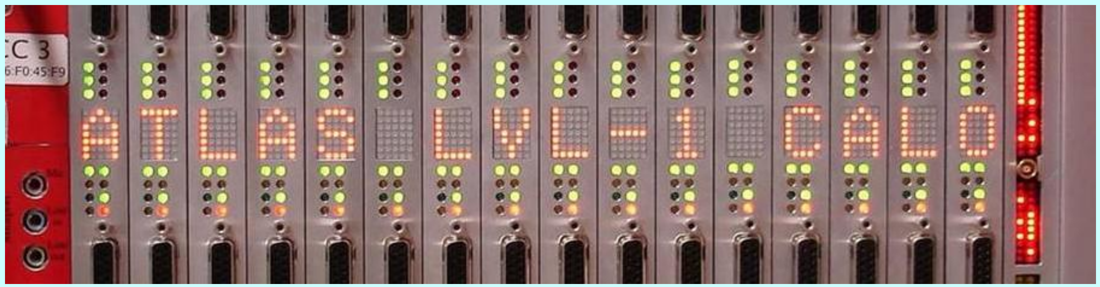
Commissioning Experience with the ATLAS Level-1 Calorimeter Trigger System

ATLAS Level-1 Calorimeter Trigger Collaboration



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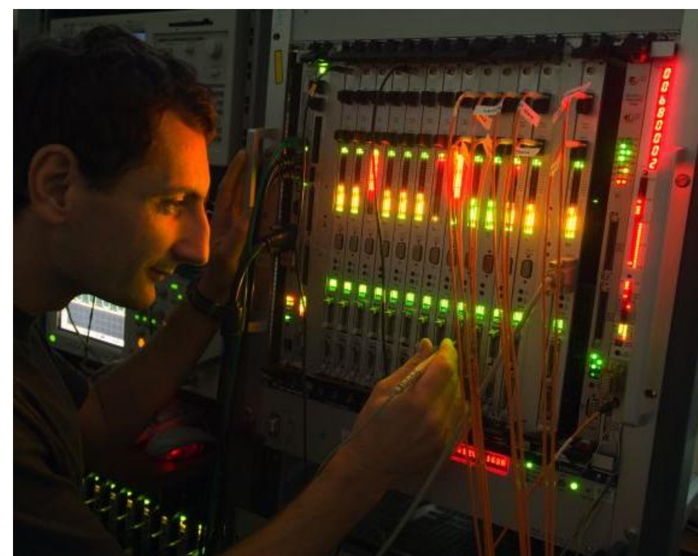


Commissioning Experience with the ATLAS Level-1 Calorimeter Trigger System

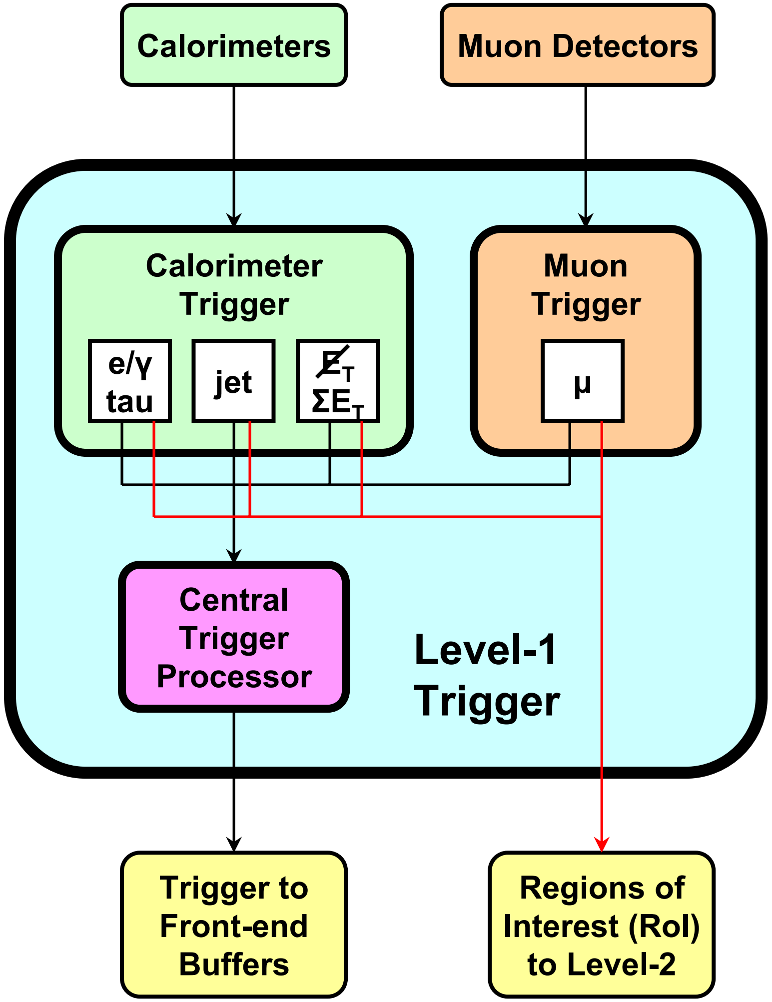
- Trigger Architecture

- Challenge of Scale
  - Rationale for architecture and size
  - Implications for Installation
  - Full scale crate tests

- Commissioning and Integration
  - Integration into ATLAS Data Acquisition
  - First signals from Calorimeters

Level-1 triggering in ATLAS

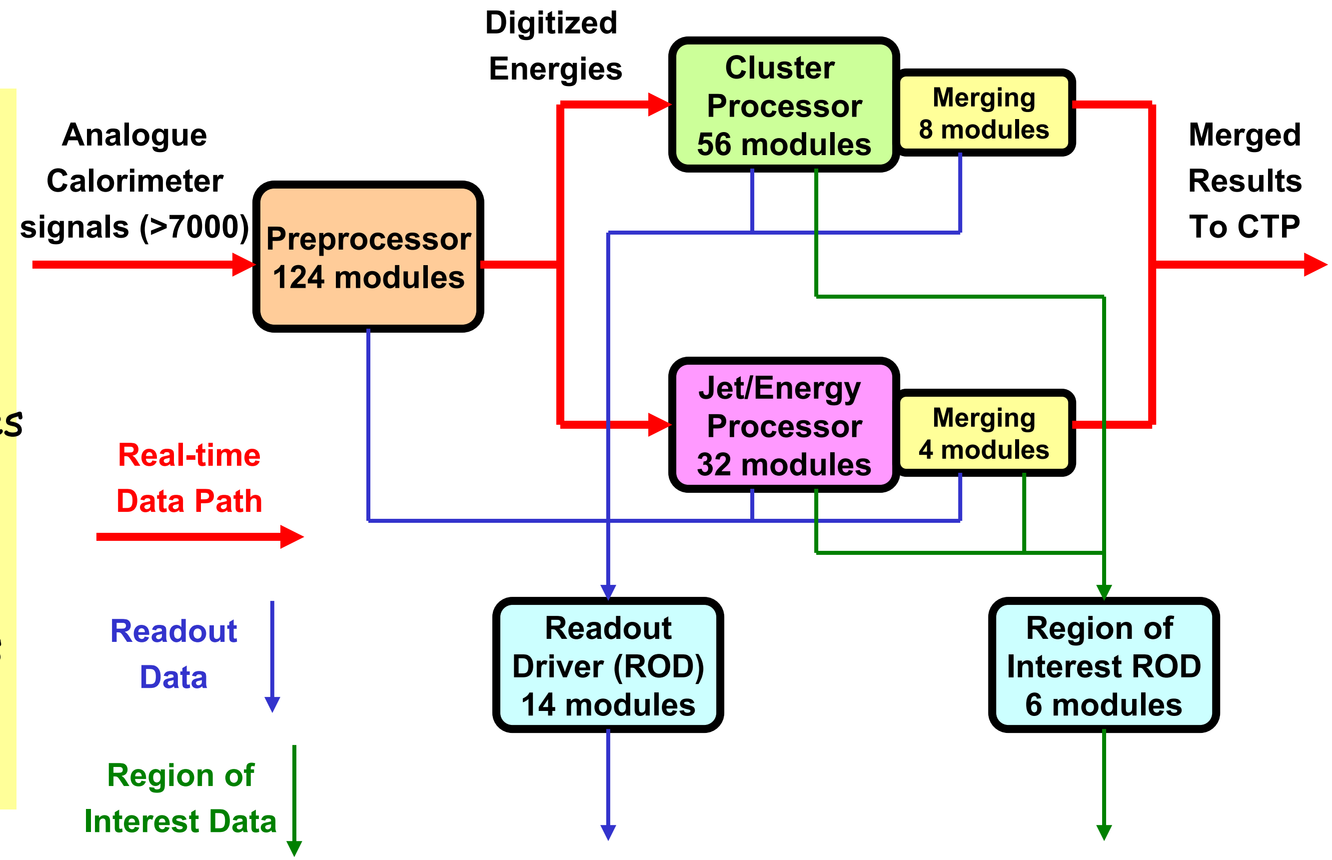
- Three-stage triggering system
  - Level-1: custom-built hardware, fixed latency – target rate 75 kHz
  - Level-2: mostly software, RoI-based selection – target rate 1000 Hz
  - Event Filter: software, full detector – target rate 200 Hz
- All data buffered at bunch-crossing rate of 40 MHz for 2.5 μs
- Level-1 has three sub-systems:
  - Calorimeter Trigger
  - Muon Trigger
  - Central Trigger (CTP)



Calorimeter Trigger Architecture

Features:

- Real-time Path: Fixed Latency (~1μs)
- Many processing stages
- Massive parallelism
- Multi-purpose modules
- Heavily FPGA based

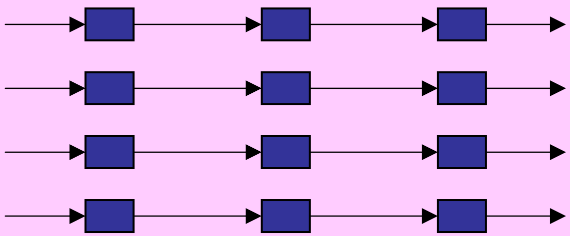


Five Main Types of Custom 9U Modules: **PPM** **CPM** **JEM** **CMM** **ROD**

Compromise of Scale

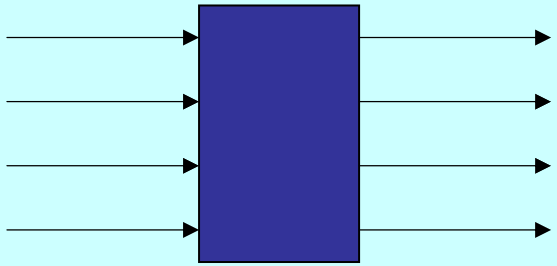
Main motivations leading to:

Extensive Parallel System



- Physical Size of Connectors
  - e.g. 496 inflexible analogue cables with large connectors
- Quantity of processing
- Power consumption

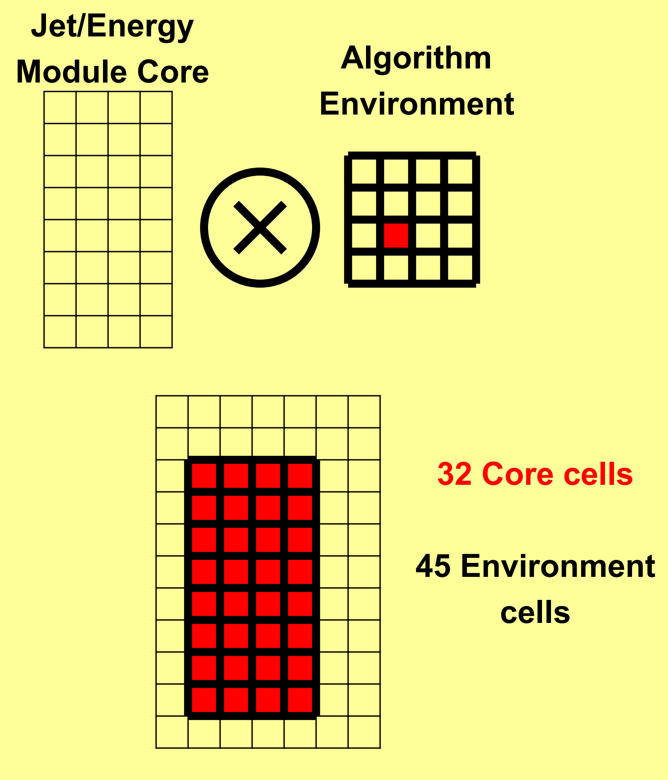
Compact Integrated System



- Latency
- Fewer data transmission stages
- Algorithm Environment
  - Sharing of information leads to extensive fanout/fanin

Influence of Overlapping Windows in Physics Algorithms

- Processor input is a matrix of tower energies
- Physics algorithms use 4x4 grid
  - 2-D pattern recognition
  - Applied throughout full input matrix
  - Windows overlap in both coordinates (eta and phi)
- To process each location, an outer 'environment' is required
- Each processor (module, crate) has a core of towers processed
- Extra 'environment' achieved by fanout
- Ratio of core:environment dependent on size
  - More parallel processing in smaller regions increases fanout requirements
  - Sub-dividing makes connectivity more difficult

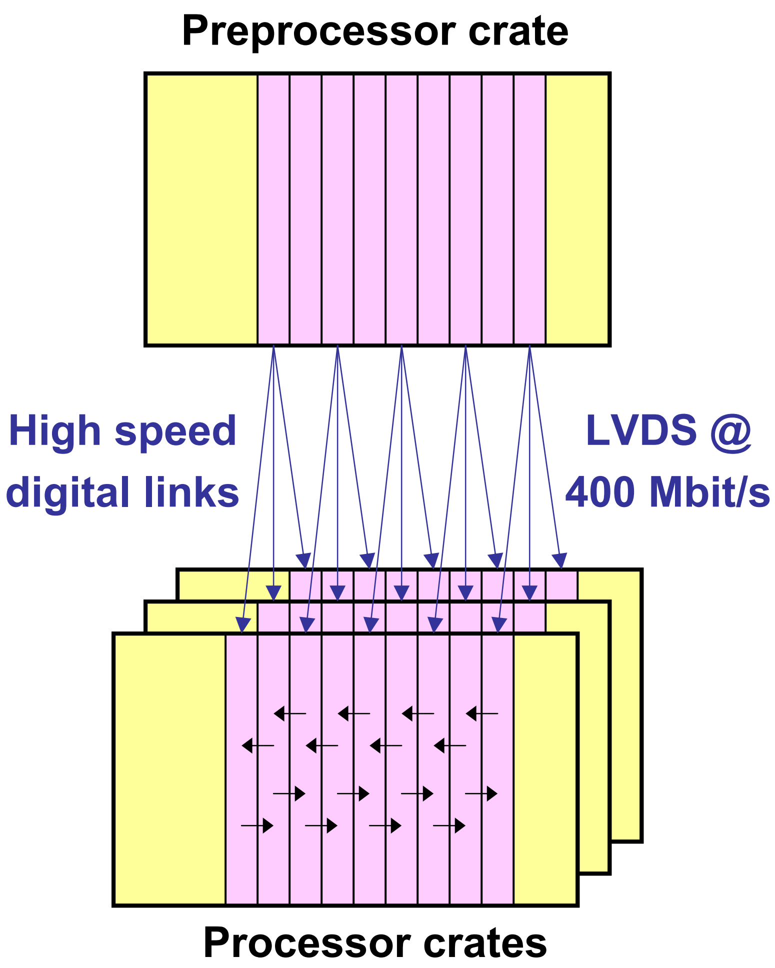


jet/energy-sum module (4x8) 32:45

e/gamma/tau cluster module (4x16) 64:69

Solution and implications

- Entirely Parallel Preprocessor
  - Size matches input cable connectors
  - Eight 9U VME crates
- High bandwidth digital cabling 'spaghetti' to:
- Parallel Processor
  - Four 9U VME crates for e/gamma/tau trigger
  - Two 9U VME crates for jet/energy-sum trigger
- Necessary fanout performed via:
  - Digital cables to processors
    - ~25% of duplication required
    - In one plane (fanout in phi)
  - Custom backplane in processor
    - ~75% of duplication required
    - In other plane (fanout in eta)



Installation Reality Check: Input Analogue Cables

496 cables into 8 crates

Four cables just fit front of one 9U module

Installation Reality Check: Digital Cabling into Processor Crates

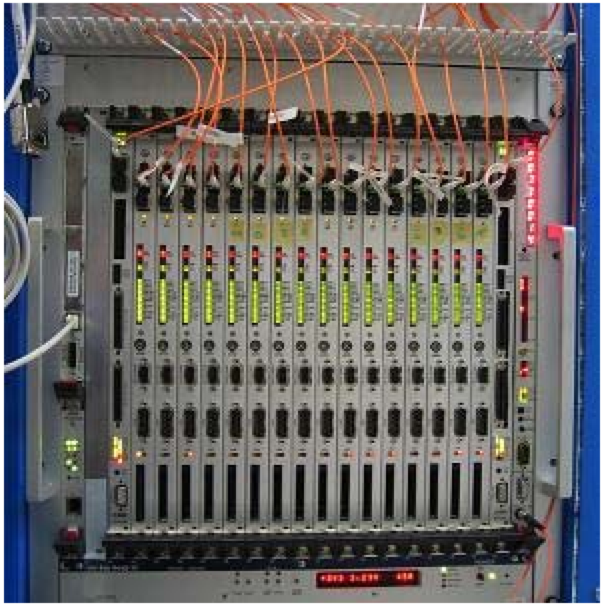
Up to 1400 individual LVDS signals into one crate

More than 500 Gbit/s data input

Full Scale Crate Tests

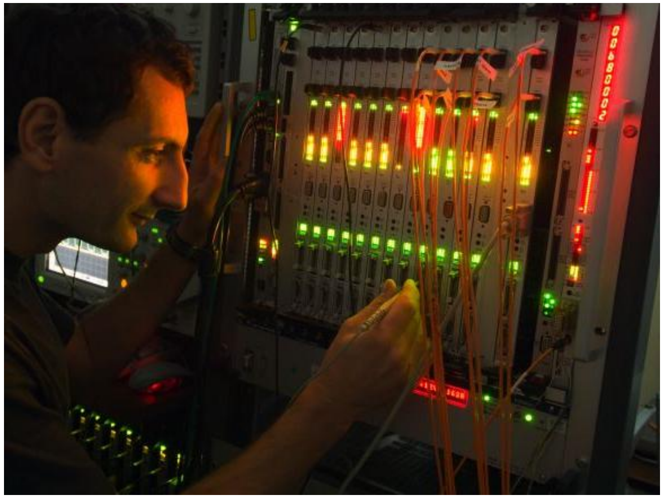
- Comprehensive tests performed with all subsystems
- Performance scaled well
- One new hardware problem:
  - Processor backplane

Preprocessor



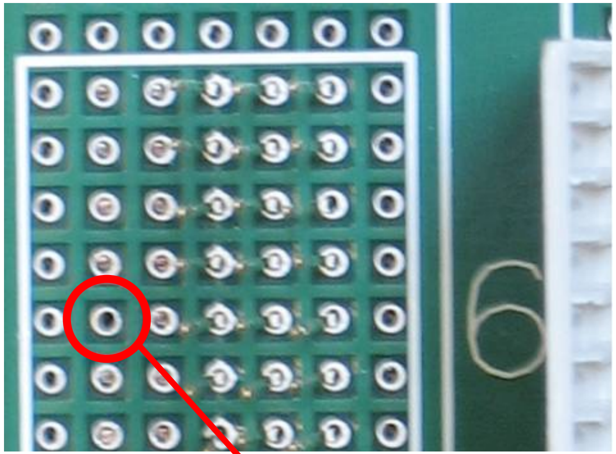
Jet/Energy Processor

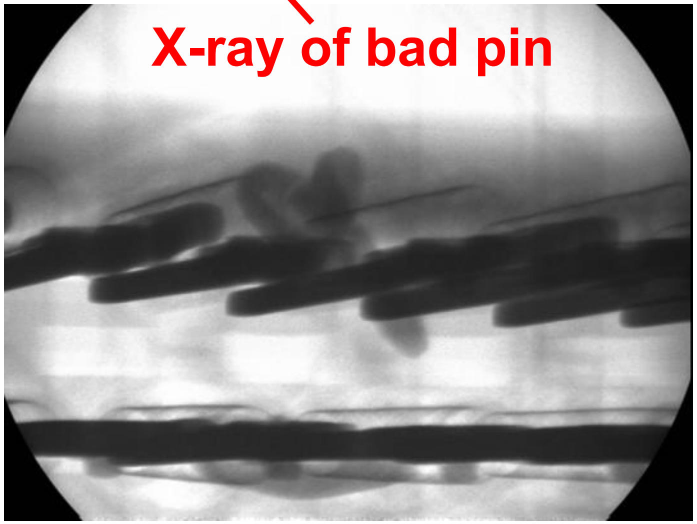
Cluster Processor



Backplane Problems and Status

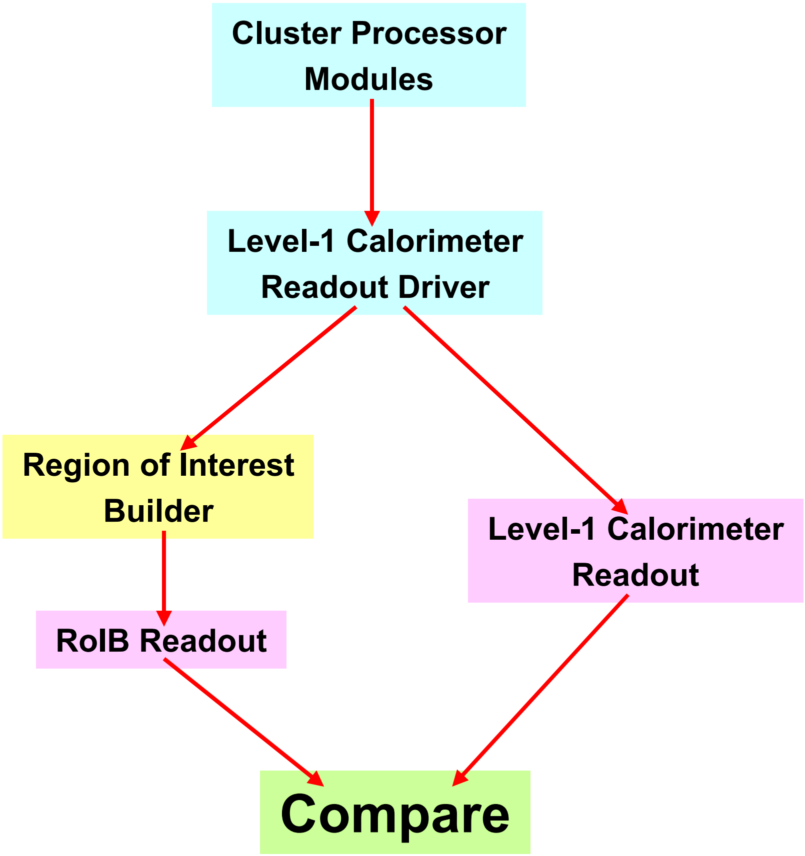
- Dense, high bandwidth backplane
  - Up to 1150 pins per slot
  - About 22,000 pins in all
- After production, pin problems at ~0.01% level
  - ie about 1-2 errors per backplane!
- Pins bent during insertion of connectors
- Currently in process of replacing bad connectors





Integration into ATLAS Data Acquisition

- Tests of output to all downstream hardware performed in situ
  - Simple setups for the moment
- Links to Readout System and Region of Interest Builder showed no data corruption
  - Tested at high rates
- Real-time links to Central Trigger Processor mostly fine
  - Minor problems
  - Now found and fixed



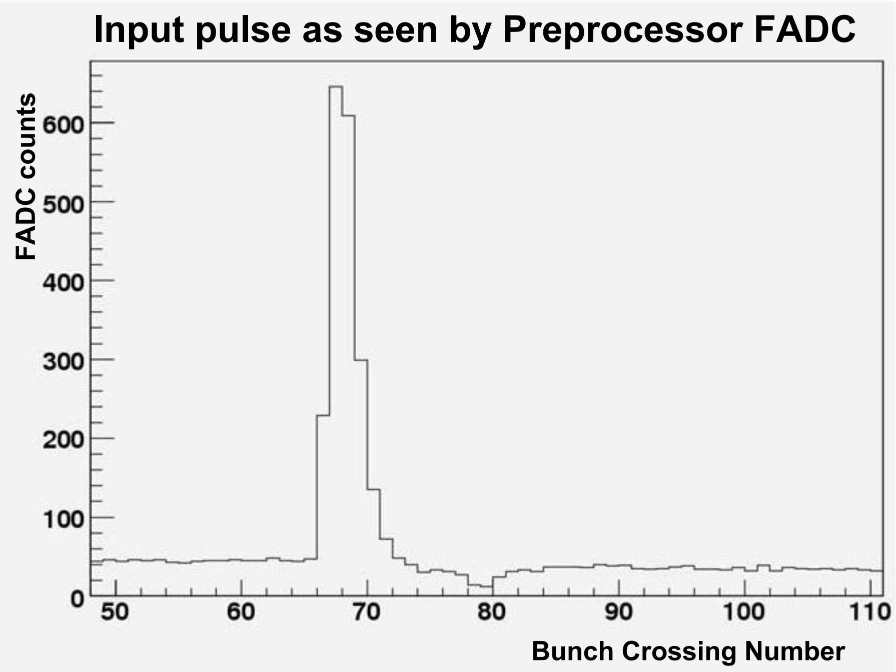
First Signals from Calorimeters

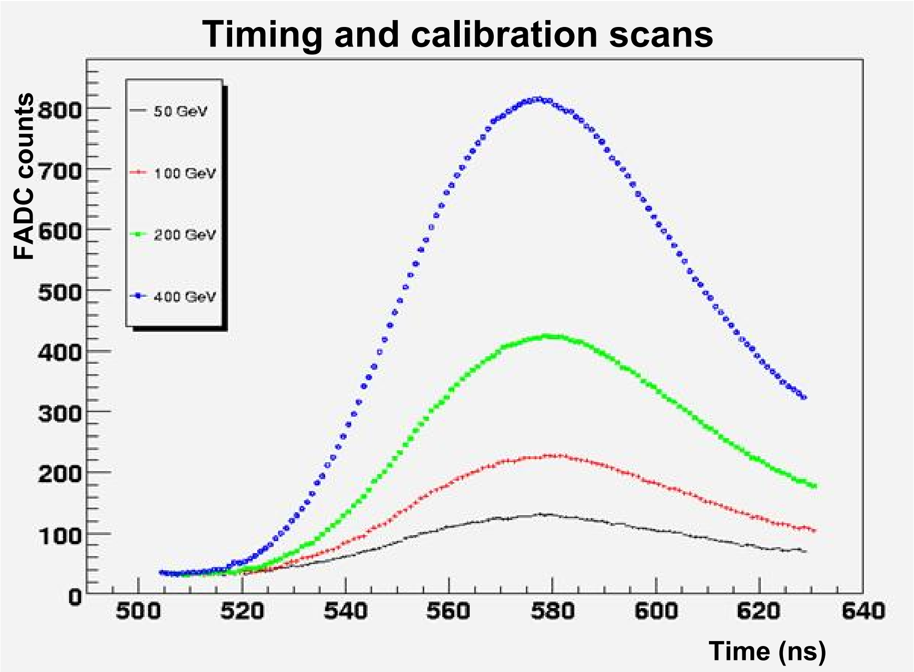
Installation at ATLAS allows:

First opportunity to see calorimeter signals since test-beam in 2004

Investigation of channel connectivity, signal quality, and tower calibration

(Using calibration systems)





Future Plans

- More integrations
  - Connect up full scale subsystems
  - Further calorimeter tests
    - More channels
    - Different parts of detectors
  - Join ATLAS combined runs
    - Commissioning runs
    - Cosmic runs
- Majority of hardware installed by mid-2007
- Will require much work to fully understand system