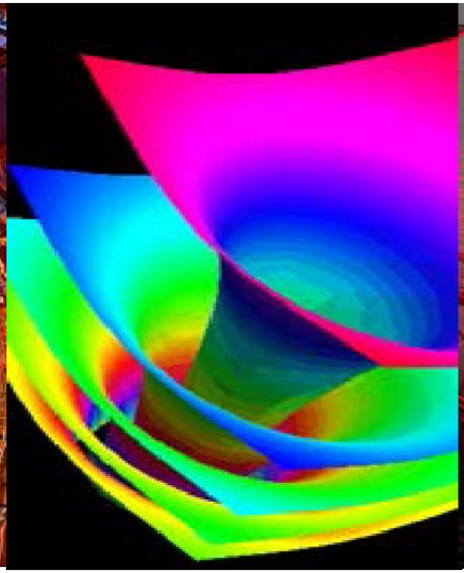
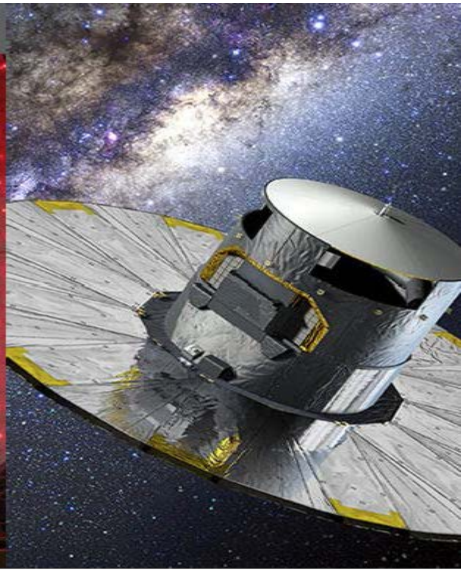





Development of instrumentation at the Technology Unit: Science and beyond

David Gascón

Technical coordination

On behalf many ICCUB colleagues

Institute of Cosmos Sciences

Universitat de Barcelona

ICCUB Winter Meeting
08/02/2022

http://icc.ub.edu/technology

Outlook

I. **Introduction**

II. Overview on current activities

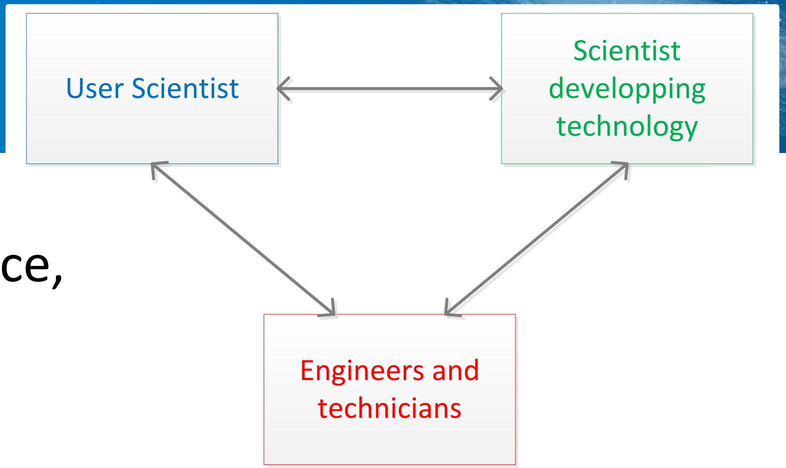
III. Technology transfer and outreach

IV. Summary

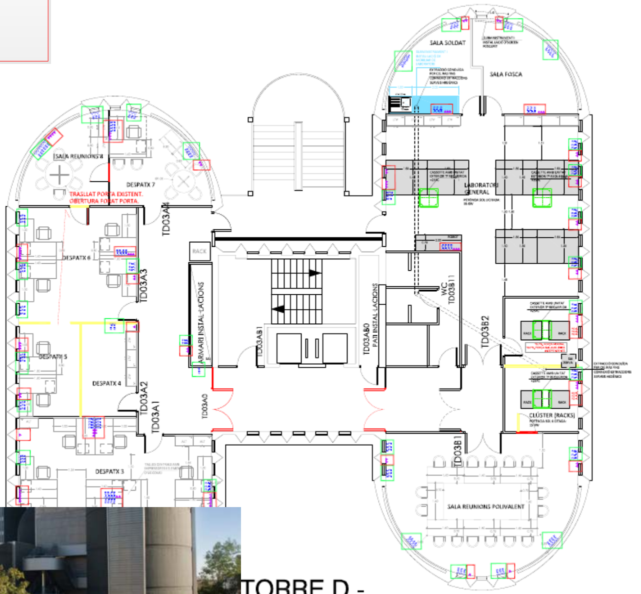
Why do we need technology in ICCUB?

- For an institute as ICCUB, technology is key
- Experimental science requires technology
  - To develop instruments & data processing systems allowing to do experimental science
  - To enable access to projects, missions and experimental collaborations as Gaia, LHCb or CTA
  - To obtain priority access to scientific data
- Technology transfer is a plus
  - Development of complex instruments & data processing systems generates knowledge that can be transferred back to Society
  - Key added value for any institute as ICCUB

Organization



- Technology roles in ICCUB
  - More than 100 scientists in astrophysics, space science, high energy physics, cosmology, etc
  - Some scientist also develop technology (FQA and electronics departments)
  - Around 20 engineers/physicists associated to tech unit
- Technological activities were conducted by independent groups
  - Different departments of the Physics Faculty
- **ICCUB technology unit** was created in 2016
  - New premises and Barcelona science park (PCB)
    - More than 500 m^2 with laboratories dedicated only to ICCUB
  - Centralized organization of "engineering" services to optimize support key projects
  - Main limitation: still no permanent staff in the technological unit except few professors



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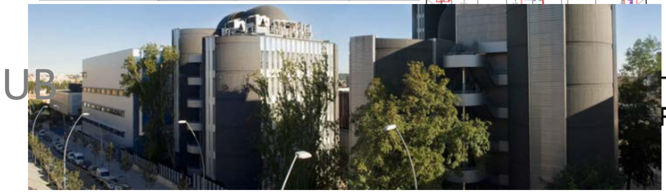

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EXCELENCIA MARÍA DE MAEZTU

I. Introduction

- Several research unit and groups develop activities in technology:
  - ICCUB Technology Unit at PCB
    - Data processing and software engineering
    - Cameras, single photon detectors and Radiation detectors
    - Microelectronics (ASICs) and digital high speed electronics (FPGAs)
  - Astronomy and Astrophysics
    - High-Energy Astrophysics. Gamma-ray astronomy.
    - Physics of the Sun-Earth relationship. Space Meteorology
    - Image processing and high angular resolution techniques
    - Instrumentation and robotic astronomical observation
  - Radiation physics
    - Monte Carlo Simulation of Electron-Photon Transport (PENELOPE)
    - Medical physics and dosimetry
  - Systems for Instrumentation and Communications groups
    - Optical and electronics instrumentation
    - Embedded systems, communications and IoT hardware

FQA dept.

Electronics dept.

Physics Faculty and ICCUB

I. Introduction

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    - Data processing and software engineering
    - Cameras, single photon detectors and Radiation detectors
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FQA dept.

Electronics dept.

Physics Faculty and ICCUB

Sorry if we forgot something !

The limit between science and technology is fuzzy…

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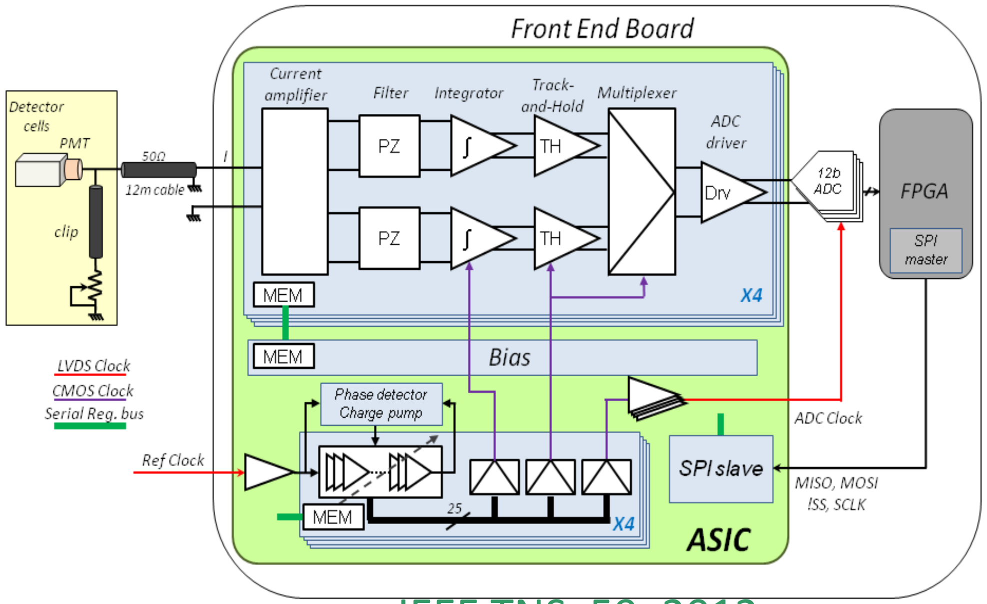
II. Activities in instrumentation: LHCb upgrade I

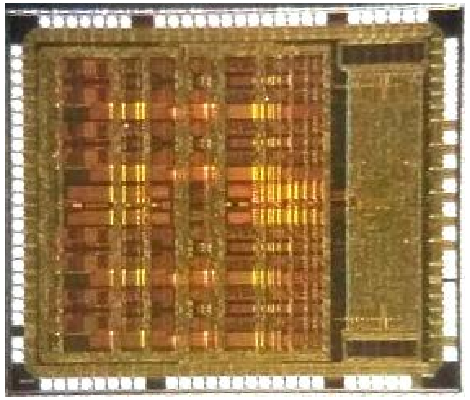
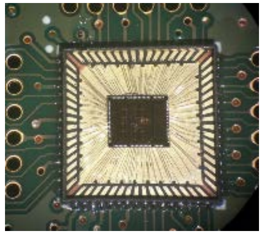
- In 2020: phase I upgrade
  - Luminosity increased by a factor 5
  - ICCUB: responsible of new FE for the complete calorimeter system
    - I am the main proponent of this new implementation
  - ICECAL chip designed, produced and validated (beam & rad tests)

See also R. Vazquez presentation



IEEE TNS, 59, 2012

JINST, 7, 2012

ICECALv3 chip:

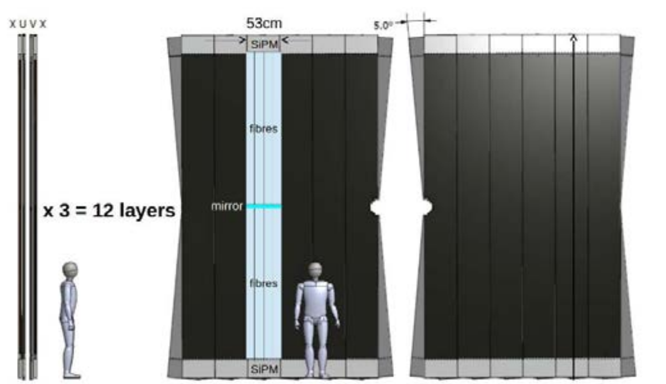
SiGe BiCMOS 0.35um

AMS 10.5 mm^2

12 bit resolution @ 40 MS/s

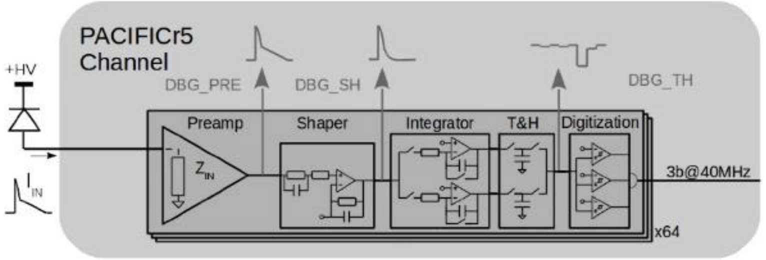
ICCUB Institute of Cosmos Sciences · Excelencia María de Maeztu

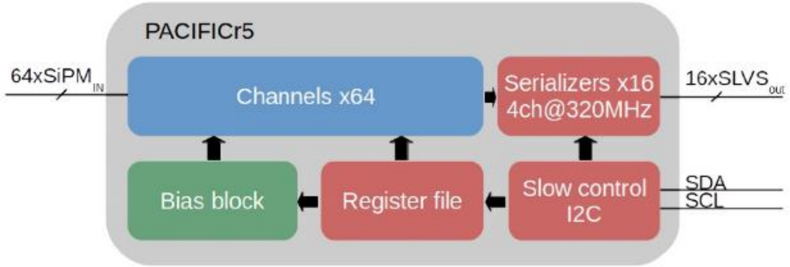
II. LHCb upgrade I



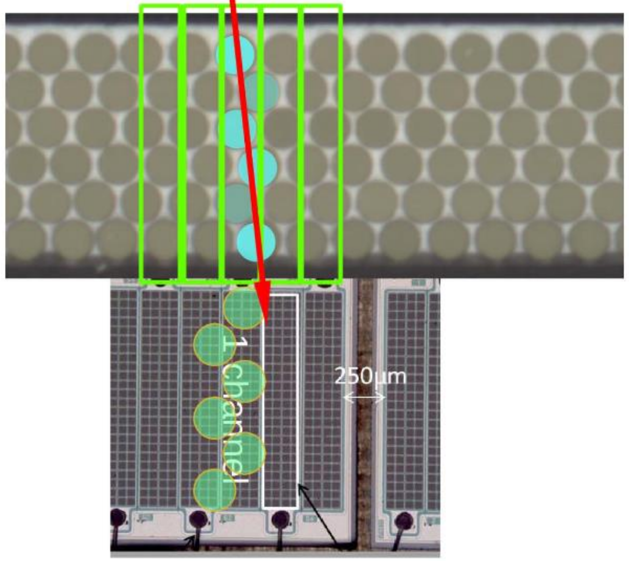
- PACIFIC chip developped for SciFi
  - ICCUB, Univ. of Heidelberg, LPC-Clermont, IFIC

Low Power ASIC for the SCIntillator FIbres traCker





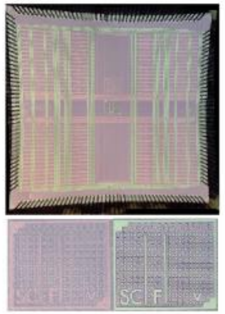
Signal spread over channels, 16-20 phe. Clustering needed:



Channel processing chain:

- High bandwidth current input.
- Anode voltage control.
- Fast Shaper for tail adjustment.
- Double interleaved gated integrator.
- Track and hold.
- Digitization with 3 hysteresis comparators.
- Serialization and slow control (std cells).

JINST, 10, 2015



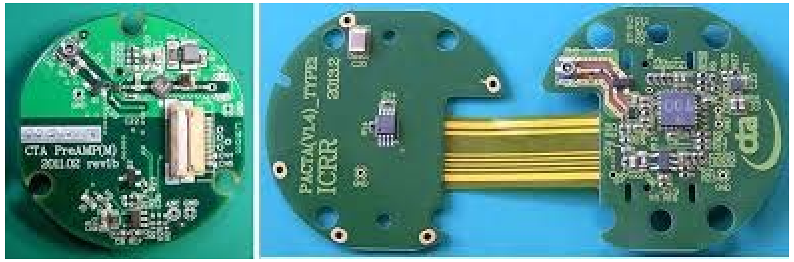
$4 \times 3.85 mm^2$

BGA package

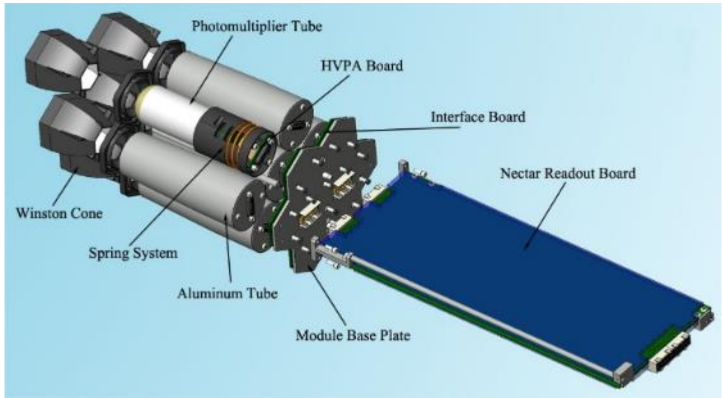
$12 \times 12mm^2$ 196pins

II. Activities in instrumentation: CTA

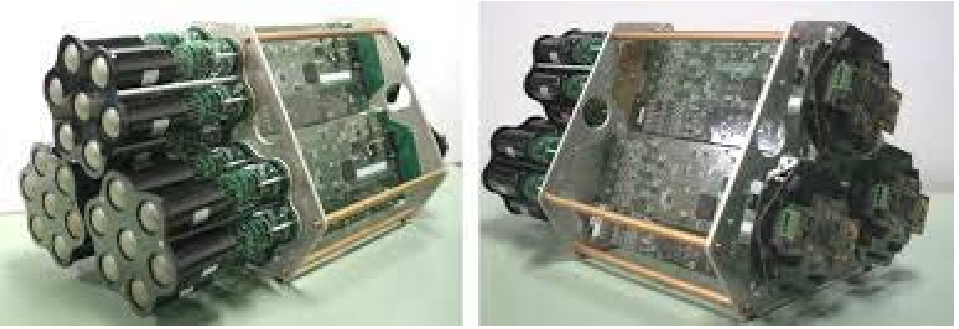
- **ICCUB has developed 3 different chips with important contributions to the cameras**
  - DragonCAM for LSTs
  - NECTArCAM for MSTs
  - **More than 30,000 chips produced to equip 5 cameras**
    - **Around 5-10 more cameras to be build**



ICRC 2013



NIMA, 639, 2011



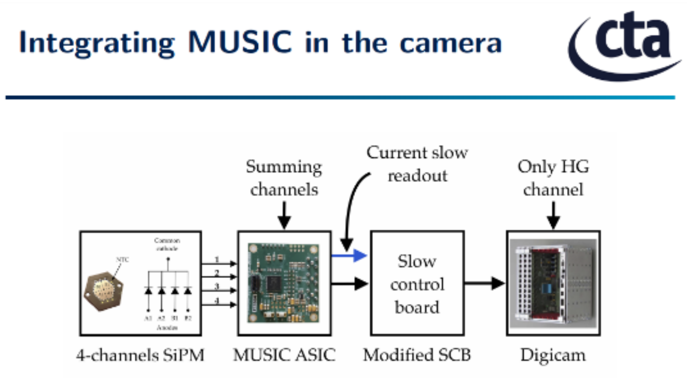
SPIE, 9151, 2014

II. Activities in instrumentation: CTA

- In the short and mid-term we plan to consolidate our contribution to the CTA cameras:
  - Working in the production and quality control of the PACTA, ACTA and L0 trigger ASICs for 15 NECTAr MST cameras
  - Preparing the production of ASICs for additional LST cameras
  - Contributing to the installation and commissioning of the cameras in the North site at La Palma

- SSTs cameras and LSTs/MSTs (long term) upgrades will be based in SiPMs
  - MUSIC chip was the first step in this direction
  - New versions with enhanced performances and additional functionalities

LST-1



- 1 output channel per pixel ⟹ 1 MUSIC to sum the 4 anodes of a single pixel ⟹ 1 MUSIC per pixel ⟹ expensive, power consuming
- Currently DC coupled → MUSIC is AC coupled ⟹ we have to use the slow readout current to monitor baseline shifts
- SCB needs to be modified to readout slow integration output

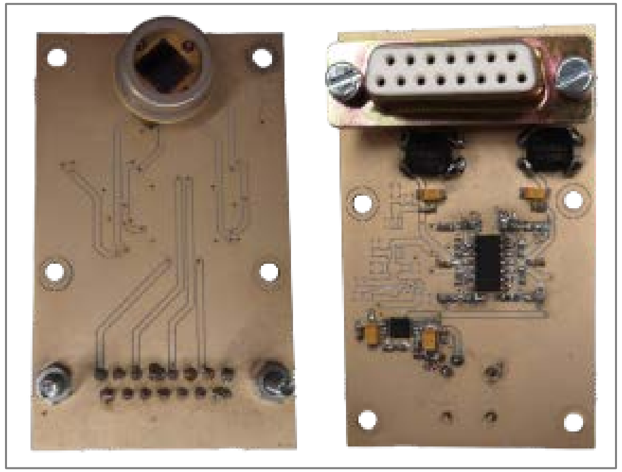
CTA Lugano 2019 N. De Angelis (UniGe) Study of MUSIC ASIC for SST-1M 6

Software/Computing + Instrumentation: **Virgo**

VIRGO

- ICCUB is full member of Virgo since July 2019
  - Now 11 members, will add 3 this year. Contributions on: Computing, Instrumentation, Data analysis, Science, Outreach
- Instrumentation:
  - Quantum Noise Reduction:
    2D Position Sensitive Devices + electronics + mechanics + test
    (to be operated in **vacuum** → outgassing tests)

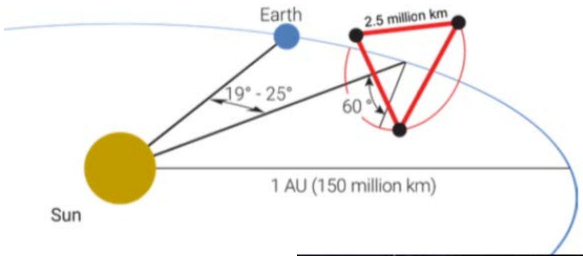
(see R. Bondarescu and J. Portell talks)

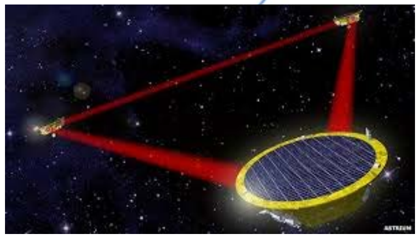


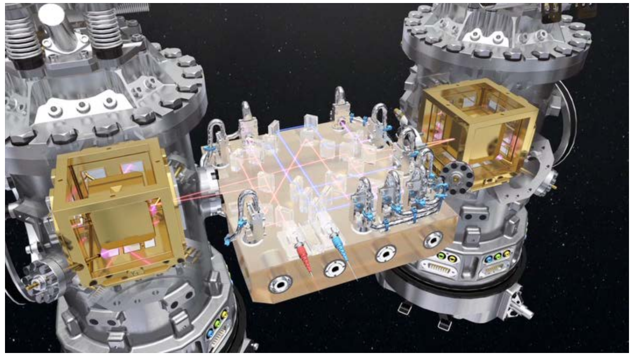
II. Activities in instrumentation: LISA

Control and diagnostic PI : M Nofrarias (IEEC-ICE)

- LISA is the concept selected for ESA L3 mission slot (2034)
  - Constellation of 3 satellites in heliocentric orbit
  - Space-craft are drag-free
    - Test mass (TM) inside which is in nominal free fall
  - Differential arm-length measured by laser interferometry
- High energy environment responsible for test-mass charging
  - Affects the capacitive control of the test masses: acceleration noise
- ICCUB contribution to common IEEC project
  - Monte Carlo simulation
    - To understand better the effective TM charging
  - Study radiation monitor for LISA mission
    - Transversal project within ICCUB: space weather, interaction of radiation with matter, particle physics, technology unit
  - Also, possible contribution to integration of readout electronics of new concept miniaturized magnetometer with a very low noise floor
    - IEEC's MELISA project







Institut d'Estudis Espacials de Catalunya

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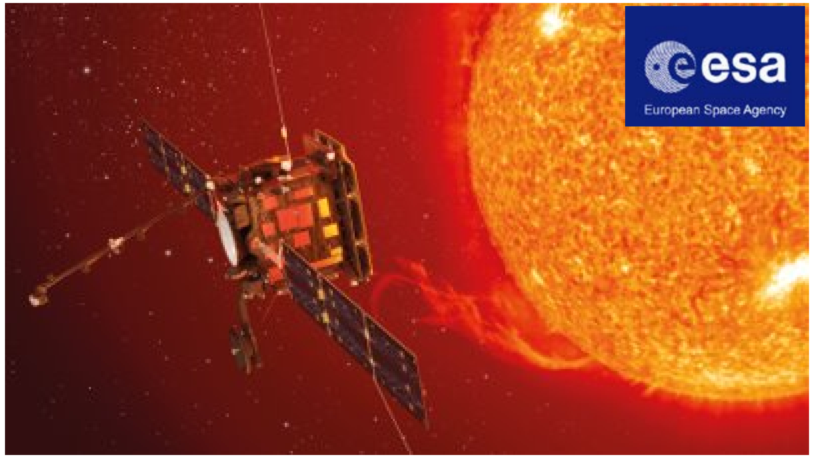
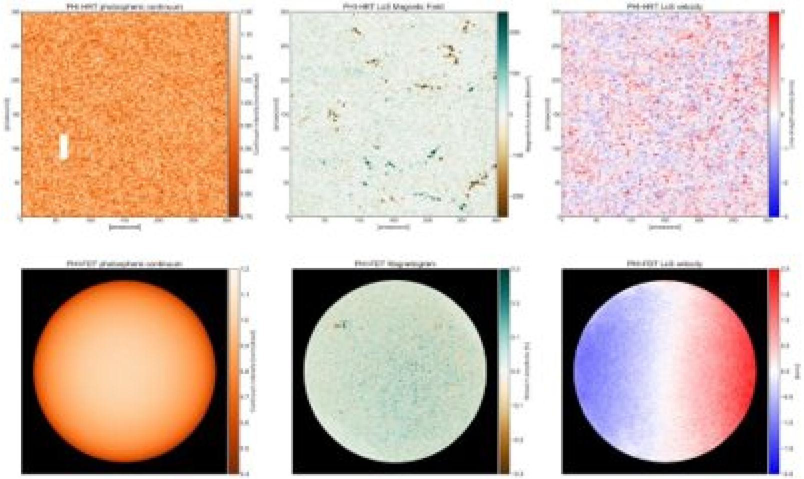
II. Activities in instrumentation: Solar Orbiter, MIRADAS, Ariel

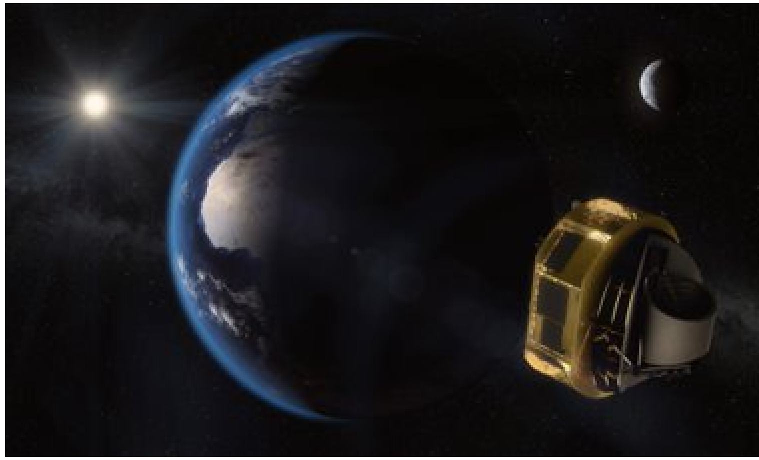
- Solar Orbiter: Launched 2021, first results available
  - Image stabilisation system fulfills the requirements



- MIRADAS: First release of the Probes planner has been provided
  - Improving the robustness of the algorithm



- Ariel: Mission approved 2021
  - Telescope Control Unit under development



Contact: J. M. Gomez (jm.gomez@ub.edu)

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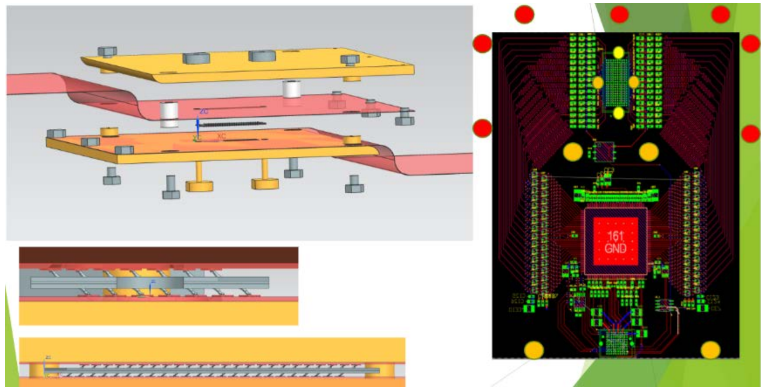
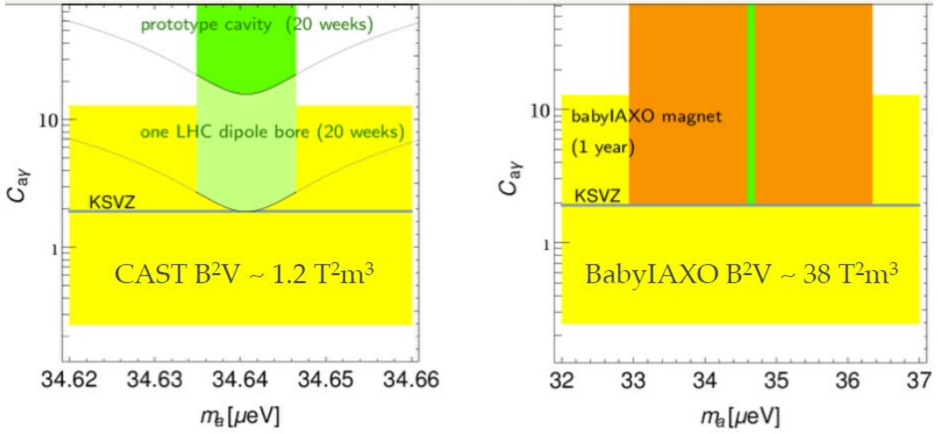
II. Activities in instrumentation: axion searches

- ICCUB is involved both in helioscope and haloscope @ IAXO
- Developing a radiopure version of the FE electronics
  - Collab. with UniZar & CEA/Irfu
  - Improve SNR ➡ improve sensitivity
  - Radiopurity simulations
    - Detector + electronics
  - Front end electronics redesign
- R&D on RF cavities for RADES
  - RADES collaboration
  - New initiative to detect DM axions in WBAND led by LSC (Can Franc) !
  - Characterization of RF cavities
  - Development of new data acquisition system

(see J. Miralda talk)

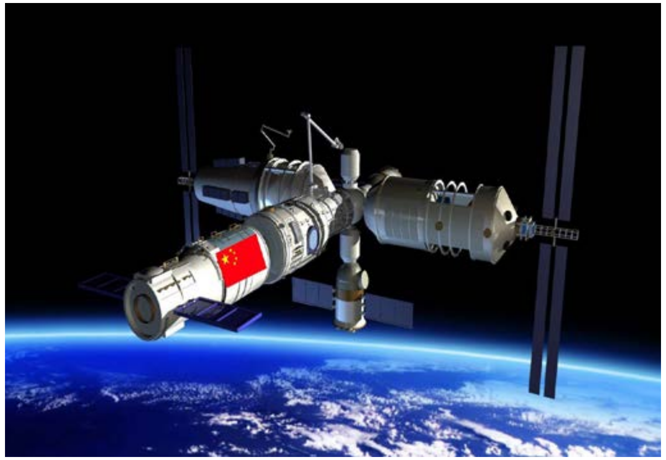




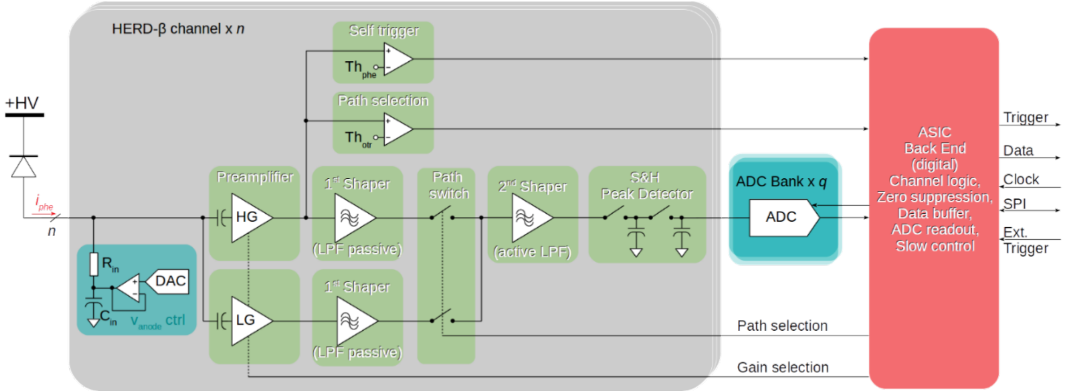
Institute of Cosmos Sciences

II. Activities in instrumentation: HERD

- The High Energy cosmic-Radiation Detection (HERD) experiment is proposed to understand key problems in fundamental physics:
  - to search for signatures of the annihilation/decay products of DM
  - to measure precisely the energy spectra and composition of primary cosmic rays up to the cosmic rays 'knee' structure
  - to make wide FoV monitoring of the high energy gamma-ray sky



- HERD (2027) will be unique
  - No other planned or approved mission with comparable scientific capabilities
- Flagship scientific experiment on the Chinese Space Station (CSS)
- Our key contribution is Beta ASIC for Fiber Tracker and PSD subdetectors



Outlook

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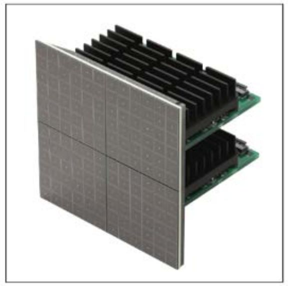
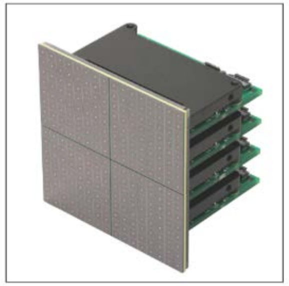
III. Technological R&D

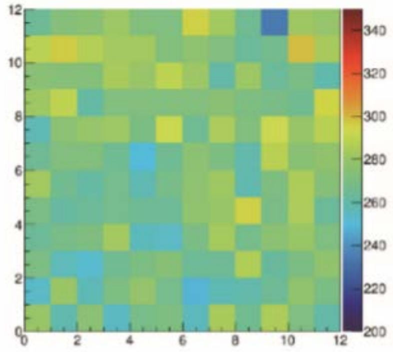
- This line is producing several patents and industrial contracts
- *Our technology is present in the most advanced ToF-PET modules of* ***Hamamatsu photonics…***

... and we are already working in next 100 ps generation





HAMAMATSU
Photon is our business



Also several patents an FP9 (EU) and NIH (USA) funding applications

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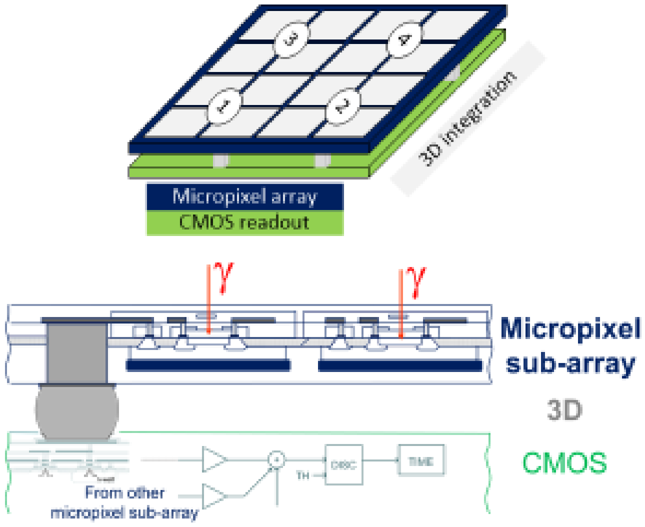
III. R&D on photosensor technology
Our approach: a new hybrid photosensor

- FastIC collaboration with CERN microelectronics section
  - https://ep-news.web.cern.ch/content/fastic-and-fasticpix-developments
  - FastIC chip baseline for LHCb RICH upgrades (Ib and II, LS3-LS4)
  - ATTRACT project to explore new sensor architecture

DEVELOPING BREAKTHROUGH TECHNOLOGIES FOR SCIENCE AND SOCIETY — ATTRACT

FastICPix: Integrated Signal Processing for a New Generation of Active Hybrid Single Photon Sensors with Picosecond Time Resolution

The Idea is to combine actively the signal of small micropixel sub-arrays based on the fastest single photon sensor technologies with ultrafast readout electronics using 3D integration.



It could have applications in medical imaging by enabling real time PET (Positron Emission Tomography), LIDAR, fluorescence lifetime imaging, homeland security and IOT / vision systems.

Our project is coordinated by the University of Barcelona **in partnership with** CERN.

It is part of wider collaborative effort involving sensor and ASIC design, 3D integration, module and applications with additional collaborators: CEA, EPFL, FBK, IFAE, LAL and University of Geneva.

Contact email dgascon@fqa.ub.edu

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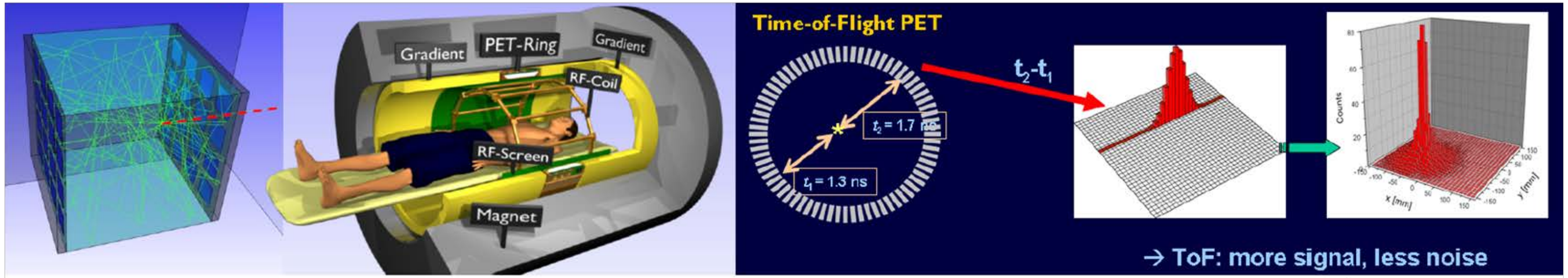
III. R&D on photosensor technology
Our approach: **a new hybrid photosensor**

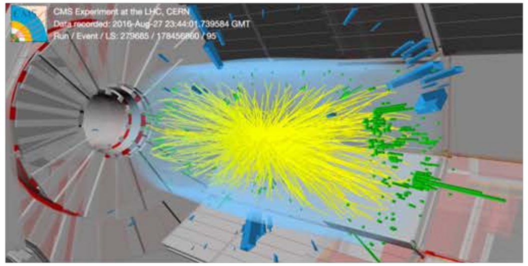
Applications

When detecting time of arrival of single photon with ps time resolution makes the difference

Medical imaging: PET-ToF

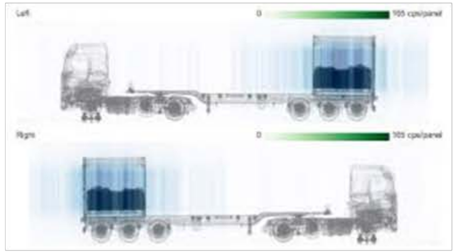


Particle physics: high luminosity colliders

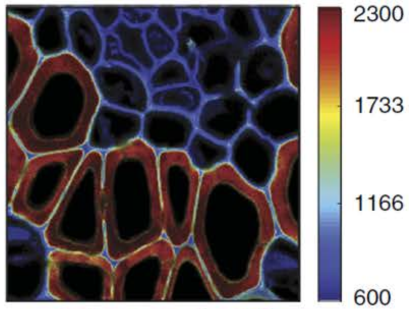


VERY INTERESTED IN EXPLORING OTHER POTENTIAL APPLICATIONS

Autonomous driving, vision around the corners



Cargo inspection



Biophotonics

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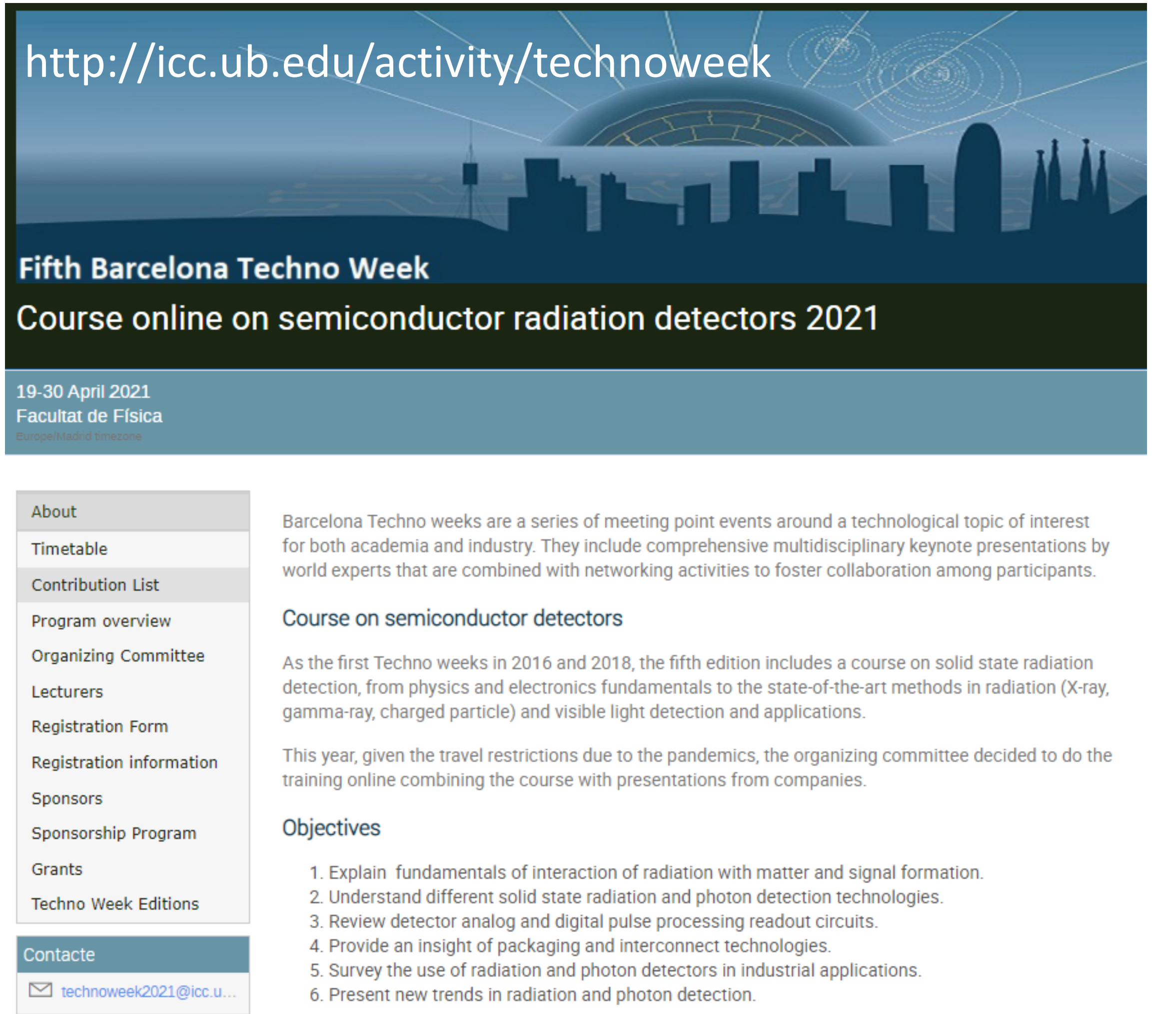
III. Barcelona Techno Week

- **Barcelona Techno Week:** a new series of meeting point events between academia and industry, organized around a technological topic of interest for both worlds
  - 4 editions
  - Topics: semiconductors detectors & nanosatellites
- Last edition (online)
  - More than 100 students
  - Nearly 150 attendees in total
  - Industrial participation



ams Sensing is life.

πtec

CERN Knowledge Transfer Accelerating Innovation

Direct Conversion A VAREX IMAGING COMPANY

HAMAMATSU PHOTON IS OUR BUSINESS

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Outlook

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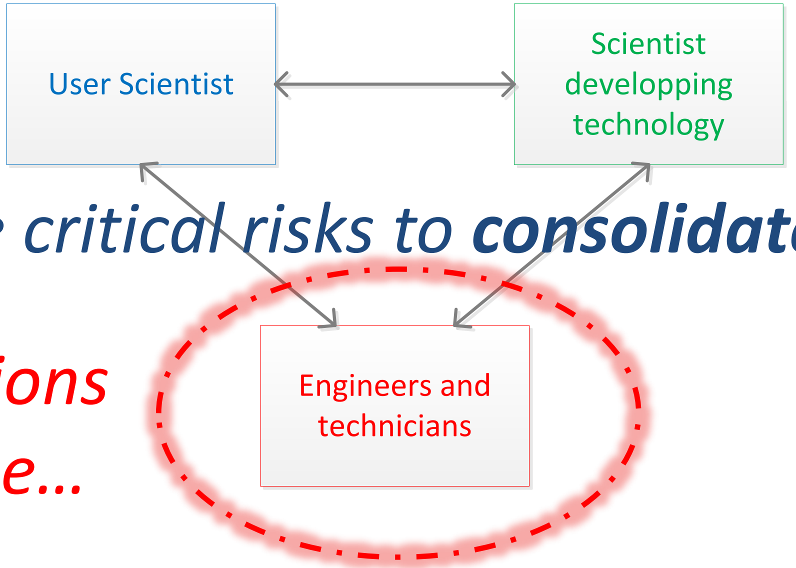
IV. Summary

- Very high impact considering limited resources
- Thanks to the collaboration of different departments in the Physics Faculty and the participation in larger scale organizations: IEEC, ESA, CERN, etc
- Thanks to the collaboration of different actors involved in ICCUB technology



*But we need to face critical risks to **consolidate** these achievements*

No permanent positions so far: risk of collapse…

Thanks a lot for your attention !!!

http://icc.ub.edu/technology

Thanks a lot for materials and contributions:

A. Aran, P. Barneo, C. Cogollos, J. M. Gomez-Cama, S. Gomez, B. Julia, X. Luri, J. Mauricio, J. Miralda, E. Picatoste, M. Nofrarias, F. Salvat, A. Sanuy and many more !

dgascon@fqa.ub.edu **jportell@fqa.ub.edu**

UNIVERSITAT DE BARCELONA

ICCUB Institute of Cosmos Sciences EXCELENCIA MARÍA DE MAEZTU

II. Activities in instrumentation: Quantum Technologies

- New collaborative activity involving researchers different departments
  - Solid expertise in algorithm, simulation, etc (see Bruno's talk)
  - Initial hardware activities
- Setting up and entangled photon source with parametric down conversion
- IDEAS proposal to ESA to develop an entangled photon source for use in space.

Contact: B. Julia and J. M. Gomez

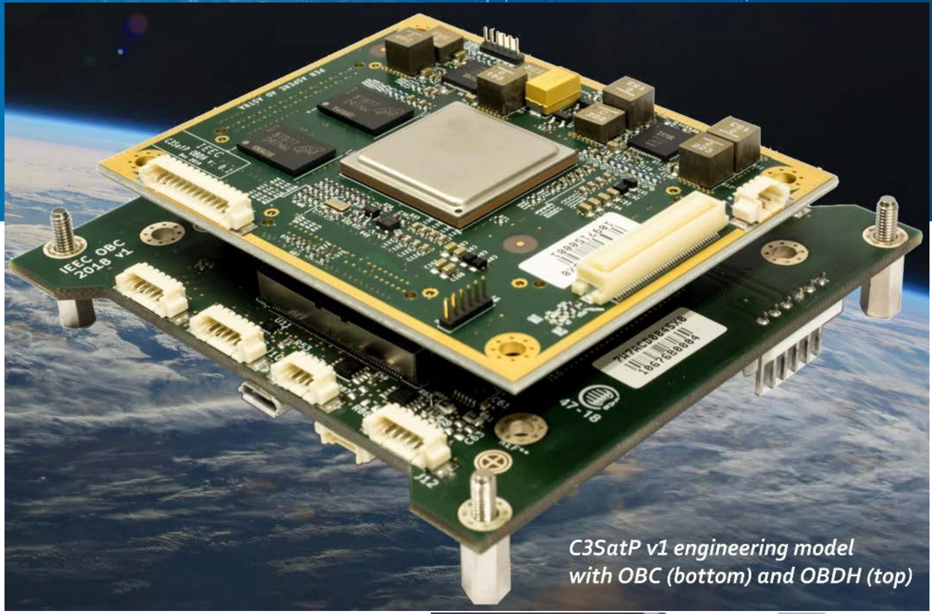
Introduction

- Many groups in the ICCUB are carrying research where technology is a key element
  - Development tool → new instruments for fundamental science
  - Product → transferred to scientific community or industry

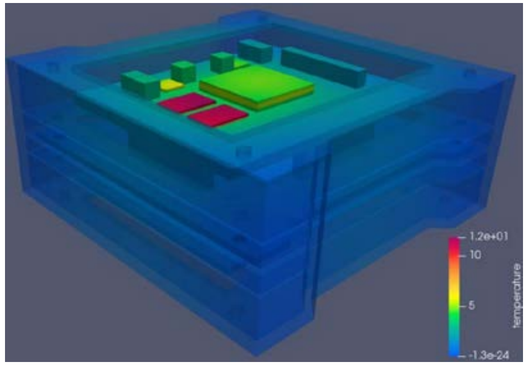
- Quick overview of main current activities in:
  - Instrumentation
  - Electronics
  - Very large data processing
- for:
  - Space missions and ground instruments
  - Particle physics experiments
  - Other fields

Software + Electronics: **Nanosatellites**

- Transversal activity at IEEC involving all units:
  ICCUB, ICE/CSIC, CRAE/UPC, CERES/UAB
  - **Catalan NewSpace Strategy recently approved**
  - First cubesat funded by Catalan Government launched this year: **IoT from Space**
  - Next cubesat: **Earth Observation** (multi-spectral camera)
  - Also: future **4D Cube** mission on **Space debris** (ESA call for ideas / OSIP)
- ICCUB contributes on:
  - Hardware design and implementation:
    Identify adequate COTS and electronics
    Design and routing of PCBs
    Mechanical design
    Connectors
  - Thermal analysis
  - Onboard software (mainly on payload downlink):
    OS kernel adjustments
    Error Detection And Correction codes (Reed-Solomon)
    Efficient data compression (up to **42 MB/s** in software on ARM CPU)
  - Initial design of SDR signal modulations
- Very good perspectives on cubesats activity at IEEC and ICCUB


C3SatP v1 engineering model with OBC (bottom) and OBDH (top)

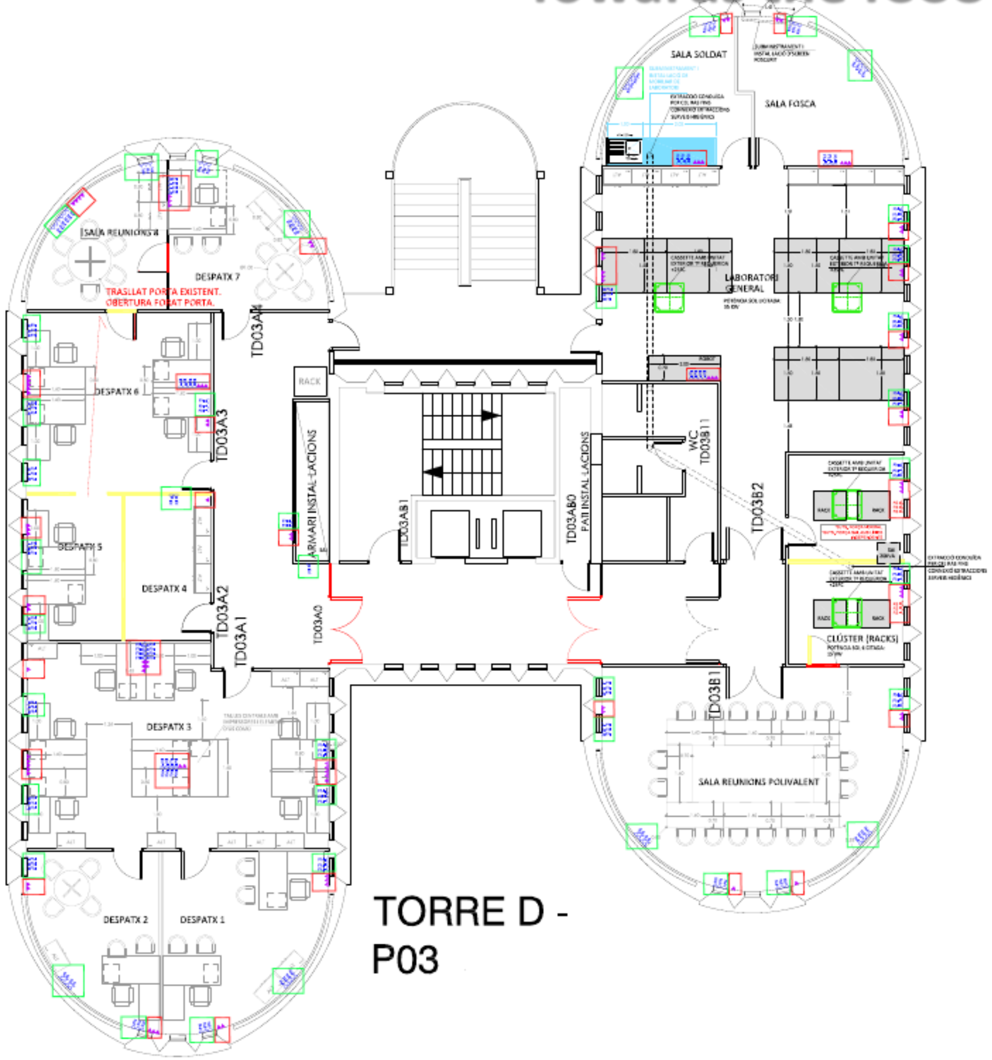
4D Cube

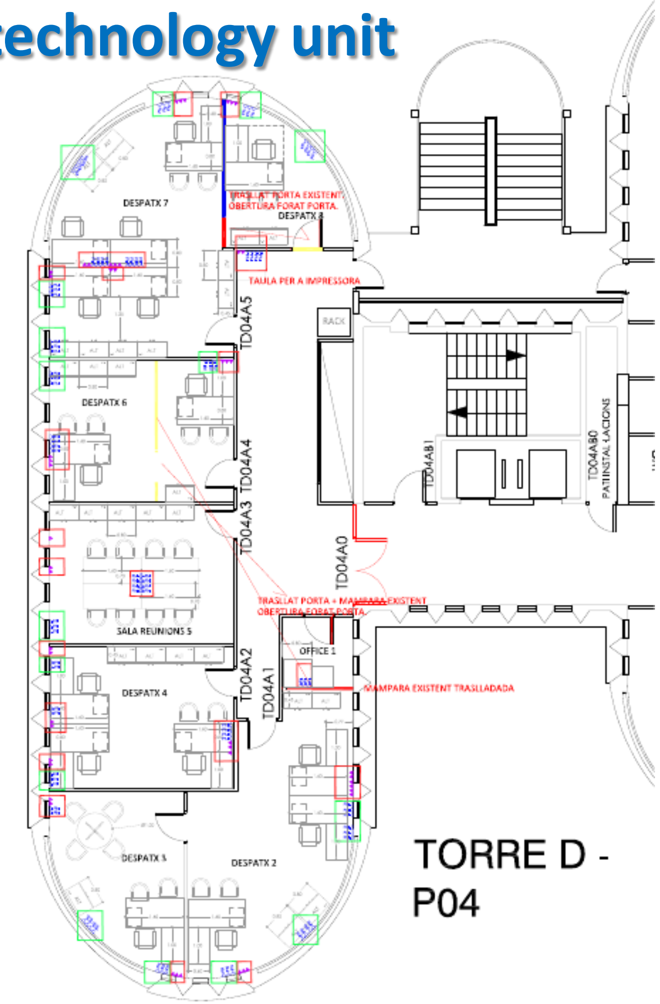


New premises: ICCUB Technology Unit

- **LHCb + Gaia/DPAC** engineering teams are moving to the PCB (~Feb/Mar’17)

Towards the ICCUB technology unit





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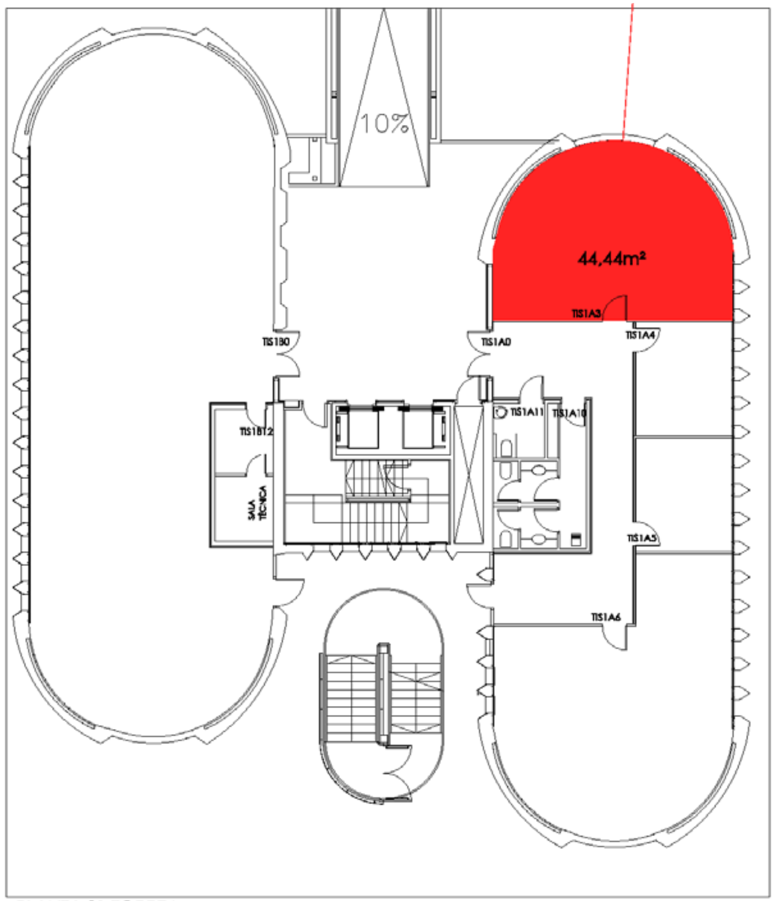
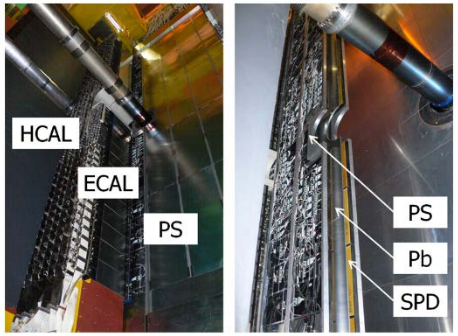


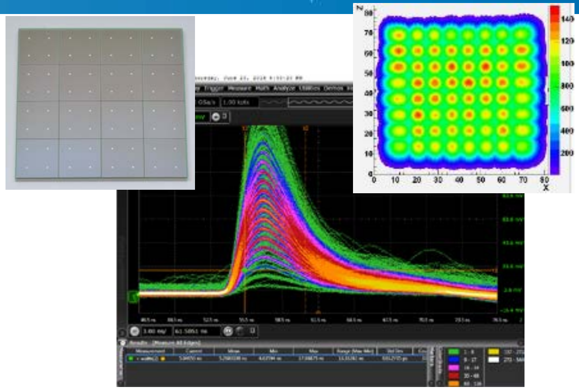
- **Torre I: new lab for precision measurements**
  - Optical test benches
  - Radiation detectors
  - Clean room for assembly and test

II. Activities in instrumentation

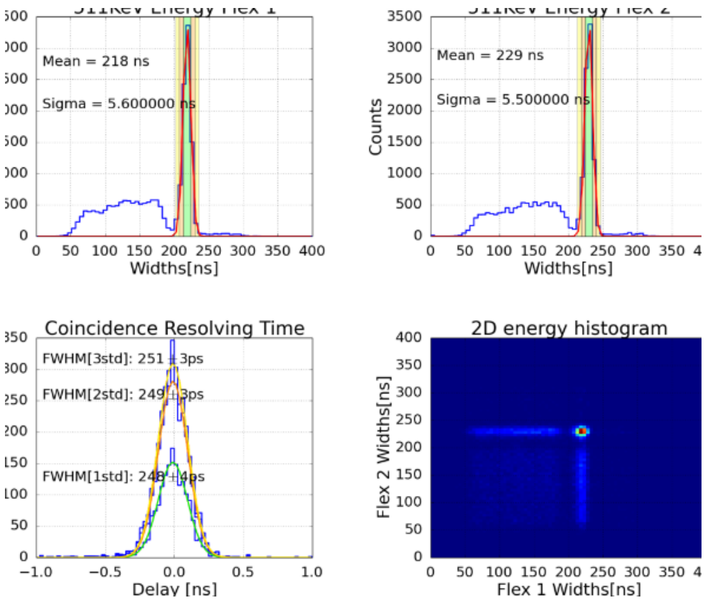
Telescope cameras



Particle detectors at CERN

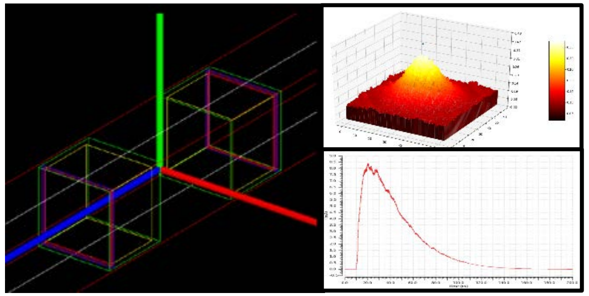


Single-Photon Sensors

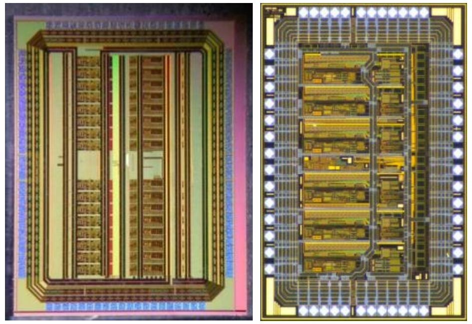


Positron Emission Tomography with Time-of-Flight (ToF-PET)

Axion and Dark Matter searches



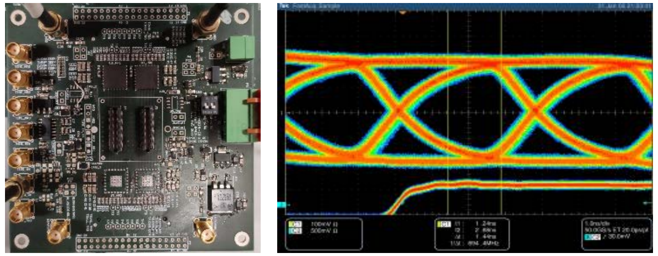
Monte Carlo simulations



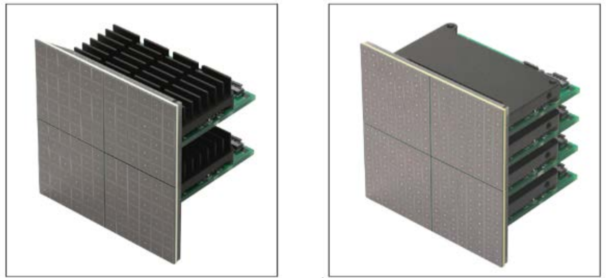
Microelectronics (Chip Design)

esa
European Space Agency

Space missions



Electronics



Medical Imaging (industrial collab.)

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EXCELENCIA MARÍA DE MAEZTU

II. Activities in instrumentation

Part of the *ICCUB technology unit* (*TU* has 2 sections: instrumentation/electronics and software/data processing)

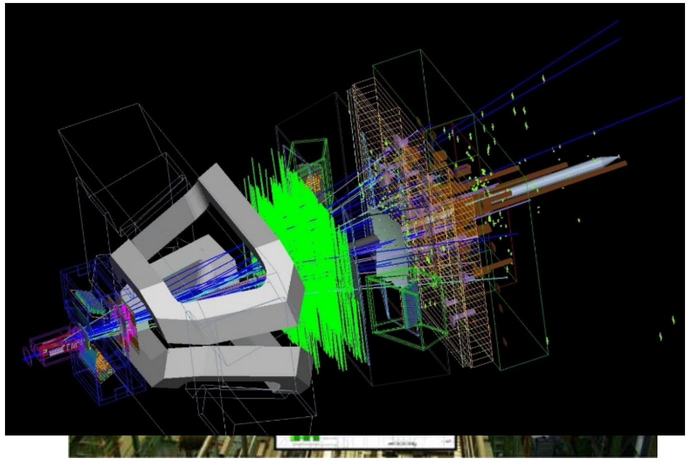
Enabling key contributions on instrumentation to ICCUB to *high impact collaborations*:

- Particle physics: LHCb, IAXO
- Ground instruments: CTA, VIRGO
- Space missions: LISA (ESA-L3), HERD

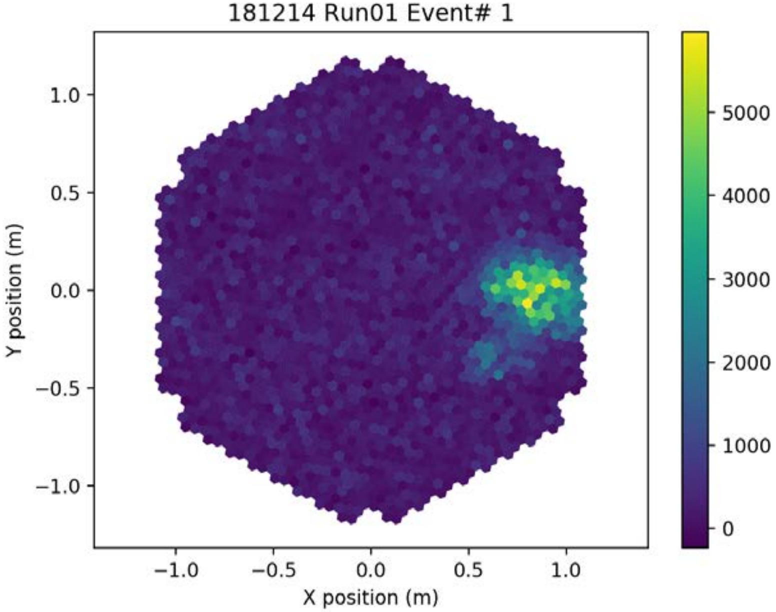
Close coordination other ICCUB research groups and Electronics Department (Solar Orbiter, Ariel and others)

Technological R&D: photosensors, medical imaging and quantum technologies

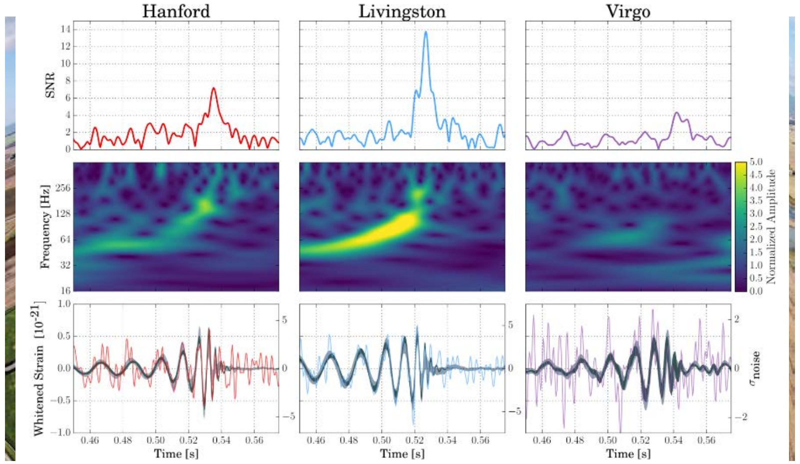
LHCb detector at LHC (CERN) with the Experimental Particle Phsyics group



Cherenkov Telescope Array with the High Energy Astrophysics group



VIRGO gravitational wave detector involves many groups and the 2 sections of the TU



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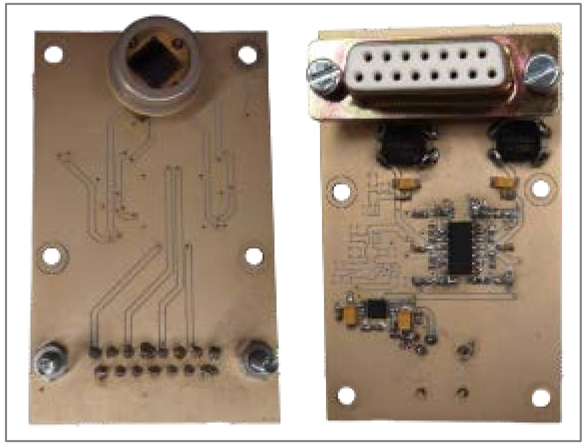
EXCELENCIA MARÍA DE MAEZTU

II. Activities in instrumentation: VIRGO

- The ICCUB is full member of the Virgo Collaboration since July 2019
- Main ICCUB contributions:
  - Quadrant Photodetectors
    - Quantum Noise Reduction / Squeezing Injection subsystem
    - Sensors + electronics (in vacuum)
  - DetChar shifts, electronics reviews



Institute of Cosmos Sciences

EXCELENCIA MARÍA DE MAEZTU

Outlook

I. Introduction

II. LHCb upgrades

III. Gamma-ray astronomy

IV. GWs: Virgo and LISA

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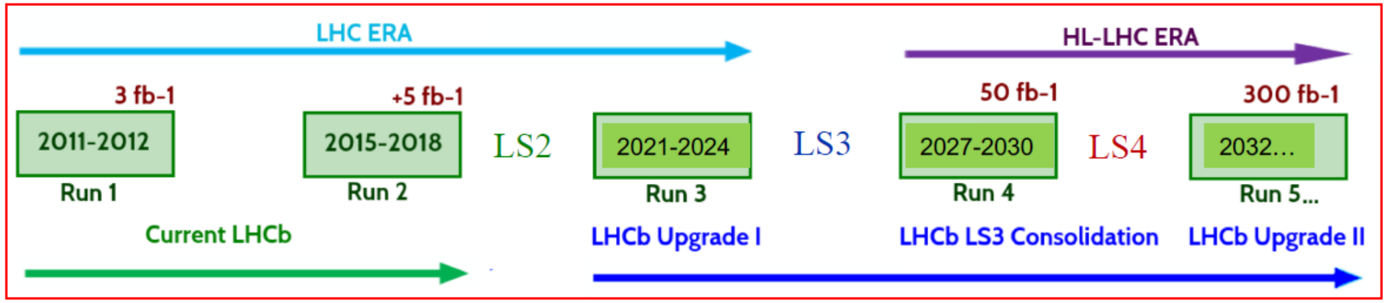
VI. Technological R&D

II. LHCb upgrade II

LHCb ECAL Upgrade II

Updated Schedule 12.12.2019



2021 - 2024: → submit Technical Design Reports

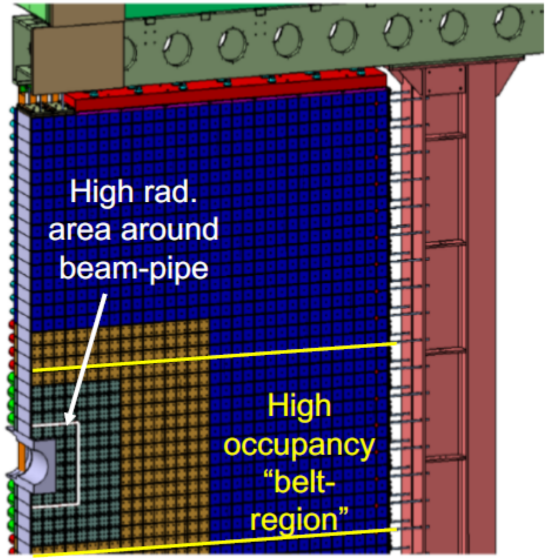
- 2021: **Framework TDR** for Upgrade II
  followed by sub-detector **"Consolidation" TDRs**
- 2023/24: Sub-detector **TDRs for Upgrade II**

LS3 in 2025/26: → **Consolidation**

- **Replace modules around beampipe** compatible with $L=2\times10^{33}$ $cm^{-2}s^{-1}$
  (minimal consolidation: ~32 modules)

LS4 in ≥2031: → **LHCb Upgrade II**

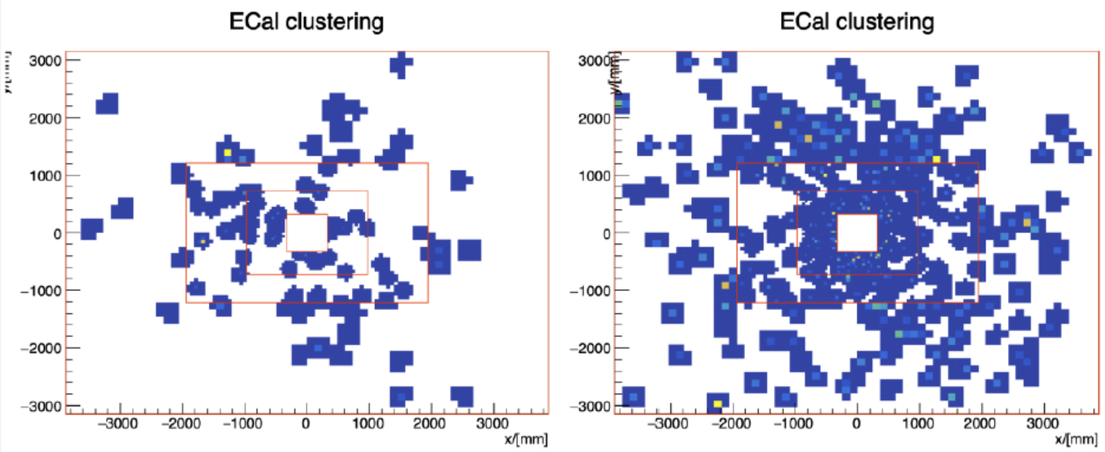
- **Rebuilt ECAL in high occupancy "belt-region"**
  compatible with luminosity up to $L \leq 2\times10^{34}$ $cm^{-2}s^{-1}$
- Include **timing information** to mitigate multiple interactions/crossing



19 December 2019 | Electronics Brainstormimg | Andreas Schopper | 3

Upgrade II conditions

- Luminosity = 1.5×10^{34} $cm^{-2}.s^{-1}$, $\nu = 57$
- Width of the luminous region ~200 ps
- Biggest challenge is the occupancy, that degrades resolution and increases background level



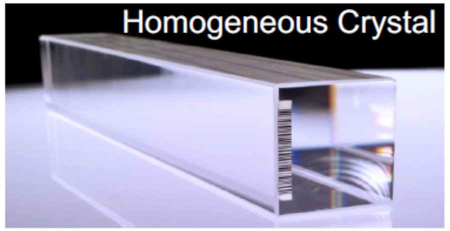
- Left plot with Upgrade1 luminosity ($\sim 2\times10^{33} cm^{-1}s^{-1}$)
- Right plot with Upgrade2 luminosity ($\sim 1.5\times10^{34} cm^{-1}s^{-1}$)

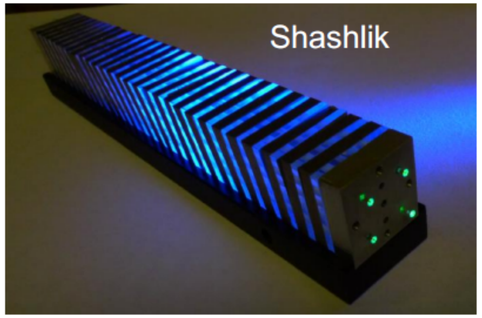
Zehua Xu

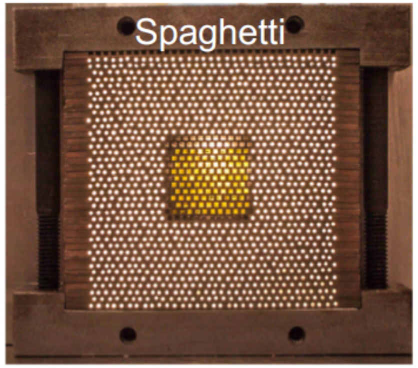
Possible options for new ECAL modules

Pros and cons of different options:

Sampling Technologies







Homogeneous Crystal:
- requires long crystal of ~40cm to contain 25 X_0
- "given" Moliere Radius
- very good homogeneity
- potentially very good E-resolution (<10%)
- large volume of crystal → high cost

Shashlik type module:
- can be made very compact ~15-20cm
- Moliere Radius "tunable"
- **no rad. hard WLS fibers (yet) to transport light!**
- can be optimized to reach good E-resolution
- some cost optimization possible

Spaghetti type module:
- can be made very compact ~15-20cm
- **fibers scintillate AND transports light!**
- Moliere Radius "tunable"
- challenging optimization to reach good E-resolution
- some cost optimization possible

- Started generic R&D on spaghetti type module (SPACAL)

(with Crystal Clear Collab.)

19 December 2019 Electronics Brainstormimg Andreas Schopper 11

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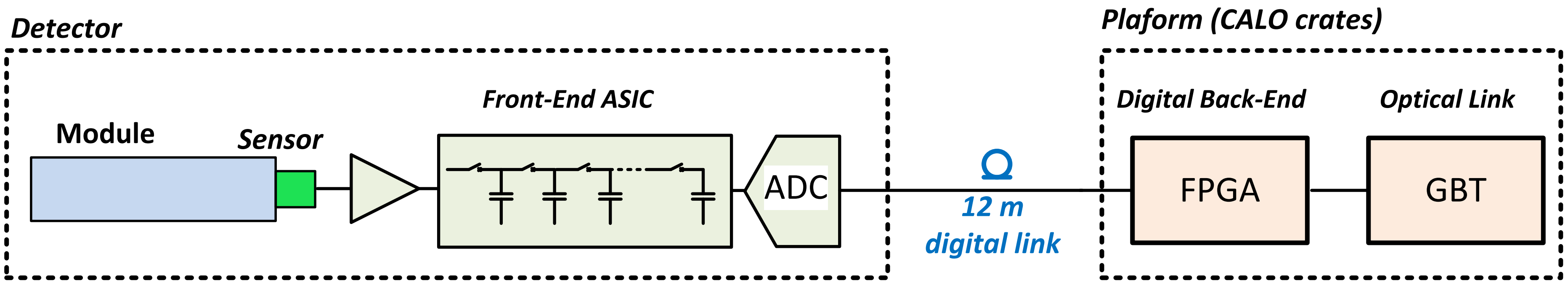
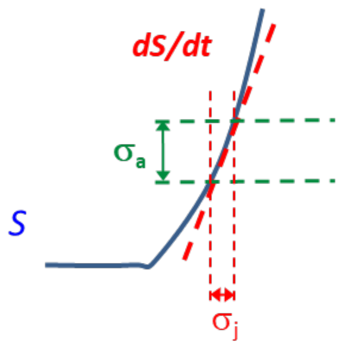
II. LHCb upgrade II



- Challenging requirements in case on detector FE ASIC:
  - Radiation hardness: probably 65 nm CMOS tech can work
  - Density: need to match 1 cell size area
- Back-end digital processing will be performed in the location of current calo crates:
  - FE (on-detector): analog derandomization and sparsification
  - Back-end (crates): processing including time pick-up



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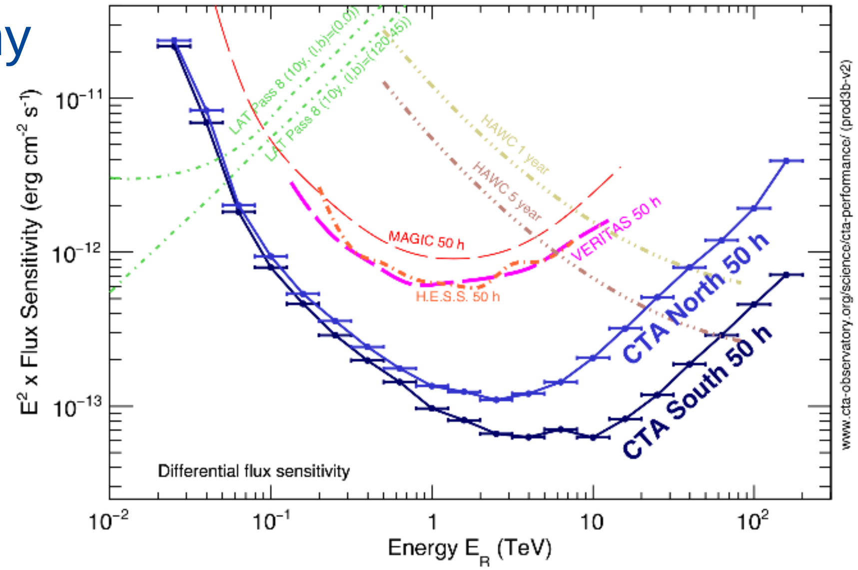
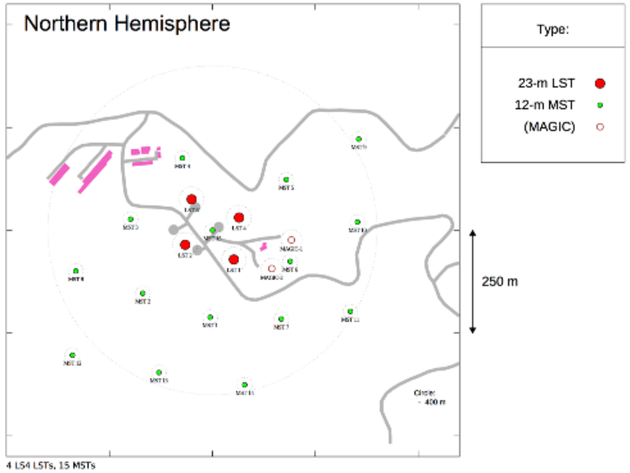
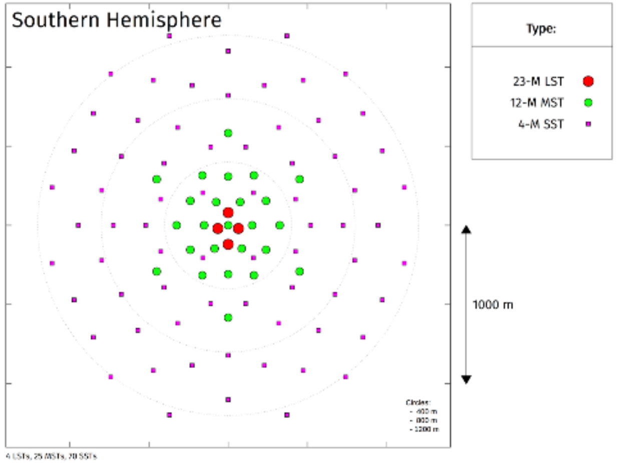
III. CTA

- Unprecedented gamma-ray astronomy
  - Energy range & sensitivity
- Large array (>1 km2)
  - 50-100 telescopes
  - Dish from 6 to 24 m
- North (La Palma) & South site (Chile)



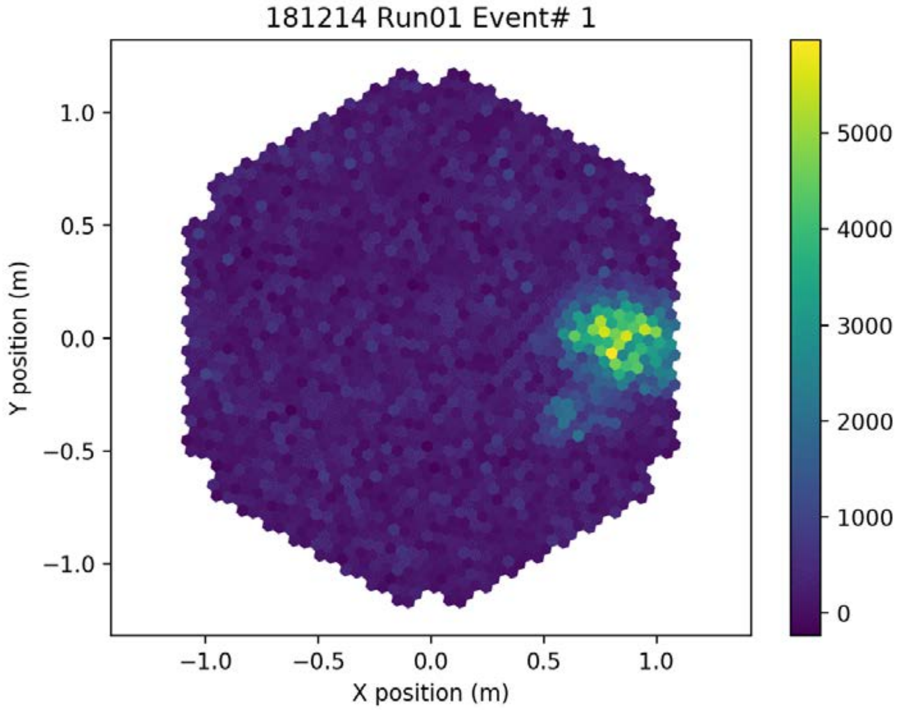




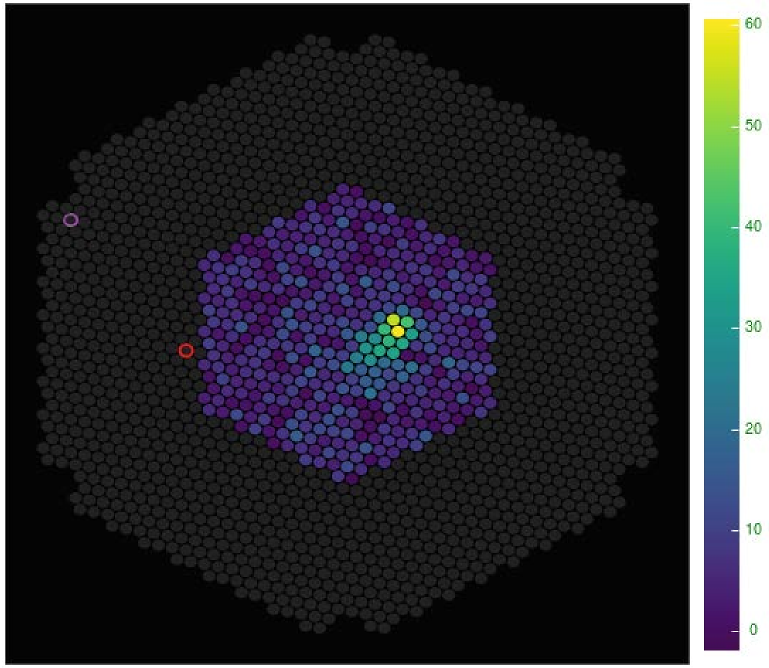
LST-1

III. CTA

- LST1 and MST1-NectarCAM have seen first light

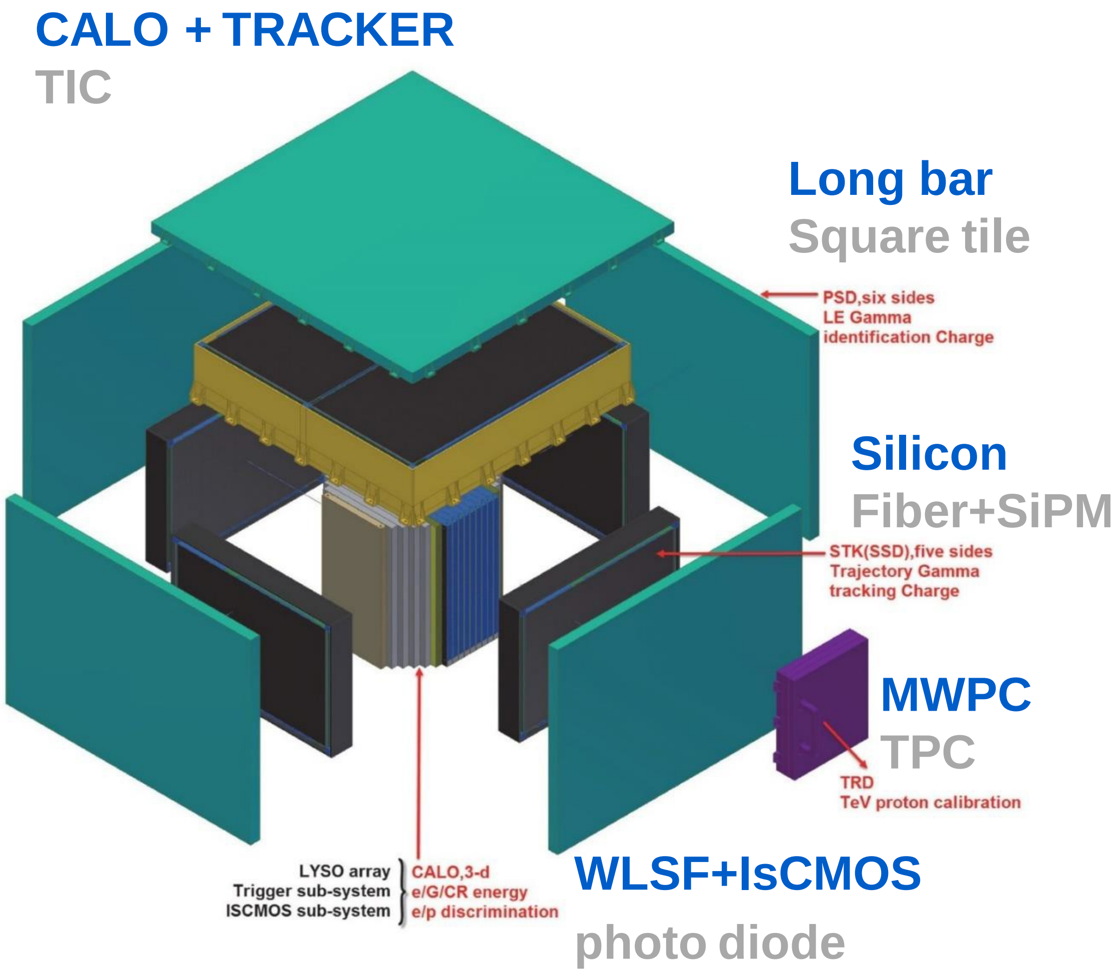


LST1 in La Palma



MST1 prototype in Berlin

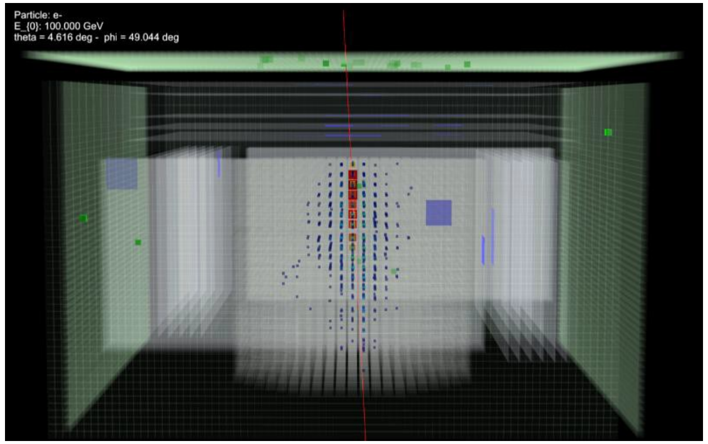
III. HERD Payload



Black: baseline design
Gray: alternative approach

FIber Track (FIT)

Tracker In Calorimeter (TIC) techniques



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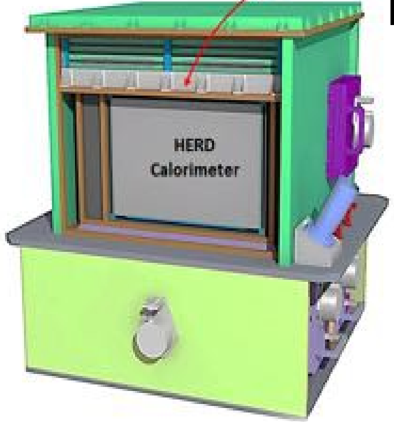
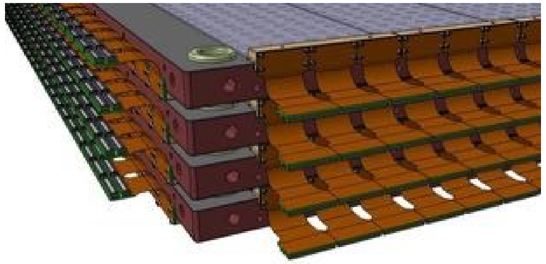
III. HERD
Fiber Tracker (FIT)

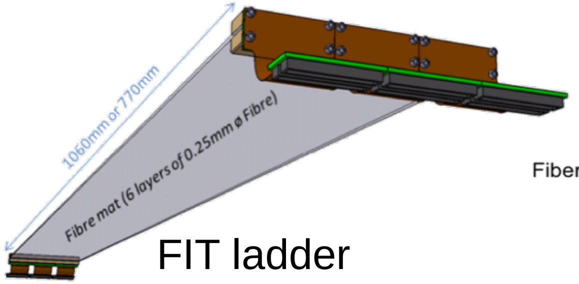
Proposed by University of Geneva



FIT will be mounted in the 4 lateral sides of the calorimeter

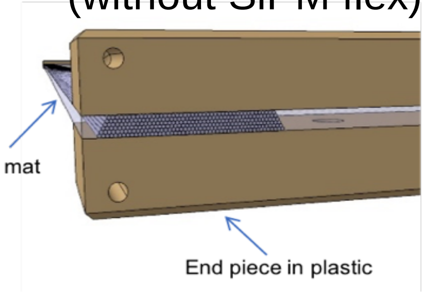


FIT is made of four trays on which are glued the fiber ladders

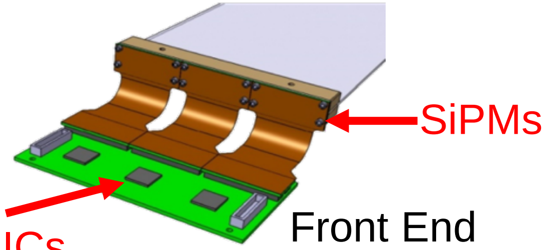


FIT ladder

End of FIT mat (without SiPM flex)



End of FIT mat (with SiPM flex)



III. HERD

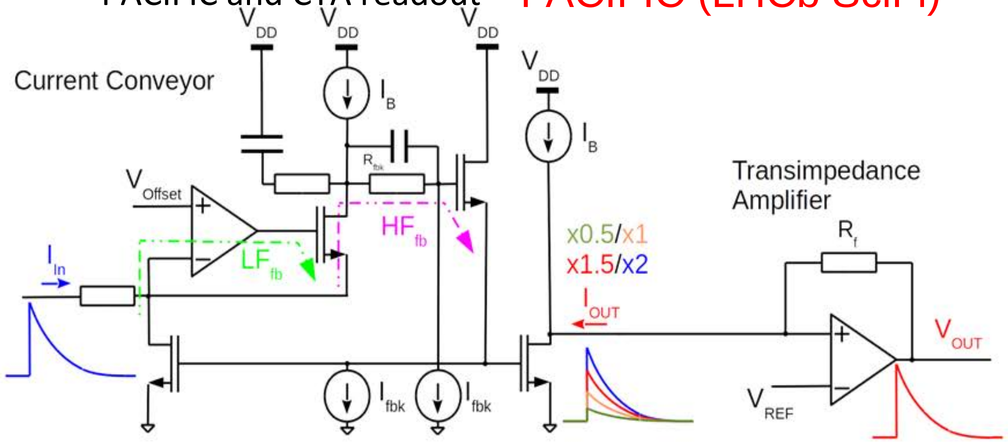
Working Hypothesis and Objectives

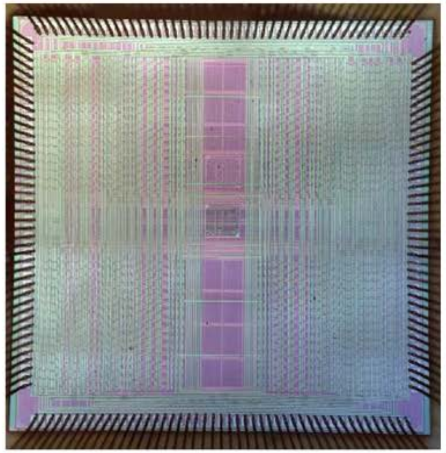
Front-End electronics of FIT: **ASIC**

Thanks to our expertise:

PACIFIC and CTA readout

PACIFIC (LHCb SciFi)





HERD raw data will not be made public beyond the HERD collaboration

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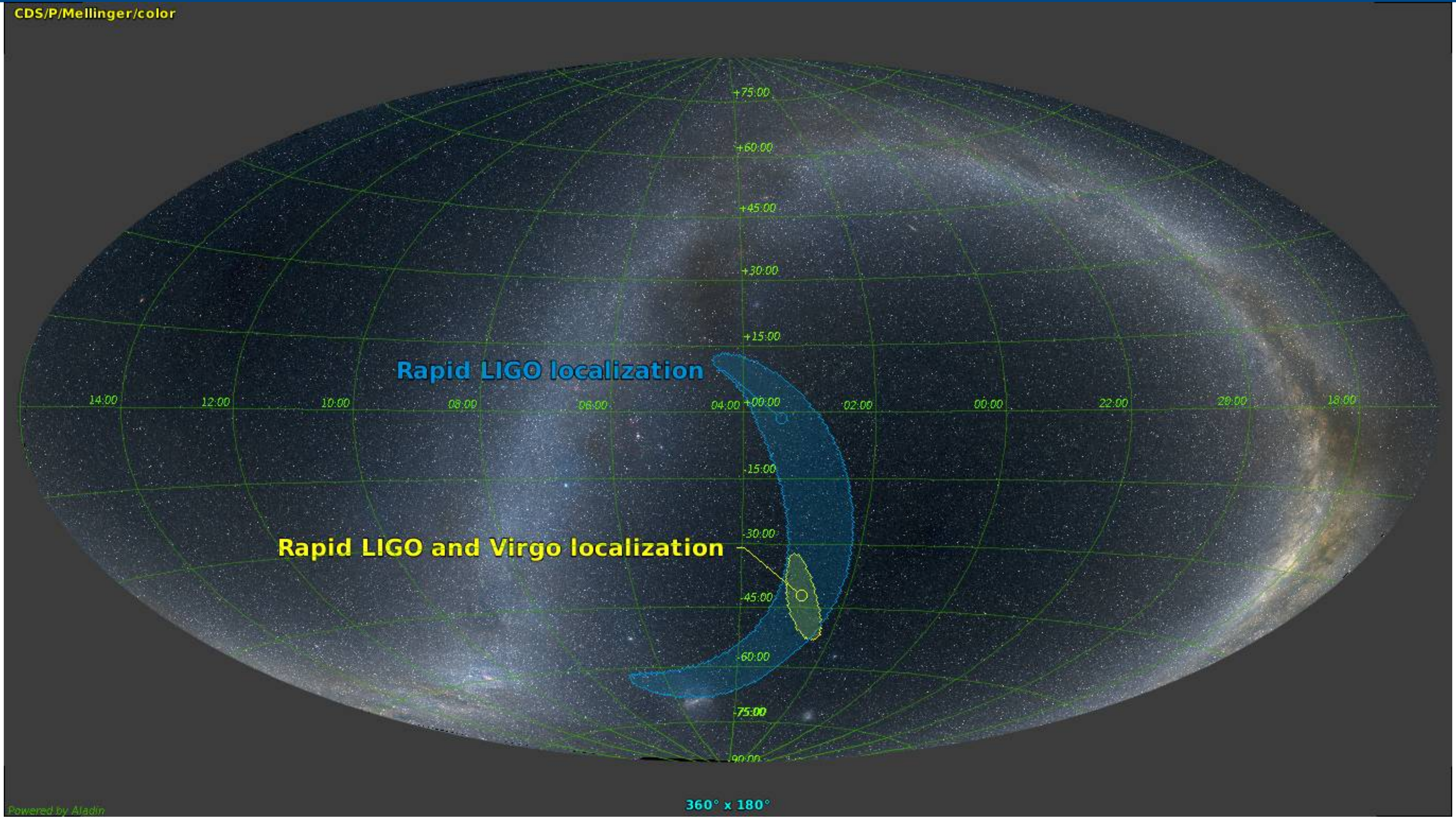
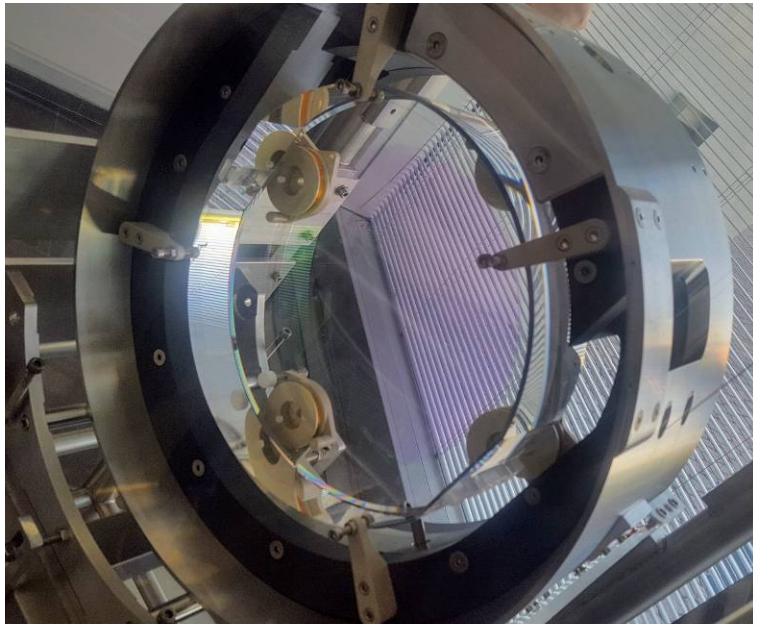
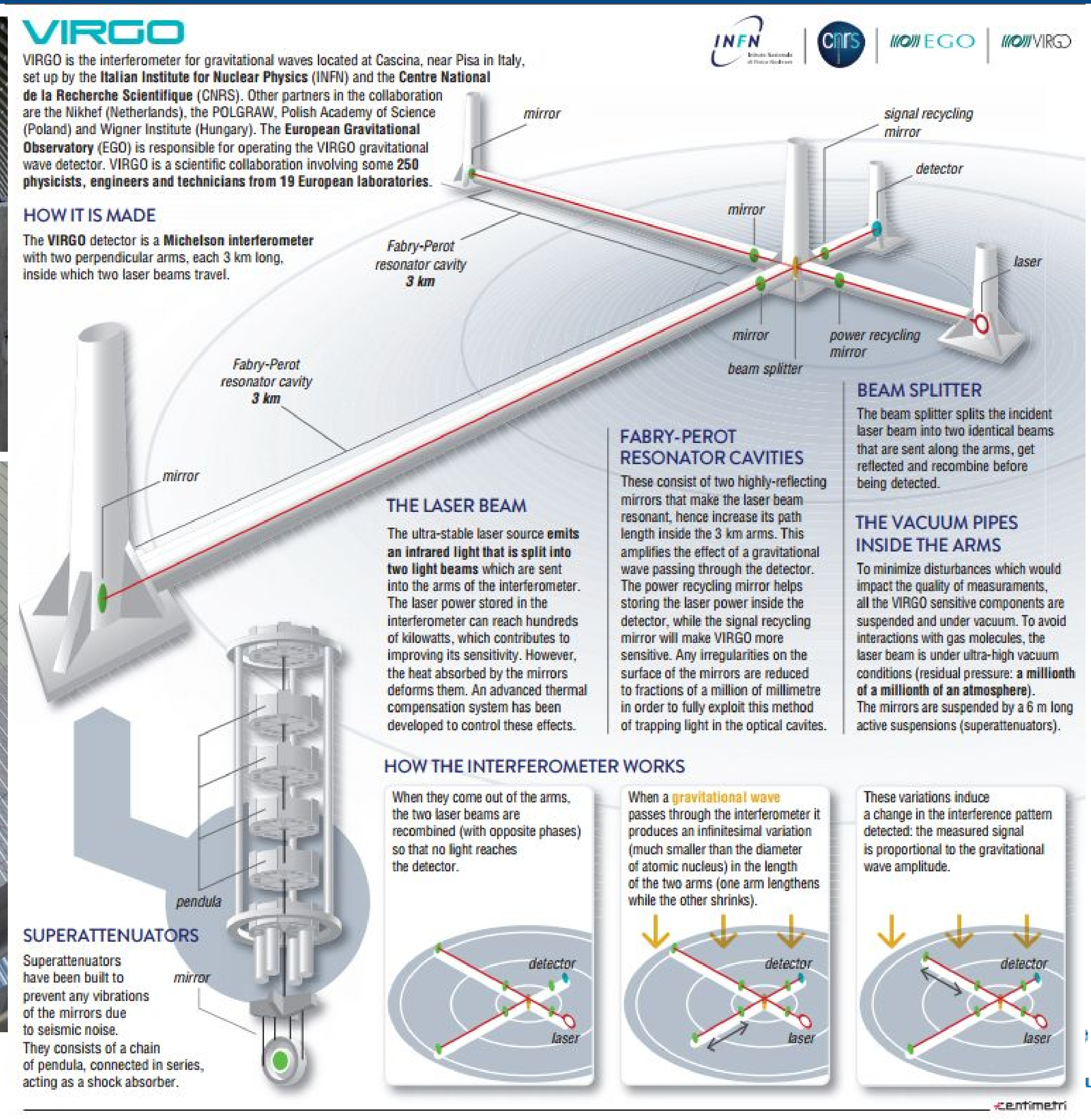
IV: Virgo

IV: Virgo


CDS/P/Mellinger/color
+75:00
+60:00
+45:00
+30:00
+15:00
Rapid LIGO localization
14:00
12:00
10:00
08:00
06:00
04:00
+00:00
02:00
00:00
22:00
20:00
18:00
-15:00
-30:00
Rapid LIGO and Virgo localization
-45:00
-60:00
-75:00
-90:00
Powered by Aladin
360° x 180°

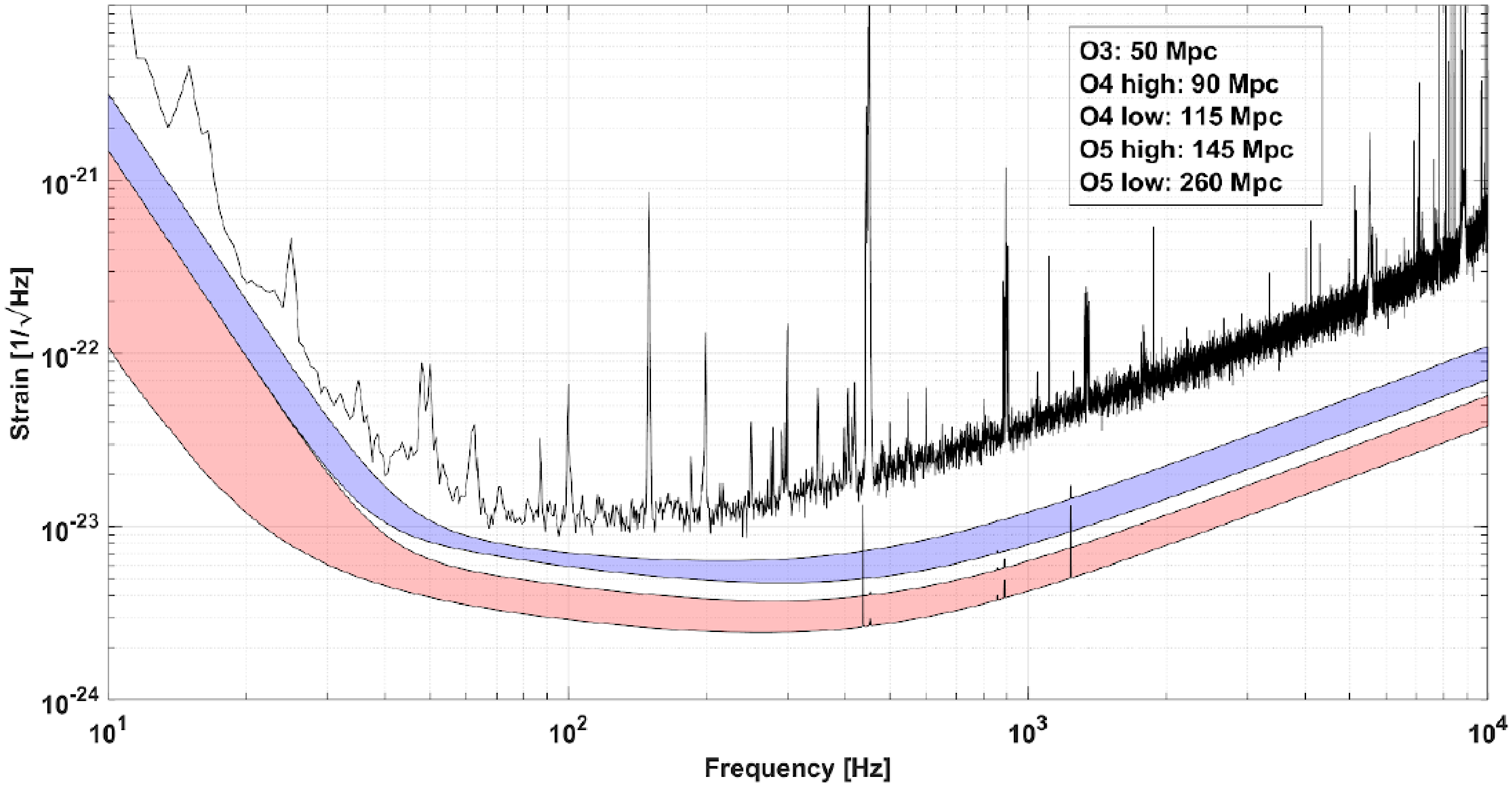
IV: Virgo




VIRGO
VIRGO is the interferometer for gravitational waves located at Cascina, near Pisa in Italy, set up by the Italian Institute for Nuclear Physics (INFN) and the Centre National de la Recherche Scientifique (CNRS). Other partners in the collaboration are the Nikhef (Netherlands), the POLGRAW, Polish Academy of Science (Poland) and Wigner Institute (Hungary). The European Gravitational Observatory (EGO) is responsible for operating the VIRGO gravitational wave detector. VIRGO is a scientific collaboration involving some 250 physicists, engineers and technicians from 19 European laboratories.
INFN
EGO
VIRGO
HOW IT IS MADE
The VIRGO detector is a Michelson interferometer with two perpendicular arms, each 3 km long, inside which two laser beams travel.
mirror
signal recycling mirror
detector
mirror
laser
Fabry-Perot resonator cavity 3 km
mirror
power recycling mirror
beam splitter
Fabry-Perot resonator cavity 3 km
mirror
BEAM SPLITTER
The beam splitter splits the incident laser beam into two identical beams that are sent along the arms, get reflected and recombine before being detected.
FABRY-PEROT RESONATOR CAVITIES
These consist of two highly-reflecting mirrors that make the laser beam resonant, hence increase its path length inside the 3 km arms. This amplifies the effect of a gravitational wave passing through the detector. The power recycling mirror helps storing the laser power inside the detector, while the signal recycling mirror will make VIRGO more sensitive. Any irregularities on the surface of the mirrors are reduced to fractions of a million of millimetre in order to fully exploit this method of trapping light in the optical cavites.
THE LASER BEAM
The ultra-stable laser source emits an infrared light that is split into two light beams which are sent into the arms of the interferometer. The laser power stored in the interferometer can reach hundreds of kilowatts, which contributes to improving its sensitivity. However, the heat absorbed by the mirrors deforms them. An advanced thermal compensation system has been developed to control these effects.
THE VACUUM PIPES INSIDE THE ARMS
To minimize disturbances which would impact the quality of measurements, all the VIRGO sensitive components are suspended and under vacuum. To avoid interactions with gas molecules, the laser beam is under ultra-high vacuum conditions (residual pressure: a millionth of a millionth of an atmosphere). The mirrors are suspended by a 6 m long active suspensions (superattenuators).
HOW THE INTERFEROMETER WORKS
When they come out of the arms, the two laser beams are recombined (with opposite phases) so that no light reaches the detector.
When a gravitational wave passes through the interferometer it produces an infinitesimal variation (much smaller than the diameter of atomic nucleus) in the length of the two arms (one arm lengthens while the other shrinks).
These variations induce a change in the interference pattern detected: the measured signal is proportional to the gravitational wave amplitude.
detector
laser
detector
laser
detector
laser
pendula
SUPERATTENUATORS
Superattenuators have been built to prevent any vibrations due to seismic noise. They consists of a chain of pendula, connected in series, acting as a shock absorber.
mirror
centimetri

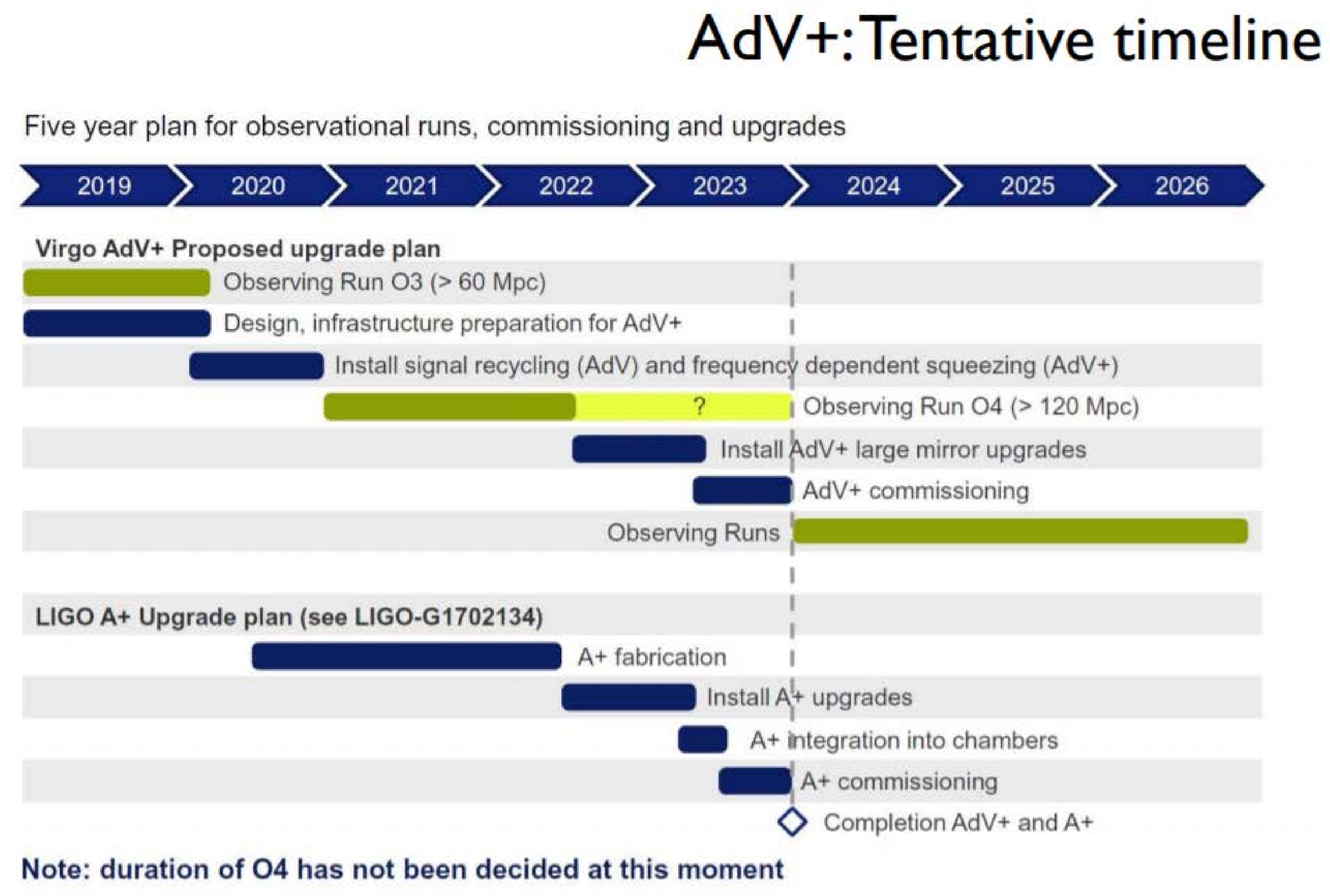
IV. VIRGO Adv+ upgrade

- Adv+ upgrade to improve senstivity after O3



The blue band shows the range of sensitivities achievable by AdV+ Phase I and II

IV. VIRGO Adv+ upgrade

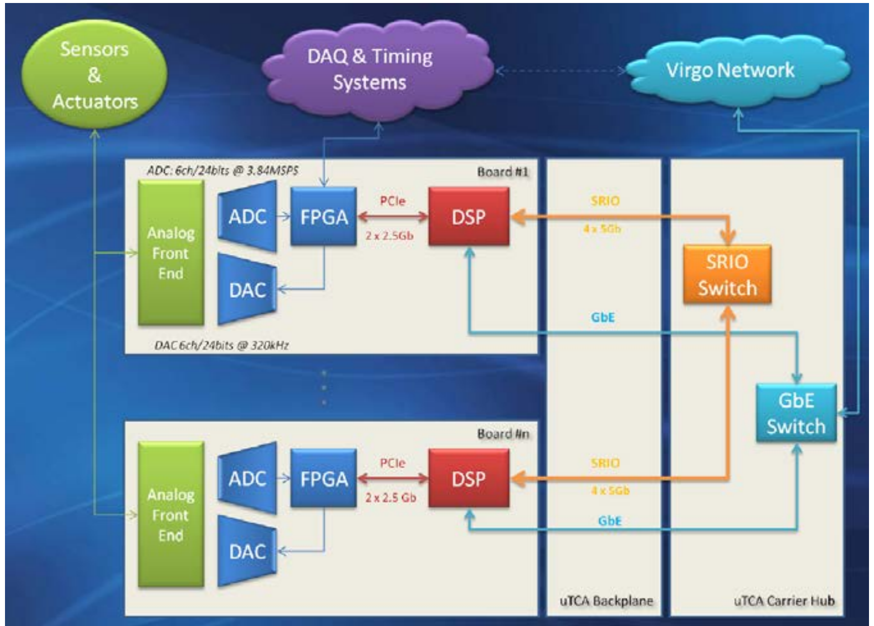


IV. Contributions to VIRGO Adv+

- The main goal of AdV+ Phase I is to reduce the interferometer sensing noise: Quantum Noise Reduction (QNR)
  - Subsystems: Squeezing Global Design (GSD), the Squeezed Vacuum Source (SVS), the Filtering cavity (FLT) and the Squeezing Injection (SIN)
    - Contribution to SIN subsystem
- To achieve the goals of Phase II, several tasks needs to be started during Phase I. The main ones are listed here below:
  - Design of the beam geometry in the interferometer arms
  - Upgrade of the LMA infrastructure to be able to coat and characterize 55 cm diameter mirrors
  - Procurement of super-polished substrates to be ready for the mirror coatings
  - Study of new payloads and of superattenuators upgrade to suspend 100 kg mirrors
    - Contribution to SAT subsystem
  - Development of advanced coatings with lower thermal noise

IV. Contributions to VIRGO Adv+: SAT

- VIRGO mirrors are suspended by seismic isolators (superattenuators)
- Each seismic isolator system has inertial sensors, displacement sensors, stepping motors and magnet-coil actuators.
- Multiple UDSPT Boards control the suspension of the mirrors
- The ICCUB will help in the development of a new generation of boards:
  - o Actual board is in Rev 2 with a total delay of 40-45us
  - o Develop Rev 3 and achieve and overall improvements of all the specs
  - o Also, increase the scalability of the system

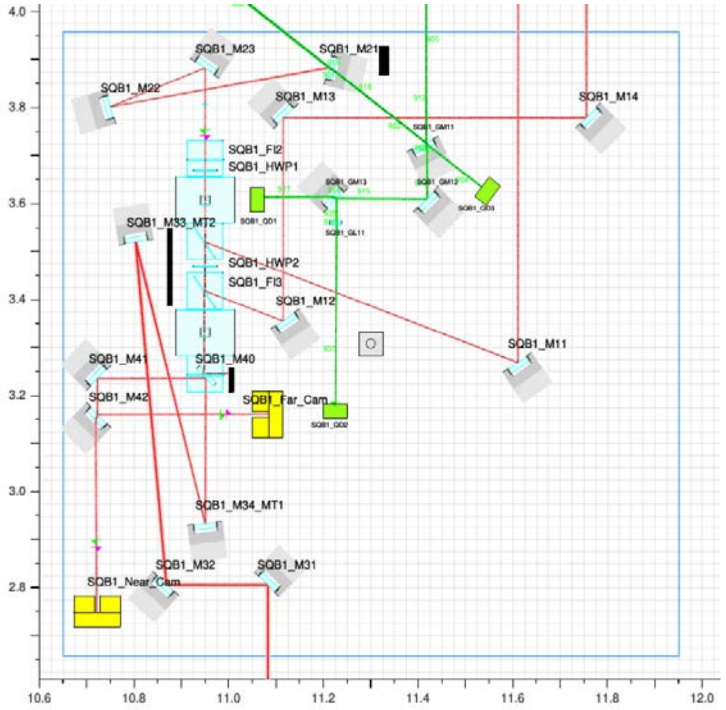


Team @ ICCUB:
J. Mauricio (project leader)
G. Guixé (PhD student)
Collaborarion with Pisa Univ.

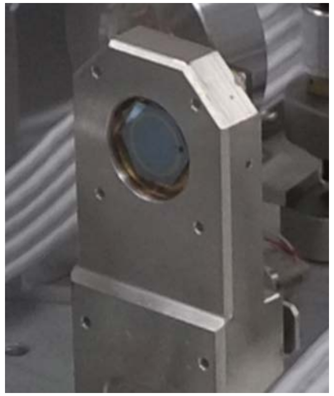
ICCUB Institute of Cosmos Sciences

IV. Contributions to VIRGO Adv+: QNR/SIN

- Quadrant photodetectors on-board suspended benches under vacuum
  - To detect green laser beams to keep aligned the suspended benches with the beams
- Selection of 532 nm DC quadrants
- Development of low noise (DC) electronics to interface with ADC design by Annecy
- Devices have to be operated in vacuum. Outgassing control as for space project.
- Schedule:
  - Installation should happen in July 2020.
  - Should be operative in October 2020.



Suspended sQueezing Bench 1 (SQB1)



Team @ ICCUB:
A. Sanuy (project leader)
C. Pujol (TFG student)
J.M. Gomez (TFG supervisor with A. Sanuy)

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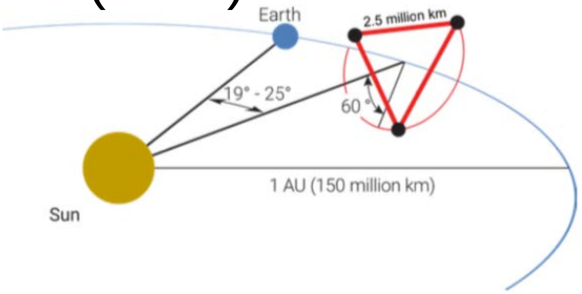
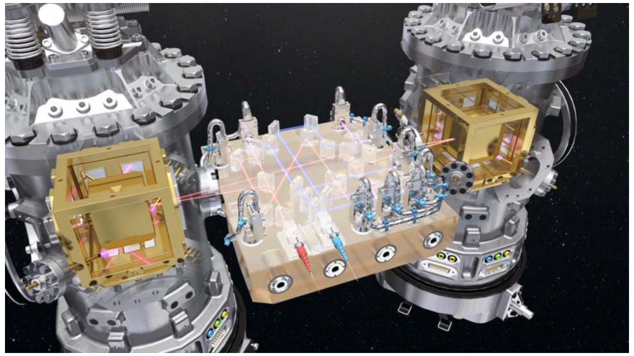
IV. LISA L3: radiation monitor

Control and diagnostic PI : M Nofrarias (IEEC-ICE)

- LISA is the concept selected for ESA L3 mission slot (2034)
- ISA (Laser Interferometer Space Antenna):
  - Constellation of 3 satellites in heliocentric orbit
  - Space-craft are drag-free
    - Test mass (TM) inside which is in nominal free fall
  - Differential arm-length measured by laser interferometry



- High energy environment responsible for test-mass charging
  - Affects the capacitive control of the test masses: acceleration noise
  - Two sources: Solar Event Particles (SEPs) and Galactic Cosmic Rays (GRCs)
- Possible collaboration (as IEEC-ICCUB)
  - Monte Carlo simulation
    - To understand better the effective TM charging
  - Develop a radiation monitor for LISA mission
  - Transversal project within ICCUB:
    - F. Salvat, A. Aran, L. Garrido, E. Grauges…
  - Application for an Innovative Training Network (ITN GRAVITAS)
    - Two roles: IEEC (R&D) + UB (PhD programme)



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Outlook

I. Introduction

II. LHCb upgrade II

III. Gamma-ray astronomy

IV. GWs: Virgo and LISA

V. IAXO

VI. Technological R&D

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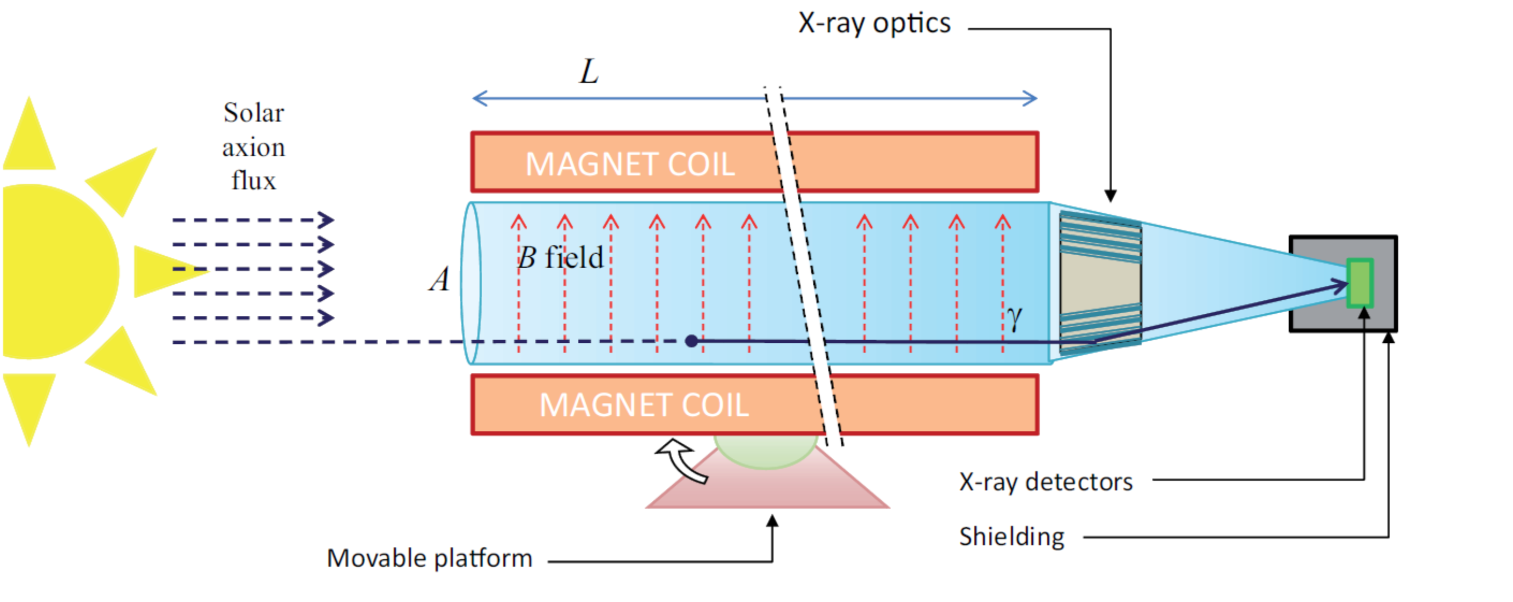
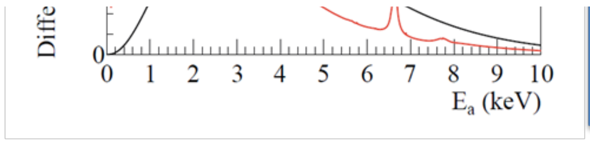
V: IAXO

Solar Axions

- Solar axions produced by photon-to-axion conversion of the solar



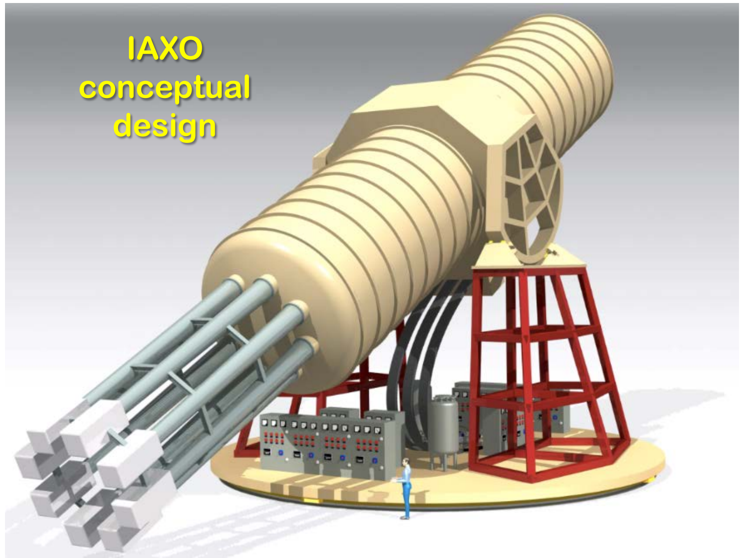
CERN, November-17

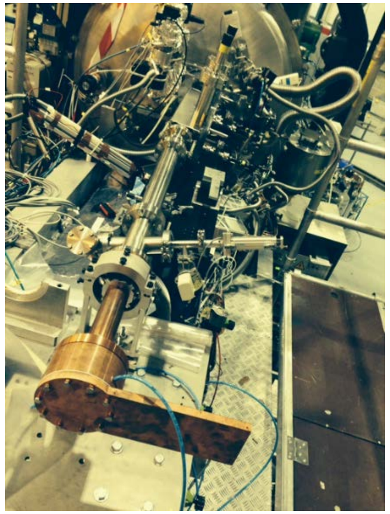


* if the axion couples with the electron (g_{ae})
(non hadronic axion)

V: IAXO

- Next generation "axion helioscope" after CAST
- Purpose-built large-scale magnet
  - >300 times larger B^2L^2A than CAST magnet
  - Toroid geometry
  - 8 conversion bores of 60 cm Ø, ~20 m long
- Detection systems (XRT+detectors)
  - Scaled-up versions based on experience in CAST
  - Low-background techniques for detectors
  - Optics based on slumped-glass technique used in NuStar
- ~50% Sun-tracking time
- Large magnetic volume available for additional "axion" physics (e.g. DM setups)





IAXO pathfinder system at CAST

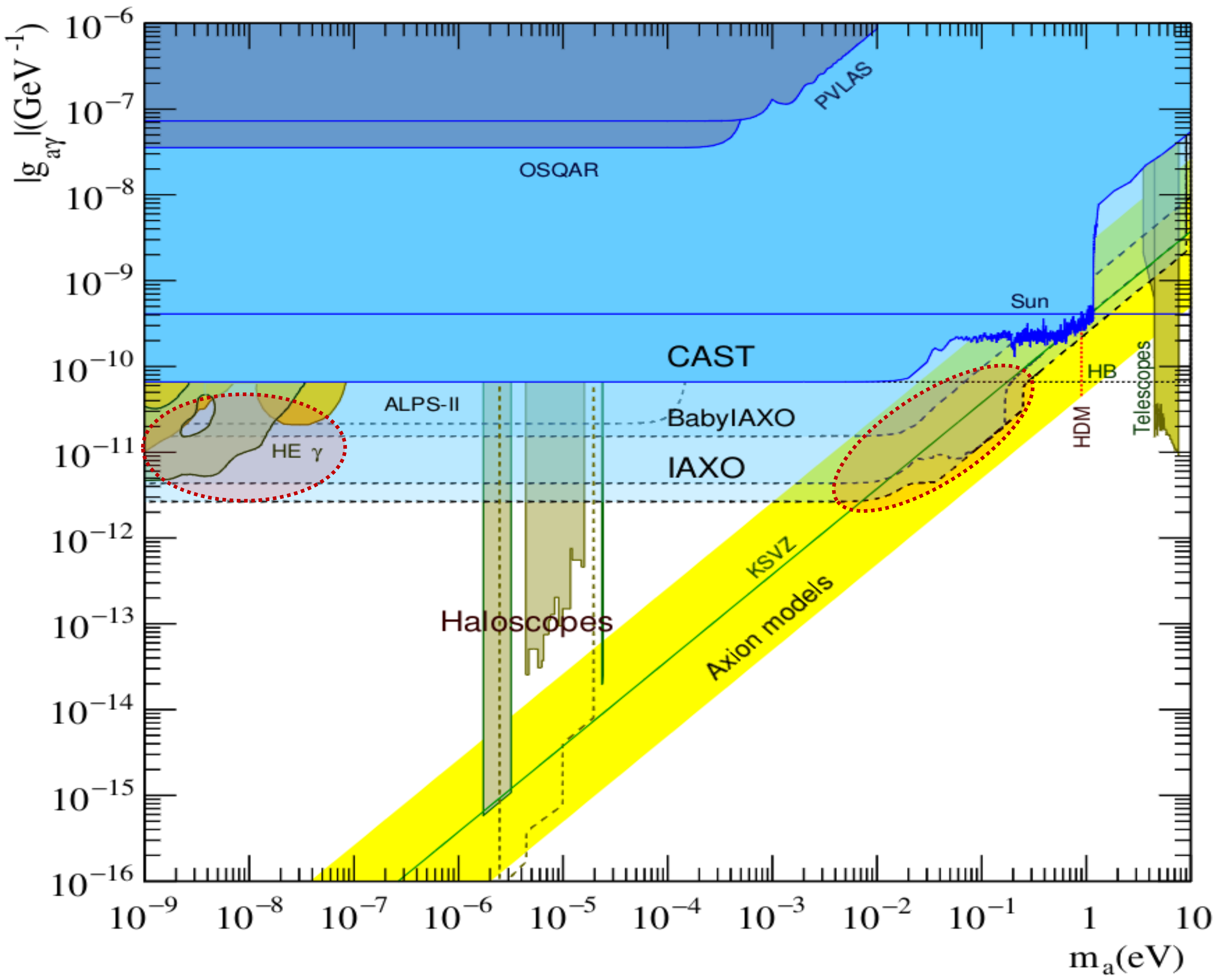
In operation in 2014-15

Last CAST results published in Nature Physics last May
Nature Phys. 13 (2017) 584-590

Igor G. Irastorza, Beyond Colliders, CERN, November-17

V: IAXO

Igor G. Irastorza,
Beyond Colliders,
CERN, November-17



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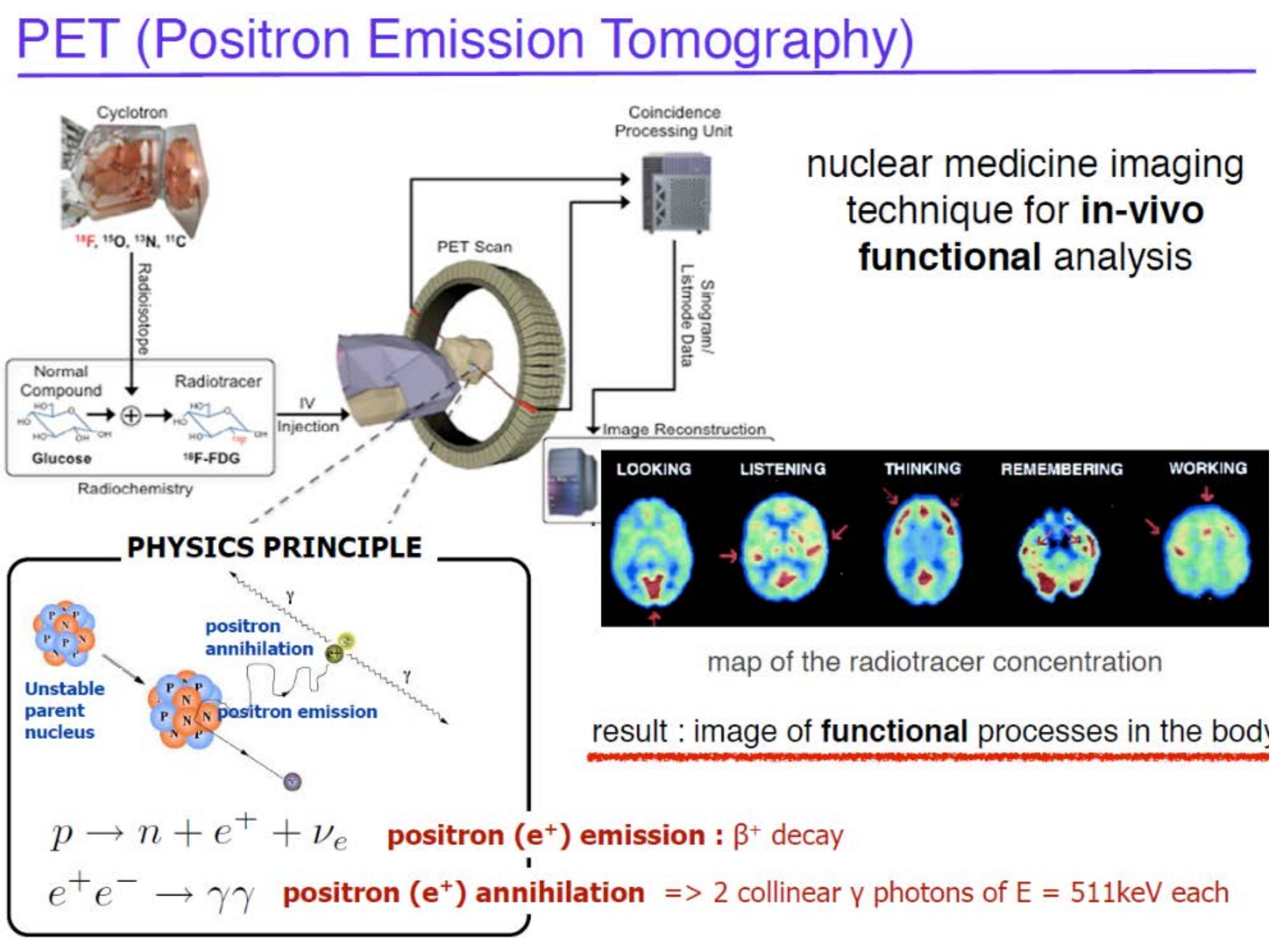
VI. Technological R&D



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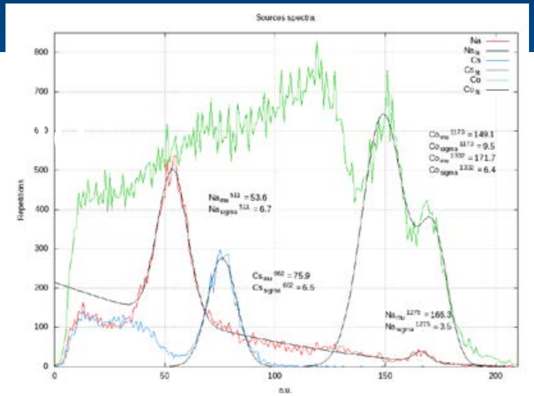
VI. Technological R&D



CIEMAT, I3M-CSIC, IFIC-CSIC, Pisa University, CERN, etc

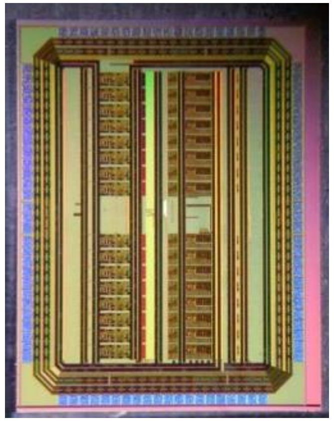
Full detector Monte Carlo simulation and optimization

FE electronics (FlexToT chip family) and Time-to-Digital Converters (TDC, MATRIX family)

Characterization and precise evaluation of spatial and temporal resolution

HRFlexToT

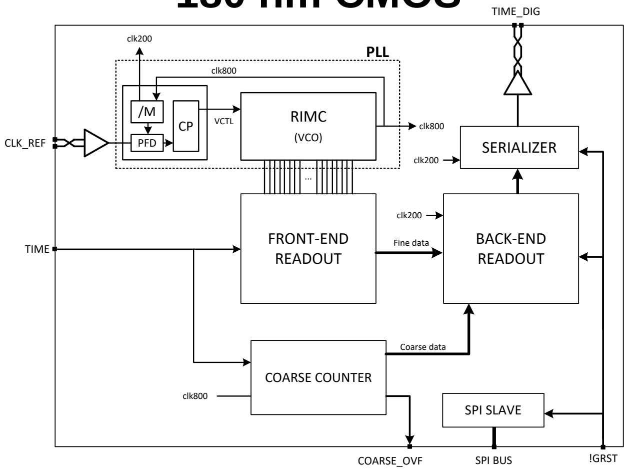
180 nm CMOS



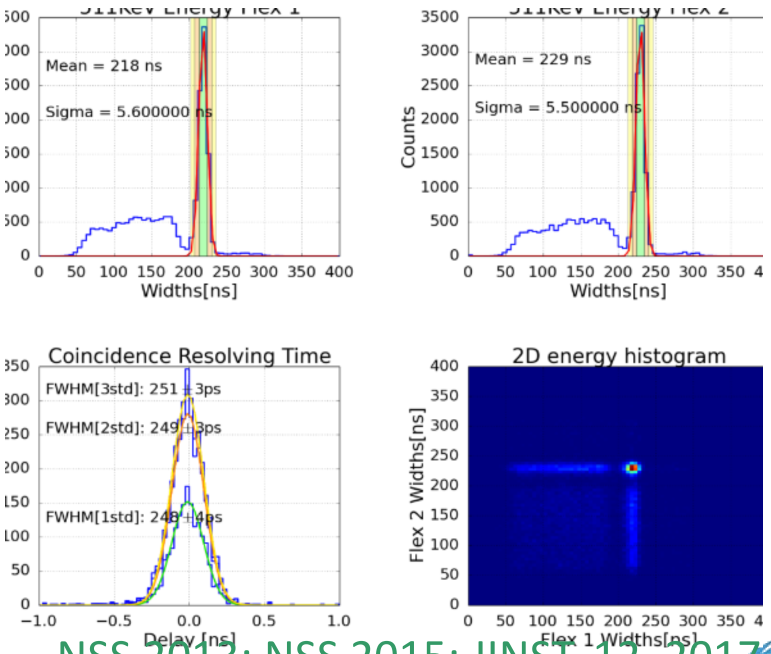
NSS 2013

MATRIX

180 nm CMOS



JINST, 12, 2016



NSS 2013; NSS 2015; JINST, 12, 2017

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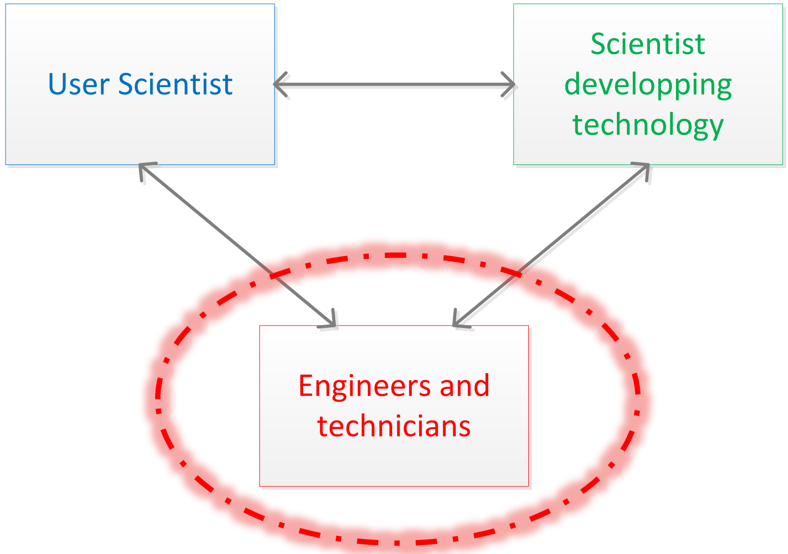
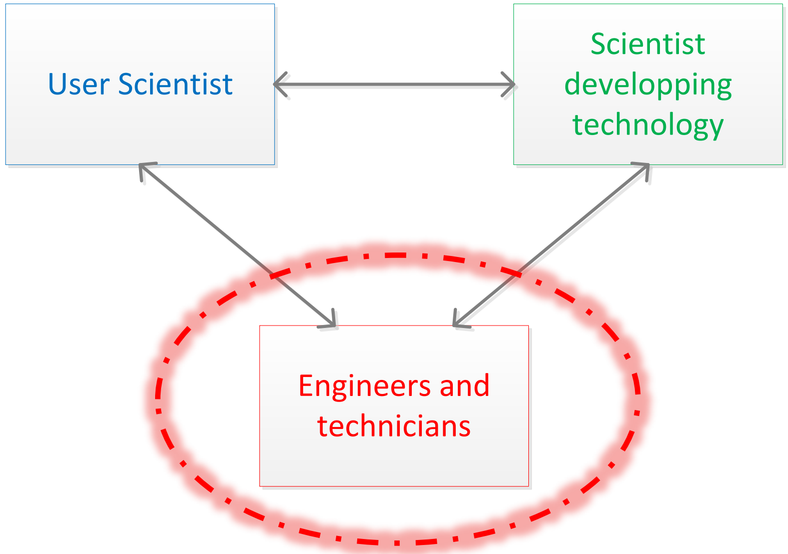
IV. Summary

- No permanent personnel in the technology unit
  - Experienced (>15 years) engineers and physicists with no permanent position
  - This personal is required to be able to develop significant contributions in experiments
    - It is not a researcher in electronics or technology (also needed)
    - It is a service: make large experiment/misison work is often not compatible with development of academic CV
  - Several people left in last years: difficult to replace (sometimes impossible): e.g.: VIRGO grid computing
    - Need small core team capable to execute and coordinate specialized tasks in different projects at the same time



IV. Summary

- Example: J. Mauricio
  - PhD Engineer but he is not a post-doc who can complete an important contribution in 2-3 years and leave
  - Digital ASIC design: LHCb, CTA, HERD and medical imaging
  - FPGAs and software: CTA, nanosat IEEC program, IAXO, HERD and medical imaging
  - Commissioning, operation and maintenance: LHCb
- And nearly everything in the same period!
- Around ***7 core people*** in the data and instrumentation divisions of the tech unit are in similar situation



IV. Summary

- Top-level science in ICCUB: many possible “user” scientists
- But not so many experimental scientists
- It is critical to recruit leading permanent experimentalists particularly in key priority lines:
  - Gravitational Waves, Quantum technologies, Dark Matter and axion searches among others