

Clustering Analysis of Fast Ion Driven Instabilities

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**Abstract**

Beam ions often drive Alfvén eigenmodes and other instabilities unstable in DIII-D. Many of these modes have been unambiguously identified but some frequently occurring features have been neglected. In this work, datamining and analysis techniques1 that successfully analyzed magnetics data from the H-1NF Heliac are applied to arrays of magnetic and electron cyclotron emission (ECE) data from DIII-D. The clustering techniques group instabilities with similar toroidal magnetic features into clusters of identical mode numbers. Similar analysis is performed on DIII-D’s poloidal magnetic array and ECE probes. Something about ECE results here, later.

**Introduction**

Plasma is one of the four fundamental states of matter and makes up an estimated 99% of the matter in the observable universe. A plasma can be thought of as an quasineutral medium of unbound positively and negatively charged particles. These moving charged particles generate local magnetic fields which affect the motion of other nearby particles leading to *collective behavior*, or motion that depends on the physical state of the plasma in local regions.

Harnessing nuclear fusion is one of the prime motivators of studying plasma physics. Nuclear fusion produces more energy per amount of fuel than any other available fuel source. For instance, one gallon of heavy water (water with all of the hydrogen atoms replaced with deuterium atoms) provides 10,000 times more energy when fused than a gallon of gasoline. Deuterium-tritium (D-T) plasmas are known as the most efficient plasma for energy production due to their high mass-to-charge ratio, making it easier to overcome the weak force and fuse together. There are four main reactions that occur in D-T plasmas.

Above, D is a deuterium ion, T is a tritium ion, p is a proton, n is a neutron, and is a nucleus.

Many research plasmas require temperatures on the order of 108 K, making the plasma hot enough to destroy anything it comes into contact with2. For this reason, strong magnetic fields are used to shape and contain the plasma. The introduction of these magnetic fields, while necessary, can lead to some undesirable effects such as unwanted resonances, instabilities, and particles escaping from the plasma and colliding with the inner walls. The study of these interactions is crucial for creating higher quality magnetically confined plasmas.

**Background Physics**

**Cyclotron Motion**

Charged particles trapped in magnetic fields exhibit circular orbits and is known as cyclotron motion. For a non-stationary particle moving at velocity, , with charge, , in a magnetic field, , the force, is equal to:

It is easy to show that there is no work done by this force.

Since is perpendicular to both and , where W is work. The total energy of the particle does not change. We can rewrite velocity in terms of a new basis

where and represent the components of velocity perpendicular and parallel to the magnetic field, respectively. We can then rewrite .

We are able to say goes to zero since its magnitude, , is equal to

This force causes charged particles to rotate in circles as they travel along magnetic field lines, all while keeping their parallel velocity constant (see figure 1). Equating the magnetic force to the centripetal force and solving for the radius of curvature yields an expression for the radius of curvature of this gyrating charge known as the Larmor radius, .

From the Larmor radius, one can also determine a parameter known as the cyclotron frequency, :

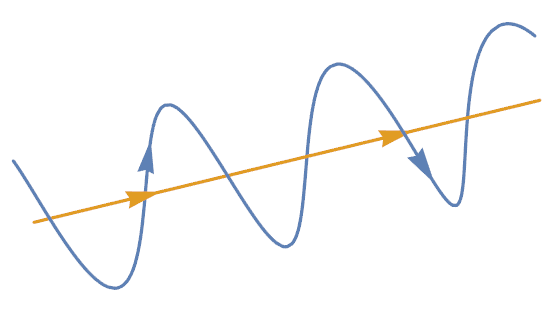


Figure 1. Graphical representation of the path of a charged particle (blue) travelling along a magnetic field line (yellow).

It is widely known that accelerating charged particles emit radiation in the form of photons. When this radiation is caused by a charged particle in cyclotron motion, it is called electron cyclotron emission (ECE).

**Bibliography**

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