Architecture and Implementation of the Control & Monitoring System for CMS

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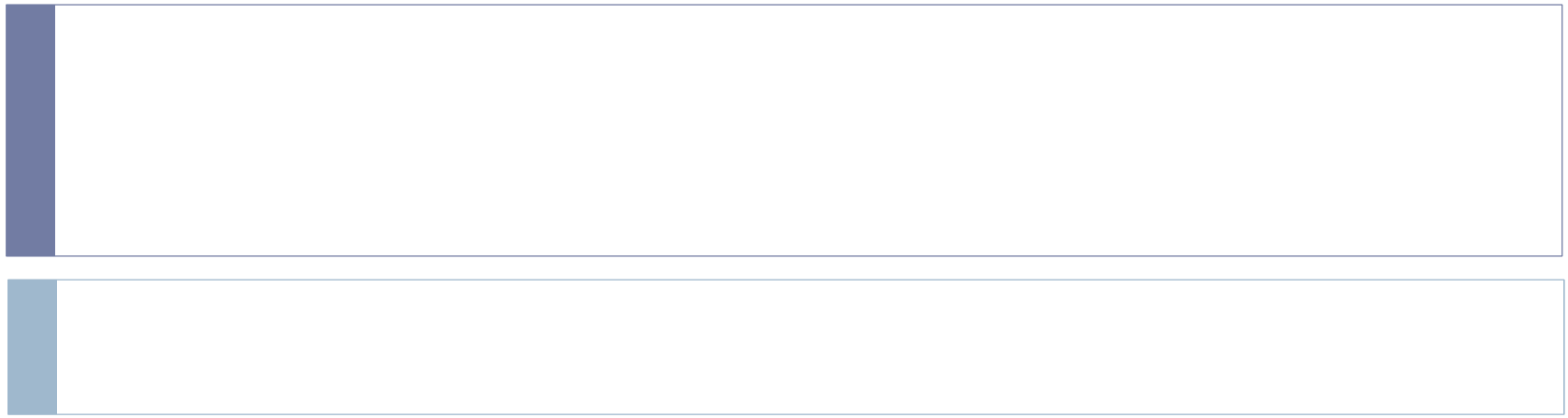
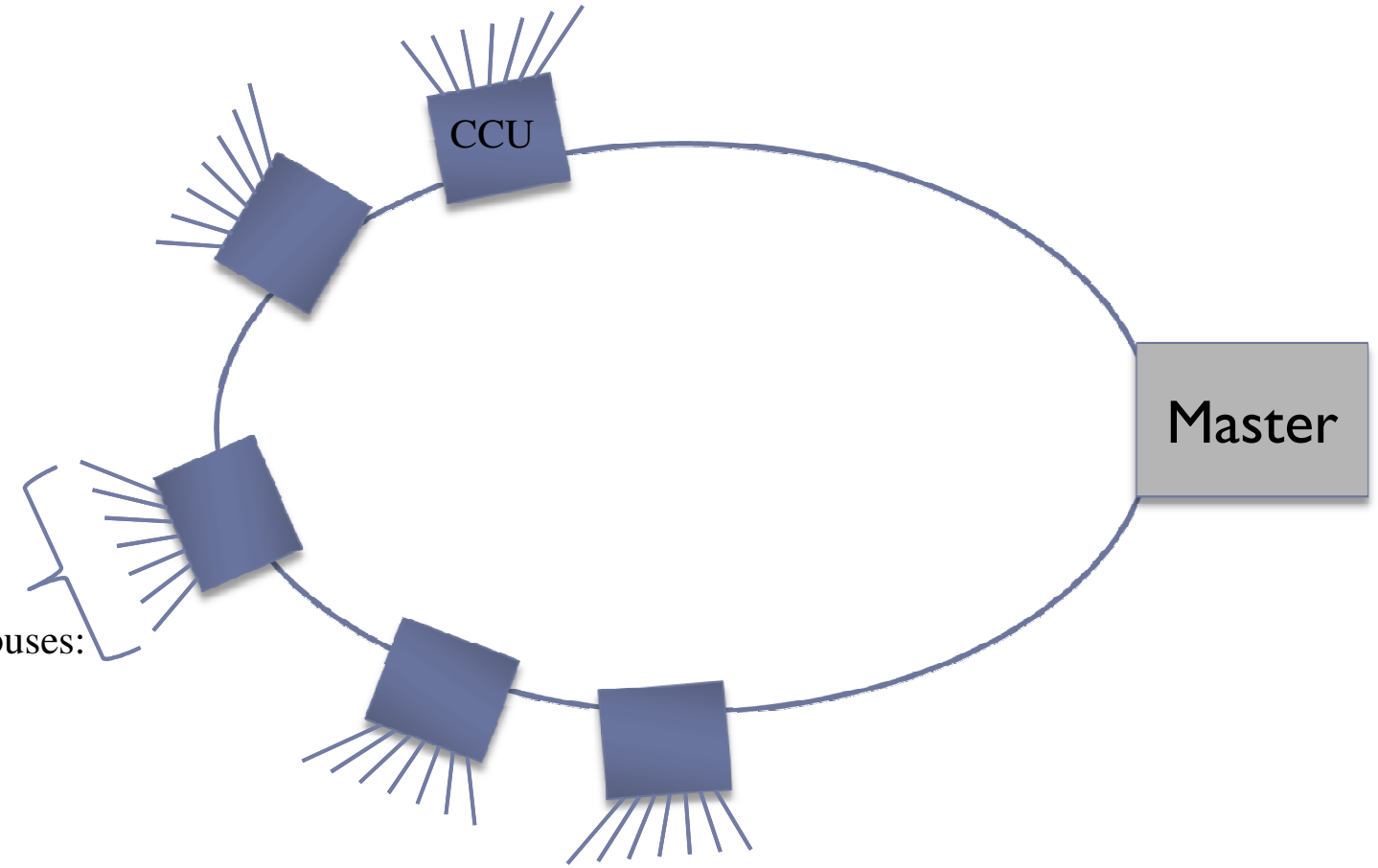


General aims for experiment control

- Provide a path for control and monitoring of front end electronics
  - Interface to general purpose local buses
    - I2C, JTAG, Parallel bus, Memory bus
  - Redundant paths to avoid loss of control
  - Long distance optical links, short range electrical
- Rad-tol and SEU robust
- Distribute critical LHC timing and trigger info
  - 40 MHz machine clock
  - 100 KHz trigger info with low latency

General Architecture: Ring Network

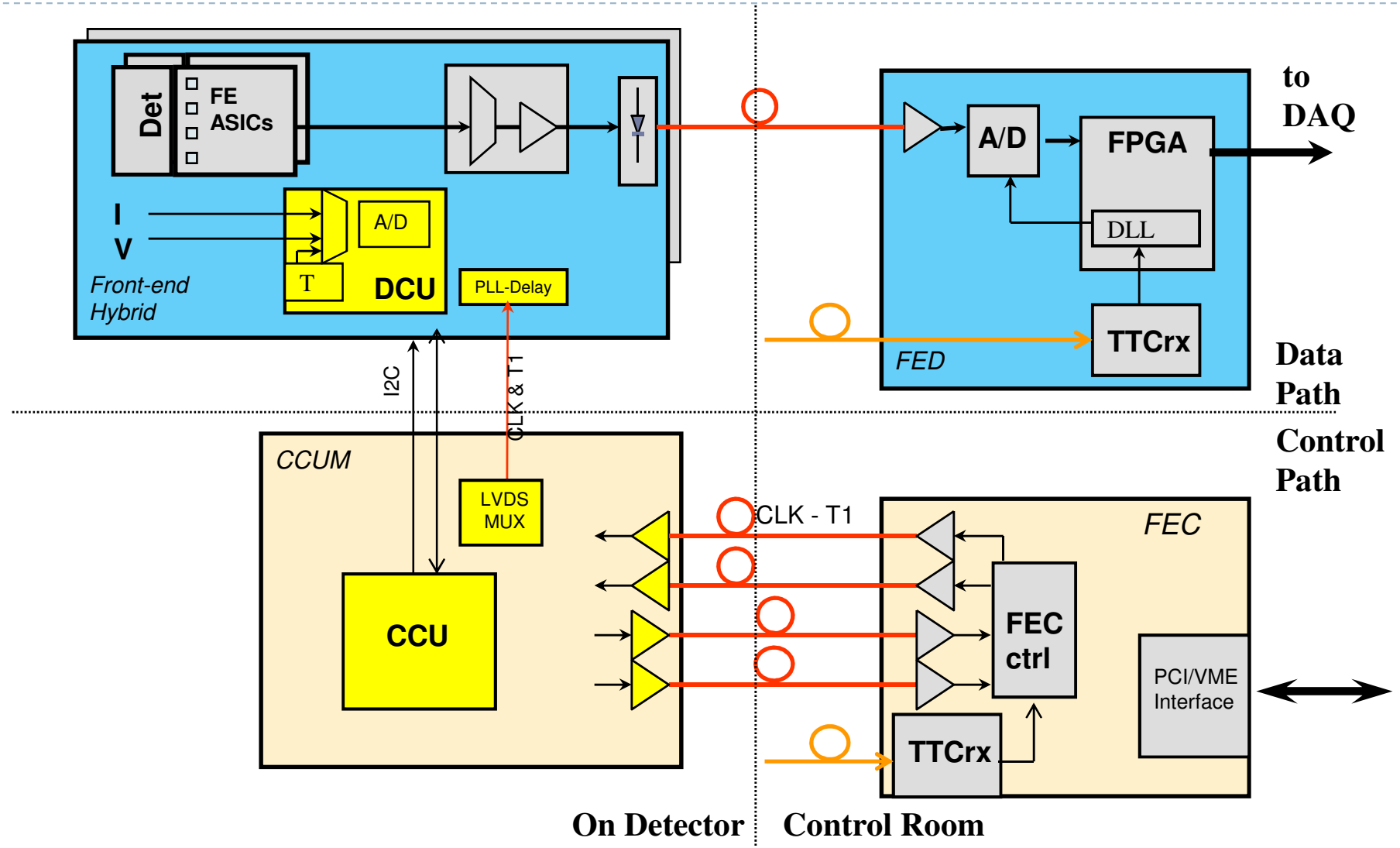


Local Control buses:
- I2C
- JTAG
- Parallel
- etc.

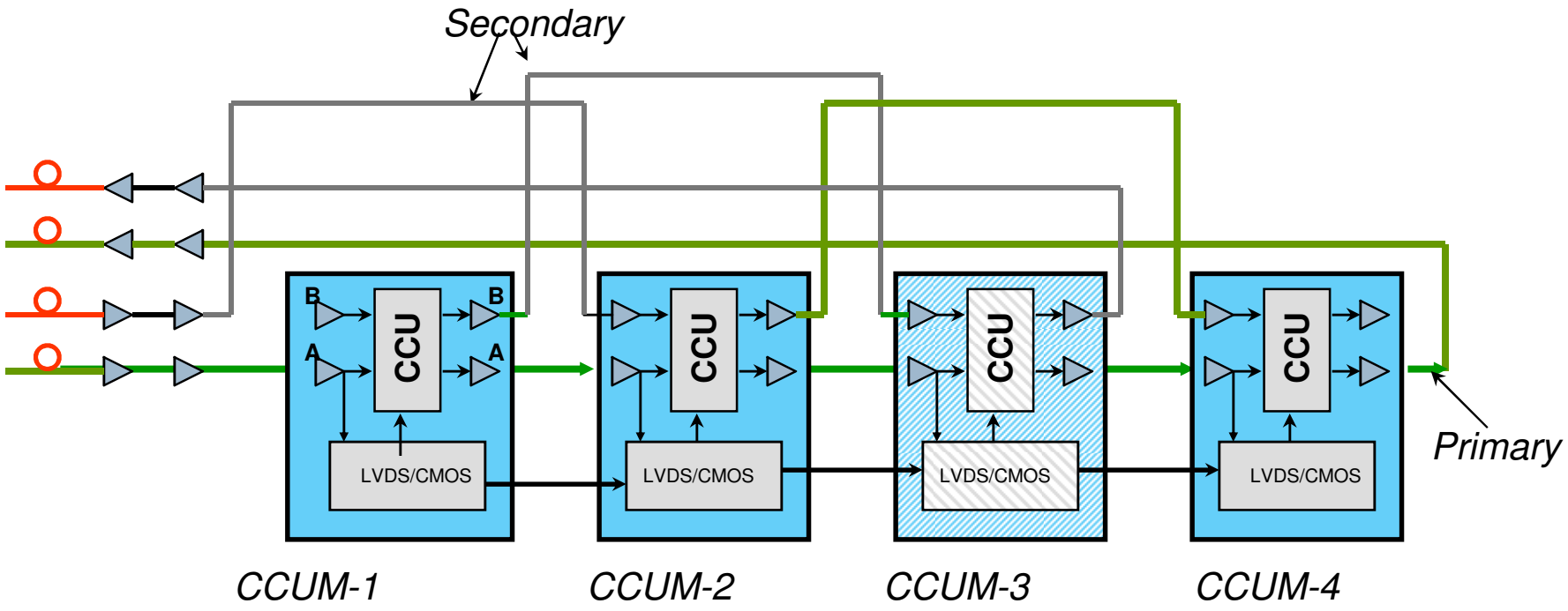
Ring Architecture

- Ring can address up to 255 CCU controllers
- Distance between master and first (and last) CCU limited only by opto-components
- Distance between pairs of embedded CCUs up to ~ 2.5 meters
- Ring can "skip" faulty CCUs as long as no two faults are adjacent

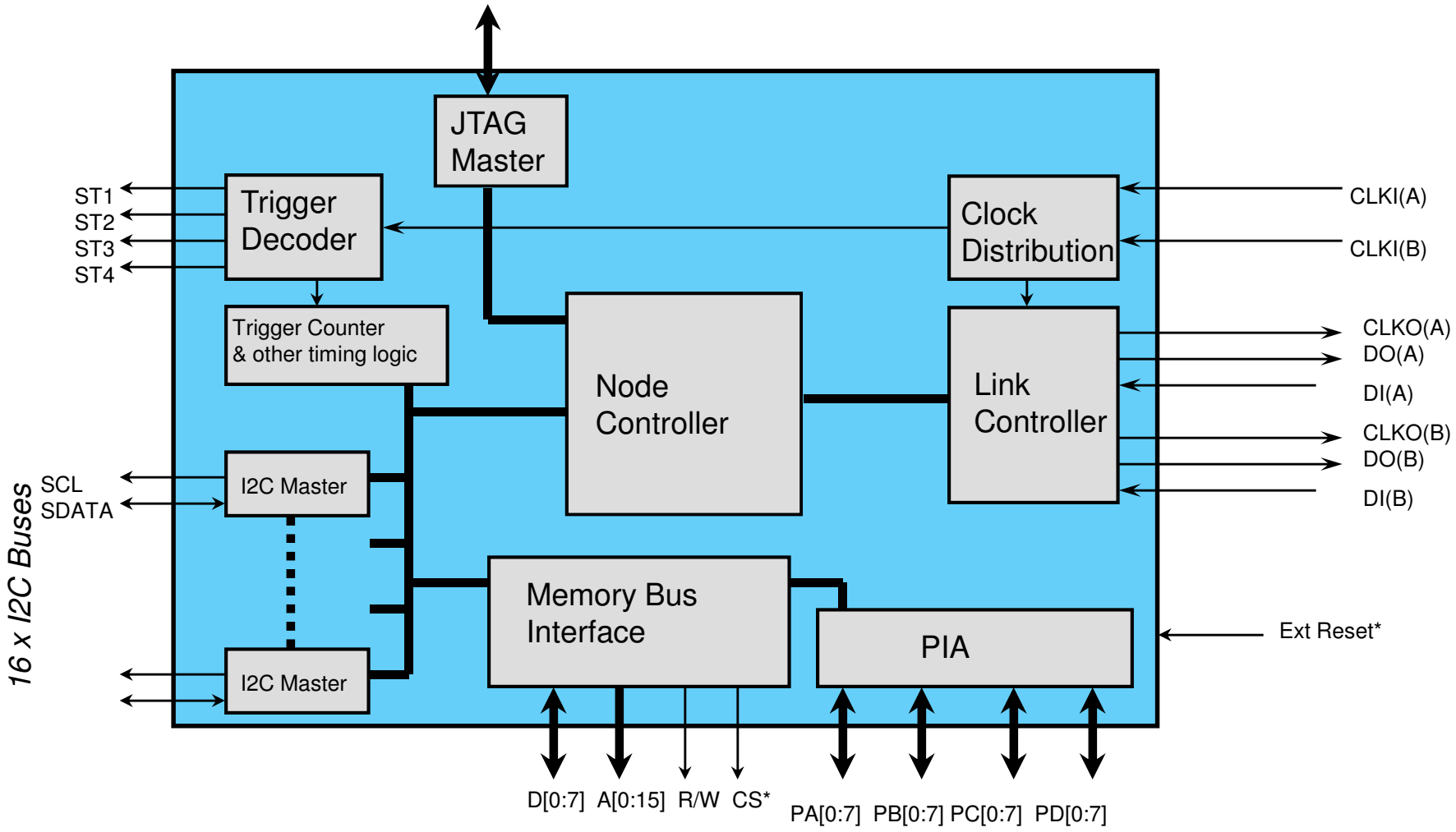
System Architecture



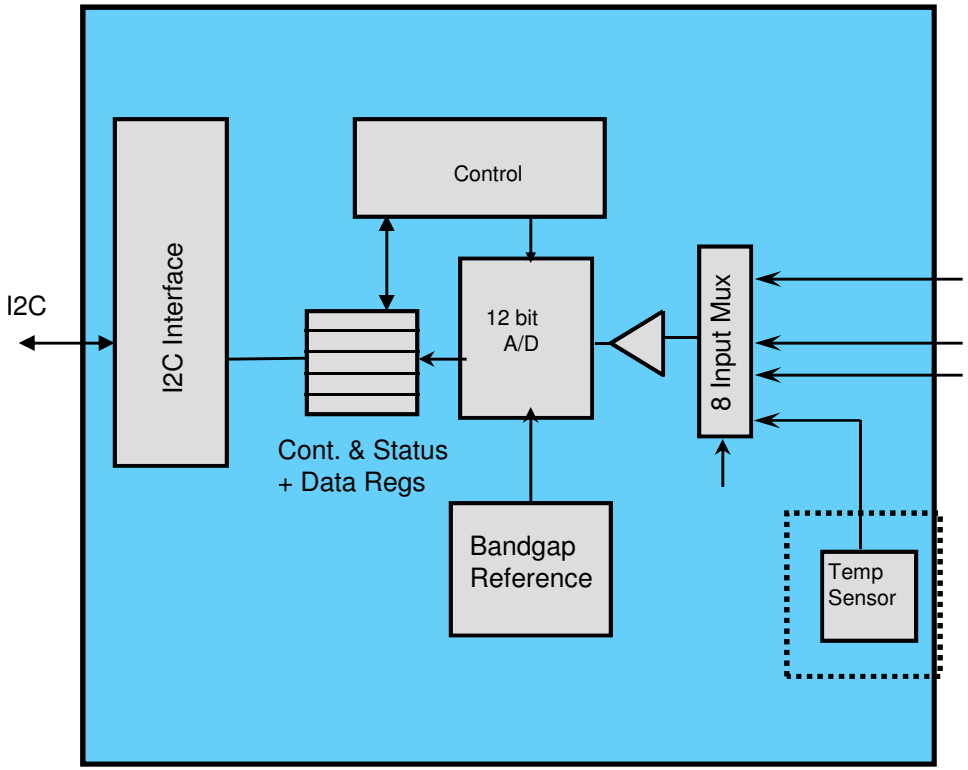
Redundancy Architecture



Network Controller:
CCU: Communication and Control Unit



Monitoring chip: the DCU



- Specifications:
  - Resolution: 12 bit
  - f_{CLK} : 40 MHz
  - Temp: -25 ÷ 50° C
  - Power: < 50 mW
  - Vin : 0 ÷ 2.5 V in two ranges
  - Requires in-system calibration
  - Conversion time: ~ 1 ms
  - Single 2.5 V V_{DD}
  - 24 pin QFN

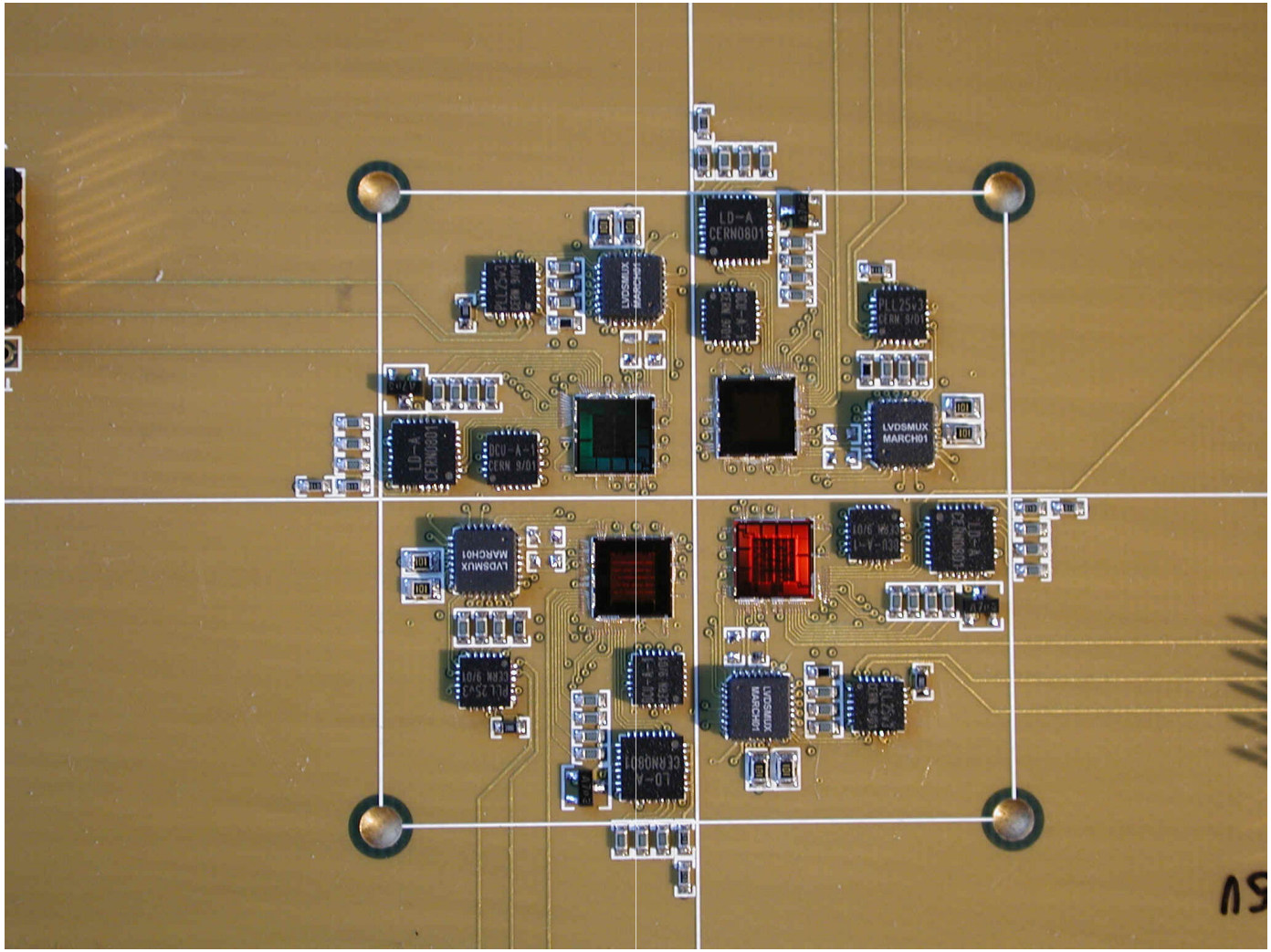
Implementation details

- The CCU (and all auxiliary chips) are implemented in 0.25 micron CMOS rad-tol (by design) technology.
- Triple module redundancy is used for SEU robustness

- Power consumption:
  - CCU: < 400 mW
  - DCU: 50 mW
- Single 2.5 V supply
- No interface voltage higher than 2.5V is allowed!

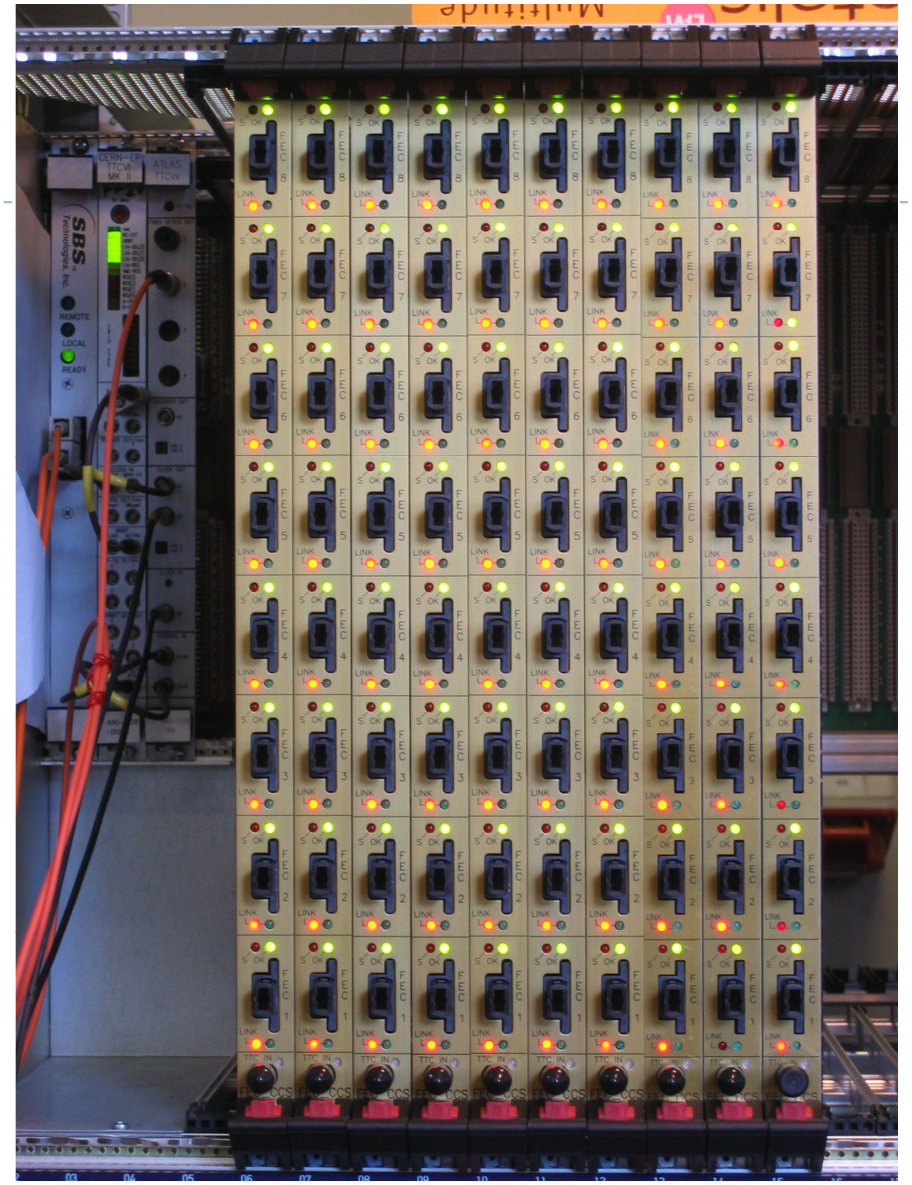
- Ring path redundancy is obtained architecturally

Rad-Test of Control Chips



CCU in CMS

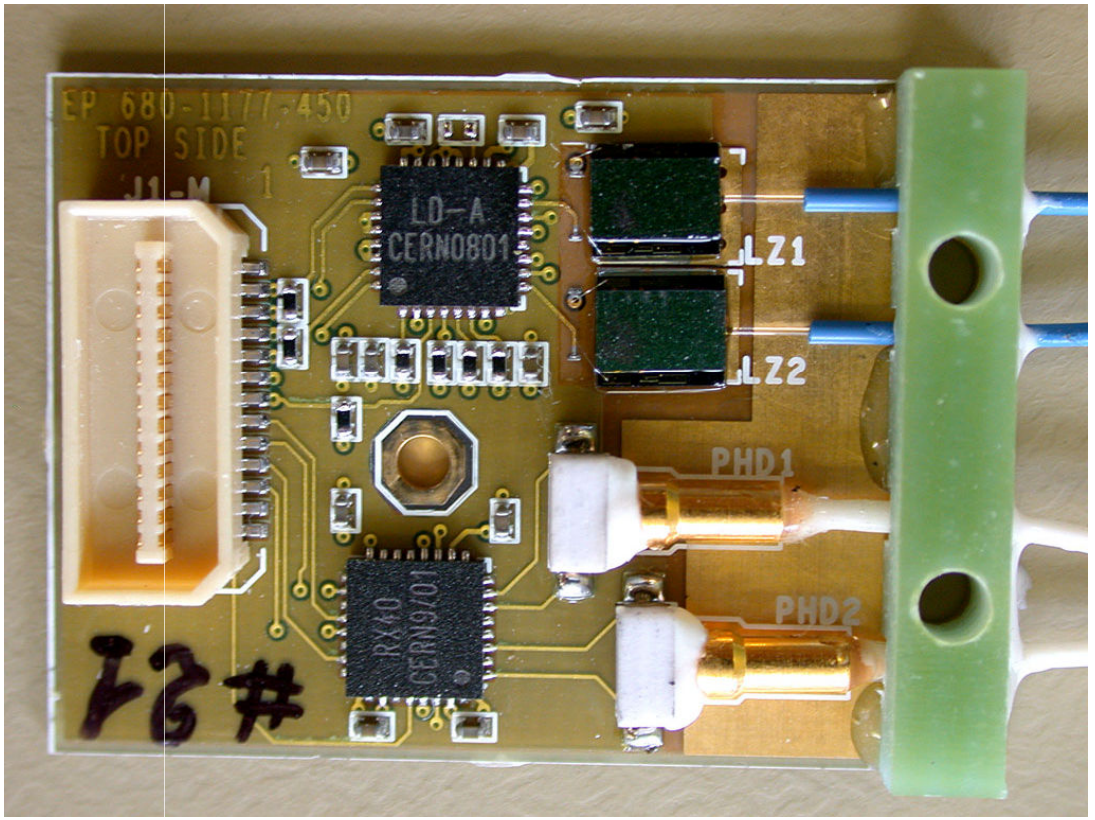
Network node in system



FEC Master in counting room

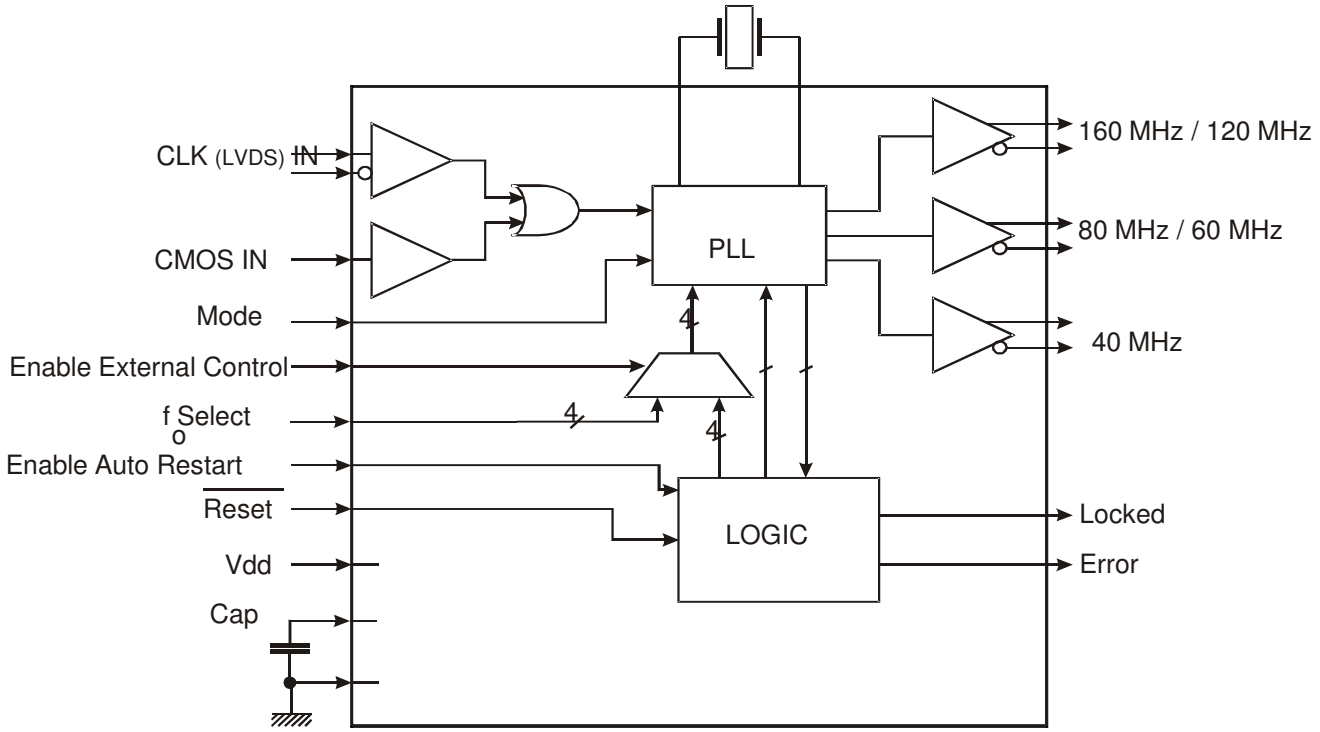
Long-distance opto-links links used

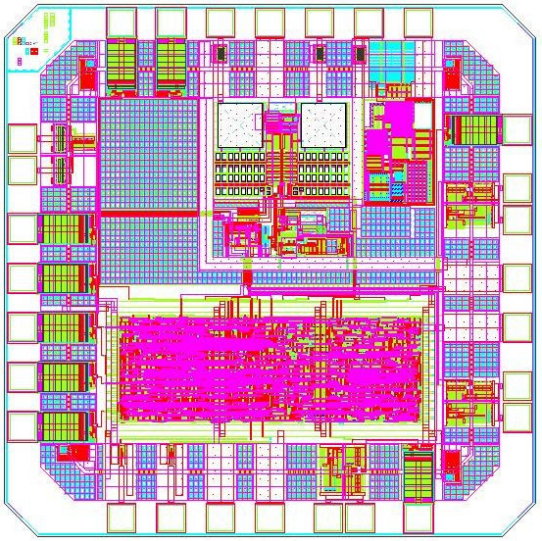
- Distance
  - 100 m (and more)
- Two pairs for separate CLK & Data
- Rad-Tolerant components
  - Driver and Receiver
- Small form factor
- LVDS electrical interface
- 2.5V Supply



QPLL

Very low jitter timing produced by additional QPLL chip





Quantities and costs in CMS

- The Tracker, Pixel, e-Cal and Preshower detectors use about 50,000 control chips, organized in several hundred rings
- About 50 FEC cards in VME-9U cards (8 rings max each) to control the tracker

- Chip designs and development: ~700K
- Manpower: 2-5 man-years per chip
- Manufacturing cost from CCU: ~10 CHF/piece
- Additional chips:
  - PLL, DCU, LVDSMUX: < 5 CHF/piece in quantities > 50K

Software

- Developing software for these components in the end required an effort larger than the development of the HW!
- Integration in a robust slow control (software) system has been a major project which has demanded a very large effort and will have to be adapted to the specific needs of any new applications/environment.

Summary

- Rad-tol requirements have been the main driver for the design of the CMS control system
- Harmonization of control system in CMS is obtained by using mostly one single control system
- Decision in CMS was not to have programmable processors embedded
  - This was considered too risky, but it could be reconsidered in a lower radiation environment
- Several hundred control rings are installed since 2003 in CMS and thousand of work-hours have been accumulated successfully.