KKMC – Status and Outlook

S. JADACH
in collaboration with B.F.L. Ward and Z. Wąs

IFJ-PAN, Kraków, Poland

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More material on http://jadach.web.cern.ch/

What is KKMC?

KKMC is the MC event generator for the process:

$$\boxed{e^- e^+ \to f\bar{f} + n\gamma}$$

$f = \mu, \tau, \nu, u, d, s, c, b, \quad n = 0, 1, 2 ... \infty.$

Interfaced with TAUOLA+PHOTOS
and with electroweak library DIZET.
Published version $\boxed{4.13}$ (to be cited):

- Comput.Phys.Commun. 130(2000) 360, hep-ph/9912214, F77 code description and user guide (manual).
- Phys. Rev. D63 (2001) 113009, hep-ph/0006359 physics content, CEEX exponentiation of QED corrs.

"Workhorse" in data analysis of all four LEP collaborations.

(Replacement of earlier MC's KORALZ and KORALB.)
(Not aplicable for $e^- e^+ \to e^- e^+$)

More KKMC versions available since 2000

http://jadach.web.cern.ch/jadach/KKindex.html

- Production Version 4.16, Oct. 2001, (KKMC-v.4.16d-export.tar.gz). Improved $\nu\bar{\nu}$ matrix elm. RRes module for $\gamma^* \to$ *narrow resonances* at LEP.
- Developement Version 4.19, Sept. 2002, (KKMC-v.4.19.b-export.tar.gz). C++ wrapper. Improved $\nu\bar{\nu}$ matrix element and RRes for low energy colliders. ISR with complete NLO corrs, as in Phys.Rev. D65(2002) 073030 by S.J., M.Mells, B.F.L.Ward and S.A. Yost. Collinear beamstrahlung for NLC/ILC.
- Developement Version 4.22, June 2013, (KKMC_v4_22.tgz). Tested $\mu^-\mu+$ and $q\bar{q}$ beams (instead of e^-e^+) at fixed energy. Optionaly, collinear PDFs for $q\bar{q}$ beams instead of beamstrahlung, as a patch in the source code (temp. solution).
- The complete "algebraic" description of the NNLO formulas has been published in Phys.Rev. D73 (2006) 073001 (an extension of the work in Phys.Rev. D65 (2002) 073030), the code still not public. PHOKHARA MC is an alternative here for low energy colliders.

Hidden treasures in KKMC

Can be useful for LHC?

KKMC is special because:

- Resummed (exponentiated) multiphoton effects at the AMPLITUDE level (CEEX). $\sim$10 man-years of work in QED.
- QED rad. corrections up to third LO and NLO, both in the initial and final state plus (exponentiated) initial-final interference.
- Complete spin effects, including transverse correlations, for incoming beams and outgoing femions (needed for taus).

KKMC can be useful in the LHC data analysis,
without major developments beyond the existing code:

- Testing/calibrating PHOTOS for FSR in leptonic decays of Z/W.
  An obvious thing and Zbyszek Was is doing this all the time...
- Studies/estimations of ISR-FSR interferences in $q\bar{q} \to Z \to l + \bar{l}$ data
- Electroweak+QCD corrections in the for Z production.cross section
- Spin correlations in $Z \to \tau^- \tau^+$, already being done by Zbyszek
- What else???? Any new ideas????

More on KKMC version 4.22 (2013)
Technical points

- Old benchmarks, Table III in Pys.Rev. D 63 (2001) and more, are reproduced under SLC5 and SLC6, after adjustments of flags in makefile's and minor corrections in f77 code.
- Unpublished (public) v.4.16,4.19 include varying subset of extra subdirectories, not included in v4.13. Also not in v.4.22.
- System of original interrelated custom *Makefile*'s is renamed *Makefile* $\rightarrow$ *KKMakefile* and preserved.
- *Atomake*/*Autotools* are introduced (*makefile.am* etc.).
  Hence KKMC is more platform independent
  and can be easily put under *kdevelop*3 or *eclipse*.
- Interface to C++ is provided. Main program (histogramming, etc) can be in C++, using optionally ROOT. (On request, or in v4.19)
- Scripts for running on PC-farms slightly upgraded and working.
- Old versions of PHOTOS and TAUOLA.

More on KKMC version 4.22 (2013)
Table III in Pys.Rev. D 63 (2001) reproduced

$v_{\max}$	$\mathcal{KK}$sem Refer.	$\mathcal{O}(\alpha^3)_{\rm EEX3}$	$\mathcal{O}(\alpha^2)_{\rm CEEX}$ intOFF	$\mathcal{O}(\alpha^2)_{\rm CEEX}$
	$\sigma(v_{\max})$ [pb]			
0.01	1.6712 ± 0.0000	1.6736 ± 0.0018	1.6738 ± 0.0018	1.7727 ± 0.0021
0.10	2.5198 ± 0.0000	2.5205 ± 0.0020	2.5210 ± 0.0020	2.6009 ± 0.0024
0.30	3.0616 ± 0.0000	3.0626 ± 0.0022	3.0634 ± 0.0022	3.1243 ± 0.0026
0.50	3.3747 ± 0.0000	3.3745 ± 0.0022	3.3761 ± 0.0022	3.4254 ± 0.0026
0.70	3.7223 ± 0.0000	3.7214 ± 0.0022	3.7249 ± 0.0022	3.7648 ± 0.0027
0.90	7.1430 ± 0.0000	7.1284 ± 0.0022	7.1530 ± 0.0022	7.1821 ± 0.0026
0.99	7.6136 ± 0.0000	7.5974 ± 0.0021	7.6278 ± 0.0021	7.6567 ± 0.0026
	$A_{\rm FB}(v_{\max})$			
0.01	0.5654 ± 0.0000	0.5661 ± 0.0012	0.5661 ± 0.0012	0.6121 ± 0.0014
0.10	0.5664 ± 0.0000	0.5667 ± 0.0009	0.5667 ± 0.0009	0.5931 ± 0.0011
0.30	0.5692 ± 0.0000	0.5694 ± 0.0008	0.5693 ± 0.0008	0.5864 ± 0.0010
0.50	0.5744 ± 0.0000	0.5744 ± 0.0008	0.5743 ± 0.0008	0.5870 ± 0.0009
0.70	0.5863 ± 0.0000	0.5858 ± 0.0007	0.5857 ± 0.0007	0.5953 ± 0.0008
0.90	0.3105 ± 0.0000	0.3107 ± 0.0004	0.3100 ± 0.0004	0.3176 ± 0.0004
0.99	0.2851 ± 0.0000	0.2856 ± 0.0003	0.2848 ± 0.0003	0.2918 ± 0.0004

Energy cut-off study of total cross section σ and charge asymmetry $A_{\rm FB}$ for annihilation process $e^-e^+ \to \mu^-\mu^+$, at $\sqrt{s}$ =189GeV.
Energy cut: $v < v_{\max}$, $v = 1 - M^2_{f\bar{f}}/s$.
From http://arxiv.org/abs/arXiv:1307.4037

More on KKMC version 4.22 (2013)
Physics extensions, 1st step: lepton beams

Lepton beams $\neq e^{\pm}$, for instance $\mu^-\mu^+$, $q\bar{q}$, etc.

Mainly the problem of transfering properly mass of beam leptons.

A few corrections, et voilá! $\mu^-\mu^+ \to e^-e^+$ at 189GeV.

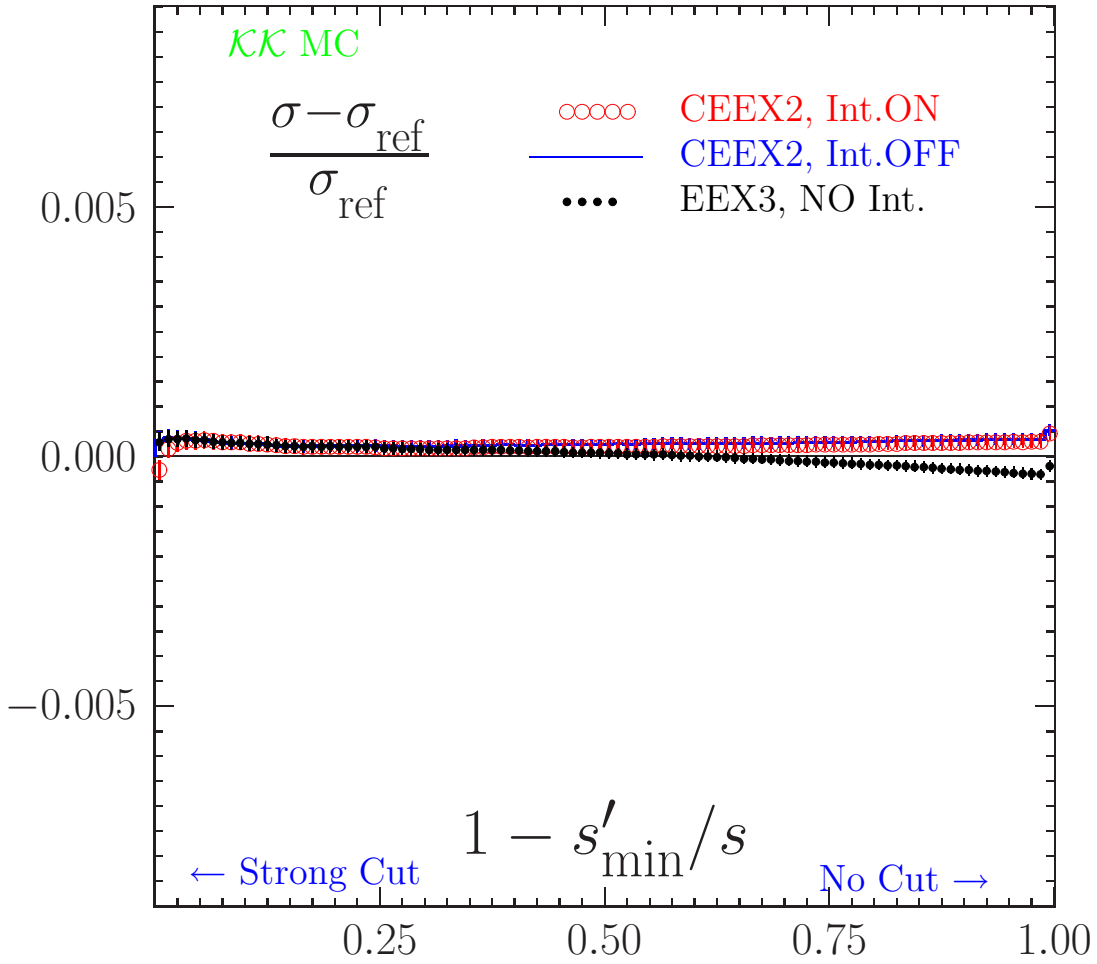
$v_{\max}$	$\mathcal{KK}$sem Refer.	$\mathcal{O}(\alpha^3)_{\rm EEX3}$	$\mathcal{O}(\alpha^2)_{\rm CEEX}$ intOFF	$\mathcal{O}(\alpha^2)_{\rm CEEX}$
	$\sigma(v_{\max})$ [pb]			
0.01	1.6703 ± 0.0000	1.6716 ± 0.0040	1.6718 ± 0.0040	1.7721 ± 0.0048
0.10	2.5076 ± 0.0000	2.5119 ± 0.0046	2.5123 ± 0.0046	2.5946 ± 0.0055
0.30	3.0153 ± 0.0000	3.0192 ± 0.0048	3.0203 ± 0.0048	3.0813 ± 0.0057
0.50	3.2808 ± 0.0000	3.2839 ± 0.0049	3.2867 ± 0.0049	3.3348 ± 0.0058
0.70	3.5252 ± 0.0000	3.5277 ± 0.0049	3.5338 ± 0.0049	3.5712 ± 0.0059
0.90	5.4288 ± 0.0000	5.3946 ± 0.0047	5.4412 ± 0.0047	5.4699 ± 0.0057
0.99	5.7248 ± 0.0000	5.6824 ± 0.0046	5.7414 ± 0.0046	5.7697 ± 0.0057
	$A_{\rm FB}(v_{\max})$			
0.01	0.5654 ± 0.0000	0.5664 ± 0.0028	0.5664 ± 0.0028	0.6132 ± 0.0032
0.10	0.5659 ± 0.0000	0.5666 ± 0.0021	0.5666 ± 0.0021	0.5934 ± 0.0025
0.30	0.5675 ± 0.0000	0.5684 ± 0.0019	0.5684 ± 0.0019	0.5855 ± 0.0022
0.50	0.5705 ± 0.0000	0.5710 ± 0.0018	0.5710 ± 0.0018	0.5835 ± 0.0021
0.70	0.5774 ± 0.0000	0.5776 ± 0.0017	0.5777 ± 0.0017	0.5870 ± 0.0020
0.90	0.3844 ± 0.0000	0.3873 ± 0.0011	0.3848 ± 0.0011	0.3921 ± 0.0012
0.99	0.3613 ± 0.0000	0.3652 ± 0.0010	0.3622 ± 0.0010	0.3683 ± 0.0012

More on KKMC version 4.22 (2013)
Physics extensions, 2nd step: quark beams

Quark beams at fixed energy.

Mainly the problem of transfering properly weak isospin of beams.

$u\bar{u} \to e^- e^+ + n\gamma$ at $\sqrt{s} = M_Z$. Again KKMC vs. KKsem.



Quark beams at energies varying according to PDFs.

Main problem in the code: variable $\sqrt{s}$ from one MC event to another.
Luckily already solved for beamstrahlung.

Test for $\boxed{u\bar{u} \to e^- e^+ + n\gamma}$ at $\sqrt{s} = M_Z$.

KKMC vs. KKsem not available:(
Only kinematics was tested, see event printout next slide.

More on KKMC version 4.22 (2013)
Physics extensions, 3rd step: PDFs for quark beam

```
*********************************************************************
*                      KK Monte Carlo                               *
*            Version       4.22          May 2013                   *
*    7000.00000000                 CMS energy average      CMSene    a1 *
*       0.00000000                 Beam energy spread      DelEne    a2 *
*              100                 Max. photon mult.       npmax     a3 *
*                0                 wt-ed or wt=1 evts.     KeyWgt    a4 *
*                1                 ISR switch              KeyISR    a4 *
*                1                 FSR switch              KeyFSR    a5 *
*                2                 ISR/FSR interferenc     KeyINT    a6 *
*                1                 New exponentiation      KeyGPS    a7 *
*                0                 Hadroniz.  switch       KeyHad    a7 *
*       0.20000000                 Hadroniz. min. mass     HadMin    a9 *
*       1.00000000                 Maximum weight          WTmax    a10 *
*              100                 Max. photon mult.       npmax    a11 *
*                2                 Beam ident              KFini    a12 *
*       0.03500000                 Manimum phot. ener.     Ene      a13 *
*   0.10000000E-59                 Phot.mass, IR regul     MasPho   a14 *
*    1.2500000                     Phot. mult. enhanc.     Xenph    a15 *
*       0.00000000                    PolBeam1(1)          Pol1x    a17 *
*       0.00000000                    PolBeam1(2)          Pol1y    a18 *
*       0.00000000                    PolBeam1(3)          Pol1z    a19 *
*       0.00000000                    PolBeam2(1)          Pol2x    a20 *
*       0.00000000                    PolBeam2(2)          Pol2y    a21 *
*       0.00000000                    PolBeam2(3)          Pol2z    a22 *
*********************************************************************

                        Event listing (summary)
   I particle/jet KS     KF  orig    p_x      p_y      p_z       E        m
   1 !u!           21      2     0    0.000    0.000   22.668   22.668    0.005
   2 !ubar!        21     -2     0    0.000    0.000 -245.458  245.458    0.005
   3 (Z0)          11     23     1   23.016   18.370  -80.068  115.249   77.487
   4 gamma          1     22     1  -30.989   -6.132 -128.905  132.719    0.000
   5 gamma          1     22     1    0.000    0.000    0.031    0.031    0.000
   6 gamma          1     22     1    7.973  -12.238  -13.848   20.127    0.000
   7 gamma          1     22     1    0.000    0.000 3477.332 3477.332    0.000
   8 gamma          1     22     1    0.000    0.000-3254.542 3254.542    0.000
   9 tau-           1     15     3  -24.701   21.657  -20.217   38.613    1.777
  10 tau+           1    -15     3   47.716   -3.287  -59.851   76.635    1.777
                  sum:  0.00          0.000    0.000    0.000 7000.000 7000.000
```

Cont.

```
                                Event listing (summary)
 I particle/jet KS     KF  orig    p_x      p_y      p_z       E        m
 1 !u!          21      2     0    0.000    0.000  271.908  271.908    0.005
 2 !ubar!       21     -2     0    0.000    0.000   -6.542    6.542    0.005
 3 (Z0)         11     23     1    0.047    1.133  244.401  257.454   80.928
 4 gamma         1     22     1   -0.047   -1.133   20.965   20.996    0.000
 5 gamma         1     22     1    0.000    0.000 3228.092 3228.092    0.000
 6 gamma         1     22     1    0.000    0.000-3493.458 3493.458    0.000
 7 mu-           1     13     3    0.601   14.537    2.005   14.687    0.106
 8 mu+           1    -13     3   -0.554  -13.404  242.396  242.767    0.106
                sum:  0.00          0.000    0.000    0.000 7000.000 7000.000
                                Event listing (summary)
 I particle/jet KS     KF  orig    p_x      p_y      p_z       E        m
 1 !u!          21      2     0    0.000    0.000 1816.851 1816.851    0.005
 2 !ubar!       21     -2     0    0.000    0.000   -1.137    1.137    0.005
 3 (Z0)         11     23     1    0.011    0.003 1810.259 1812.532   90.760
 4 gamma         1     22     1   -0.012   -0.002    5.371    5.371    0.000
 5 gamma         1     22     1    0.000    0.000 1683.149 1683.149    0.000
 6 gamma         1     22     1    0.000    0.000-3498.863 3498.863    0.000
 7 mu-           1     13     3   12.468  -25.466 1612.743 1612.992    0.106
 8 mu+           1    -13     3  -12.457   25.469  197.516  199.540    0.106
                sum:  0.00         -0.001    0.001   -0.084 6999.916 6999.916

 ************************************************************************
 *                      KK2f_Finalize  printouts                        *
 *    7000.00000000                  cms energy total          cmsene   a0 *
 *             5000                  total no of events        nevgen   a1 *
 *                ** principal info on x-section **                      *
 *     233.95163953  +- 1.04896414   xs_tot MC R-units         xsmc     a1 *
 *       0.41468908                  xs_tot    picob.          xSecPb   a3 *
 *       0.00185933                  error     picob.          xErrPb   a4 *
 *       0.00448368                  relative error            erel     a5 *
 *       0.82048782                  WTsup, largest WT         WTsup   a10 *
 *                      ** some auxiliary info **                         *
 *       0.00219522                  xs_born   picobarns         xborn  a11 *
 *       0.73760000                  Raw phot. multipl.                 === *
 *       5.00000000                  Highest phot. mult.                === *
 *                      End of KK2f_Finalize                              *
 ************************************************************************
```

Possible other extensions?

Could one include/improve QCD correction for the incoming beams?
Yes, for example classic NLO corrs, Powheg style etc.

In this case the upper level of KKMC would be replaced by C++ code, which is already in place in some simple form.

The extension to $q\bar{q} \to W \to l + \nu$ is thinkable, but would require update of the QED matrix element (EW corrs. ?)

NB. t-canel W exchange with h.o. QED is already there for $\nu\bar{\nu}$ chanel and could be exploited as a starting point.

However, the bottom line still vailid is:
Let us exploit the existing KKMC as much as we can for LHC!!!

Summary

KKMC still alive and possibly still useful!