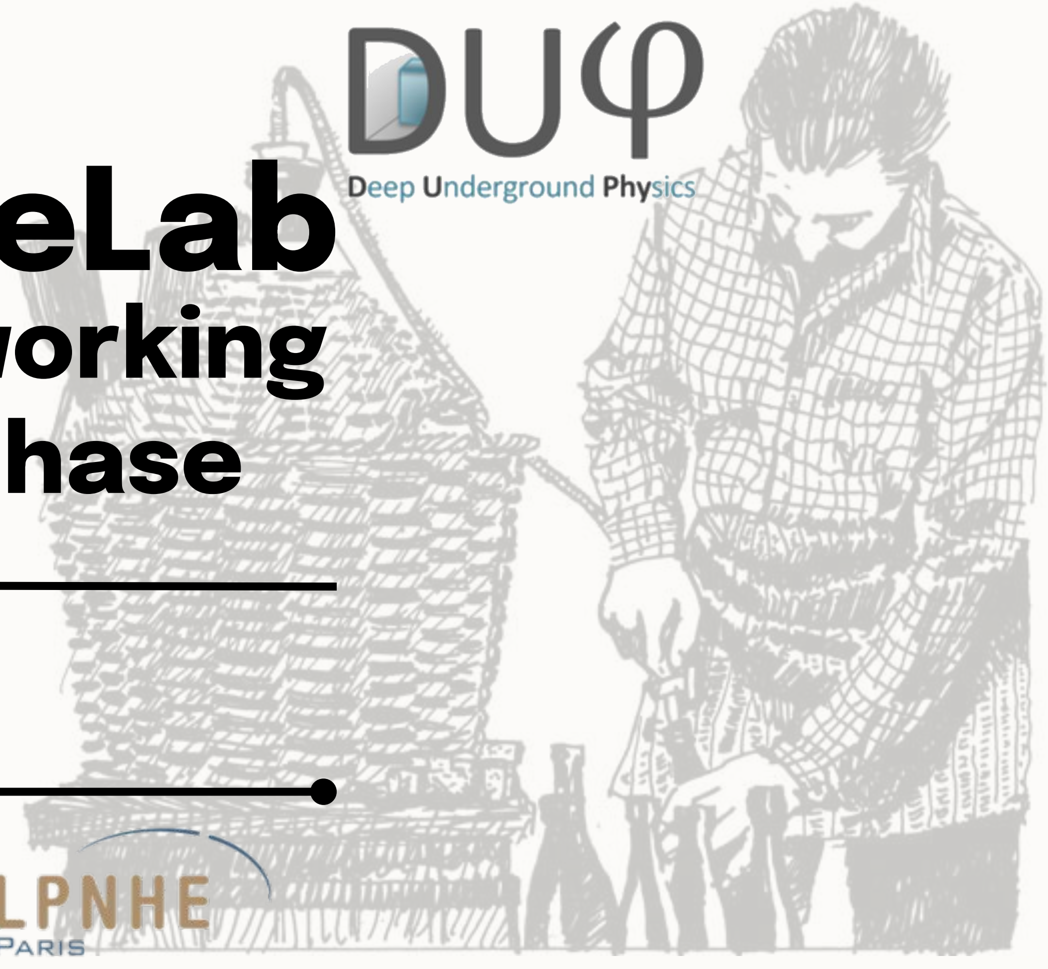
XeLab Project   Journées R&T   18th Oct. 2022

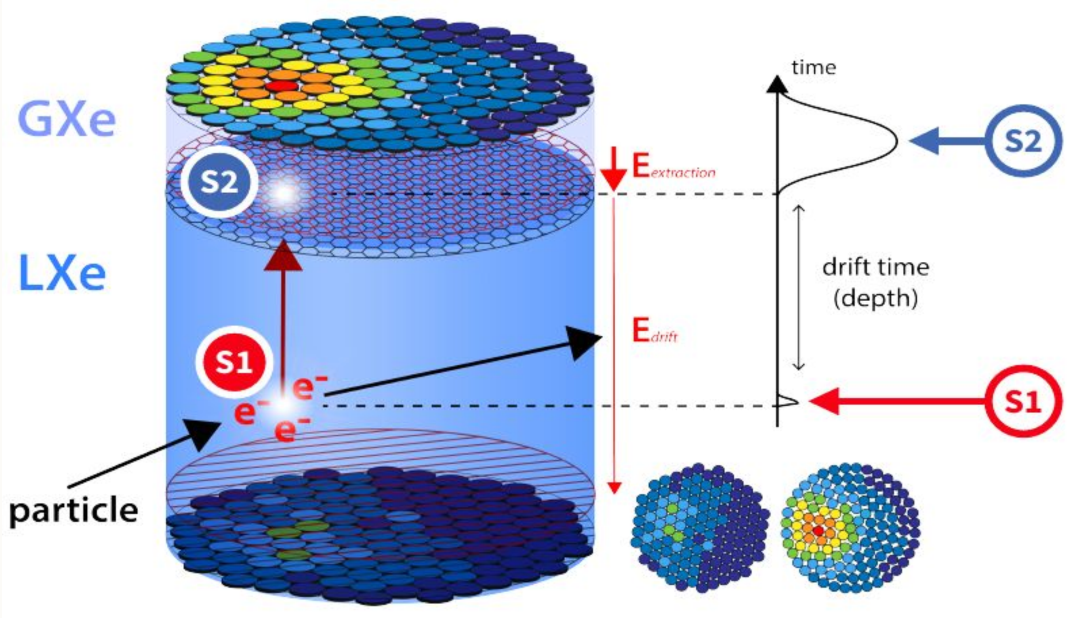
XeLab

Laboratory working with a dual-phase LXe TPC



Yajing Xing – Subatech
Nabil Garroum – LPNHE
Luca Scotto Lavina -LPNHE

Searching for Dark Matter with LXe TPC

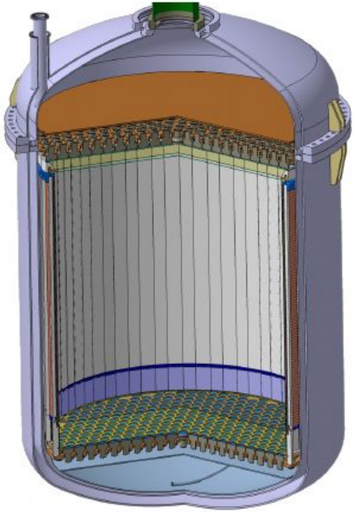


Evolution of XENON project

FUTURE

PAST

PRESENT



	XENON10	XENON100	XENON1T	XENONnT	DARWIN
Height	15 cm	30 cm	96 cm	148 cm	**2.6 m**
Diameter	20 cm	30 cm	97 cm	133 cm	**2.6 m**
Total mass	25 kg	161 kg	3.2 tons	8.3 tons	**50 tons**
Active mass	14 kg	62 kg	2.0 tons	5.9 tons	**40 tons**

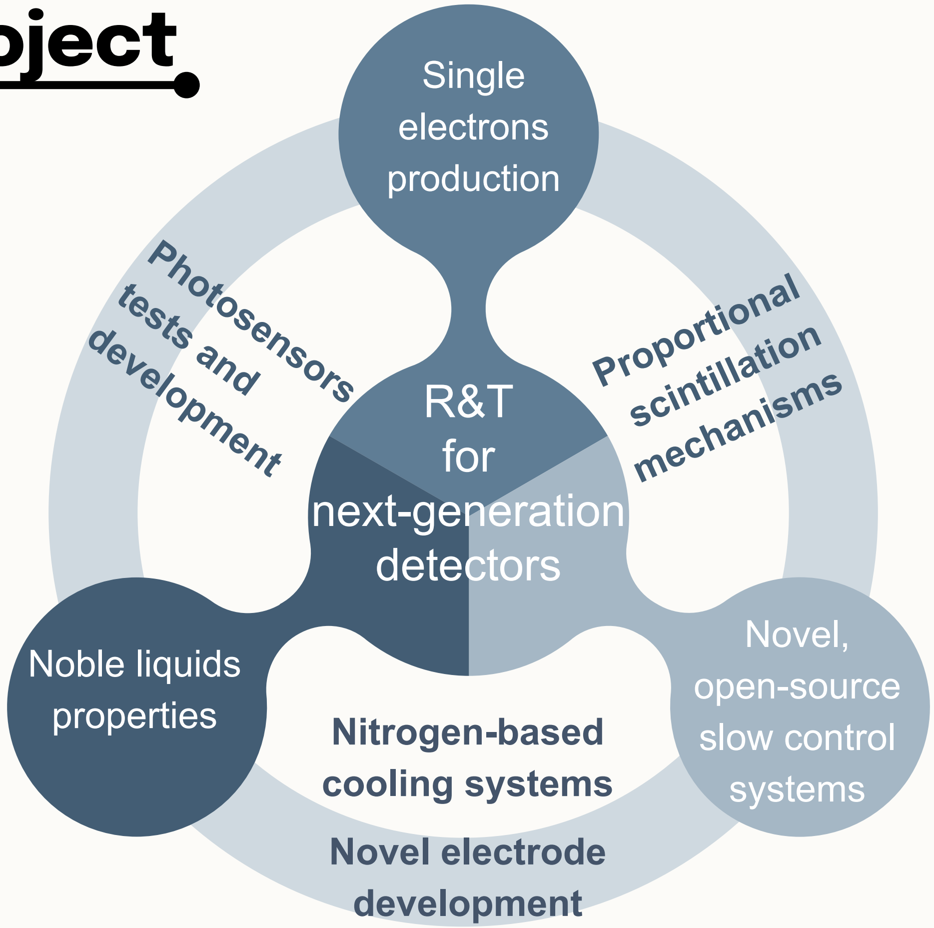
Noble liquids TPC: when size M increases

Increase in target mass	Increased electrostatic voltage of the electrodes	→ electric shocks
Increased self-shielding ↓ Background reduction	Increased Distortions: Gravity, Electrostatic Induction, Archimedean Force	→ non-uniform detector response
	Increase in materials	→ more radioactivity

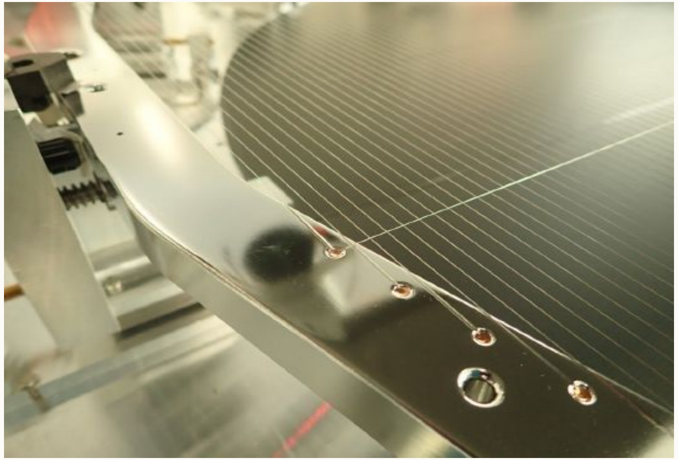
Increasing the size of the target is **advantageous for the search for dark matter**, but there are **technological challenges** for which we do not yet have an optimal solution.

The XeLab Project

- First site in France working with a dual-phase LXe TPC (with liquid phase TPC @Subatech)
- Meant as platform to perform R&D for next-generation detectors
- Funded by IN2P3 with local support by LPNHE and Subatech
- Many side-projects on the way, nice attractor for students
- Integrated Quality procedure

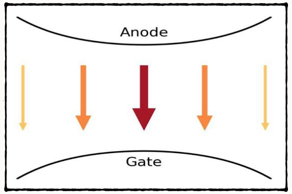


XENONnT difficulties on the electrodes



With the aim of increasing the optical transparency of all electrodes
→ **Only parallel wires**

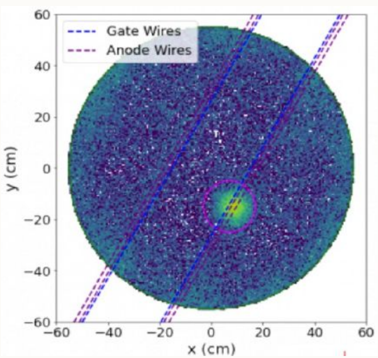
To reduce mechanical distortions (sagging) between Gate and Anode
→ **Perpendicular wires**

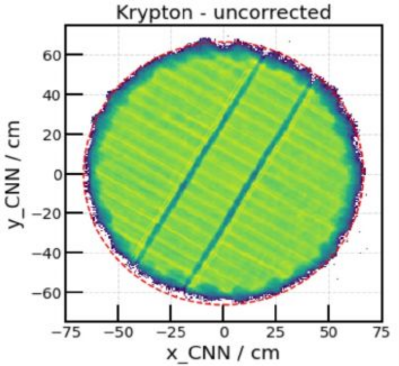


Sagging caused by gravity and the electrostatic force between the anode and the gate still present.

⇢ micro electric discharges (hot-spots)

⇢ Non-uniform detector response (x, y)





Essential to do R&T to develop new ideas, to solve these difficulties for current detectors but especially for those of the next generation (DARWIN)

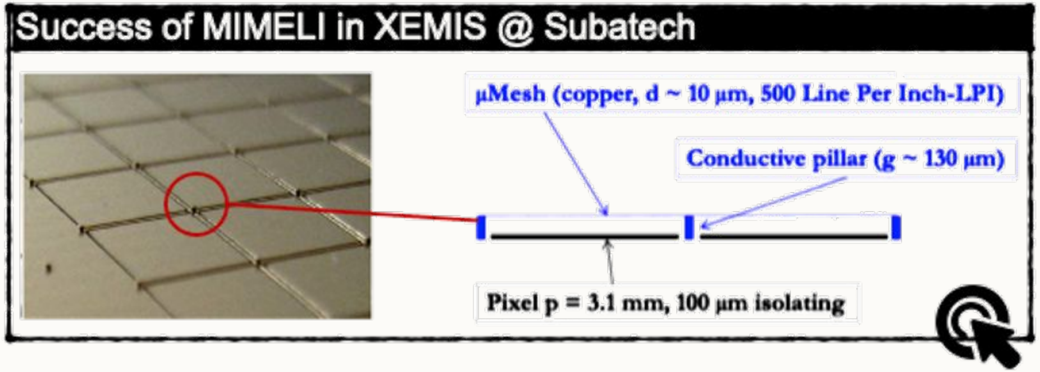
Electrode R&T in XeLab

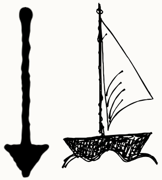
Goals:

- Minimize mechanical distortion
  → possibility of reducing the
  grid↔anode distance
  → better energy resolution

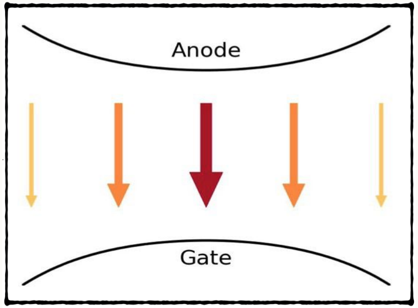
- Optical transparency as close as possible to that of parallel wires

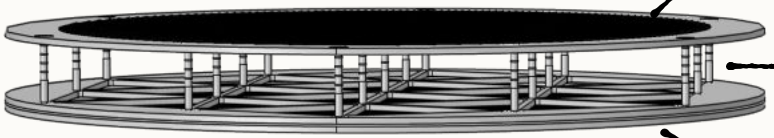
- More uniform signal response over x, y





floating electrode with supporting pillars

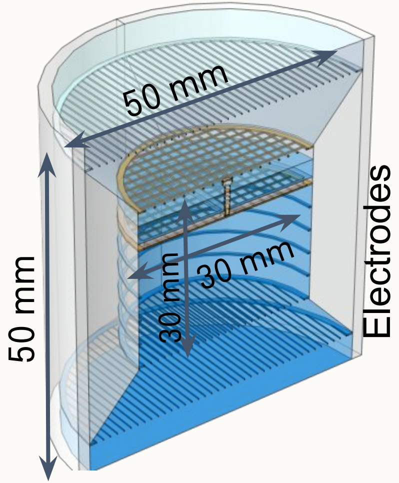




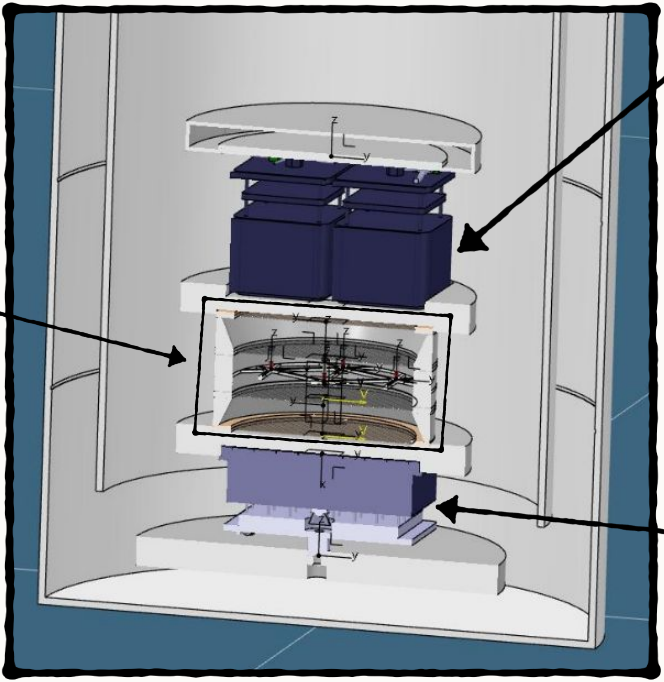
Sagging
Electrostatic force (dominant)
Gravitational force (~ O(1) lower)

TPC under development

Small-size TPC prototype to test the performance of novel electrode with support pillar



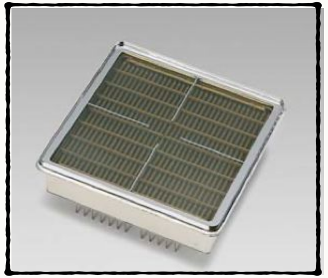
Electrostatic and further mechanic simulation with COMSOL and Ansys



Top PMTs array

Hamamatsu R8520-406
Effective area : 20.5 x 20.5 mm

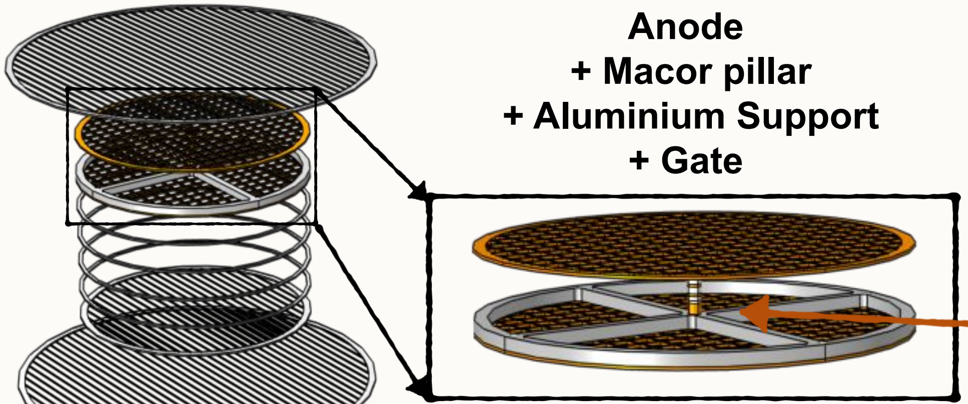
Bottom PMT



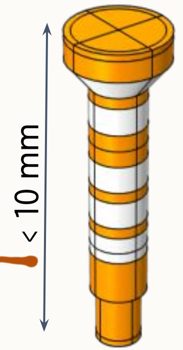
Hamamatsu R12699-406-M4
2 x 2 multianode
Effective area : 48.5 x 48.5 mm

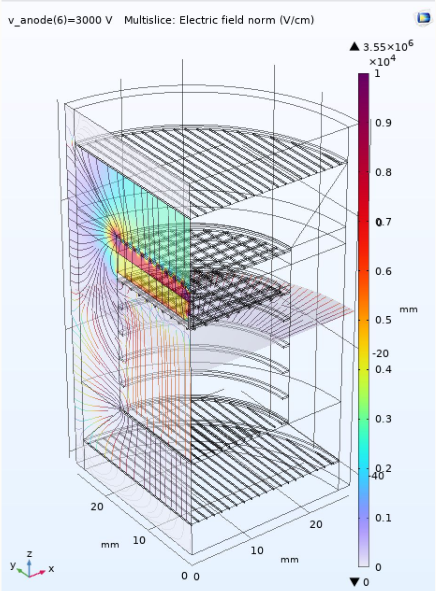
Design of electrodes

Anode
+ Macor pillar
+ Aluminium Support
+ Gate



Novel electrodes



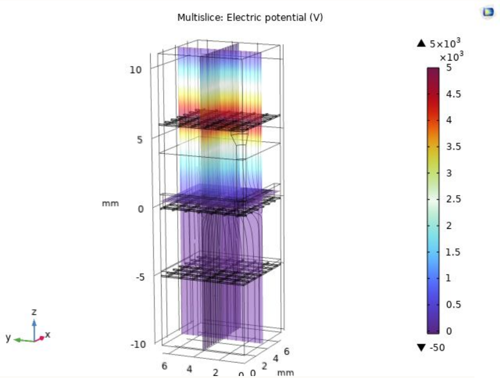


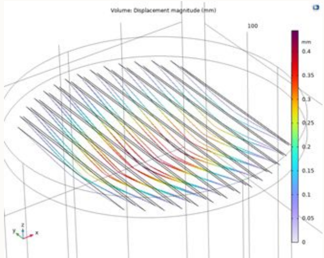
TPC electrodes	Type	Material	Wire diameter	Wire pitch	Transparency	z-Position	Electric potential
Top screen	Parallel wires	Stainless steel	0.05 mm	1.25 mm	96%	10 mm	0 V
Anode [Gantois]	Woven mesh	Stainless steel	0.236 mm	1.736 mm	75%	0 mm	3000 V
Gate [Gantois]	Woven mesh	Stainless steel	0.236 mm	1.736 mm	75%	-6 mm	0 V
Cathode	Parallel wires	Stainless steel	0.05 mm	1.25 mm	96%	-26 mm	-100 V
Bottom screen	Parallel wires	Stainless steel	0.05 mm	1.25 mm	96%	-36 mm	0 V

Design of electrodes

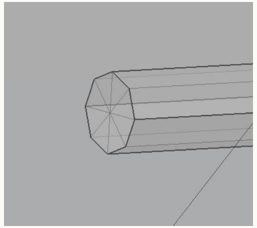
Modeling challenges :

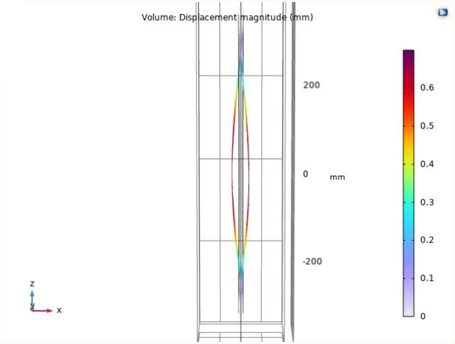
- Integrate technical feedback from XENONnt to optimize XeLab
- Make coupled modeling Electrostatic / Mechanical : Balance between electrostatics / Gravity / Archimede / mechanics
- Electrons Tracks to LXe/Gxe interface.
- Wires = Small Structures in Wide volume, multiscale approach FEM/BEM approach : need for HPC resources

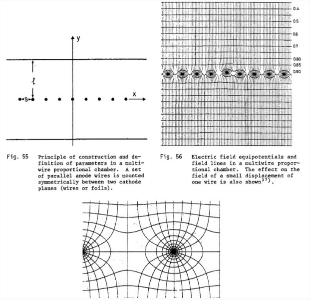


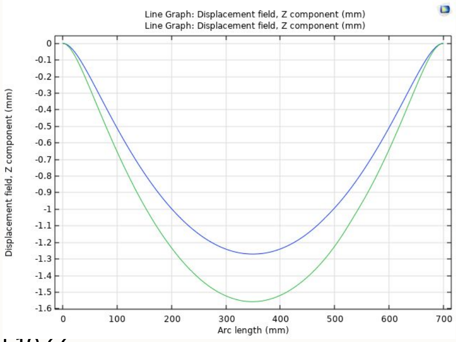


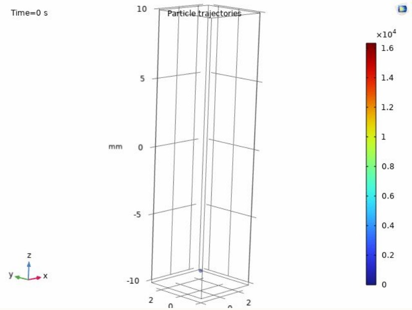
Sagging model









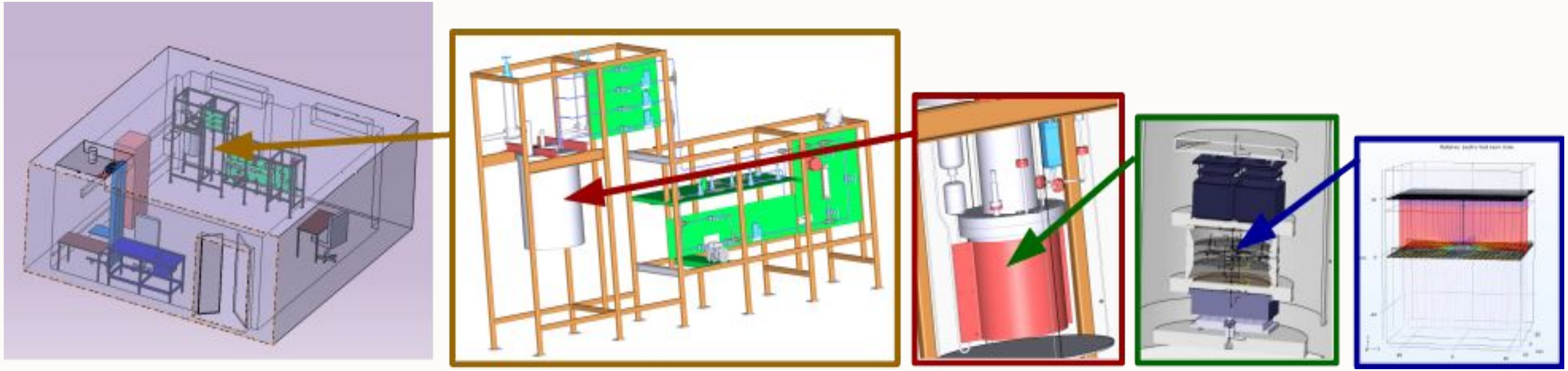


Electron Drift Model in LXe

Back to simple Physics , F. SAULI, CERN 1977

Installation in LPNHE

Dedicated direct line with a 15k liters nitrogen reservoir from Sorbonne, Jussieu

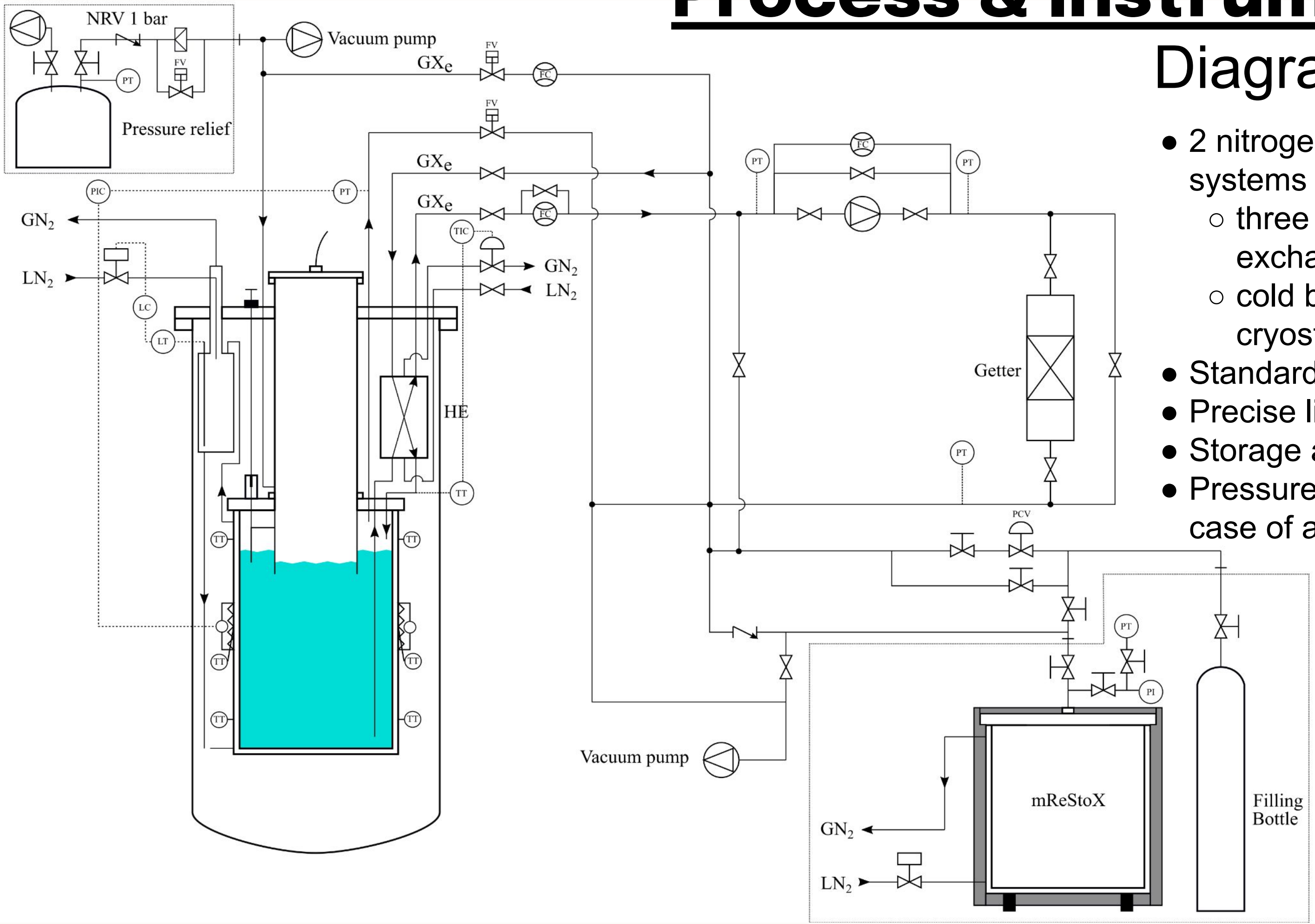


Campus Jussieu, LPNHE, Salle 12-13-SS03

Designed by LPNHE and under construction by DATE company

Under design by Subatech

Process & Instrumentation Diagram (P&ID)



- 2 nitrogen-based cooling systems
  - three phases heat exchanger
  - cold belt around inner cryostat
- Standard purification
- Precise liquid level tuning
- Storage and recovery system
- Pressure release system in case of accident

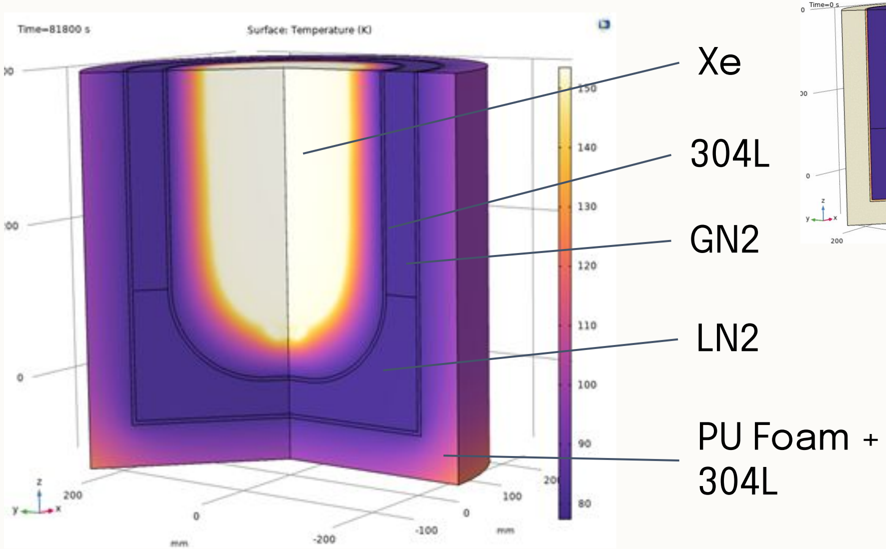
Slow Control.... ...and DAQ systems

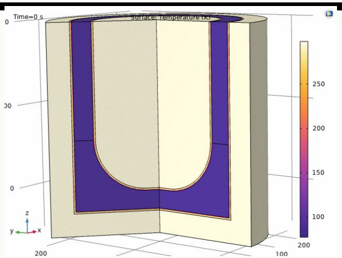
REVOLUTION PI

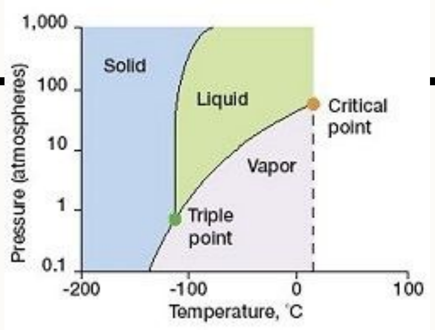
- Open source software
- International standard with CODESYS
- Robust and reliable for monitoring and alarms.
- Monitoring through Grafana

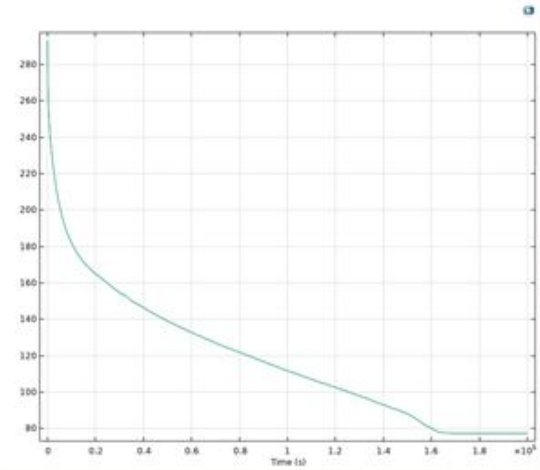
- CAEN V1720 digitizer (8 channels, 12 bits, 250 MS/s)
- HV power generator at 8kV
- System similar to XENONnT one
- Hence, similar data acquisition software and data processing tools

CryoPumping : mResToX







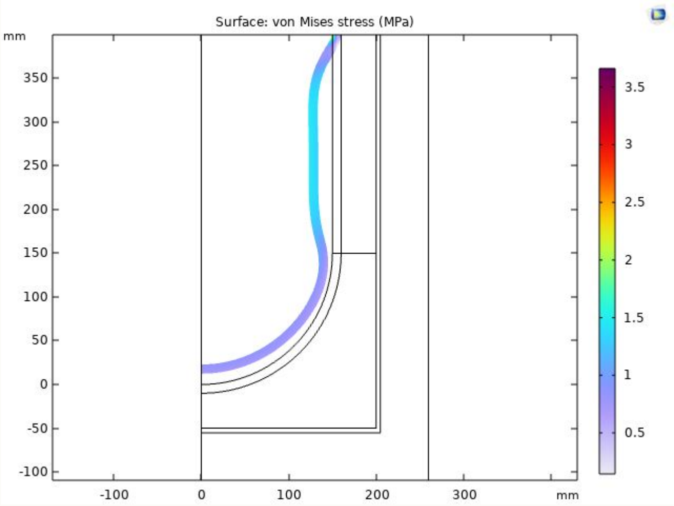


- Use LN2 supply to cryo-pump Xenon, 10Kg
- LN2 level control.
- Phase Change Gas/Solid
- Material Choice : 304L, Ti, insulator…
- Optimization with Comsol: Thermal/mechanics

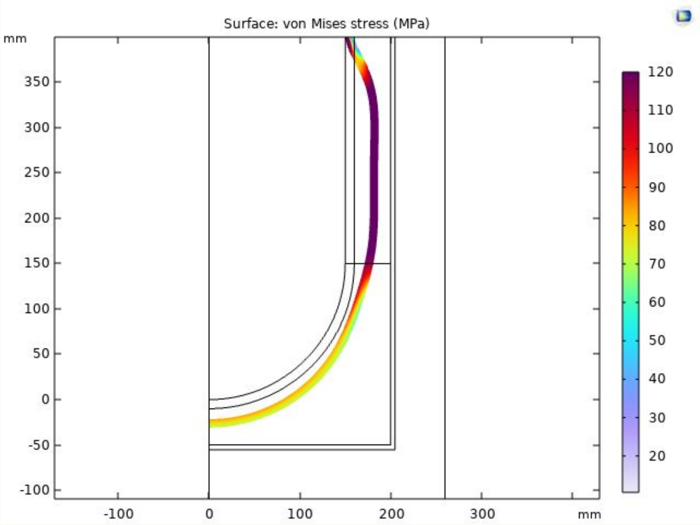
Necessary Cryo-pumping Time : 48h

CryoPumping : mResToX

- CryoTank must hold vacuum and pressure



Under vacuum (line purge)



Under 100 bar pressure, in case of LN2 loss.
Xe Pressure (10Kg, 30°C, 0.025m3): 70bars

⇨ We started prospecting for a supplier with PED integrated certification.

Conclusions and next steps

First double phase LXe TPC in France for R&T

- A clear roadmap for forthcoming 2-3 years (electrodes, single electrons), contribution on DARWIN R&D
- Several side-projects on technology : cryogenics, Slow Control, electrodes, computing.
- Funding secured, equipment mostly purchased (IN2P3, LPNHE, Subatech)

- Installation of the cryogenic system by end of the year
- 1st milestone : TPC operative by summer 2023
- 2nd milestone : first results by end of 2023

Thanks!

Do you have any questions?