PHYSICS AT THE TERA SCALE
Helmholtz Alliance

DESY

GENSER Validation with the HepMC Analysis Tool

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Generator Services meeting
5th May 2010

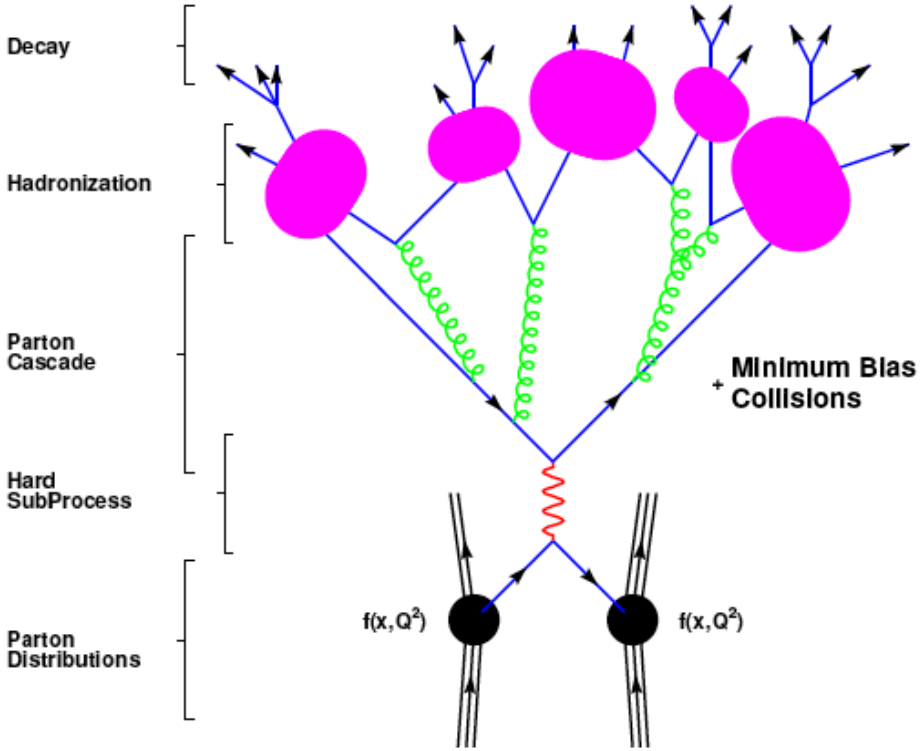
Outline

- The HepMC Analysis Tool
- GENSER Validation
- Outlook

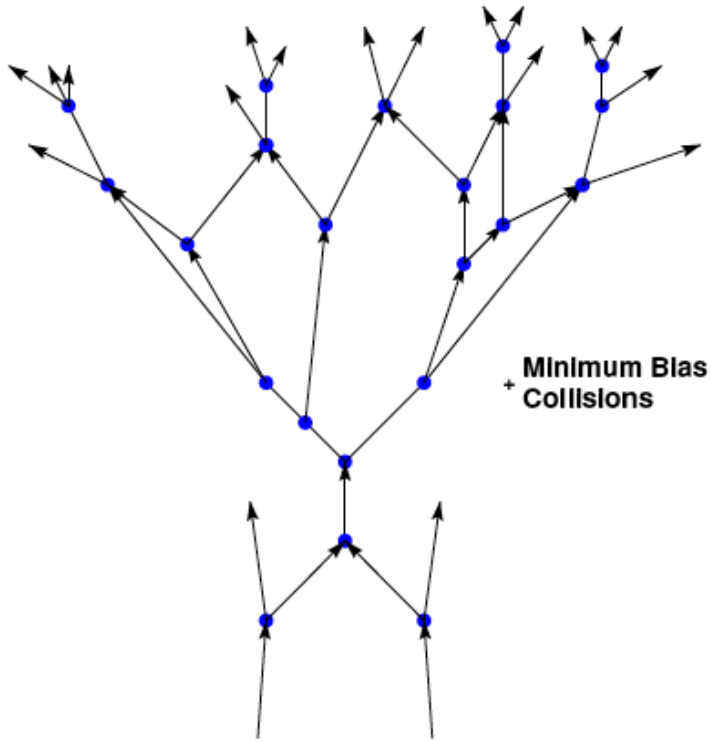
The Hep MC record

M. Dobbs and J.B. Hansen, Comput. Phys. Commun. 134 (2001) 41

- Object oriented, C++, event record.
- Predecessor: HEPEVT, the Fortran HEP standard (Many extensions supported HepMC)



HepMC →



Events stored in graph structure.

The Hep MC record

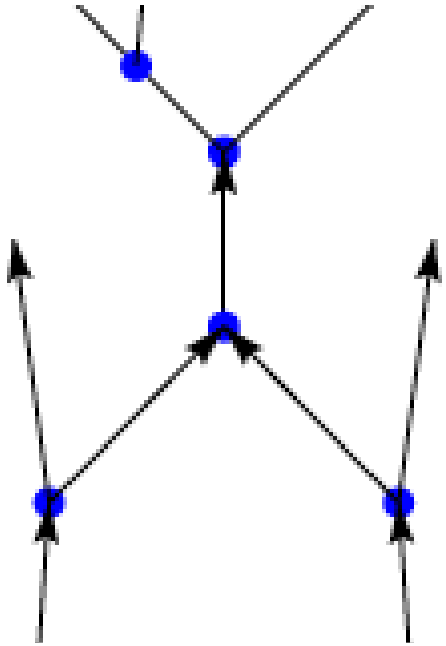
M. Dobbs and J.B. Hansen, Comput. Phys. Commun. 134 (2001) 41

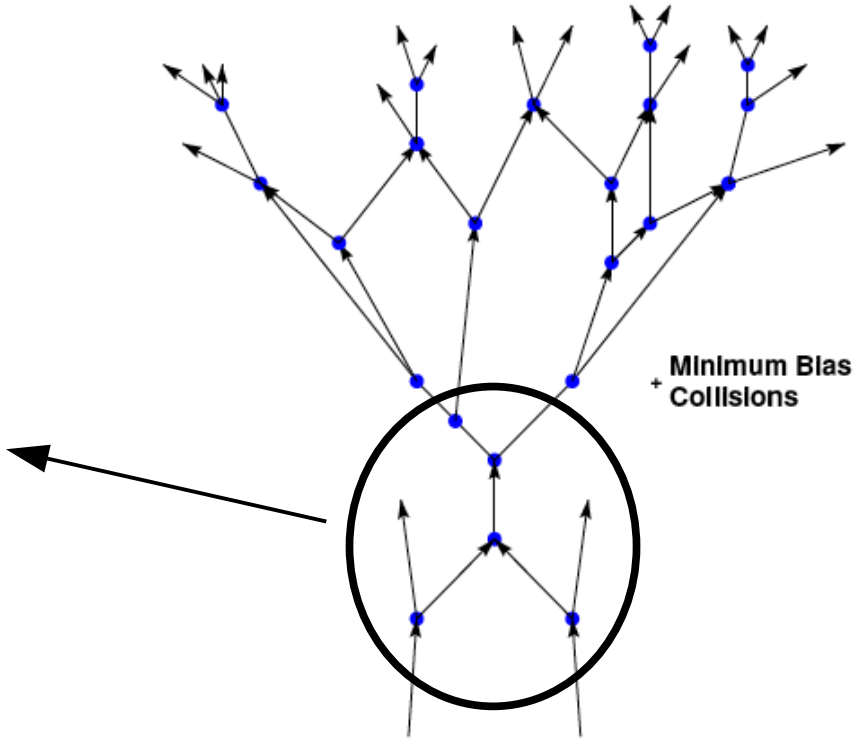
- Object oriented, C++, event record.
- Predecessor: HEPEVT, the Fortran HEP standard (Many extensions supported HepMC)

Example of Classes:

HepMC::GenEvent
Beam particles,
events weights,
iterators, etc.

HepMC::GenParticle
PDG-ID,
4-momenta,
masses,
mother/daughter vertices,
etc





The HepMC Analysis Tool

- Tool for generator validation and comparison by performing analysis on the HepMC event record. Provides a simple set-up for generator analysis.

- Used for generator studies in experiments and MC schools.

- Originally developed as an extension to the number based checks done by the GENSER team.

- Analysis possible for all aspects of the MC event:
  Hard process, parton level studies, hadron level studies, decays.
  Jet algorithm integrated in HepMC Analysis tool (FastJet package).

The HepMC Analysis Tool

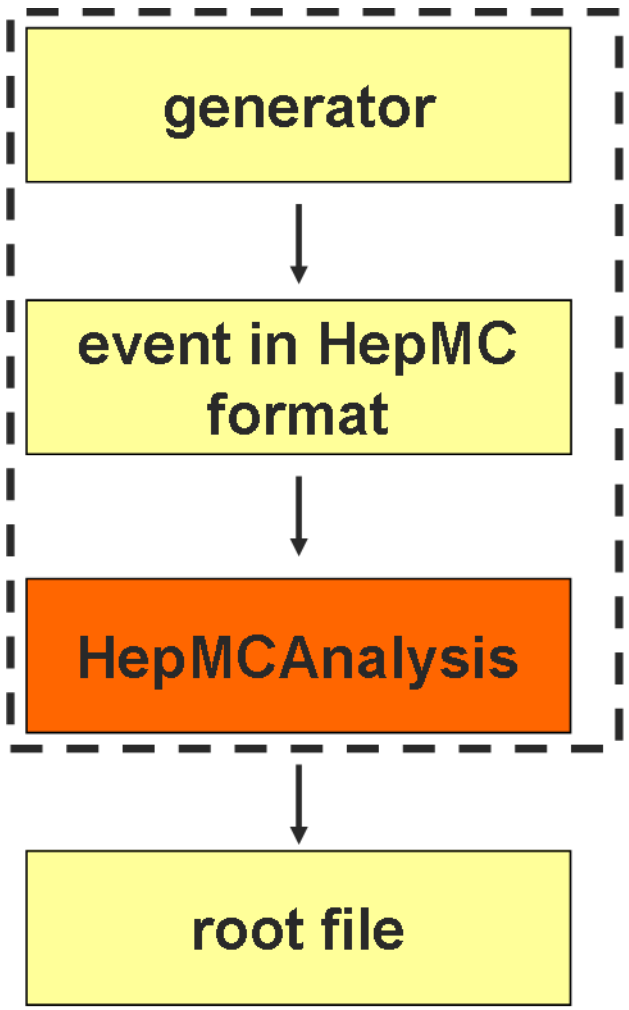
- **Minimal dependency on other software packages**
  – only needs root besides the GENSER installation.

- **Homepage: http://hepmcanalysistool.desy.de/**
  (tar-ball, instructions, documentation, talks, etc...)

- **Easy to install: Good instructions on**
  http://hepmcanalysistool.desy.de/Doxygen/html/index.html

- **Straight forward to use with the existing analysis classes and the provided examples for Cascade, Herwig, Herwig++, Pythia 6, Pythia8.**

Technical Implementation

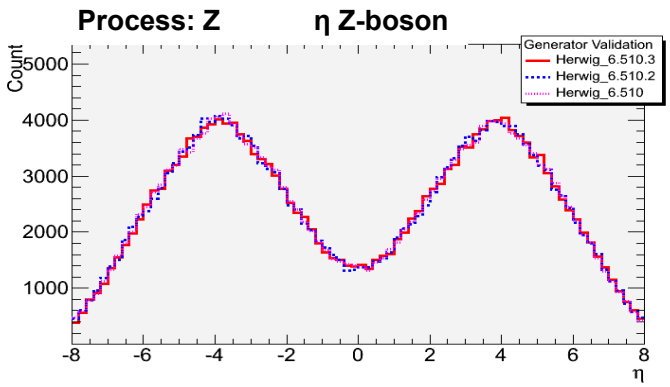


example programs and steering files.

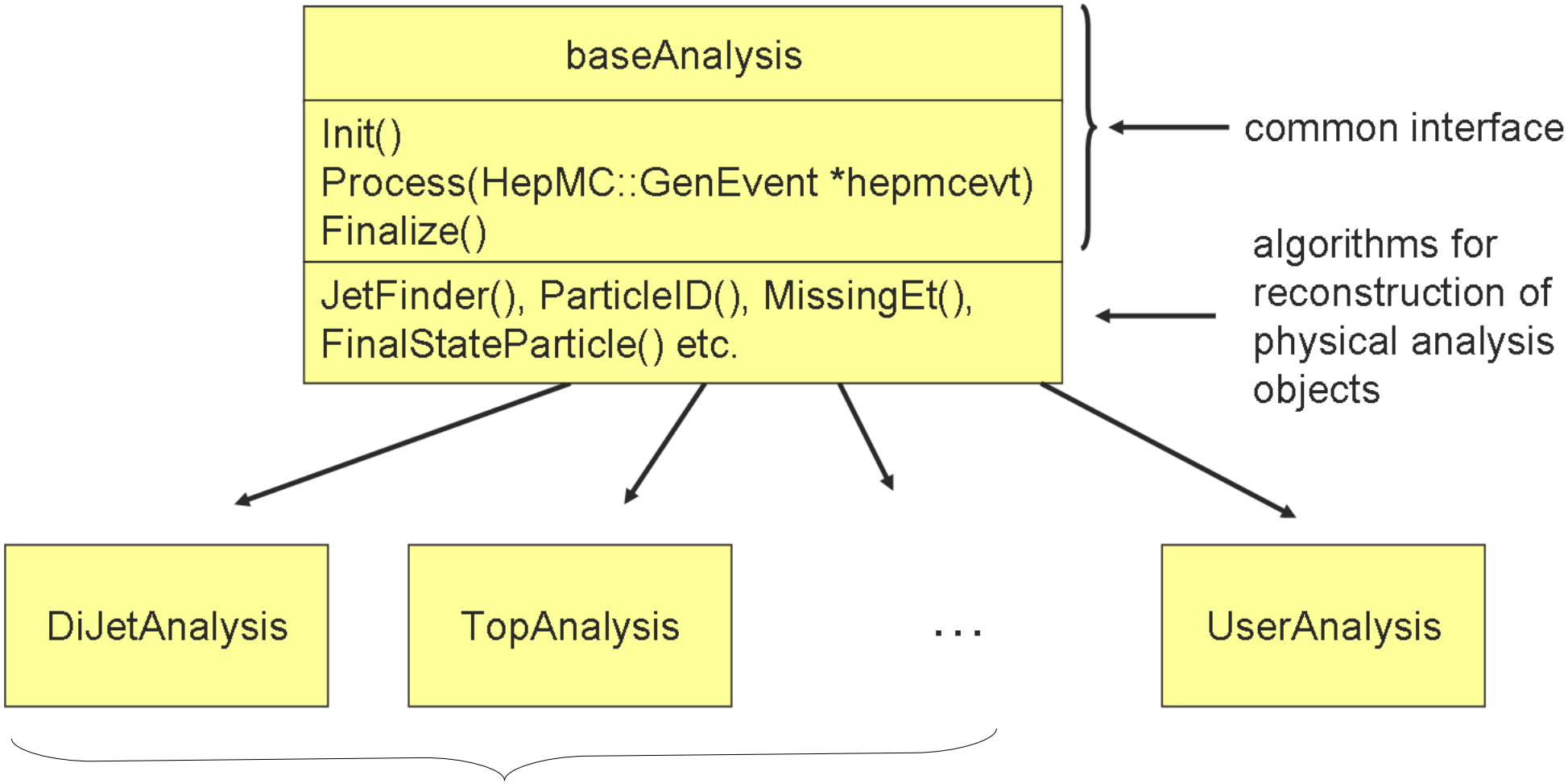
All libraries from GENSER.

class library with physics analyses

scripts for comparisons + web display



Technical Implementation



The HepMC Analysis Tool currently provides ready made analyses for:

Di-jet, Top, W+Jet, Z, Etmiss, UE, Elastic Scattering

Validation of MC generators

Validation of MC generators

Validation philosophy:

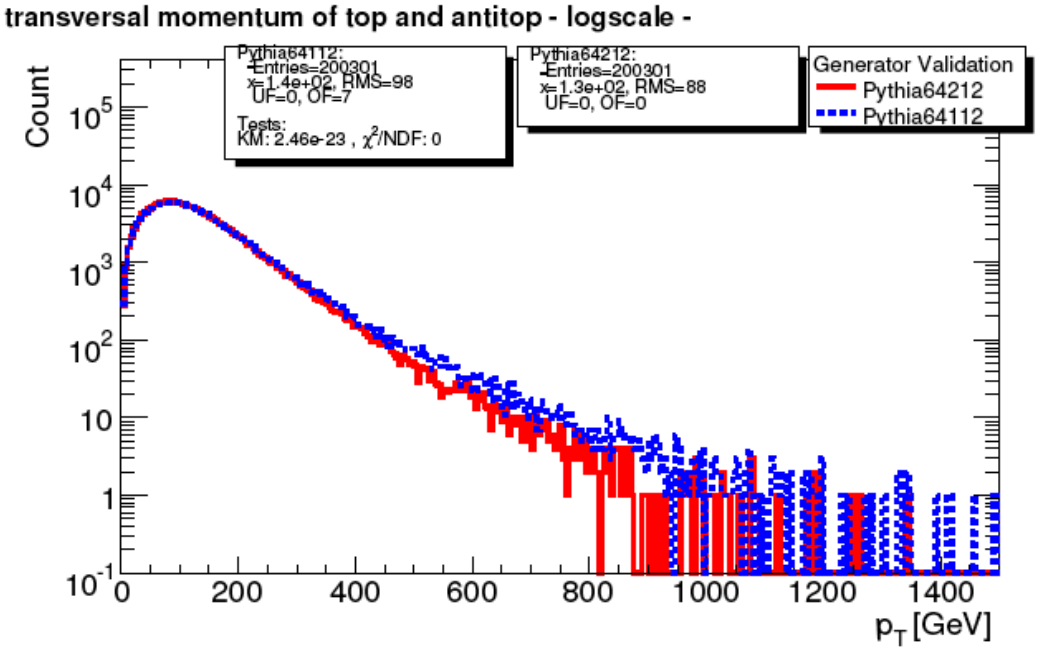
Compare new releases with previous generator versions.
Differences should be understood.

Validations have been done for the lastest GENSER builds of the following processes and generators:

	Pythia8	Pythia6	Herwig++	Herwig6	CASCADE	Tauola (with Herwig6)
Di-jet	OK	OK	OK	OK	OK	-
Top	OK	OK	OK	OK	only latest version	-
Tau	OK	OK	OK	OK	-	Only latest version
W	OK	OK	OK	OK	-	-
Z	OK	OK	OK	OK	-	-
W+Jet	OK	OK	OK	OK	-	-
Z+Jet	OK	OK	OK	OK	-	-
UE	OK	OK	OK	-	-	-
Elastic scat	OK	-	-	-	-	-

More processes and generators to come...

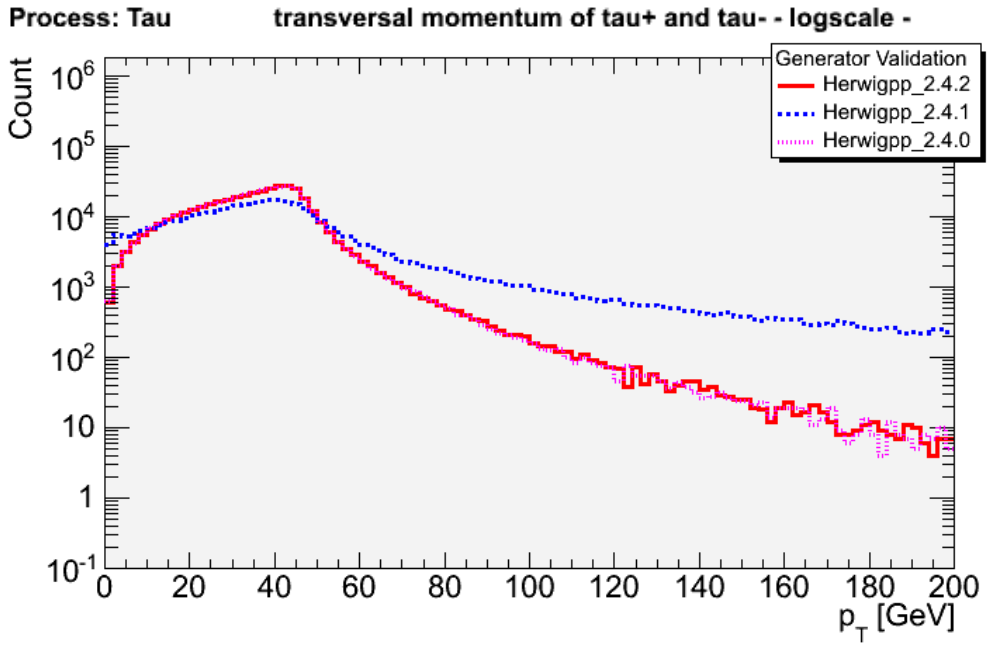
Validation examples



Top production in Pythia 6.4.11 / 6.4.21

Transverse momentum spectra of top quarks.

A bug was found in 6.4.11. This was fixed in 6.4.19 and later version.



Tau production in Herwig 2.4.0-2.4.3
$qqbar \rightarrow Z \rightarrow \tau\tau$

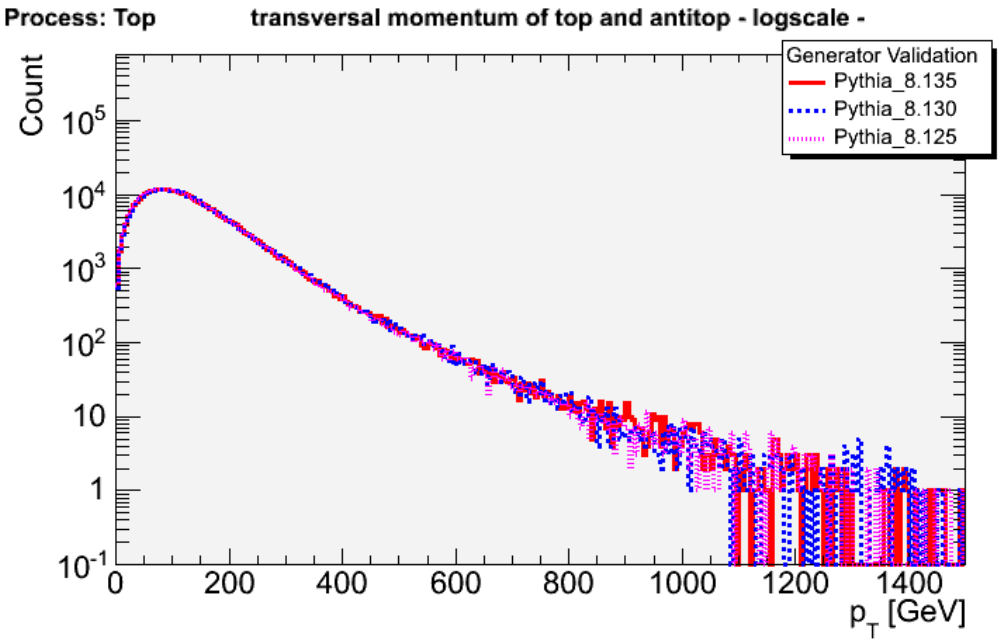
Large deviation between 2.4.0 and 2.4.1. but possibly fixed in 2.4.2.

Release notes for 2.4.2 concerns boosts and tau decays, e.g.: *"Fixes to the numerical stability of tau decays which should address many of the momentum violation problems that have been reported."*

Need to clarify with authors...

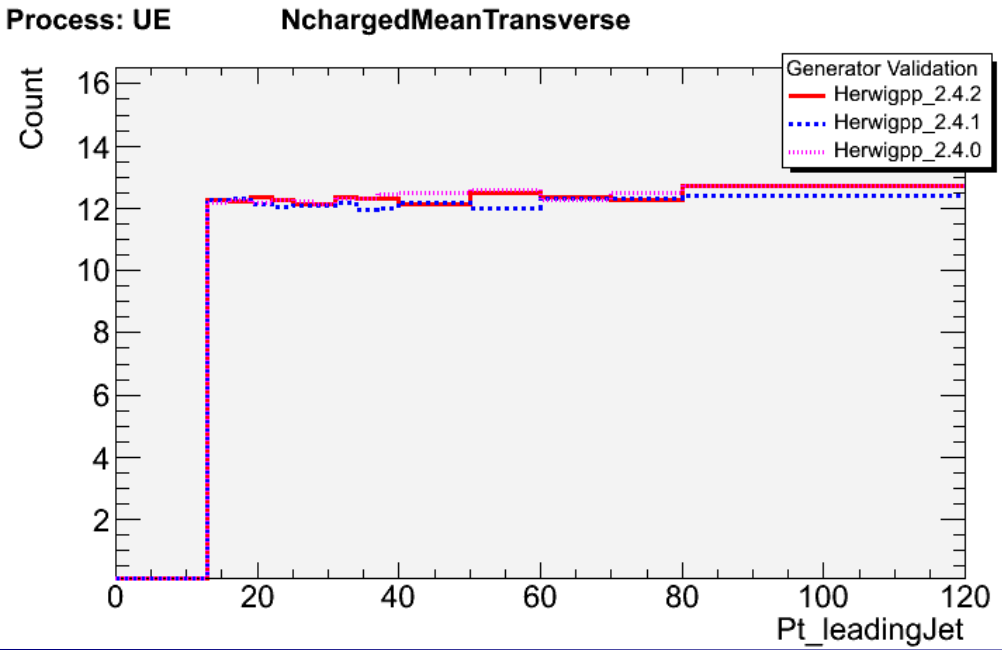
Validation examples

But in most cases things look good:



Top production in Pythia 8.125 - 8.135

Transverse momentum spectra of top quarks.



Underlying event in Herwig 2.4.0-2.4.3

Averaged charged mean multiplicity transverse to the leading jet in di-jet events.

Generator Validation web page

Genser Homepage: http://lcgapp.cern.ch/project/simu/generator/ →
Generators Validation → Validation using HepMC Analysis Tool

HepMC Analysis Tool Validation

Generator Services | Last modified 05/04/2010 21:49:55

PYTHIA6: Di-Jets Top Tau Z W Z+Jet W+Jet UE (dijet events) (6.422.2 ok)
PYTHIA8: Di-Jets Top Tau Z W Z+Jet W+Jet UE (dijet events) Elastic Scat. (8.135 ok)
HERWIG6: Di-Jets Top Tau Z W Z+Jet W+Jet (6.510 ok)
HERWIG++: Di-Jets Top Tau Z W Z+Jet W+Jet UE (dijet events) (2.4.2 ok)
CASCADE: Di-Jets (2.0.2 ok) Top (Only latest version)
Tauola: Tau (Only latest version)

Latest generator version (above in parantheses) is validated against previous generator version(s).

Contact: albert.knutsson[nospam]desy.de

Home of the HepMCAnalysisTool: http://hepmcanalysistool.desy.de/

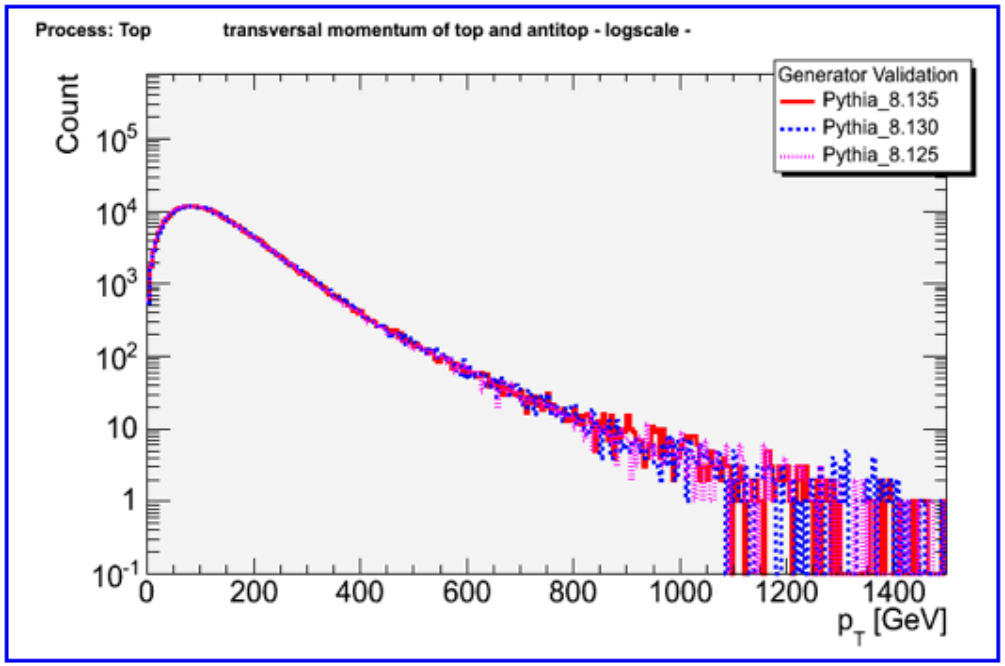
Generator validation

Validation plots - Pythia8 - Top

For these plots the following setup was used:
configuration for HepMC Analysis Tool (analysis kind, steering file, etc.)
common steering of the generator
steering of the generator process
source code of the analysis

Links to processes: Di-Jets Top Tau Z Z+Jet W W+Jet UE (dijet events) Elast. Scatt. --Back to Generators Overview--

gif png eps tiff



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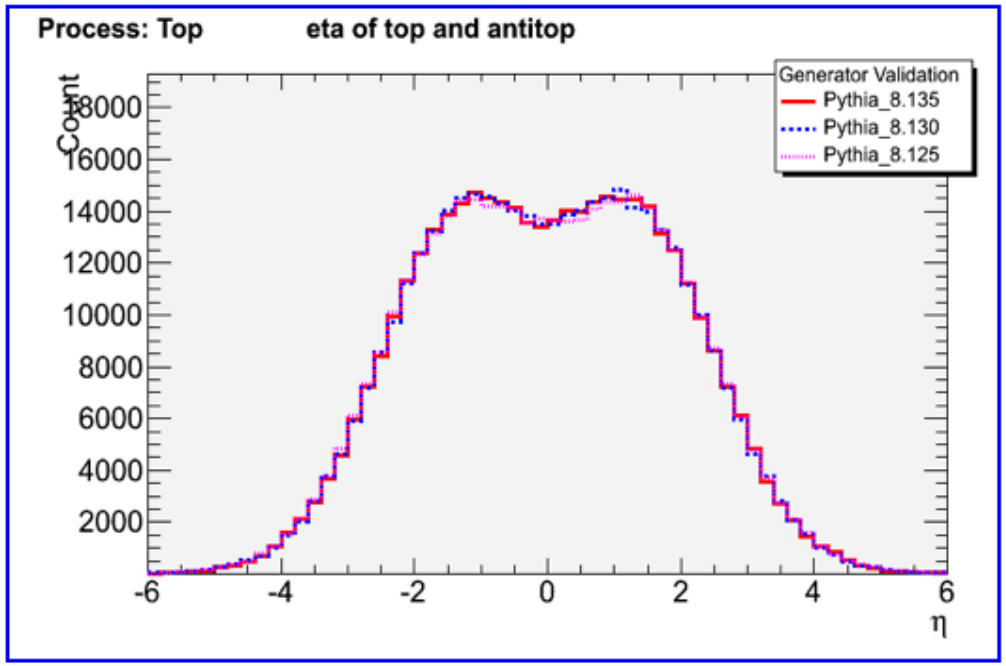
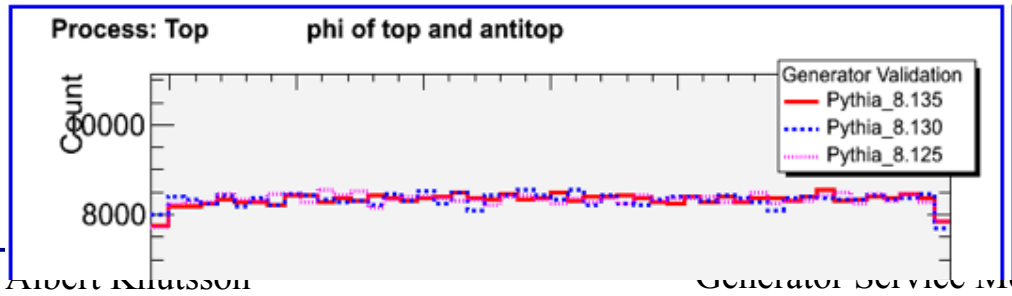
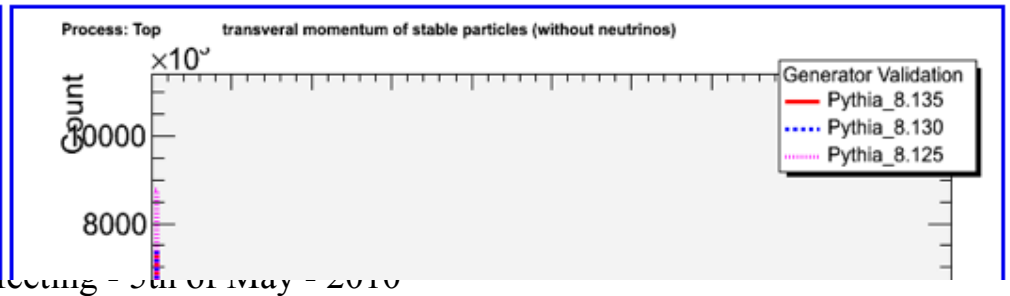


gif png eps tiff



gif png eps tiff



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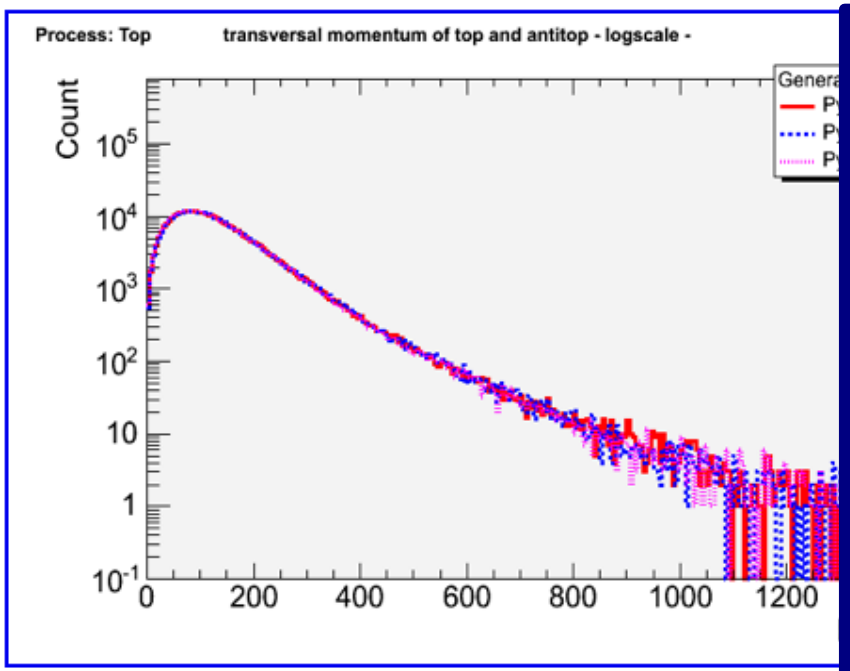
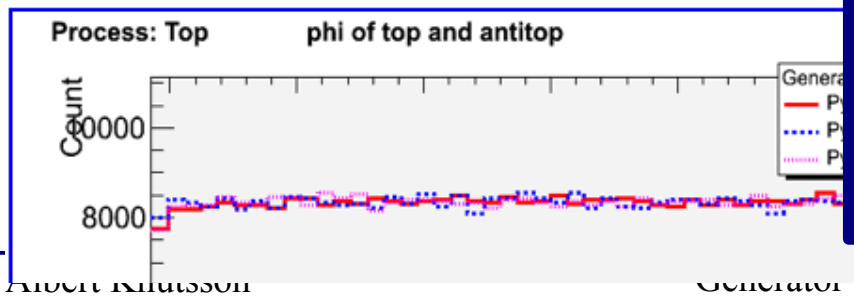


gif png eps tiff



gif png eps tiff

+ many more distributions. Example for top analysis:

- **transversal momentum of top and antitop**
- **transversal momentum of top and antitop**
- **eta of top and antitop**
- **phi of top and antitop**
- **transveral momentum of stable particles (without neutrinos)**
- **eta of stable particles (without neutrinos)**
- **phi of stable particles (without neutrinos)**
- **transveral momentum of charged stable particles**
- **eta of charged stable particles**
- **phi of charged stable particles**
- **number of charged particles in the event**
- **transvers momentum of top pair**
- **phi between W from top and W from tbar**
- **phi between top and tbar**
- **phi between W (from top) and top (also for tbar)**
- **transversal momentum of W**
- **eta of W**
- **phi of W**
- **Nr of Jets**
- **Leading Jet Transverse Momentum**

Generator validation

Validation plots - Pythia8 - Top

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Links to processes: Di-Jets Top Tau Z Z+Jet

Typical steering card for the HepMC analysis tool...

```
# Nr of Events to be generated
nevents                          200000
# randomseed ...
# if no randomseed is specified time in seconds will be set
rseed                            1234567

# The histograms will be saved into File
OutputFileName                   pythia8_Pythia8_top.cmnd_125_200000ev.root

# use the following Configuration files for the generator
# several may be specified
ConfigFileNames                  configfiles/Pythia8_Common.cmnd
ConfigFileNames                  configfiles/Pythia8_top.cmnd

# enable Analysis to be performed
dijet_analysis                   false
z_analysis                       false
wplusjet_analysis                false
tau_analysis                     false
top_analysis                     true
ue_analysis                      false
etmiss_analysis                  false
elasScat_analysis                false
user_analysis                    false

# master switches for FSR, ISR and MI
# these switches are set in Pythia6_Common.config

# set Jet parameter
jet_coneRadius                   0.4
jet_overlapThreshold             0.75
jet_ptmin                        15.0
# lepton_ptmin                   15.0
# DeltaR_lepton_track            0.4
# max_eta                        2.5 # cut on tracks for jet finder
# min_pt                           0.5 # cut on tracks for jet finder
```

Generator validation

Validation plots - Pythia8 - Top

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Links to processes: Di-Jets Top Tau Z Z+Jet W W+Jet UE (dijet events) Elast. Generators Overview--

```
! ttbar production from gg fusion and qqbar
Top:gg2ttbar = on
Top:qqbar2ttbar = on
```

```
BeamRemnants:maxValQuark = 3
BeamRemnants:pickQuarkNorm = 5.00000
BeamRemnants:pickQuarkPower = 1.00000
BeamRemnants:primordialKT = on
BeamRemnants:primordialKThard = 2.10000
BeamRemnants:primordialKTremnant = 0.40000
BeamRemnants:primordialKTsoft = 0.40000
BeamRemnants:reconnectColours = on
BeamRemnants:reconnectRange = 2.50000
BeamRemnants:valenceDiqEnhance = 2.00000
BeamRemnants:valencePowerDinP = 2.00000
BeamRemnants:valencePowerMeson = 0.80000
BeamRemnants:valencePowerUinP = 3.50000
Beams:allowMomentumSpread = off
Beams:allowVertexSpread = off
Beams:eA = 7000.000
Beams:eB = 7000.000
Beams:eCM = 14000.000
Beams:frameType = 1
Beams:idA = 2212
Beams:idB = 2212
Beams:LHEF = void
Beams:maxDevA = 5.00000
Beams:maxDevB = 5.00000
Beams:maxDevTime = 5.00000
Beams:maxDevVertex = 5.00000
Beams:offsetTime = 0.0
Beams:offsetVertexX = 0.0
Beams:offsetVertexY = 0.0
Beams:offsetVertexZ = 0.0
Beams:pxA = 0.0
Beams:pxB = 0.0
Beams:pyA = 0.0
Beams:pyB = 0.0
Beams:pzA = 7000.000
Beams:pzB = -7000.000
Beams:sigmaPxA = 0.0
Beams:sigmaPxB = 0.0
Beams:sigmaPyA = 0.0
Beams:sigmaPyB = 0.0
Beams:sigmaPzA = 0.0
Beams:sigmaPzB = 0.0
Beams:sigmaTime = 0.0
Beams:sigmaVertexX = 0.0
Beams:sigmaVertexY = 0.0
Beams:sigmaVertexZ = 0.0
BoseEinstein:Eta = on
BoseEinstein:Kaon = on
BoseEinstein:lambda = 1.00000
BoseEinstein:Pion = on
BoseEinstein:QRef = 0.20000
BoseEinstein:widthSep = 0.0200000
Bottomonium:all = off
Bottomonium:gg2QQbar[1S0(8)]g = off
Bottomonium:gg2QQbar[3P0(1)]g = off
Bottomonium:gg2QQbar[3P1(1)]g = off
Bottomonium:gg2QQbar[3P2(1)]g = off
Bottomonium:gg2QQbar[3PJ(8)]g = off
Bottomonium:gg2QQbar[3S1(1)]g = off
Bottomonium:gg2QQbar[3S1(8)]g = off
Bottomonium:Ochib03P01 = 0.0900000
Bottomonium:OUpsilon1S08 = 0.0200000
```

... and so on...

Generator validation

Validation plots - Pythia8 - Top

For these plots the following setup was used:
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source code of the analysis

Links to processes: Di

TopAnalysis.cc

Go to the documentation of this file.

```
00001 #include <iostream>
00002 #include <sstream>
00003 #include <stdio.h>
00004 #include "HepMC/GenEvent.h"
00005 #include "HepMC/IO_GenEvent.h"
00006 #include "HepMC/GenParticle.h"
00007 #include "HepMC/GenVertex.h"
00008 #include "HepMC/IO_AsciiParticles.h"
00009 #include "HepMC/SimpleVector.h"
00010 #include "CLHEP/Vector/LorentzVector.h"
00011
00012 using namespace std;
00013
00014 // ROOT headers
00015 #include "TH1.h"
00016 #include "TH2.h"
00017 #include "TFile.h"
00018 #include "TMath.h"
00019 #include "TLorentzVector.h"
00020
00021 //top analysis header
00022 #include "../include/TopAnalysis.h"
00023
00024 //**********************
00025
00026 // empty default constructor
00027 TopAnalysis::TopAnalysis()
00028 {
00029 }
00030
00031 /// empty default destructor
00032 TopAnalysis::~TopAnalysis()
00033 {
00034 }
00035
00036
00037 int TopAnalysis::Init(double tr_max_eta, double tr_min_pt)
00038 {
00039   // specify default eta cut
00040   m_max_eta=tr_max_eta;
00041
00042   // specify default pt cut
00043   m_min_pt=tr_min_pt;
00044
00045   // default Output file name
00046   m_outputFileName="TopAnalysis.root";
00047   m_outputRootDir="Top";
00048
00049   //declaration of histograms
00050   m_evtnr=initHist(string("evtnr"),string("Event number"),string("Eventnumber"),1000, 0., 1000.);
00051   m_toppt=initHist(string("toppt"),string("transversal momentum of top and antitop"),string("p_{T} [GeV]"),300, 0., 1500.);
00052   m_toppt_log=initHist(string("toppt_logscale"),string("transversal momentum of top and antitop - logscale -"),string("p_{T} [GeV]"),300, 0., 1500.);
00053   m_topeta=initHist(string("topeta"),string("eta of top and antitop"),string("#eta"),60, -6., 6.);
00054   m_topphi=initHist(string("topphi"),string("phi of top and antitop"),string("#phi"),48, -3.15, 3.15);
```

Generator validation

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Direct links to the other processes

- Scripts for creating similar web-pages are provided for the user in the HepMC Analysis Tool tar-ball.

- To be added soon:
  - Link to log-file, e.g. for debugging.
  - More info: e.g. beam particles and c.o.m.

Outlook and Summary

Outlook / Plans

The visual histogram validation for GENSER is fully functional, but we want to do more...

- Fine tuning of scripts, web-page, plots, etc.
- Include more generators and processes in the validation.
- Higher statistics for better visual validation of tails...
- Complement histos with info from numerical tests:
  - Chi2 and Kolmogorov–Smirnov already implemented and used by the HepMC analysis crew (Johnert et al)
- Interface for studies on 4-vectors in the Les Houches Event Files as given by the MC generators
- **Goal: Automatic validation of the nightly GENSER builds**

Summary

- **The HepMC Analysis Tool and its usage for GENSER validation were presented.**

- **The validation is fully functionally and performed for the majority of the multipurpose generators.**

- **Work in progress and more ideas for improvements (suggestions welcome)**

albert.knutsson@cern.ch