Support for Online Calibration in the ALICE HLT Framework

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Abstract. The ALICE detector employs sub detectors sensitive to environmental conditions such as pressure and temperature, e.g. the time projection chamber (TPC). A precise reconstruction of particle trajectories requires precise calibration of these detectors. Performing the calibration in real time in the HLT improves the online reconstruction and potentially renders certain offline calibration steps obsolete, speeding up offline physics analysis. For LHC Run 3, starting in 2020 when data reduction will rely on reconstructed data, online calibration becomes a necessity. In order to run the calibration online, the HLT now supports the processing of tasks that typically run offline. These tasks run massively in parallel on all HLT compute nodes and their output is gathered and merged periodically. The calibration results are both stored offline for later use and fed back into the HLT chain via a feedback loop in order to apply calibration information to the online track reconstruction. Online calibration and feedback loop are subject to certain time constraints in order to provide up-to-date calibration information and they must not interfere with ALICE data taking. Our approach to run these tasks in asynchronous processes enables us to separate them from normal data taking in a way that makes it failure resilient. We performed a first test of online TPC drift time calibration under real conditions during the heavy-ion run in December 2015. We present an analysis and conclusions of this first test, new improvements and developments based on this, as well as our current scheme to commission this for production use.

1. Introduction
ALICE (A Large Heavy Ion Experiment) is one of the four major experiments at the Large Hadron Collider (LHC) at CERN. The High Level Trigger (HLT) is an online compute farm, which reconstructs events measured by the ALICE detector in real-time. The HLT uses a custom online data-transport framework to distribute the data and the workload among processing components running in parallel on 180 compute nodes.

2. Online calibration
The main ALICE tracking device, the time projection chamber (TPC) is a large gaseous detector where electrical charges liberated through ionization by particles crossing the gas volume drift
to the readout end plates where the arrival time and the amount of deposited charge is recorded. It needs precise calibration of the electron drift velocity to relate the measured arrival time to spacial z positions of the deposited energy. Global track reconstruction quality depends on this calibration to associate found tracks to the correct interaction vertex. To first order, the ionized trail deposited by a particle (a track) drifts as a whole towards the readout plate with a constant velocity along the z axis. TPC track finding is therefore largely unaffected by the lack of or wrong drift velocity calibration. The TPC drift velocity depends on environmental conditions such as ambient pressure and temperature and needs to be determined as a function of time. The calibration parameters are semi-stable within a 15 minute interval. Drift velocity calibration is performed by comparing independently fitted TPC track parameters to the matching track found in the inner tracking system (ITS) [1]. Approximately 3000 Pb–Pb events are needed to achieve sufficient precision.

**Figure 1.** Online calibration cycles during data taking. Calibration parameters are recalculated periodically to account for time variation of calibration parameters within a run.

In order to track the time dependence of the drift velocity calibration, the procedure needs to be repeated periodically (see figure 1). The cycle starts with accumulation of statistics by processing components running in parallel on all the HLT nodes. When enough statistics have been processed, the resulting calibration parameters are merged and processed. Processing consists of calculating cluster transformation maps which are used to correct cluster positions before the track finding step. Finally, the maps are shipped to the beginning of the processing chain where they are used by the reconstruction procedure. The time needed for the full cycle must be within the time window of 15 minutes where the calibration remains stable. The time window at the beginning of the run used to calculate the first set of calibration parameters does not have valid (online) calibration itself. The data associated with that period can only be calibrated offline using e.g. the calibration parameters calculated during the first online iteration.

### 3. Using offline code online

ALICE drift velocity calibration is implemented within the ALICE analysis framework which is optimized for the processing of the Event Summary Data (ESD). ESD files are produced by offline reconstruction and are stored on the GRID. The ESD itself is a complex ROOT [2] data structure holding all the reconstructed information pertaining to an event. In addition to the ESD object used on most physics analyses an additional structure called the ESD friend is produced. It contains additional information used by calibration procedures like track seeds and information about clusters attached to tracks. Due to its size, the ESD friend is only stored for the selected data that is used for calibration.

In the HLT framework the data between the components is transported in contiguous buffers. ROOT objects must therefore be serialized for sending and deserialized after receiving a buffer. The amount of resources needed for a serialization/deserialization cycle for ESD (and ESD friend) objects is comparable to reconstruction and therefore deemed prohibitively expensive.
4. Asynchronous processing

In order to solve this problem a custom data representation was developed called Flat ESD. Both ESD and Flat ESD use the same virtual interface for interchangeability but the underlying data store in the case of the Flat ESD is a single contiguous buffer with, by construction, zero serialization/deserialization overhead. Since the ESD interface is virtual, there is a small overhead related to the virtual function table pointer restoration. The overall cost of construction, serialization and deserialization of the Flat ESD data is negligible compared to the offline ESD as shown in figure 2.

In some cases the original ESD interface offers access to polymorphic data structures via pointers. Since storing such structures in the flat ESD buffer directly causes non-negligible overhead, special access methods were developed to cover those cases.

Offline TPC calibration tasks were ported to use the new virtual ESD interface such that they can be used both online and offline.
introducing additional latencies, as illustrated in figure 3. Running offline code in a separate process in addition provides protection against resource leaks and other code misbehaviour. In case of a crash the offending process can optionally be restarted and the main chain remains unaffected.

![Figure 3](image)

**Figure 3.** Processing of long running offline tasks in the HLT chain asynchronously.

5. Calibration feedback loop
On each compute node the calibration components process the incoming data asynchronously to the main data flow. After gathering sufficient statistics the components send their output to an asynchronous merger. The merged calibration objects are sent to a single asynchronous process which calculates the cluster transformation maps. In the last step these correction maps are distributed to the beginning of the chain for use in the online reconstruction until a new map for the next calibration period becomes available. The asynchronous transport method using ZeroMQ [3] for this distribution step is described in [4]. Figure 4 shows how the entire feedback loop fits in the global HLT processing diagram.

6. Performance
Depending on the availability of computing resources (determined by the beam- and trigger conditions) 3 to 5 calibration workers run on each of the 170 selected compute nodes. The required 3000 Pb–Pb events per calibration interval are processed within a 2 minute time window. Afterwards the calibration workers start gathering statistics for the next calibration interval. The subsequent merging of the data, transformation map calculation and distribution to all reconstruction processes takes about 30s in addition. In total, one calibration cycle takes around 2.5 minutes, never exceeding the time window of 15 minutes where calibration remains stable.

The processing time of the calibration components depends approximately quadratically on the event size due to the need for track matching between the TPC and a reference detector.
The latency of the calibration step can therefore be trivially reduced by fine tuning the event selection without modifying the offline calibration code. Other optimisations are also considered. For more than 90% of the runs the calibration results are in agreement with the offline algorithm. Cluster positions corrected using the online and offline calibration objects are of the order of the intrinsic TPC space point resolution (<1mm). The remaining 10% comprise largely short periods of data taking for which not enough statistics could be processed or test and technical runs which are not used for physics analysis. Since the persisted data are not modified, calibration procedures can in all cases be performed offline as a fallback.

7. Conclusions
Real-time closed loop calibration of the ALICE TPC drift velocity was developed. The performance of the newly developed online calibration support in the HLT is sufficient to handle the time dependence of the calibration parameters. In view of the upcoming Run 3 where online calibration will become a necessity, further studies of this topic are needed; the scheme presented here will be further optimized and additional, more fine-grained calibration algorithms that are used in offline calibration (e.g. space charge calibration needed in Run2 due to higher detector occupancies) are being considered as an exercise of online calibration for the online-offline computing system (O2[5, 6]) being developed for LHC Run 3.

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