The Gamma-400 space mission

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(on behalf of the Firenze, Pisa/Siena, Roma2, Trieste collaboration)

RD11 – 10° International Conference on Large Scale Application and Radiation Hardness of Semiconductor Detectors (6-8 Jul 2011)

Gamma-400

- Russian mission originally devoted to the study of high-energy (30 GeV – 3 TeV) gamma rays and high-energy electrons and positrons (Ginzburg).

- Italian PAMELA groups officially asked by the Russians to consider participation in the project (several meetings already).

- The characteristics of the satellite (scientific payload 2600 kg, power budget 2 kW, expected lifetime 10 years) provide excellent opportunities to configure the apparatus for accomplishing extremely important physics tasks:
  - **Study of the p and He spectra up to the "knee" region (10^{14} – 10^{15} eV)**
  - **Extension of the gamma capability in the 50 – 300 MeV region**

- The Italian contribution to the project (with key responsibilities in hardware and analysis) would concentrate on these two items

- Preliminary simulation work already well established in Trieste, Florence, Pisa/Siena and Roma 2 (several possible configurations under study)

GAMMA-400

- Russian Project for the detection of High Energy Gamma's and Electrons (RAS + MEPhI + ...)
- Angular resolution better than 0.01° (@100GeV) and energetic resolution ~ 1% (>10GeV) (Fermi-GLAST (0.05^{O}, ~10%))
- Very high apogee (300,000 km) elliptical orbit
- Approved by *ROSCOSMOS (2.600kg, 2kW power, > 8 m^3 for the instrument)*
- Availability for a revision of the project that does not alter the original objectives

AC - anticoincidence detectors
C1 - 2 layers x 2 single side Si 0.3mm (pitch 0.5 mm)
C2 - Converter - total 1 Xo
1 layer W 0.7 Xo (2.45 mm) +Si (x,y) 0.5mm (pitch 0.1mm)
2 layers W 0.1 Xo (0.35 mm) +Si (x,y) 0.5 mm (pitch 0.1 mm)
2 layers W 0.05 Xo (0.175 mm) +Si (x,y)0.5 mm (pitch 0.1 mm)
1 layer Si (x,y) 0.5 mm (pitch 0.1 mm)

CDmidl - Si (x,y) detectors (pitch 0.1 mm)

S1, S2 - TOF detectors

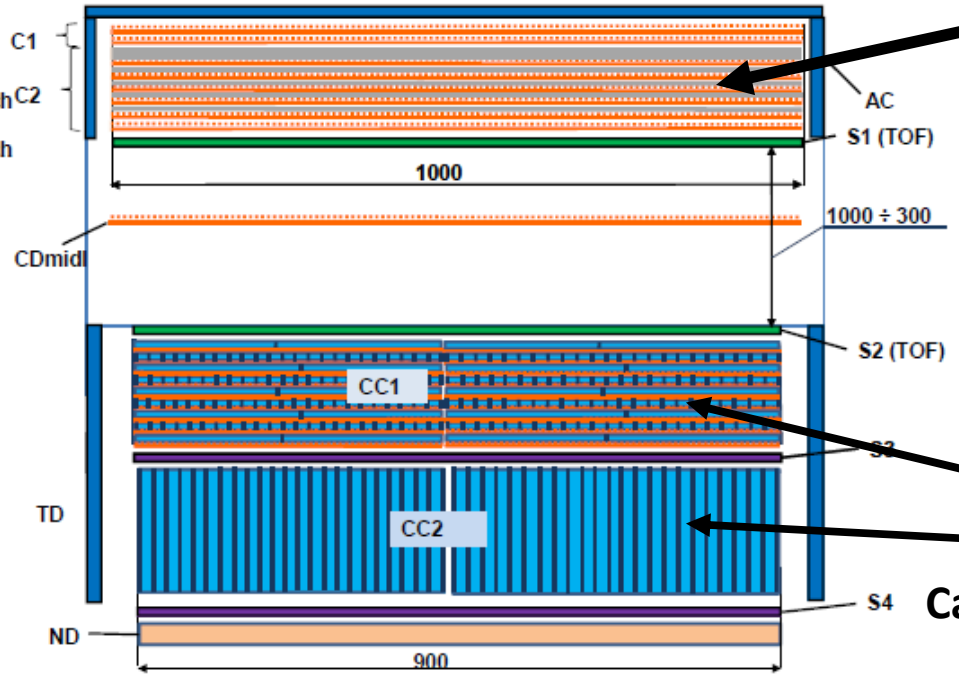
S3, S4 trigger detectors

CC1 - imaging calorimeter (10Xo)
10 layers BGO 1.12x2.24x23 + 1.12x2.24x22 cm
(20+20)x4x10 crystals
(WLS 1mm 2 layers x, 2layers y) Si (x,y)(pitch 1cm)

CC2 - electromagnetic calorimeter BGO (14Xo)
2.24x2.24x15.7cm - 400x4 crystals

ND - neutron detector

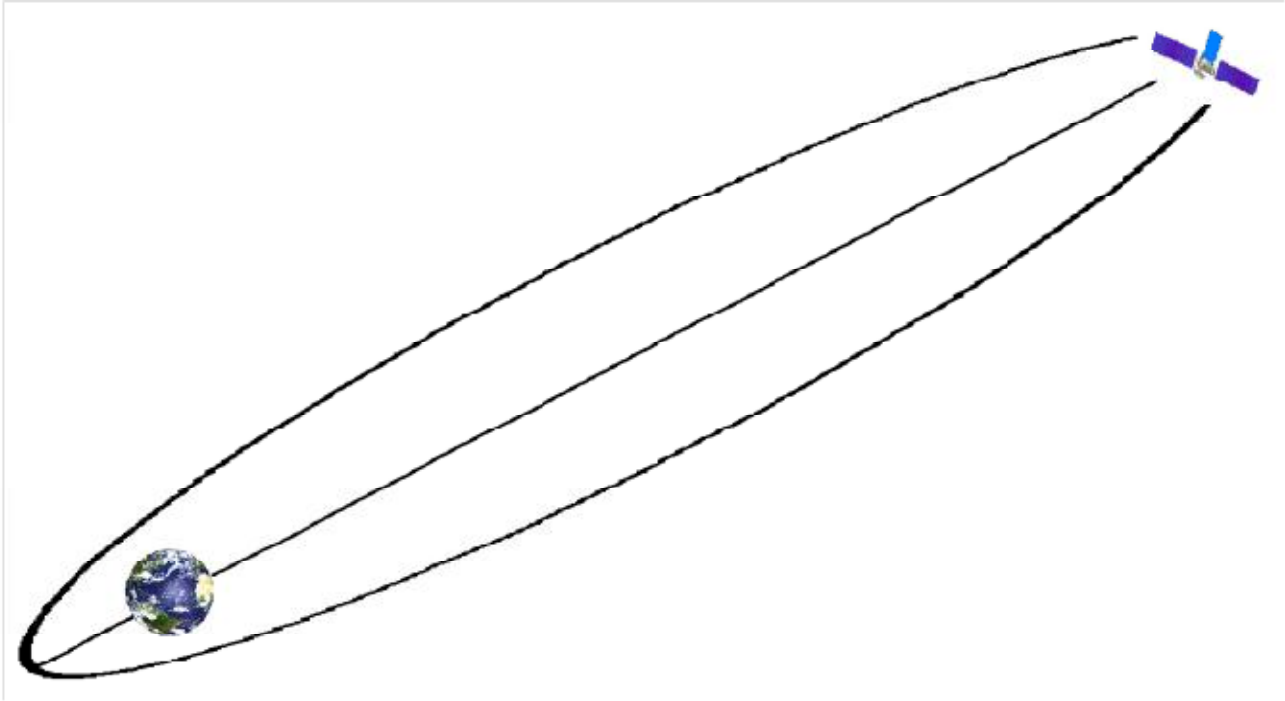
TD - 4 trigger detectors



Converter/Tracker (W+Si)

Imaging homogeneous Calorimeter (BGO)

GAMMA-400 ORBIT



GAMMA-400 space observatory with the Navigator service module will be launched by Zenit-2SB rocket into a high-apogee orbit (apogee 300000 km, perigee 500 km, inclination 51.8°).

Gamma-400 main parameters

Gamma-ray energy range	0.1-3000 GeV
Calorimeter	90 x 90 cm^2 ~ 30 X_o
Angular resolution (Eγ ≥ 100 GeV)	~ 0.01°
Energy resolution (Eγ ≥ 10 GeV)	~ 1%
Proton rejection	10^6
Telemetry downlink	100 GB/day
Power consumption	2000 W
Max. dimensions	2x2x3 m^3
Total mass	2600 kg

PHYSICS of COSMIC RAYS from SPACE

Search for signals from annihilation of dark matter

↓

Differential fluxes of antimatter (antiprotons and positrons)

Search for anomalies in the electron spectrum

by

Magnetic spectrometers (**PAMELA** and **AMS-2**)

Study of origin and propagation of cosmic rays in the Galaxy

↓

Differential fluxes of proton and nuclei

Measurament of the ratio between Primary and secondary cosmic rays

by

Magnetic spectrometers (**PAMELA** and **AMS-2**)

Calorimeters (**ATIC** and **CREAM** on balloons)

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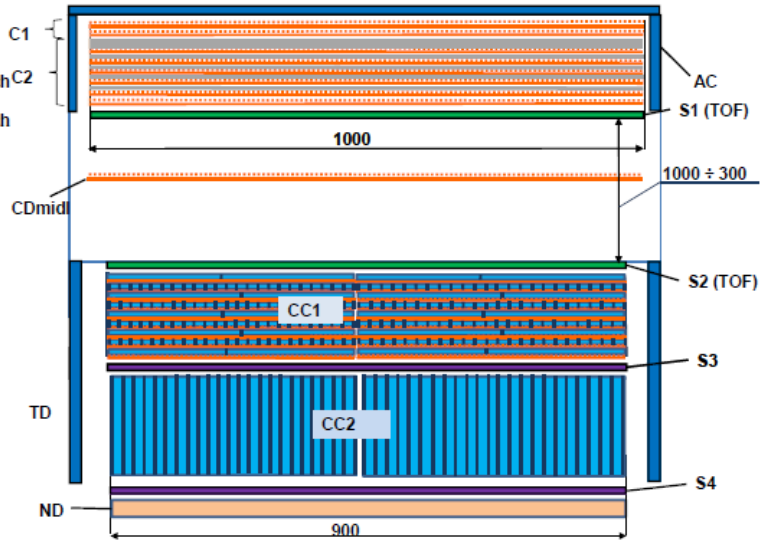
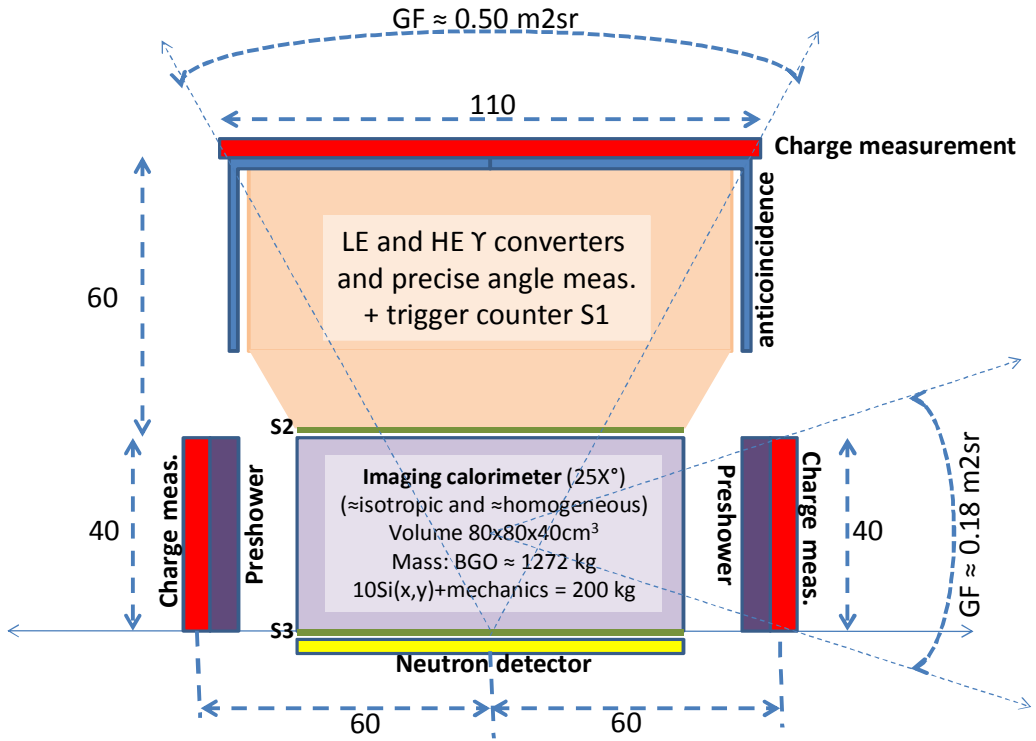


GAMMA 400 R&D

INFN teams from PAMELA,AGILE,FERMI-GLAST

Two years of R&D (project of the new instrument, simulations, prototypes)



+ Low energy gamma's (E>10MeV)

+ High energy nuclei up to the knee region with high geometry factor (~ 1m²sr)

Converter+tracker for good angular resolution

1X° (5 layers: 0.7+0.1+0.1+0.05+0.05) of W
interleaving 6 microstrip Si(x,y) layers (thick=0.5mm, pitch=0.1mm)

+ 1 middle microstrip Si(x,y) layer (thick=0.3mm, pitch=0.1mm)

Calorimeter for good energy resolution

Deep imaging calorimeter (>24X°)
large area (>0.6m^2) for pointing

Extention to low energy gamma's

it must be added a number of very thin W layers on top,
interleaved by Si(x,y) layers (thick=0.5mm, pitch=0.5mm)

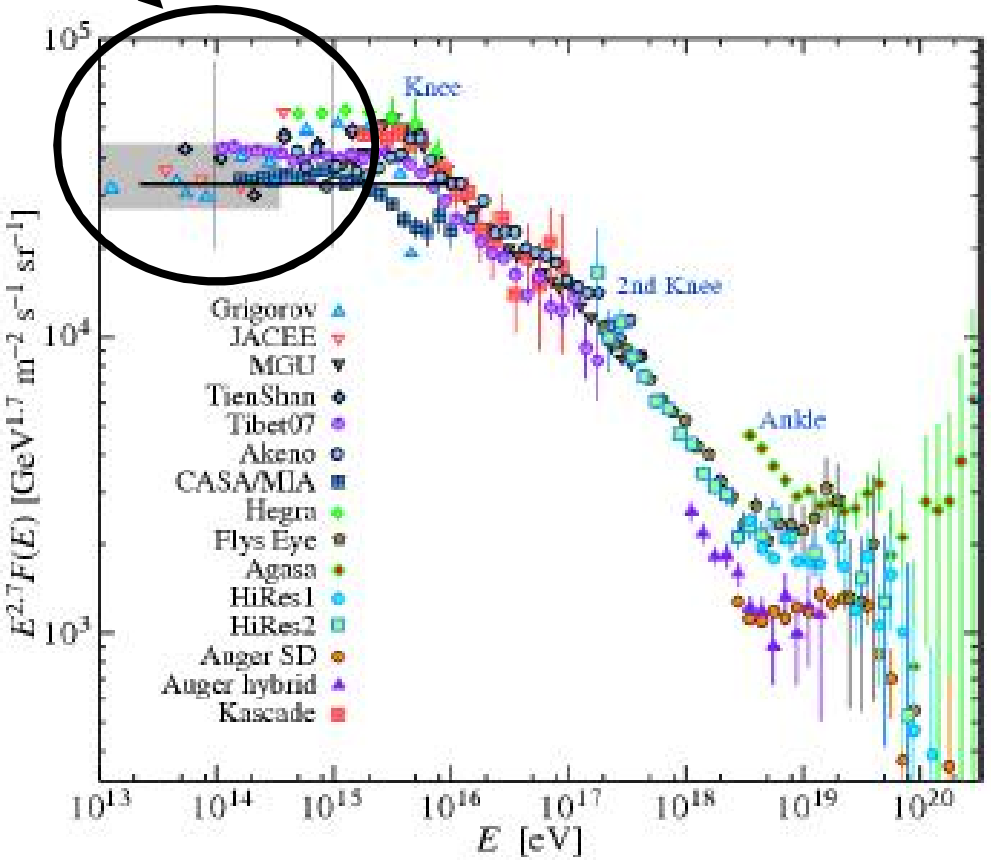
STUDY OF THE ORIGIN AND PROPAGATION OF COSMIC RAYS

@ knee until now only indirect measurements on ground:
very difficult to understand the chemical composition

Direct measurements possible
up to 10^{15}-10^{16} eV

Deep calorimeter needed
(>25 X°, 1.5λ)

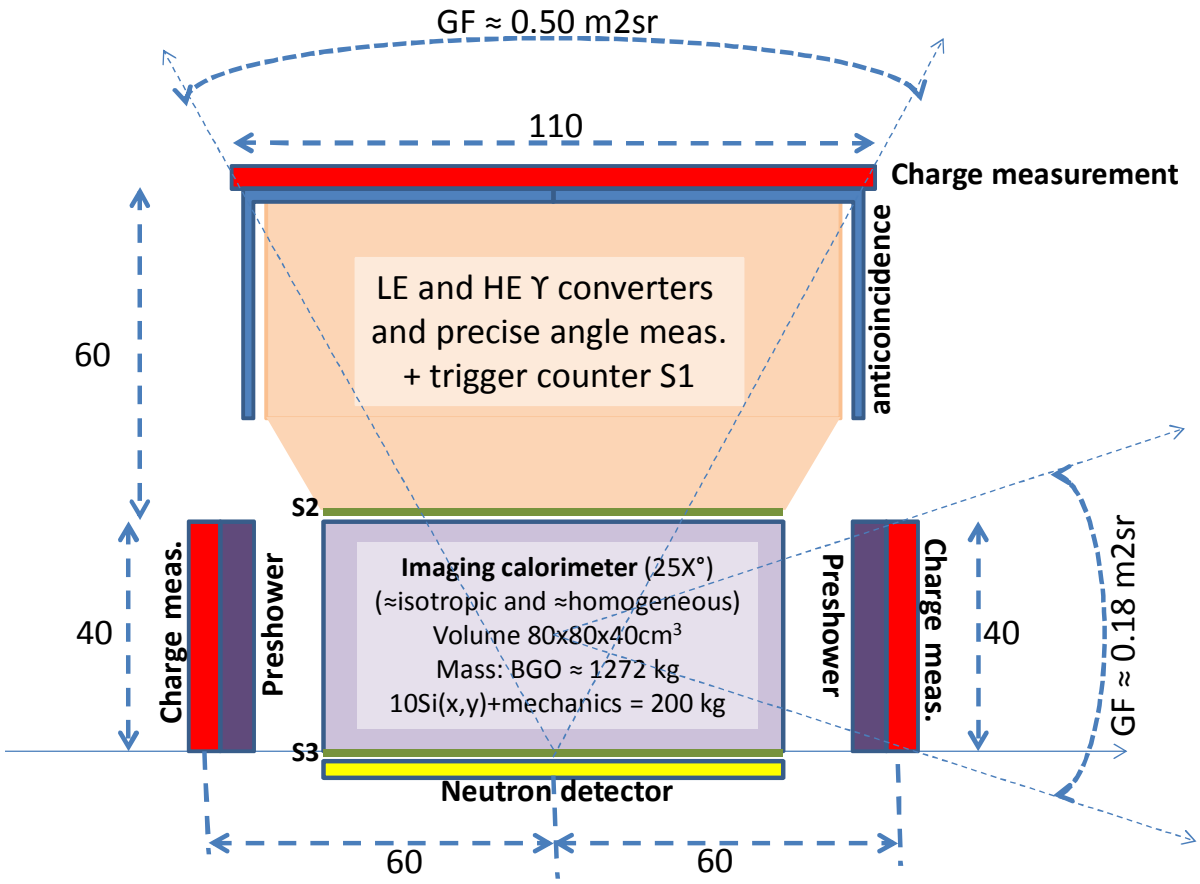
Large acceptance x time needed
(GF≥1m^{2}sr for 5 years on satellite
>10^3 events in the 10^{14}-10^{15}eV)



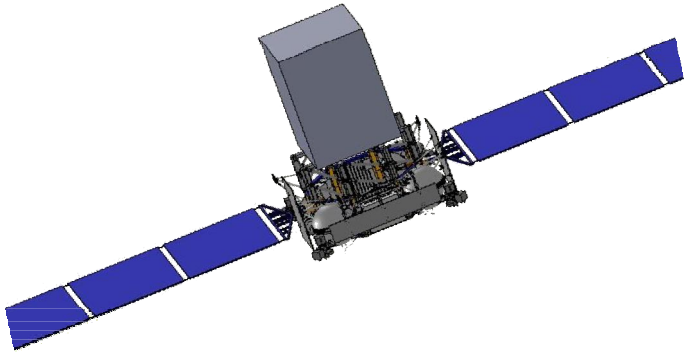
Present situation:
AMS-2 calorimeter GF = 0.04 m^{2}sr
CALET experiment (2014-2018) GF = 0.12 m^{2}sr

Modifications for high energy protons and nuclei:

- Charge measurement: resolution and dynamics.
- Make use of the sides of the calorimeter for increasing the geometry factor



It must be developped an ISOTROPIC configuration of the instrument and of the calorimeter

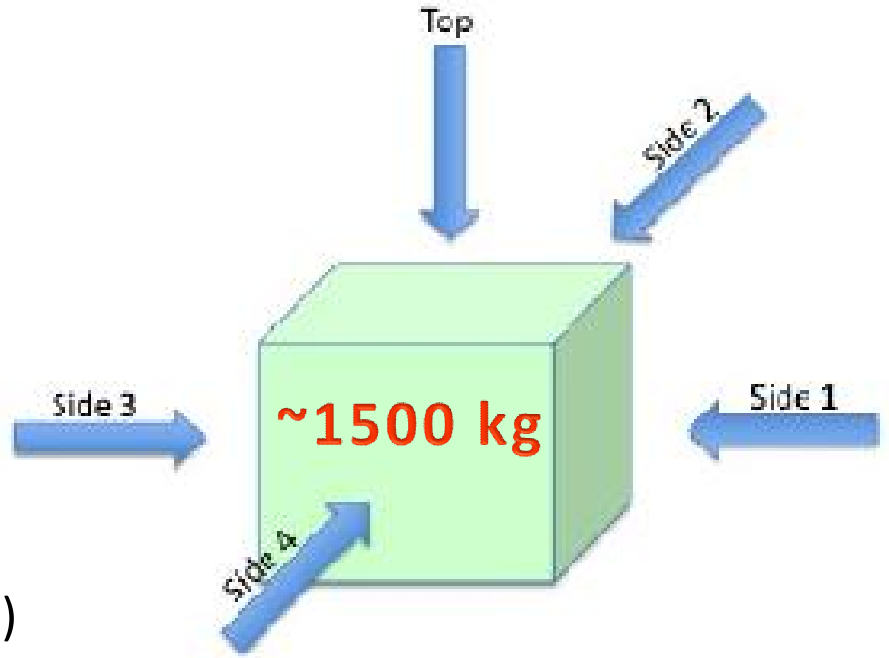


Side views are free

Calorimeter for Gamma-400 - 1

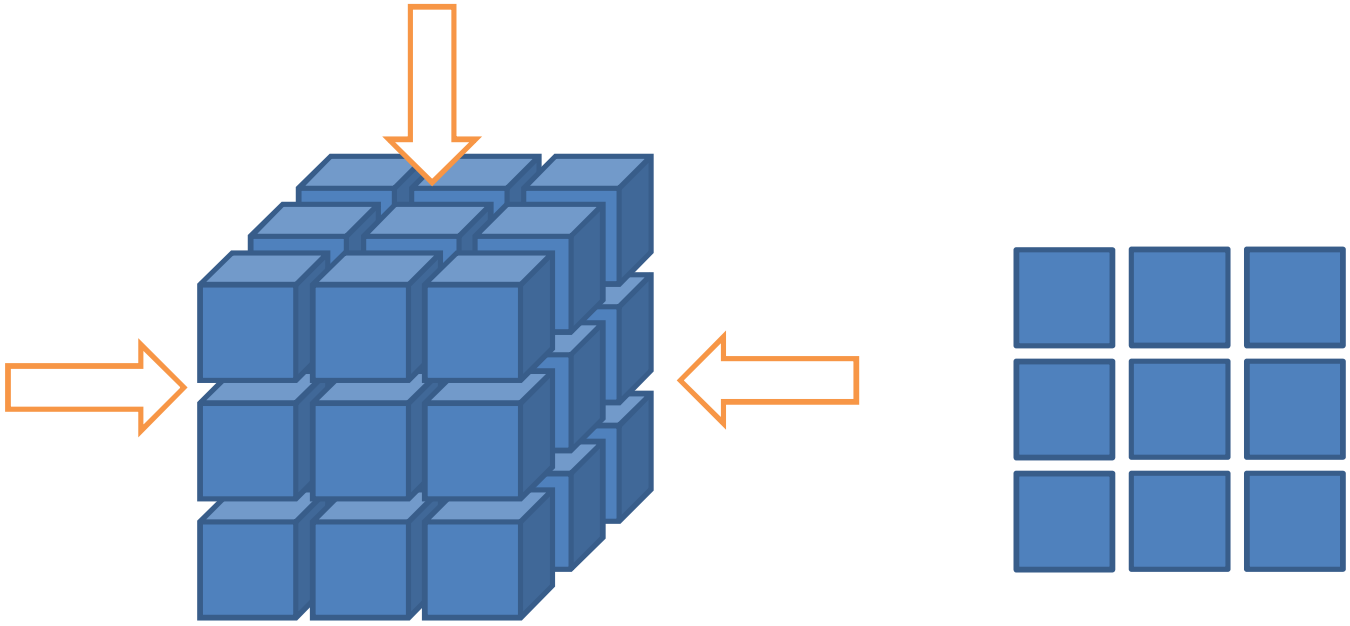
- Simulation of different structures of the detector and their characterization for the measurement of nuclei and gamma's
- Study and design of the calorimeter

- Features :
  - Depth` (~1.5 λ for protons)
    → shower containment
  - high granularity (~1 X_0)
    → e/h separation (by shower topology)
  - Homogeneity
    → Energy resolu□on (reduced fluctua□ons)
  - **Isotropy**
    → uniform response for the top and side particles



Calorimeter for Gamma-400 - 2

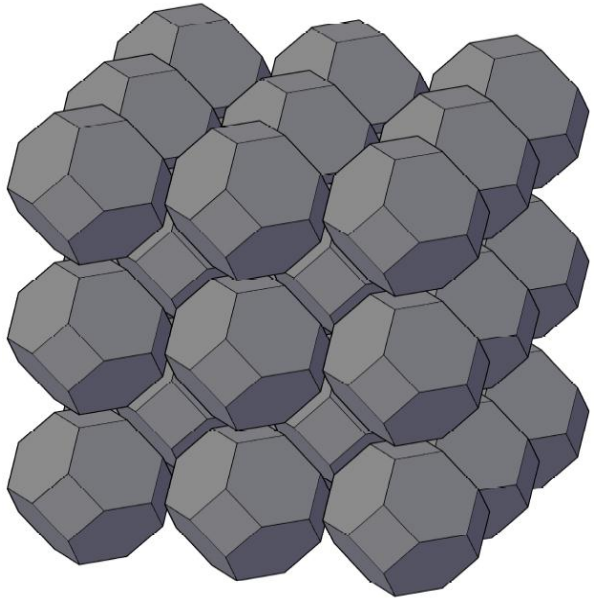
- Design of a calorimeter composed by cubic (~2×2×2 cm^3) BGO crystals
  - Study by simulations of the impact on the performance of the experiment.
  - Design – Feasibility study (signal output) and realization and test of a prototype(~4×4×8 elements)-



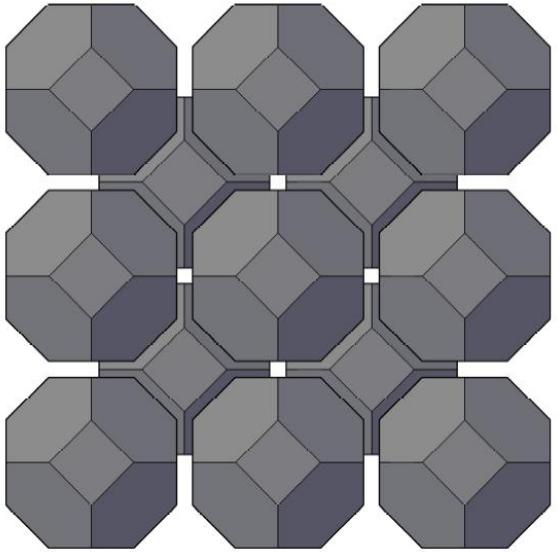
Calorimeter for Gamma-400 - 3

Å Feasibility study for a calorimeter composed by **trucked octahedron** shaped crystals.

- ï Study by simulation of the performance and comparison with the cubic lattice calorimeter
- ï Realization of crystal prototypes and test of single elements to verify the influence of the manifacturing on their properties.



- ÅUniform and cubic symmetric tessellation of the space.
- ÅReduced dead zone in comparison to cubic lattice.
- ÅPossibility of increasing the GF spacing the crystals, for equal mass.



Aim of the R&D activities:

Design of a multipurpose instrument for the Gamma-400 mission:

High precision measurements of high energy gamma's
(source position, E and E variation)
Extention of gamma's measurements down to <30MeV
(source position, E and E variation)
High precision measurement of electron spectrum (up to > 3 TeV)
Measurement of the energy spectrum of protons beyond 2 PeV
Measurement of the energy spectrum of helium beyond 1 PeV/nucleon
Measurement of the spectra of nuclei up to actinides

With the following main parameters:

Mass=2600 Kg
Power=2kW
# of channels ≈ $5*10^5$

Thank you for your attention