



XENON

Axe RCMN - Matière Noire

Équipe XENON

Luca Scotto Lavina

Biennale LPNHE, 28 Mai 2024

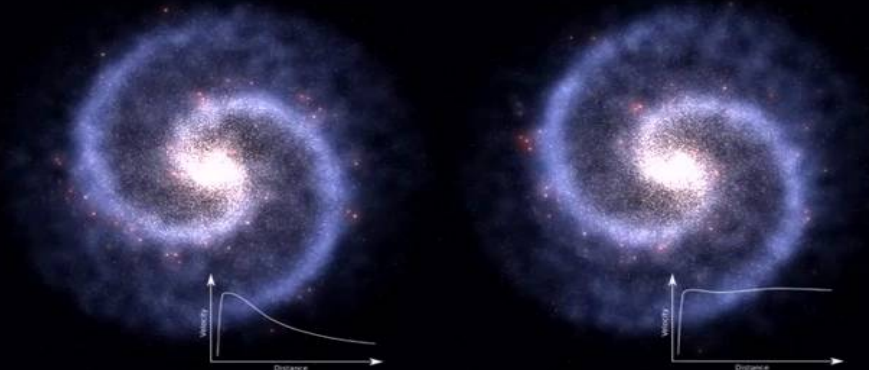


Intro

Il y a bien longtemps, dans un prés très,
très bas . . .

Pourquoi sommes-nous si convaincus que la matière noire existe ?

Rotation des galaxies



Sans matière noire

Avec matière noire

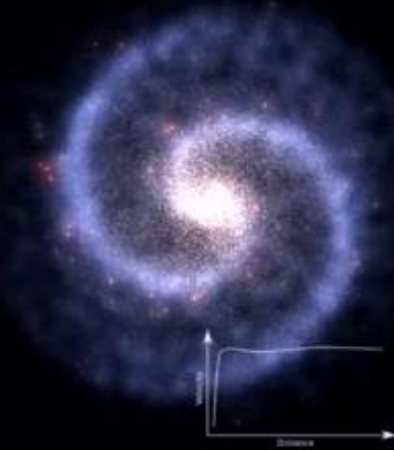
Pourquoi sommes-nous si convaincus que la matière noire existe ?

Rotation des galaxies

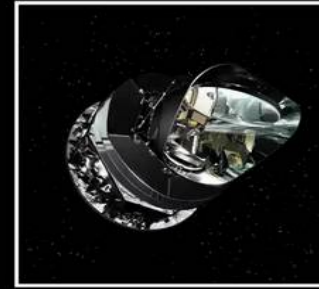
Fond diffus cosmologique



Sans matière noire

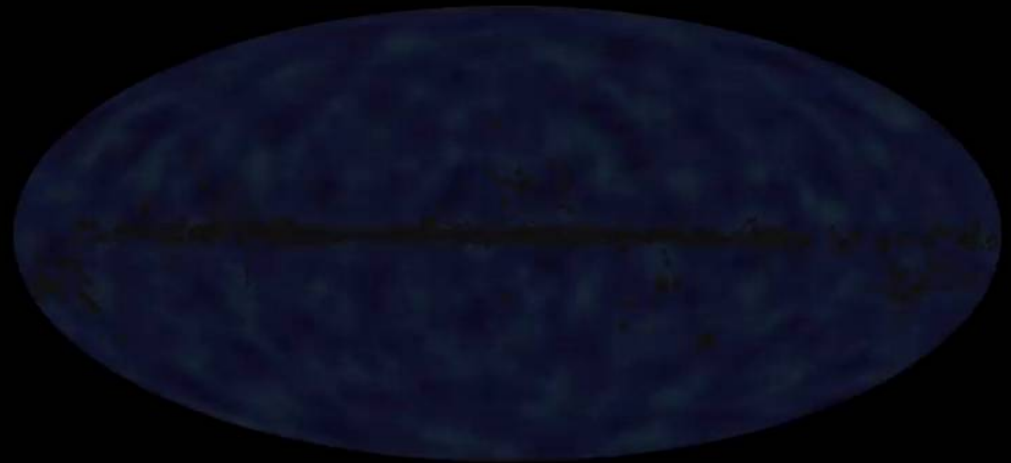
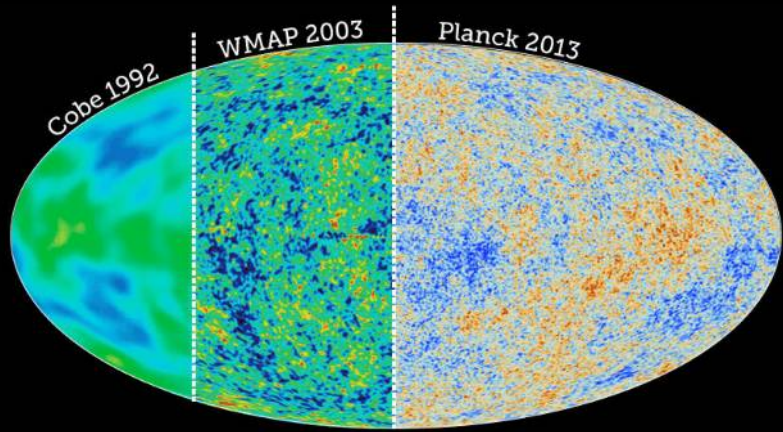


Avec matière noire

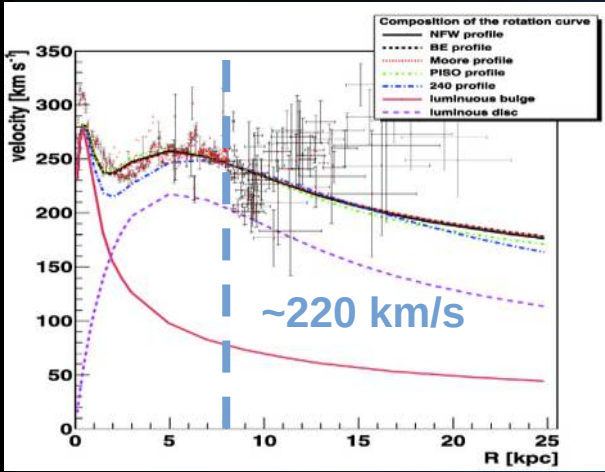


PLANCK SATELLITE

Le bilan sur notre Univers

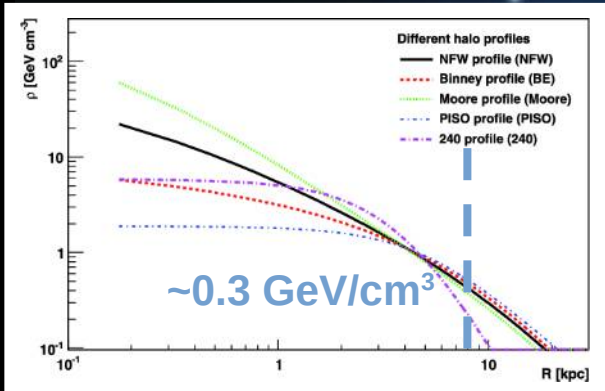


Motivations de la recherche directe de matière noire



Sa vitesse contre nous
et sa densité

M. Weber, W. de Boer, *Astron.Astrophys.*509:A25,2010



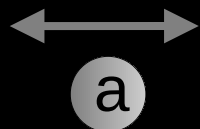
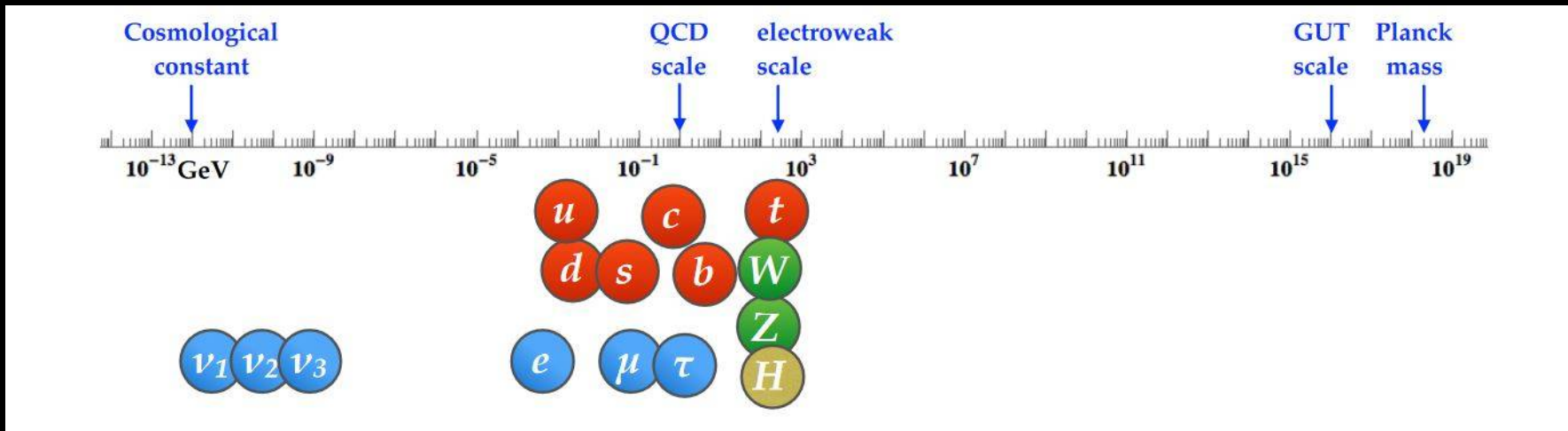
Halo de
matière
noire



“vent” de matière noire
provenant d’une seule
direction (constellation
Cygne)

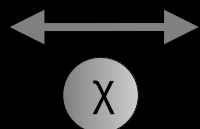


Oui, mais, quoi chercher ?



axion

(si 300 neV)
un milliard de
milliards dans
un litre



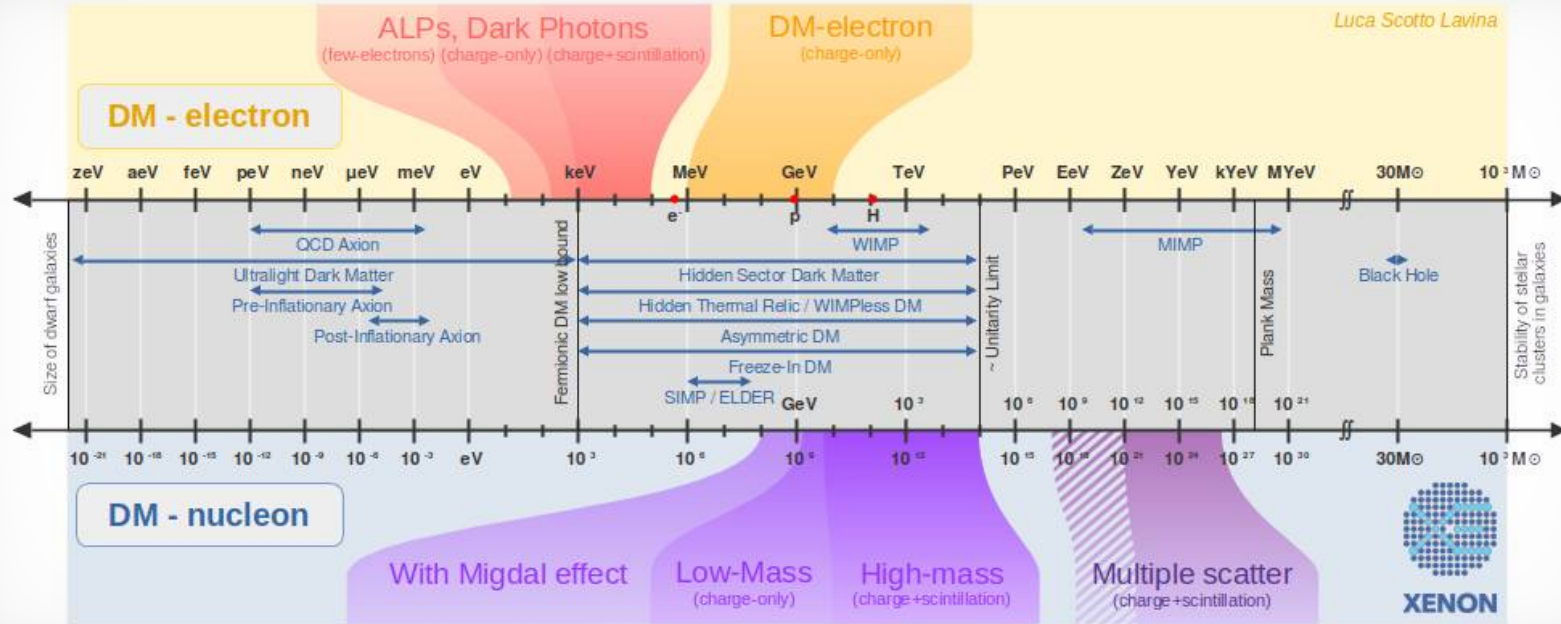
WIMP

(si 30 GeV)
dix dans un
litre

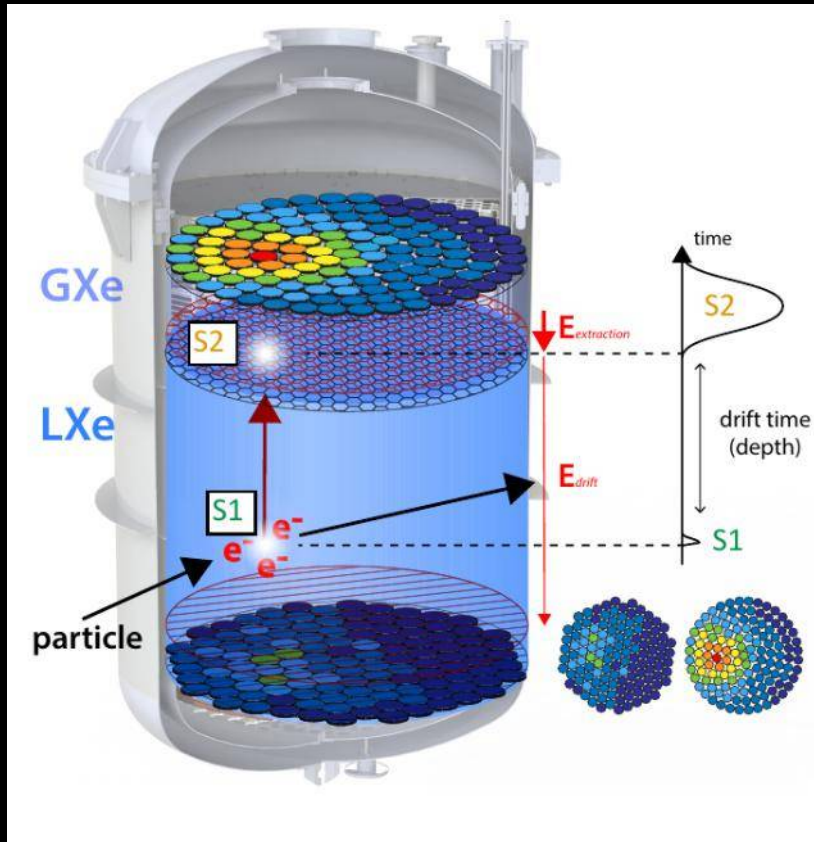
$\sim 0.3 \text{ GeV/cm}^3$

Bilan équipe XENON

Recherche directe de matière noire et ce que XENON peut chercher



Principe de fonctionnement d'une TPC avec deux phases de xénon

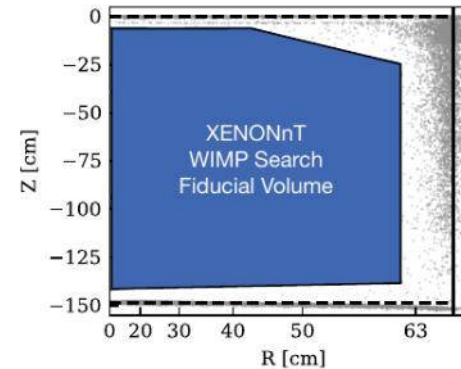


Light and Charge readout

- Prompt scintillation signal (**S1**)
- Secondary proportional scintillation signal in GXe from drifted electrons (**S2**)

Event reconstruction

- **3D Position:**
 - **Z** from drift time
 - **(X, Y)** from PMTs hit pattern
- **Energy** → $E = W \cdot (n_{ph} + n_e)$



Collaboration XENON



XENON Collaboration Meeting @ LPNHE, Paris, Sept 2023

Italie



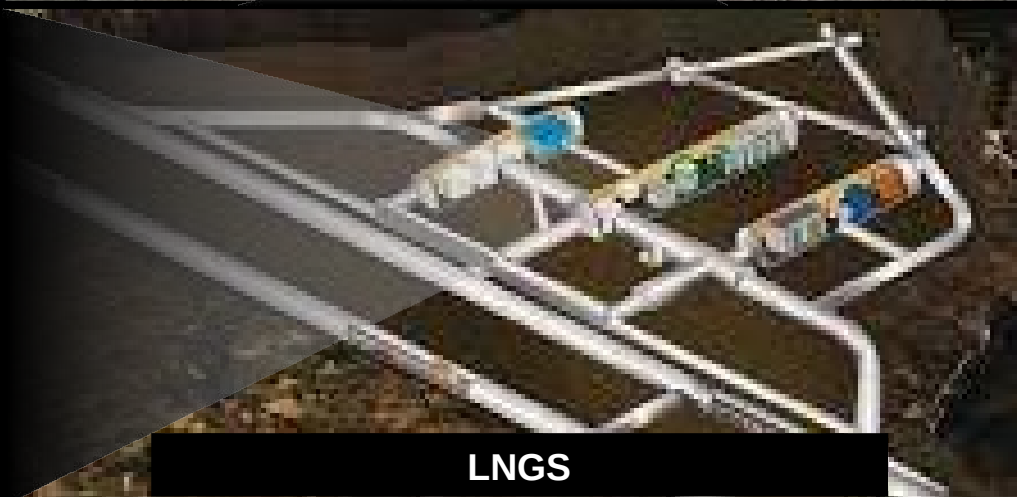
Parc National du Gran Sasso



XENON



LNGS



Équipe XENON + XeLab

Chercheurs :

Luca Scotto Lavina, DR

Bernard Andrieu, CR

Frederic Girard, postdoc

Etudiants :

Layos Daniel Garcia, Doctorant

Quentin Pellegrini, Doctorant

Yongyu Pan, Doctorant

Jean-Baptiste Plançon, Stage M2

Leslie Juigne, Stage M2

Sofia Najih, Stage DUT, Génie électrique et informatique

IT (1.1 FTE attribués) :

N. Garroum, Informatique

Romain Gaior, Électronique

Fabien Frérot, Électronique

Olivier Dadoun, Informatique

Sebastien Colinot, Mécanique

Gestion financière :

Marjorie Stievenart-Ammour

Visiteurs 2024 :

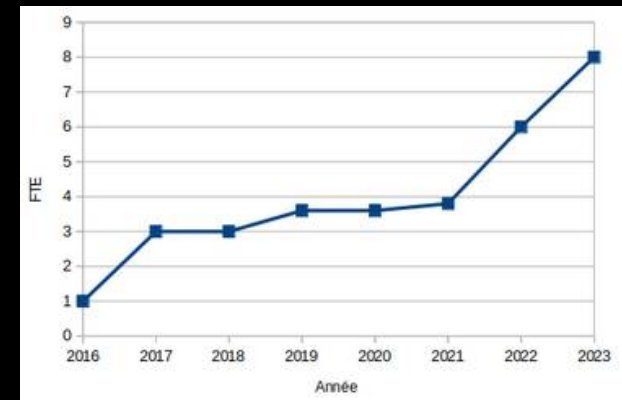
Lorenzo Principe, Doctorant, Subatech

Yajing Xing, Postdoc, Melbourne

Owen Stanley, Doctorant, Melbourne

Salem Hoceini, Postdoc, CTP, Fontainebleau

Evolution du groupe depuis sa naissance en 2016
(sauf stagiaires et visiteurs)



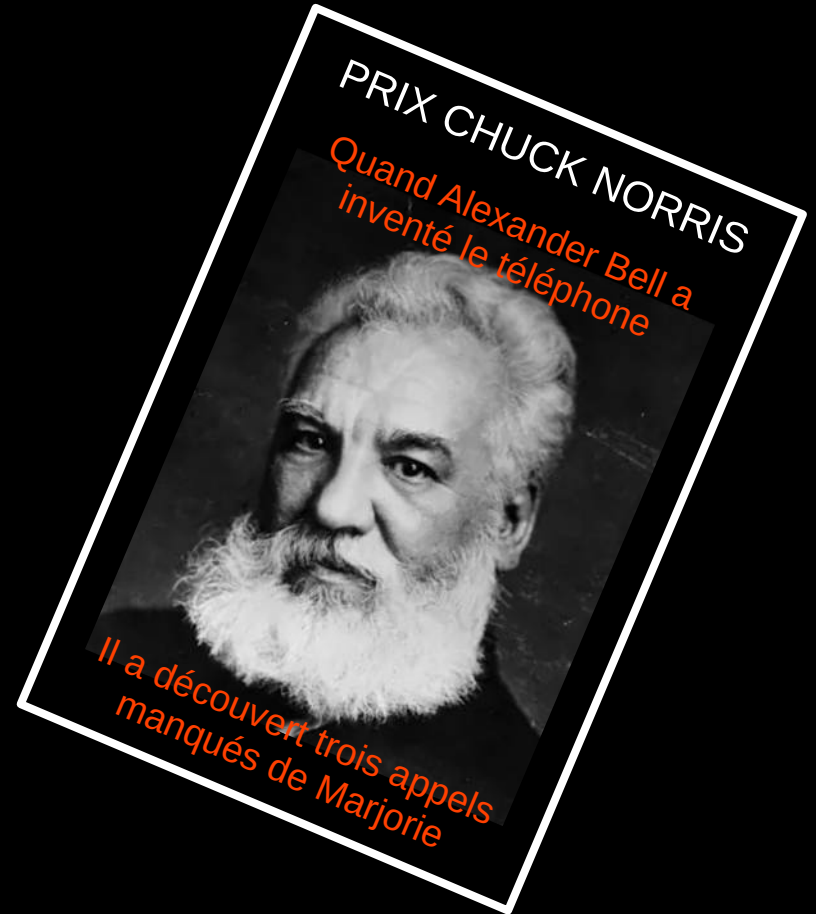
Gestion financière

Prix spécial “Chuck Norris” à Marjorie Stievenart-Ammour



Dans les dernier an :

- 50 commandes passés sur XeLab
- Équivalent de 300 outils/composants
- 1 Collaboration Meeting
- 30 missions
- La clôture d'un PUMA sur XeLab



• Different dark matter models that can be probed:

Low-E Nuclear Recoils (NR)

SI elastic scattering

SD elastic scattering (LXe-specific)

WIMP-pion coupling

Effective Field Theory on WIMPs (+iDM) (LXe-specific)

Mirror DM

Electronic Recoils (ER)

Dark Photons

Bosonic SuperWIMPs, Magnetic dark matter

Solar axions and Axion-like Particles

Luminous DM

Both (NR+ER)

Inelastic DM

Annual modulation search

Low mass WIMPs (<10GeV)

Multiply-Interacting Massive Particles (MIMPs)

Migdal Effect and Bremsstrahlung

• New physics can be scoped:

Neutrinos

Solar 8B neutrinos (CEvNS → NR)

Neutrinoless double-beta decay (LXe-specific)

Neutrino magnetic moment

Supernovae neutrinos

Rare events

Double electron capture (LXe-specific)

Gravitational wave search

New particles

Solar Dark Photons

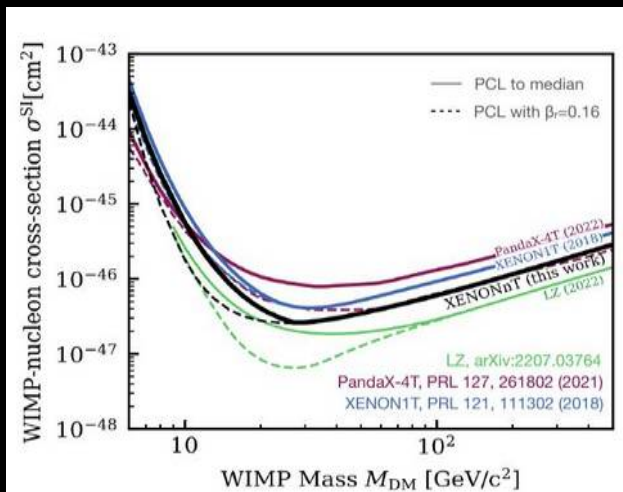
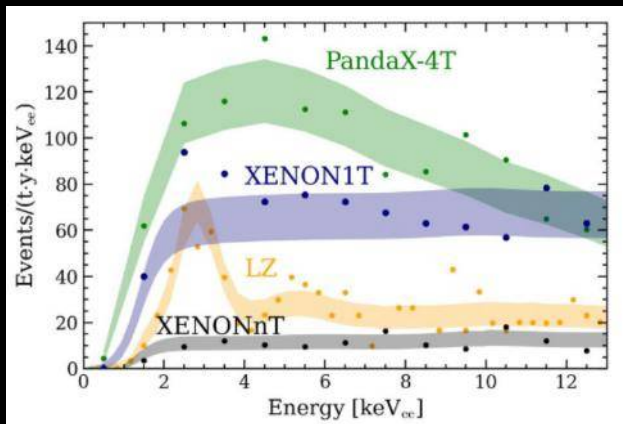
Quentin Pellegrini
(2eme / 3)

Yongyu Pan
(2eme / 4)

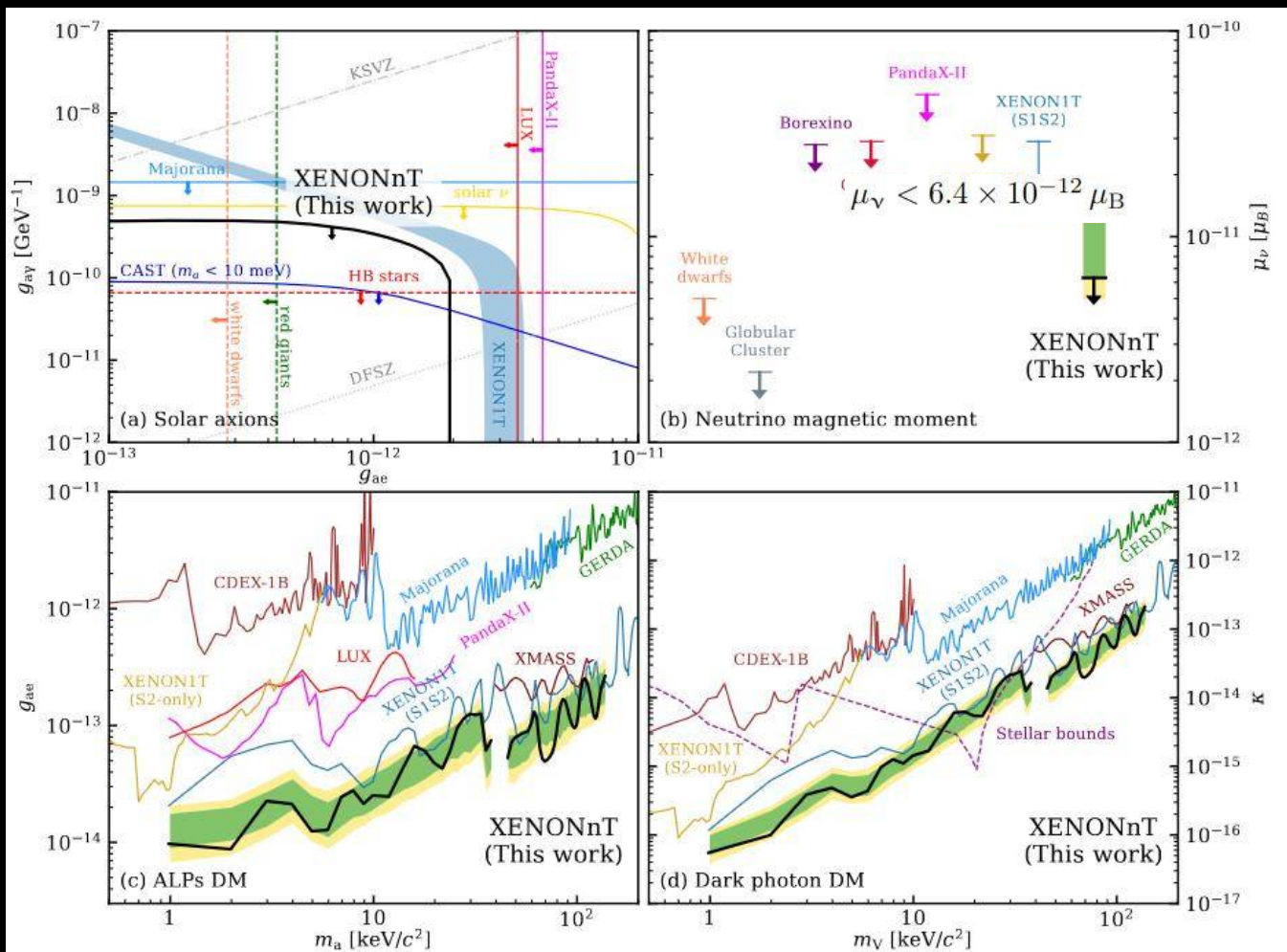
Poster analyses
XENONnT

Layos Daniel Garcia
(3eme / 3)

Résultats de XENONnT avec le Science Run 0 (2022 ER et 2023 NR)

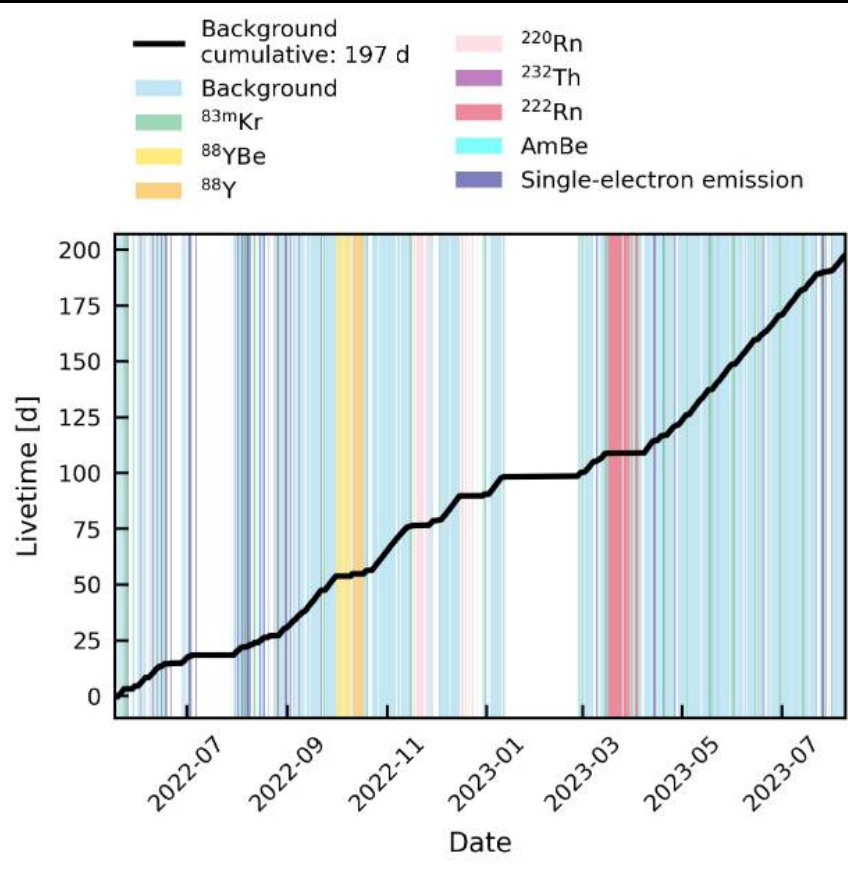


Same PCL applied to results of other recent LXe experiments

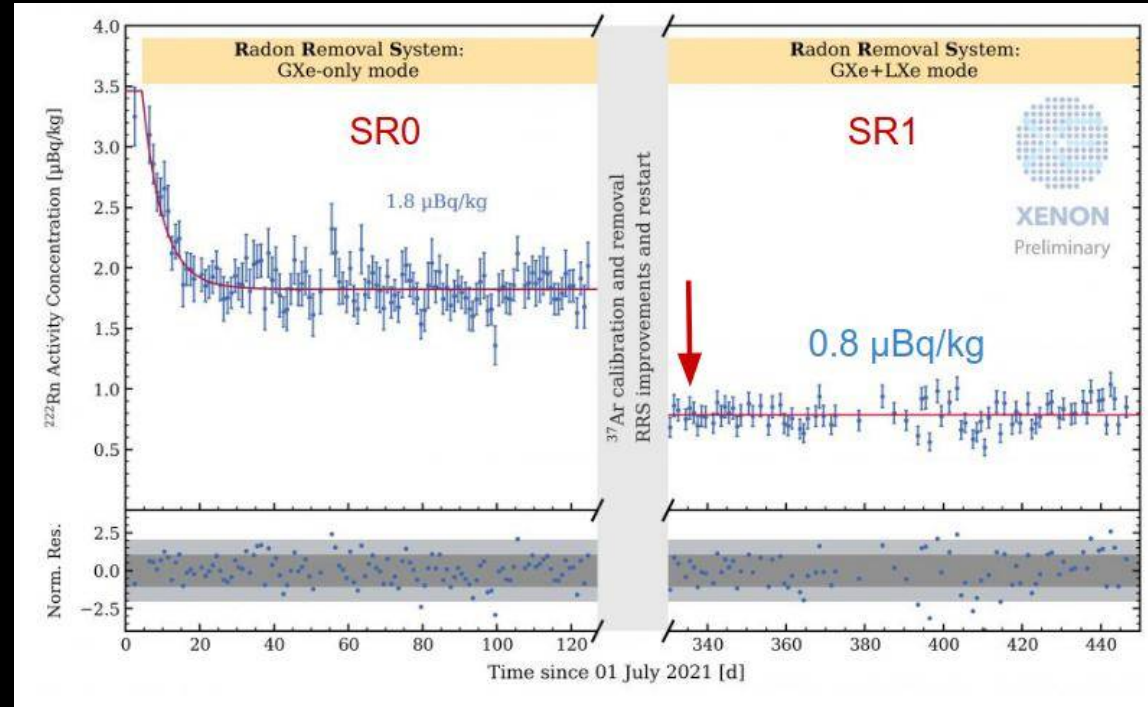


Prospectives de XENONnT (Science Runs 0, 1 et 2)

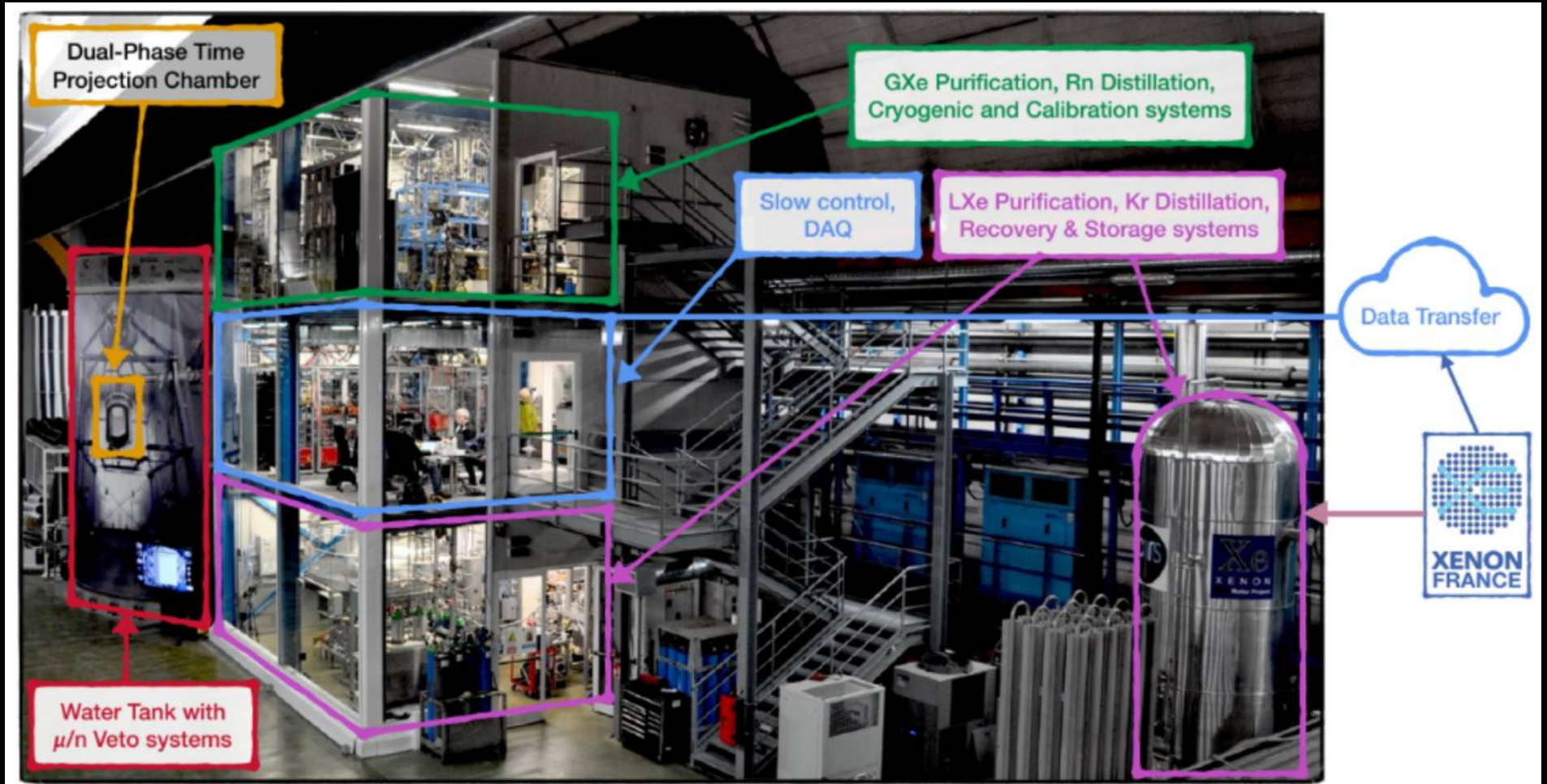
SR1 : x3 plus de statistique



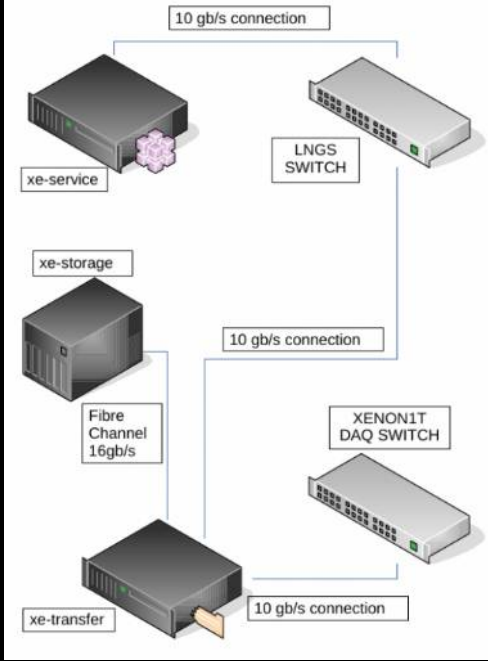
Encore moins de bruit de fond Radon



Responsabilités LPNHE

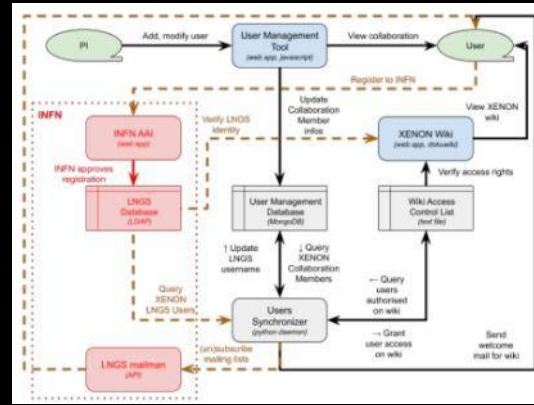


Infrastructure au LNGS



Computing

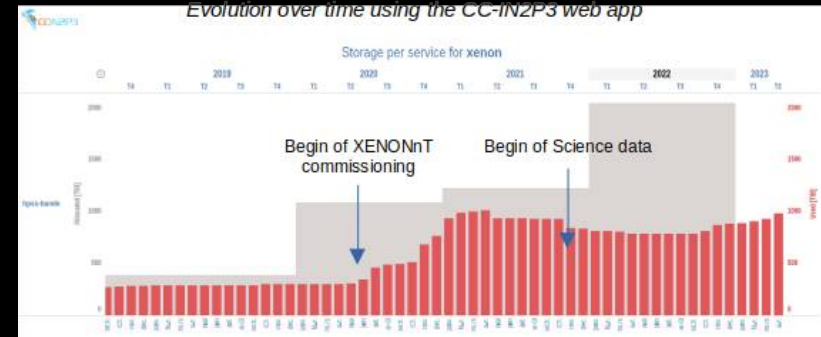
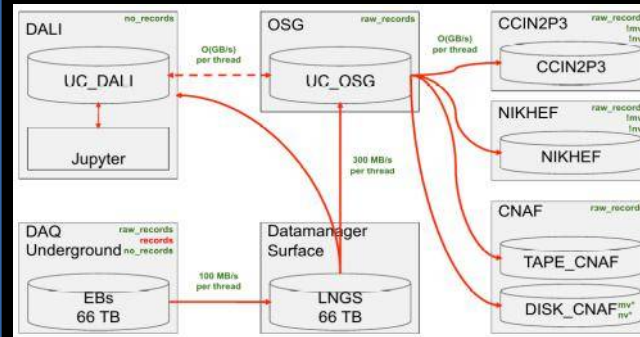
Gestion des usagers : github, IAM, mailman, LNGS LDAP, Users Database, liste des auteurs



XOM (Xenon Offline Monitoring) pour suivre la qualité des données



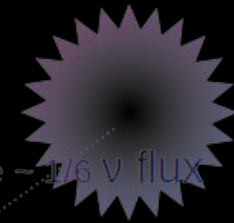
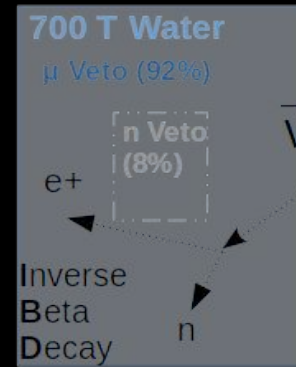
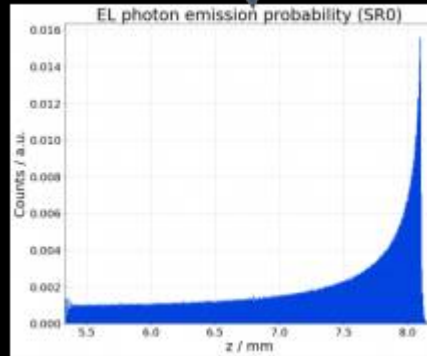
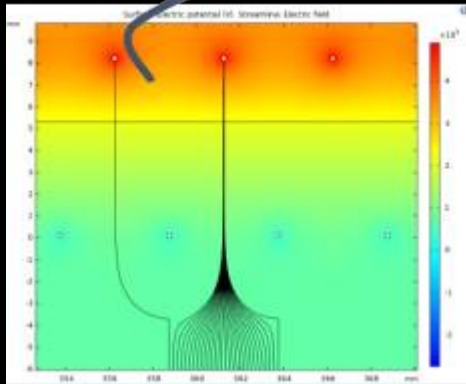
Gestion des données avec aDMIX : transfert, archivage, élimination



Simulations Monte Carlo

Taches accomplies:

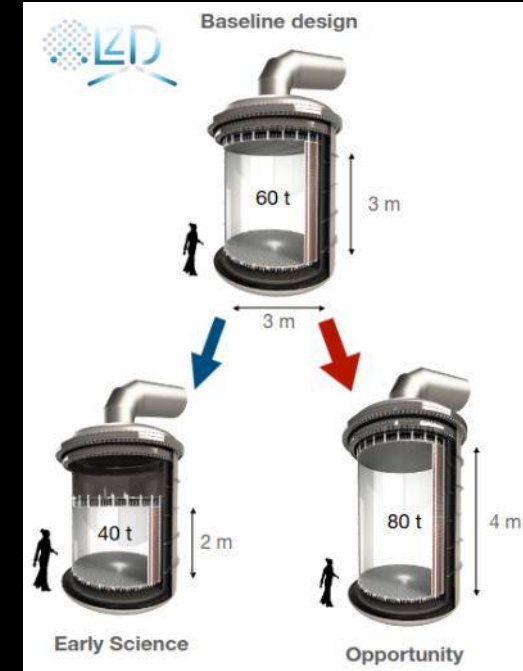
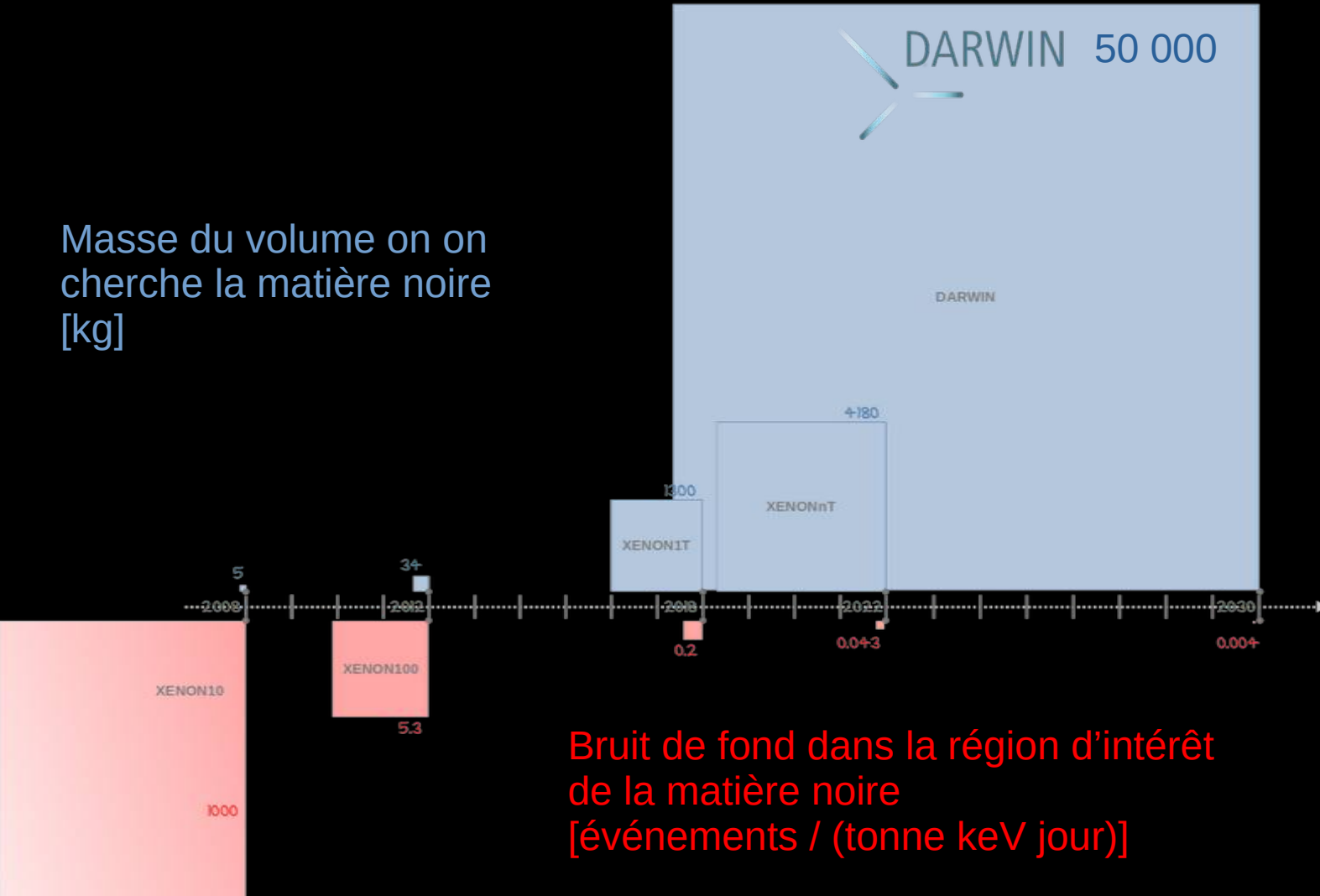
- Géométrie plus réaliste et physique sur les **électrodes** (*sagging* et fils transverses sur la *gate* et l'anode)
- Simulation des photons optiques produites par électroluminescence des électrons extraites dans le gaz
- Comparaison Data/MC (processus de scintillation, **effet *shadowing***, uniformité du signal...)
- Simulations améliorés et digitation des données de **Neutron Veto** et **Muon Veto**



Parcours et perspectives

De plus en plus grands et de plus en plus « silencieux »

Masse du volume on on
cherche la matière noire
[kg]



Credits : Frédéric Girard

Bruit de fond dans la région d'intérêt
de la matière noire
[événements / (tonne keV jour)]

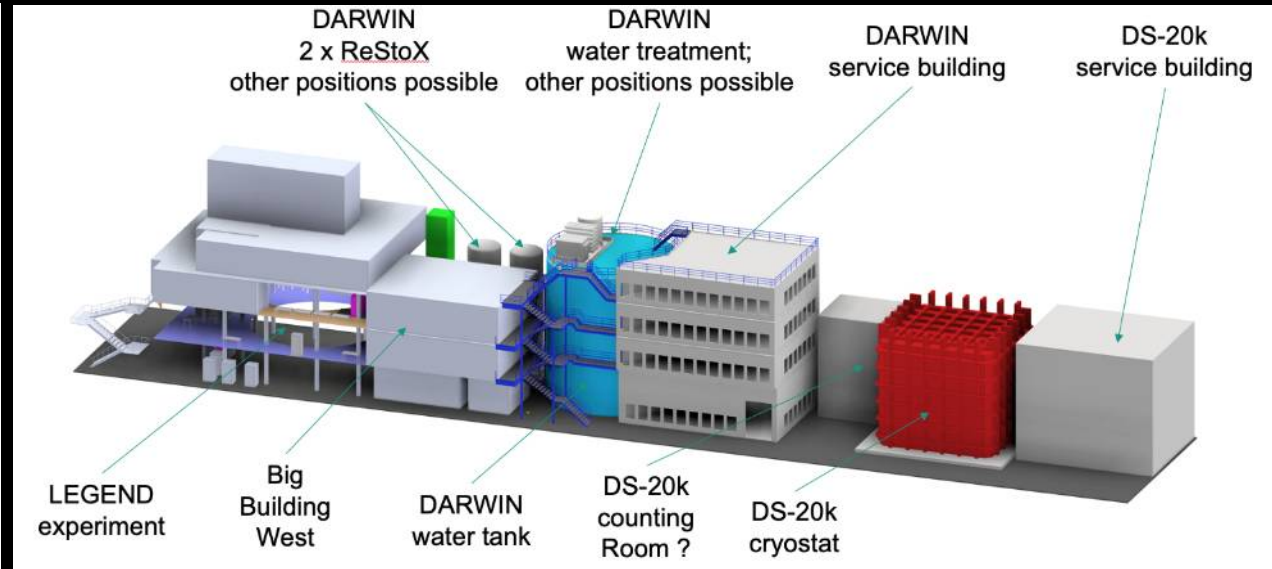
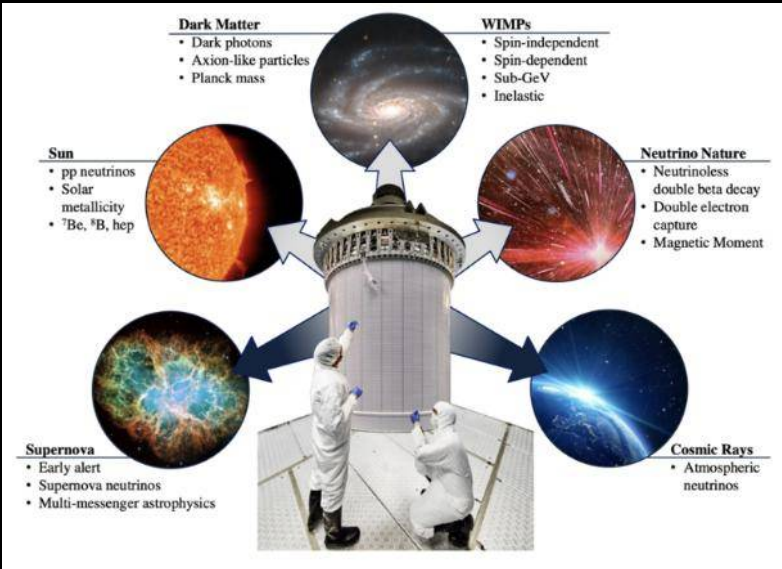


Vers un *Technical Design Report*

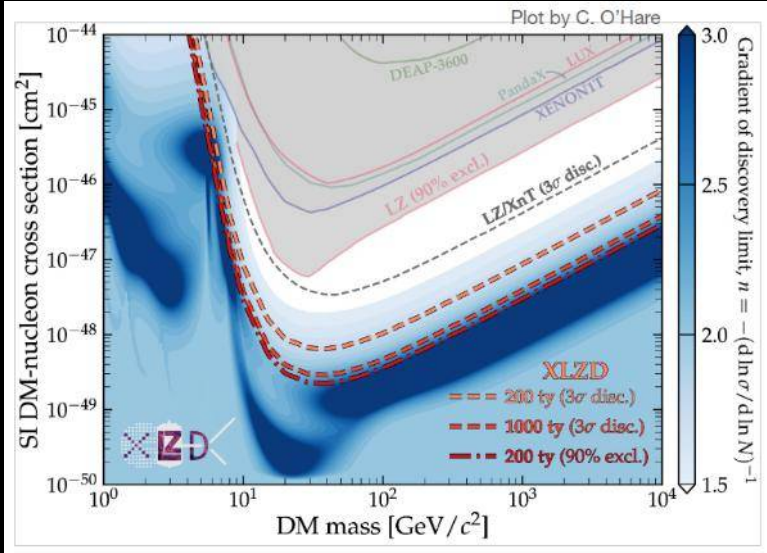
Passé au Conseil Scientifique du LNGS

Possibilité d'une phase DARWIN0 (aka : XENONnT++)

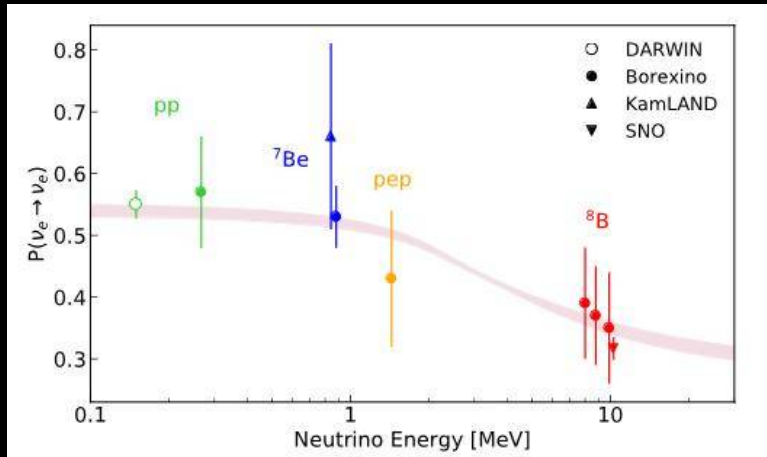
Prix du xénon réduit aux minimum historiques (~1k€ / kg) → 5 fois moins cher



Recherche des WIMPs

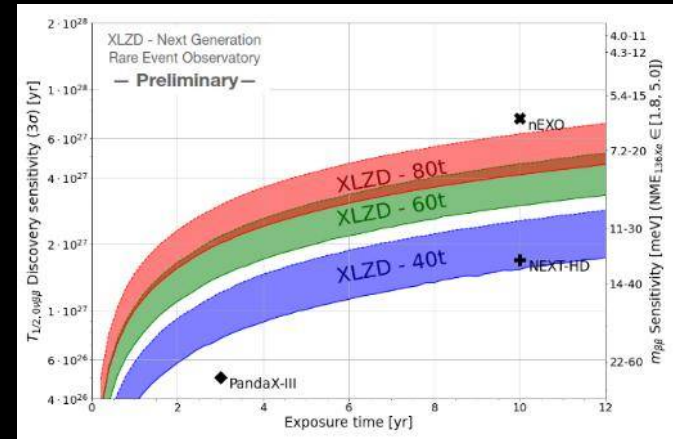
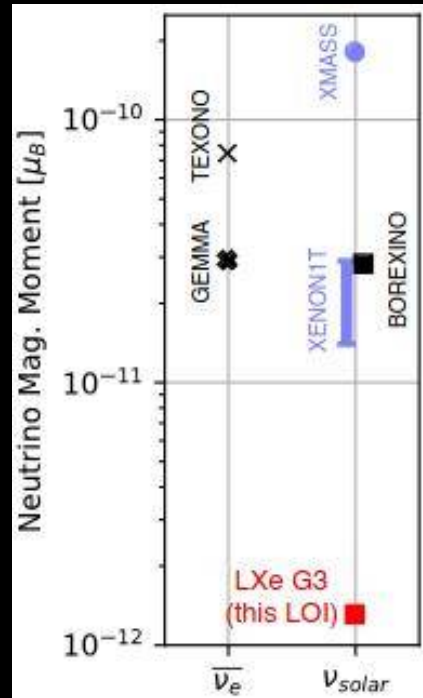


Neutrinos solaires

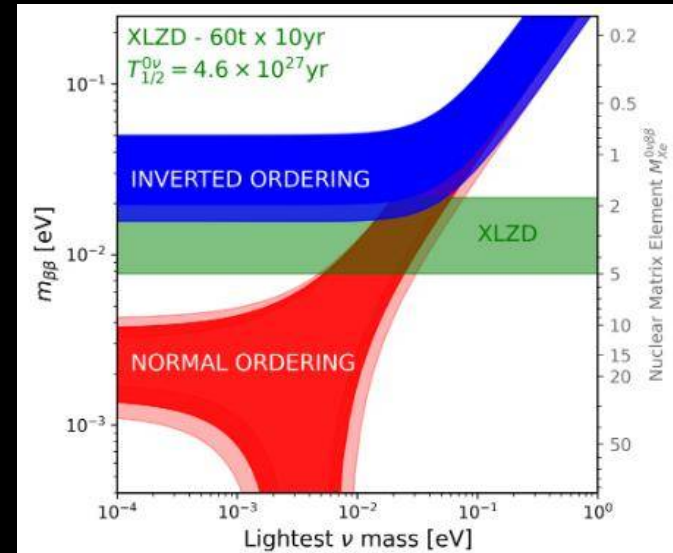


Résultats attendus

Moment magnétique du neutrino

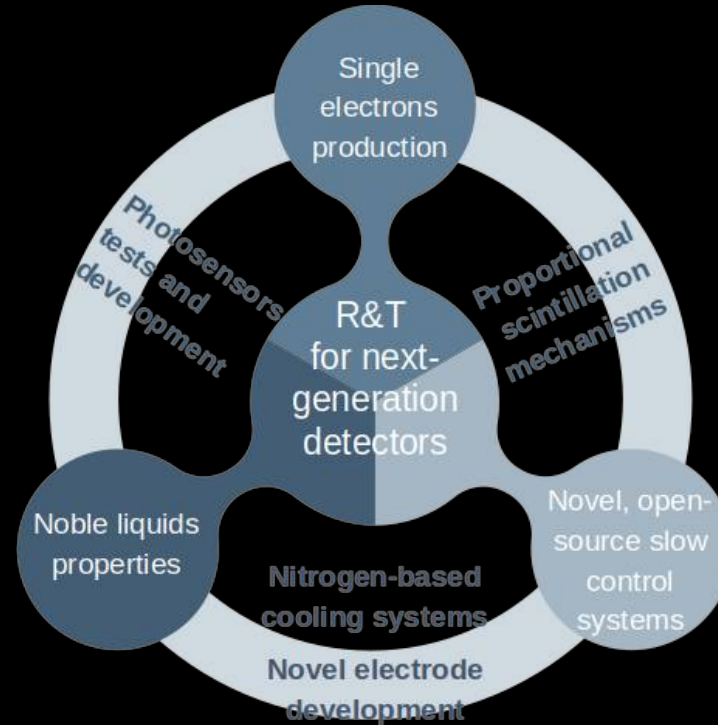


Double désintégration beta sans neutrino

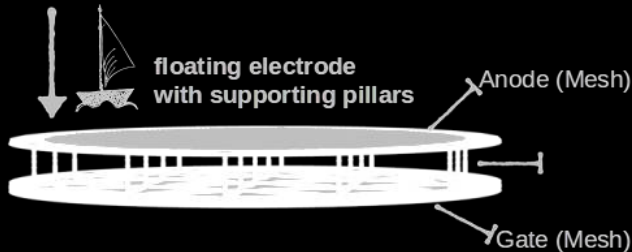




R&T avec XeLab

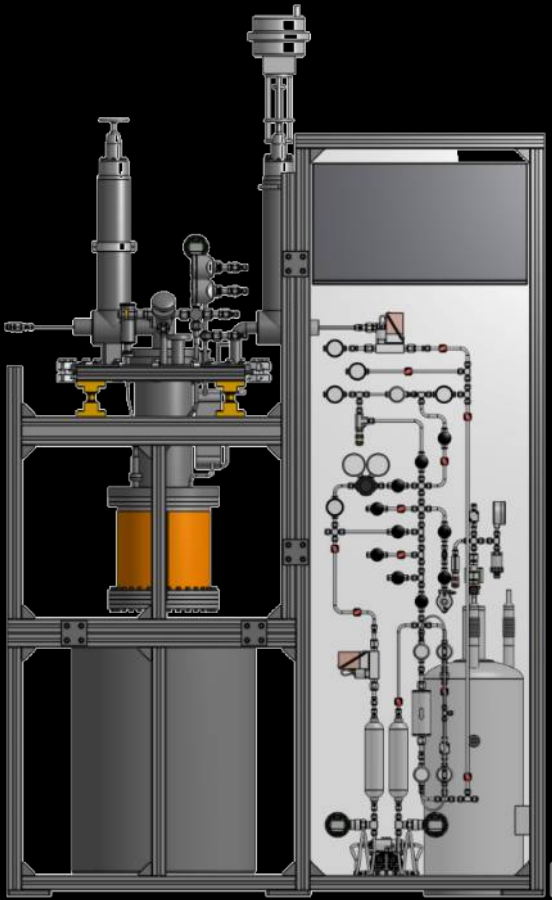


- R&T Master Project
- Collaboration avec Subatech
- R&D de DARWIN et XLZD
- IRL DMLab (CNRS-Helmoltz) et IRP avec Melbourne
- ECFA roadmap
- DRD2 (*liquid targets*)
- Présenté dans conférences internationales (XeSat23, ICRC23) et locaux (Journées R&T, GDR DUPhy)
- Proceedings: <https://hal.science/hal-04186811>





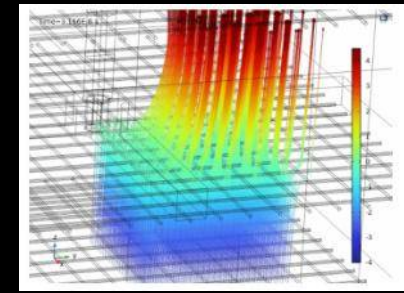
R&T avec XeLab



R&D
Levelling system



R&D
Storage and recovery system



R&D
Simulations electrodes



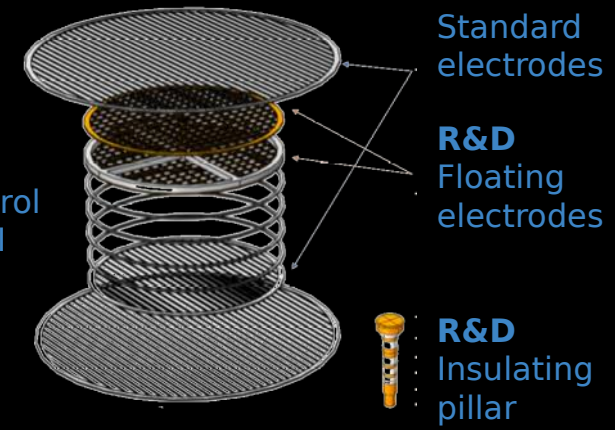
R&D
Three-way heat exchanger



R&D
Cryostat LN2-cooling with copper belt



R&D
Slow Control with RevPI



Standard electrodes

R&D
Floating electrodes

R&D
Insulating pillar



Design and Construction, Moving Towards Commissioning

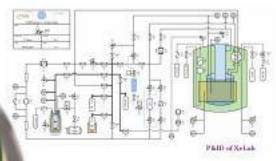
Frédéric Girard, on behalf of the XeLab Team, LPNHE-Paris

XeLab

Built in the context of the DARWIN Observatory, XeLab is an R&D platform used to test innovative designs of electrodes for use in large detectors. It is the first dual-phase xenon TPC deployed and operated in France. Additionally, the installation will be used to perform complementary R&D on photosensors, on other liquefied gases such as argon, and much more! The construction of the facility was completed at the beginning of 2024. XeLab now enters its commissioning phase.

Xenon Gas Handling and Purification

- Gas handling system designed and assembled at LPNHE
- Xenon gas purifier: Entegris Gatekeeper GPU Getter
- Xenon compressor: KNF Neuberger model N026ANE

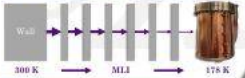


Time Projection Chamber



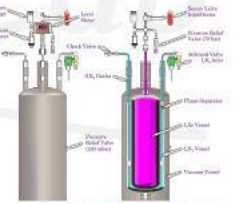
Multi-Layer Insulation

- 2x 10 layers of double-sided aluminized polyethylene sheets (Mylar)
- Each sheet separated by woven polyethylene layer
- Individual sheet reflectivity: ~ 95%
- Heat transmission via IR radiation: $< 0.6 \text{ W/m}^2$



First Cryogenic Tests

MiniReStoX



Deux Posters à la Biennale

Cryogenie : terminée (tests sous vide et sous froid)

Slow Control : presque terminé

DAQ : terminé

Data processor : en cours

Simulation G4 : en cours

TPC : en cours (Subatech)



Slow Control and Data Acquisition systems

XeLab Team, LPNHE-Paris

PMT

- 5x PMTs
- low temperature operation
- UV spectral range (LXe scintillation wavelength = 178 nm)
- PMT readout base from UZH (Zurich)

Visualisation



Alert system based on Grafana

Sensors

Controlled with the RevPi

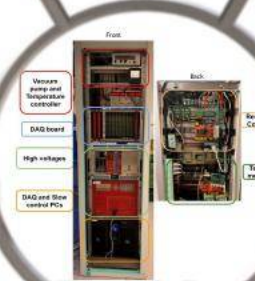
- Gas control**
- 6x pressure gauges
 - 2x gas flow meters

- Liquid level**
- 1x level meter in MiniRestoX (LN2)
 - 4x thermocouples and in-house made (Subatech) capacitive sensor for level monitoring in the TPC cryostat (LXe)

- LN2 flow**
- 1x cryogenic valve positioner

DAQ

- CAEN V1720 board (Subatech)
- 8 channels 12bits 250MS/s
- Optical to USB3 data transfer
- DAQ software inherited from UZH



High Voltage

- Electrodes**
- CAEN NDT1471H
 - 4 channels reversible polarity
 - +/- 5.5kV
 - Flexible for electrode tests
 - Modern interface (Ethernet./ USB)

Temperature

- In house made readout using Arduino and PT100/PT1000 readout chip (MAX31865xAP)
- 6 channels per Arduino mezzanine board (up to 3 stackable boards)
- Data saved to InfluxDB data base

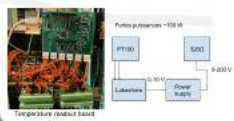
Revolution Pi



- CAEN Sy527 Power supply system
- RS232 interface
- Up to 48 channels
- Inherited from HESS



- RevPi Connect S 8GB: PLC based on Raspberry Pi hardware conditioned in industrial packaging, low-cost modular option.
- 3 analog modules for 4-20 mA signal, RTD, other analog signals
- 1 digital module for relays
- Programmed with Codesys software to comply with industrial standards
- 2 additional Raspberry Pi for development

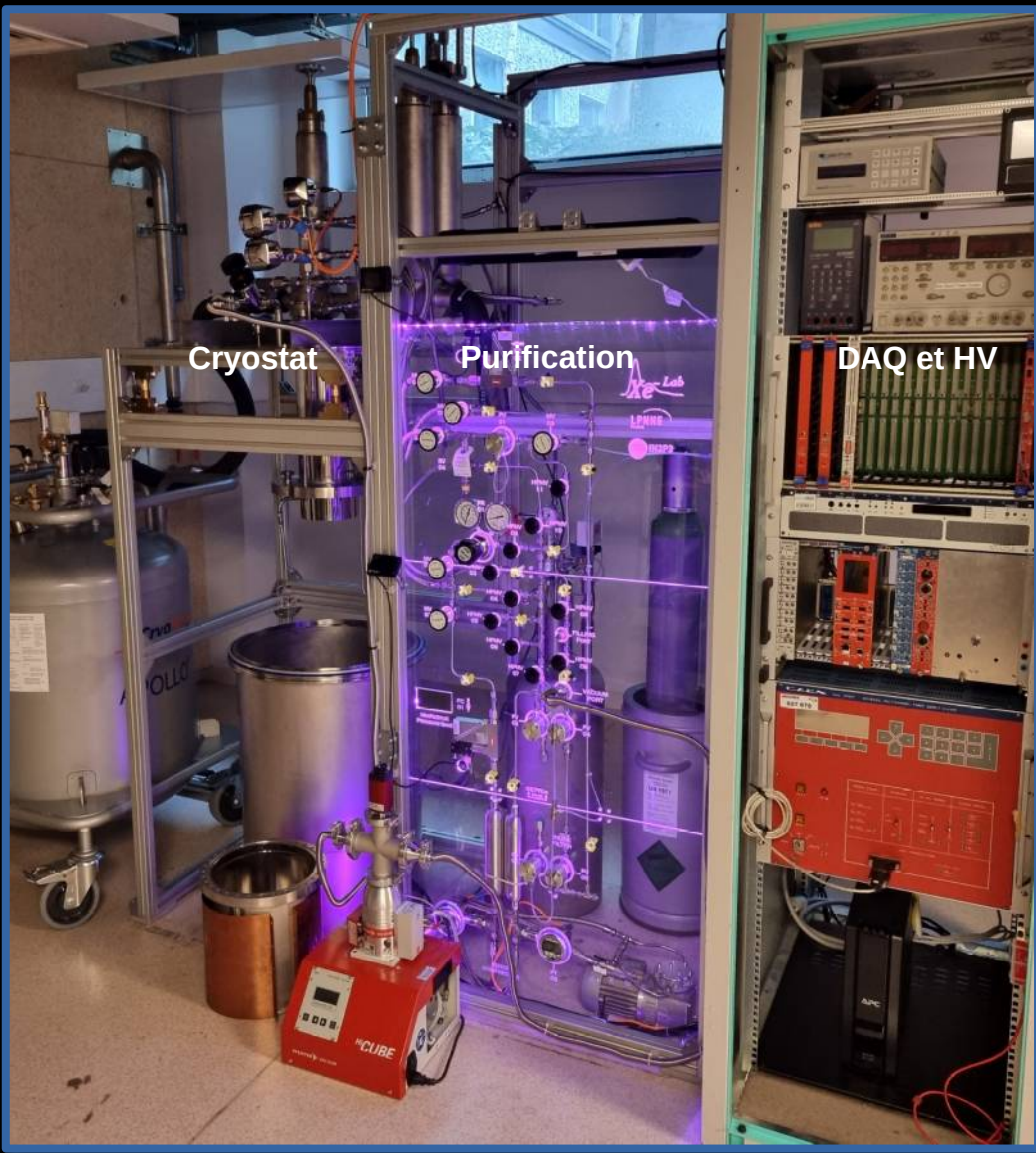
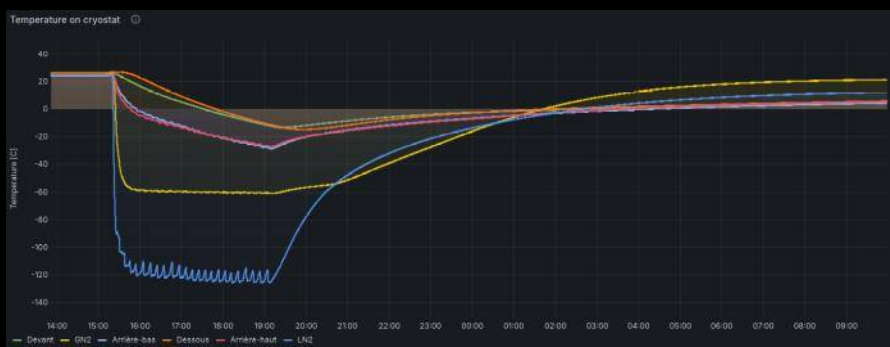


Temperature regulation will be done with a cryo-controller (Lakeshore 325) and additional power supply for larger power

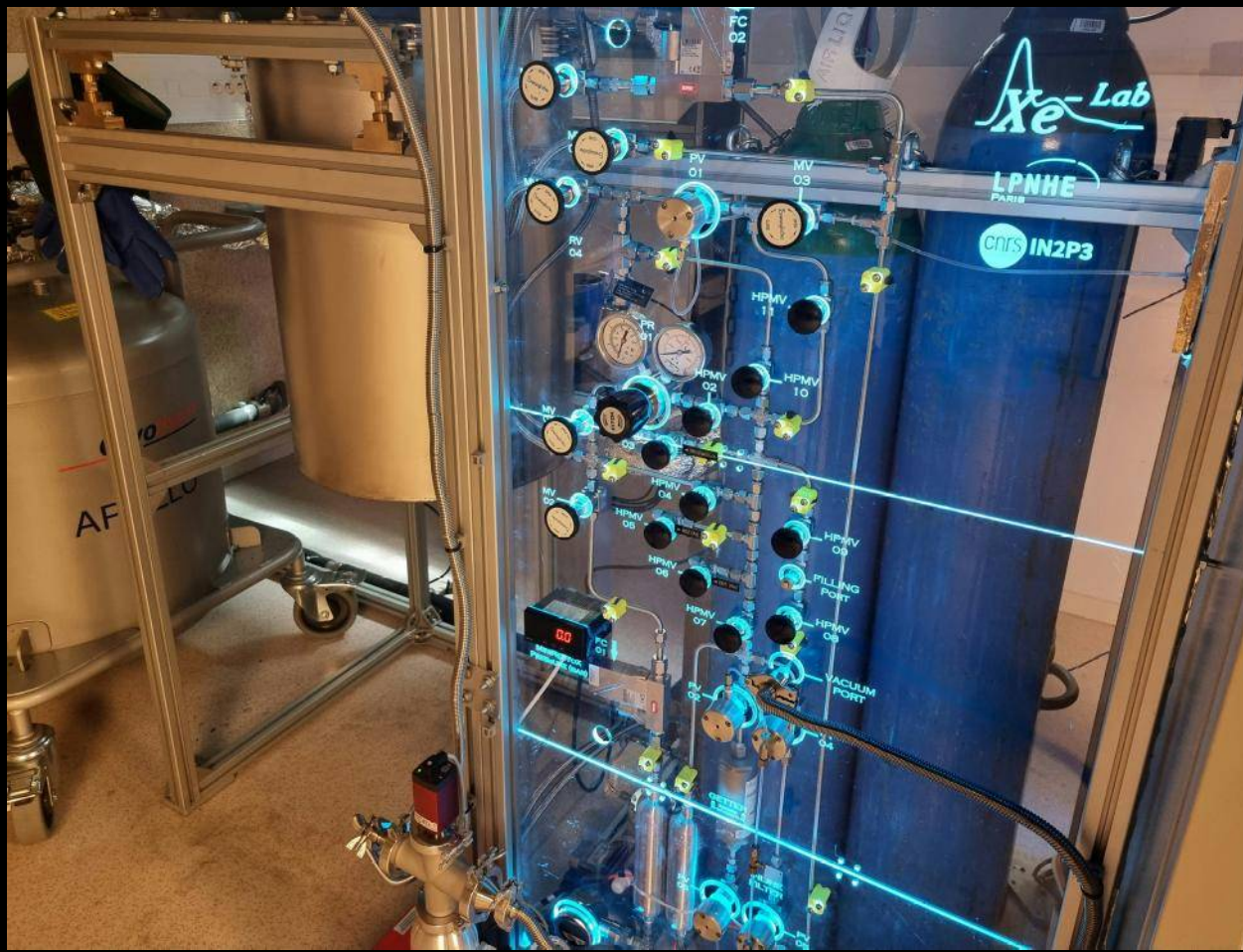
Premières tests sur froid de la chemise en cuivre



Premières tests sur froid de l'échangeur à trois voies



Finale avec propagande



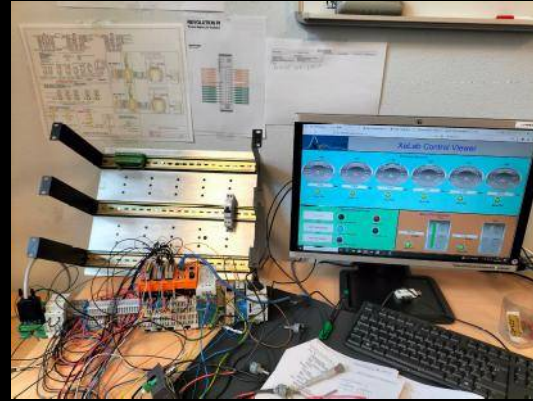
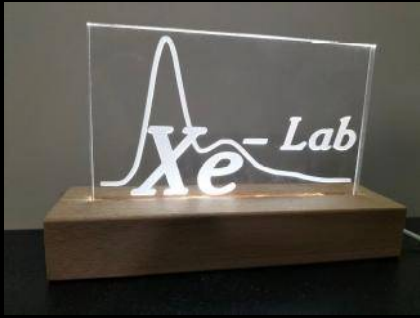
Si vous aimez l'esthétique ...

Candidate au concours photo "L'IN2P3 en images"
<https://phototheque.in2p3.fr/index.php?/category/2237>

Si vous aimez la nature ...



Si vous aimez bricoler ...



Si vous aimez le travail d'équipe ...



Si vous êtes suffisamment fous...



Alors, rejoignez l'équipe XENON !



avant qu'il soit trop tard



(la direction nous dit toujours de nous anticiper et voila, on s'anticipe, on aura des départs à la retraite dans 20 ans)



XENON



Merci

