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COMMISSIONING OF MIMAS, NEW ACCUMULATOR BOOSTER RING FOR SATURNE

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INTRODUCTION

MIMAS is a low energy (187,5 KeV/amu) Accumulator Booster Ring (12 MeV/amu) dedicated to polarized and heavy Ions. Thanks to this new Injector the beam intensities of SATURNE [1] (3 GeV proton, 1,15 GeV/amu HI) have increased by a factor 10 in H.I up to Argon and 5 to 10 in polarized particles (p, d). Recently Krypton has also been delivered to Physics Experiments.

MIMAS [2] [3] was commissioned from April 87 to Fall 87. This period of time includes all tests and the first operation with a Physics Experiment. All the goals planned during the design of MIMAS have been fully reached and since 1987 a 98% availability is routinely observed.

In this paper the machine is described as well as the different beam manipulations (stacking of n EBIS pulses, adiabatic capture, dynamic transfer between MIMAS and SATURNE).

GENERAL DESCRIPTION

A general lay-out of the SATURNE NATIONAL LABORATORY is given fig 1.

MIMAS is a 8 period synchrotron which the circumference is choosen to be about 1/3 of the SATURNE circumference to allow a full recapture of the MIMAS bunch into one of the 3 circulating empty bunchs of SATURNE.

The 8 straight sections are used for : two RF cavities, an injection electrostatic inflector, a betatron core for the multiturn injection, an extraction septum magnet, a kicker magnet, a RFKO, and a low intensity pick-up electrode (fig. 2).

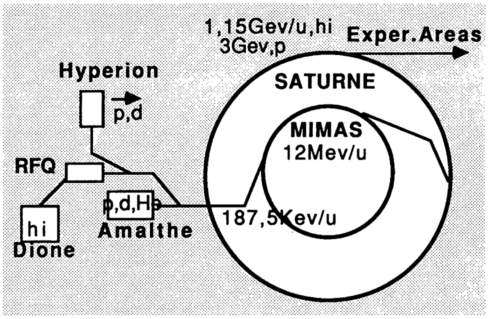

Figure 1

CLOSED ORBIT AND CHROMATICITY CORRECTIONS

Considering the large stored emittance at injection it is necessary to correct both the closed orbit and the tune spread produced by the momentum dispersion.

For this, one corrector dipôle and one corrector sextupôle are installed in each of the 16 quadrupôles of MIMAS. Such correctors are simply printed

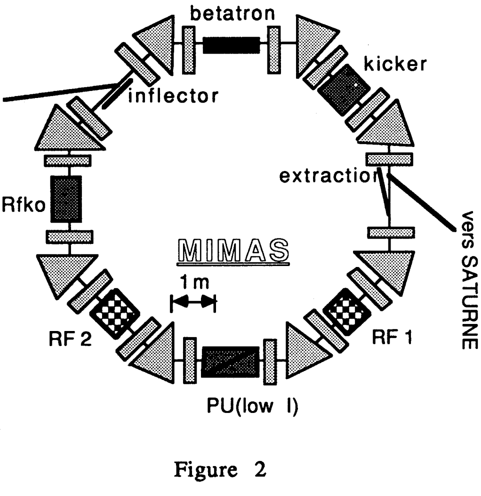

Figure 2

circuits sphaped around the vaccum chamber in the bore diameter of the quadrupôles. The same technique is also used in the beam lines (injection and extraction).

The natural closed orbit, resulting of the mis-positioning and magnetic quality variations from one to another magnetic elements is about ± 5 mm in both the plans.

A entirely automatic push button closed orbit correction procedure using the 16 pick up electrodes (located next to the quadrupôles) and the 16 correctors can be activated. The result displayed for the operators. It is easy to obtain a remaining ± 1 mm and less after some iterations. The corrections are cycled up to 2 Binj according to the same law as the mains.

Due to the large $\Delta p/p = \pm 4$ % and the natural chromaticity of the machine ($\Delta Qx = \pm 0.07$; $\Delta Qy = \pm 0{,}1$) and the tune shift by space charge for 2.10^{11} charges ($\Delta Qx = -0{,}045$; $\Delta Qy = -0{,}05$) the 2 families of sextupôles are adjusted in order to get a tune number constant in the useful aperture of the vacuum chamber. They are also cycled up to 2 Binj.

MULTITURN INJECTION AND ADIABATIC CAPTURE

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The 3 preinjectors of MIMAS 4) can deliver a large variety of ion species : polarized protons and deuterons, heavy ions. The beams which are delivered by the sources have different time structures. The heavy ions are produced in short times (50 µs) and the the amount of charges per burst is constant (about 10^{10} elec.ch.). The bursts can be repeatedly delivered by intervals of 20 - 50 ms. In the case of the polarized protons ans deuterons the pulse can last up to 1 ms at constant intensity allowing for a constant filling rate of MIMAS.

The injection in MIMAS is realized in the synchrotron phase space by a multiturn injection 5) process (fig. 3). In this type of injection only the central part of the beam emittance is, turn by turn, injected into the machine. In MIMAS, while the magnetic field is kept constant, the particles selected by the acceptance window, located at the inflector, are slowly decelerated by the betatron core 6) installed in one of the 8 straight sections. A negative $\Delta p/p$ of 4 % is enough to inject the beam but 2,6 % more are still necessary to center the coasting beam on the machine mean radius. After the following adiabatic capture by RF cavities the final $\Delta p/p$ becomes 8 %. When using the heavy ions préinjector the 4 % of $\Delta p/p$ can be filled up by successive deceleration of several bursts (up to 7 bursts of 50 µs). For polarized particles the pulse duration is enough to be stored continuously.

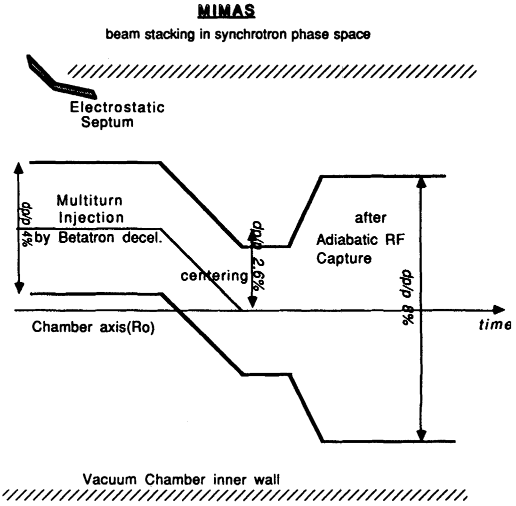

Figure 3

In the transverse plans the final emittances of the beam are respectively :

$Exx'/\pi = 300$ mm. mrd and $Ezz'/\pi = 900$ mm. mrd.

In the vertical plan the large final emittance is given by a vertical sweeping of the beam during injection in order to reduce the tune shift caused by space charge forces.

The main parameters for protons, deuterons and fully stripped ions are given in the table I.

	-> P	-> d	H.I
BRHO T.m	0.088	0.125	0.125
TZERO us	4.34	6.14	6.14
Exx'/π µm.rd	310.	310.	310.
Ezz'/π µm.rd	900.	900.	900.
(Δp/p)b* %	4.	4.	4.
(Δp/p)c* %	2.6	2.6	2.6
(Δp/p)t*.10^{-4}	3.	3.	3.
n of turns	133.	133.	133.
SIGMA mm/t.	.5	.5	.5
pulse dur.µs	580.	820.	80
dØ/dt Wb/s	225.	225.	225.

* b, c, t, for beam, centering, turn.

Table I

Multiturn injection leads to small acceptance window at the electrostatic inflector location. A necessary fine tuning of the injection line must be obtained. A usual order of magnitude for the beam centroid is ± 0.2 mm ± 0,1 mrd while the ellipse orientation of the horizontal emittance has to be fitted at the same time. The injection beam line is tuned with profile monitors, emittance measurements and intensity monitors to stick to these requirements.

During the injection time the RF voltage is kept as close as possible to zero by the control loop, then the cavities are slowly turned-on according to a parabolic-like law which satisfies $dV/dT_S(v)$ = constant (Ts for synchrotron period). This causes the full adiabatic bunching of the particles in a stationary bucket. The final value is choosen so as to get a future dynamic separatrix which fully includes the injected beam longitudinal area 7).

Typically for deuterons the RF voltage is 2 KV (peak to peak) and the duration for 95 % of capture efficiency is obtain in about 5 ms (Ts ~ 1 ms).

CYCLING AND ACCELERATION

The cycles of MIMAS and SATURNE are shwon on the fig. 4. For polarized particles one pulse of 1 ms from HYPERION is enough to fill up the ± 2 % dp/p in synchrotron phase space of MIMAS. For the heavy ions, the ± 2 % dp/p are obtained by addition of up to 7 short bursts of DIONE.

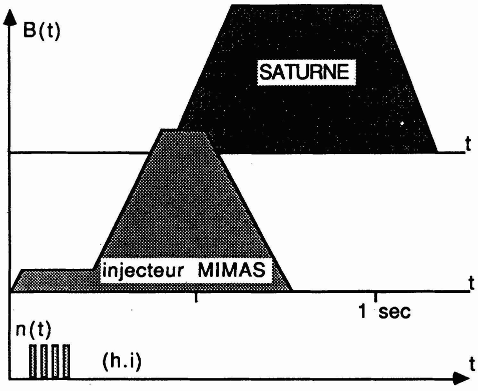

Figure 4

After the injection time (at constant B) the RF frequency as well as currents in the dipôles and the quadrupôles of MIMAS are ramped to reach Bmax = 0,97 T at a rate of 5 T/sec. At the maximum energy 8) 9) (B = 1 T.m for all ion species), after a df/f of 3 % (at constant B) and an additional local closed orbit distortion of 50 mm, the beam is kicked out by a set of kickers and a septum magnet. Just before this fast extraction, the bunch of MIMAS is compressed by the RF cavities in order to fit exactly the already circulating empty bucket of SATURNE.

The recapture is routinely 100 % successfull and leads to a perfect acceleration to the top energy of SATURNE (B = 13 T.m). The slow extraction process then takes place for a variable time which depends on the Users. To face the full range of ion species from polarized protons ($q/_A$ = 1.) to heavy ions of $q/_A$ = .25 the RF cavities of MIMAS must be tuned over a large frequency and voltage scale : 0,163/2.48 MhZ and 1/4 kv. In this domain, the feedback loops closed on the MIMAS bunch detection (radius and phase), remain efficient down to 10^8 elect-charges. For less (Krypton case), the P.U electrodes have not enough sensitivity and a copy of voltage and frequency law for same $q/_A$ but more intense beam is used (example : $K_r{}^{30}_{84}$ - N^{5}_{14}).

VACUUM REQUIREMENTS

The storage at low velocity (beta = 0,02) of partially or fully stripped ions requires very low residual pressure in the vacuum chamber. For polarized protons and deuterons some 10^{-9} Torr and 100 ms are tolerable when considering the emittance growth by multiple scattering (practically no visible effect).

For other ions the necessary residual pressure is imposed by the species, the state of charge and the time between successive pulses during the storage. Typically in 5.10^{-11} Torr 7 pulses of Nitrogen (N^{7+}) by 50 ms intervals no loss is observed. The Krypton (K_r= $^{30+}$) at the same velocity is totally lost in 30 ms i.e before the second pulse is launched by the source (150 ms).

This pressure of 5.10^{-11} Torr is obtained in MIMAS thanks to :

1 - a previous chemical and physical processing of materials (cleaning and baking 1000° in vacuum before assembly).

2 - in - situ, fully computer controlled baking of the vaccum chamber up to 300° C (about one week is needed to go up and down).

3 - the pumping system which consists of 13 Titanium getter pumps and 4 triode ionic pumps distributed along the vacuum chamber (stainless steel 316 L).

RESULTS

The commissioning of MIMAS was lead step-by-step to tune carefully all its main function. As a result of the Saturne commissioning in 1978 the computer controls were active in MIMAS from the beginning as well as most of the diagnostics 11) 12).

Very early the multiturn injection was available for a first tuning of the lattice and injection line optimization.

IONS	Nb imp SOURCE (per cy.)	Nb nucl. in SAT.2	Tmax GeV/u
Ppol	1	1.5 10^{11}	3.
Dpol	1	2.10^{11}	1.145
C 6+$_{12}$	5	9.10^8	1.145
N 7+$_{14}$	4	$7,8.10^8$	1.145
N 6+$_{14}$	4	10.10^8	0.912
N 7+$_{15}$	4	$6,4.10^8$	1.036
0 8+$_{16}$	4	$1,2.10^8$	1.145
Ne 10+$_{20}$	4	$1,4.10^8$	1.145
Ar 16	3	$1,1.10^8$	0.820
Kr 30+$_{84}$	1	2.10^6	0.688

Table II

The adiabatic capture did not put any particular problem and PU electrodes could be used for closed obit measurements and corrections in both plans as well as, using RFKO, chromaticity corrections by the 2 families of sextupôles.

Some more time was spent for the dynamic transfer of the Mimas stationary bunch into one of the dynamic empty bucket of SATURNE because the need of accurate synchronization between the RF cavities, the kickers, the magnetic fields of both the Synchrotrons. Some incidents of youth like sparks in the main power supply transformer, sudden bursts of pressure caused by misunderstanding in computer interfaces or operation errors have also been cured.

To date the main performances of MIMAS and SATURNE are given in the table II.

CONCLUSION

MIMAS as new injector of SATURNE meets all the requirements envisioned at the original step of the design. It is able to provide to SATURNE from polarized protons and deuterons to Krypton. For the heavy ions the multiple ion source pulses stacking is used thanks to an original deceleration technique (betatron core).

To reach Xenon or higher masses the present pressure of 5.10^{-11} Torr has to be still reduced in order to limit the losses by charge exchange at low velocities.

*** The Main characteristics of MIMAS :**

Injection energy :	187,5 KeV/amu
Maximum final energy :	47 MeV for protons
($B\rho$ = 1 T.m)	12 Mev/amu for Ions of q/a = .5
Number of Cells :	8 FODO
Physical Radius :	5,85 m
Tune numbers Qx/Qy :	2,22/2,18
Beta Max / Min :	5/1,5 m
Rg Max / Min :	1,8/1,2 m
Natural Chromaticity :	ξ x = - 0,75 ξy = - 1,07
Horizontal available aperture :	± 13 cm
Vertical available aperture :	± 8 cm
RF Frequency range :	0,15 to 2,5 MHZ (h = 1)
RF Peach voltage/cavity :	2 KV
Repetition rate (max) :	2 HZ
Residual Pressure :	3.10^{-11} Torr

*** Technical Characteristics**

dipoles :	window-frame, rectangular,	0.84 length
	radius of curvature	1,1 m
	angular deviation	45°
	gap height	18 cm
	induction Min/Max	0,08/0,97 T
	dB/dt	5 T/sec.
quadrupôles :	length	0,4 m
	bore radius	13 cm
	gradient Min/Max	0,041/1,847 T/m
vacuum chamber	wall thickness	0,6 mm
	corrugation height (in dipôles only)	8 mm
	in-situ bakeable at	300° C
power supplies :	dipôles :	150/2200 A $\pm 5.10^{-4}$
	quadrupôles : foc	60/1100 A ± 10^{-3}
	defoc	20/600 A ± 10^{-3}
kickers :	Mimas	rise time at 1% 200 ns flat top 550 ns
	Saturne	fall time at 1% 950 ns flat top 550 ns

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