Status and perspectives of PHOTOS and TAUOLA comments on KKMC and BHLUMI

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- *What is new or important?* **Time limits → not a coherent presentation.**
- *especially for interpretators of new experimental data (low and high energy):*
- TAUOLA: extra weights for multidimensional fits with MC. T. Przedzinski, V. Cherepanov, P. Golonka.
- MC-TESTER for automated comparisons and its database, P. Golonka, N. Davidson
- universal interface of TAUOLA: N. Davidson, E. Richter-Was, T. Przedzinski
- PHOTOS for radiative correction in decays: NLO in W-decays. G. Nanava.
- KKMC S. Banerjee, B. Pietrzyk, J.M. Roney

This talk in slightly shorter version was presented at TAU08 Novosibirsk conference.

My web page is at http://home.cern.ch/wasm

• TAUOLA: basic structure

- Phase space × Matrix elements, it is a must
- Electroweak vertex can stay in theorist hands only.
- Semileptonic decays are difficult: Hadronic current need to remain experiments' property, in cases expoeriment wish so.
- The last point enforces constraint for program organization and requests good communication between experimentalists, model builders and TAUOLA authors.
- This topic is being developped now with contributions from Vladimir Cherepanov (Novosibirsk), Tomasz Przedzinski (Krakow) and Piotr Golonka (CERN).
- Larger activity in the near future?
- TMVA Toolkit for Multivariate Data Analysis with ROOT http://tmva.sourceforge.net/ can be useful?
- People (and/or data) from Berlin, Beijing, Charkov, Frascati, Katowice, Karlsruhe, KEK, Novosibirsk, SLAC. Big topic for private discussions (too many directions).

Semileptonic decays: Phase-space × weak-current × hadronic-current

- The differential partial width for the channel under consideration reads

$$d\Gamma_X = G^2 \frac{v^2+a^2}{4M} d\mathrm{Lips}(P; q_i, N)(\omega + \hat{\omega} + (H_\mu + \hat{H}_\mu)s^\mu)$$

- The phase space distribution is given by the following expression where a compact notation with $q_5 = N$ and $q_i^2 = m_i^2$ is used

$$d\mathrm{Lips}(P; q_1, q_2, q_3, q_4, q_5) = \frac{1}{2^{23}\pi^{11}} \int_{Q^2_{min}}^{Q^2_{max}} dQ^2 \int_{Q^2_{3,min}}^{Q^2_{3,max}} dQ_3^2$$

$$\int_{Q^2_{2,min}}^{Q^2_{2,max}} dQ_2^2 \quad \times \quad \int d\Omega_5 \frac{\sqrt{\lambda(M^2, Q^2, m_5^2)}}{M^2} \int d\Omega_4 \frac{\sqrt{\lambda(Q^2, Q_3^2, m_4^2)}}{Q^2}$$

$$\times \quad \int d\Omega_3 \frac{\sqrt{\lambda(Q_3^2, Q_2^2, m_3^2)}}{Q_3^2} \int d\Omega_2 \frac{\sqrt{\lambda(Q_2^2, m_2^2, m_1^2)}}{Q_2^2}$$

$$Q^2 = (q_1 + q_2 + q_3 + q_4)^2, \quad Q_3^2 = (q_1 + q_2 + q_3)^2, \quad Q_2^2 = (q_1 + q_2)^2$$

$$Q_{min} = m_1 + m_2 + m_3 + m_4, \quad Q_{max} = M - m_5 \; Q_{3,min} = m_1 + m_2 + m_3, \quad Q_{3,max} = Q - m_4$$

$$Q_{2,min} = m_1 + m_2, \qquad Q_{2,max} = Q_3 - m_3$$

- These formulas if used directly, are inefficient for a Monte Carlo algorithm if sharp peaks due to resonances in the intermediate states are present. The changes affect the program efficiency, but the actual density of the phase space remains intact. No approximations are introduced.

General formalism for semileptonic decays

- Matrix element used in TAUOLA for semileptonic decay

$$\tau(P,s) \to \nu_\tau(N) X$$
$$\mathcal{M} = \frac{G}{\sqrt{2}} \bar{u}(N)\gamma^\mu(v + a\gamma_5)u(P)J_\mu$$

- J_μ the current depends on the momenta of all hadrons.
- I can provide only prototypes for J_μ. Here TAUOLA must be open to experiment interior. difficult in mixed C++ Fortran environment, and of different experiments software.

$$|\mathcal{M}|^2 = G^2 \frac{v^2+a^2}{2}(\omega + H_\mu s^\mu)$$
$$\omega = P^\mu(\Pi_\mu - \gamma_{va}\Pi^5_\mu), \qquad H_\mu = \frac{1}{M}(M^2\delta^\nu_\mu - P_\mu P^\nu)(\Pi^5_\nu - \gamma_{va}\Pi_\nu)$$
$$\Pi_\mu = 2[(J^* \cdot N)J_\mu + (J \cdot N)J^*_\mu - (J^* \cdot J)N_\mu]$$
$$\Pi^{5\mu} = 2\,\mathrm{Im}\,\epsilon^{\mu\nu\rho\sigma} J^*_\nu J_\rho N_\sigma, \qquad \gamma_{va} = -\frac{2va}{v^2+a^2}$$

- If τ coupling $v + a\gamma_5$ and $m_{\nu_\tau} \neq 0$ is allowed, one has to add to ω and H_μ:

$$\hat{\omega} = 2\frac{v^2-a^2}{v^2+a^2} m_\nu M (J^* \cdot J)$$
$$\hat{H}^\mu = -2\frac{v^2-a^2}{v^2+a^2} m_\nu \,\mathrm{Im}\,\epsilon^{\mu\nu\rho\sigma} J^*_\nu J_\rho P_\sigma$$

Main references:

1. R. Decker, S.Jadach, M.Jeżabek, J.H.Kuhn, Z. Was, Comput. Phys. Commun. 76 (1993) 361, ibid. 70 (1992) 69, ibid. 64 (1990) 275
2. P. Golonka, B. Kersevan ,T. Pierzchala, E. Richter-Was, Z. Was, M. Worek, Comput.Phys.Commun.174:818-835,2006
3. J.H.Kuhn, Z. Was, hep-ph/0602162, Acta Phys. Polon. 39, (2008) 47 (5-pions)

Also:

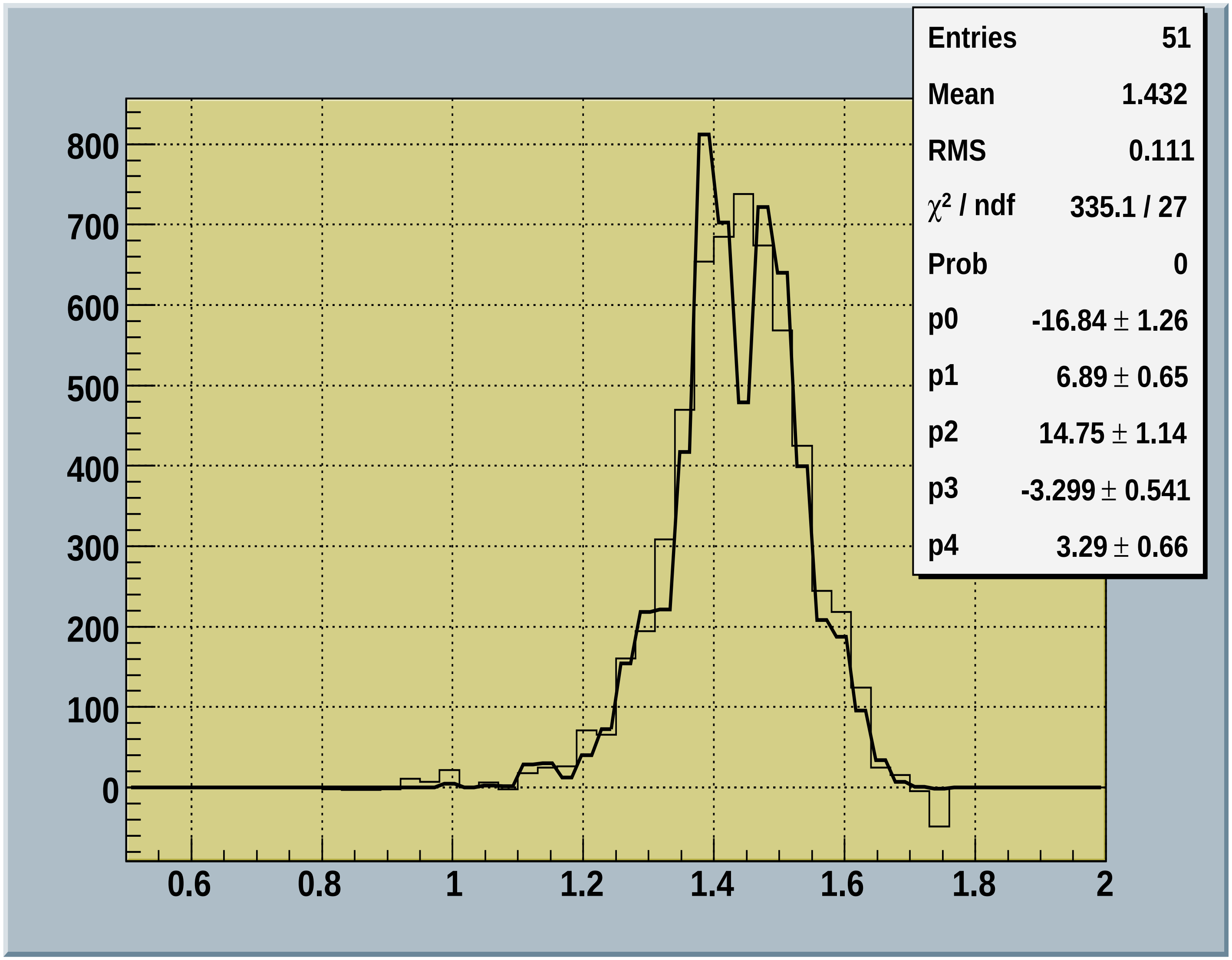
1. ● Alain Weinstein www home page: http://www.cithep.caltech.edu/˜ajw/korb_doc.html#files
2. ● B. Bloch, private communications.
3. R. Decker, M. Finkemeier, P. Heiliger and H.H. Jonsson, Z. Phys. C **70** (1996) 247, now standard 4π formfactors.
4. A. E. Bondar, S. I. Eidelman, A. I. Milstein, T. Pierzchala, N. I. Root, Z. Was and M. Worek, Comput. Phys. Commun. **146**, 139 (2002)
5. P. Abreu et al., Phys. Lett. B426 (1998) 411 (alternative 3π formf.)
6. Sherry Towers alternative formf. in K$\pi\pi$ modes, hep-ex/9908013, Eur. Phys. J. **C13** (2000) 197.

Formfactors secret life

The studies within collaborations often rely on private form-factors, wealth of versions were/are regularly created for more general, or specific purposes. I have seen some.

Arrangements for multidimensional fits with MC.

- for two hadron final states fits are easy, for three, one can separate contributions of different resonances chains using angle dependent projection operators (J. H. Kuhn, E. Mirkes Z.Phys.C 1992), but loss of sensitivity and systematic errors. For more hadrons nobody even tried. Too many interferences ...
- For each tau decay calculate wector of weights for alternative decay models
- Choose the best one comparing simulated sample with data. If dependence is linear in current it is qadratic in weight. Fit function can be analyticall all over parameter space. Otherwise linearization/iteration necessary.
- Arrangement works for TAUOLA standalone and also for KKMC as installed in Belle software. *Thanks to A. Bozek for help.*
- First result point to control of relation between model assumptions and unitarity.
- Exact phase space brings consequences. Unitarity discipline is a must:



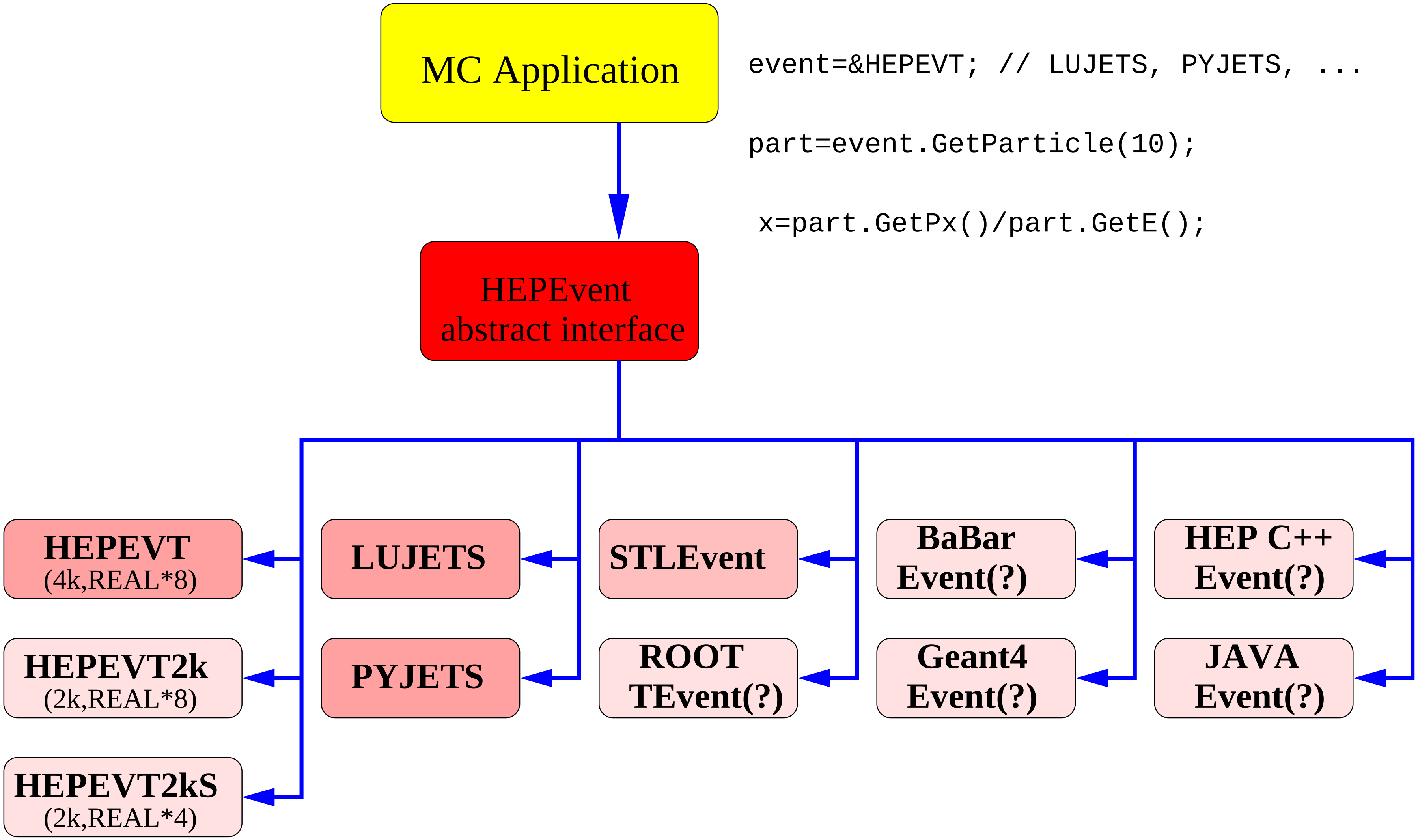
Technical test from the work with V. Cherepanov. Good teaching example. ρ system propagator has to have proper phase space depenent width, $\tau \longrightarrow \eta\pi\pi\nu$.

MC-TESTER was developped to automate comparisons

- It was essential in our work on TAUOLA, and we expect it to be even more essential in the future, also for debugging.
- The same is true for our projects on PHOTOS developments.
- necessary tool for migration from Fortran to C++ .
- Now installed in ATLAS collaboration ATHENA system and used by LCG MC group at CERN.
- Thanks to P. Golonka, T. Przedzinski and N. Davidson for efforts!
- Now we can use it with C++ HepMC event record and all C++ generators as well.

MC-tester

This tool can be used for any MC storing events in standard common blocks: HEPEVT, PYJETS, ... It may also be extended to adopt new event-record data-structures (i.e. in C++). Recent attempt to have standard: T. Sjostrand et al. A standard format for Les Houches Event Files, hep-ph/0609017. Is it going to be useful and accepted (this time)?

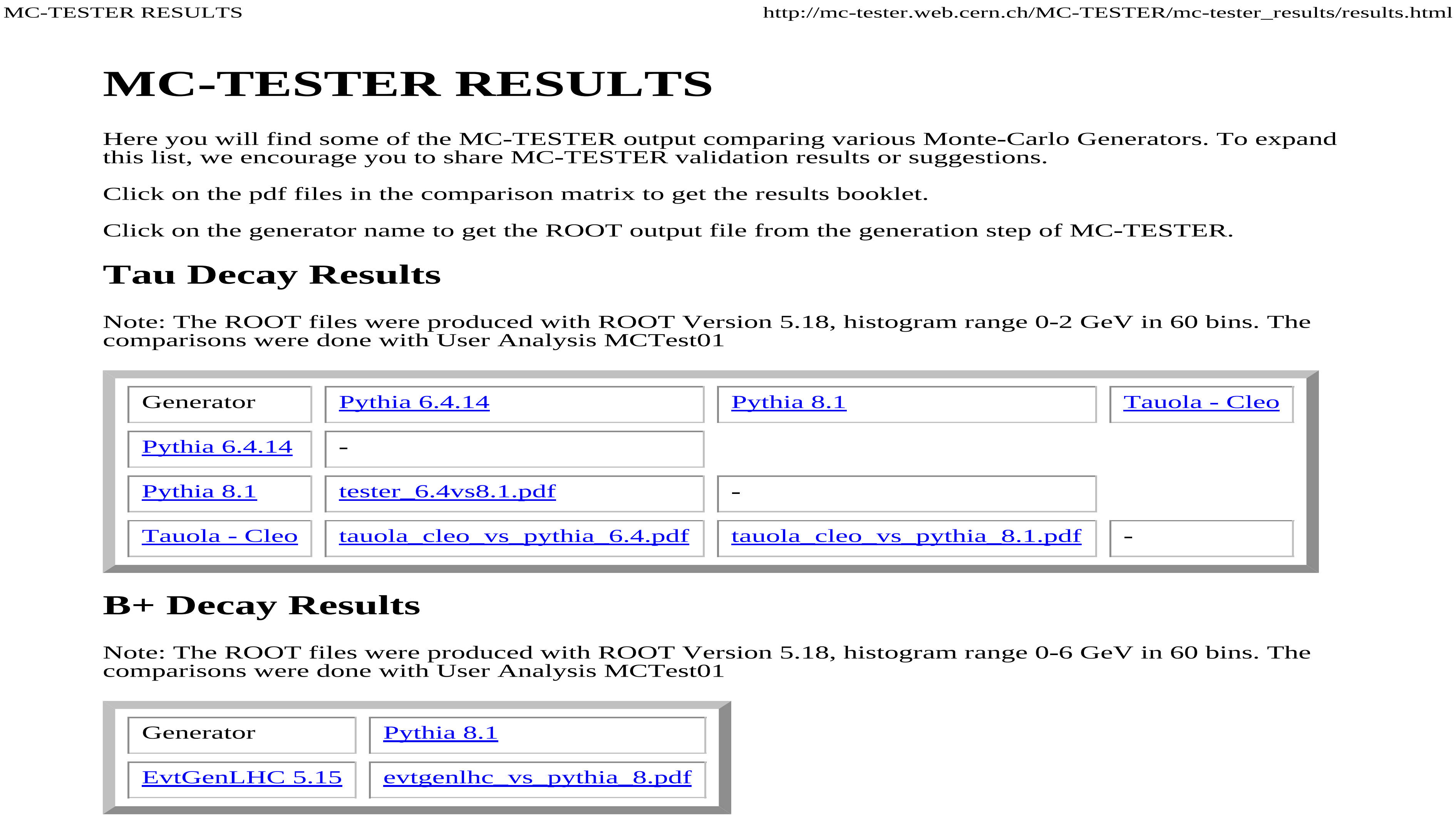


```
event=&HEPEVT; // LUJETS, PYJETS, ...

part=event.GetParticle(10);

 x=part.GetPx()/part.GetE();
```

MC-tester: NEW FEATURES



MC-TESTER RESULTS http://mc-tester.web.cern.ch/MC-TESTER/mc-tester_results/results.html

MC-TESTER RESULTS

Here you will find some of the MC-TESTER output comparing various Monte-Carlo Generators. To expand this list, we encourage you to share MC-TESTER validation results or suggestions.

Click on the pdf files in the comparison matrix to get the results booklet.

Click on the generator name to get the ROOT output file from the generation step of MC-TESTER.

Tau Decay Results

Note: The ROOT files were produced with ROOT Version 5.18, histogram range 0-2 GeV in 60 bins. The comparisons were done with User Analysis MCTest01

Generator	Pythia 6.4.14	Pythia 8.1	Tauola - Cleo
Pythia 6.4.14	-		
Pythia 8.1	tester_6.4vs8.1.pdf	-	
Tauola - Cleo	tauola_cleo_vs_pythia_6.4.pdf	tauola_cleo_vs_pythia_8.1.pdf	-

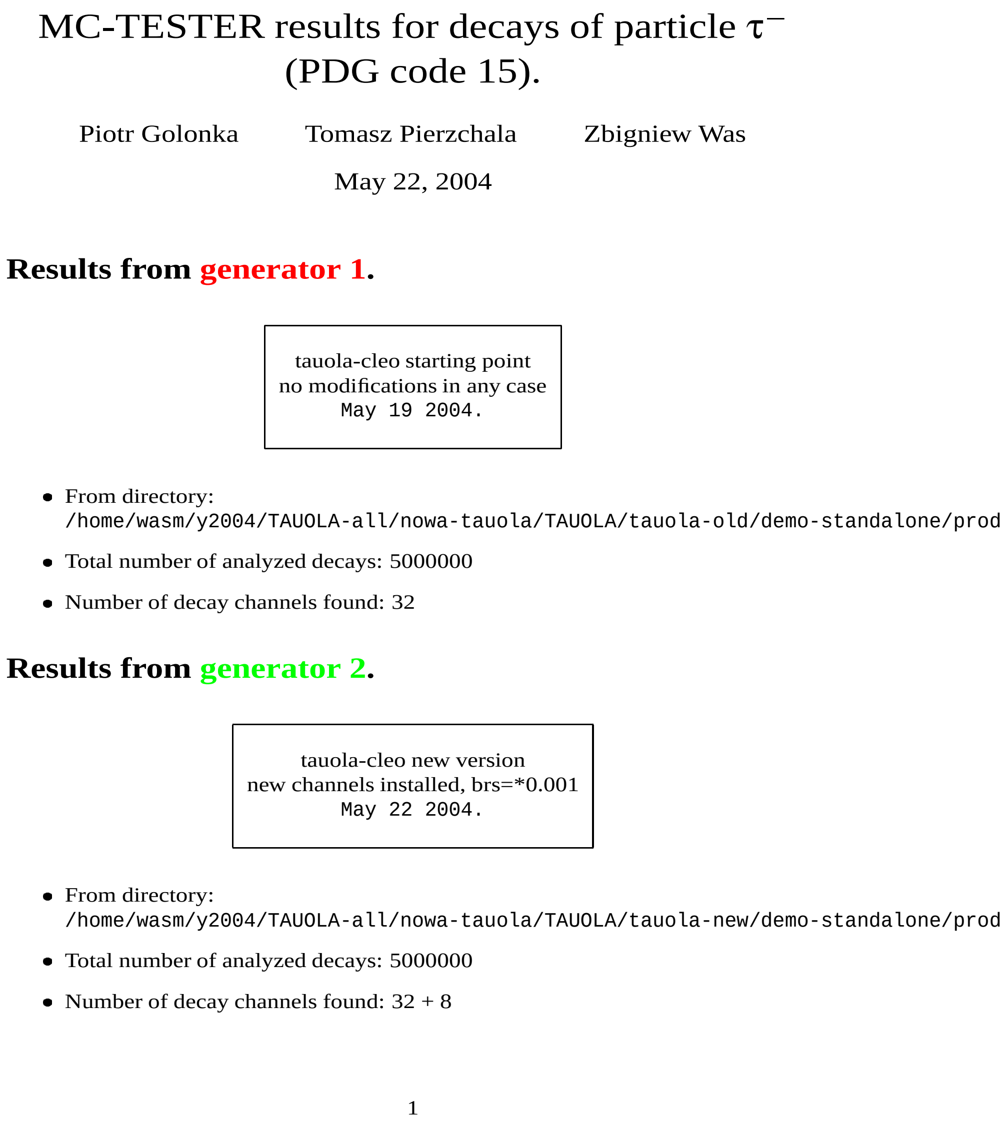
B+ Decay Results

Note: The ROOT files were produced with ROOT Version 5.18, histogram range 0-6 GeV in 60 bins. The comparisons were done with User Analysis MCTest01

Generator	Pythia 8.1
EvtGenLHC 5.15	evtgenlhc_vs_pythia_8.pdf

web-page http://mc-tester.web.cern.ch/MC-TESTER/mc-tester_results/results.html Most of the test results are hidden in Atlas repository. In particular one can find there tests of tau decays in HERWIG Sherpa etc.

MC-tester: NEW FEATURES



MC-TESTER results for decays of particle τ^- (PDG code 15).

Piotr Golonka Tomasz Pierzchala Zbigniew Was

May 22, 2004

Results from generator 1.

tauola-cleo starting point
no modifications in any case
`May 19 2004.`

- From directory: `/home/wasm/y2004/TAUOLA-all/nowa-tauola/TAUOLA/tauola-old/demo-standalone/prod`
- Total number of analyzed decays: 5000000
- Number of decay channels found: 32

Results from generator 2.

tauola-cleo new version
new channels installed, brs=*0.001
`May 22 2004.`

- From directory: `/home/wasm/y2004/TAUOLA-all/nowa-tauola/TAUOLA/tauola-new/demo-standalone/prod`
- Total number of analyzed decays: 5000000
- Number of decay channels found: 32 + 8

MC-TESTER booklet: Page 1. Run like for installation tests.

MC-tester: NEW FEATURES

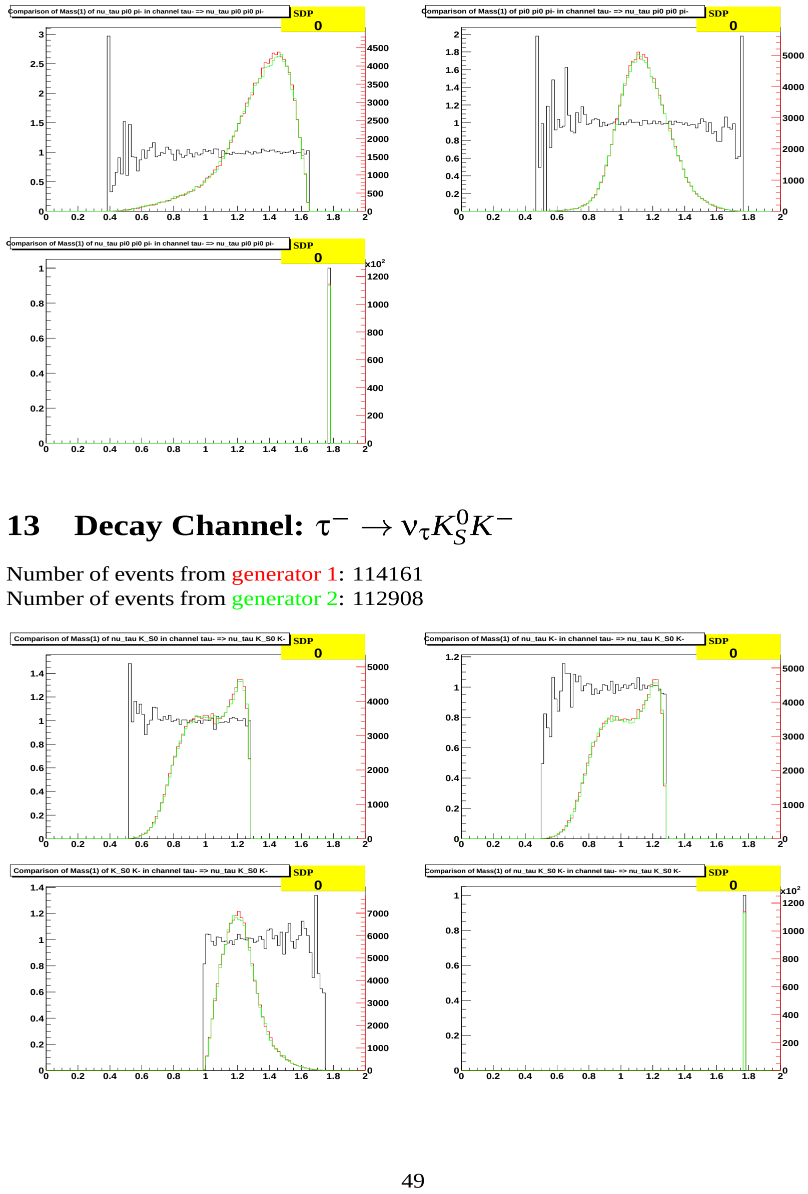
Found decay modes:

Decay channel	Branching Ratio ± Rough Errors		Max. shape dif. param.
	Generator #1	Generator #2	
$\tau^- \to \nu_\tau K^-$	4.5460 ± 0.0095%	4.5500 ± 0.0095%	0.00000
$\tau^- \to \nu_\tau \pi^0 \pi^0 \pi^+ \pi^- \pi^-$	4.5460 ± 0.0095%	4.5425 ± 0.0095%	0.00000
$\tau^- \to \nu_\tau \pi^+ \pi^+ \pi^- \pi^- \pi^-$	4.5457 ± 0.0095%	4.5303 ± 0.0095%	0.00000
$\tau^- \to \nu_\tau \pi^0 \pi^0 \pi^0 \pi^+ \pi^- \pi^-$	4.5449 ± 0.0095%	4.5271 ± 0.0095%	0.00000
$\tau^- \to \nu_\tau \pi^0 \pi^0 \pi^0 \pi^-$	4.5416 ± 0.0095%	4.5366 ± 0.0095%	0.00000
$\tau^- \to \nu_\tau \pi^0 \pi^+ \pi^- \pi^-$	4.5392 ± 0.0095%	4.5371 ± 0.0095%	0.00000
$\tau^- \to \nu_\tau \gamma \pi^0 \pi^-$	4.5368 ± 0.0095%	4.5160 ± 0.0095%	0.00000
$\tau^- \to \nu_\tau \pi^0 \pi^0 K^-$	4.5268 ± 0.0095%	4.5468 ± 0.0095%	0.00000
$\tau^- \to \nu_\tau \pi^0 \pi^- \eta$	4.5236 ± 0.0095%	4.5154 ± 0.0095%	0.00000
$\tau^- \to \mu^- \tilde{\nu}_\mu \nu_\tau$	4.3942 ± 0.0094%	4.3919 ± 0.0094%	0.00000
$\tau^- \to e^- \tilde{\nu}_e \nu_\tau$	3.8276 ± 0.0087%	3.8245 ± 0.0087%	0.00000
$\tau^- \to \nu_\tau \pi^0 \pi^0 \pi^-$	2.2907 ± 0.0068%	2.2669 ± 0.0067%	0.00000
$\tau^- \to \nu_\tau K^0_S K^-$	2.2832 ± 0.0068%	2.2582 ± 0.0067%	0.00000
$\tau^- \to \nu_\tau \pi^0 K^0_L K^-$	2.2825 ± 0.0068%	2.2698 ± 0.0067%	0.00000
$\tau^- \to \nu_\tau K^0_L K^-$	2.2795 ± 0.0068%	2.2725 ± 0.0067%	0.00000
$\tau^- \to \nu_\tau \pi^0 K^0_L \pi^-$	2.2756 ± 0.0067%	2.2680 ± 0.0067%	0.00000
$\tau^- \to \nu_\tau K^0_L \pi^- K^0_S$	2.2756 ± 0.0067%	2.2667 ± 0.0067%	0.00000
$\tau^- \to \nu_\tau \pi^0 K^0_S K^-$	2.2717 ± 0.0067%	2.2606 ± 0.0067%	0.00000
$\tau^- \to \nu_\tau \pi^0 \pi^- K^0_S$	2.2582 ± 0.0067%	2.2663 ± 0.0067%	0.00000
$\tau^- \to \nu_\tau \pi^+ \pi^- \pi^-$	2.2449 ± 0.0067%	2.2822 ± 0.0068%	0.00000
$\tau^- \to \nu_\tau \pi^0 K^-$	1.5545 ± 0.0056%	1.5441 ± 0.0056%	0.00000
$\tau^- \to \nu_\tau \pi^- K^0_S$	1.5047 ± 0.0055%	1.4819 ± 0.0054%	0.00000
$\tau^- \to \nu_\tau K^0_L \pi^-$	1.5019 ± 0.0055%	1.4915 ± 0.0055%	0.00000
$\tau^- \to \nu_\tau \pi^- K^+ K^-$	4.5561 ± 0.0095%	4.5349 ± 0.0095%	0.00000
$\tau^- \to \nu_\tau \pi^-$	4.5501 ± 0.0095%	4.5291 ± 0.0095%	0.00000
$\tau^- \to \nu_\tau \pi^+ \pi^- K^-$	4.5465 ± 0.0095%	4.5461 ± 0.0095%	0.00000
$\tau^- \to \nu_\tau \pi^0 \pi^-$	4.5528 ± 0.0095%	4.5405 ± 0.0095%	0.00000
$\tau^- \to \nu_\tau K^0_L K^0_L \pi^-$	1.1407 ± 0.0048%	1.1324 ± 0.0048%	0.00000
$\tau^- \to \nu_\tau \pi^0 \pi^+ \pi^+ \pi^- \pi^- \pi^-$	4.5557 ± 0.0095%	4.5381 ± 0.0095%	0.00000
$\tau^- \to \nu_\tau \pi^- K^0_S K^0_S$	1.1340 ± 0.0048%	1.1404 ± 0.0048%	0.00000
$\tau^- \to e^- \tilde{\nu}_e \nu_\tau \gamma$	0.7181 ± 0.0038%	0.7164 ± 0.0038%	0.00000
$\tau^- \to \mu^- \tilde{\nu}_\mu \nu_\tau \gamma$	0.1507 ± 0.0017%	0.1489 ± 0.0017%	0.00000

2

MC-TESTER booklet: Page 2. Run like for installation tests.

MC-tester: NEW FEATURES



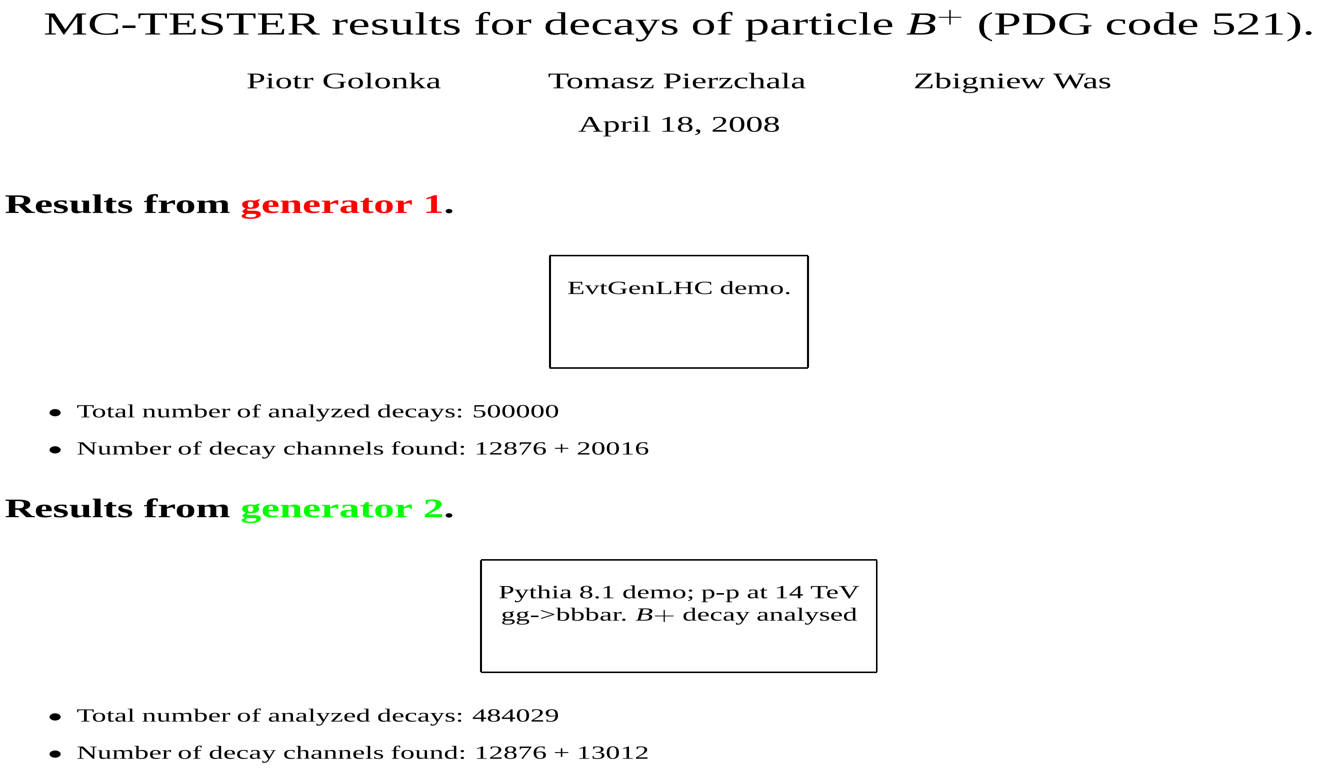
13 Decay Channel: $\tau^- \to \nu_\tau K_S^0 K^-$

Number of events from generator 1: 114161
Number of events from generator 2: 112908

49

MC-TESTER booklet: Page 49. Run like for installation tests.

MC-tester: NEW FEATURES



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

taken from http://mc-tester.web.cern.ch/MC-TESTER/mc-tester_results/results.html web page. Nice results for B+ decays. Compared MC are EvtGenLHC 5.15 and Pythia 8.1. In total 50 k-channels found, 1000+ pages booklet created.

PHOTOS for bremsstrahlung in decays and precision

E. Barberio, B. van Eijk, Z. Was, Comput. Phys. Commun.(1991) ibid. (1994)

See also: P. Golonka et al. hep-ph/0312240, Comput.Phys.Commun.174 (2006) 818.

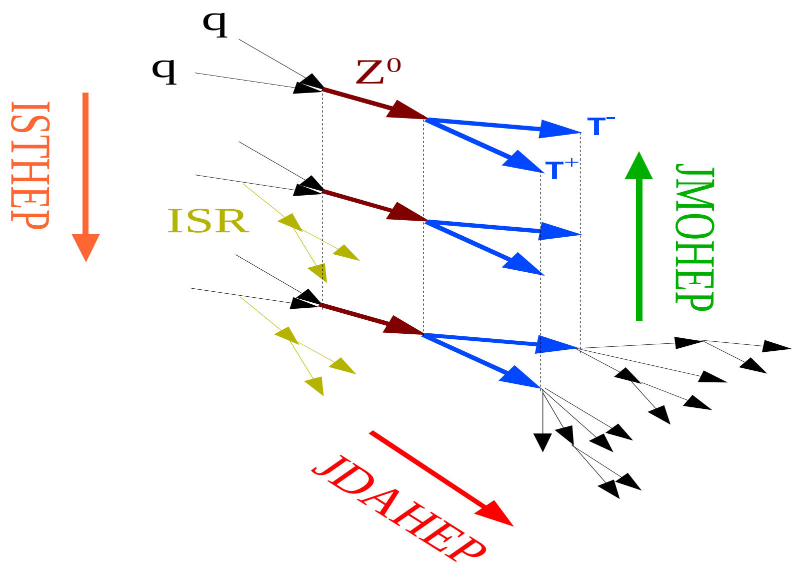
P. Golonka and Z. Was hep-ph/0604232 EPJC (2007), G. Nanava and Z. Was hep-ph/0607019 EPJC 2007

- It was developed as single photon emission. starting from MUSTRAAL (F. Berends, R. Kleiss, S. Jadach, Comput. Phys. Commun. (1982)) option for final state bremsstrahlung in Z decay only.
- Factorization of phase space for photonic variables and two-body decay phase space was studied. Similarily for matrix element: process independent kernel was found. Phase space is exact.
- Interference between emission from μ^+ and μ^- is dropped and re-introduced later.
- The algorithm of the antenna type was created: full phase space NLO ready
- Works for single emission (orthodox ME Monte Carlo)
- Fixed order (up to double emission), useful for tests with second order ME.
- Fixed order (up to quatric emission) or multiphoton.
- Nice environment to study options of factorization schemes, relations between exponentiation structure function evolution, etc.

PHOTOS

- Generally kernels in PHOTOS, are not better than LL. To improve, process dependent weights are needed. Complications for users, but otherwise straightforward!
- Special weights with complete matrix elements are available now for: $Z \to \mu^+\mu^-$ (2005), and for $B^+ \to K^+\pi^0$, $B^0 \to K^+\pi^-$, etc. (2006), for B^0 and $B^\pm$ decays – scalar QED)
- $W \to l\nu$ (2008)
- We will see that effects are small, it is sufficient to keep them for tests only.
- Lots of numerical tests.
- For other decay modes such exercises easy to repeat, if matrix elements are available.
- As consequence: PHOTOS is ready for improvements with measured data as well!
- PHOTOS uses mother-daughter relations in HEPEVT.
- C++ version is prepared but not distributed, need to migrate to HepMC event record.
- Program analyze whole event record and may add bremsstrahlung at any branching.
- Appropriately modifies particles momenta of the whole cascade!
- Algorithm is vulnerable on the way *how* HEPEVT is filled in. Any new inconistency and ...

Problems With Event Record



1. Hard process
2. with shower
3. after hadronization
4. Event record overloaded with physics beyond design ⟶ gramar problems.
5. Here we have basically LL phenomenology only.

This Is Physics Not F77!

Similar problems are in any use of full scale Monte Carlos, lots of complaints at MC4LHC workshop, `HEPEVTrepair` utility (C. Biscarat and ZW) being probed in D0.

Design of event structure WITH some grammar requirements AND WITHOUT neglecting possible physics is needed NOW to avoid large problems later.

$Z \to \mu^+\mu^-$ standard PHOTOS vs. Matrix Element.

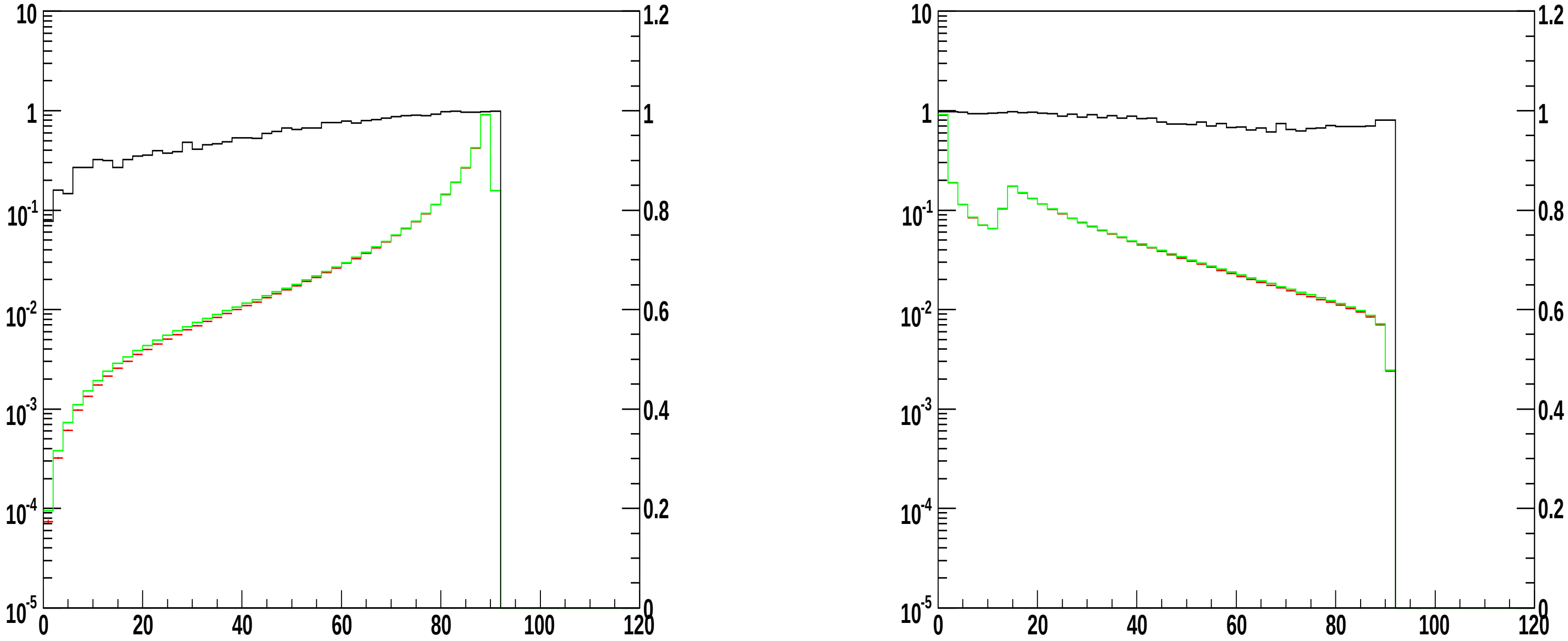


Figure1: Comparison of standard PHOTOS and KORALZ: single photon emission level. On the left hand side the invariant mass of the $\mu^+\mu^-$ pair; SDP=0.00534. On right hand side the invariant mass of $\mu^-\gamma$; SDP=0.00296. The distributions for $\mu^+\gamma$ are identical to $\mu^-\gamma$. The histograms produced by the two programs (logarithmic scale) and their ratio (linear scale, black line) are plotted on both figures. Test1, as defined in Section 3, is used, overall SDP=0.00534, fraction of events with hard photon was 17.4863 $\pm$ 0.0042% for KORALZ and 17.6378 $\pm$ 0.0042% for PHOTOS.

$Z \to \mu^+\mu^-$ PHOTOS vs. Matrix Element.

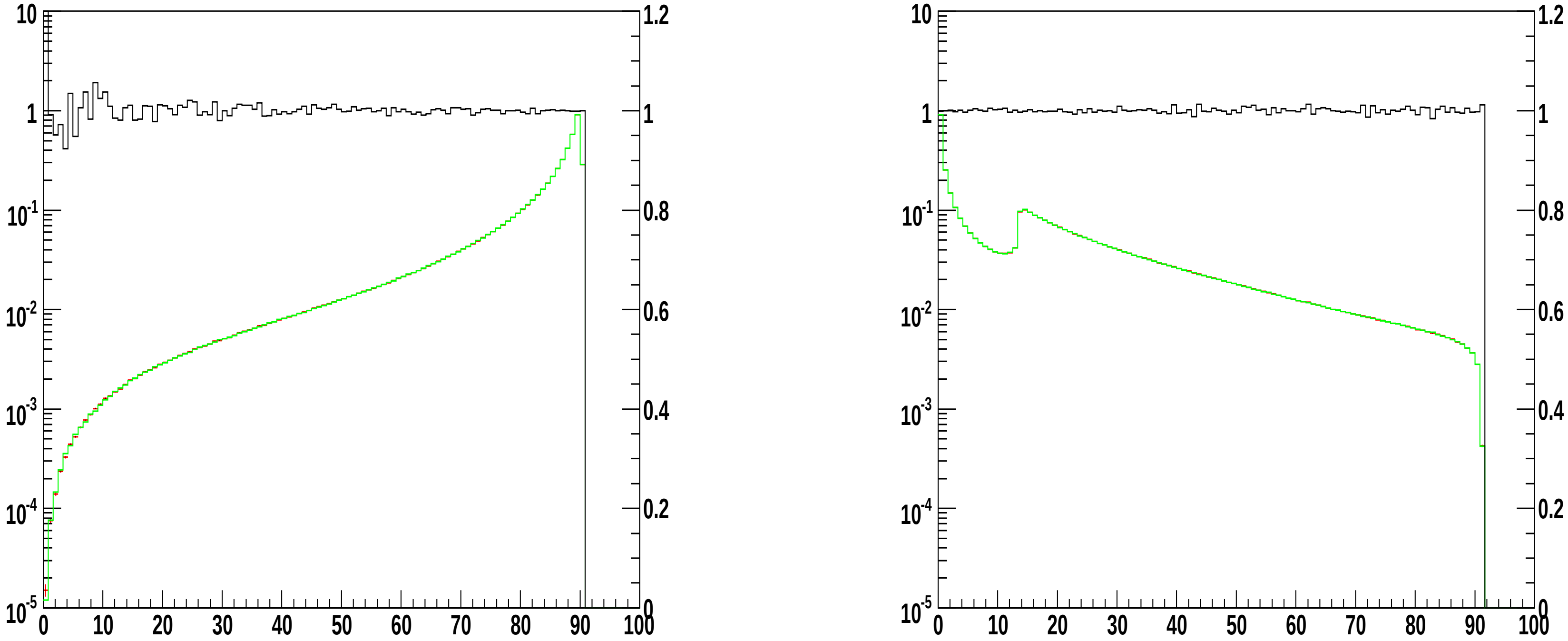


Figure2 Comparisons of improved PHOTOS and KORALZ: single photon emission level. On the left hand side the invariant mass of the $\mu^+\mu^-$ pair. On right hand side the invariant mass of $\mu^-\gamma$ is shown. In both cases differences between PHOTOS and KORALZ are below statistical error. As in Fig 1 distributions for $\mu^+\gamma$ are skipped. Test1, as defined in Section 3, is used, overall SDP=0.0, fraction of events with hard photon was 17.4890 $\pm$ 0.0042% for KORALZ and 17.4926 $\pm$ 0.0042% for PHOTOS.

$Z \rightarrow \mu^+\mu^-$ PHOTOS vs. Matrix Element. γ, γ conf.

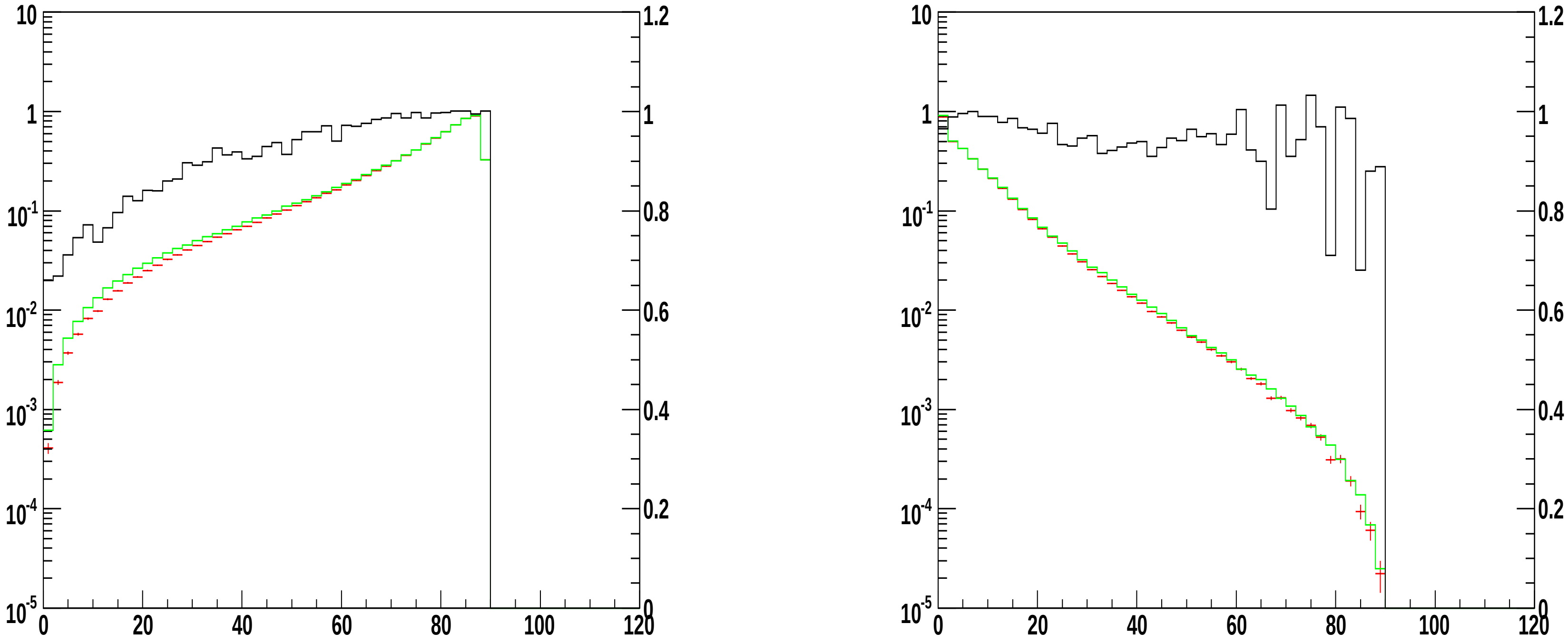


Figure5: Comparisons of standard PHOTOS with multiple photon emission and KKMC with second order matrix element and exponentiation. Two comparison figures of worst agrement were selected from 2 hard photon configurations. On the left hand side the invariant mass of the $\mu^+\mu^-$ pair is shown; SDP= 0.00918. On the right hand side the invariant mass of the $\gamma\gamma$ pair; SDP=0.00268. Test2, as defined in Section 3, is used, overall SDP=0.00918, fraction of events with two hard photons was 1.2659 $\pm$ 0.0011% for KORALZ and 1.2952 $\pm$ 0.0011% for PHOTOS.

$Z \rightarrow \mu^+\mu^-$ NLO PHOTOS vs. Matrix Element γ, γ conf.

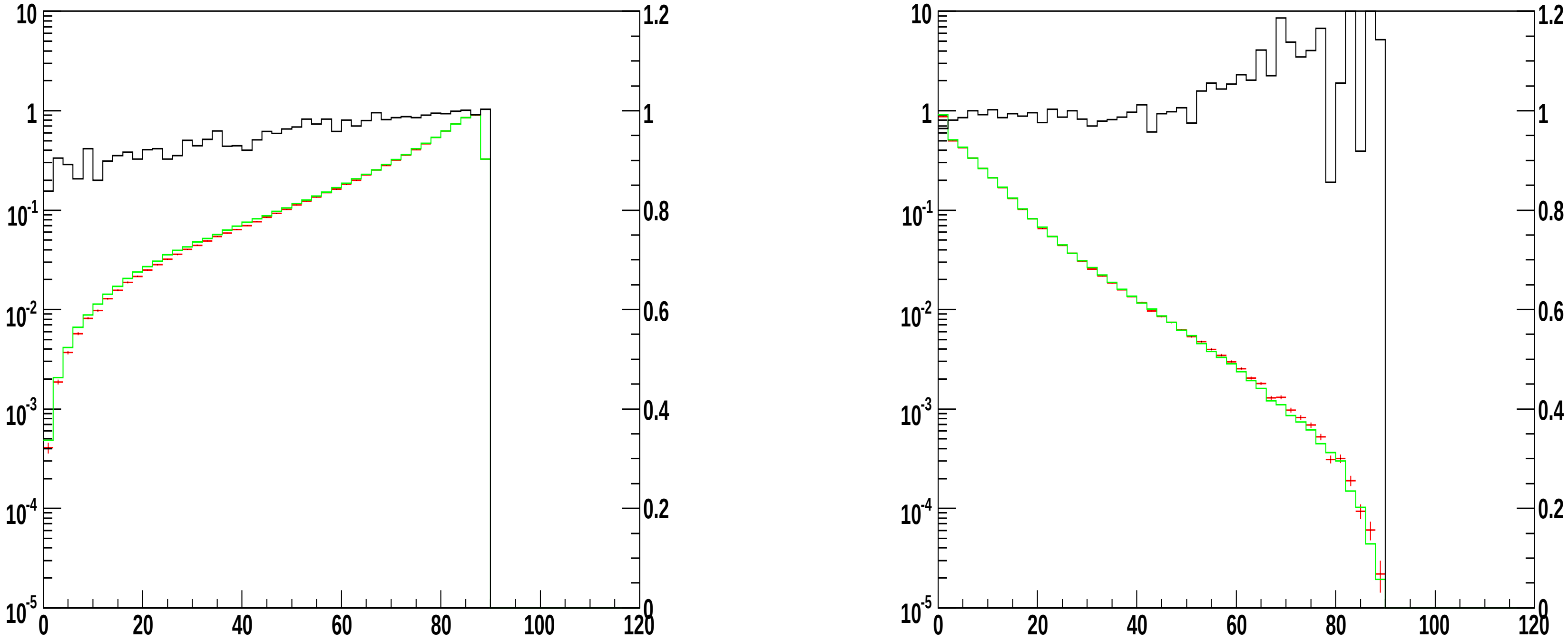


Figure6: Comparisons of improved PHOTOS with multiple photon emission and KKMC with second order matrix element and exponentiation. Two comparison figures of worst agreement were selected from two-hard-photon configurations. On the left hand side the invariant mass of the $\mu^+\mu^-$ pair is shown; SDP= 0.00142. On the right hand side the invariant mass of the $\gamma\gamma$; SDP=0.00293. Test2, as defined in Section 3, was used, overall SDP= 0.00293, fraction of events with two hard photons was 1.2659 $\pm$ 0.0011% for KORALZ and 1.2868 $\pm$ 0.0011% for PHOTOS.

PHOTOS

Figure 1: Results from PHOTOS, standard version, and SANC for $B^- \to \pi^0 K^-(\gamma)$ decay are superimposed on the consecutive plots. Standard distributions, as defined in the text, are used. Logarithmic scales are used. The distributions from the two plots overlap almost completely. Samples of 10^9 events were used.

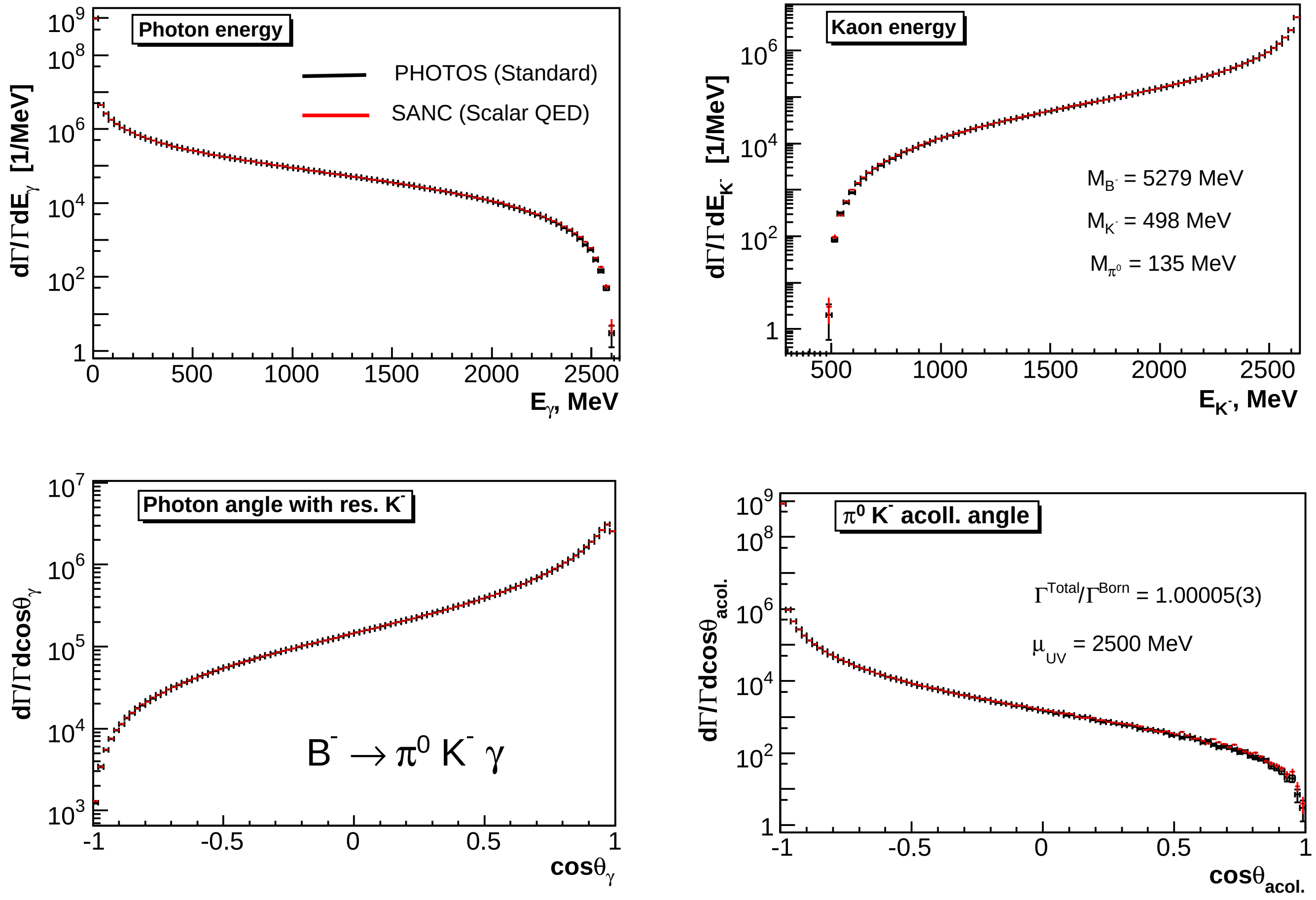
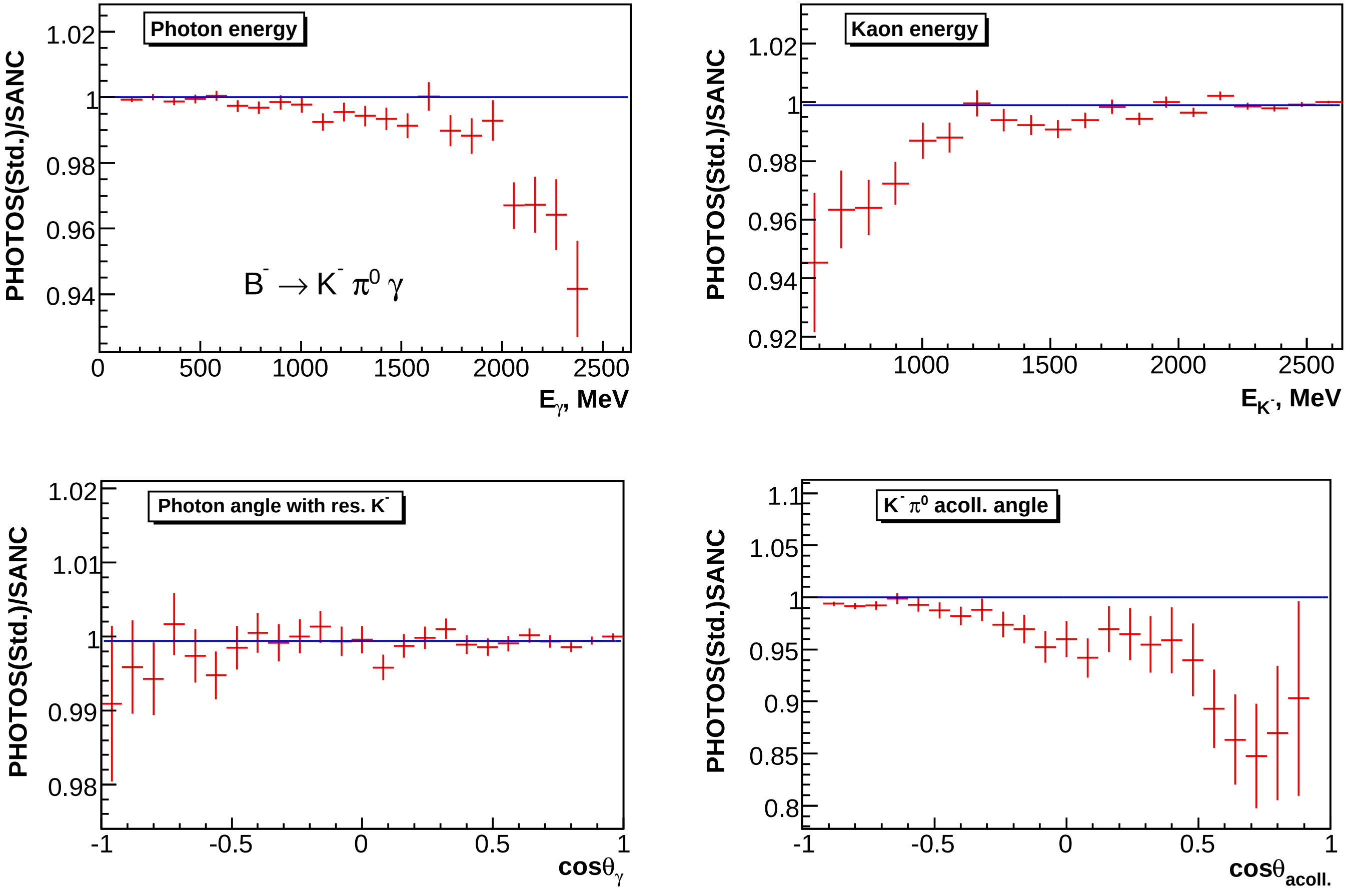
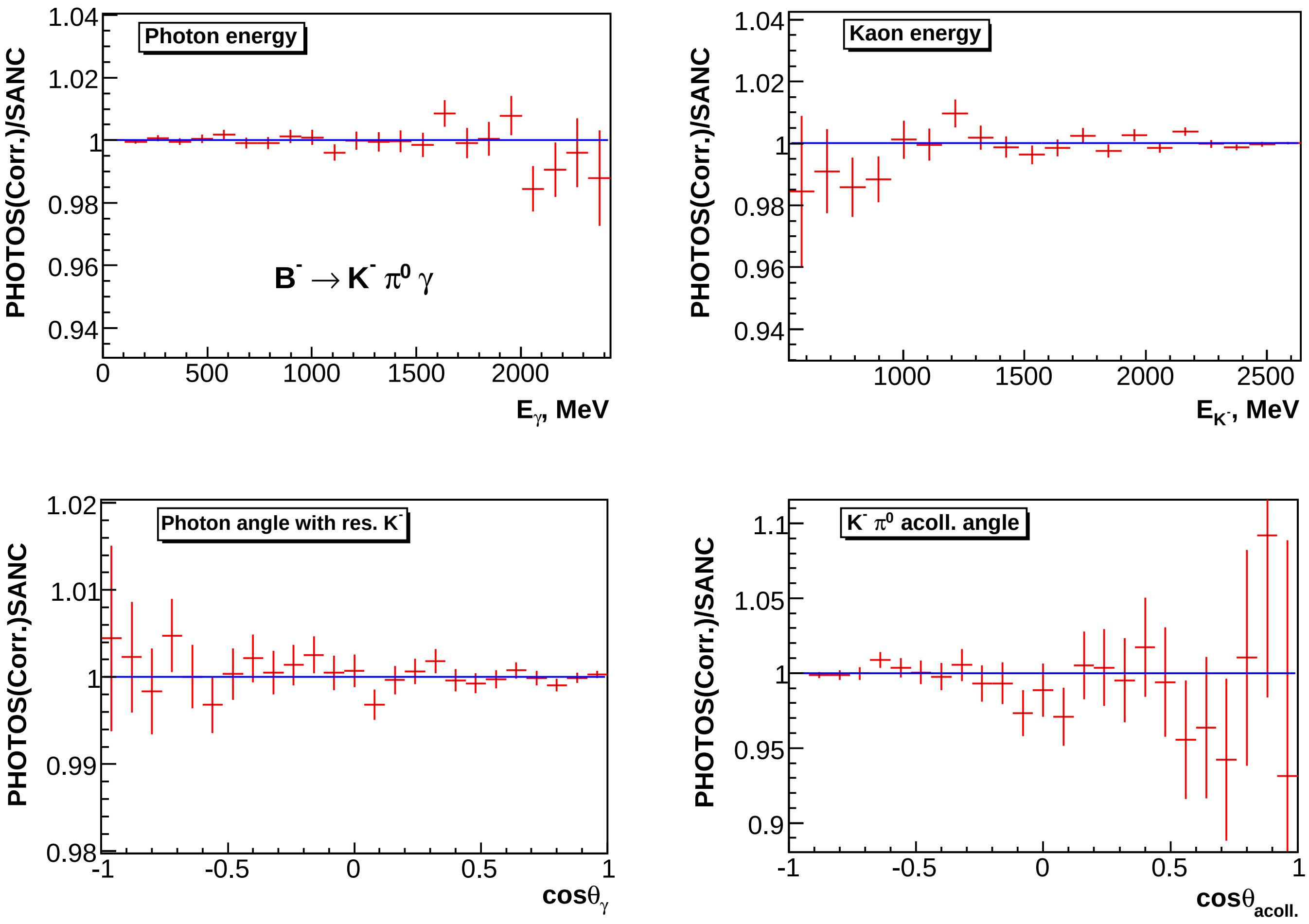


Figure 2: Results from PHOTOS, standard version, and SANC for ratios of the $B^- \to \pi^0 K^-(\gamma)$ distribution in fig.1 are presented. Differences between PHOTOS and SANC are small, but are clearly visible now.

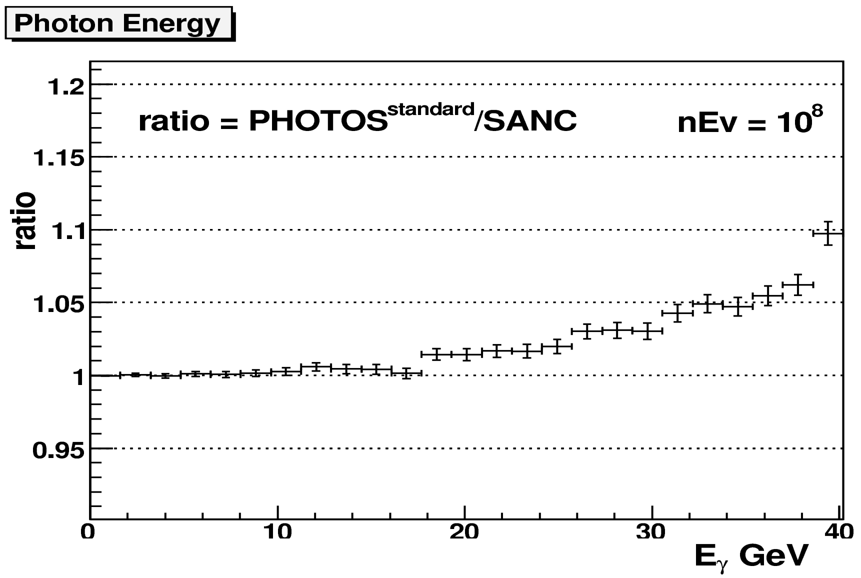


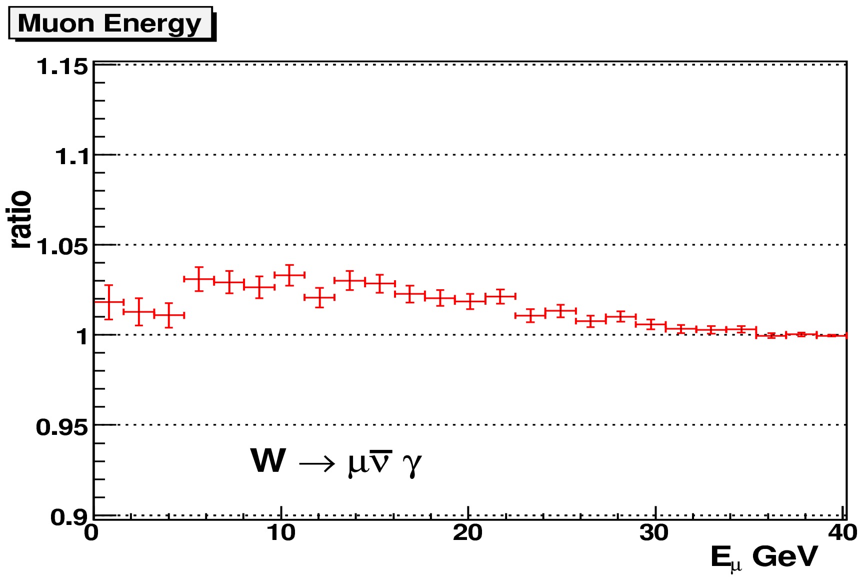
PHOTOS

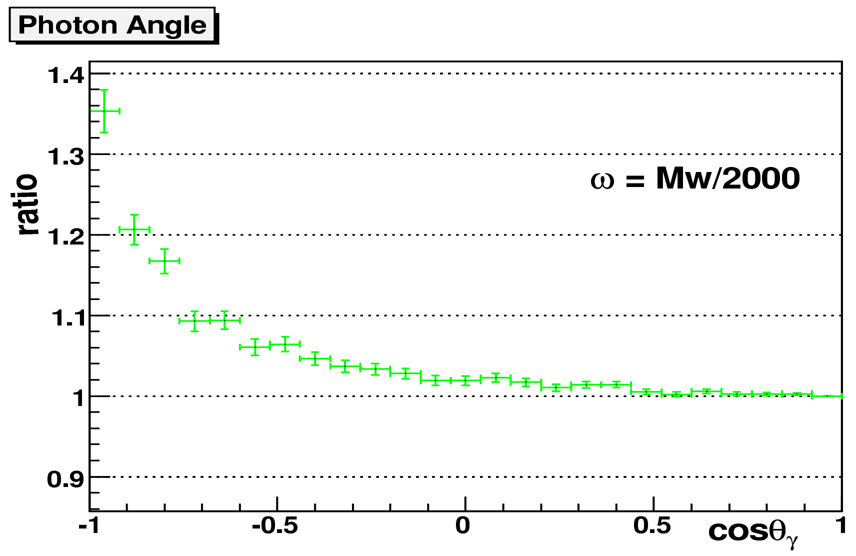
Figure 3: Results from PHOTOS with the exact matrix element, and SANC for ratios of the $B^- \to \pi^0 K^- (\gamma)$ distributions. Differences between PHOTOS and SANC are below statistical error for samples of 10^9 events.

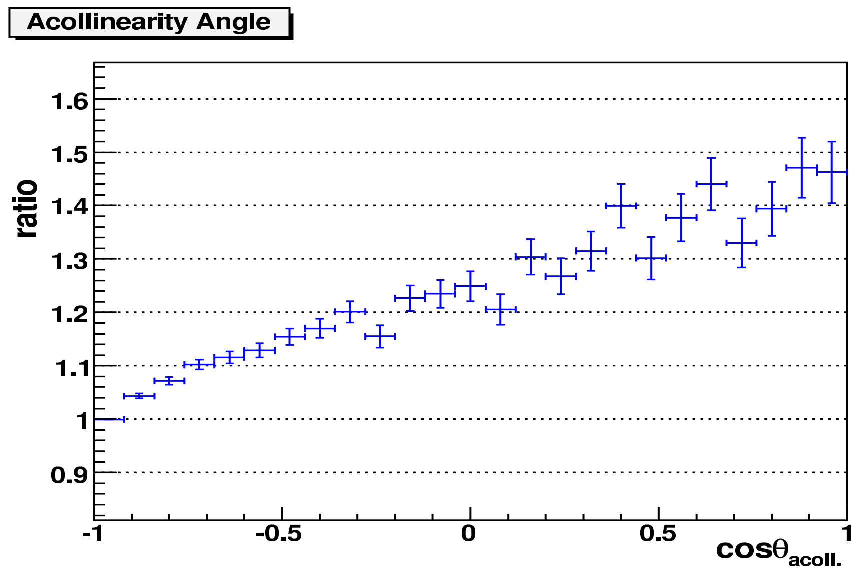


PHOTOS



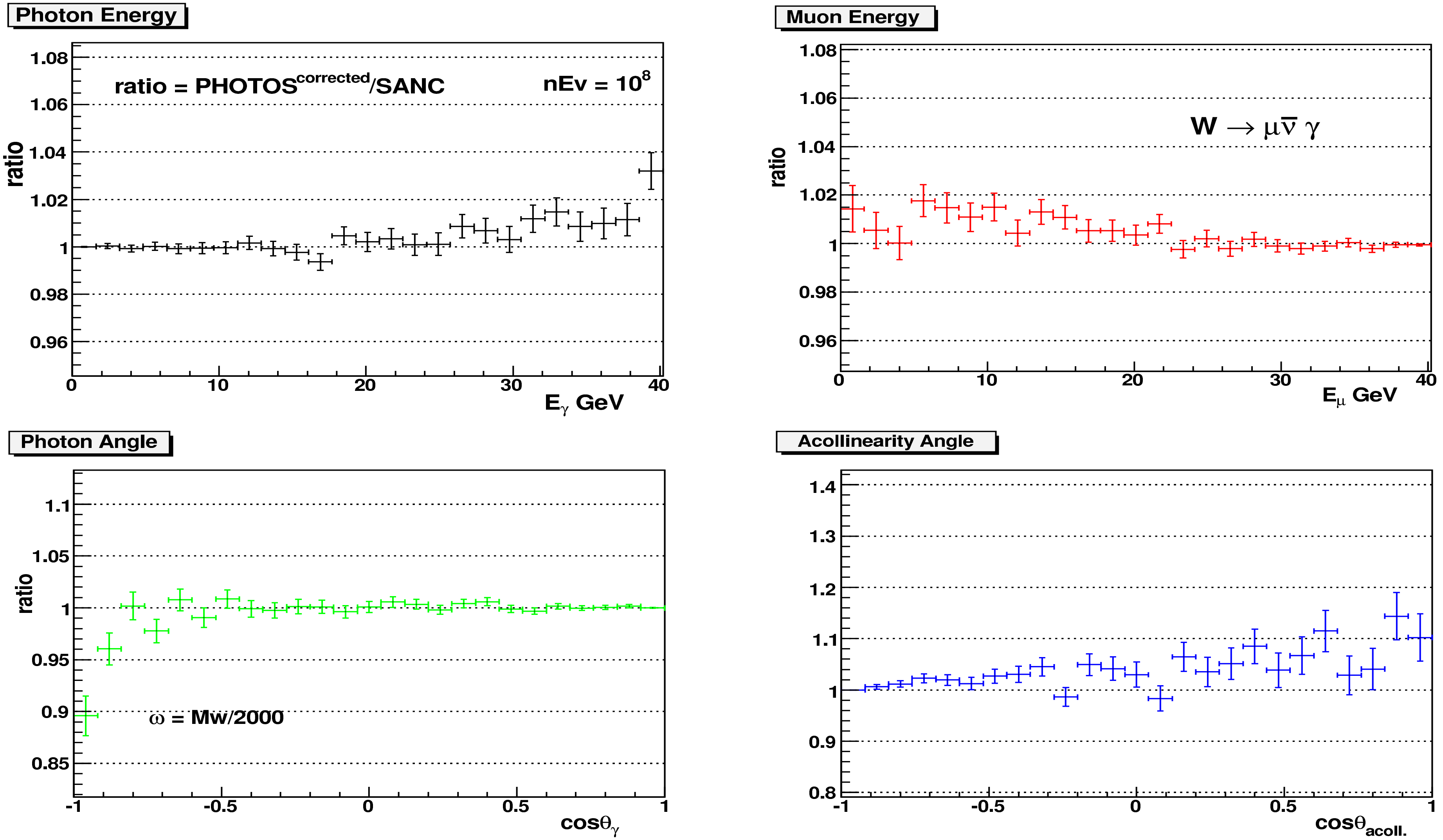






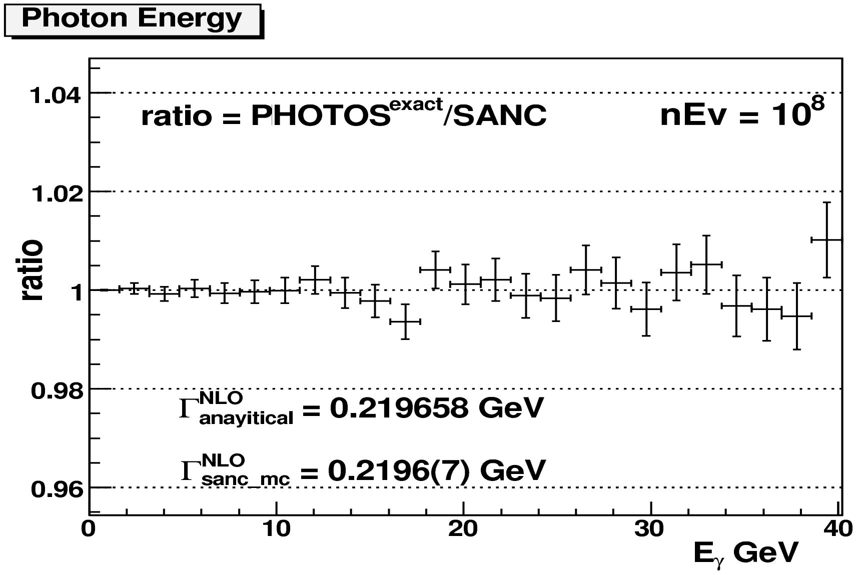
Results from PHOTOS without any correcting weight, and SANC for ratios of the $W \rightarrow l\nu(\gamma)$ distributions. Distribution shapes are similar to those of B- deays (and we skip them).

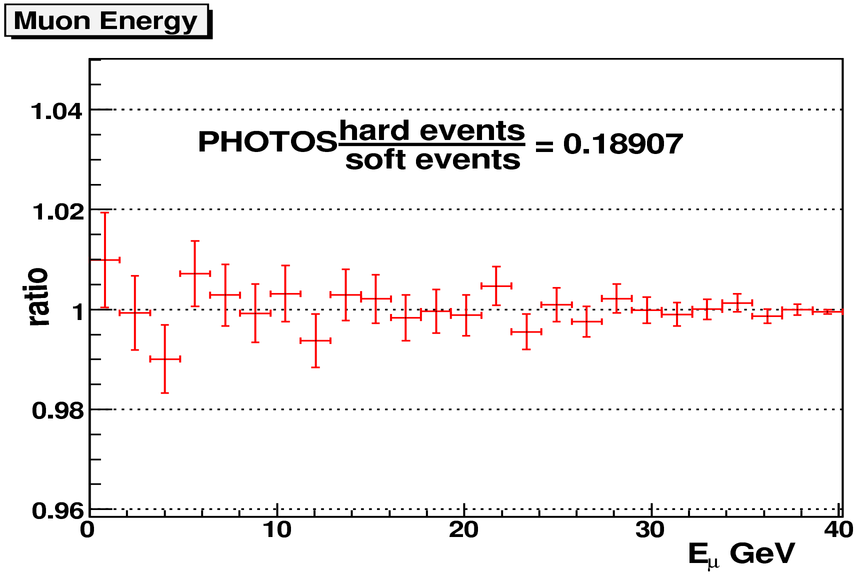
PHOTOS

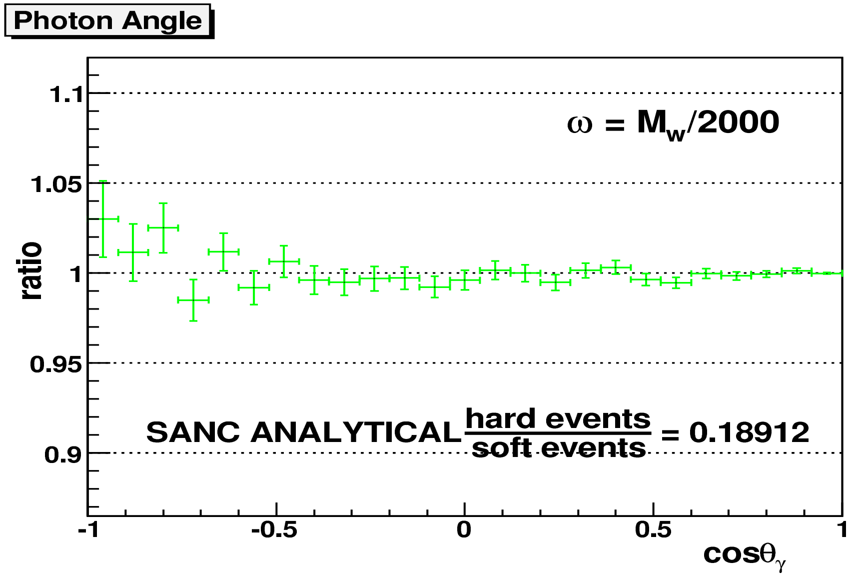


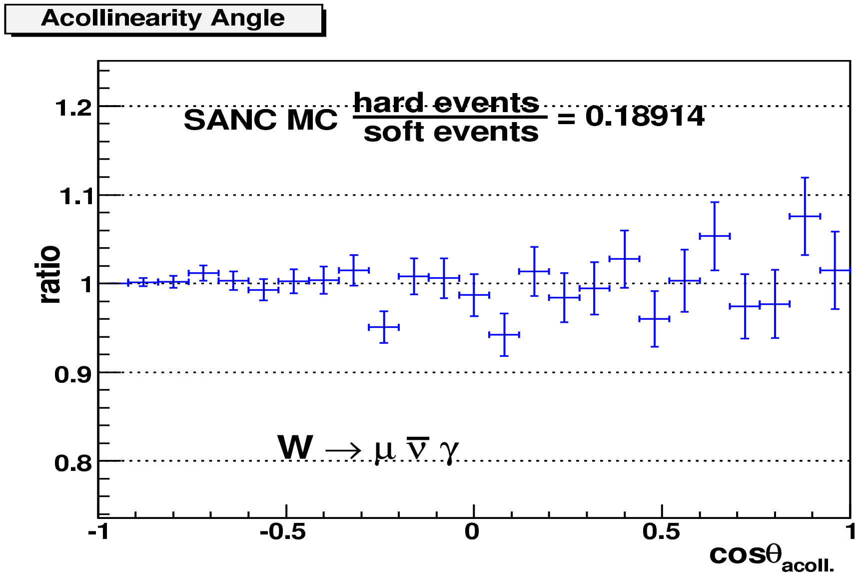
Results from PHOTOS with the corecting weight of 2003, and SANC for ratios of the $W \to l\nu(\gamma)$ distributions.

PHOTOS









Results from PHOTOS with the exact matrix element, and SANC for ratios of the $W \to l\nu(\gamma)$ distributions. Differences are below statistical error of 10^8 events..

Conclusion on PHOTOS

- **PHOTOS work exellently for statistical samples of up to 10^9 events**
- **Matrix element used in generation is explicitly localized**
- **Even though in case of scalars as decay products, results means not much direct progress in itself, possibility to play with measurements of form-factors opens.**
- **Standard PHOTOS is most probably sufficient for many years to go.**
- **In case of doubts or ‘big’ measuremens technique of validation is prepared.**
- **Extensions to QCD is an open possibility now.**

TAUOLA universal interface

- **To run, generator for tau decays must be combined with the part for tau production.**
- **In cases of our packages such as KORALB, KORALZ, KKMC host programs provide environment for TAUOLA use.**
- **I will concentrate on physics points in case when only information from event records is used.**
- **I will skip technicalities related to the way how HEPEVT common block is filled in 3 versions of PYTHIA conventions and HERWIG.**
- **also I will skip new developments in domain of event records.**
- **TAUOLA universal interface reads information from HEPEVT common block, there τ leptons to be decayed are found,**
- **and their spin states are calculated from kinematical configurations of hard processes leading to τ's.**

Formalism for $\tau^+\tau^-$

- Because narrow τ width approximation can be obviously used for phase space , cross section for the process $f\bar{f} \to \tau^+\tau^- Y; \tau^+ \to X^+\bar{\nu}; \tau^- \to \nu\nu$ reads:

$$d\sigma = \sum_{spin} |\mathcal{M}|^2 d\Omega = \sum_{spin} |\mathcal{M}|^2 d\Omega_{prod}\ d\Omega_{\tau^+}\ d\Omega_{\tau^-}$$

- This formalism is fine, but because of over 20 τ decay channels we have over 400 distinct processes. Also picture of production and decay are mixed.

- but (only τ spin indices are explicitly written):

$$\mathcal{M} = \sum_{\lambda_1\lambda_2=1}^{2} \mathcal{M}^{prod}_{\lambda_1\lambda_2}\ \mathcal{M}^{\tau^+}_{\lambda_1} \mathcal{M}^{\tau^-}_{\lambda_2}$$

- Formula for the cross section can be re-written

$$d\sigma = \Big(\sum_{spin} |\mathcal{M}^{prod}|^2\Big)\Big(\sum_{spin} |\mathcal{M}^{\tau^+}|^2\Big)\Big(\sum_{spin} |\mathcal{M}^{\tau^-}|^2\Big) wt\ d\Omega_{prod}\ d\Omega_{\tau^+}\ d\Omega_{\tau^-}$$

universal interface

- where

$$wt = \Big(\sum_{i,j=0,3} R_{ij} h^i h^j \Big)$$

$$R_{00} = 1, \quad < wt >= 1, \quad 0 \le wt \le 4.$$

  R_{ij} can be calculated from $\mathcal{M}_{\lambda_1 \lambda_2}$
  and h^i, h^j respectively from $\mathcal{M}^{\tau^+}$ and $\mathcal{M}^{\tau^-}$.

- Bell inequalities tell us that it is impossible to re-write wt in the following form

$$wt \ne \Big(\sum_{i,j=0,3} R^A_i h^i \Big) \Big(\sum_{i,j=0,3} R^B_j h^j \Big)$$

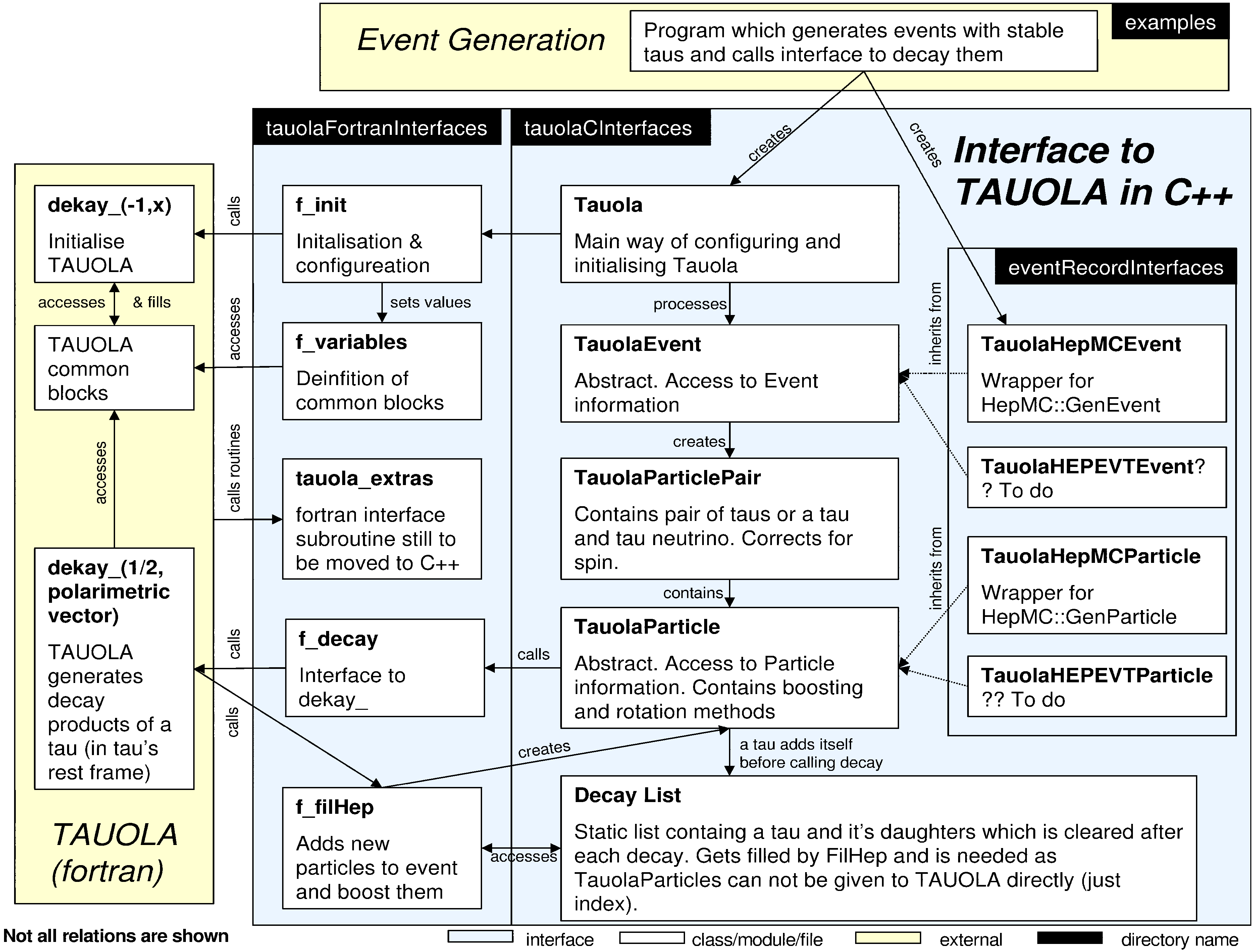
  that means it is impossible to generate first τ^+ and τ^- first in some given ‘ quantum state’ and later perform separatelly decays of τ^+ and τ^-

- It can be done only if approximations are used !!!

- May be often reasonable, but nonetheless approximations.

Also in C++

1. Many young people prefer that language ...
2. Many new LHC generators use C++ HepMC structure to store events ...
3. Universal interface is mostly about helping experimental physicist. It must remain in their hands, but it is not their main worry or work direction.



Interface to TAUOLA in C++

Event Generation

Program which generates events with stable taus and calls interface to decay them

examples

tauolaFortranInterfaces

f_init
Initalisation & configureation

f_variables
Deinfition of common blocks

tauola_extras
fortran interface subroutine still to be moved to C++

f_decay
Interface to dekay_

f_filHep
Adds new particles to event and boost them

tauolaCInterfaces

Tauola
Main way of configuring and initialising Tauola

TauolaEvent
Abstract. Access to Event information

TauolaParticlePair
Contains pair of taus or a tau and tau neutrino. Corrects for spin.

TauolaParticle
Abstract. Access to Particle information. Contains boosting and rotation methods

Decay List
Static list containg a tau and it's daughters which is cleared after each decay. Gets filled by FilHep and is needed as TauolaParticles can not be given to TAUOLA directly (just index).

eventRecordInterfaces

TauolaHepMCEvent
Wrapper for HepMC::GenEvent

TauolaHEPEVTEvent?
? To do

TauolaHepMCParticle
Wrapper for HepMC::GenParticle

TauolaHEPEVTParticle
?? To do

TAUOLA (fortran)

dekay_(-1,x)
Initialise TAUOLA

TAUOLA common blocks

dekay_(1/2, polarimetric vector)
TAUOLA generates decay products of a tau (in tau's rest frame)

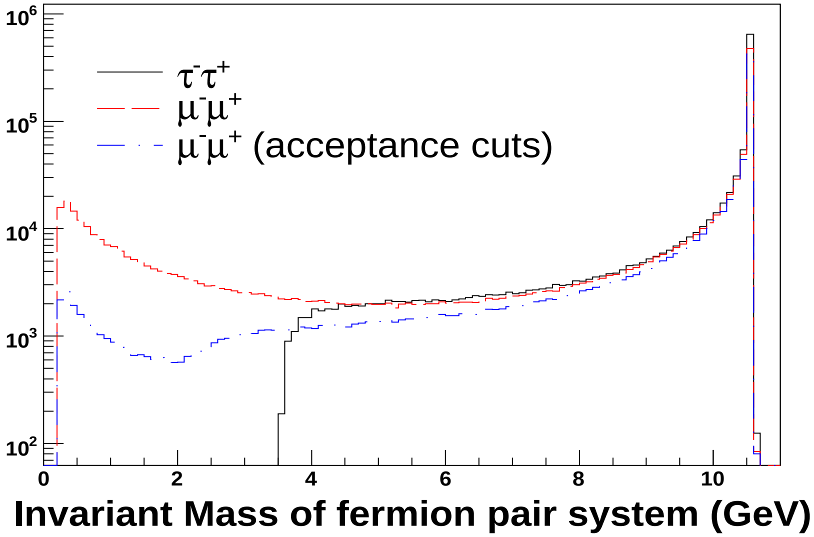
Not all relations are shown

▭	interface
▭	class/module/file
▭	external
■	directory name

web-page http://www.ph.unimelb.edu.au/ ndavidson/tauola/doxygen/index.html β version. No spin effects yet.

KKMC at 10 GeV

For 0.1% precision at low energies ...



1. vacuum polarization
2. mass terms also in interference
3. pair corrections
4. S. Banerjee et al. Phys.Rev.D77:054012,2008. Precision tag for 10 GeV CMS ebe is just 0.35 % ($\tau^+\tau^-$) and 0.44 % ($\mu^+\mu^-$). But it was quickfix.
5. Coulomb interaction
6. hadronic currents instead of $\mu^+\mu^-$ final states?

.. one need technical work

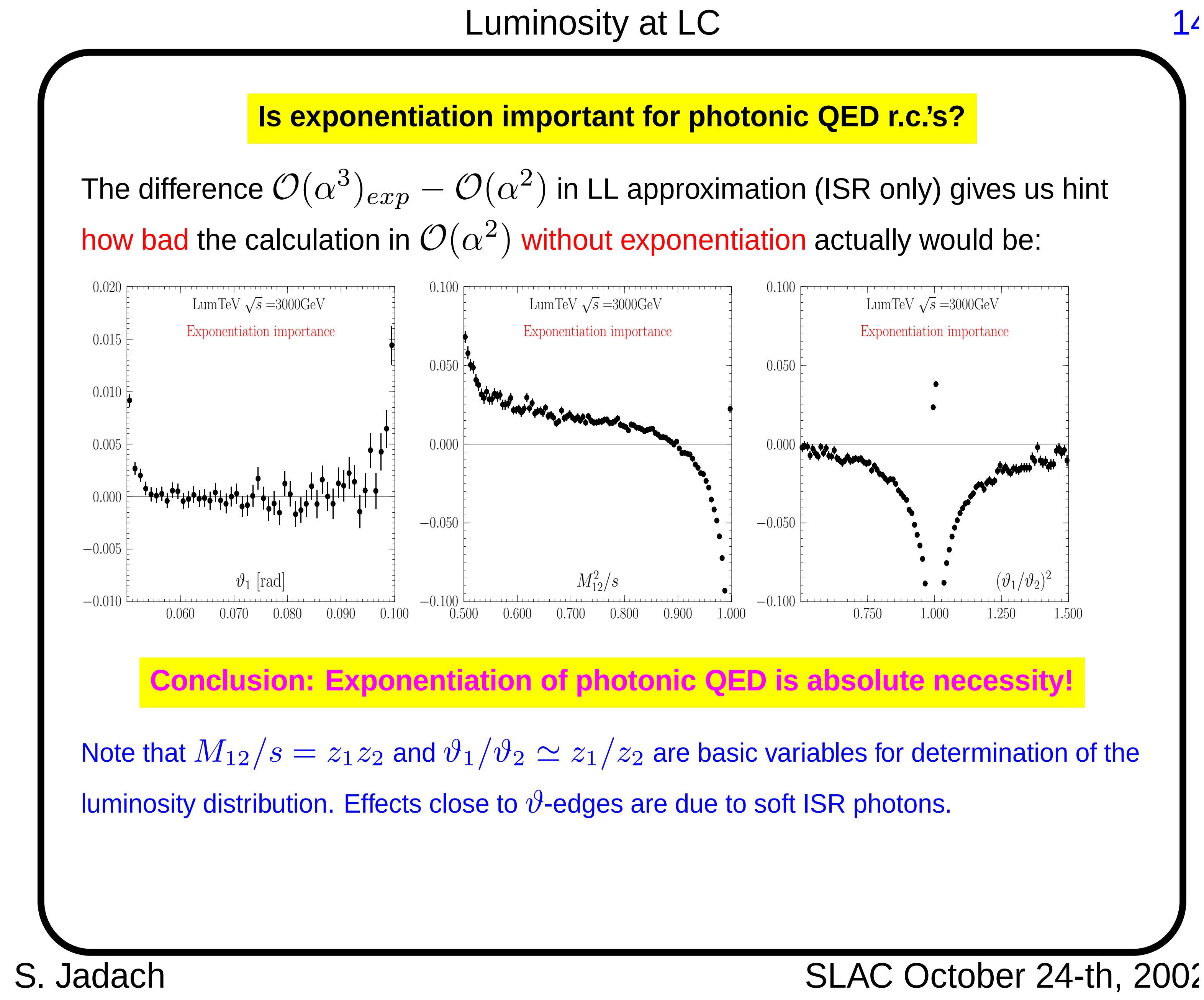
This is mostly question of manpower and organization of workshare.

Nothing of what in principle is OK at high energies will work without attention

KKMC at 10 GeV

We are basically as in: http://home.cern.ch/jadach/public/frascati_nov_2001.pdf

BHLUMI, essential for 0.04 % precision



Is exponentiation important for photonic QED r.c.'s?

The difference $\mathcal{O}(\alpha^3)_{exp} - \mathcal{O}(\alpha^2)$ in LL approximation (ISR only) gives us hint how bad the calculation in $\mathcal{O}(\alpha^2)$ without exponentiation actually would be:

Conclusion: Exponentiation of photonic QED is absolute necessity!

Note that $M_{12}/s = z_1 z_2$ and $\vartheta_1/\vartheta_2 \simeq z_1/z_2$ are basic variables for determination of the luminosity distribution. Effects close to ϑ-edges are due to soft ISR photons.

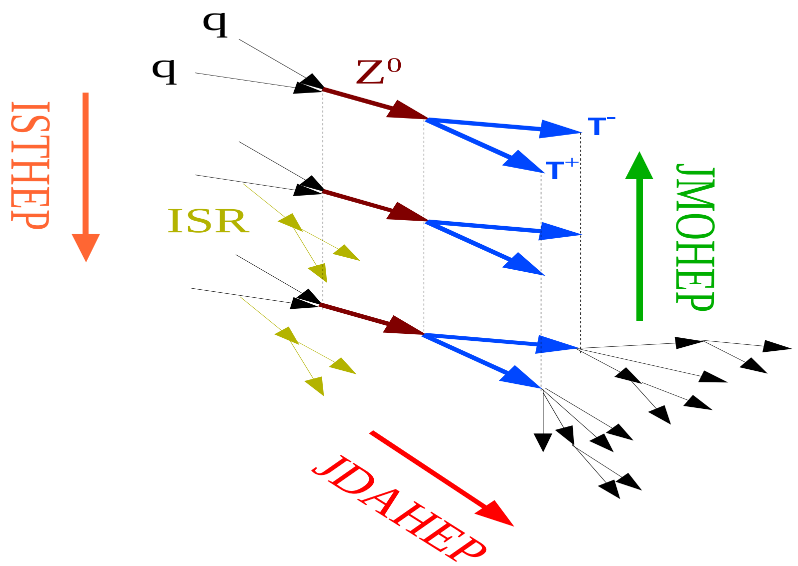
from http://home.cern.ch/jadach/public/LumLCslac.pdf Warning on α^3 and cut-off dependence

Summary

- *We have reviewed news on the following tools for simulation of τ physics:*
  - *TAUOLA as generator for τ decays: additinal weights to be used for fits.*
  - *PHOTOS as generator for radiative corrections in decays: new precision results for W decays.*
  - *benchmark distribution strategies and MC-TESTER now also for C++ applications*
  - *Universal interface of TAUOLA, migration to C++ is on its way*
  - *Uncertainty of total cross section at lower energies as predicted by KKMC is now reduced to 0.3-0.5 %, if appropriate imrovements of photon vacuum polarzation are installed (S. Banerjee, Phys.Rev. D77:054012,2008).*
  - *stability of C++ event records, need verification still*
  - *encapsulation and inconvenience for end users, problems seem to be under control.*

Summary

Problems With Event Record



1. Hard process
2. with shower
3. after hadronization
4. Event record overloaded with physics beyond design ⟶ gramar problems.
5. Here we have basically LL phenomenology only.

This Is Physics Not F77!

Similar problems are in any use of full scale Monte Carlos, lots of complaints at MC4LHC workshop, `HEPEVTrepair` utility (C. Biscarat and ZW) being probed in D0.

Design of event structure WITH some grammar requirements AND WITHOUT neglecting possible physics is needed NOW to avoid large problems later.

Summary

Future

- **TAUOLA and associated programs seem to be a living project**
- **As in the past different parametrizations will be developed within collaborations. Also, as in the past, will function as private code. Huge machinery.**
- **Some "cross talk" may be useful. Non-tau experiments like LHC may profit.**
- **We have prepared, updated TAUOLA version, with open slots for many new currents to be studied simultaneously.**
- **High precison of PHOTOS verified for W decays (NLO kernel). We need to enter into phenomenological project where analysis of data is essential.**
- **Fortran to C++ shift is mainly community issue, technicaly not a problem.**
- **There is little activity on KKMC and BHLUMI. Some work to control perecision at lower energies is a must. Especially for vacuum polarization and effects like Coulomb interaction.**
- **Let us have private discussions now.**