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ALICE Zero Degree Calorimeters
The new readout system in LHC run 3

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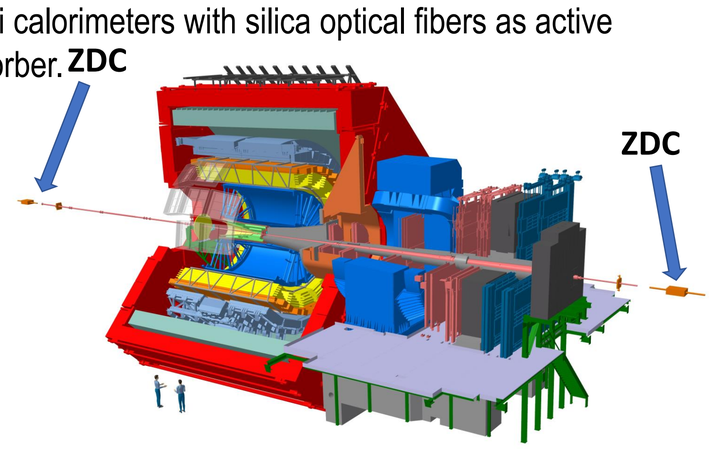
Research context and motivation

- The ZDC consists in two identical sets of calorimeters located on both sides relative to the interaction point IP2, 112.5 meters away from it. In that region the two LHC beams circulate in two different pipes. Each set of detectors consists of a neutron (ZN) and a proton (ZP) calorimeter. The ZN is placed at zero degree with respect to the LHC axis, between the two beam pipes, while the ZP is positioned externally to the outgoing beam pipe. Collisions may occur in fixed time slots named bunch crossings (BC) that are separated by ~25 ns. ZDC is mainly sensitive to spectator nucleons. The spectator protons are separated from the ion beams by means of the dipole magnet D1, while spectator neutrons fly at zero degree without further changing direction. The ZDC detector is completed by 2 forward EM calorimeters (ZEM) placed at about 7.35 m from IP2, on side A, covering the pseudo rapidity range $4.8 < \eta < 5.7$.
- The ZDCs are quartz-fiber spaghetti calorimeters with silica optical fibers as active material embedded in a dense absorber.
- The main purpose of these calorimeters is to provide an independent measurement of the time of the collision, of the vertex position, centrality, event plane and to measure the luminosity in heavy ion operation.



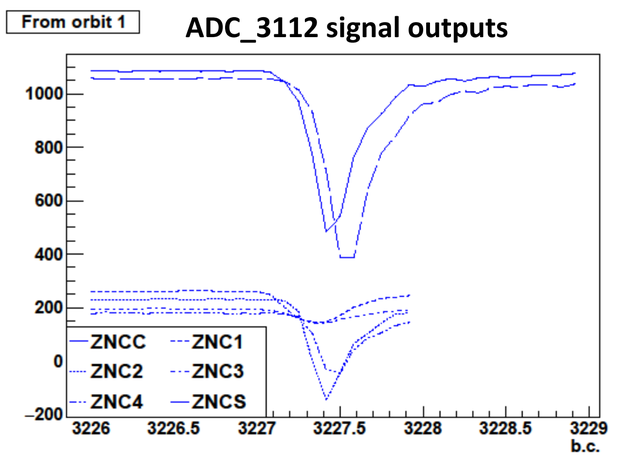
Addressed research questions/problems

In order to exploit the potential offered by the increased luminosity in run 3, the ALICE experiment upgraded its trigger and readout system.

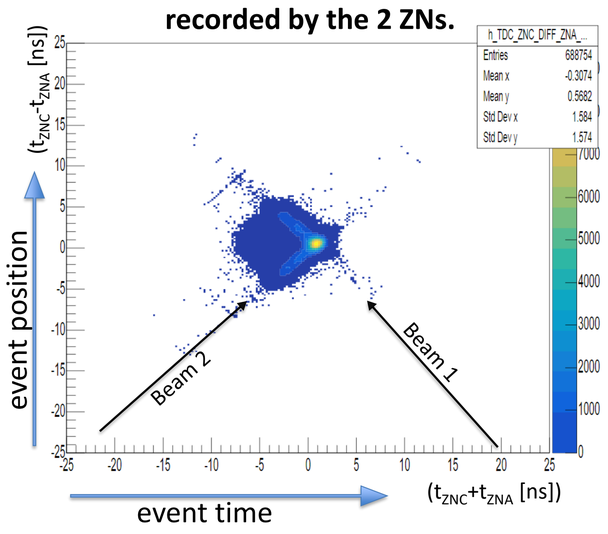
- Data acquisition in continuous readout mode without dead time at a trigger rates in Pb-Pb collisions of ~2.5 MHz, due to hadronic + EMD processes.
- Efficient triggering in the presence of a large signal dynamics (from a single neutron signal to ~60 neutrons for Pb-Pb collisions).
- Interval between consecutive interactions of ~50 ns (lower than the length of the signal of ~60 ns).
- Estimate of the baseline in the firmware in events where no collision takes place.
- Real time monitoring of the collision rate.

Commissioning with beam

- The commissioning with proton beam was performed during week 38.
- Measurements on detector performance and auto-trigger parameters optimization are currently on-going.



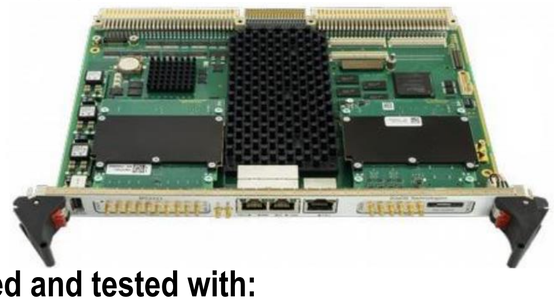
Difference vs Sum of times recorded by the 2 ZNs.

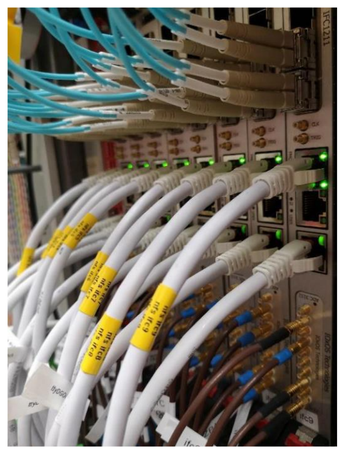


Adopted methodologies

Hardware installed

- IOXOS FMC digitizer ADC 3112, mounting a TI ADS5409 digitizer. Maximum sampling rate of 1 Gsps, 1 Vpp dynamics, 12-bit resolution with ENOB of 10-bit, 4 channels per module, DC coupling (important for unipolar photomultiplier signals), working with digital filtering and decimation by 2.
- IOxOS ifc1211 carrier equipped with two FMC ports, a Xilinx FPGA Kintex Ultrascale xcku040-1ffva1156 and a PowerPC processor.
- 8 carriers are currently deployed in ALICE CR4. There are a total of 32 usable channels.



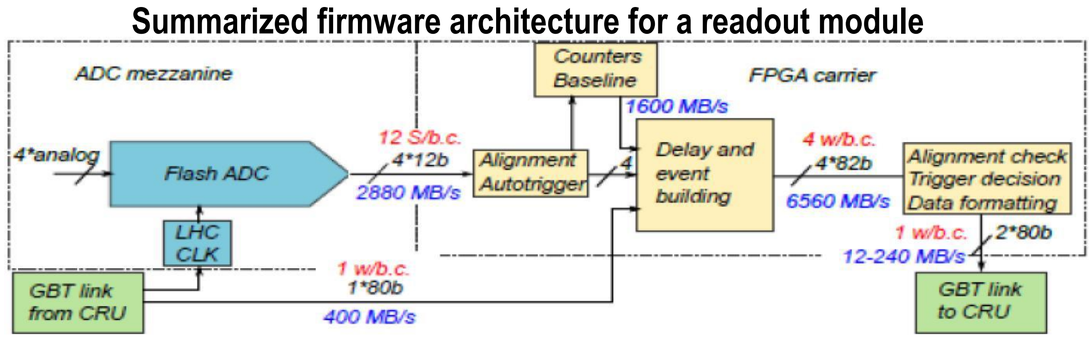


Readout chain developed and tested with:

- A pulse generator.
- A laser to stimulate the photomultipliers.

Under commissioning now in p-p collisions at LHC.

Summarized firmware architecture for a readout module



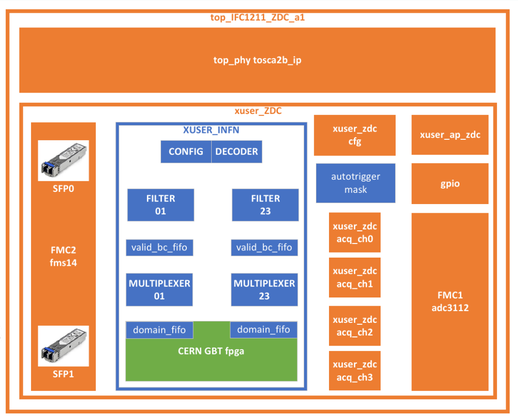
Novel contributions

Personal contributions

- Firmware development and detector commissioning

Firmware structure

- Orange: IOXOS (tosca2b; ADC IP; auto-trigger).
- Green: CERN gbt link IP (two links for each carrier).
- Blue: Turin INFN code.
- 80-bit words at 40.08 MHz -> maximum rate.
- Logic is working at about ~240MHz (six clock cycles are available to process the information produced in a bunch crossing and to perform data reduction).
- Commands to the FPGA firmware are provided through the CERN developed 5 Gbps optical GigaBit Transceiver (GBT) link.



Future work

- Automatic evaluation of the configuration parameters when there are changes in the beam conditions (auto-aligning).
- The ZDC will be finally commissioned during the Pb-Pb data taking scheduled for late 2022.
- Analysis of the possible issues and optimization of the firmware for the final data taking conditions.

Submitted and published works

- S. C. Zugravel, P. Cortese, N. De Marco, P. De Remigis, L. Lombardo, M. Sitta. ALICE Zero Degree Calorimeters. The new readout system in LHC Run 3 [poster]. Topical Workshop on Electronics for Particle Physics (TWEPP-22), 19-23 September 2022, Bergen, Norway.

List of attended classes

- 01UNVRV– Navigating the hiring process: CV, tests, interview (18/11/2021, 2)
- 08IXTRV – Project management (23/11/2021, 5)
- 01SHMRV – Entrepreneurial Finance (26/11/2021, 5)
- 01SYBRV – Research integrity (25/11/2021, 5)
- 01SWQRV – Responsible research and innovation, the impact on social challenges (29/11/2021, 5)
- 01RISRV – Public speaking (24/11/2021, 5)
- 02LWHRV – Communication (26/11/2021, 5)

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