MEASUREMENTS OF MODES IN THE HERA-B VERTEX CHAMBER EXCITED BY THE HERA PROTON BEAM

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Abstract

The vertex chamber of the HERA-B experiment presents a cavity for the HERA proton beam. RF-shielding is used to reduce the coupling impedance to avoid exciting instabilities of the beam and heating of vertex detector components. A small loop antenna is installed inside the vertex chamber to detect modes excited by the beam. In the years 1996 and 1997 three different types of rf-shielding have been tested: a pipe with holes, four strips and eight wires. The measured line spectra are compared for these different shielding. The absolute impedance cannot be calculated from the measurements since the antenna is not calibrated. Nevertheless, the Q-values of a few modes are estimated from the measured revolution line spectra. Furthermore, the heating of the eight wires due to image currents is discussed and compared with the operation experience during the machine shifts in October 1997 which indicates heating problems for this choice of rf-shielding.

1 INTRODUCTION

The goal of the HERA-B experiment at DESY is to study CP violations in decays of B mesons. Protons from the halo of the HERA 820 GeV proton beam are brought into collision with target wires inside the vertex chamber. Fig. 1 shows the vertex chamber on a platform as installed in HERA hall West. Several movable silicon detectors are installed in the vertex chamber to measure particles generated in the collision of the protons with the target wires. The proton beam excites rf-fields inside the vertex chamber which can drive instabilities of the beam and may also heat vertex detector components. Therefore rf-shielding is used to reduce the coupling impedance. Several designs have been investigated with computer simulations [1, 2] and with measurements on a 1:2 scale model at the INFN in Naples [3]. During the run periods of 1996 and 1997 three different rf-shields have been installed in the vertex chamber: a pipe with holes, four strips and eight wires. The goal is to achieve good shielding with a minimum amount of material between the vertex and the particle detectors. The main properties the different designs are summarized in table 1. The length of the rf-shielding is about 180 cm, filling the gap between the target cage and the aluminum window at the end of the vertex chamber. The four rf-shielding strips mounted at the target cage in the vertex chamber are shown in Fig. 2.

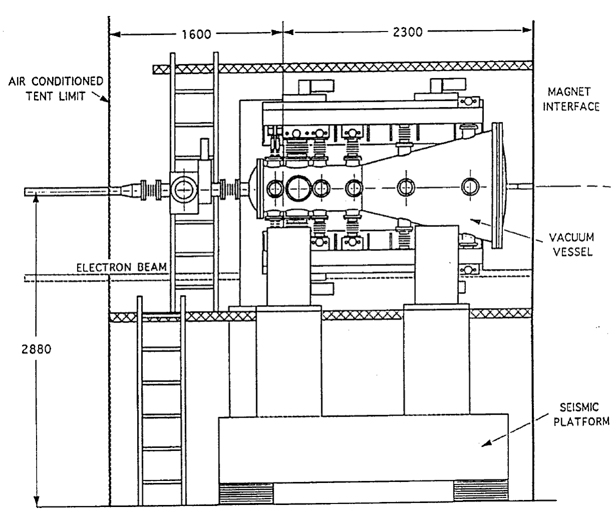

Figure 1: The HERA-B Vertex Chamber.

year	**rf-shielding**
1996	pipe with holes ($150\,\mu$m thick)
1997	4 strips of width 12.7 mm ($5\,\mu$m thick)
Oct. 97	8 wires of diameter $125\,\mu$m

Table 1: The different rf-shielding designs

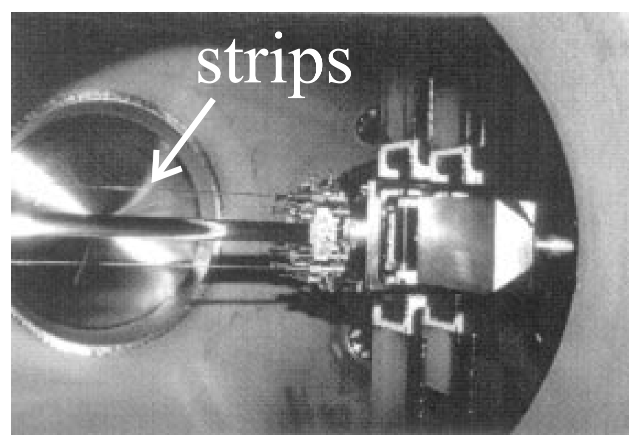

Figure 2: View into the vertex-chamber through a flange, rf-shielding: 4 strips

2 THE BUNCH SPECTRUM

A luminosity-fill of the HERA proton ring contains 180 proton bunches. The spacing between the bunches is 96 ns or 5 buckets of the 52 MHz rf-system. After 10 bunches one position is left empty and after 60 bunches there is a gap of 5 free positions. The bunch spectrum will be dominated by discrete lines with a spacing of 1/96 GHz = 10.4 MHz corresponding to the bunch spacing. There are additional lines which are multiples of the revolution frequency $\omega_0 = 2\,\pi\,\cdot\,47.3$ kHz. The bunch train will excite several modes in the vertex chamber which are characterized by an impedance $Z(\omega)$. The power spectrum which can be measured by a loop antenna is given by:

$$P(p\,\omega_0) = {I_0}^2\ A(p\,\omega_0)\ 2\ \mathrm{Re}[Z(p\,\omega_0)]\, e^{-(p\,\omega_0\,\sigma_t)^2}\ S_p,$$

where p is an integer, I_0 the single bunch current, σ_t the rms bunch length, $A(\omega)$ the (unknown) calibration function of the antenna, and S_p is a sum of phase factors (see [4]). The function $10 \cdot \log_{10}\left(e^{-(p\omega_0\,\sigma_t)^2}\ S_p\right)$ is plotted in Fig. 3 as a function of the frequency $f = p \cdot 47.3$ kHz.

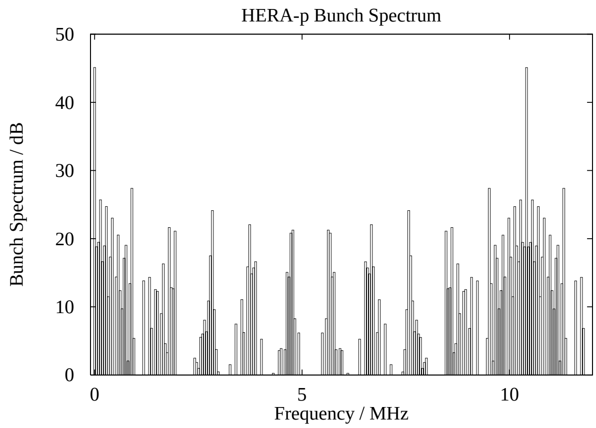

Figure 3: Spectrum of the HERA-p bunches in a logarithmic scale

3 MEASUREMENTS

3.1 The Loop Antenna

A small loop antenna has been installed at one of the flanges of the conical part of the vertex chamber, see Fig. 4. The antenna is shown schematically in Fig. 5. The vacuum

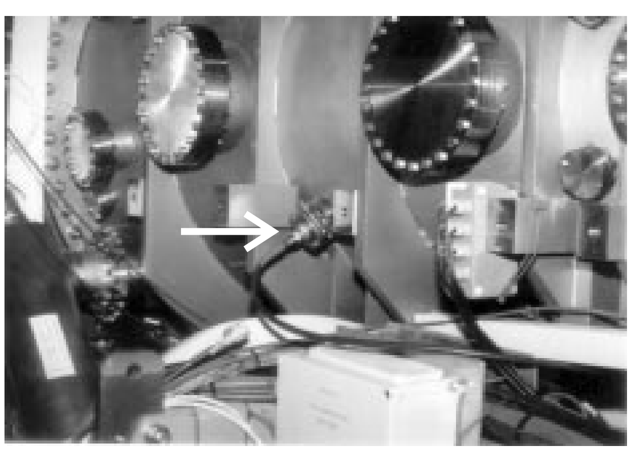

Figure 4: Loop antenna at one of the flanges of the vertex chamber.

is closed by a ceramic cap on a cylinder. The antenna itself can be rotated around the axis of the cylinder. At the time of these measurements the loop was in a horizontal orientation as in Fig. 5.

3.2 Mode Spectra

The signal of the antenna has been analyzed in the frequency domain. Many resonances have been found in the

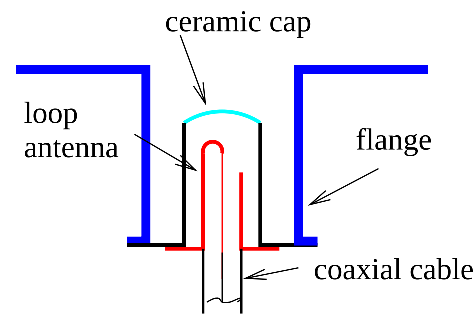

Figure 5: Schematic view of the loop antenna.

frequency range of up to 1 GHz. The line spectra around the resonances can be interpreted in terms of the bunch spectrum. The measurements cannot be used to measure the impedance of the modes since the antenna is not calibrated. But the Q-values and the frequencies of the modes can be determined and in this way it is possible to compare quantitatively the different rf-shielding designs.

The measured mode spectrum around a resonance at 322.75 MHz is shown in Fig. 6. The power is given in dBm, i.e. $\mathrm{P_{dBm}} = 10\,\log_{10}(\mathrm{P}/1\,\mathrm{mW})$. The scale is always 10 dBm per division. The four strips were used as rf-shielding. The current in the 180 bunches was 72 mA during this measurement. The pattern of the revolution lines corresponds to the predicted bunch spectrum (see Fig. 3). The resolution bandwidth was 1 kHz for this measurement. From these

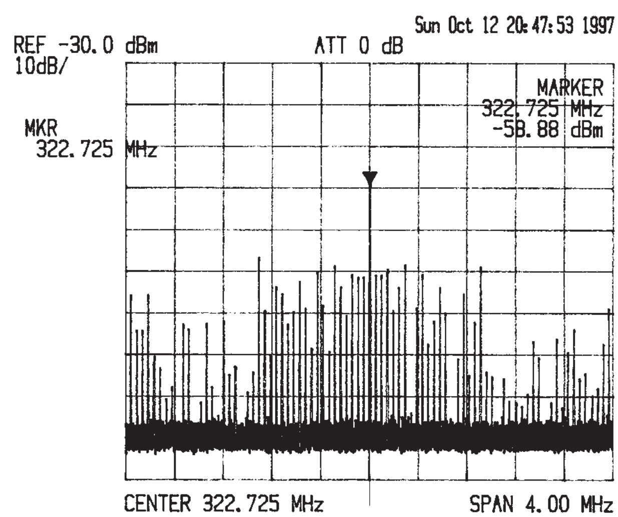

Figure 6: Measured mode spectrum around a resonance of 322.75 MHz. Rf-shielding: 4 strips, resolution bandwidth 1 kHz.

high resolution measurements it is possible to estimate the Q-value of the resonance using an equivalent circuit model for the impedance. The highest Q-values are in the range of 2000 to 3000, see [4]. The measurements with a resolution of 100 kHz, shown in Fig. 7, can be used to compare different rf-shielding in a wider frequency range. During the machine shifts in October 1997 the eight wires were tested. Comparing Fig. 8 to Fig. 7c, it is obvious that shielding is less effective than the 4 strips, since the power level is about 20 dBm higher. The pipe with holes is an effective rf-shield [4] but places an unacceptable amount of material between the vertex and the detector.

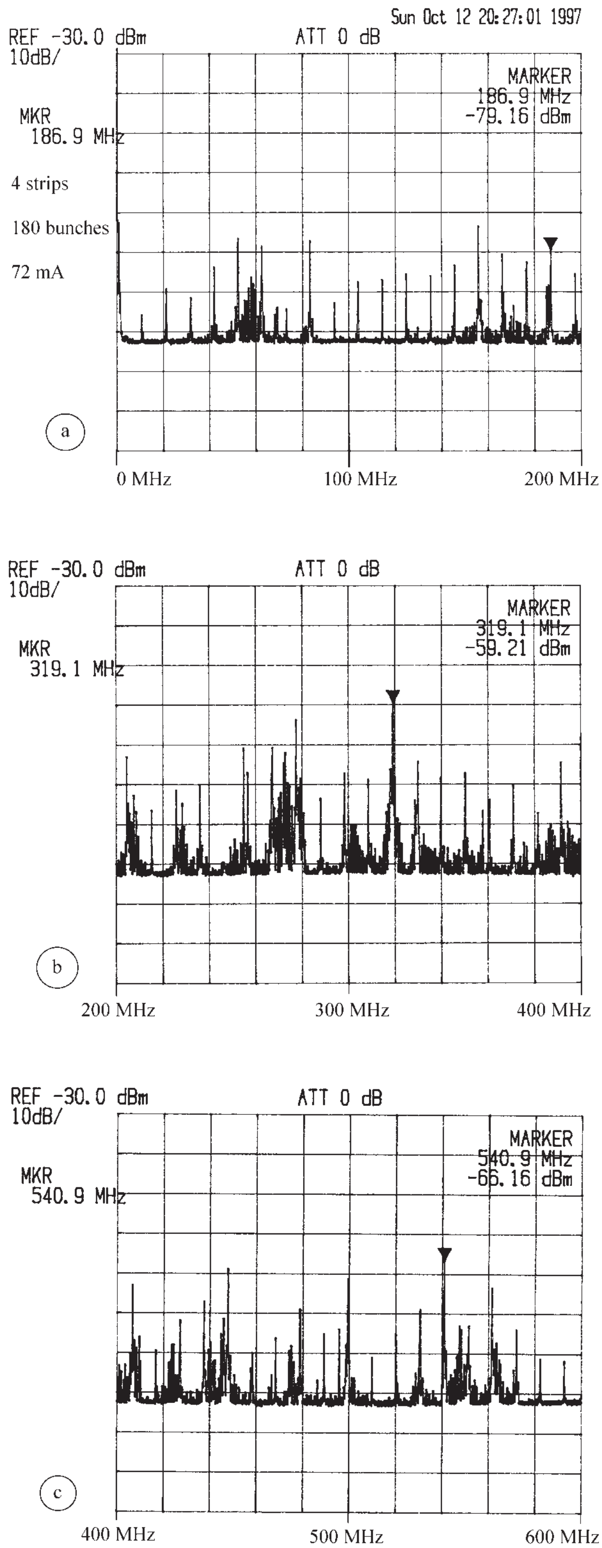

Figure 7: Measured mode spectra from 0 to 600 MHz, rf-shielding: 4 strips, resolution bandwidth 100 kHz.

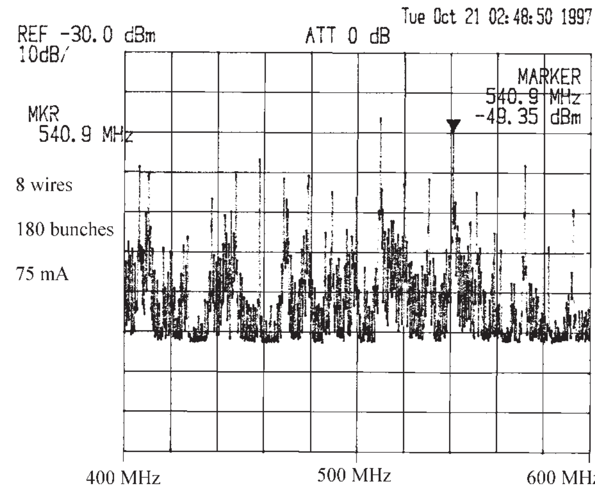

Figure 8: Measured mode spectrum from 400 to 600 MHz, rf-shielding: 8 wires, resolution bandwidth 100 kHz.

3.3 Thermal Effects

While the rf-shielding with 8 wires seems good enough to avoid beam instabilities the thermal heating due to image currents finally caused one wire to break. An increase of the temperature by $\Delta T = 200\ \mathrm{K}$ will lengthen the wire by 6 mm, which can still be compensated by the tension of a spring, which are mounted at the end of each wire. Unfortunately, the temperature increase exceeds this limit at an intensity of about 80 mA in 180 bunches and a bunch length of 1.5 ns (FWHM), if the proton beam transverses the vertex chamber 10 mm off center.

4 CONCLUSIONS

The rf-shielding by 4 strips avoids beam instabilities, heating of components and places a tolerable amount of material between the vertex and the detector components. During the 1998 run period a modified (movable) rf-shield consisting of 4 strips will be tested.

Acknowledgment

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5 REFERENCES

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