Preparing our future instruments

Astroparticle and cosmology experiments

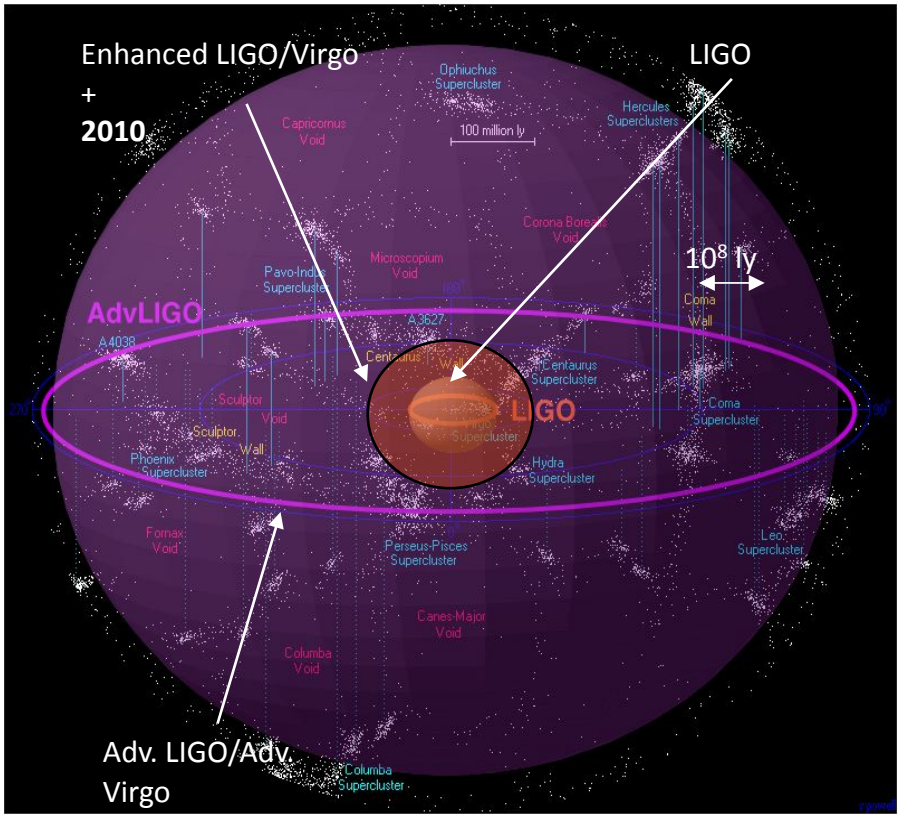
Projets and R&D in astropaticle and cosmology

New projects under development to explore the origin of the mass, the origin of dark matter and dark energy:

- Gravitational waves
  - Advanced Virgo: From the first detection to gravitationnal astrophysics
- Cosmology:
  - LSST: Dark Energy and Dark Matter in the universe
  - NIKA: Preparation of the future CMB space mission.
- Identifying Dark Matter:
  - Mimac: Direct Detection.
  - CTA: High energy gamma-ray, Dark matter indirect search

Advanced Virgo

- Advanced Virgo will improve on initial Virgo by a factor of 10 in sensitivity
- Neutron stars coalescence
  - 1 000 galaxies in Virgo range. ~1/century
  - 1 000 000 galaxies in AdVirgo range. ~10/year
- black holes coalescence:
  - up to 1 Gpc

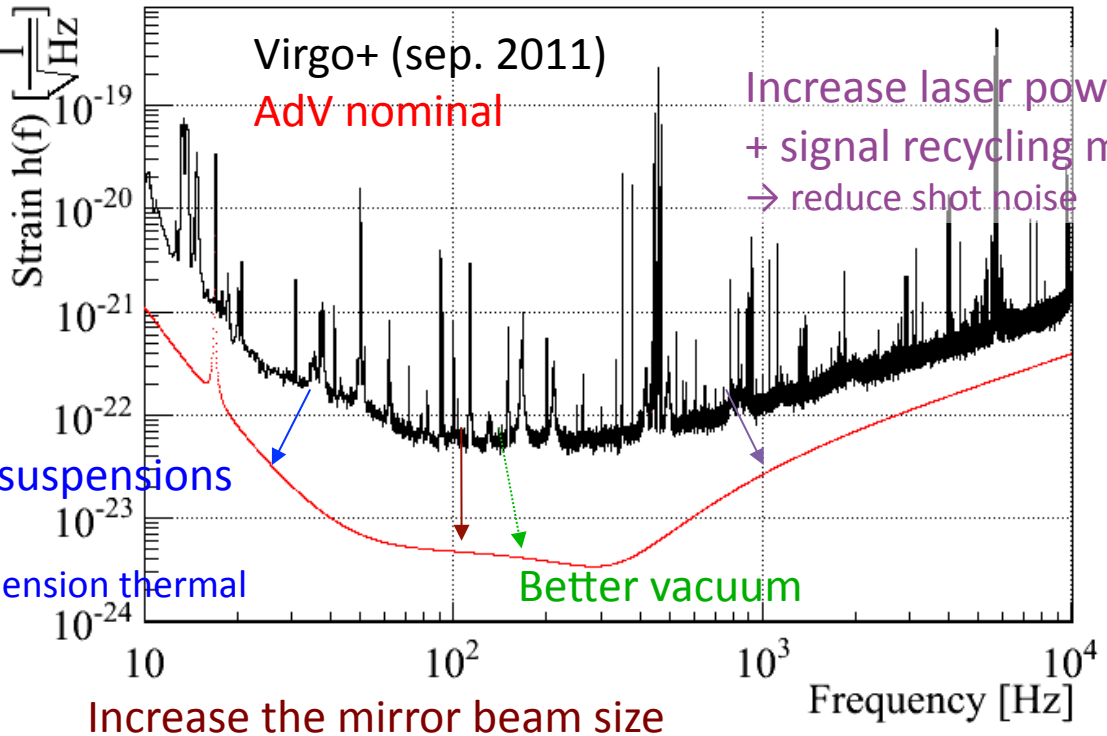


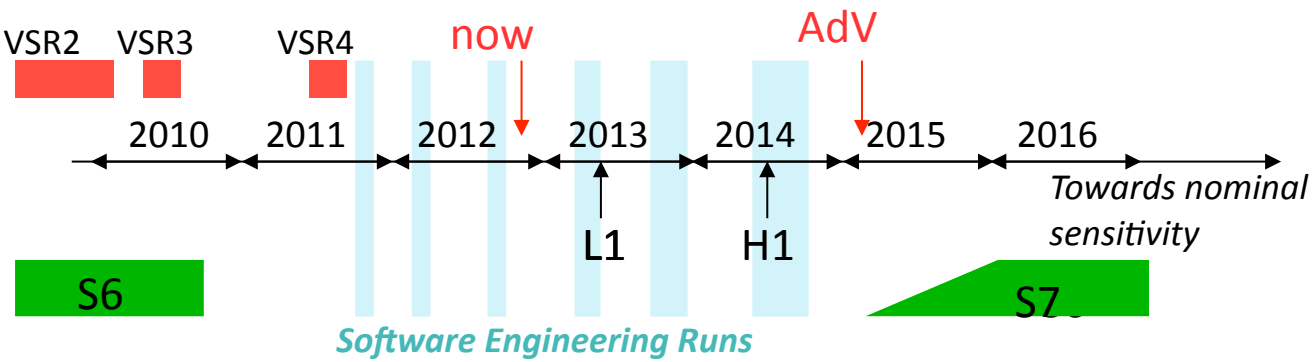
Credit: R.Powell, B.Berger

→ Likely detections:

Beginning of gravitationnal wave astrophysics 2015-2020

The main challenges of Advanced Virgo

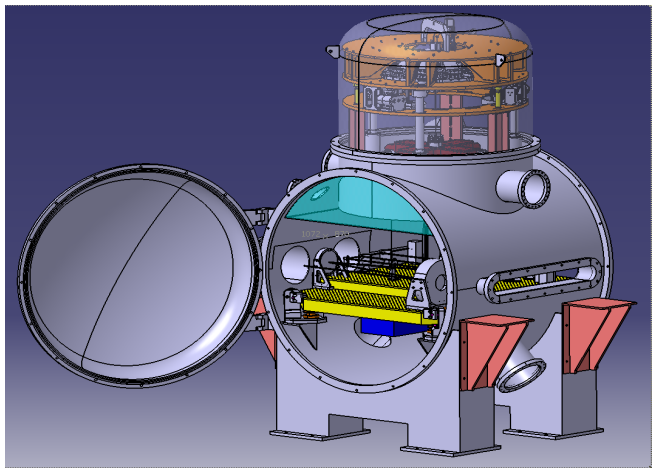


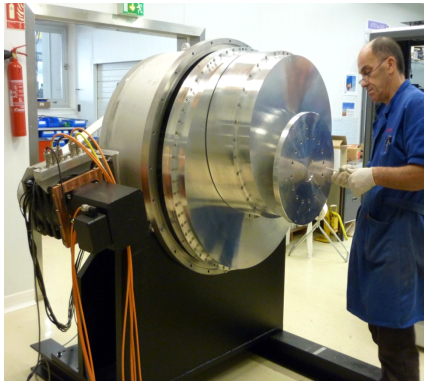


Tight schedule,
to be running with
LIGO in 2015 – 2016

Advanced Virgo @ LAPP

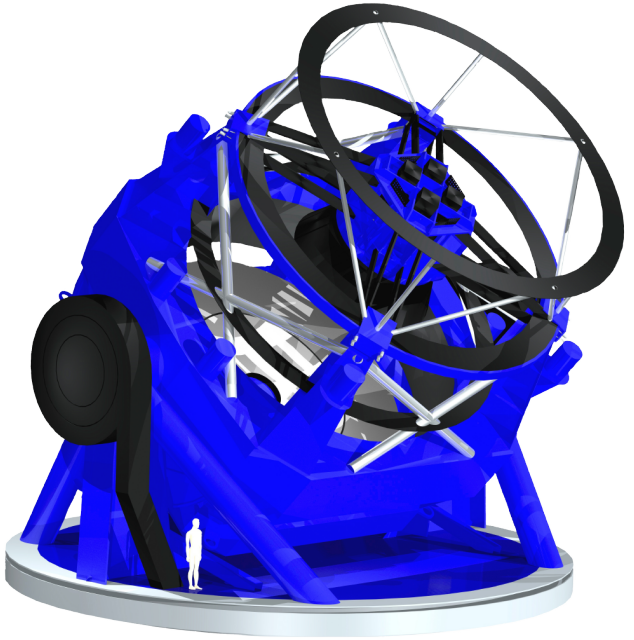
- Design of new optical benches and new « mini-towers ».
- Improvement of mirror quality: robot for corrective coating.
- Modification of the sensing of the lasers beams (Photodiodes and pre-amplification, beam filtering, Cameras for beam imaging/position control)
- Acquisition/digitization of the data for the Virgo control
  - Camera box and visualization software
  - DAQ box
  - Improvement of the ADC boards
  - Data acquisition, electronics and software for VIRGO control

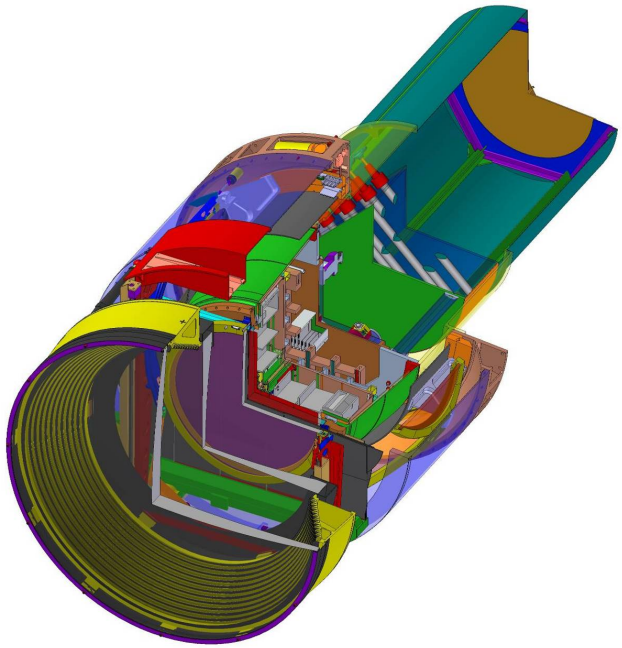




Large Synoptic Survey Telescope (LSST)

- LSST will produce a 6-band (0.3-1.1 micron) wide-field deep astronomical survey of the southern sky.
- Location: Northern Chile (Cerro Pachon)
- Wide range of scientific goals: Nature of dark energy, dark matter mapping, galaxy structure, solar system…



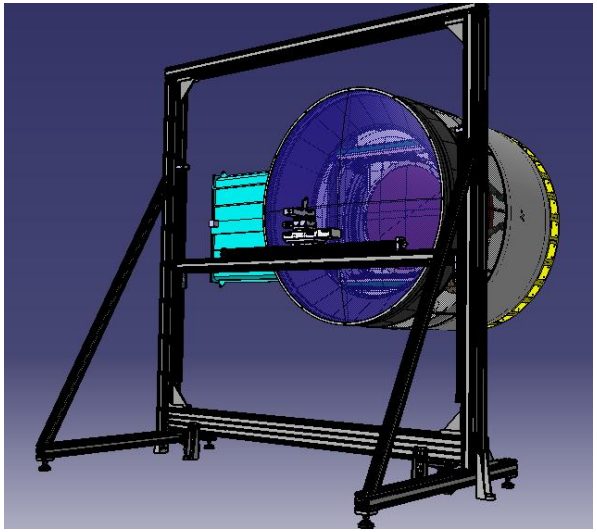


- 8.4-meter telescope with a special three-mirror design, creating an exceptionally wide field of view.
- LSST camera: largest digital camera ever constructed : diameter 64 cm, 3.2 Gigapixel
- Planning: 1st light in 2020, 10 years of observation

LSST@LPSC

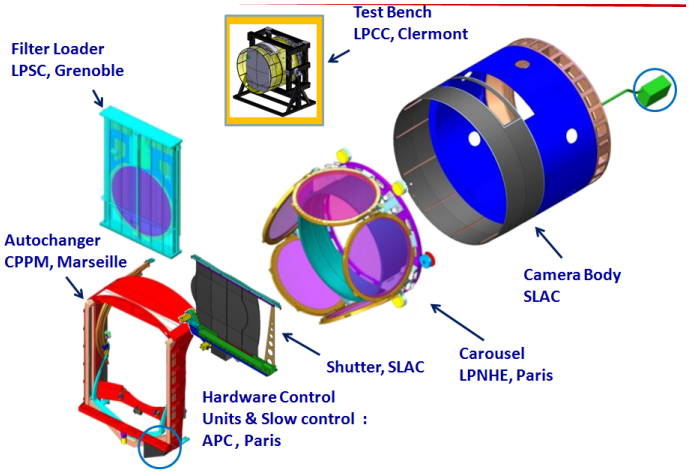
- LSST Camera calibration:
  - Camera FP response at 0.5% (relative)
  - Complex system (CCD, Lens, filter)

  —> Camera Calibration optical bench (CCOB):
    - First light for the LSST camera,
    - Calibrate the FP response,
    - Commissioning of the camera.

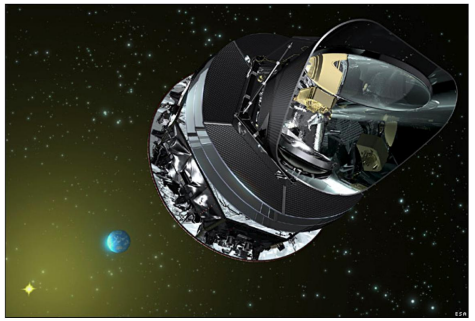


Mechanics, light sources, optics, control/positioning system, electronics, software under development

- LSST Filter loader.
  - Design and study of the system used to load the 5 LSST filters in the carrousel.

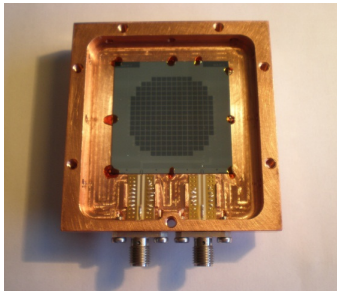


NIKA



- Planck mission: first cosmological results to be released soon
  - CMB temperature & polarization maps
- NIKA project:
  - Polarization: Improve the sensitivity
  - Temperature: Improve the resolution

    → Need to increase the density of detectors in the focal plane:

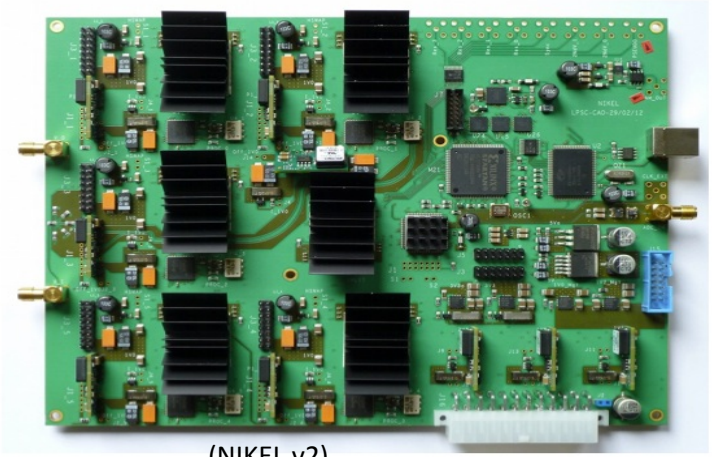


Individual detector (bolometer) → Arrays of detectors: Kinetic Inductance Detectors (KIDs) (Supraconductor microwave resonator)

- NIKA Science goals:
  - To be installed on the 30-meter IRAM telescope (Pico Veleta – Granada) : millimeter astrophysics and Sunyaev-Zeldovich effect studies.
  - Preparation of the future CMB space mission generation (CORE,…)

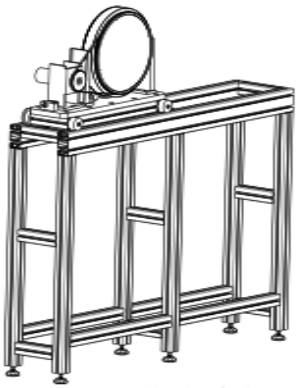
NIKA

- Technological challenges:
  - Array of +1000 detectors: building process.
  - Design of a full system (optic + KIDs + electronics) very sensitive to the temperature and polarization.
  - Electronic: Need for high level of multiplexing



(NIKEL v2)

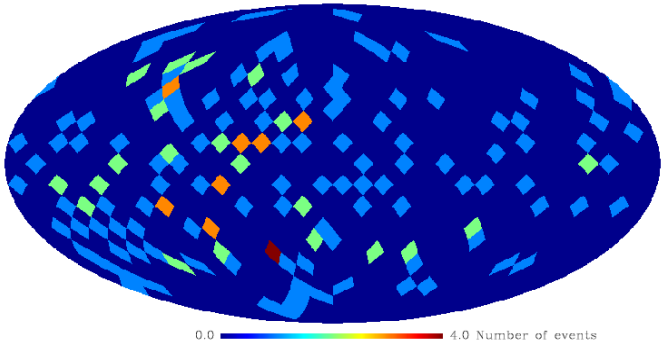
- NIKA@LPSC
  - Electronics (HF, multiplexing, digitization)
  - Polarization (quarter-wave plate, rotation system, test bench)

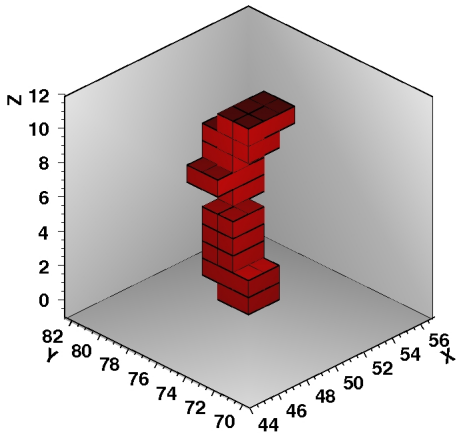


Mimac (MIcro-tpc MAtrix of Chambers)

- Dark Matter directional detector
  - Direction (3D) and energy of the nuclear recoil produced by elastic scattering of WIMPs.
    → The ultimate signature:
  - Signal pointing to the Cygnus constellation
- Strategy:
  - Matrix of micro-TPC (~50 mbar)
  - Energy (ionization) and 3D track
  - Multi-target (^{1}H, ^{19}F, …)
  - Axial Interaction (spin-spin) and scalar
  - ^{4}He, CH_4, C_4H_{10}, CF_4 has been tested !

A map in galactic coordinates of events

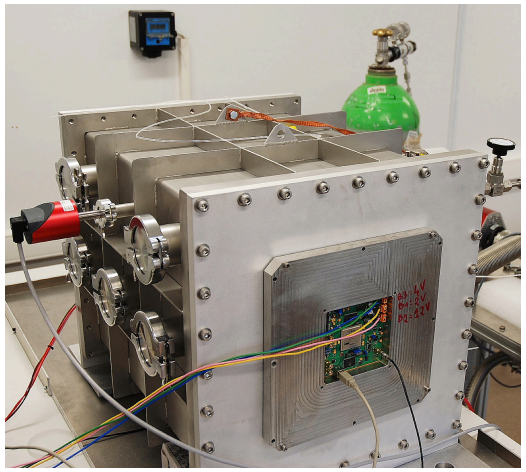


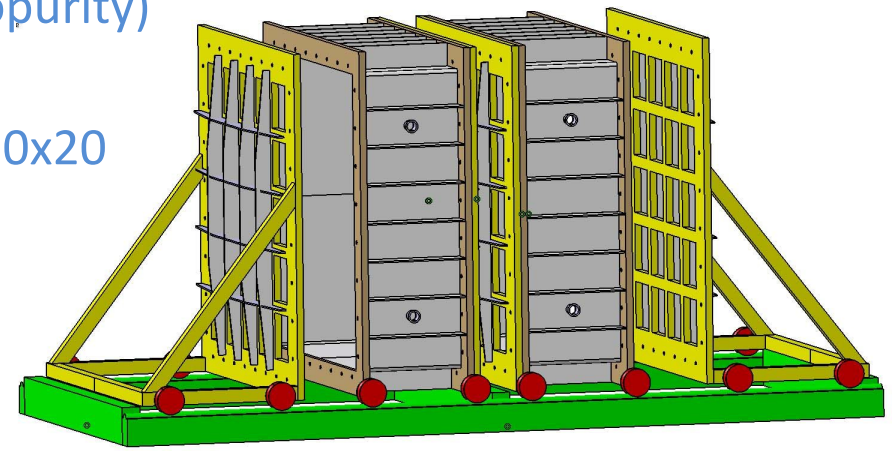


Recoil ^{19}F (measured)
(E_{ion}~40 keV) 50 mbar CF4 + CHF3 (30%)

Mimac

- Prototype installed at Modane – Fréjus (France) in June 2012
  - Bi-chamber 5 l: 2x (10x10x25 cm^3)
  - Working at 50 mbar (CF_4 + 30% CHF_3) in a permanent circulating mode since June
- MIMAC – 1m^3: 50 bi-chambers
  - Mechanics: Light and clean (radiopurity) materials.
  - Detector: new development for 20x20 cm^2 anode.
  - Electronics:
    - new 1000 channels board.
    - DAQ
    - Monitoring/Control

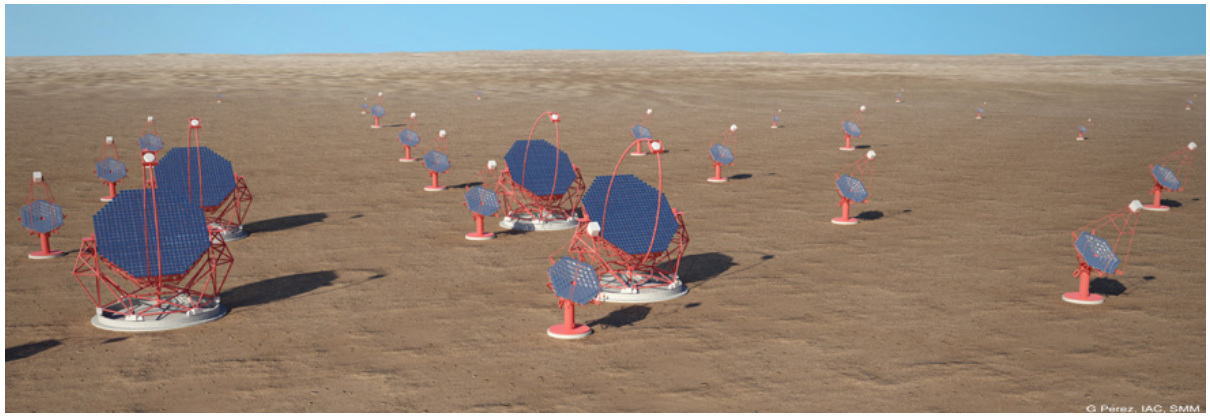




MIMAC – 1 m^3

Cherenkov Telescope Array (CTA)

- Next generation ground-based very high energy gamma-ray instrument.
- Array of many tens of telescopes of different sizes (4 m – 23 m):

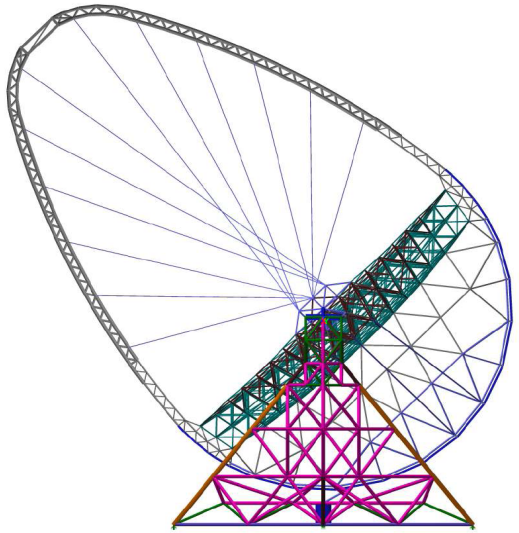


  - Factor of 5-10 improvement in sensitivity
  - Extension of the accessible energy range from well below 100 GeV to above 100 TeV.
  - Improved angular resolution.

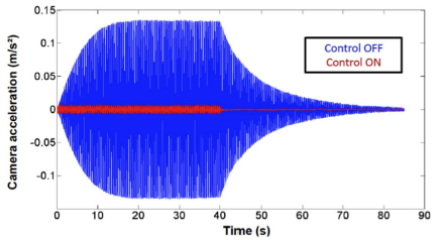
→ Large discovery potential in key areas of astronomy, astrophysics and fundamental physics research: origin of cosmic rays, dark matter search….

CTA @ LAPP: Mechanics and control

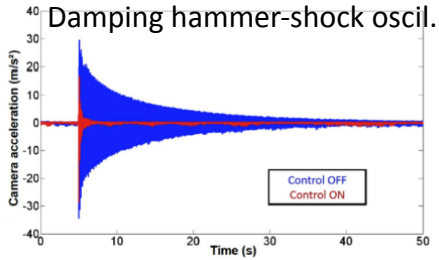
- Design of the upper part of the Large Size Telescopes (LST, 23 m):
  - Camera masts (“Arch”) and camera frame R&D: Hybrid discrete components (tubes) in Carbon Fibers.
  - Active camera damping and control system: stabilizing the camera at <10 mm for an LST moving at 10m/s.
    - Mock-up prototype (Done !).
    - Real size design study.

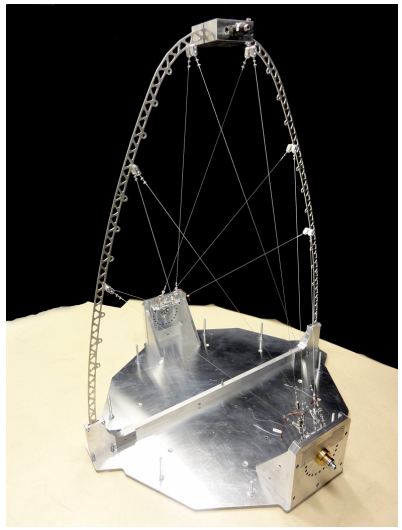


Damping sinusoidal oscillation



Damping hammer-shock oscil.





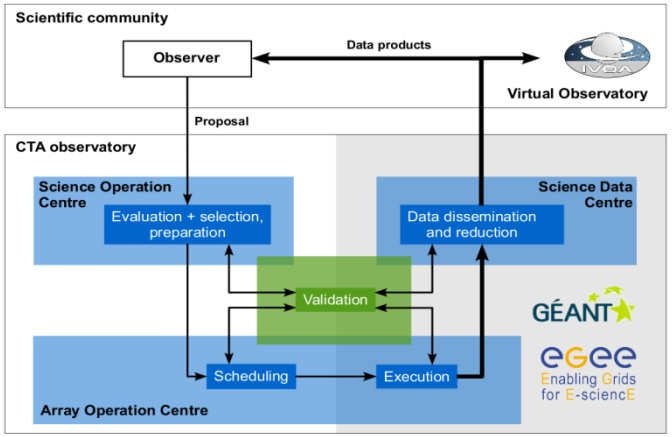
CTA @ LAPP

- Design, prototype and test of the global mechatronics architecture for instruments control, telescope drive, monitoring and safety.

- Computing and E-Infrastructure for data management:
  - Expected CTA data stream : 1 to 10 GB/s for 1 to 10 PB data per year.
  - Large MC production (Preparatory Phase)and for data calibration.

→ Development of the CTACG (CTA Computing Grid)

→ Designing the offline “data operation & science center” for CTA.



Conclusions

- New projects under development to explore the gravitation, the origin of dark matter and dark energy.
- Large variety of instruments: from astronomical telescope to particle detectors.
- Various locations: underground, mountain, space. Extreme conditions …
- Technical fields: Integration of mechanics, detectors, electronics, control, and computer science in complex systems.