TOF Tray Mechanical Design Dimensions & Tolerances

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Contents

1 Introduction

There is relatively little constructed-parts contingency in the STAR TOF project. Only 126 full trays, and the MRPCs for exactly 126 trays, will be built. If a dimension of an object built as part of the TOF project is larger or smaller than some limit, the object will not fit and cannot be used. In order to avoid such contretemps, the external constraints must be understood, the critical dimensions identified, and the allowable range of values of these dimensions agreed upon across the three TOF subsystems (Detectors & Mechanical, MRPCs, and Electronics).

This document summarizes aspects of the dimensions and dimension tolerances for the TOF trays, the MRPCs inside the trays, and the electronics that close the trays. The critical dimensions, and the allowed range of values for each, are proposed.

This document will be updated as necessary to reflect the upcoming discussions of these aspects of the project. Once the dimensions and tolerances are agreed upon across TOF subsystems, and with the STAR Technical Support Group, this document will become a "TOF Note" under the standard TOF project change control procedure [1].

The trays are discussed first in Section 2, The MRPCs are discussed in Section 3, and the electronics are discussed in Section 4.

2 Trays

The entire mechanical structure of the trays [2] must fit into a cylindrical shell between the STAR TPC and BEMC detectors. The (R,ϕ) dimensions of this shell are discussed first, then the Z dimensions are discussed.

2.1 Dimensions in (R,ϕ)

The trays are physically mounted onto TPC "rails". These are long Aluminum extrusions that are glued onto the TPC's gas containment vessel. The upper section of Figure 1 shows the end-view of a rail from STSG Drawing TPC125-D-1, while the lower section shows how the trays register onto a rail. The bottom face of each rail has been machined to a three chord profile across the width to maximize glue surface contact with the outer radius of the TPC, while the upper half is flat, so as to match the flat bottom of a CTB/TOF tray. There are 60 rails and each extends the entire length of the TPC. The total length of a rail is 181" ± 0.06". "Feet" are attached to the tray body, and the feet and the tray bottom form U-shaped sections that wrap around both ears of a rail. The same mounting strategy and component dimensions and positioning was used for the 120 CTB trays, the TOFp tray, and the three TOFrX prototype trays.

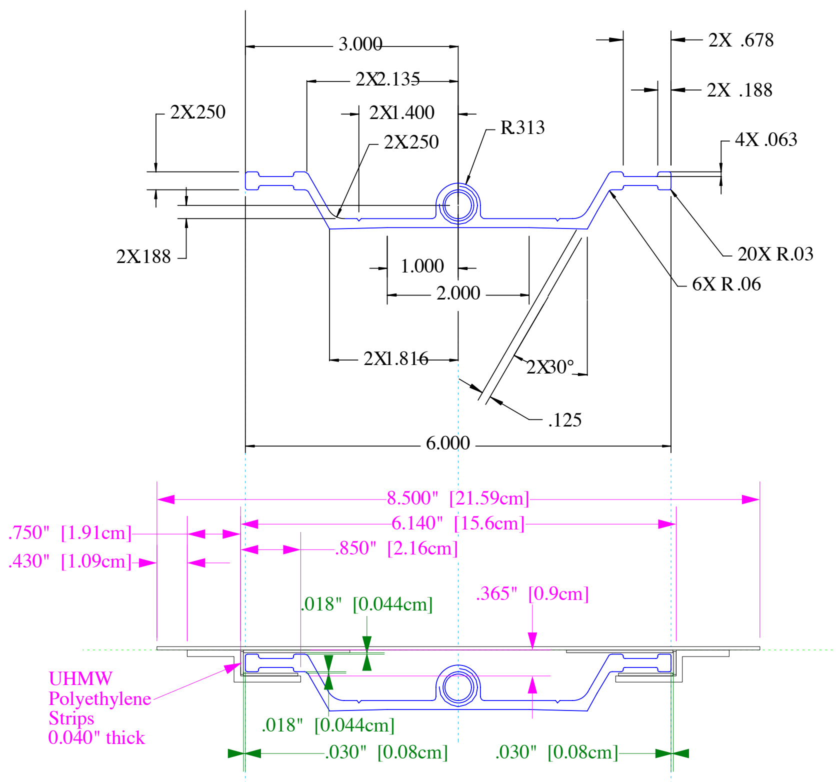

Figure 1: In the upper section, an R-ϕ view of a "rail", and in the lower section, a rail with the TOF tray "feet" (below) which hold the trays in place on the TPC gas containment vessel.

The tolerances on the rail width and height, and their relationship to the tray feet inner width and inner height are described in turn in the following two subsections.

2.1.1 Tray Feet Inner Width

The dimension discussed in this subsection is the inner width of the feet attached to the TOF trays. This dimension is mostly parallel to STAR ϕ direction. The default inner width is 6.140". This must account for two layers of UHMW polyethylene strips (each 0.040"-thick), as well as the fabrication tolerances on the width of the rails as well as the positioning of the feet with respect to the tray body.

A rail is nominally 6.000" within 0.020" wide, with a straightness not to exceed 0.075" over its total length of 181". The worst-case-maximum rail width is thus 6.000 + 0.020"/2 (max. width tolerance) + 0.019 (evaluating the maximum rail straightness tolerance of 0.075" at the mid-length of any one TOF tray), or 6.029".

The worst-case-maximum rail width must fit inside the inner width of the tray feet. The nominal inner width spacing is 6.140" − 0.080" (for two UHMW polyethylene strips) = 6.060". The worst-case-maximum rail is 6.029" wide, leaving a gap of nominally 0.031". The positioning and straightness of the mounting of the feet with respect to the tray body must thus be better than 0.031".

The worst-case-minimum rail width assumes perfectly straight rails and is thus 6.000 − 0.020"/2, or 5.990".

For a tray where the rail positions are perfectly 6.140" inner-width and perfect straightness, then the minimum slop across this width would be 0.031" for a worst-case-maximum rail width. The maximum slop would be 6.060" − 5.990" = 0.070" for the worst-case-minimum rail width. Thus the tray positional variation in ϕ would be 0.031" minimum to 0.070" maximum.

The width of the lower sections of the feet is 0.850". This is significantly larger than the full range of rail widths (5.990" worst-case minimum to 6.029" worst-case maximum, or a full-range of 0.039"). The correlation between the tray *radial* position and the actual bend angle of the tray feet[1] (nominally 90 degrees as shown in figure 1) due to this 39mil tolerance on the TPC rail width is ignored here.

2.1.2 Tray Feet Inner Height

The dimension discussed in this subsection is the inner height of the feet attached to the TOF trays. This dimension is mostly parallel to the cylindrical radius in STAR. The default inner height is 0.365". This must account for two layers of UHMW polyethylene strips (each 0.040"-thick), as well as the fabrication tolerances on the rail height as well as the inner height of the feet as fabricated.

The ears of a rail are nominally 0.250" ± 0.010" thick. The worst-case-maximum rail ear thickness is thus 0.250" + 0.010" (as only one-half of a rail is seen by any one TOF tray), or 0.260".

The worst-case-maximum rail height must fit inside the inner height of the tray feet. The nominal inner height spacing is 0.365" − 0.080" (two UHMW polyethylene strips) = 0.285". The worst-case-maximum rail is 0.260" high, leaving a gap of nominally 0.025". The inner height and straightness of the feet as fabricated must thus be better than 0.025". This has assumed perfectly straight rails.

When including the worst-case-maximum rail straightness, the worst-case-maximum rail height would be 0.250" + 0.020"/2 + 0.019" = 0.279", leaving a minimum gap of 0.365" − 0.080 − 0.279" = 0.006". The maximum gap (which again one assumes an undersized and perfectly straight rail) would be 2×0.018" + 0.020"/2 = 0.046". Thus, the tray radial position variation would be 0.006" minimum to 0.046" maximum.

[1] The bends in the feet are formed by a brake, and hence the 90 degree bends are achieved to within a few degrees.

2.1.3 Tray-to-Tray Positioning

Figure 2 shows an R-ϕ view of two trays near 12 o'clock. The TOFr5 design includes the STAR-standard 8.5" wide tray bottom assembly but is taller overall than the CTB (4.5in *vs.* 3.5in) and wider than it near the tray top due to TOFr5's "shoebox" design (8.68" *vs.* 8.5").

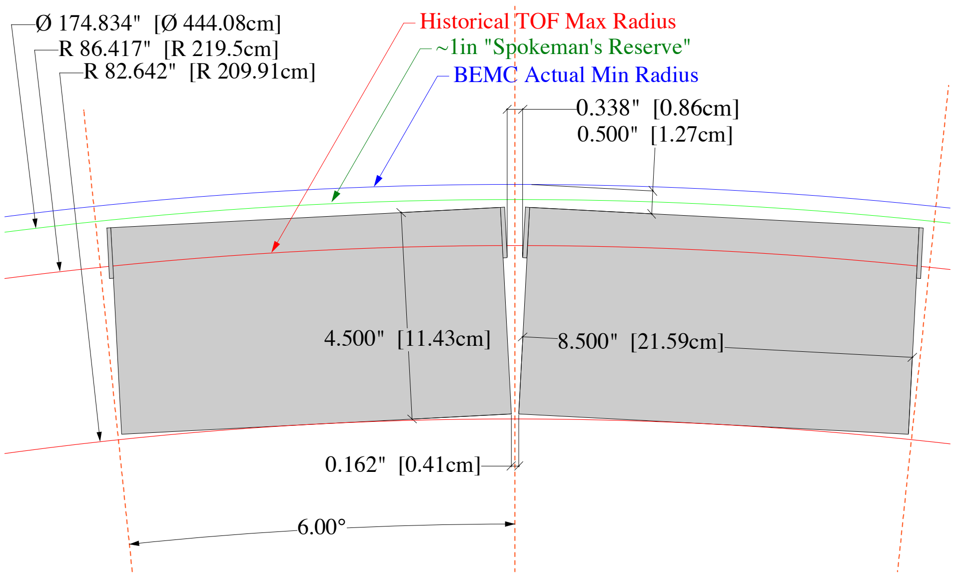

Figure 2: An R-ϕ view of the cylindrical shell within which the TOF trays must fit.

At the radius of this system, the nominal free space between trays in ϕ is 0.162" near the bottom of the trays and 0.336" at the lowest-radius edges of the tray top assemblies. The constraint on the tray ϕ-positioning is thus set by the lower-radius separation. The nominal tray-to-tray ϕ-spacing of 0.162" allows for the 0.070" maximum variation in the tray ϕ-position resulting from the feet positioning with respect to the tray bottom, and for the tolerances in the positioning of the rails on the TPC.

In radius, the TOF system violates the upper edge of the historical TOF integration envelope of 86.417". TOFr5 is nominally 4.5" tall as measured from the underside of the tray bottom to the top side of the tray cover. This leaves a 0.5" radial space between the top of TOFr5 and the inner face of the BEMC. This 0.5" radial space was measured directly before Run-6. This 0.5" spacing allows for the misalignment of the TPC with respect to the magnet (max ~1/8") and the 0.046" maximum variation in the tray R-position resulting from the inner height of the tray feet.

The tolerance on the tray total height (nominal 4.5") has three components - The manufacturing tolerance of the tray bottom, top, and cover assemblies (10mils), plus the positioning tolerance of the top with respect to the bottom and the positioning tolerance of the cover with respect to the top (due to the diameter of the through holes for the screws that tie these pieces together). The total tolerance on the tray height is thus taken to be 30mils.

2.2 Dimensions in Z

The length of the TOFr-series of prototypes has generally been significantly (~6") less than the CTB trays next door. CTB trays are 95.1" long. In the final system, the trays will be as long as possible, so as to allow for the mounting of the TCPU boards at the high-η end of each tray (see also section 4 below).

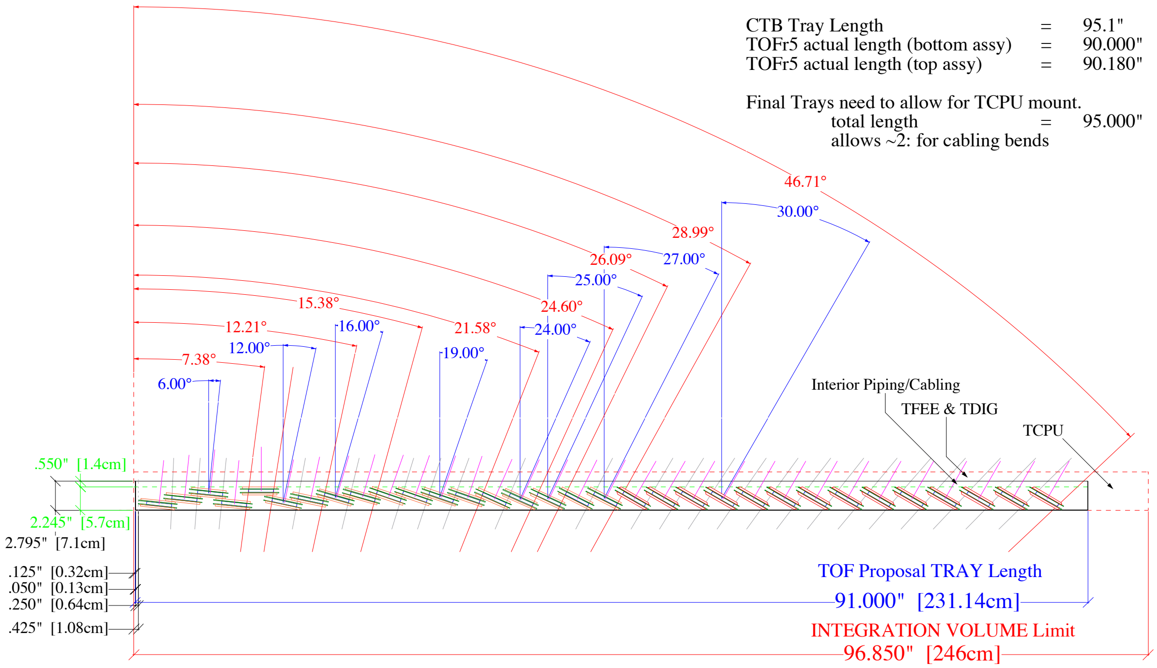

Figure 3: An R-Z view of the trays and their integration volume limits.

A view of the TOF tray from the TOF Proposal [3] and the TOF integration volume in Z are shown in Figure 3. The total length of the TOF integration volume is 96.85”. Space must be allowed at the tray end for connectors (*e.g.* gas & HV). Allowing ∼1.7” inches for connectors (both jacks and plugs), the total length of a TOF tray cannot exceed ∼95”. More details on the tray length are discussed in section 4.1.2 below.

2.3 Tray Tolerances Table

This section summarizes the critical dimensions of the trays. For each critical dimension, the nominal values are listed along with the minimum and maximum allowable values.

Table 1: The critical dimensions on the tray and the nominal, minimum, and maximum allowed values of each dimension.

Dimension	Nominal (in)	Minimum (in)	Maximum (in)
Rail, Width (over full length)	6.000	5.980	6.020
Rail, Straghtness (over full length)	0.000	0.000	0.075
Rail, Ear thickness (over full length)	0.250	0.240	0.260
Strips, thickness	0.040	0.001	0.001
Feet, Inner Separation	6.140	6.130	6.150
Feet, Inner Height	0.365	0.355	0.375
Position Tolerance: Tray ϕ	0	0.031	0.070
Position Tolerance: Tray R	0	0.006	0.046
Tray Bottom Assy Outer Width	8.5	8.49	8.51
Tray Bottom Assy Inner Width	8.4	8.39	8.41
Integration Volume Length	96.85		
Tray Outer Length	94.85	94.75	94.95
Tray Total Height	4.5	4.47	4.53
Tray Flatness (in Z-direction)	0.0	0.00	0.03

3 MRPCs

The MRPCs are to be constructed in China using locally-supplied parts. The manufacturing methods are well understood by the many rounds of MRPC prototype fabrication for the TOFr-series of trays. A final "Manufacturing Plan" will be defined and detailed by the China group and reviewed and approved by the TOF Project Management Office. The scope of the manufacturing plan will address materials specification, fabrication techniques and assembly procedures, along with in-process inspection and witness points. In addition there should be a well defined manufacturing schedule detailing the critical paths of parts flow through the module assembly and delivery. This plan also needs to address quality assurance processes, variance reporting, and module process travelers.

The three-dimensional space within which the MRPCs must fit is defined by the tray dimensions. Considering a tray lying horizontally with the cover assembly up, the MRPCs are held in place in Z and Y by the so-called "Inner Sides." These are long pieces of 1/4"-thick lexan which hang from backets underneath the top assembly and which contain "reveals" (or slots) that hold each MRPC at a specific (Y,Z) position and angle with respect to the top assembly. The MRPCs are constrained in X (*a.k.a.* ϕ in STAR) by the interior edges of the walls of the tray bottom assembly.

3.1 MRPC Tolerances Table

This section summarizes the critical dimensions of the MRPCs. For each critical dimension, the nominal values are listed along with the minimum and maximum allowable values. Of the three dimensions of the MRPCs (length, height, and width) the most critical is the length.

Also included in the table are the lengths of the HV pigtails (two per MRPC) and signal ribbon cables that have been agreed upon by the US and China groups. For these two types of cables a tolerance on the lengths of 1/4" is assumed and reasonable.

Table 2: The critical dimensions on the MRPCs and the nominal, minimum, and maximum allowed values of each dimension.

Dimension	Nominal	Minimum	Maximum
Length, nominal	8.346	8.327	8.366
Width, nominal	3.701	3.681	3.720
Height, nominal	0.705	0.665	0.744
HV Pigtail length	7”	6.75”	7.25”
Signal ribbon length	10”	9.75”	10.25”

4 Electronics

The electronics are extremely tightly integrated with the tray design. TINO is effectively the “6^{th}” wall of the gas volume. The water path flows between the TINO and TDIG layers.

As the trays are produced early in the project, while the electronics are produced throughout the project (like the MRPCs), it is crucial to adhere to strict specification on the mechanical aspects of the electronics. These mechanical aspects include the footprint size and mounting hole positions, which are discussed in subsection 4.1, and the board heights *including all components*, which are discussed in subsection 4.2.

4.1 Footprints

There are seventeen electronics boards mounted on each final TOF tray. There are eight pairs of TINO and TDIG boards, which have the same exterior dimensions and mounting hole positions.

There is also one TCPU board per tray which is attached to the tray at the high-η end. The TCPU board is presently undesigned.

4.1.1 TINO & TDIG

The footprint dimensions and mounting hole positions for the TINO board are shown in figure 4. The board dimensions are 9.1” (parallel to the STAR Z dimension and the long axis of the tray) by 8.2” (parallel to the STAR ϕ-direction).

There are eighteen mounting holes in TINO which are sized for 6-32 PEM studs embedded into the tray top assembly. This is the same technique used in TOFr’ and TOFr5.

For the final trays, the PEM studs will be shorter for the 2∼4 screws along the short sides of TINO compared to those along the long sides. This because the cooling loop runs along the long sides of TINO, and to allow more space for components on TDIG. That is, the TDIG boards will use only the $2{\times}5$ screws along their long sides. This is depicted in figure 5.

4.1.2 TCPU

The TCPU design is presently scheduled for completion in the 4th quarter of FY06, but a maximum integration envelope as been established.

Its footprint dimensions are constrained by the Z-length of the integration volume. The first TINO board (at low-η) is offset from the end of the tray by 1” to allow for the radius of curvature of the cooling loop. The Z-distance between each TINO/TDIG pair is at least 0.9” to allow for the upper brackets that attach the cover assembly to the top assembly.

The board-to-board spacing in Z increases with Z to match the MRPC positioning inside the tray. In TOFr5, an additional 1” gap was added in between every group of 4 MRPCs to

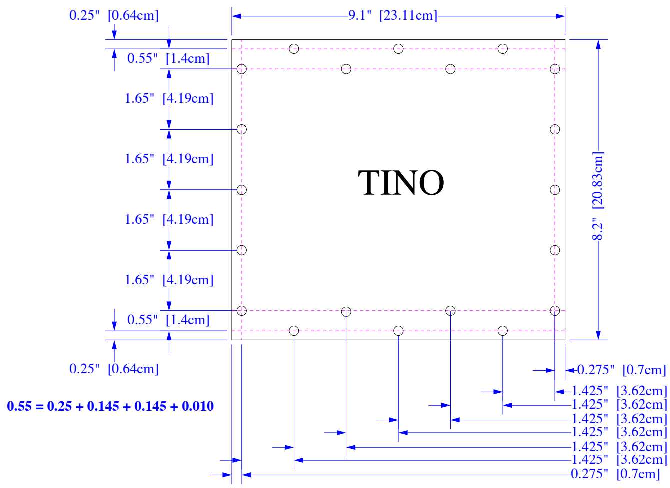

Figure 4: The footprint dimensions and mounting hole positions for the TINO board.

allow for the upped and lower brackets. These additional gaps are no longer necessary in a final tray that uses (9.1"-long) TINO boards.

Shown in Figure 6 is a side view of a tray without the additional spacing of every 4 MRPCs needed for TOFr5 (and its 9.9"-long TAMP boards). The high-Z edge of the eighth TINO card is at approximately 85". This leaves 11.725" of space for three things - the TCPU card, the terminal blocks and strain relief for the various on-board cabling, and the space needed for the on-board cabling to bend to allow the cabling to join up with the STAR cable trays.

The TCPU board can thus be 8.2" wide and 6" long maximum. This allows for a modest separation of TCPU from the TINO/TDIG boards (0.5"), and the LV and cable strain-relief areas (3.5"), which leaves 1.725" of space at the end of the tray to allow for cables to bend into their paths.

4.2 Height

The vertical distance between the TINO and TDIG boards is defined by the choice of the connectors on each the electrically connect TINO to TDIG. This inner vertical distance (top of TINO to bottom of TDIG) is 7/16". The TINO board is 90 mils-thick, while the TDIG board is 110mils-thick. The side view of the electronics is shown in Figure 7.

The vertical dimension of the cooling loop is 3/8", which is less than the inner vertical distance between the TINO and TDIG boards (7/16") by 1/16". This remaining vertical space is filled with the same type of thermally conductive plastic shims as used in TOFr5.

The maximum height of any component on the top side of TDIG is the same as that allowed in TOFr5 of 0.5". An additional vertical space is allowed beyond this to allow for the tolerances in the cover fabrication. The total height of the cover, which is 50mils-thick, is 1.3".

The height of the components on TCPU must not exceed the maximum height of the TDIG components. As TCPU mounts directly to the tray top assembly (underneath the cooling loop), the maximum board thickness for TCPU is 0.063", to allow for electrical isolation between the underside of TCPU and the top of the tray top assembly. The maximum height of components above TCPU is set at 0.5" to allow for cabling.

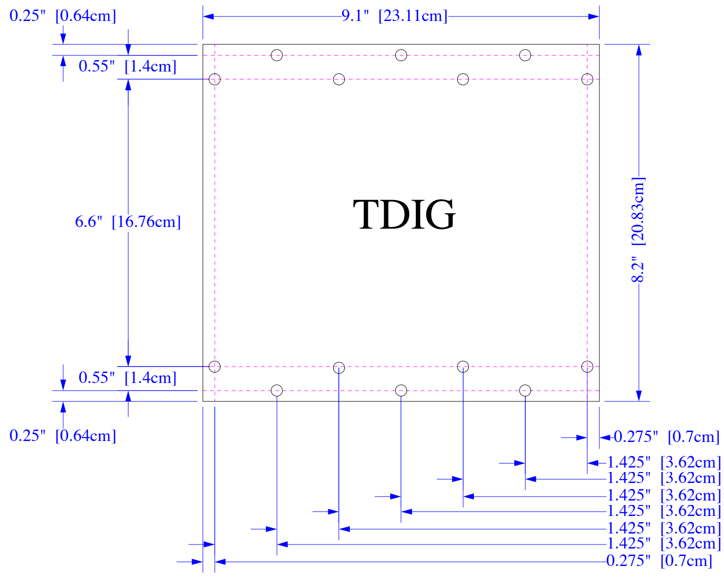

Figure 5: The footprint dimensions and mounting hole positions for the TDIG board.

4.3 Electronics Tolerances Table

This section summarizes the critical dimensions of the electronics. For each critical dimension, the nominal values are listed along with the minimum and maximum allowable values.

Table 3: The critical dimensions on the electronics and the nominal, minimum, and maximum allowed values of each dimension.

Dimension	Nominal	Minimum	Maximum
TINO/TDIG length	9.100		9.110
TINO/TDIG width	8.200		8.210
TCPU length	6.000		6.010
TCPU width	8.200		8.210

References

[1] `https://wjllope.rice.edu/dav/Project Office/TOF Note Change Control Procedure.pdf` (standard TOF operations password required).

[2] `http://wjllope.rice.edu/~TOF/TOFr5/Documents/tofr5.pdf`

[3] `http://wjllope.rice.edu/~TOF/TOF/Documents/TOF_20040524.pdf`

[4] `http://wjllope.rice.edu/~TOF/TOF/MRPCdimensions/MRPCpage.html`

[5] Wang Yi *et al.*, Nucl. Inst. and Methods, Section A, **537**, 698 (2004).

[6] Y.E. Zhao *et al.*, Nucl. Inst. and Methods, Section A, **547**, 334 (2005).

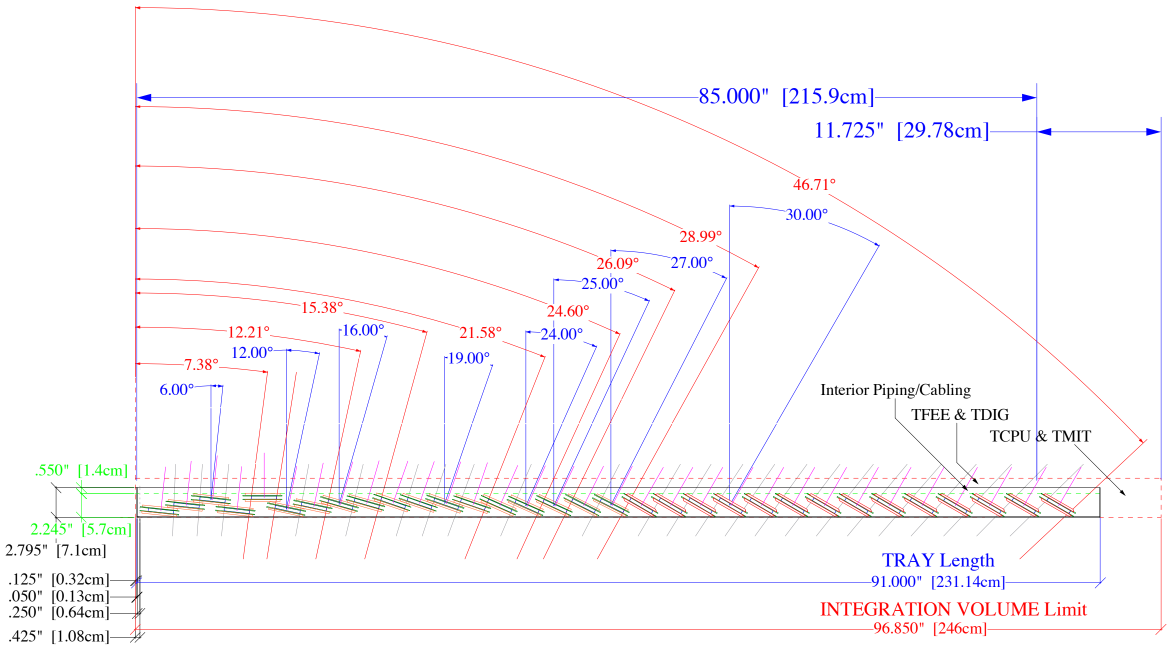

Figure 6: The vertical positioning of the on-board electronics boards TINO and TDIG.

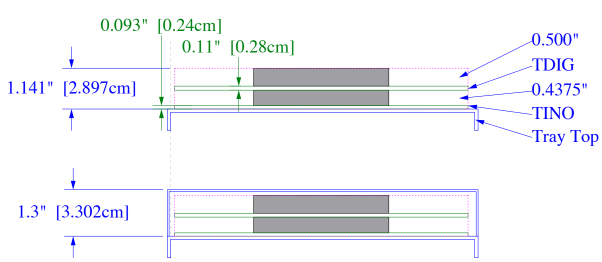

Figure 7: The vertical positioning of the on-board electronics boards TINO and TDIG.