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Relativistic Heavy Ion Collider and the Large Hadron Collider for Heavy Ion Fusion

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Abstract

Heavy Ion Fusion makes use of the Relativistic Heavy Ion Collider at Brookhaven National Lab and the Large Hadron Collider in Geneva, Switzerland for Inertial Confinement Fusion. Two Storage Rings, which may or may not initially be needed, added to each of the Colliders increases the intensity of the Heavy Ion Beams making it comparable to the Total Energy delivered to the DT target by the National Ignition Facility at the Lawrence Livermore Lab. The basic Physics involved gives Heavy Ion Fusion an advantage over Laser Fusion because heavy ions have greater penetration power than photons. The Relativistic Heavy Ion Collider can be used as a Prototype Heavy Ion Fusion Reactor for the Large Hadron Collider.

Keywords

Heavy Ion Fusion, Relativistic Heavy Ion Collider, Large Hadron Collider, Inertial Confinement Fusion, National Ignition Facility

1. Heavy Ion Fusion (HIF) Background

HIF was originally proposed by Alfred Maschke of Brookhaven National Laboratory (BNL) in Upton, Long Island, NY around the end of 1976. My involvement in the project as a theoretical physicist was due to my Ph.D. on Collective Accelerators using plasma (electron, proton) beams for fusion at the University of California, Irvine. While the intensity of the plasma beams was much greater than the intensity of beams from conventional accelerators, the final energies were much lower, and using plasma beams was a newer technology compared to the technology of the already well-established conventional accelerators. The HIF program was funded from 1977 to 1980 by the Department of Energy. The funding was for 3 labs to participate in the research program viz. BNL, Argonne National Lab, and Lawrence Berkley Lab (LBL). I was offered jobs at BNL and

LBL and I picked BNL because of the larger Accelerator Department located there. I left BNL when the funding for HIF at all the 3 labs was terminated in 1980. At that time, the other idea was to use the Alternating Gradient Synchrotron (AGS) at BNL to inject ions into the Intersecting Storage Accelerator (ISABELLE). Much later when the plans for constructing ISABELLE were aborted, AGS was used to inject Heavy Ions into the Relativistic Heavy Ion Collider.

2. Accelerator and Laser Parameters

Alpha rays that are helium nuclei are more penetrating than beta rays that are electrons which are more penetrating than gamma rays that are high energy photons. Hence the larger the mass the more penetration it has and that is why heavy ions have the greatest penetration power into the fuel target, much greater than electron and proton beams or lasers. Therefore, heavy ion accelerators have the potential to be much more efficient in terms of delivering energy to the fuel pellet. While typical laser-based "drivers" have overall efficiency on the order of 1%, heavy-ion systems aim for 30% or more.

Multiple laser beams (192) at the National Ignition Facility (NIF) at Lawrence Livermore National Lab deliver total energy of 2.05 MJ = 12.80 × 10^{18} eV to DT pellets. At NIF the first fusion experiment was carried out to achieve scientific breakeven on December 5, 2022, with the experiment producing 3.15 Megajoules of energy from a 2.05 Megajoule input of laser light for an energy gain of over 1.5 while charging the lasers consumed about 400 Megajoules. A Protype Fusion Reactor had been suggested for Inertial Confinement Fusion (ICF) at NIF [1] by turning the laser beam into separate $e^- - e^+$ beams that would bombard the DT pellet by creating an explosion as the electron and positron beams are made to come together inside the Reactor Chamber in the vicinity of the DT pellet.

The difference between the Relativistic Heavy Ion Collider (RHIC) and the Large Hadron Collider (LHC) is that RHIC is dedicated to accelerating gold atoms full time at 100 GeV per nucleon per beam with total Au energy of 19.7 TeV = 19.7 × 10^{12} eV per beam, while the LHC accelerates lead atoms at 2.76 TeV per nucleon per beam or with a total Pb energy of 571.32 TeV = 571.32 × 10^{12} eV per beam only one month per year and is dedicated to accelerating proton beams for the remainder of the year. While the circumference of RHIC is 3834 m, the circumference of LHC is 26,659 m. To match the energy at NIF both RHIC and LHC would need to be equipped with two storage rings, one for each circulating beam. Since there are two beams directed at the DT pellet from opposite directions the total energy needed per beam would be 1.025 MJ or 6.4 × 10^{18} eV. For RHIC the storage ring would need to have 6.4 × 10^{18}/19.7 × 10^{12} = 3.25 × 10^{5} injections into it, while LHC would need to have 6.4 × 10^{18}/571.32 × 10^{12} = 11,202 injections to bring the intensity of the beams at par with the laser beams at NIF. Because of the greater penetration power by heavy ions into the DT pellets these injection numbers would be an absolute maximum since HIF could be accomplished at much lower energies than at NIF and the possibility of operating RHIC and LHC for HIF as is, without the need for two storage rings is a possibility. RHIC can be used as a Prototype HIF Reactor whose results can later be extended to LHC.

3. Conclusion

We have calculated the maximum energy required for HIF by comparing it to the energy delivered by the NIF. Noting that heavy ions have greater penetration power than photons giving HIF an advantage over lasers and electron and proton beams for ICF. Since RHIC is dedicated to accelerating Heavy Ions, we propose using RHIC as a Prototype for the LHC without initially making any changes to the two machines such as adding Storage Rings. If higher intensities for the heavy ion beams become necessary, then the two Storage Rings for each machine can be deployed later.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

References

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