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Energy Flow using the PCPA neutral particles

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Abstract

This note is intended to help the reader to use the neutral particles stored in the bank PCPA, together with the charged tracks, in order to compute the desired global variables for each event : total energy, jets, etc...

The basic algorithms which are used in Julia to build the PCPA bank are briefly described, as well as the code which loads them into the Alpha Q-vector. Then, an example of a user's code is given, which computes a few simple quantities.

Finally, some results obtained by this sample job are given.

1 Principles of the energy flow algorithm

The Aleph TPC allows the determination of the momentum of charged particles with a high degree of precision. However, this is only some 50% of the total energy in typical hadronic events. The remaining half is distributed evenly between photons and neutral hadrons. For these, we must use the calorimeters, with a resolution of $20\%/\sqrt{E}$ and $80\%/\sqrt{E}$ respectively. The optimal solution would be to measure the charged particles with the TPC, and use the calorimeters for the neutral particles. This is imposible because the calorimeters are sensitive to charged particles as well as to neutrals.

The algorithm on which the PCPA particles are based takes advantage of the high granularity of our calorimeters to isolate geometric regions where only neutral particles have deposited energy. These are the isolated photons, in the ECAL , and the isolated neutral hadrons, identified as neutral ECAL or HCAL clusters. Isolated neutral hadrons comprise however only some 50% of the total neutral hadronic energy (3 Gev in a total of some 6 Gev), the rest being mixed with energy deposited by charged particles (mainly pions). For these, a simple subtraction procedure is not adequate, because the error on the difference between hadronic energy and TPC momentum would be dominated by the resolution of the calorimeters. Such a subtraction should then be applied only in the regions where the chances are high that a neutral particle has deposited its energy. They are identified by comparing the calorimetric energy deposit with the momentum of associated tracks. For this purpose, the association between TPC tracks, ECAL and HCAL clusters is important, because it defines the so-called calobjects, in which the above defined subtraction is done.

Section 2 describes how the PCPA bank is built in Julia, as a summary of a calorimetric reconstruction, and section 3 describes how it should be used at the analysis level. This includes the appropriate cuts on charged and neutral particles, which may be physics dependent and were not applied at the Julia level.

2 Building the PCPA bank

The reconstruction algorithms have been detailed elsewhere [1] [2] [3] [4] . Here, we simply describe the principal steps :

- Associate calorimeter cells into clusters, separately in the ECAL and HCAL;
- Associate TPC tracks with ECAL clusters ;
- Search for electromagnetic particles : electrons and gammas, using ECAL alone;
- Search for muons, use HCAL and muon chambers;
- Associate TPC tracks with HCAL, produce calobjects. Calobjects are assemblies of ECAL and HCAL clusters such that one given particle should not have deposited energy in more than one calobject;
- Create the calorimeter neutral particles; these are the gammas which were found at the ECAL level, plus neutral hadrons which are issued from the neutral objects, and finally the so-called residual particles, which are for each charged calobject the difference between the calobject energy and the sum of contributions of all associated charged tracks. When computing the calobject energy, the appropriate e/π ratio is applied to the hadronic part of the ECAL contribution : everything which has not been identified as electromagnetic is considered as hadronic.

  A special treatment is devoted to muons, for which the expected energy deposit is different from the momentum.

  The residual particles can have positive or negative energy. In order to make their selection easier at the analysis level, the sum of momenta of all tracks associated to the same calobject is stored in one word of the PCPA bank.

- During the TPC treatment, tracks are claŝsified into :

    1. good tracks from the origin
    2. good tracks with momentum $> E_{beam}$
    3. good tracks issued from a V_0
    4. bad tracks

  This is done by the subroutine UFITQL, and stored in one word of the bank FRID. Tracks from classes 2 and 4 are not subtracted from the calorimeters. Therefore, in order to avoid double counting, they should also be ignored when neutrals and charged are combined at the analysis level

The set of banks : PCRL, PPRL, PEHY, PCHY contain the information about the relations between PCPA, ECAL clusters, HCAL clusters and calobjects.

On the miniDST, two different banks contain the information abou isolated neutral and residual particles respectively. The relation banks are not any more available, but these are not necessary for simple operations. The information on the particle type, energy and momentum of associated tracks, necessary for the neutral particles selection, are available.

3 Using the PCPA particles

The PCPA particles should be used in conjunction with the charged tracks, in the following manner :

- ignore bad tracks and good tracks with momentum $> E_{beam}$ (lock them if Alpha is being used);
- merge gammas issued form the same PECO, and hadronic particles issued from the same calobject, in order to reduce fluctuations;
- reject PCPA residual particles whose energy is lower than $\alpha\sqrt{P}$, where P is the total momentum of all associated tracks, and alpha is 0.5 for calobjects which are fully contained in the ECAL, and 1.0 for calobjects which span over ECAL and HCAL.

  This ensures that fake residual energy due to the limited resolution of the calorimeters is not used. It also eliminated the negative residuals which occur for example in the case of sailthrough pions, where the deposited energy is much lower than the track momentum.

If one uses Alpha, the operations above are done by default by the subroutines PCPATQ and QFNEOB, apart from locking the tracks, which might not always be desirable, and is left to the user's responsability (an example of how to do it is given in appendix 1, routine NEOBFL). The merged and selected neutral particles are in bank PCQA, and can be accessed in the usual manner by a loop between the first and last neutral tracks : KFNET and KLNET.

Particles from bank PCQA are also loaded into the class "NEOB" of Alpha particles. Therefore, if the statement :

CALL QJOPTR('CH','NEOB')

is executed, charged tracks plus neutrals from PCQA will be used into subsequent computations of global event variables such as sphericity, jets finding etc...

Appendix 1 gives an example of a user's code to compute and histogram the total energy and number of jets. This code is also in the UPHY disk, es EFLOW.INPUT. Help on the use of the PCPA particles can be found in EFLOW.DOC on the UPHY disk, and in the Alpha manual [5] .

Figure 1 shows a plot of the distribution of total energy for hadronic events, computed with this same code.

It is worth mentioning that exactly the same Alpha jobs runs on DST or miniDST files. The Alpha code which reads the event will identify the kind of data on which it is working, and take appropriate action. The results are identical, down to the accuracy with which data are stored on the miniDST (a few Mev)

4 Comparison between DST and miniDST : measurement of the lepton transverse momentum

We studied the distribution of the transverse momentum of leptons in hadronic events with respect to their associated jet. This was done separately on the DST and miniDST, and the final results were compared. Leptons with momentum above 2 Gev only were taken into account. A sample of 9000 hadronic events was used, of which some 1800 were selected. The lepton was included in the jet when computing its total 4-vector .

The code to compute the transverse momentum is given in appendix 2, as an example of how to navigate between reconstructed particles and jets.

Figure 3 shows the distribution of the difference (one entry per lepton) between the results obtained by the two methods. It is nicely peaked at 0, and the width is less than 1 Mev. This should have no effect on any analysis.

However, a few more significant differences were found and identified as being due to a lower degree of precision on the miniDST.

As an example, the ECAL estimators are stored on the miniDST with one decimal figure only, and the rounding has the effect that the region between say -1.55

and -1.65 is concentrated on exactly -1.60. If the central value is rejected, more events will be selected on the miniDST; if it is rejected, the opposite will be true.

- At the selection level :

  events with at least one lepton were selected. This is done by running QMUIDO for the muons, and using the ECAL estimators for the electrons. The miniDST sample contains 20 more events then the DST sample.

- At the comparison level :
  - We apply a 400 Mev cut on the neutral hadrons, and 200 Mev on photons energy. One neutral can be selected on the miniDST, and not on the DST. This causes the parameters of the jet to be different, and is the origin of a difference of more than 2 Mev on the transverse momentum in 6 of our events. This does not happen with the charged particles because thay are selected according to the quality word in the FRID bank, which is integer.
  - Even when the same particles are used, because of the different precision, the jet clustering algorithm can behave differently on the DST and miniDST. This is the case for 4 events with a difference of more than 2 Mev.

We conclude that the agreement on the events selection is at the level of 1%, while the agreement in the computation of the transverse momentum, on the selected events, is at the level of 0.5%.

5 PCPA and GAMPEC

By default, the photons which are included in the PCPA bank have been identified by the package EBNEUT, inside JULIA.

The package GAMPEC is known to give a better identification and energy resolution.

The file PCPUPD.INPUT on the UPHY disk contains the necessary code to replace the EBNEUT photons by GAMPEC photons, at the Alpha level. All relations to calobjects, PECO and PHCO are updated, as well as the PCPA bank. Because this routine manipulated bos banks, it is important to call it before QFILL, i.e. inside QMEVNT.

The data card UPDA, if present, triggers the replacement of EBNEUT photons by GAMPEC photons : even if you linked with PCPUPD, you can still use the non-updated PCPA bank by simply omitting the UPDA card.

This code works at present only on DST files, but since all the necesary information is available, there is no reason why it should not be feasible on the miniDST as well.

The results can be seen in figure 2, and comparison with figure 1 shows that the energy resolution is essentially unchanged, but that the average value is increased towards a more realistic value. This is due to a better identification of the photons : using EBNEUT, some hadronic energy is seen as electromagnetic, and not multiplied by the e/π ratio.

6 Conclusion

Using the PCPA particles in combination with charged tracks allows a determination of the total energy of hadronic events with an accuracy of some 8 Gev. The amount of computations involved is negligible since most of the process has been done at the Julia level. The Alpha structure allows easy manipulation of the energy flow components, on DST as well as miniDST files.

Further refinement is possible, using the GAMPEC photons. At present, this requires the execution of some code at the analysis level. In the future, the use of GAMPEC for the construction of the PCPA bank inside Julia is foreseen.

References

[1] J.P. Albanese, J.J. Aubert, A. Bonissent, "Charged Clusters Identification Using Hcal, Ecal and TPC Information" Aleph emcal 153, 22-07-85

[2] J.P. Albanese, J.J. Aubert, A. Bonissent, "New Developments on Charged Clusters Identification Using Hcal, Ecal and TPC Information" Aleph emcal 58, 06-05-86

[3] A. Bonissent, "Energy Measurement with Neutral Calorimeter Particles" Aleph 90-72 emcal 90-1.

[4] J.P. Albanese, A. Bonissent, "Calorimeter Reconstruction,Status of Reconstruction Algorithms," Ed. J. Knobloch, P. Norton. February 11, 1991

[5] Alpha User's guide

Appendix 1 : Alpha code to compute the energy flow components

```
*DK NEWDECK
      SUBROUTINE QUEVNT (QT,KT,QV,KV)
*CA QCDE
      DIMENSION QT(KCQVEC,1), KT(KCQVEC,1), QV(KCQVRT,1), KV(KCQVEC,1)
      DIMENSION XNT(15)
      CHARACTER*3 TAGT(15)
      DATA TAGT /'NRN','NVT','NJA','ESA','PSA',
     ,           'NCH','ECH','NGA','EGA',
     ,           'NNH','ENH','NRE','ERE','NSE','ESE'/
      LOGICAL FIRST/.TRUE./
*CA QMACRO
      IF(FIRST) THEN
         CALL QBOOKN(1,'EFL',15,TAGT)
         FIRST=.FALSE.
      ENDIF
      XNT(1)=KRUN
      XNT(2)=KEVT
C
C        Now work with ALAIN'S charged+neutrals
C
      CALL NEOBFL(IER,NCH,ECH,NGA,EGA,NNH,ENH,NRE,ERE,NSE,ESE)
      IF(IER.NE.0.OR.NCH.LT.5.OR.ECH.LT.10.) RETURN
C     now find jets, etc
      CALL QJMMCL(NJETS,'JET1',KRECO,0.02,0.)
      XNT(3)=NJETS
C        add up momenta
      CALL QJADDP(PSUM,'ALL1',KRECO)
      IALL1=KPDIR('ALL1',KRECO)
      XNT(4)=QE(IALL1)
      XNT(5)=QP(IALL1)
      XNT(6)=NCH
      XNT(7)=ECH
      XNT(8)=NGA
      XNT(9)=EGA
      XNT(10)=NNH
      XNT(11)=ENH
```

```
      XNT(12)=NRE
      XNT(13)=ERE
      XNT(14)=NSE
      XNT(15)=ESE
C
      CALL HFN(1,XNT)
C
      RETURN
      END
C
      SUBROUTINE NEOBFL(IER,NCH,ECH,NGA,EGA,NNH,ENH,NRE,ERE,NSE,ESE)
C
C     Call routines to copy PCPA objects into ALPHA Qvector
C     Select charged tracks + PCPA objects
C     Lock bad tracks and CAL objects not wanted for EFLOW
*CA QCDE
      DIMENSION QT(KCQVEC,1), KT(KCQVEC,1), QV(KCQVRT,1), KV(KCQVEC,1)
      INTEGER UFITQL
      EXTERNAL NLINK
*CA QMACRO
C        select reconstructed tracks
      CALL QJOPTR('CH','NEOB')
C        make sure banks exist
      KFRID = NLINK('FRID',0)
      IF (KFRID.LE.0) GO TO 999
C        lock bad charged tracks
      NCH=0
      ECH=0.
      DO IALP=KFCHT,KLCHT
         IJUL=KTN(IALP)
C
C For versions of ALPHA higher than 113, access to track quality
C can be done more easily  : XFRIQF(IALP); see ALPHA113.NEWS
C
         IQUL=ITABL(KFRID,IJUL,11)
C Test for old production data
         IF(IQUL.LT.1.OR.IQUL.GT.4) THEN
             WRITE(6,*)
     ,       ' *** JULIA PRODUCTION VERSION TOO OLD TO USE PCPA ***'
             RETURN
         ENDIF
```

```
          IF(IQUL.NE.1.AND.IQUL.NE.3) THEN
              CALL QLTRK(IALP)
          ELSE
              NCH=NCH+1
              ECH=ECH+QE(IALP)
          ENDIF
        ENDDO
        KPCQA=NLINK('PCQA',0)
        EGA=0
        NGA=0
        ENH=0
        NNH=0
        ERE=0
        NRE=0
        ESE=0
        NSE=0
        DO IALP=KFNET,KLNET
           IJUL=KTN(IALP)
           INAT=ITABL(KPCQA,IJUL,1)
           ENER=RTABL(KPCQA,IJUL,5)
C
C For versions of ALPHA higher than 113, access to the particle's nature
C can be done more easily  : KPCQNA(IALP); see ALPHA113.NEWS
C
           IF(INAT.LT.14) THEN
C             gamma
              EGA=EGA+QE(IALP)
              NGA=NGA+1
           ELSEIF(INAT.EQ.17) THEN
C             neutral hadron
              ENH=ENH+QE(IALP)
              NNH=NNH+1
           ELSEIF(INAT.GE.18.AND.INAT.LE.20) THEN
C             residual energy particle
              ERE=ERE+QE(IALP)
              NRE=NRE+1
           ELSE
C             something else (eg LCAL object)
              ESE=ESE+QE(IALP)
              NSE=NSE+1
           ENDIF
```

```
      ENDDO
      IER=0
      RETURN
 999  IER=1
      RETURN
      END
*RD PHY:ALPHA113.CORR
```

Appendix 2 : Alpha code to compute the lepton's transverse momentum

```
C================================================================
C-- THIS PROGRAM SELECT LEPTONS
C-- PROCESS PCPA ENERGY FLOW
C-- PROCESS TRANSVERSE IMPULSION OF THE LEPTON
C-- WITH THE LEPTON INSIDE THE JET
C================================================================
      SUBROUTINE QUEVNT (QT,KT,QV,KV)

*CA QCDE
      DIMENSION QT(KCQVEC,1), KT(KCQVEC,1), QV(KCQVRT,1), KV(KCQVRT,1)
      COMMON/SELECT/NEVSEL

C--
*CA QMACRO
C--

C-- PCPA ENERGY FLOW (LOCKING BAD TRACKS)
        CALL NEOBFL(IER,NCH,ECH,NGA,EGA,NNH,ENH,NRE,ERE,NSE,ESE)
        IF(IER.NE.0.OR.NCH.LT.5.OR.ECH.LT.10.) RETURN

        CALL HFILL(5000,5.,0.,1.)
        CALL QJADDP(PSUM,'ALL1',KRECO)
        IDALL1=KPDIR('ALL1',KRECO)
        EVIS = QE(IDALL1)
        YCUT = (6./EVIS)**2

C-- FIND JETS
        CALL QJMMCL(NJET,'JET',KRECO,YCUT,EVIS)

C--ELECTRON SEARCH

        DO 60 JTK = KFCHT,KLCHT

           IF (XLOCK(JTK)) GOTO 60
C
C Select leptons with routine LEPTID
C
```

```
          CALL LEPTID(JTK,KLEP)
          IF (KLEP.EQ.0) GOTO 60

C-- LOOP ON THE JETS
          PTLP   = -1.
          IJET   = KPDIR('JET',KRECO)
          DO 10 J = 1,NJET
             IF(J.GT.1) IJET = KFOLLO(IJET)

C-- SELECT IF THE LEPTON IS IN THE JET
                 IF(XSAME(IJET,JTK)) THEN

C-- REMOVE JET WITH ONLY ONE PARTICULE
                 NPJ = 0
                 DO 11 K = KFCHT,KLCHT
                    IF (XSAME(IJET,K)) NPJ = NPJ + 1
  11             CONTINUE
                 IF (NPJ.EQ.1) GOTO 60

C-- HERE IS THE TRANSVERSE LEPTON MOMENTUM
                 PTLP= QPPER(JTK,IJET)
              ENDIF
  10       CONTINUE

  60    CONTINUE

C --
  999 RETURN
      END
```

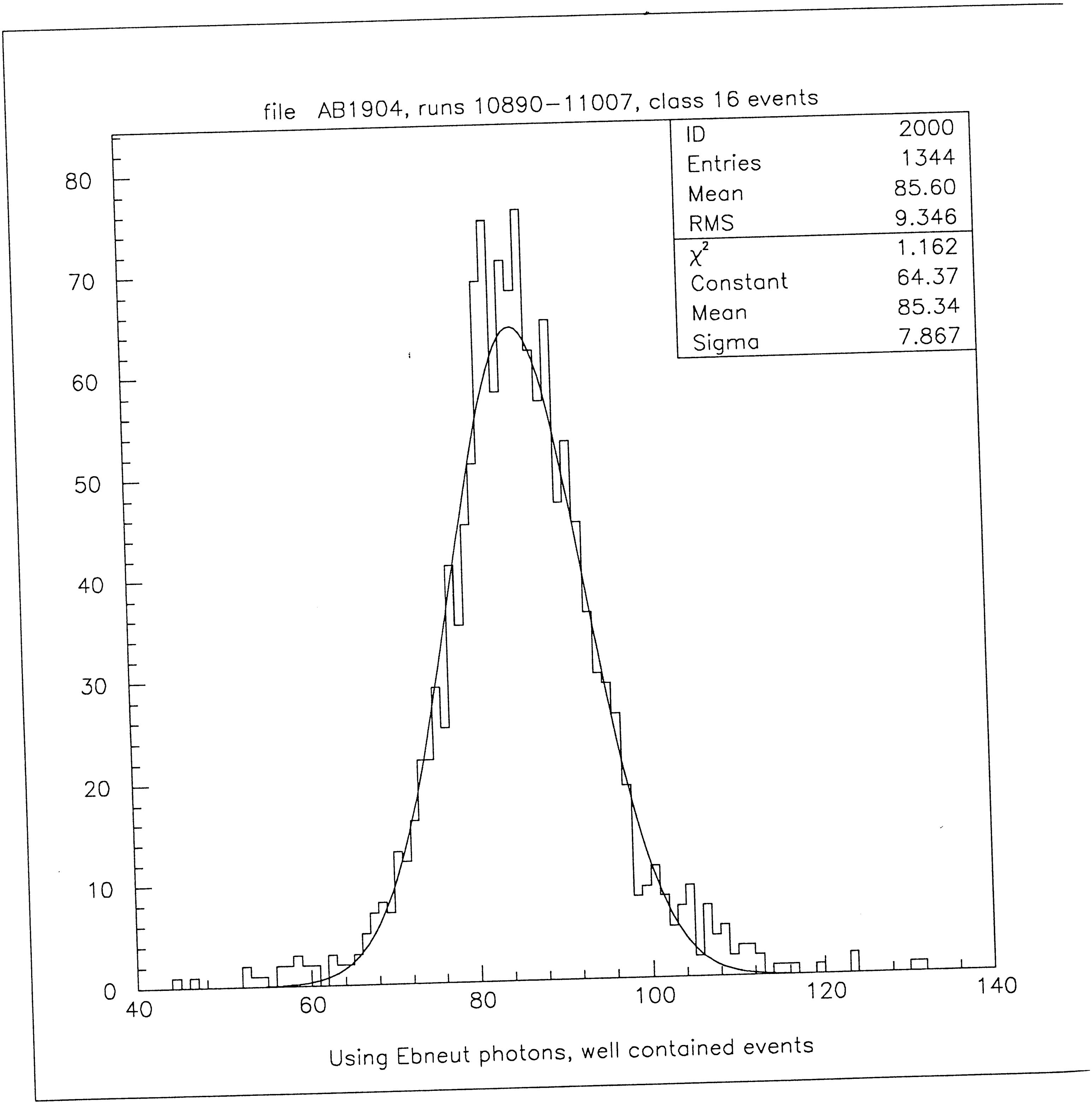
file AB1904, runs 10890–11007, class 16 events
ID 2000
Entries 1344
Mean 85.60
RMS 9.346
χ² 1.162
Constant 64.37
Mean 85.34
Sigma 7.867
80
70
60
50
40
30
20
10
0
40
60
80
100
120
140
Using Ebneut photons, well contained events

Figure 1

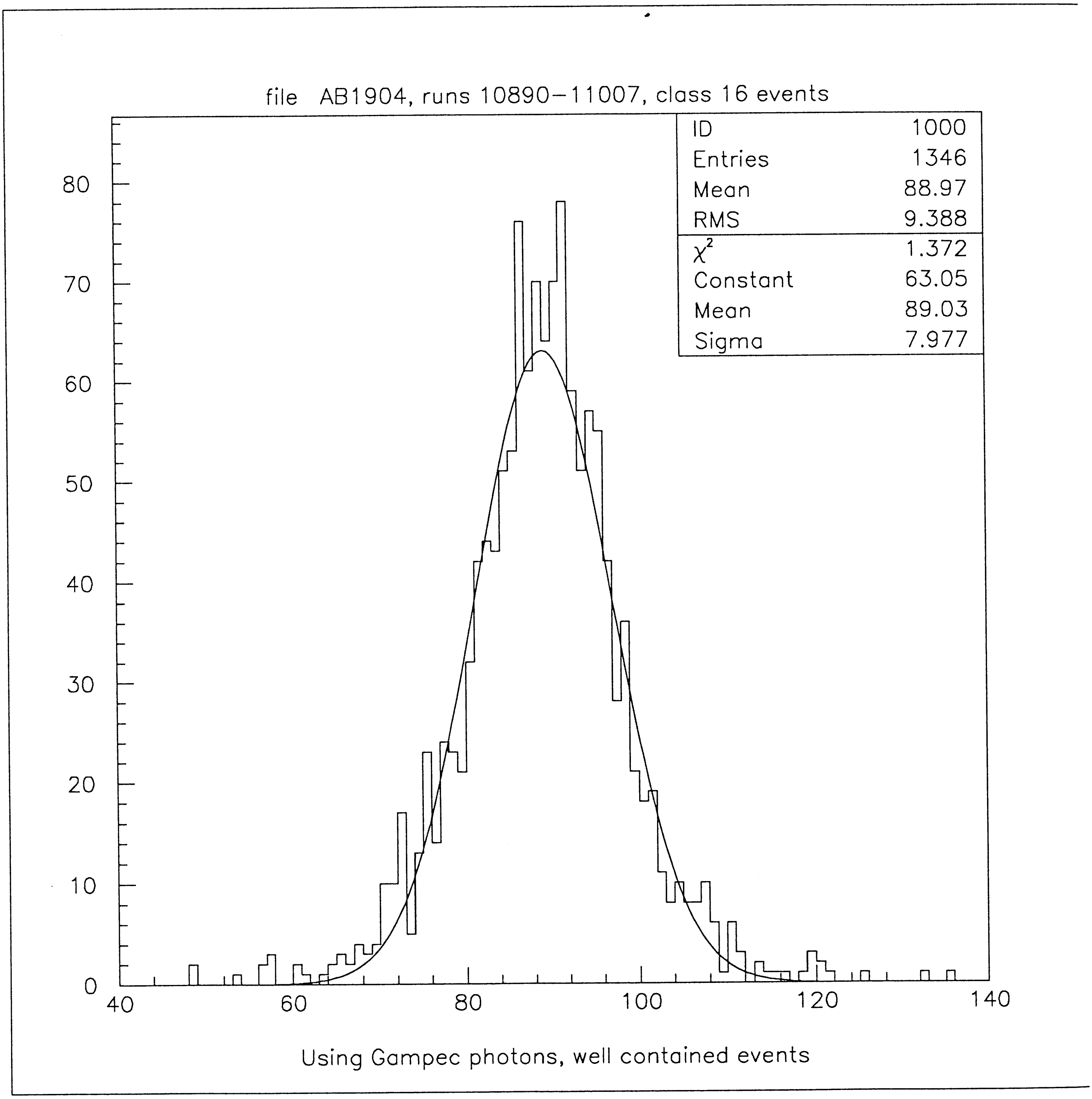
file AB1904, runs 10890–11007, class 16 events
ID 1000
Entries 1346
Mean 88.97
RMS 9.388
χ^2 1.372
Constant 63.05
Mean 89.03
Sigma 7.977
0
10
20
30
40
50
60
70
80
40
60
80
100
120
140
Using Gampec photons, well contained events

Figure 2

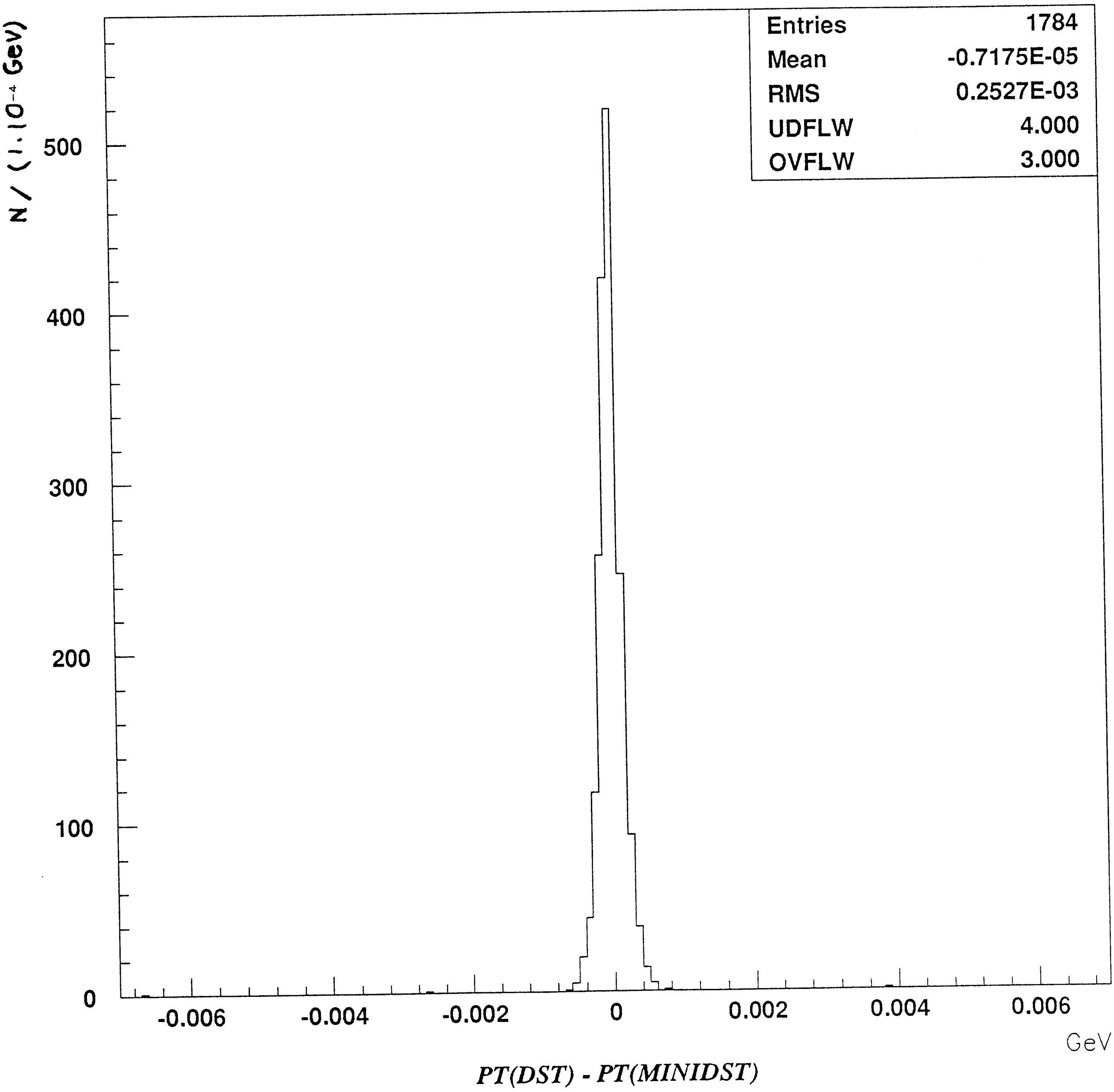
Entries 1784
Mean -0.7175E-05
RMS 0.2527E-03
UDFLW 4.000
OVFLW 3.000
N / (1.10⁻⁴ GeV)
500
400
300
200
100
0
-0.006
-0.004
-0.002
0
0.002
0.004
0.006
GeV
PT(DST) - PT(MINIDST)

Figure 3