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ADONE: PRESENT STATUS AND EXPERIMENTS

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Abstract.

The present status of the electron-positron storage ring Adone is reported, together with the foreseen improvements. Some recent measurements are also reported.

Status.

The second generation experimental setups were installed on the ring during a five-month shut-down. Among other, a 4 Kgauss, 2 MW, 1 meter inner radius transverse field magnetic detector (MEA)[1] has been installed and is now running.

Major improvements were also carried out on the machine: a feedback on the longitudinal relative oscillations, and a distributed pumping system in the magnets on both sides of three experimental sections, have been installed; the control system has been further improved.

Tests on the magnetic field distribution of MEA, performed before the installation of the magnet on the ring, were repeated with the first circulating beam with satisfactory results as far as a single beam is concerned. The detector magnetic field is compensated by means of two compensating magnets mounted on the same straight section; integrated field compensation is such that a residual closed orbit of the order of 1 mm in the vertical plane is easily reproduced at $Q_x = Q_z = 3.05$, E = .5 GeV and with the detector running at its maximum field (4 KGauss). The corresponding compensation error is of the order of 1.5 Gauss x meter over the 2.5 m length of the section, versus a specified figure of 2.5 Gauss x meter. The quadrupole component integral is also within specifications: the $\Delta Q/\bar{Q}$ is of the order of .6°/oo per KA/GeV.

The sextupolar component integral changes the machine natural cromaticity by approximately 10% versus a specification of 20% (maximum).

The detector is at present running for experiments, although for reasons not yet fully understood, at low machine energies the maximum luminosity can not be attained when the detector is running at high current.

The feedback system to cure longitudinal relative oscillations of the three bunches[2] has been brought into operation. The system makes use of two RF cavities running at 8th harmonic of the revolution frequency (22.8 MHz), not a multiple of the RF frequency (8.568 MHz). The system prevents destructuve oscillations from occurring and makes storage of currents, as high as 60 mA/beam much easier.

A complete bakeout of the vacuum chamber has not yet been carried out and the average pressure without beams is $\sim 5 \cdot 10^{-10}$ torr.

Beam lifetime is nevertheless quite good because of the installation of distributed pumping in six out of twelve magnets (~ 8 ÷ 10 hours depending on energy).

Distributed pumping has also appreciably improved the pressure in the experimental sections: data taken at E = 1.2 GeV, with a total current of 78 mA are given in the following table:

Exp. Section	pressure with distr. pump.	pressure without distr. pumping
5	.53 ntorr	1.2 ntorr
9	1.9 "	4.1 "
11	2 "	5.6 "

A complete bakeout of the chamber, plus the installation of the rest of the distributed pumping system, should further improve both local and average pressures by at least a factor of 2 or 3.

Experiments on beam size control.

Some preliminary tests on the possibilities afforded by the method proposed by M. Bassetti[3], who suggested that natural beam transverse dimensions can be controlled by modifying the ring magnetic structure, were recently carried out.

As discussed in detail in Ref. 3, transverse beam dimensions can be modified by acting on the average value in the dipoles ($\bar{H}$) of the well known function[4]

$$H(s)=\frac{1}{\beta_x(s)}\left[\psi^2(s)+(\beta_x(s)\psi'(s)-\frac{1}{2}\beta'_x(s)\psi(s))^2\right] \quad (1)$$

The original magnetic structure of Adone was modified by introducing a third harmonic resonant perturbation.

The actual way to do it is to lower the strength of three pairs of radial focussing quadrupoles located at the ends of three equally spaced, non--interaction straight sections. The $\psi(s)$ function is thus distorted, causing $\bar{H}$ to grow.

The measurements were done by shunting away a fixed amount (3%) of the quadrupole excitation currents.

The $\beta(s)$ and $\psi(s)$ functions, for the modified structure ($\beta^x(s)$ and $\psi^x(s)$) are shown in fig. 1, 2 and compared with the same functions for the imperturbed machine.

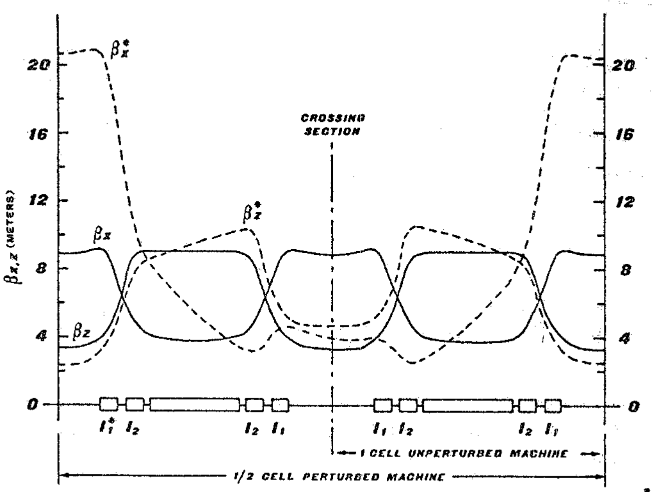

Fig. 1 - β functions with (β_x^*, β_z^*) and without (β_x, β_z) shunted quadrupole perturbation.

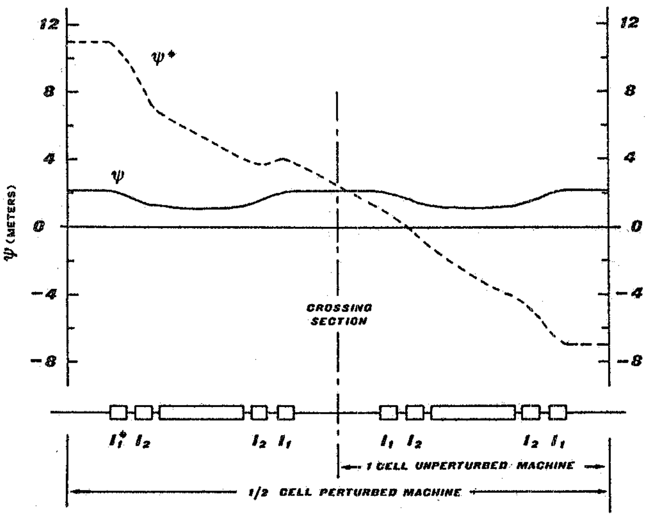

Fig. 2 - Off-energy function with (ψ^*) and without (ψ) shunted quadrupole perturbation.

The maximum currents that could be stored in a stable two-beam configuration, without beam "flipping" or short lifetimes were measured, in the energy range from .5 to .6 GeV. Luminosity measurements were also carried out.

Luminosity values obtained with the Bhabha scatteringluminometer were corrected to account for the bunch lengthening effect which, at a given energy, is larger than for the original structure, mainly due to the increase of the stored currents.

Preliminary results seem to be in rough agreement with expectations. In the .5 to .6 energy range, currents higher by a factor of ~2 were stored and brought into head-on collision: the maximum obtained luminosities were higher by a factor of 1.5 than the corresponding unperturbed machine values, in rough agreement with what expected under the hypothesis that the maximum attainable value of ξ_z (the beam-beam interaction parameter) is the same as for the unperturbed machine.

Further experimenting is needed, to obtain more accurate data and to actually check whether the behaviour of the structure has been fully understood.

An interesting aspect of the perturbed machine is that, due to the large distortion of function $\psi^*(s)$, radiation losses in the quadrupoles are larger, and the RF frequency range beyond which antidamping of the sychrotron or the betatron modes occurs should therefore be narrower by large factors. This would open the possibility of changing the damping partition numbers, and therefore beam dimensions (see references 5 and 6), by working at a slightly different frequency.

Strong beam - weak beam interaction measurements.

The behaviour of a positron beam colliding with an electron beam of much lower intensity has been studied in same detail.

We first measured the maximum attainable strong beam current (defined as the value I_L at which the weak beam shape begins to change) as a function of energy. We then measured luminosity at several energies, with strong beam currents lower than but near to I_L.

Measurements were carried out with three bunches in the strong beam and one bunch in the weak beam. This because more accurate beam shape measurements can be carried out with our present detection apparatus on a single-bunch beam.

It should also be recalled that, with our machine parameters, higher current densities are obtained with one bunch per beam [8], so that one could argue that, for a given weak beam current per bunch, the strong beam is less perturbed by a single-bunch weak beam.

All measurements were carried out with the machine tuned at $\nu_x = \nu_z = 3.05$.

A definition of how weak the weak beam should be, in order not to affect the strong beam, is needed.

Recalling from our strong beam/strong beam work that $I/E^{4.5}$ is a good parameter to characterize beam-beam interaction-induced shape modifications (see discussion in ref. (8)), we assume that a relevant parameter could in our case be

$$R = \frac{(I \cdot i)^{1/2}}{E^{4.5}} \qquad (2)$$

I and i being the strong and the weak beam currents respectively.

Under this tentative assumption we then chose to define the weak beam intensity to be negligible when (I being only slightly lower than I_L) R is ≤ 25 mA/GeV$^{4.5}$, a figure that can be deduced from the data of Fig. 5 of Ref. (8) by somewhat arbitrary arguments.

Experimental values of I_L versus E, for $R \leq 25$ mA/GeV$^{4.5}$ are shown in fig. 3.

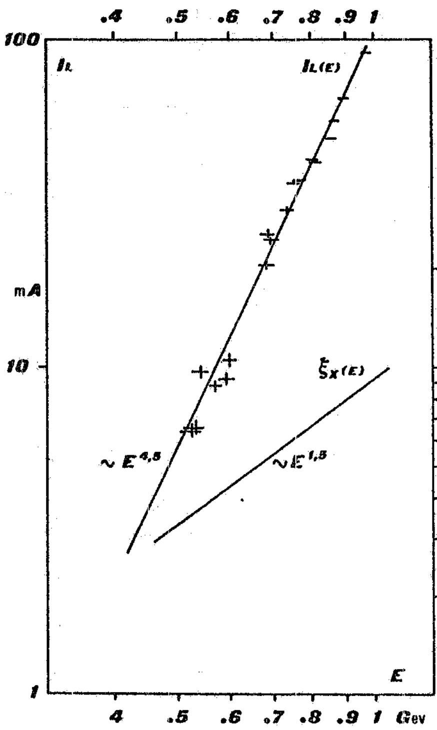

Fig. 3 - Maximum current in the strong beam I_L versus energy.

Measurements were carried out over a period of approximately one month and were found to be reproducible to within the experimental uncertainties.

A power-law best fit through the data shows that

$$I_L = I_o E^{4.34} \qquad (3)$$

with a χ^2/N value of 1.3 (N = 18).

Luminosity measurements performed at different R values and at several energies were used to calculate the ratio of the effective interaction cross section to σ_p^2, S_o^M, defined as

$$S_o^M = K \frac{I_s\, i}{L E^2} \qquad (4)$$

σ_p being the r.m.s. energy spread in the beam and K being equal, for our tune values, to 2.5 10^{30} $GeV^2/$ $/mA^2 \cdot s$. We also define S_o^o as the natural single beam radiation cross section on the coupling resonance divided by σ_p^2 [8].

Fig. 4 shows a plot of S_o^M/S_o^o versus R.

The data are not incompatible with the assumption that the interaction effective measured cross section in the vicinity of the weak beam space-charge limit is proportional to E^2, and that the strong beam cross section is equal to $S_o^o \cdot \sigma_p^2$, at least for R $\leq$ 25 $mA/GeV^{4.5}$. Given the large experimental errors on most points a more refined analysis of the data would not be meaningful. Further measurements should however be carried out on this important point, with greater accuracy.

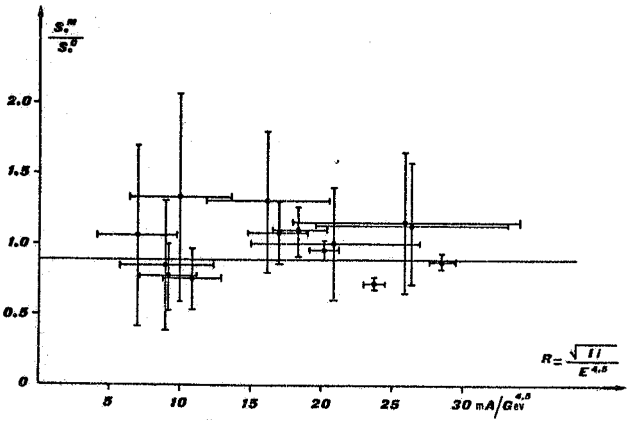

Fig. 4 - Behaviour of S_o^M/S_o^o as a function of R.

A possible explanation for the slightly lower value one gets fitting a horizontal straight line through the data (.88) is that, due to beam-beam interaction, the actual weak beam tune is far off coupling (see Ref. 9).

If the strong beam has its natural on-coupling resonance dimensions, we know how to calculate the value of the interaction parameter ξ_x (as seen by the weak beam) corresponding to I_L, as a function of energy (with our parameters and for natural on-coupling beam dimensions, $\xi_x \approx 1.07\ \xi_z$). The result is shown in fig. 3.

The data presented here are incompatible with the $I_L \propto E^3$ law we deduced for strong beam/weak beam interaction in Ref. 8 and that one would expect from a simple thin lens model for the interaction. A fit through the present data with an E^3 dependence has a χ^2/N value of 14.5, and is therefore highly improbable.

A best fit with $I_L \propto E^{4.5}$ which is our strong beam/strong beam energy dependence, gives a χ^2/N value of 1.5 and is therefore still compatible with the data.

It should be said however that previous measurements were carried out with three bunches per beam and over a very narrow energy range (.5÷.6 GeV); control system improvements have since allowed the energy range to be extended, and more accurate current measurements to be performed. We also can not exclude that the exact definition of I_L has an important role.

It should also be borne in mind that the fact that the actual weak beam tune is far off-coupling, so that the weak beam density is by no means well known, is an unaccounted-for part of the picture that may be important.

Future improvements.

In the attempt to eliminate the problems arising from the several modes of longitudinal oscillation which take place with the present RF system, the installation on Adone of a new 200 KV single-gap cavity, operating at 51.4 MHz is planned. The RF driver system will be delivered in September and the cavity is expected to be delivered at the end of this year.

Accompanying changes will have to be made on the Linac beam choppering system which will have to provide 10 ns long pulses at a repetition frequency ranging from ~3 MHz (1 bunch) to ~17 MHz (6 bunches) (up to six bunches are required to be stored in Adone when used as a booster for the SuperAdone project ring[7]).

To compensate for the decrease in the injection rate due to the reduced RF time acceptance, a factor of two in the peak Linac current has to be provided, together with an increase in the positron injection energy from .31 to .36 GeV allowing the injection repetition rate to be increased by a factor of approximately 1.5.

This also involves a substantial improvement in the control instrumentation of the beam transfer lines from the Linac to the ring.

Aknowledgments.

All members of the Adone group have contributed to the work reported in this paper. We would like to aknowledge in particular the contribution of M. Vescovi who, besides partecipating in all measurements, was mainly responsible for the proper operation of the machine.

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