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PHYSICS I
ELECTRONICS EXPERIMENTS COMMITTEE

PROPOSAL
FOR COHERENT PRODUCTION EXPERIMENT BY PIONS AND PROTONS ON A SOLID STATE DETECTORS TARGET USING THE OMEGA

by

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<u>P H Y S I C S   I</u>

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1 - Introduction

The nuclear coherent production experiments made up to now, especially the CERN magnetic spark chamber experiment, pointed out that [1-3]:

1) at very high energy the selection rules expected for diffractive dissociation via Pomeron exchange seem dominate the coherent production in forward direction (in fact the ω exchange contribution falls roughly as $1/p$, where p is the incident momentum);

2) in $\pi \to 3\pi$ and $K \to \pi\pi K$ channels, the produced systems mass distributions show broad bumps, in the A_1 and Q regions respectively, 0.4 and 0.3 GeV/c^2 wide;

3) the dependence of the total cross section for $\pi \to 3\pi$ and $\pi \to 5\pi$ channels vs the atomic weight of the nucleus target, is well fitted by an optical model, where the nuclear absorption is taken into account. The fitted value of the nuclear cross section for the produced system is consistent with the typical π - nucleon cross section, whatever should be the produced mass.

On the other hand many problems are unresolved and many channels are practically unexplored.

Up to now only the $\pi \to 3\pi$ and $K \to \pi\pi K$ channels have been studied with rather good statistics, but also in these channels the analysis was limited to very small momentum transferts, in order to minimize the incoherents background. So it is certainly important to extend to the full $\underline{t}'$ range, and to other channels, the study of the produced systems, with unbiased angular distributions. This can be an important contribution to the understanding of the diffractive dissociation phenomena [(4)].

For this purpose we think useful to study the following points:

a) $\pi \to 3\pi$ channel: spin-parity of the produced system as function of the mass, the helicity structure and generally the produced systems properties up to very high four momentum transfers, until now unexplored. These analyses can help in clarifying the nature of the broad bumps produced in coherent interactions and their production mechanisms.

b) $\pi \to 5\pi$ channel: up to now there is no unbiased sample of this reaction except ~100 heavy liquid bubble chamber events [(5)]. So the first obvious field of investigation is the structure of the outgoing systems and their correlations;

c) $p \to p\pi\pi$ channel: many problems need investigation in this channel: the possible production of the same 1470 enhancement suggested by a pN diffraction dissociation experiment [(6)], the nature of this bump, the possibility to explain features of the experimental data with the Berger's double Regge model.

Moreover it is very important to obtain an incoherent productions sample, cleaned of coherents, also at very small t', in order to obtain a further check of theoretical models, applying them to the incoherent productions. This analysis can be performed as complementary to the previous ones.

We believe the problems mentioned above can be successfully studied by an experiment to be performed with the Omega apparatus, using a silicon detector target.

2 - Proposed experiment

We propose to study the coherent productions :

a) $\pi^- + \text{Nucleus} \rightarrow \text{Nucleus} + \pi^+ + 2\pi^-$

b) $\pi^- + \text{Nucleus} \rightarrow \text{Nucleus} + 2\pi^+ + 3\pi^-$

c) $p + \text{Nucleus} \rightarrow \text{Nucleus} + p + \pi^+ + \pi^-$

at the highest available momentum, through an experiment to be performed to Omega apparatus, using a silicon detector target.

The use of the Omega will provide unbiased samples for the three channels and good measurements on the secondary tracks. The silicon detector target gives the possibility of a direct selection of coherent events from the incoherent ones, in the full t' range.

Our aim is to collect 200.000 events from the channel a), 20.000 from the channel b) and 20.000 from the channel c).

3 - Experimental set-up and trigger

Apparatus: the general set-up is described in fig. 1.

The target is placed 50 cm upstream the first spark chamber plate. So we can define an acceptance cone of ± 45° opening angle and have a minimum measurable secondary track length of 20 cm.

Around the target the scintillators G_1 and G_2 anticoincide the beam particles incident outside of the target sensitive area and the outgoing protons or nuclear fragments emitted at large angle. S_1 is an array of four lead scintillator sandwiches, (6 radiation lengths), which reject the large-angle gammas; S_2 and S_3 are also lead scintillators sandwiches, defining the forward acceptance cone, by rejecting charged particles and gammas emitted at angles larger than 45°. P is a multiwire proportional chamber, which selects the wanted range of charged multiplicity.

The target is a telescope of 10 silicon detector sheets 200 μm thick and 2 cm in diameter, each of them connected with an indepen dent amplification chain.

Chamber geometry: no special features are needed for our experiment.

The only possible change could be the replacement of the first Omega spark chamber plates in order to eliminate the hole for the hydrogen target. This requirement is not stringent.

Trigger: the trigger signature is ($\bar{G}_1\ \bar{G}_2\ \bar{S}_1\ \bar{S}_2\ \bar{S}_3$ P $\bar{D}$) where p gives a coincidence only when the charged secondaries multiplicity is 3, or 5 for the reactions from incident π^- and only 3 for those from incident protons.

D comes from the silicon detectors target: it is a veto when more than one silicon detector gives a pulse consistent with being crossed by a highly ionizing proton (see § 4).

4 - Target

The target we plane to use in this experiment is a telescope of silicon detectors (*).

The principle underlying the use of the silicon target is that, at a fixed momentum transfer the recoil nucleus releases in the detector an energy 28 times smaller than a recoiling proton. It is worth reminding that the incoming and the outgoing fast particles release in the target an ionization energy of the order of 40 keV/100 μm ± the Landau fluctuation, which is added to the

(*) A silicon detectors target has been already tested by us in a previous experiment [2], where it was used in order to select at the analysis stage the coherent events from incoherent background. The technical details and the selection criteria are described in references [7,8].

recoil energy. So it is necessary to use many independent thin sheets, instead of only one detector of large thickness.

To select the coherent events both the following requirements should be fulfilled :

1 - a) no more than one detector must give a pulse corresponding to an energy higher than three (or five) fast particles crossing it. In fact the recoiling nucleus range is always on the order of the μm, while easily a proton recoil escapes from the thin sheet, where the interaction took place. This requirement rejects a great part of incoherent interaction with a recoiling proton;

b) the detectors preceeding the one where the coherent interaction took place must give a pulse corresponding to an energy consistent, inside the errors, with one and only one relativistic particle crossing it; the detector where the interaction took place should give a pulse consistent with at least one fast particle and all the following detectors a pulse consistent with three (five) relativistic particles.

2) The recoil energy E_{si} measured in the target should be consistent, inside the errors, with the energy E_{Kin} coming from the kinematical fit of the interaction, using the measurements of the secondary tracks in the magnetic spark chambers. On the basis of the detectors resolution and of the measurements precision (see below) it is possible to state that this last requirement allows to reject the incoherent interactions where only neutrons are emitted ($E_{Kin} > E_{si}$) and those where the emitted protons (recoils or evaporation) do not cross more than one detector ($E_{si} > E_{Kin}$).

The electronic amplification chain for this experiment has been planed and realized in a proto-type [8], in order to fit the conflicting requirements of high resolution in the energy measurements and of short time constant operation. It consists of a current preamplifier plus a wide band amplifier plus a time varying filter. Its resolution, when connected with a 200 μm thick detector of 300 mm^2 of surface, is ~25 KeV. The full width of the pulse is of the order of 100 nsec (*).

In order to evaluate the overall resolution of the target, it is necessary to take into account, in addition to the electronic noise, the Landau fluctuations on the fast particles ionization energy losses and the uncertainty about the position of the interaction inside the detector sheet. The best compromise between the requirements of having a good resolution in the recoil energy mesurements (small thickness) and of obtaining a good evaluation of the fast particles number (large thickness), seems to be a 200 μm thick detector. With this choice the resolution on the recoil measurements is 70 KeV and the energy losses from 1, 2, 3 minimum ionizing particles are 80 ± 34, 160 ± 41, 240 ± 47 Kev, respectively. We remind that a resolution of 70 KeV in energy corresponds to 0.004 $(GeV/c)^2$ of nuclear recoil four-momentum and for instance the first minimum in the <u>t</u>' distribution for coherent processes on Si is in 0.04 - 0.05 $(GeV/c)^2$ range.

Taking into account the cross sections values for the three channels we want to study the rate and background requirements, we planned a target with ten 200 μm thick detectors, connected with 10 independent amplification chains.

Due to the short time constant operation of the electronic chain it will be possible to put directly in the trigger the target selection, limitedly to the point 1 a).

(*) The electronic chain performances have been substantially improved with respect to the previous expgriment where the resolution was of 60 KeV with 200 ns $(RC)^2$ differentiating network.

5 - Geometrical efficiency and experimental resolution

The geometrical efficiences have been evaluated taking into account an angular acceptance cone for the secondaries of $\pm$ 45° (see experimental set-up and fig. 1). These efficiencies for the produced system mass distribution have been calculated by retracing in the Omega apparatus coherent events obtained in a heavy liquid bubble chamber experiment at 16 GeV/c. As it can be seen in figs. 2, 3, 4 (full line crosses) (*) the efficiency is 100% up to 2.5 Gev/c^2 for $\rho\pi$ system, up to 2.4 for $f^{\circ}\pi$ and up to 2.8 for 5π . Taking into account the effect of the nuclear form factor on the produced masses distribution at the possible incident energies of this experiment, we conclude that geometrical cuts are negligible for 3π and 5π coherent productions. The same conclusion can be accepted also for the incoherents sample at small t'. For $p\pi\pi$ channel, the mass distribution for coherent production at 28 GeV/c [6] falls at 2 GeV/c^2, where the Q value is smaller than in 3π coherent channel. So also for $p\pi\pi$ coherent channel in Omega, the geometrical bias are negligeable.

The resolution of secondary measurements have been calculated by retracing in the Omega apparatus a sample of coherent events coming from experiment of reference (2) with the standard error matrix elements and the Omega parameters(**), and the measuring error for the Plumbicon of ε = 600 μm. The results give:

$$\frac{\delta P}{P} \sim 0.3\ \%; \qquad \delta M_{\pi\pi} \simeq 13\ \text{MeV}; \qquad \delta M_{3\pi} \simeq 17\ \text{MeV} \qquad (***)$$

(*) For comparison in the same figures are represented the correspondent efficiencies (broken lines crosses) for the CERN magnetic spark chamber (little omega) used in the experiment of reference 2); in these calculations it was not taken into account a further inefficiency coming from a scintillator hodoscope used in the experiment.

(**) B = 18 Kgauss, volume = 300 x 150x150 cm^3, X_O=70 m, N = 1/3.

(***) In the case of the optical chambers ($\varepsilon \sim \pm$ 0.02 cm) these figures are $\delta p/p \sim 0.2\%$, $\delta M \sim 9$ MeV, $\delta M_3 \sim 12$ MeV.

6 - Background

The rates of 3π , 5π , $p\pi\pi$ coherent productions and those of the reactions that will give background triggers have been studied assuming the partial cross sections obtained from heavy liquid bubble chamber experiments with 16 GeV/c π^- and 28 GeV/c P. The selection of multiplicities is given by the multiwire proportional chamber P, placed just after the target.

The channels contributing to the background are the incoherent productions of 3π , 5π and $p\pi\pi$ charged particles, the same channels with additional π^0's and a fraction of events belonging to channels with charged multiplicity different from the wanted ones,

The contributions to the background due to the incoherent productions and to the channels with π^0's is strongly reduced by the charged secondaries and fast recoil protons hitting the counters defining the acceptance cone (trigger $\bar{S}_1\ \bar{S}_2\ \bar{S}_3\ \bar{G}_1\ \bar{G}_2\ P$ second column of Table 1).

A further reducing factor can be obtained putting $\bar{D}$ in the trigger with the requirement 1 a) described in § 4, which cuts the slow recoil protons incoherent events (trigger $\bar{S}_1\ \bar{S}_2\ \bar{S}_3\ \bar{G}_1$ $P\ \bar{D}$ third column of Table 1). (*)

T A B L E 1

channel	coherent events	events accepted by the trigger $\bar{S}_1\ \bar{S}_2\ \bar{S}_3\ \bar{G}_1\ \bar{G}_2\ P$	avents accepted by the trigger $\bar{S}_1\ \bar{S}_2\ \bar{S}_3\ \bar{G}_1\ \bar{G}_2\ P\ \bar{D}$
$\pi^+2\pi^-$	1	5.1	3.7
$2\pi^+3\pi^-$	1	8.3	6.5
$P\pi^+\pi^-$	1	9.3	7.0

(*) Alternatively this reducing factor can be obtained by on line selection in the data acquisition stage.

7 - Trigger rate and P S requirement

From the preceeding experiments we assume for the coherent productions at the proposed energy the following cross sections: $\sigma(2\pi^-\pi^+)$ = 4 mb/nucleus, $(3\pi^-2\pi^+)$ = 0.35 mb/nucleus and $(p\pi^+\pi^-)$ = 0.5 mb/nucleus. The trigger cross sections, evaluated allowing for the trigger efficiency, are listed in second column of Table 2. The rate for our target (2 mm of total thickness) is of 1 trigger/mb/10^5 incident particles.

A trigger wich selects simultaneously the 3 and 5 π's channels seems convenient, if we take into account that the upper limit of beam intensity acceptable for the silicon target is of 10^5 particles/burst (we assume 400 msec for the spilling time).

The figure of Table 2 are calculated on the basis of the trigger $\bar{S}_1\ \bar{S}_2\ \bar{S}_3\ \bar{G}_1\ \bar{G}_2\ P\ \bar{D}$. The possible inefficiency of the simultaneous 3 and 5 π's trigger by the multiwire proportional chamber was not taken into account in this calculation.

We will collect also a sample of events with the $\bar{S}_1\ \bar{S}_2\ \bar{S}_3\ \bar{G}_1\ \bar{G}_2\ P$, in order to obtain on unbiased statistic of incoherent interactions.

T A B L E 2

channel	trigger cross-section (mb)	beam intensity/burst	trigger/hour	coherent events/hour
$\pi^+2\pi^-$ + $2\pi^+3\pi^-$	17.1	10^5	30.000	7.800
$p\pi^+\pi^-$	3.5		6.300	900

On the basis of the rates of the coherent events (column 5 of Table 2), it is possible to obtain 2.10^5 (3π) coherent with ~ $2\cdot10^4$ (5π) in 30 hours of run and $2\cdot10^4$ $(p\pi^+\pi^-)$ in 22 hours.

In addition ~5 hours are sufficient in order to obtain some thousand of incoherent productions with the $\bar{S}_1\ \bar{S}_2\ \bar{S}_3\ \bar{G}_1\ \bar{G}_2$ P trigger.

Allowing for interruptions, periodical calibrations, etc., we require a total running time of 5 - 7 days.

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3) Orsay, Brookhaven, Berkeley, Milano, Saclay Collaboration - Three meson states coherently produced on nuclei by K^- beams of 5.5, 10.0 and 12.7 GeV/c, Submitted to the Amsterdam Elementary Particles International Conference

4) See for example: H.Satz and K.Schilling, Aspects of diffraction dissociation, Colloquium on Multiparticle Dynamics, Helsinki, 1971

5) Orsay, Milano, Berkeley Collaboration, Phys.Letters, 28B, 208, 1968

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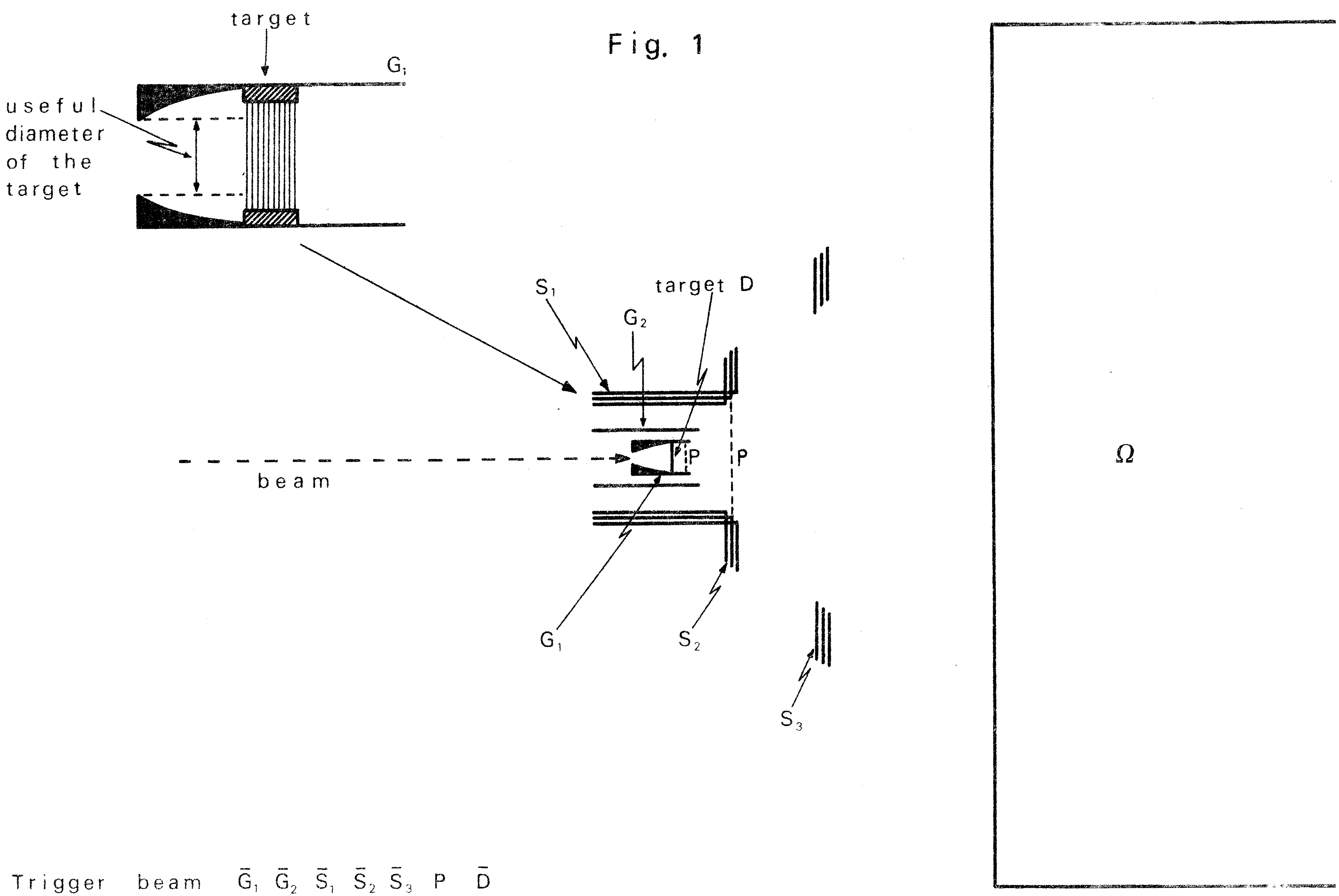
8) P.F. Manfredi, D.Misler, V.Varoli - Limitations in the performances of silicon detectors used as live targets in high-energy experiments - Proceedings of the Topical Seminar on Interactions of Elementary Particles with nuclei - Trieste 15 - 17 sept. 1970.

Fig. 1



Trigger beam $\bar{G}_1$ $\bar{G}_2$ $\bar{S}_1$ $\bar{S}_2$ $\bar{S}_3$ P $\bar{D}$

Fig. 2

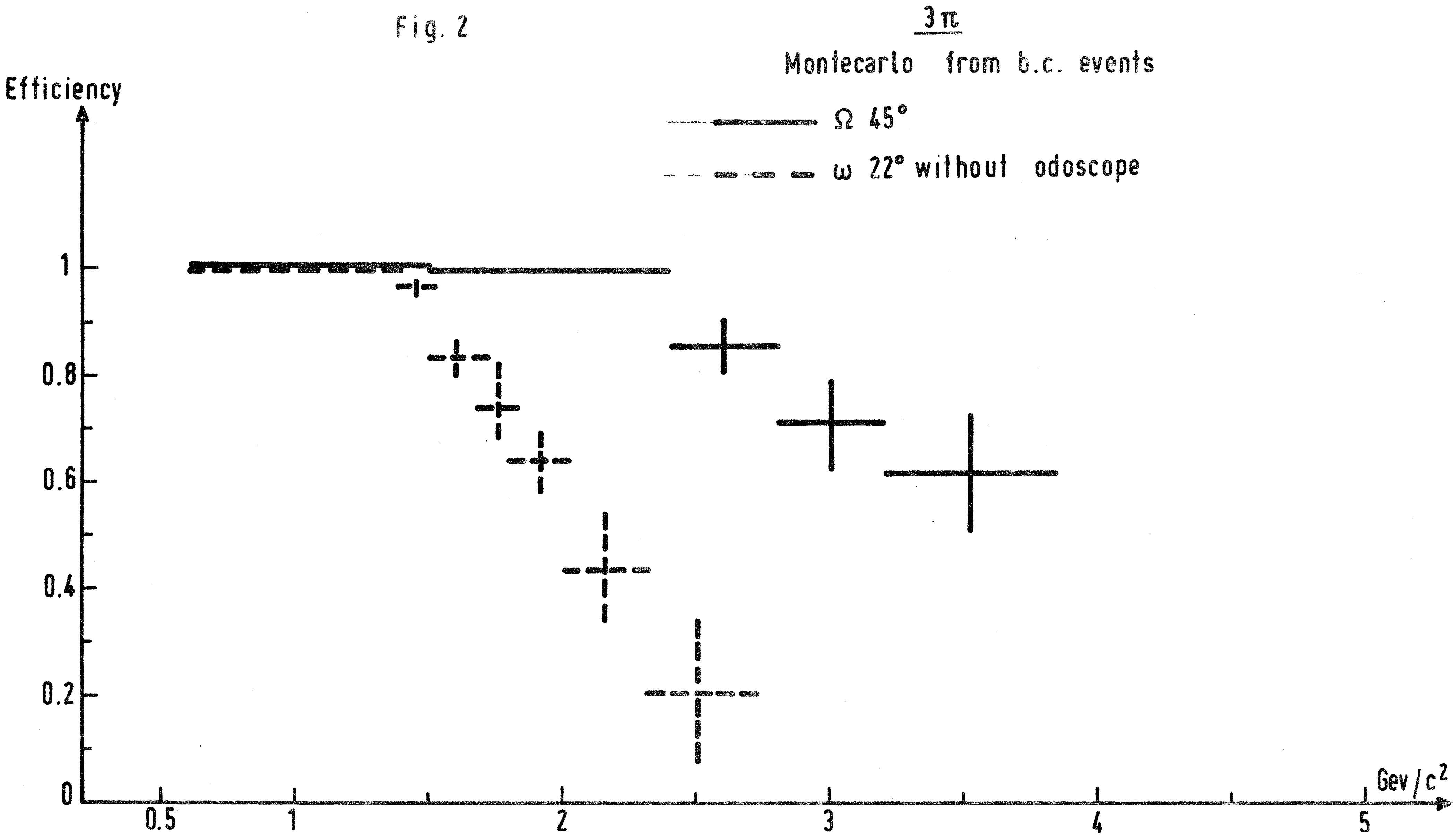

3π
Montecarlo from b.c. events
Ω 45°
ω 22° without odoscope
Efficiency
1
0.8
0.6
0.4
0.2
0
0.5
1
2
3
4
5
Gev/c²

Fig. 3

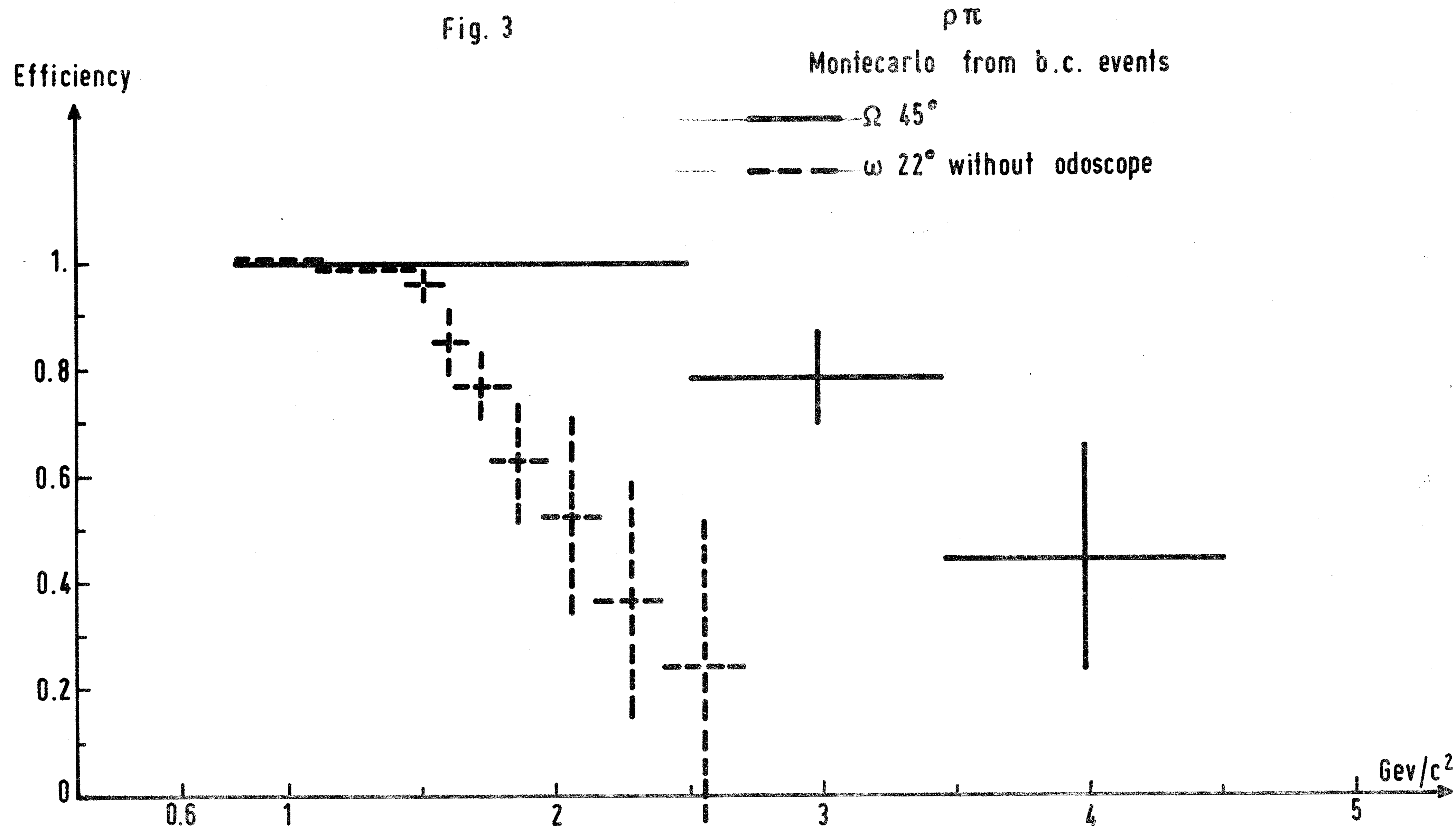
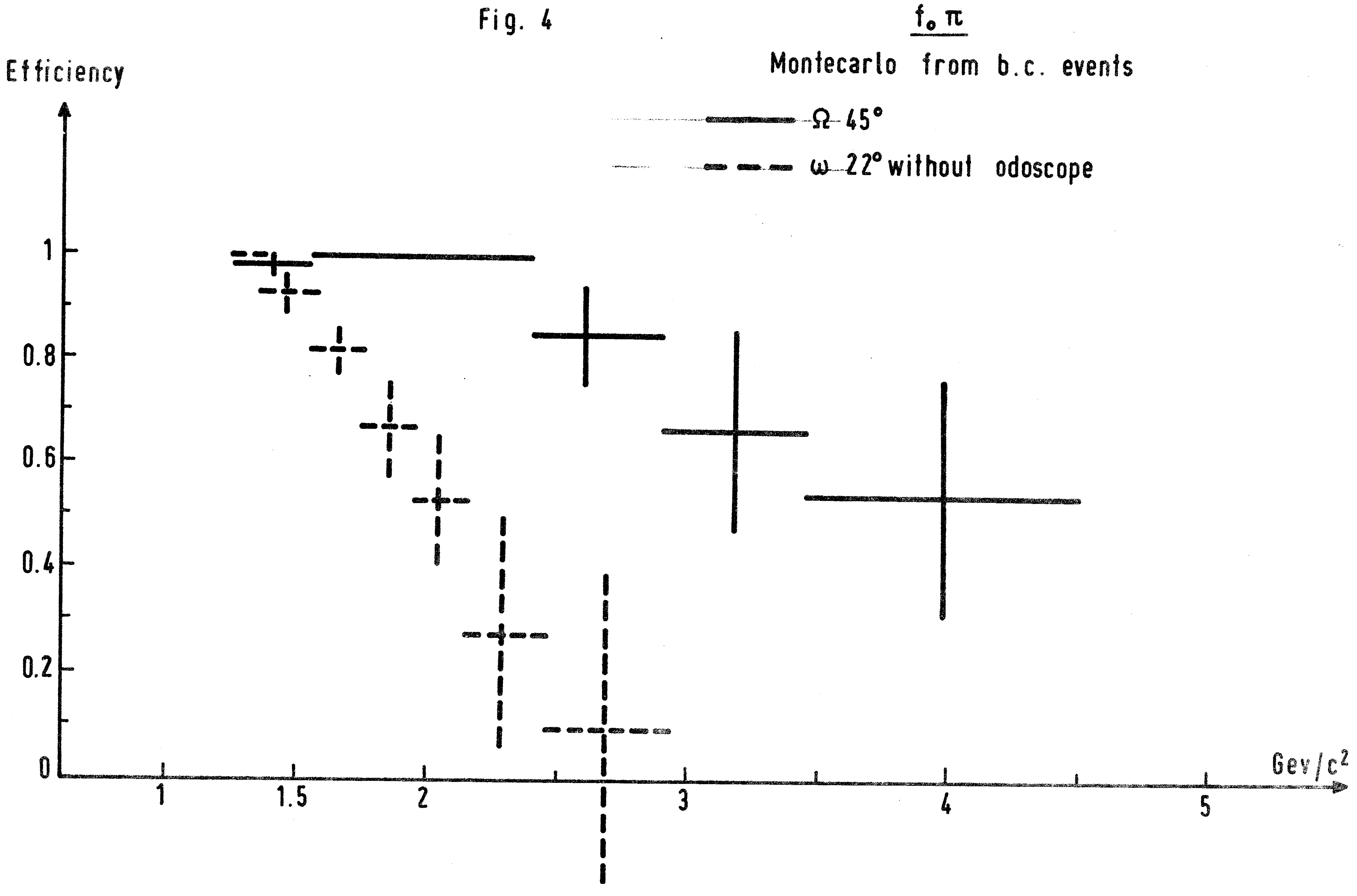
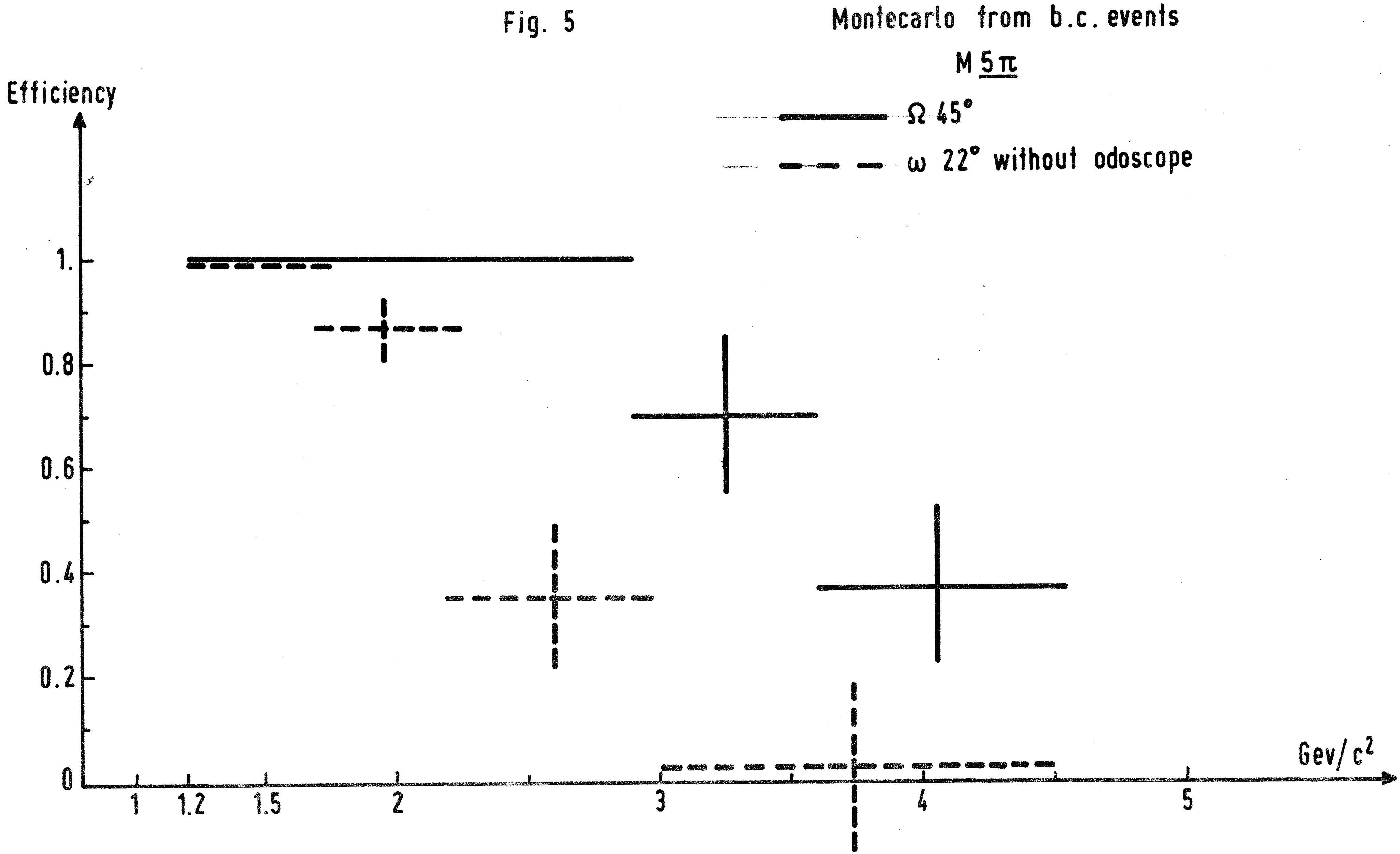

ρπ
Montecarlo from b.c. events
Ω 45°
ω 22° without odoscope
Efficiency
1.
0.8
0.6
0.4
0.2
0
0.6
1
2
3
4
5
Gev/c²

Fig. 4



$f_0 \pi$
Montecarlo from b.c. events
Ω 45°
ω 22° without odoscope
Efficiency
1
0.8
0.6
0.4
0.2
0
1
1.5
2
3
4
5
Gev/c²

Fig. 5


Montecarlo from b.c. events
M 5π
Ω 45°
ω 22° without odoscope
Efficiency
1.
0.8
0.6
0.4
0.2
0
1
1.2
1.5
2
3
4
5
Gev/c²