Summary of Tau Decays Test with MC-Tester in Athena

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Short reminders about MC-Tester

- Developed originally for comparing tau decays between different versions of Tauola, and now interfaced to Athena for wider range of use.

- The result from this tool is mainly a pdf & latex booklet including:

  - A summary table showing all decay modes with the branching ratios

  - Comparison plots of invariant mass distributions of tau daughters

    Any combination of the daughters in certain decay mode

    Root histograms for these plots are also available

what I did…

- Initial idea is to perform some tests for tau decays in Herwig++
- To this end, comparing tau decays amongst Herwig++, Herwig, Herwig +Tauola+ Photos, Pythia, Pythia+Tauola+Photos, and Sherpa.
- Using the same physics process for all generators :
  q qbar -> W -> tau nu_tau, tau -> anything possible
- 60000 events privately generated in Athena for each generator except that Sherpa, for which I generated the events standalone, then read them into Athena by the interface.
- For generator parameters, most of them are the generator defaults. Using Atlas CSC production parameters for Tauola and Photos.
- The test is based on the generator-level output files in HepMC format.

Branching ratios check:

Comparison of branching ratios for the decay modes

Decay Channel	Branching Ratio ± errors (the errors for the generators are just statistics error)						
	PDG(06)	Herwig++2.2.0	Pythia6.4	Pythia6.4+tauola + Photos	Herwig6.5	Herwig6.5+Tauola +Photos	Sherpa1.1.1
$\tau^- \to \pi^- \nu_\tau$	**10.90** ±0.07%	**11.0090** ± 0.2053%	**11.0606** ±0.2081%	**10.8747** ±0.2062%	**11.5979** ±0.2149%	**10.6939** ±0.2058%	**10.5953** ±0.2042%
$\tau^- \to \pi^- \pi^0 \nu_\tau$	**25.50** ±0.10%	**25.3254** ±0.3114%	**25.2076** ±0.3142%	**25.0039** ±0.3127%	**25.4740** ±0.3185%	**25.3010** ±0.3166%	**24.5859** ±0.3110%
$\tau^- \to \pi^- \pi^0 \pi^0 \nu_\tau$	**9.25** ±0.12%	**9.4626** ±0.1903%	**8.8516** ±0.1862%	**9.0127** ±0.1878%	**8.6666** ±0.1858%	**9.1096** ±0.1899%	**9.0373** ±0.1886%
$\tau^- \to \pi^- \pi^- \pi^+ \nu_\tau$	**9.33** ±0.08%	**9.2329** ±0.1880%	**9.2276** ±0.1901%	**8.9970** ±0.1876%	**9.1604** ±0.1910%	**8.5868** ±0.1844%	**8.8366** ±0.1865%
$\tau^- \to \pi^- \pi^- \pi^+ \pi^0 \nu_\tau$	**4.46** ±0.06%	**4.4557** ±0.1306%	**4.3397** ±0.1304%	**4.4750** ±0.1323%	**4.3014** ±0.1309%	**4.4043** ±0.1321%	**4.2452** ±0.1292%
$\tau^- \to \pi^- \pi^0 \pi^0 \pi^0 \nu_\tau$	**1.04** ±0.08%	**1.1790** ±0.0672%	**1.1750** ±0.0678%	**1.2978** ±0.0713%	**1.2586** ±0.0708%	**0.8080** ±0.0566%	**1.1685** ±0.0678%
$\tau^- \to \nu_\tau \tilde{\nu}_\mu \mu^-$	**17.36** ±0.05%	**17.8380** ±0.2613%	**17.6563** ±0.2630%	**16.9614** ±0.2576%	**16.8870** ±0.2593%	**16.7617** ±0.2577%	**16.9847** ±0.2585%
$\tau^- \to \nu_\tau \tilde{\nu}_e e^-$	**17.84** ±0.05%	**17.9758** ±0.2623%	**17.9069** ±0.2648%	***14.6299*** ±0.2392%	**17.5562** ±0.2644%	***15.3200*** ±0.2463%	***15.1198*** ±0.2439%
$\tau^- \to \gamma \nu_\tau \tilde{\nu}_e e^-$	**1.75** ±0.18%			***2.7069*** ±0.1029%		***2.8042*** ±0.10539%	***2.7108*** ±0.10327%
$\tau^- \to \gamma \nu_\tau \tilde{\nu}_\mu \mu^-$	**0.36** ±0.04%			**0.6885** ±0.0519%		**0.7921** ±0.05601%	**0.6846** ±0.05190%

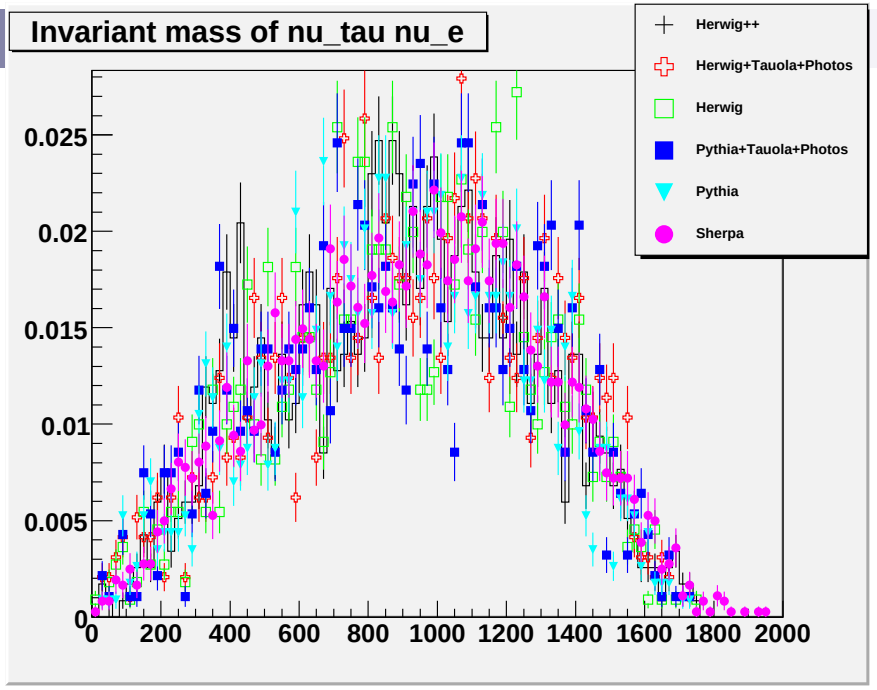
summary of the comparison table

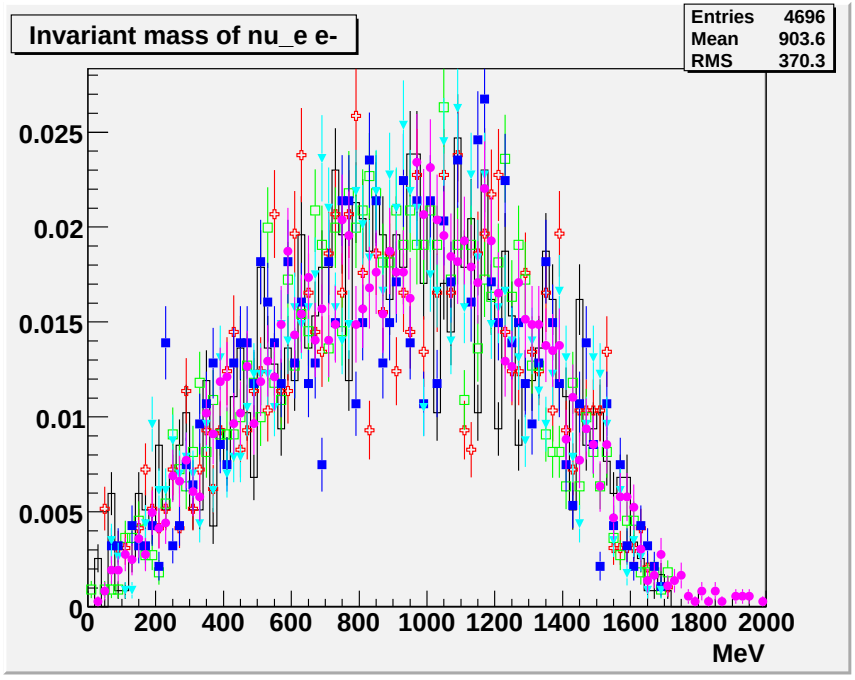
- Totally ten decay modes compared in the table, including hardronic decay, leptionic decay and the the additional photon radiation in leptonic decay.
- Photon radiation is not implemented in Herwig++ and Herwig
- PDG has no cuts on photon radiation, one should calculate the branching rations of leptonic decay and the ones of photon radiation decay together for comparison with PDG values
- For the photon radiation decay modes, the numbers I got from Herwig+Tauola+Photos, Pythia+Tauola+Photos and Sherpa are about two times larger than PDG values, which should be related to different cuts setting between the above generators and PDG.
- Anyway, all these numbers look fine and they are consistent at reasonable level for different generators

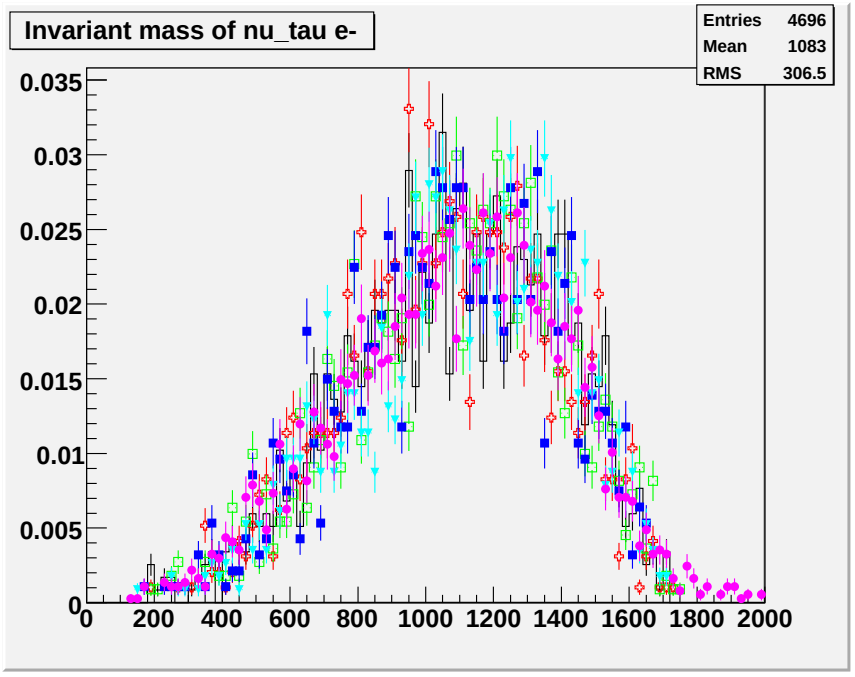
Invariant mass distribution check:

$$\tau^- \rightarrow \nu_\tau \tilde{\nu}_e e^-$$

Similar distributions for all of the generators!



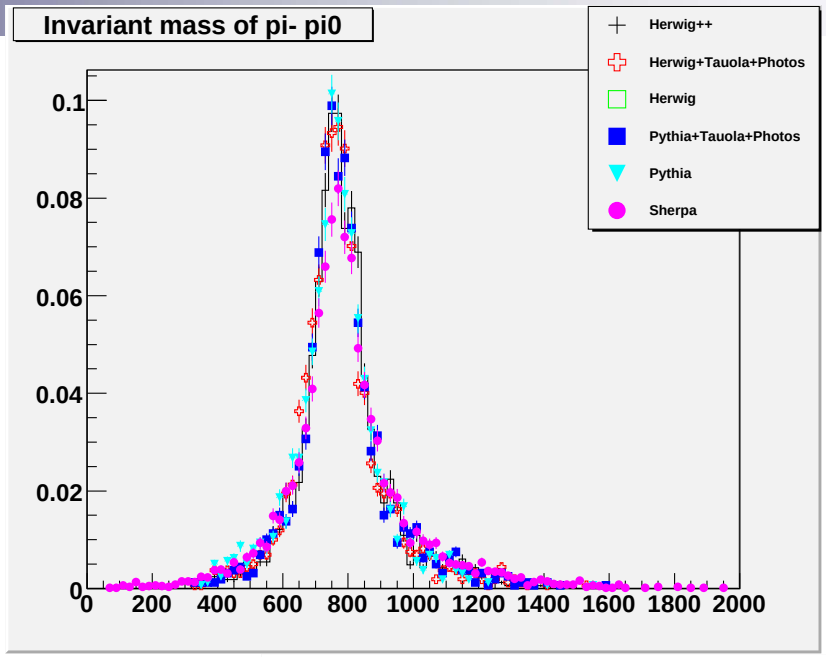


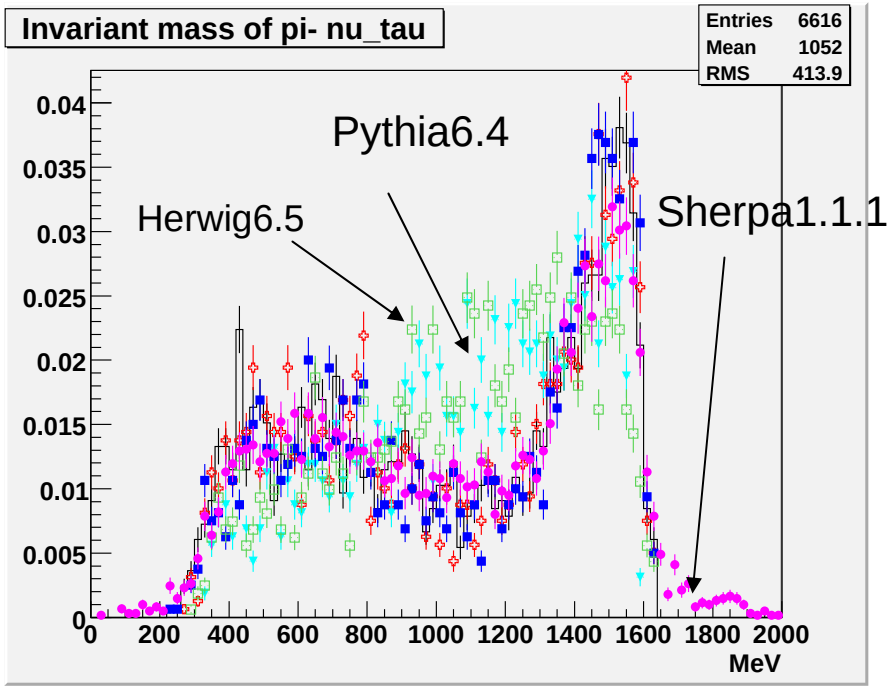


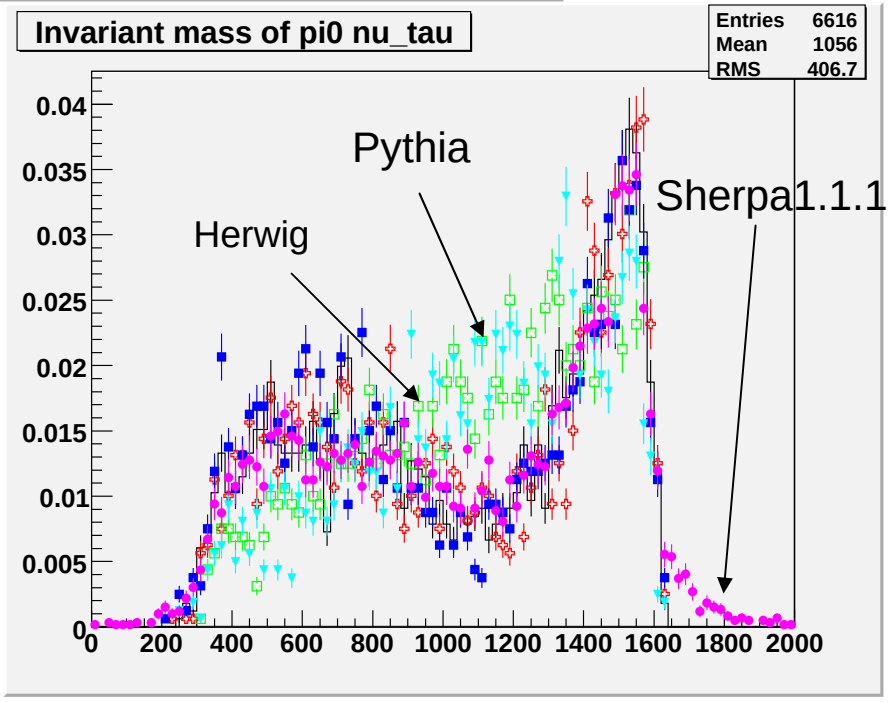
$$\tau^- \rightarrow \pi^- \pi^0 \nu_\tau$$

1) the distributions for Herwig and Pythia appear the different from others;

2)Sherpa has a high mass tail

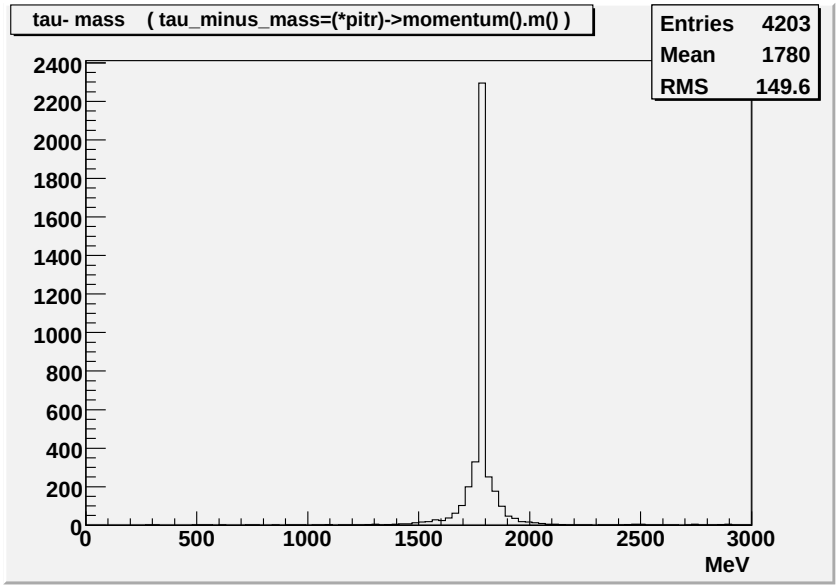




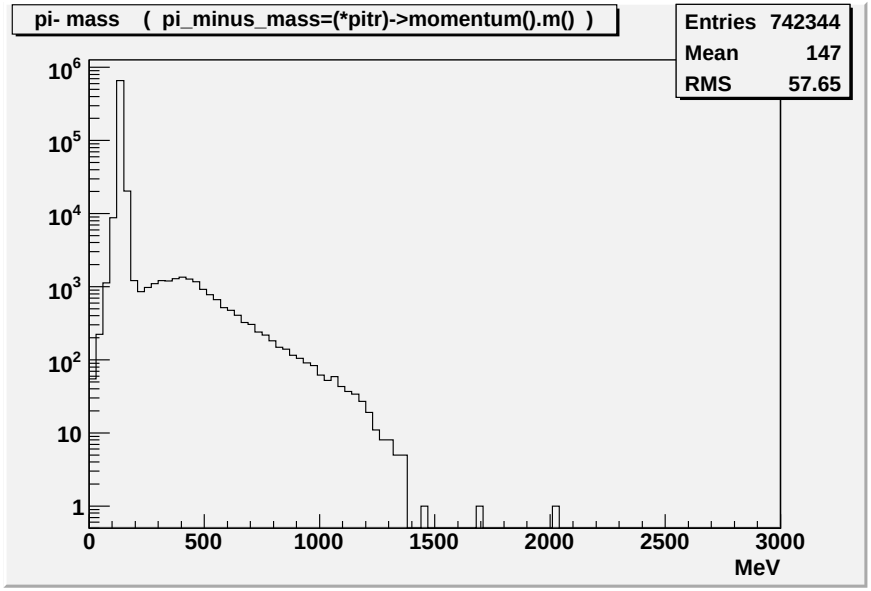


- The difference appearing for Herwig and Pythia is due to :
  Simplified Matrix Element in Pythia and Herwig (lack of spin correlation between intermediate rho and neutrino)

- For Sherpa high mass tail, some further tests below:



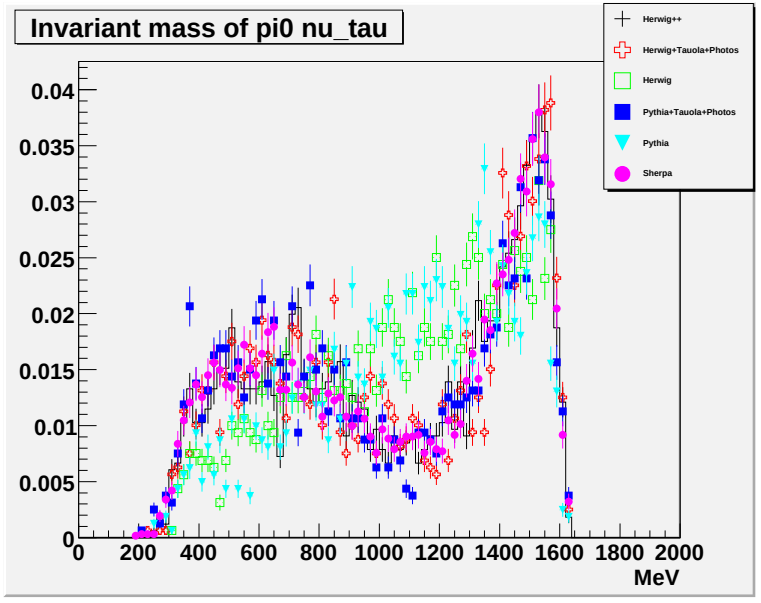
Tau Mass distribution

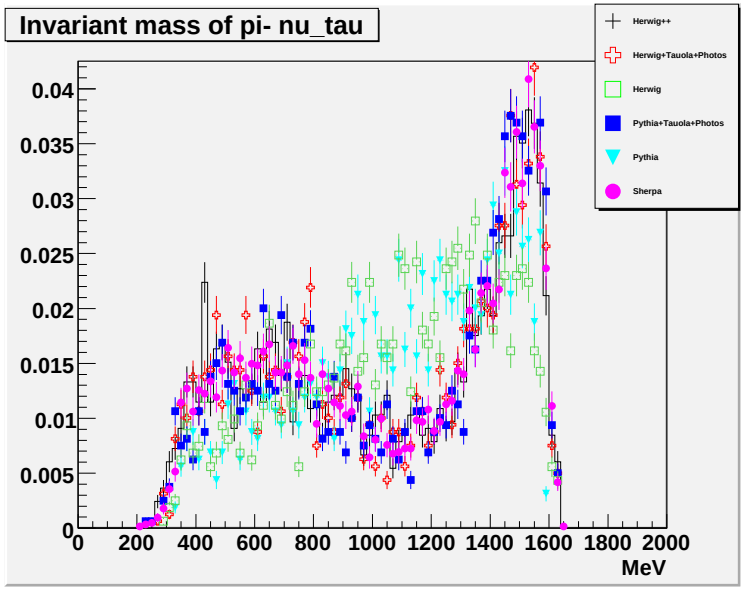


Pi- Mass distribution

Finally, the sherpa tau mass problem is specified to its output precision:

- Sherpa using by default a 6 significant number for momentum and other when writing out event data, so if you access some observable having small values, you will face a precision problem.
- Solutions are: increasing the output precision or run Sherpa in athena on the fly





Run Sherpa in Athena, the tau high mass tail disappears.
(Also the pi mass distribution is correct.)

Summary

- Did the tau decays test for up to five generators by using MC-Tester
- branching ratios check looks ok, no significant difference found.
- For invariant mass comparison, found a problem for Sherpa and solved it.
- This shows this kind of test is necessary, and MC-Tester is a nice tool
- Should mention that no obvious problems found for Herwig++ in the test.