The impact of applying WildCards to disabled modules for FTK pattern banks on efficiency and data flow

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1 ATLAS Fast TracKer (FTK)
- A custom electronics system that reconstructs tracks in all events passing ATLAS L1 trigger [2].
- Reads data from silicon pixel and strip (SCT) detectors including Insertable B-layer (IBL) and operates up to 3 x 10^{12} p/cm^2 s^-1.
- Highly parallelized: divided into 4 x 16 x 9 regions (“towers”) that process data simultaneously.
- Provides track parameters and associated hits to HLT for all tracks with p_T > 1 GeV.

2 FTK System Design
- Pixel and strip data are transmitted from the Read Out Drivers (ROD) to the Data Formatters (DF).
- DF perform cluster finding and distribute hits according to FTK geometric segmentation (9 = 0 towers).
- The Associative Memories (AM) compare hits to 10^5 preloaded track patterns simultaneously.
- The Data Organizer (DO) receives the road ID numbers from the AM and fetches the associated full resolution hits then sends them to the Track Fitter (TF).
- Duplicate track removal is carried out by the Hit Warrior (HW).
- The Second Stage Boards (SSB) perform fit for the remaining 4 layers not used in the 1st fit.
- The FTK Level 2 Interface Card (FLIC) organizes the tracks and sends them to the HLT ROBs.

3 Pattern recognition
- The pattern recognition is the heart of FTK, a special Content Addressable Memory with 128K addresses per AM chip (1 billion in system) operating at 100 MHz.
- Data is simultaneously compared to predefined hit patterns (from simulated muons).
- Valid roads (matched patterns) where 7 or 8 layers have a match are used for the track fit.
- Pattern recognition is complete shortly after the last hit has been transmitted from the ROBs.

4 Variable resolution (Don’t Care (DC) bits)
- To prepare the patterns bank used in the pattern recognition, one billion patterns per tower are generated. → Only 16.8M addresses are available in the AM chips.
- As a solution, variable resolution patterns are implemented using DC bits [3].
- Similar patterns, which differ only at the ternary bit positions, are merged in a single address.
- Variable resolution reduces the number of patterns and fake matches.

5 WildCards algorithm
- In the real state, there are some disabled modules in the pixel and in the SCT detectors, which cause a decrease in tracking efficiency by ∆ε ∼ 2–4%.
- To recover the efficiency loss, we will use WildCards (WC) algorithm, which treats all strips/pixels in disabled modules as if they have hits always.
- WC algorithm improves efficiency while increasing the number of fake tracks which causes higher data flow, that may exceed the hardware limitation.
- To overcome this, WC penalty algorithm is used which control how to use WildCards with ternary bit, and thus avoids putting WildCards and wide patterns at the same time.

6 WildCards optimisation
To optimize how to apply WC algorithm to achieve better performance we compare:
5 different patterns banks:
- Patterns bank for ideal detector (nominal bank);
- Four banks with WildCards and Penalty from 0 to 1;
7 different FTK Simulation [4] with Single muons and f < p_T < 60 GeV;
- FTK Simulation using nominal bank (no disabled modules and no WildCards) (ideal);
- FTK Simulation using nominal bank with WildCards set in simulation step (WC_SIM);
- FTK Simulation using nominal bank with disabled modules set in simulation step (DM_SIM);
- Four FTK Simulations using bank with WC and Penalty (WC_P0, WC_P1, WC_P2, WC_P3).

7 Conclusions
- The patterns bank has direct effect on the patterns recognition and thus on the full FTK system.
- The existence of disabled modules leads to tracking inefficiency at level of ∆ε ∼ 2–4%.
- With WildCards algorithm we can recover efficiency but we get also higher data flow.
- WildCards with penalty equal 3 seems to be the best choice: we can have a data flow close to the ideal bank while recovering the inefficiencies caused by disabled modules to a large extent.

References

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