BNL-104001-2014-TECH

AGS.SN123;BNL-104001-2014-IR

Longitudinal Impedance Measurement at 3 BeV/c

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April 1979

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USDOE Office of Science (SC)

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AGS STUDIES REPORT NUMBER 123

Date 4/14/79 Time 2200-0530 Experimenters E. Raka, L. Ahrens, E. Gill

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OBSERVATIONS AND CONCLUSION

Procedure:

A flat top was set up using the Gauss clock in a closed loop to determine p. Some difficulty was encountered in operating this loop at 3 BeV/c, but stable operation was finally achieved. Another problem contributed to the long set-up time required for this run. It became necessary to obtain stable operation at less than 1.2×10^{12}/pulse. Although a reduction in intensity from the previous run at 4.2 BeV was anticipated (see below) a factor greater than two was not expected. It was therefore necessary to make temporary changes in the low level rf control system.

Observations:

The operating intensity was dictated by the need to stay at or just below the level that resulted in spontaneous growth of coupled bunch oscillations. At 4.2 BeV this threshold was at 2.4×10^{12} while at 5 GeV it was $> 4 \times 10^{12}$. Since this behavior is inconsistent with theory (see below) an exact prediction of the level was not possible. Growth was seen around both lines (h = 13, 14) so that the impedance causing it must be broadband. As usual the measurements of stimulated growth, (at $< 1.2 \times 10^{12}$) made around these lines, gave similar results for f_q and f_d.

Results:

We found $f_q - f_d = -11$~ but with an error of $\pm$ 3-4 cycles. Since $f_d = 1239$ we obtained a $V_{ext} = 245.6$ kV (at 1500 on the AGC level) and a bunch area of .5 eV-sec with $\tau_\ell \cong 45$ nsec. This gives a $Z/n = -257\ j\Omega$ for Legendre modes and $-176 j\Omega$ for sinusoidal modes. This value when plotted with the results at 4.2 and 5.1 BeV indicate the rate of change of Z/n with decreasing energy is slowing down (i.e. is less than exponential).

Discussion:

Theory predicts that $Z/n \sim \varphi_\ell^5/I_{th}$ where I_{th} is the beam current at the threshold for spontaneous growth and φ_ℓ is the bunch length (assumed to be < 1 rad). Since φ_ℓ decreases with energy for a fixed bunch area one expects the threshold current to increase at lower momentum if Z/n does not grow more rapidly than $1/\beta\gamma^2$ as predicted for the space charge interaction. Now Z/n as determined by the $(f_q - 2f_d)$ measurement does not seem to be growing more rapidly than this, i.e. between 4.1 and 3.1 BeV the ratio is 1.87 measured vs 1.7 for a simple $1/\beta\gamma^2$ law. However, if we use the threshold current measurements and assume a φ_ℓ^5 dependence then the Z/n at 3.1 BeV would have to be ≈ 8 times larger than the 4.1 BeV value. This then is an additional divergence from the simple model assumed for the dependence of Z/n on beam energy. The other is the large absolute value of the measured values of Z/n obtained below the transition energy (see Studies Report 122).

It thus seems necessary to make another measurement at ≈ 2 GeV to determine both the Z/n and the threshold current. The intensity reduction slits in the linac can be used to reduce the injected current since shorter pulse lengths are not suitable for stable operation. Also one can use one of the old PUE position stations for radial control and increase the gain in the rf sum channel to provide operation at 5×10^{11} or even less if necessary.