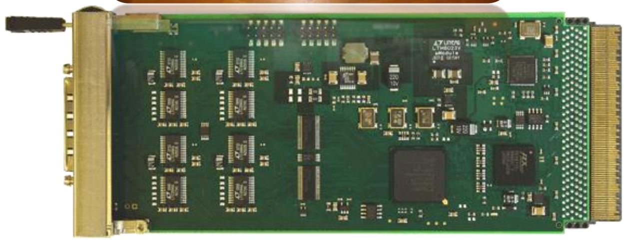


# Modular Electronics:
# Present and Future in the LHC experiments

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# Outline

- Modular electronics in the current systems
- What has been good with VME or "VME-like" systems
- Possible replacement options
- On-going work in the LHC experiments



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# Modular electronics in the current systems

- Modular electronics in
  - The trigger systems
  - The TTC and control systems
  - Some of the the readout systems
- Mainly VME or "VME-like"
  - ALICE 69 crates
  - ATLAS 219 crates
  - CMS 194 crates
  - LHCb 146 crates (including the TELL1 crates)
  - ***Total 628 crates***
- CMS uses also CompactPCI at one stage
  - Easy interface to PCs


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# Use in the trigger systems

- Mainly VME 9U version used
  - Number of I/Os
  - Boundaries between boards to be avoided
- Standard mechanics and power supplies but adhoc backplanes
  - Interconnections between boards



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# Use in the readout systems

- At the exception of (a part of) ALICE, there is an intermediate stage between the front-end and the DAQ
  - ROD in ATLAS, FED in CMS, TELL1 in LHCb, Router for the ALICE Pixel
- Main functionalities
  - Gathering several low speed FE links
    - E.g. more than 8000 40-Mbps links for the ATLAS SCT
  - Implementing analogue to digital conversion
    - E.g. analogue readout of the CMS tracker
  - Data compression and fast processing
    - E.g. energy, timing and quality factor calculation for calorimeters
    - Data compression and formatting in the TELL1



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# Use in the readout systems (cont)



- The VMEbus does not see the main dataflow
  - Even no VMEbus in the LHCb TELL1 crates
  - Main dataflow through point to point links to upper stages
    - S-Link or S-Link64 in ATLAS and CMS
    - GbE in LHCb
- VMEbus used for control and monitoring
  - Dedicated common software in ATLAS and CMS
    - ROD Crate DAQ and XDAQ
  - Credit Card PC in the LHCb TELL1
- Additional backplanes for TTC distribution and/or dedicated functionalities where needed



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# What has been good and less good with VME

## *Mechanics and Power Supplies*

- Reasonable mechanical design
  - 6U, 9U and mixed
- Reliable power supplies and easy integration in the bin
  - Capability to insert and remove PS without tools
  - 2% failure rate in 2012
- Easiness of adhoc backplanes installation
- Rear transition modules (RTM) of all sorts
  - Heavily used
- Availability of a CERN purchase and maintenance contract
- Too many options for the power supplies
  - 5 V, 3.3 V, ± 12 V, 48 V with different power capabilities


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# What has been good and less good with VME

## *VMEbus and Interfaces*

- VMEbus is very well known in the community
  - About 30 years of experience
- Simple interface implementation
- Availability of Single Board Computers or performing interfaces
  - ATLAS and ALICE using a family of SBC from Concurrent Technologies
  - CMS using a CAEN interface and a PC
  - In both case easy evolution
- Capability of providing standard common software
  - ROD Crate DAQ and XDAQ
  - VME libraries
- Relatively cheap despite a high-end crate
  - 640 ChF per slot for a 9U system & 470 ChF per slot for a 6U system
  - Including bin, fan-tray, power supply and SBC
- Parallel bus requiring a lot of connector space and a lot of components
- A bit of an overkill for control applications



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# Modular electronics for the upgrades

- Is there still a need?
  - Certainly for the trigger
  - Readout might be different from today
    - All front-end digital
    - Use of GBT in a lot of places
    - → more standardisation possible
- Could VME do the job?
  - Bandwidth is not an issue
    - Main data flow not through the crate backplane
    - Level-1 has special requirements
  - VME is already an old standard and we have to consider a system lasting until 2030 – 2040

- Off-detector readout electronics mainly based on FPGAs and will rely on high density of high speed links
  - Large power needed per board (VME 9U limited to less than 100 W)
  - Large space between boards to accommodate heat sinks
  - 3.3 V and 5 V power supplies not adapted

→ ***Useful to consider a replacement***



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# What could be a replacement to VME?



- VXS as a natural successor of VME
- ATCA or µTCA
- Direct readout in PCs
  - For readout part only
- No standard
  - Define a bin with Fan Trays and power supplies
  - (GB)Ethernet interfaces on each board
  - Ethernet switches and PCs
  - i.e. a poor man xTCA…

- Next slides on what is going on in the community

- Details about the different standards can be obtained in a presentation by Markus Joos in https://indico.cern.ch/conferenceDisplay.py?confId=196590



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# On-going activities

- ALICE
  - Readout upgrade expected at LS2
  - Upgraded version of the DDL for the DAQ
  - No specific development yet for modular electronics located before
- ATLAS
  - Short term upgrades (CSC RODs, Topological Trigger, FTK) as well as upgrades for LS2 using ATCA
  - Willing to be compatible with upgrades to be done during LS3
- CMS
  - New FEDs (Pixels, HCAL, end-cap GEMs) and upgraded trigger using μTCA
  - No decision concerning LS3
- LHCb
  - Upgrade for LS2 using ATCA (Tell1 → Tell40)

***xTCA is clearly the replacement option...***



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# ATCA in a nutshell

- Advanced Telecommunications Computing Architecture
- 8U board size (called blade)
- Up to 16 boards (blades) per crate (called shelf)
- Up to 400 W per board
- 48 V power line distributed to boards
  - Local point of load DC-DC converters on the board
- Point to point high speed links
  - Up to 200 differential lines per blade
  - Full mesh or dual star
  - Up to 40 Gbps per channel
  - Agnostic
  - Base Interface and Fabric Interface
- Complete (and complex) management of the boards based on Intelligent Platform Management Interface (IPMI)
  - 1 or 2 shelf managers per shelf
- Three connector zones
  - Power, Data Transfer, User defined
- Rear Transition Modules (RTM) capability


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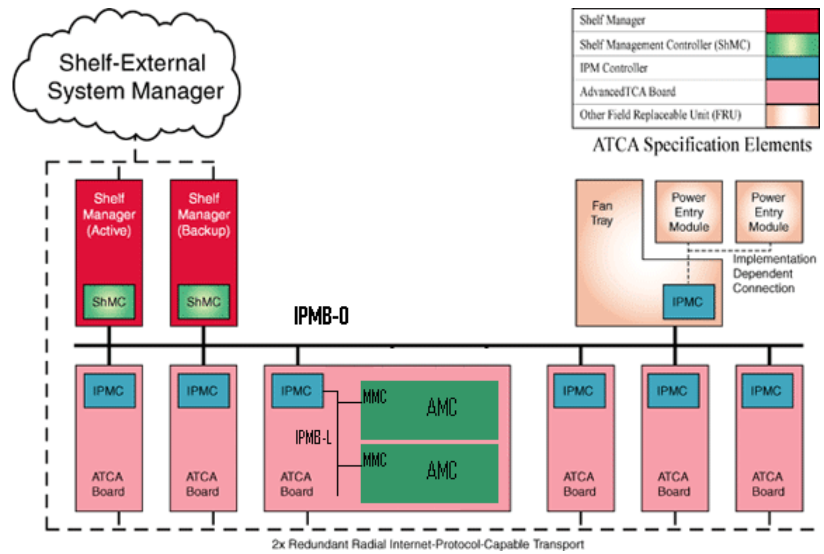
# ATCA: a bit more

- Redundancy
  - Power supplies
  - Fans
  - Shelf managers
  - Switch blades
- Hot swap
- Intelligent cooling
- Monitoring and control
  - Low level: IPMI on $I^2C$
  - High level: Simple Network Management Protocol (SNMP) and other protocols on top of TCP/IP
- Degree of freedom
  - Communication protocols
  - Backplane routing (full mesh, dual star, ...)




Dedicated tree for control and monitoring



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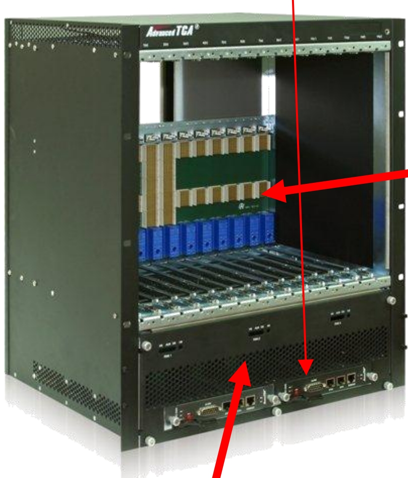
# ATCA components



Shelves

Shelf manager(s)



Backplane

Hot-swap fans

Switch blade

Payload card

AMC carrier

Rear Transition Module

*Courtesy Markus Joss*



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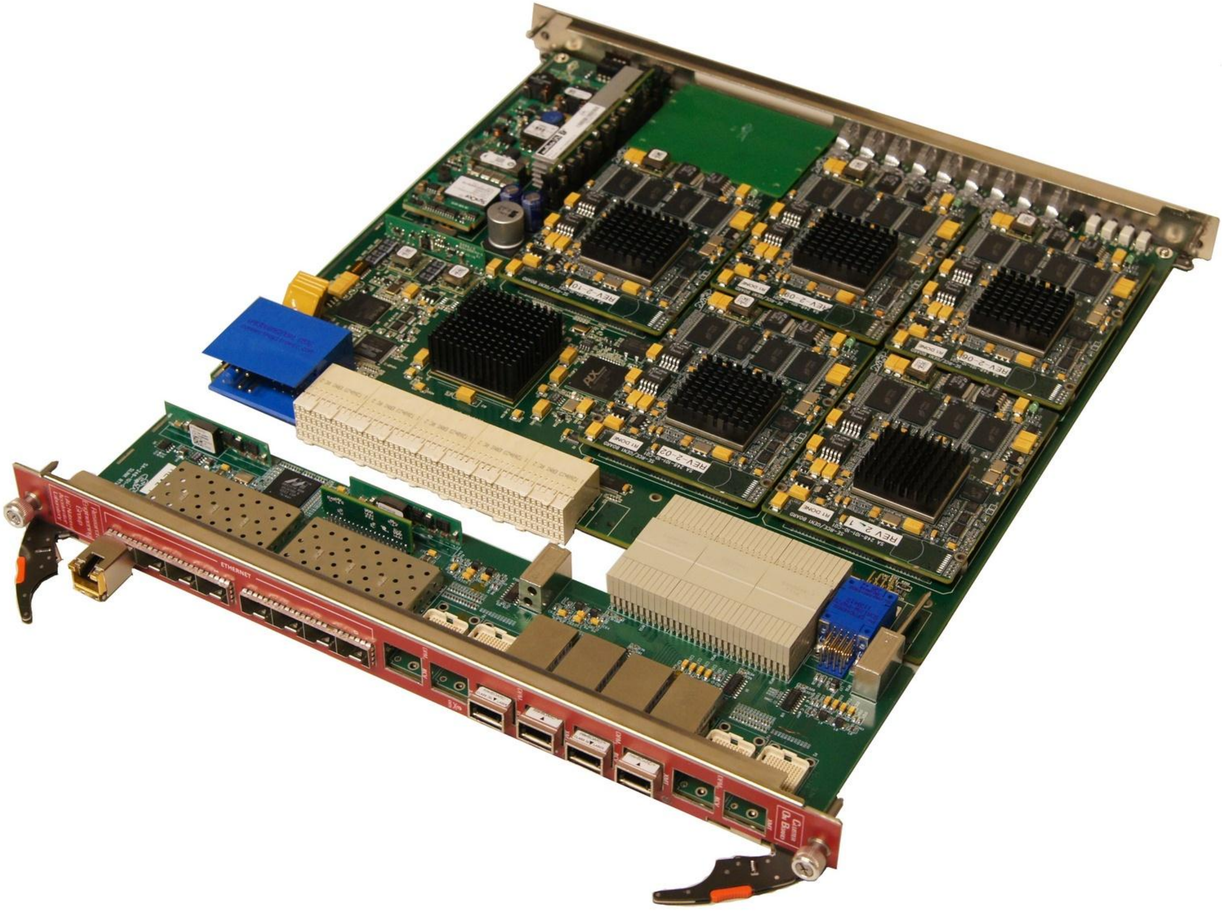
# SLAC blade

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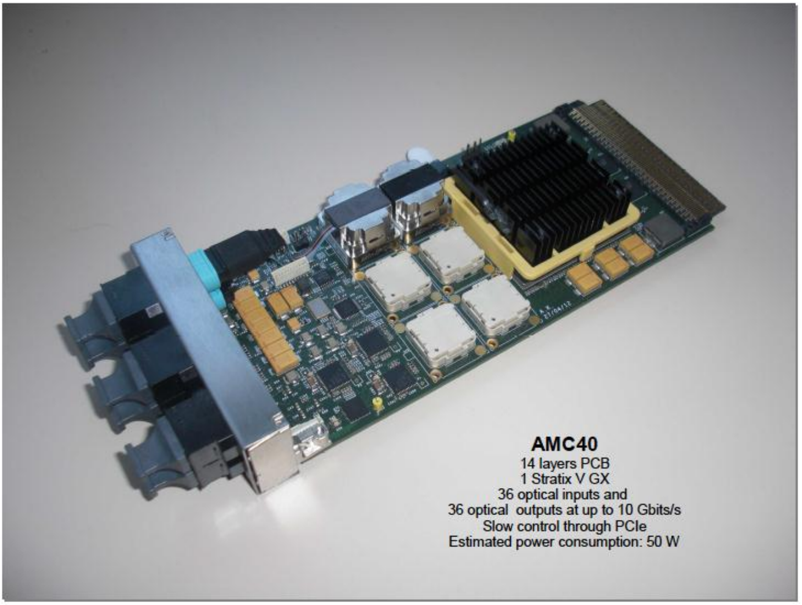
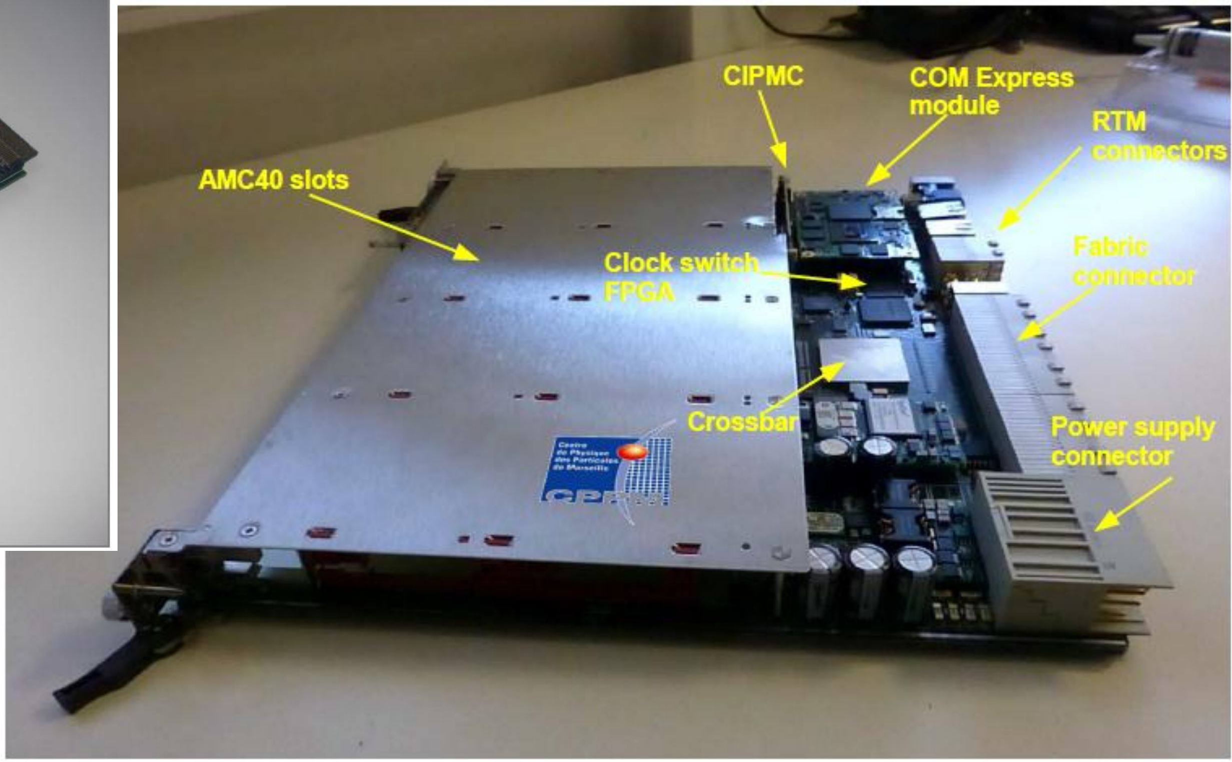
# LHCb TELL40



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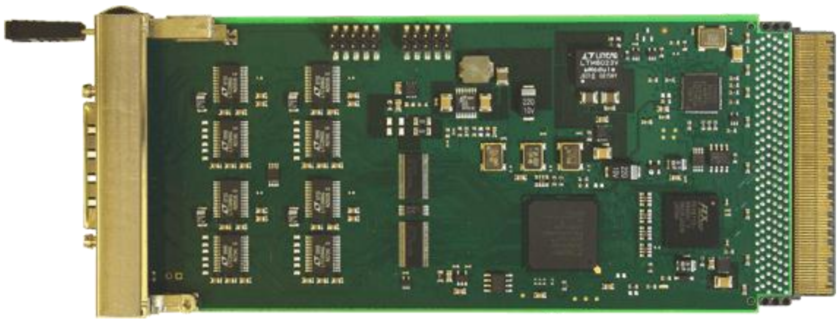
# Advanced Mezzanine Cards (AMC)



- Mezzanine cards for ATCA blades to modularize if needed
- 6 form factors
  - 2 widths, 2 heights and 1 depth
- 80 W max – 12 V supply
- 40 LVDS pairs for connectivity
  - Ethernet, PCIe, RapidIO, ...
- Basis for µTCA

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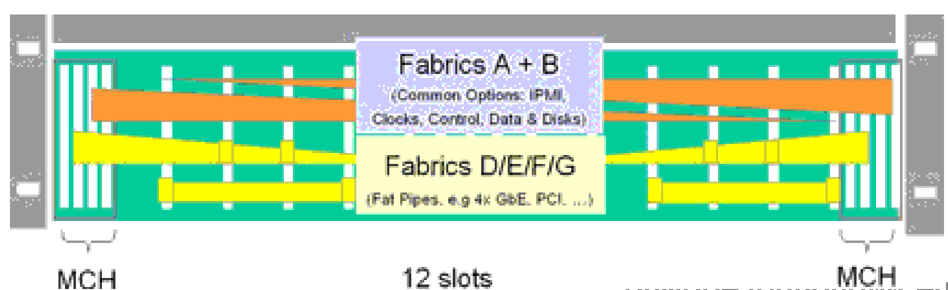
# µTCA in a nutshell

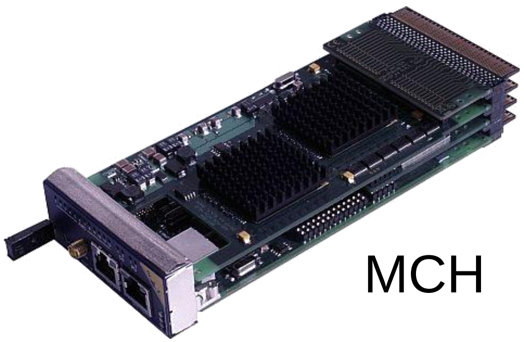
- Try and make a smaller and cheaper (?) system tan ATCA and put AMCs directly in a shelf
- Connectivity:
  - 4 AMC LVDS pairs defined as "Common Options" (2 Eth. & 2 SAS ports) and connect to 1 or 2 MCH boards which provide the switching
  - 8 AMC LVDS pairs defined as (extended) fat pipes (1 or 10 G Eth, PCIe, RapidI/O). Connection to MCH not fully standardized
  - Remaining 8 LVDS pairs not defined (can be used e.g. for direct connection to neighboring module or as a timing distribution bus)
- System management based on IPMI / I2C
- MTCA.4 adds RTMs and other features (µTCA for physics)
- Hot-swap support for AMC, MCH, PSU & cooling
- High degree of freedom
  - Height (13, 18 & 28 mm) and width (74 &149 mm)
  - Communication protocol
  - Backplane routing



# µTCA Components




Shelves



MCH

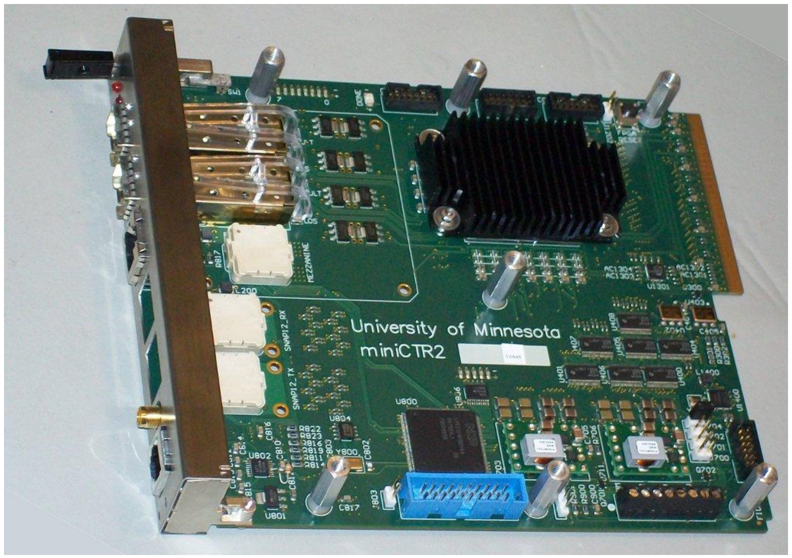
*Courtesy Markus Joss*


AMCs

# CMS Developments

SFP Optical Transceivers

SNAP12 Optical arrays




**For HCAL upgrade**

**For trigger upgrade**
**72 x 10 Gb bidirectional optical links**



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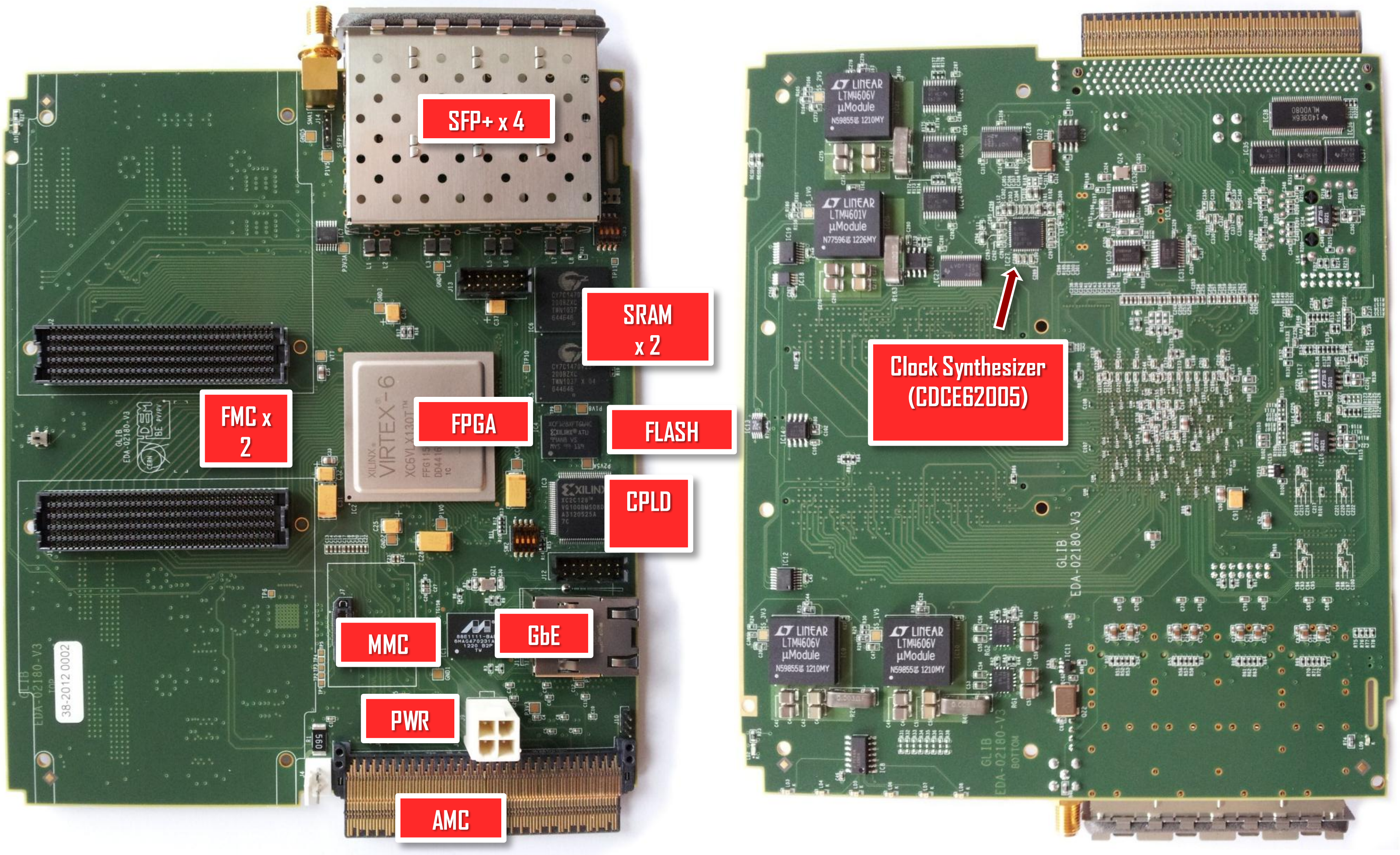
# GLIB



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# What do we want/need?

- Hardware
  - Decide on a standard with a limited number of variants
  - Get the same kind of procurement and maintenance contracts as we have for VME
  - As common as possible basic bricks and components
- Software
  - Provide the same kind of infrastructure as today
    - E.g. XDAQ and ROD Crate DAQ for ATLAS and CMS
  - Be able to control and monitor the hardware (power supplies, cooling, temperatures,...) in DCS


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# What's going on?

- CMS has selected μCTA and they plan procurement of crates relatively soon
- LHCb has selected ATCA for their TELL40 (see later)
  - Installation during LS2
- ATLAS is (slowly) defining a minimum set of requirements
  - Power, preferred protocol for the fabric and the base interface, TTC distribution, cooling, backplane topology (full mesh preferred)
  - Start looking at integration in DCS and ways of implementing the ROD crate DAQ (see later)
  - Discussion with LHCb to have commonalities
  - During LS1 very few systems to be installed. More during LS2. No large deployment before LS3



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# Crates Procurement

- The CERN ESE team taking care of the VME crates is starting looking at ATCA and µTCA systems in view of putting in place procurement and maintenance contracts
  - Investigating interoperability issues
  - Developing some "tools" for future H/W evaluations
  - That will take a bit of time (~2 years)
- It is very likely that ATLAS and LHCb will agree on a common ATCA crate
  - Based on highest demand
    - E.g. Full Mesh backplane
- There might be a schedule problem with the procurement of the CMS µTCA crates
- Some equipment will be made available in the electronics pool
- Available tool for checking interoperability of xTCA devices



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# Integration in existing systems

- Nice piece of hardware which requires “a bit” of software and xTCA is not the simplest system we can think of...
- It needs to be integrated in
  - DCS
  - In the DAQ framework (e.g. XDAQ and ROD Crate DAQ for CMS and ATLAS)


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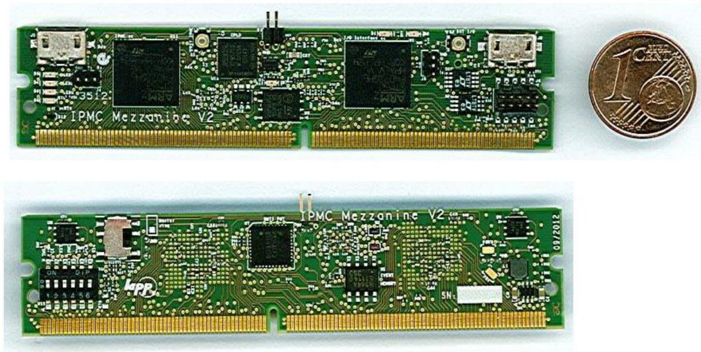
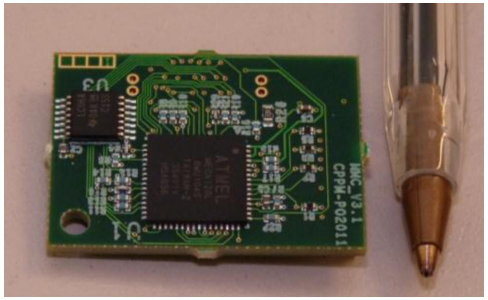
# Integration in DCS

- IPMI is a very powerful tool
- IPMC and MMC needed
  - Two common developments available
  - To be used by all
- Software tools
  - LHCb: ipmitool -> DIM -> DCS (WIN-CC)
  - ATLAS: ipmitool -> (open) HPI -> SNMP -> PVSS (WIN-CC-OA)
  - For "basic" control



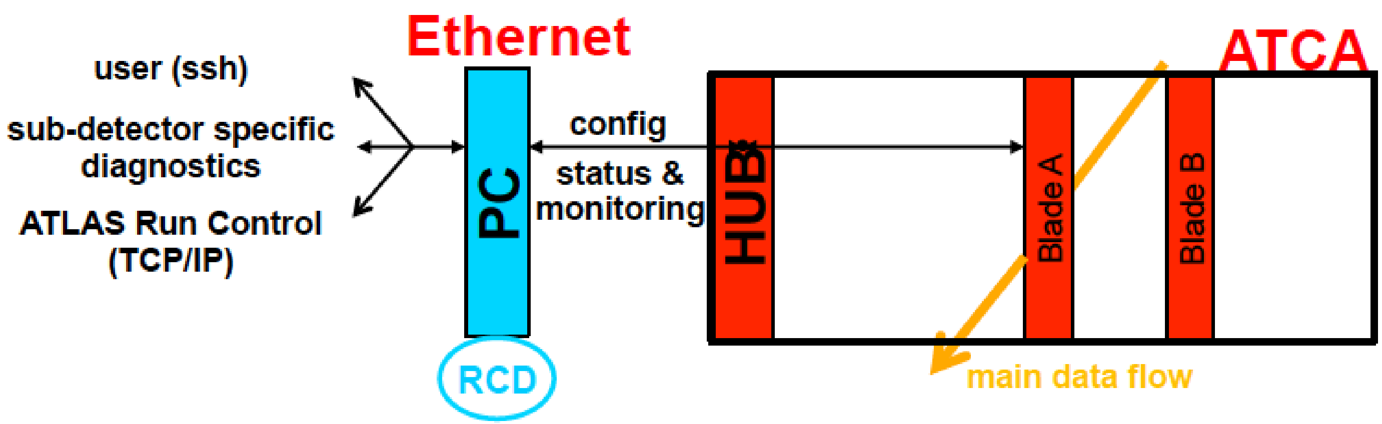
**IPMC (LAPP)**

**MMC (DESY/CPPM/CERN)**



# ROD Crate DAQ

→ <u>use a PC and a protocol over Ethernet for hardware access:</u>




*Courtesy Ralf Spiwoks*

- PC runs ROD Crate DAQ controller
- PC communicates with blades using Ethernet via a hub. IP (UPD?) packets routed over hub in ATCA crate to each blade (base or fabric).
- Requires a protocol on top of UDP/IP in order to provide hardware-specific transactions (READ/WRITE), e.g. like IPBus
- Features:
  - mapping of addresses very similar to VMEbus
  - requires UDP/IP stack in the firmware

***Developed by CMS. Based on UDP. Simple way to access registers etc.***



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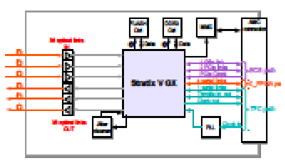
# LHCb TELL40

AMC40

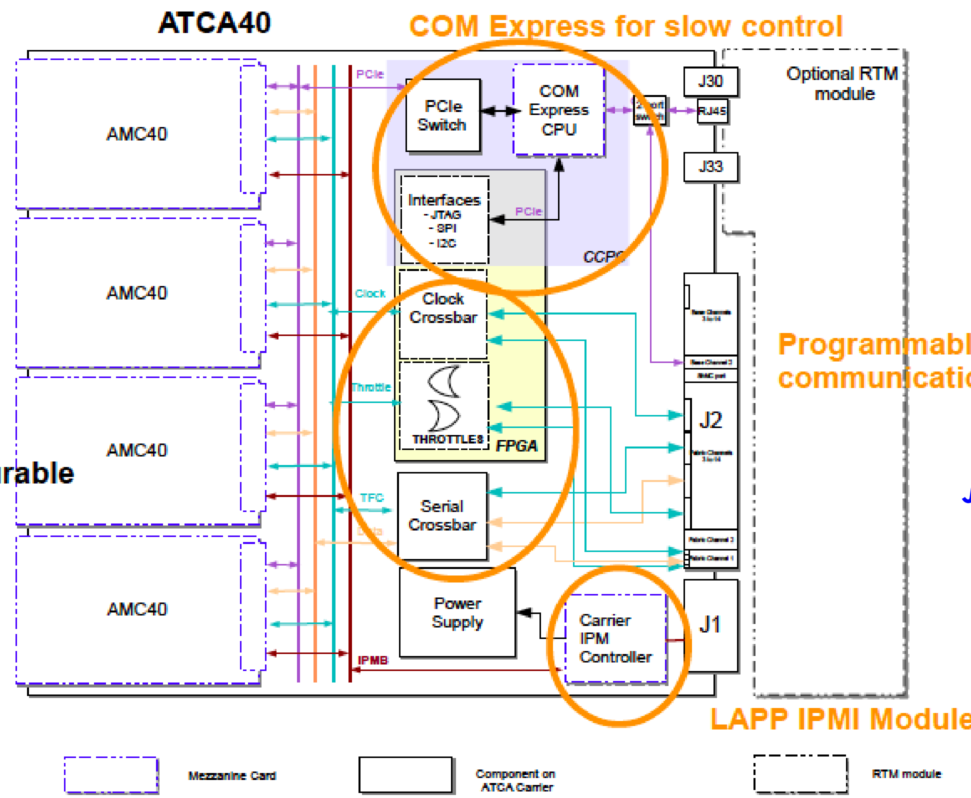
36
36




Flexible and reconfigurable carrier board

**144 optical links :**
**- 96** GBT links
**- 48** 10GbE links

ATCA40




*Courtesy*
*Jean-Pierre Cachemiche*

**Only firmware** and **datapath programming** change
to implement readout, time distribution, slow control or trigger interface

- Can really be of interest for a lot of applications



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# Summary (1)

- There is still a need for modular electronics in the future
- VME has been very successful but is not really adapted to future needs
- All the developments are in xTCA
  - Good mechanics, good cooling, powerful control
  - High complexity
  - Easy to get incompatible profiles
- Aim at having the same kind of support as we had for VME
  - Will require a bit of time
- Common effort on some parts (hardware and software) already started
  - IPbus, IPMC, MMC, IPMItool, ...


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# Summary (2)

- We are not alone
  - ITER, DESY, ...
- xTCA Interest Group (Markus Joos)
  - Next meeting in April at CERN
  - xTCA IG web site twiki.cern.ch/twiki/bin/view/XTCA/WebHome
  - Mailing list xtca-news@cern.ch
- We can share common designs much more than in the past


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*Thanks to all those I bothered with stupid questions and to whom I requested nice pictures which I have not been able to present*



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