HepML, an XML-based format for describing simulated data in high energy physics

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Abstract

In this paper we describe a HepML format and a corresponding C++ library developed for keeping complete description of parton level events in a unified and flexible form. HepML tags contain enough information to understand what kind of physics the simulated events describe and how the events have been prepared. A HepML block can be included into event files in the LHEF format. The structure of the HepML block is described by means of several XML Schemas. The Schemas define necessary information for the HepML block and how this information should be located within the block. The library \textit{libhepml} is a C++ library intended for parsing and serialization of HepML tags, and representing the HepML block in computer memory. The library is an API for external software. For example, Matrix Element Monte Carlo event generators can use the library for preparing and writing a header of a LHEF file in the form of HepML tags. In turn, Showering and Hadronization event generators can parse the HepML header and get the information in the form of C++ classes. \textit{libhepml} can be used in C++, C, and Fortran programs. All necessary parts of HepML have been prepared and we present the project to the HEP community.

Key words: HepML, XML, Markup language, Monte Carlo Simulation, Monte Carlo event generators

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1 Introduction

In the last 10-15 years Monte-Carlo simulation programs have become one of the main research tools both in phenomenological studies and experimental analyses in high energy physics (HEP). This resulted in a burst of new programs available for researchers. Since several such programs should be usually interfaced to each other in practical calculations, importance of the interfacing is rising. Generally, programs can be interfaced either in computer memory, via shared libraries or unified executables, or externally, via data files. The latter approach is more flexible and simpler in realization, although it can be less reliable, since data files can be corrupted, lost, etc. Currently intermediate data files, as a means of interfacing programs and a method of data storage, are widely spread in HEP. In this paper we propose a new markup language for a unified description of Monte-Carlo simulated events at the parton level. This format, called High energy physics Markup Language (HepML), is an extension for the Les Houches agreements and an attempt to overcome several limitations of the Les Houches event format (LHEF) [1].

Let's describe the problem we are going to tackle in this paper in a stricter manner. In order to simulate collisions of two particles at an accelerator in a physical model realistically we have to pass through several steps of simulation (see more details in [2]). At first, we generate so called “partonic events” for a production process of one or several particles we are interested in. The events are points in the phase space, distributed according to the process matrix element squared. Examples of programs, which can prepare such events, are ALPGEN [3], CompHEP [4], MadGraph [5], HELAC [6], Whizard/OMega [7], AMEGIC++ [8], Comix [9], and Grace [10]. However, these events are not what we can observe in particle detectors, since most the final particles in the events are not real physical degrees of freedom. The final partons should form hadrons, which can decay; the final leptons can irradiate photons. This phase of simulation is called showering (since the most important effect added here is the QCD showers), hadronization, and decays. Currently, the most important players at this stage of simulation are Pythia [11], Herwig++ [12], and Sherpa [13]. After applying these effects we receive events with observable particles in the finale state. However, these events are not what experimentalists in HEP are interested in, since detector effects must be added into the events in order to receive realistic simulated detector output. Since the effects are detector dependent every HEP experiment develops its own simulation software, in most cases not publicly available. Different agreements and file formats exist for transferring of simulated data through the whole simulation chain. As we state above the HepML format is thought to be a part of the LHEF format, which is currently a standard format for storing partonic event files. In our opinion, the main limitation of LHEF is rigidity of the format structure. Certainly it is not a problem to develop a simple and compact
record for several phase space points - momenta of all particles in an event and several additional numbers, which characterize the event. But LHEF does not have any means to keep an information on physical model parameters, applied cuts, and other highly important information. The main obstacle for that is internal heterogeneity of the information. Thus we are trying to propose a rather simple format, which can include blocks of data with various structure. Parsers of the format should be relatively simple and be able to parse the HepML block if it contains superfluous information. This format should be also based on some standard programming tools.

Therefore our main goal is to overcome rigidity of the LHEF format by means of some standard tools. To achieve this we chose the ideology of markup languages [14]. Markup languages, strictly speaking procedural markup languages, are perfectly suitable for this goal, since the languages are used for describing structure of complex data. XML [15], as a standard instrument for developing markup languages, is the most appropriate base for such format. Thus, HepML is a markup language describing structure of data within the LHEF format. Employing the standard software technologies allows users and developers to re-use a lot of reliable and well-designed software, developed in the industry of software development. Fig. 1 represents a place of the HepML language and libraries in the full simulation chain in HEP.

XML has been applied in many programming projects in HEP, mainly in experimental HEP. In particular, the CMS experiment stores detector geometry data in XML [16], ATLAS uses XML tools for management of analysis software [17], Monte-Carlo simulation program Geant4 [18] stores detector geometry by means of a special markup language GDML [19]. XML-based formats also prove their usefulness in many other scientific areas. We mention several successful examples only:

- Chemical Markup Language [20] formalizes the structure of information
about molecules, chemical reactions, analytical data, etc. It is extensively used in computational chemistry, quantum chemistry, material sciences. A lot of chemistry oriented software support the standard.

- MathML [21] aims at providing ability to use mathematical notations in HTML documents. The format is supported in all major Web browsers and in an enormous number of applications, such as programs for distant education, computer algebra systems, formula editors, etc.

- CellML [22] was originally created for describing mathematical models in cardiac research. Now it is used as a description format for computational models, in many other areas of biology and other sciences, such as the computer science.

Traditional event file formats, such as standard file headers in CompHEP [4] and MadGraph[5], a format of output files of showering/decay Monte Carlo generators HepMC [23], have a fixed structure. This approach has both benefits and drawbacks. Generally, a format of this type can look simpler and more human-readable, than XML code, in ordinary text editors. It also requires less programming efforts. However, any small correction of an output/input file format of a program forces to modify both the program itself and all programming clients of the program. As we mentioned earlier, current simulation chain in HEP is rather long and quite complicated. So, constant modifications in some parts of the chain cause work in other parts. More stable file formats, such as HepML, will prevent this.

The next section conveys general conceptions of HepML. HepML XML Schemas are described in the section 3. Since the format itself is a markup language only, a software library for interpretation of the language is necessary. The section 4 describes a programming API for this format. It is a C++ library, called libhepml. The section 5 explains how to use the library. To date we have two software projects which already adapt the HepML format and/or the library. The section 6 outlines these projects and a role of HepML in them. We summarize conclusions and future plans in the section 7.

2 General description

A HepML block in a LHEF event files is an XML document with a pre-defined structure. i.e. it is a piece of ordinary text marked up with tags. The text has to contain an information enough to understand what kind of physics the events describe and how the events have been prepared. The only place in a LHEF file, which can accommodate the HepML block, is the tag <header></header>, because the LHEF format does not define contents of the tag. Since a LHEF file is *not* an XML document, the file with a HepML block can not be an XML document too. We intentionally do not propose
to store event records in the XML style, since this will add repeated tags in the records and makes the event file larger. Since a typical event file can be huge with hundreds of thousands of event records, these new tags in the event records would be too expensive for manipulating with the files. On the other hand, extracting contents of the tag `<header>` is quite simple programming task.

Tags in an HepML block are arranged in a determined structure. Several XML Schemas [24] define the pre-defined structure. Tags used in the block can be either standard ones, i.e. defined in the XML Schemas, or user-defined tags. The latter tags must obey XML rules only. The HepML XML Schemas define data types and relative disposition of all tags in an XML document. The main principle we keep in the setup can be formulated in the following manner: “do not remove or change the standard tags, add your own tags”. This means we assume users will use existing tags from the HepML Schemas, will not change the tags, and will introduce any new tags if and only if the existing are not appropriate for the users’ goals. These new tags can be organized into new XML Schemas. The HepML XML Schemas validate a HepML block, i.e. a validator should conclude whether this set of tags is a HepML document or not. If, we get a positive answer, an XML parser can process the document automatically. It is essential to understand the HepML Schemas validate the standard tags only. If a user adds new tags, (s)he should develop a code in order to extract and use an information from these new tags in a program. Another obvious condition for any new tags – a HepML block with the new tags must be an XML document. Meaning of all standard tags is rather clear and can be derived from names of the tags (see Appendix of the paper). The next section describes the HepML XML Schemas in detail.

The second necessary part of HepML is an application programming interface (API). The main goal of the API is parsing a HepML block in an event file. Currently our programming interface is realized as a C++ library, called `libhepml`. The library consists of object classes, which correspond to complex structures in the HepML XML Schemas, parsing classes, and serialization classes. All information read from a HepML block is stored in the object classes of the API. Thus, a user should create instances of the classes in his/her program and extract needed information from the classes. Sections 4 and 5 describe `libhepml` in detail.

HepML can be useful in applications of several types. Further we follow terminology of [25]. Any ME (Matrix Element) Monte Carlo event generator can generate a HepML block in an output event file, if the program supports the Les Houches event format. A SH (Showering and Hadronization) Monte Carlo event generator can use data from the block for further processing events from the file. An information stored in a HepML block is useful for describing event files in data bases of the files. As an example of the DB we shall...
consider MCDB [26]. The last class of applications can be called event manipulators. Usually it is not a stand-alone program, but a part of a large Monte Carlo program package or an experimental software environment. The program processes an event file (or several files) and generates a new event file. For example, a manipulator can apply a new kinematical cut and store all events passed the cut in a new event file. Since all applied cuts are stored in HepML we should modify the HepML block and add an information about this new cut in the output event file. Another manipulator mixes several event files into one. In this case we have to check whether we can mix events from the files at all. If yes, the program combines HepML blocks from the files in one HepML block in the output event file. Parsing the HepML blocks in the input event files is the key problem in manipulators. Fig. 2 represents an interaction between programs of different types via HepML blocks and API routines needed for that. The same manipulator can be both producer and consumer of a HepML information.

![Diagram](image)

**Fig. 2.** A simple scheme of interaction of programs via HepML data blocks.

The current HepML library depends on either Xerces [27] or Expat [28]. Many developers try to exclude external dependencies as much as possible. In fact, `libhepml` is a necessary tool for parsing only. If a program writes a HepML block down into an event file, the dependency on xml libraries can be excluded. In this case the program has to have internal routines for generation of XML
tags. Certainly, if the structure of the HepML block changes, the code should be modified according to the changes.

3 HepML XML Schemas

The HepML XML Schemas provide a general and formal description of an information about events which should be kept in HepML files. In other words, the Schemas represent a formal agreement how to represent and handle such descriptions. Besides the Schemas can be used for automated generation of a program code to handle HepML documents. For example, see the description of *libhepml* in the next chapter. Though a natural way to operate with HepML documents is to use *libhepml*, having the standard and extensible XML Schemas allows users to make their own implementation of specific parsers, output routines and validators.

Authors of MC codes can use the XML Schemas in developing of I/O routines. If a routine is consistent with the Schemas, event files generated by the routine can be read by another program without changes in input routines of the program. Also the Schemas can be used for validation of event files if the files are written according to HepML specifications.

One of the main goals of HepML is to store all significant information on simulated events as well as generator input parameters and setup in XML documents. The first task, a detailed description of events, is done by the LCG group, the second task is carried out by CEDAR [29]. Since these problems are complement to each other, Schemas, developed by both groups, are united in the main XML Schema of the HepML language *hepml.xsd*. Here and below we consider the LCG Schemas only. Lets mention the main parameters described in a typical HepML document. It should contain a general information about what kind of problem the events have been prepared for, a generator name, description of the physical process, description of the physical model in use, applied cuts, a general information on the event file:

- **General information**: title, abstract, authors, experiment and/or groups.
- **Event files**: physical process/subprocesses, the number of events, the total cross sections and its errors, file name, location(s).
- **Physics process**: initial and final states, QCD scales, parton density functions (PDFs) applied, subprocesses.
- **Used generator**: name and version, description, home page.
- **Theoretical model**: name, description, parameters and their values with author’s description.
Applied cuts cut objects, minimal and maximal possible values, and description.

There are three main Schemas in the LCG part of HepML. The first XML Schema lha1.xsd corresponds to the whole set of parameters composing the first LHA agreement [25]. The other two Schemas are sample-description.xsd and mcdb-article.xsd. The first one describes parameters which are necessary to generate an XML data for an event sample. The second Schema determines representation of data from LCG MCDB, it is used to form an LCG MCDB article for the sample. The CEDAR team develops other XML Schemas for other tasks arising in the problem of automatisation of data processing in HEP. Now all the Schemas are unified in one general formal XML Schema hepml.xsd. The Schema includes all the other Schemas as sub-Schemas. This solution leaves freedom to develop new Schemas and software independently, but to use Schemas of both groups in one software project. All the Schemas are available in [30].

4 Code Structure Description

In this section we present a library implementing the HepML standard. The library is called libhepml. Classes of this library can parse HepML blocks in LHEF files, represent data from the blocks in computer memory, combine several HepML blocks in one, and serialize C++ objects into HepML documents in files. Libhepml consists of several types of C++ classes:

- **object classes** represent complex types from the HepML XML Schemas. The main object class is “Article”. This class describes a set of event files. All other object classes are intended for implementation of some pieces of information in “Article”, such as a physical model, a cut, beams, etc. “Article” includes these classes as internal objects.

- “Acting” classes. “Parser” is the main parsing class. All complexity of parsing of XML tags and translating data to object classes is hidden in methods of the class. “Mixer” is the main class for merging HepML objects. “Writer” is the interface class for serialization of HepML documents.

- **XML generating classes** serialize contents of an object class to XML tags.

- **Parsing classes** parse HepML tags. These internal classes are not intended for direct use by end-users of the library.

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1 Since an event file can contain events for several independent subprocesses, cuts in the HepML record are subprocess specific, i.e. there can be several sets of cuts for every subprocess kept in the files.
• **Implementing classes** translate data from parsing classes to object classes. Every parsing class has its own implementing class.
• **Interacting classes** interact with classes of external libraries, currently with classes of Xerces or Expat.

Three first types of classes realize a user API of the library. The last three types of classes fulfil basic functionality in the library. All these basic internal classes have been prepared partly by means of XSD [31] This software prepares a set of classes for parsing XML documents according to an XML Schema. In our case, the parsing and implementing classes realize the HepML XML Schemas.

Strictly speaking the “Article” class is a container for all information from a HepML block. The class interface looks like:

```cpp
class Article {
public:
    Article();
    virtual ~Article();
    int& id();
    int& id(int id);
    string& title();
    string& title(const string&);
    string& abstract();
    string& abstract(const string&);
    string& comments();
    string& comments(const string&);
    ExperimentGroup& experimentGroup();
    ExperimentGroup& experimentGroup(const ExperimentGroup&);
    vector<Author>& authors();
    vector<Author>& authors(const vector<Author>&);
    const string postDate();
    Process& process();
    Process& process(const Process&);
    Generator& generator();
    Generator& generator(const Generator&);
    Model& model();
    Model& model(const Model&);
    CutsVector& cuts();
    CutsVector& cuts(const CutsVector&);
    vector<File>& files();
    vector<File>& files(const vector<File>&);
    vector<string>& relatedPapers();
    vector<string>& relatedPapers(const vector<string>&);
};
```
We can see the class has paired methods with the same names for getting/setting parameters. Information stored in the parameters correspond to information stored in tags of the HepML tag `<samples>` (see Appendix to the paper). For example, the class Generator stores an information (name, version, description, homepage) for a Monte Carlo generator which has been used for simulation of events. The method “abstract()” returns a text of an abstract of the HepML document.

The “acting” API classes are “Writer”, “Parser”, “Mixer”. The first class generates HepML documents from an “Article” object. The second class is responsible for parsing one or several HepML blocks, e.g. ones stored in LHEF event files. It fills out an “Article” object. The “Mixer” class merges several HepML blocks into a new block. “Mixer” follows the algorithm:

- Sum cross sections of all event samples and combine their errors;
- Concatenate string parameters, such as model and generator descriptions, authors, etc. The parameters for different HepML blocks are separated with semicolons;
- Compare beams. They must be the same in all HepML blocks. Otherwise “Mixer” aborts execution and returns an error;
- Subprocesses from all HepML blocks are combined in one array;
- Combine cut sets. A cut set is added to the array of cut sets if the array does not have it yet;
- Combining physical models is more complicated problem. If a model parameter is not found in the combined model it is appended to the array of model parameters. If it is found, but it has a different value, it is added only if the special flag “hepml::force::merge” is assigned in “Mixer::mixObjects(...)”. Otherwise the library aborts execution with error.

Combination of several subprocesses from several event files into one array of subprocesses has one subtle point. Different cuts can be applied in these subprocesses. Therefore, we have to unify events into one event sample and keep these cuts separately. In order to solve the problem we apply the following algorithm. Every subprocess is assigned an id number. This number is kept as an attribute in the tag `<subprocess>`, for example: `<subprocess cutset_id="2" >`. All cuts applied for events of the subprocess are unified inside the tag `<cutSet>` with the same attribute, for example: `<cutSet cutset_id="2">`. All `<cutSet>` are combined in an array and located inside the tag `<cuts>`. Thus, the final HepML document will have two arrays of subprocesses and corresponding cut sets.

The last part of the API is generating classes. They serialize C++ objects, corresponding to object classes, to XML code, i.e. they produce HepML documents. Every object class has its own generating class. The set of XML tags generated for the “Article” class can be used both as an XML independent
document or as a block of information, which can be included to files in other formats, e.g. event files in the LHEF format produced with a Monte Carlo generator.

Figure 3 represents a diagram of typical interaction between a parsing class and an object class for filling out a HepML object. We use “model parameters” as an example. For simplicity we omit most of methods in the classes and keep methods needed only for the purpose of the picture. At first, low-level methods of interfacing classes parse the whole HepML block and extract one by one tags corresponding to complex types in the HepML Schemas. Libhepml has a parsing class for every such tag. Classes of this type has a postfix “_pskel”. The parsing class analyses the tag name and assigns the tag content to a cache variable. The variable can be of either a standard type (int, string, etc.) or another complex type (any HepML tag nested in the tag). These operations are carried out by the method “start_element_impl”. “start_element_impl” verifies also whether the tag name belongs to the hepml namespace (a C++ realization of the vocabulary of HepML tags). After that the method “end_element_impl” assigns the cache variable to a corresponding internal variable in “Article” or another HepML class, via methods we call assigning methods. However, these assigning methods are not implemented in the parsing class. Realisation of the methods is the main goal of the implementing classes. Every implementing class inherits to a corresponding parsing class. The implementing classes are instantiated by the “hepml::Parser” class, the main “acting” parsing class in the API. Since a typical HepML block contains lots of tags, all corresponding parsing objects have to be combined. It happens via callback methods called “parsers(...)”. Every parsing class has its own “parsers” method. In terms of the HepML schemas the method defines tags which have to exist inside the tag, the parsing class corresponds to.

All classes of libhepml can deal with tags of the HepML Schemas only. However, there can be necessity to introduce new user-defined tags in HepML blocks. If one needs a simple tag without any nested tags, a user can modify existing parsing/implementing/object classes for a complex type in the HepML Schemas. If a more complicated set of tags is necessary, a new object class should be created. There is an example of such a set of classes in the library.

5 How to use libhepml

Libhepml can perform tasks of three types: creating an article object in a program and send the object to an output stream, parse an HepML document in a file and keep information from the block in the article object, and merge several HepML documents into one. Below we present simplified examples for
In order to use \textit{libhepml}, three C++ headers should be added to code:

\begin{verbatim}
#include <hepml/hepml.hpp>  // general object classes
#include <hepml/writer.hpp>  // to produce HepML documents
#include <hepml/parser.hpp>  // to parse and merge HepML documents
\end{verbatim}

Note: if one of two last headers are included, there is no need in the first one.

At first an instance of the main object class “Article” should be created\footnote{We assume the hepml namespace is defined in the source file via the standard C++ instruction “using namespace hepml;”. So, all \textit{libhepml} classes are used without the namespace prefix “hepml::”:}:

\begin{verbatim}
Article a;
\end{verbatim}

Lets fill out the object with information. There is two different ways how to assign values to parameters of the object. For example:

\begin{verbatim}
a.title("p,p->Wbbj->l,nu,b,b,j process from CompHEP");
\end{verbatim}

or

\begin{verbatim}
a.abstract() = "There are about 1.1M events for the process p,p->W,b,b,j with leptonic decays of W-boson."
\end{verbatim}
The object classes have several arrays for authors, model parameters, subprocesses, and cuts. Let’s create an author record and add it to the article object:

```java
Author author;
author.firstName() = "James";
author.lastName() = "Johnson";
author.email() = "James.Johnson@nospamcern.ch";
author.experiment() = "CMS";
author.experimentGroup() = "CMS Top group";
author.organization() = "CERN";
a.authors().push_back (author);
```

After that we should introduce and describe a physical process in the article. At first, we describe initial beams:

```java
Process p;
p.beam1().particle = Beam::Particle("p");
p.beam1().energy = Beam::Energy(7000, Beam::Energy::GeV);
p.beam1().pdf.name = "CTEQ6L";
p.beam1().pdf.lhaPdfSet = 3;
qc = QcdCoupling();
qc.lambda = 2.0;
qc.nLoopsAlpha = 2;
qc.nFlavours = 5;
p.beam1().qcdCoupling = qc;
```

The second beam is set in the same manner (certainly, beam2() should be used instead of beam1()). We have to describe the final state, assign information on a cross section, and add a description of the process to our article:

```java
p.finalState() = "l,nu,b,b,j";
p.finalStateNotation().plain = "l,nu,b,b,j";
p.finalStateNotation().html = "<i>l,nu,b,b,j</i>";
CrossSection cs = CrossSection( 22.78, CrossSection::pb );
cs.errorPlus = cs.errorMinus = 0.02;
p.crossSection() = cs;
a.process() = p;
```

If we have several subprocesses in the process, we add them to the subprocesses array in the article object:

```java
Subprocess sp;
sp.notation() = "u,D -> nm,M,G,b,B";
sp.crossSection().value = 1.3221;
sp.crossSection().unit = CrossSection::pb;
```
sp.crossSection().errorPlus =
sp.crossSection().errorMinus = 2.68e-03;
a.process().subprocesses().push_back( sp );

We should keep information on a generator and append the information to
the article:

gen.name() = "CompHEP";
gen.version() = "4.5.2";
gen.homepage() = "http://comphep.sinp.msu.ru";
gen.description() = "Funny Monte Carlo event generator";
a.generator() = gen;

The next important step is an introduction of a physical model:

Model& m;
m.name() = "Standard Model";
m.description() = "There can be a long and detailed
description of the model";

Model parameters should be added one by one:

Model::Parameter param = Model::Parameter( "Ms", "0.117" );
param.mathNotation().plain = "Ms";
param.mathNotation().html = "m<sub>s</sub>";
param.description() = "parameter1 description";
m.parameters().push_back(param);

If any kinematical cuts have been applied we can add description of the cuts.

cut.object() = "M(l,nu)";
cut.minValue() = "100 GeV";
cut.maxValue() = "";
cut.objectNotation().html = "html object notation";
a.cuts().push_back(cut);

After that we assign an information about the event file:

File f;
f.eventsNumber() = 195644;
f.size() = 407736817;
f.crossSection() = CrossSection(22.78, CrossSection::pb);
f.checksum().type = File::Checksum::mda5;
f.checksum().value = "8957a237dc062b96987a21c86774eb5e";
a.files().push_back(f);
As soon as the article is created and filled out with necessary information, it can be serialized to an output stream, for example to the standard output stream:

```cpp
hepml::Writer writer;
std::cout << writer.toHepml( a );
```

In this case the article will be printed out in the form of a HepML block. If a parameter in the “Article” object is necessary (according to the HepML Schemas) and it is undefined, it will be assigned to a reasonable value, an empty string for a string parameter, 0 for int, etc. If the parameter default value is specified in the HepML Schemas, the value will be used.

The second typical task performed by libhepml is HepML parsing. In order to parse a HepML block in a file and fill out an instance of the “article” class we should define instances of the “Article” and “Parser” classes and parse the LHEF files by means of the parseObject object:

```cpp
Article a;
Parser parser;
::std::string file = "hepml_examples/general/example1.xml";
parser.parseObject (a, file);
```

After that, all information from the HepML block is available in the object “a”. We can manipulate the information. For example:

```cpp
cout << "Generator name: " << a.generator().name() << endl;
cout << "Model: " << a.model().name() << endl;
cout << " with parameters:"
for (int i(0); i < a.model().parameters().size (); ++i) {
    cout << " name: " << a.model().parameters()[i].name() << " value: " << a.model().parameters()[i].value() << endl;
}
```

If we have several LHEF files and want to merge HepML blocks in the files, we can use the “Mixer” class and the mixObjects method; the second argument should be a vector of file names.

```cpp
Article article;
Mixer mixer;
vector< ::std::string> files(2);
files[0] = "hepml_examples/general/example1.xml";
files[1] = "hepml_examples/general/example2.xml";
try {
    mixer.mixObjects(article, files);
}
```
catch (const ::std::exception m) {
    m.what();
    return 1;}

The merging algorithm was explained in detail in the previous section. The only subtle point here is merge of models with a parameter, which has different values in different HepML blocks. In order to merge the HepML blocks in this case we should use a special flag:

... try {
    mixer.mixObjects(article, files, force::merge);
} catch (const ::std::exception m) {
    m.what();
    return 1;}

6 Current HepML applications

6.1 LCG MCDB

In the last years there was a need for common place to store sophisticated Monte Carlo event samples prepared by experienced theorists. Also such samples should be accessible in a standardized manner to be easily imported and used in experiments’ software environments. The main motivation behind the LCG MCDB project [26,33] is to make the sophisticated Monte Carlo event samples and their structured descriptions available for various groups of physicists working at the LHC. All these data from MCDB are accessible for end-users in several convenient ways from Grid, on the Web, and via an application program interface.

The main content of MCDB are event files and their detailed descriptions. These descriptions are fully compatible with the information which can be provided in HepML blocks. So, the main way to automate an access to MCDB is to use HepML documents in interaction with MCDB. An event sample description can be both exported from MCDB or uploaded to the data base. In other words, an MCDB article can be obtained as a HepML document. Otherwise, a new article can be created automatically in MCDB using a HepML description of an event file.

The CMS collaboration [34] already uses MCDB in its productions of simulated events. Event files can be downloaded from MCDB by means of internal
routines of the CMSSW software simulation environment. The routines are based on classes of libhepml. There is also an option to upload new event files to MCDB using a special uploading script. The script supports LHEF files with two types of header blocks, HepML and MadGraph.

6.2 CompHEP Monte-Carlo generator

The Monte Carlo event generator CompHEP produces events on the partonic level for particle decays and particle collisions at colliders. The main file format for the event files in CompHEP is LHEF, although two obsolete native event file formats are still in use for backward compatibility. More information about the program can be found in [4,35].

Since CompHEP generates partonic level events it is a natural target for implementing HepML. Currently, by default, CompHEP needs neither an xml library no libhepml in order to produce a HepML block, since the task of generating XML code is rather simple programming problem, and the output format is rather stable. The block is constructed with internal CompHEP routines. However, CompHEP can be compiled with the libxml2 library. It is a standard GNOME XML library.

There are several problems where CompHEP HepML block should be parsed and modified. It means the libxml2 parser should be used. CompHEP generates events per subprocess, i.e. a physical process with fundamental model
particles in the initial and final states. However, in many cases we need to sum over several initial or final states. For example, this happens if we have a composite particle, like proton, in the initial state. Therefore we come up with several event files, which should be combined into one event sample. This problem is a particular case of the merging problem we discussed in Sect. 4. HepML blocks of subprocess event files should be merged into one block. There is a special mixing program, called “mix”, for that in CompHEP. If “mix” is linked against libxml2 it combines all HepML blocks from input files and adds a new block to the final event file.

Since two authors of the paper are also members of the CompHEP collaboration, we plan to expand usage of HepML in CompHEP. Namely, we plan to add support of HepML to the “addcut” and “cascade” programs. The former program applies a new cut to events kept in a CompHEP event file. So we have to add the cut to the HepML block in the output event file. The latter program replaces heavy decaying resonances in final states with their decay products. Therefore the output event file contains subprocesses with different final states. A list of these new subprocesses should replace the old list of subprocesses. In the future, we plan to use libhepml instead of libxml2 in CompHEP, since this will help significantly to simplify codes of programs, where HepML is used.

7 Conclusion and Plans

In the article we present HepML, a new markup language for describing events on the partonic level in a uniform and flexible manner. Blocks of HepML tags can be painlessly implemented into LHEF files. HepML allows Monte Carlo event generators to prepare self-documented event files. It means we have all necessary information about events, such as physical model, applied cuts, etc., inside of the event file. HepML is constructed as an extensible language. Users can extend the set of XML schemes or add new tags into the format. The only requirement to these new tags is that they should follow XML rules. The structure of a HepML block is defined with several HepML XML Schemas.

HepML is equipped with an API in the form of a C++ library. It is called libhepml. The library consists of object classes for representing information from a HepML block in computer memory, parsing classes, and classes for serialization the object classes into HepML tags. This library can use either Xerces or Expat XML parser for low-level parsing of XML tags. There is a possibility to add processing of new user-defined tags into the library. Libhepml provides a unified interface for the automatic event description at different levels of Monte-Carlo simulation in HEP.
The developed HepML schemes, documentation and code of the libhepml library are available publicly on the MCDB web server [33].

There are several projects which have already started to exploit HepML. LCG MCDB uses HepML information in all its external interfaces. The CompHEP Monte Carlo event generator adds HepML blocks into event files and uses the blocks for mixing of several event files into one event file. HepML has been implemented in the software environment of the CMS collaboration (CMSSW) in order to document externally simulated event samples, kept in LCG MCDB.

We are going to develop the project further in the framework of an open source project [36] and encourage people interested in development of XML-based formats to join the project.

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9 Appendix. HepML tags.

The main LCG HepML Schema consists of a number of tags. Here we collect information about the tags:

- `<samples>` is the root tag of a HepML block. It contains information on each event file (in the `<files>` tag) and a common description of events in the files (in the `<description>` tag).
- `<description>` describes an article. It should have several simple tags ( `<title>`, `<abstract>`, `<authorComments>`, `<relatedPapers>`) and several tags with nested tags ( `<experimentGroup>`, `<generator>`, `<model>`, `<process>`, `<cuts>`, `<authors>`) .
- `<authors>` contains a list of all authors of the event sample.
- `<author>` describes an author, i.e. contains tags for first and last author’s names, his/her email and affiliation (group, experiment, organization).
- `<title>` contains a title of the article.
- `<abstract>` contains an abstract of the article.
- `<relatedPapers>` contains a list of related articles.

3 A simple tag contains a text only and does not have any nested tags.
• `<authorComments>` contains additional authors’ comments to the article. All information not marked up with tags should be stored within the tag.
• `<experimentGroup>` contains an information about an experiment and/or a group, which produce the events. It consists of several simple tags (`<experiment>`, `<group>`, `<responsiblePerson>`, and `<description>`).
• `<generator>` contains an information on a Monte Carlo event generator used. There are several simple tags in the tag: `<name>`, `<version>`, `<homepage>`, and `<description>`.
• `<model>` describes the physical model for the events, i.e. all parameters in the model. It has `<name>` and `<description>` tags, and an array of parameters within `<parameters>` tag. Each `<parameter>` describes an element of the model by means of four tags: `<name>`, `<value>`, `<description>`, and `<notation>`.
• `<process>` describes a physical process. It contains several tags:
  ◦ `<beam1>`, `<beam2>` describe initial beams. It means each beam tag defines the particle info (tag `<particle>`), energy (tag `<energy>`), structure functions (tag `<pdf>`), and an information on the QCD coupling related to the structure function (tag `<QCDCoupling>`).
  ◦ `<QCDCoupling>` defines an information on the QCD coupling if it is not defined in beams.
  ◦ `<finalState>` defines a final state for the process.
  ◦ `<crossSection>` sets the total cross section of the process.
  ◦ `<subprocesses>` defines a list of subprocesses for this physical process. Each subprocess has the following characteristics: notations for initial and final states, the total cross section, and factorization and renormalization scales.
• `<cuts>` contains a list of applied cuts. These cuts are grouped in several cut sets (tag `<cutSet>`). `<cutSet>` has a special attribute (cutset_id), which couples a `<cutSet>` tag and a `<subprocess>` tag. It means if the tags have the same value of the attribute, cuts from the `<cutSet>` tag are applied for events of the subprocess.
• `<cut>` defines a cut.
• `<files>` is a list of event files. This element can be both used separately and inside the `<samples>` tag.
• `<file>` contains an information about one event file. A type of the file can be specified in the attribute `type`. It has the following nested tags:
  ◦ `<eventsNumber>` – the number of events in the file.
  ◦ `<crossSection>` – the total cross section for events in the file.
  ◦ `<fileSize>` – the file size in bytes.
  ◦ `<checksum>` – a check sum of the file (a type of the check sum is specified in the `type` attribute).
  ◦ `<comments>` – an author’s comment for the file.
  ◦ `<location>` – a list of locations of the file (CASTOR, Grid or others).
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