Single high $p_\perp$ μ Physics from PHENIX

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Abstract. The PHENIX muon system took its first data during the 2001-2002 run of RHIC. The experiment recorded 1.06×10^8 events in AuAu collisions and 3.0×10^8 events in pp collisions at integrated luminosities of $45\,\mu\mathrm{b}^{-1}$ and $0.15\,\mathrm{pb}^{-1}$ respectively at a cm energy of $200\,\mathrm{GeV}$. High $p_\perp$ muon production via heavy flavour decay in high energy pp collisions is sensitive to both G and ΔG nucleon structure functions. Raw PHENIX data for high $\mathrm{p}_\perp$ single muons, produced in **pp** collisions, will be presented. In addition, a description will be given of the technique for extracting the heavy flavour component of the muon $p_\perp$ spectrum.

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1. Introduction

The PHENIX experiment, shown in Figure 1, consists of 3 major detector systems: a central arm group of detectors, a North muon system and a South muon system. The muon systems can identify and precisely track muons up to $50\,GeV/c$ in momentum within an angular acceptance of $1.2 <\mid \eta \mid< 2.5$. Each muon system consists of a muon identification system, MuId, and associated set of 3 muon tracking stations, MuTr, which employ cathode strip readout technology. The brass nosecones and pole faces of the central magnet serve to filter out most of the penetrating hadronic flux. Only the South muon system was installed in time for the 2001 run. Detailed descriptions of these detectors can be found in the literature (ref). It should be noted that the data from the beam-beam counters (BBC) is also essential for high $p_\perp$ single muon analyses. Key performance patterns for single muon physics analysis are: 1) π rejection factor of 10^{-3} for $p_\perp > 5$ GeV/c, 2) $100\,\mu m$ hit resolution in the bend plane implying a J/Ψ mass resolution of $150\,MeV/c^2$, and 3) a BBC z-vertex resolution of $2\,cm$.

The quality of the tracking is sufficient such that high $p_\perp$ inclusive muon spectra can be measured with better than $10\,\%$ systematic uncertainty. At sufficiently high $p_\perp$ the spectra are dominated by muons produced from D and B meson decays. For running at $\sqrt{s} = 200\,GeV$, which is a major portion of the scheduled RHIC beam time, the contribution from W decays occurs only at the edge of the phase space. Thus a strong heavy flavour signal is expected and heavy flavour prouduction has a good sensitivity to gluon dynamics. LO pQCD predicts that heavy flavour production occurs almost exclusively from flavour excitation at RHIC energies (ref).

Heavy flavour production is relevant to the entire RHIC/PHENIX physics program. In heavy ion collisons it serves as an important baseline in gauging J/Ψ suppression effects as a function of the centrality of events and the ion species. Continuum charm production can be used to determine the thermalization time of the QGP (ref). One can distinguish between “hot” and “cold” nuclear matter effects by comparing heavy ion results with data from **pA** collisions. In addition, **pA** collisions allow the study of gluon shadowing and EMC (ref.) effects. The modification of parton distributions by the nuclear medium is an important correction for obtaining the proper estimate of binary scaling behaviour in the heavy ion data.

There is also a polarized **pp** program at RHIC, which is allotted $30\,\%$ of the total beam time. From proton-proton collisions one can of course obtain the hydrogen point for the binary scaling behaviour of heavy ion collisions, but in addition it is possible to address current fundamental issues regarding the structure of the nucleon. Unpolarized **b-quark** production is particularly sensitive to the proton’s gluon structure function. It is important to verify the NLO calculations with the RHIC data at $\sqrt{s} = 200\,GeV$ and $\sqrt{s} = 500\,GeV$ and compare them with the TEVATRON results where the $q\bar{q}$ annihilation component is much less suppressed. Indeed the recent TEVATRON measurements of high $p_\perp$ muon production indicate an excess over the NLO predictions for $b\bar{b}$ production. Some have argued this as evidence for physics beyond the standard

Table 1. Breakdown of the 2001 Muon Data

Trigger type	Number of events
Minimum bias	196×10^6
Single μ	34×10^6
di-μ	4.8×10^6

model (ref.)! Polarized **pp** collisons allow measurement of the longitudinal gluon spin structure function, $\triangle G$ of the proton. At RHIC $\triangle G$ can be studied via $b\bar{b}$, $jet + jet$ and $\gamma + jet$ production. At the moment virtually nothing is experimentally known about this quantity and results are urgently needed to address the spin crisis of the nucleon, which has arisen because of the observed violation of the Ellis-Jaffe sum rule in deep inelastic scattering experiments (ref).

2. PHENIX Muon System for the 2001 Run

The first **pp** run was primarily for commissioning RHIC and PHENIX recorded just $.15\,pb^{-1}$ of integrated luminosity. The accelerator was able to store polarized beams with $P = 20\%$, but transverse only because the spin rotator magnets had not yet been installed. Thus at this stage $\triangle G$ measurements are not possible. However, in these early polarized **pp** runs it is possible to try and separate the heavy flavour signal from the background spectrum and determine σ_{TOT} for heavy flavour. Table 1 summarizes the muon data obtained for **pp** beams. After data quality cuts that are generic to all muon analyses a z-vertex cut of $-20.0 < z - vertex < 40.0\,cm$, based on the BBC data, is applied. A cut in pseudorapidity, η, is made such that the angular acceptance is uniform within the z-vertex fiducial. After further kinematic cuts of $p_\perp > 1.5\,\mathrm{GeV/c}$ and $P > 2.5\,GeV/c$ $17\,K$ high $p_\perp$ single muon events remain for physics analysis. The raw, uncorrected $p_\perp$ spectra for these event are plotted in Figure 2.

3. Determining the Heavy Flavour Background

There are two sources of background to the heavy flavour muon decay spectrum. The principal source is $\pi^\pm, K^\pm \to \mu^\pm\nu$ decays. These can occur in the space between the nosecones, "free" decays, or in the nosecone and pole face of the central magnet. The latter component is strongly attenuated by the nuclear interaction probability of the parent mesons. The other source of background affects the high momentum part of the muon spectrum and consists of high energy hadrons penetrating all the way into the last active layer of the MuId, causing a false muon signal. The latter is referred to as punchthru.

3.1. Computing the background spectrum

The first step in computing the background spectrum to heavy flavour production is to obtain the “free” decay spectrum. For this one relies on the z-vertex distribution of the events. The total charged π and K production must be known for the other two backgrounds to be determined, but a simple decay monte carlo can be used to obtain the parent π and K spectrum from that of the “free” decay background. From this, the known response of the MuId will yield the punchthru spectrum, and using a simple simulation of the absorber and nosecone material the second decay component is obtained. One then adds these three backgound spectra together and compare with the *corrected* single muon p$_\perp$ spectrum to see if there is a significant excess.

3.2. “Free” decay spectrum

The z-vertex distribution corresponding to the p$_\perp$ spectra of Figure 2 is plotted in the top of Figure 3. Note the asymmetric z-vertex fiducial. This is necessary for computing the background properly, since in this case all particles within the angular cut impinge on the South nosecone's face. The distribution in the figure contains a z-vertex dependent and a z-vertex independent part. The former contains all and only the “free” decay background. This component is obtained by subtracting the p$_\perp$ spectrum correspondiong to region 1 from that of region 2. Multiplying this difference by a geometric scale factor based on the mathematical form of the z-vertex distribution, including an extrapolation to the face of the South nosecone at 40 cm, yields an extimate of the “free” decay background, shown in the bottom of Figure 2 together with the raw muon p$_\perp$ spectrum. The size of the “free” decay background is small enough to warrant further quantification of the entire background. However, three corrections have not been done: 1) the correction for z-dependent bunch intensity, 2) the correction for acceptance losses in South arm due to HV and electronics channels becoming disabled, and 3) a smearing correctiuon due to finite resolution. Therefore we cannot make any physics statement about a heavy flavour signal in the single muon p$_\perp$ spectrum at this point.

4. Summary

The PHENIX muon system successfully took data during the 2001 run of RHIC, and a high p$_\perp$ single muon spectrum has been obtained. Further work is required to precisely quantify the background to heavy flavour production. We hope to complete this study within the next few months before analysis of the 2003 polarized proton data begins. The 2003 run should yield at least 4 times more single muon data.

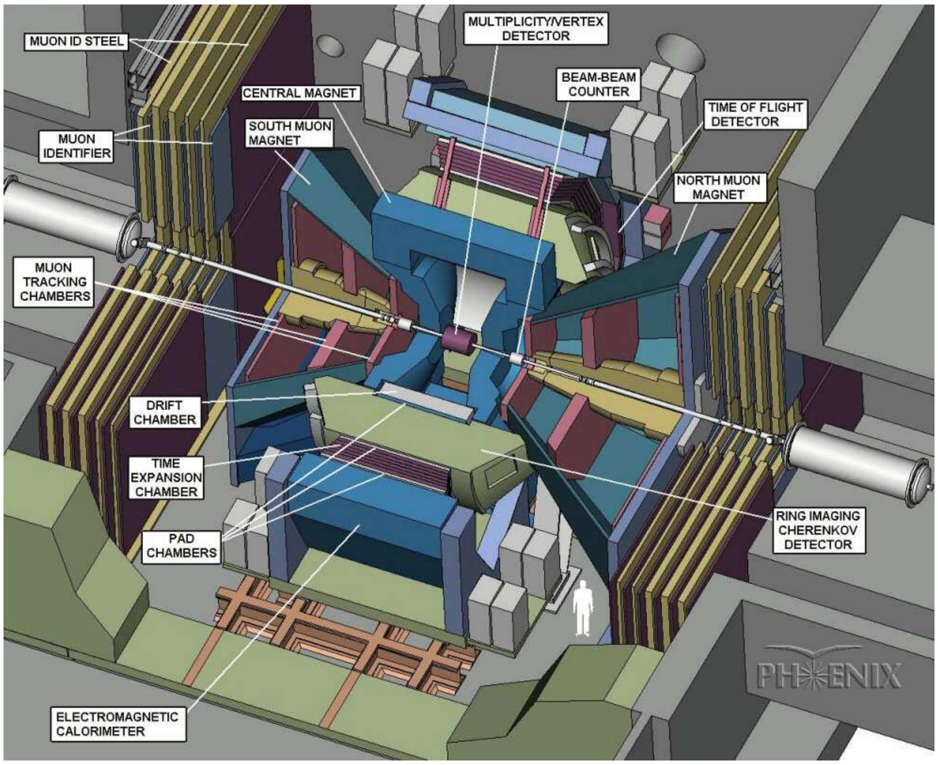

Figure 1. The PHENIX detector system.

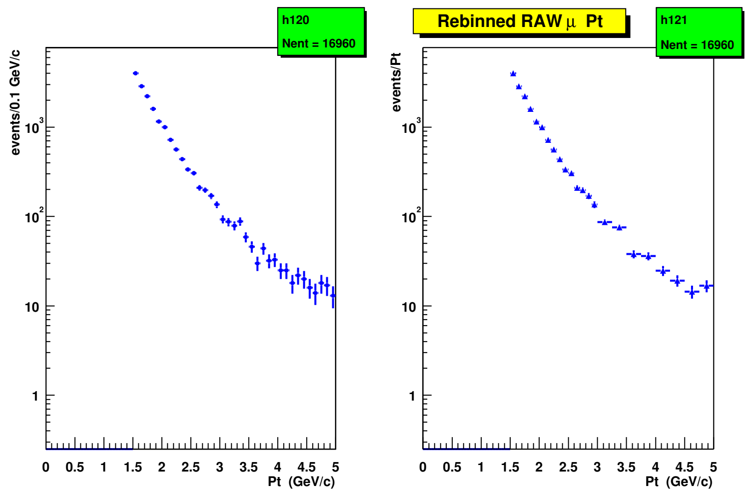

Figure 2. Raw single muon $p_\perp$ spectra from the 2001 run.

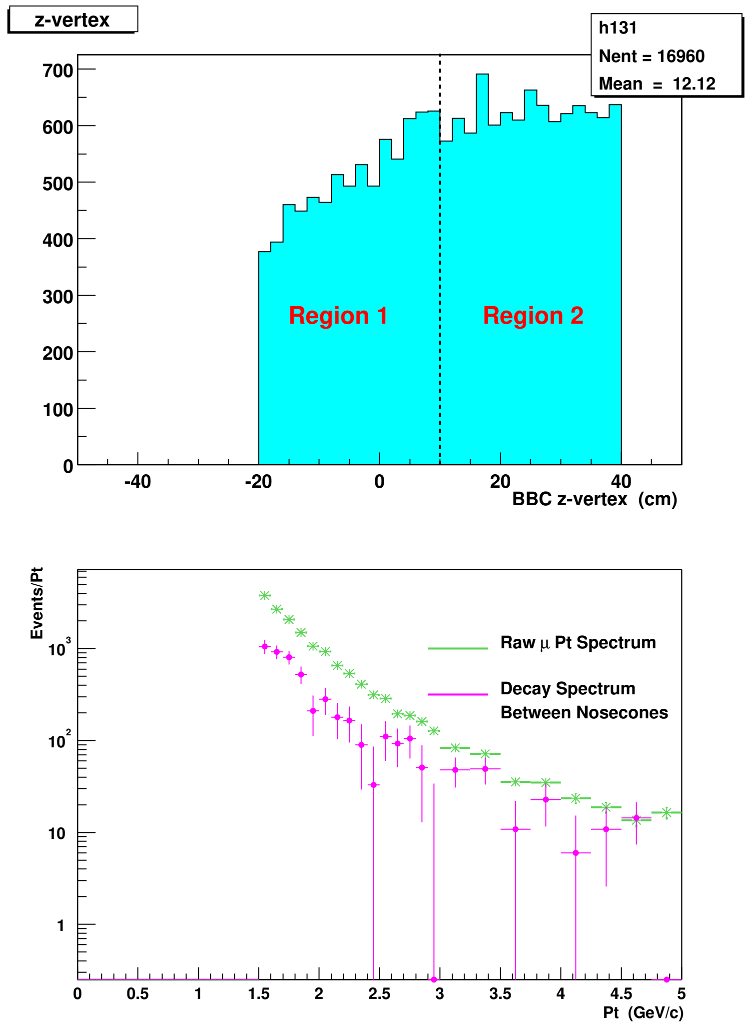

Figure 3. Top: Z-vertex distribution of single muon events corresponding to the raw $p_\perp$ spectra. Bottom: "Free" decay background spectrum estimate.