MIT Kavli Institute   Chandra X-Ray Center

MEMORANDUM
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To:	Jonathan McDowell, SDS Group Leader
From:	Glenn E. Allen, SDS
Subject:	`acis_process_events` spec
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1 `acis_process_events`

This spec, which is incomplete, describes some of processing steps for continuous-clocking mode data.

1.1 Description

1.2 Input

1.3 Output

1.4 Parameters

1.5 Processing

1.5.1 Error checking

The following steps are performed once prior to the processing of the data for each input ACIS event.

1. `infile`:

    (a) Existence:
    If the `infile` does not exist, then `acis_process_events` exits with an error message.

    (b) Permission:
    If the `infile` exists, but the file permissions do not allow it to be read, then `acis_process_events` exits with an error message.

    (c) Validation:

i. `CONTENT`:
If the `infile` does not have an HDU h_{in} with the keyword

$$
\begin{aligned}
\texttt{CONTENT} &= \text{EVT0 or} & (1)\\
\texttt{CONTENT} &= \text{EVT1 or} & (2)\\
\texttt{CONTENT} &= \text{TGEVT1 or} & (3)\\
\texttt{CONTENT} &= \text{EVT2,} & (4)
\end{aligned}
$$

then `acis_process_events` exits with an error message. Hereafter, the value of this keyword is referred to as $\texttt{CONTENT}_{\mathrm{in}}$.

ii. `DATAMODE`:
The `DATAMODE` is read from the HDU h_{in} keyword of the same name. If the HDU h_{in} does not include the keyword `DATAMODE` or if

$$
\begin{aligned}
\texttt{DATAMODE} &\neq \text{CC33\_FAINT and} & (5)\\
\texttt{DATAMODE} &\neq \text{CC33\_GRADED and} & (6)\\
\texttt{DATAMODE} &\neq \text{FAINT and} & (7)\\
\texttt{DATAMODE} &\neq \text{FAINT\_BIAS and} & (8)\\
\texttt{DATAMODE} &\neq \text{GRADED and} & (9)\\
\texttt{DATAMODE} &\neq \text{VFAINT,} & (10)
\end{aligned}
$$

then `acis_process_events` exits with an error message. Hereafter, the value of this keyword is referred to as $\texttt{DATAMODE}_{\mathrm{in}}$.

iii. `TIME`:
If HDU h_{in} of the `infile` does not include the column `TIME`, then `acis_process_events` exits with an error message. Hereafter, this column is referred to as $\texttt{TIME}_{\mathrm{in}}$.

iv. `TIME_RO`:
If

$$
\begin{aligned}
\texttt{DATAMODE}_{\mathrm{in}} &= \text{CC33\_FAINT or} & (11)\\
\texttt{DATAMODE}_{\mathrm{in}} &= \text{CC33\_GRADED,} & (12)
\end{aligned}
$$

if

$$
\begin{aligned}
\texttt{CONTENT}_{\mathrm{in}} &= \text{EVT1 or} & (13)\\
\texttt{CONTENT}_{\mathrm{in}} &= \text{TGEVT1 or} & (14)\\
\texttt{CONTENT}_{\mathrm{in}} &= \text{EVT2,} & (15)
\end{aligned}
$$

and if HDU h_{in} of the `infile` does not include the column `TIME_RO`, then `acis_process_events` exits with an error message. Hereafter, this column is referred to as $\texttt{TIME\_RO}_{\mathrm{in}}$.

v. `EXPNO`:
If HDU h_{in} the `infile` does not include the column `EXPNO`, then `acis_process_events` exits with an error message. Hereafter, this column is referred to as $\texttt{EXPNO}_{\mathrm{in}}$.

vi. `CCD_ID`:
   A. If

$$
\texttt{CONTENT}_{\mathrm{in}} = \text{EVT0} \qquad (16)
$$

and if HDU h_{in} of the `infile` does not include the keyword `CCD_ID`, then `acis_process_events` exits with an error message. Hereafter, this keyword is referred to as $\texttt{CCD\_ID}_{\mathrm{in}}$.

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B. If

$$\text{CONTENT}_{\text{in}} \quad = \quad \text{EVT1 or} \tag{17}$$
$$\text{CONTENT}_{\text{in}} \quad = \quad \text{TGEVT1 or} \tag{18}$$
$$\text{CONTENT}_{\text{in}} \quad = \quad \text{EVT2} \tag{19}$$

and if HDU h_{in} of the `infile` does not include the column `CCD_ID`, then `acis_process_-events` exits with an error message. Hereafter, this column is referred to as $\text{CCD\_ID}_{\text{in}}$.

vii. `CCDX`:

A. If

$$\text{CONTENT}_{\text{in}} \quad = \quad \text{EVT0} \tag{20}$$

and if HDU h_{in} of the `infile` does not include the column `CCDX`, then `acis_process_-events` exits with an error message. Hereafter, this column is referred to as CCDX_{in}.

viii. `CHIPX`:

A. If

$$\text{CONTENT}_{\text{in}} \quad = \quad \text{EVT1 or} \tag{21}$$
$$\text{CONTENT}_{\text{in}} \quad = \quad \text{TGEVT1 or} \tag{22}$$
$$\text{CONTENT}_{\text{in}} \quad = \quad \text{EVT2} \tag{23}$$

and if HDU h_{in} of the `infile` does not include the column `CHIPX`, then `acis_process_-events` exits with an error message. Hereafter, this column is referred to as CHIPX_{in}.

ix. `CCDY`:

A. If

$$\text{CONTENT}_{\text{in}} \quad = \quad \text{EVT0,} \tag{24}$$

if

$$\text{DATAMODE}_{\text{in}} \quad = \quad \text{FAINT or} \tag{25}$$
$$\text{DATAMODE}_{\text{in}} \quad = \quad \text{FAINT\_BIAS or} \tag{26}$$
$$\text{DATAMODE}_{\text{in}} \quad = \quad \text{GRADED or} \tag{27}$$
$$\text{DATAMODE}_{\text{in}} \quad = \quad \text{VFAINT,} \tag{28}$$

and if HDU h_{in} of the `infile` does not include the column `CCDY`, then `acis_process_-events` exits with an error message. Hereafter, this column is referred to as CCDY_{in}.

x. `TROW`:

A. If

$$\text{CONTENT}_{\text{in}} \quad = \quad \text{EVT0,} \tag{29}$$

if

$$\text{DATAMODE}_{\text{in}} \quad = \quad \text{CC33\_FAINT or} \tag{30}$$
$$\text{DATAMODE}_{\text{in}} \quad = \quad \text{CC33\_GRADED} \tag{31}$$

and if HDU h_{in} of the `infile` does not include the column `TROW`, then `acis_process_-events` exits with an error message. Hereafter, this column is referred to as TROW_{in}.

xi. `CHIPY`:

A. If

$$\text{CONTENT}_{\text{in}} \quad = \quad \text{EVT1 or} \tag{32}$$
$$\text{CONTENT}_{\text{in}} \quad = \quad \text{TGEVT1 or} \tag{33}$$
$$\text{CONTENT}_{\text{in}} \quad = \quad \text{EVT2} \tag{34}$$

and if HDU h_{in} of the `infile` does not include the column CHIPY, then `acis_process_-events` exits with an error message. Hereafter, this column is referred to as CHIPY_{in}.

xii. RA_TARG, DEC_TARG, RA_NOM, DEC_NOM, TIMEDEL, CHIPY_TG, CHIPY_ZO, and TG_M:
If

$$\text{DATAMODE}_{\text{in}} \quad = \quad \text{CC33\_FAINT or} \tag{35}$$
$$\text{DATAMODE}_{\text{in}} \quad = \quad \text{CC33\_GRADED} \tag{36}$$

then

A. RA_TARG, DEC_TARG, RA_NOM, DEC_NOM, and TIMEDEL:
If HDU h_{in} of the `infile` does not include the keywords RA_TARG, DEC_TARG, RA_NOM, DEC_NOM, and TIMEDEL, then `acis_process_events` exits with an error message. Hereafter these keywords are referred to $\text{RA\_TARG}_{\text{in}}$, $\text{DEC\_TARG}_{\text{in}}$, $\text{RA\_NOM}_{\text{in}}$, $\text{DEC\_NOM}_{\text{in}}$, and $\text{TIMEDEL}_{\text{in}}$, respectively.

B. CHIPY_TG, CHIPY_ZO, and TG_M:
If

$$\text{CONTENT}_{\text{in}} \quad = \quad \text{TGEVT1} \tag{37}$$

and if HDU h_{in} of the `infile` does not include the columns CHIPY_TG, CHIPY_ZO, and TG_M, then `acis_process_events` exits with an error message. Hereafter these columns are referred to as $\text{CHIPY\_TG}_{\text{in}}$, $\text{CHIPY\_ZO}_{\text{in}}$, and TG_M_{in}, respectively.

2. `stop`:

(a) Lowercase:
The parameter string is converted to contain only lower case letters.

(b) Validation:
If

$$\text{stop} \quad \neq \quad \text{none and} \tag{38}$$
$$\text{stop} \quad \neq \quad \text{chip and} \tag{39}$$
$$\text{stop} \quad \neq \quad \text{tdet and} \tag{40}$$
$$\text{stop} \quad \neq \quad \text{det and} \tag{41}$$
$$\text{stop} \quad \neq \quad \text{tan and} \tag{42}$$
$$\text{stop} \quad \neq \quad \text{sky,} \tag{43}$$

then `acis_process_events` exits with an error message.

3. `acaofffile`:

(a) Validation for CC mode:
If

$$\text{DATAMODE}_{\text{in}} \quad = \quad \text{CC33\_FAINT or} \tag{44}$$
$$\text{DATAMODE}_{\text{in}} \quad = \quad \text{CC33\_GRADED,} \tag{45}$$

then

i. Setting:
   If

$$acaofffile = \text{none or} \tag{46}$$
$$acaofffile = \text{NONE,} \tag{47}$$

then `acis_process_events` exits with an error message.

ii. Existence:
   If the `acaofffile` does not exist, then `acis_process_events` exits with an error message.

iii. Permission:
   If the `acaofffile` exists, but the file permissions do not allow it to be read, then `acis_process_events` exits with an error message.

iv. CONTENT:
   If the `acaofffile` does not have an HDU h_{acaoff} with the keyword

$$\mathtt{CONTENT} = \text{ASPSOL,} \tag{48}$$

then `acis_process_events` exits with an error message.

v. Keyword:
   If HDU h_{acaoff} of the `acaofffile` does not include the keyword `TSTART`, then `acis_process_events` exits with an error message.

vi. Columns:
   If HDU h_{acaoff} of the `acaofffile` does not include the columns `TIME`, `RA`, `DEC`, and `ROLL` then `acis_process_events` exits with an error message. Hereafter, these columns are referred to as $\mathrm{TIME}_{\mathrm{acaoff}}$, $\mathrm{RA}_{\mathrm{acaoff}}$, $\mathrm{DEC}_{\mathrm{acaoff}}$, and $\mathrm{ROLL}_{\mathrm{acaoff}}$.

vii. Sequential:
   If more than one valid `acaofffile` is specified, but the the values `TSTART` are not in increasing order, then `acis_process_events` exits with an error message.

4. `doevtgrade`:

   (a) Lowercase:
   The parameter string is converted to contain only lower case letters.

   (b) Validation:
   If

$$doevtgrade \neq \text{yes and} \tag{49}$$
$$doevtgrade \neq \text{no,} \tag{50}$$

then `acis_process_events` exits with an error message.

5. `apply_cti`:

   (a) Lowercase:
   The parameter string is converted to contain only lower case letters.

   (b) Validation:
   i. Setting:
      If

$$apply\_cti \neq \text{yes and} \tag{51}$$
$$apply\_cti \neq \text{no,} \tag{52}$$

then `acis_process_events` exits with an error message.

ii. PHAS:

If

$$\texttt{apply\_cti} \quad = \quad \text{yes} \tag{53}$$

and if the `infile` does not include the column `PHAS`, then `apply_cti` is changed to "no" and `acis_process_events` produces a warning message.

iii. doevtgrade:

If

$$\texttt{apply\_cti} \quad = \quad \text{yes and} \tag{54}$$
$$\texttt{doevtgrade} \quad = \quad \text{no,} \tag{55}$$

then `apply_cti` is changed to "no" and `acis_process_events` produces a warning message.

6. alignmentfile:

   (a) Validation for CC mode:

   If

   $$\texttt{DATAMODE}_{\text{in}} \quad = \quad \text{CC33\_FAINT or} \tag{56}$$
   $$\texttt{DATAMODE}_{\text{in}} \quad = \quad \text{CC33\_GRADED,} \tag{57}$$

   then

   i. Setting:

   If

   $$\texttt{alignmentfile} \quad = \quad \text{none or} \tag{58}$$
   $$\texttt{alignmentfile} \quad = \quad \text{NONE,} \tag{59}$$

   then `acis_process_events` exits with an error message.

   ii. Existence:

   If the `alignmentfile` does not exist, then `acis_process_events` exits with an error message.

   iii. Permission:

   If the `alignmentfile` exists, but the file permissions do not allow it to be read, then `acis_process_events` exits with an error message.

   iv. CONTENT:

   If the `alignmentfile` does not have an HDU $h_{\text{alignment}}$ with the keyword

   $$\texttt{CONTENT} \quad = \quad \text{ASPSOL,} \tag{60}$$

   then `acis_process_events` exits with an error message.

   v. Keyword:

   If HDU $h_{\text{alignment}}$ of the `alignmentfile` does not include the keyword `TSTART`, then `acis_process_events` exits with an error message.

   vi. Columns:

   If HDU $h_{\text{alignment}}$ of the `alignmentfile` does not include the columns `DY`, `DZ`, and `DTHETA` then `acis_process_events` exits with an error message.

   vii. Sequential:

   If more than one valid `alignmentfile` is specified, but the the values `TSTART` are not in increasing order, then `acis_process_events` exits with an error message.

7. badpixfile:

(a) Validation:
    If

$$badpixfile \neq none \text{ and} \tag{61}$$
$$badpixfile \neq NONE, \tag{62}$$

    then

   i. Existence:
     If the badpixfile does not exist, then badpixfile is changed to "none" and acis_process_events produces a warning message.

   ii. Permission:
     If the badpixfile exists, but the file permissions do not allow it to be read, then badpixfile is changed to "none" and acis_process_events produces a warning message.

  iii. CONTENT:
     If the badpixfile does not have one or more HDUs h_{badpix} with the keyword

$$CONTENT = BADPIX \text{ or} \tag{63}$$
$$CONTENT = CDB\_ACIS\_BADPIX, \tag{64}$$

     then badpixfile is changed to "none" and acis_process_events produces a warning message.

  iv. Keyword:
     If the HDU(s) h_{badpix} of the badpixfile do not include the keyword CCD_ID, then badpixfile is changed to "none" and acis_process_events produces a warning message.

   v. Columns:
     If the HDU(s) h_{badpix} of the badpixfile do not include the columns CHIPX, CHIPY, TIME, TIME_STOP, and STATUS, then badpixfile is changed to "none" and acis_process_events produces a warning message. Hereafter these columns are referred to as $\mathrm{CHIPX}_{\mathrm{badpix}}$, $\mathrm{CHIPY}_{\mathrm{badpix}}$, $\mathrm{TIME}_{\mathrm{badpix}}$, $\mathrm{TIME\_STOP}_{\mathrm{badpix}}$, and $\mathrm{STATUS}_{\mathrm{badpix}}$, respectively.

8. ctifile:

  (a) Validation:
     If

$$ctifile \neq caldb \text{ and} \tag{65}$$
$$ctifile \neq CALDB, \tag{66}$$

     then

   i. Existence:
     If the ctifile does not exist, then apply_cti is changed to "no" and acis_process_events produces a warning message.

   ii. Permission:
     If the ctifile exists, but the file permissions do not allow it to be read, then apply_cti is changed to "no" and acis_process_events produces a warning message.

  iii. CONTENT:
     If the ctifile does not have one or more HDUs h_{cti} with the keyword

$$CONTENT = CDB\_ACIS\_CTI, \tag{67}$$

     then apply_cti is changed to "no" and acis_process_events produces a warning message.

iv. Columns:
If the first such HDU of the ctifile does not include the columns CCD_ID, CHIPX_LO, CHIPX_HI, CHIPY_LO, CHIPY_HI, PHA, VOLUME_X, VOLUME_Y, FRCTRLX, FRCTRLY, TCTIX, and TCTIY, then apply_cti is changed to "no" and acis_process_events produces a warning message.

9. clobber:

(a) Lowercase:
The parameter string is converted to contain only lower case letters.

(b) Validation:

i. Setting:
If

$$\text{clobber} \neq \text{yes and} \tag{68}$$
$$\text{clobber} \neq \text{no,} \tag{69}$$

then clobber is changed to "no" and acis_process_events produces a warning message.

ii. Permission:
If

$$\text{clobber} = \text{yes} \tag{70}$$

and the outfile exists, but the file permissions of the outfile do not allow it to be overwritten, then acis_process_events exits with an error message.

iii. Don't overwrite:
If

$$\text{clobber} = \text{no} \tag{71}$$

and the outfile exists, then acis_process_events exits with an error message.

10. pix_adj:

(a) Lowercase:
The parameter string is converted to contain only lower case letters.

(b) Validation:

i. Setting:
If

$$\text{pix\_adj} \neq \text{centroid and} \tag{72}$$
$$\text{pix\_adj} \neq \text{edser and} \tag{73}$$
$$\text{pix\_adj} \neq \text{none and} \tag{74}$$
$$\text{pix\_adj} \neq \text{randomize,} \tag{75}$$

then pix_adj is changed to "none" and acis_process_events produces a warning message.

ii. stop:
If

$$\text{pix\_adj} = \text{centroid or} \tag{76}$$
$$\text{pix\_adj} = \text{edser or} \tag{77}$$
$$\text{pix\_adj} = \text{randomize} \tag{78}$$

and if

$$\texttt{stop} \quad \neq \quad \text{sky}, \tag{79}$$

then pix_adj is changed to "none" and acis_process_events produces a warning message.

   iii. PHAS:
      If

$$\texttt{pix\_adj} \quad = \quad \text{centroid} \tag{80}$$

and if the infile does not include the column PHAS, then pix_adj is changed to "none" and acis_process_events produces a warning message.

   iv. FLTGRADE:
      If

$$\texttt{pix\_adj} \quad = \quad \text{edser} \tag{81}$$

and if the infile does not include the column FLTGRADE, then pix_adj is changed to "none" and acis_process_events produces a warning message.

11. subpixfile:

  (a) If

$$\texttt{pix\_adj} \quad = \quad \text{edser}, \tag{82}$$

then

    i. Existence:
      If the subpixfile does not exist, then pix_adj is changed to "none" and acis_process_events produces a warning message.

    ii. Permission:
      If the subpixfile exists, but the file permissions do not allow it to be read, then pix_adj is changed to "none" and acis_process_events produces a warning message.

   iii. Validation:

     A. CONTENT:
        If the subpixfile does not have one or more HDUs h_{subpix} with the keyword

$$\texttt{CONTENT} \quad = \quad \text{AXAF\_SUBPIX}, \tag{83}$$

        then pix_adj is changed to "none" and acis_process_events produces a warning message.

     B. Keyword:
        If the HDUs h_{subpix} of the subpixfile do not include the keyword CCD_ID, then pix_adj is changed to "none" and acis_process_events produces a warning message.

     C. Columns:
        If the HDUs h_{subpix} of the subpixfile do not include binary tables with the columns FLTGRADE, NPOINTS, ENERGY, CHIPX_OFFSET, and CHIPY_OFFSET, then pix_adj is changed to "none" and acis_process_events produces a warning message. Hereafter these columns are referred to as $\text{FLTGRADE}_{\text{subpix}}$, $\text{NPOINTS}_{\text{subpix}}$, $\text{ENERGY}_{\text{subpix}}$, $\text{CHIPX\_OFFSET}_{\text{subpix}}$, and $\text{CHIPY\_OFFSET}_{\text{subpix}}$, respectively.

1.5.2   Initializations

1. Aim-point CCD:
   The CCD_ID of the detector at the aim-point is determined. Hereafter this value is referred to as CCD_ID$_{\text{aimpt}}$.

2. Zeroth-order coordinates:
   If

$$\text{DATAMODE}_{\text{in}} \quad = \quad \text{CC33\_FAINT or} \tag{84}$$
$$\text{DATAMODE}_{\text{in}} \quad = \quad \text{CC33\_GRADED,} \tag{85}$$

   and if

$$\text{CONTENT}_{\text{in}} \quad = \quad \text{TGEVT1,} \tag{86}$$

   then the CHIPY_ZO$_{\text{in}}$ coordinates are processed to obtain the minimum, median, and maximum values:

$$\text{CHIPY\_ZO}_{\text{min}} \quad = \quad \text{minimum}\left(\text{CHIPY\_ZO}_{\text{in}}\right), \tag{87}$$
$$\text{CHIPY\_ZO}_{\text{med}} \quad = \quad \text{median}\left(\text{CHIPY\_ZO}_{\text{in}}\right), \text{ and} \tag{88}$$
$$\text{CHIPY\_ZO}_{\text{max}} \quad = \quad \text{maximum}\left(\text{CHIPY\_ZO}_{\text{in}}\right). \tag{89}$$

3. acaofffile:
   If

$$\text{DATAMODE} \quad = \quad \text{CC33\_FAINT or} \tag{90}$$
$$\text{DATAMODE} \quad = \quad \text{CC33\_GRADED,} \tag{91}$$

   then

   (a) RA$_c$ and DEC$_c$:
   The acaofffile data are processed to determine the right ascension and declination coordinates near the center of the dither pattern:

$$\text{RA}_c \quad = \quad \text{median}\left(\text{RA}_{\text{acaoff}}\right) \text{ and} \tag{92}$$
$$\text{DEC}_c \quad = \quad \text{median}\left(\text{DEC}_{\text{acaoff}}\right). \tag{93}$$

   (b) TIME$_c$:
   The acaofffile data are processed to determine the time TIME$_c$ at which the quantity

$$\cos\left(\text{DEC}_{\text{acaoff}}\right)\cos\left(\text{DEC}_c\right)\cos\left(\text{RA}_{\text{acaoff}} - \text{RA}_c\right) + \sin\left(\text{DEC}_{\text{acaoff}}\right)\sin\left(\text{DEC}_c\right) \tag{94}$$

   is maximized (i.e. the time at which the telescope is pointed the closest to (RA$_c$, DEC$_c$).

   (c) RA_ADJ$_I$, DEC_ADJ$_I$, RA_ADJ$_S$, DEC_ADJ$_S$:
   The effective values of RA and DEC are computed for the ACIS-I and ACIS-S arrays. These coordinates are used to determine the values of TIME and CHIPY_ADJ.

   i. ACIS-I aimpoint:
   For the ACIS-I array, the values of RA_ADJ$_I$ and DEC_ADJ$_I$ are initialized assuming that the source is at the ACIS-I aimpoint [i.e. that (TIME, CCD_ID, CHIPX, CHIPY) = (TIME$_c$, 3, 932, 1009)].

   ii. ACIS-S aimpoint:
   For the ACIS-S array, the values of RA_ADJ$_S$ and DEC_ADJ$_S$ are initialized assuming that the source is at the ACIS-S aimpoint [i.e. that (TIME, CCD_ID, CHIPX, CHIPY) = (TIME$_c$, 7, 205, 480)].

iii. Target location:

For the CCD at the aimpoint (i.e. $\text{CCD\_ID}_{\text{aimpt}}$), the values of CHIPY are computed at each $\text{TIME}_{\text{acaoff}}$, assuming that the source is at the location specified by $\text{RA\_TARG}_{\text{in}}$ and $\text{DEC\_TARG}_{\text{in}}$. These values of CHIPY are referred to as CHIPY_TARG. If

$$\min(\text{CHIPY\_TARG}) \geq 0.5 \text{ and} \tag{95}$$
$$\max(\text{CHIPY\_TARG}) < 1024.5, \tag{96}$$

then

A. ACIS-I:
   If

$$\text{CCD\_ID}_{\text{aimpt}} \geq 0 \text{ and} \tag{97}$$
$$\text{CCD\_ID}_{\text{aimpt}} \leq 3, \tag{98}$$

then

$$\text{RA\_ADJ}_{\text{I}} = \text{RA\_TARG}_{\text{in}} \text{ and} \tag{99}$$
$$\text{DEC\_ADJ}_{\text{I}} = \text{DEC\_TARG}_{\text{in}}. \tag{100}$$

B. ACIS-S:
   If

$$\text{CCD\_ID}_{\text{aimpt}} \geq 4 \text{ and} \tag{101}$$
$$\text{CCD\_ID}_{\text{aimpt}} \leq 9, \tag{102}$$

then

$$\text{RA\_ADJ}_{\text{S}} = \text{RA\_TARG}_{\text{in}} \text{ and} \tag{103}$$
$$\text{DEC\_ADJ}_{\text{S}} = \text{DEC\_TARG}_{\text{in}}. \tag{104}$$

1.5.3 Loop over events

The following steps are performed, in sequence, for each event.

1. STATUS:

   (a) Exists:
       If HDU h_{in} of the infile includes a 32-bit column named STATUS, then

       i. The values of the bits for an event are read from the infile.
       ii. The value of STATUS[k] is set to zero for bits $k = 1$–5, 14, 16–19, and 23 (of 0–31), bits that can be set by acis_process_events.
       iii. If

$$\text{doevtgrade} = \text{yes}, \tag{105}$$

       then the value of STATUS[20], the other bit that can be set by acis_process_events, is set to zero.

   (b) Does not exist:
       If HDU h_{in} does not include a 32-bit column named STATUS, then

       i. A set of 32 bits are allocated for the event.
       ii. The values of the 32 bits are initialized to zero.

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2. EXPNO:

    (a) Read:
        The value of EXPNO for an event is given by EXPNO_in.

    (b) Validation:
        If

        $$\text{EXPNO} \quad < \quad 0 \text{ or} \tag{106}$$
        $$\text{EXPNO} \quad \geq \quad 10^8, \tag{107}$$

        then `acis_process_events` produces a warning upon completion with a count of the total number of events for which one or the other of these conditions is true. These values should not occur.

3. CCD_ID:

    (a) Read:
        The value of CCD_ID for an event is given by CCD_ID_in.

    (b) Validation:
        If

        $$\text{CCD\_ID} \quad < \quad 0 \text{ or} \tag{108}$$
        $$\text{CCD\_ID} \quad > \quad 9, \tag{109}$$

        then `acis_process_events` exits with an error message because CCD_ID-dependent computations could fail if the value of CCD_ID is unphysical.

4. CHIPX:

    (a) Read:
        i. Level 0:
           If

           $$\text{CONTENT}_\text{in} \quad = \quad \text{EVT0}, \tag{110}$$

        then the value of CHIPX for an event is given by

        $$\text{CHIPX} \quad = \quad \text{CCDX}_\text{in} + 1. \tag{111}$$

        ii. Level 1, 1.5, or 2:
            If

            $$\text{CONTENT}_\text{in} \quad = \quad \text{EVT1, or} \tag{112}$$
            $$\text{CONTENT}_\text{in} \quad = \quad \text{TGEVT1, or} \tag{113}$$
            $$\text{CONTENT}_\text{in} \quad = \quad \text{EVT2}, \tag{114}$$

        then the value of CHIPX for an event is given by CHIPX_in.

    (b) Validation:
        i. Unphysical:
           If

           $$\text{CHIPX} \quad < \quad 1 \text{ or} \tag{115}$$
           $$\text{CHIPX} \quad > \quad 1024, \tag{116}$$

        then `acis_process_events` exits with an error message because CHIPX-dependent computations could fail if the value of CHIPX is unphysical.

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ii. Unexpected:
   If

$$\text{CHIPX} = 1 \text{ or} \tag{117}$$
$$\text{CHIPX} = 1024, \tag{118}$$

then `acis_process_events` produces a warning upon completion with a count of the total number of events for which one or the other of these conditions is true. Although these values are not unphysical, they should not occur.

5. `NODE_ID`:

   (a) Calculate:
   The `NODE_ID` of an event is given by

$$\text{NODE\_ID} = \text{int}\left(\frac{\text{CHIPX} - 1}{256}\right), \tag{119}$$

where "int" means the integer portion of (i.e. truncate or round down) the quantity in parentheses.

6. `CHIPY`:

   (a) Read:
      i. Level 0:
         If

$$\text{CONTENT}_{\text{in}} = \text{EVT0}, \tag{120}$$

      then
      A. TE mode:
         If

$$\text{DATAMODE}_{\text{in}} = \text{FAINT or} \tag{121}$$
$$\text{DATAMODE}_{\text{in}} = \text{FAINT\_BIAS or} \tag{122}$$
$$\text{DATAMODE}_{\text{in}} = \text{GRADED or} \tag{123}$$
$$\text{DATAMODE}_{\text{in}} = \text{VFAINT}, \tag{124}$$

      then the value of `CHIPY` for an event is given by

$$\text{CHIPY} = \text{CCDY}_{\text{in}} + 1. \tag{125}$$

      B. CC mode:
         If

$$\text{DATAMODE}_{\text{in}} = \text{CC33\_FAINT or} \tag{126}$$
$$\text{DATAMODE}_{\text{in}} = \text{CC33\_GRADED}, \tag{127}$$

      then the value of `CHIPY` for an event is given by

$$\text{CHIPY} = \text{TROW}_{\text{in}} + 1. \tag{128}$$

      ii. Level 1, 1.5, or 2:
         If

$$\text{CONTENT}_{\text{in}} = \text{EVT1 or} \tag{129}$$
$$\text{CONTENT}_{\text{in}} = \text{TGEVT1 or} \tag{130}$$
$$\text{CONTENT}_{\text{in}} = \text{EVT2}, \tag{131}$$

then the value of `CHIPY` for an event is given by CHIPY_{in}.

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(b) Validation:

    i. Unphysical:

      A. TE mode:

        If

$$\begin{aligned}
\texttt{DATAMODE}_{\text{in}} &= \text{FAINT or} & (132)\\
\texttt{DATAMODE}_{\text{in}} &= \text{FAINT\_BIAS or} & (133)\\
\texttt{DATAMODE}_{\text{in}} &= \text{GRADED or} & (134)\\
\texttt{DATAMODE}_{\text{in}} &= \text{VFAINT} & (135)
\end{aligned}$$

        and if

$$\begin{aligned}
\texttt{CHIPY} &< \ 1 \text{ or} & (136)\\
\texttt{CHIPY} &> \ 1024, & (137)
\end{aligned}$$

        then `acis_process_events` exits with an error message because `CHIPY`-dependent computations could fail if the value of `CHIPY` is unphysical.

      B. CC mode:

        If

$$\begin{aligned}
\texttt{DATAMODE}_{\text{in}} &= \text{CC33\_FAINT or} & (138)\\
\texttt{DATAMODE}_{\text{in}} &= \text{CC33\_GRADED} & (139)
\end{aligned}$$

        and if

$$\begin{aligned}
\texttt{CHIPY} &< \ 1 \text{ or} & (140)\\
\texttt{CHIPY} &> \ 512, & (141)
\end{aligned}$$

        then `acis_process_events` exits with an error message because the `CHIPY` value is out of range and `CHIPY`-dependent computations could fail if the value of `CHIPY` is unphysical (especially if it is less than 1).

    ii. Unexpected:

      A. FAINT, FAINT_BIAS, or GRADED:

        If

$$\begin{aligned}
\texttt{DATAMODE}_{\text{in}} &= \text{FAINT or} & (142)\\
\texttt{DATAMODE}_{\text{in}} &= \text{FAINT\_BIAS or} & (143)\\
\texttt{DATAMODE}_{\text{in}} &= \text{GRADED} & (144)
\end{aligned}$$

        and if

$$\begin{aligned}
\texttt{CHIPY} &= \ 1 \text{ or} & (145)\\
\texttt{CHIPY} &= \ 1024, & (146)
\end{aligned}$$

        then `acis_process_events` produces a warning upon completion with a count of the total number of events for which one or the other of these conditions is true. Although these values are not unphysical, they should not occur.

      B. VFAINT:

        If

$$\texttt{DATAMODE}_{\text{in}} = \text{VFAINT} \qquad (147)$$

and if

$$\text{CHIPY} = 1 \text{ or} \tag{148}$$
$$\text{CHIPY} = 2 \text{ or} \tag{149}$$
$$\text{CHIPY} = 1023 \text{ or} \tag{150}$$
$$\text{CHIPY} = 1024, \tag{151}$$

then `acis_process_events` produces a warning upon completion with a count of the total number of events for which one or another of these conditions is true. Although these values are not unphysical, they should not occur.

C. CC33_FAINT or CC33_GRADED:
If

$$\text{DATAMODE}_{\text{in}} = \text{CC33\_FAINT or} \tag{152}$$
$$\text{DATAMODE}_{\text{in}} = \text{CC33\_GRADED} \tag{153}$$

and if

$$\text{CHIPY} = 1 \text{ or} \tag{154}$$
$$\text{CHIPY} = 512, \tag{155}$$

then `acis_process_events` produces a warning upon completion with a count of the total number of events for which one or the other of these conditions is true. Although these values are not unphysical, they should not occur.

7. `TG_M`:

   (a) CC mode with gratings:
   If

   $$\text{DATAMODE}_{\text{in}} = \text{CC33\_FAINT or} \tag{156}$$
   $$\text{DATAMODE}_{\text{in}} = \text{CC33\_GRADED} \tag{157}$$

   and if

   $$\text{CONTENT}_{\text{in}} = \text{TGEVT1}, \tag{158}$$

   then

   i. Read:
      The value of `TG_M` for an event is given by TG_M_{in}.
   ii. Validation:

      A. If

      $$\text{TG\_M} < -99, \tag{159}$$

      then

      $$\text{TG\_M} = -99 \tag{160}$$

      and `acis_process_events` produces a warning upon completion with a count of the total number of events for which this condition is true. These values should not occur.

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B. If

$$TG\_M \;>\; 99, \tag{161}$$

then

$$TG\_M \;=\; 99 \tag{162}$$

and `acis_process_events` produces a warning upon completion with a count of the total number of events for which this condition is true. These values should not occur.

8. `CHIPY_TG`:

   (a) CC mode with gratings:
   If

$$\mathrm{DATAMODE_{in}} \;=\; \mathrm{CC33\_FAINT \;\; or} \tag{163}$$
$$\mathrm{DATAMODE_{in}} \;=\; \mathrm{CC33\_GRADED} \tag{164}$$

   and if

$$\mathrm{CONTENT_{in}} \;=\; \mathrm{TGEVT1,} \tag{165}$$

   then
   i. Read:
   The value of `CHIPY_TG` for an event is given by $\mathrm{CHIPY\_TG_{in}}$.
   ii. Validation:

      A. If

$$TG\_M \;>\; -99 \text{ and} \tag{166}$$
$$TG\_M \;<\; 99, \tag{167}$$

      and if

$$\mathrm{CHIPY\_TG} \;\leq\; 0 \text{ or} \tag{168}$$
$$\mathrm{CHIPY\_TG} \;\geq\; 1025, \tag{169}$$

      then `acis_process_events` exits with an error message because `CHIPY_TG`-dependent computations could fail if the value of `CHIPY_TG` is unphysical.
      B. If

$$TG\_M \;>\; -99, \tag{170}$$
$$TG\_M \;<\; 99, \text{ and} \tag{171}$$
$$\mathrm{CHIPY\_TG} \;<\; 1, \tag{172}$$

      then

$$\mathrm{CHIPY\_TG} \;=\; 1. \tag{173}$$

      C. If

$$TG\_M \;>\; -99, \tag{174}$$
$$TG\_M \;<\; 99, \text{ and} \tag{175}$$
$$\mathrm{CHIPY\_TG} \;>\; 1024, \tag{176}$$

      then

$$\mathrm{CHIPY\_TG} \;=\; 1024. \tag{177}$$

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9. `CHIPY_ZO`:

  (a) CC mode with gratings:
    If

$$\text{DATAMODE}_{in} = \text{CC33\_FAINT or} \tag{178}$$
$$\text{DATAMODE}_{in} = \text{CC33\_GRADED} \tag{179}$$

    and if

$$\text{CONTENT}_{in} = \text{TGEVT1}, \tag{180}$$

    then
      i. Read:
        The value of `CHIPY_ZO` for an event is given by CHIPY_ZO_{in}.

10. `TIME_RO`:

  (a) CC mode:
    If

$$\text{DATAMODE}_{in} = \text{CC33\_FAINT or} \tag{181}$$
$$\text{DATAMODE}_{in} = \text{CC33\_GRADED}, \tag{182}$$

    then
      i. Read:
        A. Level 0:
          If

$$\text{CONTENT}_{in} = \text{EVT0}, \tag{183}$$

          then the value of `TIME_RO` for an event is given by TIME_{in}.
        B. Level 1, 1.5, or 2:
          If

$$\text{CONTENT}_{in} = \text{EVT1, or} \tag{184}$$
$$\text{CONTENT}_{in} = \text{TGEVT1, or} \tag{185}$$
$$\text{CONTENT}_{in} = \text{EVT2}, \tag{186}$$

          then the value of `TIME_RO` for an event is given by TIME_RO_{in}.
      ii. Validation:
        If

$$\text{TIME\_RO} < 0 \text{ or} \tag{187}$$
$$\text{TIME\_RO} \geq 3 \times 10^{9}, \tag{188}$$

      then `acis_process_events` produces a warning upon completion with a count of the total number of events for which one or the other of these conditions is true. These values should not occur.

11. `TIME` and `CHIPY_ADJ`:

  (a) Read or calculate:

i. TE mode:
   If

$$\text{DATAMODE}_{\text{in}} = \text{FAINT or} \tag{189}$$
$$\text{DATAMODE}_{\text{in}} = \text{FAINT\_BIAS or} \tag{190}$$
$$\text{DATAMODE}_{\text{in}} = \text{GRADED or} \tag{191}$$
$$\text{DATAMODE}_{\text{in}} = \text{VFAINT,} \tag{192}$$

   then

$$\text{TIME} = \text{TIME}_{\text{in}} \text{ and} \tag{193}$$
$$\text{CHIPY\_ADJ} = \text{CHIPY.} \tag{194}$$

ii. CC mode without grating data:
    If

$$\text{DATAMODE}_{\text{in}} = \text{CC33\_FAINT or} \tag{195}$$
$$\text{DATAMODE}_{\text{in}} = \text{CC33\_GRADED} \tag{196}$$

   and if

$$\text{CONTENT}_{\text{in}} = \text{EVT0 or} \tag{197}$$
$$\text{CONTENT}_{\text{in}} = \text{EVT1 or} \tag{198}$$
$$\text{CONTENT}_{\text{in}} = \text{EVT2,} \tag{199}$$

   then
   A. TIME$'$:
      The approximate time of arrival

$$\text{TIME}' = \text{TIME\_RO} - (512 + 1028) \times \text{TIMEDEL}_{\text{in}}. \tag{200}$$

   B. CHIPY_ADJ$'$:
      If

$$\text{CCD\_ID}_{\text{aimpt}} \geq 0 \text{ and} \tag{201}$$
$$\text{CCD\_ID}_{\text{aimpt}} \leq 3, \tag{202}$$

   then CHIPY_ADJ$'$ (the approximate value of CHIPY_ADJ) is given by the CHIPY location (on
   the aimpoint CCD) of the coordinates RA_ADJ$_\text{I}$ and DEC_ADJ$_\text{I}$ at the time TIME$'$. If

$$\text{CCD\_ID}_{\text{aimpt}} \geq 4 \text{ and} \tag{203}$$
$$\text{CCD\_ID}_{\text{aimpt}} \leq 9, \tag{204}$$

   then CHIPY_ADJ$'$ is given by the CHIPY location (on the aimpoint CCD) of the coordinates
   RA_ADJ$_\text{S}$ and DEC_ADJ$_\text{S}$ at the time TIME$'$.
   C. TIME:
      The value of CHIPY_ADJ$'$ is used to obtain a better estimate of the time of arrival

$$\text{TIME} = \text{TIME\_RO} - (\text{CHIPY\_ADJ}' + 1028) \times \text{TIMEDEL}_{\text{in}}. \tag{205}$$

   D. CHIPY_ADJ:
      If

$$\text{CCD\_ID}_{\text{aimpt}} \geq 0 \text{ and} \tag{206}$$
$$\text{CCD\_ID}_{\text{aimpt}} \leq 3, \tag{207}$$

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then the value of CHIPY_ADJ is given by the CHIPY location (on the aimpoint CCD) of the coordinates RA_ADJ$_\mathrm{I}$ and DEC_ADJ$_\mathrm{I}$ at the time TIME. If

$$CCD\_ID_{\mathrm{aimpt}} \geq 4 \text{ and} \qquad (208)$$
$$CCD\_ID_{\mathrm{aimpt}} \leq 9, \qquad (209)$$

then the value of CHIPY_ADJ is given by the CHIPY location (on the aimpoint CCD) of the coordinates RA_ADJ$_\mathrm{S}$ and DEC_ADJ$_\mathrm{S}$ at the time TIME.

iii. CC mode with ACIS-S grating data:
If

$$DATAMODE_{\mathrm{in}} = CC33\_FAINT \text{ or} \qquad (210)$$
$$DATAMODE_{\mathrm{in}} = CC33\_GRADED, \qquad (211)$$

if

$$CONTENT_{\mathrm{in}} = TGEVT1, \qquad (212)$$

and if

$$CCD\_ID_{\mathrm{aimpt}} \geq 4 \text{ and} \qquad (213)$$
$$CCD\_ID_{\mathrm{aimpt}} \leq 9, \qquad (214)$$

then

A. Source events:
If

$$TG\_M > -99 \text{ and} \qquad (215)$$
$$TG\_M < 99, \qquad (216)$$

then

$$CHIPY\_ADJ = CHIPY\_TG \text{ and} \qquad (217)$$
$$TIME = TIME\_RO - (CHIPY\_ADJ + 1028) \times TIMEDEL_{\mathrm{in}}. \qquad (218)$$

B. Background events with zeroth order on the array:
If

$$TG\_M = -99 \text{ or} \qquad (219)$$
$$TG\_M = 99 \qquad (220)$$

and if

$$CHIPY\_Z0_{\mathrm{min}} \geq 0.5 \text{ and} \qquad (221)$$
$$CHIPY\_Z0_{\mathrm{max}} < 1024.5, \qquad (222)$$

then

$$CHIPY\_ADJ = CHIPY\_Z0 \text{ and} \qquad (223)$$
$$TIME = TIME\_RO - (CHIPY\_ADJ + 1028) \times TIMEDEL_{\mathrm{in}}. \qquad (224)$$

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C. Background events with zeroth order off the array:
If

$$\texttt{TG\_M} \quad = \quad -99 \text{ or} \tag{225}$$
$$\texttt{TG\_M} \quad = \quad 99 \tag{226}$$

and if

$$\texttt{CHIPY\_ZO}_{\max} \quad < \quad 0.5 \text{ or} \tag{227}$$
$$\texttt{CHIPY\_ZO}_{\min} \quad \geq \quad 1024.5, \tag{228}$$

then

$$\texttt{CHIPY\_ADJ} \quad = \quad 512 + (\texttt{CHIPY\_ZO} - \texttt{CHIPY\_ZO}_{\mathrm{med}}) \text{ and} \tag{229}$$
$$\texttt{TIME} \quad = \quad \texttt{TIME\_RO} - (\texttt{CHIPY\_ADJ} + 1028) \times \texttt{TIMEDEL}_{\mathrm{in}}. \tag{230}$$

iv. CC mode with ACIS-I grating data:
If

$$\texttt{DATAMODE}_{\mathrm{in}} \quad = \quad \text{CC33\_FAINT or} \tag{231}$$
$$\texttt{DATAMODE}_{\mathrm{in}} \quad = \quad \text{CC33\_GRADED,} \tag{232}$$

if

$$\texttt{CONTENT}_{\mathrm{in}} \quad = \quad \text{TGEVT1,} \tag{233}$$

and if

$$\texttt{CCD\_ID}_{\mathrm{aimpt}} \quad \geq \quad 0 \text{ and} \tag{234}$$
$$\texttt{CCD\_ID}_{\mathrm{aimpt}} \quad \leq \quad 3, \tag{235}$$

then

A. $\texttt{TIME}'$:
   The approximate time of arrival

$$\texttt{TIME}' \quad = \quad \texttt{TIME\_RO} - (512 + 1028) \times \texttt{TIMEDEL}_{\mathrm{in}}. \tag{236}$$

B. $\texttt{CHIPY\_ADJ}'$:
   $\texttt{CHIPY\_ADJ}'$ (the approximate value of $\texttt{CHIPY\_ADJ}$) is given by the $\texttt{CHIPY}$ location (on the aimpoint CCD) of the coordinates $\texttt{RA\_ADJ}_{\mathrm{I}}$ and $\texttt{DEC\_ADJ}_{\mathrm{I}}$ at the time $\texttt{TIME}'$.

C. $\texttt{TIME}$:
   The value of $\texttt{CHIPY\_ADJ}'$ is used to obtain a better estimate of the time of arrival

$$\texttt{TIME} \quad = \quad \texttt{TIME\_RO} - (\texttt{CHIPY\_ADJ}' + 1028) \times \texttt{TIMEDEL}_{\mathrm{in}}. \tag{237}$$

D. $\texttt{CHIPY\_ADJ}$:
   The value of $\texttt{CHIPY\_ADJ}$ is given by the $\texttt{CHIPY}$ location (on the aimpoint CCD) of the coordinates $\texttt{RA\_ADJ}_{\mathrm{I}}$ and $\texttt{DEC\_ADJ}_{\mathrm{I}}$ at the time $\texttt{TIME}$.

(b) Validation:
   i. If

$$\texttt{TIME} \quad < \quad 0 \text{ or} \tag{238}$$
$$\texttt{TIME} \quad \geq \quad 3 \times 10^9, \tag{239}$$

then `acis_process_events` produces a warning upon completion with a count of the total number of events for which one or the other of these conditions is true. These values should not occur.

ii. If

$$\text{CHIPY\_ADJ} \quad < \quad 0.5 \text{ or} \tag{240}$$
$$\text{CHIPY\_ADJ} \quad \geq \quad 1024.5, \tag{241}$$

then `acis_process_events` exits with an error message because `CHIPY_ADJ`-dependent computations could fail if the value of `CHIPY_ADJ` is unphysical.

12. Bad-pixel:

(a) If

$$\text{badpixfile} \quad \neq \quad \text{none and} \tag{242}$$
$$\text{badpixfile} \quad \neq \quad \text{NONE} \tag{243}$$

and if the `badpixfile` includes a valid HDU h_{badpix} where $\text{CCD\_ID}_{\text{badpix}} = \text{CCD\_ID}$, then the HDU h_{badpix} is searched as follows to determine if the event should have one or more `STATUS` bits set to one.

i. If $\text{DATAMODE}_{\text{in}} = \text{CC33\_FAINT}$ or $\text{DATAMODE}_{\text{in}} = \text{CC33\_GRADED}$ and if there are one or more rows r in HDU h_{badpix} where

$$\text{CHIPX} \quad \geq \quad \text{CHIPX}_{\text{badpix},r}[0], \tag{244}$$
$$\text{CHIPX} \quad \leq \quad \text{CHIPX}_{\text{badpix},r}[1], \tag{245}$$
$$\text{TIME} \quad \geq \quad \text{TIME}_{\text{badpix},r}, \tag{246}$$
$$\text{TIME} \quad < \quad \text{TIME\_STOP}_{\text{badpix},r} \tag{247}$$

and where

$$\text{STATUS}_{\text{badpix},r}[5] \quad = \quad 1 \text{ or} \tag{248}$$
$$\text{STATUS}_{\text{badpix},r}[6] \quad = \quad 1 \text{ or} \tag{249}$$
$$\text{STATUS}_{\text{badpix},r}[9] \quad = \quad 1, \tag{250}$$

then

$$\text{STATUS}[0] = 1 \tag{251}$$

for the event. Here $\text{CCD\_ID}_{\text{badpix}}$ is the value of the keyword `CCD_ID` in HDU h_{badpix} of the `badpixfile`, $\text{CHIPX}_{\text{badpix},r}[0]$ and $\text{CHIPX}_{\text{badpix},r}[1]$ are the first and second values in the vector column named `CHIPX` of row r of HDU h_{badpix} of the `badpixfile`, and $\text{TIME}_{\text{badpix},r}$ and $\text{TIME\_STOP}_{\text{badpix},r}$ are the values in the columns named `TIME` and `TIME_STOP`, respectively, of row r of HDU h_{badpix} of the `badpixfile`.

ii. If $\text{DATAMODE}_{\text{in}} = \text{CC33\_FAINT}$ or $\text{DATAMODE}_{\text{in}} = \text{CC33\_GRADED}$ and if there are one or more rows r in HDU h_{badpix} where

$$\text{CHIPX} \quad \geq \quad \text{CHIPX}_{\text{badpix},r}[0], \tag{252}$$
$$\text{CHIPX} \quad \leq \quad \text{CHIPX}_{\text{badpix},r}[1], \tag{253}$$
$$\text{TIME} \quad \geq \quad \text{TIME}_{\text{badpix},r}, \tag{254}$$
$$\text{TIME} \quad < \quad \text{TIME\_STOP}_{\text{badpix},r} \tag{255}$$

and where

$$\text{STATUS}_{\text{badpix},r}[0] \quad = \quad 1 \text{ or} \tag{256}$$
$$\text{STATUS}_{\text{badpix},r}[1] \quad = \quad 1 \text{ or} \tag{257}$$

$$\text{STATUS}_{\text{badpix},r}[7] \quad = \quad 1 \text{ or} \tag{258}$$
$$\text{STATUS}_{\text{badpix},r}[11] \quad = \quad 1 \text{ or} \tag{259}$$
$$\text{STATUS}_{\text{badpix},r}[12] \quad = \quad 1 \text{ or} \tag{260}$$
$$\text{STATUS}_{\text{badpix},r}[13] \quad = \quad 1 \text{ or} \tag{261}$$
$$\text{STATUS}_{\text{badpix},r}[14] \quad = \quad 1 \text{ or} \tag{262}$$
$$\text{STATUS}_{\text{badpix},r}[16] \quad = \quad 1, \tag{263}$$

then
$$\text{STATUS}[4] = 1 \tag{264}$$

for the event.

iii. If $\text{DATAMODE}_{\text{in}} = \text{CC33\_FAINT}$ or $\text{DATAMODE}_{\text{in}} = \text{CC33\_GRADED}$ and if there are one or more rows r in HDU h_{badpix} where

$$\text{CHIPX} \quad \geq \quad \text{CHIPX}_{\text{badpix},r}[0], \tag{265}$$
$$\text{CHIPX} \quad \leq \quad \text{CHIPX}_{\text{badpix},r}[1], \tag{266}$$
$$\text{TIME} \quad \geq \quad \text{TIME}_{\text{badpix},r}, \tag{267}$$
$$\text{TIME} \quad < \quad \text{TIME\_STOP}_{\text{badpix},r} \tag{268}$$

and where

$$\text{STATUS}_{\text{badpix},r}[8] \quad = \quad 1 \text{ or} \tag{269}$$
$$\text{STATUS}_{\text{badpix},r}[10] \quad = \quad 1, \tag{270}$$

then
$$\text{STATUS}[5] = 1 \tag{271}$$

for the event.

iv. If $\text{DATAMODE}_{\text{in}} = \text{CC33\_FAINT}$ or $\text{DATAMODE}_{\text{in}} = \text{CC33\_GRADED}$ and if there are one or more rows r in HDU h_{badpix} where

$$\text{CHIPX} \quad \geq \quad \text{CHIPX}_{\text{badpix},r}[0], \tag{272}$$
$$\text{CHIPX} \quad \leq \quad \text{CHIPX}_{\text{badpix},r}[1], \tag{273}$$
$$\text{TIME} \quad \geq \quad \text{TIME}_{\text{badpix},r}, \tag{274}$$
$$\text{TIME} \quad < \quad \text{TIME\_STOP}_{\text{badpix},r} \tag{275}$$

and where

$$\text{STATUS}_{\text{badpix},r}[3] \quad = \quad 1, \tag{276}$$

then
$$\text{STATUS}[6] = 1 \tag{277}$$

for the event.

v. If $\text{DATAMODE}_{\text{in}} = \text{CC33\_FAINT}$ or $\text{DATAMODE}_{\text{in}} = \text{CC33\_GRADED}$ and if there are one or more rows r in HDU h_{badpix} where

$$\text{CHIPX} \quad \geq \quad \text{CHIPX}_{\text{badpix},r}[0], \tag{278}$$
$$\text{CHIPX} \quad \leq \quad \text{CHIPX}_{\text{badpix},r}[1], \tag{279}$$
$$\text{TIME} \quad \geq \quad \text{TIME}_{\text{badpix},r}, \tag{280}$$
$$\text{TIME} \quad < \quad \text{TIME\_STOP}_{\text{badpix},r} \tag{281}$$

and where

$$\text{STATUS}_{\text{badpix},r}[2] \quad = \quad 1 \text{ or} \tag{282}$$
$$\text{STATUS}_{\text{badpix},r}[4] \quad = \quad 1, \tag{283}$$

then

$$\text{STATUS}[8] = 1 \tag{284}$$

for the event.

vi. If $\text{DATAMODE}_{\text{in}} = \text{CC33\_FAINT}$ or $\text{DATAMODE}_{\text{in}} = \text{CC33\_GRADED}$ and if there are one or more rows r in HDU h_{badpix} where

$$\text{CHIPX} \quad \geq \quad \text{CHIPX}_{\text{badpix},r}[0], \tag{285}$$
$$\text{CHIPX} \quad \leq \quad \text{CHIPX}_{\text{badpix},r}[1], \tag{286}$$
$$\text{TIME} \quad \geq \quad \text{TIME}_{\text{badpix},r}, \tag{287}$$
$$\text{TIME} \quad < \quad \text{TIME\_STOP}_{\text{badpix},r} \tag{288}$$

and where

$$\text{STATUS}_{\text{badpix},r}[15] \quad = \quad 1, \tag{289}$$

then

$$\text{STATUS}[16] = 1 \tag{290}$$

for the event.

vii. In summary, the mapping between a bad-pixel STATUS bit and the corresponding event STATUS bit is listed in Table 1.

Table 1: Bad-pixel to event STATUS bit mapping

Bad-pixel STATUS bit	Event STATUS bit
0	4
1	4
2	8
3	6
4	8
5	0
6	0
7	4
8	5
9	0
10	5
11	4
12	4
13	4
14	4
15	16
16	4

13. PHAS:

(a) If HDU 1 of the infile includes the column PHAS, then

i. the values of PHAS for an event are read from the `infile`.
  ii. If $\mathtt{PHAS}[4] <$ the split threshold, then $\mathtt{STATUS}[k] = 1$ for bit $k = 1$.
  iii. If $\mathtt{PHAS}[4] \leq \mathtt{PHAS}[j]$, for one or more $j = 0$–3 or 5–8, then $\mathtt{STATUS}[k] = 1$ for bit $k = 1$.
  iv. If $\mathtt{PHAS}[j] > 4095$, for one or more $j = 0$–8, then $\mathtt{STATUS}[k] = 1$ for bit $k = 2$.

14. PHAS_ADJ:

   (a) If HDU 1 of the `infile` includes $\mathtt{DATAMODE_{in}} = \mathrm{CC33\_FAINT}$, if the parameter $\mathtt{apply\_cti} = \mathrm{yes}$, and if the `ctifile` and `mtlfile` are specified, then the CTI-adjusted pulse heights are computed as follows.

   i. The real-valued arrays for the serial CTI adjustment Δ_x, the parallel CTI adjustment Δ_y, and the adjusted pulse heights PHAS_ADJ are initialized such that

$$\Delta_x[j] \quad = \quad 0, \tag{291}$$
$$\Delta_y[j] \quad = \quad 0, \text{ and} \tag{292}$$
$$\mathtt{PHAS\_ADJ}[j] \quad = \quad \mathtt{PHAS}[j] \tag{293}$$

   for every element $j = 0$–8, where the starting point for the adjusted pulse heights are the unadjusted pulse heights PHAS. Note that the values of the unadjusted pulse heights PHAS remain unchanged to ensure that it is possible to remove the CTI adjustment or to reapply the adjustment if the algorithm or calibration data are modified.

   ii. The CTI iteration counter n is initialized such that

$$n = 1. \tag{294}$$

   iii. The temporary variables Δ'_x, Δ'_y, and PHAS_ADJ$'$ are set such that

$$\Delta'_x[j] \quad = \quad \Delta_x[j], \tag{295}$$
$$\Delta'_y[j] \quad = \quad \Delta_y[j], \text{ and} \tag{296}$$
$$\mathtt{PHAS\_ADJ}'[j] \quad = \quad \mathtt{PHAS\_ADJ}[j] \tag{297}$$

   for each element j.

   iv. A. If there is a serial CTI trap-density map in the `ctifile` for CCD_ID and if NODE_ID $= 0$ or 2, then the values of Δ_x are given by

$$\Delta_x[0] \quad = \quad c_x[0]s_x\rho_x[0]V_x[0], \tag{298}$$
$$\Delta_x[1] \quad = \quad c_x[1]s_x\rho_x[1]V_x[1] - c'_x[0]s_x\rho_x[0]V_x[0], \tag{299}$$
$$\Delta_x[2] \quad = \quad c_x[2]s_x\rho_x[2]V_x[2] - c'_x[1]s_x\rho_x[1]V_x[1], \tag{300}$$
$$\Delta_x[3] \quad = \quad c_x[3]s_x\rho_x[3]V_x[3], \tag{301}$$
$$\Delta_x[4] \quad = \quad c_x[4]s_x\rho_x[4]V_x[4] - c'_x[3]s_x\rho_x[3]V_x[3], \tag{302}$$
$$\Delta_x[5] \quad = \quad c_x[5]s_x\rho_x[5]V_x[5] - c'_x[4]s_x\rho_x[4]V_x[4], \tag{303}$$
$$\Delta_x[6] \quad = \quad c_x[6]s_x\rho_x[6]V_x[6], \tag{304}$$
$$\Delta_x[7] \quad = \quad c_x[7]s_x\rho_x[7]V_x[7] - c'_x[6]s_x\rho_x[6]V_x[6], \text{ and} \tag{305}$$
$$\Delta_x[8] \quad = \quad c_x[8]s_x\rho_x[8]V_x[8] - c'_x[7]s_x\rho_x[7]V_x[7]. \tag{306}$$

where

$$
c_x[j] = \begin{cases} 0 & \begin{cases} \mathtt{PHAS}[j] + \Delta'_x[j] + \Delta'_y[j] < \text{ split threshold} \\ \quad (\text{for all } j), \end{cases} \\[2pt] \mathtt{FRCTRLX} & \begin{cases} \mathtt{PHAS}[j] + \Delta'_x[j] + \Delta'_y[j] \geq \text{ split threshold and} \\ \mathtt{PHAS}[j] + \Delta'_x[j] + \Delta'_y[j] < \\ \quad \mathtt{PHAS}[j-1] + \Delta'_x[j-1] + \Delta'_y[j-1] \\ \quad (\text{for } j = 1,2,4,5,7,8), \end{cases} \\[2pt] 1 & \begin{cases} \mathtt{PHAS}[j] + \Delta'_x[j] + \Delta'_y[j] \geq \text{ split threshold} \\ \quad (\text{for } j = 0,3,6) \\ \mathtt{PHAS}[j] + \Delta'_x[j] + \Delta'_y[j] \geq \text{ split threshold and} \\ \mathtt{PHAS}[j] + \Delta'_x[j] + \Delta'_y[j] \geq \\ \quad \mathtt{PHAS}[j-1] + \Delta'_x[j-1] + \Delta'_y[j-1] \\ \quad (\text{for } j = 1,2,4,5,7,8), \end{cases} \end{cases}
$$

$$
c'_x[j] = \begin{cases} 0 & \begin{cases} \mathtt{PHAS}[j] + \Delta'_x[j] + \Delta'_y[j] < \text{ split threshold or} \\ \mathtt{PHAS}[j+1] + \Delta'_x[j+1] + \Delta'_y[j+1] < \text{ split threshold or} \\ j \to \mathtt{CHIPX} = 1, 256, 513, \text{ or } 768 \\ \quad (\text{for } j = 0,1,3,4,6,7), \end{cases} \\[2pt] \mathtt{FRCTRLX} & \begin{cases} \mathtt{PHAS}[j] + \Delta'_x[j] + \Delta'_y[j] > \\ \quad \mathtt{PHAS}[j+1] + \Delta'_x[j+1] + \Delta'_y[j+1] \text{ and} \\ \mathtt{PHAS}[j+1] + \Delta'_x[j+1] + \Delta'_y[j+1] \geq \text{ split threshold} \\ \quad (\text{for } j = 0,1,3,4,6,7), \end{cases} \\[2pt] 1 & \begin{cases} \mathtt{PHAS}[j] + \Delta'_x[j] + \Delta'_y[j] \leq \\ \quad \mathtt{PHAS}[j+1] + \Delta'_x[j+1] + \Delta'_y[j+1] \text{ and} \\ \mathtt{PHAS}[j] + \Delta'_x[j] + \Delta'_y[j] \geq \text{ split threshold} \\ \quad (\text{for } j = 0,1,3,4,6,7), \end{cases} \end{cases}
$$

$$
s_x = 1 + \mathtt{TCTIX}\,(T - \mathtt{FP\_TEMP0}), \tag{307}
$$

$$
\begin{cases} s_x \text{ is a temperature dependent scaling factor,} \\ \mathtt{TCTIX} \text{ is the } \mathtt{CCD\_ID} \text{ dependent value in the column } \mathtt{TCTIX} \text{ of the} \\ \quad \mathtt{ctifile}, \\ \mathtt{FP\_TEMP0} \text{ is the name of a keyword in the } \mathtt{ctifile}, \end{cases}
$$

$$
T = \left(\frac{t' - t'_k}{t'_{k+1} - t'_k}\right)(\mathtt{FP\_TEMP}_{k+1} - \mathtt{FP\_TEMP}_k) + \mathtt{FP\_TEMP}_k, \tag{308}
$$

$$
\big\{\; T \text{ is the time dependent focal plane temperature,}
$$

$$
t' = t + \mathtt{TIMEDEL}_{\text{in}}\,(\mathtt{TIMEPIXR}_{\text{evt}} - 0.5), \tag{309}
$$

$$
\begin{cases} t \text{ is the } \mathtt{TIME} \text{ of the event,} \\ \mathtt{TIMEPIXR}_{\text{evt}} \text{ is a keyword in the } \mathtt{infile}, \end{cases}
$$

$$
t'_k = \mathtt{TIME}_k + \mathtt{TIMEDEL}_{\text{mtl}}\,(\mathtt{TIMEPIXR}_{\text{mtl}} - 0.5), \tag{310}
$$

$$
\begin{cases} \mathtt{TIME}_k \text{ is the } k^{\text{th}} \text{ element of the column } \mathtt{TIME} \text{ in the } \mathtt{mtlfile}, \\ t'_k \leq t', \\ \text{If } t' < t'_k \text{ for } k = 0, \text{ then } k = 0, \\ \mathtt{FP\_TEMP}_k \text{ is the } k^{\text{th}} \text{ element of the column } \mathtt{FP\_TEMP} \text{ in the } \mathtt{mtlfile}, \\ \mathtt{TIMEDEL}_{\text{mtl}} \text{ is a keyword in the } \mathtt{mtlfile}, \\ \mathtt{TIMEPIXR}_{\text{mtl}} \text{ is a keyword in the } \mathtt{mtlfile}, \end{cases}
$$

$$
t'_{k+1} = \mathtt{TIME}_{k+1} + \mathtt{TIMEDEL}_{\text{mtl}}\,(\mathtt{TIMEPIXR}_{\text{mtl}} - 0.5), \tag{311}
$$

$$\begin{cases} \texttt{TIME}_{k+1} \text{ is the } (k+1)^{\text{th}} \text{ element of the column } \texttt{TIME} \text{ in the } \texttt{mtlfile}, \\ t'_{k+1} > t', \\ \text{If } t' > t'_k \text{ for } k = n, \text{ where } n \text{ is the last element, then } k = n, \\ \texttt{FP\_TEMP}_{k+1} \text{ is the } (k+1)^{\text{th}} \text{ element of the column } \texttt{FP\_TEMP} \text{ in the} \\ \quad \texttt{mtlfile}, \end{cases}$$

$$\rho_x[j] \quad = \quad \text{serial trap density}, \tag{312}$$

$$\begin{cases} \rho_x[j] \text{ depends upon the } \texttt{CCD\_ID} \text{ and upon the } \texttt{CHIPX} \text{ and } \text{nint}(\texttt{CHIPY\_ADJ}) \\ \quad \text{coordinates associated with element } j \text{ of } \texttt{PHAS\_ADJ}[j] \text{ (see Fig. 1)}, \end{cases}$$

$$V_x[j] \quad = \quad \left(\frac{\texttt{PHAS}[j] + \Delta'_x[j] + \Delta'_y[j] - \texttt{PHA}_l}{\texttt{PHA}_{l+1} - \texttt{PHA}_l} \right) (\texttt{VOLUME\_X}_{l+1} - \texttt{VOLUME\_X}_l) +$$

$$\texttt{VOLUME\_X}_l, \tag{313}$$

$$\begin{cases} \texttt{PHA}_l \text{ is the } l^{\text{th}} \text{ element of the column } \texttt{PHA} \text{ in the } \texttt{ctifile}, \\ \texttt{PHA}_l \text{ (and } \texttt{PHA}_{l+1}) \text{ are } \texttt{CCD\_ID} \text{ depdendent}, \\ \texttt{PHA}_l \leq \texttt{PHAS}[j] + \Delta'_x[j] + \Delta'_y[j], \\ \text{If } \texttt{PHA}_l > \texttt{PHAS}[j] + \Delta'_x[j] + \Delta'_y[j] \text{ for } l = 0, \text{ then } l = 0, \\ \texttt{PHA}_{l+1} \text{ is the } (l+1)^{\text{th}} \text{ element of the column } \texttt{PHA} \text{ in the } \texttt{ctifile}, \\ \texttt{PHA}_{l+1} > \texttt{PHAS}[j] + \Delta'_x[j] + \Delta'_y[j], \\ \text{If } \texttt{PHA}_{l+1} \leq \texttt{PHAS}[j] + \Delta'_x[j] + \Delta'_y[j] \text{ for } l = n, \text{ where } n \text{ is the last} \\ \quad \text{element, then } l = n, \\ \texttt{VOLUME\_X}_l \text{ is the } l^{\text{th}} \text{ element of the column } \texttt{VOLUME\_X} \text{ in the } \texttt{ctifile}, \\ \texttt{VOLUME\_X}_l, \text{ which is } \texttt{CCD\_ID} \text{ depdendent, is associated with } \texttt{PHA}_l, \\ \texttt{VOLUME\_X}_{l+1} \text{ is the } (l+1)^{\text{th}} \text{ element of the column } \texttt{VOLUME\_X} \text{ in the} \\ \quad \texttt{ctifile}, \text{ and} \\ \texttt{VOLUME\_X}_{l+1}, \text{ which is } \texttt{CCD\_ID} \text{ depdendent, is associated with } \texttt{PHA}_{l+1} \end{cases}$$

B. If there is a serial CTI trap-density map in the `ctifile` for `CCD_ID` and if `NODE_ID` $= 1$ or 3, then the values of Δ_x are given by

$$\Delta_x[0] \quad = \quad c_x[0]s_x\rho_x[0]V_x[0] - c'_x[1]s_x\rho_x[1]V_x[1], \tag{314}$$

$$\Delta_x[1] \quad = \quad c_x[1]s_x\rho_x[1]V_x[1] - c'_x[2]s_x\rho_x[2]V_x[2], \tag{315}$$

$$\Delta_x[2] \quad = \quad c_x[2]s_x\rho_x[2]V_x[2], \tag{316}$$

$$\Delta_x[3] \quad = \quad c_x[3]s_x\rho_x[3]V_x[3] - c'_x[4]s_x\rho_x[4]V_x[4], \tag{317}$$

$$\Delta_x[4] \quad = \quad c_x[4]s_x\rho_x[4]V_x[4] - c'_x[5]s_x\rho_x[5]V_x[5], \tag{318}$$

$$\Delta_x[5] \quad = \quad c_x[5]s_x\rho_x[5]V_x[5], \tag{319}$$

$$\Delta_x[6] \quad = \quad c_x[6]s_x\rho_x[6]V_x[6] - c'_x[7]s_x\rho_x[7]V_x[7], \tag{320}$$

$$\Delta_x[7] \quad = \quad c_x[7]s_x\rho_x[7]V_x[7] - c'_x[8]s_x\rho_x[8]V_x[8], \text{ and} \tag{321}$$

$$\Delta_x[8] \quad = \quad c_x[8]s_x\rho_x[8]V_x[8]. \tag{322}$$

where

$$c_x[j] = \begin{cases} 0 & \begin{cases} \texttt{PHAS}[j] + \Delta'_x[j] + \Delta'_y[j] < \text{ split threshold} \\ \quad \text{(for all } j), \\ \texttt{PHAS}[j] + \Delta'_x[j] + \Delta'_y[j] \geq \text{ split threshold and} \\ \texttt{PHAS}[j] + \Delta'_x[j] + \Delta'_y[j] < \\ \quad \texttt{PHAS}[j+1] + \Delta'_x[j+1] + \Delta'_y[j+1] \\ \quad \text{(for } j = 0, 1, 3, 4, 6, 7), \end{cases} \\ \text{FRCTRLX} & \begin{cases} \texttt{PHAS}[j] + \Delta'_x[j] + \Delta'_y[j] \geq \text{ split threshold} \\ \quad \text{(for } j = 2, 5, 8) \end{cases} \\ 1 & \begin{cases} \texttt{PHAS}[j] + \Delta'_x[j] + \Delta'_y[j] \geq \text{ split threshold and} \\ \texttt{PHAS}[j] + \Delta'_x[j] + \Delta'_y[j] \geq \\ \quad \texttt{PHAS}[j+1] + \Delta'_x[j+1] + \Delta'_y[j+1] \\ \quad \text{(for } j = 0, 1, 3, 4, 6, 7), \end{cases} \end{cases}$$

$$c'_x[j] = \begin{cases} 0 & \begin{cases} \texttt{PHAS}[j] + \Delta'_x[j] + \Delta'_y[j] < \text{ split threshold or} \\ \texttt{PHAS}[j-1] + \Delta'_x[j-1] + \Delta'_y[j-1] < \text{ split threshold or} \\ j \to \texttt{CHIPX} = 257, 512, 769, \text{ or } 1024 \\ \quad \text{(for } j = 1, 2, 4, 5, 7, 8), \end{cases} \\ \text{FRCTRLX} & \begin{cases} \texttt{PHAS}[j] + \Delta'_x[j] + \Delta'_y[j] > \\ \quad \texttt{PHAS}[j-1] + \Delta'_x[j-1] + \Delta'_y[j-1] \text{ and} \\ \texttt{PHAS}[j-1] + \Delta'_x[j-1] + \Delta'_y[j-1] \geq \text{ split threshold} \\ \quad \text{(for } j = 1, 2, 4, 5, 7, 8), \end{cases} \\ 1 & \begin{cases} \texttt{PHAS}[j] + \Delta'_x[j] + \Delta'_y[j] \leq \\ \quad \texttt{PHAS}[j-1] + \Delta'_x[j-1] + \Delta'_y[j-1] \text{ and} \\ \texttt{PHAS}[j] + \Delta'_x[j] + \Delta'_y[j] \geq \text{ split threshold} \\ \quad \text{(for } j = 1, 2, 4, 5, 7, 8), \end{cases} \end{cases}$$

and s_x, T, t', t'_k, t'_{k+1}, $\rho_x[j]$, and $V_x[j]$ are given by eqns. 307, 308, 309, 310, 311, 312, and 313, respectively.

v. If there is a parallel CTI trap-density map in the `ctifile` for `CCD_ID`, then the values of Δ_y are given by

$$\Delta_y[0] = c_y[0]s_y\rho_y[0]V_y[0], \tag{323}$$
$$\Delta_y[1] = c_y[1]s_y\rho_y[1]V_y[1], \tag{324}$$
$$\Delta_y[2] = c_y[2]s_y\rho_y[2]V_y[2], \tag{325}$$
$$\Delta_y[3] = c_y[3]s_y\rho_y[3]V_y[3] - c'_y[0]s_y\rho_y[0]V_y[0], \tag{326}$$
$$\Delta_y[4] = c_y[4]s_y\rho_y[4]V_y[4] - c'_y[1]s_y\rho_y[1]V_y[1], \tag{327}$$
$$\Delta_y[5] = c_y[5]s_y\rho_y[5]V_y[5] - c'_y[2]s_y\rho_y[2]V_y[2], \tag{328}$$
$$\Delta_y[6] = c_y[6]s_y\rho_y[6]V_y[6] - c'_y[3]s_y\rho_y[3]V_y[3], \tag{329}$$
$$\Delta_y[7] = c_y[7]s_y\rho_y[7]V_y[7] - c'_y[4]s_y\rho_y[4]V_y[4], \tag{330}$$
$$\Delta_y[8] = c_y[8]s_y\rho_y[8]V_y[8] - c'_y[5]s_y\rho_y[5]V_y[5], \tag{331}$$

where

$$c_y[j] = \begin{cases} 0 & \begin{cases} \text{PHAS}[j] + \Delta'_x[j] + \Delta'_y[j] < \text{ split threshold} \\ \quad \text{(for all } j\text{)}, \end{cases} \\ \text{FRCTRLY} & \begin{cases} \text{PHAS}[j] + \Delta'_x[j] + \Delta'_y[j] \geq \text{ split threshold and} \\ \text{PHAS}[j] + \Delta'_x[j] + \Delta'_y[j] < \\ \quad \text{PHAS}[j-3] + \Delta'_x[j-3] + \Delta'_y[j-3] \\ \quad \text{(for } j = 3,4,5,6,7,8\text{)}, \end{cases} \\ 1 & \begin{cases} \text{PHAS}[j] + \Delta'_x[j] + \Delta'_y[j] \geq \text{ split threshold} \\ \quad \text{(for } j = 0,1,2\text{)} \\ \text{PHAS}[j] + \Delta'_x[j] + \Delta'_y[j] \geq \text{ split threshold and} \\ \text{PHAS}[j] + \Delta'_x[j] + \Delta'_y[j] \geq \\ \quad \text{PHAS}[j-3] + \Delta'_x[j-3] + \Delta'_y[j-3] \\ \quad \text{(for } j = 3,4,5,6,7,8\text{)}, \end{cases} \end{cases}$$

$$c'_x[j] = \begin{cases} 0 & \begin{cases} \text{PHAS}[j] + \Delta'_x[j] + \Delta'_y[j] < \text{ split threshold or} \\ \text{PHAS}[j+3] + \Delta'_x[j+3] + \Delta'_y[j+3] < \text{ split threshold or} \\ j \to \text{CHIPY} = 1 \text{ or } 1024 \\ \quad \text{(for } j = 1,2,3,4,5\text{)}, \end{cases} \\ \text{FRCTRLY} & \begin{cases} \text{PHAS}[j] + \Delta'_x[j] + \Delta'_y[j] > \\ \quad \text{PHAS}[j+3] + \Delta'_x[j+3] + \Delta'_y[j+3] \text{ and} \\ \text{PHAS}[j+3] + \Delta'_x[j+3] + \Delta'_y[j+3] \geq \text{ split threshold} \\ \quad \text{(for } j = 0,1,2,3,4,5\text{)}, \end{cases} \\ 1 & \begin{cases} \text{PHAS}[j] + \Delta'_x[j] + \Delta'_y[j] \leq \\ \quad \text{PHAS}[j+3] + \Delta'_x[j+3] + \Delta'_y[j+3] \text{ and} \\ \text{PHAS}[j] + \Delta'_x[j] + \Delta'_y[j] \geq \text{ split threshold} \\ \quad \text{(for } j = 0,1,2,3,4,5\text{)}, \end{cases} \end{cases}$$

$$s_y = 1 + \text{TCTIY}\left(T - \text{FP\_TEMP0}\right), \tag{332}$$

$$\begin{cases} s_y \text{ is a temperature dependent scaling factor,} \\ \text{TCTIY is the CCD\_ID dependent value in the column TCTIY of the} \\ \quad \text{ctifile,} \\ \text{FP\_TEMP0 is the name of a keyword in the ctifile,} \end{cases}$$

$$\rho_y[j] = \text{parallel trap density,} \tag{333}$$

$$\begin{cases} \rho_y[j] \text{ depends upon the CCD\_ID and upon the CHIPX and nint(CHIPY\_ADJ)} \\ \quad \text{coordinates associated with element } j \text{ of PHAS\_ADJ}[j] \text{ (see Fig. 1)}, \end{cases}$$

$$V_y[j] = \left(\frac{\text{PHAS}[j] + \Delta'_x[j] + \Delta'_y[j] - \text{PHA}_l}{\text{PHA}_{l+1} - \text{PHA}_l}\right)\left(\text{VOLUME\_Y}_{l+1} - \text{VOLUME\_Y}_l\right) +$$
$$\text{VOLUME\_Y}_l, \tag{334}$$

$$\begin{cases} \text{PHA}_l \text{ is the } l^{\text{th}} \text{ element of the column PHA in the ctifile,} \\ \text{PHA}_l \text{ (and PHA}_{l+1}\text{) are CCD\_ID depdendent,} \\ \text{PHA}_l \leq \text{PHAS}[j] + \Delta'_x[j] + \Delta'_y[j], \\ \text{If PHA}_l > \text{PHAS}[j] + \Delta'_x[j] + \Delta'_y[j] \text{ for } l = 0, \text{ then } l = 0, \\ \text{PHA}_{l+1} \text{ is the } (l+1)^{\text{th}} \text{ element of the column PHA in the ctifile,} \\ \text{PHA}_{l+1} > \text{PHAS}[j] + \Delta'_x[j] + \Delta'_y[j], \\ \text{If PHA}_{l+1} \leq \text{PHAS}[j] + \Delta'_x[j] + \Delta'_y[j] \text{ for } l = n, \text{ where } n \text{ is the last} \\ \quad \text{element, then } l = n, \\ \text{VOLUME\_Y}_l \text{ is the } l^{\text{th}} \text{ element of the column VOLUME\_Y in the ctifile,} \\ \text{VOLUME\_Y}_l, \text{ which is CCD\_ID depdendent, is associated with PHA}_l, \\ \text{VOLUME\_Y}_{l+1} \text{ is the } (l+1)^{\text{th}} \text{ element of the column VOLUME\_Y in the} \\ \quad \text{ctifile,} \\ \text{VOLUME\_Y}_{l+1}, \text{ which is CCD\_ID depdendent, is associated with PHA}_{l+1}, \end{cases}$$

and T, t', t'_k, and t'_{k+1}, are given by eqns. 308, 309, 310, and 311, respectively.

vi. The CTI-adjusted pulse heights

$$\texttt{PHAS\_ADJ}[j] = \texttt{PHAS}[j] + \Delta_x[j] + \Delta_y[j] \tag{335}$$

for all j.

vii. A. If

$$
\begin{aligned}
|\texttt{PHAS\_ADJ}'[j] - \texttt{PHAS\_ADJ}[j]| &< \texttt{cticonverge} \ \text{(for all } j\text{) and} & (336) \\
n &\le \texttt{max\_cti\_iter}, & (337)
\end{aligned}
$$

then the computation of $\texttt{PHAS\_ADJ}$ is complete for the event.

B. If

$$
\begin{aligned}
|\texttt{PHAS\_ADJ}'[j] - \texttt{PHAS\_ADJ}[j]| &\ge \texttt{cticonverge} \ \text{(for one or more } j\text{) and} & (338) \\
n &< \texttt{max\_cti\_iter}, & (339)
\end{aligned}
$$

then $n = n + 1$ and steps 1.5.14(a)iii–1.5.14(a)vii are repeated.

C. If

$$
\begin{aligned}
|\texttt{PHAS\_ADJ}'[j] - \texttt{PHAS\_ADJ}[j]| &\ge \texttt{cticonverge} \ \text{(for one or more } j\text{) and} & (340) \\
n &\ge \texttt{max\_cti\_iter}, & (341)
\end{aligned}
$$

then no additional iterations are performed, the values of $\texttt{PHAS\_ADJ}[j]$ from the most recent iteration are used as are, and $\texttt{STATUS}[k] = 1$ for bit $k = 20$ to indicate that the CTI adjustment did not converge.

15. `FLTGRADE`:

   (a) If

$$
\begin{aligned}
\texttt{DATAMODE}_{\text{in}} &= \ \text{CC33\_FAINT and} & (342) \\
\texttt{apply\_cti} &= \ \text{yes}, & (343)
\end{aligned}
$$

then

$$\texttt{FLTGRADE} = c_f[0] + 2c_f[1] + 4c_f[2] + 8c_f[3] + 16c_f[5] + 32c_f[6] + 64c_f[7] + 128c_f[8], \tag{344}$$

where

$$c_f[j] = \begin{cases} 0 & \text{if } \texttt{PHAS\_ADJ}[j] < \text{split threshold} \\ 1 & \text{otherwise}, \end{cases} \tag{345}$$

and the elements $j = 0$–3 and 5–8 of $\texttt{PHAS\_ADJ}$ are depicted in Figure 1.

   (b) If

$$
\begin{aligned}
\texttt{DATAMODE}_{\text{in}} &= \ \text{CC33\_FAINT and} & (346) \\
\texttt{apply\_cti} &= \ \text{no}, & (347)
\end{aligned}
$$

then

$$\texttt{FLTGRADE} = c_f[0] + 2c_f[1] + 4c_f[2] + 8c_f[3] + 16c_f[5] + 32c_f[6] + 64c_f[7] + 128c_f[8], \tag{348}$$

where

$$c_f[j] = \begin{cases} 0 & \text{if } \texttt{PHAS}[j] < \text{split threshold} \\ 0 & \text{if } \texttt{PHAS}[j] > 4095 \\ 0 & \text{if } \texttt{PHAS}[j] > \texttt{PHAS}[4] \text{ for } j = 0-3) \\ 0 & \text{if } \texttt{PHAS}[j] \ge \texttt{PHAS}[4] \text{ for } j = 5-8) \\ 1 & \text{otherwise}. \end{cases} \tag{349}$$
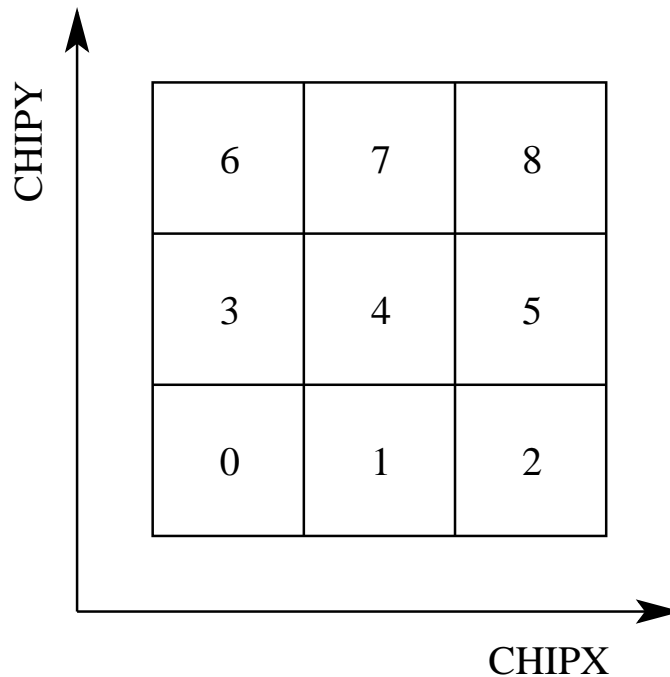
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Figure 1: The relative CHIPX and CHIPY coordinates of the nine elements $j = 0$–8 of a 3 pixel $\times$ 3 pixel event island PHAS[j] or PHAS_ADJ[j].

   (c) If

$$\text{DATAMODE}_{\text{in}} \quad = \quad \text{CC33\_GRADED}, \tag{350}$$

then the FLTGRADE of an event is equal to the value of FLTGRADE for the event in the infile.

16. GRADE:

   (a) If the gradefile is specified, then the GRADE of an event is determined from the FLTGRADE of the event as follows.

      i. The appropriate HDU of the gradefile is identified. This HDU is the one where the header keyword CBD10001 includes the DATAMODE$_{\text{in}}$ of HDU 1 of the infile.

      ii. The row i of the appropriate HDU of the gradefile is identified. This row is the one where

$$\text{FLTGRADE}_{\text{grade},i} = \text{FLTGRADE}, \tag{351}$$

where FLTGRADE$_{\text{grade}}$ is a column in the gradefile.

      iii. The GRADE of the event is given by

$$\text{GRADE} = \text{GRADE}_{\text{grade},i}, \tag{352}$$

where GRADE$_{\text{grade}}$ is a column in the gradefile.

17. PHA_RO:

   (a) If

$$\text{DATAMODE}_{\text{in}} = \text{CC33\_FAINT}, \tag{353}$$

then

$$PHA = \sum_{j=0}^{8} \beta[j]p[j], \tag{354}$$

where

  i.

$$p[j] = \texttt{PHAS}[j]. \tag{355}$$

  ii. The elements $j = 0$–8 of $\texttt{PHAS}$ are depicted in Figure 1.

  iii.

$$\beta[j] = 0 \quad \text{if} \quad p[j] < \text{split threshold}. \tag{356}$$

  iv.

$$\beta[j] = 0 \text{ if } \begin{cases} p[j] > p[4] \ (\text{for } j = 0\text{--}3) \\ p[j] \geq p[4] \ (\text{for } j = 5\text{--}8) \end{cases} \tag{357}$$

  v. If $\texttt{CORNERS} = -1$, then

$$\beta[0 = \beta[2] = \beta[6] = \beta[8] = 0. \tag{358}$$

  vi. If $\texttt{CORNERS} = 1$, then

$$\beta[0] = 0 \quad \text{if} \quad \beta[1] = 0 \text{ and } \beta[3] = 0. \tag{359}$$
$$\beta[2] = 0 \quad \text{if} \quad \beta[1] = 0 \text{ and } \beta[5] = 0. \tag{360}$$
$$\beta[6] = 0 \quad \text{if} \quad \beta[3] = 0 \text{ and } \beta[7] = 0. \tag{361}$$
$$\beta[8] = 0 \quad \text{if} \quad \beta[5] = 0 \text{ and } \beta[7] = 0. \tag{362}$$

  vii. If $\texttt{CORNERS} = 2$, then

$$\beta[0] = 0 \quad \text{if} \quad \beta[1] = 0 \text{ or } \beta[3] = 0 \text{ or } \texttt{GRADE} \neq 6. \tag{363}$$
$$\beta[2] = 0 \quad \text{if} \quad \beta[1] = 0 \text{ or } \beta[5] = 0 \text{ or } \texttt{GRADE} \neq 6. \tag{364}$$
$$\beta[6] = 0 \quad \text{if} \quad \beta[3] = 0 \text{ or } \beta[7] = 0 \text{ or } \texttt{GRADE} \neq 6. \tag{365}$$
$$\beta[8] = 0 \quad \text{if} \quad \beta[5] = 0 \text{ or } \beta[7] = 0 \text{ or } \texttt{GRADE} \neq 6. \tag{366}$$

(b) If

$$\texttt{DATAMODE}_{\text{in}} = \text{CC33\_GRADED}, \tag{367}$$

then

  i. If

$$\texttt{CONTENT}_{\text{in}} = \text{EVT0}, \tag{368}$$

then the value of $\texttt{PHA\_RO}$ for the event is the value of $\texttt{PHA}$ in the `infile`.

  ii. If

$$\texttt{CONTENT}_{\text{in}} = \text{EVT1, TGEVT1, or EVT2}, \tag{369}$$

then the value of $\texttt{PHA\_RO}$ for the event is the value of $\texttt{PHA\_RO}$ in the `infile`.

18. $\texttt{PHA}$ including time-dependent gain:

(a) If

$$\texttt{DATAMODE}_{\text{in}} = \text{CC33\_FAINT}, \tag{370}$$

then

$$PHA = \sum_{j=0}^{8} \beta[j]p[j], \tag{371}$$

where

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i.
$$p[j] = \begin{cases} \texttt{PHAS\_ADJ}[j] & \text{if } \texttt{apply\_cti} = \text{yes} \\ \texttt{PHAS}[j] & \text{if } \texttt{apply\_cti} = \text{no} \end{cases} \tag{372}$$

ii. The elements $j = 0$–8 of $\texttt{PHAS\_ADJ}$ (or $\texttt{PHAS}$) are depicted in Figure 1.

iii.
$$\beta[j] = 0 \quad \text{if} \quad p[j] < \text{split threshold.} \tag{373}$$

iv. If the CTI adjustment is not performed, then
$$\beta[j] = 0 \text{ if } \begin{cases} p[j] > p[4] \text{ (for } j = 0\text{--}3) \\ p[j] \geq p[4] \text{ (for } j = 5\text{--}8) \end{cases} \tag{374}$$

v. If $\texttt{CORNERS} = -1$, then
$$\beta[0] = \beta[2] = \beta[6] = \beta[8] = 0. \tag{375}$$

vi. If $\texttt{CORNERS} = 1$, then
$$\beta[0] = 0 \quad \text{if} \quad \beta[1] = 0 \text{ and } \beta[3] = 0. \tag{376}$$
$$\beta[2] = 0 \quad \text{if} \quad \beta[1] = 0 \text{ and } \beta[5] = 0. \tag{377}$$
$$\beta[6] = 0 \quad \text{if} \quad \beta[3] = 0 \text{ and } \beta[7] = 0. \tag{378}$$
$$\beta[8] = 0 \quad \text{if} \quad \beta[5] = 0 \text{ and } \beta[7] = 0. \tag{379}$$

vii. If $\texttt{CORNERS} = 2$, then
$$\beta[0] = 0 \quad \text{if} \quad \beta[1] = 0 \text{ or } \beta[3] = 0 \text{ or } \texttt{GRADE} \neq 6. \tag{380}$$
$$\beta[2] = 0 \quad \text{if} \quad \beta[1] = 0 \text{ or } \beta[5] = 0 \text{ or } \texttt{GRADE} \neq 6. \tag{381}$$
$$\beta[6] = 0 \quad \text{if} \quad \beta[3] = 0 \text{ or } \beta[7] = 0 \text{ or } \texttt{GRADE} \neq 6. \tag{382}$$
$$\beta[8] = 0 \quad \text{if} \quad \beta[5] = 0 \text{ or } \beta[7] = 0 \text{ or } \texttt{GRADE} \neq 6. \tag{383}$$

(b) If
$$\texttt{DATAMODE}_{\text{in}} = \text{CC33\_GRADED}, \tag{384}$$
then the value of $\texttt{PHA}$ for the event is read from the $\texttt{infile}$.

(c) If
$$\texttt{apply\_tgain} = \text{yes}, \tag{385}$$
then
$$\texttt{PHA} = \texttt{PHA} + \text{int}\left[\left(\frac{\texttt{TIME} - \texttt{EPOCH1}}{\texttt{EPOCH2} - \texttt{EPOCH1}}\right)(\delta_2 - \delta_1) + \delta_1 + \epsilon\right], \tag{386}$$
where

$$\begin{aligned} \text{int} &= \text{the integer portion of (i.e. truncate or round down),} & (387) \\ \texttt{TIME} &= \text{the time of the event,} & (388) \\ \texttt{EPOCH1} &= \text{a keyword in the } \texttt{tgainfile}, & (389) \\ \texttt{EPOCH2} &= \text{a keyword in the } \texttt{tgainfile}, & (390) \\ \delta_1 &= \left(\frac{\texttt{PHA} - \texttt{PHA}_m[r]}{\texttt{PHA}_{m+1}[r] - \texttt{PHA}_m[r]}\right)(\texttt{DELTPHA1}_{m+1}[r] - \texttt{DELTPHA1}_m[r]) + & (391) \\ & \quad \texttt{DELTPHA1}_m[r], & (392) \end{aligned}$$

$$\begin{cases} r \text{ is the row of the } \texttt{tgainfile} \text{ where} \\ \quad \begin{cases} \texttt{CCD\_ID}[r] = \texttt{CCD\_ID}, \\ \texttt{CHIPX\_LO}[r] \leq \texttt{CHIPX}, \\ \texttt{CHIPX\_HI}[r] \geq \texttt{CHIPX}, \\ \texttt{CHIPY\_LO}[r] \leq \text{nint}(\texttt{CHIPY\_ADJ}), \text{ and} \\ \texttt{CHIPY\_HI}[r] \geq \text{nint}(\texttt{CHIPY\_ADJ}). \end{cases} \\ m \text{ is the element of row } r \text{ where} \\ \quad \begin{cases} \texttt{PHA}_m[r] \leq \texttt{PHA} \text{ and} \\ \texttt{PHA}_{m+1}[r] > \texttt{PHA}. \\ \text{If } \texttt{PHA} < \texttt{PHA}_m[r] \text{ for } m = 0, \text{ then } m = 0. \\ \text{If } \texttt{PHA} \geq \texttt{PHA}_m[r] \text{ for } m = M \text{ and } M \text{ is the last element of } \texttt{PHA}[r], \\ \quad \text{then } m = M - 1. \end{cases} \\ \text{The } \texttt{tgainfile} \text{ includes a binary table with columns named} \\ \quad \texttt{CCD\_ID}, \texttt{CHIPX\_LO}, \texttt{CHIPX\_HI}, \texttt{CHIPY\_LO}, \texttt{CHIPY\_HI}, \texttt{PHA}, \texttt{DELTPHA1}, \text{ and} \\ \quad \texttt{DELTPHA2}. \end{cases} \tag{393}$$

$$\delta_2 = \left(\frac{\texttt{PHA} - \texttt{PHA}_m[r]}{\texttt{PHA}_{m+1}[r] - \texttt{PHA}_m[r]} \right) (\texttt{DELTPHA2}_{m+1}[r] - \texttt{DELTPHA2}_m[r]) + \tag{394}$$

$$\texttt{DELTPHA2}_m[r], \tag{395}$$

$$\epsilon = \text{ is a uniform random deviate in the range } [0, 1), \tag{396}$$

$$\{ \text{ If } \texttt{rand\_pha} = \text{no, then } \epsilon = 0. \tag{397}$$

(d) If

$$\texttt{PHA} \geq 32767, \tag{398}$$

then $\texttt{STATUS}[k] = 1$ for bit $k = 3$.

19. CORN_PHA:

(a) If

$$\texttt{DATAMODE}_{\text{in}} = \text{CC33\_GRADED}, \tag{399}$$

then the value of CORN_PHA is read from the infile.

20. ENERGY:

(a) If the parameter $\texttt{calculate\_pi} = \text{yes}$, if the parameter gainfile is specified, and if $\texttt{PHA} > 0$, then

    i. The row i in the gainfile is identified such that

$$\texttt{CCD\_ID} = \texttt{CCD\_ID}_{\text{gain},i}, \tag{400}$$

$$\texttt{CHIPX\_MIN}_{\text{gain},i} \leq \texttt{CHIPX} \leq \texttt{CHIPX\_MAX}_{\text{gain},i}, \qquad \text{and} \tag{401}$$

$$\texttt{CHIPY\_MIN}_{\text{gain},i} \leq \text{nint}(\texttt{CHIPY\_ADJ}) \leq \texttt{CHIPY\_MAX}_{\text{gain},i}, \tag{402}$$

where $\texttt{CCD\_ID}_{\text{gain}}$, $\texttt{CHIPX\_MIN}_{\text{gain}}$, $\texttt{CHIPX\_MAX}_{\text{gain}}$, $\texttt{CHIPY\_MIN}_{\text{gain}}$, and $\texttt{CHIPY\_MAX}_{\text{gain}}$ are columns in the gainfile.

    ii. A uniform random deviate Δp is computed over the interval from $[-0.5, +0.5)$.

    iii. The element j of row i of $\texttt{PHA}_{\text{gain}}$ is identified such that

$$\texttt{PHA}_{\text{gain},i}[j] \leq (\texttt{PHA} + \Delta p) < \texttt{PHA}_{\text{gain},i}[j + 1], \tag{403}$$

where $\texttt{PHA}_{\text{gain}}$ is a vector column in the gainfile. If $\texttt{PHA} + \Delta p < \texttt{PHA}_{\text{gain},i}[0]$, then $j = 0$. If $\texttt{PHA}_{\text{gain},i}[\texttt{NPOINTS} - 2] \leq \texttt{PHA} + \Delta p$, then $j = \texttt{NPOINTS} - 2$, where NPOINTS is a column in the gainfile.

iv. The ENERGY of an event is computed from the PHA of the event:

$$
\begin{aligned}
\texttt{ENERGY} \;=\;& \left(\frac{\texttt{PHA} + \Delta p - \texttt{PHA}_{\mathrm{gain},i}[j]}{\texttt{PHA}_{\mathrm{gain},i}[j+1] - \texttt{PHA}_{\mathrm{gain},i}[j]} \right) \left(\texttt{ENERGY}_{\mathrm{gain},i}[j+1] - \texttt{ENERGY}_{\mathrm{gain},i}[j] \right) + \\
& \texttt{ENERGY}_{\mathrm{gain},i}[j],
\end{aligned}
\tag{404}
$$

where $\texttt{ENERGY}_{\mathrm{gain}}$ is a vector column in the `gainfile`.

v. If ENERGY < 0, then ENERGY $= 0$.

(b) If the parameter `calculate_pi` $=$ yes, if the parameter `gainfile` is specified, and if PHA ≤ 0, then ENERGY $= 0$.

(c) If the parameter `calculate_pi` $=$ no or if the parameter `gainfile` is not specified, then

    i. If the `infile` includes the ENERGY of an event, then the ENERGY of the event is equal to the ENERGY in the `infile`.

    ii. If the `infile` does not include the ENERGY of an event, then ENERGY $= 0$.

21. PI:

(a) If

$$
\texttt{calculate\_pi} = \text{yes}, \tag{405}
$$

then

    i.

$$
\texttt{PI} = \text{int} \left(\frac{\texttt{ENERGY}}{\texttt{pi\_bin\_width}} \right) + 1, \tag{406}
$$

where "int" indicates the integer portion of what is in parentheses (i.e. the value is truncated or rounded down).

    ii. If

$$
\texttt{PI} < 1, \tag{407}
$$

then PI $= 1$.

    iii. If

$$
\texttt{PI} > \texttt{pi\_num\_bins}, \tag{408}
$$

then PI $=$ `pi_num_bins`.

(b) If

$$
\texttt{calculate\_pi} = \text{no} \tag{409}
$$

and if the `infile` includes the value of PI for an event, then the value of PI is read from the `infile`.

22. `pix_adj`:

(a)

$$
\texttt{CHIPX\_ADJ} \;=\; \texttt{CHIPX}. \tag{410}
$$

(b) If

$$
\texttt{pix\_adj} = \text{centroid}, \tag{411}
$$

then

$$
\texttt{CHIPX\_ADJ} \;=\; \texttt{CHIPX\_ADJ} - w'[0] + w'[2] - w'[3] + w'[5] - w'[6] + w'[8] \tag{412}
$$

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and if

$$\text{DATAMODE} \quad = \quad \text{FAINT or} \tag{413}$$
$$\text{DATAMODE} \quad = \quad \text{FAINT\_BIAS or} \tag{414}$$
$$\text{DATAMODE} \quad = \quad \text{GRADED or} \tag{415}$$
$$\text{DATAMODE} \quad = \quad \text{VFAINT}, \tag{416}$$

then

$$\text{CHIPY\_ADJ} \quad = \quad \text{CHIPY\_ADJ} - w'[0] - w'[1] - w'[2] + w'[6] + w'[7] + w'[8] \tag{417}$$

and if

$$\text{DATAMODE} \quad = \quad \text{CC33\_FAINT or} \tag{418}$$
$$\text{DATAMODE} \quad = \quad \text{CC33\_GRADED}, \tag{419}$$

then

$$\text{TIME} \quad = \quad \text{TIME} + (w'[0] + w'[1] + w'[2] - w'[6] - w'[7] - w'[8]) \times \text{TIMEDEL}_{\text{in}}, \tag{420}$$

where

$$w'[j] = \frac{w[j]}{\sum_{j=0}^{8} w[j]}, \tag{421}$$

$$w[j] = \begin{cases} p[j] & \text{if the pixel is valid} \\ 0 & \text{if the pixel is invalid}, \end{cases} \tag{422}$$

$$p[j] = \begin{cases} \text{PHAS\_ADJ}[j] & \text{if apply\_cti} = \text{yes} \\ \text{PHAS}[j] & \text{if apply\_cti} = \text{no}, \end{cases} \tag{423}$$

and the pixel is invalid if

$$\beta[j] \quad = \quad 0 \text{ or} \tag{424}$$
$$\text{STATUS}[0] \quad = \quad 1 \text{ or} \tag{425}$$
$$\text{STATUS}[1] \quad = \quad 1 \text{ or} \tag{426}$$
$$\text{STATUS}[2] \quad = \quad 1 \text{ or} \tag{427}$$
$$\text{STATUS}[3] \quad = \quad 1 \text{ or} \tag{428}$$
$$\text{STATUS}[4] \quad = \quad 1 \text{ or} \tag{429}$$
$$\text{STATUS}[11] \quad = \quad 1 \text{ or} \tag{430}$$
$$\text{STATUS}[13] \quad = \quad 1 \text{ or} \tag{431}$$
$$\text{STATUS}[14] \quad = \quad 1 \text{ or} \tag{432}$$
$$\text{STATUS}[15] \quad = \quad 1 \text{ or} \tag{433}$$
$$\text{STATUS}[16] \quad = \quad 1. \tag{434}$$

Note that it is possible for the centroid algorithm to yield an adjustment to CHIPX_ADJ and/or CHIPY_ADJ that is greater than half a pixel. However, the adjustment cannot equal or exceed one pixel.

(c) If

$$\text{pix\_adj} = \text{edser}, \tag{435}$$

then

$$\text{CHIPX\_ADJ} \quad = \quad \text{CHIPX\_ADJ} + \left(\frac{\text{ENERGY} - E[k]}{E[k+1] - E[k]} \right) (\Delta X[k+1] - \Delta X[k]) + \Delta X[k] \tag{436}$$

and if

$$\text{DATAMODE} \;=\; \text{FAINT or} \tag{437}$$
$$\text{DATAMODE} \;=\; \text{FAINT\_BIAS or} \tag{438}$$
$$\text{DATAMODE} \;=\; \text{GRADED or} \tag{439}$$
$$\text{DATAMODE} \;=\; \text{VFAINT,} \tag{440}$$

then

$$\text{CHIPY\_ADJ} \;=\; \text{CHIPY\_ADJ} + \left(\frac{\text{ENERGY} - E[k]}{E[k+1] - E[k]} \right)(\Delta Y[k+1] - \Delta Y[k]) + \Delta Y[k] \tag{441}$$

and if

$$\text{DATAMODE} \;=\; \text{CC33\_FAINT or} \tag{442}$$
$$\text{DATAMODE} \;=\; \text{CC33\_GRADED,} \tag{443}$$

then

$$\text{TIME} \;=\; \text{TIME} - \left(\frac{\text{ENERGY} - E[k]}{E[k+1] - E[k]} \right)(\Delta Y[k+1] - \Delta Y[k]) + \Delta Y[k], \tag{444}$$

where $E[k]$ and $E[k+1]$, $X[k]$ and $X[k+1]$, and $Y[k]$ and $Y[k+1]$ are the k and $(k+1)^{th}$ elements of the vector columns $\text{ENERGY}_{\text{subpix}}$, $\text{CHIPX\_OFFSET}_{\text{subpix}}$, and $\text{CHIPY\_OFFSET}_{\text{subpix}}$, respectively. These columns are in the HDU of the `subpixfile` where the value of the keyword CCD_ID is equal to the value of the CCD_ID of the event. The appropriate row of these columns is the one where $\text{FLTGRADE}_{\text{subpix}} = \text{FLTGRADE}$. The values of k are the ones where

$$\text{ENERGY} \;\geq\; E[k] \text{ and} \tag{445}$$
$$\text{ENERGY} \;<\; E[k+1]. \tag{446}$$

Note that if

$$\text{ENERGY} \;\leq\; E[0], \tag{447}$$

then $k = 0$. Similarly, if

$$\text{ENERGY} \;\geq\; E[\text{NPOINTS}_{\text{subpix}} - 2], \tag{448}$$

then $k = \text{NPOINTS}_{\text{subpix}} - 2$.

(d) If

$$\text{pix\_adj} = \text{none,} \tag{449}$$

then the values of CHIPX_ADJ and CHIPY_ADJ remain unchanged.

(e) If

$$\text{pix\_adj} = \text{randomize,} \tag{450}$$

then

$$\text{CHIPX\_ADJ} \;=\; \text{CHIPX\_ADJ} + \epsilon_x \tag{451}$$

and if

$$\text{DATAMODE} \;=\; \text{FAINT or} \tag{452}$$
$$\text{DATAMODE} \;=\; \text{FAINT\_BIAS or} \tag{453}$$
$$\text{DATAMODE} \;=\; \text{GRADED or} \tag{454}$$
$$\text{DATAMODE} \;=\; \text{VFAINT,} \tag{455}$$

then

$$\text{CHIPY\_ADJ} \quad = \quad \text{CHIPY\_ADJ} + \epsilon_y \tag{456}$$

and if

$$\text{DATAMODE} \quad = \quad \text{CC33\_FAINT or} \tag{457}$$
$$\text{DATAMODE} \quad = \quad \text{CC33\_GRADED,} \tag{458}$$

then

$$\text{TIME} \quad = \quad \text{TIME} - \epsilon_y \times \text{TIMEDEL}_{\text{in}}, \tag{459}$$

where ϵ_x and ϵ_y are uniform random deviates in the range $[-0.5, +0.5)$ pixel.

(f) If

$$\text{CHIPX\_ADJ} \quad < \quad 0.5, \tag{460}$$

then

$$\text{CHIPX\_ADJ} \quad = \quad 1. \tag{461}$$

(g) If

$$\text{CHIPX\_ADJ} \quad \geq \quad 1024.5, \tag{462}$$

then

$$\text{CHIPX\_ADJ} \quad = \quad 1024. \tag{463}$$

(h) If

$$\text{CHIPY\_ADJ} \quad < \quad 0.5, \tag{464}$$

then

$$\text{CHIPY\_ADJ} \quad = \quad 1. \tag{465}$$

(i) If

$$\text{CHIPY\_ADJ} \quad \geq \quad 1024.5, \tag{466}$$

then

$$\text{CHIPY\_ADJ} \quad = \quad 1024. \tag{467}$$

23. TDETX and TDETY:

(a) If

$$\text{stop} \quad = \quad \text{tdet or} \tag{468}$$
$$\text{stop} \quad = \quad \text{det or} \tag{469}$$
$$\text{stop} \quad = \quad \text{tan or} \tag{470}$$
$$\text{stop} \quad = \quad \text{sky,} \tag{471}$$

then the values of TDETX and TDETY are computed using the values of nint(CHIPX_ADJ) and nint(CHIPY_ADJ). Here, "nint" indicates that the real-valued coordinate is rounded to the nearest integer before the computation of the TDET coordinate.

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24. `DETX` and `DETY`:

   (a) If

$$\texttt{stop} = \text{det or} \tag{472}$$
$$\texttt{stop} = \text{tan or} \tag{473}$$
$$\texttt{stop} = \text{sky,} \tag{474}$$

then the values of `DETX` and `DETY` are computed using the real-valued coordinates `CHIPX_ADJ` and `CHIPY_ADJ`.

25. `X` and `Y`:

   (a) If

$$\texttt{stop} = \text{sky,} \tag{475}$$

then the values of `X` and `Y` are computed using the real-valued coordinates `CHIPX_ADJ` and `CHIPY_ADJ`.

26. `SKY_1D`:

   (a) If

$$\text{DATAMODE}_{\text{in}} = \text{CC33\_FAINT or} \tag{476}$$
$$\text{DATAMODE}_{\text{in}} = \text{CC33\_GRADED} \tag{477}$$

and if

$$\texttt{stop} = \text{sky,} \tag{478}$$

then the value of `SKY_1D` is computed.

1.5.4 Write `outfile`

1. `PIX_ADJ`:

   (a) If

$$\texttt{pix\_adj} = \text{centroid,} \tag{479}$$

then

$$\texttt{PIX\_ADJ} = \text{CENTROID,} \tag{480}$$

   (b) If

$$\texttt{pix\_adj} = \text{edser,} \tag{481}$$

then

$$\texttt{PIX\_ADJ} = \text{EDSER,} \tag{482}$$

   (c) If

$$\texttt{pix\_adj} = \text{none,} \tag{483}$$

then

$$\texttt{PIX\_ADJ} = \text{NONE,} \tag{484}$$

(d) If

$$\texttt{pix\_adj} \;\; = \;\; \text{randomize}, \tag{485}$$

then

$$\texttt{PIX\_ADJ} \;\; = \;\; \text{RANDOMIZE}, \tag{486}$$

2. `RAND_SKY`:

(a) If

$$\texttt{pix\_adj} \;\; = \;\; \text{centroid}, \tag{487}$$

then

$$\texttt{RAND\_SKY} \;\; = \;\; 0.0, \tag{488}$$

(b) If

$$\texttt{pix\_adj} \;\; = \;\; \text{edser}, \tag{489}$$

then

$$\texttt{RAND\_SKY} \;\; = \;\; 0.0, \tag{490}$$

(c) If

$$\texttt{pix\_adj} \;\; = \;\; \text{none}, \tag{491}$$

then

$$\texttt{RAND\_SKY} \;\; = \;\; 0.0, \tag{492}$$

(d) If

$$\texttt{pix\_adj} \;\; = \;\; \text{randomize}, \tag{493}$$

then

$$\texttt{RAND\_SKY} \;\; = \;\; 0.5, \tag{494}$$

3. `TIME_ADJ`:

(a) If

$$\texttt{DATAMODE}_{\text{in}} \;\; = \;\; \text{FAINT or} \tag{495}$$
$$\texttt{DATAMODE}_{\text{in}} \;\; = \;\; \text{FAINT\_BIAS or} \tag{496}$$
$$\texttt{DATAMODE}_{\text{in}} \;\; = \;\; \text{GRADED or} \tag{497}$$
$$\texttt{DATAMODE}_{\text{in}} \;\; = \;\; \text{VFAINT}, \tag{498}$$

then

$$\texttt{TIME\_ADJ} \;\; = \;\; \text{NONE.} \tag{499}$$

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(b)   i. If

$$\text{DATAMODE}_{\text{in}} \quad = \quad \text{CC33\_FAINT or} \qquad (500)$$
$$\text{DATAMODE}_{\text{in}} \quad = \quad \text{CC33\_GRADED,} \qquad (501)$$

if

$$\text{CONTENT}_{\text{in}} \quad = \quad \text{EVT0 or} \qquad (502)$$
$$\text{CONTENT}_{\text{in}} \quad = \quad \text{EVT1 or} \qquad (503)$$
$$\text{CONTENT}_{\text{in}} \quad = \quad \text{EVT2,} \qquad (504)$$

if

$$\text{CCD\_ID}_{\text{aimpt}} \quad \geq \quad 0 \text{ and} \qquad (505)$$
$$\text{CCD\_ID}_{\text{aimpt}} \quad \leq \quad 3, \qquad (506)$$

and if

$$\cos\left(\text{DEC\_ADJ}_{\text{I}}\right)\cos\left(\text{DEC\_TARG}_{\text{in}}\right)\cos\left(\text{RA\_ADJ}_{\text{I}} - \text{RA\_TARG}_{\text{in}}\right) + \qquad (507)$$
$$\sin\left(\text{DEC\_ADJ}_{\text{I}}\right)\sin\left(\text{DEC\_TARG}_{\text{in}}\right) < \qquad (508)$$
$$4.855 \times 10^{-11}, \qquad (509)$$

then

$$\text{TIME\_ADJ} \quad = \quad \text{TARGET.} \qquad (510)$$

ii. If

$$\text{DATAMODE}_{\text{in}} \quad = \quad \text{CC33\_FAINT or} \qquad (511)$$
$$\text{DATAMODE}_{\text{in}} \quad = \quad \text{CC33\_GRADED,} \qquad (512)$$

if

$$\text{CONTENT}_{\text{in}} \quad = \quad \text{EVT0 or} \qquad (513)$$
$$\text{CONTENT}_{\text{in}} \quad = \quad \text{EVT1 or} \qquad (514)$$
$$\text{CONTENT}_{\text{in}} \quad = \quad \text{EVT2,} \qquad (515)$$

if

$$\text{CCD\_ID}_{\text{aimpt}} \quad \geq \quad 4 \text{ and} \qquad (516)$$
$$\text{CCD\_ID}_{\text{aimpt}} \quad \leq \quad 9, \qquad (517)$$

and if

$$\cos\left(\text{DEC\_ADJ}_{\text{S}}\right)\cos\left(\text{DEC\_TARG}_{\text{in}}\right)\cos\left(\text{RA\_ADJ}_{\text{S}} - \text{RA\_TARG}_{\text{in}}\right) + \qquad (518)$$
$$\sin\left(\text{DEC\_ADJ}_{\text{S}}\right)\sin\left(\text{DEC\_TARG}_{\text{in}}\right) < \qquad (519)$$
$$4.855 \times 10^{-11}, \qquad (520)$$

then

$$\text{TIME\_ADJ} \quad = \quad \text{TARGET.} \qquad (521)$$

(c) i. If

$$\text{DATAMODE}_{\text{in}} \quad = \quad \text{CC33\_FAINT or} \tag{522}$$
$$\text{DATAMODE}_{\text{in}} \quad = \quad \text{CC33\_GRADED,} \tag{523}$$

if

$$\text{CONTENT}_{\text{in}} \quad = \quad \text{EVT0 or} \tag{524}$$
$$\text{CONTENT}_{\text{in}} \quad = \quad \text{EVT1 or} \tag{525}$$
$$\text{CONTENT}_{\text{in}} \quad = \quad \text{EVT2,} \tag{526}$$

if

$$\text{CCD\_ID}_{\text{aimpt}} \quad \geq \quad 0 \text{ and} \tag{527}$$
$$\text{CCD\_ID}_{\text{aimpt}} \quad \leq \quad 3, \tag{528}$$

and if

$$\cos\left(\text{DEC\_ADJ}_{\text{I}}\right)\cos\left(\text{DEC\_TARG}_{\text{in}}\right)\cos\left(\text{RA\_ADJ}_{\text{I}} - \text{RA\_TARG}_{\text{in}}\right) + \tag{529}$$
$$\sin\left(\text{DEC\_ADJ}_{\text{I}}\right)\sin\left(\text{DEC\_TARG}_{\text{in}}\right) \geq \tag{530}$$
$$4.855 \times 10^{-11}, \tag{531}$$

then

$$\text{TIME\_ADJ} \quad = \quad \text{AIMPOINT.} \tag{532}$$

ii. If

$$\text{DATAMODE}_{\text{in}} \quad = \quad \text{CC33\_FAINT or} \tag{533}$$
$$\text{DATAMODE}_{\text{in}} \quad = \quad \text{CC33\_GRADED,} \tag{534}$$

if

$$\text{CONTENT}_{\text{in}} \quad = \quad \text{EVT0 or} \tag{535}$$
$$\text{CONTENT}_{\text{in}} \quad = \quad \text{EVT1 or} \tag{536}$$
$$\text{CONTENT}_{\text{in}} \quad = \quad \text{EVT2,} \tag{537}$$

if

$$\text{CCD\_ID}_{\text{aimpt}} \quad \geq \quad 4 \text{ and} \tag{538}$$
$$\text{CCD\_ID}_{\text{aimpt}} \quad \leq \quad 9, \tag{539}$$

and if

$$\cos\left(\text{DEC\_ADJ}_{\text{S}}\right)\cos\left(\text{DEC\_TARG}_{\text{in}}\right)\cos\left(\text{RA\_ADJ}_{\text{S}} - \text{RA\_TARG}_{\text{in}}\right) + \tag{540}$$
$$\sin\left(\text{DEC\_ADJ}_{\text{S}}\right)\sin\left(\text{DEC\_TARG}_{\text{in}}\right) \geq \tag{541}$$
$$4.855 \times 10^{-11}, \tag{542}$$

then

$$\text{TIME\_ADJ} \quad = \quad \text{AIMPOINT.} \tag{543}$$

(d) If

$$\text{DATAMODE}_{\text{in}} \quad = \quad \text{CC33\_FAINT or} \tag{544}$$
$$\text{DATAMODE}_{\text{in}} \quad = \quad \text{CC33\_GRADED} \tag{545}$$

if

$$\text{CONTENT}_{\text{in}} \quad = \quad \text{TGEVT1} \tag{546}$$

and if

$$\text{CCD\_ID}_{\text{aimpt}} \quad \geq \quad 4 \text{ and} \tag{547}$$
$$\text{CCD\_ID}_{\text{aimpt}} \quad \leq \quad 9 \tag{548}$$

then

$$\text{TIME\_ADJ} \quad = \quad \text{GRATING.} \tag{549}$$

(e) If

$$\text{DATAMODE}_{\text{in}} \quad = \quad \text{CC33\_FAINT or} \tag{550}$$
$$\text{DATAMODE}_{\text{in}} \quad = \quad \text{CC33\_GRADED} \tag{551}$$

if

$$\text{CONTENT}_{\text{in}} \quad = \quad \text{TGEVT1} \tag{552}$$

if

$$\text{CCD\_ID}_{\text{aimpt}} \quad \geq \quad 0 \text{ and} \tag{553}$$
$$\text{CCD\_ID}_{\text{aimpt}} \quad \leq \quad 3 \tag{554}$$

and if

$$\cos\left(\text{DEC\_ADJ}_{\text{I}}\right)\cos\left(\text{DEC\_TARG}_{\text{in}}\right)\cos\left(\text{RA\_ADJ}_{\text{I}} - \text{RA\_TARG}_{\text{in}}\right) + \tag{555}$$
$$\sin\left(\text{DEC\_ADJ}_{\text{I}}\right)\sin\left(\text{DEC\_TARG}_{\text{in}}\right) < \tag{556}$$
$$4.855 \times 10^{-11}, \tag{557}$$

then

$$\text{TIME\_ADJ} \quad = \quad \text{TARGET.} \tag{558}$$

(f) If

$$\text{DATAMODE}_{\text{in}} \quad = \quad \text{CC33\_FAINT or} \tag{559}$$
$$\text{DATAMODE}_{\text{in}} \quad = \quad \text{CC33\_GRADED} \tag{560}$$

if

$$\text{CONTENT}_{\text{in}} \quad = \quad \text{TGEVT1} \tag{561}$$

if

$$\text{CCD\_ID}_{\text{aimpt}} \quad \geq \quad 0 \text{ and} \tag{562}$$
$$\text{CCD\_ID}_{\text{aimpt}} \quad \leq \quad 3 \tag{563}$$

and if

$$\cos\left(\texttt{DEC\_ADJ}_\mathrm{I}\right)\cos\left(\texttt{DEC\_TARG}_\mathrm{in}\right)\cos\left(\texttt{RA\_ADJ}_\mathrm{I} - \texttt{RA\_TARG}_\mathrm{in}\right) + \tag{564}$$

$$\sin\left(\texttt{DEC\_ADJ}_\mathrm{I}\right)\sin\left(\texttt{DEC\_TARG}_\mathrm{in}\right) \geq \tag{565}$$

$$4.855 \times 10^{-11}, \tag{566}$$

then

$$\texttt{TIME\_ADJ} \quad = \quad \text{AIMPOINT}. \tag{567}$$

2 TBD

- Complete the spec to include all of the timed exposure mode processing.

- Complete sections 1.1, 1.2, 1.3, and 1.4.

- Should CONTENTs other than EVT0, EVT1, TGEVT1, and EVT2 be included?

- Should CONTENT = EVT2 be dropped?

- Should DATAMODEs other than CC33_FAINT, CC33_GRADED, FAINT, FAINT_BIAS, GRADED, and VFAINT be included?

- Are the RA_TARG, DEC_TARG, RA_NOM, DEC_NOM, and TIMEDEL keywords in the output of afe (need obsfile sometimes)?

- What if TIME_RO is not in the infile (output of afe? EVT2 files?)?

- What if a small fraction of the values of CHIPY_TARG are off the chip due to bad aspect?

- Make sure that the STATUS bits are unset and reset properly.

- What about aoff and soff files instead of asol files?

- Are the CHIPX and CHIPY aim-point locations stored in a CALDB file?

- Are the β in PHA_RO the same as the β in PHA?

- Should something be done about SKY_1D?