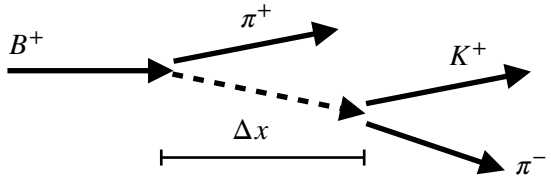
COMPUTING METHODS FOR PHYSICS
27 JANUARY 2021

Please submit your exam by **Wednesday 27 Jan at 13:30** following the instructions at https://www.roma1.infn.it/people/rahatlou/index.php?link=Didattica&sublink=cmp/exams



$m_B = 5.280\,\text{GeV}, \tau_B = 1.6\,\text{ps}$
$m_D = 1.865\,\text{GeV}, \tau_D = 0.4\,\text{ps}$
$m_\pi = 140\,\text{MeV}, m_K = 494\,\text{MeV}$

Distance between two decaying particles

Consider the following decay of charged B mesons $B^+ \to \bar{D}^0\pi^+$ followed by the decay of the charmed meson $\bar{D}^0 \to K^+\pi^-$. The lifetime and the mass of the particles are provided in the table. Assuming B mesons are produced at the origin, $x = 0$, and move along the x axis, we want to see the distribution of $\Delta x = x_D - x_B$, the distance between the decay vertex of the B and D mesons along the x axis. Simulate the process for 10^4 B mesons with momentum of 2 GeV. **Make sure all plots have proper labels, legend, and units**.

You can use C++ and ROOT or python/jupyter. The following steps help you implement the program

1. Implement a function (or class) to compute the two-body decay. The decay products must have a correct random distribution (while conserving energy and momentum) in the rest frame of the decaying particle.
    a. sanity check: plot the invariant mass of the decay products and you should obtain a Dirac function at the mass of the decaying particle
2. Implement a function (or class) to boost the decay products to the laboratory frame
3. Plot the distribution of K momentum in the LAB frame (save K_momentum.pdf)
4. For each B and D meson extract the distance it travels before decaying, by taking into account its lifetime
5. Plot the distribution of x_B (save xB.pdf)
6. Plot the distribution of x_D (save xD.pdf)
7. Plot the distribution of $\Delta x = x_D - x_B$ (save dx_truth.pdf)
8. To account for the experimental resolution, apply a smearing of 2% to the generated x_B and a smearing of 2% to the generated x_D. Plot the distribution of Δx after smearing (save dx_measured.pdf)
9. Overlay the smeared Δx and the original Δx (before smearing) with different colors and print their mean value on the plot. Which distribution has the larger mean?