CB-Note 343

LEAR Crystal Barrel Experiment, PS 197 Energy Problem in Flight – Solutions and Implications

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Contents

1 Abstract

The missing energy problem of the all neutral data in flight is solved. The solution consists of a new set of energy correction functions in the BCTRAK routine BCEGAM.F and a corresponding calibration with the proper annihilation vertex. The correction consists of theta and energy dependent functions which result together with a new vertex definition the problem of missing energy and momentum for the all neutral data, taken 1996 in flight.

2 Energy problem

Since September 1995 data taking, a well known problem of in flight data is the missing total energy and the missing total momentum. For the scan run 1996 evaluated with the standard CB software there is a missing energy of about 1.5 % and a missing momentum of about 3% for all neutral data. These deviations are of the order of 30–50 MeV (MeV/c) and cannot be neglected, because they might affect the efficiency, the overall normalization and/or partial wave analysis of the data. A kinematical fit with a free z–vertex determined the vertex to be about -1.5 cm backwards (table 1). Thus, the fit tries to compensate the missing energy/momentum by shifting the vertex which is equivalent to an increased lorentz boost.

	1350 MeV/c	**1525 MeV/c**	**1642 MeV/c**	**1800 MeV/c**
ΔE / E	-1.98 %	-1.62 %	-1.85 %	-1.31 %
ΔP /P	-3.56 %	-2.84 %	-3.22 %	-2.44 %
z–vertex reco at 0.0	-1.31 cm	-1.39 cm	-1.64 cm	-1.15 cm

Table 1: *Missing energy and momentum for three scan points.*

To correct for this behaviour, a main constraint is, that Monte Carlo and Data act the same way. However, Monte Carlo events do not show big problems with energy/momentum and behave rather properly (table 2, first column). Several approaches have been made so far to solve the energy missing problem. An overview about the deviations between reconstructed and correct values for the π^0 and η invariant masses and of total energy and momentum for the different energy correction methods is given in figure 1.

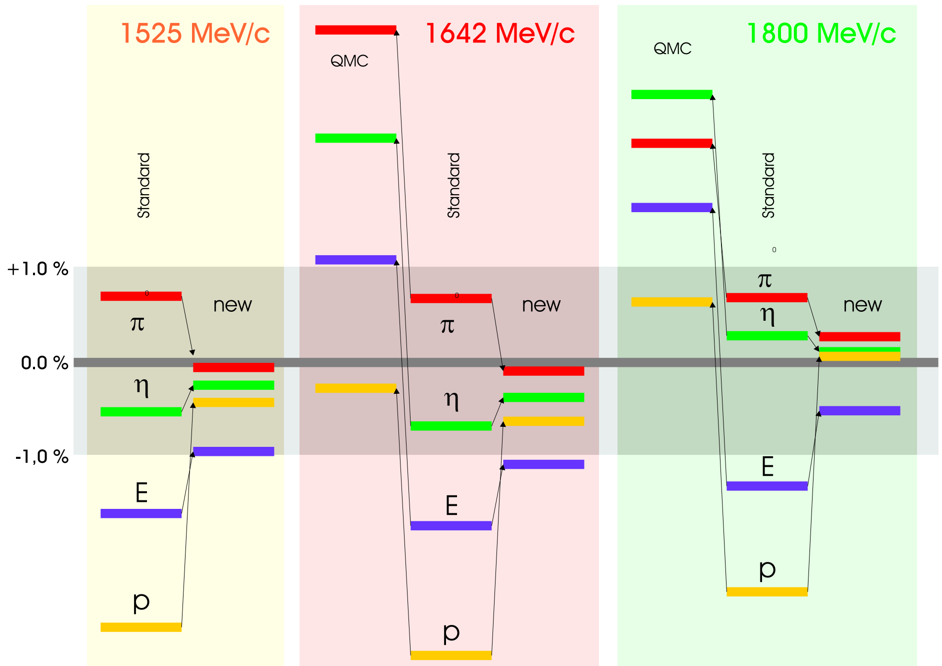


Figure 1: *The figure gives an overview between reconstructed and correct values for the π^0 and η invariant masses and of total energy and momentum for different energy correction methods.*

2.1 Standard software

The energy correction functions which are used in the standard Crystal Barrel software, have been developed by Nigel Hessey [2] for at rest data and therefore are valid only for photons below 1 GeV. Nigels correction, however, was not correct, because the mean values of the deviation data–Monte Carlo were taken and not the peak values (see [3]).

Also clusters with merged pions were included for the determination of high energy photon correction. This gives a strong bias, as you can see in figure 2.1, where you can see the "blop" of merged pions in the lower right edge, which affects the correction function, if it is not peak oriented but average oriented.

Furthermore, there are different mechanisms for energy losses in single photon and multi-photon clusters. The second kind has an energy sharing problem between the PEDS. This yields different energy dependencies. The low energy PEDS suffer from randomly accepted crystals around the threshold (due to noise)

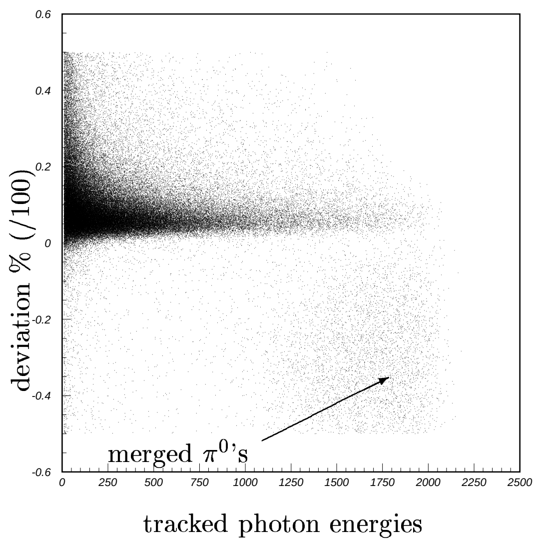


Figure 2: *The figure shows the deviation in percent of the tracked photon Monte Carlo energies to the generated Monte Carlo energies for a $3\pi^0$ data set at 1940 MeV/c.*

at the cluster edges. However, the standard offline uses the same correction for all photons.

2.2 QMC

The QMC method [1], in which a 3 % correction to all photon energies is applied, does not work. This method works fine for total momentum and the z–vertex, but invariant masses are far off and the total energy is slightly too high (see also figure 1).

2.3 Munich

The method developed in Munich by I.Uman [3] is much better and handles Monte Carlo and Data in the same way (apart from a different multiplicative factor for MC and Data for their energy correction function). A calibration using their new correction functions was not performed.

2.4 Bochum

2.4.1 Energy correction function

In Bochum we have used $3\pi^0$ and $\pi^0\pi^0\eta$ Monte Carlo events at a beam momentum of 1940 MeV/c (20 000 each) providing a proper set of high and low energy

Photons as well as merged π^0's and determined new energy correction functions (taking the problems mentioned into account). For each ring of crystals we have determined a θ–correction by a MINUIT–fit, requiring the invariant masses for π^0/η to be correct as well as energy/momentum conservation. We applied those corrections afterwards and determined by additional fits three different correction functions:

- dE1(E) for clusters with one PED and no merged pions
- dE2H(E) for the PED with the highest energy in a multiped cluster
- dE2L(E) for all other PEDS in a multiped cluster

In figure 3, for $\theta = 1$ and $\theta = 4$, these correction functions are plotted and compared to the "old", standard method.

At low energies, the behaviour of all functions is grossly the same, but the old parametrization overestimated the losses by far. Abovet 200 MeV the new functions are flatter equivalent to [3] and correspond much more to the theoretical expectation: The peak at low energies is due to the fact that some crystals on the boundary of a cluster add randomly some energy around the threshold of 1 MeV! Due to the problem of sharing the energy of a cluster between PEDS the high energy PEDS are always lowered while the low energy PEDS are enhanced. This effect is clearly seen in the new function dE2L which is lower than dE1.

This new set of functions lowers the deviations between reconstructed and generic MC data at 1940 MeV/c (2):

	standard		**new**	**theoretical**
E_{tot}	3082 MeV	$\rightarrow$	3096 MeV	(3095 MeV)
P_{tot}	1926 MeV/c	$\rightarrow$	1932 MeV/c	1940 MeV/c
M_{π^0}	135.0 MeV/c^2	$\rightarrow$	134.7 MeV/c^2	134.9 MeV/c^2
M_η	543.1 MeV/c^2	$\rightarrow$	547.3 MeV/c^2	547.3 MeV/c^2

Table 2: *The improvement of Monte Carlo data (at 1940 MeV/c beam momentum) using the new energy correction functions.*

The values (e.g. E_{tot} or η–mass) go in the right direction, but for real data the new correction functions do not yield a big improvement (Table 3):

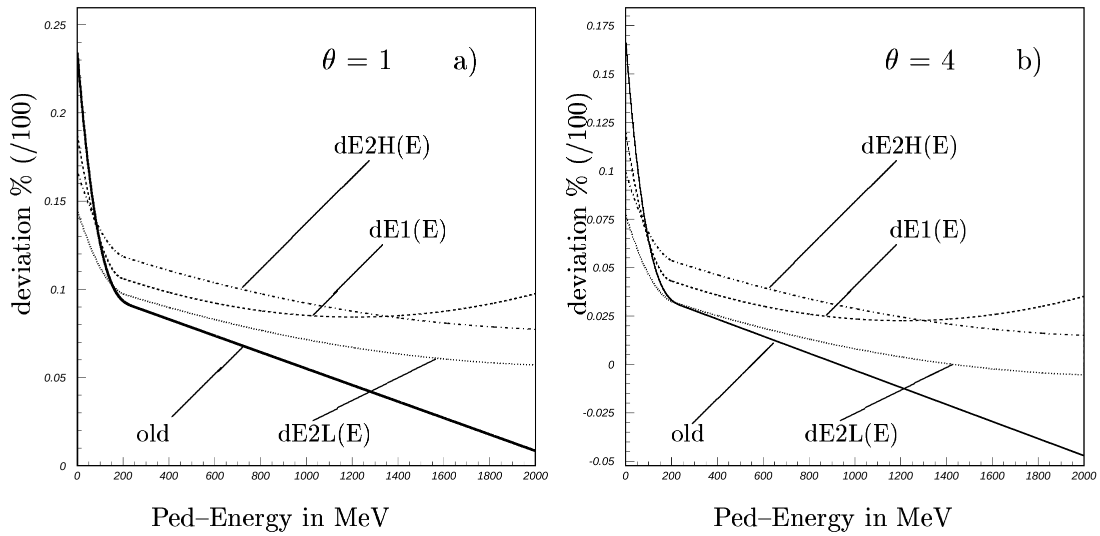


Figure 3: *The plot shows the correction functions a) for $\theta = 1$ and b) for $\theta = 4$. Be aware of the different 0 % deviation line.*

	standard		**new**	**theoretical**
E_{tot}	3055 MeV	$\rightarrow$	3056 MeV	(3095 MeV)
P_{tot}	1907 MeV/c	$\rightarrow$	1927 MeV/c	1940 MeV/c
M_{π^0}	134.6 MeV/c^2	$\rightarrow$	134.2 MeV/c^2	134.9 MeV/c^2
M_η	538.7 MeV/c^2	$\rightarrow$	543.4 MeV/c^2	547.3 MeV/c^2

Table 3: *The improvements in real data (September1995 data at beam momentum 1940 MeV/c) using the new energy correction functions.*

2.4.2 z–vertex calibration

Since the kinematically fitted z–vertex deviates strongly from the reconstructed vertex, we have used the new correction functions, but have calibrated at other z-vertices, to see if there is any improvement. It was expected, because 1 cm z–vertex displacement changes the mass of a 600 MeV π^0 in forward direction by more than 3%. Since we calibrate with such π^0's, the wrong vertex spoils the whole calibration.

If the vertex lies upstream (i.e. the z–vertex is negative), the pion turns out to be reconstructed (at z = 0.0) with a too heavy mass. That means, all calibration constants in forward direction will decrease and will increase in backward direction.

Some of this effect can be recovered by the calibration, but, since the net number of π^0's in forward and backward direction is different the total energy must be wrong.

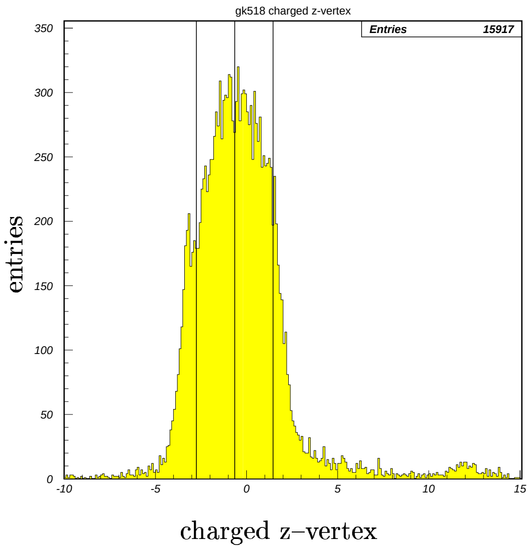


Figure 4: *The figure shows the charged z–Vertex of DLT GK518, a mixed triggered scan data tape at 1800 MeV/c. The centered line defines the z–vertex at -0.65 cm, the other lines define the target size* $\pm 2.1cm$.

2.4.3 Results

The new calibration was performed for data at 1525 MeV/c in 1996 using vertices $(x = 0, y = 0, z = z_0)$ with $z_0 = 0.0, -0.5, -1.0, -1.5cm$. It turned out, that the optimum lies around $z_0 = -0.65cm$ (see figure 5 a)). The new calibration with z–vertex at $-0.65cm$ has been used for further analysis and is now the reference calibration. The value for $z_0 = -0.65cm$ is supported by charged event data (see figure 4). Furthermore, the deviation of the π^0–mass, η–mass, E_{tot} and P_{tot} is minimal, as you can see in figure 5 a).

This result has been checked with data from 1642 MeV/c (1 run) and 1800 MeV/c (1 DLT) and the vertexposition was supported by these momenta (see figure 5 b) and c)). The residual errors, using the new method, are:

E_{tot}	$\sim 1\%$ too small (systematically)
P_{tot}	$\left\|\frac{\Delta P}{P}\right\| < 0.6\%$ ($<$ 10MeV/c)
M_{π^0}	$\left\|\frac{\Delta M}{M}\right\| < 0.1\%$ ($<$ 100keV/c^2)
M_η	$\left\|\frac{\Delta M}{M}\right\| < 0.4\%$ ($<$ 2MeV/c^2)

Table 4: *The residual errors of the new method*

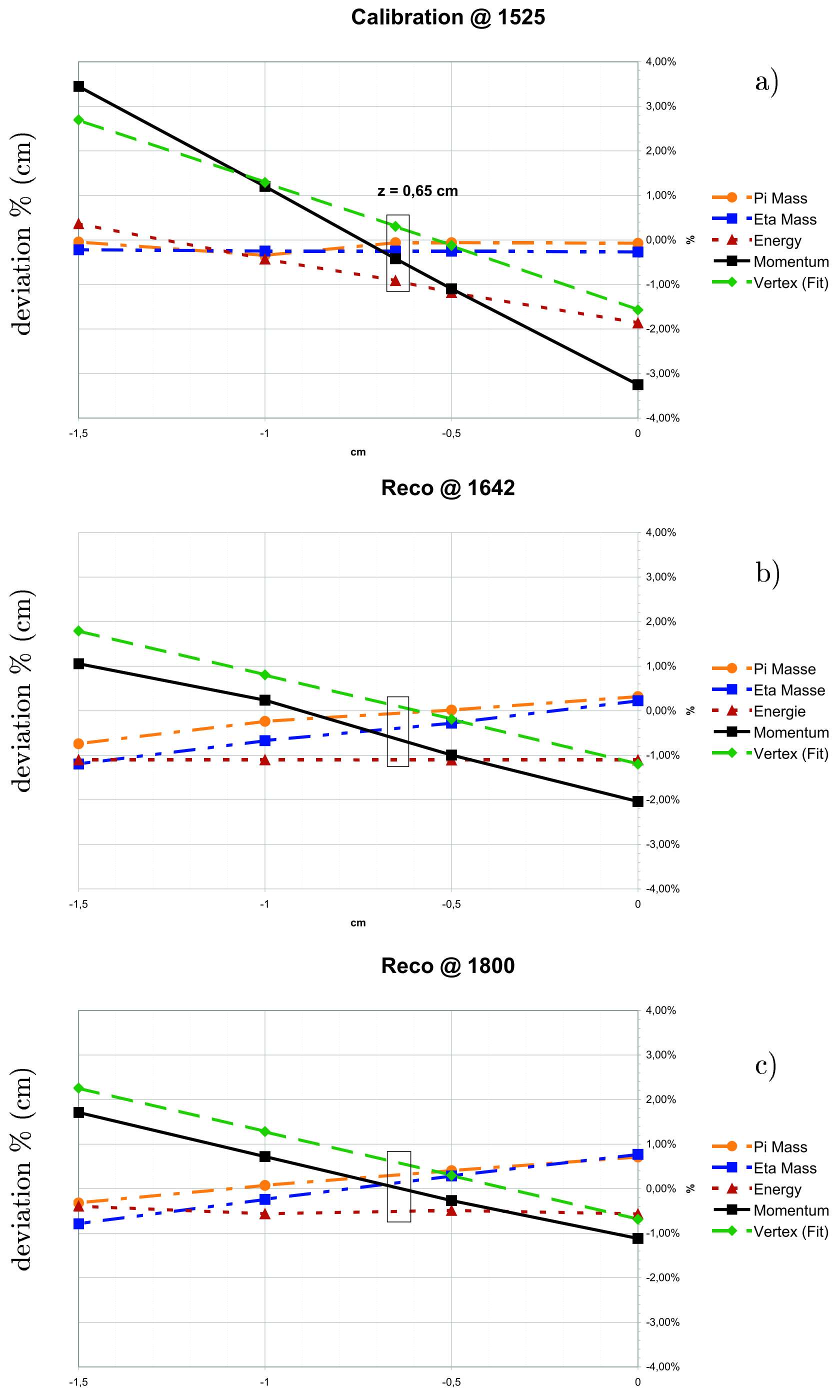


Figure 5: *Plot a) shows the deviation in % (vertex in cm) for different vertex positions which were used for calibrations at a beam momentum of 1525 MeV/c. As best vertex position* $z_0 = -0.65$ *was found. b) and c) show the deviation in dependence of a shifted vertex using the new calibration at z= -0.65 cm at*

different beam momenta.

2.5 Consequences

The benefit of the new method is an improved acceptance ϵ (integrated over phasespace) relative to the standard offline. Table 5 gives an overview about the relative improvements.

$\frac{\Delta\epsilon}{\epsilon}$	**1525 MeV/c**	**1800 MeV/c**
$\pi^0\pi^0$	5.8 %	–
$\pi^0\omega$	9.7 %	12.5 %
$\eta\omega$	18.4 %	18.5 %
$\eta\prime\omega$	27.3 %	28.7 %

Table 5: *The relative improvement $\frac{\Delta\epsilon}{\epsilon}$ of the new method (includeing the new calibration) for two beam momenta and several final states.*

Table 6 compares the numbers of reconstructed events for two reconstruction methods and for different photon multiplicities. The standard method and the new method are compared for one DLT with 992697 events at 1525 MeV/c beam momentum. The improvement is biggest for the 5 γ phase space events (fitted with 1 % confidence level).

	standard software		new method	
Photon mult.	global tracking	"Brain"	global tracking	"Brain"
4	19770	21016	21740 (10.0 %)	23079 (9.8 %)
5	21048	24359	24275 (15.3 %)	27949 (14.7 %)
6	62956	64731	67023 (7.0 %)	68470 (5.8 %)
7	37727	38222	40026 (6.1 %)	40811 (6.8 %)
8	42946	41272	44527 (3.7 %)	42596 (3.2 %)
9	24448	23227	25453 (4.1 %)	24281 (4.5 %)
10	22722	19006	22946 (1.0 %)	18877 (-0.7 %)

Table 6: *Comparison of the standard reconsruction with the new method (includeing the new calibration) for DLT GK548, a 1525 MeV/c tape with 992697 events. The photon multiplicity is phase space fitted with a confidence level of 1 %.*

The improved acceptance leads to a different angular distribution. The differences are **not** flat and therefore could affect a Partial Wave Analysis! In figure

6 a) you can see the ω–angular distribution (production and decay) and in b) the difference (in percent) of the standard method compared to the new method. Obviously, the deviation distribution is not flat. This behaviour is checked with 1800 MeV/c data. Figure 8 a) shows the difference between the new method compared to the standard method, 8 b) shows the difference new method – QMC method and finally in c) the comparison QMC method – standard method is performed. As before, the structure in the plots is not flat.

For the two pseudoscalar final state $\pi^0\pi^0$ the behaviour is the same. In figure 7, the comparison is made for the $\pi^0\pi^0$ angular distribution at beam momentum 1525 MeV/c. a) shows the difference new method–standard method and b) the comparison new method – QMC method. Again the deviations are not flat.

Due to these results it is necessary to reproduce all scan data in order to perform a proper Partial Wave Analysis.

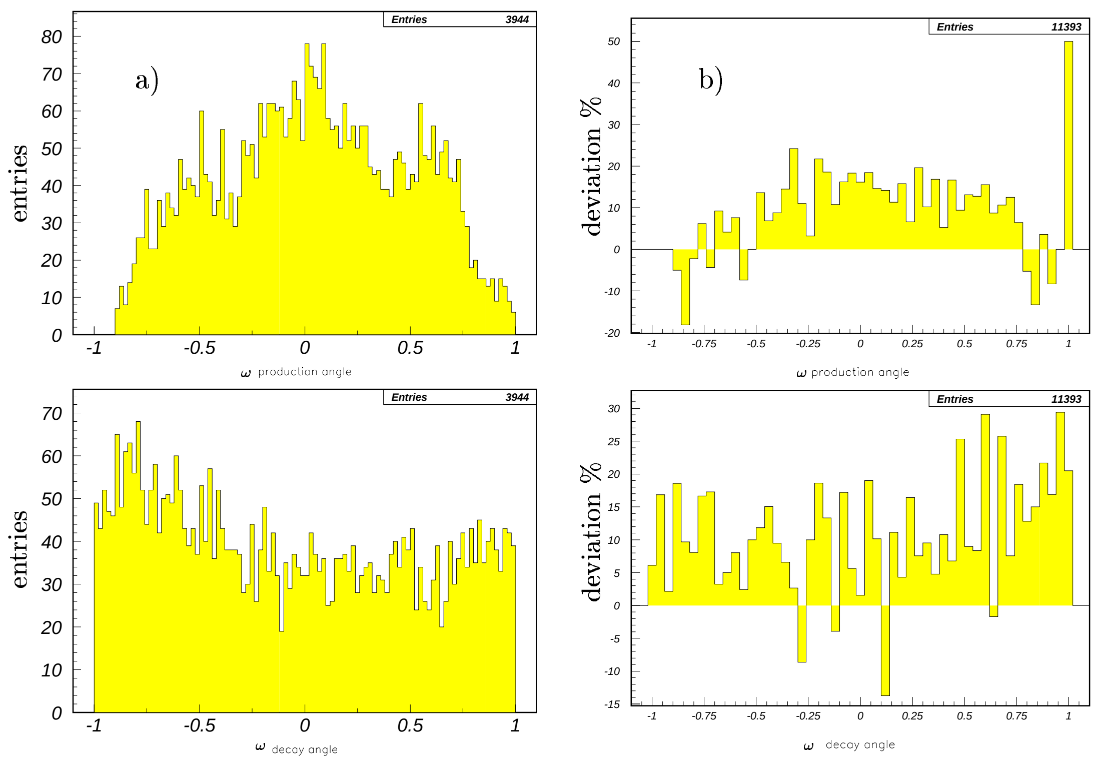


Figure 6: *ω–production and decay angular distributions for the $\omega\pi^0$ final state at 1525 MeV/c beam momentum. In a) the angular distributions are shown, in b) the deviations in percent of* the (new method - standard method)/standard method *are shown.*

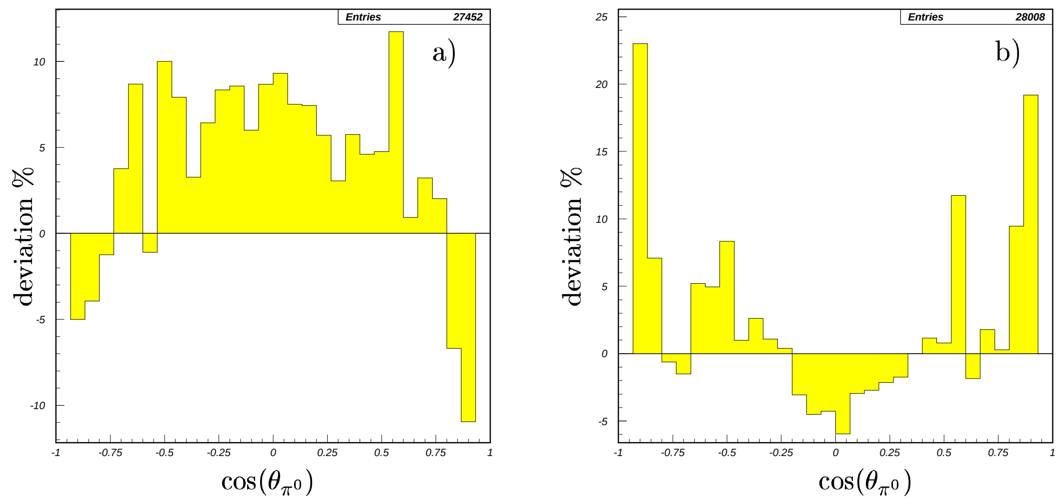


Figure 7: *The π^0 angular distribution is plotted for the $\pi^0\pi^0$ final state at 1525 MeV/c beam momentum. 7a): Deviation* New–Method / Standard Method, *7b):* New–Method / QMC–Method

3 Summary

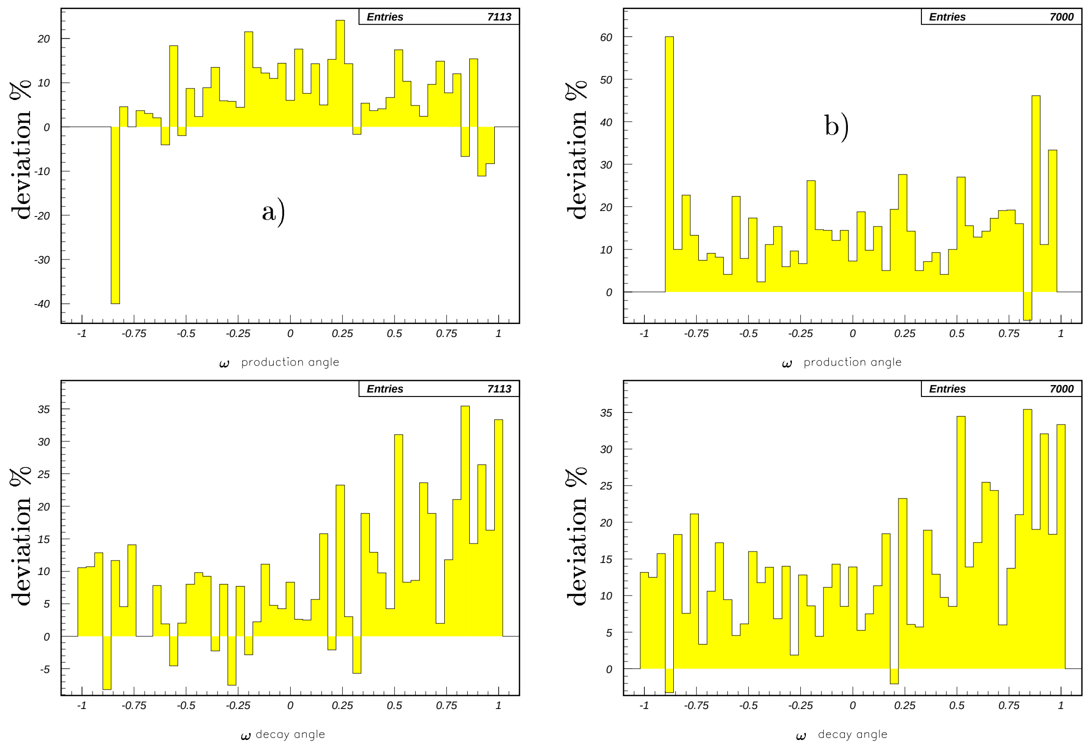
The investigation has shown that a proper z–vertex position of z = -0.65 cm is vital for the calibration of the scanning run in 1996.

New energy correction functions have been developed which work up to 2 GeV and improve the overall quality of the data.

The new calibration with a displaced z–vertex and the new correction functions improve the acceptance $\Delta\epsilon/\epsilon$ between 5% and 25 % for the 4 and 5 γ channels.

Even more important are the implications on the angular distributions: The production– and decay angles which are vital for a Partial Wave Analysis are clearly changed by applying the new corrections..

The new method provides a very good reconstruction and a match between Monte Carlo– and data–events.



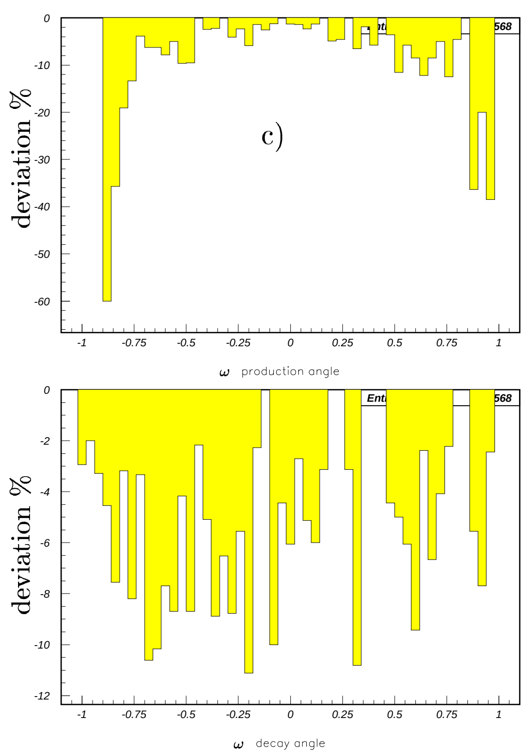


Figure 8: *The plots show the* ω *production (upper plot) and decay (lower plot) angle for the* $\omega\pi^0$ *final state at a beam momentum of 1800 MeV/c (DLT gk518). a) shows the deviation* ((new method - standard soft)/new method, *b) shows the deviation* ((new method - QMC method)/new method) *and c)* ((QMC method - standard soft)/standard soft)

A BCEGAM.F

```
      FUNCTION BCEGAM (ENER, ITHE, NPED, ECCC)

      REAL ENER, BCEGAM, COENER, ECCC, ENER2
      INTEGER ITHE, NPED

      REAL A1,B1,C1,D1,E1,A2,B2,C2,D2,E2,OFFSET
      PARAMETER (A1 = 1.24629E-2, B1 = 1.54265, C1 = 0.20700)
      PARAMETER (D1 = -3.70963E-5, E1 = 1.72970E-2, A2 = 1.39487E-2)
      PARAMETER (B2 = 0.72527, C2 = 0.22356, D2 = -3.46757E-5)
      PARAMETER (E2 = 8.13916E-3, OFFSET = 1.0575)

*     theta correction factor one ped cluster
      REAL ET1(26)
      DATA ET1/ 1.10092, 1.03440, 1.03044, 1.03829, 1.02799, 1.02085,
     &  1.02085, 1.02085, 1.01717, 1.01717, 1.01717, 1.01717, 1.03576,
     &  1.03576, 1.01717, 1.01717, 1.01717, 1.01717, 1.02085, 1.02085,
     &  1.02085, 1.02799, 1.03829, 1.03044, 1.03440, 1.10092/

*     theta correction factor higher energetic two ped cluster
      REAL ET2(26)
      DATA ET2/ 1.11111, 1.03913, 1.03102, 1.04669, 1.03440, 1.02332,
     &  1.02332, 1.02332, 1.01862, 1.01862, 1.01862, 1.01862, 1.03317,
     &  1.03317, 1.01862, 1.01862, 1.01862, 1.01862, 1.02332, 1.2332,
     &  1.02332, 1.03440, 1.04669, 1.03102, 1.03913, 1.11111/

*     theta correction factor lower energetic two ped cluster
      REAL ET3(26)
      DATA ET3/ 1.09014, 1.00757, 1.00022, 1.02562, 1.00733, 0.99735,
     & 0.99735, 0.99735, 1.00275, 1.00275, 1.00275, 1.00275, 1.02202,
     &  1.02202, 1.00275, 1.00275, 1.00275, 1.00275, 0.99735, 0.99735,
     &  0.99735, 1.00733, 1.02562, 1.00022, 1.00757, 1.09014/

      ENER2 = ENER * OFFSET
      IF(NPED .EQ. 1) THEN
         IF(ENER2 .LT. C1*1000) THEN
            COENER = A1 + D1 * ENER2 + B1 * (ENER2/1000 - C1)**2
         ELSE
            COENER = A1 + D1 * ENER2 + E1 * (ENER2/1000 - C1)**2
         END IF
         BCEGAM  =  (COENER + 1) * ET1(ITHE) * ENER2
      ELSE
         IF(ENER2 .LT. C2*1000) THEN
            COENER = A2 + D2 * ENER2 + B2 * (ENER2/1000 - C2)**2
         ELSE
            COENER = A2 + D2 * ENER2 + E2 * (ENER2/1000 - C2)**2
         END IF
         IF(ENER2/ECCC .GT. 0.5) THEN
            BCEGAM  =  (COENER + 1) * ET2(ITHE) * ENER2
         ELSE
            BCEGAM  =  (COENER + 1) * ET3(ITHE) * ENER2
         END IF
      END IF
      END
```

References

[1] D. Bugg et al. , *$p\bar{p} \rightarrow \eta\pi\pi$,* CB-Note 326, February 1998

[2] N. Hessey , *Photon energy correction function derived from response means,* CB-Note 161, June 1991

[3] I. Uman, O. Kortner , *A new Photon Energy Correction Function and the JDC z–Scaling for Inflight Data,* CB-Note 341, October 1998