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Detector Description Database for the DELPHI Time of Flight Counter

P. Allen[1], M. de Fez[1], A. Ferrer[1], J. Cuevas[2], A. Ruiz[2]

Abstract

This note describes the physical and geometrical constants of the various components of the DELPHI time of flight Scintillation Counter. We describe the construction of a database which enables this information to be organized for use in the analysis of data. We list in detail the meaning of each word in the database.

[1] Instituto de Física Corpuscular (IFIC), Centro Mixto Universidad de Valencia-CSIC, Avda. Dr. Moliner 50, E-46100, Burjasot (Valencia)

[2] Facultad de Ciencias, Universidad de Santander, Avda. de los Castros, E-39005 Santander

INTRODUCTION

The high energy physics group of the Instituto de Física Corpuscular at the University of Valencia has constructed a Time of Flight Scintillation Counter (TOF), for use at the DELPHI intersection of the LEP e^+e^- colliding beam facility. The detector is located in the barrel region of DELPHI between the superconducting coil on the inner side and the Hadron Calorimeter on the outer side. It consists of one hundred and seventy-two strips of scintillator each equipped with two photomultipliers (PM), distributed among forty-four of the sectors on the barrel. The aims of TOF are –

1. To provide to the other detectors of the barrel region a trigger signal derived from the passage of cosmic ray muons.
2. To participate in levels 1 and 2 of the general DELPHI triggers.
3. To digitize the time of flight and point of impact of charged particles originating from LEP collisions, for use in the (software)DELPHI T3 trigger.
4. To estimate the total amount of energy deposited in the detector by the passage of charged particles.

In section 1 we describe the geometry of the various elements of the counter and also its mechanical support system. In section 2 we describe briefly the modules used to readout data from the PMs. In section 3 we describe the design of a database which serves the purpose of detector description. It contains two files — a Calibration Database file and a Geometry Database file. In the appendix we list in detail the meaning of each word in the database. We describe how the calibration database is updated.

1 DETECTOR DESCRIPTION

The barrel of DELPHI is divided into two halves, one adjacent to the endcap A, called TOFL, and the other adjacent to the endcap C, called TOFR. The centre of the coordinate system is at the centre of the barrel, the positive z axis in the direction of motion of the electron beam, the positive y upwards, and the positive x such as to complete a right-handed orthogonal triad (fig. 1). Each half of the barrel is sub-divided into twenty-four sectors subtending an azimuthal range of fifteen degrees. TOF is located around the barrel. The innermost plane of the scintillator is at a radial distance of 310.0 cm from the point of interaction. The outermost plane of the device is a mechanical support affixed to the iron of the Hadron Calorimeter at a radial distance of 318.5 cm from the point of interaction.

It was initially planned that each of the forty-eight sectors would contain four scintillators, each equipped with two PMs. The detector would comprise one hundred and ninety-two scintillators and three hundred and eighty-four PMs. However, some space had to be yielded to allow for the feet supporting the coil of the magnet. The sectors numbered 9 and 16 in fig. 1 are devoid of counters. In addition, the sectors below these, numbered 10 and 15, are missing a counter nearest to the empty sectors. The same arrangement prevails on both halves of the barrel. This leaves a total of one hundred and seventy-two counters and three hundred and forty-four PMs.

1.1 ELEMENTS of the COUNTER

The counter ensemble consists of the scintillator proper, two semi-cylindrical light guides, two trapezoidal light guides, two quasi-cylindrical light guides (fig. 2) and two PMs enclosed in shields. The scintillator is a strip of plastic of type NE110, 350.0 cm long, and consists of two equal strips cemented together at the middle. The width of the scintillator is 20.0 cm and its thickness is 1.9 cm. It is covered in aluminized foil for better containment of the light [1]. All the elements have been wrapped in black tape.

At each extremity of the scintillator a semi-cylindrical plexiglass light guide has been attached by means of optical cement. The length of the semi-cylinder is 20.0 cm in the (x) direction of the width of the scintillator. The radius of the cylindrical part is 2.6 cm (i.e the dimensions of the plane face are 20 cm in width and 5.2 cm in height). The scintillator and the semi-cylinders together define an extension of 355.2 cm on either side of the barrel. We have assumed that there is no separation between the inner extremities of the counters of the two halves.

The plexiglass trapezoidal light guides sit atop the scintillator adjoining the semi-cylinders and direct the light backwards towards the centre of the ensemble. The surfaces of the scintillator and trapezoid are separated in height by about 0.2 cm due to the wrapping. The end of the trapezoid adjoining the semi-cylinder is 20.0 cm in width (x) and 3.1 cm in height (y). The other parallel side has a square cross section, 3.1 cm by 3.1 cm. The length of the trapezoidal guide is 100.0 cm (z).

A quasi-cylindrical plexiglass light guide adjoins the trapezoid. Its purpose is to raise the path of the light into the PM. (This is necessary because of the shields which surround the PM.) The length of the quasi-cylinder is in all 17.5 cm, directed along the z axis. The face adjoining the trapezoidal guide is of square cross-section, again 3.1 cm wide (x) and 3.1 cm high (y). This geometry is maintained for a length of 3.0 cm (z). The far end which adjoins the PM is a cylinder of radius 1.5 cm and length 5.5 cm. Its outer radius rises 0.9 cm above the top of the square end. The middle section of the guide, 9.0 cm long, modulates between the square and cylindrical shapes.

The final element is the PM, type 9920KB (Thorn EMI). The radius of the tube is 1.935 cm and its length of 9.85 cm is prolonged by a base of 2.2 cm length. The general features the PM are described in [2]. The PM is closely wrapped in plastic, then surrounded by a shield of mu metal, 11.9 cm long, with inner radius 2.01 cm and outer radius 2.12 cm. Finally there is an outer cylinder of iron, threaded at both ends. This is 19.2 cm long and fits into rings which prolong it by 0.5 cm at either end. The outer radius is 2.46 cm, the inner radius 2.28 cm at the end of the cylinder. The inner radius is less than this in the central section of the tube. One of the rings serves to press a spring mechanism strongly against the base of the PM. The other ring fits into a loose ring, 0.6 cm long, which rests on the quasi-cylindrical guide. This ensures better optical and mechanical contact between the light guide and the entrance window of the PM. The arrangement of the cylinders overlaps this guide by about 3 cm.

1.2 MODIFICATIONS to the COUNTERS

Some minor modifications have been made to the scintillators in special cases. The highest lying counter in the sectors 1 and 24 and the lowest lying counter in sectors 12 and 13 have been shortened by 50.0 cm at the ends furthest from the centre of the barrel, to allow for ventilation. The same arrangement prevails in both TOFR and TOFL, as indicated in fig. 1. The positions of the remaining elements at the shortened end of the counter are shifted by 50.0 cm towards the centre of the barrel. Finally, in sectors 10 and 15, the scintillator nearest to the position of the "missing" scintillator has been narrowed to 19.0 cm, for reasons of space.

1.3 POWER SUPPLIES

The power supply for the PMs derives from three CAEN HV 127 main-frames. Each may contain ten HV units of various kinds with four outlets apiece. The type of unit chosen is A333N. It operates in either of two modes −4 KV/2000 μamp or −2 KV/3000 μamp. We have taken the former.

The original (runs of 89 and 90) wiring arrangement was to use one outlet to power the four PMs of one half-sector (eighty-eight HV channels). In the case of sectors 10 and 15 where one of the half-sectors contains only one counter, the corresponding HV channel powered only two PMs. However later experience showed that it was better not to have a rigid relationship between half-sectors and HV channels. It remains generally, but not universally, true that the HV channels power four PMs, but these are not usually in the same half-sector. We retain the possibility to alter the relationship between the HV channels and the PMs. This relationship must be explicitly stated in the Calibration Database. The voltage applied to each PM and the resulting gain are needed in the subsequent analysis.

1.4 TOF MECHANICAL SUPPORT

A metal frame secures the counter ensemble to the iron of the Hadron Calorimeter, the detector immediately outside TOF. The inner part of the support is a set of two parallel metal bars 2.0 cm wide separated on the inner side by 15.4 cm. The length of the bars is 360.6 cm. They fit loosely into a guide rail or channel which runs along most of the length of the scintillators (fig. 3). There are six grooves along the bars which facilitate the strapping of the counter ensemble to the bars with strong tape. Each pair of bars is joined at their ends by a cross bar, 18.2 cm wide and 1.95 cm long. This fits into a T-piece arrangement on the barrel.

The arrangement of the bars and attached counters of each sector slides into a set of guide rails attached to an aluminium plate 0.2 cm thick, 83.6 cm wide, screwed to the hadron calorimeter. The length of the plate is 360.0 cm on the TOFR side and 370.0 cm on the TOFL side. (The lengths were chosen so that the plates do not meet at the centre of the barrel as it would be difficult to screw them together at this point.) The design of the plate is such that the counters can only be introduced at the centre. The extreme counters are first inserted here and then rotated into position (fig. 4).

Some modifications are necessary in the case of the "non-standard" sectors. For sectors 10 and 15, which contain only three counters, the width of the aluminium plate is 63.6 cm. For sectors 1, 12, 13 and 24, which contain one short counter, the outermost 52.0 cm of the plate is only 63.6 cm wide.

2 READOUT MODULES

When a scintillator registers the passage of a charged particle the output pulses from the anodes of its PMs go through a stage of amplification and are then divided by a splitter. Approximately 75% of the output of the splitter is directed to a module called a Tof Sector Unit or TSU [3]. The remainder is directed to ADC modules. Both TSUs and ADCs are housed in Fastbus crates, from which the data may be acquired.

2.1 The TSU MODULES

The TSUs further the aims of TOF by providing trigger signals and digitizing the time of flight. The output trigger signals will not be considered here.

There are forty-four TSU cards, one for each active sector of TOF. The cards have eight inputs, to receive the signals from the eight (six) PMs of one sector. Another input receives a signal derived from LEP. For each LEP collision (without imposing any trigger conditions) the derived signal gives rise to a voltage ramp which serves as a common START signal for the entire card. Signals from the PMs of the struck scintillator(s) pass through a stage of discrimination on the TSU. On emerging they enter the Time Digitizing Circuit (TDC). They give rise, in order of time of arrival, to individual STOP ramps. After a fixed time from the beginning of the START ramp a Delayed Start Signal is always generated to terminate the growth of the ramps. Each of the eight (six) START — STOP voltage differences is determined in turn and digitized in an eight-bit flash ADC (dynamic range 128 ns). The response of the TDC is linear in time. If there is no output from a PM its digitization registers an overflow value.

The time/voltage recorded here contains a number of effects apart from the true time of flight. It reflects the time of propagation of the emitted light along the scintillator and the light guides, the transit time in the PM, delays introduced by the cables, amplifier and discriminator. A correction factor (called T_0) must be obtained by subsequent calibration of the data. This quantity is different for each PM/TDC channel. We also need to calibrate the level at which each TDC channel registers an overflow and its initial threshold count. The values of T_0 and of the saturation and threshold counts as well as the conversion factor to relate TDC counts to nsec are needed in the Calibration Database. These quantities vary in time for a given channel.

An output signal is derived from each TSU, an AND of the ORs from the external and internal PMs. This serves as an input to a LeCroy 96-channel multihit TDC (model 1879). The values of T_0 for these channels must be calibrated.

2.2 The ADC MODULES

We have four standard LeCroy 96-channel ADCs (model 1885F). They have two ranges for the current integrals, differing by a factor of eight. The pedestal counts of each channel, for both ranges, must be included in the Calibration Database.

3 DELPHI DETECTOR DESCRIPTION DATABASE

DELPHI has selected the CARGO Database Management System [4] for its databases. This relies on the KAPACK [5] method of accessing records by means of keywords. Successive editions of CARGO have progressively improved the KAPACK method in respect of both the density of packing records and the speed of access.

Several applications of the CARGO method have been defined. Each lays down its own rulings on the characteristics of the records and data fields. Two database files [6], components of the DELPHI Offline Database, are employed for "Detector Description" in analysis and simulation. The files are –

- The Calibration + Sensing Device File (CALB_DB) containing one tree with information on the electronic aspects of the detector (section 3.1).

- The Geometry File (GEOM_DB), which contains two trees used to describe the position of the elements (section 3.2) and their material composition (section 3.3). A preliminary description appears in [7].

This note describes how these Data Structures have been used in the case of the TOF. In addition every database must contain a so-called "systems file " (section 3.4).

3.1 THE CALB_DB

The CALB_DB contains information on the characteristics of the scintillator, PMs and readout system. CARGO has been applied in an especially simple manner in this case. There is one tree named CALB. Two types of database records are allowed, called GLOB(al) and SENS(ing). The root level is in fact a record of type GLOB. It may give rise to branches of GLOB records at the next level. Likewise, they may give rise to further generations of GLOB records. Any GLOB record may give rise to branches of SENS records. The SENS records do not hang any others. Each detector is free to use any number of GLOB and SENS records in the manner best suited to its particular case. The design adopted for the TOF CALB_DB is shown in fig. 5.

In general terms a GLOB record, as the name implies, should contain items which are relevant to its own level and those descended from it. Thus the GLOB record at ROOT level would contain the status and parameters common to the entire detector. The lower level GLOB records contain the status and parameters which are common to some part or aspect of the detector. The SENS records have paramaters of the individual components of the detector e.g. a PM. Their status has no wider significance.

At the highest level (GLOB ROOT record, named TOF*) there is, in our case, no physical parameter which is common to the entire detector, so no data is stored here. The status is assumed to be good. A detailed listing of the use of the words in the fields of this record is given in the Appendix (section A1). This level serves to hang three structures at the next level down. They are also records of type GLOB and are named CAEN (section 3.1.1), TOFL and TOFR (section 3.1.2).

3.1.1 The CAEN record and its CAnn records

At the second level we have placed a record of type GLOB, named CAEN. This exists only to hang the descending CAnn records. The status in the CAEN record is taken to be always good.

There are eighty-eight CAnn records, of type GLOB, with names from CA01 to CA88. They correspond exactly to the eighty-eight CAEN High Voltage channel outputs which supply power to the PMs. The records contain two important fields –

- The LEAD field, in which we find the status of the CAEN channel. This is good if the corresponding High Voltage channel is in the (hardware) state of ON; otherwise it is bad.
- The SLOW field, in which we find the current value of the voltage applied to certain PMs by the channel (see below).

A detailed listing of the use of the words in the fields of this record is given in the Appendix (section A2). The values of the status and the voltage are updated periodically in real time, as explained in the Appendix (section A4).

3.1.2 The TOFL (TOFR) record and its lower level records

The TOFL (and TOFR which is completely analogous) are records of type GLOB at the second level. They contain the status of the A side, $Z < 0$ (C side, $Z > 0$) of the detector. Since there is no physical parameter common to the entire half-detector, we take the status of the segments as always good.

Each side of the detector is further sub-divided into forty-eight records of type GLOB, one for each half-sector (i.e. two scintillators, four PMs). They are named from HS01 to HS48. We include dummy records for the inactive half-sectors. Again, there is in general no parameter common to the entire half-sector, so its status is assumed to be good if it contains counters. If all the PMs in one half-sector were powered by the same CAEN HV channel then the half-sector would have a well defined status, that of the corresponding HV channel.

At the lowest level each HS record descends a record of type SENS. This contains information on the counters and PMs in the half-sector. The most important fields are –

- The STAT field, which contains the statuses of each counter and its PMs.
- The LINK field, which gives the names of the record in the GEOM_DB, to which the SENS record corresponds.
- The CALW field which contains constants relative to the scintillator and PMs, and calibration information for the appropriate channels of the TSU and ADC.
- The USER field which contains cross references to the records CAnn, telling where to find the Voltage applied to each PM.

A detailed listing of the words in the fields of these records is given in the Appendix (section A3). The material in these fields will need frequent revision. The quantities concerned are not surveyed by the Slow Controls process, and so the updating has to be made later by analysis of recorded data, as discussed in the Appendix (section A5).

3.2 THE GEOM_DB, TREE GEOM

The GEOM_DB uses a tree named GEOM to organize the information on the location and shape of the various components of the detector. One type of database record named DETG(eometry) is defined for this tree. The root level is a record of type DETG. It may give rise to several branches of DETG records. They in turn descend further branches (fig. 6).

At the highest level is the DETG (ROOT) record named TOF*, which summarizes the entire detector, including both its active parts and its mechanical support. There are two important fields –

- The SHAP field containing the geometrical description of the detector (code = CYL1) as a full cylinder about the z axis. The coordinate system is by default that of DELPHI. The inner radius of the cylinder is 310.0 cm (the innermost plane of the scintillator) and the outer radius 318.5 cm (the outer plane of the support). The length is 355.2 cm in the z coordinate on either side of the origin, assuming no separation between the counters of TOFL and TOFR.

- The MATS field describes the detector as made of "TOAV". The default material (for any volume which remains after summing the components described by the lower levels) is AIR. The physical characteristics of these materials must be given in the tree MATC (section 3.3).

A detailed listing of the use of the words in the fields of this record is given in the Appendix (section B1). This level hangs three lower levels which are the left and right halves of the detector, TOFL and TOFR, and the outer mechanical support, TOFM. The records TOFL and TOFR correspond exactly to the records named TOFL and TOFR in the CALB_DB. There is no analogy therein to the TOFM records.

3.2.1 The TOFL, TOFR and TOFM level

At the second level the record named TOFR treats the part of the detector on the C side ($Z > 0$) of the barrel. The coordinate system (field REFR) is translated from that of DELPHI to $z = 177.6$ cm, the distance from the centre of the barrel to the mid-length of the counter ensemble. The half-detector is described in the TOFR reference frame (field SHAP) as a full cylinder (code = CYL1) about the z axis with inner radius 310.0 cm. The outer radius, 317.02 cm, is obtained by adding to this the thicknesses of the scintillator and the plastic (1.9 cm and 0.2 cm respectively) and the outer diameter of the shields surrounding the PMs (4.92 cm). The length is 177.6 cm in the z coordinate on either side of the centre of the half-detector. This length is determined by the sum of the lengths of the scintillator and the radii of the adjoining semi-cylindrical guides. The TOFL record is identical to the TOFR except that the origin of its coordinate system is translated from that of DELPHI to $z = -177.6$ cm. The material used (field MATS) is "TOAV" and the default material is AIR.

The record named TOFM is used to describe approximately the outer mechanical support. The coordinate system is that of DELPHI. The shape is that of a complete cylinder (code = CYL1) about the z axis, with inner and outer radii 317.02 cm and 318.5 cm, and the same length as the detector. The material used is "TOMA" and the default material is AIR.

A detailed listing of the words in the fields of these records is given in the Appendix (section B2). The branches TOFR and TOFL both descend branches named Snnn and FUTn to describe the active and inactive sectors. Each Snnn and FUTn record corresponds to two records named HSmm in the CALB_DB. The TOFM branch does not descend any further branches.

3.2.2 The Sector and Foot records

The barrel of DELPHI comprises twenty-four contiguous sectors on each half subtending $\Delta\phi = 15$ degrees in azimuth. In the case of TOF only twenty-two sectors are active in the sense of containing counters (1 to 8, 10 to 15, and 17 to 24). They are described by records named Snnn. The sectors 9 and 16 provide space for the feet of the coil. They are described by records named FUTn ($n = 1, 2$). The Snnn records serve as a frame for the ensemble of the counters of the sector. The FUTn records describe the feet in detail.

In the case of the Snnn records the origin has been translated from that of TOFR (TOFL) to a point at the centre of volume of the sector. The x and y coordinates of this point are defined by the middle radius of the sector (313.05 cm) and its middle azimuth ϕ, while the z coordinate remains unchanged. The coordinate system is rotated through ϕ about the z axis (first Eulerian angle). This rotation effectively removes the effect of the curvature of the barrel. We can visualize the sector as a simple parallelepiped (code = BRIK), in a coordinate system fixed to the centre of its volume. The width of the sector is entirely in the y direction and the thickness in the x direction, as if the sector were at $\phi = 0$. The full extent of the sector is $\Delta x = 7.02$ cm, $\Delta y = 80.0$ cm (the width of four counters) and $\Delta z = 355.2$ cm. This is the same for all Snnn records. The differences of the "non-standard" sectors are introduced at a lower level. The material is "TOAV" and the default is AIR.

The FUT1 and FUT2 records are described in the coordinate system of TOFR (TOFL). They are seen as incomplete cylinders about the z axis, subtending $\Delta\phi = 11$ degrees. The inner and outer radii are 310.0 and 314.0 cm, and the range in the z coordinate from 98.5 cm to 178.5 (FUT1) or −98.5 to −178.5 (FUT2). The material and the default material are "FEET".

A detailed listing of the words in the fields of these records is given in the Appendix (section B3). The Snnn records descend four records named Cnnn which describe ensemble of a single counter. Some sector records (sectors 10 and 15) descend only three. Two Cnnn records (with their hanging Ennn records) correspond to one record named COUN in the CALB_DB. The FUTn records do not hang any others.

3.2.3 The Counter and Element levels

The fourth level of records named Cnnn (nnn = 1 to 4) serves as a frame for the counter ensemble of the scintillator, light guides and PMs. These records each hang, at the fifth level, a number of records named Ennn (nnn = 1 to 9) which describe the individual components of the counter in detail (fig. 7). We translate the coordinate system from that of the sector to the centre of volume of each of the counters in turn. This needs only a translation in the y coordinate. We then see the counter ensemble as a parallelepiped (code = BRIK) with $\Delta x = 7.02$ cm, $\Delta y = 20.0$ cm and $\Delta z = 355.2$ cm. This is the same for all counters. The material and default material are "TOAV" and AIR. This section describes the treatment of the "standard" elements.

The record named E001 describes the actual scintillator. The coordinate system is translated from that of the counter to the centre of the volume of the scintillator. We need only translate in x from the centre of thickness of the counter at radius 313.05 to the centre of thickness of the scintillator at radius 310.95 cm, i.e. $x = -2.56$ cm. No translation is needed in y or z. We view the scintillator as a parallelepiped (code = BRIK) about this origin, its extent being $\Delta x = 1.95$ cm, $\Delta y = 20.0$ cm and $\Delta z = 350.0$ cm. The material and the default material are SCIN(tillator).

The records E002 and E003 describe the semi-cylindrical light guides. The coordinate system is translated to the centre of the plane face of the semi-cylinder. The x coordinate of the new origin is at −0.91 cm (as seen from the counter system) and z is at 175.0 cm (E002) or −175.0 cm (E003).

We rotate the coordinate system by 270^0 about the x axis (second Eulerian angle). We may now visualize the semi-cylinder with its axis and the positive z direction pointing upwards. The objects are described in this system as incomplete solid cylinders about the (local) z axis (code = CYL1). They have a radius of 2.6 cm, and a length of 10.0 cm on either side. They subtend azimuthal angles of 180 to 360^0 (E002) or 0 to 180^0 (E003). The material and the default material are PLEX(iglass).

The records E004 and E005 describe the trapezoidal light guides atop the scintillator, separated from it by plastic wrapping. They are described by a complex shape called a four sided box (code = FORB). The protocol requires that the coordinate system be set up in a specified way. The similar parallel faces are in the yz plane, the dissimilar parallel faces in the xz plane, the smaller of them having the lower value of y. It defines an axis of symmetry pointing from the centre of the small dissimilar face to the centre of the large dissimilar face. The origin of the coordinate system should lie on the axis of symmetry.

The needed orientation of the coordinate system is obtained from that of the counter by rotating through 90^0 (E004) or 270^0 (E005), about the x axis (second Eulerian angle). We may visualize the trapezoid standing on its square end, the y axis and the axis of symmetry pointing upwards, the z axis parallel to the top and bottom edges. We translate the origin to a point at the centre of the volume of the trapezoid as this lies on the axis of symmetry. The translations are to x = 0.14 cm and z = 125.0 cm (E004) or −125.0 cm (E005). The extension along the axis of symmetry is ±50.0 cm, along the z direction ±1.55 cm (short edge) and ±10.0 cm (long edge), the depth of the box 3.1 cm. The material and the default material are PLEX.

The records E006 and E007 describe the quasi-cylindrical light guides. These complex objects have one extreme which is a parallelepiped the other a cylinder. These shapes are described exactly. However the central part cannot be described precisely by any of the shapes in the protocol. It has been treated as a cone. Each part has its own REFR and SHAP fields and these are combined in a COMG field to describe the entire object. This gives a reasonable presentation as seen in the program DVUP [8]. For the end adjoining the trapezoid we translate the origin of the coordinate system to the centre of its volume at x = 0.14 cm and z = 73.5 cm (E006) or −73.5 cm (E007). It is is described by the shape BRIK with Δx = 3.1 cm , Δy = 3.1 cm and Δz = 3.0 cm. The parameters of the central part have been treated semi-empirically. The origin is translated to x = 0.59 cm and z = 67.5 cm (E006) or −67.5 cm (E007). It is described as a complete cone (code

= CYL3) with length ± 4.5 cm and radii 1.7 cm adjoining the square end, and 1.6 cm at the other end. For the cylindrical part the coordinate system is translated to x = 0.99 cm and z = 60.25 cm (E006) or −60.25 cm(E007). It is described as a full cylinder (code = CYL1), of length ± 2.75 cm and radius 1.5 cm. The material and default material are PLEX.

The records E008 and E009 describe (approximately) the arrangement of shields and rings around the PMs. The coordinate system is translated to x = 1.05 cm and z = 56.0 cm (E008) or z = −56.0 cm (E009). This allows them to overlap the quasi-cylinders by 3.0 cm. They are taken as complete hollow cylinders about the z axis with inner and outer radii 2.28 cm and 2.46 cm, and 20.2 cm in length. The material and the default material are FE. A detailed listing of the words in the fields of these records is given in the Appendix (section B4).

3.2.4 Modifications to the Counter and Element Records

The sectors 10 and 15 contain only three counters. The elements are standard, and are described by the technique of replication (see below). A modification has been necessary in the case of the highest and lowest lying counters. On both sides of the barrel, the scintillator in these counters (sector 1, counter 1; sector 12, counter 4; sector 13, counter 1; sector 24, counter 4) has been shortened by 50.0 cm. We have described in detail the elements of a counter shortened at the positive end. The description differs from that given above only in that the elements on the shortened end have the z coordinates of their reference systems reduced by 50.0 cm and of course the scintillator has also been shortened. Analogously we have described a counter with the scintillator shortened at the negative end.

3.2.5 Technique of replication

Since detectors generally contain many identical elements in different locations, the protocol allows a technique of replication to be used instead of repetitive description. If replication is decided at a certain level the replicated object will assume all the fields of the model object at that level unless given explicit alternatives. It is implied that all levels of the replicated object below the level of replication are identical to the model object.

It is not possible to replicate one half-detector from the other. TOFR contains some scintillators shortened at the positive end (of the TOFR coordinate system), while TOFL has some scintillators shortened at the negative end of its system. The replication must be made at lower levels.

We have described in detail (fields MATS, REFR and SHAP) the elements of counter 1 of sector 2 in TOFR as the model of a standard counter ensemble. The remaining counters of the sector are located by REFR fields and then replicated from the model object. This gives the model of a standard sector. All similar sectors of TOFR and TOFL are located by a REFR field and then replicated from TOFR/S002. The sectors containing three counters have been described in detail (fields MATS, REFR and SHAP). The counters 2 to 4 in sector 10 and 1 to 3 in sector 15 are placed in position (field REFR) and replicated individually from the model counter.

The elements of counter 1 in sector 1 of TOFR are described in detail as the model of a counter with the scintillator shortened at the positive end. The sector is described in detail and then built up from its own counter 1 and the standard counter replicated three times in the appropriate positions. Like sectors (12, 13 and 24) are described in detail and built up by replicating one model shortened counter (counter 4 in sectors 12 and 13; counter 1 in sector 24) and three model standard counters.

The elements of counter 1 in sector 1 of TOFL are described in detail as the model of a counter with the scintillator shortened at the negative end. Thereafter we have a complete analogy to the previous case. The replicated object refers to the model object by the name of the model object at the level of replication if only that name differs. If other names differ the full set of names of the model object must be supplied.

3.3 THE GEOM_DB, TREE MATC

The GEOM_DB uses a tree named MATC to contain the information on the composition of the materials referred to in the various fields named MATS in the tree GEOM of the file. One type of database record called MATE(rial) is defined in the tree. The root level is of this type and does not descend any lower levels. Three records named SCIN, PLEX and TOMA specify the physical characteristics of the scintillator, the plexiglass and the material of the mechanical support. The other materials referred to in the TREE GEOM (such as the standard elements) are known to the database.

A detailed listing of the use of the words in the fields of this record is given in the Appendix (section B5).

3.4 THE SYSTEMS FILE

Each database must contain a so-called "systems file", in addition to the data files originated by the user. It is organized in a manner similar to that of the user's file. It contains the "systems records" in a tree named CARGO+. Below this level are records of type FILE, one for each file in the database. These in turn descend into records of type TREE (one for each tree in the file), then records of type RECO (one for each type of record defined in the tree). Then come records of the type FILD for each defined field and records of type CODE for each code defined in the field. Finally there are records of the type WORD which define the format and limiting values of each word in the field. Thus the systems file contains a complete definition of the protocol.

The systems file is made by importing into the database some "systems ASCII files" which correspond to the applications of CARGO needed for the database. The systems file must exist before any user data file can be imported and it must always be accessed when using the database.

4 CONCLUSIONS

Within the framework of the CARGO Database Management System we have made two files which describe the Valencia Time of Flight Scintillation Counter. The Calibration Database file contains data on the electronic features of the photomultipliers and readout channels. The Geometry Database contains information on the position, dimensions and material composition of the components of the detector. This provides the necessary data for the reconstruction and analysis of raw data.

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APPENDIX

In this appendix we list in the meaning of the words contained in the two files of the DELPHI Detector Description Database (Time of Flight contribution).

A THE CALIBRATION DATABASE

The Calibration + Sensing Device file (CALB_DB) contains information on the electronic features of the detector, including its readout system.

A 1 THE ROOT LEVEL

This record is of type GLOB and is named TOF*. It contains the following data fields – [1]

- RECORD TOF*, FIELD LEAD.
  This is a field of variable length with Integer words. Eight words have been used.
  WORD 1 = ival1 : The status of the current and lower levels.
  IVAL1 = 0 : GOOD. We always take this (see section 3.1)
  Words 2 – 8 = ival2,...
  They are flags to indicate to a subsequent program which version of its code to use in the interpretation of the data in the next seven fields of this record. These fields have been included for future reference, but are empty in our case.

- RECORD TOF*, FIELD SLOW
  This is a field of variable length with Integer words, to contain data which could be updated by the Slow Controls process (see section A4 below).

- RECORD TOF*, FIELD SHAR
  This is a field of variable length with Real words, to contain constants shared by all channels at this level.

[1] In all data fields the first word (WORD 0, always Integer) contains the number of words which follow in the field.

- RECORD TOF*, FIELD ROTG
  This is a field of variable length with Real words, to contain the relationship between the readout channel numbers and the physical channel numbers.

- RECORD TOF*, FIELD TABL
  This is a field of variable length with Integer words, analagous to the previous field.

- RECORD TOF*, FIELD CSMI
  This is a field of variable length with Integer words, to contain additional constants required for the analysis of cosmic data.

- RECORD TOF*, FIELD CSMR
  This is a field of variable length with Real words analagous to the previous field.

- RECORD TOF*, FIELD USER
  This is a field of variable length with Real words, whose meaning has not been defined by the protocol. A program which reads the database will need to know how to use these words. Finally we have –

- RECORD TOF*, FIELD COMM
  This is a field of variable length with Alphanumeric words. It contains a general comment on the nature of the items at this level.

A 2 THE CAEN BRANCH

This branch contains items relating to the voltages applied to the PMs by the CAEN High Voltage units. At the second level we have the records named CAEN and at the third level records named CAnn (nn = 1 to 88). All records are of type GLOB.

A 2.1 The CAEN Record

This record exists in order to hang the next level down. There are dummy LEAD and SLOW fields. The status in the LEAD field is assumed to be good. (The other fields defined for records of this type have not been inserted.)

A 2.2 The CAnn Records

There are eighty-eight records named from CA01 to CA88, identical in form. They contain two extremely important fields which are accessed in the real time updating of this database from the Slow Controls process (section A4). The fields are –

- RECORD TOF*/CAEN/CAnn, FIELD LEAD
  This a field of variable length with Integer words. One word has been defined.
  WORD 1 = ivall : The current status of the corresponding CAEN HV channel.
  It confers in effect, if not structurally, a status on the PMs powered from that channel.
  IVAL1 = 0 : The corresponding CAEN HV channel is ON.
  IVAL1 = 1 : The corresponding CAEN HV channel is not ON.

- RECORD TOF*/CAEN/CAnn, FIELD SLOW
  This a field of variable length with Real words. One word has been defined.
  WORD 1 = rvall : The current value of the voltage applied by this channel.

A 3 THE TOFL(TOFR) BRANCH

This branch contains all paramaters (except the applied voltages) pertaining to the A side ($Z < 0$) of the detector. At the second level we have records of type GLOB, named TOFL. At the third level we have records of type GLOB, named HSnn (nn = 1 to 48). At the fourth and lowest level we have records of type SENS, named COUN.

A 3.1 The TOFL Record

This is analagous in every way to the ROOT level record and contains the same fields, which now apply to only this half of the detector. Again, there is no physical paramater which could confer a status on the entire half-detector and so the status is taken to be good.

A 3.2 The HSnn Records

There are forty-eight records, of type GLOB named from HS01 to HS48, each relating to one half-sector. The fields which have been inserted are –

- RECORD TOF*/TOFL/HSnn, FIELD LEAD
  This is a field of variable length, with Integer words. One word has been used.
  WORD 1 = ival1 : The status of the half-sector and its PMs.
  IVAL1 is taken = 0 (good), except for the half-sectors which are devoid of counters (numbers 16, 17, 31 and 32), for which IVAL1 = 1.

- RECORD TOF*/TOFL/HSnn, FIELD SLOW
  This is a field of variable length with Integer words, to contain data which could be updated by the Slow Controls process (see section A4 below). This field is presently dummy.

A 3.3 The COUN Records

Each HSnn record hangs one record of type SENS, named COUN. The fields of this record contain data pertaining to the individual scintillators and PMs. This is at the lowest level.

- RECORD TOF*/TOFL/HSnn/COUN, FIELD LEAD
  This is a field of variable length with Integer words. Nine words have been used.
  WORD 1 = 2 : The number of channels described in this record.
  WORD 2 = 1 : A flag for the CHAN field, meaning that channel numbers are listed individually.
  WORD 3 = ival3 : A version flag for reading the (unused) LOCC field.
  WORD 4 = ival4 : A version flag for reading the (unused) SIZC field.
  WORD 5 = −1 : A flag for the STAT field, meaning we list only imperfect channels.
  WORD 6 = 42 : The number of constants per channel in the CALW field.
  WORD 7 = ival7 : The number of words of packed data per channel in the (unused) CALP field.
  WORD 8 = ival8 : The version flag for unpacking the CALP field.
  WORD 9 = ival9 : The version flag for reading the CALW field.
  WORD 10 = ival10 : The version flag for reading the CALP field.

WORD 11 = ival11 : The version flag for the (unused) ALIG field.
WORD 12 = ival12 : The version flag for the USER field.

- RECORD TOF*/TOFL/HSnn/COUN, FIELD LINK
  This is a field of variable length with Alphanumeric words to contain the names of records in the GEOM_DB file which correspond to this half-sector. For example, we could have in CALB_DB record TOF*/TOFL/HS01/COUN, FIELD LINK –
  TOF*, TOFL, S001, C001 (see section B below).

- RECORD TOF*/TOFL/HSnn/COUN, FIELD STAT
  This is a field of variable length with Integer words containing the status of the individual channels.
  WORD 1, 2 = ival1, 2 : The status of each channel in this record.
  IVALI = channel number : for GOOD channels.
  IVALI = (channel number)*100 + n : for BAD channels, where n is an arbitrarily assigned number from 1 to 9, representing increasingly BAD channels. The following (TOF) convention prevails –
  n = 1 : External PM is BAD.
  n = 2 : Internal PM is BAD.
  n = 3 : Both are BAD.
  n = 9 : Half-sector has no counters.

- RECORD TOF*/TOFL/HSnn/COUN, FIELD CHAN
  This is a field of variable length with Integer words, to contain the channel numbers in this record.
  WORD 1, 2 = ival1, 2 : The channel numbers.

- RECORD TOF*/TOFL/HSnn/COUN, FIELD USER
  This is a field of variable length with Real words, to contain the numbers of the CAEN HV channels which power each of the PMs of this half-sector. It contains therefore, the part nn of the name of the record CAnn where the current status and voltage of the channel may be found (see section A2.2).
  WORD 1, 2, 3, 4 = rval1,...
  If rvali = –i, : this particular PM is not connected to the power supply.

- RECORD TOF*/TOFL/HSnn/COUN, FIELD CALW
  This is a record of variable length with Real words, containing electronic constants pertaining to the two scintillators, four PMs, and the devices which read out from them.

WORD 1 – 84 = rval1,...
WORD 1 : The counter number of the lower numbered counter as in the CHAN field.
WORD 2 : The attenuation length of the scintillator as determined using the external PM (cm).
WORD 3 : As WORD 2, but using the internal PM.
WORD 4 : Effective Velocity of light in the scintillator (cm/nsec).
WORD 5 : Redundant.
WORD 6, 7 : The slope and intercept of a plot of Gain versus Voltage for the external PM.
WORD 8, 9 : Similarly for the internal PM.
WORD 10, 11 : The delay between the time of impact at centre of the counter and the readout for the external and internal PMs,T_0 (nsec).
WORD 12, 13 : The standard deviations of the two previous quantities.
WORD 14, 15 : The saturation value of the TDC channels which read the external and internal PMs (arbitrary units).
WORD 16, 17 : The standard deviations of the two previous quantities.
WORD 18, 19 : The pedestal on the low range of the ADC channel which reads out the external and internal PMs (arbitrary units).
WORD 20, 21 : The standard deviations of the two previous quantities.
WORD 22, 23 : The factor for converting TDC counts, on the readout of the external and internal PMs, to ns (nsec/count).
WORD 24, 25 : The pedestal on the high range of the ADC channel which reads out the external and internal PMs (arbitrary units).
WORD 26, 27 : The standard deviations of the two previous quantities.
WORD 28, 29 : Threshold of the TDC channels which read the external and internal PMs (arbitrary units).
WORD 30, 31 : The standard deviations of the two previous quantities.
WORD 32 : T_0 for the multihit TDC (nsec).
WORD 33 – 42 : Not yet defined.
WORD 43 – 84 : Repeat for the higher numbered counter.

The TOFR branch contains all paramaters (except the applied voltages) pertaining to the C side ($Z > 0$) of the detector. This is entirely analagous to the TOFL branch both at the higher and the lower levels.

A 4 REAL TIME UPDATING OF CALB_DB

The CALB_DB may be updated from the Slow Controls process during the actual running of the beam. This process cannot be described in detail here. We mention briefly that a micro-computer, called the G64, can control experimental equipment, such as the CAEN HV units. The program which runs on the G64 is called SKELETON, and is a complete, though relatively inaccessible, way of controlling the equipment. To facilitate users, SKELETON communicates with a program, called the ELEMENTARY PROCESS (EP), executing on the VAX. Commands may be passed from the EP on the VAX to SKELETON on the G64, using the Remote Procedure Call (RPC) facility . Messages generated on the G64 are sent to EP.

Any physical parameter which is monitored by the G64 and is needed for the subsequent analysis could serve as a means of updating a LEAD or SLOW field at any level of CALB_DB. In our case there are two such paramaters, the status of the CAEN channels and their voltage. They obviously relate to the CAnn records in the CAEN branch.

We have a Slow Controls file [SC_DB], also made according to the rules of CARGO. We shall not attempt to describe its rather complex structure here. We mention that it contains a branch of eighty-eight records with the nominal values of the operational parameters of the CAEN HV channels. There is a one to one relationship between these records, named 00nn (nn = 1 to 88) in SC_DB and the records named CAnn (nn = 1 to 88) in CALB_DB. A field in SC_DB gives the relation explicitly for each record. When the user submits EP he may set a flag to update or not to update the CALB_DB. The actual case of updating may arise in one of three instances –
1). When EP is submitted, or resumes after loss of contact with the G64.
2). By the continuous monitoring of the status byte of each Caen channel.
3). By the periodic check of the voltages.
We consider these three cases -
1). In this case EP looks at three separate items –

- 1a). It reads the status byte of each Caen channel. It notes if it is in a valid state (ON) or in an invalid state (anything else). It compares the actual status with the (latest) status for that Caen channel in the LEAD field in CALB_DB to which the Caen channel points. If it finds a conflict it will generate a new record with the names and types specified in SC_DB and a field LEAD with the value of the first word corresponding to the current status of the Caen channel. This field update record, of class .F, will be valid from the present time onwards, or until superseded by a later record of similar class.

- 1b). It reads the status byte of each whole crate. This does not give rise to any updates.

- 1c). It reads the voltage in each of the Caen channels. If this differs by more than a certain amount (we have chosen 50 Volts) from the nominal value then it generates a new record with the names and types specified in SC_DB and with a SLOW field containing the present value of the voltage in its first word. A new reference value is established. This field update record, of class .F, will be good from the present time onwards, or until superseded by a later record of similar class.

- 2) When SKELETON is running it continuously checks the values of the status byte of each Caen channel and the crate status byte. It notes any change in the value of the byte with respect to the previous round. If the difference was from a valid to an invalid state or vice versa, then EP will update the status of that channel in CALB_DB, as in 1a) above. It does not check the voltage in this process.

- 3) At a certain interval (we have put 1 hour) the VAX calls on the SKELETON to check the voltages. If it finds that the actual voltage differs by more than 50 Volts (our choice) from the value in the SLOW field of the corresponding CAnn record then it follows the procedure in item 1c) above. The choices of the checking interval and the tolerance are made in SC_DB.

A 5 OFFLINE MODIFICATIONS

Many paramaters, other than those monitored by the Slow Controls process, need to be updated from time to time. The values of these quantities can only be obtained by offline analysis of recorded data at a later time. It is necessary to modify the existing database with new records the validity of which may be backdated in time.

CARGO allows the making of two types of updates which may be used for this purpose. They are the field update (class .F) and the word update (class .W). In the first case the user supplies a record containing the date and time from which it is valid, and the new values of all quantities in the field. Is is not necessary to provide a new field for the other fields in the original record. Unlimited numbers of field updates may be supplied with successively later validity dates. In the second case the user provides a record containing the the field to be updated, the date and time from which it is valid, the position of the word in the field and its new value.

B THE GEOMETRY DATABASE

The Geometry file (GEOM_DB) contains information on the location (TREE GEOM) and composition (TREE MATC) of the components of the detector.

B 1 TREE GEOM, ROOT LEVEL

This record is of type DETG and is named TOF*. It contains the following data fields –

- RECORD TOF*, FIELD SHAP
  This is a coded field. The code CYL1 determines a field of fixed length with one Alphanumeric and six Real words. [2]
  WORD 1 = CYL1 : A right circular cylinder about the z axis.
  WORD 2, 3 = 0.0, 360.0 : Minimum, maximum azimuths of the detector (deg).
  WORD 4, 5 = 310.0, 318.5 : Minimum, maximum radii of the detector (cm).
  WORD 6, 7 = −355.2, 355.2 : Mimimum, maximum z coordinate of the detector (cm).
  All coordinates are in the standard reference frame of DELPHI (by default).

- RECORD TOF*, FIELD MATS
  This is a field of variable length, with Alphanumeric words. Two words have been defined.
  WORD 1 = TOAV : The material of the detector.
  WORD 2 = AIR* : Default material for the detector.
  The properties of the materials are listed in tree MATC (section B 5).

[2] A coded field means that a number of alphanumeric codes have been defined for WORD 1 of the field. Each code determines the number and meaning of the remaining words in the field.

B 2 The TOFR, TOFL and TOFM LEVEL

This level contains the records which describe the two halves of the detector TOFR and TOFL, and its outer support TOFM.

B 2.1 The TOFR Record

There is one record of type DETG, named TOFR.

- RECORD TOF*/TOFR, FIELD REFR
  This is a field of variable length with Real words. Six words have been defined. The origin is translated to the longitudinal centre of the counter ensemble on the right half of the barrel.
  WORD 1, 2, 3 = 0.0, 0.0, 177.6 : Coordinates (in DELPHI frame) of origin of the TOFR reference frame (cm).
  WORD 4, 5, 6 = 0.0, 0.0, 0.0 : Eulerian rotation angles of TOFR frame with respect to the DELPHI frame (deg).

- RECORD TOF*/TOFR, FIELD SHAP
  The code CYL1 determines a field of fixed length with one Alphanumeric and six Real words.
  WORD 1 = CYL1 : A right circular cylinder about the z axis.
  WORD 2, 3 = 0.0, 360.0 : Minimum, maximum azimuths of TOFR (deg).
  WORD 4, 5 = 310.0, 317.02 : Minimum, maximum radii of TOFR (cm).
  WORD 6, 7 = −177.6, 177.6 : Minimum, maximum z coordinate of TOFR (cm).
  (All coordinates are in the reference frame of TOFR.)

- RECORD TOF*/TOFR, FIELD MATS
  WORD 1 = TOAV : The material of the half-detector.
  WORD 2 = AIR* : Default material for the half-detector.

B 2.2 The TOFL Record

There is one record of type DETG named TOFL.

- RECORD TOF*/TOFL, FIELD REFR
  This is a field of variable length with Real words. Six words have been defined. The origin is translated to the longitudinal centre of the

counter ensemble on the left half of the barrel.
WORD 1, 2, 3 = 0.0, 0.0, −177.6 : Coordinates (in DELPHI frame) of origin of the TOFL reference frame (cm).
WORD 4, 5, 6 = 0.0, 0.0, 0.0 : Eulerian rotation angles of TOFL frame with respect to the DELPHI frame (deg).

- RECORD TOF*/TOFL, FIELD MATS; FIELD SHAP
  As in the case of TOF*/TOFR.

B 2.3 The TOFM Record

There is one record of type DETG named TOFM.

- RECORD TOF*/TOFM, FIELD SHAP
  The code CYL1 determines a field of fixed length with one Alphanumeric and six Real words.
  WORD 1 = CYL1 : A right circular cylinder about the z axis.
  WORD 2, 3 = 0.0, 360.0 : Minimum, maximum azimuths of TOFM (deg).
  WORD 4, 5 = 317.02, 318.5 : Minimum, maximum radii of TOFM (cm).
  WORD 6, 7 = −355.2, 355.2 : Minimum, maximum z coordinate of TOFM (cm).
  As there is no REFR field the coordinate system remains the same as that of the previous level, TOF*.

- RECORD TOF*/TOFM, FIELD MATS
  WORD 1 = TOMA : The material of the support.
  WORD 2 = AIR* : Default material for the support.

B 3 The SECTOR and FOOT LEVEL

At the third level the Snnn records describe the active sectors of TOFR and TOFL. FUTn records describe the supports of the coil.

B 3.1 The Snnn Records

There are twenty-two records of type DETG named from S001 to S008, S010 to S015 and S017 to S024, in each of TOFR and TOFL. Some of the fields described in this section have been inserted by replication.

- RECORD TOF*/TOFR/Snnn, FIELD REFR
  This is a field of variable length with Real words. Six words have been defined.
  WORD 1, 2, 3 = X(Snnn),Y(Snnn), 0.0 (cm).
  Coordinates (in TOFR) of centre of volume of Snnn; X = R(cos ϕ_{nnn}), Y = R(sin ϕ_{nnn}), where R is the middle radius and ϕ is the azimuth at the centre of the sector; ϕ = 82.5 −(nnn-1) *15 degrees.
  WORD 4, 5, 6 = 0.0, $-\phi$, 0.0 (deg).
  Eulerian angles of rotation of the Snnn system. One should supply here the negative value of the angle of rotation .

- RECORD TOF*/TOFR/Snnn, FIELD SHAP
  The code BRIK determines a field of fixed length with one Alphanumeric and three Real words.
  WORD 1 = BRIK : A parallelepiped.
  WORD 2, 3, 4 = 7.02, 80.0, 355.2 : Full extent of the sector in the x, y and z coordinates (cm).

- RECORD TOF*/TOFR/Snnn, FIELD MATS
  WORD 1 = TOAV : The material of the sector.
  WORD 2 = AIR* : Default material for the sector.

B 3.2 The FUTn Records

There are two records, of type DETG, named FUTn (n = 1, 2) in each of TOFR and TOFL. They describe the feet of the coil.

- RECORD TOF*/TOFR/FUT1(FUT 2), FIELD SHAP
  The code CYL1 determines a field of fixed length with one Alphanumeric and six Real words.
  WORD 1 = CYL1 : An element of cylinder about the z axis.
  WORD 2, 3 = 317.0, 328.0 : Minimum, maximum azimuths of foot (deg).
  WORD 4, 5 = 310.0, 314.0 : Minimum, maximum radii of foot (cm).
  WORD 6, 7 = 98.5, 178.5 : Minimum, maximum z coordinate of foot (cm).
  For FUT2; WORD 2, 3 = 212.0, 223.0
  As there is no REFR field, the coordinate system is that of the previous TOFR level.

- RECORD TOF*/TOFR/FUTn, FIELD MATS
  WORD 1 = FEET : The material of the support.
  WORD 2 = FEET : Default material for the support.

- RECORD TOF*/TOFL/FUT1(FUT 2), FIELD SHAP, FIELD MATS
  As in the case of TOF*/TOFR except in FIELD SHAP –
  WORD 6, 7 –178.5, –98.5

B 4 The COUNTER and ELEMENT LEVELS

The fourth and fifth levels contain the records which describe the counter ensemble in the sectors and the individual components of each counter. Some of the fields described in this sector have been made by replication.

B 4.1 The Cnnn Records

The Sector records each have four records of type DETG named Cnnn, nnn = 1 to 4. (The record S010 has three records, nnn = 2 to 4; the record S015 has nnn = 1 to 3.)

- RECORD TOF*/TOFR/Snnn/Cnnn, FIELD REFR
  This is a field of variable length with Real words. Six words have been defined.
  WORD 1, 2, 3 = 0.0, Y(Cnnn), 0.0 (cm).
  Coordinates (in Snnn) of the centre of volume of the counter : Y = 30.0, 10.0, –10.0, –30.0 for counters nnn = 1, 2, 3, 4.
  WORD 4, 5, 6 = 0.0, 0.0, 0.0 : Eulerian angles of rotation with respect to the Snnn system (deg).

- RECORD TOF*/TOFR/Snnn/Cnnn, FIELD SHAP
  The code BRIK determines a field of fixed length with one Alphanumeric and three Real words.
  WORD 1 = BRIK : A parallelepiped.
  WORD 2, 3, 4 = 7.02, 20.0, 355.2 : Full extent of the counter in the x, y and z coordinates (cm).

- RECORD TOF*/TOFR/Snnn/Cnnn, FIELD MATS
  WORD 1 = TOAV : The material of the counter ensemble.
  WORD 2 = AIR* : Default material for the counter ensemble.

B 4.2 The Ennn Records

A Cnnn record has nine records of type DETG named Ennn, nnn = 1 to 9.

- RECORD TOF*/TOFR/Snnn/Cnnn/E001, FIELD REFR
  This is a field of variable length with Real words. Six words have been defined. They refer to the scintillator itself.
  WORD 1, 2, 3 = −2.56, 0.0, 0.0 : Coordinates (in Cnnn) of the centre of volume of the scintillator (cm).
  WORD 4, 5, 6 = 0.0, 0,0, 0.0 : Eulerian angles of rotation with respect to the Cnnn system (deg).

- RECORD TOF*/TOFR/Snnn/Cnnn, FIELD SHAP
  The code BRIK determines a field of fixed length with one Alphanumeric and three Real words.
  WORD 1 = BRIK : A parallelepiped.
  WORD 2, 3, 4 = 1.9, 20.0, 350.0 : Full extent of the scintillator in the x, y and z coordinates (cm).

- RECORD TOF*/TOFR/Snnn/Cnnn/E001, FIELD MATS
  WORD 1 = SCIN : The material of the scintillator.
  WORD 2 = SCIN : Default material for the scintillator.

- RECORD TOF*/TOFR/Snnn/Cnnn/E002(E003), FIELD REFR
  This is a field of variable length with Real words. Six words have been defined. They refer to the semi-cylindrical light guides.
  WORD 1, 2, 3 = −0.91, 0.0, 175.0 : Coordinates (in Cnnn) of centre of the plane face of the guide (cm).
  WORD 4, 5, 6 = 0.0, −270.0, 0.0 : Eulerian angles of rotation with respect to the Cnnn system (deg).
  For E003; WORD 3 = −175.0

- RECORD TOF*/TOFR/Snnn/Cnnn/E002(E003), FIELD SHAP
  The code CYL1 determines a field of fixed length with one Alphanumeric and six Real words.
  WORD 1 = CYL1 : An element of cylinder about the z axis.
  WORD 2, 3 = 180.0, 360.0 : Minimum, maximum azimuths of semi-cylinder (deg).
  WORD 4, 5 = 0.0, 2.6 : Minimum, maximum radii of semi-cylinder (cm).
  WORD 6, 7 = −10.0, 10.0 : Minimum, maximum z coordinate of semi-

cylinder (cm).
For E003; WORD 2, 3 = 0.0, 180.0

- RECORD TOF*/TOFR/Snnn/Cnnn/E002(E003), FIELD MATS
  WORD 1 = PLEX : The material of the semi-cylinder.
  WORD 2 = PLEX : Default material for the semi-cylinder.

- RECORD TOF*/TOFR/Snnn/Cnnn/E004(E005), FIELD REFR
  This is a field of variable length with Real words. Six words have been defined. They refer to the trapezoidal light guides atop the scintillator.
  WORD 1, 2, 3 = 0.14, 0.0, 125.0 : Coordinates (in Cnnn) of centre of the volume of the guide (cm).
  WORD 4, 5, 6 = 0.0, −90.0, 0.0 : Eulerian angles of rotation with respect to the Cnnn system (deg).
  For E005; WORD 3 = −125.0, WORD 5 = −270.0

- RECORD TOF*/TOFR/Snnn/Cnnn/E004(E005), FIELD SHAP
  The code FORB determines a field of fixed length with one Alphanumeric and nine Real words.
  WORD 1 = FORB : A four sided box with parallel sides.
  WORD 2 = 90.0 : Azimuth of the symmetry axis (deg).
  WORD 3 = 90.0 : Angle of the symmetry axis to the top edge (deg).
  WORD 4, 5 = −50.0, 50.0 : Distance along symmetry axis to the lower and upper edges of the guide (cm).
  WORD 6 = 3.1 : Thickness of the guide (cm).
  WORD 7, 8, 9, 10 = : −10.0, 10.0, −1.55, 1.55 : The minimal and maximal values of z at the upper and then the lower edge (cm).

- RECORD TOF*/TOFR/Snnn/Cnnn/E004(E005), FIELD MATS
  WORD 1 = PLEX : The material of the trapezoid.
  WORD 2 = PLEX : Default material for the trapezoid.

- RECORD TOF*/TOFR/Snnn/Cnnn/E006(E007), FIELD REF1
  This is a field of variable length with Real words. Six words have been defined. They refer to the section of the quasi-cylindrical light guides which adjoins the trapezoidal guides.
  WORD 1, 2, 3 = 0.14, 0.0, 73.5 : Coordinates (in Cnnn) of the centre of volume of the section (cm).
  WORD 4, 5, 6 = 0.0, 0.0, 0.0 : Eulerian angles of rotation with respect to the Cnnn system (deg).
  For E007; WORD 3 = −73.5

- RECORD TOF*/TOFR/Snnn/Cnnn/E006(E007), FIELD SHA1
The code BRIK determines a field of fixed length with one Alphanumeric and three Real words.
WORD 1 = BRIK : A parallelepiped.
WORD 2, 3, 4 = 3.1, 3.1, 3.0 : Full extent of the section in the x, y and z coordinates (cm).

- RECORD TOF*/TOFR/Snnn/Cnnn/E006(E007), FIELD REF2
This is a field of variable length with Real words. Six words have been defined. They refer to the central section of the quasi-cylindrical light guides.
WORD 1, 2, 3 = 0.59, 0.0, 67.5 : Coordinates (in Cnnn) of the centre of volume of the section (cm).
WORD 4, 5, 6 = 0.0, 0.0, 0.0 : Eulerian angles of rotation with respect to the Cnnn system (deg).
For E007; WORD 3 = −67.5

- RECORD TOF*/TOFR/Snnn/Cnnn/E006(E007), FIELD SHA2
The code CYL3 determines a field of fixed length with one Alphanumeric and eight Real words.
WORD 1 CYL3 : A right circular cone about the z axis.
WORD 2, 3 = 0.0, 360.0 : Minimum, maximum azimuths of cone (deg).
WORD 4, 5 = −4.5, 4.5 : Minimum, maximum z coordinate of cone (cm).
WORD 6, 7 = 0.0, 1.6 : Minimum, maximum radii of cone at the minimal z (cm).
WORD 8, 9 = 0.0, 1.7 : Minimum, maximum radii of cone at the maximal z (cm).
For E007; WORD 7 = 1.6, WORD 9 = 1.7

- RECORD TOF*/TOFR/Snnn/Cnnn/E006(E007), FIELD REF3
This is a field of variable length with Real words. Six words have been defined. They refer to the section of the quasi-cylindrical guides which adjoins the PM.
WORD 1, 2, 3 = 0.99, 0.0, 60.25 : Coordinates (in Cnnn) of the centre of the section (cm).
WORD 4, 5, 6 = 0.0, 0.0, 0.0 : Eulerian angles of rotation with respect to the Cnnn system (deg).
For E007; WORD 3 = −60.25

- RECORD TOF*/TOFR/Snnn/Cnnn/E006(E007), FIELD SHA3
The code CYL1 determines a field of fixed length with one Alphanumeric and six Real words.
WORD 1 = CYL1 : A right circular cylinder about the z axis.
WORD 2, 3 = 0.0, 360.0 : Minimum, maximum azimuths of cylinder (deg).
WORD 4, 5 = 0.0, 1.5 : Minimum, maximum radii of cylinder (cm).
WORD 6, 7 = −2.75, 2.75 : Minimum, maximum z coordinate of cylinder (cm).

- RECORD TOF*/TOFR/Snnn/Cnnn/E006(E007), FIELD COMG
This is a field of variable length with Alphanumeric words. Three words have been defined.
WORD 1, 2, 3 1:1 + 2:2 + 3:3 Add the shapes SHA1 in REF1, SHA2 in REF2 and SHA3 in REF3.

- RECORD TOF*/TOFR/Snnn/Cnnn/E006(E007), FIELD MATS
WORD 1 = PLEX : The material of the entire quasi-cylinder.
WORD 2 = PLEX : Default material for the entire quasi-cylinder.

- RECORD TOF*/TOFR/Snnn/Cnnn/E008(E009), FIELD REFR
This is a field of variable length with Real words. Six words have been defined. They refer to the iron shields and rings surrounding the PMs.
WORD 1, 2, 3 = 1.05, 0.0, 50.4 : Coordinates (in Cnnn) of the centre of the shield (cm).
WORD 4, 5, 6 = 0.0, 0.0, 0.0 : Eulerian angles of rotation with respect to the Cnnn system (deg).
For E009; WORD 3 = −50.4

- RECORD TOF*/TOFR/Snnn/Cnnn/E008(E009), FIELD SHAP
The code CYL1 determines a field of fixed length with one Alphanumeric and six Real words.
WORD 1 = CYL1 : A right circular cylinder about the z axis.
WORD 2, 3 = 0.0, 360.0 : Minimum, maximum azimuths of the shield. (deg).
WORD 4, 5 = 2.28, 2.46 : Minimum, maximum radii of the shield (cm).
WORD 6, 7 = −10.1, 10.1 : Minimum, maximum z coordinate of the shield (cm).

- RECORD TOF*/TOFR/Snnn/Cnnn/E008(E009), FIELD MATS
  WORD 1 = FE : The material of the shield.
  WORD 2 = FE : Default material for the shield.

The treatment of the counters containing one shortened scintillator differs from the above, as described in the main text (section 3.2.4).

B 5 TREE MATC

There are three records of type MATE, with names SCIN, PLEX and TOMA. They describe the physical characteristics of the scintillator, the plexiglass of the light guides and the material used in the construction of the outer mechanical support.

- RECORD SCIN (PLEX, TOMA), FIELD MATF
  This is an *obligatory* field of variable length with Real words.
  WORD 1 = 1.0 : A flag, meaning that the Radiation and Absorption lengths are specified.
  WORD 2 : Material density.
  WORD 3 : Nuclear charge.
  WORD 4 : Atomic weight.
  WORD 5 : Radiation length.
  WORD 6 : Absorption length.
  The values inserted for the three materials are as shown in Table 1.

Material	$\rho\ gr.cm^{-3}$	Z	A	X_{rl}	λ_{nucl}
SCIN	1.032	5.65	11.15	42.4	82.0
PLEX	1.18	6.24	12.4	34.4	83.6
TOMA	0.412	14.1	29.6	55.	107.

Table 1 **Materials in the TOF GEOM_DB, TREE MATC**

FIGURE CAPTIONS

Fig. 1 Schematic view of TOF on the barrel of DELPHI.

Fig. 2 Partial view of the sintillator and light guides.
(a) Side and (b) Top

Fig. 3 Partial view of the metal frame attached to the counter.
(a) Side and (b) Top

Fig. 4 Arrangement of the plate and guide rails for attaching TOF to the Hadron Calorimeter.

Fig. 5 Design of the TOF CALB_DB.

Fig. 6 Design of the TOF GEOM_DB, Tree GEOM.

Fig. 7 Elements of the counter ensemble.

REFERENCES

1 J.M. Benlloch et al.
Nucl. Inst. and Meth. A290(1990) 327.

2 J.M. Benlloch et al.
Anales de Física B85(1989) 342.

3 P. Allen et al.
Nucl. Inst. and Meth. A277(1989) 347.

4 Y. Belokopytov and V. Perevozchikov
DELPHI 90 – 36 PROG – 153 (1990).

5 R. Matthews
CERN Program Library long write-up Z303 (1986).

6 Y. Belokopytov et al.
DELPHI 90 – 38 PROG – 155 (1990).

7 J. Cuevas and A. Ruiz
DELPHI 87 – 98 PROG – 101 (1987).

8 E. Chernyaev et al.
DELPHI 87 – 30 PROG – 74

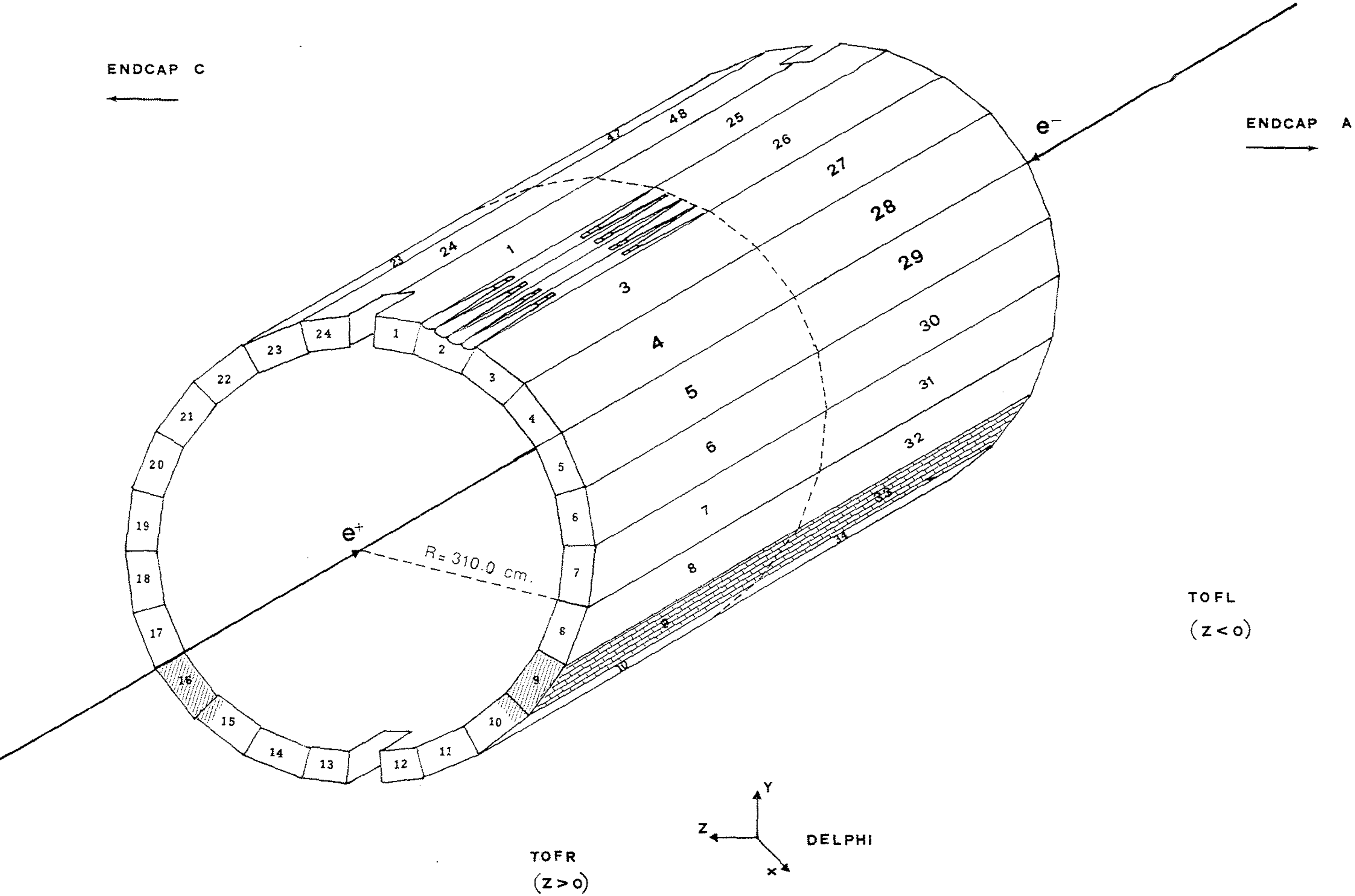


FIG. 1

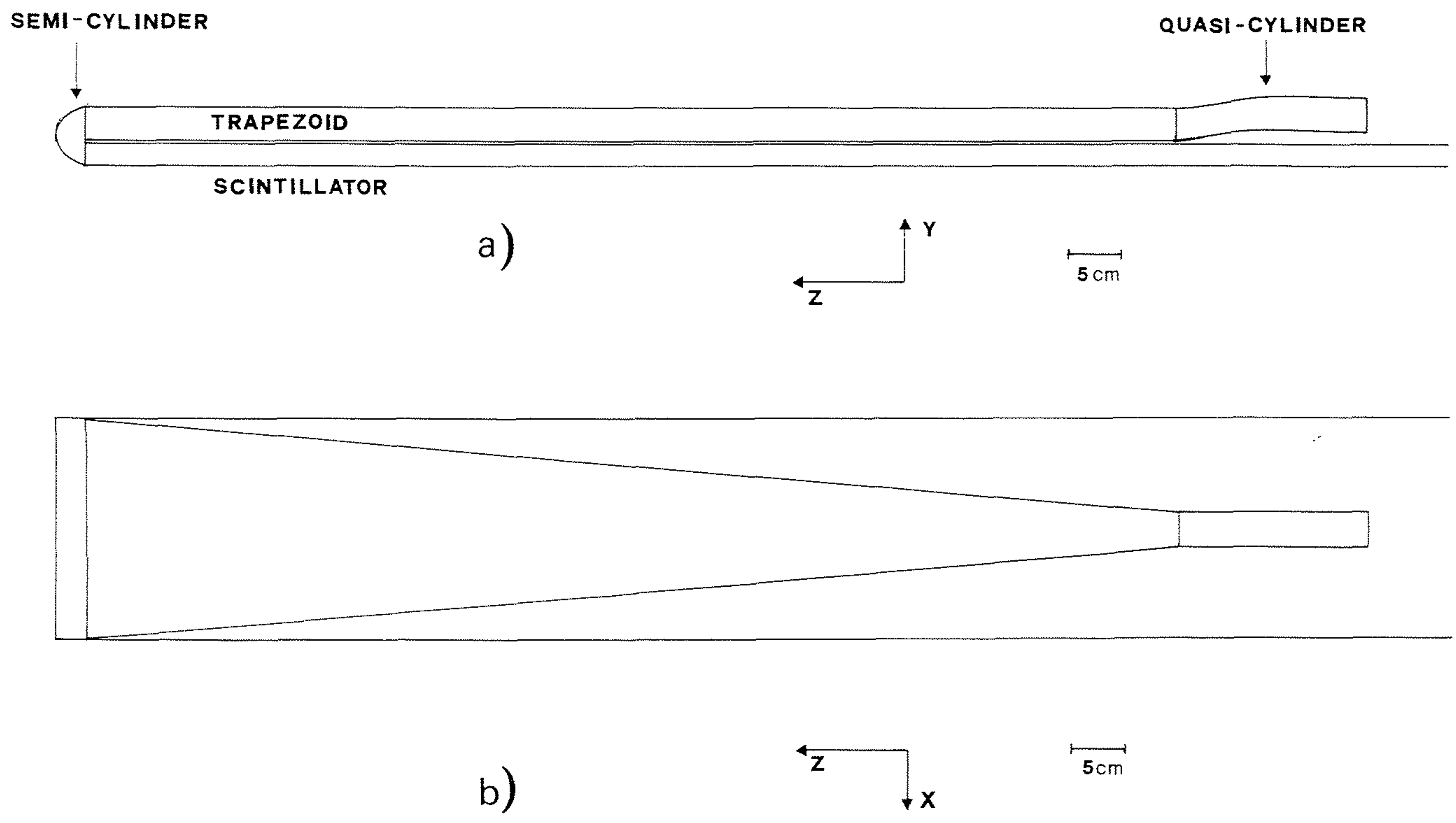

SEMI-CYLINDER
QUASI-CYLINDER
TRAPEZOID
SCINTILLATOR
a)
Y
Z
5cm
Z
X
5cm
b)

FIG. 2

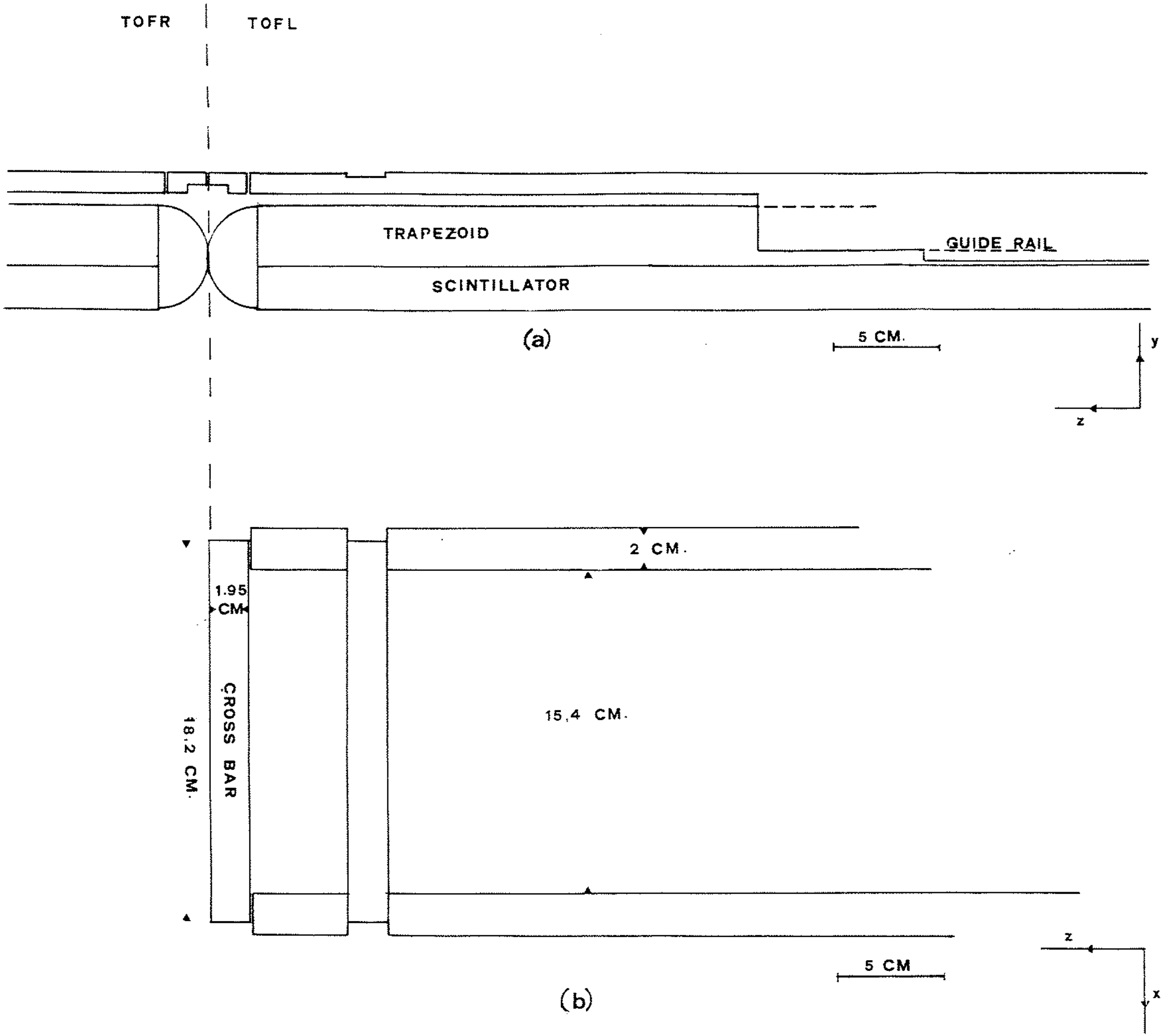

TOFR
TOFL
TRAPEZOID
GUIDE RAIL
SCINTILLATOR
(a)
5 CM.
y
z
2 CM.
1.95 CM
CROSS BAR
18.2 CM.
15.4 CM.
5 CM
z
x
(b)

FIG. 3

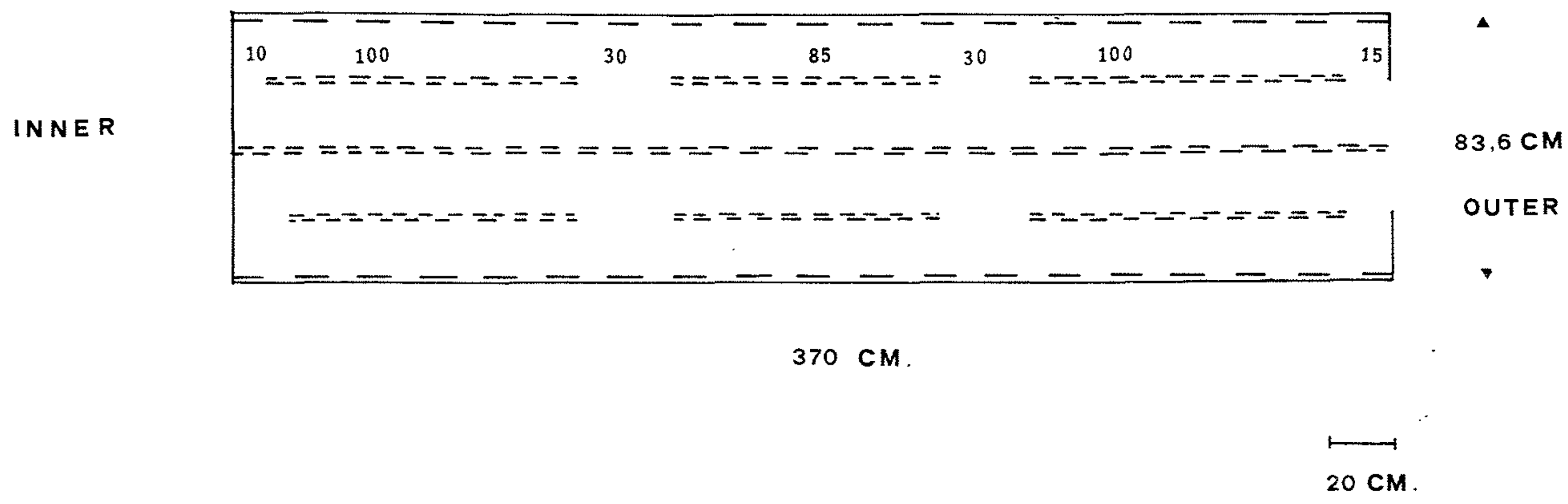
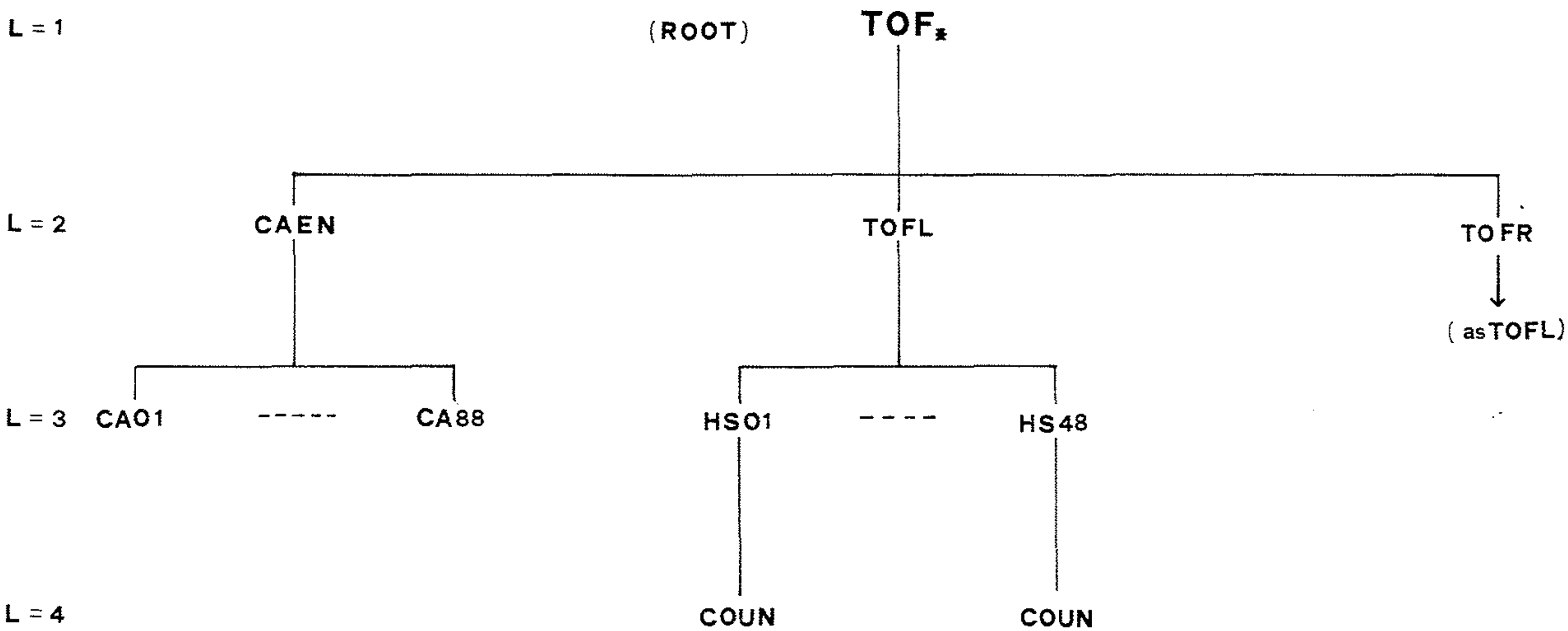


FIG. 4


L = 1
L = 2
L = 3
L = 4
(ROOT)
TOF*
CAEN
TOFL
TOFR
(as TOFL)
CA01

CA88
HS01

HS48
COUN
COUN

FIG.5

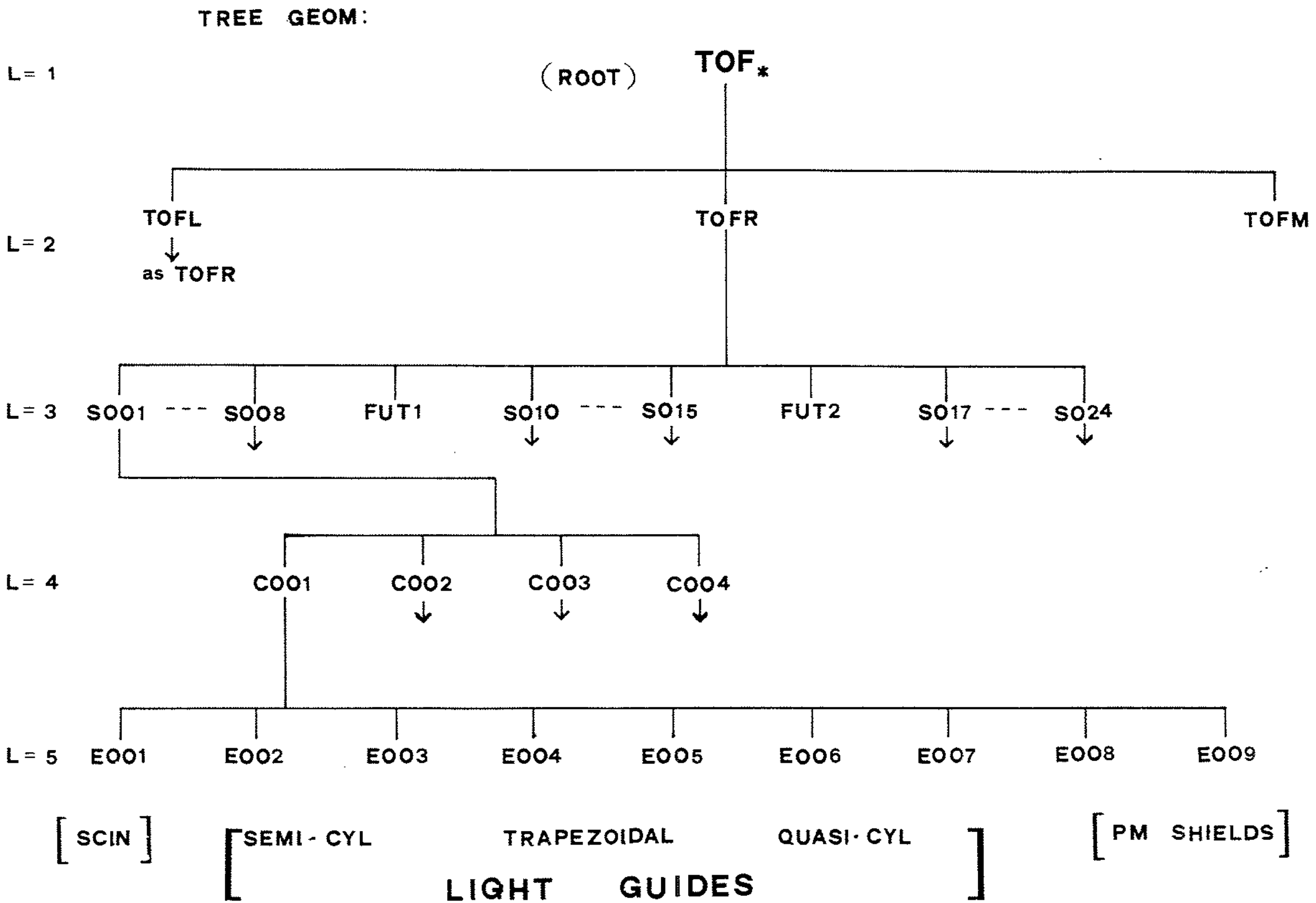

TREE GEOM:
L= 1
(ROOT)
TOF*
L= 2
TOFL
as TOFR
TOFR
TOFM
L= 3
S001 --- S008
FUT1
S010 --- S015
FUT2
S017 --- S024
L= 4
C001
C002
C003
C004
L= 5
E001
E002
E003
E004
E005
E006
E007
E008
E009
[SCIN]
[SEMI-CYL
TRAPEZOIDAL
QUASI-CYL
LIGHT GUIDES]
[PM SHIELDS]

FIG.6

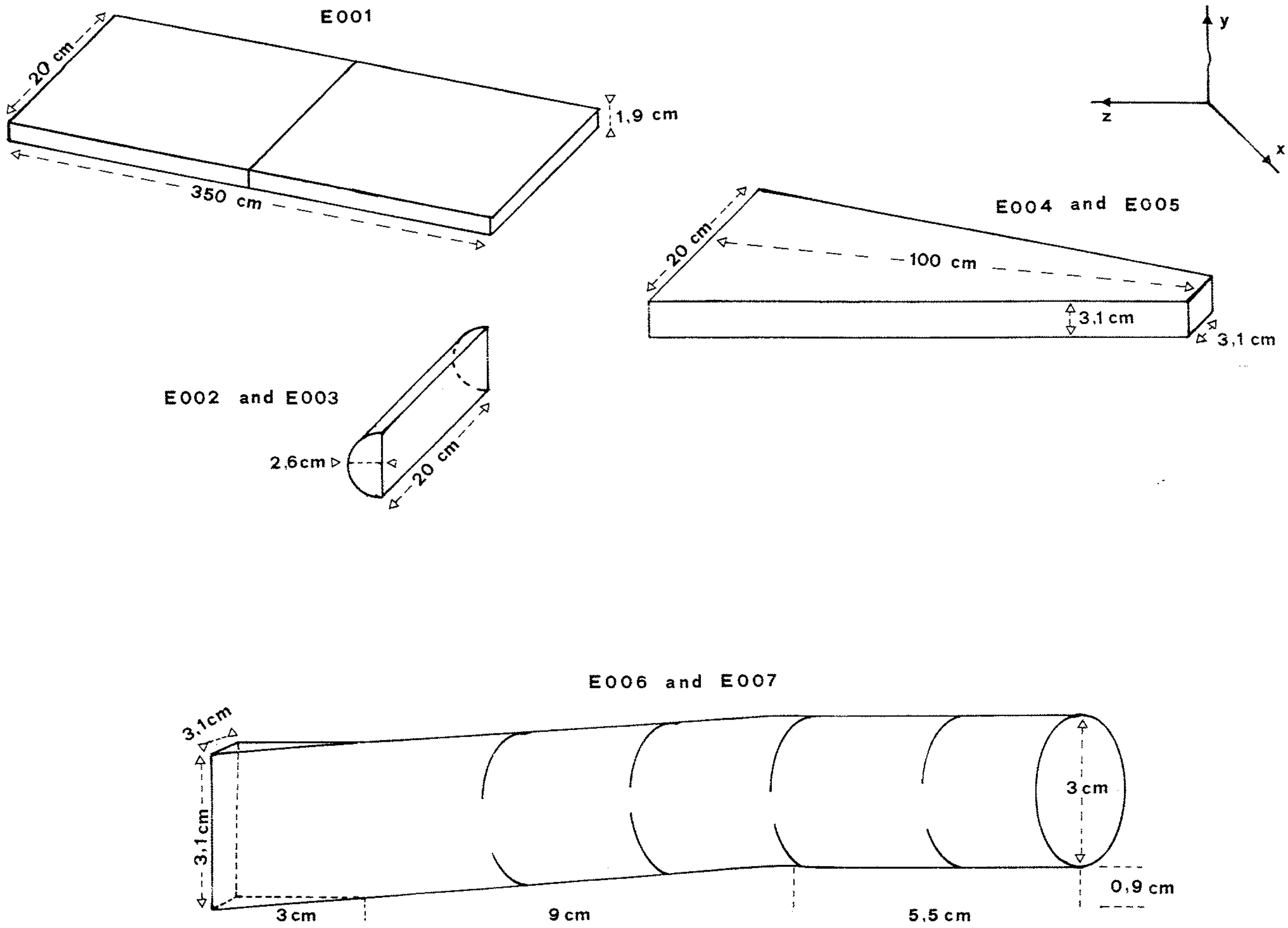

E001
20 cm
1,9 cm
350 cm
y
z
x
E004 and E005
20 cm
100 cm
3,1 cm
3,1 cm
E002 and E003
2,6cm
20 cm
E006 and E007
3,1cm
3,1cm
3 cm
3 cm
9 cm
5,5 cm
0,9 cm

FIG. 7