BEAM DIAGNOSTICS FOR HEAVY AND POLARIZED IONS IN THE RANGE OF 10 keV/amu to 1 GeV/amu

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Abstract

In connection with the heavy and polarized ion programs, a wide variety of diagnostics has been developed for the Ebis ion source, the Mimas storage ring, the main ring Saturne and the beam transport lines : profilers, Faradays cups, beam current transformers, electrostatic electrodes and secondary emission detectors. Weak beams of 10^8 elementary charges/bunch as well as high intensity beams in the range of 10^{12} elementary charges/bunch can be detected with these devices.

Thanks to the developments which have been achieved, Saturne is now a facility which provides a great variety of particles in a wide range of intensities and energies. In connection with this, the storage ring Mimas has been put into operation in October 1987; two ion sources are associated with it : a polarized proton and deuteron source, and the new Ebis ion source, Dioné, which produces heavy particles N^{7+}, C^{6+}, O^{8+}, Ne^{10+}, Ar^{16+}). The previously existing linac has been preserved to directly inject light ions (protons, deuterons, ^3He, ^4He) into Saturne. The great majority of accelerated particles are now heavy and polarized ions.

The different types of diagnostics which are summarized in this paper are well fitted to this situation and they allow the detection of a wide range of intensities (10^8 to 10^{12} elementary charges/cycle) as bunched or coasting beams. Some detectors must tolerate a baking temperature of 300°C.

Beam profilers

They allow the position and focusing adjustments in the beam transport lines on each side of Mimas ; they can be used for intensities above 100 nA.

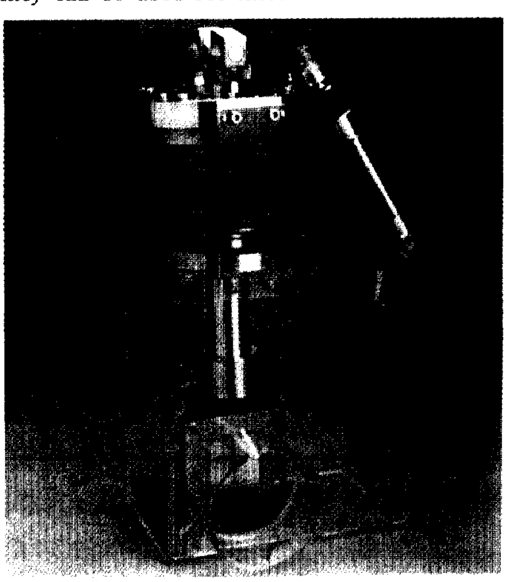


Photo 1 : Bakable profiler of the low energy beam transport line of Mimas

In the sections where a baking of the vacuum chamber is not needed, the profilers are planes of 32 gold-plated tungsten wires (Φ 20 μm) mounted on a teflon-glass frame ; the usuable surface is about 70 x 70 mm and they can support a maximum temperature of 80°C.

When a baking is needed the profilers are alumina plates [1. 2. - photo 1] , 1 mm thick upon which 32 or 48 strips of gold are printed by a silk-screen process; the spacing of the strips ranges from 250μm to 2.5 mm and the thickness of the layer of gold is 20 μm. The detectors with 250 μm spacing are particularly dedicated to the automatic emittance measurements at the exit of Dioné [3].

Double detectors have also been developed [photo 2] ; they provide simultaneously the horizontal and the vertical profiles with two 90° crossed layers, each of 32 gold wires.

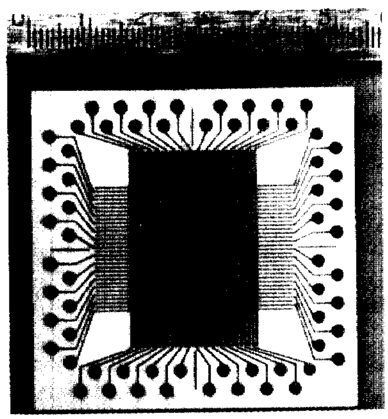


Photo 2
Double alumina Beam profiler

The upper layer is deposited on 32 insulating alumina strips which electrically isolate it from the lower one. The minimum spacing which has been used till now is 650 μm. This inexpensive procedure allows close and accurate spacing. Provided that the connections are welded with a brazing mixture the melting temperature of which is sufficiently high (320°C with 93% Pb, 5,2% Sn, 1,8% Ag) these profilers can withstand the baking of the vacuum chamber. They are destructive of the beam and are moved by pneumatic devices which are under manual or computer control.

Beam current transformers

They complement the Faraday cups and are not destructive. In addition to the intensity measurement of the accelerated beam they provide, after an integration, the total beam charge. Two types of transformers are in use ; three have been bought and respectively placed in Mimas, Saturne and in the beam transport line between these rings ; they provide the transfer efficiency measurements. Their low sensitivity (.1 V/A) restricts their use, especially with heavy ion beams. They will be replaced by transformers which are now being designed ; a very high permeability amorphous material (Vitrovac) with a low number of secondary turns has been chosen.

Another type of transformer has been developed for ion source Dioné [1. 4. - Photo 3]. The aim was to make small and well shielded devices with a good sensitivity ; for this purpose, they are placed in the vacuum chamber. The magnetic circuit is made of five toroïdal srip wound cores of Perminphy 3 ; the strip is .1 mm thick and the dimensions of each core are : external diameter = 27,4 mm ; internal diameter = 18 mm ; length = 10 mm ; the residual noise corresponds to about 1 μA of beam (10^8 elementary charges at the exit of Dioné).

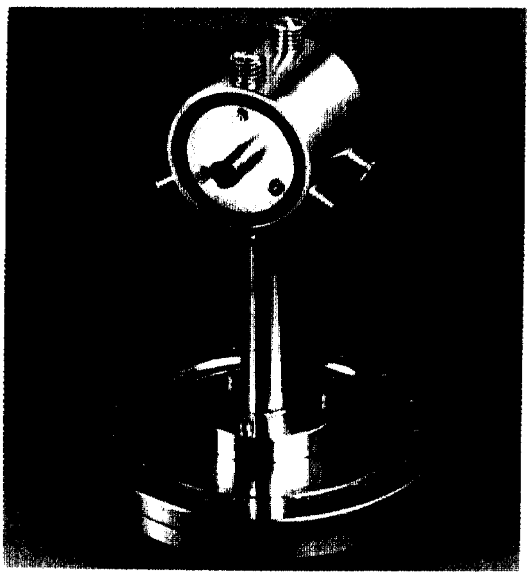


Photo 3 : Beam current transformer of the heavy ion source Dioné

The pick up electrodes

At the time of its construction in 1978, Saturne II was supplied with 24 metallized alumina electrodes for the position measurement of the accelerated beam and with two wide-band electrodes for the RF observation of bunches and the phase control of the accelerating frequency [5]. These monitors are usable with intensities in the range of 10^{10} to 2.10^{12} charges/cycle ; for lower intensities (10^8 charges) a set of 3 electrodes has been installed in a straight section ; one of them gives the longitudinal distribution of the beam, the other ones allow the measurement of the beam positions at a given location in the ring.

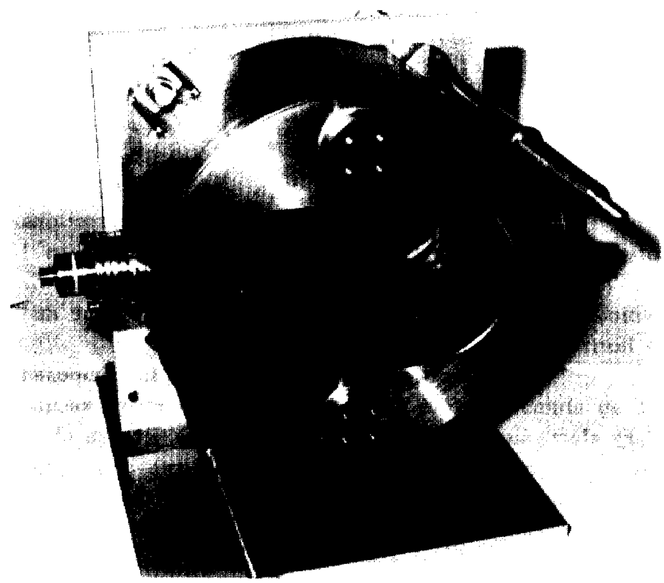
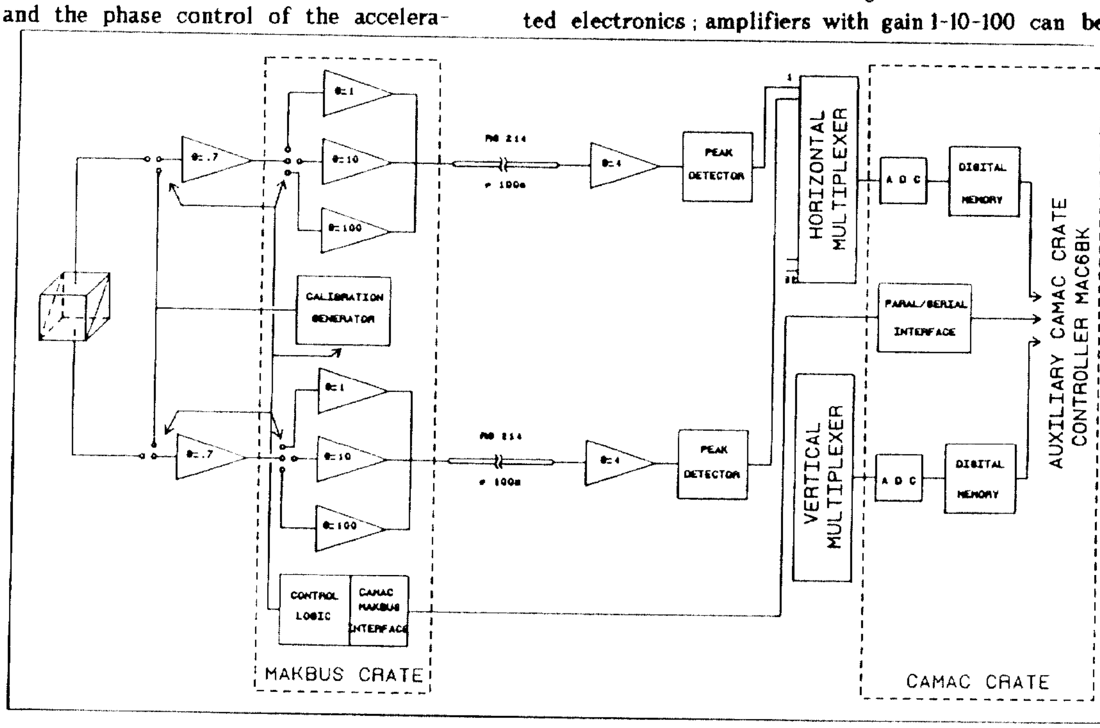


Photo 4 : A Mimas PU monotor before its mounting on the quadrupole vacuum chamber

Other PU electrodes have been recently developed for Mimas ; 16 position electrodes (one for each quadrupole) for the closed orbit display and a wide-band PU are located in the ring ; 8 position detectors of this type have been placed in the beam transport line between Mimas and Saturne ; all are made of stainless steel [photo 4] ; their capacitance is 115 pf and they can be baked at 300°C. The figure 1 shows the associated electronics ; amplifiers with gain 1-10-100 can be put

Figure 1 : Mimas position monitor electronics



into operation to cover the intensity range ; in the beam transport line, the peak detectors have been replaced by integrators. These devices are computer controlled by an auxiliary Camac crate controller MAC68 which uses a processor 68000 and performs the gain switching, the position calculation and the closed orbit display ; position measurements can be made with intensities in the range of some 10^8 charges/cycle. A set of 3 well shielded electrodes has been also placed in a straight section . They will be used for the detection of very weak beams (krypton).

Secundary emission detectors [6-7-8]

They are located in the two extraction sections of Saturne : the energy of the beam can reach then 1 GeV/amu. Each section contains one extraction detector which gives the beam current as a function of time and 4 horizontal profilers.

The extraction detectors [photo 5] is composed of an aluminium foil, 5 μm thick, which emits secundary electrons as the beam passes through ; these electrons are collected by two gold-plated tungsten grids (95% transparency) situated on both sides of the emitting foil ; the emission efficiency is about 2% with protons of 1 GeV. The associated electronics is mainly composed of a current-voltage converter (1V/nA) and allows the observation of beams of some 10^8 protons with energy 1 GeV.

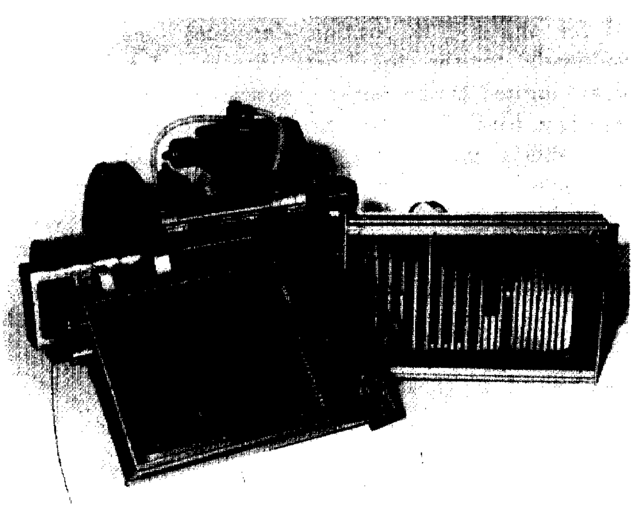


Photo 5 : Secundary emission detector and its associated electronics for the control of the extraction in Saturne

The beam profilers use the same principle and they involve 25 aluminium foils, 20 μm thick, the width of which ranges between 1 and 2 mm depending on the location of the detector in the extraction line . A charge amplifier is connected to each foil ; the signals are then multiplexed, digitally converted and transmitted to the control room where the profiles are displayed on a computer screen. The minimum visible intensity corresponds also to a beam of some 10^8 protons.

Acknowledgements

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