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The VXNFIT User Manual

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Contents

1 Introduction

The VXNFIT software package is a collection of numerical algorithms to reconstruct the neutral $K^0(\overline{K^0})$ decay vertex in the reaction chain $(\overline{p}p)_{rest} \rightarrow K^{\mp}\pi^{\pm}K^0(\overline{K^0})$ with a subsequent decay $K^0(\overline{K^0}) \rightarrow \pi^0\pi^0 \rightarrow \gamma\gamma\gamma\gamma$ (or $K^0(\overline{K^0}) \rightarrow \pi^0\pi^0\pi^0) \rightarrow \gamma\gamma\gamma\gamma\gamma\gamma$ in the CPLEAR detector. At present the package offers the following tools for the analysis of the 4γ final state:

- The 'Decay Length Variation Method', which is better known as the Nakada Method, to estimate the $K^0(\overline{K^0})$ decay vertex [1].
- Several constraint fits using the track information, the photon impact points and the photon energies to reconstruct the $K^0(\overline{K^0})$ decay vertex [1].
- The 'Loop Method' to calculate from the error on the $K^0(\overline{K^0})$ flight direction an $K^0(\overline{K^0})$ decay length error [2].
- The 'New Loop Method' to calculate a $K^0(\overline{K^0})$ lifetime error [2].
- The 'Shower Direction Method' to estimate the $K^0(\overline{K^0})$ decay vertex from the $K^0(\overline{K^0})$ flight direction and the directions of the photon showers in the calorimeter [3].

There are in addition two constraint fits for the reconstruction of the $K^0(\overline{K^0}) \rightarrow \pi^0\pi^0\pi^0$ decay vertex and special constraint fits to identify $(\overline{p}p)_{rest}$ annihilation background.

The intention of this document is not to describe the functionality of the coded algorithms, but is aimed to provide the user with all the essential information he/she needs to apply the algorithms. For more detailed information about the algorithms the reader is referred to the references. Especially reference [4] illustrates the use of several algorithms for the $K^0(\overline{K^0}) \rightarrow \pi^0\pi^0 \rightarrow \gamma\gamma\gamma\gamma$ analysis.

2 Fundamentals

2.1 Files of the VXNFIT package

The VXNFIT package consists of three files (VMS syntax):

- **VXNFIT.CAR:** The Patchy based source code.
- **VXNFIT.OLB:** The library of all supported routines of the source code.
- **VXNFIT.INCL:** The FORTRAN include file with the basic input/output commons.

2.2 User interface

Most algorithms in the VXNFIT package for the reconstruction of the $K^0(\overline{K^0})$ decay vertex are accessible by a subroutine call of the form:

CALL VXNstring(NUMRUN,NUMEVE,IPER,para,IER)

where 'string' is a unique identifier of the algorithm and 'para' is a set of algorithm specific parameters. The meaning of the other stated parameters is as following:

NUMRUN, NUMEVE
Run number and event number.

IPER

This variable specifies the π^0-$\gamma\gamma$ pairing. If IPER=0, then an internal loop over all possible π^0-$\gamma\gamma$ pairings is performed. IPER=1,2 or 3 selects one specific π^0-$\gamma\gamma$ pairing (see section 2.5 for more details).

IER

This flag indicates on input a debug level and serves on output as an error flag:

	IER	Meaning
Input	0	no debug
	1	subroutine tracing
	2	subroutine tracing and printing of input and output variables
	≥ 3	quite verbose messages
Output	0	normal termination
	≥ 1	error

The second part of the user interface consists of the VXNFIT include file **VXNFIT.INCL** or the sequence **VXNINC** in a Patchy environment. It allows the user to set manually all input variables of the selected algorithm and to access its results. A list of all generic input variables the user is allowed to touch is given below (the dimension of the variables is given in the [ ] parenthesis):

PMOKCM [3]

Measured charged kaon momentum at the track fit reference point (p_x,p_y,p_z).

PMOKCE [3,3]

Covariance matrix of PMOKCM.

PMOPCM [3]

Measured charged pion momentum at the track fit reference point (p_x,p_y,p_z).

PMOPCE [3,3]

Covariance matrix of PMOPCM.

PMOKCL [3]

Measured charged kaon momentum at the annihilation vertex (p_x,p_y,p_z).

PMOPCL [3]

Measured charged pion momentum at the annihilation vertex (p_x,p_y,p_z).

ANVTXM [3]

Measured annihilation vertex (x,y,z).

ANVTXE [3,3]

Covariance matrix of ANVTXM.

GFOOTM [6,3]

Measured impact points of the photon showers (r,φ,z).

GANGLM [6,2]
Measured directions of the photon showers (θ,ϕ).

GFOANE [6,5]
Covariance matrix of GFOOTM and GANGLM (r,φ,z,θ,ϕ).

GENERM [6]
Measured photon energy.

GENERE [6]
Variance of GENERM.

Algorithm specific input variables and the output variables are explained in the later sections, when describing these algorithms.

2.3 CPLEAR software environment

When processing events in the MINRAW format with CPREAD or a MINI standalone program, it is possible to fill the input variables of the previous section (2.2) by the call:

CALL VXNAPB(ITKC,ITPC,NG,IG,IOPT)

Parameters:

ITKC
Track number of the present kaon candidate.

ITPC
Track number of the present pion candidate.

NG
Number of photon showers to process.

IG [20]
List of the NG photon showers to process.

IOPT
= 0 : use shower foot (DRFSHO,DPFSHO,DZFSHO)
= 1 : use shower foot (RFOSHO,PFOSHO,ZFOSHO)

Warning:
At present no impact point errors and direction errors of the photons are stored on the MINRAW tapes. Therefore the user must define the variable GFOANE explicitly!

2.4 Outside the CPLEAR software environment

When using the VXNFIT package outside the CPLEAR software environment, e.g. in a mini MC program, the source code of VXNAPB is a good example how to fill the input variables. In addition the following line must be added to the user program before calling any algorithm of the VXNFIT package

LTRROT = .TRUE.

(The variable LTRROT is defined in VXNFIT.INCL).

2.5 Some conventions

- **π^0 and photon arrays:**
  In the arrays, which are related to the neutral pions, the pions are numbered from '1' to '2' (or '3') and in arrays, which are related to the photons, the photons are numbered from '1' to '4' (or '6'). In such arrays, eg. PMOPIS(i,k) or GANVES(i,k), see section (3), the first index always corresponds to the π^0 or the photon number. The user should not be confused by the fact, that the first dimension of the arrays is often larger than the number of π^0's or γ's in the present problem.

- **π^0-$\gamma\gamma$ pairing convention:**
  In the $K^0(\overline{K^0}) \to \pi^0\pi^0 \to \gamma\gamma\gamma\gamma$ decay there are three different possibilities to pair the two neutral pions with the four photons. We use the definition:

π^0-$\gamma\gamma$ pairing number	$\gamma\gamma$ pair of π^0 number '1'	$\gamma\gamma$ pair of π^0 number '2'
1	(1,2)	(3,4)
2	(1,3)	(2,4)
3	(3,2)	(1,4)

In the $K^0(\overline{K^0}) \to \pi^0\pi^0\pi^0 \to \gamma\gamma\gamma\gamma\gamma\gamma$ decay there are 15 different possibilities to pair the three neutral pions with the six photons.

π^0-$\gamma\gamma$ pairing number	$\gamma\gamma$ pair of π^0 number '1'	$\gamma\gamma$ pair of π^0 number '2'	$\gamma\gamma$ pair of π^0 number '3'
1	(1,2)	(3,4)	(5,6)
2	(1,2)	(3,5)	(4,6)
3	(1,2)	(4,5)	(3,6)
4	(1,3)	(2,4)	(5,6)
5	(1,3)	(2,5)	(4,6)
6	(1,3)	(4,5)	(2,6)
7	(1,4)	(2,3)	(5,6)
8	(1,4)	(2,5)	(3,6)
9	(1,4)	(3,5)	(2,6)
10	(1,5)	(2,3)	(4,6)
11	(1,5)	(2,4)	(3,6)
12	(1,5)	(3,4)	(2,6)
13	(2,3)	(4,5)	(1,6)
14	(2,4)	(3,5)	(1,6)
15	(2,5)	(3,4)	(1,6)

2.6 Units

The CPLEAR unit convention is used: cm, rad, MeV, MeV/c, MeV/c^2

3 $K^0(\overline{K^0}) \rightarrow \pi^0\pi^0 \rightarrow \gamma\gamma\gamma\gamma$: Decay Length Variation Method

The method, which uses the annihilation vertex, the track momenta of the kaon and the pion candidates and the four photon impact points to reconstruct the $K^0(\overline{K^0})$ decay length [1], is executed by the call:

CALL VXNEST1(NUMRUN,NUMEVE,IPER,IOPT,IER)

Input variables (see also VXNFIT.INCL description):

ANVTXM [3]

PMOKCL [3] (or **PMOKCK** [3], see explanation below)

PMOPCL [3] (or **PMOPCK** [3], see explanation below)

GFOOTM [6,3]

In the argument list of VXNEST1 the parameter IOPT steers the momentum variables to use:

IOPT = 0 : use PMOKCL and PMOPCL
= 1 : use PMOKCK and PMOPCK

This feature enables the user to store in (PMOKCL,PMOPCL) the measured momenta and in (PMOKCK,PMOPCK) the momenta of a $K^0(\overline{K^0})$ missing mass 1c-fit.

Output variables (VXNFIT.INCL):

IEREST
Error flag (the same as IER).

YLEEST
$K^0(\overline{K^0})$ decay length.

DECEST [3]
$K^0(\overline{K^0})$ decay vertex (x,y,z).

IPERME
π^0-$\gamma\gamma$ pairing number (see section 2.5).

PMOPIS [3,3]
Neutral pion momentum (p_x,p_y,p_z).

GENEST [6]
Photon energies.

GANVES [6,3]
Unit vectors in photon flight direction (x,y,z).

An annihilation vertex $K^0(\overline{K^0})$ missing mass 1c-fit [1] is implemented in the VXNFIT package to feed the decay length variation method with improved track kinematics: the 1c-fit fills the momentum variables PMOKCK and PMOPCK, that can be used by a subsequent VXNEST1 call by choosing the option IOPT=1.

CALL VXNK0M(NUMRUN,NUMEVE,IER)

Input variables (see also VXNFIT.INCL description):

PMOKCM [3]

PMOKCE [3,3]

PMOPCM [3]

PMOPCE [3,3]

PMOKCL [3]

PMOPCL [3]

ANVTXM [3]

ANVTXE [3,3]

Output variables (VXNFIT.INCL):

IERK0M
Error flag (the same as IER).

ITDK0M
Number of iterations.

CHIK0M
Chi square.

PCHIK0
Probability of CHIK0M.

PMOPCK [3]
Iterated charged pion momentum (p_x,p_y,p_z).

PMOKCK [3]
Iterated charged kaon momentum (p_x,p_y,p_z).

PMOK0K [3]
$K^0(\overline{K^0})$ momentum (p_x,p_y,p_z).

FFFK0M [4]
Constraints.

CVWK0M [6,6]
Covariance matrix of PMOPCK and PMOKCK.

CVXK0M [3,3]
Covariance matrix of PMOK0K.

CVWXK0 [3,6]
Correlation of PMOK0K with PMOPCK and PMOKCK.

4 $K^0(\overline{K^0}) \to \pi^0\pi^0 \to \gamma\gamma\gamma\gamma$: Constraint Fits

The constraint fits to reconstruct the $K^0(\overline{K^0})$ decay vertex have common output variables. The most important ones are (VXNFIT.INCL):

IERTTT
Error flag.

ITDTTT
Number of iterations.

CHITTT
Chi square.

PCHITT
Probability of CHITTT.

NFREET
Degrees of freedom of cfit.

ICOMBT
π^0-$\gamma\gamma$ pairing number (see section 2.5).

PMOKCT [3]
Iterated charged kaon momentum (p_x,p_y,p_z).

PMOPCT [3]
Iterated charged pion momentum (p_x,p_y,p_z).

ANVTXT [3]
Iterated annihilation vertex (x,y,z).

GFOOTT [6,3]
Iterated impact points of photon showers (r,φ,z).

GANGLT [6,2]
Iterated directions of photon showers (θ,ϕ).

GENERT [6]
Iterated photon energy.

YLENGT
$K^0(\overline{K^0})$ decay length.

DVTXTT [3]
$K^0(\overline{K^0})$ decay vertex (x,y,z).

PMOK0T [3]
$K^0(\overline{K^0})$ momentum (p_x,p_y,p_z).

PMOPIT [3,3]
π^0 momentum (p_x,p_y,p_z).

GANVTT [6,3]
Unit vectors in photon flight direction (x,y,z).

FFFTTT [*]
Constraints.

CVWTTT [*,*]
Covariance matrix of observables

CVXTTT [*,*]
Covariance matrix of unknowns.

CVWXTT [*,*]
Correlation matrix of observables and unknowns.

The *'s in the last four variables should not concern the user, because these dimensions are under frequent revision.

The following classification of the constraint fits depends on the used photon observables.

4.1 Photon observables: Impact points and energies of all four photons

4.1.1 6c-fit

CALL VXN06A1(NUMRUN,NUMEVE,IPER,IER)

Constraints:

(1) Energy conservation

(2-4) Momentum conservation

(5) $K^0(\overline{K^0})$ mass

(6-7) π^0 masses

Unknowns:

- $K^0(\overline{K^0})$ decay length

Input variables:

Track variables
(see VXNK0M input, section 3).

GFOOTM [6,3]

GFOANE [6,5]
Only elements (r,φ,z) have to be set.

GENERM [6]

GENERE [6]

YLSTRT [15]
Estimate of the unknown $K^0(\overline{K^0})$ decay length. The index corresponds to the variable IPER.

The variable YLSTRT is set automatically by a previous call to VXNEST1.

4.1.2 5c-fit

CALL VXN05A1(NUMRUN,NUMEVE,IPER,IER)

This is the previous 6c-fit, section (4.1.1), without the constraint on the $K^0(\overline{K^0})$ mass.

4.1.3 4c-fit

CALL VXN04A1(NUMRUN,NUMEVE,IER)

This is the previous 6c-fit, section (4.1.1) without the constraints on the π^0 masses. Note the missing variable IPER in the argument list of the subroutine call.

4.2 Photon observables: Impact points of all four photons

4.2.1 2c-fit

CALL VXN02E1(NUMRUN,NUMEVE,IPER,IER)

Constraints:

(1) Energy conservation

(2-4) Momentum conservation

(5) $K^0(\overline{K^0})$ mass

(6-7) π^0 masses

Unknowns:

- $K^0(\overline{K^0})$ decay length
- Photon energies

Input variables:

Track variables
(see VXNK0M input, section 3)

GFOOTM [6,3]

GFOANE [6,5]
Only elements (r,φ,z) have to be set.

YLSTRT [15]

GESTRT [15,6]
Estimate of the unknown photon energies. The first index corresponds to variable IPER.

The variables YLSTRT and GESTRT are set automatically by a previous call to VXNEST1.

4.3 Photon observables: Impact points and energies of all four photons, but one impact point z component is missing

4.3.1 5c-fit

CALL VXN05Z1(NUMRUN,NUMEVE,IPER,IER)

Constraints:

(1) Energy conservation

(2-4) Momentum conservation

(5) $K^0(\overline{K^0})$ mass

(6-7) π^0 masses

Unknowns:

- $K^0(\overline{K^0})$ decay length
- Impact point z component of one photon

Input variables:

Track variables
(see VXNK0M input, section 3)

GFOOTM [6,3]

GFOANE [6,5]
Only elements (r,φ,z) have to be set.

GENERM [6]

GENERE [6]

YLSTRT [15]

The photon with the missing impact point z component must be photon number '4'. In GFOOTM(4,3) an estimate of the unknown z component has to be stored.

4.4 Photon observables: Impact points and energies of three photons

4.4.1 3c-fit

CALL VXN03X1(NUMRUN,NUMEVE,IPER,IER)

Constraints:

(1) Energy conservation

(2-4) Momentum conservation

(5) $K^0(\overline{K^0})$ mass

(6-7) π^0 masses

Unknowns:

- $K^0(\overline{K^0})$ decay length
- Impact point of photon number '4'
- Energy of photon number '4'

Input variables:

Track variables
(see VXNK0M input, section 3)

GFOOTM [6,3]

GFOANE [6,5]
Only elements (r,φ,z) have to be set.

GENERM [6]

GENERE [6]

YLSTRT [15]

GESTRT [15,6]

The missing photon must be number '4'. In GFOOTM(4,*) an estimate of the unknown impact point and in GESTRT(*,4) an estimate of the unknown energy has to be stored (the '*' component in these arrays runs over all possible values).

5 $\mathrm{K}^0(\overline{\mathrm{K}^0}) \to \pi^0\pi^0\pi^0 \to \gamma\gamma\gamma\gamma\gamma\gamma$: Constraint Fits

The generic output variables are the same as for the $\mathrm{K}^0(\overline{\mathrm{K}^0}) \to \pi^0\pi^0 \to \gamma\gamma\gamma\gamma$ constraint fits.

5.1 Photon observables: Impact points and energies of all six photons

5.1.1 7c-fit

CALL VXN07U1(NUMRUN,NUMEVE,IPER,IER)

Constraints:

(1) Energy conservation

(2-4) Momentum conservation

(5) $\mathrm{K}^0(\overline{\mathrm{K}^0})$ mass

(6-8) π^0 masses

Unknowns:

- $\mathrm{K}^0(\overline{\mathrm{K}^0})$ decay length

Input variables:

Track variables
(see VXNK0M input, section 3)

GFOOTM [6,3]

GFOANE [6,5]
Only elements (r,φ,z) have to be set.

GENERM [6]

GENERE [6]

YLSTRT [15]
Estimate of the unknown $\mathrm{K}^0(\overline{\mathrm{K}^0})$ decay length. The index corresponds to the variable IPER.

5.1.2 6c-fit

CALL VXN06U1(NUMRUN,NUMEVE,IPER,IER)

This is the previous 7c-fit, section (5.1.1) without the constraint on the $\mathrm{K}^0(\overline{\mathrm{K}^0})$ mass.

6 $\mathrm{K}^0(\overline{\mathrm{K}^0}) \rightarrow \pi^0\pi^0 \rightarrow \gamma\gamma\gamma\gamma$: Loop Method

The Loop Method uses the annihilation vertex, the $\mathrm{K}^0(\overline{\mathrm{K}^0})$ momentum, the $\mathrm{K}^0(\overline{\mathrm{K}^0})$ momentum covariance matrix, the photon impacts points, the photon energies and the photon energy covariances to calculate the $\mathrm{K}^0(\overline{\mathrm{K}^0})$ decay length and a $\mathrm{K}^0(\overline{\mathrm{K}^0})$ decay length error [2].

CALL VXNGER1(NUMRUN,NUMEVE,IPER,IOPT,IER)

Input variables (see also VXNFIT.INCL description):

ANVTXM [3]

PMOKER [3]
$\mathrm{K}^0(\overline{\mathrm{K}^0})$ momentum (p_x,p_y,p_z).

CVPKER [3,3]
$\mathrm{K}^0(\overline{\mathrm{K}^0})$ momentum covariance matrix.

GFOOTM [6,3]

GENERM [6]

GENERE [6]

PMRKER [3,3]
Estimate for a $\mathrm{K}^0(\overline{\mathrm{K}^0})$ momentum that lies on the loop (p_x,p_y,p_z).

YLEKER [3]
Estimate for a $\mathrm{K}^0(\overline{\mathrm{K}^0})$ decay length that corresponds to PMRKER.

The variable **IOPT** in the VXNGER1 argument list is presently not used.

Output variables (VXNFIT.INCL):

IERGER
Error flag (the same as IER).

YAVGER [3]
$\mathrm{K}^0(\overline{\mathrm{K}^0})$ decay length (mean value, no energy weighting).

YMXGER [3]
$\mathrm{K}^0(\overline{\mathrm{K}^0})$ decay length (most probable value, no energy weighting).

DYAVER [3]
Error of YAVGER.

DYMXER [3]
Error of YMXGER.

YAVEER [3]
$K^0(\overline{K^0})$ decay length (mean value, energy weighting).

YMXEER [3]
$K^0(\overline{K^0})$ decay length (most probable value, energy weighting).

DYAEER [3]
Error of YAVEER.

DYMEER [3]
Error of YMXEER.

The first index of PMRKER, YLEKER, YAVGER, YMXGER, DYAVER, DYMXER, YAVEER, YMXEER, DYAEER, DYMEER corresponds to the variable IPER.

7 $K^0(\overline{K^0}) \to \pi^0\pi^0 \to \gamma\gamma\gamma\gamma$: New Loop Method

The New Loop Method uses the annihilation vertex, the track parameters, the hit multiplicities and the directions of the photon showers in the calorimeter to calculate the $K^0(\overline{K^0})$ lifetime and a $K^0(\overline{K^0})$ lifetime error [2].

CALL VXNNLO1(NUMRUN,NUMEVE,IPER,IER)

Warning:

- The algorithm is not foreseen to run outside the CPLEAR software environment (the cluster and shower banks are touched as well as the parametrization of the photon hit multiplicities)!
- The argument IPER = 0 is not supported!

Input variables (see also VXNFIT.INCL description):

Track variables
(see VXNK0M input, section 3)

GFOOTM [6,3]

GANGLM [6,2]

YLENVL
Estimate for the unknown $K^0(\overline{K^0})$ decay length.

GENEVL [4]
Estimate for the photon energies at YLENVL.

PPK0VL [3]
Estimate for the $K^0(\overline{K^0})$ momentum at YLENVL (p_x,p_y,p_z).

Output variables (VXNFIT.INCL):

IERRVL
Error flag (the same as IER).

TTAVVL
$K^0(\overline{K^0})$ lifetime.

TTSDVL
$K^0(\overline{K^0})$ lifetime standard deviation.

8 $K^0(\overline{K^0}) \to \pi^0\pi^0 \to \gamma\gamma\gamma\gamma$: Shower Direction Method (Author: O. Behnke)

The Shower Direction Method uses the $K^0(\overline{K^0})$ flight direction, and the impact points and shower directions of the photons in the calorimeter to estimate a $K^0(\overline{K^0})$ decay length [3].

CALL VXNVSH1(NUMRUN,NUMEVE,UX,UY,UZ,AX,AY,AZ,IER)

Input variables (see also VXNFIT.INCL description):

UX,UY,UZ
A unit vector in the $K^0(\overline{K^0})$ flight direction.

AX,AY,AZ
A reference point on the $K^0(\overline{K^0})$ flight path.

GFOOTM [6,3]

GANGLM [6,2]

GFOANE [6,5]

Output variables (VXNFIT.INCL):

IEROUT
Error flag (the same as IER).

PAIMIN
$K^0(\overline{K^0})$ decay length.

SIGLSH
$K^0(\overline{K^0})$ decay length error.

PCHMIN
Chi square.

9 Special constraint fits

9.1 $(\overline{p}p)_{rest} \to \pi^+\pi^-\pi^0\pi^0$

9.1.1 5c-fit

If one replaces the $K^+(K^-)$ mass of the 5c-fit of section (4.1.2) against the $\pi^+(\pi^-)$ mass, one gets a 5c-fit to identify the annihilation channel $(\overline{p}p)_{rest} \to \pi^+\pi^-\pi^0\pi^0$. Note that this constraint fit still works with a free decay length!

CALL VXP05A1(NUMRUN,NUMEVE,IPER,IER)

9.1.2 6c-fit

CALL VXP06A1(NUMRUN,NUMEVE,IPER,IER)

This is the previous 5c-fit, section (9.1.1), with the decay length fixed at zero.

9.2 $(\overline{\mathrm{p}}\mathrm{p})_{rest} \rightarrow \mathrm{K}^{+}\mathrm{K}^{-}\pi^{0}\pi^{0}$

9.2.1 5c-fit

If one replaces the $\pi^{+}(\pi^{-})$ mass of the 5c-fit of section (4.1.2) against the $\mathrm{K}^{+}(\mathrm{K}^{-})$ mass, one gets a 5c-fit to identify the annihilation channel $(\overline{\mathrm{p}}\mathrm{p})_{rest} \rightarrow \mathrm{K}^{+}\mathrm{K}^{-}\pi^{0}\pi^{0}$ Note that this constraint fit still works with a free decay length!

CALL VXK05A1(NUMRUN,NUMEVE,IPER,IER)

9.2.2 6c-fit

CALL VXK06A1(NUMRUN,NUMEVE,IPER,IER)

This is the previous 5c-fit, section (9.2.1), with the decay length fixed at zero.

10 Example

The following FORTRAN code illustrates the application of the VXNFIT package in the CPLEAR software environment.

```
C===========================================
C Make the input/output variables available
C===========================================
C
       INCLUDE 'VXNFIT.INCL'
C
C============================================================
C Fill the generic input variables with the MINI information
C============================================================
C
      ITKC=2            ! The charged kaon is track number 2
      ITPC=1            ! The charged pion is track number 1
C
      NG=4              ! Number of photons
C
      IG(1)=2
      IG(2)=4           ! The photons correspond to the
      IG(3)=5           !   showers 2,4,5 and 6
      IG(4)=6
C
      IOPT=1            ! Lets work with t h e s e impact points
C
      CALL VXNAPB(ITKC,ITPC,NG,IG,IOPT)
C
C===============================================================
C Call the 1c-fit to use its track momenta in the Nakada method
C===============================================================
```

```
C
      IER=0         ! No debug
      CALL VXNKOM(NUMRUN,NUMEVE,IER)
      IF (IER.NE.0) GOTO 999                    ! Skip event
C
      PXK01C=PM0K0K(1)
      PYK01C=PM0K0K(2)     ! Get the K0 momentum of the 1c-fit
      PZK01C=PM0K0K(3)
      PPK01C=SQRT(PXK01C**2+PYK01C**2+PZK01C**2)
C
C=======================
C Call the Nakada method
C=======================
C
      IPER=0            ! Loop over all pi0-gamma-gamma pairs
C
      IOPT=1            ! Use the track momenta of the 1c-fit
C
      IER=0         ! No debug
      CALL VXNEST1(NUMRUN,NUMEVE,IPER,IOPT,IER)
      IF (IER.NE.0) GOTO 999                    ! Skip event
C
C================
C Call the 6c-fit
C================
C
      IPER=0            ! Loop over all pi0-gamma-gamma pairs
C
      IER=0         ! No debug
      CALL VXN06A1(NUMRUN,NUMEVE,IPER,IER)
      IF (IER.NE.0) GOTO 999                    ! Skip event
C
      IF (PCHITT.LT.0.05) GOTO 999      ! Cut on probability of 6c-fit
C
      YLEN6C=YLENGT    ! Get K0 decay length of 6c-fit
C
      E16C=GENERT(1)
      E26C=GENERT(2)   ! Get photon energies of 6c-fit
      E36C=GENERT(3)
      E46C=GENERT(4)
C
      PXK06C=PM0K0T(1)
      PYK06C=PM0K0T(2)     ! Get the K0 momentum of the 6c-fit
      PZK06C=PM0K0T(3)
      PPK06C=SQRT(PXK06C**2+PYK06C**2+PZK06C**2)
C
C================================
C Call the Shower Direction Method
C================================
C
      UX=PXK01C/PPK01C
      UY=PYK01C/PPK01C  ! Use K0 flight direction of 1c-fit
      UZ=PZK01C/PPK01C
C
      AX=ANVTXM(1)
      AY=ANVTXM(2)      ! Use measured annihilation vertex
      AZ=ANVTXM(3)
C
      IER=0
      CALL VXNVSH1(NUMRUN,NUMEVE,UX,UY,UZ,AX,AY,AZ,IER)
      IF (IER.NE.0) GOTO 999         ! Skip event
C
      IF (PCHMIN.LT.0.01) GOTO 999   ! Cut on probability of method
C
C====================
```

```
C Call the Loop Method
C======================
C
      IPER=ICOMBT  ! Use pi0-gamma-gamma pairing of the previous 6c-fit
      IOPT=0 ! Dummy
C
      PMOKER(1)=PXK01C
      PMOKER(2)=PYK01C    ! Use the K0 momentum of the 1c-fit
      PMOKER(3)=PZK01C
      CVPKER(1,1)=CVXKOM(1,1)
      CVPKER(1,2)=CVXKOM(1,2)
      CVPKER(1,3)=CVXKOM(1,3)
      CVPKER(2,1)=CVXKOM(2,1)
      CVPKER(2,2)=CVXKOM(2,2)   ! K0 momentum covariance matrix of
      CVPKER(2,3)=CVXKOM(2,3)   ! the 1c-fit
      CVPKER(3,1)=CVXKOM(3,1)
      CVPKER(3,2)=CVXKOM(3,2)
      CVPKER(3,3)=CVXKOM(3,3)
      PMRKER(ICOMBT,1)=PXK06C ! Use the K0 momentum and the K0
      PMRKER(ICOMBT,2)=PYK06C ! decay length of the previous
      PMRKER(ICOMBT,3)=PZK06C ! 6c-fit as an estimate of a
      YLEKER(ICOMBT)=YLEN6C   ! point on the loop
C
      IER=0         ! No debug
      CALL VXNGER1(NUMRUN,NUMEVE,IPER,IOPT,IER)
      IF (IER.NE.0) GOTO 999                    ! Skip event
C
C==========================
C Call the New Loop Method
C==========================
C
      IPER=ICOMBT  ! Use pi0-gamma-gamma pairing of the previous 6c-fit
      YLENVL=YLEN6C  ! Use K0 decay length of 6c-fit
      GENEVL(1)=E16C
      GENEVL(2)=E26C ! Use photon energies at YLEN6C
      GENEVL(3)=E36C
      GENEVL(4)=E46C
      PPK0VL=PPK06C  ! Use K0 momentum at YLEN6C
C
      IER=0
      CALL VXNNL01(NUMRUN,NUMEVE,IPER,IER)
      IF (IER.NE.0) GOTO 999                    ! Skip event
C
C==================
C Further analysis
C==================
C
      ...
C
 999  CONTINUE                         ! Take next event
```

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