

Large KKMC-ee developments

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KKMC Background.

- Theoretical foundations of KKMC developed at LEP time. Only then 0.1% precision was needed. Not only the main authors S. Jadach B.F.W Ward and ZW contributed. Impact of separation of SM results into QED and remaining genuine parts essential for 0.1% precision in most of $e^+e^- \rightarrow l^+l^-$ observables.
- Concept of technical statistical and physics ambiguities was established as precision evaluation basis.
- It was as essential as exclusive exponentiation (no approximation) in Monte Carlo.
- Reordering of QED perturbative expansion to YFS $\beta_0, \beta_1, \beta_2 \dots$
- Upgrading to complete electroweak corrections: EW form-factors.
STEP possible, because extra interactions are mediated by massive bosons. It was not straightforward. Massive effort needed.

- **CHALLENGE** improve precision from 0.1% to better than 0.01% level. That means beyond simultaneous $\mathcal{O}(\alpha)$ EW, $\mathcal{O}(\alpha^2)$ QED, $\mathcal{O}(\alpha^3)$ eikonal.
- Unfortunately essential players. Not only D. Bardin and S. Jadach are not anymore, many others are close or in retirement, or worse pushed to administration or out of physics.

Who is now available, at least potentially and/or part time?

B.F.L.Ward, S. Yost, A. Price, A. Siodmok, M. Kazanecki, J. Holeczek, M. Chrzaszcz, ZW

Ananya Tapadar, Jim John, now learning to get ready for future work.

S.Banerjee (also essential for F77 version in Belle2), A. Korchin helping with anomalous couplings implementations and some New Physics extensions to 4-fermion processes.

What next?

- New processes (mostly four fermions and New Physics)
- Precision regimes (i) 1% (ii) 0.3% (iii) **0.1 % and beyond.**
- Man power, daily servicing, training.

New processes

- KKMC was optimized for 2-fermion s-channel production, then conformal symmetry helpful for crude level. Extensions to t-channel $e^+e^- \rightarrow \bar{\nu}_e\nu_e n(\gamma)$ use of expansion from contact approximation.
- For four fermion production it is not straightforward preservation of precision challenging (so far was not really needed). More complex structure of collinear enhancements.
- At lower precision (for added New Physics only), solutions based on KKMC+PHOTOS Monte Carlo for four fermion production (e.g. dark photon) are operational, but to go beyond 0.1% level is a long way to go.

Better precision, some aspects

- Second Order matrix elements are needed together with details of experimental acceptance. one need to re-visit matrix elements: (i) separate into eikonal parts and remaining parts. (i) All parts need to be useful for multi-particle final states. (ii) Enable use of electroweak form-factors, preserve (iii) gauge cancellations and (iv) foundation of spin amplitude techniques, such as of Kleiss-Stirling.

Man Power

How to avoid missing corners. Who and how will continue the efforts: [full time](#), [part time](#)? How to train and keep motivated new contributors.

References, see references therein too:

My CERN-TH talk: <https://indico.cern.ch/event/1654778/> also <https://kkmcee.docs.cern.ch/>

KKMC-ee web page: <https://github.com/KrakovHEPSoft/KKMCee> also:

<https://holeczek.web.cern.ch/public/KrakovHEPSoft/KKMCee-dev/>

Some applications associated with KKMC and documenting steps of training,

<https://th.ifj.edu.pl/kkmc-demos/index.html>

TAUOLA, PHOTOS web pages:

<https://tauolapp.web.cern.ch/tauolapp/>

<https://photospp.web.cern.ch/photospp/>

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