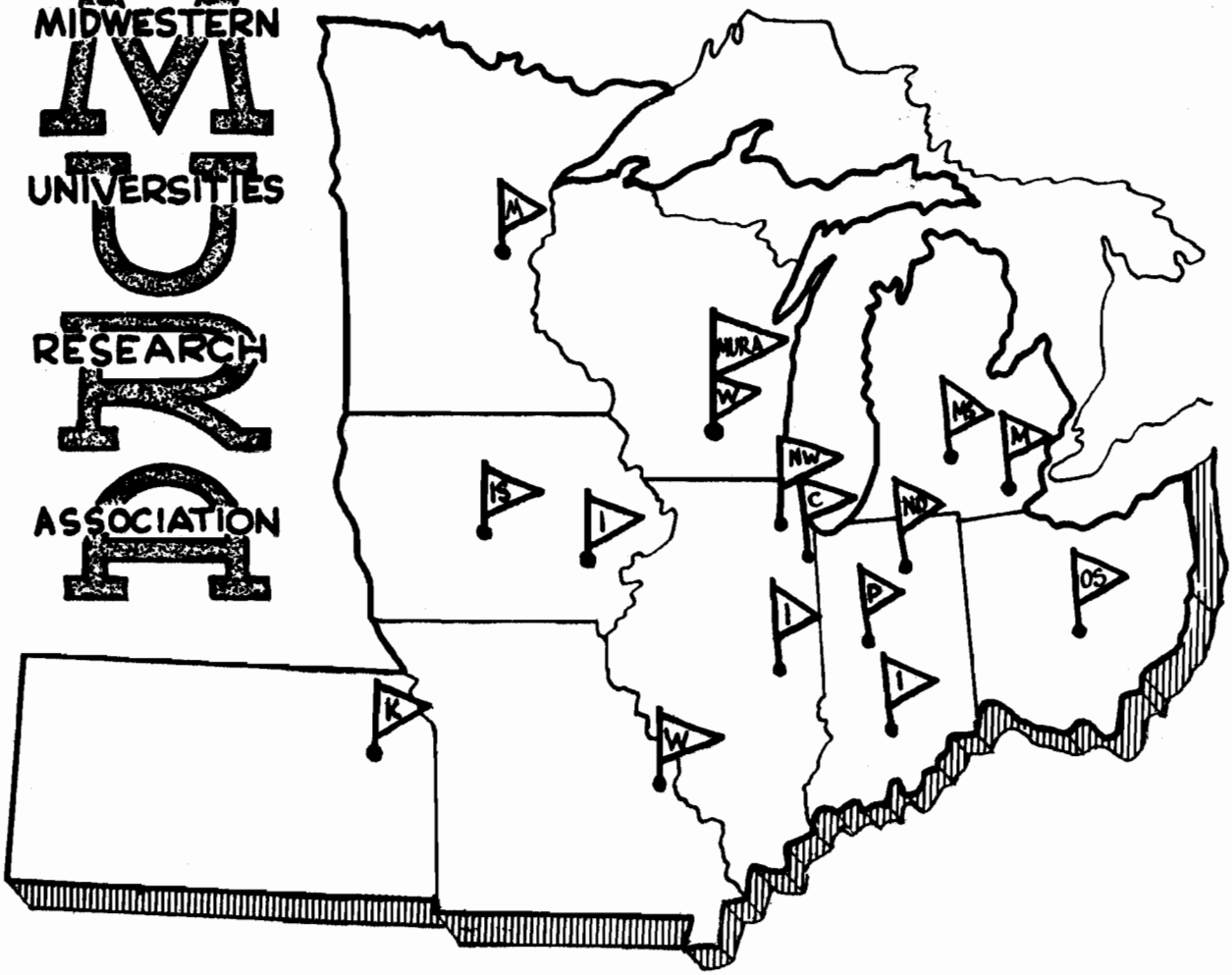
Fermilab Library
0 1160 0038806 0

519

FOR INTERNAL USE ONLY

MIDWESTERN UNIVERSITIES RESEARCH ASSOCIATION



REPORT ON VISITS TO THE CENTER FOR NUCLEAR STUDIES, SACLAY, FRANCE

R. O. Haxby, F. E. Mills and K. R. Symon

REPORT **NUMBER** 519

FOR INTERNAL USE ONLY

MURA-519
Internal

MIDWESTERN UNIVERSITIES RESEARCH ASSOCIATION*

2203 University Avenue, Madison, Wisconsin

REPORT ON VISITS TO THE CENTER FOR NUCLEAR STUDIES, SACLAY, FRANCE

R. O. Haxby,** F. E. Mills and K. R. Symon

October 15, 1959

*AEC Research and Development Report. Research supported by the Atomic Energy Commission, Contract No. AT(11-1)-384.

**On leave from Purdue University.

Saturne, a 3 Gev proton synchrotron at Saclay, has been in operation for about one year. The beam intensity is around 10^{10} protons per pulse. It is interesting to note that although Saturne has been operating satisfactorily for about a year a considerable amount of time and effort is still being put into an attempt to gain a better understanding of the operation of the machine and to improve its operation. About three days per week are devoted to experiments in high energy physics, two days to the study and improvement of the accelerator and one day for maintenance.

A comprehensive description of Saturne and of the results of the first six or eight months of operation is contained in the June, 1959 issue of L'Onde Electrique.

One of the outstanding unsolved problems with regard to Saturne is a discrepancy between the n values obtained from magnetic measurements and those obtained from studying the behavior of beam. Dynamic measurements of the magnetic field and of the n value are made with suitably arranged pickup coils placed in the magnetic field. The field and n values are obtained by integrating electronically the output of the pickup coils with initial values given by preliminary measurements of the remanent field. Saturne is a conventional weak focusing synchrotron with four magnet sectors and four straight sections. Because of the straight sections, the magnetic field is not uniform azimuthally and it is therefore necessary to define an effective n value as follows:

$$\nu_r^2 = (1 - n)(1 + k)$$
$$\nu_z^2 = n(1 + k)$$

where n is the effective n value and k is the ratio of straight section length to magnet length. The oscillation frequencies ν_r and ν_z are obtained by an approximate numerical integration of the equations of motion using the n values and magnetic field which are measured as a function of azimuthal angle θ. The equivalent n and k are then calculated from the above equations. The measured value in the magnets is $n = 0.70$. The effective n value calculated as above from the magnetic measurements, including edge effects, is $n_m = 0.73$. The value of k is about 0.3 and agrees with the value expected from the geometry of the magnets. The effective value of n can also be obtained in a number of independent ways from measurements of the behavior of the beam. The momentum compaction can be determined from the rate at which the injected beam spirals in in radius as the magnetic field increases. From this an n value can be calculated which turns out to be $n_b = 0.81 \pm 0.02$. Alternatively the betatron oscillation frequencies ν_r, ν_z can be measured. An electrostatic deflector has been provided at the output from the Van de Graaff injector which makes it possible to switch the injected beam quickly into or out of the injection channel. In this way it is possible to inject a short pulse roughly one-third of a revolution in length with sharp leading and trailing edges. Such a pulse is extremely useful in many studies of the injection process and of beam dynamics. In particular, by observing the frequencies induced on suitably arranged pickup electrodes, it is possible to measure the

radial and vertical betatron oscillation frequencies. Using the formulas given above, one then finds $k = 0.29 \pm .02$, $n_b = 0.80 \pm .01$. (Actually, it is not possible to inject at $n = 0.80$ and so a known correction Δn is made by means of correction coils so as to bring the tune to a value allowing injection. ν_r and ν_z are measured, k and n are calculated, and then $-\Delta n$ is added to the calculated n to obtain the effective uncorrected value n_b quoted.) A third method consists in passing a current through Δn correction coils which are provided on the magnet faces in order to change the n value. These coils have been calibrated so that when the current through them is known the resulting Δn can be calculated. By changing n until the beam arrives at a resonance, for example, the resonance $n = 0.5$, one can calculate from the known n at resonance and the Δn value an original n value without the correction. For $n = 0.5$, one finds $\Delta n = -0.29 \pm 0.03$ and hence $n_b = 0.79 \pm 0.03$. Note that all of the methods of measuring n based on measurements of the beam itself agree in giving the value of n for the uncorrected machine of about 0.8. The discrepancy with the effective n resulting from field measurements (0.73) is still not explained.

There was initially a small amount of AC ripple in the magnetic field. Particularly troublesome was a variation between magnets due to the finite propagation time of the magnet ripple around the accelerator. These difficulties have now been corrected. With the short injected pulse, the individual turns in the beam can be observed for about six or eight turns. During this time, a fairly marked growth of amplitude of betatron oscillations is observed.

Since the beam is not lost, this growth cannot continue for more than eight or ten turns but it is not known just what happens after the first six or eight turns which can be observed.

An interesting scheme is used for controlling the injection cycle in Saturne. During the interval between acceleration periods, a small continuous current of about 1 microampere is provided by the Van de Graaff and passes down the injection channel into the accelerator. This current is used in the first place to control the Van de Graaff energy by detecting the position of the beam after it has passed through bending and focusing devices in the injection channel. It is used in the second place to determine the proper timing of the injection pulse. Three electrostatic inflectors bending in alternate directions provide an achromatic inflection channel into the accelerator vacuum chamber. When the magnetic field is too weak, the inflected beam travels almost tangentially and strikes the wall of the vacuum chamber. As the magnetic field increases, the inflected beam begins to bend until finally it strikes a pickup electrode downstream from the injector. When the 1 microampere controlling beam strikes this pickup electrode, a signal is sent to the injector control circuit which, after a delay of 10 microseconds, pulses on the current source for the Van de Graaff which then provides a pulse current of 1 milliampere. This pulse can be either a short pulse a third of a turn in length for diagnostic purposes as described above, or, in normal operation, it lasts for about 40 turns during which it is possible to inject into Saturne.

A fairly extensive experimental program in high energy physics is under way at Saturne. It is interesting to note that the first bubble chamber pictures of high energy events were exhibited at the "Atoms for Peace Conference" in Geneva September, 1958, within three weeks after the first beam had been obtained. There are now available several beams of π^+ and π^- mesons of various energies available from internal targets in Saturne with suitable focusing and analyzing channels. A number of groups are engaged in carrying out experiments utilizing two hydrogen bubble chambers, a propane bubble chamber, a 50% propane 50% methyl iodide bubble chamber for detecting strange particle events involving neutral particles, a Wilson cloud chamber, and a counter group engaged in measuring π scattering cross sections.

A small group is about to be formed under the leadership of H. Bruck to carry out studies aimed at the eventual construction of a small high current FFAG electron accelerator whose primary purpose will be to permit the study of relativistic plasma effects. Another group including S. Winter, J. Lutz, and A. Schram are engaged in studying basic plasma physics. Their aim is not to develop thermonuclear power but simply to study the basic principles of plasma physics experimentally and theoretically. One subject in which they are particularly interested at the moment is the attainment of ultrahigh vacuum.