A Large Ion Collider Experiment

The ALICE C-RORC GBT card, a prototype readout solution for the ALICE upgrade

Filippo Costa

ALICE O^2 & CRU
CERN

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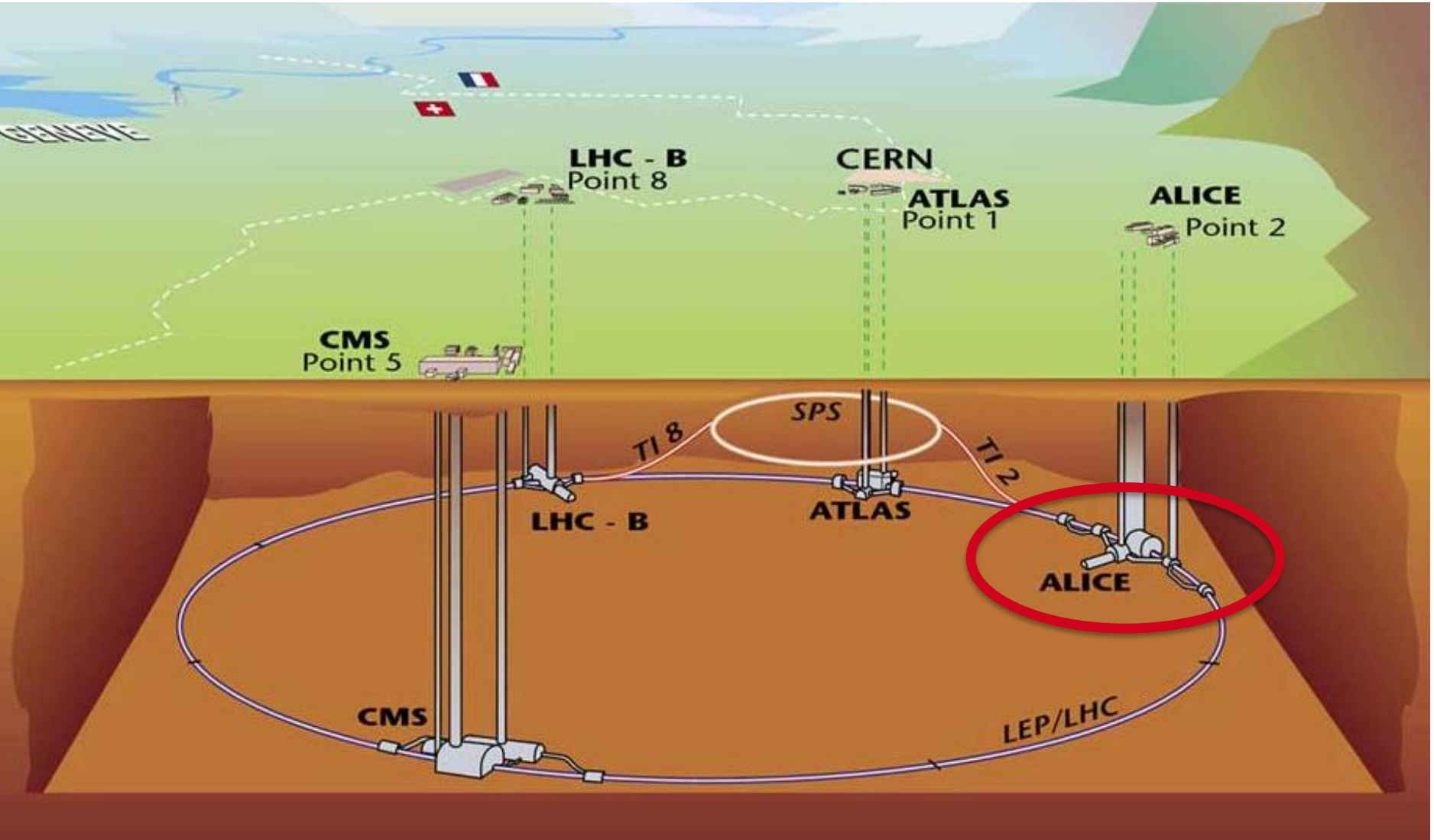
OUTLINE

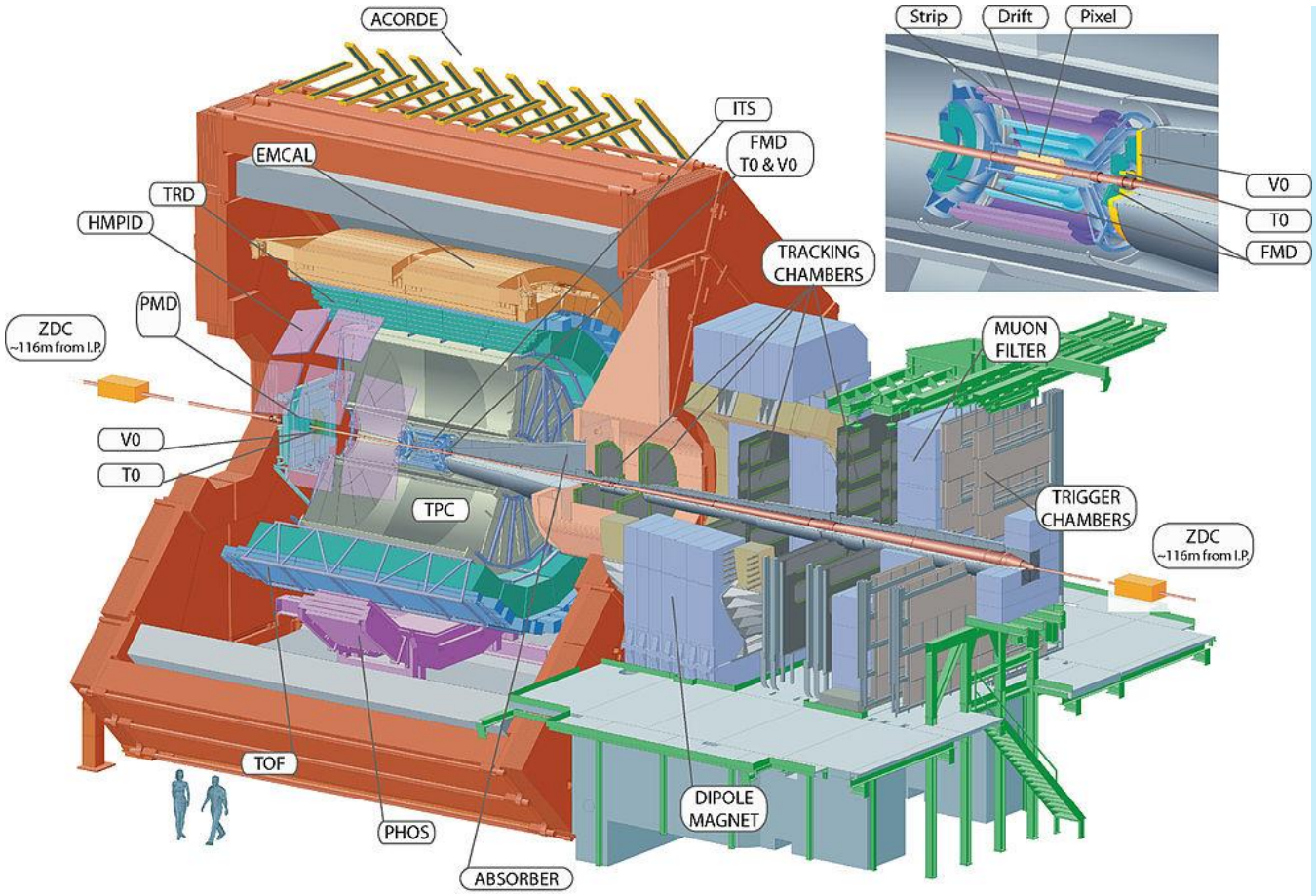
- 1st PART: THE ALICE EXPERIMENT
  - INTRODUCTION TO ALICE & ALICE UPGRADE
- 2nd PART : R&D
  - Motivation
  - Hardware
  - Firmware
- 3rd PART : testing facilities and the results
  - The data generator
  - Test with detectors
  - Conclusions

INTRODUCTION TO ALICE

ALICE @ LHC


GENEVE
LHC - B
Point 8
CERN
ATLAS
Point 1
ALICE
Point 2
CMS
Point 5
SPS
TI 8
TI 2
LHC - B
ATLAS
ALICE
CMS
LEP/LHC

ALICE (A Large Ion Collider Experiment)



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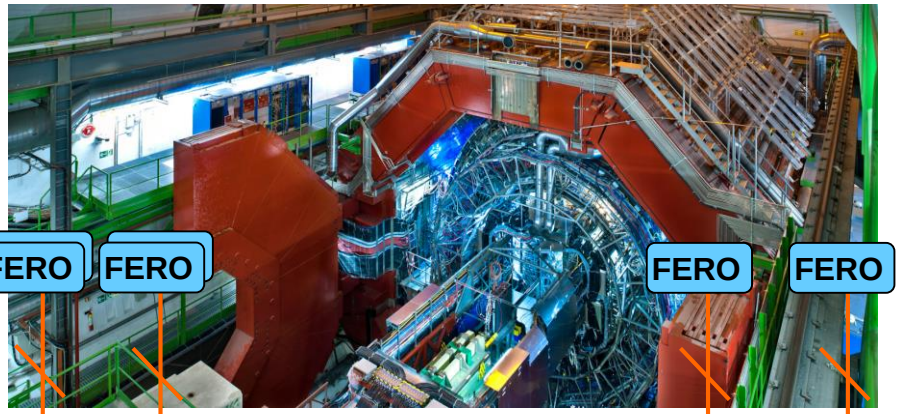
ALICE is a general purpose, heavy ion collision detector at the CERN LHC. It is designed to study the physics of strongly interacting matter, and in particular the properties of Quark Gluon Plasma (QGP), using proton-proton nucleus-nucleus and proton-nucleus collisions at high energies.

It consists of 19 sub-detectors:

- A Cosmic Ray Detector (ACORDE)
- ITS (SPD, SDD, SSD)
  - Silicon Pixel Detector
  - Silicon Drift Detector
  - Silicon Strip Detector
- Forward Multiplicity Detector (FMD)
- T0
- V0
- Muon Chamber
- Muon Trigger
- Zero Degree Calorimeter ZDC
- PHOton Spectrometer PHOS
- Time Of Flight TOF
- Time Projection Chamber TPC
- Transition Radiation Detector TRD
- ElectroMagnetic CALorimeter EMCAL
- Photon Multiplicity Detector PMD
- High Momentum Particle Identification HMPID
- Charged Particle Veto CPV
- ALICE Diffractive AD

ALICE data flow



FERO FERO FERO FERO

DDL DDL DDL DDL

HLT

C-RORC C-RORC C-RORC C-RORC C-RORC C-RORC

LDC LDC LDC LDC LDC

180 nodes

500 DDL links

NETWORK

GDC

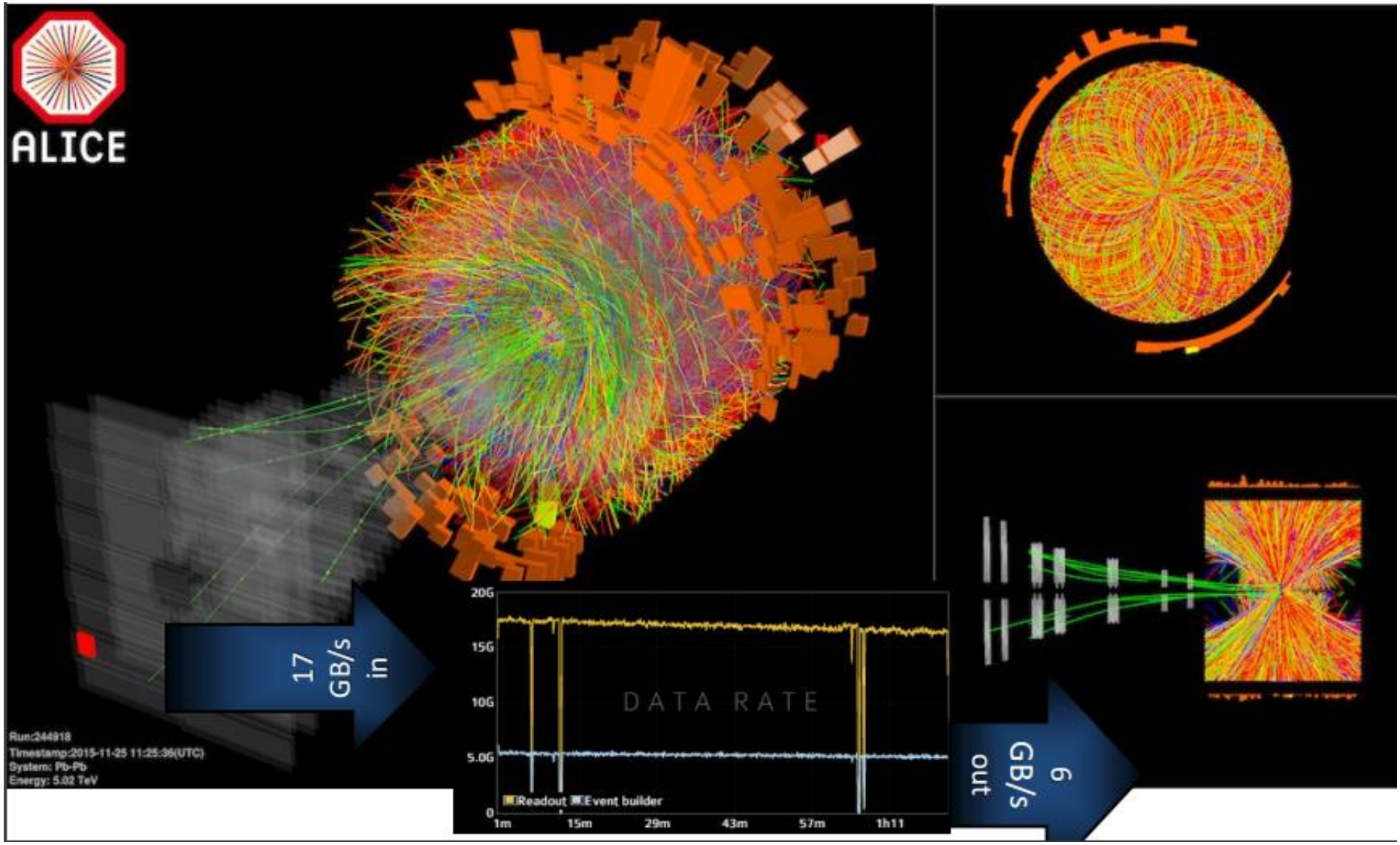
Fiber channel

LOCAL STORAGE

CASTOR (CERN CC)

ACRONYMS
FERO : Front End Read Out
DDL : Detector Data Link
C-RORC : Common Readout Receiver Card
LDC : Local Data Concentrator
GDC : Global Data Concentrator
HLT : High Level Trigger

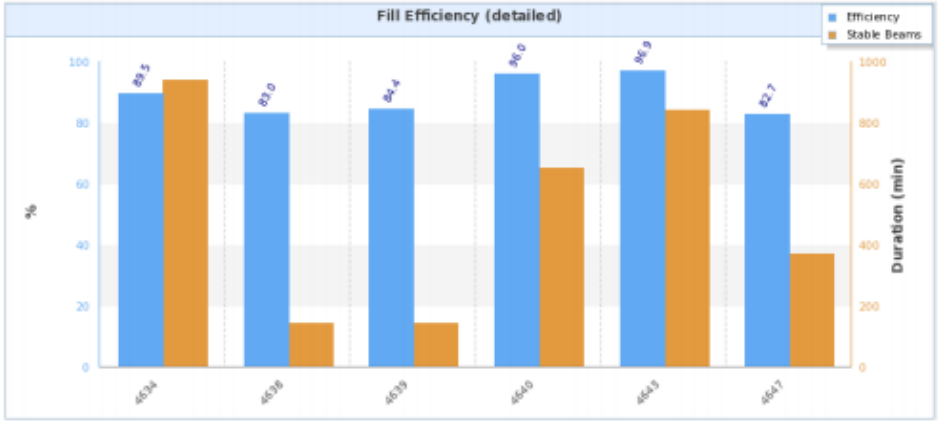
Stable collisions in ALICE



Stable collisions in ALICE

Fill	AFS	Lumi Hz/μbarn	duration	# of Good Runs	Efficiency %
4634	Multi_44b_22_22_22_4bpi12inj	0.2	15:38:23	11→10	90 →89.5
4638	25ns_219b_207_174_180_28bpi8inj	2 / 1	2:20:53	4→4	83→83
4639	25ns_889b_877_828_828_72bpi15inj	1	2:21:47	3→2	84.4→84.4
4640	25ns_1465b_1453_1218_1248_144bpi13inj_sp	1	10:51:04	5→5	96→96
4643	25ns_1825b_1813_1438_1248_144bpi16inj_sp	1	14:00:52	3→3	97→97
4647	25ns_1825b_1813_1438_1248_144bpi16inj_sp	1	6:08:32	9→6	84.3->82.7

- **Very good efficiency in all fills (~93%)**
  - Just few runs per fill

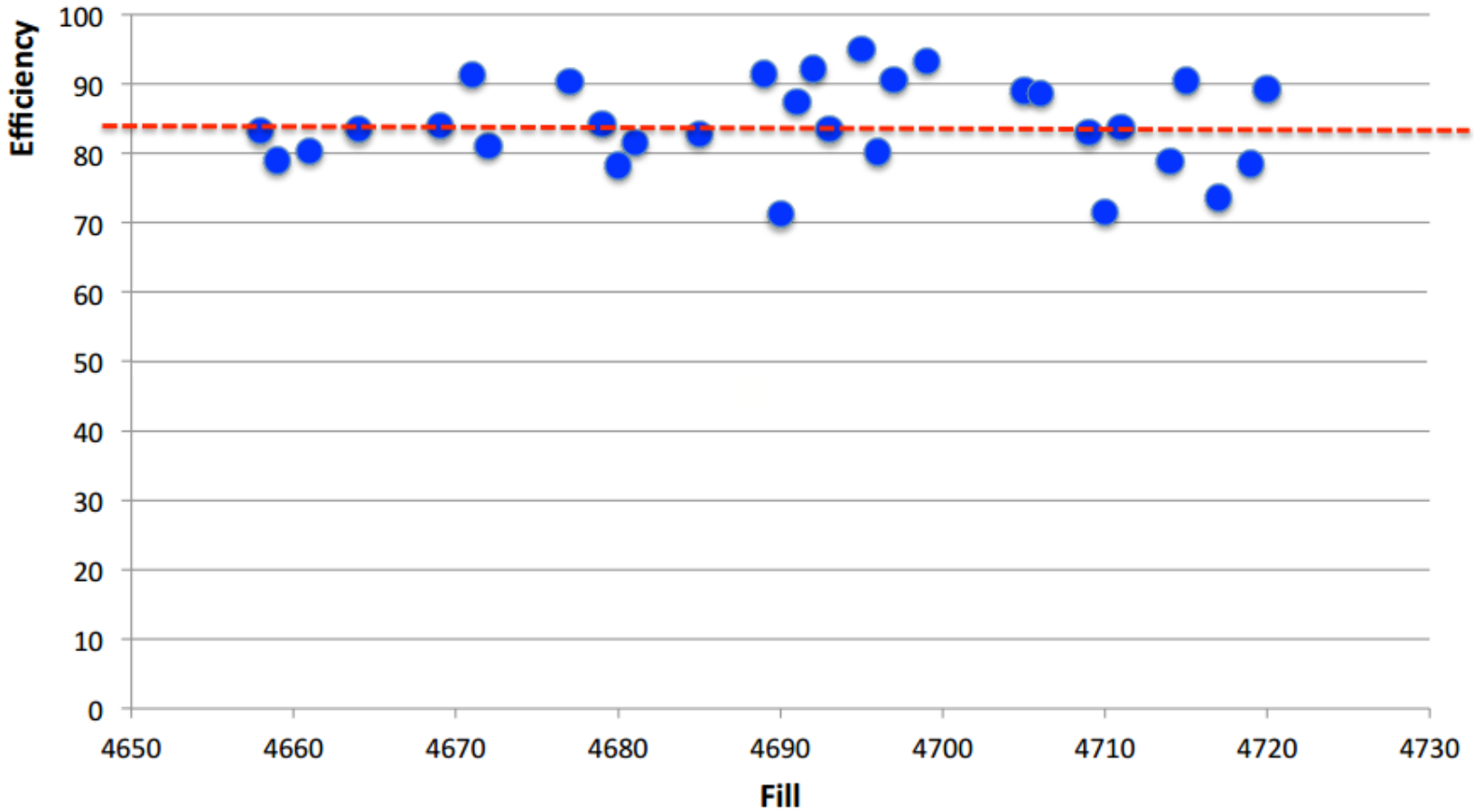


Stable collisions in ALICE

- Luminosity: delivered **433 ub-1**/ integrated **363 ub-1**
  - **Taken 84% of what the machine sent us**

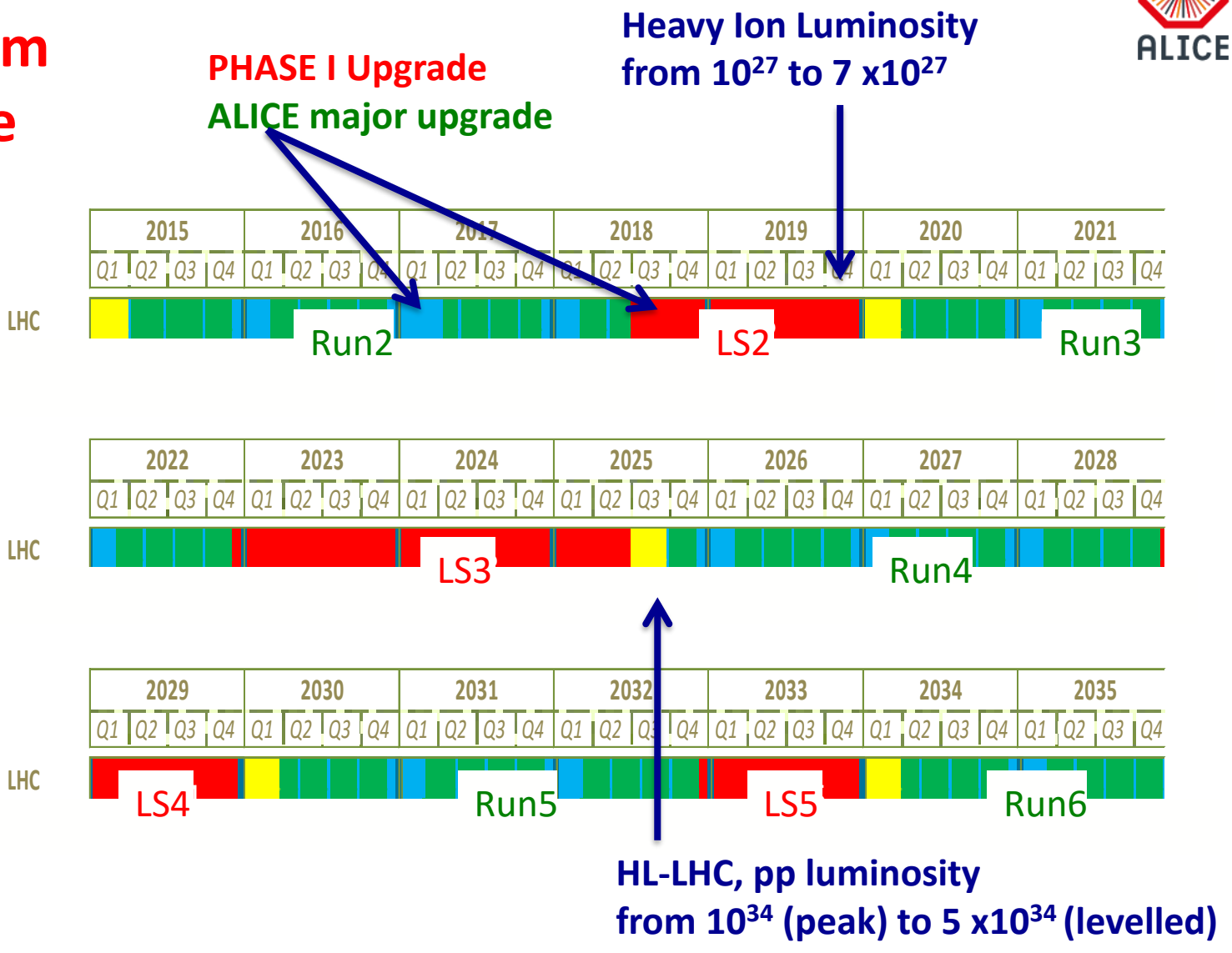
Total time in stable beam: 195h 9min 53s
Total time in data-taking: 163h 18min 11s

Run considered:
- **PHYSICS_1 partition**
- **"Good" runs**
- **Duration >5 min**
- **With at least ITS & TPC**



INTRODUCTION TO ALICE UPGRADE

Long Term Schedule



ALICE will operate beyond LS3 in the HL-LHC era

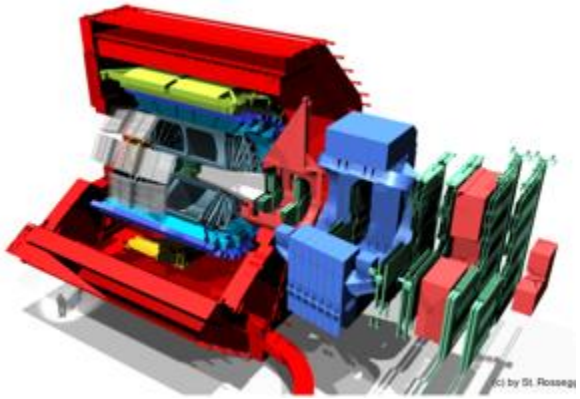
ALICE Upgrade Strategy

GOAL:

- High precision measurements of rare probes at low p_T which cannot be selected with a trigger. Target a recorded Pb-Pb luminosity > 10 nb^{-1} => $9x10^{10}$ events to gain a factor 100 in statistics over the Run1 + Run2 programme.
- Significant improvements of vertexing and tracking capabilities

DETECTOR:

- Read-out all Pb-Pb interactions at a maximum rate of 50kHz (i.e. L = $6x10^{27}$ $cm^{-1}s^{-1}$) upon a minimum bias trigger
- Read-out all pp and p-Pb interaction at a maximum rate of 200 kHz.
- Perform online data reduction based on reconstruction of cluster and tracks
- Improve vertexing and tracking at low p_T => New Inner Tracking System (ITS)



ALICE Upgrade

ALICE Upgrade

New Inner Tracking System (ITS)
- improved pointing precision
- less material -> thinnest tracker at the LHC

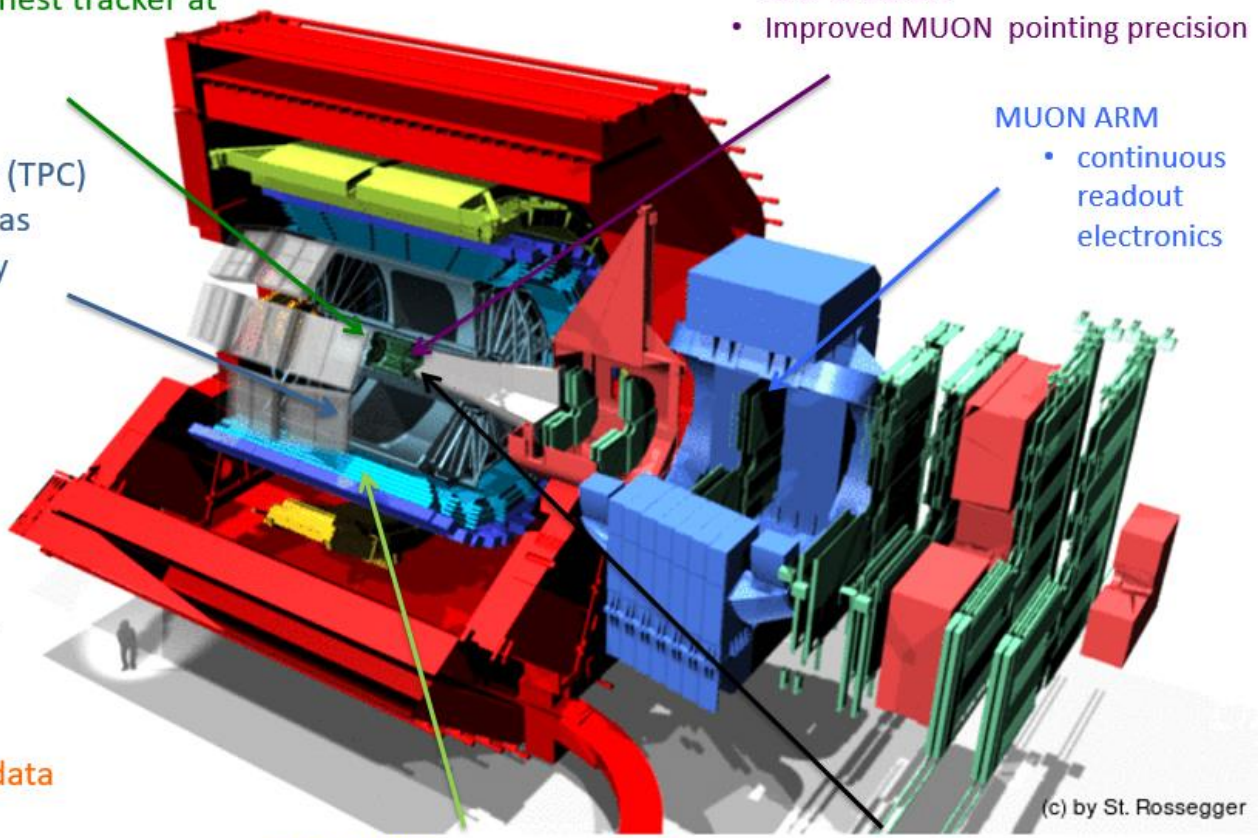
Muon Forward Tracker (MFT)
- new Si tracker
- Improved MUON pointing precision

MUON ARM
- continuous readout electronics

Time Projection Chamber (TPC)
- New Micropattern gas detector technology
- continuous readout

New Central Trigger Processor (CTP)

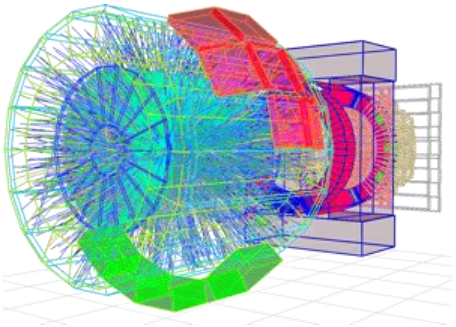
Data Acquisition (DAQ)/ High Level Trigger (HLT)
- new architecture
- on line tracking & data compression
- 50kHz Pb-Pb event rate



TOF, TRD
- Faster readout

New Trigger Detectors (FIT)

ALICE in 2018



O^2 computing farm:

- ~ 100 k CPU cores
- ~ 5000 GPUs and ~500 FPGAs
- ~ 60 PB of storage

3.6 TByte/s into PC farm

O^2 (Online Offline) System

Partial calibration and reconstruction online, replacing the original raw data with compressed data

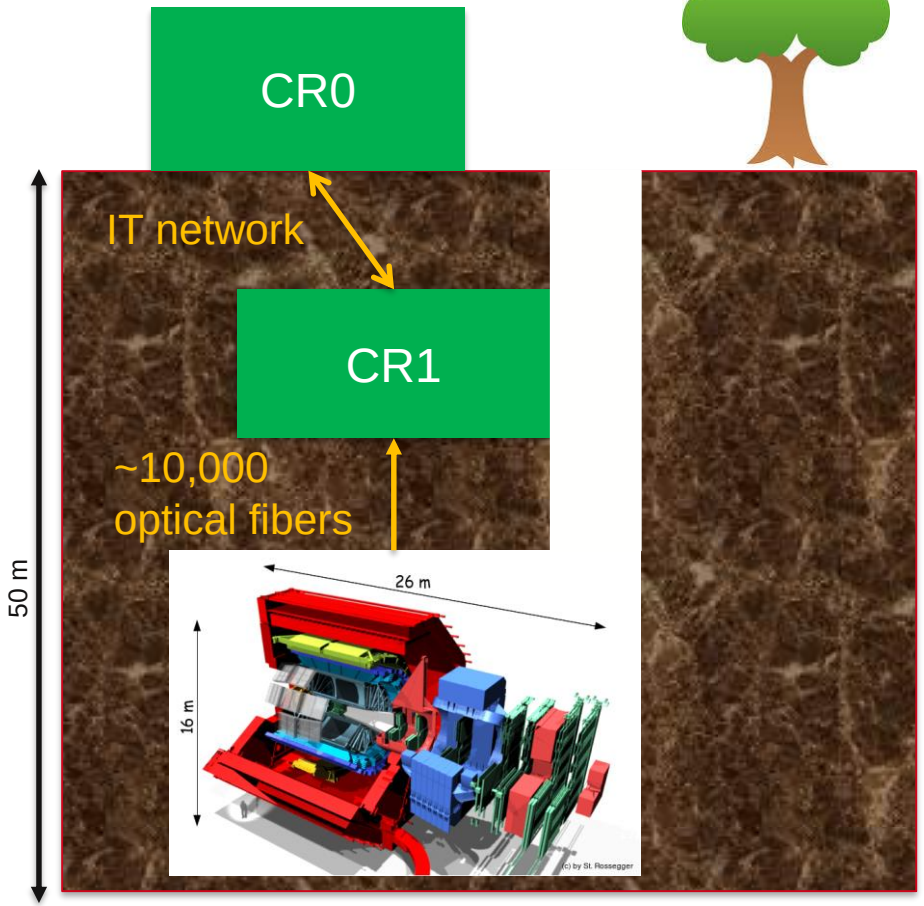
STORAGE

90 GB/s

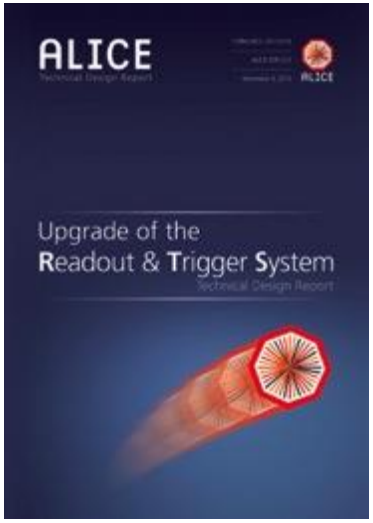
Acq rate:
Pb-Pb 50 kHz
pp and p-Pb up to 200 kHz

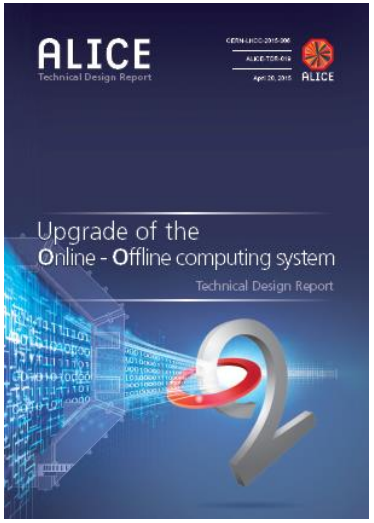
Complete change in detector readout
- continuous
- triggered

New DAQ - HLT - OFFLINE systems.



ALICE LS2 Technical design reports



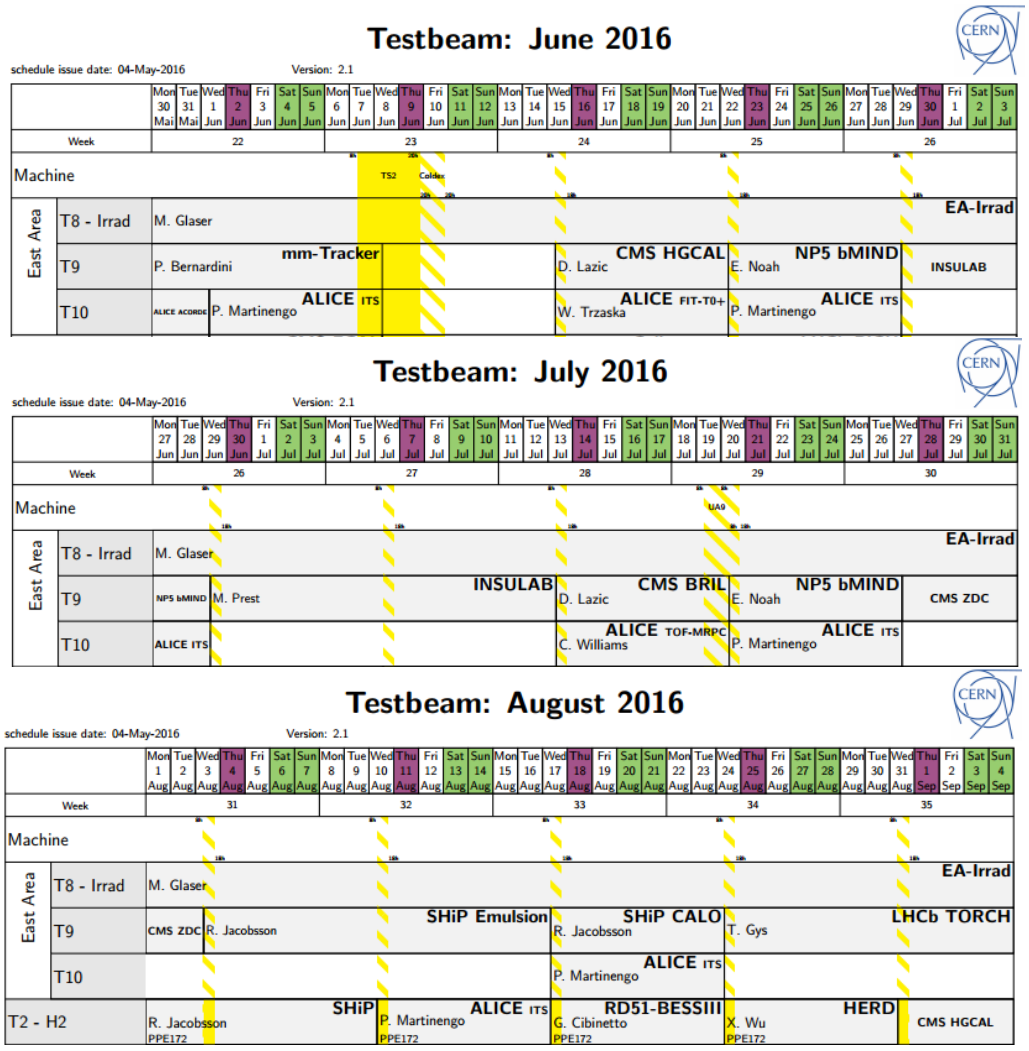


The approved ALICE LS2 upgrade is detailed in 5 Technical Design Reports

- **ITS**
- **Readout and Trigger System**
- **TPC**
- **MFT**
- **Online Offline System**

ALICE C-RORC GBT PROTOTYPE READOUT CHAIN

The motivation



In 2016 several test-beams have been scheduled to characterize prototypes or parts of new detectors and their new FEE (Front End Electronics).

Test beam lasts a couple of weeks max.

It is important to have a stable readout system to collect as much statistics as possible during this limited period of time.

The importance of a stable readout system

Why data taking software didn't start?

A segmentation fault in the new sw

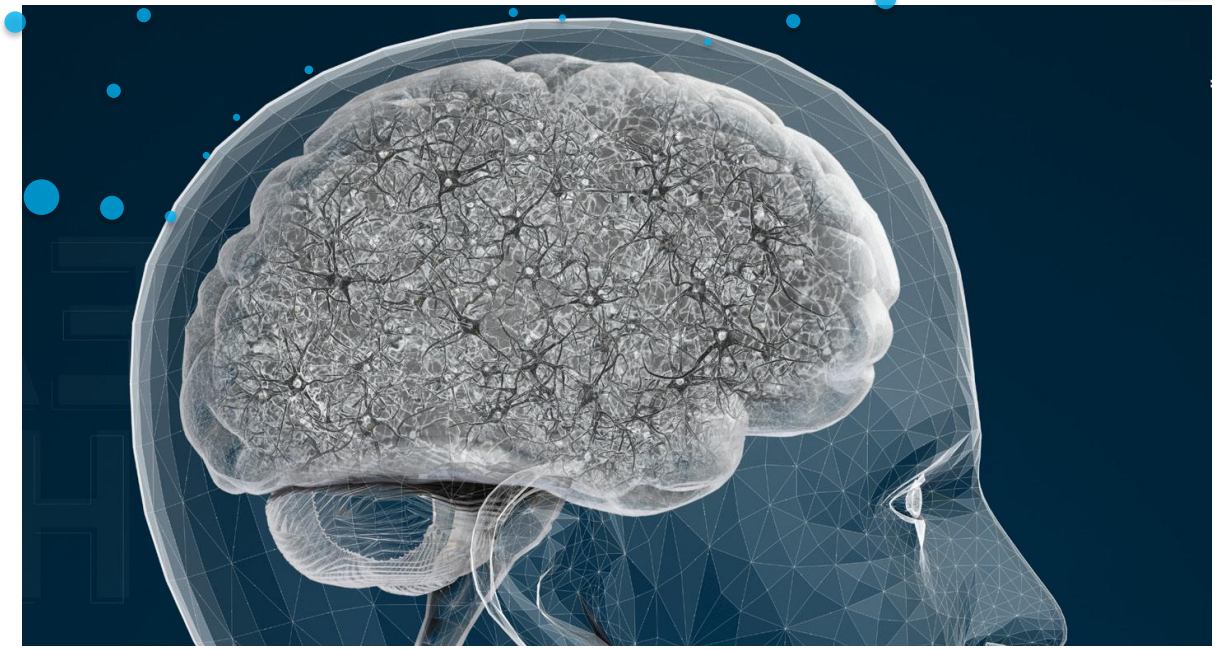
Maybe it is a problem with the new software.

Did I configure the FEE?

VOLTAGE is correct?

Should I call the support?

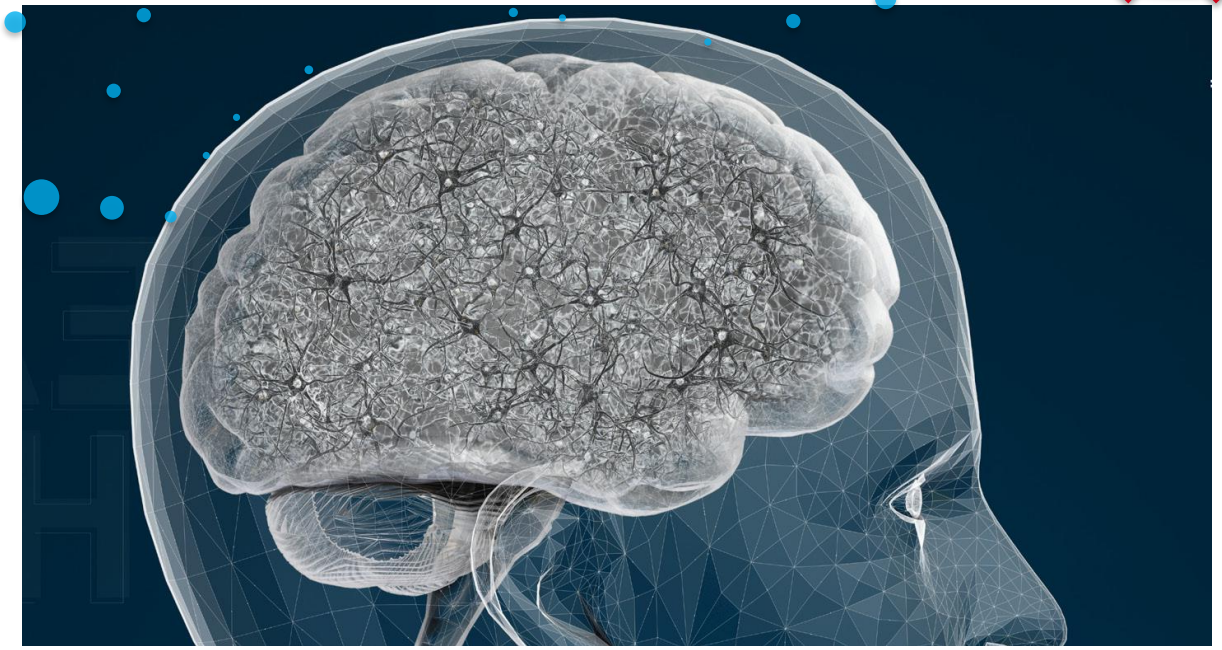
What is this error code?



The importance of a stable readout system

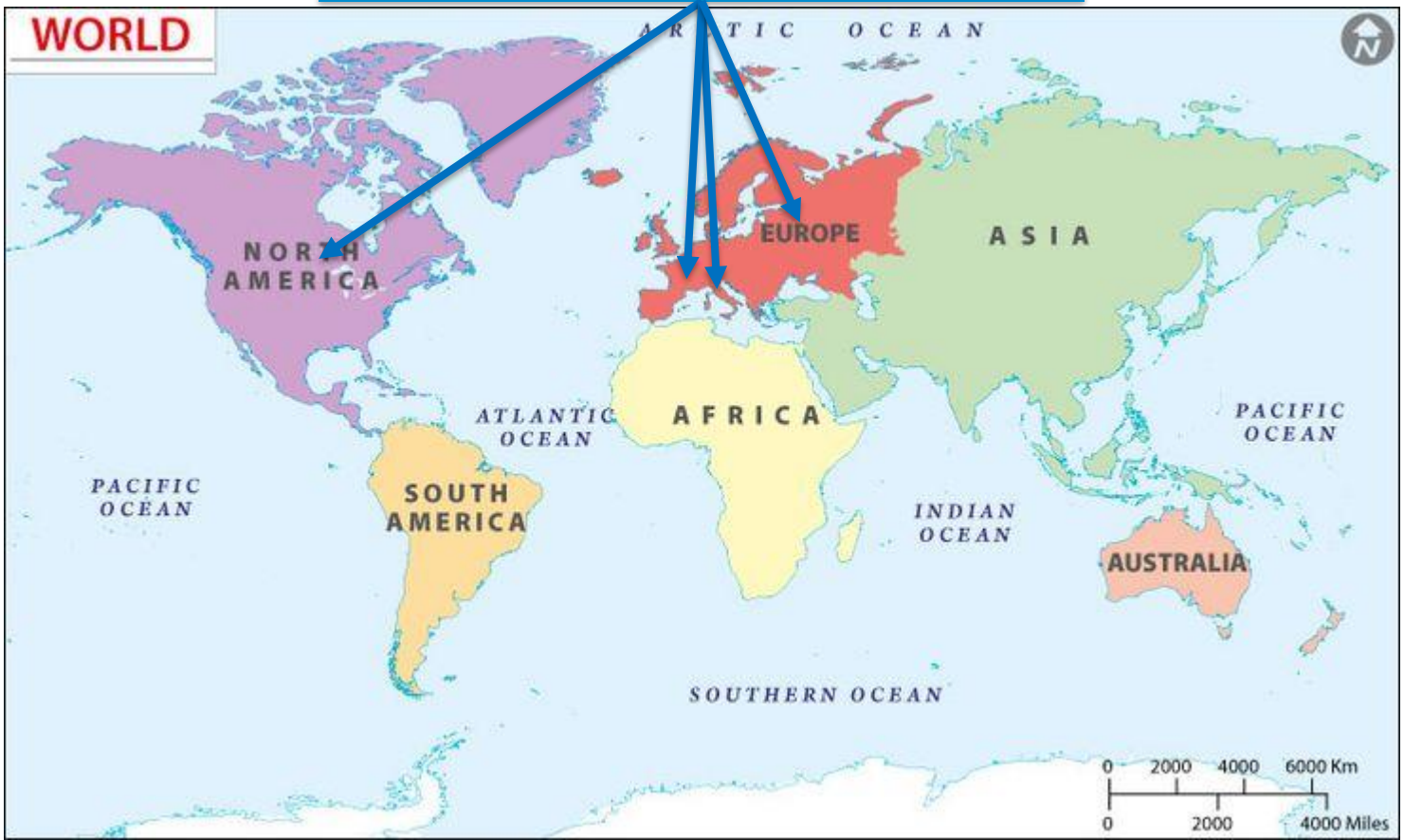
Did I configure the FEE?

VOLTAGE is correct?

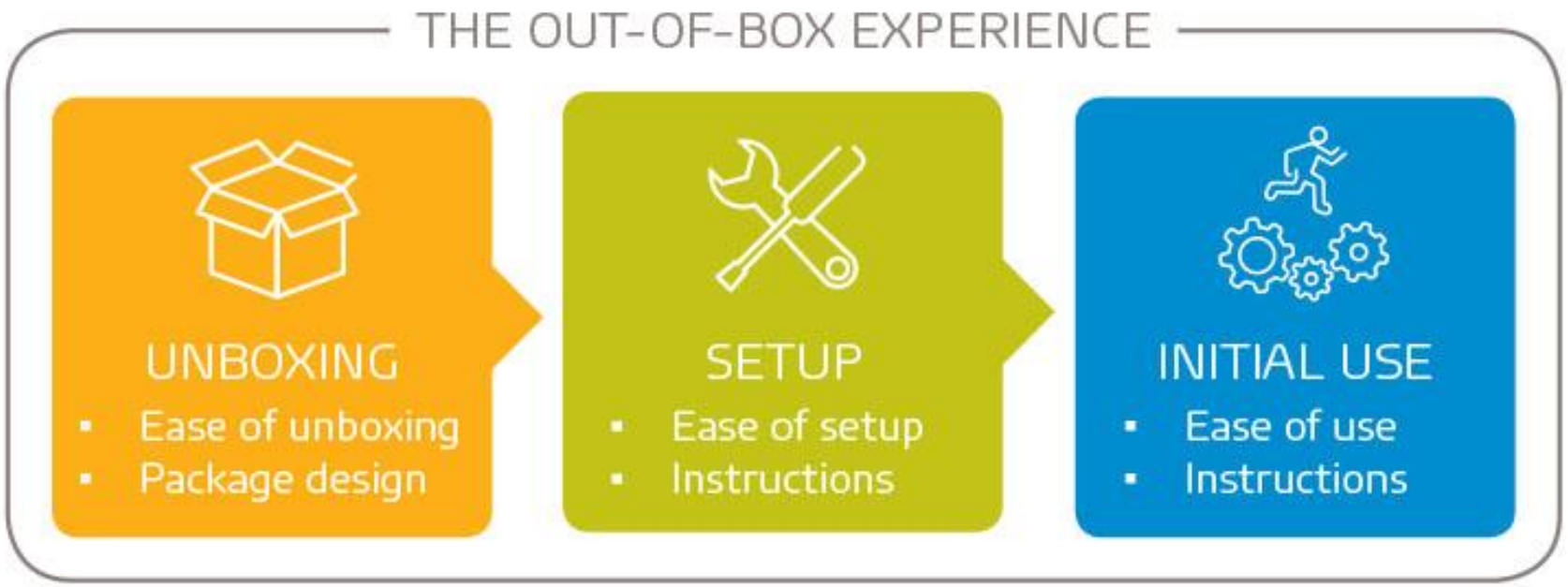


The importance of a stable readout system

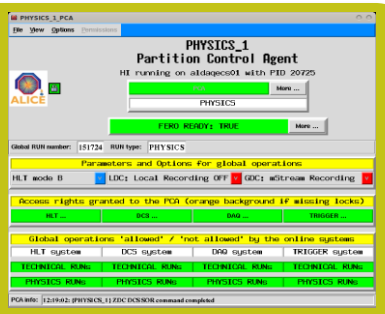
DIFFERENT TEST SYSTEMs
around the world
BIG EFFORT in SUPPORT



The out of the box solution



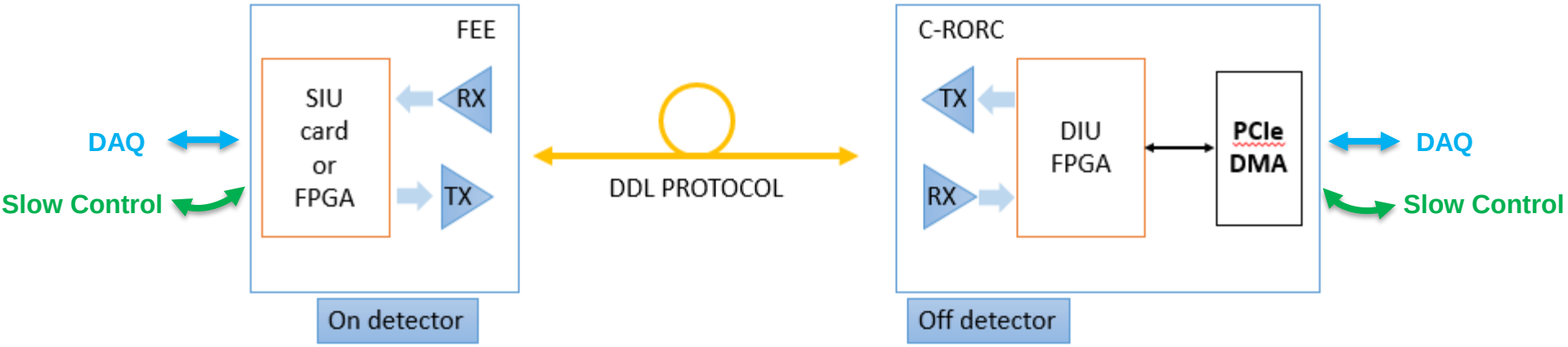
Standard PCIe card,
can be easily installed in several servers



The DATE software can be installed using RPM/YUM and it comes with script for initial set-up and configuration.

The ALICE DAQ is a stable solution in production since 15 years.
Support from the ALICE DAQ group and the ALICE community.

The current readout solution

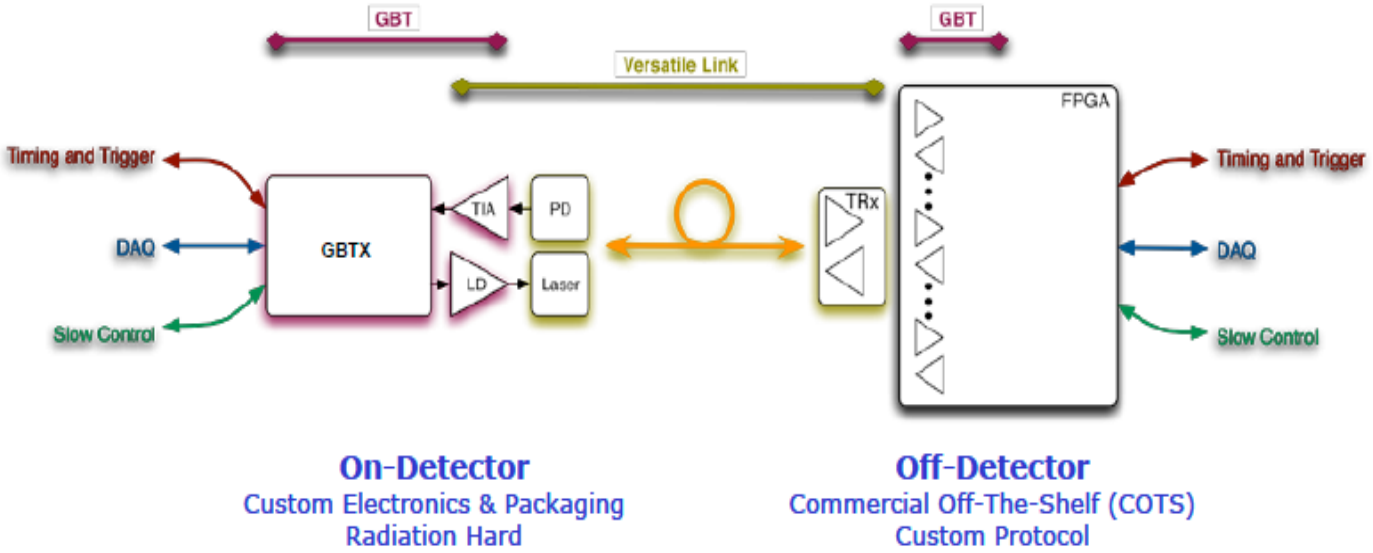


Current readout DAQ chain based on **DDL (Detector Data Link)**

- **DDL SIU** (Source Interface Unit)
- **DDL** fiber (point-to-point bi-directional connection)
- **DDL DIU** (Destination Interface Unit)

The DDL allows to transmit DAQ and Slow Control information on the same link in both directions, but not at the same time.
It implements a XOFF feature for the data integrity, the SOURCE can be paused if the DESTINATION can't accept additional data.

The new link



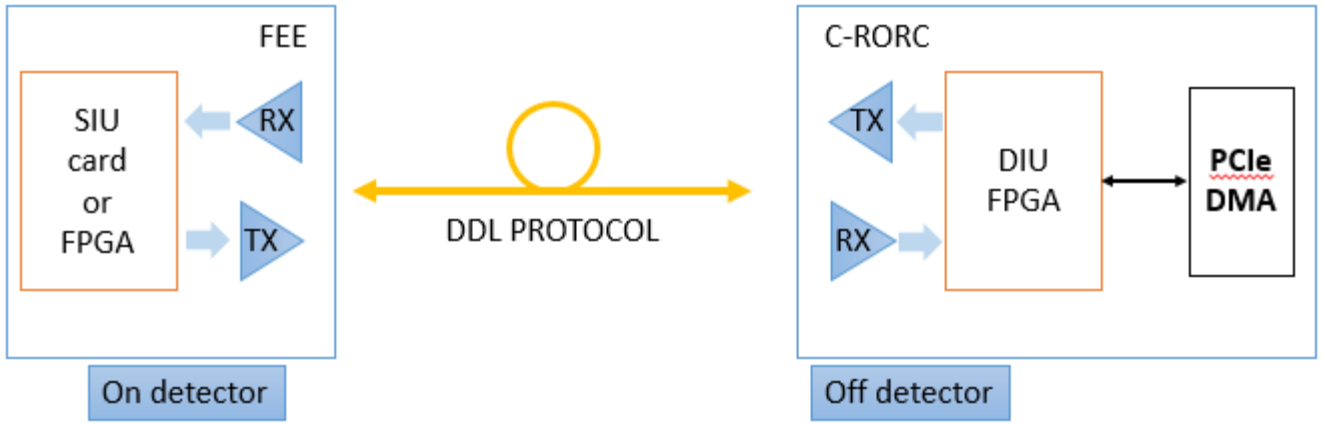
The new readout link is called GBT (GigaBit Transceiver).
It allows to transmit over a single fiber connection, at the same time, 3 streams:

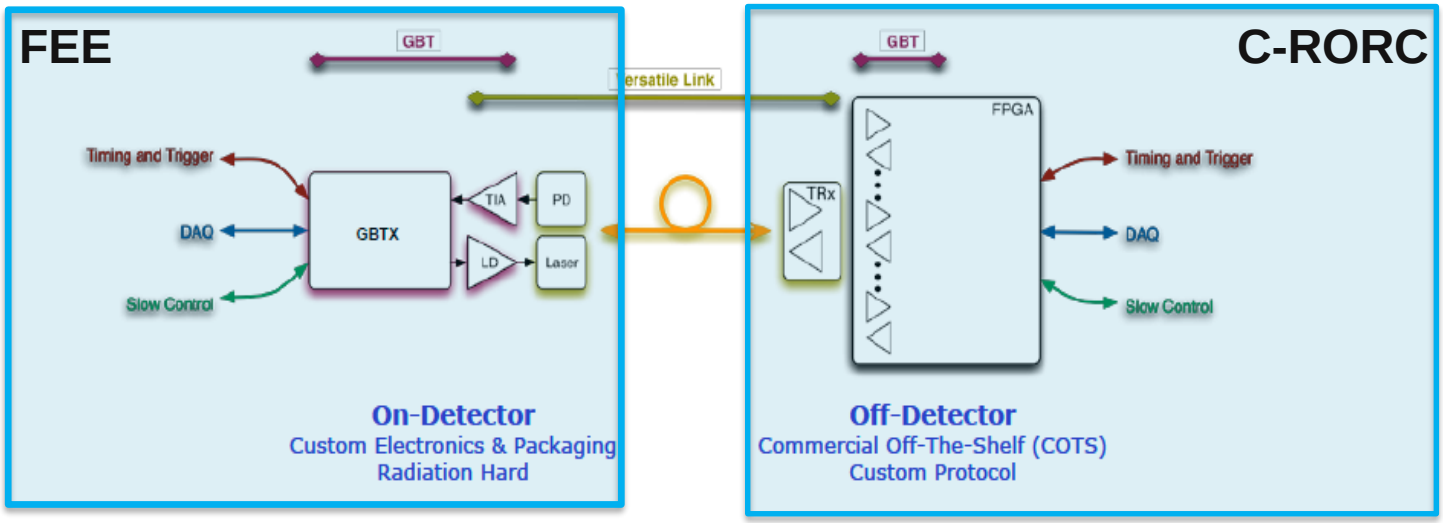
- **DAQ**
- **Timing and Trigger**
- **Slow Control**

The main components are:
- The **GBTx chip** or **GBT-FPGA.**
- **Versatile link:** a point-to-point connection that can work in the harsh radiation environment of HEP experiments at CERN.

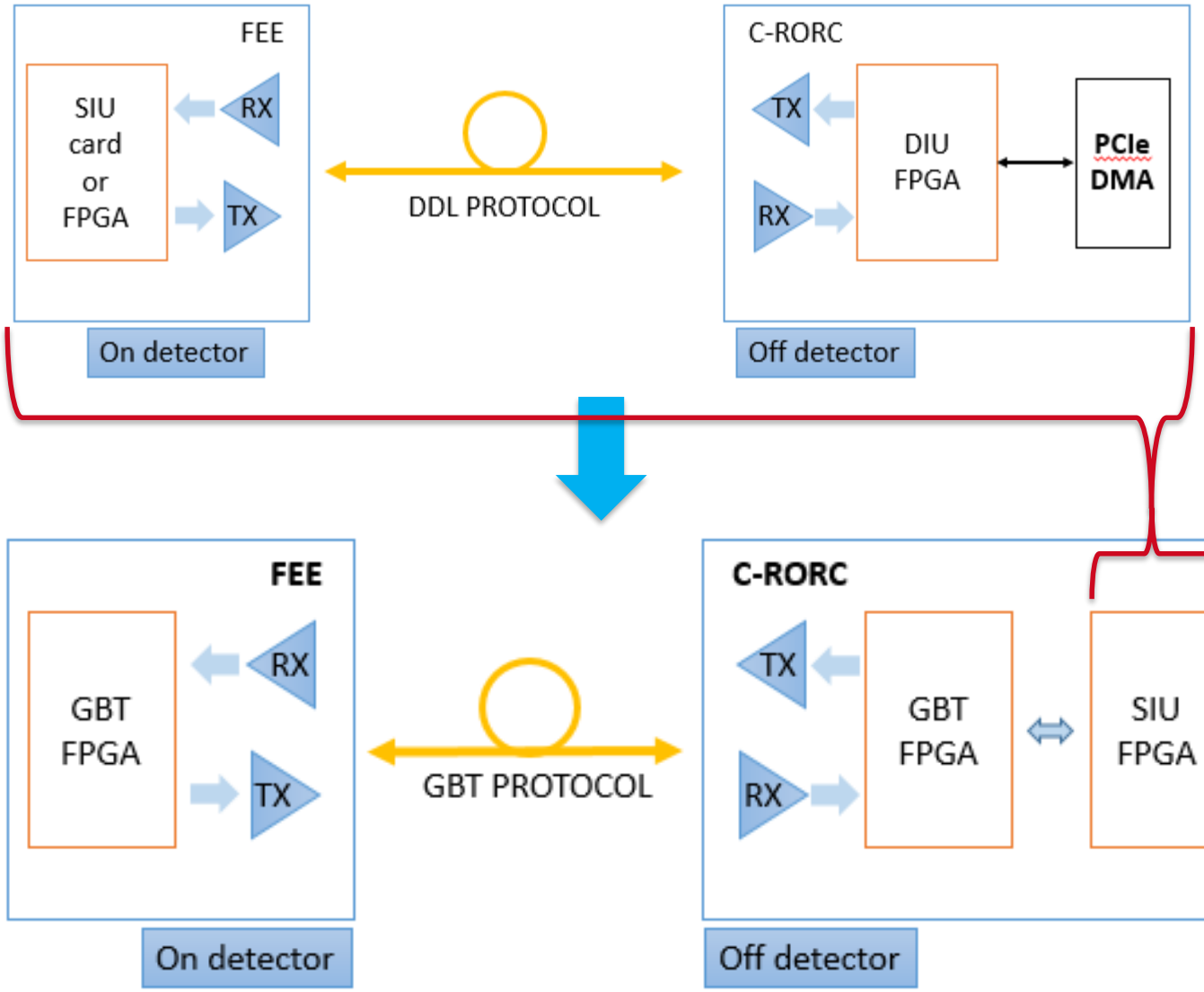
Developed by CERN electronic group

The proposed readout solution



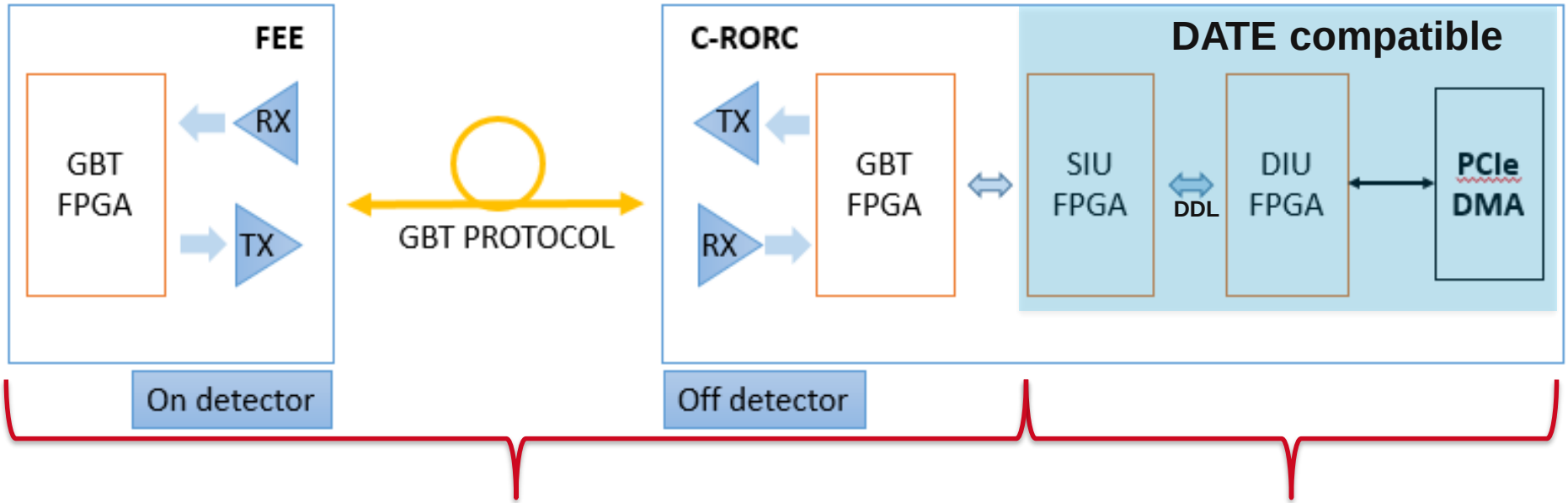


The new readout chain



To readout the new detectors using GBT and to keep the compatibility with **DATE**, the **DDL components (SIU – DIU)** have been ported in the C-RORC firmware.

Compatibility with the current readout system



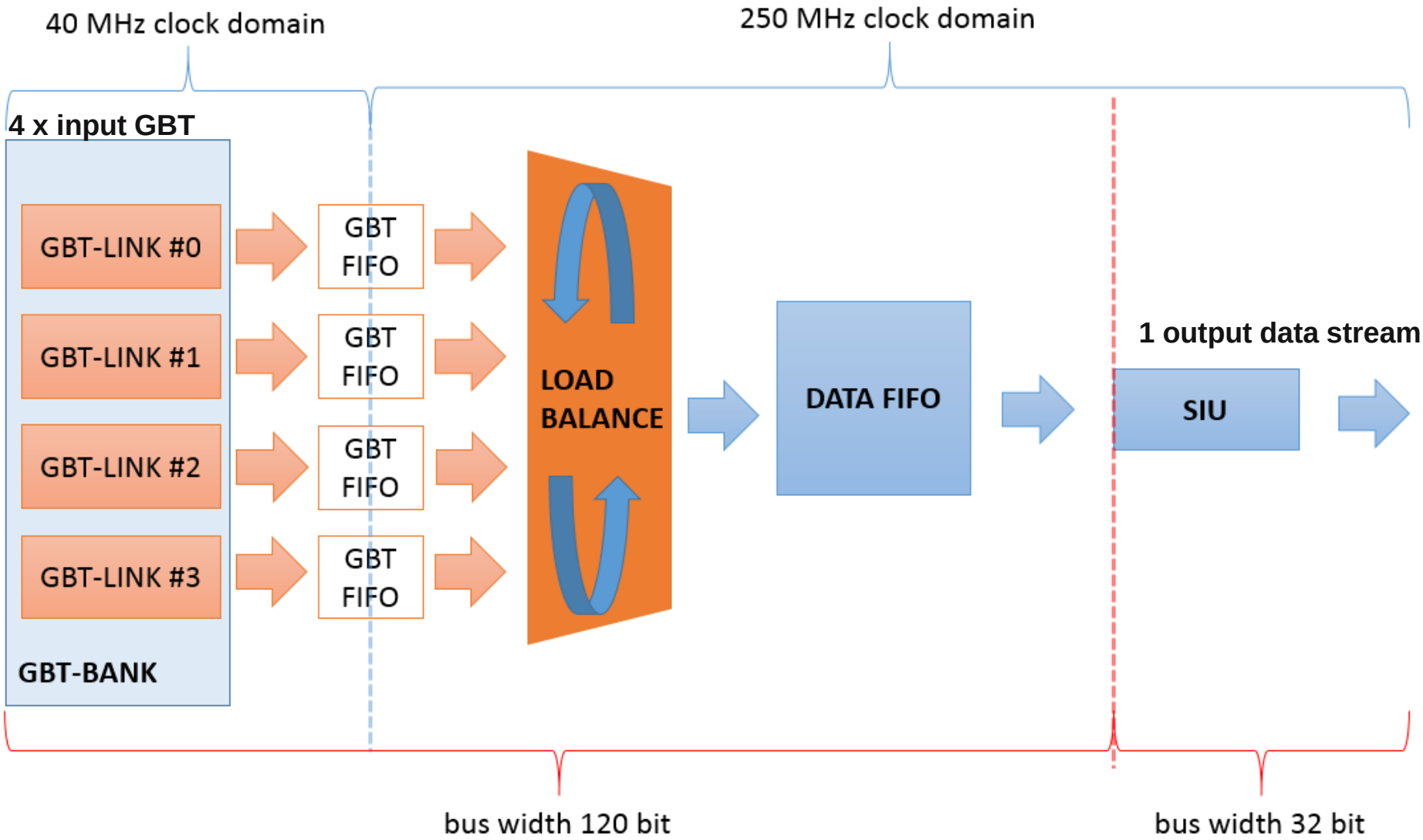
New readout chain
(Run 3)

Present readout chain
(Run 2)

DATA FLOW

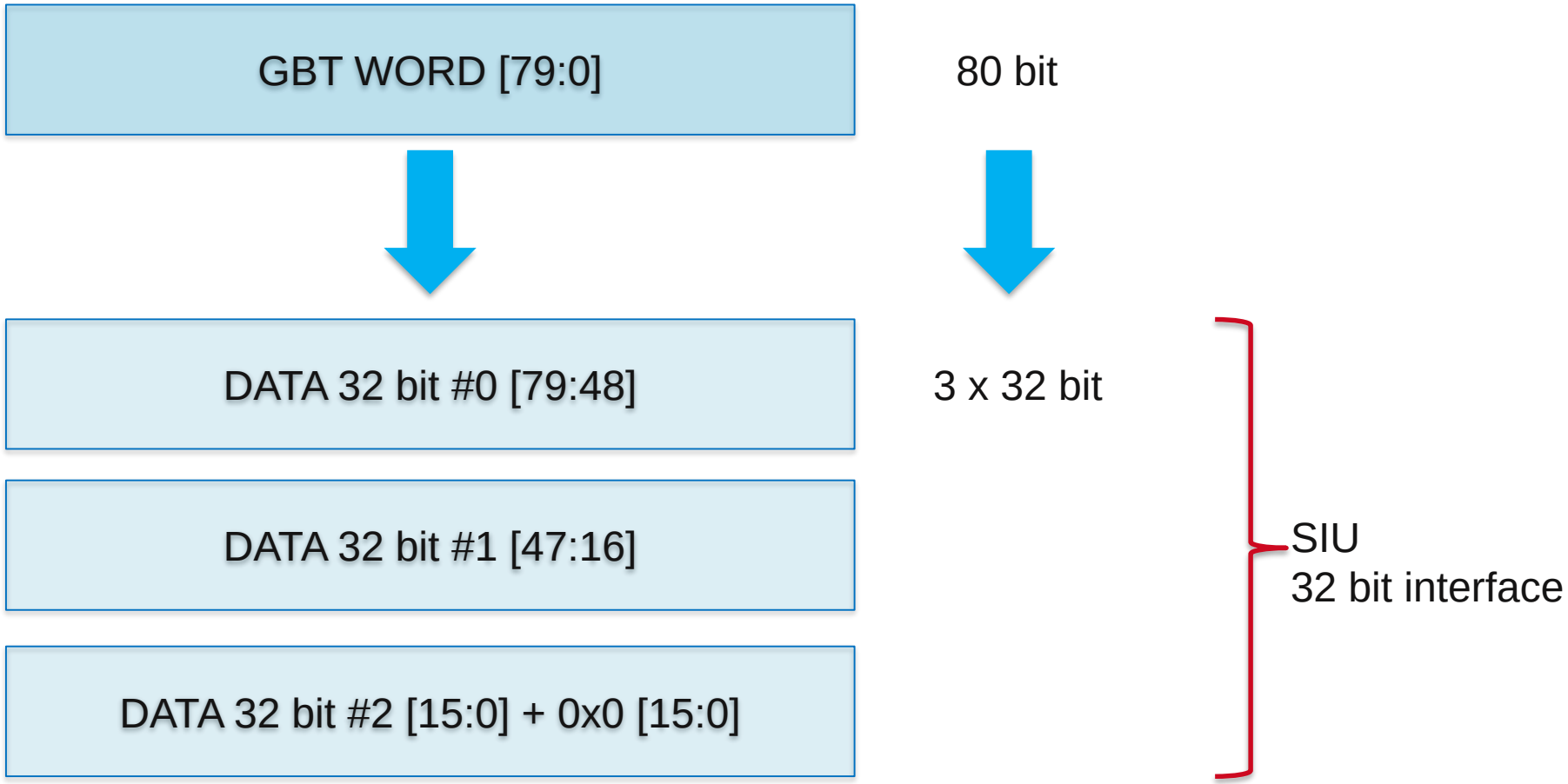
FEE ➔ C-RORC

Data flow (FEE ➔C-RORC)



4 bit (Slow Control) + 80 bit (DATA) + 32 bit (error correction/extra data)

From GBT (80 bit) to SIU (32 bit)

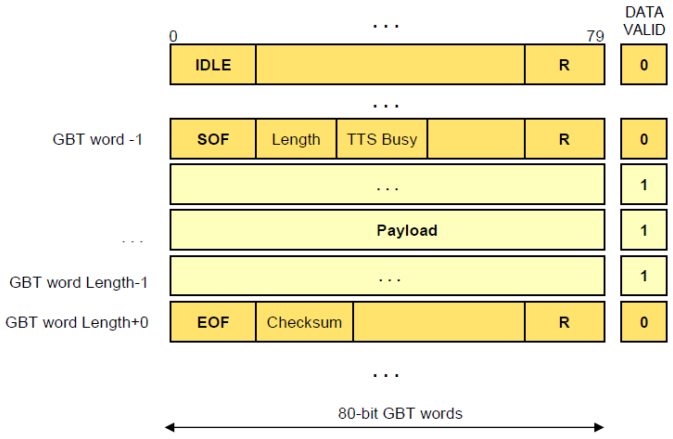


Readout mode

Packets protocol:

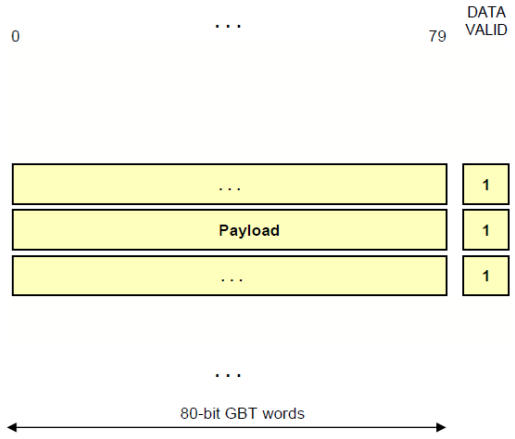
for every trigger the detector generate a packet:

- ***SOF*** (Start of Frame)
- **PAYLOAD**
- ***EOF*** (End Of Frame)

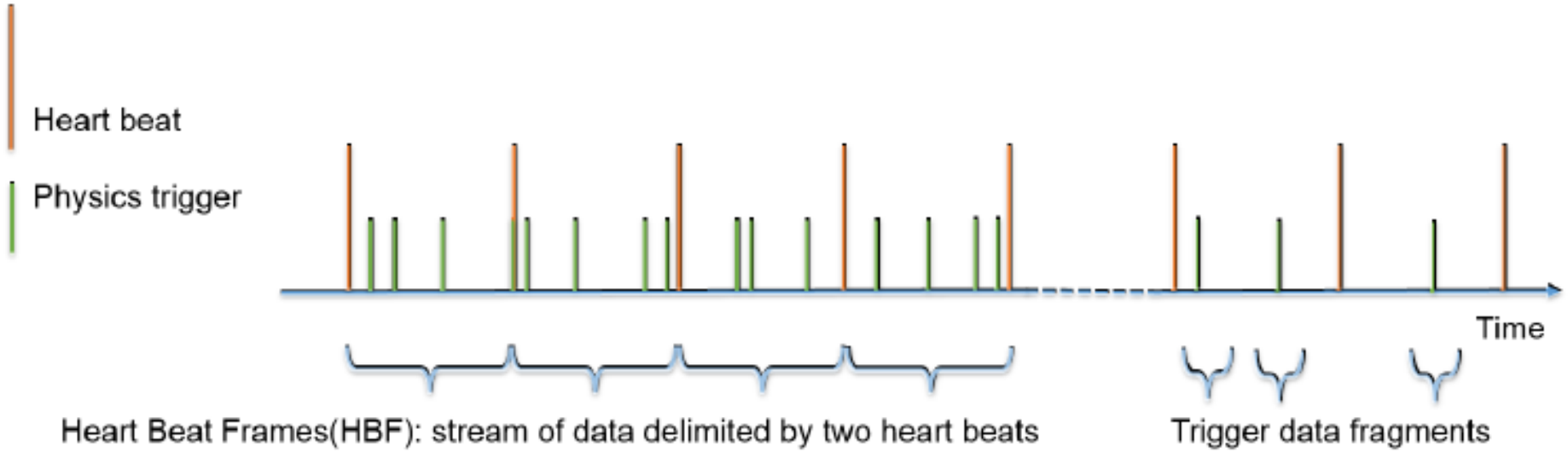


Continuous protocol:

the detector produces a continuous flow of data without timing information. It is responsibility of the **readout card** to packetize the information and tag the data adding event identification

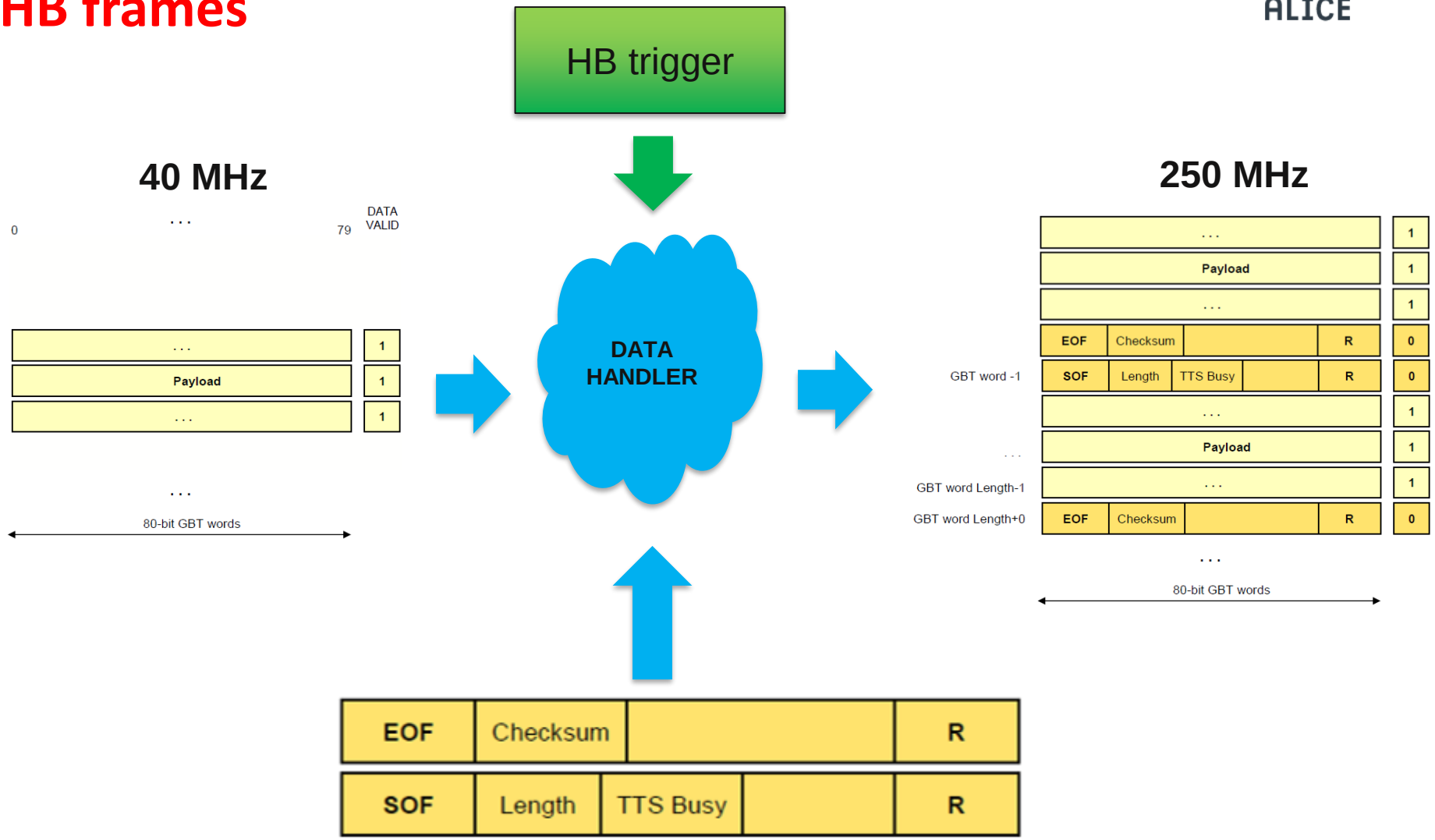


Continuous readout : the HeartBeat trigger



In continuous read-out mode data is not delimited by physics trigger.
The HB triggers are marker at constant frequency (10 kHz) used to chop the data flow into manageable HB frames.

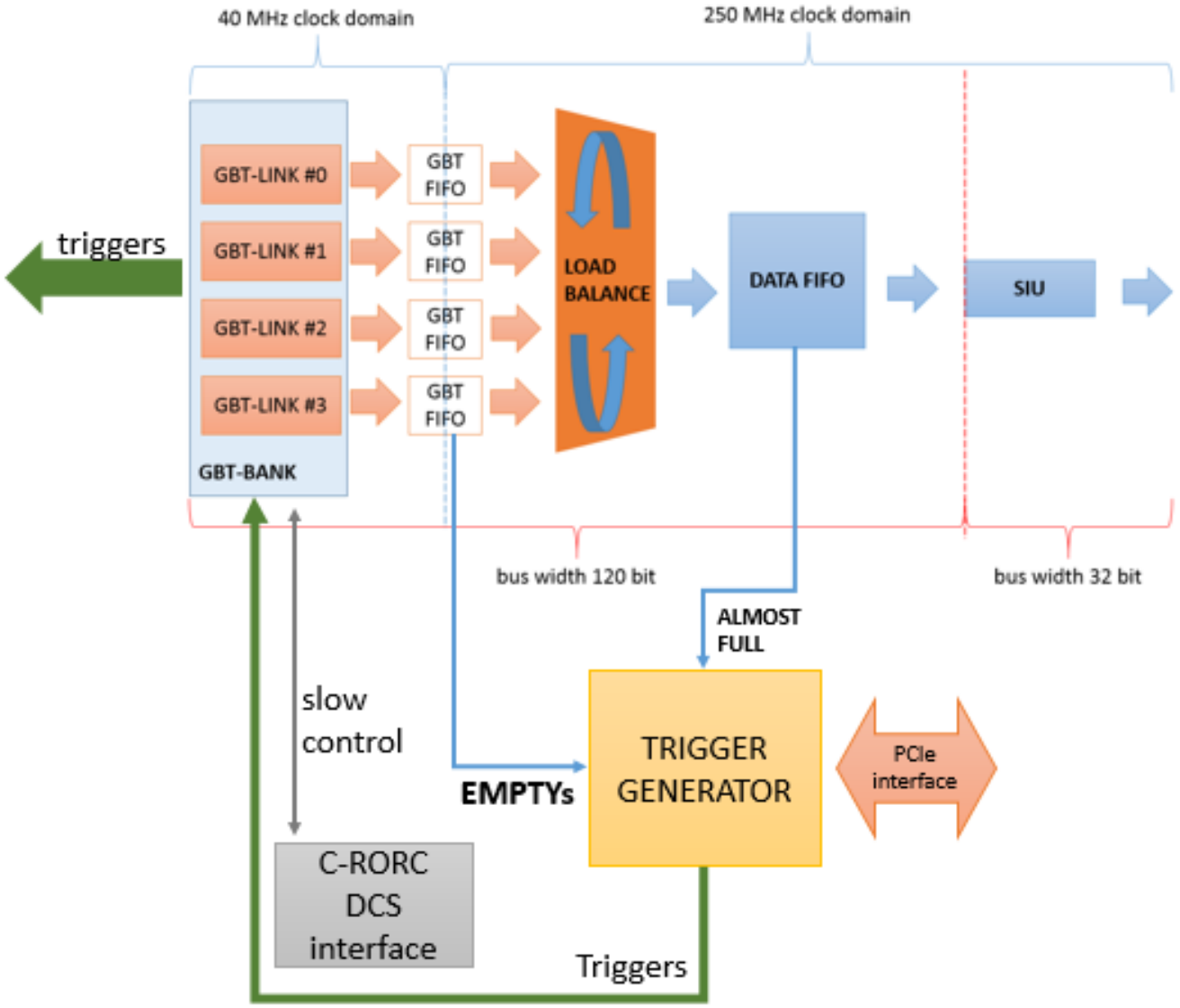
HB frames


HB trigger
40 MHz
0
79
DATA VALID
Payload
80-bit GBT words
DATA HANDLER
250 MHz
Payload
EOF
Checksum
R
SOF
Length
TTS Busy
GBT word -1
GBT word Length-1
GBT word Length+0
80-bit GBT words
EOF
Checksum
R
SOF
Length
TTS Busy
R

DATA FLOW

FEE ← C-RORC

Trigger & Slow Control

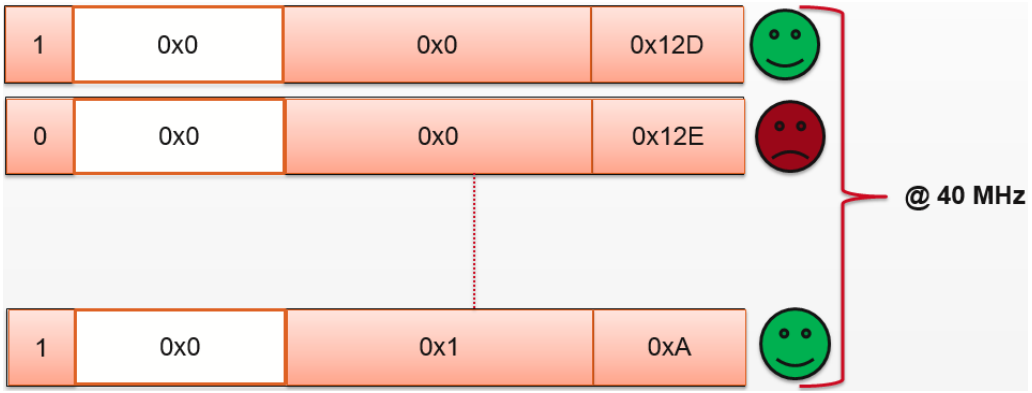


Triggers format over GBT

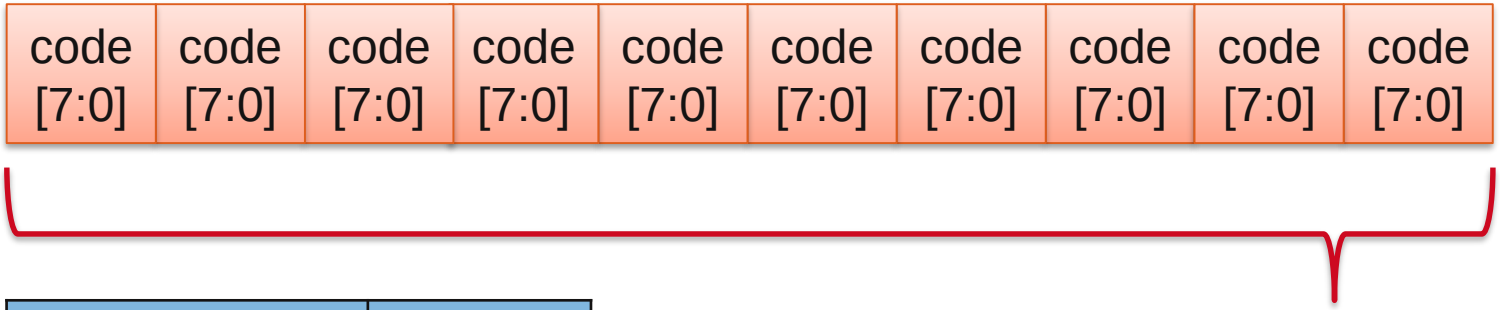
TRG [79]	SPARE bits [78:44]	ORBIT [43:12]	BC [11:0]

Bit value:

TRG : used to validate the trigger (1 ok, 0 no trigger)
ORBIT : counter 32 bit, it increment every time the BC overlaps
BC : counter 12 bit, it increments every 25 ns



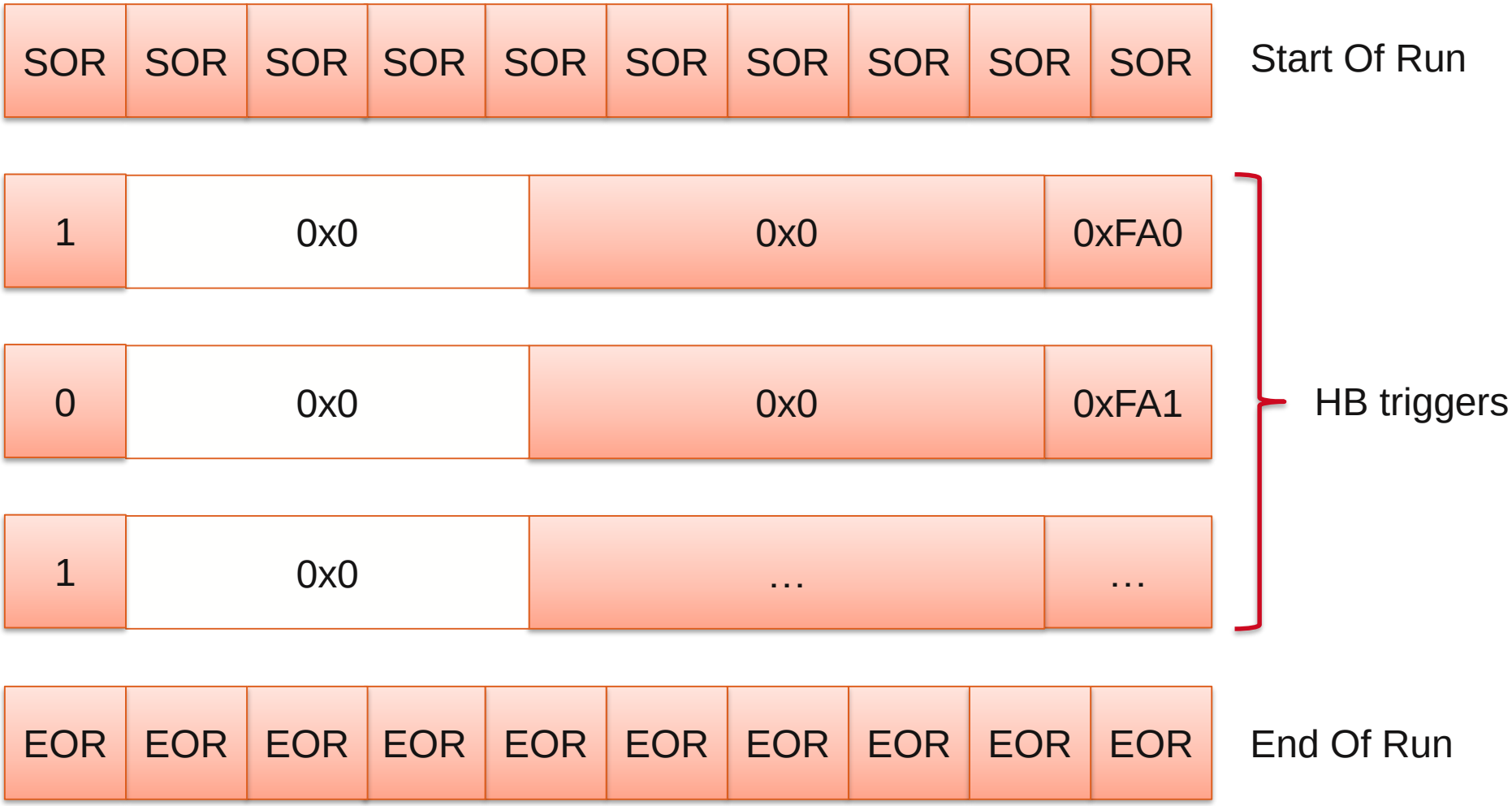
HB trigger codes



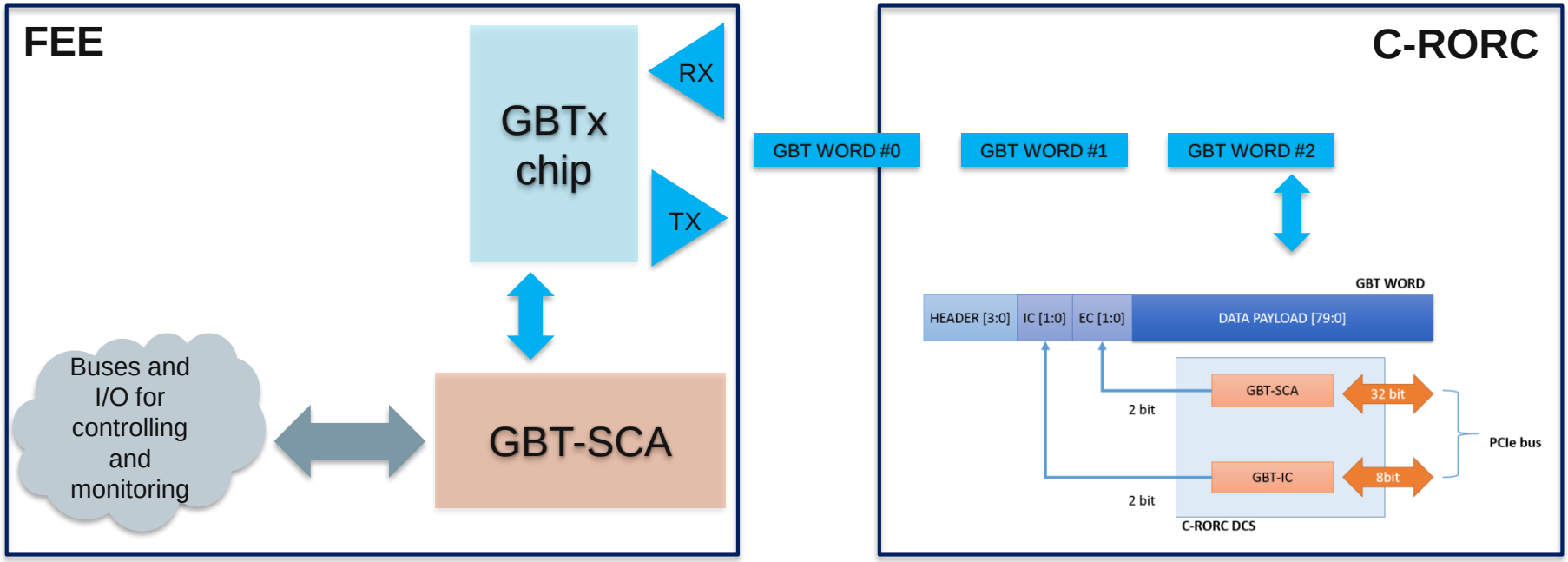
GBT word 80 bit
(8 bit code x 10)

CODE	value
SYNC	0x01
RESET	0x02
DUMP	0x04
CALIBRATE	0x08
RESUME	0x10
PAUSE	0x20
EOR	0x40
SOR	0x80

HB trigger sequence

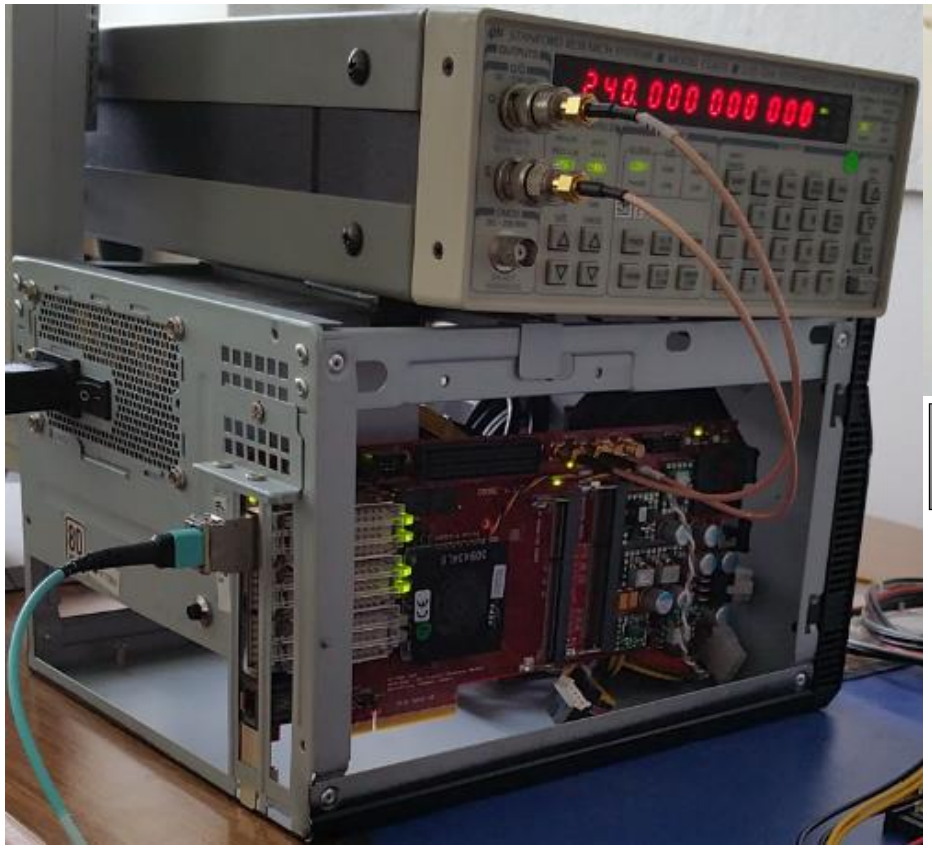


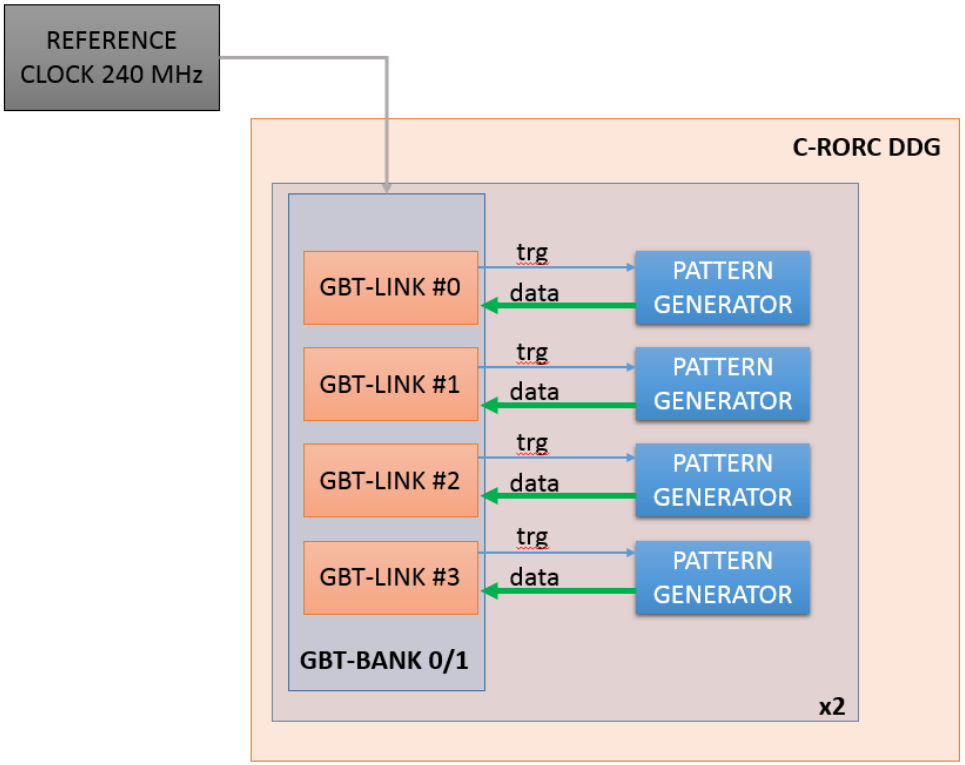
Slow Control information



IC : configuration data for the GBTx chip
EC : configuration data for the GBT-SCA chip

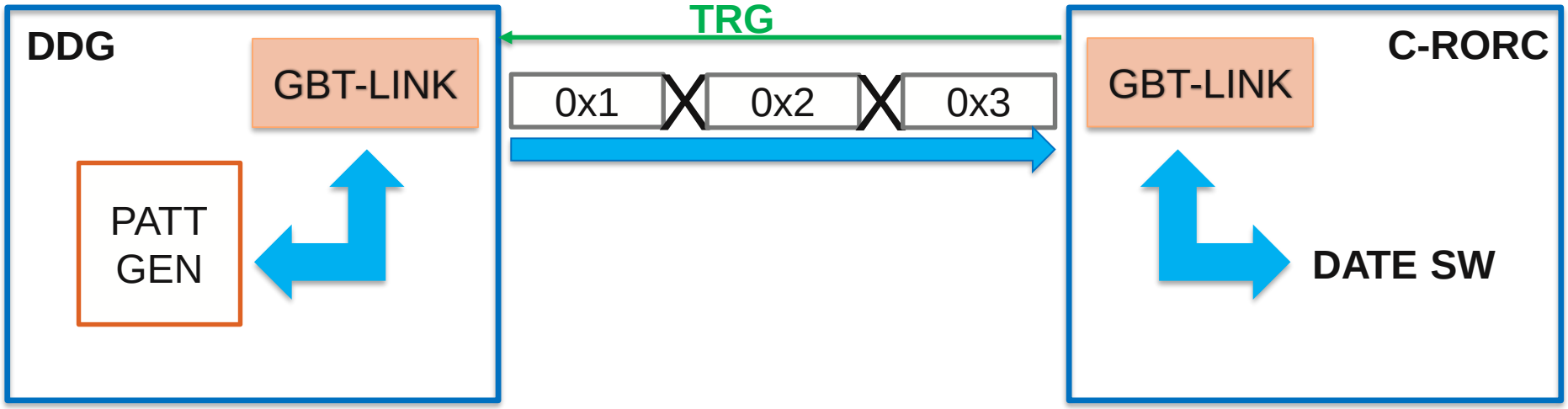
The DDG (Detector Data Generator)





The C-RORC card with a dedicated firmware is used as DATA generator.

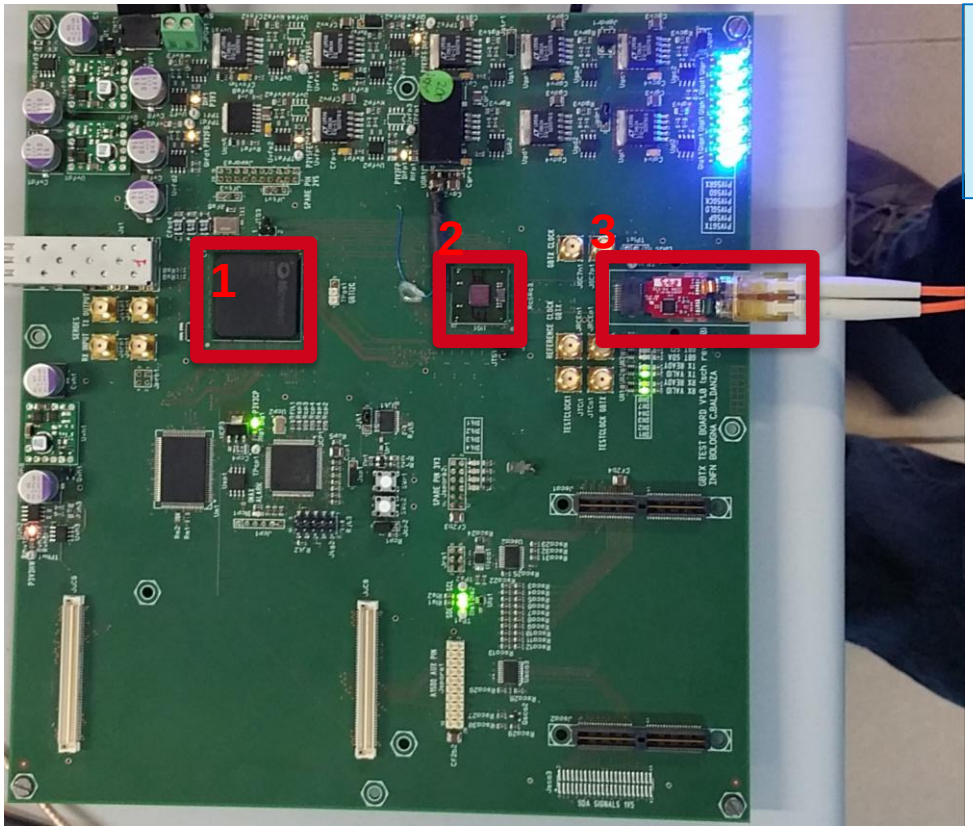
The DDG (Detector Data Generator)



Test with detectors

DETECTOR	STATUS	Readout mode	LOCATION
TOF	tests started	triggered	ITALY
TPC	work in progress	continuous	USA
MID	work in progress	continuous	FRANCE
Muon TRK	work in progress	continuous	FRANCE
FIT	work in progress	triggered	RUSSIA

Test withTOF



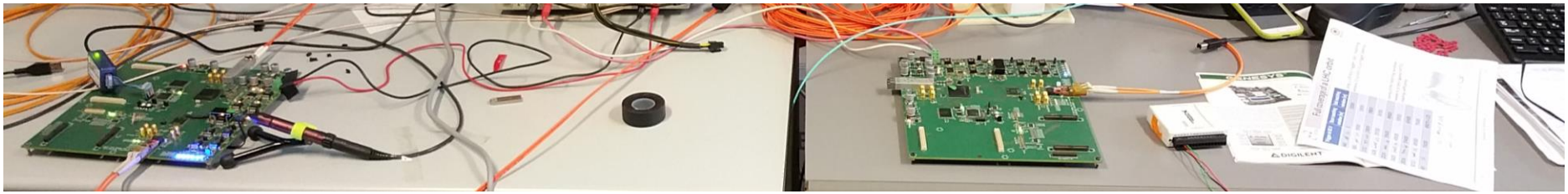
1. IGLOO FPGA MICROSEMI
2. GBTx CHIP
3. VTrx (versatile link)

For more information on the TOF readout card see the POSTER of Davide Falchieri

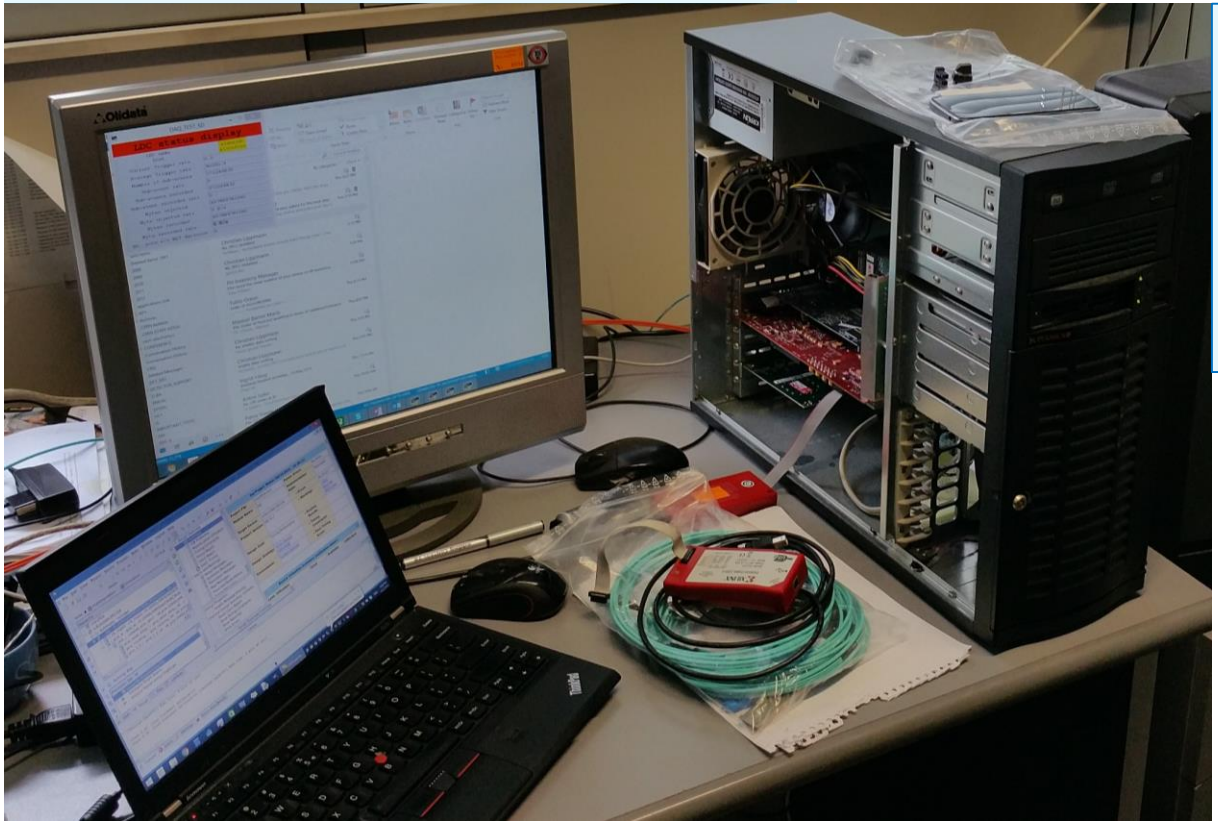
095 Design and test of a GBTx based board for the upgrade of the ALICE TOF readout electronics

Test withTOF

2 x TOF FEE cards



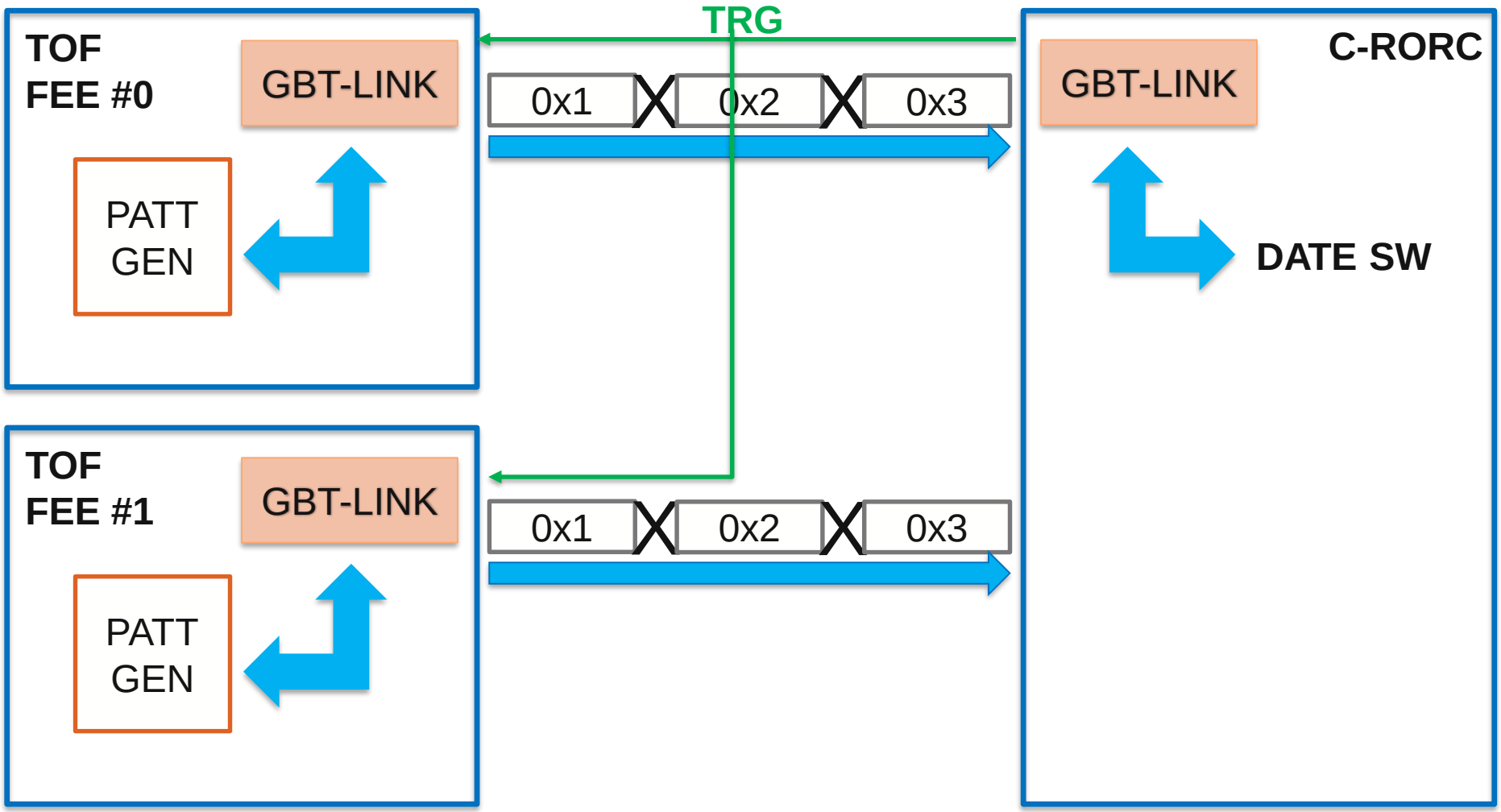
DATE SOFTWARE & C-RORC



The two cards were connected to a **C-RORC** controlled by **DATE**.

Acq rate : **340 kHz**
Event Size : **1.7 kB**

TOF setup


TOF
FEE #0
GBT-LINK
PATT
GEN
TRG
0x1
0x2
0x3
C-RORC
GBT-LINK
DATE SW
TOF
FEE #1
GBT-LINK
PATT
GEN
0x1
0x2
0x3

Conclusions

The ALICE upgrade includes a complete change of the detector read-out.
A transition strategy has been established using components of the present read-out system.

The GBT C-RORC firmware has the following features:

- 8 x GBT links.
- Trigger generation.
- Detector configuration over GBT link.

Tests with real detector have started.
Results obtained with TOF proved the good performance of the prototype readout system.

Most of the development and experience gained with the C-RORC will be used for the future readout system development.

Thank you for your attention

References

- GBT : https://cds.cern.ch/record/1235836?ln=fr
- "**The GBT-FPGA core: features and challenges**" TOPICAL WORKSHOP ON ELECTRONICS FOR PARTICLE PHYSICS 2014, 2015 JINST 10 C03021
- "**The ALICE experiment at the CERN LHC**", 2008 JINST 3 S08002, 2008
- "**The ALICE data acquisition system**" Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment, Volume 741, 21 March 2014, Pages 130–162.
- " **The C-RORC PCIe card and its application in the ALICE and ATLAS experiments**" Topical Workshop on Electronics for Particle Physics 2014., 2015 JINST 10 C02022.