Readout Chain Muon Identifier

Readout architecture, functionalities and prototypes

ALICE
MUON MEETING 2017

Grotta Giusti, Tuscany, Italy 15 May 2017

Subatech, IN2P3/CNRS-UBL, Nantes, F44307, France
J.-L. Béney, S. Martinez, P. Pichot, Ch. Renard, Alice-Muon-Trigger-Upgrade
http://www-subatech.in2p3.fr/~electro/projets/alice/dimuon/trigger/upgrade/

Readout Chain Muon Identifier

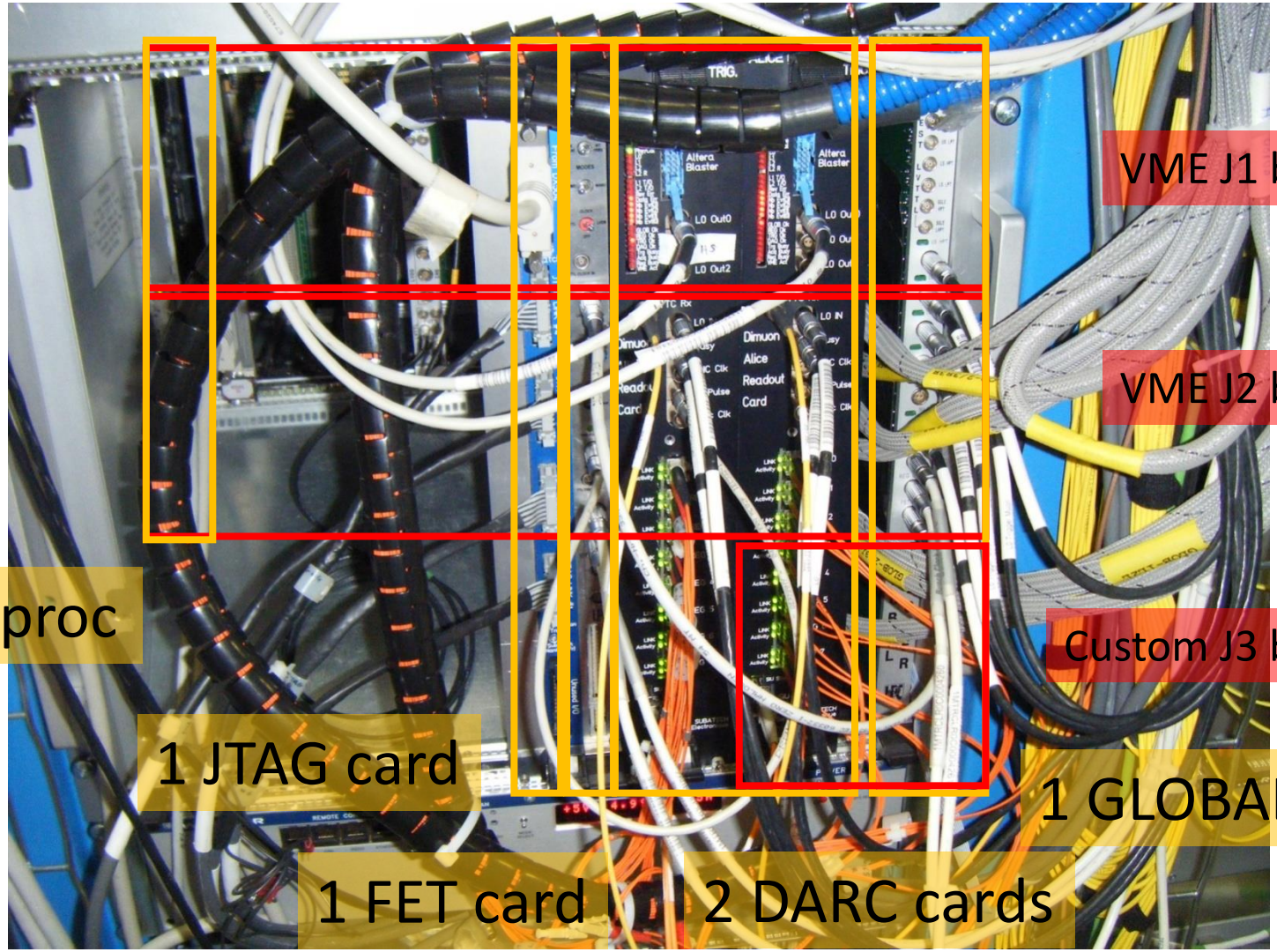
Readout architecture, functionalities and prototypes

Architecture

Subatech, IN2P3/CNRS-UBL, Nantes, F44307, France
J.-L. Béney, S. Martinez, P. Pichot, Ch. Renard, Alice-Muon-Trigger-Upgrade
http://www-subatech.in2p3.fr/~electro/projets/alice/dimuon/trigger/upgrade/

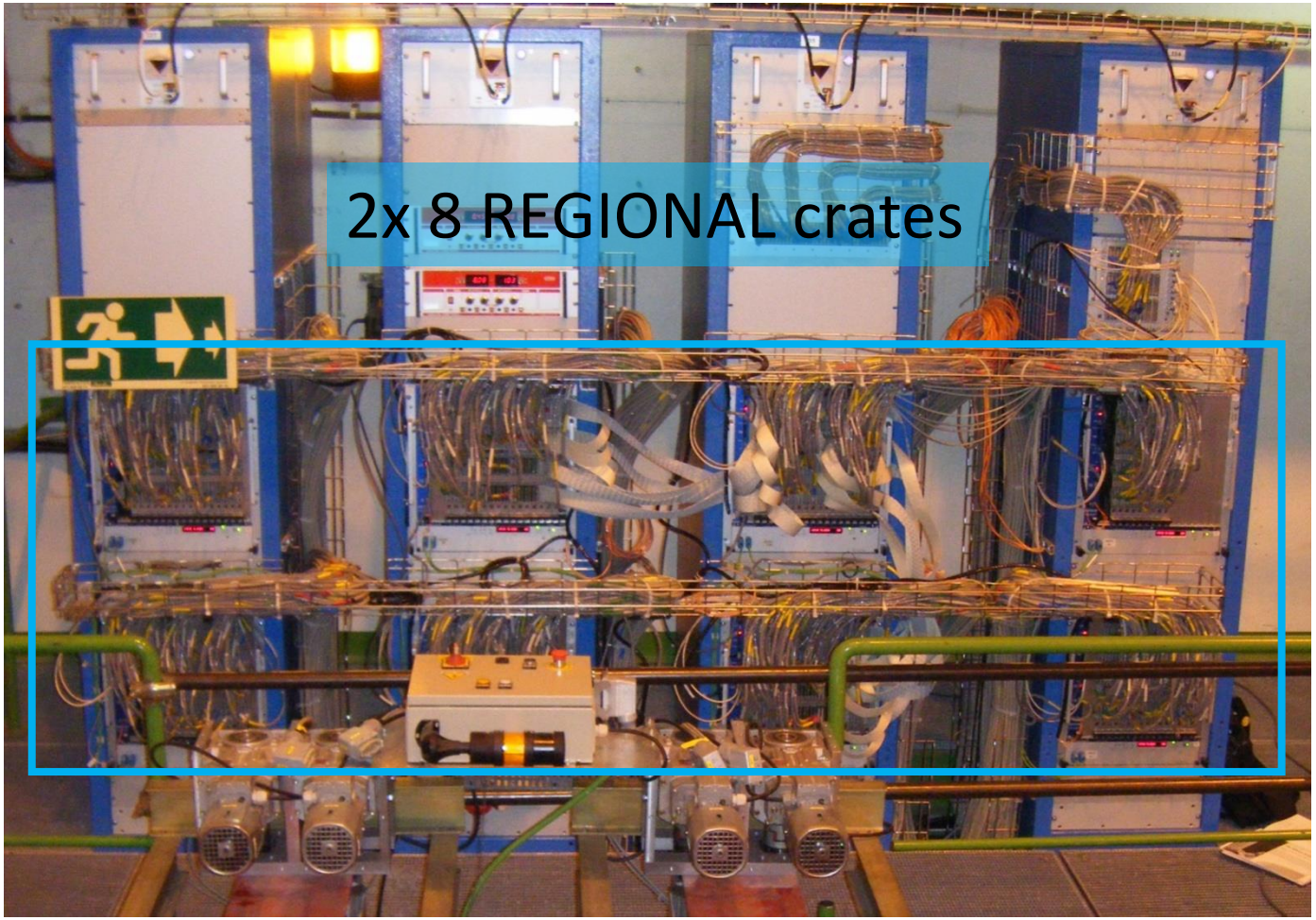
Readout Chain Muon Identifier

Actual Muon Trigger readout chain (1/3)



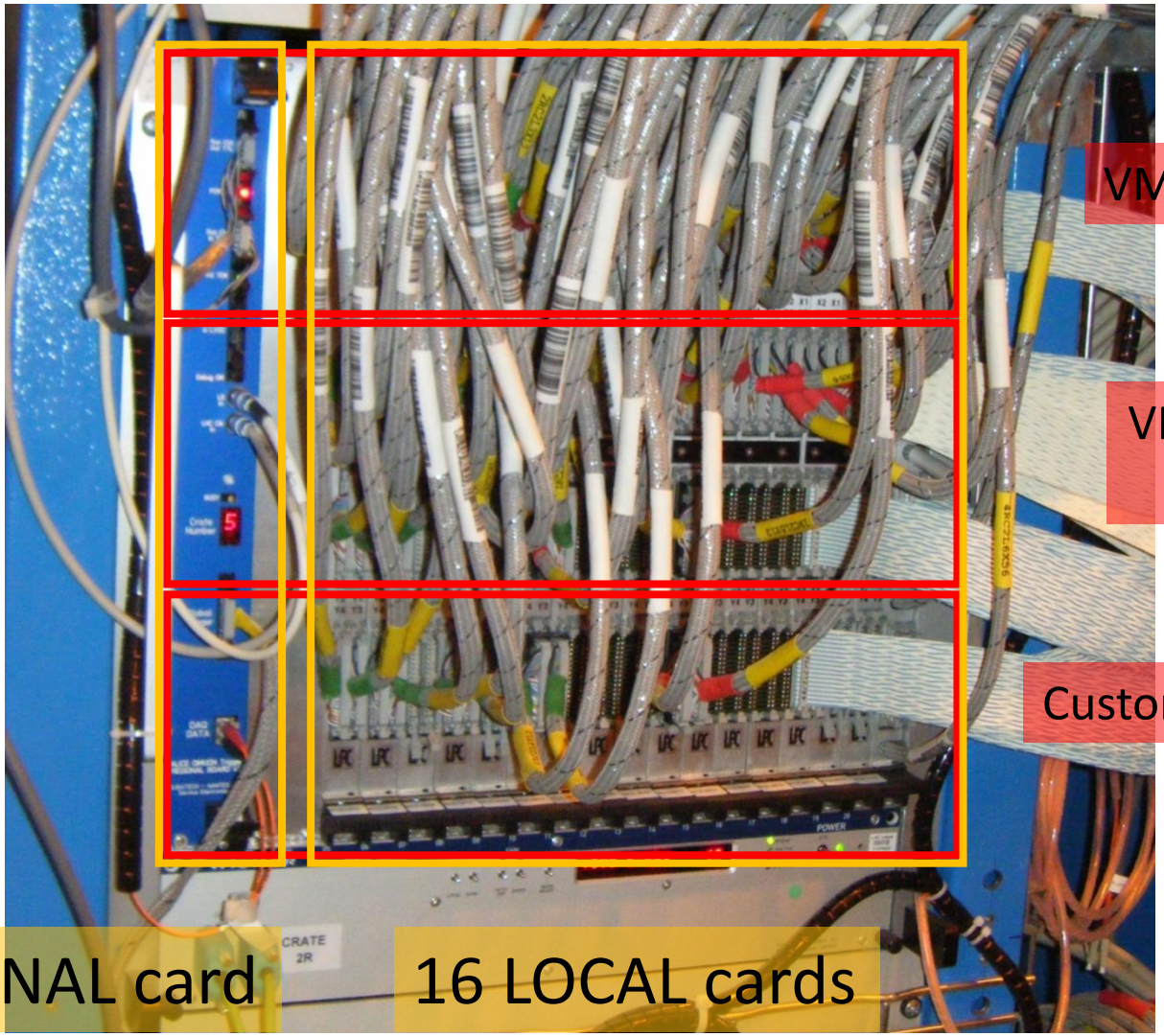
Readout Chain Muon Identifier

Actual Muon Trigger readout chain (2/3)



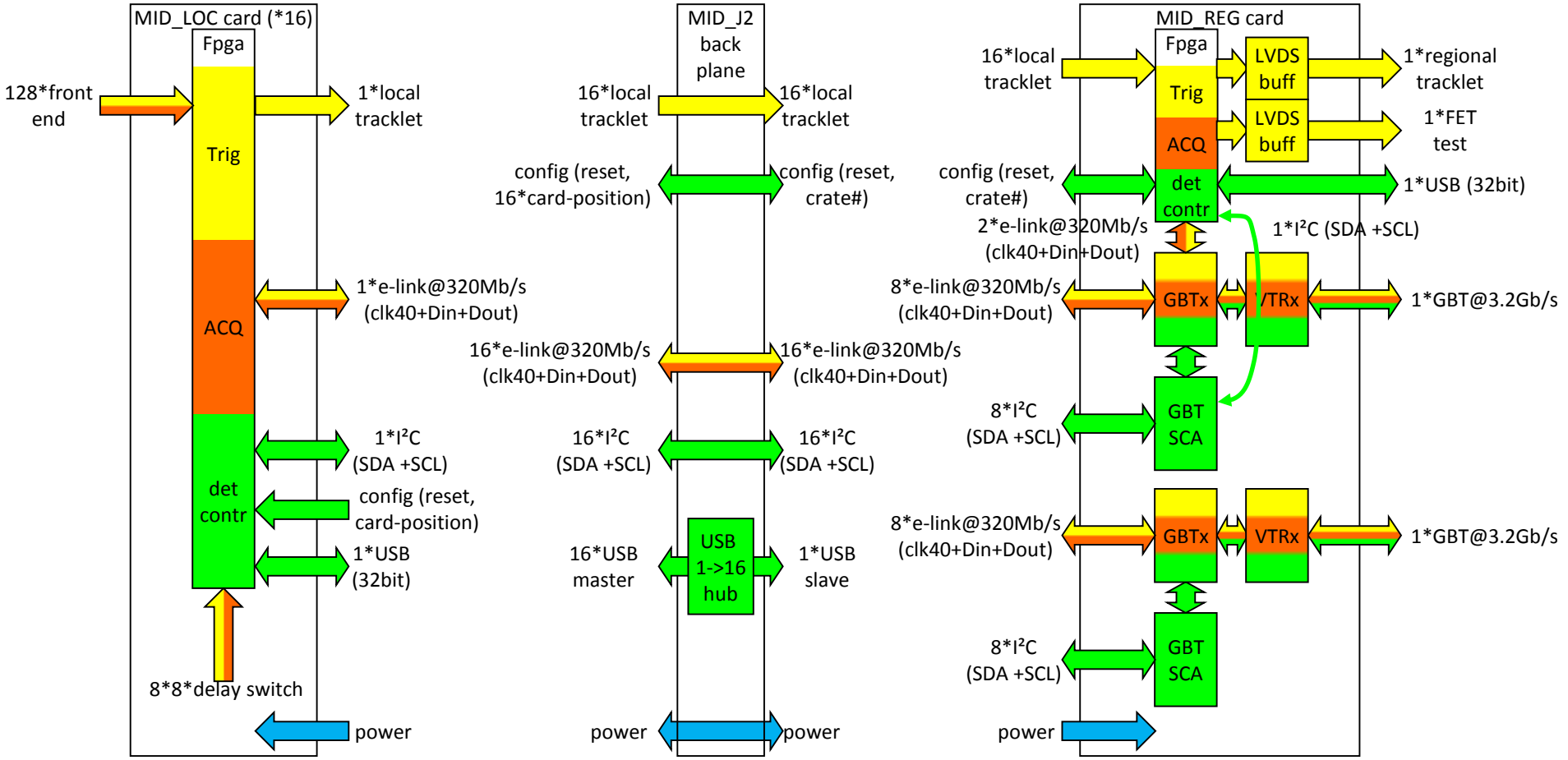
Readout Chain Muon Identifier

Actual Muon Trigger readout chain (3/3)



Readout Chain Muon Identifier

REGIONAL crate upgrade (EDR on 16 June 2015)



LOCAL with 128 LVDS inputs, 1 e-link@320Mb/s (clock@40MHz), 1 I²C, 1 FPGA, 1 LVDS output, 1 LHC-clock, 8x8 delay switch, power, config, USB3.0

J2 with 16 LVDS lines, 16 e-link@320Mb/s, 16 I²C, power, config, 1-to-16 USB3.0 hub

REGIONAL with 16 LVDS inputs, 16 e-link@320Mb/s (clock@40MHz), 2 GBTx, 2 GBT-SCA, 2 GBT links @3.2Gb/s, 1 FPGA, 1 LVDS output, power, config, USB3.0, 1-to-2 USB3.0 hub

Readout Chain Muon Identifier

MID data flow (continuous readout)

Slide from Pascal Dupieux LPC-Clermont

- **RPC counting rate (hence data flow) dominated by single background hits**

Pb-Pb √s=5.5 TeV, 100 kHz		p-p √s=14 TeV, 200 kHz	
RPC counting rate (mean)	RPC counting rate (peak)	RPC counting rate (mean)	RPC counting rate (peak)
75 Hit/s/cm^2	125 Hit/s/cm^2	6 Hit/s/cm^2	15 Hit/s/cm^2

- **Re-evaluation (2016) of the data flow : thesis of Victor Feuillard**
  - **Takes into account the data format proposed for MID**
  - **Based on real data : Pb-Pb 2015@5TeV and p-p 2016@13 TeV**
  - **Makes use of the dead-time free scalers registered continuously during the runs**

=> available bandwidth sufficient with large safety margins at all levels

Pb-Pb √s=5.5 TeV, 100 kHz		p-p √s=14 TeV, 200 kHz
Total data flow to CRU	Mean (max.) data flow per link Local-Regional	Total data flow to CRU
3 Gbit/s (100 Gbit/s available)	8 (20) Mbit/s (320 Mbit/s available)	0,3 Gbit/s

Readout Chain Muon Identifier

Readout architecture, functionalities and prototypes

Functionalities

Subatech, IN2P3/CNRS-UBL, Nantes, F44307, France
J.-L. Béney, S. Martinez, P. Pichot, Ch. Renard, Alice-Muon-Trigger-Upgrade
http://www-subatech.in2p3.fr/~electro/projets/alice/dimuon/trigger/upgrade/

Readout Chain Muon Identifier

REGIONAL crate upgrade (heartbeat [1][2])

Behaviour of the cards when receiving heartbeat triggers

TRIGGER	*CRU*	*Code sent by CRU to FEE*	*REGIONAL*	*LOCAL*
SOC (Start Of Continuous)	Update internal Orbit and BCID counters Transmit command to all e-links **Reset internal bunch counter**	0x80	**Reset internal bunch counter** Reset acquisition FIFO Assert "Active" bit Start writing PHY events into acquisition FIFO (First event = SOC)	**Reset internal bunch counter** Reset acquisition FIFO Assert "Active" bit Start writing PHY events into acquisition FIFO (First event = SOC)
EOC (End Of Continuous)	Update internal Orbit and BCID counters Transmit command to all e-links **Reset internal bunch counter**	0x40	**Reset internal bunch counter** De-assert "Active" bit Stop writing PHY events into acquisition FIFO (Last event = EOC)	**Reset internal bunch counter** De-assert "Active" bit Stop writing PHY events into acquisition FIFO (Last event = EOC)
PAUSE (reject)	Update internal Orbit and BCID counters Transmit command to all e-links **Reset internal bunch counter**	0x20	**Reset internal bunch counter** Assert "Rejecting" bit Stop writing PHY events into acquisition FIFO (Last event = PAUSE)	**Reset internal bunch counter** Assert "Rejecting" bit Stop writing PHY events into acquisition FIFO (Last event = PAUSE)
RESUME (accept)	Update internal Orbit and BCID counters Transmit command to all e-links **Reset internal bunch counter**	0x10	**Reset internal bunch counter** De-assert "Rejecting" bit Start writing PHY events into acquisition FIFO (First event = RESUME)	**Reset internal bunch counter** De-assert "Rejecting" bit Start writing PHY events into acquisition FIFO (First event = RESUME)
CALIBRATE	Update internal Orbit and BCID counters Transmit command to all e-links **Reset internal bunch counter**	0x08	**Reset internal bunch counter** Write one event = CALIBRATE into acquisition FIFO Send LVDS pulse to Front-End Test cards	**Reset internal bunch counter** Write one event = CALIBRATE into acquisition FIFO
SPARE	Update internal Orbit and BCID counters Transmit command to all e-links **Reset internal bunch counter**	0x04	**Reset internal bunch counter** Write one event = SPARE into acquisition FIFO	**Reset internal bunch counter** Write one event = SPARE into acquisition FIFO
RESET	Update internal Orbit and BCID counters Transmit command to all e-links **Reset internal bunch counter**	0x02	**Reset internal bunch counter** Stop writing PHY events into acquisition FIFO De-assert "Active" bit & "Rejecting" bit Reset acquisition FIFO Write one event = RESET into acquisition FIFO	**Reset internal bunch counter** Stop writing PHY events into acquisition FIFO De-assert "Active" bit & "Rejecting" bit Reset acquisition FIFO Write one event = RESET into acquisition FIFO
HC (Health Check) or T_Fstart	Update internal Orbit and BCID counters Transmit command to all e-links **Reset internal bunch counter**	0x01	**Reset internal bunch counter** Write one event = HC into acquisition FIFO	**Reset internal bunch counter** Write one event = HC into acquisition FIFO

[1] O² Project CWG4. Proposal of an Heartbeat trigger for ALICE Run 3. Technical report, The ALICE Collaboration, 2013

[2] O² project WP1. Raw data and trigger message format preliminary proposal, R. Divià CERN/ALICE, 27 April 2017

Readout Chain Muon Identifier

REGIONAL crate upgrade (MID_LOC data format)

MID_LOC data format at each e-link input in CRU

*Coding of SOC, EOC, RESET events in **LOCAL***	*Number of bits*
START BIT (always '1')	1
CARD TYPE (always '1'=LOCAL)	1
LOCAL BUSY ('0'=OK; '1'=FIFO full)	1
LOCAL DECISION (tracklet)	1
ACTIVE ('0'=OFF; '1'=ON)	1
REJECTING ('0'=OFF; '1'=ON)	1
MASKED ('0'=OFF; '1'=ON)	1
OVERWRITED ('0'=OFF; '1'=ON)	1
SOC	1
EOC	1
PAUSE (always '0')	1
RESUME	1
CALIBRATE (always '0')	1
SPARE	1
RESET	1
HC	1
Internal bunch counter	16
LOCAL board position in crate (0-15)	4
Status: "0xF"	4
Status: Masks on inputs [(X4, Y4), (X3, Y3), (X2, Y2), (X1, Y1)]	32*4
Total number of bits	168
Bunches needed to send	21

*Coding of CALIBRATE events in **LOCAL***	*Number of bits*
START BIT (always '1')	1
CARD TYPE (always '1'=LOCAL)	1
LOCAL BUSY ('0'=OK; '1'=FIFO full)	1
LOCAL DECISION (tracklet)	1
ACTIVE ('0'=OFF; '1'=ON)	1
REJECTING ('0'=OFF; '1'=ON)	1
MASKED ('0'=OFF; '1'=ON)	1
OVERWRITED ('0'=OFF; '1'=ON)	1
SOC (always '0')	1
EOC (always '0')	1
PAUSE (always '0')	1
RESUME	1
CALIBRATE	1
SPARE	1
RESET (always '0')	1
HC	1
Internal bunch counter	16
LOCAL board position in crate (0-15)	4
Data: "0xF"	4
Data: all strip patterns [(X4, Y4), (X3, Y3), (X2, Y2), (X1, Y1)]	32*4
Total number of bits	168
Bunches needed to send	21

*Coding of PAUSE, RESUME, SPARE, **HC** events in **LOCAL***	*Number of bits*
START BIT (always '1')	1
CARD TYPE (always '1'=LOCAL)	1
LOCAL BUSY ('0'=OK; '1'=FIFO full)	1
LOCAL DECISION (tracklet)	1
ACTIVE ('0'=OFF; '1'=ON)	1
REJECTING ('0'=OFF; '1'=ON)	1
MASKED ('0'=OFF; '1'=ON)	1
OVERWRITED ('0'=OFF; '1'=ON)	1
SOC (always '0')	1
EOC (always '0')	1
PAUSE	1
RESUME	1
CALIBRATE (always '0')	1
SPARE	1
RESET (always '0')	1
HC	1
Internal bunch counter	16
LOCAL board position in crate (0-15)	4
Always '0'	4
N/A	0
Total number of bits	40
Bunches needed to send	5

*Coding of **self triggered physics** event in **LOCAL***	*Number of bits*
START BIT (always '1')	1
CARD TYPE (always '1'=LOCAL)	1
LOCAL BUSY ('0'=OK; '1'=FIFO full)	1
LOCAL DECISION (tracklet)	1
ACTIVE (always '1'=ON)	1
REJECTING (always '0'=OFF)	1
MASKED ('0'=OFF; '1'=ON)	1
OVERWRITED ('0'=OFF; '1'=ON)	1
Always '0'	8
Internal bunch counter	16
LOCAL board position in crate (0-15)	4
Data: Non zero detector plane(s) (1 bit / word)	4
Data: Non zero strip pattern(s) [(X4, Y4), (X3, Y3), (X2, Y2), (X1, Y1)]	32*i (i=1 to 4)
Total number of bits	40+ 32*i (i=1 to 4)
Bunches needed to send	9 to 21

Readout Chain Muon Identifier

REGIONAL crate upgrade (MID_REG data format)

MID_REG data format at each e-link input in CRU

*Coding of SOC, EOC, RESET events in **REGIONAL***	*Number of bits*
START BIT (always '1')	1
CARD TYPE (always '0'=REGIONAL)	1
REGIONAL BUSY ('0'=OK; '1'=FIFO full)	1
REGIONAL DECISION (tracklet)	1
ACTIVE ('0'=OFF; '1'=ON)	1
REJECTING ('0'=OFF; '1'=ON)	1
MASKED ('0'=OFF; '1'=ON)	1
OVERWRITED ('0'=OFF; '1'=ON)	1
SOC	1
EOC	1
PAUSE (always '0')	1
RESUME	1
CALIBRATE	1
SPARE	1
RESET	1
HC	1
Internal bunch counter	16
REGIONAL crate number (0-15)	4
Status: Masks on tracklet inputs	4
N/A	0
Total number of bits	40
Bunches needed to send	5

*Coding of PAUSE, RESUME, CALIBRATE, SPARE, **HC** events in **REGIONAL***	*Number of bits*
START BIT (always '1')	1
CARD TYPE (always '0'=REGIONAL)	1
REGIONAL BUSY ('0'=OK; '1'=FIFO full)	1
REGIONAL DECISION (tracklet)	1
ACTIVE ('0'=OFF; '1'=ON)	1
REJECTING ('0'=OFF; '1'=ON)	1
MASKED ('0'=OFF; '1'=ON)	1
OVERWRITED ('0'=OFF; '1'=ON)	1
SOC (always '0')	1
EOC (always '0')	1
PAUSE	1
RESUME	1
CALIBRATE	1
SPARE	1
RESET (always '0')	1
HC	1
Internal bunch counter	16
REGIONAL crate number (0-15)	4
Always '0'	4
N/A	0
Total number of bits	40
Bunches needed to send	5

*Coding of **self triggered physics** event in **REGIONAL***	*Number of bits*
START BIT (always '1')	1
CARD TYPE (always '0'=REGIONAL)	1
REGIONAL BUSY ('0'=OK; '1'=FIFO full)	1
REGIONAL DECISION (tracklet)	1
ACTIVE (always '1'=ON)	1
REJECTING (always '0'=OFF)	1
MASKED ('0'=OFF; '1'=ON)	1
OVERWRITED ('0'=OFF; '1'=ON)	1
Always '0'	8
Internal bunch counter	16
REGIONAL crate number (0-15)	4
Data: All tracklet inputs	4
N/A	0
Total number of bits	40
Bunches needed to send	5

Readout Chain Muon Identifier

REGIONAL crate upgrade (DCS)

Control registers (GBT-SCA-I²C) foreseen in the cards

	REGIONAL (x16)		*LOCAL (x256)*
r-	ID	ID	ID
r-	Date	Date	Date
r-	Status	Status	Status
rw	Config	Config	Config
rw	masks	masks	masks
rw			Masks
rw			Masks
rw			masks
r-	GBTx0 switches & status	GBTx1 switches & status	Delay switches Xi
r-			Delay switches Yi

Readout Chain Muon Identifier

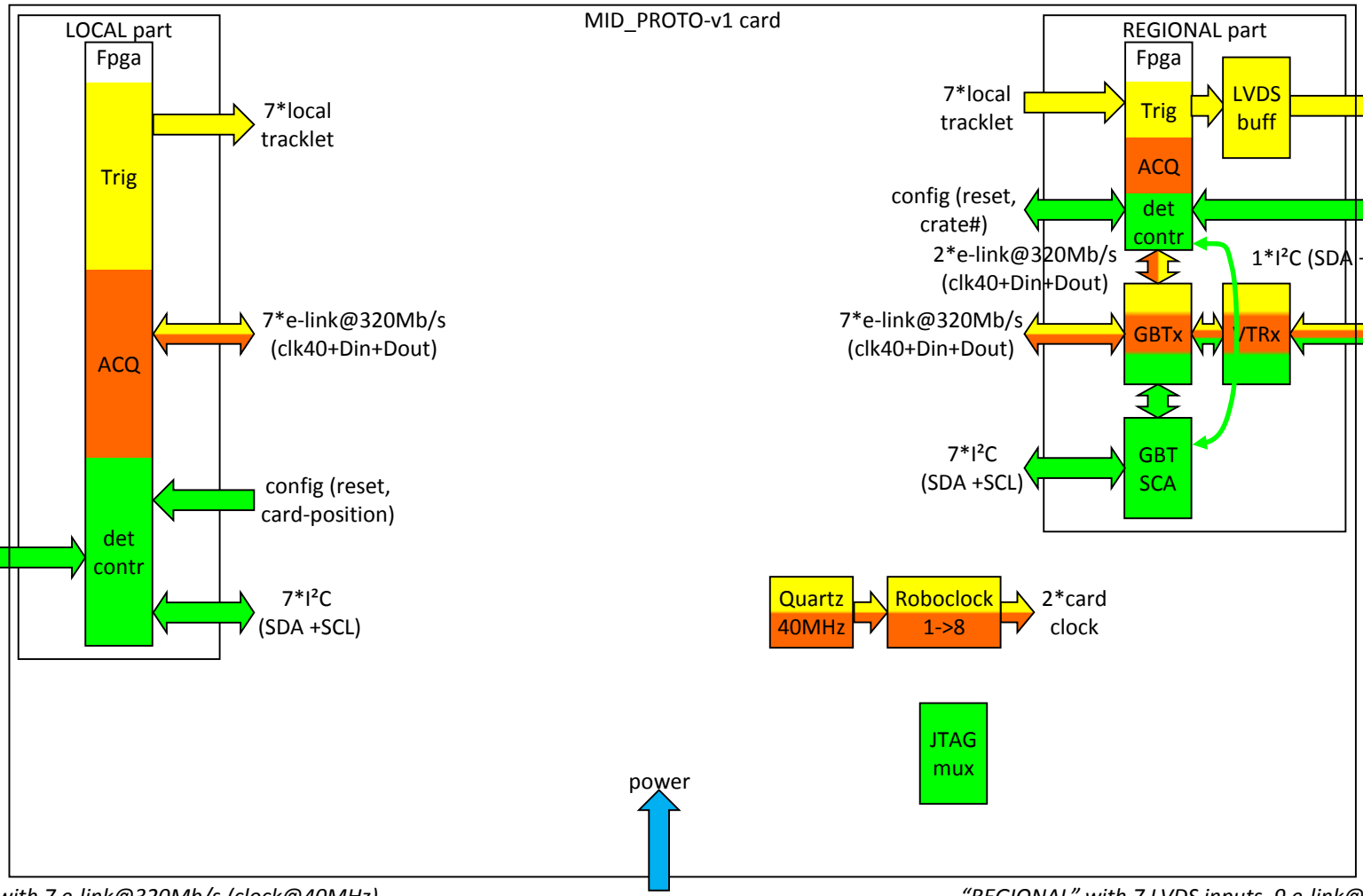
Readout architecture, functionalities and prototypes

Prototypes

Subatech, IN2P3/CNRS-UBL, Nantes, F44307, France
J.-L. Béney, S. Martinez, P. Pichot, Ch. Renard, Alice-Muon-Trigger-Upgrade
http://www-subatech.in2p3.fr/~electro/projets/alice/dimuon/trigger/upgrade/

Readout Chain Muon Identifier

REGIONAL crate upgrade (prototype)



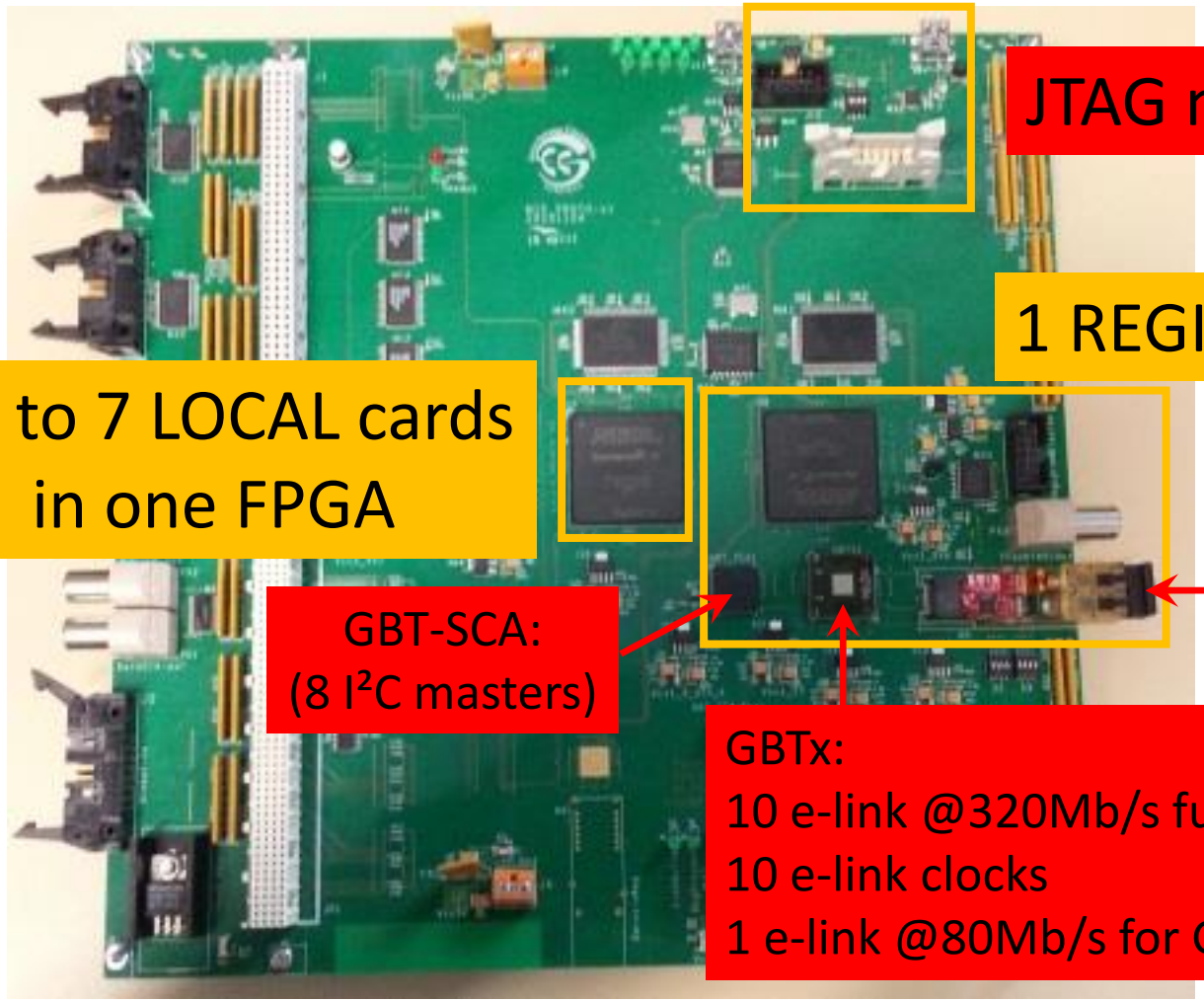
"LOCAL" with 7 e-link@320Mb/s (clock@40MHz), 7 I²C, 1 FPGA, 7 LVDS output, config, USB (8bit)

"REGIONAL" with 7 LVDS inputs, 9 e-link@320Mb/s (clock@40MHz), 1 GBTx,1 GBT-SCA, 8 I²C, 1 GBT links @3.2Gb/s, 1 FPGA, 1 LVDS output, config, USB (8bit)

Readout Chain Muon Identifier

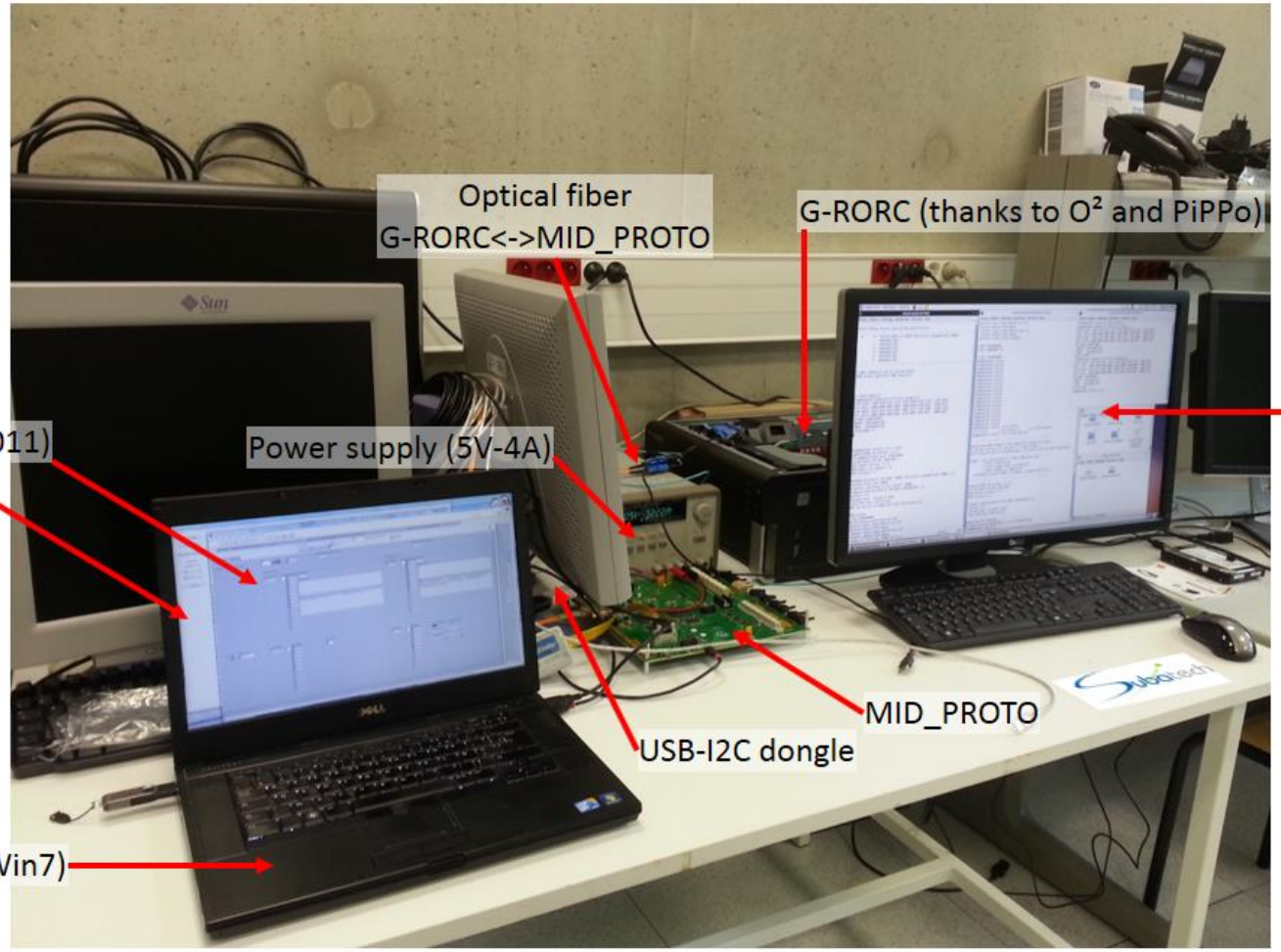
REGIONAL crate upgrade (prototype)

At SUBATECH since 21 January 2016



Readout Chain Muon Identifier

REGIONAL crate upgrade (prototype)
Tests summary (1/2)



Readout Chain Muon Identifier

REGIONAL crate upgrade (prototype)
Tests summary (2/2)

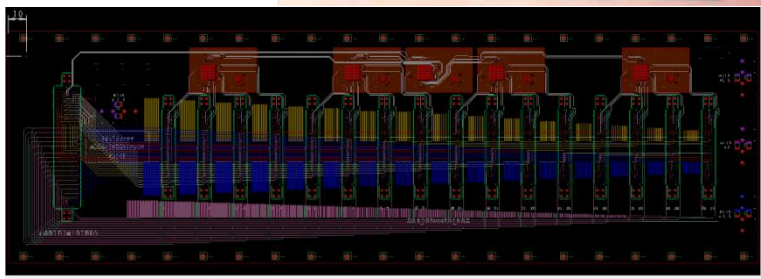
- ✓ Firmware simulated in VHDL testbench
  - ✓ continuous readout
  - ✓ heartbeat triggers
  - ✓ USB debug
  - ✓ I²C detector-control

- ➢ MID_PROTO-v1 card with G-RORC as testbench
  - ➢ G-RORC lent by ALICE-DAQ (Pierre Vande Vyvre & Filippo Costa)
  - ➢ Recent version of DATE installed in PC (Frédéric Lefèvre)
  - ➢ G-RORC installed in PC (Jean-Luc Beney)
  - ➢ Installed firmware developed by ALICE-0² (Filippo Costa)
  - ➢ Write on disk events corresponding to answers to heartbeat triggers
  - ➢ Write on disk events corresponding to self-trigger on incoming signals
  - ➢ Write and read-back a register in GBT-SCA

Readout Chain Muon Identifier

REGIONAL crate upgrade ()
Next steps

- MID_PROTO-v1 card with G-RORC as testbench
  - Write a script to test DCS using GBT-SCA-I²C
- MID_LOC-v1 card (Christophe & Patrice)
  - ✓ 3 cards at SUBATECH
  - Finalise Firmware under simulation
- MID_REG-v1 card (Christophe & Patrice)
  - CAD progressing well
  - Finalise Firmware under simulation
- MID_J2 card-v1 (Christophe & Stéphane)
  - CAD files ready for fab
  - Purchase order signed
  - 5 weeks delay for fab
- Replace the G-RORC by a CRU as testbench



Readout Chain Muon Identifier

REGIONAL crate upgrade ()
Good News

- A team from South Africa joined the MID
  - They have engineers working on the user firmware for MID in the CRU

See next presentation

Thanks for your attention

Subatech, IN2P3/CNRS-UBL, Nantes, F44307, France
J.-L. Béney, S. Martinez, P. Pichot, Ch. Renard, Alice-Muon-Trigger-Upgrade
http://www-subatech.in2p3.fr/~electro/projets/alice/dimuon/trigger/upgrade/

Readout Chain Muon Identifier

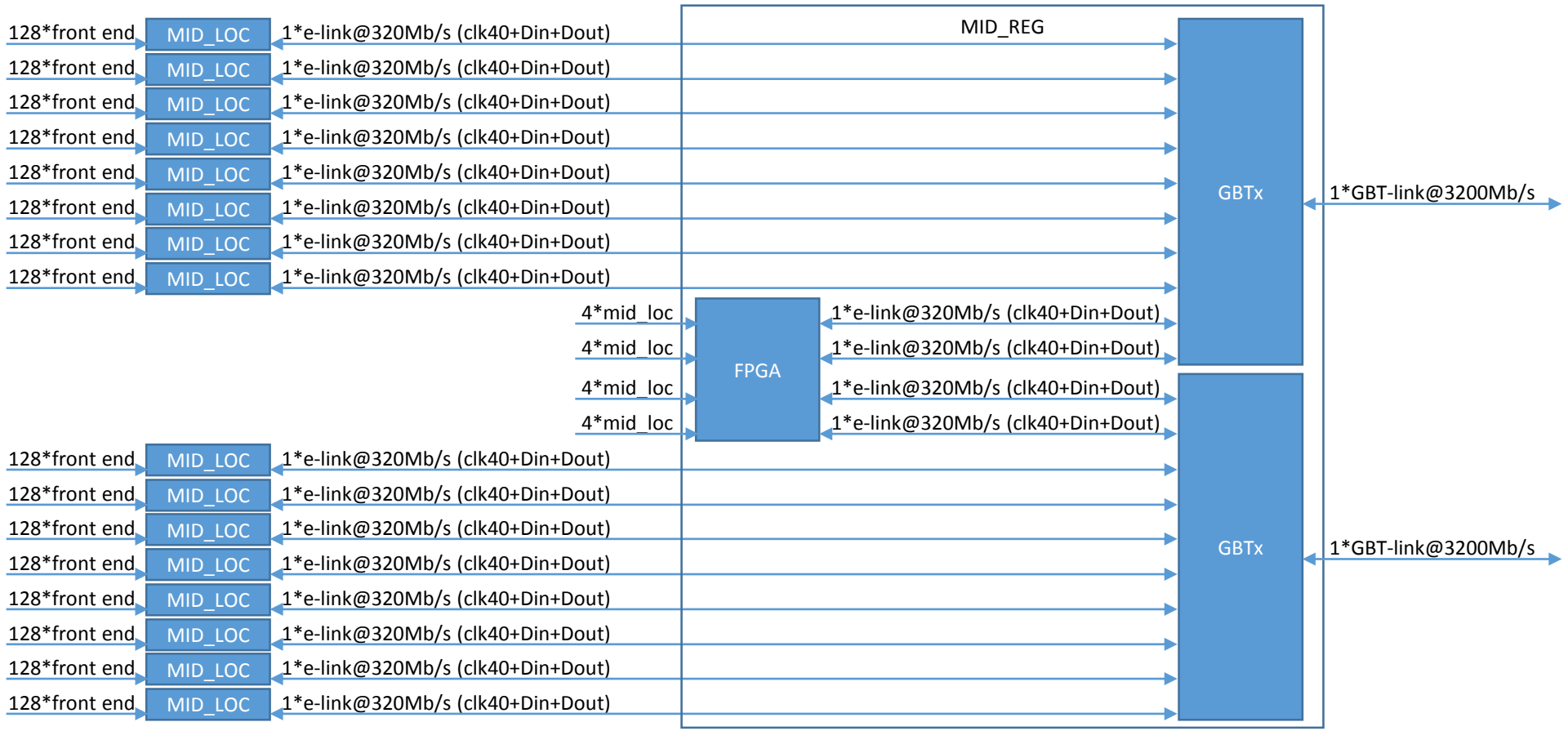
Readout architecture, functionalities and prototypes

Backup

Readout Chain Muon Identifier

REGIONAL crate upgrade (EDR on 16 June 2015)

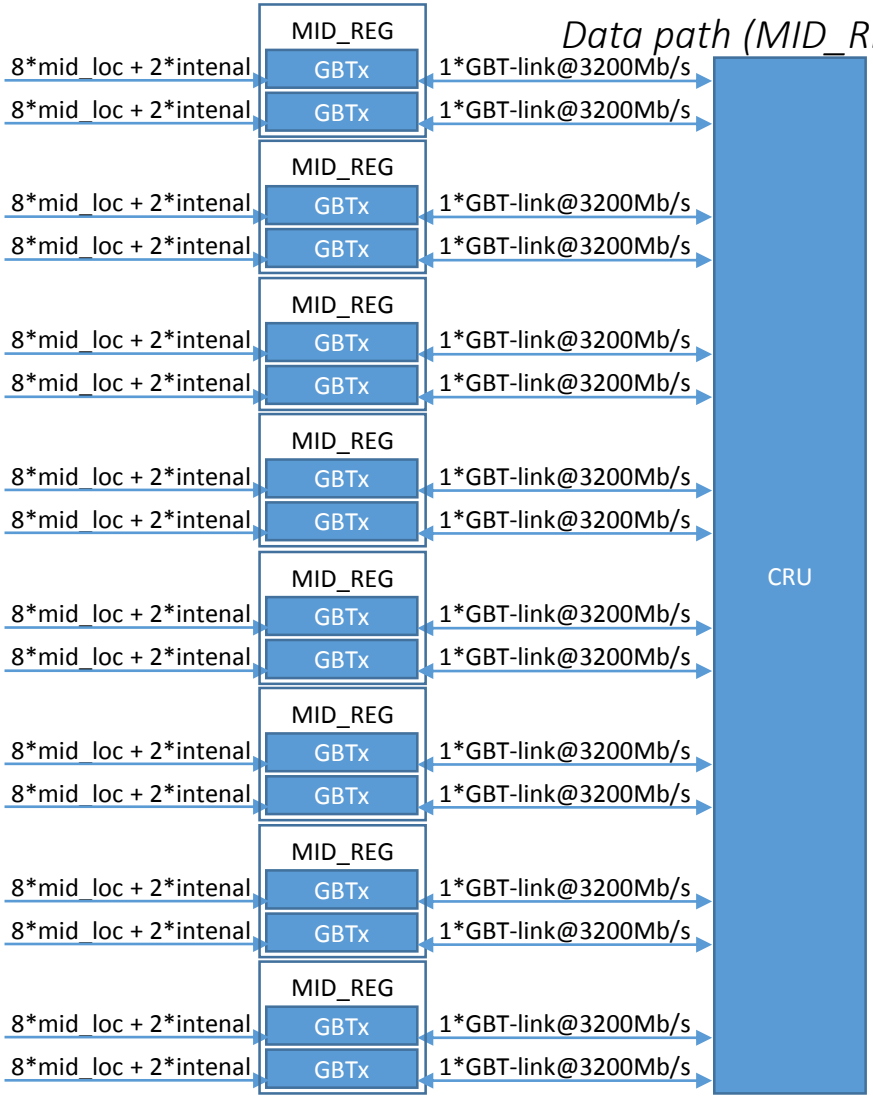
Data path (Front-End -> MID_LOC -> MID_REG)



Readout Chain Muon Identifier

REGIONAL crate upgrade (EDR on 16 June 2015)

Data path (MID_REG -> CRU)



Readout Chain Muon Identifier

REGIONAL crate upgrade ()
CRUs needed

2 CRUs of type “24/24” in the counting room
- 1 with 16 bidir GBT links to I36
- 1 with 16 bidir GBT links to O36

1 CRU of type “24/24” in South Africa
- for user firmware development/maintenance in CRU

1 CRU of type “24/24” in Nantes
- for firmware development/maintenance in readout electronics