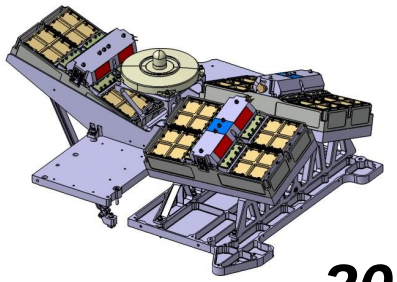
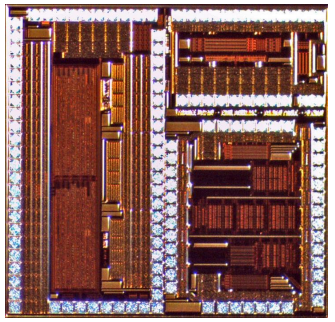
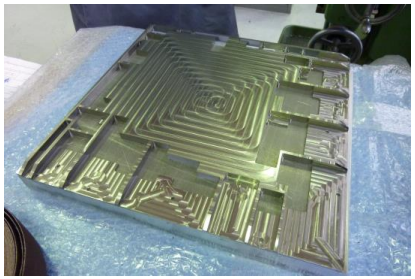


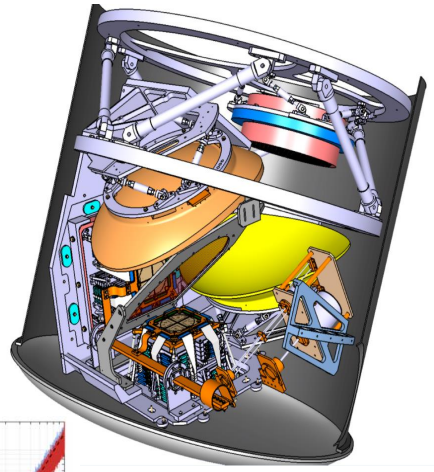


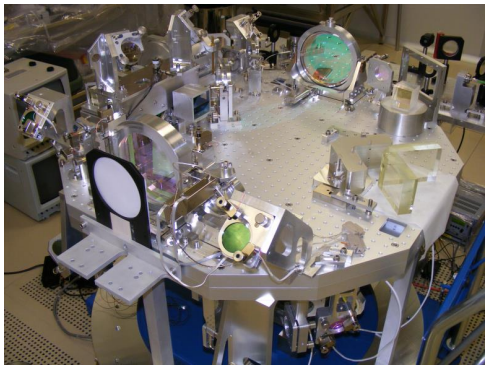
2012-2016 APC Laboratory Technical Activities

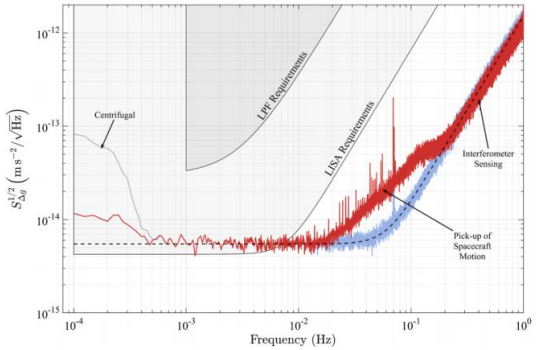
T. Zerguerras

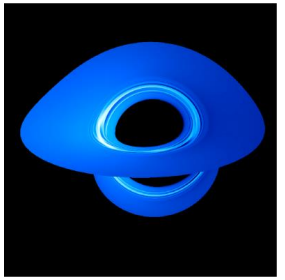
on behalf of the Technical Departments







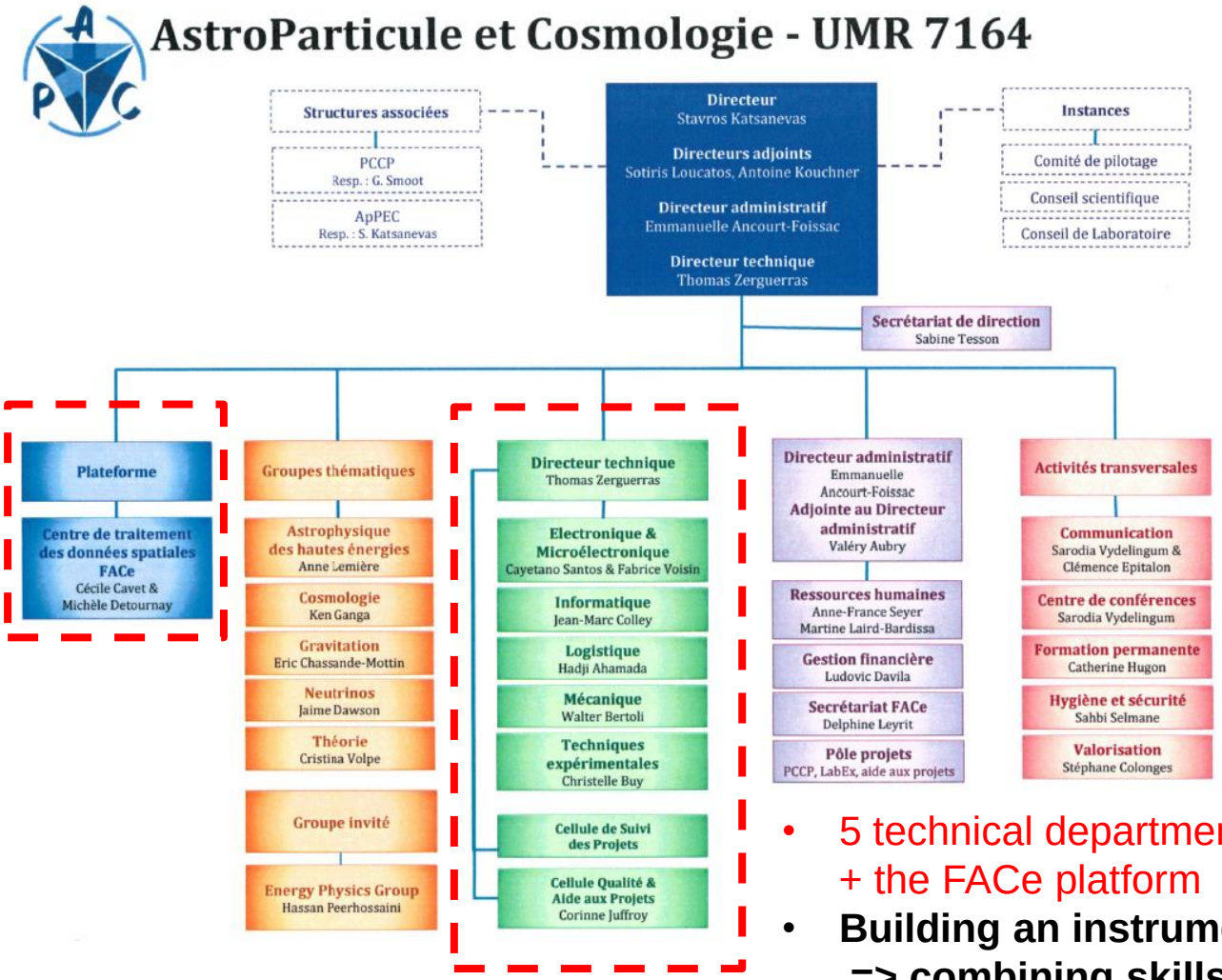




Technical Departments

- **Organisation**
- **Equipment, facilities and platform**
- **Instrumentation Department (Techniques Expérimentales)**
- **Electronics and Microelectronics Department**
- **Mechanics Department**
- **IT Department**
- **Quality Unit**
- **R&D: CMB µelectronic, Compton, GAMMACUBE,** Liquido
- **Analysis & Prospects**

General organisation



- 5 technical departments + Quality Unit + the FACe platform
- **Building an instrument => combining skills**

Technical departments organisation

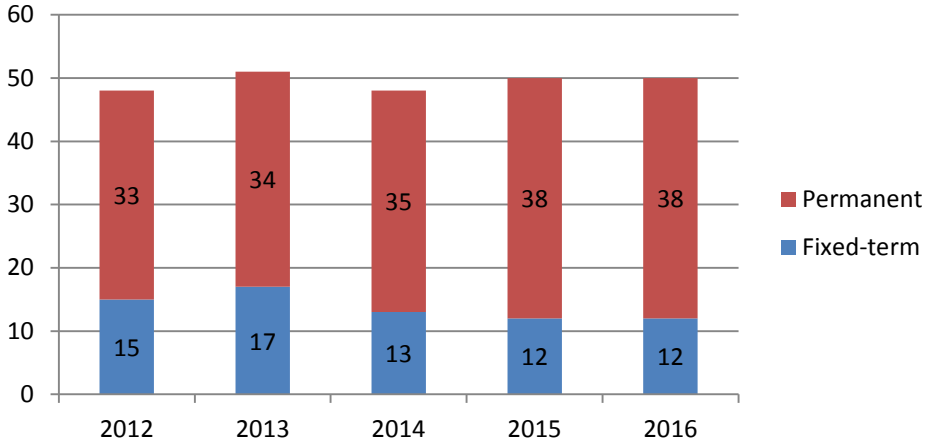
- ✓ **Matrix organisation structure:** Project/Department (Assignment to a department, participation to projects)
- ✓ One specific skill (Mechanics, Electronics/µelectronics, Instrumentation, IT, QA/PA)
- ✓ Transverse activities of the Quality Unit
- ✓ Supervision : Head of department
- ✓ Project coordination: Project manager
- ✓ Indicator Boards for activities and assignments monitoring
- ✓ Project Monitoring Committee (Comité de Suivi de Projets CSP)

This organisation aims to create a bond of trust with funding and tutelage agencies

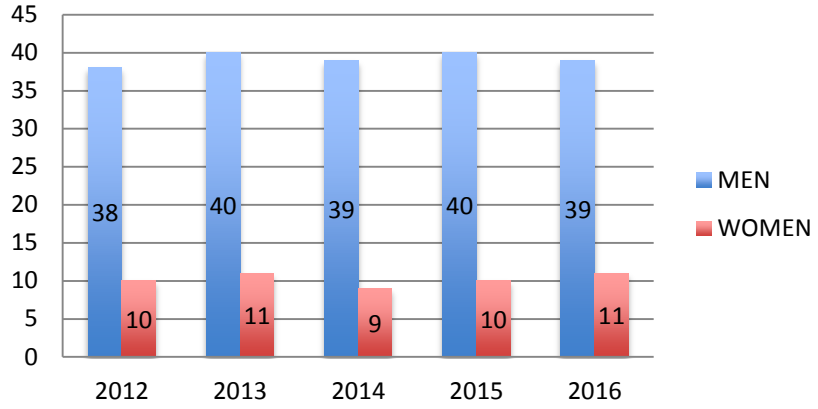
Organisation: Technical staff evolution

On 31/12

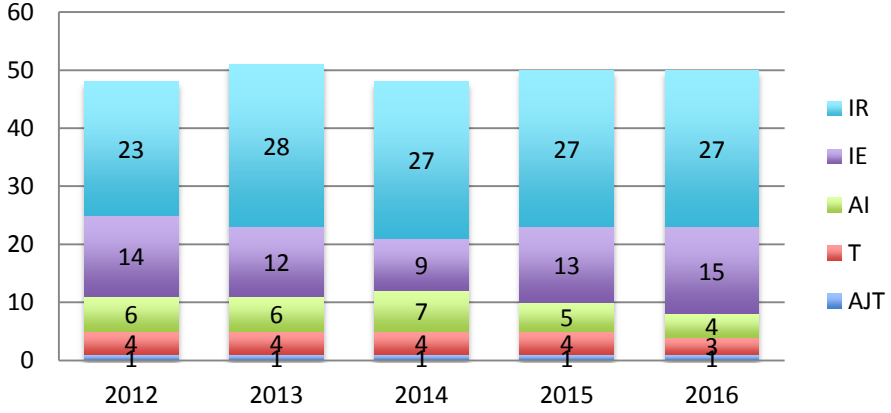
Technical departments staff evolution



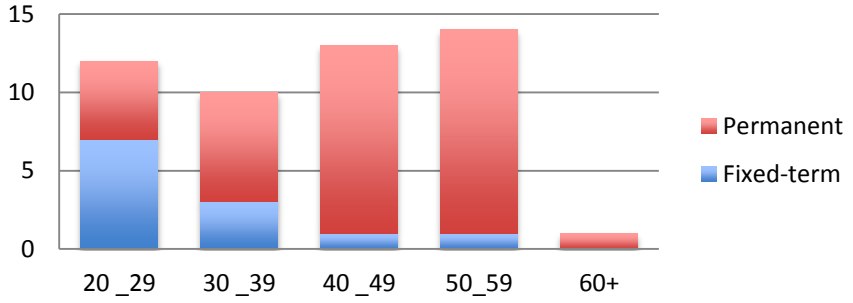
Technical departments staff - Gender



Technical departments staff - Skill level



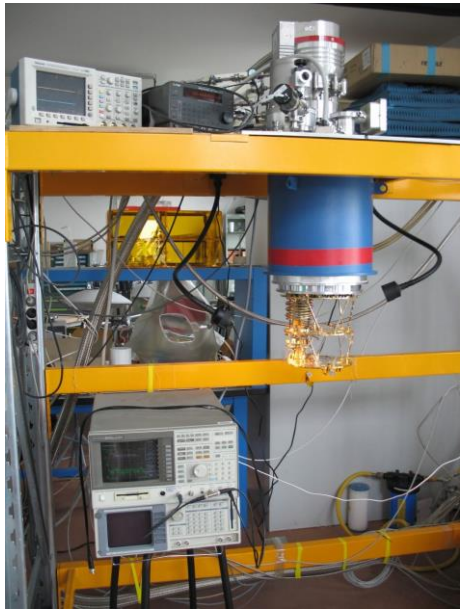
Age distribution - 31/12/2016



Equipment and facilities

ISO8 Cleanroom (128m²):
- Integration room
- LISA room
- VIRGO room

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



Millimetric Laboratory: 100mK dilution-free cryostat (Oxford Instrument)
(Cooling power : 160µW @100mK, No cryogenic fluid)

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

Equipment and facilities

Low electronic noise test room (37,5 m²)
including a Faraday cage to test components and circuits from 0.1mHz to 10Hz

Mouting hall

Mechanics Workshop

Photodetection Laboratory

3D Printing Stratasys Fortus FDM250mc
(ABS stable thermoplastic)

Platform: FACe

Started in 2010, support of IPGP in the framework of the Paris-Diderot University Space Campus – Application to the CNRS/IN2P3 Platform Label

- **Scientific Manager:** Cécile Cavet (IT Department)
- **Technical Manager :** Michèle Detournay (IT Department)

Missions:

✓ Building and infrastructures management (machines, electrical facilities, CDF, CVC, maintenance, subcontracting management)

✓ Computing infrastructures management

✓ Services to projects (data bases, web applications, development platform, training and user support)

Equipement:

✓ Computing parallel cluster: 652 cores et 42Tb storage

✓ 80 virtual servers for astroparticle and space projects (storage: 180Tb)

✓ Concurrent Design Facility (CDF): design and operations (LISAPathfinder, LISA …)

Projects: PLANCK, INTEGRAL, CODEEN (EUCLID) …

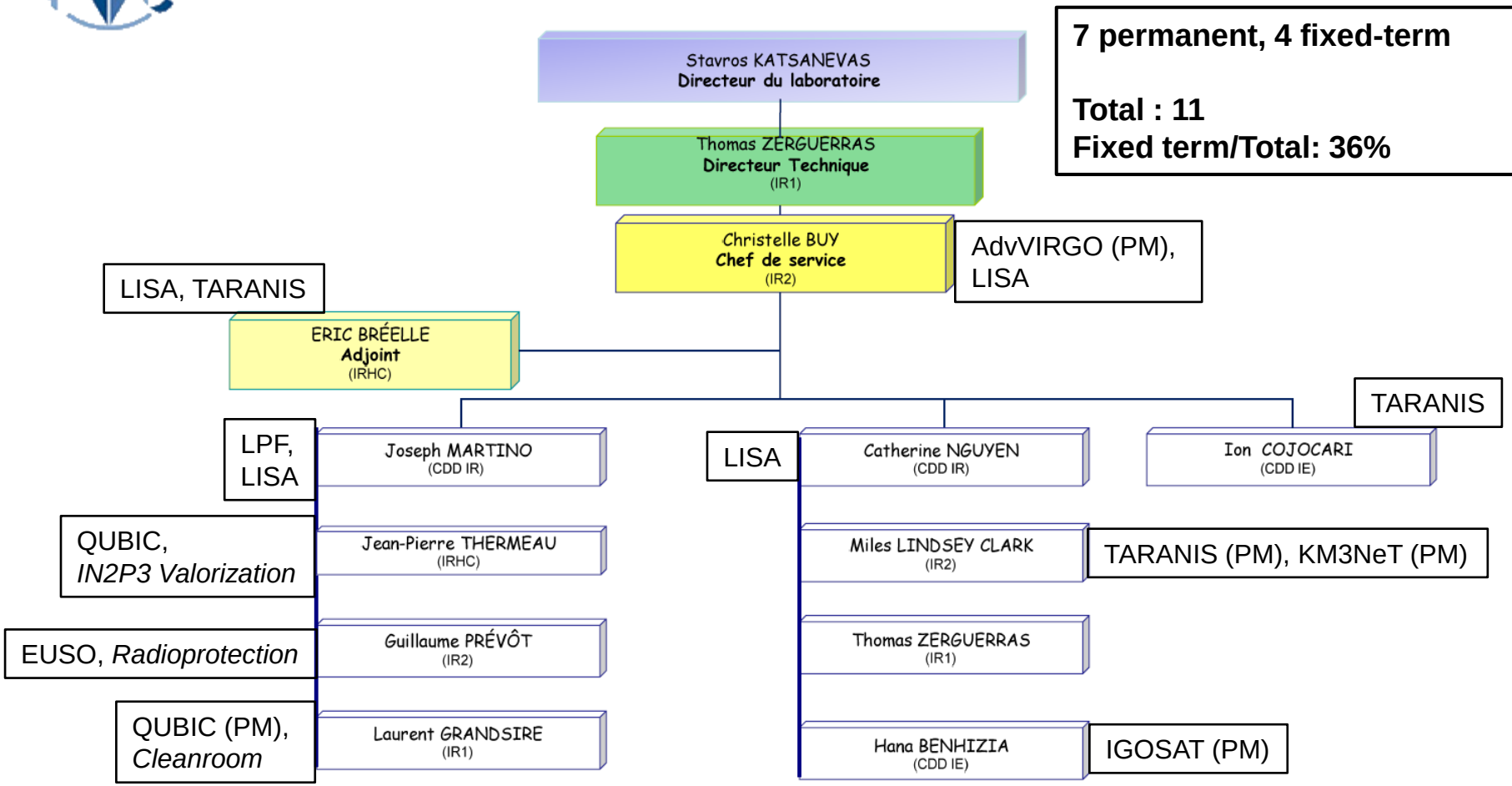
Next:

❑ **FACe relocation in 2018**

❑ **Contribution : LISA DPC, SVOM pipeline**

Cécile Cavet
FACe presentation

Instrumentation Department : Organisation



7 permanent, 4 fixed-term

Total : 11
Fixed term/Total: 36%

2012-2016: 10 departures, 11 arrivals
May 2017: end of fixed-term IE hiring contract (QUBIC, EUCLID)

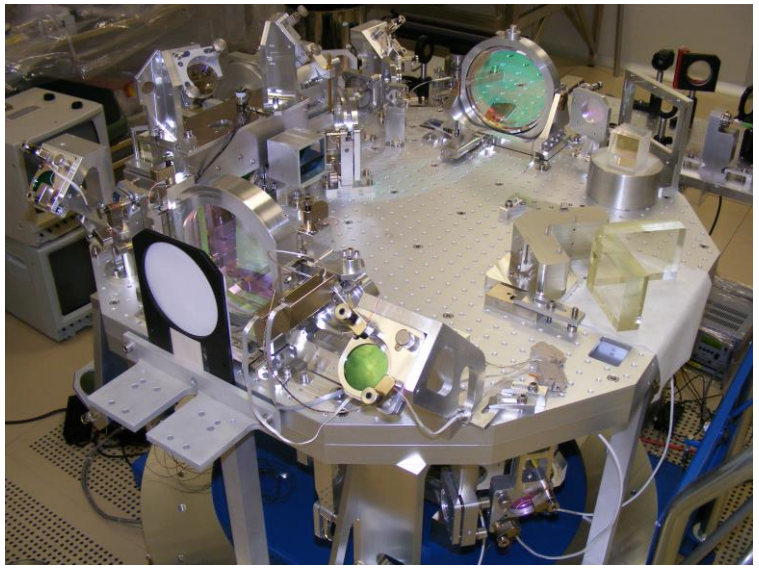
2017: 2 permanent positions opened (Instrumentation IE, System IR)

Instrumentation Department: Skills

- ✓ Optics and interferometry
- ✓ System engineering
- ✓ AIT/AIV
- ✓ Vacuum and cryogeny
- ✓ Bolometer
- ✓ Photodetection and spectroscopy
- ✓ Simulations (Zemax, Fred, Matlab …)
- ✓ Test benches design for detector characterization
- ✓ Data acquisition (ex: Labview)
- ✓ Data analysis (ex: Matlab)
- ✓ Spatial and QA background (environment qualifications …)
- ✓ Cleanroom
- ✓ Project management

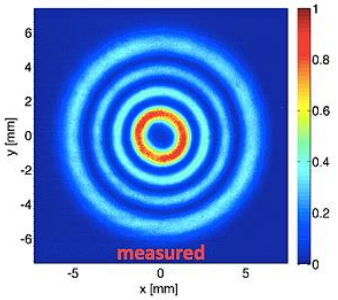
Instrumentation Department: AdVIRGO and post-AdVIRGO R&D

- ✓ **Telescopes for Advanced Virgo (2011-2015)**:
  - ✓ **Adapting beam size from a few mm (laser bench) to 5 cm in cavities (and vice-versa)**
  - ✓ **Workpackages:**
    - **Optical simulations and design**
    - **Validation tests in the APC cleanroom**
    - **Definition of alignment procedures**
    - **Installation of 5 telescopes on site.**



GW detection in coincidence with LIGO (August 2017)

- ✓ **Laguerre-Gauss modes**
  - ✓ **MAJOR EVENTS:**
    - ✓ **Production of higher-order LG modes : PRL 2010**
    - ✓ **Interferometry : first lock (2014)**
    - ✓ **Thermal compensation of aberrations : PRD 2015**
- ✓ **Prospects:**
  - ✓ **Einstein Telescope:** Third generation GW detector (underground, cryogenic, …) : LG modes integration



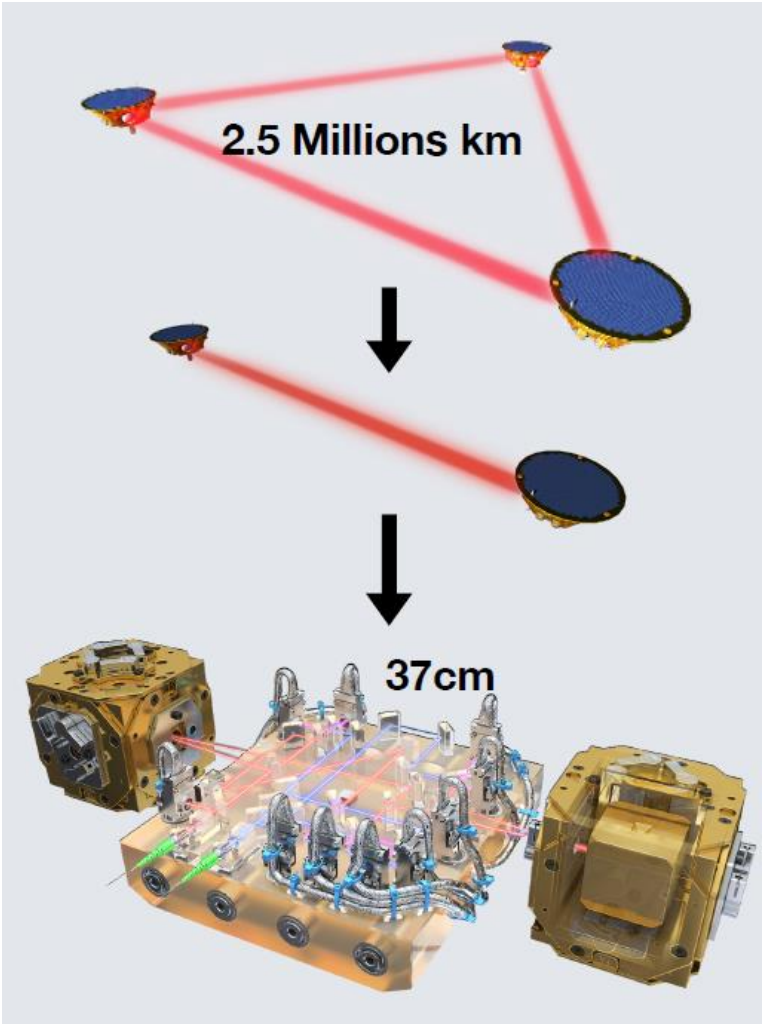
PHYSICAL REVIEW D **90,** 122011 (2014)

Fabry-Pérot-Michelson interferometer using higher-order Laguerre-Gauss modes

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

Contribution: Mechanics Dpt

Instrumentation Department: LISAPathfinder

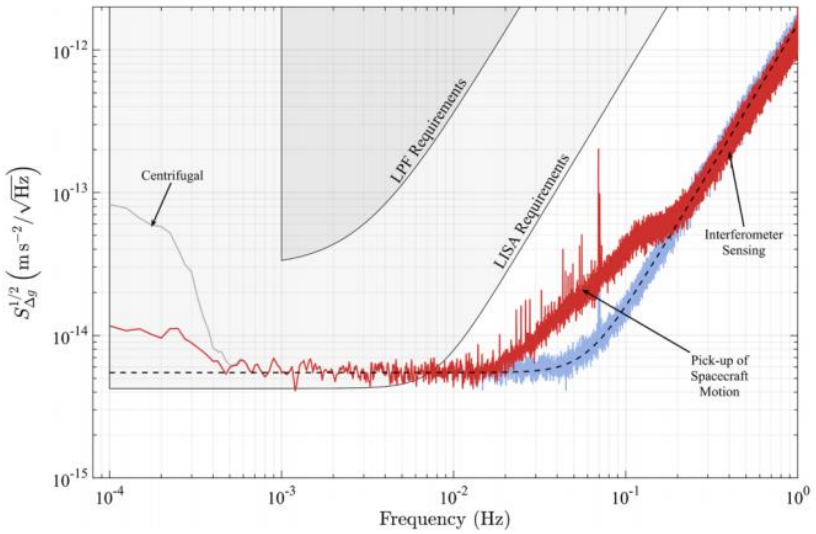


Successfully launched on **03/12/2015** (**end : July 2017**)

Validation of the technology for LISA:
measurement of the distance between two free-falling test masses by laser heterodyne interferometry

Major contribution of the APC to data analysis and interpretation (**μ-thrusters, deglitch** …)

Interferometer noise performances one order of magnitude better than LPF requirements



LISA selected as ESA L3 mission (launch: 2034)

Instrumentation Department: LISA

AIT/AIV Phase 0 CNES and ESA

LISA On Table (LOT)

Hardware simulator of LISA to test in a representative acquisition chain:

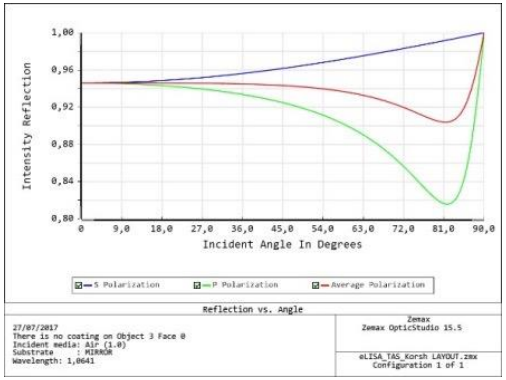
- ✓ Noise reduction techniques
- ✓ Instruments (photometers, phasemeter)
- ✓ 1st TDI tested
- ✓ Preparation for operations in vacuum (10^{-1}mbar)
- ✓ Funding: R&T CNES

Straylight studies

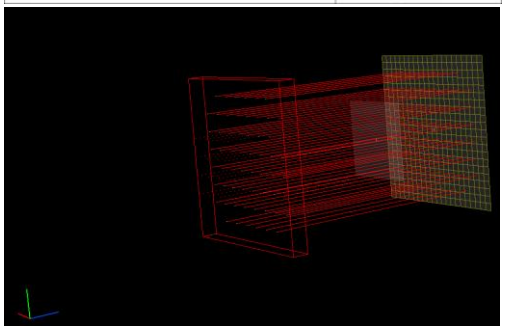
Simulations to estimate the scattered light from LISA telescopes:

- ✓ Specifications on surface properties with micro-roughness models ; cleanliness
- ✓ Polarization of scattered lights
- ✓ Funding: ESA ITT (collab: Thalès Alenia, APC, ARTEMIS, LMA)

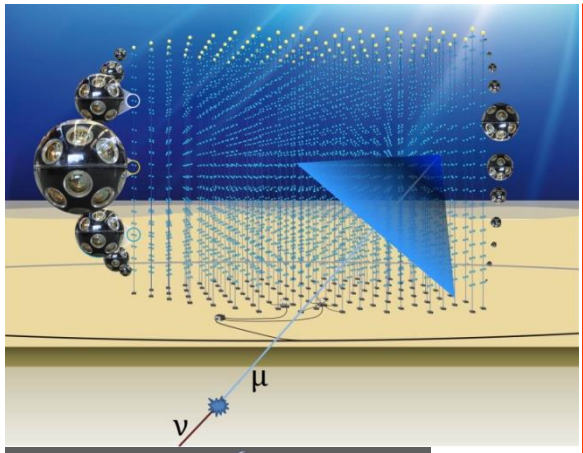
Zemax

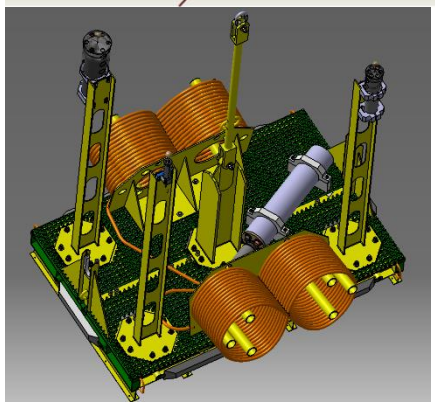


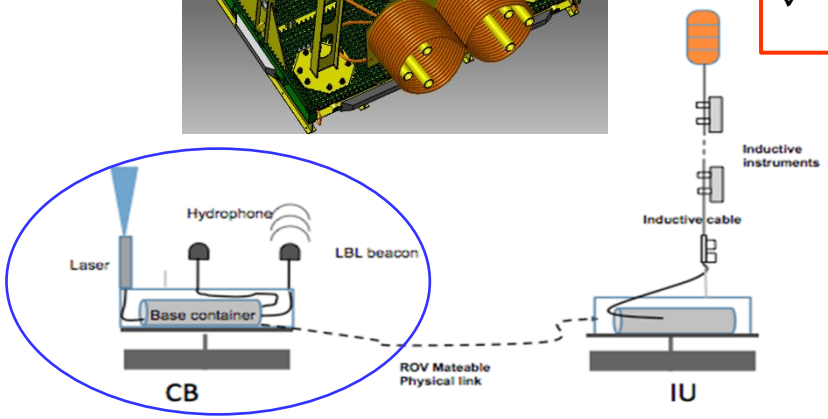
FRED Optimum



Instrumentation Department: KM3NeT



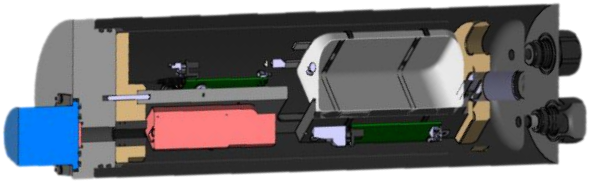




Project started @ APC in 2014

APC in charge of (CB+IU) project management

- ✓ **Design, integration, characterization and qualification of a new generation Laser Beacon for time calibration**



- ✓ **Design, integration and deployment of a calibration unit for the KM3NeT detector**
- ✓ **Collaboration with the CPPM (Marseille, France) in charge of the instrumentation line**
- ✓ **Funding FEDER + CNRS/IN2P3: 400 k€ (CB + IU)**
- ✓ **Starting operation : mid-2019**

Calibration test bench for DOM @ APC Memphyno tank

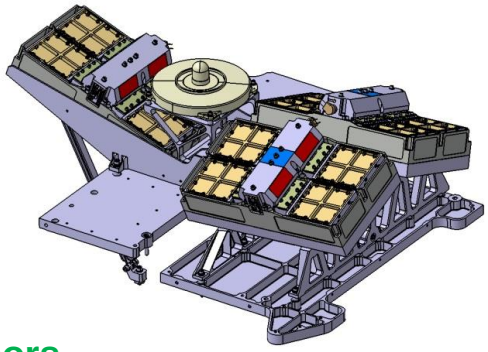
Contributions:
- **Mechanics**
- **Electronics**
- **QA/PA**

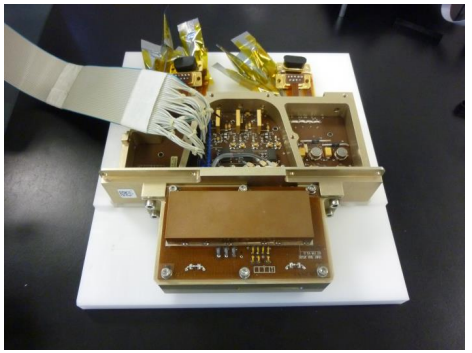
Instrumentation Department: TARANIS

CNES Microsatellite to study TLEs occuring during large storms

Design, production and validation of the XGRE sensor (3 x 4 DU: LaBr3, plastic scintillators, PMT).

Instrumentation AIT/AIV (EGSE and MGSE development, design and fabrication of QM and FM, environment tests implementation).





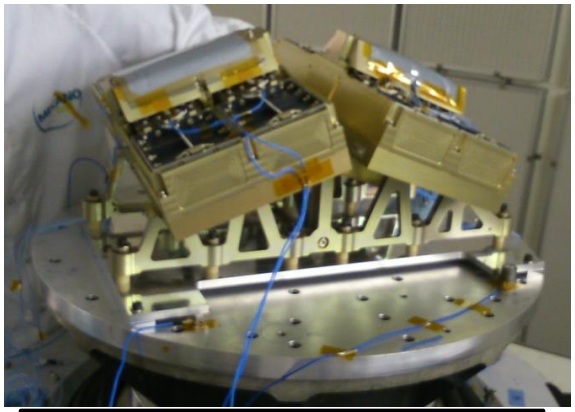
- ✓ **Production and validation of the XGRE QM sensors (vibration and thermal vacuum tests) completed (August 2015)**
- ✓ **Production and validation of the XGRE FM sensors**
  - ✓ **SM2 qualifications @ CNES (February 2016)**
  - ✓ **AIT FM sensors & vibration qualif. tests (March 2016)**
  - ✓ **Schock qualif. tests (April 2016)**
    - ✓ **Anomaly detected on LaBr3 (loss of performances)**

    -> Production process upgrade by St Gobain

    -> June 17: delivery of new LaBr3 (12 FM DUs + 4 QM DUs)

    -> July 2018: delivery of FM Dus

    -> End 2018- mid 2019: AIT on satellite and calibration



Contributions:
- **Mechanics**
- **QA/PA**
- **Electronics**
- **NEXEYA (QA/PA and AIT/AIV)**

Instrumentation Department: EUSO

Towards UHECR detection from space using UV light

- **Major facts / key milestones achieved**

✓ **2012-2014: successful flight of the EUSO-Balloon mission (12 countries, funding CNES+ Collaboration = 1,7 M€)**

Project management + integration & calibration focal surf @ APC

→ Congratulations from CNES for the scientific return + funding for a second flight

✓ **Test campaigns in collaboration with the Telescope Array collaboration (USA+Japan) and in Turlab (Torino)**

→ First UHECR detection using JEM-EUSO prototype

✓ **Funding from Europe (EuHIT), Campus Spatial (Paris Diderot) and CNES for second flight (Total for APC and LAL: 225 k€)**

✓ **April 2017: EUSO-SPB (long duration balloon flight) by NASA :**

Design, integration and calibration of the detector @ APC

- **Upcoming milestones**

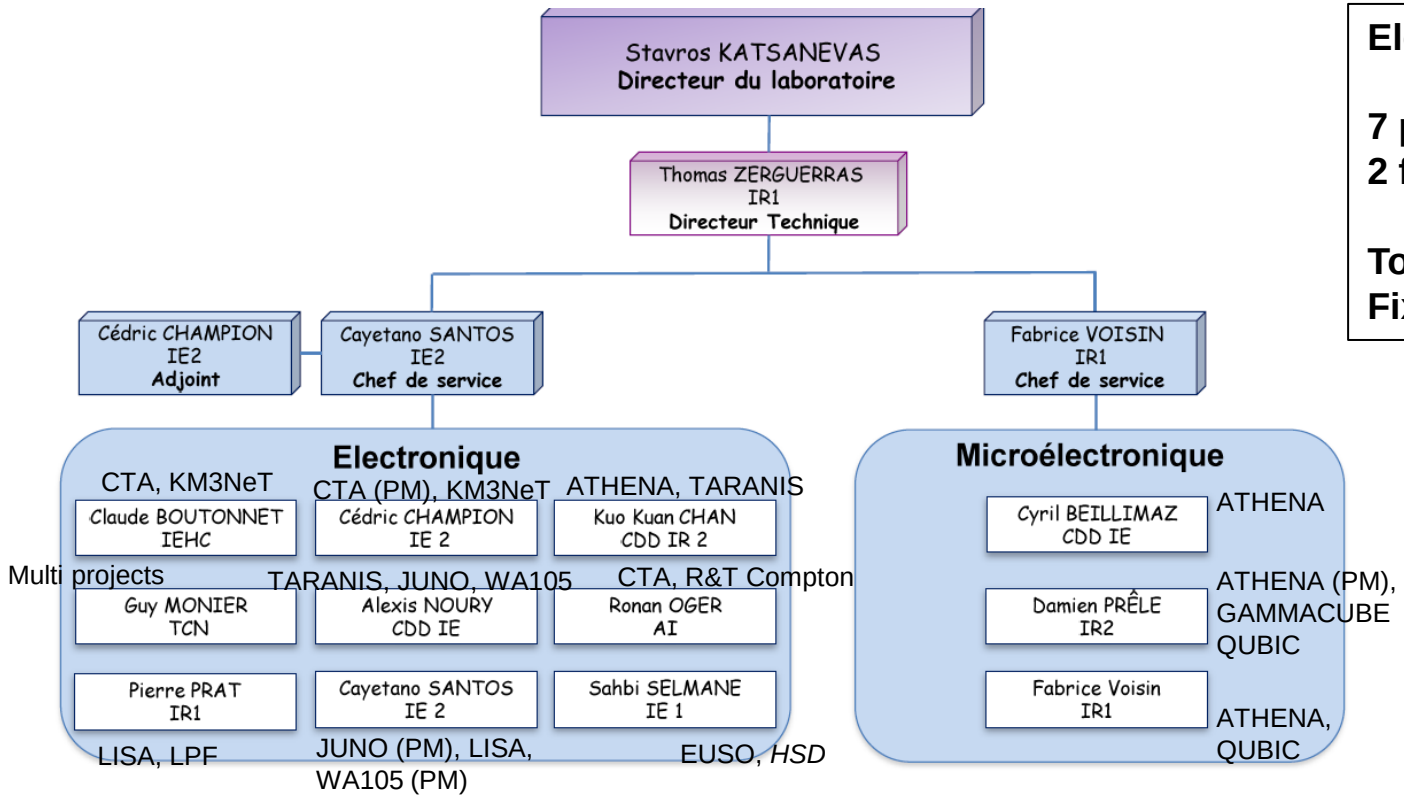
✓ **Dec. 2018: launch of the mini-EUSO mission towards ISS**

Design, integration and calibration of PDM and HV system @ APC

✓ **April 2020 : Second SPB flight, POEMMA prototype, selected as NASA Probe studies program in 2017**

Contributions:
- **Mechanics**
- **Electronics**
- **QA/PA**

Electronics and Microelectronics Department : Organisation



Electronics:

7 permanent
2 fixed term

Total: 9
Fixed term/Total: 22 %

Microelectronics (creation in 2016)

2 permanent
1 fixed term

Total: 3
Fixed term/Total: 33%

Electronics Dpt:

- **2 retirements in the next 5 years**
- **End of the 2 fixed-term hiring contracts (31/12/2017 and 04/09/2018)**

Microelectronics Dpt:

- **End of the fixed-term IE hiring contract in 2018**
- **Need of a 3rd permanent IR**

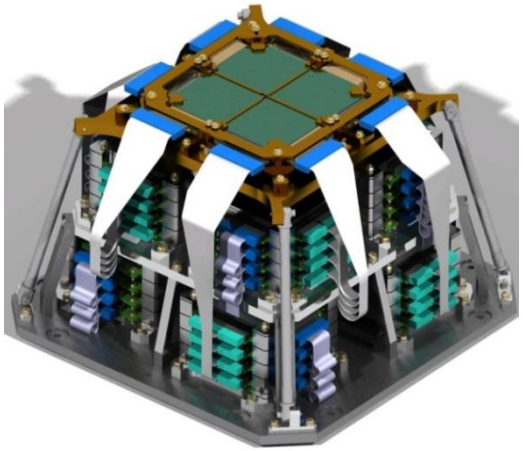
Electronics and Microelectronics Department : Skills

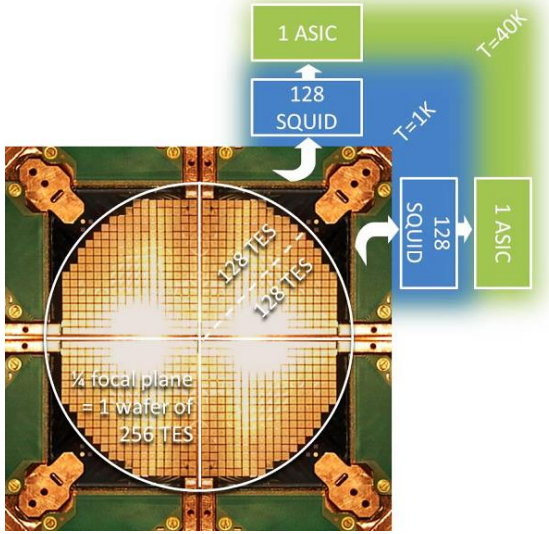
- ✓ **Analog/Digital electronics**
- ✓ **Cryogenic microelectronics**
- ✓ **ASICs definition, design and characterization**
- ✓ **FPGA programming (ALTERA, XILINX …)**
- ✓ **PCB design & integration (CADENCE)**
- ✓ **Timing and clock distribution systems (White Rabbit)**
- ✓ **Simulations: ASICs (VIRTUOSO), VHDL, PCB (ALLEGRO)**
- ✓ **Tests and characterization (ex: OMEGA ROC ASICs)**
- ✓ **Spatial and QA backgrounds (RadHard qualifications …)**
- ✓ **Project management**

Microelectronics Department: QUBIC

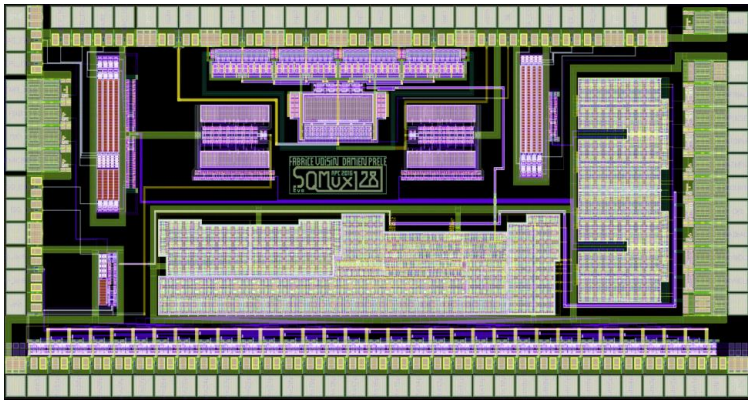
Focal plane:

- **4 wafers made of 256 TES @300mK each**
- **Readout: time multiplexing**
- **128 SQUID @ 1K + 1 ASIC @ 40 K for ⅛ focal plane**





SQMUX128 v2:
ASIC Cryo. AMS BiCMOS SiGe 0,35µm standard



Includes: LNA with multiplexed inputs (1:4)
Multiplexed current supply (1:32) for SQUIDs bias
Digital circuit for addressing and serial link

Summer 2015: Integration and validation of ¼ focal plane @ APC

15/06/2016: ASIC v2 delivered - Successfull test in the dilution-free cryostat

September 2016: Starting QUBIC demonstrator integration (2x 1/4 focal planes, 512 channels)

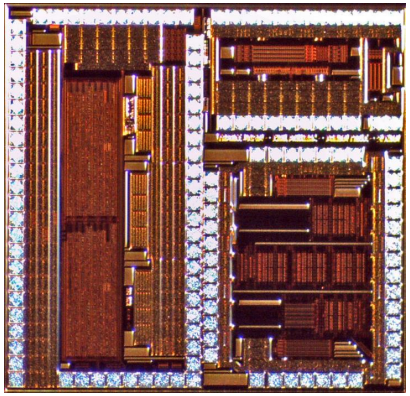
Other contributions:

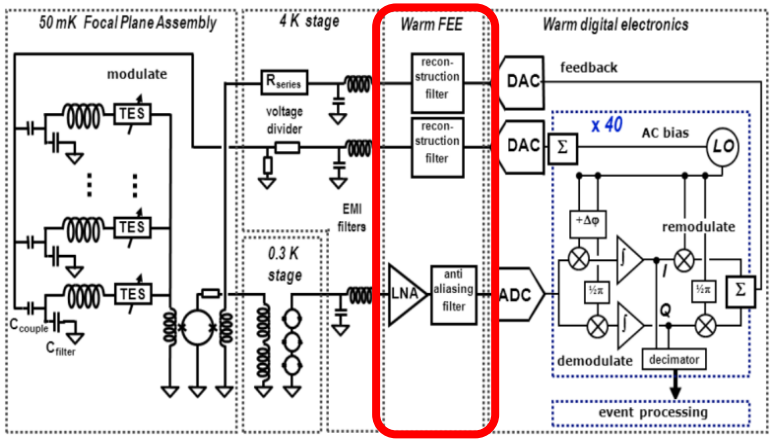
- **Mechanics**
- **Instrumentation**

Microelectronics Department: ATHENA

Warm Front-End Electronic (FEE) for the X-IFU instrument

- ✓ **96 LNA** (100V/V, 1-6MHz, 1nV/√Hz)
- ✓ Box for cryostat + EMI filters
- ✓ **SQUIDs biasing**
- ✓ Bias regulation, HK, SQUID deflux





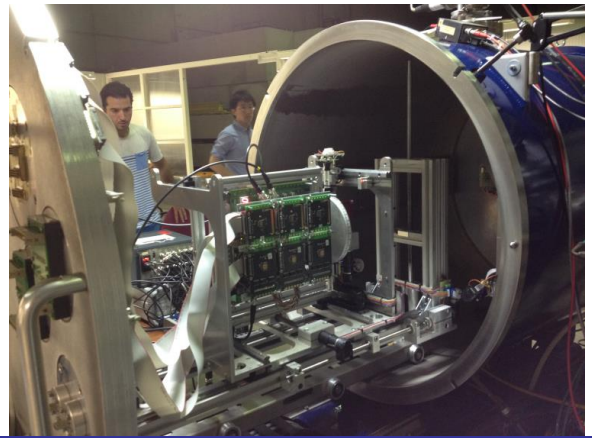
Phase A:

2015- 2019

- ASIC production + RadHard qualif.
- EGSE test benches
- Mechanics integration

awaXe_v1:

ASIC AMS BiCMOS SiGe 0,35µm



Goals:

- ✓ **Test and characterization of several architectures**
- ✓ **Validation of Rad Hard digital libraries**
- ✓ **awaXe_v1 delivered on 01/08/2016.**
- ✓ **Successful RadHard test campaign @ Cocase (high-intensity 60Co source) and latch-up tests @ Louvain-la-Neuve (heavy ions)**
- ✓ **ASIC v2 in preparation**

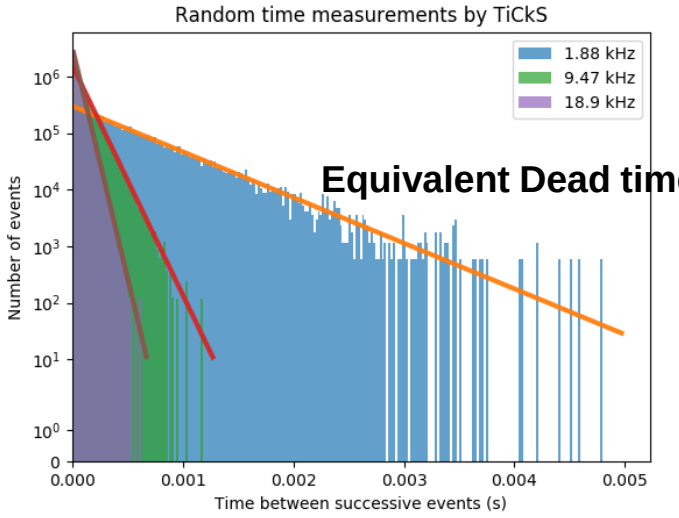
Electronics Department: TiCkS board for CTA

TiCkS board (Time and Clock Stamping) based on the White Rabbit (WR) SPEC node:

- ✓ **Providing ns-precision Time Stamps (TS) of input signals**
- ✓ **Transmission of these TSs to a central collection point for use in any CTA camera**

Modification in the Spartan-6 FPGA :

- ✓ **Addition of a 1ns precision TDC for the TSs** (collab. CEA/IRFU)
- ✓ **UDP stack :**
  - send TSs on WR fiber (**No loss up to 320kHz @ fixed frequency**)
  - Receive config & slow control commands on the same fiber
  - Send PPS and event counter
- ✓ **2 versions :**
  - TiCks –UCTS (FMC) soon available in the WR Open Hardware repository
  - TiCKs-CTA (2xRJ45)



C. Champion et al., **Proc. ICALEPCS2017, Barcelona, Spain October 8-13 2017 (accepted)**

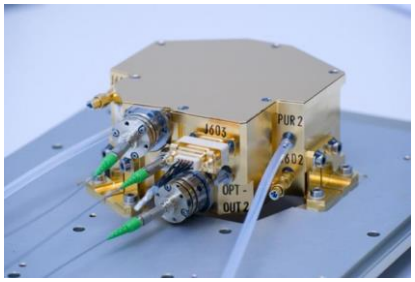
Next:

- ✓ TiCkS on NectarCAM test bench: end of 2017
- ✓ Network of 8 TiCks: end Q1 2018

Other contribution: QA/PA

Electronics Department: LISAPathfinder and LISA

LISAPathfinder: LASER MODULATOR: beam splitter + 2 AOM + actuators
Validation of test procedures with the manufacturer
Monitoring during the mission



LISA R&T: Electronics development for the LISA On Table simulator

- ✓ Servo electronics for laser amplitude and optical paths stabilization
- ✓ Implementation and modification of a phasemeter developed at the AEI Hannover
  - building hardware for RF electronics and DDS kits
  - external clock synchro + jitter correction
  - Upgrade to 14 bits @200MHz sampling
- ✓ Low frequency noise measurements on RF components and voltage references

REFIMEVE: Developing the Servo electronics of an optical link between the cleanroom and the low electronic noise room for the transmission of an ultra-stable 1GHz clock

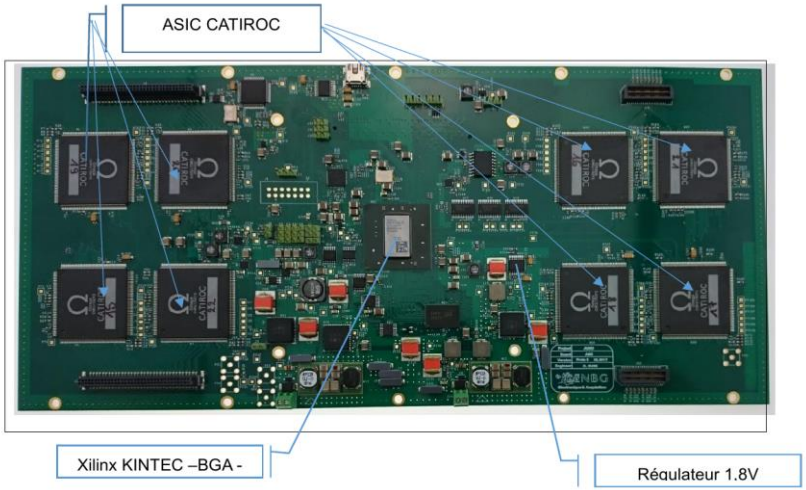
Electronics Department: Electronics readout for large PMTs assemblies

Card design, firmware and data acquisition

JUNO @ APC

Joint effort with CENBG and OMEGA

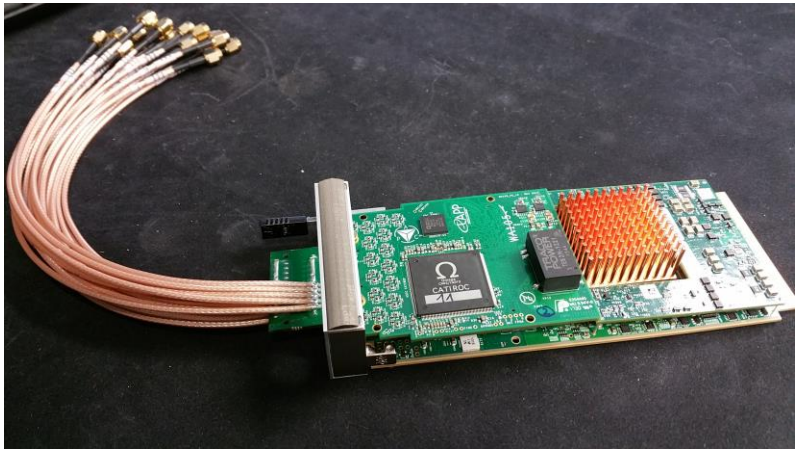
- **128 channels**
- **8x CATIROC ASICs**
- Kinde 7 FPGA
- FMC connector



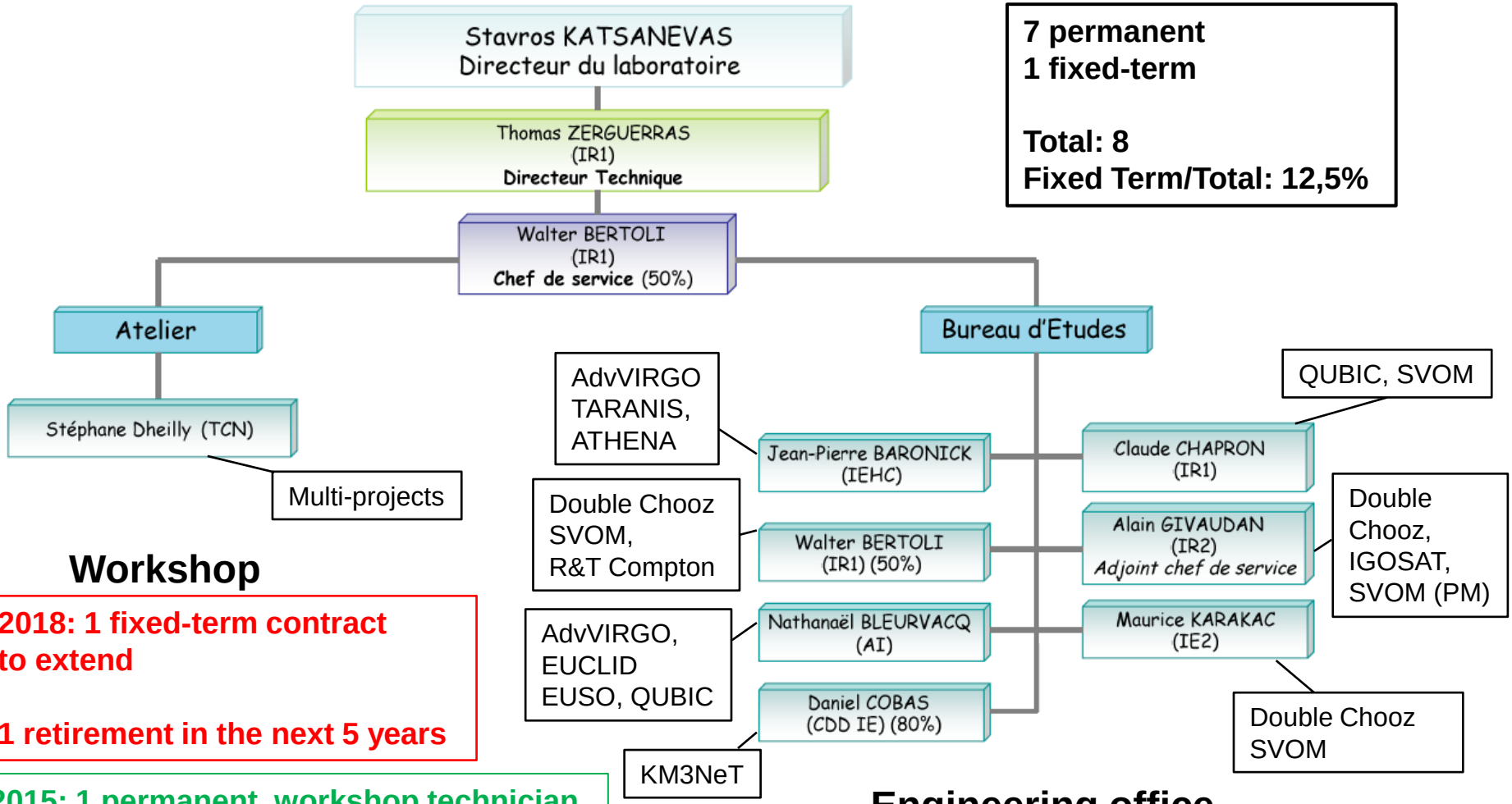
WA105 @ APC

Collaboration with IPNL, LAPP and OMEGA

- **16 channels**
- **1x CATIROC ASICs**
- 65 Msps ADC
- µTCA AMC
- FMC connector



Mechanics Department: Organisation



7 permanent
1 fixed-term

Total: 8
Fixed Term/Total: 12,5%

Workshop

2018: 1 fixed-term contract to extend

1 retirement in the next 5 years

2015: 1 permanent workshop technician
2016: 1 permanent IE

Mechanics Department: Skills

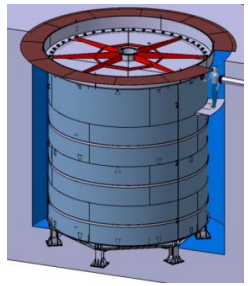
- ✓ **Mechanical design in specific environment (space, undersea, vacuum, cryogeny, high-level cleanliness)**
- ✓ **CAD (CATIA)**
- ✓ **Finite-element analysis (transition from Samcef to ANSYS): isotrope materials, mechanics, thermal management**
- ✓ **Dimensionnal metrology (mechanics) + programmation**
- ✓ **Spatial and QA background (environment qualifications …)**
- ✓ **Project management, call of tenders for public contracts**
- ✓ **Subcontracting monitoring**
- ✓ **Workshop: CNC machine 2,5 axes (drilling)/assembly, numerically controlled machining center.**

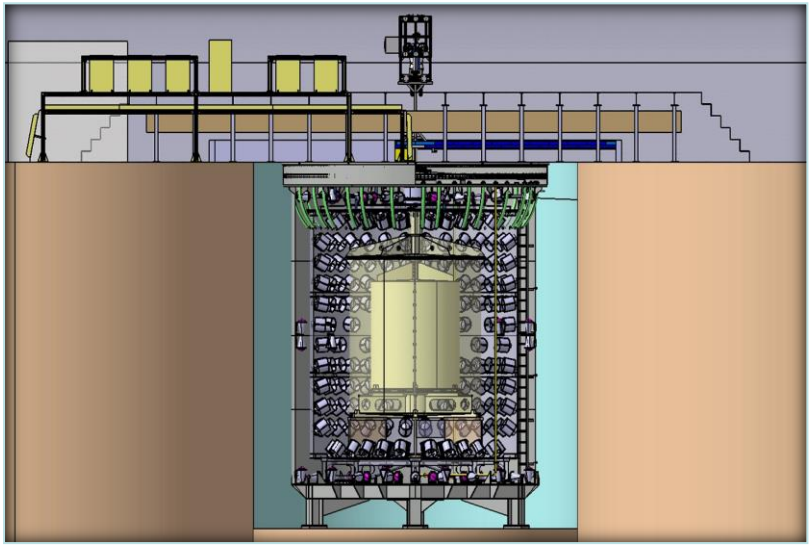
Mechanics Department: Double Chooz

Far Detector: Design, production and installation (2011)

Near Detector: Design, production and installation (2012-2014)

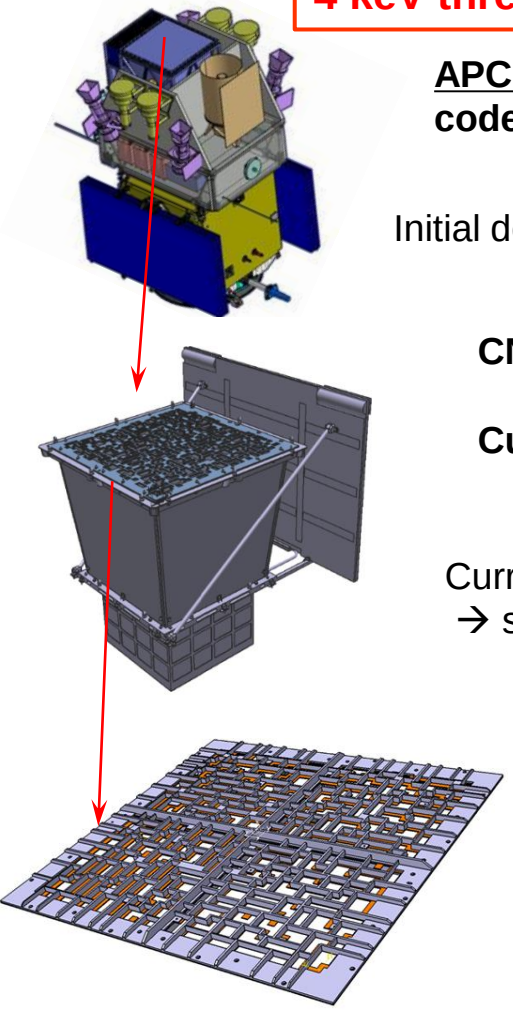
- ✓ Shielding: 1m water (except steel on top)
- ✓ Stainless steel tank on steel supports (outer vessel)
- ✓ Support stiffness strenghtened to prevent any deflection > 1mm of the bottom (45 tons thrust load)
- ✓ Upper shielding (steel), platform and electronic hut





Mechanics Department: SVOM

French-Chinese Space Mission for detection of X and gamma bursts with a 4 keV threshold



APC workpackage: Design, production, test and validation of the coded mask for the ECLAIRs instrument:

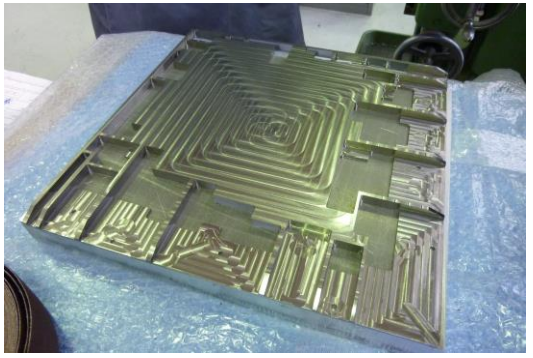
- ✓ Pattern area 540x540mm^2 , 40% transparency, self-supporting mask

Initial design : pre-tensed foil made of allied Tantalum 0.6mm thick (4000 random holes)

CNES review (B phase) : September 2016

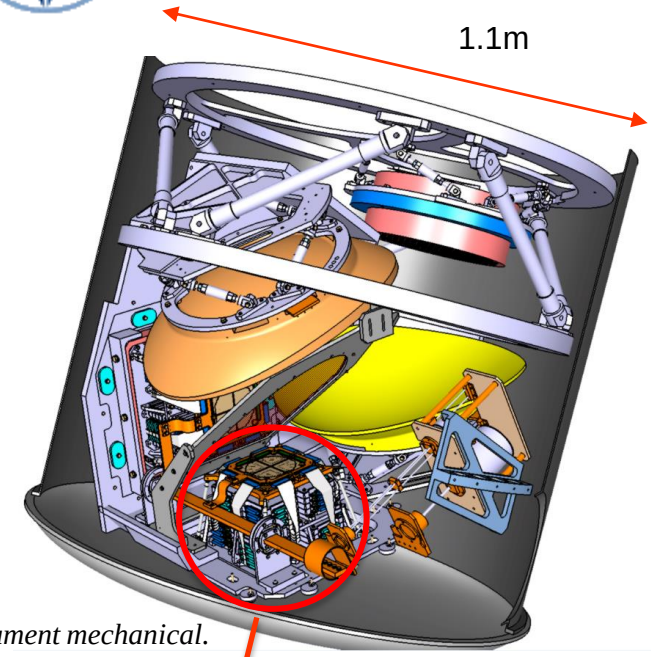
Currently: Phase C

Current design: new pattern with enlarged holes
→ sandwich Ti/Ta/Ti 33.6mm thick

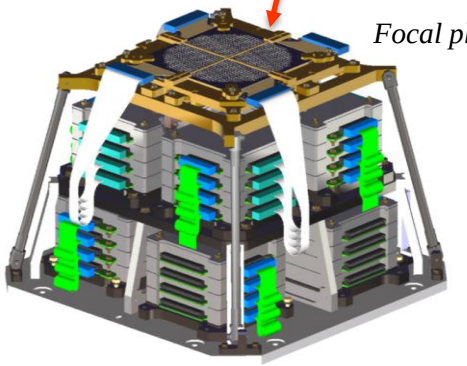


- ✓ Production of SM for further vibration test: End 2017
- ✓ Structural Thermo Model delivery : May 2018
- ✓ FM Mask: 2019
- ✓ Launch : 2021

Mechanics Department: QUBIC



Instrument mechanical. architecture



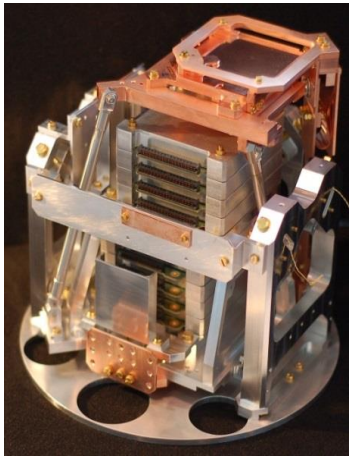
Focal plane tower

APC mechanics workpackages :

- ✓ Thermal & mech. design of focal plane towers
- ✓ Therm. & mech. design of the instrument architecture inside vessel
- ✓ Mech. design of the switches / R&D on horns manufacturing
- ✓ Integration process of instrument inside vessel and tests

Technical challenges

- ✓ Mass optimization
- ✓ Keeping optics alignment when instrument is cooled
- ✓ EMC optimization
- ✓ Many interfaces
- ✓ Integration



¼ Focal plane prototype

Milestones:

- ✓ Technical Demonstrator design finalized
- ✓ Production plan finalized
- ✓ Production : laboratories for small components (GEPI, LAL, APC), subcontracting for the biggest

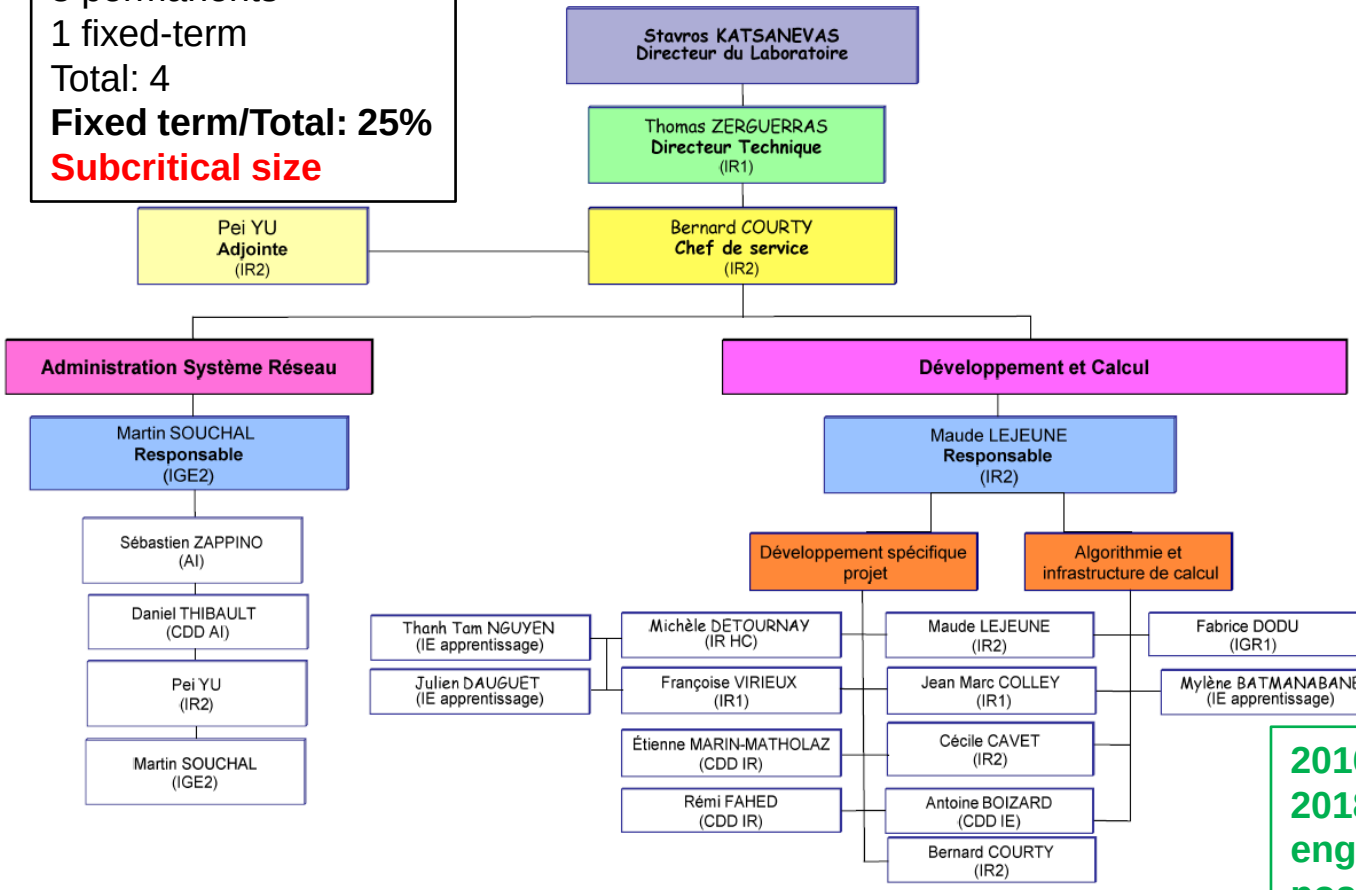
Other contributions:

- **Microelectronics**
- **Instrumentation**

IT Department : Organisation

2 subdepartments:
- ✓ **Networks and systems administration**
- ✓ **Development and calculation**

Networks & systems administration:
3 permanents
1 fixed-term
Total: 4
Fixed term/Total: 25%
Subcritical size



Development & calculation:
7 permanent
3 fixed-term +
3 apprentice
Total: 13
(FT+Appr.)/Total: 46%
High ratio of non-permanent members of staff

2016: 1 permanent IR (repl.)
2018: Opening of a software engineering IR permanent position (LSST, LISA)

IT Department: Skills

- ✓ **Network & System Administration :** network, storage, Unix account, databases, identification system
- ✓ **Support: material (hard & soft) and users**
- ✓ **APC Website management** (Drupal)

- ✓ **Infrastructures for calculation and projects:** parallel calculation cluster (~ 800 CPU), APC cluster (~ 600 CPU), **collaborative platforms**, EGEE grid, **cloud computing (OpenStack) and Big-Data (Hadoop cluster)**

- ✓ **Control & command, real-time:** architecture of distributed applications, control and monitoring of mechanical components (motor, presence detector, lock …), data acquisition (PXI and USB bus), multi-threading and multi-processing architecture

- ✓ **Data analysis:** data analysis chain development (ex: CMB cards), parallel and distributed programming in shared distributed memory

- ✓ **Simulations:** processes in astrophysics (plasma jets from black holes, accretion disk), HPC, instrumental data (ex: EUCLID telescope)

IT Department: CTA PHP

Generalities : a web interface to manage proposals for scientific observations

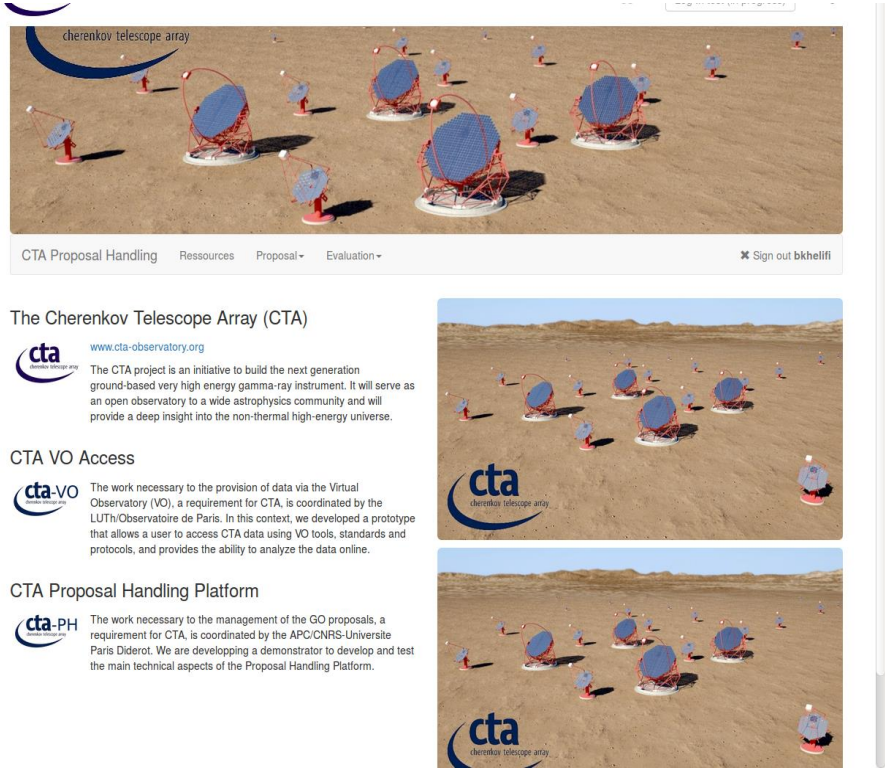
Preparation | Submission | Evaluation | Follow-up | Admin

Planning

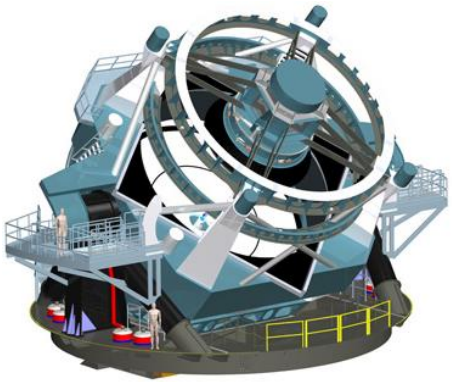
2015- Mid-2016: demonstrator dev. phase
Mid-2016- Mid-2018: Implementation
Mid- 2018: operationnal demonstrator version for the consortium
Mid-2020: First release to the observatory

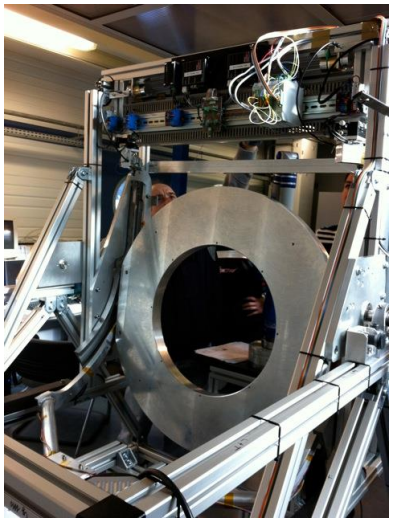
Technical Team

- Developper engineer: TT. Nguyen, J J. Dauguet
- Project manager: M. Detournay



IT Department: LSST





- ✓ **JAVA development framework for the CCS camera:** Monitoring and managing communications between subsystems (filters change, shutter, cooling, power supply management) and information flux between databases. **Concept proposed by the APC laboratory and selected by the collaboration**

- ✓ **FCS subsystem (filter changer) Control/Command: 6 filters (motion control, exchange, positionning).** **Critical (1 filter = 700k€)**

- **Successfull reviews: Director NSF-DOE JSR (2016), RSP IN2P3 (2017), FCS MRR (2017)**

- **Scale 1 prototype under construction @ LPSC, CPPM and LPNHE**

F. Virieux (PM), E. Marin-Matholaz

IT Department: Data analysis & Computing

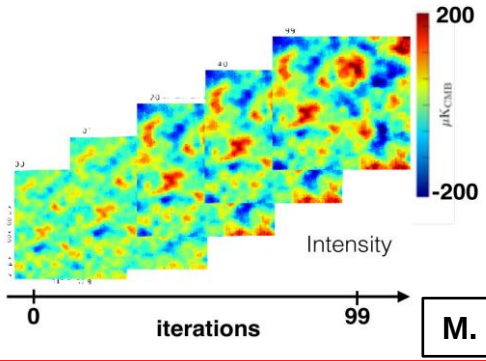
Map-making for CMB data analysis

How to keep refined data analysis when data volume is exploding ?

Number of detectors :
Polarbear I: 1200 -> Polarbear II: 7500
-> SIMONS array (2018): 22000

Size =n_t (10^9) x n_pix (10^7)

Unbiased mapmaking (iterative) to get full map recovery at optimized CPU cost

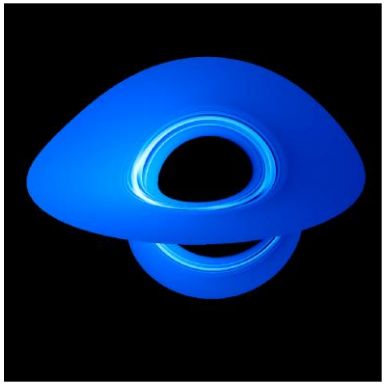


M. Le Jeune

High Performance Computing

Studies of disk instabilities around black hole accretion disk

- Support : FACe (7 nodes bought by the HPC project team), CINES
- Scientific library compilation, optimization, installation
- Visualization for very big data : a new challenge



F. Dodu

Quality Unit: Organization

3 permanent
1 apprentice

Total: 4
+
1 external consultant

CQAP
Corinne JUFFROY (IR1)
Quality Manager

Management
Quality Project
CNRS Quality in Research Network Steering Committee
IN2P3 and INSU Quality Networks

Stéphane COLONGES (IR2)
Product Assurance

Catherine HUGON (IE2)
Information Systems

Sebastien GAUCHERY
Apprentice Engineer

Ghania MEDJDOUB
Nexeya Consulting
Product Assurance

Electronics
Product
Assurance

Information
Systems

KM3Net

TARANIS

Valorisation Deputy
GTR FIDES
CNRS Electronics Network

Training Deputy
Démocrite Network

2012: 1 no-replaced IR departure

Multi-projects and transverse activities for the laboratory

Quality Unit:Skills

Quality Assurance Support:

- ✓ **Setting up quality and management procedures to continuously improve scientist instruments produced by the laboratory**
- ✓ **Includes:**
  - ✓ **Documentation management**
  - ✓ **Non-conformities management**
  - ✓ **Traceability process implementation**
  - ✓ **Control of assembly operations**

Electronics Product Assurance:

- ✓ **Components qualification for commercial products or specific ASICs : Radhard qualification process, studies of reliability and ITAR process for space electronics components**

Information and indicators management:

- ✓ **Electronics documentation management**
- ✓ **Scientific bibliography**
- ✓ **Database studies and development for laboratory management**

Quality Unit: Involvement in projects

TARANIS

Quality Project + Electronic Product Assurance (the whole project)

Quality AIT/AIV

CTA / NectarCam

Reliability analysis of the MUTIN circuit Board and clock distribution.

RAMS activities for NectarCam : (RAMS = Reliability Availability Maintenability Safety)

KM3NeT

Reliability analysis of DOM (Digital Optic Module) and other subsystems

EUCLID

NISP sensor RadHard test campaigns for EUCLID focal plan

SVOM

Quality Project Documentation

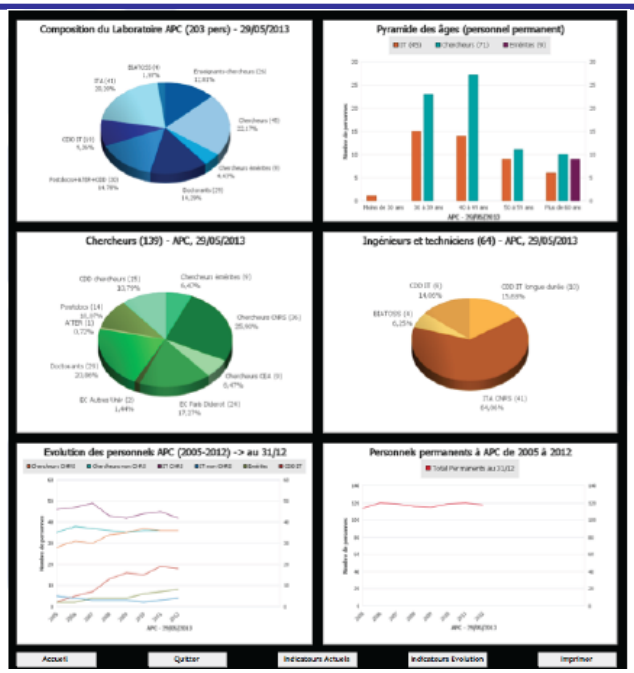
ATHENA

Quality Project + RADHARD Qualification

Quality Unit: Achievements

Indicators Database Human Resources:

- ✓ Information on Human Resources of the laboratory for tutelage agencies, scientific committee and the AERES



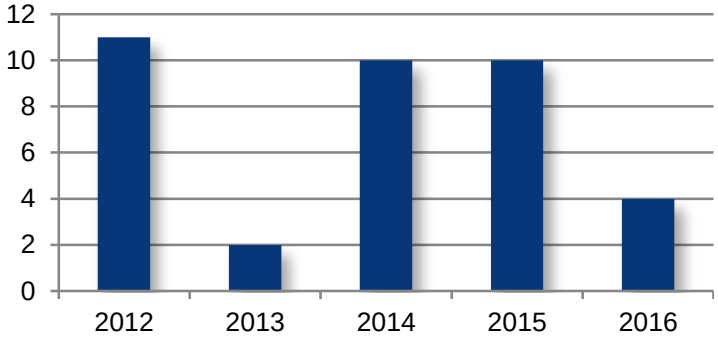
Project resources database:

- ✓ Overview on human resources assigned to each project for a better visibility
- ✓ Production of indicators (statistics, charts, graphics)

Documentation:

- ✓ Provision of documentation templates for projects
- ✓ Provision of an on-line documentation system (ATRIUM) for centralisation and storage
- ✓ Assistance to project reviews (CSP) organisation and reports management

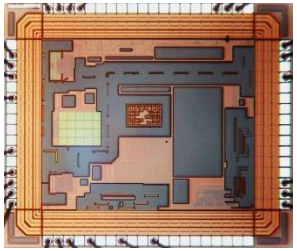
2012-2016: 37 internal reviews



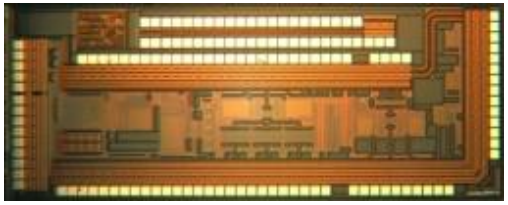
R&D: Microelectronics @ Millimetric Laboratory

SQUID multiplexed architecture and cryogenic ASICs for large TES assemblies readout

SQMUX8 : 2x4 TDM SQUIDs readout (R&D Bolo)

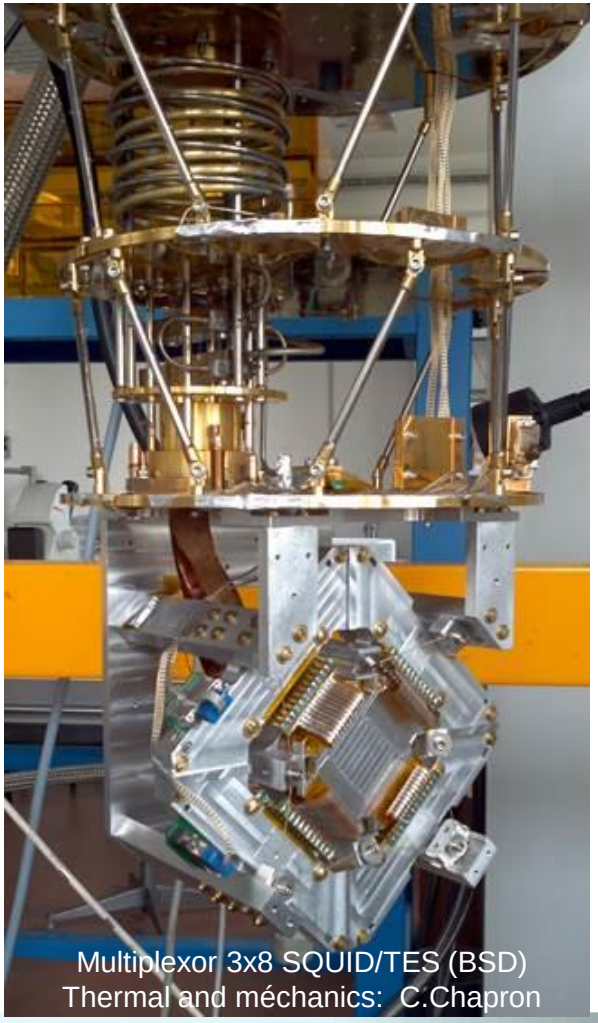


SQMUX24 : 3x8 TDM SQUIDs readout(R&T CNES DCMB)



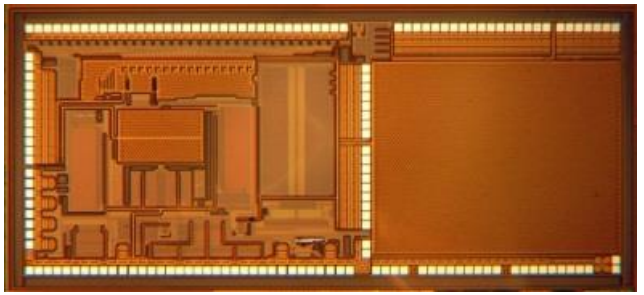
Skills:

- ASIC Cryo (4,2K) design and implementation
- SQUID multiplexing + linearization (FLL)
- 2x2 / 3x8 / 4x32 prototypes integration
- Current/noise TES operation and characterization (collaboration with IEF/CSNSM)

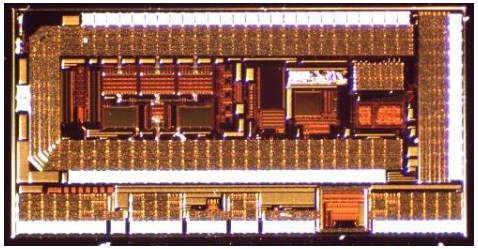


Multiplexor 3x8 SQUID/TES (BSD)
Thermal and méchanics: C.Chapron

SQMUX128 :
4x32 TDM SQUIDs readout
(R&D CNES BSD / QUBIC)



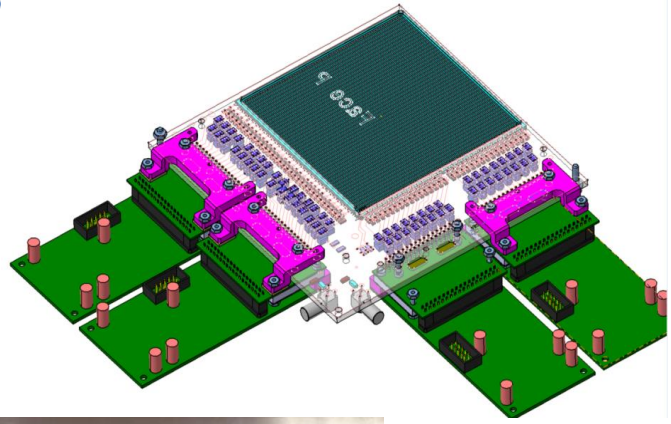
PMO_SQMUX24 :
3x8 TDM SQUIDs readout
(Chinese PMO Col.)

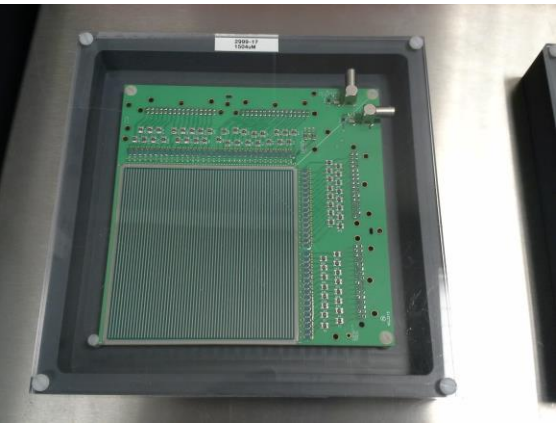


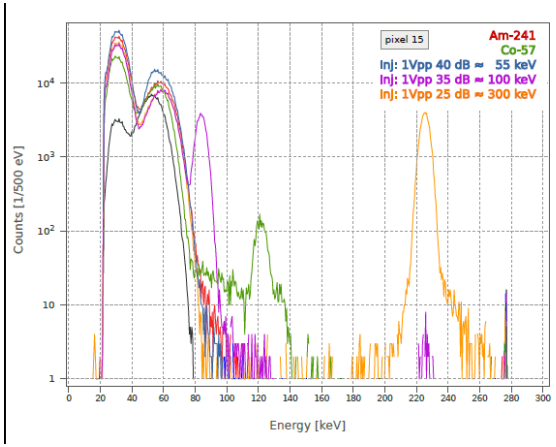
D. Prêle, F. Voisin

2006 — 2017

R&D: R&T Compton







2 DSSD 10x10cm^2, 1.5 mm thick mounted on dedicated hybrid PCBs, Design @ APC Manufacturing by the MICRON Semiconductor.

CNES milestones reached:

- ✓ **Validation of the readout electronics (CEA FE including IDeF-X chips) with a Tristan silicon detector**
- ✓ **2 DSSD mounted on hybrid PCBs delivered in August 2016**
- ✓ **First spectrum measured with DSSD read with CEA FE**

Next:

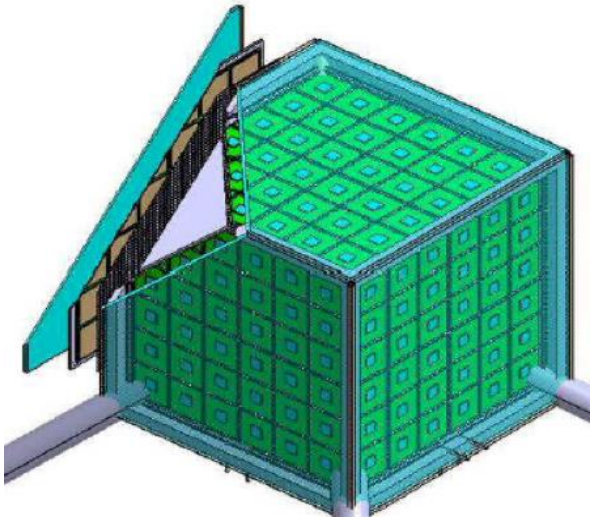
- ✓ Design of a new digital electronics (FPGA + ADC) compatible with the NARVAL acquisition system
- ✓ Integration in a Compton mini-camera (DSSDs + Scintillators) in collaboration with the IPN Orsay and the CSNSM Orsay (COCOTE)

W. Bertoli (PM), G. Monier, R. Oger

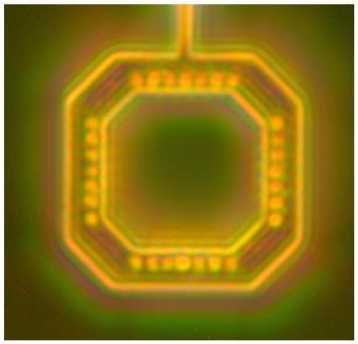
Scientists: P. Laurent, D.Maier

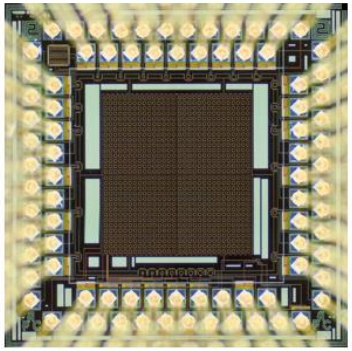
R&D: GAMMACUBE

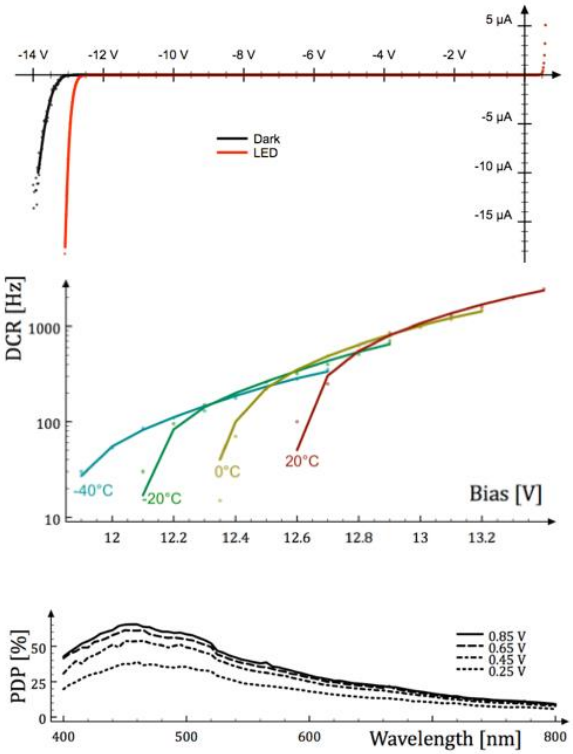
Gamma telescope, tracks reconstruction in the 5–100 MeV range



1. **Cube of plastic scintillators** (1 m^3)
2. **Micro-lenses network** (plenoptic imager)
3. **Large-size Imager** (few 10 cm), **high spatial resolution** (a few 10 µm), **single-electron detection capability**







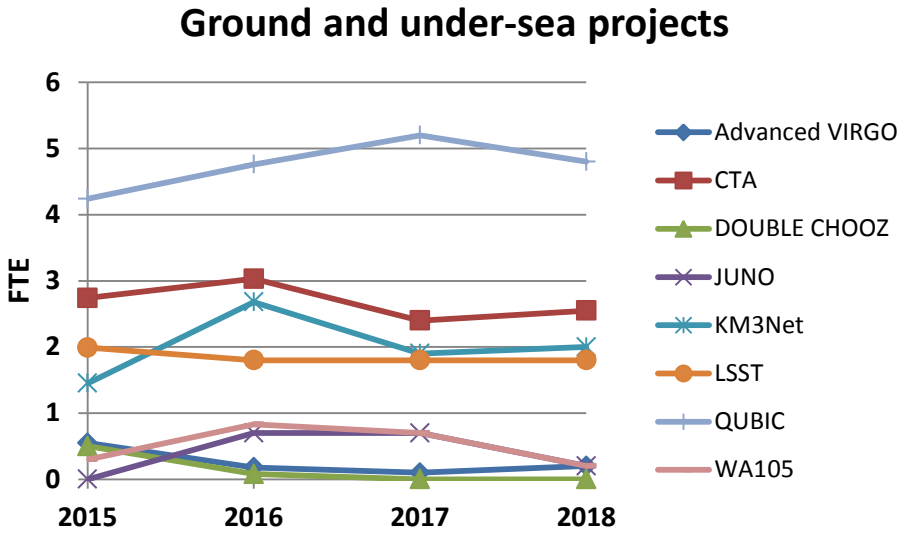
• SPAD - Single-Photon Avalanche Diodes (10 µm in opto technology CMOS 0.35 AMS)
• **ASIC IMACUP** (Col. LE2I), Multiplexed **SPAD matrix** (30x30) for imagery
• Optical and electrical characterization

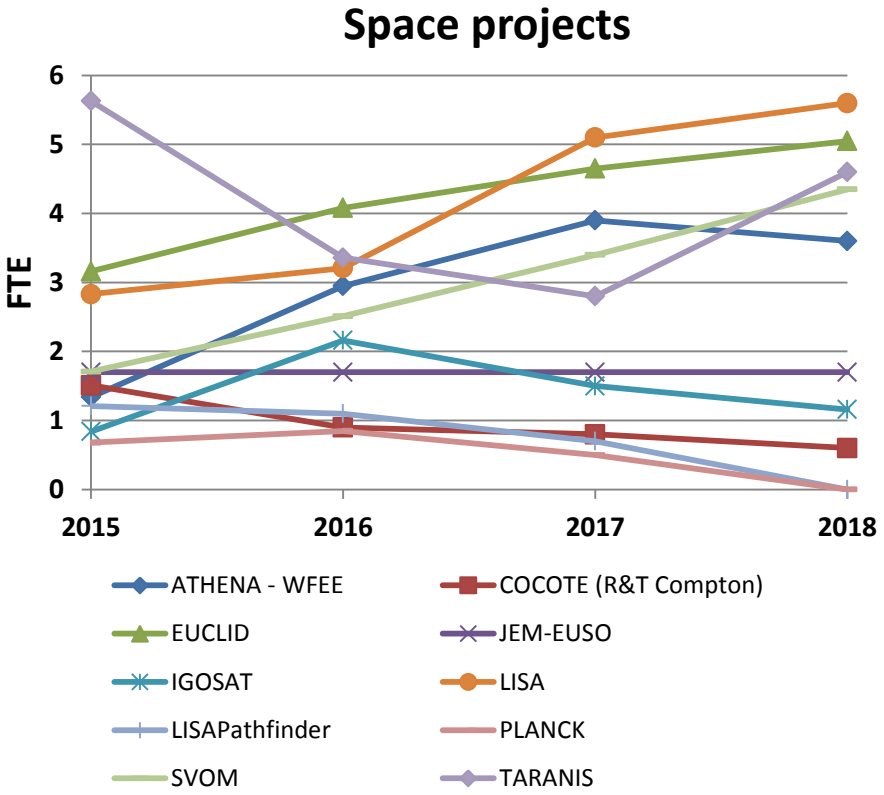
→ Patent, SATT for industrial valorization (medical applications)

D. Prêle

Scientist: R. Terrier

Analysis & Prospects: Technical FTE





Analysis and prospects: Projects roadmap

	Preparation
	Construction
	Exploitation
	End

Projects	2016	2017	2018	2019	2020	2021
Advanced VIRGO - Telescopes	Construction	Construction	Exploitation	Exploitation	Exploitation	Exploitation
ATHENA - WFEE	Preparation	Preparation	Preparation	Preparation	Preparation	Preparation
CTA - TiCkS	Preparation	Preparation	Construction	Construction	Construction	Construction
CTA - NECTARCAM- RAMS	Preparation	Preparation	Construction	Construction	Construction	Construction
CTA -GATE	Construction	Exploitation	Exploitation	Exploitation	Exploitation	Exploitation
CTA-PHP	Construction	Construction	Construction	Construction	Construction	Exploitation
COCOTE (R&T Compton)	Construction	Construction	Exploitation	Exploitation	Exploitation	Exploitation
DOUBLE CHOOZ	Exploitation	Exploitation	End			
EUCLID-CODEEN	Construction	Construction	Construction	Construction	Exploitation	Exploitation
EUCLID-EXT	Preparation	Preparation	Construction	Construction	Exploitation	Exploitation
EUCLID-NISP Rad Hard	Construction	Exploitation	End			
EUCLID-SIMULATIONS	Construction	Construction	Construction	Construction	Exploitation	Exploitation
mini-EUSO (ISS)	Construction	Construction	Construction	Exploitation	End	
EUSO-SPB	Construction	Exploitation	End			
EUSO-SPB 2		Preparation	Construction	Construction	Exploitation	End
IGOSAT	Preparation	Construction	Construction	Exploitation	Exploitation	End
JUNO - Electronics	Preparation	Preparation	Preparation	Construction	Construction	Construction
KM3NeT - Calibration Unit	Construction	Construction	Construction	Exploitation	Exploitation	Exploitation
LISA AIT/AIV	Preparation	Preparation	Preparation	Preparation	Preparation	Preparation
LISA-DPC	Preparation	Preparation	Preparation	Preparation	Preparation	Preparation
LISAPathfinder	Exploitation	Exploitation	End			
LSST - CCS et FCS software	Construction	Construction	Construction	Construction	Construction	Construction
PLANCK	Exploitation	Exploitation	End			
QUBIC- Demonstrator	Construction	Construction	Construction	Exploitation	Exploitation	End
QUBIC-FI	Preparation	Preparation	Preparation	Construction	Construction	Exploitation
SVOM - ECLAIR coded mask	Preparation	Construction	Construction	Construction	Construction	Exploitation
SVOM- Pipeline	Preparation	Construction	Construction	Construction	Construction	Exploitation
TARANIS - XGRE	Construction	Construction	Construction	Exploitation	Exploitation	Exploitation
WA105 – Electronics	Construction	Construction	Exploitation	Exploitation	Exploitation	Exploitation

Analysis & Prospects: SWOT Analysis

Strengths	Weaknesses
• ***Specific skills:*** *optics, photodetection, cryogenic µelectronic, space AIT/AIV (mechanics & instrumentation), QA/PA, virtualization and cloud* • ***Skills in space and balloons projects managemement*** • ***Recognition as a key actor in space projects by the CNES*** • ***National and international visibility***	• ***Imbalance between projects needs and available technical HR*** • ***High turn-over*** • ***Risk of losing strategic skills*** *(fixed-term contract, mobility, retirement …)* • ***Some skills*** *(ex: optics, AIT/AIV, electronics PA, mechanics workshop technician)* ***owned by a permanent member of staff*** • ***Strong commitment in projects limits involvement in generic R&D and general technologic surveys*** • ***Logistics support reduced***
Opportunities	**Threats**
• ***Space and funding agencies, tutelage organisations, national and international collaborations calls of tender*** • ***Long-term projects:*** *EUCLID, CTA, KM3NeT, LSST, QUBIC, LISA, ATHENA …* • ***Multi-messenger astronomy rising***	• ***Financial cut from funding agencies and partners*** • ***Time-consuming non-technical task increasing*** (ex: management, institutionnal consultancy, funding applications …) • ***Specific skills difficult to find on the labor market*** • ***Unfavorable change in tutelage agencies hiring policy*** • ***More and more restrictive administrative regulating*** (ex: Sauvadet, GBCP)

Thank you for your attention !

Back-up

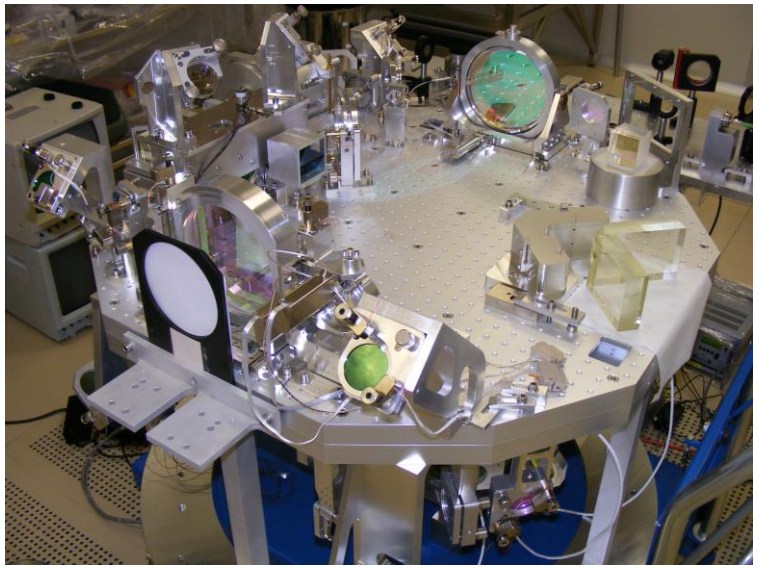
Instrumentation Department: Involvement in projects

Ground and under-sea experiments: AdvVIRGO, KM3NeT, QUBIC

Spatial projects: EUCLID, IGOSAT, LISAPathfinder, LISA, EUSO, TARANIS

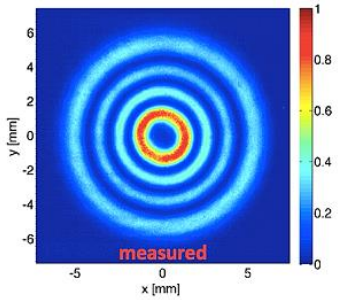
Instrumentation Department: AdvVIRGO and post-AdvVIRGO R&D

- ✓ **Telescopes for Advanced Virgo**:
  - ✓ **Adapting beam size from a few mm (laser bench) to 5 cm in cavities (and vice-versa)**
  - ✓ **MAJOR EVENTS:**
    - ✓ **Optical design validation (end of 2011)**
    - ✓ **Installation of the INJ telescope (February 2014)**
    - ✓ **Installation of the DFT telescope, SPRB and SNEB/SWEB (2015)**



GW detection in coincidence with LIGO (August 2017)

- ✓ **Laguerre-Gauss modes**
  - ✓ **MAJOR EVENTS:**
    - ✓ **Production of higher-order LG modes : PRL 2010**
    - ✓ **Interferometry : first lock (2014)**
    - ✓ **Thermal compensation of aberrations : PRD 2015**
- ✓ **Prospects:**
  - ✓ **Einstein Telescope:** Third generation GW detector (underground, cryogenic, …) : LG modes integration



PHYSICAL REVIEW D **90,** 122011 (2014)

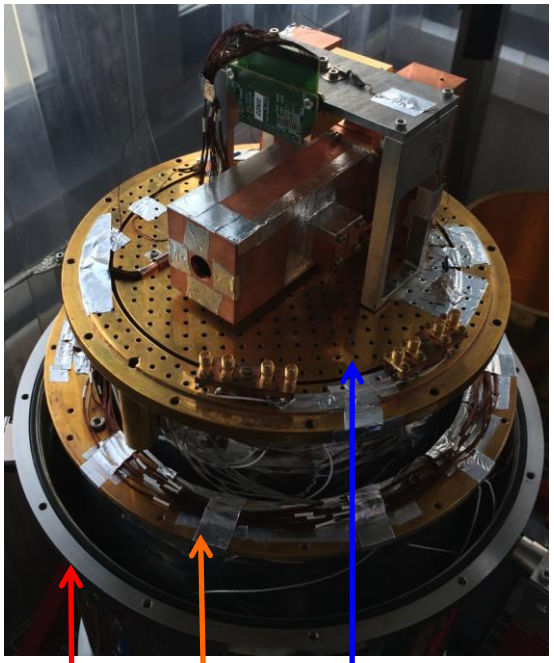
Fabry-Pérot-Michelson interferometer using higher-order Laguerre-Gauss modes

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

Contributions: Mechanics

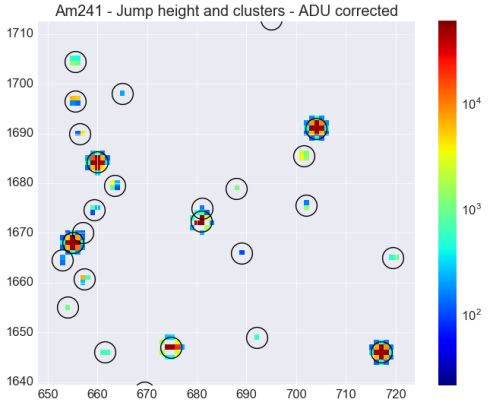
EUCLID

Radiation hardness characterization of a EM NISP H2RG Teledyne detector up to a dose equivalent to 5 years operation in space



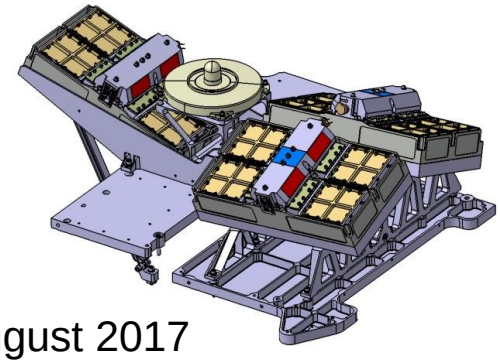
- ✓ Cryogenic test bench for the detector and its ASIC
- ✓ Thermal regulation system (Detector: 90K +/- 0.1 K, ASIC: 140K +/- 0.1K)
- ✓ Specific cabling
- ✓ Irradiation test campaigns:
  - LPSC Grenoble (January 2016) with X and α sources
  - Louvain-La-Neuve (December 2016) with a 23MeV proton beam

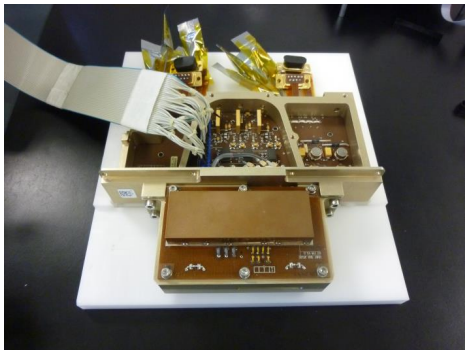
- ✓ Data analysis under progress

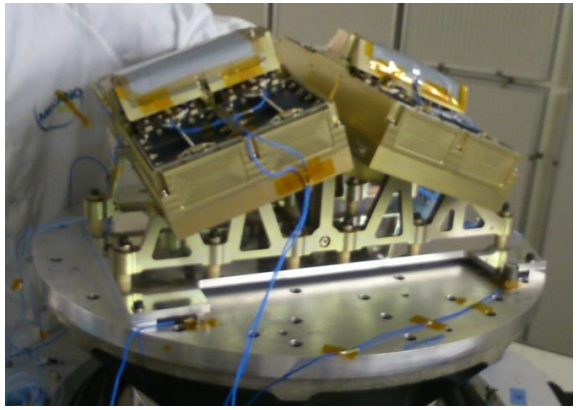


Contributions:
- **Instrumentation**
- **Mechanics**
- **QA/PA**

TARANIS





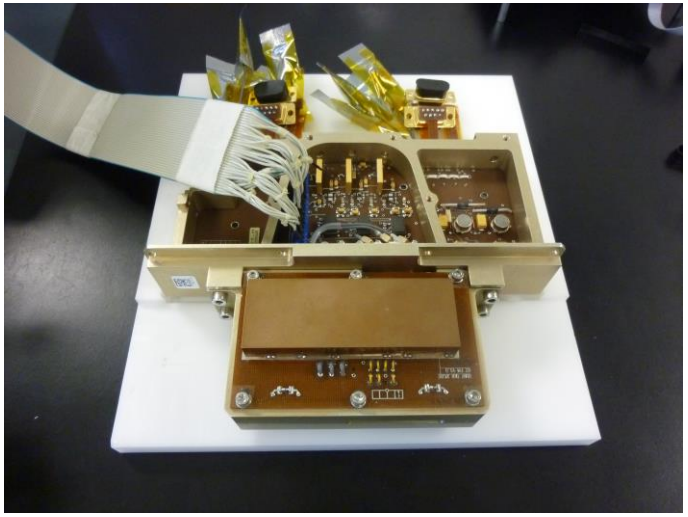


Planning:

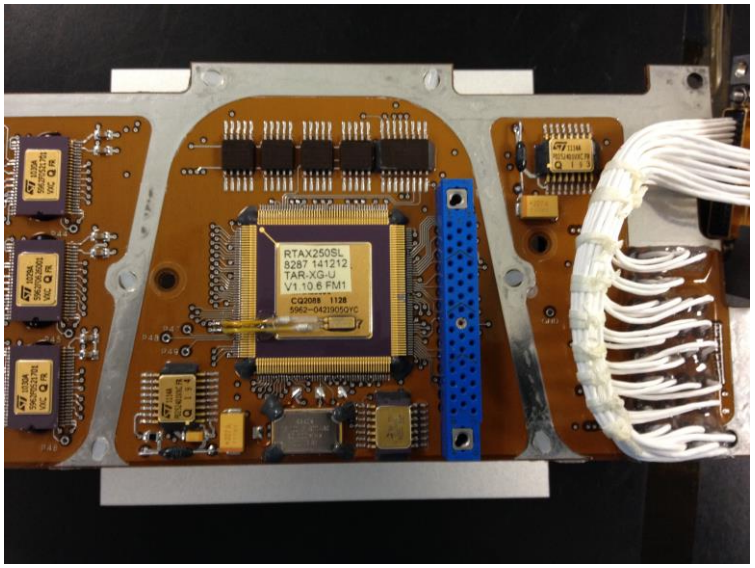
- ✓ New LaBr3: July 2017
- ✓ VT, schock campaign on LaBr3 QM: July-August 2017
- ✓ AIT 12 UD FM and 4 UD QM: September 2017- February 2018
- ✓ AIT + FM sensors calibration: January-February 2018
- ✓ Coupling with EM analyzer: February 2018
- ✓ FM sensors thermal cycling in nitrogen gas: March 2018
- ✓ FM sensors calibration: March-April 2018
- ✓ Unmounting FM UD: April 2018
- ✓ Assembling hybrid sensor (4 QM UD) : April 2018
- ✓ VT hybrid sensor: May 2018
- ✓ Delivery to CNES + VT SAT: May-June 2018
- ✓ Remounting UD FM in sensors + validations: June 2018
- ✓ Final delivery : July 2018

TARANIS

TARANIS: CNES µstaellite for Transient Luminescent Events studies



FEA card and HV modules

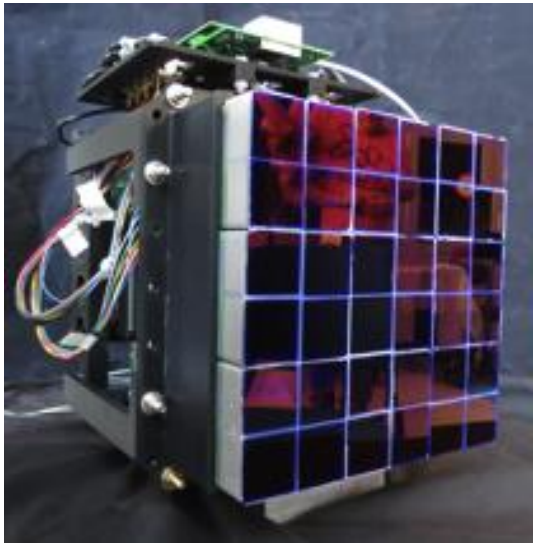


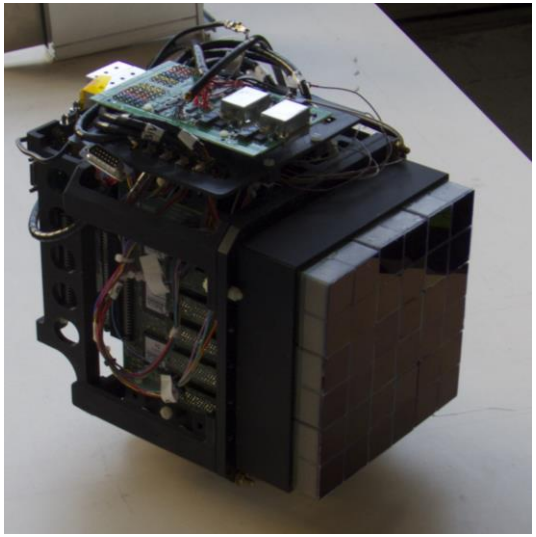
FEN card -FPGA

- ✓ **Embedded electronics readout of the XGRE instrument** (photons and electrons detection from 20keV to 10MeV)
- ✓ **ECSS standards** (*European Cooperation for Space Standardization*) for CAD design
- ✓ **RadHard FPGA**
- ✓ **Radhard VHDL programmation**
- ✓ **Analogic : EMC and qualified components**

JEM-EUSO

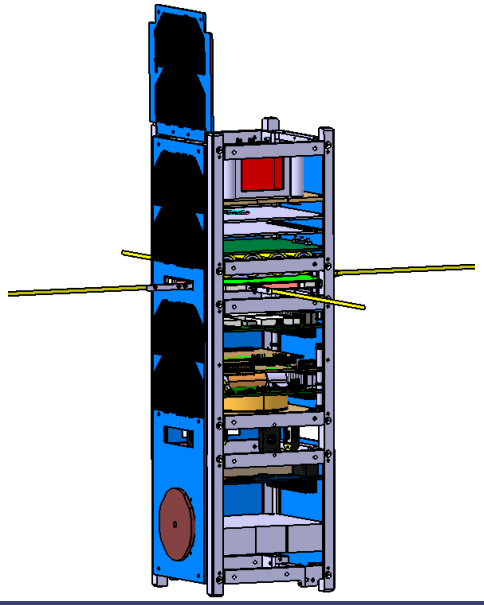
MPMT Hamamatsu R-11265 (8x8 pixels) + UV filters
ASIC : **SPACIROC 3**
FPGA: **Xilinx** (ballon 2014 et 2017)and **Zynq** (ISS 2018)
HV Cockroft Walton

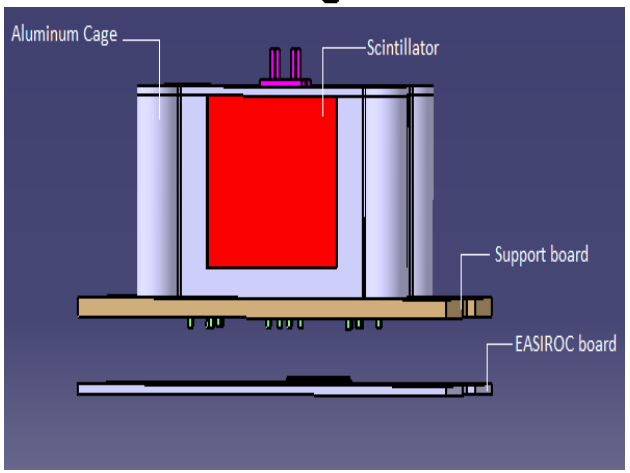




Instrumentation Department: IGOSat

- **3U CubeSat (LEO, 600Km<Altitude<700Km)**
- **Student nanosatellite for measuring :**
  - **Gamma radiation Spectrum** (from 20 keV to 2 MeV) and electrons (from 1 MeV to 20 MeV) above aurora zones and South Atlantic Anomaly (SAA)
  - **The Total Electron Content** (TEC) in the Ionosphere
- **2 payloads:**
  - A Gamma-ray detector: Scintillator
  - Dual Frequency GPS
- **More than 200 students** already worked on the project
- **Currently in Phase D** (CDR last September)
- **Technology development**
  - **Most of the sub-systems are home-made (made by students):** Scintillator Payload, Electrical Power System (EPS), Attitude Determination Control System (ADCS), On-Board Computer (OBC)
- **An operational Ground Station in Lamarck for satellite tracking and telemetry**





Contributions:
- **Mechanics**
- **IT**
- **Electronics**

Electronics and Microelectronics Department: Involvement in projects

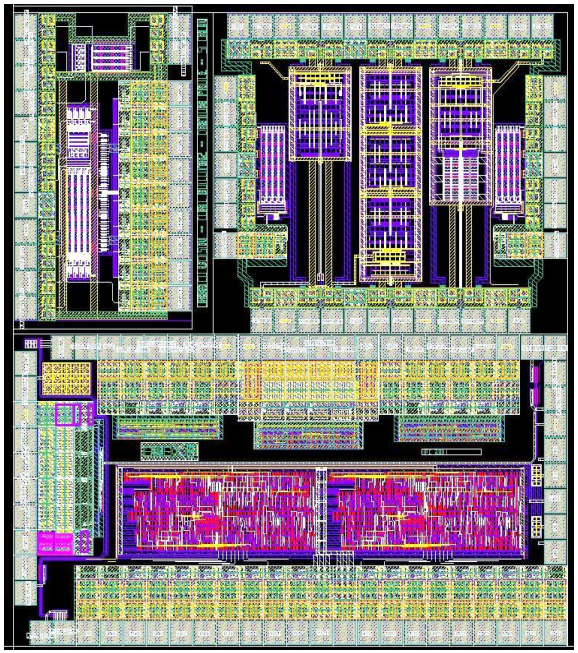
Ground experiments: KM3NeT, CTA , JUNO, QUBIC, R&D Millimetric Laboratory, WA105.

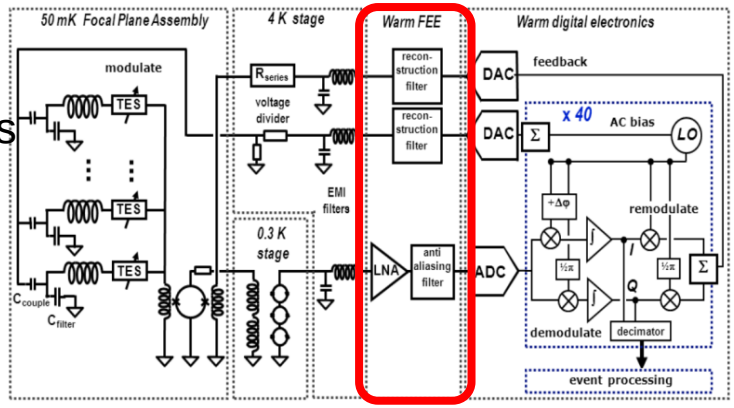
Spatial projects: ATHENA, EUSO, GAMMACUBE, LISAPathfinder, LISA, R&T COMPTON, TARANIS

Electronics and Microelectronics Department: ATHENA

Warm Front-End Electronic (FEE) for the X-IFU instrument

- ✓ **96 LNA** (20V/V, 1-6MHz, 1nV/√Hz)
- ✓ Box part of the cryostat + EMI Filters
- ✓ **Low noise adjustable SQUID bias**
- ✓ Power reg., HK, SQUID deflux …





Phase A:

2015- mi 2018

- Production of ASIC + RadHard qualif
- EGSE test benches
- Mechanics integration

awaXe_v1:

ASIC AMS BiCMOS SiGe 0,35µm

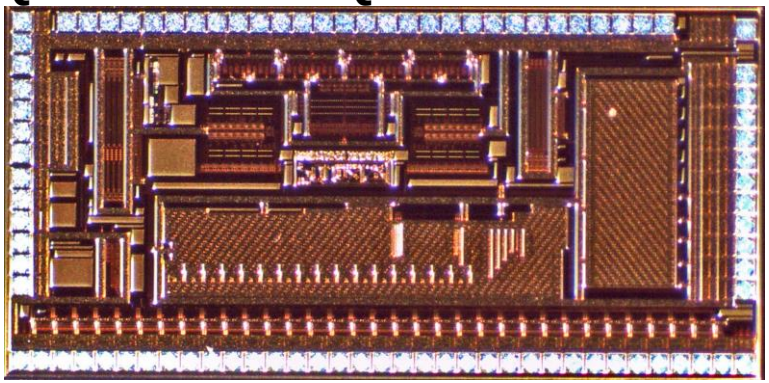
Goals:

- ✓ **Test and characterization of several architectures**
- ✓ **Validation of radiation-hard numerical libraries**
- ✓ **awaXe_v1 delivered on 01/08/2016.**
- ✓ **Successfull Rad tests @ Cocase (high activity 60Co gamma source) and latch-up tests @ Louvain-la-Neuve (heavy ions)**
- ✓ **ASIC version 2 under preparation**

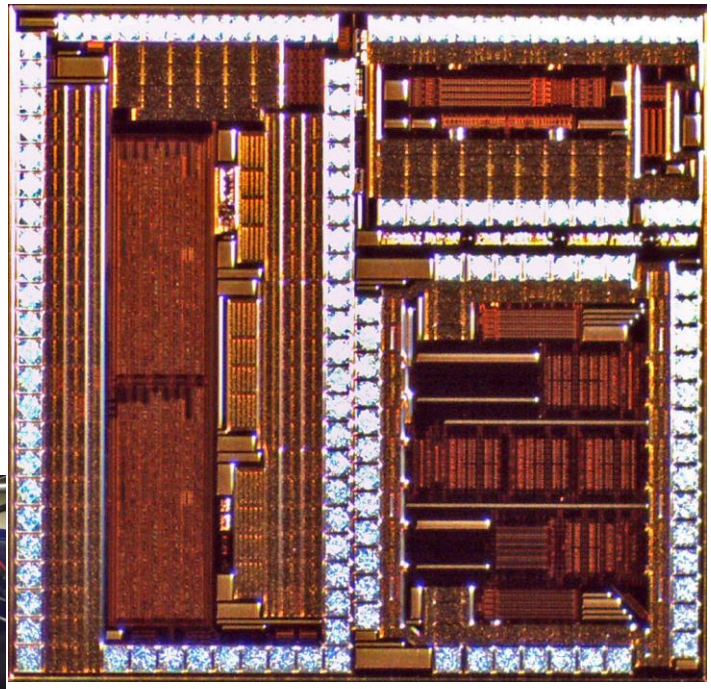
D. Prêle (Project Manager), C. Beillimaz, F. Voisin
Si Chen (AHE PhD), J.P. Baronick (Mechanics), K.K. Chan (Electronics)
S. Colonges, C. Juffroy (Quality)

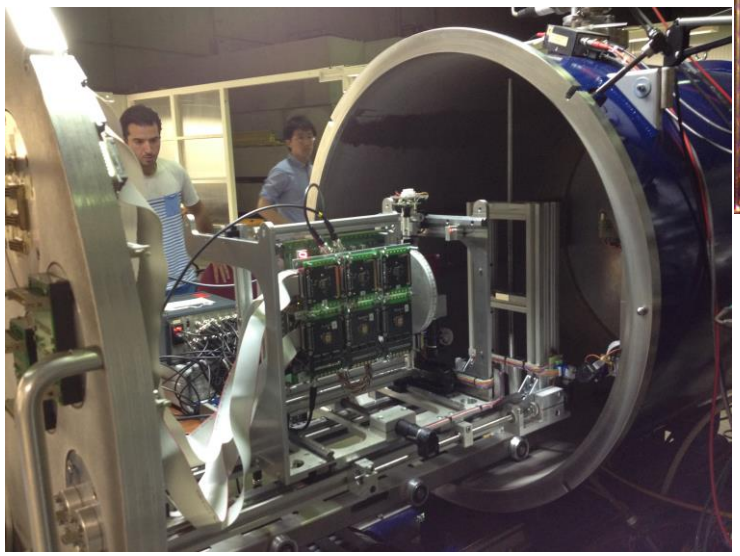
Electronics and Microelectronics Department: QUBIC & ATHENA ASICs

QUBIC: ASIC SQUMUX128 Version 2



ATHENA: ASIC Awaxe Version 1

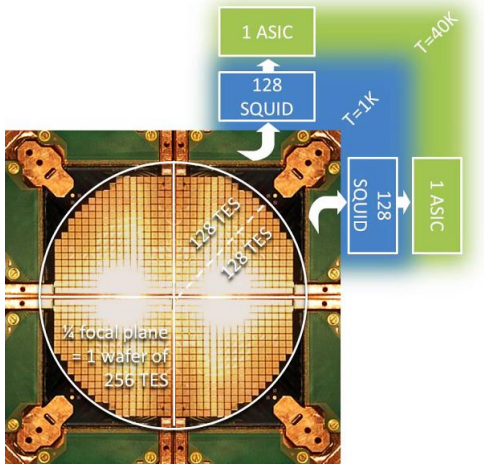




Louvain-la-Neuve test set-up for ATHENA

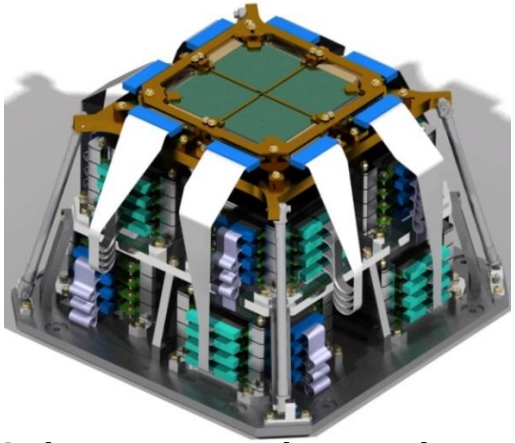
QUBIC

Bolometric interferometry for measurements of the CMB polarized B-modes

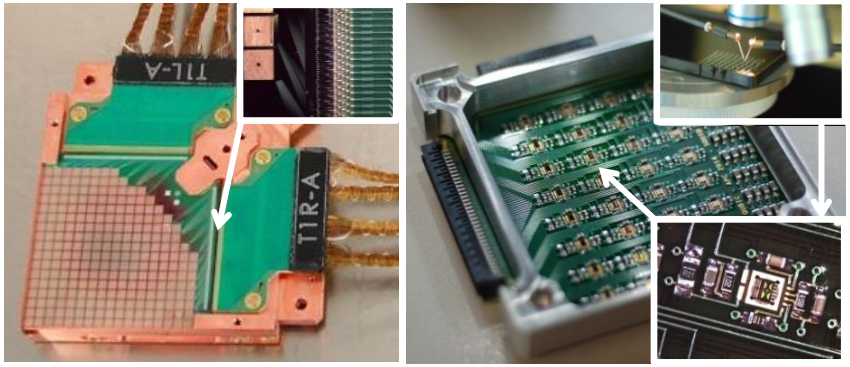


½ focal plane:

- 4 wafers de 256 TES @300mK
- Readout: TDM
- 128 SQUID @ 1K + 1 ASIC @ 40 K for ⅛ de focal plane

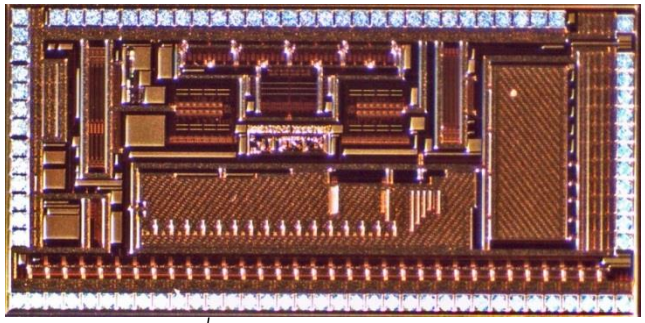


QUBIC demonstrator integration



- Supra. interconnections.
- Specific PCB
- TES characterization, SQUID definition and chips selection

SQMUX128_evo (AMS BiCMOS SiGe 0,35µm)



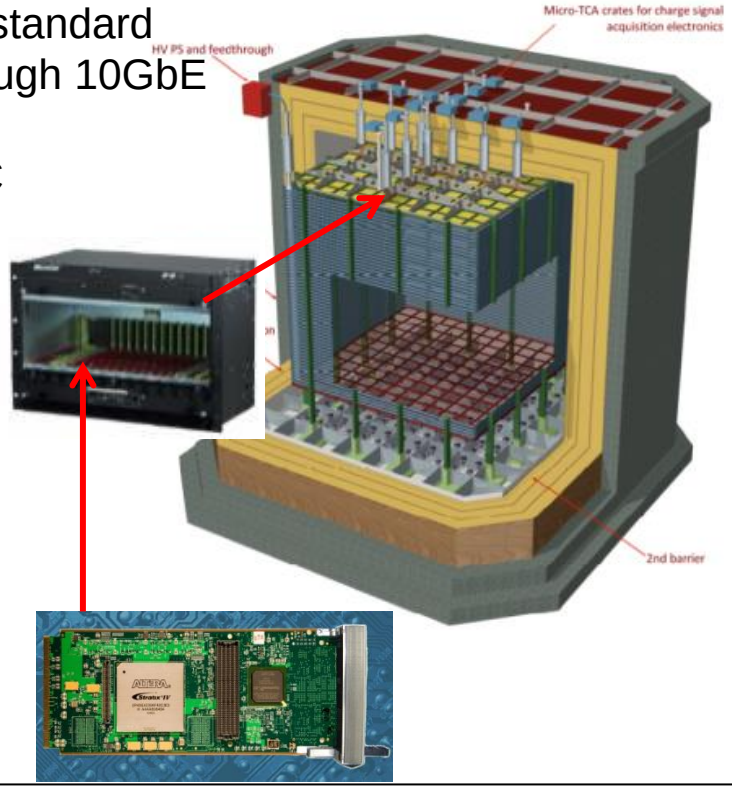
- LNA (< 0,2nV/√Hz) with multiplexed inputs
- Multiplexed current supply for SQUID bias
- Digital circuit for addressing and serial link

Electronics and Microelectronics Department: WA105 (LAGUNA)

Collaboration: **Omega - APC – LAPP - IPNL**

Goal:

- Thousands of channels of digital electronics
- WA105 DAQ Demonstrator based on µTCA standard
- Control through GbE, data transmission through 10GbE
- Prototyping with AMC S4AM from Bittware
- FMC mezzanine board, 16 channels + FADC
- **ASIC technology: 16 channels CATIROC**



Work in progress

- FMC Card 16 channels
- µTCA standard communication
- Stand-alone firmware and software development

Next:

- Electrical tests
- Production firmware and software for the experiment @CERN
- Integration and test @CERN (Q1 2018)

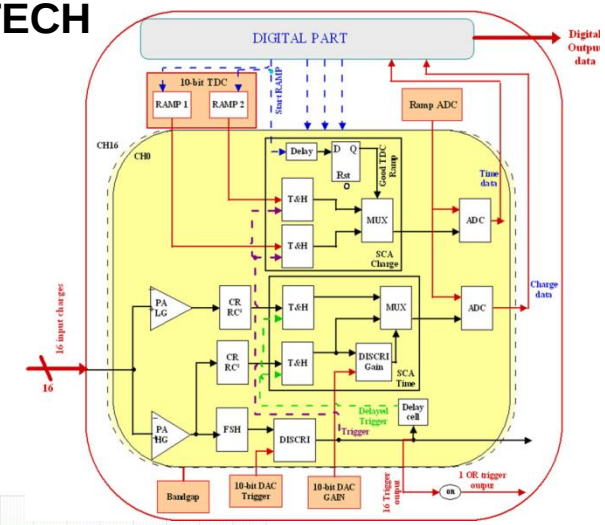
IT APC: C. Santos (Project Manager), A. Noury (end of hiring contract 31/12/2017)

Electronics and Microelectronics Department: JUNO

Collaboration: **APC – Omega – CENBG - SUBATECH**

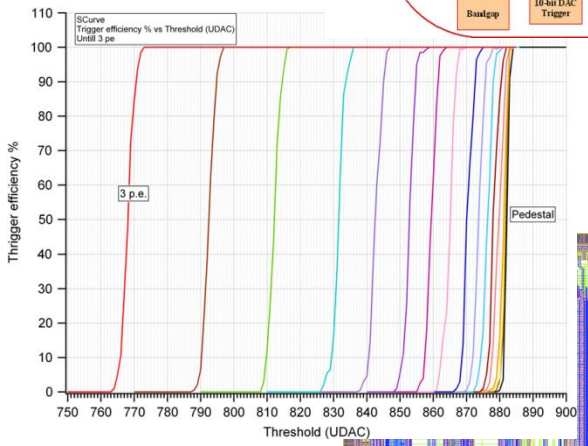
Goal:

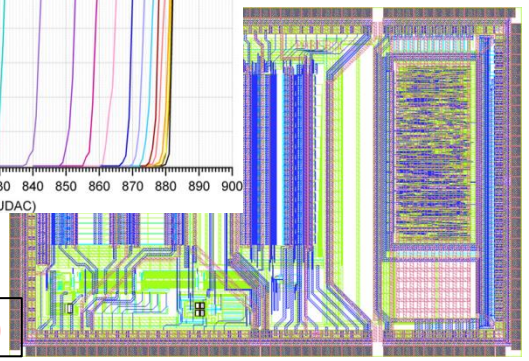
- Small PMT assembly
- Hundreds of channels of digital electronics
- Development and integration of ASIC based instrument
- **Based on latest generation ASIC: 16 channels CatiROC**
- V0: Module of 128 channels + FPGA + DDR3



Achievements:

- ASIC under test using OMEGA test board (APC + OMEGA)
- Home-made full DAQ developed (APC)
- Software and firmware (APC)
- 128 channels card design and routing ready (CENBG)





Work in progress:

- In depth data analysis
- Issues understanding
- Production and tests of the V0 card (Summer 2017)

IT APC: C. Santos (Project manager), A. Noury (end of hiring contract 31/12/2017)

Mechanics Department: Involvement in projects

Ground and undersea experiments: Advanced VIRGO, Double Chooz, KM3NeT, QUBIC

Spatial projects: ATHENA, EUCLID, EUSO, R&T COMPTON, SVOM, TARANIS

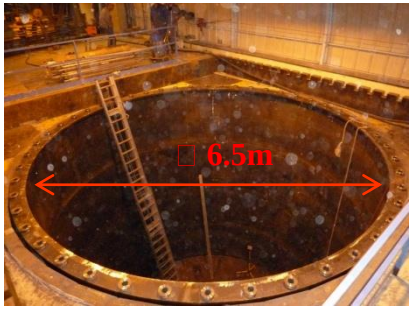
Double Chooz

Far detector (2011):

- ✓ Steel tank + liquid scintilator + 350 tons of steel for shielding (150-mm thick)
- ✓ Airtightness
- ✓ Integration: vessel floating on water for welding
- ✓ Interfaces for PMT, cabling …

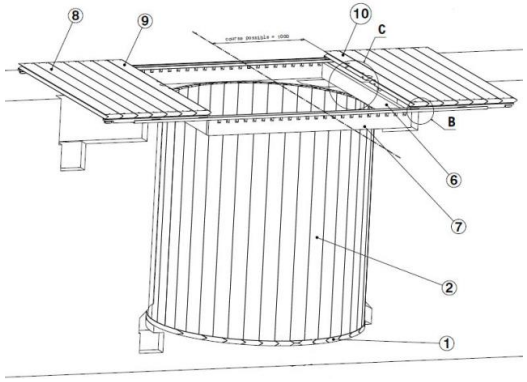
Near Detector: Design, production and installation (2012-2014)

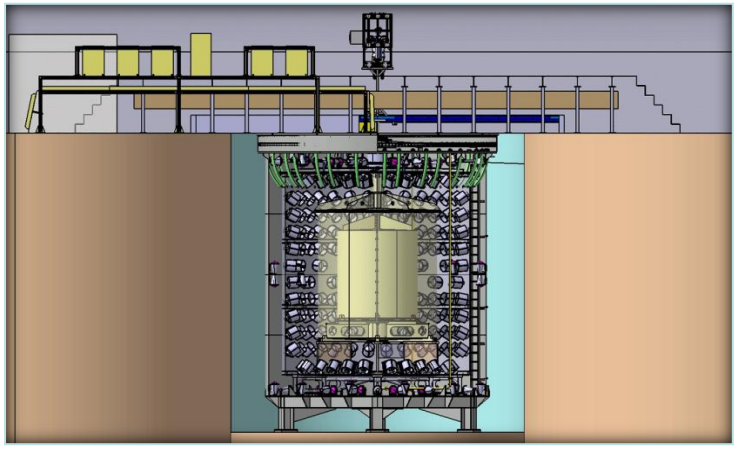
- ✓ Shielding: 1m water (except on top)
- ✓ Stainless steel tank on steel supports (outer vessel)
- ✓ Support stiffness strenghtened to prevent any deflection > 1mm of the bottom due to water pressure (45 tons thrust load)
- ✓ Upper shielding (steel), platform and electronic hut

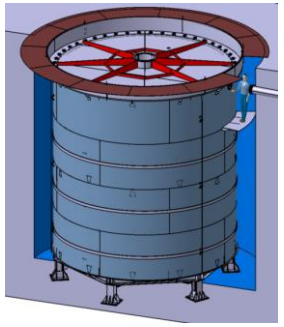


Peinture blanche réflective

Cout de fabrication = 1.4 M€







Mechanics Department: AdvVIRGO

Telescopes (Injection / Detection / Pick-off / End of arms)

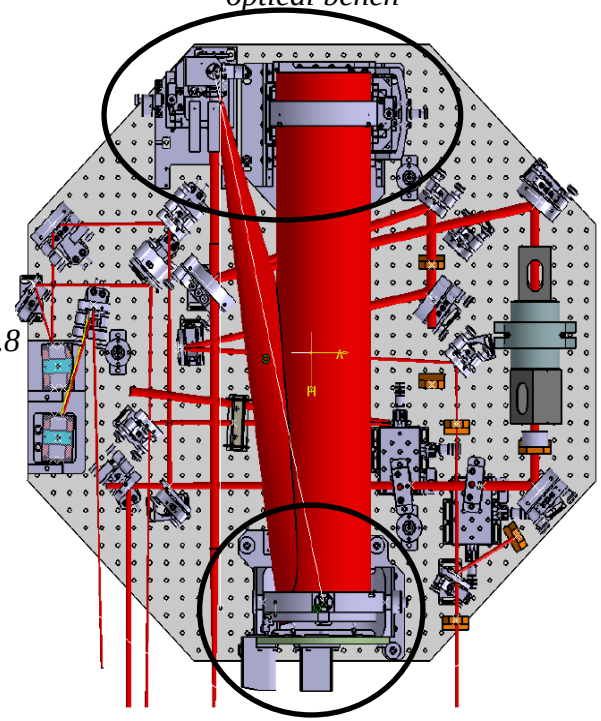
6 translation and/or rotation motorized mounts (injection and détection telescopes)

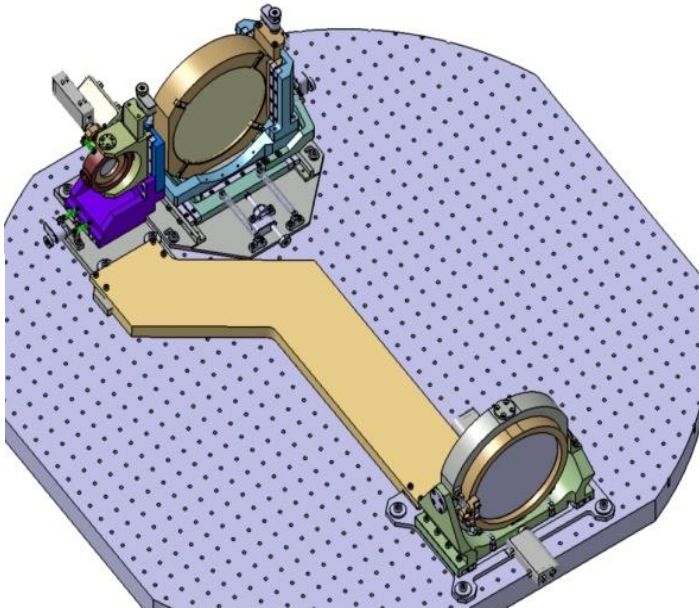
4 tunable mounts (pick-off and end of arms telescopes)

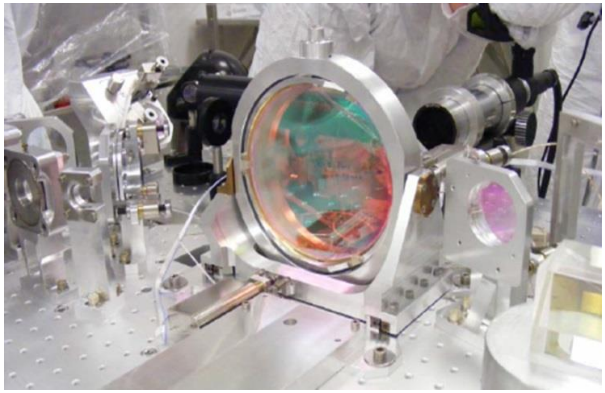
Design, construction and installation on site

- *Cumbersomeness*
- *Linearity, moving reproductibility*
- *Position stability*
- *Operation under vacuum*
- *Contamination*
- *Vibration response*
- *Construction@ APC workshop (1.5 to 0.8 FTE)+ subcontracting*
- *MMT metrology*

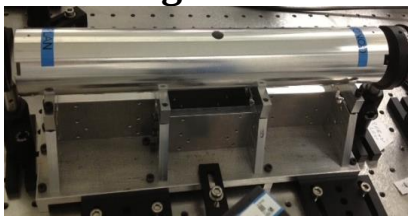
Suspended under-vacuum optical bench







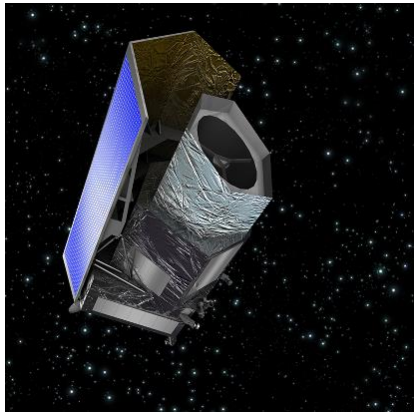
R&D Laguerre-Gauss



Cavité Fabry-Pérot en Invar
300 mm – miroir 1'' sur monture piézo

IT Department: EUCLID

- **Ground Segment : phase C2**
  - CODEEN :
    - Continuous integration platform for software development
    - Administration and user support, migration on the OpenStack@CC-IN2P3 cloud in 2017



  - EXT/SIM :
    - Ground observatories data integration
    - Development of simulator and data analysis pipeline (démarrage EXT-generic starts in 2017, EXT-LSST in 2018 if Euclid/LSST agreement)
  - SDC France scientific coordination (CC-IN2P3) :
    - Interface between the IN2P3 et the EUCLID project
    - Production infrastructure sizing and ressources allocation

C. Cavet (PM), A. Boizard, J.M. Colley, M. Detournay, R. Fahed, M. Le Jeune, M. Souchal

IT Department: DPC LISA

France in charge of the Data Processing Centre (DPC) :

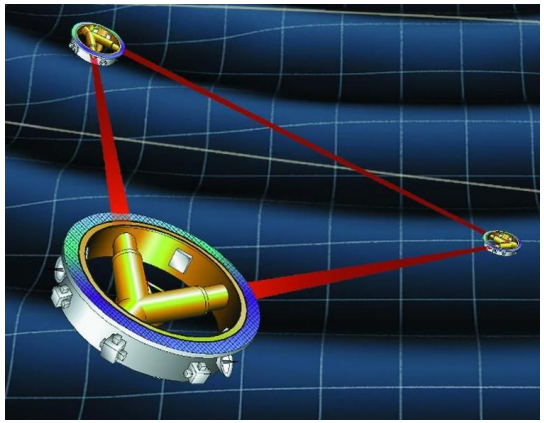
✓CNES phase 0 : load peaks management

=> hybrid cluster (continuous load) / cloud (peak) system.

✓R&T CNES/ATOS : Docker containerization of applications

Objective: provide hardware and software tools to the consortium to host and process LISA data analysis.

Context: APC + CNES leadership, relatively small data volume (1Tb/year) but some processing tasks are CPU demanding



-> use distributed/on-demand CPU (~ 5000 cores/center, ~ 3 centers, including the main French center)

-> develop luggable tools and services (virtualization, containers)

Ongoing activites: 1) APC provides the proto-DPC (continuous Integration) + (due to end 2017) proto-database expected for the next data challenge.

2) CNES, APC and the LISA consortium write the definition document and specify workpackages.

M. Le Jeune, C. Cavet, E. Marin-Matholaz, M. Batmanabane

IT Department: Scientific Computing in CMB Data

- Computing issues in CMB data analysis are **growing fast**
- The **MapMaking** example : problem size = n_t (10^9) x n_pixel (10^7)

2012-2015	POLARBEAR I	1200 detectors
2016	POLARBEAR II	7500 detectors
2018	SIMONS ARRAY	22000 detectors
	CMB STAGE IV	100000 detectors

How to keep refined analysis techniques when data volume is exploding ?

- **Filtered mapmaking**

$$\left(\mathbf{A}^T\mathbf{N}^{-1}\mathbf{A}\right)\hat{\mathbf{s}} = \mathbf{A}^T\mathbf{F}\mathbf{d}$$

- Flat-sky MASTER power spectrum estimation (Hivon et al 2002) with daily cross-spectra

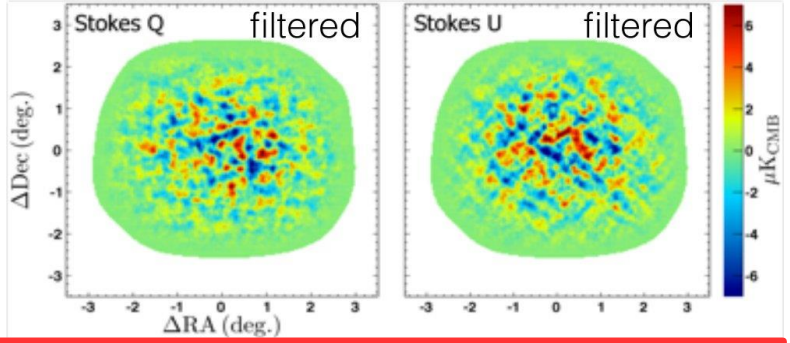
Cross check and validation

- **Unbiased mapmaking (iterative)**

$$\left(\mathbf{A}^T\mathbf{F}\mathbf{A}\right)\hat{\mathbf{s}}_i = \mathbf{A}^T\mathbf{F}\mathbf{d}$$

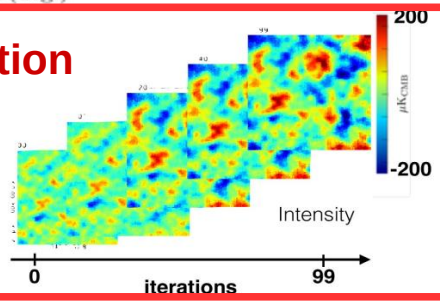
- Curve sky pure-pseudo power-spectrum estimation (Smith et al 2006, Grain et al 2009)

Low CPU cost, biased solution (smoothed maps)

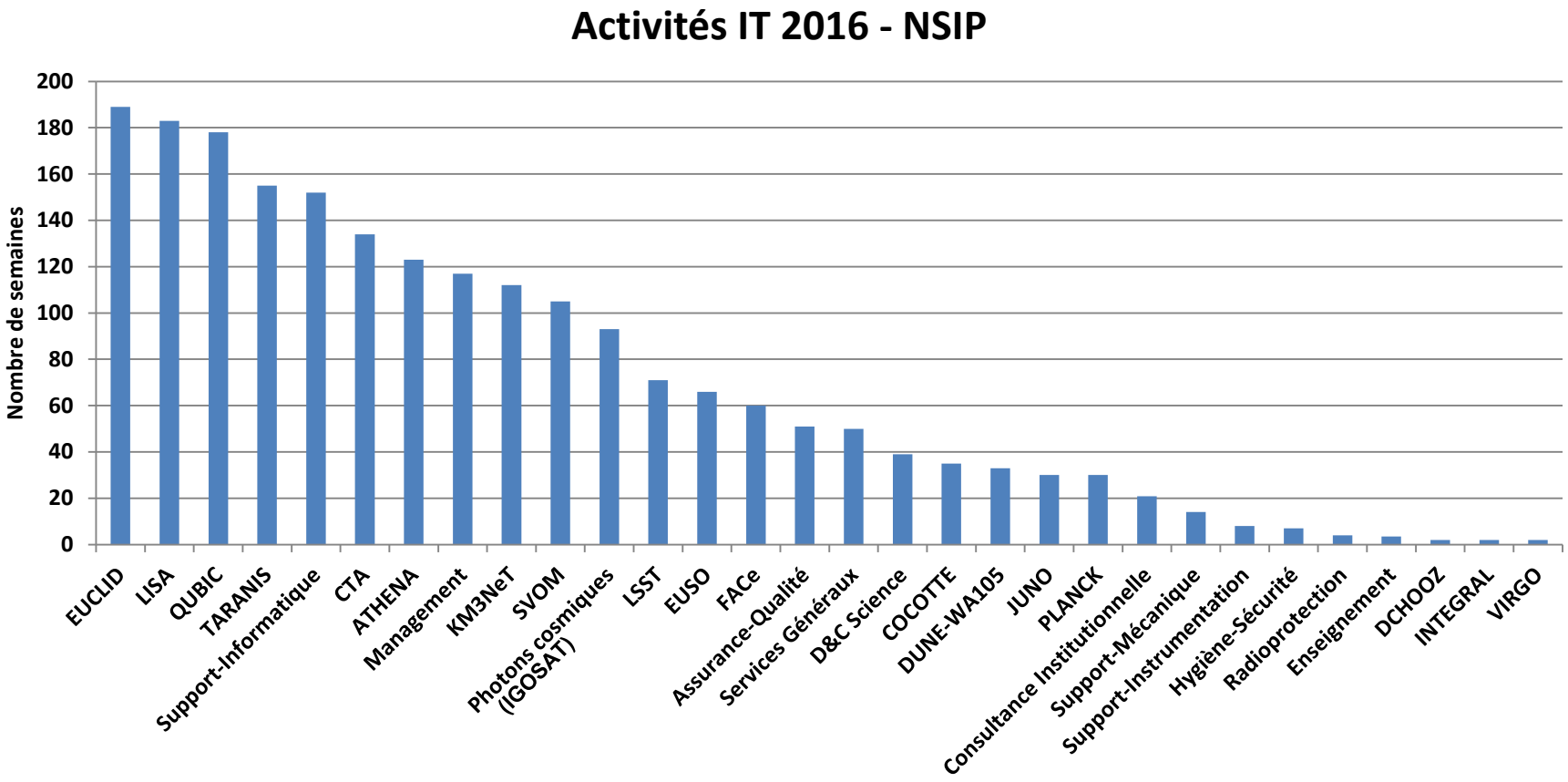


APC POLARBEAR group contribution

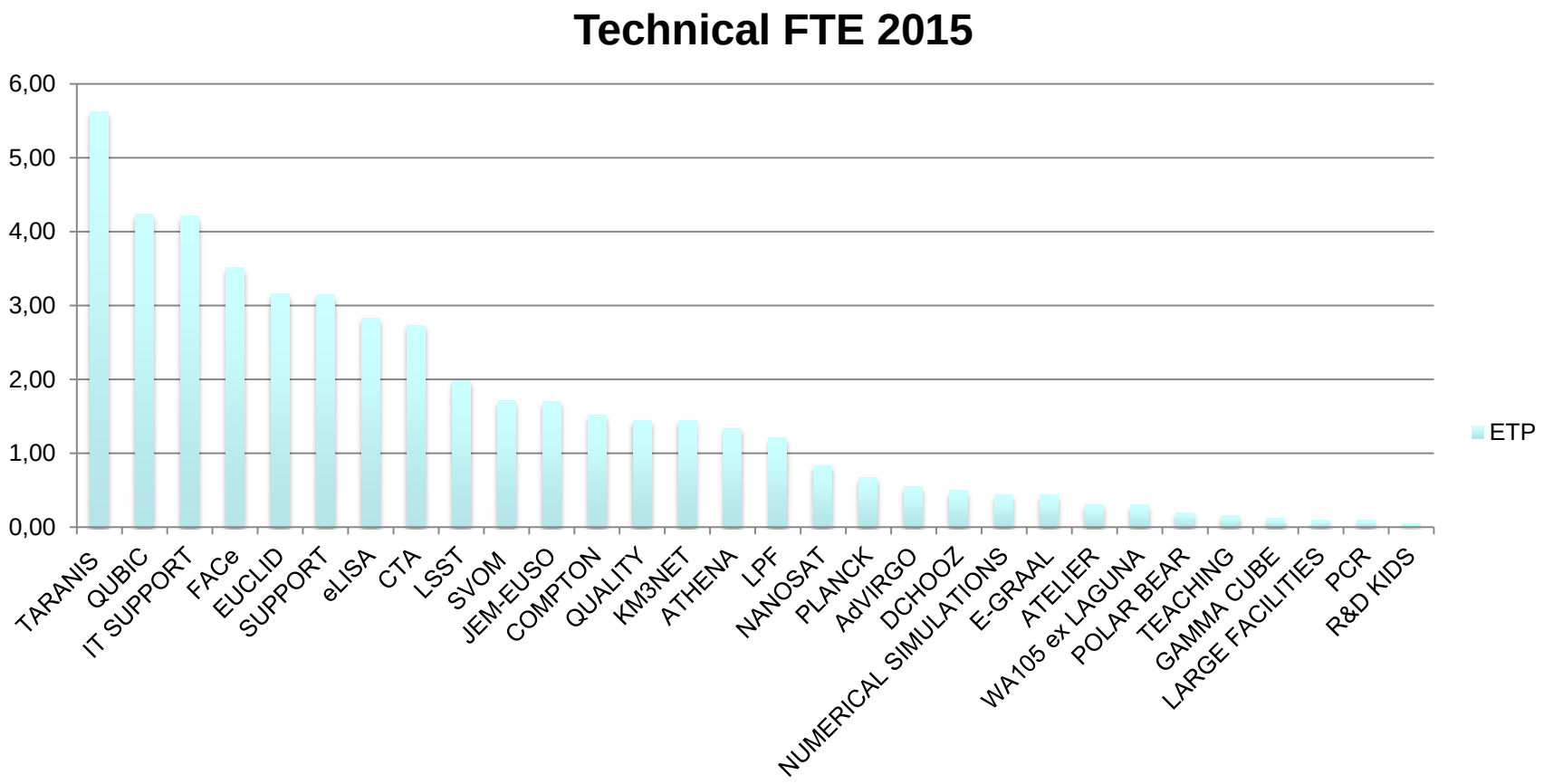
Higher CPU cost but full recovery of all scales



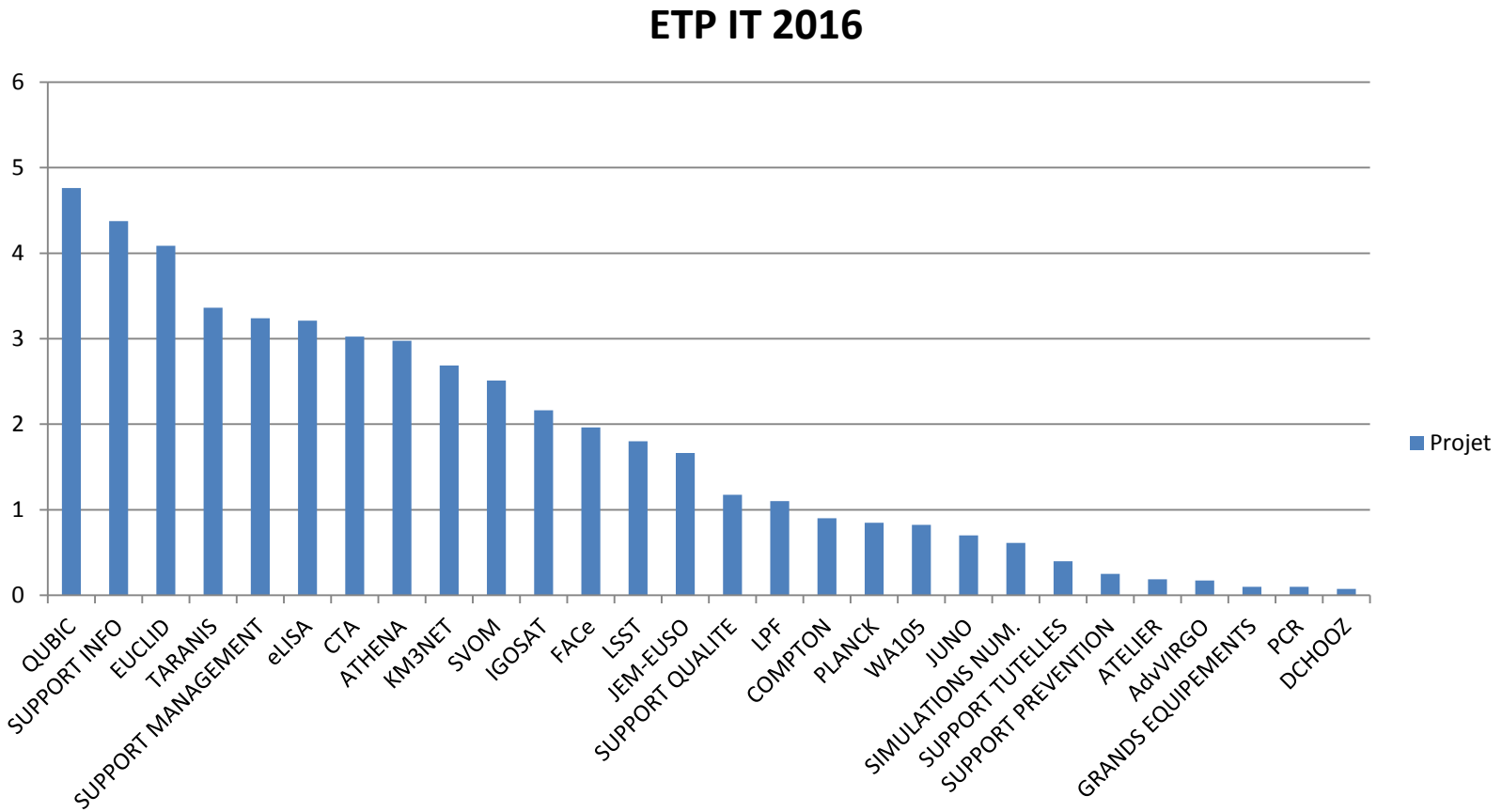
IT 2016 – NSIP data



Technical FTE 2015



Technical FTE 2016



Summary and prospects

- ✓ Diversity and complementarity of skills, recognized expertises:
  - ✓ Cloud and distributed computing, data analysis architecture
  - ✓ Space projects management
  - ✓ QA/PA
  - ✓ AIT/AIV (Mechanics, Electronics, Instrumentation)
  - ✓ Optics & Photodetection
  - ✓ Cryogenic detectors & dedicated ASICs

✓ A significant fraction of the technical manpower relies on fixed-term staff

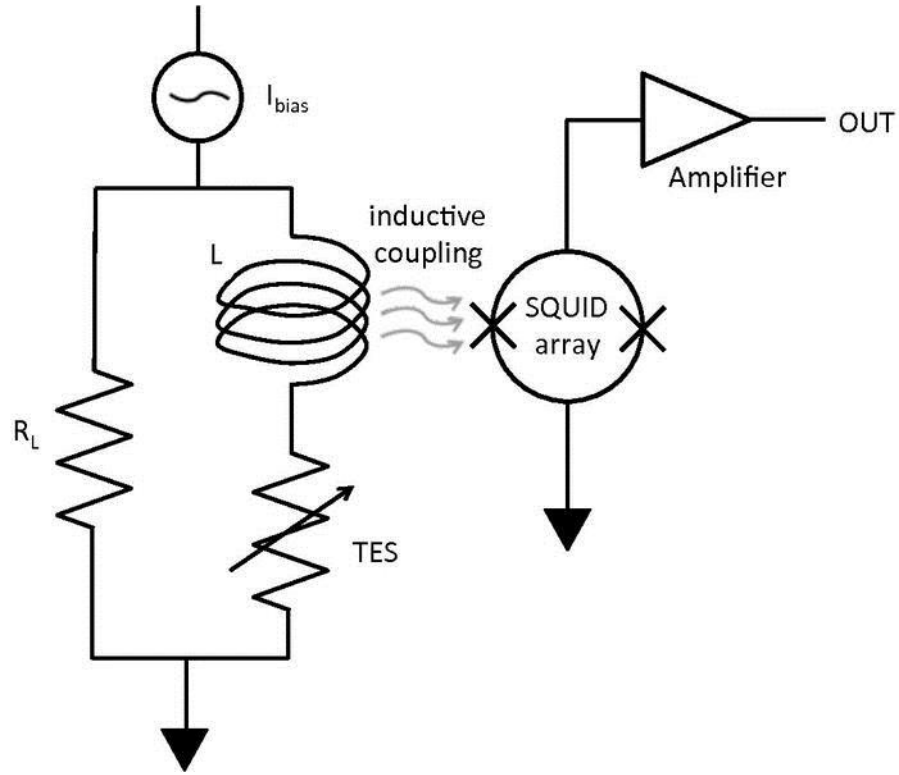
→ Turn-over, loss of skills

→ Mid-term and long-term strategy to stabilize the staff in a context where propositions of permanent positions are scarce

✓ Technical departments are to their manpower limits

→ Departures of technical staff members generate difficulties for projects and technical departments (4 departures in less than one year including 3 project managers, 2 non-replaced retirements in 2016)

→ Finding a reasonable compromise between the technical human ressources and the scientific commitments


I_{bias}
OUT
Amplifier
inductive
coupling
L
SQUID
array
R_L
TES