NAL PROPOSAL No. 147

Scientific Spokesman:
Jacques Hebert
Department of Physics
University of Ottawa
Ottawa 2, Canada

Telephone: 613-231-3375

PROPOSAL OF AN EXPERIMENT ON THE FISSION OF VERY HEAVY NUCLEI INDUCED BY 200 GeV PROTONS

M. DEBEAUVAIS, J. RALAROSY, G. REMY, R. STEIN, J. TRIPIER
Laboratoire de Physique Corpusculaire
CENTRE DE RECHERCHES NUCLEAIRES
Strasbourg-Cronenbourg
France

HEBERT J.
Departement de Physique
UNIVERSITE D'OTTAWA
Canada

July 1971

SPOKESMAN BY INTERIM
Pr HEBERT

PROPOSAL OF AN EXPERIMENT ON THE FISSION OF VERY HEAVY NUCLEI INDUCED BY 200 GeV PROTONS

-:-:-:-:-:-

M. DEBEAUVAIS, J. RALAROSY, G. REMY, R. STEIN, J. TRIPIER
Laboratoire de Physique Corpusculaire
CENTRE DE RECHERCHES NUCLEAIRES
STRASBOURG-CRONENBOURG
(FRANCE)

HEBERT J.
Département de Physique
UNIVERSITE D'OTTAWA
(CANADA)

S U B J E C T

BINARY AND TERNARY FISSION INDUCED BY VERY HIGH ENERGY PROTONS IN HEAVY NUCLEI (U, Th, Bi, Pb, Au).

I - INTRODUCTION

The solid detector group of the "Laboratoire de Physique Corpusculaire de Strasbourg Cronenbourg" has studied for many years reactions named "BINARY FISSION" and "TERNARY FISSION" induced by high energy protons (GeV range) in heavy nuclei (1, 2, 3, 4).

The term FISSION of an order of multiplicity N corresponds only to a phenomenological description of reactions specific of very heavy nuclei into several fragments the masses of which are larger than a fixed value depending on the nature of the solid detector used.

The technique used is that named "Makrofol sandwich" with which it is possible to record in 4π geometry the products of the disintegration of the studied target nuclei provided that their masses exceed 12 AMU.

We distinguish :

- single tracks
- binary events
- ternary events

Spatial coincidences are observable with an optical microscope.

Quantities measured

- directly
  1°) Branching cross sections of the three kinds of previously listed events.
  2°) Angular distribution of fragments - F/B ratio.
  3°) Range distribution of fragments.

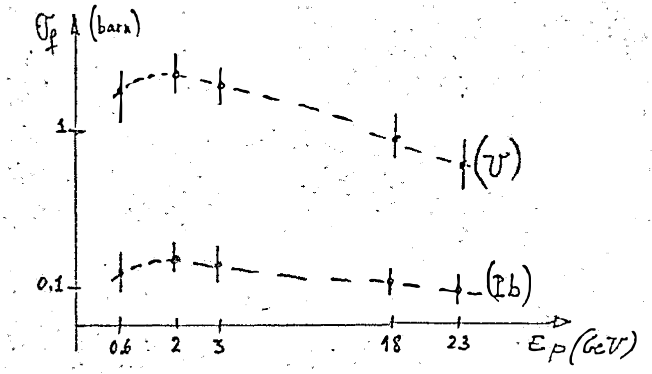
- by calculation

The range energy relations we have previously established in Makrofol allow the determination of the fragment masses emitted from some events satisfying particular geometrical criteria.

II - MAIN RESULTS OBTAINED

Production cross sections of binary and ternary events from reactions of 0.6, 2, 3, 18 and 23 GeV protons on uranium and lead targets.

1°) Binary events cross sections

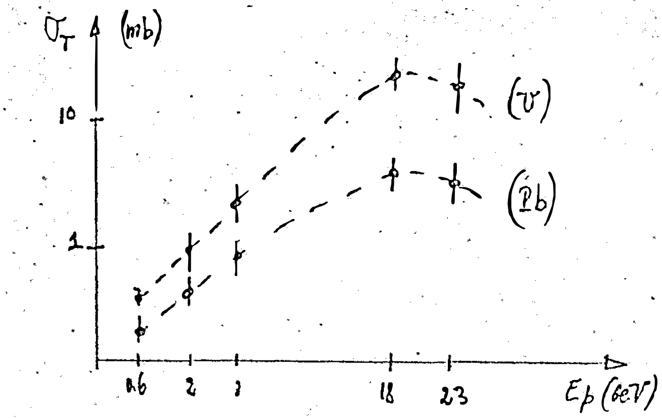


Remarks

* $\frac{\sigma_U}{\sigma_{Pb}} \simeq 10$

* decrease from 3 GeV

2°) Ternary events cross sections



Remarks

* σ_T increase rapidly between 0.6 and 18 GeV

* decrease of σ between 18 and 23 GeV - to be confirmed experimentally at higher energy.

3°) Transverse momenta for binary events

In the case of the binary events, two classes can be distinguished :

a) events in which the angle α between the projections of the two correlated fragment-tracks on a plane perpendicular to the direction of the incoming proton equals 180° [(π) events].

b) Beam conditions

- Beam as "defocused" as possible, in order to obtain a homogeneous density over 1.5 cm^2 of our target-detector system.

- acceptable integrated fluxes (*)
10^{10} to 10^{12} protons/cm^2

c) Machine time

- 10 to 30 pulses

Targets to be studied : U, Th, Bi, Pb and Au
Target thickness : 20 - 100 $\mu g/cm^2$
Number of stack samples to be irradiated : 10

Consequently, 10 flux measurements will be done by an activation method (on C or Al).

For the scanning, the group has at its disposal 4 scanners.

- Measurements for cross section determination could be realised quickly for 2 targets (approximatively two months).

- For fragment mass and energy determinations, length measurements must be done and, therefore, the scanning and the calculation could require several months.

Note that these detectors are note sensitive to α, p, β of high energy and there is no fading versus time. Therefore, sandwiches can be irradiated and can wait for etching and scanning without disadvantage.

On the contrary, flux measurement must be done on the spot and immediately after exposure.

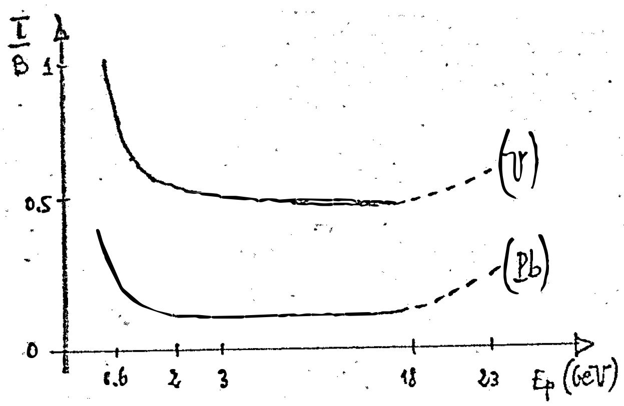
(*) As one of the objects of the experiment is the accurate determination of the cross sections of some reactions, a precise monitoring of the beam is indispensable.

b) events in which $\alpha \neq 180°$ $\left[(\pi^*) \text{ class}\right]$.

- In case (a), the resultant of the transverse momentum is null.
- In case (b), it can be supposed that some light particles are emitted which are not recorded in the detector. These particles would account for the missing transverse momentum.

As (π) events are analogous to low energy fission, (π^*) ones would correspond to a fragmentation reaction, i.e. a disintegration of the target nucleus into several fragments two of which are very heavy.

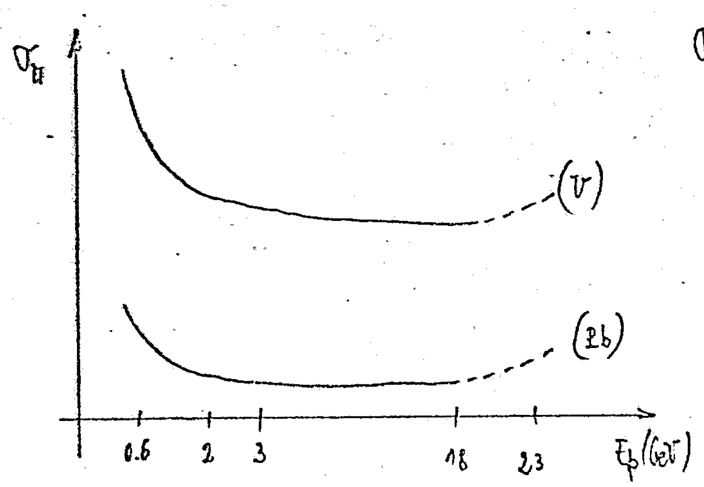
The ratio of the total number of class (a) events to the total number of binary events (b) (branching ratio) is shown on the following diagram :

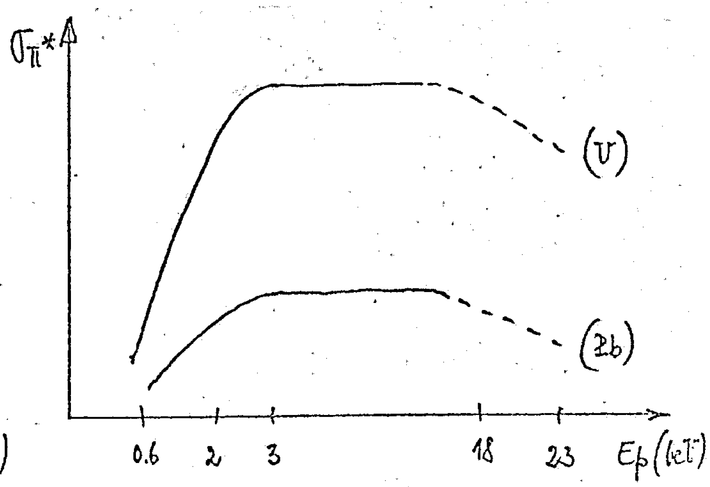


Remarks :

1) in U : π events are produced with a probability higher than π^* ones.
2) in Pb : inverted statement.
3) in both cases : the π probability seems to increase beyond 18 GeV.

The partial cross sections σ_π and σ_{π^*} show the following behavior.





4°) Conclusion

One notes :

- * the similarity between the cross section cruves for ternary events and for binary events of type (π^*).
- * the decrease of the production cross section of ternary events and (π^*) events beyond 18 GeV.

It is clear that the (π) events on the one hand and the (π^*) and ternary ones on the other hand belong to two different mechanisms. The former ones correspond to the FISSION concept as defined at low energy and the latter ones correspond to a mechanism occurring exclusively at high incident energies (and very likely also for high excitation energies) and can be associated with the fragmentation process.

III - EXPERIMENT AT VERY HIGH ENERGY

A - Object of the study

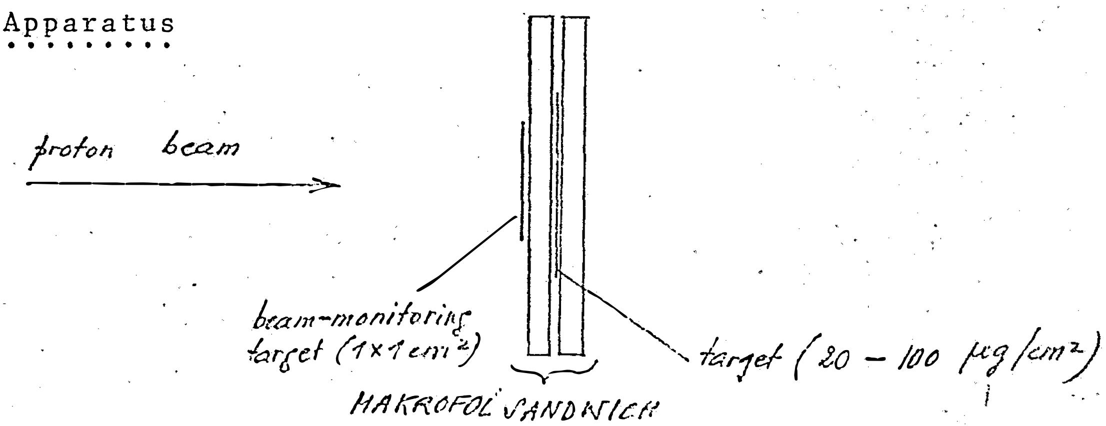
The data on the fission of heavy nuclei obtained up to now with protons of energy between 0.6 and 23 GeV show the interest of pursuing this study at higher incident energies.

Such a study would effectively :

1°) permit the absolute measurement of binary and ternary fission cross sections at these energies (not yet known).
2°) confirm or invalidate the trend of the cross sections for (π), (π^*) and ternary events indicated by our results at 18 and 23 GeV.
3°) establish the differences in the mechanisms for these three kinds of events. It would be interesting to examine the probability of quaternary and higher order disintegrations at the highest incident energies.

B - Experimental

a) Apparatus



REFERENCES

1°) "Spallation and fission fragments of heavy nuclei induced by 18 GeV protons registered by means of solid plastic detectors".

M. DEBEAUVAIS, R. STEIN, J. RALAROSY, P. CÜER.- Nucl. Phys., Vol. A90, p. 186-198 - (1967).

2°) "Quelques résultats sur la fission et la fragmentation par protons de 3, 18 et 24 GeV dans des cibles d'U et de Pb à l'aide des détecteurs ionographiques solides".

M. DEBEAUVAIS, R. STEIN, G. REMY, J. RALAROSY.- Suppl. J. de Phys., n° 1, 29 C1 127 (1968).

3°) "Heavy fragment emission in high energy reactions on heavy nuclei".

G. REMY, J. RALAROSY, R. STEIN, M. DEBEAUVAIS, J. TRIPIER.- J. de Phys., T31, 27 (1970).

4°) "Cross sections for binary and ternary fission induced by high energy protons in uranium and lead".

G. REMY, J. RALAROSY, R. STEIN, M. DEBEAUVAIS, J. TRIPIER.- Nucl. Phys. A 163 (1971) 583-591.