CLAS-NOTE-93-004

Stand-Alone Region 3 Track Reconstruction Algorithm

MIKHAIL KOSSOV, NIKOLAI PIVNYUK
APRIL 16, 1993

We studied the possibilities of Stand Alone Region 3 reconstruction of the values of momentum of the particle and its polar θ and asimuthal ϕ angles assuming point-like target. As input information we used only the numbers of fired Time-of-Flight scintillator counters (SC) slabs and the array of fired wires in axial and stereo superlayers of drift chamber Region 3.

The program may use TDC values of Drift Chamber Region 3 (TDC reconstruction) or just use the wire position information (HIT reconstruction). The third procedure takes into account the TDC information only for wires in axial superlayer. In this document it will be referred to as the MIXED-reconstruction.

The program solves three problems sequentially. First - extracting wire clusters in the axial and stereo superlayers which are located on the particle path, rejecting all background hits. Second - definig the trajectory of particle in Region 3 assuming that it is a straight line. Third - reconstructing the values of momentum, θ and ϕ angles at the point of particle origin.

1 General method of reconstruction.

The main idea of the reconstruction procedure is shown in Fig.1. Let us consider the middle plane. If you fix the target position T, the point A, and the value θ_{exit} of the particle in the middle plane, then you will find that there exists only one unambiguously defined pair of values θ_{id} and P^{mid} which correspond to track passing through A. It's impossible to take into consideration the continium of points A and we need to introduce some structure. This structure is naturally defined by the array of scintillator counters SC. In other words for each SC number i exists a pair of functions $\theta_{id} = f_i(\theta_{exit})$, i = 1,...,48 and $P^{mid} = g_i(\theta_{exit})$, i = 1,...,48. If you are able to calculate these functions f_i and g_i and if you are able to reconstruct the value of θ_{exit}, or in other words the output of your program θ_{rec} reproduces θ_{exit} with a reasonable amount of accuracy, and if you calculate correctly the value of asimuthal angle ϕ, you obtain a chance to reconstruct the initial characteristics of the track at the point of its origin (assuming a point-like target).

2 General remarks.

In the REG3_hit program we assume the following :

1) a point like target,

2) the track in drift chamber Region 3 is a straight line.

Input information :

1) number of SC fired,

2) numbers of wires fired in superlayer 5 (axial), numbers of wires fired in superlayer 6 (stereo),

3*) TDC values for fired wires in Reg.3.

Program REG3_hit performs the following :

1) finds wires clusters in axial and stereo superlayers in Reg.3,

2) reconstructs θ_{rec} in the middle plane and ϕ,

3) using as an argument θ_{rec} and functions f_i and g_i (2 functions per slab, total = 2×48 = 96) makes predictions on θ_{id} and P^{mid},

4) using the reconstructed values of θ_{id}, ϕ and P^{mid} gives the polar angle θ, azimuthal angle ϕ and the momentum of the particle P (or lower limit on the momentum) at the point of particle origin.

Program REG3_hit may reconstruct θ_{rec} and ϕ in three ways :

1) TDC-reconstruction (wire position and TDC vallues),

2) HIT-reconstruction (wire position and SC position),

3) MIXED-reconstruction (TDCs are used only in axial superlayer).

3 Three methods of reconstruction.

First let us consider the TDC procedure of track reconstruction. This procedure is shown in Fig.2. The main problem here is to reconstruct in the middle plane the axial e^m_{ax} and stereo e^m_{st} vector projections of the track. Then you obtain two planes $e^m_{ax} \times w_{ax}$ and $e^m_{st} \times w_{st}$. The intersection of this two planes gives you the particle track in Reg.3. Here w_{ax} and w_{st} are unit vectors in the direction of axial wires and stereo wires respectively.

The second reconstruction procedure - HIT-reconstruction - is presented in Fig.3. At the first stage we reconstruct the axial projection of the track in the middle plane $y=ax+b$. It is possible because we take into account the position of the SC fired (x_0,y_0) and the average value θ^m_{rec}, where nax is the total number of axial wires in cluster. After this we calculate d - the average value of the distance between the stereo wire positions in the middle plane and the axial projection of the track $y=ax+b$ and the value of y_{st} which is the average y coordinate of stereo wires in midplane, nst is the total number of wires in stereo cluster. The obtained values of y_{st} and d allow us to calculate the value of asimuthal angle ϕ and after this to calculate the particle track in Reg.3 (point and unit vector along the track).

Finally a third procedure to reconstruct the track was used, the MIXED-reconstruction (see fig 4,a). The axial projection of the track on the middle plane ($y=ax+b$, θ^m_{rec}) we find exactly in the same way as we do in TDC-reconstruction, but then we find ϕ in the way as we do in HIT-reconstruction, see Fig.4,a.

4 No magnetic field. Test on track finding.

The simplest way to test how the program extracts clusters, discriminates against background and finds the straight line trajectory in Reg.3 is to switch off the magnetic field and compare the characteristics of the simulated track and the reconstructed one. In Fig.5 we show the differences THid-THrec (θ_{id}-θ_{rec}) and PHIid-PHIrec (ϕ_{id}-ϕ_{rec}) for the forward SC # 13 - 18. The obtained accuracy (for polar angle RMS $\simeq 0.18°$ and for asimuthal $\simeq 1.4°$) looks quite satisfactory for this approximate method which takes into account only Region 3 information. For comparison in Fig.5 we also show the results for HIT-reconstruction.

5 Reconstruction. Full magnetic field.

What do the functions $\theta_{id} = f_i(\theta_{exit})$ and $P^{mid} = g_i(\theta_{exit})$ look like ? There are some examples for SC # 13 -18 in Fig.6 (θ_{id} vs. θ_{rec} in the middle plane) and in Fig.7 (P^{mid} vs. θ_{rec} in middle plane).

The results of TDC and HIT reconstruction for positively charged particles with momentum P = Pid = 1500 MeV/c and θ = THid and ϕ = PHIid for SC # 13 - 18 are shown in Fig.8. The results for the backward SC # 44 - 48 and P = Pid = 350 MeV/c are shown in Fig.9. The HIT reconstruction gives better results in reconstruction of the direction of the momentum (θ=θ_{id}, ϕ=ϕ_{id}), but the reconstruction of the absolute value of the momentum is better in the the TDC procedure.

6 Distortion of ϕ reconstruction in nonuniform magnetic field.

The recostruction of the asimuthal angle ϕ may be distorted significantly in the nonuniform CLAS magnetic field. It may take place in a way as shown in Fig.4,b. The value of the asimuthal angle ϕ=ϕ_{exit} = PHIexit with which a particle leaves Reg.3 may differ significantly from the value of ϕ=ϕ_{id} = PHIid at the point of the particle origin. The comparison of the results of reconstruction of the asimuthal angle ϕ for all three TDC, HIT and MIXED reconstruction procedures are shown in Fig.10 (P = 1500 MeV/c) and Fig.11 (P = 350 MeV/c). The MIXED reconstruction gives the best result for low momentum particles, when the distortion of ϕ is large (see distribution labeled "NO reconstruction").

7 Summary.

It seems that more simple and, what is important, more fast procedure - HIT reconstruction - gives better results in reconstructing momentum direction at the point of the particle prigin, then TDC reconstruction, in which we don't explore the information about SC position.

The more complicated and more slow procedure - TDC reconstruction provides more success in the reconstruction of the absolute value of the particle momentum.

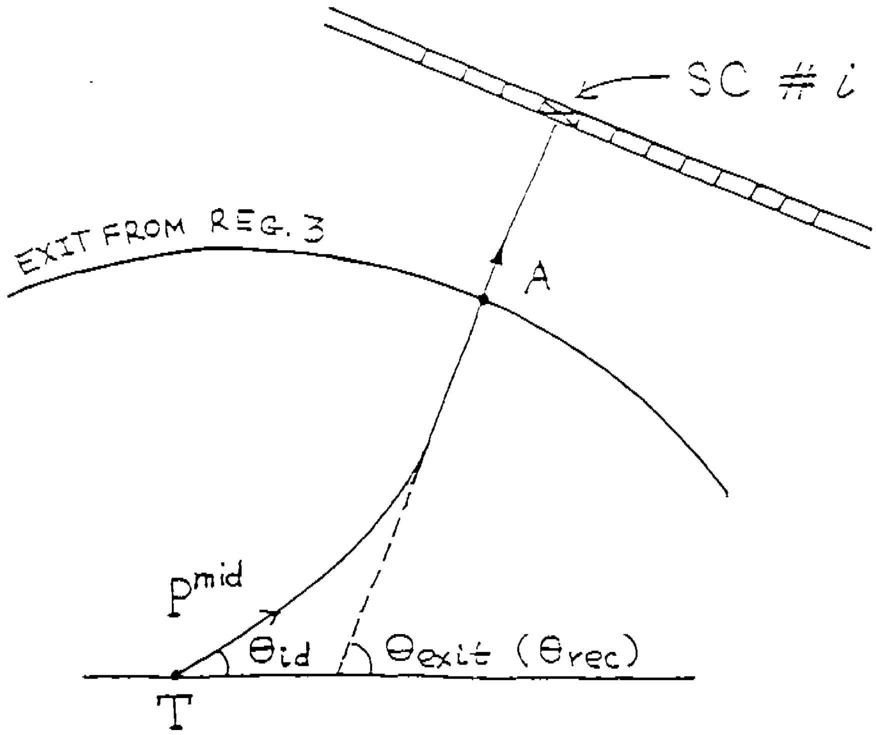
Unfortunatly we had not time enough to finish our investigation for negatively charged particles and for 1/2 magnetic field.

8 Acknowledgements.

We would like to thank Bernhard Mecking for fruitful discussions and support of our work. We also thank Dave Doughty for the support and fruitful discussions.

This work couldn't have been done without the help and daily support of Bogdan Niczyporuk. Program REG3_hit was created, debugged and operated as a part of SDA program. We thank him a lot.

This document has been created in relatively short time due to the crucial help of William Brooks. We thank him a lot.



$$(T, A, \theta_{exit}) \longrightarrow \theta_{id},\ p^{mid}$$

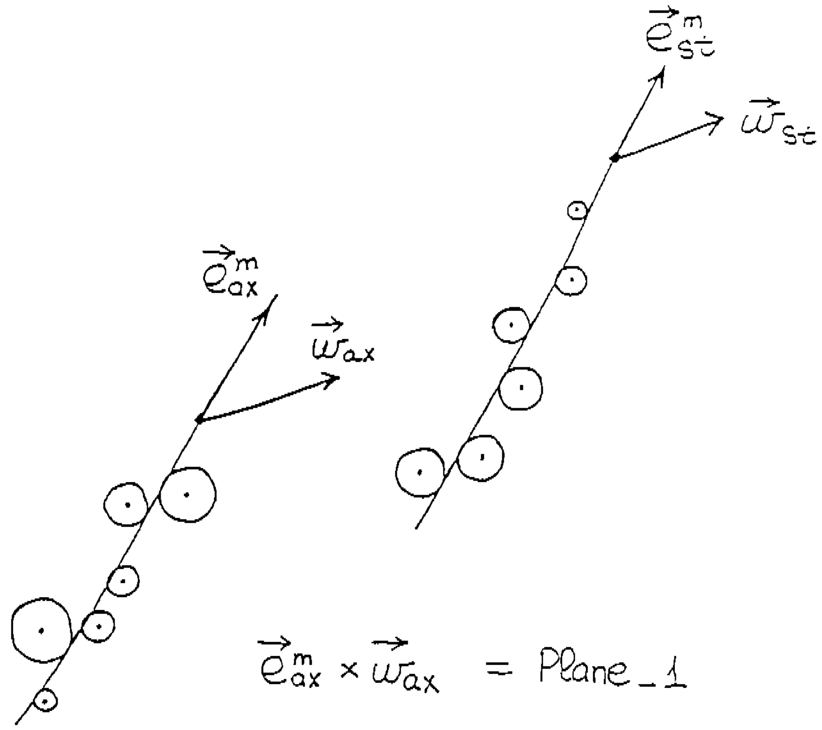
For a fixed SC # i (and point like target T)

$$\theta_{id} = f_i(\theta_{exit}) \quad , \quad i = 1, \ldots, 48$$

$$p^{mid} = g_i(\theta_{exit}) \quad , \quad i = 1, \ldots, 48$$

Program REG3_hit reconstructs θ and φ, reconstructs P or gives low limit for P.

Fig. 1.



$$\vec{e}^{\,m}_{ax} \times \vec{w}_{ax} = Plane\_1$$

$$\vec{e}^{\,m}_{st} \times \vec{w}_{st} = Plane\_2$$

Intersection Plane_1 and Plane_2

$$\text{track} = (x_0, y_0, z_0, \cos_x, \cos_y, \cos_z)$$

TDC - reconstruction

$\vec{e}^{\,m} = \vec{e}^{\,m}$ (wire positions, TDCs)

$\vec{w}$ - *unit vector along the wire*

Fig. 2.

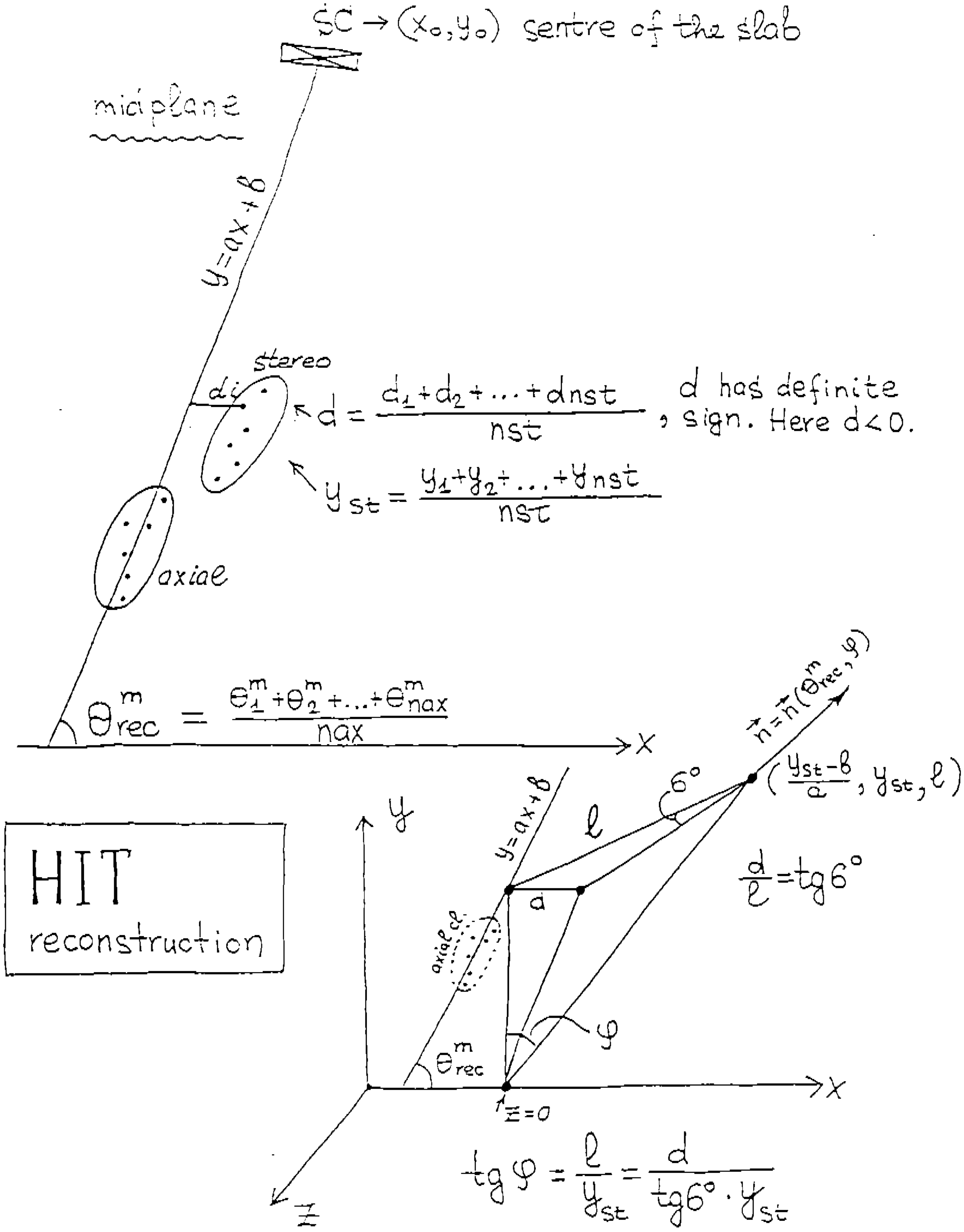
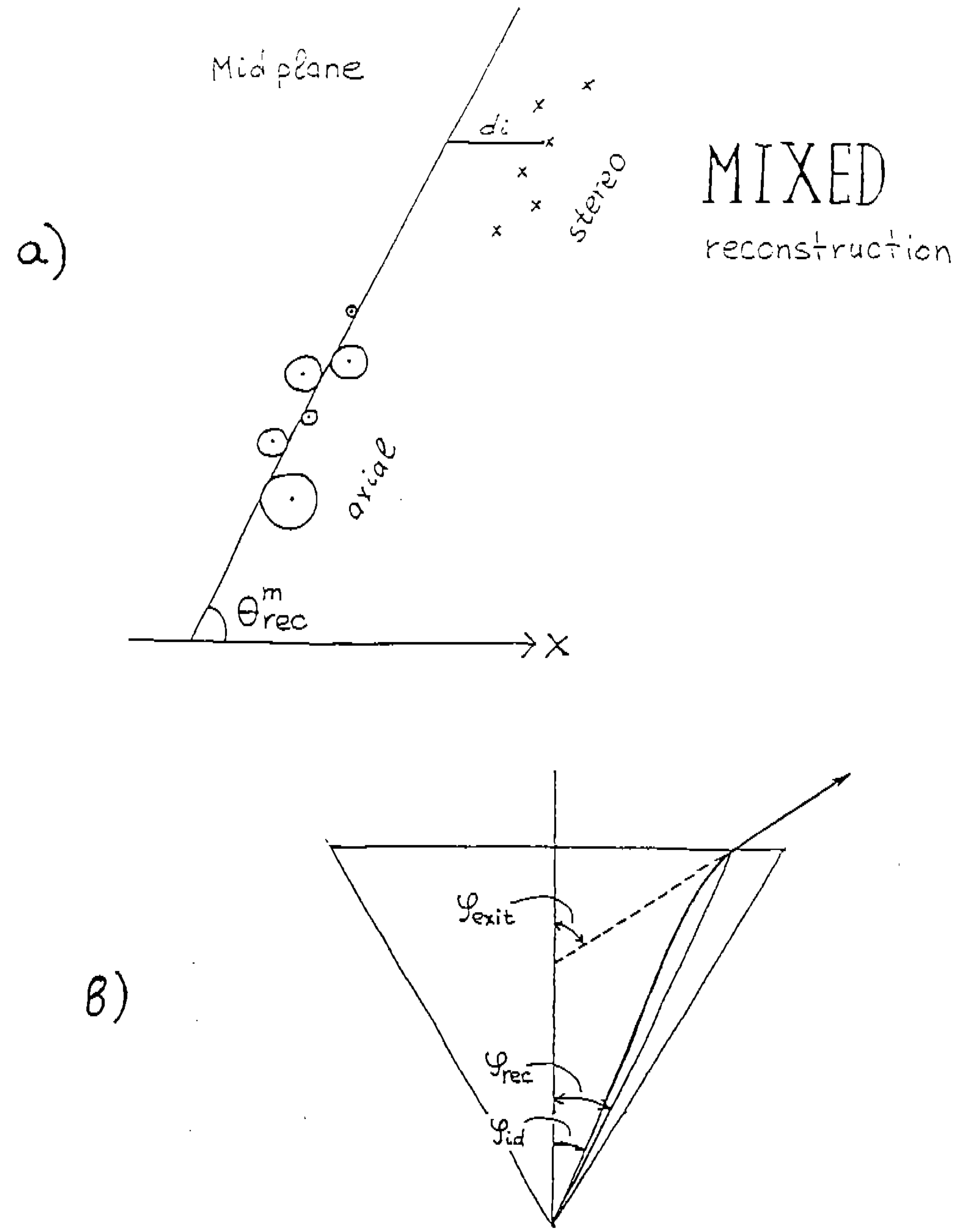

SC → (x₀, y₀) sentre of the slab
midplane
y=ax+b
stereo
di
d = (d₁+d₂+...+dnst)/nst
d has definite sign. Here d<0.
y st = (y₁+y₂+...+ynst)/nst
axial
θ^m rec = (θ^m₁+θ^m₂+...+θ^m nax)/nax
X
n = n(θ^m rec, φ)
6°
((yst−b)/a, yst, ℓ)
y
y=ax+b
ℓ
d
d/ℓ = tg6°
HIT
reconstruction
axial
φ
θ^m rec
z=0
X
Z
tg φ = ℓ/yst = d/(tg6°·yst)

Fig. 3.



a)
Mid plane
di
stereo
MIXED
reconstruction
axial
θ^m_rec
X
β)
φ_exit
φ_rec
φ_id

Fig. 4.

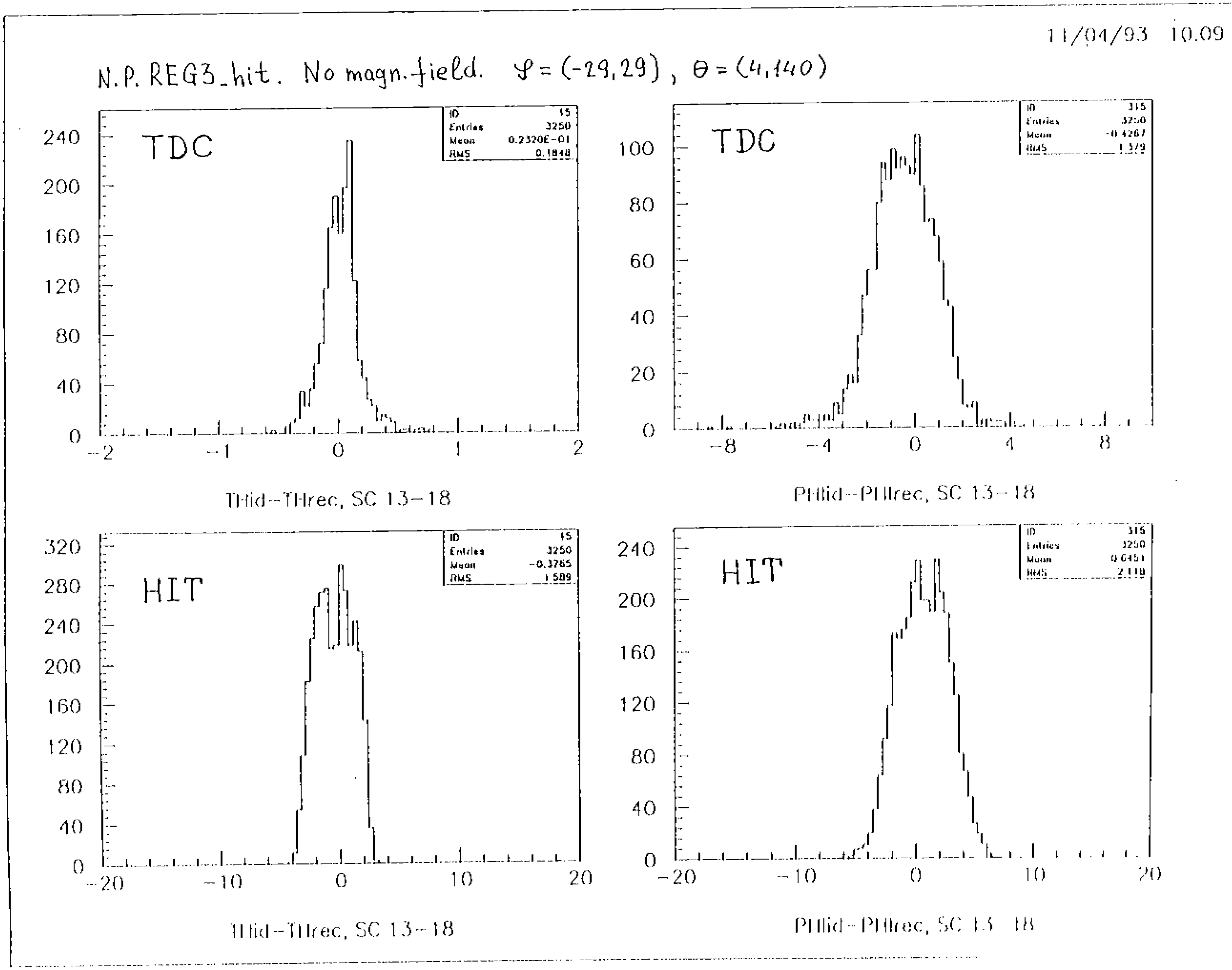
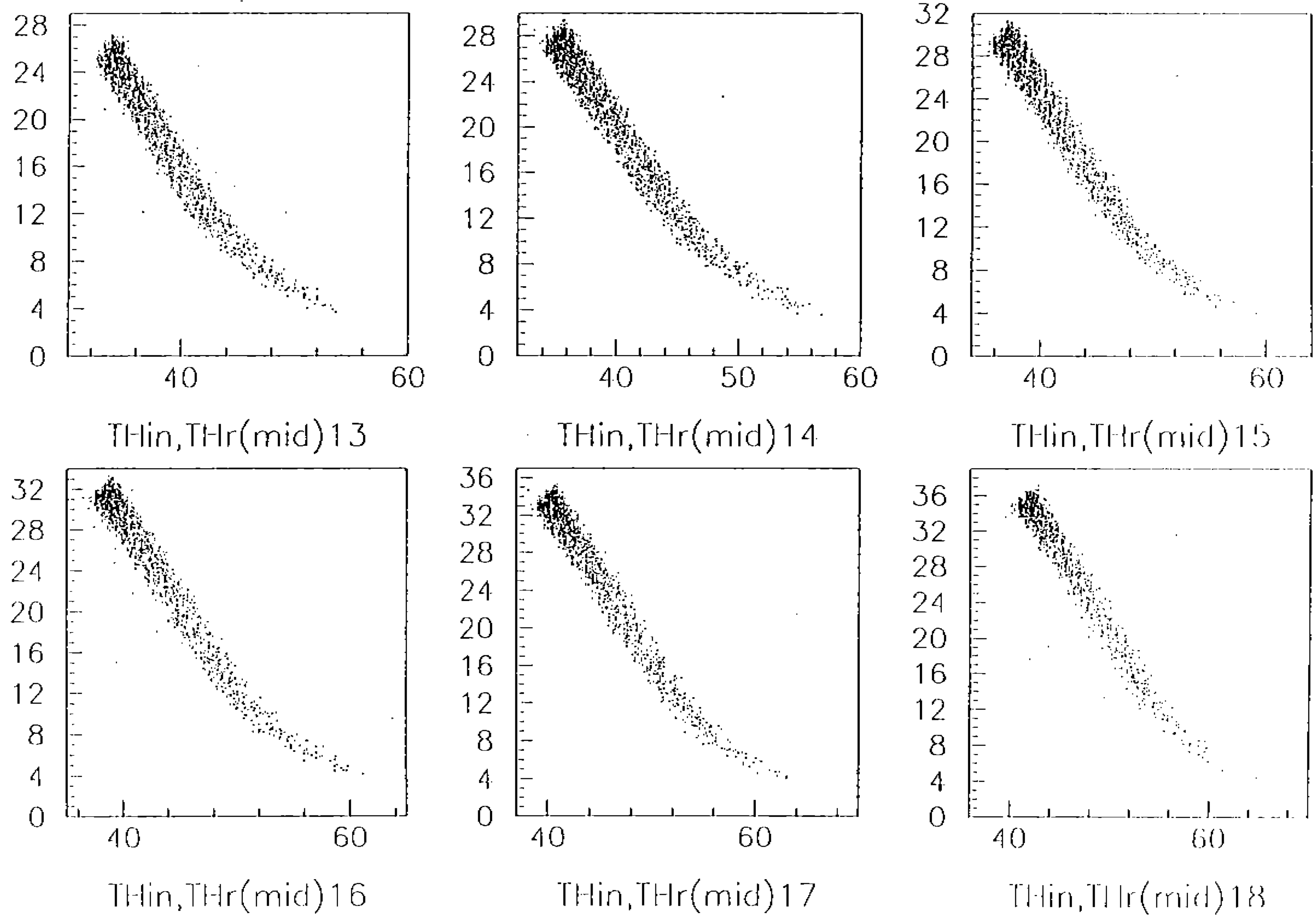

11/04/93 10.09
N.P. REG3_hit. No magn. field. φ = (-29,29), θ = (4,140)
TDC
ID 15
Entries 3250
Mean 0.2320E-01
RMS 0.1848
THid-THrec, SC 13-18
TDC
ID 315
Entries 3250
Mean -0.4267
RMS 1.379
PHid-PHrec, SC 13-18
HIT
ID 15
Entries 3250
Mean -0.3785
RMS 1.589
THid-THrec, SC 13-18
HIT
ID 315
Entries 3250
Mean 0.6451
RMS 2.119
PHid-PHrec, SC 13-18

Fig. 5

Region 3 Stand Alone Program (With magnetic field)
phi =(−29,29), theta = (4,140), P = 0.2 − 4.0

22/03/93 14.04

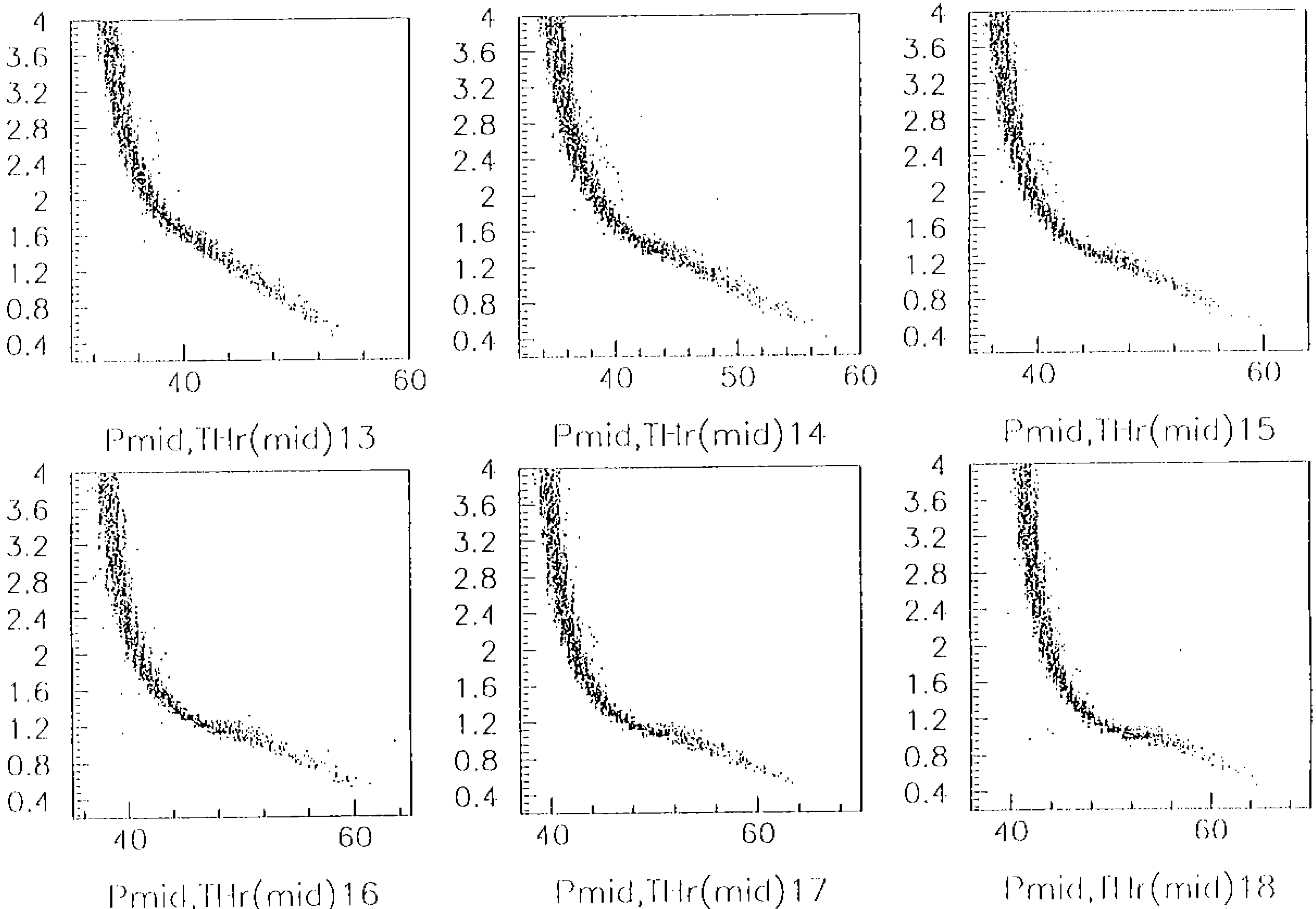


NP IDC reconstruction

Fig.6

Region 3 Stand Alone Program (With magnetic field)
phi =(-29,29), theta = (4,140), P = 0.2 - 4.0

22/03/93 14.03



H.P. IDC -reconstruction

Fig. 7

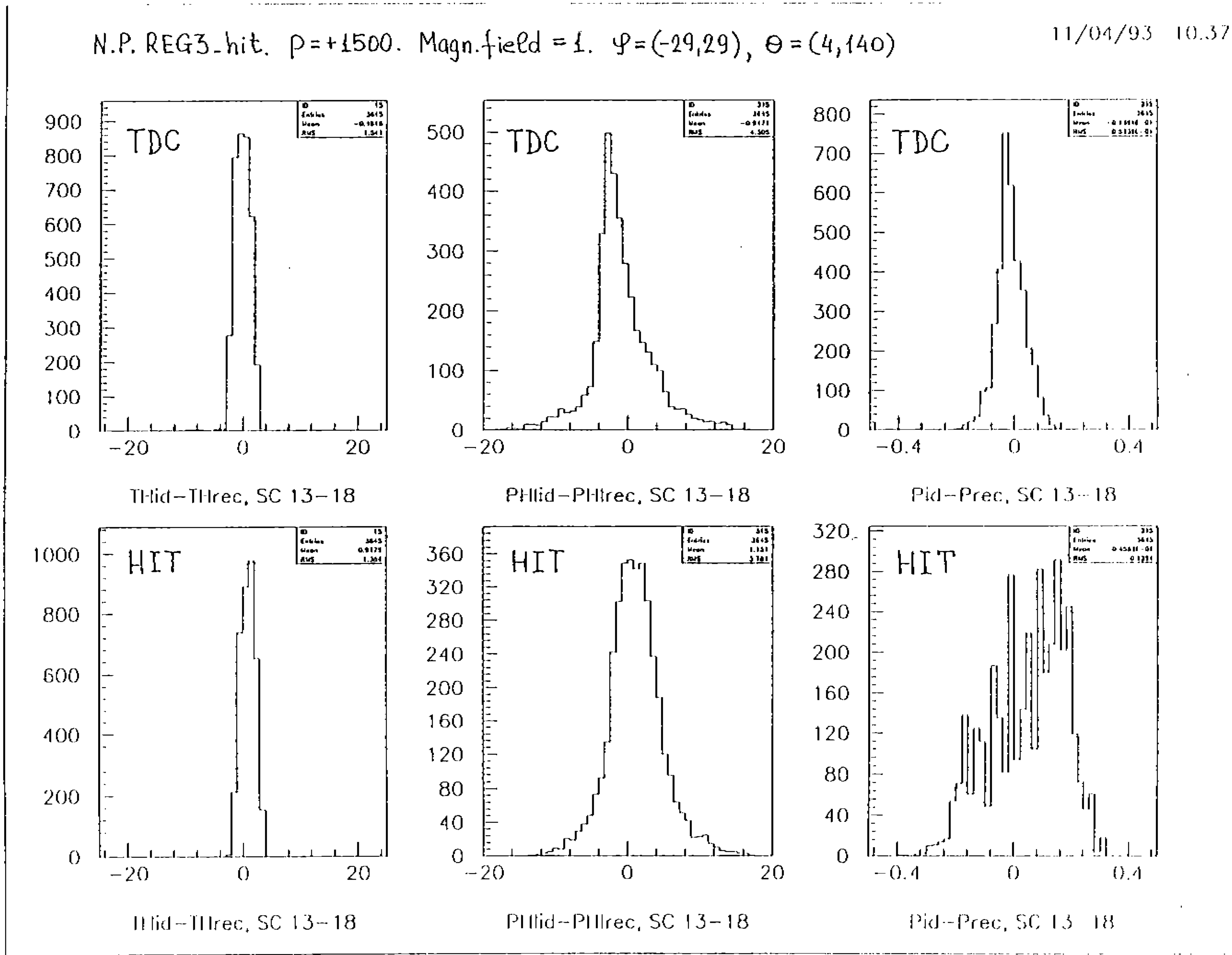

N.P. REG3_hit. ρ=+1500. Magn.field = 1. φ=(-29,29), Θ=(4,140)
11/04/93 10.37
TDC
THid−THrec, SC 13−18
TDC
PHlid−PHlrec, SC 13−18
TDC
Pid−Prec, SC 13−18
HIT
THid−THrec, SC 13−18
HIT
PHlid−PHlrec, SC 13−18
HIT
Pid−Prec, SC 13−18

Fig. 8

11/04/93 10.47

N.P. REG3_hit. P=+350. Magn.field=1. φ=(-29,29), Θ=(4,140)

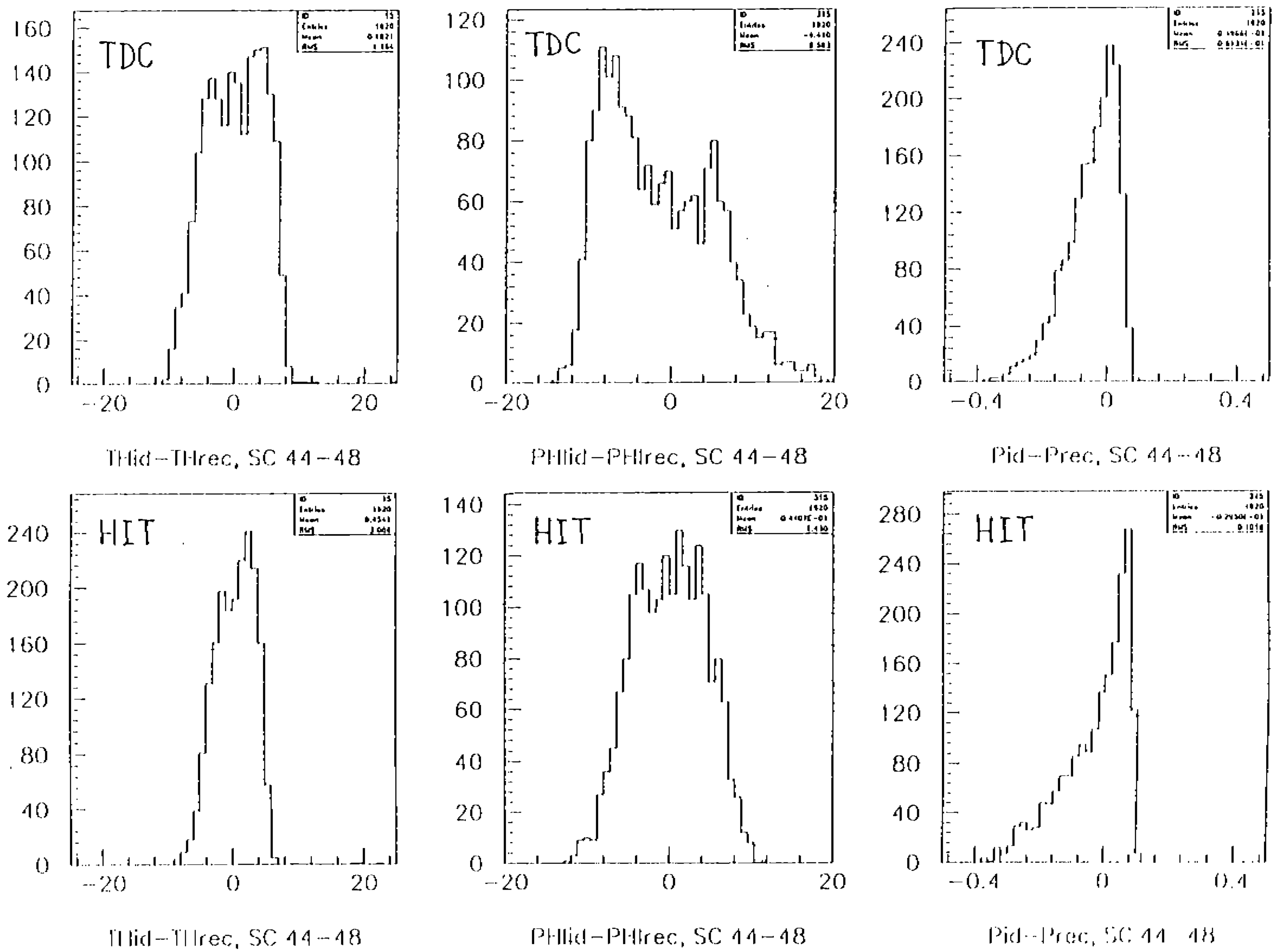


Fig. 9

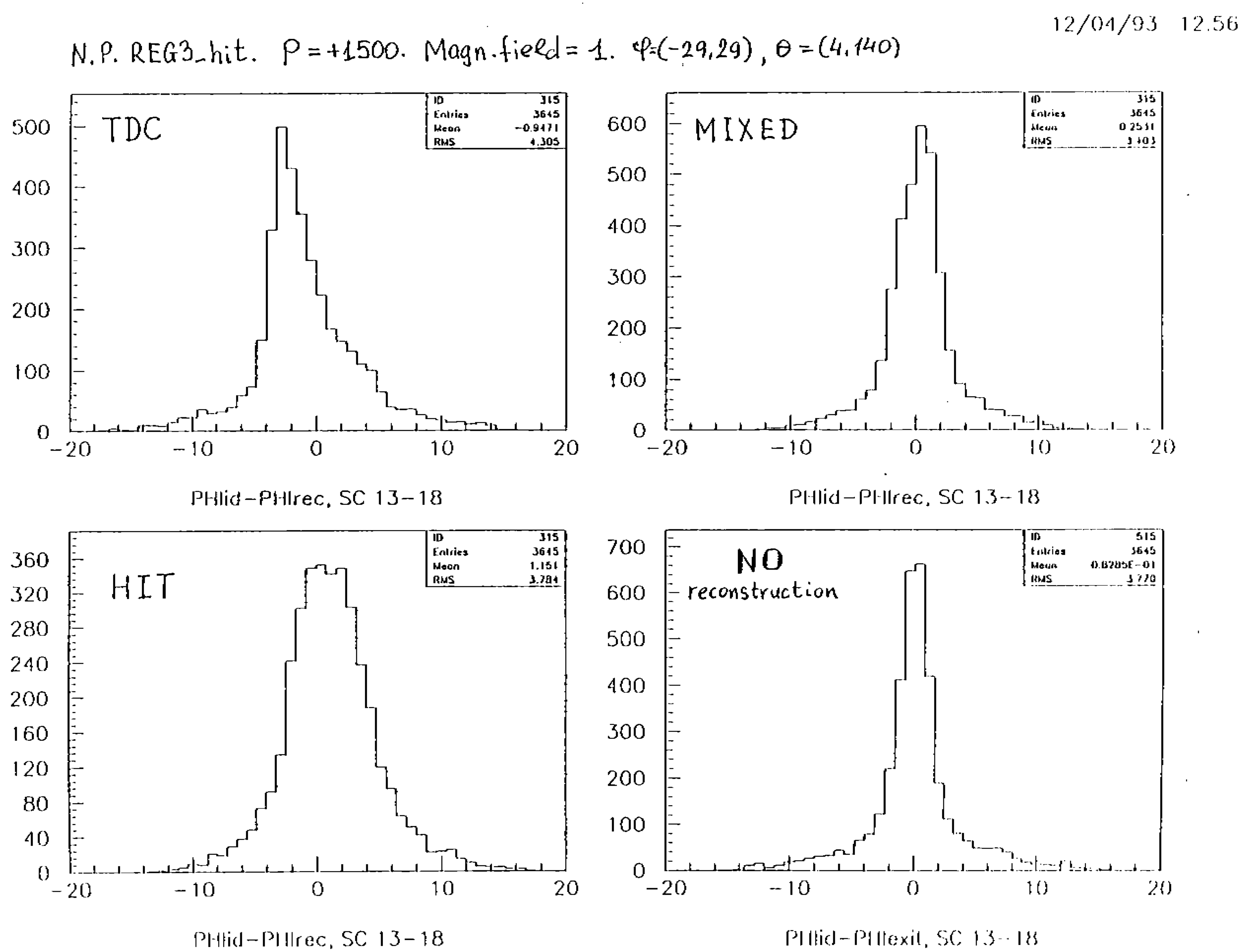

12/04/93 12.56
N.P. REG3_hit. P=+1500. Magn.field=1. φ=(-29,29), θ=(4,140)
TDC
ID 315
Entries 3645
Mean -0.9471
RMS 4.305
PHIid-PHIrec, SC 13-18
MIXED
ID 315
Entries 3645
Mean 0.2531
RMS 3.403
PHIid-PHIrec, SC 13-18
HIT
ID 315
Entries 3645
Mean 1.151
RMS 3.784
PHIid-PHIrec, SC 13-18
NO reconstruction
ID 515
Entries 3645
Mean 0.8285E-01
RMS 3.770
PHIid-PHIexit, SC 13-18

Fig. 10.

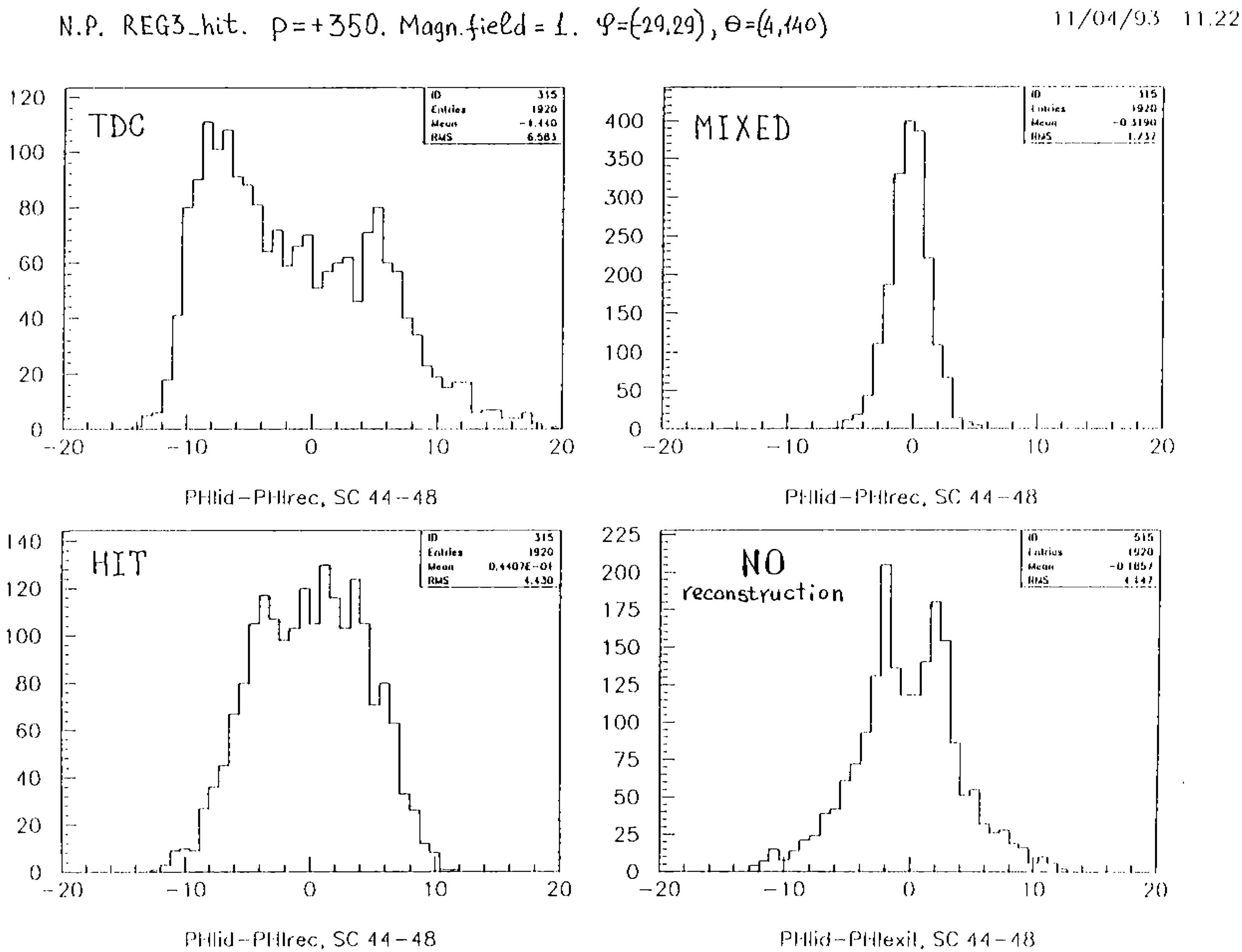

N.P. REG3_hit. p=+350. Magn.field = 1. φ=(-29,29), θ=(4,140)
11/04/93 11.22
TDC
MIXED
HIT
NO reconstruction
PHIid-PHIrec, SC 44-48
PHIid-PHIrec, SC 44-48
PHIid-PHIrec, SC 44-48
PHIid-PHIexit, SC 44-48

Fig. 11