

Computing Methods for Physics 1

Lecturer: Francesco Pannarale

Hands-on lab session 2A-2B, A.Y. 2021-22

The goal of these sessions is to use the `ROOT` random generator to

1. simulate the decay of a particle to two lower mass particle, and to
2. assess the impact of the detector resolution on the measured invariant mass of the particles.

Instructions:

- Generate a data sample with 10^4 events.
- In each event a B meson ($M_B = 5279$ MeV) decays to a π ($m_\pi = 140$ MeV) and a K ($m_K = 500$ MeV); the B meson has a momentum of 300 MeV along the x axis. In the center of mass of the B meson, the decay products have momentum

$$p^* = \frac{\sqrt{M_B^4 + m_\pi^4 + m_K^4 - 2M_B^2 m_\pi^2 - 2M_B^2 m_K^2 - 2m_\pi^2 m_K^2}}{2M_B}$$

and their direction is **random**.

- Pay attention to the proper generation of angles θ^* and ϕ^* in the center of mass, e.g., use the method `sphere()` in `TRandom`.
- Use the class `TLorentzVector` to boost the momentum of the π and the K to the laboratory reference frame and in this frame:
 1. compute the invariant mass of the π and K and fill a 1D histogram, with proper legend, axis label and units [you should obtain a \sim delta function at the B mass]
 - save the plot as `true-mass.pdf`;
 2. compute the opening angle between the K and the π and fill a 1D histogram, with proper legend, axis label and units
 - save the plot as `opening-angle.pdf`.
- Simulate the effect of the detector in measuring the momentum: assume the tracking detector has a Gaussian resolution $\sigma = 3\%$ [this process is called **smearing**].
 - Call `p_K_0` and `p_pi_0` the magnitude of the momentum of the K and the π in the laboratory, respectively; the detector does not change the direction of the particles.
 - Generate the measured momentum `p_K_meas` and `p_pi_meas` of the particles using a Gaussian model for the detector.
 - Compute the new 4-momentum of the particles in the laboratory.
 - Compute the invariant mass of the measured K and π and fill a 1D histogram.

- * what are the mean and the width of the distribution?
 - * is the distribution in agreement with your expectation?
 - * save the plot as `measured-mass.pdf`
- Plot the 1D histogram of the true mass (before smearing) and overlay the measured mass (after smearing)
 - * save the plot `invariant-mass.pdf`
- Simulate the effect of different detectors with 1%, 5%, and 10% momentum resolution
 - Compute the distribution of the invariant mass for each detector
 - Plot them all together (change the color or histogram filling for each detector)
 - Store the simulated sample in a `TTree`. Each event should have the following branches:
 1. `p_B`
 2. `nDau`
 3. `nmass[nDau]`
 4. `p[nDau]`
 5. `theta[nDau]`
 6. `phi[nDau]`

In our case `nDau = 2` for all events.