Drift Chamber Material Budget

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Abstract

Specifically addressing one of the recommendations of the March 2007 Drift Chamber Review committee, we present design options for reducing the amount of material in the GlueX drift chambers.

In March 2007, the drift chamber designs for GlueX underwent an external review. One of the main recommendations of the review committee was that "priority should be given to studying design modifications that would significantly reduce the amount of material in the GlueX tracking chambers" [1]. This report documents the design changes that we are pursuing and prototyping in order to address this recommendation.

The nominal FDC design presented to the review committee consisted of four packages each with six chamber units. Each chamber unit consisted of two cathode planes flanking an anode wire plane. The anode-cathode separation was 5 mm. In the HDGeant Monte Carlo simulation, each cathode plane was composed of 5-μm thick copper strips on a 50-μm thick Kapton backing, mounted to 4.87-mm thick low-density Rohacell foam. The chamber units were electrically separated from each other by 25-μm thick aluminized-Mylar ground planes. In the simulation, the chamber gas was 85% Argon/ 15% CO_2 by weight. Table 1 lists the contributions of the materials in the active area to the total thickness of all four packages in radiation lengths.

Material	Number of layers	Thickness per layer (g/cm^2)	Radiation Length (g/cm^2)	X/X_0
Kapton	48	0.007100	40.56	0.008402
Copper	48	0.004480	12.86	0.016722
Epoxy	48+42	0.003250	41.91	0.006979
Mylar	42	0.003475	39.95	0.003653
Argon	24	0.001320	19.55	0.001620
CO_2	24	0.000370	36.20	0.000245
Rohacell	48	0.01558	41.04	0.018227
Total				0.0558

Table 1: Material budget for the FDC active area for the design presented to the Drift Chamber Review committee.

The FDC chamber frames were 12-cm thick annuli composed of G10. The inner and outer radii of each annulus were 53.6 cm and 60 cm, respectively. Each annulus was flanked by 2-mm thick rings of stainless steel meant to mock up an early idea for end-plates that provided a means to compress the numerous O-rings in each package. The total thickness in radiation lengths for each package in the beam direction was about 0.987 X/X_0, of which 0.760 X/X_0 came from the G10. Our original design called for the pre-amplifier circuit boards to be mounted to the frames in "diving board" fashion (i.e. oriented along the z-direction) just outside the 60-cm radius. These were simulated as rings with an inner (outer) radius of 60.5 cm (60.61 cm), composed of 60% polyethylene, 26% G10, and 14% silicon by weight. The readout cables were also implemented in the simulation. More details of the simulation model can be found in Ref. [2] and the references cited therein.

The CDC model consisted of 23 rings of straw tubes encircling the target. Each straw tube was modeled as a hollow 0.8 cm outer radius cylinder of aluminized-Kapton (110-μm thick) enclosing a tungsten wire. The gas mixture was assumed to be the same as for the FDC. On the downstream end, the tubes were plugged with 1-cm thick Delrin plugs and supported by a 0.6-cm thick aluminum plate. A 600-μm thick aluminum shell forms the inner cylindrical surface of the CDC.

As described above, the FDC packages and the CDC end-plate present a significant amount of material downstream of the target. The greater the amount of material in this region, the more likely that photons emerging from the target will convert before they can be detected by the calorimeters. Fig. 1 shows where the photons are likely to convert [4]. The effect of the CDC end-plate and the aluminum skin can be seen clearly in the figure. More importantly, the conversion rate increases by an order of magnitude relative to the target material in the four FDC packages. This is mostly due to the support frames. Fig. 2 shows another view of the conversions for forward-going photons where the CDC skin, the CDC end-plate and the FDC frames are readily apparent. Conversions far upstream of the forward calorimeter make photon reconstruction almost impossible for certain classes of events.

We are presently pursuing a new FDC design in which the thickness of the copper on the cathode planes is reduced from 5 μm to 1–2 μm and the Kapton thickness is reduced from 50 μm to 25 μm. We are presently working to procure boards of this design to study their performance in our existing cathode strip prototype chamber. We are also considering removing the Rohacell from the active area. This move is only possible if we can achieve the desired flatness tolerance of ± 100 μm in our cathode plane surfaces. Our prototype studies to date without the Rohacell backing have focussed on tensioning the cathode plane, while working to reduce lateral distortions of the cathode strips to an acceptable level. Finally, the 25-μm thick Mylar layers (for the ground planes between neighboring cathodes) will be replaced by 6.3-μm layers of Mylar with 1000 A° of aluminum on each side. The new material budget for the FDC active area (with the Rohacell replaced by air) is listed in Table 2. Due to Lorentz effect considerations, the gas mixture is likely to be closer to 40% Argon/60% CO_2 and this change is also reflected in the table. A factor of 4–5 reduction in material thickness relative to the old nominal design appears to be feasible.

Our revised plan for the FDC support rings calls for replacing the G10 frames of the cathode planes with a carbon fiber/E-glass/Rohacell laminate. The wire frame will still be composed of G10, but the spacer ring required to maintain the anode-cathode gap on the other side of the wire plane will be polyethylene instead of G10. The new frame concept is described in more detail in Ref. [3]. The revised thickness in radiation lengths of each 12-cm thick (radially) support annulus is 0.39 X/X_0, a factor of 2 reduction relative to the 0.76 X/X_0

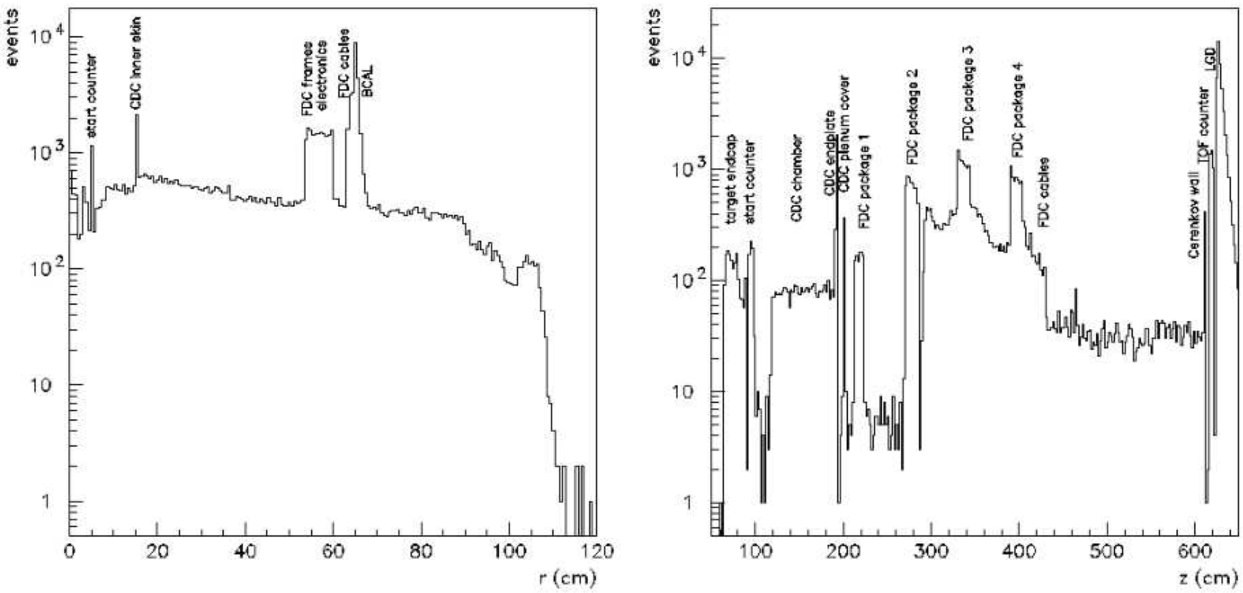

Figure 1: Photon conversion profile as a function of z (along the beam-line) and r (radially from the beam-line) (units in cm). The contributions of the different elements of the GlueX detector system are labeled, including the contributions from the FDC and CDC systems. Figure taken from Ref. [4].

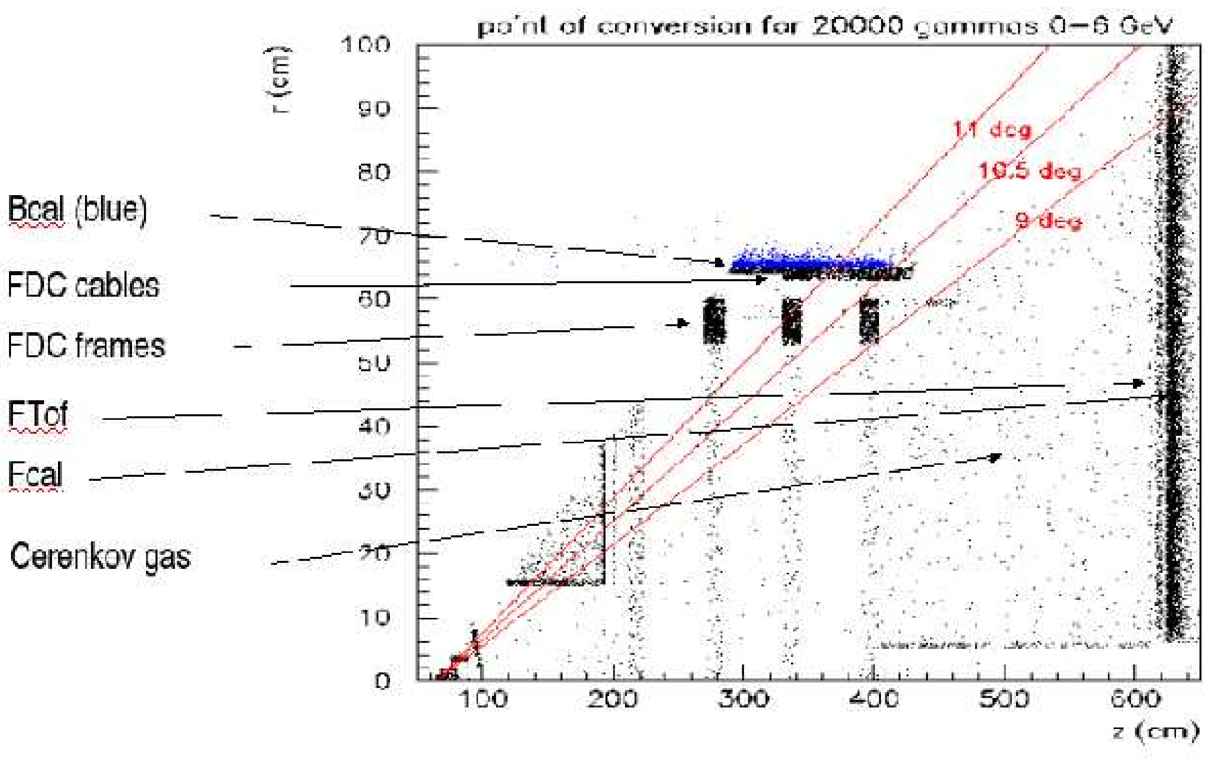

Figure 2: Photon conversion profile in a correlation plot of r vs. z (units in cm). The dark regions indicate places were the probability of photon conversion is high. Figure taken from Ref. [4].

Material	Number of layers	Thickness per layer (g/cm^2)	Radiation Length (g/cm^2)	X/X_0
Kapton	48	0.003550	40.56	0.004201
Copper	48	0.001792	12.86	0.006689
Ground planes	48	0.000930	38.47	0.001160
Argon	24	0.000660	19.55	0.000810
CO_2	24	0.001110	36.20	0.000736
Air	48	0.000603	36.60	0.000790
Total (2 μm Cu)				0.0144
Total (1 μm Cu)				0.0110

Table 2: Material budget for the re-designed FDC active area.

Material	Thickness (cm)	Thickness (g/cm^2)	Radiation Length (g/cm^2)	X/X_0
Aluminum	0.6	1.62	24.01	0.06747
G10	0.6	1.146	30.17	0.03798
Delrin	0.6	0.852	38.46	0.02215
Carbon fiber	0.4	0.752	42.38	0.01773

Table 3: Thicknesses (in the beam direction) of various options for the CDC end-plate.

thickness of G10 in the original design. We are also working to design the readout cables with the minimum jacket and total copper thickness required for acceptable shielding. There is already promise that some non-negligible improvements can be made in this area in terms of reducing the thickness of the materials in the inactive regions of the FDC system.

We are considering several different materials for the CDC end-plate to replace the aluminum. So far the most attractive option is a carbon fiber/epoxy composite material, from which we can construct a 0.4-cm thick wall instead of a 0.6-cm wall due to its stiffness. The thickness in radiation lengths of this material plus other possibilities are tabulated in Table 3. For the carbon fiber option, we assumed 60% carbon fiber in 40% epoxy resin. A factor of 2-3 improvement can be achieved by replacing the aluminum with a less dense (and possibly thinner) material.

References

[1] D. Christian, M. Kelsey, D. Hasell, and B. Mecking, "Hall B and D Drift Chamber Review Report", March 16, 2007.

[2] R. Jones, "Detector Models for GlueX Monte Carlo Simulation: the CD2 Baseline", GlueX-doc-732-v4.

[3] S. Taylor, "A proposal to reduce the FDC support material thickness", GlueX-doc-800-v2.

[4] R. Jones, "Discussion of the Detector Material Budget", GlueX-doc-789-v1.