Reference frames

Use for example the Particle Data Group booklet:
https://pdg.lbl.gov/
that has a chapter where this subject is briefly introduced:
"Reviews, Tables, Plots" → "Kinematics, cross-section formulae and plots" →"Kinematics (rev.)"

Wikipedia: search for Lorentz transformations: boosts and rotations

In introductory physics books, search for concepts like physics observables and invariants (examples: speed of light, mass and charge of a particle,…)

In our analysis, several observables are frame dependent. The longitudinal momentum of a particle depends on boost, but it is invariant under rotations. The transverse momentum of a particle is invariant under boosts. The Feynman-x (x_F), x_1 and x_2 are other examples of frame-dependent observables.

Reference frame transformations in ROOT

In the ROOT online manual, https://root.cern/ , search for the TLorentzVector class reference. Most likely, you will want to use the methods:

- Boost(p)
- BoostVector()
- TLorentzRotation()
- RotateZ(), RotateX() and RotateY()

A simple example is given in $PHAST/user/u00_K0_Kstar_search.cc

Reference frames relevant in this analysis

We start in the laboratory frame, where the momenta of particles is measured. From there:

- Define the TLorentzVectors for beam pion, target nucleon, negative muon and positive muon. Define also the TLorentzVector of the “dimuon” (i.e. virtual photon that decays to mu+mu-)
- Now work in the change of frame, and transport each TLorentzVector accordingly, step by step:
  - First put the z-axis along the beam direction
  - Now rotate to have the photon with pT along the x-axis: you are now in the Target Rest Frame (TRF)
  - Do a boost, defining as TBoostVector -(pion + nucleon) , to go from TRF to the new Hadron Collision Frame (HCF)

Definitions and verifications

The Feynman-x (x_F), and Bjorken-x for beam (x_1) and target (x_2) are measured in the HCF (CMS of the hadrons collision), using the following definitions:

- $x_F = \frac{P_{z\gamma^*}}{P_{z\gamma^*}^{max}}|_{CMS} = \frac{P_{z\gamma^*}}{\sqrt{s}/2}|_{CMS}$
- $x_1 = 0.5 * (\sqrt{x_F{}^2 + \frac{4Q^2}{s}} + x_F)$
- $x_2 = 0.5 * (\sqrt{x_F{}^2 + \frac{4Q^2}{s}} - x_F)$

Check that the dimuon mass remains the same in the lab frame, TRF and HCF. Check that the dimuon pT chages from the lab frame to the TRF, but remains the same between TRF and HCF.