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F. Nessi-Tedaldi, M. Nessi, R. Stanek, A. Penzo and A.M. Zanetti:

SET-UP AND TRIGGER FOR THE MEASUREMENT OF THE INCLUSIVE PRODUCTION OF STRANGE PARTICLES IN THE E-704 TEVATRON EXPERIMENT

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SET-UP AND TRIGGER FOR THE MEASUREMENT OF THE INCLUSIVE PRODUCTION OF STRANGE PARTICLES IN THE E-704 TEVATRON EXPERIMENT

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Abstract

We have studied the criteria for selecting strange particles in the interactions of polarized protons produced at the Tevatron, for measuring spin effects at high energies.

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2) Argonne National Laboratory, Argonne

3) INFN, Sezione di Trieste

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1 Introduction

A polarized proton and antiproton beam around 200 Gev/c has been designed and constructed at Fermilab as a part of the Tevatron II program and successfully commissioned at the end of 1987 at a mean momentum of 185 Gev/c.
The polarized protons are obtained from the parity violating decay of Λ^0 produced when the primary beam of 1 Tev strikes a production target. A unique feature of this project is that an antiproton beam can be realized as well, using $\overline{\Lambda}^0$ instead of Λ^0 .

In the last years,high energy polarization esperiments could only be done with polarized targets or by measuring the polarization of the reaction products or with polarized beams up to the AGS energy, that is well below the Fermilab one.
The E581 polarized beam facility will allow to perform single spin experiments on an hydrogen target and to perform two spin experiments with the aid of a polarized target at the highest available energies.

The physics goals of experiment E704[1], that will make use of this polarized beam, are the measurement of $\Delta\sigma_L$, the total cross section difference in pure spin states, and the studies of the inclusive production of neutral pions around $x_F \cong 0$ and large p_T, of charged pions at large x_F, and of Λ^0 and Σ^0 at large x_F. These measurements will contribute to a better investigation in the framework of the physical problems already raised by the previous experimental results, that is:

- the origin of the polarization mechanism if pairs of quarks produced in strong interaction are polarized, as seems to be indicated by the polarization in hyperon production;
- implications for perturbative QCD of hard scattering, which predicts vanishing single spin effects, if the large asymmetries observed in π^0 production will persist at large p_T;
- mechanism of transmission of the spin to costituents in a transverse polarized proton and his effect as a function of x_F and p_T.

2 High energy spin effects

Measuring important spin effects at high energy implies a non trivial coincidence of specially favourable experimental conditions and the presence of interaction mechanisms responsible for spin dependence.

It is particularly significant that the most remarkable spin effects at the highest energies have been discovered in hyperon production since the first experiments with unpolarized beam of more then 10 years ago gave unexpected results. In hyperon production spin properties can be measured already without polarized beams or targets due to the self-analyzing power of parity-non-conserving decays.

In the last years a lot of inclusive reactions of hyperon production were studied showing that the produced particles are in most cases highly polarized and this behaviour turned out to be almost energy independent[2].

The presence of such big effects in inclusive reactions and their persistence at high energies were very unexpected because of the complexity of the events and it was considered very unlikely that the contribution from different channels would add up in such a way as to produce a large overall effect.

This experimental results seem to suggest that the processes can be simple at the level of constituents.

Unfortunately, no experiment as yet been able to reach a sufficiently high value of p_T to eventually question the validity of perturbative QCD. Therefore the understanding of the experimental situation has been so far mostly phenomenological and is based on simple parton recombination models[3].

In this framework it is important that the polarization mechanisms is better understood by measurements where the incoming particles are polarized, allowing to determine the analyzing power A and polarization transfer D in addition to the final hyperon polarization P[4].

The advent of the new high energy polarized proton beam at Fermilab provides a unique facility to perform experiments with a polarized beams at energies at least a factor ten greater than before.

3 Measurement criteria

The study of the inclusive production of Λ^0 and Σ^0 is a major part of the E704 experiment (fig.1).
Λ^0 decays in p e π^- with a branching fraction of 64% and Σ^0 decays almost exclusively in Λ^0 and γ. The γ coming from the Σ^0 is detected by the lead glass placed very far downstream from the target. Both the Λ^0 coming from interactions in the target and the ones from Σ^0 decay are revealed by the measurement of the decay products for the process $\Lambda^0 \rightarrow p\pi^-$, with the aid of MWPCs and hodoscopes positioned both upstream and downstream of the spectrometer magnet.
The basic criteria to identify Λ^0 are the following[5]:

- precise definition of the direction of incoming polarized protons and their transverse impact position at the target using the beam defining hodoscopes (the same used for $\Delta\sigma_L$ measurement);

  detection of the Λ^0 decay products through hodoscope coincidences taking advantage from the magnet bend to separate proton from pion allowing to realize a quite powerful two-arm trigger.
  The proton and π^- are measured separately by checking if the hit pattern on the hodoscopes is allowed by kinematics and if it corresponds to the events we are interested in. This is realized by storing in MLUs the information of the hit pattern we want to retain.
  It has to be remarked that the recognition of the decay products takes place in a region sufficiently remote from the target in such a way that the local multiplicity is low (lower energy particles have been swept away by the magnetic field);

- vertex finding, using the fast processor ESOP[6] that reads all the relevant informations from the MWPC readout system and after defining candidate tracks extrapolates them to the decay region in order to check for a neutral decay vertex. An active filter for non-decaying particles checks if the detected tracks come directly from the target or not. Reconstruction of event topology checking momentum correlation of proton and pion could also be used with the aid of a second processor;

- multiplicity jump in two multistrip semiconductor detectors (MSD), defining the decay region. The number of hit elements plus the pulse amplitude of the single strips would allow to distinguish all the particles despite the high multiplicity of particles present in this part of the apparatus.

Vertex finding, event topology, multiplicity jump, non-decaying particles filter could be implemented as a second level trigger, strobed by the fast first level hodoscopes trigger. The level of sophistication of these selection criteria will be matched to the real complication of the events to be discriminated.

4 E-704 setup

The incoming beam is defined by the hodoscopes HB1 and HB2 at the trigger level and by a set of MWPC and MSD. The MSD upstream the target are used to define the proton track and the impact parameter with high precision.

The snake magnets flip frequently the spin of the proton beam from up to down in these measurements and in association with the tagging information will define the actual spin direction at the target.

A LH_2 target will be initially used thus extending the previous hyperon production measurements performed with unpolarized beams. Subsequentely data will be taken with polarized targets as well, for studying polarization correlation parameters.

It has been chosen to accept Λ^0's that decay in the region between PC1 and PC2 where a vacuum tube is placed to minimize the number of interactions that could fake the secondary vertex of Λ^0 decay.

Almost all the MWPC's in front of the magnet have 4 coordinate planes and the smaller ones have 1 mm wire spacing to be able to deal with the high multiplicity of charged particles of this part of the apparatus.

The BM109 magnet has a field of approximately 14 KG and is used to magnetically analyze the p and π^- coming from the Λ^0 decay.

The p and π^- are measured by chamber telescopes in front and after the magnet as well as hodoscopes for trigger purposes.

The Čerenkov information can be used as a tag to eventually reject in the off-line analysis events with pions going through the $\check{C}$ and giving therefore a signal.

The γ from Σ^0 decay are detected by LG_{Σ^0}. The calorimeter has two sequential sections: upstream is a set of 124 lead glass modules (6.35 cm x 6.35 cm) which provides the necessary position resolution; downstream is a lead-scintillator sandwich.

5 Monte-carlo calculations

Monte Carlo studies were done to look for correlations between the position of the p and π^-,coming from the Λ^0 decay, in different X-Y planes along the apparatus[7].

The guiding idea is that a tight correlation would mean that they could be accepted with a trigger which selects a small fraction of phase space and presumably accepts much less background than a simple loose trigger.

The studies were carried out generating Λ^0 with a uniform distribution for x_F and p_T in the kinematical region we are interested in, that is for $0.5 \leq x_F \leq 0.8$ and for $0.15 \leq p_T \leq 1.35$ Gev/c. Furthermore it was decided to generate Λ^0 with $-30° \leq \phi \leq 30°$ and $150° \leq \phi \leq 210°$ to optimize the acceptance of the apparatus and the efficiency of the trigger for this region.

Outside this region the higher p_T events are intercepted by the magnet and a bigger acceptance for small p_T events, that have anyway a big cross section, is not important for our purposes.

To have a more clear situation the Λ^0 produced with $-30° \leq \phi \leq 30°$ and the ones with $150° \leq \phi \leq 210°$ were treated separatly; these events correspond to Λ^0 going to the left and to the right of the beam, respectively, looking downsteam. The reason for this way of proceeding is that the apparatus is not right-left symmetrical and furthermore the non-interacting beam protons strike part of the region where the protons, coming from Λ^0 produced to the left, go but they do not interfere with the protons coming from Λ^0 produced to the right. Looking just for Λ^0 going to the right is not a limitation for our measurement but it would be nice to detect as many as possible of the other events to increase the statistics.

In fig. 2 the X and Y position of the protons and pions before the magnet in PC2 and in H2, after the magnet in H3 and H4 and in the back at H5 for the Λ^0 right produced are shown. From these plots it's clear that the spectrometer magnet is able to separate the protons from the pions at H4 although not completely for the smallest p_T. The geometrical acceptance in p_T and x_F for the generated events is essentially only limited by the requirement that the Λ^0 decays in the region between PC1 and PC2 and as shown in fig. 3 this amounts to more or less 25% of the decays.

Due to the fact that the magnetic field is in the Y direction, the important coordinate for our studies is the X coordinate of the proton and the pion.

A variety of two-dimensional correlation histograms between p and p, π^- and π^- and p and π^- X-coordinate were considered. It is worth to remark that the hodoscopes at the downsteam position (hod. H5) was a good place to start our investigation since at this point the protons are best magnetically analized and pions below roughly 100 Gev/c momentum don't get there at all due to the sweeping by the spectrometer magnet.

A nice correlation between the proton X-position in H2 and the proton X-position in H5 was found (fig. 4). This, anyway, just reflects the information about the kinematics of the proton; we also would like to extract in some way the kinematical correlations due to the Λ^0 decay. Besides, at the level of H2 the multiplicity and the density of charged particles is quite high. The correlation between the pion before the Č (at H4 hodoscope) and the proton in H5 (fig. 5) was the best we have found using only two detectors; on the other end, this correlation is not tight if the Λ^0 were accepted over the whole range of p_T considered.

We guessed that having a three way correlation between different quantities, which can carry more kinematical information, might help. The method for searching three-way correlations was as follow: bins of 14 cm at H5 (physical segmentation of H5), looking for the protons away from other particles, were used to cut the data: two dimensional plots of the other possibly correlated variables were made for each of these cut bins. The only significant improvement respect to the simple

H5-H4 correlation for p and π^- ,was the correlation between the pion right after the magnet (H3 hodoscope) and the pion at H4 (fig. 6). Even if the correlation is not so tight, the regions selected by the pion in these plots for protons reaching different bins in H5 do not overlap completely (fig. 7), this meaning that a trigger using this information would reduce more the accepted phase space.
So we plan to implement a Λ^0 trigger with the vertical hodoscopes, using:
-a three-fold correlation of the single elements of: 1) back hodoscope H5, 2) hodoscope H4 before the Č with 10 cm segmentation, 3) hodoscope at H3 right after the magnet with 5 cm segmentation;
-a two-fold coincidence of the single elements of H5 and H2 to implement the correlation shown before between the proton positions at this hodoscopes.

It has been searched for geometrical correlation for the Y-coordinates of the particles as well, for which there is basically no influence due to the magnetic field.
A good correlation for the proton in H2 and in H5 (fig. 8) and for selected bins in H5 of 14 cm was found again and it was seen that something can be gained looking at the Y-position of the pions in H4; the distribution is such that the pions slightly shifts when looking to proton in different H5 hodoscopes elements.
It is thus also possible to implement this informations as well with a trigger using horizontal hodoscopes.

6 Trigger

The three-way correlation explained in the previous section doesn' t seem to be very strong and so it is not clear if the advantages we gain with this trigger scheme are worth the complicated trigger implementation with a big number of MLU's that it would require. This would obviously depend from the background characteristics and from the multiplicity is necessary to handle downstream the BM109 magnet. From preliminary background simulation the situation seems not to be very critical. So it is appealing to work out a simpler trigger using the corripondent global correlation.

Two separate triggers for right or left produced Λ^0's are been foreseen. The detailed trigger scheme for Λ^0's to the right is the following (figure 9):

- multiplicity requirements in the different hodoscopes are used, together with the "GOODBEAM" to strobe the PLU's and the MLU's. It is produced running the LeCroy 4413 discriminator current sum output through a discriminator. For H5 this is realized running all the elements into a Multiplicity Logic unit, using its Analog Summing Output. At least 2 hits in hodoscopes H3 and H4 and at least one hit in H5 are required;
- parallel processing of the hodoscopes outputs through MLU's to implement the following correlation:
  - correlation between hodoscope elements to the right of the beam can allow the selection of a rather stiff positive charged particle. This correlation practically allows to select high x_F events, since a fast proton corresponds to a fast Λ^0. The correlation between elements in H4 and elements in H5 (fig. 10) shows a particularly high slope and requires correspondences between few elements of each hodoscope; it has also the advantage to involve only hodoscopes not affected by high multiplicity. It can be implemented using 9 elements of H4 and 8 elements of H5 with the aid of two MLU's;
  - the correlation between hodoscope H3 and H4 (Fig.6) for pions. It allows to require a negative charged particle in the event and to match the distributions of pions emerging from Λ^0 decays. It is realized with two MLU's using 8 elements of H3 and 8 elements of H4. Correlation between pions in H4 and H5 (fig. 11) can be significant as well and could be implemented provided the H5 hodoscope has sufficient elements to cover all the interesting region on the pion side;
  - a correlation between π^- in H4 and p in H5 (Fig. 5), that contains the most of the information about the structure of the Λ^0 decay. Due to the strong dependence on x_F and p_T, this correlation appears to be looser than the others, but it can also contribute to a better suppression of background events.

It can be realized with the encoded elements of hodoscope H5 (4 bits) and 8 elements in H4 as input of an MLU.

7 Conclusions

The extensive work carried out either on the optimization of the experimental setup and on the trigger side makes us confident to have developped a good system for measuring spin effects in hyperon production. The performance of the first level trigger discussed in the previous section has been tested using a background produced as minimum bias events with ISAJET. Detailed tests are in progress, but a global background suppression of 95% has already been proven, which is a very good result for this kind of scheme.
Furthermore the crucial values of the charged particles multiplicity at different Z-position have also been investigated. We observe that after the analysing magnet the multiplicity is reduced to an average of 3 (fig. 12). This result is also important for a good performance of such a trigger, based on correlations between different hodoscope elements. This basic trigger configuration will be followed by more refined selection hardware as described in section 3.

References

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   A. M. Zanetti and D. Underwood, " Studies of a possible Λ^0 trigger", (July 1985).

FIGURE CAPTIONS

Figure 1: *Basic setup for the E704 experiment.*

Figure 2: *Y-coordinate versus X-coordinate of p and π^- for right produced Λ^0's at various detectors along the apparatus. a) p and π^- in PC2 and H2: b) p and π^- in H3 and H4; c) p and π^- in H5.*

Figure 3: *Geometrical acceptance normalized over the original distribution as a function of p_T and x_F.*

Figure 4: *Correlation plots for right and left produced Λ^0's: proton X-coordinate in H2 versus proton X-coordinate in H5.*

Figure 5: *Correlation plot for right produced Λ^0's: pion X-coordinate in H4 versus proton X-coordinate in H5.*

Figure 6: *Correlation plot for right produced Λ^0's: pion X-coordinate in H4 versus pion X-coordinate in H3.*

Figure 7: *Separate correlation plots for right produced Λ^0's for proton hitting the H5 hodoscope within a certain X band: pion X-coordinate in H4 versus pion X-coordinate in H3.*

Figure 8: *Correlation plots for right produced Λ^0's: pion Y-coordinate in H4 versus pion Y-coordinate in H3 and proton Y-coordinate in H5 versus proton Y-coordinate in H3.*

Figure 9: *Λ^0 trigger scheme.*

Figure 10: *Correlation plot for right produced Λ^0's: proton X-coordinate in H4 versus proton X-coordinate in H5.*

Figure 11: *Correlation plot for right produced Λ^0's: pion X-coordinate in H4 versus pion X-coordinate in H5.*

Figure 12: *a) Particle multiplicity at various MWPC positions along the apparatus: b) Particle multiplicity versus x_F for the Λ^0's accepted by the trigger.*

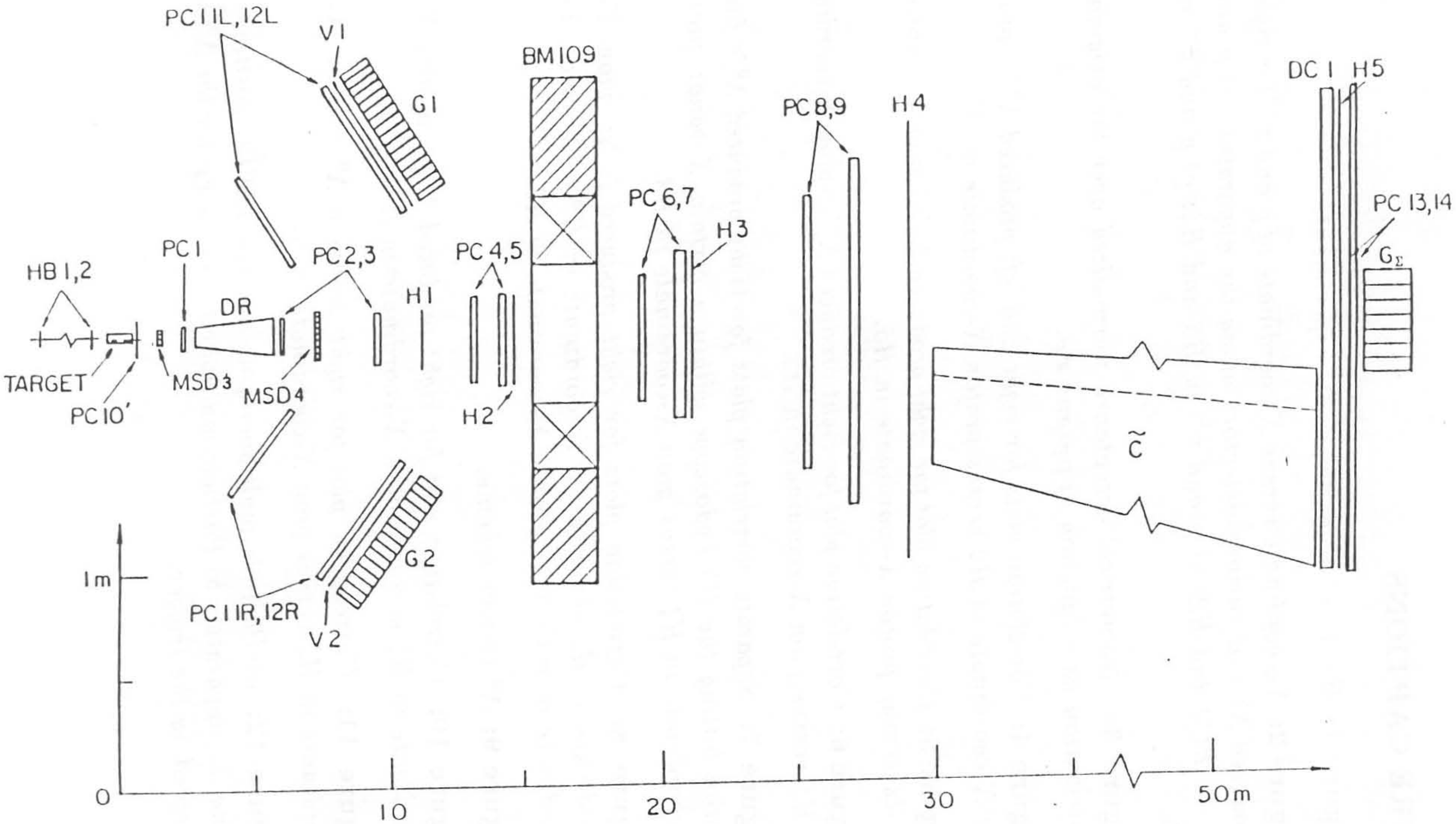

PC 11L, 12L
V1
G1
BM109
DC 1
H5
PC 8,9
H 4
PC 13,14
PC 6,7
H3
G_{Σ}
PC 1
PC 2,3
PC 4,5
HB 1,2
DR
H1
TARGET
PC 10′
MSD 3
MSD 4
H2
$\tilde{C}$
1m
G 2
PC 11R, 12R
V 2
0
10
20
30
50m

Fig. 1

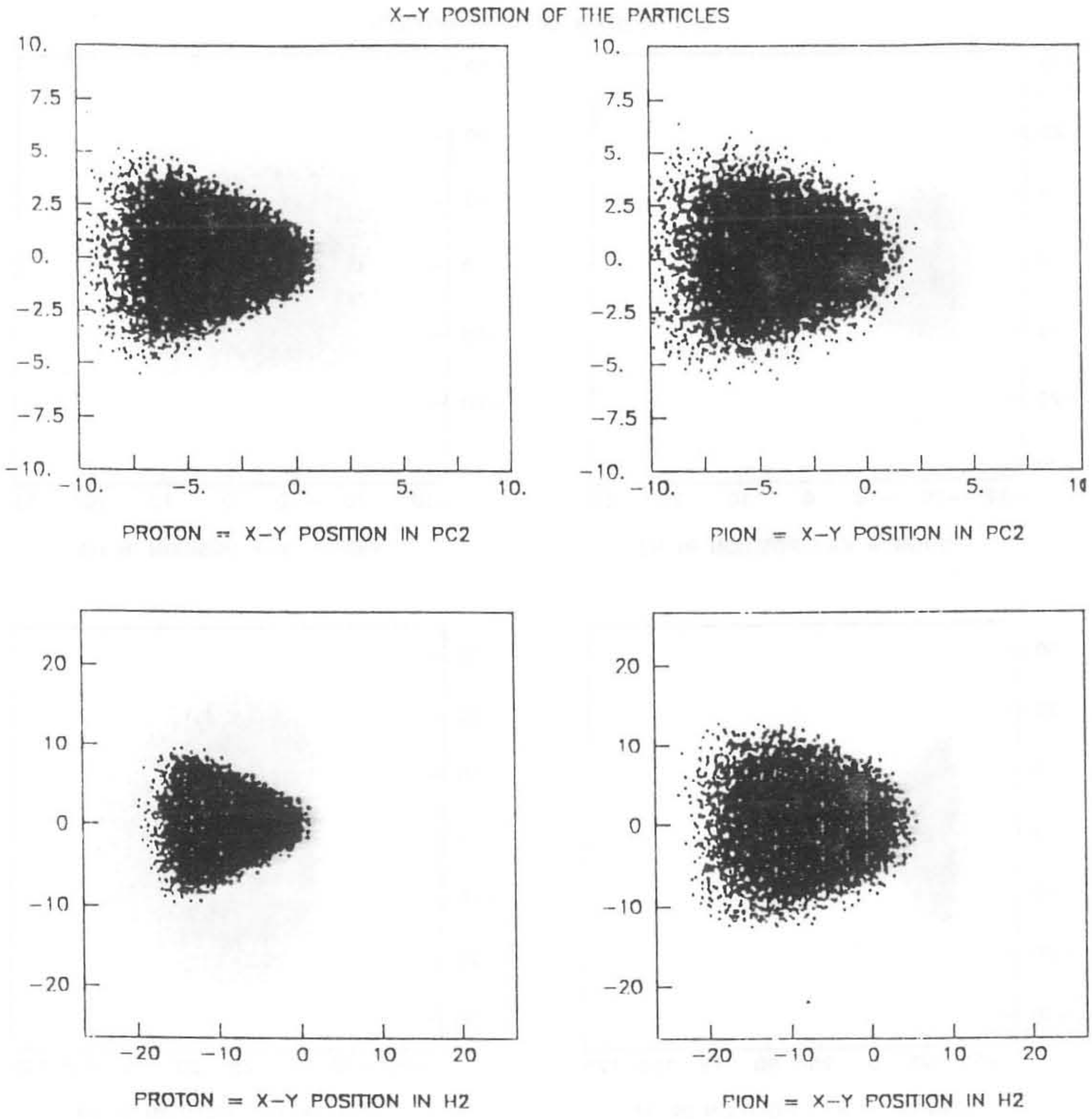

X–Y POSITION OF THE PARTICLES
PROTON = X–Y POSITION IN PC2
PION = X–Y POSITION IN PC2
PROTON = X–Y POSITION IN H2
PION = X–Y POSITION IN H2

Fig. 2a

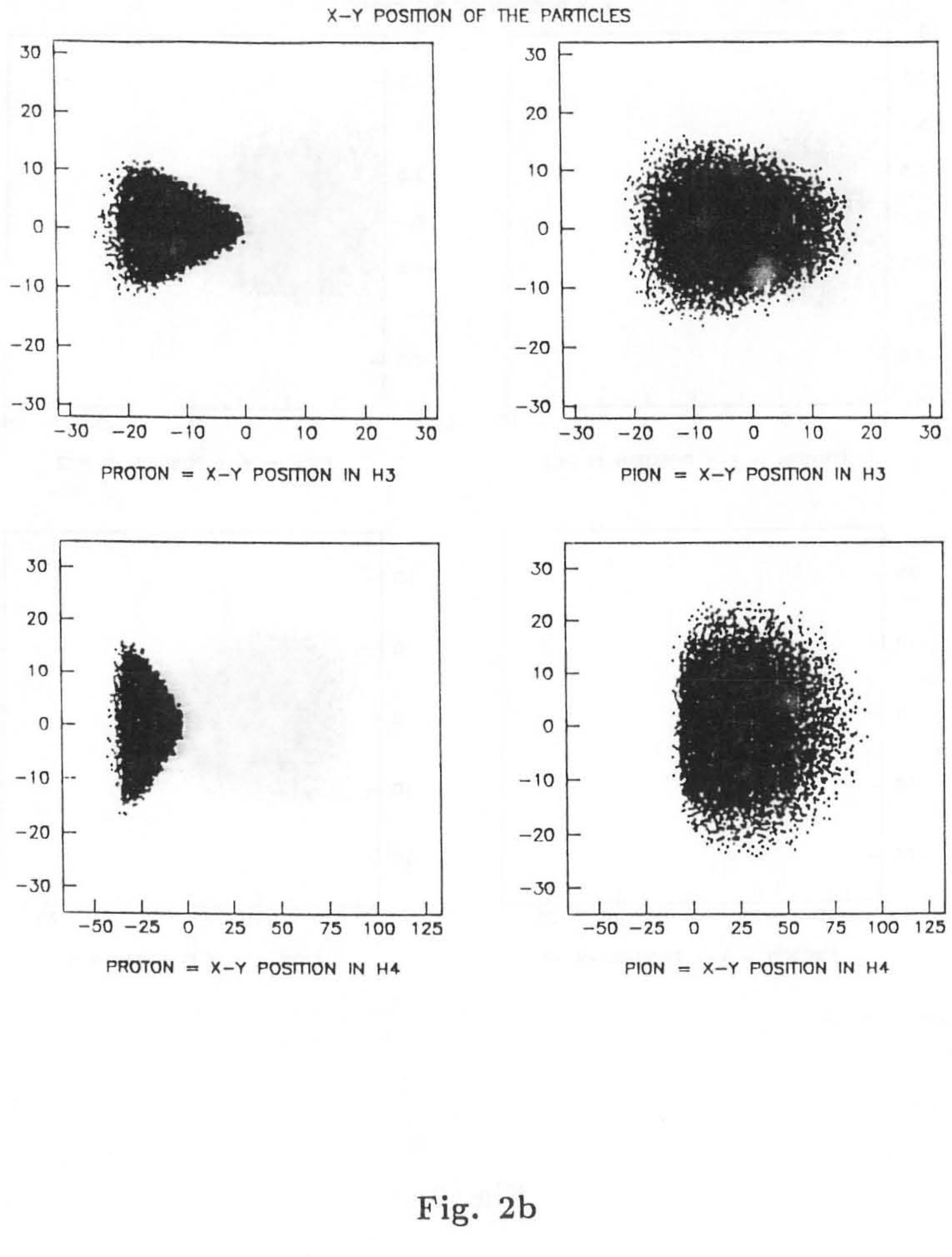

X–Y POSITION OF THE PARTICLES
PROTON = X–Y POSITION IN H3
PION = X–Y POSITION IN H3
PROTON = X–Y POSITION IN H4
PION = X–Y POSITION IN H4

Fig. 2b

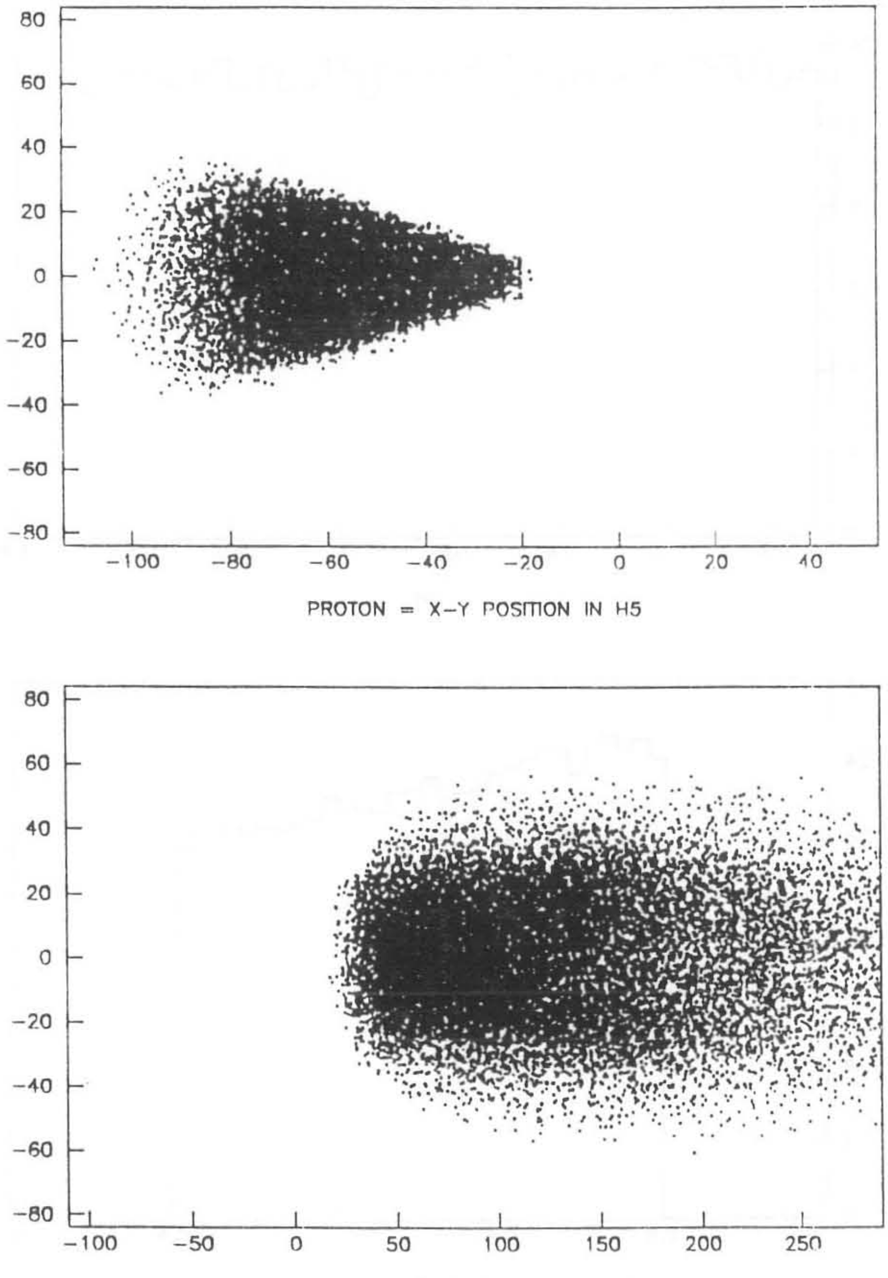

80
60
40
20
0
-20
-40
-60
-80
-100
-80
-60
-40
-20
0
20
40
PROTON = X-Y POSITION IN H5
80
60
40
20
0
-20
-40
-60
-80
-100
-50
0
50
100
150
200
250
PION = X-Y POSITION IN H5

Fig. 2c

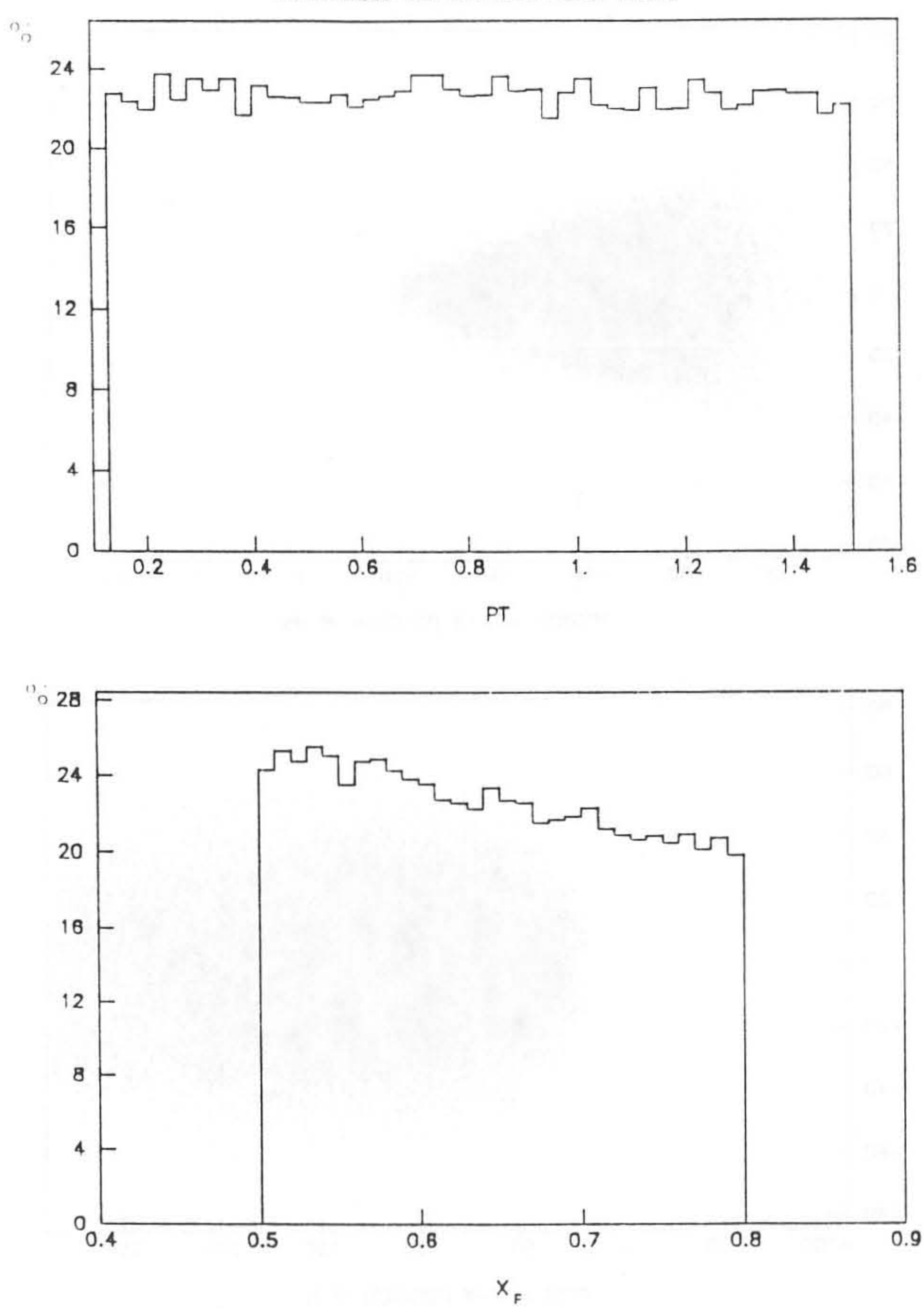

NORMALIZED GEOMETRICAL ACCEPTANCE
%
24
20
16
12
8
4
0
0.2
0.4
0.6
0.8
1.
1.2
1.4
1.6
PT
%
28
24
20
16
12
8
4
0
0.4
0.5
0.6
0.7
0.8
0.9
X_F

Fig. 3

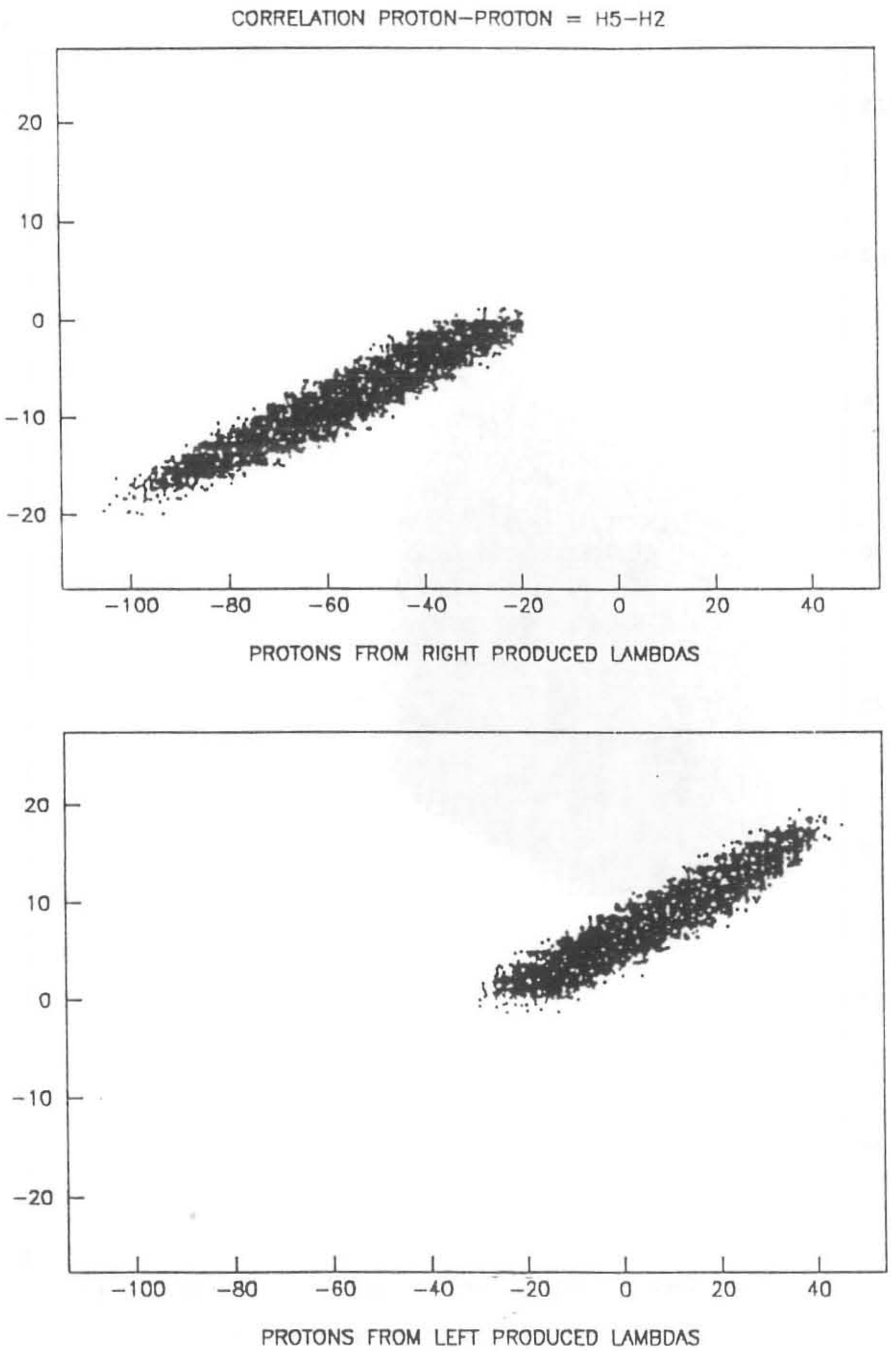
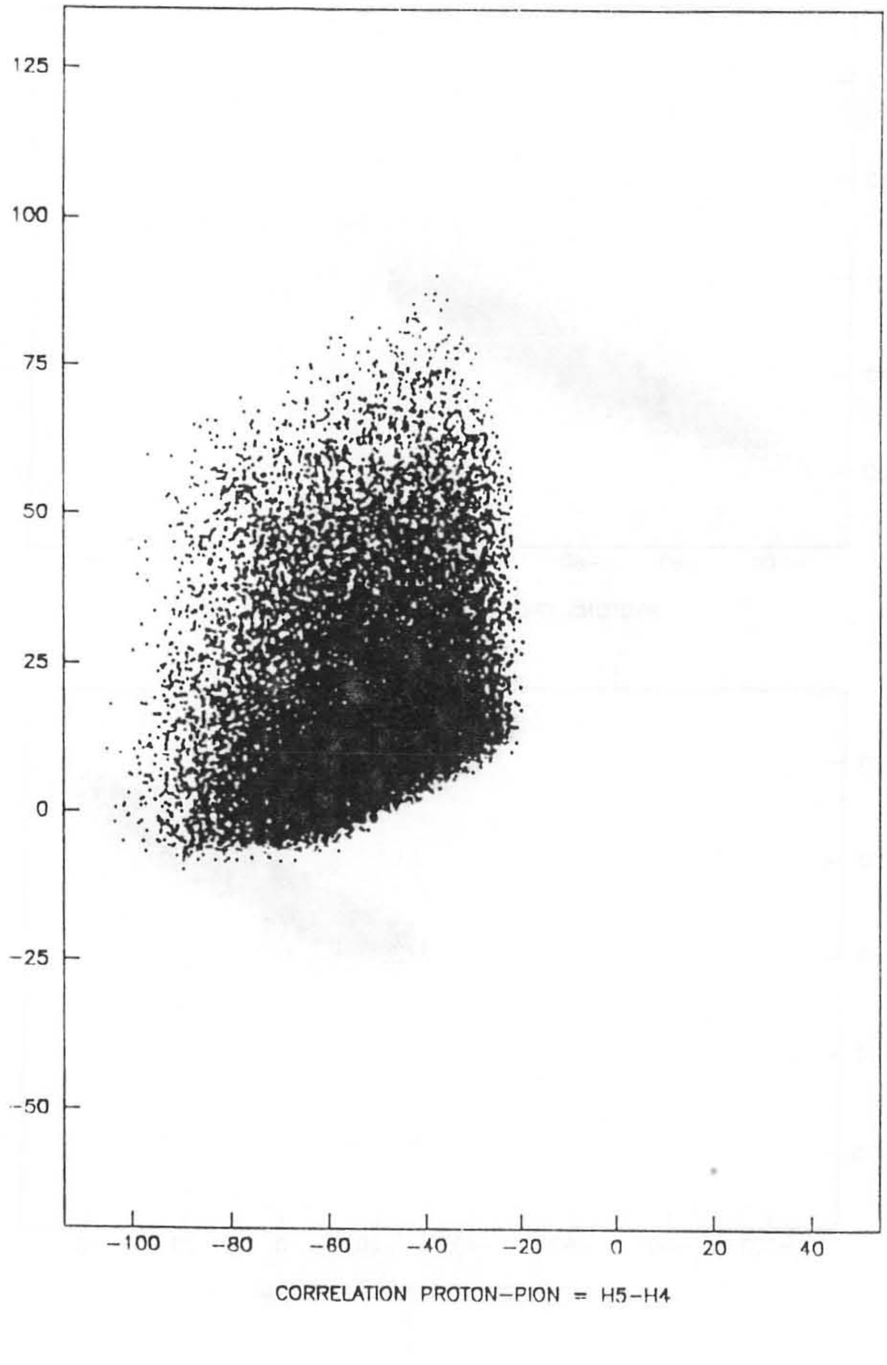

CORRELATION PROTON-PROTON = H5-H2
20
10
0
-10
-20
-100
-80
-60
-40
-20
0
20
40
PROTONS FROM RIGHT PRODUCED LAMBDAS
PROTONS FROM LEFT PRODUCED LAMBDAS

Fig. 4


125
100
75
50
25
0
-25
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-100
-80
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-40
-20
0
20
40
CORRELATION PROTON-PION = H5-H4

Fig. 5

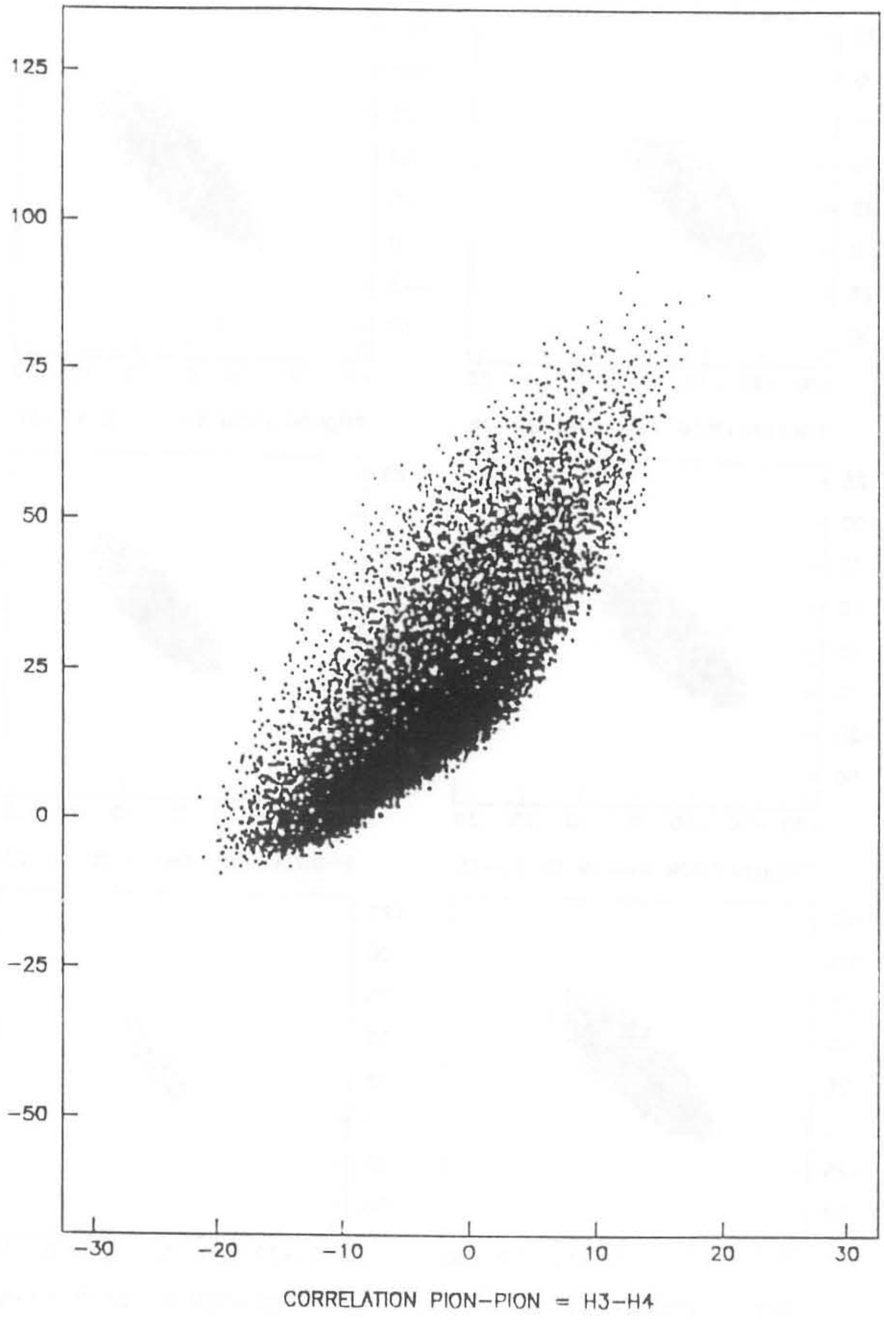

125
100
75
50
25
0
−25
−50
−30
−20
−10
0
10
20
30
CORRELATION PION−PION = H3−H4

Fig. 6

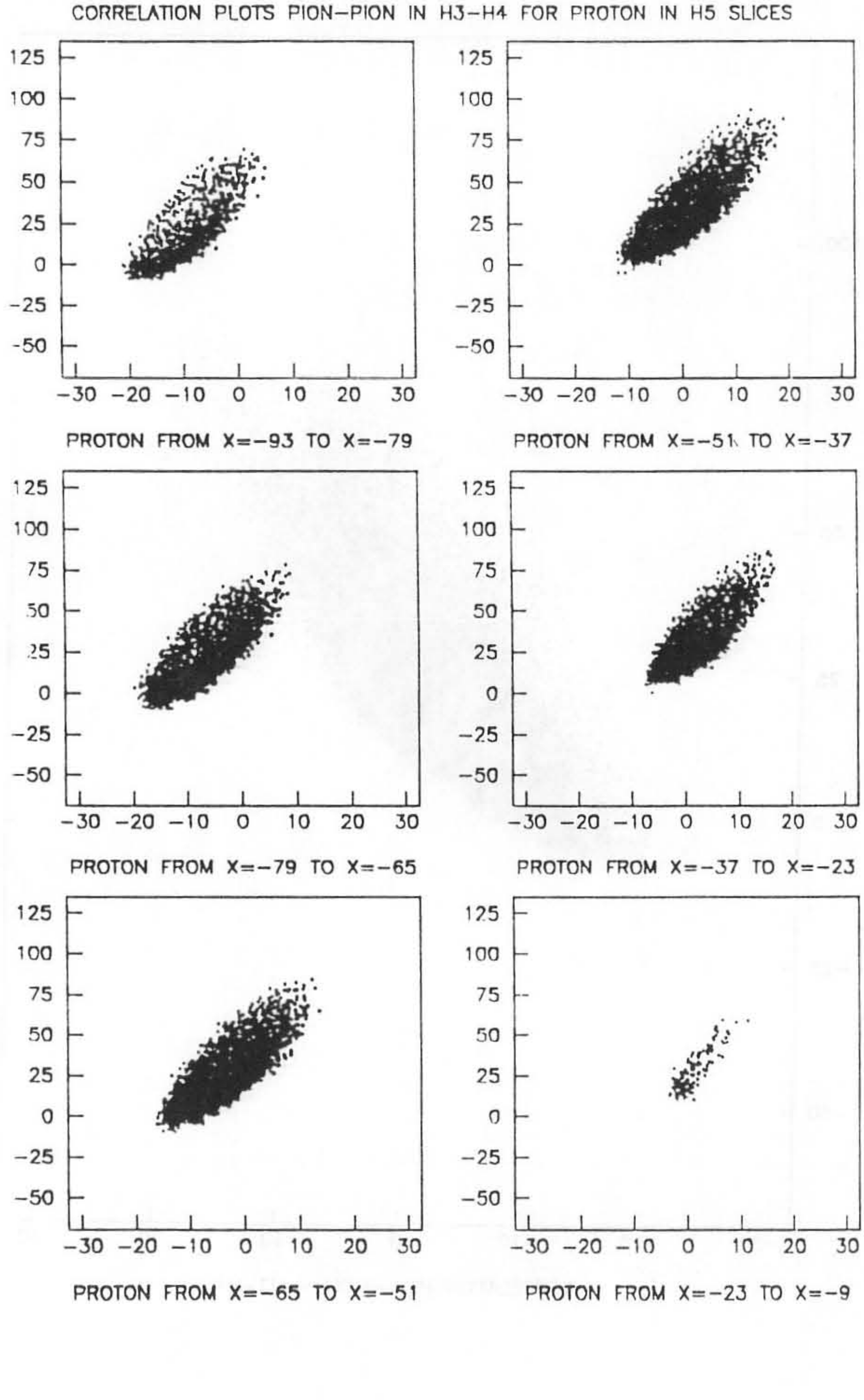

CORRELATION PLOTS PION–PION IN H3–H4 FOR PROTON IN H5 SLICES
PROTON FROM X=–93 TO X=–79
PROTON FROM X=–51 TO X=–37
PROTON FROM X=–79 TO X=–65
PROTON FROM X=–37 TO X=–23
PROTON FROM X=–65 TO X=–51
PROTON FROM X=–23 TO X=–9

Fig. 7

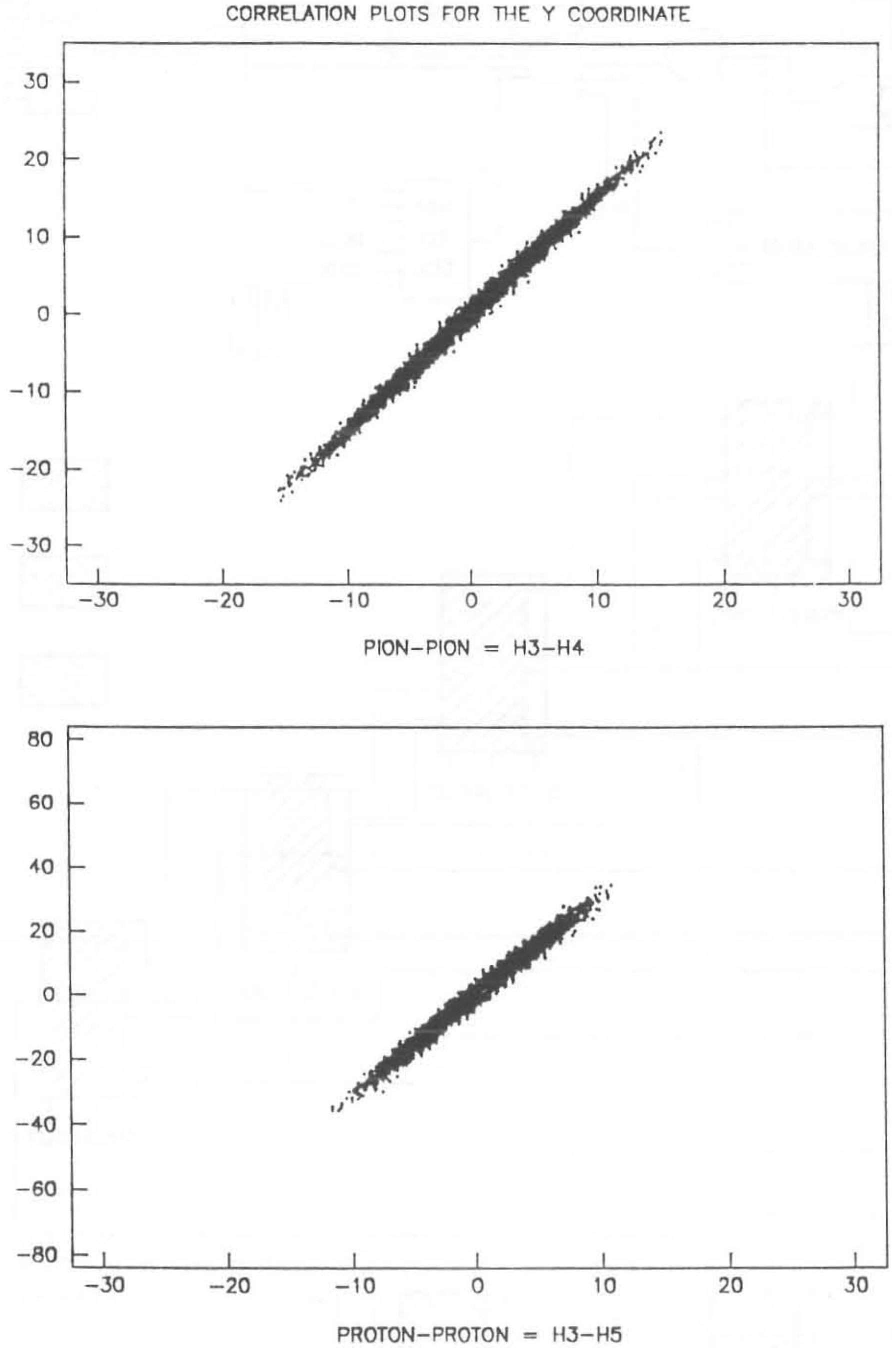

CORRELATION PLOTS FOR THE Y COORDINATE
30
20
10
0
−10
−20
−30
−30
−20
−10
0
10
20
30
PION−PION = H3−H4
80
60
40
20
0
−20
−40
−60
−80
−30
−20
−10
0
10
20
30
PROTON−PROTON = H3−H5

Fig. 8

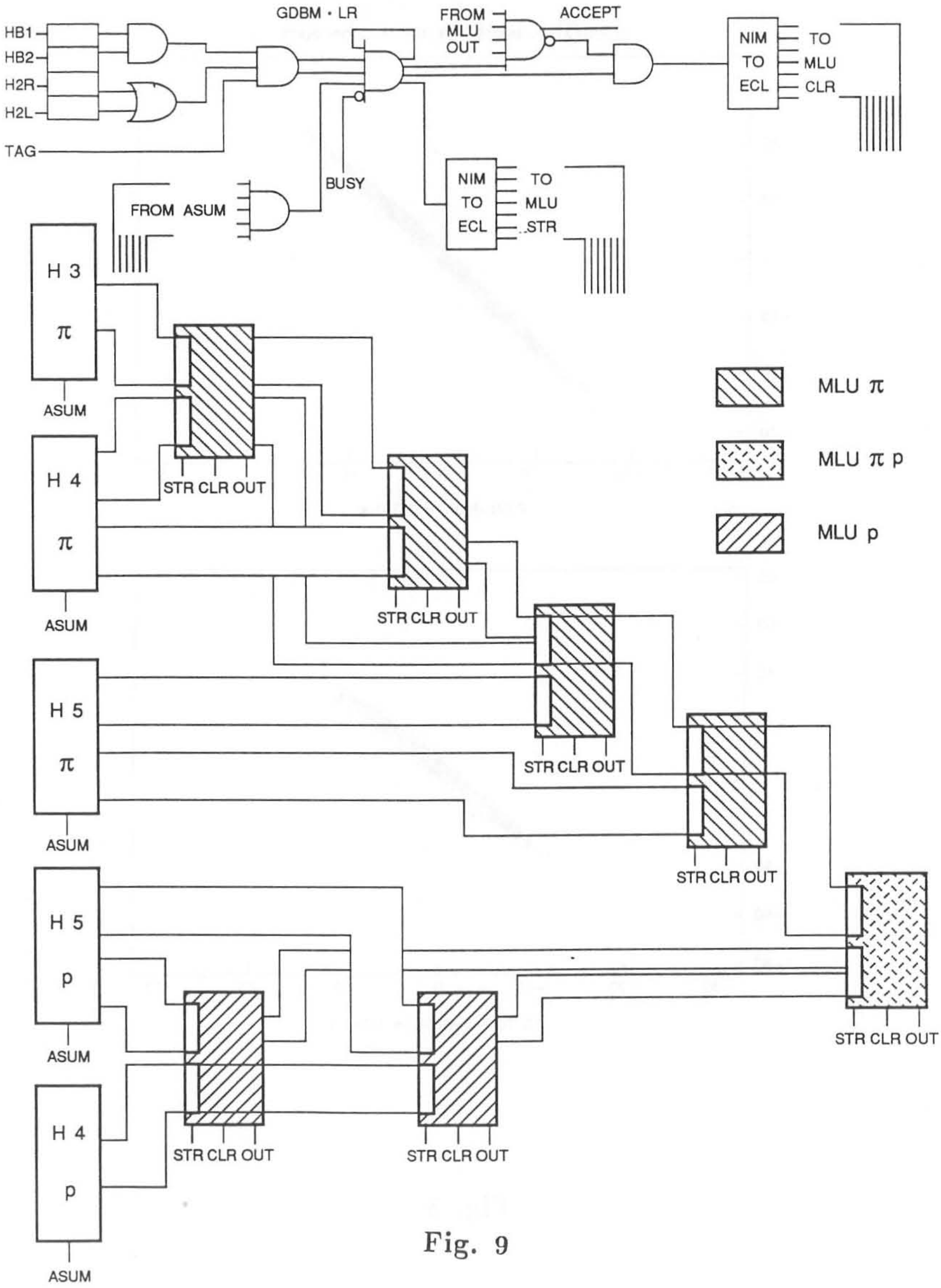
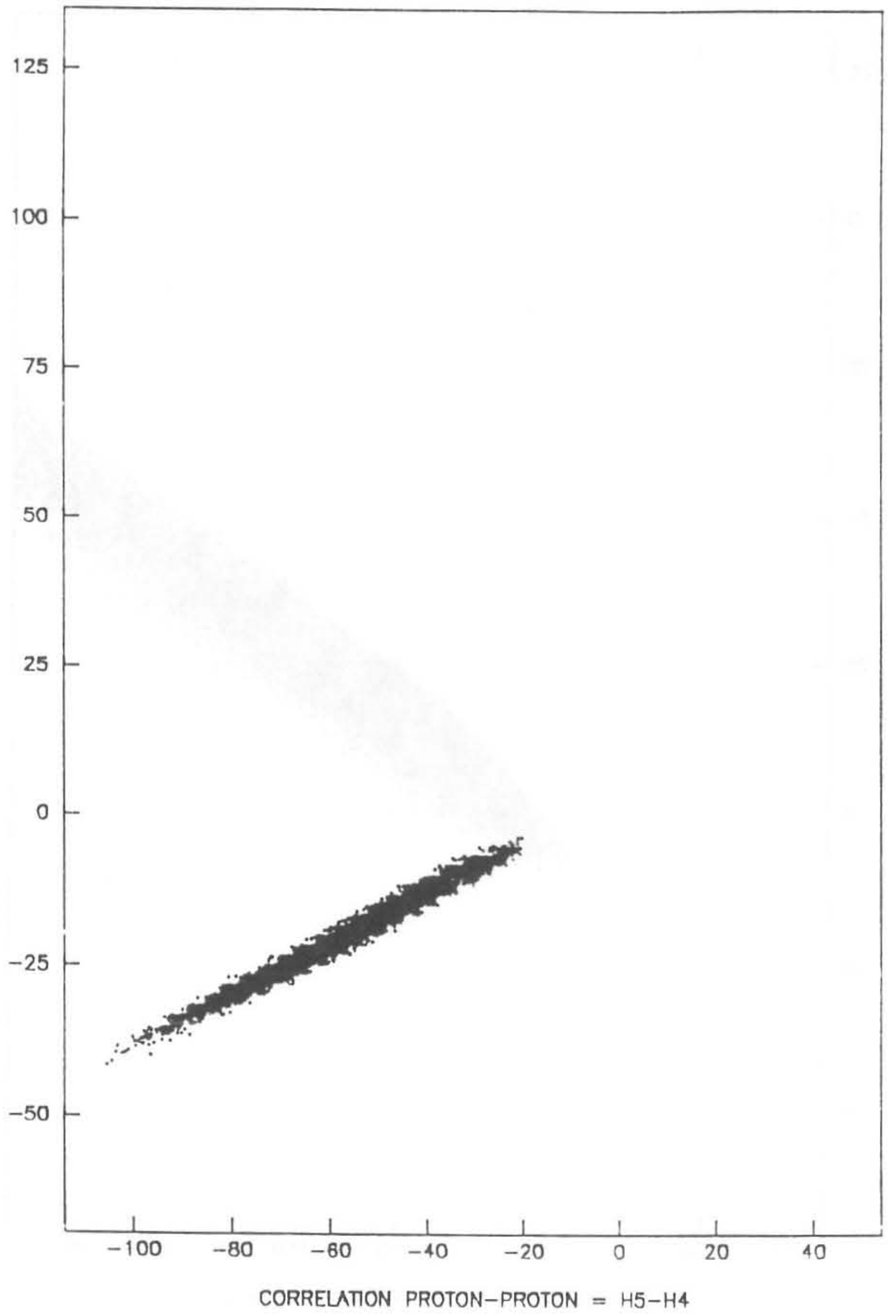
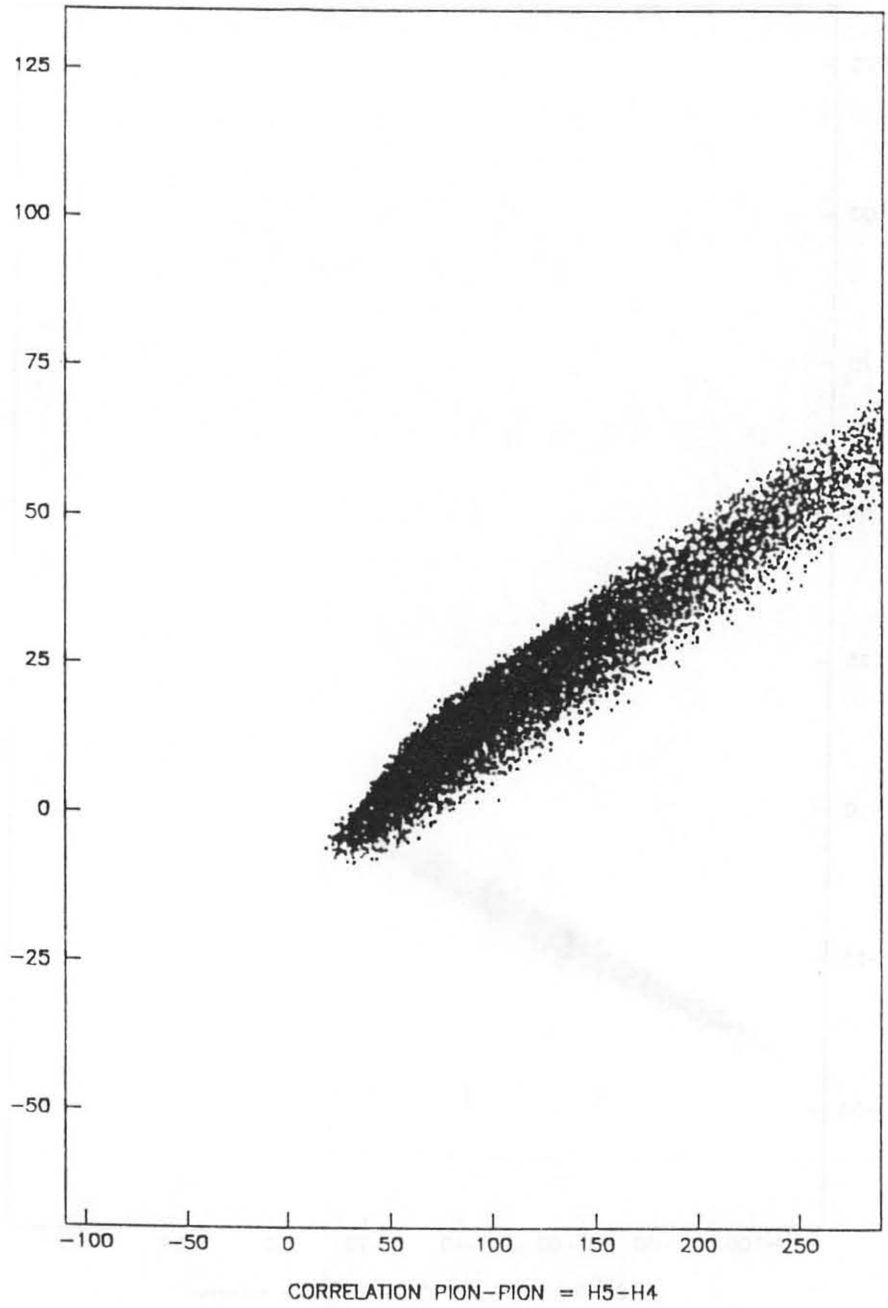

HB1
HB2
H2R
H2L
TAG
GDBM · LR
BUSY
FROM MLU OUT
ACCEPT
NIM TO ECL
TO MLU CLR
FROM ASUM
NIM TO ECL
TO MLU STR
H 3 π
ASUM
H 4 π
ASUM
H 5 π
ASUM
H 5 p
ASUM
H 4 p
ASUM
STR CLR OUT
MLU π
MLU π p
MLU p

Fig. 9



125
100
75
50
25
0
−25
−50
−100
−80
−60
−40
−20
0
20
40
CORRELATION PROTON−PROTON = H5−H4

Fig. 10


125
100
75
50
25
0
-25
-50
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0
50
100
150
200
250
CORRELATION PION-PION = H5-H4

Fig. 11

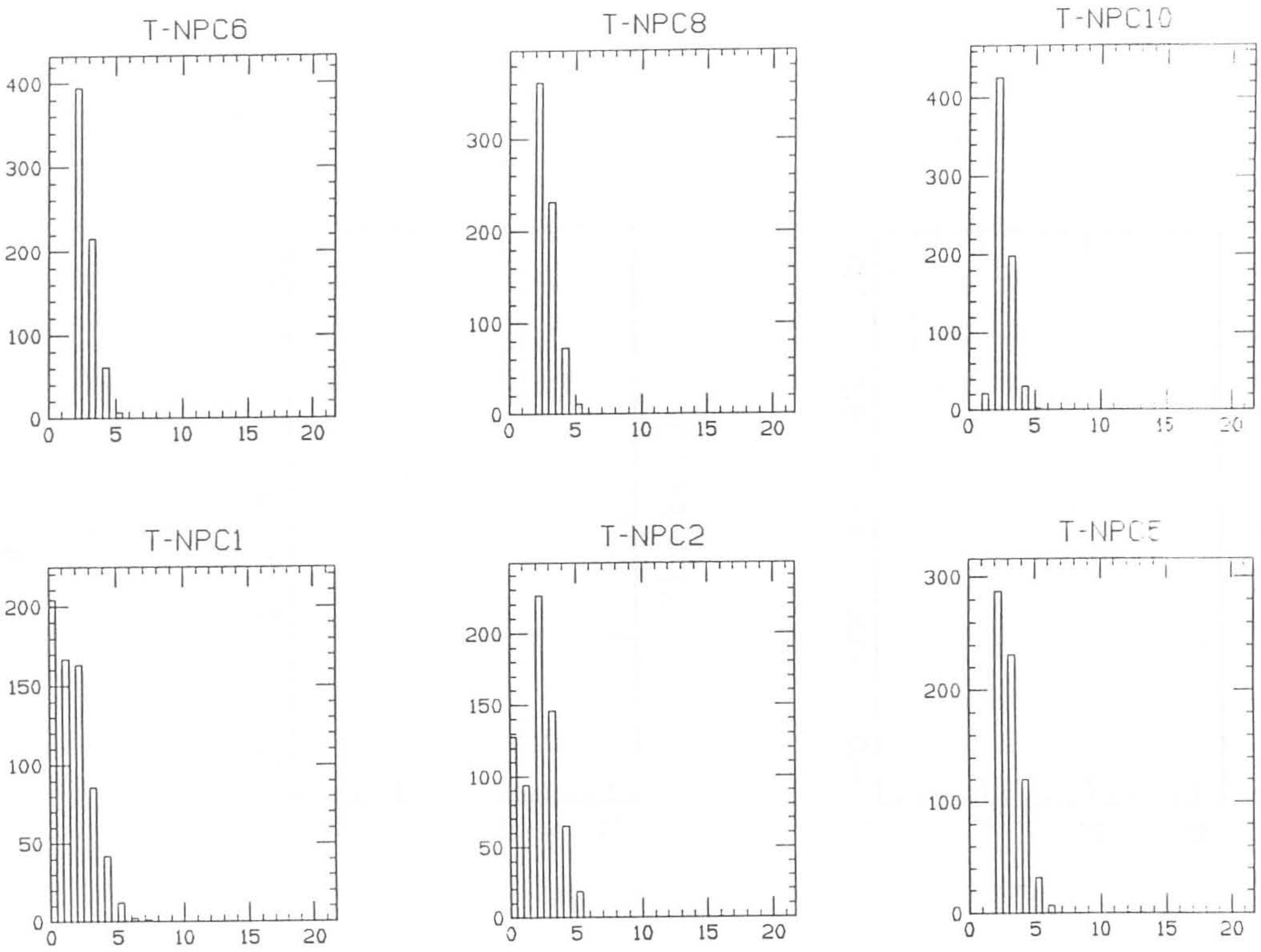
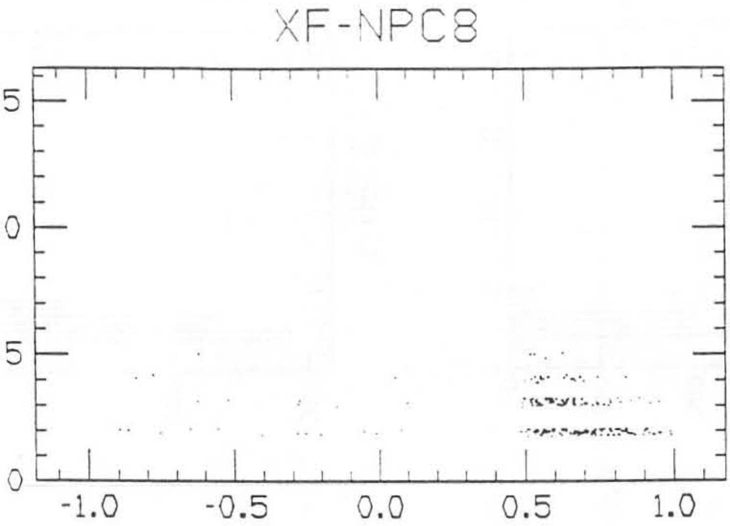


Fig. 12a



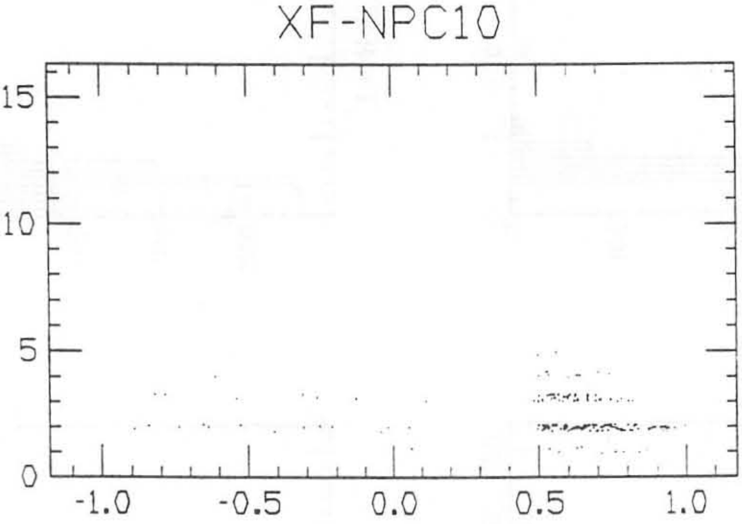


Fig. 12b