Problem 4: Average transverse momentum I

Calculate the average transverse momentum at rapidity $y = 0$ of particles with an invariant cross section

$$E \left.\frac{\mathrm{d}^3\sigma}{\mathrm{d}^3p}\right|_{y=0} = A \exp\left(-\frac{p_T}{T}\right) .$$

Problem 5: Average transverse momentum II

The jupyter notebook fit_jpsi_pt_spectrum_homework.ipynb contains the Lorentz-invariant J/ψ yield as a function of transverse momentum. Complete the notebook by fitting the yield $\mathrm{d}n_{J/\psi}/\mathrm{d}p_T$ with

$$\frac{\mathrm{d}n_{J/\psi}}{\mathrm{d}p_T} = a \frac{p_T}{\left(1 + \left(\frac{p_T}{p_0}\right)^2\right)^n}$$

and by calculating the $\langle p_T \rangle$. (Hint: Look at the example fit_phi_pt_spectrum.ipynb)

Problem 6: Bjorken energy density in *pp* collisions

Estimate the energy density at $\tau = 1\,\mathrm{fm}/c$ in inelastic pp collisions at $\sqrt{s} = 7\,\mathrm{GeV}$ assuming $\langle m_T \rangle \approx 0.65\,\mathrm{GeV}$ for charged hadrons and $\mathrm{d}N_{\mathrm{ch}}/\mathrm{d}y \approx 4.5$. Consider head-on collisions for simplicity and a proton radius of $r_{\mathrm{p}} = 0.8\,\mathrm{fm}$. Would the energy density be sufficient for the creation of a QGP?

Problem 7: N_{coll} and heavy-quark yields in central Pb–Pb collisions

The nuclear overlap function for Pb–Pb collisions for impact parameters $b < 10\,\mathrm{fm}$ can be well approximated by the Gaussian

$$T_{\mathrm{AB}}(b) = A \exp\left(-\frac{b^2}{2s^2}\right) \tag{1}$$

with $A \approx 305\,\mathrm{fm}^{-2}$ and $s = 4.85\,\mathrm{fm}$.

a) Calculate the average number of nucleon-nucleon collisions for the impact parameter interval $0 \leq b \leq 5\,\mathrm{fm}$ at $\sqrt{s_{\mathrm{NN}}} = 2760\,\mathrm{GeV}$ ($\sigma_{\mathrm{NN}}^{\mathrm{inel}} = 64\,\mathrm{mb}$).

b) Calculate the average number of $c\bar{c}$ and $b\bar{b}$ quark pairs per unit rapidity at midrapidity for this impact parameter interval assuming $\mathrm{d}\sigma_{\mathrm{c\bar{c}}}/\mathrm{d}y = 200\,\mu\mathrm{b}$ and $\mathrm{d}\sigma_{\mathrm{b\bar{b}}}/\mathrm{d}y = 20\,\mu\mathrm{b}$.

Problem 8: Glauber Monte Carlo

Download the macro glauber_mc.C from the lecture website and run it under root. Modify it to answer the following questions:

a) What is the average number of nucleon-nucleon collisions in inelastic p-Pb collisions?

b) What is the average number of nucleon-nucleon collisions in p-Pb collisions with impact parameter $b = 0$?

c) What is the average number of nucleon-nucleon collisions in Pb-Pb collisions with impact parameter $b = 0$?

Use an inelastic nucleon-nucleon cross-section of $\sigma_{\mathrm{NN}}^{\mathrm{inel}} = 64\,\mathrm{mb}$.