Backgrounds from Random Pions and Muons from Pion Decay at $\sqrt{s} = 200$ GeV

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1. Introduction

As we near the construction phase of both muon arms it is important to know whether the muon identification requirements of the south arm, justified as an upgrade for high-luminosity pp collisions, are different from those of the north arm. Costs of the south arm alone are now approaching the 10M$ level. If there is any chance to save enough money to instrument muon ID stations for one or two of the central magnet arms, it seems likely that some of the savings must come from the endcap muID.

2. Event Generation and Reconstruction

I have made a comparison of the event rates from Drell-Yan (DY) production to those from random coincidences in the region of pair masses greater than 2 GeV. Both kinds of events were run in PISA using the south muon arm as currently configured, 12°-35°, with a shortened muon endcap, and no Pb or neutron shield. Random events were generated with the UA1 pion generator, restored to the original UA1 parameterization (for $\sqrt{s} = 200$ GeV $p\bar{p}$ collisions). The event multiplicity was taken to be 14 charged pions/(pp event). These can be scaled to yield results for ersatz AuAu collisions at the double HIJET value of 10^4/collision. The UA1 events were run with a high threshold, 2 GeV and 4 GeV, in order to be able to throw several million events before I retire. Pat McGaughey is currently investigating background and multiplicity issues with a complementary low-threshold configuration.

3. Drell-Yan and Random Event Spectra for pp Collisions

Momentum and mass spectra were generated from PISA ntuples using a very simple output analysis. The UA1 events which reach the muon ID consist largely of muons from pion decay before the nosecone of the south arm. A potentially important background source is pions which do not shower in the nosecone, central magnet pole, or muon arm backplate. Figure 1 shows the number of muons and pions at two locations, at muID plane 3, and at muID plane 6, using the UA1 generator. The momentum is the "reconstructed" value; for the cognoscenti, that means the momentum the particle has in ntuple 1010 prior to reaching

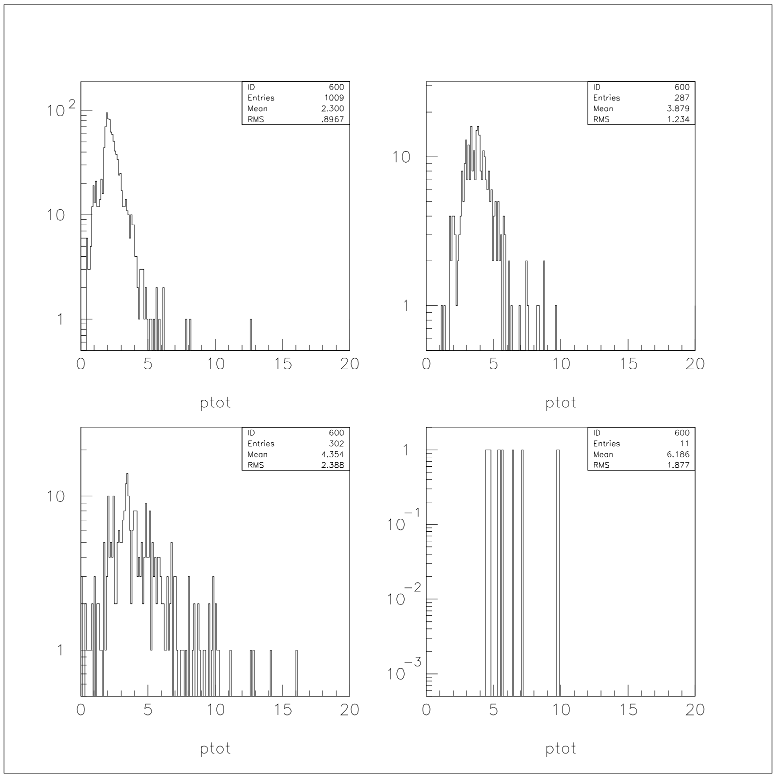

Figure 1: Muons from pion decay reaching station 3 of the muon identifier, top left; non-showering pions which create a signal in plane 3 of the muon identifier, bottom left; Muons from pion decay reaching station 6 of the muon identifier, top right; nonshowering pions which create a signal in plane 6 of the muon identifier, bottom right.

the nosecone (the momentum a perfect tracker would give). The left panels, with the muID condition of a hit in plane 3, were generated from a 2×10^6 event data set with $p_{min}=2$ GeV, the right panels, with the muID condition of a hit in plane 6, were generated from a 4×10^6 event data set with $p_{min}=4$ GeV. It is clear that decay muons are much more numerous than the non-showering pions, but that the latter extend to relatively higher momenta, as expected. This result is certainly familiar from the PHENIX CDR and from the June 1993 TAC review document.

Pair mass spectra are readily created from the singles spectra by event mixing with an assumed operating luminosity. We take this to be the enhanced luminosity of polarized pp collision (RSC proposal value), $L = 8\times10^{31}cm^{-2}sec^{-1}$. This corresponds to a pp collision rate of $r_{pp} = 3.2\times10^6/sec$. The random rate is then $F = N_iN_j\tau$, where $i,j = \pi,\mu$ and $\tau = 110ns$.

The singles rates from Fig. 1 (left panel) provide a good indication of the level one trigger rates from single pions and muons. To penetrate to muID plane 3 particles require ≈ 2 GeV. The ≈ 1300 events of Fig. 2 (left panel) translates to ≈ 2000 /sec at $L = 8\times10^{31}cm^{-2}sec^{-1}$, or $\approx 2\times10^{-4}$ per bunch crossing.

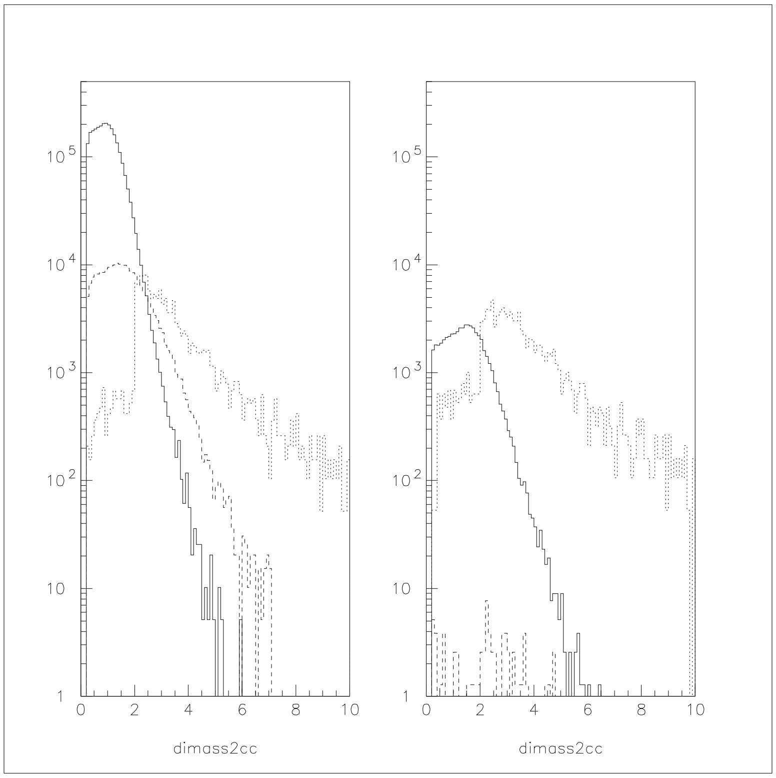

Figure 2: Mass spectra from random coincidences of muons from pion decays and nonshowering pions compared to Drell Yan events. The left frame spectra are generated with the requirement of a signal in muID plane 3, while at the right the requirement is muID plane6. The solid, dashed, and dotted lines are respectively, random muons, random pions, and DY events.

The rate of DY events is easily calculated and run through PISA with the same ntuple analysis as for the random events. Our calculations used the leading order DY equation with a K-factor of 2 and the Duke S1.1 (leading order) structure functions from the CERN PDF library. This gives excellent agreement with the newly published absolute cross sections for DY production at $\sqrt{s} = 38.7$ GeV from E772. The integrated cross section for $M_{\mu\mu} > 2(4)$ GeV at $\sqrt{s} = 200$ GeV is 6.5(1.5) nb, giving agreement with Table 3.3 of the PHENIX CDR. Figure 2 displays the results in terms of the absolute number of events recorded with an integrated luminosity of $8 \times 10^{38} cm^{-2}$ ($10^7 sec.$ of running time). For simplicity of display, the random spectrum from a muon and a pion in coincidence has been omitted.

It is clear, even at the assumed very high luminosity, that there is *no serious* competition to the DY rate from pion or decay backgrounds. Further, comparison of the the two panels of Fig. 2 shows that most of the pions have showered by the time plane 6 is reached. Thus the requirement of a hit in plane 6 is sufficient to guarantee dominance of the background by decay muons.

Figure 3 shows that there is no loss in efficiency for DY masses greater that 3.5 GeV

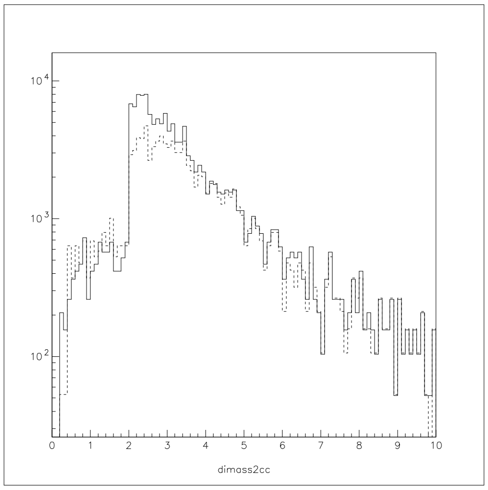

Figure 3: Comparison of DY spectra requiring signals in the 3rd (solid) and 6th (dashed) muID planes.

from the requirement that the muons penetrate to the back of the identifier. Recall that our muon identification algorithm is the simplest of all imaginable — penetration to plane x.

4. Drell-Yan and Random Event Spectra for Central AuAu Collisions

The previous results may be extended to central AuAu collisions using approximate scaling laws. For the DY process one has, $\sigma_{AA}^{DY} \propto A^2\sigma_{pp}^{DY}$. Happily the PHENIX/CDR luminosity of AuAu collisions, 2×10^{27} gives $7.7\times10^{31}cm^{-2}sec^{-1}$ for DY events, thus requiring no correction for comparison to pp. Soft particle production in central collisions scales as $\sim A^{2/3}\times\sigma_{pp}^{soft}$. While pions in the region $p > 2$ GeV may have a nuclear dependence closer to unity, we will assume 2/3 for the present case. This gives $\sigma_{AA}^{random} \propto A^{4/3} \times \sigma_{pp}^{random}$, so that the signal-back-ground gets worse by $A^{2/3}$ with respect to DY. Figure 4 shows the spectra of Fig. 2 with the random backgrounds multiplied by $197^{2/3} \approx 34$. This is a somewhat more optimistic signal to background than Fig. 3.6 of the PHENIX-CDR where the decay and DY signals are shown crossing at about 5 GeV.

5. Conclusions (preliminary — of course)

Taken at face value these calculations indicate for pp collisions that:

- There are no serious backgrounds to DY events above $M_{\mu\mu} = 4$ GeV from random pions or random muons from pion decay,[1]
- The muon identifier provides ample hadron rejection without shower identification,
- Fewer that 6 planes of depth segmentation could be tolerated in the south arm muon ID system.

[1] Backgrounds from heavy-quark decays will, of course, be present – see PHENIX/CDR.

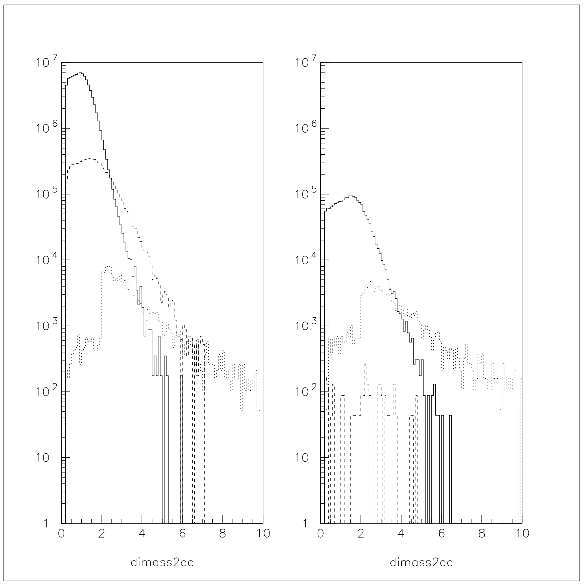

Figure 4: Same as Fig. 2 but with random coincidences scaled for central AuAu collisions.

Before the above statements are taken as gospel, high threshold PISA runs must be combine with the typical multiplicity distributions from very low threshold runs. Additionally, one needs to look into the background from beam gas interactions. My guess is that these further refinements won't change the outcome much. They will, however, allow one to define the required channel count in the muID for the south arm.

I would like to add a few more items to the list which require further scrutiny for the south arm muID system. These are:

- Given the vastly simpler pattern recognition requirements for pp compared to central AuAu collisions (multiplicities down by $\sim A^{4/3}$), does one need pad readout?
- Could the $r - \phi$ road finding of the PHENIX/CDR-Update be replaced with an x-y scheme?
- How much money is to be saved by designing the muID for pp collisions. How well would it work for central AuAu?

These are some of the issues which need to be on the table if we are to make intelligent use of the funds for the spin upgrade.