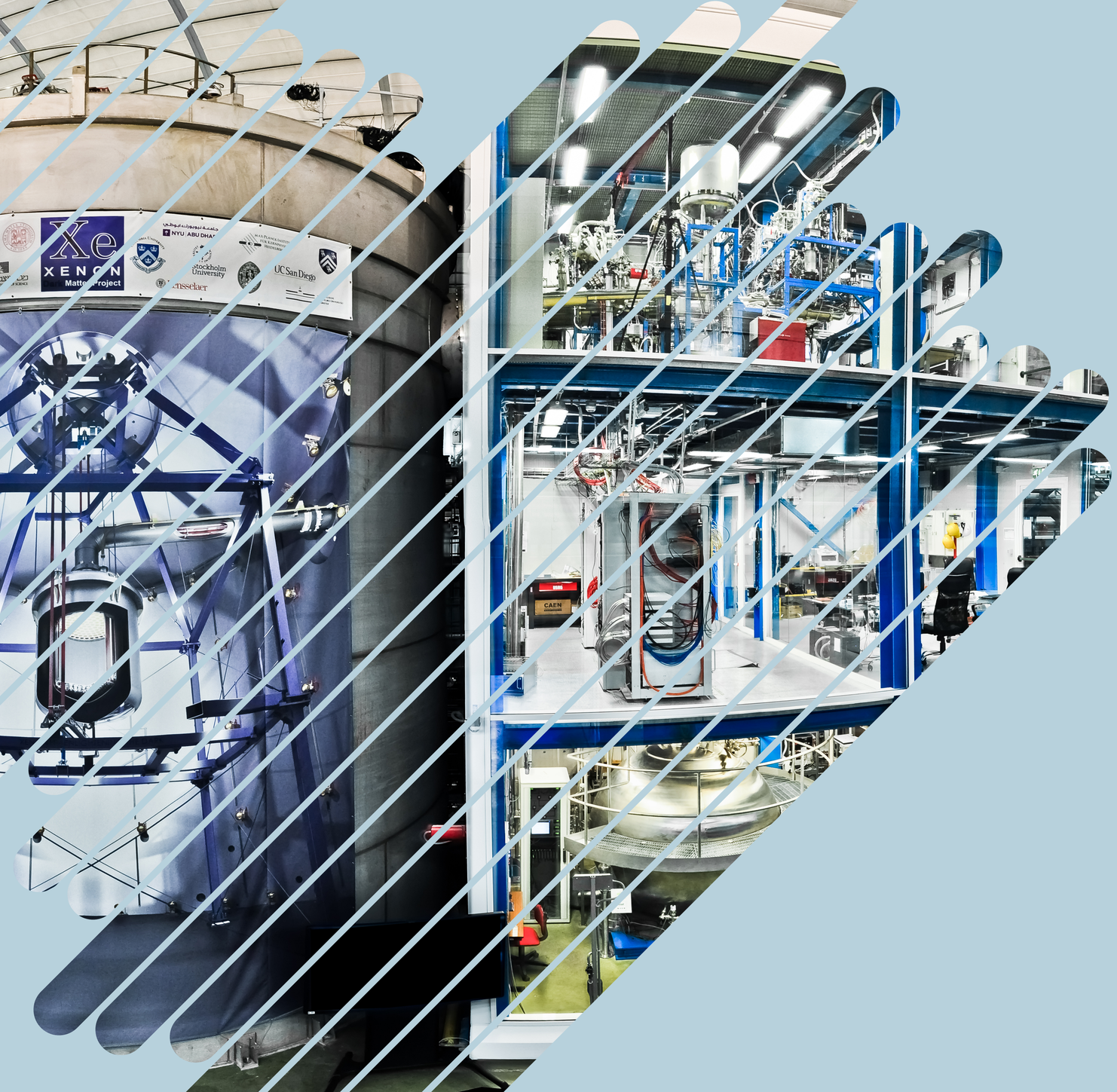


XENONnT

ON THE HORIZON

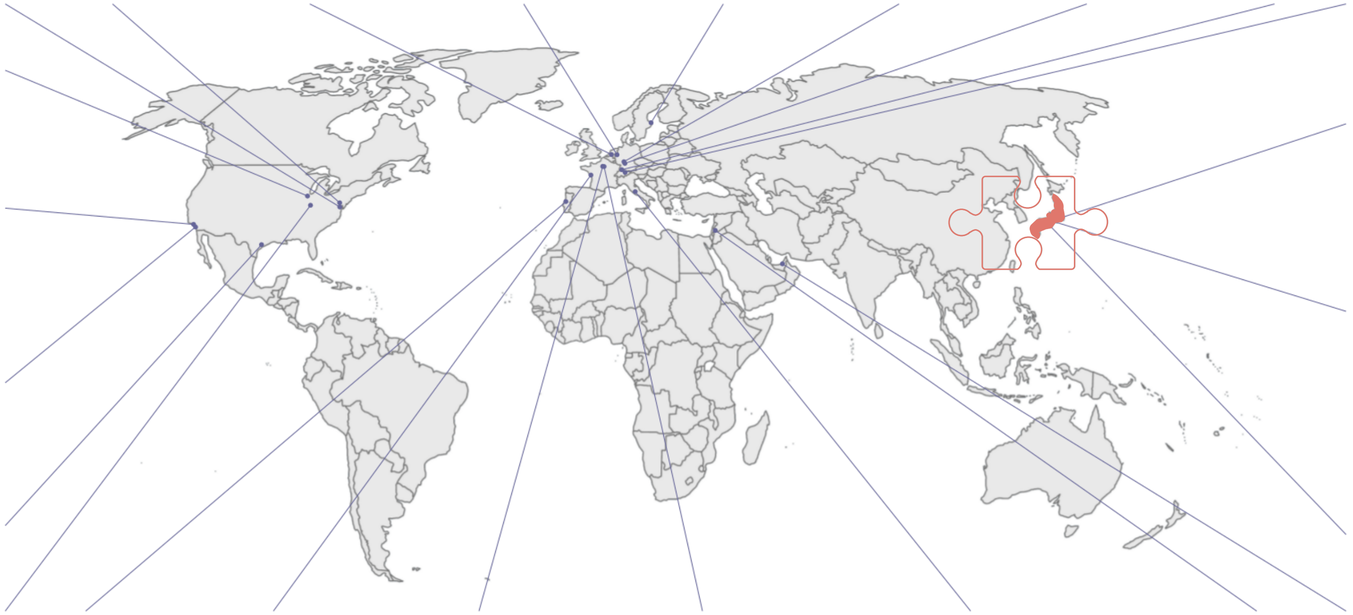
Luca Grandi
The University of Chicago
Enrico Fermi Institute
KICP

FOR THE XENON COLLABORATION

XENON Collaboration

Columbia · RPI · Nikhef · Muenster · Stockholm · Mainz · MPIK · Freiburg · Zurich

Chicago



Tokyo

UCLA

Nagoya

UCSD

Rice

Kobe

Purdue · Coimbra · Subatech · LPNHE · LAL · Bologna · LNGS · Torino · Napoli · Weizmann · NYUAD

SUMMARY

XENONnT in a nutshell

Minimal Upgrade

The XENON1T infrastructure and sub-systems were originally designed to ***accommodate a larger LXe TPC***.

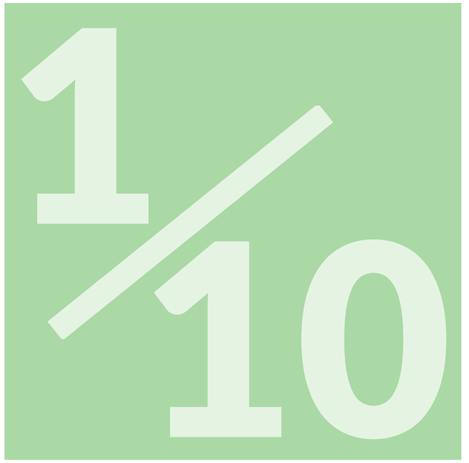
Fiducial Mass

XENONnT TPC features:

total Xe mass = 8 t

target mass = 5.9 t

fiducial mass = ~4 t



Background

Record low-background levels in XENON1T dominated by ^{222}Rn-daughters.

Identified strategies to effectively ***reduce ^{222}Rn by ~ a factor 10***.

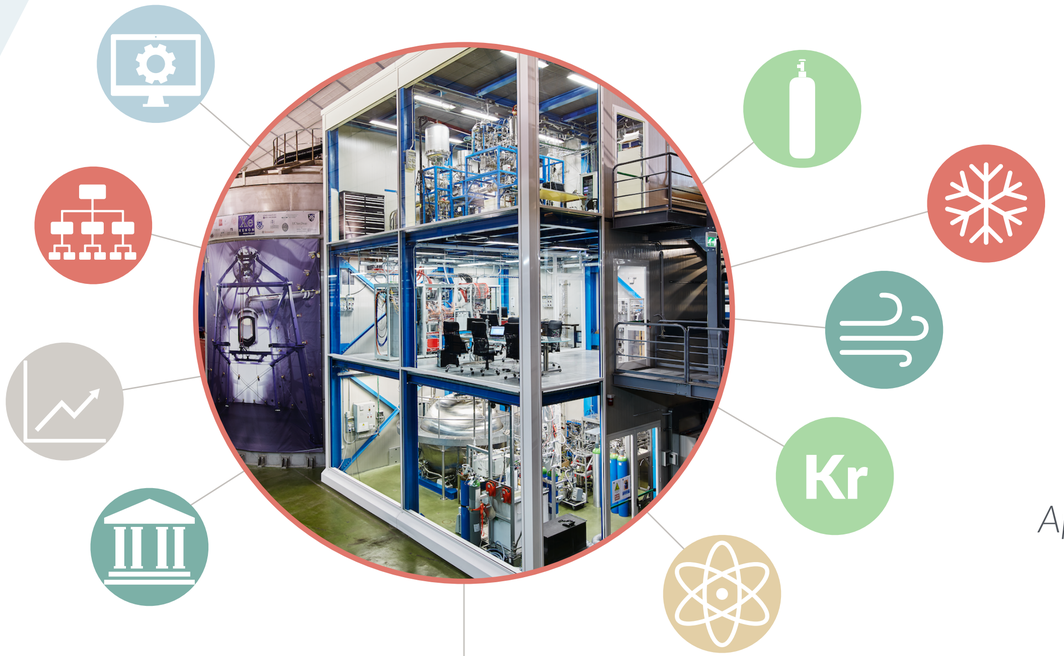
Fast Turnaround

Most XENON1T sub-systems, already thoroughly tested, will be ***re-used***.

Fast pace:

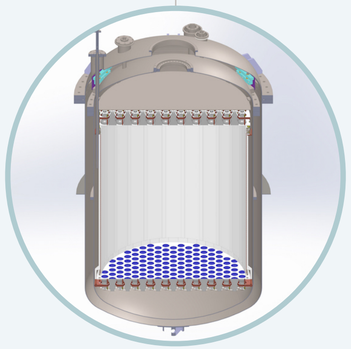
start running Apr 2019

complete commissioning by Sep 2019.



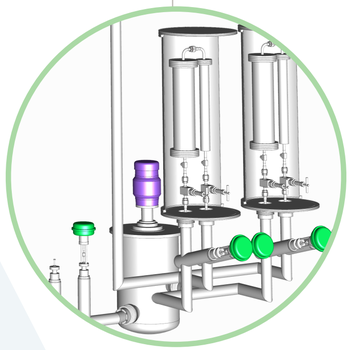
XENON1T Infrastructure and sub-Systems (already operative)

Aprile et al., Eur. Phys. J. C (2017) 77: 881



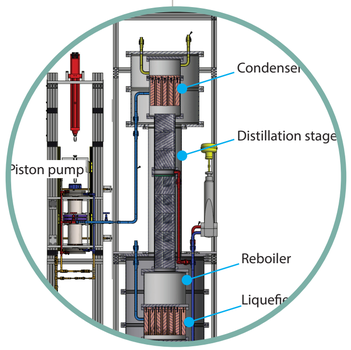
New TPC

5.9-ton Time Projection Chamber



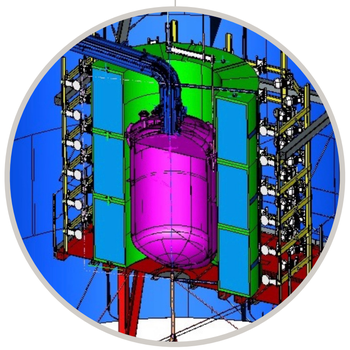
LXe Recirculation

Combined with LXe purification



Radon Distillation

To online remove the ^{222}Rn emanated inside the detector

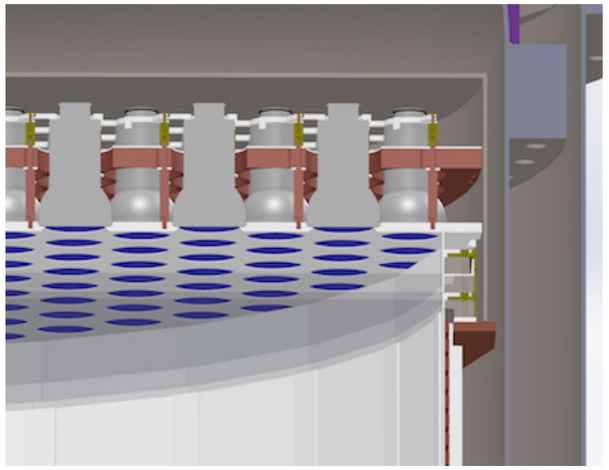


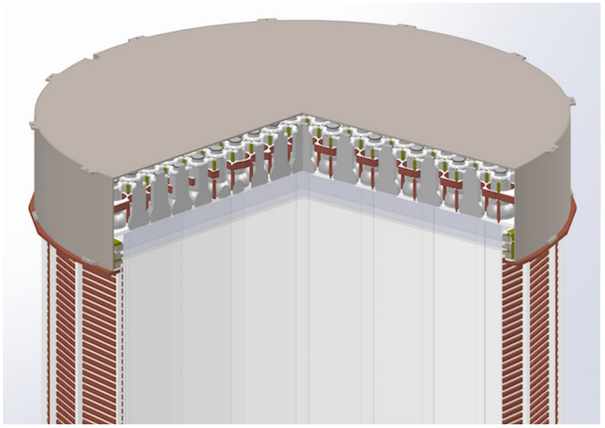
Neutron Veto

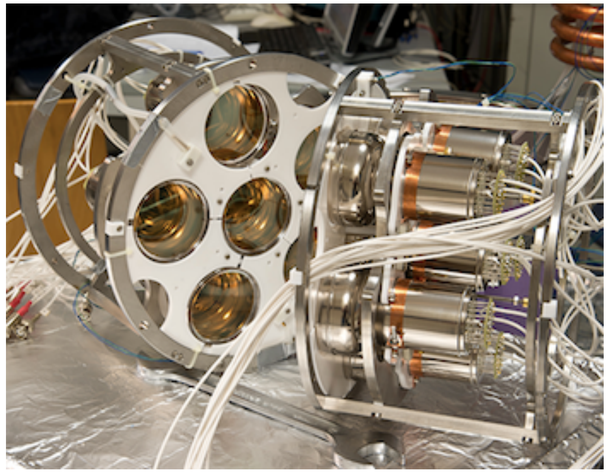
To tag and measure in situ neutron-induced background

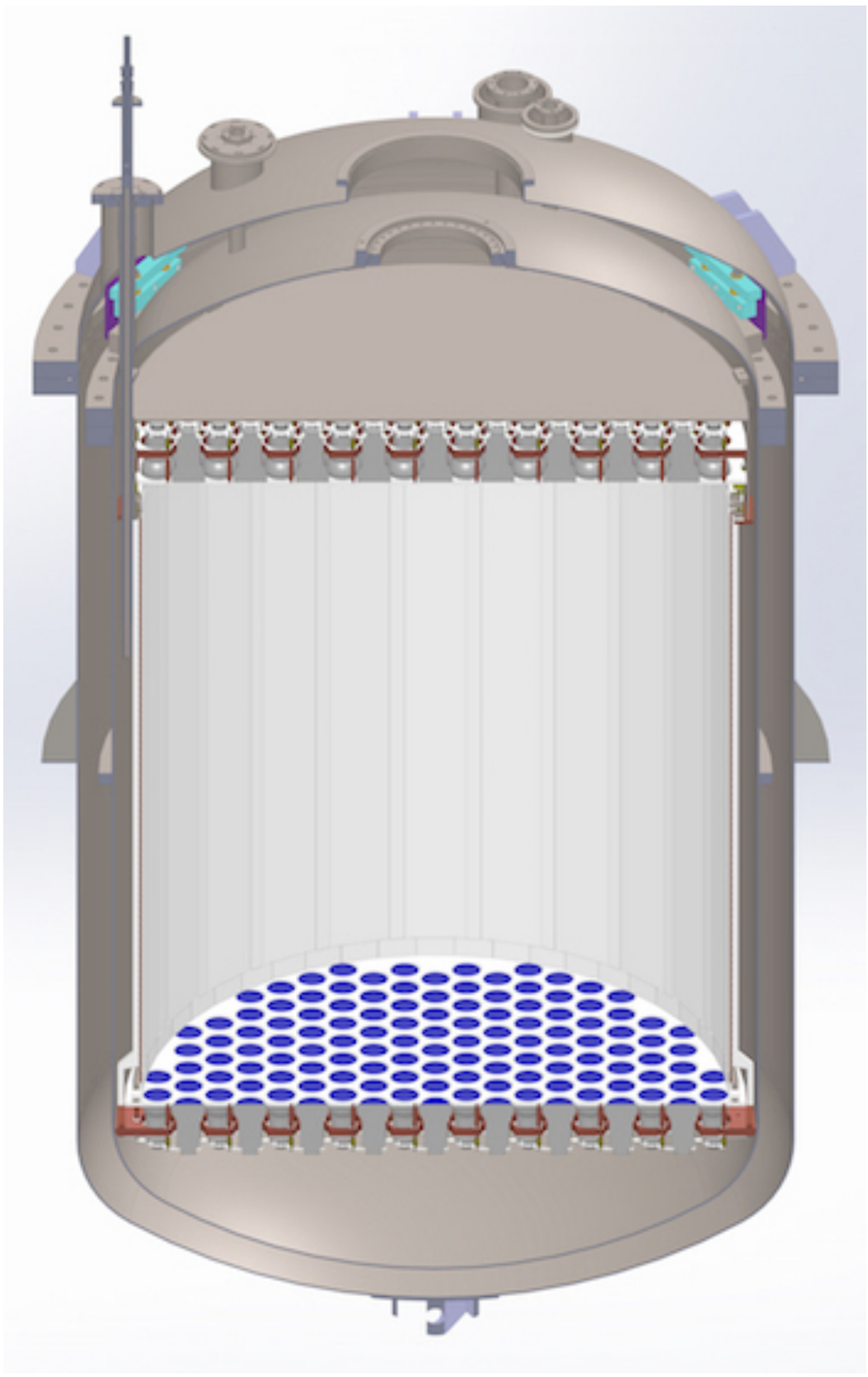
Time Projection Chamber

- ***Largest*** TPC ***fitting*** in the XENON1T ***outer vessel:***
  - ➡ *Use* ***same holding structure*** *and* ***leveling*** *mechanism.*





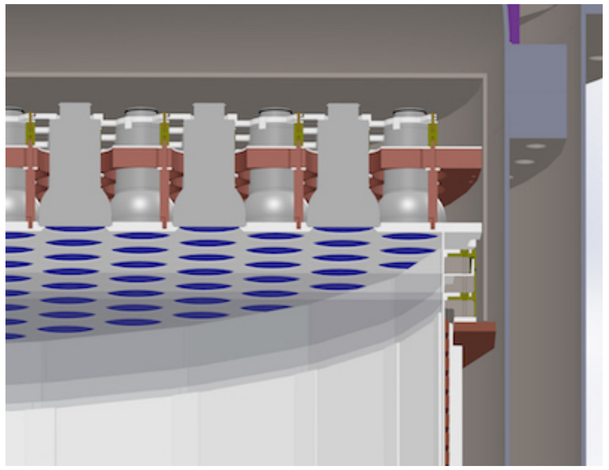


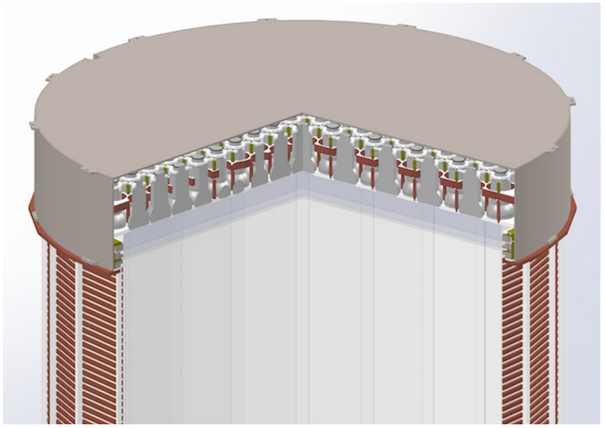


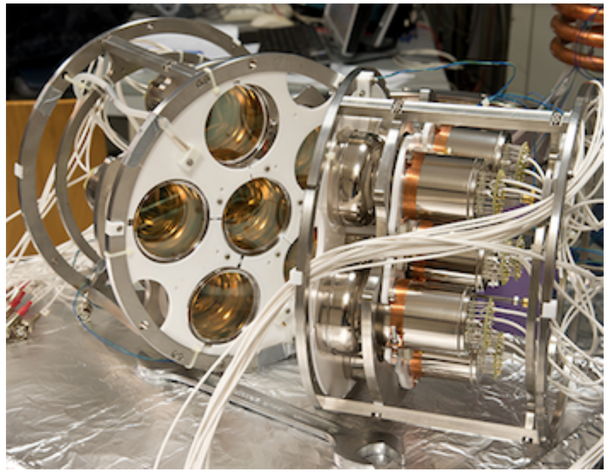
Time Projection Chamber

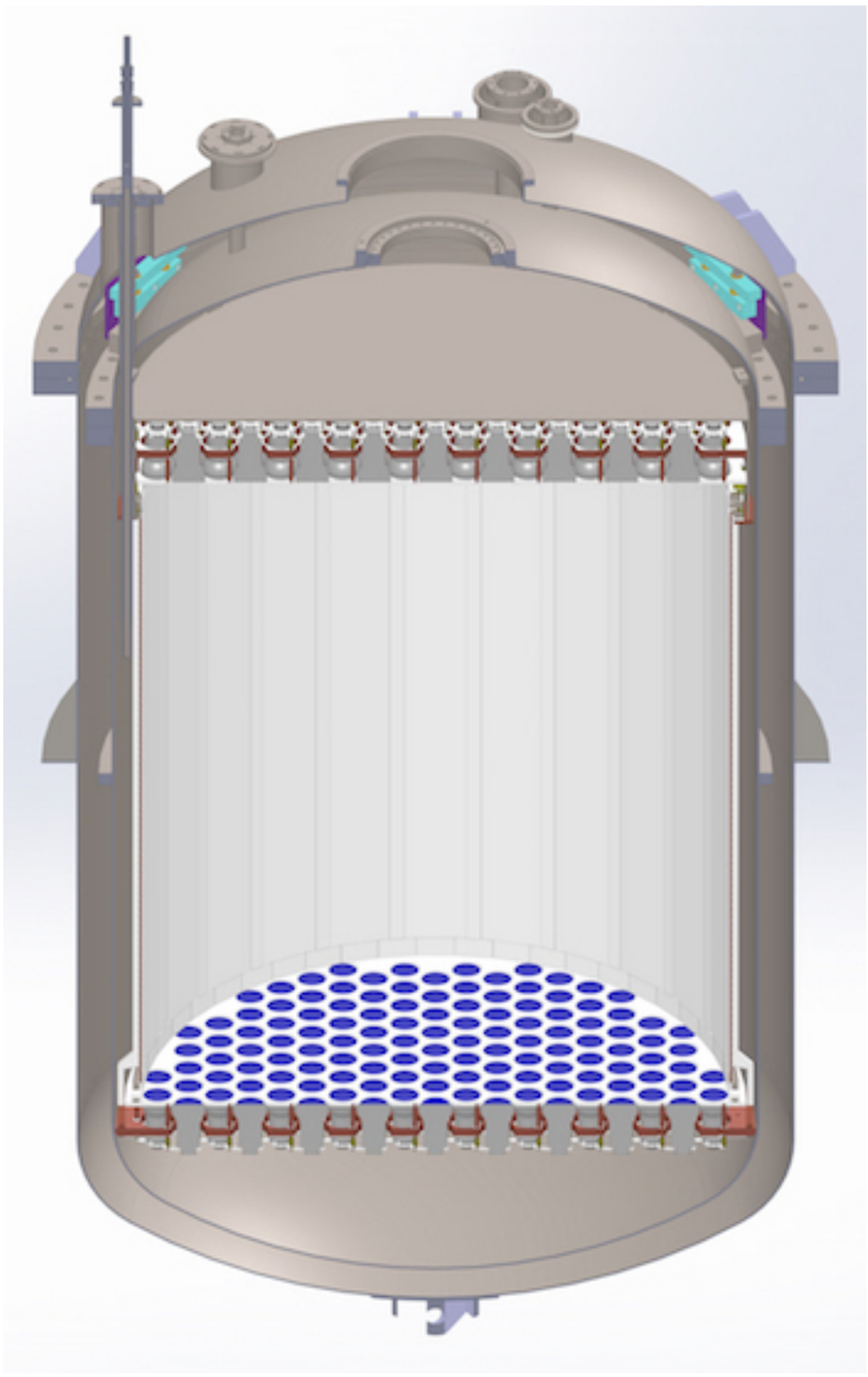
- ***Largest*** TPC ***fitting*** in the XENON1T ***outer vessel:***
  - ➡ *Use **same holding structure** and **leveling** mechanism.*

Dimensions (⌀, height)	1340mm, 1578mm (cold)
Target Mass	5.9 t (cold)
# of PMT in Top array	253
# of PMT in Bottom array	241
Design drift electric field	200V/cm
Design extraction field	8kV/cm



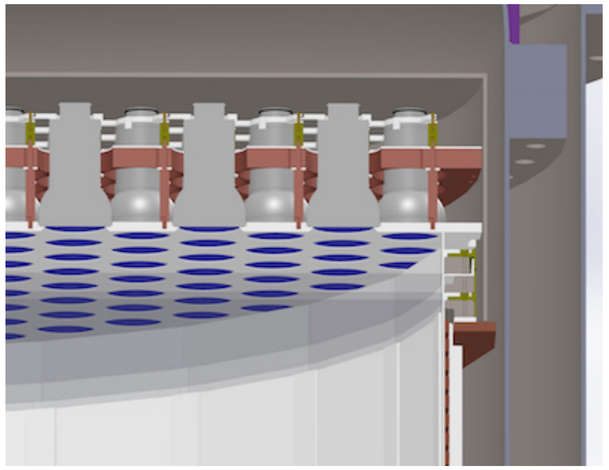


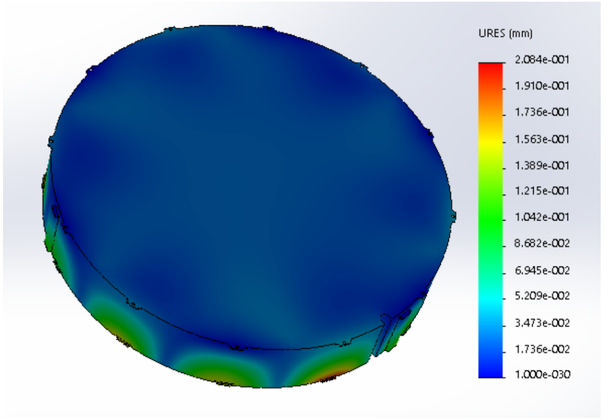


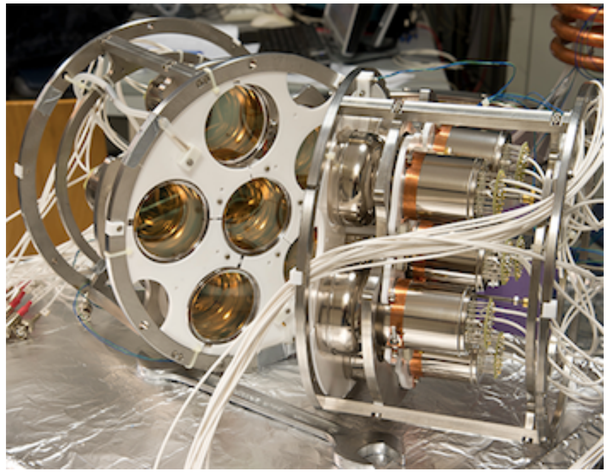


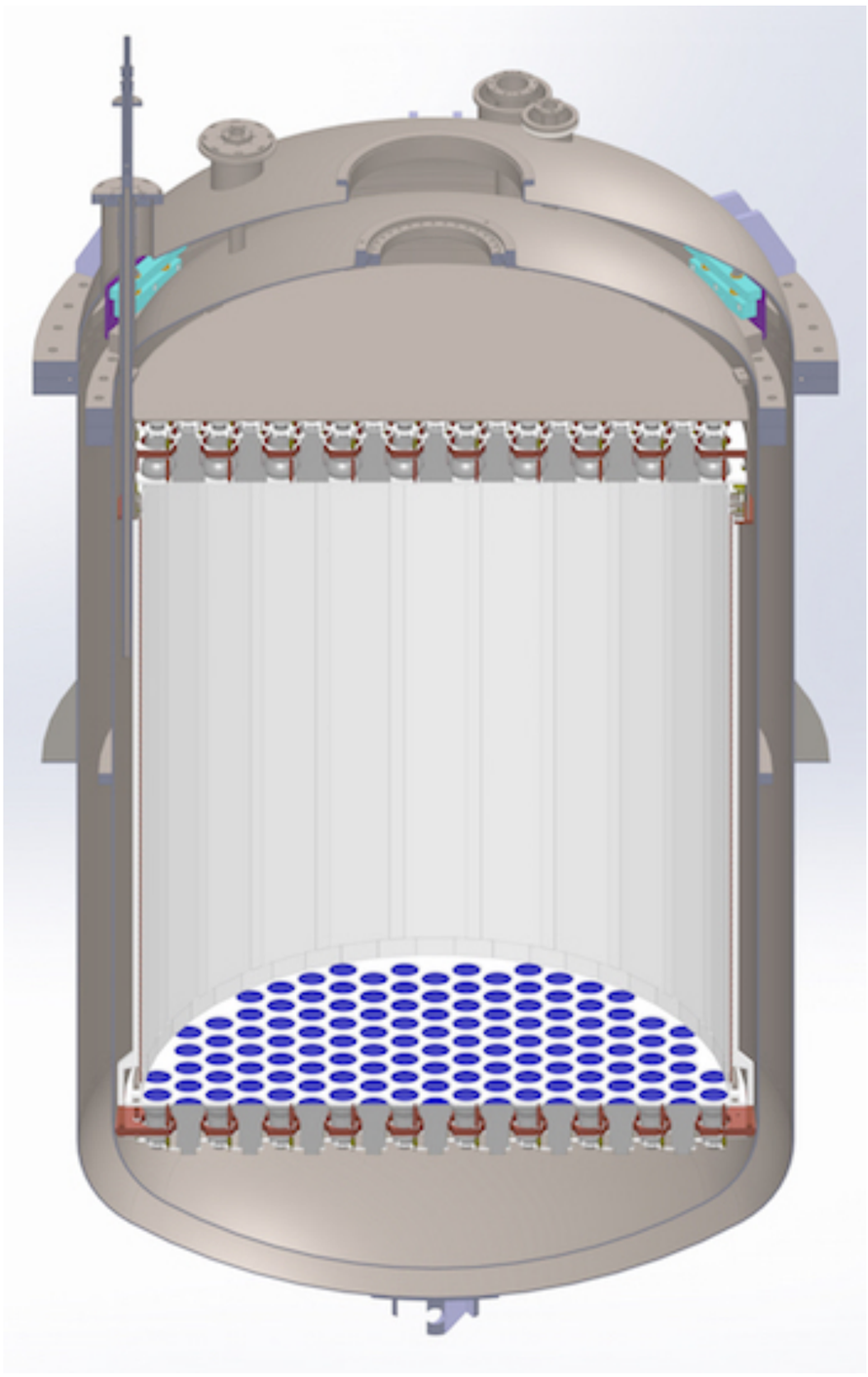
Time Projection Chamber

- ***Largest*** TPC ***fitting*** in the XENON1T ***outer vessel:***
  - ➡ *Use **same holding structure** and **leveling** mechanism.*
- ***Concept design finalized:***
  - ➡ *Raw **materials** under **procurement** and **screening** ongoing.*
- ***Technical design and FEM*** in advance stage:
  - ➡ ***mockup components under production*** to freeze the design.
- ***PMTs procured*** and under ***test*** in LXe in test facilities @ZURICH, @STOCKHOLM and @MPIK.

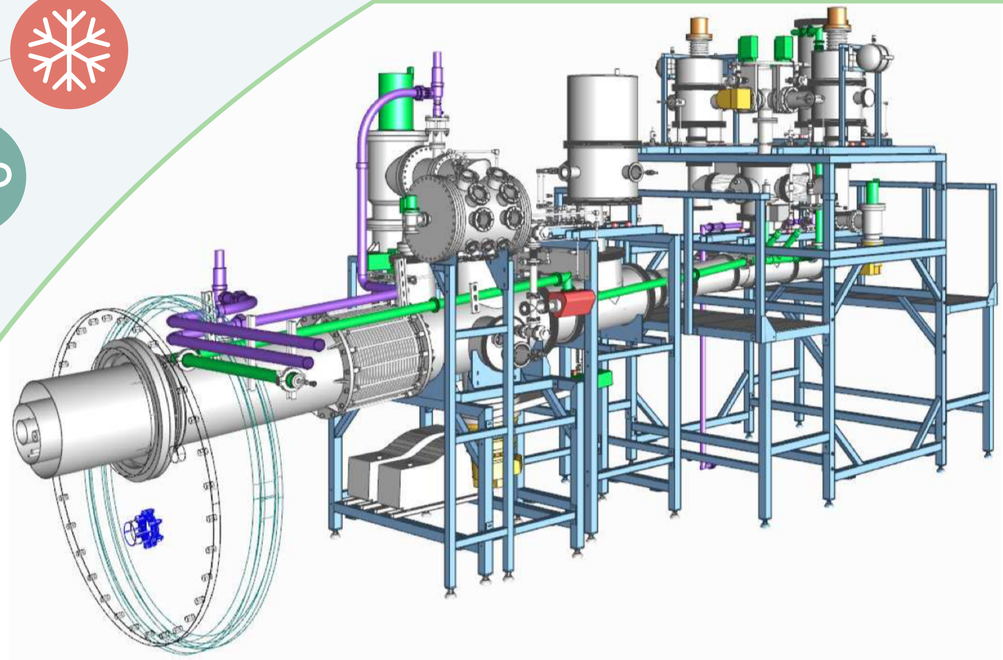








Cryogenics



In ***XENON1T***:

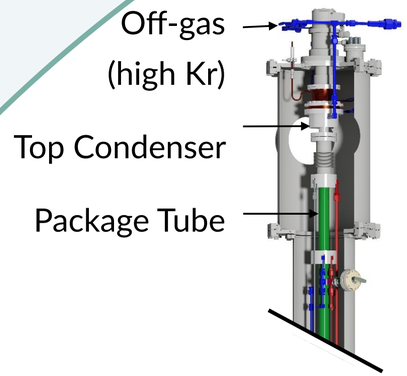
- ***2 Pulse Tube Refrigerators*** (cooling power 240W)
- ***1 LN cold head*** (cooling power >300W).
- ***BUT only 1 PTR is used*** (total heat load = 150W).
- The LN cold head kicks in in case of massive power failure.

In ***XENONnT use SAME cryogenic system:***

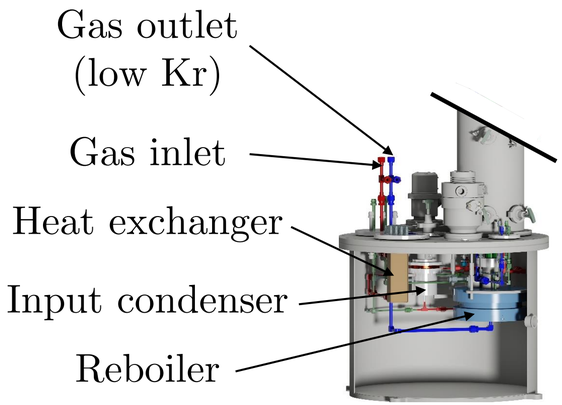
- expected total heat load = ***~245W***;
- operated with a ***single PTR*** (~150W) ***+ LN cold head*** (remaining)

	XENONnT Getter+Cryo
Total heat load	~245 W
Vessel (static)	~40 W
GXe/LXe purification	<40 W
Cryogenic LXe purification	~70 W@5000 SLPM
Heat pipe loss (dynamic)	~85 W
PMT arrays	$\lesssim$ 10 W

Kr cryo-distillation

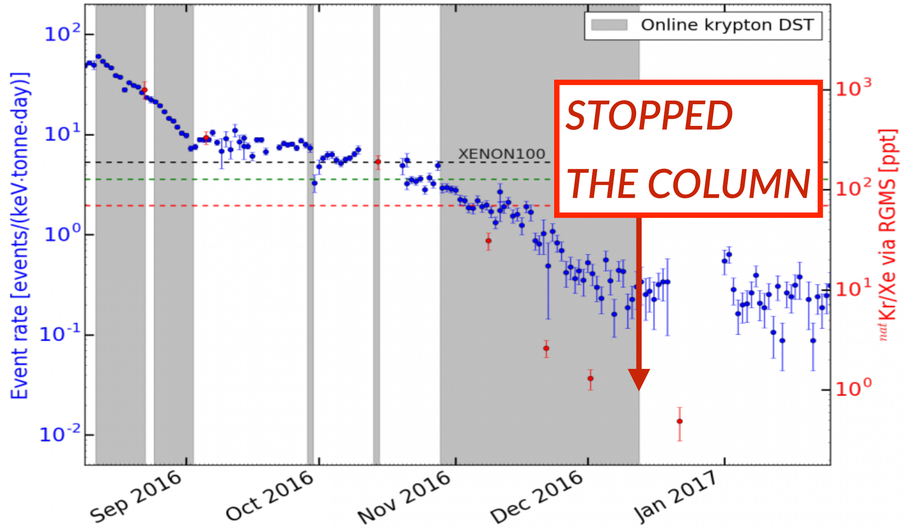


Aprile et al.,
Eur. Phys. J. C (2017) 77: 275



In ***XENON1T:***

- ***operated Kr-distillation column online*** for *~70 days*
  - ➡ *reduced ^{nat}Kr/Xe concentration from few ppm to **0.3ppt** (~1/3300th!)*
  - ➡ ***stopped when subdominant** wrt ^{222}Rn*



For ***XENONnT use the SAME column:***

- ***pre-distilled 8t of gas**. **Start** run with about **0.2ppt**;*
- *operate the column **online** at the start of the run*
  - ➡ *improve only by a factor 10 (small!), down to **20ppq**.*

The column was shown to reach ***^{nat}Kr/Xe <26ppq***.

SAME computing/ processing framework as ***XENON1T.***

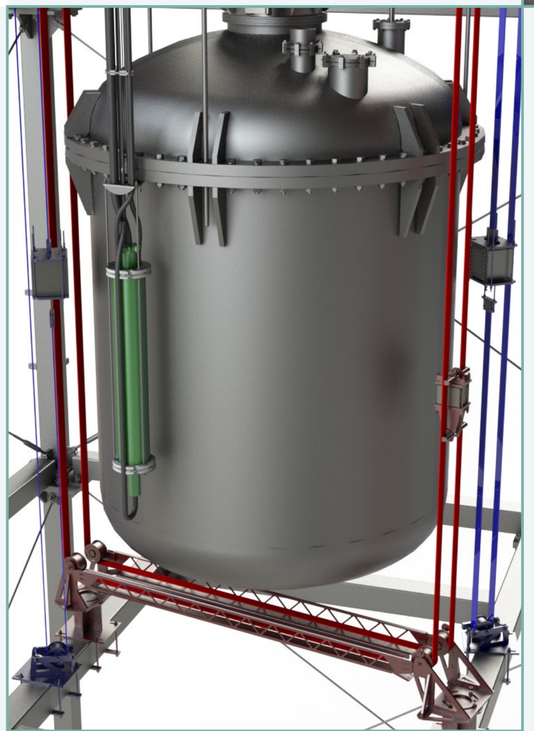
Scalable since based on *OSG/EGI* resources and ***LHC***-developed ***data management***.

Extra storage under procurement.

SAME source deployment system as ***XENON1T***.

+

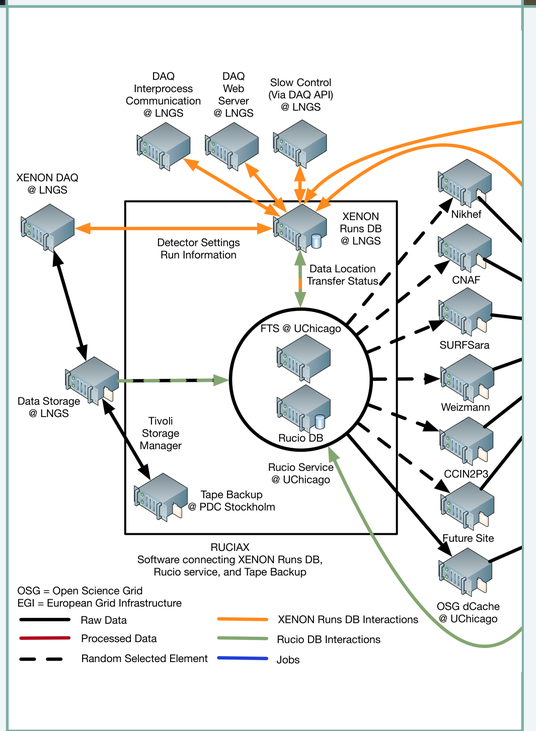
pulsed-neutron generator



SAME DAQ as ***XENON1T*** (reached ***96% up-time*** fraction).

Digitizers/CPUs for extra channels (+246) already *purchased*.

Double Gain Amplifiers under production (0v2b)

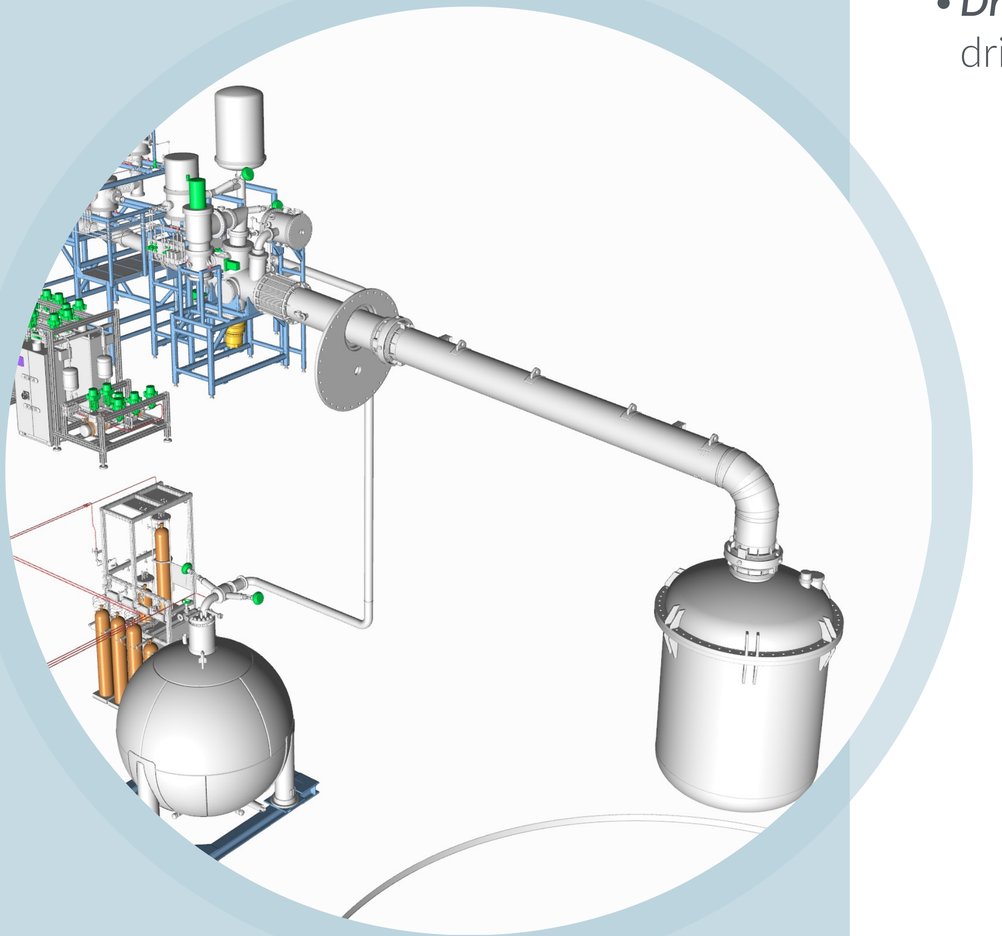


SAME Slow Control as ***XENON1T.***

Thoroughly tested and certified during the last 2 years.

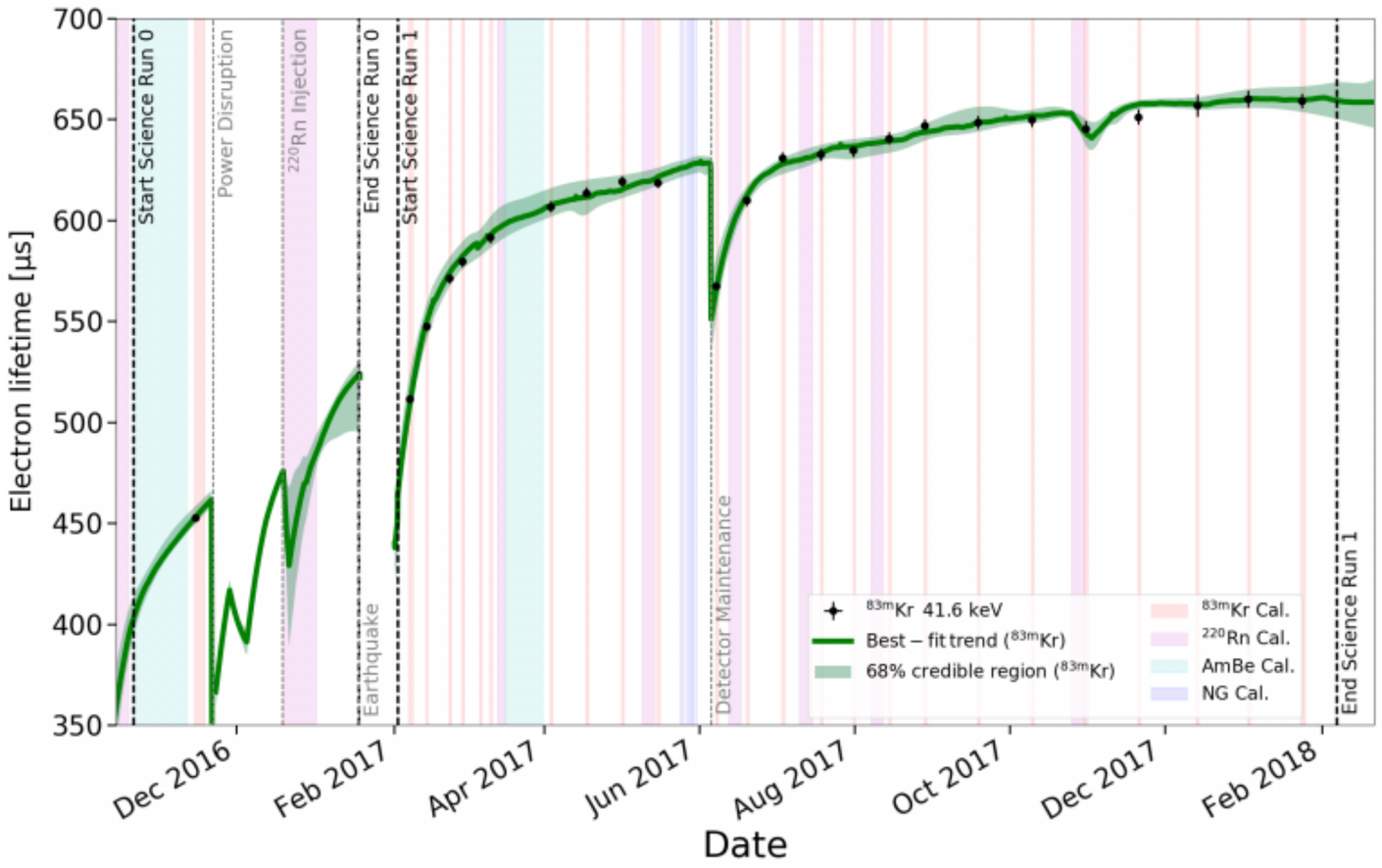
UPGRADED

Purification System



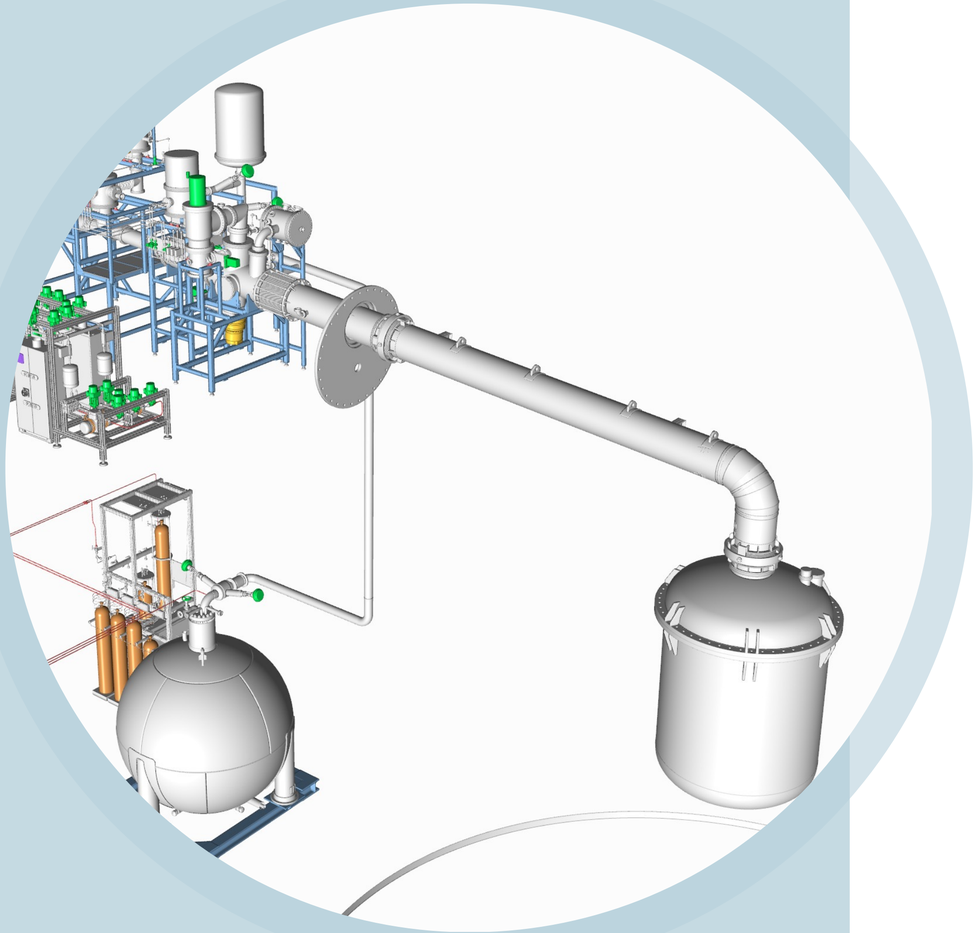
In ***XENON1T***:

- ***Gaseous recirculation/purification*** through a hot getter;
- Typical recirculation flow ~ ***55 SLPM***;
- ***Drifting electron lifetime*** plateauing at around ***650us*** (to be compared with maximum drift time of ~760us);



UPGRADED

Purification System



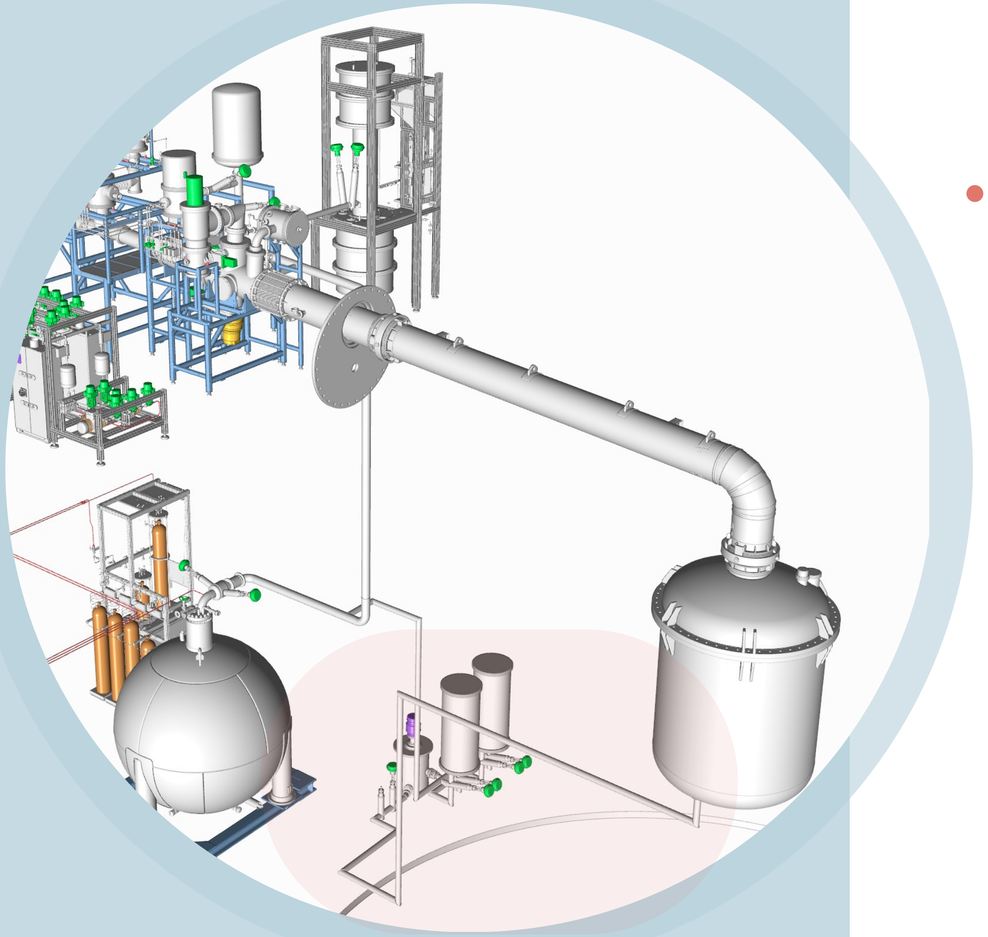
In ***XENONnT***:

- ***SAME Gaseous recirculation/purification*** system as ***XENON1T*** through a hot getter;
- ***+ New gaseous recirculation pump*** (100 SLPM);

+

UPGRADED

Purification System

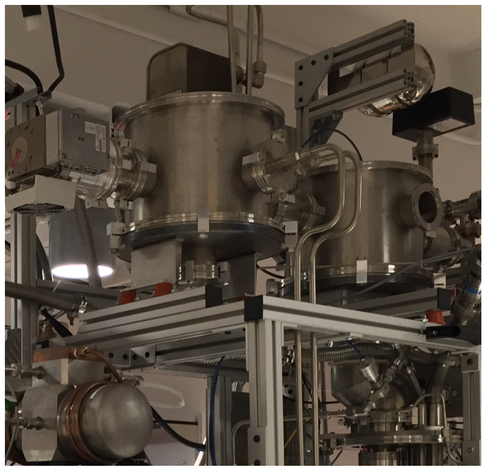


In ***XENONnT***:

- ***SAME Gaseous recirculation/purification*** system as ***XENON1T*** through a hot getter;
- ***+ New gaseous recirculation pump*** (100 SLPM);

+

- ***LIQUID recirculation and purification;***
  - ➡ Planned recirculation flow ~ ***5 L/min (LXe)***;
  - ➡ 2 redundant commercially-available ***cryogenic liquid pumps*** (Barber-Nichols);
  - ➡ Two custom-developed, regenerable, ***cryogenic filters*** ($2Cu+O_2 \rightarrow 2CuO$);
  - ➡ Installed inside independent vacuum-insulated enclosures for maintenance;
  - ➡ ***optimization*** of filters material and ***measurements*** of LXe purity ongoing in a test facility @ COLUMBIA



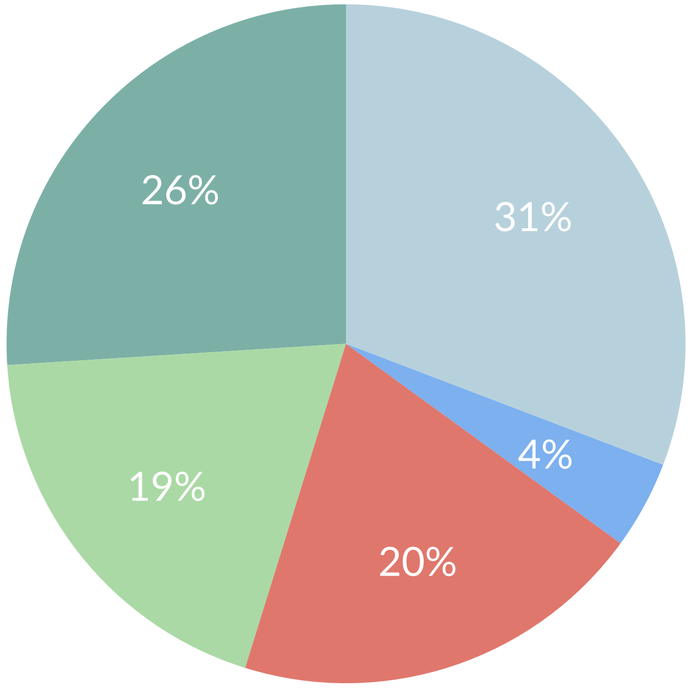
Rn-budget breakdown: emanations measured in **XENON1T**

TPC+Cryostat

^{222}Rn emanated by materials inside the TPC

Type-I Sources

10uBq/kg



Is the source emanating around the active volume?

Piping + Cables

^{222}Rn emanated by materials within the recirculation and cable pipes

Cryopipe

^{222}Rn emanated within the cryogenic pipe used to transfer LXe

Hot Getter

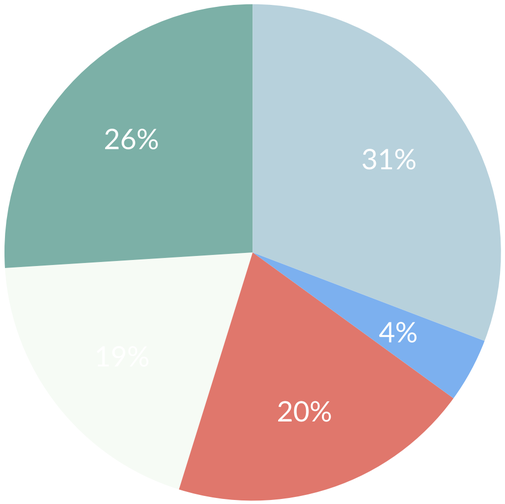
^{222}Rn emanated by the hot getter used to remove electronegative impurities

QDrive Pumps

^{222}Rn emanated by plastic materials within the recirculation pumps

Type-II Sources

Online removal of Rn from Type-II Sources



QDrive Pumps

Piping + Cables

Hot Getter

Cryopipe

NEW dedicated cryogenic distillation column:

- operated ***continuously*** to extract xenon gas (from pipes, etc, …) and ***remove*** ^{222}Rn emanated by Type-II sources:
- ***extraction*** flow of xenon gas ***~20slpm***;
- ***reduction*** factor ~***100***.

~0.3%

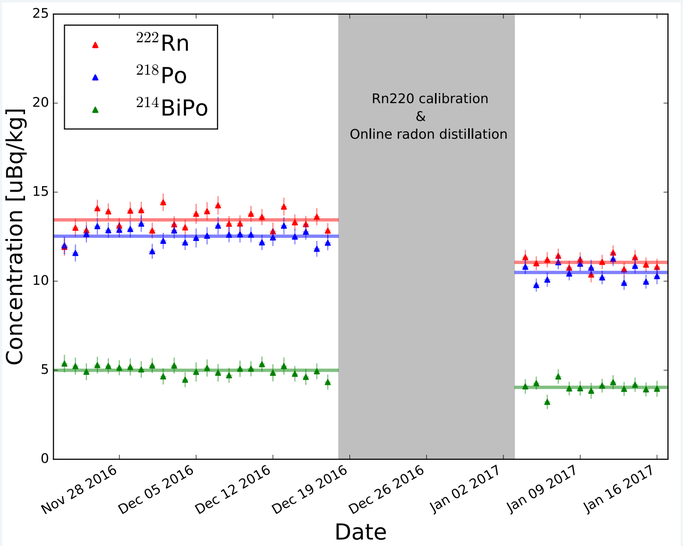
~0.04%

~0.2%

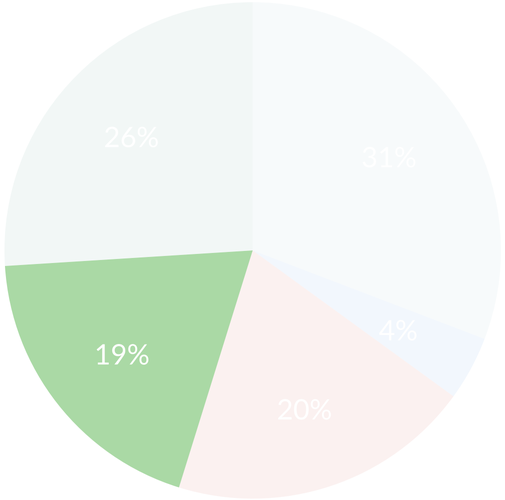
~0.3%

The concept was:

- ***Successfully*** tested in ***XENON100*** *[EPJ C 77 (2017) 358]*
- ***Successfully*** tested in ***XENON1T***
  - ➡ *operated **Kr-column** in reverse mode to mimic a **Rn-column (@ 3slpm,** non-optimized**).***
  - ➡ ***Measured 20% reduction of the background*** *(despite not being optimized).*

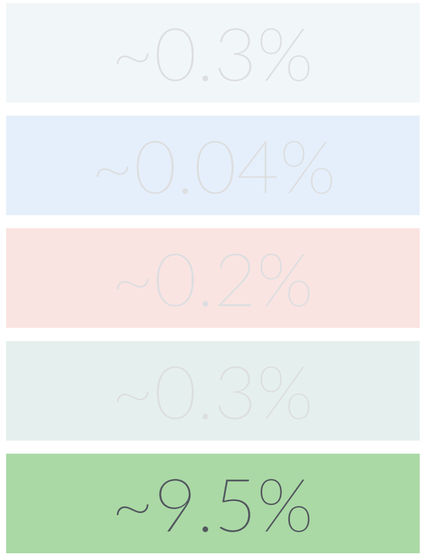


Online removal of Rn from Type-I Sources



- For Type-I Sources the Rn-concentration in the active volume depends only on ***circulation rate***.
  - ➡ ***Distill the xenon fast enough wrt ^{222}Rn*** mean lifetime (5.5 days).

- ***High-flux online cryogenic distillation column***:
  - ➡ *Same concept as other tested columns, just **more powerful** (~3kW)*
  - ➡ ***Extracting** xenon from active volume @ **200slpm** (8t ~ 5d);*
  - ➡ ***Intrinsic reduction** factor **~100**;*
  - ➡ *Overall reduction in the active volume **~2**;*
  - ➡ *Designed to be upgradable to **~600slpm** (adding more cooling power);*



Online removal of Rn

~0.3% +

~0.04% +

~0.2% +

~0.3% +

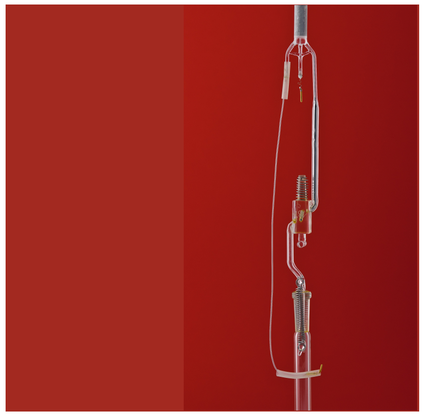
~9.5% =

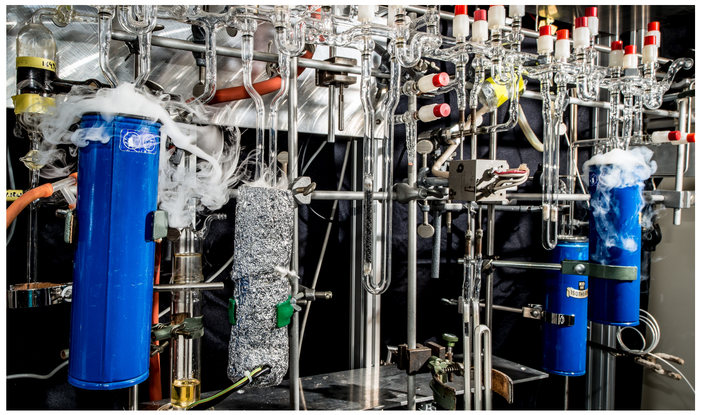
~1uBq/kg

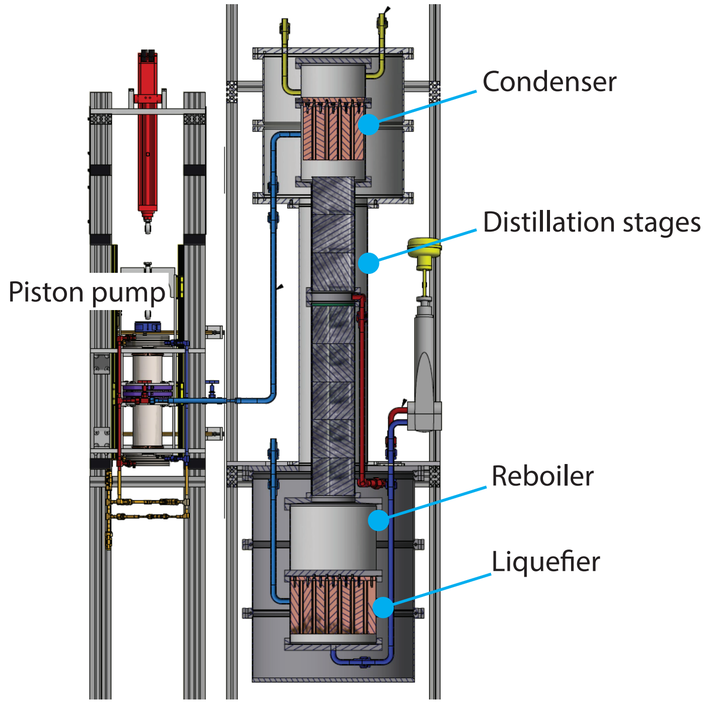
- ***Radon-mitigation: screening facility*** @ MPIK working at full load to certify material and cleaning procedures, to ***further reduce Rn-emanation*** wrt to XENON1T.

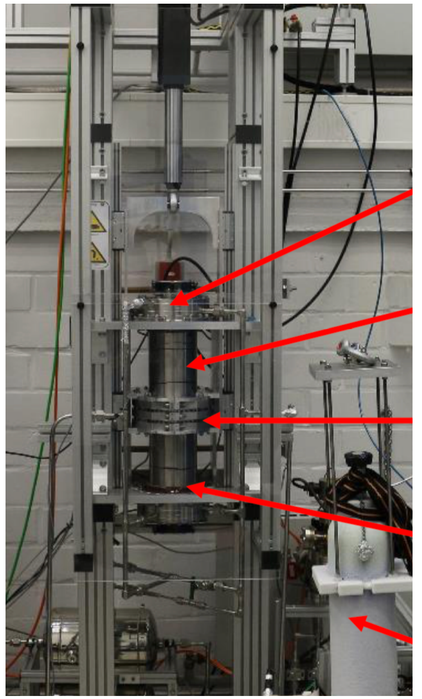
+

- A single dedicated column to remove Rn emanated both in ***gas*** and ***liquid phases***.
- ***Under assembly*** @ MÜNSTER
- ***Integrated*** within existing ***liquid*** and ***gaseous recirculation system;***







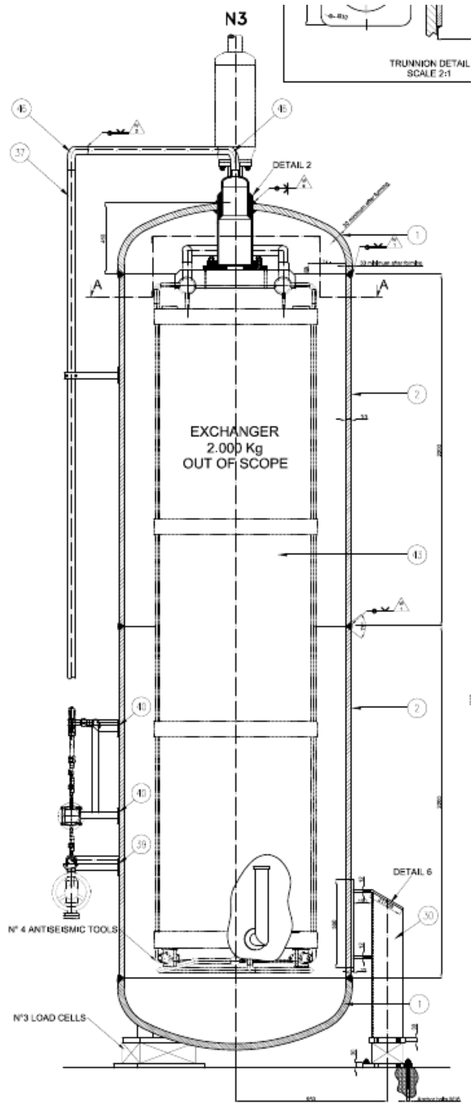


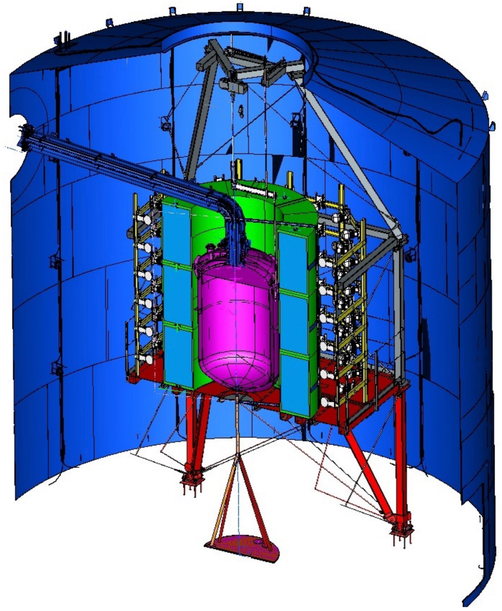
Recovery of XENON

In ***XENON1T***: ***ReStoX***

- Storage system with ***3.6 tons*** of capacity
- Pre-purification of xenon
- LN2 based cooling system
- Fast recovery in case of accident/maintenance

- For XENONnT use ReStoX + ***ReStoX2*** :
- Capacity of ***10 tons*** (gazeous, liquid or solid)
- Very fast recovering with xenon crystallization (1 ton/ hour expected)
- ***Design completed and presently in fabrication at the manufacturer site***



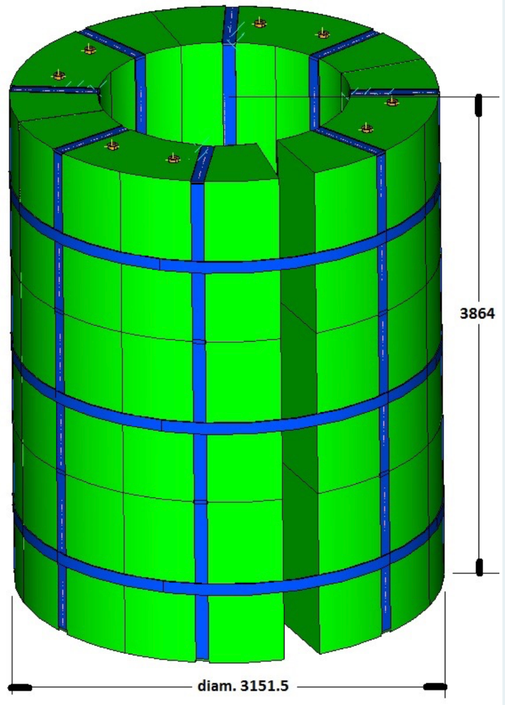


Liquid Scintillator Neutron Veto

Mixture samples presently under study @ Mainz to ***certify the production procedure***.

Expertise available @ MPIK where the DOUBLE CHOOZ scintillator was produced.

- ~***15t*** of ***Gd-loaded LAB Scintillator***
- contained in 12 transparent ***Acrylic Vessels***
- readout by ***120*** Hamamatsu R5912Assy ***8" PMTs***
- radiogenic neutron bck down to ***less than 1 in the total fiducial exposure*** (~75% tagging)



Acrylic Module (1.2t) ***pre-filled at the production plant***, sealed and transported to LNGS.

Vessel ***engineering*** study under ***final review*** with Reynolds Polymer Technology, Inc.

Ongoing Risk Analysis of the LS veto, to be submitted to LNGS in Spring 2018.

Production plant and transportation system for large quantities is coming together.

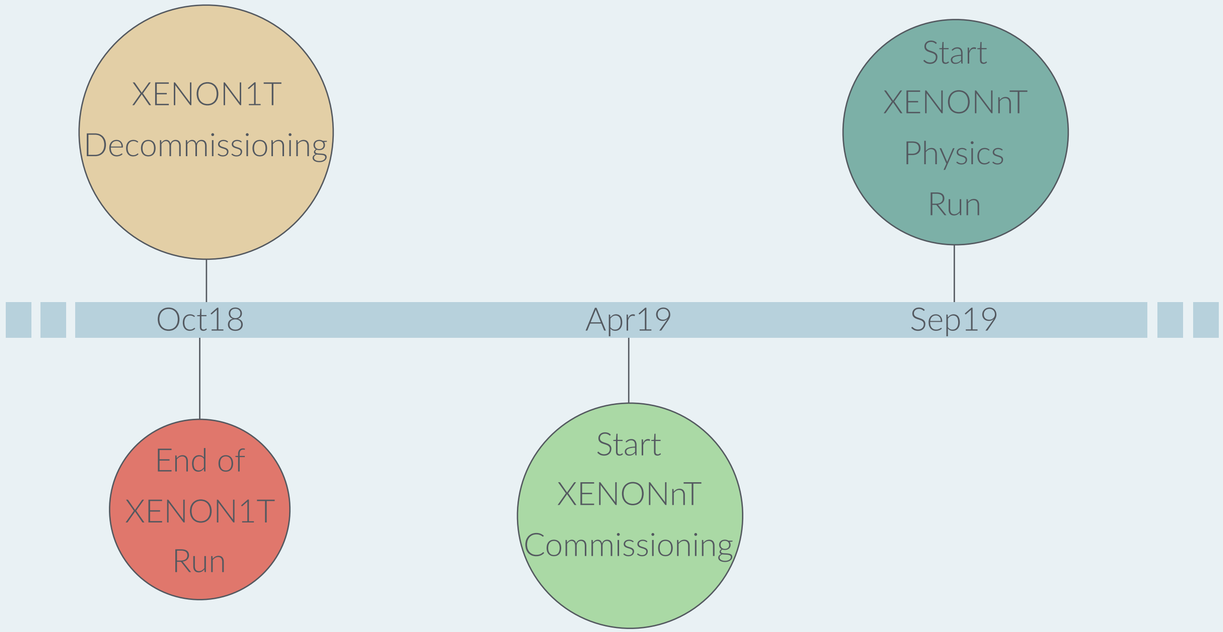
It leverages on ***infrastructure built and operative*** @ MPIK for DOUBLE CHOOZ.

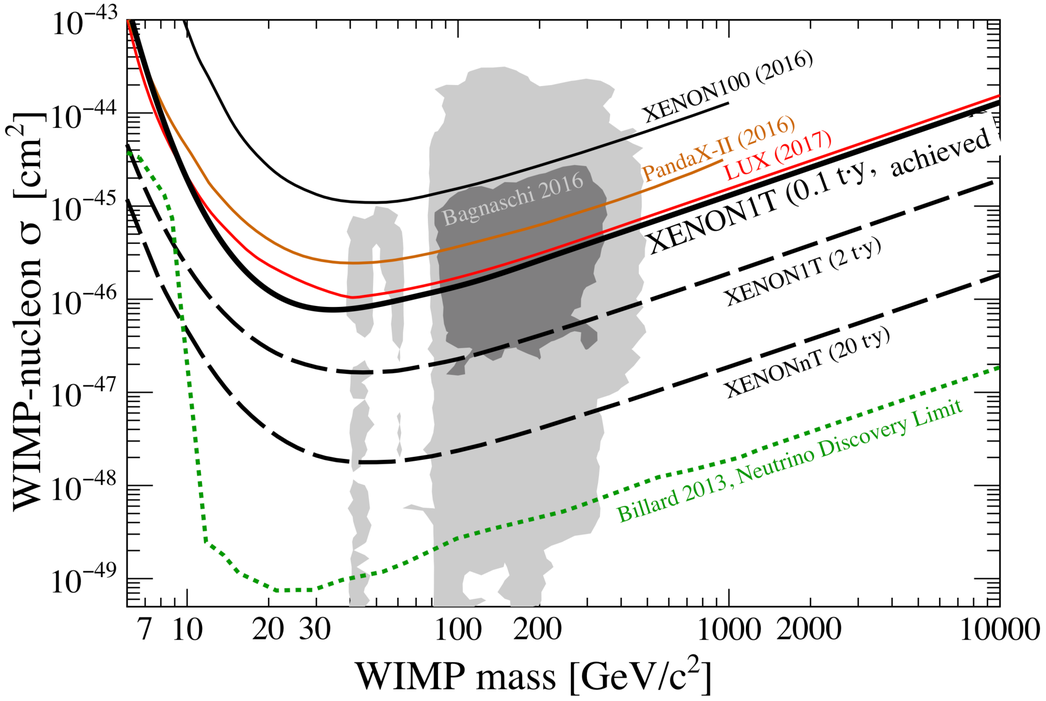
SENSITIVITY & SCHEDULE

XENONnT on the Horizon

Source	ER events/4t/y in 1-12 keVee (no discr.)	NR events/4t/y in 5-50 keVr (no accept.)	Background events/4t/y 99.75% ER Reject. 40% Accept.
ER from material	35	/	0.09
^{85}Kr (0.02ppt)	12	/	0.03
^{222}Rn (1uBq/kg)	250	/	0.63
Solar ν (92% pp, 7% 7Be)	140	/	0.35
2ν2β of ^{136}Xe	35	/	0.09
Radiogenic neutrons	/	0.35	0.14
CNNS (atmospheric)*	/	0.23	0.09
Total	**472**	**0.58**	**1.41**

* at very light WIMP mass CNNS from ^{8}B should be considered as well





XENONnT

On the Horizon

Aprile et al., Eur. Phys. J. C (2017) 77: 881. *XENON1T sub-systems*

Aprile et al., JCAP 77 (2016), 358. *online Rn-removal*

Aprile et al., Eur. Phys. J. C (2017) 77: 275. *online Kr-removal*

Aprile et al., JCAP 4 (2016), 27. *sensitivity*