HECTOR

High Energy Collider Testing Our Reality

Jeremy Atkinson | Simon Minton | Ofer Ronen | Stella Vlahou Gomez

Supervised by: Hector Garcia Morales

GOAL The goal of our project was firstly to get familiar with the key parameters of a collider. As well as overall project management, teamwork and finally identify and address the limitations of the project due to current (and future) technologies.

IDEAS After numerous approaches to orbital colliders (such as collider on the surface of the moon or the earth) we decided to address a collider in a loop around the equator with a radius of 7,000 km.

Future Technologies

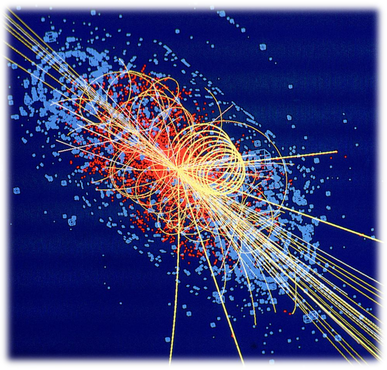
For this project we have chosen to assume that there will be certain technologies in the future which are currently being researched. The most important one would be nuclear fusion (NF) as a power source. Currently centers such as CERN syphon power from the electricity grid, which would be impossible in space. We would therefore require power plants attached to the collider, and the most powerful and efficient method would be through the use of NF. Thus, we have designed HECTOR with two fusion centers to power the beam. Known technology, such as the solar panels currently in use on the ISS, will be used to power the manned bases. NF will also be used to power the large fleet of reusable rockets, such as the ones being designed by Space X and Virgin Galactic, which will be required to transport the thousands of tones of material into orbit.

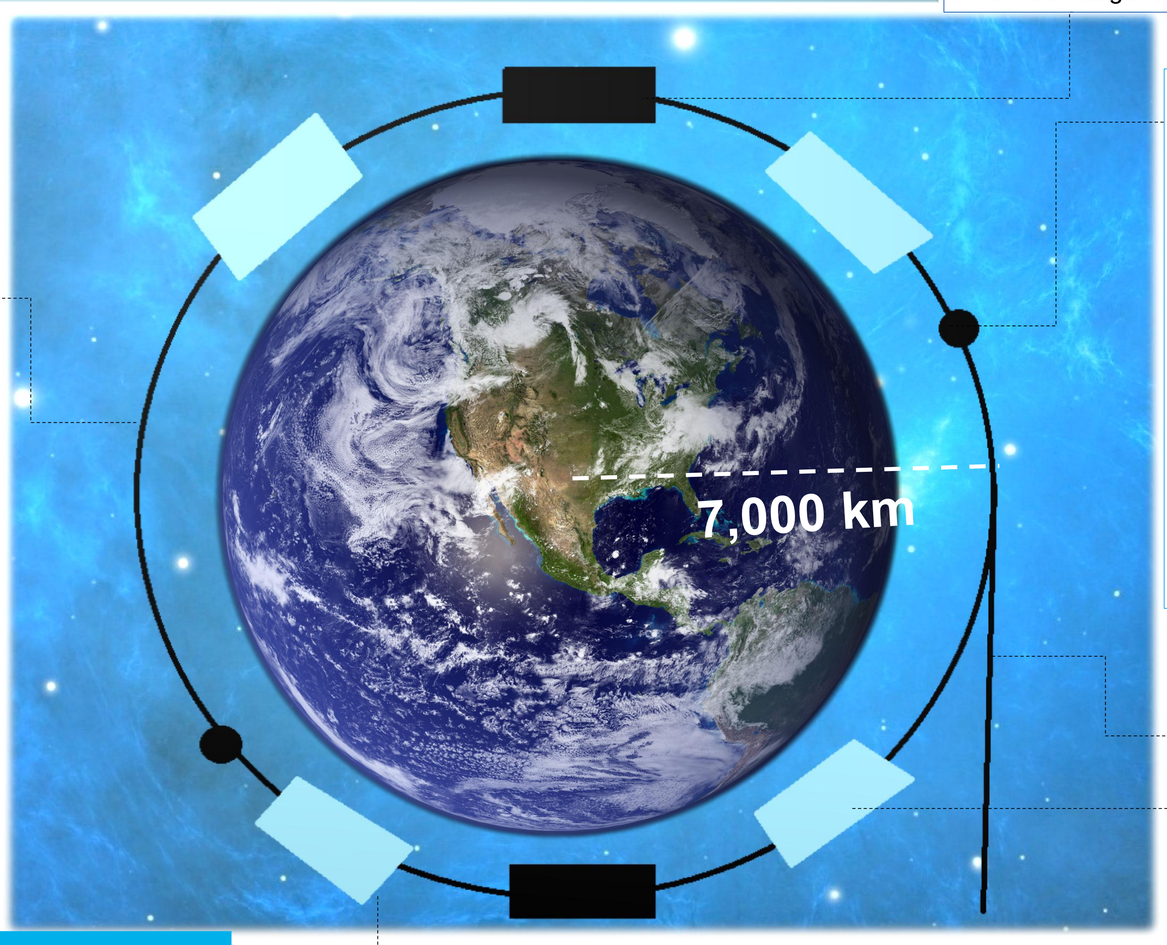
Due to the high quantity of data which will be collected by the detectors analyzing the collisions on HECTOR, we are also taking into consideration that quantum computers will have been developed. Access to such computing power both on the manned stations and back on Earth will allow physicists to analyze and store a much greater amount of information than is currently possible.

Human bases & maintenance

Maintenance is a crucial part of every structure, especially mega structures laid out in space.
HECTOR will be built using the most advanced technologies we can imagine, yet constant bombardment of cosmic rays, solar winds, space scraps and more will require frequent maintenance. Most of the work will be conducted by robots, yet we believe that in a 100 years from now human presence will still be necessary. Therefore, HECTOR will have two main human bases, each located in between of the different detectors. The bases will contain life support system, tools, supplies, and will be connected to the power plants and the detectors via network of trains, attached externally to HECTOR's main structure. The human bases can also be used as a stage for space research - similarly to the ISS, but on a much larger scale.

The beam pipe will be made of a number of layers. The main interior layer will be very similar to the LHC beam pipe, including the super cooling systems in place. Exterior to this will be a heat shield to protect the pipe from the extreme temperature fluctuations as it is illuminated by the Sun. On the surface of the pipe solar panels similar to those found on the ISS will be used to power the manned bases and other smaller energy consumption sites.





Fusion Reactors

The reaction which occurs between the protons and neutrons of atomic nuclei at close proximity to one another. The threshold proximity is defined at the point where protons and neutrons from both nuclei in question react with each other. When fusion between 2 hydrogen atoms occurs (D + T), the amount of energy released is 17.6 MeV.

Using this value we can calculate how much hydrogen is required to power different collider facilities (using the hydrogen that can be extracted from water molecules):

LHC stored beam energy 392[MJ] -> 4.16[mg] of water.
FCC stored beam energy 8.4[GJ] -> 0.09[gr] of water.
GOD stored beam energy 4.23[PJ] -> 830[Kg] of water.
World energy consumption (2013) 567[EJ] -> 6000 Tons of water -> 2.4 Olympic swimming-pools.

High Energy Litter Liquidator (HELL)

Instead of using a beam dump such as the one used at the LHC, at the end of an experiment, our collider would simply eject the beams into space.

Enormous Analytical Space Yard (EASY)

Another possible future detector

Giant Orbital Detector (GOD)

Similar layout to ATLAS whilst utilising the technology from the current (2017) CMS to enable **GOD** to be more compact.

PARAMETERS	LHC	FCC	HECTOR
Circumference (km)	26.7	100	44000
Straight sections	8	12	2200
Average straight section length (km)	0.528	1.4	20
Number of IP's	4	2 + 2	4
Number of man bases	-	-	2 large ones (+1 for each detector)
Number of fusion power plants	-		2
BEAM			
Number of bunches (25 ns)	2,808	10,600	6,285,000
Bunch population	1.15	1.00	1.00
Nominal transverse Normalized emittance [mm] (25 ns)	3.75	2.20	2.50
CM energy [TeV]	14	100	1560
Peak Luminosity $10^{34} cm^{-2} s^{-1}$	1.00	5.00	947.35
Synchrotron radiation power per proton 10^{-11} W	1.93	45	45
Dipole field [T]	8.33	16	0.332
Beta function at IP	0.55	1.10	0.15

EQUATIONS

Synchrotron radiation power per proton
$$P = \frac{2}{3}\frac{e^2 c \gamma^4}{4\pi\varepsilon_0 \rho^2}$$

The area of the proton bunch
$$\sigma = \sqrt{\epsilon\beta^*}$$

Luminosity
$$\mathcal{L} = \frac{N_p^2 n_b f_{\mathrm{rev}}}{4\pi\sigma_x^*\sigma_y^*}$$

Accelerator momentum formula
$$B\rho = 3.3p[\mathrm{GeV}]$$

- Having such a large collider allows us to reach enormous beam energies. Theoretically, HECTOR could reach 42 PeV of energy, but synchrotron radiation sets a constraint of only 700 TeV.
Its size also means that the curvature of the beam is quite minimal, thus the magnetic field strength required in the bending dipole magnets is greatly reduced to only 0.332 T.
- The proton beam can be sent out into space instead of requiring a beam dump.
- It also reduces many of the problems that would occur on Earth. Most importantly it removes any political border issue, as it will not have to be built across potentially opposing countries. It also means that there are no environmental issues as large caverns will not have to be dug below possible protected land or the collider built underwater.

- Issues however arise as astronauts will be subject to similar problems as the ISS personnel, such as cosmic radiation and bone weakening due to a low gravity environment.

- All of the material also has to be sent 600 km above the surface of the Earth, which will require an enormous amount of energy.

- The overall cost of designing, building and maintaining such a collider would be astronomical.

CERN | S'Cool LAB

SOURCES

Particle physics:
– P. Janot: "Physics at Future Colliders", CERN Summer School 2016: lecture 1,lecture 2,lecture 2.
Accelerator physics:
– Taking a closer look to the LHC website – F.Zimmermann, "Collider beam physics".
Technology:
– D.Schulte: "Future Collider Technologies", CERN Summer School 2016: lecture 1, lecture 2
Accelerator project management:
– LHC design report. Volume 1, Volume 2 – FCC Study website