ITALIAN SPACE AGENCY BALLOON PROGRAM

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[1] Agenzia Spaziale Italiana

In collaboration with Italian research institutes, Universities companies and international partners

ASI Balloon Borne Activities

- **National Balloon Borne experiments**:

  - OLIMPO (PI, Silvia Masi, Sapienza University)
  - LSPE/SWIPE (PI, Paolo de Bernardis, Sapienza University)

- **International Collaborations**:

  - Hemera, funded by the Horizon 2020 framework Programme
  - Collaboration with Nasa:
    - ➢ EUSO-SPB2 (Scientific Italian Reponsable: Giuseppe Osteria, INFN-Napoli)
    - ➢ GAPS (Scientific Italian Reponsable: Mirko Boezio, INFN-Trieste)
    - ➢ OLIMPO (Scientific Italian Reponsable: Silvia Masi, Sapienza University)

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- **National Balloon Borne experiments**:

  - OLIMPO (PI, Silvia Masi, Sapienza University)
  - LSPE/SWIPE (PI, Paolo de Bernardis, Sapienza University)
  - Support to Hemera Payload developments (several Italian Research institutes and Universities)

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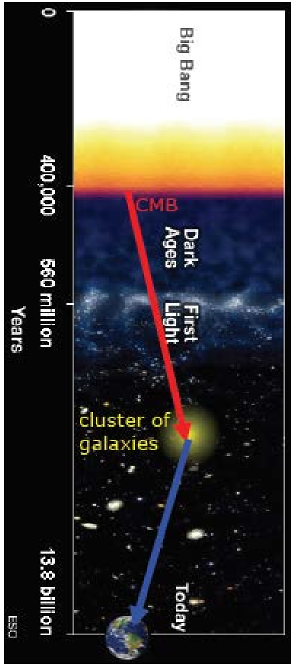
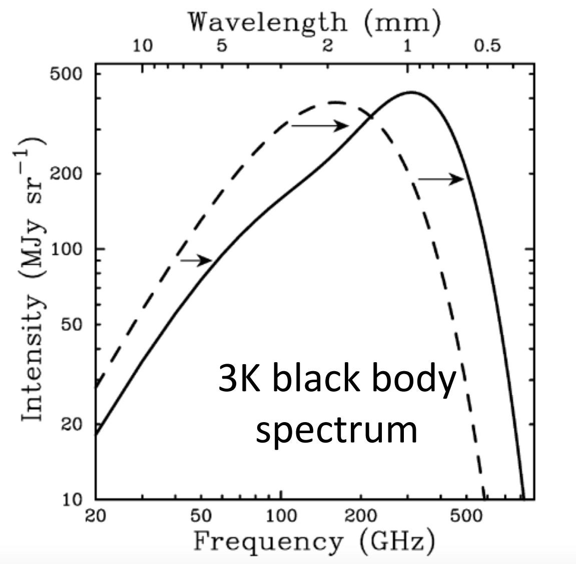
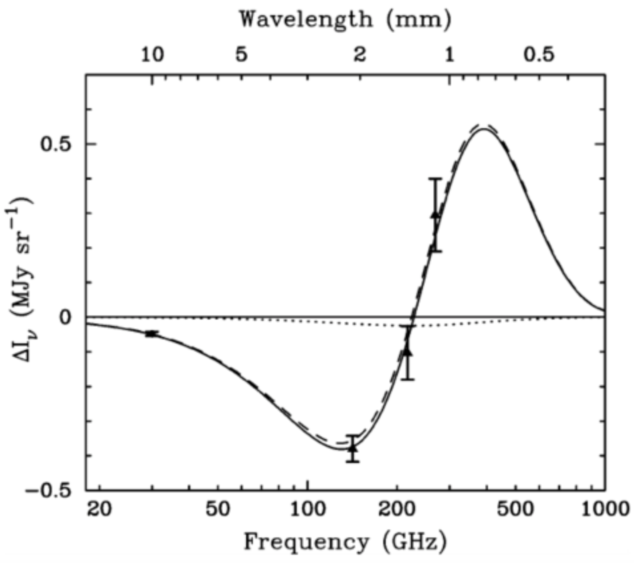
    - ➢ GAPS (Scientific Italian Reponsable: Mirko Boezio, INFN-Trieste)
    - ➢ OLIMPO (Scientific Italian Reponsable: Silvia Masi, Sapienza University)

OLIMPO Science Goals: measurement of the distortion of the spectra of the Cosmic Microwave Background (CMB) in the direction of a cluster of galaxies

CMB photons gain energy interacting with the hot electrons ($T \sim 10^7$-10^8 K) of the intracluster plasma: **Sunyaev-Zeldovich Effect (SZE)**







From SZ spectrum it is possible to study:

- CMB parameters (improve the cosmological models)
- Clusters physics

OLIMPO: the instrument

- **2.6 m** aperture telescope
- a wet LN_2+L^4He cryostat with a ^3He refrigerator to reach 0.3 K
- 4 horn-coupled **Kinematic Inducance Detectors (KIDs)**;
- plug–in room–temperature **Differential Fourier Transform Spectrometer (DFTS)**;

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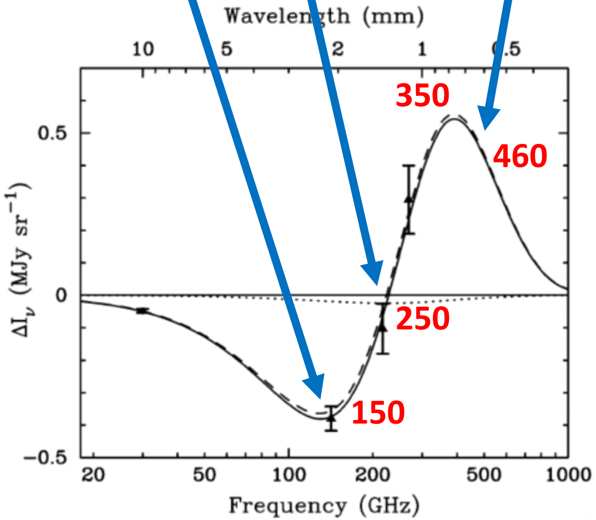
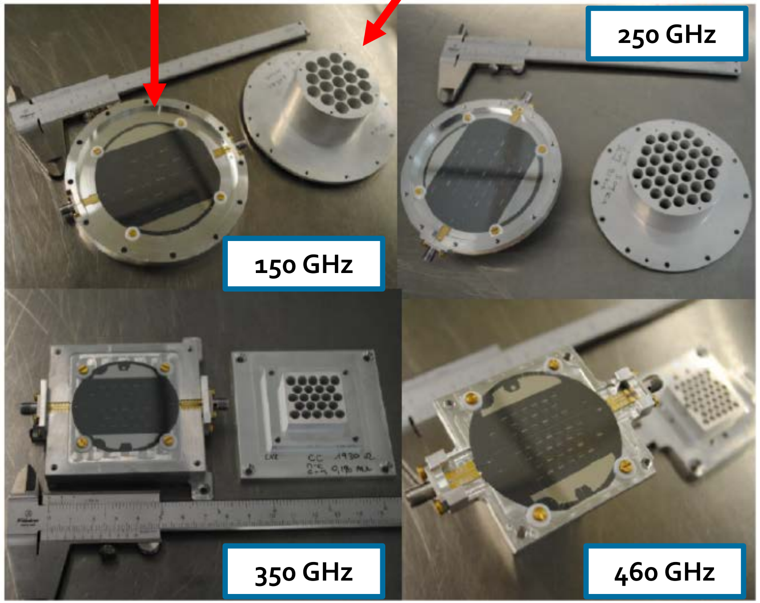
Core Technologies of OLIMPO

4 horn-coupled **KIDs** arrays centered at 150, 250, 350, 460 GHz matching the negative, zero, and positive regions of the SZ spectrum



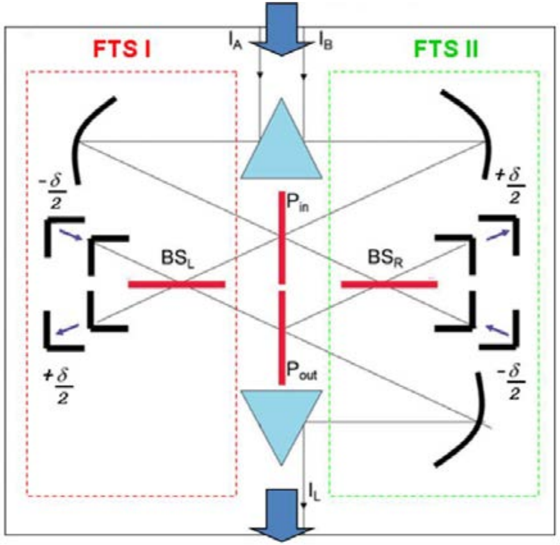
Kinematic Inductance Detectors (KIDs)

Feed-horns

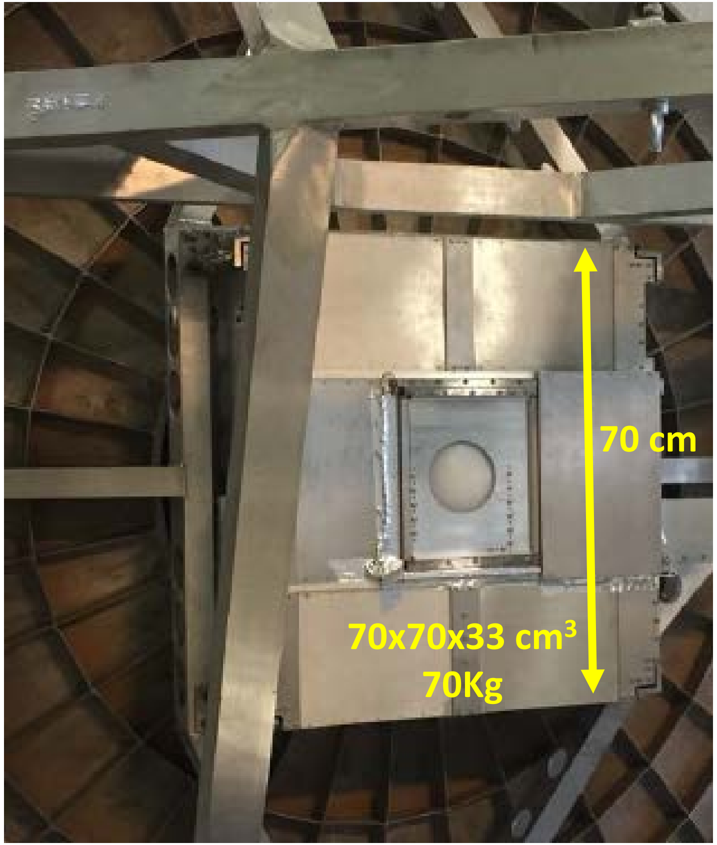


Core Technologies of OLIMPO

A plug–in room–temperature **Differential Fourier Transform Spectrometer** (DFTS)



The actual measurements are photometric. The OLIMPO experiment is a first attempt to perform spectroscopic measurements of the SZE



OLIMPO: The flight

- Launch site: Longyearbyen airport (78 N), Svalbard Islands
- Launch operator: Swedish Space Corporation
- Flight duration : 5 days (goal: 14 days). Termination over Canada
- Successfully recovered.

- **First time: large telescope**, **DFTS** and **KIDs** flown on a stratospheric balloon

- First time that KIDs operated in a representative space-like environment. They performed very well and the results achieved during the flight represent an important step in the **TRL advancement** of KID technology in a LEO environment, in view of future satellite missions.

Large Scale Polarization Explorer (LSPE): Science Goals

Linear Polarization pattern of the CMB (E-mode and **B-mode**) → information about early phases of the Universe

↓

produced by **tensor perturbations** at large angular scales (**Inflationary gravitational waves**)

$$\textbf{Tensor to scalar ratio r} = \frac{\text{Amplitude of Tensor perturbations}}{\text{Amplitude of scalar (density) perturbations}} \quad \boxed{\propto E_{inflation}}$$

Current measurements: $r < 0.032$ → LSPE: $\boxed{\mathbf{r < 0.01}}$

- B-modes are very tiny signals: need of control of systematics and foregrounds (synchrotron and thermal dust emission) →

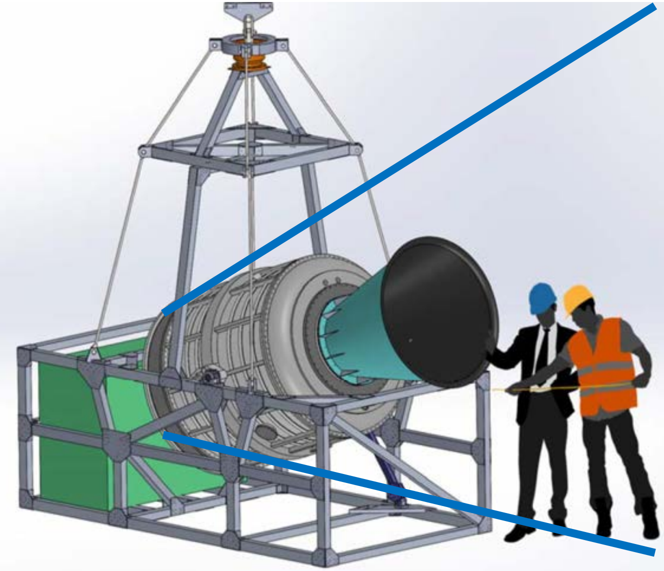
LSPE/STRIP: low frequency ground-based telescope
40 and 90 GHz bands to monitor synchrotron

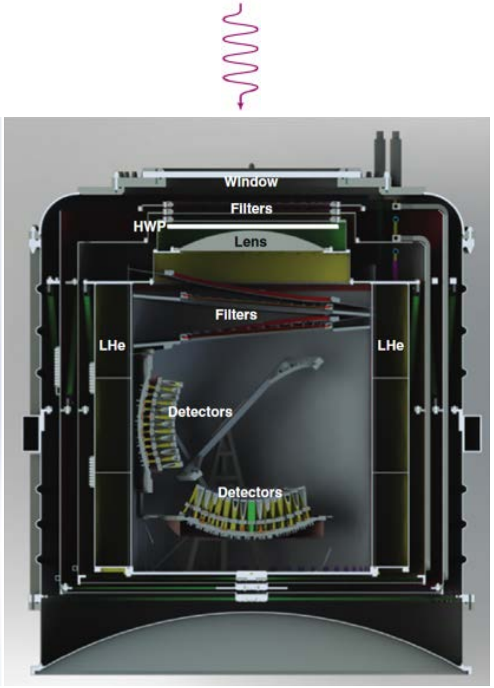
LSPE/SWIPE: high frequency **balloon-borne instrument**
140 GHz to measure the CMB polarization
220-260 GHz to monitor thermal dust

LSPE/SWIPE: the instrument

γ

Gondola





Cryogenic system : vacuum shell, L^4He tank, ^4He vapour shields, L^3He refrigerator (0.3 K)

The core technologies

- 50 cm **rotating** Half Wave Plate (HWP)
- 50 cm aperture refractive telescope
- Two Focal Planes:
  - **330 Trasistor Edge Sensors (TES)**
  - **330 multi-mode cavity** + Feedhorns
  - Frequency Domain Multiplexing readout electronics

LSPE/SWIPE: the core tecnology

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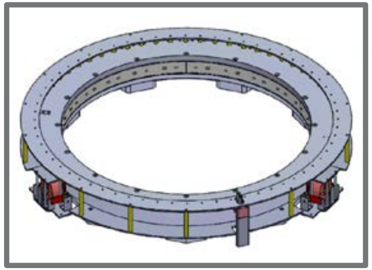
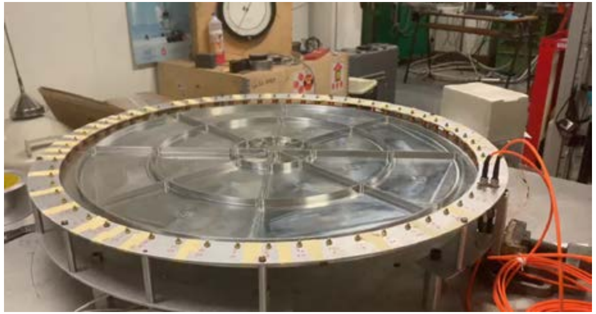
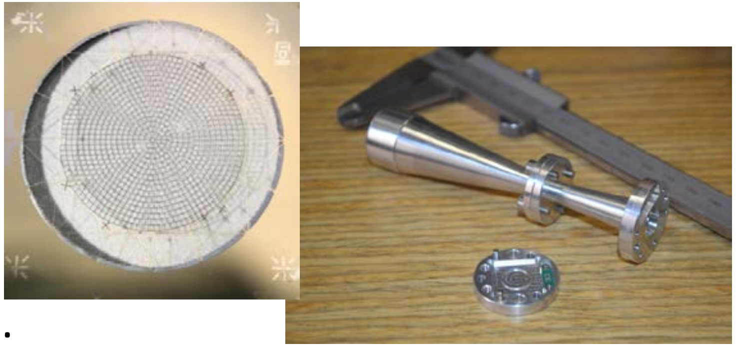
50 cm **rotating** Half Wave Plate (HWP)

330 multi-mode Trasistor Edge Sensors



superconducting magnetic suspension system modulating at 4 Hz



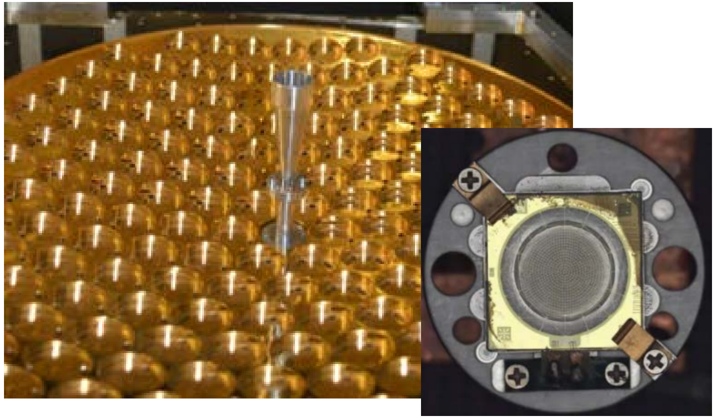


8800 radiation modes: Sensitivity boost by a factor

$\cancel{\sqrt{330}}$

$\downarrow$

$\sqrt{8800}$



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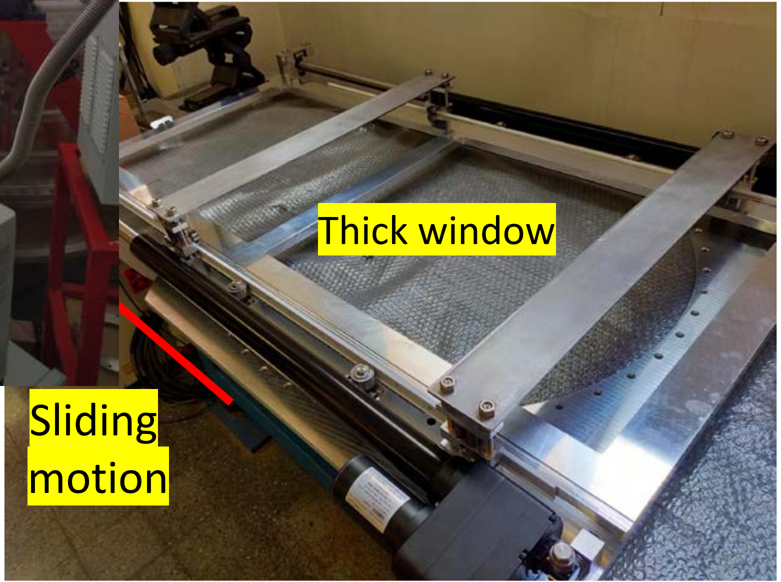
LSPE/SWIPE: work in progress

Star sensors
photodiods



LSPE/SWIPE: the flight

CMB B-modes are very small →

- avoid solar irradiation
- reduce instrument and environment temperature
- observe the northen sky

→ dark condition more than 8 days (goal 15 days) → Flight in Arctic winter

- The launch campaign challenges:
  - payload trajectories (winter circulation in the northern hemisphere is more unstable than the summer one)
  - ground meteo (more difficult in winter)
  - darkness conditions (latitude)
  - overflight and landing permissions (trajectories in winter could be wider and overfly more territories)
  - recovery opportunities (more difficult due to the whaeter conditions)
  - safety (operators and population)
  - logistics

- The northern hemisphere offers the Svalbard and Esrange (Swedish Space Corporation facility) launch sites

Hemera Project: the ASI contribution

- New Launch Site: individuation and analysis: the aim of the work package was to analyse new launch sites in order to offer a wider range of launch opportunities to the scientific community. The sites analysed were Italy, Africa, Morocco, Svalbard, Brazil and Antarctica sites.

- New telemetry subsystem developed by Italian company

- Involvement of Italian community to the project

- Enlarging the community

Hemera Project: new telemetry subsystem

- Assembly and integration procedures simplification.
- Update of the GPS system.
- Upgrade of Power supply system.
- Increase the throughput data of the telemetry system.
- Increase the storage unit capacity.
- Update the ground procedures maximizing the speed of the data transfer

www.len.it

Telemetry main characteristics:

- Envelope: 41 x 33 x 15 cm
- Mass: 9,1 kg + telecomunication system weight
- Double telecomunication systems connection
- Possibility to reset and restart during the flight
- Autoreset by watchdog
- Global coverage
- Scientific data transmission > 1Mbit/s
- Data storage on board of 256Gb with easy possibility to increase the Gb
- Analogical and digital input/output, power output, RS232 and RS485, LAN interface
- Programmable with metalanguage

State of the art:

- ✓ A detailed analysis of user requirements was conducted in order to identify the user’s needs. This allowed to prepare a new set of specifications
- ✓ Telemetry ground demonstrator and tests have been concluded
- ✓ Telemetry flight model realization is completed
- ✓ Qualification tests of the flight model are foreseen to be performed in summer 2022 during Hemera launch campaigns

ASI Supports to some of the Italian Payloads seleced by Hemera

21 Italian experiments was selected for flights. Some of them has been founded by ASI

First call

- GRASS
- DUSTER
- Low noise static FTS
- STRAINS
- CorMAg
- Hermes

Second call

- BADG3R
- GRASS2
- I-FTS

ASI Supports to some of the Italian Payloads seleced by Hemera

Measurement of the gamma rays and cosmic rays background for a correct data exploitation in Gamma-ray Astronomy.

First call

- GRASS
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Second call

- BADG3R
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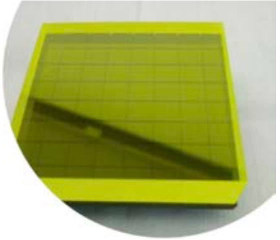
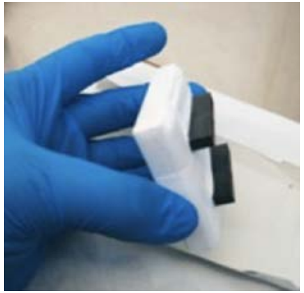
- I-FTS





Gagg scintillator optically coupled to a single large sensitive area SiPM (Silicon Photo Multiplyer) array

Launch performed by SSC from Kiruna in September 2021

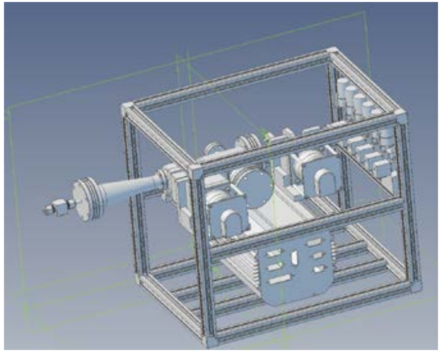
PI: Lorenzo Natalucci

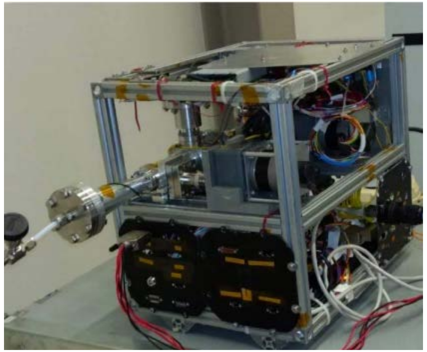
ASI Supports to some of the Italian Payloads seleced by Hemera

Collection and retrieval of uncontaminated solid aerosol particles, in the submicron/micron range, from the upper stratosphere

First call
- GRASS
- DUSTER
- Low noise static FTS
- STRAINS
- CorMAg
- Hermes

Second call
- BADG3R
- GRASS2
- I-FTS





The particles are collected in a ultra high vaccum collecting chamber.
The experiment is designed to have very low particles contamination.

Launch performed by SSC from Kiruna in summer 2019 and September 2021

PI: Vincenzo Della Corte

ASI Supports to some of the Italian Payloads seleced by Hemera

First call

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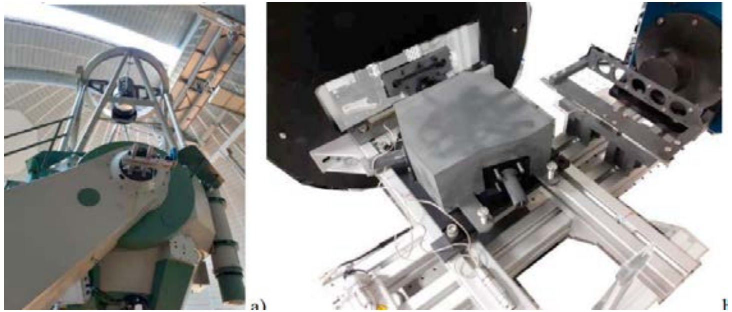
Tecnological flight: Demonstration of a static Fourier Spectrometer, in the optical and IF bands, that uses Littrow prisms as dispersive elements.
The instrument has high signal to noise ratio and high luminosity



Launched performed by CNES from Aire-sur-l’Adoure in October 2021

PI: Fabio Frassetto

CNR IFN Istituto di Fotonica e Nanotecnologie

ASI Supports to some of the Italian Payloads seleced by Hemera

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First call
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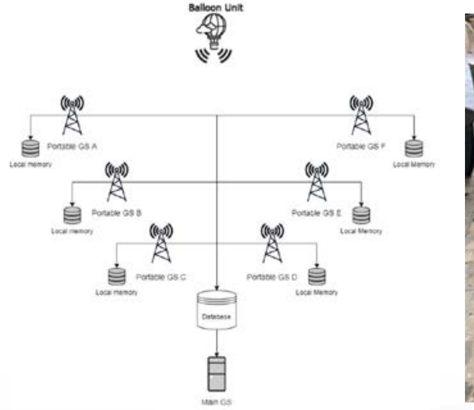
Second call
- BADG3R
- GRASS2
- I-FTS



Technological flight: demonstration of innovative tracking systems:

- TDOA (Time Difference of Arrival)
- FDOA (Frequency Difference of Arrival)
- single station tracking

The flight segment was a radio trasmitting signals from the balloon that were received by several portable ground stations and by an antenna located in Esarange.

Launch performed by SSC from Kiruna in September 2021

SAPIENZA UNIVERSITÀ DI ROMA

PI: Fabio Santoni

ASI Supports to some of the Italian Payloads seleced by Hemera

First call

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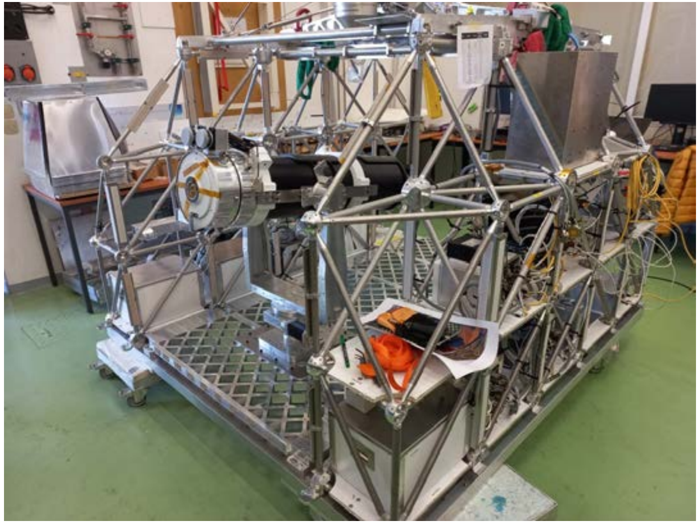
Second call

- BADG3R
- GRASS2
- I-FTS



Coronagraph to study the physical processes that govern the heating and acceleration of the fast and slow solar wind

Launch scheduled by SSC
from Kiruna
in Summer 2022

PI: Silvano Fineschi

ASI Supports to some of the Italian Payloads seleced by Hemera

First call

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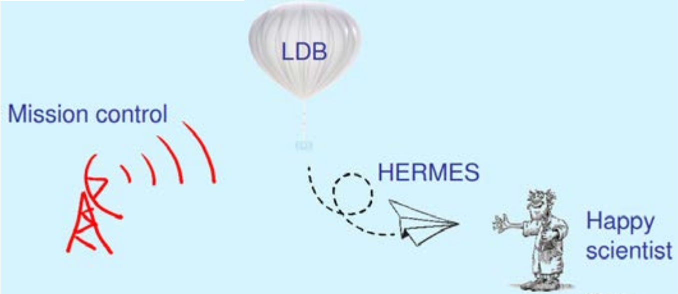
- Hermes

Second call

- BADG3R
- GRASS2
- I-FTS

Small glider released by the stratospheric balloon able to bring scientific data stored in a solid state memory to a recovery point on the ground

Launch scheduled by SSC
from Kiruna
in Summer 2022



PI: Alessandro Iarocci

ASI Supports to some of the Italian Payloads seleced by Hemera

First call
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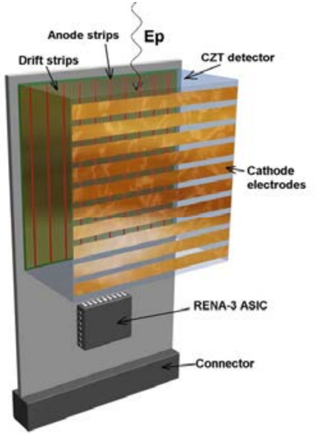
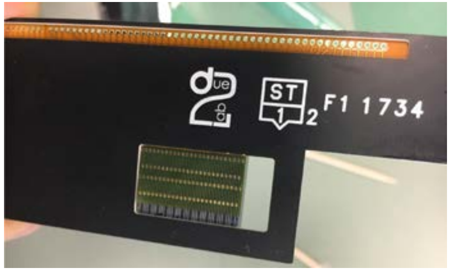
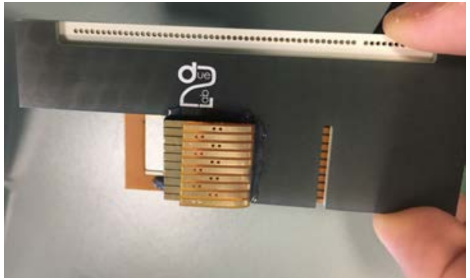
- DUSTER
- Low noise static FTS
- STRAINS
- CorMAg
- Hermes

Second call
- **BADG3R**
- GRASS2
- I-FTS

Tecnological flight: Demonstration of a 3D spectro-imager with polarimetric capability, based on CZT semiconductor detectors (Cadmium Zinc Telluride) to be used for high energy astrophysics







Launch scheduled by SSC from Kiruna in Summer 2022

PI: Stefano Del Sordo

ASI Supports to some of the Italian Payloads seleced by Hemera

First call

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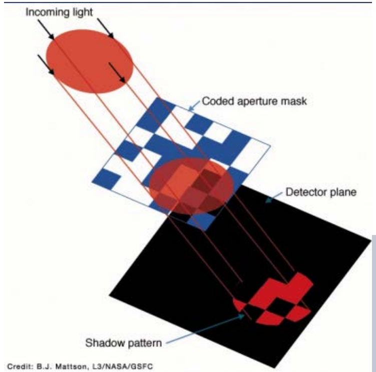
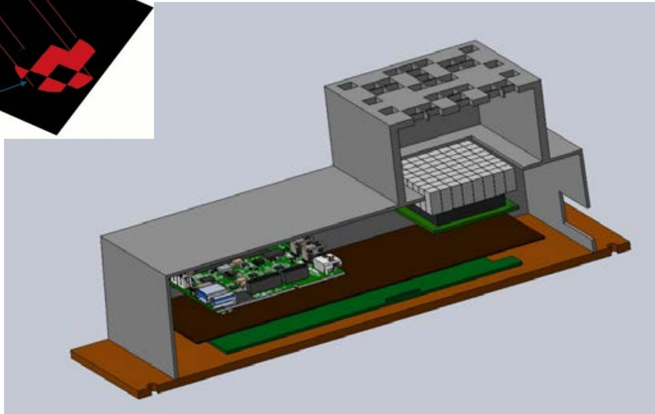
Measurement of the gamma rays and cosmic rays background for a correct data exploitation in Gamma-ray Astronomy.

More advanced prototype: more light collection, higher spatial resolution, imaging capability



- 8x8 scintillator array instead of a monolithic scintillator
- 16 channels ADC readout instead of a 4
- Use of a coded mask



Launch scheduled by CNES from Timmins in Summer 2022

PI: Lorenzo Natalucci

ASI Supports to some of the Italian Payaloads seleced by Hemera

First call

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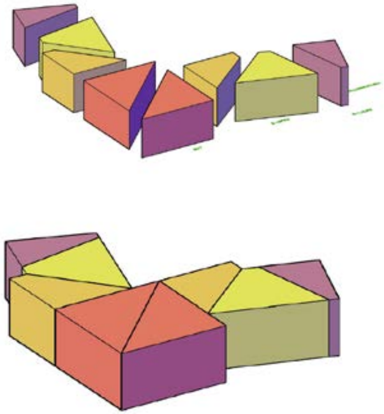
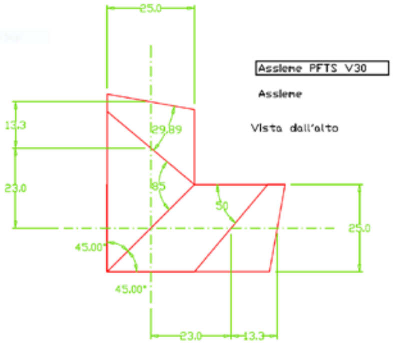


Launched scheduled by CNES from Aire-sur-l'Adoure In summer 2022



Second call

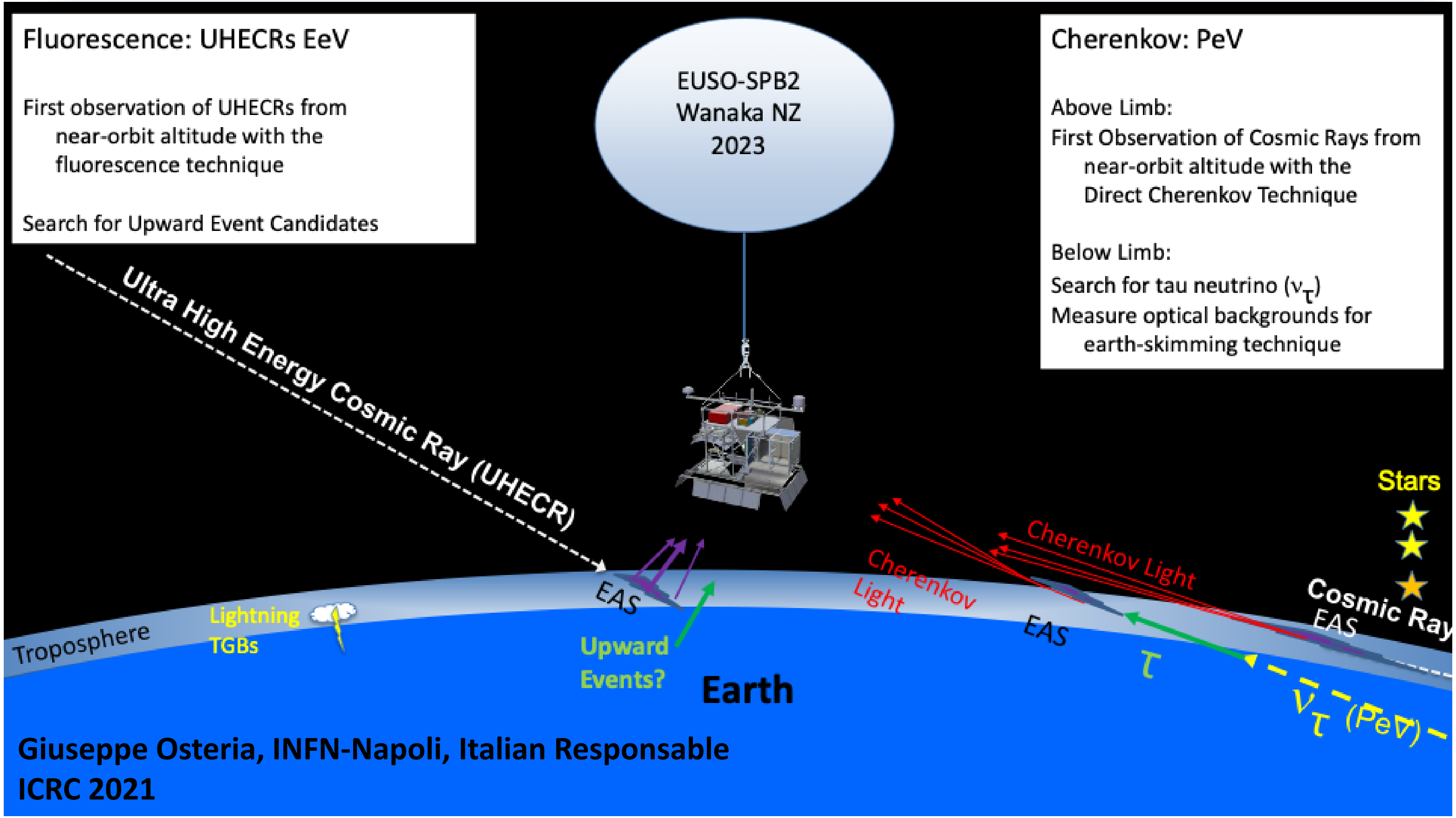
- BADG3R
- GRASS2
- I-FTS

Tecnological flight: Demonstration of a static Fourier Spectrometer, in the optical and IF bands, that uses Littrow prisms as dispersive elements. The instrument has high signal to noise ratio and high luminosity.

In this prototype the prisms are directly glued to the beam splitter, making the instrument more compact, more robust with respect to vibrations and, avoiding air gaps, more protected by dust

PI: Fabio Frassetto

Collaboration with NASA: EUSO SPB2



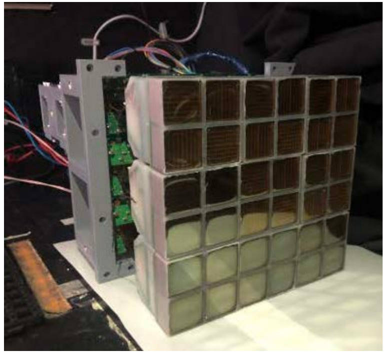
PI: Angela Olinto

Collaboration with NASA: EUSO SPB2

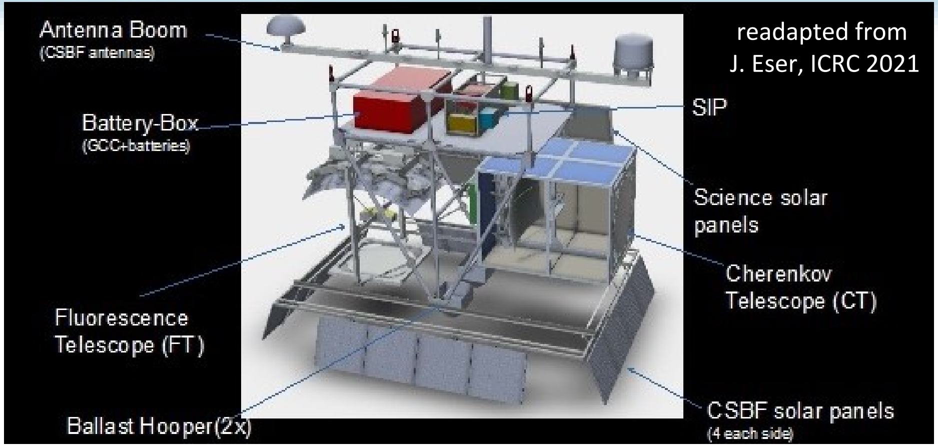
IT contribution:

- Acquisition system
- Power system

Fluorescence Telescope



Camera:
3 PDMs with each 2304px
290-430nm detection window
Integration time of 1μs



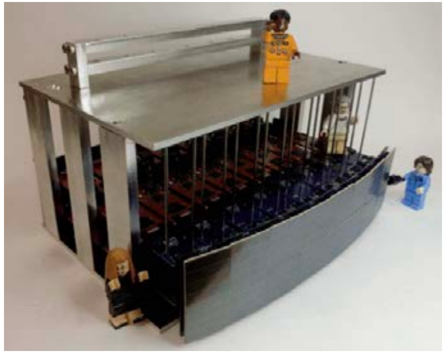
First observation of UHECR via fluorescence from suborbital space

Optics:
Schmidt system, 1m diameter
FoV ~12x36deg (~36 km2 on ground)
Nadir pointing

BG measurements, Earth-skimming neutrinos, above-the-limb CR

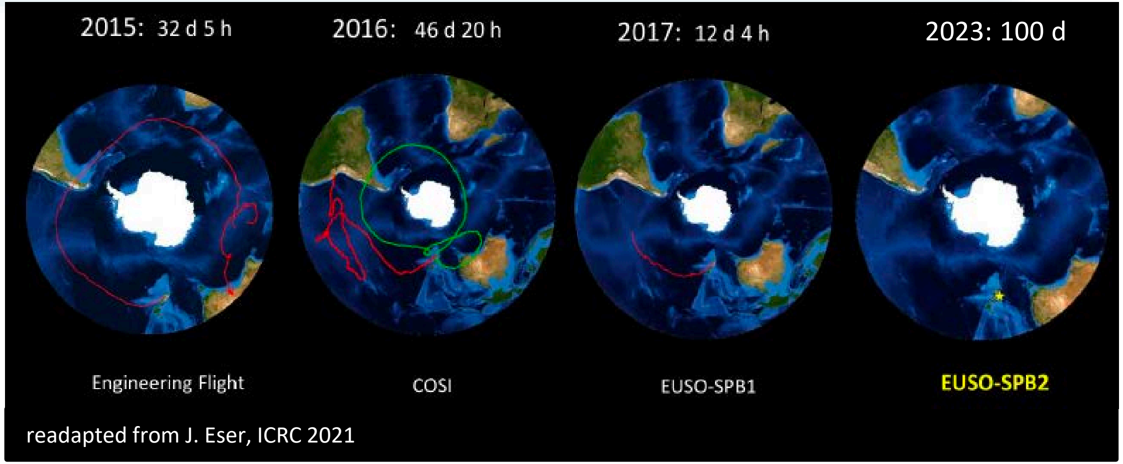
Optics:
Schmidt system 1m diameter
FoV ~ 6.4 deg x 12.8 deg
Bi-focal for noise reduction
Pointing +/-10 deg around Earth's zlimb

Cherenkov Telescope



Camera:
512 SiPM based pixels
10ns integration time
200-800nm spectral range

Collaboration with NASA: EUSO SPB2



EUSO-SPB2 is the next step towards space based UHECR observation

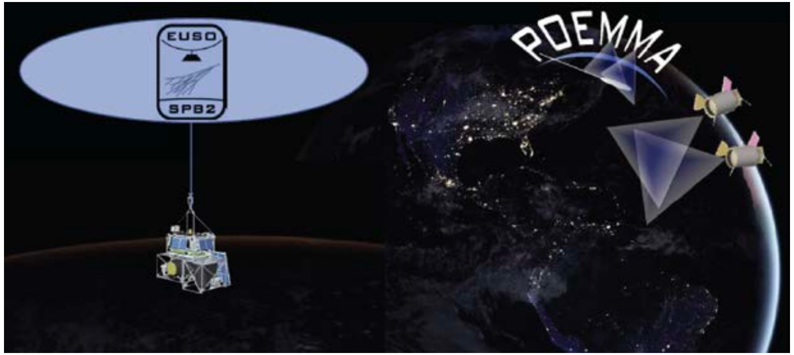
Preparations are on going for a planned launch in 2023 from NZ as an SPB payload

First observation from UHECR via fluorescence from suborbital space
0.12 tracks per hour from UHECR

First time of Cherenkov Telescope in suborbital space
first time background for upwards going neutrino events

100 events per hour from above the limb direct cosmic rays in the CT
EUSO-SPB2 could detect neutrinos from astrophysical event

POEMMA target launch at 2030 as a dual satellite probe class mission
will open two new Cosmic Windows (UHECR above 20EeV, neutrinos from ToO)
will benefit from the EUSO-SPB2 design and flight



Collaboration with NASA: GAPS (General Antiparticle Spectrometer)

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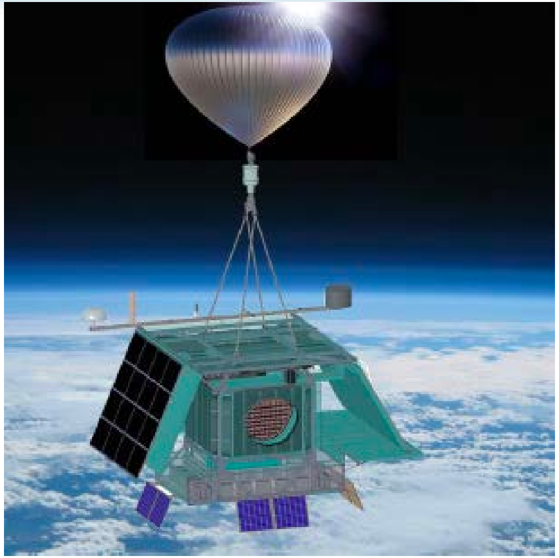
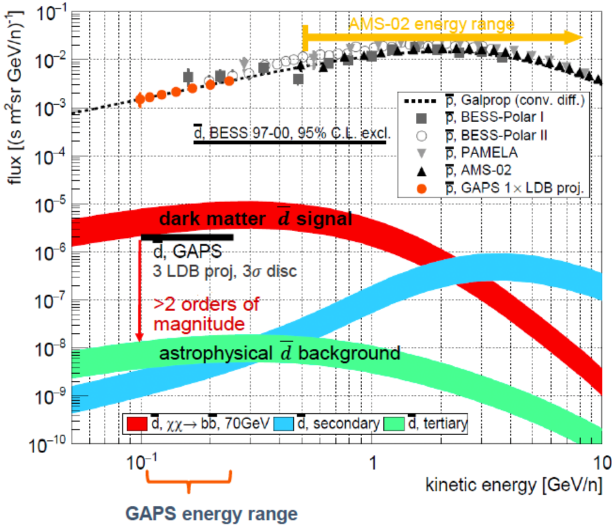


Novel method for detection of nuclear antimatter in CRs by analysis of decay signatures of exotic atoms from interactions of antimatter nuclei with the detector materials

Main Goals:
search for low-energy Antideuterons as signature of new physics.
High statistics measurement of low-energy Antiproton

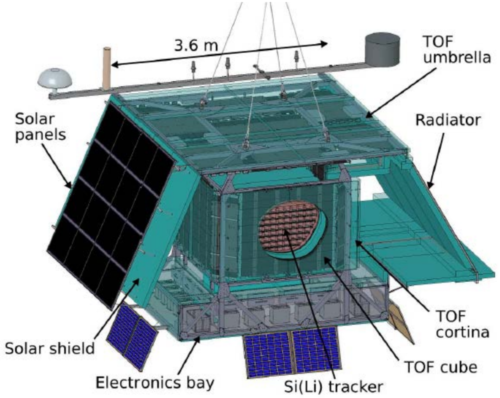
Cosmic-ray antinuclei as messengers of new physics: status and outlook for the new decade: JCAP08 (2020) 035

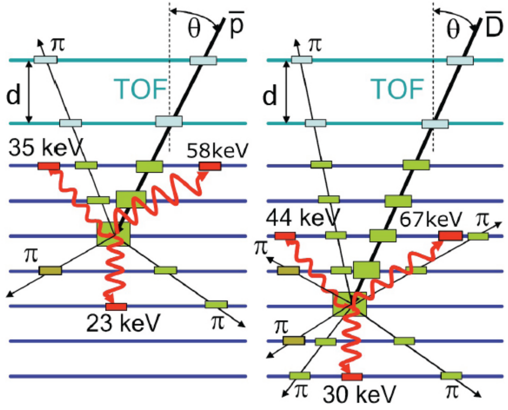


Antideuterons: cosmic messenger of ***new physics*** signatures with *essentially zero* conventional astrophysical background GAPS sensitivity 2 orders improved w.r.t. current limits

Detection approach independent from magnetic spectrometer satellites (i.e.: PAMELA, AMS)

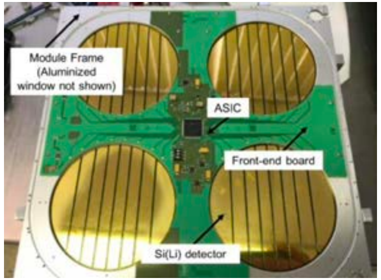
Collaboration with NASA: GAPS (General Antiparticle Spectrometer)





Time-of-flight system
1.8m (max) Plastic scintillators over 50m2 area Silicon
Photomultiplier readout, timing resolution better than 500 ps

Approx. 100% hermeticity
velocity and dE/dx measurement
Trigger and veto



Si(Li) tracker
1440 diameter sensors over 10 planes
10 cm-diameter, 2.5 mm-thick, 8-strip lithium drifted silicon (Si(Li)) sensors
4 keV energy resolution, 10 keV-100keV range

Stopping depth and dE/dX measurement
X-ray identification
Vertex reconstruction

Different decay signature from exotic atoms made of Pbar or Dbar

Antiparticles (pbar,Dbar) are identified by:
- Stopping range and dE/dX
- Pion and proton multiplicity
- Atomic X-ray energies

Antimatter identification without magnetic field

Collaboration with NASA: GAPS (General Antiparticle Spectrometer)

Italian Responsable: Mirko Boezio, INFN-Trieste

To reach the scientific objectives three flights have been foreseen, from Antarctica with a SPB:

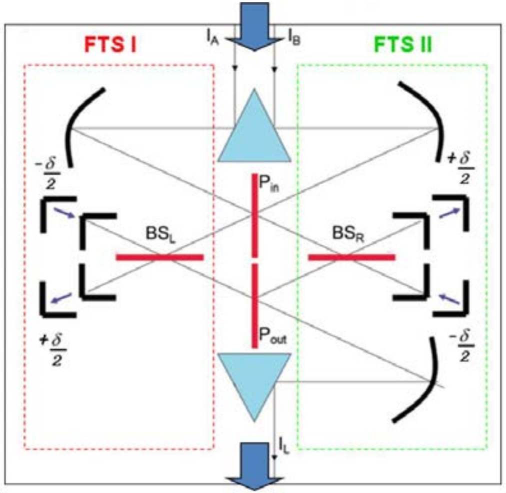
- The first flight is dedicated to the measurement of the antiproton
- and the other two will improve the current best limits on antideuterium.

GAPS subsystems integration and tests are undergoing.

Possible future collaboration with NASA

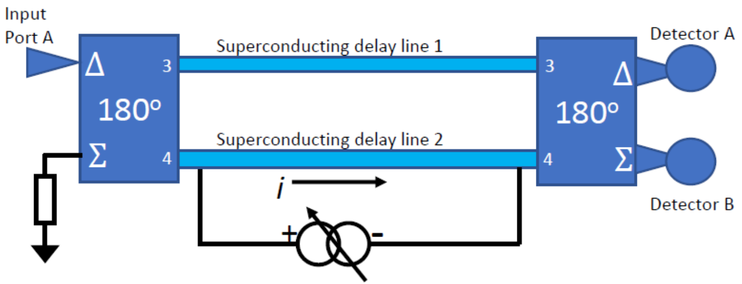
OLIMPO second flight (proposal to be submitted to NASA): Differences from current configuration

DFTS



spectrometer on chip (in one of the 4 channels):

Planar superconducting circuits on Si wafers



Two superconducting delay lines:

Different optical paths → Phase delay

optical path difference of cm → GHz spectral resolution

DC in one the delay line → Phase delay

few mm + 1 mA DC current → sub-GHz spectral resolution

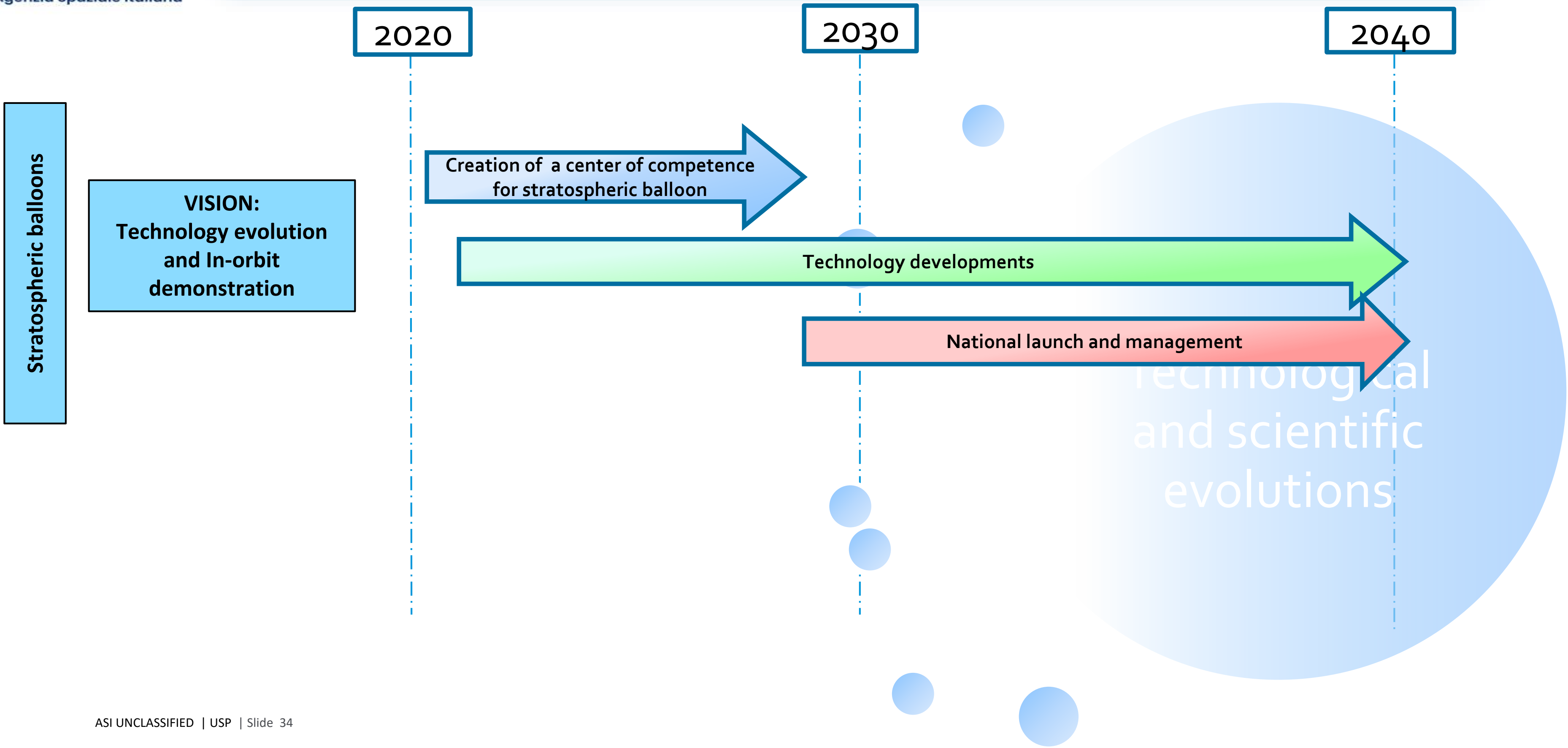
Possible future collaboration with NASA

OLIMPO: the refurbishment

- Repair the gondola
- Substitute the batteries and the solars panels
- Substitute the cables that were cut during the recovery
- Repair some cryostat supports and clean it
- Clean the primary and secondary mirrors and repair the secondary mirror mechanical support
- Review the mechanical structure of the DFTS (with 3 of the 4 channels will be fed by the DFTS, TBD)

➢ ASI also endorsed **Blast Observatory** for investigating how the stars are formed, and what the role of the galactic magnetic field is in the process. The main Italian contribution will be the telescope, if selected.

Stratospheric activities roadmap



Feasibility study

Launch base

Objectives: to create a stable center for launch of stratospheric balloons, for the maintenance and calibration of launch systems and for integration tools.

Launch team

Objectives: to achieve knowledge in order to have a national launch autonomy

Technologies

Objectives: to achieve innovative technologies and industrial growth

Conclusions

- The Italian community is very active in ballon borne scientific and techonological field: there are many universities, research instututes and companies able of designing and developing payloads in many different reseach fields

- In these years ASI is supporting, coordinating and enlarging the community, promoting the networking, the national and international collaborations and supporting innovative developments

- ASI will support the continuation of Hemera program and the collaboration with the Hemera partners, and will make a feasibility study to evaluate the possibility to create a national launch capacity fostering international interoperability.