



MicroTCA and AdvancedTCA equipment evaluation and developments for LHC experiments

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Outline

- **Introduction**
- **MTCA**
 - Custom vertically cooled shelf
 - DC/DC power module
- **ATCA**
 - Shelf evaluation
 - In-rack cooling simulations and measurements
- **AC/DC rectifiers for xTCA**
- **Board management**
 - MMC software update
 - IPMC evaluation
- **Summary**

Introduction

- **MTCA and ATCA (xTCA) industry standards selected as modular electronics platforms for current and future upgrades of the backend electronics for LHC experiments at CERN**
- **CMS upgrades until Phase-I (2019): MTCA**
 - Trigger, TCDS, HCAL (installed during LS1)
 - Pixel (Phase-I 2017/18), GEM (LS2)
 - Considering also ATCA for Phase-II
- **ATLAS upgrades until Phase-I: ATCA**
 - Trigger, LAr calorimeter, CSC readout, FTK, muon new small wheel, ...
- **xTCA evaluation project in the PH-ESE group at CERN**
 - Technical evaluation of selected commercial MTCA and ATCA components for use in experiments at CERN
 - Focus effort on infrastructure components (shelves, power supplies, ...)
 - Make equipment recommendations
 - Establish a purchasing framework and provide support



Shelves & Power Modules

MTCA equipment evaluation

MicroTCA Crates

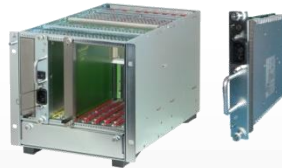
Vadatech VT892 MTCA



Schroff MTCA.4
11890



Schroff MTCA.4 + AC/DC CM100



ELMA MTCA.4
043-012



ELMA MTCA.4
045-821



Power Modules (PM)

NAT DC840
840W



Vadatech
UTC010 792W



Vadatech
UTC020 936W



Wiener AC/DC
1000W



Telkoor AC/DC
600W



NAT AC/DC AC600
600W



AMCs

ELMA Load Board



Processor
Kontron AM5030



ESD ADIO24



Processor
CCT AM310



MCH

Vadatech
UTC001



NAT



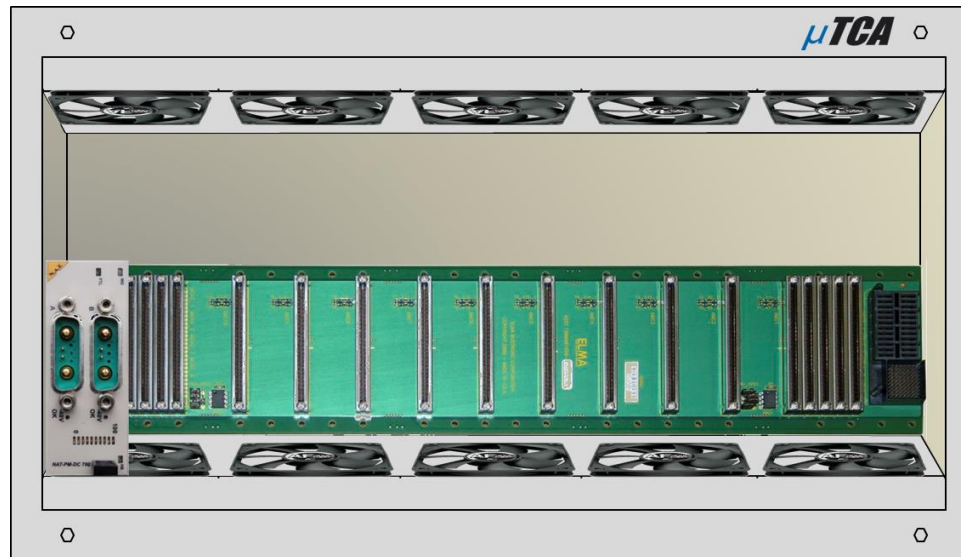
Kontron
AM4904



Evaluation reports available: <https://espace.cern.ch/ph-dep-ESE-BE-uTCAEvaluationProject>

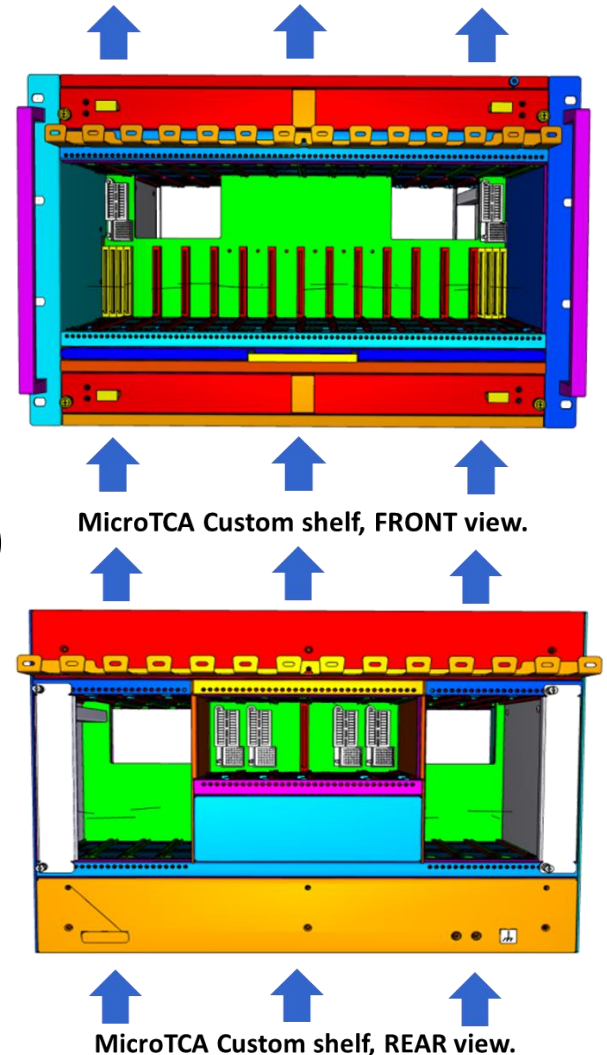
MTCA infrastructure components

- Specification & price enquiry for vertically cooled MTCA shelf and Power Module (PM)
- Motivation:
 - Attempt to standardize MTCA components
 - Simplify purchasing procedure at CERN
 - Provide support for standardized equipment



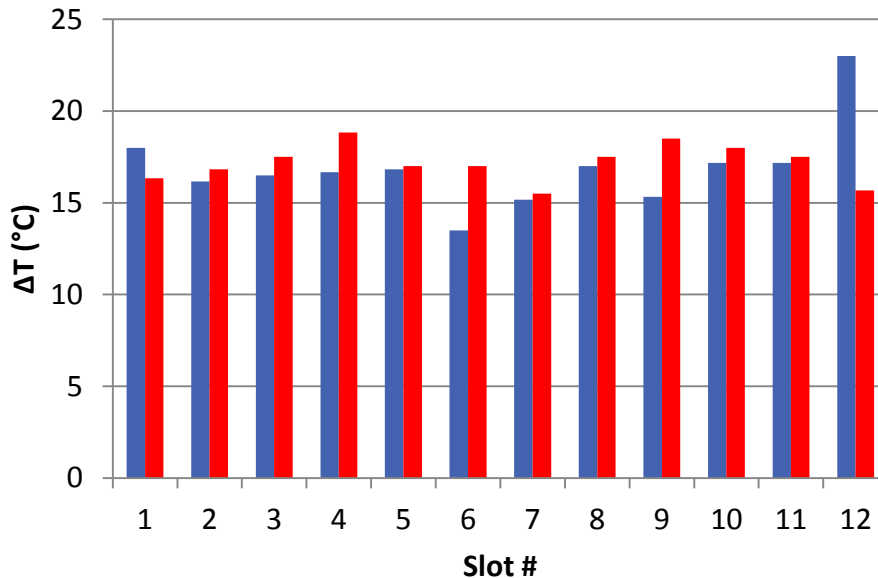
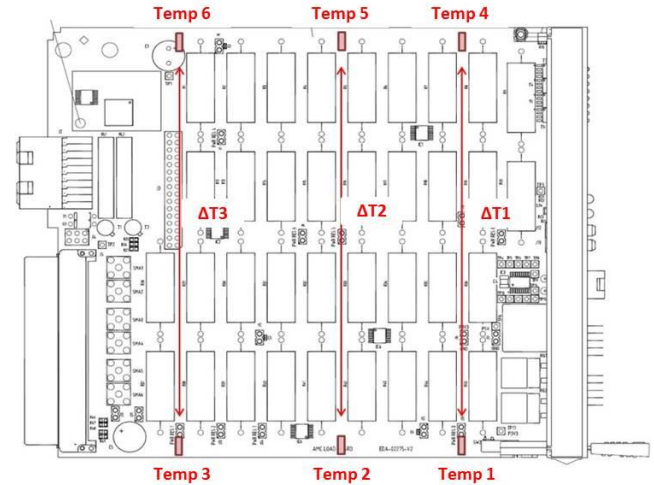
Custom MTCA shelf (1)

- Custom MTCA shelf compatible with vertical airflow in the LHC experiment rack infrastructure specified
- Characteristics:
 - 19"/7U high
 - Vertical airflow
 - 80W per slot
 - 12 full-size, double-width AMC slots
 - 6 RTM slots (MTCA.4 like)
 - 6 PM slots (2 front/4 rear)
 - 2 possible backplane topologies (MTCA.4 & CMS)
 - Rear JTAG switch module slot (JSM)
- Price enquiry completed
 - Selected supplier: Schroff
- Pre-series units being evaluated
- Available for purchase beginning 2016



Custom MTCA shelf (2)

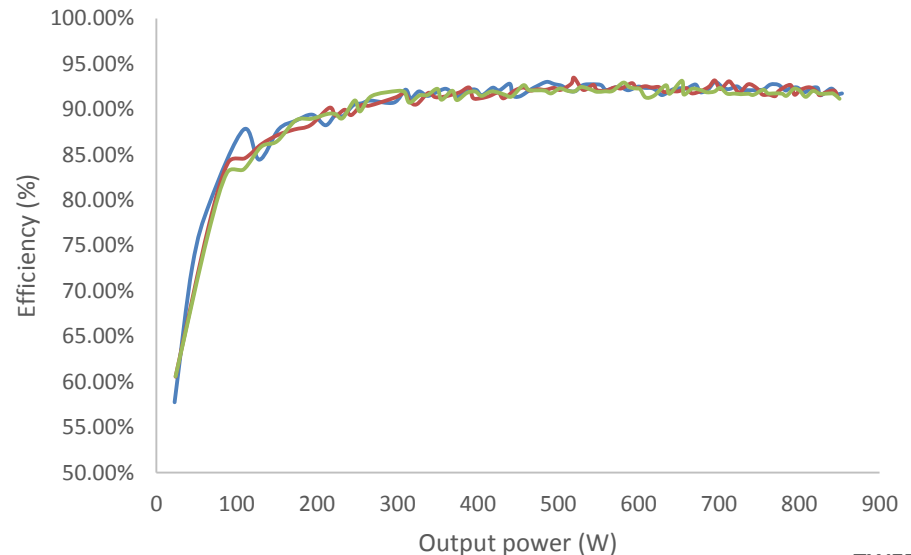
- **Cooling performance evaluation**
 - Measure temperature difference and cooling homogeneity
 - Custom designed AMC/RTM load modules
 - Temperature measured at 6 points on load modules



Custom MTCA shelf with load AMCs

MTCA Power Module (PM)

- **PM specifications:**
 - DC/DC (-48V/12V)
 - Total output power >800W
 - Efficiency above 90% (for load >40% of max.)
 - Support for 16 output channels: 12 AMCs, 2 CUs, 2 MCHs
 - Support for N+1, 2+2 redundancy and shared load topologies
- **Comprehensive electrical tests performed**
- **PM-DC840 from NAT selected**
- **Pre-series of 3 units evaluated: compliant with specification**
- **Available for purchase beginning 2016**



Advanced TCA[®]

Shelves

ATCA shelves evaluated

- Standard commercial shelves (front-to-back airflow)



Schroff 14-slot 13U ATCA



ASIS 14-slot 13U ATCA



Comtel 14 slot

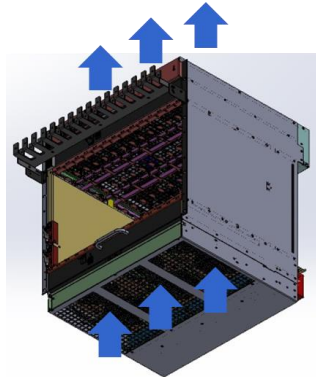


ELMA 14 slot

- ASIS custom shelf (vertical airflow for standard LHC rack)



ASIS custom shelf



Schroff 2-slot ATCA
11990-705

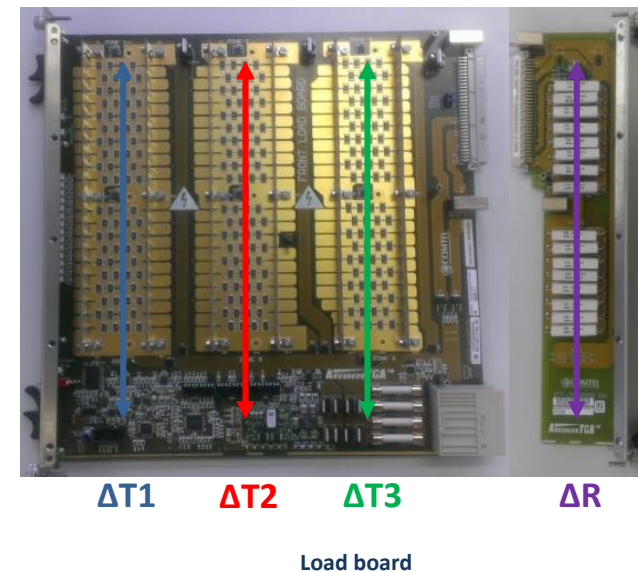
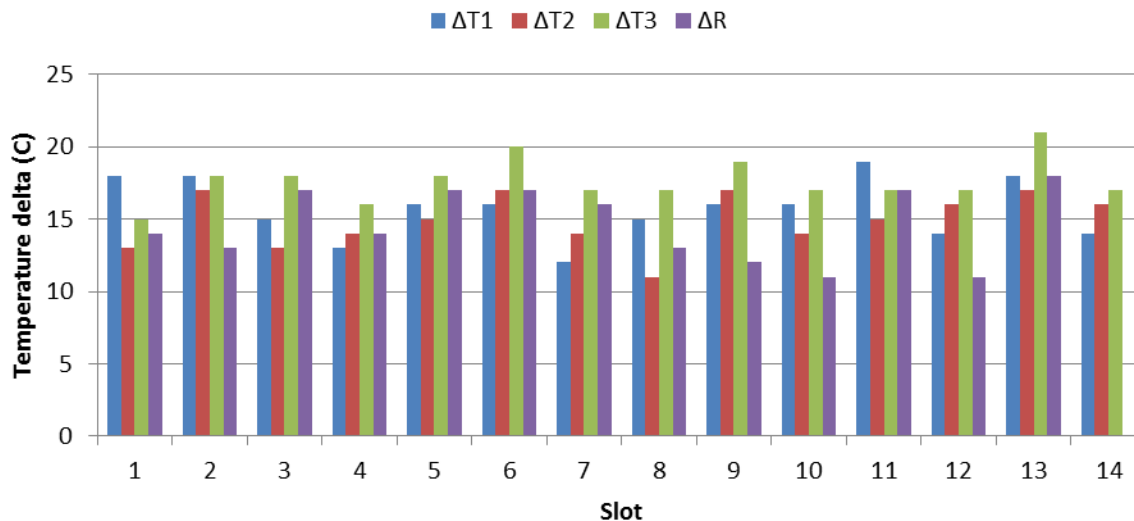


- Evaluation reports available:

<https://espace.cern.ch/ph-dep-ESE-BE-ATCAEvaluationProject>

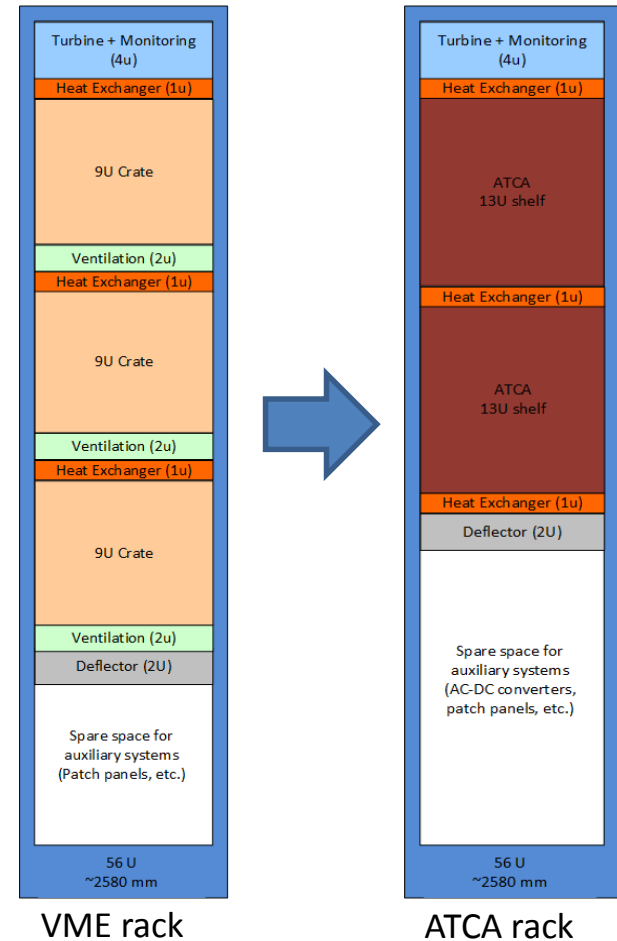
ATCA shelf cooling evaluation

- Commercial ATCA load modules (COMTEL)
 - Maximum load: 300W front blade + 50 W RTM
 - On-board temperature sensors
- 14 slots loaded at 250W front/50W RTM
- Test performed at maximum fan speed
- Results for ASIS custom shelf with vertical airflow:
 - Temperature increase $\sim 15^{\circ}\text{C}$, 21°C worst case



Rack airflow simulation

- Thermal and airflow simulation of ATCA in standard LHC rack
- Simulation performed by ASIS (using FloTHERM)
 - Simplified blade thermal/airflow model
- LHC rack with 2 ATCA shelves and 1U heat exchangers
 - Custom 13U ASIS vertical airflow shelves with pull-only fan configuration
 - Different rack configurations simulated
- Power dissipation per shelf up to 6.5kW
 - 9U VME < 3kW



Airflow simulation results

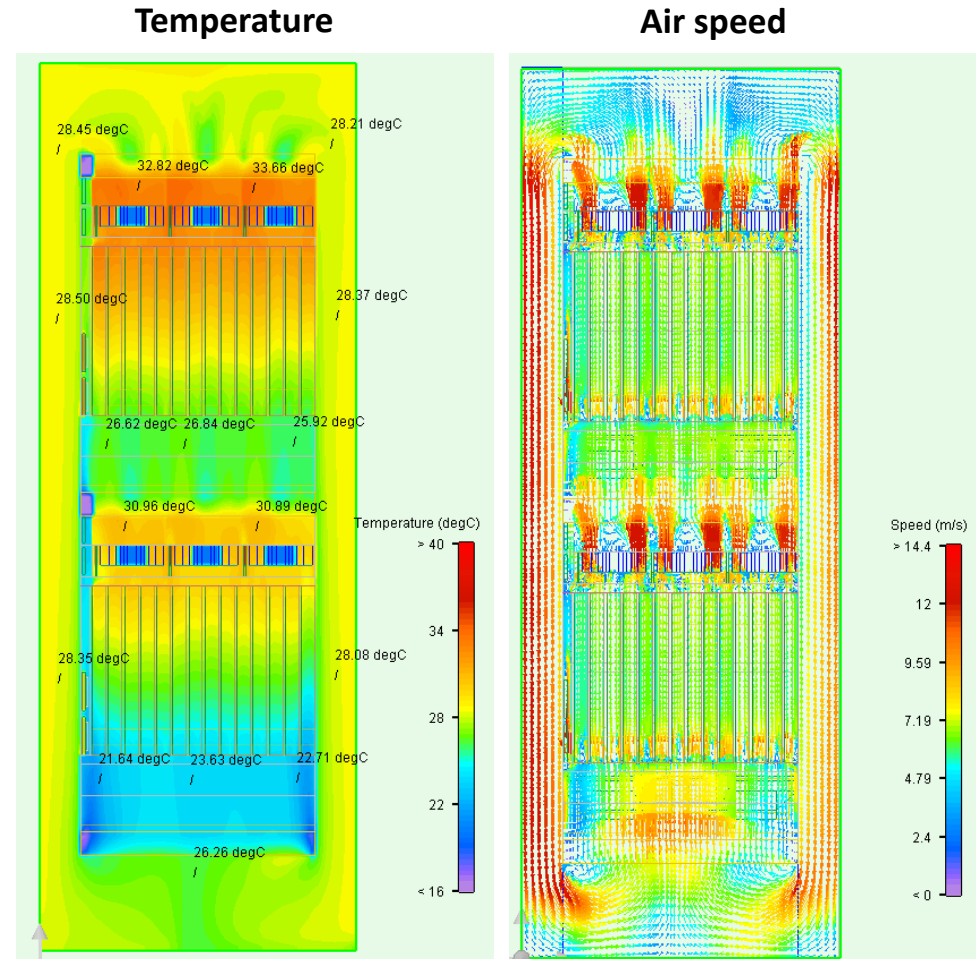
- 400W per slot (350W front/50W rear)
- Power dissipation ~6500W per shelf (incl. fans)
- Water temperature 16°C, 1 L/s

Results

- Air temperature in rack remains below 35°C
- ATCA fans provide sufficient airflow to cool the rack
- Turbine and chassis should be removed to avoid air resistance

Next steps

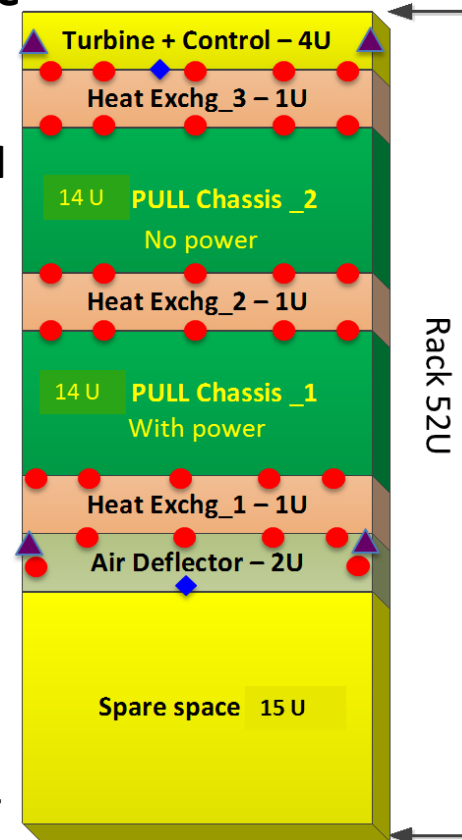
- Detailed blade level simulations
- 3D model of ATCA carrier blade with 4 AMCs (LHCb design)



Rack cooling measurements (1)

- ATCA cooling test with vertical airflow in a standard LHC rack in the ATLAS underground counting room in collaboration with ATLAS technical coordination (C. Bortolin et al.)
 - Check cooling capabilities of standard LHC racks when moving from VME crates to ATCA shelves
 - Identify potential in-rack bottlenecks and airflow resistance sources
 - Mechanical improvements of the rack to optimize the cooling performance (e.g. removal of turbine chassis, etc...)
- 2 ASIS custom vertical airflow shelves installed in rack in USA15
- 14 COMTEL load boards
- Instrumented rack with temperature, air speed and pressure sensors

- Temperature sensor
- ◆ Pressure sensor
- ▲ Velocity sensor



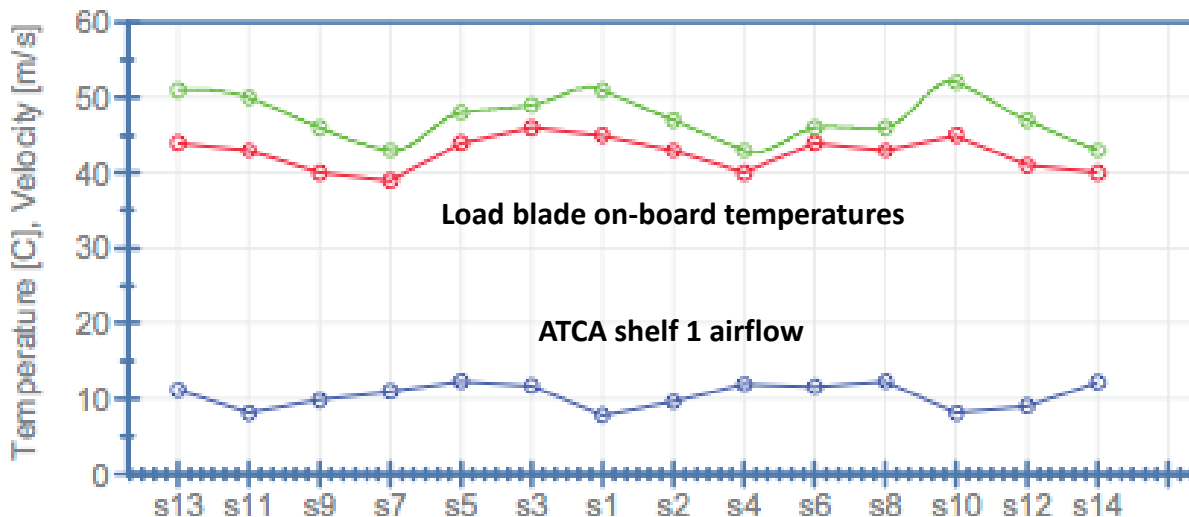
Rack configuration



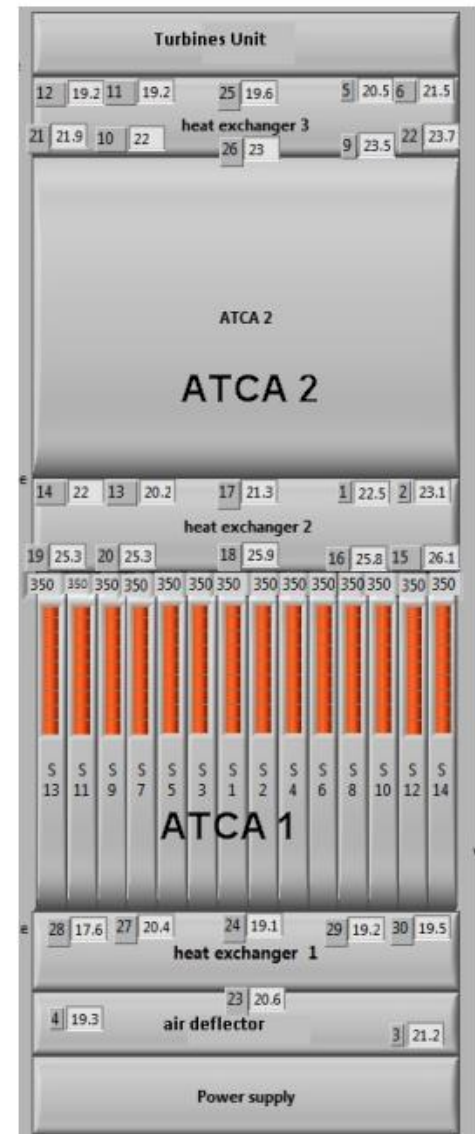
Rack in USA15

Rack cooling measurements (2)

- 350W per slot (maximum of load blade)
- Air temperature in rack 20 – 26°C
- Power fully removed by water cooling
- Caveat:
 - Only one ATCA chassis loaded, half the target power
- Discrepancies between measurement and simulation
 - Currently being investigated
- Next steps: acquire additional load modules (ASIS 650W per slot) to load two shelves



ATCA 1 14 x 350W, ATCA 2 only fans



AC-DC power rectifiers

- Tested modular AC/DC rectifiers for xTCA applications
- Install in bottom of rack to supply ATCA shelves with -48V DC
- Example: Bel Power Guardian
 - Up to 5 AC/DC rectifier modules in 3U
 - 2900W per rectifier module, 14.5 kW
 - N+1 redundancy
 - Remote control (USB + ethernet)
 - 8 circuit breaker outputs (32A)
 - High efficiency (95% reached)
- Evaluation reports available:
<https://espace.cern.ch/ph-dep-ese-be-PS-Evaluation>



Bel Power Aspiro (4.8 kW, 2U)



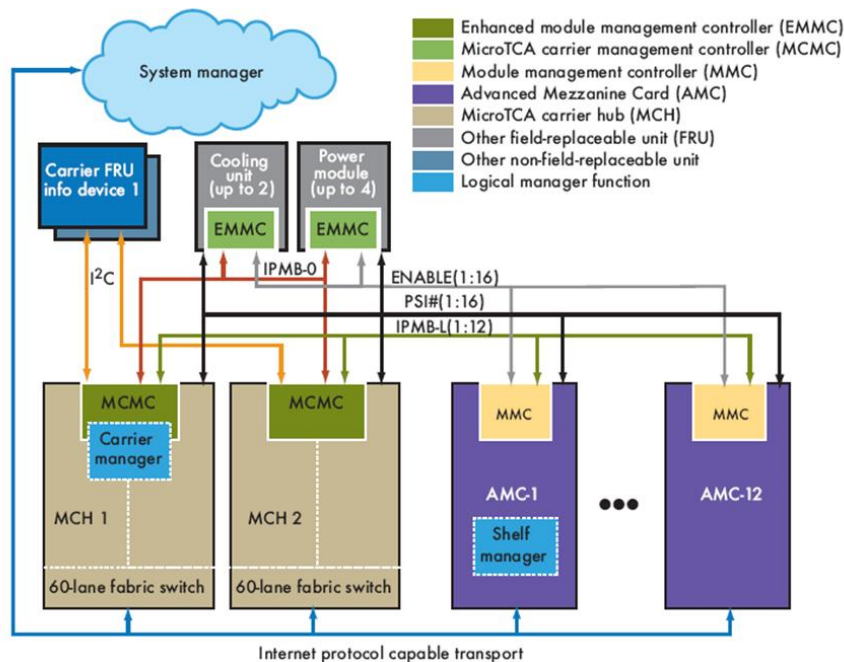
Bel Power Guardian (3U 14.5 kW)



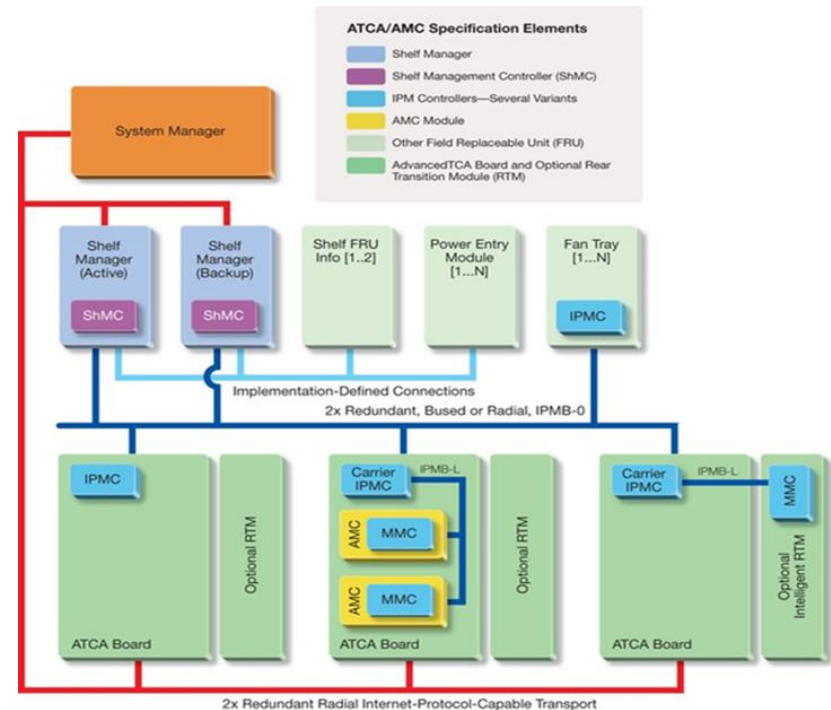
Emerson Networks NetSure501
(10 kW, 5U)

Board Management

- **MMC (Module Management Controller)**
 - Microcontroller on AMC modules
- **IPMC (Intelligent Platform Management Controller)**
 - Microcontroller on ATCA blades



MTCA hardware platform management



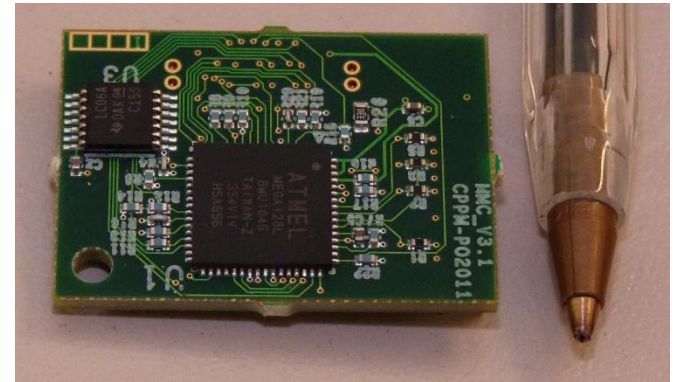
ATCA hardware platform management

ATCA/AMC Specification Elements

Shelf Manager
Shelf Management Controller (ShMC)
IPM Controllers—Several Variants
AMC Module
Other Field Replaceable Unit (FRU)
AdvancedTCA Board and Optional Rear Transition Module (RTM)

CERN MMC

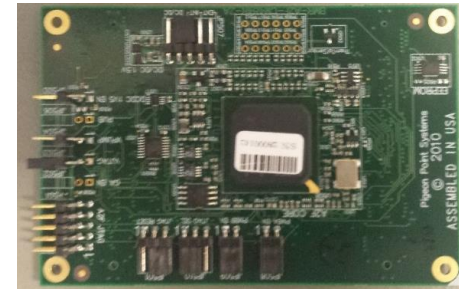
- Simple Atmel ATmega128L design
 - Based on development by DESY/CPPM
- Small mezzanine card available
- Can also be easily integrated directly on AMC modules
- New MMC software release features:
 - HPM.1 support
 - E-keying support
 - FRU editor
- Bug fixes
- Code restructured/rewritten to improve standards compatibility
- MMC compliancy software test fully passed (Polaris Networks)
- Successfully tested on in-house and externally designed AMCs
- S/W and documentation for MMC available (under GPL):
https://espace.cern.ch/ph-dep-ESE-BE-uTCAEvaluationProject/MMC_project
- Porting of S/W to 32-bit microcontroller (Atmel AT32UC3A3256) on-going
 - Microcontroller used on CMS designed AMCs



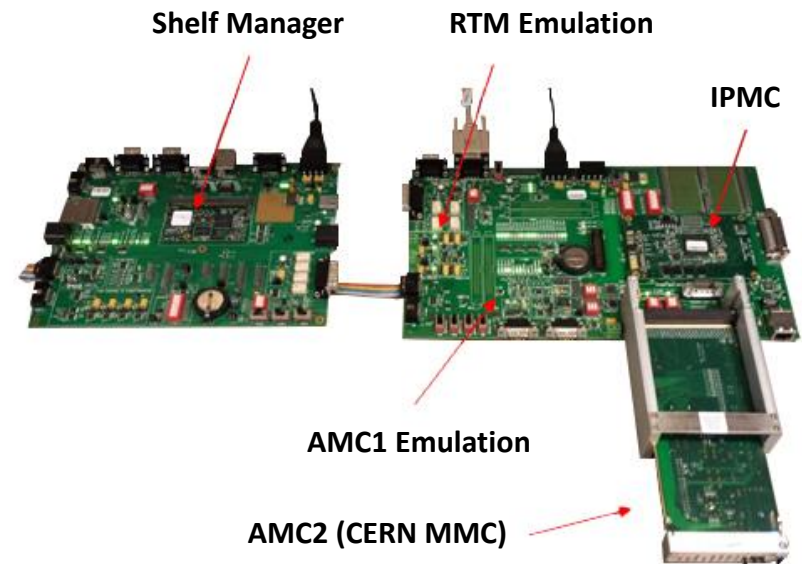
CERN MMC mezzanine

IPMC evaluation (1)

- **Commercial IPMC solution from PigeonPoint**
 - Market leader in ATCA management
 - Recently acquired by Pentair/Schroff
- **CERN PH-ESE acquired IPMC license**
 - Includes S/W, reference design & starter kit
 - H/W based on Microsemi SmartFusion SoC mixed-signal FPGA
- **Bench-top tests successful**
 - PigeonPoint S/W & F/W adapted to LAPP IPMC specification
- **Adapter card developed to fit PigeonPoint IPMC mezzanine in LAPP IPMC connector**



PigeonPoint IPMC mezzanine

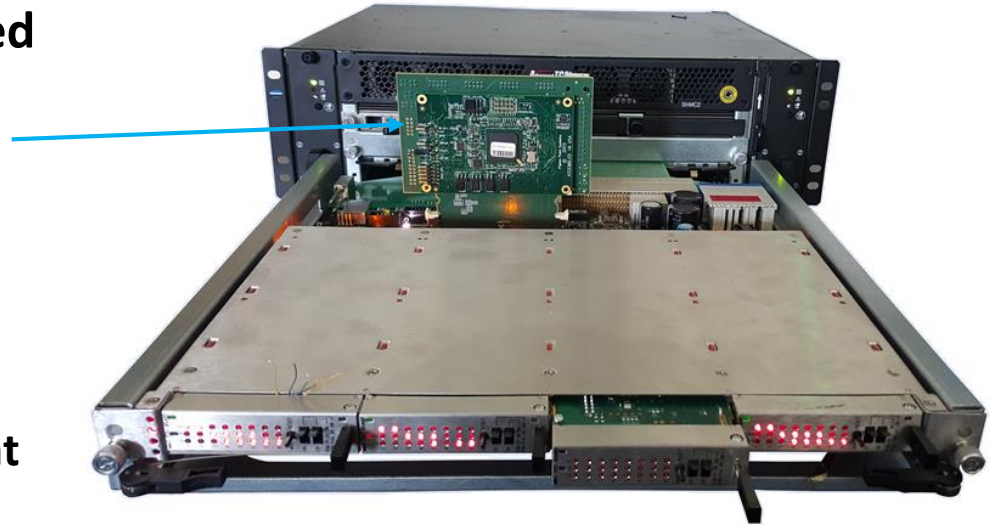


PigeonPoint IPMC starter kit hardware

IPMC evaluation (2)

- IPMC mezzanine successfully tested on LAPP IPMC test blade using adapter card

- Blade management
- AMC management
- Sensor reading
- IPMI standard compliance
- RTM to be tested with on a different ATCA blade

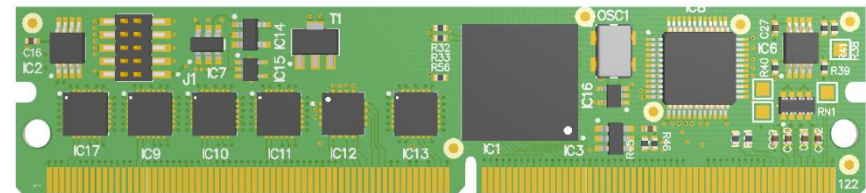


PigeonPoint IPMC on an existing ATCA blade
(LAPP IPMC test blade)

- Next steps

- Implementation of PigeonPoint IPMC design in VLP mini-DIMM form factor
- PCB layout on-going
- Test compatibility with other ATCA blades

- See also poster by J. Mendez:
Evaluation of a commercial AdvancedTCA board management controller solution (IPMC)



PigeonPoint IPMC in VLP mini-DIMM form factor

Summary (1)

MTCA

- Evaluation phase completed
- Specifications for custom vertically cooled shelf and PM defined and pre-series units evaluated
- Available for order for CERN experiments beginning 2016
- Possible next step:
 - Define and make available a MTCA benchtop kit including MCH and AC/DC PM through electronics pool at CERN

ATCA

- Various candidate shelves evaluated
- Vertically cooled ATCA shelf prototype from ASIS available and tested
- Thermal/airflow simulations of standard LHC rack with 2 vertical cooling ATCA shelves
 - Detailed blade level modelling and simulations ongoing
- Collaboration with ATLAS for LHC rack cooling measurements

Summary (2)

ATCA (cont.)

- **Next steps:**
 - Continue program of cooling simulations and measurements
 - Decide on horizontal/vertical airflow based results
 - Produce shelf specification by mid 2016

Board management

- **New MMC software release**
 - HPM.1 and e-keying support, full AMC standard compliancy
 - Porting to 32-bit microcontroller on-going
 - Provide MMC hardware reference design and support
- **Evaluation of PigeonPoint IPMC software/firmware positive**
 - Test IPMC design implemented in LAPP form factor
 - Check RTM functionality
- **AC/DC modules for powering xTCA shelves have also been evaluated**

Questions?