An event display for the Transition Radiation Detector in ALICE

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Abstract. Particle collider experiments generate huge volumes of complex data, and event displays provide a useful visual representation to accelerate the learning process towards physics results. Event displays are also used to verify expected behaviour, identify anomalous data, or explain important results. They often have a steep learning curve, a high barrier to entry, or are tightly bound to a specific environment. The upgrade of ALICE in preparation for Run 3 of the LHC requires modifications to existing event displays. We present here a cross-platform, browser-based event display, focused on interactive 2-dimensional projections of collision data from ALICE, specifically focused on the operation of the Transition Radiation Detector (TRD). It is driven by a flexible intermediate JSON data format suitable for web-based displays, and a generic task to convert existing data acquired in previous runs to this format. The relationship between raw and reconstructed data in the TRD is illustrated through a novel pairing of raw and reconstructed data in a unified interactive view. A formal design study methodology was used to guide these choices, and the display was evaluated by both scientists and the public, through a series of case studies.

1. Introduction

The Large Hadron Collider (LHC) at the European Organisation for Nuclear Research (CERN) is the largest particle accelerator in the world, and produces proton and heavy-ion collisions that are studied by ALICE (A Large Ion Collider Experiment). Physicists visualise this event data to verify expected behaviour, identify anomalous data, or explain important results. They often use simple visualisations, typically 1 or 2-dimensional histograms as well as line or bar graphs. More complex visualisation is handled by event displays, visual representations of both raw and reconstructed data from a collision. ALICE is currently being upgraded to significantly increase the quantity of data it records during Run 3 of the LHC.

2. The Transition Radiation Detector

The Transition Radiation Detector (TRD) is one of the 18 detectors within ALICE, and is used for event triggering, particle tracking and electron identification. It consists of 18 sub-detectors around the collision vertex (referred to as sectors), and each sub-detector is further sub-divided into 5 stacks in beam direction and 6 radial layers. The event display uses these divisions to refer to 2D projections perpendicular to (sector views) and parallel to (stack views) the beams.

Transition radiation is the emission of a photon that can occur when an energetic charged particle crosses the boundary between two media with different dielectric constants [1, 2]. The TRD employs multi-wire proportional chambers (MWPC) with a drift region preceded by a

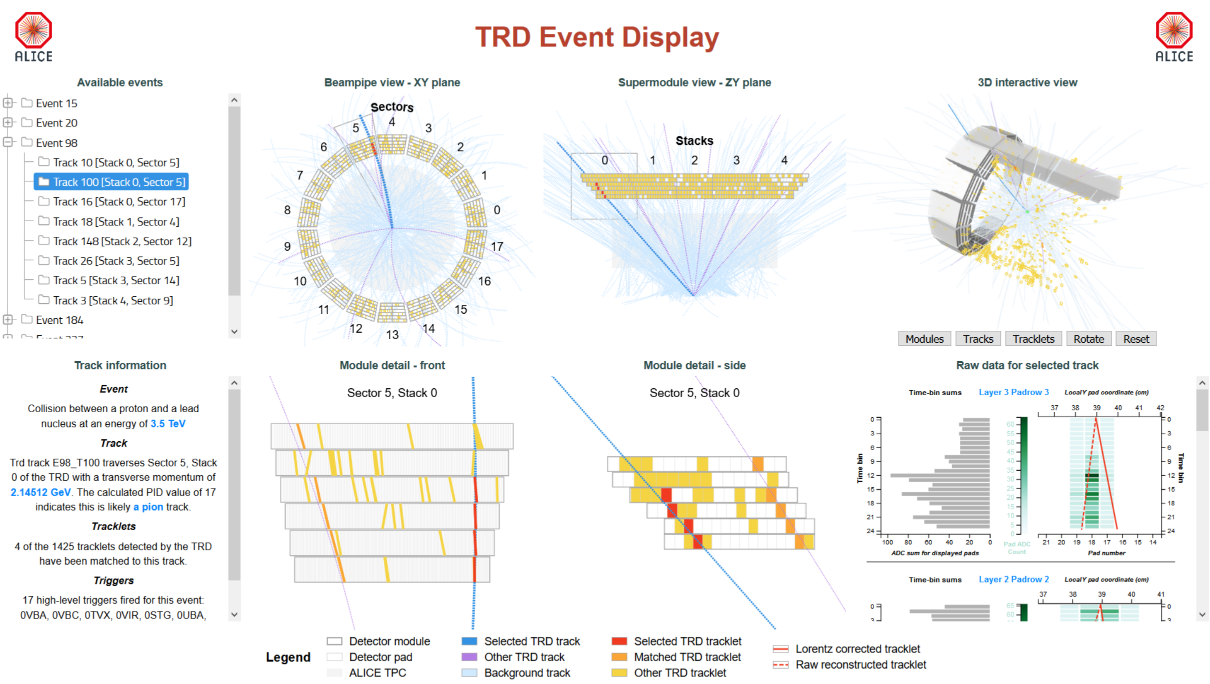


Figure 1. View of the full event display.

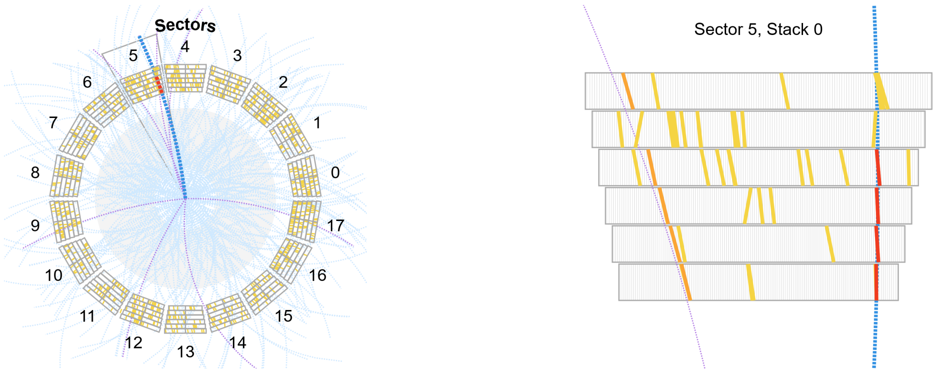
radiator. It uses Transition Radiation to additionally enable discrimination between electrons and other particles. A multi-wire proportional chamber (MWPC) is a type of gaseous ionisation detector used for particle tracking through high-resolution location measurements [3].

The TRD's discrimination capability is most effective for fast electrons with momenta above $1\,\mathrm{GeV}/c$, which are associated with the production of rare probes like quarkonia and heavy quarks [4]. Quarkonium production is sensitive to deconfinement and, in the case of the J/ψ, to the abundance of charm quarks in the Quark-Gluon Plasma (QGP), while open heavy flavour hadrons can test the initial state of the colliding nuclei [5]. These particles decay with known branching ratios to electrons and positrons and escape without strong interactions, making them an ideal signature for heavy-quark production, quarkonium suppression and J/psi regeneration [6].

Online processing of TRD data collected in Run 2 begins with the deposited charge measured on the pads in a pad row, which is translated by an analogue-to-digital converter (ADC) into a numerical count. This is repeated over a number of time-bins (usually 24 or 30), resulting in a 3-dimensional dataset representing the quantity of deposited charge on each pad over time. The quantity of deposited charge, and its time dependence, are used to perform particle identification. This data is also converted via straight-line fit into a **tracklet**. The tracklet represents an approximation to the path of the detected particle through a specific module, with $140\,\mu\mathrm{m}$ resolution in the y-direction and 7 cm resolution in the z-direction. This tracklet has a slope correction applied to account for Lorentz drift in the electric field [1]. The intercept and slope of this fitted tracklet, as well as the PID (particle identification value) are output by the front-end electronics (FEE) to the global tracking unit (GTU).

3. Design

A formal, user-centric design study methodology guided the development of this prototype event display to: support the move to the new *O*2 framework [7]; help debug and guide development of



(a) Sector global view (b) Sector zoomed-in view

Figure 2. The sector views show a a projection of tracks and TRD tracklets along the beam axis, in the bending plane of the magnetic field. Global tracks are shown light blue and tracks with associated TRD tracklets in purple. Optionally, the selected track is highlighted in dark blue. Selected tracklets are coloured red, non-selected tracklets yellow, and tracklets matched to a track that is not the selected track are coloured orange.

both simulation and reconstruction software; assist with detector calibration and error detection; and enable comparison of global tracks (reconstructed using data from other ALICE detectors) with tracks reconstructed by the TRD using tracklets. The ability to select and compare multiple tracks aids interpretation of data that are usually displayed as histograms [8]. We conducted interviews with potential users, who felt that existing software did not effectively illustrate the detailed operation of the TRD, and specific effects unique to it. A simple event display was also found to be a useful introduction to the experiment in general, and the TRD in particular. Users were able to understand the geometries involved, and the relationship to the underlying data. The display could also therefore be used for outreach activities to non-scientists.

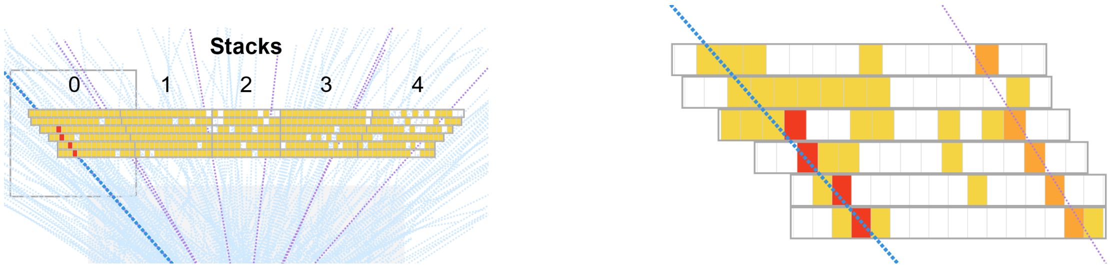
4. Results

Over three iterations of interviews and development, we refined our event display into the final version in Figure 1, which was presented at CERN Open Days 2019.

The display uses multiple linked views of the same dataset, where the primary 2D track and tracklet projections are the central focus of the display, with navigation, context and raw data on the periphery. The interactive 3D display in the top right provides an overview of the experiment and data. The raw data display in the bottom right illustrates the complete process by which raw data is reconstructed into tracklets. These views bring together diverse data representations not normally visualised in a single display.

The tree in the top left is used to select events and tracks in the dataset. The textual information component in the bottom left displays track specific information, with data values highlighted in blue. The empty spaces in the stack and sector overviews were filled with a low opacity toroidal projection representing the TPC, the largest detector in ALICE.

Animated transitions maintain user orientation as the displayed data changes in response to selection changes. A consistent colour scheme, as shown in the legend to Figure 1 and described in Figure 2, is used across all components of the display. Tracks are coloured blue through purple, tracklets are coloured red through yellow, and raw ADC data is shown in shades of green.



(a) Supermodule global view (b) Supermodule zoomed-in view

Figure 3. The supermodule views show a projection of tracks parallel to the beams, using the same colour scheme as Figure 2. The tracklets are represented as large rectangles with a length in the beam direction proportional to the length of the pad row.

4.1. 2D-projection views

Figure 2(a) is an orthogonal projection of tracks and tracklets, equivalent to looking in the beam direction towards the muon arm. The gray triangle in this figure highlights the selected sector, illustrated in greater detail in Figure 2(b).

Figure 3(a) is a view of tracks and tracklets parallel to the beams. Data is mapped so each supermodule is individually rotated about the beams until its centre lies on the vertical-axis. All tracks passing through a supermodule are then rotated about the beams direction with the corresponding rotation, before being orthogonally projected onto a single plane. A gray rectangular box is positioned over the stack containing the selected track, illustrated in an expanded view in Figure 3(b).

Figures 2(b) and 3(b) are zoomed-in views that show both the track of the interacting particle and the TRD tracklets that were matched to that track. This view allows a user to visually determine what fraction of the six potential tracklets were attached to a reconstructed track, and whether those chosen appear plausible.

4.2. Raw data view

Our novel contribution is a based on an illustration in [1] that combines two related views of raw ADC data from the TRD to illustrate how tracklets are reconstructed. The time-bin view in Figure 4 shows the reconstructed tracklet before and after Lorentz drift slope correction, differentiated by line style to maintain the red selected tracklet colour encoding.

The right side of this component shows the charge deposition on a range of pads (horizontal axis) over time (vertical axis) as a flat 2D histogram, with the quantity of charge encoded as shades of green. The left side of this figure is a gray histogram showing the total deposited charge per time-bin, summed over the range of pads displayed on the right, allowing the general shape of the distribution to be compared against expectation. The combined view provides a link between the reconstructed track and tracklet data views, and the raw ADC data that is the input to the reconstruction. It accurately shows the location, slope and angle of the fitted tracklet.

4.3. Implementation details

The final event display is entirely browser based, and a responsive design approach [9] was adopted and tested on all four major browsers (Firefox, Chrome, Safari, Edge) to ensure it was truly cross-platform. The display was also verified to be functional on mobile devices, but the user experience was far from ideal. The 3D display component was implemented using WebGL, an industry standard for displaying 3D graphics on the web, and three.js, a JavaScript library for rendering 3D graphics in a web browser.

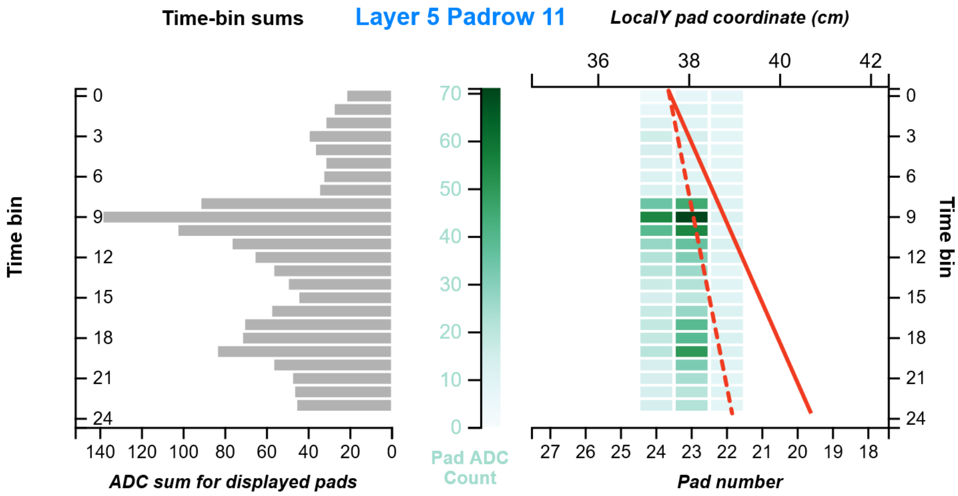


Figure 4. Time-bin component showing raw (histogram) and reconstructed (line) data. The dashed red line is the raw reconstructed tracklet, the solid line is the same tracklet after applying a Lorentz correction.

5. Conclusion

We have developed a portable browser-based event display, focused on the TRD, that combines raw and reconstructed data views. We have additionally defined JSON data formats for reconstructed and raw data that can be used and extended by future event displays. A generic C++ software tool was implemented to convert both raw and reconstructed data from Run 2 of the LHC into this JSON format. An online demonstration version of this display is available at `https://alicetrd.web.cern.ch/alicetrd/eventdisplay/` [10] with code available at `https://github.com/samperumal/alice-trd-event-display`.

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