Endcap Muon Alignment System

The *Endcap Muon Alignment System is* based on the need to locate each of the 360 Endcap cathode strip chambers (CSC) with respect to the CMS Tracking System with an accuracy ~200 µm. It is part of the overall Muon Alignment effort, which also includes the *Barrel Muon Alignment System* and the *Link Alignment System.*

The *Barrel Muon Alignment System* is built around a rigid and dimensionally stable lattice works called MABs (Module for Alignment of Barrel). There are 6 MABs attached to the barrel yoke at each end of the barrel, 60 degrees apart in phi. These outer MAB positions are defined in the CMS tracker coordinate system by the Link Alignment System.

The *Link Alignment System* will monitor the position of the central Tracker using laser sources and transparent 2D CMOS CCD sensors. Each Link system ϕ plane is defined by measurement of three points in the tracker (via the Link laser and sensors) plus laser levels. This plane is then turned and projected onto two MAB sensors. With these point measurements, MAB laser levels and MAB calibration, the positions of the outer MABs are defined in the Central Tracker system.

The *Endcap Muon Alignment System* utilizes 2D CCD optical Transfer Line reference sensors mounted on these MABs to define six cross hair laser lines which transit across all of CMS from one Endcap to the other. These sensors are our fiducials for position definition in the Tracker system. Laser sources on each end of these Transfer lines operate alternately to provide a total of twelve lines of alignment reference. The system relies on the MABs position and rigidity to align the CSCs in phi, R and Z **(Figure 1)**.

The Endcap Muon Alignment System utilizes an optical sensor composed of four linear CCDs (2048 pixels) in a picture frame configuration to sense the position of two crossed lines of laser light passing through the sensor. These CCDs are perpendicular to and rotated ninety degrees from the laser lines. Through the use of a tapered roof reflector, optical attenuator windows, diffuser and background optical filter; the sensor is capable of detecting laser cross lines from two opposing directions. This provides position measurement from two directions. The readout of the sensor is controlled by a DSP which scans in the double sampling CCD pixel data, stores digital conversions, stores and makes background subtraction to the data, and generates fits to the digital data spectra (means, rms). The system transmits the data (LVDS in CSC region) finally through a sequence of one or more Interface boards onto a RS422 data-control line to a server and host. This system is called DCOPS; digital CCD optical position sensor **(Figure 2)**.

The Endcap Muon Alignment System will use the 2D CCD optical sensors attached to the MABs to define twelve Transfer Optical lasers cross hair lines across CMS. The derived Transfer cross hair laser lines will locate endpoint 2D CCD optical Transfer sensors and mechanical Transfer plates on all Endcap Iron discs. See Figure 1.

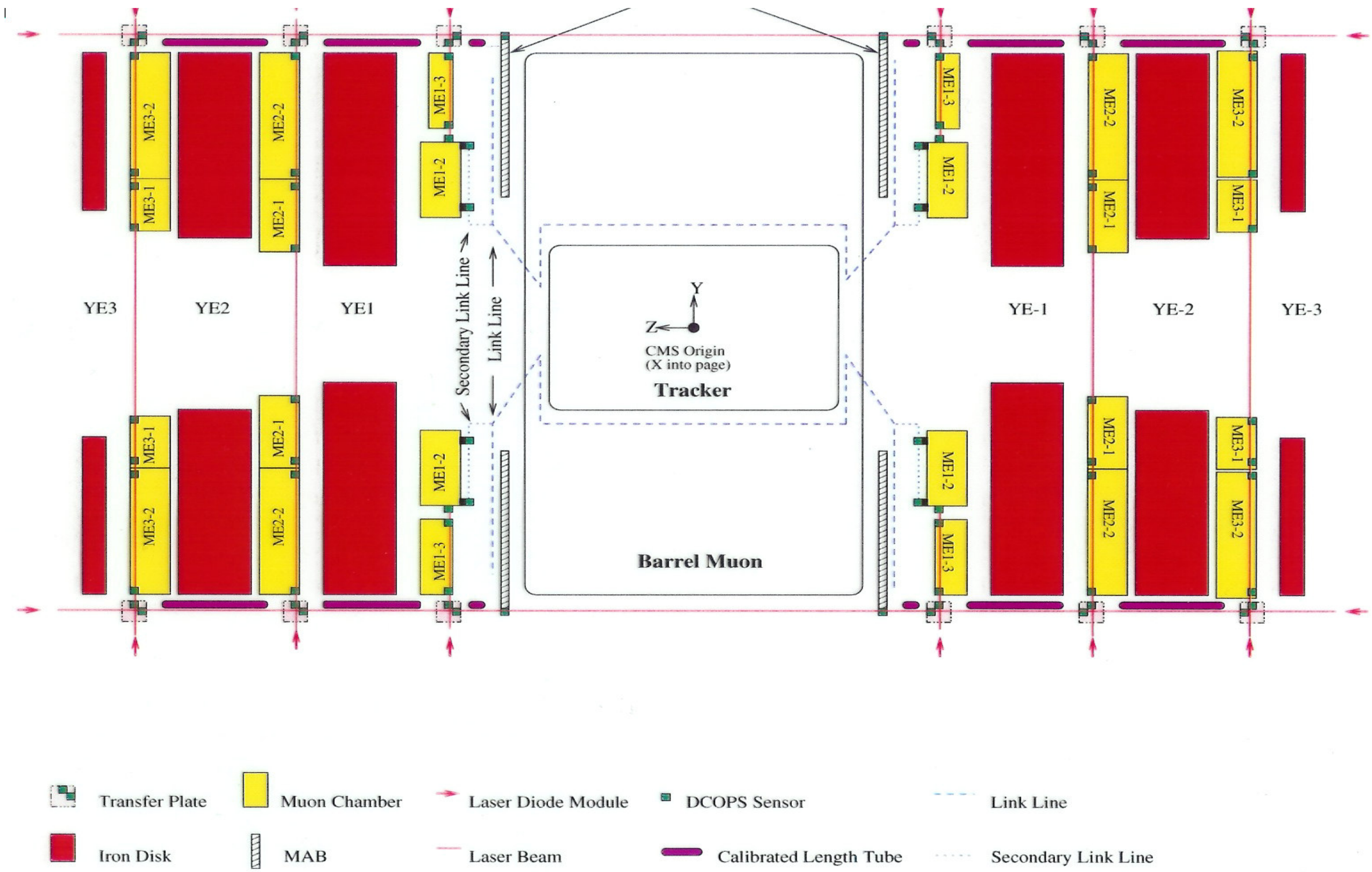

Figure 1

SECTION VIEW OF EMPMS TRANSFER LINE AND SLM LINE CONNECTION OF CSC LAYERS

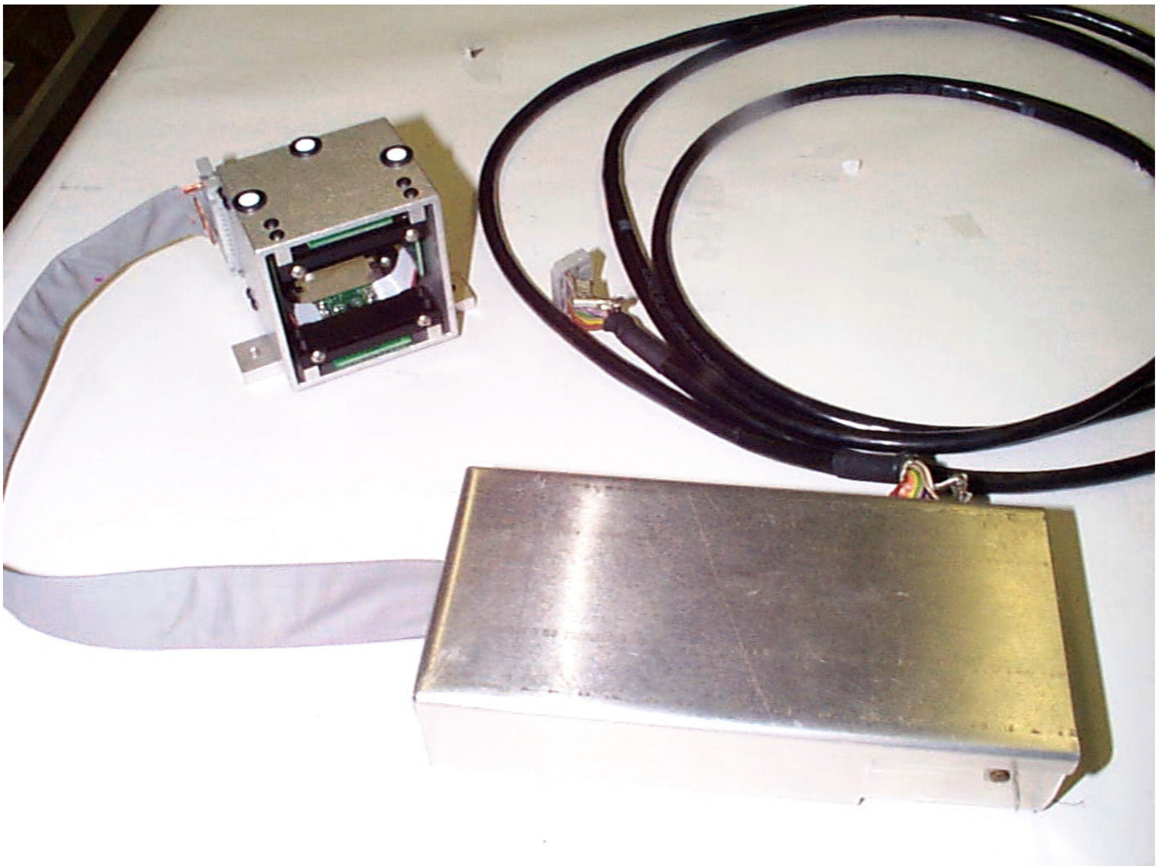

Figure 2. CCD Optical Position Sensor and Digital Readout (DCOPS)

The Transfer plates for each CSC layer define the positions of six 2D CCD optical Reference Sensors for CSC layer laser cross hair Straight Line Monitors at the periphery of the Endcap discs. The six Reference sensors are used in opposing pairs to define three laser lines across the CSC layers. These are the Straight Line Monitors (SLM). Each line is actually two sets of cross hair lines generated by lasers at the two opposing ends of the lines. A pair of 2D CCD optical sensors mounted on CSCs under these laser lines are used to define the axis of the active area of the cathode strips in these CSCs. Two lasers provide redundant measurement and fitting of sensor positions to these lines (**Figure 3**).

The same 2D digital CCD optical position sensors and electronics (DCOPS) are used in both the Transfer lines and CSC layer Straight line monitors. The configuration (lasers, optical filters, and sensor apertures) is custom to each to allow a distributed string of sensors to detect the same diffusing crosshair laser lines.

There is a second, parallel Analog sensor system made up of mostly passive DC sensors readout by commercial DAQ into the same serial servers and host (**Figure 4**). These electrical-mechanical analog sensors (laser distance meters, inclinometers, rulers, potentiometers) are used to establish the R and Z reference positions. Temperature measurements are also made in this system. The temperature sensors, laser distance meter, wire extension potentiometer, and spring loaded potentiometer are all off-the-shelf items. The Analog system includes a simple Analog Interface, a Proximity Interface, and Temperature Conversion board. These provide Reference local low voltage and multiplexing of sensors into collective readout cables into DAQ. The Temperature Conversion board is a trimmed voltage divider at the DAQ which converts the T sensor current into voltage.

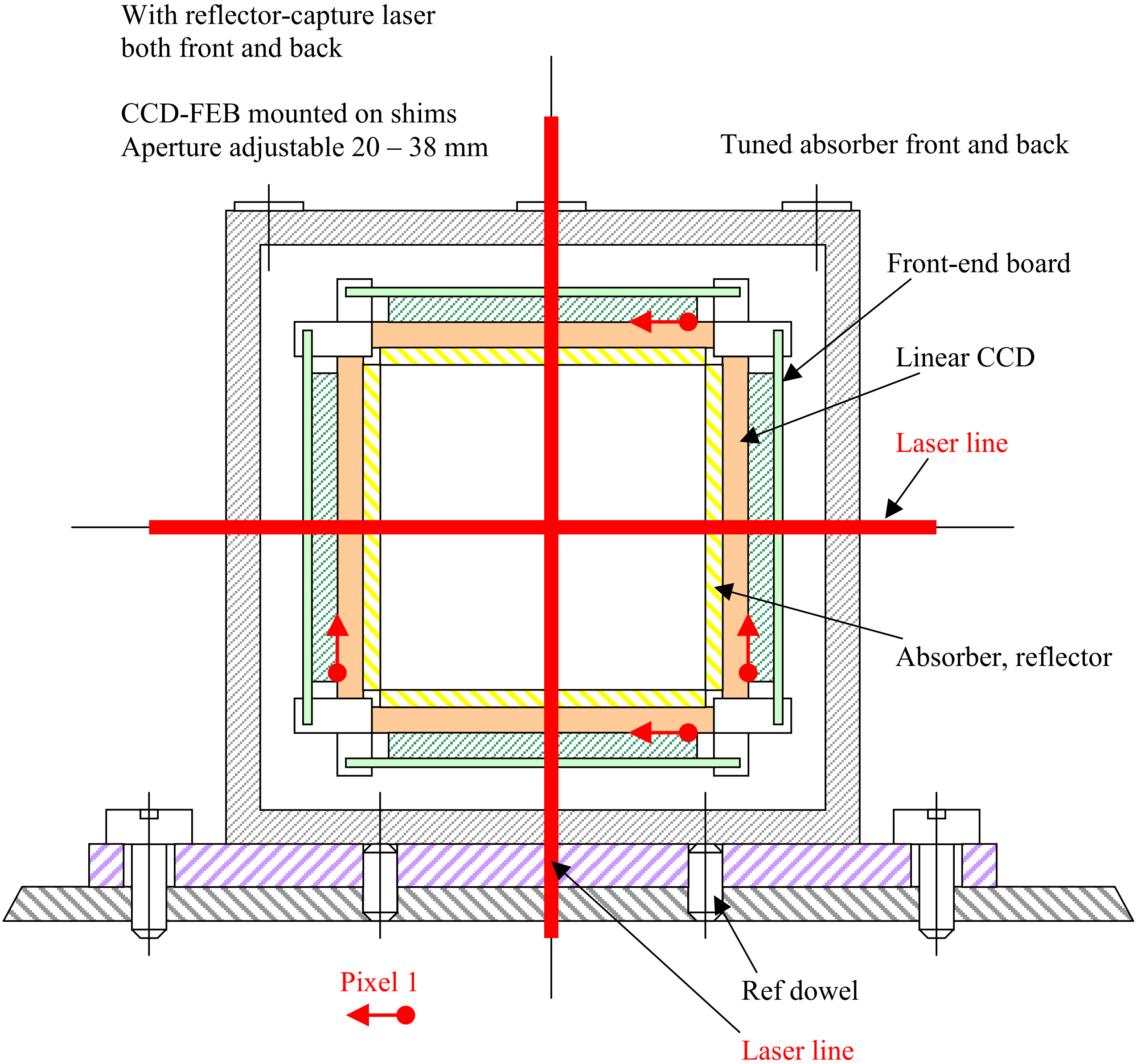

Figure 3. CCD Optical Position Sensor

- Analog interface board at periphery of disk at the end of each SLM
- 6 analog interface boards per station; 1 serial hub per station

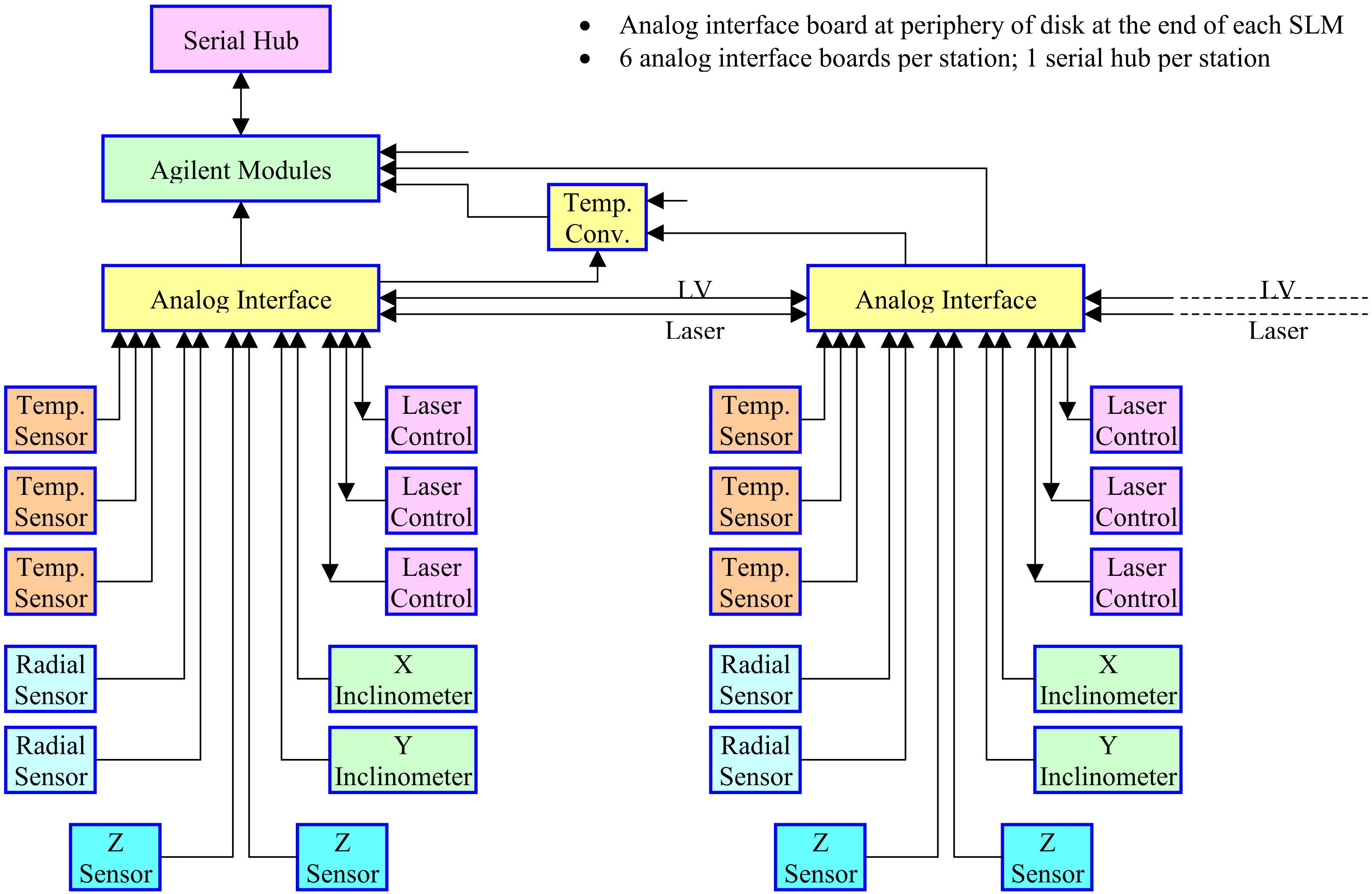

Figure 4. Analog Readout System

We set as requirements for the EMU Alignment: measurements to have uncertainties in the $R\phi$ direction, of ~75 μm for the ME1/2 and ~150 μm for the other CSCs. Detailed COCOA simulation studies of the complete system using sensor test results (ISR2000, MW8 SLM 2001), calibrations, and estimated mechanical errors indicate we can meet these requirements. This is analyzed and demonstrated in detail in a Thesis: SIMULATION AND STUDY OF THE CMS ENDCAP MUON ALIGNMENT SYSTEM; Robert H. Lee, May 2002, Purdue University using COCOA (CMS Object Oriented Code for Optical Alignment.