CLAS 12 Drift Chamber Design

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CLAS 12 Drift chamber Design

General Idea

The CLAS12 Drift chamber has 3 regions arranged as shown in fig.1 below

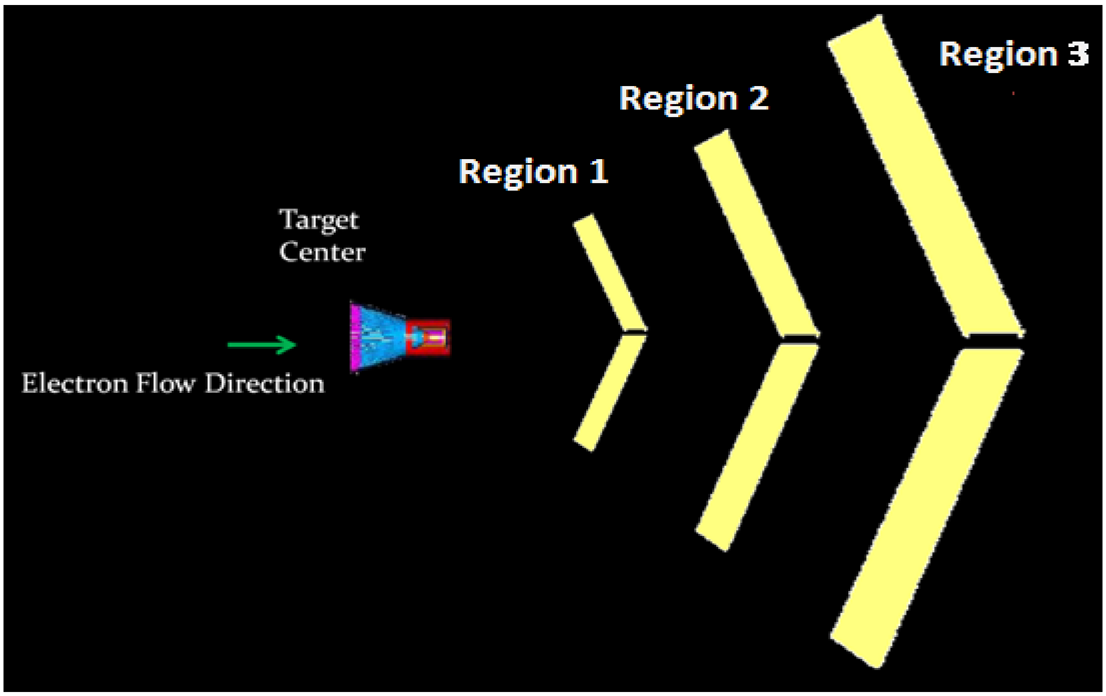

Fig.1. Location of Target center and Regions 1, 2, 3

The electrons released from the target center will flow through region 1, region 2 and region 3. All these regions look the same way. However, their sizes and the materials with which they are made are different. Due to the fact their sizes are different; some of them have some structural add-ons to support their structural abilities. The chambers are arranged in such a way that every chamber receives the same number of electrons. Apart from that, the chambers were shaped in such a way that all the electrons travel approximately the same distance before they hit a particular chamber.

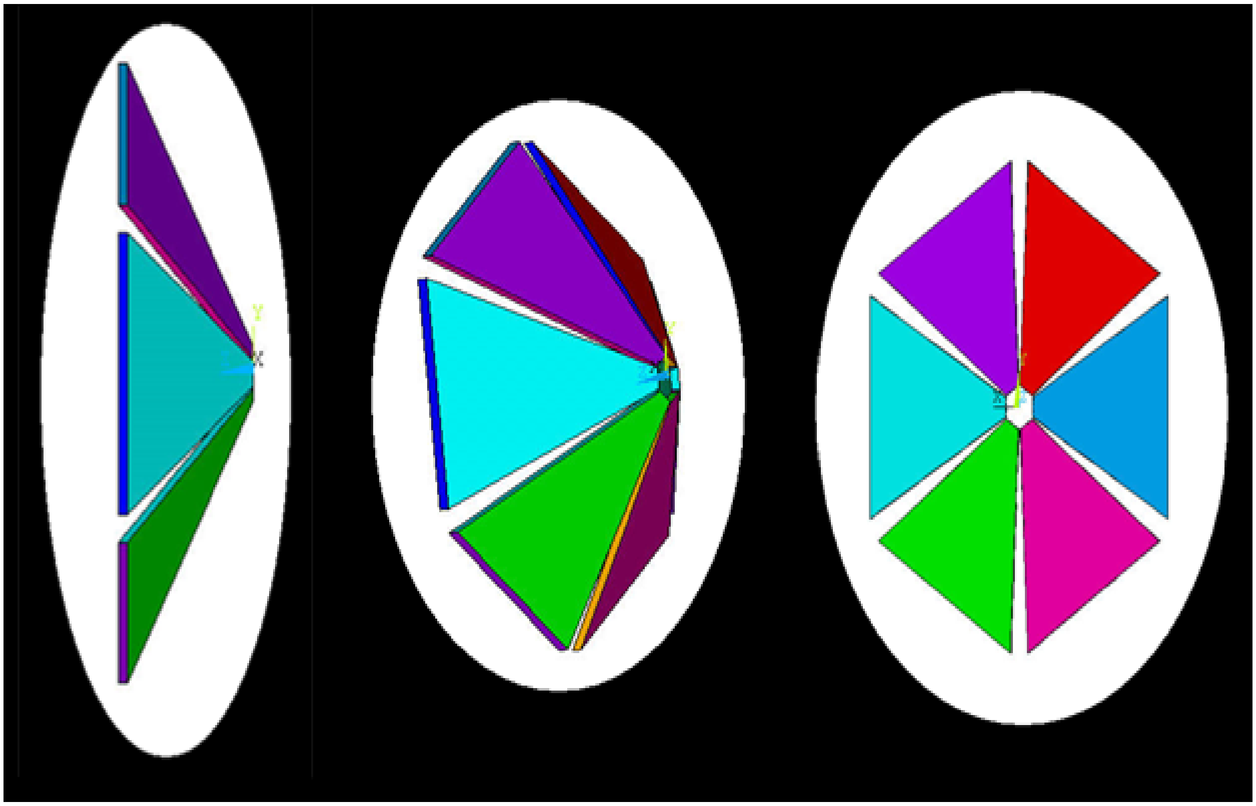

Fig.2 View Showing Triangular piece alignment in each chamber

Each and every chamber has 6 equal sized pieces which are shaped similar to a triangular piece (see fig.2). All of these pieces are arranged and bowed inward to resemble sectors in a 6 sector umbrella.

As discussed before, each region will be sized different. Region 3 will be the biggest of all as region 3 has to cover a larger electron span (surface area).

Introduction to Plates in each Triangular Piece

Although these pieces are termed as triangular, these are not triangular in reality. The nose which is the smallest of all is very small compared to the other plates, which will make us to visualize this as a triangular piece.

Ar Co_2 (90/10) gas is maintained in each of these chambers at an operating pressure of 0.001444 Psi and a peak pressure 5 times higher.

In turn there are about 4928 very sensitive wires (112 Sense wires with 44 Wire Layers) connected across the plates inside each piece.

Fig.3 shows an exploded view of the region 3 drift chamber triangular piece. Fig.4 shows the Nose plate, end plates and back plate. Fig.5 is a complete view of the drift chamber given by Jefferson lab.

These pieces enclose the triangular piece on all the six sides

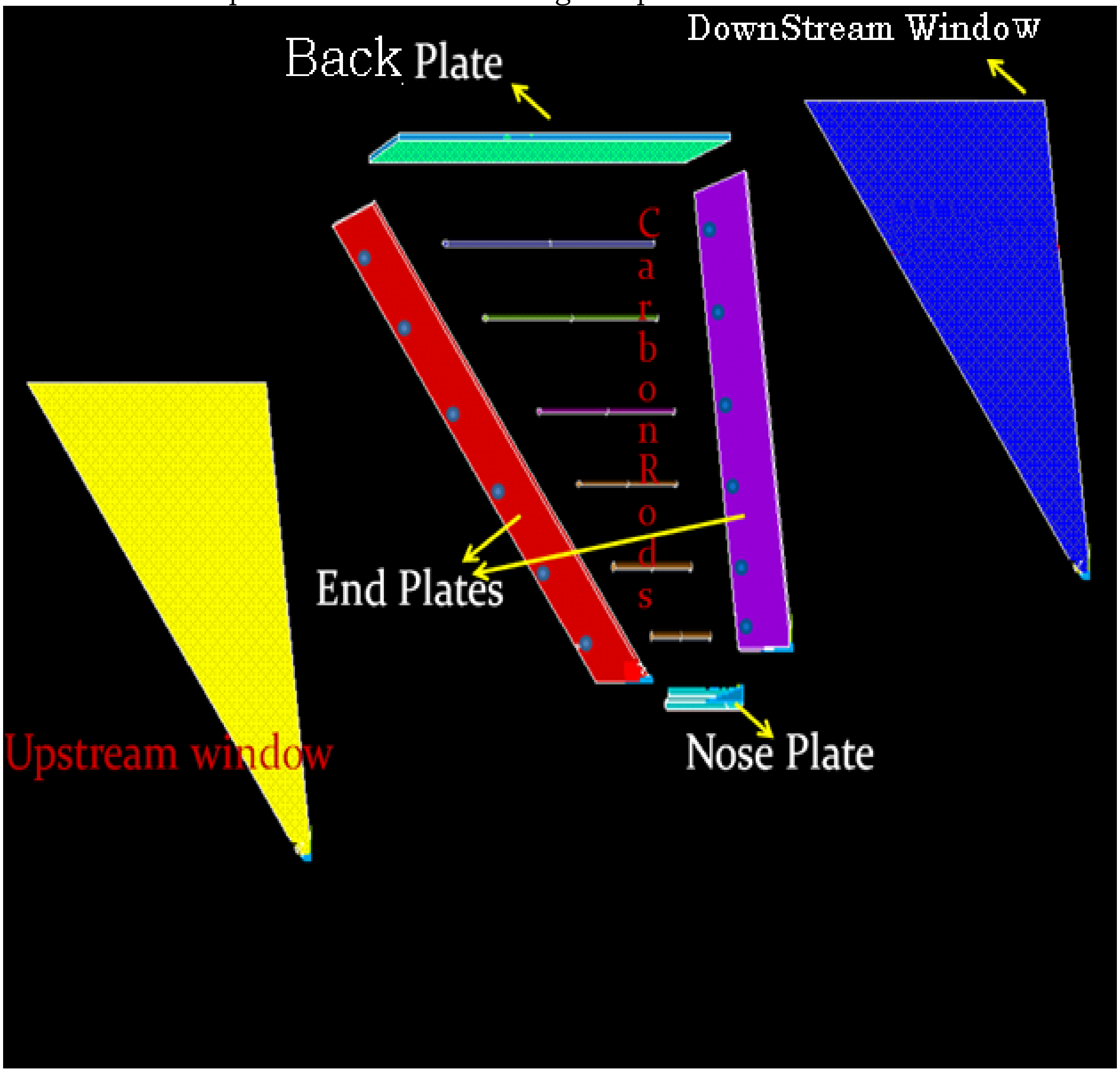

Fig.3 Parts in each Triangular Piece

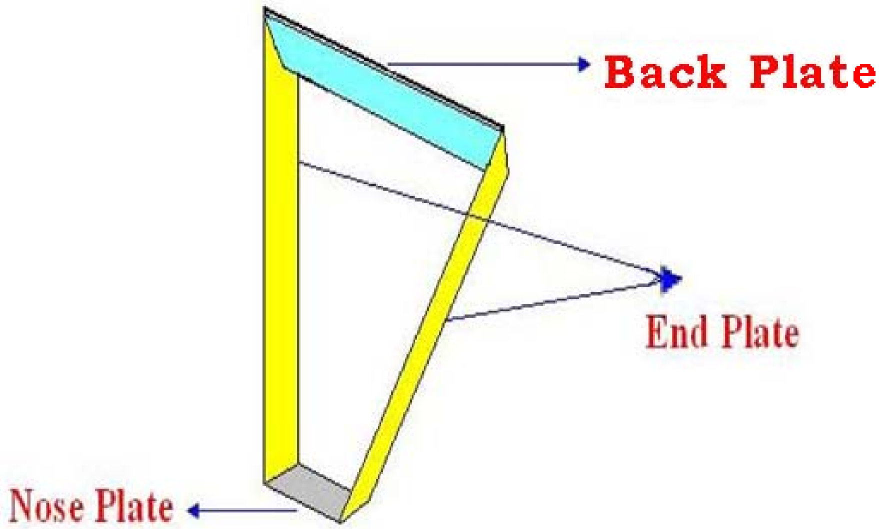

Fig.4 Plates in Triangular Piece

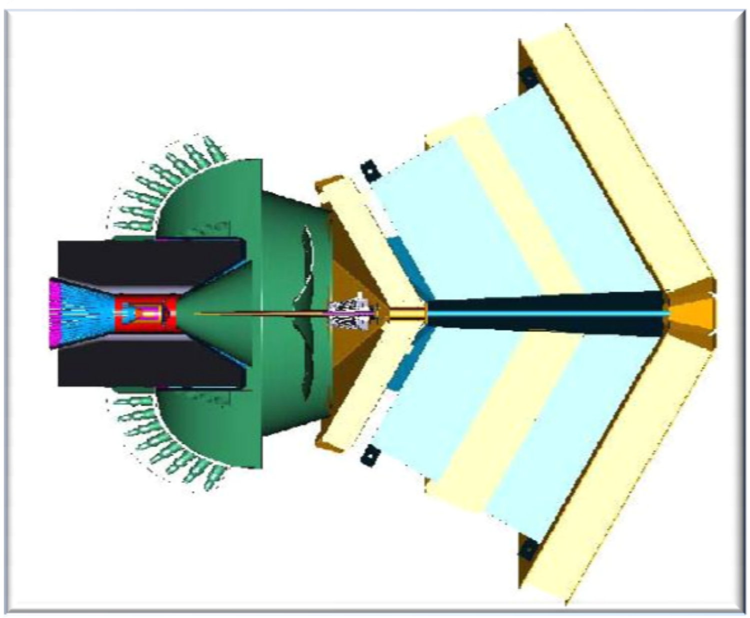

Fig.5 Complete View of the Chamber

Wire patterns

Although these pieces are termed as triangular, these are not triangular in reality. The nose plate is very small compared to all the other plates. Therefore we can assume that this is a triangular piece as shown in fig.6 below.

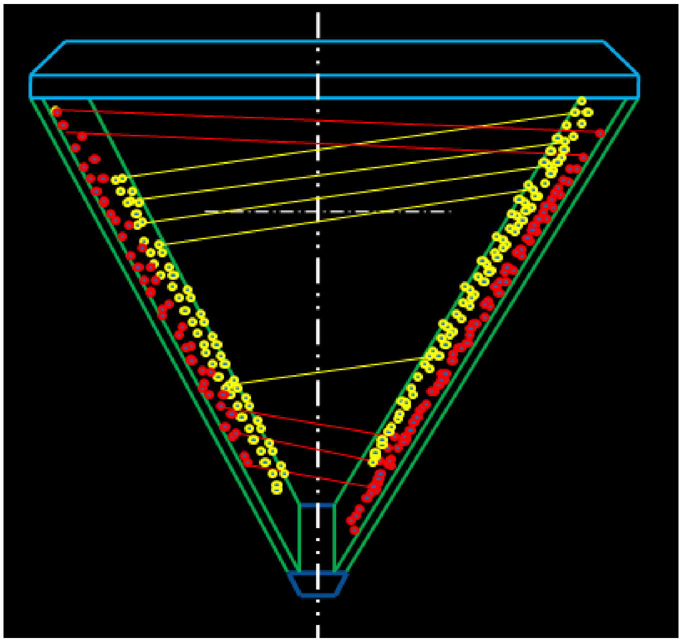

Fig.6 Wire Patters in each Triangular piece

The wires intersect at 6 degrees to the horizontal as shown in fig.7 below. The wires in the 2 super layers are angled opposite as shown in fig.8 wires in each super layer has opposite slopes to each other.

$ArCo_2$ (90/10) gas is maintained in each of these chambers at an operating pressure of 0.001444 Psi and a peak pressure 5 times higher. In turn there are about 4928 (112 Sense wires with 44 Wire Layers) very sensitive wires connected across the plates inside each piece.

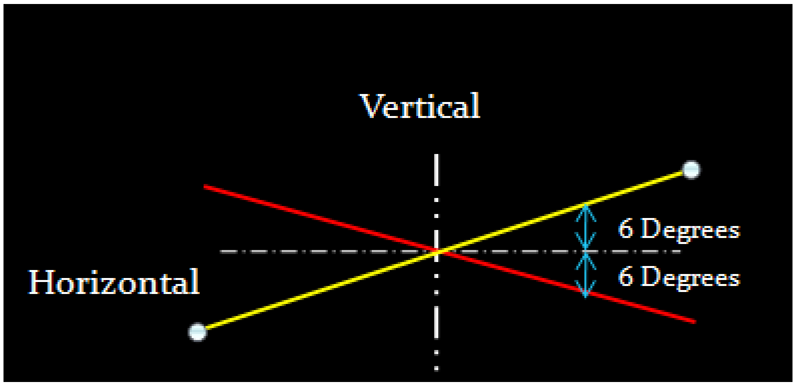

Fig.7 Showing wire angles

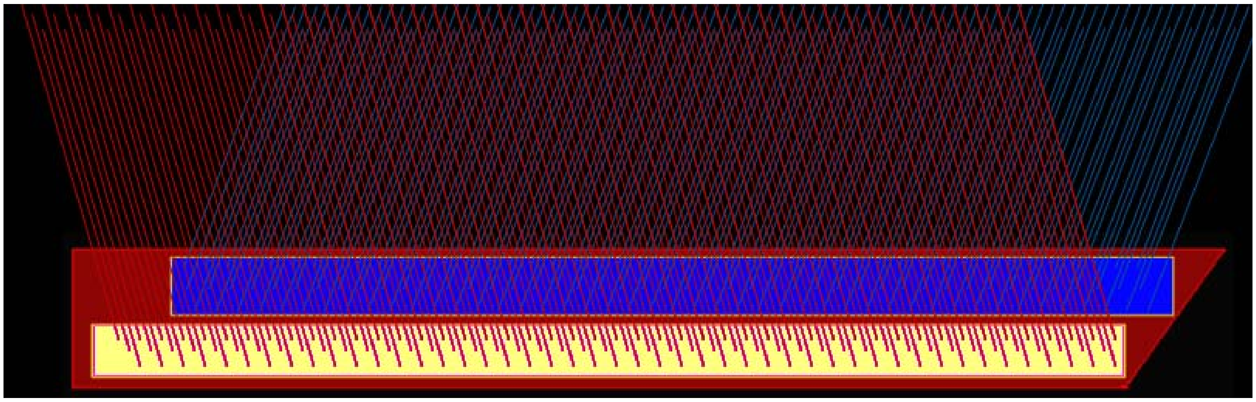

Fig. 8 Showing wire alignment with opposite slopes

The initial Parameters considered in the design

Given below are the parameters given by Jefferson lab

- **Distance from target to first sense wire plane along a ray which is normal to the end plate = 4746.5 mm**
- **Chamber Tilt Angle = 25 Degrees (see fig.9)**

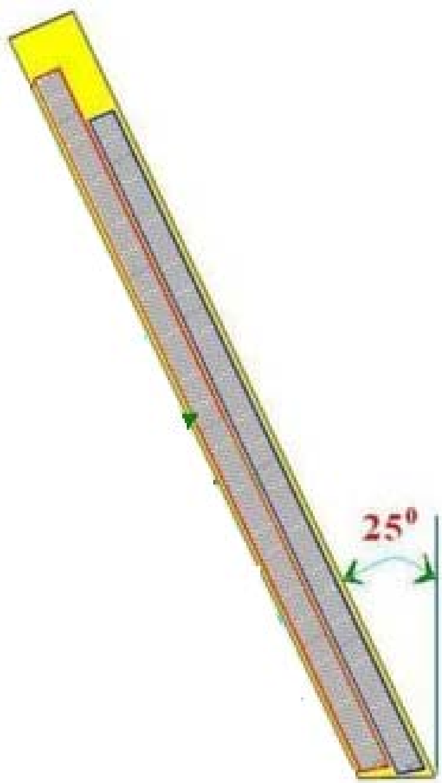

Fig.9. Chamber Tilt angle

- **Maximum Scattering Angle = 45 Degrees (see fig.10)**
- **Minimum Electron Scattering angle = 5 Degrees (see fig.10)**

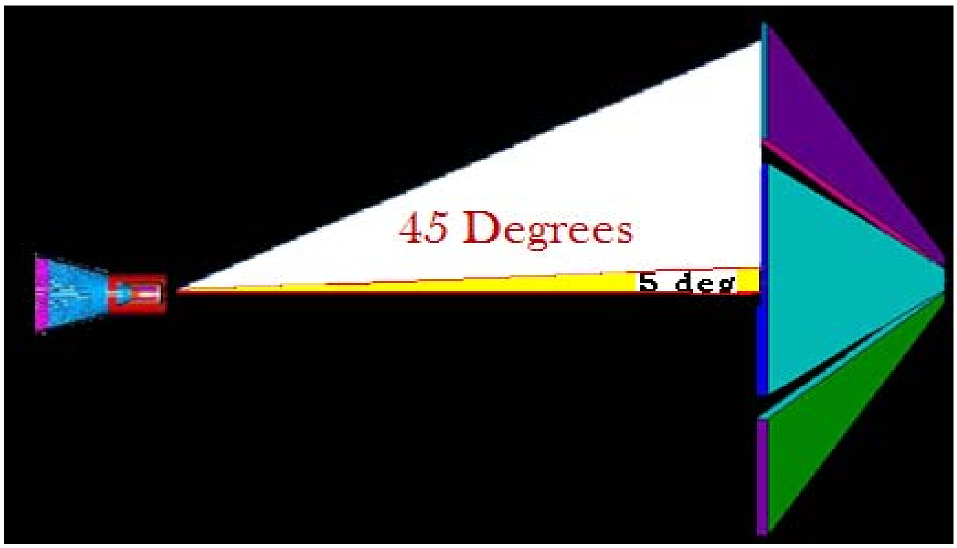

Fig.10 scattering angles

Design Requirements

The region 3 drift chamber will be designed to fulfill the following design requirements.

- The Maximum Deflection should not exceed 50 microns in the endplate

- Conform to the wire locations, tilt angles and scattering angles as given by Jefferson lab.

- Ensure stresses are within the failure criteria.

- To provide proper mountings to interface with the Jefferson lab design criteria.

- Ensure material compatibility as per Jefferson lab design criteria.

Plates in each Triangular Piece

Below is a description of each of the design pieces

Back Plate & Nose Plate

The back Plate (see fig.11) and nose plates (see fig.12) will be made of rigid material since the supporting mechanism will be attached to these plates.

The materials and the exact dimensions are not yet decided. The back plate) will be sized to connect the two end plates. The nose plate will connect the bottoms of the two end plated and provides the interface.

Fig.11 back Plate

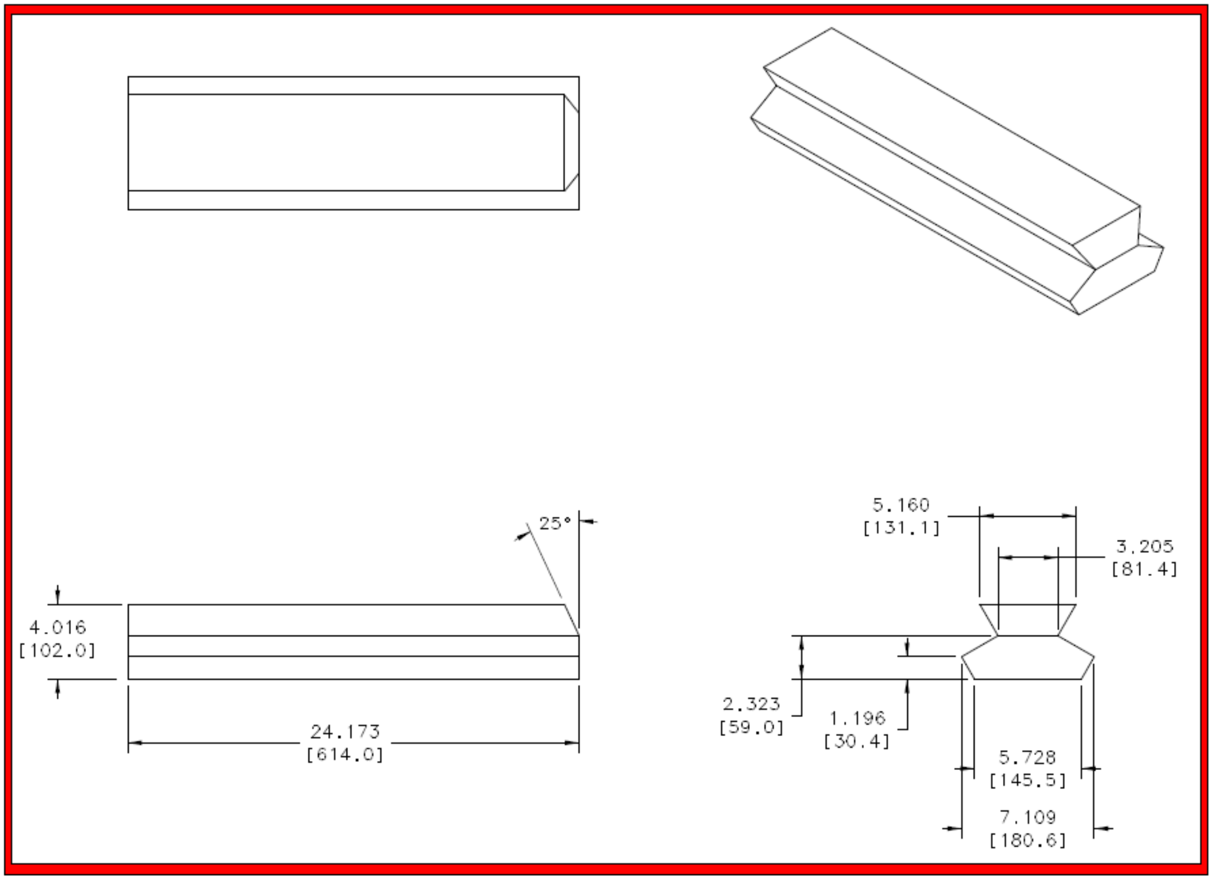

Fig.12 Nose Plate

End Plate

The End plate is about 4830 mm and 4665mm in length along the longitudinal length and about 525mm in width. Fig.13 shows the end plate with the corresponding dimensions. It has approximately about 5000 holes with an approximate diameter of 6mm on the surface and about 9mm inside the surface

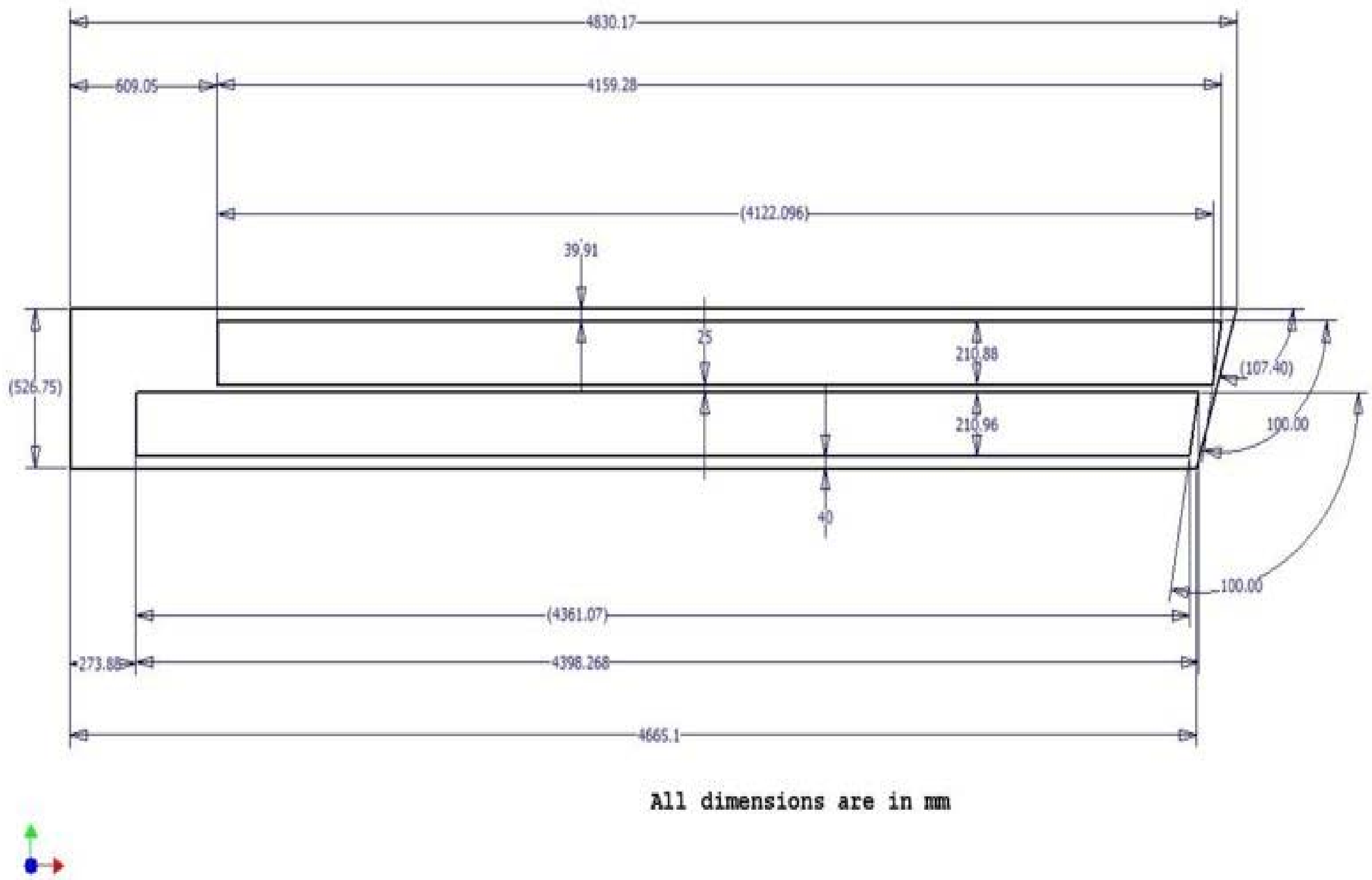

Fig.13 End Plate

End plate (see fig.14) is a composite material made by sandwiching stainless steel and polyurethane. Slices are glued together. The sheets are stainless steel + Polyurethane + stainless steel with thickness (1.2192 + 50.8 + 1.2192) mm respectively.

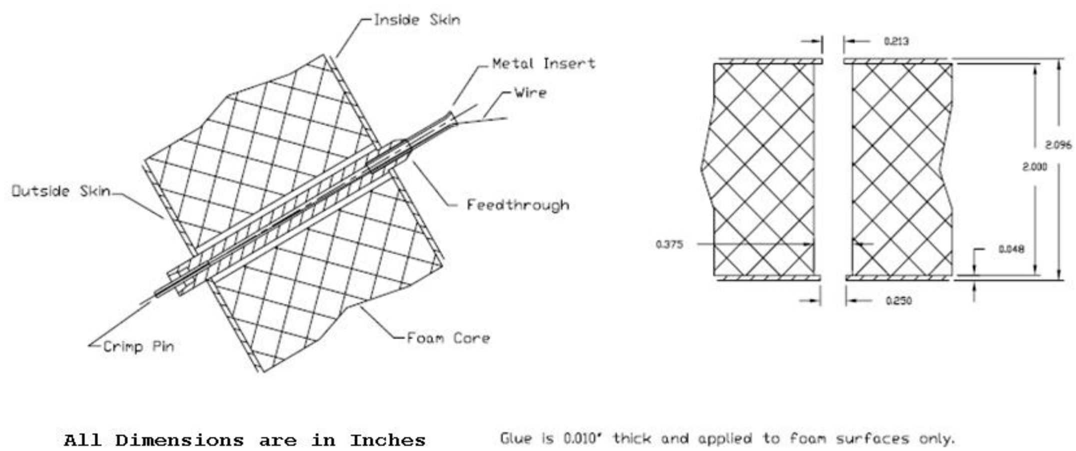

Fig.14 sandwiching of the End plate

Carbon fiber Rods

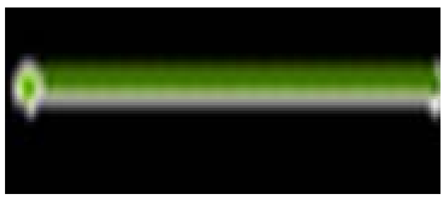

Fig.15 Carbon Rod

These carbon fiber rods (see fig.15) are hollow rods with a outer diameter of 50.8mm and a thickness of 1.27mm. In the current analysis 6 rods were used to reduce the deflection. These rods are equally spaced between each other (750mm). The distance between the nose plate and the first rod from the bottom side is 400mm and the distance between the back plate and the top rod is 515.1mm.

Upstream and downstream windows

Upstream window (the closest to the target center) is made of aluminized Mylar sheet with a thickness of 0.0254 mm (0.001 inch). The downstream window (see fig.16) is made of Hexcel Honeycomb foam HRH 10-1/8 -1.8. This foam is impregnated with graphite fabric. The downstream window thickness (T) is 39.116mm. The Cell size will be 1/8th of an inch (3.175mm)

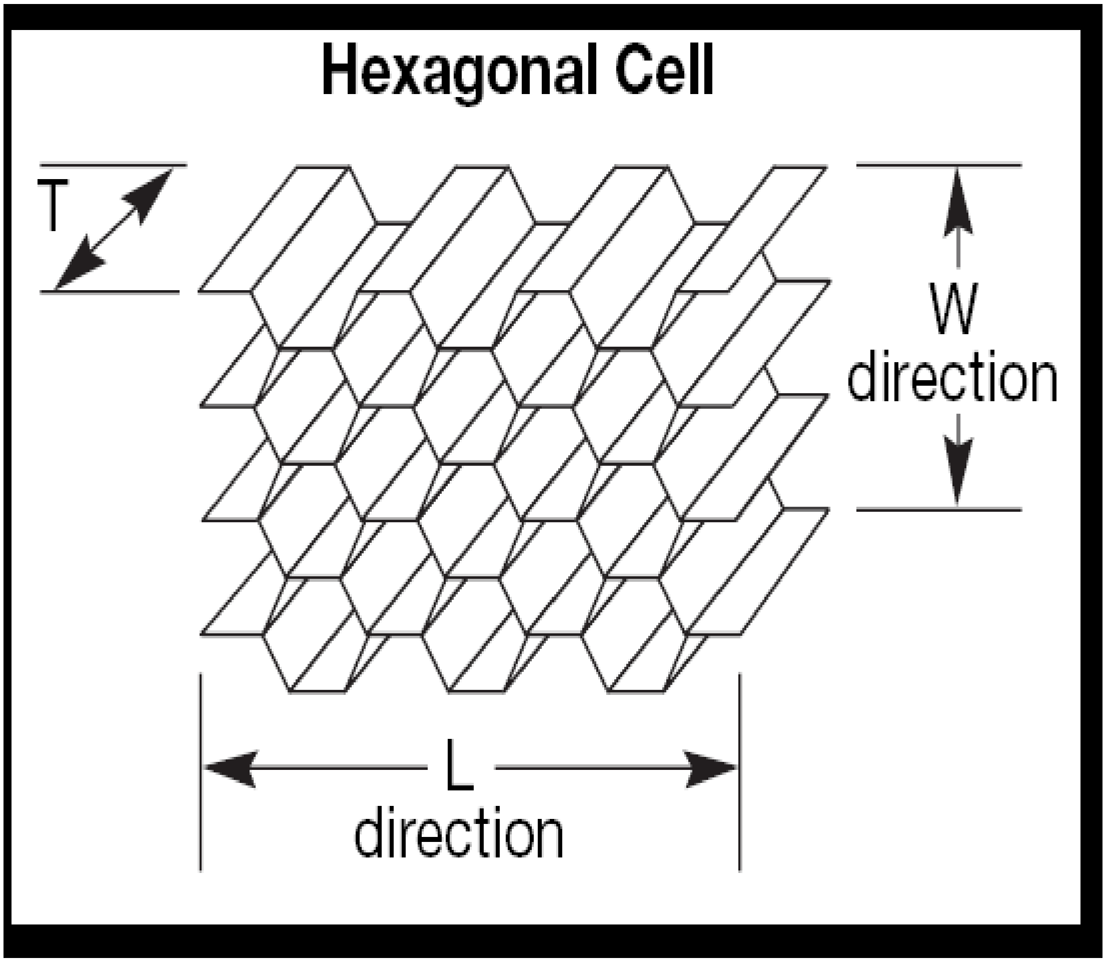

Fig.16 Structure of the Downstream Window

Loads

The following loads were considered to perform the deflection analysis.

Wire loads

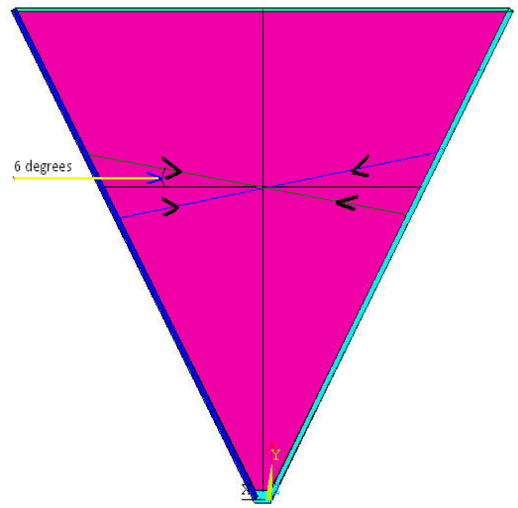

Fig.17 Direction of Wire Loading

A load of 680 Pounds (see fig.17) is applied on each end plate. This 680 Pounds (3024.77N) is split into 2 parts and applied by each super layer at opposite 6 degrees to the horizontal.

Gravity Loads:

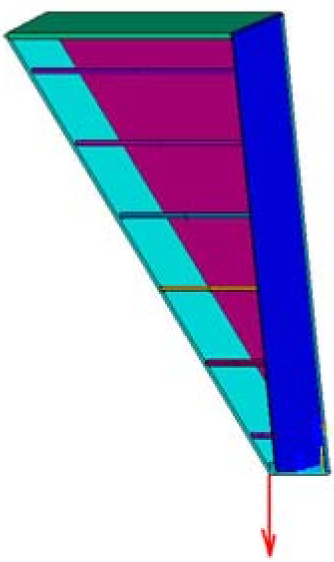

Fig.18 Direction of Gravity Loading

Load due to gravity is applied depending on the piece orientation. For the general orientation 9.81 m/sec^2 is applied along negative y axis.

Window Loads

A total load of approximately 900 pounds (see fig.19) will be applied on the edges of the plates due to the gas pressure inside the chamber. These loads are a result of the ArCo2 gas pressure inside the piece

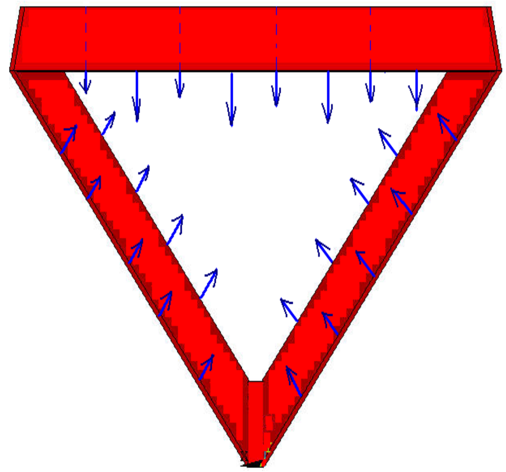

Fig.19 Location of Window Loading

Due to this pressure, the Mylar sheet and the Hexcel sheets are expected to bulge outwards and further pulling the end plates and the back plate close to each other. So, 150 pounds of load is applied on each edge of the end plates (4 No's) and Back Plate (2 No's)

Coordinate System

The coordinate system used in the analysis is displayed below

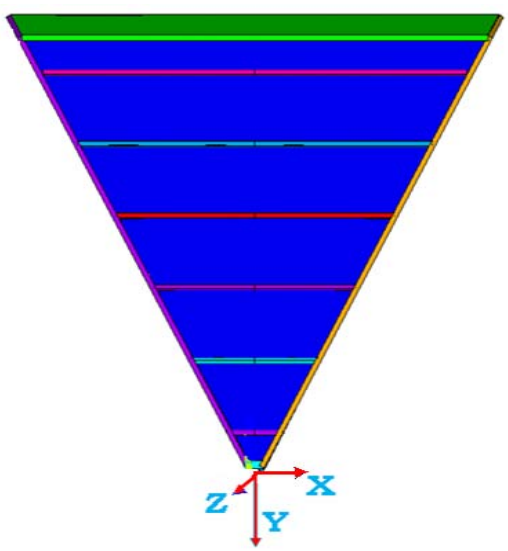

Fig.20 Coordinate System Used

Positive X is from left to right, Positive Y from Top to bottom, Positive Z towards target center (see fig.20).

Constraints

Constraints (see fig.20) are the areas where the system is restricted for movement.

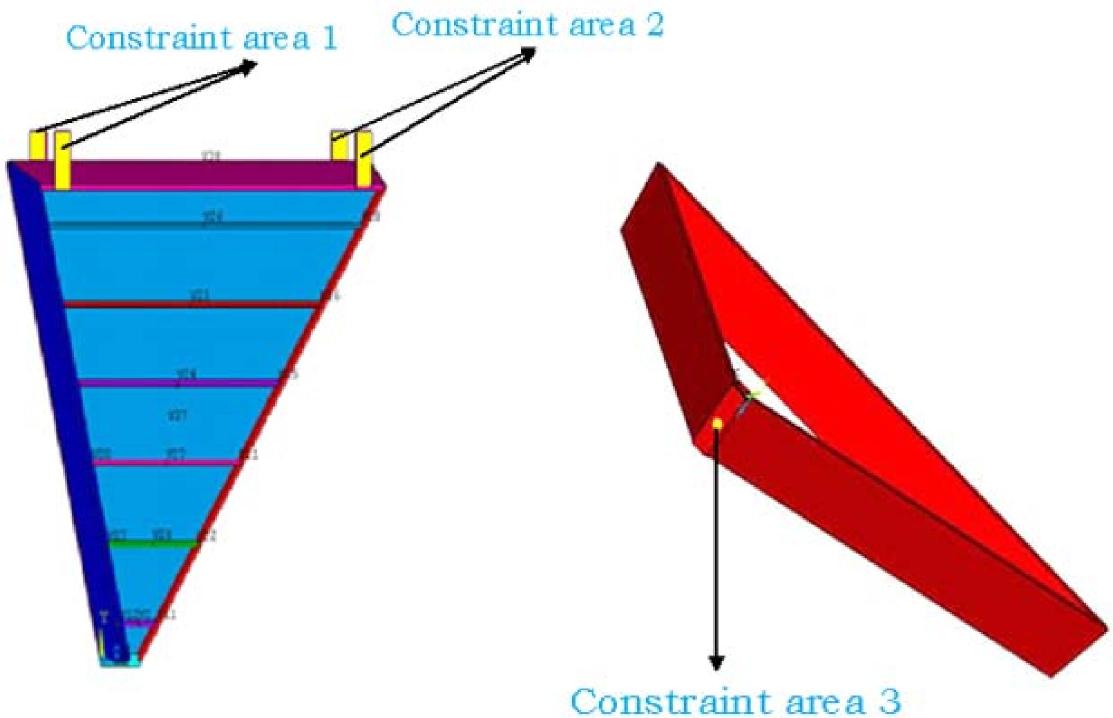

Fig.21 Showing Constraint locations

The constraint area 1 and 2 in the top are the areas where the linear motion is constrained. The bottom constraint area is where it is constrained to resemble a ball joint

There are 2 cases in the way we constrain the movement in these areas.

The same are tabulated below.

	Case 1			Case 2		
	X	Y	Z	X	Y	Z
Constraint Area 1	Yes	Yes	Yes	Yes	No	Yes
Constraint Area 2	No	Yes	Yes	No	No	Yes
Constraint Area 3	No			Ball Joint		

Table.1 Showing Constraint participation in x, y, z Directions

Technical Specifications

Name	Material	Young's Modulus	Density
End Plate	Slices of steel and polyurethane	140×10^3 N/mm^2	2.4×10^{-7} kg/mm3
Back Plate	Aluminum or Polyurethane (Not Decided)	73×10^3 N/mm^2	2.7×10^{-6} kg/mm3
Nose Plate	Aluminum or Polyurethane (Not Decided)	73×10^3 N/mm^2	2.7×10^{-6} kg/mm3
Upstream Window	Mylar Sheet	3.8×10^3 N/mm^2	1×10^{-6} kg/mm3
Downstream Window	Hexcel HRH 10-1.8-1/8	45×10^3 N/mm^2	2.88×10^{-8} kg/mm3
Support Rods	Carbon Fiber	210×10^3 N/mm^2	5.8×10^{-7} kg/mm3

Table.2 Showing Material Properties

Deflection analysis:

The deflection analysis was performed as follows

Analysis 1: Deflections observed when FR-3700 Foam is used with slices of steel on both the sides and 6 fixed carbons fiber rods of diameter 2 inches

Analysis 2: Deflection Analysis of the End plate (Slices of Polyurethane And stainless steel) with fixed carbon rods and Hexcel foam sheet

Analysis 1

Deflections observed when FR-3700 Foam is used with slices of steel on both the sides and 6 fixed carbon fiber rods with a diameter 2 inches

6 Carbon Fiber rods are placed on one side of the end plate along the edge. These rods are arranged as such, they restrict the deflection of the end plate. With a total load of 680 pounds on the end plate at 6 degrees to the imaginary vertical line, the deflections (see fig.22) are observed as follows

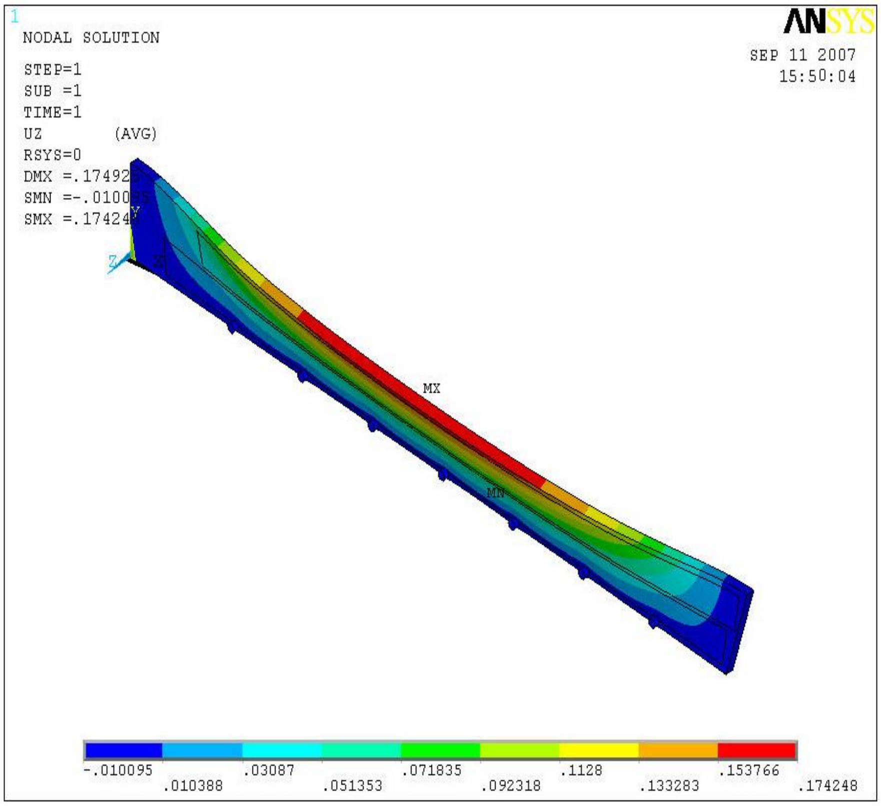

Fig.22 deflection in y direction in analysis 1

Max Deflection Observed is 0.174248mm

Analysis 2

Deflection Analysis of the End plate (Slices of Polyurethane and Steel) with fixed carbon rods and Hexcel foam sheet

A Hexcel Foam Sheet HRH 10-1/8 -1/8 is introduced in the model to reduce the deflection. This sheet is pre impregnated with thin sheets of metal on either side along the face of the end plate. The layout can be assumed as 0.010 (Skin 1) + 1.520 (Core) + 0.010 (Skin 2) inches in thickness. In this analysis the carbon rods and Hexcel foam sheet are assumed to be completely restricting the movement on the edges (see fig.23)

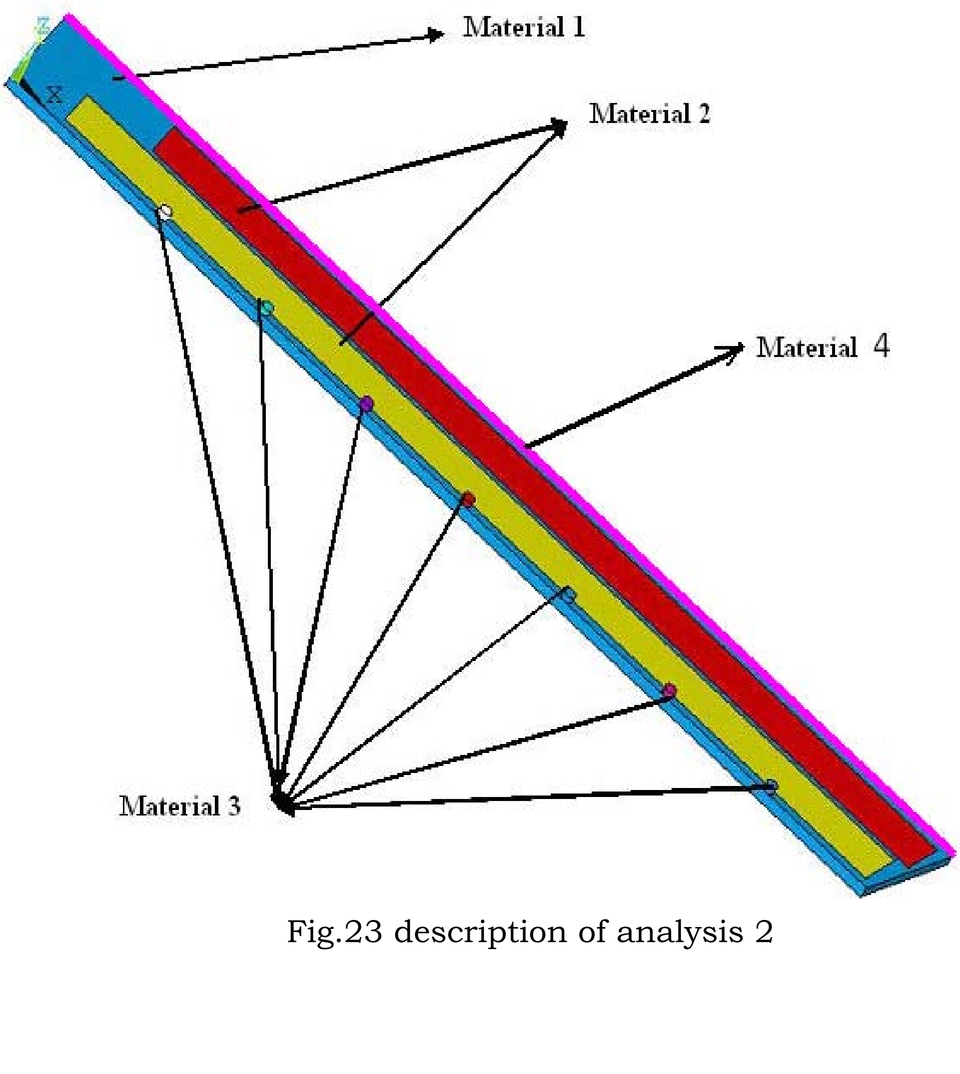

Fig.23 description of analysis 2

Loading conditions:

- The regions shown as material 3 and material 4 are fixed with carbon rods and Hexcel foam sheet respectively
- The areas on the side view (face attached to the nose plate and the face attached to the face (top) plate) is also constrained for movement
- Load at 6 degrees on material 2 as usual
- Gravity downwards i.e. on –y direction

The material description is shown below.

Material No	Description	Young's Modulus	Density
Material 1	Polyurethane + Steel Slices	**9293.893 N/mm^3**	**5.86248×10^{-7} kg/mm^3**
Material 2	Hole region (Polyurethane + Steel Slices)	**9293.893 N/mm^3**	**5.1897×10^{-7} kg/mm^3**
Material 3	Carbon Rods	NA	NA
Material 4	Hexcel Sheet	NA	NA

Table.3 Material properties in analysis 2

Carbon steel rods and Hexcel sheet:

In this particular model, they are just a fixed reference and the properties are not of interest.

Deflection in Y-direction from analysis 2

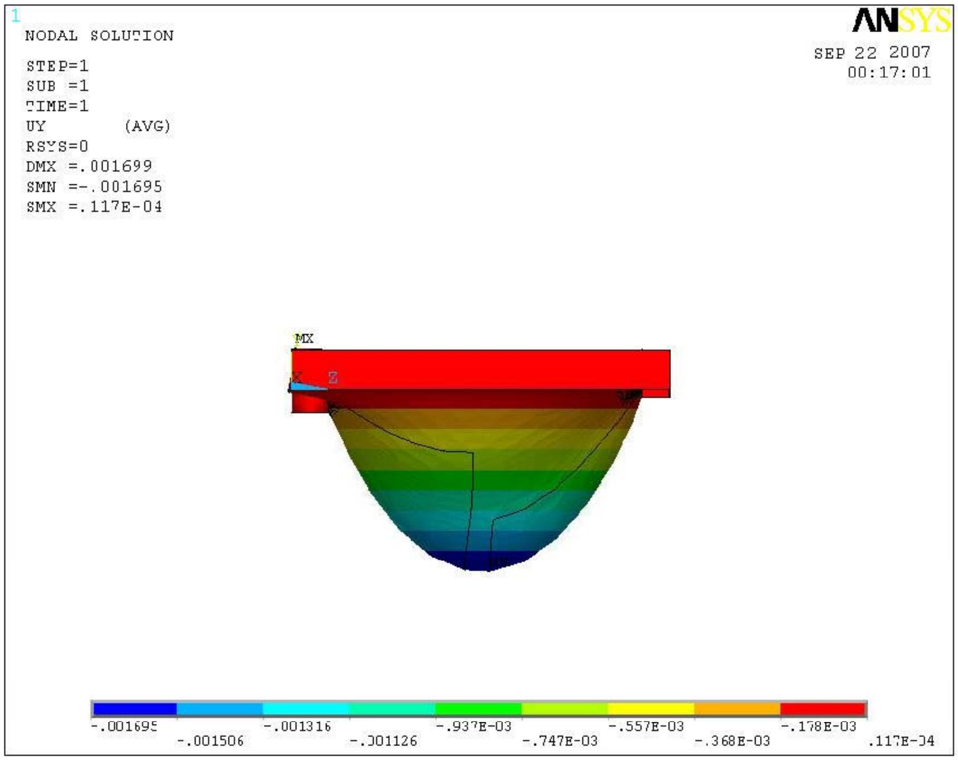

Fig.24 deflection in y direction in analysis 2; view-1

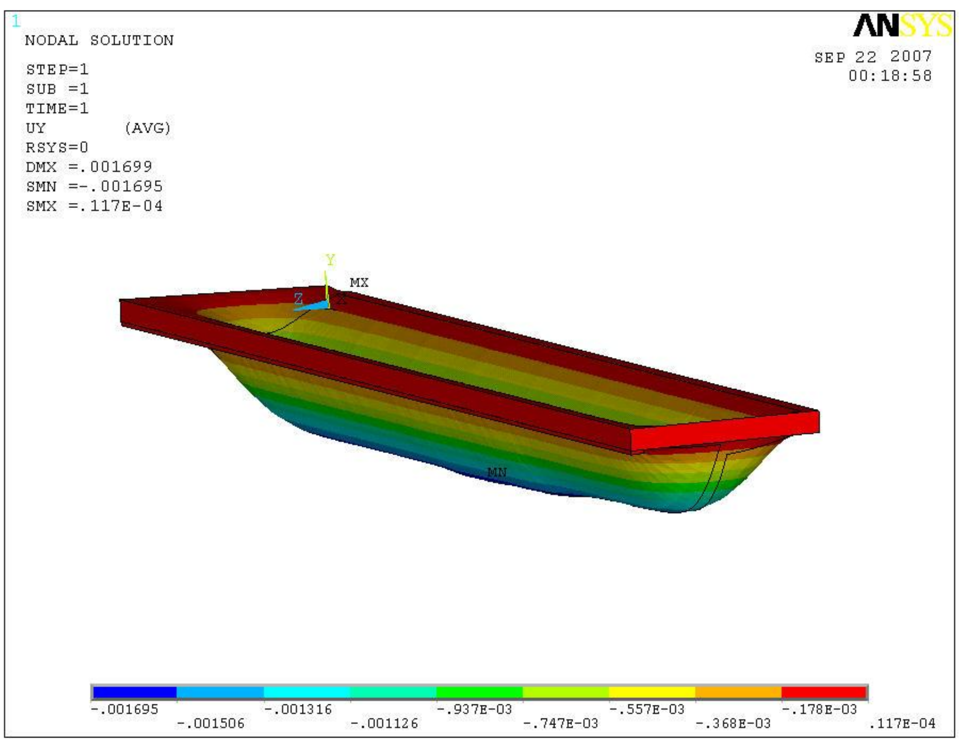

Fig.25 deflection in y direction in analysis 2; view-2

Summary of results:

Several cases were considered by changing the orientation, loading and constrain degrees and the results are summarized as follows

					Deflection (mm)					
					Y - Direction		X - Direction		Z - Direction	
	Gravity	Loading	Carbon Steel Rods	Hexcel sheet	Negative	Positive	Negative	Positive	Negative	Positive
Case 1	Positive Y	Downward	Yes	NO	-0.010095	0.174248	-0.010095	0.174248		
Case 2	Negative Y	No	No	NO	-3.063	0.000607	-0.53198	0.53199	-0.007365	0.007363
Case 3	No	Downward	No	NO	-12.969	0.00257	-0.223801	0.008287	-0.031099	0.031315
Case 4	Negative Y	Downward	No	NO	-16.037	0.003161	0.277022	0.281503	-0.038478	0.038693
Case 5	Negative Y	No	Yes	NO	-0.071532	0.004216	-0.002152	0.002071	-0.001044	0.006391
Case 6	No	Downward	Yes	NO	-0.284923	0.017069	-0.007418	0.008816	-0.007109	0.025461
Case 7	Negative Y	Downward	Yes	NO	-0.354106	0.021178	-0.009409	0.01084	-0.00892	0.31637
Case 8	Negative Y	Downward	Yes	Yes	-0.001695	0.0000117	-0.000102	0.000168	-0.000307	0.000263

Table.4 Results

Conclusion:

The deflection observed in the end plate deflection analysis with the wire and gravity loading is observed to be well below the design criteria limits. However the assumptions of considering the edges of carbon rod side and Hexcel sheet side has to be refined. In reality these edges will not completely restrict the deflection. This will be done in the next model where we will design the whole triangular piece.