Extensive Halos in Beams due to Noise

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The influence of noise on the structure of phase space and the extent of halo was investigated carefully in semi-realistic regimes. These experiments suggest strongly that there is an effect that seems to be generic, since it appeared in all the different models used. Because of the noise the evolutionary history of some particles changes, and the extent of halo becomes bigger.

Noise is an unavoidable annoyance, to one extent or another, in practically every experimental system. Nevertheless, simulators of real experiments usually choose to ignore it, assuming that it does not affect the physics in any important way. It is true that today's experimental hardware is constructed with utmost care to minimize imperfections, and consequently noise; still one can easily argue that it is possible that even small noise may have a significant effect on the evolutionary history of a small number of particles. Now, one may wonder in what cases such an effect may be important; one suspicious case to investigate is the particles that escape to the halo. If the population and/or the extent of a halo is enhanced because of small hardware imperfections, then this may be important enough to affect the operation of an accelerator. In any case, it is one issue that has to be investigated in simulations.

A series of experiments were performed in a number of different models, all of them generic, in order to investigate carefully how noise affects the physics of a configuration [1-3]. The model potentials were all time-dependent in keeping with the presence of mismatch. Models were chosen to isolate the physics so it can be more easily understood. Complexities associated with realistic simulations were dropped. The disadvantage is that one does not study what happens in the real system; however it is often useful to understand and quantify the physics in simple and generic systems, and then ask if the same physics is present in realistic systems of interest.

Numerical experiments were performed in models which other investigators had studied carefully to understand how and why halos are generated [4,5]. The only addition was the inclusion of numerical noise inside the equations. The extent of the halo and the numbers of particles escaping to the halo were studied extensively as the noise level was increased.

The most exhaustive of these experiments were performed in a direct-curent, cylindrically symmetric beam modeled as a warm-fluid Kapchinskij-Vladimirskij equilibrium configuration possessing a self-consistent spectrum of collective, stable, axisymmetric flute modes [6]. The numerical experiments used 10^6 noninteracting particles, and each particle was assigned it own unique realization of noise. What was found was that the evolutionary history of a statistically small number of particles changes significantly. The important point was that although this number is a small percentage of the particles of the experiment, in real experiments it would suffice to generate halos extensive enough to create problems. It was shown that noise affects the structure of the phase space and cooperates with the collective modes to eventually break tori. This makes the picture of the phase space more fuzzy but also causes extension of the halo. How extensive the halo will be depends on both the size of noise and the length of the simulation. Integration time (machine size) matters. Short-time, big noise, big mismatch and long-time, small noise, small mismatch give generically the same effect [7].

The physics discovered in these semi-realistic experiments is currently being extended into realistic simulations of beams [8]. The results suggest strongly that the phenomenon is generic. This means that it needs to be taken into consideration especially in future projects related to accelerator construction.

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[1] C. L. Bohn and I. V. Sideris, Phys. Rev. Lett. **91**, 264801 (2003).
[2] I. V. Sideris and C. L. Bohn, Phys. Rev. ST. Accel. Beams **7**, 104202 (2004).
[3] I. V. Sideris and H. E. Kandrup, Ap. J. **602**, 678 (2004).
[4] R. L. Gluckstern, Phys. Rev. Lett. 73, 1247 (1994).
[5] T. P. Wangler, K. R Crandall, R. D. Ryne, T. S. Wang, Phys. Rev. ST. Accel. Beams **1**, 084201 (1998).
[6] S. Strasburg, R. C. Davidson, Phys. Rev. E. **60**, 1567 (1999).
[7] C. L. Bohn, AIP Conf. Proc. **737** 456 (2004).
[8] P. S. Yoon, W. Chou, C. L. Bohn, Proceedings of the 2005 Particle Accelerator Conference, Knoxville,Tennessee (16-20 May 2005) (in press).