Thursday
12/11/2003
YKS

- Introduction: Ed's criterium
  Yuri's "
- Deuteron EDM

issues:

1) Status of Yuri's technique for Longer Spin Coherence Time

2) Deuteron Polarizability

3) Electron trapping Issues

4) A method to minimize the Twist & Saucer effects

The present state of the quadratic nonlinearity investigation with the aim of canceling all dephasing quadratic terms in $\Delta\omega_a$

EDM Note #

7 December 2003

Yuri F. Orlov, Cornell University

A non-designed nonzero $\Delta\omega_a$, among other things, defines the dephasing time. For our accuracy in the deuteron EDM experiment, it is crucial to have the dephasing time bigger than 10 seconds. To achieve this goal, one of the most important elements is the synchrotron stability provided by an RF longitudinal electric field, which equalizes the average momenta of the deuterons. The central momentum, ideally equal for all particles, is defined by the RF frequency and by the betatron oscillation parameters. However, there are small quadratic effects proportional to $(\Delta p/p)^2$, as well as the betatron oscillation terms x^2, y^2, $(dx/ds)^2$, $(dy/ds)^2$, which are individual, i.e., different for different particles and therefore cannot be equalized. It can be seen that with some reasonable parameters of our storage ring, and without losing the reasonable beam admittance, the needed dephasing time >10 s cannot be achieved if the dephasing effects of these quadratic terms are not canceled. So I am investigating the possibility of canceling them using a specially designed quadratic nonlinearity of the magnetic field, in both dipoles and sextupoles installed in the ring for this purpose. (Commonly, sextupoles are used only to cancel chromaticity of betatron oscillations, and we must do that also.) The basic idea of this "quadratic" dephasing cancellation was explained in [1]. It was shown that the $(\Delta p/p)^2$ terms in $\Delta\omega_a$ can certainly be canceled, and that the same quadratic nonlinearity works in the correct direction to cancel the horizontal quadratic betatron terms in $\Delta\omega_a$. So there was a big hope of canceling all of them (promising, correspondingly, the coherent time >100s, that means, undoubtledy >10s).

A lot of things unknown at that time are clear now, but it is still not clear whether the horizontal betatron oscillation effects in $\Delta\omega_a$ can be completely canceled together with the complete cancellation of the $(\Delta p/p)^2$ effects. In my latest design of the EDM ring based on the (not much) redesigned BNL g-2 ring, I got the following equations for the quadratic terms cancellations:

$$0.146q_1 + 0.295q_2 = 0.50, \quad \text{for the } (\Delta p/p)^2 \text{ terms cancellations,} \tag{1}$$

and

$$0.143q_1 + 0.281q_2 = 1.05, \quad \text{for the betatron terms cancellations,} \tag{2}$$

$$q_{1,2} = \frac{1}{2}\frac{R^2\partial^2 B_{1,2}/\partial x^2}{B}. \tag{3}$$

Indices 1, 2 corespond to two different quadratic nonlinearities of the magnetic field installed at two different azimuths. We see that the left sides of equations (1) and (2) are practically the same (and maybe are precisely the same, theoretically). This means that, for some reasons which are still not understood, there is only one, not two, independent parameter for the two simultaneous cancellations (1) and (2). By cancelling the $(\Delta p/p)^2$ terms, I will cancel only a half of the betatron terms.

The identity of the left sides in (1) and (2) comes from the similarity between the betatron β function, $\beta = \beta(s)$, and the "synchrobetatron" *d*-function,

$$x_{equilibrium} = D(s)\frac{\Delta p}{p} + d(s)\left(\frac{\Delta p}{p}\right)^2. \tag{4}$$

Nobody has ever investigated *d*-functions. Now, we will investigate first, whether the similarity between *d(s)* and $\beta(s)$ is a general effect. If it is clear that it is a general, hence, unavoidable effect, ***the solution to our problem of the longer coherent time will still certainly exist. It is the following.***

Since there isn't, and cannot be, a similarity between the *d*-function (horizontal, by definition) and the betatron *vertical* β-function, we undoubtedly can cancel simultaneously the $(\Delta p/p)^2$, and the y^2, $(dy/ds)^2$ terms in the $\Delta\omega_a$, the usual pitch effect included. To cancel simultaneously the betatron horizontal and betatron vertical terms in the $\Delta\omega_a$ is impossible, in principle. Because of this, if we satisfied equations (1), (2), then we would make the vertical betatron size of the beam much smaller that its horizontal size, in order to satisfy the coherent time condition. Now, if, instead of the horizontal, we canceled the vertical betatron terms in the $\Delta\omega_a$, then we must accept only the correspondingly small betatron horizontal oscillations—in order to satisfy the coherent time condition. This task does not seem difficult. For example, we may first increase, *adiabatically,* the betatron horizontal size of the beam by moving the beam closer to some half-integer resonance, then **to** cut the horizontal betatron size, and then adiabatically decrease the horizontal betatron size by moving the beam back out of that resonance. The momentum distribution can be easily not perturbed by such operations. In such a procedure, we will have the usual good acceptance of the longitudinal and the betatron vertical phase spaces.

[1] Orlov's talk "Design for a longer spin coherence time" at the EDM collaboration meeting, BNL, 12 Nov. 2003.