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Modeling of the Effects of Random Fields in Front of LH Grills on the Local Fast Particle Production

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Thermal electrons can be accelerated in front of a lower hybrid (LH) wave-guide array by the electric field of the slow LH wave [1,2]. They may cause high thermal loads and erosion observed on parts of the grill and tokamak vessel. This generation of fast electrons in front of LH frequency antennas is known to be caused by Landau damping of high $N_{//}$ components of the launched spectrum. Therefore, advanced LH wave launchers, like the PAM launcher for ITER [3], are being developed with features aiming to reduce the energy contained in the high $N_{//}$ components. However, according to theoretical estimates [4], the electron acceleration in front of the grill may be significantly enhanced by random fields spontaneously generated near the antenna. In this contribution, we explore fast electron generation in front of LH grills, taking into account the presence of random fields. The model of random fields is based on recent measurements of fluctuating toroidal electric fields in front of the CASTOR tokamak LH grill mouth [5]. In each numerical experiment, five thousand of test electrons are injected in front of the grill, and their trajectories are computed. The content of high $N_{//}$ components in the LH spectrum is varied in the numerical model. Using a random field representation in agreement with the measurements [5], we demonstrate that the enhancement of electron acceleration by the random fluctuating fields can lead to a significantly high fast particle production, even if the content of high $N_{//}$ components in the LH grill spectrum is low.

In the numerical computations, we assume a very long LH grill. The higher spatial harmonics of the launched LH wave field are artificially reduced in the computations by the parameter “reduce”, while keeping the LH wave energy density constant. The values of amplitudes and toroidal wavelengths of the fluctuating fields are chosen according to recent rf probe measurements in front of the CASTOR tokamak LH grill [6]. In the first series of the numerical modeling presented in Fig. 1, the launched lower hybrid electric field is assumed to be rather low, E_{LH} = 1.33 kV/cm.

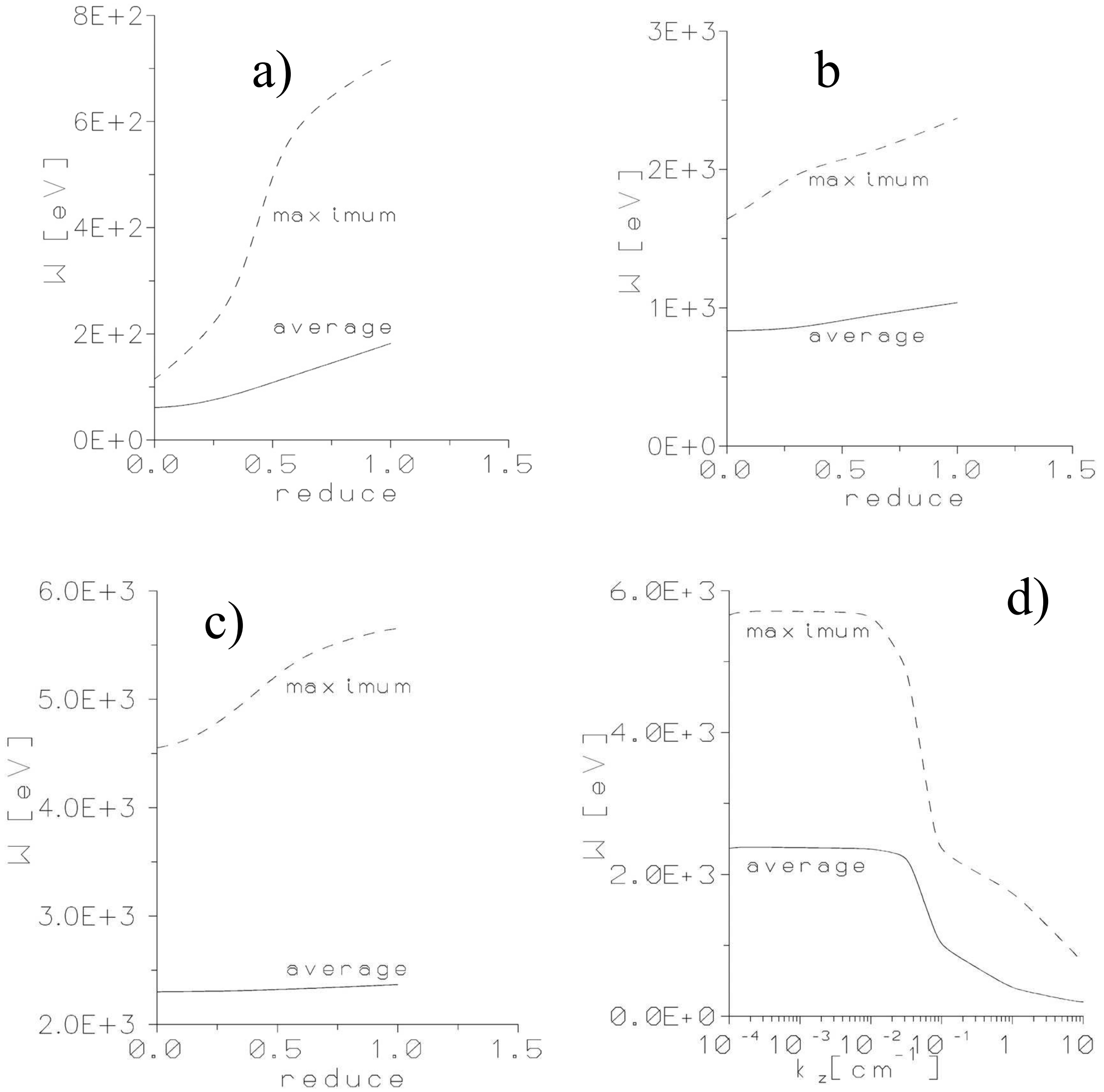

Fig. 1. The maximum and ensemble averaged electron energy W (eV) as a function of the parameter „reduce“: a) E_{st} = 0, b) E_{st} = 0.1kV/cm, c) E_{st} = 0.3 kV/cm; E_{LH} = 1.33 kV/cm; d) the maximum and ensemble averaged electron energy W (eV) as a function of the wave vector k_z of the fluctuating electric field E_{st} for the case c, reduce=1.

Figures 1 a) - c) show the maximum and ensemble averaged electron energy W (eV) as a function of the parameter "reduce", for varying amplitudes E_{st} of the fluctuating electric fields: a) E_{st} = 0, b) E_{st} = 0.1kV/cm, c) E_{st} = 0.3 kV/cm. Figure 1 d) then shows the maximum and ensemble averaged electron energy W (eV) as a function of the wave vector k_Z of the fluctuating electric field E_{st} for the case 1 c), i.e., E_{st} = 0.3 kV/cm. Figure 2 then shows show the maximum electron energy W (eV) as a function of the parameter "reduce" and as a function of the varying amplitudes E_{st} of the fluctuating electric fields. Dash curves in Figures 1 a, b, c show plane cuts of the in figure 2 presented surface for E_{st} equal to 0, 0.1 and 0.3 kV/cm, respectively.

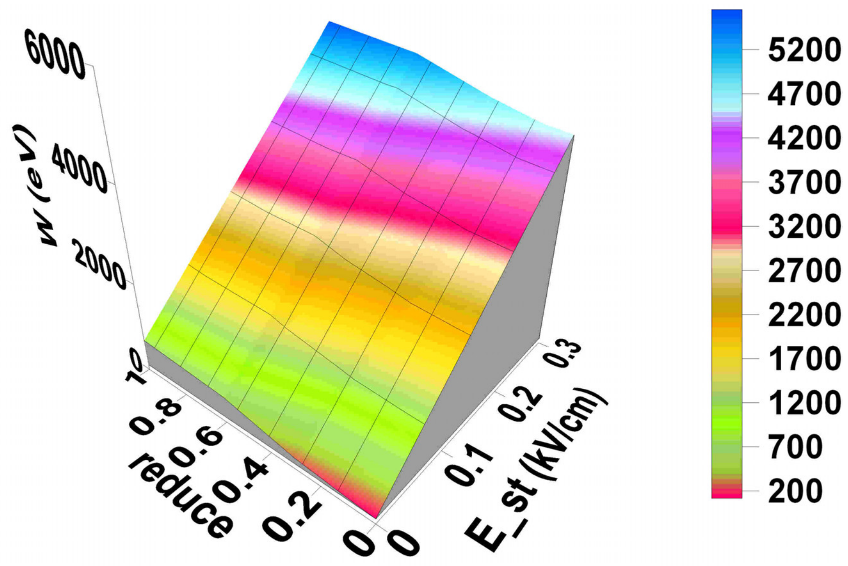

Fig. 2. The maximum electron energy W (eV) as a function of the parameter "reduce" and as a function of the varying amplitudes E_{st} .

Figures 3. a) - b) show the maximum and ensemble averaged electron energy again as a function of the parameter "reduce", for varying amplitudes E_{st} of the fluctuating electric fields: a) E_{st} = 0.1kV/cm, b) E_{st} = 0.3 kV/cm; however, the launched lower hybrid electric field is now higher, E_{LH} = 3 kV/cm. For this higher LH wave field, the resulting accelerated electron energy is significantly higher than in figure 1 and 2. In both cases of lower and higher LH wave field, the effects of random fields are very important. The construction of advanced LH launchers [3] for ITER aims at a low value of higher harmonics, to reduce the value of the electron acceleration [1]. In our modeling this is the case of low values of the parameter "reduce". As can be seen from figures 1 – 3, even for low values of "reduce", there is significant electron acceleration when random fields are present.present. When the parameter "reduce" vanishes, i.e. when higher harmonics are completely absent from the spectrum, then electrons are still significantly accelerated in front of the grill. Therefore, reducing the amplitude of higher spatial harmonics (high $N_{//}$) of the launched LH wave, such as foreseen for advanced LH launchers being developed for ITER (e.g., the PAM grill), might not remove all problems with the hot spots caused by particles locally accelerated in front of the grill mouth. As our numerical modeling implies, it is also necessary to ensure a low level of fluctuating fields. This might not be easy. Recent CASTOR tokamak measurements [5] demonstrate generation of large electric field fluctuations in front of the LH grill at LH wave launching. The amplitude of the fluctuating electric fields reaches values of about 0.1 kV/cm, with typical frequencies about several tens of kHz. Similarly, the growth of fluctuation level with the LH power is measured also in Tore Supra. As the next step, the level of the fluctuating electric fields produced by an active advanced launcher (PAM) should be measured, and then the fast electron production could be modeled specifically for the case of the PAM launcher.

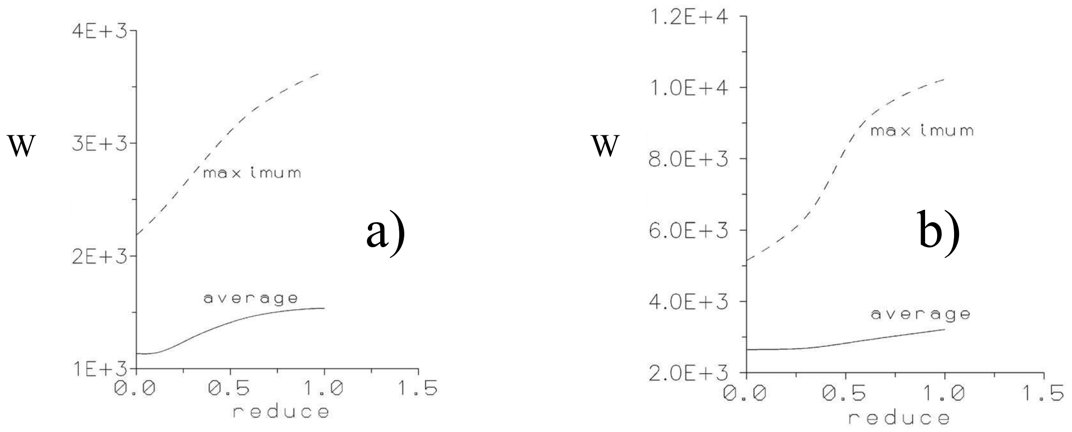

Fig. 3. The maximum and ensemble averaged electron energy W (eV) as a function of the parameter „reduce“: a) E_{st} = 0.1kV/cm, b) E_{st} = 0.3 kV/cm; E_{LH} = 3 kV/cm.

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