Further HDFast simulations of the FDC

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Abstract

This document presents further Monte Carlo studies of the FDC using HDFast, including studies of the effects of adding material and taking away packages and chambers from the baseline configuration of four packages each consisting of six cathode-anode-cathode sandwiches. Reduction of the number of chambers in the system adversely affected the momentum resolution in a significant way.

In my previous note (GlueX-doc-418-v2) I described several places where the results obtained from the HDFast simulation did not agree with expectations. Although the source of the strange behavior was never identified, I have identified parts of the simulation that do make some sense for a restricted angular range. The purpose of this document is to glean as much reasonable information about the arrangement and composition of the FDCs from the fast simulation as possible and bring this chapter to a close.

As before, the benchmark configuration consisted of four equally separated packages each consisting of six cathode-anode-cathode sandwiches (chambers) separated by Mylar ground planes. The cathode layers were composed of a 25 μm layer of Kapton®[1] and a 17 μm (= 1/2 oz) layer of copper. The cathodes were separated from the anodes and from the ground planes by 0.5 cm such that each chamber is 2 cm wide. The anode wires were separated by 10 mm. The cathodes were divided into strips with 5 mm pitch. The strips were orientated at $\pm 45^\circ$ with respect to the wires. Each chamber was rotated by 60° with respect to its neighbor. The entrance window for the first chamber was at z=224 cm (relative to the origin) and the exit window of the last chamber was at z=400 cm. The center of the target was at z=65 cm.

[1] Kapton® is a registered trademark of Dupont.

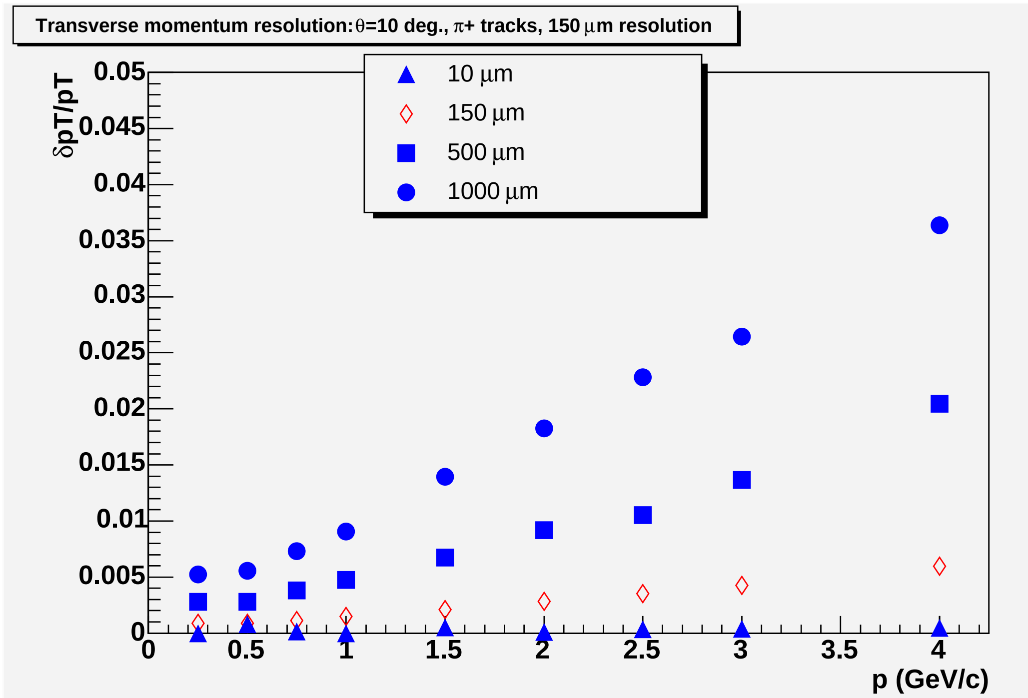

Figure 1: Dependence of momentum resolution on hit (position) resolution. There was no material in the FDC.

The packages subtended an angular range of roughly 1–20° relative to the z-direction from the target. A particle traveling at 10° relative to the beam line is likely to pass through all the chambers, so this angle was used for the studies described in this document. I generated π^+ tracks in the momentum set $\{0.25, 0.5, 0.75, 1.0, 1.5, 2.0, 2.5, 3.0, 4.0\}$ GeV/c at $\theta = 10°$, uniformly distributed in ϕ.

One of the chief design parameters of the FDC development is the position resolution on each space point. This directly impacts the momentum resolution achievable with this device. The design goal is $\sigma_{x,y} < 150$ μm for each chamber. In the simulation, the position resolution σ_u for each detector plane was fixed to the same value. Figure 1 shows the relative transverse momentum resolution as a function of position resolution and particle momentum for the case where the FDC material is ignored. The momentum resolution rises linearly with p and monotonically with σ_u. These results agree qualitatively with expectations.

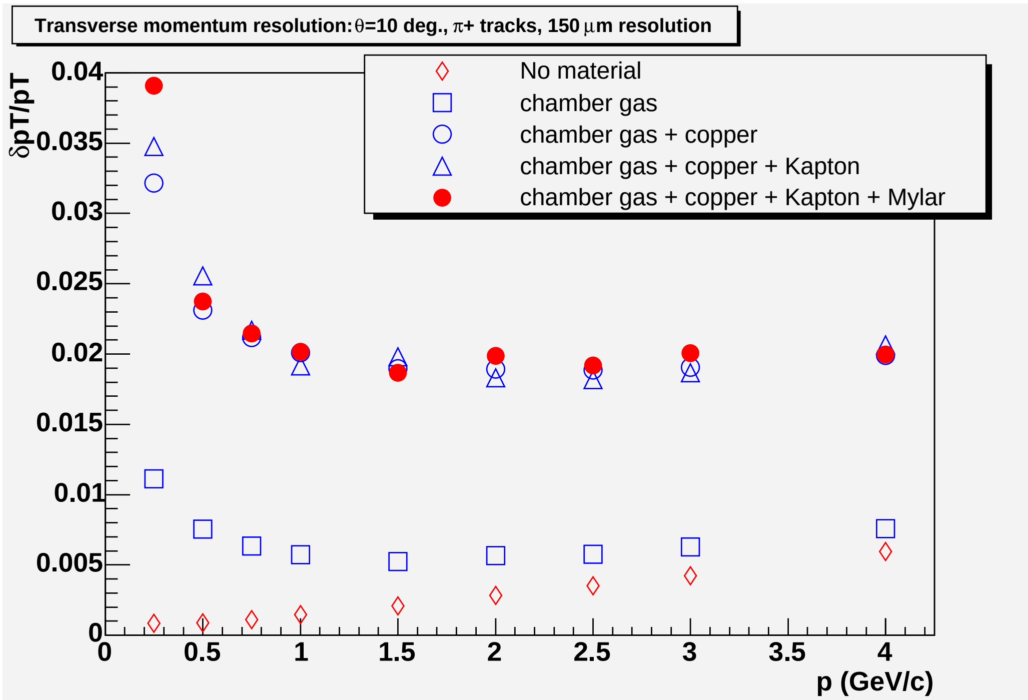

Figure 2: Dependence of transverse momentum resolution on material. The hit resolution on each active detector was assumed to be 150 microns.

Figure 2 shows the effects of adding material to the FDC for the 150 μm position resolution case. The relative momentum resolution rises rapidly as the projectile momentum decreases. This agrees qualitatively with the $1/\beta$ dependence expected from multiple scattering.

The benchmark configuration for the FDCs leads to a large number ($\sim$14000) of readout channels. To reduce the cost of the device I considered reducing the number of packages from four to three. A comparison of the three and four chamber solutions is shown in figure 3. For the three package case, the separation between the first and second and the second and third packages was fixed to the same value. The relative momentum resolution is generally much worse for the three package solution, especially as the pion momentum increases. Whereas the four package solution tends to be dominated by multiple scattering for higher momentum, the three package solution appears to be dominated by the position resolution (hence the linear rise).

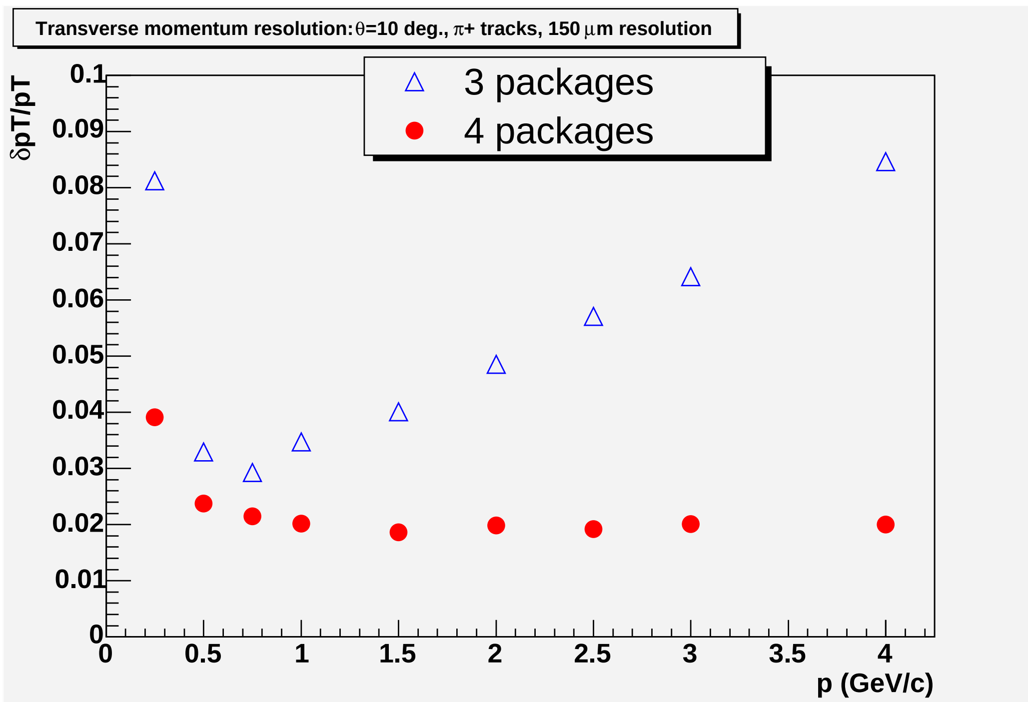

Figure 3: Comparison of 3 package solution to 4 package solution.

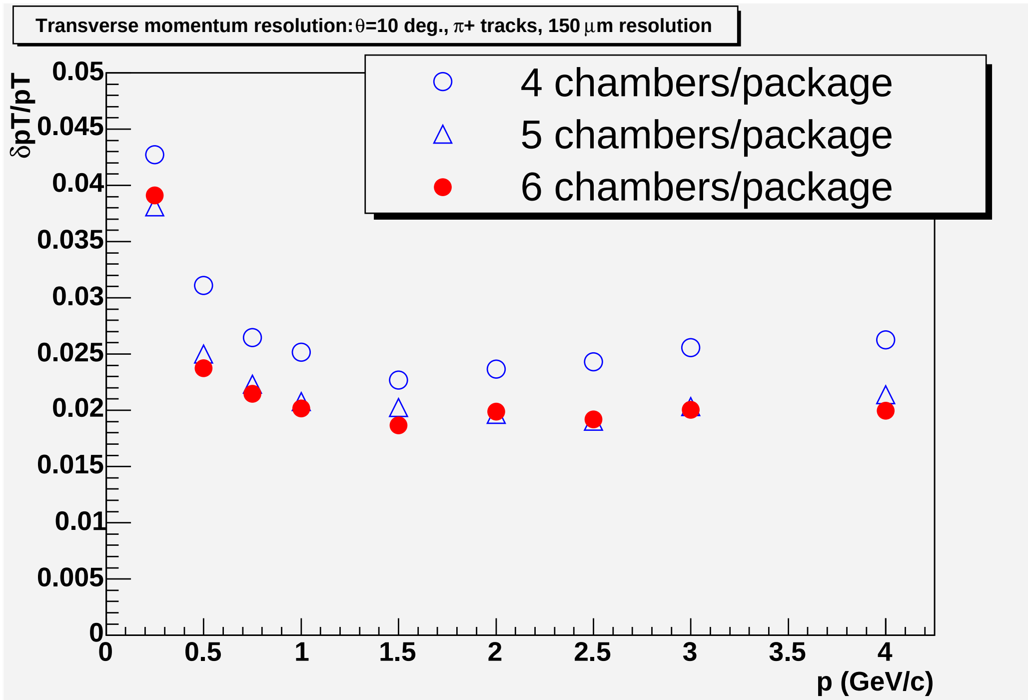

Figure 4: Dependence of momentum resolution on the number of chambers per package. There were four packages in the study in each case.

Since the three package solution is noticeably worse than the four package solution, the next thing I tried was to reduce the number of chambers in each package from 6 down to 5 and 4. A comparison of the momentum resolution for the three cases is shown in figure 4. The four chambers/package solution gives worse resolution than the 5 or 6 chamber cases, which are more or less equivalent. For the purposes of pattern recognition the six-chamber solution is probably still preferable.

The "half-gap" (the distance between the anode plane and each of the cathode planes in a chamber) is an important quantity that needs to be maintained to high degree of accuracy. Concern about the stiffness of the Kapton® and observation of creases and valleys in one of the prototype cathode planes prompted the consideration of low-density materials such as NOMEX®[2] honeycomb as backing material/stiffeners for the cathode

[2]NOMEX® is a registered trademark of E.I. duPont de Nemours and Company: DuPont Advanced Fibers Systems, Customer Inquiry Center, 5401 Jefferson Davis High-

planes. For the purpose of the simulation I assumed a density of 0.029 g/cm^3. A sketch of the revised geometry with NOMEX® layers added is shown in figure 5. The honeycomb layers add to the multiple scattering of tracks passing through the FDC. The effect on the momentum resolution is shown in figure 6. The copper layers were still the dominant contributors to the resolution.

These simulation results support the baseline four package/six chambers per package configuration. Adding the honeycomb does not appear to worsen the transverse momentum resolution excessively.

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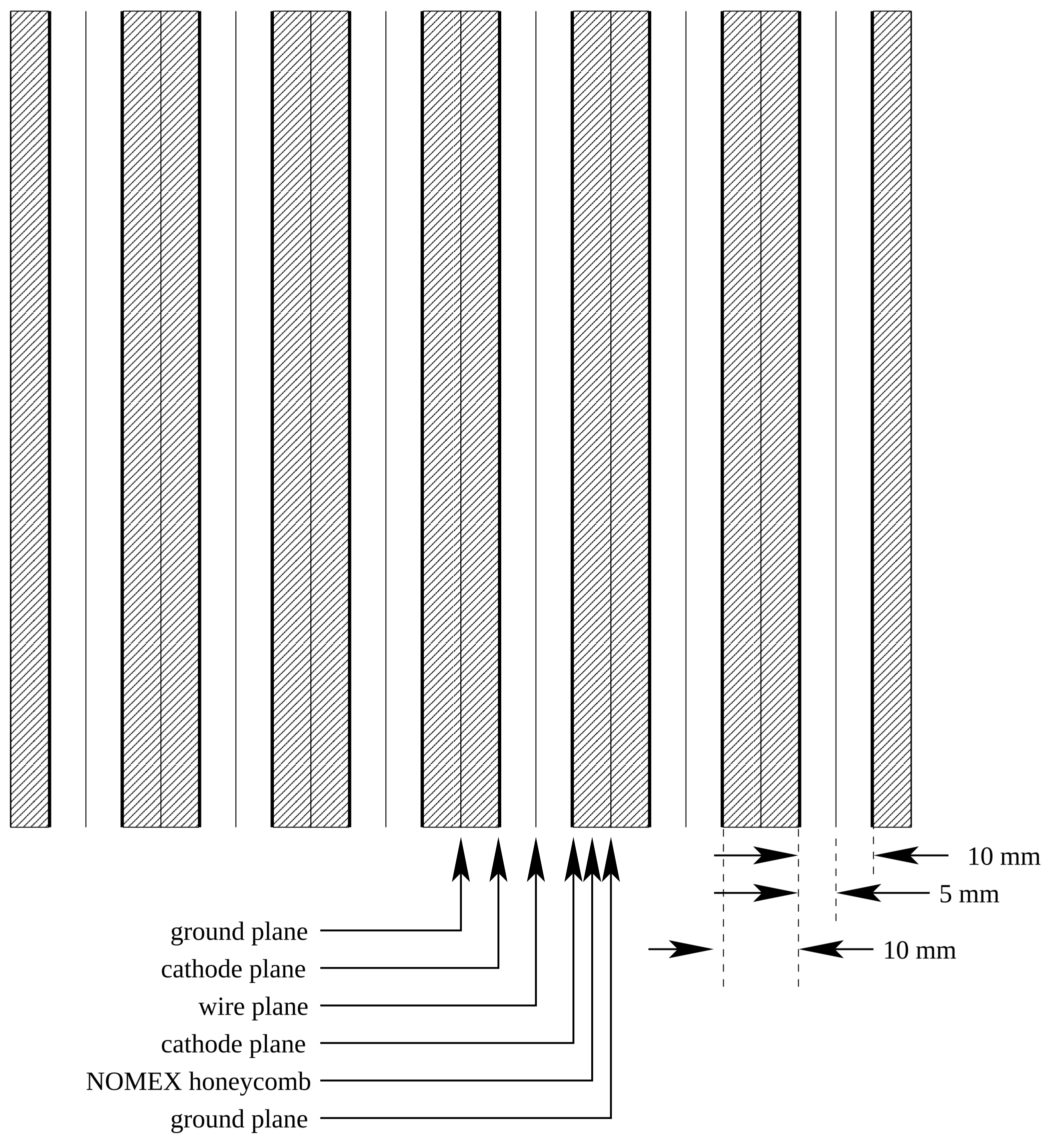

Figure 5: Sketch of single package geometry with honeycomb layers added.

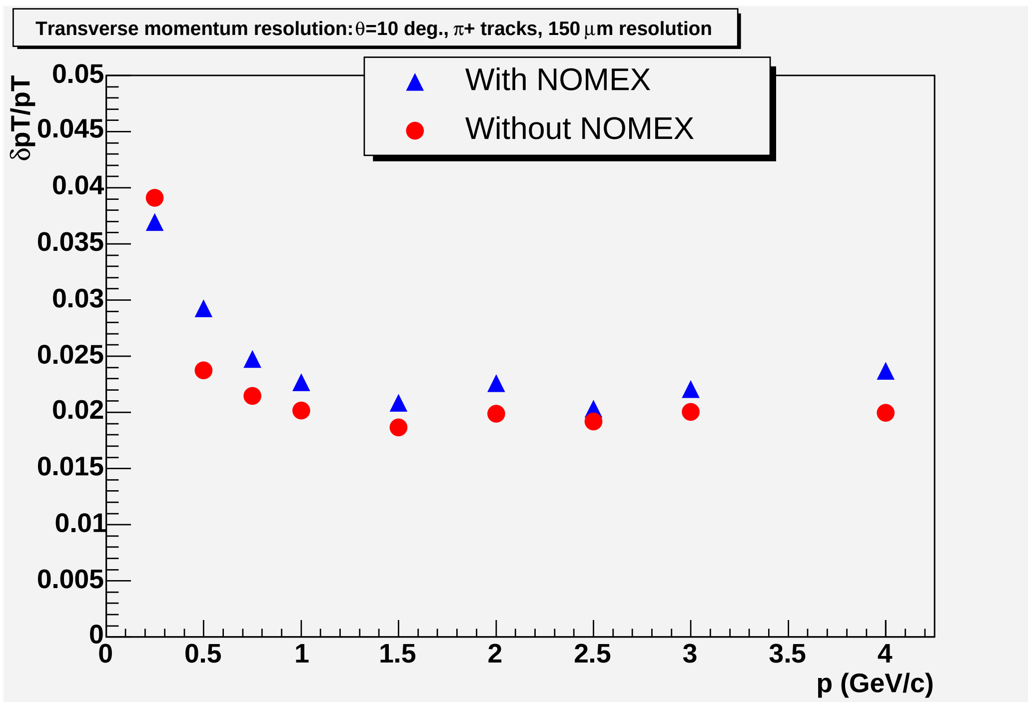

Figure 6: Effect on the momentum resolution from adding honeycomb to the chambers. The position resolution at each plane was 150 microns and the Mylar, cathode material, and chamber gas were in the simulation.