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MIMAS : PROJECT OF LOW ENERGY ACCUMULATOR-INJECTOR FOR SATURNE

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ABSTRACT

This new injector would take advantage of Cryebis and would be operated with polarized protons and heavy ions as well. We propose to store and accelerate a few pulses of Cryebis in a 7 meters diameter ring maintained at an average pressure of 10^{-10} torr. This unusual approach at v/c $\sim$0.02 faces the space charge limits, charge changing effects, fast storage, fast acceleration and extraction. The approval of such a facility would place Saturne at one of the very first ranks when compared to polarized proton and heavy ion physics machines presently in operation.

INTRODUCTION

In 1975, when Saturne was still under study or calling for order, the growing interest for heavy ion production led the Laboratory to develop a major effort in favor of Cryebis source. Saturne is now in operation (1). The Cryebis source (2) will be set up in summer 1979 and would be in operation in early 1980.

The injector of Saturne is a linac designed for protons (3) operated on the 2βλ mode in deuterons and helions (4). As a matter of fact this linac can be tuned for nuclei from ε = q/A = 0.5 down to 0.41 provided the RF field remains under severe breakdown limitations. ε cannot therefore get down lower. For that reason (efficiency v.s.ε) and the pressing need of boosting as high as possible the polarized proton intensity, a new concept of injection was developed and led to Mimas, the synchrotron described here. Typically, the expected goals on user's target are :

- 2.10^{11}/sec.polarized protons
- 10^{10} Ne/sec.
- a few 10^{8} Kr_{80}.

MIMAS, A POSSIBLE NEW INJECTOR FOR SATURNE

Cryebis cannot be employed at its best on the present injector. Three short comings are to be noted :

1) - the total efficiency between the source and Saturne is rather poor, when adding up losses in the linac, during injection and trapping (3% for ε$\sim$0.5).

2) - It is utterly impossible to accelerate heavy ions with ε <.41 (terminal voltage limit, RF limitations in the linac).

3) - Only one pulse of Cryebis is usable per cycle of Saturne even though the source is capable of pulsing at a much higher rate.

These problems can be solved quite adequately if the linac is bypassed by a synchrotron booster operated at a low injection energy. In the present case, low energy means 212,5 KeV/A for heavy ions (ε= 0.5) or 425 KeV for polarized protons.

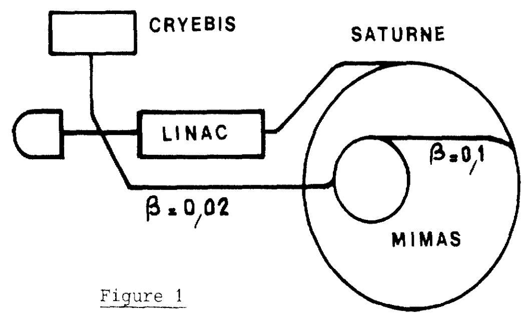

Figure 1

This little synchrotron can be matched with Cryebis and Saturne in order to upgrade the efficiency up to 35% (instead of 3%). Several pulses from the source can be stored at low energy before acceleration and transferred to Saturne.

Mimas has been designed so that its single bunch fits exactly one of the three bunches of Saturne. For polarized protons and light ions the whole set is only limited by space charge in Saturne (one bunch of Saturne = 7.10^{11} charges). For heavier ions the limitations come from the 10^{11}/q law of Cryebis and higher vacuum requirements in Saturne. Therefore, in the scheme proposed here, the injector is not a limitation any more.

The Figure 1,3 shows the general lay out of the Mimas-Saturne facility. The circumference of the Mimas ring is 1/3 of Saturne for longitudinal matching. The little synchrotron surrounded by Saturne is not mandatory, but guided by the hope of builing Mimas while operating Saturne and also to shorten the 5 MeV/A beam transfer line, the lenthtening of the 187 KeV/A beam line being less expensive.

a) - General features -

At transfer energy which is assumed to be 20 MeV for polarized protons or 5 MeV/A for heavy ions, beam emittances in the three phase spaces are the same in Mimas and Saturne. The standard Bρ damping in Mimas leads to the following values at injection :

- transverses emittances $\frac{\varepsilon x}{\pi}$ = 300 mm.mrd

  $\frac{\varepsilon z}{\pi}$ = 880 mm.mrd
- longitudinally $\frac{\Delta P}{P} = \pm 8.10^{-3}$ and total bunch length 20 m.

These figures dictate the circumference of Mimas and the transverse useful aperture as well.

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Main parameters are listed hereafter :

- mean radius R = 3.4 m
- Lattice structure : separated functions with two superperiods
- bending magnets : number 8
  - index n = 0
  - edges z = 11°25
  - gap e = .14 m
  - radial useful aperture : x = .1 m
    - injection field : .08 T
    - extraction field : .59 T
- focusing by 12 quadripoles arranged in four triplet lens :
  - . useful aperture r = .12 m
  - . maximum field on pole .4 T
  - . betatron tunes $\nu_{x_z} \sim 1.75$
  - . maximum βx 3.3 m
    βz 10.5 m
  - . momentum compaction α = .38
  - . maximum dispersion $\frac{x}{\frac{\Delta P}{P}} = 1.5$ m
- kickers : number 2
  - deviation angle 5° or .06 Txm
  - $\frac{\Delta B}{B} < \pm 1.10^{-2}$
  - rise time : 50 ns

An ACO type lattice (Fig.2) tuned to the neighbourhood of 1.75 both planes has been chosen. Working below transition energy helps when considering intra-beam scattering effect.

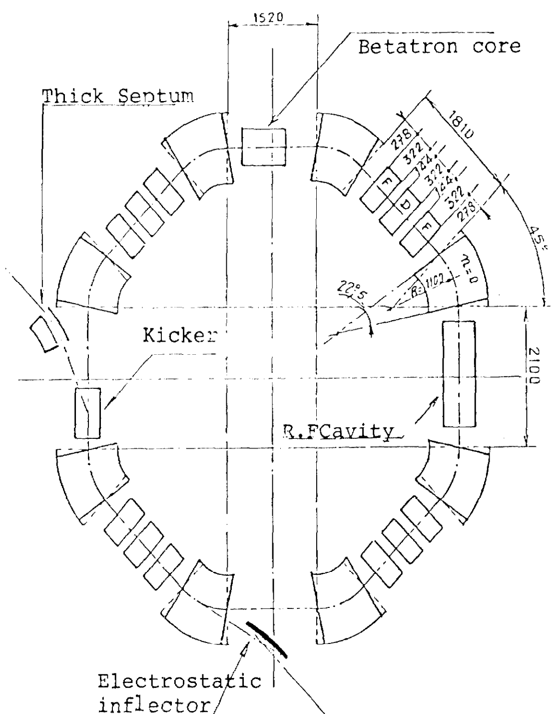


Figure 2

b) - Injection and storage -

Injection process is a combination of energy stacking and multiturn injection. The necessary spiralling is obtained by means of a betatron core. The expected efficiency stands around 55%.

Since Cryebis pulsing rate gets lower as ions become heavier, the storage duration for maximum intensity becomes too long and leads to vacuum problems. Then storage is really efficient for light ions only. Around $10^{12}/q$ particles are expected before trapping, and the corresponding LASLETT ν shift is .12 both planes.

c) - RF handling -

RF handling is divided into three stages :

- . adiabatic trapping for gathering injected particles into one bunch ($\sim$70% efficiency)
- . fast acceleration up to extraction energy (50 ms rise time)
- . beam preparation on flat top in view of transfer.

d) - Extraction -

In synchronism with Saturne RF, the beam is extracted at once by means of a fast kicker. The beam transport line between the two machines, has an essential part to play since it must achieve the exact matching of the two lattices. At last, the line joins one of the straight sections of Saturne into which the beam is once again kicked for acceleration.

e) - Vacuum requirements -

Highly charged ions like Ne^{10+}, Ar^{18+}, Kr^{34+}, offer the great advantage of interacting with residual gas in a quite similar way : electron capture (5). The storage, in Mimas is carried out at $\beta = v/c \sim 0.2$ which means severe charge changing effects. The acceleration between 0.02 to 0.1 takes 50 msec. and does not affect the constraint on the residual pressure too much. The residual gas is assumed to be air (we know that a safety factor of 3 or 4 can be expected on σ_C by considering H_2 at 10^{-10} torr). In Saturne the problem is around A = 60-70 (non fully stripped ions) for which Cryebis gives q not too apart from $\bar{q}$ at $\beta = \beta$ injection. So, both σc and σl compete with different laws. Many results were extracted from the bibliography (6) (7) (8) (9) (10) and it was taken great care of the areas of validity.

Typically, get with the following pressures :

Mimas at 10^{-10} torr :

- . Ne^{10+} storage : 80% transparency
- . Kr^{34+} (see figure after for cross sections) 20 % transparency
- . Kr^{34+} acceleration up to = 0.1 68 % transparency.

Saturne at 5.10^{-9} torr dictated by A 60 and acceleration rate of 1.4 keV/A per turn during 0.5 sec. This pressure allows 96,5% transparency for the Ne and 20% for Kr.

The pressure requirements are not guided by multiple scattering considerations even in the polarized proton case. No pressure bump effects were considered since we do not have enough information so far.

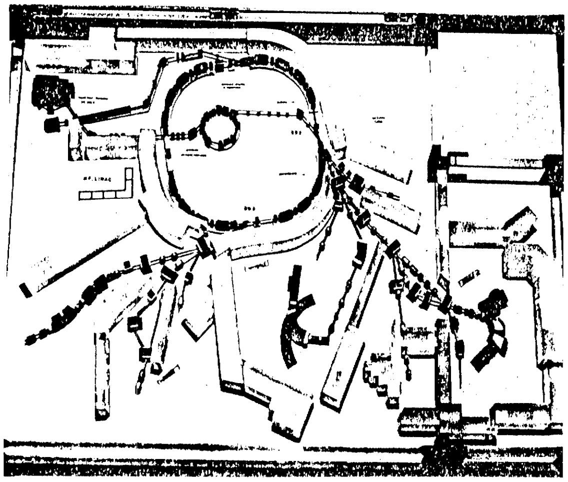


Figure 3

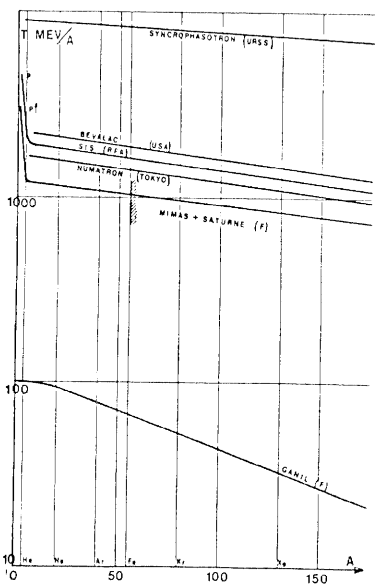
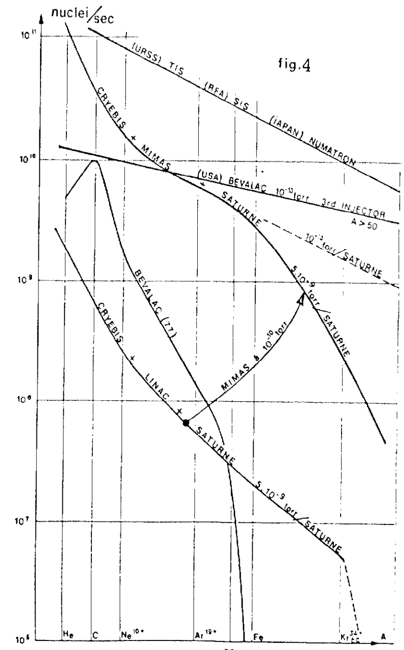


Figure 4



PERFORMANCE LEVELS

Figure 4 shows the specific kinetic energy of relativistic heavy ions facilities in operation (Bevalac, Synchrophasotron) and in project. Saturne beam intensity without Mimas vanishes at A∿50 due to poor injector efficiency. The adding of Mimas would permit to deliver Kr, see Xe, at 1 GeV/A or less with reasonable intensity expected. The situation of the existing injector is considerably helped by using a very expensive Krypton isotope (Kr_{80}) which brings q/m to the minimum value accepted by the linac. A good order of magnitude for the intensity benefit is (Fig.5) factor 100 for all particles from polarized protons (2.10^{11}/sec.) to krypton ($2,5.10^{8}$/sec.)

For higher masses the situation of this new injector is not competitive any longer when considering ions like Pb, U.

CONCLUSION

In the solution we propose, the existing injector of Saturne is bypassed by a little synchrotron as booster and storage ring as well. The versatility of this new injector makes possible the acceleration in Saturne of a large variety of particles with an improved efficiency of a factor 100. These expected results are however limited to masses A∿100.

A special effort must be undertaken to deal with the :

- vacuum requirements (in Saturne),
- kicker technology (rise time, flat topping, outgassing).

Provided we met these points we expect on the user's target :

- $2,10^{11}$ polarized protons,
- $2,5.10^{8}$/sec. Kr.

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