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Database for GLAST Tracker Construction

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Abstract

The GLAST tracker consists of many components such as about 10000 silicon strip detectors, 600 HDI's (High-Density Interface; a readout electronics unit), 300 detector trays, and so on. Since those components should be kept track of during assembly of GLAST tracker, we need relational database to include assembly status, test results, and relationship between components. In this document, I summarize what functionality of the database we will need, based on our experience in construction of the GLAST BTEM (Beam-Test Engineering Model) tracker. Also, names of tracker components and definition of tracker coordinate system are proposed for use in the database.

1 Introduction

A database for the GLAST tracker assembly (hereafter the assembly database) should store component description, tracker configuration, assembly status, measurement results, and assembling history of assembled components. In addition to simple manipulations such as sorting records, the assembly database should support the tracker construction by promptly giving proper information to operators, the production manager, and other collaborators.

The assembly database should start functioning, at least partially, by January 2001. From January to March 2001, SLAC will receive approximately 300 detectors from a manufacturer. Since all or some of them may be used for the GLAST flight instrument, these detectors should be kept track of from the start in the same way as in the future. It is essential, therefore, to define the structure of the database and build it within year 2000. Also, we should try to make it as close to the final version as possible.

This document describes structure of the assembly database, definition of its contents, the functionality and the accessibility of its user-interface. Most of information here is based on our experience on BTEM tracker construction in 1999 performed mainly at SLAC and at UCSC.

1.1 Model of Tracker Construction

In this document we assume 17 towers will be assembled, 18 detector planes per tower, 4 detector ladders per detector layer, 4 detectors in a detector ladder, 384 strips per detector, and 24 front-end chips per detector layer. Also, all of these components will be assembled as illustrated in Figure1, we assume. If one or more of those numbers change in the future, or if one or more assembly processes will be modified, some part of this document should be modified appropriately.

Construction of the GLAST flight instrument will be done worldwide; SLAC will assemble detector ladders, trays, and towers, Pisa will assemble ladders and trays, UCSC will assemble HDI's, and Hiroshima University will sample and test silicon detectors. Therefore, secure and easy sharing of information is essential for the database design.

1.2 Assembly Processes and Data Tables

The assembly database is a collection of data tables, each of which corresponds to a tracker component or an assembly process (see Section 3 for details). On each assembly process, some information should be taken from one or more data tables to give an instruction to an operator at the assembly site, and results of the operation should be recorded into a table corresponding to the assembly process.

Table 1 lists all the assembly processes we assume in this document, with associated data tables for each of them. Table names used here correspond to the ones defined in definitions of the data tables given later in Section 3.

1.3 Data Tables for Repairs

There are a few data tables recording repairs of a component. In case of replacing a detector in a ladder, a ladder on a tray, or a tray in a tower, the repair record should be recorded in dedicating data tables for them, named “old ladder”, “old tray”, or “old tower”. This is to keep track of re-assignment of subcomponents in a component, such as a detector in a ladder. All the other repairs, such as re-bonding and replacement of chips on an HDI, should be recorded in a data table named “general repair”. Definitions of them are also given later in Section 3.

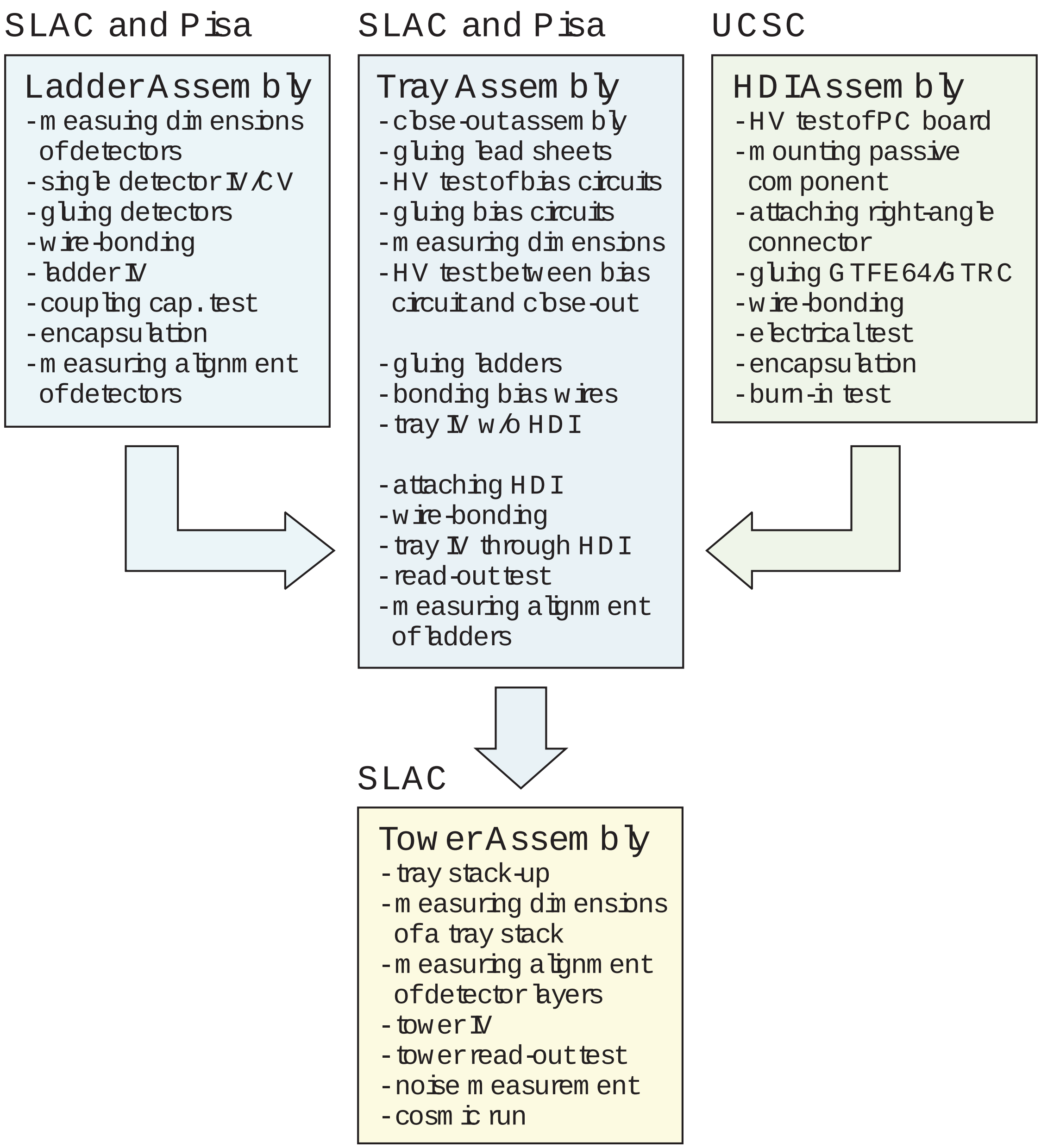

Fig. 1. Flow of tracker construction.

Table 1. Assembly processes and associated data tables in the assembly database

	Table name(s)	
Ladder assembly process	info taken from	data enters to
Measuring dimensions of a detector	Detector	Detector dimension
Single detector IV	Detector, IV curve[a]	IV curve
Single detector CV	Detector, CV curve[a]	CV curve
Gluing detectors	Ladder	Ladder assembly
Wire-bonding	Ladder	Wire-bonding
Ladder IV	Ladder, IV curve[a]	IV curve
Coupling cap. test	Ladder, Detector[b]	Ladder cap-test
Encapsulation	Ladder	Ladder assembly
Measuring alignment of detectors	Ladder	Det-align in ladder
Ladder IV	Ladder, IV curve[a]	IV curve
HDI assembly process		
HV test of PC board	—	HDI assembly
Mounting passive component	HDI	HDI assembly
Attaching right-angle connector	HDI	HDI assembly
Gluing GTFE64 and GTRC	HDI	HDI assembly
Wire-bonding	HDI	Wire-bonding
Electrical test	HDI	HDI E-test
Encapsulation	HDI	HDI assembly
Burn-in test	HDI	HDI burn-in
Tray Assembly process		
Close-out assembly	Tray	Tray assembly
Gluing lead sheets	Tray	Tray assembly
HV test of bias circuits	Tray	Tray assembly
Gluing bias circuits	Tray	Tray assembly
Measuring dimensions	Tray	Tray dimension
HV test between bias circuit and close-out	Tray	Tray assembly
Gluing ladders	Tray, Ladder	Tray assembly
Bonding bias wires	Tray	Wire-bonding
Tray IV w/o HDI	Tray, IV curve[a]	IV curve
Attaching HDI	Tray, HDI	Tray assembly
Wire-bonding	Tray	Wire-bonding
Tray IV through HDI	Tray, IV curve[a]	IV curve
Read-out test	Tray, Detector[b], Ladder cap-test[b], HDI E-test[b]	Tray E-test
Measuring alignment of ladders	Tray	Det-align on tray
Tower assembly process		
Tray stack-up	Tower	Tower assembly
Measuring dimensions of a tray stack	Tower	Tower dimension
Measuring alignment of detector layers	Tower	Det-align in tower
Tower IV	Tower, IV curve[a]	IV curve
Tower read-out test	Tower, Tray, Detector[b], Ladder cap-test[b], HDI E-test[b]	Tray E-test
Noise measurement	Tower, Tray, Detector[b], Ladder cap-test[b], HDI E-test[b]	Tray E-test
Cosmic run	Tower	Cosmic run

a) For results from the previous measurements to compare with.
b) For lists of bad strips such as a strip with a coupling short.

2 Access to Assembly Database

The assembly database should not be merely a storage of component description, tracker configuration, assembly status, measurement results, and assembling history of assembled components. It also should assist operators to assemble a component, provide easy data entry, help the tracker administrator and the production manager to monitor the production, and be simple and robust in keeping records secured.

Below are described functions of the assembly database required for smooth construction of tracker towers. Note that tracker towers will be constructed at SLAC (ladder, tray, tower), UCSC (HDI), Pisa (Italy; ladder, tray), and Hiroshima (Japan; detector initial test). Accesses to the assembly database from those institutes are illustrated in Figure 2.

2.1 Data Entry and Operator Assistance

The assembly database should have a user interface to assist operators to assemble components. For example, results of tests or measurements should be automatically sent to the assembly database with minimum operation. At the detector gluing station, for another example, it should display a schematic drawing of a ladder, so that an operator can easily find four detectors to be glued, their gluing order, their orientations, and so on.

Below are such helpful assistance for assembly operators.

Automatic data-transfer Result of measurements or tests should be automatically sent to the assembly database.

Semi-automatic logging Date, time, temperature, operator's name, etc., should be acquired and recorded automatically.

Instruction at each assembly step For each assembly step, a list of components ready for the assembly step should be displayed. For example, an operator should be able to get a list of ladders ready for wire-bonding at wire-bonding step.

Instant diagnosis of test results Results of measurements and tests should be diagnosed immediately at the point of a measurement or a test, with relatively conservative criteria. The check result should be displayed for an operator to handle the component appropriately. The component failed to pass should be removed from the production line to be diagnosed by an expert.

2.2 Production Management

The assembly database should assist a tracker-construction manager to control tracker assembly. For example, it should provide an easy way to check overall status of the production. Also, it should automatically assign detectors to a ladder, based on mechanical dimensions, bad strips, leak currents, and so on. In case of rejection or repair, history of measurements and tests on individual component should be easily obtained to help diagnose it.

Web-based browsing interface The access to the database is preferably web-based with access control, so that it can be accessed by collaborators in foreign countries such as Italy and Japan.

Production summary The assembly database should create a summary of tracker construction automatically and periodically and send it to the GLAST tracker team.

Automatic assignment of components For example, detectors gluing into a ladder should be chosen based on results from mechanical measurements or electrical tests, in order to align strips between detectors, or to put a strip with a pin-hole at the farthest from readout electronics. Similar things can be carried out for assigning ladders to a tray, HDI's to a tray, trays to a tower, and so on.

History of measurements or tests of a component All the results from measurements or tests on a component should be easily displayed to diagnose the component. For example, when a detector is rejected due to high leak current, all the current measurements of the detector should be plotted in one plot.

2.3 Distributed Database

The main database will reside at SLAC for various reasons. On the other hand, the operator assistance by the database will be essential in tracker construction, since the numbers of components are enormous. In other words, information from the database should be present right at the assembly sites, or at SLAC, at Pisa, and at UCSC. Web-based access will work for us in some cases such as production summary. Database access over network, however, should not be relied on too much in some cases, such as automatic data-transfer and automatic logging of assembly operation. More specifically speaking, a network traffic congestion or a network down should not affect the tracker construction severely.

One way to fulfill those requirements is to have a local copy of a part of the database at Pisa and at UCSC, separately. The part of the database to be copied should be determined based on consideration on operator assistance at assembly sites. To keep them synchronized and updated, the partial copy of the database should be "mirrored" between SLAC and Pisa and between SLAC and UCSC, separately. Frequency of synchronization is once a day, for example. In this way, a network problem will not affect tracker construction unless it lasts more than a day.

2.4 Technical Implementation and User Interface

Access to the assembly database should be easy and fast enough at assembly sites. Also, the database should be accessible through internet for production management. In addition, both accesses should be easy for operators and browsers, so graphical user interfaces are preferred. Considering resources available at present, following choices are likely.

Oracle with SQL for the master database: The master database can be hold in the database system at SLAC. The total size of the assembly database is very preliminarily estimated as a few GB. The number can change by large amount with progress of the database design. The number also may change if the tracker design or the database design change in the future.

Database system at assembly sites for operator assistance: It is to be discussed and determined what database system to use for the partial copy of the master database at assembly sites. It should be capable to retrieve data from the master database at SLAC and update it over the internet. It also should interface to software testing and measurement, such as LabVIEW, for operator assistance.

LabVIEW at assembly sites: One LabVIEW program (or subprogram) should be written for each assembly table for an operator to get an operation instruction from the assembly database, run a test or a measurement through LabVIEW if that is the operation, and send results of assembly operation or a measurement to the right table to update. With such a user interface, all an operator should do is to choose the assembly operation he or she is about to perform on the front panel.

JAVA/SQL for web access: Several query forms and limited data entries should be implemented, mainly for the production manager to keep track of the production, to give a production schedule, and to assign components if necessary. Data entries should be limited only for production managing purposes. Data browsing can be open to non-manager members of the GLAST team, while some access controls are favored.

Among these above, the user interface with LabVIEW will be a key for operator assistance at assembly sites. Especially, the access speed should be fast enough to give a comfortable environment for assembly operators. On the contrary, the web access could be slow since they will not be urgent anytime. The LabVIEW program(s) should be shared among SLAC, Pisa, and UCSC to save resources for development of the LabVIEW codes.

2.5 Issues to be Determined

Following issues are to be determined in near future to complete the database design. Note that the assembly database should start functioning within year 2000 at the latest, since we are receiving the first batch of detectors in January 2001.

- database system for the partial copy at assembly sites
- data transfer method between the master database and the partial copy at assembly sites
- data transfer method between the partial copy and software for testing and measurement
- list of queries for the production manager

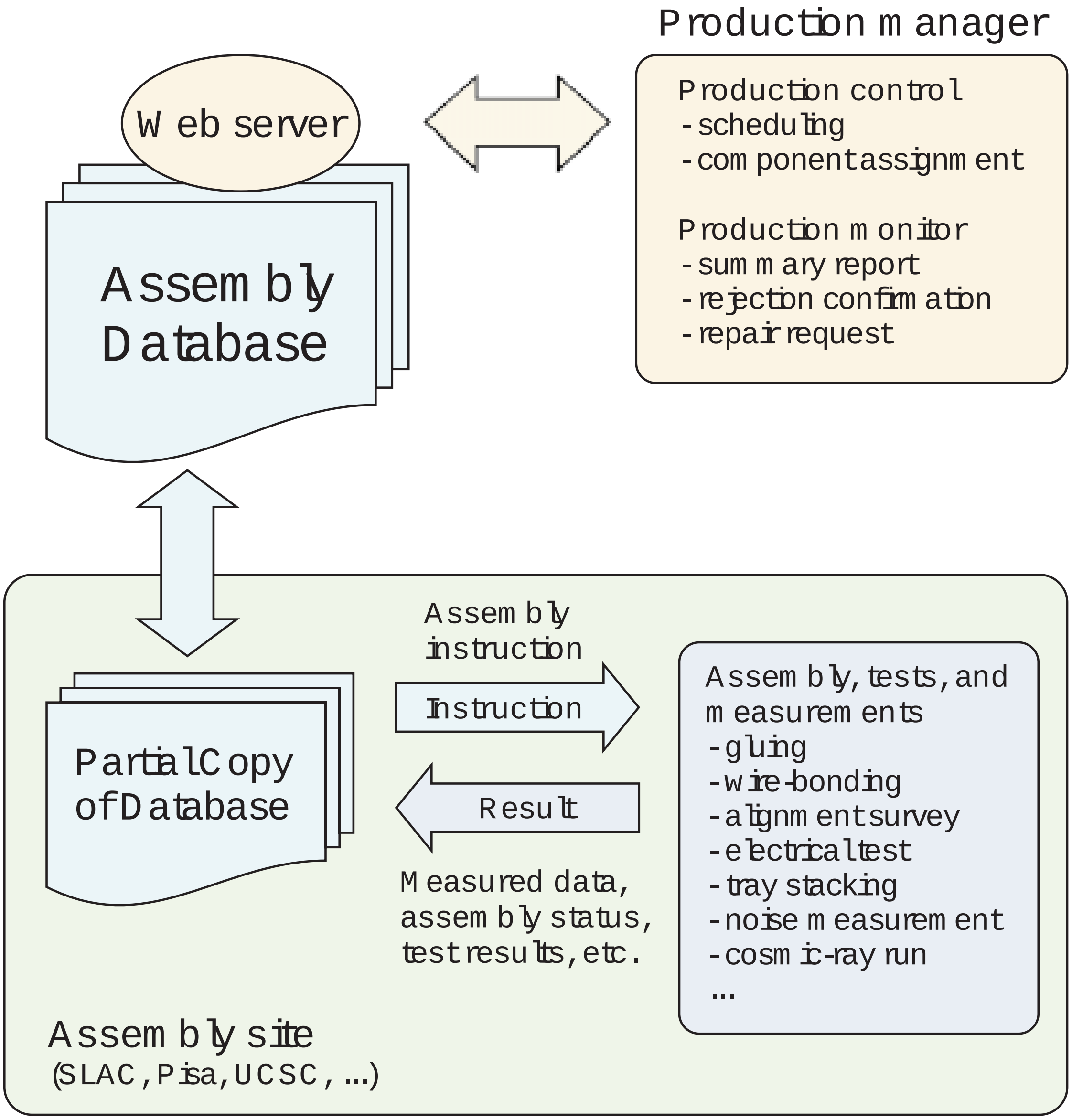

Fig. 2. Illustration of database access over collaborating institutes.

3 Data Tables in Assembly Database

The assembly database consists of two types of data tables; component tables and assembly tables. A component table corresponds to a major component of tracker, such as a detector, a tray, and an HDI. An assembly table logs an assembly process, such as a list of IV curves, mechanical measurements, electrical tests, and so on. Repairs and refurbishing are also recorded in an assembly table. In this section below, definitions of the tables and their contents are described. See the appendix for naming convention for tracker components, which is used in this section.

For use in data analysis and in satellite operation, contents of the assembly database may have to be reorganized after the production. A good example is a bad strip table, which lists a strip with any kind of problem such as a coupling short to mask the strip in analysis. However, definitions of these tables are not shown here, since it is not critical to build the assembly database and make it functioning. The definitions of such tables should be determined elsewhere.

3.1 Component tables

A component table is a list of a component's ID number, names of components that it consists of, a name of a component that it belongs to, and its location in the component that it belongs to. See Table 2 for the definition of all the component tables. It also includes an overall status for quick look of the component's status at the assembly site. An overall status is a summary of results of tests and operations performed on the component. It takes one of values allowed as a result of operation or test in assembly tables (See Table 3).

3.2 Assembly tables

Philosophy of assembly tables are following. Every assembly process should be recorded in chronological order. Some assembly processes may repeat in case of re-measurements and repairs. All the assembly tables, except for the HDI burn-in table, should include common records such as date and time and operator's name. Common records in an assemble table is listed in Table 3.

Some assembly processes needs a dedicated table for the process, and others can be shared with a couple of assembly processes. The table for ladder cap-test is a good example of the former, since it should includes a list of problematic strips with type of their problem (e.g., coupling short and metal strip broken). On the other hand, he IV curve table can be easily shared among assembly processes measuring single detector IV's, ladder IV's, tray IV's, and tower IV's, being a good example of the latter.

A list of all the assembly tables are given in Table 4, 5, 6, 7, 8, and 9.

3.3 Note on repairs and refurbishing

A repair is also regarded as an assembly process. In case of replacement of a subcomponent in the component being repaired, such as replacement of a detector in a ladder, a copy of all the identification records should be saved for future reference, in addition to standard records for an assembly table (date, initials, etc.; see Table 3). This type of repair may be performed on a detector ladder (replacement of a detector), a tray (replacement of an HDI, or a ladder), and a tower (replacement of a tray).

All other repairs should be considered a "general repair", to be recorded in a free format. It should contain the reason and the description of the repair, as well as all the standard records for an assembly table as listed in Table 3. This type of repair may be performed on most of components. An example is a replacement of a broken front-end chip with a fresh one on an HDI.

Table 2. List of component tables

Table name	Record	Remark
Detector	Detector ID number	Unique
	Manufacturer name	
	Detector batch	
	Date of delivery	
	Bad-strip list by manufacturer	
	Assigned location[a]	Search result over table "Ladder" e.g. "L1234B"
	Overall status[b]	Search result over assembly tables
Ladder	Ladder ID number	Unique
	List of detector ID numbers	Definition of assignment
	Assigned location[a]	Search result over table "Tray"; e.g. "T123B3"
	Overall status[b]	Search result over assembly tables
HDI	HDI ID number	Unique
	Assigned location[a]	Search result of table "Tray" e.g. "T123B"
	Overall status[b]	Search result over assembly tables
Tray	Tray ID number	Unique
	Lead thickness	"0 %", "2.5 %", or "25 %"
	List of ladder ID numbers	Definition of assignment
	List of HDI ID numbers	Definition of assignment
	Assigned location[a]	Search result over table "Tower" e.g. "G05 deck 9"
	Overall status[b]	Search result over assembly tables
Tower	Tower ID number	Unique
	List of tray ID numbers	Definition of assignment
	Assigned location	Position and orientation of the tower on a satellite; TBD
	Overall status[b]	Search result over assembly tables

a) See Appendix B for explanation and definition of location names.
b) An overall status is a summary of results of tests and operations performed on the component. It takes one of values allowed as a result of operation or test in assembly tables (See Table 3).

Table 3. Common records in an assembly table

Record	Remark
Sequence number	Unique
Date & time	Should be recorded down to a second.
Name of operator	
Location of operation	SLAC, Pisa, Hiroshima, or UCSC
Operator's comment	
Result of operation or test	One of followings: 1) good 2) accepted with minor problem(s) 3) postponed to use 4) rejected

Table 4. List of tables for refurbished components and repair records

Table name	Record	Remark
General repair[a]	Common records	Unique; see Table 3
	Reason for the repair	
	Description of the repair	
Old ladder[a]	Common records	Unique; see Table 3
	Ladder ID number	
	List of detector ID numbers before refurbishing	
	Assigned location before refurbishing	
	Reason for refurbishing	
Old tray[a]	Common records	Unique; see Table 3
	Tray ID number	
	Lead thickness before refurbishing	
	List of ladder ID numbers before refurbishing	
	List of HDI ID numbers before refurbishing	
	Assigned location before refurbishing	
	Reason for refurbishing	
Old tower[a]	Common records	Unique; see Table 3
	Tower ID number	
	List of tray ID numbers before refurbishing	
	Assigned location before refurbishing	
	Reason for refurbishing	

a) Tables "old ladder", "old tray", and "old tower" include a complete copy of records in corresponding component table before refurbishing it. The table "general repair" includes records of all repairs that does not change assignment of components, such as replacement of chips on an HDI and removal of a bond-wire from a strip.

Table 5. List of common assembly tables

Table name	Record	Remark
IV curve	Common records	Unique; see Table 3
	Component name	Detector ID, ladder ID, tray ID, or tower ID
	Temperature	
	Relative humidity	
	Currents	Raw data at 10, 20, ..., and 200 V
	Currents at 25°C	Corrected data at voltages above
Wire-bonding	Common records	Unique; see Table 3
	Type of bonding	"On ladder", "On HDI", or "Ladder to HDI"
	Wire spool	
	Wedge changed at	Date and time that the bonding wedge changed last time
	Overall bond quality	
	List of failure/re-bonding	
Picture	Common records	Unique; see Table 3
	Component name	Detector ID, ladder ID, tray ID, or tower ID
	Picture	Filename or picture itself (TBD)
	Short description	To make a photo album

Table 6. List of ladder assembly tables[a]

Table name	Record	Remark
Detector dimension	Common records	Unique; see Table 3
	Detector ID number	
	Mechanical dimensions	
CV curve	Common records	Unique; see Table 3
	Ladder ID number	
	Temperature	
	Relative humidity	
	Body capacitance	Raw data at 10, 20, ..., and 200 V
Ladder assembly	Common records	Unique; see Table 3
	Ladder ID number	
	Assembly operation	"Detector gluing", or "Encapsulation"
	Jig ID	
	Adhesive batch	
Det-align in ladder	Common records	Unique; see Table 3
	Ladder ID number	
	Measurement result	Locations of fiducial points of detectors in the ladder
Ladder cap-test	Common records	Unique; see Table 3
	Ladder ID number	
	List of bad strips	

a) IV curves and wire-bonding records should be stored in a common assembly table listed in Table 5.

Table 7. List of HDI assembly tables[a]

Table name	Record	Remark
HDI assembly	Common records	Unique; see Table 3
	HDI ID number	
	Operation type	Passive component mounted, Right-angle connector mounted, GTFE64/GTRC mounted & wire-bonded, or HDI encapsulated
	Adhesive batch	
HDI E-test	Common records	Unique; see Table 3
	HDI ID number	
	Currents	AVDD, AVDD2, and DVDD
	GTRC address	for R0 (left) and R1 (right)
	Test situation	Initial, Pre-burn-in, Post-burn-in, On-tray, etc.
	List of dead channels	
HDI burn-in	Sequence number	Unique
	HDI ID numbers	List of HDI's in burn-in setup
	Starting date & time	
	Name of starter	
	Ending date & time	
	Name of ender	
	Location of test	

a) Wire-bonding records should be stored in a common assembly table listed in Table 5.

Table 8. List of tray assembly tables[a]

Table name	Record	Remark
Tray assembly	Common records	Unique; see Table 3
	Tray ID number	
	Operation type	Tray close-out assembly, Lead/Kapton attachment, HV test, Ladder mounting, or HDI mounting
	Adhesive batch	if any
Tray dimension	Common records	Unique; see Table 3
	Tray ID number	
	Mechanical dimensions	
Det-align on tray	Common records	Unique; see Table 3
	Tray ID number	
	Measurement result	Locations of fiducial points of ladders on the tray
Tray E-test	Common records	Unique; see Table 3
	Tray ID number	
	Test situation	pre-stack, post-stack, etc.
	List of dead and noisy channels	

a) IV curves and wire-bonding records should be stored in a common assembly table listed in Table 5.

Table 9. List of tower assembly tables[a]

Table name	Record	Remark
Tower assembly	Common records	Unique; see Table 3
	Tower ID number	
	Tension of threads	
Tower dimension	Common records	Unique; see Table 3
	Tower ID number	
	Dimensions of the tower	
Det-align in tower	Common records	Unique; see Table 3
	Tower ID number	
	Measurement result	Z-height of detector layers in the tower
Cosmic run	Common records	Unique; see Table 3
	Tower ID number	
	Run number	

a) IV curves should be stored in a common assembly table listed in Table 5. Records of readout test and noise measurements should be stored in a tray assembly table listed in Table 8.

A Tracker Coordinate

A tracker coordinate system should be defined to connect information in the tracker database to data analysis carried out later. It is important to make it straightforward to relate measurement/test results during tracker construction to analysis criteria, such as removal of noisy strips from track fitting. On the other hand, however, it should not bring any complexity into tracker assembly process.

Here is our proposal on the tracker coordinate system. Also, naming convention for detector layer is proposed below, since it is related to tracker coordinate system and important to define it to avoid future confusion.

A.1 Coordinate Axis

Tracker coordinate system has X- and Y-axis on a detector plane, Z-axis pointing from bottom to top, where "top" side of a tower is defined as a top face of a top tray. This Z-axis is also a pointing direction of the entire instrument. Another "historical" requirement is to have a Y-measuring detector layer at the top of a tower.

A.2 Coordinate Value

For data acquisition and data analysis, there also need to be straight numbering of strips on a detector layer and that of a detector plane.

X- and Y-coordinate — strip numbering on a detector layer
: A strip needs is numbered from 0 (zero) to 1535 on each detector layer for purposes of data acquisition and data analysis. Using the strip number, a strip can be called "strip 0" through "strip 1535" of a detector layer.

Z-coordinate — numbering of a detector plane in a tower
: A detector plane is numbered from 0 (zero) to 17, from bottom to top, where a "bottom" plane means the closest to a calorimeter block. Using the detector plane number, a detector plane is called "plane 0" through "plane 17".

A.3 Detector Layer Name

A detector layer can be uniquely identified by a combination of its measuring axis and a plane number. For example, X-measuring layer of plane 13 is named "X13", Y-measuring layer of plane 5 is "Y5", and so on.

Note that prefix "X" or "Y" is defined as its measuring axis, not as the axis its strips are running along. Strips of layer Xn is running along Y-axis, and those of layer Yn is running along X-axis, where n is a plane number (0 – 17).

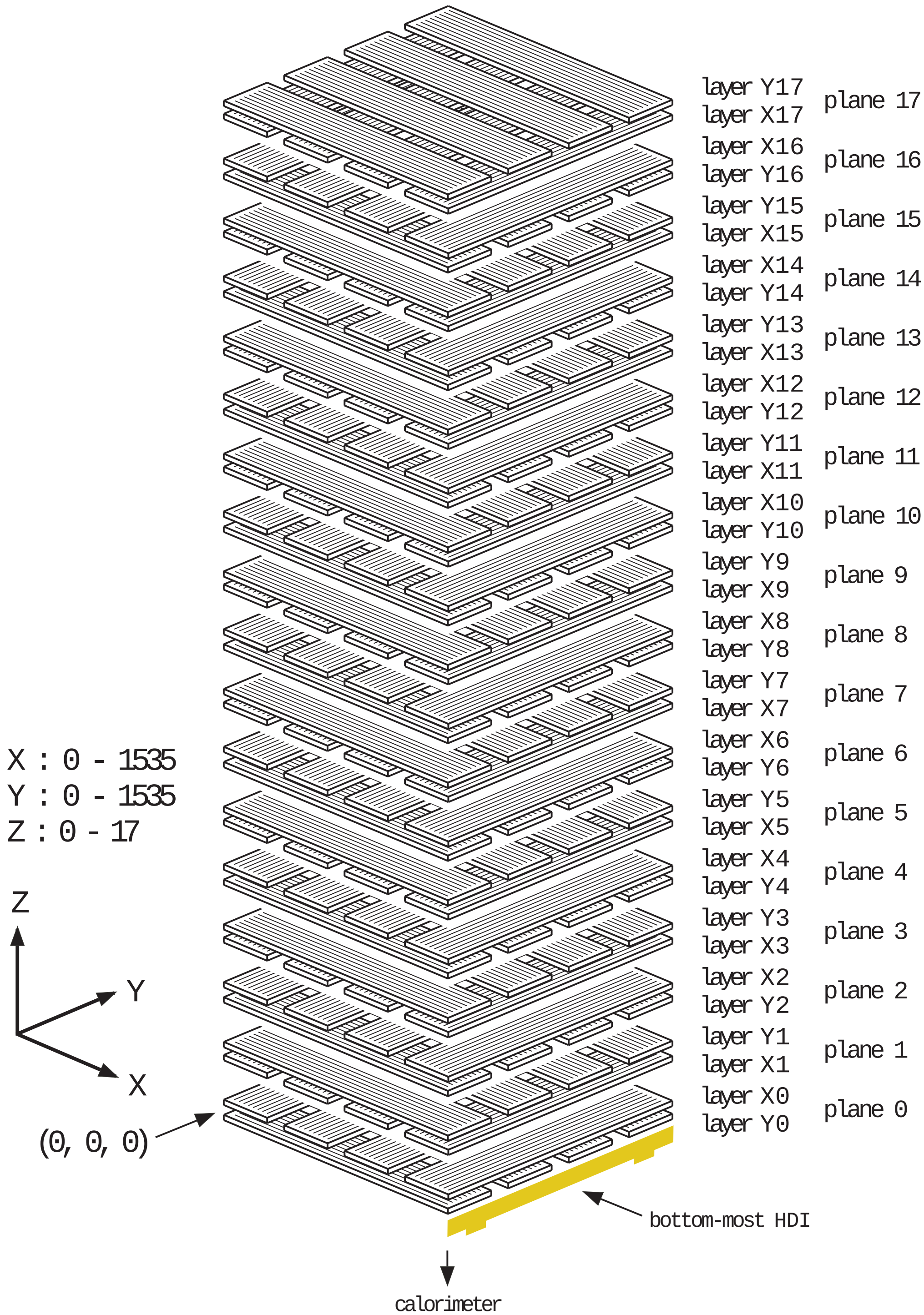

Fig. 3. Definition of Tracker Coordinate System.

B Naming Convention

Two types of names are needed to keep track of tracker assembly: a component name and a location name. A component name corresponds to actual components of a tracker, such as a silicon strip detector, an HDI, a tray, and so on. A location name is to specify a location of subcomponent of a certain component, such as a position of a detector in a ladder, a stack position of a tray in a tracker tower. For example, a detector at location "B" of ladder "L0123" can be called "a detector at L0123B", so you can say "DH04321 is assigned to L0123B."

Definitions of component names and location names are proposed below. Tables 10 and 11 list those names we propose.

B.1 Component Name

A component name consists of a component specifier and an ID number. A component specifier is a single character to uniquely specify a component of tracker; for example "D" for detector and "H" for HDI. An ID number is an integer specifying one physical object of that component. For example, "H012" is a name of an HDI. We propose component names listed in Table 10.

B.2 Location Name

A location name is a suffix to a component name to specify a location of subcomponent which belongs to the component. Typical use of a location name is seen in assigning subcomponents to assemble onto a higher-level component, for example, assigning a ladder "L1234" to a tray location "T123B2".

Another usage of location name is to specify an unnamed component, such as front-end chips, controller chips, bonding wires, and so on. For example, "H123C05" specifies a front-end chip on HDI "H123" whose address is "5". So, you can say "H123C05 was replaced with a new chip." Another example is "S123C" specifying a bonding wire on location "C" on "S123", or the third wire from the readout side on the strip 123. With this expression, you can say "S123C was bonded twice" and so on.

See Table 11 for all the location names proposed here.

B.3 Other Name

There are names for a detector layer and a detector plane (a pair of two neighboring detector layer). They are named using the tracker coordinate defined in Appendix A. See Appendix A for their definitions.

Table 10. Tracker Component Names

Component	Name[a]	Remark
Strip ID	S*nnn*	*nnn* should match printed number on a detector, but with preceding zero(s), i.e., 001 though 384. *nnn* = 000 or 385 for a bias ring for bonding purpose.
Detector ID	D*Mnnnnn*	*M* : Manufacturer ID (e.g., "H" for Hamamatsu) Numbering is not necessarily continuous.
Ladder ID	L*nnnn*	
HDI ID	H*nnn*	
Kapton Cable ID	K*Tnnn*	*T* : Cable type, "A" through "D"
Tray ID	T*nnn*	*nnn* is a close-out ID number
Tower ID	G*nn*	G for GLAST

a) n is a single digit integer forming an ID number of component. An ID number will be a unique identifier of each component in a database.

Table 11. Location Names

Location of		Name	Example
Detector	in Ladder	"A" through "D" "A" is the closest one to the readout electronics	L0123B
Bonding wire	on Strip	"A" through "D" "A" is the closest one to the readout electronics	S123C
Front-end chip	on HDI	"F0" through "F23" "F0" for the left-most[a] chip on an HDI ID number (0–23) should match front-end chip address.	H123F04
Controller chip	on HDI	"R0" or "R1" "R0" for the left[a] one on an HDI "R1" for the right[a] one	H123R0
Tray surface	on Tray	"T" or "B" "T" for the top side "B" for the bottom side	T123T
Ladder	on Tray	"T1" through "T4" on the top side "B1" through "B4" on the bottom side "T1" and "B1" is the left-most[a] one for an HDI to read out the ladder	T123B2
Tray	in Tower	"deck 1" through "deck 19" "deck 1" is the bottom one and "deck 19" the top	G03 deck 8
Kapton Cable	on Tower	"cable 0" through "cable 8"	G05 cable 3
Tower	in Satellite	TBD	—

a) The "left" side of an HDI is defined as the left side in top view with front-end chips lined-up on the top of the HDI (See also Figure 5).

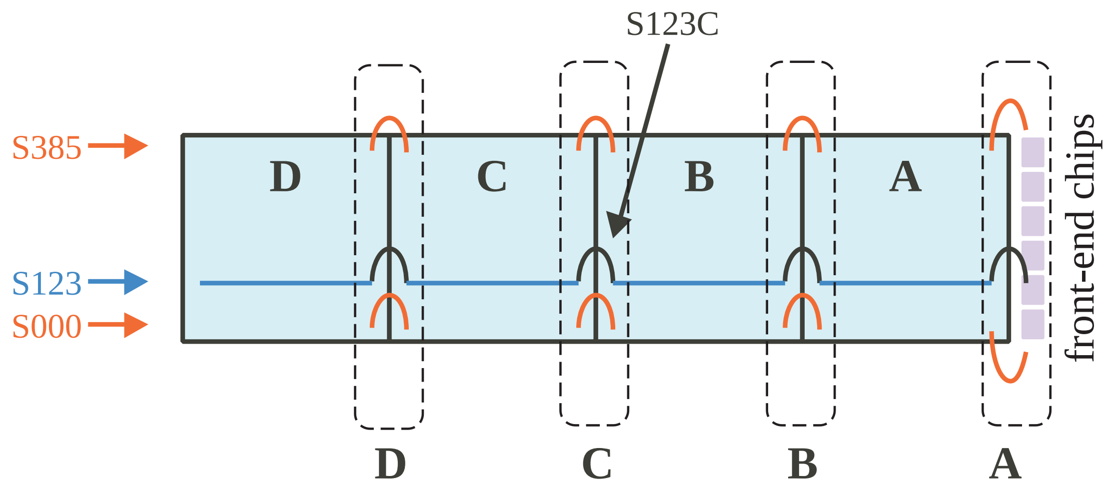

Fig. 4. Names of strips, bonding-wires, detector locations, and bonding rows.

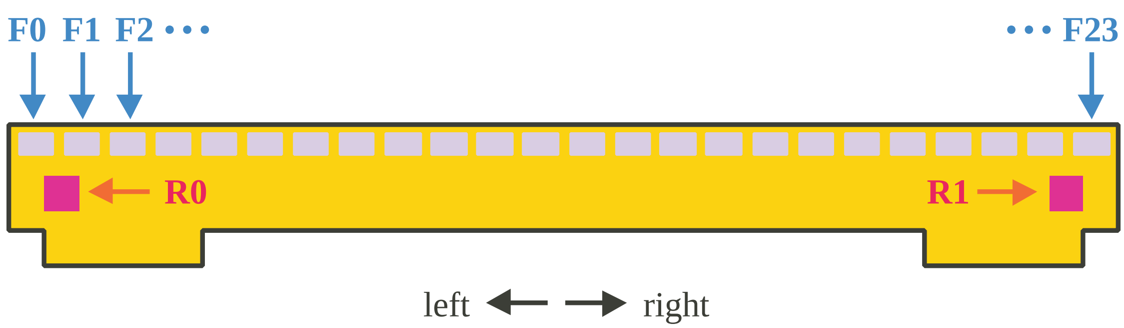

Fig. 5. Names of front-end chip locations, controller chip locations. Also, definitions of “left” and “right” of HDI are shown. The “left” side of an HDI is defined as shown in Figure, or as the left side when looking at an HDI with front-end chips lined-up at the top.

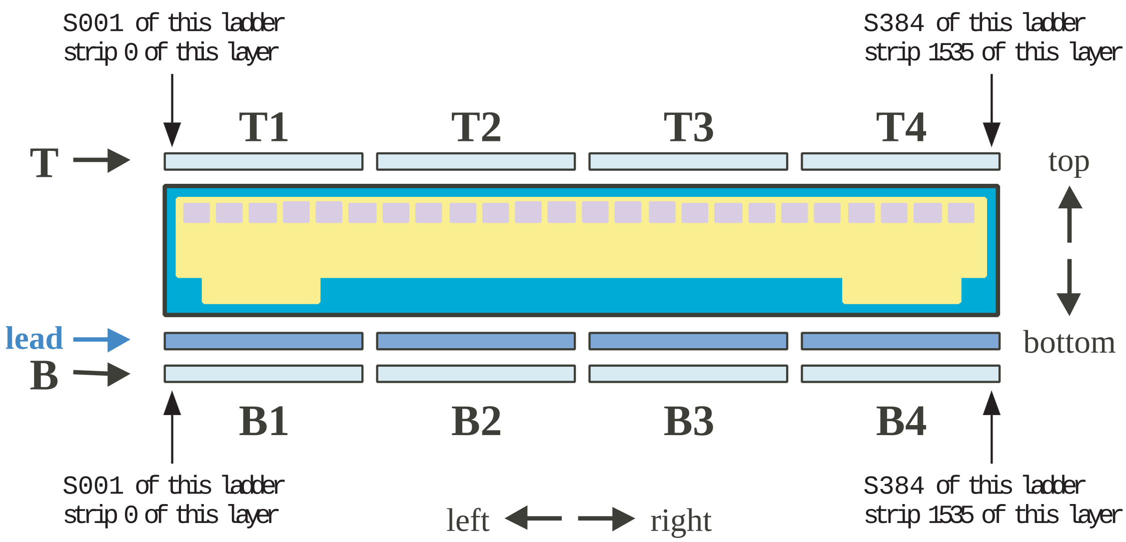

Fig. 6. Names of ladder locations and sides of a tray. Also, definitions of "left" and "right" of tray are shown. The "left" of a tray comes at the left when looking at a top-side-reading HDI with front-end chips lined-up at the top. Note that the left side of an HDI are always at the left side of the tray once mounted, whichever side of the tray (top or bottom) the HDI is mounted. In addition, the figure shows strip numbers on a tray. On each side of a tray, strip number starts with 0 and increases from left to right. With names defined in Appendix B, S001 of a ladder at T1 or B1 of a tray is strip 0 of the detector layer. And S384 of a ladder at T4 or B4 on a tray is strip 1535 of the detector layer.

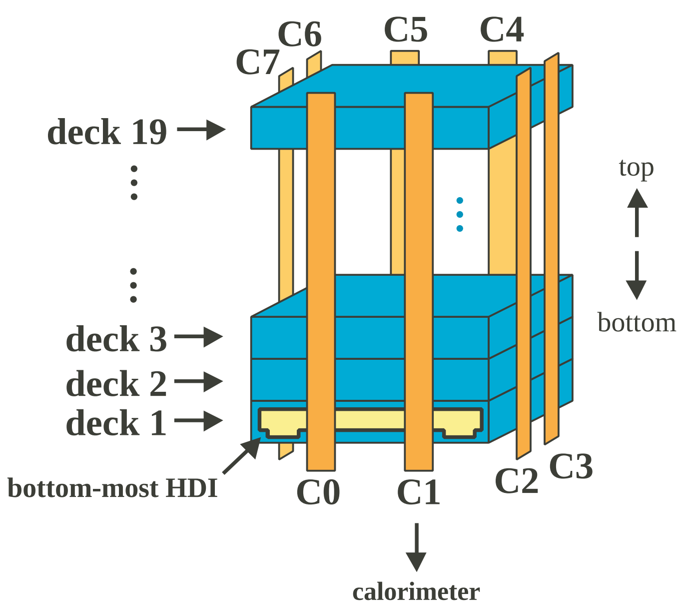

Fig. 7. Names of Kapton cable locations and stack positions of tray.

C Natural Link between Construction, DAQ, and Analysis

Naming convention and numbering scheme must be useful for tracker construction, but at the same time, it should be easy for us to use it in data acquisition software and in analysis/simulation software. From our experience in the BTEM construction, we propose orientation of tray stack as follows. Also, it is shown that our scheme is useful for data acquisition software to calculate a hit location in tracker coordinate.

C.1 Tray Orientation in Tray Stack

There are three requirements on orientation of trays in a tracker tower from analysis and simulation points of view. The requirements are visualized in Figure 3.

1. Tracker coordinate system should be right-handed.
2. The top-most layer should measure Y-position of a track. In other words, strips on the layer are parallel to X-axis.
3. Strip number should increase with X- or Y-coordinate.

In addition, following convention is helpful to relate results from tests or measurements in construction to information needed in analysis. For example, with convention below, it will be easy to correlate noisy strips identified in analysis with a list of bad strips found in the construction.

1. Strip number should increase left to right on a tray as shown in Figure 6. In other words, strip 0 of a detector layer is always connected to the left-most channel of an HDI, hence, it is always read out with front-end chip at "F0".

Fortunately, all of those requirements and convention can be satisfied simultaneously; indeed, they uniquely determine orientation of all trays in a tower as shown in Figure 8.

C.2 Obtaining Hit Location in Tracker Coordinate

For a TEM board to uniquely identify a "hit" in a tower, we use a combination of three numbers: a strip number on a detector layer with the hit, GTRC address of an HDI reading out the detector layer, and a location name of a Kapton cable connecting the HDI (see a left diagram in Figures 9).

By definition, a strip number gives X- or Y-coordinate of a track immediately. Strip numbering on a detector layer is defined as in Figure 6 and illustrated in Figure 8.

A pair of GTRC address and cable location tells us Z-coordinate of the hit, measuring axis (X or Y) of the layer, and physical location of the cable (right or left of towards the side of the tower). Once GTRC address and cable location are expressed in binary, one can extract those information as shown in the right of Figures 9.

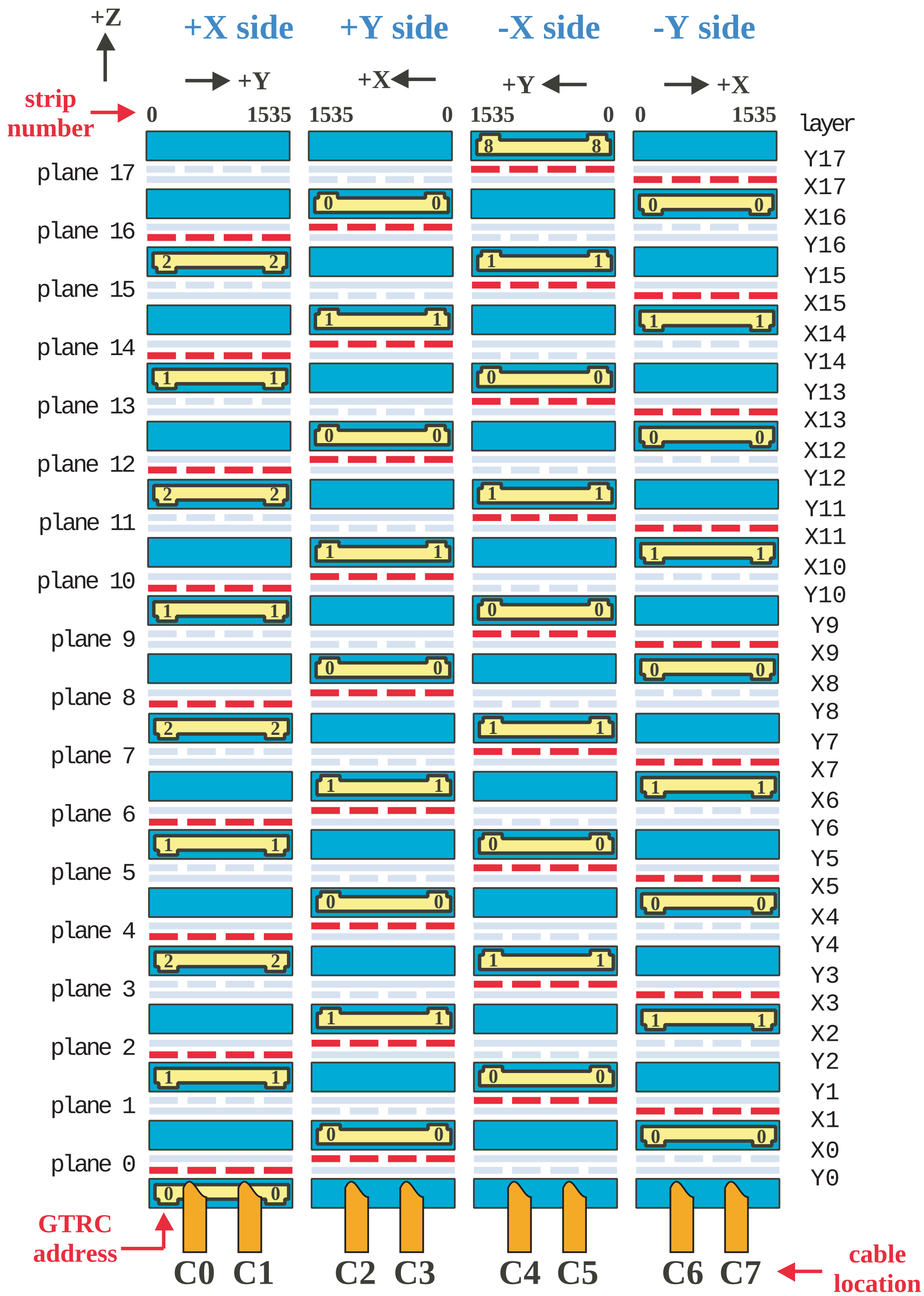

Fig. 8. Side views of a tracker tower, or definition of tray-stack orientation. Names of detector layers and detector planes are also shown. Horizontal bars between trays indicates a detector ladder; red (darker) one is the one to be readout on HDI nearby (right below or right above), and light blue (dimmer) one is the one not to be readout on that side. Also, it illustrates GTRC addresses, cable location names, and strip numbers, for use to identify a strip in a tower. GTRC address of each HDI on a Kapton cable is hard-wired on a Kapton cable and ranges from 0 (zero) to 8. The HDI closest to a tower controller, or TEM (Tracker Electronics Module), has address 0.

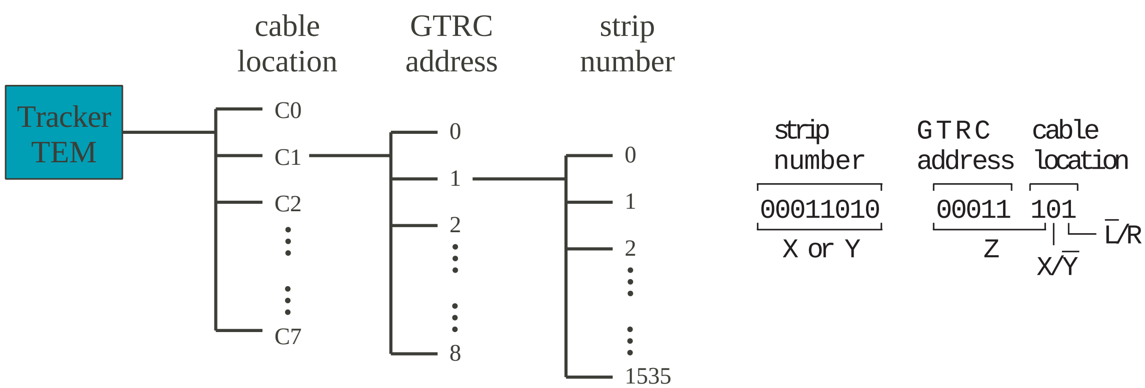

Fig. 9. A strip is identified uniquely in a tower by a combination of Kapton cable location, GTRC address and a strip number in a detector layer. In addition, a hit location in tracker coordinate (X or Y, and Z of a hit) can be easily calculated as shown in the figure.