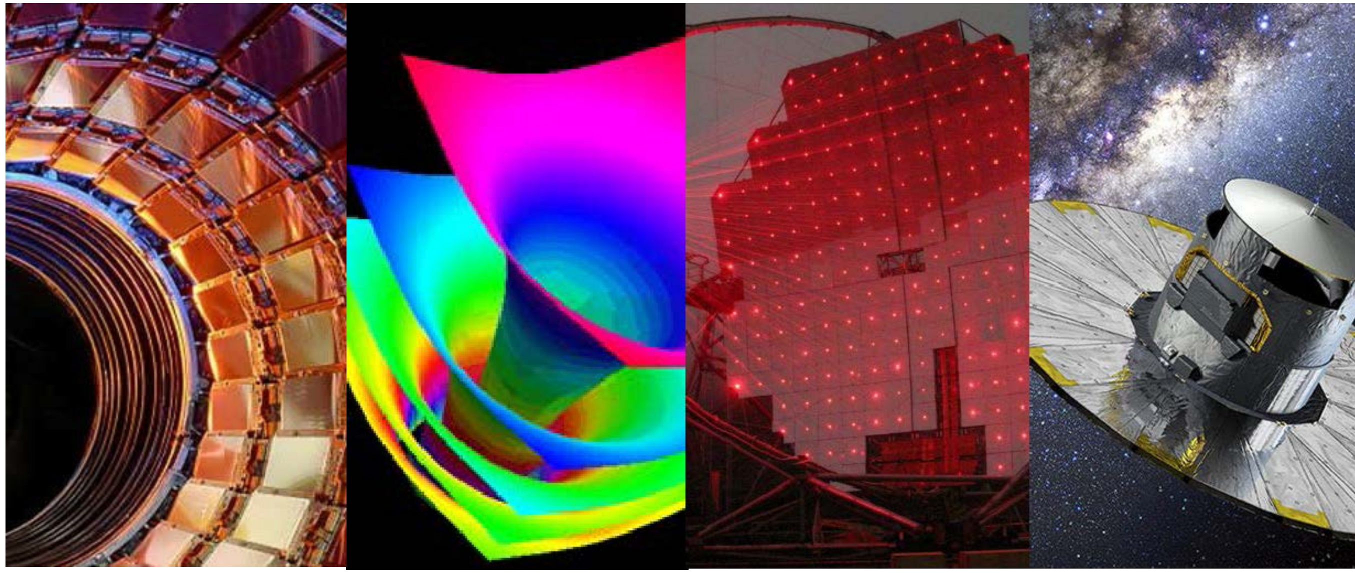
Institute of Cosmos Sciences



Detector development in the ICCUB

David Gascón on behalf

ICCUB Technical Unit

ICCUB-IEEC

09/07/2018

http://icc.ub.edu/technology

I. Introduction

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

- Quick overview of main current activities in:
  - **Instrumentation**
  - **Electronics**
  - **Very large data processing**

for:

- Space missions
- Particle physics experiments
- Other fields

II. Activities in instrumentation

- Several research groups develop activities in instrumentation, hardware and electronics, mainly (sorry if we miss something!):
  - Experimental High Energy Physics group. Colliders.
    - Part of Ideas UB instrumentation service (SiUB)
    - Cameras, single photon detectors and Radiation detectors
    - Microelectronics (ASICs) and digital high speed electronics (FPGAs)

    http://siub.ub.edu
  - Astronomy and Astrophysics
    - High-Energy Astrophysics. Gamma-ray astronomy.
    - Physics of the Sun-Earth relationship. Space Meteorology
    - Astronomical image processing and high angular resolution techniques
    - Instrumentation and robotic astronomical observation

    http://www.am.ub.edu
  - Radiation physics
    - Monte Carlo Simulation of Electron-Photon Transport (PENELOPE)
    - Medical physics and dosimetry

    http://www.ecm.ub.edu
  - Systems for Instrumentation and Communications
    - Part of the Department of Electronics
    - Optical and electronics instrumentation
    - Embedded systems, communications and IoT hardware

    Departament d' Electrònica, Universitat de Barcelona

    http://www.el.ub.es/

Part of ICCUB FQA department

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II. Activities in instrumentation

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    http://www.am.ub.edu
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Sorry if we forgot something !

Just starting and the limit between science and technology is fuzzy…

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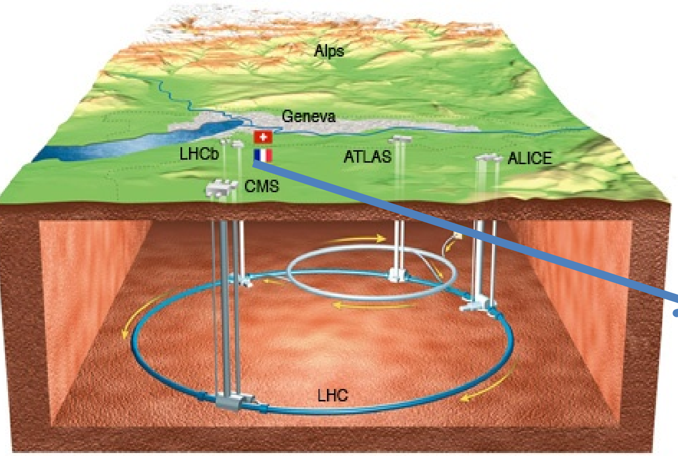
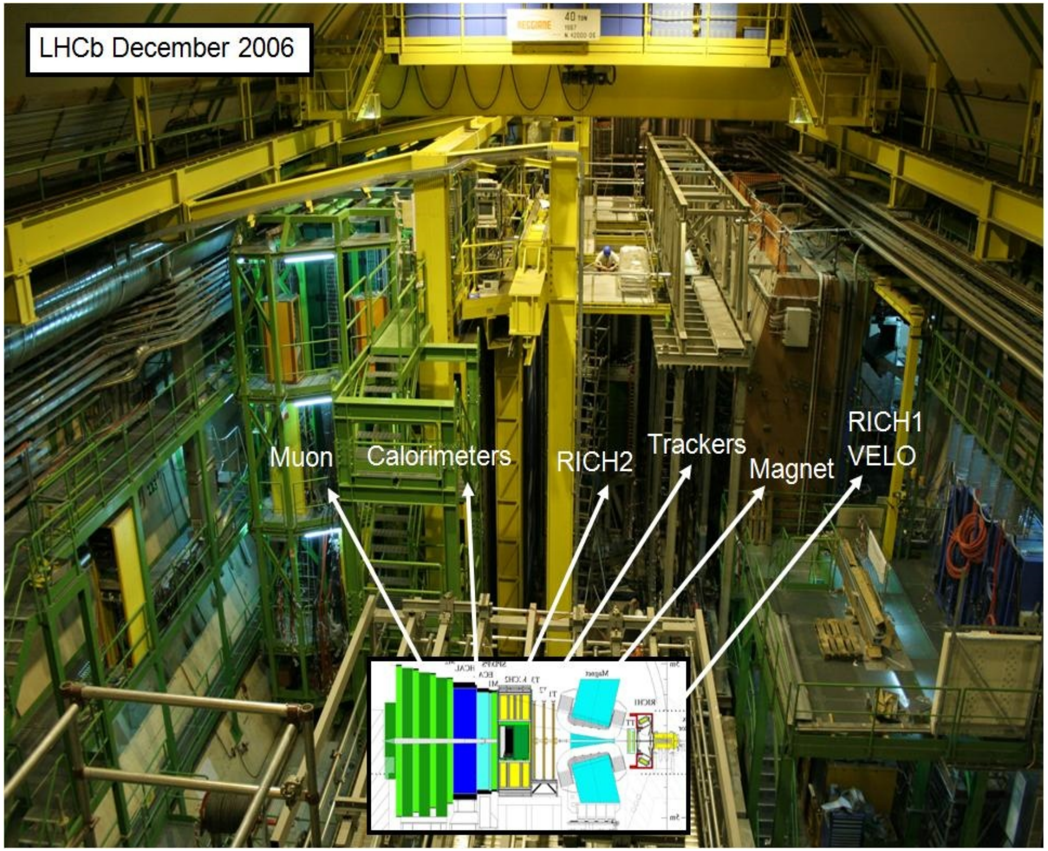
LHCb



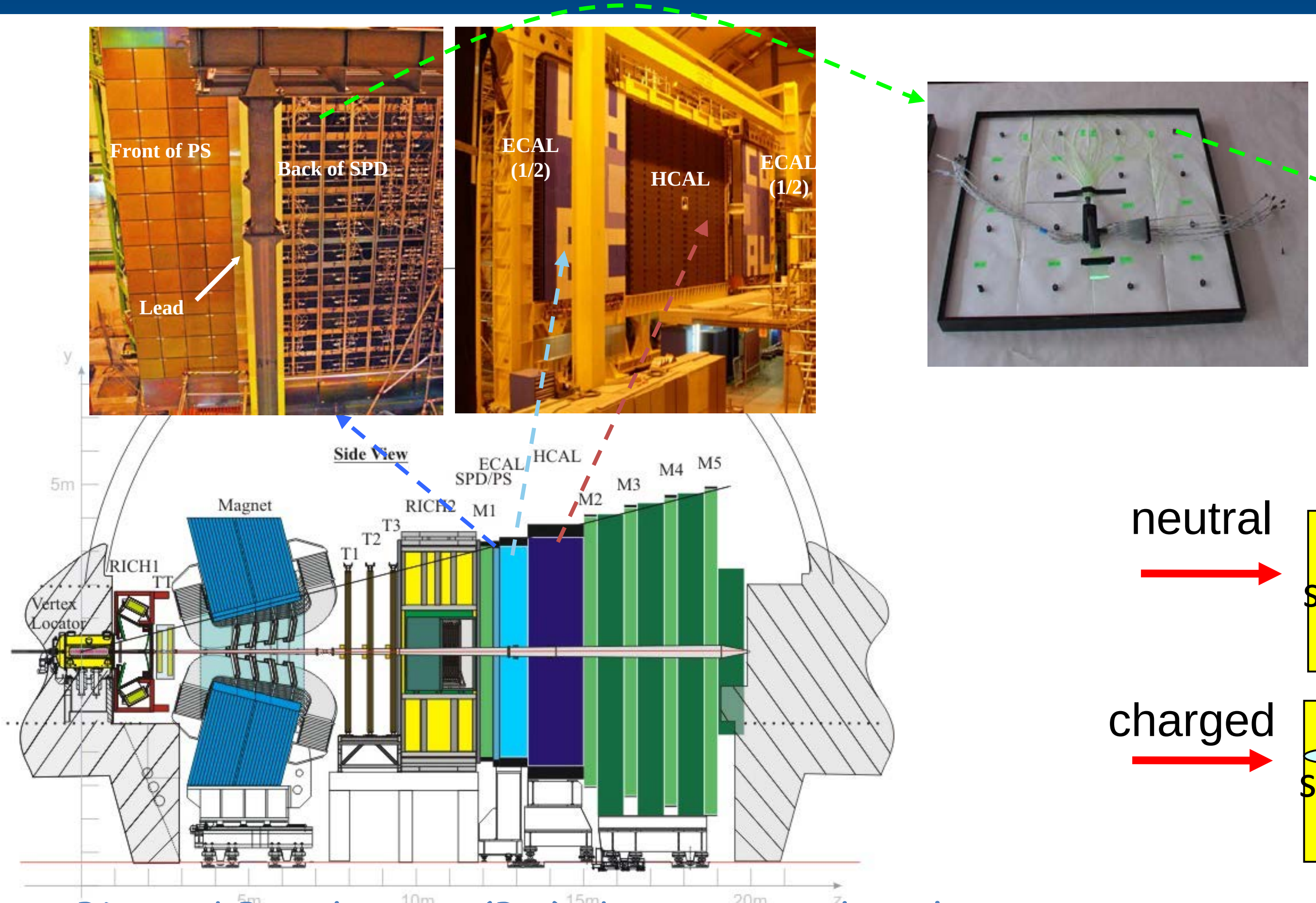
LHCB detector at LHC (CERN)

http://lhcb-public.web.cern.ch/lhcb-public/

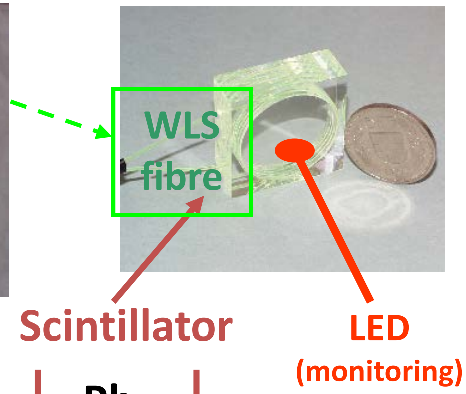


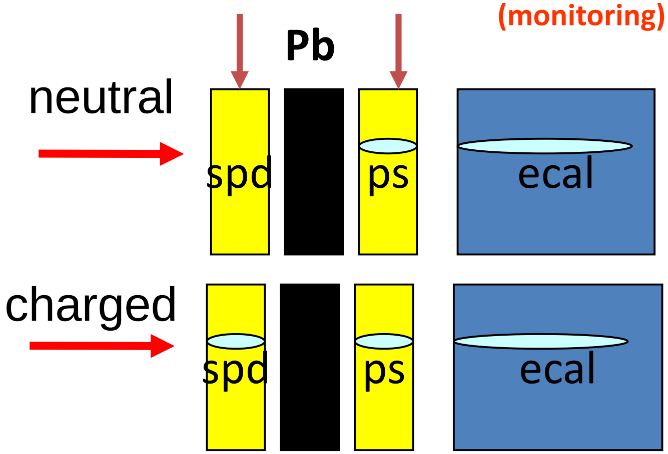
- Design of the Front End electronics of the first detector of the calorimeters:
  - 100 acquisition cards of 64 ch
  - 800 ASICs (8 ch)
  - Slow control system
  - High speed links (2.5 GB/s)
- Now working in the upgrade
  - New ASIC: ICECAL
  - 12 bit dynamic range @ 40 MHz
  - Low noise

LHCb: calorimeters



- 6000 pieces





- SPD and Preshower (PS) determine the electromagnetic nature of energy deposited in the electromagnetic calorimeter (ECAL).
- Input to trigger system **without dead time**
  - $\Rightarrow$ signal processing in beam crossing period: **25 ns** (40 MHz)
- SPD to discriminate charged from neutrals: **binary detector**

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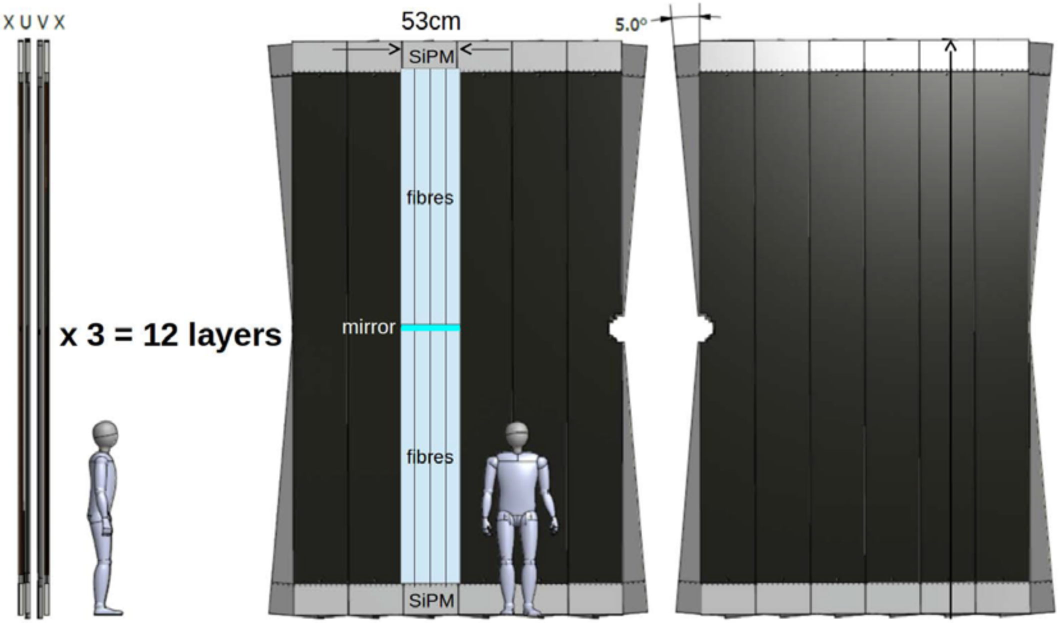
LHCb upgrade: SciFi

© A. Comerma (Univ. Heidelberg)

SciFi Overview

- Scintillating Fibre Tracker:
  - Light detector, $< 1\% X_0/layer$
  - Large area, total of $6 \times 5m^2$
  - XUVX planes on each station
  - Full detector is 3 stations
  - Total radiation up to 35kGy
- Requirements:
  - Hit efficiency $\approx 99\%$
  - High granularity $250\mu m$
  - Hit resolution $< 100\mu m$



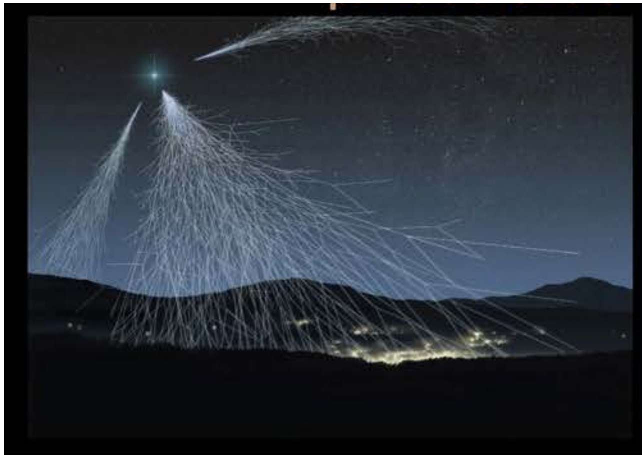
CTA

- Large energy range & sensitivity
  - Large array (>1 km^2)
  - 50-100 telescopes
  - Dish from 6 to 24 m
- North (La Palma) & South site (Chile)
- Designed 3 different chips and made important contributions to the cameras

Close collaboration with HEAP group:
http://www.am.ub.edu/ca/node/926

Cherenkov telescope array observatory

http://www.cta-observatory.org



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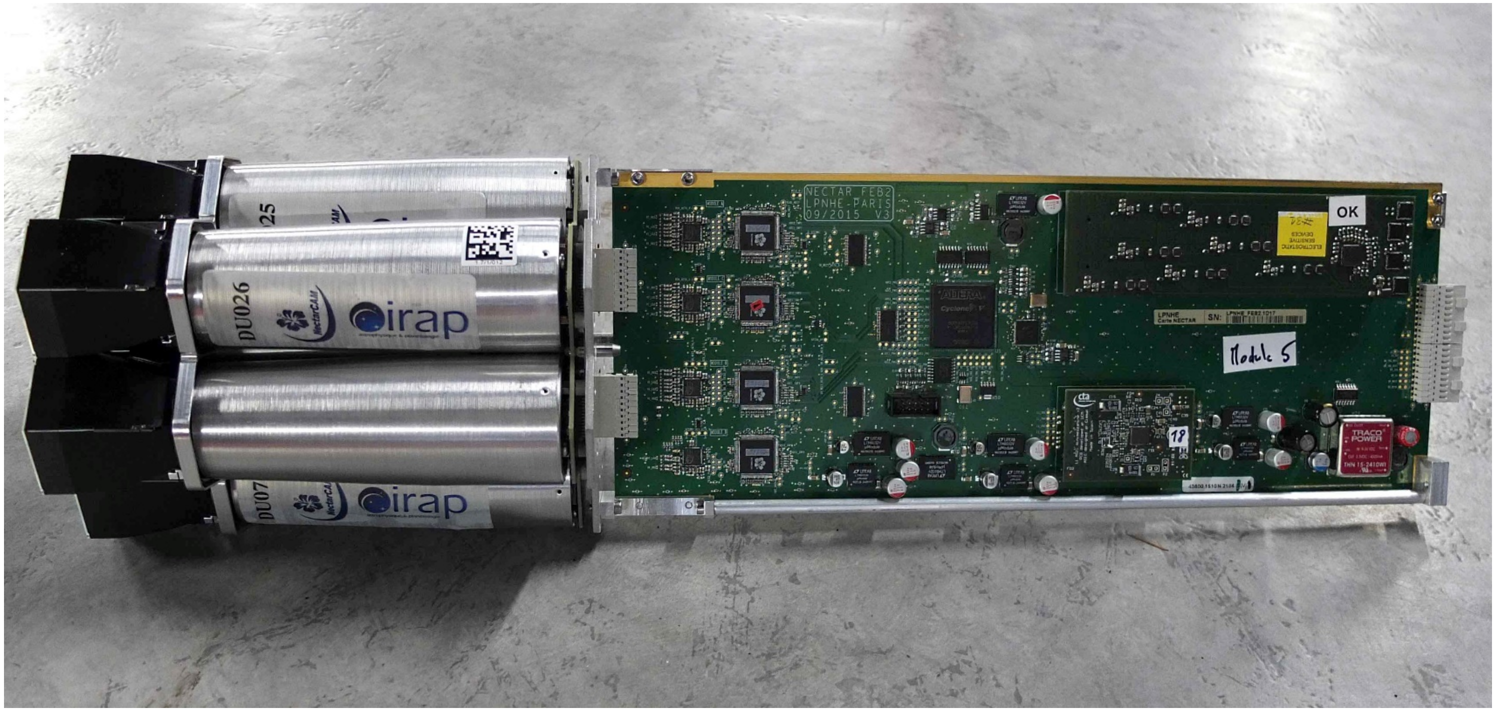
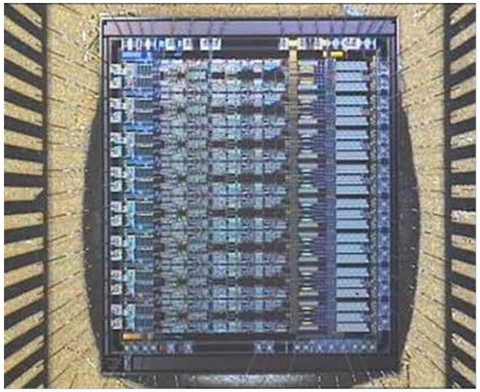
CTA Cameras

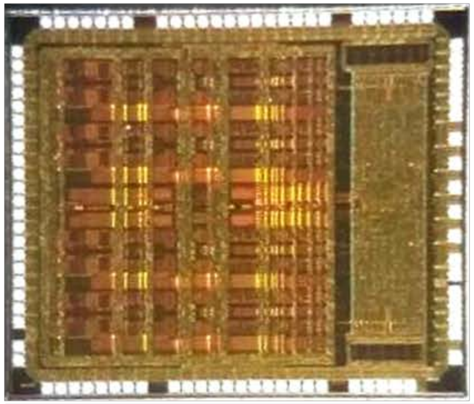
- Different components for DragonCAM (LSTs) and NECTArCAM (MSTs)
  - Preamplifier: PACTA
  - Signal conditioning: ACTA
  - Trigger system in collaboration with IFAE, CIEMAT and UCM

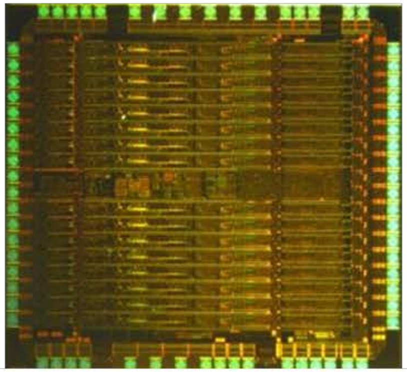


Nectar CAM module: http://inspirehep.net/record/1491931

ASICs







LHCb SPD: amplification, shaping, and discrimination. AMS BICMOS 0.8 um, radiation tolerant

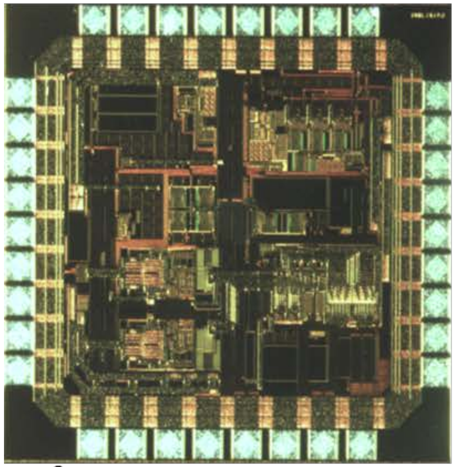
LHCb calo upgrade: analog signal processing. Radiation tolerant

AMS SiGe BiCMOS 0.35 µm

FlexToT

Readout circuit for SiPM arrays

SiGe BiCMOS 0.35um



2

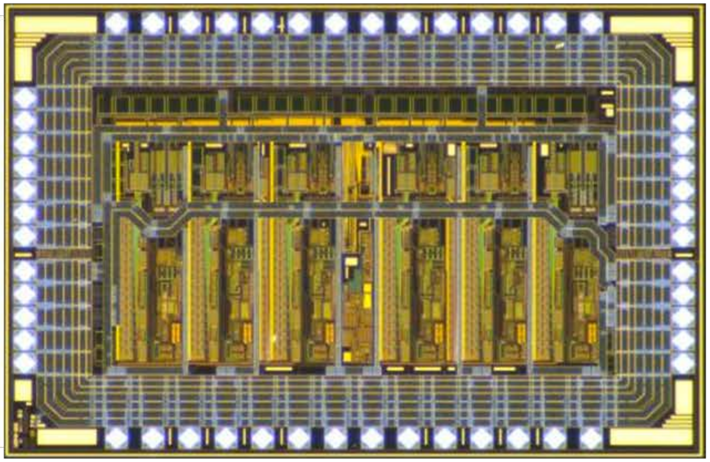
ASICs for CTA:

← Low noise and high dynamic range preamplifier for photomultiplier tubes

AMS SiGe BiCMOS 0.35 µm

Signal conditioning and → amplification

AMS CMOS 0.35 µm



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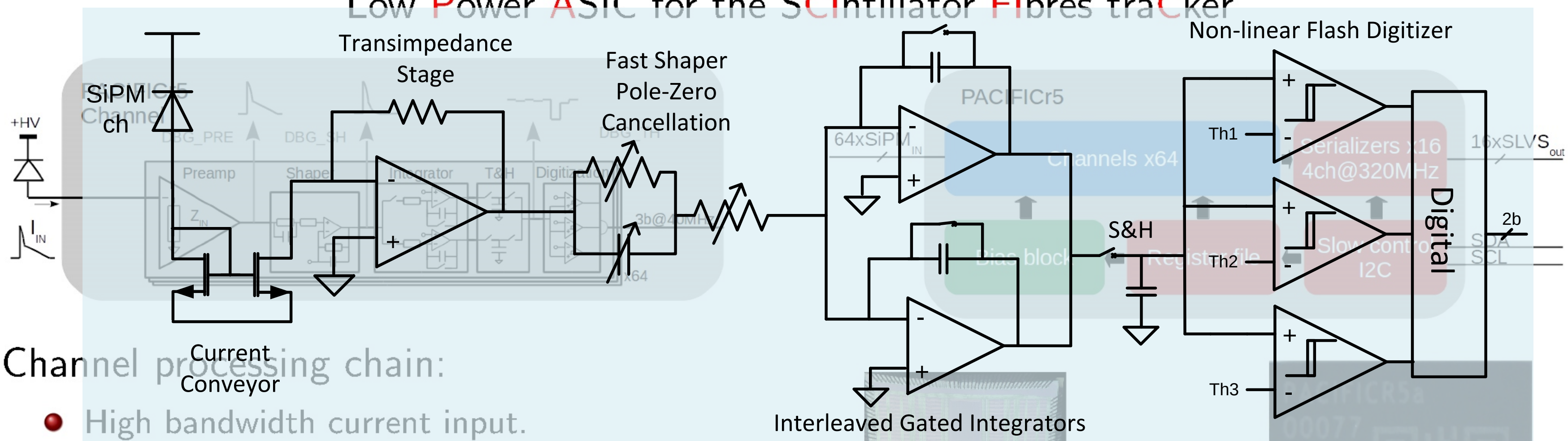
LHCb (PACIFIC)

© A. Comerma (Univ. Heidelberg)

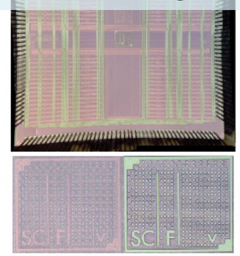
PACIFIC Collaboration: Heidelberg, ICCUB , LPC-Clermont, IFIC-Valencia

Low Power ASIC for the SCIntillator FIbres traCker



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).



4x3.85mm^2

BGA package

$12 \times 12mm^2$ 196pins

ASICs: automated quality control

- More than 100,000 chips to be tested in 2018
  - Automated quality control

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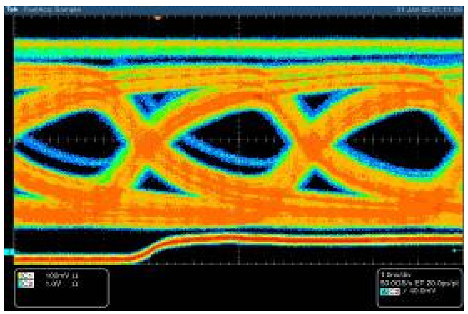
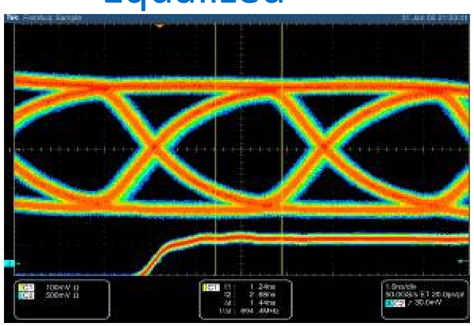
Cards and links

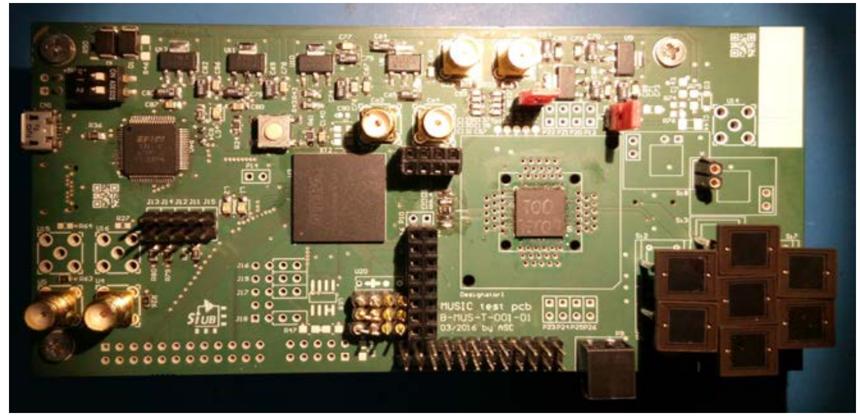
- High speed links
- Custom cable compensation
  - o 2.5 Gb/s data rate (27m !)

Unequalized

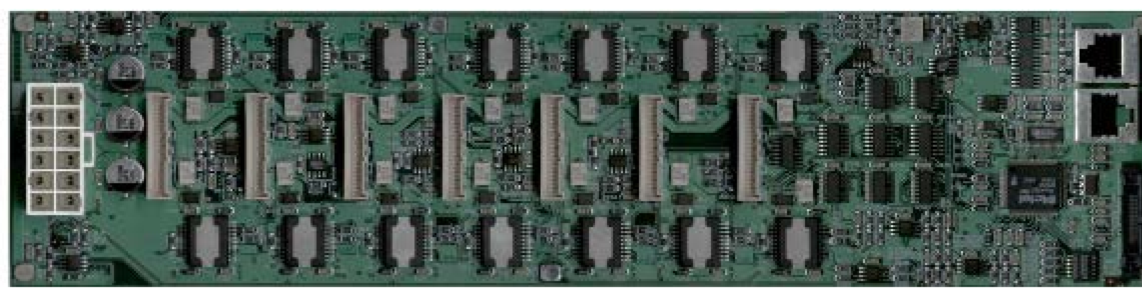


Equalized





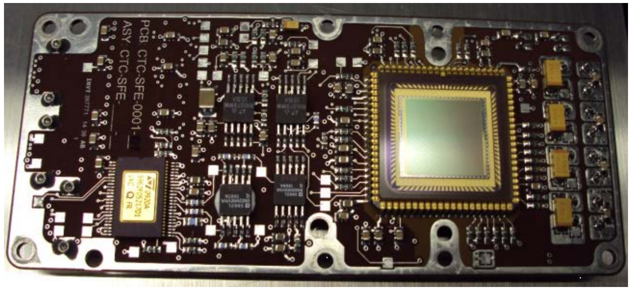
- Single photon sensors (PMTs, SiPMs)
- Low noise front end, DAQ and control
- FPGA based, USB interface



- Control and power distribution
- FPGA based
- Radiation tolerant

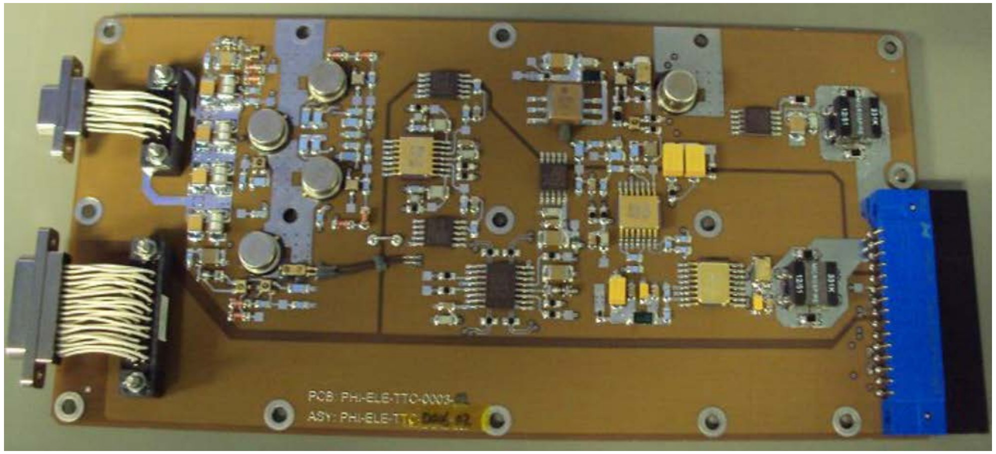
Solar Orbiter (ESA)

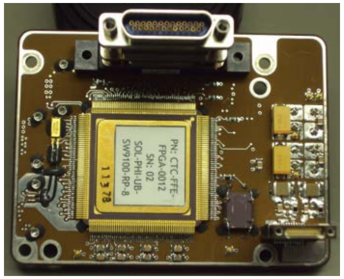
- Polarimetric and Helioseismic Imager of Solar Orbiter mission
- Image Stabilization System for SO/PHI, which includes:
  - Correlation Tracking Camera: based on STAR1000 sensor (1MPx)
  - Tip-Tilt Controller: that drives a Piezo-Electric TT Mirror
  - Firmware: Manages the ISS and stabilizes images using a Correlation Algorithm
- ISS has been made jointly with Sener and it is at TRL8 ("Flight Qualified")



CTC Sensor board

TTC board





CTC Control board

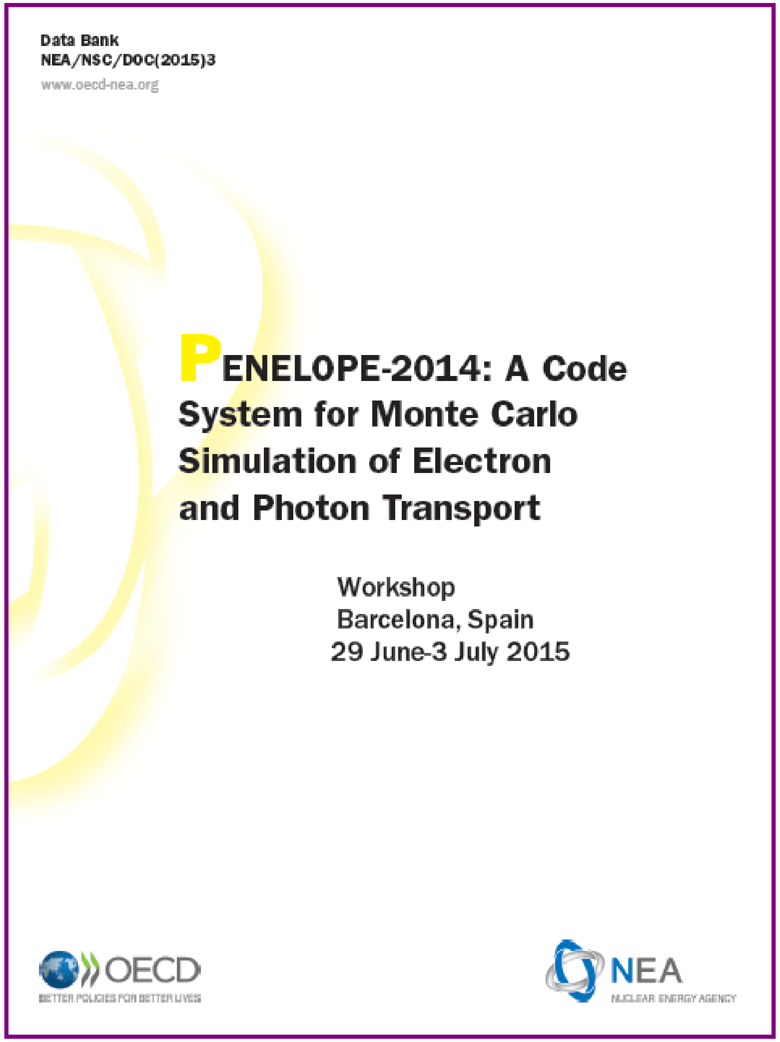
Monte Carlo: PENELOPE

F. Salvat, J.M. Fernández-Varea

PENELOPE (PENetration and Energy Loss of Positrons and Electrons, and photons)

Applications:
- Radiation metrology
- Dosimetry
- Detector design
- X-ray sources
- External radiotherapy
- Braquitherapy

Proton transport included recently as an extension


Data Bank
NEA/NSC/DOC(2015)3
www.oecd-nea.org

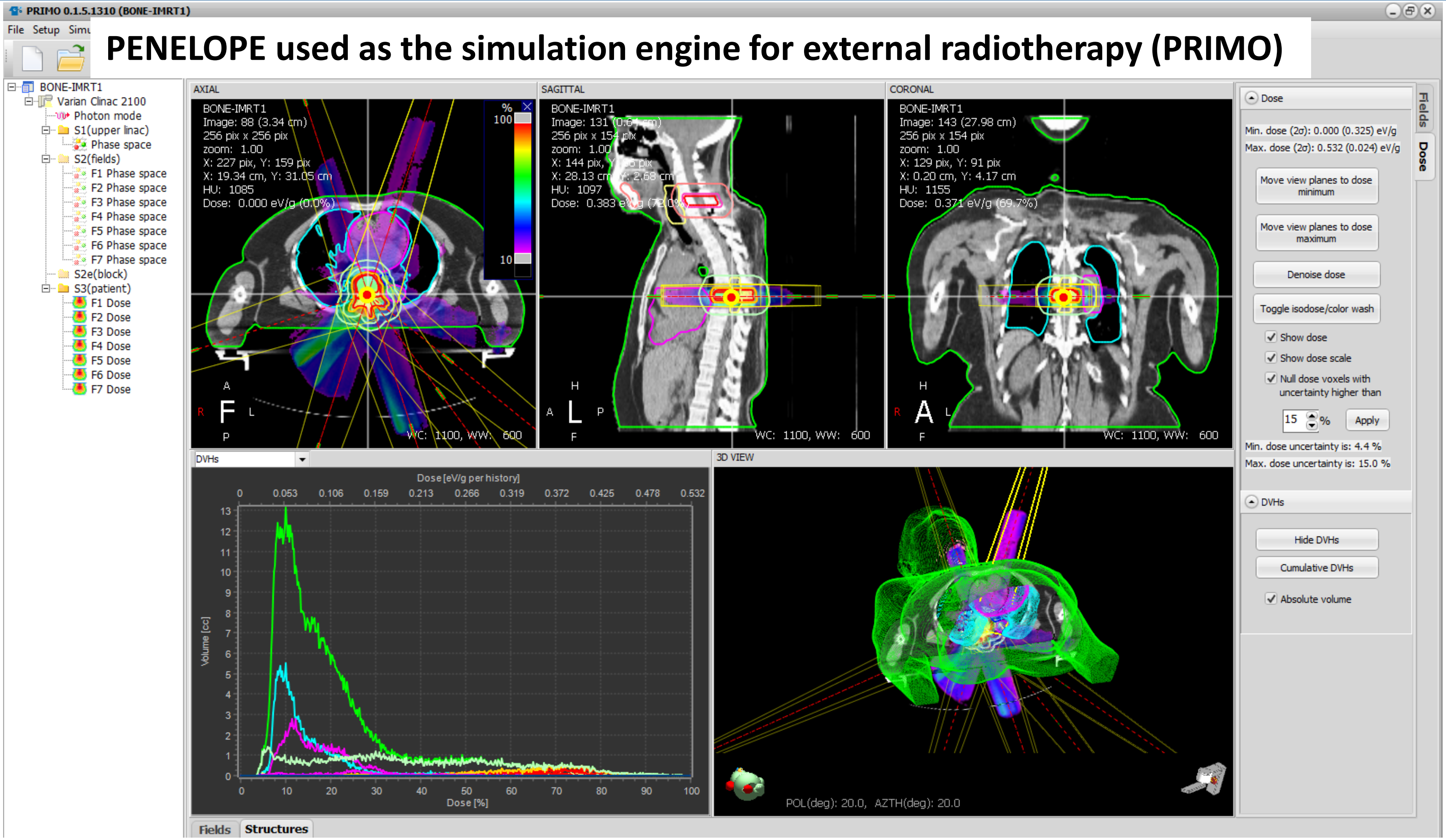
PENELOPE-2014: A Code System for Monte Carlo Simulation of Electron and Photon Transport

Workshop
Barcelona, Spain
29 June-3 July 2015

OECD
BETTER POLICIES FOR BETTER LIVES
NEA
NUCLEAR ENERGY AGENCY

Monte Carlo: PENELOPE

PENELOPE used as the simulation engine for external radiotherapy (PRIMO)



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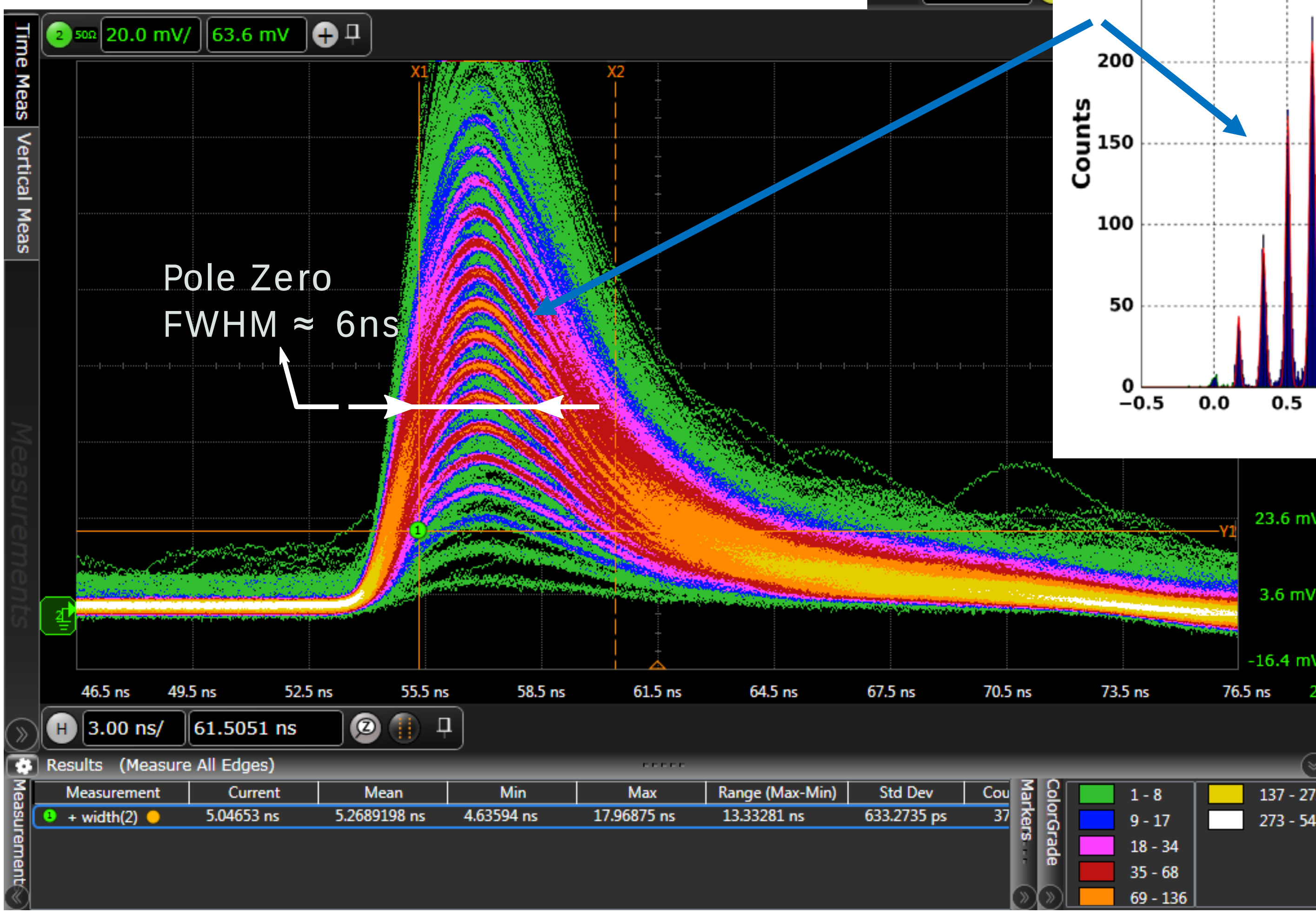
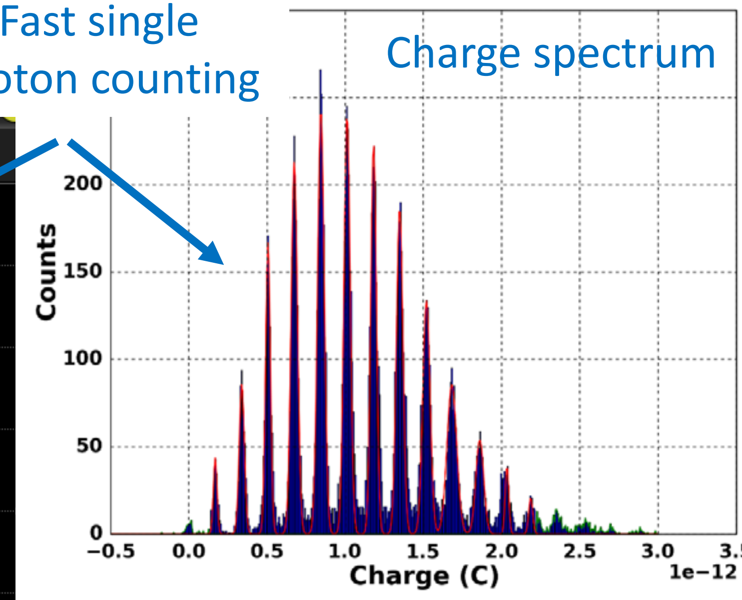
R&D: photon sensors and readout ASICs

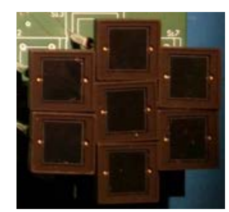
In many projects: single photon detection, low noise & high speed



Fast single photon counting



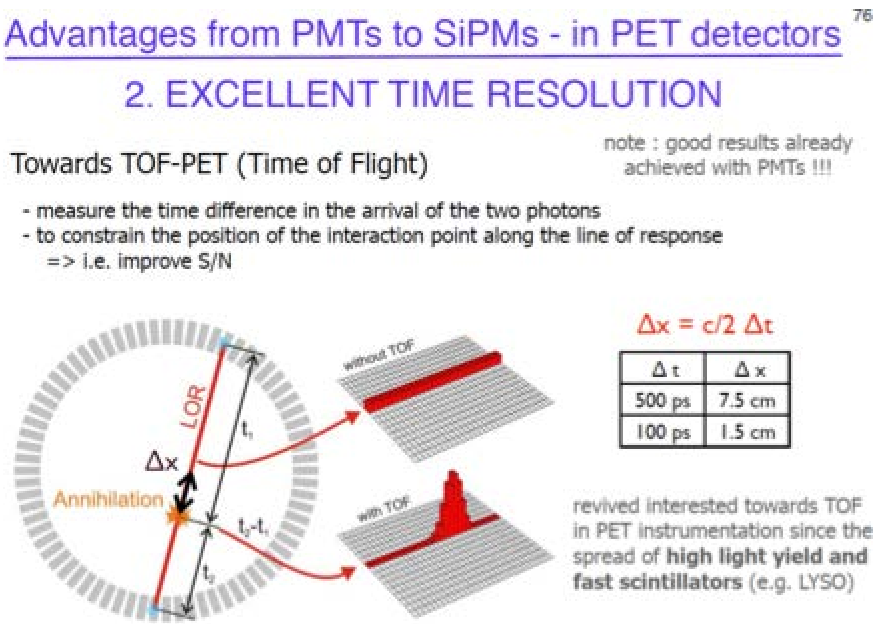
SiPM



PMTs

Knowledge Transfer

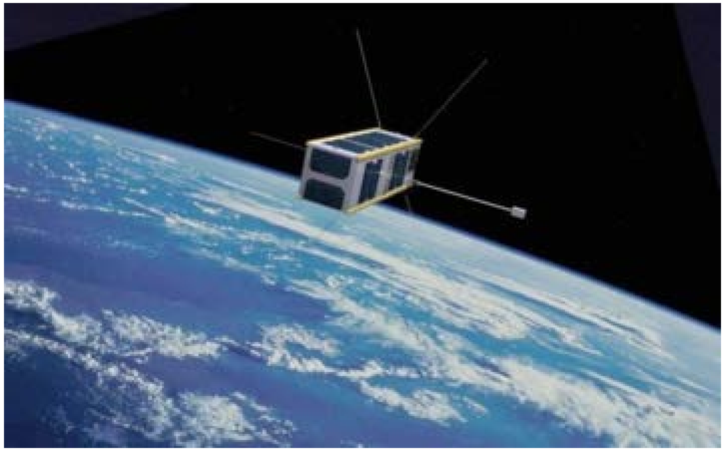
Medical applications:



- Family of ASICs originated form our contributions to LHCb and CTA RO electronics: FLEXTOT ….
- New research projects for new applications: fast light detection

Nanosatelites:

A transversal project of the IEEC (Institut d’Estudis Espacials de Catalunya: CSIC,UPC,UAB and UB).



ICCUB possible contribution:

- Electronics
- Control
- Data handling

Activities in Computing & Data Processing

- Main research groups:
  - Gaia/DPAC group of Barcelona:
    - Instrument and Galaxy models and simulations
    - Very large data processing and analysis for the Gaia mission
    - Data mining and visualization techniques
    - High-Performance Computing (HPC) and efficient database systems
    - Software engineering
  - DIRAC / cloud computing:
    - DIRAC is a resource management solution that was born as a necessity to manage LHCb computing,
    - But has grown to be fully integrated solution used by many other scientific communities.
  - High-performance data compression:
    - FAPEC entropy coder
    - Pre-processing (decorrelation) algorithms
    - Technology transfer: DAPCOM Data Services S.L.

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Thanks a lot for your attention !!!

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

IEEC

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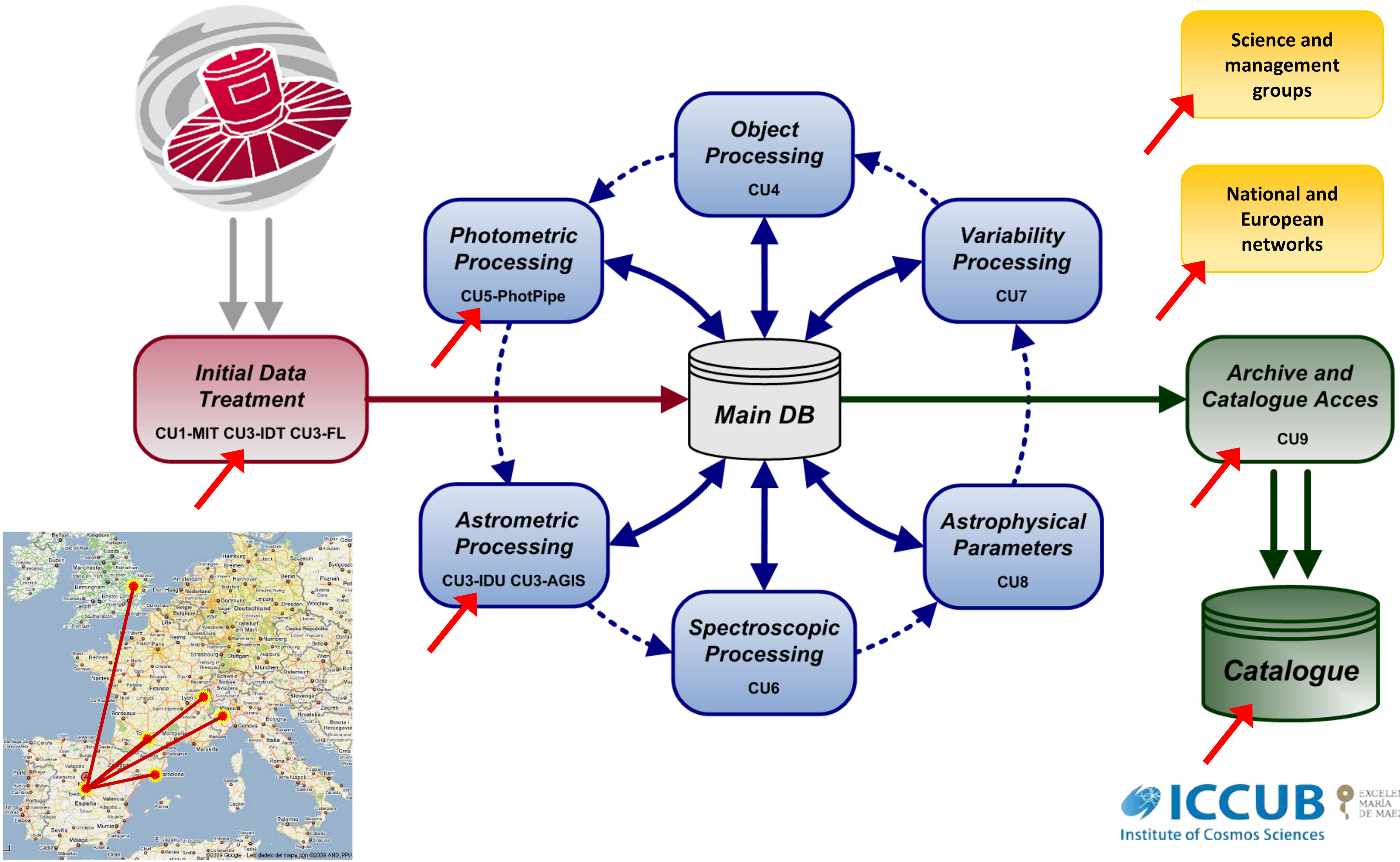
Computing & Data Processing: Gaia/DPAC

- Gaia Data Processing and Analysis Consortium (DPAC)



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Computing & Data Processing: DIRAC

DIRAC: Our painkiller

- DIRAC was created as a distributed data production and analysis system used by the LHCb experiment
- Includes workload and data management components
- The main goals are:
  - Ease access to computing resources to scientists
  - Minimize human intervention at sites
  - Provide a central place to enforce community policies
  - Add up resources to:
    - increase resource occupancy
    - Offer a higher amount of computing power to researchers

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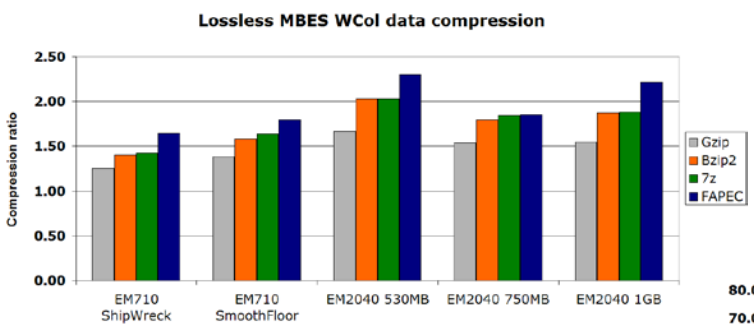
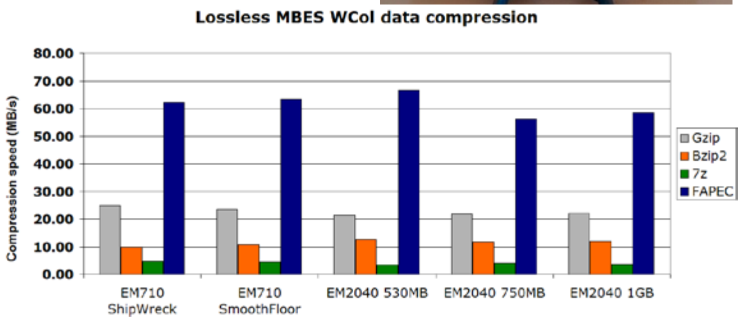
Computing & Data Processing: FAPEC

- High-performance data compression solution: FAPEC
  - Efficient entropy coder
  - Suite of pre-processing algorithms: instrumental data, images, text, genomics, watercolumn…
  - Fast, performant, resilient, secure
  - **Spin-off: DAPCOM Data Services S.L.**
  - Applications: nanosats, medicine, genomics, geosciences, physics, astronomy…
  - FPGA prototype in SpaceFibre board





FAPEC Compression

DAPCOM Data services

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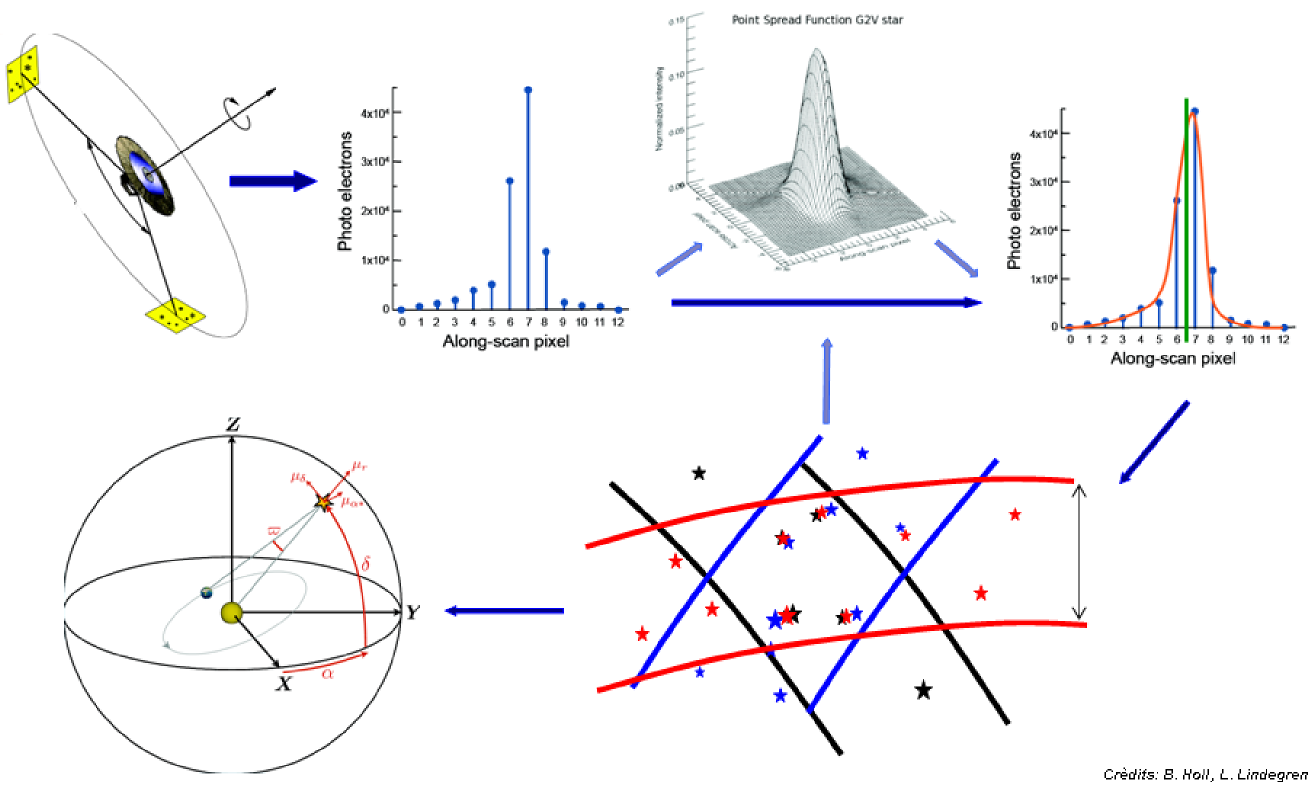
Computing & Data Processing: Gaia/DPAC

- Main ICCUB contributions and know-how:
  - Models: Instrument, calibration, Universe
  - Algorithms: Data processing
  - Techniques: Monitoring, validation, visualization, data mining
  - Engineering: Software (Java, Python, SQL, …)
  - Systems: Operation and monitoring



Crèdits: B. Holl, L. Lindegren

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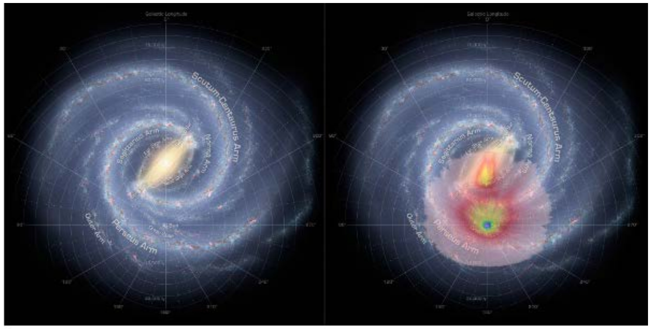
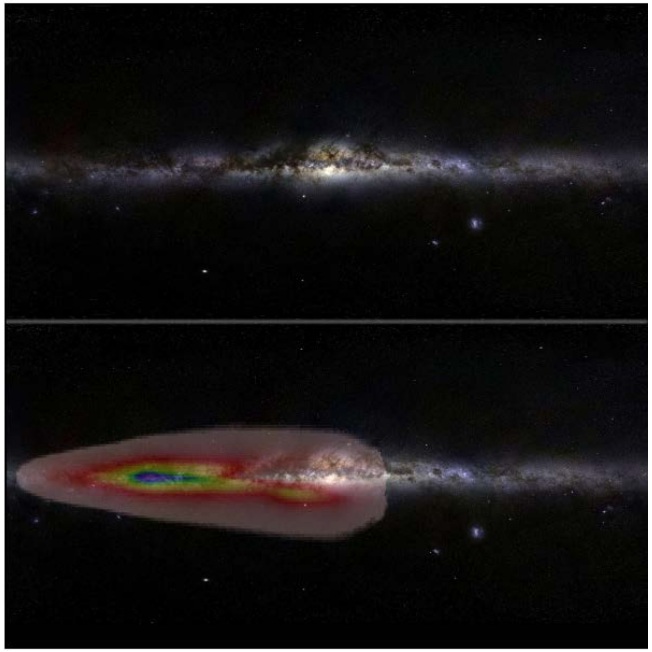
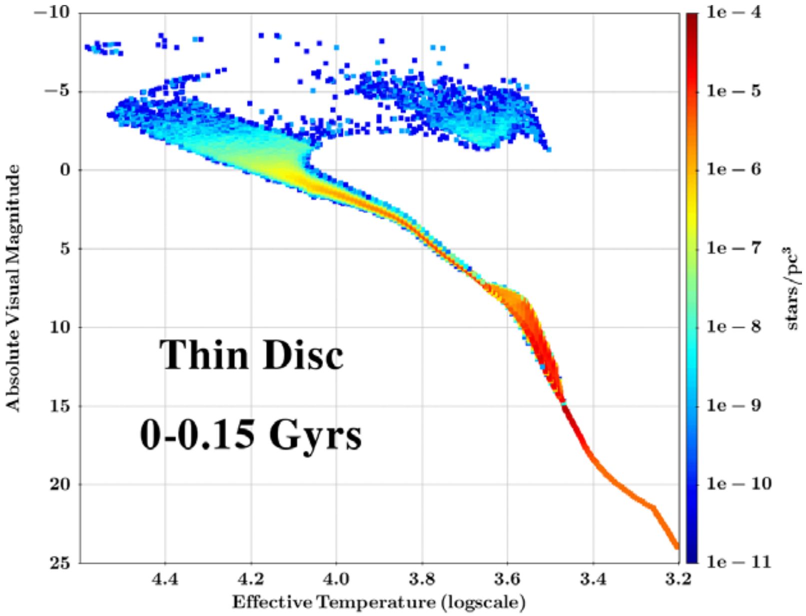
Computing & Data Processing: Gaia/DPAC

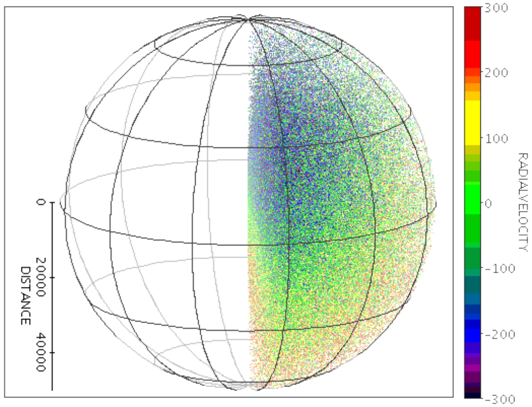
- Some example contributions:

  Gaia simulator: TBs of data generated (raw telemetry + sources + DB entries)





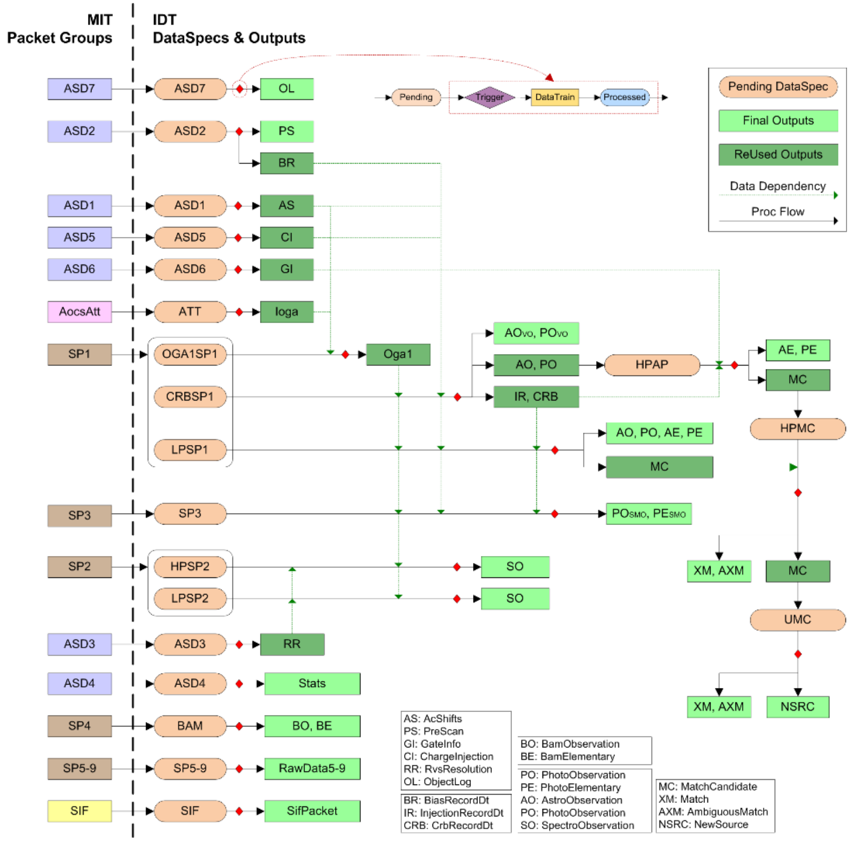


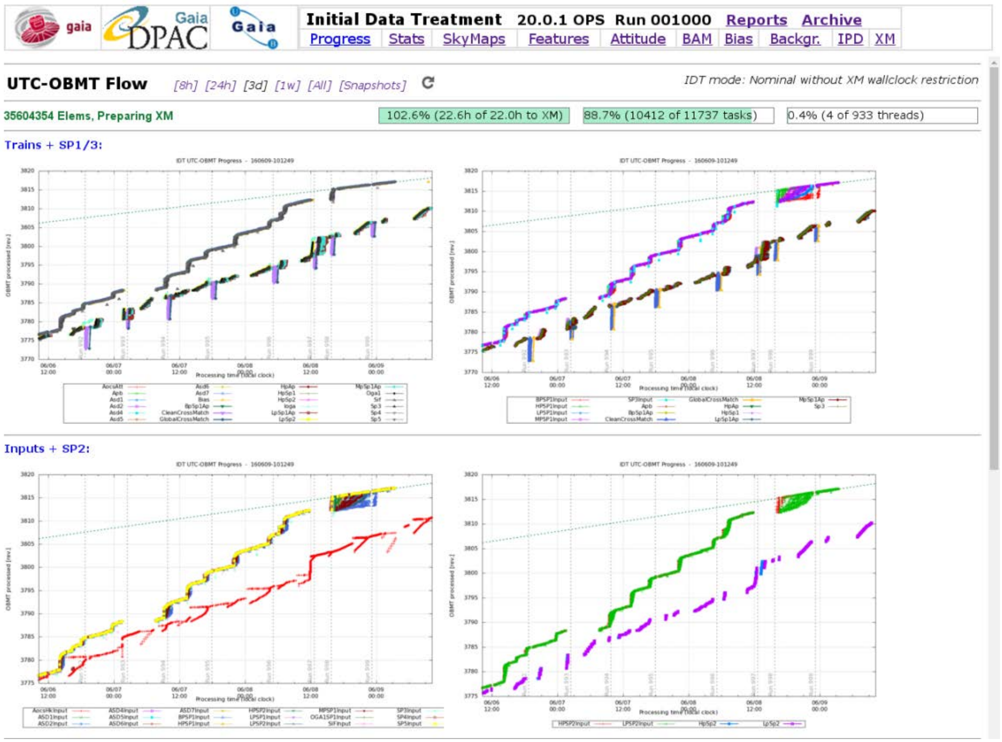


Computing & Data Processing: Gaia/DPAC

- Some example contributions:

  Initial Data Treatment: Overall system specification, framework design and implementation, algorithms integration and testing, monitoring and validation…





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Computing & Data Processing: Gaia/DPAC

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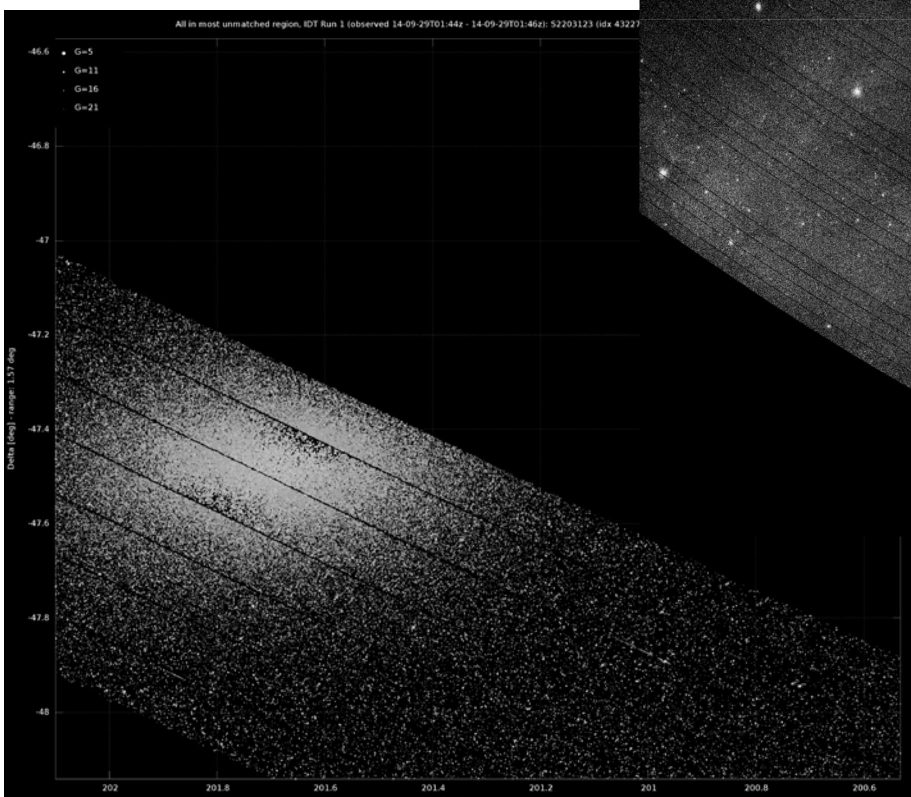

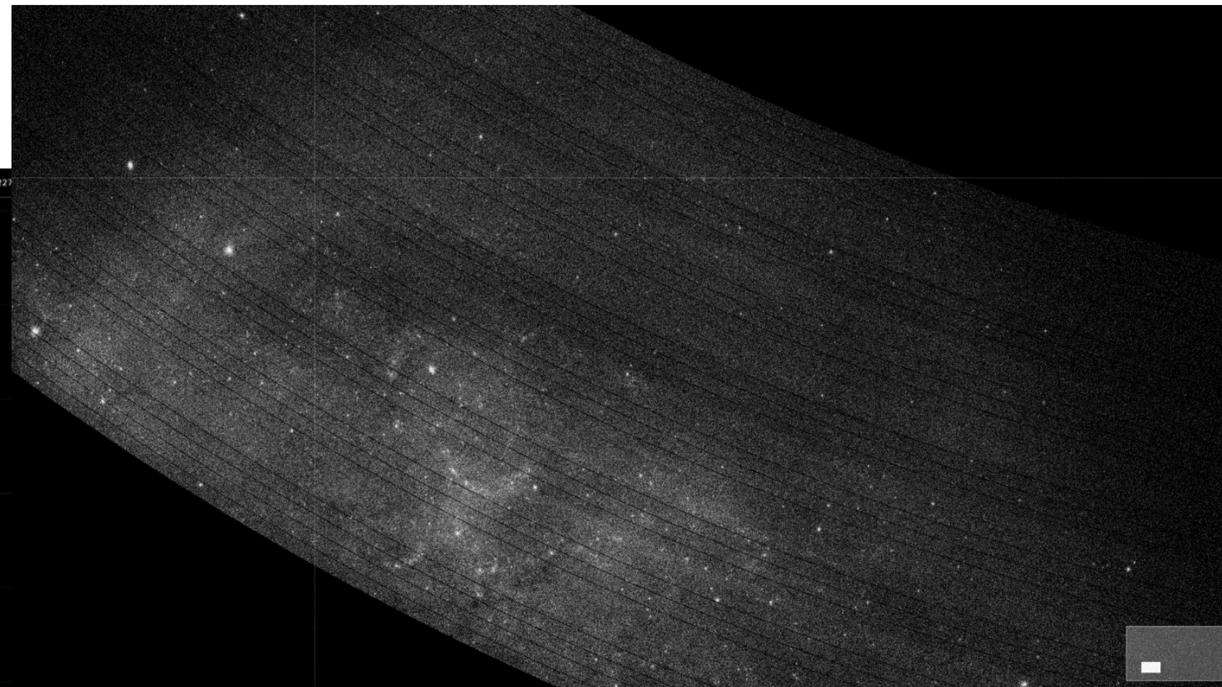

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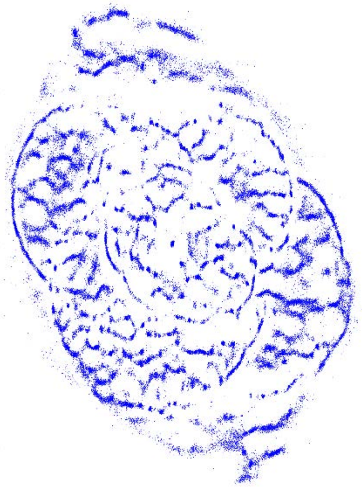
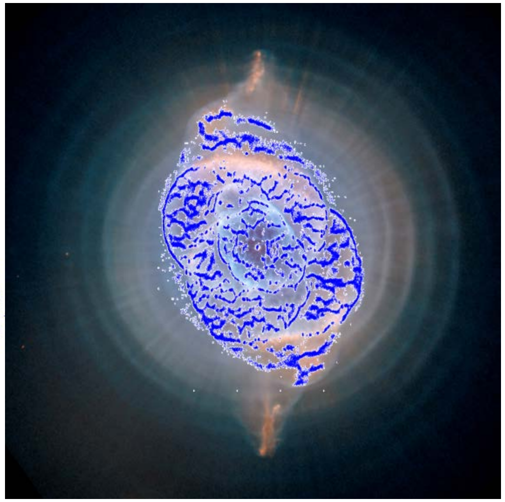
Computing & Data Processing: Gaia/DPAC

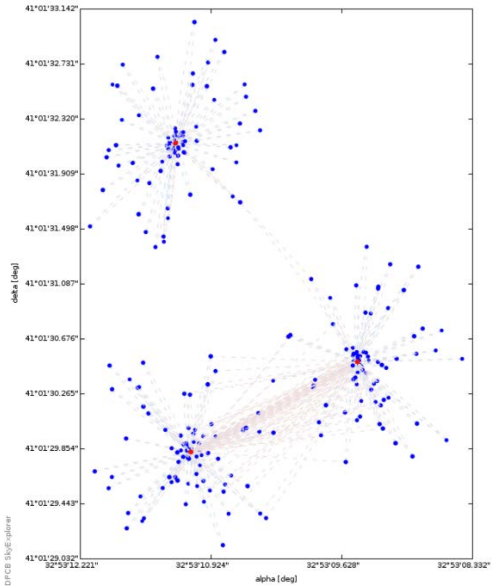
- Some example contributions:

  Intermediate Data Updating: Overall system specification, framework design and implementation, algorithms integration and testing, monitoring and validation…

  Main Cross-Matching algorithm: resolution of the main Gaia source list (clustering algorithm)







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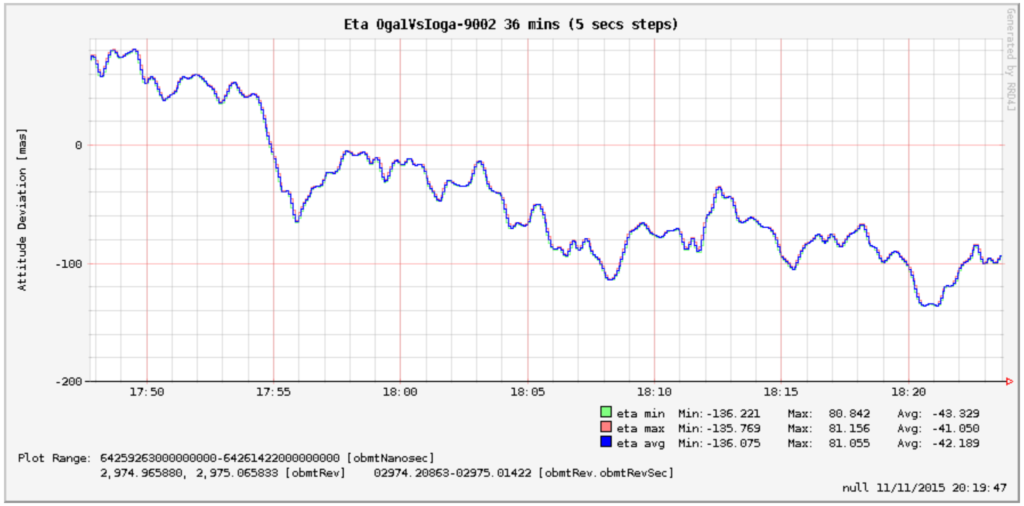
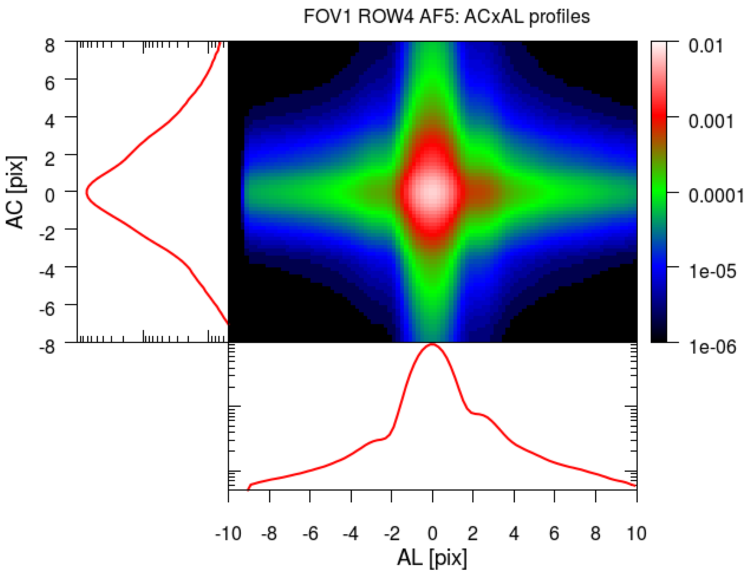
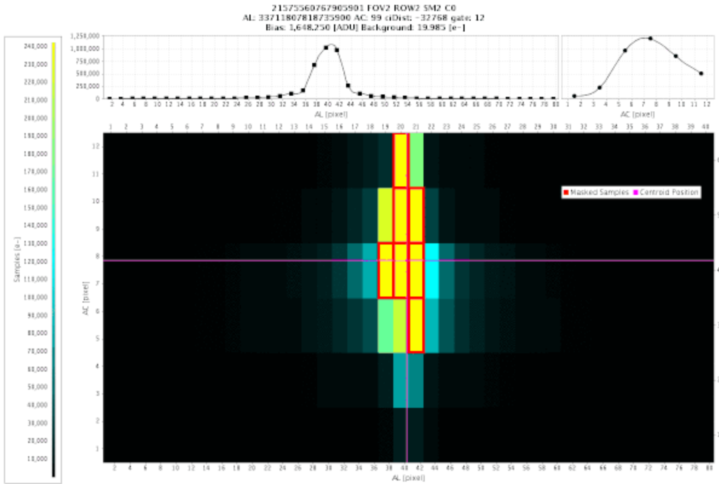
Computing & Data Processing: Gaia/DPAC

- Some example contributions:

  Algorithms: Satellite attitude reconstruction, photometric calibration and reduction, raw data reconstruction, …



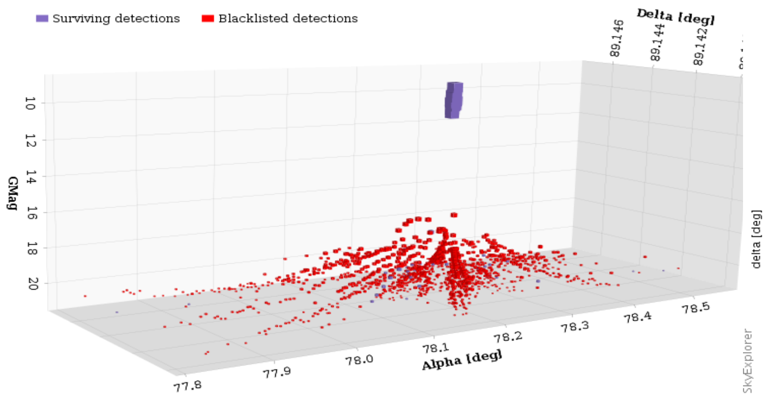


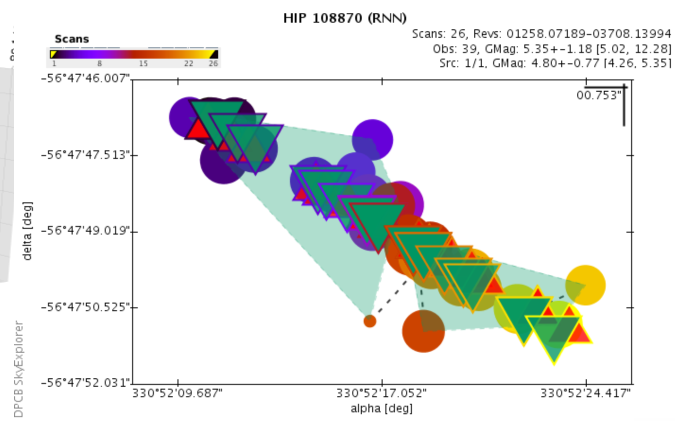


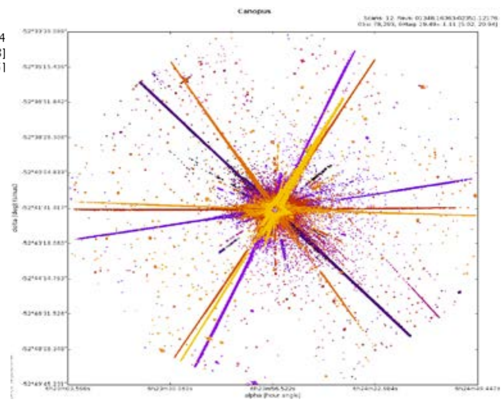
Computing & Data Processing: Gaia/DPAC

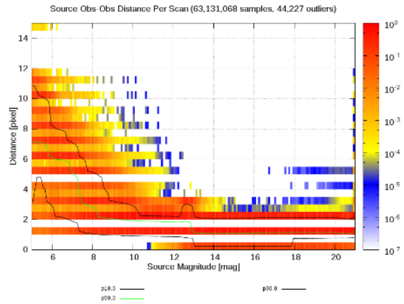
- Some example contributions:

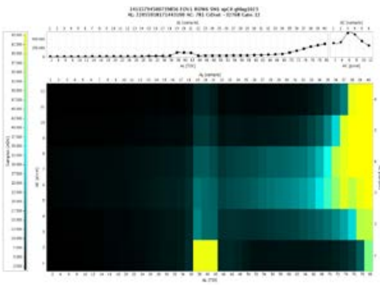
  Software Engineering: implementation and testing of data simulation, processing and monitoring; data mining; tailored data visualization tools; …

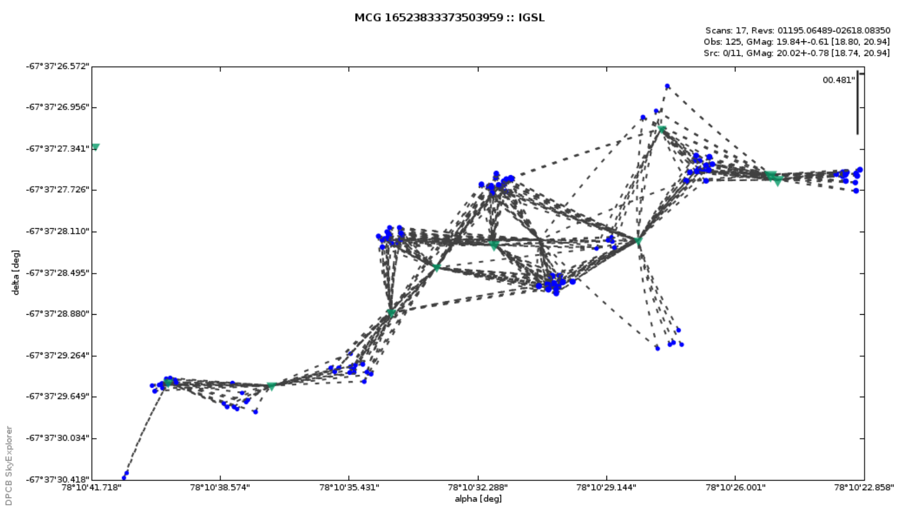


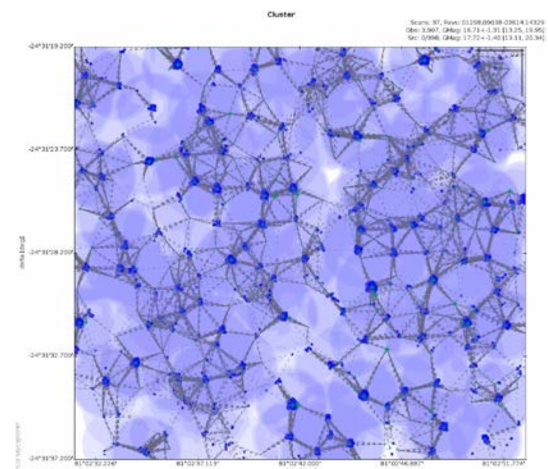












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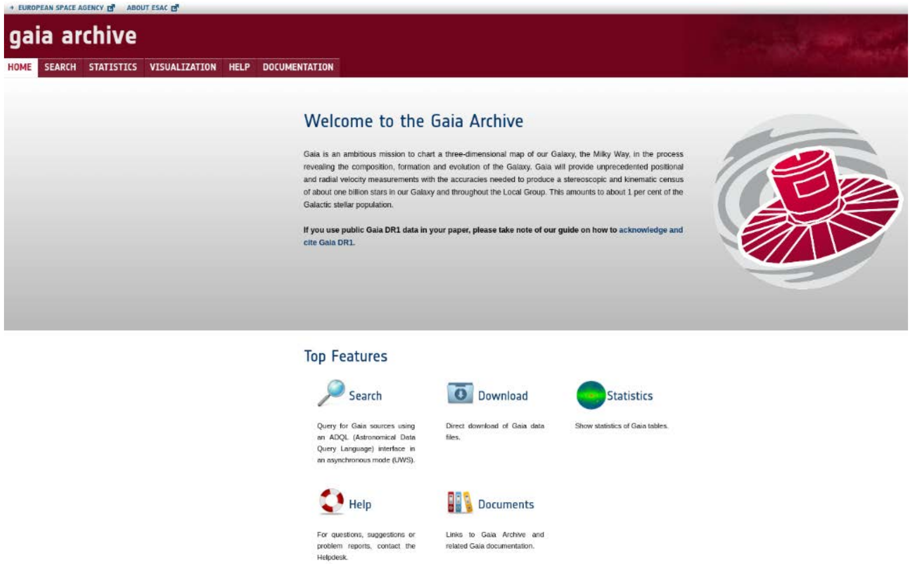
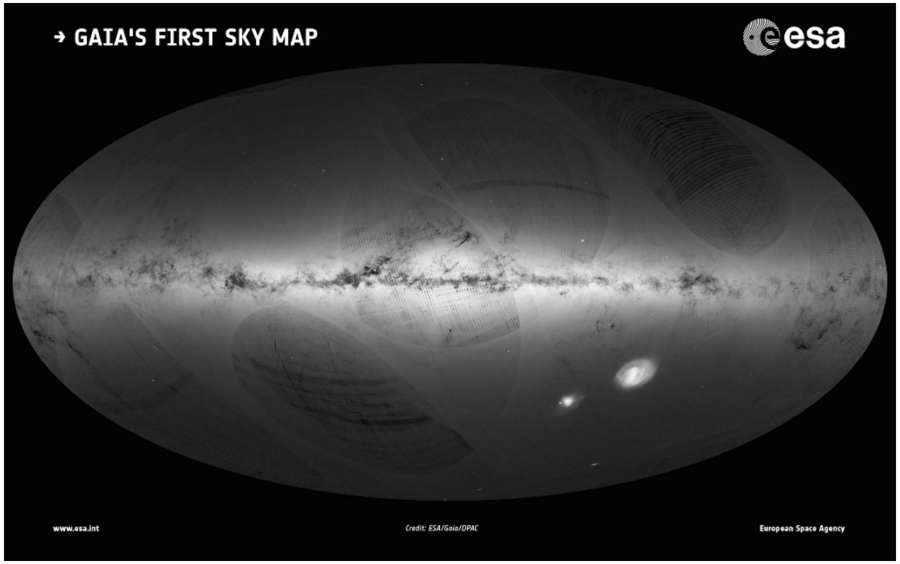
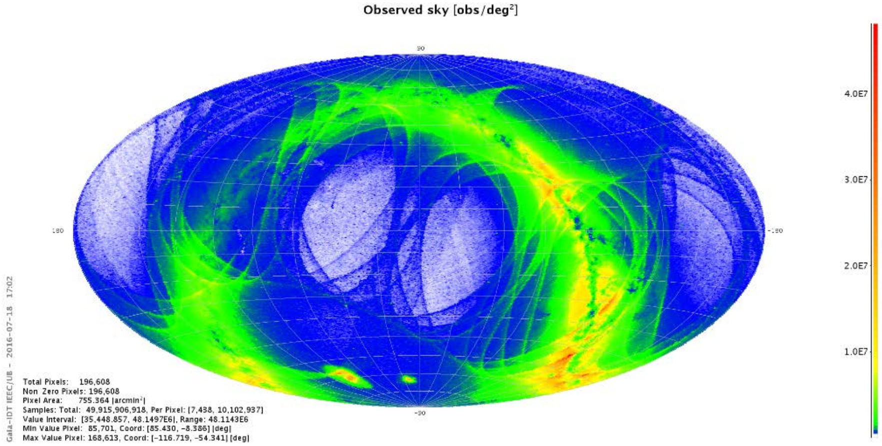
Computing & Data Processing: Gaia/DPAC

- Some example contributions:

  Gaia Archive: Validation and definition of the final Gaia Data Release contents







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Computing & Data Processing: Gaia/DPAC

- Some example contributions:

GENIUS FP7 606740 project: Gaia data mining and improved user services

Traditional technologies → not enough to cope with TBs of data
Big Data technologies ➔ unlock the full scientific potential of Gaia data

Gaia-UB team: Big Data platform to enable data analysis on the Gaia archive
GDAF (Gaia Data Analysis Framework)

Based on **Apache Spark** framework as Big Data engine
Hadoop distributed services for storing, scheduling and resource management

- Browse & query the archive in seconds (standard SQL, no relational DB)
- Compatible with Java, Python and Scala
- Data flow oriented
- Powerful Machine Learning tools

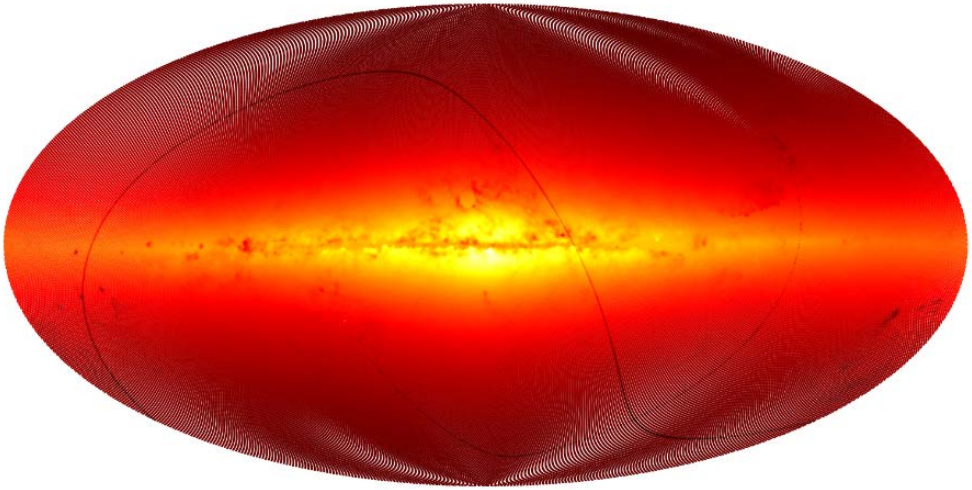
Computing & Data Processing: Gaia/DPAC

- Some example contributions:

  GENIUS FP7 606740 project: Gaia data mining and improved user services

Highly scalable:
Astronomical catalogues can be added to the framework alongside existing ones and equally accessed, enabling **huge cross-match** tasks.

In **10 minutes**, a **full-sky** density map can be computed using about 40 lines of code (Scala and Python):



Goal of the platform:
Astronomers to use it as a tool to execute tasks on the data themselves.
Test platform available as Virtual Machine image with miniaturized version of GDAF.

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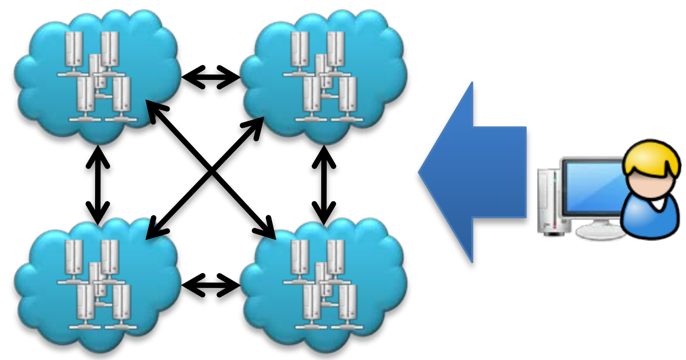
DIRAC origins (LHCb)

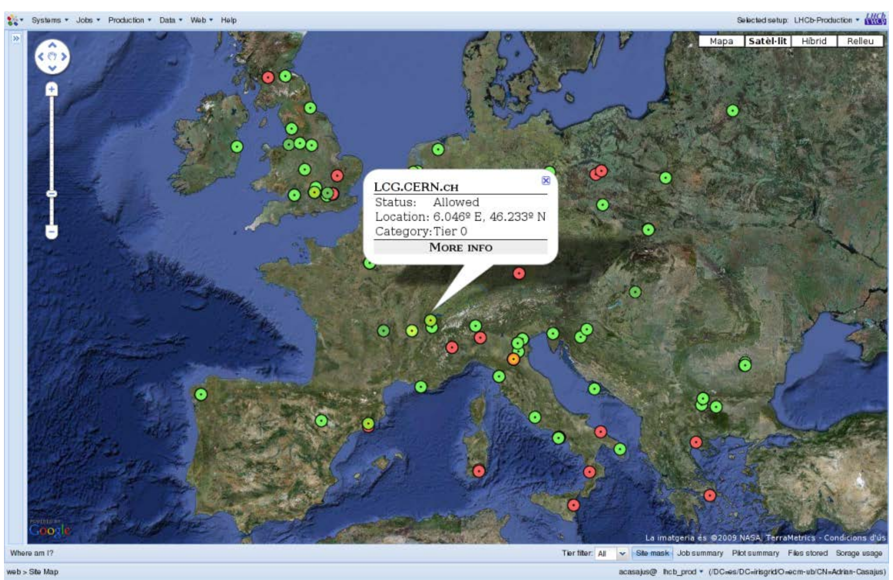
- LHCb is an experiment built on the LHC at CERN
- LHCb generates ~2 PBs of RAW data each year
  - All the LHC experiments will generate roughly 15PBs annually
    - Even more after the LHC upgrade!
- Lots of data to analyze…
- Huge computing facility required
  - WLCG

Computing & Data Processing: DIRAC

What's the WLCG?

GRID: Combination of computer resources from multiple domains applied to a common task





~10^6 processors
170 sites
34 countries

Computing & Data Processing: DIRAC

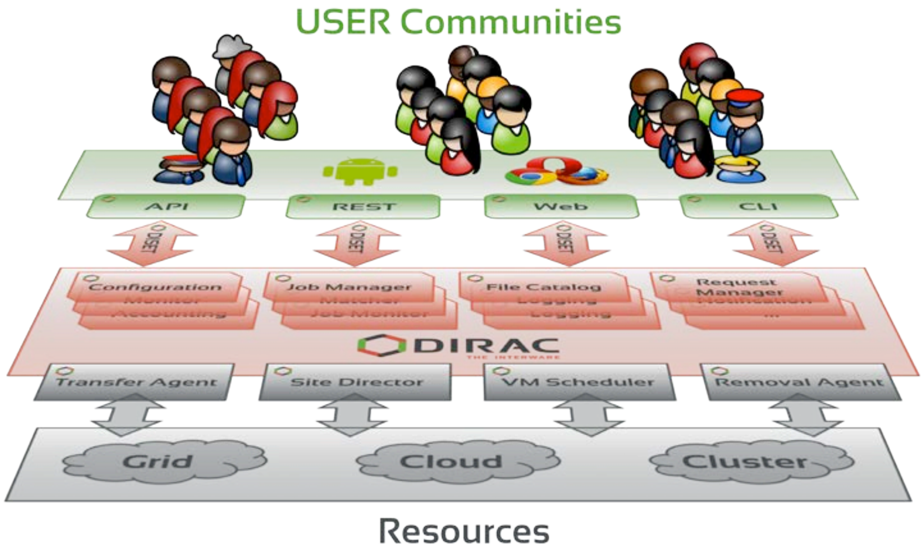
Large community issues

- Dealing with heterogeneous resources
  - Various computing clusters, grids, etc (yandex…)
- Dealing with the intracommunity workload management
  - User group quotas and priorities
  - Priorities of different activities
- Dealing with a variety of applications
  - Massive data productions
  - Individual user applications, etc
- Most of the users are not tech-savvy

Computing & Data Processing: DIRAC

What does it do?

Integrates all the heterogeneous computing resources available to a community under an homogeneous hood

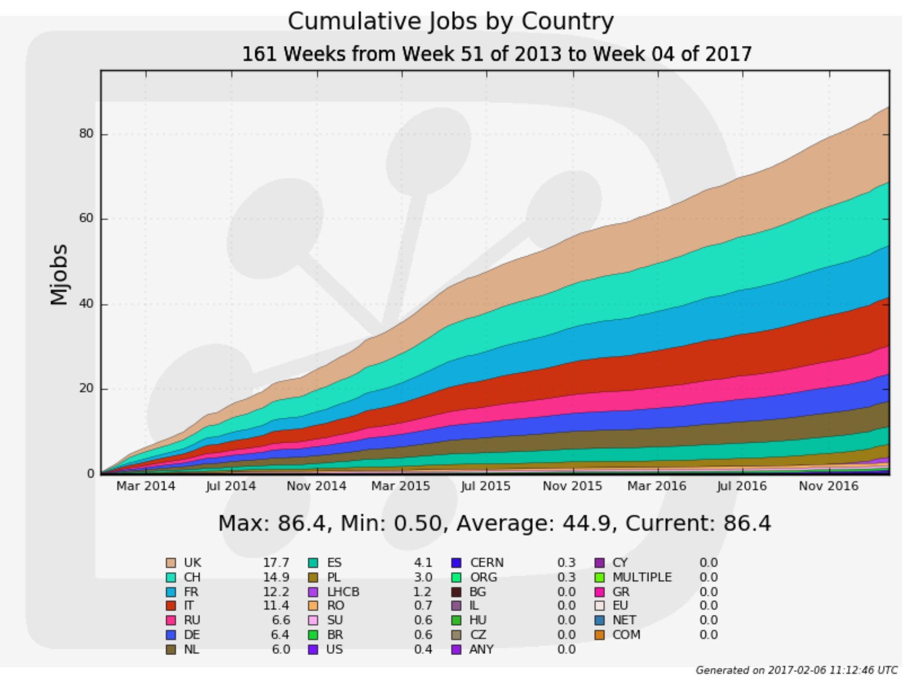


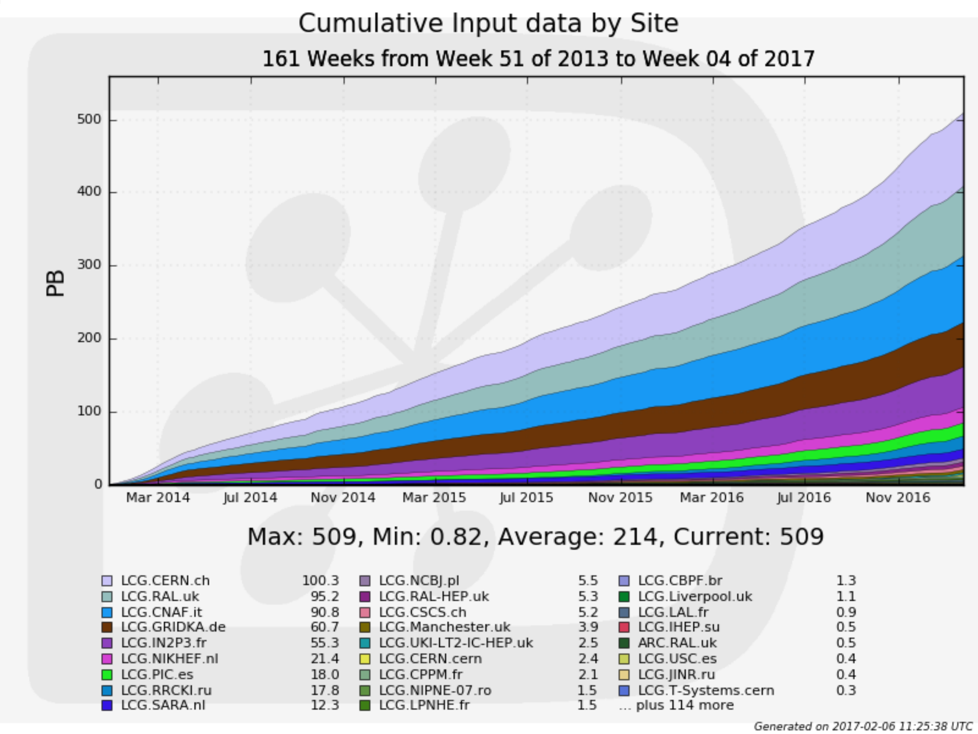
- Allows a community to define activities that will be executed automatically and enforce policies, quotas and priorities upon users
  - Without sites intervention

Computing & Data Processing: DIRAC

LHCb statistics

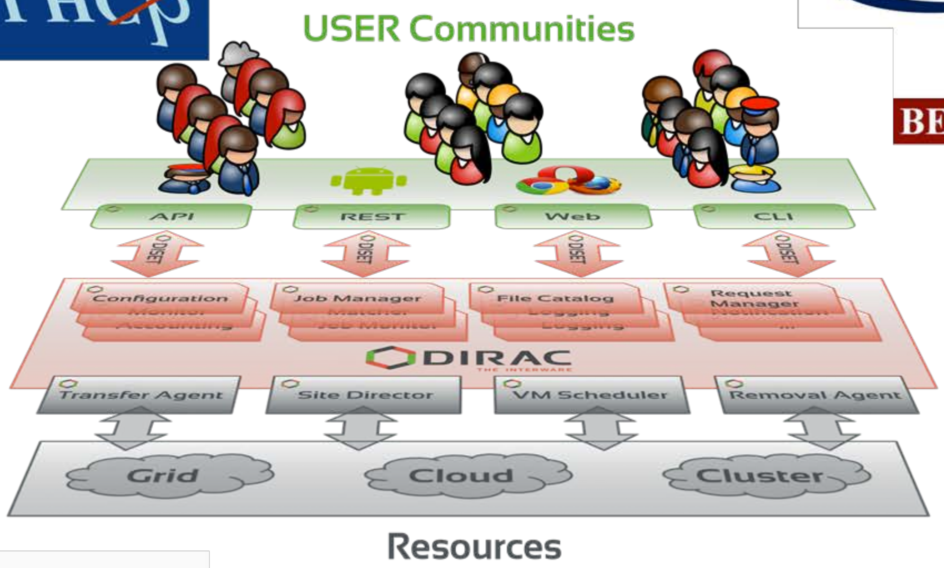
In 2014-2017 DIRAC managed more than 80M jobs in 23 countries that processed +500PB of data





Computing & Data Processing: DIRAC

Current actors



LHCb/WLCG
Clouds
EGI Fedcloud
FG Clouds

7

The origin of SiUB

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rf.el.ub.es

Research

Particle and nculear physics, astrophysics, space

RF, communications and EMC

Analog & Mixed Signal Design

Bioelectronics and harvesting (D2in)

www.ibecbarcelona.eu

Service

siub.ub.edu

ASICs, FPGA, PCB, control systems, etc