Magnetic Radiation Shielding for Space Travel

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Introduction

- Task: protect astronauts from cosmic rays in interplanetary travel.
- Our idea: active protection with a magnetic shield generated by an empty toroidal coil.

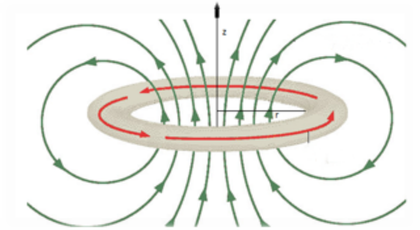

Figure: The field topology.

The electromagnetic model

- **Theoretical model:** we supposed that the torus behaves like a single coil running at the core. Then we integrated numerically from Biot-Savart law.
- **Discrete approximation:** we verified the theoretical model by discretization of the torus surface in multiple coils.

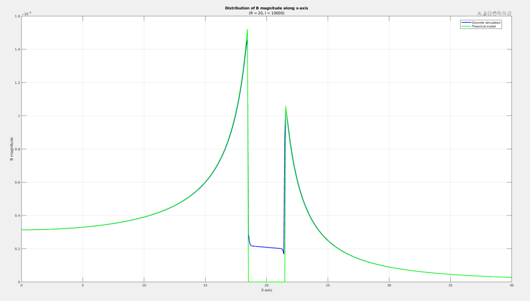

Figure: Confrontation of computational models ($R = 20m$, $I = 10^4 A$).

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2 Particles simulations

Trajectory computation

2 Particles simulations

- We have developed two main codes to simulate trajectories.
- A MATLAB code to compute and plot a particle trajectory in 3d space, given the mass, charge and initial position and speed.

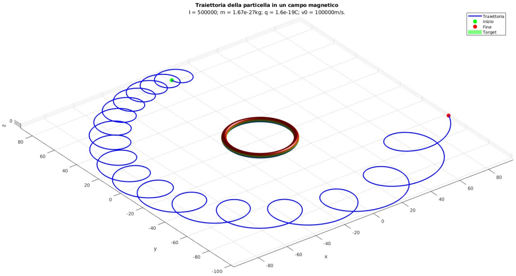

Figure: Trajectory of a proton ($v = 10^5 m/s, I = 5 * 10^5 A$).

Monte Carlo simulations

2 Particles simulations

- C++ code to simulate swarms of different energetic particles and heavy nuclei,
- Initial speeds sampled with a Monte Carlo method from Maxwell-Boltzmann distribution and initial positions sampled uniformly across a sphere.
- Uses the Boris integration method with an adaptive time step.

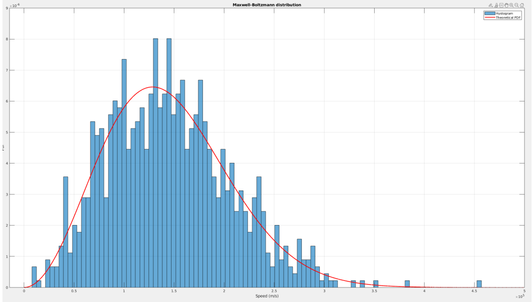

Figure: Maxwell-Boltzmann sampling for a proton ($T = 10^6 K$).

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Results

3 Results and conclusions

- Health risks: inside the Torus there is a static magnetic field of $\approx 2 \cdot 10^{-4} T$ for $10^4 A$.
- Monte Carlo simulations: we have observed that the Torus deviates well the ultra-light particles (electrons and positrons). Also, at equals eV, it performs better on heavier nuclei, while the most penetration is seen with protons and helium nuclei.
- Power requirements.

Energy (eV)	**Temp. (K)**	**Current (A)**	**Iron**(eV%)	**Proton**(eV%)
$10^2 - 10^4$	10^7	10^4	99.5	62.6
$10^3 - 10^5$	10^8	10^4	67.3	25.7
$10^4 - 10^6$	10^9	10^5	99.5	62.1
$10^5 - 10^7$	10^{10}	10^5	67.6	25.7

Table: Deviation of incoming energy for different energies and particles.

Further development

3 Results and conclusions

- Other simulations: more advanced Monte Carlo simulations will provide better insights on the functioning of the shield.
- Structural issues: further evaluations on whether the toroidal structure is optimal or feasible are required, possibly leading to exploration of other spacecraft configurations.
- Field enhancements: oscillating fields may be studied, keeping in mind their lower compatibility with human life.
- Superconductors: superconductive material may provide better electrical properties, thus reducing the power requirements, but it is to study the compatibility with the operative thermal constraints.

Questions and reproducibility

If you have any question, please feel free to ask.

The code is available at this GitHub link:

https://github.com/s348174/Magnetic_Active_Radiation_Shielding.git.

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Thank you for listening!