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Event visualisation in ALICE - current status and strategy for Run 3

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Abstract. A Large Ion Collider Experiment (ALICE) is one of the four big experiments running at the Large Hadron Collider (LHC), which focuses on the study of the Quark-Gluon Plasma (QGP) being produced in heavy-ion collisions. The ALICE Event Visualisation Environment (AliEve) is a tool providing an interactive 3D model of the detector’s geometry and a graphical representation of the data. Together with the online reconstruction module, it provides important quality monitoring of the recorded data. As a consequence it has been used in the ALICE Run Control Centre during all stages of Run 2. Static screenshots from the online visualisation are published on the public website - ALICE LIVE. Dedicated converters have been developed to provide geometry and data for external projects. An example of such project is the Total Event Display (TEV) - a visualisation tool recently developed by the CERN Media Lab based on the Unity game engine. It can be easily deployed on any platform, including web and mobile platforms. Another external project is More Than ALICE - an augmented reality application for visitors, overlaying detector descriptions and event visualisations on the camera’s picture. For the future Run 3 both AliEve and TEV will be adapted to fit the ALICE O2 project. Several changes are required due to the new data formats, especially so-called Compressed Time Frames.

1. Introduction
The aim of all event visualisation software in High Energy Physics is to display the data collected by detectors in a human-understandable way. The applications can be very different though, depending on the needs of the user. One can divide users in the following categories: operation crew, detector experts, physicists and the general public. While the first three groups have in general similar requirements, the latter one is different and needs a specific approach.

In this paper we will first present the current visualisation system of ALICE \cite{1}. The interface between the internal ALICE data and geometry formats and external applications will be presented. Finally, the development strategy for Run 3 incorporating the ALICE O2 project \cite{2} will be described.

2. Visualisation system
ALICE uses a visualisation system built from several modules. The general scheme is shown in Fig. 1, which shows all the pieces from the data-flow point of view. Starting from the main raw data flow, the system takes a small sample of events which are sent to the online reconstruction. Reconstructed objects are passed to the Storage Manager, which distributes them to the main
visualisation module (AliEve) and other external applications (More than ALICE, TEV etc.). Static screenshots from AliEve are also published on the website called ALICE LIVE. All the aforementioned modules will be described in detail in the following sections.

![Diagram](image)

**Figure 1.** Full scheme of the current visualisation system of ALICE.

### 2.1. ALICE Event Visualisation Environment

AliEve is a visualisation tool based on the ROOT’s TEveManager [3]. It provides a 3D and 2D visualisation of detector’s geometry read from ROOT files. On top of the geometry visualisations of different data types are displayed: particle tracks, V0s, kinks, cascades, clusters, calorimeter towers, hits and raw data. Currently AliEve supports three different data types: online reconstruction, High Level Trigger (HLT) reconstruction and local ROOT files.

The application allows for an easy navigation between events and easy changes of the visualisation’s appearance, from rotation and zoom of the 3D view, through changes to the colouring scheme used for tracks, to the colour adjustment of the detectors and the background. Finally, it provides an option to generate ready-to-use high-resolution screenshots, containing the ALICE logo and event information, on a single mouse click. Such pictures are very useful for presentations and publications, as well as for outreach purposes.

### 2.2. Online reconstruction

The online visualisation system relies on the online reconstruction, which takes a small sample from the main raw data flow coming from the ALICE detector. Offline reconstruction algorithms are used to generate, in online mode, objects representing mainly reconstructed parameters of
the particles registered in the collision (Event Summary Data - ESD). Reconstruction publishes ESD objects on the ZeroMQ socket [4], making them accessible for the Storage Manager.

2.3. Storage Manager
The Storage Manager subscribes to the socket created by the online reconstruction, fetching all the ESDs. Events are then saved to the dedicated storage and for each of them an entry is added to the dedicated database. This permits an easy search for events matching some criteria, such as low or high multiplicity, beam energy, collision system, trigger class etc. The Storage Manager provides a communication socket, on which other applications can ask for a list of events matching a query, or for an ESD object.

2.4. ALICE LIVE
As pictures generated by AliEve are great for outreach purposes, we want to share them with the outside world as soon as possible. For that reason a website called ALICE LIVE was created. For every event being displayed in the ALICE Run Control Centre a screenshot is automatically generated and sent to ALICE LIVE. Thanks to this solution everyone can enjoy online visualisation of collisions seen by ALICE almost in a real time.

2.5. Data and geometry converters
The main drawback of the ALICE LIVE is that is provides static pictures only. To increase the appeal of the visualisation for the general public it is important to incorporate some element of interactivity. For this reason we developed data and geometry converters, translating internal ROOT objects into popular formats. For the geometry we chose the Collada [5] format based on XML, which can be read by most external graphics editors. The converter of the data currently supports XML and JSON, providing only the information crucial from the visualisation point of view, such as particle types, momenta or trajectories in the form of polylines.

Geometry and data in ROOT-independent formats can then be used by external visualisation tools. One of them is the Total Event Display, which is described in the next section.

2.6. Total Event Display
The Total Event Display (TEV) is a project of the CERN Media Lab [6]. It has been developed using the game engine called Unity [7]. The big advantage of this solution is that it can be deployed on many platforms, including mobile and web platforms. It also provides a very attractive, modern look with animations. All of the major LHC experiments have already integrated their visualisation tools with TEV.

Another advantage of Unity is that it is very modular and one project can be easily combined with another. Thanks to this we can use Total Event Display as a visualisation tool inside another application. It is already the case for the Microcosm exhibition at CERN. Another project in which TEV could be used is More than ALICE.

2.7. More than ALICE
More than ALICE is an augmented reality application for ALICE visitors. Its goal is to overlay the description of different sub-detectors on top of the camera’s image of the mobile devices during visits to the experimental cavern. It is based on the Unity engine, which makes it easy to include Total Event Display in the application. Using this feature, it is possible to superimpose not only the detector descriptions but also event visualisation on top of the camera’s image of the ALICE detector. An example screenshot from the application can be seen in Fig. 2.

As visits in the cavern are not possible during the LHC operations, future versions will also work with the paper model of ALICE, which one can buy, cut and assemble oneself. In Fig. 3
Figure 2. Screenshot from More than ALICE showing detector indicators on top of the camera’s image.

the scheme of the future versions of More than ALICE is presented. Data collected by the detector are gathered by the Storage Manager, which provides events in JSON format to the external applications (Total Event Display in this case) using the dedicated converter. Geometry from ROOT format is converted to a Collada file and can also be included in TEV. Then, the visualisation from TEV is plugged into More than ALICE, exploiting the modularity of the Unity engine.

From the visitor’s point of view, one has to assemble the paper model of ALICE, download an application from the store and point the camera of the mobile device on the model. The application will automatically detect different elements of the model to display online events on top of it and position it correctly, regardless of the movement of the device.

3. Usage of the visualisation system in Run 2
AliEve has been used in production for many years, including all major steps in preparation for and during Run 2. This includes first tests of the LHC’s transfer line, where collisions of the beams with the absorber located upstream of ALICE produce particles which can reach the detector. An example is shown in Fig. 4. In this case visualisation is very simple, including only raw data or clusters. Next, ALICE started to collect cosmic events, measuring particles coming from cosmic radiation and the products of their collisions with the surrounding matter - see Fig. 5.

After several months of tests, the Run 2 started with collisions of protons at the center-of-mass energy of 13 TeV - AliEve was running online, providing fast feedback on the correctness of the reconstruction as well as screenshots used for internal meetings, outreach and media communication (see Fig. 6). Finally, in November 2015 LHC started to run with lead ions, providing collisions with centre of mass energy of 5.02 TeV per nucleon pair.

A screenshot from the first heavy-ion collisions in Run 2 (Fig. 7) was published at CERN’s official Twitter account and was then used in tens of magazines, including very well-known international newspapers. This shows how important is the role played by event visualisation for outreach.
4. Changes required for Run 3
In Run 3 there will be several changes in the visualisation system, starting from the main data flow. A summary of these changes is presented in Fig. 8. Elements that need to be adopted to the new data types are indicated by the dashed lines. The system will not only display the raw data, but also Compressed Time Frames (CTF). Indeed, the computing system of ALICE
in Run 3 will be characterised by the online reconstruction of all the interactions seen by the experiment. As a consequence a dedicated online reconstruction for visualisation is not anymore needed.

The Storage Manager and data converter will need to be adapted to use new data formats. The geometry will have to be recreated and the corresponding converter will need to be tested. Finally, AliEve must be updated to work with new data types. As the events will be grouped into time frames until the asynchronous final reconstruction producing the AODs, visualisation will now have a time dimension as well, so tracks should fade in and out smoothly, like a movie.

Despite a few changes which can be seen by comparing Fig. 1 with Fig. 8, the current scheme of the visualisation system will largely stay the same as in Run 2.

5. Conclusion

Events visualisation in ALICE is a very important aspect for both experts and general public. It provides early feedback on the data quality and reconstruction correctness, it is an important tool for visual inspection by experts and it produces publicity pictures that are widely used for the outreach.

The application being currently used in production is AliEve - a ROOT based solution with many expert-level functionalities. Together with online reconstruction and the Storage Manager it forms the core of the online visualisation system of ALICE. AliEve has been successfully used for many years, including the preparation and the start of Run 2.

Static screenshots are published on the website called ALICE LIVE. To add interactivity, dedicated geometry and data converters have been developed, which can be used by external
Figure 6. One of the first proton-proton collisions at 13 TeV recorded by ALICE.

Figure 7. A Pb-Pb collision recorded by ALICE during one of the first runs at centre of mass energy or 5.02 TeV per nucleon.

applications such as Total Event Display. For visitors, an augmented reality application called More than ALICE is available. It overlays detector descriptions and event visualisations on camera image displayed on mobile devices.
Figure 8. Diagram showing elements which will change in Run 3 (dashed lines).

For Run 3 several changes are required, mainly due to the new data formats. Online reconstruction will no longer be needed as part of the visualisation system and AliEve will have to account for the continuous readout. A new geometry needs to be created and converters must be tested. All in all, the general scheme of the visualisation system will stay the same and the main challenge will be to update different modules to work with the new data types.

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