HDFast Simulation Study of the FDC

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Abstract

This note describes some of the systematic studies of the FDC momentum resolution performed with HDFast. The momentum resolution as a function of projectile momentum behaves in unexpected ways when material is added to the FDC.

1 Introduction

The Forward Drift Chambers (FDC) are a set of horizontal drift chambers with each layer of anode wires sandwiched between two planes of cathode strips. They are intended to measure forward-going tracks in the GlueX detector downstream of the CDC. The optimum number of layers and the position along the beam line (in the $\hat{z}$ direction) of each of the layers has yet to be determined. This note details the most recent Monte Carlo studies of the FDC using the HDFast simulation engine.

A set of π^+ tracks with discrete momenta in the set $\{0.25, 0.5, 0.75, 1.0, 1.5, 2.0, 2.5, 3.0, 4.0\}$ GeV/c were generated uniformly in ϕ and within an angular range of 5–10° in θ. This range was chosen such that the tracks primarily pass through the FDC and not the CDC. These tracks were then processed by HDFast, in which the vertex position is smeared within the target and the particles are traced through the 2.24 T solenoidal field of the GlueX detector. Multiple scattering and energy loss are not taken into account at this stage. During the "pseudo-fit" stage the track is traced back to the target. At each step of the trace as the particle passes through material, the multiple scattering and detector position resolution terms (if the material layer is active) are added to the covariance matrix for the track and the initial momentum of the track is smeared according to the values in this matrix, thereby giving a measure of the tracking resolution.

The FDC is divided into 3–4 packages each comprising several chambers. In the present simulation, each chamber consisted of Mylar windows enclosing a 2 cm thick layer of $Ar - CO_2$ gas and two cathode planes separated by 1 cm. The anode layer was considered to be at the center of the gas layer and the cathode planes were arrange symmetrically about it. The actual wire material was ignored. The Mylar windows were 25 μm thick. The cathodes were 52 μm thick and were composed of a copper-Kapton mixture to mock up the cathode planes currently being studied in the FDC prototype. Each layer of the FDC was modeled as silicon disk detector due to the constraints of the geometry package available in the MCFast library underlying the HDFast simulation. The inner radius of each disk was 3.5 cm and the outer radius was 60 cm. The wire pitch was 1.0 cm and the strip pitch was 0.5 cm. Within a chamber, the strips are arranged at 45° angles with respect to the wires and 90° with respect to each other. Adjacent chambers are rotated 60° relative to each other.

For completeness here is the HALLD.cmd file I used when running HDFast:

```
! GlueX Spectrometer command file for MCFast.
!
max_ev    25000                    !Max number of events
!max_ev    25                    !Max number of events
max_print 4                      !max # events to print
! Change the geofile location below to the value of $HDFAST_DIR
! note that mcfast needs that actual name and not the env var.
!file_geo $HDFAST_DIR/HDFast.geo       !Geometry file
file_geo   HDFast.db       !Geometry file
ranseed  0                     !Random seeds =0 use time()
file_type 1                      !MCFio input file; 1 = StdHep file.
file_in input.evt                  !data files: enter either
mcfio_out output.evt      ! Output file.
batch ON
!
make_decays FALSE
make_pair_convert FALSE
trace_integrated FALSE
```

```
trk_max_turns 1
```

The “trace_integrated FALSE” line is set to TRUE in the default version of the file. This only seems to affect the lowest momentum point.

2 Systematic Studies

The MCFAST code upon which HDFast is built is essentially a black box. In order to verify that the simulation behaves in a manner consistent with my expectations, I performed several studies with various effects turned on and off. As will be shown later, these studies revealed some seemingly strange behavior of the simulation. The initial studies were done with four equidistant packages each consisting of six cathode-anode-cathode layers.

In the absence of material (i.e., for hypothetically massless detectors with some non-zero resolution), the relative momentum $\delta p/p$ should be proportional to the momentum p. The momentum resolution under this condition for various choices of the detector position resolution is shown in figure 1. The detector resolution was assumed to be the same at each layer. The plot shows the expected monotonic rise in both momentum and detector resolution.

The presence of material causes the projectile to undergo multiple scattering. This should lead to an approximately flat (β dependent) contribution to the relative momentum uncertainty for the chosen set of momenta according to[1]

$$\frac{\delta p_{MS}}{p} \sim \frac{p}{\left|\vec{B}\right|}\sqrt{\left\langle\frac{\theta_s^2}{2}\right\rangle L}, \tag{1}$$

where $\vec{B}$ is the solenoidal magnetic field (assumed to be pointing along the $\hat{z}$ direction), L is the track length in the material, and

$$\left\langle\frac{\theta_s^2}{2}\right\rangle = \frac{1}{2}\left(\frac{0.91E_S}{\beta pc}\right)^2 \frac{\rho}{X_0}\left[1 + 0.04\ln\left(\frac{\rho L}{X_0}\right)\right]^2 \tag{2}$$

for singly-charged projectiles where ρ is the density of the material, X_0 is the radiation length (in g/cm^2) of the material, and $E_S = 0.0212$ GeV, so that $\delta p_{MS}/p \sim 1/\beta$. To see this effect in the simulation, I set the detector resolution to 0.1 μm and turned on the material in the FDC. The result is shown in figure 2. The curve shows the expected $1/\beta$ dependence scaled by

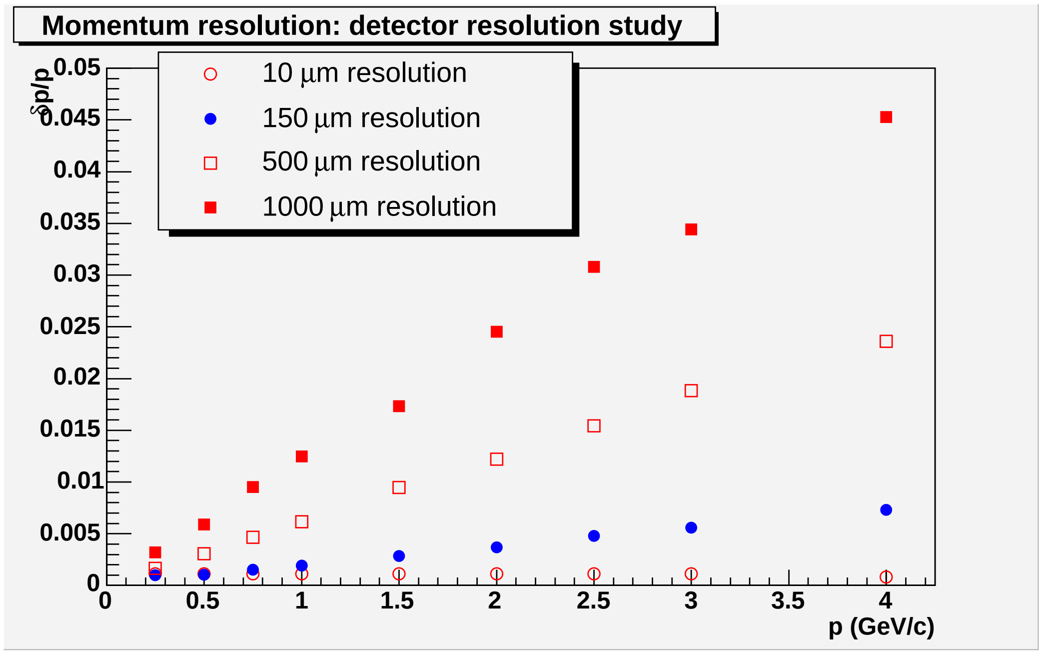

Figure 1: Momentum resolution for massless detectors for varying detector resolution.

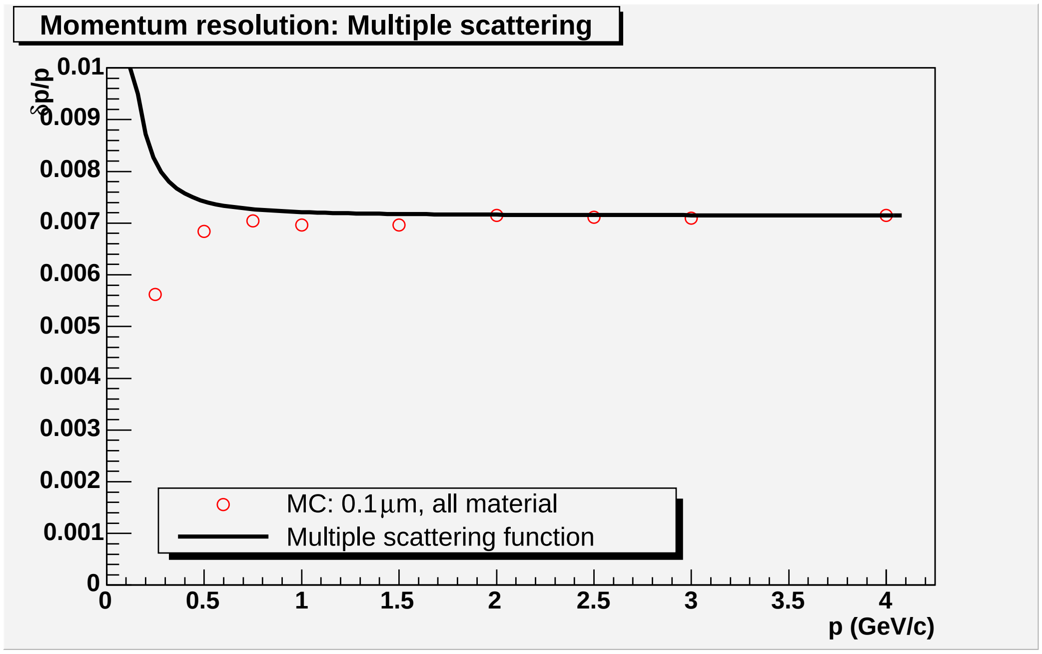

Figure 2: Momentum resolution for near-perfect-resolution massive detectors.

the value of $\delta p/p$ at the 4 GeV/c point. The trend as a function of momentum behaves as expected for high momentum but starts to deviate significantly for low momentum.

Figure 3 shows the momentum resolution when the multiple scattering and hit resolution (150 μm per detector plane) are both turned on. For comparison the results from the previous studies are superimposed. The red triangles show the expectation from simple error propagation: i.e., the sum in quadrature of the resolutions obtained with either the hit resolution or the material turned on. The blue squares show the full simulation result. The resolution is about a factor of 2 larger than expected.

Following a study originally done by Ed Brash, I looked at the effect of turning off the material for individual packages. The results of this study for the nominal 150 μm setting are shown in figure 4. The material in packages 1 and 4 has relatively little impact on the momentum resolution (compare closed red triangles to open blue squares). However, if either package 2 or package 3 is massive, the degradation of the momentum resolution is significant. Most of the apparent strange behavior when both the hit resolution

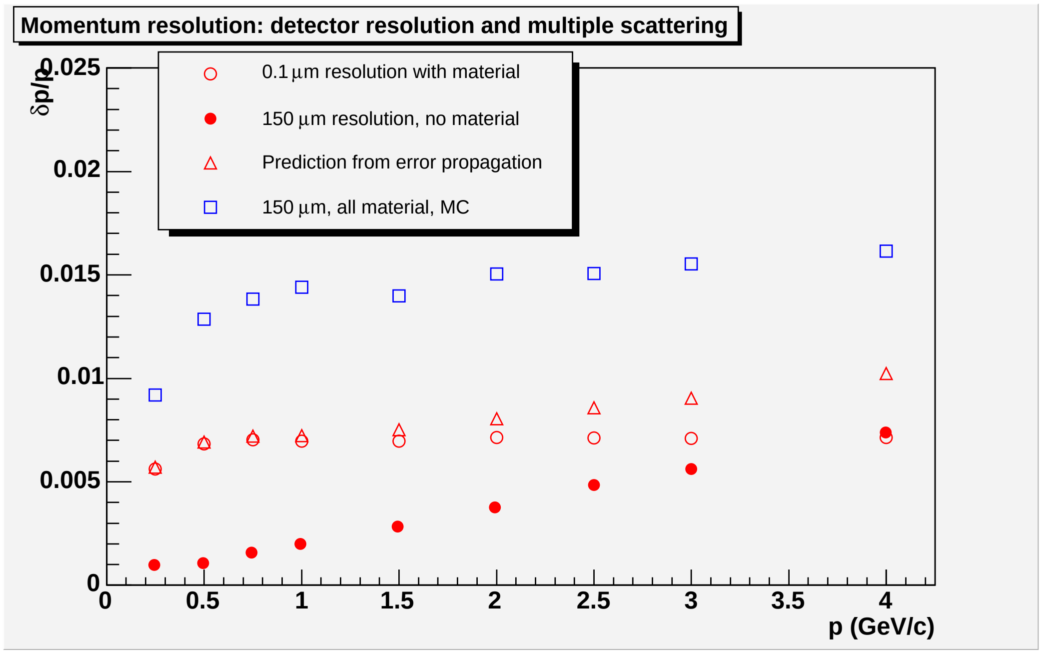

Figure 3: Momentum resolution for non-zero detector resolution and massive detectors. Comparison to other studies with either no material or near perfect resolution.

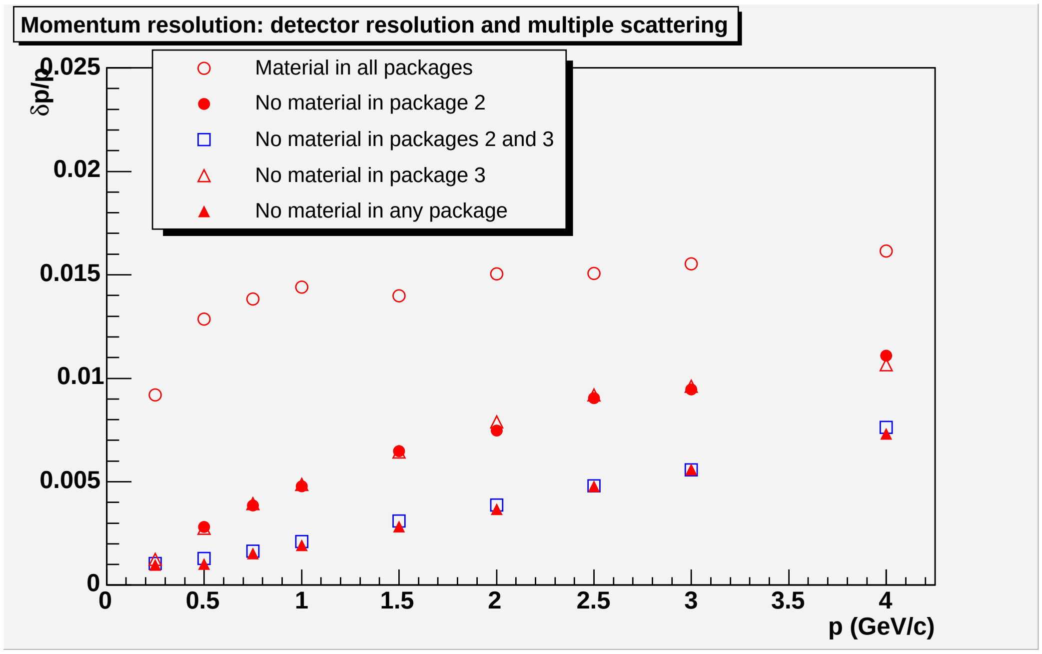

Figure 4: Effect of turning on the materials for packages 2 and 3.

and the material are turned on to reasonable values is due to the middle two packages.

References

[1] R. Fruehwirth, M. Regler, R.K. Bock, H. Grote, and D. Notz, Data Analysis Techniques for High-Energy Physics, Cambridge, U.K.: Cambridge University Press, 2000 (2nd edition), p. 308.