The ATLAS Pixel nSQP Readout Chain

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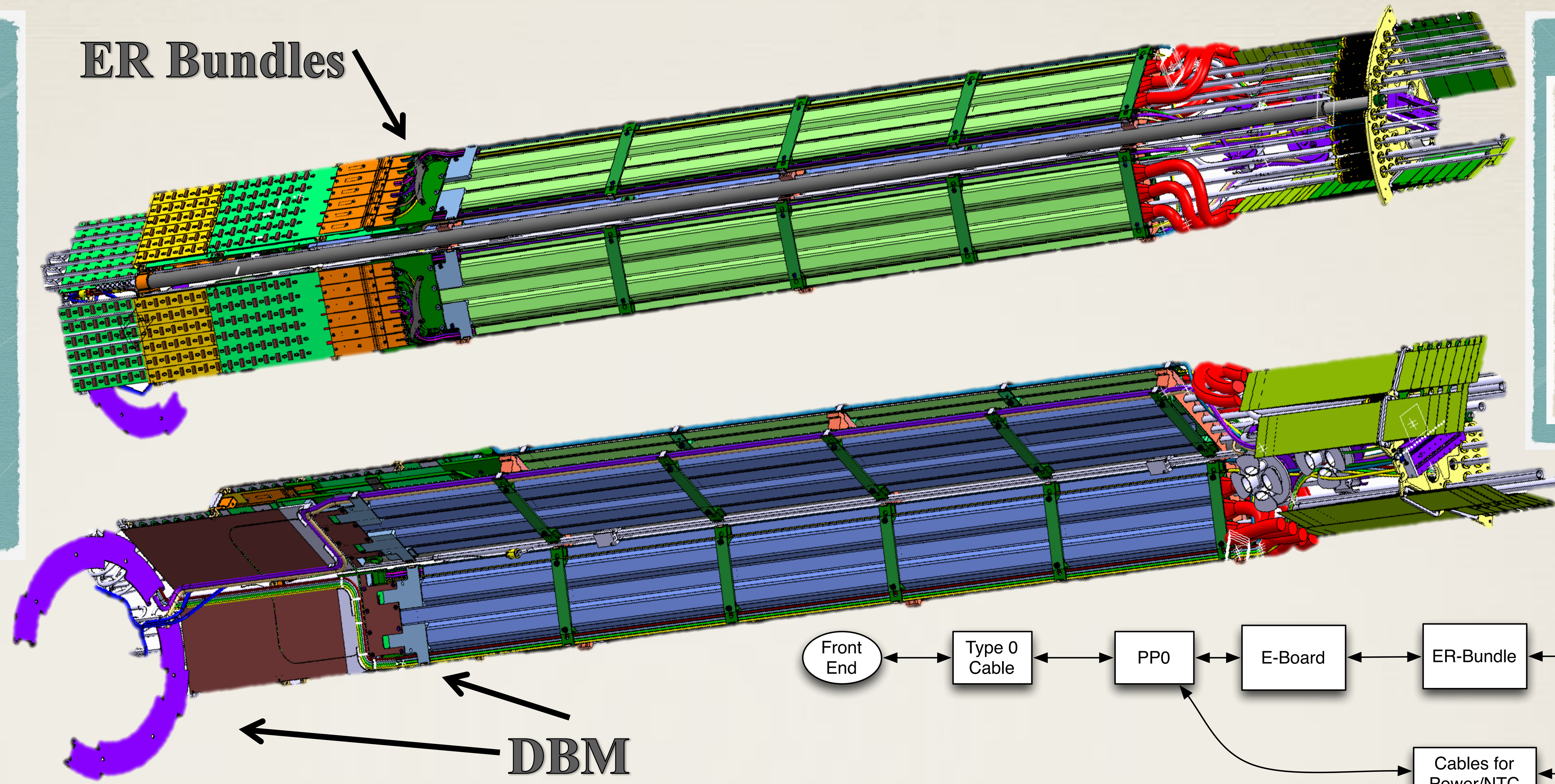
Introduction to the Pixel Detector Readout

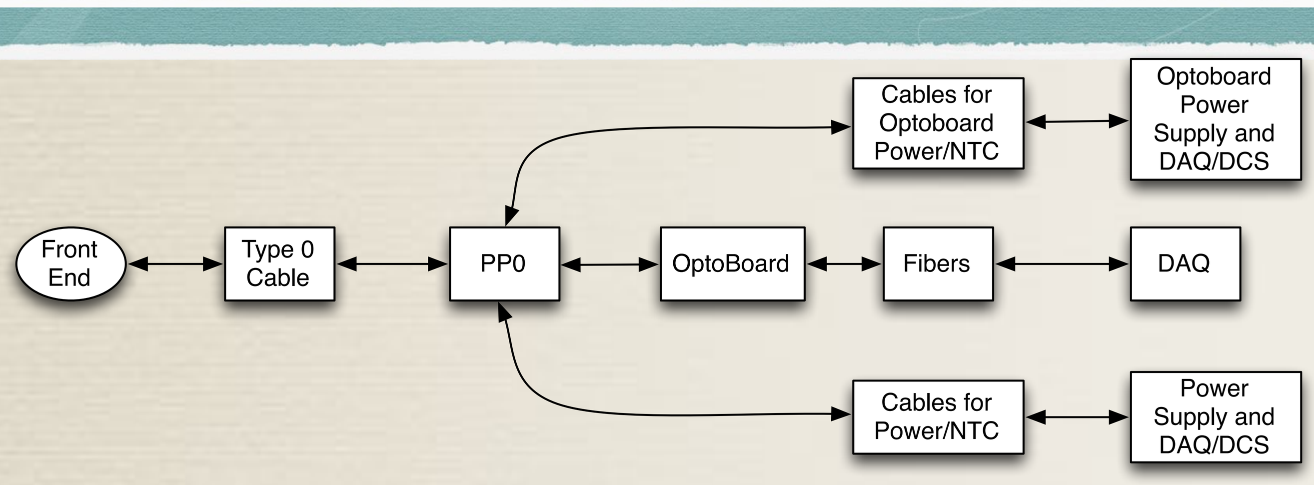
The ATLAS Pixel Detector consists of **1744 individual silicon sensor modules**. Each front end module is read out via one or two LVDS links.

The LVDS links operate at either **40 or 80 Mbit/s**. Each LVDS link consists of about 1 meter of electrical twisted pair (Type 0 Cable) and create the connection between each detector module and one out of eight service quarter panels (SQPs).

The SQPs are installed with the detector and carry electrical power, cooling and optical data both into and out of the detector. They also house the electro-optical converters (Optoboards), which enable bidirectional conversion of electrical and optical signals.

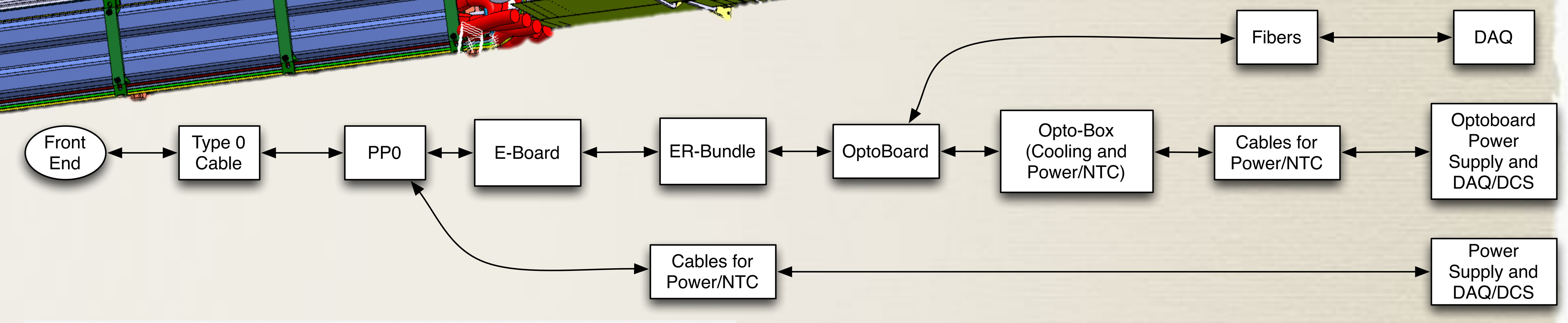
The Optoboards use laser arrays, to convert electrical signals from the LVDS drivers into optical signals. They also contain a PIN diode for conversion of optical signals into electrical signals. The optical signals are carried by ~80m of optical fiber out of the detector cavern and towards the readout system.





Failure of Optical Link Components

During operation of the ATLAS Pixel Detector, lasers started to fail in the off-detector systems. The same type of lasers are used in the Optoboards. Naturally, the Pixel community began to question the lifetime of the on-detector lasers and the cause of the few failures that had occurred. Since the Optoboards are integrated into the service quarter panels they cannot be accessed without removing the detector from ATLAS. This would be a long process that carries a lot of risk. **Therefore, a project has been started to build new service panels**, which enable the Optoboards to be moved into a serviceable area by extending the original 1 meter electrical readout by an additional 6.6 meters.



New Services Quarter Panel E-Readout

The nSQP Project was started with the intention of moving the Optoboards to an accessible location so they can be serviced more easily. To do this an extended electrical readout system was needed. The approach was to reconstruct identical panels. The electrical power, initial electrical readout, and cooling systems were reproduced exactly, but **the optical readout and the Optoboards were replaced by a new electrical readout.**

Extending the initial 1 meter electrical bundle was considered not an option because it was believed the signal was not strong enough to be transmitted an **additional 6.6 meters**. Instead **an radiation hard electrical repeater chip is used to boost the signal. This repeater chip is used to create an active buffer component to replace the Optoboard. The E-Board feeds a newly designed electrical readout harness, the ER-Bundle.** The E-Boards have the same electrical connections to the service quarter panels and the same form factor as the original Optoboards. However instead of Laser Drivers and Pin Diodes rad hard LVDS repeater ICs are used.

The ER-Bundles consist of 21 or 28 twisted pairs enclosed in tubular Kevlar and Nomex braids. **These ER-Bundles take the place of the optical fibers in the service quarter panels. The ER-Bundles terminate into Optoboards** that are located on the detector end plate where they are more easily accessible.

The Optoboards preform the same function as in the original readout system, acting as bidirectional electro-optical converters. The Optoboards are connected to the readout system through ~70 meters of optical fiber.

Since failure of on detector components has been such a large issue the E-Readout was designed to be as reliable as possible.

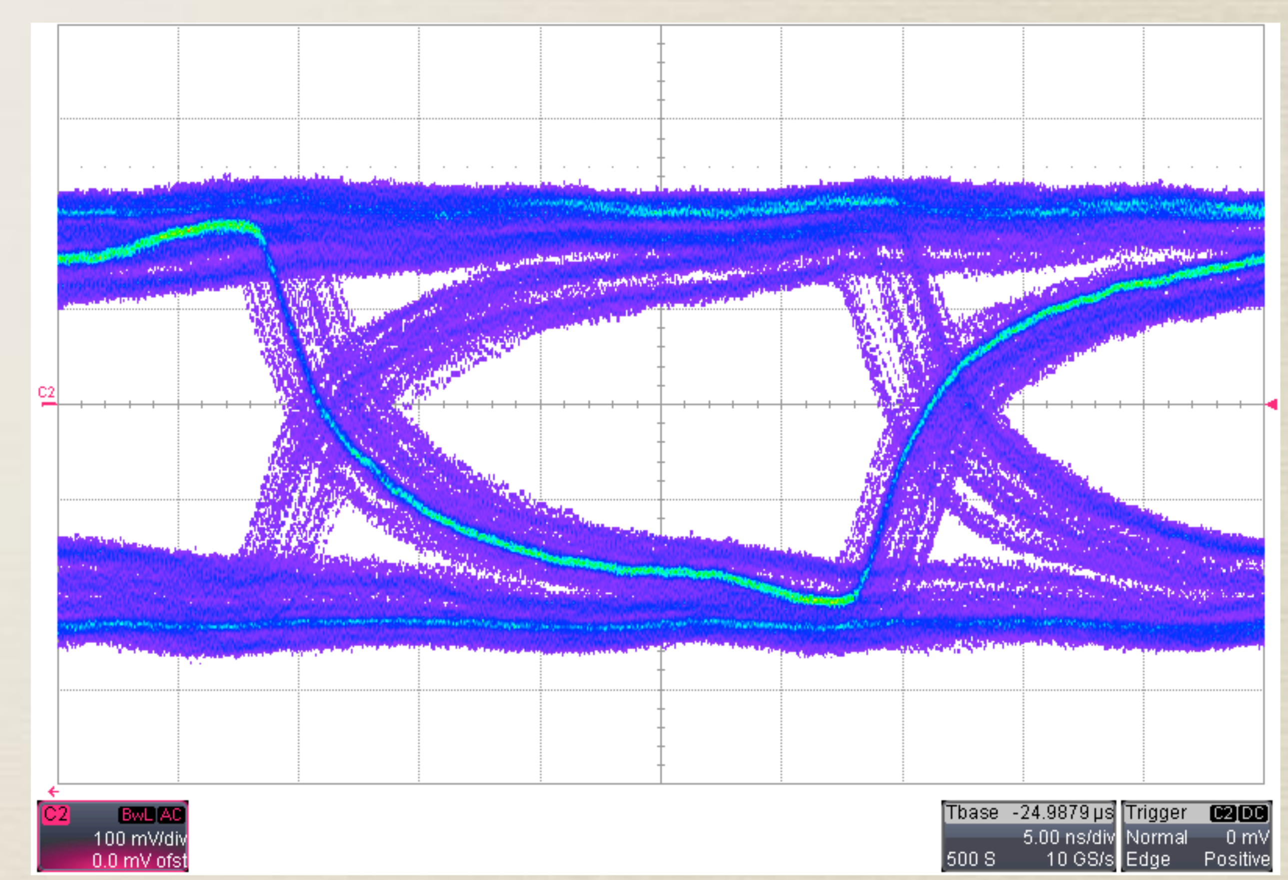
DBM: Motivation and Overview

The nSQP project presents a unique opportunity to add some additional features to the current inner detector. The Diamond Beam Monitor will help augment the current BCM system. Stating in 2014 the Luminosity of the LHC will increase the mean Pileup. The current beam conditions monitor (BCM) will begin to saturate, having too large an acceptance to not be struck by a particle in every bunch crossing. Right now, the BCM gives a reliable measurement of the instantaneous luminosity given by the colliding beams inside ATLAS. The natural solution to provide proper luminosity measurements in the future is a segmented detector at high eta. **The new detector will perform the exact same measurement as the BCM, but with a smaller acceptance.**

In order to properly distinguish between interactions and beam background, 8 telescopes of pixelised diamond detectors are being set up. These telescopes make up the diamond beam monitor (DBM). The telescopes are pointed at the interaction point (IP) and will allow for clearly distinguish beam-parallel particle tracks from tracks coming from the IP. Each DBM sensor will be equipped with a custom-made interface chip allowing a defined trigger area to be set in each telescope. Having these triggers defined will allow self-seeded triggering of the DBM system.

Layer 1 Bandwidth Upgrade

The ATLAS Pixel detector consists of three layers of Pixel Modules. As stated in the Introduction to the Pixel Detector section, each module has the capability for two readout channels and either 40 or 80 MBits/s. Layer 0 is configured such that every module uses both readout channels and has an 80 MBits/s data rate on each channel. Layer 1 is currently configured to use only one readout channel at 80 MBits/s data rate. Finally, Layer 2 is configured to use only one readout channel at 40 MBits/s data rate. **nSQP allows for the opportunity to increase the bandwidth of layer 1 to be the same as layer 0.** This increase in readout speed will allow to move more data out of the detector, making it suitable for operation at higher luminosities as currently predicted in the LHC schedule.



E-Readout Testing

Since the E-Readout is a new system many tests were conducted on the individual components and system. **The performance of the ER-Bundles and E-Board were studied independently in order to make sure that the an acceptable level of signal integrity was maintained in the final system.** These components were then combined and the signal integrity was studied again. The Eye Diagram shown here is an example of the data quality in the new E-Readout System. The **200 mV** opening shown is about twice what is required. Once independent tests were complete the new **E-Readout was then integrated it into the Toothpix system for systems test.** While the **tests were successful**, they triggered some design changes that help to increase the operational range and thereby improve the long term reliability of the system. **These tests present a confidence that the new E-Readout will have data integrity as high as the current system.**

Production components are held to the highest levels of quality and reliability. All materials have been checked and studied for radiation hardness. Also, all production components are subjected to extensive testing to ensure that an acceptable level of reliability is achieved. These measures ensure **that failure is not an option.**