CMS Calorimeter Trigger Upgrade

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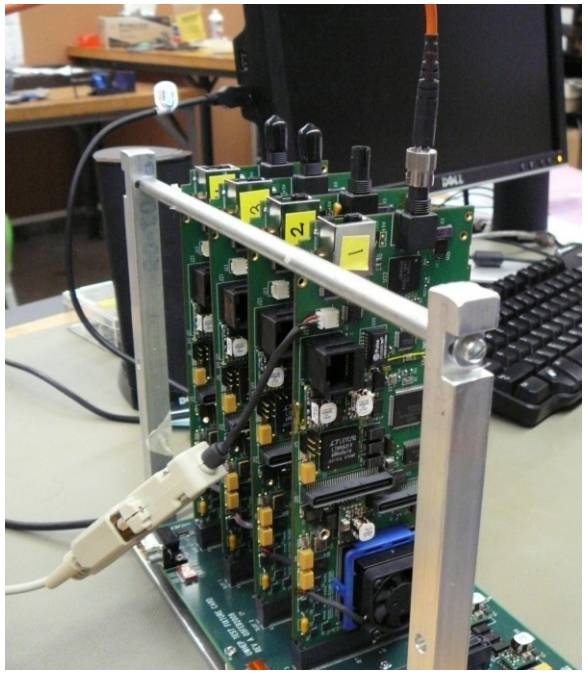
9 March 2011

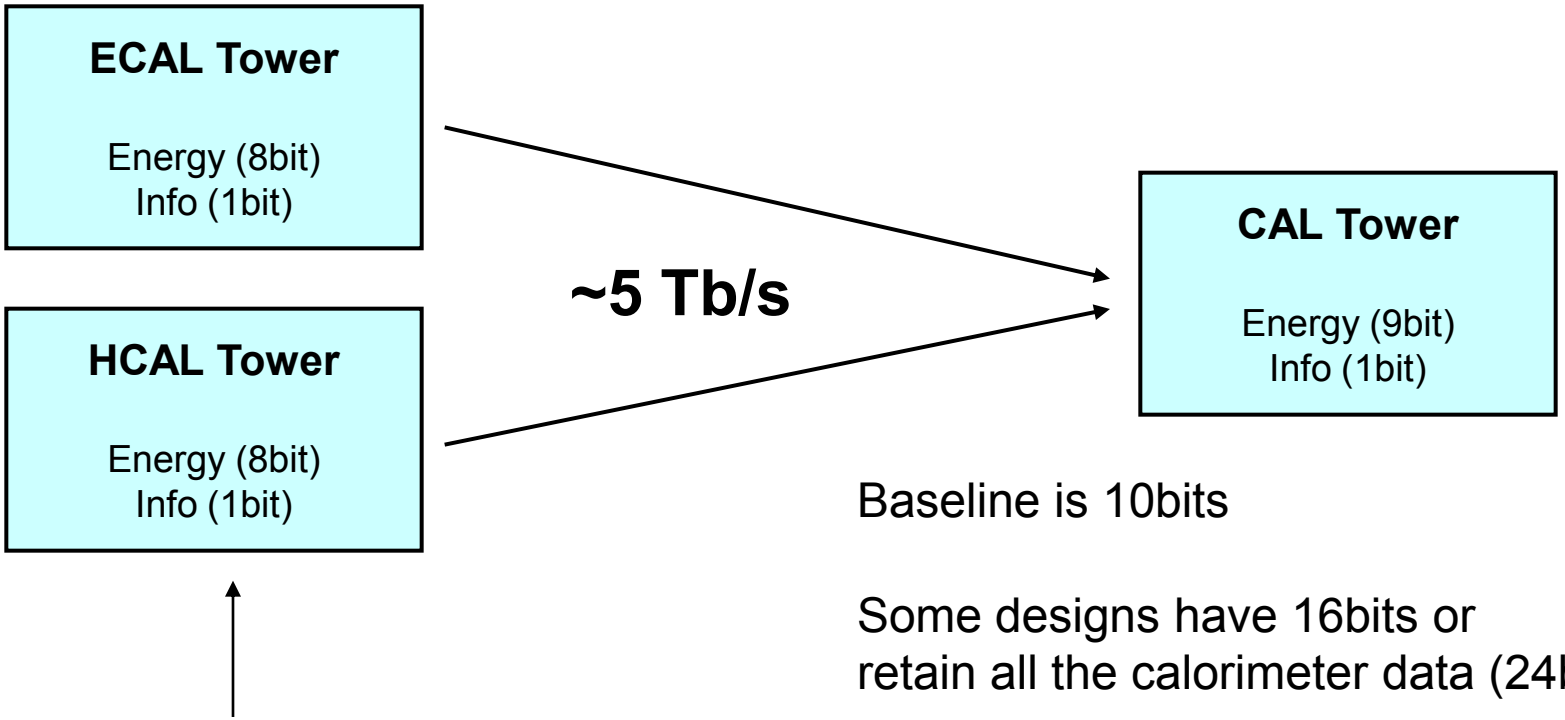
Calorimeter Trigger Designs

- Two approaches for Calorimeter Trigger
  - Compact Trigger: **CT**—early formation of 2x2 clusters (with fractional tower resolution) leading to reduction in hardware footprint
  - Time Multiplexed Trigger: **TMT** – similar to HLT, enables entire calorimeter to be processed in a single FPGA
- Currently evaluating different designs and how to integrate them into the LHC schedule and into CMS.



Concepts

In the beginning everything is the same...



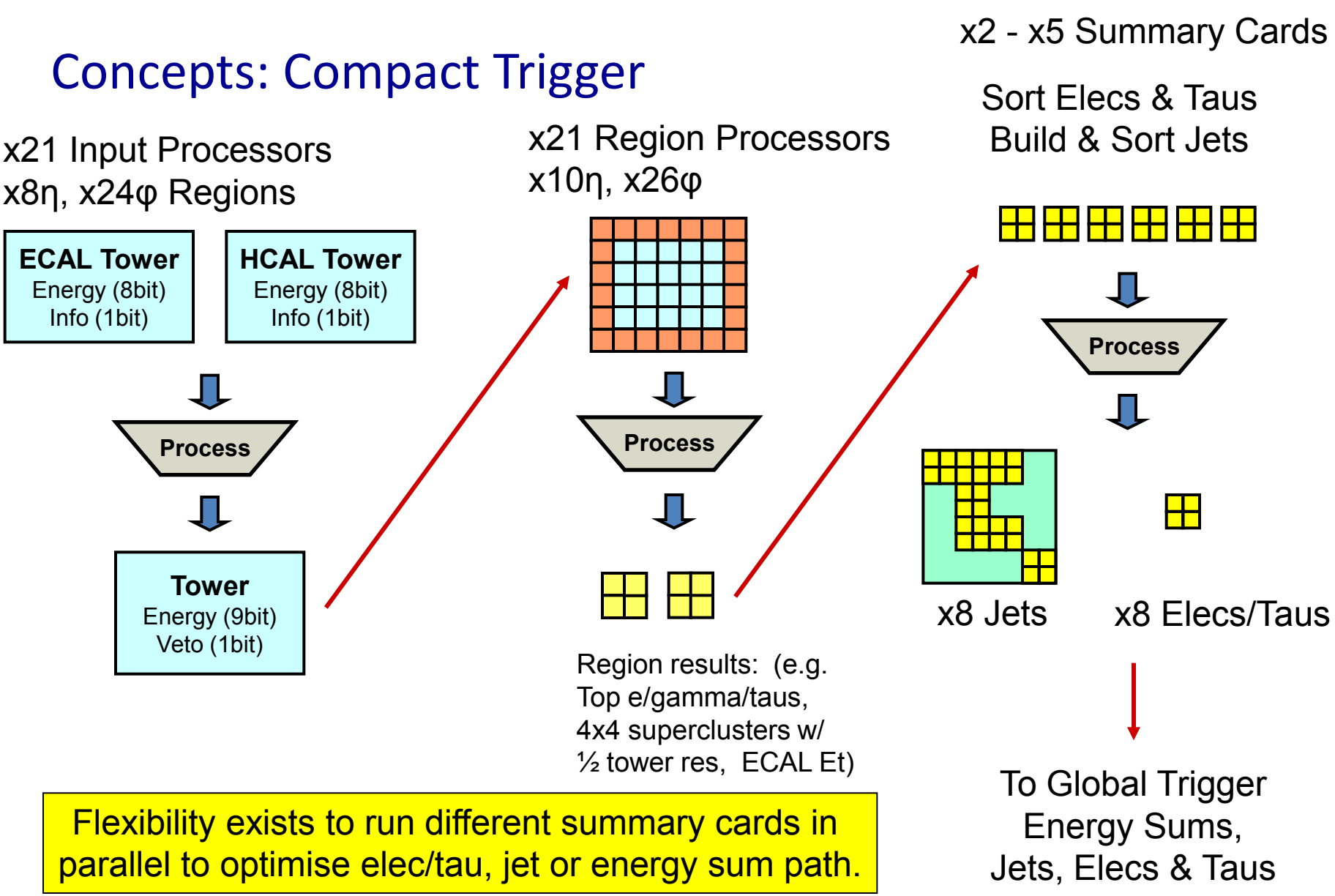
Baseline is 10bits

Some designs have 16bits or retain all the calorimeter data (24bits).

Trade-off between capability and cost, risk, size of a system

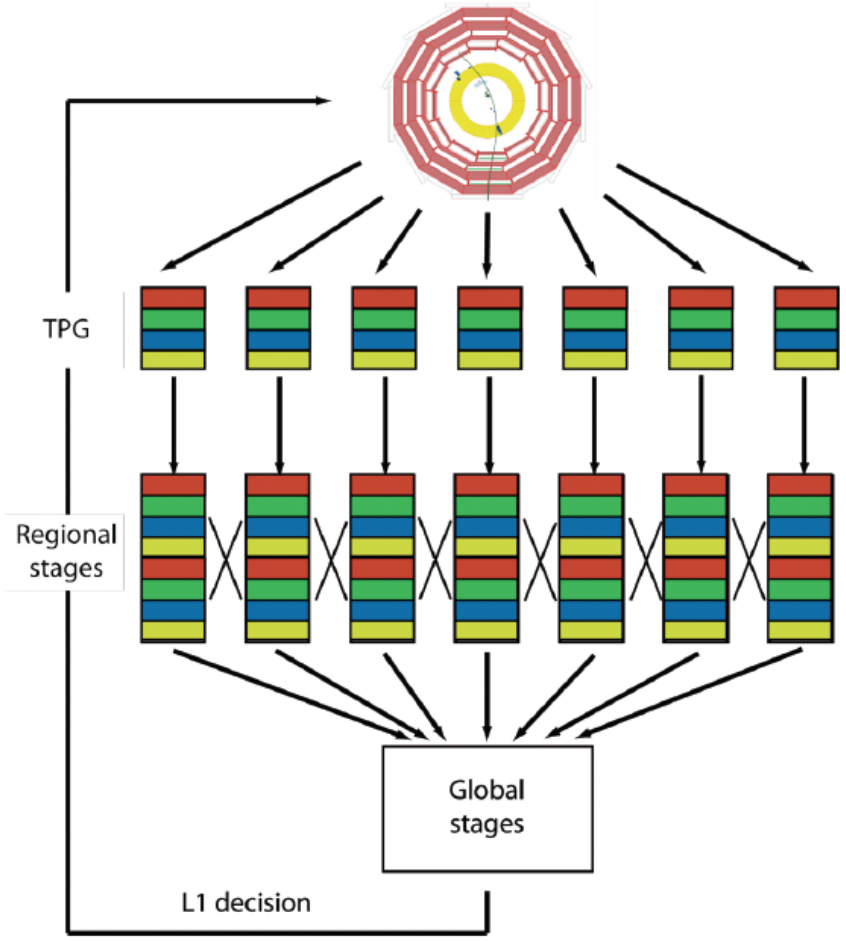
Could increase to 12bits
e.g. Depth segmentation information

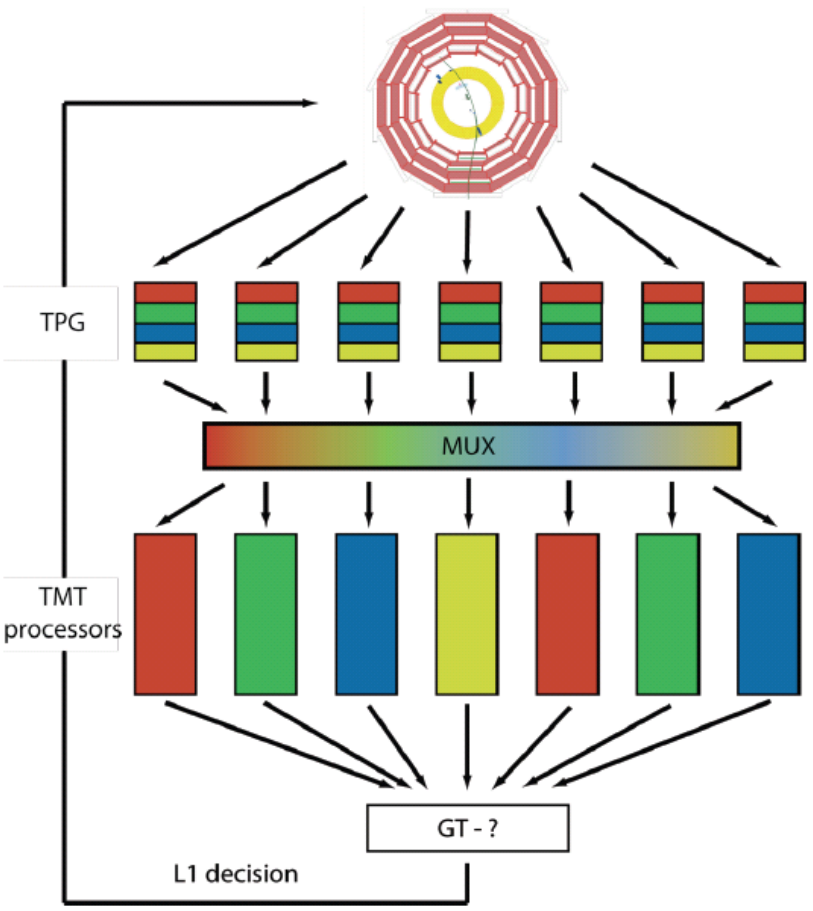
Concepts: Compact Trigger



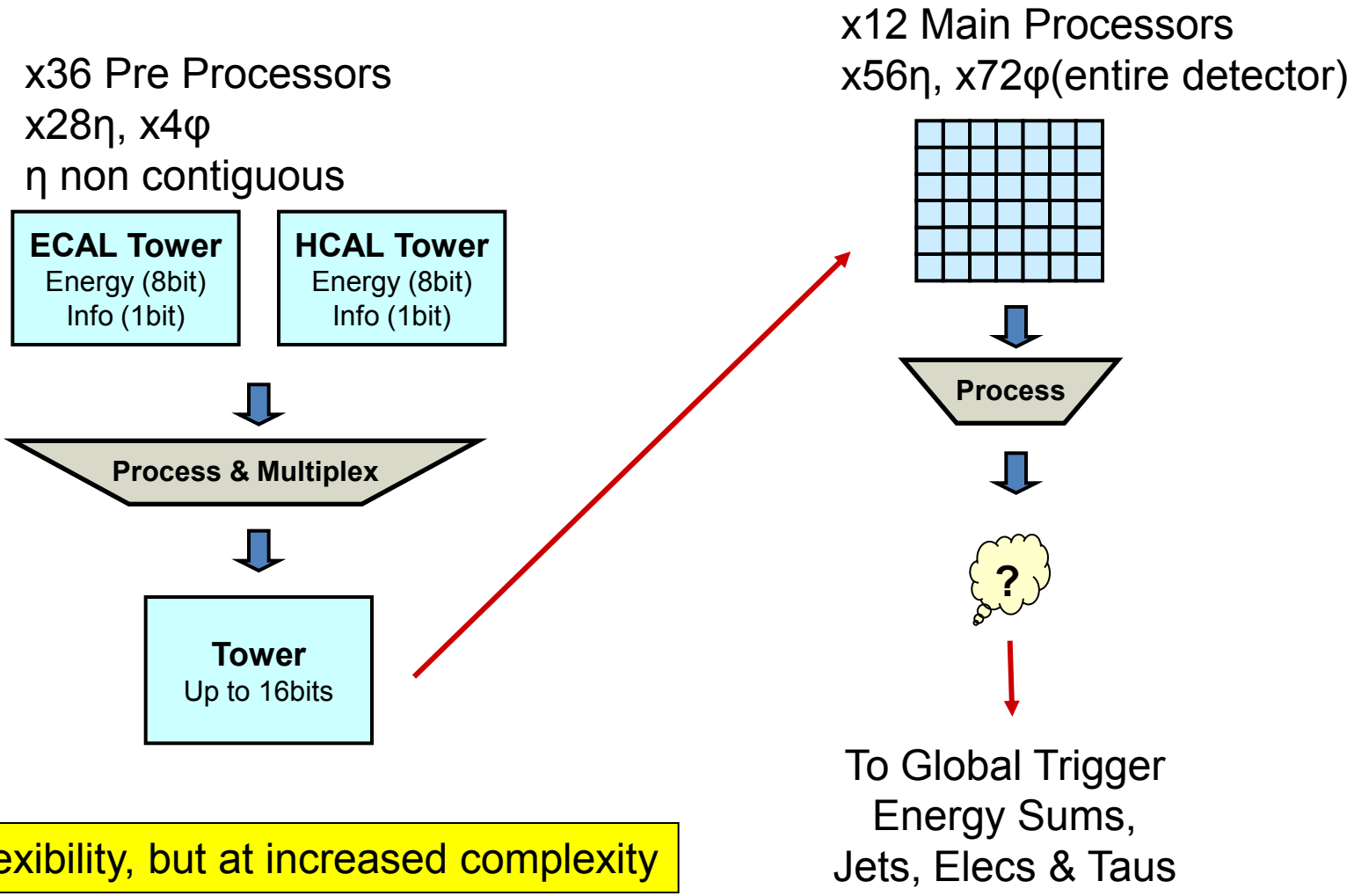
2.4Gb/s input reduces processing areas by 2, but otherwise no change to fundamental operation

Concepts: Time Multiplexed Trigger





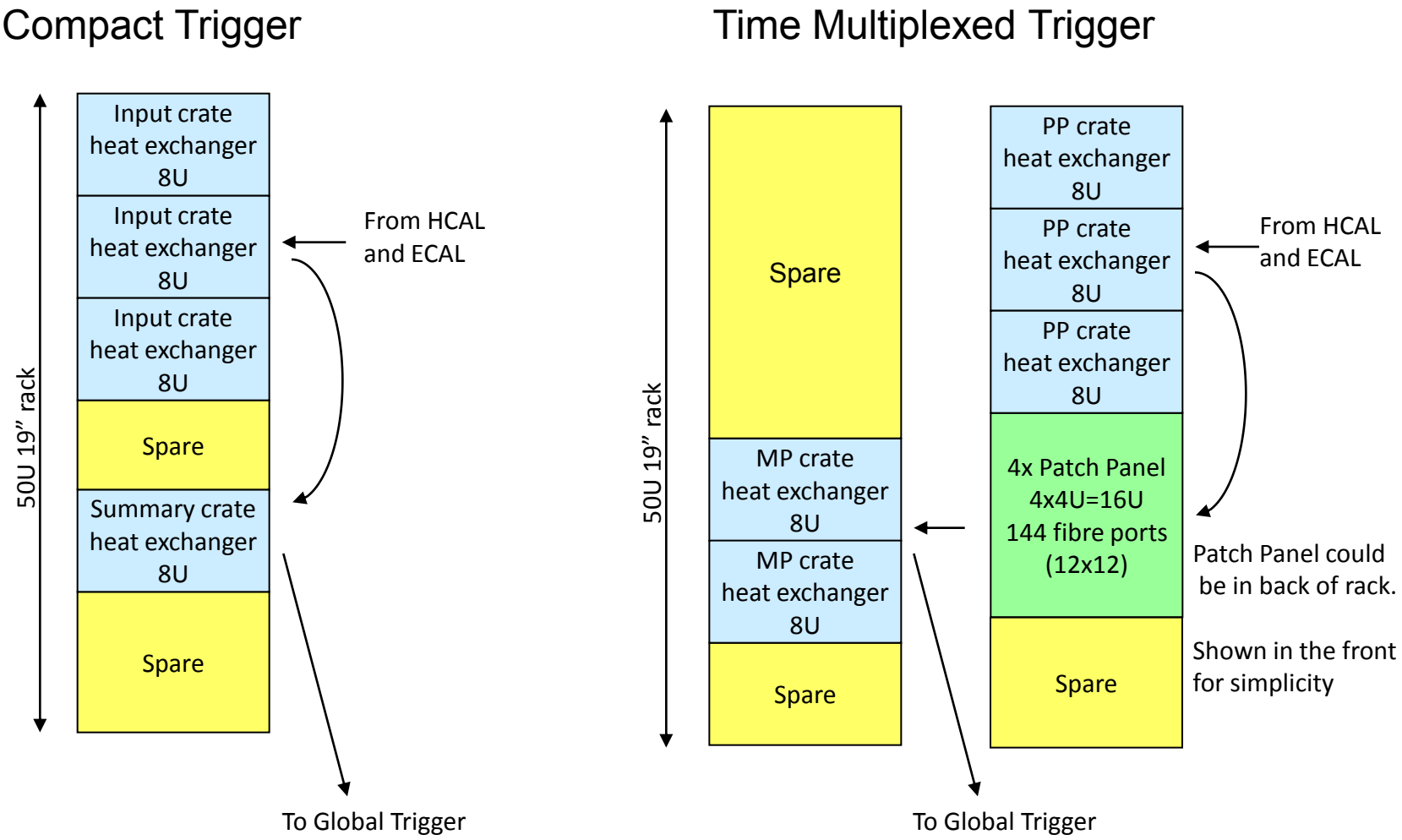
Concepts: Time Multiplexed Trigger



Max flexibility, but at increased complexity

2.4Gb/s input forces processing area to be spit over 2 FPGAs, albeit with large (8-12) tower overlap

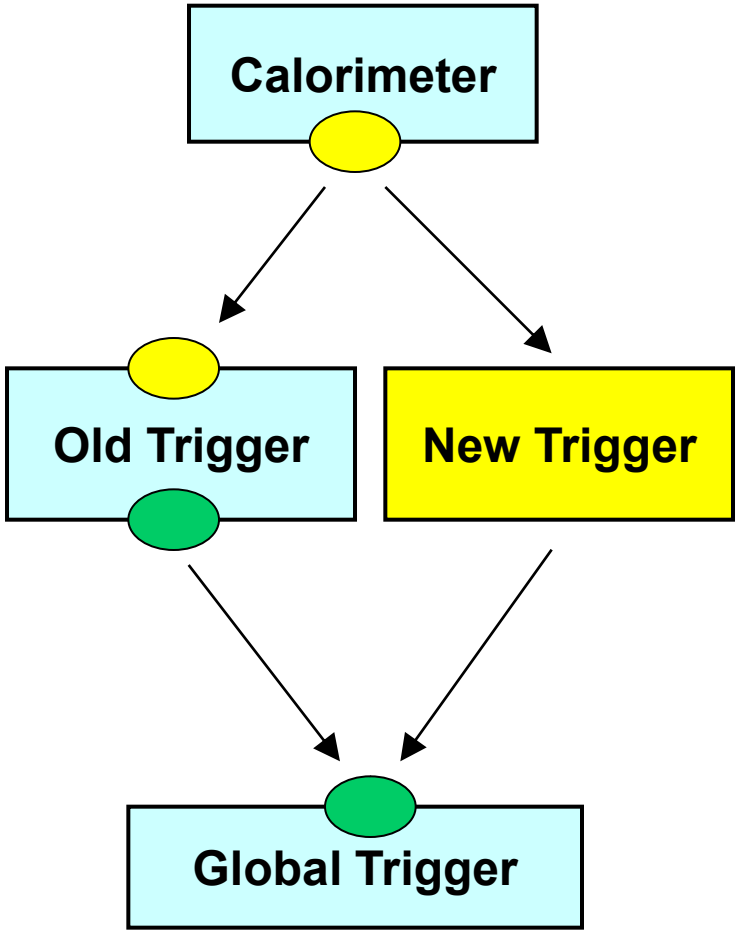
Rack Space with TPs @ 4.8 Gbps



Old system uses more than 10 racks !

Decouple Trigger Upgrade from CMS?

- Duplicate data at calorimeters
  - Extra Hardware
  - But decouples Trigger Upgrade from CMS
- Choose between 2.4Gb/s and 4.8Gb/s input links
  - Impact on CT v TMT, but also integration
  - 2.4Gb/s: Probably only duplicate part of CMS Trigger. Can debug in parallel for a long time, but final switchover fast (i.e. winter stop)
  - 4.8Gb/s: Can duplicate entire trigger but depends on availability Xilinx Kintex parts. If not available then cost increase substantial.

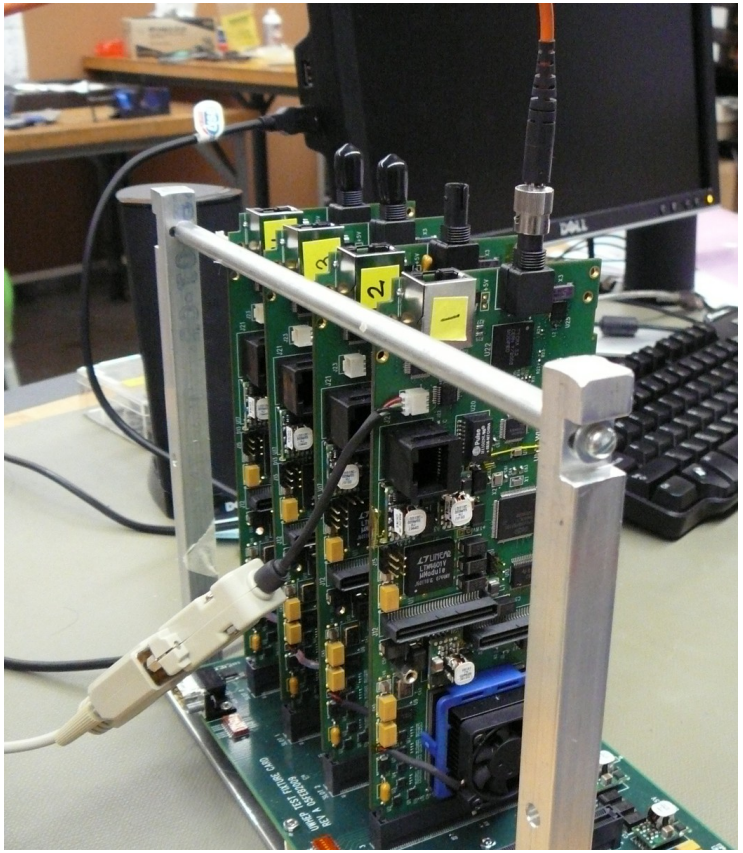


Status

- Wisconsin & Imperial examining physics cases to see if there is any physics motivation to choose one design or other at luminosity of $2x10^{34}$ with 50ns spacing

Hardware Demonstrators

Aux Card:
Demonstrating link alignment over multiple cards and serdes links.



MINI-T5 Card:
Demonstration of Electron & Tau algorithm and DAQ in Time Multiplexed Trigger

Calorimeter Trigger Infrastructure

- **IPMI Development**: Tom Gorski
  - Management Interface to AMC cards
  - Thermal & Power diagnostics
  - Distribution of IP address
    - In collaboration with Vim Beaumont

- **Ethernet Communication**: TCP/IP & UDP/IP
  - Two approaches

  - Embedded Processor for TCP/IP (Tom Gorski)
    - Based on Xilinx MicroBlaze
  - State machines for UDP/IP (Andrew Rose & Dave Newbold)
    - Based on core from Jeremy Mans

Calorimeter Trigger Infrastructure

- **SPI-over-LAN**: Tom Gorski
  - Writing Flash via TCP/IP connection over Fabric A GbE connection using a prototype server and GPIO pins implementing a serial interface (SPI)

- **Link alignment**: Tom Gorski & Greg Iles
  - Ensuring data from serdes links synchronized.

MicroHAL: What is this all about?

- xTCA has no standardized protocol for register access
- Common method to access registers
- J. Mans (CMS HCAL) proposed a packet format, **IP-Bus,** specification compatible with TCP/IP and UDP/IP
  - Also supplied firmware core
- **MicroHAL** – Advanced software layer for register access
  - **Redwood** package provides infrastructure
  - Developed by Andrew Rose

Hierarchical

- Include calls to other module files

```
<chip name="FPGA1">
  <leaf name="LEDs" address="0x0010" />
  <array count="12" spacing="0x00004000" >
    <module path="examples/algo.xml"
            name="algo"
            address="0x0000"/>
  </array>
</chip>
```

- Where examples/algo.xml contains

```
<module name="algo" mask="0x001FFFFF" >
  <branch name="module_algo">
    <leaf name="epim_lut" address="0x00000000" />
    <leaf name="ecal_lut" address="0x00000800" />
    <leaf name="hcal_lut" address="0x00001000" />
  </branch>
</module>
```

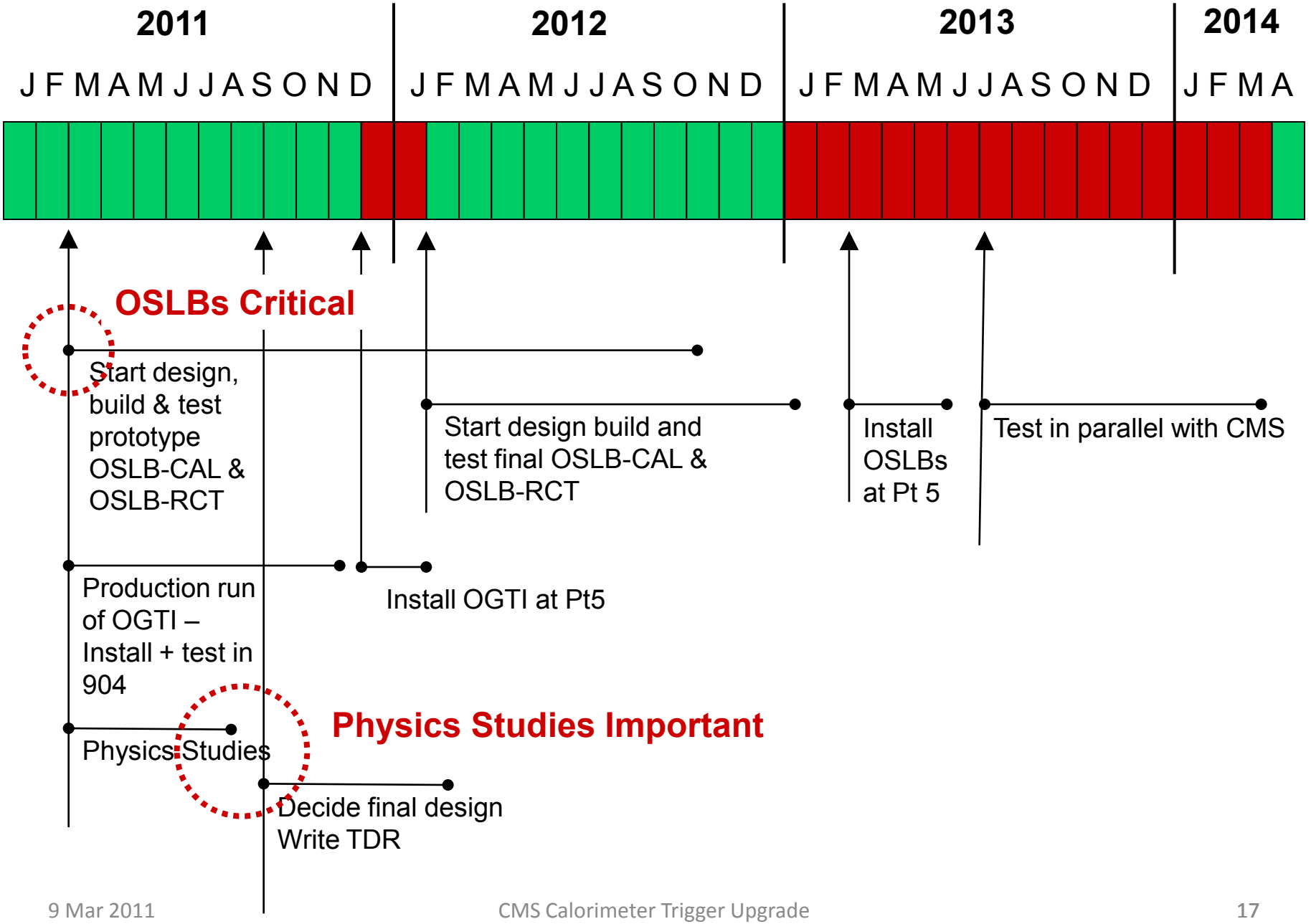
MicroHAL

- Supports all basic commands
  - e.g. Read/Write, RMW, Block Read/Write
- Automatically concatenates commands together
  - Important given IP latency
  - Commands executed sequentially by firmware or micro-processor
- Hierarchical nature
  - Allows modular design
- Scalable design
  - Uses Telecom software tools for critical parts
- PC has full knowledge of FPGA memory / registers
  - Can map onto database

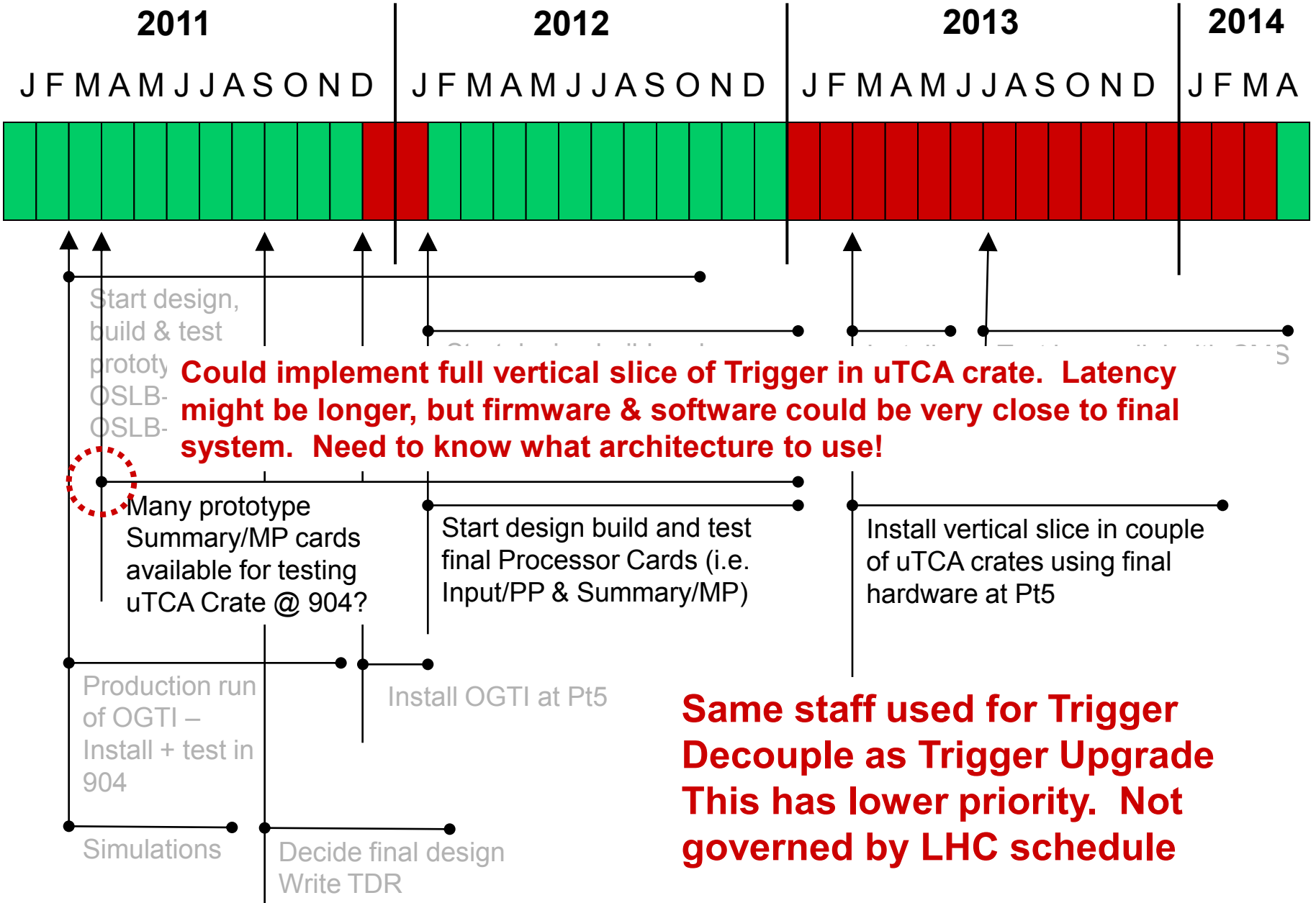
Plan to 2014

- Now have extra year until first shutdown (2013/14)
  - Opportunity to install parallel connections to at least a full RCT crate (1/18)
  - Remainder during technical stops
    - Decouples Trigger Upgrade from existing system
    - Allows Trigger Upgrade to be commissioned while LHC is running.
    - Allows upgrade to be fully verified before switchover
    - Not low cost (several $100k), but does guarantee that Trigger fully operational during critical period for CMS

Decoupling of Trigger Upgrade from ECAL/HCAL & GT



Installation of Trigger Upgrade



Links

- Compact Trigger CMS Note: CMS IN-2010/035
  http://cms.cern.ch/iCMS/jsp/openfile.jsp?type=IN&year=2010&files=IN2010_035.pdf

- Time Multiplexed CMS Note
  - http://giles.web.cern.ch/giles/publications/A_Time_Multiplexed_Trigger_for_CMS_with_Addendum.pdf

- MicroHAL
  - Project website
  - http://projects.hepforge.org/cactus/index.php
  - HepForge repository
  - http://projects.hepforge.org/cactus/trac/browser/trunk
  - Software User Manual, Instant Start Tutorials and Developers Guide
  - http://projects.hepforge.org/cactus/trac/export/148/trunk/doc/user_manual/Redwood.pdf
  - More info: Please contact Andrew Rose: andrew.rose01@imperial.ac.uk