Current and neutron scaling for megajoule plasma focus machines

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Abstract
In a 2007 paper Nukulin and Polukhin surmised from electrodynamical considerations that, for megajoule dense plasma focus devices, focus currents and neutron yield \( Y_n \) saturate as the capacitor energy \( E_0 \) is increased by increasing the capacitance \( C_0 \). In contrast, our numerical experiments show no saturation; both pinch currents and \( Y_n \) continue to rise with \( C_0 \) although at a slower rate than at lower energies. The difference in results is explained. The Nukulin and Polukhin assumption that the tube inductance and length are proportional to \( C_0 \) is contrary to laboratory as well as numerical experiments. Conditions to achieve \( Y_n \) of \( 10^{13} \) in a deuterium plasma focus are found from our numerical experiments, at a storage energy of 3 MJ with a circuit peak current of 7.6 MA and focus pinch current of 2.5 MA.

1. Introduction

In a 2007 paper Nukulin and Polukhin [1] surmised that the peak discharge current \( I_{\text{peak}} \) in a plasma focus reaches a limiting value when the storage energy of its capacitor bank is increased to the megajoule level by increasing the bank capacitance \( C_0 \) at a fixed charging voltage \( V_0 \). The crux of their argument is that for such large banks, increasing \( C_0 \) increases the discharge current risetime which then requires an increase in the length of the focus tube in order for the axial transit time to match the current risetime. According to their reasoning the axial tube inductance \( L_a = 2 \times 10^{-7} \ln(b/a)z_0 \) (their equation (5)) where \( b \) and \( a \) are the outer and inner radii, respectively, and the length of the coaxial section is \( z_0 = (\pi/2)(L_a C_0)^{0.5} v_a \) (their equation (4)). We rewrite their equations in SI units throughout except where stated otherwise. Here \( v_a \) is the average axial speed in the rundown stage which in experimental situations is known to be best kept at a value around \( 10^5 \) (or 10 cm \( \mu \text{s}^{-1} \)). This argument leads