Large scale production of the Multi-Chip Module of the ATLAS Level-1 Calorimeter Trigger

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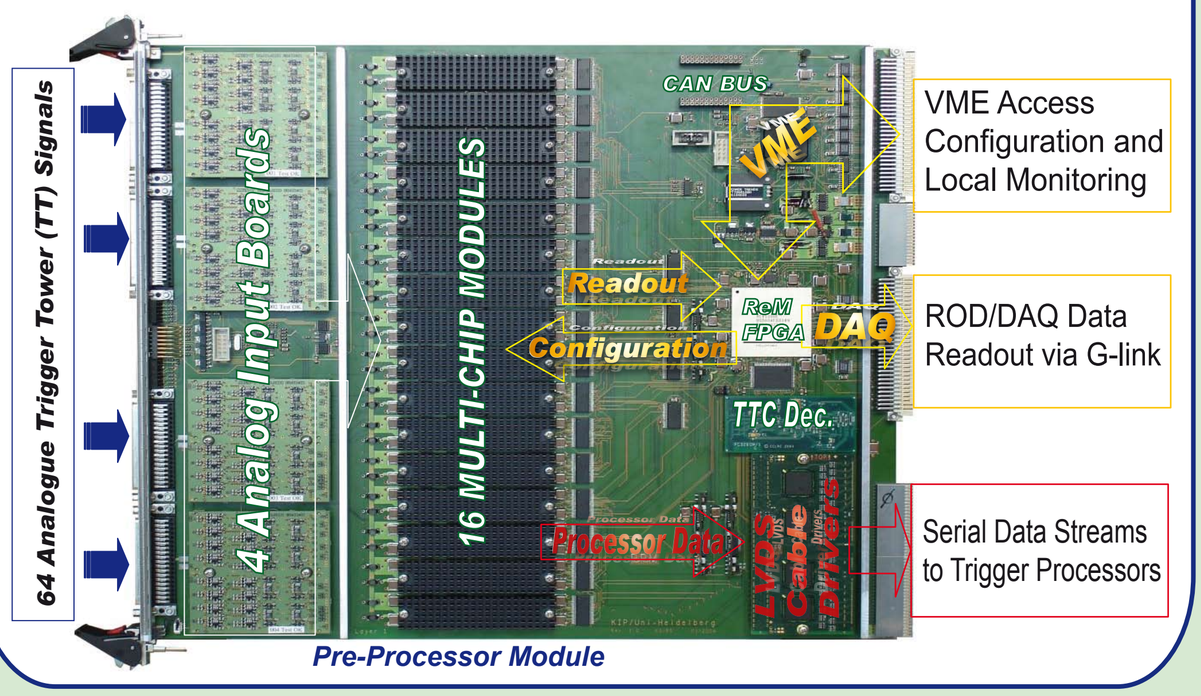
on behalf of the ATLAS Level-1 Calorimeter Trigger Collaboration

Introduction

The Pre-Processor of the ATLAS Level-1 Calorimeter Trigger receives ~7200 analog calorimeter signals, summed in the projective Trigger Towers with a granularity in η ×φ space of 0.1×0.1.
The Pre-Processor is an 8 crate system. Each crate contains 16 Pre-Processor Modules (PPMs) that can each receive and process 64 analog inputs. The PPM is the main building block of the Pre-Processor and carries 16 Multi-Chip Modules (MCM). The MCM is the smallest exchangeable unit of the Pre-Processor.
The ATLAS experiment will have 2048 MCMs installed on 128 PPMs of the Pre-Processor system. Including spares, the total number runs up to 3000.
These MCMs are the key components of the Pre-Processor, they hold the main functionality of the system and perform complex signal processing, namely the digitization, calibration and Bunch-Crossing-Identification (BCID) of calorimeter signals.

The Pre-Processor Module

The **PPM** is a 9U VME board (standard 367 x 400 mm) designed to pre-process 64 analog input signals from ATLAS calorimeters. The digitally processed data are then transmitted to the Cluster Processor (**CP**) and Jet/Energy-sum Processor (**JEP**) subsystems.



Pre-Processor Module

The Multi-Chip Module (MCM)

The MCM is a mini printed-circuit board which contains 9 dice:

- **4 Flash-ADCs**

Tasks: digitize the input signals with 10-bit resolution and a sampling frequency of 40 MHz.

- **1 Timing chip (PHOS4)**

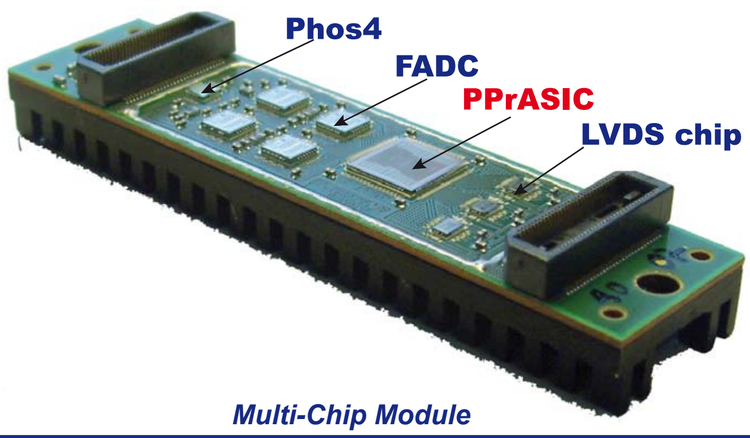
Tasks: delay the **FADC** clock with respect to the system clock, in steps of 1 ns within an LHC clock cycle.

- **Pre-Processor ASIC (PPrASIC) processing four digital channels and providing readout**

Tasks: real-time bunch-crossing identification, channel synchronization, final transverse-energy calibration,pedestal subtraction pre-summing of jet elements, bunch-crossing multiplexing, serial data transmission.

- **3 LVDS serializer chips**

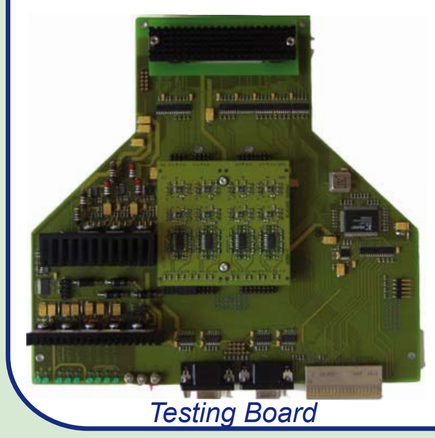
Tasks: transmit the processed data to the subsequent processors at a rate of 400 Mbits/s.



Multi-Chip Module

MCM Production Tests

The Test environment is a VME-based infrastructure including: a crate, an analog signal generator and a specially developed Test Board emulating the **MCM** environment on the PPM.


Testing Board

The Test software is implemented with a graphical user interface containing various test routines to verify different **MCM** functional blocks. It can be used in two testing modes:

- **Wafer test (~1 min.)**

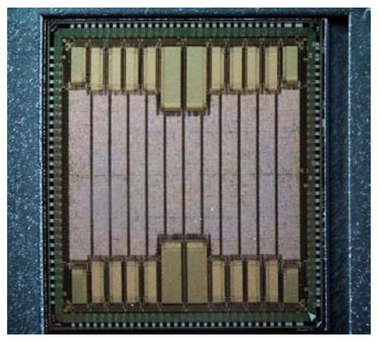
Test PPrASIC on the wafer

- **MCM test (~2.5 min.)**

Test all chips on a fully mounted MCM

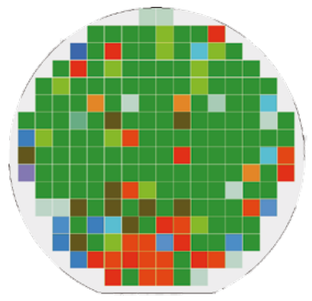
PPrASIC Wafer Tests

The **PPrASIC** is a custom-designed chip designed at KIP and fabricated with a 0.6um feature size by AMS:


PPrASIC Layout

Characteristics:

Dice/wafer	192
Chip-size/mm^2	8.370 *8.375
Channels/chip	4
Transistors/chip	950 000
Memory/chip	8.125 KByte

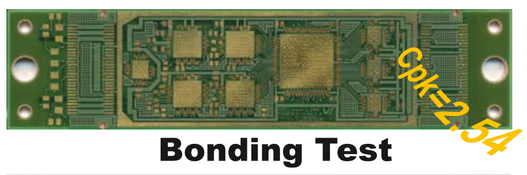

Wafer Color Map

From 53 wafers with 10176 untested dice, 4306 were selected by chip testing, giving a yield of ~42%. The complete set of **PPMs** requires 2048 ASICs, the rest are spares.

Production Cycle

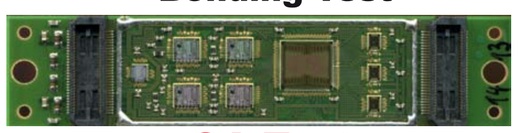
The assembly of the **MCM** was split into several production steps performed by two commercial companies, Würth and HASEC. The intermediate **Quality Assurance** tests take place at KIP:

- Production of 4-layer FR4 substrate with gold surfaces.

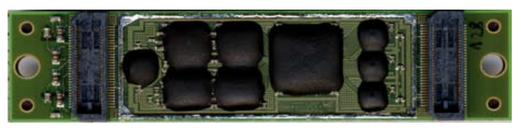


Bonding Test

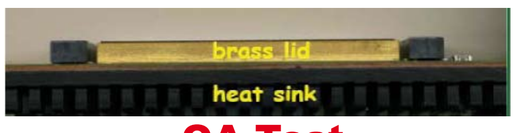
- Passive components soldering, done by applying SMT technology. Die placing and fixing, wire bonding, visual inspection.


QA Test

- ”Glob-top” is applied over the 9 active chips.



- Soldering of the hermetic brass lid. Glueing heat sink for dissipated heat exchange.



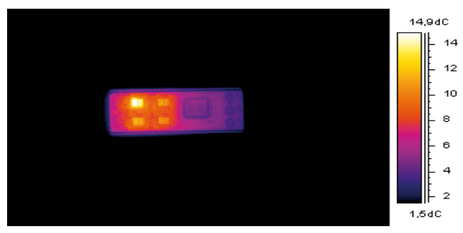
QA Test

The **QA Tests** allow identification of faulty MCMs at any stage of production.

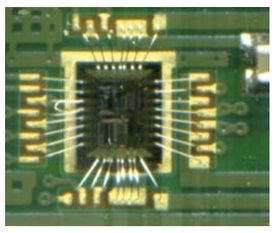
Examples of MCM Faults

Investigate faulty MCMs using a microscope, an infrared camera, an oscilloscope and software.

Detect problematic functional blocks on chips and replace them if possible.



short-circuit in ADC


bond fault

Production Statistics

Total number	3788
Faulty MCMs	613
Functional MCMs	3175
Installed in the system	2048
Spares	1027

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