

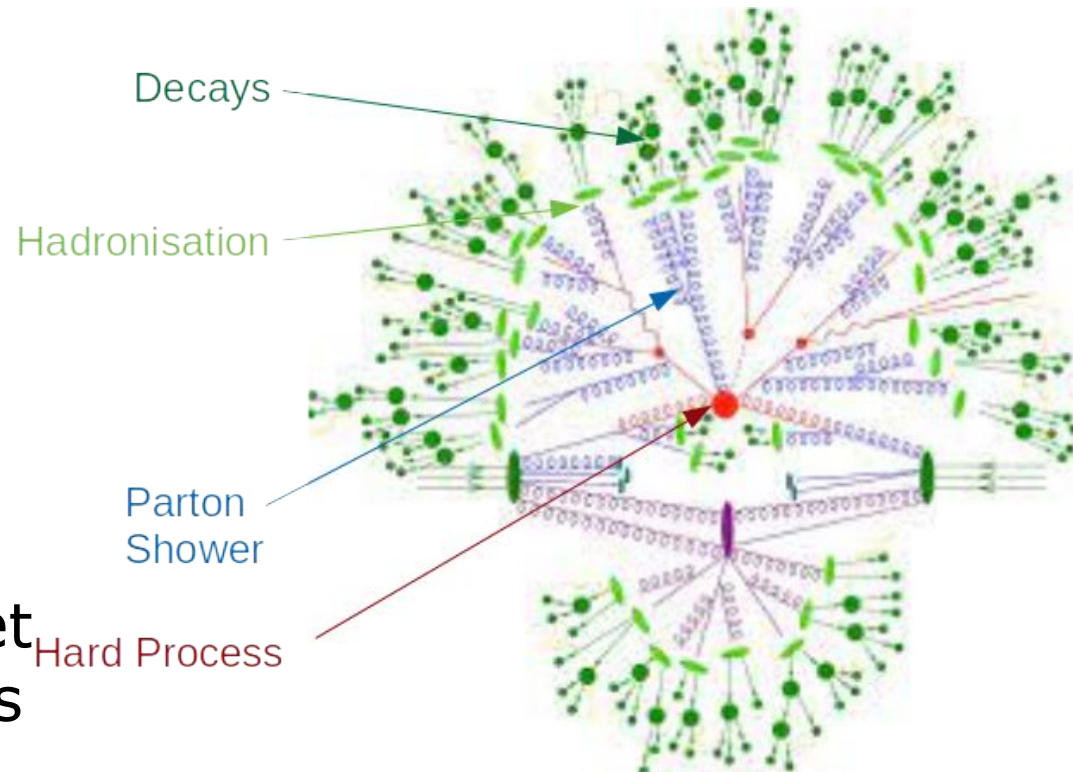
Herwig 7 Tutorial

CMS Off-shell Higgs workshop

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Introduction

- Herwig is a multi-purpose event generator
- Notable features:
 - Angular ordered and dipole parton showers
 - Cluster hadronisation model
- Particularly relevant for e.g. VBF topologies or jet substructure observables



H7 modes in CMS

1) Standalone

LO ME+PS - not covered here

2) Shower/Hadronization for externally provided LHE

ME calculation is done elsewhere, gridpack is given as input to H7

3) H7-matchBox

possibility to **use external ME** generators of higher accuracy **within H7** e.g., aMCatNLO, openLoops

CMS Herwig7Interface

Herwig is called from CMSSW using the Herwig7interface:

<https://github.com/cms-sw/cmssw/tree/master/GeneratorInterface/Herwig7Interface>

Provides the Herwig7GeneratorFilter (for generating full events in Herwig) and the Herwig7HadronizerFilter (for showering external LHE files)

Documentation on:

<https://twiki.cern.ch/twiki/bin/viewauth/CMS/Herwig7Interface>

Which CMS release?

H7 supported in:

CMSSW_10_6_X (Run II UL production)

CMSSW_12_4_X (2022 production)

CMSSW master

Always use latest/greatest last digit (updated semi-regularly)

Latest CMSSW versions have **H7.2.2**

To check your Herwig version: ``scram tool info herwig7``

Upgrade to Herwig 7.3/7.4 under consideration - **let us know if you need newer features!**

CMSSW lxplus setup

In this tutorial we will use: **CMSSW_13_3_2** on **lxplus 9**

All cards, as well as the commands to run, are available at:
<https://github.com/Offshell-Workshop-LPC/Herwig-tutorial>

```
# login to lxplus, we assume bash as shell
```

```
# i.e., echo $SHELL should print out '/bin/bash'
```

```
cmsrel CMSSW_13_3_2
```

```
cd CMSSW_13_3_2/src
```

```
cmsenv
```

```
# Clone the repository for this tutorial:
```

```
git clone git@github.com:Offshell-Workshop-LPC/Herwig-tutorial.git
```

**H7 with externally
provided LHE**

Hadronising external LHEs

Herwig can be used to generate full events from external ME providers (in CMS usually Madgraph or POWHEG)

Gives more accurate predictions of hard process
Most common mode of running in CMS

Older cards did this using the Herwig7GeneratorFilter, but this lead to a bug where the incorrect LHE events were saved

In this tutorial we will use the new Herwig7HadronizerFilter

Looking at the fragment

```
from Configuration.Generator.Herwig7Settings.Herwig7StableParticlesForDetector_cfi import *
from Configuration.Generator.Herwig7Settings.Herwig7CH3TuneSettings_cfi import *
from Configuration.Generator.Herwig7Settings.Herwig7_7p1SettingsFor7p2_cfi import *
from Configuration.Generator.Herwig7Settings.Herwig7LHECommonSettings_cfi import *
from Configuration.Generator.Herwig7Settings.Herwig7LHEMG5aMCatNLOSettings_cfi import *
```

Herwig settings for lhe

```
externalLHEProducer = cms.EDProducer("ExternalLHEProducer",
    args =
    cms.vstring('/cvmfs/cms.cern.ch/phys_generator/gridpacks/2018/13TeV/powheg/v2/gg_H_quark-mass-effects_ZZ_NNP31_13TeV/gg_H_quark-mass-effects_ZZ12nu_NNP31_13TeV_M250/v2/gg_H_quark-mass-effects_ZZ12nu_NNP31_13TeV_M250.tgz'),
    nEvents = cms.untracked.uint32(5000),
    numberOfParameters = cms.uint32(1),
    outputFile = cms.string('cmsgrid_final.lhe'),
    scriptName = cms.FileInPath('GeneratorInterface/LHEInterface/data/run_generic_tarball_cvmfs.sh'),
    generatorModule = cms.untracked.string('LHEInterface'),
    postGenerationCommand = cms.untracked.vstring('mergeLHE.py', '-n', '-i', 'thread*/cmsgrid_final.lhe', '-o', 'cmsgrid_final.lhe'),
)
```

LHE generation from gridpack

Merge lhes from different threads and number events

```
generator = cms.EDFilter("Herwig7HadronizerFilter",
    herwig7StableParticlesForDetectorBlock,
    herwig7CH3SettingsBlock,
    herwig7LHECommonSettingsBlock,
    herwig7LHEMG5aMCatNLOSettingsBlock,
    herwig7p1SettingsFor7p2Block,
    configFiles = cms.vstring(),
    process_settings = cms.vstring('set /Herwig/EventHandlers/EventHandler:CascadeHandler:MPIHandler NULL'),
    parameterSets = cms.vstring('herwig7CH3PDF', 'herwig7CH3AlphaS', 'herwig7CH3MPISettings', 'hw_7p1SettingsFor7p2',
    'herwig7StableParticlesForDetector', 'hw_lhe_common_settings', 'Herwig7LHEPowhegSettings', 'process settings'),
    crossSection = cms.untracked.double(-1),
    dataLocation = cms.string('${HERWIGPATH:-6}'),
    eventHandlers = cms.string('/Herwig/EventHandlers'),
    filterEfficiency = cms.untracked.double(1.0),
    generatorModule = cms.string('/Herwig/Generators/EventGenerator'),
    repository = cms.string('${HERWIGPATH}/HerwigDefaults.rpo'),
    run = cms.string('GluGluHToZZTo2L2Nu_M250_Powheg_JHUGen_Herwig7'),
    runModeList = cms.untracked.string("read,run"),
    seed = cms.untracked.int32(12345)
)
```

Predefined settings

<https://github.com/cms-sw/cmssw/tree/master/Configuration/Generator/python/Herwig7Settings>

ls \$CMSSW_RELEASE_BASE/src/Configuration/Generator/python/Herwig7Settings

Herwig7CH2TuneSettings_cfi.py and **Herwig7CH3TuneSettings_cfi.py**

tunes containing PDF, α_s and MPI settings- CH3 is the recommended default

Herwig7_7p1SettingsFor7p2_cfi.py revert certain settings to Hw7.1 defaults - required for tune

Herwig7StableParticlesForDetector_cfi.py set stable particles

Herwig7LHECommonSettings_cfi.py settings for reading in the files

Herwig7LHEPowhegSettings_cfi.py additional settings for POWHEG lhes

Herwig7LHEMG5aMCatNLOSettings_cfi.py additional settings for MG5 lhes

Herwig7CommonMergingSettings_cfi.py settings for merging to ME processes with extra jets

Herwig7PSWeightsSettings_cfi.py turn on saving Parton Shower weights - not currently recommended, see:

<https://indico.cern.ch/event/1282424/contributions/5392893/attachments/2642930/4574147/presentation.pdf>

Settings block cheat-sheet

For all processes:

Herwig7CH3TuneSettings,
Herwig7StableParticlesForDetector,
Herwig7_7p1SettingsFor7p2

Also documented on:

<https://twiki.cern.ch/twiki/bin/viewauth/CMS/Herwig7Interface>

Setup	Additional required blocks	Notes
Standalone Herwig (LO)	-	
Powheg LHE	Herwig7LHECommonSettings, Herwig7LHEPowhegSettings	
MG5 (no additional jets)	Herwig7LHECommonSettings, Herwig7LHEMG5aMCatNLOSettings	
MG5 mlm merging (LO)	Herwig7CommonMergingSettings	Include the following in the process settings: 'set FxFxHandler:MergeMode TreeMG5', 'set FxFxHandler:njetsmax N'
MG5 FxFx merging (NLO)	Herwig7CommonMergingSettings	Include the following in the process settings: 'set FxFxHandler:MergeMode FxFx', 'set FxFxHandler:njetsmax N'
Matchbox	"Matchbox" block from today's example	"Matchbox" block will be added into Common settings once Herwig Gridpacks have been implemented

Looking at the output

Now try running this fragment (instructions in the README)

Produces a number of different files:

- **HerwigConfig.in** - Herwig input file produced by CMSSW
- `GluGluHToZZTo2L2Nu_M250_Powheg_JHUGen_Herwig7.run` - non-human readable run card produced by Herwig
- **`GluGluHToZZTo2L2Nu_M250_Powheg_JHUGen_Herwig7-S123456790.log`** - Detailed Herwig log (includes full event record for a few events)
- **`GluGluHToZZTo2L2Nu_M250_Powheg_JHUGen_Herwig7-S123456790.out`** - Herwig process summary (including xs)
- `GluGluHToZZTo2L2Nu_M250_Powheg_JHUGen_Herwig7-S123456790.tex` - Herwig credits
- `GluGluHToZZTo2L2Nu_M250_Powheg_JHUGen_Herwig7.root` - CMS GEN data-tier ROOT file for further processing
- `GluGluHToZZTo2L2Nu_M250_Powheg_JHUGen_Herwig7_inNANOAOGEN.root` - Events in NanoAOD-like format
- `GluGluHToZZTo2L2Nu_M250_Powheg_JHUGen_Herwig7.yoda` - Rivet histograms

Have a look at the text files in **red**, as well as the NanoAODGen record

Try producing plots of the rivet histograms using `rivet-mkhtml`

H7-matchbox

H7matchbox

Preferred method to run Herwig, gives access to:

- Dipole Shower
- More advanced Matching+Merging
- More ME providers (e.g. VBFNLO, Njets - still need to be implemented)

Not yet used much in CMS (though some [DY examples](#) available)

“Herpacks” to ship integration grids in development

Many processes need to be validated and some features need to be implemented - contact us if you are interested in developing a process for your analysis

Matchbox fragment

```
Matchbox = cms.vstring( 'read snippets/Matchbox.in',
'read snippets/PPCollider.in',
'cd /Herwig/EventHandlers',
'set EventHandler:LuminosityFunction:Energy 13000*GeV',
'## Model assumptions',
'read Matchbox/StandardModelLike.in',
'read Matchbox/DiagonalCKM.in',
'## Set the order of the couplings',
'cd /Herwig/MatrixElements/Matchbox',
'set Factory:OrderInAlphaS 0',
'set Factory:OrderInAlphaEW 2',
'## Define l = e, mu, tau',
'do Factory:StartParticleGroup l+',
'insert Factory:ParticleGroup 0 /Herwig/Particles/e+',
'insert Factory:ParticleGroup 0 /Herwig/Particles/mu+',
'insert Factory:ParticleGroup 0 /Herwig/Particles/tau+',
'do Factory:EndParticleGroup',
'do Factory:StartParticleGroup l-',
'insert Factory:ParticleGroup 0 /Herwig/Particles/e-',
'insert Factory:ParticleGroup 0 /Herwig/Particles/mu-',
'insert Factory:ParticleGroup 0 /Herwig/Particles/tau-',
'do Factory:EndParticleGroup',
'## Select the process',
'do Factory:Process p p -> l+ l-',
'# read Matchbox/MadGraph-GoSam.in',
'# read Matchbox/MadGraph-MadGraph.in',
'read Matchbox/MadGraph-OpenLoops.in',
'set /Herwig/Cuts/ChargedLeptonPairMassCut:MinMass 50*GeV',
'set /Herwig/Cuts/ChargedLeptonPairMassCut:MaxMass 14000*GeV',
'cd /Herwig/MatrixElements/Matchbox',
'set Factory:ScaleChoice /Herwig/MatrixElements/Matchbox/Scales/LeptonPairMassScale',
'read Matchbox/MCatNLO-DefaultShower.in',
'# read Matchbox/NLO-NoShower.in',
'# read Matchbox/LO-NoShower.in',
'read Matchbox/FiveFlavourScheme.in',
'do /Herwig/MatrixElements/Matchbox/Factory:ProductionMode',
),
```

Set coupling orders for
hard process

Define process

Choose hard process
provider

How does the
dipole shower
fragment differ?

Conclusions

Herwig is a multi-purpose event generator - can be used to understand parton shower and hadronisation uncertainties, and can provide better modelling in some regions (e.g. VBF)

Herwig7HadronizerFilter can shower external lhe files - remember to use correct settings blocks for tune and matching to external ME

Matchbox provides a newer method with much more functionality - if you would like to validate a new process, contact us!

Further resources

Herwig session in CMS generators tutorial:

<https://indico.cern.ch/event/1360658/#b-542339-herwig-session-part1>

Herwig website - tutorials for basic usage:

<https://twiki.cern.ch/twiki/bin/viewauth/CMS/Herwig7Interface>

CMS Herwig twiki: <https://herwig.hepforge.org/>

If you have any questions, feel free to contact me (Dominic Stafford) or Konstantinos Theofilatos!