A CDR for a new Scattering Chamber for HAll A - Preliminary

R.A. Lindgren

December 14, 2001

1 Overview

A new scattering chamber is under design and will be constructed for use in Hall A for experiments E01014 and E01015, which are expected to run in late summer 2003 and 2004, respectively. The new chamber is required in order to fully utilize the large vertical acceptance of BigBite and to provide vacuum coupling to BigBite and the HRS through the septum magnets. The pivot point will be shifted about 80 cm upstream to accommodate the septum magnets. The chamber is also to be constructed so that it can be used with the conventional Hall A pivot post for experiments requiring a large vertical acceptance without the septum such as experiment E01015. The current plan is to replace the middle aluminum chamber of the existing three tier system consisting of a top steel hat enclosing the cryo-target, middle aluminum chamber, and bottom steel chamber. For purposes of this report, the scattering chamber consists of of the aluminum middle ring, associated flanges for coupling to HRS, BigBite, beamline or septum, and the pivot post. The BigBite vacuum can, exit window, hydrogen target cell, and multi-wire proportional counters will be the subject of another report. A summary of the important criteria used to design and finalize the specifications of the chamber are listed below followed by a discussion of the main items:

- Replace standard Hall A chamber to utilize large acceptance without septum.
- Accomodate the large vertical acceptance of BigBite on both sides of the beam line.
- In-plane coverage must be as large as possible.
- Utilize the existing cryo-target system without substantial changes.
- Maintain outer dimensions as close as possible to previous chamber.
- Accomodate septum for electron from $6 - 12^{\circ}$ on either side of beam line.
- Minimize energy loss/multiple scattering for low energy charged particles.
- No loss in acceptance for 10 cm long 1 cm diameter targets.
- Provide flanges for vacuum coupling to spectrometers.
- Maintain adequate support strength to resist deformation.

2 Scattering Chamber System

An exploded view of the scattering chamber system and asociated supports and coupling flanges is shown in Fig. 1.

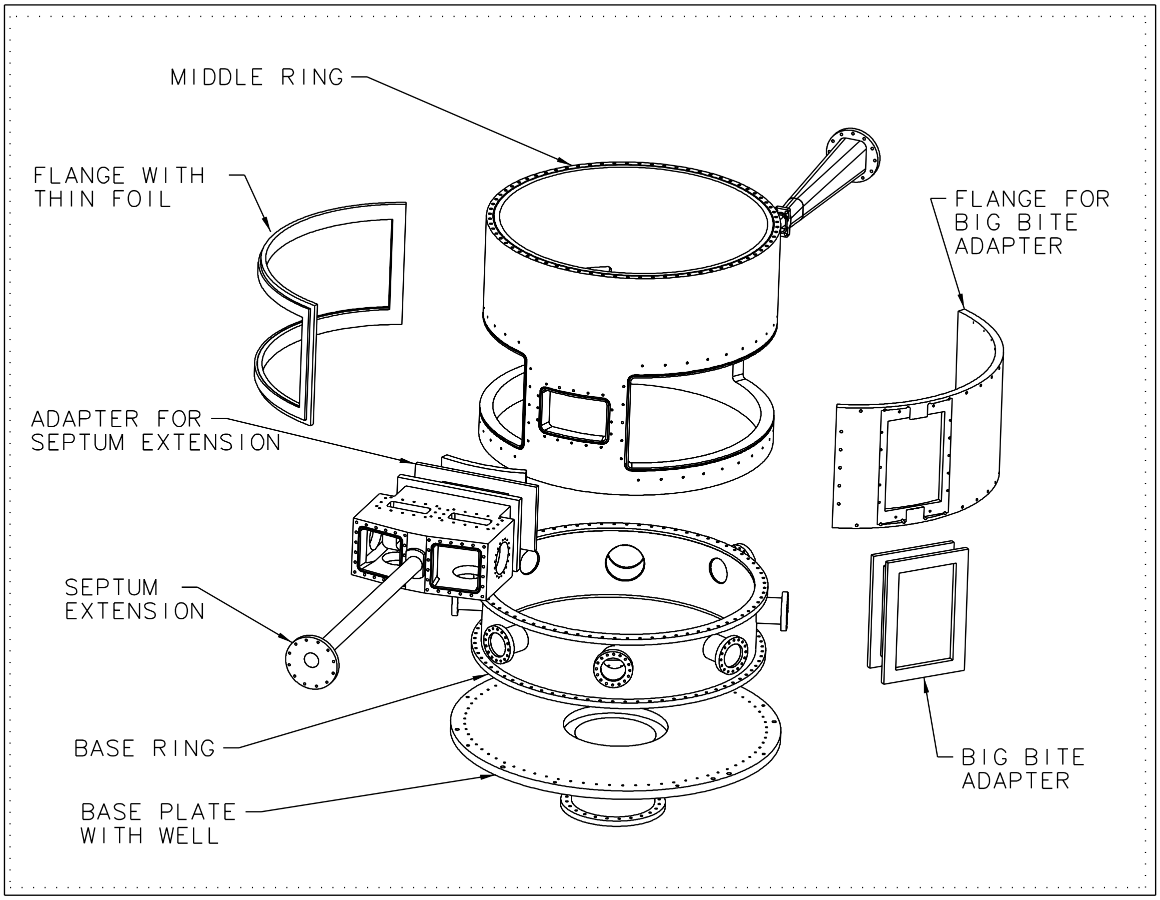

Figure 1: Scattering chamber exploded view

The scattering chamber consists of the aluminum middle ring shown with large openings on each side to accomodate the large vertical acceptance of BigBite. For experiment E01014 the curved flange on the left side in the figure will contain a thin foil for electrons detected in a shower counter for calibration and the flange on the right side will contain a fixed port for vacuum coupling to BigBite. An adaptor shown in the figure will be built to couple it to the septum extension. A base plate possibly with a well in the center to accomodate the cryotarget ladder plus solid targets will be required for use with the septum. The steel base ring is the standard base ring used with present chamber and the septum extension will be available from another experiment. An isometric view of the middle aluminum ring or chamber is shown in Fig. 2.

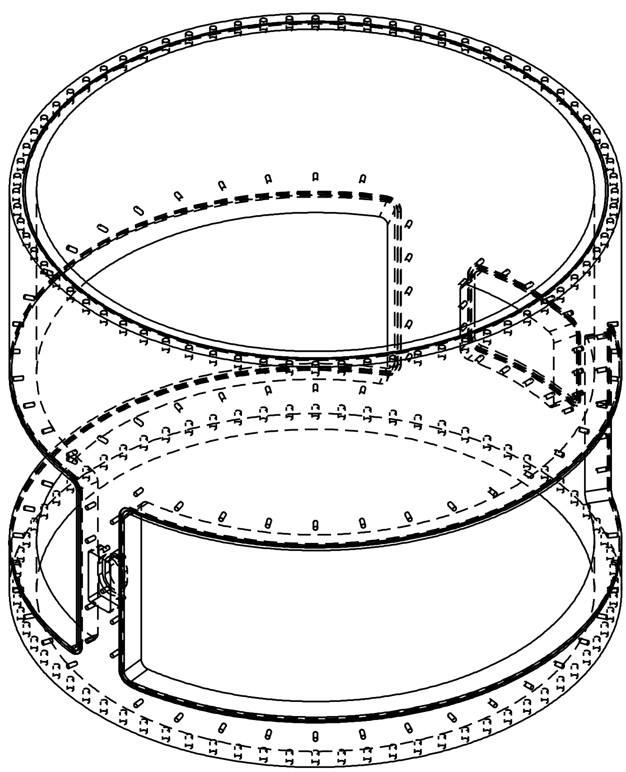

Figure 2: Middle aluminum ring

The basic size and outer dimensions of the chamber are given below:

- Height = 36.0 in. (0.991 m)
- Outer Diameter = 45.0 in. (1.143 m)

- Inner diameter = 41.0 in. (1.041 m)

Various methods of constructing the middle ring are being considered. One is from rolled aluminum plate with a welded seam and finally machined to provide precision surfaces for alignment and high vacuum applications. Forging and centrifually casting are also being considered. They provide a more dense structure instead of the latter method where the welded seam may cause vacuum and structural problems.

2.1 Vertical and Horizontal Acceptance

The present chamber does not have sufficient vertical opening to utilize the full vertical acceptance of BigBite. At a target distance of 1 meter from the fringe field of the magnet, the vertical acceptance of BigBite is $\theta_v = \pm 300$ mr ($\pm 17.2°$) and the horizontal acceptance is $\theta_h = \pm 80$ mr ($\pm 4.6°$). The vertical opening of the present Hall A chamber is about 1/2 of the above value. For purposes of allowing for slightly larger acceptance, we have rounded off the vertical acceptance angle to $\pm 18.0°$. At the outer radius of the chamber 57.15 cm, this corresponds to an opening of 37.1 cm. Adding 1 cm for target height brings this number to 38.1 cm or 15 in. Two openings 15 inches high and centered 12 inches from the base of the chamber will be available on each side of the chamber. These openings are shown in the sectional view in Fig. 3 and in Fig. 4. The horozontal width of the window on each side will range from $30° - 173.7°$ as shown in Fig. 3. In the present Hall A chamber, the window ranges from $6.3° - 171.2°$.

2.2 Septum

The septum permits the HRS to reach scattering angles from 6 - 12 degrees on either side of the beamline. The scattering chamber will require a window centered on the beamline of dimensions 6.639 in. high by 10.20 in. wide along the circumference corresponding to angles $\pm 13.0°$ wide. These dimensions are chosen to match an adapting flange to couple to the septum magnet.The adaptor flange and septum extension are shown in Fig. 5. Support material containing bolts holes will range from 13 to 23 degrees about 4.0 in. wide on both sides.

2.3 Standard operation without septum

When the septum is not used, the scattering chamber may be rotated 180 degrees, reversing the entrance and exit ports, and mounted on the standard pivot post. This will permit either HRS to have access to the same range of forward scattering angles as the present scattering chamber. See Fig. 3

2.4 Flanges

Several flanges are needed for experiments E01014 and E01015. The two flanges required for E01014 are shown in Fig 1. It is suggested to make these semi- circular flanges by machining cylindrical stock instead of bending flat aluminum stock. Hence, two middle rings will be manufactured with one of them having an ID corresponding to the OD of the other one. We would expect to have sufficient material to machine four flanges. One flange will be constructed that will vacuum couple to Big-Bite in order to cover angular positions of 49.5 and 53.5 deg. without moving the chamber or flange. The distance between the front coils of BigBite and the chamber wall is about 14 cm. This space is not sufficient to permit conveniently a flange and bellows system. Some thought has to be given to this or we have to simply move BigBite back further giving up some acceptance. Another flange will be constructed with a thin foil for situations that do not require vacuum coupling such as the lead-glass shower counter for calibrating Big-Bite in experiment E01-014. An additional flange with two ports for connecting Big-Bite at 90 deg and the HRS at a forward angle will be required for experiment E01-015.

2.5 Budget

The estimated cost of the scattering chamber and required flanges as quoted by Precision Fabricators, Stuarts Draft, Virginia is shown in the table. This is not final.

Table 1: Cost of Scattering chamber and flanges

Item Number	Item	Cost
1	Scattering chamber (rolled aluminum plate)	\$25,000
2	Base plate with well for target ladder (Al)	\$7,000
3	One right flange from 44.0° to 59.0° for E01014	\$9,000
4	One left flange with opening at 90.0° and 40.0° for E01015	\$9,000
5	One left flange with wide opening for thin foil on electron side	\$9,000
	subtotal	\$59,000
7	Beam exit flange adaptor for septum	\$800
8	Beam entrance tube and flange	\$1,000
9	Beam exit tube/flange for 180° rotation	\$1,200
10	Beam entrance tube/flange for 180° rotation	\$1,200
	subtotal	\$4,200
11	One flexible vacuum coupler to BigBite	\$2,000
12	BigBite vacuum chamber and support	\$10,000
	subtotal	\$12,000
	Total	\$75,200

2.6 Stress analysis

In the existing Hall A chamber, calculations of the stresses near the midplane support area of the middle ring and deflection of the window opening were made using the finite element analysis code ANSYS. The work was done by a graduate student in the Department of Civil Engineering at the University of Virginia. Also a scaled down model of the middle ring was built and used to test the ANSYS code. Agreement between the code and experimental data on the deflection of the window opening were within $\pm 10\%$. Results from ANSYS for the middle ring on the maximum deflection of the opening of the middle ring varied from 0.007 in to 0.015 in when the ring was loaded with 25,000 pds(1/2 weight of aluminum chamber + weight of top hat + weight for cryotarget + effect of atmospheric pressure). The range was dependent on how the load was applied. This was decided to be a safe limit Compressional stresses calculated using ANSYS assuming the middle ring was attached to the top hat and loaded with 25,000 pds were less than 3000 psi everywhere. However, stresses over small areas rose to levels 6000 psi near the entrance and exit holes.These calculations indicate that we do not exceed the safety limit of 15,000 psi for aluminum. A simple model calculation of the compressional stress can be obtained using the formula:

$$f = \frac{W}{A} + \frac{W.e}{S}$$

where the first term is the compressive stress related to the total weight plus the added force due to atmospheric pressure when the chamber is under vacuum. W is the total applied load as defined above. A is the effective cross sectional area of the support column. The second term is the bending stress which is related to the eccentricity e and the section modulus S. It is negligible compared to the first term for the present chamber. The result for the present chamber is

$$f \sim W/A = 3585psi$$

, which is considerably smaller than the allowed value of 15,000 psi. For the new chamber, the support area will increase from $30.1in^2$ to about $50in^2$. hence, the new chamber will have less compressional stress than the old one. Distortions of the window due to asymmetry loading may be different since there is less mass around the window. This has not been investigated. To reduce the risk four moveable support cylinders 2.0 in in diameter and 15.0 in high will be placed in the windows for added support. The large flanges bolted to each side of the middle ring will also add stability. Finally, to test for structural integrity a hydro test at Jlab will be performed by pressuring the chamber with water to 3 atmospheres.

2.7 Timeline

2.8 Some things needed to be done

• Need complete design drawings of scattering chamber before going out to bid
• Modify budget to include cost of an extra middle ring with larger ID so that four window flanges can be cut from cylinder.

• Design adaptor between middle ring and septum magnet for exit and scattered beam
• Design flange with fixed port/bellows system for coupling to BigBite. Only have 14 cm space.
• Need detailed design of flange for electron shower calorimeter for calibration in E01014.
• Need design of one window flange with two fixed ports for HRS and BigBite for E01015.
• Need to decide on required space on target ladder for target cells and solid targets. The question is whether we need a well in the base plate for space for the target ladder when it is fully extended.
• Hydro test middle ring at JLab for structural integrity.
• Add vacuum testing to middle ring bid requirements.

Another view of the scattering chamber is shown in Fig. 6. An overview of the layout of the scattering chamber, BigBite, and the detector plane is shown in Fig. 7.

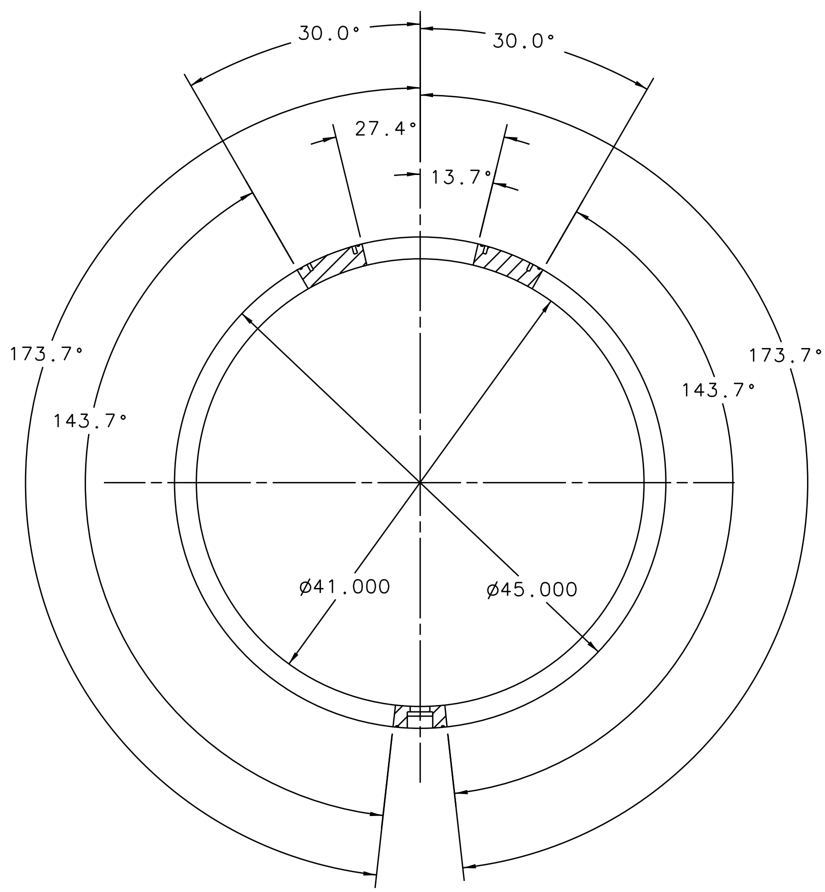

Figure 3: A sectional view of scattering chamber

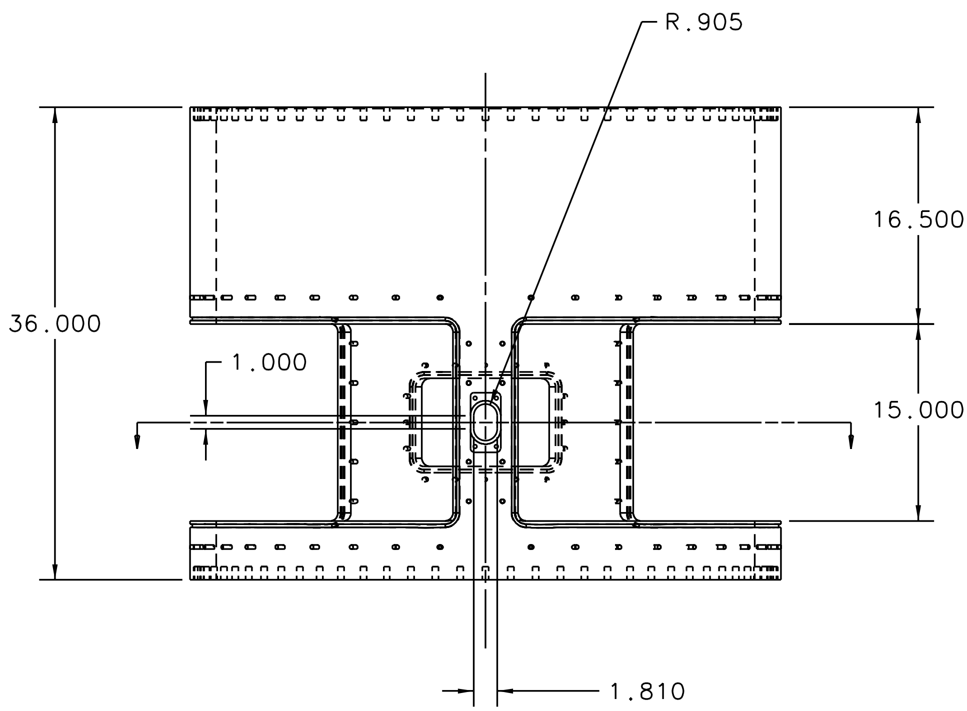

Figure 4: Front view of scattering chamber

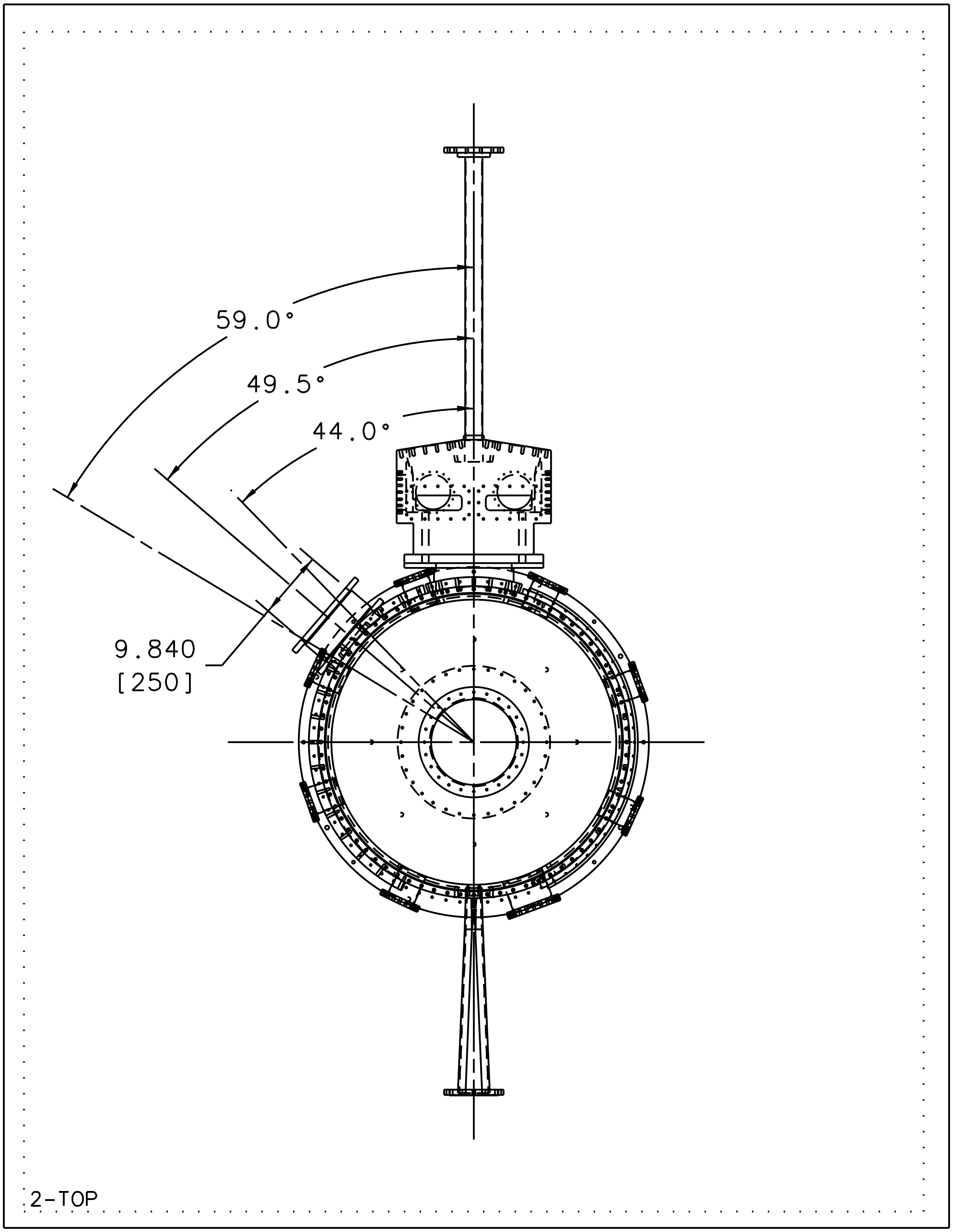

Figure 5: Topview of scattering chamber

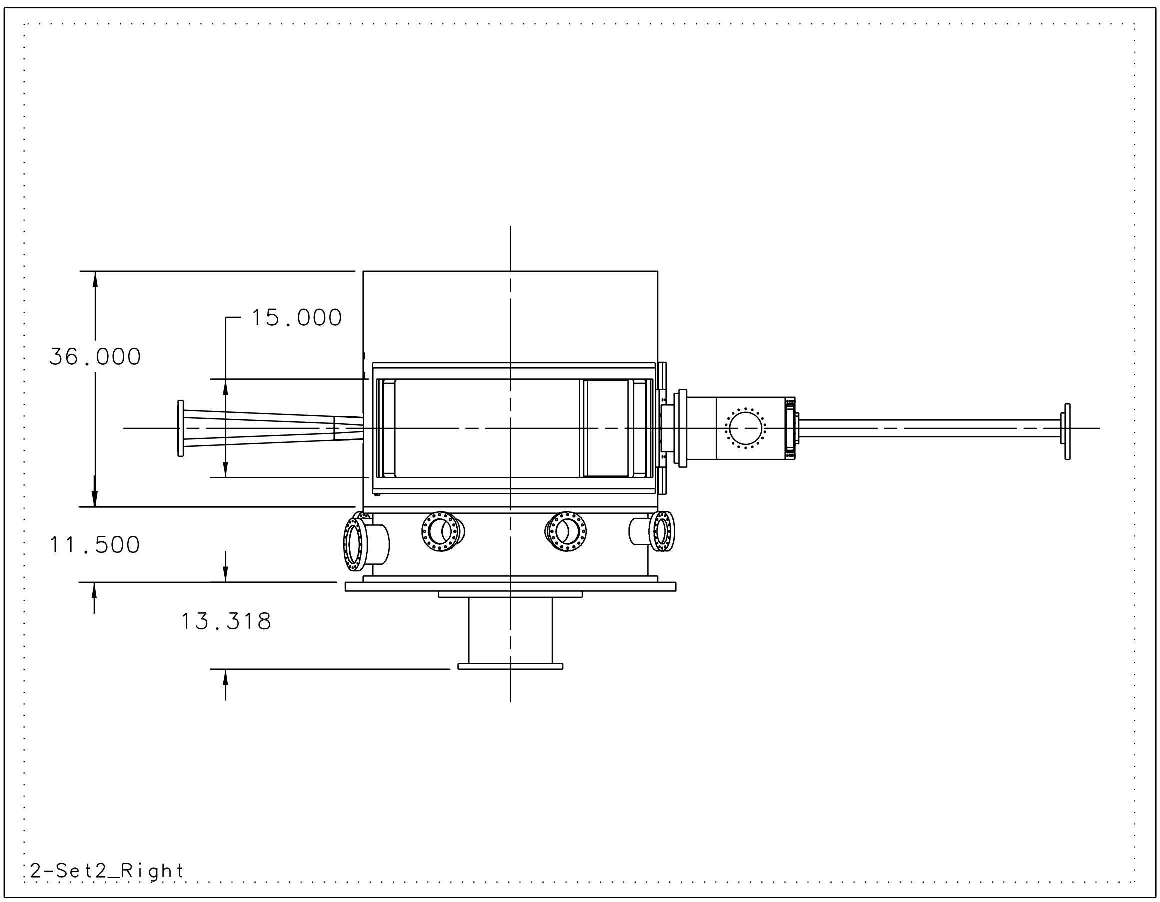

Figure 6: Side view of scattering chamber

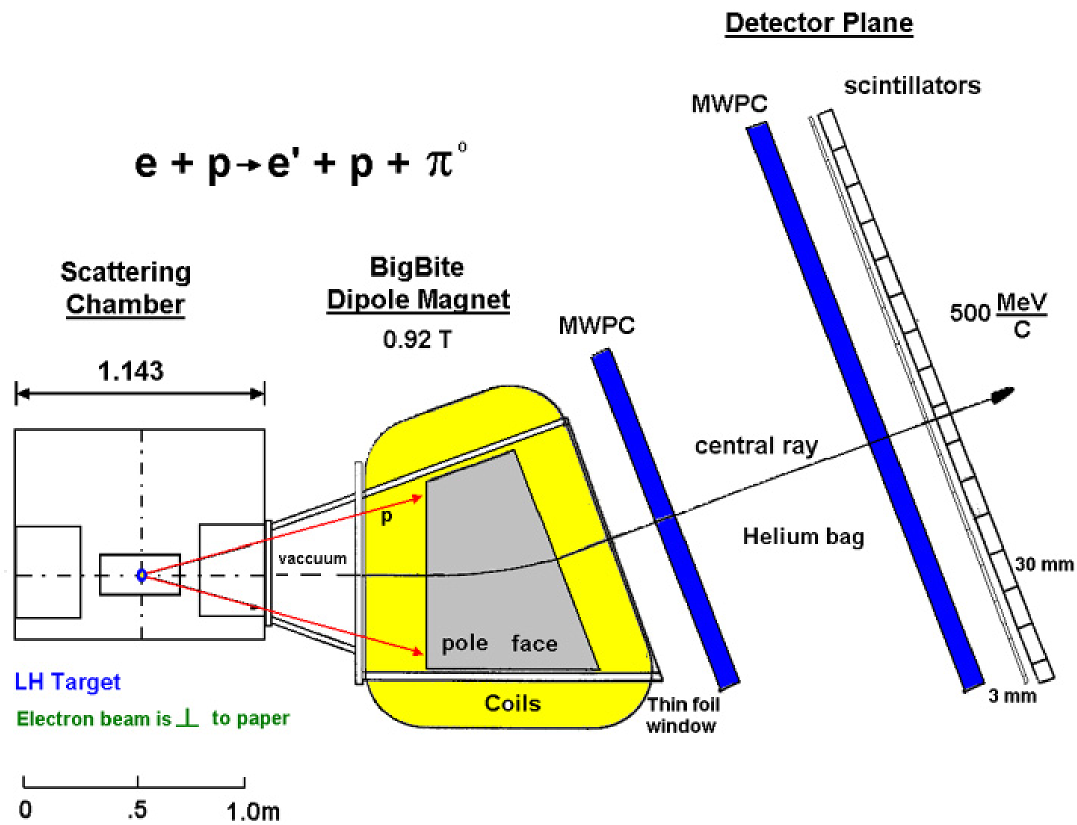

Figure 7: BigBite beam line with detector plane