3.3 Resonance (5 points)

In the year 2027 scientist finally succeeded to build and to operate a circular $\mu^+\mu^-$ collider with a center-of-mass energy of $\sqrt{s} =$ 10 TeV. Shortly afterwards, a new resonance was discovered among the decay products of the $\mu^+\mu^-$ annihilation. A preliminary invariant mass distribution is shown in Figure 1.

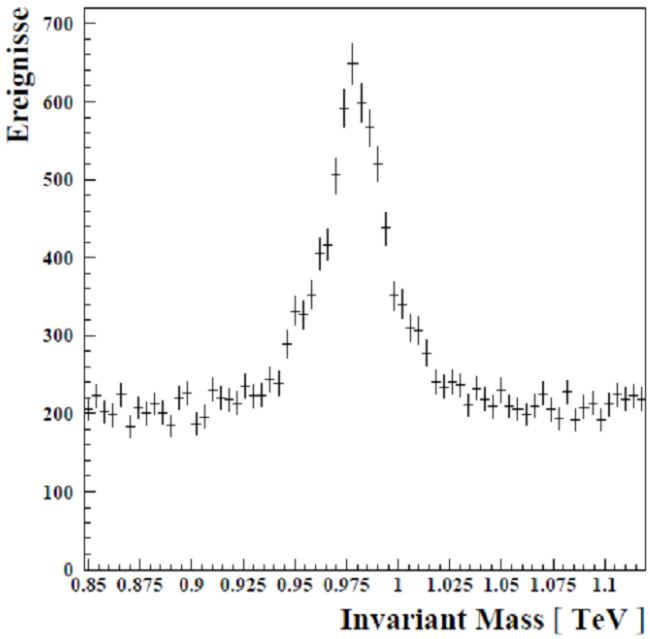

Figure 1: Invariant mass distribution from the $\mu^+\mu^-$ annihilation.

a) Estimate the mass, decay width and lifetime of the new state (Remember, in natural units 1 GeV^{-1}= 6.58×10^{-25} s)

b) The data shown in the mass distribution corresponds to data-taking of one month ($10^6 s$). For this period the machine people reported an average luminosity of $10^{32} cm^{-2} s^{-1}$. Give an estimate of the cross section (in barns) to produce the new state in $\mu^+\mu^-$ annihilations. Assume that the detection of the new events is 100% efficient.

3.4 Dalitz Plot (5 points)

Given a three-body decay $M \to 1+2+3$

a) Derive the lower and upper limits for m_{12}^2 and m_{23}^2 See Section 43 the PDG for help. Hint: The minimum is reached if the both particles have the same velocity and are both at rest in their own center of mass system.

b) Look at the distribution for $X \to p+K+\pi$ in Figure 2, measured by CDF in p-p collisions at the Tevatron. Using the results of part a), determine the mass of the decaying particle, X, from the plot. Try to find the particle, X, in the PDG. Which intermediate decays cause the specific bands in Figure 2? What does the plot tell you about the spin of the original particle and the intermediate resonances?

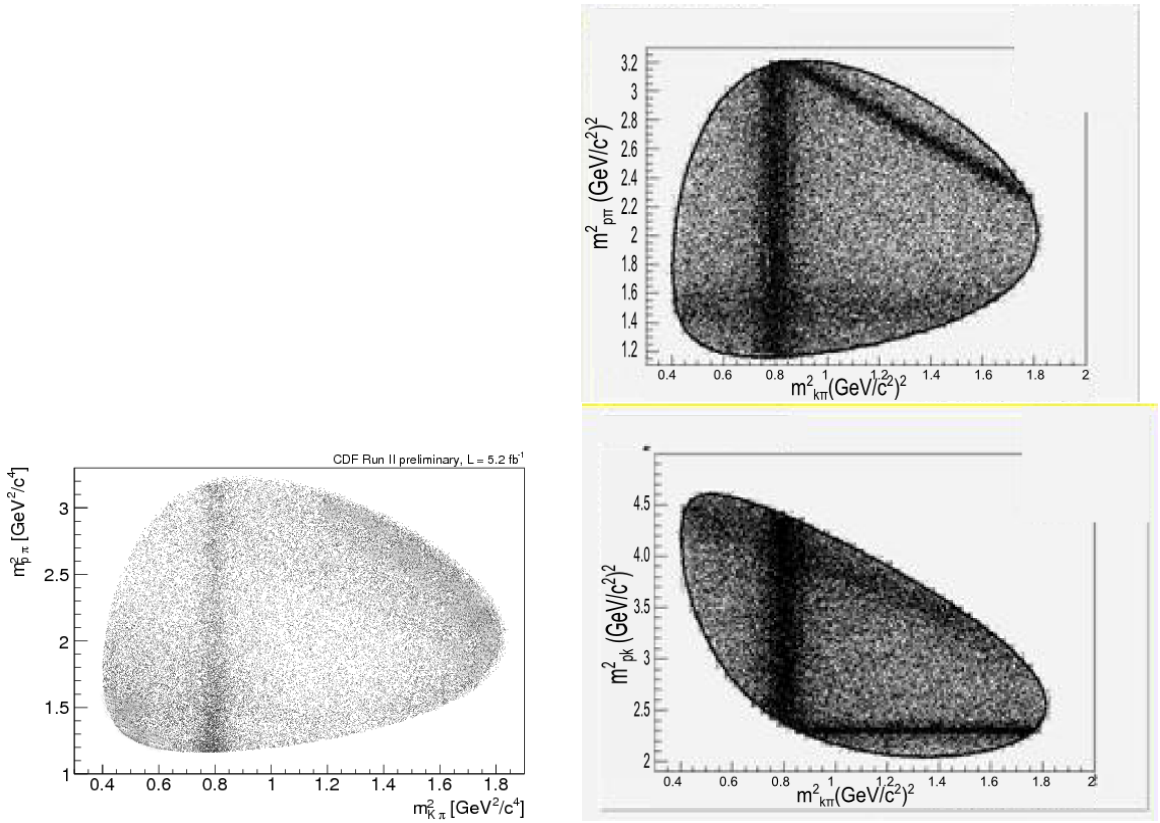

Figure 2: Dalitz plot for $X \to p+K+\pi$ measured by CDF. The left plot is CDF experimental data and the right plots are from Monte Carlo data,