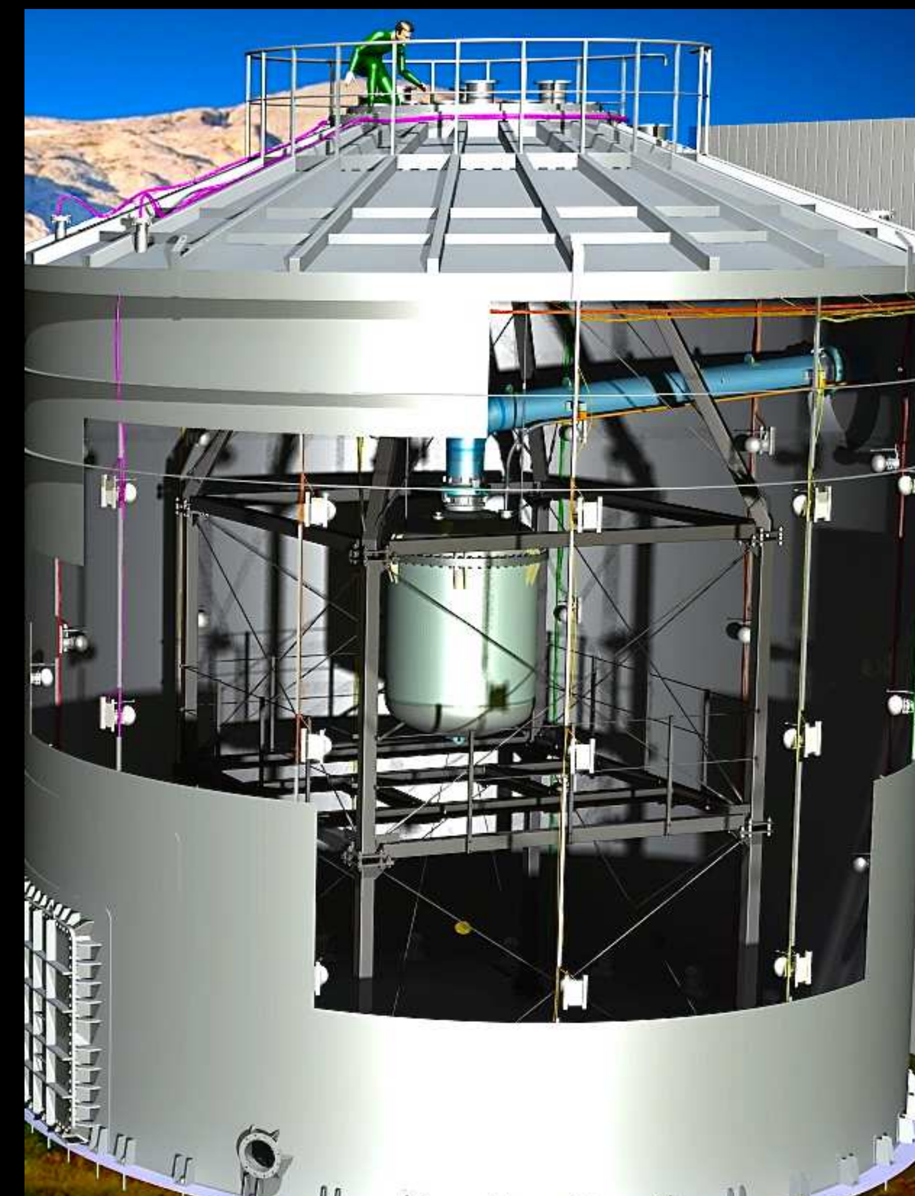
2007-2015

XENON100

30 cm drift TPC - 161 kg

~10^{-45} cm^2

2012-2022



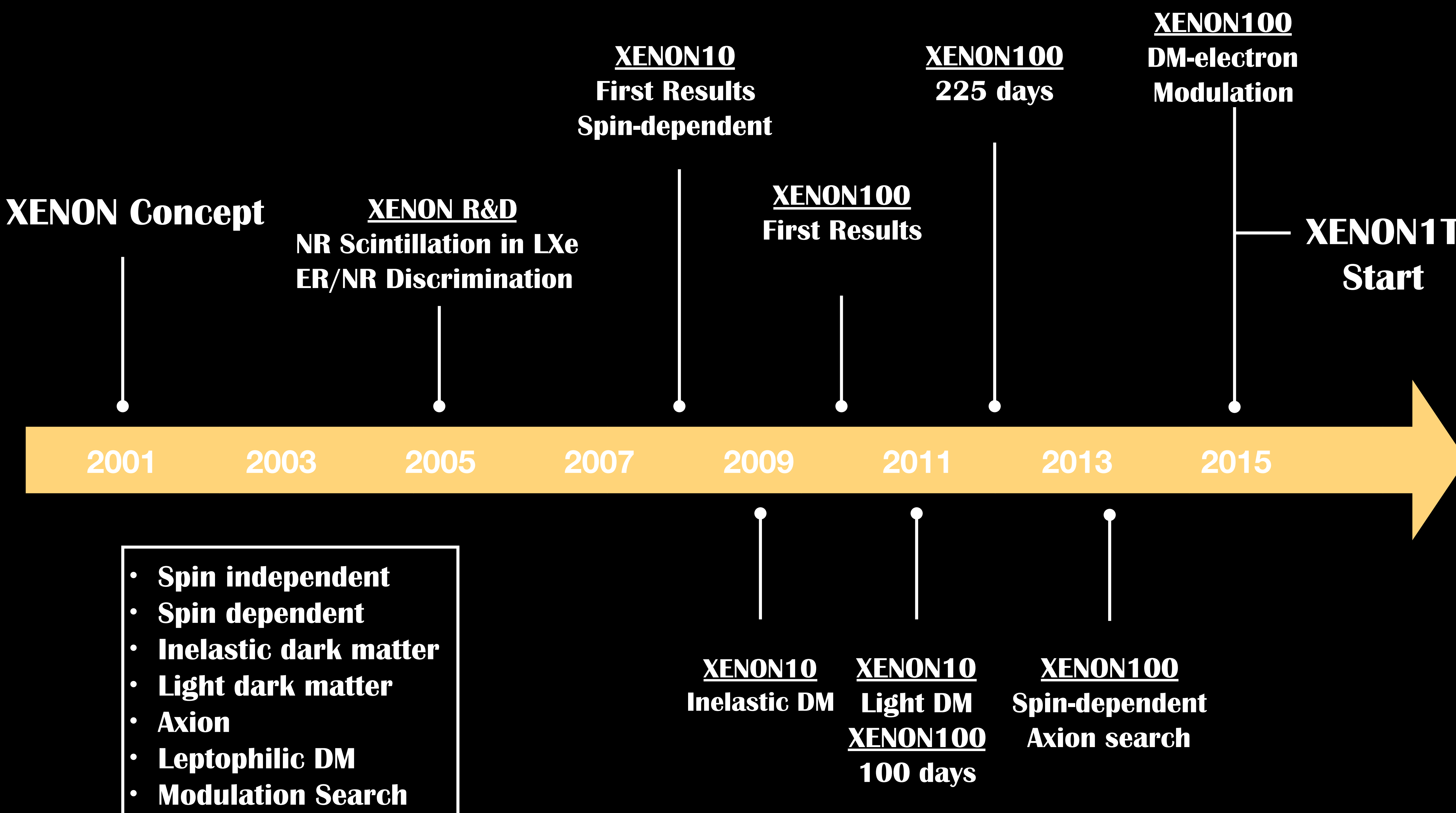
XENON1T/XENONnT

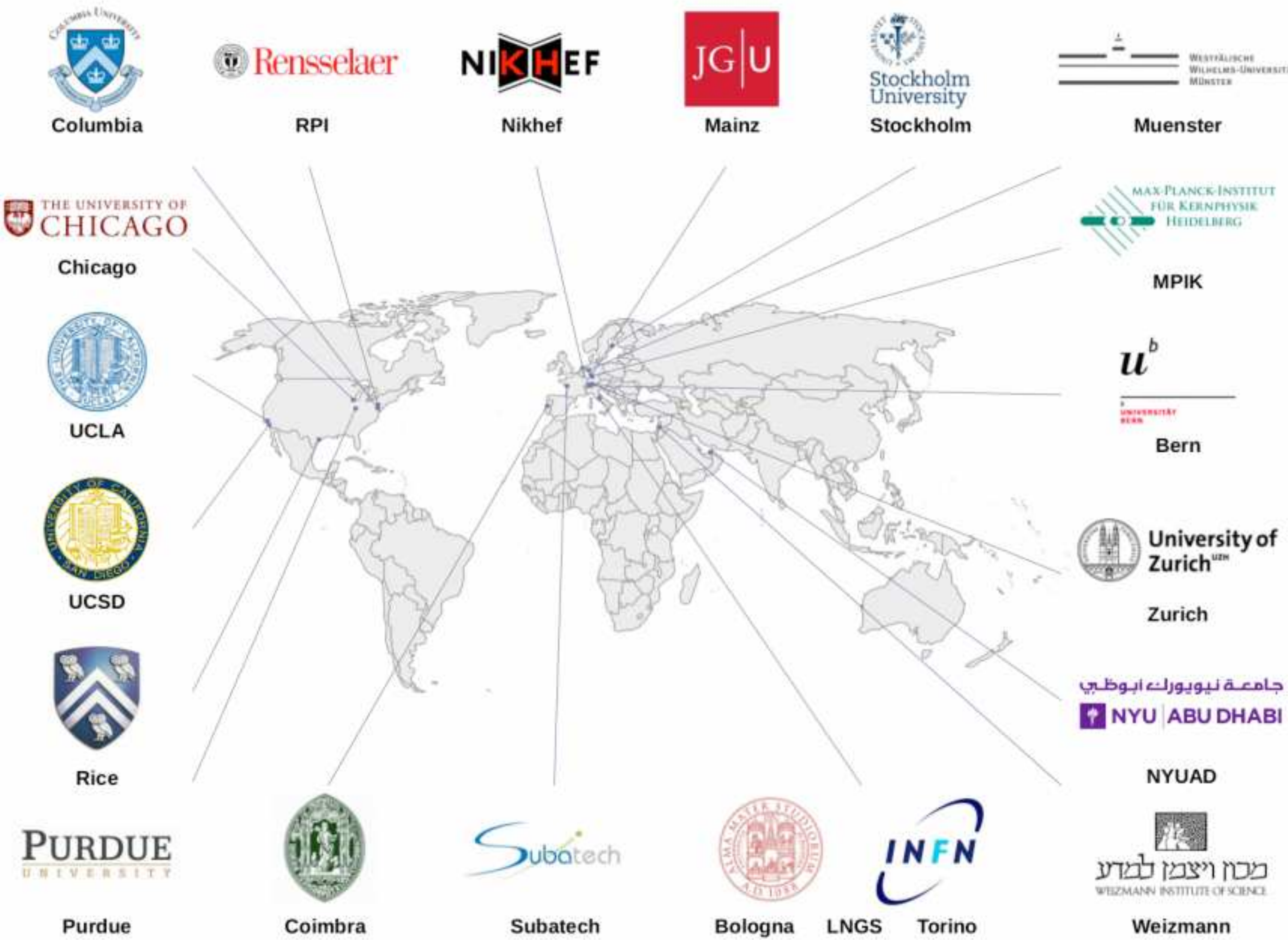
100 cm drift TPC - 3500 kg/7000 kg

~10^{-47} cm^2 / 10^{-48} cm^2

The XENON Dark Matter Program

Pioneering the Dual Phase Xe TPC to Search for Various Dark Matter Candidates




Columbia
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Nikhef
Mainz
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Muenster
Chicago
MPIK
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Bern
UCSD
Zurich
Rice
NYUAD
Purdue
Coimbra
Subatech
Bologna
LNGS
Torino
Weizmann

The XENON1T Experiment

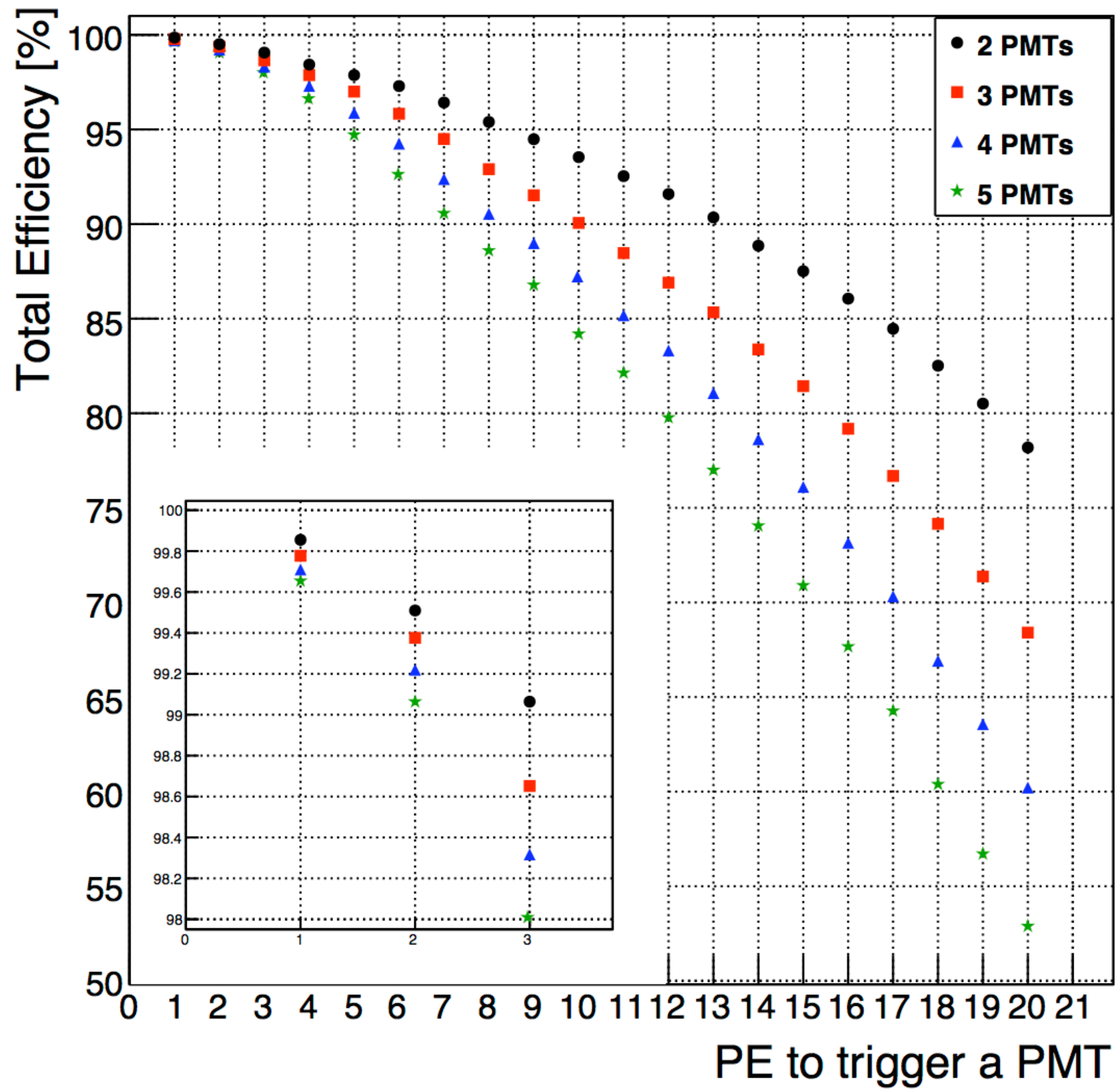
- **Science goal**: 100 x more sensitive than XENON100
- **Target/Detector**: 3.5 ton of Xe/ dual-phase TPC with 250 high QE - low radioactivity PMTs.
- **Shielding:** water Cherenkov muon veto.
- **Cryogenic Plants:** Xe cooling/purification/ distillation/storage systems designed to handle up to 10 ton of Xe. Upgrade to a larger detector ***(XENONnT)*** planned for 2018
- **Status:** All systems successfully tested. Commissioning of detector ongoing. First science run this Summer.

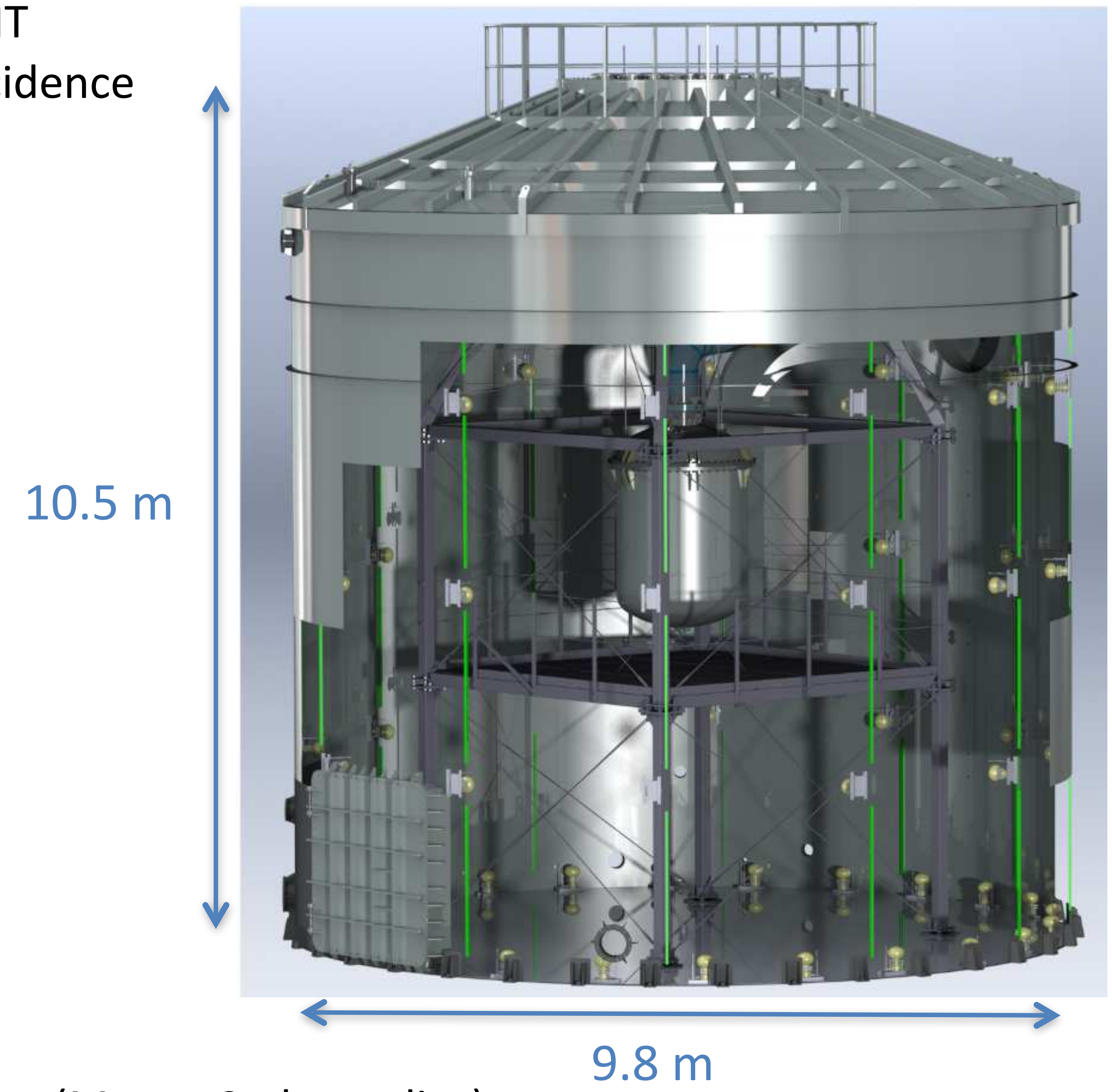
XENON1T Systems

Water Cherenkov Muon Veto

- Stainless steel tank with 700 m^3 of demineralized water
- 84 high QE PMTs (8”) sensitive to Cherenkov light
- Internal surfaces covered with reflector film
- Efficiency in tagging muon events depends on PMT threshold and required number of PMT hits in coincidence

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





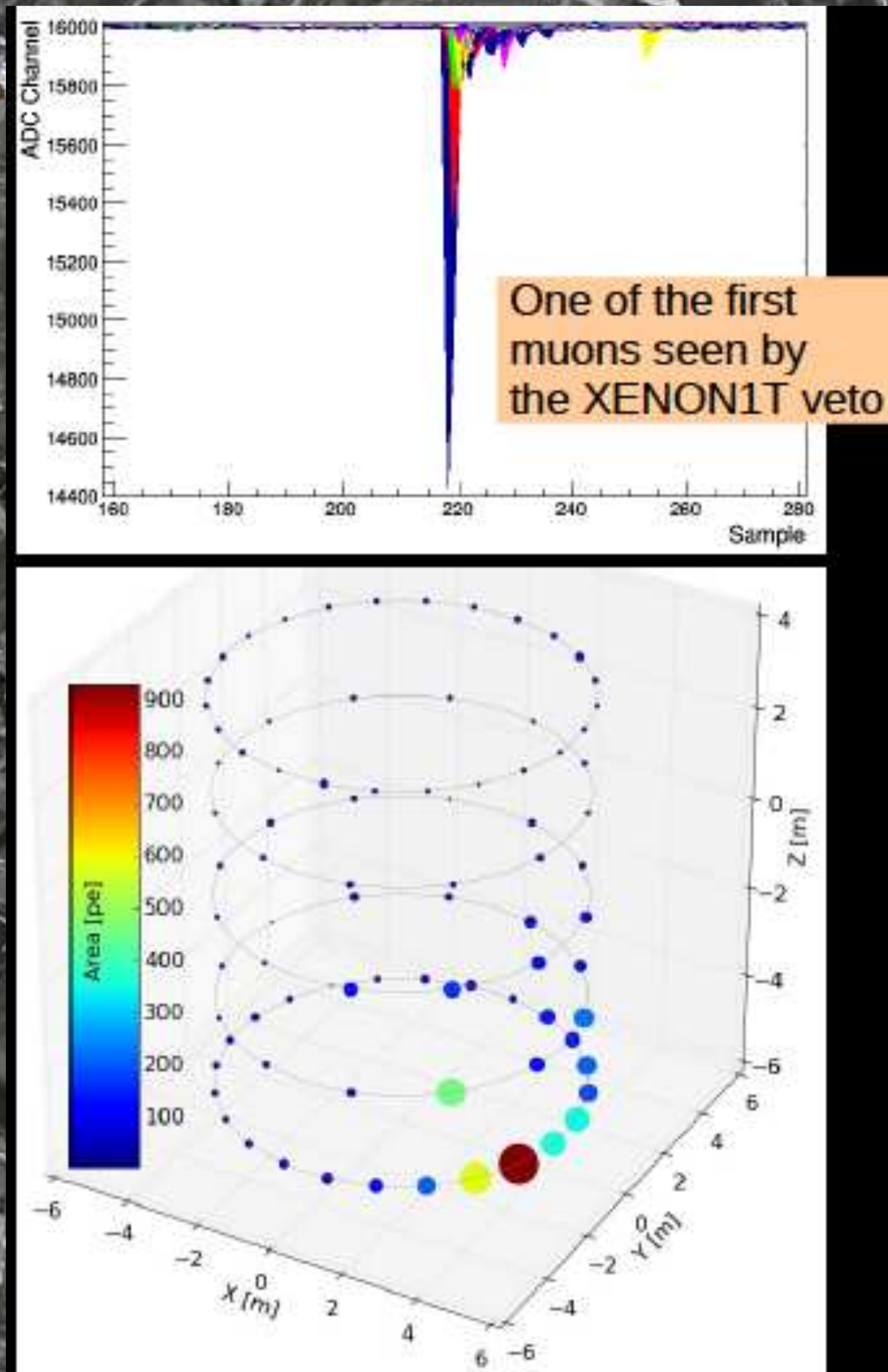
Expected efficiency in tagging muon induced neutrons (Monte Carlo studies):

➢ **>99.7%** for muons traversing the water tank (1/3 of muon events)

➢ **> 71.4%** for muons interacting in rock only (2/3 of muon events)

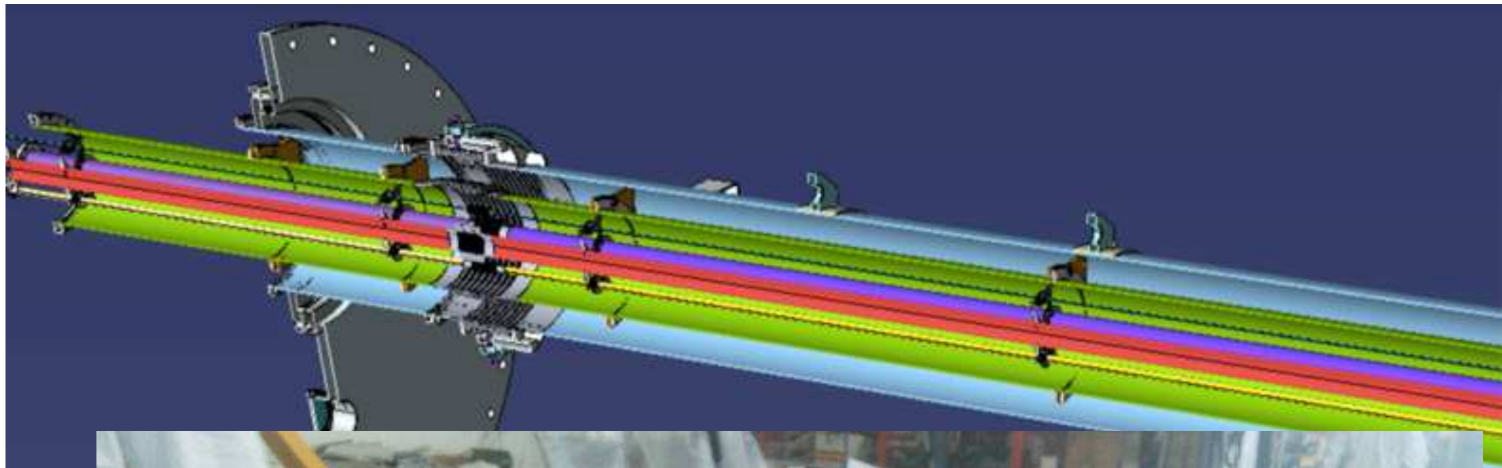
Induced neutron background in 1 ton fiducial volume < 0.01 y^{-1}

XENON1T Muon Veto

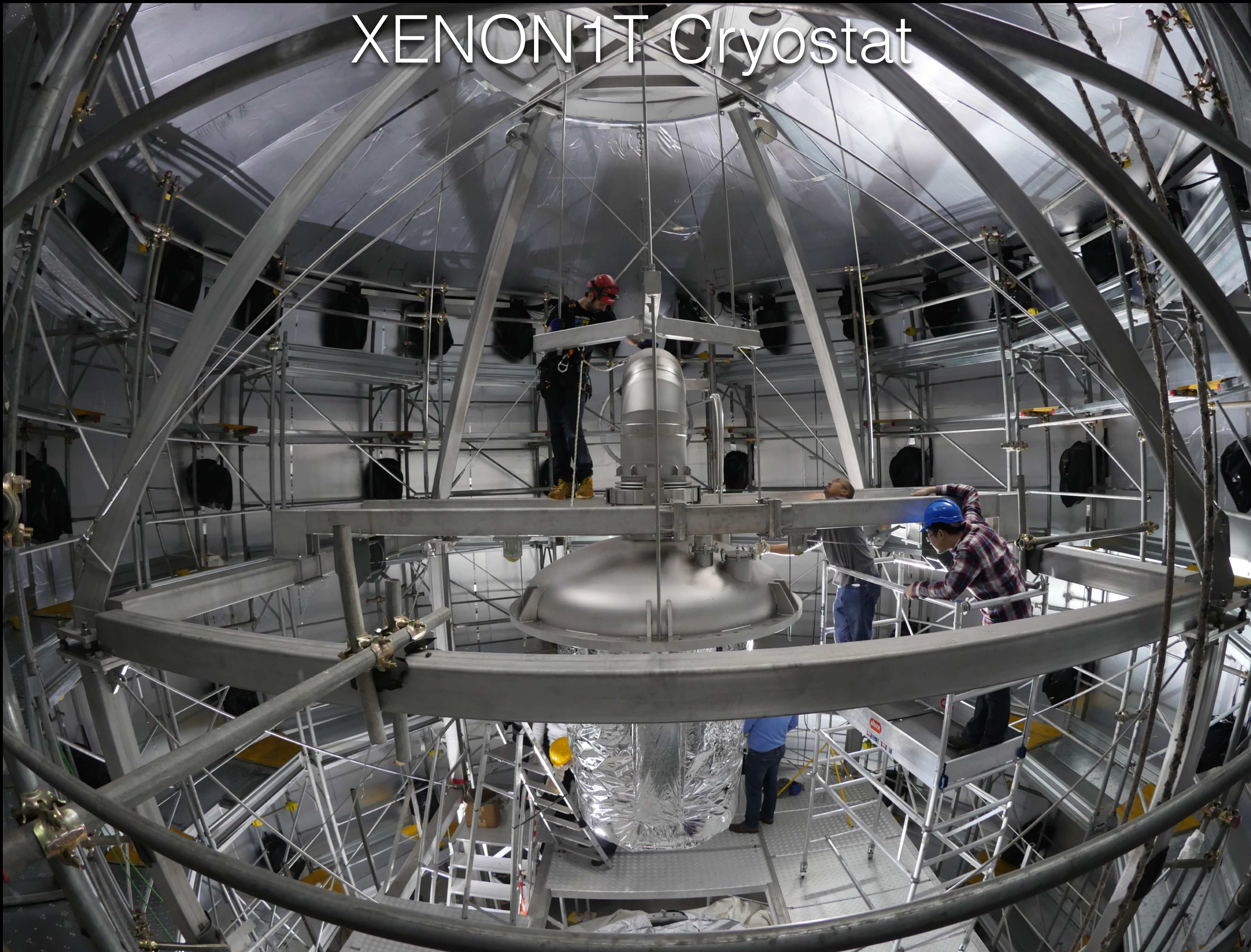


Detector Cryostat & Support Platform

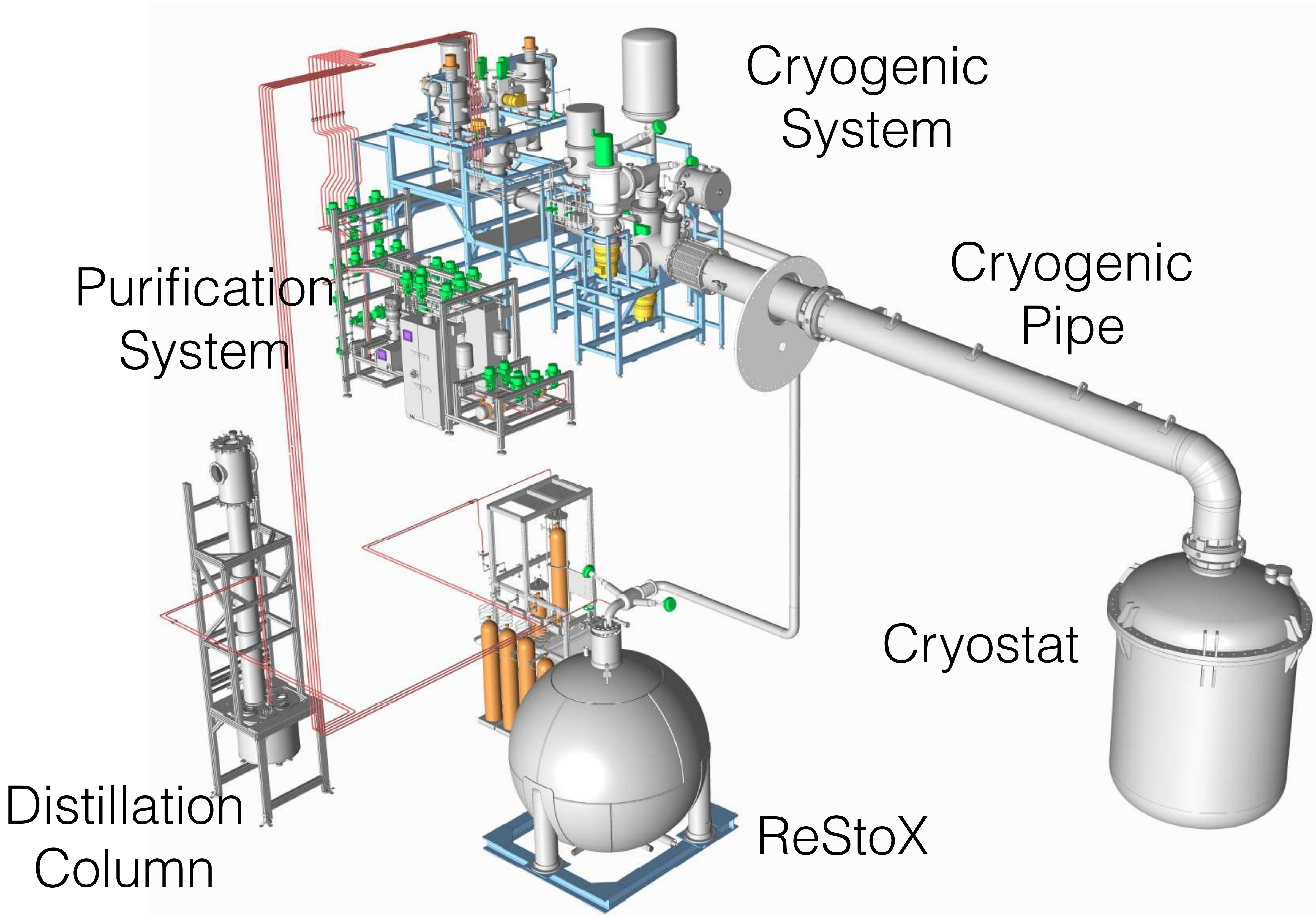
a ultra-high-vacuum, thermally insulated system made of low-radioactivity material, to contain the detector with 3.5 tons of LXe at -95 C and 2 bar pressure and to couple it to the cryogenics system outside the water shield.



XENON1T Cryostat



Cryogenic Plants



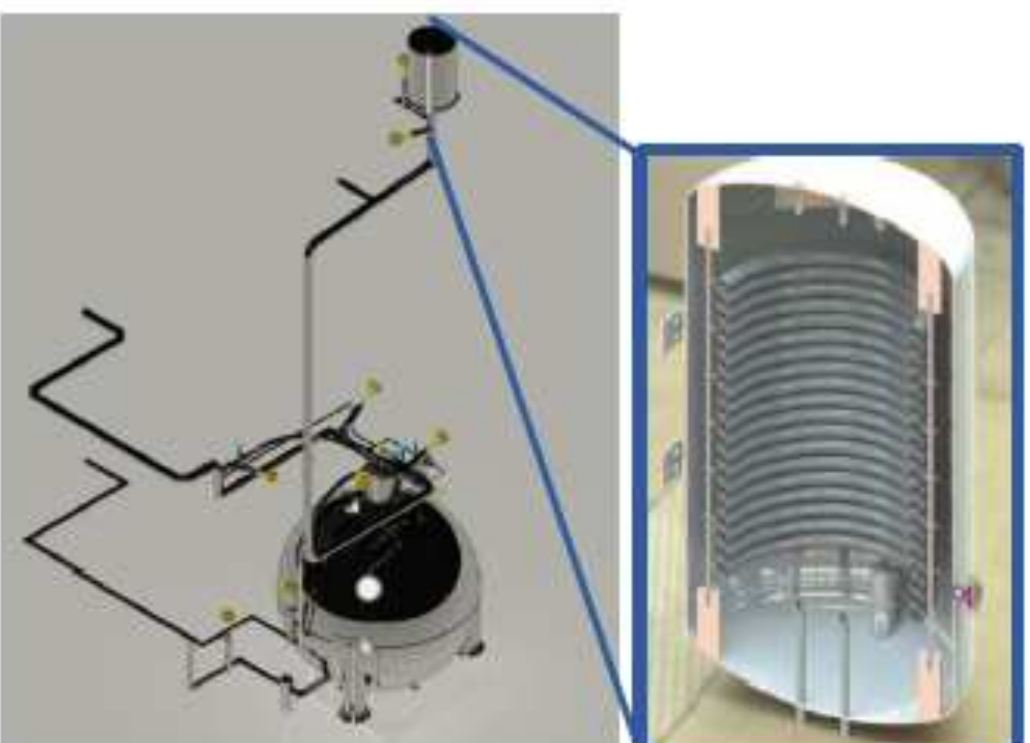
Recovery and Storage of Xe (ReStoX)

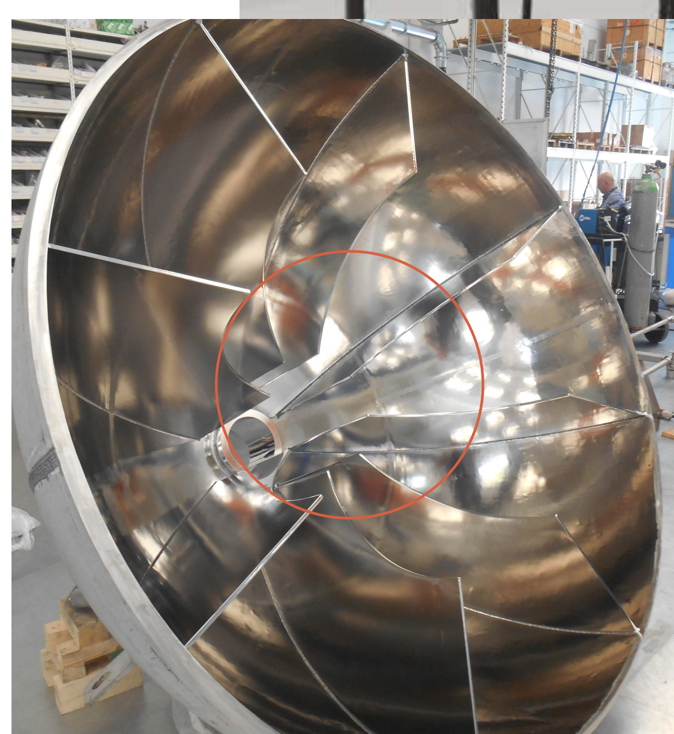
Goal:

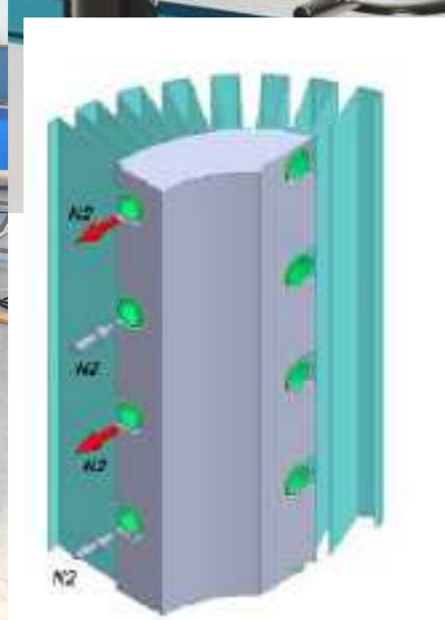
- store up to 7600 kg of Xe in gaseous or liquid phase under high purity conditions
- fill Xe in ultra-high-purity conditions into detector vessel
- recover all the Xe from the detector, within a few hours, in case of emergency

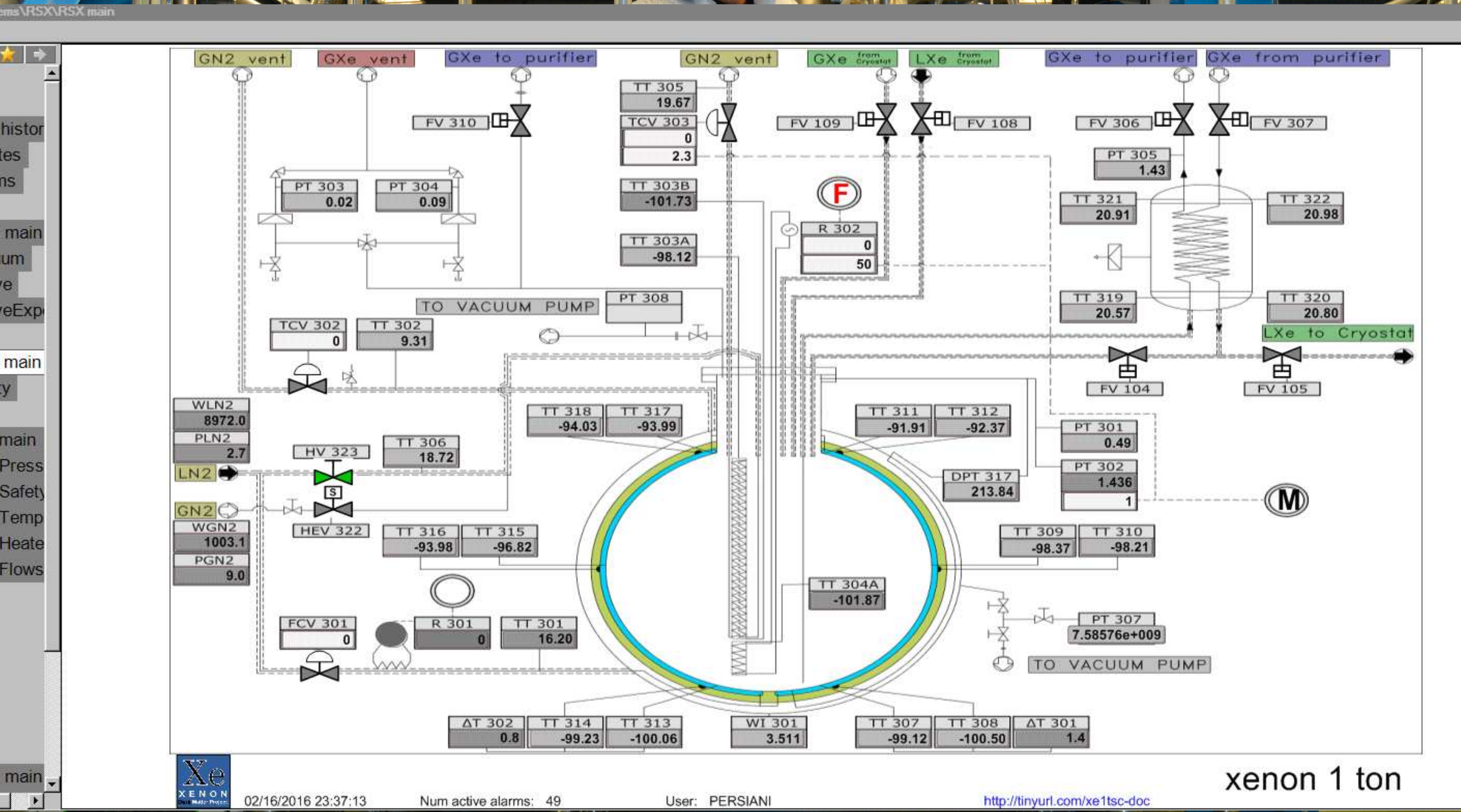
Method:

- Double walled, high pressure (72 bar) vacuum insulated sphere of 2.1 meter diameter, cooled by LN2 and by an internal LN-based condenser.





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TCV 303 0 2.3
FV 310
FV 109
FV 108
FV 306
FV 307
PT 305 1.43
PT 303 0.02
PT 304 0.09
TT 303B -101.73
F
R 302 0 50
TT 321 20.91
TT 322 20.98
TT 303A -98.12
TT 319 20.57
TT 320 20.80
TO VACUUM PUMP
PT 308
TCV 302 0
TT 302 9.31
LXe to Cryostat
FV 104
FV 105
WLN2 8972.0
PLN2 2.7
LN2
TT 318 -94.03
TT 317 -93.99
TT 311 -91.91
TT 312 -92.37
PT 301 0.49
HV 323
TT 306 18.72
PT 302 1.436 1
DPT 317 213.84
M
GN2
WGN2 1003.1
PGN2 9.0
HEV 322
TT 316 -93.98
TT 315 -96.82
TT 309 -98.37
TT 310 -98.21
TT 304A -101.87
PT 307 7.58576e+009
FCV 301 0
R 301 0
TT 301 16.20
TO VACUUM PUMP
ΔT 302 0.8
TT 314 -99.23
TT 313 -100.06
WI 301 3.511
TT 307 -99.12
TT 308 -100.50
ΔT 301 1.4
Xe XENON
02/16/2016 23:37:13
Num active alarms: 49
User: PERSIANI
http://tinyurl.com/xe1tsc-doc

xenon 1 ton


PFEIFFER VACUUM
PrismaPlus

Cryogenic Distillation Column

Goal: Active removal of Kr contamination in Xe. Natural Xe has Kr/Xe ~ 10^{-9} – 10^{-6} with trace amounts of ^{85}Kr of ^{85}Kr/^{Nat}Kr ~ 10^{-11}

Principle: cryogenic distillation based on improved package column uses the 10 times higher vapor pressure of Kr w.r.t. Xe at -95°C to reach ^{Nat}Kr/Xe < 0.2 ppt.

Diagnostics: Atom Trap Trace Analysis **(**Columbia) and Rare Gas Mass Spectroscopy (MPIK)

5m

Design parameters:

- Separation factor: 10^4 – 10^5
- Flow rate of 3kg/h -> whole XENON1T inventory can be purified within 6 weeks
- 99% Xenon recovery

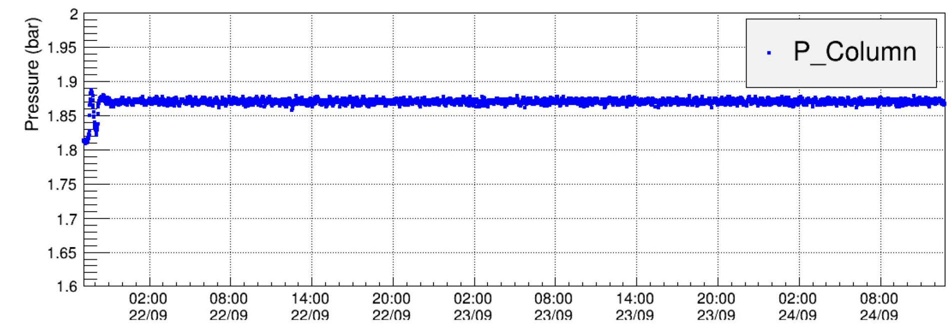
First results with distillation test facility (phase 1: 1m package material):

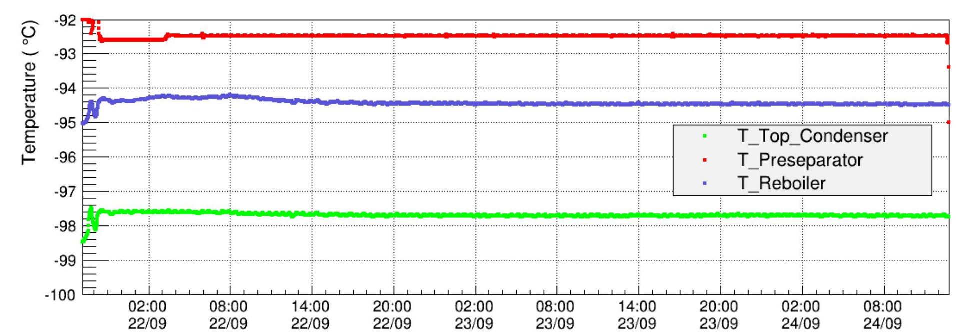
- Purified liquid out: ^{Nat}Kr/Xe < 0.026 ppt (90% c.l.)
- A factor ~10 better than required for XENON1T !
- Measured with GC-RGMS system at MPIK (S. Lindemann & H. Simgen, Eur. Phys. C 74 (2014) 2746): only a limit could be set!
- Alternative measurements by ATTA (E. Aprile et al., Rev. Sci. Instr. 84 (2013) 093105)

Reference:

- S. Rosendahl et al., JINST 9 (2014) P10010
- S. Rosendahl et al., Rev. Sci. Instr. 86 (2014) 115104
- E. Brown et al., JINST 8 (2013) P02011

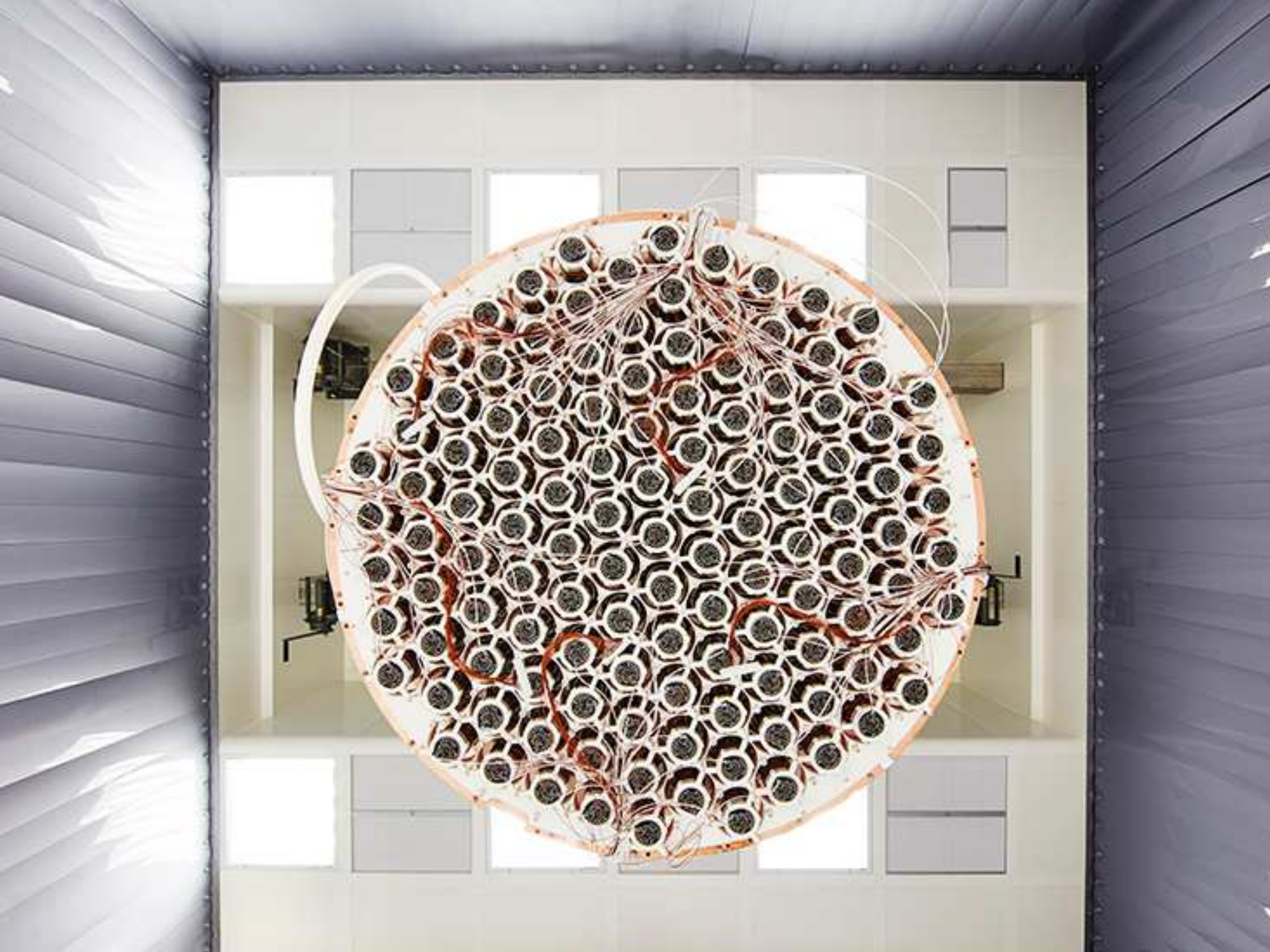
Commissioning of the distillation column on XENON1T





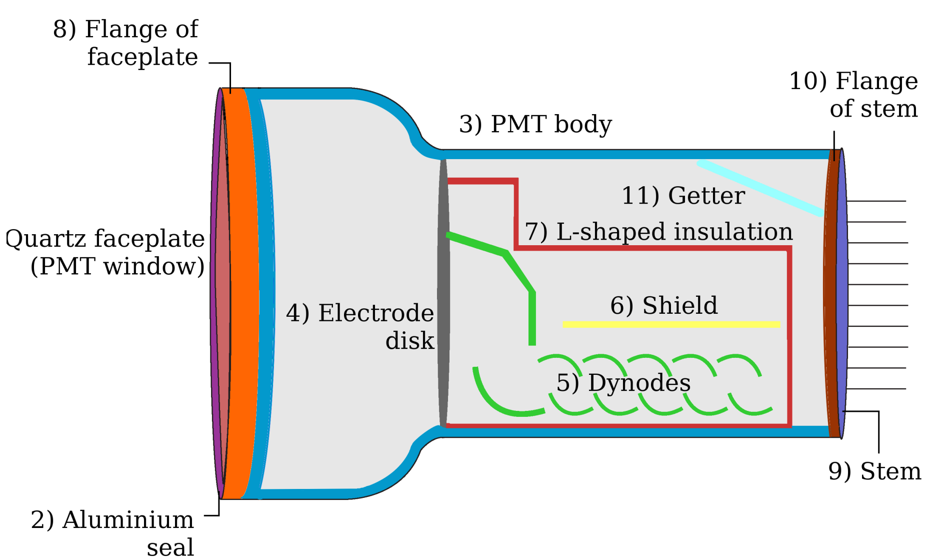
- 70 hours of continuous distillation, 210 kg processed!
- Thermodynamic stability under design parameters demonstrated!
- Separation factor >100.000 demonstrated by GC-RGMS (MPIK)

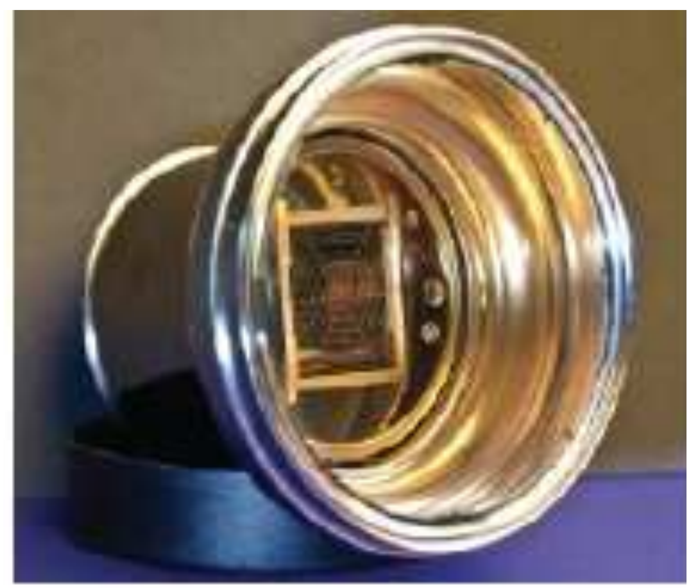
XENON1T Detector

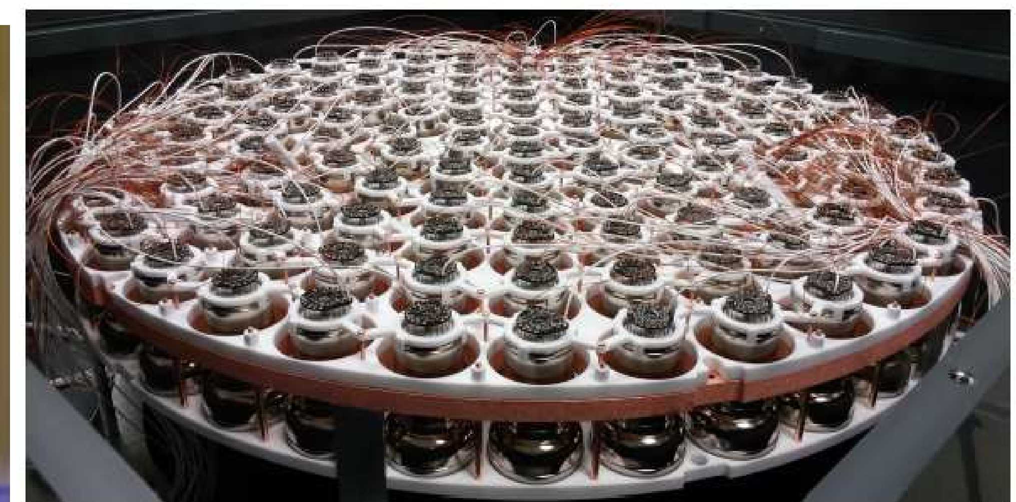


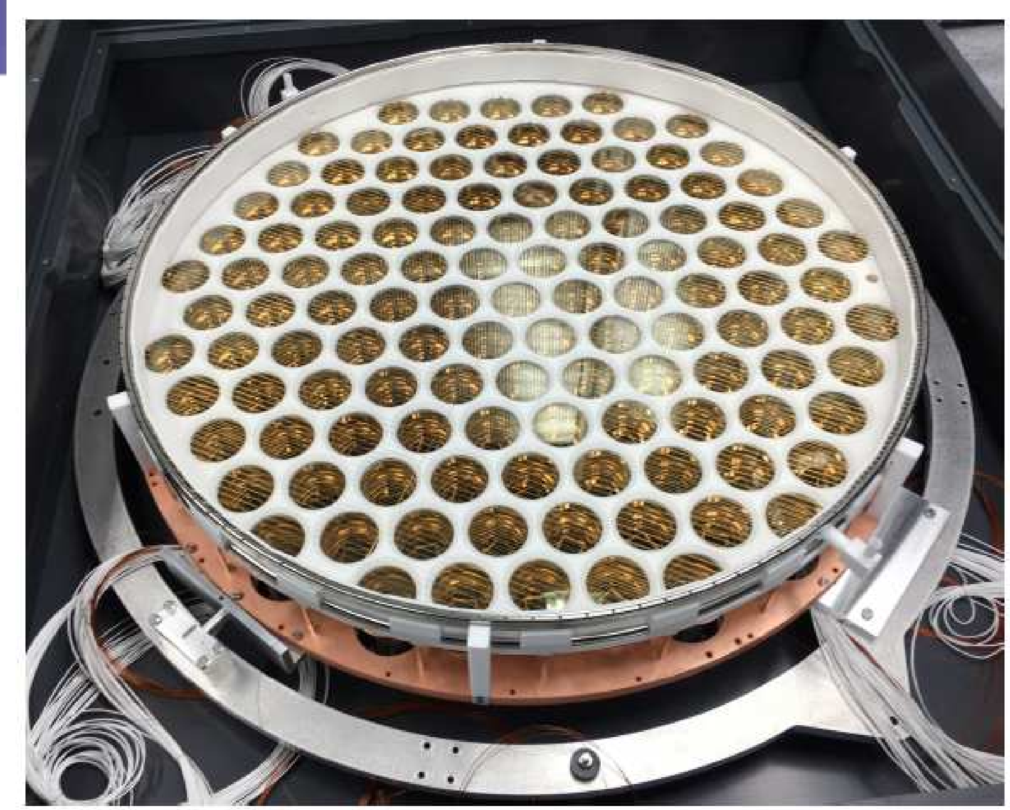
Photomultipliers

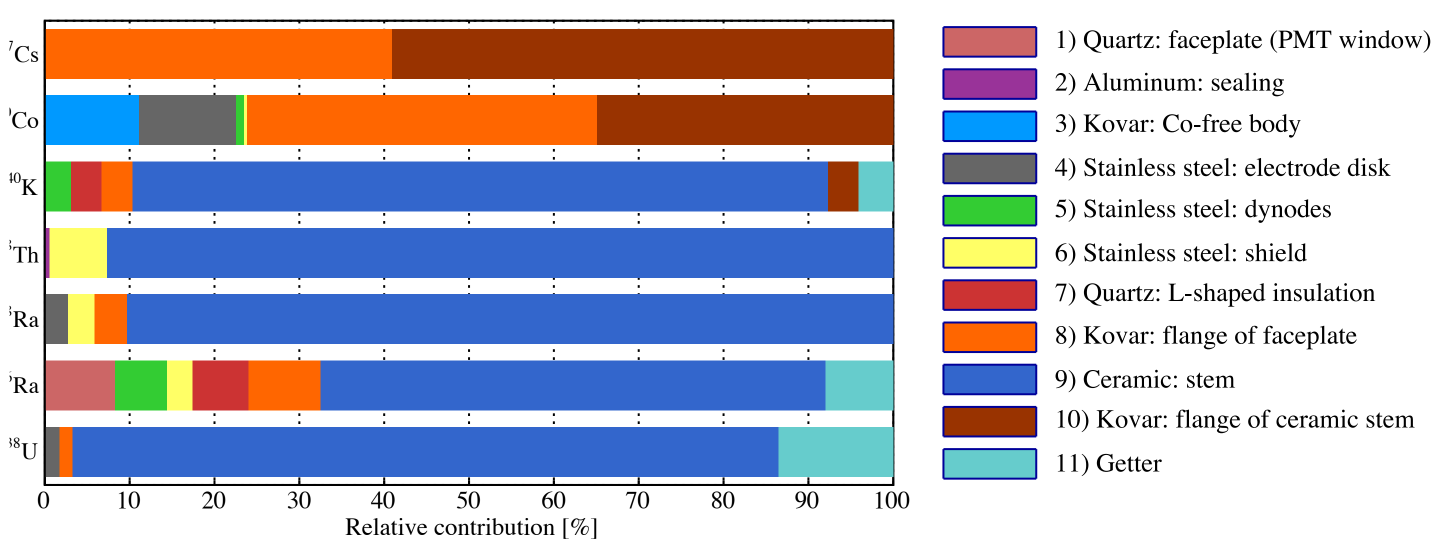
- High QE (average 34%) , low-radioactivity, 3” PMT (R11410-21) developed for XENON1T, in close collaboration with Hamamatsu to select cleanest materials. Tested stability in LXe.
- Each PMT has been screened for radioactivity and tested at room T and low T











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

Readout Electronics and Data Acquisition

Features

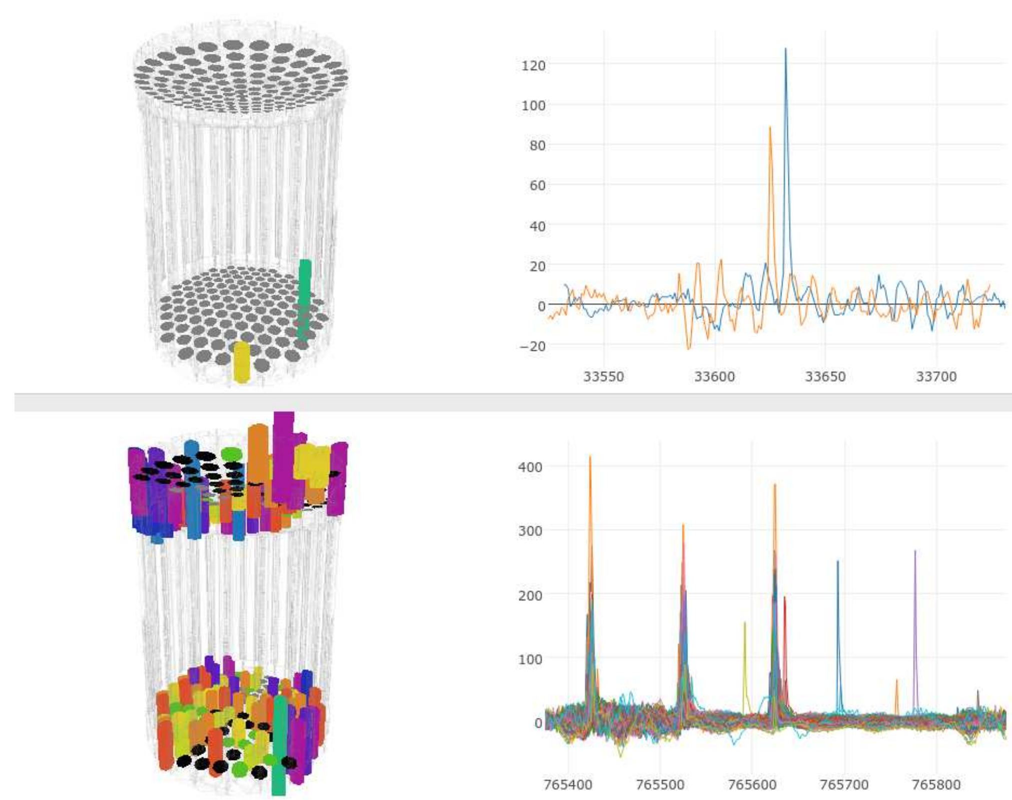
- **Triggerless readout** at ⅓ p.e.
- **Software trigger**, flexible algorithms
- **High rates** up to 1 kHz (300 MB/s) for external calibration

Technology

- **Off the shelf** electronics (incl. CAEN digitizers w/ custom firmware)
- **MongoDB:** high speed data-buffering and fast trigger queries
- **Web frontend** (Django) for system control and online data monitoring

Status:

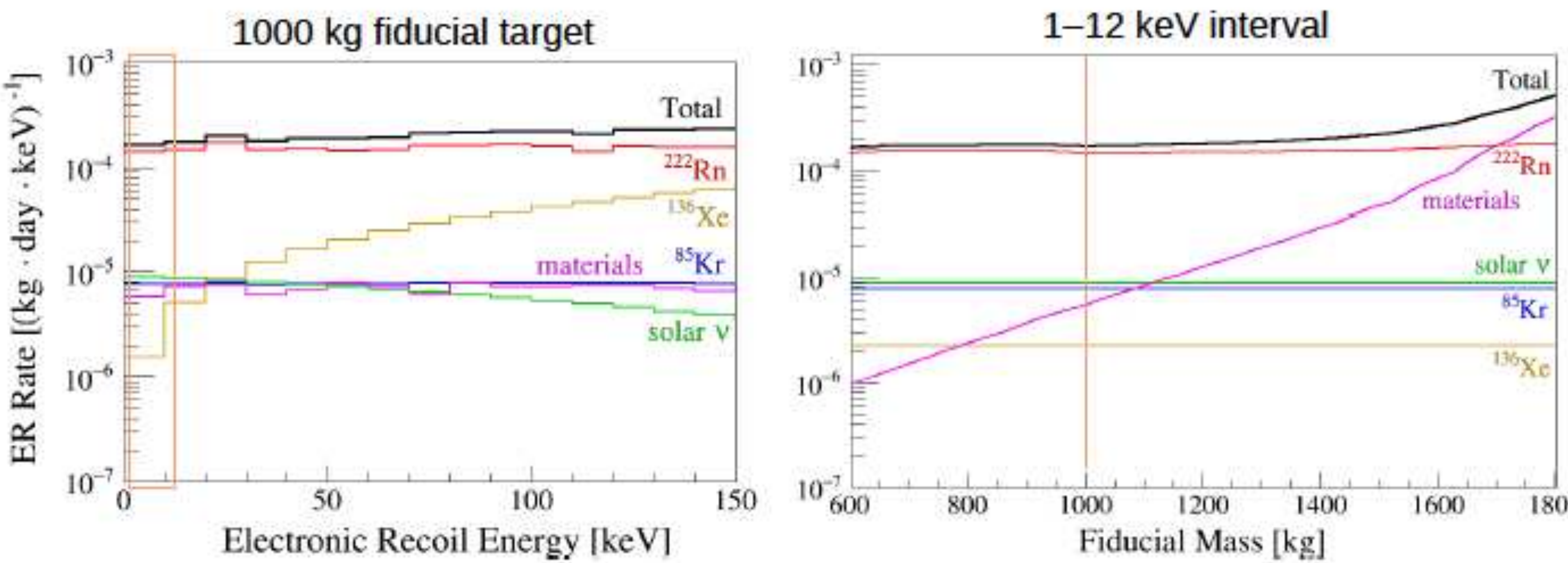
- **Installed at LNGS**
- **In use for detector commissioning**



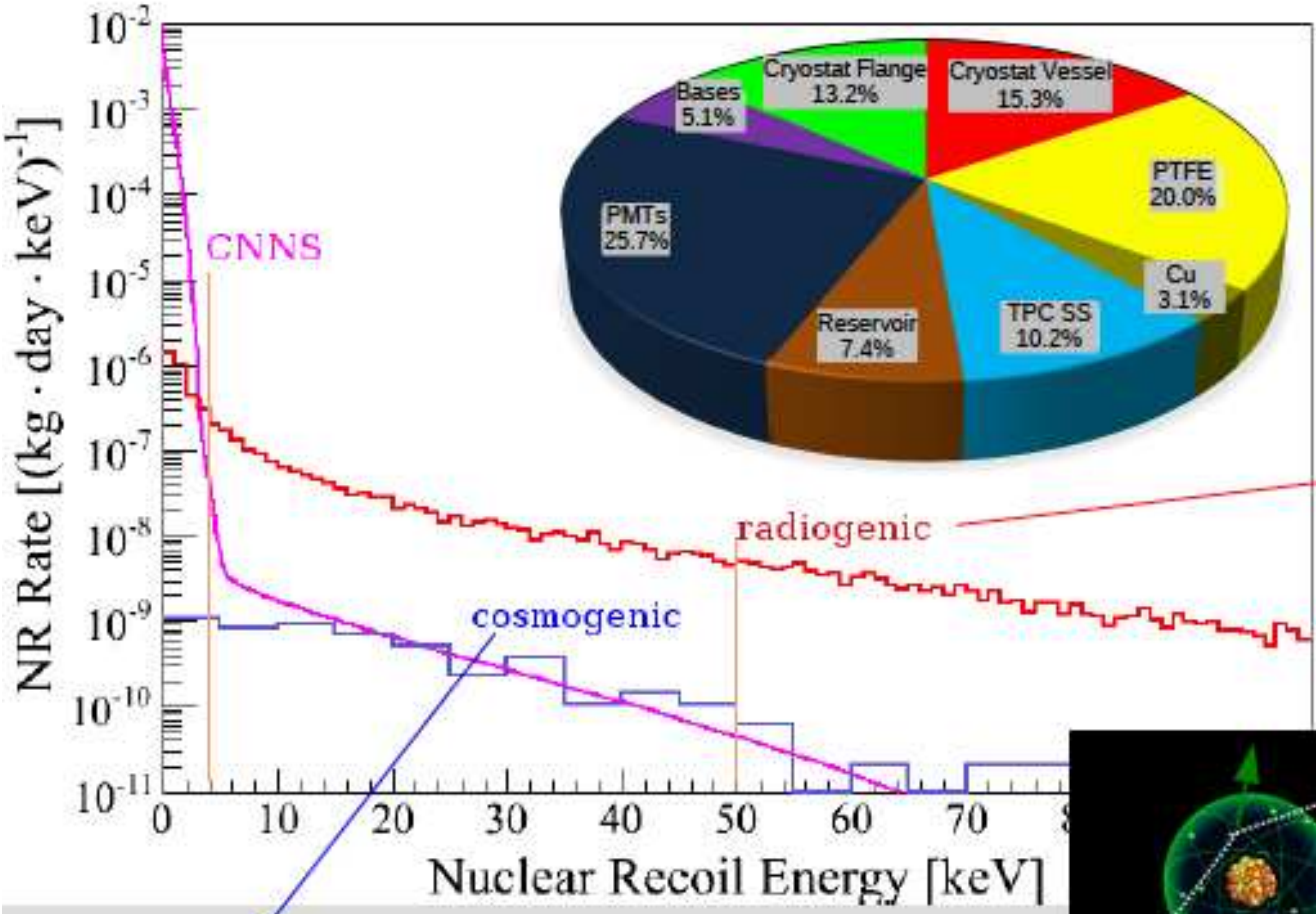
web data browser

DAQ installation at LNGS

Background: Electronic Recoils

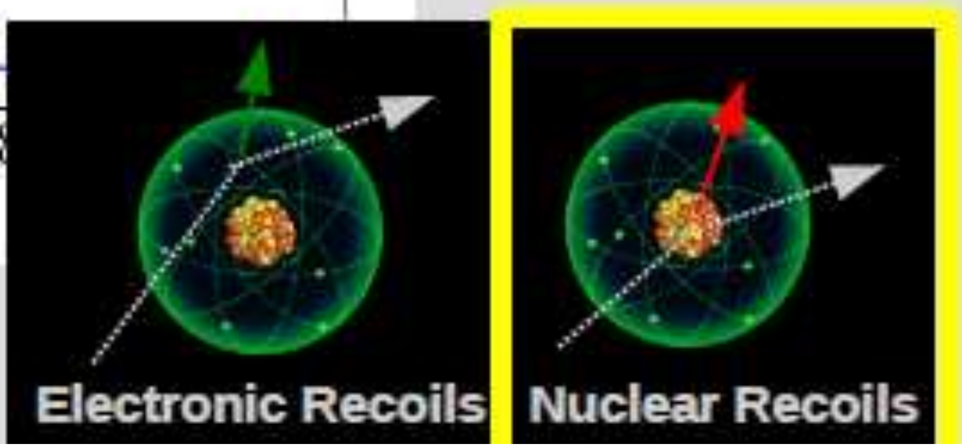


Background: Nuclear Recoils



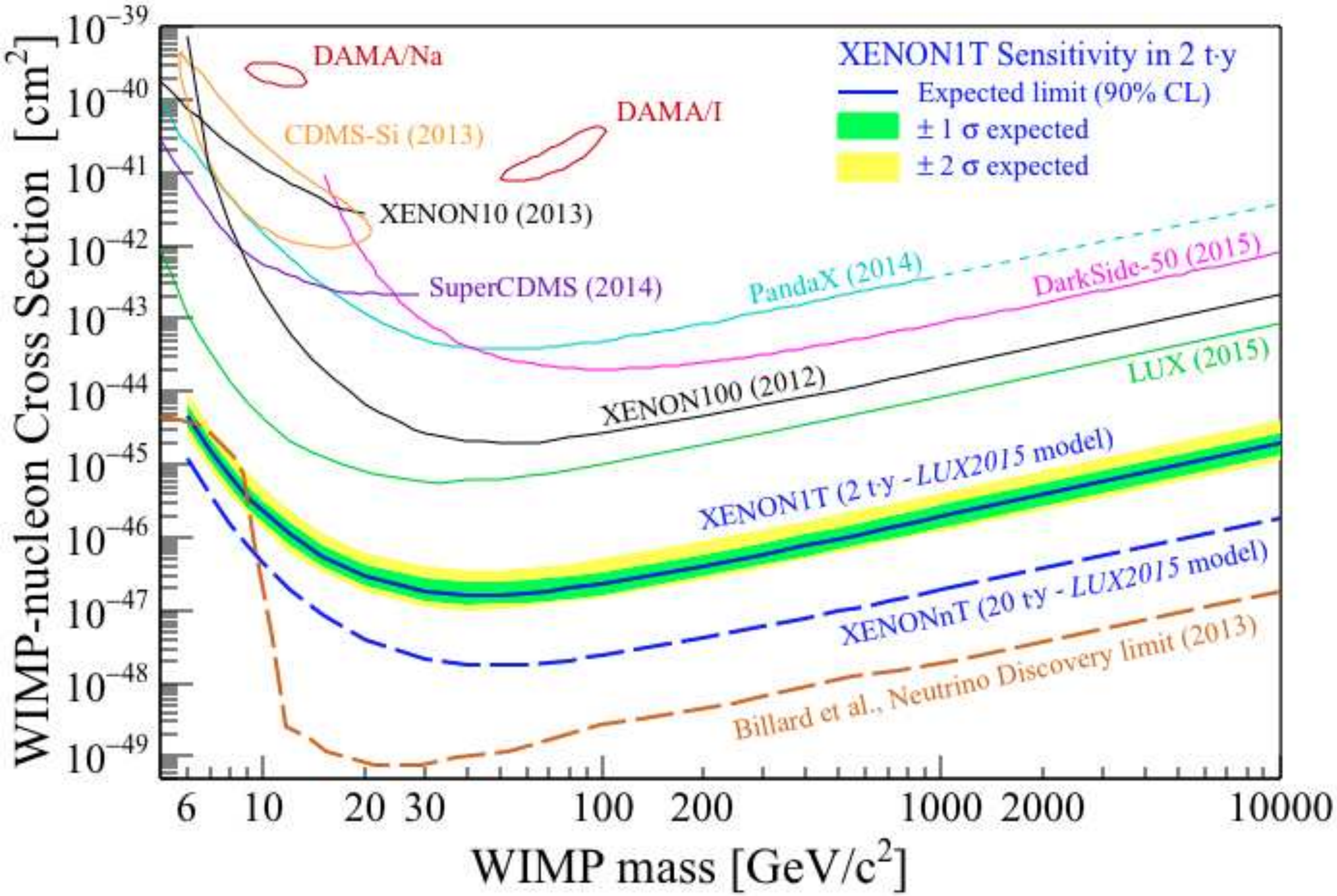
material screening, e.g. EPJ C 75, 546 (2015)

Muon veto design and performance: XENON1T, JINST 9, P11006 (2014)



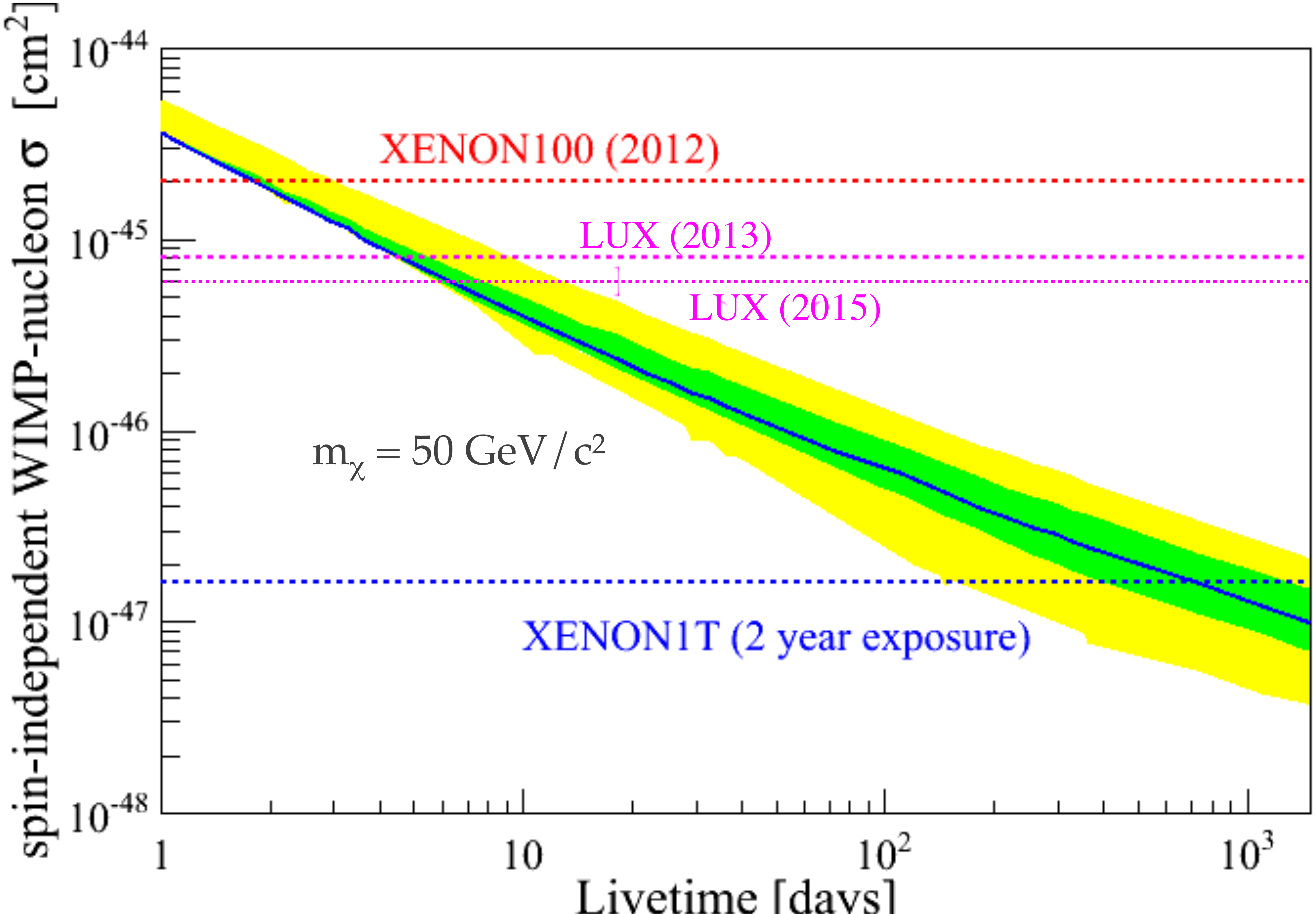
XENON1T sensitivity

XENON Collaboration: arXiv:1512.07501, accepted by JCAP



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

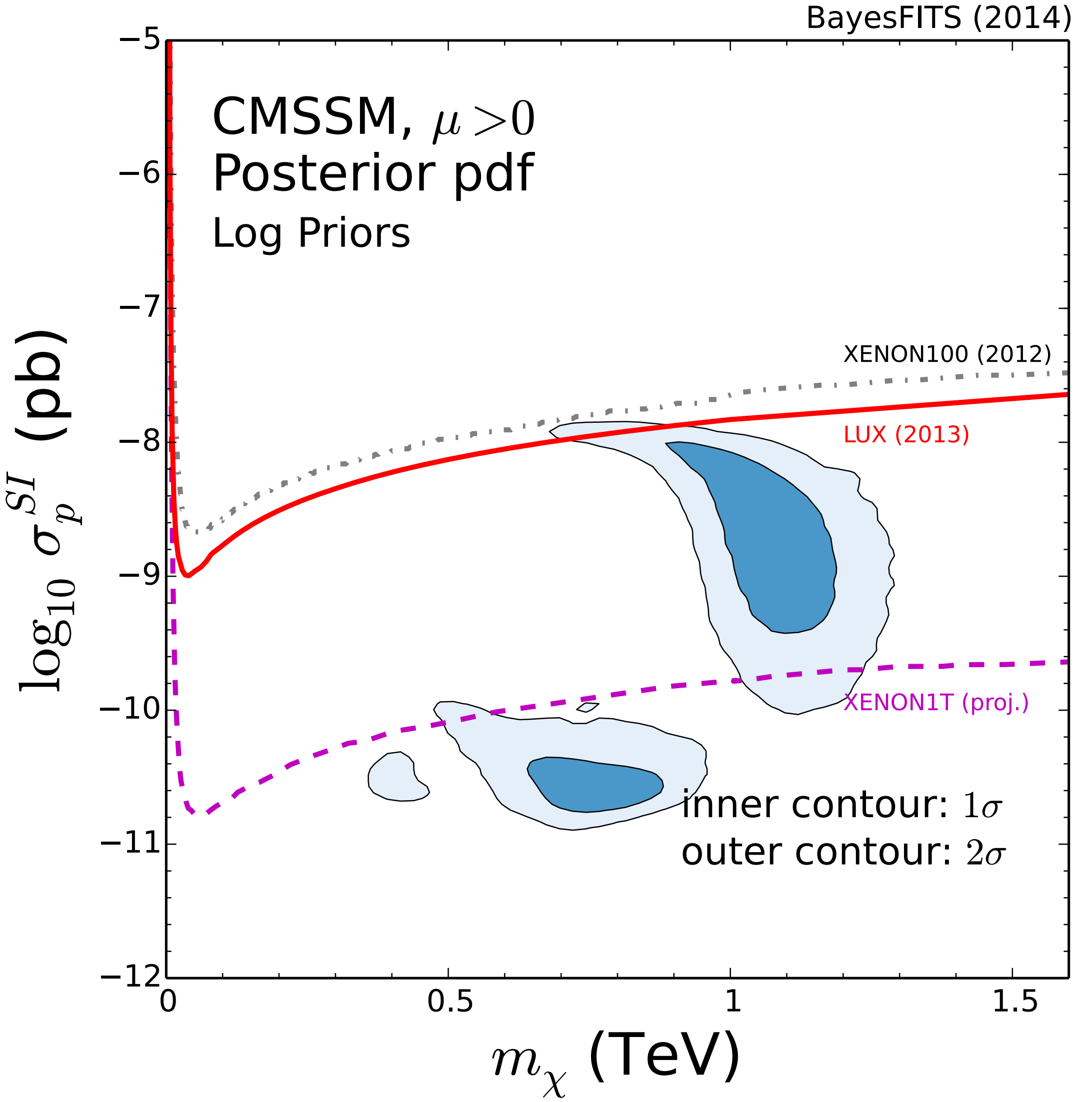
Sensitivity VS time



In less than 10 days we can reach the sensitivity of the currently running experiments

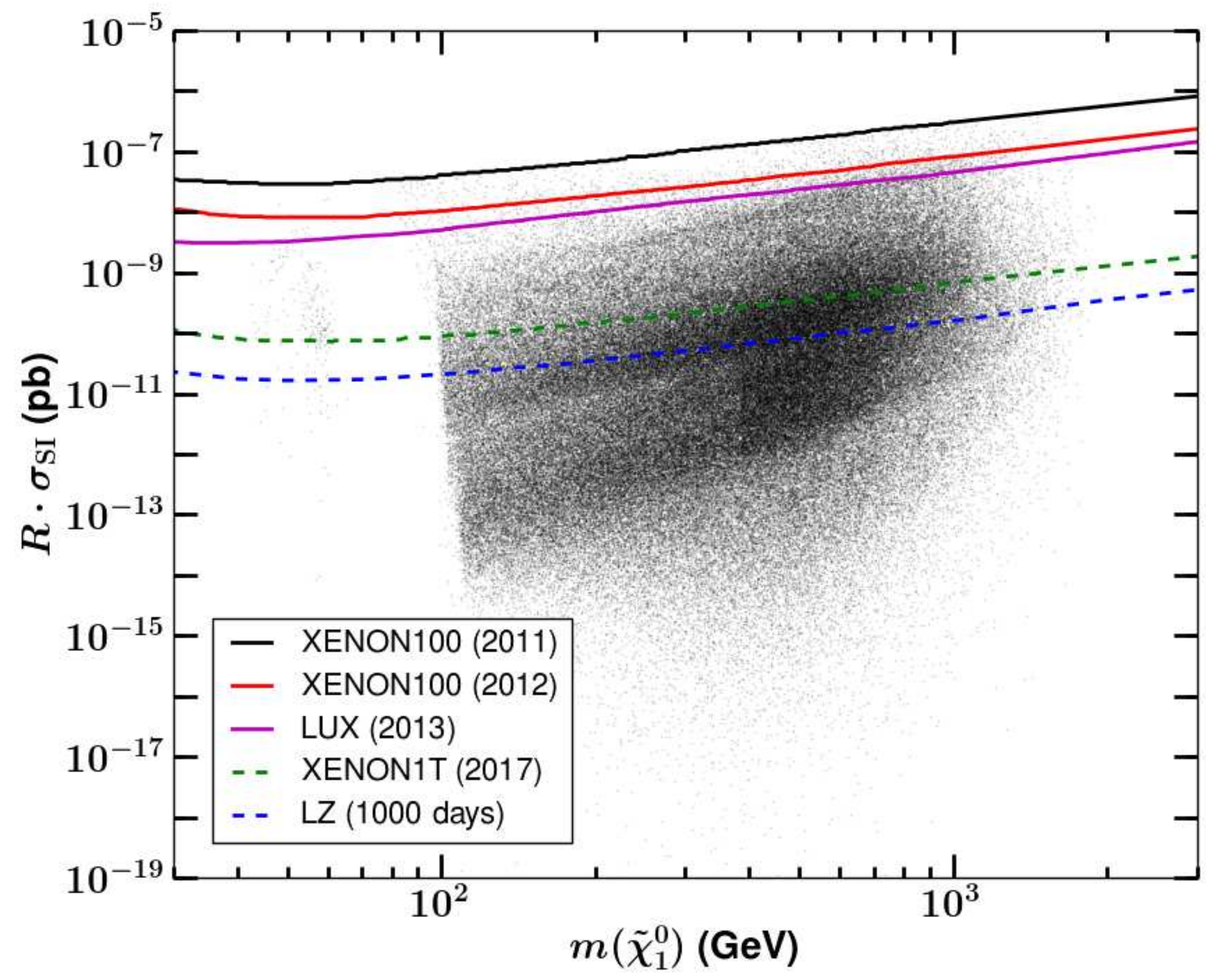
SUSY Predictions: 2 examples

CMSSM



L. Rozkowski, Stockholm 2015

pMSSM



M. Cahill-Rowley, Phys.Rev. D91 (2015) 055011

Summary

- A new era in Dark Matter Direct Detection is about to begin with the deployment of the first multi-ton scale liquid Xenon detector, XENON1T. The experiment will start science data taking this Summer.

- The technology of two-phase XeTPC has already proven to yield the best sensitivity. The challenges we meet and the solutions we invent for XENON1T will inform future efforts with noble liquid targets worldwide.

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- XENON1T/XENONnT will cover much of the high mass WIMP parameter space by ~2022. Coherent neutrino scattering will ultimately constraint the sensitivity but also provide the opportunity for a first discovery.

- XENON1T will take data at the same time as the LHC Run 2 and indirect searches. The complementarity of the three approaches is critical to either discover or rule out WIMPs as Dark Matter in the next few years.