Status and future of xTCA developments (not necessarily an exhaustive report)

Markus Joos

CERN EP/ESE

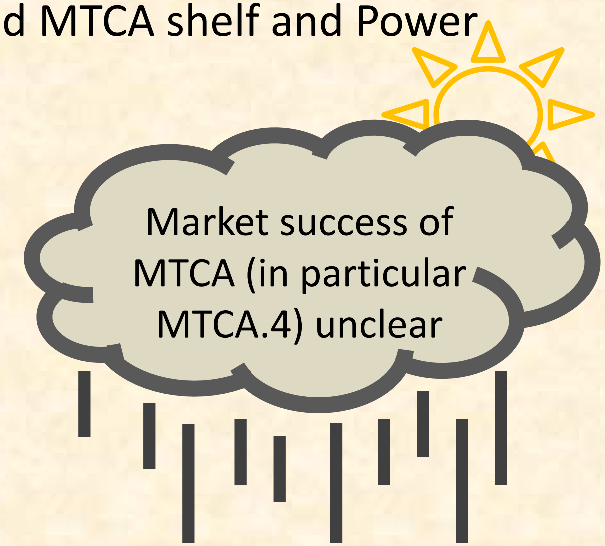
- EP/ESE
- ATLAS
- CMS

EP/ESE xTCA evaluation project (2011-2016+)

- Technical evaluations of selected MicroTCA and ATCA components
- Focus on infrastructure components (shelves, power supplies, …)
    - ATCA shelves
    - AC/DC rectifiers for ATCA
    - MTCA shelves and power modules
- ATCA rack cooling simulations and measurements
- Development of components
    - MMC software for AMCs
    - IPMC for ATCA
- Equipment recommendations and user consultancy
- Establishment of a purchasing and support framework

MTCA status and results

- Initially perceived to be simpler …
- Activity started in 2011
- Motivation
  - Attempt to standardize MTCA components
  - Simplify purchasing procedure at CERN
  - Provide support for standardized equipment
- Equipment evaluation phase mostly completed
- Evaluation reports available (shelves, power modules, MCH): https://espace.cern.ch/ph-dep-ESE-BE-uTCAEvaluationProject
- Specification & price enquiry for vertically cooled MTCA shelf and Power Module (PM) done

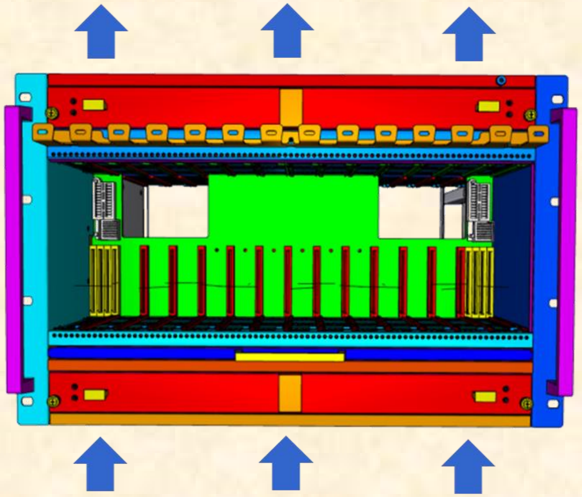


Custom MTCA shelf

- Custom MTCA shelf compatible with vertical airflow in the LHC racks
  - 19”/ 7U high
  - 80W per slot (including RTM)
  - 12 full-size, double-width AMC slots
    - MTCA.4 recommends compact size
  - 6 RTM slots (MTCA.4 like)
  - 6 PM slots (2 front / 4 rear)
    - Max. 4 active PMs
  - 2 possible backplane topologies
    - MTCA.4 & CMS
  - Rear JTAG switch module slot (JSM)
- Price enquiry completed
  - Selected supplier: Schroff
- Pre-series units qualified, report produced
- Available for purchase:

https://espace.cern.ch/ph-dep-ESE-BE-uTCAEvaluationProject/Procurement/_layouts/15/start.aspx#/SitePages/Home.aspx

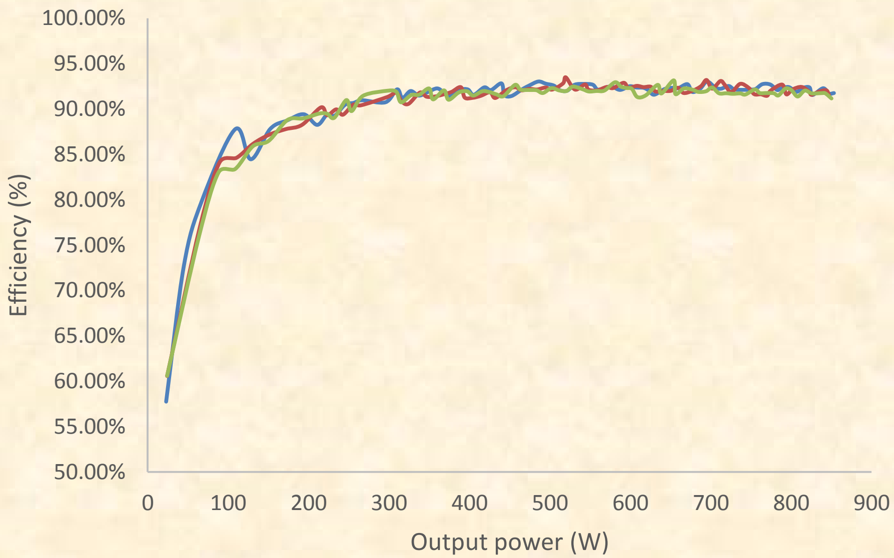
Custom MTCA shelf with load AMCs



MicroTCA Custom shelf, FRONT view.

MTCA Power Module (PM)

- PM specifications:
  - DC/DC (-48V/12V and 3.3V)
  - Total output power: 840W
  - 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 qualified, report produced
- Available for purchase: https://espace.cern.ch/ph-dep-ESE-BE-uTCAEvaluationProject/Procurement/_layouts/15/start.aspx#/SitePages/Home.aspx



ATCA shelves evaluated

- Standard commercial shelves (horizontal airflow)

Schroff 14-slot, 13U

ASIS 14-slot, 16U

Comtel 14 slot

ELMA 14 slot

- Custom shelf (vertical airflow for standard LHC rack)

ASIS custom shelf, 14U

Evaluation reports available:
https://espace.cern.ch/ph-dep-ESE-BE-ATCAEvaluationProject

Horizontal or vertical cooling?

Horizontal	Vertical
Use of **COTS** xTCA shelves	Custom xTCA shelves mandatory (related NRE costs and potential higher lead-time)
Sufficient cooling capacity available per rack (up to 15kW per cooling door)	**Limited heat-exchanger efficiency** (2/3 of surface capacity resulting in 2kW cooling power)
Heat of 48V AC-DC removed by the rack rear cooling door	48V AC-DC converter (horizontally cooled) must be placed outside of vertical airflow (below the deflector and its cooling must rely on the CR AC)
Less damage risk in case of water leak from the heat exchanger	Risk of water dripping on the ATCA electronics
Independent shelf airflow (one shelf could be turned OFF while the other is loaded)	Cross shelf airflow dependency (in case one shelf is stopped the other sees a high airflow resistance). Can lead to potential electronics overheating
Racks to be modified and equipped with rear cooling doors	Reuse of the rack (horizontal heat exchangers and deflectors may have to be repositioned)
In-rack smoke detection must be adapted for rear-cooling doors	Reuse of the existing rack infrastructure (smoke detection, monitoring and control)
Front and back **cabling must be managed appropriately** in order not to obstruct the air inlet and outlet	Free access to both sides of the shelf
Some racks are currently equipped with a full height glass front door. It is not know yet if such doors can be used with horizontal airflow	Racks can be closed with doors
Higher level of noise (~85 dbA @1 m and 75 % fan speed)	Also noisy…. Easier to install sound absorbing material

Cooling measurements

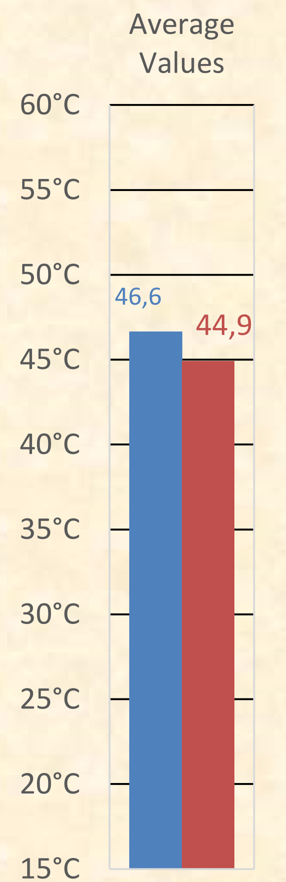
Vertical and horizontal air flow cooling tests on a standard LHC rack performed by ATLAS technical co-ordination (C. Bortolin)

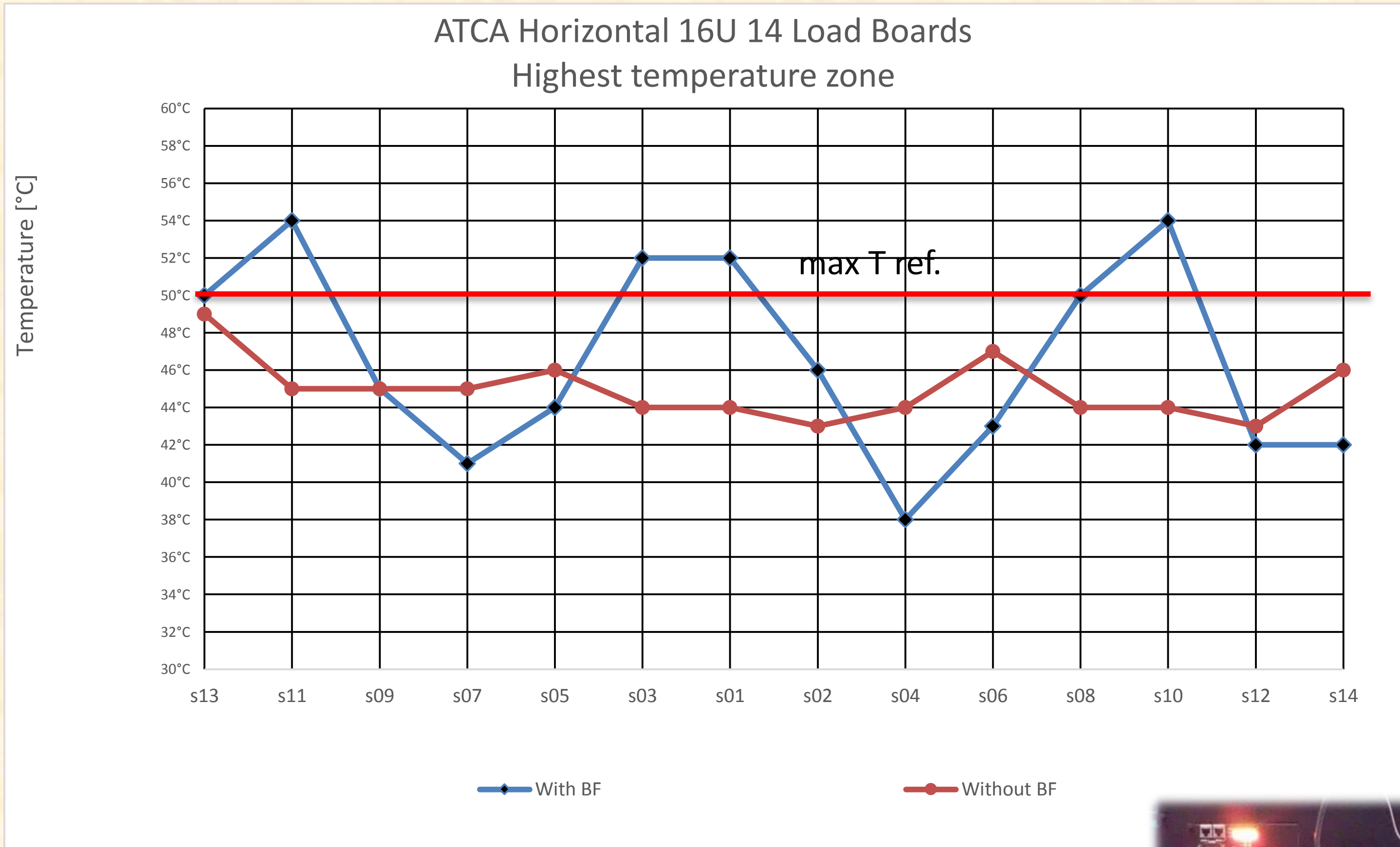
- Cooling capabilities of the LHC rack need to be checked for transition from VME to ATCA
- Identify potential in-rack airflow restrictions. Propose possible alternatives/solutions to remove them and test these adaptations. If required run complementary simulations to confirm improvement
- Mechanical improvements on the rack to optimize the cooling performance (i.e.: removal of turbine chassis, etc…)

Load blade layout. Max 600W (14x)

Sensors layout was changed according to the kind of test

ATCA Horizontal 350[W] – Comtel Load Boards



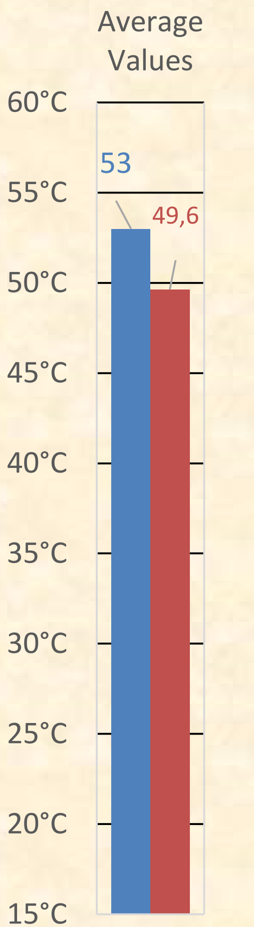


With Bottom Fans
Without Bottom Fans

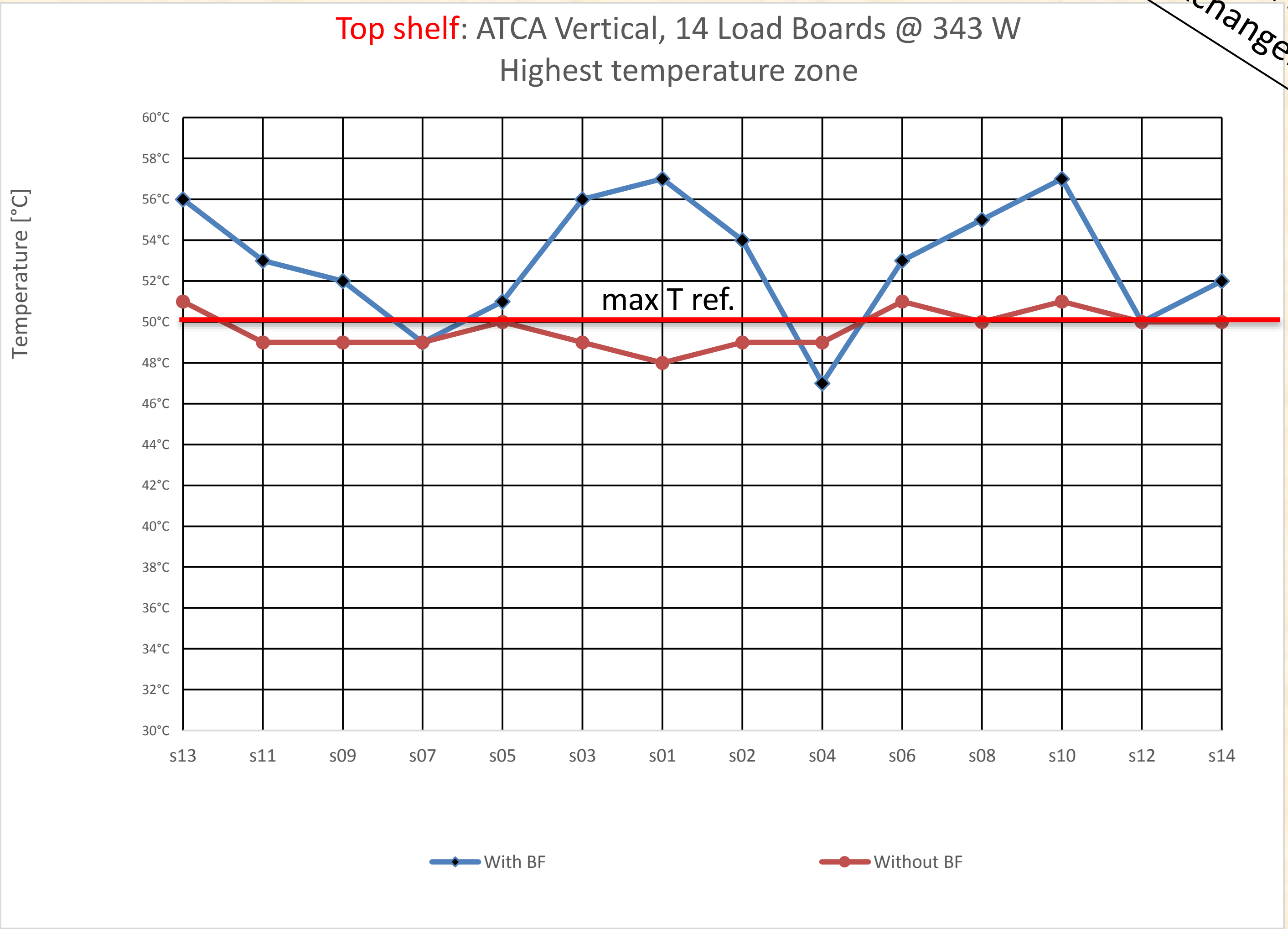
Significantly lower and more homogeneous temperatures by removing the bottom fans trays

ATCA Vertical 322[W] – Asis Load Boards (On The Bottom)
ATCA Vertical 343[W] – Comtel Load Boards (On The Top)

Rack with 3 heat exchangers



With Bottom Fans
Without Bottom Fans



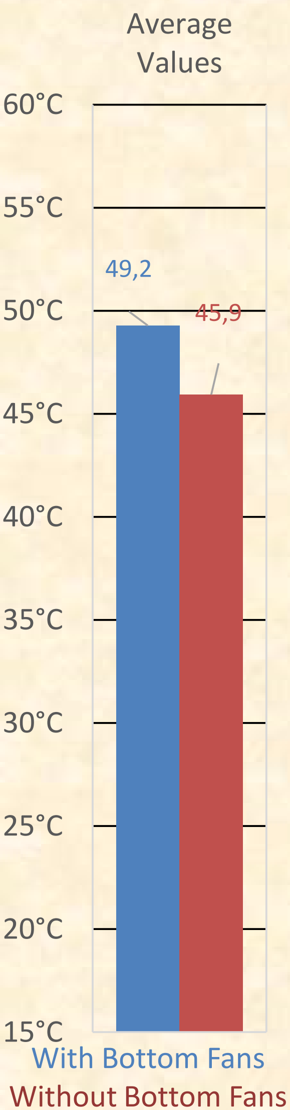
Despite the improved flow distribution (by removing bottom fans) through the blades there are board temperatures exceeding 50 C -> add 4th heat exchanger

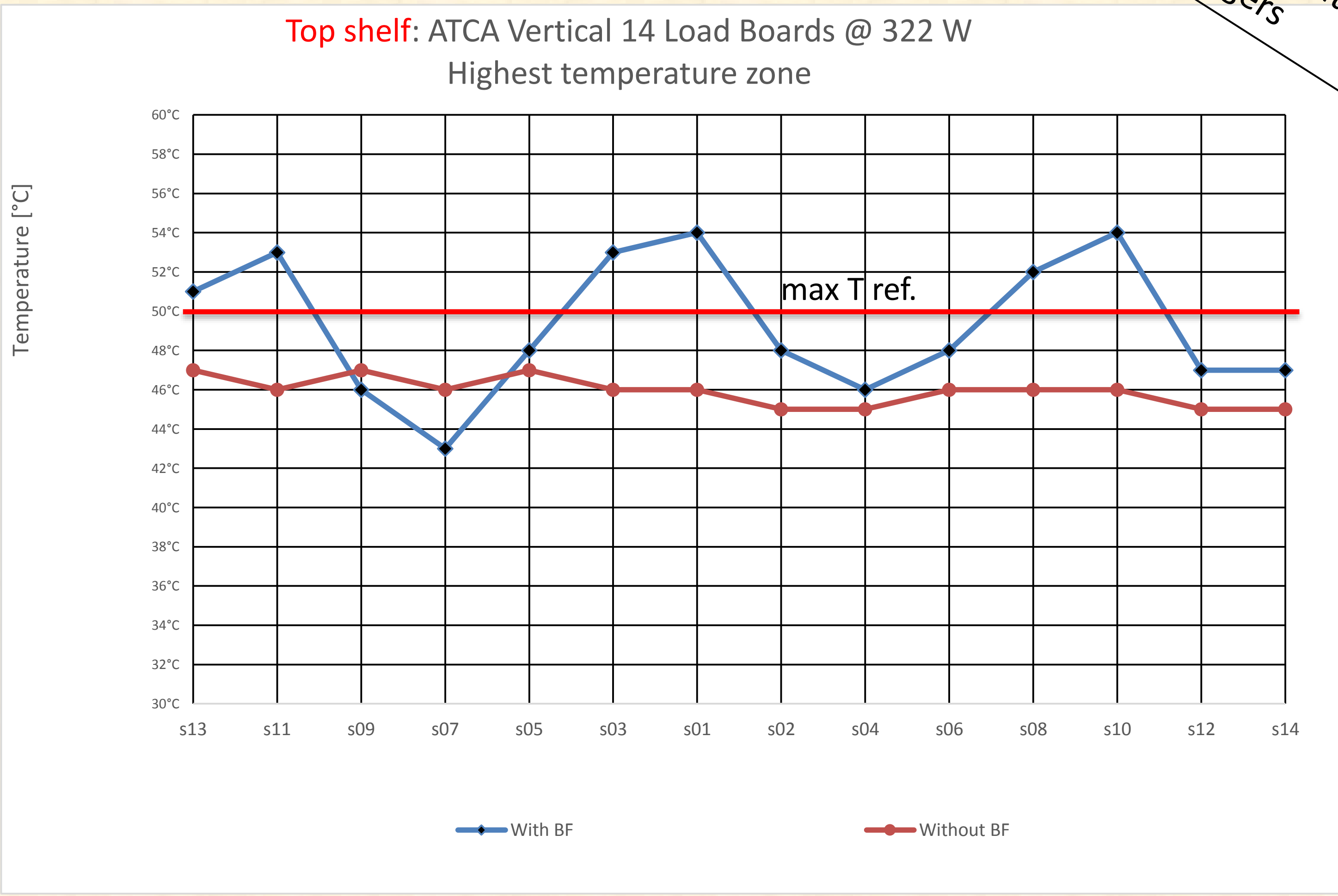
ATCA Vertical 322[W] – Asis Load Boards (On The Bottom)

ATCA Vertical 322[W] – Comtel Load Boards (On The Top)

Rack with 4 heat exchangers

Tests with higher power planned





Temperature goal achieved but less headroom as in horizontally cooled shelf

AC-DC power rectifiers

- Tested modular AC/DC rectifiers for xTCA applications
- Installed in bottom of rack to supply ATCA or MTCA shelves with -48V DC

UniPower Aspiro (4.8 kW, 2U)

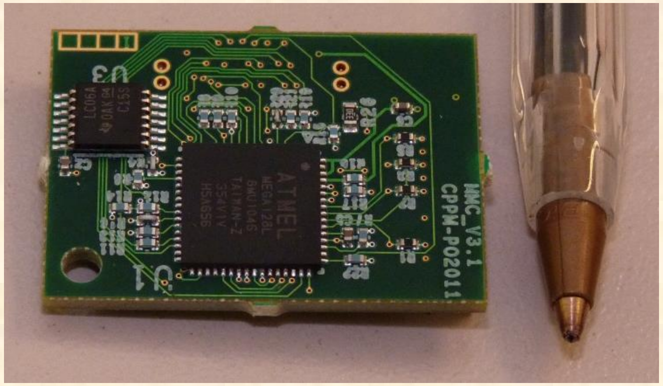
- Example: UniPower Guardian
  - Up to 5 AC/DC rectifier modules in 3U
  - 2900W per rectifier module, 14.5 kW
  - N+1 redundancy
  - Remote control (USB + Ethernet)
  - Up to 13 circuit breaker outputs (32A)
  - High efficiency (95% reached)

UniPower Guardian (3U 14.5 kW)

- Evaluation reports available https://espace.cern.ch/ph-dep-ese-be-PS-Evaluation
- Market Survey to be started……

CERN MMC

- Simple Atmel ATmega128L based design
- Small mezzanine available
- Also easily integrated directly on AMC modules
- New MMC software features:
  - HPM.1 support (in-situ F/W update)
  - E-keying support
  - FRU editor



CERN AMC mezzanine

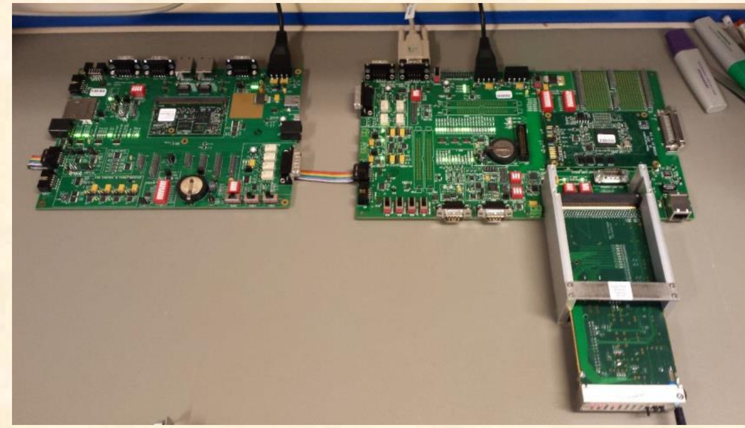
- Code restructured to improve standards compatibility and porting to other microcontrollers (porting to AT32UC3A3256 and AT32UC3A1552 done)
- MMC compliancy software test (Polaris Networks) fully passed
- Successfully tested on in-house AMCs
- S/W and documentation for MMC available (under GPL):

https://espace.cern.ch/ph-dep-ESE-BE-uTCAEvaluationProject/MMC_project

- New release available

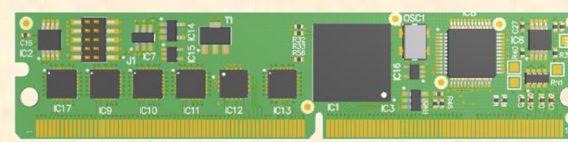
PigeonPoint IPMC evaluation

- EP-ESE acquired PigeonPoint IPMC license
  - Market leader in ATCA management
  - Recently acquired by Pentair/Schroff
  - Includes S/W, reference design & starter kit
  - H/W based on Microsemi SmartFusion SoC mixed-signal FPGA
- Initial bench-top tests promising
  - PigeonPoint S/W & F/W adapted to LAPP IPMC specification
- Adapter card developed to fit PigeonPoint IPMC mezzanine in LAPP IPMC connector
  - Successfully tested PigeonPoint IPMC on LAPP IPMC test blade
- CERN IPMC
  - Mezzanine designed
  - Next:
    - Debugging of the prototype
    - Add hooks for user code to PigeonPoint S/W



PigeonPoint IPMC starter kit hardware

PigeonPoint IPMC mezzanine



CERN IPMC

EP-ESE - Summary

MTCA

- Evaluation phase completed
- Specifications for custom vertically cooled shelf and PM defined and pre-series units evaluated
- Available for order by CERN experiments
- Possible next step:
  - Define and make available a MTCA kit including MCH and AC/DC PM through the Electronics Pool

ATCA

- Various candidate shelves evaluated
- Vertically cooled ATCA shelf prototype available and tested
- Thermal / airflow simulations of standard LHC rack with 2 vertically cooled ATCA shelves
- Close collaboration with ATLAS for LHC rack cooling measurements
- AC/DC modules for powering xTCA shelves have also been evaluated
- Next steps:
  - Continue program of cooling simulations and measurements
  - Produce shelf specification by mid 2016 followed by MS & CFT

Board management

- CERN MMC
  - HPM.1 and e-keying support, full AMC standard compliancy
  - Porting to 32-bit microcontrollers complete
    - Provide 32-bit MMC hardware reference design and support (mid 2016)
- CERN IPMC
  - Evaluation of PigeonPoint IPMC software/firmware positive
  - IPMC design implemented in LAPP form factor
    - Prototype to be tested
    - RTM functionality to be checked

ATCA in ATLAS

- Overview
  - Upgrades until Phase-I: Trigger, LAr calorimeter, CSC readout, FTK, muon new small wheel, …
- ATCA chosen for most off-detector electronics upgrades
- Number of ATCA shelves used in USA15:
  - Phase-0: 2 shelves (6-slot)
    - L1Topo (1), CSC ROD (1)
  - Phase-I: ~20 shelves (14-slot)
    - FTK (5), L1Calo eFEX / jFEX / gFEX (3-4), LAr LDPS (3), NSW (2-3), MUCTPI (1)
  - Phase-II: lAr, Tile, …..

NSW:
- ATCA board developed together with industry (Eicsys Gmbh) within RD51 framework
- full mesh backplane
- Clock and Trigger (AXIe compliant)
- Proprietary IPMC

CSC:
- One shelf with 6 cards (COB) in operation since 2015
- ATCA backplane not used for data exchange
- Shelf manager connects via Control Network to DCS
- 3 important components (G-Link, S-Link, TTC distribution) implemented in firmware instead of using dedicated hardware (G-Link Card, S-Link Hola Card, TIM), resulting in lower footprint and power consumption.

L1Track / FTK:
- Target: Phase - II
- 12 processing cards per shelf
- 2 (3?) shelves per rack
- Planned ATCA card (development not started): AMTP (Associative Memory Tracking Processor), 400 W
- Issue: ATCA allows less dense packing of AM chips than customized crate (due to wider card pitch)

ATCA in ATLAS - II

lAr

To provide a finer granularity for the LAr trigger for Phase I

Cards: ATCA Carrier blade & RTM and an AMC (LATOME)

Institutes (for the hardware): Stonybrook (carrier & RTM) and LAPP (LATOME AMC). For the firmware many more institutes.

Deployment in USA15: For Phase I in 2018 (30 carrier blades and 120 AMCs in 3 ATCA shelves)

Power consumption limits on AMC (80 W) and full blade might limit functionalities implemented in the AMC.

L1Calo

ATCA blades in development:

- eFEX –first prototype was received earlier this month.
- gFEX – prototypes exist.
- jFEX – still under design. The power consumption is estimated to be ~400W, at the edge of the specification for ATCA in ATLAS, which is a concern. Prototype expected August 2016.
- Hub – still under design. Prototype expected August 2016.

Plan to start system-level tests of these modules in Q3 2016.

One thing to note is that we've deviated from the ATCA standard in 2 ways.

- First, we've extended the form factor of the front board through Zone 3 into the rear space, to make the routing of optic fibres easier.
- Second, in the jFEX shelf, we use a dual-star configuration Fabric Interface, but with 2 of the signal pairs in reverse direction from standard, such that each Hub slot has 6 input pairs and 2 output pairs.

For the IPMB interface, we use the LAPP IPMC card.

ATCA in ATLAS - III

LAPP – IPMC Status

Hardware:

- 120 boards produced and 70 distributed: ATLAS FTK, LAr & L1Calo (e/j/g/FEX, Topo); CMS, BELLE.
- New batch of 120 boards will be produced in 2016 to cover known requests up to end 2017.

Firmware:

- ICARE-00-01-00 available since December 2015
- ATCA blade support OK
- AMC support Firmware OK
- Upgrade via tcpip 10/100MbE OK
- Not yet integrated: JTAG master (under test) and AMC E-Keying
- To be done: Polaris test

Latest presentation: https://indico.cern.ch/event/470196/

DCS

There is a JCOP framework component (fwATCA) already in operation and used by CSC and FTK. Later L1Topo will join. It is based on SNMP communication with the Pigeon Point SM.

See also:

https://twiki.cern.ch/twiki/bin/view/Atlas/AtlasDcsAtca

https://indico.cern.ch/event/355891/session/4/contribution/20/attachments/706827/970388/DCS_UpgradeWeek_04_2015.pptx -> slide 7

Open question: Does that tie ATLAS to companies that sell Pigeon Point based SMs?

xTCA in CMS

MTCA:

LS1: HCAL back-end, L1rigger, TCDS (trigger control distribution system), pixel backend EYETS16/17)
LS2: GEM

- Experiment-wide backplane signal connectivity scheme
    - Clocks, TTC, TTS (=TTC feedback to throttle trigger), DAQ
- MMC: 2 microcontrollers, 3 different S/W designs (aiming at decreasing to 2 S/W designs)
- AMC form factor: dual width, full height, no RTMs
- Power budget: 80 W (seen as limitation for next generation boards)
    - Power density on AMC makes cooling difficult.
- Systems installed in the pit: ~40
- Reliability: No failures in operation!
- Endpoint protocols: IP-bus (to CMS F/W), TCP/IP (to embedded Linux)

ATCA (LS3):

- Applications: Sub-detector read out
    - Idea: Route physics data from input blade across backplane to switch blade. Then exit on 2*40 or 100 Gbit Ethernet to N/W
- Motivation: Power and cooling (board space less of an issue)
- ATCA less adapted to TDAQ (lack of clock distribution)
    - Have to "hijack" backplane signals
- Next step: Work on connectivity standard
- Volume: 50 – 100 shelves
- Cooling: Preference for vertical cooling (VMEbus compatible)
- Shelves per rack: 3!
- IPMC: Use common design (if available in time)
- Milestones:
    - Preliminary report in June 2016
    - Sub-detector TDRs: 2017

For your agenda:

10th meeting of the xTCA interest group

Thursday, 10 March 2016 from 15:00 to 17:30

CERN (13-2-005) and Vidyo

https://indico.cern.ch/event/470196/

This afternoon!