

Direct Dark Matter Search with the experiments from the XENON Collaboration

Dominique Thers



on behalf of the XENON Collaboration
on behalf of the XENONnT CNRS MP





Master Project : XENONnT@in2p3



Lab.	Responsible	Researcher	Teacher Researcher	Postdoc	PhD	Engineer
Subatech	D. Thers	1	3	1	1+1	0
LPNHE	L. Scotto-Lavina	1+1	0	1	1+1	0,3
LAL	C. Macolino	1	0	+1	+1	1,2

Short terms priorities : 1/ Reinforce the LAL group
2/ Consolidate the new researcher @ LPNHE

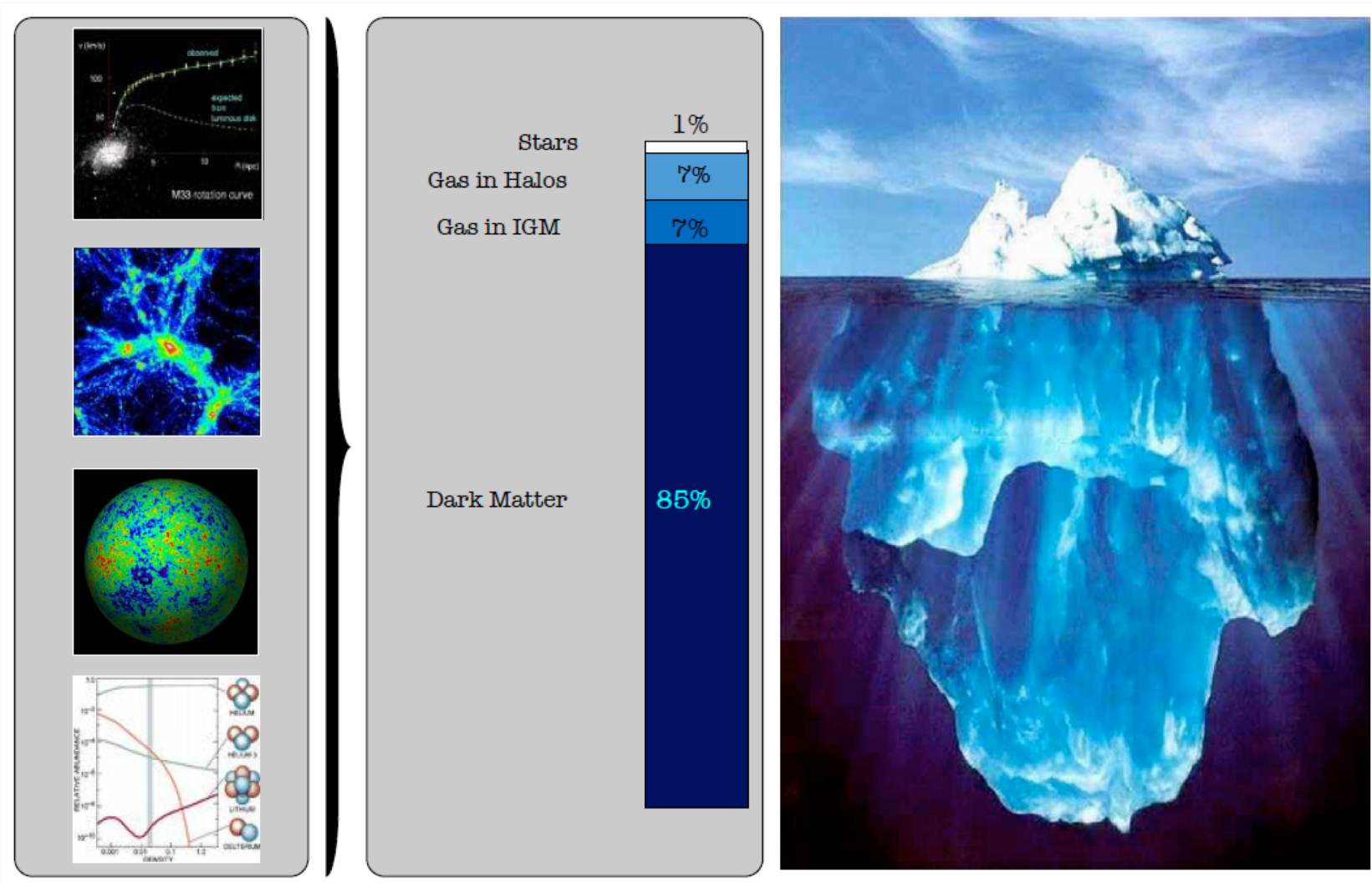
XENON collaboration today



**27 institutions
~ 170 scientists**

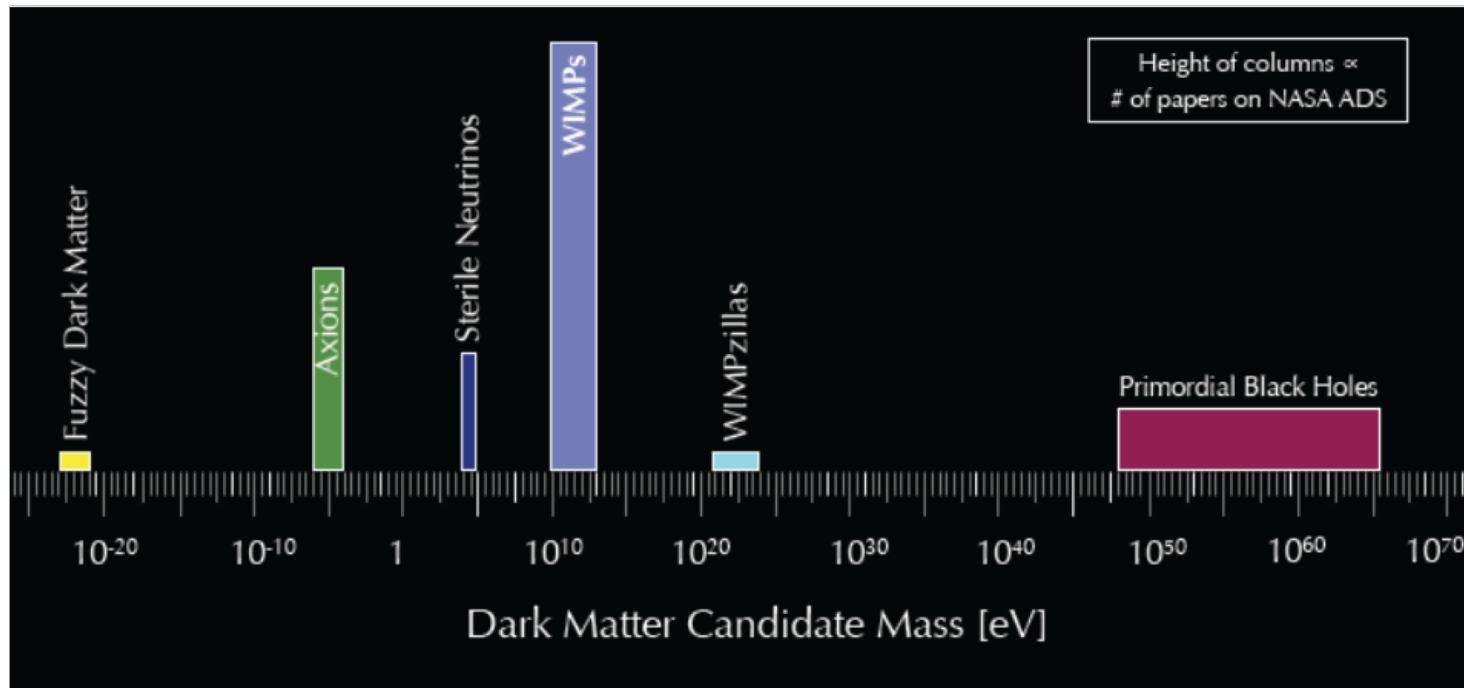
 Columbia	 RPI	 Nikhef	 Muenster	 Stockholm	 Mainz	 MPIK, Heidelberg	 Freiburg	 Zurich
 Chicago								 Tokyo
 UCLA								 Nagoya
 UCSD								 Kobe
 Rice								
 Purdue	 Coimbra	 Subatech	 LPNHE	 LAL	 Bologna	 LNGS Torino Napoli	 Weizmann	 NYUAD

Universe Matter is Dark at 85%



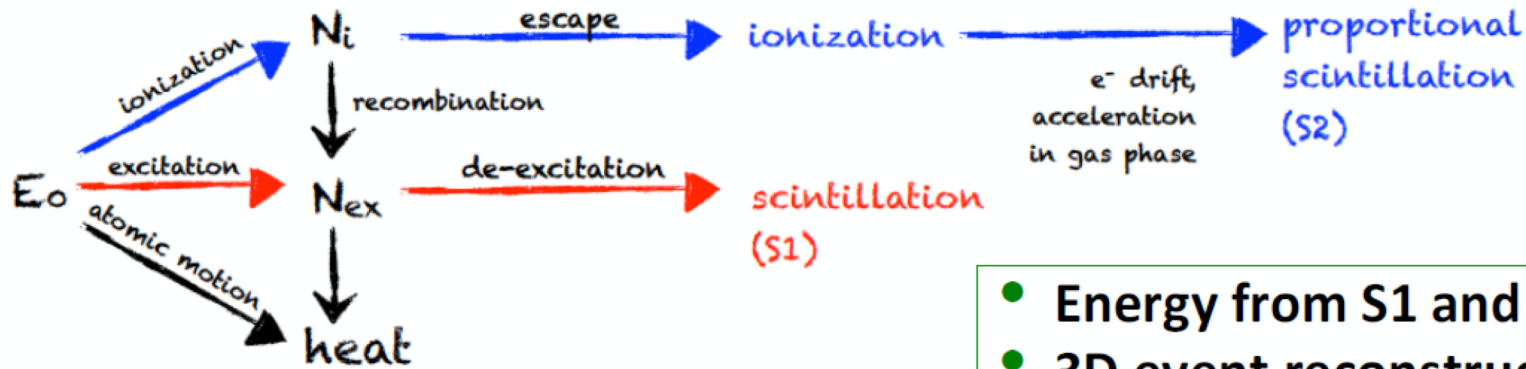
One century of mystery ...

Dark Matter

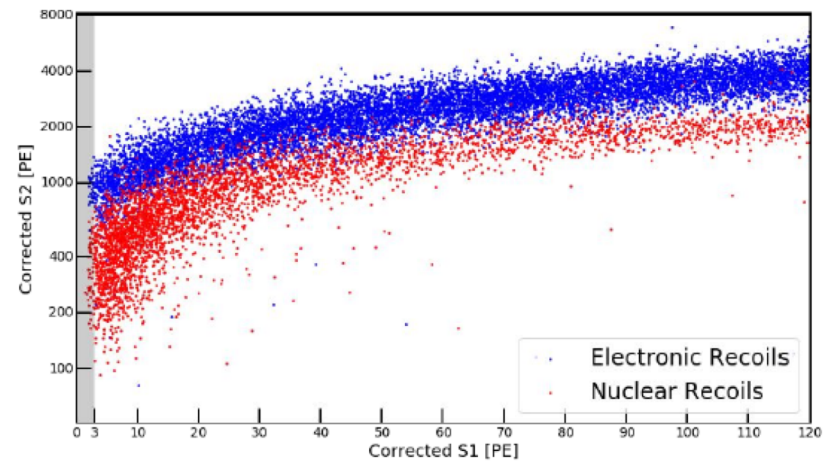
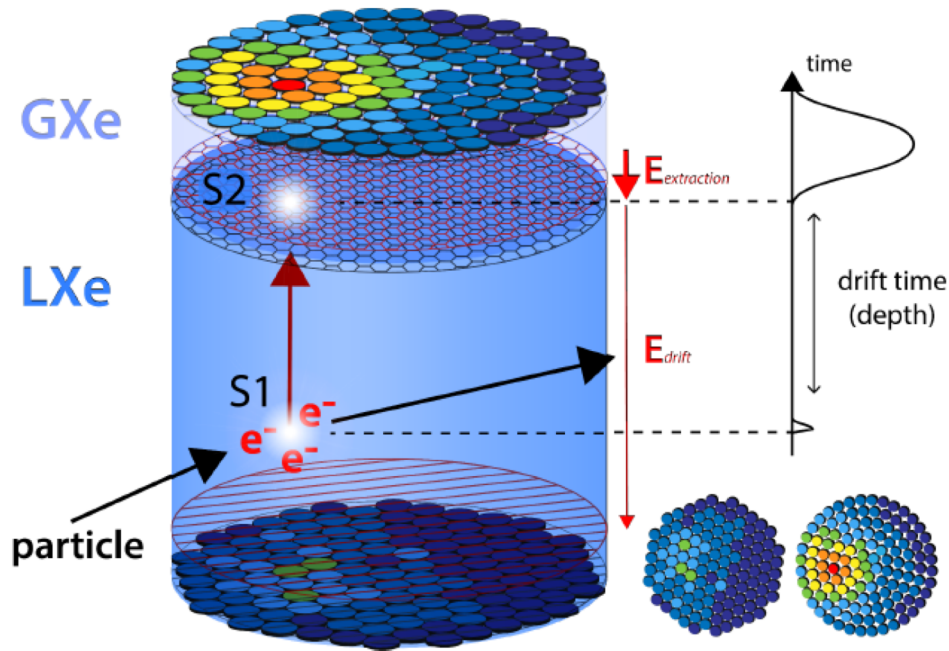


- Few hundreds of models to test
- From the smallest to the highest masses in the Universe
- WIMPs (SUSY) stay the top ranking

Dual phase LXe TPC



- Energy from S1 and S2 area
- 3D event reconstruction:
 - X, Y from S2 hit pattern on top PMTs
 - Z from electrons drift time
- ER - NR discrimination
 $(S2/S1)_{WIMP,n} < (S2/S1)_{\gamma,\beta}$

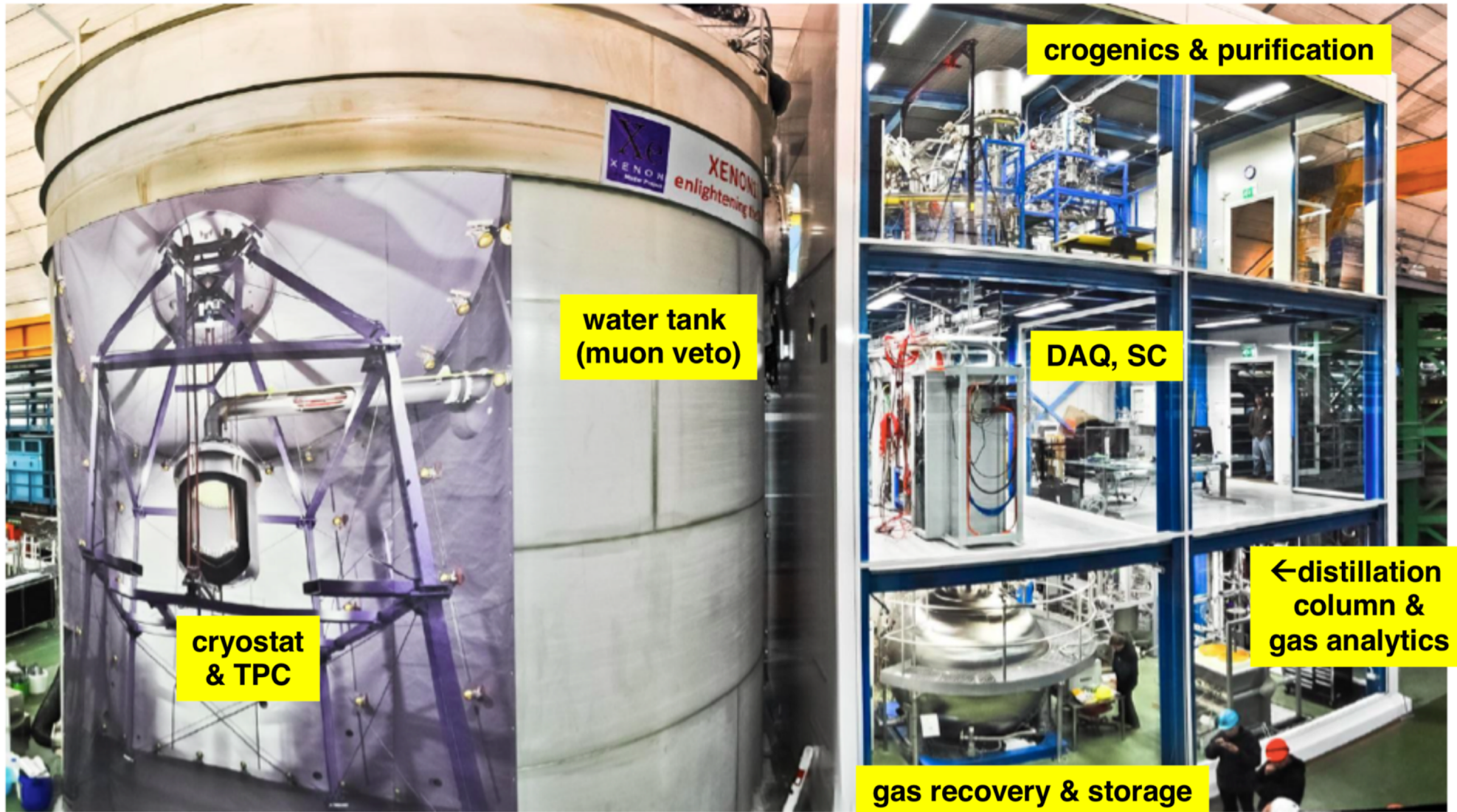


XENON collaboration Experiments



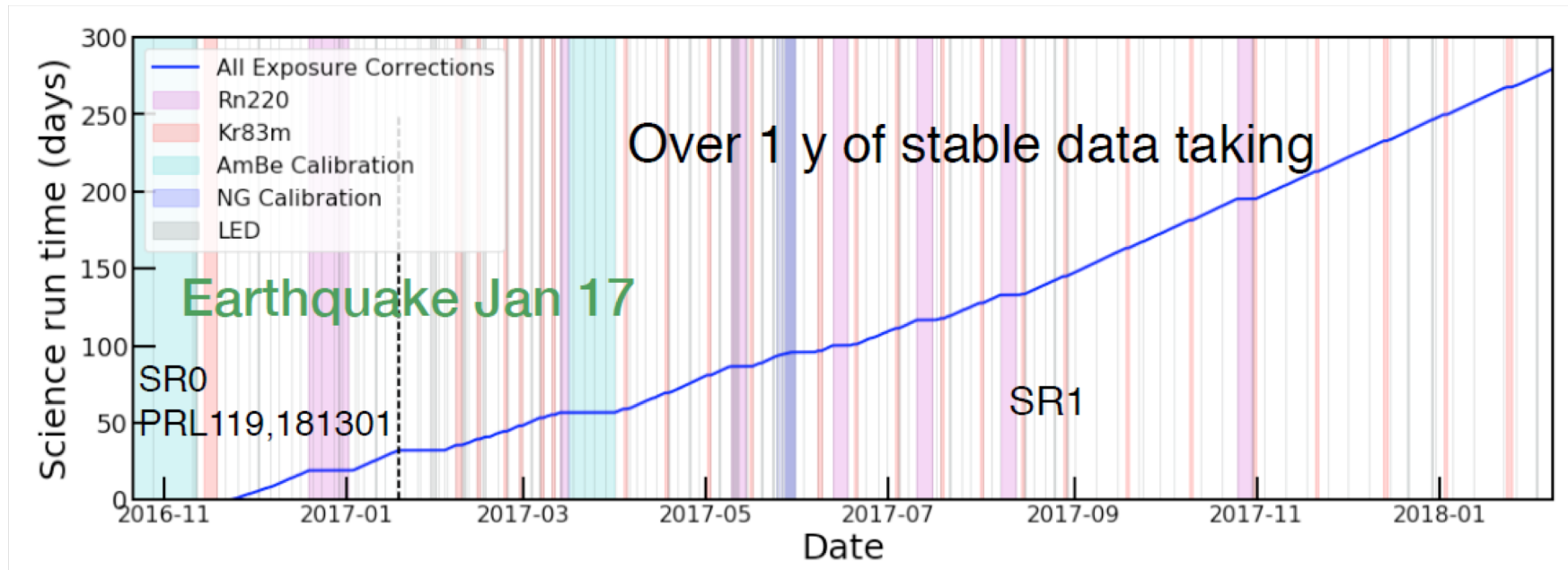
XENON10	XENON100	XENON1T	XENONnT	DARWIN
2005 - 2007	2008 - 2016	2012 - 2018	2019 - 2023	2020+
25 kg	161 kg	3200 kg	7500 kg	~ 50 000 kg
$\sim 10^{-43} \text{ cm}^2$	$\sim 10^{-45} \text{ cm}^2$	$\sim 10^{-47} \text{ cm}^2$	$\sim 10^{-48} \text{ cm}^2$	$\sim 10^{-49} \text{ cm}^2$

XENON1T Experiment

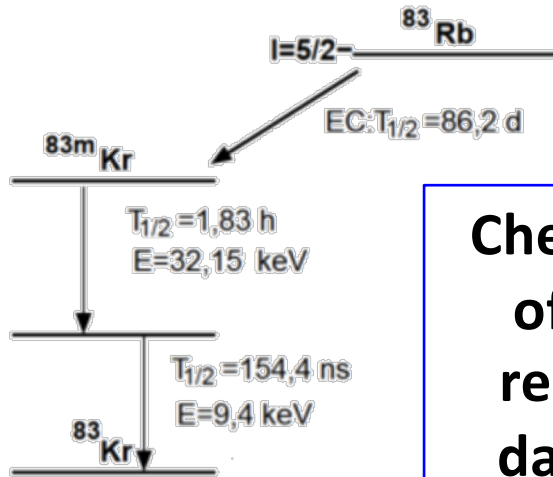


XENON1T SR0+SR1 exposure

- 278 days of exposure (~ 15 months)
- ~ 1 ton over 1 year, largest exposure
- Stability checked regularly during all the run
 - Experiment still operating now

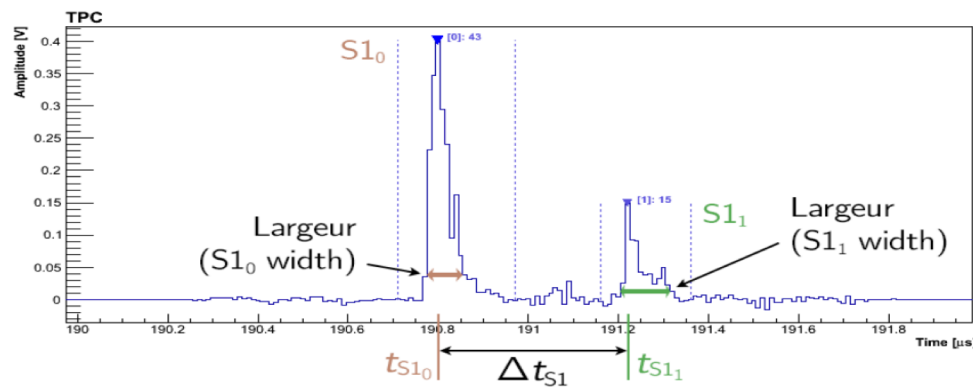
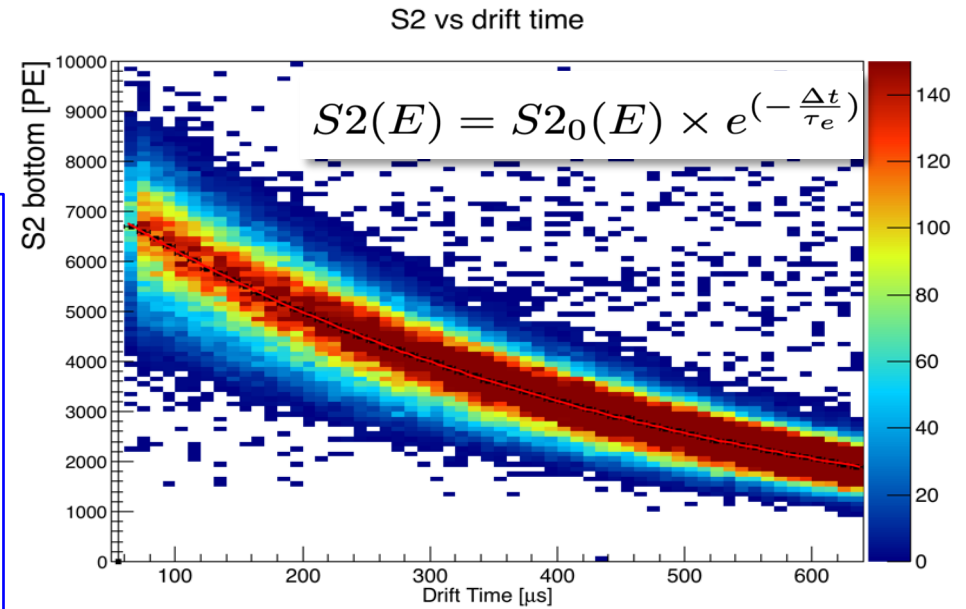


Calibration and monitoring of XENON1T with ^{83}mKr

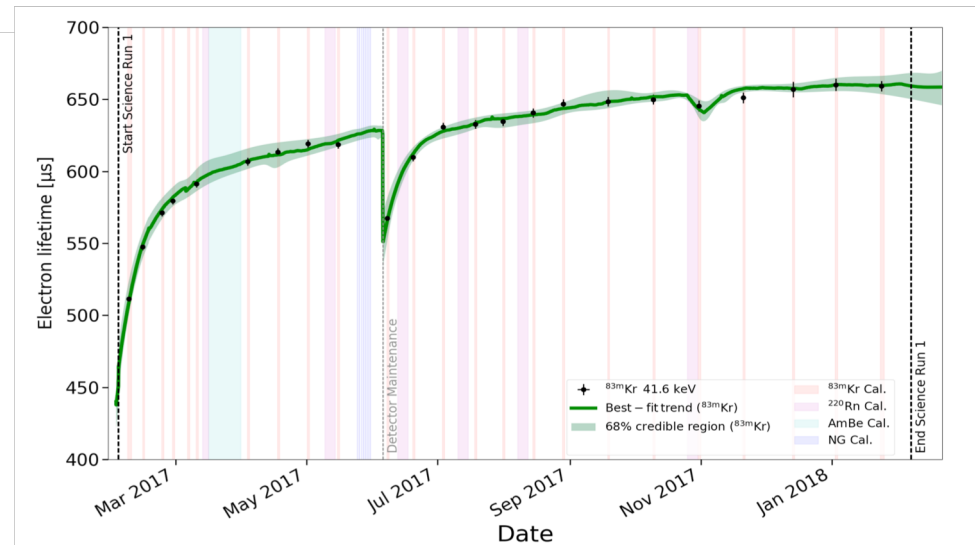


Check the stability of the detector response during data taking with Kr83m

Sara Diglio



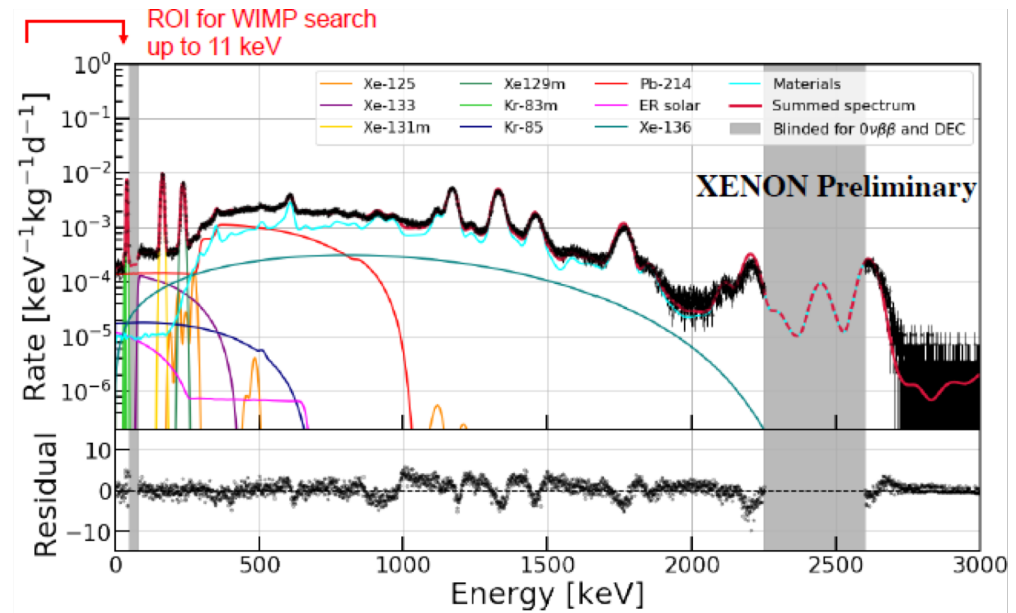
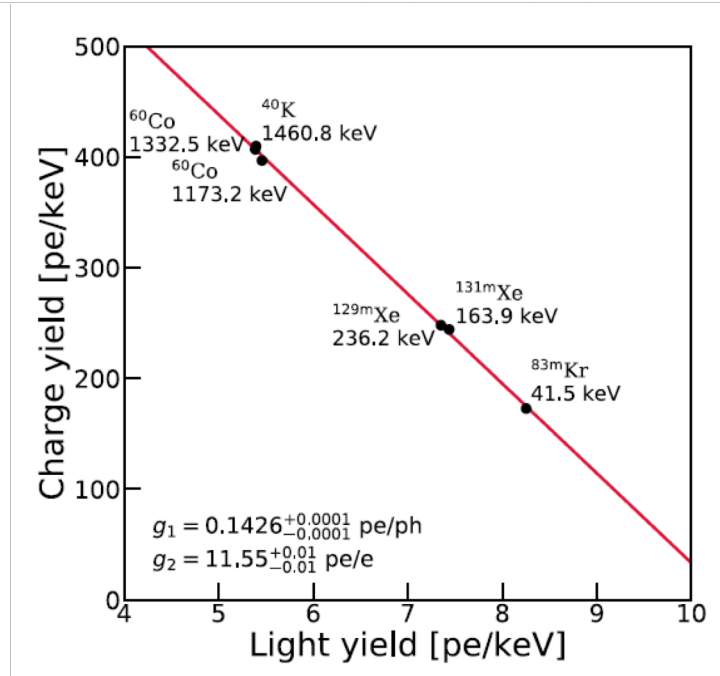
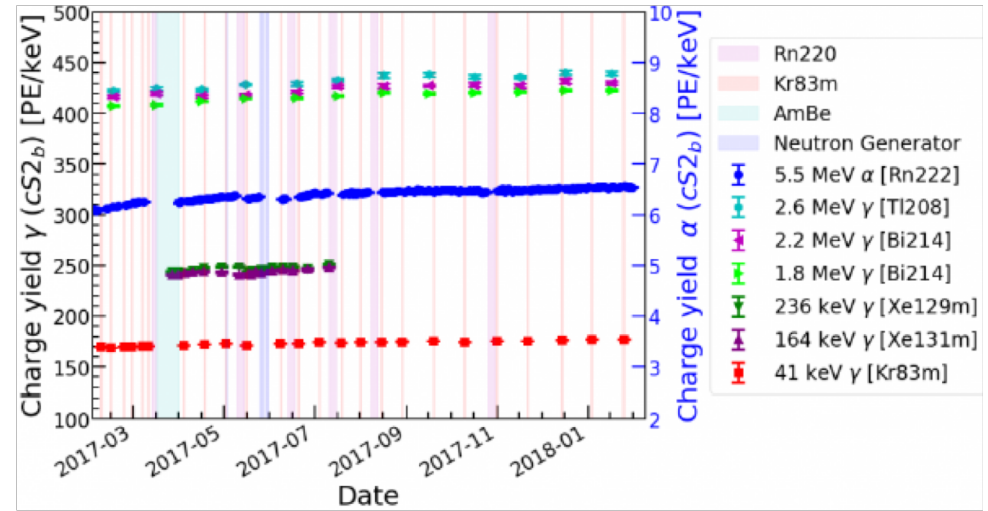
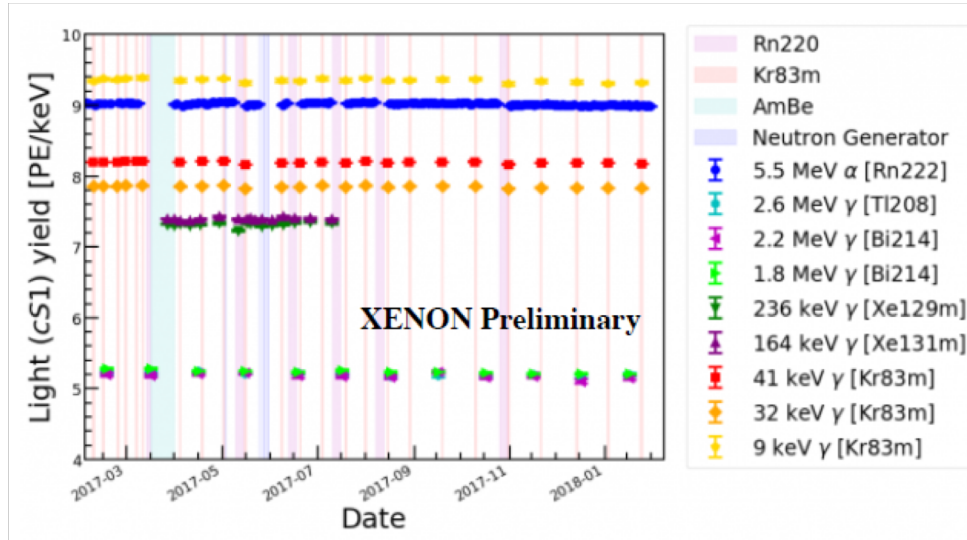
$$\Delta t_{S1} = t_{S1_1} - t_{S1_0}$$



Energy measurement with XENON1T

Scintillation Yield : S_1

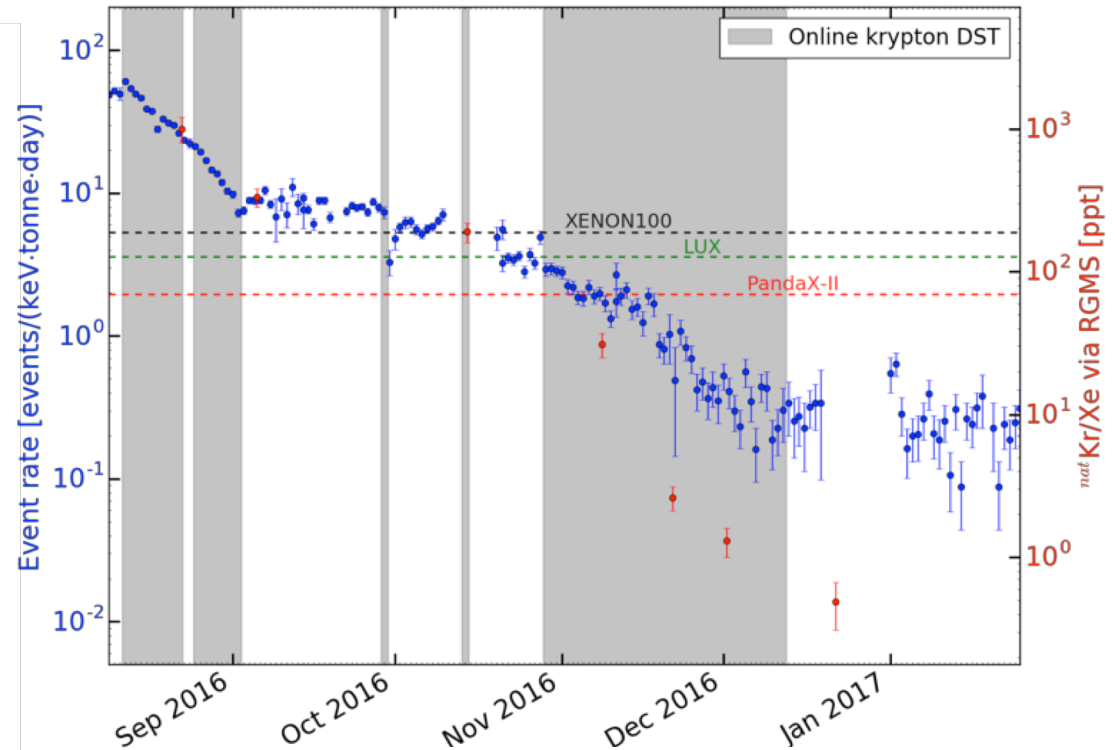
Charge Yield : S_2



Ultra low background in XENON1T

Electronic Recoils Background

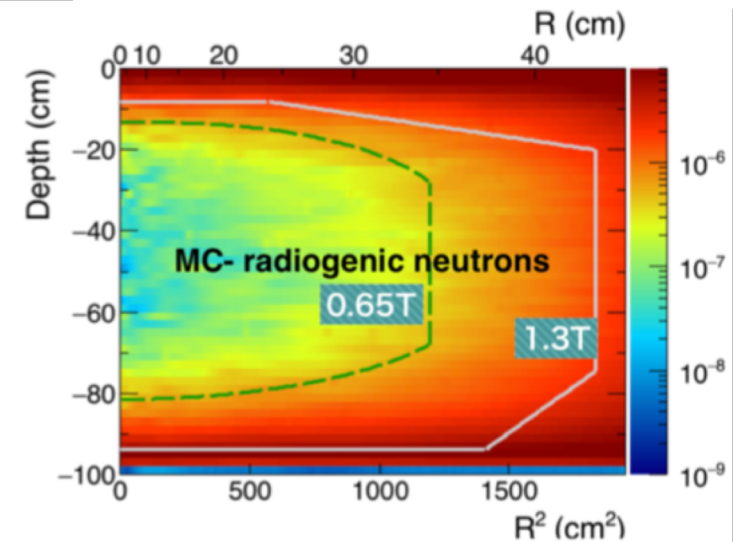
- Material γ - screening and selection during construction
- ^{222}Rn emanation measurements and selection of materials
 → achieved $10 \mu\text{Bq/kg}$ for ^{222}Rn
- online cryogenic distillation
 → ^{85}Kr removal
 → **lowest ER background ever in a DM detector**
- Select fiducial volume in the TPC



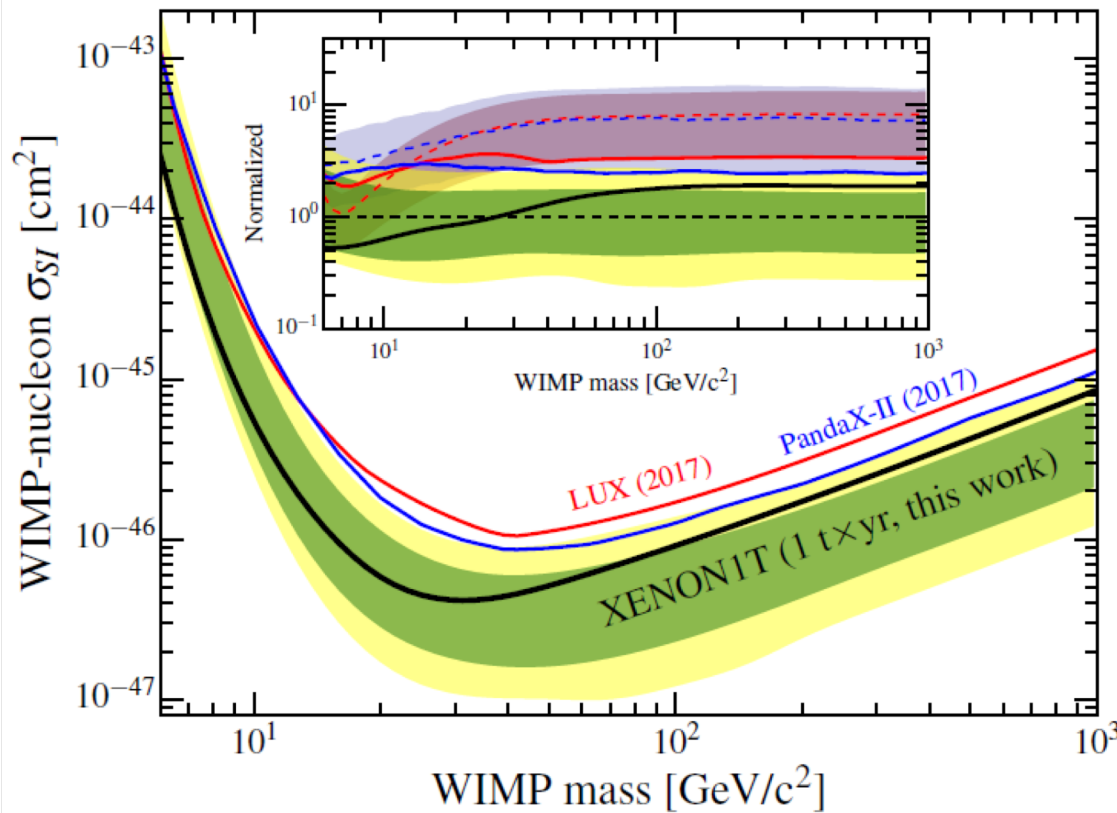
Nuclear Recoils Background

Source	Fraction of NR_{tot} [%] in 1T FV, (4-40)keV
Radiogenic neutrons	96.5
CEvNS	2.0
Muon-induced neutrons	< 2.0

JCAP04 (2016) 027



XENON1T SR0+SR1 SI DDM results



- **Best SI limit for mass > 6 GeV/c²**
- **DDM lead by dual phase LXe TPC experiments**
- **Factor 7 of improvement compared to previous LXe experiments**

PHYSICAL REVIEW LETTERS

Highlights Recent Accepted Collections Authors Referees Search Press About

Editors' Suggestion

Dark Matter Search Results from a One Ton-Year Exposure of XENON1T

E. Aprile *et al.* (XENON Collaboration)
 Phys. Rev. Lett. **121**, 111302 – Published 12 September 2018

Upcoming analysis of XENON1T data

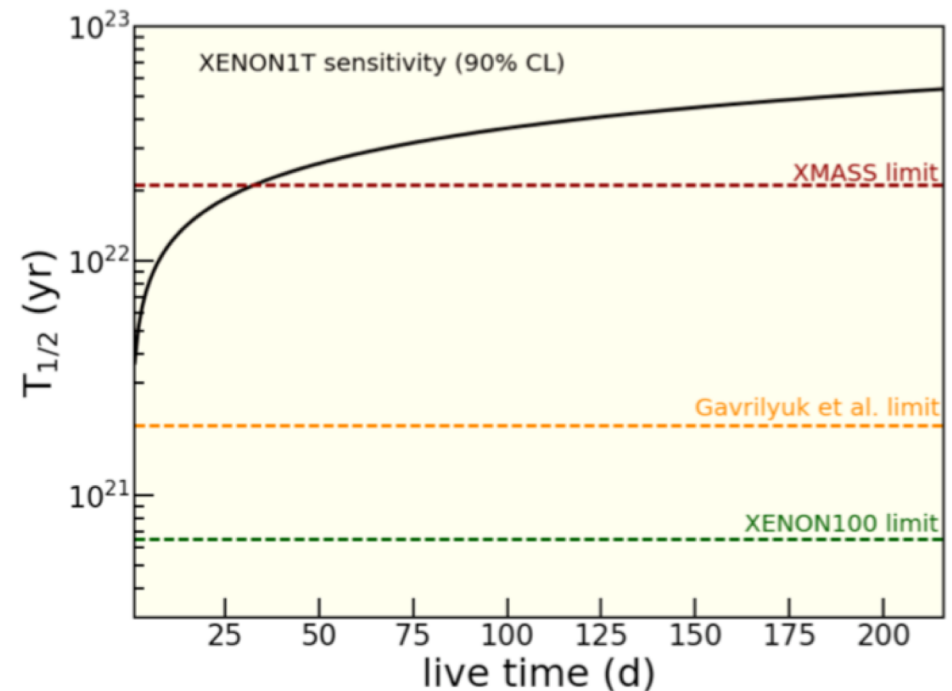
XENON1T data are most sensitive to various process

→ exciting analysis options

Examples:

- **Double electron capture of ^{124}Xe and ^{126}Xe** →
- **Annual modulation**
- **SD WIMPs**
- **Low WIMP mass searches**
(lower threshold, S2 only, ...)
- **$0\nu\beta\beta$ of ^{136}Xe**
- ...

Long list of topics & priorities → stay tuned!



Work in progress for low WIMP mass, annual modulation :

Ernesto Lopez Fune (Postdoc)

Jean-Philippe Zopounidis (PhD)

Double β decay in XENON1T

➤ Status : blinded analysis

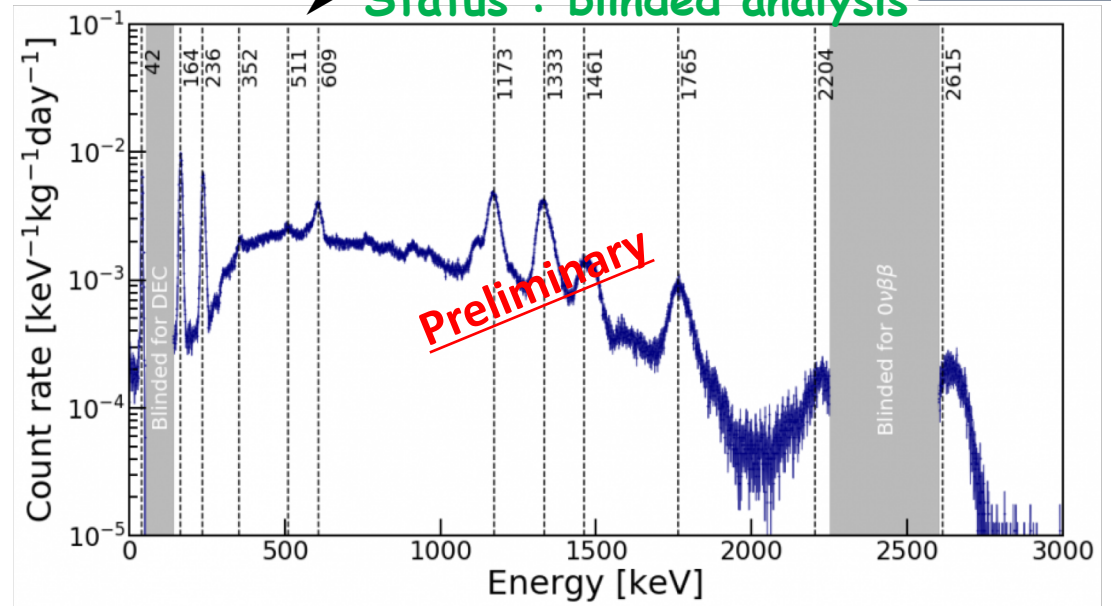
Expected energy resolution $\sim 1\%$ at Q-value

Active target under study

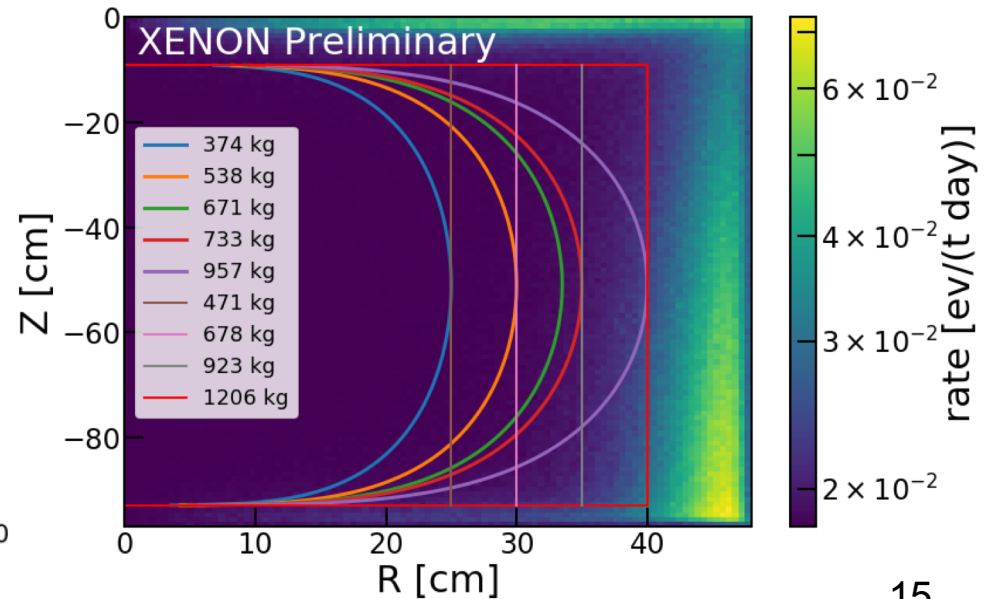
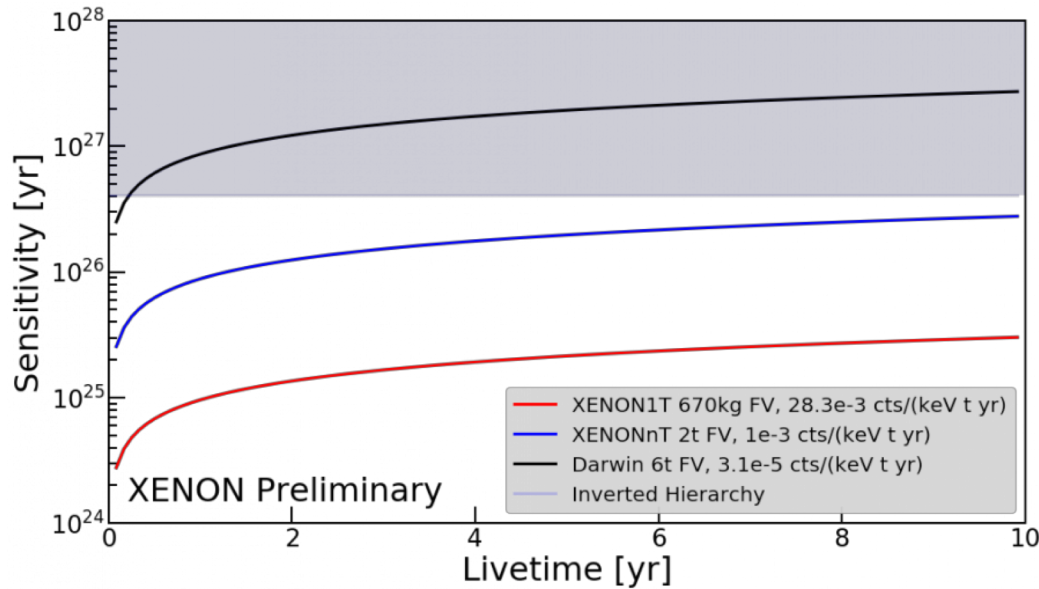
Expected efficiency $> 90\%$

Work in progress :

- Background characterization
- Energy resolution increase



PhD Thesis : Chloé Therreau



XENON1T operation since SR1

Operation of XENON1T until modifications for XENONnT start: ~January 2019

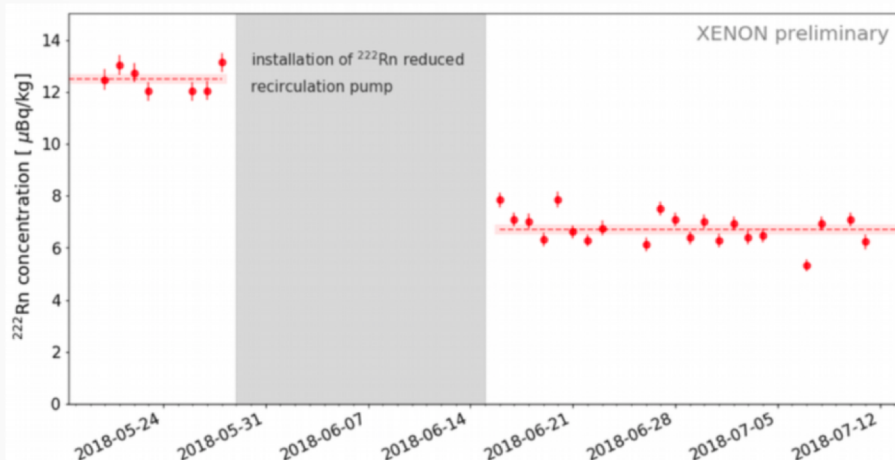
→ more data

→ tests towards XENONnT

→ improvements

Radon Reduction:

- SR1: (11.8 ± 0.2) $\mu\text{Bq/kg}$
- **New radon-free pump** (EPJ C 78 (2018) 604) (6.3 ± 0.1) $\mu\text{Bq/kg}$
- Rn reduction by **45%** w.r.t SR1

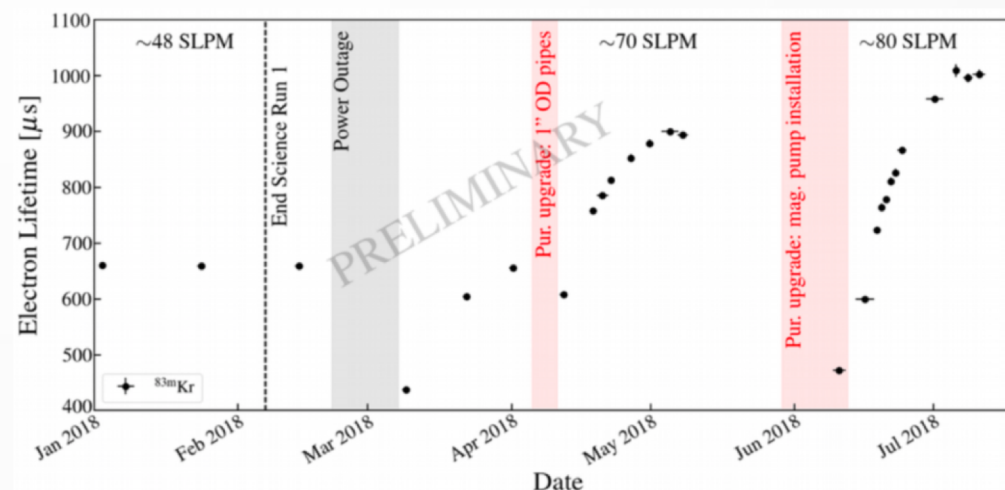


- **Online Radon distillation** allowed another reduction of **~30%** to **~4 $\mu\text{Bq/kg}$** → only factor 4 above XENONnT goal

Increased purification gas flow

- increased by **39%** w.r.t. Q-drive
- Electron lifetime of **1 ms** reached!

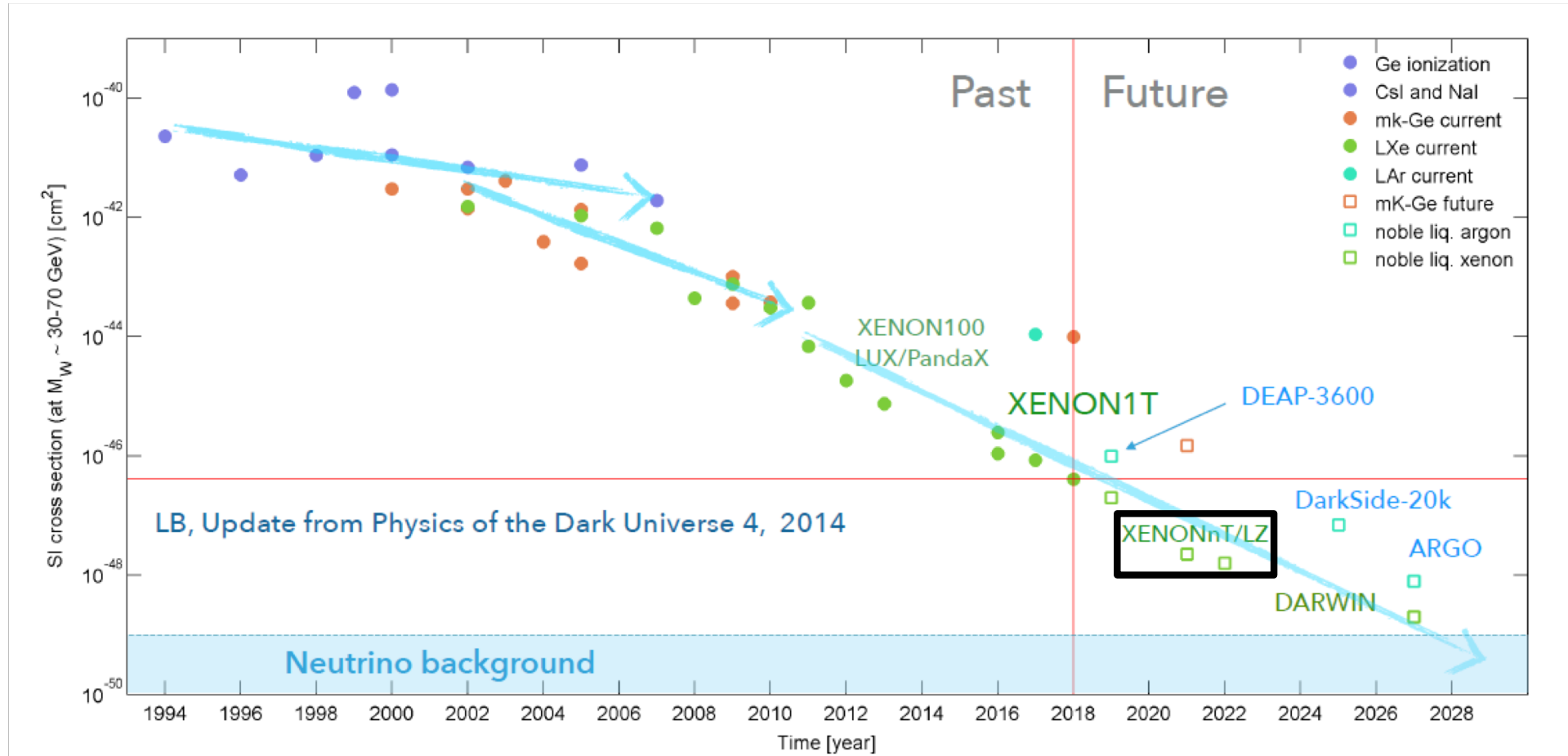
Fenches strongly involved



Important improvements for XENONnT

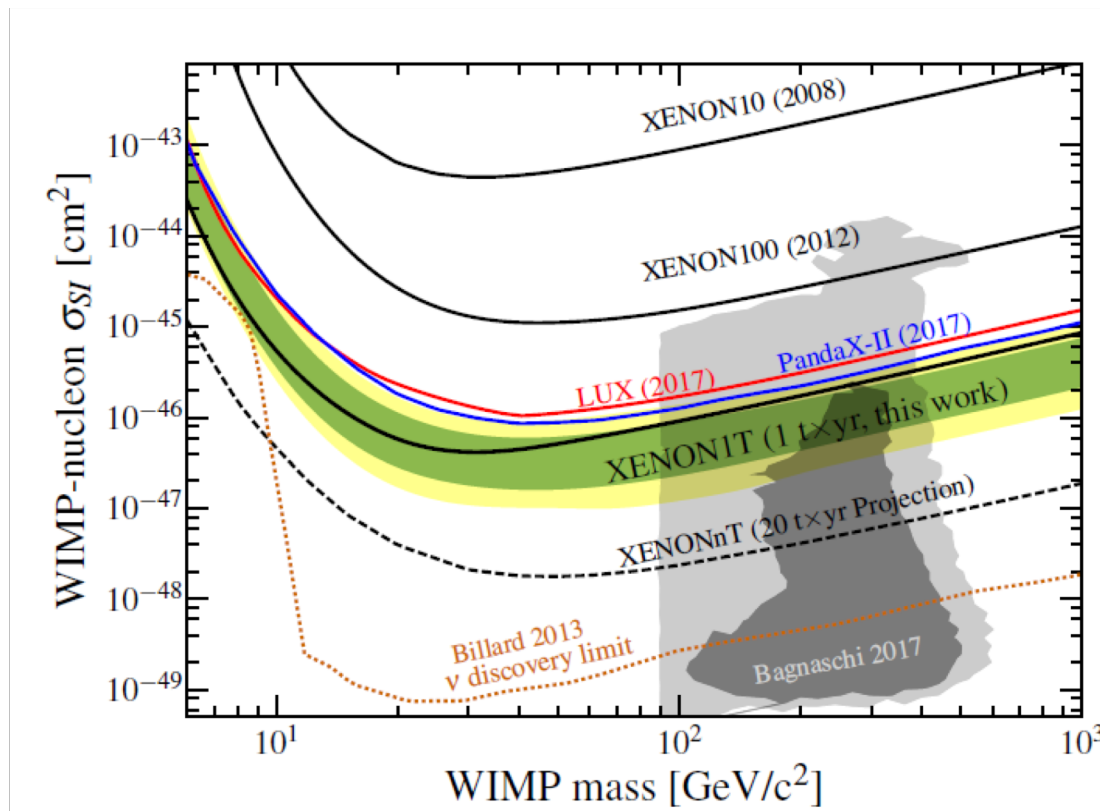
DDM Roadmap and LXe experiments

➤ Sensitivity increase ~ factor 10 every 2 years



➤ XENONnT construction is started ...

XENONnT upgrade



Active French technical contributions :

- construction and commissioning of ReStoX2
- TPC electrodes design and assembling
- computing and data processing

**Science run expected
for end 2019/beginning 2020**

XENON1T-nT Computing and data processing



Cost : only in-kind contributions

Resources from CC-IN2P3

- CPU power : 8M HS06 x h (16M requested for 2019)
- Storage : 1.2PB for data and Monte Carlo (tapes+dCache)

The highest contribution in Europe. Comparable with resources provided in US

“offline” data quality monitoring tool development

Human resources:

- Luca Scotto Lavina (also local computing responsible at LNGS)
- O.Dadoun (20%)
- R.Gaior (50%)

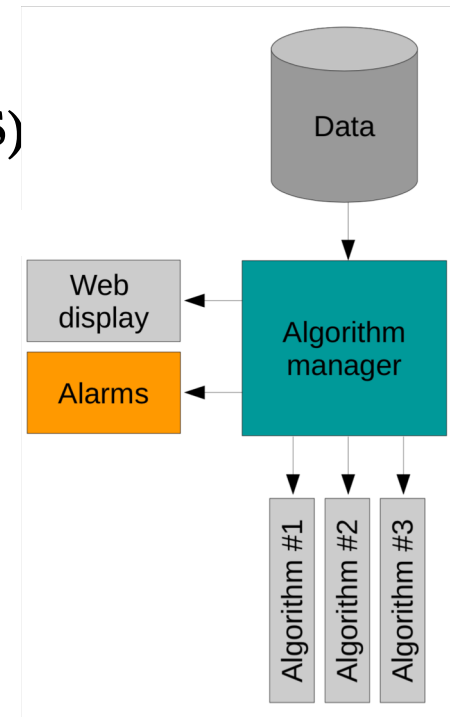
Goals :

1) *run analysis algorithms to datasets:*

xenon purity, radon background, hot-spots search, electronic background, light yield, charge yield, single electrons rate,...

2) *output : web interface to provide a quick feedback to shifters*

3) *alarms : in case some observables deviate from standard values*



ReStoX2

XENONnT WG : Subatech, LPNHE, LAL

WG coordinators : Julien Masbou
and Luca Scotto-Lavina

Cost : 300 keuros

Founded by France :
50% by in2p3

50% by labs (LAL, LPNHE, SUBATECH)

Subdivided in 3 parts :

- Main vessel (SUBATECH)
- heat exchanger (LPNHE)
- valves and piping (LAL)

High Pressure auxiliary vessel

Xenon storage capacity : **10 tons**

Directly connected to ReStoX1 and TPC

Recovering : **1t/hour speed targeted**

Working temperature : **77K to 20°C**

Cooled with LN2



ReStoX2 : the race

ReStoX2 tasks	2017				2018				2019			
1. Suppliers selection	■											
2. Manufacturing and control files redaction	■	■										
3. Main vessel construction			■	■	■	■	■	■				
4. Aluminium heat exchanger construction							■	■				
5. Assembling and instrumentation insatallation									■	■	■	■
6. Installation at LNGS												
7. Qualification and commisionning												

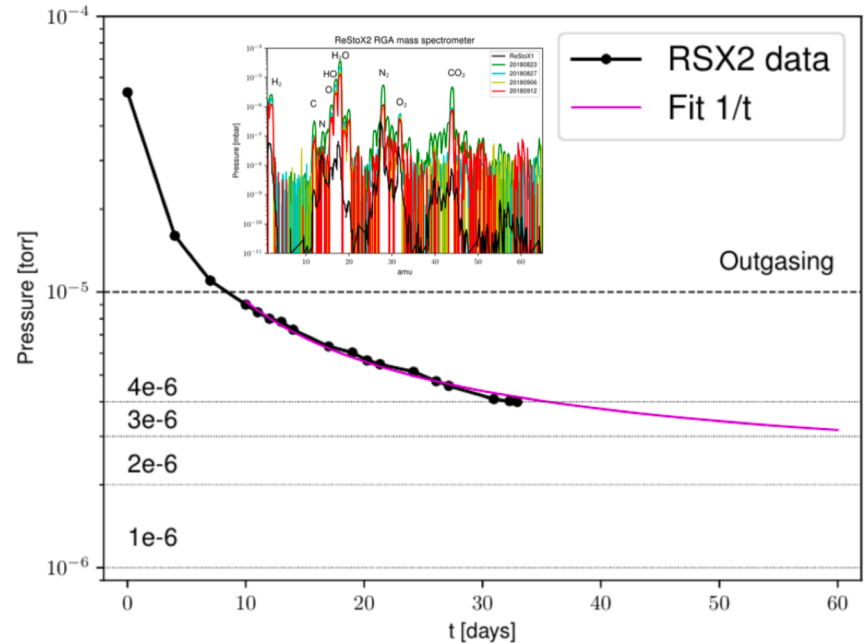
Now!

➤ **First upgrade installed for XENONnT (July 2018)**

Joaquim Palacio (Postdoc) full time at LNGS (since June) is working on XENONnT commissioning

- High Vacuum reached
- Outgasing will be accelerated by heating at 70°C until 2019
- First filling expected with 2 tons of Xe from January 2019

The 3 labs respect exactly the expected schedule



XENONnT TPC electrodes design and assembling

XENONnT WG : LAL, San Diego, Rice

Cost : 100 keuros

WG coordinators : Carla Macolino, Kaixuan Ni, Peter Shagin

Great contribution from LAL-SDTM :

- *D. DOUILLET
- *G. IAQUANIELLO
- *B. LELUAN

Conception, Design and Construction of the 5 electrodes

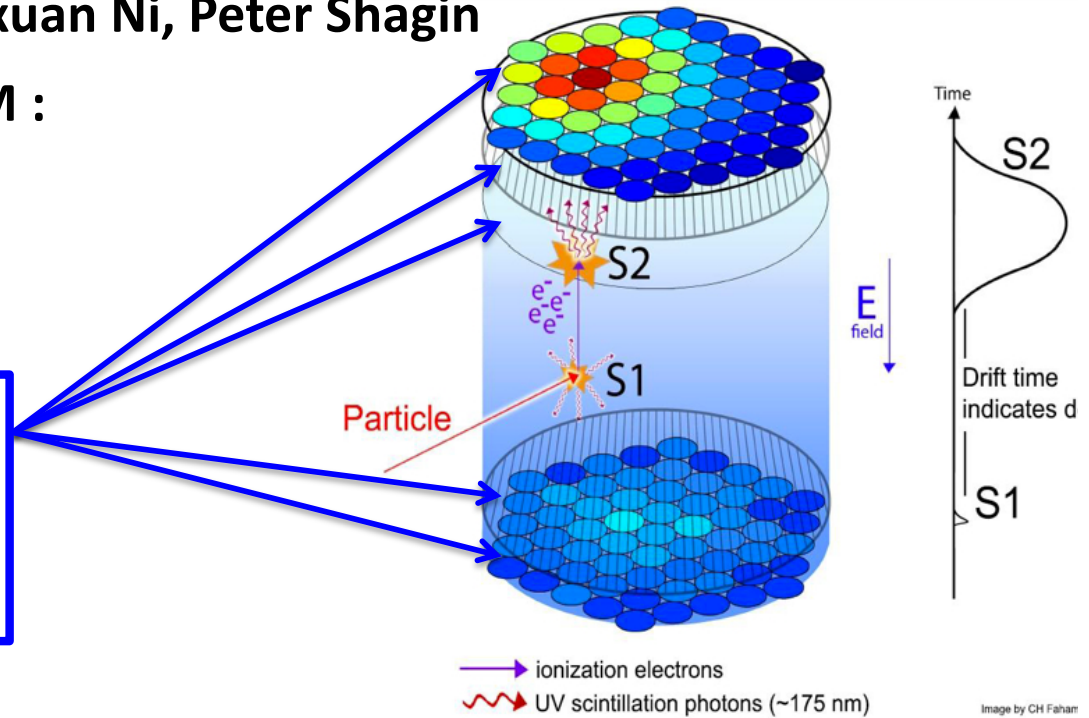
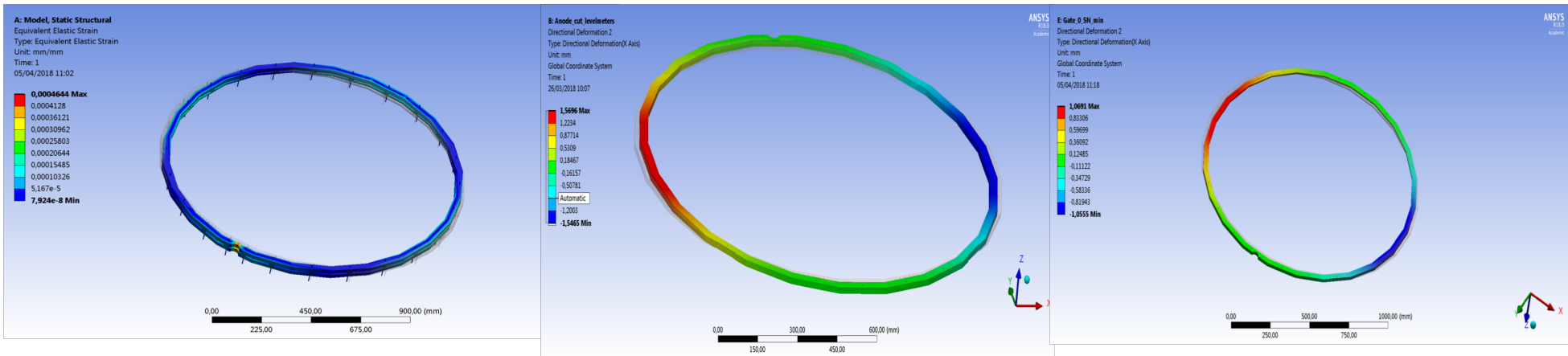


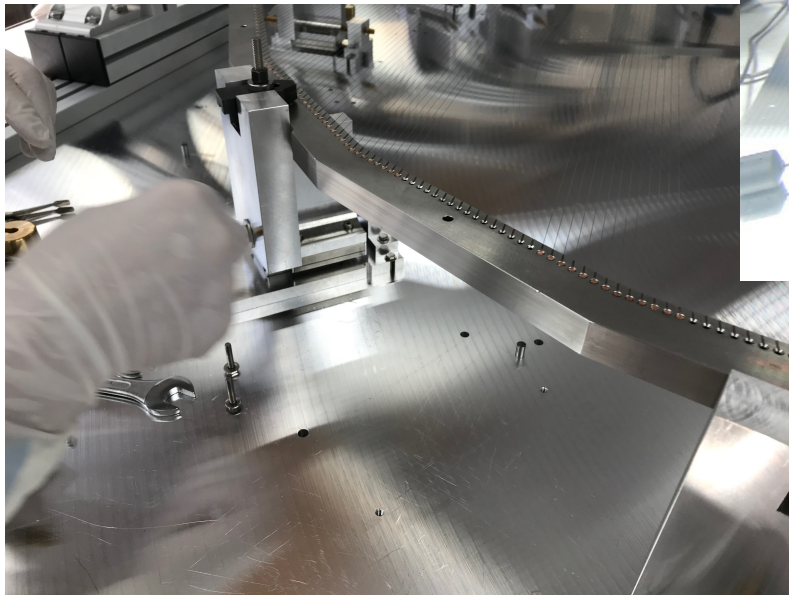
Image by CH Faham



XENONnT TPC electrodes construction : the race

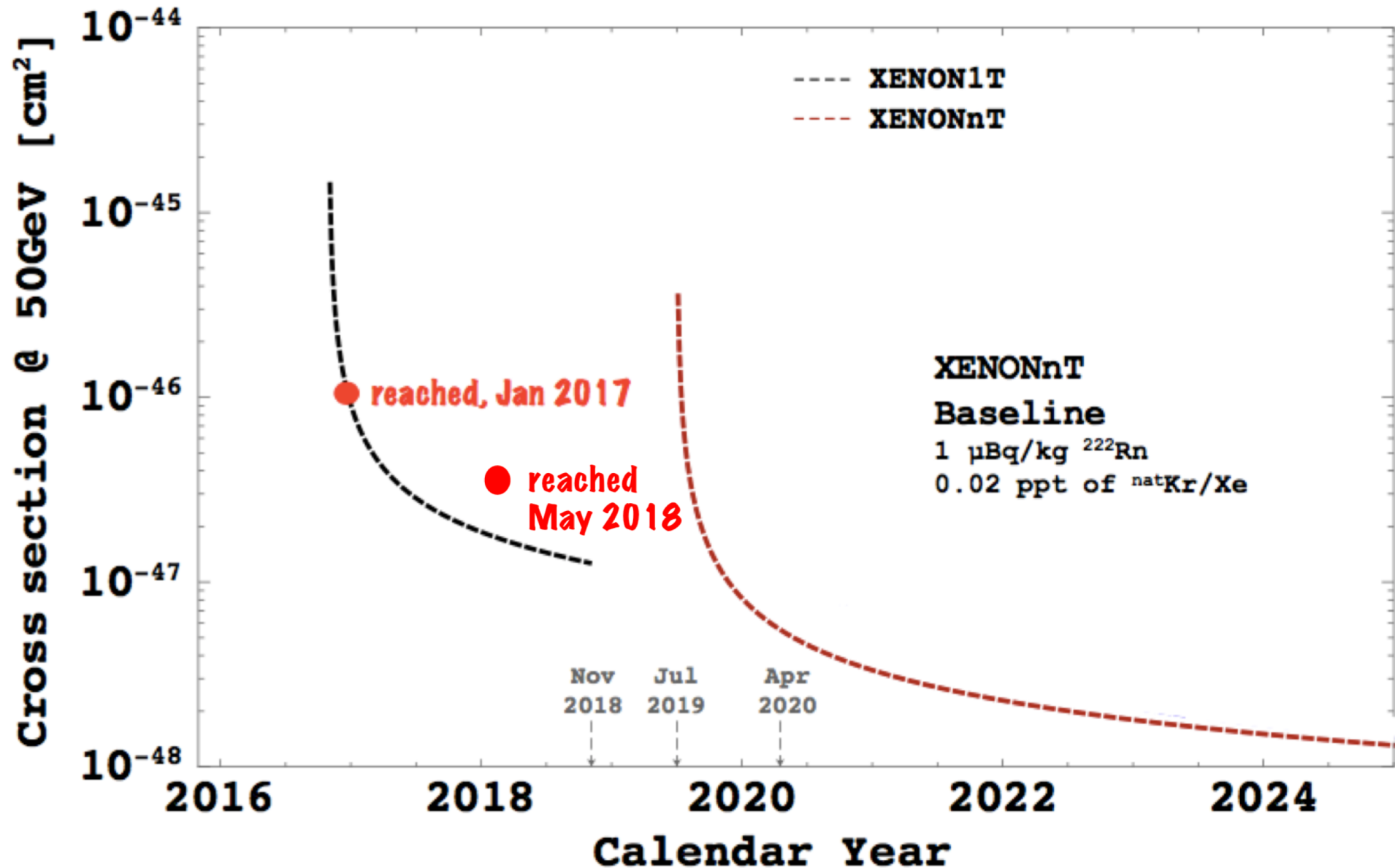
Work started in
summer 2017
*design, relationship
with companies,
mechanical simulation,
mechanical realization
and assembly ...*

**Prototype tested at LNGS
in summer 2018**

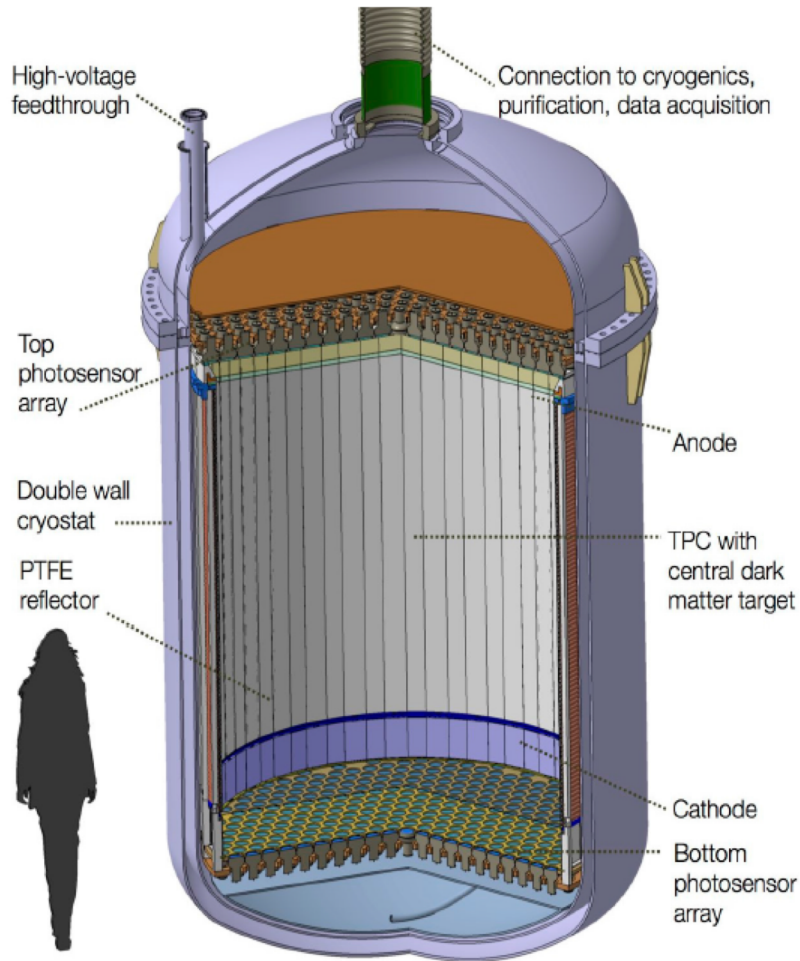


- **System feasibility demonstrated**
- **April 2019 : 5 electrodes assembled ...**

XENON1T-XENONnT Plans

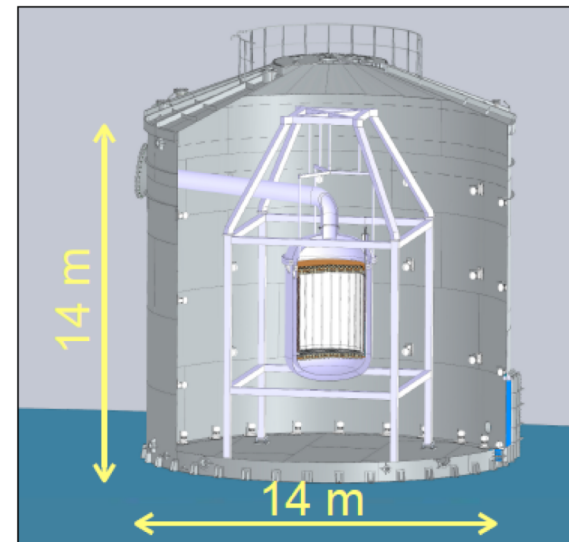


DARWIN, 40 tons of LXe to reach “neutrino floor” in 2025

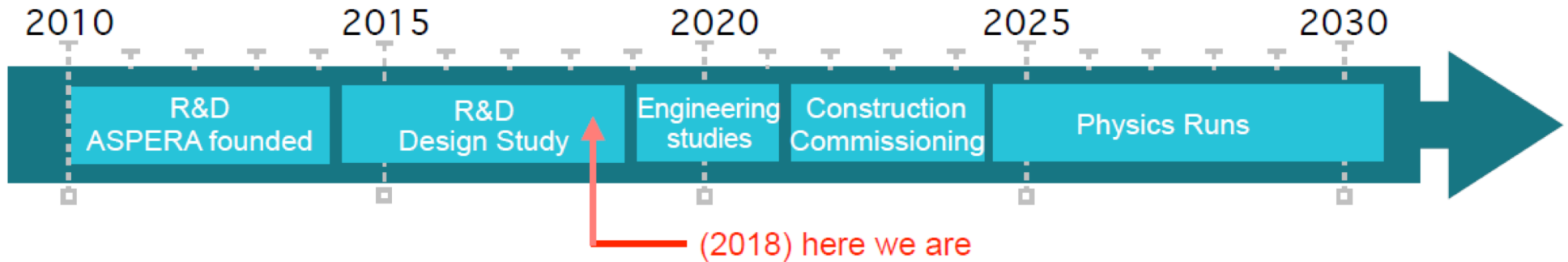


**the baseline design assumes PMTs
but several alternative photosensors
are under consideration**

- Dual-phase Time Projection Chamber (TPC).
- 50 t total (**40 t active**) of liquid xenon (LXe).
- Dimensions: **2.6 m diameter and 2.6 m height.**
- Two arrays of photosensors (top and bottom).
- 1800 PMTs of 3” diameter (~1000 of 4”).
- Drift field ~0.5 kV/cm.
- Low-background double-wall cryostat.
- PTFE reflector panels & copper shaping rings.
- Outer shield filled with water (14 m diameter).
- Inner liquid scintillator neutron veto.



*Possible realisation
of DARWIN inside
the water tank*



28 groups from 11 countries
DARWIN is in the APPEC Roadmap
Working toward a CDR and a TDR

In France, R&D on:

- large LXe solution for ReStoX
- mesh electrodes conception and design
- xenon from fission with Orano
- Modane option if possible extension

**DARWIN might be also considered
for the official future French
Roadmap targeting $2\beta_0v$ search**



Summary



XENON1T:

- continues to operate ~ **Jan. 2019**
- further important analyses are on the way **stay tuned!**

XENONnT:

- upgrade is being prepared while XENON1T runs, ReStoX2 already installed
- decommissioning of XENON1T starting Jan. 2019, TPC electrodes should be ready for April 2019, physics run planned for 2019-2020



We wish for a wide support from the In2p3 CSI

We expect to discover Dark Matter directly with the XENON collaboration