LCG Meeting, CERN
1st October 2008

# *Introduction to MC-Tester*

http://mc-tester.web.cern.ch/MC-TESTER

Nadia Davidson, Piotr Golonka, Zbigniew Was
Tomasz Pierzchala, Tomasz Przedzinski

THE UNIVERSITY OF MELBOURNE

# MC-Tester in 1 Slide

/afs/cern.ch/sw/lcg/external/MCGenerators/mctester/1.212

- The tool allows semi-automated comparisons of decays of particles or resonances between Monte-Carlo programs.
- Written by P. Golonka, T. Pierzchala, Z. Was
  - Version 1.1 documented in Comput. Phys. Commun. in 2004
- Recent extensions (2008):
  - Can test decays in HepMC.
  - Was interfaced to the ATLAS Collaboration's Athena software framework.
  - Tested on B meason decays.
- Requires: ROOT, gcc/g++. LaTex, support for event record format (eg. HepMC)
- Consists of a set of libraries, ROOT Macros and example code

# List of References

- Documentation:
  - Website: http://mc-tester.web.cern.ch/MC-TESTER
  - P.Golonka, T.Pierzchala, and Z.Was, Comput. Phys. Commun. 157(2004)1, pp 39-62 doi: http://dx.doi.org/10.1016/S0010-4655(03)00466-1
  - Doxygen: http://mc-tester.web.cern.ch/MC-TESTER/doxygen_html/index.html
  - Savannah Bug Tracking: https://savannah.cern.ch/projects/mc-tester/

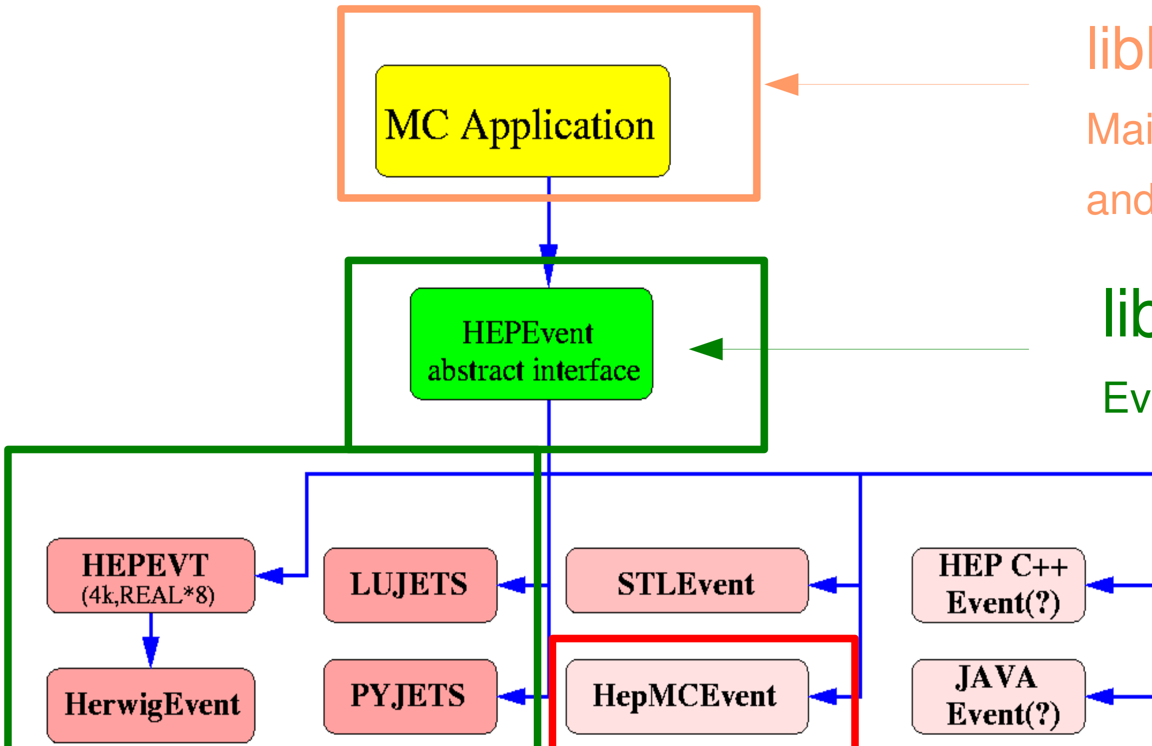
# Motivation for MC-Tester

- Very useful for the validation of programs such as TAUOLA and EVTGEN. For example:
  - Comparing a newly installed collaboration version against a benchmark version.
  - Comparing versions between experimental collaborations.
  - The migration of monte-carlo generators from Fortran to C++.

- Was originally created for tau decays from TAUOLA, but works for a variety of generators:
  - Can be Fortran or C++
  - Events written out as HEPEVT, LUJETS, PYJETS and HepMC
  - For any particle ( tau, B..)

# *MC-Tester – Technical Details*

- Implemented in C++, with FORTRAN interfaces for running within a FORTRAN Environment
- 3 dynamic (.so)/static(.a) libraries:




**event record interfaces**

libMCTester

Main code for analysing events and creating histograms

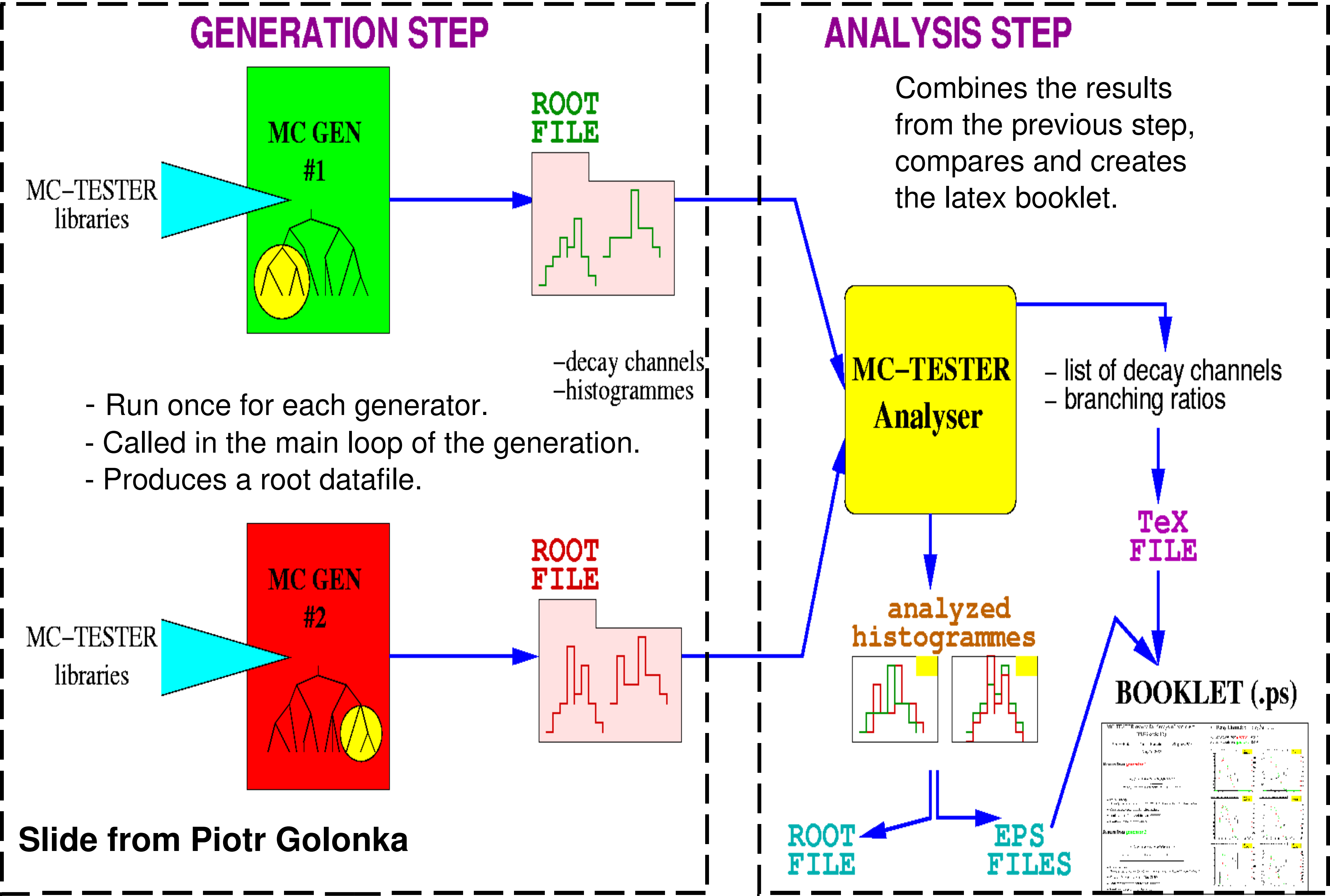
libHEPEvent

Event record interface

libHepMCEvent

HepMC event record interface

# How to run MC-Tester



# Example Output – Title Page

MC-TESTER results for decays of particle $\tau^-$ (PDG code 15).

Piotr Golonka   Tomasz Pierzchala   Zbigniew Was

March 27, 2008

**Results from generator 1.**

Pythia 8.1 demo; e-e at 92GeV, $Z^0$ single production
$Z^0$ decay to $\tau^\pm$ exclusively.
No $\pi$ decays.

- From directory:
  /afs/cern.ch/user/n/ndavidso/MC-TESTER-1.2/examples-C++/pythia
- Total number of analyzed decays: 1000008
- Number of decay channels found: 45 + 25

**Results from generator 2.**

Pythia 6.4.14 demo; e-e at 92GeV, $Z^0$ single production
$Z^0$ decay to $\tau^\pm$ exclusively. No $\pi$ decays.
Multi-body tau decay switched on.

- From directory:
  /afs/cern.ch/user/n/ndavidso/MC-TESTER-1.2/examples-F77/pythia
- Code version (from version file): PYTHIA 6.4.14
- Total number of analyzed decays: 1000000
- Number of decay channels found: 45 + 17

User Analysis: MCTest01

1

Particle decays being tested

Description as set by user for generator #1

Number of channels found (channel in common for #1 and #2 + channels unique in #1)

Total decays found in MC sample

Algorithm used for shape difference calculation

# Example Output – Channel List
## (usually a few pages long)

**Found decay modes:**

| Decay channel | Branching Ratio ± Rough Errors Generator #1 | Generator #2 | Max. shape dif. param. |
|---|---|---|---|
| $\tau^- \to \nu_\tau \pi^0 \pi^-$ | 25.3683 ± 0.0159% | 25.3085 ± 0.0159% | 0.04375 |
| $\tau^- \to e^- \tilde{\nu}_e \nu_\tau$ | 17.8479 ± 0.0134% | 18.1093 ± 0.0135% | 0.00000 |
| $\tau^- \to \mu^- \tilde{\nu}_\mu \nu_\tau$ | 17.3866 ± 0.0132% | 17.6326 ± 0.0133% | 0.00000 |
| $\tau^- \to \nu_\tau \pi^-$ | 11.0768 ± 0.0105% | 11.1765 ± 0.0106% | 0.00000 |
| $\tau^- \to \nu_\tau \pi^0 \pi^0 \pi^-$ | 9.1865 ± 0.0096% | 9.1171 ± 0.0095% | 0.09413 |
| $\tau^- \to \nu_\tau \pi^+ \pi^- \pi^-$ | 8.9837 ± 0.0095% | 8.8828 ± 0.0094% | 0.09368 |
| $\tau^- \to \nu_\tau \pi^0 \pi^+ \pi^- \pi^-$ | 4.2973 ± 0.0066% | 4.5319 ± 0.0067% | 0.30310 |
| $\tau^- \to \nu_\tau \pi^0 \pi^0 \pi^0 \pi^-$ | 1.0765 ± 0.0033% | 1.0090 ± 0.0032% | 0.00724 |
| $\tau^- \to \nu_\tau K^-$ | 0.7202 ± 0.0027% | 0.7138 ± 0.0027% | 0.00000 |
| $\tau^- \to \nu_\tau \pi^0 \pi^0 \pi^+ \pi^- \pi^-$ | 0.4990 ± 0.0022% | 0.0897 ± 0.0009% | 0.00000 |
| $\tau^- \to \nu_\tau \pi^0 K^-$ | 0.4785 ± 0.0022% | 0.4617 ± 0.0021% | 0.00000 |
| $\tau^- \to \nu_\tau K_L^0 \pi^-$ | 0.4624 ± 0.0022% | 0.4444 ± 0.0021% | 0.00000 |
| $\tau^- \to \nu_\tau \pi^- K_S^0$ | 0.4610 ± 0.0021% | 0.4449 ± 0.0021% | 0.00000 |
| $\tau^- \to \nu_\tau \pi^+ \pi^- K^-$ | 0.3902 ± 0.0020% | 0.5051 ± 0.0022% | 0.52330 |
| $\tau^- \to \nu_\tau \pi^0 \pi^- \eta$ | 0.1707 ± 0.0013% | 0.1696 ± 0.0013% | 0.00000 |
| $\tau^- \to \nu_\tau \pi^- K^+ K^-$ | 0.1704 ± 0.0013% | 0.1509 ± 0.0012% | 0.07360 |
| $\tau^- \to \nu_\tau \pi^0 K_L^0 \pi^-$ | 0.1605 ± 0.0013% | 0.2745 ± 0.0017% | 0.92850 |
| $\tau^- \to \nu_\tau \pi^0 \pi^- K_S^0$ | 0.1592 ± 0.0013% | 0.2734 ± 0.0017% | 0.93657 |
| $\tau^- \to \nu_\tau \gamma \pi^0 \pi^-$ | 0.1559 ± 0.0012% | 0.1303 ± 0.0011% | 0.00000 |
| $\tau^- \to \nu_\tau K_L^0 \pi^- K_S^0$ | 0.1510 ± 0.0012% | 0.0763 ± 0.0009% | 0.00270 |
| $\tau^- \to \nu_\tau K_L^0 K^-$ | 0.1289 ± 0.0011% | 0.0508 ± 0.0007% | 0.00000 |
| $\tau^- \to \nu_\tau K_S^0 K^-$ | 0.1287 ± 0.0011% | 0.0507 ± 0.0007% | 0.00000 |
| $\tau^- \to \nu_\tau \pi^0 \pi^0 \pi^0 \pi^+ \pi^- \pi^-$ | 0.1094 ± 0.0010% | 0.0506 ± 0.0007% | 0.00000 |
| $\tau^- \to \nu_\tau \pi^+ \pi^+ \pi^- \pi^- \pi^-$ | 0.0803 ± 0.0009% | 0.0401 ± 0.0006% | 0.00000 |
| $\tau^- \to \nu_\tau \pi^0 \pi^0 K^-$ | 0.0792 ± 0.0009% | 0.0504 ± 0.0007% | 0.29190 |
| $\tau^- \to \nu_\tau K_L^0 K_L^0 \pi^-$ | 0.0760 ± 0.0009% | 0.0372 ± 0.0006% | 0.00854 |
| $\tau^- \to \nu_\tau \pi^- K_S^0 K_S^0$ | 0.0756 ± 0.0009% | 0.0378 ± 0.0006% | 0.01189 |
| $\tau^- \to \nu_\tau \pi^0 K_L^0 K^-$ | 0.0507 ± 0.0007% | 0.0763 ± 0.0009% | 0.85321 |
| $\tau^- \to \nu_\tau \pi^0 K_S^0 K^-$ | 0.0498 ± 0.0007% | 0.0746 ± 0.0009% | 0.87506 |
| $\tau^- \to \nu_\tau \pi^0 \pi^+ \pi^+ \pi^- \pi^- \pi^-$ | 0.0186 ± 0.0004% | 0.0293 ± 0.0005% | 0.00000 |

Similarity coefficients: T1=1.881148 , T2=4.510389

Decay channel

Branching ratio for generator #1 and #2

Rough statistical errors of branching ratios

Maximal "Shape Difference Parameter"

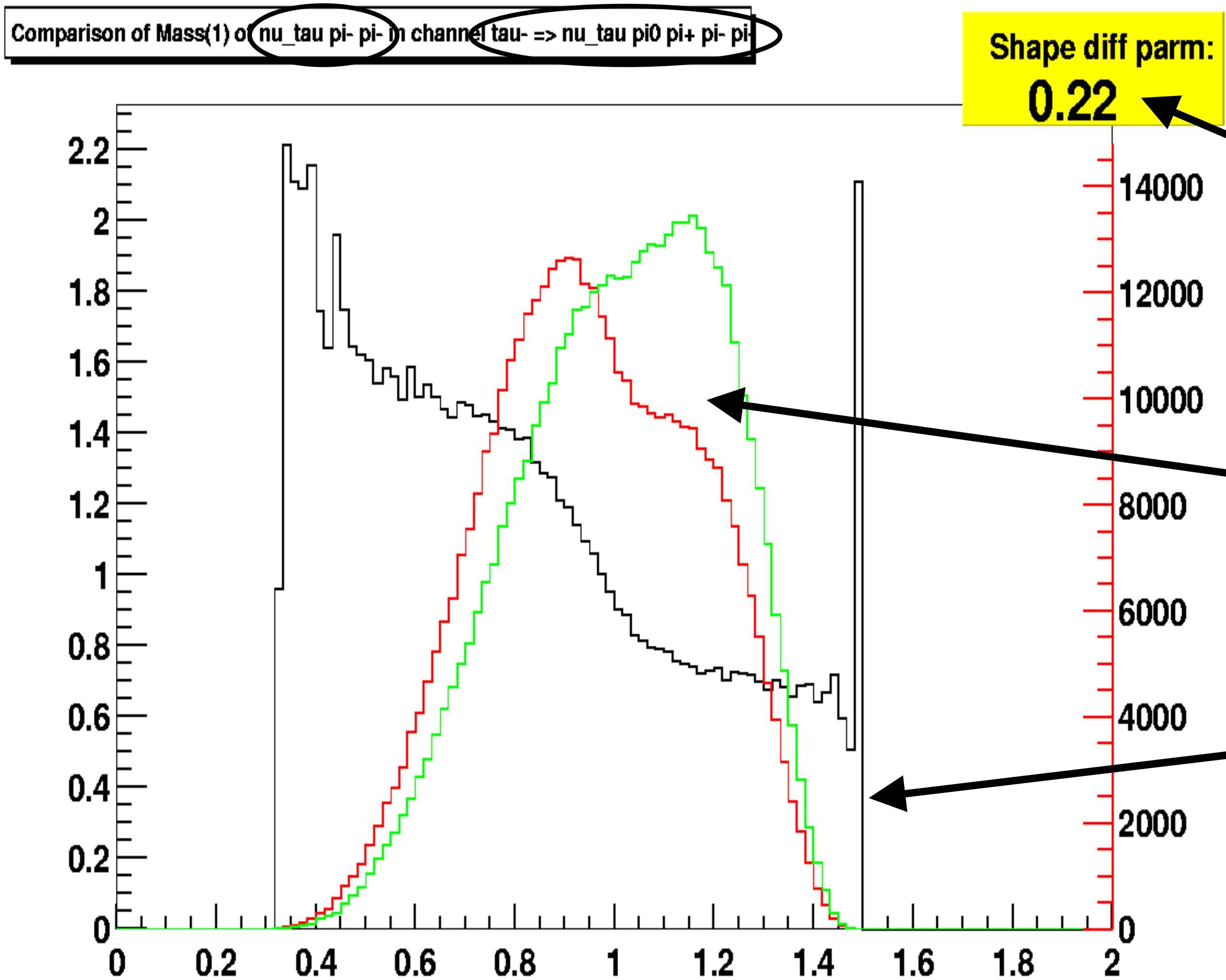
Similarity Coefficients (combined: for all decay modes)

**Slide from Piotr Golonka**

# *Example Output – Histogram of Invariant Mass*
## *(100s of these hisotgrams are produced)*

This shows the invariant mass of

nu_tau pi- pi- in mode tau -> nu_tau pi0 pi+ pi- pi-




Shape Difference Parameter value

Histograms of invariant mass from generator #1 and #2

Ratio of the two histograms (after normalisation)

# *Configurables:*

- Configured by:
  - ROOT/C++ macro file **SETUP.C** (interpreted at runtime) or
  - Using “Setup” Class in Monte-Carlo generator code
- Some important configurables:
  - Event Record type
  - Decay particle PDG code
  - Particles considered “stable” (eg. pi0)
  - Histogram binning
  - MC Description on booklet title page
  - Algorithm to calculate shape difference
    - MCTest01 (exclusive surface)
    - MCTest02 (Non-uniformity of Histograms ratio)
    - MCTest03 (Kolmogorov compatibility)
    - User Defined

# *Example of Use: Generation Step, FORTRAN*

- Example “main” and Makefile in:
  - /afs/cern.ch/sw/lcg/external/MCGenerators/mctester/1.212/share/examples-F77/tauola/
- Set the event record type in **SETUP.C**
  - Setup::EVENT=&HEPEVT
- Before event generation in the FORTRAN code add:
  - CALL MCTEST(-1) - This initialises MC-Tester
- After generation of each event use:
  - CALL MCTEST(0) – This causes MC-Tester to read the HEPEVT common block and analyse the event
- At the end of a generation run add the line:
  - CALL MCTEST(1) – This finalises MC-Tester. The root file output is produced

# Example of Use: Generation Step, C++

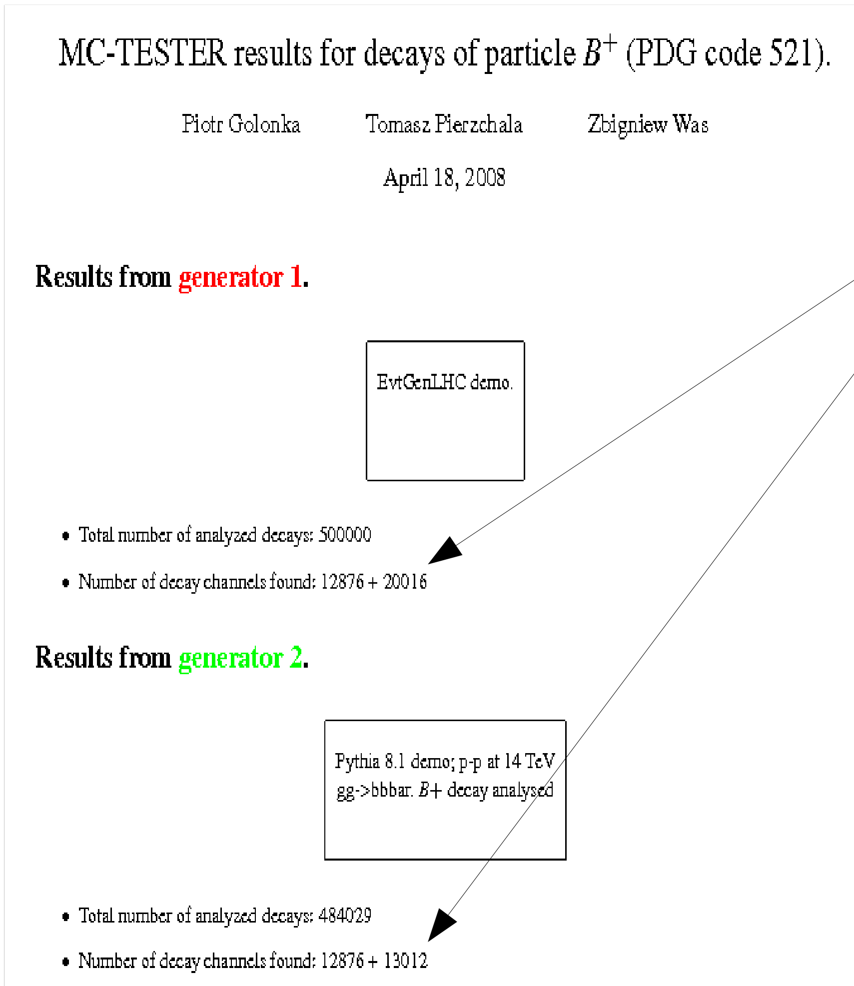
- Example main and c++ code in
  - /afs/cern.ch/sw/lcg/external/MCGenerators/mctester/1.212/share/examples-C++/pythia/
- Include the MC-Tester header files:
  - #include "Generate.h"
  - #include "HepMCEvent.H"
- Before event generation in the C++ code add:
  - MC_Initialize();
- After each event is generated make a new MC-TESTER HepMCEvent event and pass it to the tester
  - MC_Analyze( new HepMCEvent( the_event ) );
- And to finalise the run:
  - MC_Finalize();

# Example of Use: Analysis Step

- The "Analysis" code is a set of ROOT macros (see /afs/cern.ch/sw/lcg/external/MCGenerators/mctester/1.212/share/analyze)
- The two .root files produced during the Generation Step are compared, and a latex (and ps) booklet is produced.
- Traditional way of running the Analysis Step:
  - copy file1.root to the analyze/prod1/ directory
  - copy file2.root to analyze/prod2/ dirctory
  - type "make"
- When the analyze directory is not writeable (eg. lcg installation)
  - Can also be run from other directories (see example script in "extra" slides)

# Example of Use: EvtGen

- /afs/cern.ch/sw/lcg/external/MCGenerators/mctester/1.212/share/examples-C++/evtgenlhc
- Results can be see at: http://mc-tester.web.cern.ch/MC-TESTER/mc-tester_results/results.html



MC-TESTER results for decays of particle $B^+$ (PDG code 521).

Piotr Golonka Tomasz Pierzchala Zbigniew Was

April 18, 2008

**Results from generator 1.**

EvtGenLHC demo.

- Total number of analyzed decays: 500000
- Number of decay channels found: 12876 + 20016

**Results from generator 2.**

Pythia 8.1 demo; p-p at 14 TeV gg->bbbar. B+ decay analysed

- Total number of analyzed decays: 484029
- Number of decay channels found: 12876 + 13012

- Unique example:
  - Many channels and decay products:
    - Limited the number of channels for histograming to the first 200
    - Also limited the number of daughter combinations
    - Over 1000 pages!!
  - C++ code mixed with HEPEVT event record.

# *Example of Use: Athena*

- MC-Tester is run inside the ATLAS software in much the same way as the C++ Generation Step example
  - all based on HepMC event record
  - Interface code can be found at:
    http://alxr.usatlas.bnl.gov/lxr/source/atlas/Generators/MCTester_i/
    http://alxr.usatlas.bnl.gov/lxr/source/atlas/External/MCTester/
  - Doxygen documentation for the interface can be found at:
    http://atlas-computing.web.cern.ch/atlas-computing/links/nightlyDevDirectory/AtlasOffline/rel_0/InstallArea/doc//MCTester_i/html/index.html

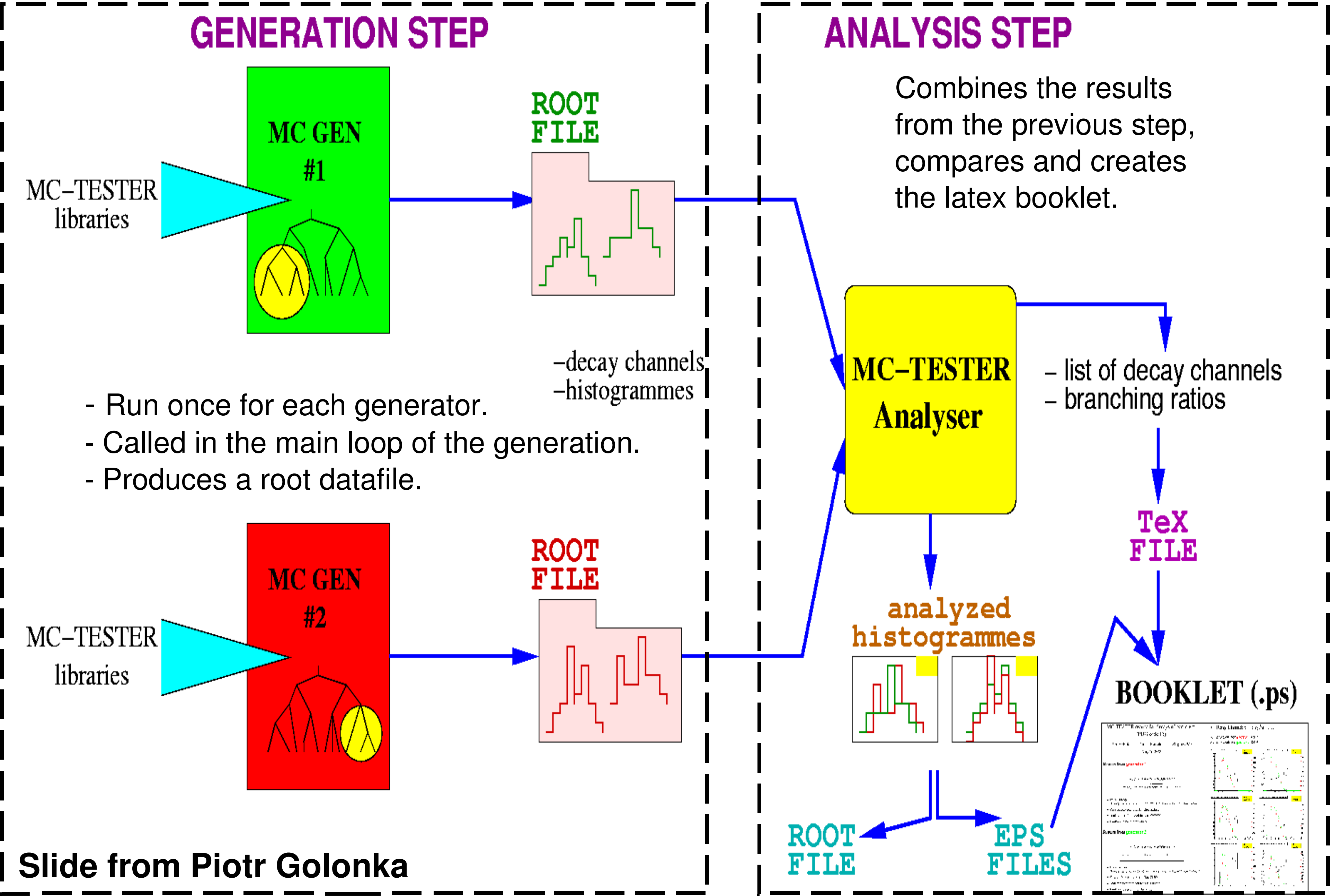
# Examples of Use

- Tests of PHOTOS Hard Brem. with KKMC, KoralZ, TAUOLA and PYTHIA (By Piotr Golonka)
  http://mc-tester.web.cern.ch/MC-TESTER/PHOTOS-MCTESTER/
- The tool has been used by members of the ATLAS collaboration:
  - In particular, Zhonghua Qin tested tau decays for Herwig++, Herwig, Herwig+Tauola+ Photos, Pythia, Pythia+Tauola+Photos, and Sherpa.
    - http://indico.cern.ch/materialDisplay.py?contribId=23&materialId=slides&confId=36346
    - A precision problem was identified with Sherpa interface read event mode.
  - Used to quickly rule-out a problem with the TAUOLA interface when discrepancies were seen between MC samples of W-> tau nu.
- A matrix of comparisons (eg. pythia 6.4 vs 8) can be found at:
  http://mc-tester.web.cern.ch/MC-TESTER/mc-tester_results/results.html

# Summary/Conclusions

- MC-Tester is a validation tool which allows comparisons of decays from monte-carlo generators (complementary to existing tools)
- It has recently been extended to read HepMC events
- Have already receive feedback from GENSER group and ATLAS Monte-Carlo group.
  - We hope to increase use of the tool and continue receiving feedback.
- Extensions... (Zbigniew and Tomasz will speak about these)
  - Possibility of getting validation files (in .root format) from Belle and BaBar as validation benchmarks.
  - Need for logarithmic scale on invariant mass histograms.

# How to run MC-Tester



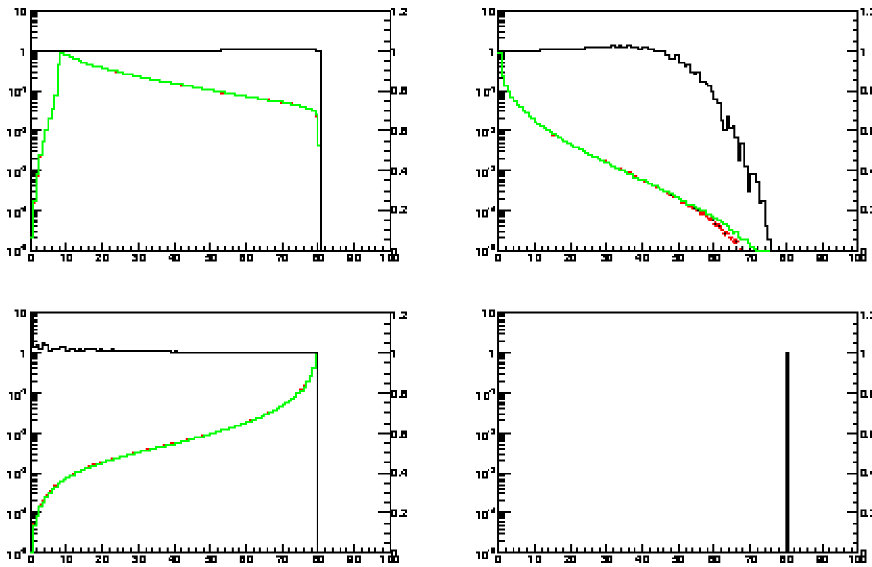

Slide from Piotr Golonka

# *Log scale*
## *- Material from Tomasz Przedzinski*

**2 Decay Channel:** $W^+ \rightarrow \gamma\nu_\mu u^+$

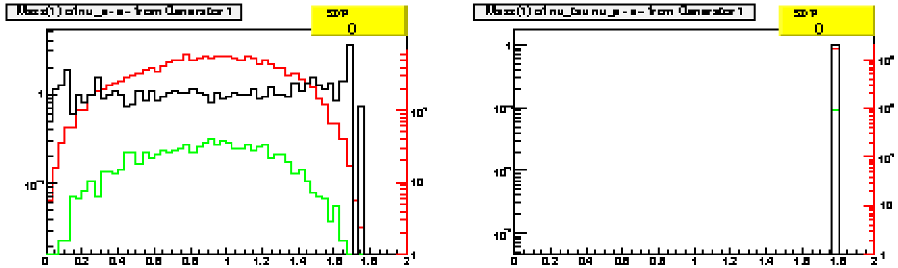
Number of events from generator 1: 9908357
Number of events from generator 2: 9903943

*Consecutive plots are:*
First row: Inv. mass of neutrino+photon (left), Inv. mass of lepton+photon
Second row: Inv. mass of neutrino+lepton (left), Inv. mass of lepton+neutrino+photon



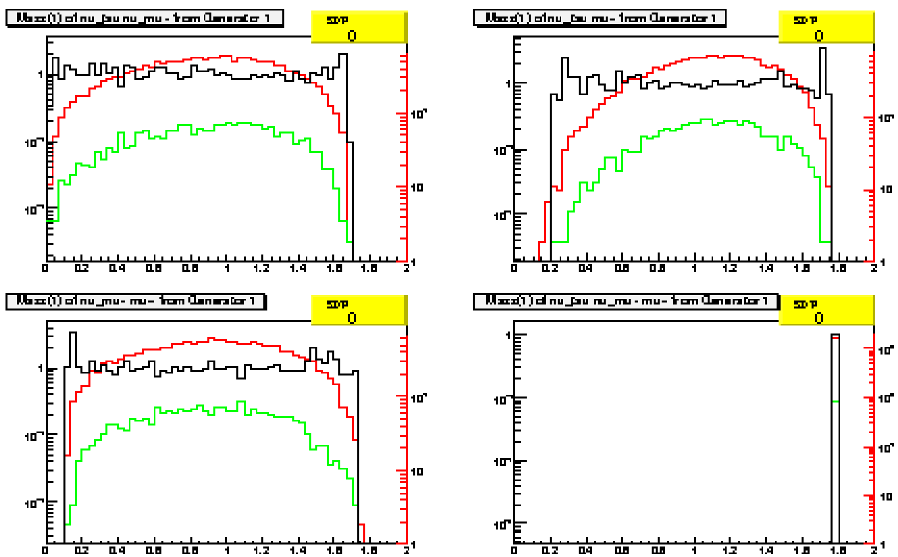
# Log scale (2)

## - Material from Tomasz Przedzinski



### 3 Decay Channel: $\tau^- \to \nu_\tau \tilde{\nu}_\mu \mu^-$

Number of events from generator 1: 17177
Number of events from generator 2: 1665



# Extra Slides

# *Example script for running the analysis step from any working directory*

```
#!/bin/bash

FILE1=myFileName2.root; FILE2=myFileName2.root

MCTESTER_DIR=/afs/cern.ch/sw/lcg/external/MCGenerators/mctester/1.212

MCTESTER_ANALYZE_DIR=${MCTESTER_DIR}/share/analyze

export MC_TESTER_LIBS_DIR=${MCTESTER_DIR}/slc4_ia32_gcc34/lib

WORKING_DIR=`pwd`

#change to MCTester directory and run macros

cd $MCTESTER_ANALYZE_DIR

root -b -q "ANALYZE.C(\"${WORKING_DIR}\",\"${WORKING_DIR}/${FILE1}\",\"${WORKING_DIR}/${FILE2}\")"

root -b -q "BOOKLET.C(\"${WORKING_DIR}\")"

cd $WORKING_DIR

#copy base .tex file needed for booklet and create

cp ${MCTESTER_ANALYZE_DIR}/tester.tex ./

latex tester.tex; latex tester.tex; latex tester.tex; dvipdf tester

#do a bit of clean up

rm -rf tester.aux tester.log texput.log tester.toc mc-results.aux booklet.aux
```