PHOTOS

as pocket parton shower – and recent developments.

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P. Golonka

CERN IT/CO-BE , Geneva

Institute of Nuclear Physics PAS, Krakow

Z. Was

Institute of Nuclear Physics PAS, Krakow *and* CERN-PH, Geneva

Web pages for transparencies and progam(s):

http://wasm.home.cern.ch/wasm/goodies.html

http://piters.home.cern.ch/piters/MC/PHOTOS-MCTESTER/

$\mathcal{M}$otivation (2004/2005): Belle/BaBar/NA48 etc.

- CKM matrix elements and new physics discovery potential of B-factories are related to Branching Fractions and shapes of distributions in decay processes
- Processes of particular interest:
  $B^0 \to \pi^+\pi^-$, $B^0 \to K^+\pi^-$
  $B^0 \to \pi^+ l^- \nu$, $B^0 \to K l^+ l^-$, $K \to \pi l \nu$
- Impact of the radiative correction comes through efficiency (ϵ): it is around 5%
- If we want to measure with precision of 1% then shape corrections due to bremsstrahlung have to be known with precision (0.3%) for related systematics to be negligible.
- Physics of these resonances, will be of some interest at LHC as well.

Motivation 2003/2004: LHC, cosmics?

- For similar purposes radiative corrections need to be included in case of simulations for measurements of W mass and couplings in TEVATRON/LHC experiments;
- Main interest: decays of W' and Z's, but also t, H

Algorithmic side – quite exciting for me.

- Iterative solution like in parton shower
- Relation to Matrix elements (virtual+real) and exact phase space
- Organization of solution from 1-dim to full phase space
- Organization from sophisticated multi dim. kernels to simple (integrable) ones.

Motivation

- PHOTOS (by E.Barberio, B. van Eijk, Z. W., P.Golonka) is used to calculate the effect of radiatiative corrections
- but we need to discuss its systematic error
- PHOTOS has not been tested for B, K decays. No works on matrix elements.
- It was not tested for new exotic heavy particles as well
- However a lot was done recently in context of Z and W decays, precision of 0.1% was established!
- Technical and algorithmic developments as well: multiple photon mode, plays at different level of crude distr ..
- The purpose of my talk is nonetheless mainly presentation of 'numerical proofs'.

$\mathcal{P}$HOTOS recent changes

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

See also: P. Golonka et al. hep-ph/0312240

- Until 2002 option for single- and double- photon emissions were available, no precision tests were performed, no work with W decays matrix elements, no related weights in PHOTOS!
- Year 2003: improvements in W decays, for 30 MeV-precision in Tevatron.
- Summer 2004: precision tests for W and Z decays, hundreds of histograms and benchmark numbers available at cern.ch/Piotr.Golonka/MC/PHOTOS-MCTESTER
- Summer 2004: new options for triple, quatric and multiple-photon emission
- January 2005: thanks to input from NA48 improvements in meson decays. Precision improved from about factor of two to 20% for decays like $K \to l^{\pm}\nu\pi^{\mp}$. Middle of the work!

- I assume here that there is no need for presentation of PHOTOS. It is a Monte Carlo of “after-burner” type which reads in event record for decay chains without radiative corrections and, sometimes, adds bremsstrahlung photons. It is weight=1 algorithm, very convenient for use with full detector acceptance simulations.

PHOTOS may work in three regimes:

1. as a universal crude tool in decays of "any" particle
2. as a precision tool in dedicated channels: Z and W decays - precision better than per-mile level, this was never assured for B, K, etc decays!
3. with explicit process-dependent ME included (never needed so far)

LL is not understood universally!

In B meson decays (like always) PHOTOS was expected to be used at LL precision level, that is for the purpose acceptance-simulations only and NOT for shape corrections. Precision was supposed to come from other programs.
PHOTOS was for easy use. Just add photons here and there in HEPEVT – favorite event record of 90's.

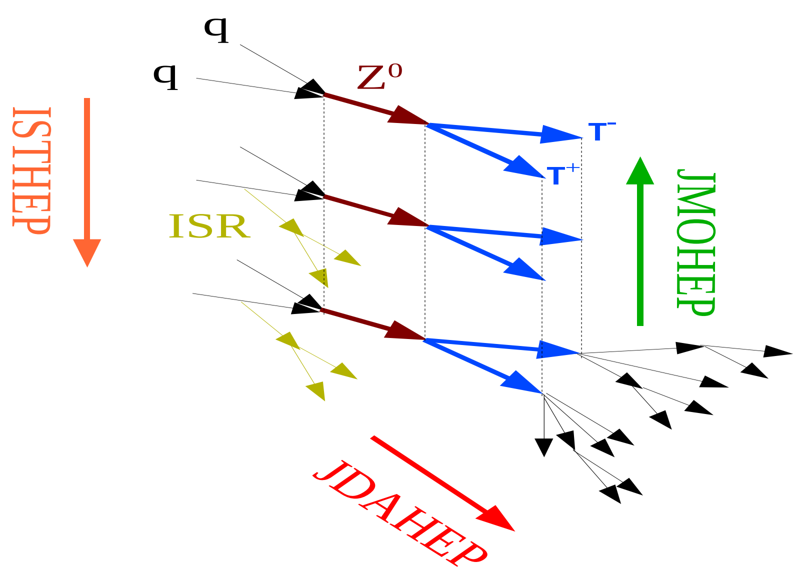
Technical developments (true life):

- **PART 1: Rounding error traps**
  - classified and those found removed
  - HEPEVT living object. Action of PHOTOS depends on its content
  - Increased physics sophistication brought additional numerical pressure
- **PART 2: Single photon emission**
  - Plays with intereference and underlying crude for angular singularities around each charge !!!
  - From 4-vectors to angular parametrization of phase space and back! Shwinger-Dyson type relations
- **PART 3: Iteration**
  - double, triple, quatric, multiple-photon emission. Reshuffling
- **I am just listing elements in game, they may give hints for QCD.**

TECHNOLOGY – PART 1:
Rounding error and traps.

- Mother daughter relations, trees etc.
- Rounding errors etc.
- **It is reality of life which kick. Topics seem mariginal, but are not.**
- Help and interaction with collaborations is acknowledged!!

Problems With Event Record



1. Hard process
2. with shower
3. after hadronization
4. Event record overloaded with physics beyond design $\longrightarrow$ 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.

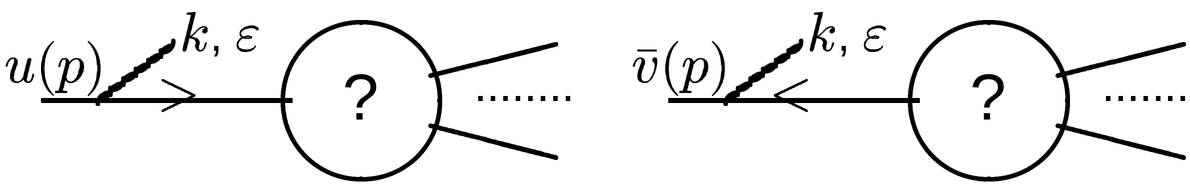
Rounding error and traps.

- Essential in development of the algoritm is it algebraic closenes
- It should go around certain lines (known to the authors).
- It is well known, that it may be different in real life, and diagnosis may be difficult.
- We had a problem of that sort, because of rounding errors.
- Part of the information analyzing one event was not erased, and was surviving to the second one.
- Effects of errors were falsely interpreted by us and blocked development by years.
- Exceptions happened every few hours of runs, and could be removed by physicalparameters. Technically aspect similar to regularization of infrared/ultraviolet singularity.
- Software engineering issues. Interesting for applied computing.

TECHNOLOGY – PART 2: Single photon emission

- with every process there can be associated another one, where in addition to normal quanta, there is additional photon added.
- If such photon is soft and/or collinear to outgoing fermion the corresponding amplitude can be written as a product of the Born amplitude and photon emission factor(s).
- single factor for soft but sum of two for collinear.
- Simmilar factorization can be done for the phase space.
- **This factorization is EXACT, complete order α, in cases like Z decay, ISR in e^+e^- collisions and probably always, also at the level of probablility distributions.**
- Our starting point consist of extra photon real or virtual!

Zaokpane lectures, CERN-TH 7154/94 Real emission ...



a) Incoming electron   b) Incoming positron

Figure 1: *Feynman diagrams for photon emission in initial state respectively from electron and positron. Dots represent all other fields entering amplitude (initial or final). Note that in case of positron arrow points in opposite direction, even though it is also initial state particle.*

and virtual ones go in pair ...

Zaokpane lectures, CERN-TH 7154/94 Virtual ...

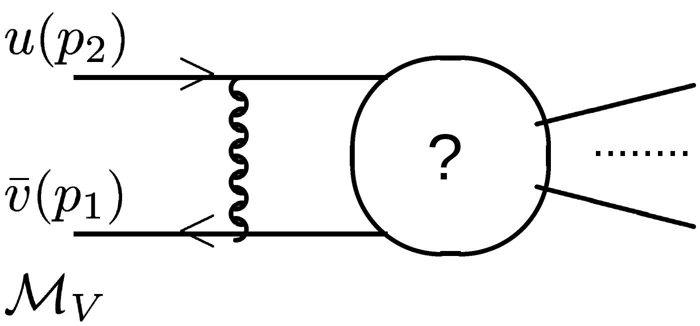


Figure 2: *Feynman diagram for the vertex-like correction in initial state in* e^+, e^- *collision. Dots represent all final state fields.*

One can form from the two contribution and the proper parametrization of phase space 'after-burner' algorithm to make events with extra photon accordingly to matrix element in case of Z decays, or accordingly to approximate treatment in other cases (unless ME is analyzed there as well) from the events without photons generated earlier and by any means.

Keywords: Interference between emission from different charges, gauge invariant emission at approximation level, k_0 cut-off.

Transformation distribution for emission from single charge takes a form of Shwinger Dyson type of transformation (as examples formulas are for ISR):

$$\begin{aligned} d\sigma &= \frac{1}{|v_1-v_2|}\frac{1}{2p_1^0}\frac{1}{2p_2^0}\frac{1}{1-x}\sum_s \mathcal{M}_B(p-k)\mathcal{M}_B^\dagger(p-k) \\ & \frac{e^2}{E^2x^2(1-\beta c_\theta)^2}\Big((1-x)s_\theta^2+(1-c_\theta)x^2\Big)\Big[kdkdc_\theta d\phi\frac{1}{2(2\pi)^3}\Big] \\ \times & \; dLips_n(p_1-k,p_2\to q_1...q_n) \end{aligned} \quad (1)$$

Complete result, including virtual corrections reduced to single dimensional splitting (it can be used as first step of constructing full event; here we also bridge full and 1-dim ph.space):

$$\begin{aligned} d\sigma(p_1,p_2\to q_1...q_n,x) &= d\sigma_{born}(p_1-k,p_2\to q_1...q_n)\cdot dx f(x) \\ f(x) &= \delta(x)+P(x) \\ P(x) &= \delta(x)\Big(\frac{\alpha}{\pi}\ln\frac{E^2}{m_e^2}\ln x_0+\frac{3}{4}\frac{\alpha}{\pi}\ln\frac{E^2}{m_e^2}\Big) \\ &+ \Theta(x-x_0)\frac{\alpha}{\pi}\ln\frac{E^2}{m_e^2}\frac{1}{x}\frac{1}{2}\Big(1+(1-x)^2\Big). \end{aligned} \quad (2)$$

The kernel is ready for iteration, but let us return to interferences first.

- formulas were for emission from one incoming line.
- interferences can be re-established by correcting weight for the combined emission from both lines, or emission kernel can be better and interference can be distributed over two emission kernels without approximations.
- To show that matrix elements have to be studied, not just leading singularity terms.
- These pictures can be understood as gauge invariant at every step. Incoming electron/positron paired with imagined pair of cancelling charges of intermediate states.

TECHNOLOGY – PART 2:
Summary

- We have studied relation between n-body process and n- (n+1)-body processes with distribution described by amplidudes modified by extra diagrams with single photon line added.
- We have so far ignored all complications due to possible presence of photons in original n-body processes.
- We have (pretended to) shown that relation R can be build at the level of fully differential distributions as mapping from one manifold (n-body phase space) into two (n-body and (n+1)-body phase space).
- Manifolds can be projected into single variable x, where $x = 0$ corresponds to manifold dimensionality n and $x > 0$ one of the variables parametrizing phase space $(n + 1)$
- Relation (evolution operator) R can be separated into parts

$R = R_A = R_{A'} \cdot R_B(R_C + R_D)$:

$--$, R_D: so far too small to care residual but well defined part with undefined properties and process dependent.

$--$, R_C: preserving energy momentum and probability

$--$, R_B: defining transformation from variable x to full manifolds and restoring conservation rules.

$--$, R_A: no preserving conservation rules generation of variable x.

$--$, R_A: no preserving conservation rules (but solvable analytically).

- All this can be done from analysis of Feynman diagrams. Fixed order plus some assumptions on factorization

$--$, Note that after iteration we get formally objects of the type of exponents, formed of non commuting operators or better to say sometimes commuting into right.

$--$, refined description with better mathematical language?

TECHNOLOGY – PART 3: Iteration

- So far we were working with single emission of photon.
- In real case multiple emission can be present and coherence need to be taken.
- Especially complex picture is in QCD. Ordering allows to ignore problems.
- We divide phase space into sectors. In each of them only one diagram dominates
- Pictures like DGLAP p_T ; CCFM angle; BFKL $x's$. provide at least partial description of transverse degrees of freedom.
- These are crude approximations, for some regions of phase space, but give some leading logs and underlying angular distributions OK.
- **It was possible to overcome at least in QED.**
- Price was some work on second/third order matrix element
- May be recent works, Nason, Witten, Papadopoulos will give solutions for QCD as well. See also some technical results in hep-ph/0406045 which we still digest.
- How to expand predictions from Field theory type A, with respect to type B, and consecutive approximations like eikonal, masless, smaller/larger gauge group, contact interaction approx., susy, etc

Zaokpane lectures, CERN-TH 7154/94 Double emission ...

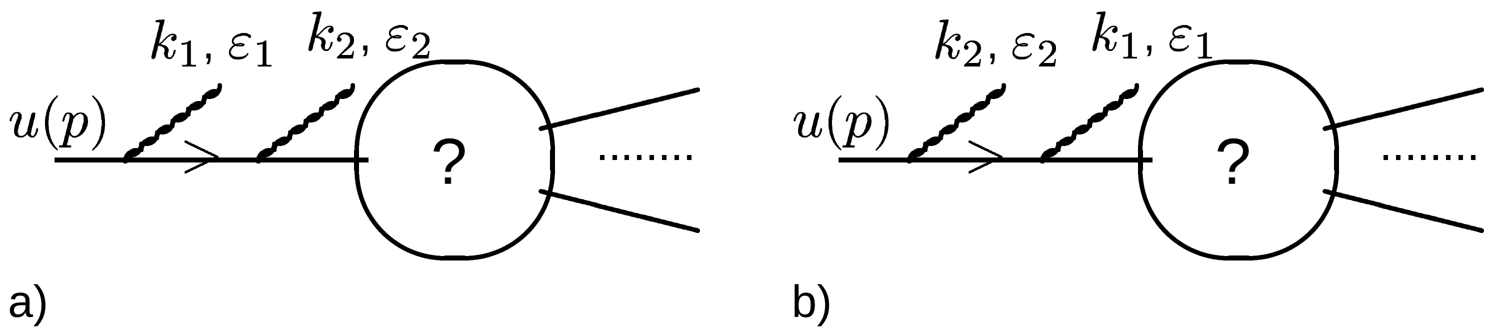


Figure 3: *Feynman diagrams for double photon emission in the initial state from electron. Dots represent all other fields entering amplitude (initial or final).*

$$\mathcal{M}_1 = \ ...\ iS_F(p - k_1 - k_2)(-ie\gamma_\mu)iS_F(p - k_1)(-ie\gamma_\nu)u(p, s)\ \varepsilon_2^\mu \varepsilon_1^\nu$$
$$\mathcal{M}_2 = \ ...\ iS_F(p - k_1 - k_2)(-ie\gamma_\mu)iS_F(p - k_2)(-ie\gamma_\nu)u(p, s)\ \varepsilon_1^\mu \varepsilon_2^\nu. \qquad (3)$$

where

$$
\begin{aligned}
\mathcal{M}_1 \quad = \quad & e^2 \frac{-1}{2k_1p} \; \frac{-1}{2k_1p + 2k_2p - 2k_1k_2} \; \ldots \\
& (\not{p} - \not{k}_1 - \not{k}_2 + m) \; \not{\epsilon}_2 (\not{p} - \not{k}_1 + m) \; \not{\epsilon}_1 u(p, s)
\end{aligned}
\tag{4}
$$

Contribution from $\mathcal{M}_2$ is analogous AND negligible ‘nearly everywhere’ if ordered phase parametrization is used.

Structure necessary for iteration can be obtained from explicit calculation to fixed orders, may be with controlled and reversible approximations, whenever possible, and from factorization properties elsewhere. For example in infrared limit we get:

$$
(\mathcal{M}_1 + \mathcal{M}_2) \Big|_{IR} = \left(e \left(\frac{\varepsilon_1 p_2}{k_1 p_2} - \frac{\varepsilon_1 p_1}{k_1 p_1} \right) \right) \left(e \left(\frac{\varepsilon_2 p_2}{k_2 p_2} - \frac{\varepsilon_2 p_1}{k_2 p_1} \right) \right) \mathcal{M}_B . \tag{5}
$$

But patching pictures of different limits and explicit Matrix Element calculation seem to be the best and unexplored technique to get best predictions for parton showers.

TECHNOLOGY – Summary

• We have defined **building blocks** how to go from study of Feynman diagrams to parton shower-like algorithms

• Steps included phase space parametrization.

• In particular relations between n-body and (n+1)-body.

• Also reduced dimensionality ‘longitudinal phase space’

• Mathematical properties of operator(s) $R = R_A + R_B + R_C + ...$

• Iteration with the help of phase space slicing to localize dominant diagrams .....

• ... or thanks to study of higher order matrix elements

• Possibility to extend to QCD?

• Recent works by Witten, Svrcek; Kosover, Glover (presentation at HERA-LHC), Papadopoulos $SU(3) = U(3) - U(1)$, Collins?

• So far I understand only my own calculations of amplitudes, as input for parton shower (with difficulty). see my hep-ph/0406045 on $e^+e^- \to \nu\bar{\nu}\gamma\gamma$. It is in context of pure QED and not quite pure QED. At least prototype exist.

Shwinger Dyson equations – Evolution equations - Structure functions – Parton showers.

- Where are approximations what is first, what is compromise rather than target.
- Formal solution of QED evolution equation, but structure of iterative relation of

Shwinger-Dyson type is basically the same (dimensionality is different here all is projected on x and e^+ is separated from e^-

$$
\begin{aligned}
f^{\infty}(x) &= \delta(x) + P(x) + \frac{1}{2!}\Big\{P \otimes P\Big\}(x) + + \frac{1}{3!}\Big\{P \otimes P \otimes P\Big\}(x) + ... \\
\Big\{P \otimes P\Big\}(x) &= \int_0^1 dx_1 \int_0^1 dx_2 \delta(x_1 + x_2 - x_1 x_2 - x) P(x_1) P(x_2). \qquad (6)
\end{aligned}
$$

- Evolution equations:

$$\frac{\partial}{\partial t} D_k(t,x) = \sum_j \int_x^1 \frac{dz}{z} P_{kj}(z) \frac{\alpha_S(t)}{\pi} D_j\Big(t, \frac{x}{z}\Big) = \sum_j \mathcal{P}_{kj}(t,\cdot) \otimes D_j(t,\cdot),$$

where

$$f(\cdot)\otimes g(\cdot)(x) \equiv \int dx_1 dx_2 \delta(x - x_1 x_2) f(x_1) g(x_2).$$

generally:

$$\frac{\partial x}{\partial t} = R(t)x \tag{7}$$

- Solutions:

$$x(t) = \Big(\sum_{n=0}^{\infty} \prod_{i=1}^{n} \int_{t_0}^{t} dt_i \Theta(t_i - t_{i-1}) R(t_i) \times \Big) x(t_0). \tag{8}$$

- Structure funct approach. very convenient, because of triple gluon vertex.

TECHNOLOGY – Mathematical Side

- We have methods for iterative construction of (n+k)-body maps for manifolds parametrizations using methods similar to iterative procedures for special functions.
- This is done with 'in principle' exact phase space parametrization.
- All is done in parallel at the level of analytically solvable iterative solutions for projected spaces which are nonetheless related to fully differential ones by operators with special 'sort of unitrary' properties.
- Relations between analytically solvable and exact ones are built with the help of careful studies of first and second order matrix elements.
- Analytically solvable parts are similar to LL language of evolution equations and structure functions, except that we mix emissions from all participating emitters.
- Delicate issues of gauge invariance. Spectator side is used.
- It seem to me that all can be formalized and extended to other applications (QCD?), but is it interesting paths?
- More studies on Shwinger-Dyson type of relations.
- But, lets see (at least) how it works numerically as program is used!

Main lines of development and underlying tests:

- **PART 1: W and Z decays: field theory input available in full**
  - correction weights for W decays
  - universal test
  - results of comparison with ME Monte Carlo and (indirectly) LEP data
- **PART 2: Semileptonic B decays**
  - some Monte Carlo (weighted events) and semi-analytical energy spectra available for tests
  - comparisons with data also useful and partly performed
- **PART 3: Non-leptonic B decays**
  - only comparisons with data are possible
- **Motto: Guilty until proven otherwise.**

PHENO – PART 1:

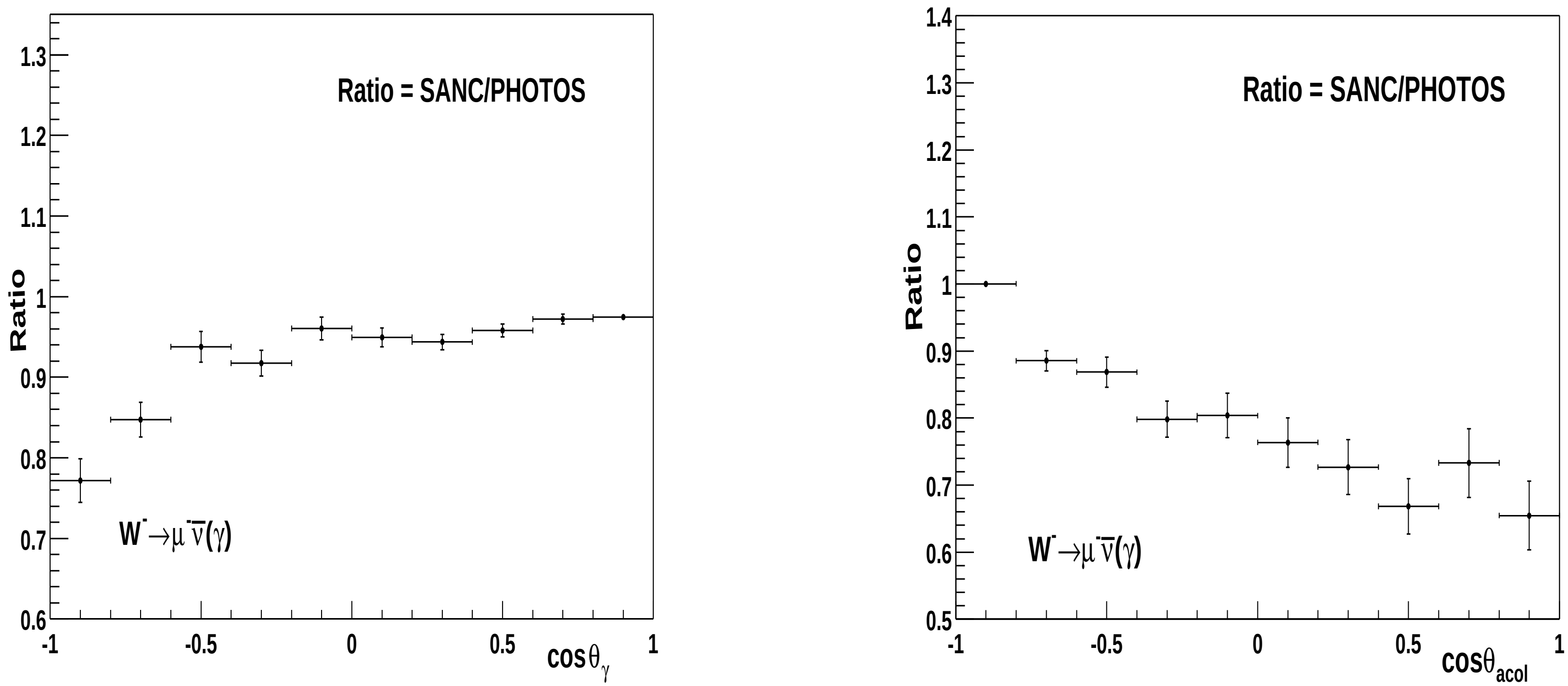
Completed scenario for improvements
in W and Z decays.

project performed for Tevatron and LHC applications

(measurement of the W mass)

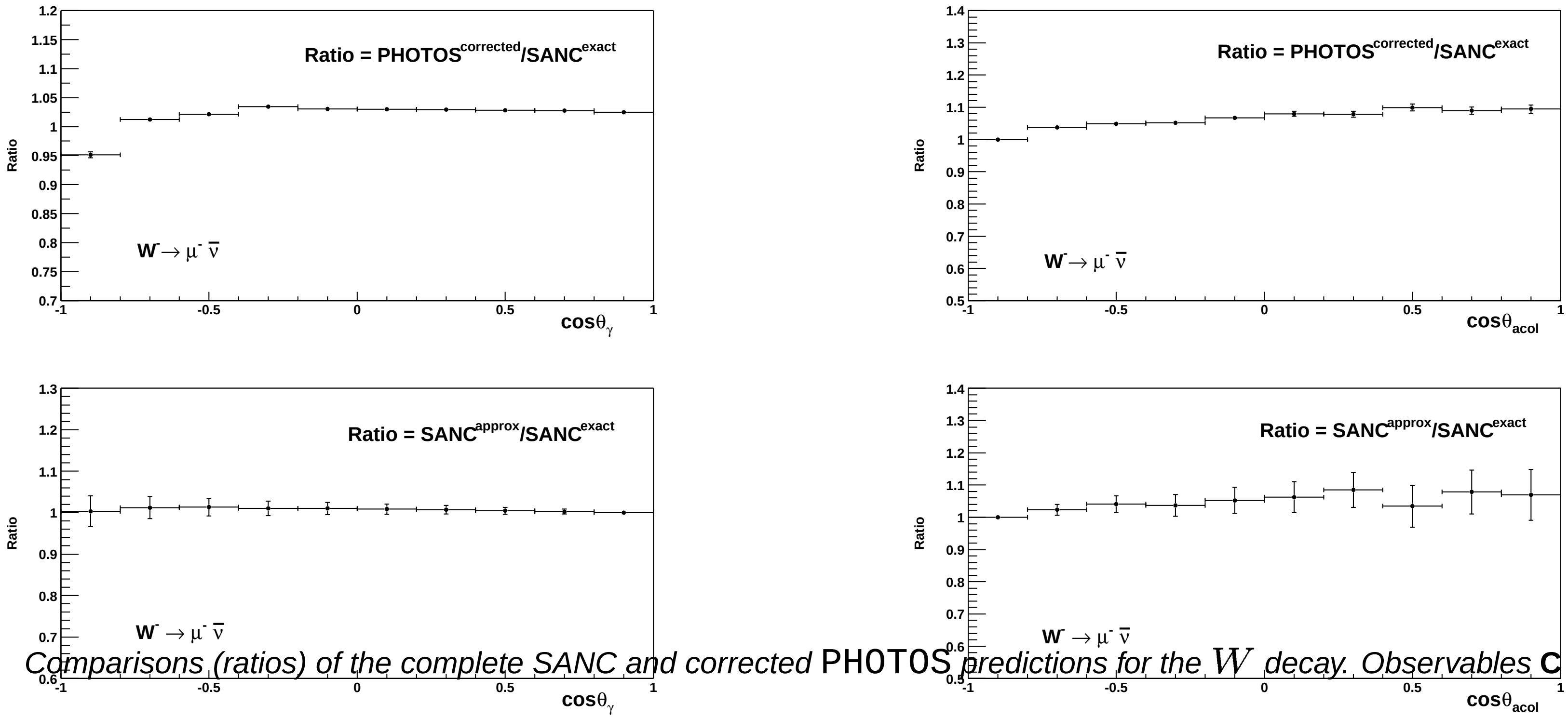
Will serve as example of the work which is done (nearly).

$W \to l\nu$ PHOTOS vs. ME, interference terms missing:



Status as of 2002/2003 (from paper by D. Bardin at al.), program works as expected but not good enough for Tevatron 2004.

$W \to l\nu$ PHOTOS with correcting weight vs. ME, 2003



Comparisons (ratios) of the complete SANC and corrected PHOTOS *predictions for the W decay. Observables* **C** *and* **D***: ratios of the photon angle with respect to μ^- (left-hand side) and $\mu^-\bar{\nu}$ acollinearity (right-hand side) distributions from the two programs. The dominant contribution is of infrared non-leading-log nature for the left-hand side plot, and non-infrared non-leading-log nature for the right-hand side one. In the lower part of the plots similar comparisons for the complete and truncated–corrected with δ predictions are given. From paper by G. Nanawa and Z. Was.*

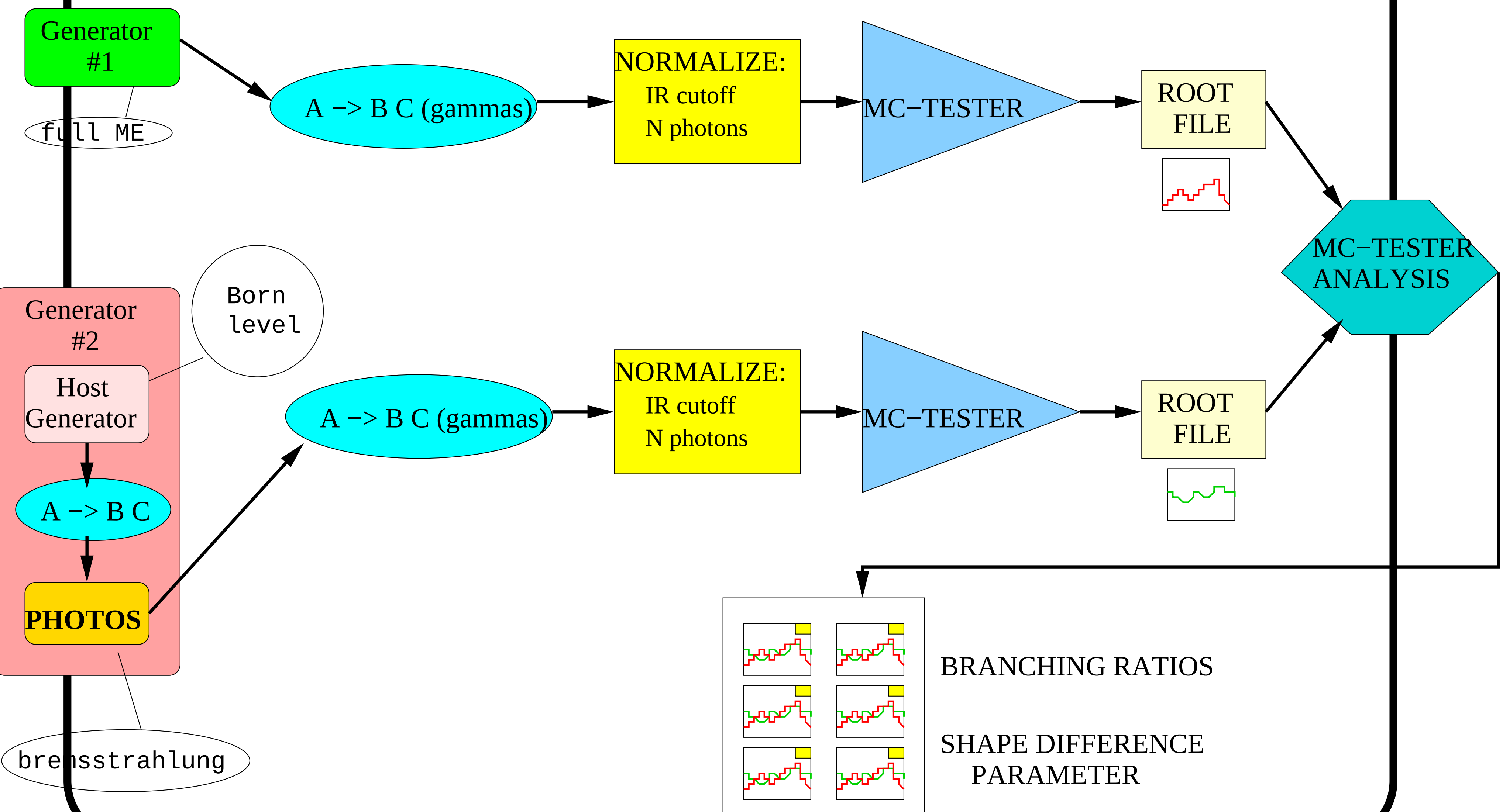
Testing procedure: comparsions of predictions of two Monte Carlo runs

- Numerical comparison tests: we heavily rely on other generators (KKMC, KORALZ, MUSTRAAL, WINHAC, TAUOLA) and work of other people:

  E. Baberio, F. Berends, R.Decker, B. van Eijk, S.Jadach, M.Jezabek, J. Kuhn, R. Kleiss, W. Placzek, B. Ward

  and, indirectly, on LEP data. No miracles: precision need work with matrix elements and/or data (on top of defining algorithm).
- Testing procedure need to be infrared-safe, see http://cern.ch/Piotr.Golonka/MC/PHOTOS-MCTESTER for details.
- Test parameter: E_{test} threshold for soft photons
- Test parameter: maximum number of photons (1 or 2);
- The softer photons' momenta added to fermions momenta (number of photons reduced to 1 or 2)
- We use MC-TESTER to perform systematic study of large number of distributions of invariant masses of decay products

Testing procedure:



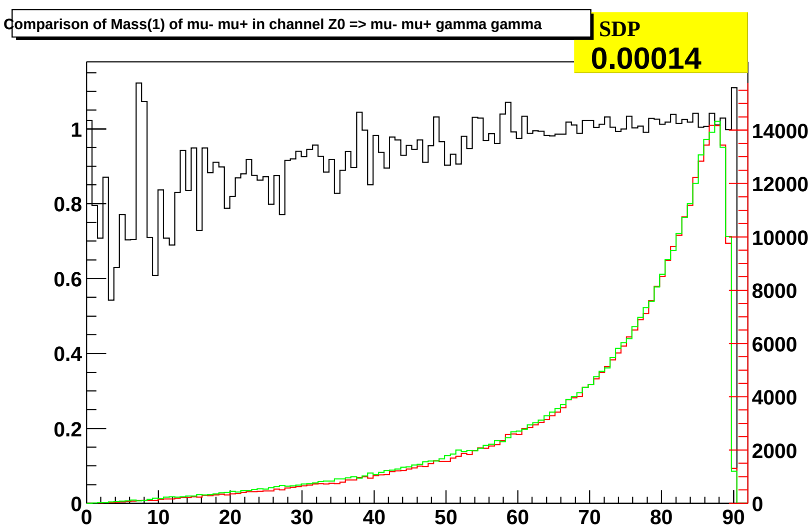
A lot of tests for W and Z decays with radiative corrrections are available at:

http://cern.ch/Piotr.Golonka/MC/PHOTOS-MCTESTER

Hard bremsstrahlung in KK and PHOTOS - results

Comparison of KK and PHOTOS.
in Z->mu mu + bremsstrahlung process at Z mass

GENERATOR	Branching ratio					Maximum SDP					T1		T2		Booklet	
	test1		test2			test1		test2			test1	test2	test1	test2	test1	test2
(n photons) ->	0	1	0	1	2	0	1	0	1	2						
E_test=1.0																
KK	83.918	16.082	83.918	14.816	1.266											
KORAL-Z	83.984	16.016	83.984	14.771	1.244	0	0.00208	0	0.00123	0.00124	0.133	0.133	0.033	0.019		
KORAL-Z O(1)	82.514	17.486				0	0.037				2.807		0.621			
PHOTOS O(1)	82.362	17.638				0	0.0314				3.111		0.528			
PHOTOS O(2)	83.925	16.075	83.925	14.630	1.445	0	0.0067	0	0.0035	0.0122	0.016	0.373	0.107	0.065		
PHOTOS O(3)	83.832	16.168	83.832	14.889	1.280	0	0.0038	0	0.0025	0.0080	0.172	0.172	0.061	0.046		
PHOTOS O(4)	83.836	16.164	83.836	14.871	1.293	0	0.0040	0	0.0027	0.0058	0.163	0.163	0.0635	0.045		
PHOTOS EXP	83.837	16.163	83.837	14.868	1.295	0	0.0041	0	0.0023	0.0092	0.161	0.161	0.066	0.044		
This is to be compared with WINHAC tests:																
KoralZ ME O(1)Exp			83.931	14.899	1.170			0	0.0009	0.0678		0.191		0.086		



A summary table points to booklets with thousands of detailed plots.

This one presents the invariant of largest (SDP<0.1% !) discrepancy between PHOTOS EXP and KKMC in Z decays. Events are referred to as 0, 1 or 2 photon configurations, when 0 1 or at least 2 photons with energy above E_{test} are present.

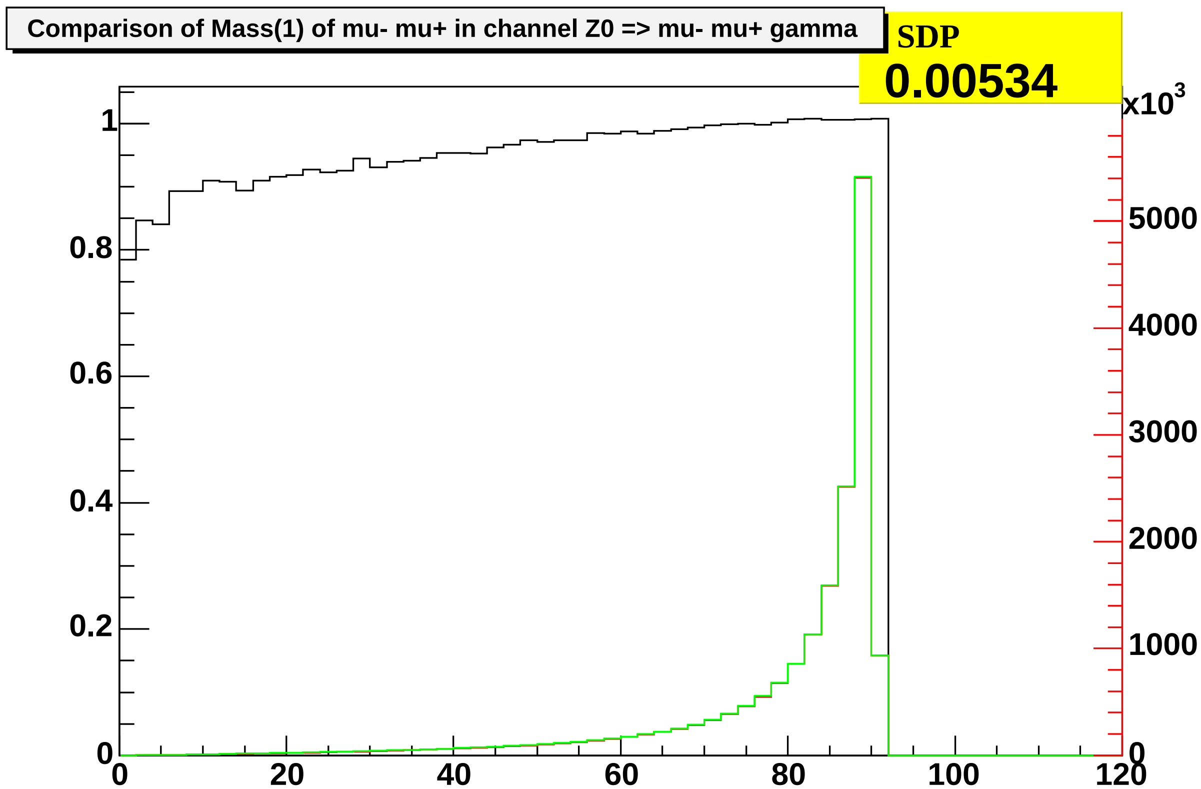
Further tests

Numerical comparison tests of the single photon emission kernel have been peformed for:

- Z^0 leptonic decays (comparisons with KORALZ and KKMC) good agreement,
  options for PHOTOS: single-, double-, triple-, quatric- and multiple-photon emission
  options for KKMC: $O(\alpha^2)$ exponentiated,$O(\alpha)$ exponentiated
  options for KoralZ $O(\alpha^2)$ exponentiated,$O(\alpha)$ exponentiated and fixed first-order (no exp).
- W leptonic decays:
  WINHAC: first-order, SANC first-order and WINHAC exponentiated,
  PHOTOS: first order and exponentiated

$Z \to \mu^+\mu^-$ PHOTOS vs KORALZ, fixed first-order

Plot of largest difference (quantifies approx. in PHOTOS necessary to iterate)

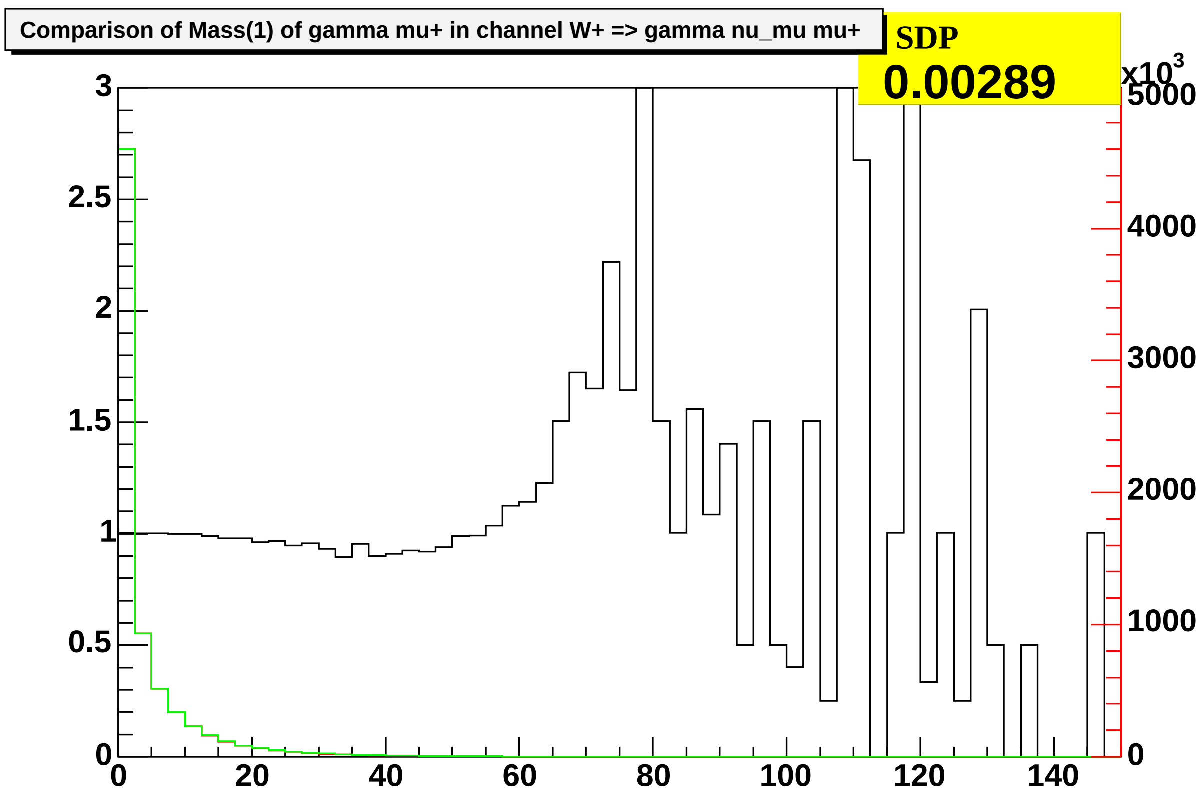


The difference in branching ratios are at fraction of permile level; BR * SDP$<$0.1%.

The differences due to approximations in PHOTOS kernel (restorable with process dep. wt. if needed).

$W \to l\nu$ PHOTOS vs. WINHAC, fixed first order

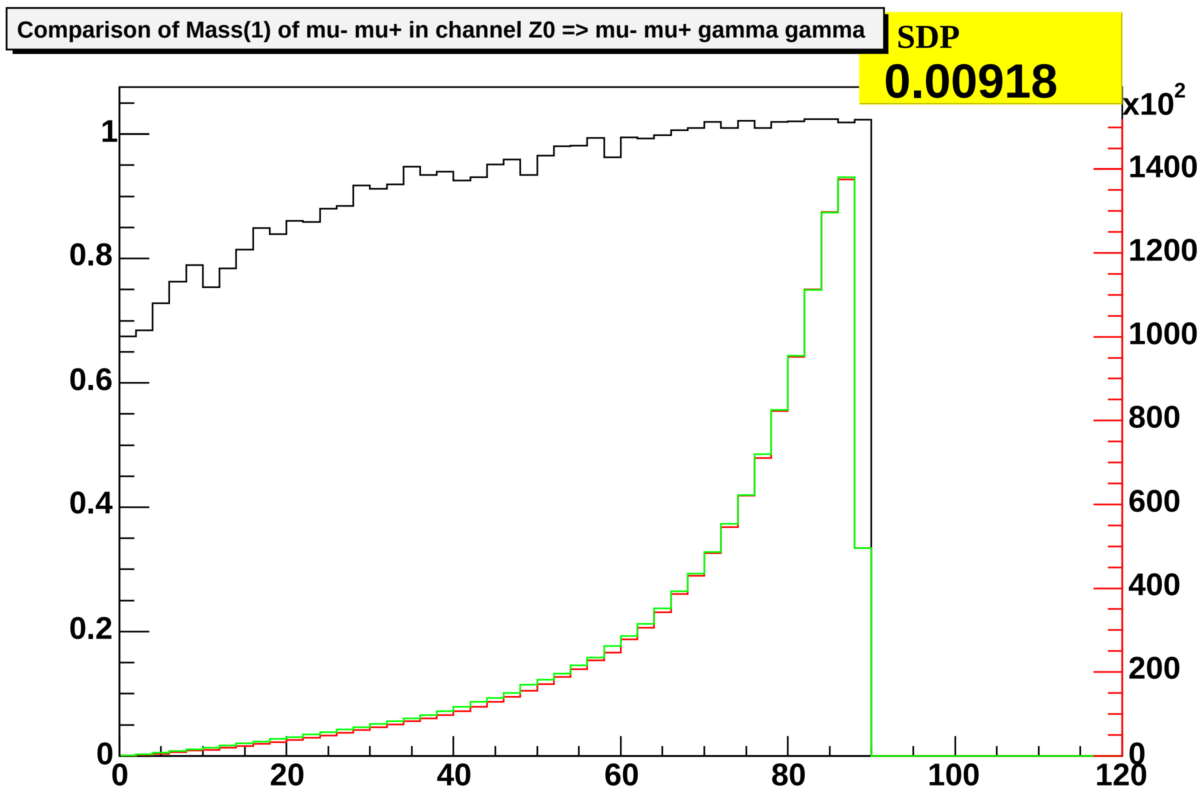
Plot of largest difference:



The difference in branching ratios are at fraction of permile level, also BR * SDP$<$0.1%.

$Z \to \mu^+\mu^-$ PHOTOS (EXP) vs. KKMC $O(\alpha^2)$

Plot of largest difference:

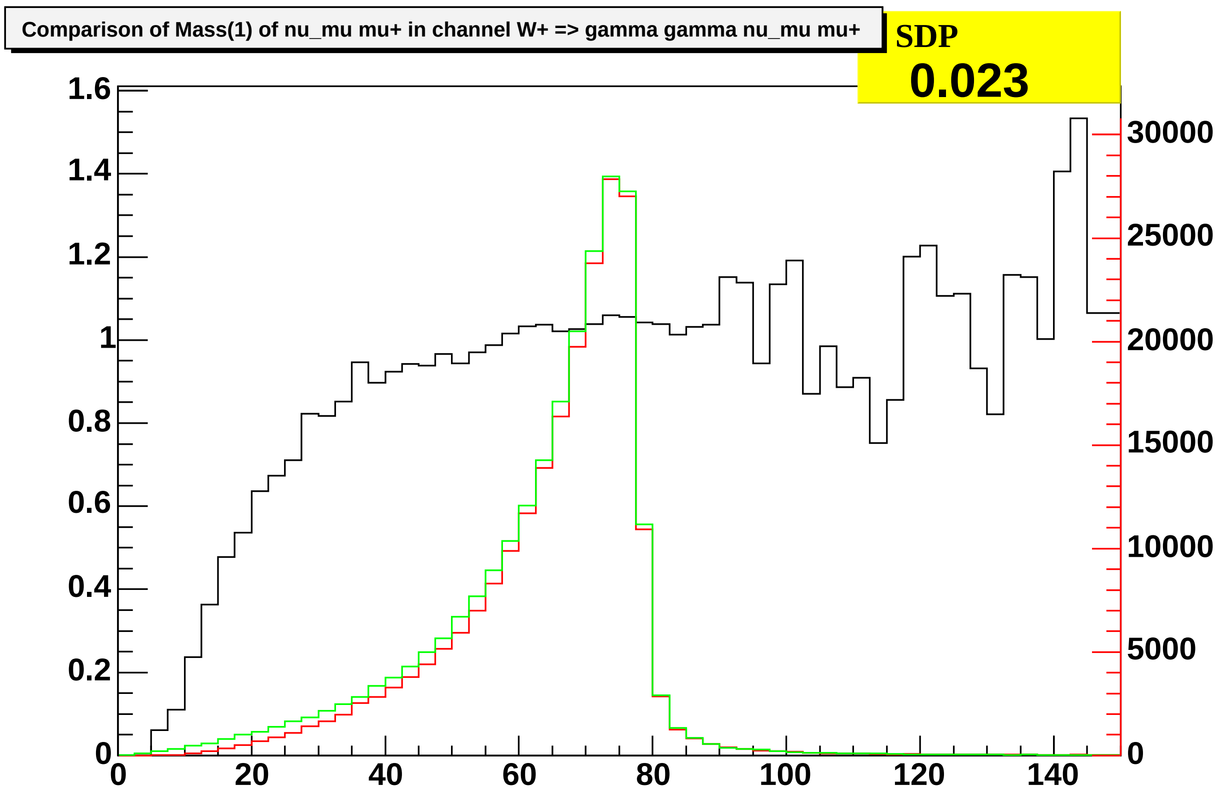


The difference in branching ratios are at permile level and BR * SDP$<$0.1%.

The agreement was good only if complete $O(\alpha^2)$ ME used in KKMC!

$W \to l\nu$ PHOTOS (EXP) vs. WINHAC $O(\alpha)$ exp

Plot of largest difference:



The difference in branching ratios are at permile level and BR * SDP $<$0.1%.

The source of residual difference not investigated; too small to bother.

WINHAC is full $O(\alpha)$ ME only; PHOTOS single-emission kernel not perfect as well

PHENO – PART 2:
Semileptonic and leptonic decays

some theoretical predictions available:

Ginsberg, Marciano, Richter-Was, Andre, FFS (NA48)

We need to test single-emission kernel.

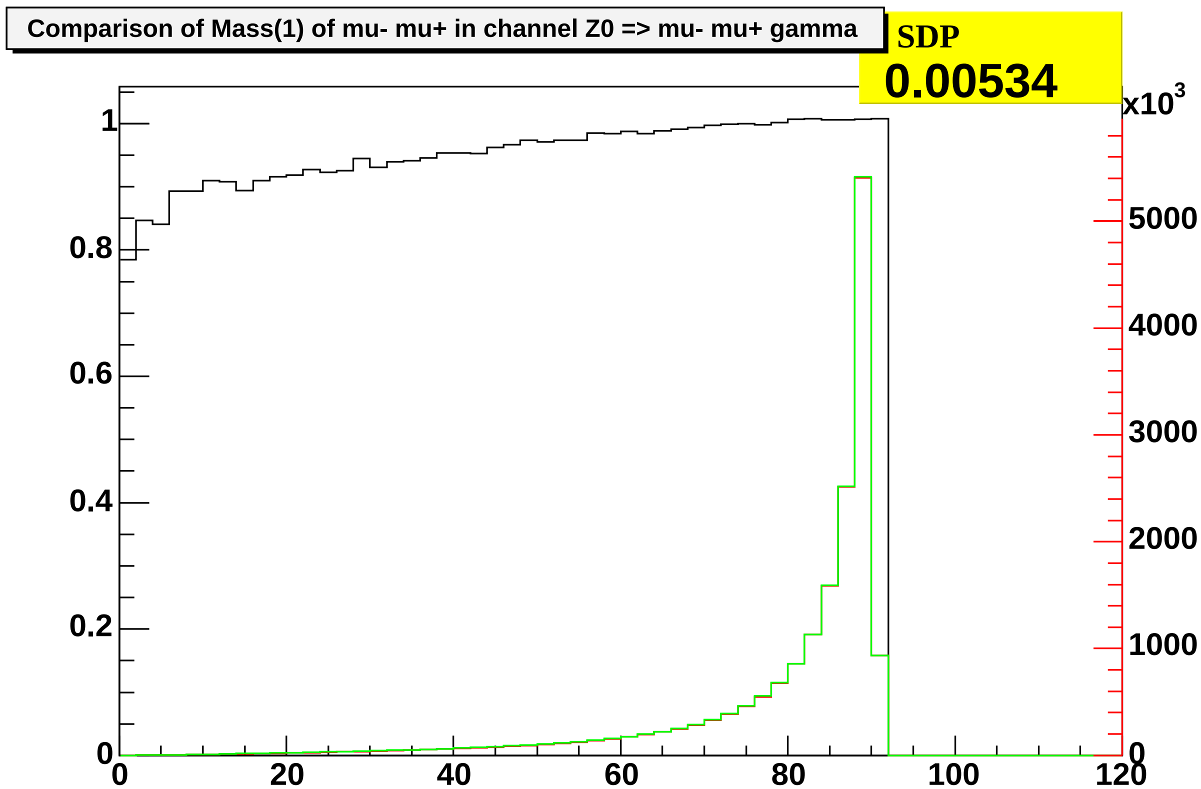
General properties of algorithm for higher-orders have been checked before.

We will profit from Z, W tests in B-decays as well.

Work in progress

$Z \to \mu^+\mu^-$ PHOTOS vs KORALZ, fixed first-order

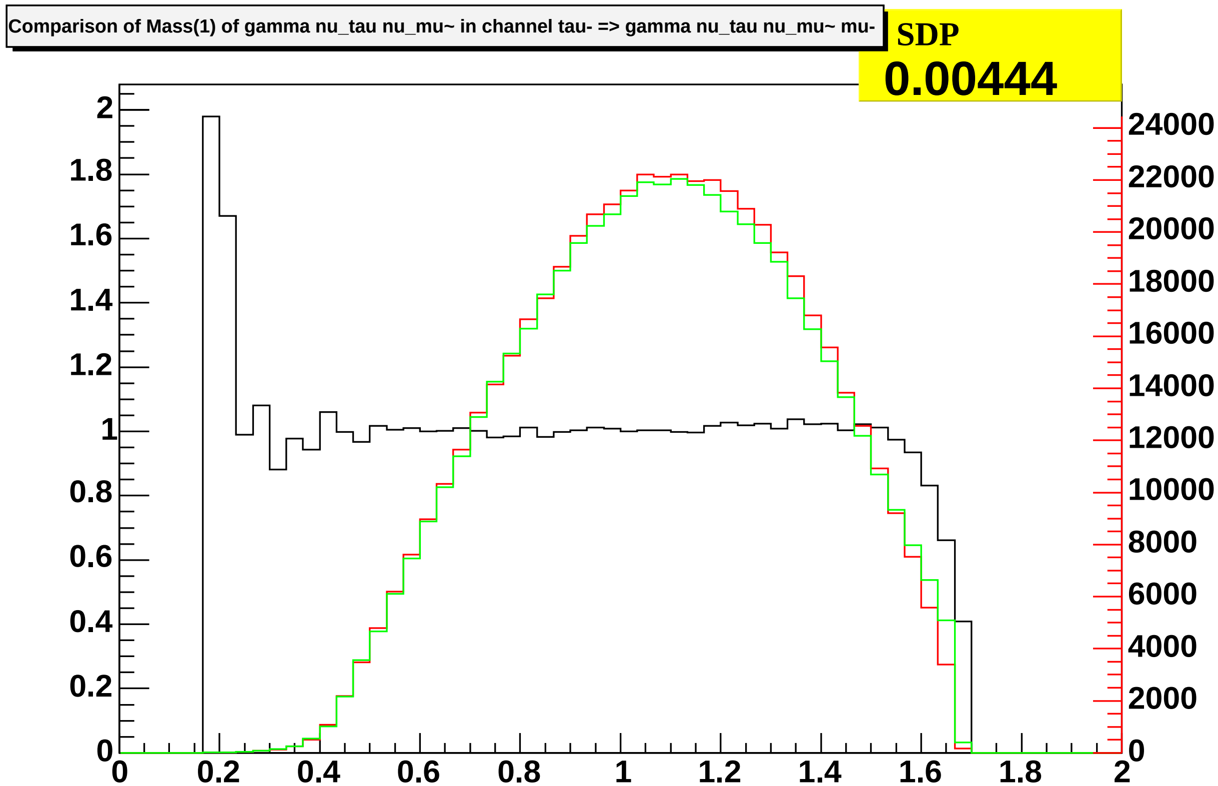
Plot of largest difference (quantifies approx. in PHOTOS necessary to iterate)



We need to find a counterpart for this result, but in case of B, K decays.

$\tau \to l\nu\bar{\nu}$ PHOTOS vs TAUOLA

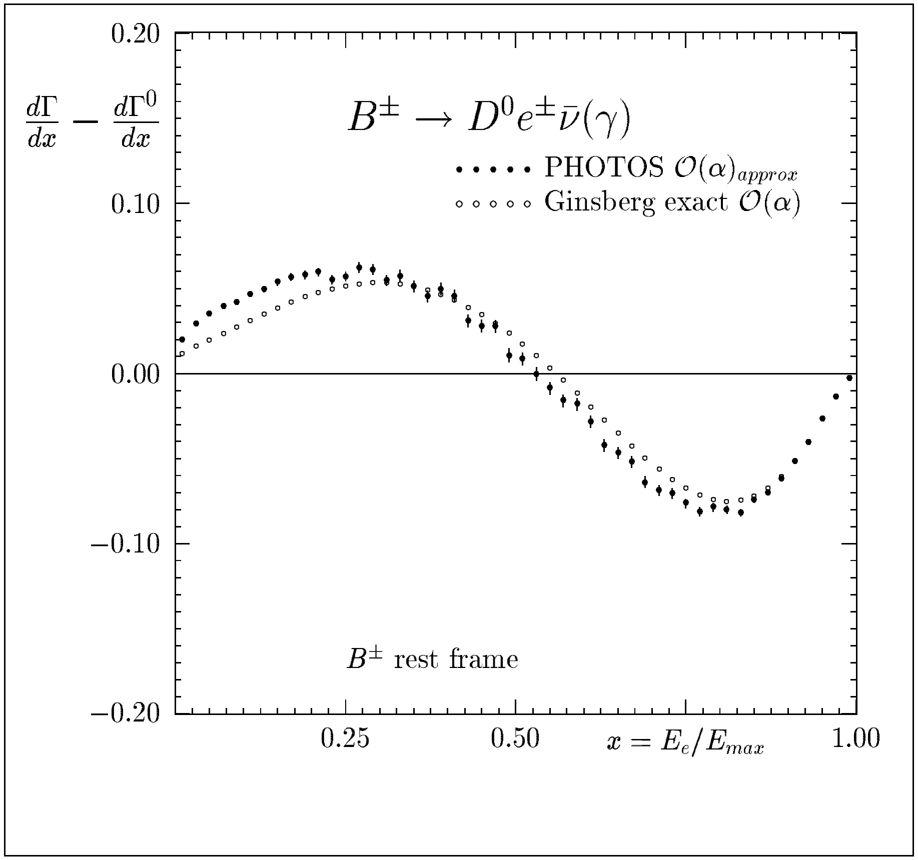
Plot of largest difference:



The difference in branching ratios are at fraction of permile level.

These are still leptonic decays, field-theory prediction available, PHOTOS works excellently.

Phys. Lett, B 303 (1993) 163-169

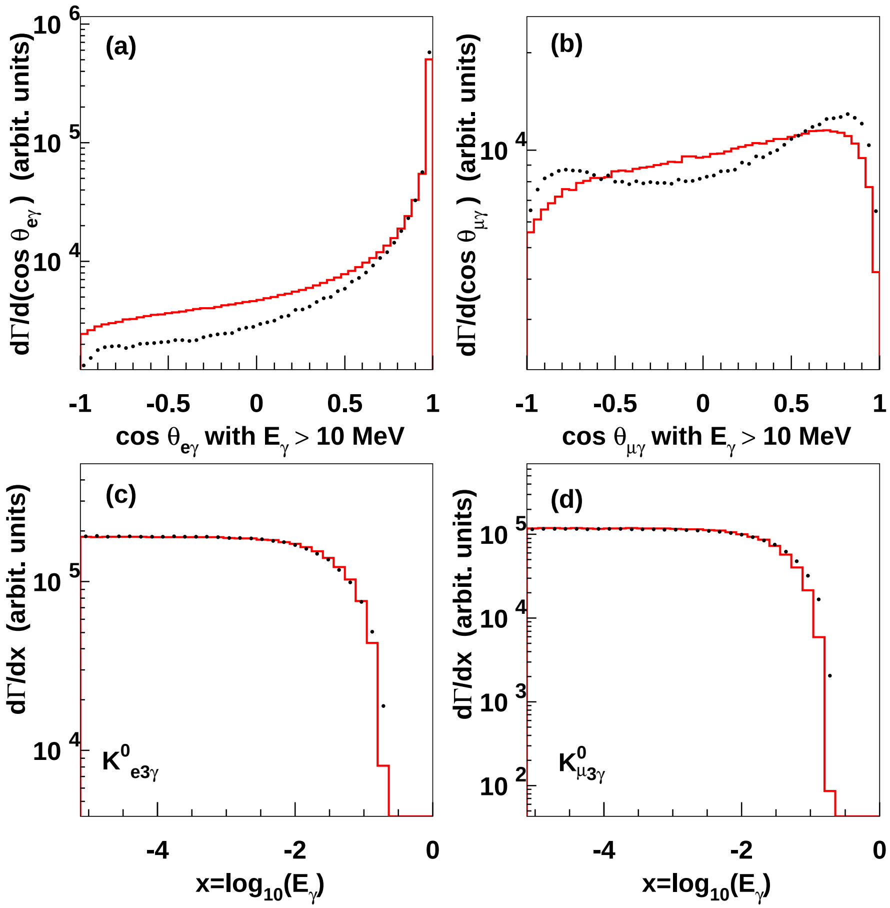


Radiative correction to the decay rate $(d\Gamma/dx - d\Gamma^0/dx)$ for $B^{\pm} \rightarrow D^0 e^{\pm} \bar{\nu}(\gamma)$ in the $B^{\pm}$ rest frame. Open circles are from the exact analytical formula [2], points with the marked statistical errors from PHOTOS applied to JETSET 7.3. A total of 10^7 events have been generated. The results are given in units of $(G_{\mu}^2 m_B^5/32\pi^3) N_{\eta} |V_{cb}|^2 |f_+^D|^2$, where $N_{\eta} = \eta^5 \int_0^1 x^2(1-x)^2/(1-\eta x)dx$ and $\eta = 1 - m_D^2/m_B^2$.

- *"QED bremsstrahlung in semileptonic B and leptonic τ decays"* by E. Richter-Was.
- agreement up to 1%
- disagreement in the low-x region due to missing sub-leading terms
- study performed in 1993 - PHOTOS 1.06

$K \to \pi l \nu$ in KLOR and PHOTOS: hep-ph:0406006

only on 28 December 2004 we realized that PHOTOS is used for K decays and precision is not sufficient. Even though, program works not worse than expected.



(a) $\cos(\Theta_{\gamma,l})\ K_{\mu 3}$

(b) $\cos(\Theta_{\gamma,l})\ K_{e3}$

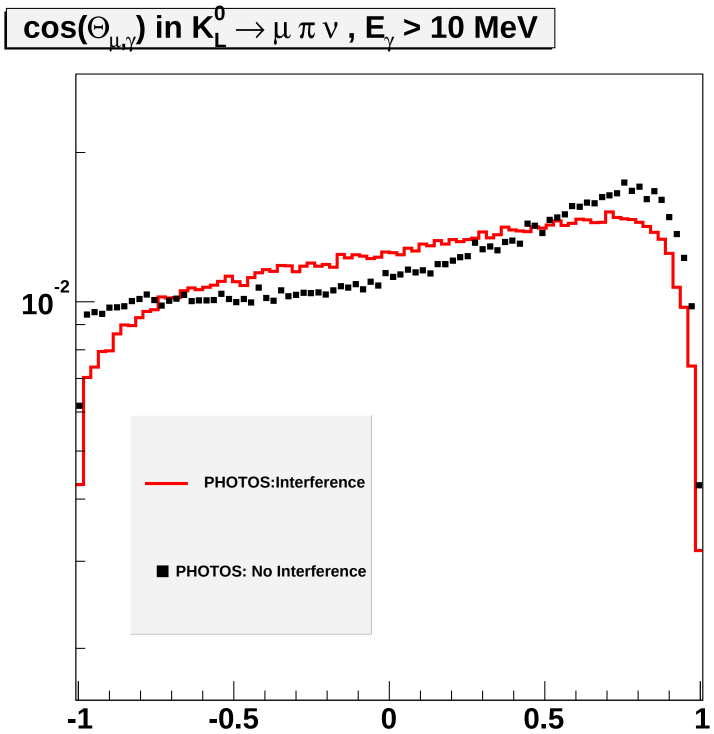
(c) $\log_{10}(E_\gamma)\ K_{\mu 3}$

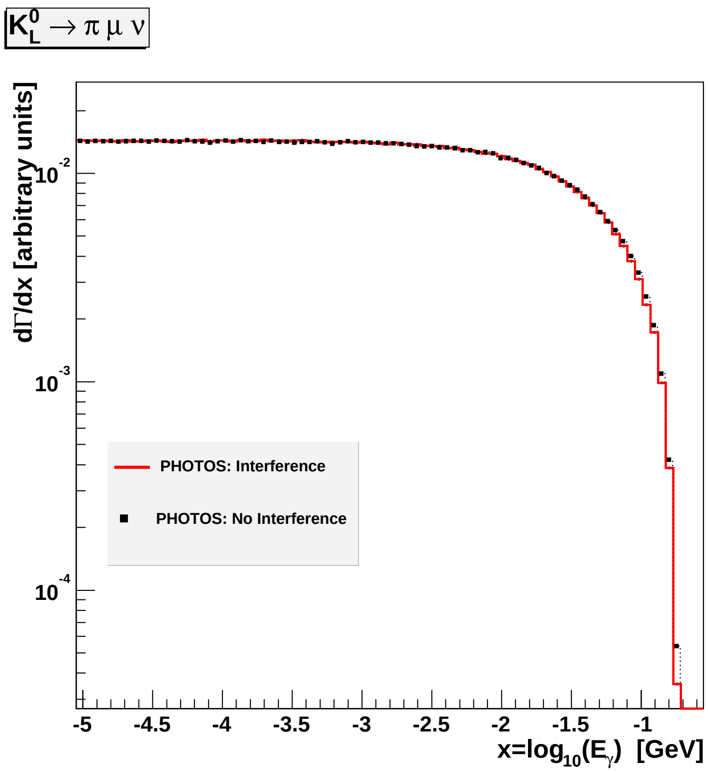
(d) $\log_{10}(E_\gamma)\ K_{e3}$

in KLOR

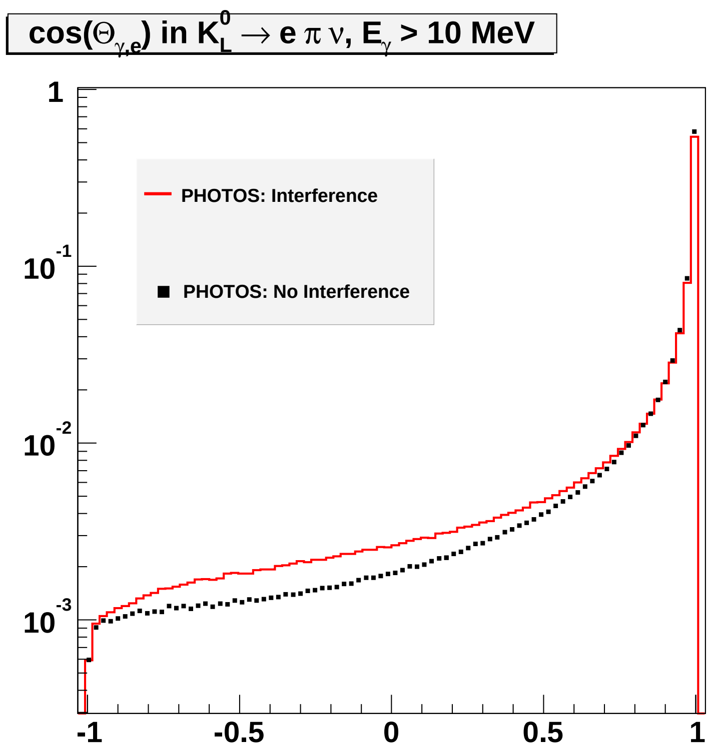
and PHOTOS

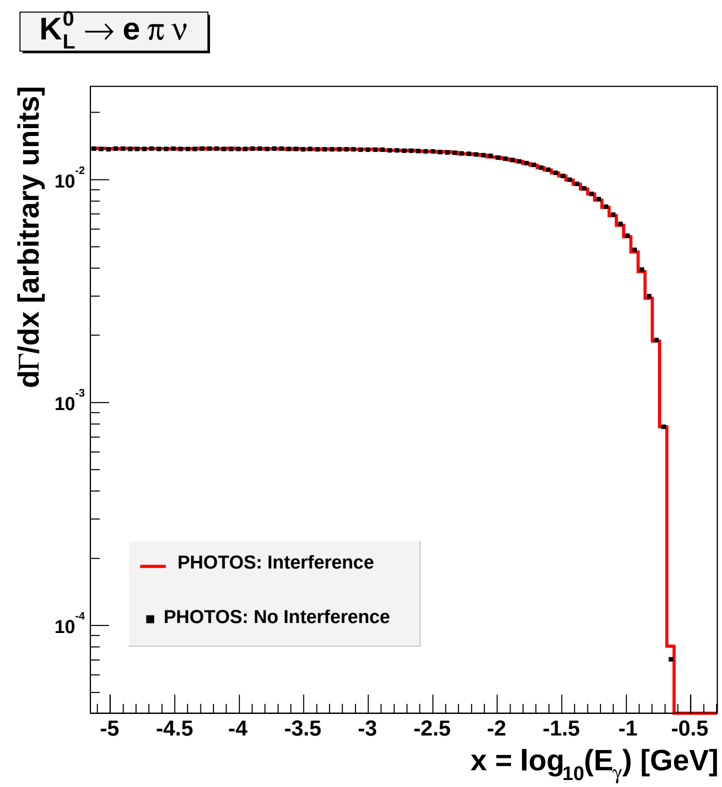
$K \to \pi\mu\nu$ + PHOTOS bremsstrahlung, interference on/off





$K \to \pi e \nu$ + PHOTOS bremsstrahlung, interference on/off

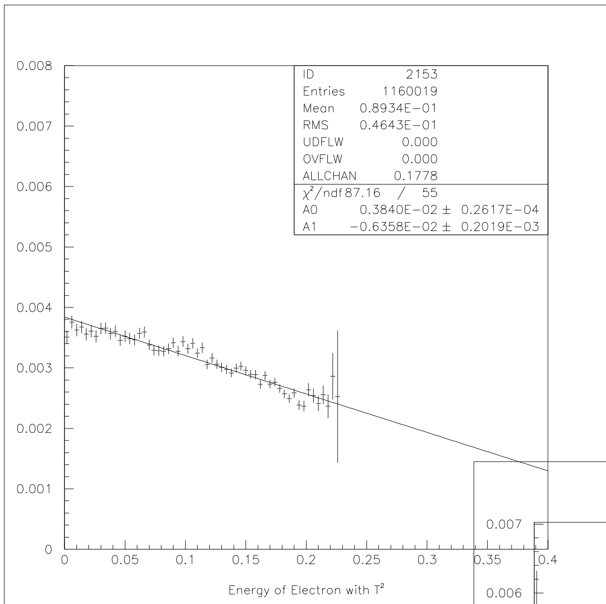


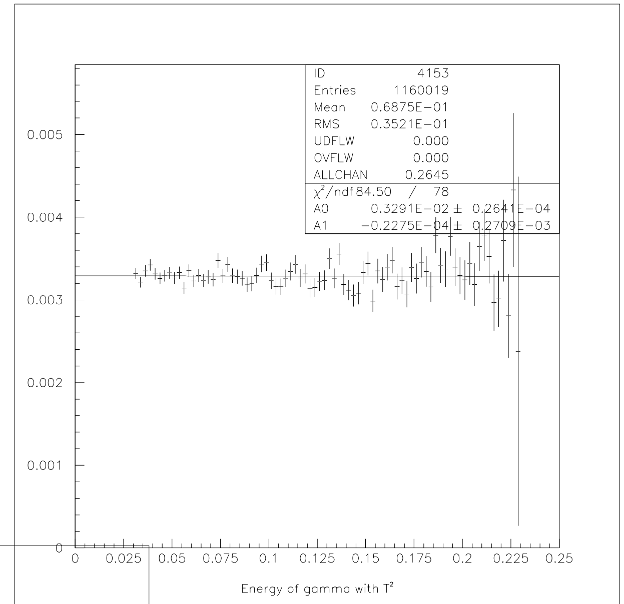


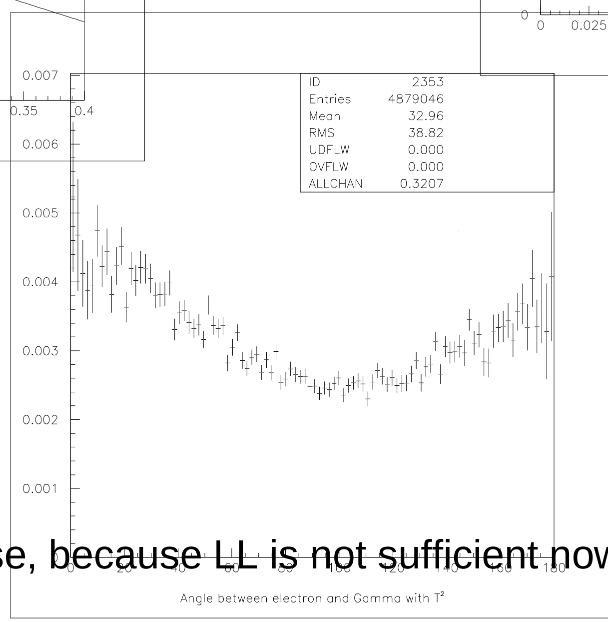
Seems that the interference weight removed the difference to a large degree, but still some inconsistencies at $\cos\Theta \simeq -1$

- We used published results which indicated improvements in PHOTOS were urgent.
- Fortunately thanks to work for W it was trivial to do.
- After initial success we need to worry about smaller, also possibly technical problems.
- Thanks to NA48 (L. Litov, et al) we proceed with further comparisons with Matrx-Element generators.
- channel $K \to \pi^{\pm} e^{\mp} \nu$
- channel $K \to \pi^{\pm} \mu^{\mp} \nu$

$K \to \pi e \nu(\gamma)$ PHOTOS (A.D. 2004) vs Gasser

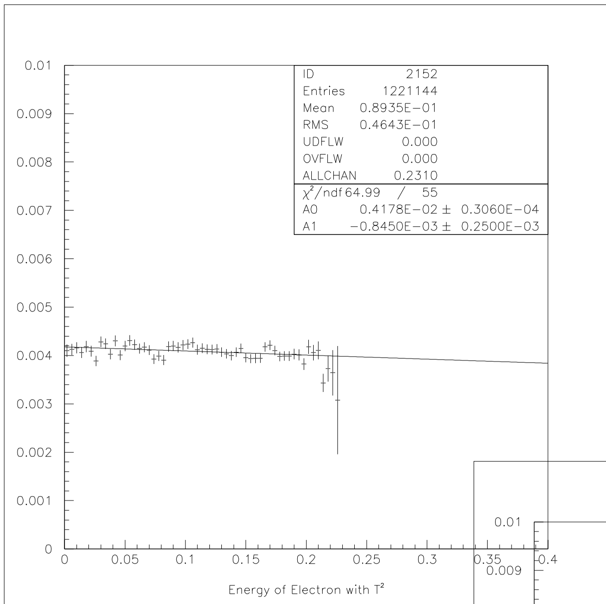


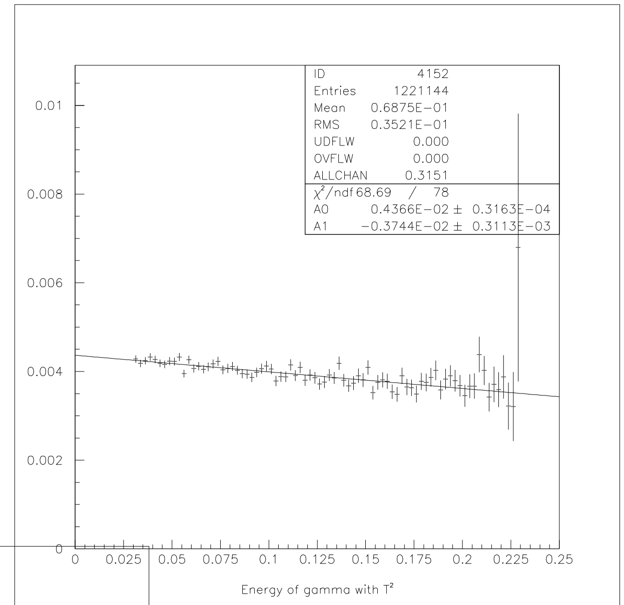


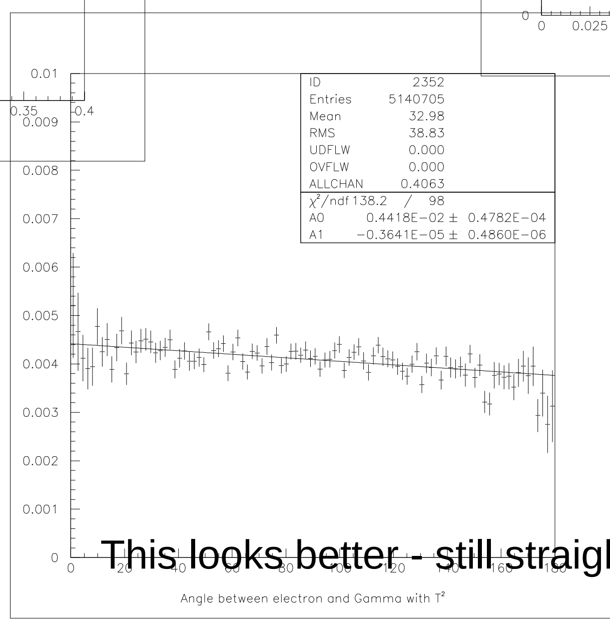


This looks bad - no surprise, because LL is not sufficient nowadays

$K \to \pi e \nu (\gamma)$ PHOTOS w/Interf vs Gasser







This looks better - still straightforward improvements possible

Events with and without photon:

$R = \frac{\Gamma_{K_{e3\gamma}}}{\Gamma_{K_{e3}}}$	PHOTOS interf	GASSER
$5 < E_\gamma < 15\,MeV$	2.38	2.42
$15 < E_\gamma < 45\,MeV$	2.03	2.07
$\Theta_{e,\gamma} > 20$	0.876	0.96

This table may indicate that residual discrepancy between new PHOTOS and KLOR for e-channel may be not real problem ...

New PHOTOS (beta version 2.13) is available (as a special patch) from http://cern.ch/wasm/goodies.html

PHENO – PART 3:
Non-leptonic decays

- **Motto: Guilty until proven otherwise.**

Testbed

- no good field-theory predictions as in Z and W decays, also ...
- no semianalytical formulas, no Monte Carlo (neither weighted nor unweighted events)
- fortunately there is a possibility to compare with data
- collaboration effort is critically needed

Summary:

- B-physics requirements were not satisfied with PHOTOS version available in 2004.
- we improved significantly, but probably we are still half-way through only...
- Present version of PHOTOS assures precision for W and Z decays, also H.
- PHOTOS is on a way from general purpose facility to precison tool in places where tests are completed.
- PHOTOS provides also interesting testbed for some parton shower-like iterative solutions.
- Presentation of news on TAUOLA is skipped to Aug 5-th, in a form of private discussion or small seminar.