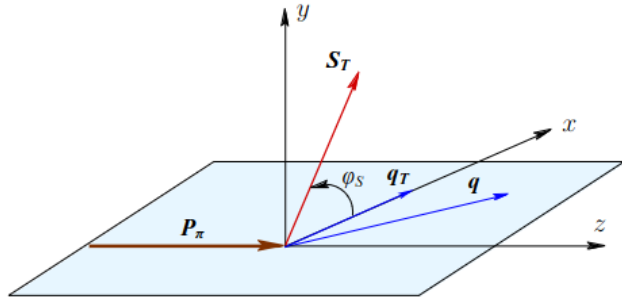
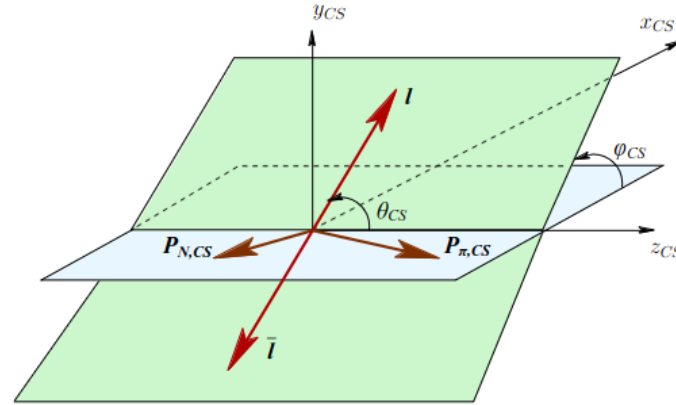


# COMPASS reference frames

## Target rest frame (TF)



## Collins-Soper frame (CSF)



$q$ : dimuon momentum vector  
 $P_\pi$ : beam momentum vector  
 $P_N$ : target momentum vector  
 $l, \bar{l}$ : muons momentum vectors

Fig. 39: Reference systems. Left panel: target rest frame. Note that  $z$ -axis ( $x$ -axis) is chosen along the beam momentum (along  $q_T$ ). Right panel: the Collins-Soper frame. It is a virtual photon rest frame obtained from the TF frame by boosting first along the  $z$ -axis and then along the  $x$ -axis so that both the longitudinal and the transverse momenta of the virtual photon vanish.

## Hadrons collision frame (HCF)

It is the center-of-mass rest frame of the collision of the pion and beam hadrons.  $P'_\pi = -P'_N$ . The  $z$ -axis is along the beam momentum,  $x$ -axis is along the dimuon transverse momentum  $q_{\perp}$ .

# Changing reference frames

1. We go from the Laboratory frame to the TF by set of rotations to make the z-axis along the beam momentum direction. In order to have the frame uniquely defined, we make another rotation that aligns the x-axis with the dimuon transverse momentum direction.
2. We go from the TF to the HCF by a boost to get the center-of-mass of the pion and beam hadrons system at rest.
3. While the Laboratory frame is always the same, the TF changes from event to event, since the beam direction also changes (slightly) from event to event. In the same way, the HCF changes from event to event.
4. There are quantities that do not depend on the frame (invariants), like the dimuon mass. Others depend on the frame where they were obtained, like the dimuon momentum.
5. Transverse momentum remains unchanged under boosts. Longitudinal momentum remains unchanged under rotations.

# Technicalities: TF

```
TLorentzVector lv1 = param.LzVec(M_mu); //defined for mu+, out of its PaTPar in vertex
TLorentzVector lv2 = paramm.LzVec(M_mu); //defined for mu-, out of its PaTPar in vertex
TLorentzVector lv = lv1+lv2; //defined for dimuon
TLorentzVector lprot(0.,0.,0.,PMASS); //defined for target hadron (with proton mass)
TLorentzVector lpi(px_pi,py_pi,pz_pi,energy_pi); // defined for beam hadron (with pion mass)
TLorentzVector lCM=lprot+lpi; //center-of-mass of the hadrons collision

// angle to put the z-axis along the beam direction:
double beamrot = atan(py_pi/px_pi);
double beamrot2 = asin(lpi.Pt()/(lpi.Vect()).Mag());

// now do the rotations:
TLorentzRotation b3;
b3.RotateZ(-beamrot);
lv *= b3; lv1 *= b3; lv2 *= b3; lprot *= b3; lpi *= b3;

TLorentzRotation b4;
b4.RotateY(-beamrot2);
lv *= b4; lv1 *= b4; lv2 *= b4; lprot *= b4; lpi *= b4;

// another rotation, to have x-axis along dimuon transverse momentum:
TLorentzRotation b5;
double beamrot3 = atan(lv.Py()/lv.Px());
if (lv.Px()<0.) beamrot3 -= TMath::Pi();
b5.RotateZ(-beamrot3);
lv *= b5; lv1 *= b5; lv2 *= b5; lprot *= b5; lpi *= b5;

// You are now in the TF. Check it with some couts of beam components and dimuon components.
```

## Technicalities: from TF to HCF

In the Lab frame you can obtain already the dimuon mass.

In the TF you can obtain the dimuon transverse momentum. In order to obtain  $x_{\pi}$ ,  $x_N$  and  $x_F$  you need to be in the HCF. Do it in sequence, from the TF, in this way:

```
// go in the colliding hadrons CM frame:
TVector3 colCM = -(lprot + lpi).BoostVector();
lv.Boost(colCM);
lv1.Boost(colCM);
lv2.Boost(colCM);
lprot.Boost(colCM);
lpi.Boost(colCM);

// You are now in the HCF. Check it with some couts of pion and proton components.
```

# Variables definitions

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

CMS: another name for HCF

$P_{z\gamma^*}$ : dimuon longitudinal momentum

$Q^2$ : dimuon mass squared

$\sqrt{s}$ : center-of-mass energy of the hadrons collision

$x_1$ : another name for  $x_{\pi}$

$x_2$ : another name for  $x_N$

To get more details, see for example the [PDG booklet](#) (from page 255)

```
// In the Lab frame, the squared center-of-mass energy of hadrons is:  
s = lprot.M2() + lpi.M2() + 2*lpi.E()*lprot.M();
```

$x_{\pi}$ : the fraction of momentum of the antiquark annihilating carried by the pion parent

$x_N$ : the fraction of momentum of the quark annihilating carried by the nucleon parent