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SMALL MOMENTUM WIDTH BEAMS IN ISABELLE -
· A USEFUL FEATURE FOR EXPERIMENTS?

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ABSTRACT

The energy width of beams in proton storage rings is an adiabatic invariant and, therefore, only a weak function of energy. For low current stacks, small momentum width beams are therefore possible. It is found that under conditions of reduced luminosities, the rms full width of the momentum distribution of the beams in ISABELLE is in the region of 5 to 20 MeV. It is interesting that for electrons, the energy width of the beams is determined by the balance of radiation damping and quantum fluctuations and is, in fact, a strong function of energy. A comparison with e^+e^- colliding beams is made, showing that fine energy resolution is unique to proton machines in the high-energy regime. The limitations on the energy width attainable due to the interaction of the beam with high frequency beam induced longitudinal fields are also considered.

The present ISABELLE proposal includes some thought provoking numbers which we feel should be underlined. The coasting stack momentum spread is expected to be $\sim 0.7\%$ at 30 GeV. At the top energy of 200 GeV, this will damp down to 0.08%. This is the full or 95% beam momentum width. The root mean square full widths are a factor of two less than these values. Thus, the rms full width of the momentum distribution can be as small as ~ 80 MeV for the high-energy case. It should be pointed out that the width essentially varies as the square root of the luminosity (that is, $\Delta p/p \propto I$ and $L \propto I^2$). Therefore, if one is willing to design an experiment for a luminosity of $10^{30} \text{ cm}^{-2}/\text{sec}$, a factor of 300 less than the design value at 10 A, an rms full width of 5 MeV may be achievable. In these considerations, we have neglected the potential high-frequency longitudinal instability. In order that stability from such effects be maintained, the momentum width cannot decrease as fast as the current. It can be shown that to keep the stability conditions unchanged, $\Delta p/p$ should decrease only as the square root of the current I , or $\Delta p/p \propto L^{1/2}$. Thus, if the high-frequency instability is the dominant factor, the energy width achievable would be on the order of 20 MeV.

No experiment presently proposed for ISABELLE requires such fine energy resolution. However, the capability is there.

We would also like to point out the ironic fact that this fine energy resolution appears to be unique to proton machines in this energy regime. Energy widths for e^+e^- machines in the 100 GeV region will be greater than $\sim 0.1\%$ or ~ 100 MeV. This limit is set by synchrotron radiation, and is not related to the luminosity. Actually, because of high-frequency beam induced electric fields, the bunch is lengthened from its natural length as determined by synchrotron radiation. Because the bunch lengthening is directly correlated with momentum widening, the energy spread of $\sim 0.1\%$ is

rather a lower limit. We show in Table I a comparison of estimated beam energy widths of the three e^+e^- machines, SPEAR, PEP AND LEP, and contrast these values with the expected beam energy widths for ISABELLE.

Table I. Energy Widths in SPEAR, PEP, LEP and ISABELLE

Machine	Energy (GeV)	Full rms Relative Energy Spread (2σ)		Energy Spread (2σ) (MeV)
		Natural	Lengthened Bunch	
SPEAR ^a	3.0	1.5×10^{-3}	4.0×10^{-3}	4.5 - 12.0
PEP ^b	15.0	2.0×10^{-3}	4.0×10^{-3}	30.0 - 60.0
LEP ^c	100.0	2.2×10^{-3}	5.5×10^{-3}	220.0 - 550.0
ISABELLE	200.0	0.4×10^{-3}	(High Luminosity)	80.0
		2.3×10^{-5}	(Low Luminosity)	4.6
		9.6×10^{-5}	(widened by instability)	19.2

^a A factor of 2.7 bunch lengthening was assumed.

^b A factor of 2 bunch lengthening was assumed.

^c A factor of 2.5 bunch lengthening was assumed.