Chapter 2

Physics Driven Design Considerations

In Chapter 1 the physics program of the PHENIX Muon Arms was laid out. This chapter will describe what design considerations on the PHENIX Muon Arms will are implied by that program. This information has been covered previously in the CDR [1] for the the Relativistic Heavy Ion (RHI) Physics goals. The goals of the Spin Physics program do not place any greater requirements of the detector design than that there be two Muon Arms and that each are can individually fulfill the RHI goals. Consequently, this chapter will only summarize what has been stated previously in the CDR and CDR Update [2].

2.1 Muon Tracking System Design Requirements

The muon tracking system will provide a measurement of the momentum and direction of flight of muons. That information will be used to reconstruct the invariant mass of dimuon pairs originating from the vertex. As stated in Chapter 1, one of the primary measurements of the Muon Arms will be the detection of vector mesons with sufficient precision to determine their rates of production in collisions ranging from pp to $Au - Au$. That will allow one to investigate possible J/ψ suppression. That in turn places a constraint on the required mass resolution of $\sigma_m \sim 100$ MeV/c^2 at the J/ψ mass in order to separate the J/ψ from the ψ' and ψ''. Similarly, in order to separate the $\Upsilon(1S)$ from the $\Upsilon(2S + 3S)$, the mass resolution of the tracking system should be $\sigma_m \sim 200$ MeV/c^2 at the mass of the Υ. In the design of the spectrometer which is being used in PHENIX, the mass resolution at the Υ will be dominated by the momentum resolution of the spectrometer and at the mass of the J/ψ it will be dominated by the multiple scattering of muons entering the spectrometer. Finally, because of the desire to study W-decays in the Spin Physics program, one would need to have a momentum resolution which would at least allow the sign of a charged particle to be determined up to a momentum of about 50 GeV/c^2. Also, as shown in Table 3.3 of the CDR, the number of accepted dimuon events from Υ-decay will be on the order of 1000 per year. Consequently, care should be taken in the design of the tracking chambers and their supports so as to reduce the acceptance of the spectrometer as little as possible beyond that which is defined by the spectrometer magnet itself.

The above criteria place further detailed design requirements on the chambers which will be used in the spectrometer. In order to meet the momentum resolution goals, the chambers should have position resolutions of $\sigma \sim 100\mu$m in the bend-plane of the spectrometer. Furthermore, the thickness of the chamber station at the center of the spectrometer (Station 2) should be less that about 1% of a radiation lenght, while those at Staions 1 and 3 can be as larger as approximately 5%. Finally, in order to do pattern recongnition (and thus event reconstruction), the occupancy of the chambers should be less than around 10% for the highest multiplicity events which we expect (which is central $Au - Au$ collisions).

2.2 Muon Identifier Design Requirements

The Muon Identifier subsystem of the Muon Arms perform two functions. They provide a Local Level 1 (LVL-1) trigger for possible muon pairs and single high-momentum muons for $e\mu$ physics, and they are used for the final particle identification of muons in later triggers and offline analysis.

In order to carry out those goals, one will need a muon identifier design which provides an overall π/μ suppression of muons from the vertex on the order of 2.5×10^{-4}. Approximately two orders of magnitude of suppression is a consequence of the fact that particles from the vertex must pass through absorbers in front of the Muon Arms (the central magnet pole pieces) and the return yoke of the Muon Magnets prior to entering the Muon Identifier. The thickness of the steel in the Muon Identifier and a comparison of particle range to the momentum measured in the tracking chambers must provide the remaining suppression. Obviously in order to accomplish that, the Muon Identifier subsystem must have some tracking capability in order to match tracks in the identifier to those in the tracking subsystem.

A further desired goal of the Muon Identifier system is that it should have a read-out time of less than one beam crossing (~106 ns) in order to simplify the LVL-1 trigger design. Consequently, the detector elements should either have a fast gas or short drift times.