Physics driven scaling laws for fusion reactors

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The scaling laws for tokamak plasmas are obtained using the Kadomtsev[1] similarity scheme, where the alpha particle heating and atomic physics effects are neglected and the confinement is depending only from the dimensionless set of parameters (q,ρ^*_T,ν^*,β_T). Since the alpha particles heating is relevant in fusion reactor burning plasmas, the Kadomtsev scheme is NOT valid[6]. Therefore new scaling laws linking the plasma dimensions , the magnetic field , the aspect ratio, useful to characterize the fusion reactors at fixed Q must be studied. In this paper New scaling laws are obtained for fusion reactors analyzing conditions where the reactor gain factor Q_0 is held fixed and alpha power of the same order of the plasma radiation (Bremsstrahlung and syncrotron radiation) , while the net power (Palpha –Pradiation) is still higher than the threshold for the transition to H-mode. Using expressions for the ITER H-mode energy confinement time [2] and threshold power for L-H transition [3], scaling laws are obtained for fusion reactors, leading to sensible dependences of reactor dimensions upon the magnetic field and aspect ratio. Additional sets of parameters can be considered to determine reactor plasma scaling laws, if *high magnetic field compact machines* are considered: for these devices small space is left for heating systems, so low power heating systems can be considered only . On this conditions the ohmic or L-mode operation of plasma is studied. Marginal H-mode operation , where the heating power is just avove the H-mode threshold is also considered. The energy confinement time used for these devices is the so.called SOC (saturated ohmic confinement) or L-mode scaling[4]. The magnetic field dependence of density limit recentily studied on FTU[5] is used in the set of conditions determining the high magnetic field device scalings. Extending the Kadomtsev method to fusion reactors , the paper presents then i) general scaling laws for fusion reactors where the plasma radiation (bremsstrahlung and syncrotron) power is of the same order of magnitude of alpha particle power ; ii) scaling laws for high field low power devices working close to density limit: two options are considered for the density limit dependences upon plasma parameters (FTU density limit scaling and Greenwald density).

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