Updated upVPD efficiency simulations for the beam energy scan

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1 Introduction & Geometry

At the BES workshop on December 17-18, 2008 at Brookhaven, I presented the results from some simple "geometrical" simulations of the upVPD efficiency in the beam energy scan [1]. UrQMD 2.3 events were generated at 5.0, 7.6, 9.2, 12.3, 17.3, 30, 45, 62, and 200 GeV and run through a GEANT3 code. The detector geometry in this code included the exact positions of the upVPD, TOF MRPC, and BBC detectors. These simulations indicated that the efficiency by which the upVPD registers an east+west coincidence in the most central collisions at the lowest beam energies was very low. Also, there is a local minimum in the upVPD efficiency that develops for $\sqrt{s_{\rm NN}} \gtrsim 30$ GeV resulting from the local minimum in the particle production rates between the spectator region and the high-η tail of the participant region depending on the beam energy (the upVPD acceptance exists in the region $4.24 \lesssim |\eta| \lesssim 5.1$). The previous simulations results from Ref. [1] are shown in Fig. 1.

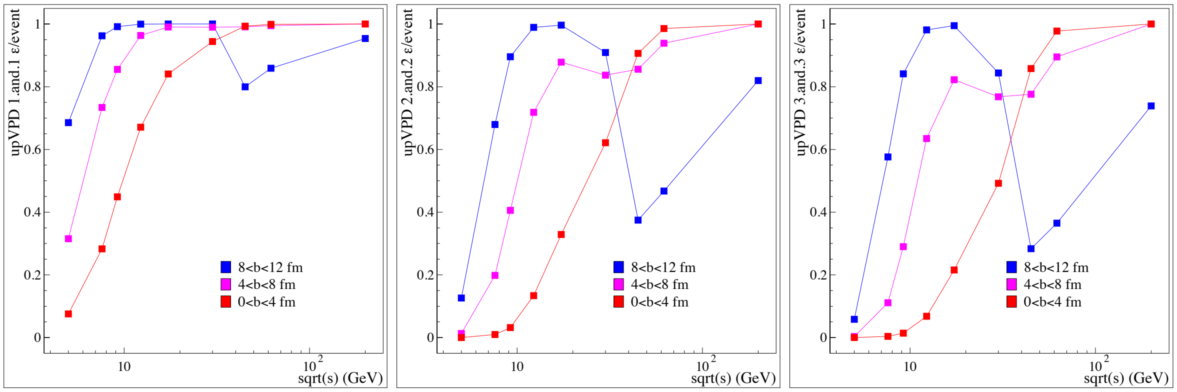

Figure 1: The results from the previous simulations (without the beam pipe or pipe support structures) that were shown at the December 2008 BES workshop. See Ref. [1] and the text below for additional details.

As the number of primary tracks in the TPC (and hitting TOF) are very large (>100) for the lowest energy but most central collisions, the plan is to develop a modified version of the TOF calibration maker to address the low-$\sqrt{s_{\rm NN}}$ efficiency issue. This code will use the plentiful stop-side information to remove the need to have a start-time in the same event. The algorithm is straightforward and well-known to the TOF community.

However, there remains an interest in the use of the upVPD as a L0 trigger detector. One question that came up in the discussion of the previous simulations of Fig. 1 concerned the possible increase in the upVPD coincidence efficiency resulting from the production and/or conversion of particles in the beam pipe and/or the pipe-support structures near the acceptance of the upVPD. Such structures were not included in the previous simulations of Ref. [1] and in principle could increase the upVPD efficiency per event.

The extension of the previous simulations to include these additional structures is described here. Photographs and the STARSIM definition of these structures can be seen in Ref. [2]. These simulation were run in a stand-alone GEANT3 code, and the pipe and pipe support materials defined in this code are shown in Fig. 2. These views can be compared to the middle-right frames of figures 4 and 5 in Ref. [2].

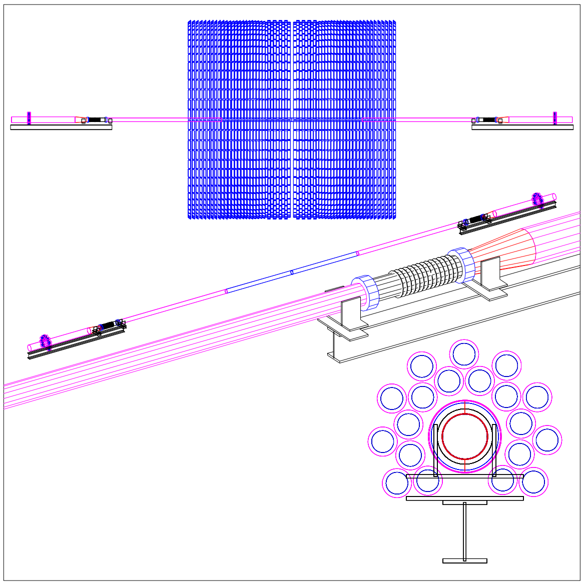

Figure 2: Various views of the detectors and the pipe and pipe support structures used in the updated simulations.

2 Simulation

The events used were obtained from UrQMD version 2.3 using default parameters. The $\sqrt{s_{NN}}$ values used were the same as the previous simulations: 5.0, 7.6, 9.2, 12.3, 17.3, 30, 45, 62, and 200 GeV. The number of events UrQMD events generated was about 100k at the lowest beam energies, and ∼10k at the highest beam energies. About 20% of the events at each energy were then run through the GEANT3 code.

Weak and EM decays were turned off in the UrQMD even generation but were turned on in the GEANT simulations. All electromagnetic and hadronic physics processes were enabled for the pipe, pipe-support, and detector volumes.

At the end of every event, the number of lit upVPD detectors on each side are calculated. The key plots made (*cf.* Fig. 1 and below) depict the probability for “1.and.1”, “2.and.2”, and “3.and.3” east.and.west coincidences in the same event. The timing resolution improves like $1/\sqrt{\mathrm{N}_{\mathrm{side}}}$. Another case of importance, but not simulated yet, is “3.or.3”. The slewing and offset corrections for a specific beam energy are done on each side of STAR separately and require that at least three upVPD detectors are lit.[1]

These simulations do not look at the total TOF of the particles producing hits. It is conceivable that some of the lit detectors in these simulations are from particles (secondaries produced in interactions in the pipe or pipe support materials) that are not “prompt.” While increasing the apparent upVPD efficiency per event, such particles clearly do not help us in reality. The study of the TOF distributions for upVPD hits with the extended geometry, as well as the “3.or.3” simulations, are items on the to-do list.

No consideration for the coalescence of very forward nucleons into fragments was made here, although some results on this are available in Ref. [1]. The simulated deuteron formation rates in the spectator regions shown in Ref. [1] is indeed significant. It is not obvious, though, that one can realistically simulate coalescence in general using the same approach as used there for (anti)deuterons. It is, however, also difficult for me to imagine why the consideration of spectator coalescence can significantly modify the present simulations. The upVPD acceptance is so

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[1] With only ∼3k events in the Run-8 9.2 GeV run, there was not a sufficient number of events to slew/offset-calibrate the upVPD in these data.

forward that the spectator nucleons travel at very close to the beam rapidity. The trajectory modification from to the momentum kick from the few-MeV photons released in spectator nucleon coalescence would seem to be a small effect, even at the lowest BES beam energies. Also, generically, fragments with a total charge, Z, deposit an energy in the upVPD scintillators that is a factor of Z larger than the same number of independent protons. I can put the consideration of spectator fragment coalescence on the to-do list if anyone disagrees with my intuition here, but in addition I don't know how realistically GEANT3 can simulate the interactions of light nuclei in the pipe structures anyway. Any comments on this particular issue would be appreciated of course.

3 Results

The results when including the pipe and pipe-support materials are shown in Fig. 3. The left, middle, and right frames show the efficiency per event for "1.and.1", "2.and.2", and "3.and.3" coincidences, respectively, versus $\sqrt{s_{NN}}$ in GeV. The open points are without the pipe and pipe-support materials, while the closed points include these structures.

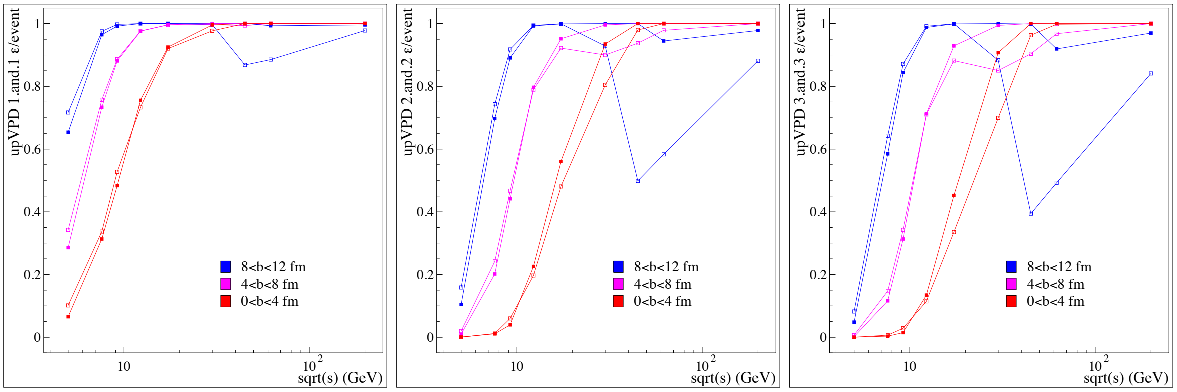

Figure 3: The results from the updated simulations including the beam pipe and pipe support structures.

There are two trends suggested by the comparison of the open and closed points in Fig. 3.

- $\sqrt{s_{NN}} \lesssim$ **12.3 GeV** – The upVPD coincidence efficiency for all three coincidence levels and all centralities is essentially unaffected by the existence of the pipe and pipe-support structures. In fact, if anything, the upVPD coincidence efficiencies *decrease* by $\sim$5% percent when including the pipe structures.
- $\sqrt{s_{NN}} \gtrsim$ **12.3 GeV** – The upVPD coincidence efficiencies increase significantly with the inclusion of the pipe structures. The "hole" seen in the previous simulations near $\sqrt{s_{NN}}$ $\sim$ 50 GeV is effectively filled in by the pipe structures.

The upshot is that the upVPD coincidence efficiency for the most central collisions at the lowest BES beam energies remains low, underscoring the need for the modified TOF calibration maker discussed in the first section.

The use of the upVPD as a "min. bias" trigger detector would result in a string bias toward the most peripheral collisions. The triggering combination of the upVPD and a mid-rapidity detector, such as TOF, would seem to be effective in filling this hole in the efficiency. In the Run-8 9.2 GeV data, there were >50 tracks at mid-rapidity in mid-central collisions, so a TOF L0 threshold of >10 or should be both efficient and well-above TOF's false trigger rate from MRPC noise hits. A quick investigation of the cause of both of these trends is discussed in the following section.

4 Discussion

To investigate the trends suggested by Fig. 3, the species of primary particles leading to upVPD hits was explored as a function of the centrality and beam energy in the same UrQMD events. The results with and without the pipe structures are shown in the left and right frames of Fig. 4, respectively. The mean number of primary particles per event that result in a hit in the upVPD (east+west) are plotted versus $\sqrt{s_{NN}}$ for the different particle species listed in the legend on the lower right. In each group of three frames, the upper left plot is for impact parameters 8<b<12 fm, the upper right plot is for 4<b<8 fm, while the lower left plot is for 0<b<4 fm.

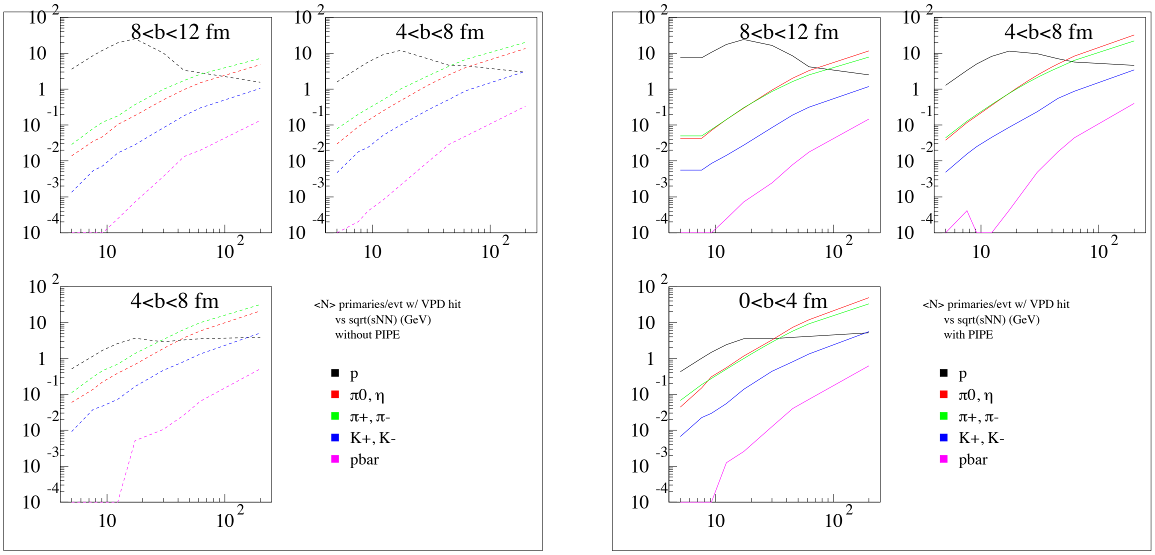

Figure 4: The mean number of primary particles per event that result in a hit in the upVPD (east+west) versus $\sqrt{s_{NN}}$ in GeV without (left three frames) and with (right three frames) the pipe structures.

According to this figure, the particles resulting in upVPD hits for $\sqrt{s_{NN}} \lesssim 12.3$ GeV are predominantly (spectator) protons. This is the case for all three centrality windows.

The "hole" near ∼50 GeV seen in Fig. 1 (and the open points of Fig. 3) is apparent in the three left frames (no pipe structures defined). It is caused by the fact that the spectator protons become too forward to be seen in the upVPD as the beam energy increases, while the hits from produced pions from the participant zone grow in importance.

Shown in Figure 5 is the comparison of the without pipe (dashed) and with pipe (solid) simulations for protons (black), π^0 and η (red), and charged π (green). From the black and green curves (protons and charged pions, respectively) and the lower beam energies, the existence of the pipe structures slightly reduces the average number of primary particles per event that lead to upVPD hits. This is assumed to result from hadronic interactions of the primary protons and charged pions in the pipe structures which remove them from the upVPD acceptance.

The dramatic increase in the upVPD coincidence efficiency for $\sqrt{s_{NN}} \gtrsim 12.3$ GeV when including the pipe structures appears to come from two sources.

- The spectator primary protons produce more upVPD hits with the pipe (solid) compared to without (dashed), again presumably due to hadronic interactions in the pipe structures.

- The number of upVPD hits from primary π^0 and η particles (red lines) increases significantly. This is assumed to result from additional conversions of the photons from these particles in the pipe structures above than that occurring in just the $1.1X_0$ Pb converter layers in the upVPD. This dominance of π^0 daughters to the upVPD hits, as converted

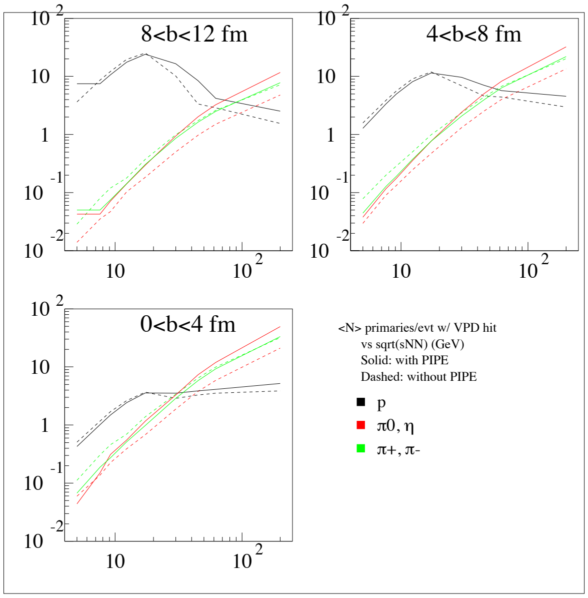

Figure 5: The mean number of primary particles per event that result in a hit in the upVPD (east+west) versus $\sqrt{s_{\rm NN}}$ in GeV from Fig. 4 but only for protons (black), π^0 and η (red), and charged π (green). The dashed lines lines are without the pipe structures, and the solid lines include the pipe structures.

in the upVPD Pb layers or the pipe support materials, was also seen in the very old simulations described in Ref. [3].

5 Summary

The simulations described in Ref. [1] were extended to include the pipe and pipe support structures shown in Ref. [2]. The following results were obtained:

- The upVPD coincidence efficiencies for $\sqrt{s_{\rm NN}} \lesssim 12.3$ GeV are essentially unchanged and still "low".
- The upVPD coincidence efficiencies for $\sqrt{s_{\rm NN}} \gtrsim 12.3$ GeV become nearly 100% due to the increased contributions from particles from the participant zone and the secondary production in hadronic interactions and the conversions of π^0 photons in the pipe structures.

A L0 trigger based on the upVPD alone will thus be heavily biased towards peripheral collisions for the lowest beam energies. A trigger based on a mid-rapidity detector would appear to be more appropriate for the most central collisions at the lowest beam energies. The planned modifications to the TOF calibration maker to implement "startless" calibrations are still required and will be crucial for TOF PID at the lowest $\sqrt{s_{\rm NN}}$ end of the BES.

References

[1] W.J. Llope, `http://wjllope.rice.edu/~WJLlope/−mypublications/LLOPE_BEStalk.pdf`

[2] W.J. Llope, `http://wjllope.rice.edu/~TOF/upVPD/ForwardSimulations/ForwardSimulations.htm`

[3] W.J. Llope, John Mitchell, and F. Geurts, "pVPD Simulations", Star Note 0416, March 6, 2000. `http://wjllope.rice.edu/~WJLlope/−myPublications/SN0416.pdf`