FIRST STUDIES OF THE EXTERNAL BEAM FROM THE ORSAY S.C. 200 MEV

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Abstract

The first measurements on the external beams of the Orsay 200 MeV proton Synchrocyclotron are presented. A brief description of the different beam lines and a survey of the monitoring and control probes are given. Special attention is given to a new step-by-step motor driven beam scanner which leads to 0.1 mm resolution in the beam position. First crude estimation of vertical emittance is given. Preliminary physical experimental results and future measurement plans are presented.

Introduction

The Orsay Synchrocyclotron conversion is in the final stage of completion. The internal beam has been obtained with good reliability for each particle (p, d, ^{3}He and ^{4}He). We will describe the status of the transport beam lines and of the external beams. The general lay out and beam lines are presented in the preceding paper about the Orsay Synchrocyclotron[1]. To avoid excessive activation of material most of the tests have been done with deuterons (108 MeV) and compared with short measurements with protons (200 MeV). All the needed control systems being not yet completed, we will just give preliminary results.

Transport System

The beam transport system has already been described in detail[2], Let us recall the main characteristics:

- matching the axis of the beam with the mechanical one for the remaining lines by means of four beam steerers.

- focusing by a quadrupole doublet to an object point where the beam characteristics can be redefined by means of slits.

- analyzing and switching with two magnets which bend the dispersed beam back toward the experimental halls.

- reducing the energy spreading by means of slits.

- transferring with two quadrupole doublets and one small magnet a maximum intensity beam to the target of on-line mass separator (Isocèle II in Hall III).

- transferring with two quadrupoles and one switching magnet a focused analyzed beam on a target in front of a small $B\rho$ spectrometer (Mathusalem in Hall II).

- transferring through one quadrupole doublet, one switching magnet and one quadrupole triplet a dispersed beam and matching the total dispersion with the one of a large $B\rho$ spectrometer to work in an achromatic mode (Montpellier in Hall I).

All the mechanical and magnetic elements are now operating. Field measurements are over. Vacuum pipes and pumps are settled. The proton beam has already hit all the target points.

Control system

Crude measurements:

Crude pictures are obtained with electronic cameras aimed at remotely operated scintillating screens.[3] As high intensities will be used, the material has to be radiation resistant. We have, therefore, chosen special "bibloc" CEMEL[4] cameras (partially studied at C.E.R.N.) with separated optics and electronics, so that the electronic components can be placed outside the beam lines halls. For the same reason, the screens used are made of Al_2O_3, more resistant than plastic or quartz. Ultrasonic engraving of circular and radial lines with a hole in the center of the screen allows a good evaluation of the position and the shape of the beam (about 1 mm precision but the light scattering enlarges the size of the observed spot). Typical spots are shown in Figure 1.

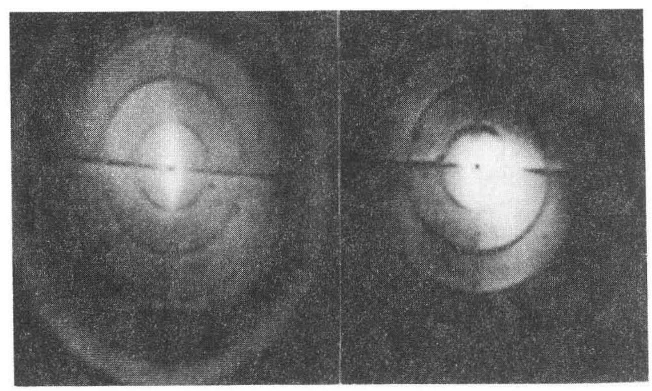

Figure 1: Observed beams in F_1
- On the left is the horizontally focused beam for transmission to Hall I and II.
- On the right is a non-focused beam for maximum intensity transmission to Hall III.

Coarse intensity measurements:

They are made with insulated beam catchers (17 cm of aluminum). Integration of the stopped charges followed by analog and digital measurements give the mean intensity at a chosen time. Three of them can be used in front of and behind the analyzing magnets A_1 - A'_1 to measure the transmission rate. The overall range is from 1 nA to 10 μA.

Alignment control apparatuses

Centering the beam is accomplished with the help of two control systems: asymmetry measurement of stopped charges on insulated slits and beam scanning with a secondary electron Mo wire probe.

Insulated slits:

All the jaws are insulated and connected with multiplexed electronics to get simultaneous measurements on two opposite jaws. When the same value is obtained on each part, the beam is supposed to be well centered. When alignment is complete, the asymmetry i.e. $\frac{I_L - I_R}{I_L + I_R}$ will be zero (I_L and I_R are the currents on the left and right, or up and down slits). Control will be done through an on-line computer.

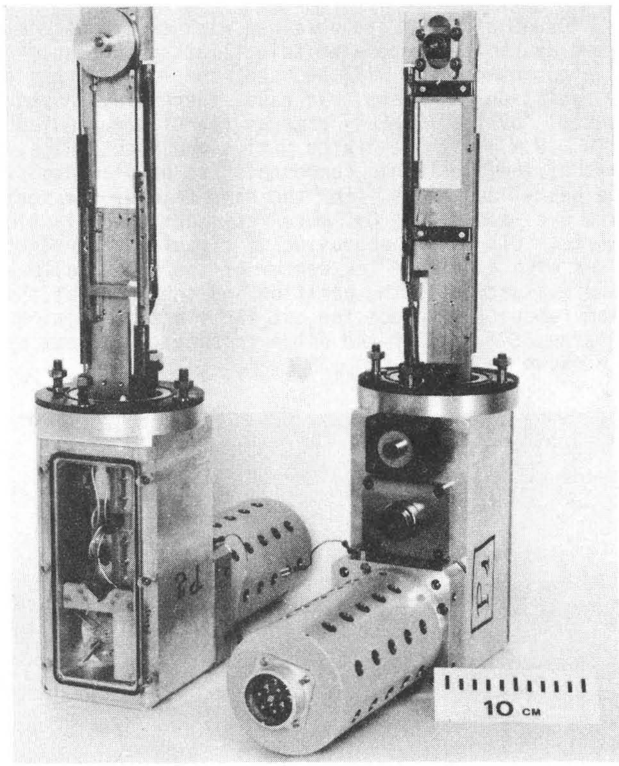

Figure 2: Small size beam scanners
The sensible Mo-wire is visible in the upper part of P_2 scanner. The step by step motor is at the bottom. Transmission to vacuum line is made by rotating articulated bellows. Position indications are given by micro-switches. Safety end-of-travel switches stop the motor. Electric connections are visible on P_1 on the left.

Beam scanner:

For some places where there are no slits and where precise position and size measurements are necessary (for instance, the center of some beam steerers), we have developed special beam scanners[5]. An insulated Mo wire driven by a stepping motor is moved through the beam while a charge measurement of secondary electron current is electronically made for each position of the wire. A multiscale storage of the events correlated with the wire position gives a precise spectrum of the beam intensity shape and localization along one axis.

Beam scanners of two sizes have been made. The small ones are 40 mm high and 64 mm long, and the great ones are 180 mm x 180 mm. They can be installed in different places along the beam lines.

Small ones are shown in Figure 2 and typical results are presented in Figure 3.

The intrinsic resolution of the scanner is 0.03 mm per step, but channels are grouped by ten or more when necessary, for a large beam spot for instance. In Figure 3, the resolution is 0.3 mm by channel. A sophisticated electronic control module is under study to allow change of the resolution interval, the duty cycle and the range of travel. At present, the range is 64 mm and a cycle lasts about 30 sec. for a standard 50 nA beam. Two small beam scanners have been used for the emittance measurements, as will be explained later.

Other controls

Faraday cups:

Absolute value of intensity will be measured with Faraday cups placed inside the beam catchers of experimental halls I and II. The required precision is 1%.

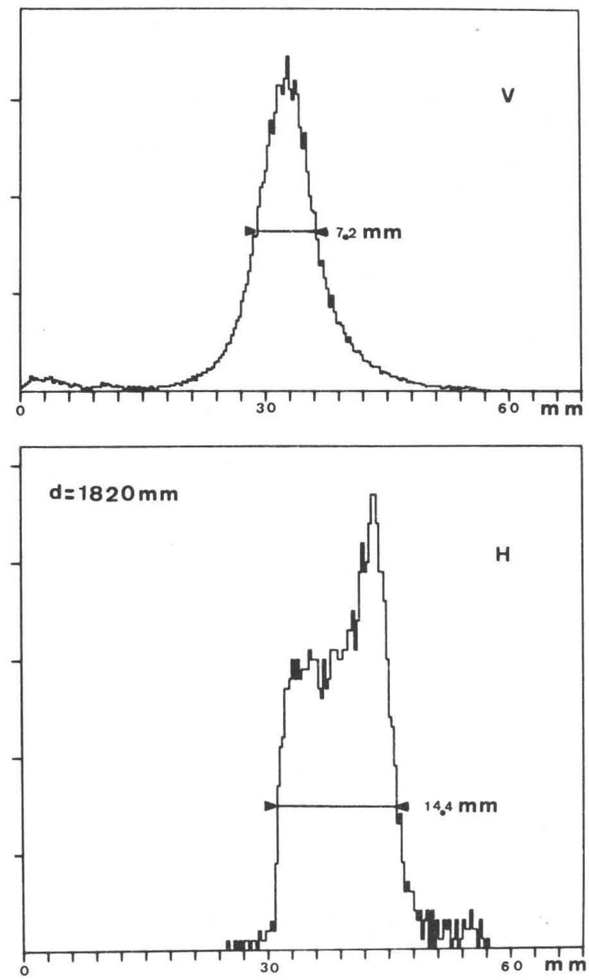

Figure 3: Vertical and horizontal profiles of the beam
One channel corresponds to 0.3 mm. Vertical units are arbitrary. Vertical plot is symmetric. Horizontal one includes dispersion and aberrations; the right high part is from two vertical horns in the beam.

Induction rings:

Relative values can be controlled by means of non-destructive induction ring monitors. It is operating well for high intensities ≥ 10 nA with the standard pulsed beam. It has also the advantage of providing picture and a measurement of the time structure of the beam; one is used in the first part of the beam line, as a beam control system independent of experiments. Three others will be in front of each target point.

Telescope monitor:

For low intensities, relative measurements will be done by a set of two telescopes of scintillating plastic and photomultiplier detectors aimed at the same thin target at two different angles. This will be completed within the next few months.

Beam studies

Beam studies have been done using the same control units progressively moved along the beam lines.

Extracted beams:

Extracted beams have been studied before any focusing by means of: cameras and scintillating screen, insulated beam-catcher and wire beam scanners. The first trials were in good agreement with the predictions. The angle made by the beam with the mechanical axis was less than the beam steerers' acceptance. The extraction rate was about 65%[5].

Emittance:

Emittance has been measured by means of the slits Fo, placed just outside of the accelerator, and with two beam scanners, placed respectively 1820 mm and 2660 mm from Fo. For each position of the slits (open 2 mm wide), the spectra from the beam scanners give the central direction and the angular width of the beam allowing an estimation of the emittance. Results obtained for vertical measurements are plotted in Figure 4, together with the theoretical value. The experimental shape contains some aberrations but is within the predicted value. For the horizontal measurements, the method does not work because of the beam energy dispersion in Fo and of the fringing magnetic field which mixes emittance figures. However, the observed sizes of the beam at different points indicate a horizontal emittance close to the expected one (≈24 π mm.mrad).

Beam direction:

The first part is well-adjusted by means of four beam steerers. Other parts have been tested with scintillating screens and beam scanners. Preliminary results have shown that the analyzing magnets A_1 - A'_1 introduce a small downward vertical deviation which has required a new vertical beam steerer on the two lines (the most reliable solution). This is now installed and everything is ready to transfer the beam to experimental areas.

Beam energy:

The energy and the energy spread have not yet been measured. This will be done with the spectrometer "Montpellier" as soon as possible. Characteristics of the extraction system correspond to 201-202 MeV protons.

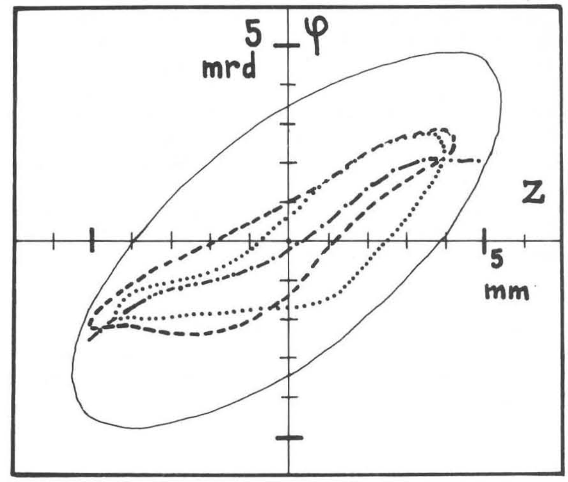

Figure 4: Vertical emittances of extracted beams
is for the theoretical value;
is for deuteron beam;
is for proton beam;
gives the central points and shows one typical aberration.

First experiments

In parallel with these measurements and experimental area installation in progress, some preliminary experiments have been conducted, mainly with the on-line mass spectrometer "Isocèle II"[6].

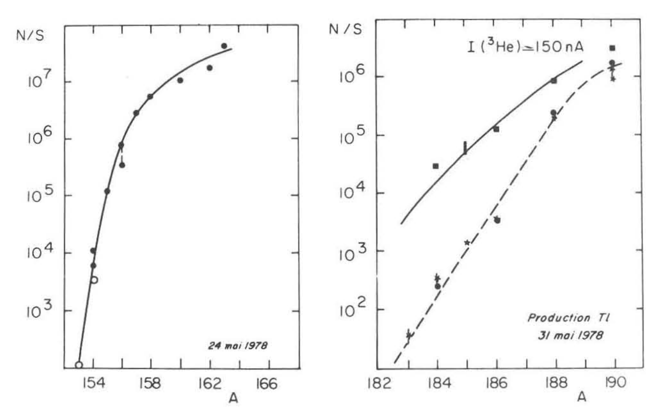

Figure 5: First production curves from "Isocele II"

The curve on the left is from Er(p,Xn)Tm at Ip ∿ 180 nA∿ 1.1 x 10^{12} p/s; absolute value is endoubted by less than + 100 %, - 50%.

The curve on the right is for Tl and Hg from Au target and $^3He^{++}$ beam.
.from γ transition $2^+ \rightarrow 0^+$ in even-even Hg
*from $XK_{\alpha 1}$ ray of Hg
▪Hg production

On-line tests of the separator started in April and the first experiment were conducted on May the 10th. Until now, experiments consisted of target tests, with protons and $^3He^{++}$ (at 200 MeV and 283 MeV respectively with 150 to 200 nA intensities). Some results are shown in Figure 5. For Tm production from protons on Er target, the observed activation is five times that from "Isocèle I". For Tl and Hg production from $^3He^{++}$ on Au, it can be said that other more recent measurements have given six times more intensity. Other targets have been tested. New isotopes have been observed: ^{136}Sm and ^{147}Dy. Intensive work will now be undertaken. Any information can be obtained by contacting Mr. Berg[7].

Moreover, the wire chamber detector to be used in the focal plane of the spectrometer of Hall I[8] (and which will be the same in Hall II) has been tested during the last experiment in July, and encouraging results have to be confirmed.

Conclusions

The Synchrocyclotron is now operating, the transfer beam lines are installed and qualities of the beams have to be measured precisely. Exact procedure of beam adjustment to reduce beam losses is under study and will progress with a better knowledge of the Synchrocyclotron machine. Connection to the computer for automatic control will be accomplished in the next months. Shielding, already tested, must be improved to allow the highest intensity. Slow extraction will soon be available. Experimental equipment has to be completed, but research has already begun.

References:

1) A. Laisné, P. Debray and the S.C. conversion Group, The Orsay 200 MeV Synchrocyclotron, VIIIth International Conference on Cyclotrons and their applications, Bloomington, (1978), I.E.E.E.

2) L. Bimbot for the Synchrocyclotron Transformation Group, The beam transport system for the modified Orsay Synchrocyclotron, Proceedings of the VIIth International Conference on Cyclotrons and their applications, Zürich (1975) 231.

3) F. Reide, Système de visualisation du faisceau par scintillant et caméra de télévision, I.P.N. Orsay, Internal report N.T.T.S. 94 (1976).

4) Société CEMEL, rue Léone de Joinville 01179 Gex, France.

5) L. Bimbot, F. Reide, Cahier des charges des systèmes de visualisation précise du faisceau, I.P.N. Orsay, Internal report N.T.T.S. 96 (1976).

6) Annuaire des Activités Générales et Recherches Techniques de l'I.P.N. Orsay (1977) G8.

7) Annuaire des Activités Générales et Recherches Techniques de l'I.P.N. Orsay (1975), G30, (1976) G21 and (1977) G20.

8) V. Berg, I.P.N. Orsay BP N^o 1, 91406 Orsay, France.

9) D. Ovazza, Thèse 3ème Cycle, I.P.N. Orsay, France, (1978).