Summary of Monte Carlo generators session

S. Jadach, IFJ PAN, Kraków

14:00 → 19:00 **Plenary: Physics generators, discussion** 222-R-001 Join

14:00 **summary of event generator requests** 20m
Speaker: Alain Blondel (Universite de Geneve (CH))

14:20 **WHIZARD generator for precision e-e+ simulations** 25m
Speaker: Jürgen Reuter (DESY Hamburg, Germany)
JRR_2019_FCCee_...

14:45 **KoralW and YFSWW3 - lessons from LEP2 for FCCee** 25m
Speaker: Maciej Skrzypek (Polish Academy of Sciences (PL))
FCCeeKoralW_CER...

15:10 **tau physics at FCC-ee** 25m
Speaker: Mogens Dam (University of Copenhagen (DK))

15:35 **tau event generators** 25m
Speaker: Zbigniew Andrzej Was (Polish Academy of Sciences (PL))

16:00 **coffee** 30m

16:30 $e^+e^- \to \gamma\gamma$ **at large angle for FCC-ee luminometry** 25m
Speakers: Dr Carlo Michel Carloni Calame (INFN - National Institute for Nuclear Physics), Carlo Michel Carloni Calame (INFN, Pavia (IT)), Carlo Michel Carloni Calame, Carlo Michel Carloni Calame

16:55 **The Path to 0.01% Theoretical Luminosity Precision for the FCC-ee** 25m
Speakers: Bennie Ward (Baylor University (US)), Bennie Ward

17:20 **Summary generators** 25m
Speaker: Staszek Jadach (Polish Academy of Sciences (PL))

WHIZARD 3.0
an example of "general purpose" MC event generator

/ 28

The WHIZARD Generator for Lepton Colliders

Jürgen R. Reuter, DESY

HELMHOLTZ
RESEARCH FOR GRAND CHALLENGES

J.R.Reuter Status of WHIZARD 11th FCCee Workshop, CERN, 10.01.19

18 / 28

BSM Models in WHIZARD

MODEL TYPE	with CKM matrix	trivial CKM
Yukawa test model	---	Test
QED with e, μ, τ, γ	---	QED
QCD with d, u, s, c, b, t, g	---	QCD
Standard Model	SM_CKM	SM
SM with anomalous gauge couplings	SM_ac_CKM	SM_ac
SM with Hgg, $H\gamma\gamma$, $H\mu\mu$, He^+e^-	SM_Higgs_CKM	SM_Higgs
SM with bosonic dim-6 operators	---	SM_dim6
SM with charge 4/3 top	---	SM_top
SM with anomalous top couplings	---	SM_top_anom
SM with anomalous Higgs couplings	---	SM_rx/NoH_rx/SM_ul
SM extensions for VV scattering	---	SSC/AltH/SSC_2/SSC_AltT
SM with Z'	---	Zprime
Two-Higgs Doublet Model	THDM_CKM	THDM
Higgs Singlet Extension	---	HSExt
MSSM	MSSM_CKM	MSSM
MSSM with gravitinos	---	MSSM_Grav
NMSSM	NMSSM_CKM	NMSSM
extended SUSY models	---	PSSSM
Littlest Higgs	---	Littlest
Littlest Higgs with ungauged $U(1)$	---	Littlest_Eta
Littlest Higgs with T parity	---	Littlest_Tpar
Simplest Little Higgs (anomaly-free)	---	Simplest
Simplest Little Higgs (universal)	---	Simplest_univ
SM with graviton	---	Xdim
UED	---	UED
"SQED" with gravitino	---	GravTest
Augmentable SM template	---	Template

- Automated models: interface to SARAH/BSM Toolbox Staub, 0909.2863; Ohl/Porod/Staub/Speckner, 1109.5147
- Automated models: interface to FeynRules Christensen/Duhr; Christensen/Duhr/Fuks/JRR/Speckner, 1010.3251
- Automated models: UFO interface [new WHIZARD/O'Mega model format]

J.R.Reuter Status of WHIZARD 11th FCCee Workshop, CERN, 10.01.19

WHIZARD 3.0

Summary & Outlook

- WHIZARD 2.7.0 event generator for collider physics (ee, pp, ep)
- High-multiplicity SM hard processes (2→10 etc.)
- Allows to simulate all possible BSM models
- Strong focus on e^+e^- physics: beam spectra, e^+e^- ISR, LCIO, polarizations
- NLO QCD (almost) done → WHIZARD 3.0 [EW validation started]
- NEW:
  - ☑ UFO models: *[WIP: still waiting for general Lorentz structures]*
  - ☑ MPI parallel integration
  - ☑ Possibility to pre-set branching ratios for factorized processes
  - ☑ Resonance matching to parton shower
  - ☑ Fully integrated PYTHIA8 interface
  - ☑ Batch mode / gridpack functionality

Main focus on BSM but also evolution towards "precision physics MC"

Another similar general purpose MC from Dubna group this

One-loop electroweak radiative corrections to $e^+e^- \to e^+e^-, f\bar{f}, ZH$ for polarized $e+e-$ beams

Yahor Dydyshka[a], L. Kalinovskaya[a],
L. Rumyantsev[a,b], R. Sadykov[a], V. Yermolchyk[a],
A. Arbuzov[c], S. Bondarenko[c]

[a] *DLNP JINR, Dubna,* [c] *BLTP JINR, Dubna,*
[b] *IoP, Southern Federal University, Rostov-on-Don, Russia*

11th FCC-ee workshop: Theory and Experiments, 10.01.2019

- FCC_{ee} and polarized beams (motivation)
- ARIeL– a SANC branch for polarized e^+e^- beams
- Born and virtual contributions
- Bremsstrahlung amplitudes
- MCSANC generator and tuned comparison
- SANC/ARIeL NLO EW results
- Conclusion and plans

Conclusion

- The background for complete one loop calculation of the EW radiative corrections for fermion pair and for associated Higgs boson production with polarized e^+e^- beams (longitudional and transversal) is created: HA for virtual part & HA for Bremsstrahlung
- Complete $O(\alpha)$ EW corrections to polarized
  - a) $e^+e^- \to e^+e^-$ (Bhabha scattering)
  - b) $e^+e^- \to \mu^+\mu^-$ $(\tau^+\tau^-)$
  - c) $e^+e^- \to ZH$ computed for the first time
- all these processes are embedded in the MC generator

KORALW and YFSWW

KoralW and YFSWW3 – lesson from LEP2 for FCCee

M. Skrzypek
in collaboration with
S. Jadach, W. Płaczek, B.F.L. Ward, Z. Wąs

FCC Physics Workshop
8-11 Jan. 2018, CERN, Geneva

http://placzek.web.cern.ch/placzek/

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POLAND

Monte Carlo programs:

- **LESKO-E & FRANEQ**: For Deep Inelastic Neutral Current Scattering at HERA (not updated since January 1993).
- **BHWIDE**: For Large-Angle Bhabha Scattering.
- **KoralW**: For 4-Fermion Production in Electron-Positron Collisions.
- **YFSWW**: For W-Pair Production and Decay in Electron-Positron Collisions.
- **YFSZZ**: For Z-Pair Production and Decay in Electron-Positron Collisions.
- **WINHAC**: For Single W-Boson Production in Hadron Collisions.

Publications:

- Search in the INSPIRE HEP Data Base

Talks *(slides in PostScript or PDF):*

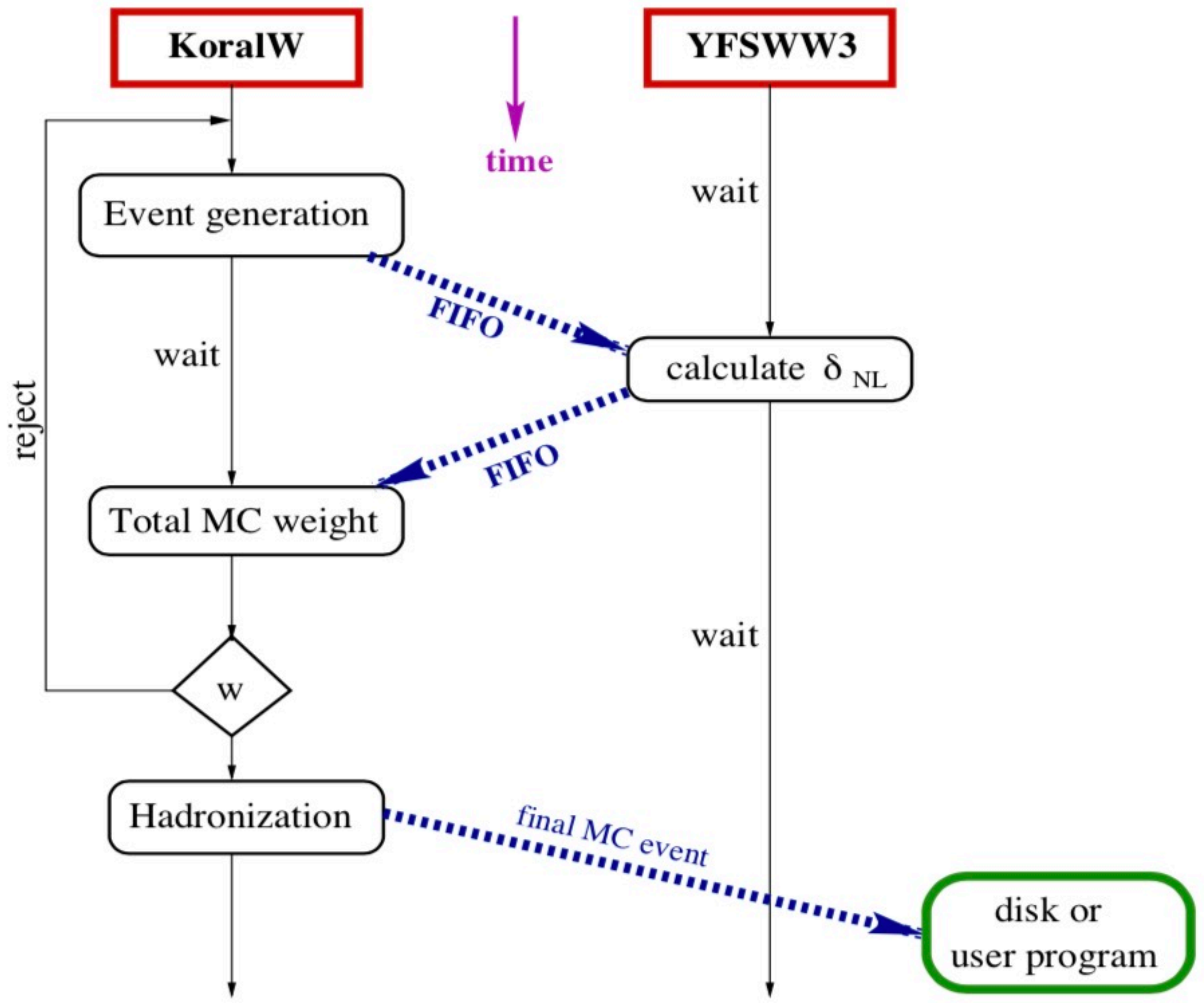
- **On WW** at LCWS 2000, Fermilab, October 24-28, 2000: PS or PDF
- **On MW** at ECFA/DESY LCWS in Krakow, September 14-18, 2001: PS or PDF
- Seminars on **WW and ZZ processes**, Warsaw University (10.12.2001) and University of Silesia, Katowice (15.01.2002): PS or PDF
- Seminar on **theoretical precision of MW and TGC at LEP2** at Jagielloniam University, Krakow, January 8, 2002: PS or PDF
- **On photonic observables in W-pair production**, LEP2 WW Working Group, CERN, January 31, 2002: PS or PDF

KORALW+YFSWW tandem

Merge of KoralW and YFSWW3 = KandY

Possible because the underlying photonic distribution is the same YFS-ISR in both codes. All other photonic effects are included as weights. So are the $\mathcal{O}(\alpha)$ EW corrs.

Concurrent realization of $\sigma_{K/Y}$ with "named pipes"

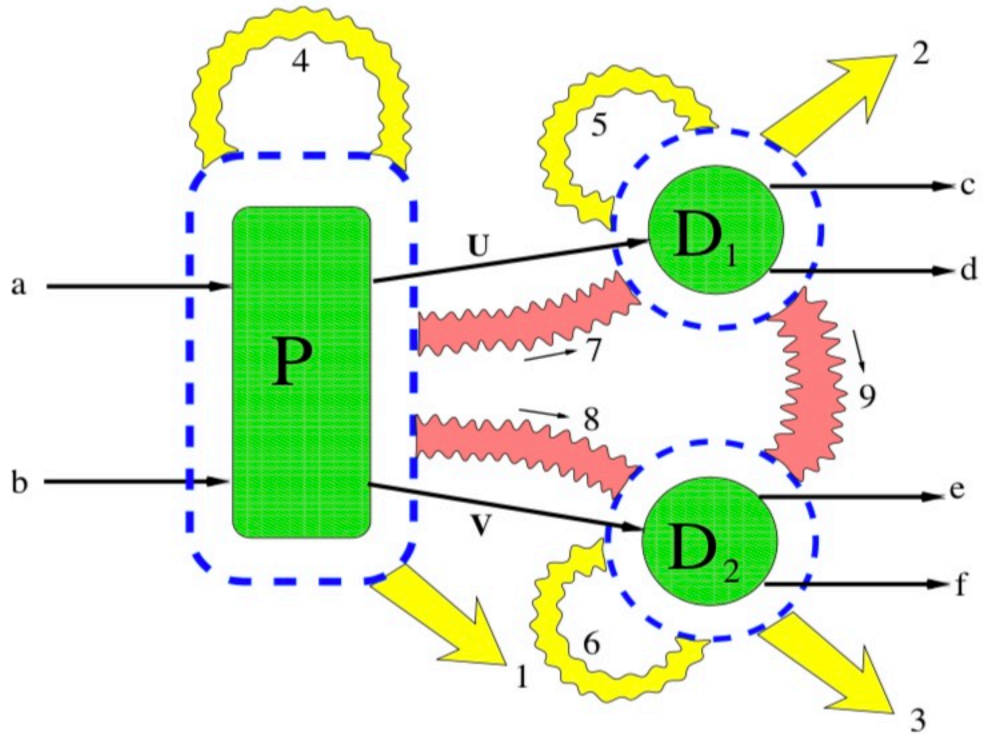


Works effectively as a single MC event generator

KORALW+YFSWW tandem

New exponentiation of interferences in YFS scheme

The YFS Monte Carlo scheme can be extended to exponentiate also the soft non-factorizable corrections (pink lines)



Not implemented in KoralW+YFSWW3 yet!

New extended YFS scheme will exponentiate *all* types of soft photons: Coulomb-like, non-factorizable interferences etc.

It can be a solid starting point to improve threshold behavior

For now the Coulomb-like corrections are by hand removed from exponentiation in YFSWW3 – standard Coulomb corr. is added into hard residuals

M. Skrzypek (IFJ PAN, Kraków, Poland) KoralW and YFSWW3 ... CERN, 8-11.01.2019 23 / 25

Conclusions and outlook

- KoralW+YFSWW3: LEP2 precision is 0.5%.
  Factor of 20 $\div$ 50 improvement is needed for FCCee
- Lesson from LEP2: be pragmatic, split into Double- and Single-Pole, pick only numerically dominant terms:
  - $\mathcal{O}(\alpha^1)$ for $e^- e^+ \to 4f$ must be implemented in MC with explicit split into Double Pole and Single Pole. Calculations exist
  - $\mathcal{O}(\alpha^2)_{DP}$ calculations for the Double-Pole production and decay parts are needed! Feasible?
  - $\mathcal{O}(\alpha^2)_{SP}$ and $\mathcal{O}(\alpha^3)$ seem to be negligible
- More detailed analysis at the threshold may be instrumental
  - EFT methods promising, but for now inclusive results only
  - Non-factorizable soft interferences can be exponentiated within YFS scheme. How much of the higher order corrs. would be reproduced this way?

The overall precision tag $\sim 2 \times 10^{-4}$ feasible (?)

YFSWW3$\oplus$KoralW with new exponentiation look like a good starting point

Desirable upgrade:
- **EW one order higher for signal and background**
- **new coherent soft photon resummation (all scales non-factorizables)**

Low angle Bhabha (BHLUMI)

The Path to 0.01% Theoretical Luminosity Precision for the FCCee

B.F.L. Ward

Baylor University, Waco, TX, USA

Oct. 23, 2018; Jan. 10, 2019

in collaboration with

S. Jadach, W. Placzek, M. Skrzypek, S. A. Yost

http://192.245.169.66:8000/FCCeeMC/wiki/bhlumi

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wiki: bhlumi

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Last modified 4 years ago

BHLUMI 4.0x source code:

- Source code of the linux version: bhlp-4.x-linux.tar.gz (2.5MB)
- Original CPC version: bhlp-4.04-export.tar.gz WARNING! will not compile under modern systems

How to compile and run simple examples: HERE

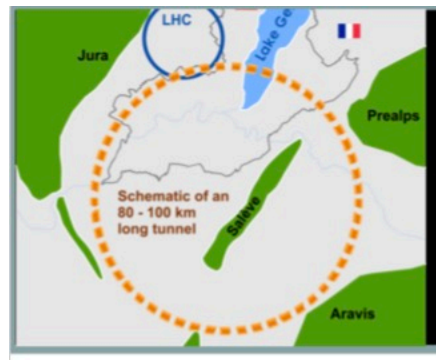
Documentation (papers):

- program description and user manual, Phys. Commun. 102 (1997)
- more papers in the attachments

Talks on low angle Bhabha and BHLUMI are HERE

▸ **Attachments**

Low Angle Bhabha (BHLUMI)



Z and s-channel gamma exchange for FCCee angular range 64-86mrad

Type of correction / Error	Update 2018	FCCee forecast
(a) Photonic $O(L_e^4\alpha^4)$	0.027%	0.6×10^{-5}
(b) Photonic $O(L_e^2\alpha^3)$	0.015%	0.1×10^{-4}
(c) Vacuum polariz.	0.014% [25]	0.6×10^{-4}
(d) Light pairs	0.010% [18, 19]	0.5×10^{-4}
(e) Z and s-channel γ exchange	0.090% [11]	0.1×10^{-4}
(f) Up-down interference	0.009% [27]	0.1×10^{-4}
(f) Technical Precision	(0.027)%	0.1×10^{-4}
Total	0.097%	1.0×10^{-4}

1. With respect to **dominant** t-channel gamma excha $|\gamma_t|^2 = \gamma_t \otimes \gamma_t$, all other contributions are suppressed (near Z) by factor <|t|>/s = 1.3 · 10^{-3} (instead 0.4 · 10^{-3} for LEP!)
2. However, **resonant** Z_s exchange gets enhanced by M_Z/Γ_Z and $\gamma_t \otimes Z_s$ term will be up to 1%.
   It is included in BHLUMI at the complete 1-st order level (with QED running couplings).
   Using results of ref. [11] its uncertainty due to QED corrections is **presently** estimate above as 0.090%
3. **Non-resonant** $\gamma_t \otimes \gamma_s$ ~0.1% is included in BHLUMI, gets small QED cor. with uncertainty 0.01%
4. Other contribution not in BHLUMI are: $|Z_s|^2$ ~0.01%, $\gamma_t \otimes Z_t$ ~ 3 ·10^{-5} , $|\gamma_s|^2 \sim 10^{-6}$ and $|Z_t|^2 \sim 10^{-6}$
5. It will be straightforward to reduce the above uncertainties ~~to ~10^{-4}~~ level by means of upgrade of the BHLUMI matrix element to the level of BHWIDE (EEX type).
6. With the implementation of the mat.el. of the CEEX type, as in KKMC, one could get for this group of contributions precision level of ~10^-5.

Study of Z and s-channel γ exchanges using BHWIDE

E_{CM} [GeV]	Δ_{tot} [%]	$\delta^{QED}_{O(\alpha)}$ [%]	$\delta^{QED}_{h.o.}$ [%]	δ^{weak}_{tot} [%]
90.1876	+0.642 (12)	−0.152 (59)	+0.034 (38)	−0.005 (12)
91.1876	+0.041 (11)	+0.148 (59)	−0.035 (38)	+0.009 (12)
92.1876	−0.719 (13)	+0.348 (59)	−0.081 (38)	+0.039 (13)

[11] S. Jadach, W. Placzek, and B. F. L. Ward, "Precision calculation of the gamma - Z interference effect in the SLC / LEP luminosity process", *Phys. Lett.* **B353** (1995) 349–361.

Low Angle Bhabha (BHLUMI)

SUMMARY

- All of LEP/SLD luminosity QED error estimates represent corrections **missing in BHLUMI v.4.04** Monte Carlo, used by all LEP and SLD collaborations.
- BHLUMI features $O(\alpha^1)$ and $O(L_e^2\alpha^2)$ corrections with YFS resumation, neglecting photonics interferences between e^+ and e^- lines, where $L_e = \ln(|t|/m_e^2)$.
- **One has to add to BHLUMI QED matrix element corrections of** $O(L_e\alpha^2)$ **and** $O(\alpha^3 L_e^3)$
- They were calculated by Cracow-Knoxville collaboration long time ago (1996-99), but there was no strong motivation to publish them in the MC form, because of large VP uncertainty.
- Interferences between e^+ and e^- lines should be added at 1-st order, with resummation.
- This class of corrections are implemented in the KKMC and BHWIDE since 1999.
- Corrections due to Z exchange and s-chanel gamma are big but easy to master (ME upgrade).
- There is (almost) enough auxiliary programs and calculations to control light pair corrections.
- Summarising there is no hard obstacles on the way to 0.01% QED precision on the theory side.
- The sticky issue is that of "technical precision".
  If BabaYaga Monte Carlo team makes sufficient progress then this problem is solved.
  But alternative solutions are available: comparing CEEX and EEX upgrades of BHLUMI,... .
- We do need sufficient theory resources.

TAUOLA for tau decays

tau event generators –
for precision tests of SM at FCC

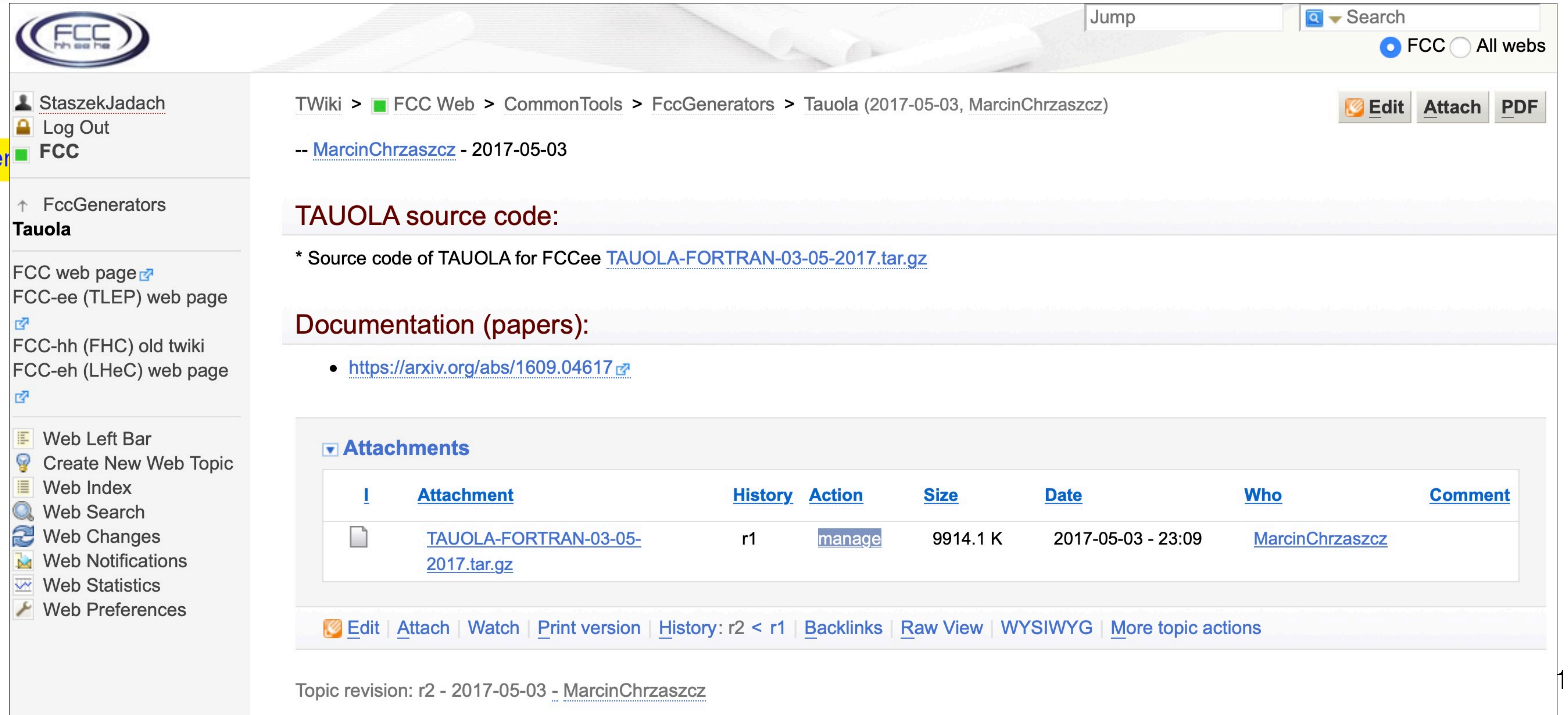
Z. Was,

Institute of Nuclear Physics, Polish Academy of Sciences Krakow

- **(1)** There is nothing particular in τ polarization as SM precision test
- **(2)** It seem to be even simpler than A_{FB} because it is less dependent of $\sqrt{s}$
- **(3)** The problem is that it is not a datapoint.
- **(4) One has to measure spectra of τ decay products. Then $\longrightarrow$**
- **(5) Beware: measurements uncetainties, decay channels cross-contamination.**
- **(6) QED FSR is sizable, also of non-QED photon production ME.**
- **(7) That is why subject deserves attention**
- **(8)** τ lepton decay event generators: in-between carrier of theory predictions and carrier of other experimen

Z. Was

https://twiki.cern.ch/twiki/bin/view/FCC/Tauola



TAUOLA for tau decays

$20 \cdot 10^{-5}$ ambiguity on $\sin^2\theta_W^{eff}$ is very pessimistic.

1. This estimate relies on size of bremsstrahlung effect and assumption that only leading logarithm terms are properly managed in simulation (e.g. by Photos Monte Carlo). That lead to $20 \cdot 10^{-5}$ on $\sin^2\theta_W^{eff}$
2. This is known to be too pessimistic since a long time:
   R. Decker and M. Finkemeier, "Short and long distance effects in the decay tau —> pi tau-neutrino (gamma)," Nucl. Phys. B **438**, 17 (1995)
3. $\sim 5 \cdot 10^{-5}$ ambiguity on $\sin^2\theta_W^{eff}$ is straightforward to achieve. Some verification on interplay of detector response and collinear photons should be sufficent. Old and new upgrades as for Photos Monte Carlo, hep-ph/0607019, 1706.05571 are available.
4. No fundamental theory for the emission of photons from scalars (not point like scalars) exist.
5. Verification with τ decay data would be necessary to go beyond $\sim 5 \cdot 10^{-5}$.

Conclusions and outlook

16

- I have adressed the main difference in list of uncertainties for precision tests of SM with τ lepton polarization.
- `Tauola, Photos, TauSpiner` projects evolve slowly but some new, useful for precision evaluation features were presented.
- Synergy with Belle was pointed. It may be needed to reduce substantially uncertainty in $\sin^2\theta_W^{eff}$ below $5 \cdot 10^{-5}$, the estimation possible with present day calculations.
- Example of application with the use of Machine Learning techniques is in follow-up slides.
- Also in this case, as for evaluation of systematic ambiguities use of event weights was helpful.
- Essential for future developments will be thus control of systematic errors for multi-dimensional distributions.
- If experimental data should have background subtracted, or if dominant backgrounds will be fitted simultaneously with the signature is technically less important.
- Question of manpower and training as well as motivation of involved people is very important. Competition for talent from other fields can not be ignored.

Baba Yaga MC of Pavia

$e^+e^- \to \gamma\gamma$ at large angle for FCC-ee luminometry

C.M. Carloni Calame

INFN Pavia, Italy

11th FCC-ee workshop: Theory & Experiment

CERN, January 8 - 11, 2019

with M. Chiesa, G. Montagna, O. Nicrosini, F.

https://www2.pv.infn.it/~hepcomplex/babayaga.html

BabaYaga@NLO

This version is a complete rewriting of the generator, which now could also simulate the production of a single dark matter massive photon decaying in e^+e^-, $\mu^+\mu^-$ pairs. The code includes also non-log order alpha corrections, which were the main source of theoretical error in the previous releases of the code. Download it here and please refer to the README file in the package for its usage.
The theoretical error of the new release is estimated to be around 0.1%, for Standard Model processes.
In the papers [1], [2] and [6], where the theoretical formulation, numerical results and comparisons to independent calculations are presented, you can find more details about the theoretical accuracy estimate of the generator.

BabaYaga 3.5

This version of the generator can be used for e^+e^-, $\mu^+\mu^-$, $\gamma\gamma$ and $\pi^+\pi^-$ final states. The radiative corrections are here included in a pure Parton Shower approach, even though it has been improved to include initial-final state radiation interference for a more accurate description of radiative events.
The estimated theoretical accuracies for the different channels are

- **Bhabha 0.5%** (superseded by BabaYaga@NLO)
- **$\mu^+\mu^-$ 1%**
- **$\gamma\gamma$ 1%**
- **$\pi^+\pi^-$ 1%** (notice that for this channel only initial state radiation is accounted for)

Download it here and please refer to the README file in the package for its usage.

BabaYaga of Pavia

Conclusions & Outlook

- ↦ The process $e^+e^- \to \gamma\gamma$ at large-angle is worth being studied as monitor for luminosity at FCC-ee
- ↦ On the theoretical side:
  - ⤳ NLO QED RCs affect differential cross sections at the $10-20\%$ level
  - ⤳ QED higher-order RCs lie in the $\%$ range
  - ⤳ EWK RCs get larger at higher energies, and lie in the $\%$ range
  - ⤳ Hadronic VP enters only at NNLO, its uncertainty is (likely) negligible
- ↦ With complete NNLO at hand, matched with QED h.o. resummation, can $e^+e^- \to \gamma\gamma$ theoretical accuracy be controlled at/better than the 10^{-4} level? Perhaps better than small-angle Bhabha?

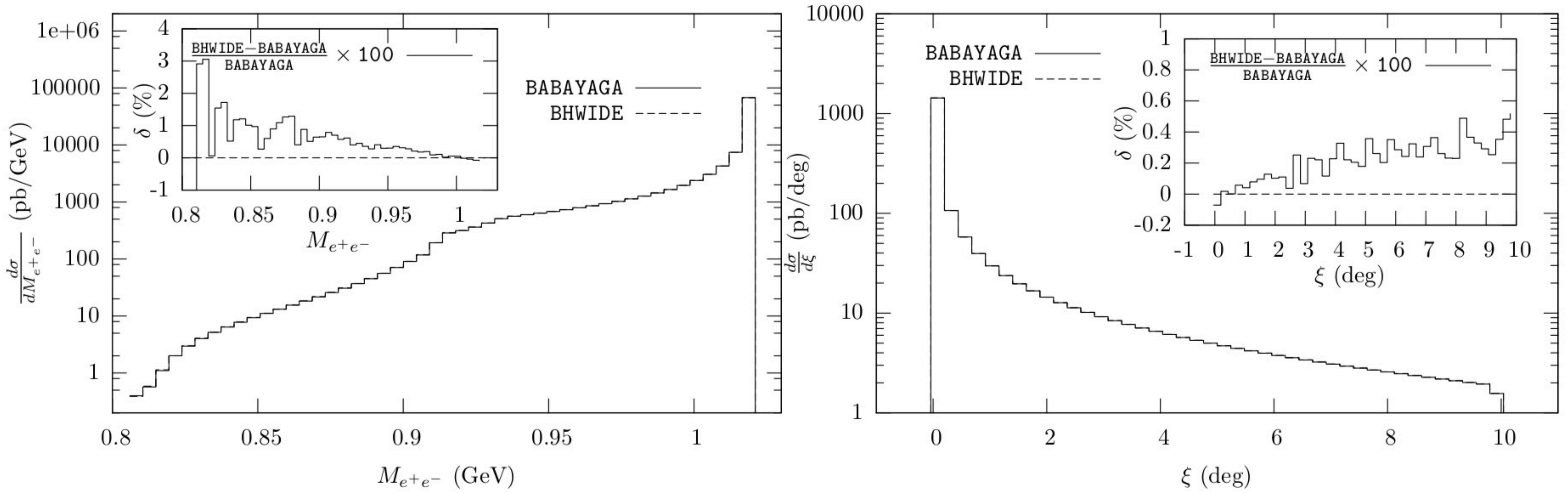
Estimating the theoretical accuracy

S. Actis et al. Eur. Phys. J. C **66** (2010) 585

"Quest for precision in hadronic cross sections at low energy: Monte Carlo tools vs. experimental data"

- It is extremely important to compare independent calculations/implementations/codes, in order to
  - ↦ asses the technical precision, spot bugs (with the same th. ingredients)
  - ↦ estimate the theoretical error when including partial/incomplete higher-order corrections
- E.g. comparison `BabaYaga@NLO` vs. `Bhwide` at KLOE

S. Jadach *et al.* PLB 390 (1997) 298



Good chance for healthy competition between upgraded BHLUMI and upgraded BabaYaga
Especially important for the notorious problem of the "technical precision"

MC partly covered in the session: RacoonWW

https://racoonww.hepforge.org

RacoonWW
a Monte Carlo generator for
4-fermion production at e+e- colliders

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- Downloads
- Publications
- Release History
- Contact

Authors

Ansgar Denner	*Universität Würzburg, Germany*
Stefan Dittmaier	*Universität Freiburg, Germany*
Markus Roth	
Doreen Wackeroth	*SUNY at Buffalo, USA*

RacoonWW provides

- lowest-order predictions for
  - all processes e+e- -> 4 fermions
  - all processes e+e- -> 4 fermions + photon
- radiative corrections to e+e- -> WW -> 4f including
  - the full electroweak O(alpha) corrections in double-pole approximation
  - higher-order leading-logarithmic initial-state radiation
  - complete off-shell Coulomb singularity
- an Improved Born Approximation (IBA) with leading universal corrections

You can download the source code of RacoonWW and its documentation here.

The release history of RacoonWW can be found here.

If you use RacoonWW for a publication, please cite the appropriate references listed here.

MCs not covered in the session: KKMC

http://192.245.169.66:8000/FCCeeMC/wiki/kkmc

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Last modified 23 months ago

KKMC for fermion pair production at electron-positron colliders

- 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). With C++ wrappers. 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.Melles, B.F.L.Ward and S.A. Yost. Collinear beamstrahlung for NLC/ILC.
- Developement Version 4.22, June 2013, (KKMC_v4_22.tgz). Tested with $\mu^-\mu+$ and $q\bar{q}$ beams (instead of e^-e^+) at fixed energy. Optionally, collinear PDFs for $q\bar{q}$ beams instead of beamstrahlung, as a patch in the source code (temp. solution).

- First version [4.24] of the **KKMCee development branch**. Beamstrahlung implementation for FCCee/ILC/CLIC is now improved, simplified and better debugged. Temporary insertions in the source code for quark beams are removed (kept and developed further in KKMChh branch, to be published).

KKMC source codes:

- Source code of KKMCee latest vers. 4.24 KKMC_v4_24a.tgz (22MB).
- Previous version 4.22 KKMC_v4_22.tgz (13MB)

How to compile and run simple examples: HERE

Documentation (papers):

- Program description and user manual, Phys. Commun. 130 (2000) | hep-ph/9912214
- Physics description and benchmarks, Phys. Rev D63 (2001) | hep-ph/0006359
- Version 4.22 arXiv:1307.4037

Talks on KKMC are HERE

MCs not covered in the session: KKMC

IFJPAN-IV-2017-11

QED Interference in Charge Asymmetry Near the Z Resonance at Future Electron-Positron Colliders ⋆

S. Jadach[a], S. Yost[b,a]

[a] Institute of Nuclear Physics, Polish Academy of Sciences, ul. Radzikowskiego 152, 31-342 Kraków, Poland

[b] The Citadel, Charleston, SC, USA

[hep-ph] 30 Nov 2018

Abstract

The measurement of the charge asymmetry $A_{FB}(e^-e^+ \to \mu^-\mu^+)$ will play an important role at the high-luminosity circular electron-positron collider FCCee considered for construction at CERN. In particular, near the Z resonance, $\sqrt{s} \simeq M_Z \pm 3.5$ GeV, A_{FB} will provide a very precise value of the pure electromagnetic coupling constant

Can we control A_FB with precision 100 better than at LEP?
Down to 0.001% level?
The question boils down to controlling QED initial-final-state interference at that level.

Not proven, but there is a fair chance!

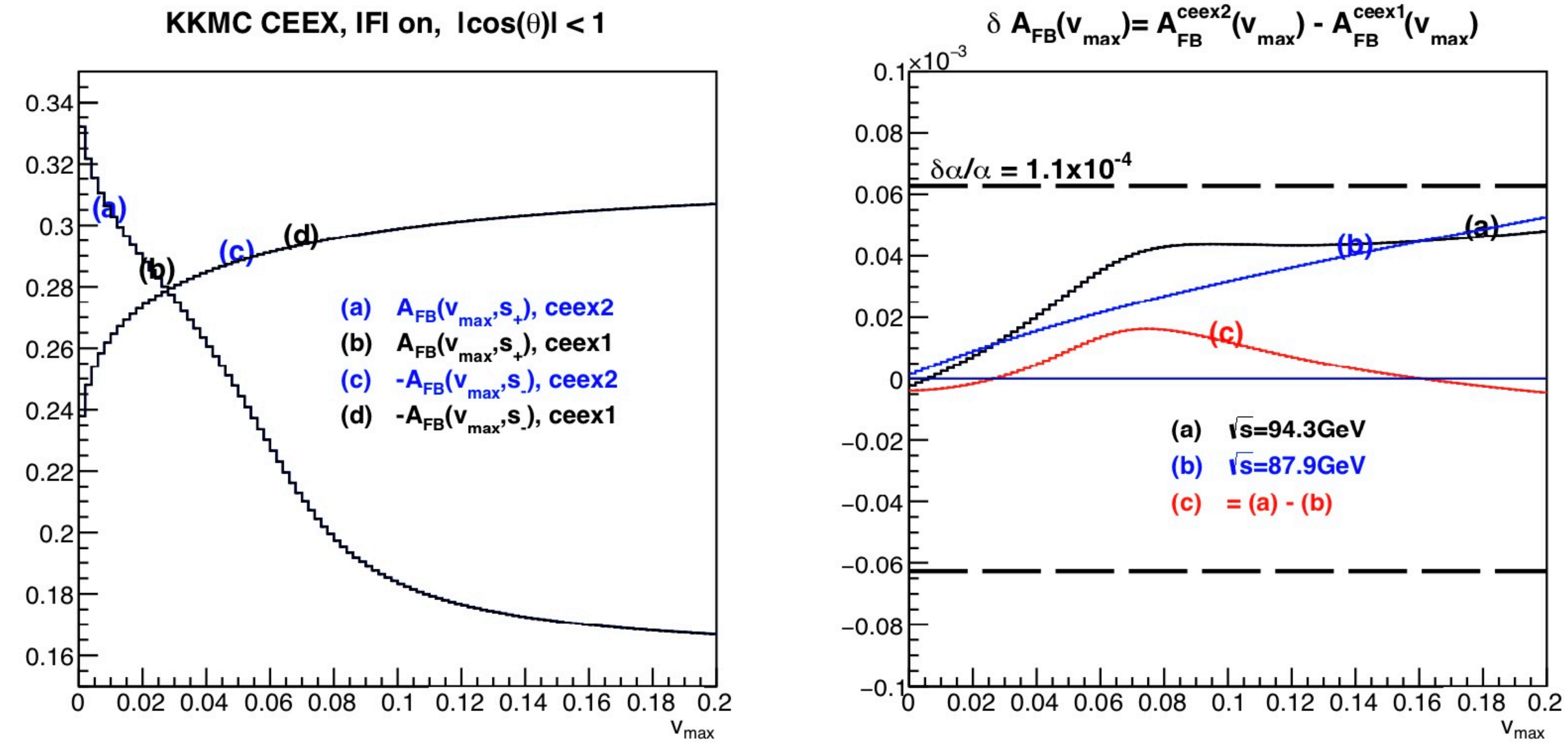

Figure 21: Differences between A_{FB} calculated using the CEEX matrix element $\mathcal{O}_{\exp}(\alpha^i)$, $i = 1, 2$ with IFI switched on.

Collection of final remarks

★Separation of QED and pure EW is an important issue, especially beyond 1st order

★Order by order and/or LO->NLO->…, is done separately/independently for two sectors:

- resumed QED
- pure EW including nonsoft/noncollinear QED

Solution is known and implemented in KKMC.

★The above can be done consistently at any order (+resumation) in case of factorisation done at the amplitude level and resumation numerically within the MC generator (only!).

★At LEP there was clear distinction between general purpose MCs like Pythia and precision MCs dedicated for single process and related group of observables.
At FCCee the distinction might be more fuzzy.

★At FCCee the role of the MC in definition and extraction or pseudo-observables and pseudo-parameters like “MC-mass” or W or t quark or “MC sin^2(theta_W)” will be bigger than at LEP.
More in my talk on EWPO’s tomorrow 9am.