General Track Finder Issues

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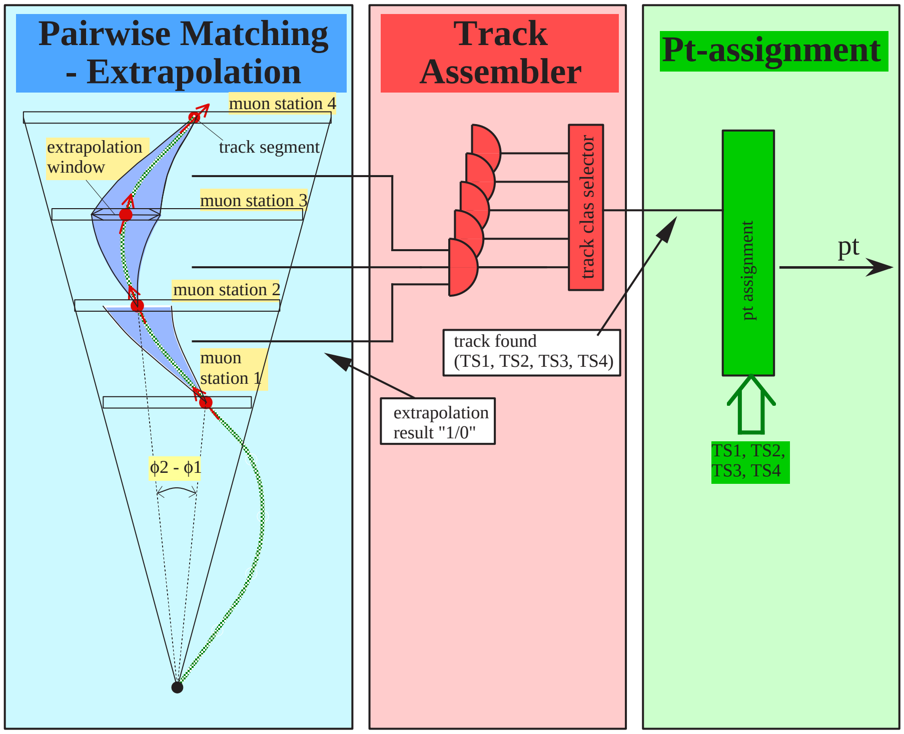
Muon Track Finding

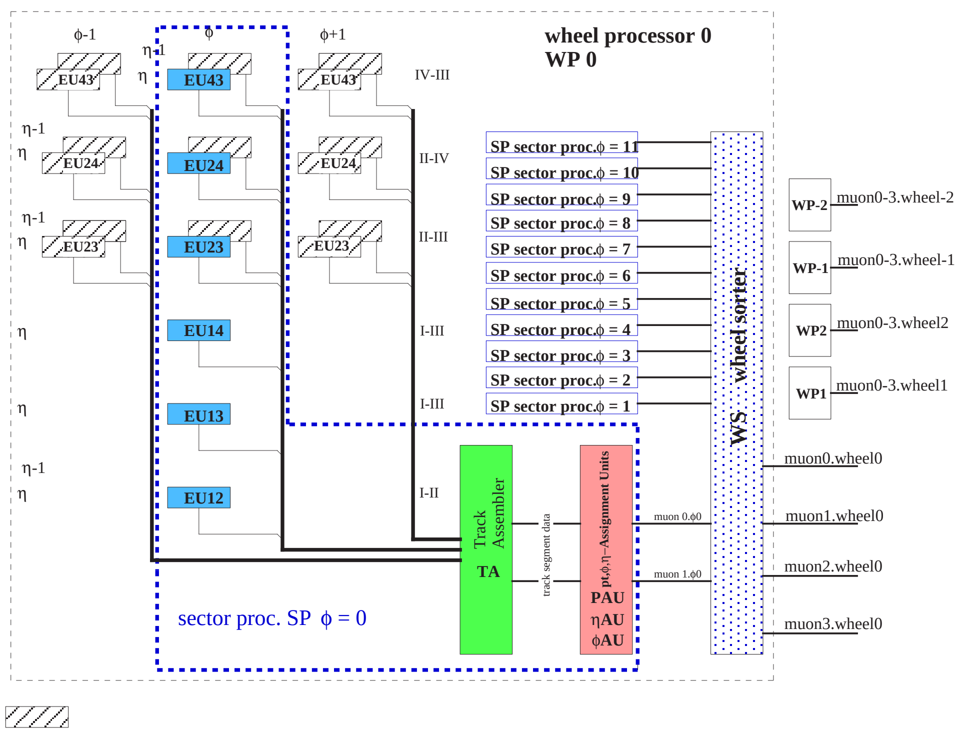
- Link trigger primitives into tracks
- Compute P_T, ϕ, η
- Send highest P_T candidates to Global L1 trigger
- Perform processing in ~14 b.x. latency

Barrel DT System:

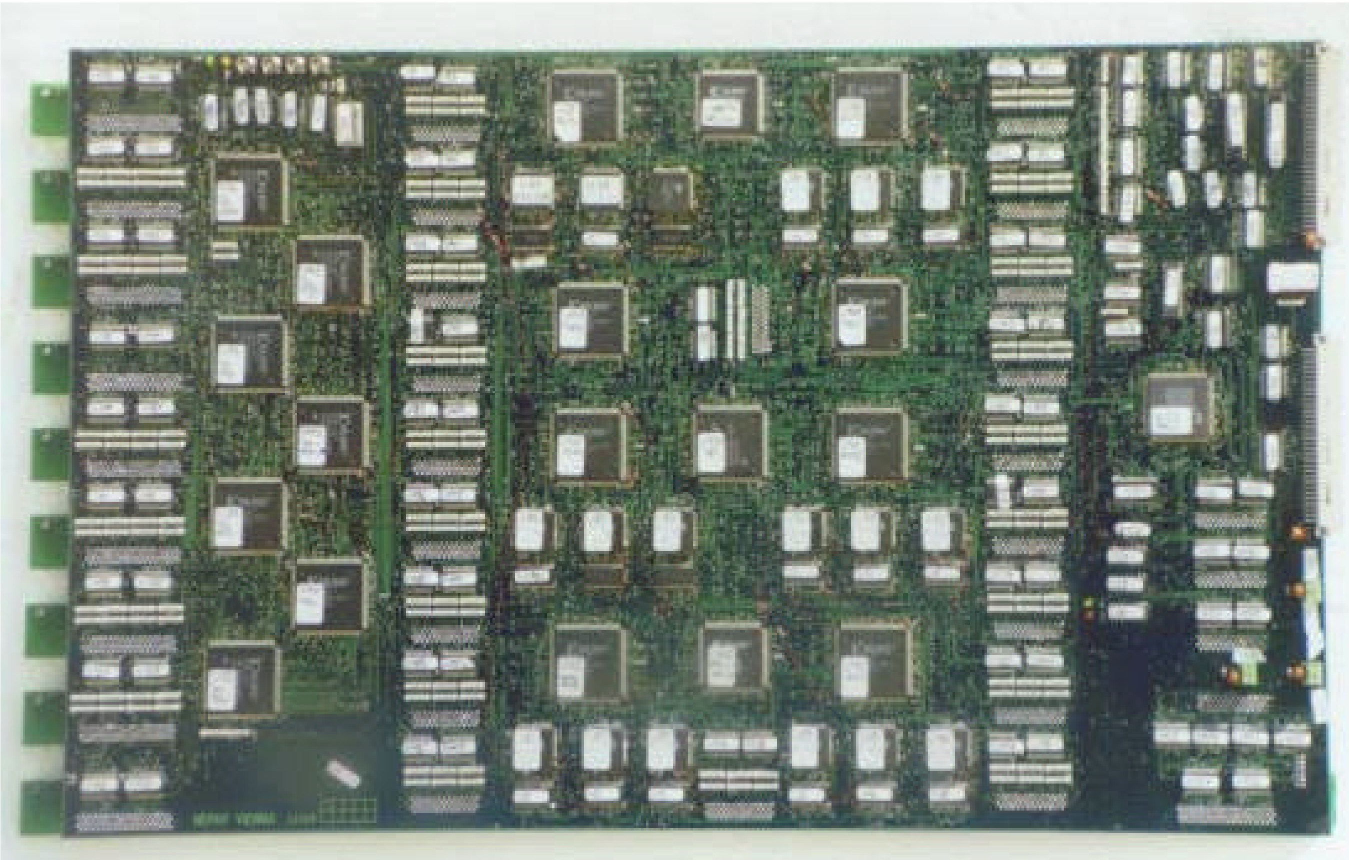
- Trigger primitives from Bunch and Track Identifier (BTI) chip -- “mean timer chip”
  - ϕ and η measured at each station
  - angular acceptance <45.7° $\Rightarrow$ $|\eta|<0.85$
- Magnetic bending independent of η
- 2D linking of primitives in ϕ only
  - station-to-station extrapolation, including neighboring sectors and wheels
  - select best track candidates
- Assign P_T, ϕ, η
- Send $\leq$ 2 tracks per sector to wheel sorter
- Prototype built by Vienna group

Barrel Track Finder (Vienna)





Barrel Track Finder Prototype



- Implemented in 19 Xilinx FPGAs and RAM
- I/O bottleneck ⇒ time multiplex I/O pins
- Runs at 20 MHz

CSC Muon Trigger

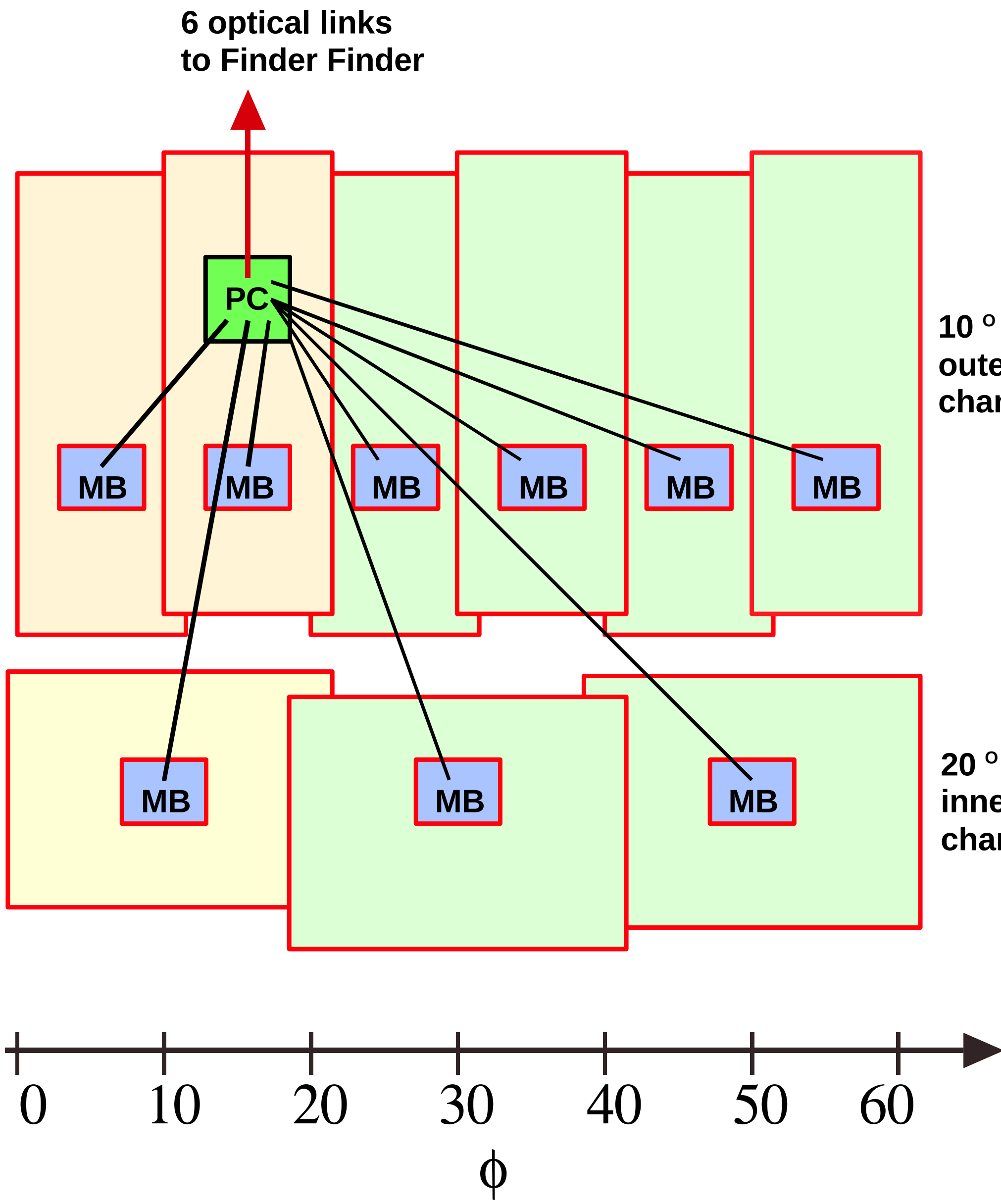
- Trigger primitives from front-end LCT chips
  - separate anode and cathode LCTs
- Trigger Motherboard (TMB)
  - correlates anode and cathode LCTs
  - sends $\leq$ 2 track stubs per xing from chamber
- Muon Port Card (MPC)
  - collects stubs from 9 chambers
    - ME1: 30° sectors
    - ME2: 60° sectors
  - sends $\leq$ 3 stubs to counting house via optical links

Track Finder:

- Sector Receiver (SR)
  - receives optical signals
  - transmits signals to CSC-overlap SR via copper
  - reformats data (LCT bit pattern $\rightarrow \phi$, $d\phi$, η, $d\eta$)
  - sends data on VME bus to SP
- Sector Processor (SP)
  - form tracks from trigger primitives
  - assign P_T, ϕ, η
  - send $\leq$ 2 tracks per sector to wheel sorter

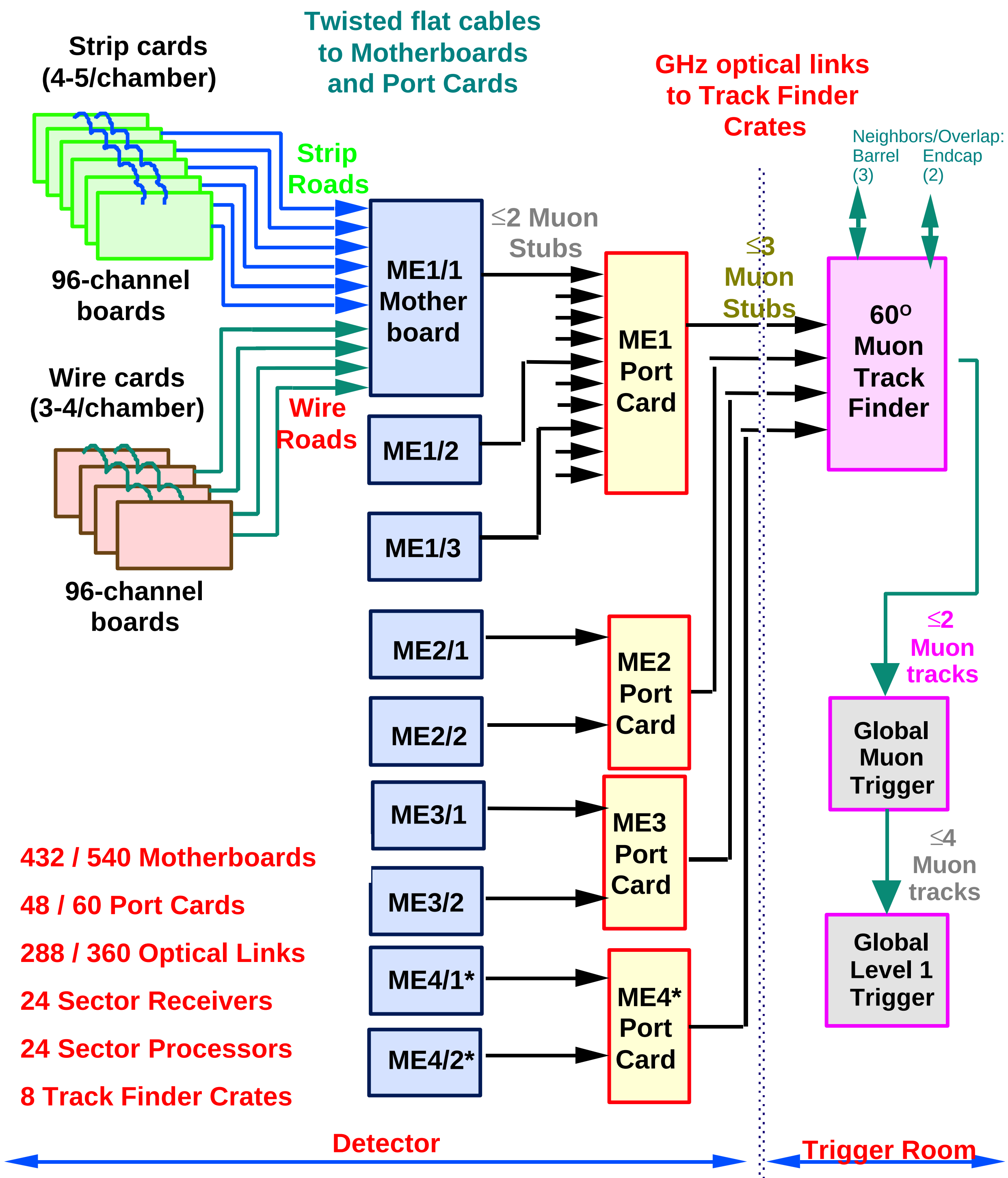
Muon Port Card Layout

MB = MotherBoard
PC = Port Card



60° sectors are a better match to barrel

CSC Muon Trigger



Design Considerations

- Tracks crossing sector boundaries are not linked by sector processors
  - reduces data flow on VME backplane
  - $P_T > 10 \Rightarrow \Delta\phi_{12} < 2°$
- Magnetic field is non-uniform in endcap
  - Extrapolation in ϕ is more complicated
  - P_T assignment depends on η
- 2D or 3D track finding?
  - Track finding in η-r to reduce combinatorics?
- Ghost suppression
  - Try all η, ϕ possibilities from chamber, or take best matches from MPC?
- Overlap region
  - Problem with ambiguity in η
- What is sector occupancy from background?

CMS Note 1997/096
G. Wrochna
Warsaw calculations

after calorimeter

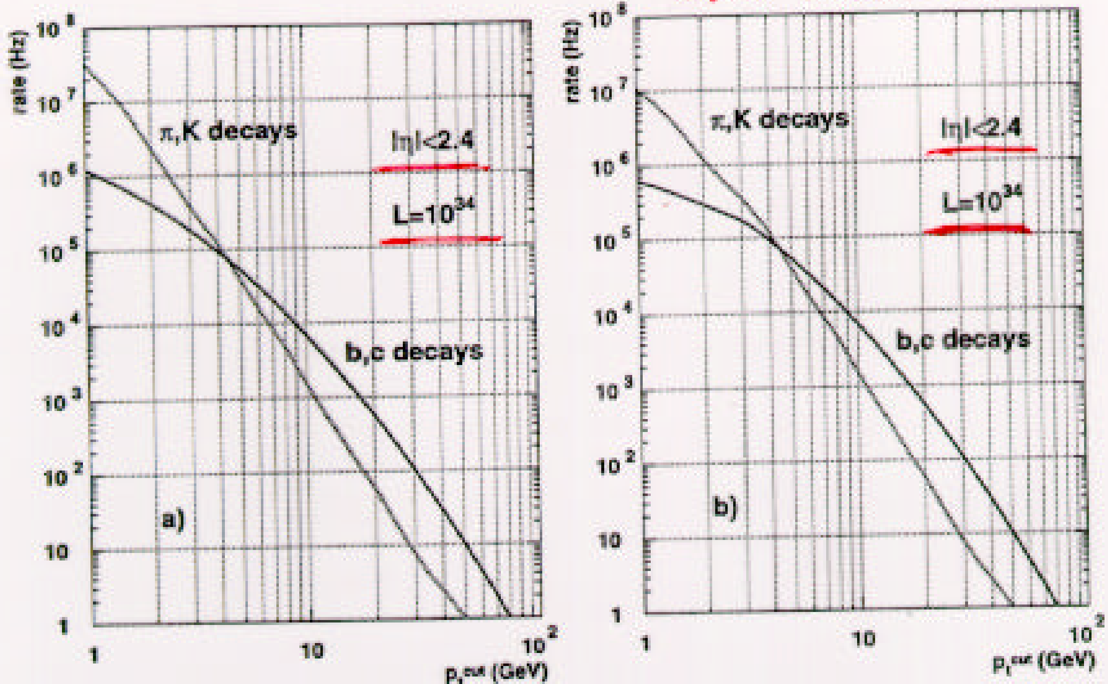


Figure 5.4: Integrated muon rates: a) before and b) after calorimeters.

P_T^{cut}

PROMPT μ's:

$$\frac{d^3 N_\mu}{d\eta\, dP_T\, dt} = a \cdot \exp\left[-\frac{(x-\mu)^2}{2\sigma^2}\right]$$

$x = \log_{10} P_T \quad \mu = -0.725 \quad a = 1.308 \cdot 10^6 \quad \sigma = 0.433$

DECAY μ's:

$$\frac{d^3 N_\mu}{d\eta\, dP_T\, dt} = A \cdot P_T^{-b}$$

$A = 5.723 \cdot 10^7 \quad b = 5.578$

Real Muon Flux

- Prompt Muons + π/K decay Muons @ $10^{34} cm^{-2} s^{-1}$

P_T Cut	Total Rate	Sector Rate	Sector Occupancy	
1.0 GeV	1.0E7 Hz	170 kHz	0.43%	30° Sector $1.4<\eta<2.4$
2.5 GeV	1.2E6 Hz	56 kHz	0.14%	
5.0 GeV	8.7E4 Hz	4.2 kHz	0.01%	60° Sectors $1.0<\eta<2.4$
10.0 GeV	8.0E3 Hz	0.4 kHz	0.001%	

Total Rate: $|\eta|<2.4$

- Punch-through may approximately double rates
- Occupancy is fairly low
- Is rate of fake stubs from neutrons negligible?

Design Possibilities

- Low occupancy ⇒ Track finder is just a coincidence unit between all 3 stations
  - But, still must calculate P_T accurately
    - Total μ rate is of order 100 kHz
    - Single μ trigger rate < 6 kHz
- High occupancy ⇒ Track Finder must employ 2D and maybe 3D track finding, resolve ghosts, and prioritize tracks
- Track Finder should be flexible enough to handle everything in between

Plans

- Start initial design of CSC sector processor for overlap region
  - Most difficult case because of ambiguity in extrapolation to DT system and because of the data flow from the CSC and DT systems
- Try to stay with FPGA technology to maintain programmability