iLCSoft Tutorial

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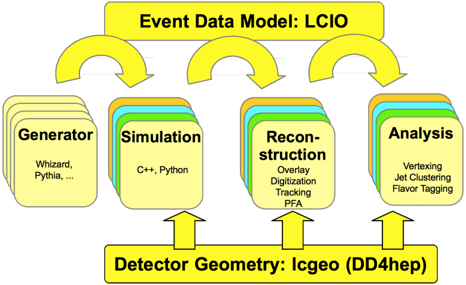
Outline

- 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

Introduction to iLCSoft

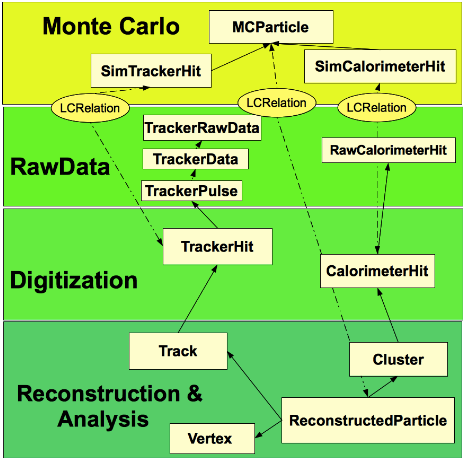
Overview iLCSoft

- 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*



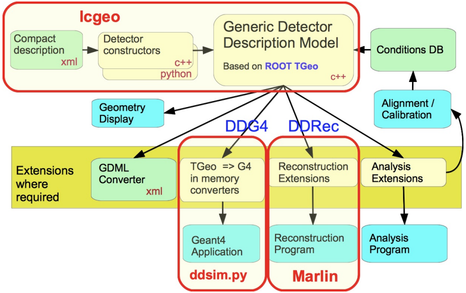
LCIO

- 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

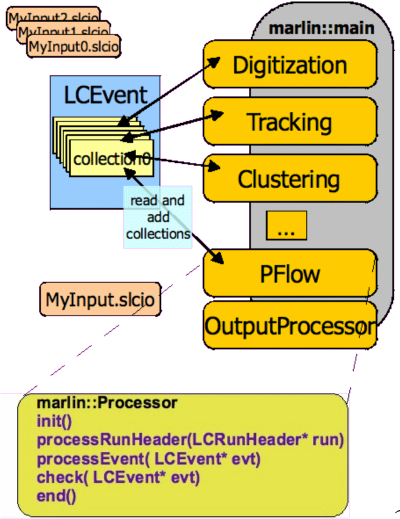
- DD4hep (*Detector Description for HEP*) is the common detector geometry description for iLCSoft
- the **same** detector model is used for:
  - simulation, reconstruction, visualization and analysis
- the detector is fully described via a set of:
  - C++ detector constructors
  - XML files (*compact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



http://aidasoft.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* or via *MarlinGUI*
- 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`

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

- got 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 *SL6* in *afs* and *cvmfs*, e.g.:

iLCSoft v02-00-01 reference installations

```
/afs/desy.de/project/ilcsoft/sw/x86_64_gcc49_sl6/v02-00-01
/cvmfs/ilc.desy.de/sw/x86_64_gcc49_sl6/v02-00-01
```

configuration files for ILD are in ILDConfig - for v02-00-01:

```
/afs/desy.de/project/ilcsoft/sw/ILDConfig/v02-00-01
/cvmfs/ilc.desy.de/sw/ILDConfig/v02-00-01
```

or download from GitHub:

```
git clone https://github.com/iLCSoft/ILDConfig.git -b v02-00-01
```

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_gcc49_sl6/v02-00-01/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
```

- 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:

```
export PYTHONPATH=$ROOTSYS/lib:$PYTHONPATH
export PYTHONPATH=${LCIO}/src/python:${LCIO}/examples/python:${PYTHONPATH}
```

- open a file dumplcio.py and paste the following code:

```python
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 m in col:
        print m.getEnergy()
```

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 three slides

Marlin steering files - execute

```
<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 unised `<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

```xml
<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

```xml
<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 ...
```

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
```

- 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
```

- 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

Exercise 4: 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

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 [1]:

```
cd RootMacros
root -l
    root [0] .x ./draw_simhits.C("bbudsc_3evt_REC_lctuple.root")
```

- see next slide for basic introduction to LCTuple

[1] example draw_etot.C is currently broken

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
  - too 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*

create your own Marlin package

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
```

create a steering file to run this package

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

Create your own Marlin package

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

```
PROJECT( mymarlin )
```

- 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 !

Exercise 5: 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

Questions ?