IN2P3 in Space Part I
« Summary » and next steps

June 2020 IN2P3 scientific council
IN2P3 in space: past and present (discussed today)
Complementary balloon adventures

1995
- Archeops

2000
- Fermi

2005
- Planck

2010
- AMS

2015
- Lisa Pathfinder

2020
- EUSO
- SVOM
- Euclid
- Planck

Fermi
- SVOM

AMS
- Euclid
Involvement of IN2P3 teams at each step

- Instrumental deliveries
- Integration, calibration
- Data analysis and simulations

Scientific results
- astroparticles
- cosmology
Contributions in various technical domains for space instruments construction:
- conception, realisation and delivery of detection systems
- mechanics for flight models: design and fabrication
- electronics & computing for on-board processing unit
- electronics for on-board cryogenic systems
- ...

**LAT calorimeter**

- IN2P3 contribution to the instrument construction
  - Design phase
    - Carbon fiber structure (LLR, from CMS)
    - Crystal encapsulation (LLR)
    - Photodiode array and readout (C. Chopra, PCC)
  - Structure fabrication (O. Ferrer, LLR)
    - Purchase of an additional (180 kE) to improve polychromatization clean room
    - Metrology (LLR) + vibration tests (externalized)
    - 24 structures delivered to INR (~2 per month)

- Quality system engineering
  - Standardised in spatial activities
  - A kind of resolution for IN2P3
  - 2 engineers were hired
    - P. Pete (PCC)
    - S. Centuriere (LLR)

**Planck @ IN2P3**

- Data Processing Unit (DPU)
  - Development and construction of the Planck HFI DPU
- Electronics for cryogeny
  - Electronic for the sorption cooler (SCE-20K)
  - Electronic for 100nm diffusion valve control (DCE)
  - Control command (SCE-20K) (soft & validation tests)
  - Cryo harness (SCE-50K)

**Contribution Française (construction)**

- 20 ingénieurs et techniciens durant la phase de construction
  (plus de 10 ans)

- PMT Front Electronic & integration
- Radiator Characterization
- Light collection system and Front End Electronics rework
Large involvements of IN2P3 teams in characterisation and calibration of instruments
- from component level characterisation
- to integrated level calibration operations in cold environment (in dedicated cryostats)
- design, fabrication and deliveries of Ground Segment Equipment for such activities
- till in-flight calibration operations
Data Analysis & simulations

- Data analysis activities in close link with instrumental developments
- Simulations, production, data processing,
- Instrumental systematics & the end of the statistics dominated error bars
- Close interactions between scientific and technical teams
- Key role of CC-IN2P3 data center for some missions
- (not to mention shifts, participation in IOT…)

Event reconstruction/selection

- Energy reconstruction (the calorimeter is only 8.6 X0 but longitudinally segmented)
  - Development of several algorithms (PCCJ1.5) to cover the full energy range (~2 TeV)

  Data version timeline
  - Pass 6: developed before launch
    - Meets performance requirements
      - First data: effective area loss (10-30%) due to off-time pile-up of cosmic protons
  - Simulation changed to include pile-up
    - Correction of the Instrument Response Functions
  - Pass 7: same reconstruction, optimized selection
    - Public release in 2011
    - Reprocessing with improved calibration (2013)
  - Pass 8: full reworking of the reconstruction (2015)
    - New tracking + clustering in calorimeter
    - Increased energy range
    - $\geq 25\%$ of effective area
    - Data partition according to direction quality
  - Strong IN2P3 contribution to these developments

Simulation at CC-IN2P3

- LAT pipeline branch at CC-IN2P3 (LUPM):
  - Development, exploitation & maintenance
    - 1200 to 1600 cores at any time
    - Virtualization (Singularity containers) in 2017-2018

- All MC simulations performed at CC-IN2P3 since launch:
  - Event reconstruction optimization, IRFs production, backgrounds
  - 380 millions of CPU hours (18806 units)

- CNES support: 4 engineering contractors at LUPM in 10 years

- IN2P3 4-kind contribution to the LAT common funds: ~1.9 M€ since 2009

Number of running jobs (09/2015-04/2017):

13
Astroparticles physics: results! and prospects

- Better characterise and hence understand the physical processes at the origin of the cosmic messengers: gamma rays, neutrinos, cosmic rays, gravitational waves…
- Constrain the models of SN, Pulsars, AGN/Blazars, …
- Hopefully get insiders to the nature of Dark Matter.

Multi-messengers

- Burst Advocates:
  - monitor LIGO-Virgo alerts and check the automatic analyses by the LAT GW pipelines
  - 11 LAT GCN circulars (flux upper limits) during LIGO-Virgo O3 run

- Flare Advocates:
  - monitor IceCube neutrino alerts, look for possible LAT counterparts in the error region
  - Run dedicated analyses on the candidates (over various timescales) and issue ATels or GCNs

Final main results

Dark matter

- Dwarf spheroidal galaxies are DM-dominated objects in the DM halo of our Galaxy
  - No gas or cosmic-ray content → no expected conventional gamma-ray signal
  - The DM content is rather well constrained → simple relation between WIMP annihilation cross-section and gamma-ray signal
  - The number of Sphs increases with time thanks to:
    - Sloan Digital Sky Survey, Dark Energy Survey, Pan-STARRS survey, LSST
Cosmology: results! and prospects

- $\Lambda$CDM and precision cosmological physics
- Tests of robustness of the concordance model
- Dark Matter and Neutrino sector constraints through cosmo
- Further constrain inflation and reheating physics (coupled with hep physics)
- Understand the accelerated expansion: a new energy component with a repulsive action, or a modification of general relativity
Return of Experience

- Learn from past experience to build the future
- Space methodology in instrumental work (quality, new procedures...)
- Confidence of space agencies in IN2P3 labs / CNES Space label for IN2P3 labs?
- The PI/consortium wrt Spokesman/collaboration model
- Importance of hardware delivery to be part of core teams
- The pressure of open data and scientific results deadlines
- Data: properties of PI at the end of the mission?
- The relation with other partners in France and its evolution with time
- ...... A lot to be digested and thought further ...
- Coherent scientific program combining ground and space (and balloon) experiments
  > astroparticles
  > cosmology
More Space @ IN2P3 ...and beyond!

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Cosmic rays</td>
<td>AUGER</td>
<td>JEM-EUSO</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neutrinos</td>
<td>IceCube</td>
<td>KM3NeT</td>
<td>IceCube-Gen2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>γ-rays</td>
<td>HESS</td>
<td>CTA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Wukong</td>
<td>INTEGRAL</td>
<td>POLAR</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>X-rays</td>
<td>HXMT</td>
<td>NuSTAR</td>
<td>Spektr-RG</td>
<td>XMM-Newton</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Multi wavelength</td>
<td>Swift</td>
<td>HST</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visible and near infrared</td>
<td>VLT</td>
<td>LSST</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Infrared</td>
<td>PLANCK</td>
<td>JWST</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>submm</td>
<td>ALMA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radio waves</td>
<td>FAST</td>
<td>SKA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LOFAR</td>
<td>KAGRA</td>
<td>Indigo</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gravitational Waves</td>
<td>Advanced Virgo</td>
<td>Advanced LIGO</td>
<td>Lisa Pathfinder</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>


Ground space complementarity on Large Scale Surveys

Cosmology with the polarized Cosmic Microwave Background

The future of the Gravitational Waves observatories
Thanks a lot to all the speakers and referees

....Not yet finished: private session of the CS tomorrow

And let’s keep in touch in autumn!

The scientific council members