Dubna HISS-School
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E1 *Conserved quantities*

Explain why those decays are possible or not:

(1) $n \rightarrow p + \pi^-$
(2) $n \rightarrow p + e^+ + \nu_e$
(3) $N^*(1520) \rightarrow p + \rho^0$
(4) $n \rightarrow p + e^- + \nu_e$
(5) $p \rightarrow \pi^+ + \pi^0$
(6) $\Lambda \rightarrow p + \pi^-$
(7) $\gamma \rightarrow \pi^0 + \pi^0$, $E_\gamma > 2m_\pi$
(8) $\Delta(1600) \rightarrow n + \pi^+ + \pi^+$

E2 *Proton-proton- and electron-proton collisions*

A liquid Hydrogen target is bombarded with protons as well as with electrons (pp- and e^-p-collisions).
a) Particle 2 with mass m_2 is at rest (fixed target), show that the center-of-mass energy $E_{cm} = \sqrt{(P_1 + P_2)^2}$ (four-momenta P_1 and P_2 of particle 1 and 2) forms to

$$E_{cm} = \sqrt{m_1^2 + m_2^2 + 2E_{1lab}m_2}\ ,\ c = 1$$

b) Compute the energy ε which is available for particle production in pp- as well as e^-p-collisions at kinetic energies of the projectile of T = 0.1 , 0.5 , 1.0 , 2.0 , 5.0, 10 , 100 GeV und 7 TeV (be aware: $T \neq E_{lab}$).

E3 *Particle production*

Compute the threshold energy (kinetic) and momentum in proton-proton collisions for production of (1.) neutral Pions π^0 , (2.) pos. charged Kaons K^+ , (3.) neg. charged Kaons K^- and (4.) vector meson ϕ in
a) a collider experiment and
b) a fixed-target experiment.
c) Is it possible that the HADES experiment produces ϕ mesons in Au+Au collisions at 1.23AGeV kinetic projectile energy?

E4 *Thermal model*

The thermal distribution is given by (for a classical distribution):

$$\Rightarrow \frac{dN}{d^3p d^3x} = \frac{g}{(2\pi)^3} e^{-(E-\mu)/T}$$

T=temperature, μ=chem. potential, E=Energy of the particle

1) Calculate the transverse mass, transverse momentum and rapidity distribution of particle from a thermal fireball

2) Calculate the total number of pions and protons emitted from a thermal fireball for a given chemical potential μ_B and temperature T.

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Discussion 1

(a) What is different between QCD, QED and Special and General Relativity?
(b) Which of theories are used in the Standard Model ?
(c) Can quarks interact with gluons? Can photons interact with gluons? Why or why not and how?

Discussion 2

(a) Name the 10 lightest hadrons including their masses, charges and valence quark content. Any observations?
(b) How many quarks and gluons are in a proton ?
(c) What is the mass and quark content of the J/Ψ ?
(d) Why does the J/Ψ not decay into an open charm pair ? Can it decay into dileptons ?

Discussion 3

(a) What are types of models commonly used to describe nucleus-nucleus collisions? Name ingredients and differences.
(b) What is the advantage/disadvantage of 3-fluid-hydro vs. 1-fluid-hydro?
(c) What are the advantages/disadvantages of transport simulations and hydrodynamics simulations?

Discussion 4

(a) How can we look inside a hot and dense fireball created in relativistic nucleus-nucleus collisions?
(b) How can you tell if a QGP was formed from experimental data?
(c) How can one measure the equation-of-state of nuclear matter ?
(d) Suppose the thermal model describes the measured data, what does it mean and how can it be ?