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Description of the Silicon Tracking Simulation

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The SDC GEANT package (SG) within the SDC SHELL program SDCSIM allows for simulation of the various SDC subsystems together using the GEANT3.14 framework. Within SG, the simulation of the individual subsystems is taken care of by several packages of routines, which are selected at link time using PATCHY control switches. The silicon strip subsystem is simulated with the Silicon Tracking (ST) package.

This note describes the silicon simulation version (v04) used for studies for the Technical Design Report. Some minor improvements which have been added since the v04 release will also be described. The ST package consists of routines to describe the detector geometry at program initialization, and hit simulation routines written by W. Kinnison of LANL which have been modified for use with the proposed SDC geometries. The present version simulates a system composed of double-sided silicon strip detectors in which multiple wafers are bonded into readout units. The detector geometry is described further in section 2. The hit simulation is rather simple, but is thought to be adequate for the present studies, and is described in section 3. A separate but quite similar package (PX) can be used to simulate layers of Pixel detectors; some details which will be described below apply also to PX. A separate package is used for reconstruction of tracks in the silicon (TS), which will be described in a subsequent note [1].

2. DETECTOR GEOMETRY

The specification of the geometry in the ST package is designed to be flexible so a variety of configurations can be studied. Nearly all parameters such as number and position of layers, pitch, stereo angles, etc., can be set at run time using commands in a text file. Alternatively, the default geometry is defined in a BLOCK DATA routine, so that unless one wishes to alter parameters, no file is needed. The default geometry in the present version is the geometry from the Conceptual Design Report (CDR), also contained in the file ST_CDR_02.KUMAC and listed in Appendix A.

The proposed silicon system layout is given in Table 1. The system is divided into three modules, a 'barrel' module and two mirror-image 'forward' modules. In the simulation and reconstruction programs, the barrel is referred to as module 1, with modules 2 and 3 being the $-z$ and $+z$ forward modules, respectively.

Table 1.
Dimensions for baseline silicon tracker

Barrel	r	z extent		Silicon Area
(1)	9 cm	30 cm		
(2)	12 cm	30 cm		
(3)	18 cm	30 cm		6.78 m^2 for Barrel
(4)	21 cm	30 cm		
(5)	24 cm	30 cm		
(6)	27 cm	30 cm		
(7)	33 cm	30 cm		
(8)	36 cm	30 cm		
Disks	r_{in}	r_{out}	z	**Silicon Area**
(1)	15 cm	39 cm	33 cm	
(2)	15 cm	39 cm	38 cm	
(3)	15 cm	39 cm	44 cm	10.16 m^2 for Disks
(4)	15 cm	39 cm	52 cm	(both sides)
(5)	15 cm	39 cm	61 cm	
(6)	15 cm	39 cm	72 cm	
(7)	15 cm	39 cm	85 cm	
(8)	15 cm	39 cm	102 cm	
(9)	15 cm	39 cm	122 cm	
(10)	22.5 cm	46.5 cm	146 cm	
(11)	28.5 cm	46.5 cm	182 cm	
(12)	34.5 cm	46.5 cm	218 cm	
(13)	40.5 cm	46.5 cm	258 cm	
		Total Area = 16.94 m^2		

Wherever possible, geometrical constructs and parameters are treated analogously in the barrel and forward modules.† In the default geometry, the barrel module is composed of 8 layers of double-sided wafers, each 6 cm in length, which are bonded together in pairs to form 12 cm long readout units (Figure 1a). The strip pitch is 50 μm on both sides of the wafer. The strips on the ohmic (n) side of the wafers have a 10 mrad stereo angle. There is an inactive border region of 600 microns at the edges and the ends of each wafer. The wafers are tilted at an angle of 7.5 degrees to the radial, to compensate for the Lorentz angle (Figure 2). The sense of the tilt angle is such that the p side is pointing outwards, which specifies the direction of the electric field within the wafer.

In the forward region, the 6 cm long wafers are wedge shaped and also bonded into 12 cm readout units (Figure 1b). The pitch is 50 μm at the location of the

† We adopt the standard SDC coordinate system, in which the x axis points towards the center of the SSC ring, y points upwards, and z points in one beam direction such that the system is right handed.

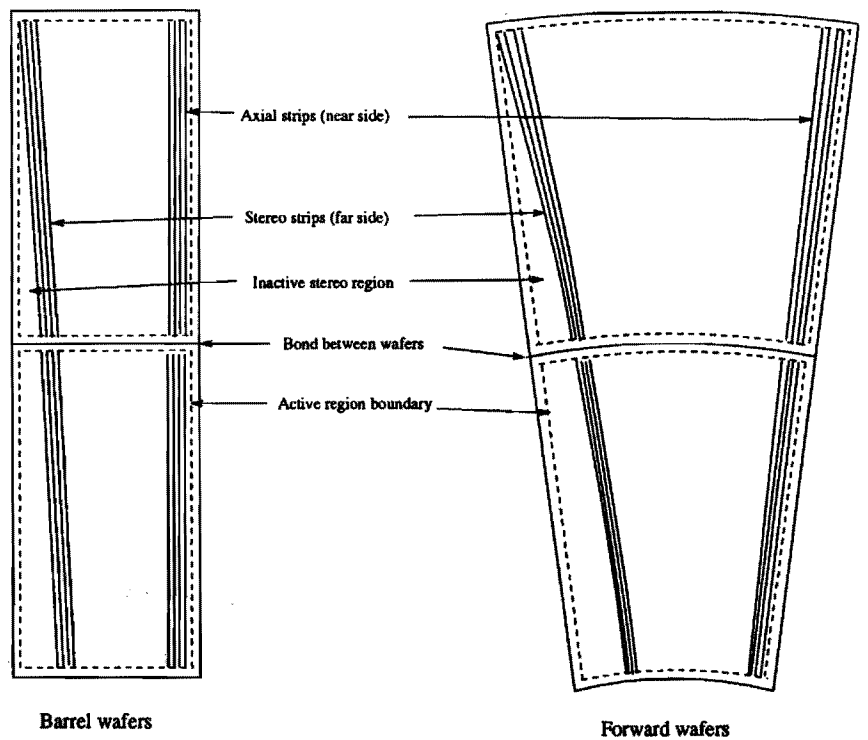

Figure 1. Examples of barrel and forward wafers, actual size.

readout chips, which are usually placed close to the outer edge of the readout unit. Thus the pitch typically ranges from 28 to 51 μm over the radial extent of the unit. The stereo strips are also tapered and have an effective stereo angle of 10 mr at the outer edge; however, these strips are not straight radial slices but actually logarithmic spirals. In the simulation, their shape is defined by the following relation between radial position and strip number (equivalent for the barrel, with the roles of z and r interchanged):

$$r = r_{edge} + p(N_{ax} - N_{st})/\tan\mu$$

where r is the radius, p the pitch, N_{ax} and N_{st} are the axial and stereo strip numbers, and μ is the stereo angle. This gives a uniform resolution for the r coordinate measurement over the surface of a wafer. Figure 3 shows how these

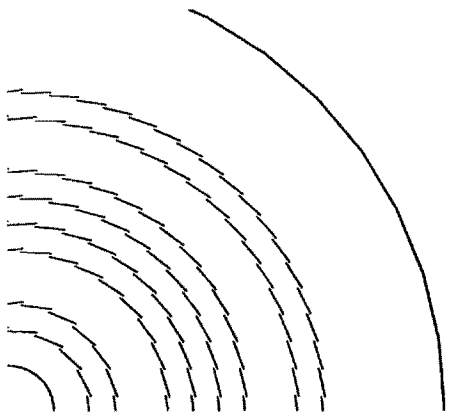

Figure 2. End view of the barrel showing the tilted wafers. The solid curves show the gas enclosure volume.

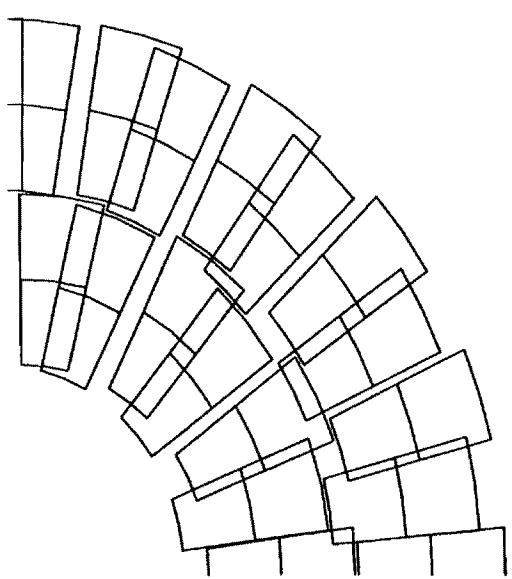

Figure 3. Angled view of a section of the forward wafers.

Table 2
Dead material in the silicon tracker simulation at η=0.

Inner radius(cm)	Thickness (cm)	Material	X_0 (%)	Description
2.5	0.038	Be	0.11	beampipe
5.0	0.050	Be	0.14	gas inner liner
8.5	1.0	diffuse C	0.20	support for layer 1
11.5	1.0	diffuse C	0.20	support for layer 2
17.5	1.0	diffuse C	0.50	support for layer 3
20.5	1.0	diffuse C	0.35	support for layer 4
23.5	1.0	diffuse C	0.35	support for layer 5
26.5	1.0	diffuse C	0.35	support for layer 6
32.5	1.0	diffuse C	0.35	support for layer 7
35.5	1.0	diffuse C	0.35	support for layer 8
50.0	0.1	Be	0.28	gas outer liner
Total Radiation Lengths for Silicon system support = 0.0318 X_0				

readout units are placed around the cooling ring to make up one of the forward layers; the readout units alternate by ± 1 cm in z around the nominal position as ϕ increases to decrease the effects of dead space and to allow for cable runs.

Rather than simulate the support structure in detail, the support material is taken into account as additional inert material uniformly distributed at each layer. The density and radial extent of the material can be set with the data cards. Table 2 summarizes this material for the default system and gives the number of radiation lengths at normal incidence. The innermost material is the beampipe which is at r=2.5 cm and is 0.038 cm thick. The silicon system is contained in a gas enclosure vessel with a 0.5 mm thick Be inner wall at r=5 cm and a 1 mm thick Be wall at r=50 cm. The support and cooling ring structures have been approximated by a cylinder at the nominal radius of the layer and with a given number of radiation lengths. The inner two layers have had this support adjusted to reflect the fact that the first support ring occurs between layers 2 and 3. A more complete study of the material in the silicon system was performed [2] and the numbers used were adjusted to reflect the findings.

The GEANT geometry is set up at initialization in the routines STGEOM, STBGEM and STFGEM. Figure 4 shows the GEANT volume hierarchy. An inner tracking volume (SGTI) is imbedded within the main tracking volume (SGTO). This volume is defined as a tube with default inner and outer diameters of 5 and 50 cm, respectively and half length of 260 cm, and is filled with air (this should probably be changed to butane, the cooling gas in the main system). At the inner and outer radial boundary of SGTI are two tube volumes (STZI,STZO) for the inner and outer gas enclosure walls, made of beryllium. The dimensions of these

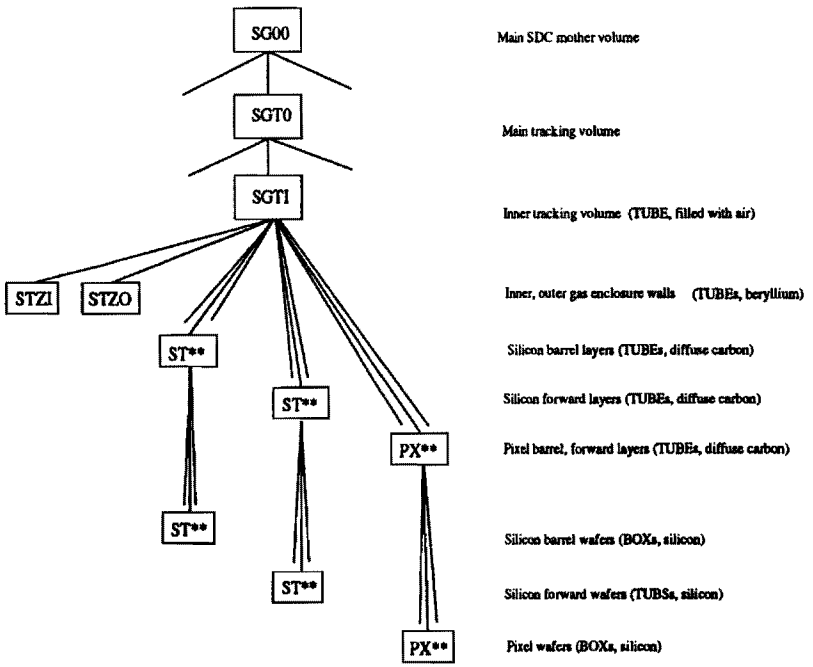

Figure 4. Geant volume hierarchy for silicon (+pixel) system.

volumes and SGTI can be set with the ST/GEOM/ENCLOSURE command as described in Appendix A. The other volumes positioned within SGTI are layer volumes for the forward and barrel silicon strip modules, and also for the pixel system.

The layer volumes are dimensioned to be large enough to contain the wafer volumes (including tilt and wafer staggering). They are filled with diffuse carbon with the radiation length set to be that of the additional support material, as described above and listed in Table 2. Inside a layer volume are a fairly large number of wafer volumes, composed of silicon and each positioned separately with its own rotation matrix. The silicon wafers are the only 'active' GEANT volumes in the system. In the barrel, the wafer volumes are BOX volumes, each with a default dimensions 6 cm length, 3.32 cm width and 300 μm thickness. In the forward they are TUBS (sections of tubes) with different dimensions for each ring and layer. Note that this is different than the actual system, in which the forward wafers will be trapezoids. The names of the wafer and layer volumes are assigned

dynamically with the routine STVNAM.

In order to speed up the simulation, the wafer geometry in a layer is optimized using the routine GUNEAR. When a particle enters a layer, GUNEAR calculates the nearest 4 wafers which could in principle be hit, instead of having all wafers searched. This saves about a factor of four in speed in the silicon system simulation. The layer volumes within SGTI are not ordered or optimized yet, so some further speed-up is possible.

All geometrical parameters are stored in a 'STGE' data structure, which is located in the COMMON BLOCK /STGE/. This data structure is copied to a ZEBRA bank and written out with the begin run record, so that the reconstruction code can automatically pick up the same geometry. To preserve backwards compatibility as the format of the 'STGE' structure changes, a set of statement functions are defined (in the PATCHY sequence SIFUNC) to access all geometry parameters. These are listed in Appendix B. All access to geometry parameters from the STGE structure should be through the statement functions.

3. Hit Simulation

In GEANT, the simulation is divided into two parts: a 'tracking' phase, in which GEANT transports particles through the apparatus and causes interactions (including dE/dx ionization loss, multiple scattering, delta rays, interactions with material and decays); and a 'digitization' phase in which the energy deposited in the silicon during the tracking phase is recorded in raw data banks.

In the tracking phase, the routine STSTEP is called whenever a particle is found inside a silicon wafer volume. On exiting a volume, the entrance and exit point, the time and the dE/dx energy deposited by a particle are stored in a GEANT 'HITS' structure. The energy loss generated by GEANT is shown in Figure 5a for 5 GeV pions in the forward detectors (solid histogram) compared with a calculation including atomic binding effects [3]. The dE/dx distribution from GEANT has a slightly lower most probable value, but the shape and lower edge agree reasonably well. The most probable ionization for 5 GeV pions (solid histogram) in GEANT is 5 to 10% less than that for very energetic ($p > 1000$ GeV) muons (dashes) as shown in Figure 5b, though one expects the difference (from the relativistic rise) to be more like 20%.

In the digitization phase, for each particle passing through a wafer, the energy is divided between strips according to the path length underneath a strip, assuming uniform deposition along the path length. At this time, the effects of diffusion and the magnetic field (the latter important for the barrel only) are not included. These effects would tend to cause broader hit clusters than the present

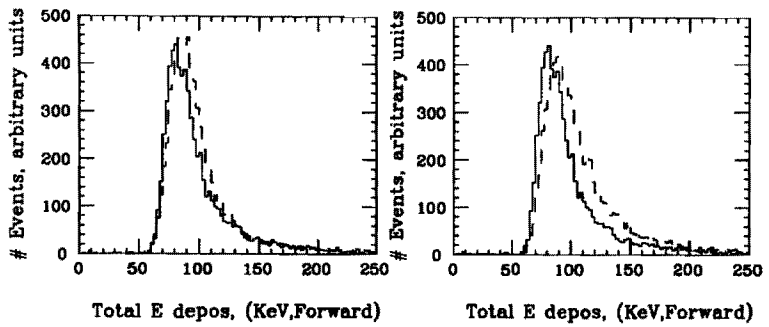

Figure 5 a) dE/dx ionization loss for 5 GeV pions (solid) compared with Unno's calculation (dashes). b) dE/dx ionization loss for 5 GeV pions (solid) compared with 500 GeV muons (dashes).

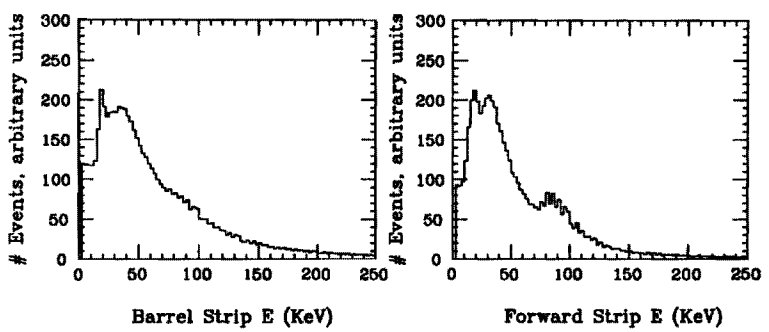

Figure 6 a) Energy deposited per barrel strip in typical jet events. b) Energy deposited per forward strip in typical jet events.

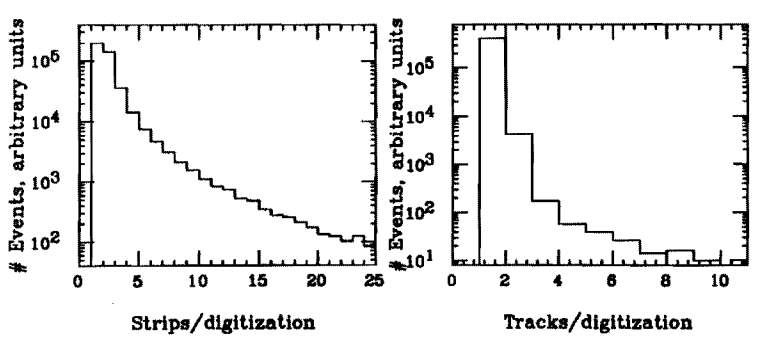

Figure 7 a) Number of strips in a digitization cluster. b) Number of tracks contributing to a cluster, in typical jet events.

simulation, but are not expected to effect the resolution dramatically. Also, noise hits and discriminator threshold smearing are not included, which would increase the occupancy somewhat and add a small inefficiency.

The energy per strip is shown in Figure 6 for barrel and forward detectors in typical jet events. These distributions are different from the previous figure because many particles have low p_t and pass through more than one strip. If the energy deposited on a strip is greater than the discriminator threshold (by default, 30 KeV or approximately 1/3 of a MIP) and the energy is deposited within a time window, a raw data signal is recorded in a GEANT 'DIGI' structure. The time window is by default $\pm$ 15 ns around the nominal time for a particle to reach a layer with $v = c$.

From the GEANT structures, the data are transferred into the corresponding SDC data structures /RAWD/RTRK/STRA/STSS/STHI, containing the Monte-Carlo hit information, and /RAWD/RTRK/STRA/STSS/STDI, for the digitized raw data. These are described in Appendix B, and also in the document TRACKING.BNK. By default, the STHI bank is not created since it is rather large and rarely used, but it can be enabled with the ST/HITS command. The STDI bank contains one entry per cluster of neighboring strips above threshold. The widths of clusters is shown in Figure 7a, for typical jet events. There are about 50% more one than two strip clusters, and there is a tail to large numbers of strips due to particles travelling in the plane of a detector wafer. Figure 7b shows the number of tracks contributing to a cluster. This is almost always one, but occasionally there are as many as 10, due to hadronic interactions within a detector wafer which can produce a high charged multiplicity.

To calculate the coordinates of a hit strip (or cluster) or axial/stereo pair, the routine STCOOR is used. The calculated position can be compared with the true position in STHI; this comparison is shown in Figures 8 and 9. For single hit clusters, the resolution in $r - \phi$ is 9.8 microns in the barrel detectors, which is 30% better than the pitch/$\sqrt{12}$ (the naive estimate, assuming only single hit clusters) since particles near the boundary cause 2 strips to be hit. In the forward detectors, the distribution is closer to a box distribution since usually only one strip is hit. The resolution in the longitudinal coordinate (z for barrel, r for forward) is 1.5 mm, compared with the naive expectation of (pitch/$\tan\mu$)/$\sqrt{6}$ = 2 mm (which assumes a triangle distribution).

No alignment errors are simulated at present. They are under study and will be included in a subsequent version.

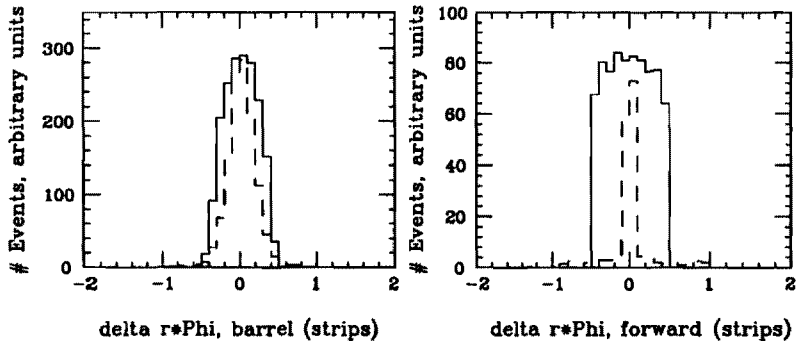

Figure 8 a) R*Phi hit residuals (reconstructed-generated) in strips for barrel. The solid (dashed) histogram is for single (double) strip clusters. b) R*Phi hit residuals for forward.

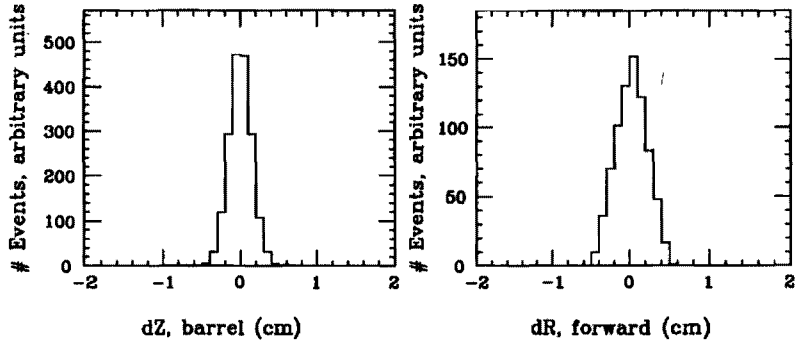

Figure 9 a) Z hit residuals (reconstructed-generated) in barrel detectors. b) R residuals for forward detectors.

APPENDIX A

KUIP Commands

A.1 Geometry commands

The silicon system geometry can be set up using KUIP commands. The default geometry is defined in BLOCK DATA statements in the code so that the user doesn't need to invoke anything to have it defined. However, if changes are going to be made, then the following KUIP commands should be used to define the silicon wafers as described in this document. Following the list of available KUIP commands is the data (KUMAC) file corresponding to the default geometry.

GEOMETRY

Set geometry parameters for the Silicon Tracking system

READ filnam

```
FILNAM      C 'file name'
```

Read geometry definition from a file. Not implemented yet.

MODULE imod nlay itype nmat thick dedw dedz denfac [waftlt]

```
IMOD      I 'module number' D=1 R=1:3
NLAY      I 'number of layers' R=0:25
ITYPE     I 'detector type code' D=1 R=1:2
NMAT      I 'support structure material number' D=6 R=1:100
THICK     R 'detector thickness (cm)' D=0.3000000E-01 R=0:1
DEDW      R 'dead region at wafer edges (cm)' D=0.5000000E-01 R=0:1
DEDZ      R 'dead region at wafer ends (cm)' D=0.5000000E-01 R=0:1
DENFAC    R 'density factor for silicon' D=1 R=0:10
WAFTLT    R 'wafer tilt angle (radians)' D=0.1309 R=0:1
```

LAYER ilay nwaf laypos lowlim hilim laythk pitch stereo radlen th resh

```
ILAY      I 'Layer number' R=1:25
NWAF      R 'Number of divisions (in z for barrel, r for forward)'
LAYPOS    R 'Position of layer (r:barrel, z:forward)'
LOWLIM    R 'Low limit of extent (z:barrel, r:forward)'
HILIM     R 'High limit of extent (z:barrel, r:forward)'
LAYTHK    R 'Thickness including support material(cm)' D=1
PITCH     R 'Strip pitch for layer (cm)' D=0.5000000E-02
STEREO    R 'Stereo angle for layer (radian)' D=0.5000000E-02
RADLEN    R 'Radiaation lengths in support for layer' D=0.5000000E-02
THRESH    R 'Discriminator energy threshold' D=0.2000000E-04
```

WAFER iwaf lowlim hilim nphi phi0 width [waftyp oddoff evenoff p itch stereo]

```
IWAF      I 'Wafer number in z for barrel, r for forward'
LOWLIM    R 'Low limit of extent (z:barrel, r:forward) (cm)'
HILIM     R 'High limit of extent (z:barrel, r:forward) (cm)'
NPHI      R 'Number of detectors in phi'
PHIO      R 'Phi position of first phi detector' D=0
WIDTH     R 'Width of each phi detector (cm:barrel, radians:forward)'
WAFTYP    I 'Wafer type code (see document)' D=1 R=-4:4
ODDOFF    R 'Placement offset for odd numbered phi wafers' D=0
EVENOF    R 'Placement offset for even numbered phi wafers' D=0
PITCH     R 'Strip pitch for wafer (cm) [supersedes layer]' D=0
STEREO    R 'Stereo angle for wafer (radians) [supercedes layer]' D=0
```


ENCLOSURE rmin rmax zmax [inwidth outwidth]

```
RMIN      R 'Inner radius of gas enclosure (cm)' D=7
RMAX      R 'Outer radius of gas enclosure (cm)' D=50
ZMAX      R 'Half-length of gas enclosure (cm)' D=300
INWIDT    R 'Width of inner wall (cm)' D=0.1
OUTWID    R 'Width of outer wall (cm)' D=0.1
```

Specify dimensions of gas enclosure

The file ST_CDR_02.KUMAC has a default description which can be used as a template for changes. Note that the commands can't be ordered randomly; *e.g.*, the ST/GEOMETRY/WAFER command uses the layer number defined in the previous ST/GEOMETRY/LAYER.

```
message "ST CDR 02.KUMAC square barrel, new default layout "
*  difference between this and st-cdr-01 is half length of enclosure vessel
*  difference between st-cdr-01 and st-cdr-00 is the amount of support
*  material in layers 1,2 3 of the barrel, and the inner gas
*  enclosure is thinner and moved.  The final number of rad lengths
*  at eta=0 is lower by .15% as well.
*
* Setup silicon system geometry
*
* Module parameters specified on ST/GEOM/MODULE command:
* ==================================================
* Module number
* Number of layers
* Detector type (unused, always 1)
* Material no. of support structure (6 for carbon)
* Thickness of silicon wafers (cm)
* Dead region at ends of wafers (cm)
* Dead region at sides of wafers (cm)
* Density factor for silicon (normally 1.0)
* Tilt angle (compensates for Lorentz angle) (radians, barrel only)
*
* Layer parameters specified on ST/GEOM/LAYER command:
* ====================================================
```

```
* Layer number
* Number of z wafers (barrel) or rings (forward)
* Position (r:barrel, z:forward, cm)
* Minimum extent (z:barrel, r:forward, cm)
* Maximum extent (z:barrel, r:forward, cm)
* Layer thickness (cm, including support material)
* Strip pitch (cm)
* Stereo angle (radians)
* Radiation lengths of support material
* Energy threshold for digitization (GeV)
*
* Wafer parameters specified on ST/GEOM/WAFER command:
* ==================================================
* Wafer number
* Minimum extent (in Z for barrel, r for forward) (cm)
* Maximum extent (in Z for barrel, r for forward) (cm)
* Number of phi wafers
* Phi offset of phi wafer 1 (radians)
* Wafer width (cm for barrel, radians for forward)
* Wafer type (see document; 1:readout at low Z or r, 2:readout at high Z or r)
* Position offset of odd phi wafers (r for barrel, Z for forward) (cm)
* Position offset of even phi wafers (r for barrel, Z for forward) (cm)
* Pitch at outer radius for forward detectors
*
* Barrel module parameters (module 1):
* ==================================
* change enclosure to be .5mm, 5 cm radius, 260 cm half length
ST/GEOM/ENCLOSURE 5. 50. 260. .05 .1
*
ST/GEOM/MODULE 1 8 1 6 .03 .06 .06 1. .1309
*
*     decrease the amount of support material
ST/GEOM/LAYER 1 10 9. -30.2  30.2   1.  .005   .010  .0020 .00003
*
ST/GEOM/WAFER 1  -30.2 -24.2 18   0.   3.32  1 0. 0.
ST/GEOM/WAFER 2  -24.2 -18.2 18   0.   3.32  2 0. 0.
ST/GEOM/WAFER 3  -18.2 -12.2 18   0.   3.32 -2 0. 0.
ST/GEOM/WAFER 4  -12.2  -6.2 18   0.   3.32 -1 0. 0.
ST/GEOM/WAFER 5   -6.0   0.0 18   0.   3.32  1 0. 0.
ST/GEOM/WAFER 6    0.0   6.0 18   0.   3.32  2 0. 0.
```



```
ST/GEOM/WAFER 7    6.0  12.0 18   0.   3.32 -2 0. 0.
ST/GEOM/WAFER 8   12.0  18.0 18   0.   3.32 -1 0. 0.
ST/GEOM/WAFER 9   18.2  24.2 18   0.   3.32 -2 0. 0.
ST/GEOM/WAFER 10  24.2  30.2 18   0.   3.32 -1 0. 0.
*
*     decrease the amount of support material
ST/GEOM/LAYER 2 10  12. -30.2  30.2   1.  .005  -.010  .0020 .00003
*
ST/GEOM/WAFER 1  -30.2 -24.2 24   0.   3.32  1 0. 0.
ST/GEOM/WAFER 2  -24.2 -18.2 24   0.   3.32  2 0. 0.
ST/GEOM/WAFER 3  -18.0 -12.0 24   0.   3.32  1 0. 0.
ST/GEOM/WAFER 4  -12.0  -6.0 24   0.   3.32  2 0. 0.
ST/GEOM/WAFER 5   -6.0   0.0 24   0.   3.32 -2 0. 0.
ST/GEOM/WAFER 6    0.0   6.0 24   0.   3.32 -1 0. 0.
ST/GEOM/WAFER 7    6.2  12.2 24   0.   3.32  1 0. 0.
ST/GEOM/WAFER 8   12.2  18.2 24   0.   3.32  2 0. 0.
ST/GEOM/WAFER 9   18.2  24.2 24   0.   3.32 -2 0. 0.
ST/GEOM/WAFER 10  24.2  30.2 24   0.   3.32 -1 0. 0.
*
* adjust the support material;  move some from lay 1 and 2
ST/GEOM/LAYER 3 10 18. -30.2  30.2   1.  .005   .010  .0050 .00003
*
ST/GEOM/WAFER 1  -30.2 -24.2 36   0.   3.32  1 0. 0.
ST/GEOM/WAFER 2  -24.2 -18.2 36   0.   3.32  2 0. 0.
ST/GEOM/WAFER 3  -18.2 -12.2 36   0.   3.32 -2 0. 0.
ST/GEOM/WAFER 4  -12.2  -6.2 36   0.   3.32 -1 0. 0.
ST/GEOM/WAFER 5   -6.0   0.0 36   0.   3.32  1 0. 0.
ST/GEOM/WAFER 6    0.0   6.0 36   0.   3.32  2 0. 0.
ST/GEOM/WAFER 7    6.0  12.0 36   0.   3.32 -2 0. 0.
ST/GEOM/WAFER 8   12.0  18.0 36   0.   3.32 -1 0. 0.
ST/GEOM/WAFER 9   18.2  24.2 36   0.   3.32 -2 0. 0.
ST/GEOM/WAFER 10  24.2  30.2 36   0.   3.32 -1 0. 0.
*
ST/GEOM/LAYER 4 10 21. -30.2  30.2   1.  .005  -.010  .0035 .00003
*
ST/GEOM/WAFER 1  -30.2 -24.2 42   0.   3.32  1 0. 0.
ST/GEOM/WAFER 2  -24.2 -18.2 42   0.   3.32  2 0. 0.
ST/GEOM/WAFER 3  -18.0 -12.0 42   0.   3.32  1 0. 0.
ST/GEOM/WAFER 4  -12.0  -6.0 42   0.   3.32  2 0. 0.
ST/GEOM/WAFER 5   -6.0   0.0 42   0.   3.32 -2 0. 0.
ST/GEOM/WAFER 6    0.0   6.0 42   0.   3.32 -1 0. 0.
```

```
ST/GEOM/WAFER 7    6.2  12.2 42   0.   3.32  1 0. 0.
ST/GEOM/WAFER 8   12.2  18.2 42   0.   3.32  2 0. 0.
ST/GEOM/WAFER 9   18.2  24.2 42   0.   3.32 -2 0. 0.
ST/GEOM/WAFER 10  24.2  30.2 42   0.   3.32 -1 0. 0.
*
ST/GEOM/LAYER 5 10  24. -30.2  30.2   1.  .005   .010  .0035 .00003
*
ST/GEOM/WAFER 1  -30.2 -24.2 48   0.   3.32  1 0. 0.
ST/GEOM/WAFER 2  -24.2 -18.2 48   0.   3.32  2 0. 0.
ST/GEOM/WAFER 3  -18.2 -12.2 48   0.   3.32 -2 0. 0.
ST/GEOM/WAFER 4  -12.2  -6.2 48   0.   3.32 -1 0. 0.
ST/GEOM/WAFER 5   -6.0   0.0 48   0.   3.32  1 0. 0.
ST/GEOM/WAFER 6    0.0   6.0 48   0.   3.32  2 0. 0.
ST/GEOM/WAFER 7    6.0  12.0 48   0.   3.32 -2 0. 0.
ST/GEOM/WAFER 8   12.0  18.0 48   0.   3.32 -1 0. 0.
ST/GEOM/WAFER 9   18.2  24.2 48   0.   3.32 -2 0. 0.
ST/GEOM/WAFER 10  24.2  30.2 48   0.   3.32 -1 0. 0.
*
ST/GEOM/LAYER 6 10  27. -30.2  30.2   1.  .005  -.010  .0035 .00003
*
ST/GEOM/WAFER 1  -30.2 -24.2 54   0.   3.32  1 0. 0.
ST/GEOM/WAFER 2  -24.2 -18.2 54   0.   3.32  2 0. 0.
ST/GEOM/WAFER 3  -18.0 -12.0 54   0.   3.32  1 0. 0.
ST/GEOM/WAFER 4  -12.0  -6.0 54   0.   3.32  2 0. 0.
ST/GEOM/WAFER 5   -6.0   0.0 54   0.   3.32 -2 0. 0.
ST/GEOM/WAFER 6    0.0   6.0 54   0.   3.32 -1 0. 0.
ST/GEOM/WAFER 7    6.2  12.2 54   0.   3.32  1 0. 0.
ST/GEOM/WAFER 8   12.2  18.2 54   0.   3.32  2 0. 0.
ST/GEOM/WAFER 9   18.2  24.2 54   0.   3.32 -2 0. 0.
ST/GEOM/WAFER 10  24.2  30.2 54   0.   3.32 -1 0. 0.
*
ST/GEOM/LAYER 7 10  33. -30.2  30.2   1.  .005  .010  .0035 .00003
*
ST/GEOM/WAFER 1  -30.2 -24.2 66   0.   3.32  1 0. 0.
ST/GEOM/WAFER 2  -24.2 -18.2 66   0.   3.32  2 0. 0.
ST/GEOM/WAFER 3  -18.2 -12.2 66   0.   3.32 -2 0. 0.
ST/GEOM/WAFER 4  -12.2  -6.2 66   0.   3.32 -1 0. 0.
ST/GEOM/WAFER 5   -6.0   0.0 66   0.   3.32  1 0. 0.
ST/GEOM/WAFER 6    0.0   6.0 66   0.   3.32  2 0. 0.
ST/GEOM/WAFER 7    6.0  12.0 66   0.   3.32 -2 0. 0.
ST/GEOM/WAFER 8   12.0  18.0 66   0.   3.32 -1 0. 0.
ST/GEOM/WAFER 9   18.2  24.2 66   0.   3.32 -2 0. 0.
```



```
ST/GEOM/WAFER 10  24.2  30.2 66   0.   3.32 -1 0. 0.
*
ST/GEOM/LAYER 8 10  36. -30.2  30.2   1.  .005  -.010  .0035 .00003
*
ST/GEOM/WAFER 1  -30.2 -24.2 72   0.   3.32  1 0. 0.
ST/GEOM/WAFER 2  -24.2 -18.2 72   0.   3.32  2 0. 0.
ST/GEOM/WAFER 3  -18.0 -12.0 72   0.   3.32  1 0. 0.
ST/GEOM/WAFER 4  -12.0  -6.0 72   0.   3.32  2 0. 0.
ST/GEOM/WAFER 5   -6.0   0.0 72   0.   3.32 -2 0. 0.
ST/GEOM/WAFER 6    0.0   6.0 72   0.   3.32 -1 0. 0.
ST/GEOM/WAFER 7    6.2  12.2 72   0.   3.32  1 0. 0.
ST/GEOM/WAFER 8   12.2  18.2 72   0.   3.32  2 0. 0.
ST/GEOM/WAFER 9   18.2  24.2 72   0.   3.32 -2 0. 0.
ST/GEOM/WAFER 10  24.2  30.2 72   0.   3.32 -1 0. 0.
*
*
* Forward module parameters (module 3 assumed to be same as module 2)
* ==================================================================
* .9 mm dead area at outer edge of readout unit
*
ST/GEOM/MODULE 3  13  1  6 .03    .06   .06    1.
*
*
ST/GEOM/LAYER  1 4   33.0  14.9 39.2  2.1 .005  -.010  .0035 .00003
ST/GEOM/WAFER  1 14.9 20.9  26  0.    0.2493308   -2 -1.  1.
ST/GEOM/WAFER  2 20.9 26.9  26  0.    0.2493308   -1 -1.  1. .00514
ST/GEOM/WAFER  3 27.2 33.2  38  0.    0.1706806   -2 -1.  1.
ST/GEOM/WAFER  4 33.2 39.2  38  0.    0.1706806   -1 -1.  1. .00513
*
ST/GEOM/LAYER  2 4   38.0  14.9 39.2  2.1 .005   .010  .0035 .00003
ST/GEOM/WAFER  1 14.9 20.9  26  0.01  0.2493308   -2 -1.  1.
ST/GEOM/WAFER  2 20.9 26.9  26  0.01  0.2493308   -1 -1.  1. .00514
ST/GEOM/WAFER  3 27.2 33.2  38  0.01  0.1706806   -2 -1.  1.
ST/GEOM/WAFER  4 33.2 39.2  38  0.01  0.1706806   -1 -1.  1. .00513
*
ST/GEOM/LAYER  3 4   44.0  14.9 39.2  2.1 .005  -.010  .0035 .00003
ST/GEOM/WAFER  1 14.9 20.9  26  0.02  0.2493308   -2 -1.  1.
ST/GEOM/WAFER  2 20.9 26.9  26  0.02  0.2493308   -1 -1.  1. .00514
ST/GEOM/WAFER  3 27.2 33.2  38  0.02  0.1706806   -2 -1.  1.
ST/GEOM/WAFER  4 33.2 39.2  38  0.02  0.1706806   -1 -1.  1. .00513
*
ST/GEOM/LAYER  4 4   52.0  14.9 39.2  2.1 .005   .010  .0035 .00003
```

```
ST/GEOM/WAFER  1 14.9 20.9  26  0.03  0.2493308   -2 -1.  1.
ST/GEOM/WAFER  2 20.9 26.9  26  0.03  0.2493308   -1 -1.  1. .00514
ST/GEOM/WAFER  3 27.2 33.2  38  0.03  0.1706806   -2 -1.  1.
ST/GEOM/WAFER  4 33.2 39.2  38  0.03  0.1706806   -1 -1.  1. .00513
*
ST/GEOM/LAYER  5 4   61.0  14.9 39.2  2.1 .005  -.010  .0035 .00003
ST/GEOM/WAFER  1 14.9 20.9  26  0.04  0.2493308   -2 -1.  1.
ST/GEOM/WAFER  2 20.9 26.9  26  0.04  0.2493308   -1 -1.  1. .00514
ST/GEOM/WAFER  3 27.2 33.2  38  0.04  0.1706806   -2 -1.  1.
ST/GEOM/WAFER  4 33.2 39.2  38  0.04  0.1706806   -1 -1.  1. .00513
*
ST/GEOM/LAYER  6 4   72.0  14.9 39.2  2.1 .005   .010  .0035 .00003
ST/GEOM/WAFER  1 14.9 20.9  26  0.05  0.2493308   -2 -1.  1.
ST/GEOM/WAFER  2 20.9 26.9  26  0.05  0.2493308   -1 -1.  1. .00514
ST/GEOM/WAFER  3 27.2 33.2  38  0.05  0.1706806   -2 -1.  1.
ST/GEOM/WAFER  4 33.2 39.2  38  0.05  0.1706806   -1 -1.  1. .00513
*
ST/GEOM/LAYER  7 4   85.0  14.9 39.2  2.1 .005  -.010  .0035 .00003
ST/GEOM/WAFER  1 14.9 20.9  26  0.06  0.2493308   -2 -1.  1.
ST/GEOM/WAFER  2 20.9 26.9  26  0.06  0.2493308   -1 -1.  1. .00514
ST/GEOM/WAFER  3 27.2 33.2  38  0.06  0.1706806   -2 -1.  1.
ST/GEOM/WAFER  4 33.2 39.2  38  0.06  0.1706806   -1 -1.  1. .00513
*
ST/GEOM/LAYER  8 4  102.0  14.9 39.2  2.1 .005   .010  .0035 .00003
ST/GEOM/WAFER  1 14.9 20.9  26  0.07  0.2493308   -2 -1.  1.
ST/GEOM/WAFER  2 20.9 26.9  26  0.07  0.2493308   -1 -1.  1. .00514
ST/GEOM/WAFER  3 27.2 33.2  38  0.07  0.1706806   -2 -1.  1.
ST/GEOM/WAFER  4 33.2 39.2  38  0.07  0.1706806   -1 -1.  1. .00513
*
ST/GEOM/LAYER  9 4  122.0  14.9 39.2  2.1 .005  -.010  .0035 .00003
ST/GEOM/WAFER  1 14.9 20.9  26  0.08  0.2493308   -2 -1.  1.
ST/GEOM/WAFER  2 20.9 26.9  26  0.08  0.2493308   -1 -1.  1. .00514
ST/GEOM/WAFER  3 27.2 33.2  38  0.08  0.1706806   -2 -1.  1.
ST/GEOM/WAFER  4 33.2 39.2  38  0.08  0.1706806   -1 -1.  1. .00513
*
ST/GEOM/LAYER 10 4  146.0  22.4 46.7  2.1 .005   .010  .0035 .00003
ST/GEOM/WAFER  1 22.4 28.4  32  0.09  0.2024845   -2 -1.  1.
ST/GEOM/WAFER  2 28.4 34.4  32  0.09  0.2024845   -1 -1.  1. .00534
ST/GEOM/WAFER  3 34.7 40.7  44  0.09  0.1471783   -2 -1.  1.
ST/GEOM/WAFER  4 40.7 46.7  44  0.09  0.1471783   -1 -1.  1. .00527
*
ST/GEOM/LAYER 11 3  178.0  28.4 46.7  2.1 .005  -.010  .0035 .00003
```



```
ST/GEOM/WAFER  1 28.4 34.4  32  0.10  0.2024845   -1 -1.  1. .00534
ST/GEOM/WAFER  2 34.7 40.7  44  0.10  0.1471783   -2 -1.  1.
ST/GEOM/WAFER  3 40.7 46.7  44  0.10  0.1471783   -1 -1.  1. .00527
*
ST/GEOM/LAYER 12 2  218.0  34.7 46.7  2.1 .005   .010  .0035 .00003
ST/GEOM/WAFER  1 34.7 40.7  44  0.11  0.1471783   -2 -1.  1.
ST/GEOM/WAFER  2 40.7 46.7  44  0.11  0.1471783   -1 -1.  1. .00527
*
ST/GEOM/LAYER 13 1  258.0  40.7 46.7  2.1 .005  -.010  .0035 .00003
ST/GEOM/WAFER  1 40.7 46.7  44  0.12  0.1471783   -1 -1.  1. .00527
```

A.2 KUIP command for options

There are also other KUIP commands defined that control the program flow, the output of the package (*i.e.*, which banks are written out) and some of the simulation parameters. They are listed below.

STATUS

Show version and status of ST package.

FLAGS flag1 flag2 flag3 flag4 flag5

```
FLAG1      I 'Geometry flag' D=1 R=0:3
FLAG2      I 'Hits flag' D=1 R=0:3
FLAG3      I 'Digitization flag' D=1 R=0:3
FLAG4      I 'Reconstruction flag' D=0 R=0:3
FLAG5      I 'Monitor routine flag' D=0 R=0:2
```

Set internal package flags for silicon code.

DIGI bnksta

```
BNKSTA     C 'Whether to create /STDI bank' D='Y' R='Y,N'
```

Enable/disable creation of /STDI raw digitized data bank. This bank is created by default.

HITS bnksta

```
BNKSTA     C 'Whether to create /STHI, /STDP banks' D='Y' R='Y,N'
```

Enable/disable creation of /STHI and /STDP banks. The /STHI bank is for Monte-Carlo true hit positions, useful for studying hit resolution, and the /STDP bank contains pointers from /STDI to /STHI. These banks are not created by default.

TOF tofmin tofmax [tofres]

```
TOFMIN     R 'Lower time limit (seconds)' D=-0.1500000E-07
TOFMAX     R 'Upper time limit (seconds)' D=0.1500000E-07
TOFRES     R 'Time resolution' D=0 R=0:0.1000000E-06
```

Set active time window and time resolution for silicon strips. Particles will generate hits and digitizations if the measured time (TOFG, smeared by resolution TOFRES) is within the interval TOF(nominal)+TOFMIN ¡ TOF ¡ TOF(nominal)+TOFMAX. The nominal TOF is the time for particles created at x=y=z=t=0 to reach the layer in question, assuming v=c.

MERGE lmerge

```
LMERGE     C 'Whether to merge digis into existingSTDI' D='N' R='Y,N'
```

Enable/disable merging digitizations with existing raw data. Useful for reading minimum-bias overlap from a file in the input stream. If disabled, program will terminate if /STDI already exists in input stream.

APPENDIX B

Description of data banks

The following is extracted from the tracking bank documentation and shows the tree structure of the "raw" data banks. Also listed are the contents of each of the banks.

```
[HEAD]
   |
 2 |--[RAWD]
   |     |
   |   3 |--[RTRK]                                                    [TRRA]
   |     |   1 |---[STRA]                . silicon barrel tracker
   |     |     |    1 |---[STSS >                . silicon layers
   |     |     |          1 |---[STHI]           . silicon MC hits
   |     |     |          2 |---[STDI >          . silicon digitizations
   |     |     |                1 |---[STDP]     . pointers to hits
   |     |     |
   |     |   2 |---[STIA]                .silicon forward tracker
   |     |     |    1 |---[STSS >                . silicon layers
   |     |     |          1 |---[STHI]           . silicon MC hits
   |     |     |          2 |---[STDI >          . silicon digitizations
   |     |     |                1 |---[STDP]     . pointers to hits
   |     |     |
/RAWD/RTRK/STRA (Silicon barrel module header bank)
/RAWD/RTRK/STIA (Silicon forward module header bank)
CA)=================================================================
C  STRA:   Silicon raw data for module
CB)=================================================================
C   version no : 1
C     no. type  contents
C-------------------------------------------------------------------
       1    I   Number of Z modules (could be Z module number, more useful)
       2    I   Number of layers in this module
       3    I   Bank structure version number
CC)-----------------------------------------------------------------
C  daughter bank 1 : STSS
C
C  created in     :   STDICR
C  referenced in  :   TSUPDI
C
C  originally defined by :
```

```
C  originally defined by :
C  history :          21/03/91  Bradley Hubbard, UC Santa Cruz    Implemented
C
C  long description :
C  The silicon system is divided into 3 modules.  There is one STRA bank for
C  the barrel module, and an STIA banks for each of the two forward modules.
C  The bank numbers are the module numbers: (1:barrel, 2:forward -Z, and
C  3:forward +Z).
CD)==================================================================
/RAWD/RTRK/STRA/STSS (Silicon barrel layer header bank)
/RAWD/RTRK/STIA/STSS (Silicon forward layer header bank)
CA)==================================================================
C  STSS:   Silicon raw data for layer
CB)==================================================================
C   version no : 1
C     no. type  contents
C-------------------------------------------------------------------
       1    I   Module number
       2    I   Layer number
       3    I   Number of sublayers (2 for axial + stereo sides)
       4    I   NWHIT Number of words per hit in STHI bank
       5    I   NWDIG Number of words per digitization in STDI bank
CC)-----------------------------------------------------------------
C  daughter bank 1 : STHI
C  daughter bank 2 : STDI
C
C  created in    :   STDICR
C  referenced in :   TSUPDI
C
C  originally defined by :
C  history :          15/07/91  Bradley Hubbard, UC Santa Cruz    Implemented
C
C  long description :
C  Raw data for the silicon system is organized in layers, each of which
C  two sides (axial and stereo), which can be considered as sublayers.
C  For each module, there is one STSS bank per layer, with the bank number
C  equal to the layer number within the module.
CD)==================================================================
/RAWD/RTRK/STRA/STSS/STHI
/RAWD/RTRK/STIA/STSS/STHI
```



```
CA)==================================================================
C  STHI: Monte-Carlo hits in silicon layers
CB)==================================================================
C   version no : 1
C     no.  type  contents
C-------------------------------------------------------------------
       1     I   IWFHI    inclusive word count            (0:60000)  integer
       2     I   ILAY     layer #                            (1:31)  integer
       3     I   NHITL    # hits in this layer            (0:10000)  integer
for hit number IH in this layer:
 4+9*(IH-1)  R  X        x coordinate (at layer center)(-200., 200.)   Real
 5+9*(IH-1)  R  Y        y coordinate       (")        (-200., 200.)   Real
 6+9*(IH-1)  R  Z        z coordinate       (")        (-600., 600.)   Real
 7+9*(IH-1)  R  XPR      x direction cosine            (-1., 1.)       Real
 8+9*(IH-1)  R  YPR      y direction cosine            (-1., 1.)       Real
 9+9*(IH-1)  R  ZPR      z direction cosine            (-1., 1.)       Real
10+9*(IH-1)  R  P        local momentum (GeV/c)        (-1.E6, 1.E6)   Real
11+9*(IH-1)  R  TOF      time (secs)                   (-1.  , 1.  )   Real
12+9*(IH-1)  I  MCTK     Monte Carlo vertex/track #                   Integer
                          track #     bits  1:16  (0:65535)
                          vertex #    bits 17:32  (0:65535)
CC)-----------------------------------------------------------------
C  daughter bank 1 : None
C
C  created in    :   STDICR
C  referenced in :
C
C  originally defined by :
C  history :          21/05/91  Bradley Hubbard, UC Santa Cruz    Implemented
C
C  long description :
C  The STHI bank contains the 'true' Monte-Carlo hit positions in each
C  layer.  There is one STHI bank per layer, with bank number 1.
C  This bank is not created by default, but can be enabled via KUIP
C  with the ST/HITS command (see ST.DOC).
CD)==================================================================
/RAWD/RTRK/STRA/STSS/STDI
/RAWD/RTRK/STIA/STSS/STDI
CA)==================================================================
C  STDI:   Digitizations in silicon layers
```

```
CB)==================================================================
C   version no : 1
C     no.  type  contents
C-------------------------------------------------------------------
       1     I   IWFHI    inclusive word count            (0:60000)  integer
       2     I   ISIDE    sublayer # (1:axial, 2:stereo)     (1:31)  integer
       3     I   NDIGL    # digis in this sublayer        (0:10000)  integer
for digitization number ID in this layer:
 4+2*(ID-1)  B   IDATUM   packed data
 5+2*(ID-1)  I   MCTK     Monte Carlo vertex/track number            integer
                          track #     bits  1:16  (0:65535)
                          vertex #    bits 17:32  (0:65535)
CC)-----------------------------------------------------------------
C  daughter bank 1 : STDP
C
C  created in    :   STDICR
C  referenced in :   TSUPDI
C
C  originally defined by :
C  history :         21/03/91  Bradley Hubbard, UC Santa Cruz    Implemented
C
C  long description :
C
C     For each layer, there are two STDI banks, numbered 1 and 2 for axial
C     and stereo data, respectively.
C
C     In the STDI structure, raw data are packed into one word:
C
C         bits    quantity                          range
C         ---------------------------------------------
C         1:8     wafer # in phi                    0:255
C         9:16    wafer # in z (r for fwd)          0:255
C         17:27   strip # in wafer                  0:2047
C         28      strip type (0:axial,1:stereo)     0:1
C         29:32   # strips in cluster -1            0:15
C
C   Optionally, if NWDIG=1 in /STSS, the Monte-Carlo track/vertex
C   number may be onitted, as would be the case for real data.
C
C   The routine TSUPDI has been provided to unpack the STDI data into
C   a temporary common, in which case the data can be accessed using
```



```
C   a set of statement functions.  These are described in ST.DOC.
C   It is recommended that the data be accessed in this fashion if possible.
C
CD)==================================================================
/RAWD/RTRK/STRA/STSS/STDP
/RAWD/RTRK/STIA/STSS/STDP
CA)==================================================================
C  STDP:   Pointers from digitizations in /STDI to hits in /STHI
CB)==================================================================
C   version no : 1
C     no. type  contents
C-------------------------------------------------------------------
       1     I   IWFDP    inclusive word count            (0:60000)  integer
       2     I   ILAY     sublayer # (1:axial, 2:stereo)     (1:31)  integer
       3     I   NDIGL    # digis in this sublayer        (0:10000)  integer
C  A variable length block is repeated for each digitizing within the layer.
..             I  NHIT     # of hits contributing to this digitizing
..+2*(IH-1)+1  I  IHIT     sequence # of hit in xxHI bank       (0:65535)
..+2*(IH-1)+2  I  MCTK     Monte Carlo vertex/track number
                          track #     bits  1:16  (0:65535)
                          vertex #    bits 17:32  (0:65535)
C  The hit address in xxHI bank would be  3 + (IHIT-1)*NWHI           integer
CC)-----------------------------------------------------------------
C  daughter bank 1 : None
C
C  created in    :   STDICR
C  referenced in :
C
C  originally defined by :
C  history :         21/05/91  Bradley Hubbard, UC Santa Cruz    Implemented
C
C  long description :
C
C  To find the pointer corresponding to a given digitizing, it is necessary
C  to count through all the pointers for that layer until the correct one is
C  reached, since the number of pointers per digitizing is variable.
C
C  This bank is not created by default, but can be enabled via KUIP
C  with the ST/HITS command (see ST.DOC).
C
CD)==================================================================
```

APPENDIX C

Utility routines

There are several routines in the ST package that may be useful to others. They primarily deal with defining or interpreting where the detectors are in space. In addition, a set of statement functions is defined which eliminates the need to access the geometry information directly from a bank or from temporary space.

The first routine, STTRKR, must be called before using the ST or TS package. It takes the variables read in by KUIP and sets up the geometry. Two other routines, STBPOS and STFPOS, calculate the x, y, z intersection of a track with a given barrel or forward detector. Perhaps the most useful routine is STCOOR which calculates the 3 dimensional coordinates of a pair of axial and stereo hits.

Following is a list of the statement functions that can be used to find geometry or hit information.

```
C
C  GEOMETRY STATEMENT FUNCTIONS
C
C    information for each module
C
C    (constants for each module:)
C    SIMLLI(M) - inner position eg inner radius for barrel
C    SIMHLI(M) - Outer position eg outer z position for module 2,3
C    SIMLAN(M) - Low angle limit wrt +z direction (eg barrel is pi/2)
C    SIMHAN(M) - High angle limit wrt +z direction (eg barrel is 3pi/2)
C    SIMDFA(M) - Density factor for support material
C    SIMDAR(M,EDGE) - dead area in cm at sides and ends of wafers
C      SIMDAR(M,1) - dead area on sides of wafer
C      SIMDAR(M,2) - dead area at end edge which has readout chips
C      SIMDAR(M,3) - dead area at end edge which has no readout chips
C    SIMDTY(M) - Detector type: barrel:  1:rectangular (BOX)
C                               forward: 1:section of tube (TUBS)
C                                        2:trapezoid (TRD1)
C    SIMNLA(M) - number of layers in the module
C    SIGOLA(M,L) - offset from the start of the module info
C              to the start of the information for that layer
C
C-----------------------------------------------------------------
```



```
C-----------------------------------------------------------------
C
C    information for each layer
C
C    (constants for each layer:)
C    SILPOS(M,L) - position of the (inner) edge of layer; r in barrel,
C                                          z in disks
C    SILLLI(M,L) - lower limit
C    SILHLI(M,L) - high limit
C    SILTHK(M,L) - wafer thickness
C    SILTLT(M,L) - tilt angle
C    SILETH(M,L) - energy threshold that was used to determine if the
C             strip was hit or not
C    SILRLN(M,L) - number of radiation lengths of SI and support, (est)
C            at normal incidence.  Support material is assumed to be
C            uniformly distributed within layer.
C    SILNRU(M,L) - number of readout units along length of layer
C             (ie 2 of the above wafers may be bonded together
C             to form a readout unit)
C    SIGORU(M,L,R) - offset from start of the layer information to
C            the start of the information for the readout units
C
C    (number and offset:)
C    SILNWA(M,L) - number of wafer divisions along extent of layer
C           (eg number of wafers in z in barrel,
C              number of rings in r in disks)
C           this should be at the WAFER level (not coupled
C           readout units)
C    SIGOWA(M,L,W) - offset from the start of the layer information to
C            the start of the information for the divisions
C             (z wafers in barrel, r rings in disk)
C
C-----------------------------------------------------------------------
C
C    information for each z wafer ring or r ring
C
C    SIWLLI(M,L,W) - lower limit of wafer set(eg z position of wafer in barrel
C    SIWHLI(M,L,W) - high limit of wafer set ( ")
C    SIWOOF(M,L,W) - position offset of odd phi wafers
```

```
C     SIWEOF(M,L,W) - position offset of even phi wafers
C     SIWWID(M,L,W) - wafer width (cm in barrel, phi in forward) including dead
C     SIWPCH(M,L,W) - wafer pitch (in cm)
C     SIWSAN(M,L,W) - wafer stereo angle
C     SIWSOF(M,L,W) - offset in cm between stereo strip 1 and axial strip 1,
C                     defined at the readout end of the wafer.  This is
C                     used to take into account additional stereo dead area
C                     in multiple wafer readout units.
C     SIWPHO(M,L,W) - lowest phi position for start of one wafer
C     SIWNPH(M,L,W) - number of detectors counted along phi
C     SIWNST(M,L,W) - number of strips in one wafer
C     SIWTYP(M,L,W) - the type of wafer in this ring.  This word indicates
C                     the sequence of the wafer in a larger readout unit.
C                     Positive (negative) values indicate that the readout
C                     unit has chips at the low (high) limit end.
C              1 => chips bonded to low limit end of this wafer
C             -1 => chips bonded to high limit end of this wafer
C              2 => the wafer has no chips, and is bonded to wafer type 1
C                   at its lower limit
C             -2 => no chips, bonded to wafer type -1 at higher limit
C     SIWRUN(M,L,W) - Readout unit number for this wafer
C     SIWSCH(M,L,W) - Stereo scheme for this wafer.
C              1 => default scheme (only one defined at present)
C
C-----------------------------------------------------------------------
C
C     Information for each readout unit
C
C     SIRWBE(M,L,R) - beginning wafer number for readout unit
C                     (the one with the chips)
C     SIRWEN(M,L,R) - end wafer number for readout unit
C
C=======================================================================
C
C   DIGITIZATION STATEMENT FUNCTIONS
C
C     Information stored for each digitization.  Name on the
C      left is function name used to retrieve info.  The arguments
C      are specified as M (module number), L(layer number),
C      W(wafer number), T (type number) and H (hit number).
```



```
C
C     SIWPHI(M,L,T,H) - wafer number in phi for a hit
C     SIWAFZ(M,L,T,H) - readout unit number in r,z for a hit (eg z for barrel)
C     SISTRP(M,L,T,H) - strip number in the wafer for a hit
C     SITYPE(M,L,T,H) - strip type (1=axial, 2=stereo)
C     SIWIDD(M,L,T,H) - cluster width
C     SIMCVT(M,L,T,H) - packed MC vertex and track number
C     SIMCVX(M,L,T,H) - MC vertex number
C     SIMCTR(M,L,T,H) - MC track number
C
C   Additional useful functions (in include SIFUNC)
C
C     SIHITS(M,L,T,H) - like the old HITSI, it returns the azimuthal hit
C              position, taking into account the width
C     SINDIG(M,L) - total number of digitizations in a layer
C     SINAXD(M,L) - number of axial digitizations in a layer
C     SINSTD(M,L) - number of stereo digitizations in a layer
C
C=======================================================================
C
C   COORDINATE STATEMENT FUNCTIONS
C
C     Information stored for each coordinate.
C     Name on the left is function name used to retrieve info.
C     The arguments are specified as M (module number), L(layer number),
C     and H (hit number).
C
C     STCRAD(M,L,H) - radius
C     STCPHI(M,L,H) - phi coordinate
C     STCZ  (M,L,H) - z coordinate
C     STVPHI(M,L,H) - phi variance
C     STVZOR(M,L,H) - z or r variance
C     STCOVR(M,L,H) - covariance
C     STCAXD(M,L,H) - index of axial digi
C     STCSTD(M,L,H) - index of stereo digi
C     STCQUA(M,L,H) - quality word
C
C     Additional useful fumctions (in include STFUNC)
C
C     STNCOO(M,L) - total number of digitizations in a layer
C
```

REFERENCES

[1] B.Hubbard et al., SDC-92-209.

[2] A. Palounek, SDC-92-255.

[3] Y. Unno, private conversation, which agrees quantitatively with the results of Geoff Hall (NIM 220:356,1984).