

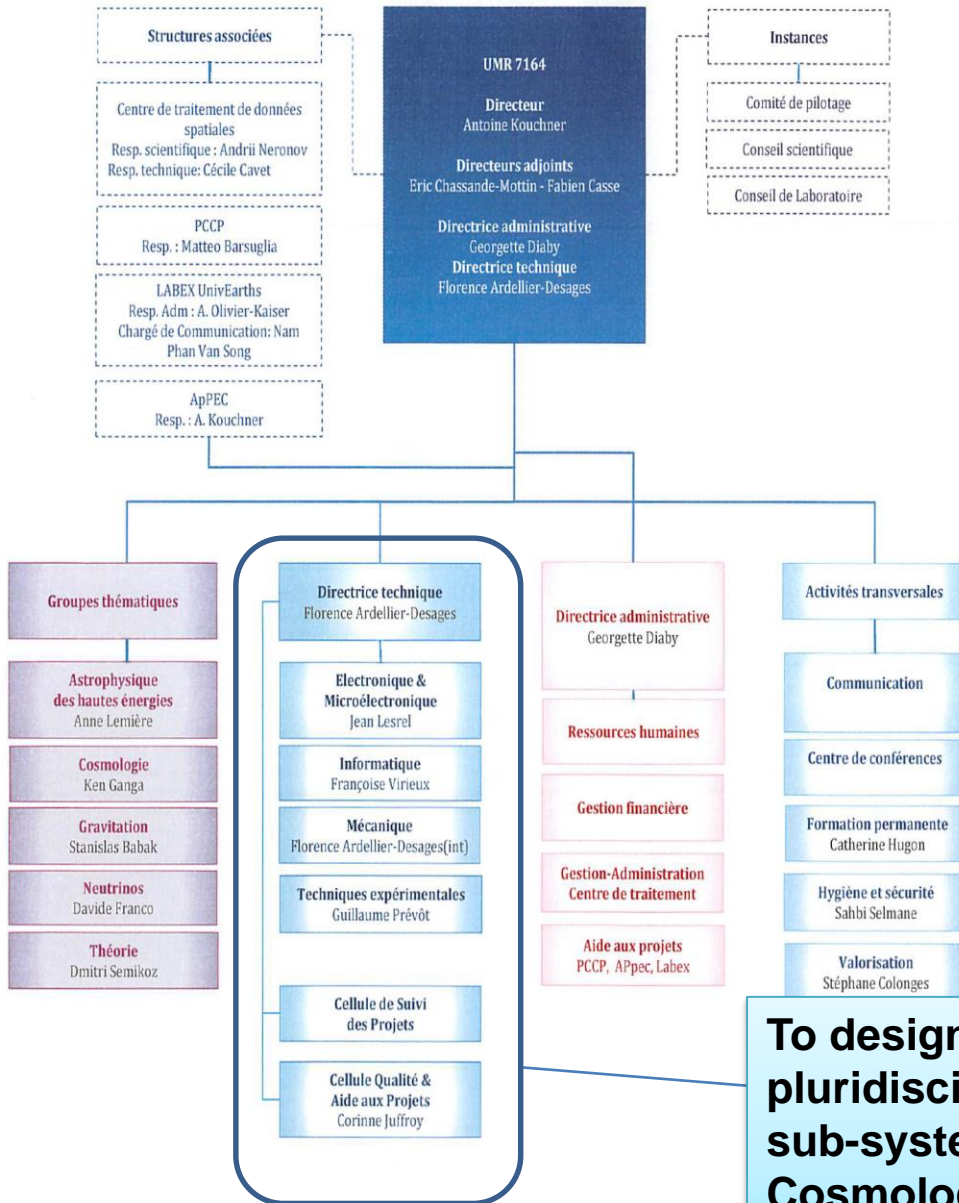
APC Scientific Council 19th-20th march 2020

TECHNICAL STATUS F. Ardellier



CONTENT

1. Highlights & APC projects main progress
2. Management of APC projects portfolio
3. Organisation of technical departments
4. Platforms, R&D, outreach
5. Technical roadmap
6. Conclusion



To design, develop, qualify, deliver pluridisciplinary innovative systems or sub-systems for AstroParticles and Cosmology Program



HIGHLIGHTS

&

APC Projects main progress

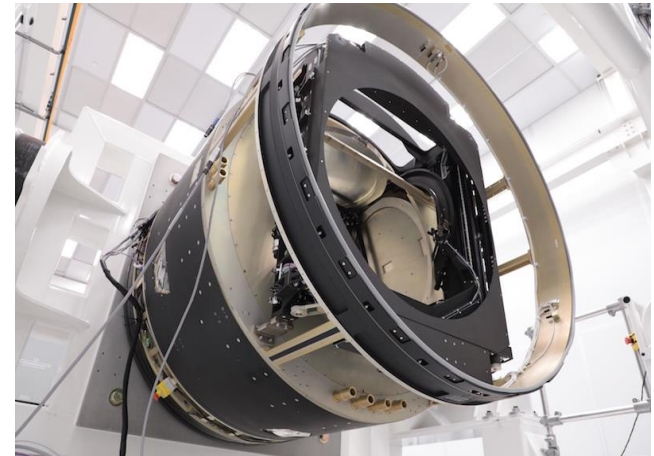


LSST / Camera Filter Changer Control System in US

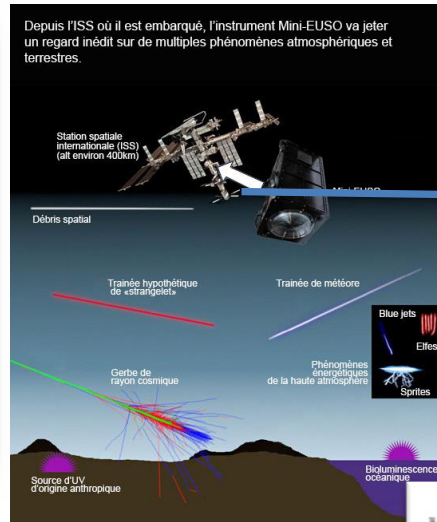
The **filter changer** of the **Vera Rubin Observatory** has been delivered in time, **in September 2019**. It has been integrated in the LSST camera at SLAC. Five IN2P3 laboratories have contributed to its design and building.

It's **control software, FCS**, has been developed at **APC**, as well as some part of the **CCS software**, which drives the whole camera system.

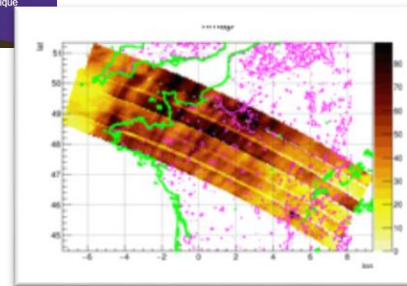
This **important milestone** have been advertised by articles in the **Journal du CNRS** and the **Lettre de l'IN2P3**.



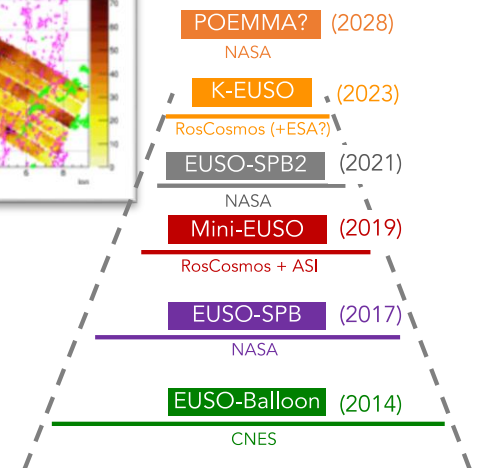
Mini-EUSO equipped with APC components is taking data in space (ISS)



9 sensitive UV detector units built at APC on board



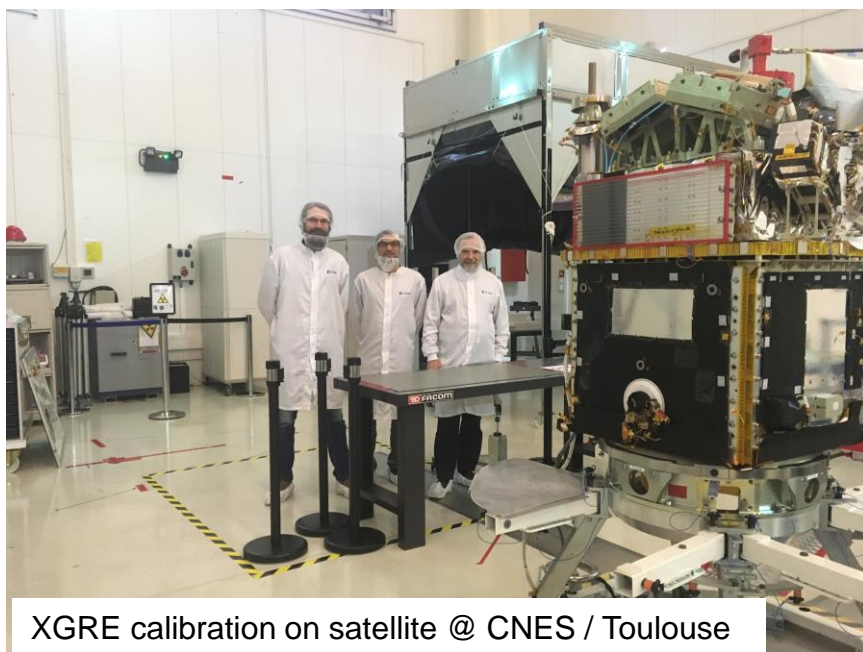
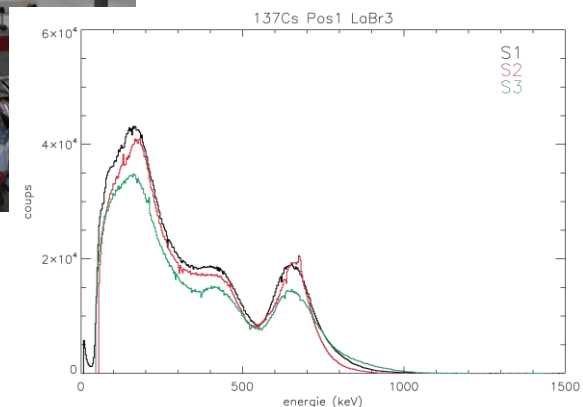
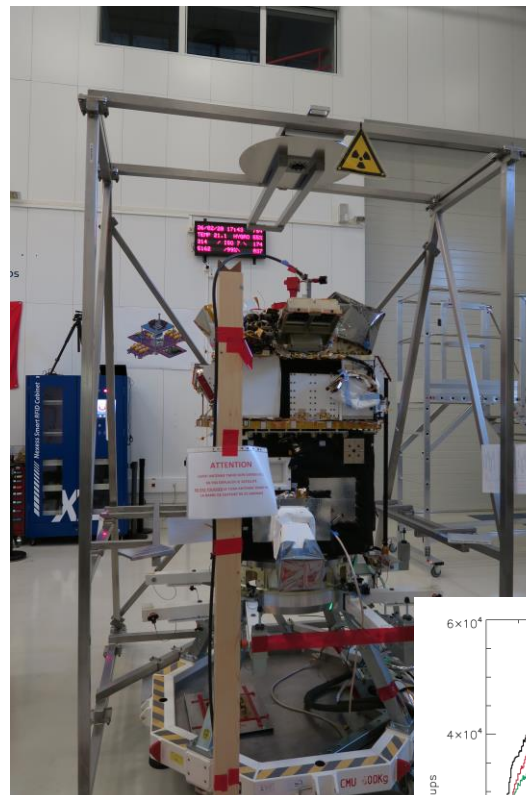
- ✓ EUSO-Balloon, EUSO-SPB1 and TUS have flown successfully – 2014
- ✓ EUSO-SPB2 is approved by NASA
- ✓ POEMMA in the 2020 NASA decadal survey
- ✓ JEM-EUSO has been confirmed in the « pool of experiments » of ESA (Nov. 2018)
- ✓ K-EUSO reviewed by ROSCOSMOS approved to go into Phase B! (April 2019)



All the detector units designed, developed, produced & characterized under the supervision of APC

TARANIS / XGRE ready to be launched

- ✓ Microsatellite CNES dedicated to the study of transient atmospheric phenomena related to thunderstorm activity
- ✓ XGRE main instrument sensors developed and integrated by APC

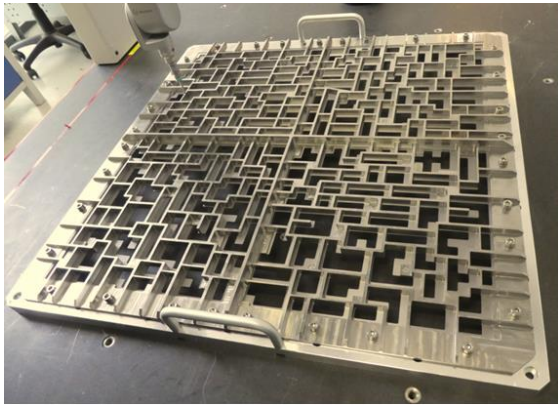


XGRE calibration on satellite @ CNES / Toulouse

Launch is planned on the 24th june @ KOUROU

SVOM ECLAIRs / Mask

- **CDR passed with success**

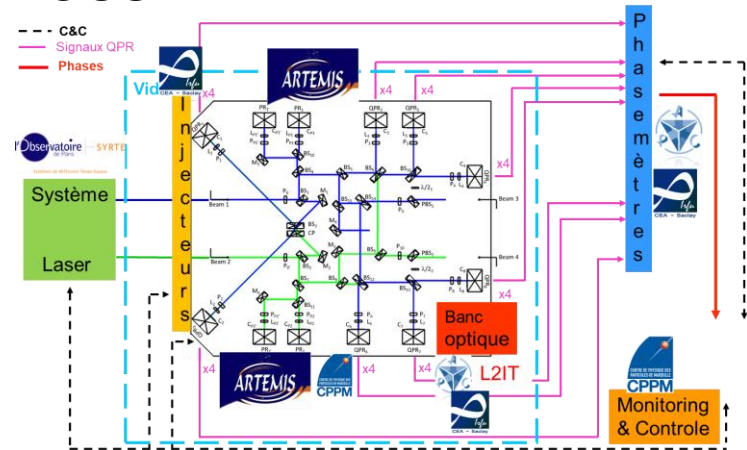


- Mask flight model under construction (delivery planned in may 2020)
- Ground Segment (pipeline) under development

LISA

Phase A 2018 – 2020 / 2021 :

1. AIVT MOSA → technical coordination for heterodyn optical bench to validate reachable perf for OGSE

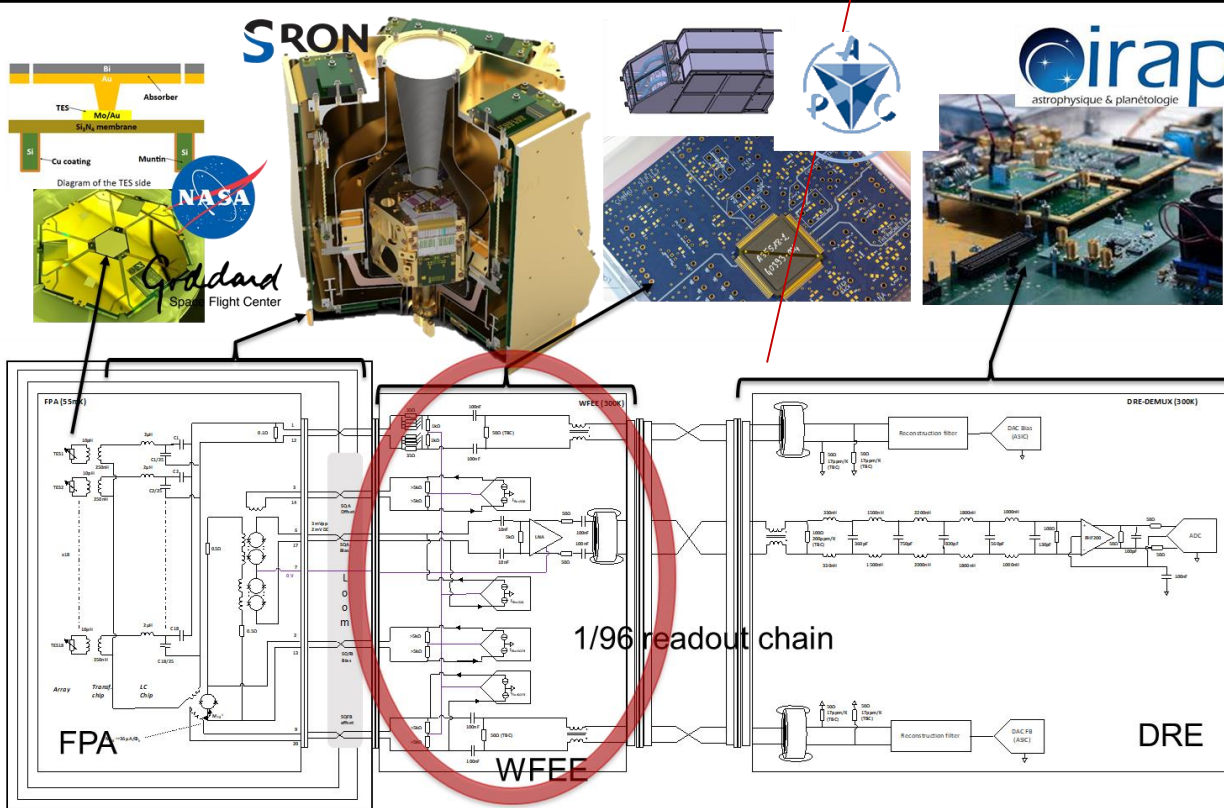


2. DDPC level 2 and 3

ATHENA X-IFU Warm Front End Electronics

IPRR passed with success in april 2019 → **Phase B launched**

→ APC in charge of Warm Front End Electronics system with **Low Noise Amplifiers (ASIC)**

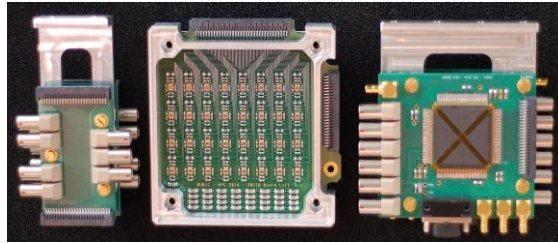
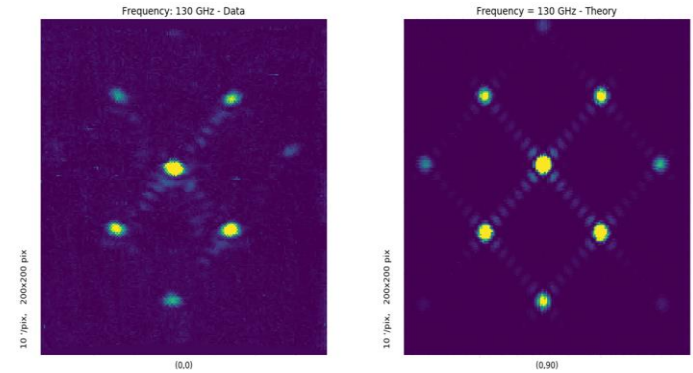
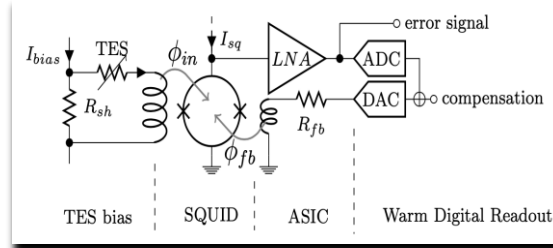


ASIC technology change to take into account

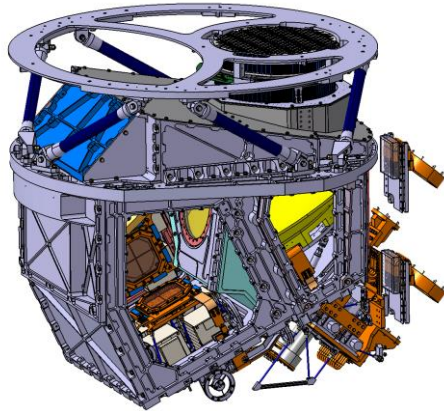
Last minute :
 Frequential Domain Multiplexing → Time Domain Multiplexing
New requirements under construction

QUBIC : First bolometric interferometer is taking data

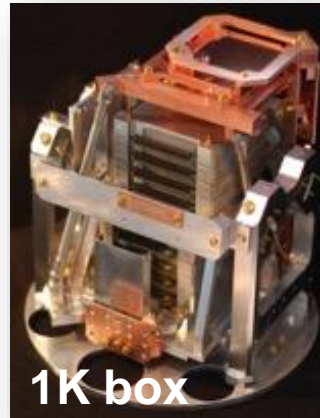
→ Demonstration phase passed successfully !



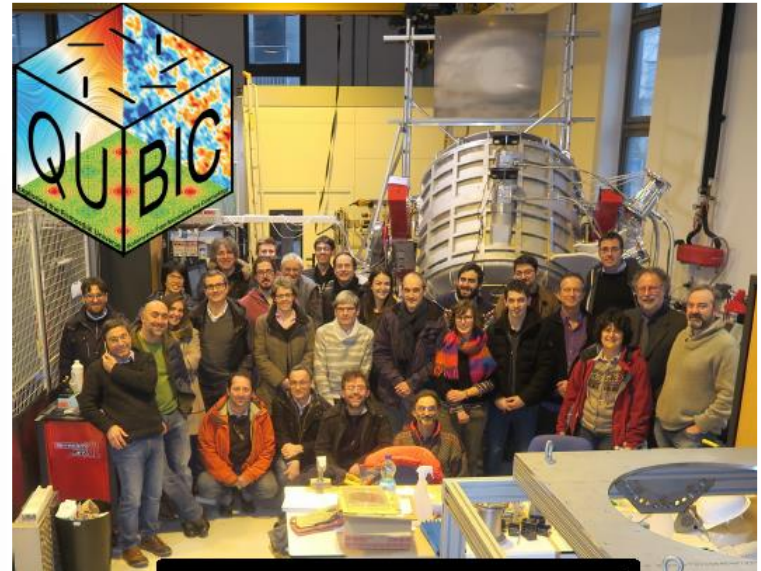
Complete cold electronic detection chain



CAD design

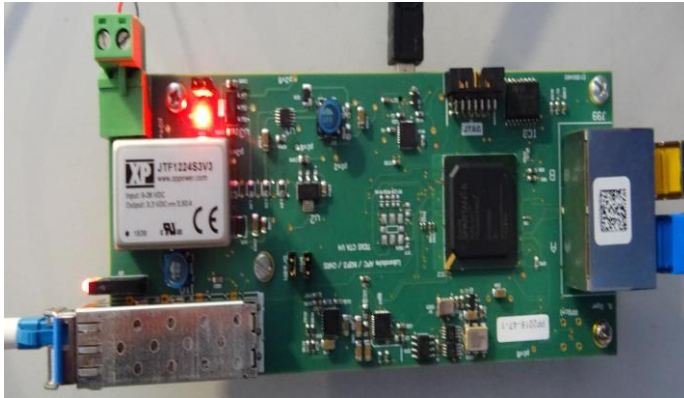


1K box

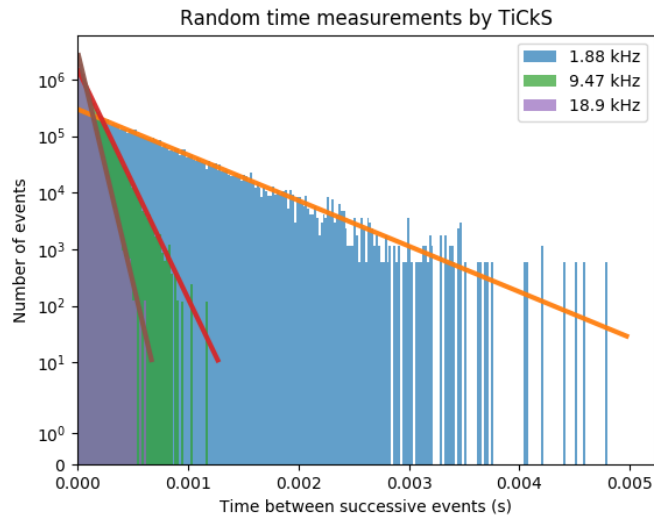
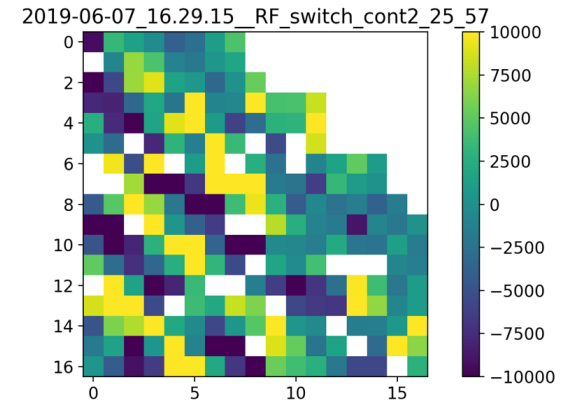


Integration & calibration

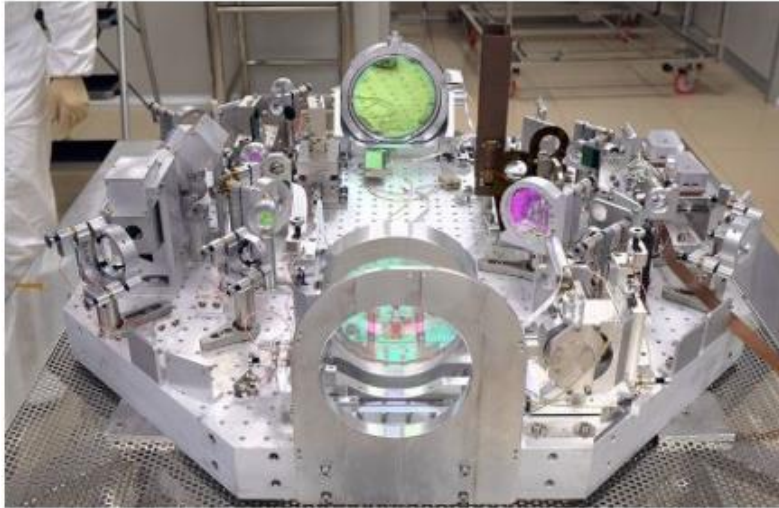
APC development



CTA timing and sampling board



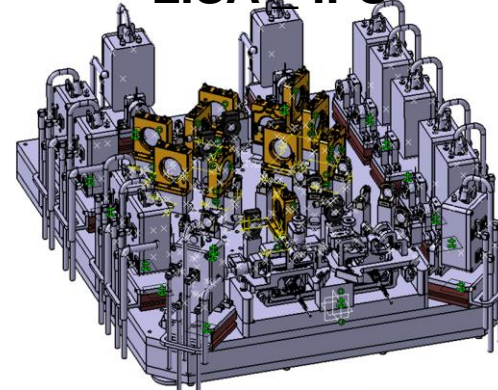
VIRGO Adv + : Scope of Work



The Virgo gravitational-wave detector near Pisa, Italy, has roughly doubled its sensitivity since 2017. Credit:

- Design, realisation and installation :
 - **Diaphragms** to reduce the scattering light
 - **Electronics** of new locking system, photodiodes (170 MHz) for beat measurement with the main Virgo laser
- **Optical design study** to adapt all telescopes to change in beam size

LISA IFO



Optical metrology : technical coordination of optical ground support equipment
proof of performances

- Aim : $\sim 10 \text{ pm}/\sqrt{\text{Hz}}$ on 0mHz-1Hz sur ZIFO.

R&D :

- Laser frequency control electronics on the optical cavity (installed @ TAMA)
- programmable very low phase noise sinusoidal signal generator with Direct Digital Synthesis (DDS) ultra-stable frequency reference

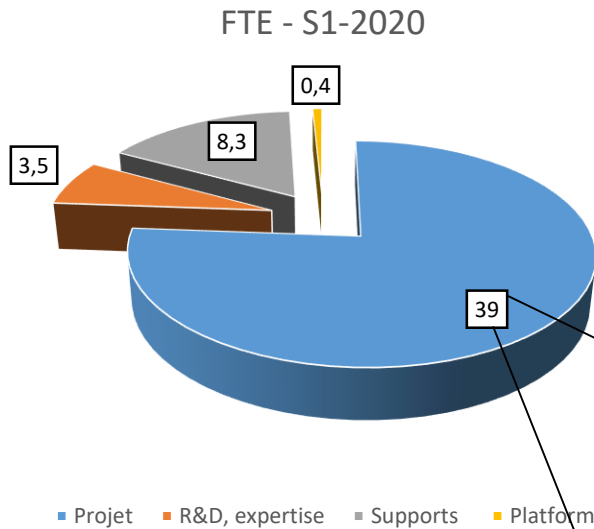


MANAGEMENT OF APC PROJECTS

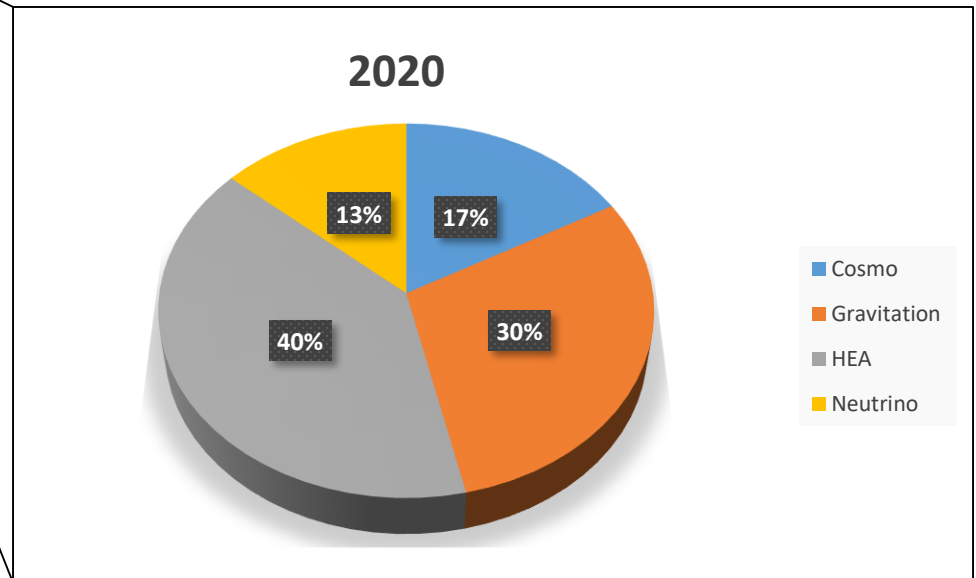
PORTFOLIO



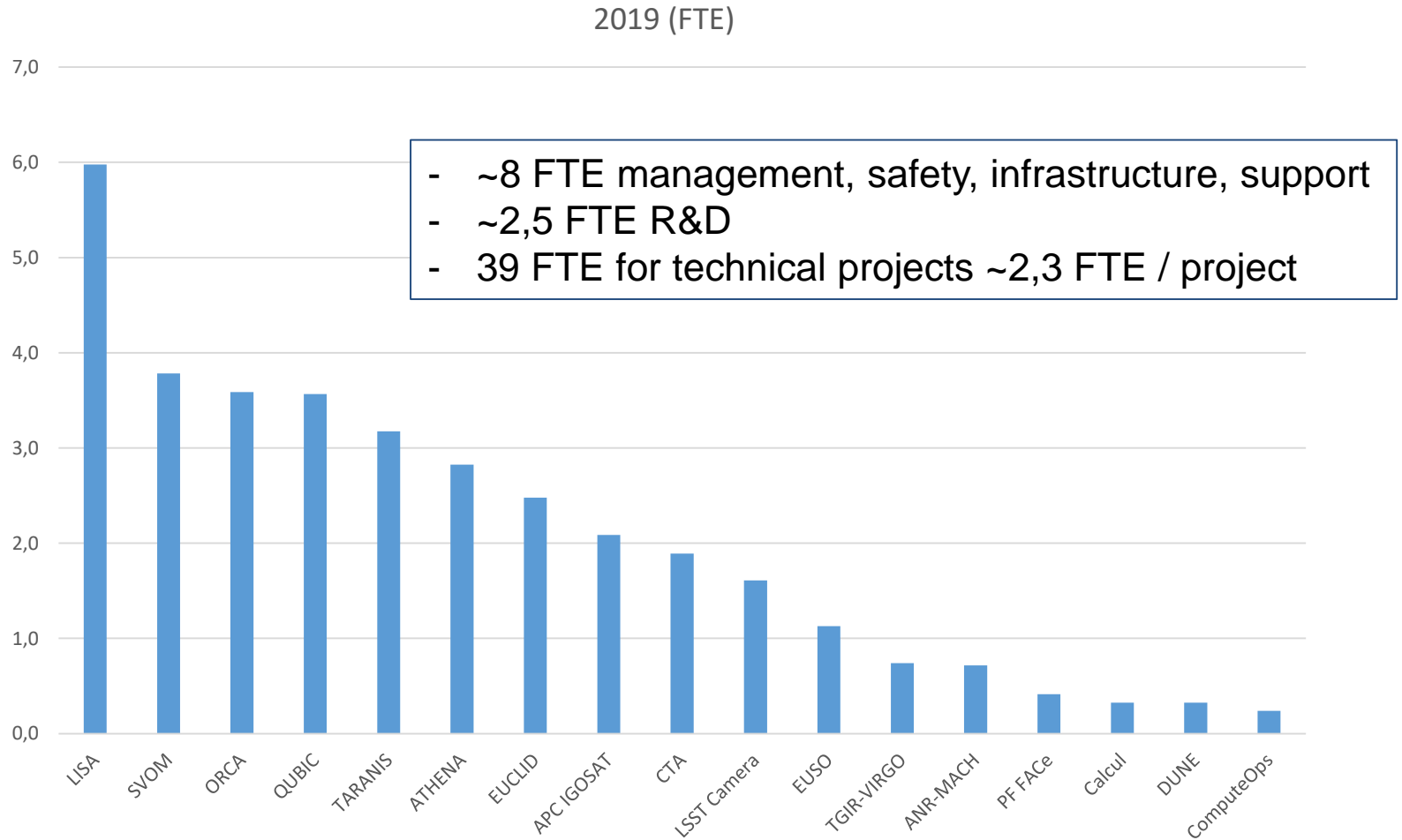
ACTIVITIES SHARED BY TECHNICAL DEPARTMENTS



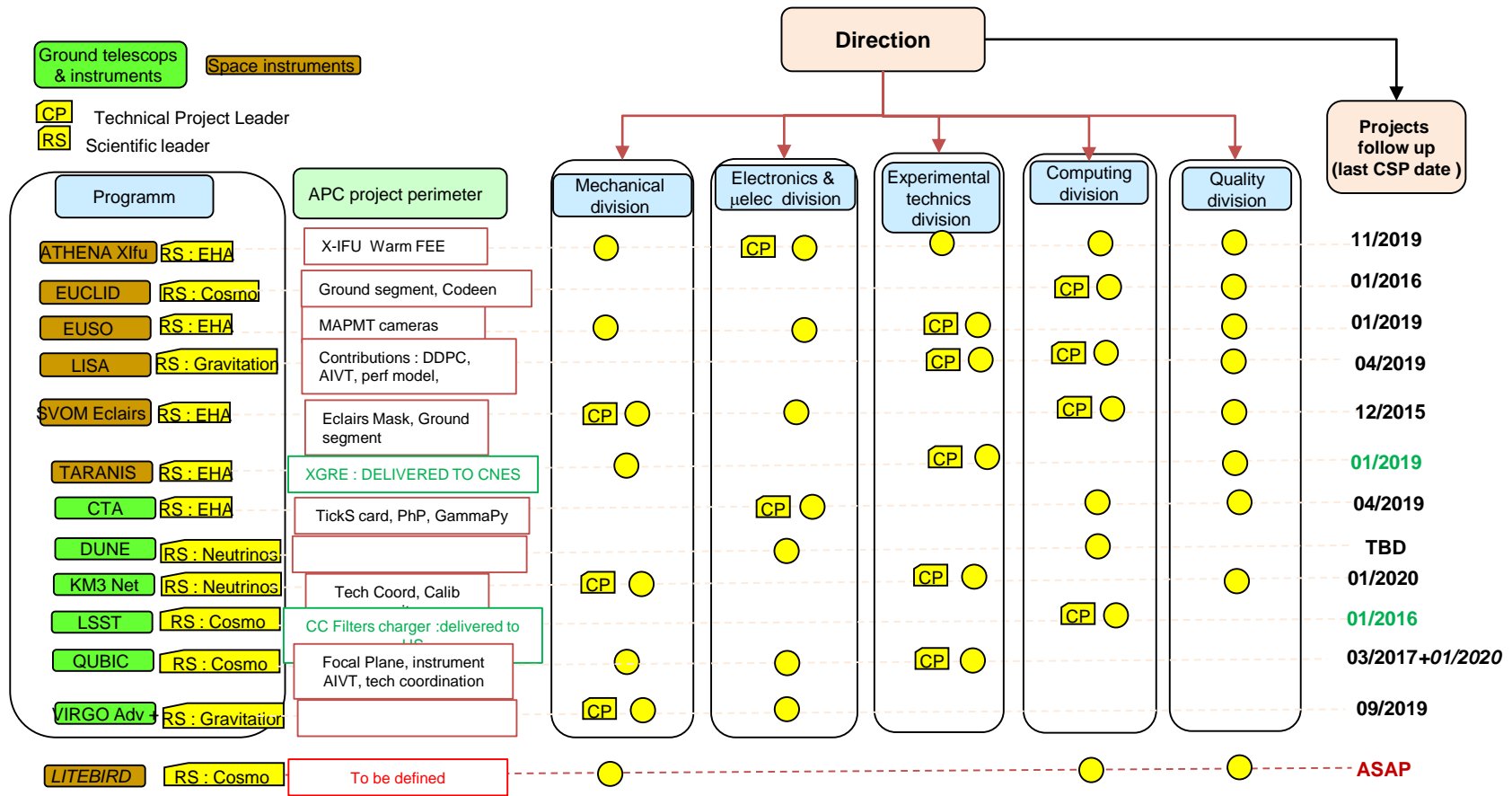
- 77 % of technical staff is working for APC projects
- 16 % of technical staff is doing management, safety, services activities (machining, cabling, computin)
- 7 % is implicated on R&D, expertises and teaching



APC technical sharing per projects



Project Portfolio Management : matrix management approach = close synergy between science and technical team



Direction : Overall resources management, risks covering, carry out arbitration

Department : Human resources management, guarantee skills

Project : develop and deliver innovative systems / sub systems compliant with performances / cost / schedule

CSP (Cellule de Suivi de Projets)

Members :

- APC direction,
- heads of departments,
- safety and infrastructure responsables,
- 4 external members (also members of Scientific Council) :
 - R. Cornat (IN2P3 / LPNHE),
 - A. Formica (CEA/ Irfu),
 - S. Couturier (INSU / IAS),
 - F. Vincent (Observatoire de Paris)

Aim :

- To evaluate the compliance of the project development with the available resources means (HR, budget, infrastructures) and the milestones

1. Steering and organisation of CSP

2. Monthly « head of department » meeting

- tracking of « highlights »
- monitoring of milestones
- evaluation of new projects / activities

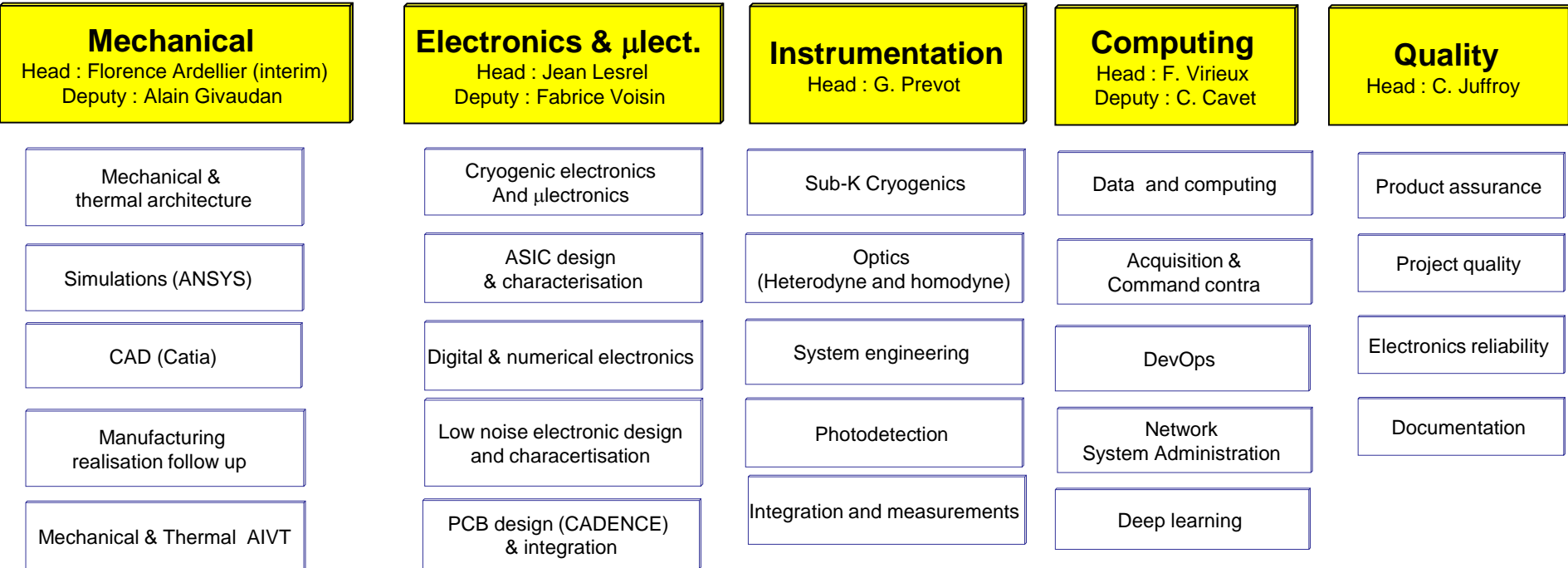
3. Workload plan monitoring with semi-annual updated

- Skills to reinforce
- Job plan
- Tools for priority management

4. Internal technical follow-up meeting

5. Project closure reviews including feedback

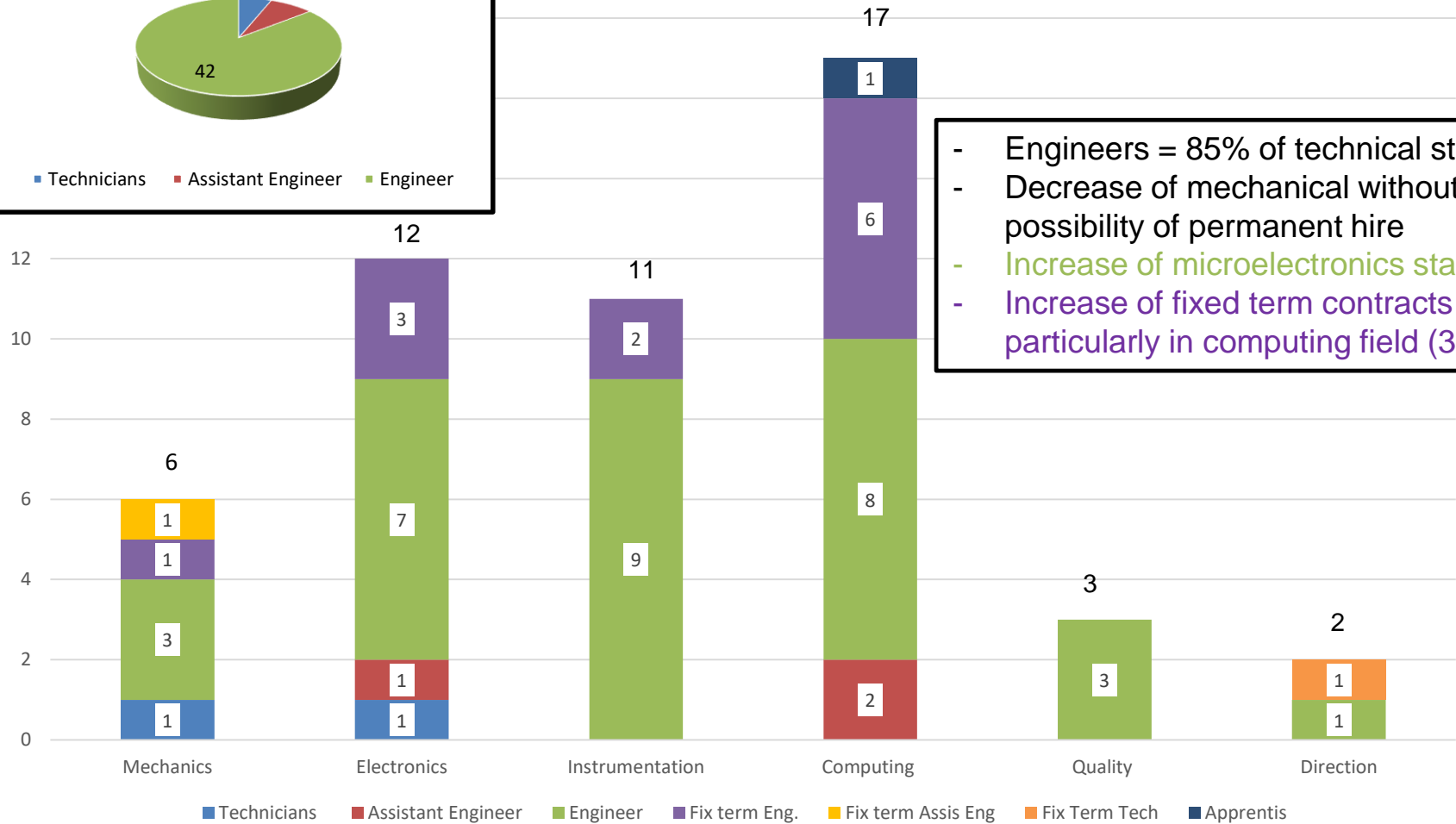
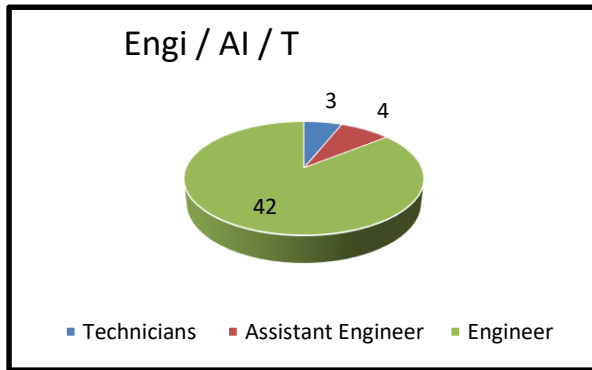
Technical APC skills are splitted into 5 departements...



49 ENGINEERS and TECHNICIANS

... to cover all the technical activities driven by APC science program

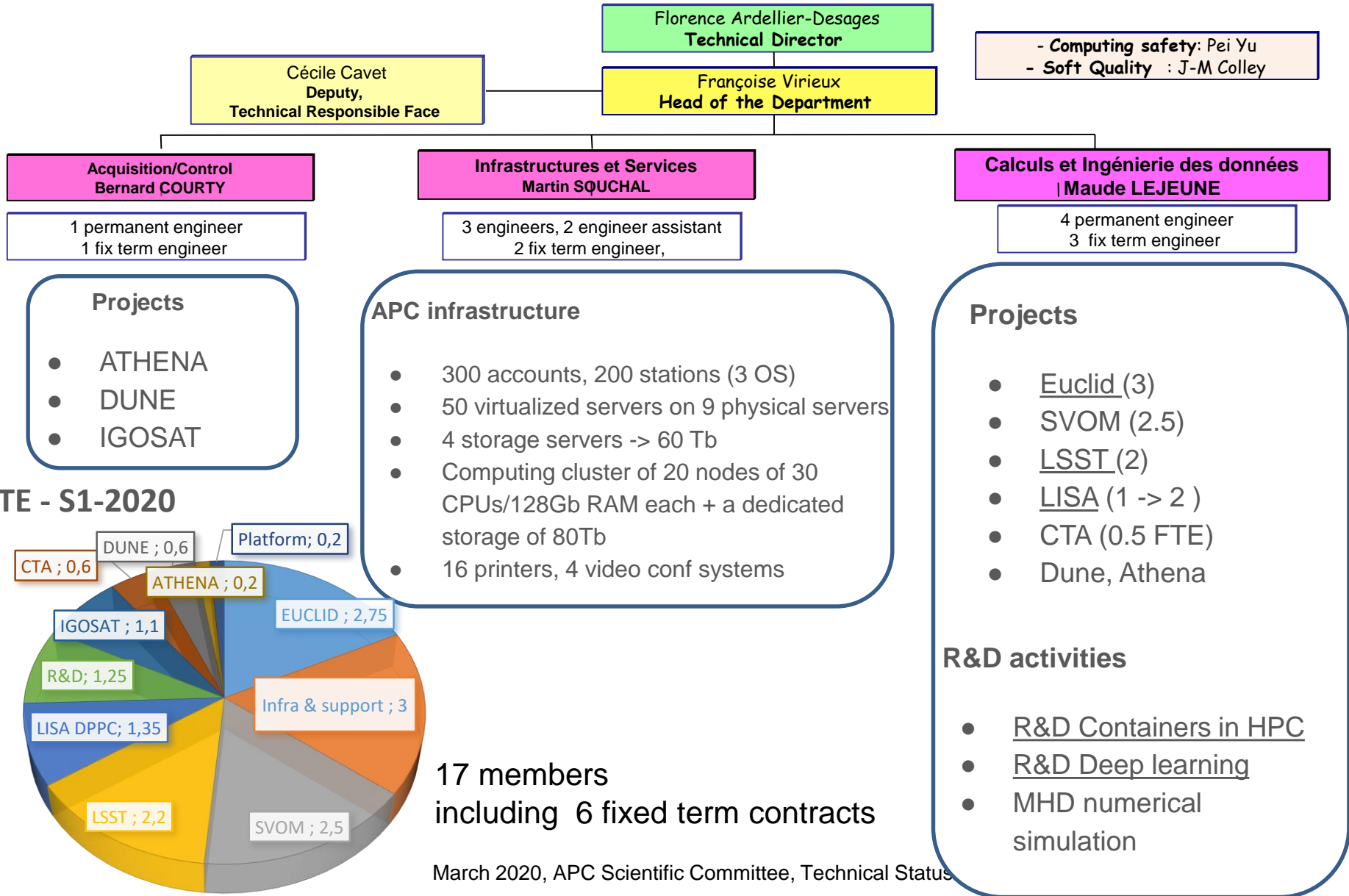
Human Resources shared per departments



- Engineers = 85% of technical staff
- Decrease of mechanical without any possibility of permanent hire
- Increase of microelectronics staff
- Increase of fixed term contracts particularly in computing field (30%)



COMPUTING DEPARTMENT



- Computing safety: Pei Yu
- Soft Quality : J-M Colley

Cécile Cavet
Deputy,
Technical Responsible Face

Florence Ardellier-Desages
Technical Director

Françoise Virieux
Head of the Department

Acquisition/Control
Bernard COURTY

1 permanent engineer
1 fix term engineer

- Projects**
- ATHENA
 - DUNE
 - IGOSAT

Infrastructures et Services
Martin SQUACHAL

3 engineers, 2 engineer assistant
2 fix term engineer,

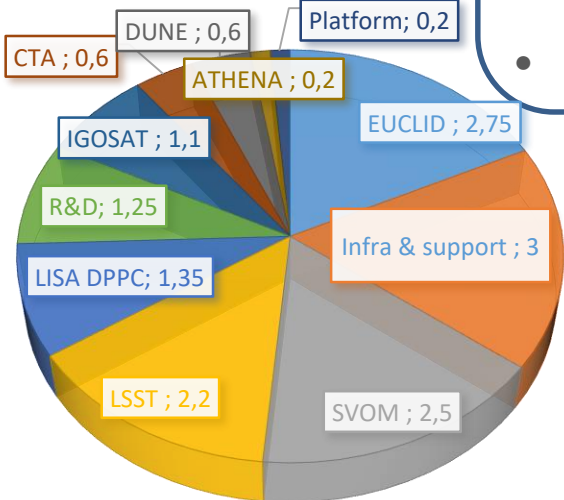
- APC infrastructure**
- 300 accounts, 200 stations (3 OS)
 - 50 virtualized servers on 9 physical servers
 - 4 storage servers -> 60 Tb
 - Computing cluster of 20 nodes of 30 CPUs/128Gb RAM each + a dedicated storage of 80Tb
 - 16 printers, 4 video conf systems

Calculs et Ingénierie des données
Maude LEJEUNE

4 permanent engineer
3 fix term engineer

- Projects**
- Euclid (3)
 - SVOM (2.5)
 - LSST (2)
 - LISA (1 -> 2)
 - CTA (0.5 FTE)
 - Dune, Athena
- R&D activities**
- R&D Containers in HPC
 - R&D Deep learning
 - MHD numerical simulation

FTE - S1-2020



17 members
including 6 fixed term contracts

Head : Guillaume PREVOT

10 engineers including 2 fixed term contracts are covering the project activities of :

Optics (design & simulations, interferometry) : LISA, VIRGO

Photodetection : EUSO, TARANIS, IGOSAT

Cryogenics : QUBIC, sub mm R&D

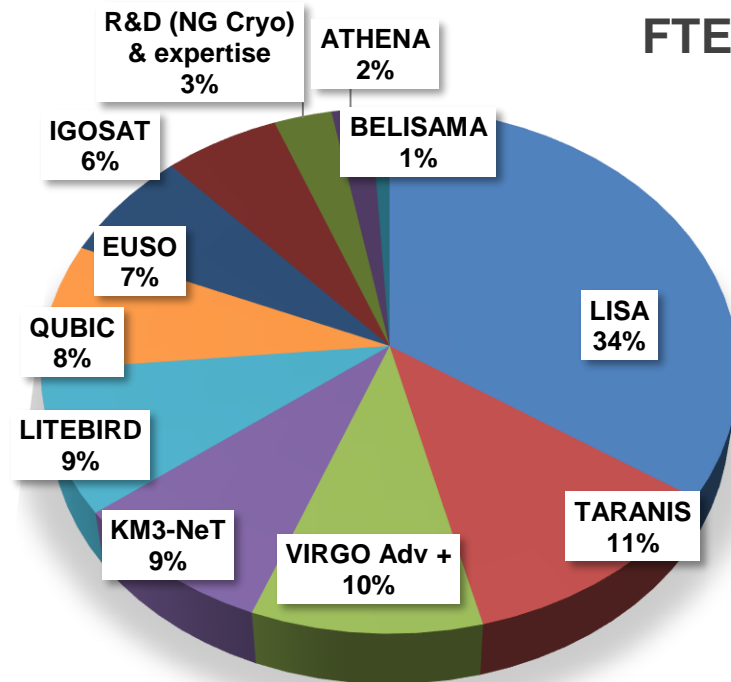
AIT/AIV : TARANIS, LISA, VIRGO, QUBIC, EUSO, ATHENA

Instrument system engineering : LISA, QUBIC, KM3NeT, EUSO

Technical coordination at consortium level : LISA, KM3NeT, QUBIC, EUSO

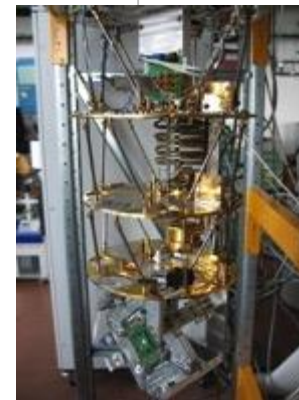
NO permanent position in optical engineering field

FTE 2020

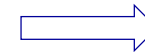


R&D activities

- KIDS
- NG Cryo

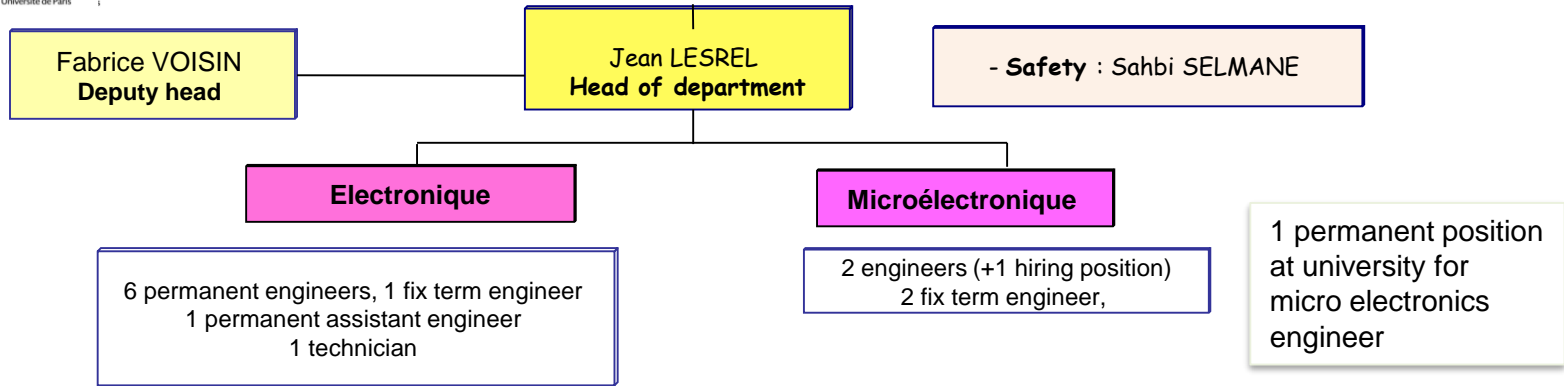


Technical Status

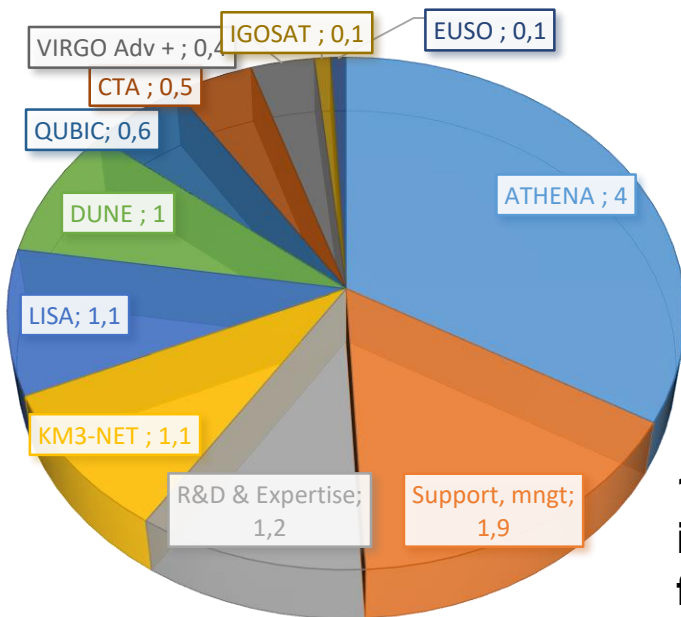




ELECTRONICS & MICROELECTRONICS DEPARTMENT



FTE S1-2020



**12 members
including 3
fixed term
contracts**

- Projects**
- ATHENA
 - CTA
 - DUNE
 - KM3 Net
 - LISA
 - IGOSAT
 - VIRGO Adv +

R&D activities

- NG Cryo : development of cryogenics ASIC with new technology
- programmable very low phase noise sinusoidal signal generator with Direct Digital Synthesis (DDS) ultra-stable frequency reference
- Technological watch : management of ASIC technology change (planned stop of AMS SiGe 0,35)

MECHANICAL DEPARTMENT

Florence Ardellier-Desages
Technical Director

Alain GIVAUDAN
Deputy head

Florence ARDELLIER-DESAGES
Head of department (interim)

No possibility to hire a permanent AI

Workshop

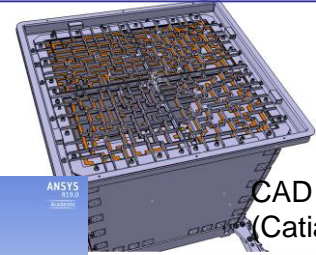
1 Technician

- Projects**
- ATHENA
 - LISA
 - IGOSAT
 - QUBIC
 - SVOM
 - VIRGO Adv +

Mechanical Design Office

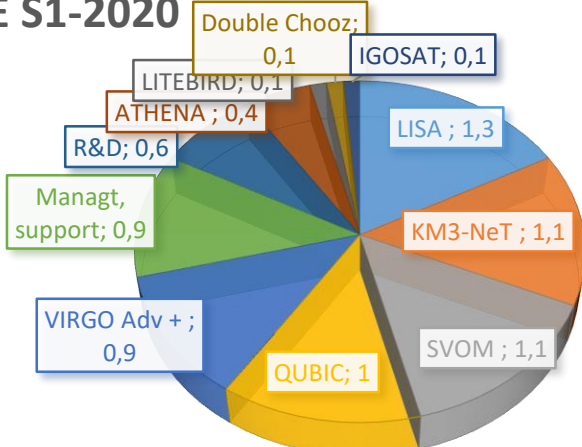
4 permanent engineers
1 fix term engineer & 1 assistant engineer

Thermo-mecha simulations (ANSYS)



CAD design (Catia v5 / v6)

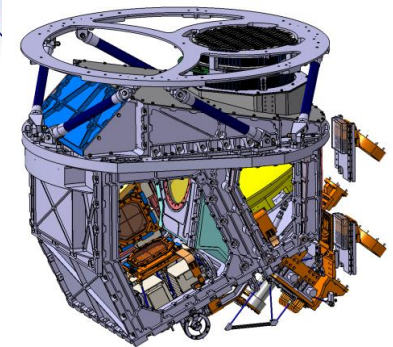
FTE S1-2020



7 members including
2 fix term contracts

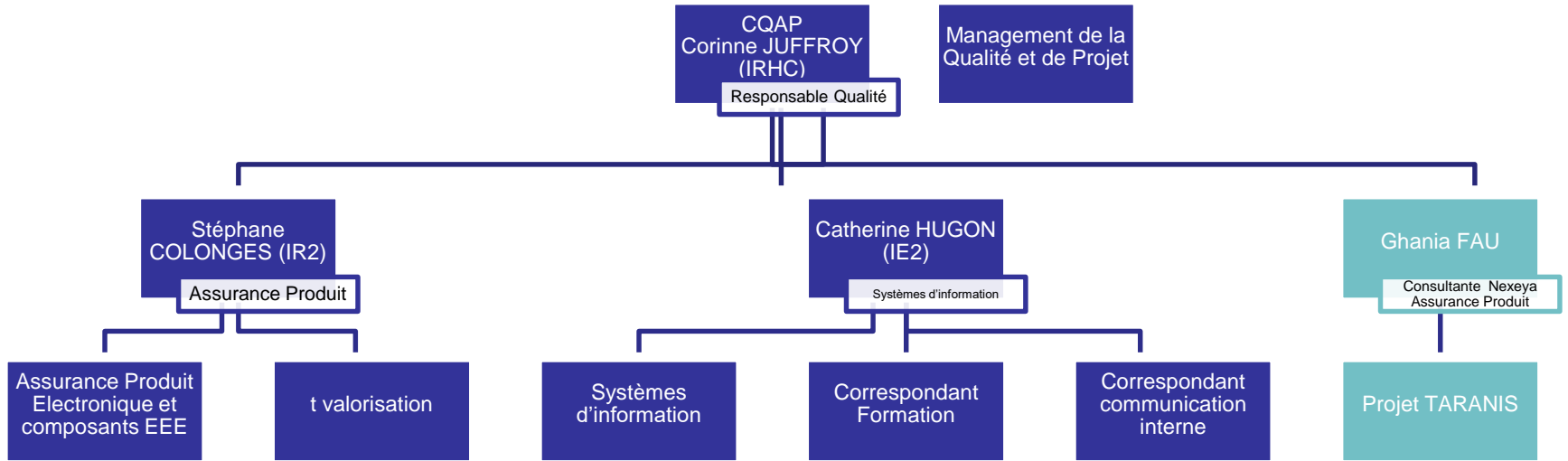


Machining and metrology



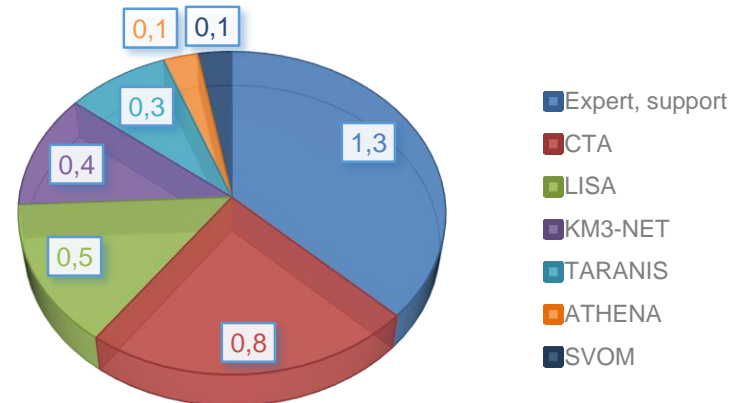
QUALITY AND PRODUCT ASSURANCE

3 permanent engineers



FTE S1-2020

- CTA : reliability studies for Nectar-Cam
- KM3 Net : electronics reliability for KM3 lings
- LISA : product assurance for APC contribution
- SVOM : production assurance for APC contribution
- TARANIS : product assurance APC contribution



PLATFORMS, R & D,

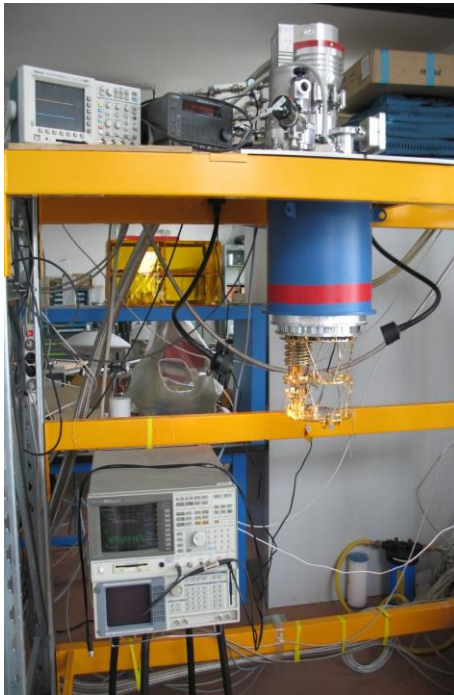
OUTREACH AND VALORIZATION

- 1. Detectors at millimetric wavelengths**
- 2. Laser interferometry and high precision metrology**
- 3. Photodetection**
- 4. Facilities**
- 5. Deep learning**

DETECTORS AT MILLIMETRIC WAVELENGTHS R&D

Cryogenic detection chain and detectors (TES & KIDS)

Millimetric lab specific facilities



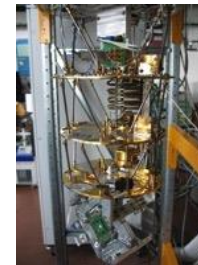
100mK dilution-free cryostat (Oxford Instrument)
(Cooling power : $60\mu\text{W}$ @ 100mK,
No cryogenic fluid)



Vector network analyzer
(characterization of antenna and filters in the frequency range 70-220GHz)

R&D : New Generation Cryo

- Aim : to master microelectronics technologies, cryogenics and metrology for KIDs applications
- APC Work packages:
 - sub-Kelvin refrigeration with continuous adsorption device

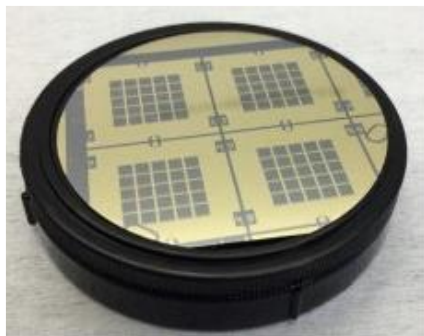


- Cryogenics microelectronics : test of new technology
BiCMOS SiGe 130nm ST Microélectronique (TherMuxCryo)
- Calibration of thermometers until 0,3 K
- Characterisation of thermal properties at sub-K field

R&D : New Generation KIDs

with the development of:

1. A 1000-pixel optical/IR KIDs array.
2. Characterization of gold and aluminum bilayer with different film thickness.
3. KIDs readout system capable of reading out 5000 pixels based on the commercial board.

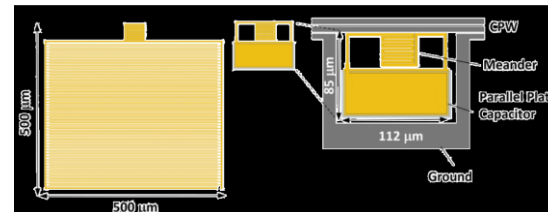


Contribution to ERC Advanced Grant

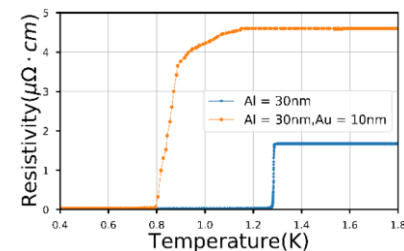
2018: SpectroPhotometric

Imaging for Astronomy with Kinetic Inductance Detectors (SPIAKID), Piercarlo Bonfacio

- WP1: optical/IR KIDs fabrication
 - Fabrication of optical/IR KIDs array of 1000 pixels
 - Use of TiN

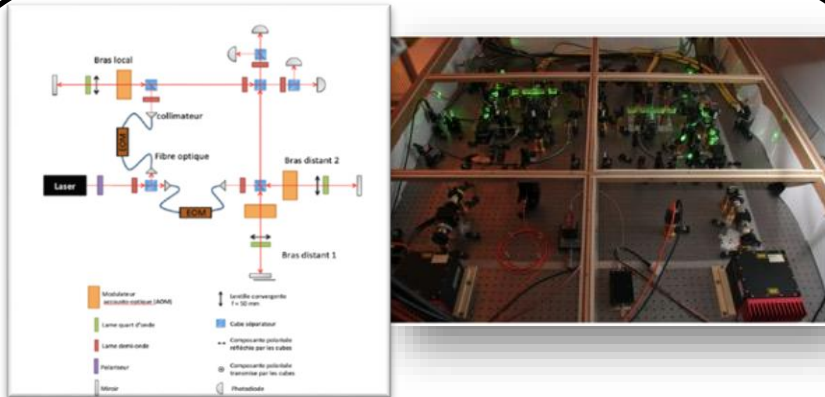


- WP2: novel KIDs devices
 - New material
 - Proximity effect (Al/Au)
 - KIDs tuning



- WP3: readout system
 - Use of commercial board (HTG-ZRF8 from Hitech Global)

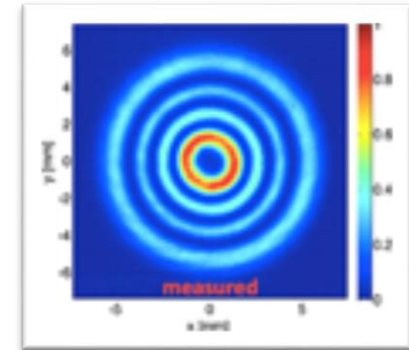




LOT : Lisa On Table (R&T CNES) : demonstration of :

- ✓ Noise reduction (by molecular stabilization or by optical cavity) and scientific exploitation
- ✓ Time Delay Interferometry (noise compensation for unequal arm interferometer)
- ✓ Photometer & phasemeter validation
- ✓ **Heterodyn interferometer validation at mHz**
- ✓ Publication article *Experimental Astronomy*

R&D post-Advanced VIRGO



PHYSICAL REVIEW D 90, 122011 (2014)
Fabry-Pérot-Michelson interferometer using higher-order Laguerre-Gauss modes

A. Gatto, M. Tacca, F. Kéfflian, C. Bay, and M. Barsuglia
*Laboratoire Astroparticule et Cosmologie (APC), Université Paris Diderot, CNRS/IN2P3, CEA/Ifs,
 Observatoire de Paris, Sorbonne Paris Cité, 10, rue Alice Domon et Léonie Duquet, 75013 Paris, France
 (Received 9 October 2014; published 31 December 2014)*

R&D Laguerre-Gauss (LG) modes

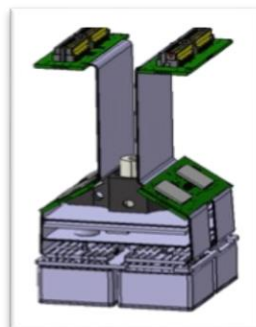
- ✓ AIT/AIV of LG homodyn interferometer
- ✓ Production de modes LG de haut-niveau
- ✓ Réduction bruit cavités et amélioration du contrôle
- ✓ Publications d'articles PRL 2010 et PRD 2015

Photodetection lab



- 3 complete PMTs tests benches
- 1 optical integrante sphere

UV & vis. ultra-sensible & versatile detector



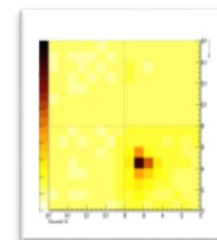
Development of photons counting systems :

- ✓ UV + visible Photons
- ✓ 256 pixels
- ✓ Large dynamic (1/3 pe à 100 pe)
- ✓ Rapide (GTU 1 μ s, resolution of 6 ns)
- ✓ Compact, coated (55 x 55 x 60 mm)
- ✓ low consumption (350 mW)
- ✓ Light (255 g)
- ✓ High TRL
- ✓ Reproducible et calibrated
- ✓ 3 vols 2014, 2017, 2019 (ISS)



Demonstration designs for the remediation of space debris from the International Space Station

Toshikazu Ebisuzaki^{*,†}, Mark N. Quinn[‡], Satoshi Wada[§],
Lech Wiktor Piotrowski[¶], Yoshiyuki Takizawa^{||}, Marco Casolino^{¶¶},
Mario E. Bertalina^{¶¶}, Philippe Gorodetzky^{¶¶}, Etienne Parizot^{¶¶},
Toshiki Tajima^{¶¶}, Rémi Souillard^{¶¶}, Gérard Mourou^{¶¶}



CLEAN ROOM for SPACE INSTRUMENTS DEVELOPMENT



ISO8 Cleanroom (128m²) equipped with:

- Integration room
- Climate chamber
- Optical bench room



Frequency comb generator
(Laser emission in a spectral band from 1 to 2 μ m with a frequency step of 250MHz)

« low electromagnetic noise room »

37,5m² Faraday thermalized room for
0,1 mHz à 1 Hz components tests



R&D for squeezing Experiment at TAMA (Tokyo – Japan)

- Development of an electronic bench of RF amplifier
 - ✓ 12 RF amplifiers driving 4 electro-optical components (3 EOM, 1 AOM), 6 RF mixers and 2 PLL
 - ✓ Gain and output power of each amplifier adapted at each driven devices
 - ✓ Installation and performance test on TAMA site

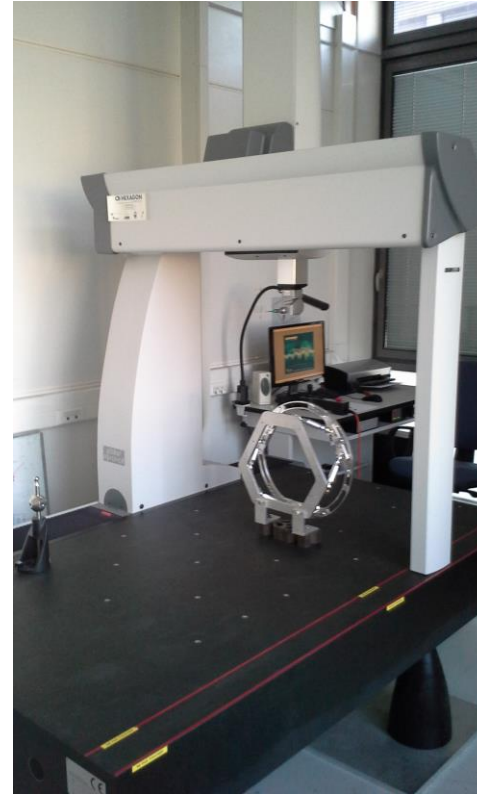
Characterisation of ATHENA ASICs and
new technology ASICs



Mechanical and metrology facilities



**Mechanical workshop
Numeric command device**



Metrology



**3D printer
(ABS plastic)**



**Integration hall
(QUBIC experiment)**

Simulations : ANSYS +
technological watch to
launch for multiphysics
approach

Since 2017, machine learning (ML) techniques took a growing place in the research ecosystem.

At APC, the use of deep learning has become more widespread

- **cosmology group** : galaxy images processing, cosmological parameters inference
- **gravitational wave group** : event and outlier detection, transfer function modeling (non-linear).

Highlights :

- **recruitment** of an **IR** with ML expertise
 - A. Boucaud (Déc 2018)
- White paper on ML for **Prospectives IN2P3** joint between GT05 et 09
 - led by E. Aubourg et A. Boucaud (Sep 2019)
- **ANR AstroDeep** grant (Oct 2019) to explore ML techniques for cosmology
 - PI : E. Aubourg, 600k€ over 4 years
- **workshop Bayesian deep learning for cosmology and gravitational waves** organized par *AstroDeep* et PCCP (Mar 2020)
 - 3 days, 80 participants over the world, big success !

Organisation:

Bastien Arcelin
 Eric Aubourg
 Matteo Barsuglia
 Alexandre Boucaud
 Eric Chassande-Mottin
 Cécile Rouelle
 Olga Szydlowska
 Agata Trovato
 Giulia Vannoni

BAYESIAN DEEP LEARNING FOR COSMOLOGY AND GRAVITATIONAL WAVES

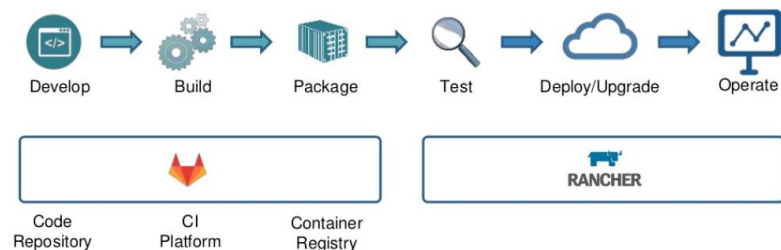
PARIS CENTRE FOR COSMOLOGICAL PHYSICS WORKSHOP SERIES
 MARCH 4-6, 2020

IN2P3 R&D project **ComputeOps**:

- Objective: Assess the performance of various container solutions, in a HPC context
- A group of ~15 members across IN2P3, **led by APC** (C. Cavet and M. Souchal)
- Internal and external partners in education-research
- Publications and tutorials : CHEP (2018, 2019), JDEV (2019), SBAC-PAD (2018), JI (2018)
- Resources and tools for the community <https://gitlab.in2p3.fr/CodeursIntensifs/ComputeOps>
- “Conteneurs en Production” school (ANF) 4-8 June 2018, **renewed for 2020**

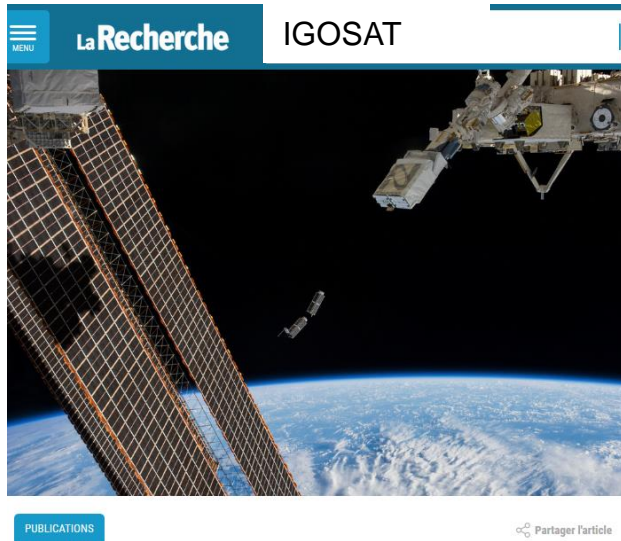
Application to **LISA** Data Processing Center

- Numerous **use cases** related to LISA data analysis
- **Design** of the production environment with continuous integration, test and deployment of composite data analysis pipelines





OUTREACH and VALORISATION



Traquer les aléas de l'ionosphère

Hubert Halloin, Pierdavid Coisson, Philippe Laurent et Hana Benhizia, université de Paris, CNRS, Institut de physique du globe, CEA dans [mensuel 549](#)
daté juillet-août 2019 (n° double 549 et 550) - 1238 mots

Soumise aux aléas de l'activité du Soleil, la très haute atmosphère voit sa composition changer au gré de divers facteurs. Conçu comme un projet néo-anonyme visant à concilier des étudiants à la mise en œuvre de projets



EDUCATION :

5 engineers are teaching in Master degrees or Engineers school.





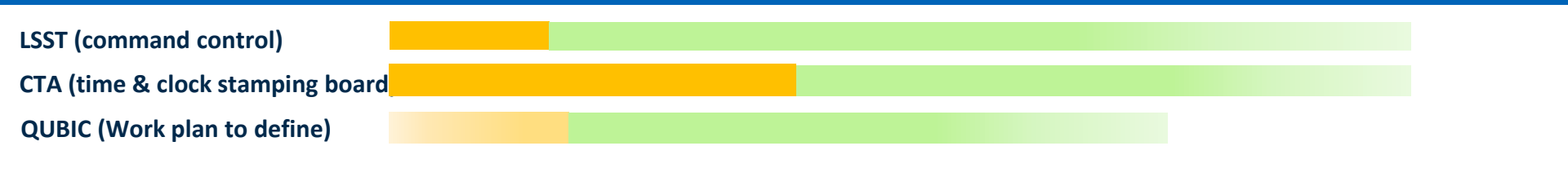
FORTHCOMING TECHNICAL ROAD MAP



Neutrino



Telescopes



Space instruments (sub system)

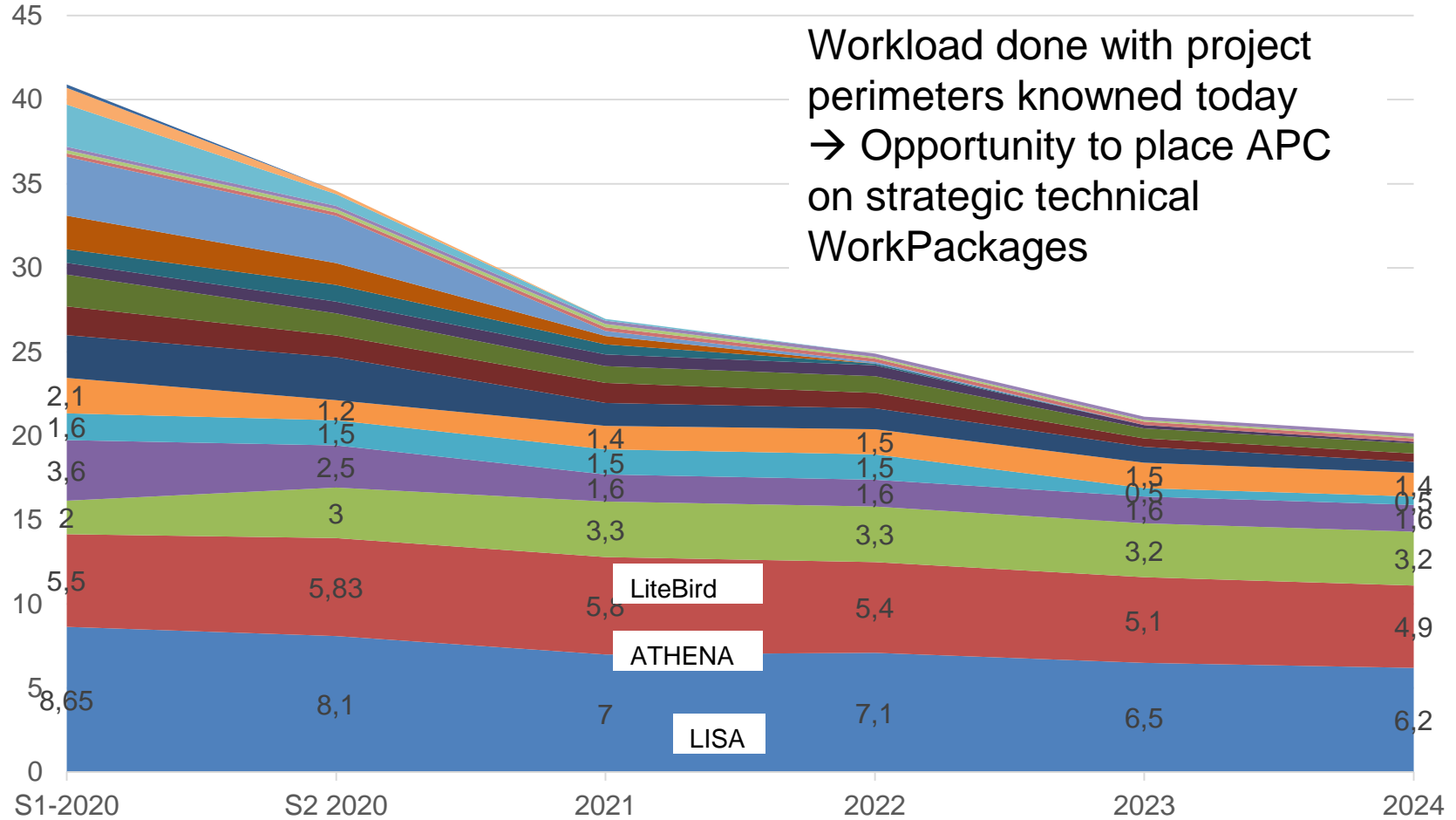


Interferometers (sub system)

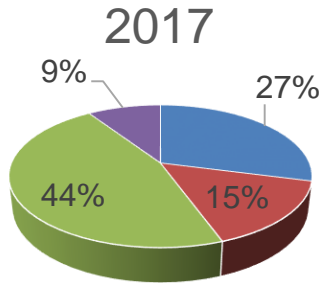


APC TECHNICAL WORKLOAD PLAN 2020-2024

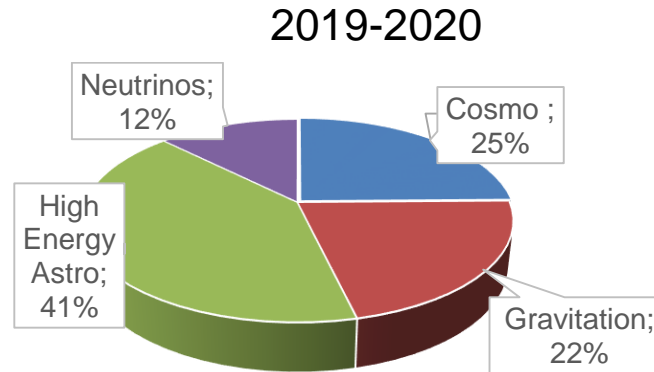
- LISA
- ATHENA
- LITEBIRD
- KM3-NeT
- DUNE
- VIRGO Adv +
- EUCLID
- LSST
- CTA
- NG-Cryo
- EUSO
- QUBIC
- SVOM
- DANTE
- FACe / DANTE
- IGOSAT
- TARANIS
- Double Chooz



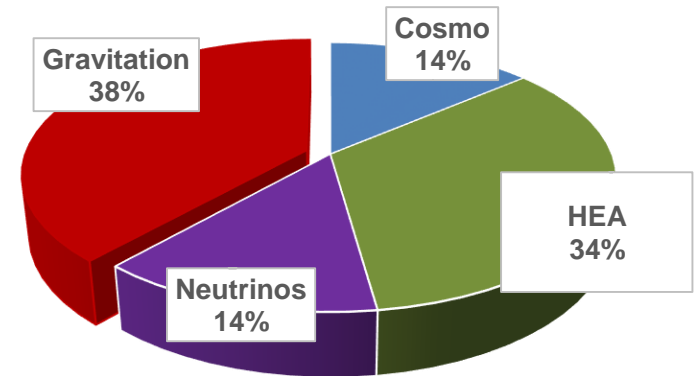
TRENDS FOR FORTHCOMING YEARS



■ Cosmo ■ Gravitation ■ HEA ■ Neutrino



2021-2024



~7 FTE « available » in 2024

■ Cosmo ■ HEA ■ Neutrinos ■ Gravitation

Main trends for 5 forthcoming years :

- Part of gravitation is increasing (LISA, Virgo Adv+, ET?)
- Part of HEA is decreasing (TARANIS, SVOM launched)
- Neutrino is increasing (DUNE opportunity)
- Cosmo is decreasing (LSST even if with LiteBird ?)



SUMMARY

Multidisciplinary team working in close synergy with scientists is a key for innovative instrument developments.

Some specific expertise have been developed

- Complete cryogenics detection chain & cryogenics microelectronics
- Optical metrology
- Photodetection
- System engineering and project management
- Space instrument development

Some Weaknesses :

- No permanent optical engineer,
→ Partially compensated with local instrumentalist physicists
→ 1 recruitment is requested
- Lack of numerical electronic engineer → new microelectronic engineer could take in charge part of this for ATHENA
- Increase of the fixed term contracts
- Dependence on industry (microelectronics)

APC technical organisation is offering **a high reactivity and flexibility** to study and take in charge new technical workpackage opportunity : LiteBird ? Einstein Telescope ? Dark Side ?

THANK YOU

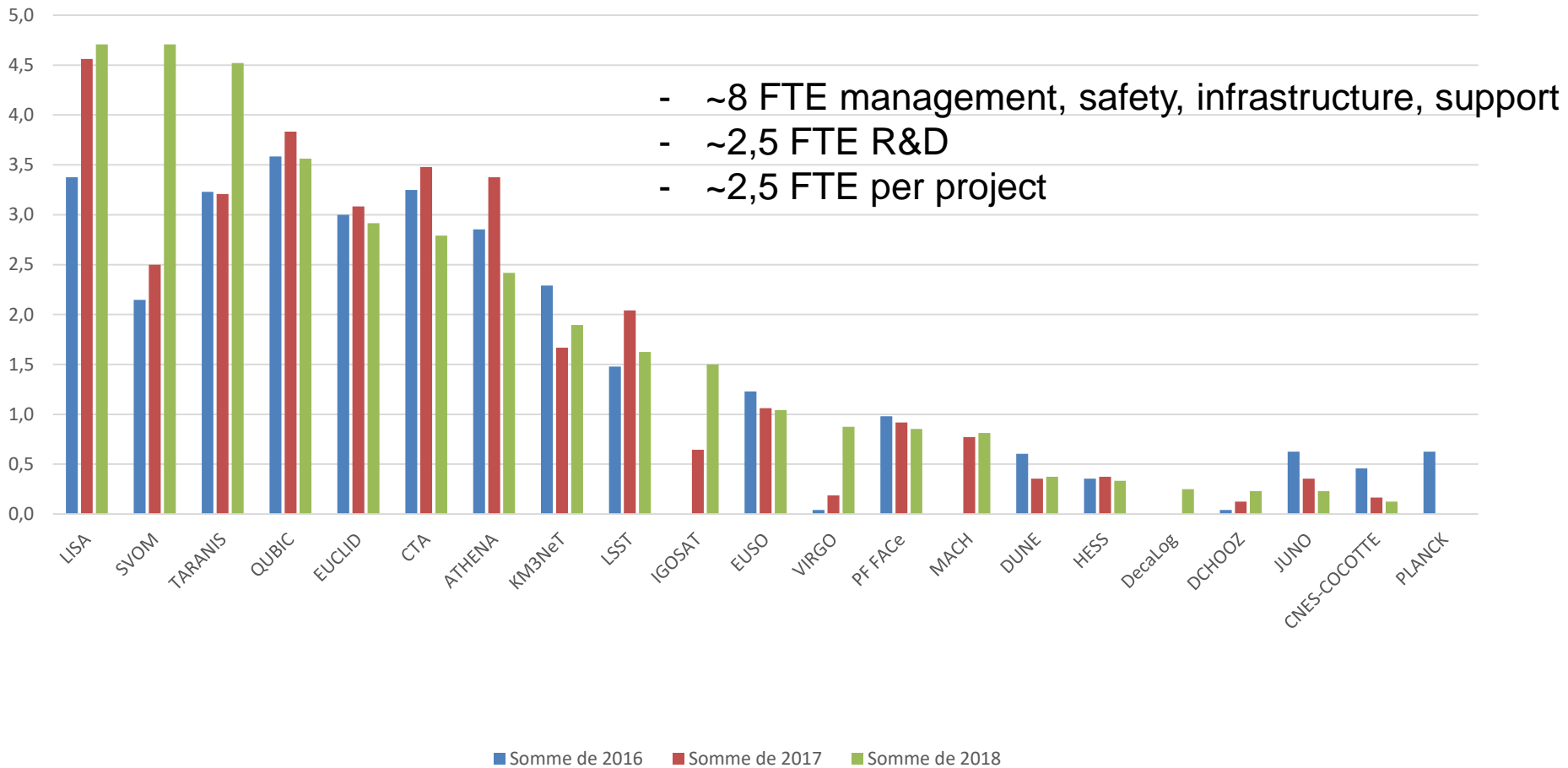


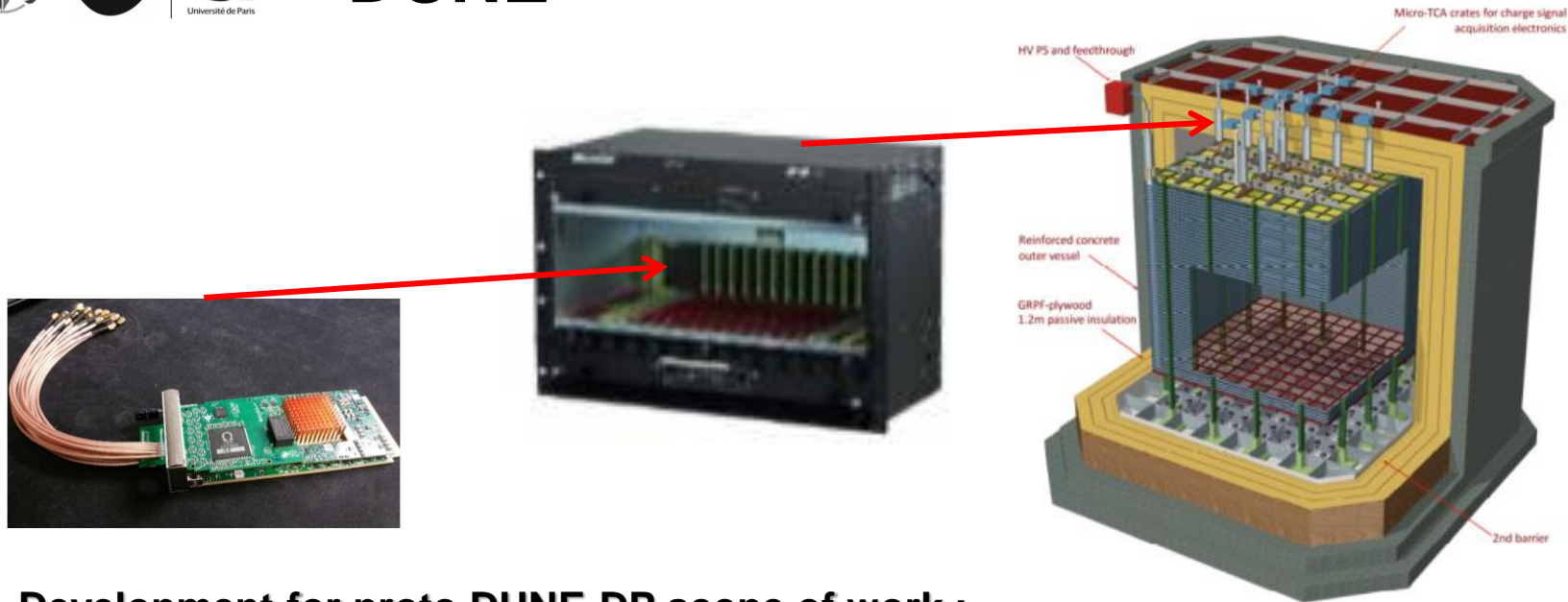
Strengths	Weaknesses
<ul style="list-style-type: none"> • Expertises in specific fields : optics metrology, cryogenic detection chains and μelectronic, KIDs, space AIT/AIV, QA/PA, virtualization and cloud, deep learning • System engineering approach from preliminary design until qualification • Synergy between technical team and scientists • Capability to realise complete challenging prototypes • Laboratory visibility 	<ul style="list-style-type: none"> • Rate of fixed term contract increase → Risk of losing strategic skills (fixed-term contract, mobility, retirement ...) • only one person specialized skill • Strong commitment in projects limits involvement in generic R&D and general technologic surveys
Opportunities	Threats
<ul style="list-style-type: none"> • Space and funding agencies, tutelage organisations, national and international collaborations calls of tender • Long-term technical road map : ATHENA, CTA, E.T. ? , KM3NeT, LiteBird ? LISA, VIRGO Adv+, ... • Multi-messenger astronomy rising 	<ul style="list-style-type: none"> • Attractivity of the institution for advances skills • Unfavorable change in tutelage agencies hiring policy • Dependance of the industrial markets (ex : change of technologies for ASICs...)



Technical sharing projects

Full Time Equivalent





Development for proto DUNE-DP scope of work :

- ↳ consists of a daughter board (IPNL, LAPP, Omega, APC) and a commercial motherboard.
- 16 channels
- Anti-aliasing low pass filter (~30 MHz bandwidth limit)
- ADC: AD9249 65 MHz, 14 bits provides waveform with a window of $\pm 4\text{ms}$ around beam trigger down-sampled to 400 ns
- ASIC: CATIROC
- Provides auto-triggered channel-wise Q, t and generates light trigger

APC project manager (electronics engineer) left the lab beginning 2019 : fix term contract is replacing him for electronic numerical developments