Practice Questions for Particle Physics Phenomenology

1. What are the main physics aspects/mechanisms that act to produce hadronic final state in pp collisions at the LHC? Which of those were also relevant at LEP, i.e. $e^+e^- \to \gamma^*/Z^0 \to q\bar{q}$?
2. Assume a "nice" (invertible primitive) function $f(x) \geq 0$, $x_{\mathrm{min}} < x < x_{\mathrm{max}}$. How would you draw a random x from it with maximal efficiency?
3. Conventional integration, e.g. Simpson's method, converges faster than Monte Carlo methods, so why still use the latter?
4. How can importance sampling and multichannel improve on crude Monte Carlo integration?
5. Assume you have a "radioactive decay" with a time-dependent decay rate $f(t)$. How would you correctly draw a radom time according to it?
6. What is the basic idea of the veto algorithm? Sketch how to prove that it works.
7. What is the winner-takes-it-all method, and when can it be useful?
8. What imperfections could a (pseudo)random number generator have?
9. What is the expression for n-body phase space? Given the proper matrix elements, what are the expressions for cross sections and decay widths?
10. Outline how n-body phase space can be split into a series of two-body ones.
11. Give the definitions of rapidity and pseudorapidity. What is the relation between them? What are the relative merits of the two measures?
12. Why plot single-particle production in terms of $\mathrm{d}\sigma/\mathrm{d}y\,\mathrm{d}p_\perp^2$?
13. Give the expressions for and describe the meaning of the Mandelstam variables in $2 \to 2$ processes. What is the physics difference between t and u?
14. What is the relationship betweeen the parton-level cross section and its hadronic counterpart in a hadron–hadron collision?
15. Where are factorization and renormalization scales used, and why do they have to be introduced?
16. Given a leading-order graph, what kind of further graphs should one expect at next-to-leading order? How do loop and legs contribute to higher orders?
17. What does it mean that higher-order calculations (seem to) converge?
18. What is the underlying reason that a hard process, e.g. the kicking of a quark into a new direction of motion, gives rise to radiation?
19. What is meant by the "equivalent photon approximation"?

20. What does the terminology of spacelike and timelike showers refer to?
21. What kinds of singularities exist in a shower, and what kind of topologies do they correspond to?
22. Why is an ordering variable introduced for showers? How can it be viewed? Give examples of variables used to this end.
23. Write down the evolution equations for final-state parton showers. Which splitting kernels exist and what do the look like (to leading order)?
24. What is the relationship between matrix elements and parton showers? Illustrate e.g. for $e^+e^- \to \gamma^*/Z^0 \to q\bar{q}g$.
25. What is a Sudakov form factor in the shower? How is it derived and what function does it fulfill?
26. What is (colour) coherence in a shower?
27. What is the eikonal approximation and how does it relate to a dipole picture?
28. How does a dipole description of (final-state) parton shower work, and why is it especially convenient in QCD (relative to QED)?
29. Write down the DGLAP evolution equation for parton distribution functions.
30. What does it mean that DGLAP is a gain–loss equation? How is this reflected in the + prescription for splitting kernels?
31. How are moments of PDF defined, and what function can they serve?
32. What is the qualitative x shape of different parton distributions at low and high Q^2.?
33. At what (kinds of) experiments are PDFs measured? Which combinations of partons are probed in some of the more common processes?
34. How are PDF fits carried out (in broad terms)? What are the characteristics of the Hessian and pseudodata methods?
35. Why is backwards evolution used to describe initial-state radiation? How do the ISR emission probability distribution differ from the final-state one?
36. Why are initial-state showers more complicated to describe than final-state ones?
37. What is resummation?
38. In which regions of phase space could parton showers offer a better description than matrix elements? In which worse?
39. What does matching and merging mean?
40. What is the relationship between the the shower Sudakov and the matrix element virtual corrections? How do we avoid doublecounting?

41. What is the qualitative difference between the MC@NLO and POWHEG methods for NLO corrections?
42. What is the point of scale reweighting?
43. What components make up the total cross section? How do they populate rapidity space?
44. What is the origin of multiparton interactions?
45. How does the perturbative QCD spectrum behave at low $p_\perp$ scales? Why should that behaviour not be trusted?
46. How are MPI's observed, directly and indirectly?
47. What is the jet pedestal effect? How could it be understood?
48. Why is a $p_\perp$-ordered description of MPI advantageous?
49. What do we mean by linear confinement? Approximately how large is the string tension κ?
50. Describe the motion of a simple $q\overline{q}$ "yo-yo" mode. How is it affected by longitudinal boosts?
51. How does the string tension change during longitudinal and transverse boosts?
52. Describe the Artru-Mennessier model. How does it differ from the Lund model?
53. Describe the longitudinal structure of the Lund model.
54. What is the typical invariant time of the string breakup process?
55. How does the tunneling breakup process operate? What consequences does it have, e.g. for the flavour composition?
56. How are $q\overline{q}g$ event described in the string model? How is the $q\overline{q}g$ string effect observed experimentally?
57. Describe the basic concepts of cluster fragmentation.
58. How and why do quark and gluons jets have a different shape on the average?
59. How and why do heavy-quark jets (here charm and bottom) differ from ordinary-quark ones?
60. What are sphericity and thrust? In what way are they different from jet algorithms?
61. Why do scattered partons give rise to jets? Why is it nontrivial to correlate a parton with a jet?
62. What is meant by collinear and infrared safety of jet algorithms?

63. Describe the $k_\perp$, anti-$k_\perp$ and Cambridge/Aachen jet algorithms. Which are the main parameters?

64. Explain the tradeoff aspects between a small and a large R value.

65. Why can jet substructure be of interest?

66. What is the approximate size of total cross sections at the LHC, and what is the relative importance of the main components?

67. What is the Froissart-Martin bound?

68. What is the relation between elastic and total cross sections?

69. Why does the $\mathrm{d}\sigma_{\mathrm{el}}/\mathrm{d}t \approx e^{Bt}$ shape break down at small $|t|$?

70. What is the Pomeron and Reggeon, from a formal and a practical point of view?

71. What is the role of cut and uncut Pomerons?

72. What event topologies are made available by the triple Pomeron vertex, and how?

73. What is the physics of the Ingelman-Schlein model?

74. What is meant by the Quark–Gluon Plasma?

75. At approximately what themperature is the QGP phase transition expected to occur?

76. Why is quarkonium production rates of interest in QGP studies?

77. What is jet quenching, and how can it be visualized?

78. What does flow imply for $\pi/K/p$ production?

79. Why is QGP called a perfect fluid?

80. What is meant by centrality?

81. What is meant by the Glauber model?

82. How is physics viewed in the core-corona model(s).

83. What is meant by custodial symmetry in the SM Higgs sector?

84. Why is a Higgs mass around 125 GeV convenient for the SM?

85. What is the seesaw mechanism for neutrino masses?

86. What are the basic concepts ot Technicolor?