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A Generalized FASTMC for the CLAS

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Abstract

In this note, we describe the program 'GENERAL FASTMC'. GENERAL FASTMC is built upon and incorporates almost all the routines used in Elton Smith's FASTMC [1] simulation of the CLAS detector. The GENERAL FASTMC can be viewed as a black box — it reads in the data provided by an event generator, and outputs the processed events into Ntuple data format. These Ntuples, in turn, can be histogramed. One need not process the events through FASTMC each time one wishes to add or change histograms.

Contents

1 Introduction

The guiding philosophy of GENERAL FASTMC is to minimize CPU expenditure — the data provided from an event generator is processed only once through the CLAS detector simulation program. In developing the analysis, one usually adds histograms or makes changes in the cuts for selecting which variables that are to be histogramed. It can take several interations before one is satisfied with the results of the analysis, for one does not usually know at first glance exactly how or what to plot. And repeatedly running the event generator data through FASTMC can be unproductive and time-consuming each time one makes such changes to the histograming. One can view GENERAL FASTMC as a blackbox, which reads in the data from an event generator and outputs the processed events in Ntuple format [2]. Most people are rightly suspicious of black boxes, and I encourage the user to investigate the routines used in GENERAL FASTMC, which can be found in CEBAF7::USER7:[COLE.FASTMC_GEN]. In the following sections, I discuss how to use GENERAL FASTMC, its differences from the canonical FASTMC, and the programs one can use to read the Ntuple output to make histograms in batch mode.

2 Event Generator

The input to the GENERAL FASTMC is in LUND data format (cf. section 4-A of [1]). In addition to the usual leptons, mesons, and baryons, GENERAL FASTMC can also handle four nuclides, which are not included in FASTMC, or the standard LUND event record [3]. The particle identifier is contained in the LUND variable K(I,2) (cf. §5.1 of JETSET v. 6.3 [3]). Below are the particle tags for the hydrogen and helium isotopes. Each of these nuclides is endowed with the correct charge, lifetime ($t = \infty$), and mass (see NUCLIDE.FOR).

K(I,2)	*Description*
91	^{2}H
92	^{3}H
93	^{3}He
94	^{4}He

3 Structure of the Output

The events processed by the GENERAL FASTMC are output into Ntuple format. Ntuples can be thought of as a two dimensional array, characterized by a **fixed** number N, specifying the number of parameters per element, and by a **length**, giving the total number of elements (see p. 3 of [2]). A set of elements of the Ntuples defines a physics event. Ntuples form a data base. And by containing the output data in Ntuple format, the user can exploit the powerful PAW package to expeditiously analyze the data.

Parameter	*Description*
1	p_x (generated)
2	p_y (generated)
3	p_z (generated)
4	E (generated)
5	p_x (reconstructed)
6	p_y (reconstructed)
7	p_z (reconstructed)
8	β (reconstructed)
9	Efficiency bit map
10	Lund particle identifier
11	Event identifier (pointer)

Eleven parameters are associated with each particle in each event. And an event may clearly contain several yield products. For example, in the reaction $\gamma + {}^3\text{He} \rightarrow \text{p} + \text{p} + \text{n} + \pi^0$ & $\pi^0 \rightarrow 2\gamma$, an event is accorded six Ntuples, i.e. the two protons, the one neutron, the neutral pion, and the two decay gammas. Parameters 1 through 4 are the true four-momentum of the generated particle. Parameters 5 through 7 are the reconstructed three-momentum of the measured particle. For charged particles not measured in any of the regions I, II or III, the components of the reconstructed momentum are assigned the unphysical value of $p_x = p_y = p_z = -1000$ GeV/c. Likewise if the charged particle deposits no energy in the TOF system, β will be given the absurd value of $\beta = -1000$. In the case of neutrals, a track may leave no hits in the wire chambers, and a electromagnetic shower counter must have registered a hit (see section 5.1), otherwise the components of the momentum and β will be set to the default value of -1000. The reconstructed β, or parameter 8, is equal to the path length divided by the time of flight for the particle. Parenthetically, the reconstructed energy of the particle can be found from the relationship $E = |\vec{p}|/\beta$, so the kinematics of the reconstructed particles are complete. Parameter 9 is the efficiency bit map, which flags whether a given detector measured the passing particle. CLAS is formed of 6 separate sets of detectors: Three regions of wire chambers, Cerenkov counters, scintillation counters, and electromagnetic shower counters (see Figure E2 in [4]). For example, if the particle is measured in all three wire chamber regions, and deposits energy in a scintillating counter, bits 0, 1, 2, and 4 will be set, or the efficiency bit map will be assigned the value $2^0 + 2^1 + 2^2 + 2^4 = 15$. Generally, the efficiency bit map will assume the value $\varepsilon = \sum_{j=0}^{5} \chi_j 2^j$, where $\chi_j = 1$ (0) if the particle is detected (undetected). Parameter 10 is the Lund particle identifier, and the final parameter tells what particle belongs to which event.

4 Reading the Ntuples in Batch

Interactive PAW uses the COMIS FORTRAN interpreter. Unfortunately, COMIS is discouragingly slow. It is not practicle to analyze large pools of data interactively, i.e. for $N > 1000$ events it may take more than 15 minutes of μVAX CPU time. PAW, moreover, possesses a few quirky and undocumented features, which one must be aware of in order to read and process the Ntuples in batch. I will not pain the reader with the particulars. Suffice to say the problem has been solved, and the user can avail him or herself of the necessary routines to process the Ntuples in batch mode.

The necessary routines for reading and processing the GENERAL FASTMC Ntuple output can be found in CEBAF7::USER7:[COLE.FAST_GEN.PAW]. See Appendices B and C.2 for further details.

5 Differences between Canonical and General FASTMC

5.1 Neutral Detection

The canonical FASTMC does not provide for energy/momentum smearing of neutrals. GENERAL FASTMC uses the routine NEUTRAL_SMEAR to account for measurement error in reconstructing the four-momentum of neutrals in the electromagnetic shower counters. We are primarily concerned with detecting neutrons or gammas; all other neutral particles will have long since decayed before reaching the electromagnetic shower counters.

There are three primary sources of error in determining the energy and momentum of the neutral particle:

1. The uncertainty of the vertex.

2. The uncertainty in the time of flight.

3. The uncertainty in where the neutral was detected in the electromagnetic shower counter.

For an extended source such as a ^{3}He target of 12.5 cm length there will be no vertex information, i.e. an event can occur anywhere in the target and the target does not constrain the vertex. Care must be taken to correctly model this uncertainty in the vertex. The target length is one of the input parameters to FASTMC (see Table 1 of [1]), and this information is used to model the error in the vertexing. Secondly, the timing resolution, σ_t, is not perfect. We have assigned a 2 nsec error in the timing. Finally, a counter of the electromagnetic shower array registers but cannot localize hits. The granularity of the electromagnetic shower counter is described by a thickness, $2\Delta z$, and a height, $2\Delta\rho$. And the width of the counter equals its height. We have set Δz ($\Delta\rho$) to 7.5 cm (5.0 cm).

The method of determining the polar angle, θ, is depicted in Figure C.2. Six possible trajectories of the neutral particle from either end of the target are selected, giving a total of twelve trajectories. A polar angle for the i^{th} trajectory is calculated via the relationship: $\theta_i = \sin^{-1}(\rho_i/L_i)$ where $L_i = \sqrt{\rho_i^2 + z_i^2}$. We find the rms error in the polar coordinate, σ_θ, to be the standard deviation of these twelve θs. We note, moreover, that $\sigma_\theta = \sigma_\theta(\theta)$. Similarly, we define the rms error in the azimuthal angle, σ_ϕ, to be $2\sin^{-1}(\Delta\rho/\langle L\rangle)$, where $\langle L\rangle$ is the average of the twelve L_is. The rms error in the timing, σ_t, is identically set to 2 nsec.

The spread in θ, ϕ, and t are assumed to be gaussian distributed and characterized by their respective σs. In Figure C.2, one can see the $\Delta\beta$ distributions for the neutrons and decay γs for the reaction $\gamma + {}^3\text{He} \rightarrow 2p + n + \pi^0$, where $\pi^0 \rightarrow 2\gamma$. Here $\Delta\beta = (\beta\text{true} - \beta\text{meas})/\beta\text{true}$. The reconstructed total momentum for the neutron is found from the relationship $|\vec{p}_{\mathbf{meas}}| = m_n\beta_{\mathbf{meas}}/\sqrt{1-\beta^2_{\mathbf{meas}}}$. The energy of the photon can be measured to an rms uncertainty of $\sigma_E = 0.085\sqrt{E}$ (cf. eqn. J5 of [4]). Clearly the energy and momentum are identical for real photons, which implies $\sigma_E = \sigma_{|\vec{p}|}$. In Figure C.2 we plot the ΔP_{tot} distributions for neutrons and photons originating from π^0 decay.

5.2 Geometry of the ESC

The electromagnetic shower counters (ESC) can be divided into two sets of arrays, and are chiefly distiguishable by by the polar angles, θ, that each of these two arrays span. For polar angles less than 45°, the ESC has full 2π azimuthal coverage. For $\theta > 45°$, however, the ESC do not completely span ϕ. But this array of the ESC can be configured into two separate settings which affords access to different regions in $\Delta\theta$ and $\Delta\phi$:

1. $\Delta\theta = 45°$ to $112°$ and $\Delta\phi = -30°$ to $+30°$.

2. $\Delta\theta = 45°$ to $78.5°$ and $\Delta\phi = -60°$ to $+60°$.

One then has the option of selecting one of the above two configurations of the ESC when compiling GENERAL FASTMC depending upon what region of the phase space the user wishes to sample.

6 Summary

We have described how the different components of the GENERAL FASTMC and the GENERAL HISTOGRAM MAKER packages and how they fit together. In subsection 5.1, we discussed neutral detection in the electromagnetic shower counters. We are in the process of improving the neutral detection algorithms, and a revised version of this CLAS-NOTE will be forthcoming once our studies are complete. This version of FASTMC has been thoroughly tested, and three separate CEBAF proposals [7], [8] and [9] used GENERAL FASTMC in their acceptance studies. Please send your suggestions for improving FASTMC_GEN or this CLAS-NOTE to CEBAF7::[COLE]

7 Acknowledgments

I wish to thank both Elton Smith and Piero Corvisiero for their help with this work.

References

[1] Elton S. Smith, "FAST Monte Carlo Program for the CLAS Detector," CLAS-NOTE 90-003

[2] R. Brun et al., PAW – Physics Analysis Workstation, CERN Program Library Entry Q121, October 1989.

[3] The Lund Monte Carlo Programs, CERN Pool Programs W5035/W5045/W5046/W5047/W5048 3 April 1987

[4] Conceptual Design Report CEBAF Basis Experimental Equipment April 13, 1990

[5] HBOOK Users Guide, CERN Program Library Entry Y250, 1987

[6] William H. Press, Saul A. Teukolsky, William T. Vetterling and Brian P. Flannery, *Numerical Recipes in FORTRAN—The Art of Scientific Computing,* (Second Edition) 1992 ISBN: 0-521-43064-X

[7] P. Rossi et al., "Study of $\gamma d \rightarrow pn$ and $\gamma d \rightarrow p\Delta^{\circ}$ Reactions for Small Momentum Transfers," PR-93-017

[8] J. Napolitano et al., "A Search for Missing Baryons Formed in $\gamma p \rightarrow p\pi^{+}\pi^{-}$ Using the CLAS and CEBAF," PR-93-033

[9] B. L. Berman et al., "Photoreactions on ^{3}He," PR-93-044

Appendices

A How to set up and run General FastMC

In order to setup and run GENERAL FASTMC, the user can either copy the executable image, FASTMC_GEN.EXE to his or her area, or the user can compile and link the programs with the command procedure FASTMC_GEN.MAK. These files can be found in USER7:[COLE.FASTMC_GEN]. Note that the executable image uses the default ACCEPT_SHOWER112.FOR (See Appendix C1). The Ntuples will be output into the data file NTUPLE.RZ

B How to set up and run General Histogram Maker

There exist two command procedures for compiling and linking the routines, and are called: HISTO_MAKER_DBG.MAK and HISTO_MAKER.MAK. The former command procedure compiles and links the routines so that the interactive debugger can be used. The user must provide his or her own booking and filling routines, which employ the standard calls to Hbook and Hfill, (See the HBOOK users guide [5] for further details). Examples of booking and filling routines used in analyzing photoreactions involving the ^{3}He nucleus can be found in CEBAF7::USER7:[COLE.3HE.PAW].

HISTO_MAKE.EXE requires the input data file HISTO_MAKE.DAT. For further details look at the sample HISTO_MAKE.DAT file in USER7:[COLE.FASTMC_GEN.PAW]

The histograms are output into the data file HISTOGRAMS.RZ, and they can be displayed and manipulated in interactive PAW.

C Routines

C.1 General FastMC

We discuss the routines particular to GENERAL FASTMC. These routines can be found in the area CEBAF7::USER7:[COLE.FASTMC_GEN]. Unless otherwise noted, the general and canonical FASTMC call the same routines.

ACCEPT_SHOWER112.FOR Electromagnetic Shower Counters for $\theta > 45°$ configured so that: $\Delta\theta = 45°$ to $112°$ and $\Delta\phi = -30°$ to $+30°$. DEFAULT.

ACCEPT_SHOWER78P5.FOR Electromagnetic Shower Counters for $\theta > 45°$ configured so that: $\Delta\theta = 45°$ to $78.5°$ and $\Delta\phi = -60°$ to $+60°$.

FASTMC_GEN_ANAL.FOR The heart of the GENERAL FASTMC package. It is a general analysis routine, which reconstructs the four-momentum of neutral and charged particles, determines geometrical and detector efficiencies, and fills the Ntuples.

FAST_HSTDEF_NTP.FOR Dummy routine

NEUTRAL_SMEAR.FOR Allows for the smearing of the reconstructed four-momentum of photons and neutrons that are detected in the Electromagnetic Shower Counters.

FAST_MAIN_NTP.FOR Modified FAST_MAIN.FOR. Allows for data to be output in Ntuple format. Driver program for GENERAL FASTMC.

FAST_SETUP_GEN.FOR Neutron detection changed.

NTP_FILL.FOR Fills the 11 parameters for each particle into its Ntuple.

NUCLIDE.FOR Augments the LUND event record to include the nuclides: ^{2}H, ^{3}H, ^{3}He, and ^{4}He.

C.2 General Histogram Maker

The routines described below are compiled and linked by the procedure HISTO_MAKER.MAK, which creates an executable image of the General Histogram Maker. Please note that the histogram IDs can range from 1 to 5000. Also note that *histogram ID=10* is *not allowed* since this is the identifier for the Ntuples.

The user should take the time to go over the following four include files

USER7:[COLE.3HE]HE3_FASTMC_COMMON.INC Used in both the GENERAL FASTMC and GENERAL HISTOGRAM MAKER packages. It extracts several useful kinematic variables.

USER7:[COLE.3HE.PAW]HE3_HIST_MAKE.INC Also extracts several useful kinematic variables and decodes the efficiency bitmap (cf. page 5).

USER7:[COLE.3HE]LUND_PART_ID.INC Assigns mneumonic variable names to the LUND particle identifiers.

USER7:[COLE.3HE]NTUPLE_DEF.INC Describes the Ntuple parameters.

These include files are used in the histograming package. They are thoroughly commented, and the user will find the kinematic variables useful for his or her analysis. Do not be disturbed by 3HE in the name of the include files. GENERAL FASTMC was developed for studying various photoreactions involving the ^{3}He nucleus, and the name remains as a historical artifact.

HISTO_HBOOK.FOR User supplied histogram booking routine.

HISTO_HFILL.FOR User supplied histogram filling routine.

HISTO_MAKER.FOR Main program for extracting kinematics from the Ntuple parameters and histograming the results.

Incidentally, the user may find the object library module, NUM_RECIPES_2E.OLB, useful for his or her analysis. The complete set of programs from the book Numerical Recipes [6] have been compiled and placed in this object library, which resides in USER7:[COLE.NUM_RECIPES.ED2]. Parenthetically, for those who have not yet purchased the second edition, the routines from the first edition are contained in the object library module, NUM_RECIPES_1E.OLB, which resides in the subdirectory USER7:[COLE.NUM_RECIPES.ED1]. Below are some routines that I have used repeatedly in my analysis, and they can be found in USER7:[COLE.FASTMC_GEN.PAW].

INV_MASS.FOR Calculates the invariant mass.

LABTOCM.FOR Converts four-momentum from lab to center-of-momentum frame.

MISSING_MASS.FOR Calculates the missing mass.

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Figure 1: Conceptual flow chart of how to use GENERAL FASTMC

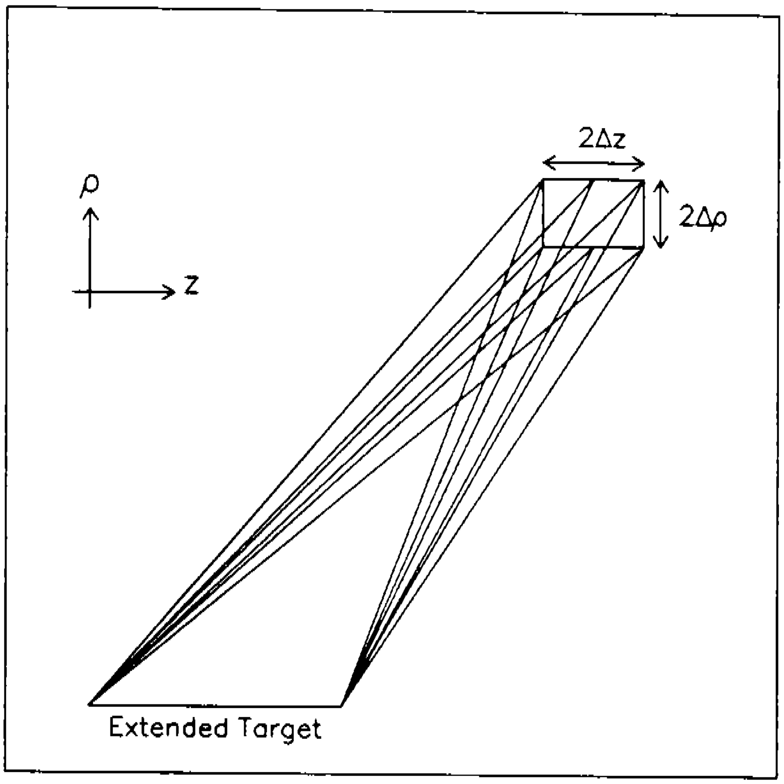

Figure 2: Possible trajectories for a neutral originating in the target and measured in an electromagnetic shower counter (NOT TO SCALE)

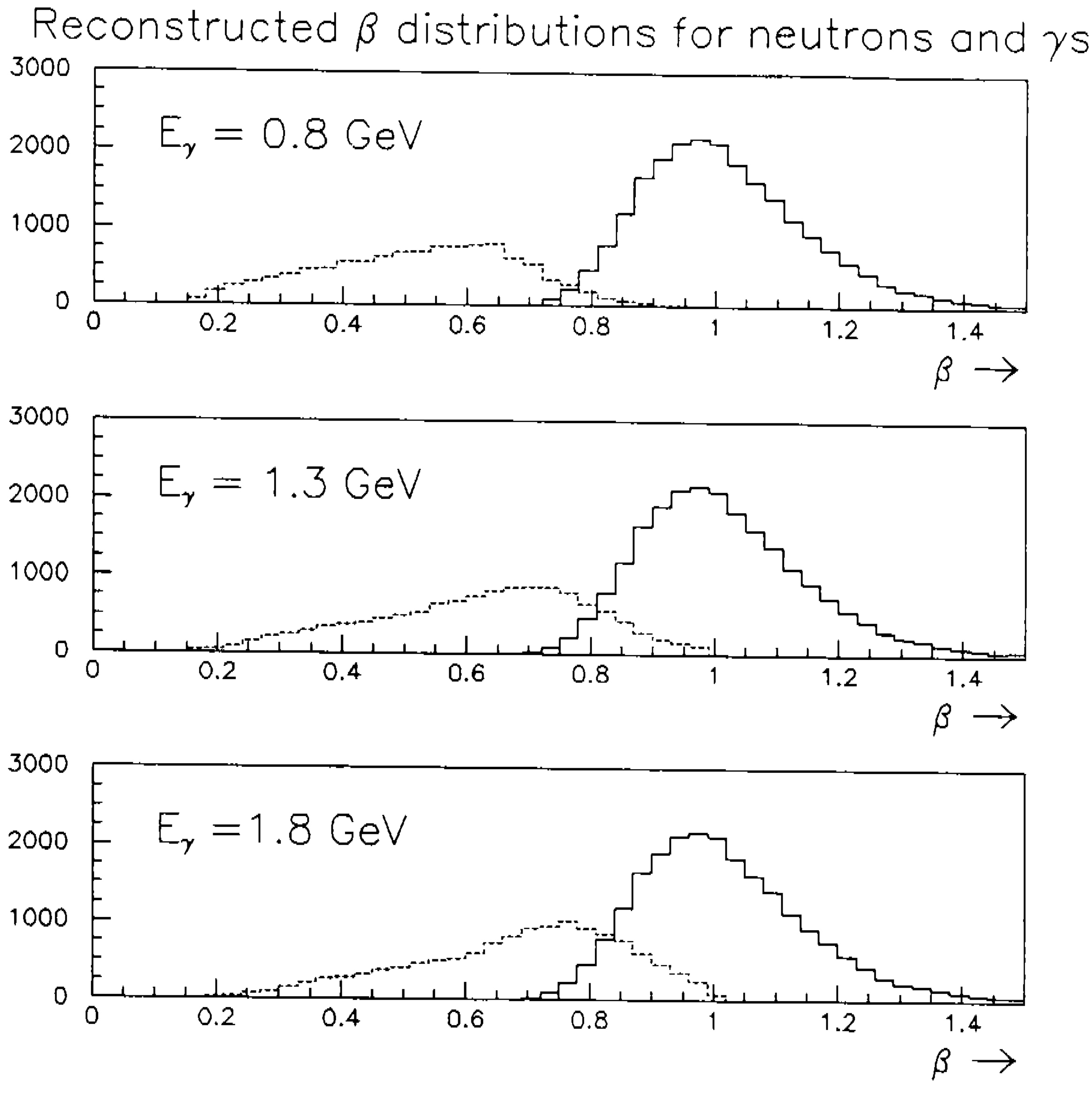

Figure 3: β distributions for neutrons and decay gammas measured in the electromagnetic shower counters for the reaction $\gamma + {}^3\text{He} \rightarrow 2p + n + \pi^0$ at three different tagged photon energies

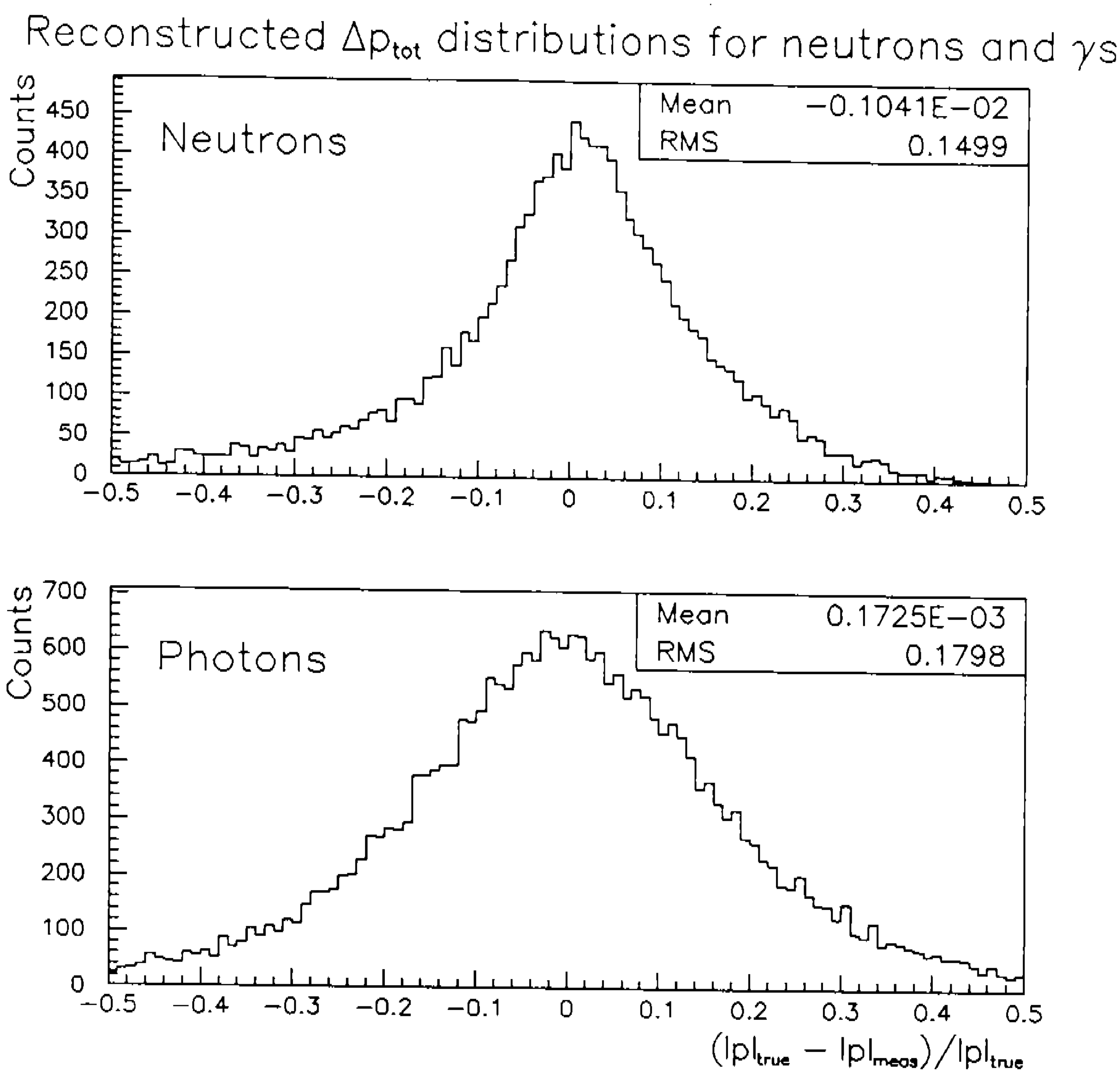

Figure 4: $\Delta P_{\rm tot}$ distributions for neutrons and decay gammas measured in the electromagnetic shower counters for the reaction $\gamma+{}^3\mathrm{He} \rightarrow 2p+n+\pi^0$ at $\mathrm{E}_\gamma = 1.3$ GeV