Computing Methods for Physics 1

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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 ($m_\pi = 140\,\mathrm{MeV}$) and a K ($m_K = 500\,\mathrm{MeV}$); the B meson has a momentum of $300\,\mathrm{MeV}$ along the x axis. In the center of mass of the B meson, the decay products have momentum

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

  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 it 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.