



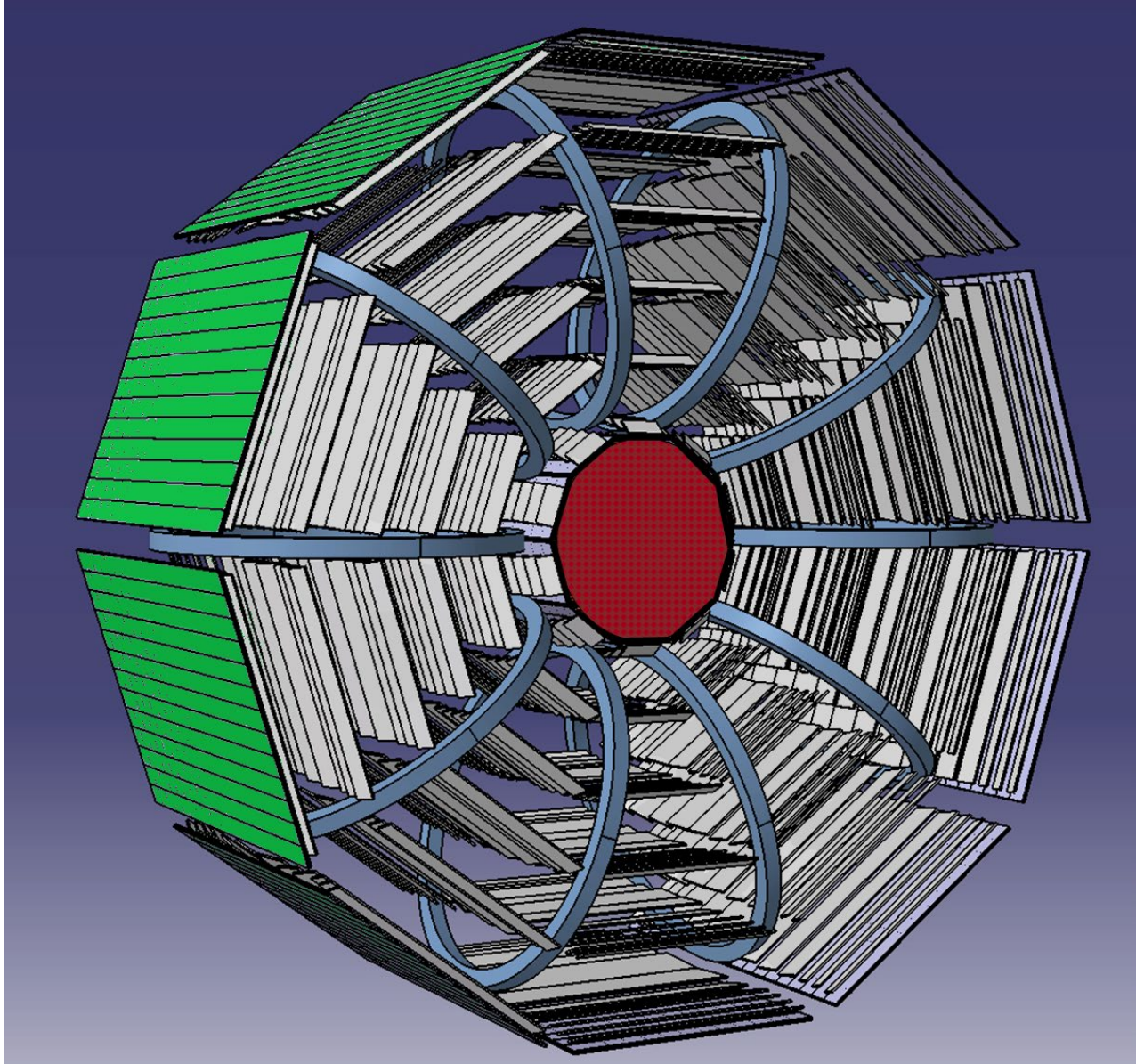
The Superconducting Space Magnet of the ALADInO Spectrometer



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ALADInO (Antimatter Large Acceptance Detector IN Orbit) is a large acceptance magnetic spectrometer based on a novel superconducting magnet technology, equipped with a silicon tracker and a 3D isotropic calorimeter. It is conceived to study anti-matter components of the cosmic radiation in an unexplored energy window which can shed light on new phenomena related to the origin and evolution of the Universe, as well as on the origin and propagation of cosmic rays in our galaxy.
For more detailed information on the detector see poster presentation “ALADInO: an Antimatter Large Acceptance Detector In Orbit” by Matteo Duranti.

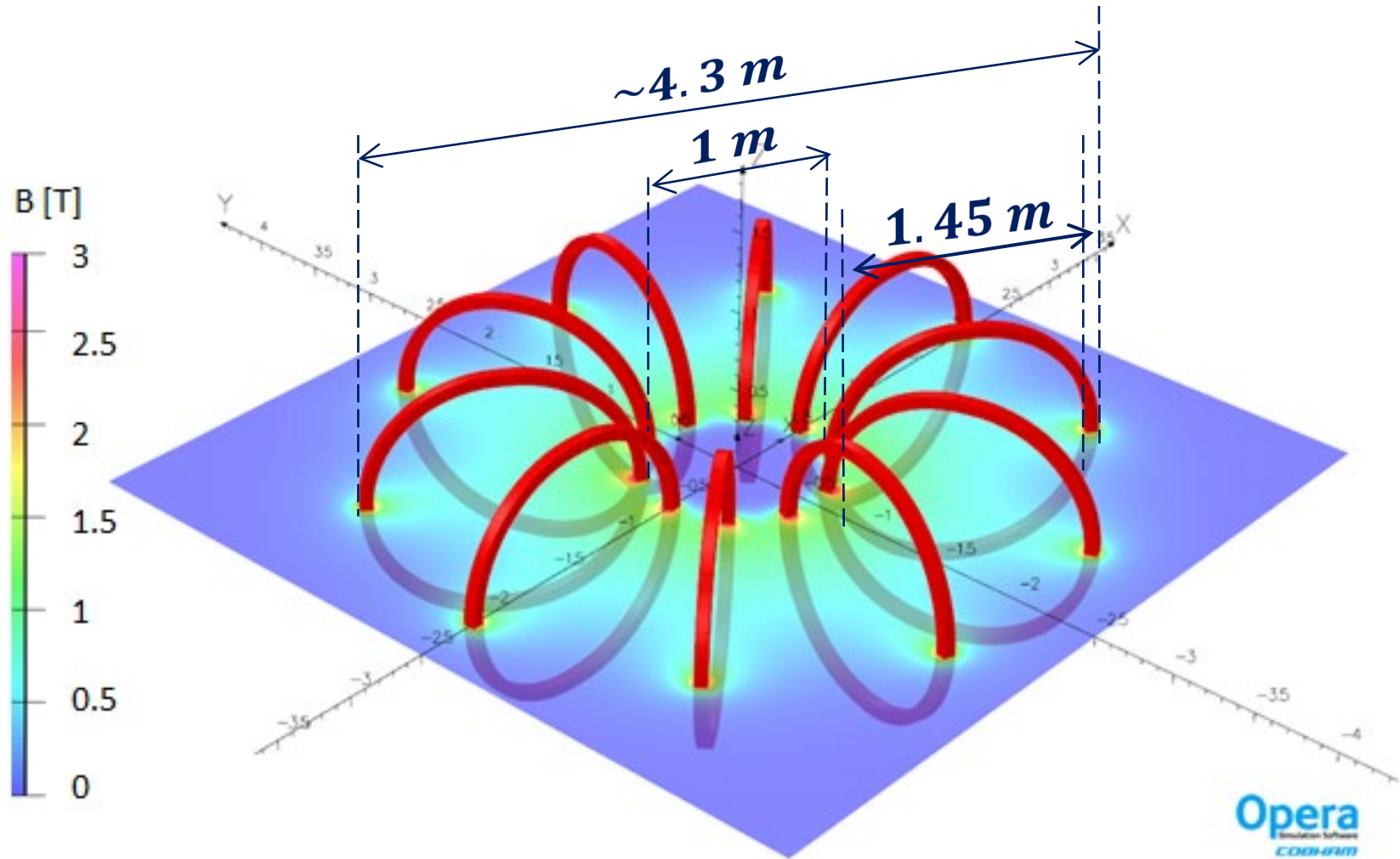
The generation of the magnetic field within ALADInO is provided by a superconducting toroidal magnet. A toroidal magnet allows confining its field within the coils, leaving light stray field on other parts of the satellite. Moreover, it minimizes the dipole moment thus limiting the interaction with the environmental field (either geomagnetic or interplanetary) and consequently forces and torques on the spacecraft.



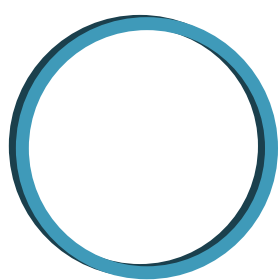
The ALADINO toroid is composed by 10 coils, a number chosen as the better compromise between two requirements:

- to maximize the magnetic field azimuthal homogeneity, which needs distributed conductors (large number of coils), and
- to maximize the field of view, which requires concentrated conductors (small number of coils).

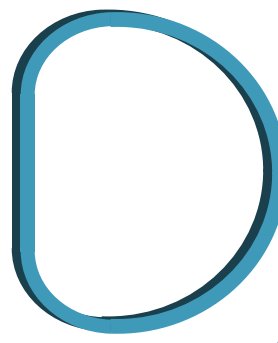
MAIN CHARACTERISTICS OF THE TOROIDAL MAGNET	
Number of coils	10
Number of turns / coil	1800
Operating current	244 A
Total current	4.4 MA-turns
Inductance	120 H
Average magnetic flux density	0.8 T
Bending power	1.1 T·m
Stored energy	3.6 MJ
Mass	1200 kg



Two possible coil shapes



Round coils



D-shaped coils
(constant stress)

Bending power of an ideal toroidal magnet

$$\Xi = \int_{R_i}^{R_e} B_{\theta} dR = \frac{\mu_0 I}{2\pi} \ln \frac{R_e}{R_i}$$

Mechanical structure is necessary to hold:

- Forces acting within each coil
- Forces exerted by each coil toward toroid axis
- Torques due to possible azimuthal asymmetry

Low density structural materials will be used: aluminum and titanium alloys, Al-B₄C and Al-Al₂O₃ composites, aramid fibers, carbon or boron fiber reinforced resins.

Superconducting space magnets – Main requirements :

- | | | |
|--|--------|--|
| (i) low mass budget, i.e. high stored energy to mass ratio | —————> | low density materials – high current density |
| (ii) low power consumption, i.e. efficient cryogenics | —————> | efficient cryocoolers and cryogenic heat pipes – low heat load |
| (iii) no liquid helium | | |
| (iv) very high stability | —————> | high temperature superconductors (REBCO or Magnesium Diboride) |

High temperature superconductors (HTS) allows operating the magnet at temperature between 15 K (MgB₂) and 40 K (REBCO).

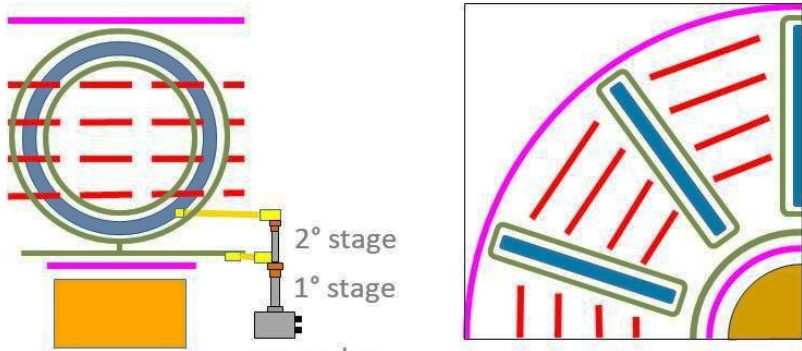
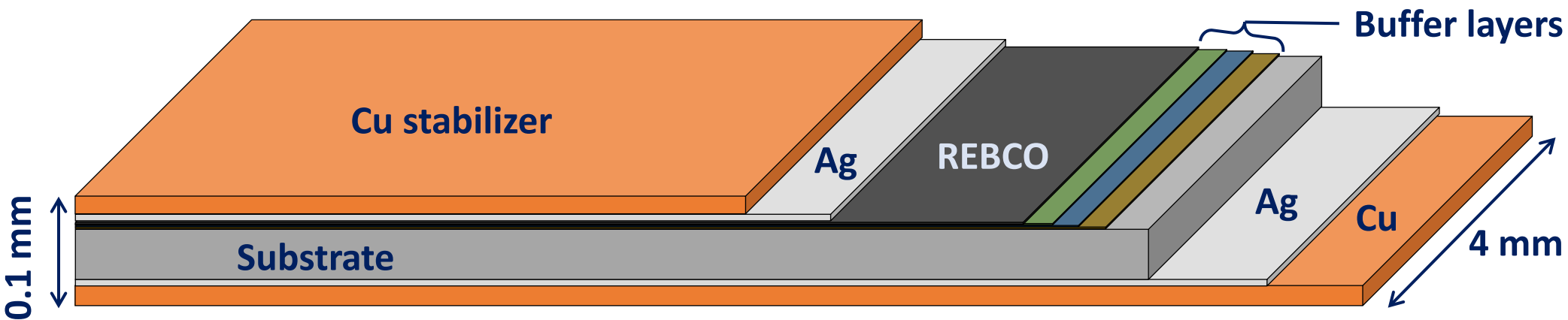
High temperature leads to :

- more efficient cryogenics
- higher stability respect to quench triggering disturbances due to higher specific heat, therefore to higher enthalpy margin.

After a trade-off, it was chosen to use REBCO (Rare Earths Barium Copper Oxide). State of the art, 4 mm wide, 0.1 mm thick, REBCO tapes have critical current $I_c(3\text{ T}, 40\text{ K}) > 300\text{ A}$.

Further developments in conductor performances can lead to the reduction of the number of turns.

Despite quench of HTS magnets is unlikely, in case it happens, protection is known to be a major issue. Possible solution: no-insulation technique (actually, controlled insulation) which allows current diffusion and protects the coils.



Side cross-sectional view Top cross-sectional view (¼)
Superconducting coil (10-40 K) Calorimeter + trigger (250 K)
Tracker (250 K) ToF + Trigger (250 K) Cryogenic shields (80 K)

The ALADInO magnet is assumed to operate at $T \approx 40\text{ K}$, cooled by cryocoolers

Thermal radiation power coming from the several sources will be intercepted by a series of radiation shields. A passive multi-layer sunshield, umbrella-like, will be used to intercept the radiation heat flux from sun.

To minimize the heat load, the magnet is meant to operate in persistent mode. Two methods are possible to charge the magnet: a power supply with disconnectable current leads or a flux pump. The latter is an attractive solution which avoid moving parts and limit the power supply size.