Re: 1

FEB 02 1989

PEP Note-320
October 15, 1979

IS IT POSSIBLE TO IMPROVE THE EVENTRATE FOR NARROW RESONANCES IN
SPEAR AND PEP?

H. Wiedemann

SLAC-PEP-NOTE--320

Stanford Linear Accelerator Center
Stanford University, Stanford, California 94305

DE89 006351

I. INTRODUCTION

The eventrate at narrow resonances, like the ψ/J and T resonances, is not only determined by the luminosity of the e^+e^- storage ring but also by the energy spread in the beam due to synchrotron radiation. This energy spread is much larger than the width of the resonances. Therefore, if the energy spread could be reduced by a factor F the event rate would increase by the same factor.

II. SCHEMES TO REDUCE THE ENERGY SPREAD IN THE BEAM

In a different PEP-Note¹⁾ it was shown that theoretically the energy spread can be reduced by the use of wiggler magnets. The technical implications, however, make this scheme totally impractical. Another method would be to tamper with the damping partition numbers. If, however, we damp the energy oscillations more the betatron oscillations get less damped or even antidamped. We may be able to change

$$\begin{aligned} &J_y \text{ from } 2 \text{ to } 2.5 \\ \text{and} \\ &J_x \text{ from } 1 \text{ to } 0.5 \end{aligned}$$

In this case the beam emittance is increased by a factor of two and the energy spread is reduced by a factor of only

$$(1) \quad (2/2.5)^{1/2} = 0.89$$

MASTER

1) H. Wiedemann PEP Note-319

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

In a note from Novosibirsk²⁾ a scheme was suggested which does not reduce the energy spread in each beam but the spread of the center of mass energy of colliding particles. For this a vertical η -function is produced at the interaction point by the use of electrical fields. Now high energy electrons collide with low energy positrons and vice versa. (Figure 1):

Figure 1

This way we have in an ideal world for each collision exactly the same center of mass energy.

In a real machine, however, the finite betatron emittance causes a smear out of this monochromatisation.

To study this in more detail we assume the electrical field to be at a place $(2n + 1) \frac{\pi}{2}$ in the vertical betatron phase away from the interaction point. We also assume that we have a horizontal η -function at this point. The electric field needed to accomplish a monochromatisation is a quadrupole field like:

$$(2) \quad E_y = g x$$

Due to horizontal η -function particles with different energies are deflected vertically proportional to the energy deviation. The vertical

2) I. Y. Protapov et.al. Preprint 79-6

beam size at the interaction point is then

$$(3) \quad \sigma_y^{*2} = \sqrt{\beta_y^* \beta_y} (kl) \left[\eta_x^2 (\sigma_\epsilon/E)^2 + \sigma_{\beta x}^2 \right] + \sigma_{\beta y o}^{*2}$$

where $k = g/B\rho$, $B\rho$ the particles rigidity, l the length of the electrical quadrupole, $(\beta_y, \eta_x, X_\beta)$ the beta - , eta-function and betatron amplitude at the electrical quadrupole, taken at the interaction point.

The spread in the center of mass energy then is given by

$$(4) \quad \frac{\sigma_{cm}}{E} = \frac{\sigma_{\beta y}^*}{\left[\eta_y^2 + \left(\frac{\sigma_{\beta y}^*}{\delta} \right)^2 \right]^{1/2}} \quad (\delta = \sigma_\epsilon/E)$$

where

$$(5) \quad \eta_y^* = \sqrt{\beta_y^* \beta_y} (kl) \eta_x$$

and

$$(6) \quad \sigma_{\beta y}^* = \left\{ \beta_y^* \beta (kl)^2 \sigma_{\beta x}^2 + \sigma_{\beta y o}^{*2} \right\}^{1/2}$$

(The suffix β indicates that only the betatron part of the quantity be taken) $\sigma_{\beta y o}^*$ is the beam height without the electric quadrupole. If we insert eq. (5) and (6) into eq. (4) we get after some manipulations

$$(7) \quad \left(\frac{\sigma_\epsilon}{\sigma_{cm}} \right)^2 = 1 + \frac{\eta_x^2 \delta^2}{\sigma_x^2} \frac{1}{1 + K^2/B}$$

where $K^2 = \epsilon_y/\epsilon_{x0}$ and $B = \beta_x \beta_y (kl)^2$

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

Since the factor $(1 + K^2/B) > 0$ we have always

$$(8) \quad \sigma_{\epsilon}/\sigma_{cm} \geq 1$$

as desired.

For a typical storage ring we take a smooth approximation which gives $\bar{\beta}_x \approx R/v_x$, $R^{-1} = \langle 1/\rho \rangle$, $\bar{\eta}_x \approx R/v_x^2$, $\epsilon_{xo} \approx C_q \gamma^2 R / (\rho v_x^3)$ and $(\sigma_{\epsilon}/E)^2 \approx 1/2 C_q \gamma^2 / \rho$. With this we get

$$(9) \quad \left(\frac{\sigma_{\epsilon}}{\sigma_{cm}} \right)^2 = 1 + \frac{1}{2} \frac{1}{1 + K^2/B}$$

From equation (9) it is clear that the maximum improvement is achieved for large values of B which gives $\sigma_{\epsilon}/\sigma_{cm} \approx 1.22$. This is little improvement and we have to look for lattice designs which sufficiently deviate from the smooth approximation. One suggestion made in Ref. (2) is to use a strong superconducting wiggler to reduce the beam emittance. Another approach is to design or special section into the lattice which maximizes the ratio η_x^2/β_x where the electric quadrupole is located.

III. EFFECTIVE LUMINOSITY AT NARROW RESONANCES

We will show in the remainder of this note that it is in principal not possible to increase the eventrate by the schemes described. To do this we define an effective luminosity which is the usual luminosity times the improvement in the spread of the center of mass energy. The ratio of this effective luminosity to the luminosity $\mathcal{L}_0$ we would have without any of the schemes described above then is given by:

$$(10) \quad \frac{\mathcal{L}_{eff}}{\mathcal{L}_0} = \frac{\sigma_{\epsilon}}{\sigma_{cm}} \frac{1}{1}^2 \frac{\sigma_{xo}^* \sigma_{yo}^*}{\sigma_x^* \sigma_y^*}$$

Here I , σ_x^* and σ_y^* are the beam current, the total beam width and height respectively at the interaction point with and without (index o) the above described scheme.

If we use no wiggler we do not change the beam emittance and the current due to the horizontal beam beam limit $\Delta v_x \sim I/\epsilon_x$ is not changed. The vertical beam beam tune shift is reduced because $\sigma_y^* > \sigma_{yo}^*$. In this case we have using eqs. (3), (7) and (10) and $\sigma_{xo}^* = \sigma_x^*$, $\sigma_{yo}^* = \sigma_{syo}^*$:

$$(11) \quad \frac{y'_{eff}}{y'_o} = \left(1 + A \frac{1}{1 + K^2/B} \right) \frac{1}{1 + (A + 1) B/K^2} = \frac{K^2}{B + K^2}$$

$$A = \eta_x^2 (\sigma_E/E)^2 / \sigma_x^2$$

From eq. (11) we can see immediately that $y'_{eff}/y'_o \leq 1$ for any strength of the electric quadrupole. So the overall event rate cannot be improved with a scheme involving only an electric quadrupole.

If we also employ a wiggler system to reduce the beam emittance we effectively change only the quantity A in eq. (11) which does not affect the effective luminosity. In addition the reduction in beam emittance requires an equal reduction in the beam current in order not to exceed the horizontal beam beam limit which further reduces the luminosity.

We conclude therefore, that the monochromatisation scheme described in Ref. 2 does not lead to a higher event rate at narrow resonances. Actually the event rate is reduced.