



## MarlinTPC: A Marlin based common TPC software framework for the LC-TPC collaboration

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### Abstract

We describe the goals and present functionality of MarlinTPC, a common software framework for the LC-TPC collaboration based on LCIO, Marlin and other ilcsoft tools.

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## 1 Introduction

Three of the four available designs for detectors at the International Linear Collider (ILC) envisage a large time projection chamber (TPC) as main tracking device. It is the task of the LC-TPC collaboration to perform the necessary R&D to be able to fulfil the TPC performance requirements derived from the ILC physics goals [1].

In the course of LC-TPC activities a rather large variety of simulation, analysis and reconstruction software packages has been developed. The usage of these packages ranges from studying TPC performance as part of an overall detector for different detector layouts and background conditions, optimising prototype designs, reconstructing and analysing cosmics and testbeam data from various small prototypes using different readout technologies to full detector physics analyses. Most of these individual software packages have become rather sophisticated in their particular field of application. Valuable experience was collected during usage and development of the software partly leading to novel techniques to cope with new challenges encountered in TPCs with new amplification or readout systems. The drawback of this specialisation is that the software often works smoothly only for particular applications or TPC setups. Exchanging code between different packages or analysing data from different sources with the same programme can be very time consuming and errorprone since the different programmes do not use commonly accepted interfaces and conventions. The goal of MarlinTPC is to overcome these drawbacks.

## 2 Design considerations

In view of the converging hardware efforts like the planned common large prototype, to improve the mutual understanding of results and to avoid further double work, it seems natural to converge on the software tools. Similar steps towards a harmonisation of software efforts were already taken by CALICE for calorimeter R&D. In June 2006 an initiative was started to take the first step towards this direction. Representatives of six LC-TPC member institutes met at DESY to find an agreement on common software standards. It was decided to transfer the existing algorithms to a new, commonly used framework, called MarlinTPC [2], building on top of LCIO [3], the *de facto* standard data format for ILC related work, and the accompanying ilcsoft tools [4]. This choice is motivated by the possibility to profit from general ILC software developments and by the fact that ilcsoft tools are already used by many other subdetector, simulation and physics analysis software projects. In particular Marlin [5] was chosen as analysis and reconstruction framework. Its modularity and well defined interfaces between its modules, called processors, ensure that different developers can work on different processors in parallel without interference and to plug'n'play with processors to easily try out e. g. different algorithms.

Further important pillars of MarlinTPC are the Linear Collider Conditions Data (LCCD) toolkit [6] and GEAR (Geometry API for Reconstruction) [7]. LCCD allows writing and reading of conditions data describing the detector status as function of time. It allows

Data structure	Processor name	input/output collection name
TrackerRawData	TrackerRawDataToDataConverterProcessor	TPCRawData
TrackerData	PedestalSubtractorProcessor TimeShiftCorrectorProcessor	TPCConvertedRawData
TrackerData	PulseFinderProcessor ChannelMapperProcessor CountsToPrimaryElectronsConverterProcessor	TPCData
TrackerPulse	HitTrackFinderTopoProcessor	TPCPulses
TrackerHit, Track	TrackSeederProcessor	TPCHits, TPCTrackCandidates
Track	TrackFitterLikelihoodProcessor	TPCSeedTracks
Track		TPCTracks

Table 1: Present MarlinTPC reconstruction processors

to tag data sets for later easy reference and to request data valid at a particular point in time. GEAR allows to access geometry information needed for the simulation, digitisation and reconstruction of events. Thereby it is made sure that consistent geometry information is used throughout MarlinTPC.

## 3 Reconstruction

In the beginning the focus was laid on the development of reconstruction processors. Therefore the reconstruction code is currently the most evolved part of MarlinTPC. It will be briefly described in this section.

### 3.1 Processor chain

The event data model (EDM) for the reconstruction is provided by the LCIO classes `TrackerRawData`, `TrackerData`, `TrackerPulse`, `TrackerHit` and `Track`. These data structures represent well-defined interfaces between the different reconstruction steps. Every processor retrieves one or several input collections which contain the input data (e. g. `TrackerData` objects), processes them (e. g. applies a pulse finding algorithm) and finally provides output collections containing the results of the applied algorithm (e. g. `TrackerPulse` objects). The output collections in turn can be read in by subsequent processors to further process the event data.

The present processor chain for the MarlinTPC reconstruction is shown in Table 1. Additional correction processors e. g. to correct for electric or magnetic field inhomogeneities or gain fluctuations can be easily added in the appropriate places if needed.

## 3.2 Present functionality

This section briefly describes the functionality of the MarlinTPC reconstruction as it is available in September 2007.

`TrackerRawDataToDataConverterProcessor` converts `TrackerRawData` objects with integer FADC counts into `TrackerData` objects with floating point numbers for the channel time spectrum. This allows for pedestal subtraction by the `PedestalSubtractorProcessor` since the pedestals are in general non-integer values. The pedestals are provided by LCCD and are read in using the Marlin `ConditionsProcessor`. Optionally further correction processors can be applied after the pedestal subtraction.

The next step is the search for pulses in the channel time spectra performed by the `PulseFinderProcessor`. It uses a threshold based method which has an individual threshold per channel depending on the noise width calculated from the pedestal. The algorithm is capable of handling signals with positive and negative polarity as well as zero suppressed data to support a large variety of possible readout electronics.

The `ChannelMapperProcessor` translates the hardware channel numbers of the electronics into GEAR pad indices. Afterwards the number of ADC counts per pulse is converted into primary electrons by the `CountsToPrimaryElectronsConverterProcessor`, using electronics and gas gain calibration factors. The channel map as well as the calibration constants are stored using LCCD.

The `HitTrackFinderTopoProcessor` performs a topological search for pulses on neighbouring pads. Pulses on contiguous pads in one pad row are grouped as hit candidates. Afterwards the hit coordinates are calculated. Contiguous hits in different pad rows within an adjustable time window are assembled to make up a track candidate. The algorithm does not make any assumption on the trajectory and thus works for straight tracks like cosmic muons in a prototype as well as for a low energetic particle curling up in the TPC, producing a helix with a changing curvature due to energy loss. It is implemented for the two available GEAR pad geometries (rectangular and circular pad row layout). An estimate for the track parameters is calculated analytically by the `TrackSeederProcessor` to have a good starting point for the succeeding fit.

The `TrackFitterLikelihoodProcessor` determines the track parameters by maximising the global likelihood for observing the measured charge distribution on all pads associated with the track. It has been shown to give better results than just minimising the mean squared distance of the reconstructed hits to the track using a  $\chi^2$  fit [8].

For bookkeeping every processor writes all its processor parameters like cuts etc. to the LCIO run header, as well as the subversion software revision of the code which was used to process the data.

So far the code has been validated with toy data only. Thus the performance of the available processors still needs to be checked with real data or more realistic Monte Carlo samples.

## 4 Simulation, digitisation and analysis

Very recently sizable development work on simulation, digitisation and analysis code has started.

The simulation part of MarlinTPC started off with the package TPCGEMSimulation from [9]. It simulates primary ionisation using a parametrisation of HEED [10] output, drifting of the primary electrons to the endplates, amplification in a triple-GEM gas amplification system and electronics shaping. Optionally an ion backdrift processor can be added. The supported gases are Ar-CH<sub>4</sub> (95-5), Ar-CH<sub>4</sub> (90-10) and Ar-CH<sub>4</sub>-CO<sub>2</sub> (93-5-2). The original package (which received geometry information as processor parameters) has been modified such that all geometry information is retrieved from GEAR now. At present it is not possible to simulate other gases or amplification systems. It is planned to separate out the digitisation components of the package and, in the long run, to make the simulation more generally usable to be able to simulate other gases or amplification systems.

Work has started on a set of digitisation processors which can be used to digitise both the output of detailed gas detector simulations generating individual ionisation clusters and the output of Geant4 [11] simulations providing rather large energy deposits instead of individual electron-ion pairs. This also includes the development of processors producing pile-up due to the large drift time of electrons (compared to the bunch crossing rate) and background from  $e^+e^-$  pairs from the fusion of beamstrahlung photons.

For analysis purposes several processors are under development which provide information according to the recommendations of the first ILC TPC Analysis Jamboree [12]. Examples are the residual distributions, the fraction of 1-pad, 2-pad, 3-pad hits, residuals as function of the position on the pad, etc.

## 5 Conclusions and outlook

Within its first year the MarlinTPC project has made significant progress. The most important reconstruction processors are available, partly using newly developed, more powerful algorithms than what was available in the old software packages. It is planned to extend the reconstruction to include algorithms needed to handle data from TPCs with pixel readout such as Medipix2 or Timepix readout chips. Efforts are under way to also get similarly powerful simulation, digitisation and analysis processors.

MarlinTPC will be finally put to the test with the completion of the common large TPC prototype. With the advent of data from this prototype it has to prove its capabilities.

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