Impact of PileUp mitigation with the Inner Tracker in the reconstruction of the Missing Transverse Energy in the ATLAS detector at HL-LHC

A precise measurement of the $E_{\text{miss}}$ is fundamental to experimentally measure the transverse momentum carried by non-interacting particles produced in the proton-proton collisions. A good $E_{\text{miss}}$ resolution is essential in any analysis at LHC and HL-LHC characterized by events with large $E_{\text{miss}}$ both for searches of new physics and precise measurements of the Standard Model.

The high number of additional proton-proton interactions, called PileUp, expected under the HL-LHC conditions makes crucial an efficient rejection of PileUp jets and an accurate selection of tracks from the hard-scatter vertex to achieve a good reconstruction of the $E_{\text{miss}}$.

The Inner Tracker, ITk, for the Phase-II upgrade of ATLAS will extend the current pseudorapidity region, $|\eta|<2.5$, to the region of $|\eta|<4.0$. This will allow to apply vertex tagging techniques also to forward tracks and jets.

**Motivation**

**PileUp at HL-LHC**

The High Luminosity LHC, HL-LHC, is expected to deliver an instantaneous luminosity from $5 \times 10^{34} \text{cm}^{-2} \text{s}^{-1}$ up to $7.5 \times 10^{34} \text{cm}^{-2} \text{s}^{-1}$, corresponding to a mean number of interaction per crossing, $\mu$, from 140 up to 200, respectively. This leads to an high number of reconstructed primary vertices, $N_{\text{pv}}$.

**PileUp jet rejection**

Among the several PileUp mitigation techniques [2], the $R_{\text{p}}$ is here considered. This variable is the scalar $p_{T}$ sum of the tracks, originating from the hard-scatter vertex (PV) and associated with the jet, divided by the fully calibrated jet $p_{T}$

$$R_{\text{p}} = \frac{\sum p_{T}}{p_{T}}$$

Small values of $R_{\text{p}}$ are less likely to correspond to PileUp jets.

**Missing Transverse Energy, $E_{\text{miss}}$, and Total Transverse Energy, $\Sigma E_{\text{t}}$, definitions**

$E_{\text{miss}}$ is measured from reconstructed and calibrated objects according to the following formula [1]:

$$E_{\text{miss}} = E_{\text{miss}}^{x} + E_{\text{miss}}^{y} + E_{\text{miss}}^{\gamma} + E_{\text{miss}}^{\tau} + E_{\text{miss}}^{\mu} + E_{\text{miss}}^{\text{soft}}$$

Where the labels $x, y, \gamma, \tau, \mu$ and soft refer to the negative of the sum of the $x, y$ components of the momenta for the electrons, photons, jets, muons and the tracks originating from the hard-scatter vertex and not associated to any of the reconstructed calibrated objects, respectively. Muons included in the $E_{\text{miss}}$ calculation are selected with loose criteria. The $\Sigma E_{\text{t}}$ quantifies the activity in the event. It is defined as the scalar sum of the transverse momenta of the objects used to calculate the $E_{\text{miss}}$:

$$\Sigma E_{\text{t}} = \sum p_{T}$$

**The ATLAS Inner Tracker, ITk**

The inclined pixel barrel layers ITk Layout [8]. Resolution of $2\sigma$ as a function of true track $p_{T}$ for single muons with $p_{T}$ of 1, 10, or 100 GeV [3]. The ITk is an all-silicon tracker with an extended acceptance up to $|\eta|<4.0$. It will be able to precisely reconstruct the vertices of PileUp events and associate for the hard-scatter event the vertex to the tracks from the hard interaction. Its acceptance will allow to apply vertex tagging techniques to also reject PileUp forward jets.

**PileUp mitigation for different luminous regions Scenarios at HL-LHC**

The HL-LHC has the potential for partly mitigating the effects of the high PileUp by varying the size and the shape of the luminous region. The shape of the luminous region can be varied by varying the size and the shape of the luminous region. The size of the luminous region can be varied by varying the size and the shape of the luminous region.

**Conclusions**

- Inner Tracker layout, beam configuration optimisation and event PileUp suppression tools are essential to mitigate the effects from the large number of multiple proton-proton collisions at the HL-LHC.
- A wider luminous region along the beam-axis is beneficial for improving the PileUp rejection with the tracker.
- The extended acceptance of the ITk leads to a significant improvement in the $E_{\text{miss}}$ resolution even in a dense PileUp environment.
- One of the most decisive Figure of Merit in the choice of the ITk Layout, which is expected to be taken in early 2017, is the impact of the tracking on the rejection of the jets from PileUp.
- New vertex tagging techniques for HL-LHC should take into account the observed degradation of the resolution of the tracking parameters in high pseudorapidity regions.

**References:**

1. University of Calabria (Italy)
2. INFN – Cosenza (Italy)