H1-12/92-260

QED Compton events in H1 : Luminosity measurement and BEMC calibration studies

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Abstract

We study the QED Compton events in *ep* collisions, with H1 detector. Since almost 80% of the final particles of the Compton process are emitted in the backward region of H1, especially in the BEMC, we first look for events in this area. Monte-carlo studies are followed by the study of real events taken in summer and automn runs, before November shut-down. Preliminary results on luminosity measurement and BEMC calibration are given.

Introduction :

The idea of measuring the absolute luminosity in HERA with H1 detector and calibrating the BEMC by using coplanar $(e-\gamma)$ events stemming from QED Compton process, was already proposed, studied and described many years ago [1] . This study is the first experimental attempt to use such an idea. The reader can refer to [1, 2] for more details.The paper is divided in three parts: in the first part we introduce briefely what we call quasi-real QED Compton, then we present results from Monte-carlo studies and, in the third part, we will report the QED Compton events obtained from analysing all available H1 data and the first results we got from studying these events.

1 Compton events and H1 acceptance :

The quasi-real QED Compton in ep collisions corresponds to the following reaction :

$$e + p \rightarrow e + \gamma + (X)$$

where the outgoing electron and photon are observed in H1. Those events are overdominated by the interaction of a quasi-real photon generated by the incident proton, with the incident electron; in other words, if we forget the hadronic part of the process, we are in the case of Compton scattering of the quasi-real photon $(Q^2 \rightarrow 0)$ with the incident electron. From this scattering, results a constrained $(e-\gamma)$ system. The main caracteristics of such a process are [3, 4] :

- The hadronic system (X) which has a very small transverse momentum escapes H1 detection.
- The $(e-\gamma)$ system has a very small transverse momentum P_t and small invariant mass W, with a very small energy of the quasi-real photon $E_{\gamma i}$ and a large boost along the direction of the incident electron :

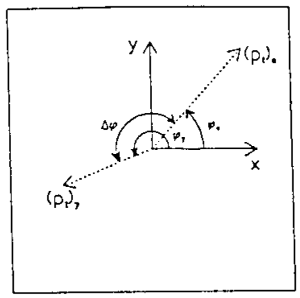
$$\beta = \frac{E_{ei} - E_{\gamma i}}{E_{ei} + E_{\gamma i}} \tag{1}$$

  where E_{ei} is the incident electron energy. It results that the outgoing electron and photon :

  - Are emitted at large angle and detected in the BEMC (fig 1). In addition if we impose that the two particles are in the BEMC acceptance, we find an upper limit of the quasi-real photon energy $(E_{\gamma i})_{max} \simeq 1.7$ GeV. The lower limits of $E_{\gamma i}$ and Q^2, which correspond to the highly probable events, are given by :

* $(E_{\gamma i})_{min} \simeq 32$ MeV with $(\mathrm{W}^2)_{min} \simeq 3.4$ GeV^2
* $Q^2_{min} \simeq 1.52\ 10^{-9}$ GeV^2 with $P_t^2 \simeq Q^2$

– Have their coplanarity angle $\Delta\varphi$ close to π, since the Compton events are dominated by very small $P_t^2 (\simeq Q^2)$ and small P_t^2/W^2 $(\simeq 10^{-8})$ [2].



– Have their visible energy E_{vis} almost equal to E_{ei}, since the energy of the two particles $(e + \gamma)$ in the final state [1] is given by :

$$E_{vis} = E_{ei} + E_{\gamma i} \tag{2}$$

and as we shown above, $E_{\gamma i}$ is very small. This means that this energy is close to [1]30 GeV. It could be smaller only in the case of a photon initial state radiation [2].

In addition to colpanarity angle and visible energy, Compton events have two supplementary constraints those, for example, linking the final particle energies to their emission angles [3]:

$$E_e(\Theta_e, \Theta_\gamma) = \frac{2E_{ei} sin(\Theta_\gamma)}{sin(\Theta_e) + sin(\Theta_\gamma) + sin(\Theta_e + \Theta_\gamma)} \tag{3}$$

$$E_\gamma(\Theta_e, \Theta_\gamma) = \frac{2E_{ei} sin(\Theta_e)}{sin(\Theta_e) + sin(\Theta_\gamma) + sin(\Theta_e + \Theta_\gamma)} \tag{4}$$

In a first step of luminosity calculation and H1 backward studies, we only look at events with both electron and photon emitted in the BEMC acceptance $(150° \leq \Theta \leq 176°)$ [5]. For such events we have three types of particle hits in the BEMC (fig 2) :

[1]We did our reconstruction with generated incident electron energy 30 GeV, however the present energy of the electron is 26.7 GeV in real data.

[2]Where E_{ei} becomes smaller, since the radiated photon takes part of the electron energy.

[3]Θ_e and Θ_γ used in $E(\Theta_e, \Theta_\gamma)$ calculation are defined with respect to the incident electron direction.

- Events with $\Theta_1 \leq \Theta \leq \Theta_2$, particles hit the front side of the BEMC, but espape from its outer limit (type 1).
- Events with $\Theta_2 \leq \Theta \leq \Theta_3$, particles go through the whole BEMC (type 2).
- Events with $\Theta_3 \leq \Theta \leq \Theta_4$, particles hit the lateral side of what we call ring0 (triangular stacks)(fig 3) (type 3) .

2 Monte-carlo studies :

2.1 introduction

In this study we generated 998 events, which we processed by standard programs of simulation and reconstruction. The smearing of the vertex of the interaction (fig 4) was introduced in the simulation. The programs used in this study were :

- COMPTON 2.00/00 for generation [6]
- H1SIM (H1FAST) 2.06/00 for simulation
- H1REC 3.00/02 for reconstruction

Since almost 80% of particles stemming from this process are emitted in backward region of H1 (fig 1), we first look for events in the BEMC.

2.2 Reconstructing Compton events in BEMC :

From the 998 generated events we get 658 (66%) giving two clusters (with $E_{cluster} \geq$ 2 GeV) in the BEMC, case where both the electron and the photon are emitted in the BEMC. 310 events (31%) give only one cluster in this area (case of emission of one of the two particles out of the BEMC acceptance).

After the reconstruction, the events with both electron and photon in the BEMC have a coplanarity distribution peaked around π, but wider than the generated one (fig 5.a). The distribution of the reconstructed visible energy E_{vis} does not reproduce the generated one (fig 5.b), it shows a tail at low energies which does not appear in the case of generated events.

Let us note that the reconstruction sets the z value of the center of gravity of the cluster in the BEMC at z=-156.4 cm. Therefore in order to compare x and y coordinates of the reconstructed clusters with the ones expected from the generation, we defined the z of the later at the same value (plane AA in fig 2). The figure 2 shows the 3 regions containing the 3 types of events defined above :

- Region (1) the outer ring of the BEMC (between the two doted circles) containing events of type 1.

- Region (2) containing events of type 2.
- Region (3) of lateral impacts (the two doted squares around BEMC inner limit) which contains events of type 3.

Looking at the layout of particle hits (fig6), we see that the reconstructed ones are not as uniform as the generated ones. Almost all hits in ring0 are reconstructed at the same point in each triangle stack (see the zoom on fig 6).

2.2.1 Reconstructed E_{cl} and φ_{cl} :

First of all we looked separately at the clusters reconstructed in ring0 and those reconstructed out. Fig 7 shows, for individual clusters, the difference between the generated and the reconstructed energies and azimutal angles . We see that energies and azimutal angles of the clusters in ring0 are not well reconstructed (flat distributions); out of this area, reconstructed energies and azimutal angles agree quite well with the generated ones.

Looking at the particles which have a badly reconstructed energy, leads to the same conclusion . We find that they correspond to events generated in ring0, especially in region (3) (lateral hits on ring0) (fig 8) and which are reconstructed at the same points in the triangular stacks.

2.2.2 Reconstructed visible energy E_{vis} :

The distribution of the reconstructed E_{vis} shows, as we already mentionned (fig 5.b), a tail coming from the events in which one of the two particles energy or both are badly reconstructed.

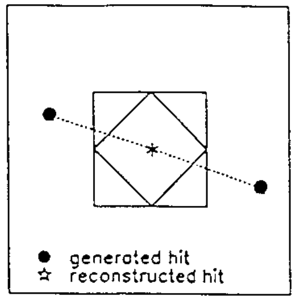
Actually, we have three types of events . When both the two clusters are reconstructed out of ring0, the reconstructed visible energy is close to the generated one (fig 9.a.1) (around E_{ei}). In the case where only one of the two clusters is reconstructed out of ring0 (fig 9.b.1), the reconstructed visible energy is not so good, because of the bad reconstruction of particle energies in region (3) of ring0. However, in this type of events it still remains some of them with good reconstructed visible energy : those emitted in ring0 but out of region (3). The worst distribution of visible energy comes from events in which the two clusters are reconstructed in ring0 (fig 9.c.1).

2.2.3 Reconstructed coplanarities $\Delta\varphi$:

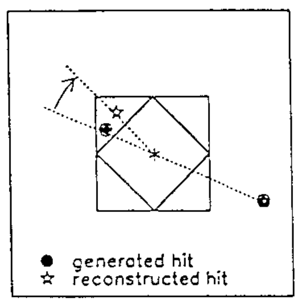
We have seen (fig 5.a) that the coplanarity angles are well reconstructed around π, but with a distribution wider than the generated ones. We apply the same repartition of events as we did just above, the best reconstructed coplanarity we obtained, is for events with both electron and photon out of ring0 (fig 9.a.2).

This good $\Delta\varphi$ reconstruction is due to good reconstruction of the hits out of this ring.

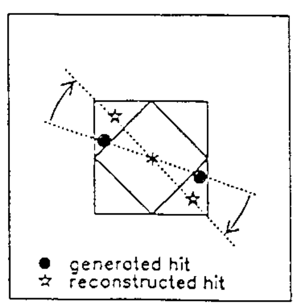
We verified that the tail for these events is physical.



The worst reconstructed coplanarity is for events with one cluster reconstructed out of ring0 and the other in it (fig 9.b.2). Since the hits in the stacks of ring0 are almost always shifted and reconstructed at the same point, even if the real coplanarity is good, the reconstructed one could be far from it.



The third kind of events (fig 9.c.2) presents a good coplanarity, but this has no physical meaning. In this case the two reconstructed hits in ring0 stacks, are always in the same point for each triangular stack, of course such events have a good coplanarity, but this is simply due to the fact that the reconstructed points are always almost coplanar.



2.3 conclusion :

We conclude from the previous study, that we have two ways to select Compton events. In both cases we look for events with 2, and only 2, clusters observed in the BEMC with a coplanarity obeing to :

$$\frac{3\pi}{4} \leq \Delta\varphi \leq \frac{5\pi}{4}$$

then :

1. Select only events out of ring0. Such events represent almost 25% of the total generated events (500 events for 1 Pb^{-1} of integrated luminosity). Fig 10 shows correlations between generated and reconstructed energies, emission angles Θ and φ of the particles. One see that these events have good correlations. The plot $E_\gamma = f(E_e)$ shows that for reconstructed energies we have $E_\gamma + E_e \simeq E_{ei}$. It results that, for such events one can use the constraints on the measured energy and the $\Delta\varphi$, using measured Θ and φ .
2. Select events with $E_{vis} \geq 20$ GeV. The events which pass such a selection represent almost 54% of the total generated ones. The advantage of such a selection is that it gives twice the number of events we obtain by the first type of selection (almost 1000 events for $1pb^{-1}$ of integrated luminosity), but obviously we lost the possibility of using stringent constraints on coplanarity. Fig 11 shows the same correlations, as for fig 10, between different parameters of the reconstructed and generated particles. In the φ correlation we see the four ring0 regions, coresponding to the triangular stacks and in which the azimutal angle is badly reconstructed.

3 H1 data studies :

3.1 Selection criteria :

In our search of QED Compton in the H1 data, we used the neutral current events with low Q^2 sample (class 11). We analysed all events taken by H1 during summer and automn 1992 period, taking into acount only good and medium runs. The selection criteria for such events are :

1. 2 clusters and only 2 clusters in the BEMC .
2. $E_{vis} = E_{cl1} + E_{cl2} \geq 20$ GeV ; $E_{cl1}, E_{cl2} \geq 2$ GeV
3. $\frac{3\pi}{4} \leq \Delta\varphi \leq \frac{5\pi}{4}$, where $\Delta\varphi = |\varphi_{cl1} - \varphi_{cl2}|$

4. No more than one good track in the central tracker, corresponding to the electron track, defined by :
   - The packed number of hits : Nhits$\geq$ 10
   - Distance of the closest approach : $|DCA| \leq 2$ cm
   - Radius at track start : Rad ≤ 30 cm
   - z at DCA : $|z_0| \leq 50$ cm
5. No forward track, from FTKR, Nhits$\geq$ 10
6. No TOF response corresponding to 110 number matching a cluster in the BEMC, which corresponds to background coming from proton interaction before interaction region.

Using such criteria we obtained about 100 events.Then we did a scanning selection which leads to 24 events.The main reasons for eliminating events were :

- Events with tracker activity without track : digits without an FTKR or CTKR reconstructed tracks.
- BEMC monitor trigger events, in which we have only BEMC activity.
- Events which do not verify the constraint on photon and electron energy, since we can use (2) and (3) to compute the two cluster energies, using BEMC cluster angles as follows :

$$E_{cl1}(\Theta_{cl1}, \Theta_{cl2}) = \frac{2E_{ei} sin(\Theta_{cl2})}{sin(\Theta_{cl1}) + sin(\Theta_{cl2}) + sin(\Theta_{cl1} + \Theta_{cl2})} \quad (5)$$

$$E_{cl2}(\Theta_{cl1}, \Theta_{cl2}) = \frac{2E_{ei} sin(\Theta_{cl1})}{sin(\Theta_{cl1}) + sin(\Theta_{cl2}) + sin(\Theta_{cl1} + \Theta_{cl2})} \quad (6)$$

  Let us note that this criterion was not strongly used, since we rejected only the events in which one of the two clusters had $\Delta E = |E_{cl} - E_{cl}(\Theta_{cl})|$ greater than 8 GeV !.

Fig 12 shows one of these 24 events (run=35174,event=14514). We see the track of the electron in central tracker; we have no calorimeter clusters except in the BEMC where we see the two clusters corresponding to the electron and the photon, and also a hit in the backward proportionnal chamber which signs the electron. This event has the following parameters :

- $E_{vis} = 28.21$ GeV , $\Delta\varphi = 157^\circ$
- $E_{cl1} = 17.95$ GeV , $E_{cl2} = 10.26$ GeV

- $E_{cl1}(\Theta_{cl1}, \Theta_{cl2}) = 16.66$ GeV , $E_{cl2}(\Theta_{cl1}, \Theta_{cl2}) = 10.15$ GeV

Fig 13 shows a summary of the main parameters caracterising the 24 events [4]. In a first step we divide them as we did above for generated ones (fig 9) : events with the two clusters out of ring0, events with only one cluster reconstructed in and events with both clusters in ring0. The result is very good(fig 14). For example, if we normalise the monte-carlo to the data number (24), we have :

- 12 events where the two clusters are out of ring0, when from monte-carlo studies we expect the same number.
- 11 events with only one cluster reconstructed in ring0, where the monte-carlo predicts 10.
- 1 event with both clusters in ring0, where we expect 2 events of this type from the monte-carlo studies.

Now, if we compare the E_{vis} and $\Delta\varphi$ distributions of real data (fig 14) with the generated ones (fig 9) we also observe quite good agreements.

3.2 Studies with the Compton sample:

3.2.1 H1 absolute luminosity measurement :

The previous monte-carlo study shows that the cut on E_{vis} at 20 GeV decreases the Compton cross section in H1 from 1.7 nb to 0.9 nb. From our 24 events we derive a preliminary result of the luminosity measurement :

$$\int \mathcal{L}dt = 27 \pm 5_{stat} \pm ?_{syst} nb^{-1} \tag{7}$$

to be compared with the $28 \pm 2nb^{-1}$[7], given by lumi group using Bremstrahlung process. The study of the systematical errors still need some efforts but also largest statistics. There is presently 2 events which does not fit well all criteria and remain doubtful (see events 4 and 6 in event sumary table (fig 13)). If we consider that one has 23 ± 1 Compton events, this does not change in practice our luminosity measurement which is dominated by statistical error and becomes $\simeq 26 \pm 6nb^{-1}$.

Let us emphasize that this study has already shown that QED Compton can be selected from data with a very high signal over noise ratio.

[4]The 19th event in the summary (run=34545, event=5773) is well defined as a QED Compton event with radiative photon on the incident line. This photon energy is measured in the photon tagger, then all the energy constraints agree well.

3.2.2 BPC and Compton events :

In such events, because we looked at DST5 sample, we have at least one BPC hit by event. However, if we avoid this BPC constraint in the selection, Compton events could be used for the efficiency study of this chamber. Our sample contains 14 events which have only one BPC hit (or cluster of hits) linked to only one of the two BEMC clusters, and 10 events in which the two clusters are linked to BPC hits. Therefore we already (with this low number of events) conclude that the photon converts in about 40% of cases in the material before the BPC.

3.2.3 BEMC resolutions :

Looking at the events with both clusters out of ring0, we observe that the measured visible energy (fig 14) tends to be a little bit larger than expected.

Since we have energy-angle relations (4) (5), we can compute energies from emission angles of the two particles in the BEMC and compare them to the measured values. We have two methods or possibilities to do that :

- Using (x,y) given by the reconstructed cluster in the BEMC.
- Using (x,y) given by the BPC hit, if it exists.

Fig 15 shows the BEMC resolution $(\Delta E)_1$, which is computed according to :

$$(\Delta E)_1 = E_{BCLR} - E(\Theta_{cl1}, \Theta_{cl2})$$

one can see that the resolution on energy using E_{BCLR} is of the order of 2 GeV. For the events in which the cluster is linked to only one BPC hit, we assume that the hit of the particle (x,y) is more known from the BPC than from the center of gravity of the cluster given by BCLR bank. Fig 15 also shows ΔR, the distance between the BEMC cluster hits and the ones deduced from BPC, at the same z value (-156.4 cm) :

$$\Delta R = \sqrt{(x_{bpc} - x_{cl})^2 + (y_{bpc} - y_{cl})^2}$$

and the angular resolutions $(\Delta\varphi)_1$ and $(\Delta\Theta)_1$, where :

$$(\Delta\varphi)_1 = \varphi(x_{cl}, y_{cl}) - \varphi(x_{bpc}, y_{bpc})$$

$$(\Delta\Theta)_1 = \Theta(x_{cl}, y_{cl}) - \Theta(x_{bpc}, y_{bpc})$$

Before being confident in the $(\Delta E)_1$ result we must check that $E(\Theta)$ computation gives the correct value, otherwise, such a comparison is meaningless. The error we can do on $E(\Theta)$, is due to the error on Θ, which is function of the z vertex and the (x,y) coordinates of the hit. In our 24 events, 5 have a vertex, because of the existence of a track in central tracker. The other events have no vertex, so its value is given by default from database and set to z=0. For verifying the z vertex influence on the Θ computation, we varied z value from z_1=-40 cm to z_2=40 cm, and compared the angle and the energy given at this z value with the angle and the energy at z=0. The result is shown in fig 16, where :

$$(\Delta\Theta)_2 = \Theta_{|z|\leq 40} - \Theta_{z=0}$$

is lower than 2° in almost all cases, while the resulting error on energy $(\Delta E)_2$:

$$(\Delta E)_2 = E(\Theta_{|z|\leq 40}) - E(\Theta_{z=0})$$

is of order of 100 MeV. Then setting z to 0 in the events(which have no track) does not affect very much the $E(\Theta)$ calculation .

Actually, the error on $E(\Theta)$ comes essentially from the error on (x,y) position of the cluster in the Θ computation. Figure 16 shows the error $(\Delta\Theta)_1$ using the events which have only one BPC hit linked to the cluster. This error is of about 2^o and leads to an error on $E(\Theta)$ of about 2 GeV.

We conclude that our method to calibrate the BEMC, or to study its resolution is very sensitive to the reconstruction of the cluster position. In the future, we will try to use the WLS of the BEMC stacks to get such a position.

4 conclusion :

Quasi-real QED Compton were observed in *ep* collisions at HERA, using H1 detector. The rate and distributions of these real events are compatible with the predictions.With our sample of 24 events we derived an HERA integrated luminosity on H1 of $\int \mathcal{L}dt = 26\pm6\ nb^{-1}$. For the BPC response one can already say that about 40% of photons convert before the chamber. The BEMC accuracy is of 2±2 GeV, the (±)2 GeV error comes essentially from the $\Theta_{cluster}$ determination, so we need more precision on the cluster position to be more accurate.

However, the results we already get with this very low statistic show that such a process is very promising.

Acknowledgments:

We are very grateful to Jozef Ferencei for illuminating discussions.

References

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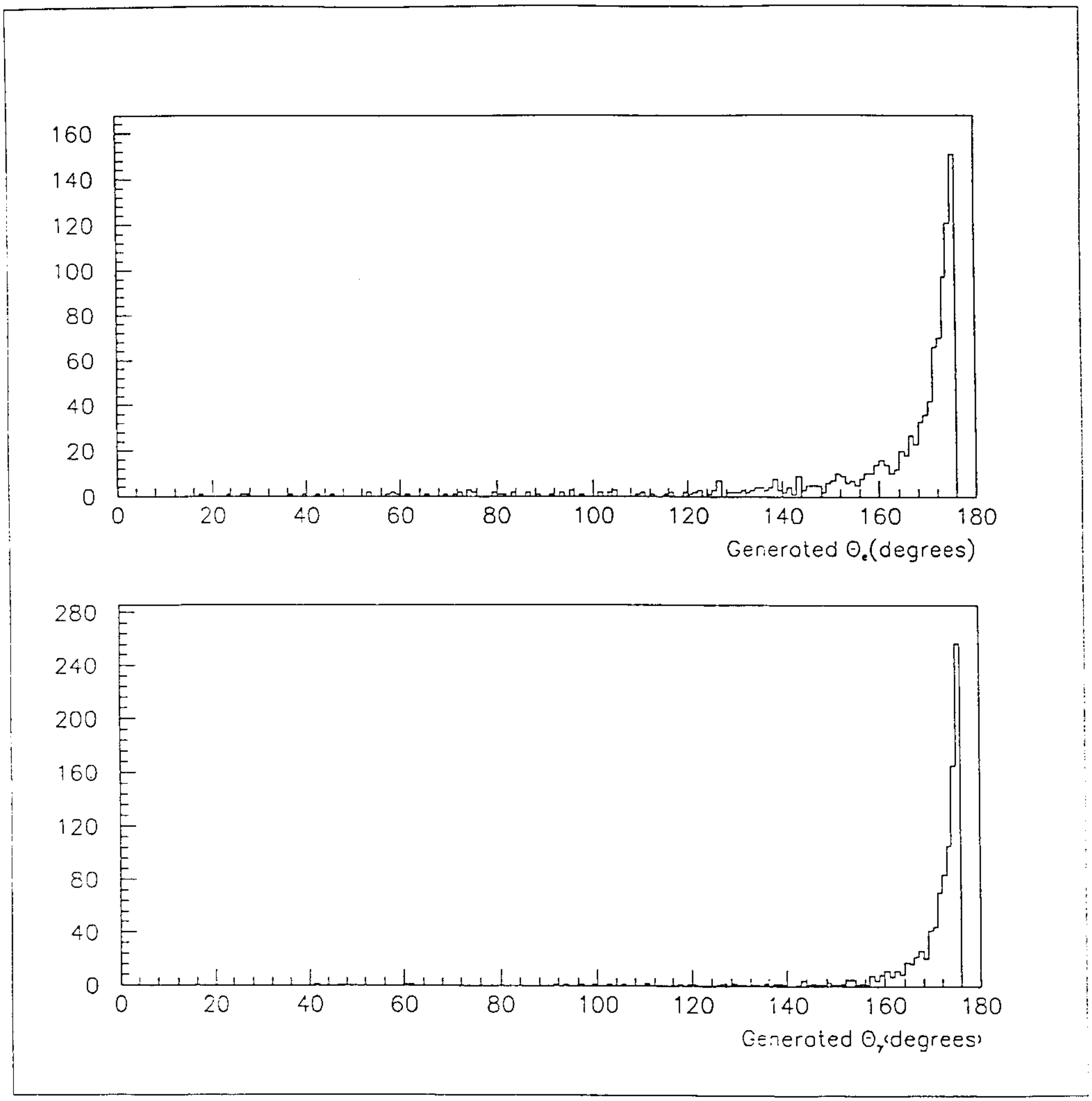
[6] T.Carli et al., Proc. Workshop on Physics at HERA, DESY, Hambourg(1991), vo. 3, p. 1468

[7] T.Ahmed et al (H1 collaboration), DESY 92-160; submitted to PL.



160
140
120
100
80
60
40
20
0
0 20 40 60 80 100 120 140 160 180
Generated Θe(degrees)
280
240
200
160
120
80
40
0
0 20 40 60 80 100 120 140 160 180
Generated Θγ(degrees)

fig 1

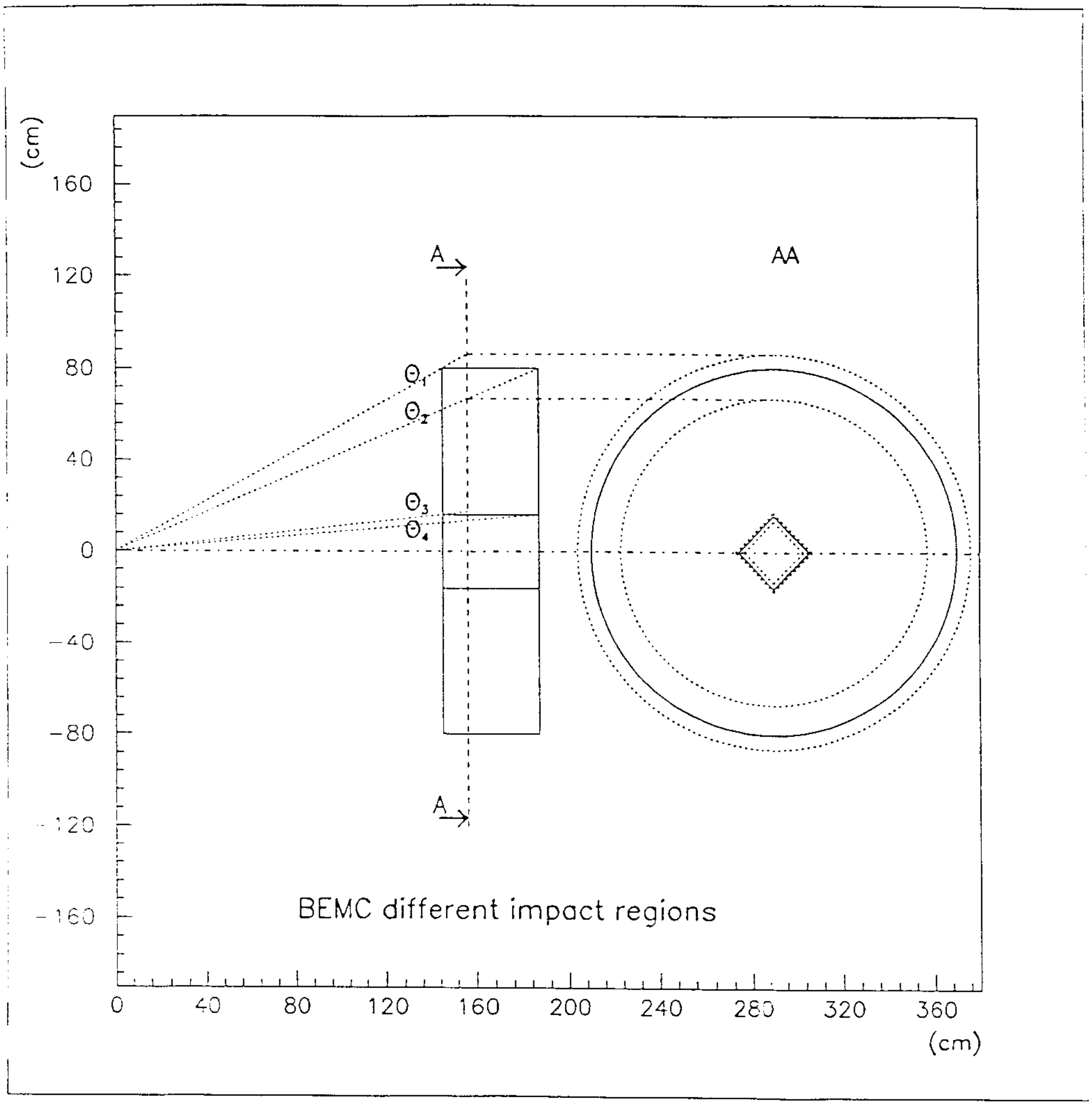
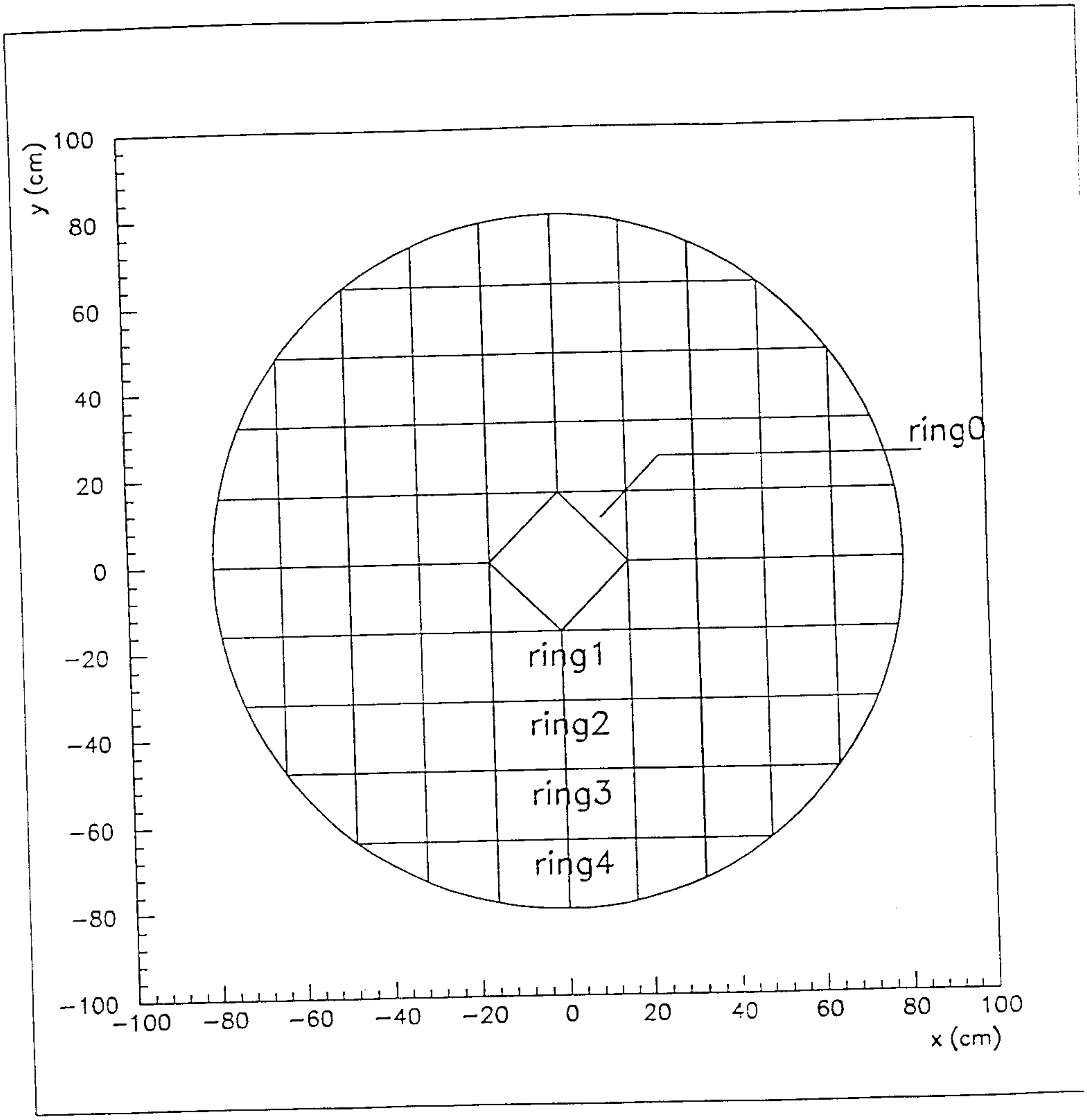
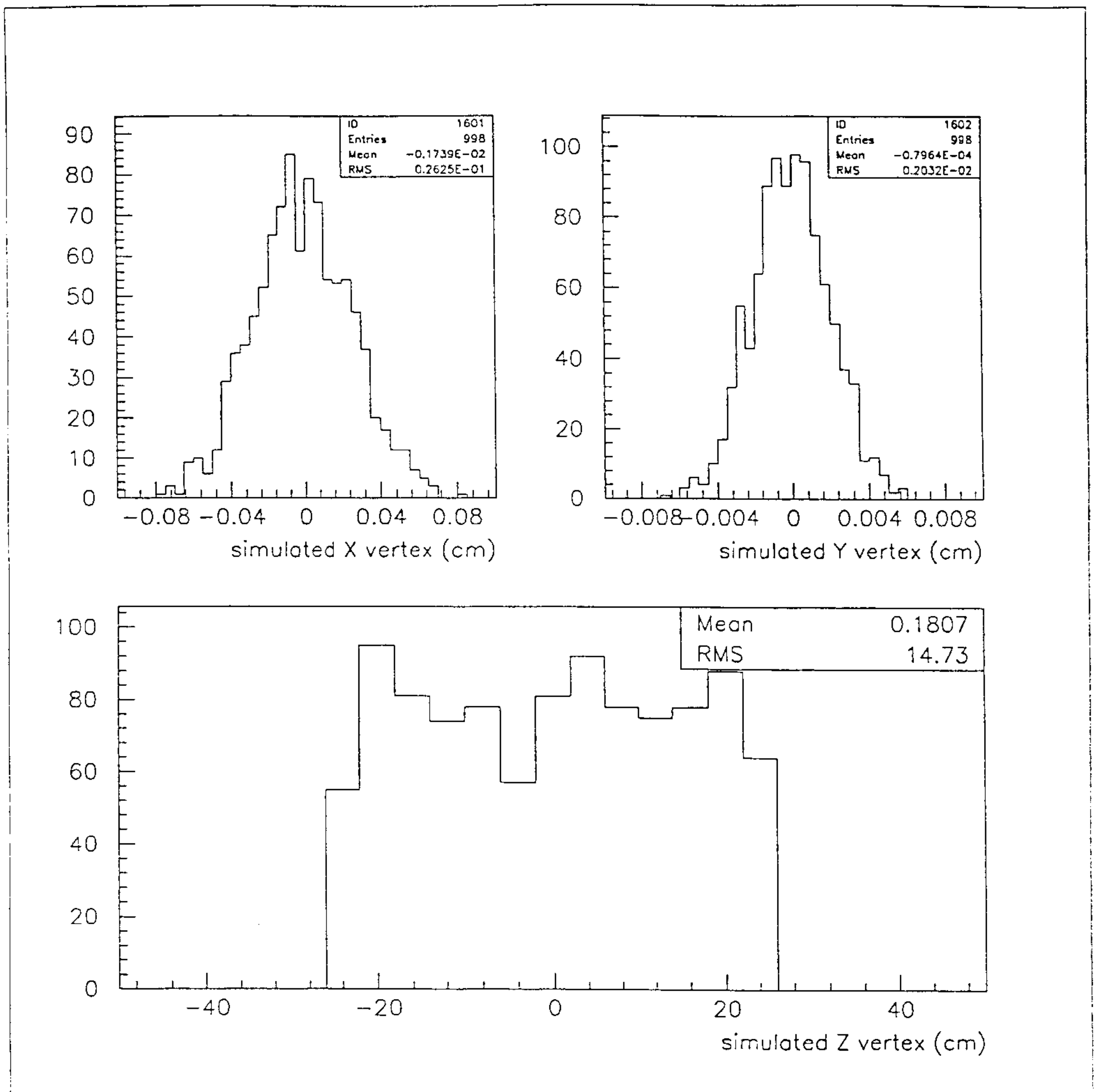

(cm)
160
120
80
40
0
-40
-80
-120
-160
A
A
AA
Θ1
Θ2
Θ3
Θ4
BEMC different impact regions
0
40
80
120
160
200
240
280
320
360
(cm)

fig 2



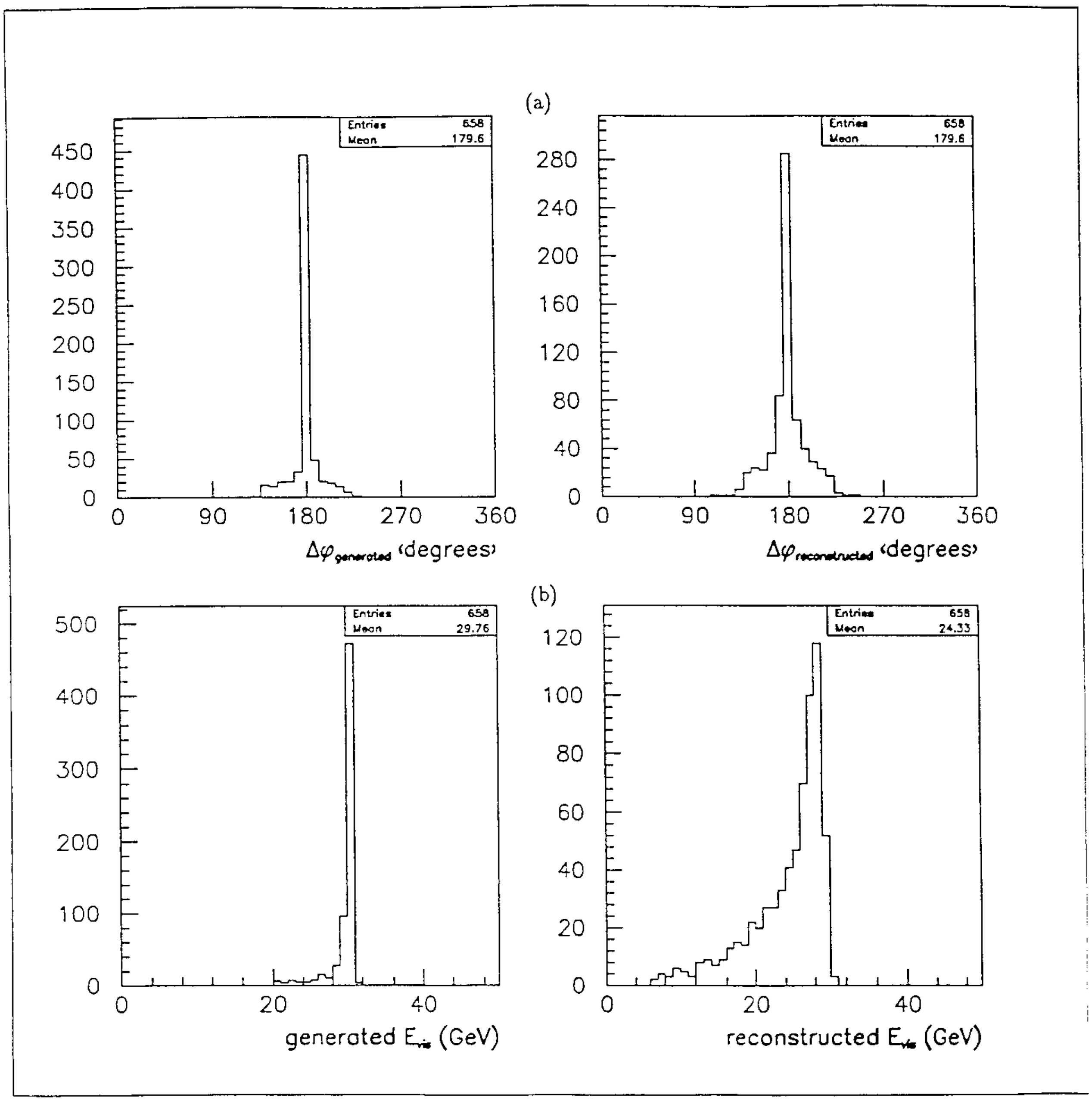
y (cm)
100
80
60
40
20
0
−20
−40
−60
−80
−100
−100
−80
−60
−40
−20
0
20
40
60
80
100
x (cm)
ring0
ring1
ring2
ring3
ring4

fig 3



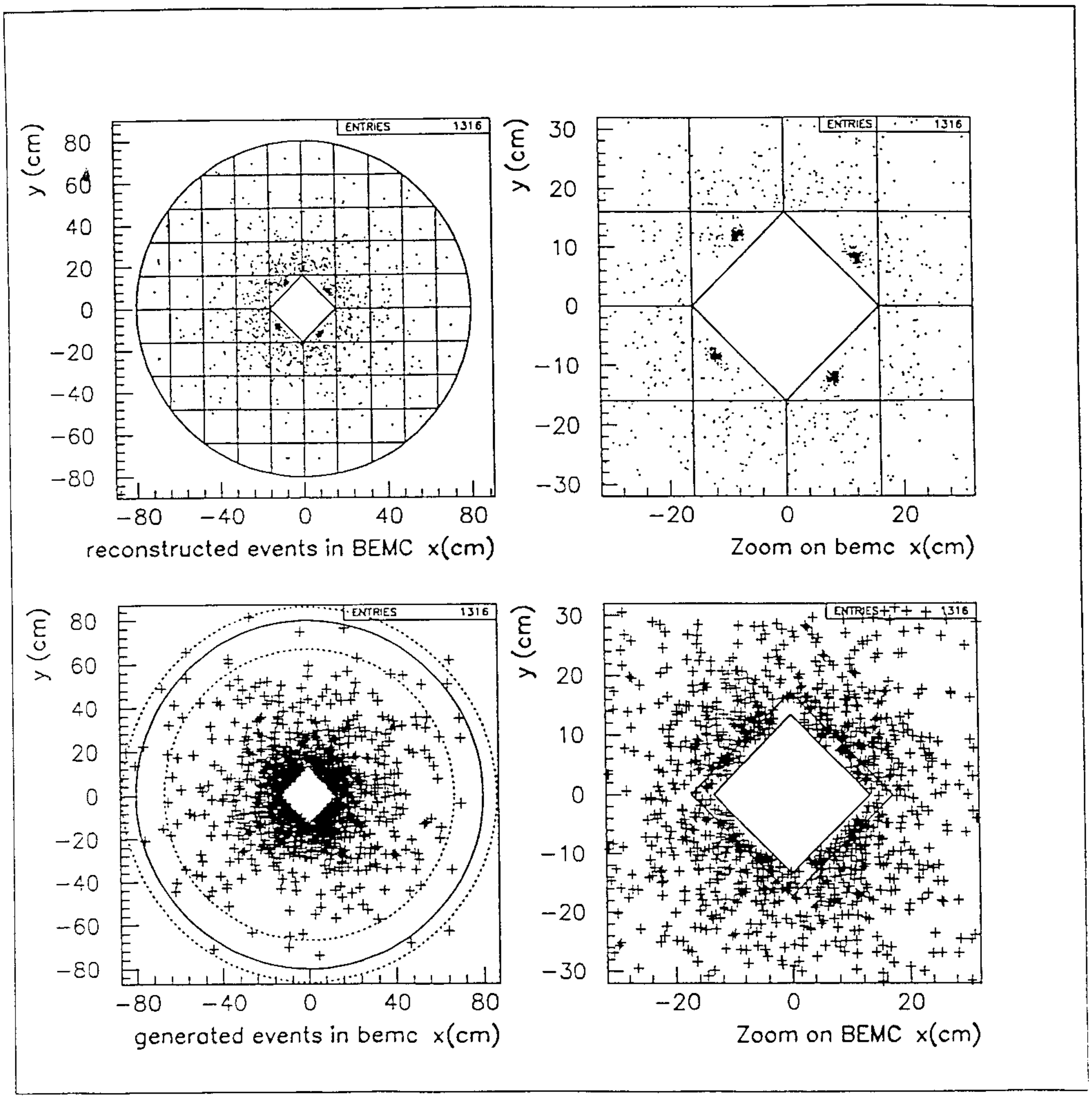
ID 1601
Entries 998
Mean −0.1739E−02
RMS 0.2625E−01
simulated X vertex (cm)
ID 1602
Entries 998
Mean −0.7964E−04
RMS 0.2032E−02
simulated Y vertex (cm)
Mean 0.1807
RMS 14.73
simulated Z vertex (cm)

fig 4



(a)
Entries 658
Mean 179.6
Δφ generated (degrees)
Entries 658
Mean 179.6
Δφ reconstructed (degrees)
(b)
Entries 658
Mean 29.76
generated E vis (GeV)
Entries 658
Mean 24.33
reconstructed E vis (GeV)

fig 5



ENTRIES 1316
y (cm)
reconstructed events in BEMC x(cm)
Zoom on bemc x(cm)
generated events in bemc x(cm)
Zoom on BEMC x(cm)

fig 6

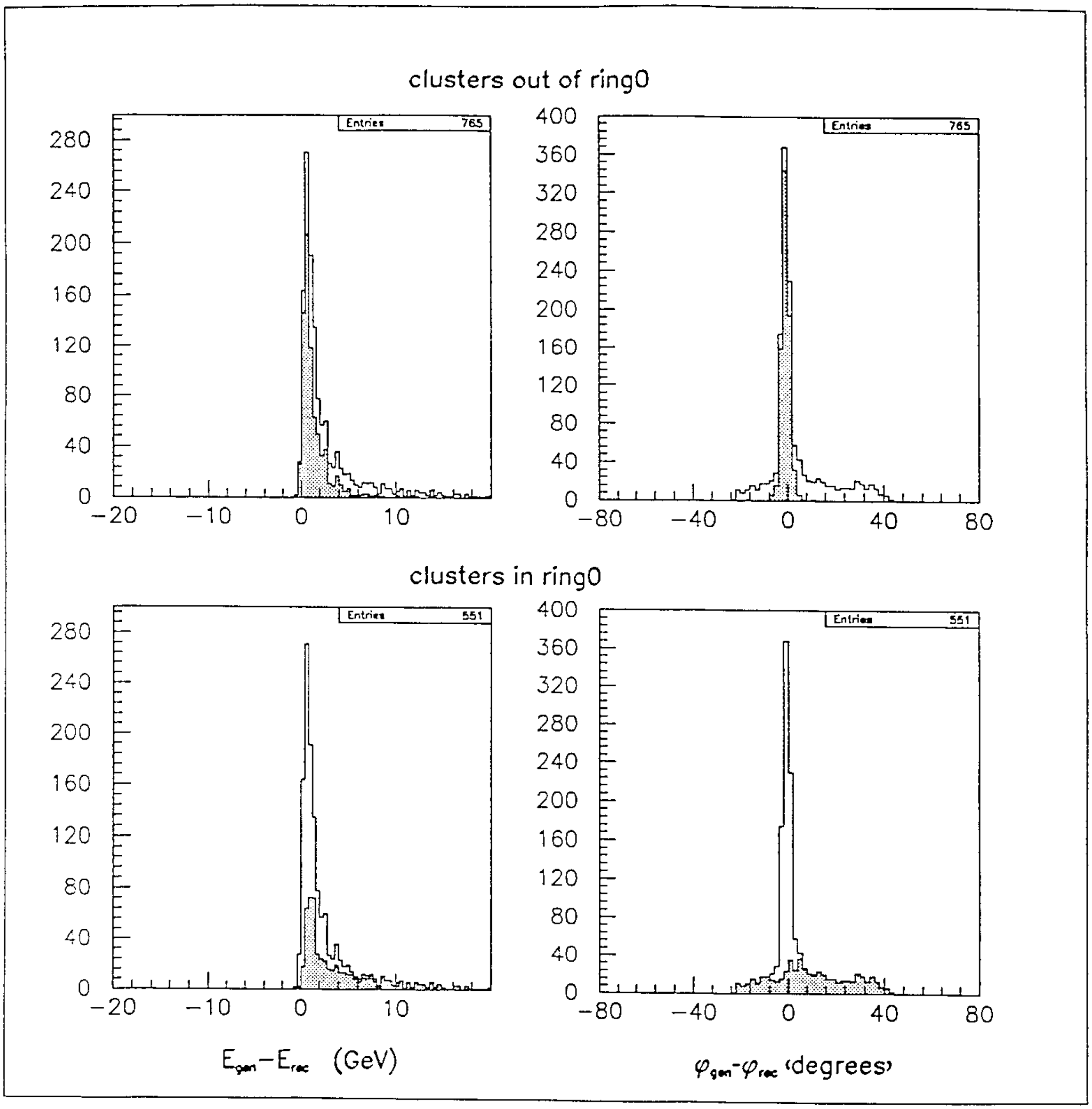

clusters out of ring0
Entries 765
Entries 765
clusters in ring0
Entries 551
Entries 551
$E_{gen}-E_{rec}$ (GeV)
$\varphi_{gen}-\varphi_{rec}$ (degrees)

fig 7

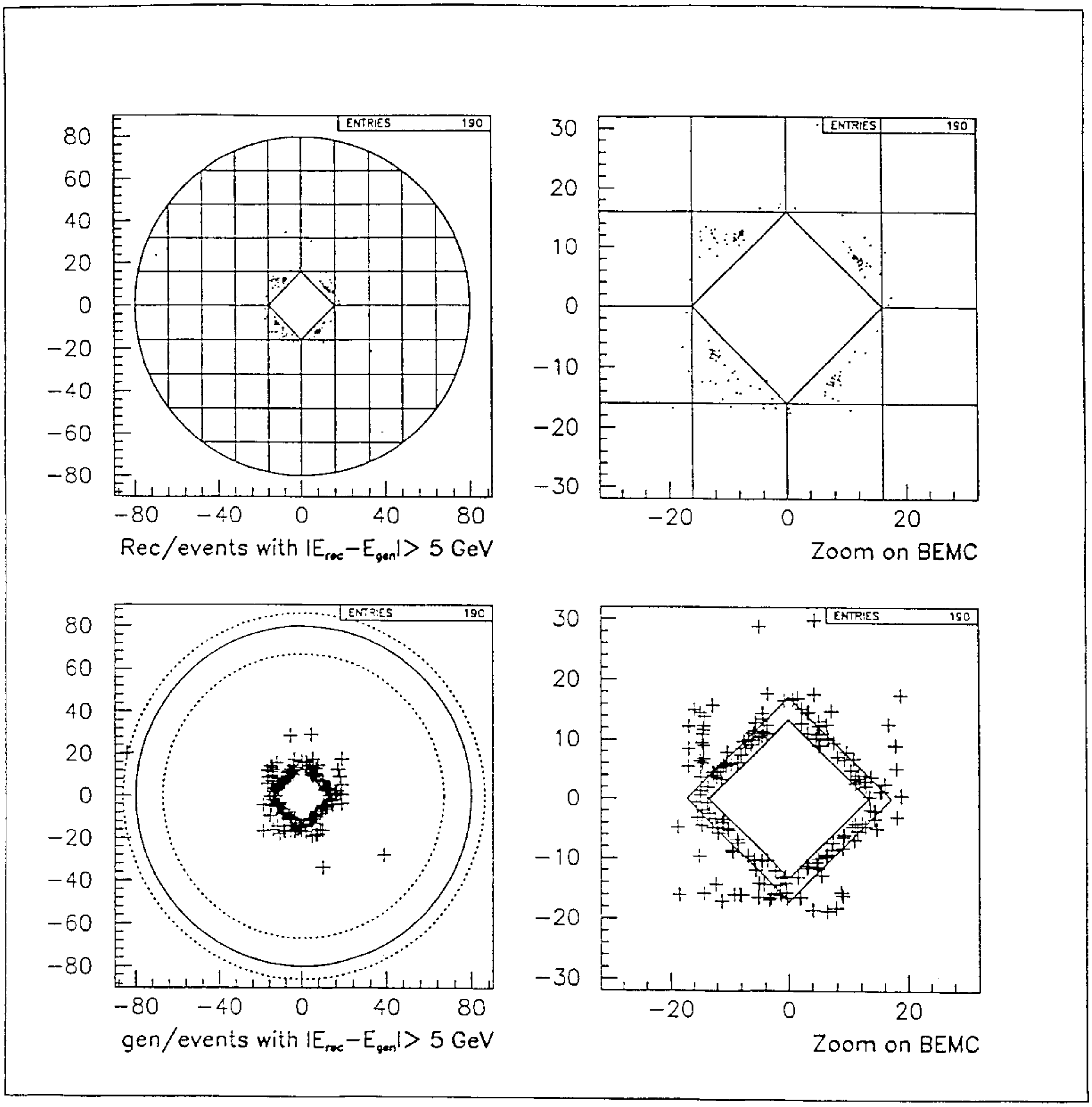
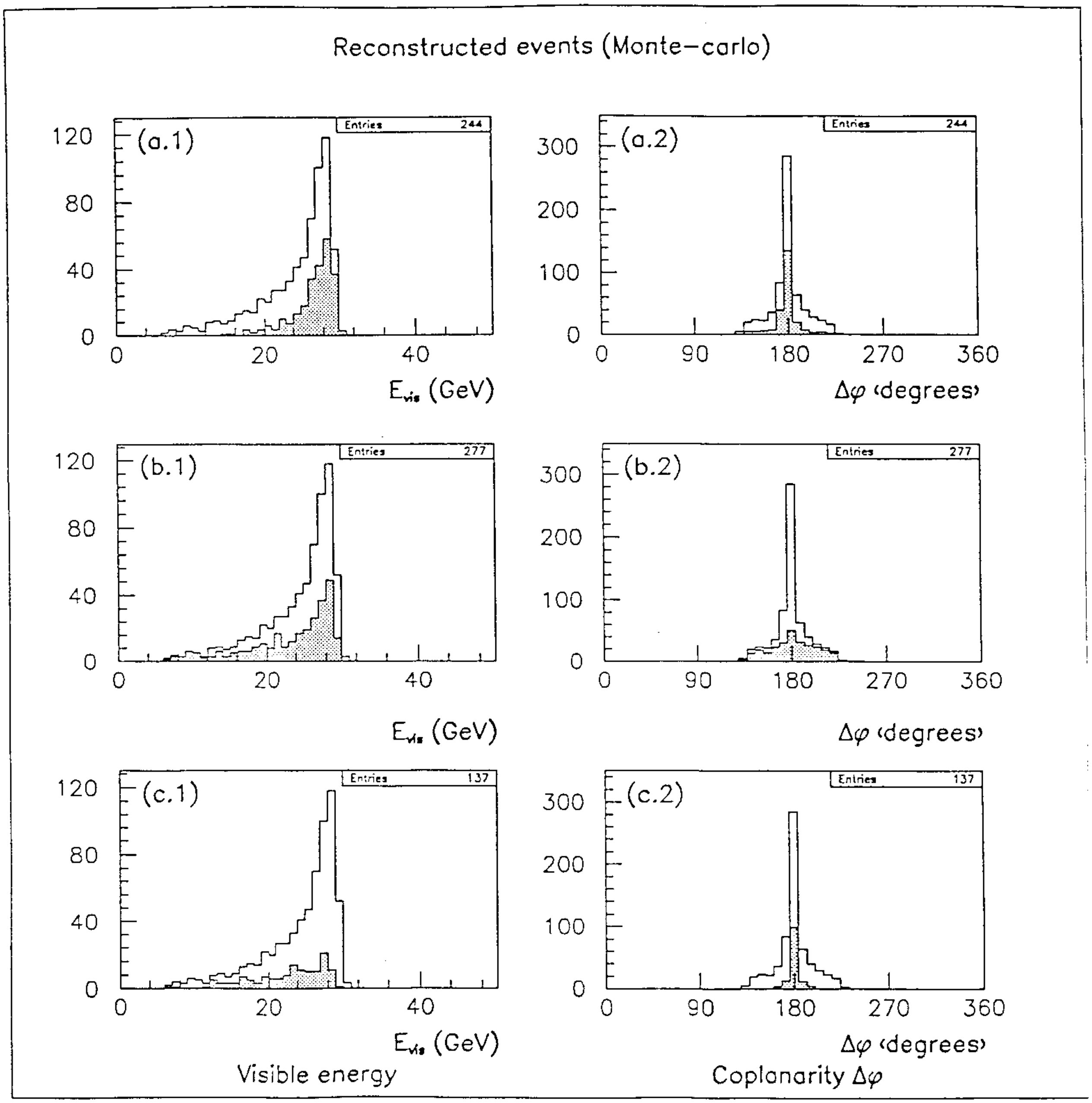
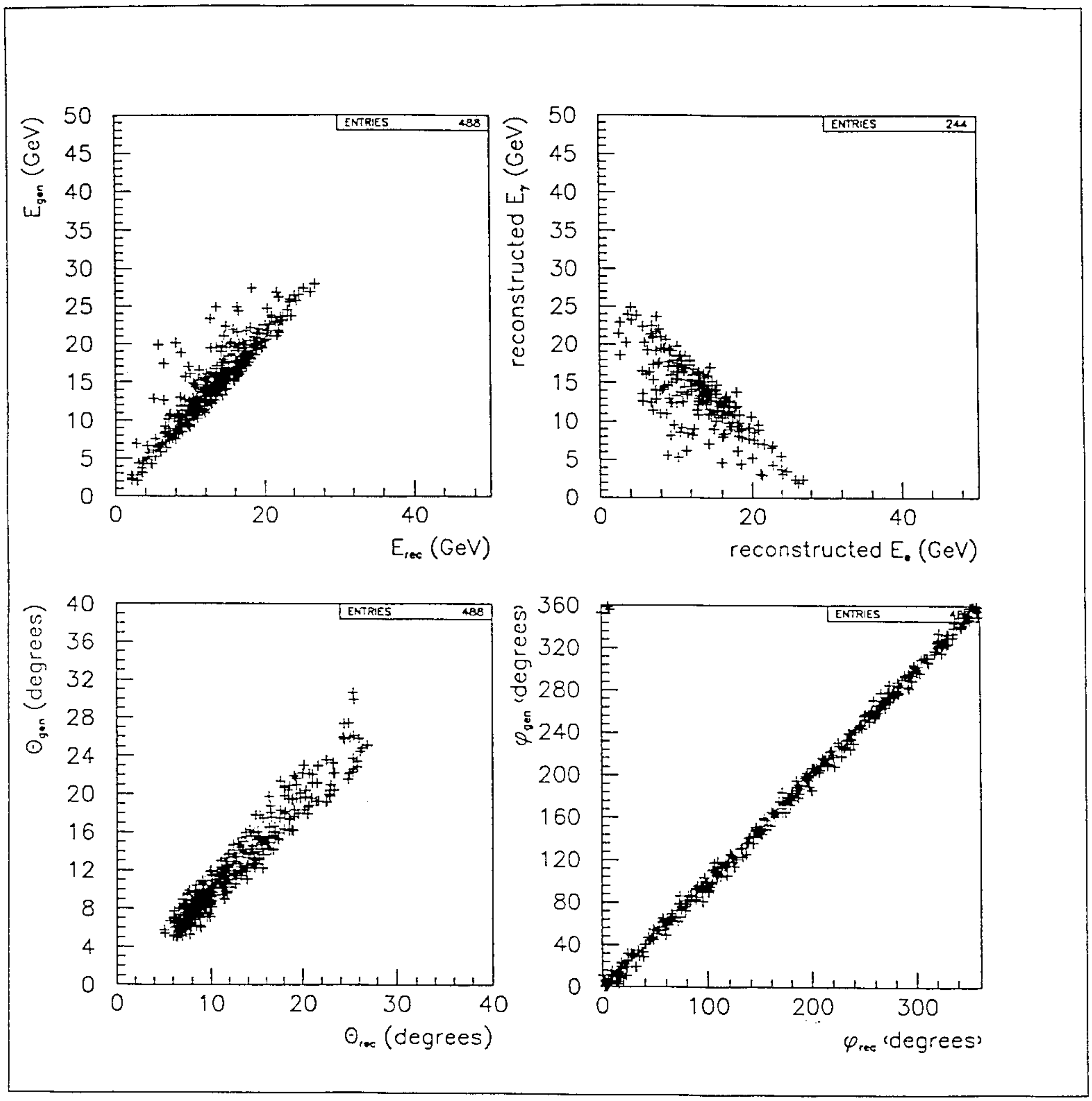

ENTRIES 190
80
60
40
20
0
−20
−40
−60
−80
−80 −40 0 40 80
Rec/events with $|E_{rec}-E_{gen}|$> 5 GeV
ENTRIES 190
30
20
10
0
−10
−20
−30
−20 0 20
Zoom on BEMC
ENTRIES 190
gen/events with $|E_{rec}-E_{gen}|$> 5 GeV
ENTRIES 190
Zoom on BEMC

fig 8



Reconstructed events (Monte-carlo)
(a.1)
Entries 244
(a.2)
Entries 244
(b.1)
Entries 277
(b.2)
Entries 277
(c.1)
Entries 137
(c.2)
Entries 137
0
40
80
120
0
100
200
300
0
20
40
0
90
180
270
360
E_vis (GeV)
Δφ (degrees)
Visible energy
Coplanarity Δφ

fig 9



ENTRIES 488
E_{gen} (GeV)
E_{rec} (GeV)
ENTRIES 244
reconstructed E_γ (GeV)
reconstructed E_e (GeV)
ENTRIES 488
Θ_{gen} (degrees)
Θ_{rec} (degrees)
ENTRIES
φ_{gen} (degrees)
φ_{rec} (degrees)

fig 10

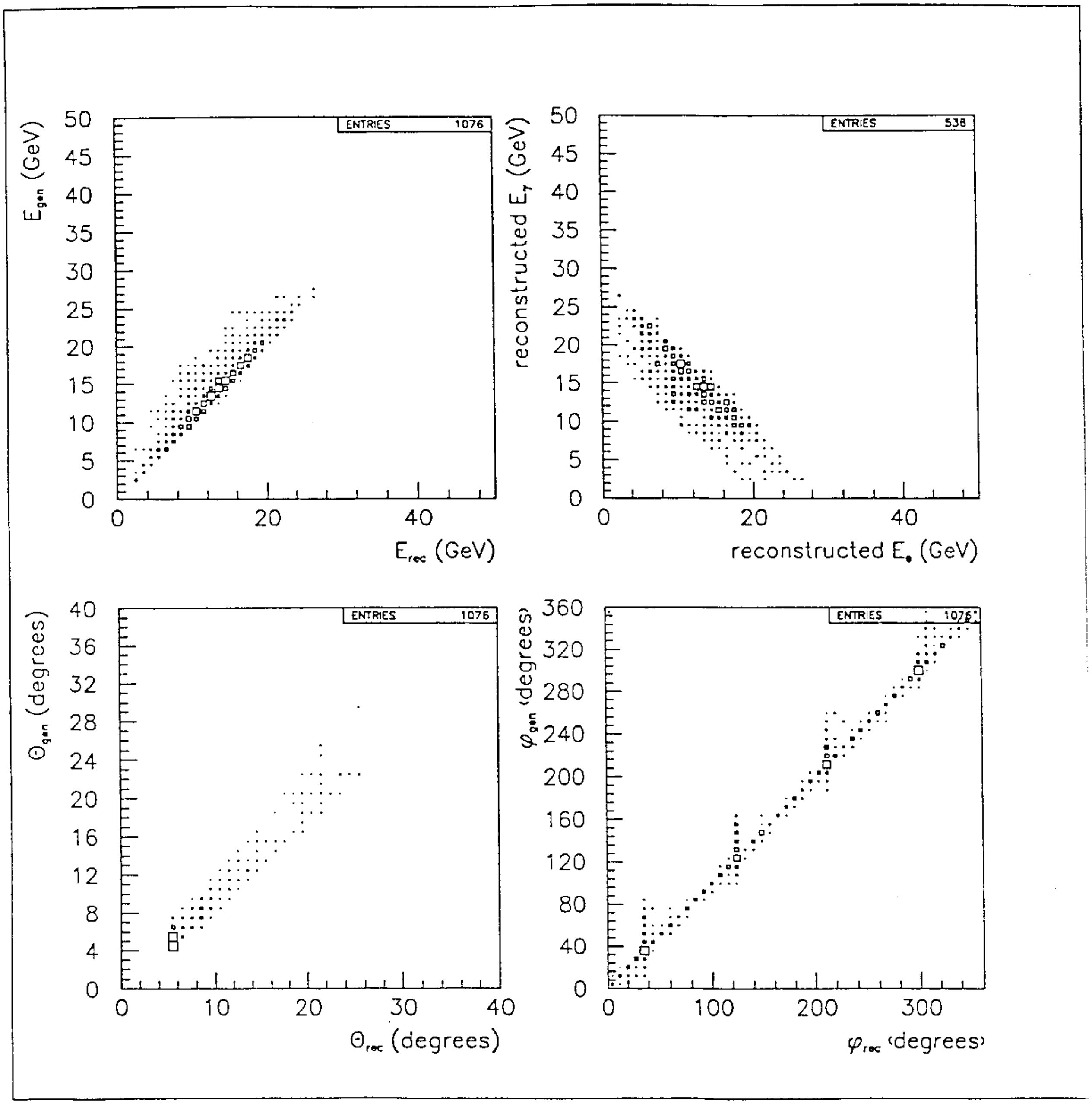

ENTRIES 1076
E_{gen} (GeV)
E_{rec} (GeV)
ENTRIES 538
reconstructed E_γ (GeV)
reconstructed E_e (GeV)
ENTRIES 1076
Θ_{gen} (degrees)
Θ_{rec} (degrees)
ENTRIES 1076
φ_{gen} (degrees)
φ_{rec} (degrees)

fig 11

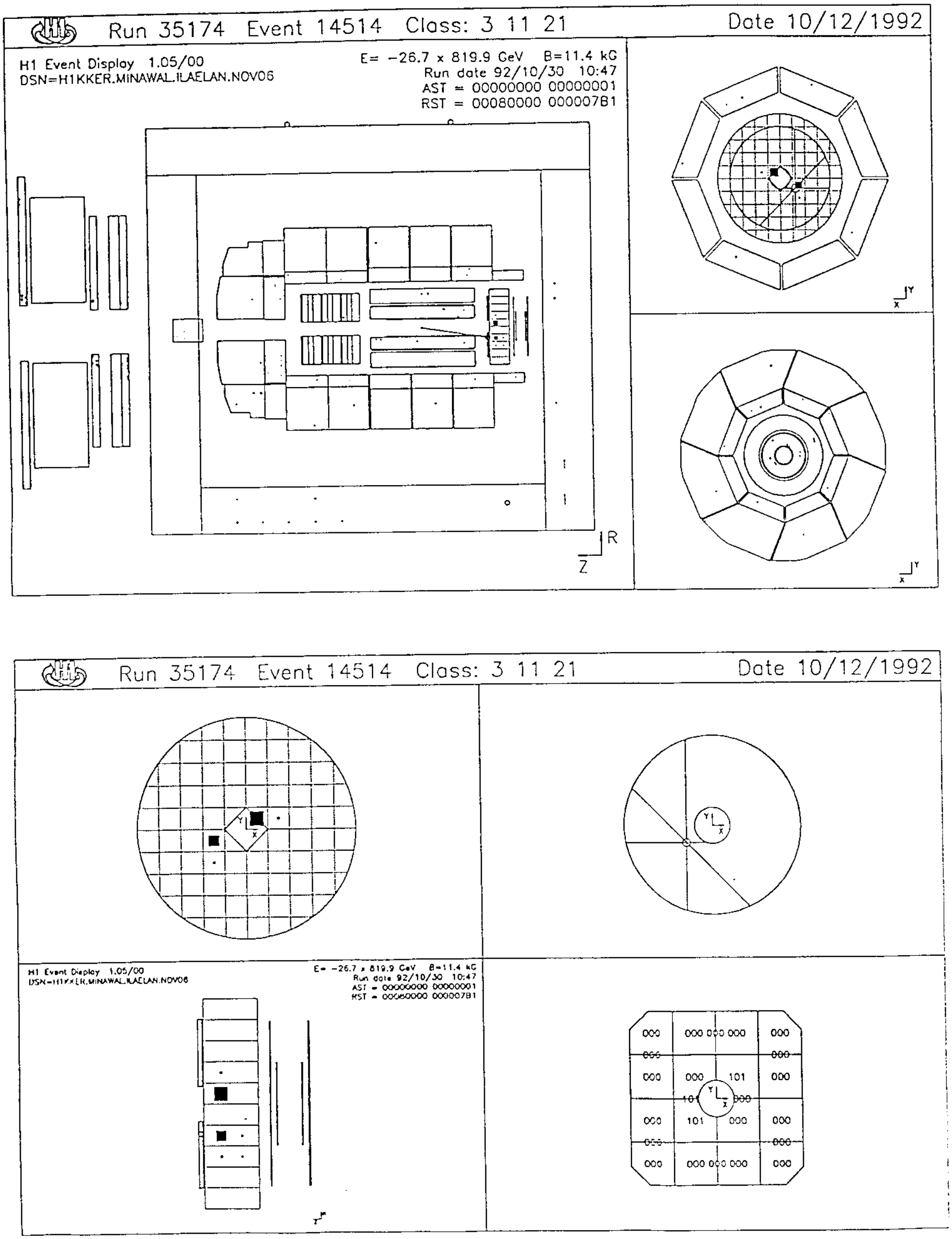

Run 35174 Event 14514 Class: 3 11 21
Date 10/12/1992
H1 Event Display 1.05/00
DSN=H1KKER.MINAWAL.ILAELAN.NOV06
E= -26.7 x 819.9 GeV B=11.4 kG
Run date 92/10/30 10:47
AST = 00000000 00000001
RST = 00080000 000007B1
R
Z
Y
X
Run 35174 Event 14514 Class: 3 11 21
Date 10/12/1992
000 000 000 000 000
000 000 101 000
101 000
000 101 000 000
000 000 000 000 000

fig 12

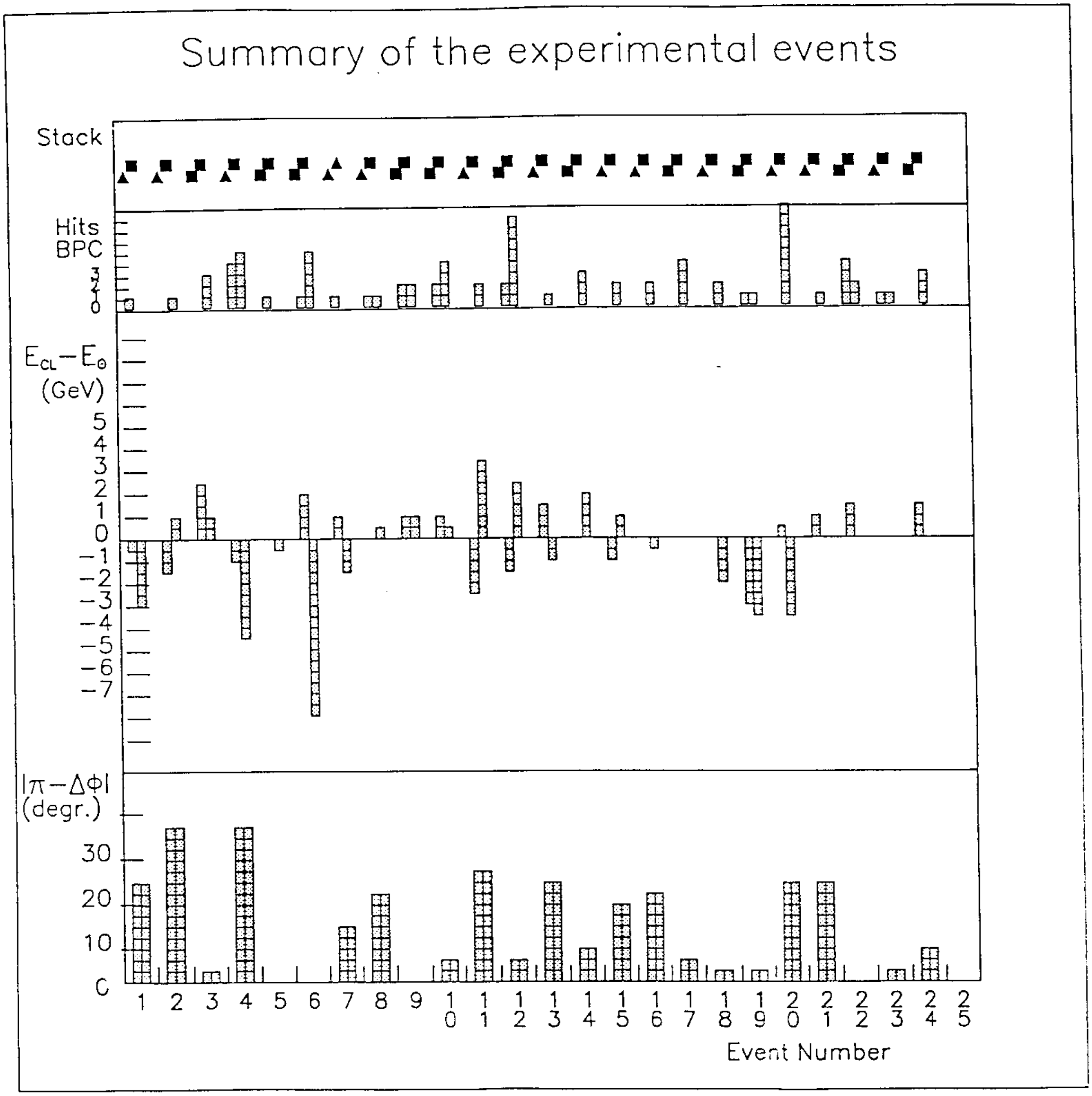

Summary of the experimental events
Stack
Hits
BPC
3
2
1
0
$E_{CL}-E_{\Theta}$
(GeV)
5
4
3
2
1
0
-1
-2
-3
-4
-5
-6
-7
$|\pi-\Delta\phi|$
(degr.)
30
20
10
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
Event Number

fig 13

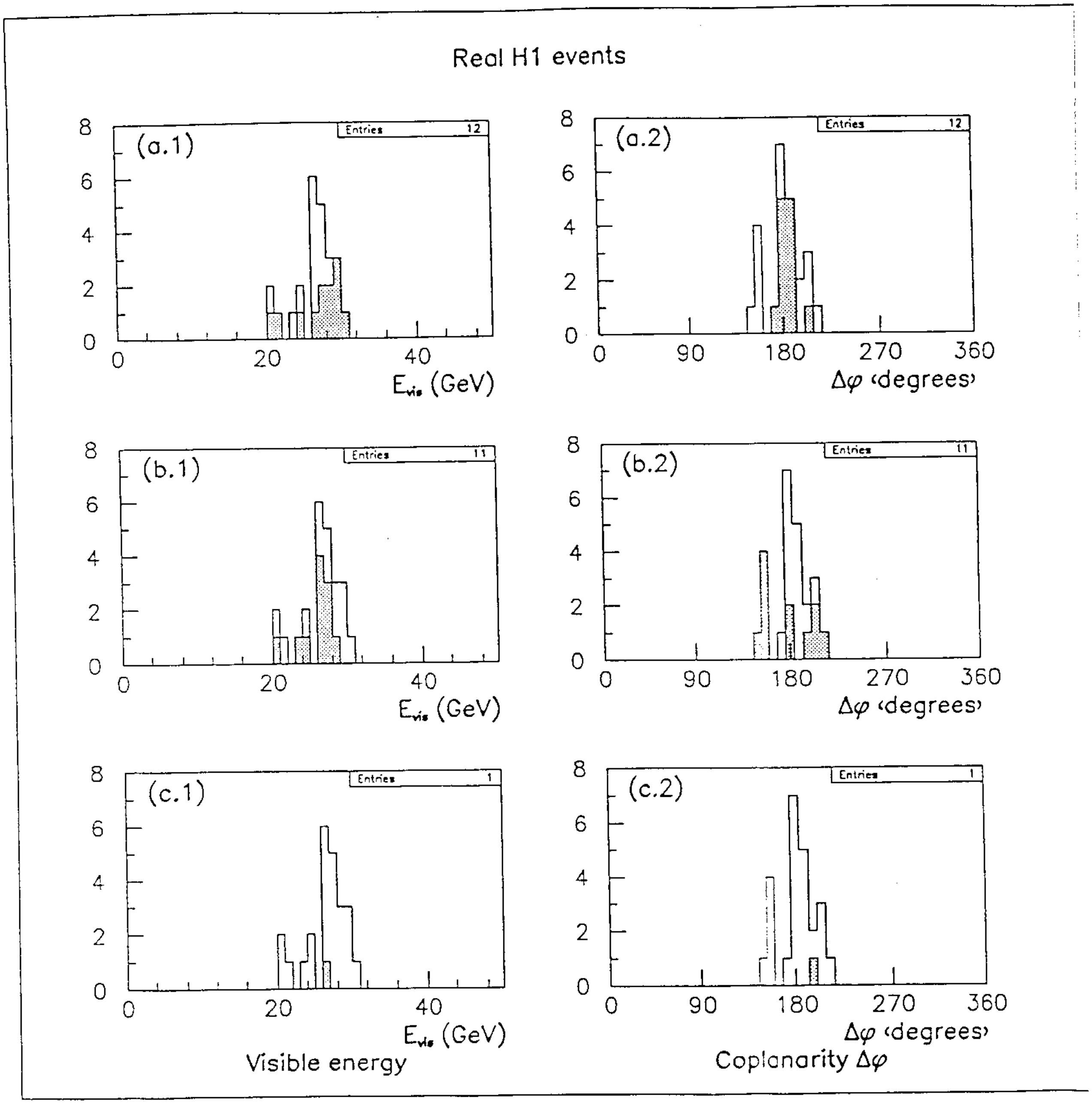
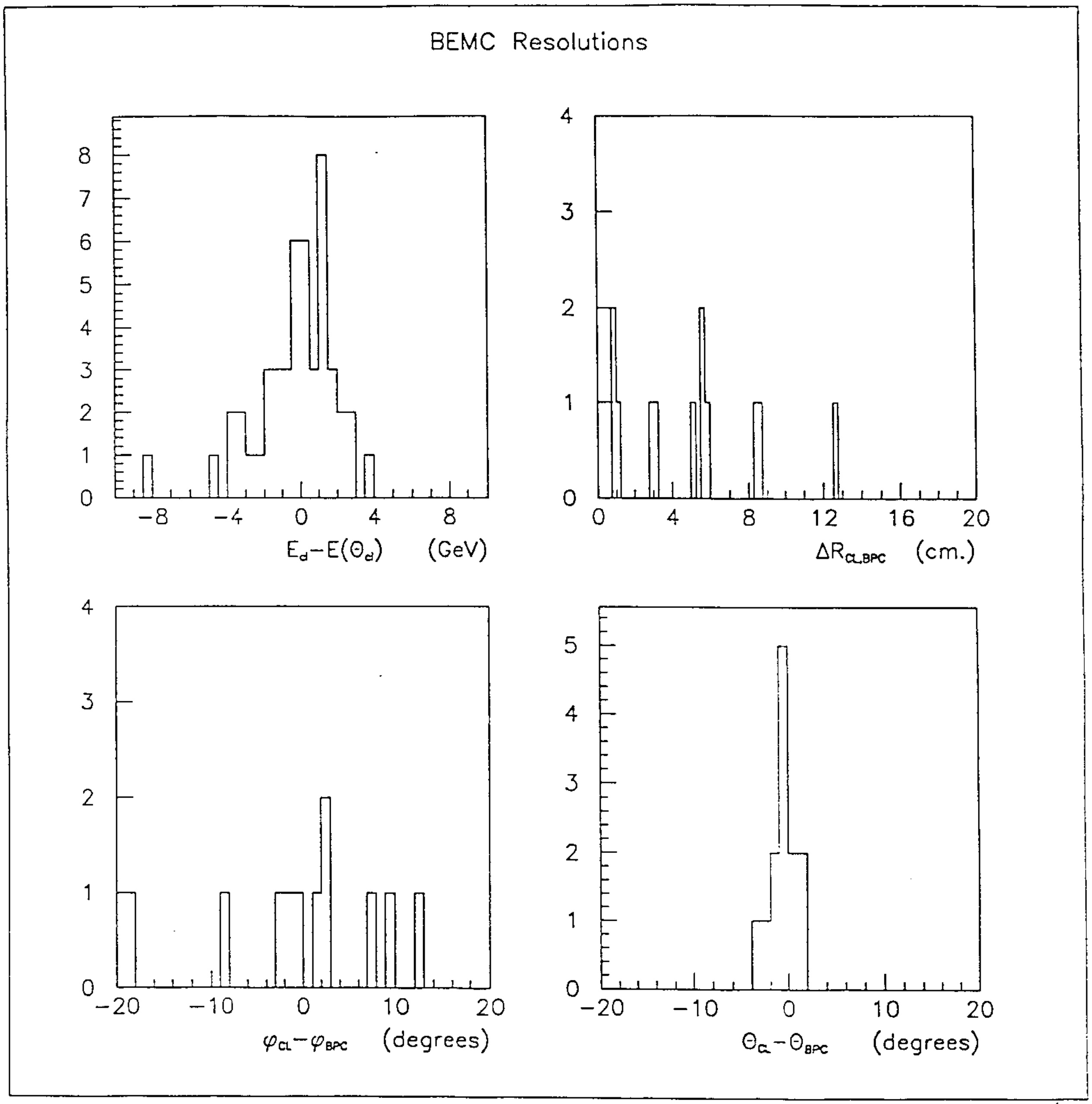
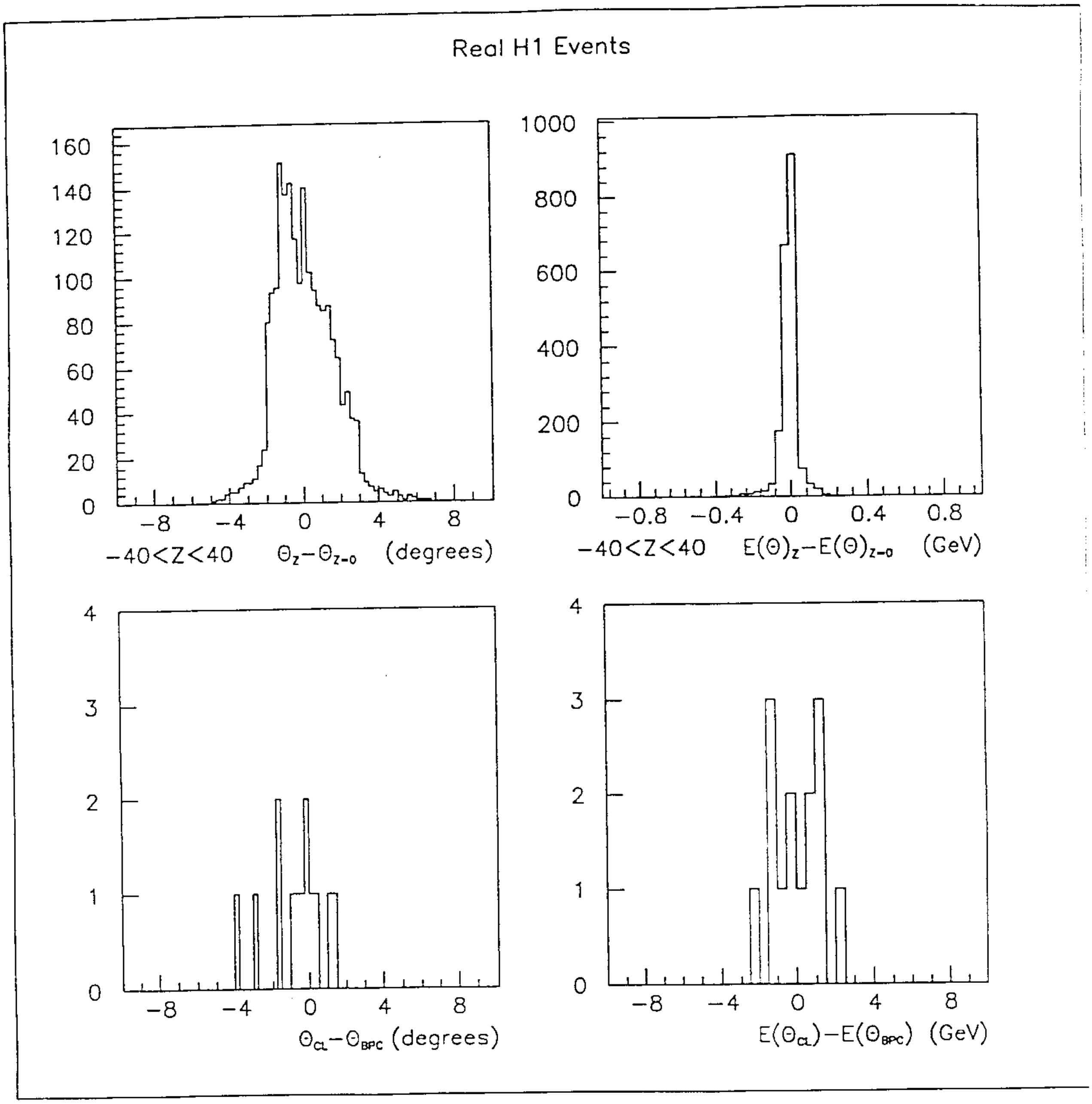

Real H1 events
(a.1)
Entries 12
E_{vis} (GeV)
(a.2)
Entries 12
Δφ (degrees)
(b.1)
Entries 11
E_{vis} (GeV)
(b.2)
Entries 11
Δφ (degrees)
(c.1)
Entries 1
E_{vis} (GeV)
Visible energy
(c.2)
Entries 1
Δφ (degrees)
Coplanarity Δφ

fig 14



BEMC Resolutions
$E_{cl}-E(\Theta_{el})$ (GeV)
$\Delta R_{CL,BPC}$ (cm.)
$\varphi_{CL}-\varphi_{BPC}$ (degrees)
$\Theta_{CL}-\Theta_{BPC}$ (degrees)

fig15



Real H1 Events
160
140
120
100
80
60
40
20
0
−8 −4 0 4 8
−40<Z<40 $\Theta_z - \Theta_{z=0}$ (degrees)
1000
800
600
400
200
0
−0.8 −0.4 0 0.4 0.8
−40<Z<40 $E(\Theta)_z - E(\Theta)_{z=0}$ (GeV)
4
3
2
1
0
−8 −4 0 4 8
$\Theta_{CL} - \Theta_{BPC}$ (degrees)
4
3
2
1
0
−8 −4 0 4 8
$E(\Theta_{CL}) - E(\Theta_{BPC})$ (GeV)

fig 16