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STRANGENESS EXCHANGE REACTION ON NUCLEI

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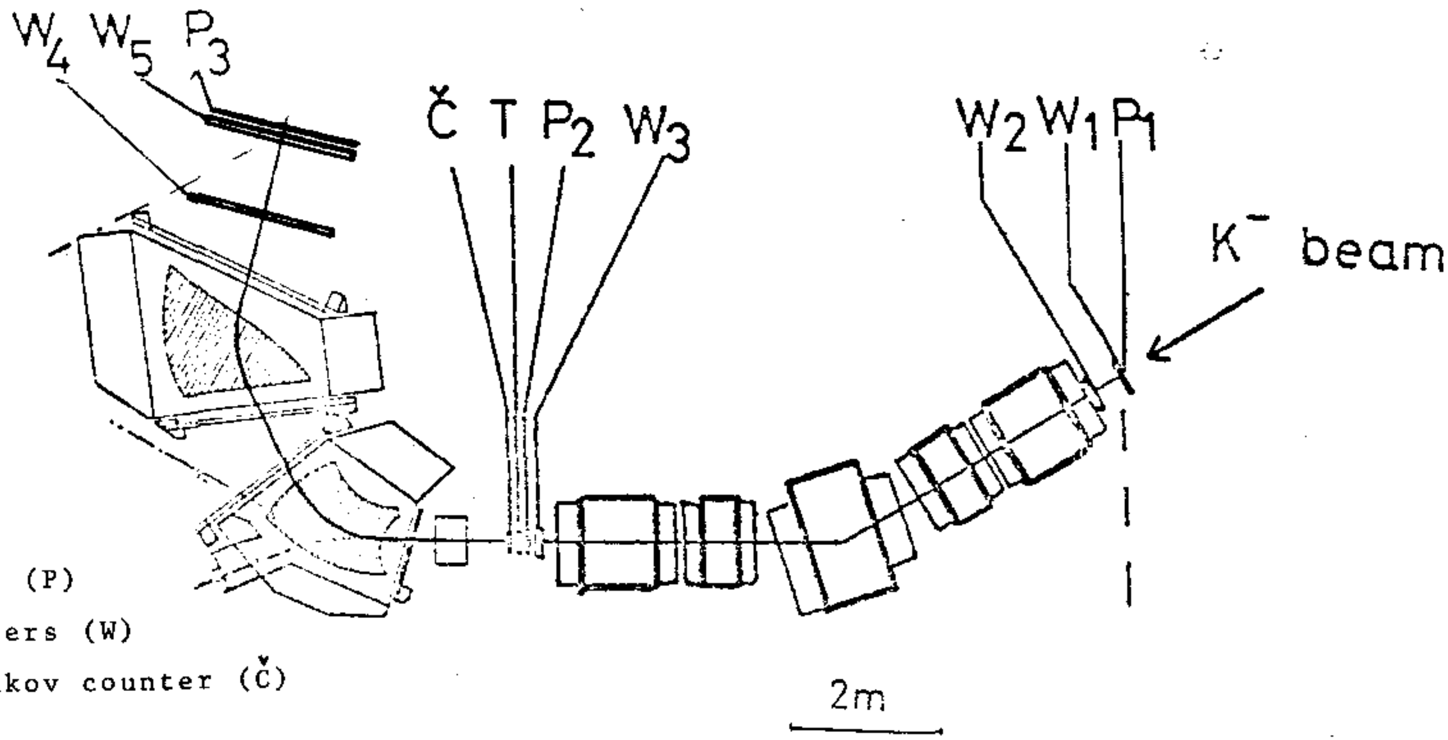
It is proposed to measure the (K^-,π^-) reaction on nuclei at the K^--momentum of 900 MeV/c. The π^- will be detected at small angles from 0^0 to 20^0. The K^--beam should provide 10^4 K^-/burst in a momentum byte of ±1.5% at the target. The momentum of the K^- is determined in the last part of the beam transport system whereas the momentum of the π^- is analysed by the Saclay Q2D spectrometer.

The aim of the experiment is to study the hypernuclear states (angular momentum and form factors) produced in the (K^-,π^-) reaction at small momentum transfer. The hypernuclear states populated are closely related to the target nucleus ground state. In a good approximation the Λ particle replaces a neutron without otherwise changing its wavefunction. It is, however, distinguishable from the nucleons and can be used as a probe particle in the nucleus.

The requested running time in 1977 and 1978 is 2400 hours of beam time at the PS equivalent to ten PS periods of ten days each. For the first one or two periods in 1977 (about 400 hours) after the 76/77 shutdown, only a parasitic beam is needed for setting up the experiment.



Plastic scintillators (P)

Multiwire drift chambers (W)

Liquid hydrogen Čerenkov counter (Č)

Target (T)

STRANGENESS EXCHANGE REACTION ON NUCLEI

INTRODUCTION

The strangeness exchange reaction (K^-,π^-) on nuclear targets has turned out to be very suitable to investigate the hypernuclei[1,2]. For K^- momenta of about 500 MeV/c and for π^- detected at 0^0 with respect to the beam the Λ recoil is zero and varies only very slowly with the incoming K^- momentum. The interest in recoilless production of Λ in nuclei is twofold: firstly, there is a high probability of forming a hypernucleus, and secondly, the hypernuclear states formed under these conditions can in good approximation be described by just replacing a neutron by a Λ without otherwise changing the wavefunction. The difference between these states in nuclei and hypernuclei is directly related to the difference between the nucleon-nucleon and the Λ-nucleon interaction in the many body system of the nucleus.

The nucleus as a system of identical, strongly interacting particles has been successfully described by nuclear models which solve the many body problem by reducing it to a one body problem in the independent particle picture. These particles are obviously some type of quasiparticles with a residual interaction to reproduce the properties of the states close to the Fermi surface. Similar approaches have been successful in many body systems such as solids, etc. The Λ particle, however, is distinguishable from the nucleons and can be used as a probe by replacing the nucleons in a well defined configuration.

In 1975 the first series of experiments on ${}^{9}_{\Lambda}Be$, ${}^{12}_{\Lambda}C$, ${}^{16}_{\Lambda}O$, ${}^{32}_{\Lambda}S$ and ${}^{40}_{\Lambda}Ca$ using recoilless Λ production have been finished at CERN by the Heidelberg Group[3] (see Fig. 1). In all the hypernuclei strong transitions to well defined states have been observed. In the lightest hypernuclei the interpretation of the observed states is believed to be straightforward. They should correspond to the interchange of a neutron in different shells by a Λ. For the heavier hypernuclei, mixing of the subshells and maybe also the mixing of different shells, enriches the structure of the spectra. The energies of the observed states, however, cannot be reproduced neither starting with the independent particle picture[3] nor with the collective one[4]. These obvious discrepancies between the experiment and the theory indicate most likely that the shell model parametrization is no more adequate for the Λ in the nucleus. This is the first indication that the Λ can be used as a probe for nuclear structure.

To improve the understanding of the hypernuclear structure it is at least necessary to determine unambigiously the angular momentum of the states, the possible fine structure for which higher statistics are needed and the determination of the ground states of the hypernuclei. To push this program through, at least a factor of 10 in the yield as compared to the previous experiment is necessary, and a spectrometer which is able to take angular distributions is required. The present proposal suggests a measurement with a K^- beam of an intensity of 10000 K^-/burst at the target and a spectrometer with an acceptance of 20 msr which should guarantee a factor of more than 10 on the previous yield.

EXPERIMENTAL SET-UP

The separated K^- beam for momenta up to 1 GeV is taken from the external transmission target in the East Hall. As a possible location of the beam and spectrometer the south branch of the e_{13} beam in the East Hall (Fig. 2) has been considered. The advantages of using this branch are twofold:

1. k_{19} and the new beam are compatible in design and operation.
2. The large bending angle requires space which could not easily be obtained elsewhere without a rearrangement in the East Hall.

The last part of the beam transport line is identical to one half of the double spectrometer used in the Experiment P11 for hypernuclei spectroscopy. The experimental set-up is shown in Fig. 3. The K^- momentum is determined by measuring the trajectory using the drift chambers W1, W2 and W3. The π^- momentum is determined by the Q2D spectrometer of Saclay described in detail in the Appendix. The trajectory of the π^- is obtained by measuring the coordinates at the target position and the coordinates in the focal plane of the Q2D by the drift chambers W3, W4 and W5 respectively. The aimed resolution for the K^- or π^- momenta is 1 MeV/c.

The (K^-,π^-) reaction is identified in three ways:

1. *A time of flight between the counters P1 - P2 and P2 - P3* requires a K^- in the last part of the beam and a π^- in the Q2D spectrometer.
2. A liquid hydrogen Čerenkov counter rejects K^- which pass the target.
3. The vertex of the trajectories of the K^- and π^- is required to lie within the target dimensions.

All these requirements have been used in the previous experiment[1] and have been proved to be sufficient to get a clean signal for the (K^-,π^-) reaction.

EXPECTED COUNTING RATES

The counting rates will be estimated for the 0^0 production only. The angular distribution will only be measured up to angles where the intensities are at least 20% of the 0^0 yield. This must be sufficient to determine the angular momentum of the observed states as well as to observe the ground states. The integrated cross section for the hypernuclei production at 0^0 is independent of the target nucleus and amounts to about 2 mb/sr. Since in most of the measurements the continuum states will be studied, a resolution of 2 MeV/c is sufficient; this allows the use of targets with a thickness of about 5 g/cm^2. Assuming 10^4 effective bursts per day (after the SPS is in operation) with 10^4 K^-/burst at the target, 10^{23} nuclei/cm^2 in the target and an acceptance of 20 msr, one gets $10^4 \times 10^4 \times 10^{23} \times 20 \times 10^{-3} \times 2 \times 10^{-27}$ = 400 events/day. The total number of events in the best spectra obtained in the previous experiment (see Fig. 1) amounts to about 400 events. For this one to two weeks of machine time was needed depending on the beam intensities granted at target $\hat{8}$.

COSTS

1. The beam is expected to be provided by CERN as well as the power supplies for the spectrometer.
2. The Saclay spectrometer as well as the transporting of it to CERN will be provided by the Saclay Group.
3. Wire chambers, counters, electronics and on-line computer will be provided by the Heidelberg Group.
4. For off-line evaluation we estimate 30 hours of computer time at the CDC per year.

PHYSICISTS PARTICIPATING

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TIMETABLE

The crucial condition in the schedule is the time in which the high performance spectrometer of Saclay is available. This spectrometer is at present in operation at the SATURN accelerator. The SATURN will be rebuilt in 1977 and part of 1978 and it is only during this time that the spectrometer can be used at CERN. Therefore the running time of the experiment, if accepted, can only be from April, 1977 until the end of 1978. We would therefore like to put the experiment on the floor during the 76/77 shutdown. The end of the experiment is also well defined by the beginning of the new SATURN.

We would like to have ten periods of machine time during 1977 and 1978 when the experiment is expected to be on the floor. The periods used for setting up of the experiment can use a parasitic beam. One or two periods are planned to be used for setting up the experiment, two periods for high statistic measurement on heavy hypernuclei at 0^0 and the rest for angular distributions and search for ground states.

REFERENCES

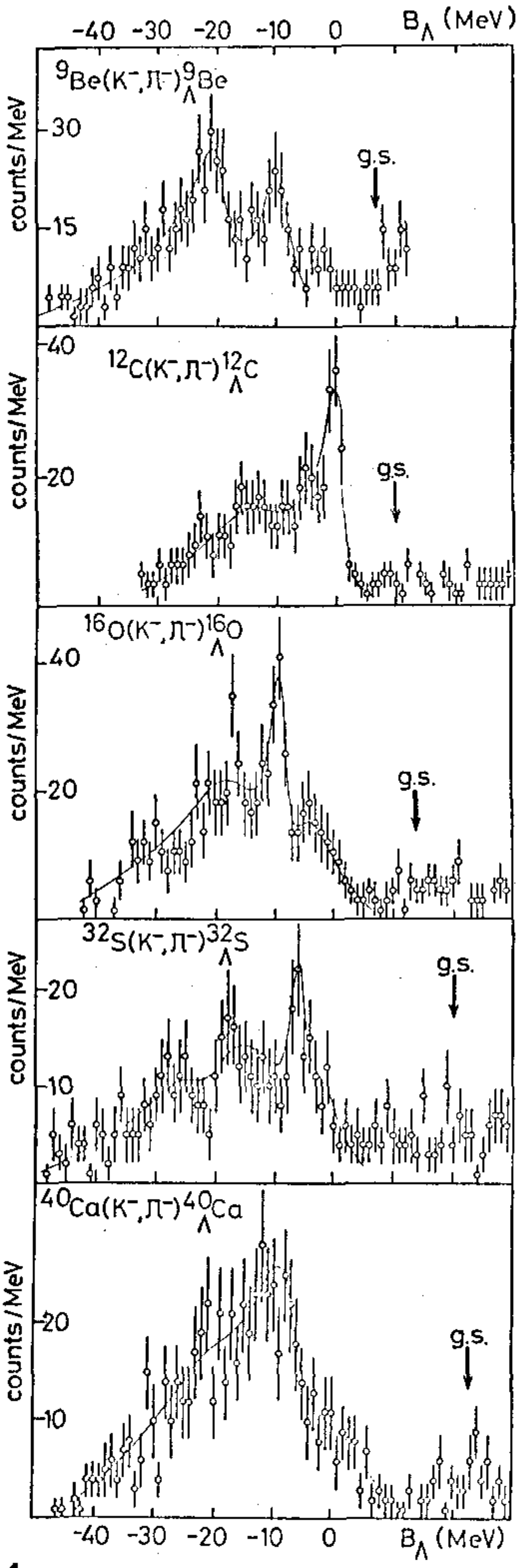
1. W. Brueckner et al., Phys. Lett. 55B, 107 (1975)
2. B. Povh, Proc. of the 6th International Conf. on High Energy Physics and Nuclear Structure, Santa Fe, 1975.
3. J. Huefner et al., Phys. Lett. 49B, 409 (1974); N. Auerbach and A. Gul, Phys. Lett. 48B 24 (1974)
4. H.J. Lipkin, Phys. Rev. Lett. 14 18 (1965)

FIGURE CAPTIONS

Fig. 1 Spectra of the K^-,π^-) reaction on ^{40}Ca, ^{32}S, ^{16}O, ^{12}C and ^{9}Be in dependance of the Λ binding energy B_Λ. $B_\Lambda = 0$ corresponds to a zero relative energy between the Λ particle and the core nucleus ground state.

Fig. 2 Possible position for beam and spectrometer in the East Hall. This suggestion has been worked out together with M. Ferro-Luzzi.

Fig. 3 Experimental set-up: Plastic scintillators (P), multiwire drift chambers (W), liquid hydrogen Čerenkov counter (Č) and target (T).



-40 -30 -20 -10 0 B_Λ (MeV)
$^{9}Be(K^-,\pi^-)^{9}_{\Lambda}Be$
counts/MeV
30
15
g.s.
$^{12}C(K^-,\pi^-)^{12}_{\Lambda}C$
counts/MeV
40
20
g.s.
$^{16}O(K^-,\pi^-)^{16}_{\Lambda}O$
counts/MeV
40
20
g.s.
$^{32}S(K^-,\pi^-)^{32}_{\Lambda}S$
counts/MeV
20
10
g.s.
$^{40}Ca(K^-,\pi^-)^{40}_{\Lambda}Ca$
counts/MeV
20
10
g.s.
-40 -30 -20 -10 0 B_Λ (MeV)

FIG. 1

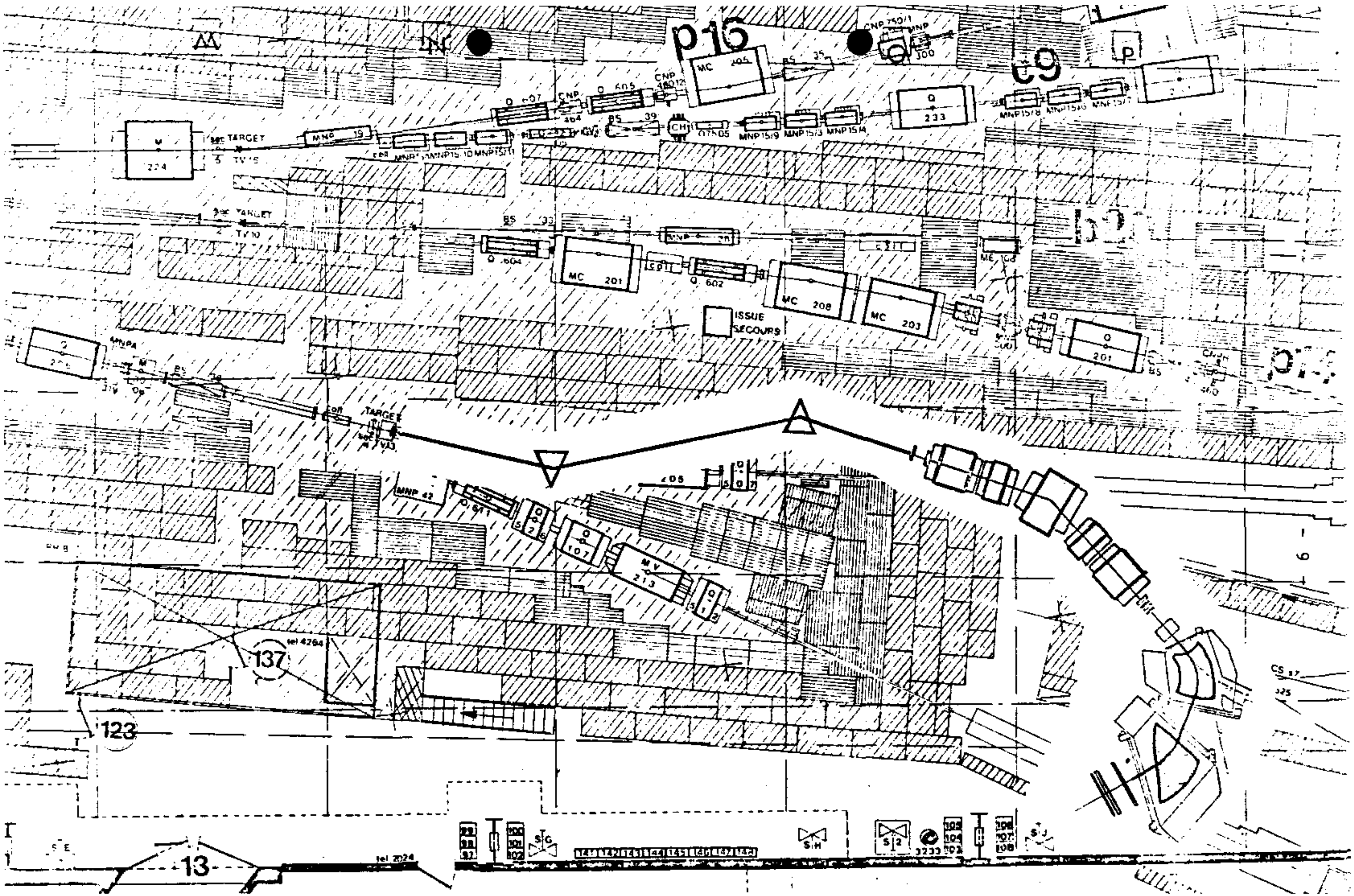

p16
c9
TARGET
TARGET
TARGET
ISSUE
SECOURS
MC 205
MC 201
MC 208
MC 203
Q 233
Q 201
M V 213
137
123
13
tel 4264
tel 2024
MNP 42

FIG.2

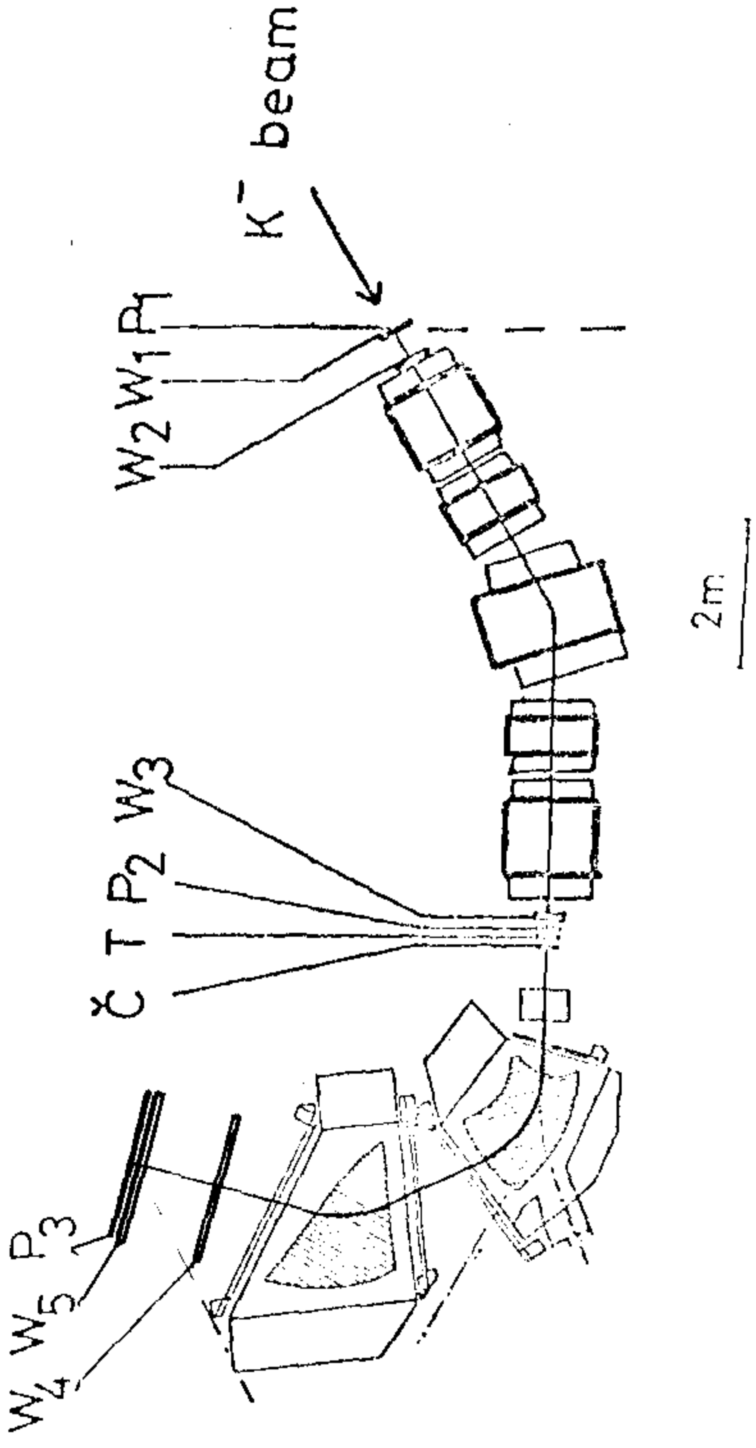


FIG. 3

APPENDIX

LE SPECTROMETRE II (Q2D)

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1° Le spectromètre II est caractérisé par:

- Une bande en moments de ±18%;
- Un angle solide de l'ordre de 2×10^{-2} stéradian;
- Une résolution en moment de 5×10^{-4} environ;
- La possibilité d'analyse des particules de 830 MeV/c pour un champ de 18 kilogauss dans les aimants;
- Une structure laissant échapper le faisceau primaire pour des angles d'analyse au voisinage de 0°;
- Une rotation sur coussins d'air permettant de faire varier l'angle d'analyse (le faisceau primaire n'étant pas stoppé par la structure à partire de 30°).

2° Le spectromètre est composé de deux aimants de même champ, alimentés électriquement en série, précédés d'un quadrupôle focalisant verticalement. Cette structure en deux aimants résulte du fait que les faces intermédiaires des pôles sont des paramètres nécessaires pour satisfaire aux impératifs de compensation des aberrations et de focalisation aux différents moments.

Afin de réduire la dimension de la détection, l'optique a été conçue de telle sorte que les orbites moyennes pour les différents moments soient sensiblement parallèles à la sortie du spectromètre, la focale horizontale étant redressée à 40° environ et ne présentant qu'une légère courbure.

3° La corréction des aberrations (donc la résolution) l'angle solide et le moment des particules analysées ne sont pas des caractéristiques indépendantes. Un exposé détaillé de leurs relations dépasserait le cadre de cette note. Il est possible cependant d'indiquer ici la nature de ces interdépendances.

Les bobinages des aimants permettent d'atteindre un champ supérieur à 19 kilogauss. Cependant, les effets de saturation du circuit magnétique, surtout sensibles au bord des pôles, limitent alors la bande en moment pour une résolution donnée. Pour cette raison, le champ maximal au cours des mesures magnétiques a été de 18 kilogauss. A ce champ, le moment au centre de la focale est 707 MeV/c et les particules ayant un moment de 800 MeV/c présenteraient un dp/p de +13% et focaliseraient à 40 cm environ du centre de la focale.

Exception faite des moments limites analysés (±18%), l'ouverture horizontale du faisceau des partcules ayant un moment donné est définie par la résolution désirée. L'ouverture verticale de ce faisceau est déterminée selon les moments des particules analysées, soit par le diamètre du quadrupôle d'entrée, soit par l'entrefer des aimants, ou encore par la hauteur et la position de la détection. Pour obtenir la meilleure résolution aux différents moments, il convient de définir, en fonction de ces moments, l'ouverture horizontale et l'ouverture verticale du faisceau analysé qui déterminent l'angle solide.

4° A Saclay, le faisceau primaire du Spectromètre II est analysé, comme celui du spectromètre I, afin d'obtenir:

- La compensation de la dispersion en énergie du faisceau incident sur la cible, par l'adaptation de la dispersion de la voie d'analyse à la dispersion inverse du spectromètre;

- La compensation des effets dus à l'ouverture de ce faisceau.

En outre, il est tenu compte des effets de la cinématique liés à l'ouverture du spectromètre, qui se traduisent par un deplacement de la surface focale.

5° Pour des angles d'analyse voisins de 0° le faisceau primaire traverse le spectromètre sans être arrêté.

En définissant par ±D le rapport du moment de ce faisceau au moment des particules analysées focalisant au centre de la focale, le signe + correspondant à des particules analysées de même charge que le faisceau primaire, les rapports ±D possibles sans que le faisceau primaire soit stoppé sont, compte tenu de l'émittance et de la dispersion du faisceau actuel de Saturne:

$$2. < +D < 3.4,$$
$$-3.8 < -D < -2.$$

Pour des angles d'analyse différents et inférieurs à 30°, le faisceau primaire est arrêté par les structures du spectromètre. Au-delà il peut à nouveau passer sans être arrêté. La rotation du spectromètre est réalisée par le châssis sur coussins d'air alimentés à une pression de 3 kg/cm^2.

Alimentation électrique et refroidissement par eau désionisée:

Caractéristiques mesurées

Champ aimants kgauss	17	18	19
Intensité (A) (stabilité 10^{-4})	3560	3850	4250
Tension (V)	325	351	388
Puissance (MW)	1.16	1.35	1.65
Elévation de température (Δt) (galette à Δt max)	16	18	23

Débit d'eau:	premier aimant	34 m^3/H
	deuxième aimant	32 m^3/H
Pressions:	Entrée	23.5 bars
	Sortie	1.5 bar

Caractéristiques Optiques:

Bande en moments analysés: $\frac{dp}{p} = \pm 18\%$

	X	B	M
Moment (M) des particules analysées (MeV/c)			
X étant la distance au centre de la focale mesurée en dp/p	0	17	670
B étant le champ des aimants en kgauss	0	18	707
	0	19	746
	+13%	18	800
	+ 7%	19	800
	+18%	18	830

Dispersion perpendiculaire à l'orbite moyenne, pour $dp/p = 10^{-3}$	3 mm
Grandissement horizontal	0.5
Grandissement vertical (centre focale)	4
Angle solide (environ)	2×10^{-2} sr
Entrefer	20 cm

Caractéristiques Mécaniques:

Aimant A1

Poids total	45 T
Poids du sous-ensemble culasse + pôle + bobine	19 T

Aimant A2

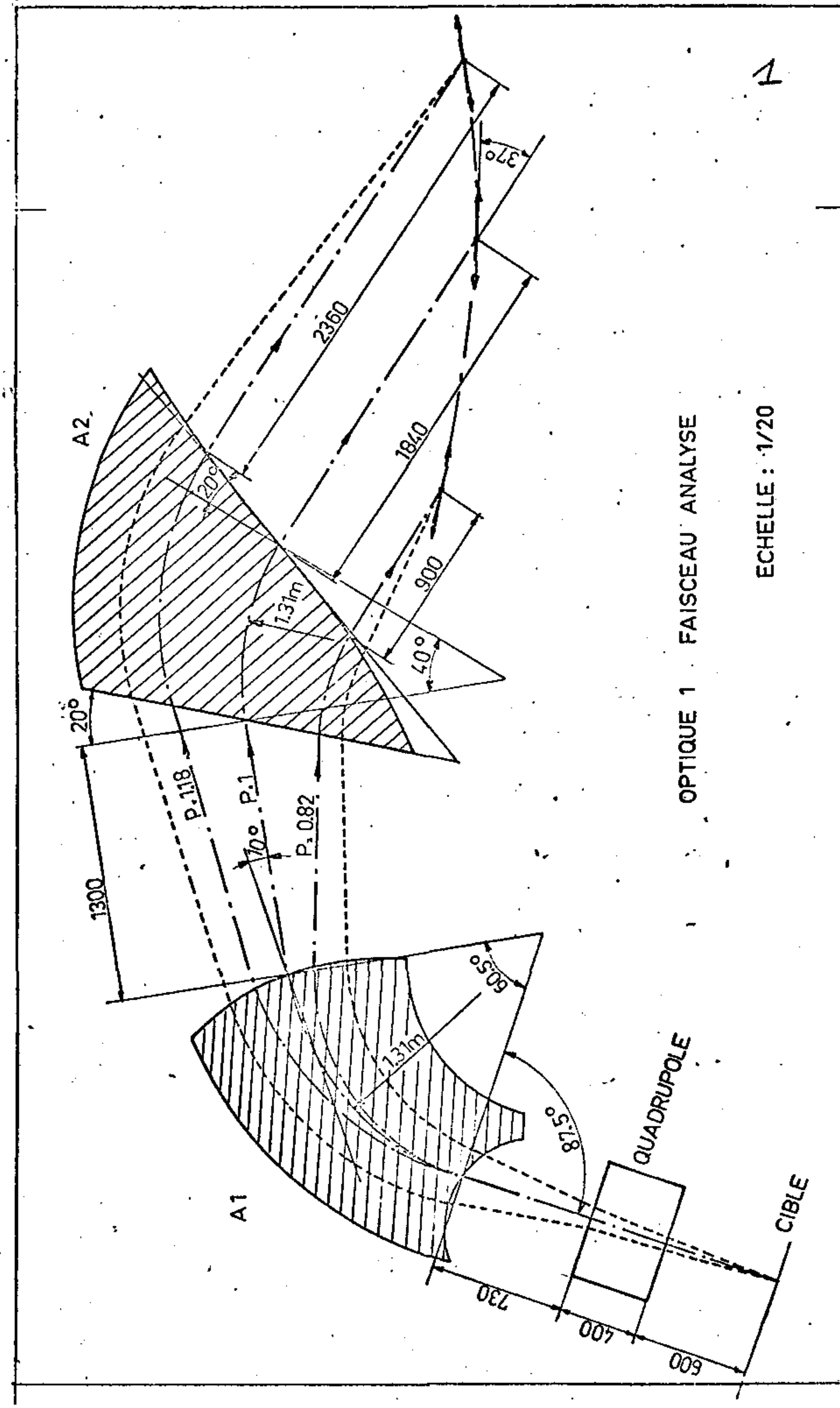
Poids total	60 T
Poids du sous-ensemble culasse + pôle + bobine	27 T

Vide secondaire dans l'ensemble du spectromètre

Châssis sur 6 coussins d'air-vitesse de rotation:

Alimentation en air comprimé

Pression $3\ kg/cm^2$


1
A2
A1
2360
1840
900
1300
730
400
600
37°
20°
40°
20°
60,5°
87,5°
10°
1,31m
1,31m
P.1,18
P.1
P.0,82
QUADRUPOLE
CIBLE
OPTIQUE 1 FAISCEAU ANALYSE
ECHELLE : 1/20