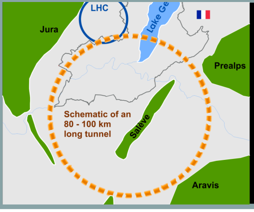
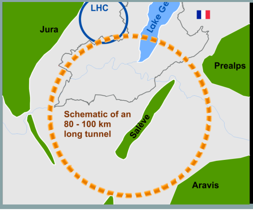


KKMCee status and planning

Stanisław Jadach

FCC Physics Workshop

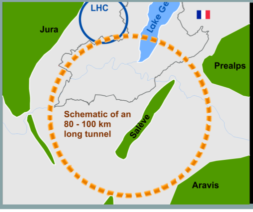
February 9th, 2022



New C++ version of KKMCee

Monte Carlo for $e^+e^- \to f\bar{f} + n\gamma, \quad f = \mu, \tau, \nu, \text{quarks}$

- New complete code of **KKMCee in C++ is ready** and tested. Resides in the yet non-public repository on GitHub.
- Interfaced with F77 electroweak library DIZET 6.45 and TAUOLA.
- Armed with Les Ouches interface for quark pair hadronization.
- Beamstrahlung for ILC/CLIC and Gaussian BES of FCCee.
- Reproduces exactly all classic benchmarks of KKMC from the 1999 LEP workshop, from PRD63 (2000) article and more…
- From the physics point of view it is identical with the F77 version.
- From now on the starting point for any future development.
- Completing documentation, article to Comp.Phys.Commun. 50% ready.
- A few more improvements planned in C++ KKMCee before publication.
- From now on **F77 KKMCee is frozen**, new devel. only in C++ version.



First version of KKMC was announced in November 1998, seminar at CERN TH

CEEX

Conclusions

Clear upgrade path for exclusive exponentiation in QED in the Monte Carlo is established. It is firmly based on spin amplitudes. The main profits are:

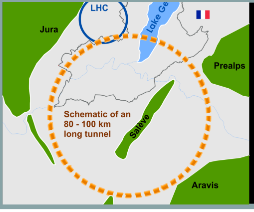
- Inclusion of interferences, ISR*FSR.
- All kind of coherence effects, including narrow resonances.
- Complete treatment of spin (also transverse) for beams and final (unstable) fermions.
- Exact M.E. for 2,3 high p_T photons (pending).

First real Monte Carlo implementation is $\mathcal{KK}$ event generator for fermion pair production at LEP, lineacs, μ-colliders, τ and b factories.
Check http://wwwcn.cern.ch/~jadach.

CERN

November 5, 1998 Stanisław JADACH

KKMC project coauthors, Z. Was, B.F.L. Ward and S. Yost



F77 versions of KKMCee

- **2000:** First public version 4.13 (to be cited, 910 citations.),
  Comput. Phys. Commun. 130 (2000) 360, hep-ph/9912214

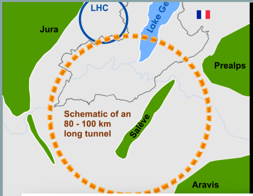
- **2001:** Production version 4.16, for LEP experiments.
  *Improved matrix elm. for the $\nu\bar{\nu}$ pairs, **RRes** module for the off-shell $\gamma^* \rightarrow$ narrow resonances.*

- **2002:** Development version 4.19, for LEP exp. and future colliders.
  C++ wrappers, further improvements for $\nu\bar{\nu}$ pairs, RRes.
  Adding non-soft $\mathcal{O}(\alpha^2 L)$ corrs. of Phys.Rev. D65(2002) 073030.

- **2013:** Development version 4.22, for future colliders
  automake/autotools system introduced. Muon collider option. Validating under various linux systems. Minor bugs.
  Source codes on http://jadach.web.cern.ch/jadach/KKindex.html

- **2017:** Development version 4.24, for future colliders
  Beamstrahlung improved/simplified. Validation under Centos7 Ubuntu16.
  Source code on http://192.245.169.66:8000/FCCeeMC/wiki/kkmc

- **2021:** Production version 4.32, for FCCee studies. Last F77 version!
  Upgrade DIZET to 6.45 version, upgrade of TAUOLA, LHE interface for hadronization. Integrated into FCCee software.
  Source code on https://github.com/KrakowHEPSoft/KKMCee



Improved MC algorithm in C++ KKMCee

$$e^+e^- \to \mu^+\mu^- + n\gamma$$

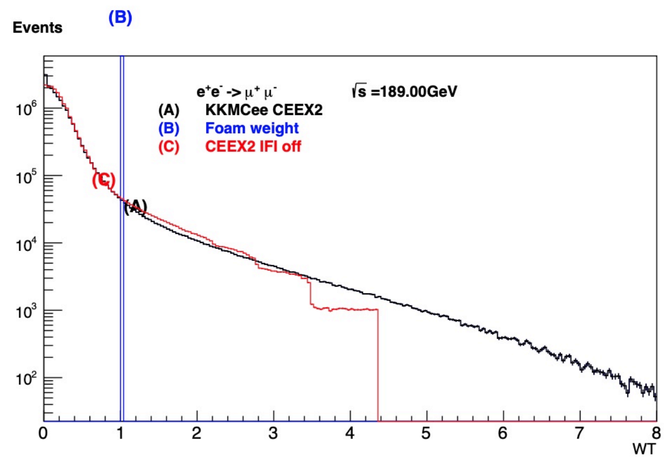


Figure 2: Weight distribution for the muon pair channel at 189GeV for classic KKMC, with flat $\cos\theta$ at the baseline level. MC sample of weighted 18M events. Weight distribution in case of IFI switched off is also shown, see curve (C).

OLD

In the old KKMC cos(theta) distr. of final fermions was generated flat and modelled by main MC WT

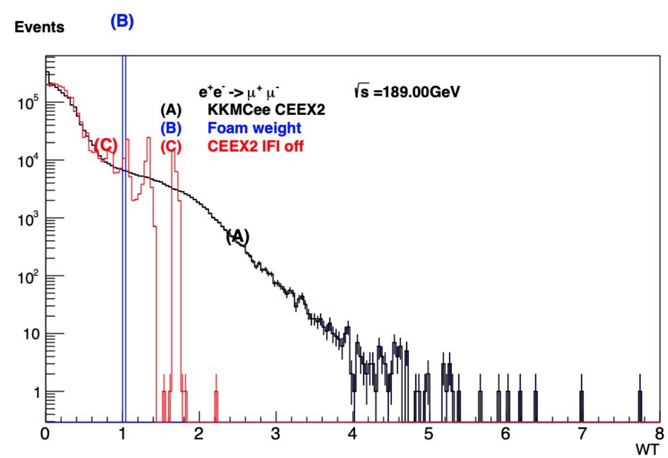
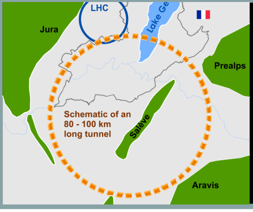


Figure 1: Weight distribution for the muon pair channel at 189GeV. MC sample of 2M variable weight events. Weight distribution in case of IFI switched off is also shown, see curve (C).

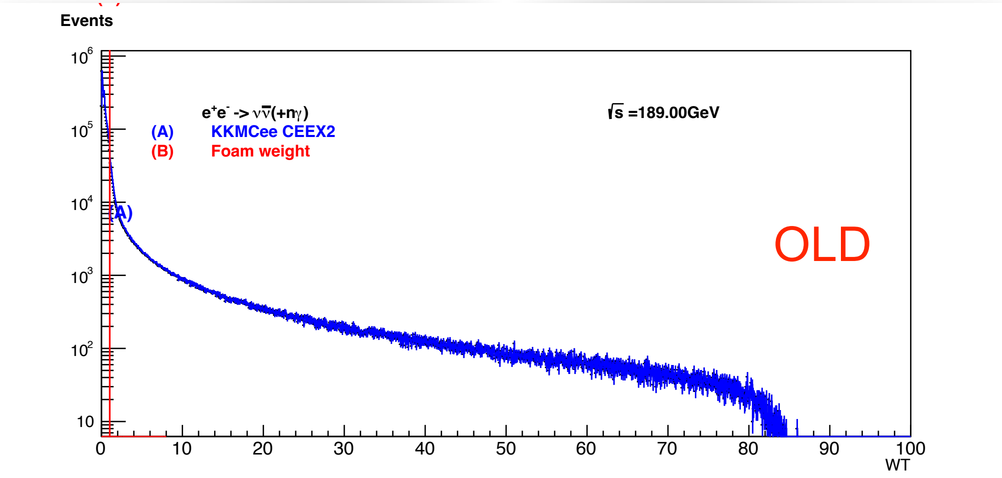
NEW

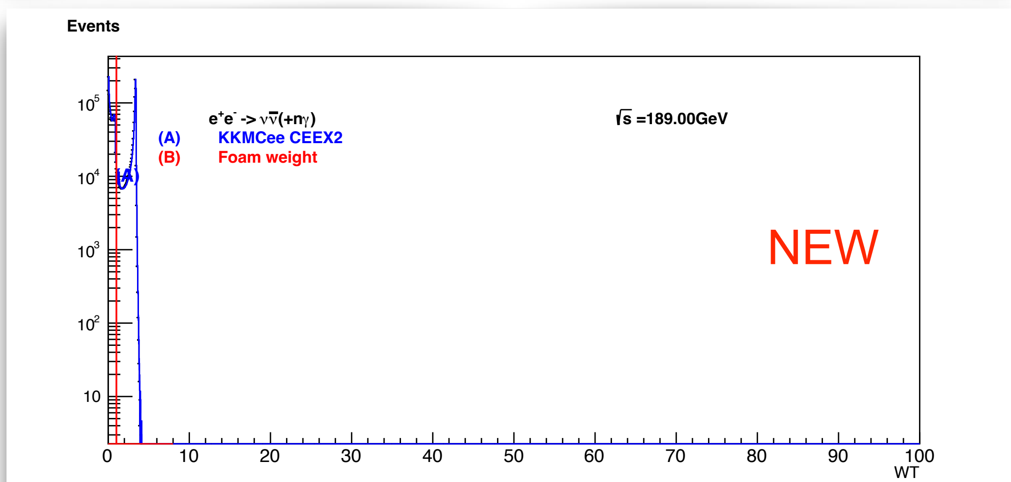
In new C++ KKMCee cos(theta) is modelled by FOAM and main MC WT has a nicer distribution, with the reduced tail by factor 2. Getting WT=1 now costs less CPU!

(Foam internally provides its “events” with WT=1)



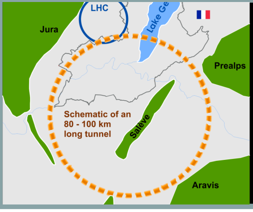
Improved MC weight in C++ KKMCee





$$e^+e^- \rightarrow \nu_e\bar{\nu}_e + n\gamma$$

- The improvement of the MC weight due to cos(theta) generation by FOAM is, however, more dramatic for the electron neutrino pair due to peak in cos(theta) from t-channel W exchange, by factor 20.



Example of benchmarking

TABLE III. Absolute predictions for the total cross section and charge asymmetry. They are for the $\mu^+\mu^-$ final state at $\sqrt{s}=189$ GeV. The results are plotted as a function of the cutoff on the total photon energy $v_{\max}=1-s'_{\min}/s$. The "reference" σ and A_{FB} in first column are from the $\mathcal{KK}$sem semi-analytical program. We have used a Higgs boson mass of 100 GeV and a top mass of 175 GeV as input parameters.

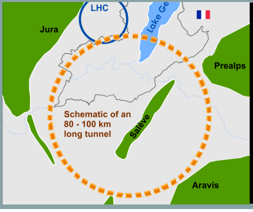
$v_{\max}$	$\mathcal{KK}$sem refer.	$\mathcal{O}(\alpha^3)_{\rm EEX3}$	$\mathcal{O}(\alpha^2)_{\rm CEEX}$ int OFF	$\mathcal{O}(\alpha^2)_{\rm CEEX}$	KORALZ	KORALZ interf.
			$\sigma(v_{\max})$ [pb], $\mathcal{KK}$ MC and KORALZ 1st order			
0.01	1.6712±0.0000	1.6687±0.0020	1.6690±0.0020	1.7679±0.0024	0.9639±0.0009	0.1610±0.0009
0.10	2.5198±0.0000	2.5164±0.0023	2.5170±0.0023	2.5967±0.0027	2.1919±0.0010	0.0880±0.0010
0.30	3.0616±0.0000	3.0565±0.0024	3.0581±0.0024	3.1190±0.0029	2.7690±0.0010	0.0545±0.0010
0.50	3.3747±0.0000	3.3682±0.0025	3.3713±0.0025	3.4203±0.0029	3.0565±0.0010	0.0385±0.0010
0.70	3.7225±0.0000	3.7131±0.0025	3.7200±0.0025	3.7596±0.0030	3.3649±0.0010	0.0246±0.0010
0.90	7.1434±0.0000	7.0904±0.0024	7.1496±0.0024	7.1789±0.0030	6.3558±0.0010	0.0210±0.0010
0.99	7.6145±0.0000	7.5511±0.0024	7.6254±0.0024	7.6542±0.0029	6.7004±0.0010	0.0213±0.0010
			$A_{\rm FB}(v_{\max})$, $\mathcal{KK}$ MC and KORALZ 1st order			
0.01	0.5654±0.0000	0.5650±0.0014	0.5650±0.0014	0.6111±0.0016	0.5765±0.0013	0.1201±0.0013
0.10	0.5664±0.0000	0.5660±0.0011	0.5660±0.0011	0.5922±0.0012	0.5784±0.0006	0.00324±0.0006
0.30	0.5692±0.0000	0.5687±0.0009	0.5686±0.0009	0.5856±0.0011	0.5818±0.0005	0.0164±0.0005
0.50	0.5744±0.0000	0.5738±0.0009	0.5737±0.0009	0.5863±0.0010	0.5868±0.0005	0.0112±0.0005
0.70	0.5864±0.0000	0.5852±0.0008	0.5852±0.0008	0.5947±0.0009	0.5972±0.0004	0.0078±0.0004
0.90	0.3105±0.0000	0.3115±0.0004	0.3096±0.0004	0.3170±0.0005	0.3260±0.0002	0.0037±0.0002
0.99	0.2851±0.0000	0.2867±0.0004	0.2843±0.0004	0.2912±0.0004	0.3039±0.0002	0.0024±0.0002

$v_{\max}$	eeFoam $_{\rm IFIoff}$	KKMCee EEX2	CEEX2 IFIoff	CEEX2 IFI on	eeFoam $_{\rm IFIon}$
			$\sigma(v_{\max})$ [pb]		
0.02	1.8916 ± 0.0002	1.8921 ± 0.0001	1.8922 ± 0.0001	1.9894 ± 0.0001	1.9907 ± 0.0002
0.10	2.5193 ± 0.0002	2.5200 ± 0.0001	2.5201 ± 0.0001	2.6015 ± 0.0001	2.6029 ± 0.0003
0.30	3.0611 ± 0.0002	3.0615 ± 0.0001	3.0618 ± 0.0001	3.1236 ± 0.0001	3.1224 ± 0.0003
0.50	3.3743 ± 0.0002	3.3737 ± 0.0001	3.3750 ± 0.0001	3.4250 ± 0.0001	3.4194 ± 0.0003
0.70	3.7218 ± 0.0002	3.7185 ± 0.0001	3.7232 ± 0.0001	3.7641 ± 0.0001	3.7500 ± 0.0003
0.90	7.1387 ± 0.0003	7.0998 ± 0.0001	7.1553 ± 0.0001	7.1849 ± 0.0001	7.1495 ± 0.0004
0.99	7.6132 ± 0.0003	7.5604 ± 0.0001	7.6302 ± 0.0001	7.6596 ± 0.0001	7.6233 ± 0.0004
			$A_{\rm FB}(v_{\max})$		
0.02	0.5657 ± 0.0001	0.5657 ± 0.0001	0.5657 ± 0.0001	0.6062 ± 0.0001	0.6029 ± 0.0001
0.10	0.5665 ± 0.0001	0.5666 ± 0.0000	0.5666 ± 0.0000	0.5931 ± 0.0001	0.5893 ± 0.0001
0.30	0.5694 ± 0.0001	0.5693 ± 0.0000	0.5692 ± 0.0000	0.5864 ± 0.0000	0.5819 ± 0.0001
0.50	0.5745 ± 0.0001	0.5743 ± 0.0000	0.5742 ± 0.0000	0.5870 ± 0.0000	0.5821 ± 0.0001
0.70	0.5864 ± 0.0001	0.5856 ± 0.0000	0.5857 ± 0.0000	0.5953 ± 0.0000	0.5906 ± 0.0001
0.90	0.3106 ± 0.0000	0.3117 ± 0.0000	0.3097 ± 0.0000	0.3174 ± 0.0000	0.3129 ± 0.0001
0.99	0.2851 ± 0.0000	0.2869 ± 0.0000	0.2845 ± 0.0000	0.2917 ± 0.0000	0.2867 ± 0.0000

Table III of Phys.Rev. D63 (2000) of $\sigma_{tot}(v_{\max})$ and $A_{FB}(v_{\max})$ is correctly reproduced using C++ version of KKMCee.

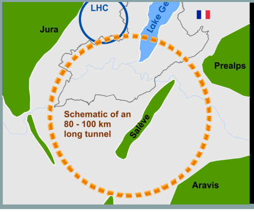
NB. Old semi-analytical tool *KKsem* for the internal x-checks of KKMC is now replaced by *KKeeFoam*, with added IFI contribution.

5-digit precision from the Monte Carlo!!!



Planning

- CEEX $\mathcal{O}(\alpha^n L^n)$ n=3 urgently needed,
  may be also for $n = 4...\infty$, without destroying soft limit?
- Automatising construction of CEEX spin amplitudes (4k lines of dense code),
  for porting it to other processes like HZ?
- Hope to get soon better $\mathcal{O}(\alpha^1)$ EW library. But $\mathcal{O}(\alpha^2)$ also need!
  NB. EW loop corrs. for differential $e^+e^- \to f\bar{f}\gamma$ distributions are still missing:(
- Parton shower like MC algorithm for complete multi-photon phase space
  with correct soft limit? Possibly more efficient in some corners of the phase space.
- Integrating Bhabha process into KKMCee???
  Thinkable, provided good quality EW library is available:)
- and more



Summary

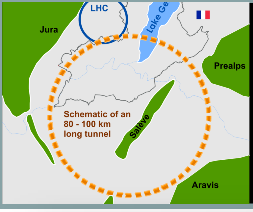
- Two web pages and public GitHub repository with the F77 source codes and extensive documentation are available.
- F77 version is frozen, all actual/future development only in C++.

- New C++ version of KKMCee is already well tested and almost ready for publication in CPC

- To be added before the publication:
- - HEPMC3 interface to TAUOLA, PHOTOS, QCD parton shower MC!
- - New electroweak library in C++ with complex mass scheme?

- (Beamstrahlung and Gaussian BES are already in F77/C++ KKMCee)

Useful discussions with KKMC project coauthors, Z. Was, B.F.L. Ward and S. Yost are acknowledged!



BES/BST distribution in KKMCee

- In KKMC is since long there is an option of the variable beam energies due to beamstrahlung (BST) distributions of ILC with CIRCE spectra.
- **BST** distributions reside in the 3-dimensional integrand of **FOAM**, along with the total energy loss due to initial state radiation ISR.
- Recently Gaussian **BES** spectrum of FCCee has been added as another new option in F77 and C++ versions of KKMCee in the FOAM integrand.