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ORIGINAL PAPER

Neutron Scaling Laws from Numerical Experiments

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Abstract Experimental data of neutron yield Y_n against pinch current I_{pinch} is assembled to produce a more global scaling law than available. From the data a mid-range point is obtained to calibrate the neutron production mechanism of the Lee Model code. This code is then used for numerical experiments on a range of focus devices to derive neutron scaling laws. The results are the following: $Y_n = 2 \times 10^{11} I_{pinch}{}^{4.7}$ and $Y_n = 9 \times 10^{9} I_{peak}{}^{3.9}$. It is felt that the scaling law with respect to I_{pinch} is rigorously obtained by these numerical experiments when compared with that obtained from measured data, which suffers from inadequacies in the measurements of I_{pinch}.

Keywords Plasma Focus · Neutron scaling · Pinch current · Focus modeling · Lee Model

Introduction

A major feature of the plasma focus is its fusion neutron yield. Even a simple trolley mounted 3 kJ device such as the UNU/ICTP PFF routinely produces [1] a yield of $Y_n = 10^8$ neutrons, operating in deuterium. A big machine such as the PF1000 typically produces 10^{11} neutrons per shot [2]. Moreover since the neutrons are produced in a short pulse of the order of 10 ns, the rate of neutron production is 10^{16} neutrons/s even for a small machine and can go up to 10^{20} for a large machine.

From a compilation of experimental data over a wide range of energies a scaling law of $Y_n \sim I_{pinch}{}^{3.3}$ was presented by Bernard [3], where I_{pinch} is the current flowing through the dense pinch in the focused plasma. Kies [4] presented another compilation showing $Y_n \sim I_{pinch}{}^{4}$ whilst Herold [5] had results showing $Y_n \sim I_{pinch}{}^{3.2}$. Gribkov [2] has recently suggested that the experimental data can be interpreted with the power law as high as 5 in particular when dealing with the same device.

One significant uncertainly in compiling such a scaling law is the interpretation of I_{pinch}. The current most conveniently measured in most experiments is the total current flowing into the tube (usually measured with a Rogowski coil placed at the collector plate just outside the tube). This total current has a maximum value I_{peak}. If one estimates I_{pinch} from the total current measurement there are two difficulties: (1) it is difficult to determine the point on the current waveform where the plasma has gone into the pinch phase, and (2) even after estimating this point, it still remains to estimate the fraction of total current that in fact flows into the pinch. One way is to use small magnetic coils to probe the pinch region. For small machines this method is not suitable because of the amount of space available and the small size of the pinch so that the probes inevitably interfere with the pinching current sheet. For large machines, results have been obtained [5] but with large errors quoted as 20%. Moreover the shot-to-shot variability of focus performance means that the final presentation of results relies greatly on how the particular research group chooses to present the results. For example the yield may be presented as a range, with some shots considered not representative discarded, and perhaps the biggest values of observed yield also presented. It is quite

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