iLCSoft Tutorial

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Outline

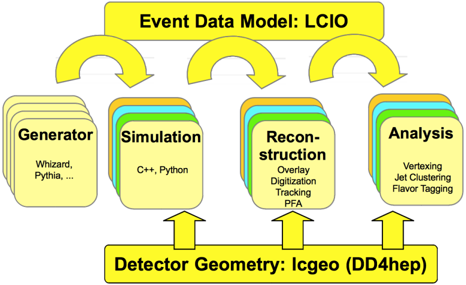
- Introduction to iLCSoft
  - the key components: LCIO, Marlin, DD4hep
  - where to find the code and installations
- First Steps: Running the complete Chain
  - Simulation
  - Reconstruction
  - *Analysis*
- How to write your own Marlin processor

Section 1

Introduction to iLCSoft

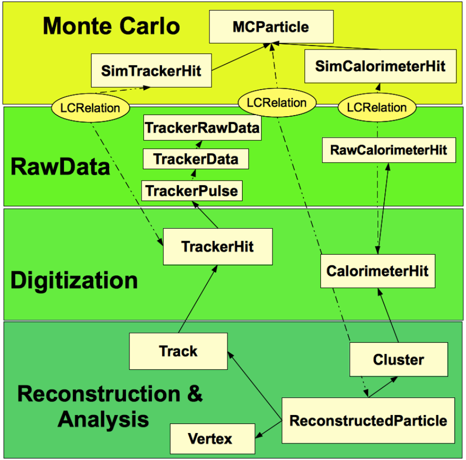
Overview iLCSoft

- iLCSoft is the common software framework for Linear Collider detector studies
  - used by CLIC, ILD, SiD, Calice, LCTPC (and friends: FCC, CEPC, HPS, EIC, . . .)
- key components in iLCSoft:
- **LCIO**
  - the common *event data model (EDM)*
- **DD4hep**
  - the common *detector geometry description*
- **Marlin**
  - the *application framework*



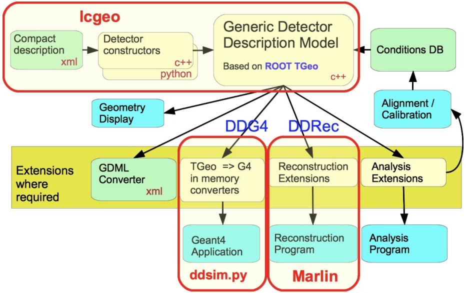
LCIO

- LCIO provides the common *EDM* and *persistency* (i.e. file format for LC studies)
- the EDM is hierarchical:
  - you can always get the constituent entities from a higher level object, e.g. the *TrackerHits* that were used to form the *Track*
  - only exception: *you cannot directly go back to the Monte Carlo Truth information*
  - this is possible via dedicated *LCRelation* collections
- everything is stored in *LCCollections*
- collections are retrieved from the *LCEvent* via their **name**
- see: **http://lcio.desy.de**



DD4hep

- DD4hep (*Detector Description for HEP*) is the common detector geometry description for iLCSoft
- the **same** detector model is used for:
  - simulation, reconstruction, visualization and analysis
- the detector is fully described via a set of:
  - C++ detector constructors
  - XML files (*compact files*)
- DD4hep is component based, i.e.
  - **DDG4** full simulation with Geant4
  - **DDRec** interface for reconstruction
- **lcgeo**: sub-package with LC detector models
- **ddsim**: python program to run a full simulation

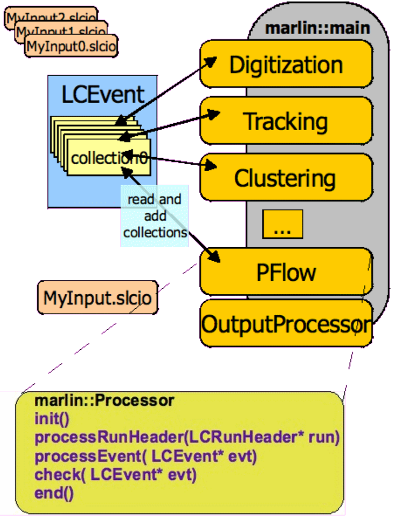


https://dd4hep.web.cern.ch/dd4hep

Marlin

- application framework used throughout iLCSoft
- every task is implemented in a *Processor*
  - task can be as trivial as digitizing a hit collection or as complex as running the full *PFA*
- Marlin appplications are fully configured via XML files, defining:
  - global parameters
  - the chain of processors to run
  - per processor parameters
- xml files created with *editor*

- more:
  http://ilcsoft.desy.de/Marlin/current/doc/html/index.html



Learn more

If you want to learn more about the philosophy, history and usage of the main tools and packages read the following papers:

- *LCIO - A persistency framework for linear collider simulation studies* (CHEP 2003)
  - https://arxiv.org/pdf/physics/0306114.pdf
- *Marlin and LCCD—Software tools for the ILC* (ACAT 2005)
  - Nucl.Instrum.Meth. A559 (2006) 177-180
- *DD4hep: A Detector Description Toolkit for High Energy Physics Experiments* (CHEP 2014)
  - http://cds.cern.ch/record/1670270/files/AIDA-CONF-2014-004.pdf
- *DDG4 A Simulation Framework based on the DD4hep Detector Description Toolkit* (CHEP 2015)
  - http://cds.cern.ch/record/2134621/files/pdf.pdf
- *Detector Simulations with DD4hep*
  - http://cds.cern.ch/record/2244362/files/CLICdp-Conf-2017-001.pdf

Where to find iLCSoft packages

- almost all iLCSoft packages are now maintained on GiHub: **https://github.com/iLCSoft**
- there you can:
  - download the software
  - make *Pull Requests* with your changes
  - submit *Issues* with problems, requests or questions for a given iLCSoft package

Get a GitHub Account

- go to https://github.com/join
- create an account using (somthing close to) your real name

Learn the git workflow for iLCSoft

- look at https://github.com/andresailer/tutorial

Where to find installed versions of iLCSoft

- reference installations of all current versions of iLCSoft for *CentOS7* in *afs* and *cvmfs*, e.g.:

iLCSoft v02-02-02 reference installations

```
/afs/desy.de/project/ilcsoft/sw/x86_64_gcc82_centos7/v02-02-02
/cvmfs/ilc.desy.de/sw/x86_64_gcc82_centos7/v02-02-02
```

configuration files for ILD are in ILDConfig - for v02-02-02:

```
/afs/desy.de/project/ilcsoft/sw/ILDConfig/v02-02-02
/cvmfs/ilc.desy.de/sw/ILDConfig/v02-02-02
```

or download from GitHub:

```
git clone https://github.com/iLCSoft/ILDConfig.git -b v02-02-02
```

Section 2

First Steps

running the complete software chain (for ILD)

- the quickest introduction to running iLCSoft can always be found in the *ILDConfig* package:

```
cd ./StandardConfig/production/
less README.md
```

- or view online (nicely fomatted due to *markdown*) at:
  - https://github.com/iLCSoft/ILDConfig/tree/master/StandardConfig/production

follow the steps in this README.md

- run the commands given in the order given
- while doing this, look at the
  - configuration files used
  - the input and output files
  - the **Code** (yes, it often helps to directly look at the code ;-))
- we will do this now, step by step ...

initialize the iLCSoft environment

- a given iLCSoft release is initialized simply via running the *init script*:

```
. /afs/desy.de/project/ilcsoft/sw/x86_64_gcc82_centos7/v02-02-02/init_ilcsoft.sh
```

- or: `. /cvmfs/ilc.desy.de/sw/x86_64_gcc82_centos7/v02-02-02/init_ilcsoft.sh`
- now you can call all iLCSoft binaries (*from this release !*) directly on the command line, e.g.

```
ddsim -h
Marlin -h
dumpevent -h
g++ -v
```

- also a number of emvironment variables are set to find the iLCSoft packages, e.g.

```
$ILCSOFT, $DD4hep_DIR, $LCIO, $lcgeo_DIR
```

- example: show all packages in the current iLCSoft release

```
find $ILCSOFT -maxdepth 2 -mindepth 2  -type d
```

running the simulation

- run a simulation from an *stdhep* generator file:

```
ddsim --inputFiles Examples/bbudsc_3evt/bbudsc_3evt.stdhep \
      --outputFile=./bbudsc_3evt_SIM.slcio \
      --compactFile $lcgeo_DIR/ILD/compact/ILD_l5_v02/ILD_l5_v02.xml \
      --steeringFile=./ddsim_steer.py  > ddsim.out 2>&1 &
```

- while this is running, take the time and investigate the main configuration files used here:
  - *ddsim_steer.py* steering the simulation
  - *ILD_l5_v02.xml* the detctor geometry model

Exercise 1

- modify *ddsim_steer.py* in order to run a simulation using a *particle gun* instead
  - simulate a few π^+ at various polar angles
  - note: make sure to create an output file with a different name

investigate LCIO files

- dump all the events and collection names with number of objects in an LCIO file, e.g.:

```
anajob bbudsc_3evt_SIM.slcio
```

- dump a given event in full detail, e.g.:

```
dumpevent bbudsc_3evt_SIM.slcio 2 | less
```

Exercise 2

- dump only the collection with the Hcal barrel *SimCalorimeterHits*
  - hint: use `anajob` and `dumpevent -h`

interlude: reading LCIO with python

- you can write your own ‘dumpevent’ using python:
- open a file `dumplcio.py` and paste the following code:

```
from pyLCIO import UTIL, EVENT, IMPL, IO, IOIMPL
import sys

infile = sys.argv[1]
rdr = IOIMPL.LCFactory.getInstance().createLCReader( )
rdr.open( infile )

for evt in rdr:
    col = evt.getCollection("MCParticle")
    for p in col:
        print(p.getEnergy())
```

- Run the script via

```
python dumplcio.py bbudsc_3evt_SIM.slcio
```

Exercise 3

- modify the above example to print the total MC-truth energy

running the reconstruction

- we can now reconstruct the simulated file:

```
Marlin MarlinStdReco.xml \
       --constant.lcgeo_DIR=$lcgeo_DIR \
       --constant.DetectorModel=ILD_l5_o1_v02 \
       --constant.OutputBaseName=bbudsc_3evt \
       --global.LCIOInputFiles=bbudsc_3evt_SIM.slcio \
       > marlin.out 2>&1 &
```

- while this is running, let's have a look at the Marlin steering file `MarlinStdReco.xml`
  - see next five slides

Marlin steering file - general structure

- A Marlin appliation is controlled via an `xml` steering file

```
<marlin>
  <execute>   [1]
      ...  // the processors and processor groups to be executed
  </execute>

  <global>    [1]
      ...  // global parameter section
  </global>

  <processor> [n]
      ...  // definition of the processor and its parameters
  </processor>

  <group> [m]
      ...    // a group of processors
    <processor> [k]
      ...  // definition of the processor and its parameters
    </processor>
  </group>
</marlin>
```

- The numbers enclosed in `[]` denote the number of allowed/required elements per type ($n, m, k \geq 0$)
- See the **documentation** of the `marlin::XMLParser` for more detailed information

Marlin steering files - execute

```xml
<execute>
  <processor name="MyAIDAProcessor"/>
  <processor name="InitDD4hep"/>
  <processor name="VXDPlanarDigiProcessor"/>
  <processor name="SITPlanarDigiProcessor"/>
  <processor name="SITDDSpacePointBuilder" />
  <!-- ... -->
  <processor name="DSTOutput"/>
</execute>
```

- define the processors that are going to be run - *in that order*
- processors are called by their name
- the type is defined in the corresponding `<processor/>` section

Marlin steering files - global

```
<global>
  <parameter name="LCIOInputFiles"> bbudsc_3evt_SIM.slcio </parameter>
  <parameter name="MaxRecordNumber" value="0"/>
  <parameter name="SkipNEvents" value="0"/>
  <parameter name="SupressCheck" value="false"/>
  <parameter name="Verbosity"> MESSAGE </parameter>
  <parameter name="RandomSeed" value="1234567890" />
</global>
```

- define global parameters to be used for the job and all proccessors
    - input files, verbosity, etc
- parameters can be overwritten on the command line, e.g.

```
Marlin --global.LCIOInputFiles=bbudsc_3evt_SIM.slcio ...
```

Marlin steering files - processor

```
<processor name="FTDPixelPlanarDigiProcessor" type="DDPlanarDigiProcessor">
  <parameter name="ForceHitsOntoSurface" type="bool">true </parameter>
  <parameter name="SubDetectorName" type="string"> FTD </parameter>
  <parameter name="IsStrip" type="bool">false </parameter>
  <parameter name="ResolutionU" type="float">0.003 </parameter>
  <parameter name="ResolutionV" type="float">0.003 </parameter>
  <parameter name="SimTrackHitCollectionName" type="string" lcioInType="SimTrackerHit"> FTD_PIXELCollection </parameter>
  <parameter name="TrackerHitCollectionName" type="string" lcioOutType="TrackerHitPlane">FTDPixelTrackerHits </parameter>
</processor>
```

- define the processor type and its parameters
  - there can be many processors of the same type (but different name)
  - there can be unused `<processor/>` sections in the file (not referenced in `<execute/>`)
- processor parameters can also be overwritten on the command line, e.g.

```
Marlin --FTDPixelPlanarDigiProcessor.ResolutionV=0.006
```

Marlin steering files - constants

```
<constants>
  <constant name="CalibrationFactor"> 0.86 </constant>
  <constant name="CalibPath"> /home/toto/data/calib </constant>
  <constant name="YourParameter"> 42.0 </constant>
</constants>
```

- define global constants that you can refer to later in your steering file, e.g

```
<processor name="MyCalibrationProcessor" type="CalibrationProcessor">
  <parameter name="CalibrationFile" type="string"> ${CalibPath}/Calib_May.txt </parameter>
  <parameter name="Factor" type="float"> ${CalibrationFactor} </parameter>
</processor>
```

- constants can be overwritten on the command line, e.g.

```
Marlin --constant.CalibrationFactor=0.485 ...
```

create a ROOT ntuple from LCIO

- create a ROOT TTree for analysis

```
Marlin --global.LCIOInputFiles=bbudsc_3evt_REC.slcio \
  MarlinStdRecoLCTuple.xml
```

- creates: StandardReco_LCTuple.root which you can analyze with ROOT in the *usual way*
- run a simple example macro:

```
cd RootMacros
root -l
root [0] .x ./draw_simhits.C("../StandardReco_LCTuple.root")
```

- see next slide for basic introduction to LCTuple

using the LCTuple

- the LCTuple package creates a flat TTree (columnwise ntuple) from LCIO files
  - (almost) all members of LCIO objects are copied directly into the tree
- naming convention
  - to allow for reasonably fast typing on the command line rather short variable names are choosen:
    - two characters for the object type, e.g **mc** for **MCParticle**
    - three characters for the actual quantity, e.g. **pdg** for **getPDG**
    - **mcpdg** corresponds to **MCParticle::getPDG()**
  - check the code if you are unsure, e.g.
    - https://github.com/iLCSoft/LCTuple/blob/master/src/MCParticleBranches.cc#L74-L96
- as there can be more than one collection in the event of a given type, these collections have to be merged in the `lctuple.xml`
  - you can select which collection(s) to use in `TTree::Draw` via the given index, stored in the **XXori** variable, e.g **stori** for the *SimTrackerHit*

use LCIO directly in ROOT macros

- It is also possible to use LCIO *proper* in ROOT macros
- Need to load the *ROOT dictionary* to work
  - Via (e.g. in `rootlogon.C`)

    ```
    gSystem->Load("$LCIO/lib/liblcioDict.so");
    ```

  - Or (at the very top of the macro)

    ```
    #ifdef __CLING__
    R__LOAD_LIBRARY(liblcioDict)
    #endif
    ```

  - Make sure that all the necessary libraries are on `LD_LIBRARY_PATH`
    - Everything should be setup properly via `init_ilcsoft.sh`!

reading an slcio file via ROOT

- Put the following into `read_slcio.C`

```
#ifdef __CLING__
R__LOAD_LIBRARY(liblcioDict);
#endif

#include "IO/LCReader.h"
#include "IOIMPL/LCFactory.h"
#include "EVENT/MCParticle.h"
#include "UTIL/LCIterator.h"
#include "lcio.h"

#include <iostream>

void read_slcio() {
  using namespace lcio;
  auto* lcReader = IOIMPL::LCFactory::getInstance()->createLCReader();
  lcReader->open("bbudsc_3evt_SIM.slcio");

  while(auto* evt = lcReader->readNextEvent()) {

    LCIterator<MCParticle> mcParticles(evt, "MCParticle");
    std::cout << mcParticles.size() << std::endl;
  }
}
```

- Run with `root -l read_slcio.C`

- Very simple example to show the minimal set of necessary steps
  - Only prints the number of `MCParticles` in each event
- Open the file via the `LCReader`
- Setup the *event loop*
- Work with the events in the same way you do in a Marlin processor

Section 3

create your own Marlin package

reminder: The processor interface

```
#include "marlin/Processor.h"
#include "lcio.h"

using namespace lcio;
using namespace marlin;

class MyProcessor : public Processor {
public:
  Processor* newProcessor() override { return new MyProcessor; }

  void init() override;
  void processRunHeader(LCRunHeader*) override;
  void processEvent(LCEvent*) override;
  void check(LCEvent*) override;
  void end() override;

  ~MyProcessor() = default;
};
```

- Every processor needs to inherit from `marlin::Processor`
- The `newProcessor` function has to be overridden
- The other virtual functions can be used to specify the behavior of the processor
  - They have an empty default implementation, so you only need to override those which you need

Build the MyMarlin example package

copy the *mymarlin* example:

```
cp -rp $MARLIN/examples/mymarlin .
cd mymarlin
```

build with the *canonical* sequence

```
mkdir build && cd build
cmake -C $ILCSOFT/ILCSoft.cmake ..
make install
```

add the new library to `MARLIN_DLL` (so it can by dynamically loaded)

```
export MARLIN_DLL=$MARLIN_DLL:$PWD/../lib/libmymarlin.so
```

create a steering file to run this package

```
MARLIN_DLL=$PWD/../lib/libmymarlin.so Marlin -x > mysteer.xml
```

Create your own Marlin package

- rename the package in `CMakeLists.txt` - change:

```
PROJECT( NewProcessorName )
```

- rename the MyProcessor

```
mv include/MyProcessor.h include/NewProcessorName.h
mv src/MyProcessor.cc src/NewProcessorName.cc
```

- make the corresponding name change in the source files !

```
sed -i 's/MyProcessor/NewProcessorName/g' include/NewProcessorName.h
sed -i 's/MyProcessor/NewProcessorName/g' src/NewProcessorName.cc
```

- Start the build sequence from a **clean build directory**
- Note that also the name of the library has changed now!
    - Need to adapt `MARLIN_DLL`

Exercise 4: write and run your Marlin processor

- add a few histograms and fill them, e.g.
  - particle kinematics for *MCParticle* and *ReconstructedParticle*
    - p, p_t, θ, ϕ for charged and neutral
  - try to use the lcio::RelationNavigator to plot some *truth* vs. *reconstructed* quantities
  - repeat steps on previous slide to build and eventually run your processor[1]

[1] Note that you will have to enable Marlin to use the AIDA package to use the `AIDProcessor::histogramFactory`. You can do this by changing the `CMakeLists.txt` to look for the AIDA package by uncommenting the lines after (and including) `FIND_PACKAGE( AIDA )`

Section 4

Questions ?

Some useful resources

- **https://ilcsoft.desy.de** - main entry point to iLCSoft
- **https://github.com/iLCSoft** - github organisation of iLCSoft (almost all packages are maintained here)
- **https://github.com/ILDAnaSoft** - github organisation hosting benchmark analysis
- **https://github.com/ILDAnaSoft/ILDDoc** - documentation repository, where also these tutorial slides will appear in the `tutorial` folder

Section 5

Bonus - Event Display

Event Display - disclaimer

The Event Display has been observed to be sensitive to the environment it is run in and the following might not work out of the box.

We are aware of the problem, but have not yet been able to conclusively fix it.

running the event display

- CED: is a client server event display, based on OpenGL and glut
- start the event display (server) first:

```
glced &
```

- then we can view the reconstructed events via Marlin:

```
Marlin MarlinStdRecoViewer.xml \
--global.GearXMLFile=Gear/gear_ILD_l5_o1_v02.xml \
--global.LCIOInputFiles=bbudsc_3evt_REC.slcio
```

- or we can start both, glced and Marlin in one go:

```
ced2go -s 1 -d $lcgeo_DIR/ILD/compact/ILD_l5_v02/ILD_l5_v02.xml \
bbudsc_3evt_REC.slcio
```

using the event display

- detailed documentation for CED:
  - https://github.com/iLCSoft/CED/blob/master/doc/manual.pdf
- basic comands (keystrokes)

Key	Command
ESC	quit CED (glced)
h	toggle display of keybord shortcuts
f	front view
s	side view
‘	toggle all object layers
$\sim$	toggle all detector layers
1-0	toggle layers 1-10

- all commands (and more) also available from the menue

Bonus Exercise: familiarize yourself with the event display

- visualize only the simulated (digitized) tracker and calorimeter hits
- visualize only the final track collection *MarlinTrkTracks*
- visualize only the final PFO collection *PandoraPFO*
- try the picking feature:
  - double click close to a hit/track/PFO object
- create a nice view with the detector partly cut away
  - save a screen shot of this