THE NEW HIGH DUTY CYCLE HIGH CURRENT 600 MeV ELECTRON-POSITRON LINEAR ACCELERATOR OF SACLAY

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Introduction

In this paper are described the facilities of the new Saclay's linac and after this the present status of the schedule is outlined.

In the next paper, a statement will be given about the features of the machine itself and some specific problems in relation with it. Therefore it is useful to show now the general purpose of the project as well as to describe the various devices which have to be used during the work of the accelerator.

The A.L.S. (Accélérateur Linéaire de Saclay) will be a source of high energy electron current; the intensity of this current, if not equal to zero in the case of the maximum possible 600 MeV energy, will often permit attainment of an average beam power of 100 kW. The power is desired to be delivered as continuously as possible versus time. This characteristic is one of the essential quality factors of the future machine for experiments of nuclear physics and low energy elementary particle physics.

The Accélérateur Linéaire de Saclay project has been designed in a way to obtain also very accurate beam characteristics. Even if such accuracy is the wish of all physicists who have to deal with experimental data, the basic reason is that it is prohibited at power levels of this kind to lose any appreciable part of the beam on the walls along the guide or in the different drift tubes of the deflection systems.

On the other hand a large range of coincidence experiments is forbidden today because the casual process ratio is excessively important during the too short pulses yield until present time by the linacs. Indeed the existing electron accelerators are:

Either machines yielding a relatively low average current with a high duty cycle (this is the case of synchrotons).

Or machines able to accelerate high current beams during very short pulses and the duty cycle does not reach higher than 10^{-3} (this is the case of present linacs).

The A.L.S. project was designed with the view of obtaining a considerable average intensity and a beam duty cycle as large as possible, i.e. 1% or 2%.

General Characteristics

The characteristics of the linear accelerator of Saclay are given in Table I and in the appendix.

Beam Handling Systems

Two deflecting systems are to be located, one after section #12, to steer the beam into the low energy experimental room, and another one after section #30, to steer the beam into the different high energy experimental rooms.

The overall view is to be seen on Fig. 1.

The particularity of both systems is that they consist of a pulsed deflection each and of one or several permanent beam bending and shaping systems. Three pulsed magnets P_1, P_2, P_3 allow, if desired, a simultaneous work in all stations, and also a permanent analysis of the beam energy. This will not reduce the quality of the final beam because only each hundredth pulse has to be used for analysis.

a) Optics of the Low Energy Analysis System

This system consists of:

A pulsed magnet P_1,

a field free drift space (of about 2 m),

a homogeneous field magnet A_1.

The characteristics are given in Table II.

The geometry of the low energy analysis system is to be seen on Fig. 2.

b) Low Energy Beam Bending System

The beam bending system consists of a set of magnets and quadrupoles (A_2, Q_1, Q_2, A_3). This is an achromatic deflector of K. Brown's type. The magnets A_2 and A_3 respectively scatter and refocus the beam and the quadrupoles Q_1 and Q_2 have only to shape symmetrical trajectories. A vertical slit will be located at the horizontal focus of the quadrupole system. The calculations were performed with the assumption that the angular divergence of an electron beam at the output of the accelerator section will be of $\pm$ 1.2 . 10^{-3} radian.

The geometry of this part is given on Fig.3. It may be remarked that the magnets A_1 and A_2 have symmetrical inputs with respect to the accelerator axis.

c) Optics of the High Energy Analysis System

This system consists of:

A pulsed magnet P_3,

a field free drift space of 11 m,

a homogeneous field magnet B_3 (with a core identical to this one of the bending magnet B_2.

Table III gives the characteristics of this system.

The geometry of the high energy analysis system is to be seen on Fig. 4.

d) High Energy Beam Bending Systems

Two bending systems are designed for the high energy station.

With the use of the pulsed magnet P_2 it will be possible to obtain a beam either on the set (B_1, Q_3, Q_4, B_2) or on the set (B_4, Q_5, Q_6, B_5). The type of device is similar to this one of the low energy station. All characteristics are given on Fig. 5 and Fig. 6.

The position of the beam analysis slit will be here a little different than in the low energy case. This point is located as the image of the output of section #30; and thus an object can be determined by means of a vertical slit at this output.

e) Water Cooled Slits

The beam analysis slits are presently under study. An experimental device has been built but today it is possible to outline only some basic ideas. The system will consist of two sets of thin turning tungsten disks. Between two consecutive disks a water jacket will allow to scatter more and more the particles and also to carry away the heat radiated by the tungsten disks. Fig. 7 gives an approximative idea of this device.

Remarks

There is no possibility of giving here a complete definition of the beam catchers which have to be located at several points of the experimental rooms and at the end of the accelerator axis. These beam catchers still need much study.

The technology of the scanning modulators for the pulsed magnets is also presently under development.

Buildings and Lay-Out

1) Accelerator Housing

The A.L.S. is to be built underground, as it was decided for safety reasons (Fig. 8).

The machine itself will be located in a gallery of a length of about 200 m. The longitudinal axis of the guide has to be at approximately 6 m below ground level; this line is defined with an accuracy of ± 1 mm in the two transverse directions. Independent concrete piles have been cast to sustain the girders of the accelerator with the best possible stability. Alignment problems are not easy to solve on these conditions with ordinary optical methods. Therefore a laser method is presently under study at C.S.F.

Reasons of shielding against radiations have led to building the high energy end of the gallery as a separated room. There will be a depth of about 3.5 m protection earth above the gallery. A wall of 2 m thickness separates the gallery from the room where the R. F. sources have to be located. Only the ceiling of this room reaches to ground level.

It is useful to mention among other facilities the independent overhead crane runways equiping the gallery and the R. F. room.

2) Experimental Rooms

Two groups of experimental rooms are provided.

a) At the "low energy station" there has been designed only one room.

b) At the "high energy station" there are designed three rooms with slits between them for various possibilities of beam transmission from one to another (also for the case of secondary beams). Walls of 4.80 m thickness are such that people may work in one room even if there is a beam in another one, the slits being properly blocked up.

A lot of rolling iron and concrete doors, of zig-zag emergency galleries, of shielded ways complete this plant.

3) Other Buildings

All other buildings including the control room, the different laboratories and shops, the water cooling system housing, the electrical supply and other accessory facilities are located as it is to be seen on the drawing (Fig. 9).

Miscellaneous Data - Economy

a) The total installed energy supply is of about 15 MW. A particularly expensive part of the electrical network is the set of alternators which have to provide a very stable voltage at the input of the R. F. amplifiers. Indeed the required accuracy is 0.5% of the voltage value.

b) The water cooling system is also very expensive. As it is pointed out in another paper, the cooling system of the accelerator sections and R. F. network consists of two circuits of demineralized deionized water, compensating one another in a way to obtain a maximum temperature variation of 1° C/day on the sections with 1° C/10 minutes of maximum instantaneous instability. The total water flow in the first circuit is of approximately 320 m^3/hour and the second circuit of 160 m^3/hour. A third circuit with a flow of nearly 320 m^3/hour is designed for cooling R. F. sources, focusing solenoids, etc...

c) The whole of the buildings, galleries and experimental rooms represents a surface of about 11 000 m^2.

Considering particularly these points it will be easy to understand why the cost of this part of the project is of about 8 million dollars. The price of the machine itself is today also about 8 million dollars.

General Schedule

The beginning of the construction takes place in March 1965.

Present Status of the Schedule

October 1966	First short experimental section is near completion. First hard-tube transmitter is under development.
December 1966	Hard-tube transmitters; first single tramsmitter under test (power transmission).
March 1967	R. F. full power tests with 3 sections.
June 1967	Beginning of assembling elements on the spot.
September 1967	Beginning of beam tests in the low energy station.
November 1967	Beginning of beam tests in the high energy station.
March 1968	End of acceptance tests.

Present Status of the Building

Some pictures show the degree of completion of principal buildings. It is to be noted that there are two parts in this schedule. First are erected accelerator housing, power supply housing and some other facilities, as well as the low energy station. This has to be finished in March 1967. A second part of work is devoted for the whole high energy station, supposed to be finished at the end of 1967.

Appendix

Main features of the accelerator:

1) Sections

Number os sections: 30
Length of each section: 6 m
Type of field: Approximately constant gradient (with 7 steps of C/V_g in one section)

R. F. Mode: $2\pi/3$

2) R. F. Sources

Number of klystrons: 15
Type TV2013
Power: 4MW/55 kW
Normal use R. F. pulse length: 12 μsec
Number of modulators: 7 driving 2 klystrons each
1 driving 1 klystron (#1)
Type of switching: Hard tubes (CSF)
Required accuracy of the R. F. pulses: .3% on the flat top

3) Electron/Positron Converter

Maximum allowed average incident power 40 kW located between section #6 and section #7.

DISCUSSION

A. SOKOLOVSKY, Saclay

PENNER, NBS: In some of your magnetic deflection systems you said that the energy slit was at the cross over for an incident parallel beam. This, I think, means that the energy passed through the slit is sensitive both to the steering in the accelerator and to the field in the pulse deflecting magnet. Could you comment on how big an effect this is?

SOKOLOVSKY: Yes, the steering of the accelerator is an important and sensitive parameter, but this parameter is sufficiently well stabilized. It is impossible to change the input angle of the beam to the pulser by more than 1.6×10^{-4} radian. On the other hand, there may be some error in the action of the pulser. An error of 1% will yield a maximum error of about 2 mm on the slit. But a level check of the pulsed magnet itself will allow one either to turn back rapidly to the initial level or to stop the injection by means of a machine protection signal. This is the case for the low-energy deflection. In the high-energy deflection, the slit on the output of section No. 30 represents an object. Consequently, there is a dependence only on the pulser's accuracy.

Table I

Duty Cycle	1%		2%	
Repetition Rate	1000 Hz		2000 Hz	
Energy (MeV)	End of the Machine	Low Energy Station	End of the Machine	Low Energy Station
E (0 mA)	554 [600]	202 [220]	380 [425]	140 [155]
E (15 mA)			340 [385]	124 [140]
E (20 mA)	500 [550]	182 [200]		
Maximum of Electron Current	600 μA		840 μA	
R.F. Peak Power at a Section's Input	4 MW		2 MW	
Electron Beam at the e^-/e^+ Converter: Zero Current Energy	90 MeV		62 MeV	
Electron Beam at the e^-/e^+ Converter: Routine Work	75 MeV 33 mA (25 kW)		54 MeV 17 mA (18 kW)	
Electron Beam at the e^-/e^+ Converter: Maximum Calculated Incident Power	42 kW		42 kW	
Maximum Expected Average Intensity of Positrons	1 μA			
Energy Spread at Accelerators Output	$\frac{\Delta E}{E}$ = 1% for 50% of the Accelerated Current			
Beam Pulse Length	10 μs			

Table II

Pulsed Magnet

Deflection angle 5°44′ (=0.1 radian)
Radius 100 cm
Field intensity (for 180 MeV/c) 6000 gauss

Analyzing Magnet A_1

Deflection angle 41°18′
Radius 60 cm
Field intensity (for 180 MeV/c) 10 000 gauss
Input side rotation angle 14°21′
Output side rotation angle 22°48′

Table III

Pulsed Magnet P_3

Deflection angle 2°34′20″ (=0.045 rd)
Radius 222.2 cm
Field intensity (for 540 Mev/c) 8100 gauss

Analyzing Magnet B_3

Deflection angle 43°13′
Radius 167.4 cm
Field intensity (for 540 MeV/c) 10 750 gauss
Output side rotation angle 9°40′

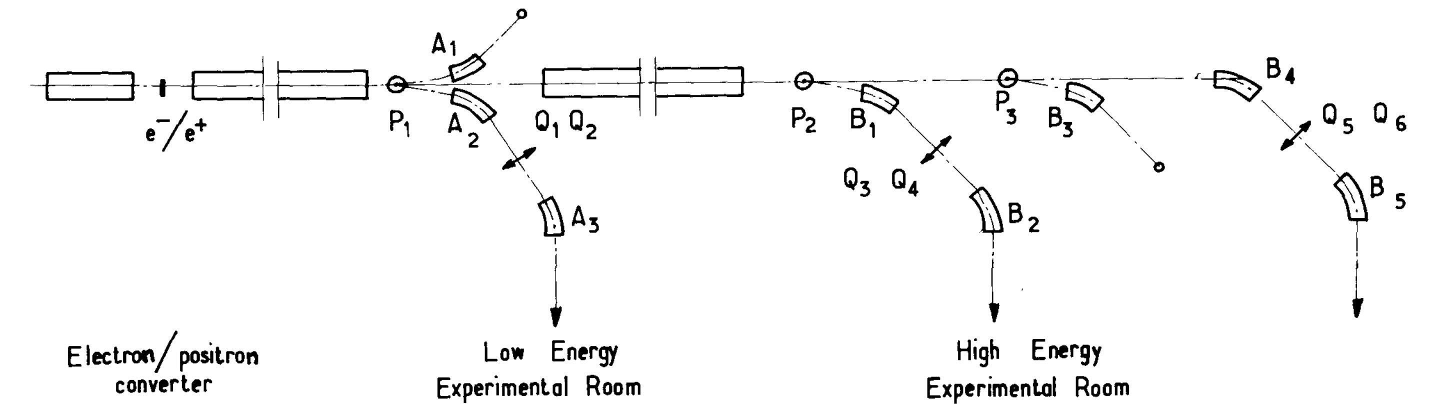

Fig. 1. Beam Handling System.

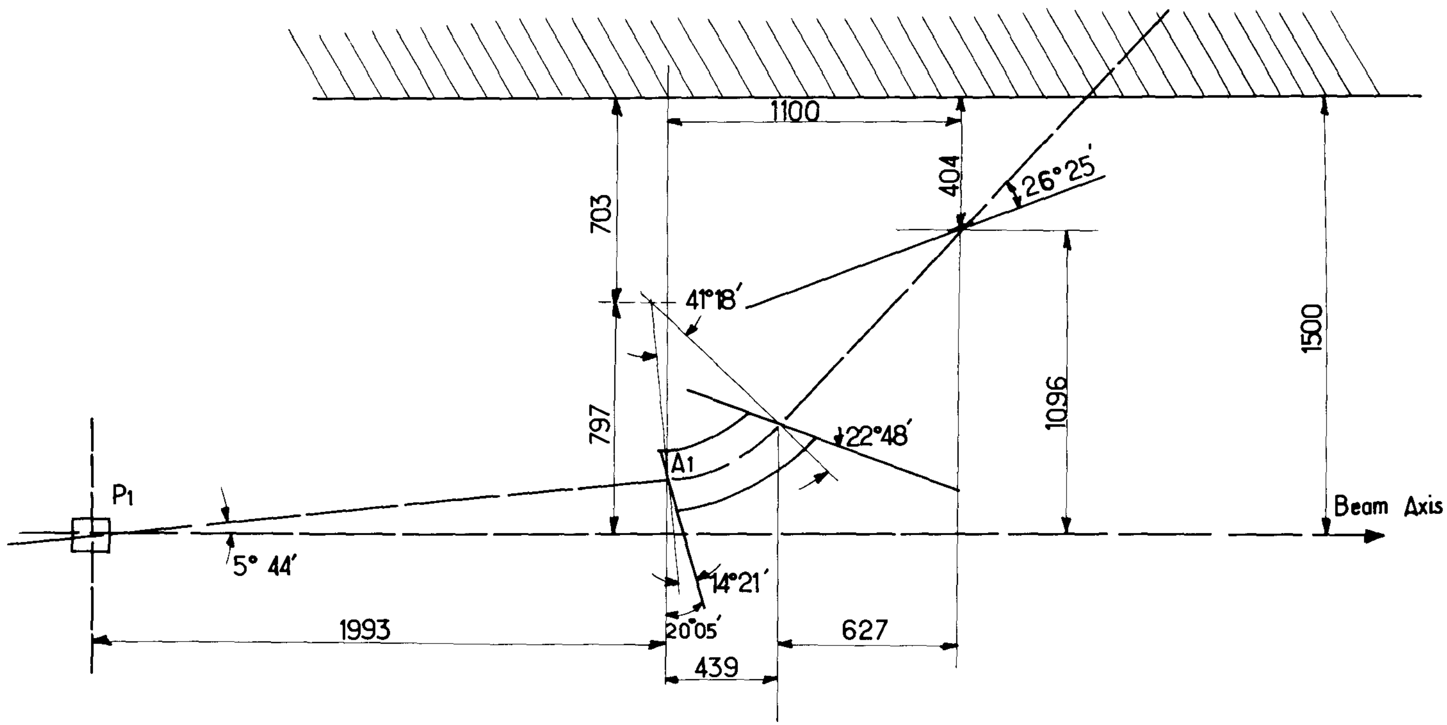

Fig. 2. Geometry of the low energy analysis system.

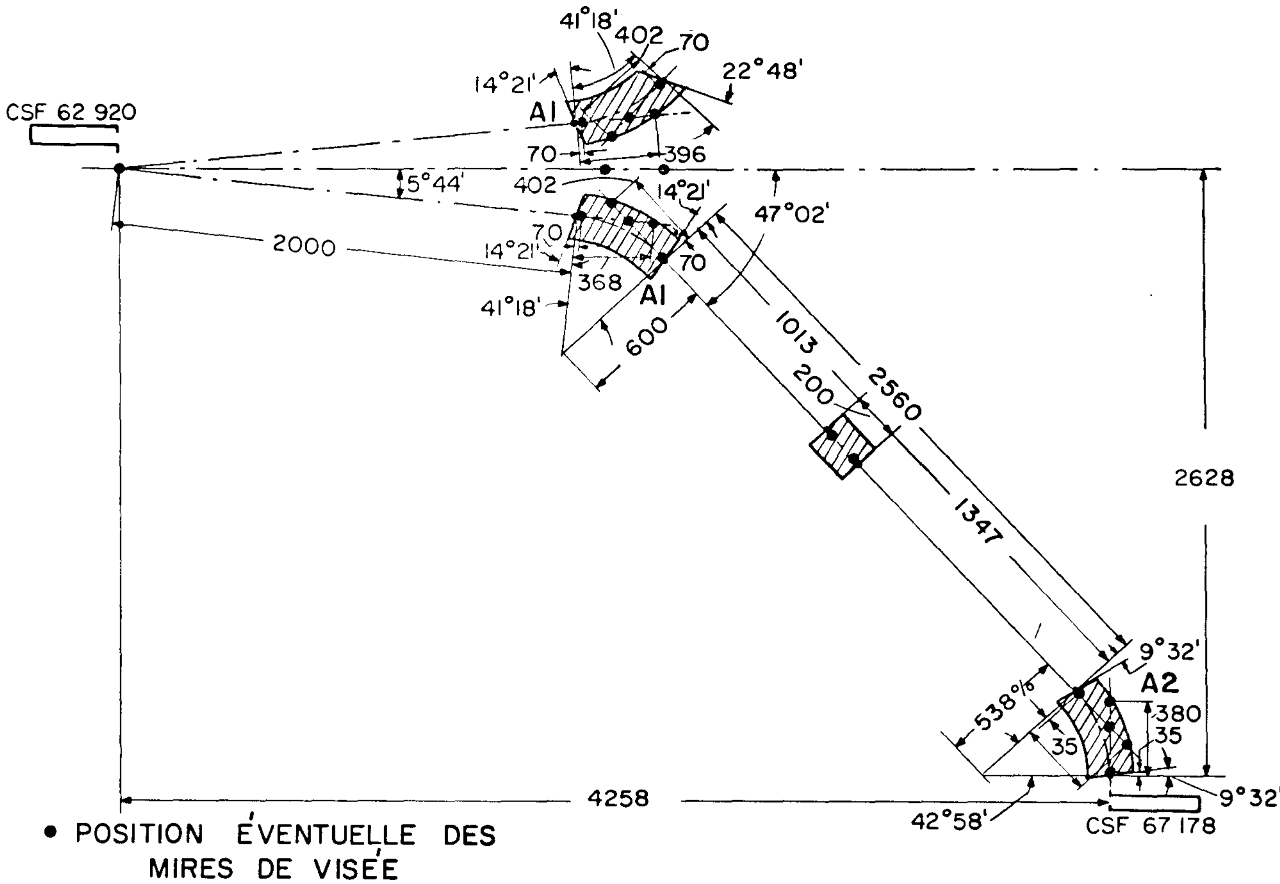

Fig. 3. Low energy beam bending system.

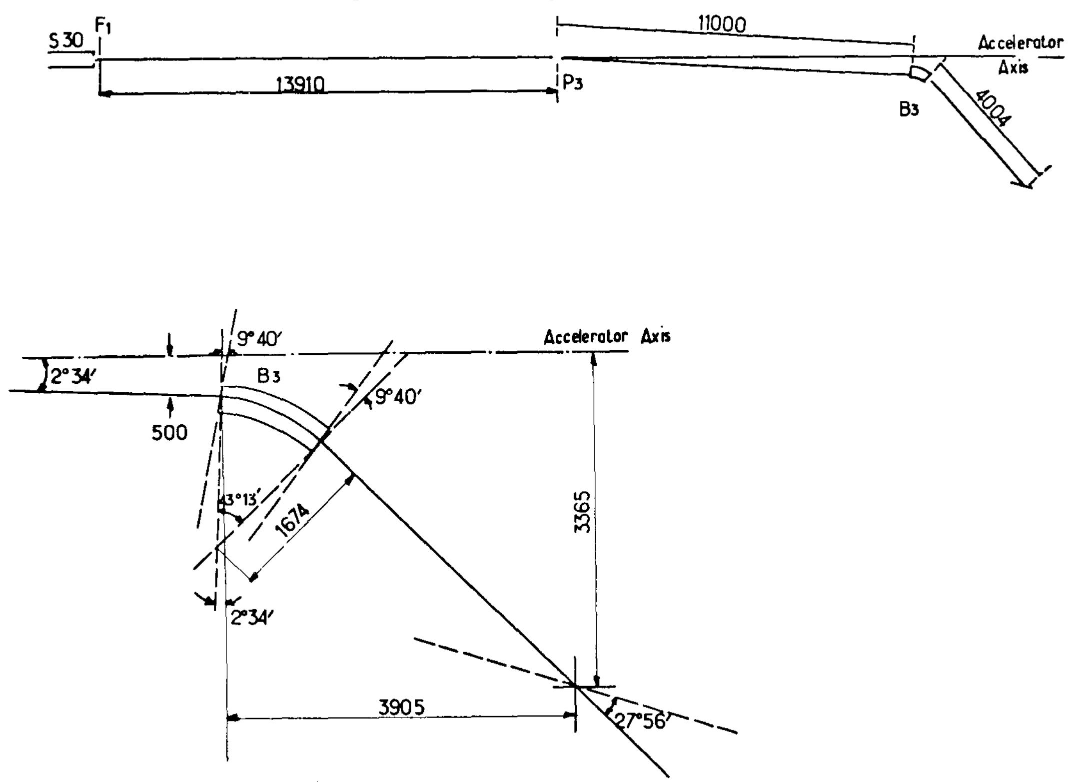

Fig. 4. Geometry of the high energy analysis system.

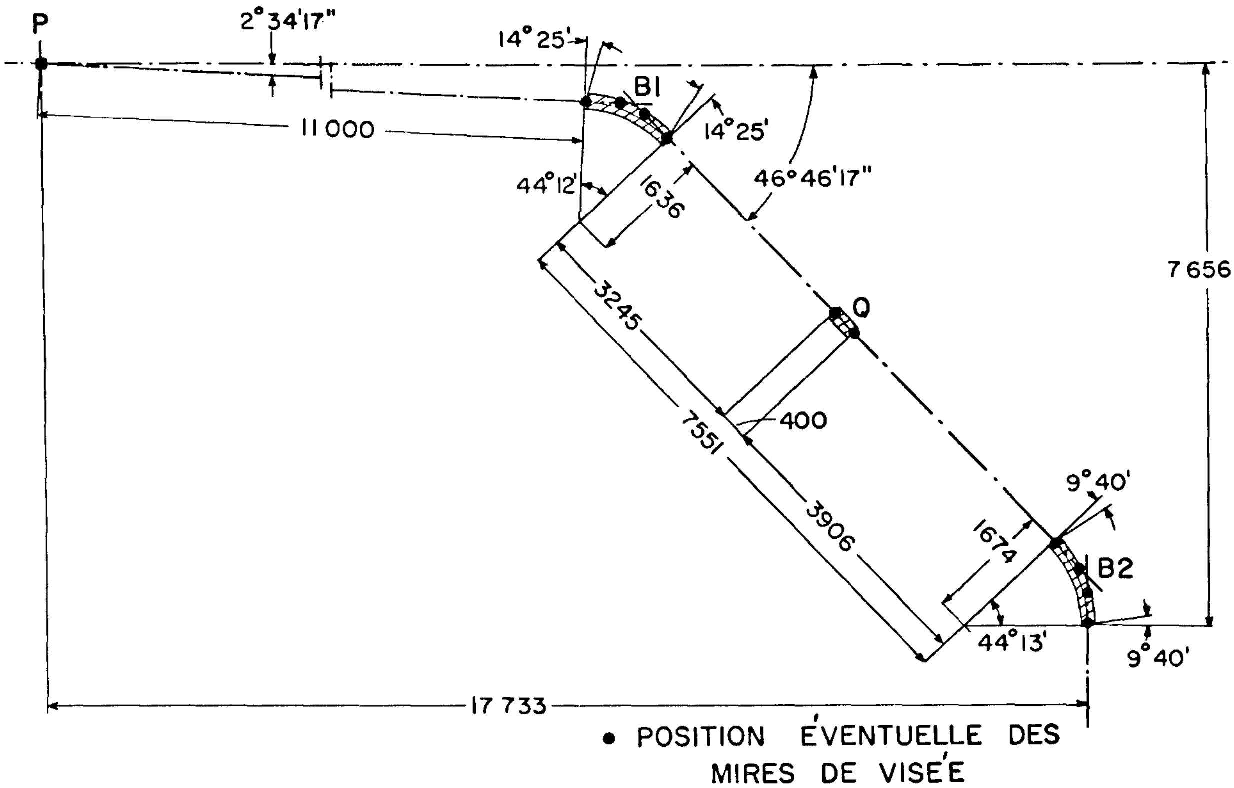

Fig. 5. High energy beam bending system (part 1).

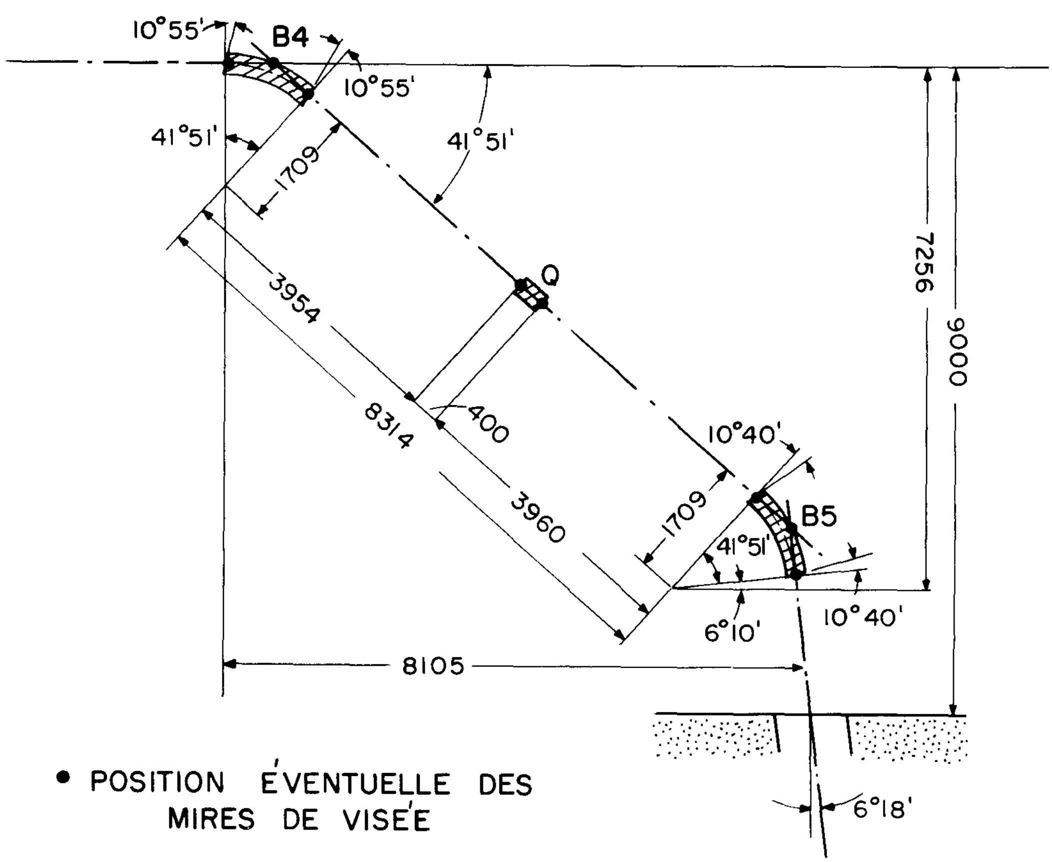

Fig. 6. High energy beam bending system (part 2).

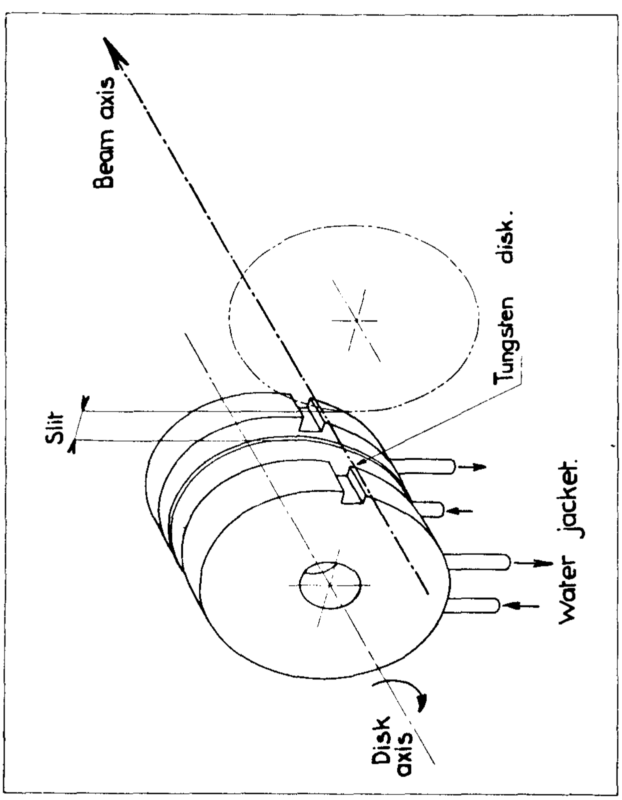

Fig. 7.
Water cooled slit.

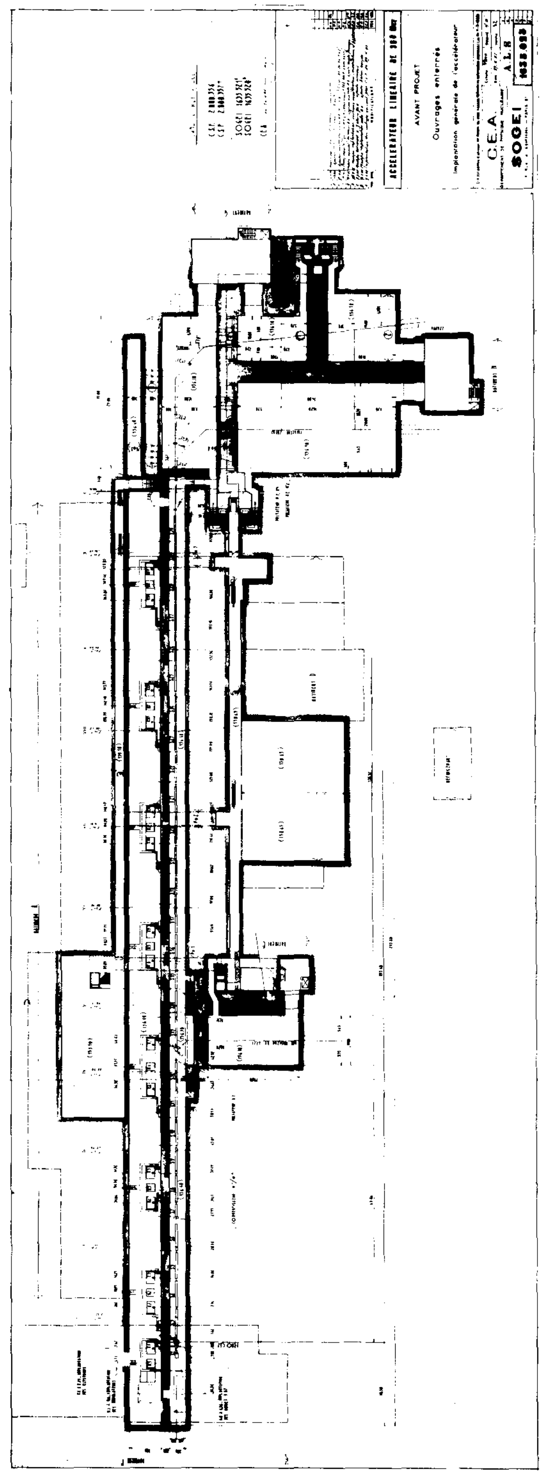

Fig. 8. Accelerator housing and experimental rooms.

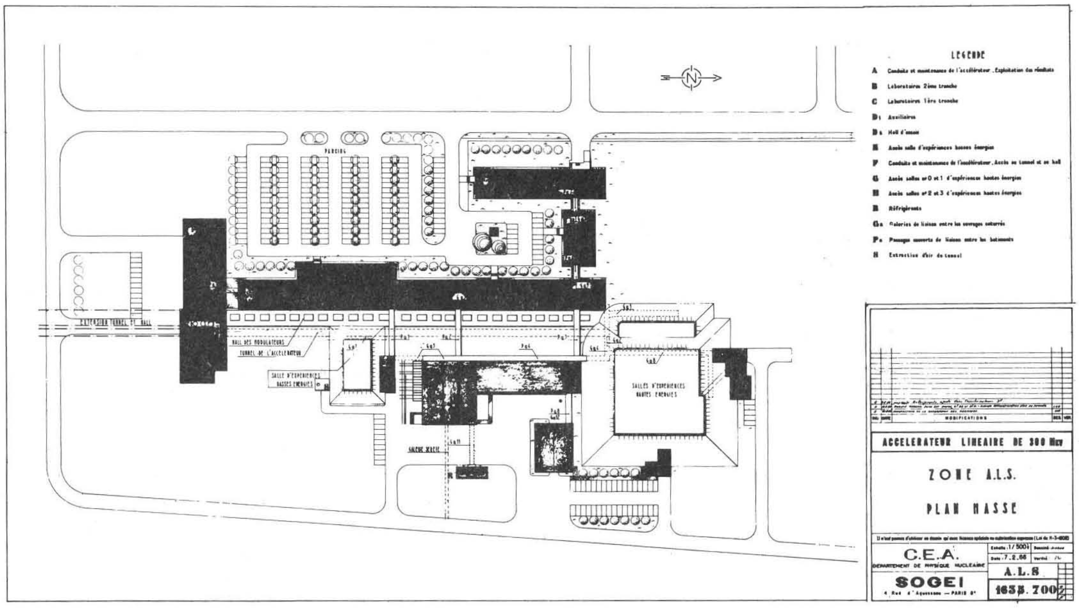

Fig. 9. General lay-out.

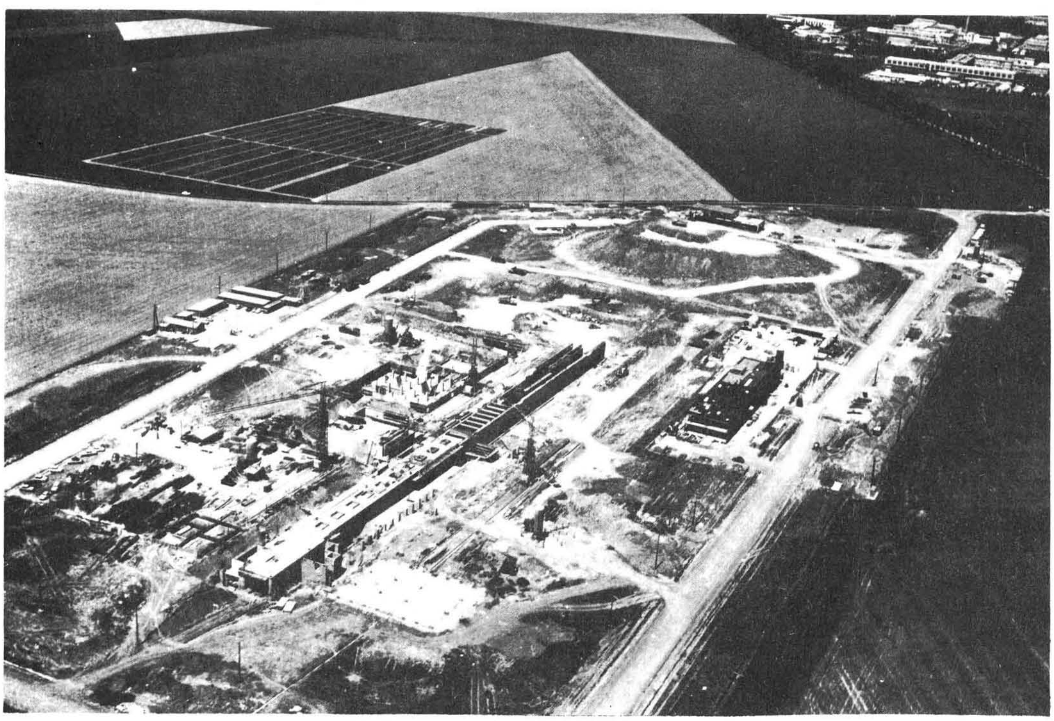

Fig. 10. Aerial view of the yard.