Generation SM particles that subsequently decay into millicharged particles

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1 Introduction

In this document we discuss the generation of SM particles that in a subsequent step will be made to decay into milliCharged particles. The key features of our approach are the following

- Use theory or some MC to generate P_T distributions for SM particles saved as histograms in ROOT files (Drell Yan is an exception, see discussion in Section 2.
- Sample the ROOT histograms to generate SM particles of a given P_T
- Pick azimuthal angles ϕ and pseudorapity η in a limited range, matched to the acceptance of milliqan.
- Decay the SM particles into milliCharged particles (this step is described in a separate note).
- When possible, keep track of theoretical uncertainties.
- In general it is sufficient to generate SM particles at low and moderate P_T since that is where the cross-section is largest.

2 Drell Yan

Golf needs to fix his bugs.

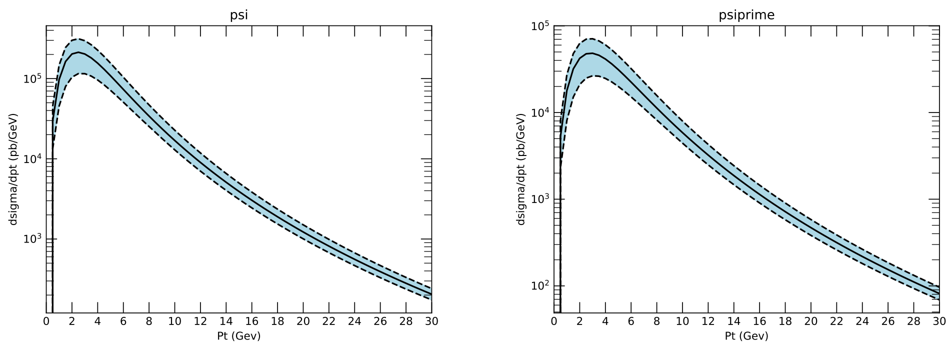

Figure 1: Transverse momentum distributions of J/ψ (left) and ψ' from bottom quark decays. Note: this is from a single b, multiply by two to include $\bar{b}$.

3 J/ψ and ψ' from b-decays

We use the tool available in
http://www.lpthe.jussieu.fr/ cacciari/fonll/fonllform.html
to generate histograms of P_T distributions (cross-sections) for charmonium from bottom decays, including theoretical uncertainties[1, 2]. See Figure 1

4 Direct onia production

For charmonium I expect that the theorists I have been communicating with will give us distributions down to zero P_T, so we can do the same thing that we did for charmonium. However for bottmium they claim that they cannot go below 15 GeV, so we need to figure out what to do.

5 π^0, η, η', ϕ, ρ, and ω

We generate these from Pythia. The measurement of the $\pi^{\pm}$ P_T spectrum from CMS[3] is in good agreement with Pythia 8 Minimum Bias at low momentum. We use this MC for all mesons. We do not attempt to use QCD $2 \to 2$ at very low P_T since the process is infrared divergent. Note that Pythia `SoftQcd:nonDiffractive` includes all hard QCD processes[4] so in principle this is all that is needed. However, one runs out of statistics at high

P_T. So at high P_T we stitch together the minimum bias distributions with distributions obtained from QCD $2 \to 2$ at moderate P_T.

Eventually we will generate Pythia events in "standalone" mode to be independent of CMS software. For now we use existing CMS Monte Carlos for Minimum Bias and for QCD. The CMS QCD samples are "P_T-binned", (15-30 GeV, 30-50 GeV, and 50-80 GeV). The Minimum Bias cross-section is taken to be 78.4 mb. Then the stitching procedure is the following:

- The QCD samples are first normalized to their LO cross-sections.
- next, we estimate a "qcd-minbias scale factor" by integrating over some region where the ratio is roughly flat
- the QCD samples are renormalized by this scale factor
- the samples are then stitched together by visually picking the P_t where the curves cross each other.

The resulting P_T curves are shown in Figure 2. It is not clear what kind of uncertainties we should assign. Let's first see how important these are at the end of the day before going crazy.

References

[1] M. Cacciari, S. Frixione, N. Houdeau, M. L. Mangano, P. Nason and G. Ridolfi, JHEP **1210** (2012) 137 [arXiv:1205.6344 [hep-ph]].

[2] M. Cacciari, M. L. Mangano and P. Nason, arXiv:1507.06197 [hep-ph].

[3] A. M. Sirunyan *et al.* [CMS Collaboration], Phys. Rev. D **96**, no. 11, 112003 (2017) doi:10.1103/PhysRevD.96.112003 [arXiv:1706.10194 [hep-ex]].

[4] http://home.thep.lu.se/$\tilde{t}$orbjorn/pythia81php/Welcome.php. Click on `QCD` on th eleft panel.

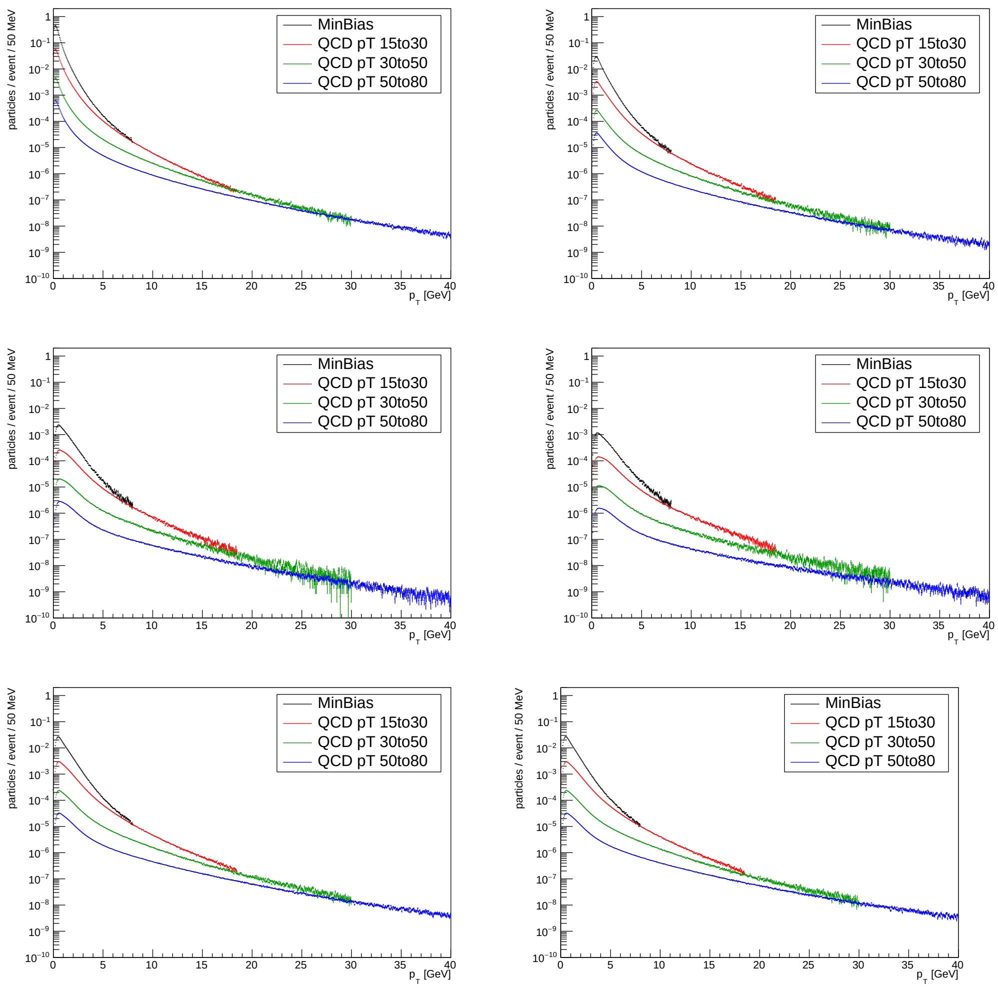

Figure 2: Transverse momentum distributions of π^0, η, η', ϕ, ρ, and ω, top left to bottom right, for $|\eta| < 1$.