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NEW DEVELOPMENTS AT PETRA

PETRA Storage Ring Group*

Presented by J. Rossbach

Deutsches Elektronen-Synchrotron DESY

2000 Hamburg 52, Germany

Summary

Installation of "mini-β-inserts", addition of 2nd harmonic cavities, and increase of energy are the main efforts at PETRA now. By reducing the free space for the high energy physics detectors to ± 4.45 m the beta-functions at the interaction points can be decreased to 6 cm vertically and 130 cm horizontally, thus decreasing the beam size by a factor of 2.5. First results of operation are presented. Theory and some experimental evidence show that with the help of 2nd harmonic cavities (1 GHz) both a vertical single bunch instability and synchro-betatron resonances can be cured. The 1 GHz system under construction will be able to reduce the longitudinal focusing in the bucket center to zero up to 11 GeV particle energy. In order to increase the maximum PETRA energy for luminosity runs from 36.7 GeV to 41.4 GeV and later on to 45.0 GeV, the 500 MHz rf system will be extended. First, the number of rf-transmitters will be doubled, and in a second step additional new type seven-cell cavities will be installed.

Introduction

The electron positron storage ring PETRA in Hamburg is by now an established machine, having provided during the last 2 1/2 years five high energy physics detectors with luminosity. About 200 high energy physics papers are based on experimental results from PETRA.

The PETRA performance at the end of 1980 was as follows:

22 % of the year was scheduled for machine studies and preparations, 28 % for shut downs, 4 % for holidays, and 46 % for high energy physics runs. The average luminosity per interaction point during that time - including all machine break downs and including the time spent on injection and acceleration - was 47 nb^{-1} per day or 0.56×10^{30} $cm^{-2}s^{-1}$. This corresponds to a total of 32 000 nb^{-1} produced in PETRA in 1980. The average of 47 nb^{-1} includes many runs at the highest energies up to 18.36 GeV per beam, where due to the limited rf-power peak luminosities drop to 0.8×10^{30} $cm^{-2}s^{-1}$ and integrated over a day to values of 20 to 40 nb^{-1}. The optimal energy for luminosity operation was 17.8 GeV where peak luminosities of 5×10^{30} $cm^{-2}s^{-1}$ were reached and integrated over a day values of 150 nb^{-1}.

The ongoing machine development program at PETRA aims at an increase of energy and increase of luminosity. For higher energies, the acceleration voltage has to be increased. More luminosity is made possible to some extent by higher beam currents - at least at c.m. energies between 30 and 34 GeV, where the luminosity in routine operation has been current limited up to now. Each success in reduction of beam beam interaction[1] raises the importance of this aspect. At all energies more luminosity is gained by smaller beta functions at the interaction points.

It has been decided at PETRA to take all three measures, and first experimental results of one of them, the mini beta scheme, are presented in this paper.

Rf-extension

Table 1 summarizes the present situation (March 81) and further steps to extend the PETRA acceleration rf system.

date	rf-power	number of 5-cell cavities	number of 7-cell cavities	total shunt impedance $R_s = \frac{V^2}{2P}$	maximum c.m.energy for luminosity operation	
now	4.4 MW (4x1.1 MW)	4 x 15	0	1080 M	36.72 GeV	
1st step (82)	8.8 MW (8x1.1 MW)	8 x 8	10	1402 M	41.4 GeV	scaled from existing 36.72 GeV
2nd step (82/83)	8.8 MW (8x1.1 MW)	8 x 8	8 x 8	2752 M	45.0 GeV	

Table 1: Development of PETRA 500 MHz acceleration rf-system

*D. Degèle, H.C. Dehne, H. Gerke, D. Heins, K. Hoffmann, R.D. Kohaupt, R. Kose, H. Kumpfert, M. Leneke, H. Mais, H. Nesemann, S. Pätzold, F. Peters, A. Piwinski, J. Roßbach, R. Rossmanith, K. Steffen, G.A. Voss, K. Wille, A. Wrulich

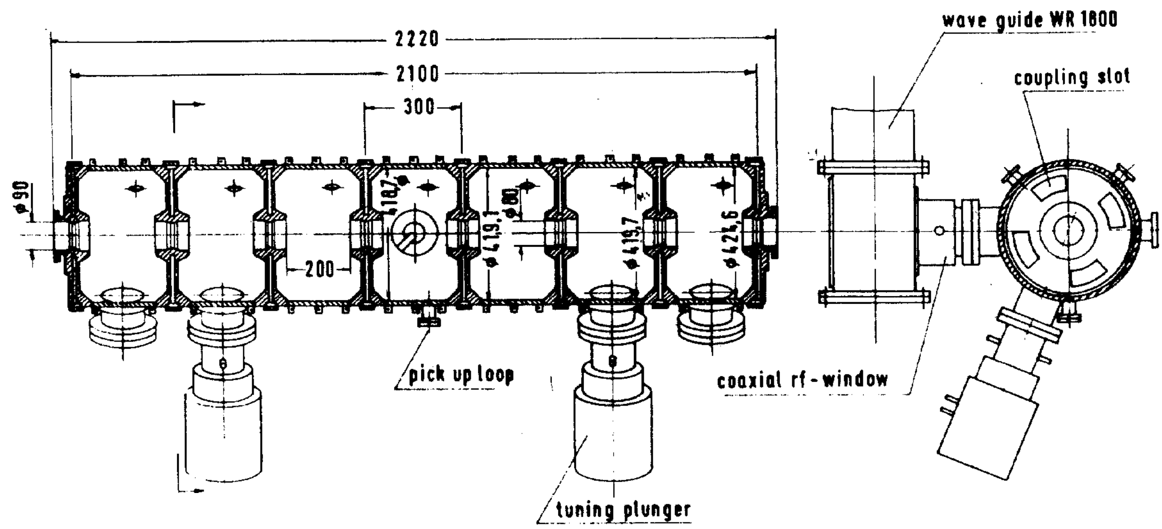

Fig. 1: PETRA new type 7-cell acceleration cavity (500 MHz)

Four transmitters with two 550 kW klystrons each are installed now to power four groups of 15 cavities in the north and south straight sections. In a first step (spring 82) the number of transmitters will be doubled and existing cavities will be rearranged to form a fourfold symmetry. This will bring the maximum c.m. energy for luminosity operation to 40.4 GeV. Addition of 10 more cavities during 1982 will increase this energy to 41.4 GeV. These and all cavities which are added later will be new 7-cell structures with two plungers; their shunt impedances ($V^2/2P$) will be as high as 25 MΩ. Figure 1 shows the geometry of these new cavities in detail.

The second step (1983) brings the total to 128 cavities and increases the maximum c.m. energy for luminosity operation to 45.0 GeV.

2nd harmonic system

At first sight there seems to be no need of higher beam currents in PETRA: The maximum currents, which have been stored up to now in luminosity optics (4x6 mA), are more than space charge forces will permit in the colliding beam mode.

On the other hand there are promising techniques within reach to reduce beam beam interaction[1], and the planned increase of beam energy will allow interaction of higher currents, too. Moreover, PETRA operation at high currents is quite critical now and careful adjustments are necessary.

There are two effects which make storage of higher currents in PETRA difficult: a vertical single bunch instability[2] and satellite resonances. Since both of them are particularly troublesome at the injection energy of 7 GeV and during the beginning of the energy ramping, the cure needs not to be extended to energies $E \gtrsim 10$ GeV.

There are good theoretical reasons[2] and experimental hints[3] that both effects can be decisively reduced with the help of higher harmonic cavities. The effect of these cavities will be to reduce the longitudinal focusing in the bucket center to zero, thereby lengthening the bunches. This should reduce the single bunch instabilities. Also the synchrotron frequency becomes very amplitude dependent. This should reduce satellite resonance excitation.

In a first step (by mid 81) 8 1000 MHz cavities will be installed, driven by one 125 kW klystron. Up to 11 GeV it will be possible to maintain a nearly zero longitudinal focusing force near the bucket center with quite strong "walls". This will result in a five times larger bunch length. The second step will be - of course dependent on the results of step one - a second 125 kW transmitter, to increase the maximum energy with full effect up to 12 GeV. All 1000 MHz cavities will be 7-cell structures with 120mm aperture. Figure 2 shows details.

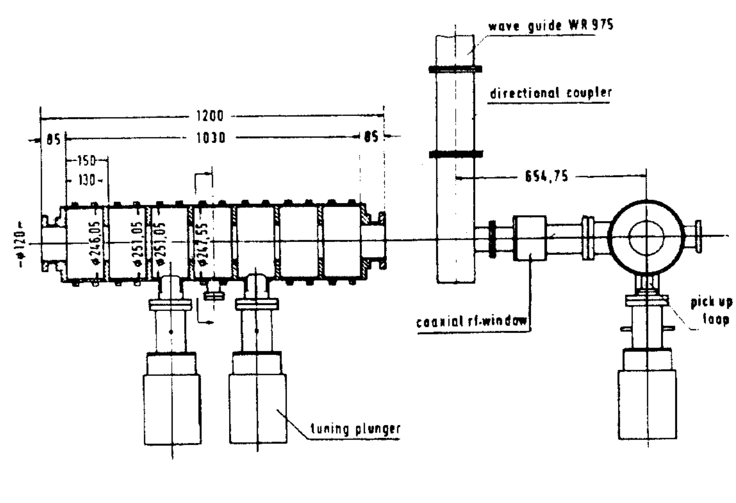

Fig. 2: PETRA 2nd harmonic (1000 MHz) cavity

PETRA mini beta inserts

At the time when the geometry of the interaction regions was fixed it was thought that there would be no severe beam-beam-interaction below a linear tune shift of $\Delta \xi = .06$ per interaction point. We now find that the beam-beam-interaction widens the vertical beam size considerably at $\Delta \xi = .015$ already[4]. Not even with sophisticated methods emerging from computer simulations[1] much more than .03 has been reached. To recover the lost factor in luminosity we decided to reduce the total drift length from 15 m to 8.9 m in all four interaction regions. Besides the addition of the mini beta quadrupoles no other quadrupoles were changed in position. Figure 3 shows the envelopes near the interaction points for the extreme mini beta optics MI 6 and for the previous luminosity optics.

The new beta values are 6 cm vertically and 130 cm horizontally as compared to 17 cm and 280 cm in last year's luminosity optics. The beam cross-section decreases and specific luminosity increases therefore by a factor of about 2.5. It is seen that the whole job is done without any increase of the maximum beta functions. On the contrary the horizontal physical acceptance is increased from 20πmradmm to 30πmradmm. The linear chromaticity increases mainly due to the shorter focal lengths of the mini beta quadrupoles. But even for the same linear chromaticity like before, the mini beta scheme would provide a smaller beam size at the interaction point by a factor of 2.

The mini beta scheme came into operation in Feb. 81. Two weeks later 4x8 mA were stored in two electron and two positron bunches at 7 GeV in a special injection optics. 4x6 mA can be transferred from injection optics at 7 GeV to luminosity optics at high energies. The lifetime at 17 GeV is good, indicating that there is sufficient acceptance. So far

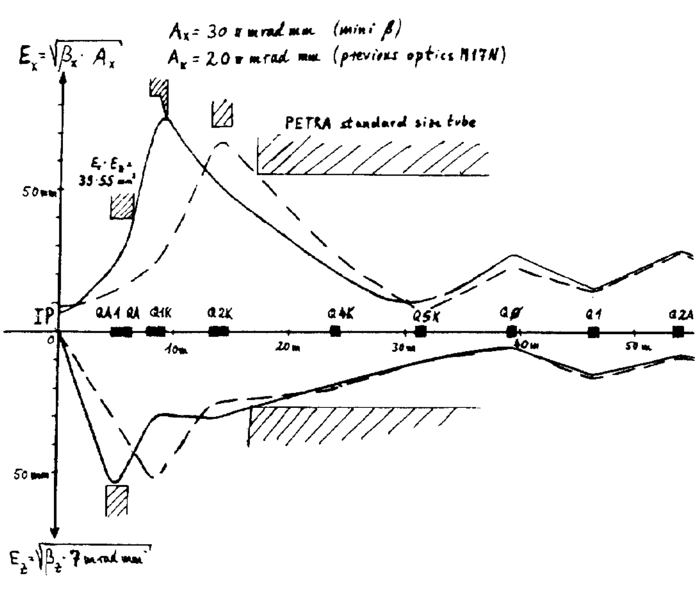

Fig. 3: Horizontal and vertical envelopes near the interaction point

previous running conditions seem to be restored. For luminosity optics the beta functions at the interaction points were checked at different energies and are in good agreement with calculations. The same holds for the horizontal emittance.

The observations of beam-beam-effects and measurements of the luminosity have only started. Especially luminosity measurements at more than 16 GeV still suffer from high background rates. But first results at 14 GeV are encouraging. Figure 4 shows measurements of the luminosity with 2x2 bunches at tunes of Q_x=25.2, Q_z=23.3, f_s=10 kHz. It is hard to compare in such an early stage these measurements with earlier luminosity runs, which had been optimized to a high degree. A typical previous luminosity curve (not the best one) is shown in comparison. It seems, that the luminosity might be up by the expected factor of 2.5 and that the beam-beam-interaction forces as measured by the linear tune shift are not more destrucitve when β is reduced to such small numbers.

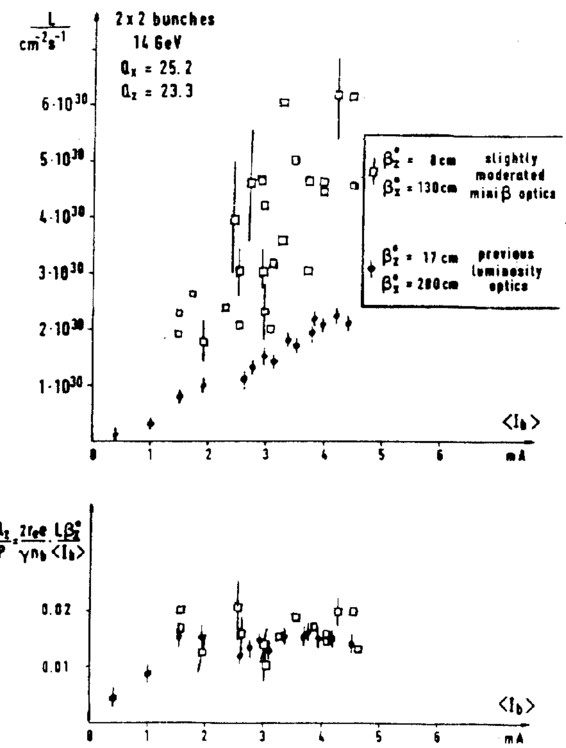

Fig. 4: Comparison of measured luminosity and vertical linear tune shift at 14 GeV with 2x2 bunches as a function of bunch current I_b

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