EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

ALICE-PUBLIC-2021-007

The Wigner ALICE Analysis Facility

ALICE Collaboration*

Abstract

The ever growing increase of computing power necessary for the storage and data analysis of the HEP experiments at CERN requires performance optimization of the existing and planned IT resources. One of the main computing capacity consumers in the HEP software workflow is the data analysis. To optimize its resource use, the ALICE Collaboration has introduced the concept of Analysis Facility (AF) in its Run 3 computing model. The AFs are special computing centres with a combination of CPU and fast interconnected disk storage resources, allowing for rapid turnaround of analysis tasks on a subset of data. This in turn allows for optimization of the analysis process and the codes before the analysis is performed on the large data samples on the WLCG Grid. In this paper, the structure and the first benchmark tests of the Wigner AF are presented, a dedicated site, that has been designed for CERN ALICE data processing for the Run 3 period (2022-2025).

*See Appendix A for the list of collaboration members

1 Introduction

During the Large Hadron Collider (LHC) [1] Long Shutdown 2 (LS2) period, the ALICE [2] experiment underwent an important upgrade of its detector, readout hardware, and the associated online and offline software. The goal of the upgrade was to enable the experiment to pursue new physics in the Run 3 period (2022-2025) and beyond by increasing the detector capabilities and the collected data sample, both in terms of number of events and data rate. As a consequence of the larger than Run 1 and Run 2 event samples, the efficiency of the data processing and Monte Carlo simulations also needs to be optimized for faster event generation and processing. Furthermore, in order to improve maintainability and scalability, and to ease the burden of the future computational challenges, it is essential to keep the infrastructural costs (electricity, High Throughput Computing hardware) within the foreseen regional funding envelope.

The data processing and simulation is performed at the Worldwide LHC Computing Grid in a hierarchical infrastructure. From 2013 to 2019 the main centre in the Grid hierarchy, Tier 0 (T0) was geographically split between CERN and the Wigner Research Centre for Physics in Budapest. However, as a result of the rapid technological improvement, the paradigm change in the CERN operation model resulted in the end of the life of the T0 Budapest site during the LS2. Nevertheless, as of 2021, the hardware and infrastructure remaining at the Wigner site are still not obsolete and can be used for data processing. Therefore, our purpose is to utilize the already available hardware and set up a specialized Analysis Facility (AF) [3], in order to improve the offline computing capabilities of the ALICE Collaboration [4].

2 Structure of the ALICE Wigner Analysis Facility

The majority of the Wigner AF is built from the legacy T0 hardware, whose processing units consist of AMD Opteron 6276 CPUs [5]. Since one of the main purpose of such analysis facilities is to effectively process a considerable amount, $\mathcal{O}$(few PB) of data on a daily basis while being able to scale up the resources, $\mathcal{O}(15\%)$ per year, it is essential to have a modular design for both the storage and compute parts and to ensure high bandwidth communication between them.

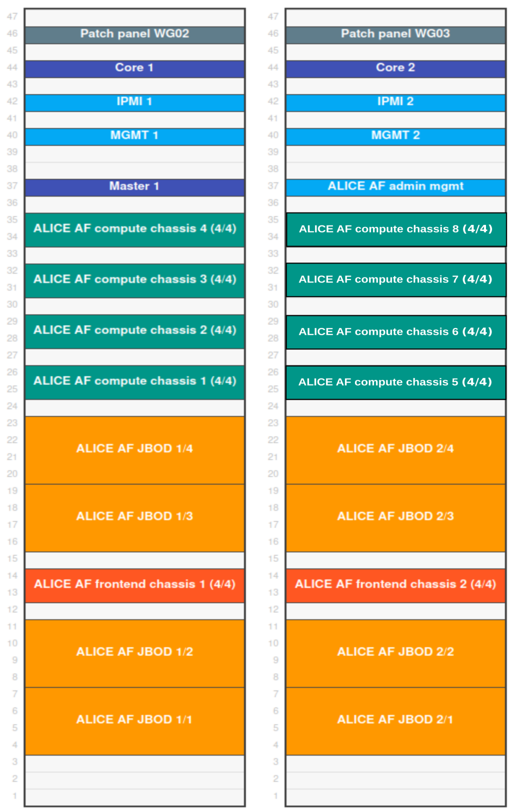

Fig. 1: The structure of the a single cell.

After several hardware tests and bandwidth optimization cycles, a dual rack-based ’cell’ has been chosen as scalable unit of the Wigner AF. Such a standalone working unit is composed by compute, frontend, storage, and services elements, as illustrated in Fig. 1. Each of the 8 *compute chassis* includes 4 dual processor machines, totaling 1024 threads per cell. The cells process the analysis jobs submitted through a dedicated interface called VO Box [6], which serves as an entry point of the AF from the global ALICE Grid infrastructure. The AF local services consist of HTCondor [7], HTCondor-CE [8], and Singularity [9]. The ALICE specific software environment is accessed through the CernVM File System [10], while the OS level orchestration of the machines is achieved through the Metal-As-A-Service (MAAS) data centre automation developed by Canonical [11]. The storage element of a cell consists of a JBOD chassis with 24 disks, controlled by the machines of the frontend chassis through XRootD [12] and EOS [13–16] services and daemons. The collection of such File Storage Server (FST) nodes is managed by the Management Server. The co-location of compute, storage, and network nodes in the same cell serves the purpose of assuring a fast data transmission required by the analysis workflow. The high-speed internal communication between the nodes is ensured by HP ProCurve 6600-24XG (J9265A) switches [17]. Utilizing the SFP+ 10 GbE ports, a high bandwidth of 10 Gbps is achieved within a cell and also between different cells.

Two chassis are maintained in the first working cell for special purposes. For future developments, a compute chassis is dedicated to machines with accelerator cards (GPUs), while the machines of another compute chassis serve management roles.

2.1 Computing capacity and network connectivity

The current setup of the Wigner AF is comparable to a mid-sized Tier 2 site, consisting 4 cells (8 racks in total). The total storage and computing power of the site is summarized in Table 1 for the period until September 2021.

Table 1: The summary of the total resources of the Wigner AF by September 2021.

Total Storage Size	Total Computing Resource
2 redundant MGM nodes	HTCondor and HTCondor-CE
32 FST node	Queues for single-core and multi-core jobs
24×3 TB raw capacity per FST node	114 worker nodes
Total raw capacity: $\sim$2.2 PB	32 vCPU, 64 GB RAM for each node
Usable capacity with RAID-1: $\sim$1.1 PB	3648 logical cores in total

The Analysis Facility is located at the KFKI campus, Budapest and it is part of the Wigner Datacenter, which is connected to the GEANT network by a 10 GBps link. The main components are displayed in Fig. 2, presenting all the required management, service, storage, and computational resources.

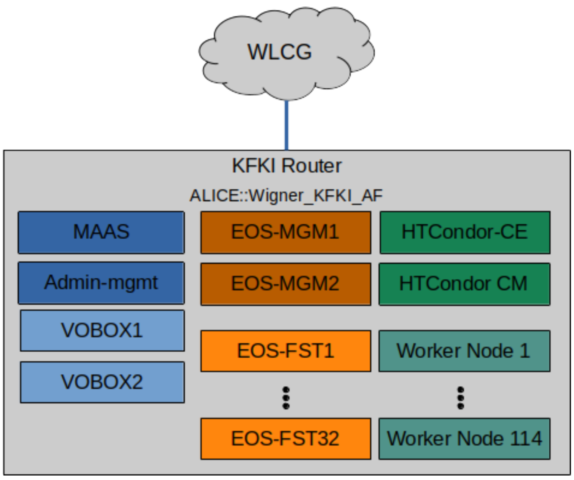

Fig. 2: The schematic view of the Wigner ALICE AF's services.

3 Utilization of the computing resources

In parallel with the hardware installation, a set of performance and optimization tests were performed. On the left panel of Fig. 3 the number of running jobs is plotted as a function of time. The execution of the first, *pilot* jobs occurred in late 2020, still during the hardware and software setup phase of the AF, while the production period with a high job success rate started in February, 2021. In late March a second job queue was introduced for 8-core jobs (i.e. for jobs that require multi-threaded execution). It should be noted that the site was continuously tested and developed in order to fine-tune its performance, therefore the job number was fluctuating in time.

On the right panel of Fig. 3 the utilization percentage of the available computing pool at a given date is shown. The orange *Mixed queue* bars are indicating the period when jobs with variable parallelization have been submitted to the multi-core queue, therefore the indicated rate is only a minimum value and the real utilization cannot be estimated precisely.

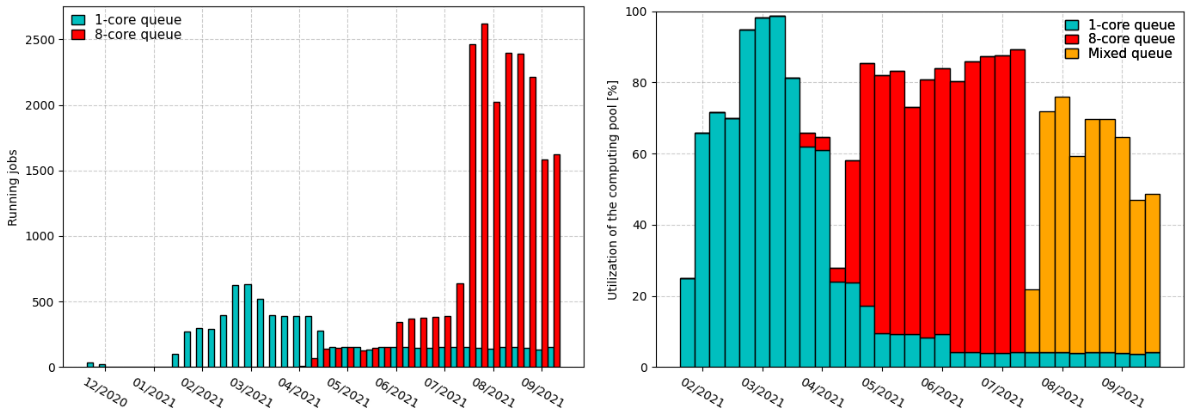

Fig. 3: The number of the running jobs and the total utilization of the pool (see text for details).

4 Benchmark results

In the ALICE analysis chain a dedicated framework called Hyperloop is utilized to optimize the payload throughput. The submitted tasks are combined together in so called *trains* [18] based on the requested input data set, thus several analyses can process the same data, optimizing the access to the storage and reducing the storage load. The tests were done on Run 2 Pb–Pb data converted to Run 3 format, which were transferred to the Wigner AF site.

The performance tests were done using two job queues: one for single-core jobs and one for 8-core jobs. For each queue type, trains with 50-200 jobs were submitted. At the time of writing of this note, the multi-core jobs are not fully optimized, therefore a future improvement is expected. Beside the data processing capabilities of the infrastructure, the raw I/O rate was also tested. In these cases jobs without real analysis payload were submitted, therefore the data access speed could be measured. The overall results of the benchmarks are summarized in Table 2.

Table 2: Main performance metrics for analysis jobs.

Measures	1-core queue	8-core queue
Job success rate	100%	99 %
Raw I/O rate	14.5 MB/s	29.1 MB/s
Analysis throughput (job overhead: startup, saving is included)	3.8 MB/s	4.4 MB/s

The tests show that adequate success rate is reached for both queue types. By extrapolating the rate for the current computing capabilities of the Analysis Facility, the estimated total throughput is 13.53 GB/s for the 1-core queue and 1.95 GB/s for the 8-core queue, projecting an estimated analysis throughput of 1.11 PB/day for the 1-core queue and 165.3 TB/day for the 8-core queue with the currently installed AF capacity.

5 Conclusions

The ALICE Wigner Analysis Facility is installed and operated at the Wigner Datacenter utilizing the hardware and the infrastructure used at the CERN's Tier 0 Budapest site. The main aspects during the designing phase of the AF were to keep the maintenance and upgrade costs reasonably low while optimizing the internal network between the different modules, therefore maximizing the data throughput. The first performance tests show a good throughput for both 1-core and 8-core analysis jobs, though the 8-core jobs are still to be optimized. Thanks to the modular design of the AF, the currently estimated 0.16-1.11 PB/day throughput can be further improved and upscaled with moderate effort, by introducing more modules to the infrastructure.

Acknowledgements

The research was supported by the Hungarian National Research, Development and Innovation Office (NKFIH) under the contract numbers OTKA K135515, and 2019-2.1.6-NEMZ_KI-2019-00011. The authors would like to express their gratitude to Ádám Pintér, József Kadlecsik and the technical staff of the Wigner Datacenter for the setup of the Analysis Facility hardware. We appreciate the support of the GRID management team.

The ALICE Collaboration would like to thank all its engineers and technicians for their invaluable contributions to the construction of the experiment and the CERN accelerator teams for the outstanding performance of the LHC complex. The ALICE Collaboration gratefully acknowledges the resources and support provided by all Grid centres and the Worldwide LHC Computing Grid (WLCG) collaboration. The ALICE Collaboration acknowledges the following funding agencies for their support in building and running the ALICE detector: A. I. Alikhanyan National Science Laboratory (Yerevan Physics Institute) Foundation (ANSL), State Committee of Science and World Federation of Scientists (WFS), Armenia; Austrian Academy of Sciences, Austrian Science Fund (FWF): [M 2467-N36] and Nationalstiftung für Forschung, Technologie und Entwicklung, Austria; Ministry of Communications and High Technologies, National Nuclear Research Center, Azerbaijan; Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq), Financiadora de Estudos e Projetos (Finep), Fundação de Amparo à Pesquisa do Estado de São Paulo (FAPESP) and Universidade Federal do Rio Grande do Sul (UFRGS), Brazil; Ministry of Education of China (MOEC) , Ministry of Science & Technology of China (MSTC) and National Natural Science Foundation of China (NSFC), China; Ministry of Science and Education and Croatian Science Foundation, Croatia; Centro de Aplicaciones Tecnológicas y Desarrollo Nuclear (CEADEN), Cubaenergía, Cuba; Ministry of Education, Youth and Sports of the Czech Republic, Czech Republic; The Danish Council for Independent Research | Natural Sciences, the VILLUM FONDEN and Danish National Research Foundation (DNRF), Denmark; Helsinki Institute of Physics (HIP), Finland; Commissariat à l'Energie Atomique (CEA) and Institut National de Physique Nucléaire et de Physique des Particules (IN2P3) and Centre National de la Recherche Scientifique (CNRS), France; Bundesministerium für Bildung und Forschung (BMBF) and GSI Helmholtzzentrum für Schwerionenforschung GmbH, Germany; General Secretariat for Research and Technology, Ministry of Education, Research and Religions, Greece; National Research, Development and Innovation Office, Hungary; Department of Atomic Energy Government of India (DAE), Department of Science and Technology, Government of India (DST), University Grants Commission, Government of India (UGC) and Council of Scientific and Industrial Research (CSIR), India; Indonesian Institute of Science, Indonesia; Istituto Nazionale di Fisica Nucleare (INFN), Italy; Japanese Ministry of Education, Culture, Sports, Science and Technology (MEXT), Japan Society for the Promotion of Science (JSPS) KAKENHI and Japanese Ministry of Education, Culture, Sports, Science and Technology (MEXT)of Applied Science (IIST), Japan; Consejo Nacional de Ciencia (CONACYT) y Tecnología, through Fondo de Cooperación Internacional en Ciencia y Tecnología (FONCICYT) and Dirección General de Asuntos del Personal Academico (DGAPA), Mexico;

Nederlandse Organisatie voor Wetenschappelijk Onderzoek (NWO), Netherlands; The Research Council of Norway, Norway; Commission on Science and Technology for Sustainable Development in the South (COMSATS), Pakistan; Pontificia Universidad Católica del Perú, Peru; Ministry of Education and Science, National Science Centre and WUT ID-UB, Poland; Korea Institute of Science and Technology Information and National Research Foundation of Korea (NRF), Republic of Korea; Ministry of Education and Scientific Research, Institute of Atomic Physics, Ministry of Research and Innovation and Institute of Atomic Physics and University Politehnica of Bucharest, Romania; Joint Institute for Nuclear Research (JINR), Ministry of Education and Science of the Russian Federation, National Research Centre Kurchatov Institute, Russian Science Foundation and Russian Foundation for Basic Research, Russia; Ministry of Education, Science, Research and Sport of the Slovak Republic, Slovakia; National Research Foundation of South Africa, South Africa; Swedish Research Council (VR) and Knut & Alice Wallenberg Foundation (KAW), Sweden; European Organization for Nuclear Research, Switzerland; Suranaree University of Technology (SUT), National Science and Technology Development Agency (NSDTA) and Office of the Higher Education Commission under NRU project of Thailand, Thailand; Turkish Energy, Nuclear and Mineral Research Agency (TENMAK), Turkey; National Academy of Sciences of Ukraine, Ukraine; Science and Technology Facilities Council (STFC), United Kingdom; National Science Foundation of the United States of America (NSF) and United States Department of Energy, Office of Nuclear Physics (DOE NP), United States of America.

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