CERN/SPSC/75-60/P 45/Add.1
October 13, 1975

Addendum to the Proposal

"AN EXTERNAL GAMMA RAY DETECTOR TO BE USED WITH BEBC WITH THE TST FOR EXPERIMENTS AT THE SPS"

(CERN/SPSC/75-24/P 45)

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Note: This author's list replaces also that of the original Proposal

INTRODUCTION

In the original proposal we describe a Forward Gamma Detector (FGD) consisting of a lead-scintillator hodoscope to detect the vertices of electro-photonic showers, followed by an array of lead glass Čerenkov counters (LGC) to measure the shower energy. We discuss its performance, its use in connection with BEBC for experiments at the SPS and its construction schedule and costs. In the past few months we have decided to change the design of the vertex detector, have built a small prototype and performed some tests with an electron beam at the SPS.

We describe here the new vertex detector and discuss at more length some points that were mentioned only briefly in the original proposal.

This addendum will consist of:

(1) The new vertex detector,

(2) The use of the FGD with BEBC,

(3) The use of the FGD with other equipment.

I. THE NEW VERTEX DETECTOR

The original vertex detector consisted of 9 layers of finger counters arranged along 3 directions, interlaced with 4 to 6 radiation lengths of converter. The finger counters were used to measure both the position of the shower vertex and the energy lost by the shower.

This set up has however two main drawbacks: it is rather delicate in the calibration and monitoring, requiring a large number of high quality photomultipliers and suffers from the fluctuations of the energy lost in the converter, which is not directly measurable. We have therefore modified the design in the following way: The lead scintillator sandwich is replaced by a first hodoscope of LGC, 4-6 radiation lengths thick, placed perpendicular to the main axis of the detector, followed by a 3-coordinate hodoscope of finger counters, each 1.5 cm wide. The design of the second hodoscope is the same as that of the vertex detector described in the original proposal, but with a single plane for each coordinate (instead of three) and without any converter between successive planes. These counters give the position of the axis of the shower by measuring the center of gravity of the shower after this has developed in the 4÷6 radiation lengths of lead glass. The energy lost by the shower before it reaches the second hodoscope is measured directly by the LGC.

We have built a small prototype following this design and have tested it with electrons up to 4 GeV in the Q12 beam. The prototype consisted of 4 LGC, 60 cm long, covering an area of 30 x 30 cm^2, in front of which was placed one plane of 10 finger counters, 1.5 cm wide, in front of which a 7.5 cm thick, 35 cm long LGC acted as a converter. A wire chamber and a Čerenkov placed on the beam identified the electrons and measured their coordinates with a resolution of ± 1 mm. The axis of the shower was then determined by taking the center of gravity of the finger counter signals. Fig. 1 shows the distribution of these centers of gravity for electrons hitting a given wire. The resolution is about ± 3 mm and depends somewhat on the position of the axis of the shower with respect to the central counter, but it never gets worse than ± 4 mm. The photomultipliers looking at the finger counters are very cheap 931A's.

The energy lost by the electrons in the 7.5 cm of the first LGC, about one third of the total suffers very large fluctuations, as Fig. 2a shows. Consequently, the energy lost in the final, total absorption LGC, fluctuates as well and by a comparable amount (Fig. 2b). However, the measurement of the total energy lost by the electron, i.e. the sum of the signals given by the two sets of LGC, shows much smaller fluctuations (Fig. 2c). The resolution obtained in this way is in accord with the empirical rule $\Delta E = \pm .05 \sqrt{E}$ (GeV).

2. THE USE OF THE FGD WITH BEBC

Since the FGD is not an instrument to be used by itself or for a single experiment, but something like a general facility we did not mention, in the original proposal, any specific experiment in which the collaboration, as such, was interested. However some of the groups have submitted independent proposals for experiments that require the use of the FGD(1). It is clear, on the other hand, that almost any hadronic experiment with BEBC would profit from a complete detection and an accurate measurement of gammas and some experiments would be impossible or much harder to do without it. The same is true for a rapid cycling bubble chamber (see Section 3).

Since the total sum required for the construction of the FGD, 2.4 MSF, cannot be supplied by the Italian and French authorities in less than two-three years, the equipment will not be ready before the end of 1978.

Although it seems that priority for the use of BEBC will be placed on neutrino physics, the interest in hadronic physics is large enough to amply justify a program of hadronic experiments. It is likely that, for the first two years, neutrino and hadronic experiments will be run simultaneously, using BEBC in a double pulsing mode. This will restrict the choice of hadronic experiments to those that can be performed with "bare" BEBC. It is conceivable that by 1978-79, when the North Area will be in operation, the rate at which neutrino pictures are being taken with BEBC will slow down somewhat, both for the fact that a large part of the groups will be busy in the analysis and for the heavy demand on primary protons by neutrino beams. There will then be the possibility of carrying out the hadronic program in BEBC without interfering with the neutrino experiments. By then, the experiments now proposed with bare BEBC will have been performed and the second generation of experiments will probably require external apparatus, like the EPI and FGD. That this is the case can be seen by reading through the 13 letters of intent for hadronic experiments with BEBC. Of these, 7 concern experiments for which the FGD and/or the TST are requested and considered essential, either right at the start of the experiment or at a later stage. The remaining 6 are for experiments with bare BEBC. However, two of them state explicitely that their requests are conditioned by the fact that the TST and FGD would not be available right away.

The same situation holds for the actual experimental proposals, although the need for TST-FGD is expressed less strongly in these, since the proposals concern, in general, experiments that the groups want to do in 1976-77. Nevertheless, of the 10 proposals for hadronic experiments with BEBC, 2 require a TST for the second half of the experiment, 1 plans to use γ conversion in H_2 and says that the use of an FGD may be required later, 3 plan to use γ conversion in H_2. The need for γ detection is then explicitely stated by more than half of the first generation experiments.

It may be worthwhile to emphasize here that the best way (may be the only good way) to insure a complete detection of the γ's produced in BEBC is the simultaneous use of a TST and a FGD. The only alternative would be a truncated target which would allow the conversion of forward emitted γ's in the N_e H_2 mixture. This solution has, however, several disadvantages:

a) it reduces the length of the target, lowering the data rate;

b) it gives rise to a large number of interactions, in the N_e H2 mixture, of the fast secondaries. This decreases the useful length for momentum determination, produces secondary gamma conversions, sends to the EPI a large number of "spurious" particles and creates a confusion zone behind the target, where the detection and measurement of primary gammas would become difficult. These last defects can be partially overcome if the number of primaries per pictures is reduced, but this would decrease further the data rate;

c) the $\Delta p/p$ and $\Delta\Theta$ for fast π^0's converted in the N_e-H_2 mixture would be much worse than those for charged tracks, or for π^0's detected by the proposed FGD (see our original proposal, page 9 and Fig. 8).

The combination of a wall-to-wall TST and a FGD gives, as we have shown in the original proposal, good efficiency and accuracy. The curves shown there were for a thickness of 2 mm of the BEBC exit window. It is of course important that as little material as possible be left between the H_2 and the external detectors. However, even if a reduction of the window thickness cannot be obtained at the present time, the FGD remains a very useful instrument, even with a 5 mm thick window. Its efficiency for π^0 detection is around 50%, to be compared with 60% for a 2 mm thickness (see P 45, page 8). More serious is the problem arising from the production of secondary gammas by bremsstrahlung in the window. As stated in the proposal, 14% of the primary gammas will give rise to secondary gammas of energy higher than 100 MeV. By placing a telescope of wire chambers close to the BEBC wall, it is possible to detect electrons produced in the window if their energy is $\geq$ 500 MeV. So, for almost all gammas of energy greater than about 1 GeV the telescope will detect at least one electron and it will be possible to know that a conversion has taken place in the window.

For at most 14% of the gammas softer than 1 GeV a secondary gamma will reach the FGD and will be taken for a primary. The resulting error in the π^0 energy and direction would not be dramatic, as the gamma's energy was low to begin with. Also, as the number of photons of less than 1 GeV is not high, the contamination should not be too severe. We propose, then to run for the first experiment with the present window thickness, but with a telescope of wire chambers as close to BEBC as possible. These chambers will also help in tracking charged secondaries to the EPI. At a later stage, when more confidence on the chamber operation will have been gained and if the first results show that the performance of the apparatus can be significantly improved by reducing the window thickness, the situation may be reconsidered.

Another potential source of trouble is gamma production, in the FGD, by neutrons or other neutral baryons. The number of these coming from mesonic beams, with energy large enough to produce a π^0 and in the small forward core covered by the FGD, is not very large. The situation will be worse with baryonic beams. However, the lack of charged baryons amongst the secondaries can be detected with good probability by the EPI or in the chamber itself and this could be used as a warning.

3. THE USE OF THE FGD WITH OTHER EQUIPMENT

The apparatus we propose to build, will convert and measure, with very high efficiency and accuracy high energy photons impinging on an area 1 x 1.5 m^2.

It will be able to record simultaneously several gammas, will have a very short dead time (50 ns), will be able to store up to 4 successive interactions before a read out is performed and can be read in about 4 ms. It can, therefore, stand without modifications very high fluxes and record up to 1000 interactions per second.

It is, therefore, a general facility type of instrument, suitable for use with any experimental apparatus that may require detection of gammas.

In the original proposal we chose BEBC to discuss the performance of the FGD in some detail because the short duration of BEBC RF burst ($\sim$ 5 μs), the presence of the exit window and the 4 π acceptance of BEBC for charged secondaries (and also for soft gammas, with the TST) pose problems that are absent or less severe with other equipment. We tried therefore to show that even under demanding and difficult conditions, the FGD could be a very useful instrument. In the meantime, proposals for a RCBC hybrid system and for experiments to perform with it have been presented (P 41, 42, 43, 44). For such a hybrid system, the detection of gammas is essential. This has been recognized by the US Collaboration working with the 30" hybrid system at FNAL, who are now adding gamma detection to their equipment and has been stressed at the recent symposium at FNAL. The addition of our FGD to the proposed RCBC at CERN would improve the quality of the physics that can be done with it. In this connection preliminary studies show that the FGD has a good efficiency for detecting π^0's produced in the forward cone (Fig. 3). The compatibility of the FGD with the chamber itself and with the other external apparatus (ISIS, drift chambers, etc...) will pose fewer and less severe problems than with BEBC. Since the FGD is easily movable, it can be used alternately with BEBC and with the RCBC according to the needs of experiments.

The collaboration is at present building the vertex detector for a FGD to be used at FNAL with the 30" hybrid system. This vertex detector is part of the final vertex detector and will be brought back to Europe when needed. By then the collaboration will have acquired experience both with the operation of the FGD and with the running and analysis of experiments with a RCBC hybrid system.

As far as the use of the FGD with spectrometers or other completely electronic detectors no compatibility problems seem to exist. The need for detection of gammas for such devices depends of course on the particular type of experiment the equipment is designed for. For one particular experiment already approved by CERN, the polarization measurement in pp and πp elastic scattering at large momentum transfer, P8, by the CERN-Trieste-Vienna Collaboration, the need for a FGD like the one we propose to build, has been explicitely expressed for the near future (2).

It is our firm opinion, in conclusion, that a FGD like the one we propose to build, would be a very useful instrument and would be used for many experiments, supplying very valuable and often essential information. We propose that it be brought at CERN and used there as a general facility.

(1) CERN/SPSC/74-47/P 14 and I 73-21; CERN/SPSC/I 73-14; CERN/SPSC/75-16/P 43

(2) G. Fidecaro; private communication.

Figure Captions

Fig. 1 Spatial resolution of the vertex detector hodoscope.

Fig. 2 Energy resolution for 4 GeV electrons:
a) in the $3X_o$ converter,
b) in the total absorption counter,
c) for the sum of a) + b).

Fig. 3 Efficiency of the FGD placed 30 m behind the RCBC as function of the Feynman variable X_{π^o} at two different primary energies.

The π^o's have been produced according to a typical inclusive distribution.

The efficiency shown is for π^o's fully detected (2 γ's both seen in the FGD).

Also shown is the contribution of an additional frame $(30 \times 60)cm^2$ of lead-glass placed on both sides and in front of the spectrometer magnet.

--- KIOWA --- HISTOGRAM NUMBER 14

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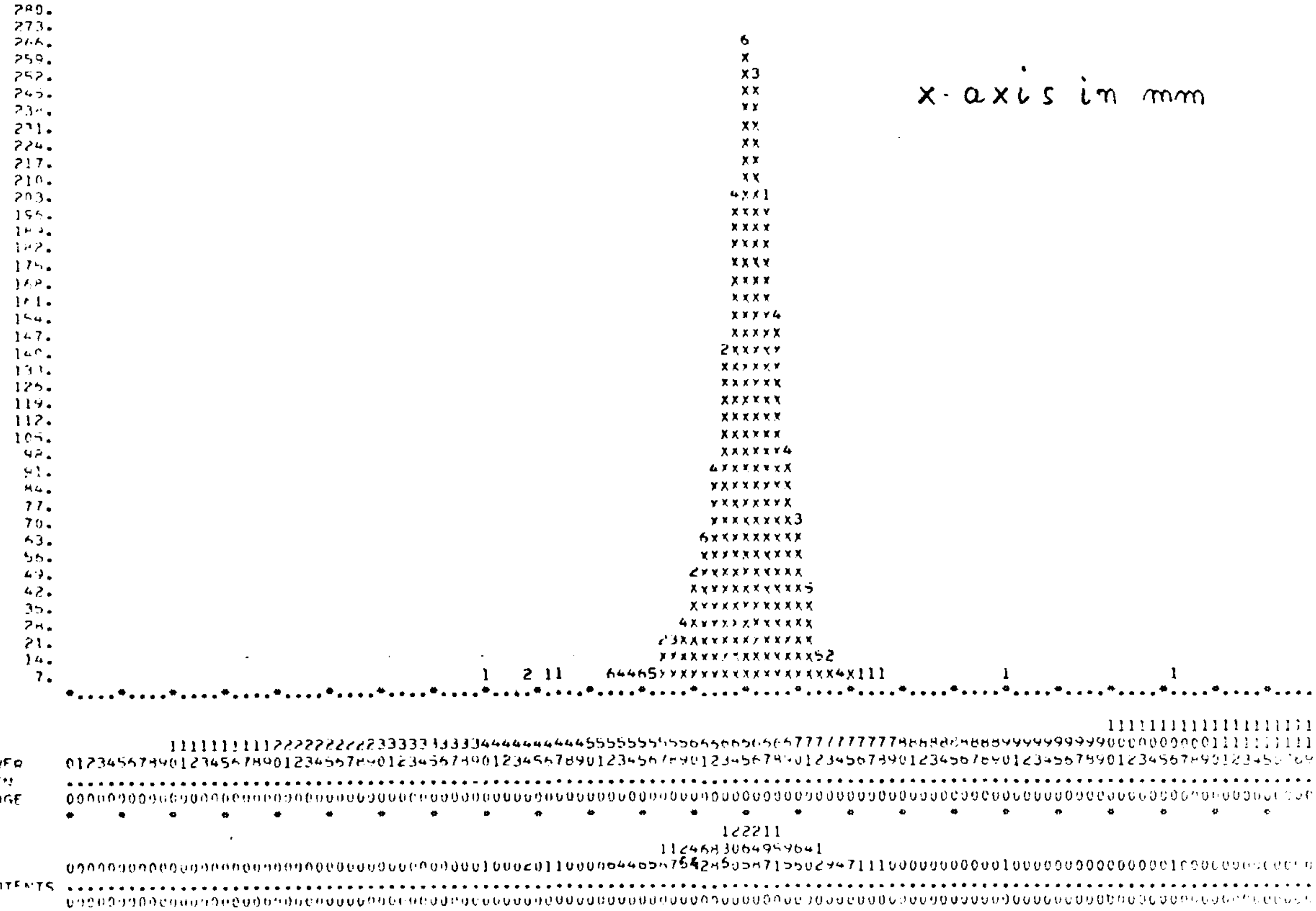

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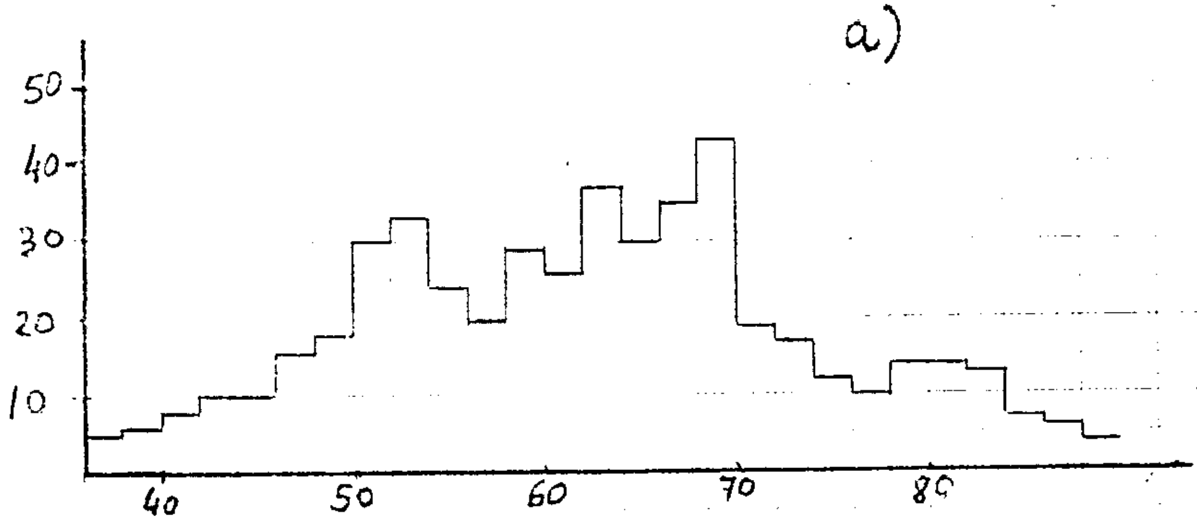
Fig 1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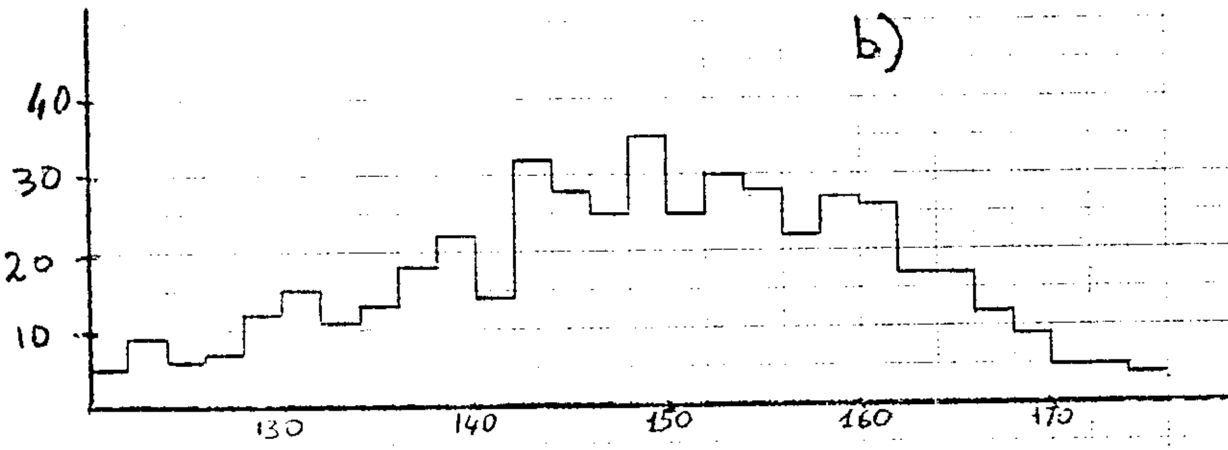
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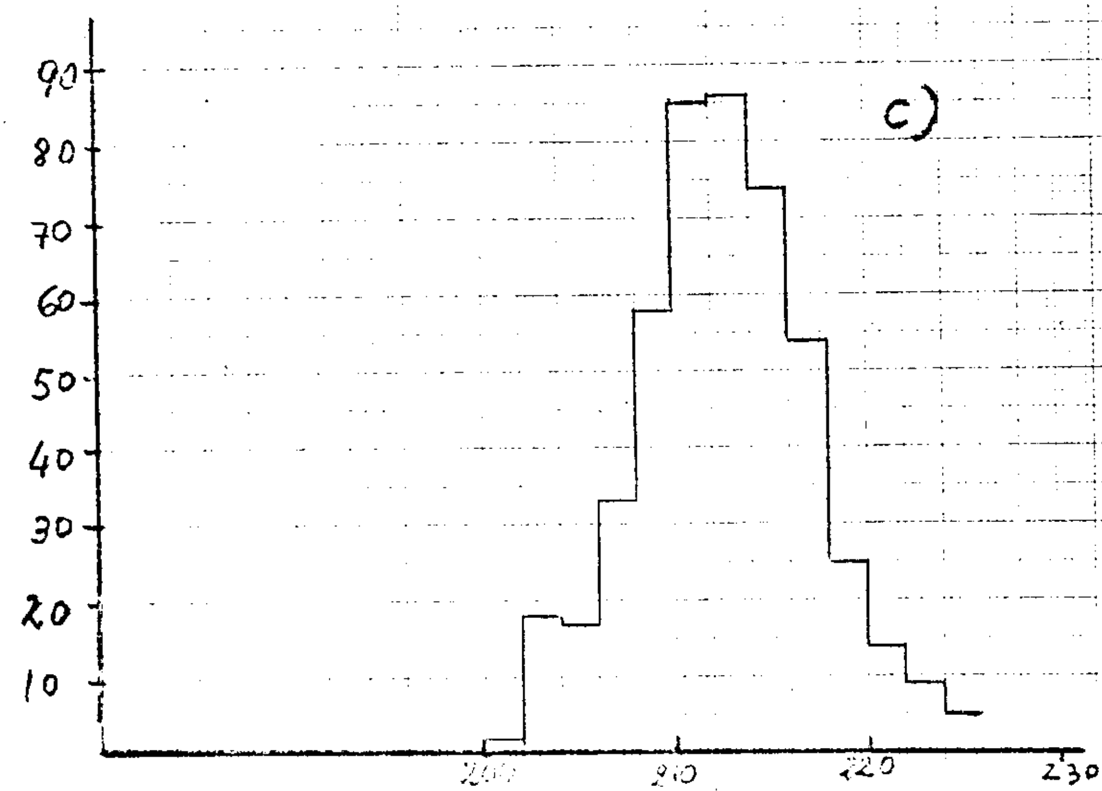
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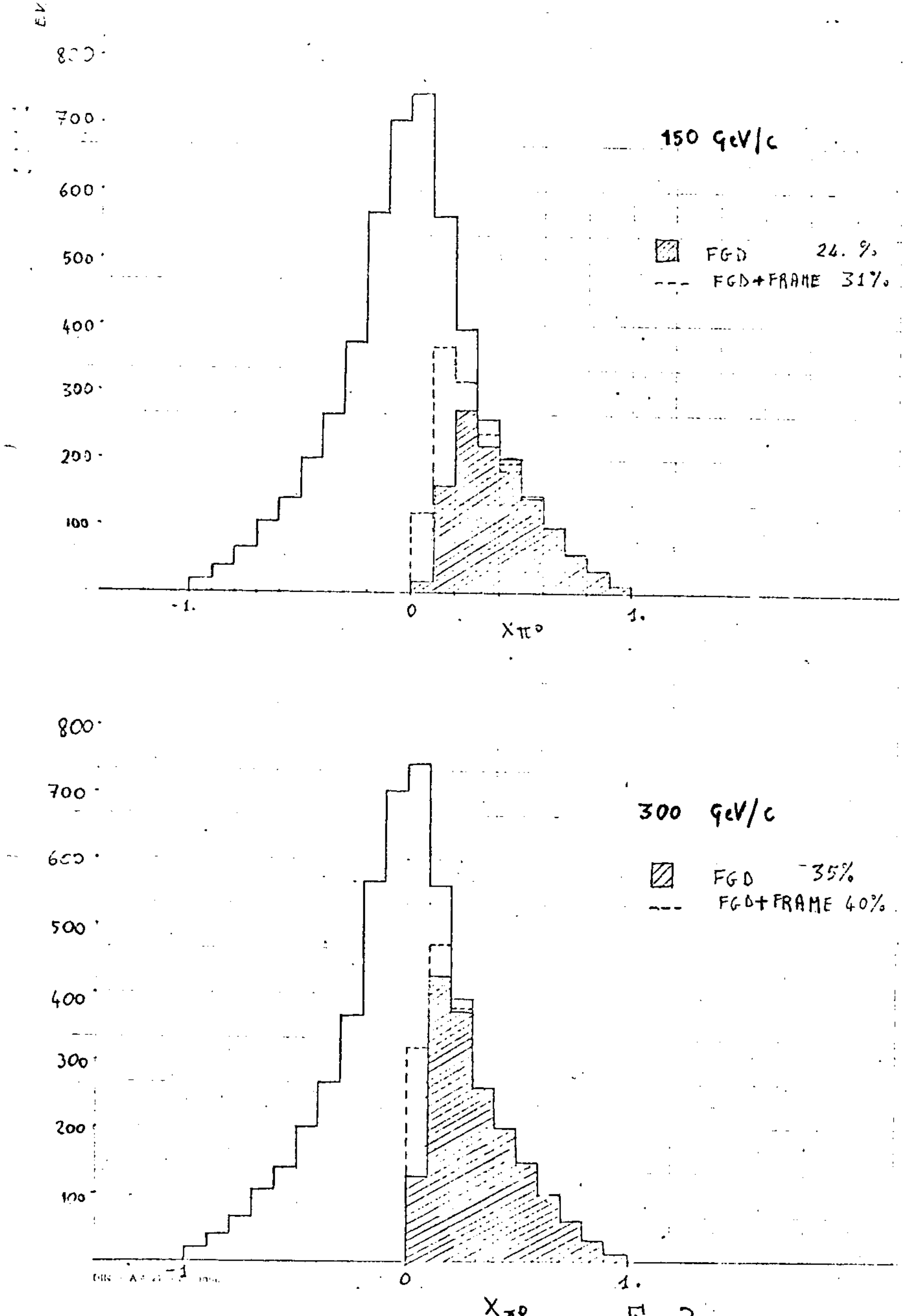

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300 GeV/c
FGD 35%
FGD+FRAME 40%
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