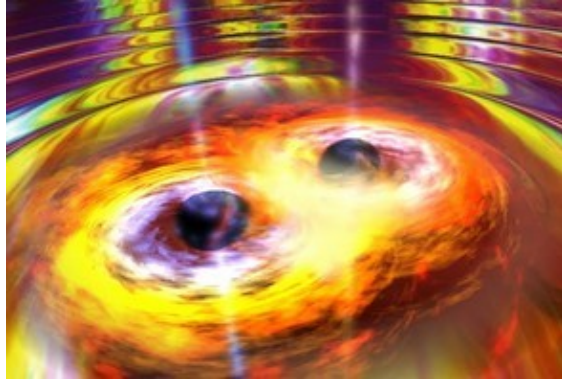




# LAPP activities on gravitational waves

16 May 2023

Loïc Rolland for the Virgo group



# The LAPP team in May 2023

**Researchers:** D. Buskulic, R. Flaminio, R. Gouaty, F. Marion, T. Regimbau, L. Rolland, E. Tournefier, D. Verkindt, M. Was,

**PhD students:** N. Andres (→ 10/2023), P. Lagabbe (→ 10/2023),  
C. Allene (→ 2024)  
C. Grimaud (→ 2025)

**Postdocs :** M. Ebersold (data analysis), V. Hui (optics, simulation), S. Sayah (electronics noise and optics)

**Engineers/technicians :**

**Mechanics:** J-P. Baud, R. Bonnand, G. Deléglise, L. Journet, A. Lacroix (temporary), B. Lieunard, F. Peltier, T. Rambure, T. Yildizkaya

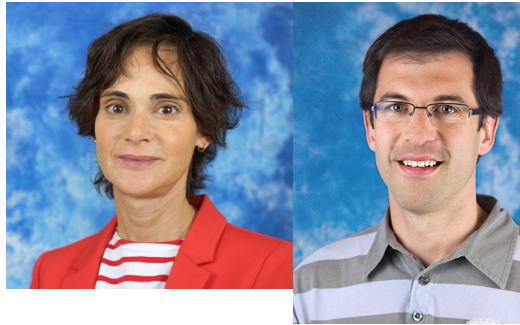
**Electronics:** F. Frappez (temporary), N. Letendre, S. Petit,

**Software:** A. Masserot, E. Pacaud

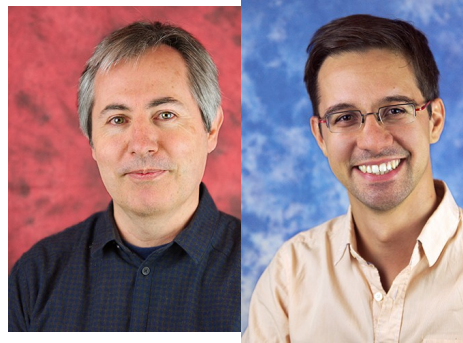
+ administration support

+ internships L3, M1, M3

# The LAPP physicists in May 2023



*Edwige*





# LAPP R&D activities for Virgo and E.T.

## Associated partner of ET PathFinder

- produced digital demodulation (DaqBoxes)

## Low noise electronics for in-vacuum sensors

- towards digital demodulation outside vacuum

*~30 kEuros  
from Labex ENIGMASS  
and University USMB*

## Optics with low optical losses and low scattering

- Need to setup a suspended optical bench in vacuum for optics R&D (+mechanics and electronics R&D)

*~200 kEuros for the clean room  
infrastructure  
570 kEuros for equipment  
425 kEuros found  
missing ~350 kEuros*

## Low thermal noise crystalline coatings

- Plan to measure thermal noise at LAPP

*On-going budget request  
to French ANR*

## Vacuum tubes for E.T.

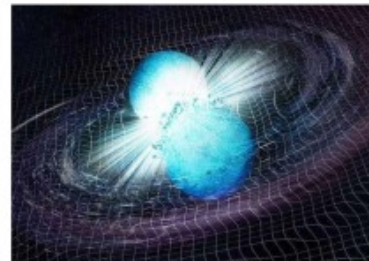
- within INFRA-DEV and the 3-year project lead by CERN#

*~10 kEuros for small  
prototype ?*

# LAPP outreach activities

## Communication and teaching

Fête de la Science  
Pint of Science  
Outreach conferences  
Schools ESIPAP, GraSPA  
Interviews, press releases, articles  
Internships (15 years-old to M2)



Virgo award 2022 given to three young Virgo scientists, whom **Eleonora Polini** for « sustained contributions to optical benches and squeezing activities »

# LAPP responsibilities in the collaborations

- |  |                                     |   |                           |
|--|-------------------------------------|---|---------------------------|
| • Deputy spokesperson  | (Frédérique Marion)                 | } | <b>Virgo</b>              |
| • Project Leader of AdV+   | (Raffaele Flaminio)                 |   |                           |
| • Deputy coordinator of AdV+ commissioning                           | (Michal Was)                        |   |                           |
| • System manager of ESC  | (Michal Was)                        |   |                           |
| • Sub-system manager of DAQ  | (Nicolas Letendre)                  |   |                           |
| • Sub-system manager of DET  | (Romain Gouaty)                     |   |                           |
| • Sub-system manager of SIN  | (Romain Bonnand)                    |   |                           |
| • Sub-system manager of CAL  | (Loïc Rolland)                      |   |                           |
| • Chair of the « Virgo Organisation Committee »                      | (Frédérique Marion)                 |   |                           |
| • Co-chair of the « Core Program Committee »                         | (Frédérique Marion)                 |   |                           |
| • Member of the « Virgo Editorial Board »                            | (Damir Buskulic )                   |   |                           |
| • Member of the « Virgo Steering Committee »                         | (Loïc Rolland, Frédérique Marion)   |   |                           |
| • Members of the postO5 committee                                    | (Edwige Tournefier, Tania Regimbau) |   |                           |
| • Co-coordinator of the reviews of the LV « Continuous Waves » group | (Damir Buskulic)                    | } | <b>LIGO-Virgo-KAGRA</b>   |
| • Co-chair of LV « Diversity Committee»                              | (Tania Regimbau)                    |   |                           |
| • Member of the LIGO program advisory committee                      | (Frédérique Marion)                 |   |                           |
| • Co-chair of the division Data Analysis                             | (Tania Regimbau)                    | } | <b>Einstein Telescope</b> |
| • Co-chair of the division Optics                                    | (Edwige Tournefier)                 |   |                           |
| • Co-chair of the workpackage Input&Output optics                    | (Michal Was)                        |   |                           |
| • Co-chair of the workpackage DAQ&real-time                          | (Loïc Rolland)                      |   |                           |
| • Chair of the workpackage « design of vacuum tubes »                | (Guillaume Deléglise)               |   |                           |
| • Co-chair of the workpackage Project Office from INFRA-DEV          | (Raffaele Flaminio)                 |   |                           |
| • Member of the Einstein Telescope Collaboration Board               | (Edwige Tournefier)                 |   |                           |

# Organigram of AdV+

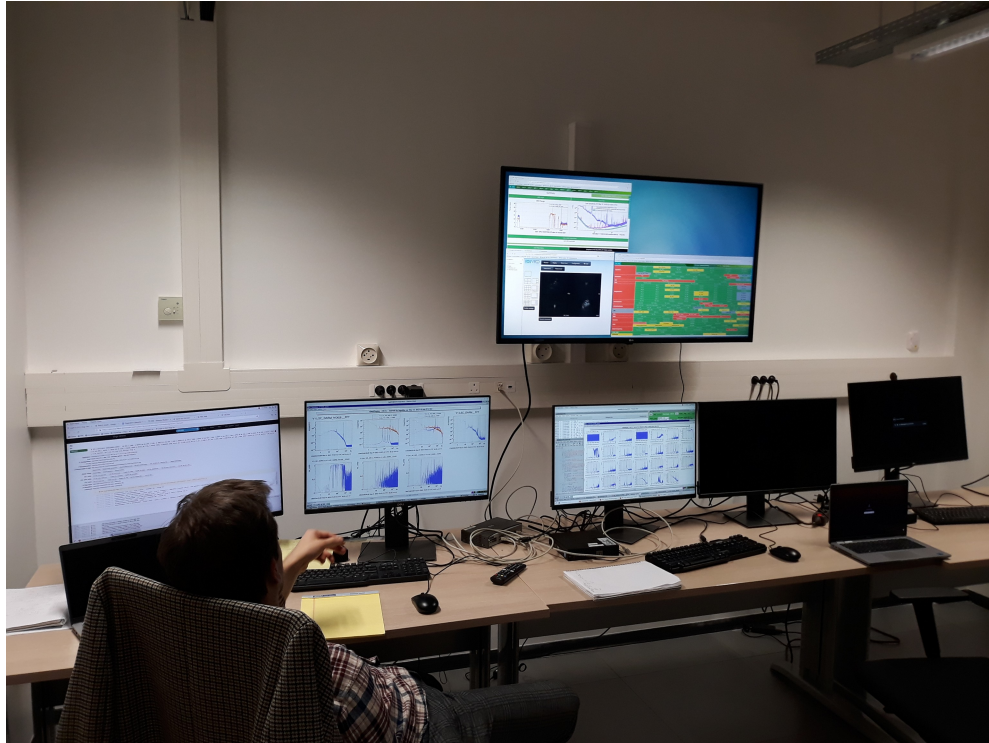




# Current PhD thesis and postdocs

- Nicolas Andres (3rd year PhD)
  - Data analysis
- Paul Lagabbe (3rd year PhD)
  - Calibration
- Christopher Allene (2nd year PhD)
  - CBC data analysis
- Cervane Grimaud (1st year PhD)
  - Calibration and reconstruction
  
- Michael Ebersold (IN2P3)
  - Stochastic data analysis and E.T. data challenge
- Victor Hui (EGO)
  - DET commissioning and optical simulations
- Sihem Sayah (ENIGMASS+EGO)
  - Noise from digital demodulation + optical measurements
  
- 4 internships (2 M2, 1 M1, 1 L3) → EGO/USMB grant for one PhD starting in Octobre 2023?

# Strong participation to the commissioning



Picture of LAPP control room for Virgo

**Remote shifts** for DET, SIN, CAL, DAQ

Support from DAQ/controls for ISC, TCS, Squeezing, ...

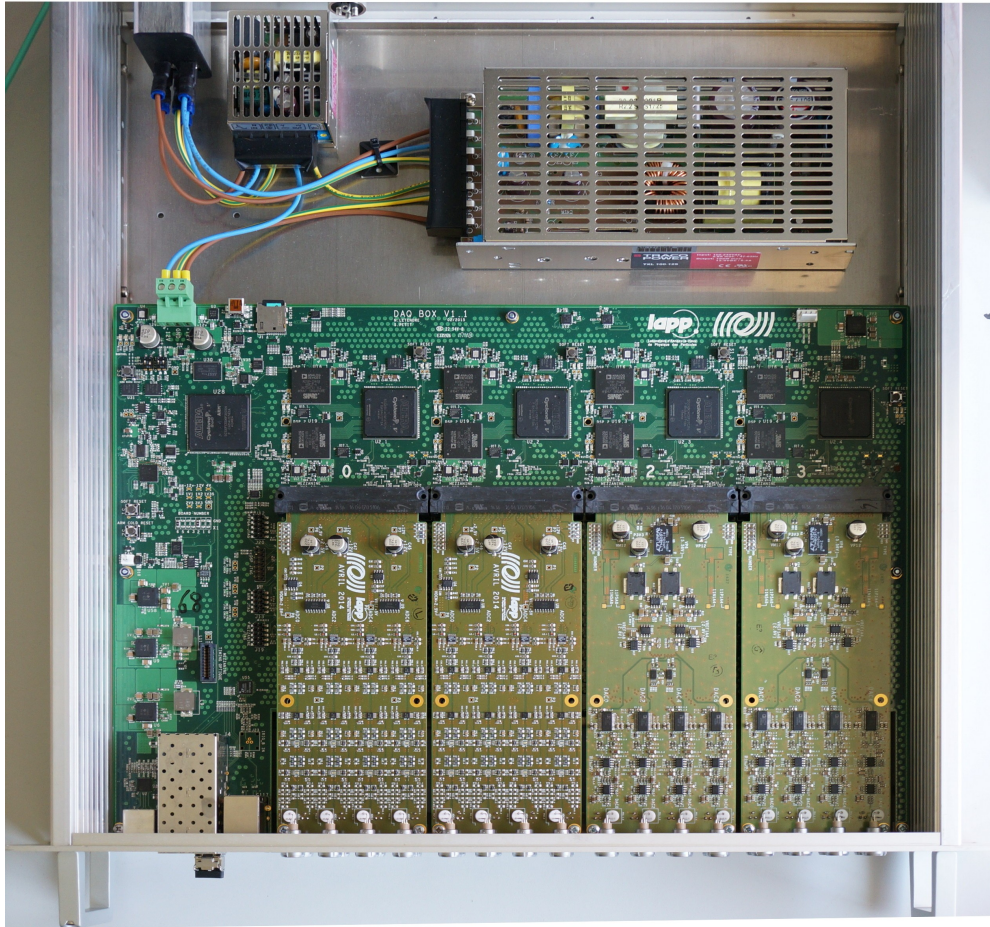
**On-site interventions** and shifts on hardware

Strong implication in **commissioning, noise hunting**

Michal, Raffaele, Romain G., Romain B., Alain, Edwige, Victor, ...

More details about the LAPP R&D plans

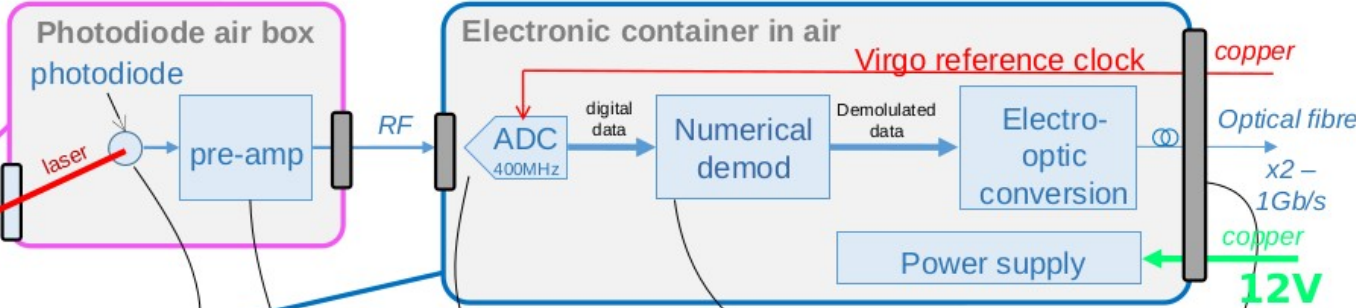
# Starting R&D about digital electronics



# Electronics R&D : current acquisition chain

## ELECTRONIC R&D : ACTUAL ACQUISITION CHAIN

### Laser beam read-out chain



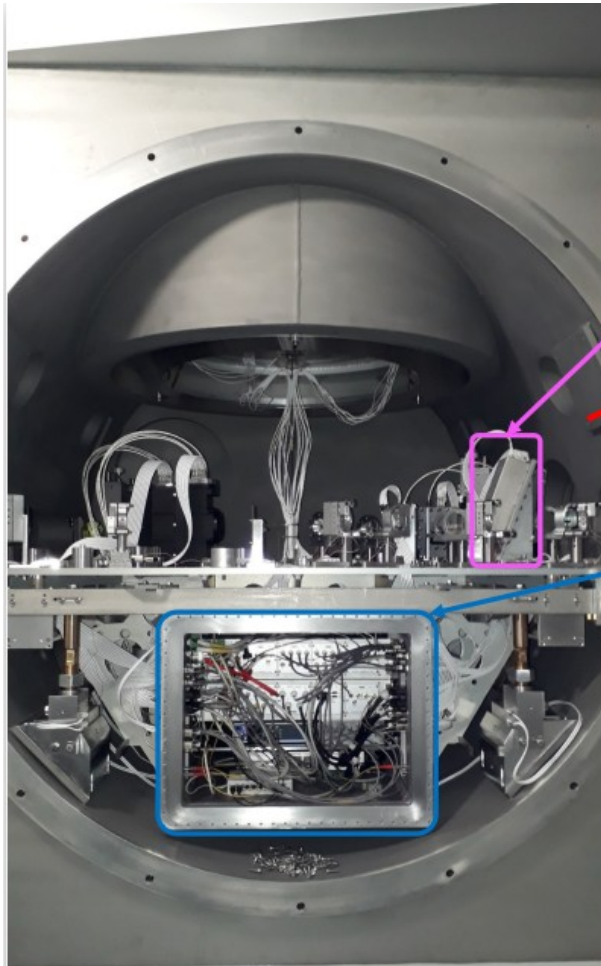
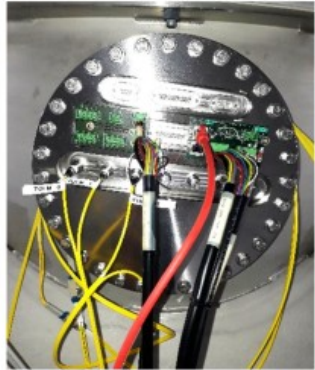
Electro-optic conversion

Analogic → digital conversion  
400 millions of bits per seconds

Electric signal amplification

digital computation

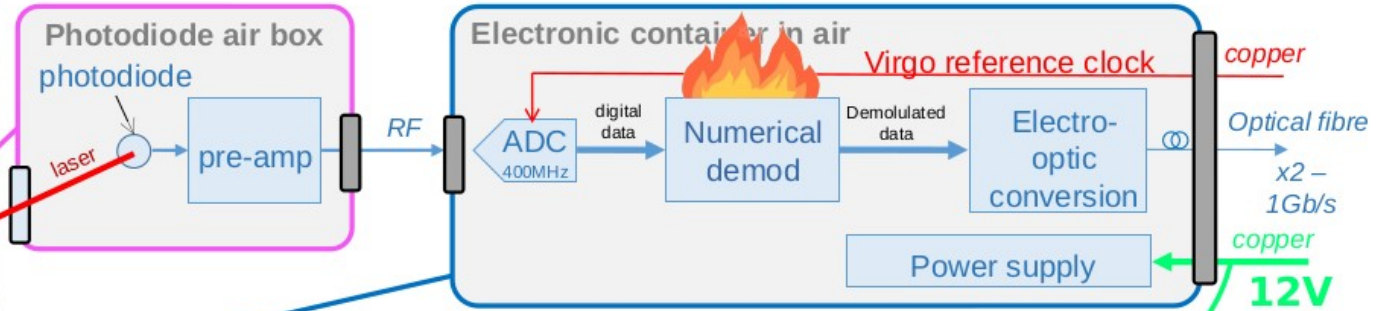
air/vacuum interface



# Electronics R&D : issues of current acquisition chain

## ELECTRONIC R&D : ACTUAL ACQUISITION CHAIN

### Laser beam read-out chain



### Clock transmission by copper cable

- Attenuation of signal
- Loss in the clock quality

### Numerical demodulation

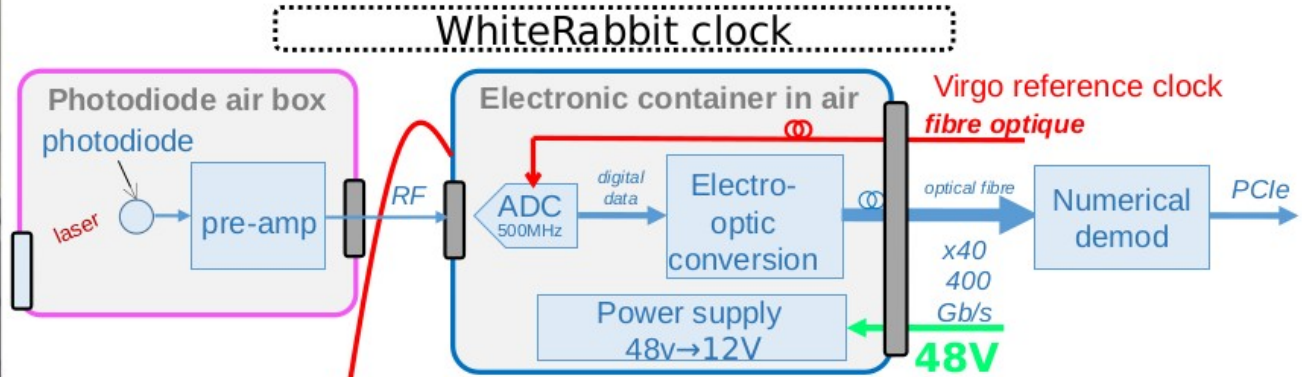
- Hot !!!
- Limited power computation

### Power supply by long cable

- Loss of power inside the cable
- Voltage varies with the consumed power

# Electronics R&D: timing

## ELECTRONIC R&D : ACQUISITION CHAIN

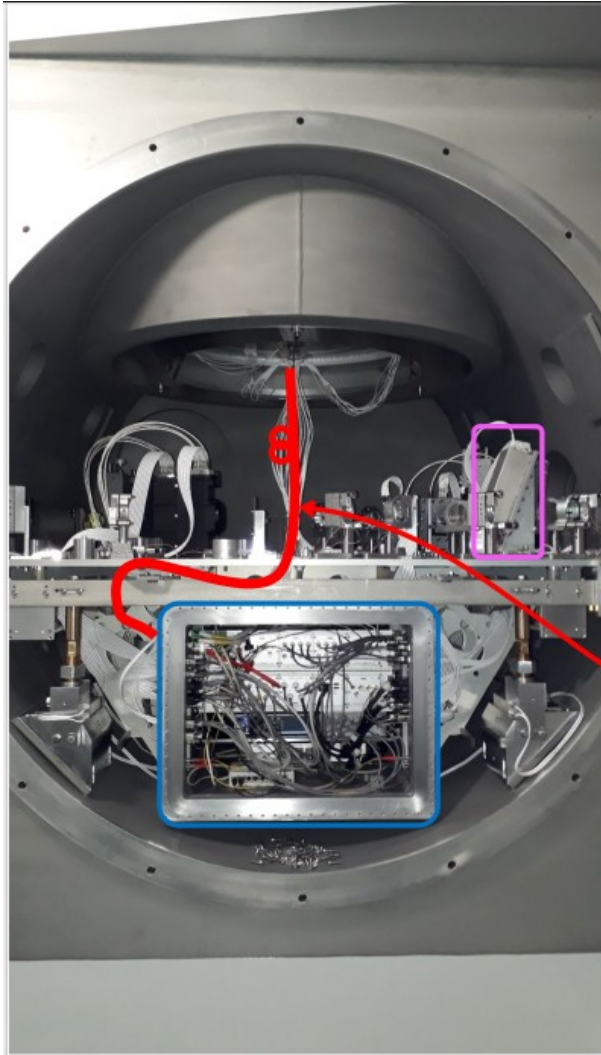


### Clock transmission

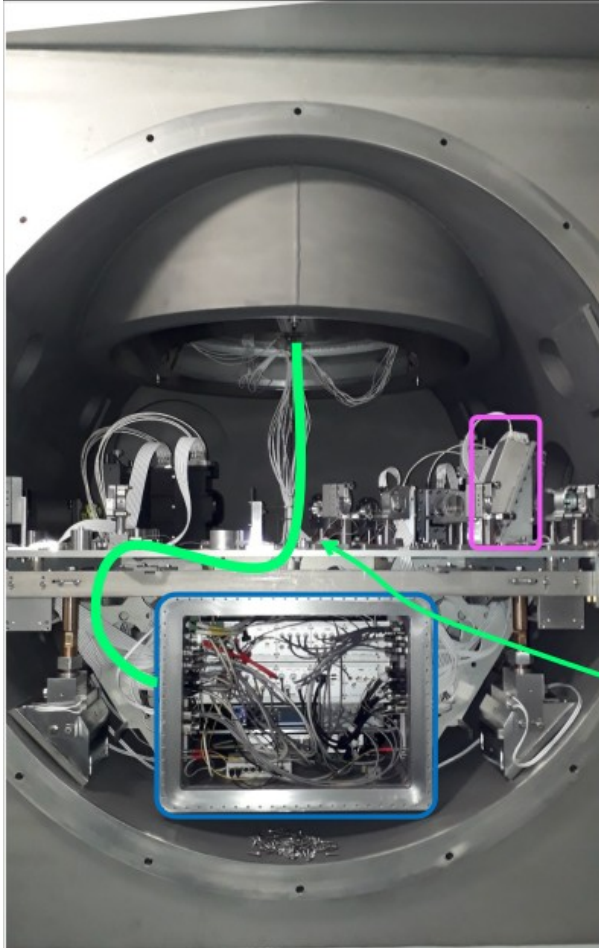
- Using optical fiber = less degradation of the signal
- WhiteRabbit protocol developed at CERN



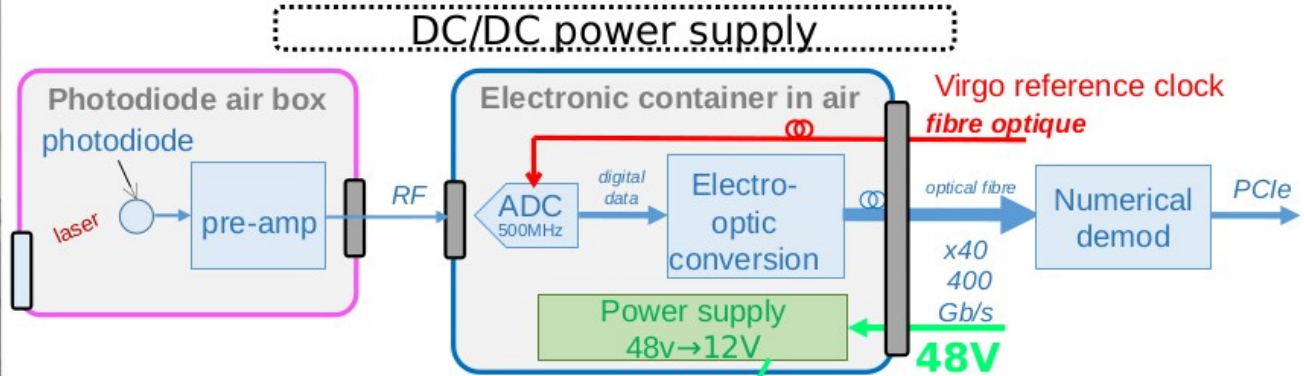
Using WhiteRabbit protocol on the LAPP electronic board



# Electronics R&D : power supply



## ELECTRONIC R&D : ACQUISITION CHAIN



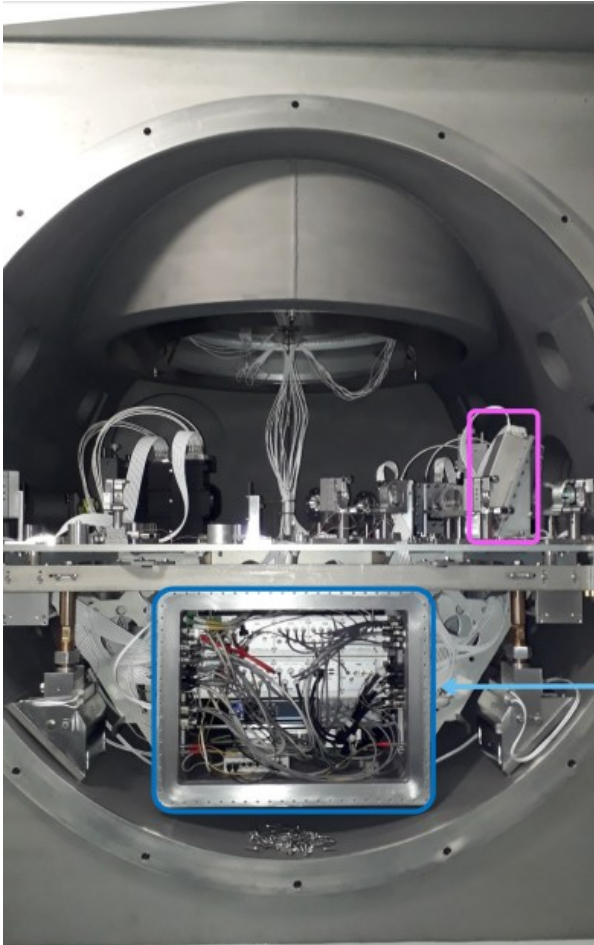
**48V power supply regulated 48V→12V**

- Less power losses along the cable
- More stable voltage

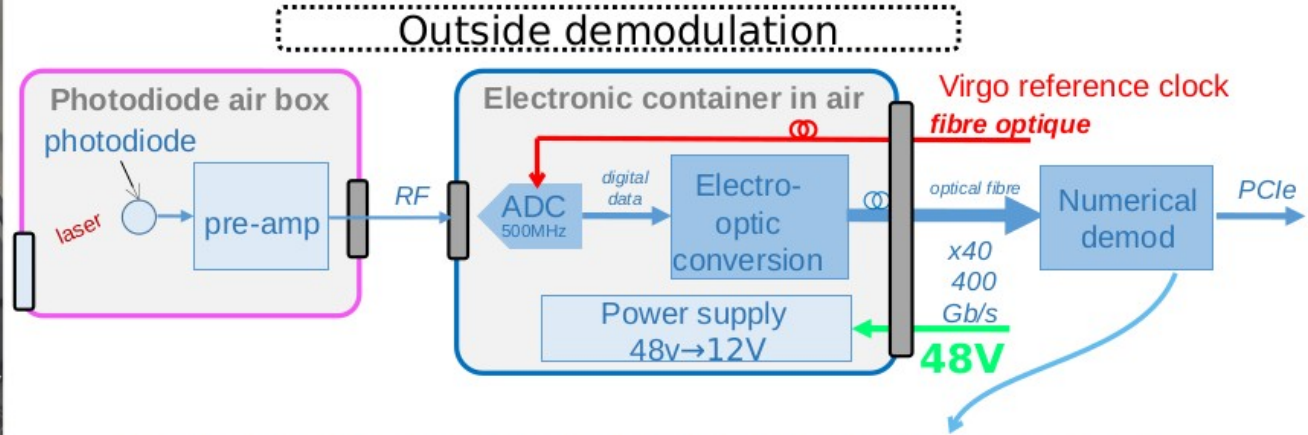
**➔** Design of a power supply electronic board



# Electronics R&D : digital demodulation



## ELECTRONIC R&D : ACQUISITION CHAIN



### Numerical demodulation outside of the mini-tower

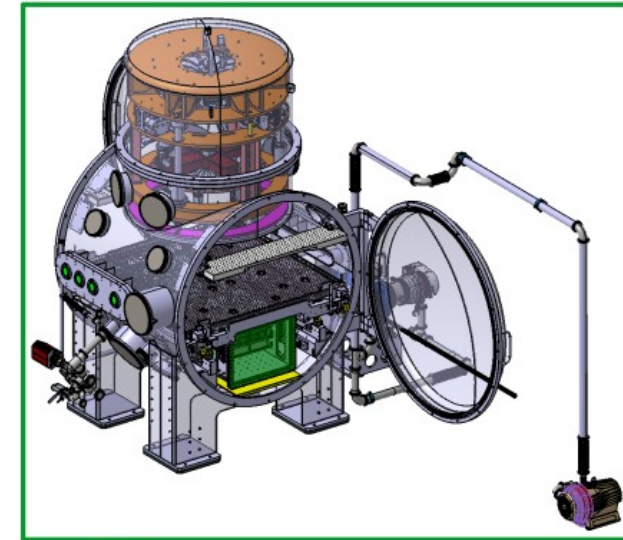
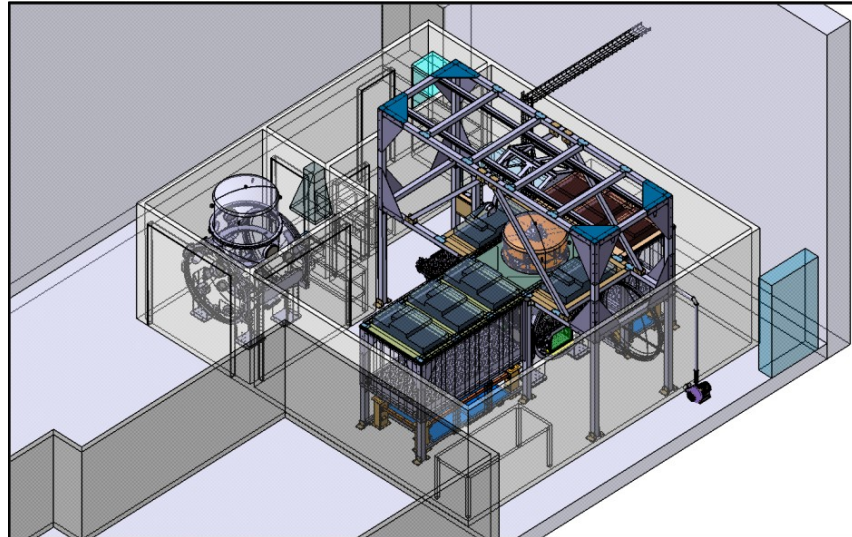
- Easier maintenance
- Higher computational power
- Upgradeable



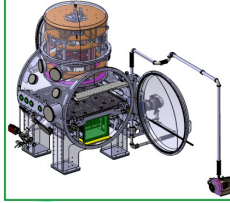
- Design of ADC electronic board (500MHz) + electro-optic converter
- Firmware development for data reception & numerical computation
- Feedthrough study : interfaces with ~40 optical fiber

# – R&D in optics —

## Preparation of a suspended optical bench in vacuum at LAPP

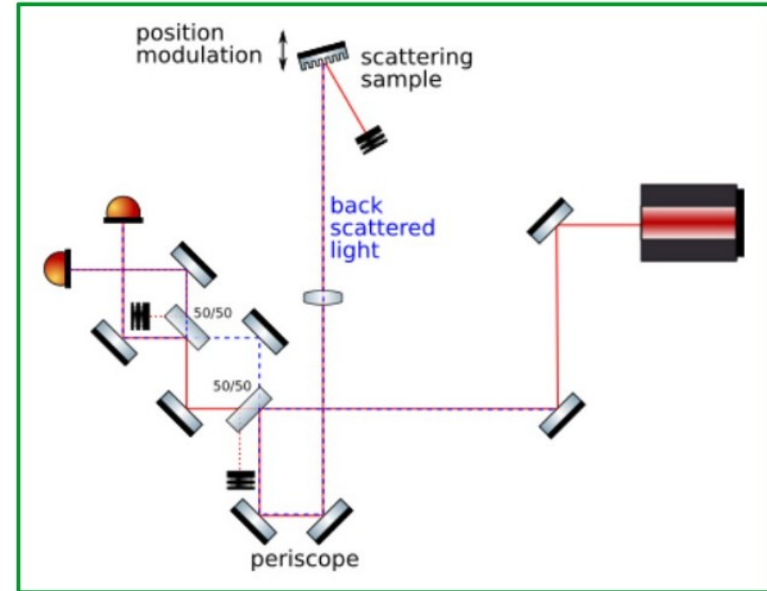


# Optics R&D: reducing scattered light

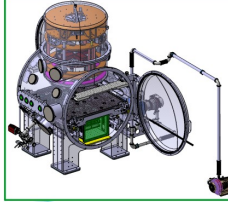


## Precise measurement of back-scattered light

- measure scattered light with sensitivity of  $10^{-16}$  in fraction of scattered light
- measure of scattering at small angle, with angular resolution of  $5 \mu\text{rad}$
- study of multiple scattering (simulations + measurements)



# Optics R&D: develop new output mode-cleaner cavities

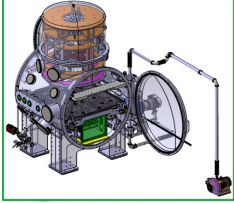


**Monolithic cavities reached their limits**  
optical losses  
thermo-refractive noise

→ **development and test of new design**



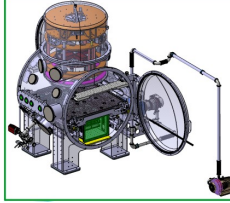
# Optics R&D: thermal noise measurement



**Development of new mirror coatings with low thermal noise**  
in collaboration with French labs and industries  
following PhD of Victor Hui

→ **development of a setup to measure thermal noise at LAPP**

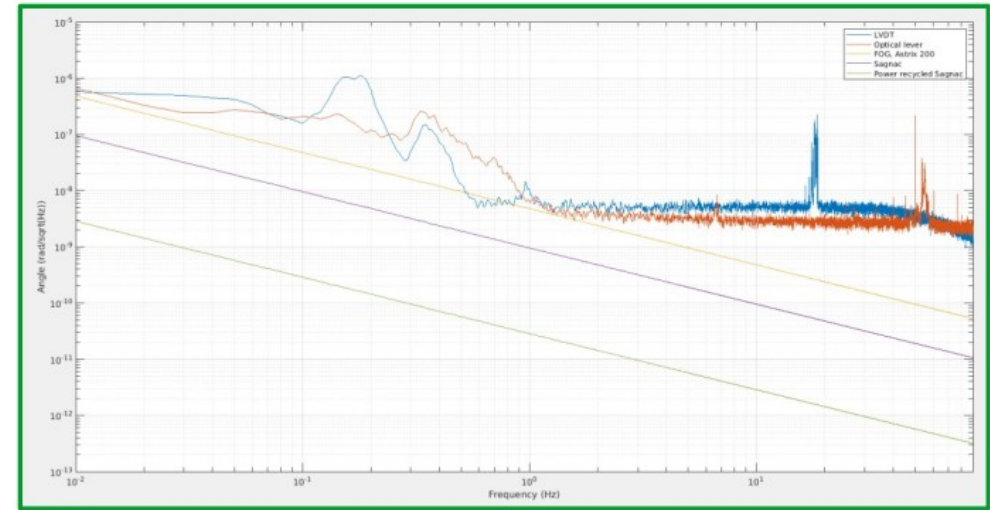
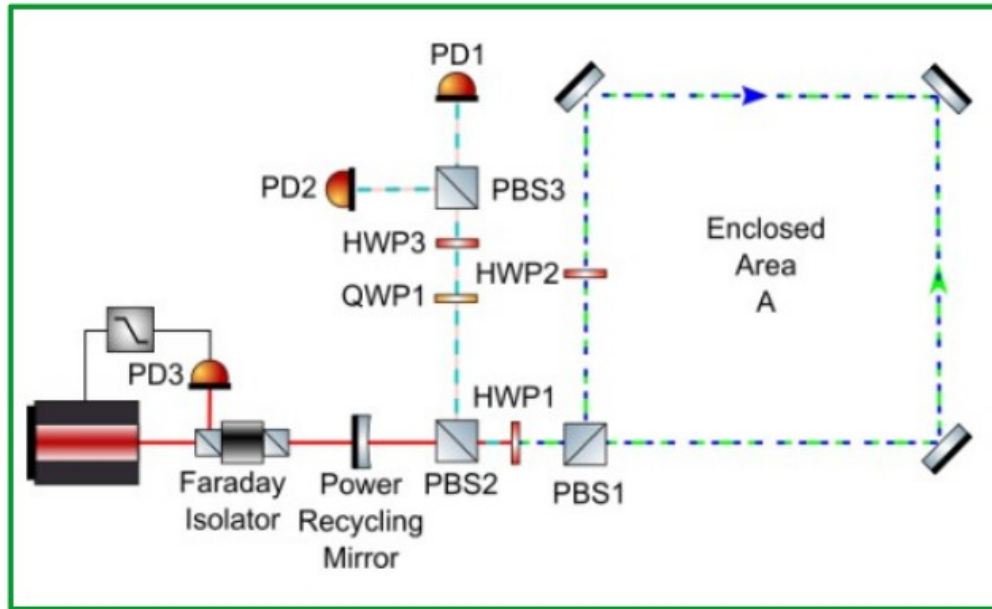
# Optics R&D: bench tilt measurement



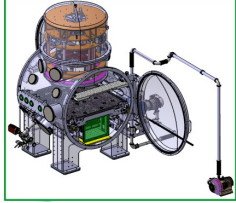
## Design and test a Sagnac interferometer as a bench tilt sensing

improve suspension controls

→ reduction coupling of tilt/translation wrt scattered light (important for E.T.)



# R&D platform at LAPP : other possible topics



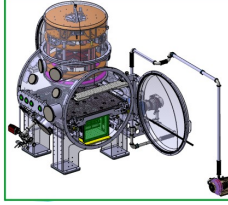
## Electronics

- Integration and test of digital electronics developments
- Characterization of new photodiodes pre-amplifiers
  - Low noise/low loss DC readout for GW detection
  - Low noise RF readout for longitudinal controls
- No contact power distribution inside minitowers ?

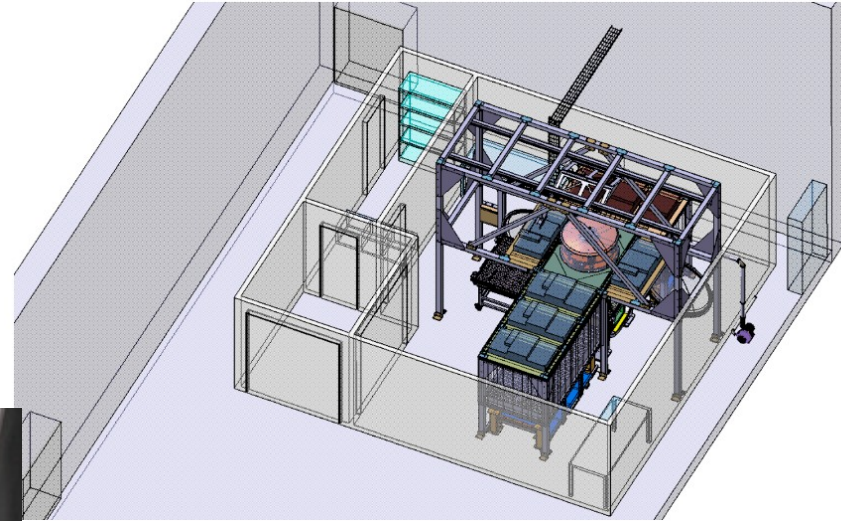
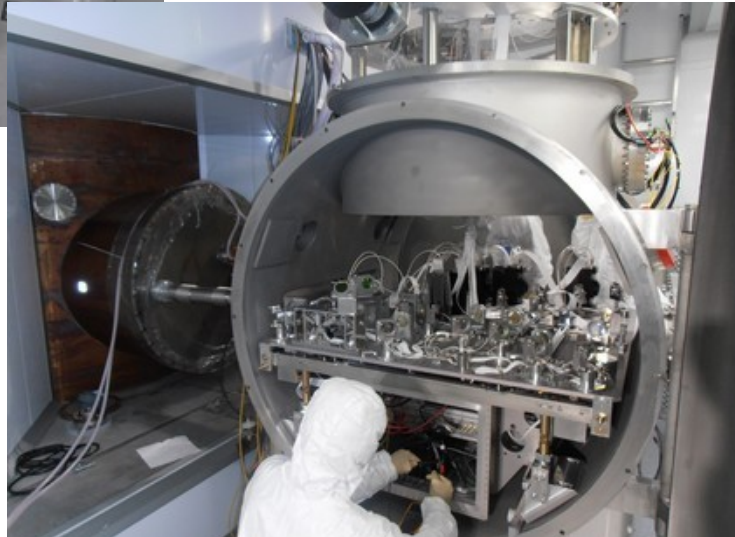
## Mechanics

- improve simulations of minitower and optical bench
  - vibration, thermal, ... by comparing to measurements
    - improve CAO of future mechanical developments for Virgo\_nEXT, E.T.
- cooling of optical bench with Peltier cells ?

# R&D platform at LAPP : suspended optical bench in vacuum



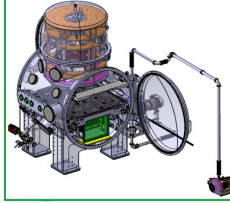
7 benches have been installed at Virgo between 2015 and 2021, and are in operation.



Need a new clean room at LAPP/Université Savoie Mont-Blanc to host the new equipment.



# R&D platform at LAPP: some budget information



## Estimation of costs

### - clean room 180-250 kEuros

on-going preparation of hiring an enterprise for project management, to better define the clean room design and estimate more precisely the budget

### - scientific equipment: 520-570 kEuros

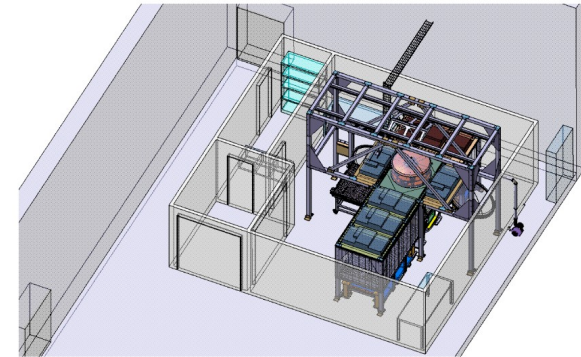
including optomechanics for scattered light measurement, as 1<sup>st</sup> experiment

## Current resources: 425 kEuros (mainly for equipment)

- 140 kEuros (Labex Enigmass: vacuum tank and bench mechanics)

- 225 kEuros (ANR: suspension and optomechanics)

- 60 kEuros (LAPP: bench mechanics, 1<sup>st</sup> step of clean room project management)



## Missing budget : 280 to 400 kEuros

- 180-250 kEuros for infrastructure (clean room)

- 110-160 kEuros for scientific equipment

**WARNING** : estimations  
done 1 to 2 years ago,  
Need to be reassessed !

# – R&D for E.T. vacuum tubes —

## Design of vacuum tubes

~120 km of tube, at least 1 m in diameter, with ultra high vacuum

### **Functional goal :**

strong tube under external pressure

### **Economic goal :**

light tube to minimise cost for material

less material to reduce electrical consumption for heating

rigid in flexion to minimize number of supports



# Some discussions

## **Importance of having a EGO R&D plan**

→ in particular for our platform with suspended bench in vacuum

## **Importance of fellowships to support Virgo activities + O5/postO5/ET preparation**

→ regular PhD, postdocs, engineers

Urgent : possibility for a 1/2 grant for the PhD?  
EGO plans for (regular?) calls for fellowships?

# Conventions

## **Maintenance** (via DR PMA)

- 2021 (25-2021, 85 kEuros max) → closed
- 2022 (1-2022, 60 kEuros max) → 56820 euros. → status at LAPP/DR11/EGO ? Facturation envoyée ou pas ?
- 2023 (49-2023, 40 kEuros max) → being signed

## **Upgrades** (via DR PMA)

- AdV+/phase1 (136-2019) → closed
- AdV+/phase2 (75-2023) → in preparation

## **Missions** (via DR11)

- 2021 → closed
- 2022 (letter 76-2022) à 110827.98 euros → being paid by EGO
- 2023 (170-2022, 53 kEuros max for 1st semester)
  - LAPP will send the list of expenses in June/July

## **Fellowships** (via DR11)

- Victor Hui (2-2022, postdoc June 2022 – June 2024, 116222 euros)
- Sihem Sayah (58-2022, postdoc ~Mars 2023-Mars 2024, 38000 euros)