

A background image showing a complex network of glowing orange and yellow lines and dots on the left, transitioning into a colorful nebula of purple, pink, and green on the right, set against a dark starry space background.

Sonder les infinis : des particules au cosmos

Scientific Council of Subatech CSS n.4

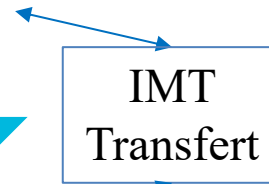
Le 16 & 17 March 2023

Amphi Kastler, Campus de Nantes d'IMT Atlantique

# Subatech in few words



**IMT Atlantique**  
Bretagne-Pays de la Loire  
École Mines-Télécom



UMR 6457 (since 1994)  
Located at IMT Atlantique  
Campus de Nantes

On March 7<sup>th</sup> 2023

204 staff

62 C & EC (24 CNRS, 21 IMT Atlantique (2 ICO), 17 NU, among them 4 Emerita)

77 IT (48 CNRS, 8 IMT Atlantique, 9 IMT Transfert, 4 NU, 9 CDD )

20 post-docs, 45 PhD students



# Human Resources 2022/2023 : leaving

## Permanent positions

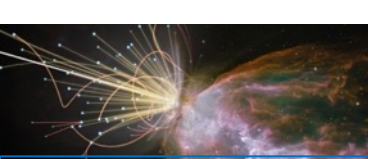
- Jean Pierre CUSSONNEAU, MC IMT Atlantique, Xenon team, deceased on April 2022
- Michael BAILLY, IT CNRS, Smart, left on June 2022
- Elisabeth LYS, MCF IMT Atlantique, Prisma team, left on September 2022
- Marcel MOKILI, IT Armines, Smart, retired on December 2022
- Jérôme PINOT, IT CNRS, Computing service, left on February 2023
- Hervé CARDUNER, IT CNRS, Mechanics service, deceased on February 2023
- Gurvan ROUSSEAU, IT IMT Transfert, Smart, left on February 2023
- Vanessa PAGANO, IT IMT Transfert, Smart, left on February 2023



# Human Resources 2022/2023 : coming

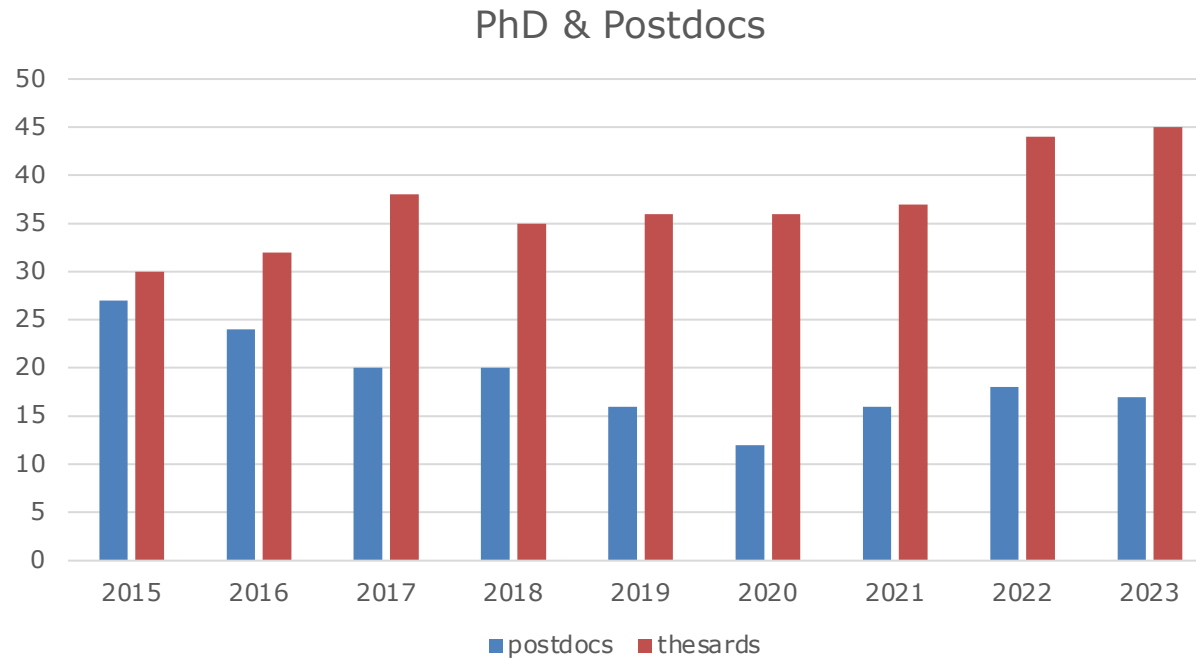
## Permanent positions

- Paul CAUCAL, MCF Nantes Université, Théorie team, September 2022
- Valetin DECOENE, MCF Nantes Université, Neutrino team, September 2022
- Catherine LEBEAU, IT CNRS, Radiochemistry team
- Nicolas BEAUPERE, MCF IMT Atlantique, Xenon Team, November 2022
- Théo BIGOURDAN, IT CNRS, Mechanical service, January 2023
- Myriam LEFERREC, IT IMT Transfert, SMART, January 2023
- Gregory DELPON (ICO), associated researcher IMT, Prisma team, 2022
- Sophie CHIAVASSA (ICO), associated researcher IMT, Prisma team, 2022

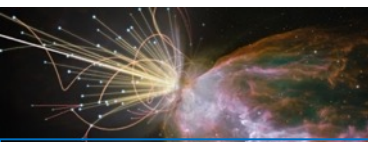


# Human Resources 2022/2023

## Postdocs and PhDs



- 45 PhD students at Subatech
- 16 PhD recruitments in 2022/2023



# Human Resources 2023/2024: Future

## Permanent positions

- Position IR CNRS, Electronic service (to be confirmed)
- Position IR CNRS, instrumentation and detection (to be confirmed)
- 1 FSEP IE CNRS , Computing service (to be confirmed)
- Position IE NOEMI, Radiochemistry team (to be confirmed)
- Position IE NOEMI, Computing service (to be confirmed)
- Position MCF IMT Atlantique, Molecular modelisation, Radiochemistry team in September 2023
- Positions MCF Nantes Université, Radiochemistry team in September 2023
- Position Professor Nuclear Physics, SEN team, in September 2023



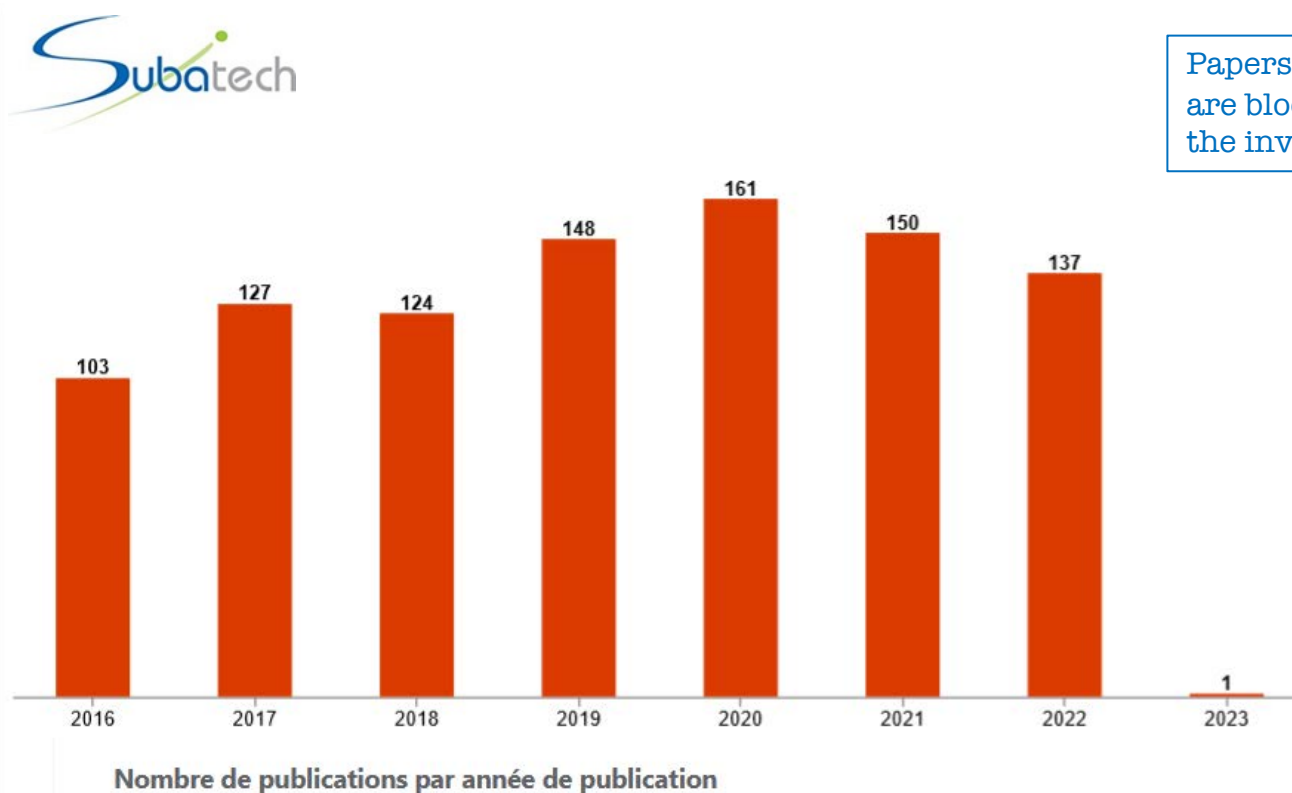
# CPER 2022-2027

- CPER 2021-2027 “ECL CONTA CONTI”
  - Submitted (Nantes Université) de 1.2M€
  - 210 k€ équipement for Radiochemistry team,
  - Equipement ICP-MS 3Q (metal analysis)
  - Since September 2022
  
- CPER 2021-2027 “SMILES”
  - Submitted by Subatech (IMT Atlantique de 1.950 M€)
  - PdL 300 k€, Etat 350 k€, Nantes Métropole 310 k€, FEDER 780 k€, CNRS 200 k€
  - Conception and construction of SMILES 1.2 M€
  - New building extension (Hall G) 750 k€
  - Since September 2022 (started by Subatech in 2021 50 k€)



# Subatech scientific publications

LODEX IN2P3 : <https://bibliometricdb-1.in2p3.lodex.fr/> Mathieu Grivès IN2P3 (mathieu.grives@cnrs.fr)

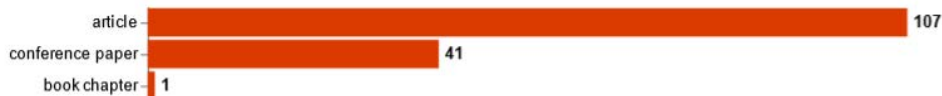


Papers from CERN (LHC, thus ALICE) are blocked since March 2022 due to the invasion of Ukraine)

Proceedings in 2022 are (of course) still low

Type de document

2019



Nombre de publications par type de document

Type de document

2022



Nombre de publications par type de document

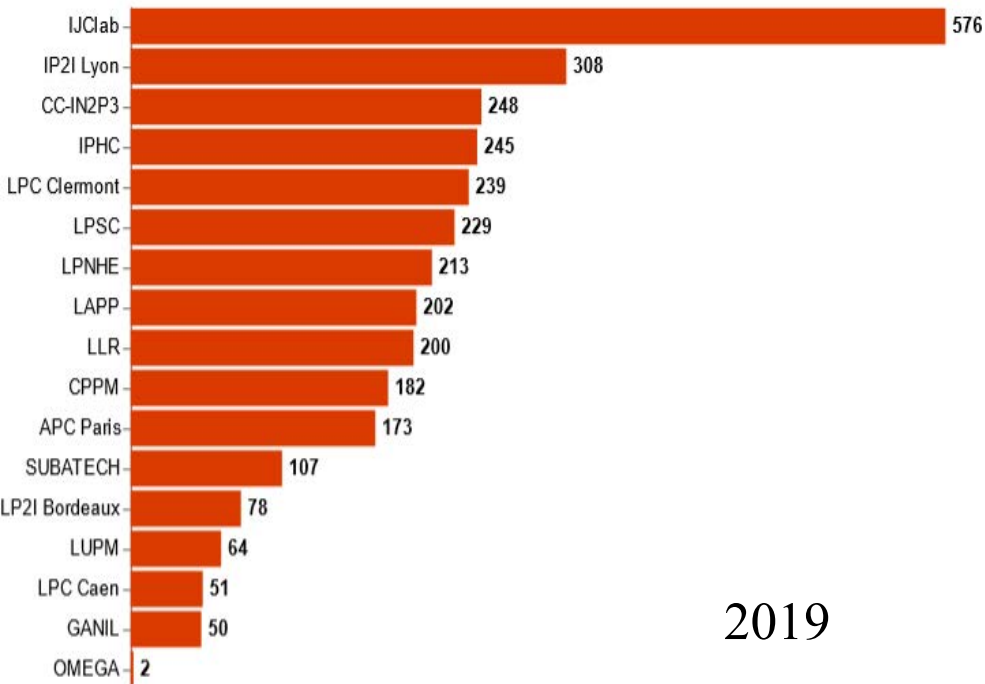




# Production Scientifique IN2P3

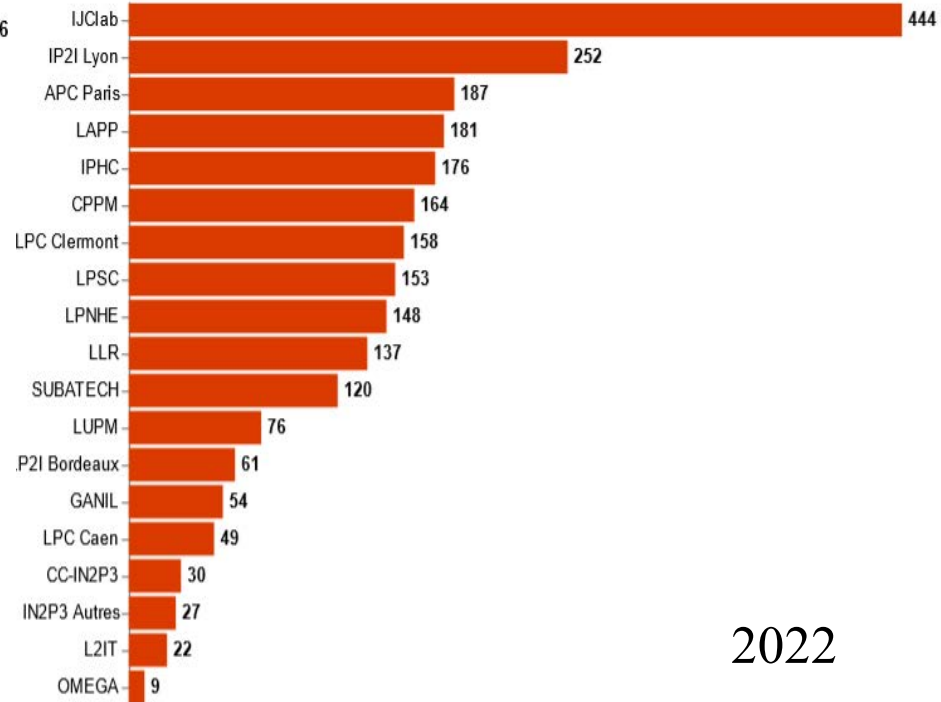
LODEX IN2P3 : <https://bibliometricdb-1.in2p3.lodex.fr/>

Labos IN2P3



2019

Labos IN2P3



2022

Type of document : « articles »  
 « article » = nearly « peer-review »



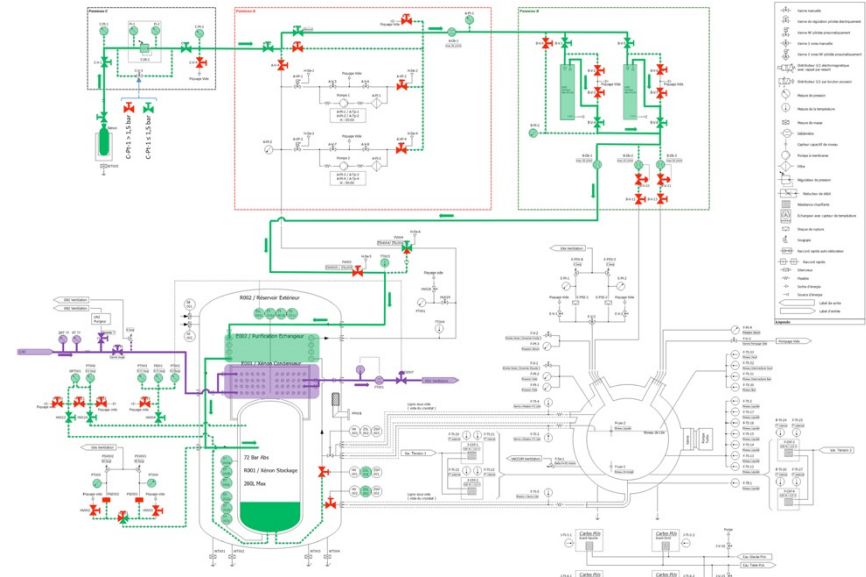
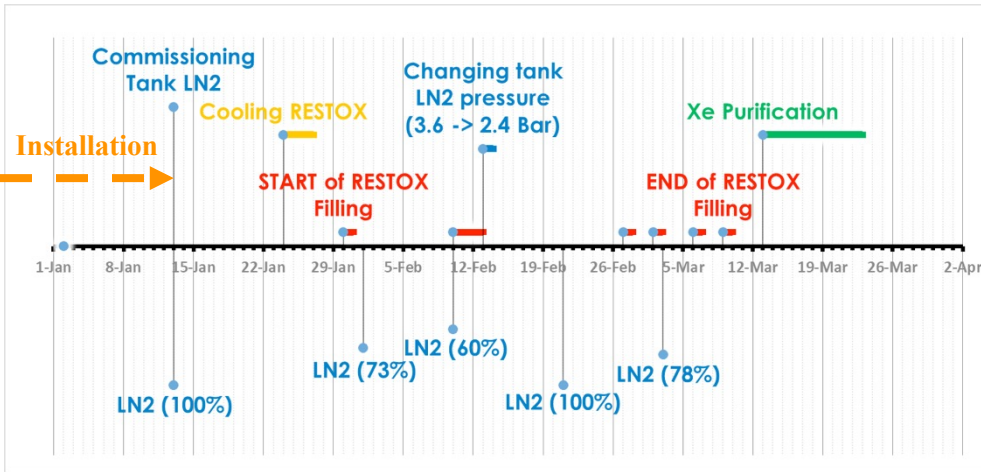
# Xemis2 Compton telescope

- XEMIS2 : presented in 2020 at CSS-Subatech
- Since CSS 2020 : Project reviews (Subatech direction), 3 per year
- Status: commissioning
  - Cryogenics and purification: operational
  - DAQ and electronics: under development, Half installed
  - Mechanics, installation: Being integrated
  - Computing, calibration and processing: under development
- Equipment fully purchased, intensive and excellent work done by Subatech services
- Currently, final assembling and installation at Nantes Hospital

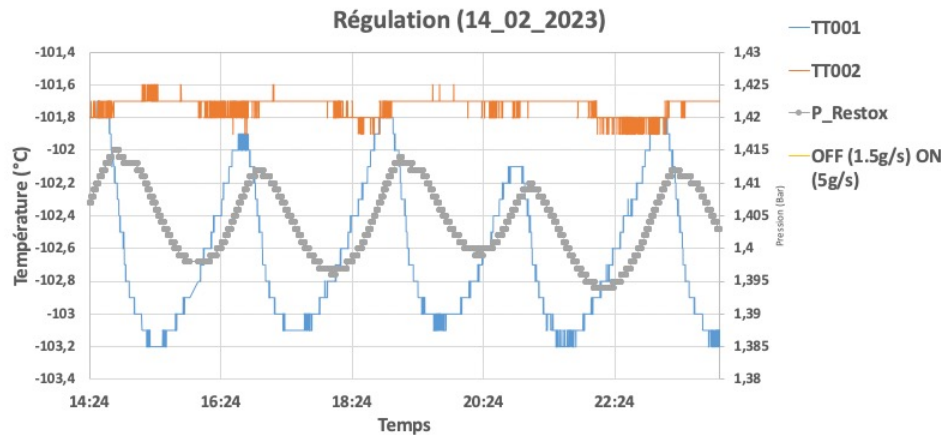
**At 6 months from the beginning of data taking!**



# Xemis2 : cryogenics and purification



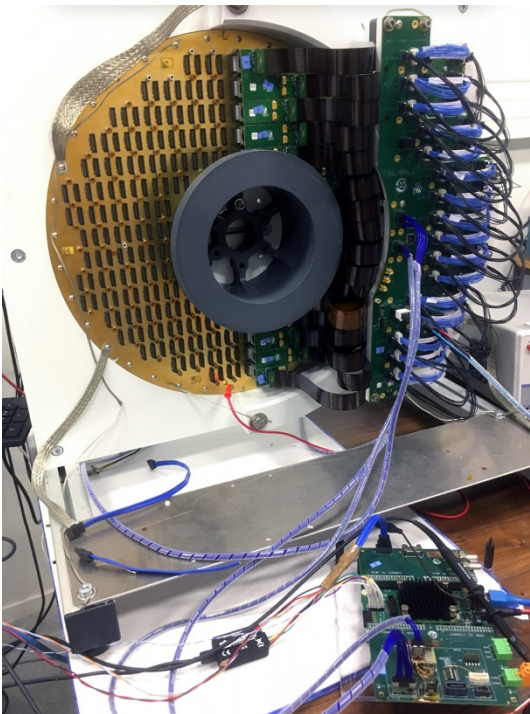
- 95% commissioned
- fine tuning under optimization to reach mbar pressure regulation
- **No Shift needed on XEMIS2 ...**





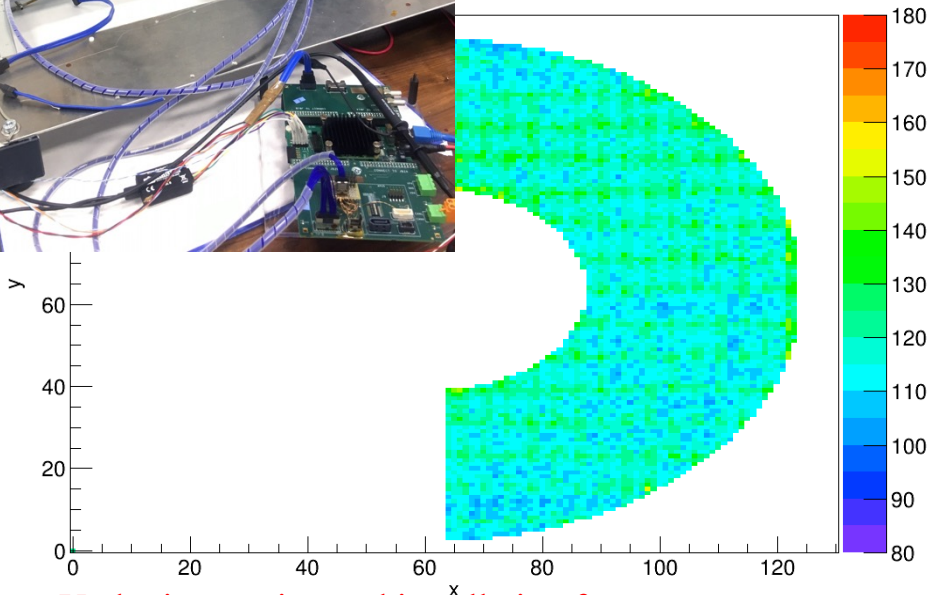
# Xemis2: Electronics

## Asics electronics for charge (20000 pixels)



Commissioning of  
4 x 5000 charge electronics  
from pixel to disc  
at Room Temperature

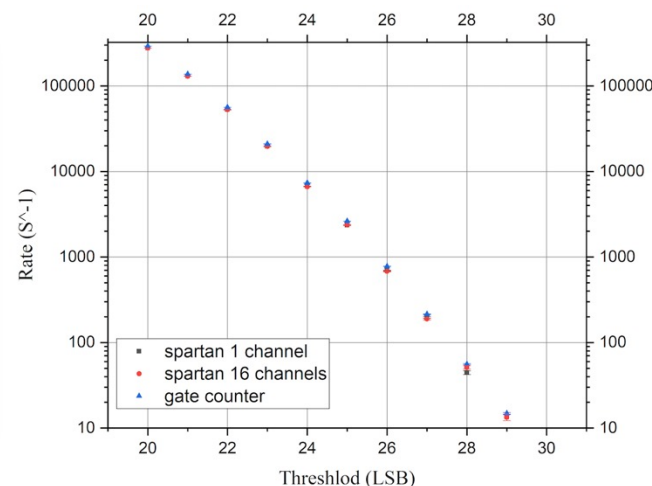
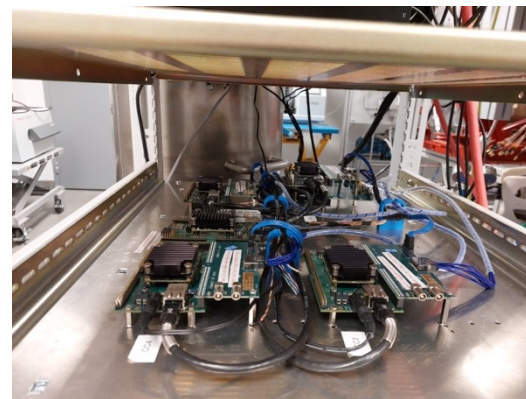
No dead channel  
Noise close to 120e RMS  
3000 signals/s/pixel on disc



Under integration and installation for  
commissioning at CHU with LXe

**15 keV  $E_{er}$  threshold self-trigger achievable**

## Discrete electronics for light (64 PMTs)

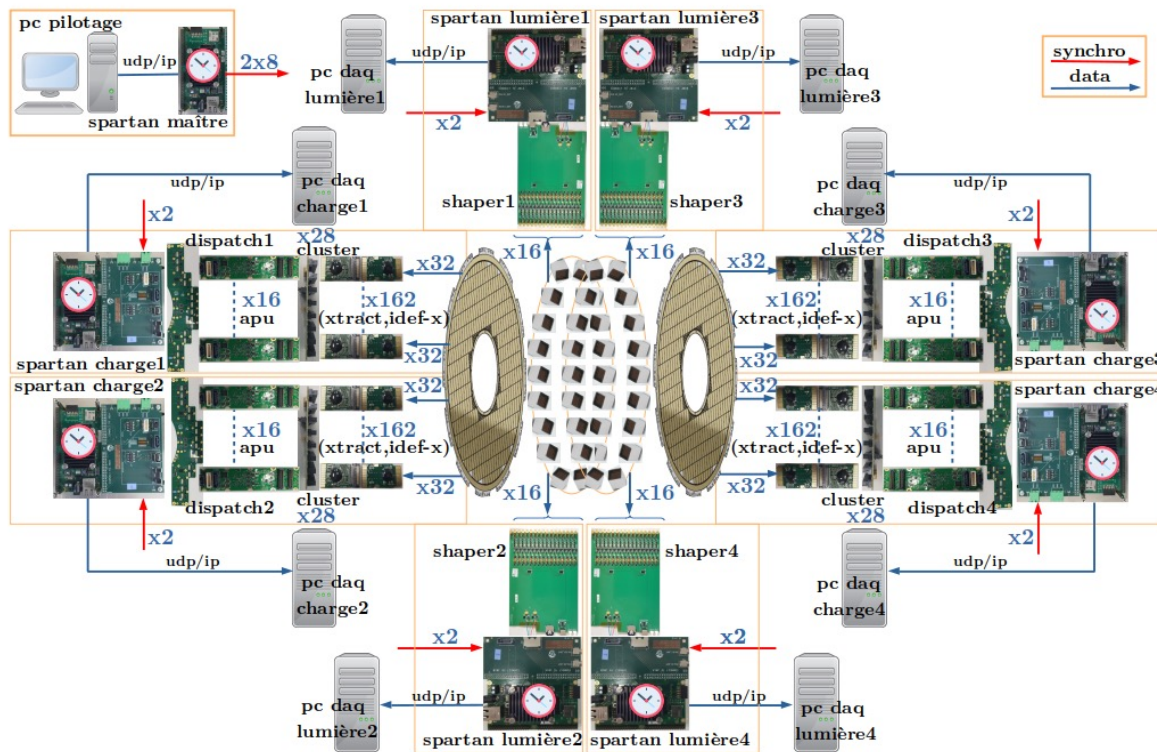


**Up to  $10^6$  S1/s/PMT on disk**

Installation completed at CHU  
**Commissioning of the calibration  
under progress**



# Xemis2 : DAQ



**Synchronization with  
200 MHz clock  
No external trigger**

**Light signal:**  
leading edge and TOT up to  
1 Mevts/s per channel on  
64 self-triggered channels

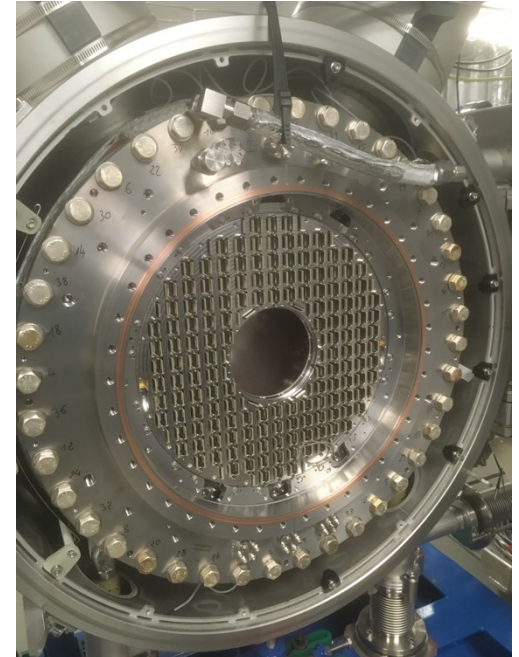
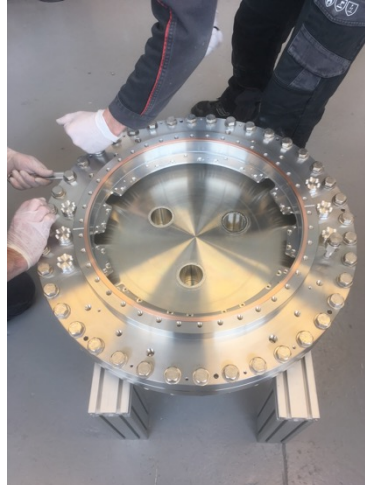
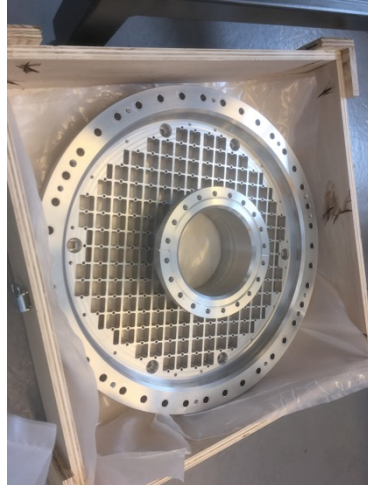
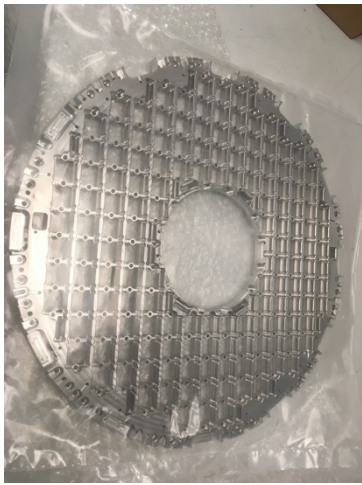
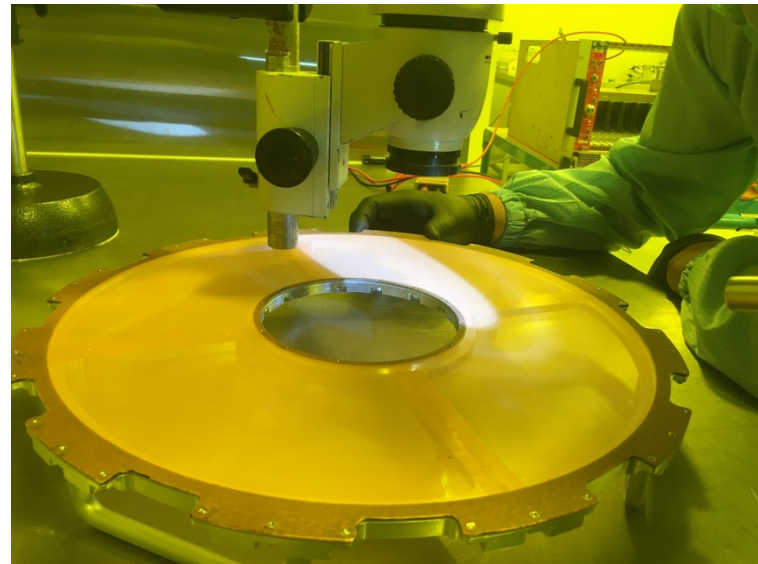
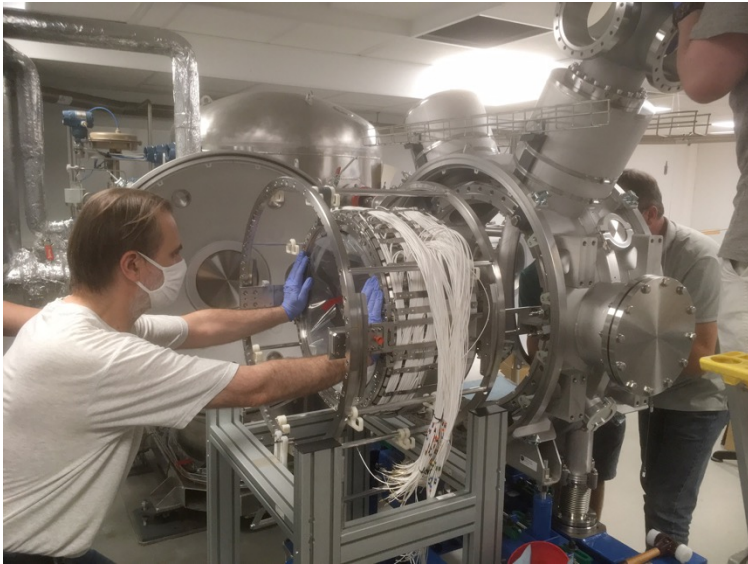
**Charge signal:**  
time and amplitude up to  
3 kevt/s per channel on  
20k self-triggered channels

**High data flow rate and transfer:  
0.5 To raw data expected on disk per 20 minutes image**

**DAQ commissioning : on progress**

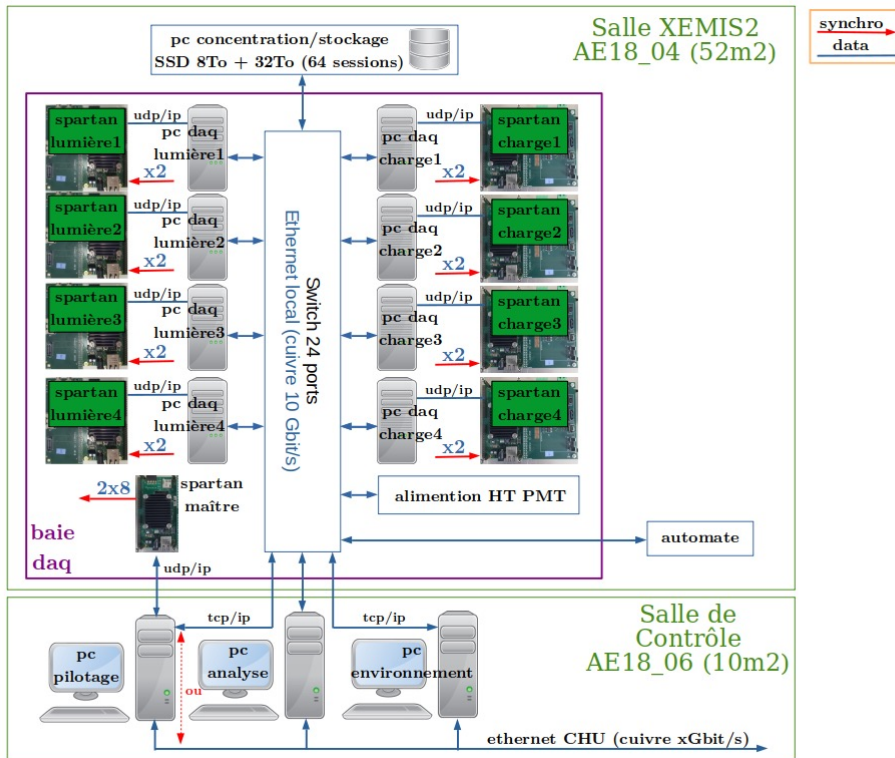


# Xemis2 : mechanics and installation



- 66 % installed, electronics and  $\mu$ meshes already tested in air

# Xemis2 : computing and processing



- Installation in progress with first calibration and data, foreseen to be fully operational in a few months



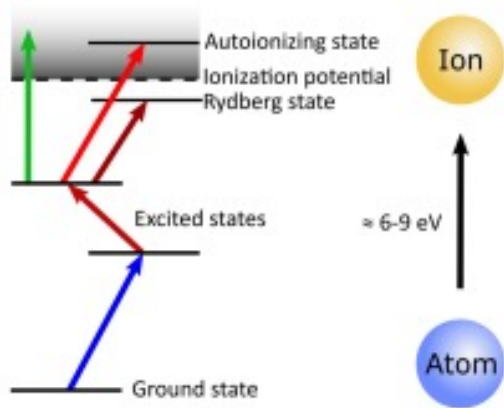
**Most of the camera should be installed for XESAT2023 (June)**

**You are welcome to register and to make XEMIS2's visit at CHU during social events**



# SMILES Project (I)

- SMILES : *Séparation en Masse couplée à l'Ionisation Laser pour des applications Environnementales et en Santé*



**Multi step  
Selective  
Ionization  
(laser)**

**Mass Separation  
(magnetic / TOF)**



61Zn 89.1 s $\epsilon = 100.00\%$	62Zn 9.186 h $\epsilon = 100.00\%$	63Zn 38.47 min $\epsilon = 100.00\%$	64Zn 243.53 d $\epsilon = 100.00\%$	66Zn STABLE 4.04%		
60Cu 23.7 min $\epsilon = 100.00\%$	61Cu 3.339 h $\epsilon = 100.00\%$	62Cu 9.673 min $\epsilon = 100.00\%$	63Cu STABLE 69.15%	64Cu 12.701 h $\epsilon = 61.50\%$ $\beta^- = 38.50\%$	65Cu STABLE 30.85%	66Cu 5.120 min $\beta^- = 100.00\%$
59Ni 7.66·4 y $\epsilon = 100.00\%$	60Ni STABLE 26.223%	61Ni STABLE 1.1399%	62Ni STABLE 3.6346%	63Ni 92.41 y $\beta^- = 100.00\%$	64Ni STABLE 0.9255%	65Ni 2.5175 h $\beta^- = 100.00\%$
58Co 70.86 d $\epsilon = 100.00\%$	59Co STABLE 100%	60Co 5.27 y $\beta^- = 100.00\%$	61Co 1.649 h $\beta^- = 100.00\%$	62Co 1.50 min $\beta^- = 100.00\%$	63Co 27.4 s $\beta^- = 100.00\%$	64Co 0.30 s $\beta^- = 100.00\%$
57Fe STABLE 2.119%	58Fe STABLE 0.282%	59Fe 44.495 d $\beta^- = 100.00\%$	60Fe 2.621·6 y $\beta^- = 100.00\%$	61Fe 5.38 min $\beta^- = 100.00\%$	62Fe 68 s $\beta^- = 100.00\%$	63Fe 6.1 s $\beta^- = 100.00\%$

Two operating modes :

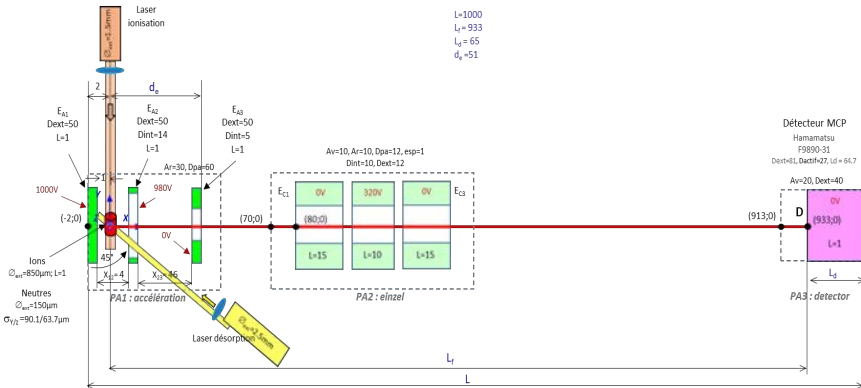
- Analytic measurement of isotopic ratios
- Isotopic Separation and Purification



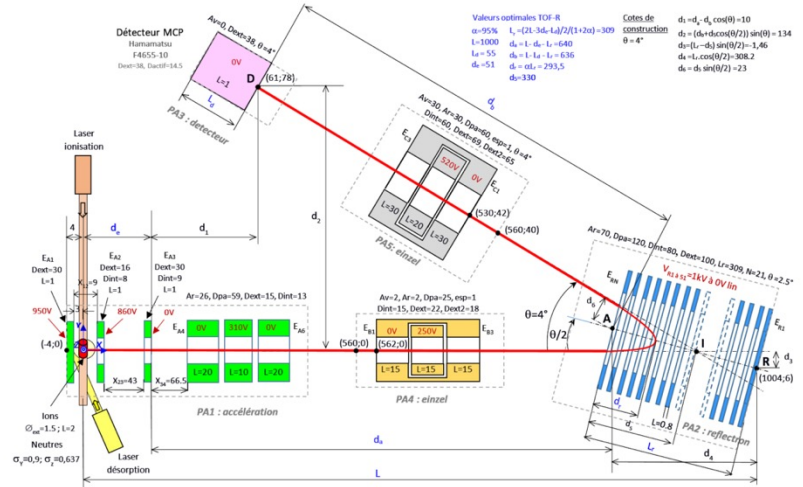


# SMILES (II)

## 1. Linear TOF



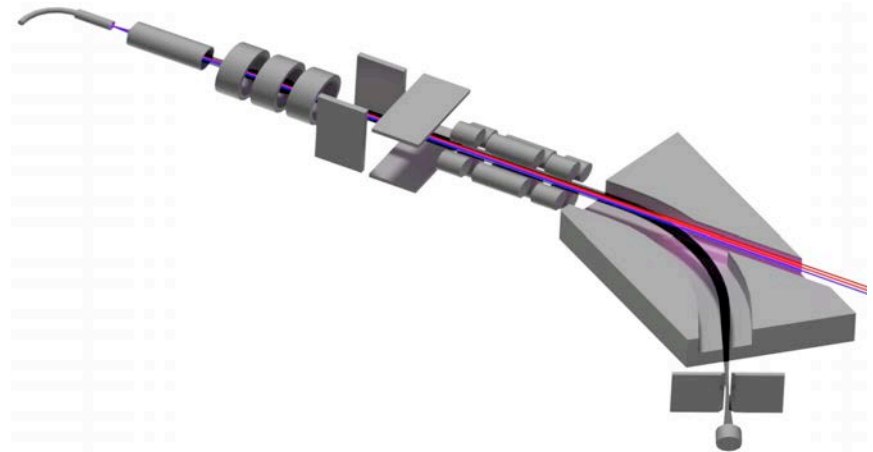
## 2. Reflectron TOF



## Développement en 3 phases

- Linear TOF (2022-2024)
- Reflectron TOF (2024-2026)
- Mass separator (2026-2028)

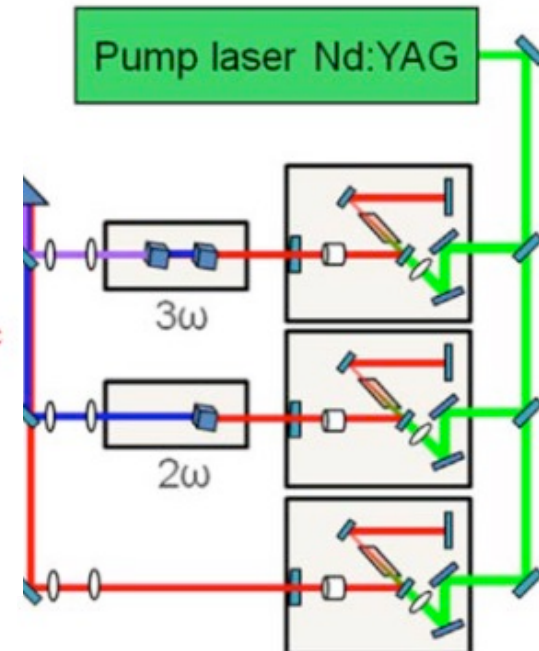
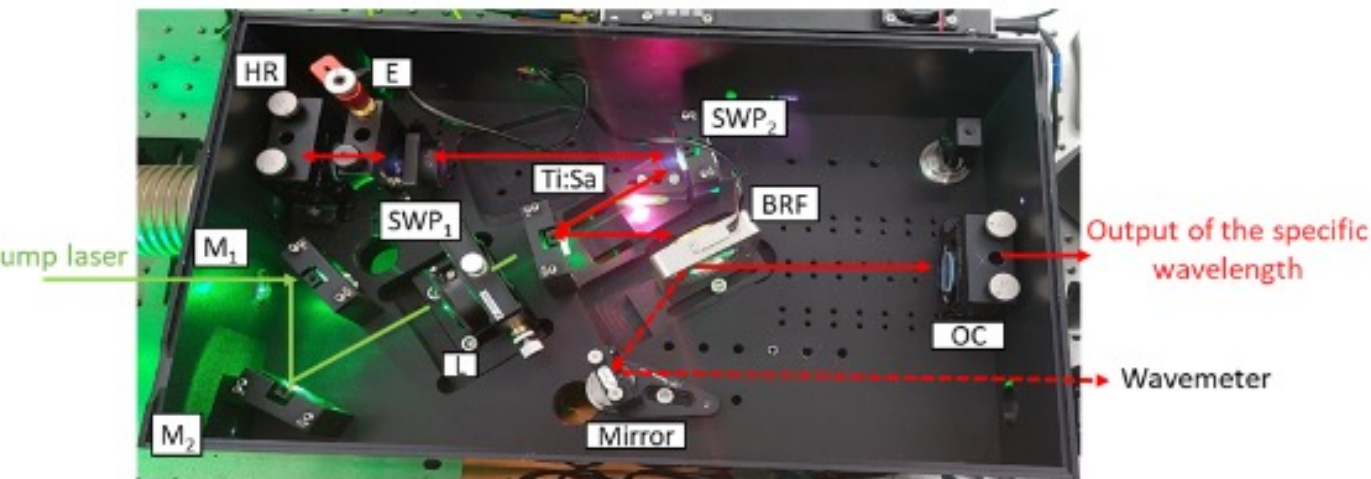
## 3. Mass separator





# SMILES (III)

- CPER 2021-2027 SMILES
  - 1,2 M€ (equipment) + 750k€ (SMILES building)
- Additional two post-doc positions (IMT Atlantique, Subatech)
- Project structure defined (organisation, work packages, produc breakdown, risk analysis, budget, TDR draft, etc ...)
- External Expert Committee : T. Cocolios (Leuven), C. Focsa (Lille), N. Lescene, (Ganil) T. Bertrand (LP2I Bordeaux) and K. Wendt (Mayence)
- 1st review on March 7<sup>th</sup> 2023 on laser system

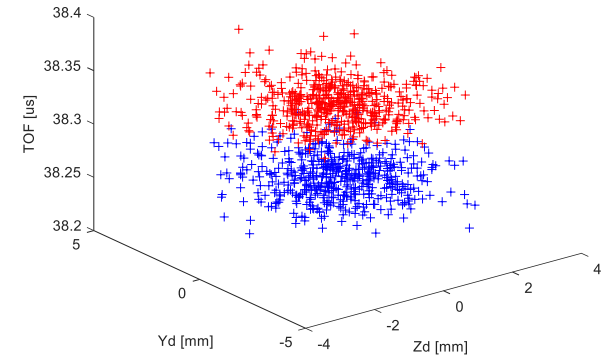
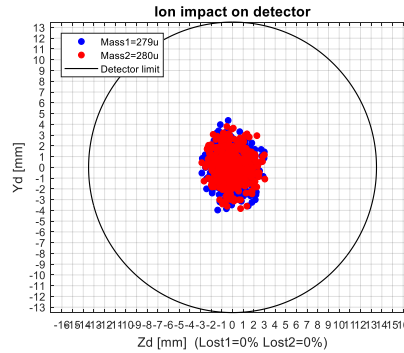
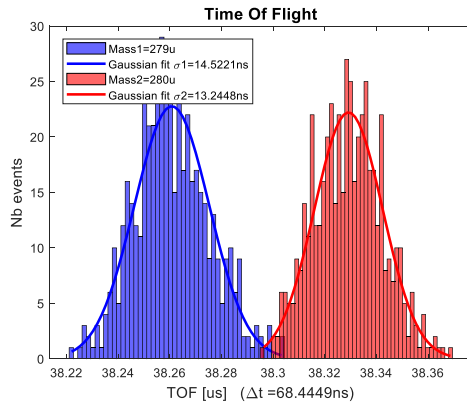




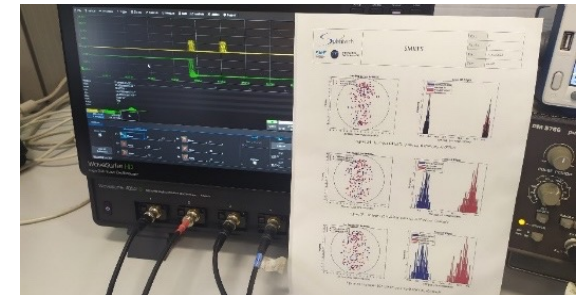
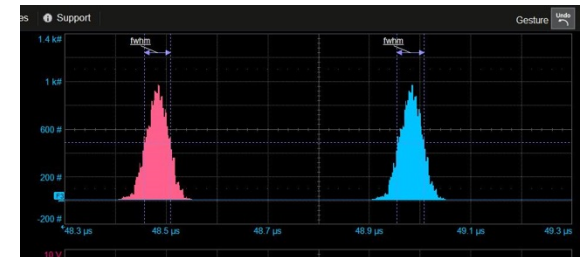
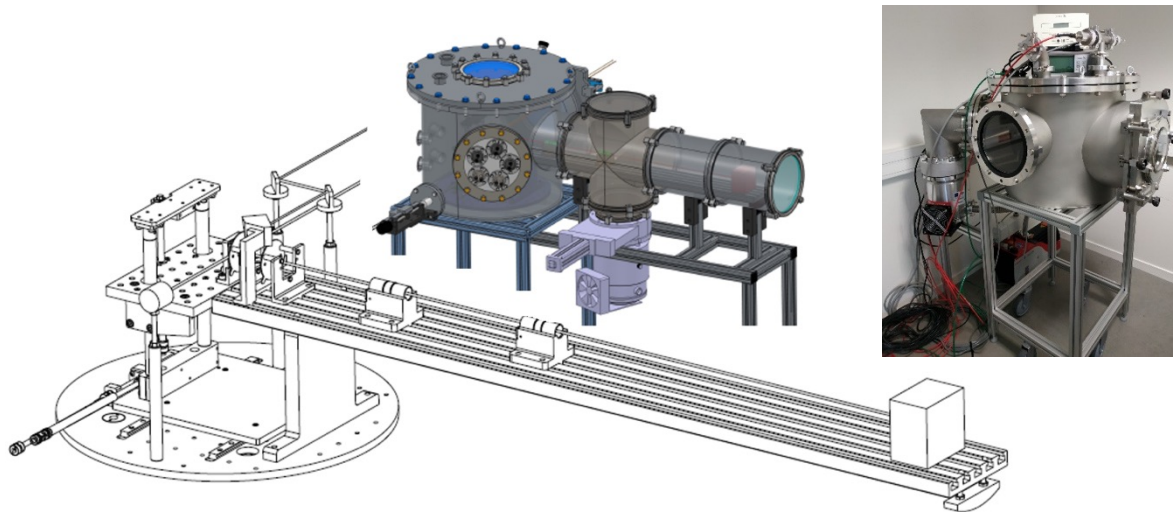
# SMILES (IV)

## Simulation of the linear TOF (and Réflectron)

K. Kamalakannan et al., ARCEBS 2023

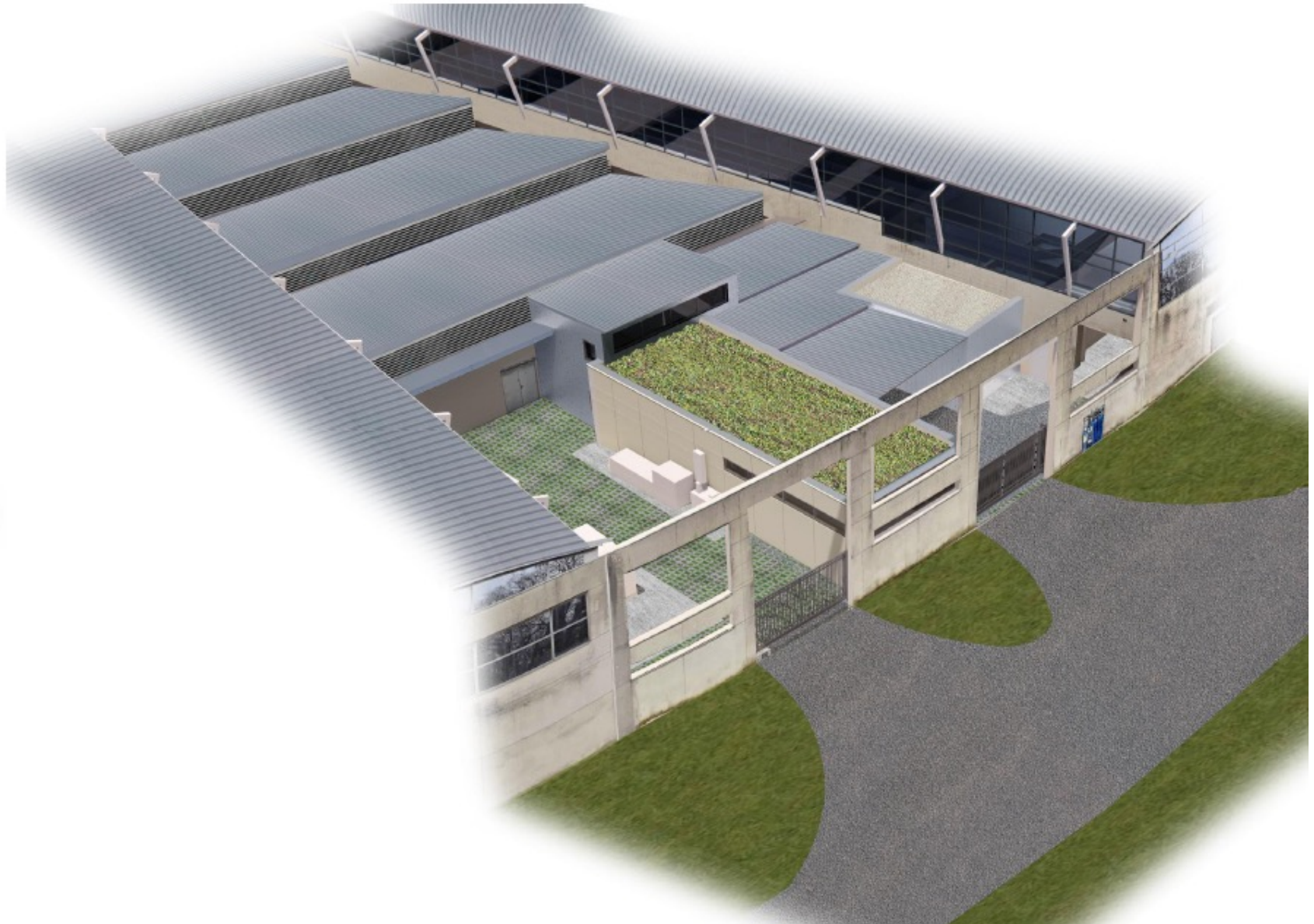


## ○ Mechanics and electronics design



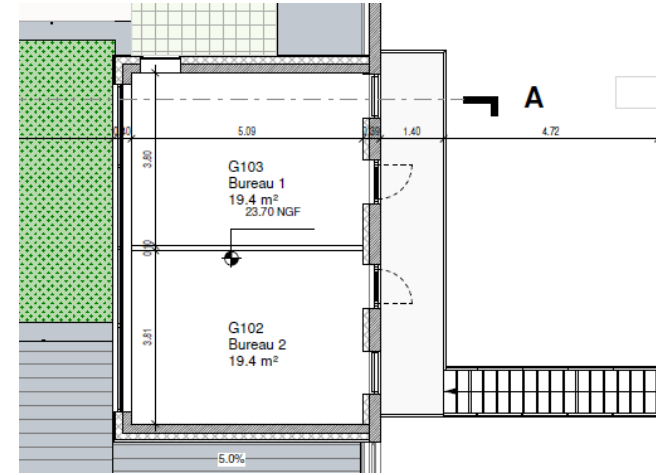
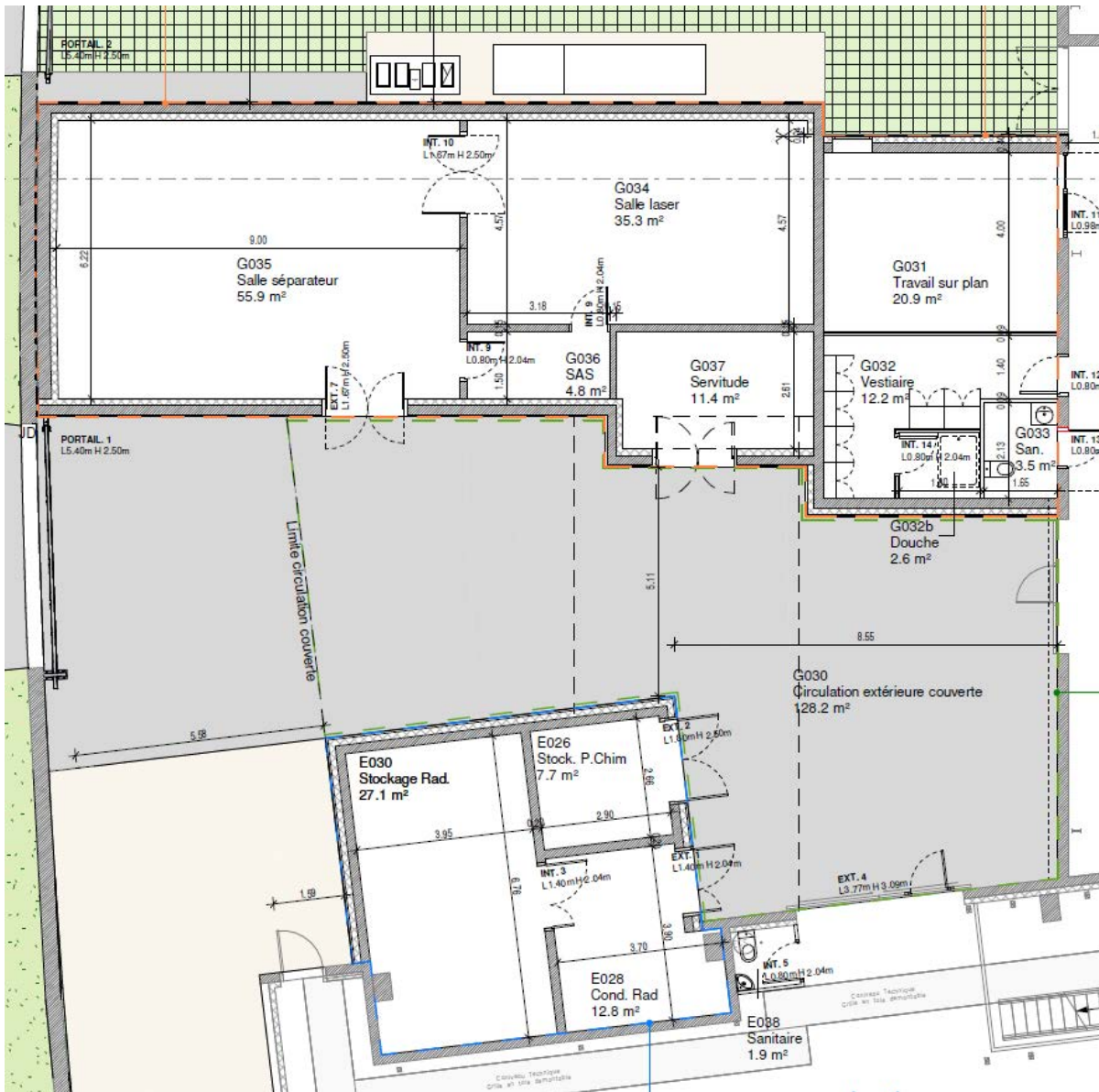


# SMILES building : Extension Hall G (I)





# SMILES Building : Extension Hall G (II)



1st floor ↑

← Ground floor



# LiquidO Project : AM-OTTECH

European  
Innovation  
Council



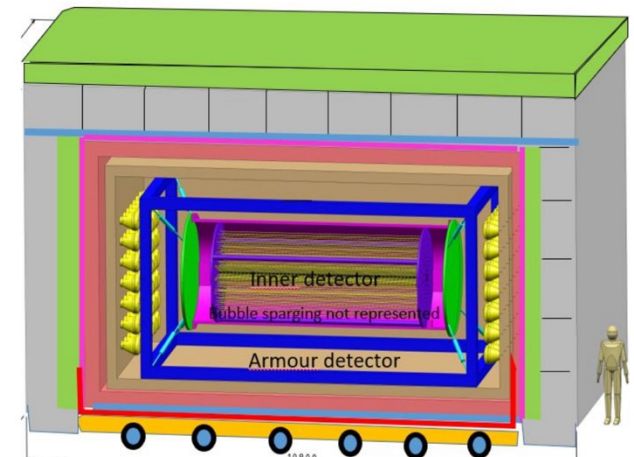
- EIC-PATHFINDER (Horizon Europe 2021-2027) AntiMatter-OTTECH (2022-2026)

- Novel Opaque Scintillator Technology for Nuclear Industry, Imaging based on Anti-Matter Detection
- Coordination IJCLAB, Co-coordination SUBATECH avec EDF, CIEMAT Madrid, University of Mainz, University of Sussex
- Nuclear reactor neutrino control
- Large scale prototype based on LiquidO Technology



- Scientific Collaboration CLOUD (Fundamental research) in the context of AM-OTTECH EIC project

- Future project SuperChooz Pathfinder.





# SuperChooz Project



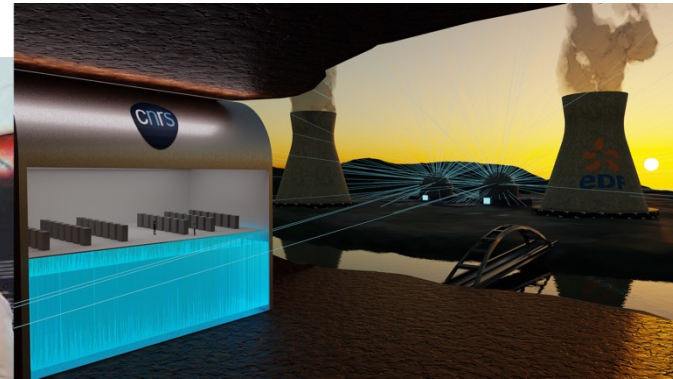
IN2P3 Les 2 infinis   
@IN2P3\_CNRS

...

## Projet SuperChooz @ Chooz

#Événement  | Le 7 sept. l'IN2P3 et @EDFofficiel ont signé l'accord exploratoire  pour tester la faisabilité d'un grand projet d'étude des #neutrinos installé sur le site de la #centrale @EDFchooz et doté d'une technologie de détection radicalement nouvelle : @LiquidODetector.

Translate Tweet



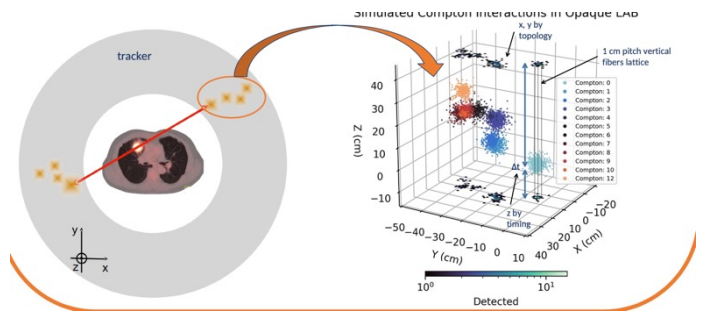


# LiquidO Project : ANR TEP-OTTECH



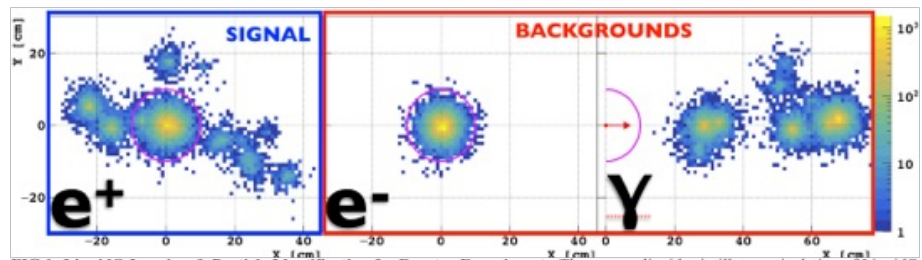
## Lancement ANR TEP-OTTECH (2022-2026)

- Démonstrateur TEP avec la technologie LiquidO
- Coordination IJCLAB, avec IPHC, LaTIM Brest, SUBATECH

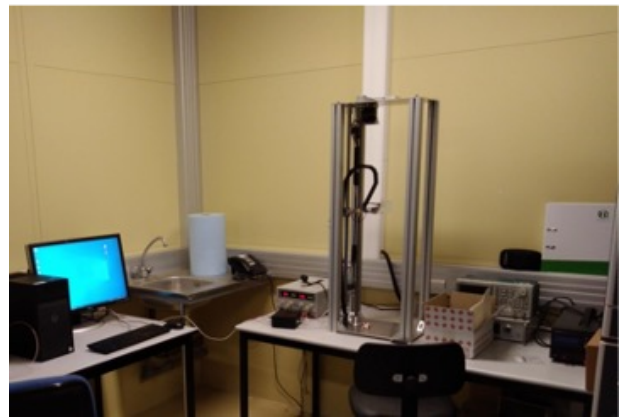


## R&D @SUBATECH: banc de Test LiquidO

- timing LiquidO + tests refroidissement



**FIG.1: LiquidO Imaging & Particle Identification for Reactor Experiments.** The opaque liquid scintillator articulation of LiquidO enables event-wise identification of the **signal** (a positron,  $e^+$ ) [blue] and the **backgrounds** (red), typically electrons ( $e^-$ ) and  $\gamma$ -rays, for reactor neutrino detection. The plots show the number of optical photons hit per fibre (z-axis) from the vertical projection (x-y position). The background rates and types are well known and can be controlled up to a few %<sup>2</sup>. The electron background arises from  $\beta^-$  decay (radiogenic or cosmogenic). Fast-neutrons normally look like electrons and are also rejected. The  $e^+$  annihilates via the emission of two back-to-back  $\gamma$ 's (511 keV of energy each) thus yielding a distinct pattern. The overall rejection factor has been estimated to be  $\geq 100\times^3$  relative to conventional technology<sup>7</sup>, including the improvement in the  $e^+$  to neutron space-time coincidence exploited in conventional detectors.







# Gender Balance Committee

- Created in 20199 and composed by 4 volunteers from the 3 partners (CNRS, IMT Atlantique, Nantes University).
- Actions of past year:
  - Participation to several working groups (WG) and formations organized by CNRS and Nantes University on several gender balance actions (careers' verification, prevention of sexual and gender based violence, improvement of personal vs working conditions)
  - Presentation of the harassment prevention unit of CNRS and Nantes University
  - Meeting with young women researchers (post-doc or PhD student at the last year) to encourage them to postulate to the CNRS concours
  - Communication through web page, mails, posters
- Foreseen for this year:
  - Continue the work with CNRS and Nantes University on gender balance WG
  - Laboratory gendered statistics
  - Organization of an awareness seminar on sexual and gender based violence
  - Communications to students of secondary school



# DDRS Committee (I)

- Carbon footprint estimate for 2019 and 2022 (work in progress) with the collaboration of bachelor students
- Presentation of the preliminary results for 2019 in an internal seminar
- Discussions of possible mitigation and reduction measures at the lab retreat in May 2022
- Presentation to middle school students visiting the lab on climate and the carbon footprint of research



# DDRS Committee (II)

- Awareness campaigns for the lab personnel on
  - Cycling to work (Mai à vélo challenge)
  - Possibility of carpooling
  - Energy savings (also related to the energy crisis)
  - Cyber World Clean Up day on the impact of remote storage (emails, cloud)
- Participation of J. Ghiglieri to the DDRS meetings of the CNRS (regional level) and IN2P3 DDRS representatives' network
- Participation of the directorate to a series of webinars targeted at CNRS lab directors
- Seminar in December 2022 on reforestation in tropical rainforests (central America)

# A Strategic Plan for French Nuclear, Particles and Astro-particles Physics in the 2030 horizon



Sonder les infinis : des particules au cosmos

[https://prospectives2020.in2p3.fr/wp-content/uploads/2023/01/FrenchRoadmap2030\\_NuclearParticleAstroparticlePhysics.pdf](https://prospectives2020.in2p3.fr/wp-content/uploads/2023/01/FrenchRoadmap2030_NuclearParticleAstroparticlePhysics.pdf)



# Major developments since 2013

Subatech in the 3/13 major developments since 2013 :

- Collective effects in heavy-ion collisions studying quark-gluon plasma physics have also been observed in the collisions of smaller systems and remains unexplained;
- our knowledge of the neutrino sector has greatly improved, notably with the measurement of the large neutrino mixing angle  $\theta_{13}$  and the first hint of CP violation paving the way to future tests of leptogenesis as the mechanism generating baryon asymmetry in the early Universe;
- An order of magnitude has been gained using underground detectors, on the cross-section upper-limit of WIMP dark matter particles interacting with ordinary matter.



# Science Drivers in the IN2P3

Subatech plans to be involved in 5 over 12 Science Drivers of the IN2P3 strategic plan :

5. Pursue the exploration of the nuclear matter phase diagram (Nuclear Matter)
7. Understand how nuclear processes shape the Universe (Nuclear Processes)
8. Use gravitational waves to explore the Universe and its fundamental laws (Gravitational Waves)
11. Explore further the physics associated with the properties of neutrinos (Neutrinos)
12. Identify the nature of dark matter (Dark Matter)



# Project Priorities for 2030 horizon (I)

Subatech plans to be involved in 9 over 25 project priorities of the IN2P3 strategic plan :

- Achieve a successful physics program on the study of QCD matter at the highest energies during Run 3 and 4 of the LHC.
- Pave the way for a strategic decision to be taken around 2025 concerning potential involvement in hadronic and hadron physics programs beyond 2030
- Complete the construction of the experimental installations S3, DESIR and NEWGAIN at GANIL as planned.
- Maintain continuous and adequate support to keep a competitive and successful GW antenna at EGO.
- Participate in the 3G GW interferometer development guided by the leveraging of French Virgo expertise and facilities.



## Project Priorities for 2030 horizon (II)

Subatech plans to be involved in 9 over 25 project priorities of the IN2P3 strategic plan :

- Support the high-energy multi-messengers approach to understand the High Energy Universe.
- Complete the KM3NeT/ORCA and JUNO experiments and prepare the determination of the neutrino mass ordering.
- Fully exploit DM physics and the NDBD potential of XENONnT.
- Develop a strategy for opportunities of a French participation in a next generation DM and NDBD experiment.





# Broader Impacts

Subatech has major contribution in subatomic research applied to energy, environment and health:

- Innovative nuclear reactor
- Study of nuclear materials
- Nuclear wastes
- Radionuclides in the environment
- Measurement of radioactivity in the environment
- XEMIS innovative camera based on Lxe
- Effect of irradiation on cells and animals
- Innovative radionuclides for health (diagnosis and therapy)

# Agenda CSS-4

16-17 March 2023, Nantes



Sonder les infinis : des particules au cosmos





# Team and service leaders

## Radiochemistry

CSS-1

Abdel ABDELOUAS  
RT Katy PERRIGAUD

## Xenon

CSS-1 (R2D2, Damic-M)  
CSS-2 (Xemis)

Dominique THERS

## Neutrino

CSS-1 (LiquidO)  
CSS-2

Frédéric YERMIA

## Prisma

CSS-2

Vincent METIVIER

## Theory

CSS-3

François ARLEO

## Budding activities

CSS-4

Scenario : Nicolas THIOLLIERE  
OG-Virgo : Benoit REVENU

## Plasma

CSS-3

Marie GERMAIN

## SEN

CSS-4

Muriel FALLOT

## Electronics

Frédéric LEFEVRE

## Administration

Isabelle OLLITRAULT

## SPR-I

Romain BERNY

## Computing

Khalil CHAWOSHI  
Deputy Gilles GRASSEAU

## SMART

Frédéric CAILLON

## Mechanics

Arnaud CADIOU



# Subatech Scientific Council 2022

- Session n.3 of Subatech Scientific Council on March 17 & 18 2022
  
- Activities reviewed :
  - Theory team
  - Plasma team
  
- Invited experts for this specific session :
  - Ingo SCHIENBEIN, CNRS/IN2P3 LPSC Grenoble
  - Frédéric FLEURET, CNRS/IN2P3 Laboratoire Leprince-Ringuet., Palaiseau
  
- Report of the CSS has been followed by several actions (in atrium and in Subatech nextcloud ([DossierPartageDirectionTous / ConseilScientificSubatech/](#)))



# Actions 2022 and beginning 2023

- EPOSHP (hard probes), renewed with 17k€ annual budget. Contribution of 1 engineer from computing service : new release of EPOS end 2022.
- Hiring of 2 postdocs in the theory team (1 on Heavy flavours and quarkonia, on jets in QGP).
- Renewal of 2 teaching assistant / postdoc positions staff.
- Positions at Nantes University, dedicated to the theory team (associate professor in 2022 professor position 2024-2026, associated professor 2025-2027).
- Top priority of Plasma team for a CNRS position in 2023 (EAOM 2022). Not retained by IN2P3 in 2023, but IN2P3 considers the opening a IR PhD in instrumentation for the team.
- CNRS post-doc position in 2023 for the plasma team.
- Hiring two PhD students (2022 nd 2023) for Run3@LHC Physics analysis.
- Strong involvement of the Plasma team for running the first pp data taking and detector calibration and data reconstruction with the upgraded ALICE detector for Run3.
- Position of associate professor Nantes Université for 2024 for the plasma team.
- 6+6 month stay of Rafael PEZZI and Guillaume BATIGNE at CERN in 2023 as MFT System Run Coordinator
- Participation of the plasma team to the Scientific Council of IN2P3.
- Continued communication actions between both teams around specific research topics. Recently : EPOS4, Open quantum systems for quarkonia production .



# Subatech Scientific Council 2023

- Session n.4 of Subatech Scientific Council on March 16 & 17 2023
  
- Activities to be reviewed :
  - Nuclear Structure and Energy team (SEN)
  - Scenario Activity
  - Gravitational waves in Subatech
  
- Invited experts for this specific session :
  - Filippo VERNIZZI (Dir Adj GDR GW),
  - Elisabeth LE NET (Dir Adj I-TESE, CEA)



# Questions (I)

Activities, present and futur projects of the "Structure et Energie Nucléaire" (SEN) team of Subatech.

We would like you to assess what are the main features (strengths/weaknesses/opportunities/threat) of Subatech's contribution, compared to the contributions of other laboratories/teams, as well as to assess what is the degree of integration of these activities (present and future) in the national and international context. We would like you to evaluate our future strategy on these activities and the coherence between the scientific ambitions and the resources allocated to these activities.



## Questions (II)

Activities related to the Scenario research and the strategy for the future.

The direction of Subatech is convinced about the crucial importance of this research topic for our society. Although only one permanent researcher is working in this topic, these activities benefit of a strong visibility at national being very well integrated in the national context (CNRS, CEA, IRSN, ...) within a solid international network. We would like you to assess what are the main features (strengths/weaknesses/opportunities/threat) of Subatech's contribution, compared to the contributions of other laboratories/teams, as well as to assess of the degree of integration of these activities (present and future) in the national and international context. We would like you to evaluate future strategy on these activities, in particular those centered on interdisciplinary research with sociology and economy and with the objective to reinforce this activity with a post-doctorant position or a tenure track position.





## Questions (III)

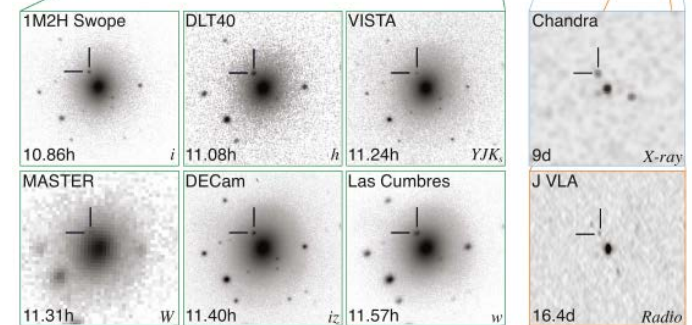
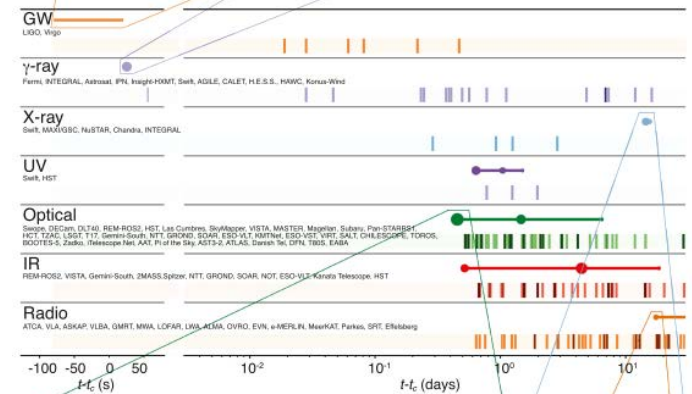
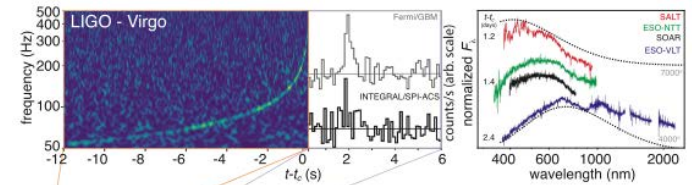
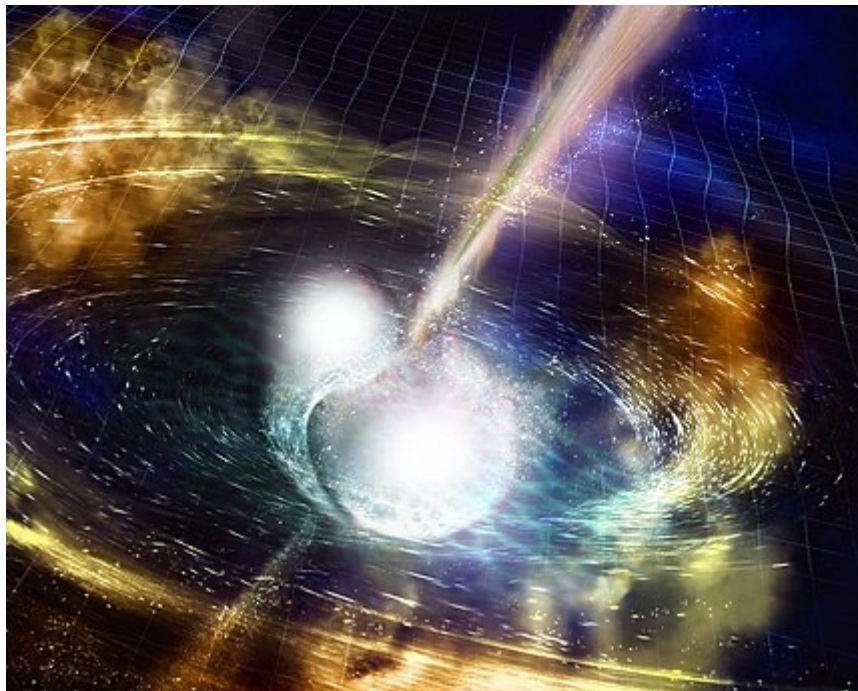
Activities and future strategy in the domain of the gravitational wave detection.

The direction of Subatech have the project to create a team working on the gravitational wave domain, motivated by the attractive and challenging projects that the community plans to develop during the next decades: Advanced Virgo, Einstein Telescope, etc. One member of Subatech is already involved in Virgo Experiment in association with the Virgo team of APC Laboratory in Paris. He has already contributed to the physics analysis for the determination of the Hubble constant from gravitational wave data. In parallel, Subatech technical services have contributed to the conception and construction of the electronics cards related to the Peltier temperature control of laser optical isolators. We would like you to evaluate our future strategy on these activities as well as the opportunity for the creation of small team (2 permanents, 1 post-doc, 2 PhD students) at the horizon of 2026, as announced in our last HCERES evaluation.



# Strategy for a GW team in Subatech (I)

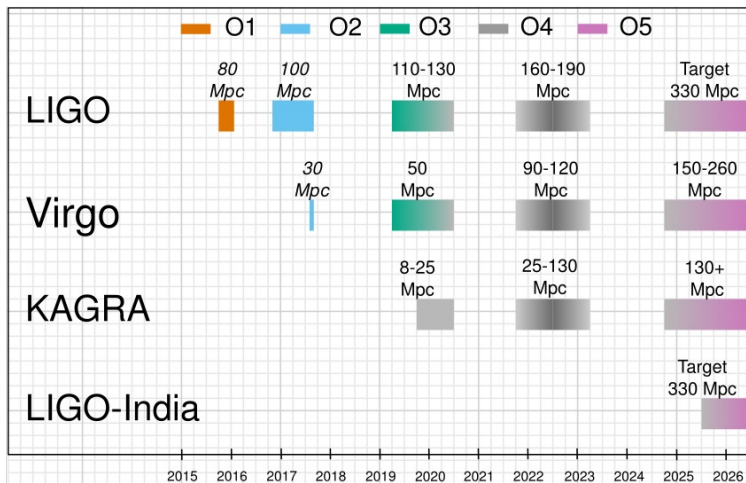
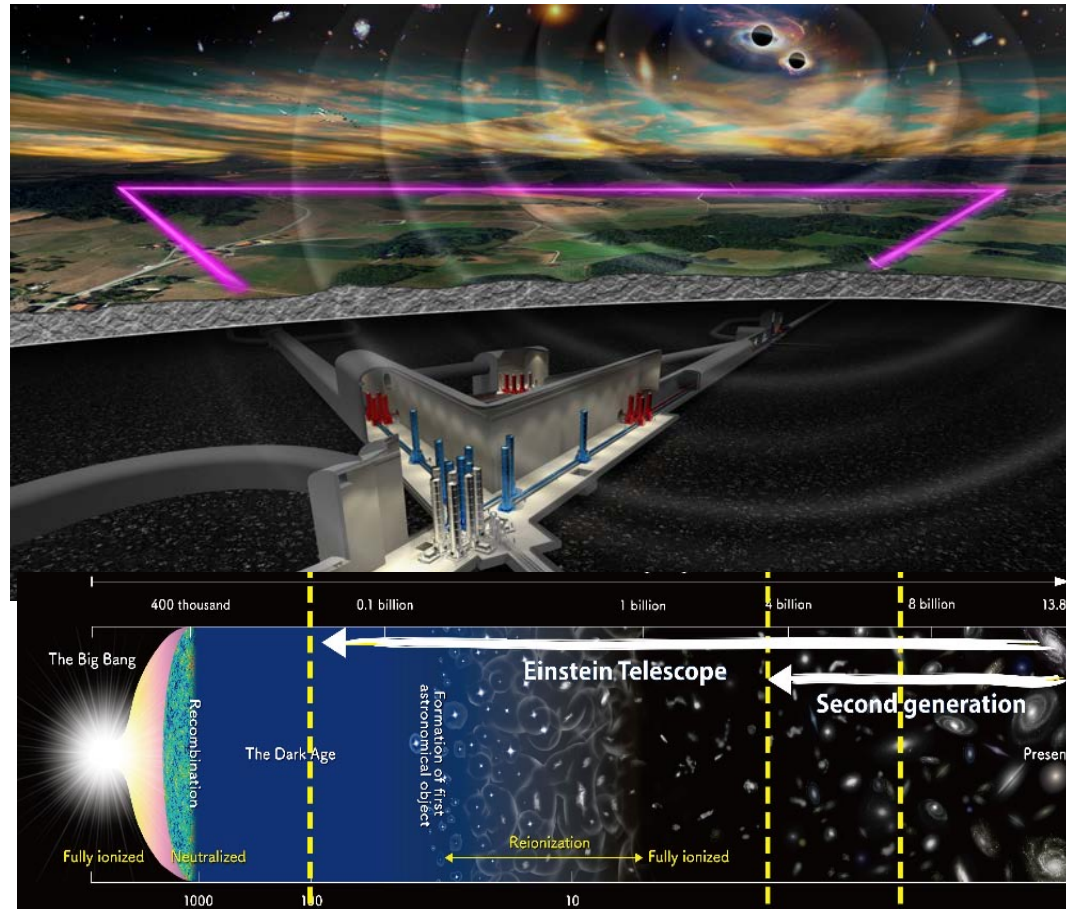
One of the great discoveries in the XXI century has been the first detection of GW from the spectacular mergers of black holes (2015) and neutron stars (2017) shading light on the equation of state of nuclear matter in dense stars and confronting general relativity in new ways.





# Strategy for a GW team in Subatech (II)

National and International effort to improve the sensitivity of Virgo experiment and to build the Einstein Telescope that will become one of the international 3rd generation GW telescopes in the 2030 decade.





# Strategy for a GW team in Subatech (III)

- Use national structuration offered by the CNRS
- Reach the needed critical mass to develop this research in Subatech
- Attractiveness : A 4-6 years “tenure track” position “environnée” (research budget, PhD and postdoctoral positions)
- Synergy with present research activities in the laboratory : i) the exploration of the nuclear matter phase diagram, and ii) the physics of high energy messengers and probe extreme astrophysical phenomena.
- Reinforce the contribution of the engineers of the electronic service to Virgo++ project and at longer term to consider future implications in the design and construction of the computing model for the Einstein Telescope

# Subatech birthday in 2024: 30 year old!



In 2024, Subatech will celebrate its 30th anniversary. For this occasion, a day is being organized to honor the laboratory. Local personalities, our supervisors, our partners and former members of the laboratory will be invited on this occasion.



# War in Ukraine



We continue to condemn the invasion of Ukraine by the Russian authorities. This war and invasion is a human tragedy and an explosive situation.

We express our support and solidarity for the Ukrainian people and scientific colleagues. We express our support to the Russian colleagues who have taken a stand against this war and invasion.

It is urgent for all of us that this conflict must become a conflict in which the use of force and violence is prohibited.

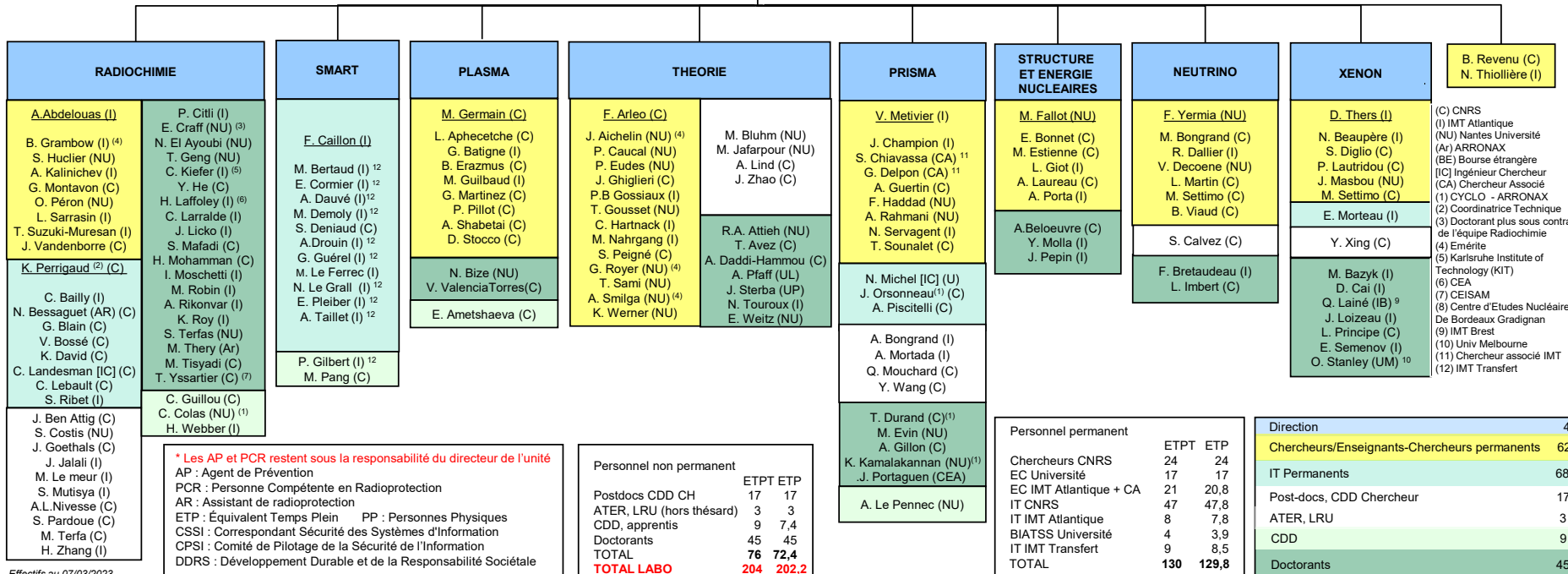
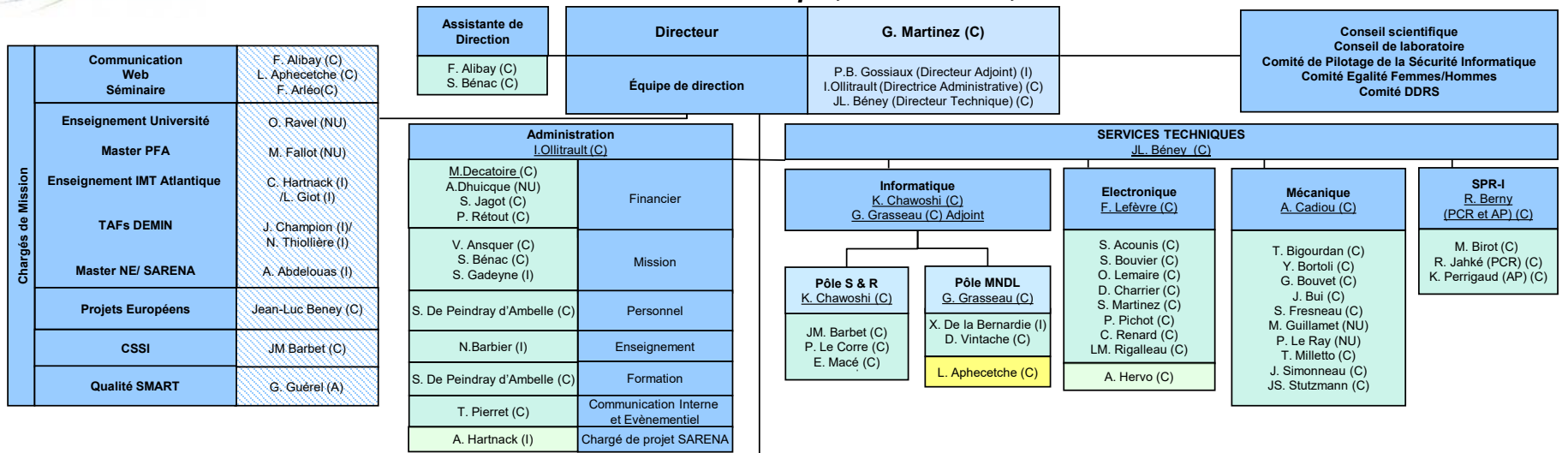
Thanks for your time and for  
your work in the CSS. Merci!



Sonder les infinis : des particules au cosmos



# Subatech Organigramme







# Production Scientifique sur inspire

Inspirehep.net : [nouveau](#)s (112 articles au 05/12/22) et [publications](#) (141 au 05/12/22)  
Nouveauté : tout document créé en 2022; Publications : tout document publié en 2022

112 results | cite all

**Anomalous dimension of transverse momentum broadening in planar  $\mathcal{N} = 4$  SYM**  
Paul Caucal (SUBATECH, Nantes) (Nov 20, 2022)  
Contribution to: *Confinement XV, IAGRG 2022* - e-Print: 2211.11007 [hep-ph]

**Investigation of the tetraquark states  $Q\bar{q}Q\bar{q}$  in the improved chromomagnetic interaction model**  
Tao Guo (CheongU. Of Tech.), Jianing Li (Tsinghua U., Beijing), Jiaxing Zhao (SUBATECH, Nantes), Liangyi He (Tsinghua U., Beijing) (Nov 19, 2022)  
e-Print: 2211.10834 [hep-ph]

**Mini review of research requirements for radioactive waste management including disposal**  
Bernd Grambow (SUBATECH, Nantes) (Nov 17, 2022)  
Published in: *Frontiers in Nuclear Engineering* 1 (2022) 1052428

**Baryon and meson masses in the Nambu–Jona-Lasinio model: a Bayesian approach**  
Antoine Pfaff (IP2), Lyon and SUBATECH, Nantes, Hubert Hansen (IP2), Lyon, Joerg Althelm (SUBATECH, Nantes), Juan M. Torres-Rincon (Barcelona U.) (Nov 17, 2022)  
e-Print: 2211.09766 [hep-ph]

**Green beam lines, a challenging concept**  
F. Osswald (Strasbourg, IPHC), E. Traykov (Strasbourg, IPHC), T. Durand (SUBATECH, Nantes and GIP ARRONAX), M. Heine (Strasbourg, IPHC), J. Michaud (LP2), Bordeaux et al. (Nov 17, 2022)  
e-Print: 2211.09611 [physics.acc-ph]

**Cosmic decoherence: primordial power spectra and non-Gaussianities**  
Assmeur Daddi Hamoui (SUBATECH, Nantes and Padua U.), Nicola Bartolo (Padua U. and INFN, Padua and Padua Observ.) (Nov 14, 2022)  
e-Print: 2211.07598 [astro-ph.CO]

**Transverse emittance measurement in 2D and 4D performed on a Low Energy Beam Transport line: benchmarking and data analysis**  
F. Osswald (Strasbourg, IPHC), T. Durand (SUBATECH, Nantes), M. Heine (Strasbourg, IPHC), J. Michaud (LP2), Bordeaux, P. Poirier (GIP ARRONAX) et al. (Nov 9, 2022)  
e-Print: 2211.04863 [physics.acc-ph]

**Therapeutic efficacy of  $^{166}\text{Ho}$  siloxane in microbrachytherapy of induced glioblastoma in minipig tumor model**  
Mehrdad Khashtkevis, Richard Brown, Sara Belluco, Ilyes Zahi, Luca Maciocco et al. (Nov 7, 2022)  
Published in: *Frontiers in Oncology* 12 (2022) 923679

**Borosilicate glass alteration in vapor phase and aqueous medium**  
Sathya Narayanasamy, Patrick Jollivet, Christophe Jégou, Milarie Moskura, Abdesselam Abdelouas (SUBATECH, Nantes) et al. (Nov 4, 2022)  
Published in: *npj Materials Degradation* 6 (2022) 1, 86

**Detecting nuclear mass distribution in isobar collisions via charmonium**  
Jiaxing Zhao (SUBATECH, Nantes and Tsinghua U., Beijing), Shuhei Shi (Stony Brook U.) (Nov 3, 2022)  
e-Print: 2211.01971 [hep-ph]

141 results | cite all

**Mini review of research requirements for radioactive waste management including disposal**  
Bernd Grambow (SUBATECH, Nantes) (Nov 17, 2022)  
Published in: *Frontiers in Nuclear Engineering* 1 (2022) 1052428

**Therapeutic efficacy of  $^{166}\text{Ho}$  siloxane in microbrachytherapy of induced glioblastoma in minipig tumor model**  
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Published in: *npj Materials Degradation* 6 (2022) 1, 86

**Unmoderated molten salt reactors design optimisation for power stability**  
A. Laureau (SUBATECH, Nantes and LPSC, Grenoble), A. Bellé, M. Allibert (LPSC, Grenoble), D. Heuer (LPSC, Grenoble), E. Merle (LPSC, Grenoble) et al. (Nov 2, 2022)  
Published in: *Annals Nucl. Energy* 177 (2022) 109265

**Couette flow of pentane in clay nanopores: Molecular dynamics simulation**  
Vasily V. Pisarev, Andrey G. Kalinichev (SUBATECH, Nantes) (Nov, 2022)  
Published in: *J. Mol. Liq.* 366 (2022) 120290

**Interaction between carbon steel and low-pH bentonitic cement grout in anoxic, high temperature (80°C) and spatially heterogeneous conditions**  
J. Gesteira (SUBATECH, Nantes), L. De Windt, C. Wittbrodt (IRSN, France), A. Abdoullouas (SUBATECH, Nantes), X. de la Bernardie (SUBATECH, Nantes) et al. (Nov, 2022)  
Published in: *Corrosion Science* (2022) 110852

**Excitation functions of deuteron induced nuclear reactions on dysprosium targets for the production of the theranostic relevant isotopes of terbium**  
Michele Colucci (INFN, Milan and Milan U.), Stefano Carniani (INFN, Milan and Milan U.), Ferid Haddad (SUBATECH, Nantes and GIP ARRONAX), Etienne Nigran (GIP ARRONAX), Flavia Groppi (INFN, Milan and Milan U.) et al. (Oct 26, 2022)  
Published in: *Eur. Phys. J. Plus* 137 (2022) 10, 1180

**Radiation exposure of microorganisms living in radioactive mineral springs**  
Sofia Kolovi (Clermont-Ferrand U.), Giovanna-Rosa Fois (Clermont-Ferrand U.), Sara Lanouar (Clermont-Ferrand U.), Patrick Chardon (Clermont-Ferrand U.), Didier Maillet (Clermont-Ferrand U.) et al. (Oct 17, 2022)  
Published in: *HNPS Adv. Nucl. Phys.* 28 (2022) 68-74 - Contribution to: HNPS2021, 68-74

**An approximate likelihood for nuclear recoil searches with XENON1T data**  
XENON Collaboration - E. Aprile (Columbia U. and Columbia U., Astron. Astrophys.) et al. (Oct 13, 2022)  
Published in: *Eur. Phys. J. C* 82 (2022) 11, 989 - e-Print: 2210.07231 [hep-ex]

**Clinical research in radiation oncology: how to move from the laboratory to the patient?**  
V. Patrino, G. Delpon (SUBATECH, Nantes), L. Olivier, L. Vaugier, M. Dore et al. (Oct, 2022)  
Published in: *Cancer/Radiopharm* 26 (2022) 6-7, 808-813

# Highlights 2022-2023



Sonder les infinis : des particules au cosmos





# Neutrino Highlights

## SoLid

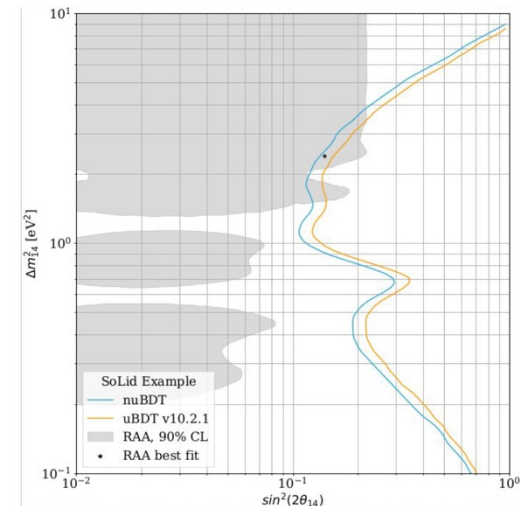
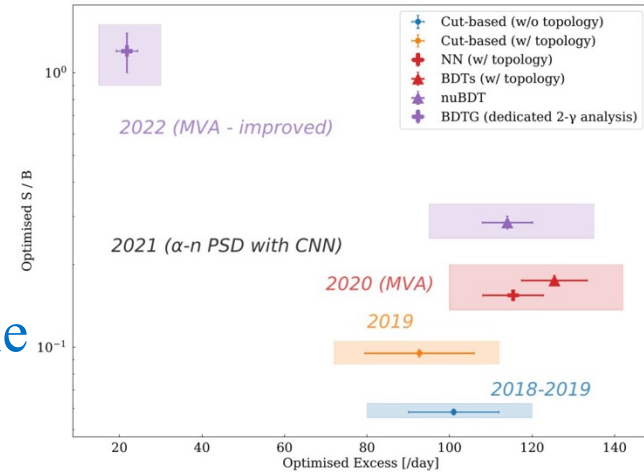
Analysis is ready, publication under internal review (SUBATECH+Oxford), publication expected in July 2023

Important effort to reduce the background (topologie + BDT) (coordination de l'analyse: SUBATECH)



*Sub-percent precision measurement of neutrino oscillation parameters with JUNO, Chin.Phys.C 46 (2022) 12, 123001*

Contribution to the analysis framework, based on the contribution for Double Chooz experiment and adapted to JUNO for the measurement of the PMNS ( $\theta_{12}$ ,  $\Delta m^2_{21}$ ,  $|\Delta m^2_{31}|$  et  $\theta_{13}$ ) parameters with JUNO.

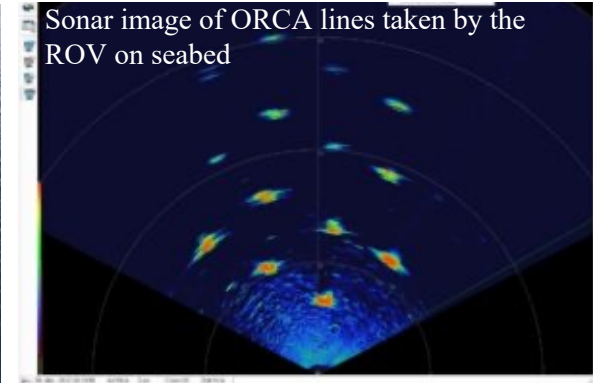
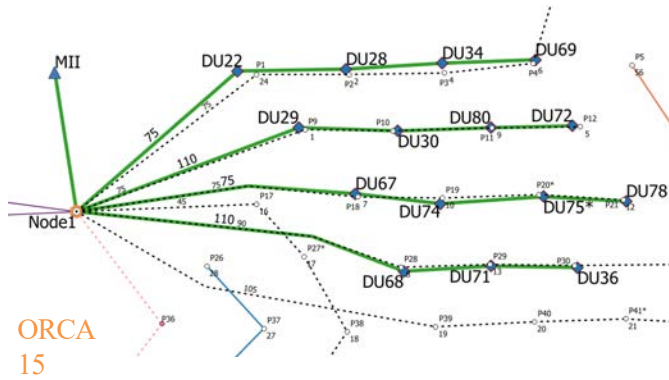




# Neutrino Highlights : KM3NeT



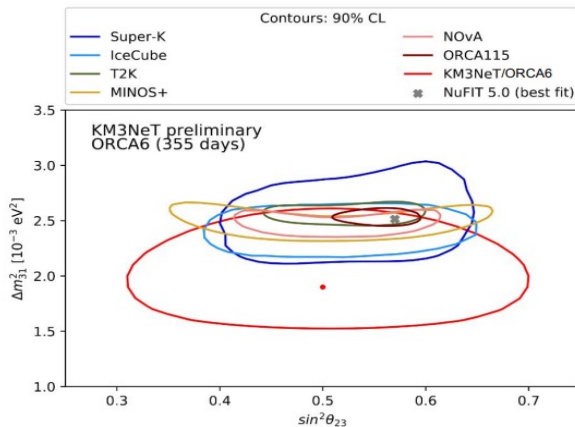
Current Status: 36 DUs deployed (ARCA 21 and ORCA15)



10 peer-reviewed papers and 57 proceedings Sept. 2021 – Sept. 2022

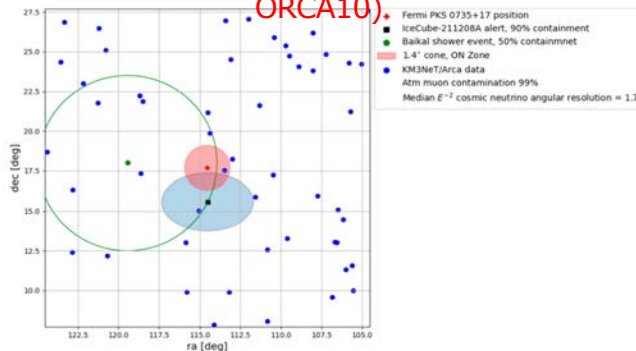
## Neutrino Physics

Oscillation analysis with ORCA6

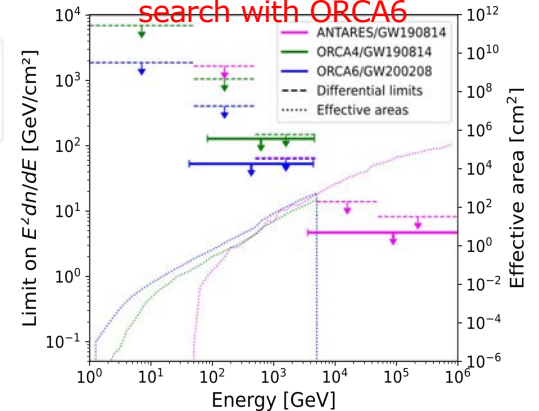


## Neutrino Astrophysics

Follow-up of IC211208A-PKS735 alerts with ARCA6 (similar with ORCA10).



UL on the GWs (o3) for ORCA4,6 and ANTARES + MeV search with ORCA6





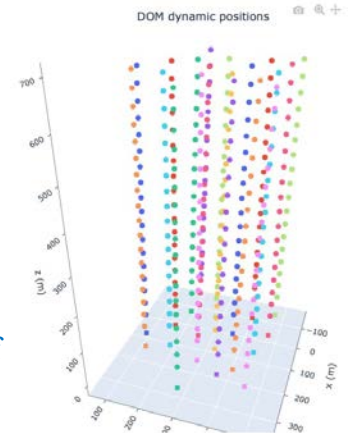
# Neutrino Highlights : KM3NeT@Subatech



## Technics

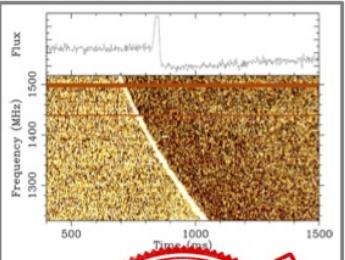
ORCA deployment (X sea operations since 2018) and DOM production (54 DOMs integrated so far, +57 for 2023)

Calibration and commissioning:  
acoustic reconstruction of DOMs position, compass calibration for DU orientation




## Neutrino and Multi-messenger Astrophysics

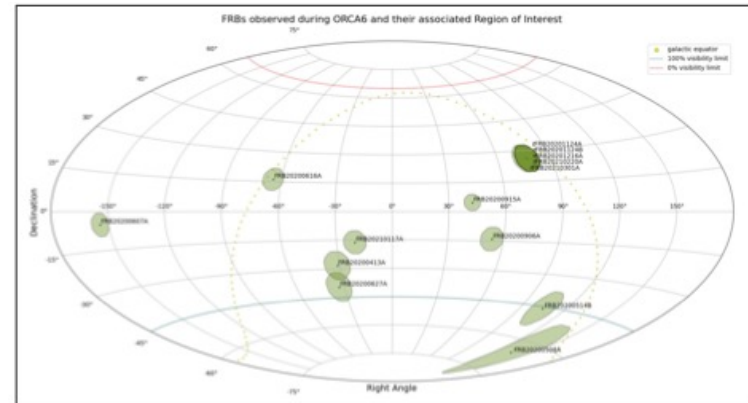
Name: Fast Radio Burst (FRB)	
Observables	
Energy (isotropic): $10^{35}$ – $10^{46}$ erg	
Duration: ~Millisecond	
Traits: Dispersion Measure Rotation Measure Scattering	
Repeating: Sometimes	
Inferred characteristics	
Source: Extra-galactic sources Magnetars(?)	
Mechanism: Coherent emission	
Environment: Energetic, dense, magnetized perturbed plasma	



Seal:



Search for Fast Radio Bursts (FRB) and neutrinos coincidences in KM3NeT data (PhD thesis) + FRB observations @ Nançay and KM3NeT follow-up

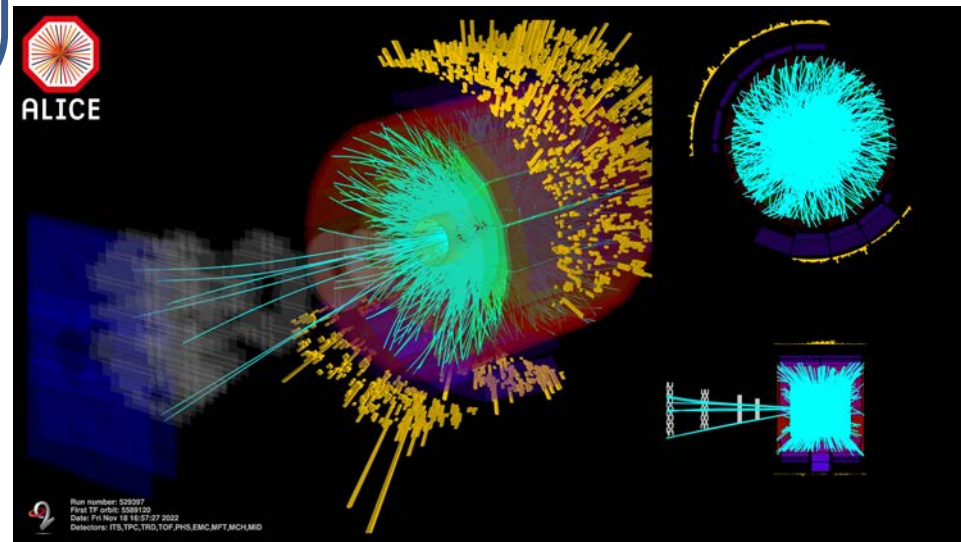
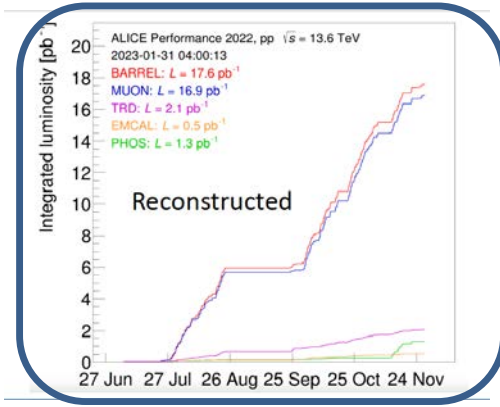
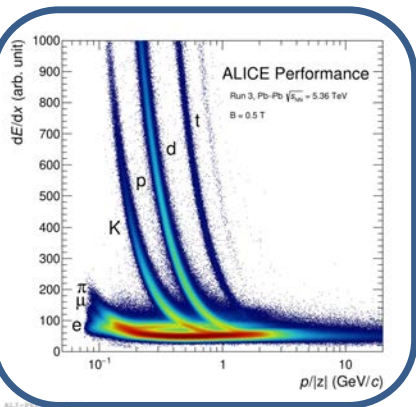
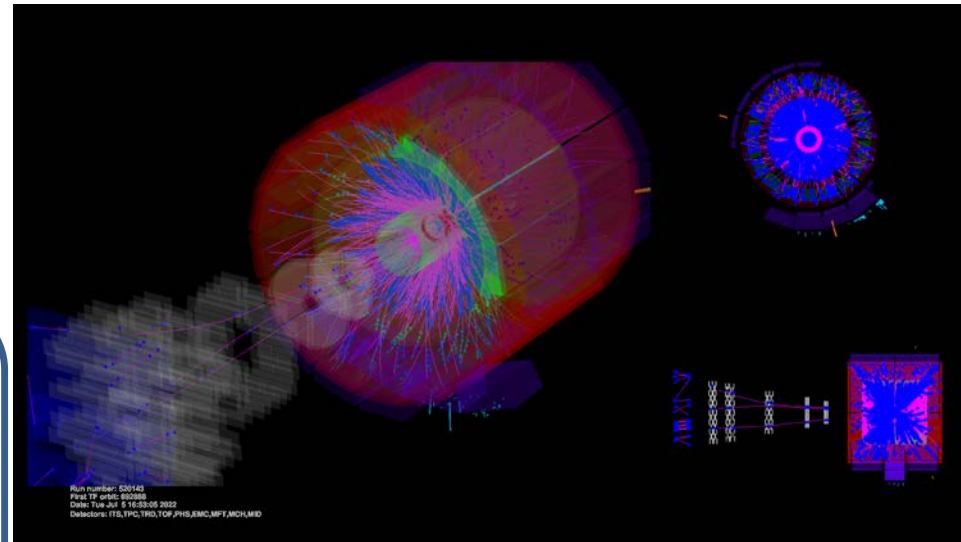




# Plasma Highlights : Alice Run 3 @ LHC

**Start of Run3: 5 July 2022**

First pp 13 TeV collisions with MFT, EMCal, MID, MCH detectors included



**Energetic Crisis: Pb-Pb run postponed to 2024**

**Test beam Pb-Pb at 5.36 TeV: 2 fills**

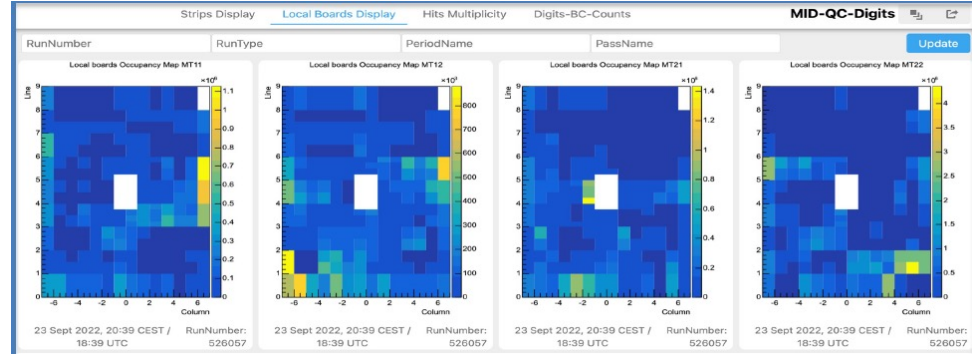
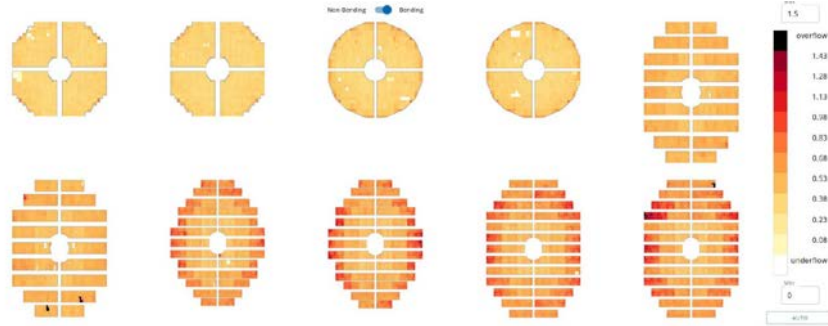
- All ALICE 15 detectors in the data taking
- Online calibrations and reconstruction (including most central events)



# Muon spectrometer for Run 3

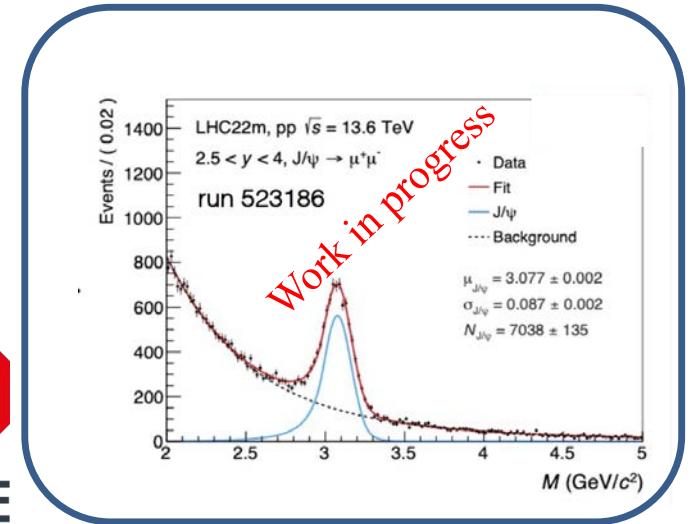
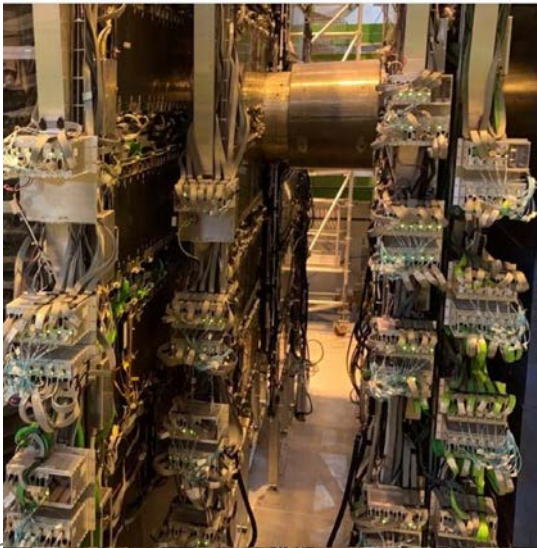
Consolidation and readout upgrade of all subsystems with Common Readout Unit (CRU)

- MCH upgrade with SAMPA ASIC : 5 tracking stations (2x5 Multi-Wire Proportional Chambers)+ absorber system
- MID(upgrade of MTR) with FEERIC ASIC : 72 Resistive Plate Chambers (RPCs) in 2 stations of 2 planes (150 m<sup>2</sup>)
- Software Upgrade with O<sup>2</sup>



Successful data taking at 500 kHz, pp

Analysis of pp 13 TeV data ongoing

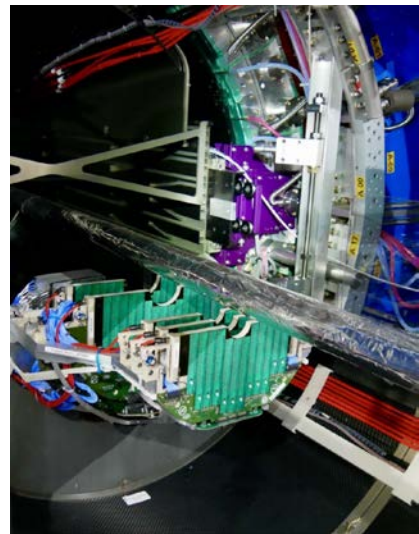




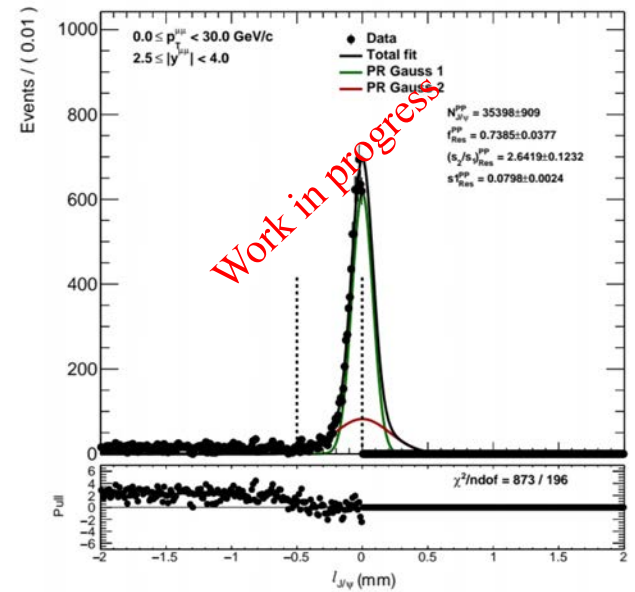
# Muon Forward Tracker

Vertex tracker for muon spectrometer between interaction point and front absorber.

- 920 ALPIDE silicon pixel sensors (0.4 m<sup>2</sup>)
- Hardware and services installed:
  - Cooling system,
  - PSU
  - Slow Control
- Commissioning finalized
- Software
  - reconstruction/tracking
  - MCH-MFT matching



Analysis of pp 13 TeV data ongoing



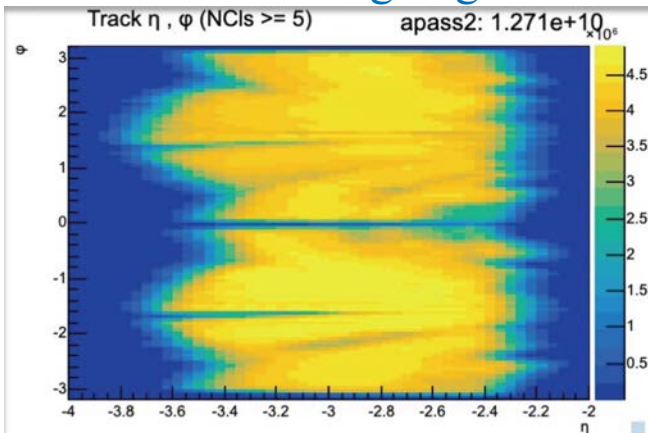
Work in progress

$$l_{J/\psi} = c\tau_{z,J/\psi} = \frac{cL_z M_{J/\psi}}{P_{z,J/\psi}}$$

Data LHC220\_pass2  
 χ<sup>2</sup><sub>MFT-MCH</sub> < 25  
 → σ ~ 80 μm

Successful data taking at 500 kHz, pp

Final alignment, calibration, reconstruction ongoing







# Plasma Highlights : Publications

2 PhD defences:

- Rita Sadek, 28 Oct 2022 , [tel-04008085](tel:04008085)
- Ophélie Bugnon 28 Sept 2022

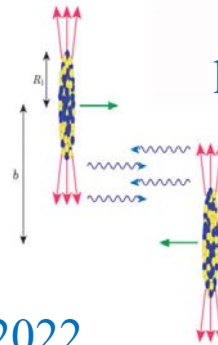
27 papers **published** since march 2022  
 + 34 ALICE papers **accepted** since march 2022  
 (LHC publication in standby since Feb 2022)

In particular:

- J/Psi photo production: [arXiv:2204.10684](https://arxiv.org/abs/2204.10684)
- Psi(2S) vs multiplicity in small syst [arXiv:2204.10253](https://arxiv.org/abs/2204.10253)
- EMCal performance paper [arXiv:2209.04216](https://arxiv.org/abs/2209.04216)
- Measurement of azimuth anisotropies with muons in high mult p-Pb [arXiv:2210.08980](https://arxiv.org/abs/2210.08980)

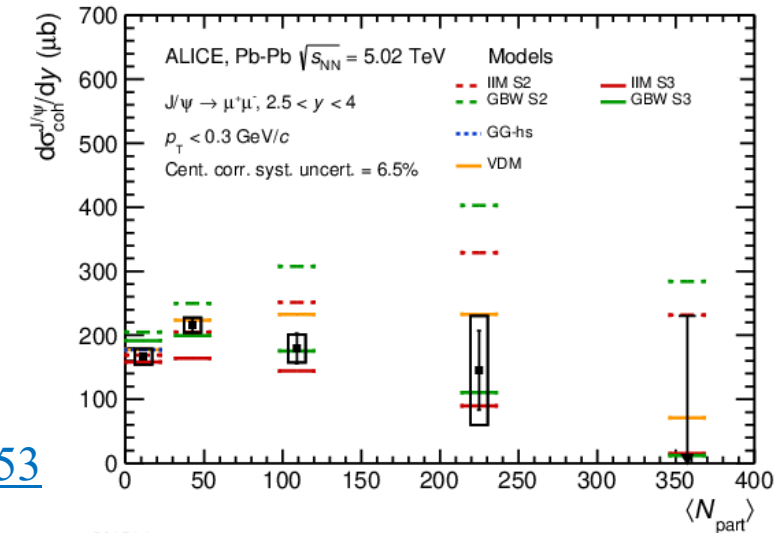
And 2 major reviews:

- ALICE upgrades during the LHC Long Shutdown 2 [arXiv:2302.01238](https://arxiv.org/abs/2302.01238)
- The ALICE experiment -- A journey through QCD [arXiv:2211.04384](https://arxiv.org/abs/2211.04384)



J/Psi photo production in peripheral hadronic collisions with nuclear overlap

[arXiv:2204.10684](https://arxiv.org/abs/2204.10684) accepted Phys.Lett.B.  
 Courier du CERN : Oct 2022



ALI-PUB-521511



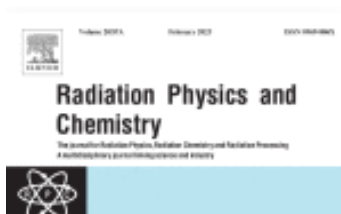
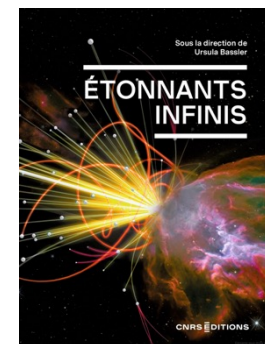
ALICE



# PRISMA Highlights

## Étonnants infinis,

Maud Baylac et al., Ursula Bassler, CNRS Editions, 2022, 9782271143808  
(chapitre F. Haddad et Anne Le Penneec )

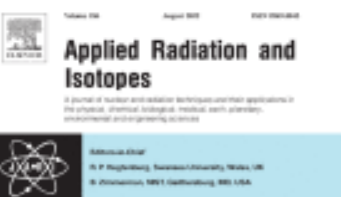


New experimental bremsstrahlung cross-section for light ion beams up to 60 MeV and comparison to theoretical models, F. Ralite et al., Radiat.Phys.Chem., 203:110605, 2023  
doi: 10.1016/j.radphyschem.2022.110605

Ultrahigh-Dose-Rate Proton Irradiation Elicits Reduced Toxicity in Zebrafish Embryos, Gaëlle Saade et al., Advances in Radiation Oncology, 8(2):101124, 2023  
doi: 10.1016/j.adro.2022.101124

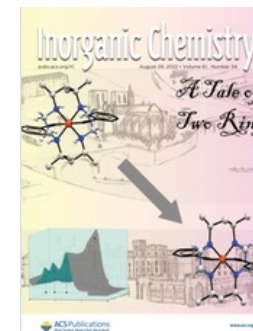
**advances**  
in radiation oncology

[www.advancesradonc.org](http://www.advancesradonc.org)



Electrochemical co-deposition of Ni-Gd<sub>2</sub>O<sub>3</sub> for composite thin targets preparation: Production of <sup>155</sup>Tb as a case study, Yizheng Wang et al. Applied Radiation and Isotopes, 186:110287, August 2022, doi: 10.1016/j.apradiso.2022.110287

Pourbaix diagram of astatine revisited: experimental investigations, Lu Liu et al., Inorganic Chemistry, 61(34):13462-13470, August 2022.  
doi: 10.1021/acs.inorgchem.2c01918  
(J. Champion corresponding author)

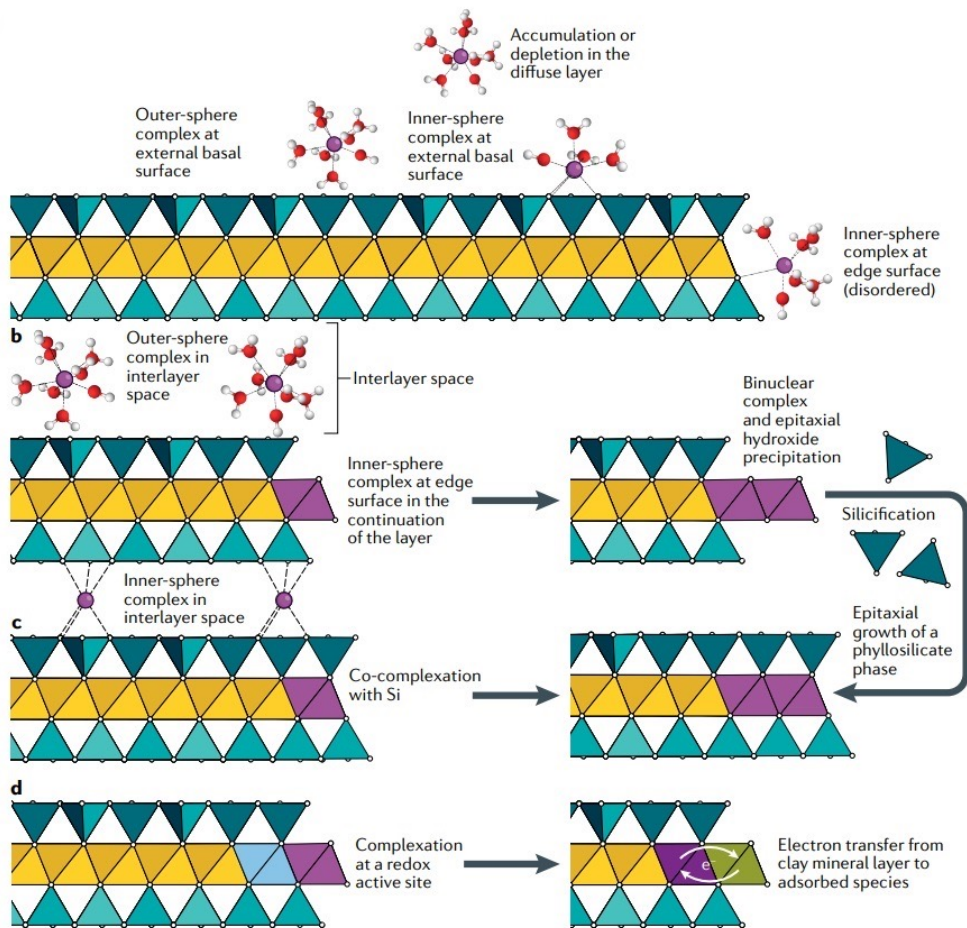




# Radiochemistry Highlights (I)

## Molecular-level understanding of metal ion retention in clay-rich materials

Xiandong Liu<sup>1,2</sup>, Christophe Tournassat<sup>3,4</sup>, Sylvain Grangeon<sup>5</sup>, Andreu G. Kalinichev<sup>6</sup>, Yoshio Takahashi<sup>7</sup> and Maria Marques Fernandes<sup>8</sup>



X.Liu et al. (2022) *Nature Reviews Earth & Environment* **3**, 461-476.

Chair Stockage (2019-2024)

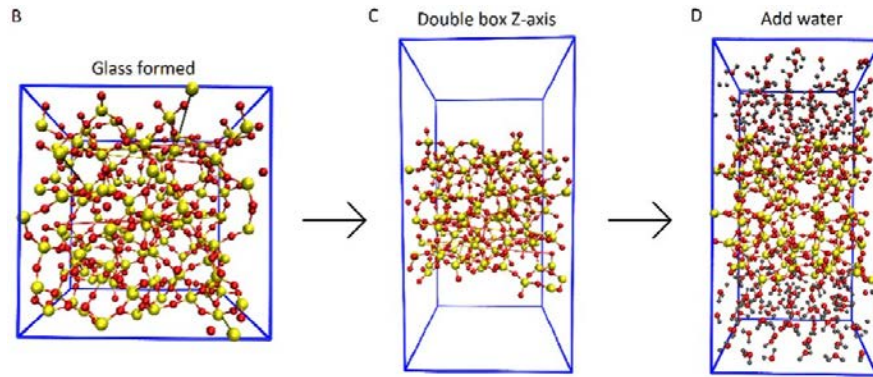


# Radiochemistry Highlights (II)



UNIVERSITÉ  
DE MONTPELLIER

Mechanisms limiting the speed of glass alteration (dissolution) in water at initial and residual phases



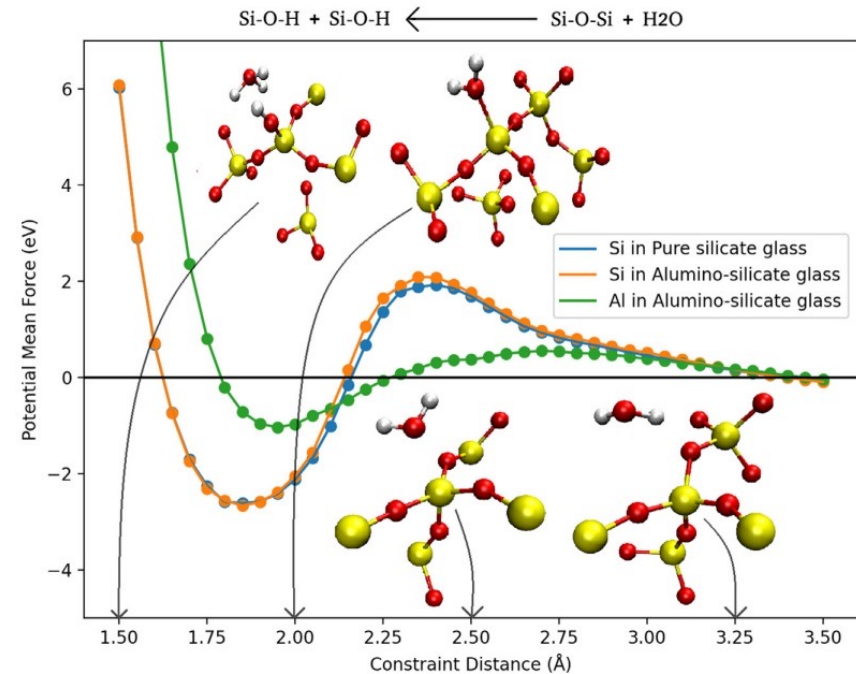
K. Damodaran, J.-M. Delaye, A.G. Kalinichev, S. Gin (2022)  
Deciphering the non-linear impact of Al on chemical durability of silicate glass. *Acta Materialia*, **225**, 117478.



U.S. DEPARTMENT OF  
**ENERGY**



**WASTE PD**  
Performance and Design

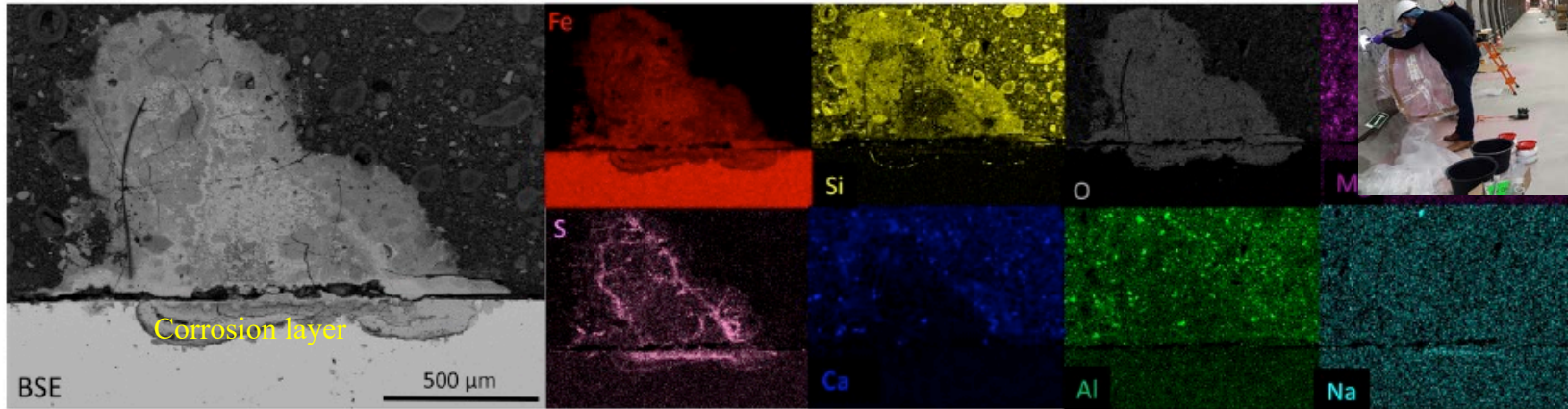




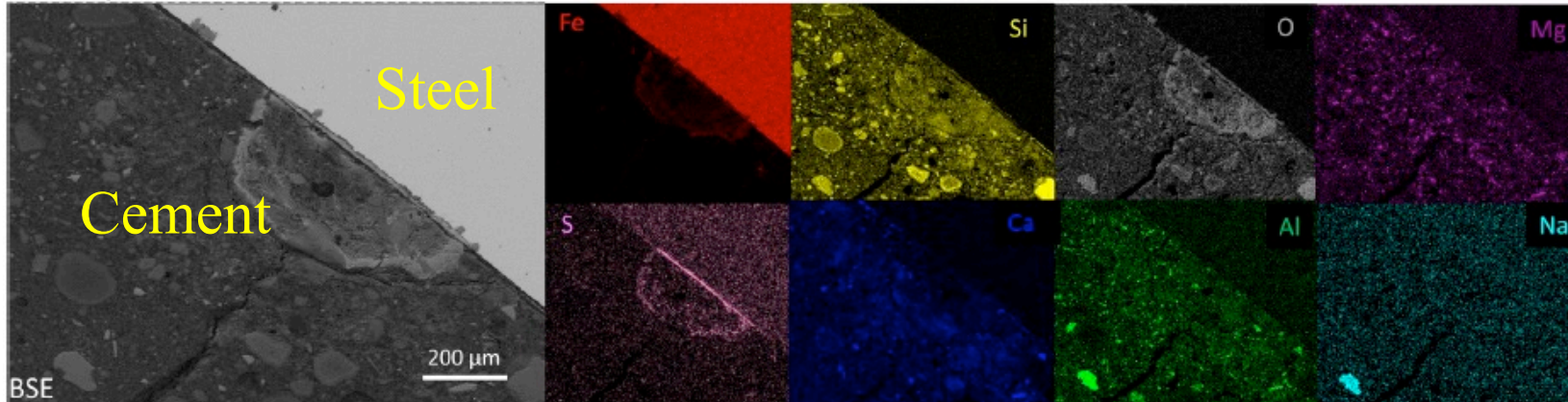
# Radiochemistry Highlights (III)

## Interphase steel-cement

147 days



224 days

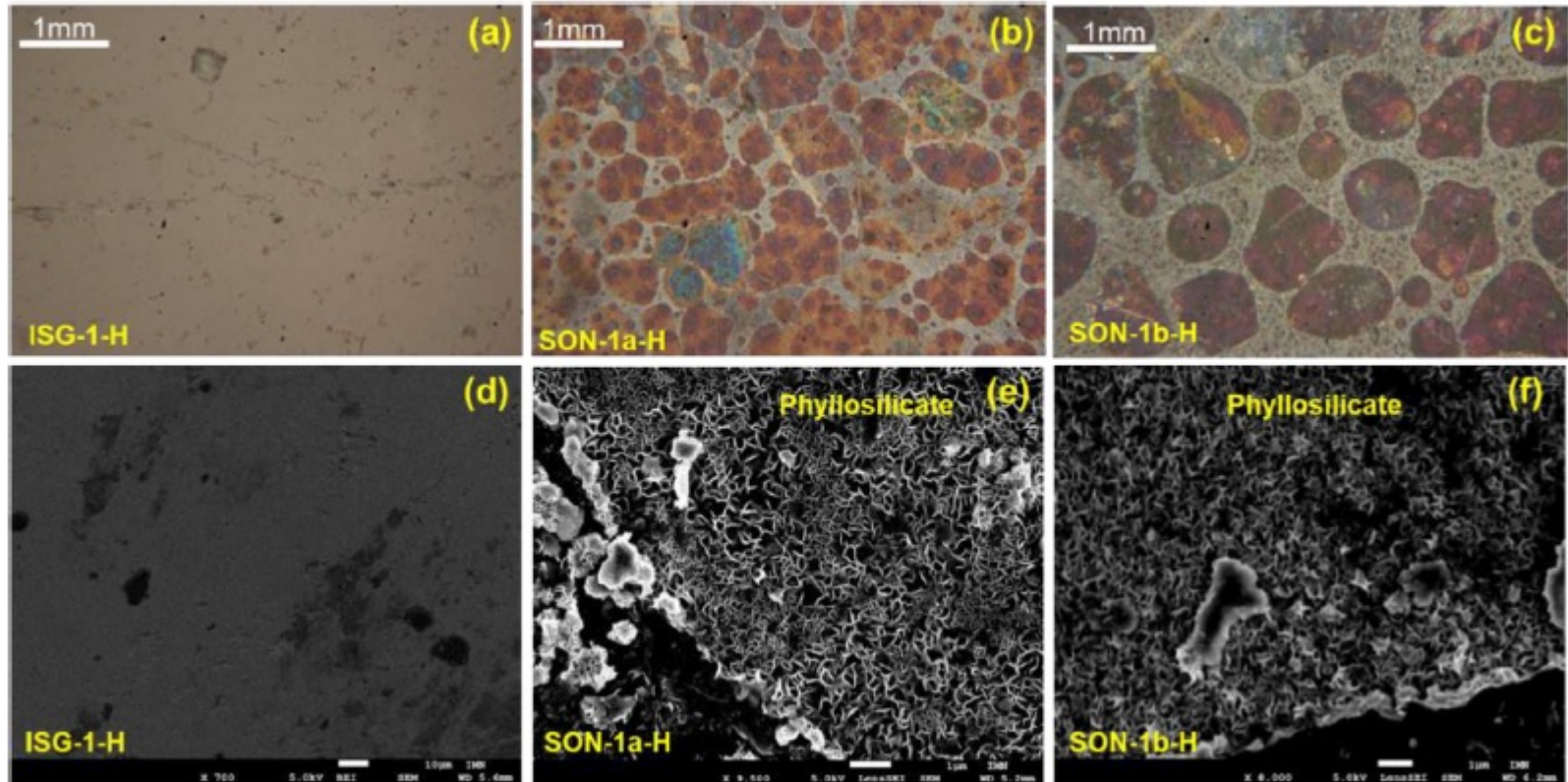


Goethals et al. Interaction between carbon steel and low-pH bentonitic cement grout in anoxic, high temperature (80° C) and spatially heterogeneous conditions. Corrosion Science 211, 110852 (2023).



# Radiochemistry Highlights (IV)

Alteration of the glass under vapour phase (80-125 C) and under radiation  
The surface of the glass is covered with secondary phases: phyllosilicates.



Zhang, H., T. Suzuki-Muresan, S. Gin, G. Blain, T. Sauvage, O. Wendling, J. Vandenberg, A. Abdelouas. Effects of vapor hydration and radiation on the leaching behavior of nuclear glass, *J. Nucl. Mater.* 578 (2023) 154368. doi:10.1016/j.jnucmat.2023.154368.

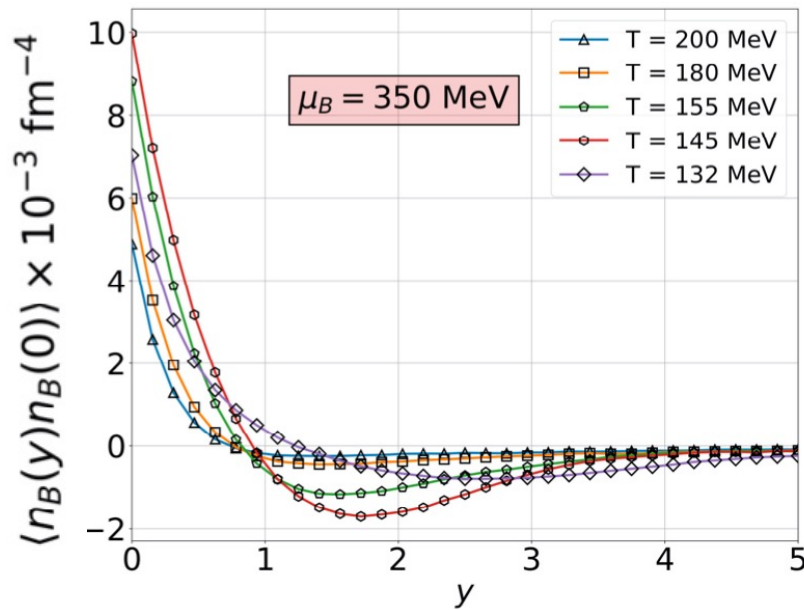


# Theory Highlights (I)

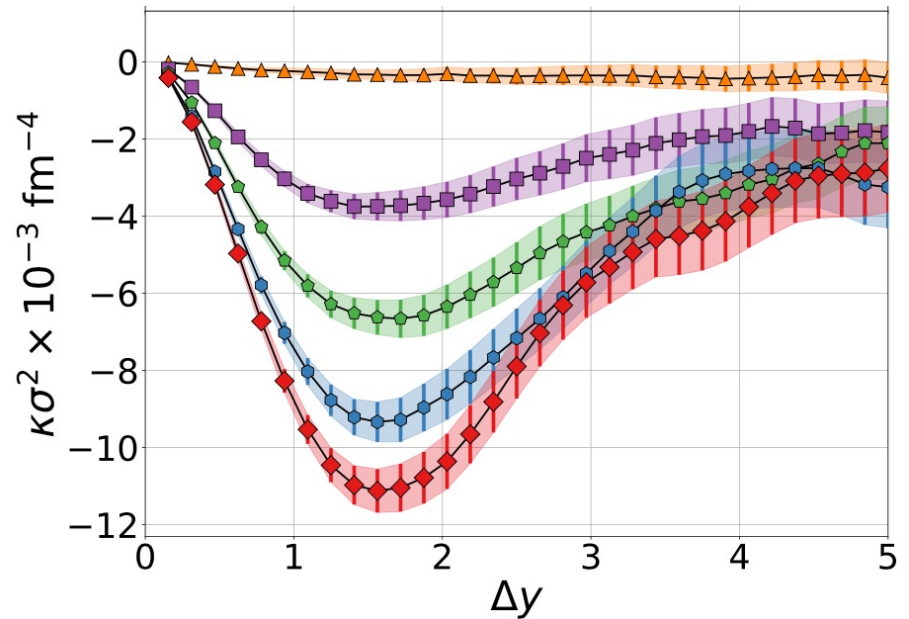
## ○ Critical net-baryon fluctuations in an expanding system

Pihan (PhD), Bluhm, Kitazawa, Sami, Nahrgang, [Phys Rev C 107, 014908](#)

- Calculation of the susceptibilities of the net baryon densities encode the critical region, the high-temperature QGP and the low-temperature hadronic gas
- Evaluate fluctuation observables such as the correlation function, variance and kurtosis



Anticorrelations of net-baryon density for a critical point

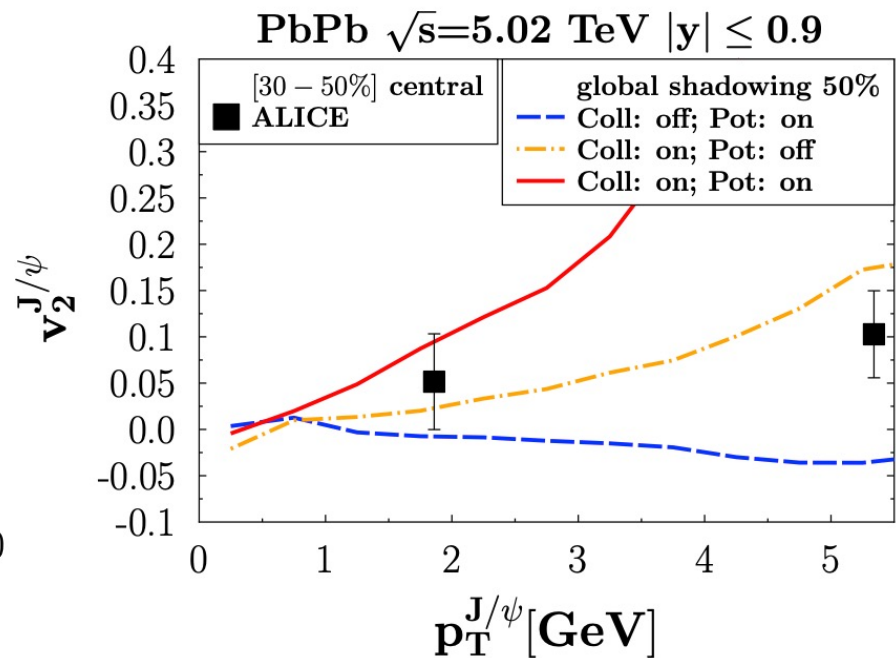
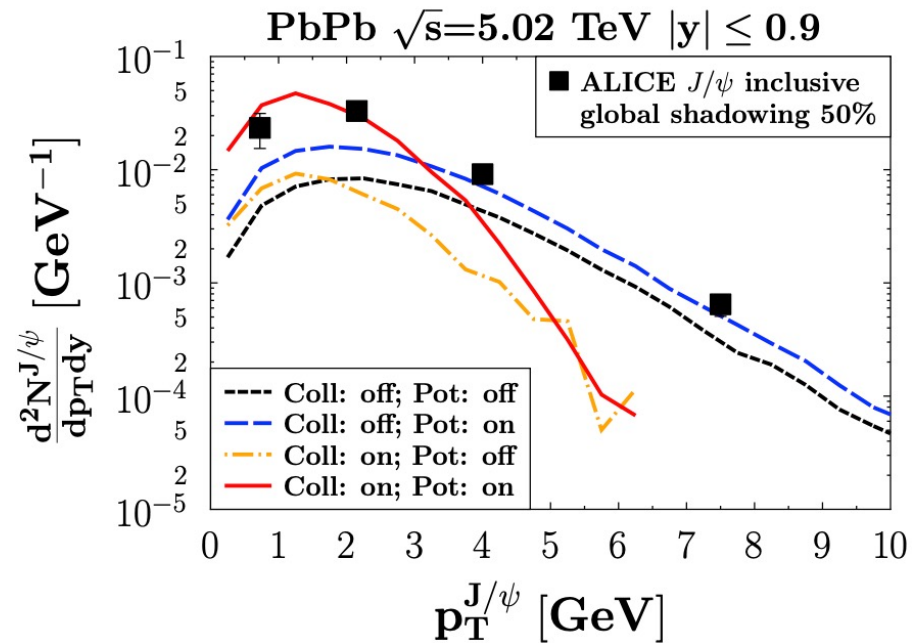


Non-monotonic rapidity dependence of the net-baryon density kurtosis for a critical point



# Theory Highlights (II)

- A new microscopic model for  $J/\psi$  production in heavy ion collisions  
Arrebato Villar (PhD), Zhao, Aichelin, Gossiaux, [2206.01308](#) (PRC to appear)
  - Calculation of  $J/\psi$  absolute production spectrum, suppression and azimuthal anisotropy
  - **More to be added**

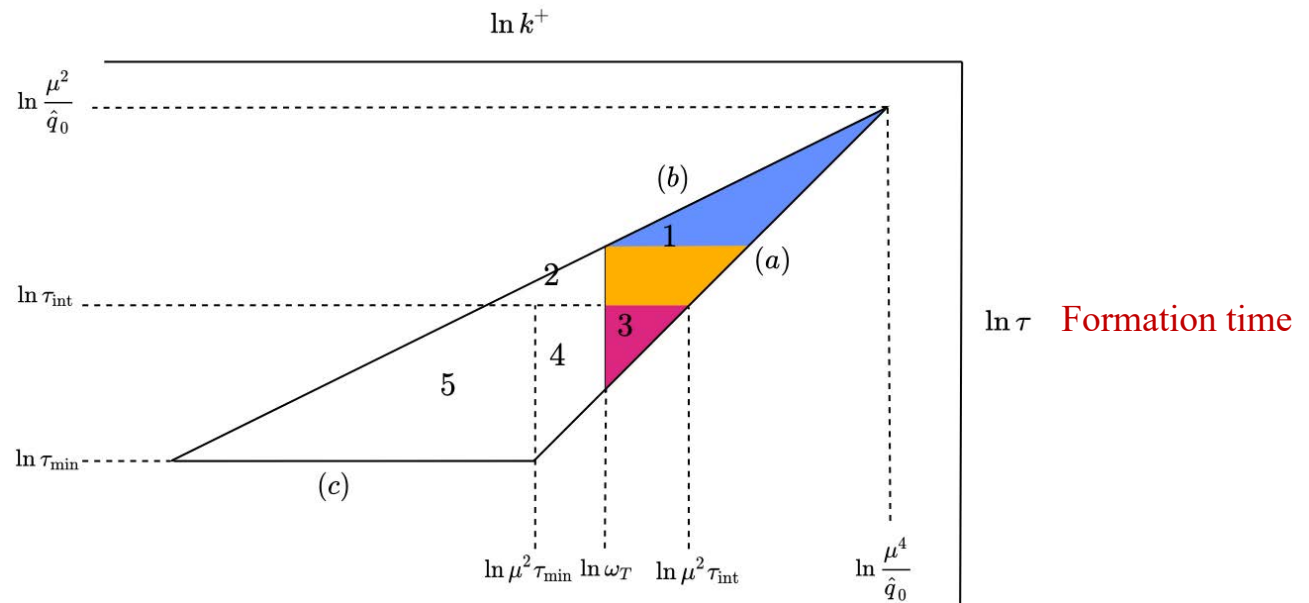






# Theory Highlights (III)

- Classical vs quantum corrections to jet broadening in a weakly-coupled Quark-Gluon Plasma  
Ghiglieri, Weitz (PhD) [JHEP 11 \(2022\) 068](#)
  - Systematic study of radiative corrections to the broadening experienced by a jet crossing quark-gluon plasma
  - Crucial role of thermal effects on the typical energy and formation time of the radiated gluon



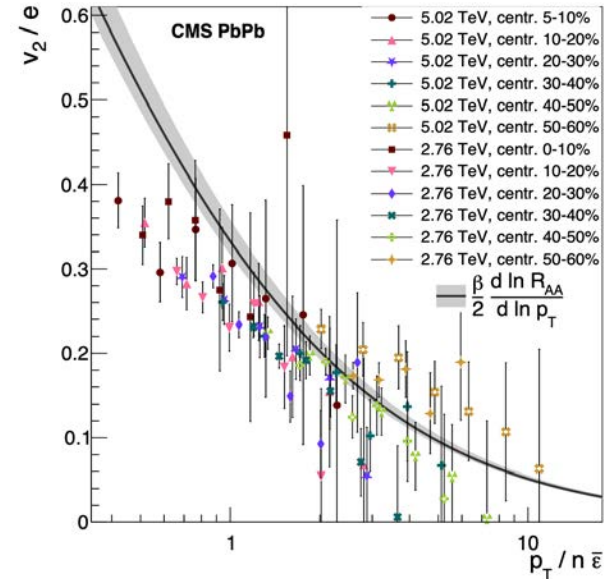
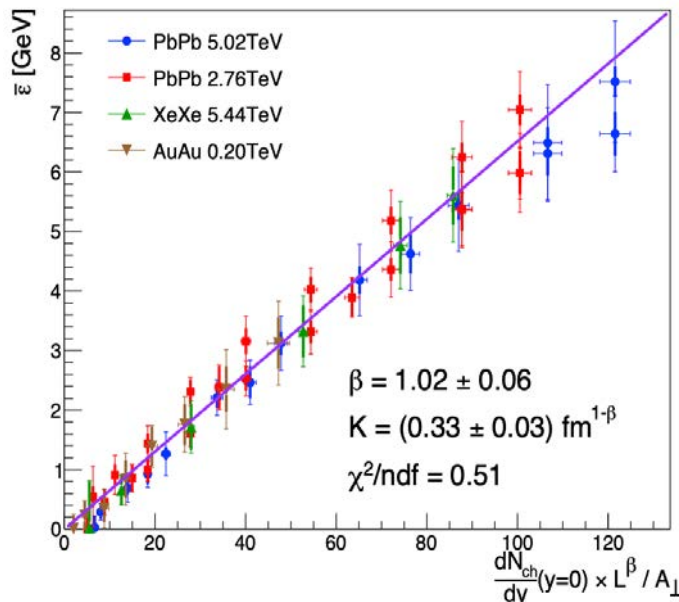


# Theory Highlights (IV)

- Path-length dependence of parton energy loss in QGP
  - Arleo, Falmagne (PhD), [2212.01324](#)
  - Data driven analysis of hadron suppression at LHC
  - Allows to determine (i) the path-length dependence and to (ii) show scaling properties of azimuthal anisotropies in heavy ion collisions

$$\Delta E \propto L^\beta$$

$$\beta = 1.02 \pm 0.06$$

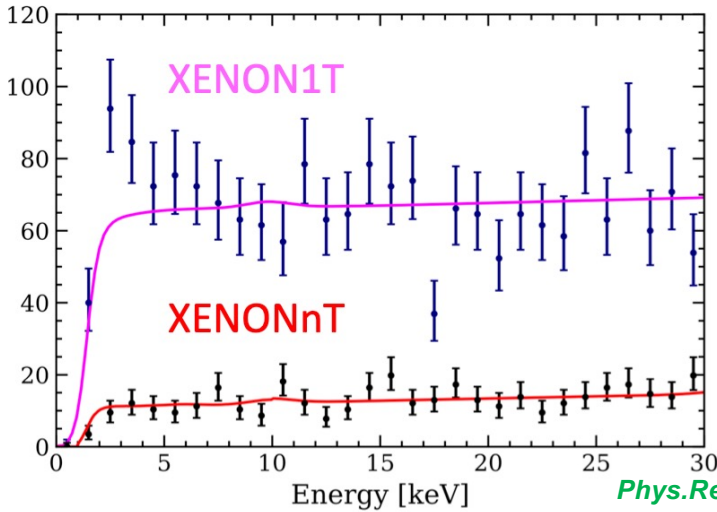




# XENON highlights

## XENONnT Results

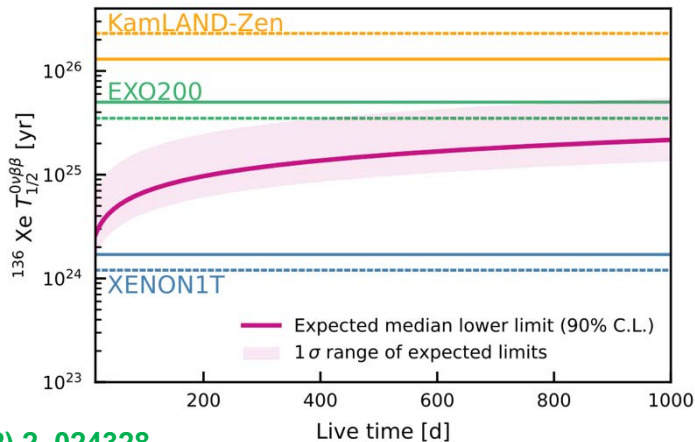
New WIMPs analysis results coming VERY SOON!



Search for New Physics in Electronic Recoil Data from XENONnT

*Phys.Rev.Lett.* 129 (2022) 16, 161805

Double-Weak Decays of  $^{124}\text{Xe}$  and  $^{136}\text{Xe}$  in the XENON1T and XENONnT Experiments



*Phys.Rev.C* 106 (2022) 2, 024328

Collaboration

SUBATECH-UniMelb



XENON Time Projection Chambers: **R&D** for future generation experiments, **0vbb** and **Dark Matter** searches

3 Joint PhDs ongoing  
1 MSCA PhD to recruit



University of Melbourne @UniMelb

Inauguration April 2022

Five new joint PhD projects have just been announced as part of our partnership with @CNRS. Tap through to read more about the partnership and see the full list of projects.



# Outreach



Sonder les infinis : des particules au cosmos





# Fête de la science 2022

The 31st edition of the Fête de la Science took place on October 15 and 16 in Hall 6.

Thanks to a team of dynamic scientists and technicians, Subatech took part in this important meeting between the general public of all ages and Science, by making them (re)discover the fog chamber, the KM3NeT experiment with the virtual reality helmet, the map of nuclei in legos and a new animation around radioactivity.





# Nuit Blanche des chercheurs 2023

The "Nuit Blanche des Chercheurs" on the theme "Vibrations" took place on February 2 at the Halle 6 West in Nantes. Once again, thanks to the presence of doctoral and post-doctoral students, Subatech was present to discuss radioactivity with the general public. By measuring different radioactive sources (from bananas to the radioactive mineral Penchblend) with radiation probes we were able to show the impact of radioactivity on humans. At the same time, at Stereolux, researchers also contributed to the success of this event by participating in science dating.



# 2023 : Le 150 ans de la SFP

**Congrès Général des 150 ans de la Société Française de Physique**  
à la Cité des Sciences et de l'Industrie **PARIS**  
du 3 au 7 juillet 2023  
[www.sfp2023.fr](http://www.sfp2023.fr)

Un panorama unique des avancées de la physique

Conférences plénières et tables rondes  
Colloques thématiques  
Sessions «Science & Société»  
Expositions industrielle et de culture scientifique  
Sessions posters  
Soirée Jeunes

Le Congrès accueillera également les  
Rencontres Enseignement et Didactique de la Physique (REDP)

Congrès général à Paris (Cité des sciences) : informations et inscription sur [www.sfp2023.fr](http://www.sfp2023.fr)

- Évènements et manifestations tout au long de l'année
- Exposition Hall IMT Atlantique (high schools)



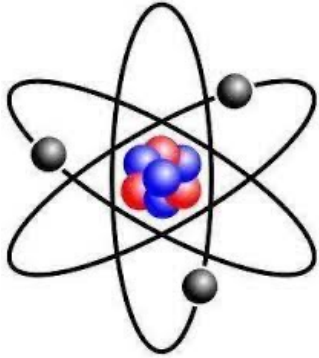
**Société Française de Physique**

**150 ANS D'ENGAGEMENT POUR LA PHYSIQUE**





# Année de la physique 2023-2024



**The main objective** is to highlight physics in order to reinforce the sensitivity towards the discipline in all its dimensions and interfaces, to make known its implication in the stakes of the society and to raise the interest of the young girls and boys for this discipline and for the professions which mobilize it. The actions aimed at schools will be implemented in close partnership between the actors of the research world and the National Education. The main goal is to create bridges between laboratories and schools to allow students to discover research in physics. It is also about Also for the teachers to update their knowledge to transmit it to their students and to find support to launch projects in their classes.

## **The proposed actions :**

- **Training of teachers and trainers**, who will go to laboratories to attend lectures by renowned physicists, visit facilities, participate in workshops and meet actors of the research world, within the framework of the National Training Plan and the Academic Training Plans. This will take place at Subatech, with about 50 teachers present. The day will consist of a morning devoted to conferences and an afternoon with scientific workshops.
- **Preparation for the baccalaureate oral exam**, during dedicated meetings between students and physicists
- **Master Class CERN**: Analysis of CERN data by high school students





# Rapport d'activité 2015 - 2020



## Le mot du directeur de Subatech

*A word from the director of Subatech*

Ayant pris la direction de Subatech au 1<sup>er</sup> septembre 2018, succédant à Bernd GRAMBOW, c'est un honneur de présenter cette synthèse de nos activités pendant le quinquennat 2015-2020.

Comme vous allez le découvrir dans ce document, la production scientifique et technique des équipes et services de Subatech a été abondante et de très bonne qualité. Elle a été accompagnée d'une implication forte dans l'enseignement de nos domaines, la valorisation de nos recherches et un engagement déterminé autour de la diffusion de la culture. La fin de cette période a été fortement affectée par la crise COVID19 à laquelle les membres de Subatech ont fait face, respectant les nouvelles règles, garantissant une continuité d'activité, participant à des projets collaboratifs pour réduire l'impact de l'épidémie et en faisant des dons de matériel lors des premiers instants incertains de cette crise inédite.

Ce bilan très positif n'aurait pas été possible sans l'engagement du personnel de Subatech, le soutien et le financement fidèle de nos tutelles, des collectivités locales, de la Région des Pays de la Loire, de l'État et de l'Europe. Merci !

Je vous souhaite une très bonne lecture.

*Since September 1st 2018, I succeeded Bernd GRAMBOW as head of Subatech. As the Director, it is an honor to present this summary of our activities during the 2015-2020 five-year period.*

*As you will reading this document, the scientific and technical production of Subatech's teams and services has been abundant and of very high quality. It has been accompanied by a strong involvement in the teaching of our fields, the valorization of our research and a determined commitment to the diffusion of culture. The end of this period was strongly affected by the COVID19 crisis, which Subatech members faced, respecting the new rules, guaranteeing business continuity, participating in collaborative projects to reduce the impact of the epidemic, and donating materials in the first uncertain moments of this unprecedented crisis.*

*This very positive assessment would not have been possible without the commitment of Subatech staff, the support and faithful funding of our supervising organisations, local authorities, the Pays de la Loire Region, the French government and European Union. Thank you for your support!*

*I wish you a very good reading.*

**Bernd GRAMBOW,**

Prof. IMT Atlantique,  
Directeur du laboratoire  
de Subatech  
de 2011 à août 2018

*Director of the laboratory  
of Subatech from 2011  
to August 2018*



**Gines MARTINEZ,**  
DR1 CNRS,

Directeur du laboratoire  
de Subatech depuis  
septembre 2018

*Director of the laboratory  
of Subatech since  
september 2018*

<http://www-subatech.in2p3.fr/images/General/rapport-activites-subatech-2015-2020.pdf>