CSC Data Rates, Formats and Calibration Methods

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With most information collected from the
The Ohio State University

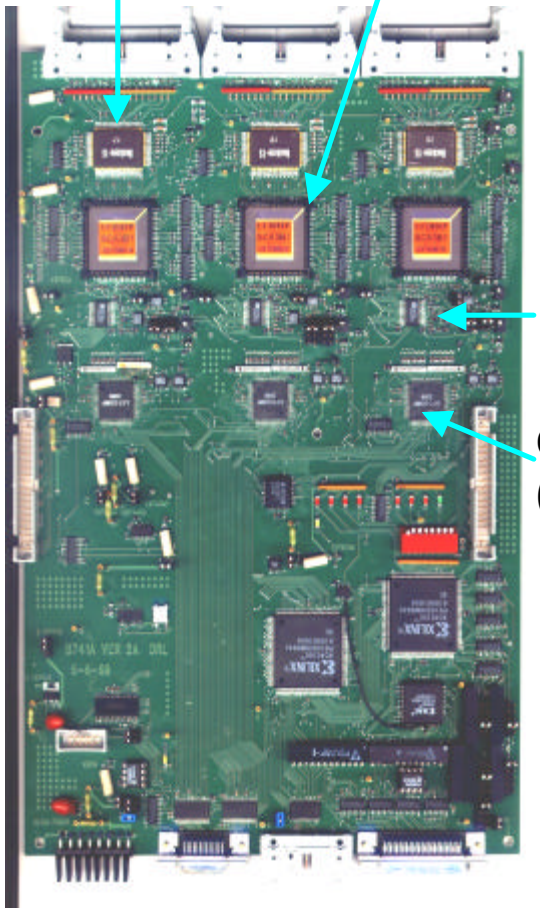
PRS March Milestones

1. **Determination of calibration methods and samples** ←
2. **Data rates, data formats, online clustering** ←
3. **CPU analysis for low-luminosity selection**

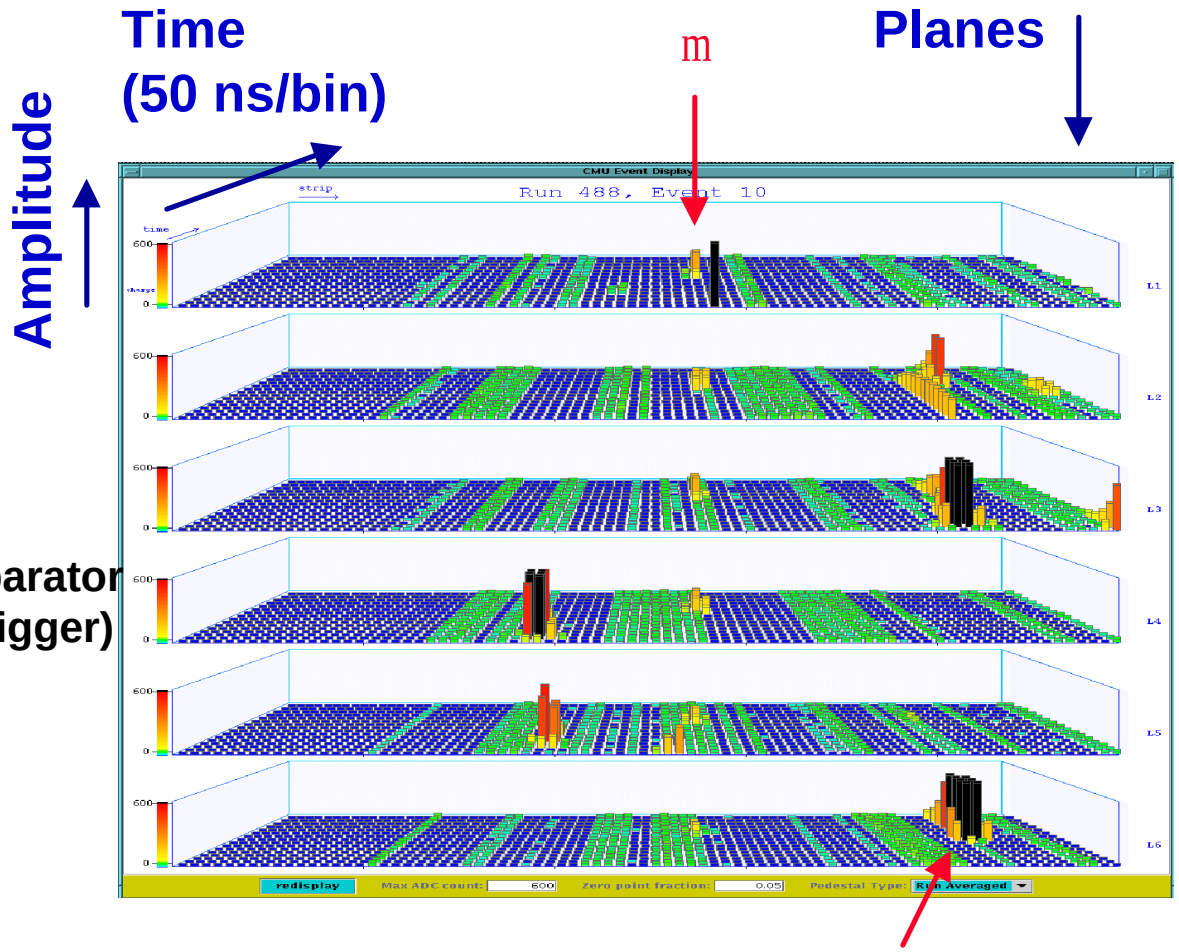
Overview of CSC DAQ

- The CSC system has 540 chambers and 0.5 million electronic channels
- The pulses from the anode wire groups are discriminated, and the digital information is read out with the trigger data
- The pulses from the cathode strips are sampled and stored in an analog memory (switched capacitor array) every 50 ns. They are also discriminated and sent into a comparator network for the trigger.
- Digitization occurs *only* if there is a L1 accept *and* if there was a local charged track (LCT) segment in the chamber
  - LCT is used to select a "region of interest" in order to reduce the DAQ bandwidth
  - 12-bit ADC for digitization (2 byte word)
- 8 or 16 time samples are read out over a region 16 strips wide by 6 layers deep (96 channels × 8–16 samples)

CSC Cathode Electronic Readout



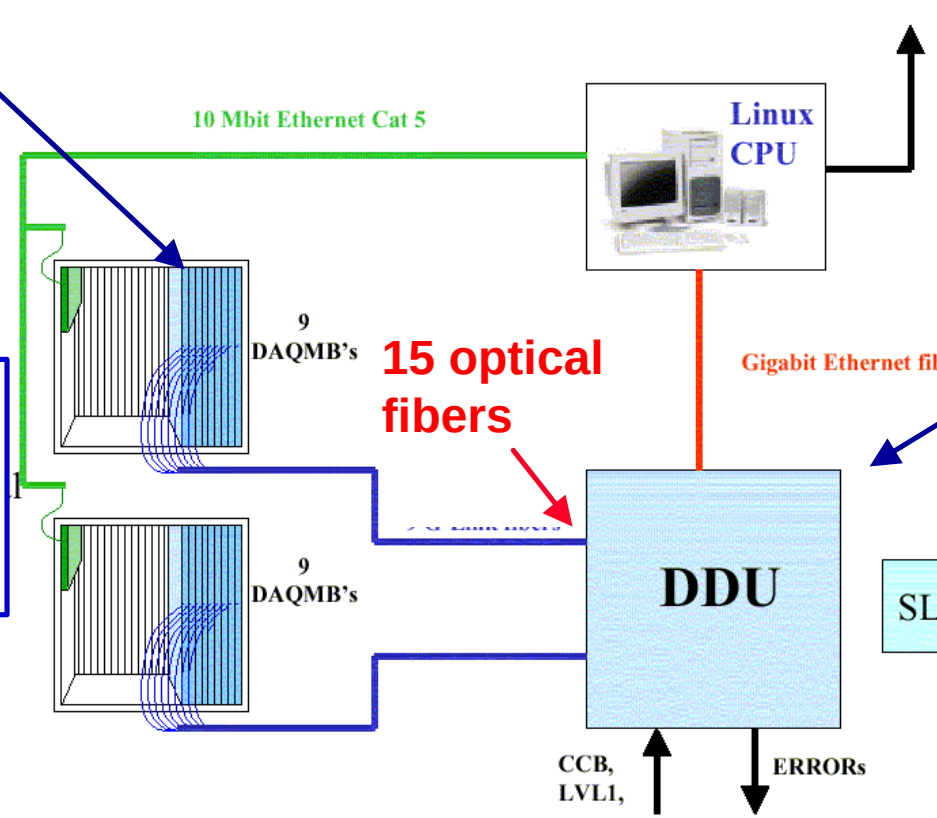
CFEB



CSC DAQ Path

1 DAQMB serves up to 5 CFEBs » 1 CSC

15 DAQMBs grouped into 20° sector (ME1–ME4)



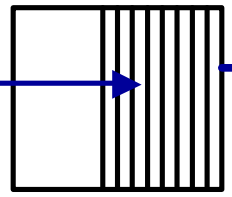
Standalone DAQ ~18 rack-mounted PCs

CSC DDU aka "FED"

DCC

SLINK

Sector Processors send L1 data



12 optical fibers

DDU

SLINK + 1

6–9 Data Concentrator Cards

CSC Data Format

Current data format includes cathode amplitude data, cathode comparator data, anode discriminator data, LCT data

- http://www.physics.ohio-state.edu/~gilmore/cms/DDUformat.html

Total data size per triggered CSC chamber (~1.5 CFEBs)

- 16 time samples (32 BX): 5400 bytes
- 8 time samples (16 BX): 3000 bytes

The event size for a single muon crossing 4 stations is 4 times larger

Average event size of a min bias collision is smaller

Bandwidth = Occupancy * L1A rate * Event Size

Overhead due to S-Link-64 Headers and Empty-Events

- L1A Rate * 16 bytes/DDU * 36 DDUs = 57.6 MB/s @ 100 kHz
- DCC lowers overhead even more (factor 4 to 6)

Estimate of CSC Data Rates

Assumptions:

- Basis of estimate is the calculated DAQ data rate from the Front-End Drivers (FEDs) of the CSC system
- Assume that the occupancy of the muon system for a typical L1 triggered event is the *same* as that for a min bias event
  - Could be higher if L1 triggers are enriched in muons
- Assume that at LHC start-up, $L = 2 \times 10^{33}$ and that L1 input rate to the DAQ is 50 kHz. Also assume no ME 4/2
- Assume that at high-lumi, $L = 10^{34}$ and the L1 input rate to DAQ is 100 kHz. Include ME 4/2

Calculation of CSC Rates

J. Gilmore estimated the LCT occupancy per BX using the *L1CSCTrigger* package by UCLA applied to an unweighted min bias sample

Final numbers still need to be updated once the CMS Note on LCT trigger rates, in preparation by UCLA, is released

Web page prepared with CSC Data rates:

- **http://www.physics.ohio-state.edu/~gilmore/cms/CSC_Occupancy2001.html**

CSC Data Rate Estimates

CSC Occupancy for LCTs per LHC Bunch

Preliminary Results based on 50,000 bunch crossings in full ORCA simulation

- Best-estimate algorithms as of September 2001
- 17 minimum bias events per crossing

L=10^{34}
100 kHz DAQ

- **First possibility: assume that only CLCT coincidence required with L1A** (16-time samples unless noted)

CSC per BX Occupancy for CLCT-only trigger	1 BX only	3 * 1 BX Result: for +/-1 BX	EMU Data Bandwidth	# Readout SLINKs Needed
No Neutrons	0.6	1.8	1070 MB/sec	6
Add Neutrons, all CSCs	1.2	3.6	2040 MB/sec	12
Add Neutrons, but no ME4/2	0.9	2.7	1560 MB/sec	9
Add **3*Neutrons**, all CSCs (imposed safety factor)	2.4	7.2	4000 MB/sec	23 [36]
Add **3*Neutrons**, but no ME4/2 (safety factor)	1.5	4.5	2530 MB/sec	15 [18]

±1 BX window on LCT requirement

CSC Data Rate Estimates (2)

- **Second possibility: assume that ALCT.and.CLCT required with L1A** (16-time samples unless noted)

CSC per BX Occupancy for ALCT+CLCT trigger	1 BX only	3 * 1 BX Result: for +/-1 BX	EMU Data Bandwidth	# Readout SLINKs Needed
No Neutrons	0.6	1.8	1070 MB/sec	6
Add Neutrons, all CSCs	0.7	2.1	1230 MB/sec	7 [9]
Add Neutrons, but no ME4/2	0.65	2.0	1180 MB/sec	7 [9]
Add Neutrons, all CSCs: **8-time samples**	0.7	2.1	730 MB/sec	5 [6]
Add Neutrons, but no ME4/2: **8-time samples**	0.65	2.0	700 MB/sec	4 [6]
Add **3*Neutrons**, all CSCs (imposed safety factor)	0.9	2.7	1560 MB/sec	9
Add **3*Neutrons**, but no ME4/2 (safety factor)	0.75	2.2	1280 MB/sec	8 [9]
Add **5*Neutrons**, all CSCs (imposed safety factor)	1.1	3.3	1880 MB/sec	11 [12]
Add **5*Neutrons**, but no ME4/2 (safety factor)	0.85	2.6	1500 MB/sec	9
Add **5*Neutrons**, all CSCs: **8-time samples**	1.1	3.3	1090 MB/sec	6
Add **5*Neutrons**, but no ME4/2: **8-time samples**	0.85	2.6	880 MB/sec	5 [6]

Summary of CSC rates

Low Lumi (2×10^{33}):

- 50 kHz DAQ, ME4 staged, 16 time samples, CLCT selection
- 200 MB/s (300 MB/s with 3× safety factor on neutrons)

High Lumi (10^{34}):

- 100 kHz DAQ, ME4, 8 time samples, ALCT*CLCT selection
- 700 MB/s (1000 MB/s with 3× safety factor on neutrons)

Heavy-Ions:

- Having attended a CMS Workshop on H.I., I estimated that the muon occupancy per min bias collision is ~20X higher in Pb-Pb than pp.
- Total hadronic rate in Pb-Pb is:
  - Rate = σ L = (8 b)(10^{27} $cm^{-2}s^{-1}$) = 8 kHz
- So even if every collision is accepted by L1, the data rate would be no more than 50% greater than pp collisions at 10^{34}

Calibration

Need to pulse anodes and cathodes:

- Find dead channels (very quick)
- Measure fC-to-ADC count conversion and linearity (cathodes)
- Measure cross-talk
- Determine comparator and discriminator thresholds
- Measure analog and digital noise
- Determine offsets to comparators (cathode trigger)
- Inject known patterns to check LCT logic

Calibration Methods

Cathodes

- Inject charge into one CFEB channel, read out all 96 channels
- Data volume per pulse:
  - 1 CFEB readout = 96 channels ´ 8 time samples ´ 2 bytes = 1536 bytes
  - Entire CSC system done in parallel (2268 CFEBs)
    - 3.5 MB per pulse
- Pulse rate:
  - 60–200 Hz since CSC DAQ bandwidth will be 200–700 MB/s
- Estimate of data volume for full calibration
  - 3.5 MB/pulse ´ 8 DAC levels ´ 96 channels ´ 100 events
  - ~300 GB
- Expect a full calibration to take 10–20 minutes
- Can use standalone DAQ system to collect data
- Calibration constants checked periodically (weekly? monthly?)
- Some tests require no beams, others could be during fills

Calibration Methods (2)

Anodes

- Pulse wire group channels
- Smaller amount of data than cathodes
  - 1 bit versus 2 bytes, since only have discriminator data

Special Triggers

Calibration data is not planned to be taken during normal collision running (i.e. during abort gaps)

- May want noise measurements with beam on, though

Time synchronization necessary during commissioning

- Histogram time distribution of ALCT triggers, look for LHC gap structure
- Significant amount of running during commissioning, but should be fixed once normal operation begins

Accelerator muon triggers (i.e. “tunnel” or “halo” muons)

- CSC Track-Finder (and GMT) will have the ability to trigger on muons traveling parallel to the beam axis during normal running
- Should be useful for in-situ alignment studies of chambers
- Amount of data needed not known, should not greatly perturb normal data rates

Special loose triggers (heavily prescaled)

- Single layer trigger to measure LCT efficiency
- Single station trigger to measure CSC Track-Finder efficiency and to collect sample of collision muons for alignment studies

Summary

- CSC data format is basically finalized since production of front-end electronics has started, and prototype FED exists
- Calibration and test procedures are being finalized at Final Assembly and Test (FAST) sites