STRATOSPOLCA: STRATOSpheric POLarimetry with Cadmium Telluride Array

H. Neves [1,2], R.M.Curado da Silva [1,2], P. Afonso [3], N. Auricchio [4], I. Carmo [5], E. Caroli [4], M. Ferreira [2], R. Gameiro [6], J. Gonçalves [7], A. Lemos [6], J. M. Maia [8,1], D. Marques [7], B. Matos [2], A. Mendonça [2], J. Mingacho [1], M. Moita [9,1], A. Neves [2], M. Neves [2], A. Oliveira [10], I. Oliveira [2], J. Pereira [2], P. Póvoa [7], S.Rodrigues [11], R. Roque [12], J. Silva [7], J. Silveirinha [1], M. Simões [2], G. Smith [3], J. Sousa [2], D. Torres [7]

[1] LIP - Laboratório de Instrumentação e Física Experimental de Partículas, Coimbra, Portugal, [2] University of Coimbra, Department of Physics, Coimbra, Portugal, [3] American River College, Physics and Astronomy Dept., Sacramento, California, USA, [4] INAF/OAS, Bologna, Bologna, Italy,, [5] University of Coimbra, Department of Mechanical Engineering, Coimbra, Portugal, [6] University of Coimbra, Department of Chemical Engineering, Coimbra, Portugal, [7] University of Coimbra, Department of Electrical and Computer Engineering, Coimbra, Portugal, [8] Universidade da Beira Interior, Department of Physics, Covilhã, Portugal, [9] Dept. of Physics and Earth Science University of Ferrara, Ferrara, Italy, [10] Dep. Eletrónica, Telecomunicações e Informática, Universidade de Aveiro, Aveiro, Portugal, [11] University of Coimbra, Faculty of Medicine, Coimbra, Portugal, LIBPhys, [12]Department of Physics, University of Coimbra, 3004-516 Coimbra, Portugal

LABORATÓRIO DE INSTRUMENTAÇÃO E FÍSICA EXPERIMENTAL DE PARTÍCULAS
partículas e tecnologia

INAF OAS BOLOGNA

ARC

12 90 UNIVERSIDADE Đ COIMBRA

FACULDADE CIÊNCIAS
Departamento de Física

universidade de aveiro

FERRARIAE UNIVERSITAS 13 91 EX LABORE FRUCTUS
Università degli Studi di Ferrara

November 2nd, 2021

The BEXUS Programme

**BEXUS: Balloon Experiments for University Students ~ 1 year**

- Idea for a balloon flight duration and altitude (~3h, 27 km;
- Application form: simple and not too long (<20 pages);
- Selection workshop;
- Student training weeks;
- Integration Progress Review;
- Experiment Acceptance Review;
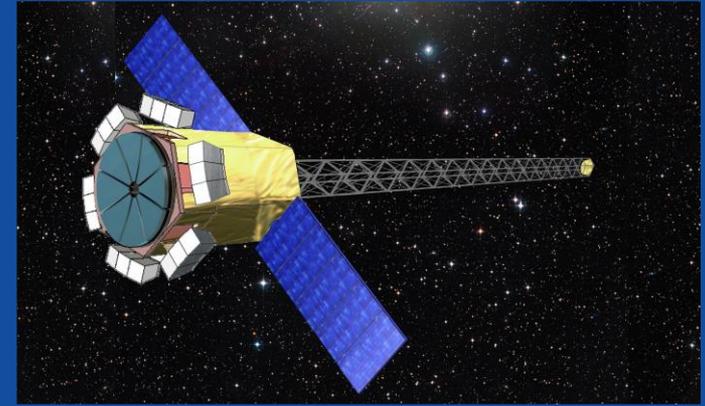- Launch from Esrange Space Centre, Kiruna, Sweden

i-Astro Activities in High-energy Astrophysics Missions
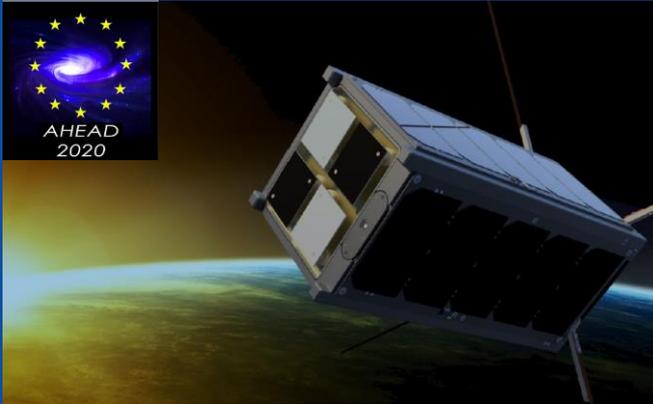
COMCube (EU)
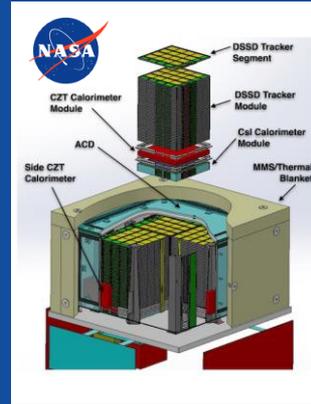
AMEGO (NASA)

ASTENA (ESA Voyage 2050)

High energy astrophysics (0.1 – 100 MeV)

Polarimetry

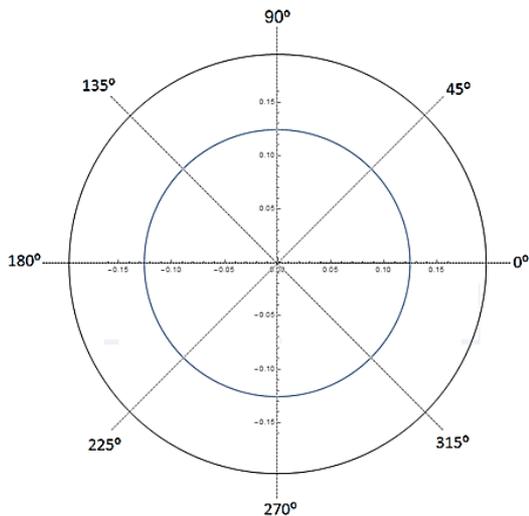- 2 extra parameters (angle and degree);
- emission production mechanism and object geometry.
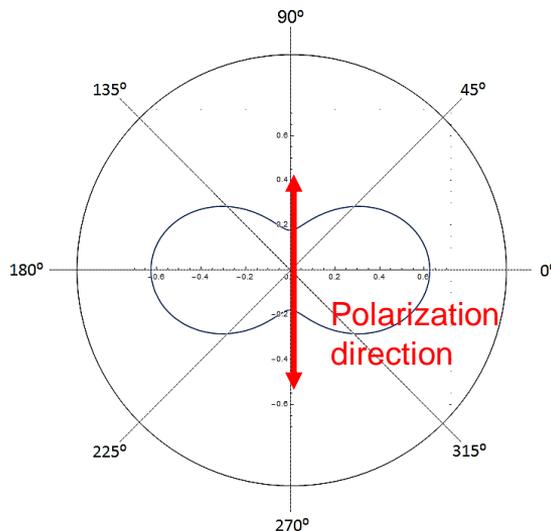
Compton
Polarimetry

Events' Multiplicity

Unpolarized Beam

$$\frac{d\sigma_{KN,U}}{d\Omega} = \frac{1}{2}r_0^2\varepsilon^2[\varepsilon + \varepsilon^{-1} - \sin^2\theta]$$
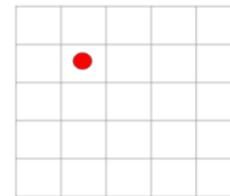
Polarized Beam

$$\frac{d\sigma_{KN,P}}{d\Omega} = \frac{1}{2}r_0^2\varepsilon^2[\varepsilon + \varepsilon^{-1} - 2\sin^2\theta\cos^2\eta]$$
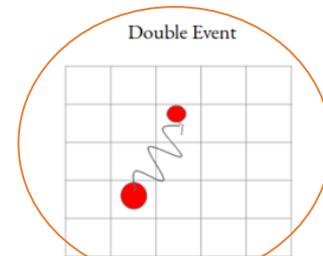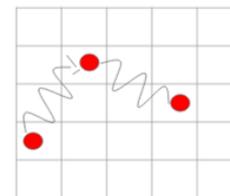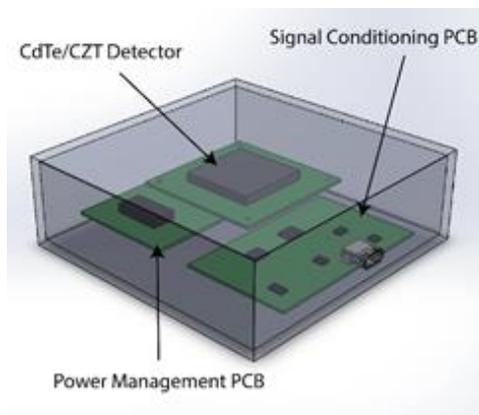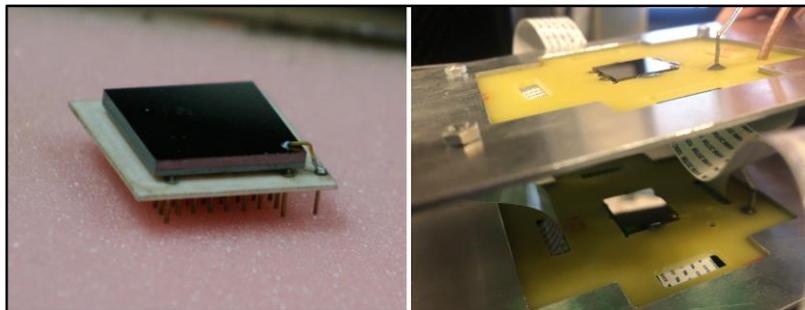
100%

Polarization direction

CdTe Prototypes

TGF Monitor Preliminary Design

TGF Monitor prototype (5 mm thickness, 8x8 pixels, total 2.56 cm² area). 150 x 150 x 50 mm case with power-supply and data collection are made via the USB port on the side.
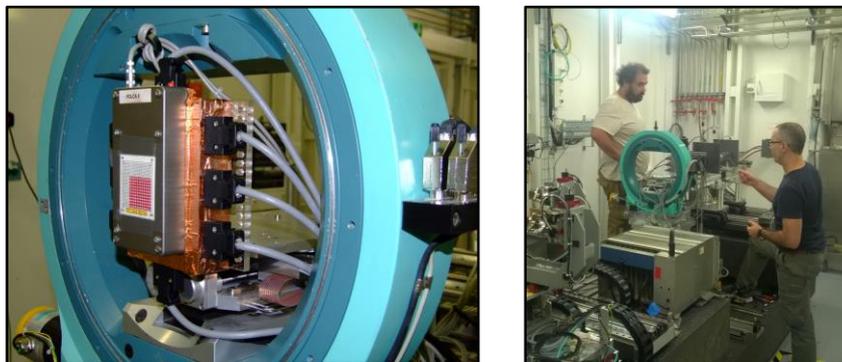
Miguel's thesis Compton prototype

CdTe Acrorad 8x8 detector   Dual CdTe plane prototype

POLCA Prototype

STRATOSPOLCA
Objectives

- measure the level of **single**, **double** and **multiple events**, drawing a profile of such events as a function of the altitude to optimise the polarimetric performances of high-energy astrophysics telescopes in an ESA BEXUS/REXUS Program balloon flight;

- compare data acquired to pre-flight simulations and measure the energy of these interactions. With this experience we also want to improve future polarimetric experiments Signal-To-Noise Ratio.

➢ To achieve our objectives the experiment is composed by a 5x5 pixel of CdTe detector, with an area of 6 cm^2, sensitive to gamma radiation where the detector and all the electronics are inside an aluminium box. The main subsystems of this experiment are the SoC FPGA and a microcontroller.
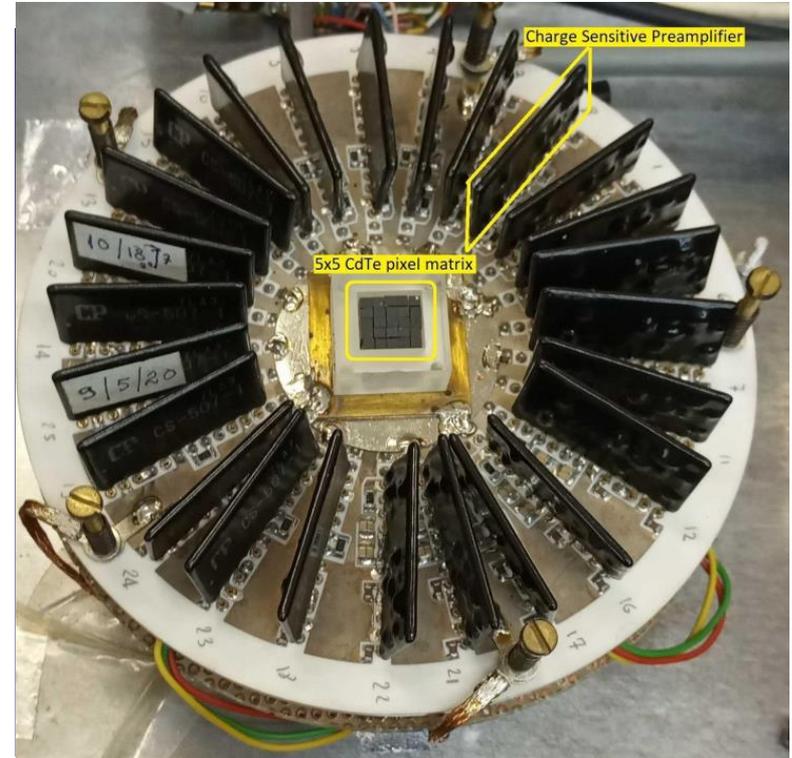
CZT detector is composed by 5×5 pixels for a total volume of 10×10×10 mm^3 bonded inside a diclad PCB 25.4 x 25.4 x 1.8 mm^3.

BEXUS
Flight Conditions

The total length of balloon system is up to 75 m.
The gondola is 1.16 m x 1.16 m x 0.84 m and can carry experiment loads up to 100 kg.

The environmental conditions of the balloon flight:

- temperatures down to -70°C;
- air pressure of down to 10 mbar;
- On-board batteries: 28V/1A;
- Ethernet connection;
- ~3 hours flight;
- maximal altitude of ~28 km;
- γ-ray transmission vs altitude see fig. on the right.

Earth's Atmosphere, γ-rays
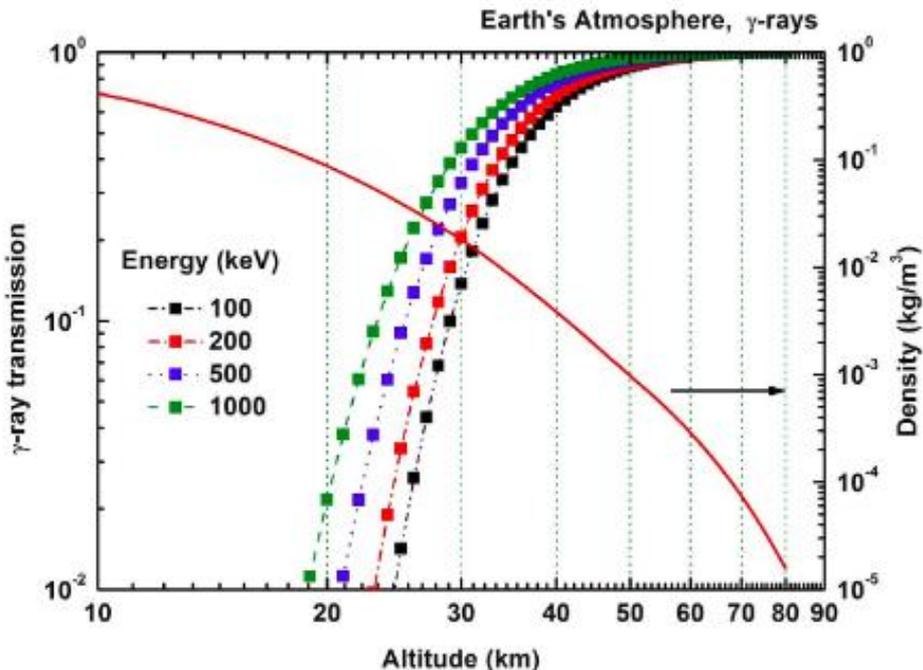
Pre-Flight Development and Testing

Thermal analysis – Finite Element Analysis software

Mechanical static acceptance test. Load with mass of ~130 kg for 2 minutes.
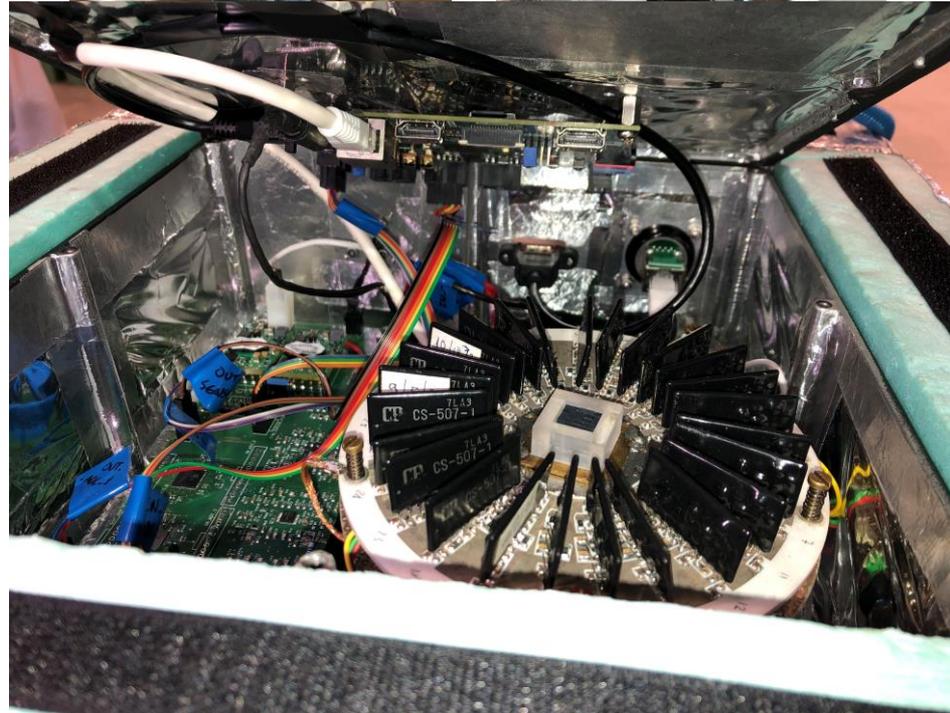
TVAC at Active Space Technologies facilities.
Temperature range: 30°C down to -51.89°C. Pressure down to ~8x10^{-2} mbar.
Detector + pre-amplifiers reached a steady state operation around 54°C
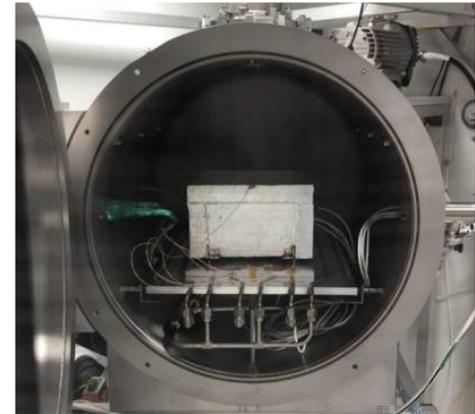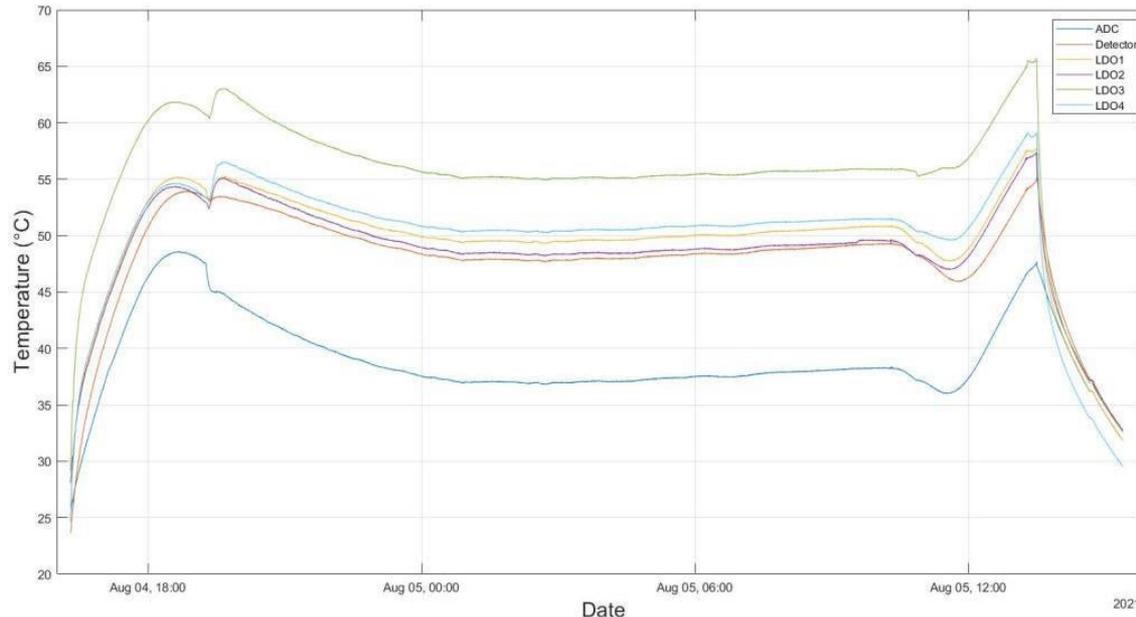
Simulation of STRATOSPOLCA mass model on MEGAlib in flight conditions

Spectroscopic measurements under radioactive sources as ^{133}Ba (356 keV);

TVAC Tests @
Active Space

The timeseries of the temperatures recorded by the critical component's sensors is shown below. The only component that fell out of the optimum range during the course of the TVAC test was the detector, which reached a steady state operation around 54°C.

Mounting STRATOSPOLCA (without thermal insulation) on the TVAC plate and chamber.

Simulation of
STRATOSPOLCA
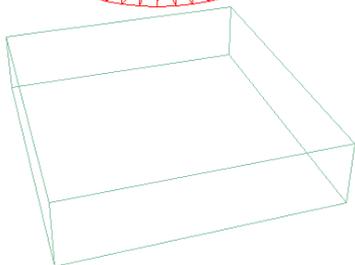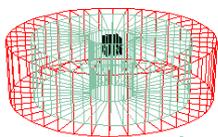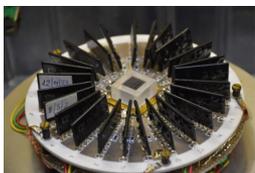
Simulation of STRATOSPOLCA on MEGAlib in flight conditions: air density @ altitude of flight

STRATOSPOLCA mass model

MEGAlib based on GEANT4

Bexus 31
Launch Campaign

Experiment Integration in the Balloon Gondola

Balloon Platform

BEXUS 31
@REXUS_BEXUS

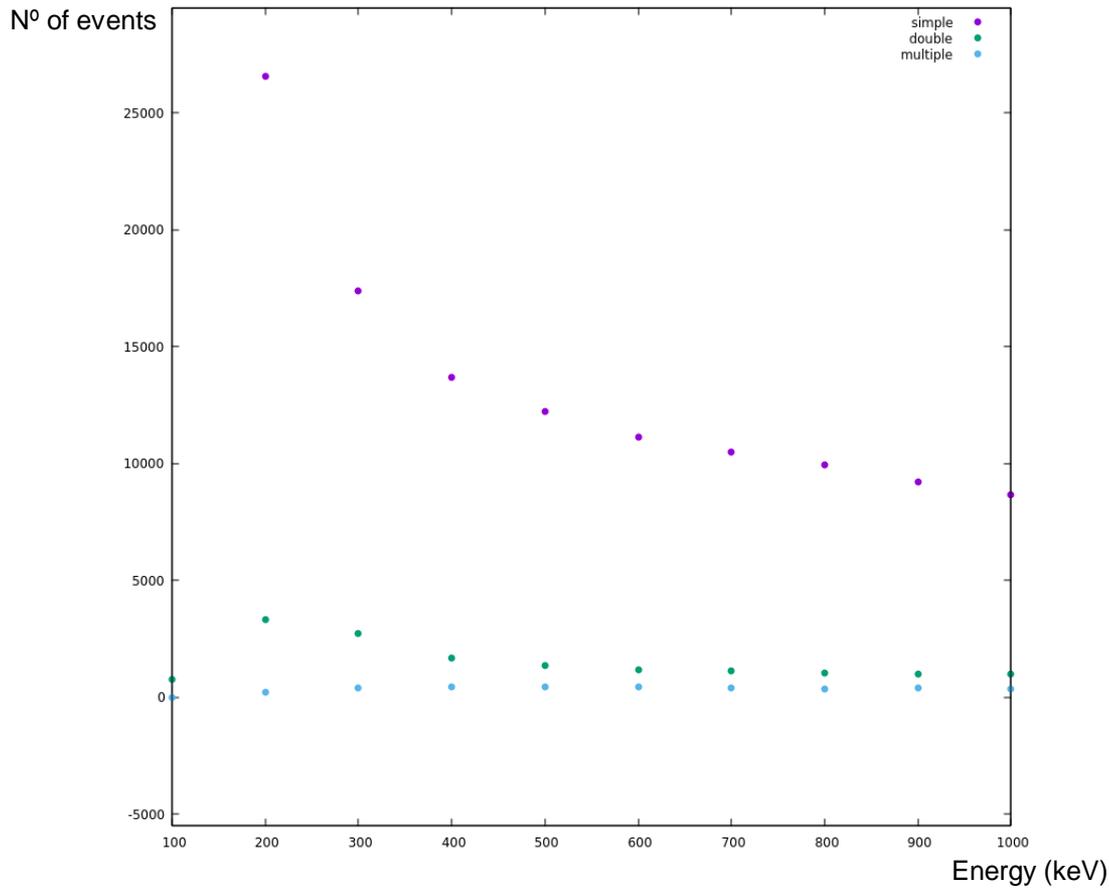|		
45m	**Balloon:** Typically a Zodiac 12 SF (12,000 m³), mass 100.6kg. Typical lift 120kg to 30km to 340kg to 25km with Helium. Lift = total mass + 12% For lighter payloads a 10 SF may be used	**Total Mass: 111.0kg**
1m	**Balloon Air Traffic Transponder (ATC)** **Cutter**	
~16m	**Parachute :** Typically 80m², 100m² or 120m² dependant on flight train mass.	Approx. 12kg (100m²)
1m	**EBASS System:** See section 5.2	Approx. 25kg
10m	**Ballast and Ballast container:** Not normally used on BEXUS **Strobe light:** SEE-BLITZ strobe light [10] Wide spectrum bright light at 0.3Hz for entire flight **Flight Train ATC:** See section 4.3 **Radar Reflector:** Passive	**Total Mass Approx. 20kg**
	Truck Plate	
25m		
4m	**Gondola and E-Link System:** See sections 4.2 and 4.3	Approx. 120kg

Bexus 31
Launch Campaign

2h48min

https://youtu.be/TOgNJ78Czgw?t=10124

Bexus 31
Launch Campaign

STRATOSPOLCA experiment was launched was launched in the **BEXUS 31** helium balloon flight on the 29th September 2021 at 9:11 local time from the Esrange Space Center near Kiruna, Sweden, in the Artic Circle.

The **maximum altitude**, 27.7 km, was recorded at 11:15.

We recorded 4GB of data during 2.6 hours in a flight of approximately **4 hours**.

Land site in northern Finland.

Future
Work

- STRATOSPOLCA Science Team started to analyse the data. These will be compared with the simulations and previous high-energy astrophysics balloon flights results

- Contribute to the optimal design of high-energy astrophysics future missions' instrument configuration for polarimetry

- Other ESA Student Calls and Projects: Fly Your Satellite, Space Rider, Euro Ageing Materials

Thank you

CdTe
Prototypes

Charge Sensitive Preamplifier

5x5 CdTe pixel matrix
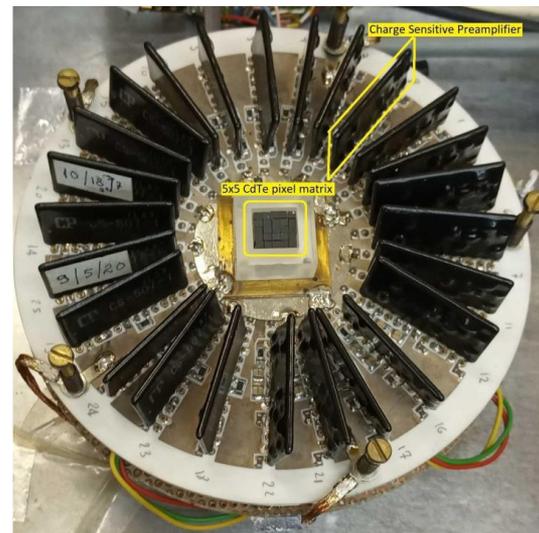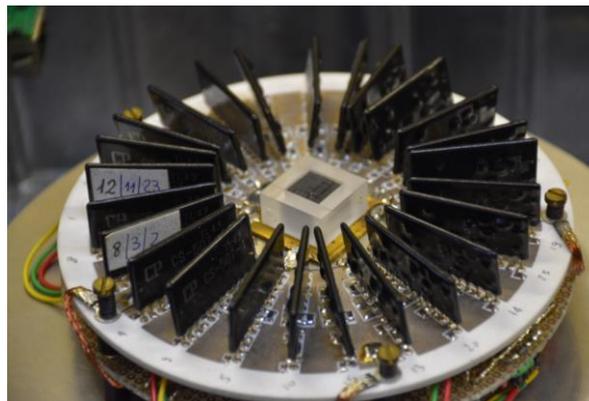
Mechanical Static

Acceptance test. The testing procedure was the following:
1. The mechanical structure of the experiment was fully assembled; the PCBs, FPGA and detector were removed to prevent unexpected damages.
2. The mechanical structure of the experiment was mounted on the T-VAC interface plate, as it mimics the interface with the Gondola. This structure was placed on the ground.
3. For the preliminar test, two H&D team members (the lightest member was on piggyback), with a combined mass of about 130 kg stepped onto the center top of the experiment for two minutes, as depicted on the left picture For the aluminum L-profiles load test, the team members were seated on the experiment top XPS. (right picture)

Old load test (steel L-profiles)
New load test (aluminum L-profiles)
4. The experiment was disassembled and each part was inspected for deformations and deflections.


18

Temperature distribution:

Thermal analysis –FEA (Finite Element Analysis)

Simplified mechanical model in static and iterative static studies to approximate transient conditions.

Verify that the components are within their operating temperatures.

 With the current thermal design, 100ºC hotspots are expected in the LDOs, but operation is safe. The detector setup should be somewhere between 4ºC and 25ºC, with the array operating at around 6ºC. The DC/DC converter in the PBC1 could be operating near the upper temperature limit.
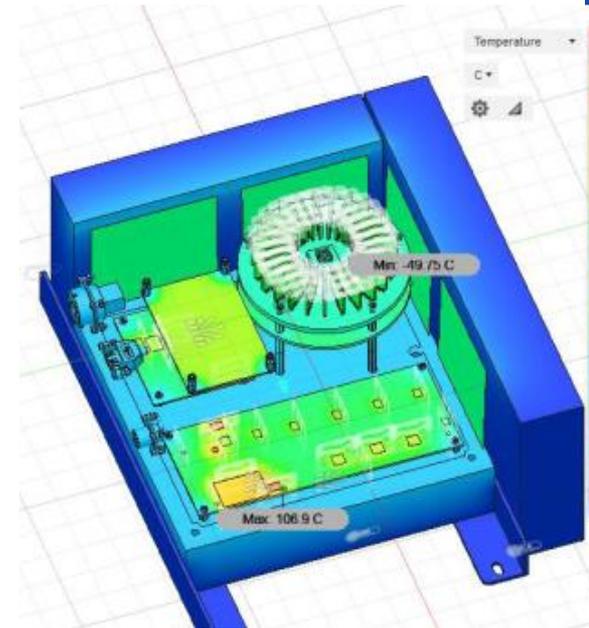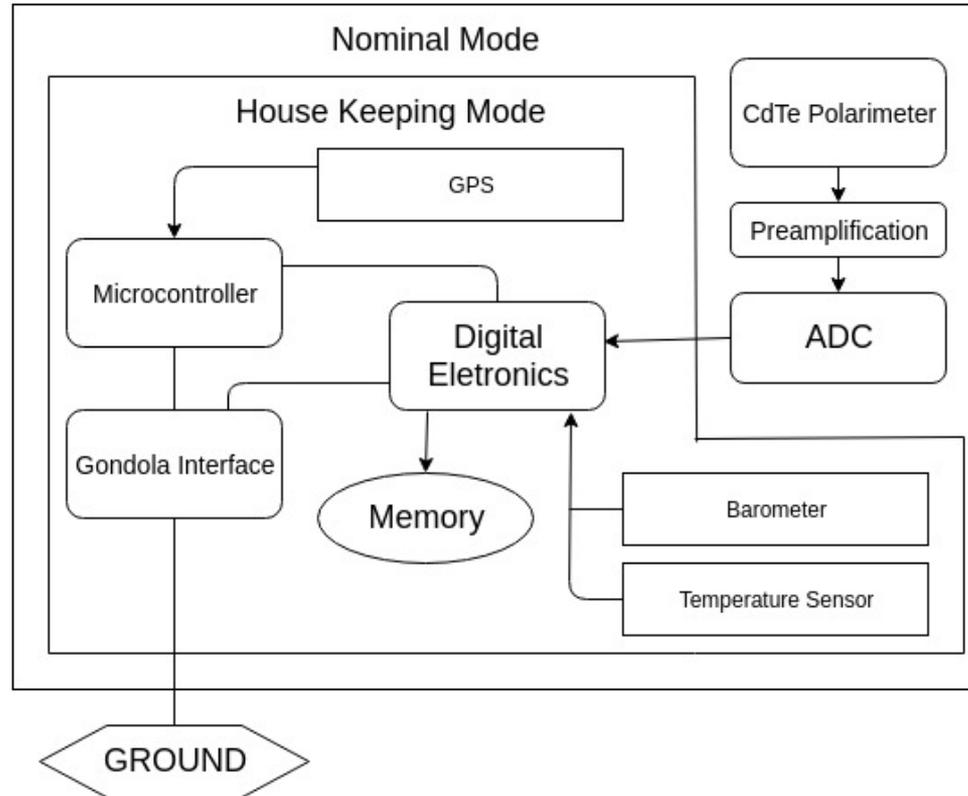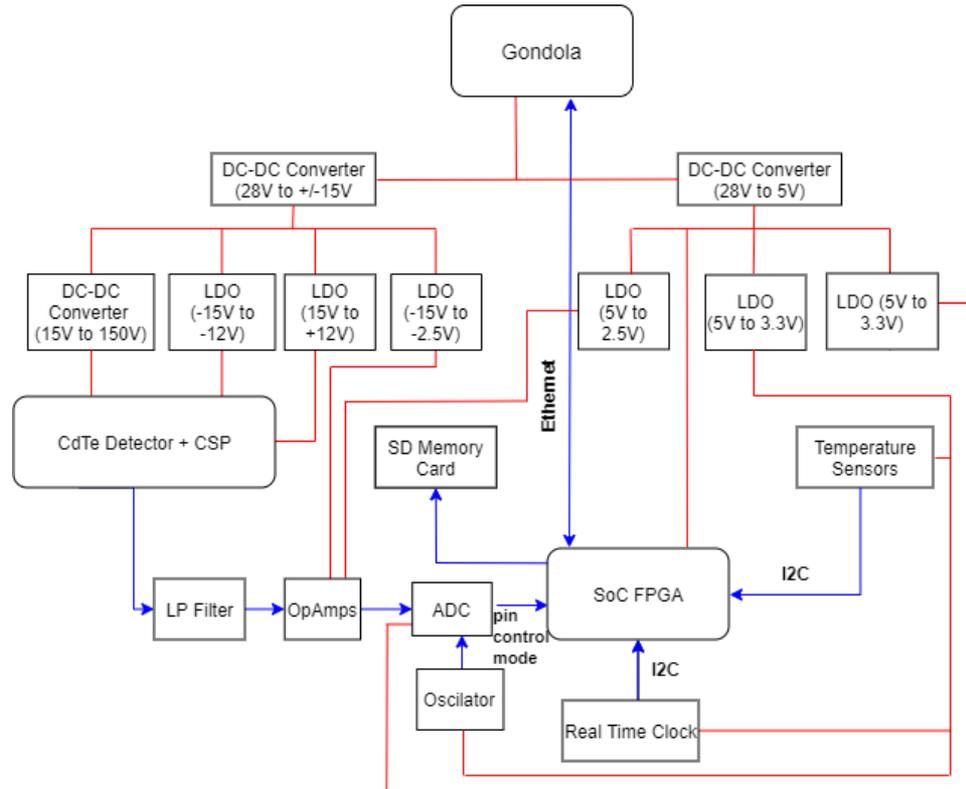
ESA Bexus Programme
STRATOSPOLCA Experiment
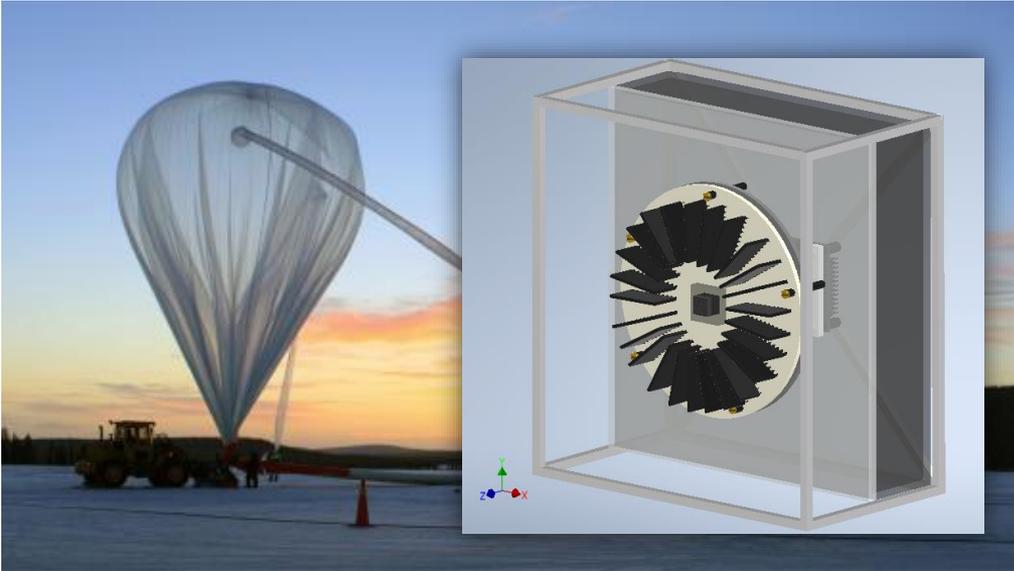
EXPERIMENT CONCEPT

General electronics block diagram. Power connections (red) and data signals (blue)