MEDIUM ENERGY BEAM FACILITY AT GANIL

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ABSTRACT

By the end of 1989 a medium energy ion beam facility, called S.M.E. (Sortie Moyenne Energie) will be operational at GANIL. It will be dedicated mainly to investigations in non-nuclear physics. This new facility will use ions that do not have after stripping the right charge state to be accelerated in the last cyclotron stage. Ions from carbon to uranium will be available in an energy range from 15 down to 5 MeV/u, with a beam emittance of 10 Π mm mrd.

1. INTRODUCTION

The accelerator complex of GANIL consists in a cascade of three cyclotrons, a compact cyclotron with an external ECR source and two separated sector-cyclotrons, CSS1 and CSS2. Between the two main cyclotrons the beam is stripped in order to increase the charge state of the ions by a factor of 2.5. For a given stripper foil, the charge state distribution of the stripped beam depends only on the kind of ion and the energy of the incident beam. The charge state q_0 to be accelerated by CSS2 is, as a rule, the most abundant of the distribution, or a neighbouring one.

The beam of the medium energy facility, called SME (in French : Sortie Moyenne Energie) is constituted by ions of charge state q different from q_0. The charge state q is separated from the others by an electromagnetic separator described further on (figure 1).

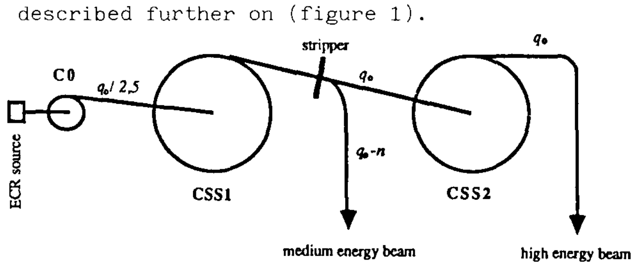

Fig. 1 - Schematic view of the SME

2. BEAM CHARACTERISTICS (*)

Figure 2 represents the charge state distribution of various kinds of ions, accelerated at the maximum energy of CSS1 and stripped by a carbon foil of the proper equilibrium thickness (100 to 200 µg/cm2). It is to be noted that the heavier the considered ion, the wider the charge state distribution. Therefore in the case of light ions (up to Argon), if the charge state to be accelerated by CSS2 is the most abundant, the available charge state for the medium energy beam facility SME represents only a small fraction of the total beam flow. However, for heavy ions, both charge states are of about the same abundance.

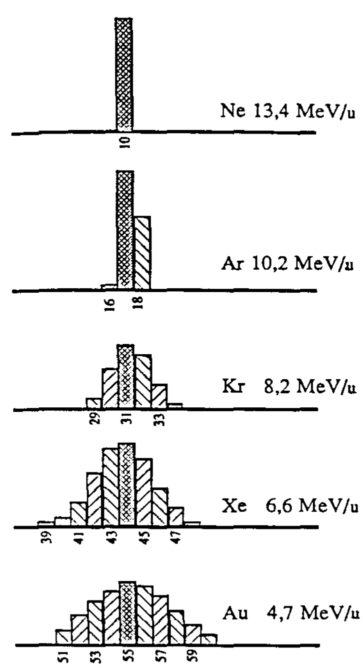

Fig. 2 - Charge state distribution when the beam is stripped by a carbon foil of equilibrium thickness (E. Baron, GANIL)

(*) taking into account the outstanding modifications of GANIL for extending the energy range and upgrading the intensity of the beam (See GANIL status Report, this Conference).

The charge state q of the SME ions, depending on the design of the electromagnetic separator, are :

$q = q_0 - 1$ if $q_0 \leqslant 25$ (∿ up to iron)
$q = q_0 - 2$ if $25 < q_0 \leqslant 50$ (∿ from iron to xenon)
$q = q_0 - 3$ if $50 < q_0$

where q_0 is the charge state of the ions to be accelerated by CSS2.

The maximum energies and the maximum intensities simultanously available for the high energy beam accelerated by CSS2 and the SME beam are shown on figure 3.

	High energy beam			SME beam		
Ions	Charge	Energy MeV/u	Intensity pps	Charge	Energy MeV/u	Intensity pps
$^{10}_{20}Ne$	10	95.9	2.10^{12}	9	13.4	2.10^{11}
$^{18}_{40}Ar$	17	69.5	3.10^{11}	16	10.2	4.10^{10}
$^{36}_{84}Kr$	32	56.3	2.10^{10}	30	8.4	4.10^{9}
$^{54}_{132}Xe$	44	43.5	6.10^{9}	42	6.6	6.10^{9}
$^{79}_{197}Au$	55	30.6	1.10^{8}	52	4.7	6.10^{7}

Fig. 3 - Maximum energy and maximum intensity of the high energy and the SME beam.

Concerning these intensities, it is supposed that the stripper foil has the equilibrium thickness and that the beam to be accelerated by CSS2 has the most abundant charge state. However in the case of light ions, the intensity of the SME beam can be significantly increased at the cost of only a small relative reduction of the high energy beam intensity, by using a stripper foil a bit thinner than the equilibrium thickness. (For instance in the case of $^{10}_{20}Ne$ quoted in the above table : 3 instead 2.10^{11} pps for the SME beam and 1.9 instead 2.10^{12}pps for the high energy beam). In addition, the use of a thinner stripper foil also presents an other advantage : it reduces the contribution of the energy scattering (inherent to the stripping process) to the energy width of the stripped beam.

The beam emittance in both transverse directions will be in the order of 10 Π mm mrd. The expected relative energy width, that depends essentially on the characteristics of the stripping foils (thickness and homogeneity), is ± 4 to $\pm 5.10^{-3}$ (The beam extracted from CSS1 will have a relative energy dispersion of $\pm 1.2\ 10^{-3}$). The phase extension of the buckets will be in the order of ± 5°.

3. DESCRIPTION

The medium energy beam facility SME is composed of two parts : the electromagnetic charge state separator and the beam transport line (see figures 4 and 5).

3.1. The charge state separator

The charge state separator, located directly after the stripper, consists of an analysing magnet M1, that separates the ions according to their charge state, and a septum magnet M5, which separates the SME beam from the beam to be accelerated by CSS2. The other charge states are stopped by adjustable slits.

Magnet M1 is the first one of an achromatic device of four dipole-magnets M1, M2, M3 and M4, that guides the beam to be accelerated by CSS2 towards the said accelerator, without degrading its optical characteristics, except for an increase of the bucket length by a few percents.

3.2. The beam transport line

The beam line guides the ions to two experimental stations, which will be installed in experimental room D1 i.e. to the station for atomic physics and to the irradiation station IRASME for the physics of condensed mater. The beam line is composed of several sections, each one having its precise optical function.

The first section, between magnets M5 and M6, contains a set of four quadrupole lenses, providing the four parameters which are needed to focus the beam on a horizontal and vertical cross-over. A symetric device of three horizontal and vertical profile monitors and adjustable slits is centered at the cross-over. The transverse emittance can be measured by the scanning method, using the central slits and the downstream profile monitors. The limitation of the emittance can be performed with the triple set of slits. Near the cross-over a second stripper can be installed in order to produce higher charge states. The charge state selection is performed by dipole magnet M6 and an adjustable slit.

The second section, between magnets M6 and M7, contains a set of four quadrupole lenses which are matched in order to deliver downstream magnet M8 a doubly achromatic beam. As a matter of fact, two focusing parameters only are necessary for this purpose, the other two being used to adjust the beam dimensions in this section.

The section situated downstream magnet M8 consists of a set of four quadrupole lenses providing a horizontal and vertical cross-over on the target of the experimental station for atomic physics.

The section that comes in prolongation of the second one, contains a set of two quadrupole lenses. These two lenses and the two last ones of the second section provide the four parameters which are needed to focus the beam on the target of experimental station IRASME. The beam can be uniformly swept over the target with a horizontal and a vertical saw-tooth excited steering magnet. On the target the beam is achromatic only in position.

3.3. Note concerning the high energy beam facility for non-nuclear physics

In room D1, where the two experimental stations of the SME are located, a high energy beam line is also installed : it guides the beam accelerated by CSS2 to irradiation device IRABAT, that is mainly devoted to solid state physics.

4. PRESENT STATE OF PROGRESS

The first serious design studies date back to 1986. But as early as 1976, when GANIL was designed, the charge state separator was already roughly designed in order to manage the required space on the beam line between the two main cyclotrons. The project, supported by CIRIL (*) since its founding in 1982, was definitively approved in January 1987.

(*) CIRIL is a laboratory installed at GANIL and devoted to non-nuclear physics. It assists the outward physicists to perform their experiments at GANIL and manage also its own research program.

Today the equipments are being set up and tested. The most advanced part is the electromagnetic separator which is now being tested with the beam.

The first physical experiments are planned for the end of 1989.

5. THE PHYSICS

The medium energy beam facility SME will be used mainly, but not only for topics in atomic physics and in the physics of condensed matter. However our first experiments in non-nuclear physics were made at GANIL as soon as it started running in 1983, with heavy ions of high energy.

With the new facility an important experimental program is already planned. Investigations in atomic physics will be concerned with : a) low energy collisions with recoil ions of a few eV and a high charge state, b) charge exchange either with channeled or non-channeled ions and c) atomic beam-foil spectroscopy. In the field of the physics of condensed mater, experiments will deal with a) defect creation by electronic excitation (and subsequent investigations of the modified matter), b) damage in materials produced by elastic collisions and c) investigations at low temperature (4° K).

Since 1983 non-nuclear physics at GANIL has been experiencing an important development. The medium energy beam facility SME represents a new step in our efforts.

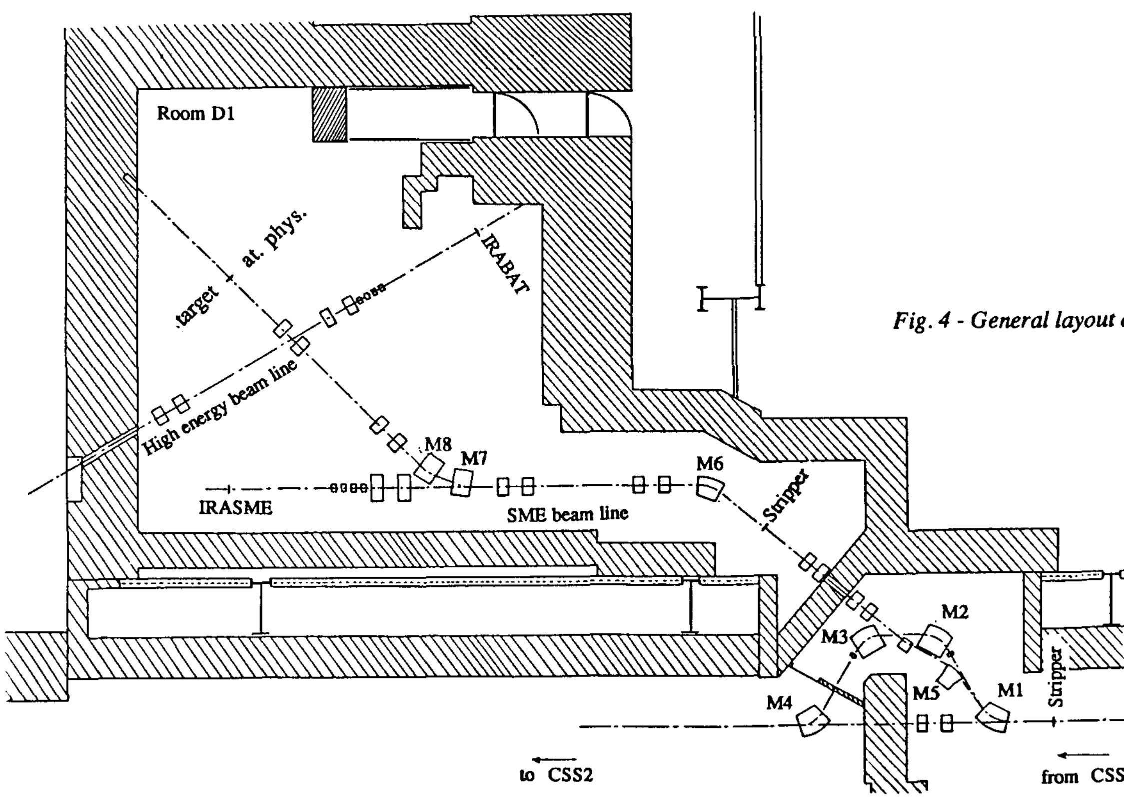

Fig. 4 - General layout of the SME

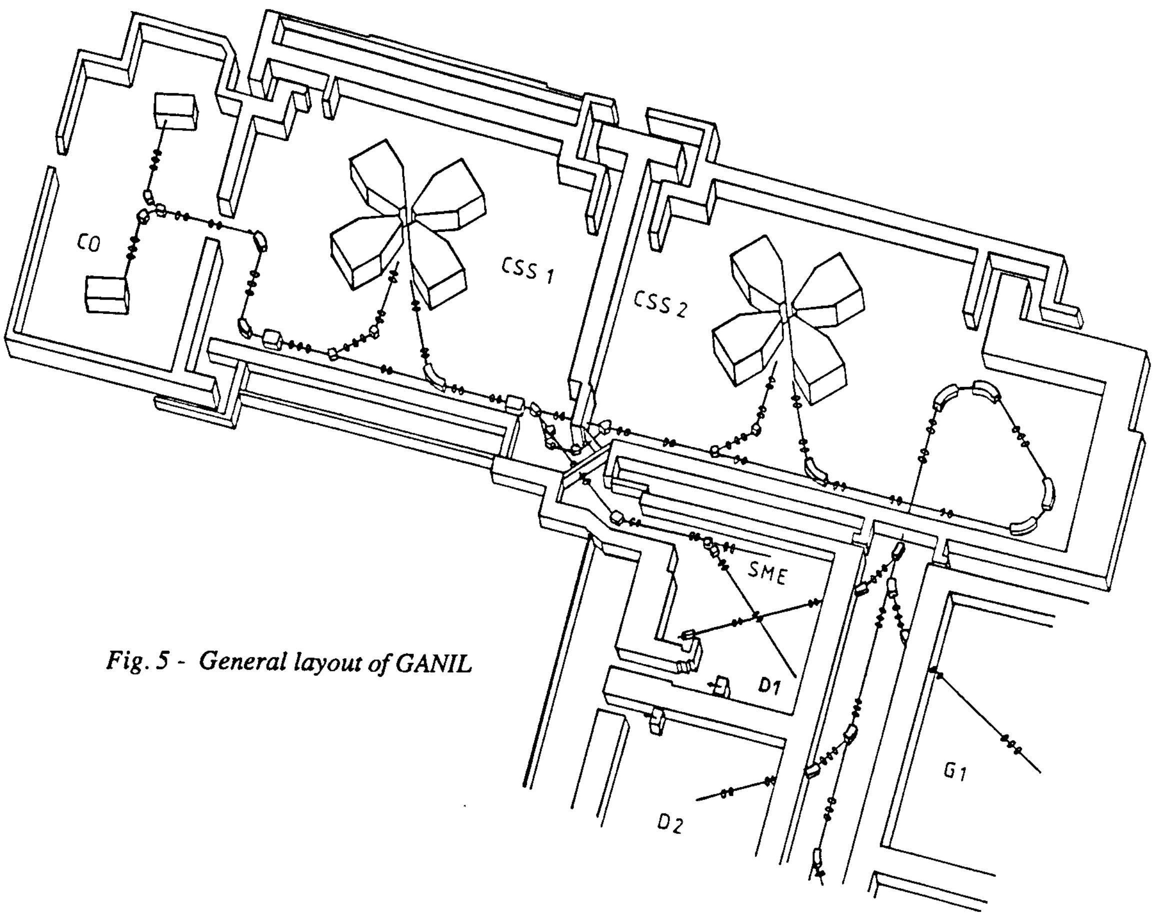

Fig. 5 - General layout of GANIL