Abstract

For the post High Luminosity LHC era, several accelerator projects are under study. The hadron-hadron based Future Circular Collider (FCC-hh) is one such project with the goal to collide proton beams at $\sqrt{s} = 100$ TeV at a bunch crossing rate of 25 ns. Some of the major challenges that the FCC-experiments have to tackle are the very large number of pile-up events ($\sim 1000$) and the data processing, namely the reduction of the huge data rate pile-up events that have to tackle are the very large number of the major challenges that the FCC-experiments have to tackle. And data rate reduction is achievable at the very first trigger level and it is shown that a significant pile-up, and thus data rate reduction is achievable at the first trigger level.

Physics Motivation

- High precision measurement of Higgs boson properties and Standard Model tests, e.g. Higgs couplings.
- Increase the discovery reach with very high energies to search for New Physics beyond the Standard Model (BSM).
- Search for rare processes with high sensitivity, e.g. $HH, ttH, VBF$.

Challenges

- High pile-up ($\sim 1000$) → high complexity → many ambiguities
- DAQ and Computing → very high data rate of $\sim 2$ PB/s at 40 MHz BX → limited data storage rate

Concept of Triplet Track Trigger (TTT)

Track Trigger: event selection based on track information.

Triplet Track Trigger: a generic detector concept to trigger all processes at the electroweak scale & to search for physics BSM.

- Three closely stacked, highly granular pixel layers allow for an easy reconstruction of triplet tracks.
- Layers placed at large radius ($> 40$ cm) along with beamline constraint allow for very good momentum determination.
- Pixel precision allows for precise z-vertex determination.
- Pile-up suppressed track-jets can be reconstructed on trigger level → highly relevant for multi-jet signatures, e.g. hh → 4b.

Triplet Track Reconstruction Algorithm

A charged particle’s trajectory in a uniform magnetic field B: a circle in the x-y plane & a straight line in the s-z plane.

1. Triplet hit selection: A search window in the $\Delta z - \Delta \phi$ is defined to search for triplet candidates. Hit combinatorial problem is largely reduced at this stage (stacked triplet layers).
2. Track Reconstruction: Two independent methods are used to determine the track parameters in the s-z plane and hit coordinates measured in,
   - all the three layers, $l_1, l_2 & l_3$, see Figures 2-3. As $\frac{\Delta p_T}{p_T} \propto \frac{B L}{m T}$ → $p_T$ is not so precise$^2$
   - $l_1$ & $l_3$ alone where a pseudo hit (0,0) is used as the third hit$^3$. Large $L$ → $p_T$ is very precise.
3. Triplet Validation: A significant number of wrongly reconstructed tracks are rejected by applying a consistency check on the curvature values determined using the two methods in 2.

Very simple and fast! Can be implemented in hardware, e.g. in an FPGA, at the very first level of a trigger system

Performance studies of the TTT for FCC-hh

Full Geant4 detector simulation

Track reconstruction efficiencies and purities $> 90\%$ for a wide range of track $p_T$ only with three tracking layers.

- The z-vertex position of tracks ($z_0$) is reconstructed with sub-mm precision, will allow significant pileup suppression and rate reduction.

Figure 4 shows a cross-section of the castellated tracker layers implemented in Geant4 for the FCC-hh baseline detector with the TTT and Figure 5 shows the hit occupancies as a function of radius in an FCC-hh like detector environment for three different pileup configurations.

- High pile-up $\Rightarrow$ very high hit occupancies
- Full data readout considered to be possible only at radii $> 40$ cm (lower combinatorics)

Tracking performance

- Track reconstruction efficiencies and purities $> 90\%$ for a wide range of track $p_T$ only with three tracking layers.
- The z-vertex position of tracks ($z_0$) is reconstructed with sub-mm precision, will allow significant pileup suppression and rate reduction.

Figure 6 shows the hit occupancies as a function of transverse momentum (Figure 6) and z-vertex resolution as a function of transverse momentum (Figure 7), for hh $\rightarrow 4b$. CMOS Monolithic Active Pixel Sensors are used as its active detector elements.

Reference


Conclusion and Outlook

- The TTT concept is based on a very simple and fast track reconstruction algorithm.
- Early access to the track vertex allows significant pile-up and rate reduction.

- Performance of triplet disc layers in the endcap is foreseen as part of future studies.
- Should be considered for tracking in Future high rate experiments.