Polish node (HNINP) activity

S. Jadach

Henryk Niewodniczański Institute of Nuclear Physics, Cracow, Poland

`Mid-Term Review Meeting`

`Durham, 10 April, 2002`

Selected works:

- Theoretical uncertainty (TU) in W mass measurement
- Angular distribution in WW process and TU of TGC
- $1W$ process by KORALW
- Chargino/neutralino sector in e^+e^- collider
- Extension of KKMC to $\nu\bar{\nu}\gamma$ channel

Theoretical Uncertainty in W mass measurement (El-Weak)

S. Jadach, W. Placzek, M. Skrzypek, B. F. Ward and Z. Was,

"On theoretical uncertainties of the W boson mass measurement at LEP2,"

Phys. Lett. B 523 (2001) 117 [arXiv:hep-ph/0109072].

- $\mathrm{M_W}$ **at LEP2 measured by direct fit to $\mathbf{W}$ invariant mass distribution**:

  Level-1: Constrained kinematic fit $\Rightarrow$ two $\mathbf{W}$ invariant masses $+$ auxiliary parameters (controlling the detector energy resolution, etc.)

  Level-2: Actual $\mathrm{M_W}$ fit using MC Event Generator (ALEPH, L3, OPAL) or analytical function (DELPHI)

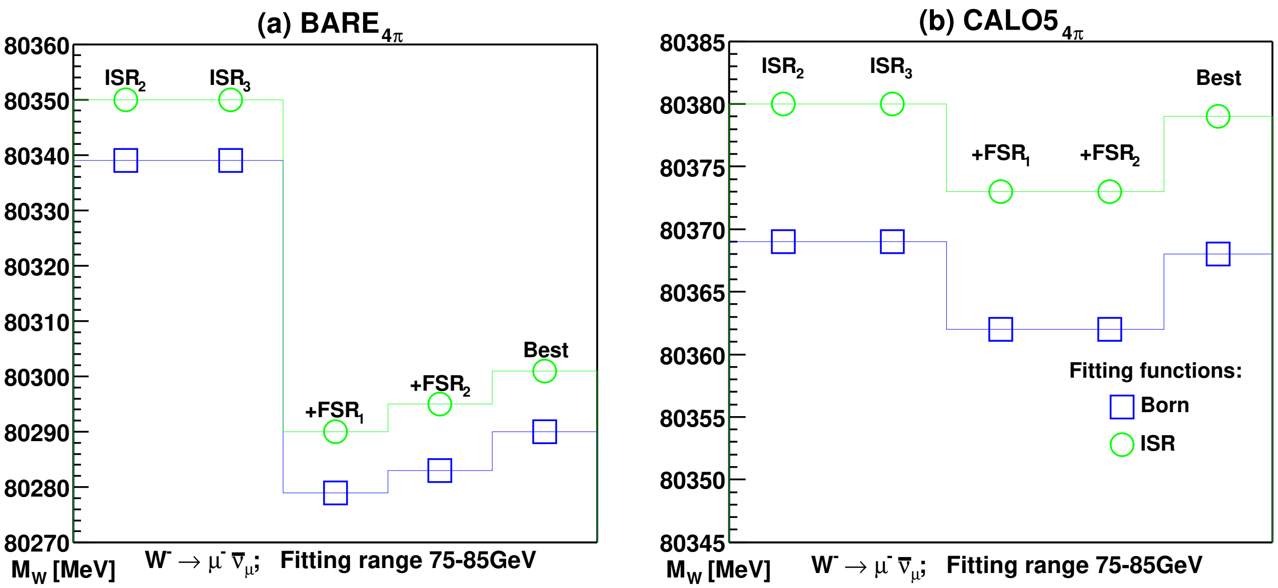
- **Final LEP2 Experimental Precision:** $\Delta\mathrm{M_W} \simeq \mathbf{30}$ **MeV**

- **Theoretical Untertainty (TU) should be:** $\leq \mathbf{15}\,(\mathbf{10})$ **MeV**

- **Missing detailed study on TU of $\mathrm{M_W}$ (before this work)**

  $\Rightarrow$ **TU of $\mathrm{M_W}$ is almost completely independent of TU on σ_{WW}** (studied in detail during 2000 LEP2 MC Workshop, cf. Report CERN 2000-009)

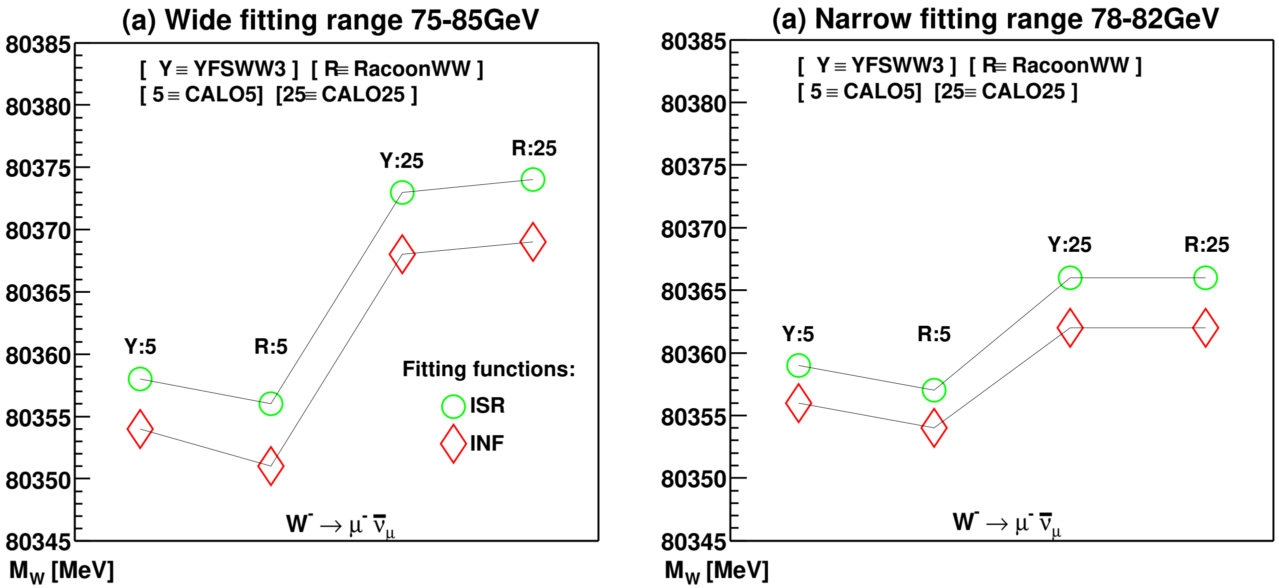
Effects of ISR and FSR on M_W



$\longrightarrow$**FSR from PHOTOS (Wąs et al.)**

- **Higher order ISR: negligible M_W shift (< 1 MeV)**
- **FSR effect large for BARE$_{4\pi}$ (~ 60 MeV) and much smaller for CALO$_{4\pi}$ (~ 7 MeV), as expected. Higher order FSR negligible for CALO$_{4\pi}$**
- **INF+NL ~ 6 MeV (with resp. to ISR with non-screened Coulomb corr.) and seems to cancel partly with FSR**

Comparison of YFSWW3 and RacoonWW:



- The comparison of **YFSWW3** with **RacoonWW** is very interesting because the two calculations differ in almost every aspect of the implementation of the ISR, FSR, NL and NF corrections.
- The results of **YFSWW3** and **RacoonWW** differ, in terms of the fitted mass, by only ≤ 3 **MeV**, slightly more for **CALO5** than for **CALO25**.

Estimation of the missing effects in the K-Y MC tandem:

ΔM_W			
Error Type	Scale Param. $\Delta M_W = \Gamma \times \epsilon$	Numerical cross-check	ΔM_W
WW production			
ISR $\mathcal{O}(\alpha^4 L_e^4)$	$\epsilon \simeq \frac{\Gamma_W M_W}{s\beta_W^2}(\frac{\alpha}{\pi})^4 L_e^4 \sim 5 \cdot 10^{-6}$	$[\mathcal{O}(\alpha^3 L_e^3) - \mathcal{O}(\alpha^2 L_e^2)]_{\rm KoralW}$	$\ll 1$ MeV
ISR $\mathcal{O}(\alpha^2 L_e)$	$\epsilon \simeq \frac{\Gamma_W M_W}{s\beta_W^2}(\frac{\alpha}{\pi})^2 L_e \sim 5 \cdot 10^{-6}$	KorWan	$\ll 1$ MeV
ISR $\mathcal{O}(\alpha^2)_{pairs}$	$\epsilon \simeq \frac{\Gamma_W M_W}{s\beta_W^2}(\frac{\alpha}{\pi})^2 L_e^2 \sim 4 \cdot 10^{-4}$	KorWan	< 1 MeV
W decay			
FSR $\mathcal{O}(\alpha)_{miss.}$	$\epsilon \simeq 0.2 \left(\frac{\pi}{8}\frac{\alpha}{\pi} 2\ln\frac{M_W}{p_T}\right) \sim 10^{-3}$	Basic tests of PHOTOS	~ 2 MeV
FSR $\mathcal{O}(\alpha^2)_{miss.}$	$\epsilon \simeq \frac{1}{2}\left(\frac{\pi}{8}\frac{\alpha}{\pi} 2\ln\frac{M_W}{p_T}\right)^2 \sim 10^{-5}$	On/off 2γ in PHOTOS	$\ll 1$ MeV
Non-factorizable QED interferences (between production and 2 decays)			
$\mathcal{O}(\alpha^1)^{inclusive}_{miss.}$	$\epsilon \simeq 0.1 \left(\frac{\alpha}{4}\frac{(1-\beta)^2}{\beta}\right) \sim 10^{-4}$	Chapovsky & Khoze	< 1 MeV
$\mathcal{O}(\alpha^2)^{inclusive}$	$\epsilon \simeq \frac{1}{2}\left(\frac{\alpha^2}{4}\frac{(1-\beta)^2}{\beta}\right)^2 \sim 10^{-7}$	None	$\ll 1$ MeV

- **TU due to LPA:** $\Delta M_W = 1$ **MeV (LPA options in YFSWW3)**

Theoretical Uncertainty in W mass measurement (El-Weak)

- The Electroweak Theoretical Uncertainty in $\mathrm{M_W}$ of the KoralW-YFSWW3 MC tandem at LEP2 energies is $\boxed{\sim 5\ \text{MeV}}$

  (< 10 MeV – targeted TU for LEP2)

- The above conclusion is strengthened by the smallness of the differences between YFSWW3 and RacoonWW (≤ 3 MeV).

  We attribute it to the standard *factorizable* corrections (ISR, FSR, etc.) and purely technical/numerical effects.

- In the above estimate we included a "safety factor" of 2, corresponding to the fact that our fits of $\mathrm{M_W}$ were done for 1-dimensional effective W mass distributions.

  In order to eliminate it, our analysis should be repeated for the realistic measurements of the LEP2 experiments.

Angular distribution in WW process and TU of TGC

R. Bruneliere, A. Denner, S. Dittmaier, S. Jadach, S. Jezequel, W. Placzek, M. Roth, M. Skrzypek, D. Wackeroth, B.F.L. Ward, Z. Was R. Bruneliere,

"On theoretical uncertainties of the W angular distribution in W pair production at LEP2 energies," arXiv:hep-ph/0201304, Phys. Lett. in print.

- $\cos\theta_W$ (cosine of W boson production angle) **distribution is used to determine the Triple Gauge Couplings (TGC) at LEP2.** $\cos\theta_W$ distribution is particularly sensitive to $\lambda = \lambda_Z = \lambda_\gamma$. We concentrate on this TGC. Analysis of other TGCs would require more observables.
- **Final LEP2 Experimental Precision:** $\Delta\lambda \simeq \mathbf{0.01}$
- **Theoretical Untertainty (TU) should be:** $\leq \mathbf{0.005}$
- **Missing detailed study on TU of** $\cos\theta_{\mathbf{W}}/\lambda$ distribution **(before this work)**
  $\Rightarrow$ **TU of** $\cos\theta_{\mathbf{W}}/\lambda$ **is almost completely independent of TU on** $\sigma_{\mathbf{WW}}$
  (studied in detail during 2000 LEP2 MC Workshop, cf. Report CERN 2000-009)

The shifts of λ_γ from various effects, obtained from YFSWW3

Effect	Acceptance	$\Delta\lambda_\gamma$
1. Best — ISR	$\mathrm{BARE}_{4\pi}$	$0.0108\,(7)$
	$\mathrm{CALO5}_{4\pi}$	$0.0110\,(7)$
2. ISR_3 — ISR_2	$\mathrm{BARE}_{4\pi}$	$0.0001\,(2)$
	$\mathrm{CALO5}_{4\pi}$	$0.0001\,(2)$
3. FSR_2 — FSR_1	$\mathrm{BARE}_{4\pi}$	$0.0001\,(3)$
	$\mathrm{CALO5}_{4\pi}$	$0.0001\,(3)$
4. $4f$-background corr. (Born)	CALO5	$0.0021\,(3)$
	CALO25	$0.0021\,(3)$
5. $4f$-background corr. (with ISR)	CALO5	$0.0005\,(3)$
	CALO25	$0.0005\,(3)$
6. EW-corr. scheme: $(B)-(A)$	CALO5	$0.0006\,(9)$
	CALO25	$0.0006\,(9)$
7. LPA_b — LPA_a	CALO5	$0.0017\,(9)$
	CALO25	$0.0018\,(9)$

The shifts of λ_γ from various effects, obtained from RacoonWW

Effect	Acceptance	$\Delta\lambda_\gamma$
1. Best — ISR	CALO5	$0.0096\,(8)$
	CALO25	$0.0158\,(8)$
2. Off-shell Coulomb effect	CALO5	$0.0001\,(10)$
	CALO25	$0.0001\,(10)$
3. $4f$-background corr. (Born)	CALO5	$0.0029\,(10)$
	CALO25	$0.0029\,(10)$
4. $4f$-background corr. (with ISR)	CALO5	$0.0008\,(10)$
	CALO25	$0.0008\,(10)$
5. On-shell projection	CALO5	$0.0003\,(10)$
	CALO25	$0.0003\,(10)$
6. DPA definition	CALO5	$0.0005\,(10)$
	CALO25	$0.0005\,(10)$

The shifts of λ_γ, obtained from YFSWW3 and RacoonWW

Fitting procedure		Fitted data			
Fitting function	Accept.	Y: Best—ISR	R: Best—ISR	Best: R—Y	Accept.
1. KorWan	BARE	$0.0114\,(6)$	—	—	CALO5
2. KorWan	BARE	$0.0115\,(6)$	—	—	CALO25
3. MPF: Y-ISR	CALO5	$0.0112\,(7)$	$0.0097\,(8)$	$0.0008\,(9)$	CALO5
4. MPF: Y-ISR	CALO5	$0.0115\,(7)$	$0.0161\,(8)$	$0.0008\,(9)$	CALO25
5. MPF: R-ISR	CALO5	$0.0112\,(7)$	$0.0097\,(8)$	$0.0008\,(9)$	CALO5
6. MPF: R-ISR	CALO5	$0.0115\,(7)$	$0.0161\,(8)$	$0.0008\,(10)$	CALO25
7. MPF: Y-Best	CALO5	$0.0113\,(7)$	$0.0098\,(8)$	$0.0008\,(10)$	CALO5
8. MPF: Y-Best	CALO5	$0.0116\,(7)$	$0.0162\,(8)$	$0.0008\,(9)$	CALO25
9. MPF: R-Best	CALO5	$0.0110\,(7)$	$0.0096\,(8)$	$0.0007\,(9)$	CALO5
10. MPF: R-Best	CALO5	$0.0113\,(7)$	$0.0158\,(8)$	$0.0008\,(9)$	CALO25
11. MPF: KoralW	ALEPH	$0.0118\,(7)$	$0.0103\,(9)$	$0.0008\,(10)$	CALO5
12. MPF: KoralW	ALEPH	$0.0122\,(7)$	$0.0172\,(9)$	$0.0009\,(10)$	CALO25

MPF= Monte Carlo parametric fit.

A simple polynomial parametrization of the normalized angular distribution $D(\cos\theta_W, \lambda_\gamma) = \frac{1}{\sigma}\frac{d\sigma}{d\cos\theta_W}(\cos\theta_W, \lambda_\gamma)$ as a function of $\cos\theta_W$ and λ_γ, determined from running the MC for several values of λ_γ. Since the distribution D is normalized, the fitted values of λ_γ depend only on the shape.

Angular distribution in WW process and TU of TGC

From all numerical exercises and the accompanying discussion we come to the following conclusions:

- The non-leading EW corrections cause shifts of $\lambda = \lambda_\gamma = \lambda_Z$ at the level of 0.01–0.02, which is comparable to the combined experimental accuracy for this anomalous TGC at LEP2. Thus, these corrections need to be taken into account in the experimental analyses.
- The EW theoretical uncertainty in λ_γ of the MC tandem KoralW&YFSWW3 and of the MC program RacoonWW is estimated to be ~ 0.005 at LEP2 energies, which is $\sim 1/2$ of the expected combined experimental error.
- The above estimate is based on the comparisons between YFSWW3 and RacoonWW and the tests of various modes/options in both programs (cf. Tables 2 and 3). We used a safety factor of 2 to account for the $\sim 30\%$ sensitivity loss due to the single-distribution fit and for possible higher-order effects missing in both programs.

Single-W production with KoralW Monte Carlo

$\boxed{\text{Problem}}$

ISR alone inadequate for FS particles collinear to beams:

- too many photons with large transverse momenta
- too strong overall energy loss

it is fixed when ISR $\otimes$ FSR interference is added.

ISR $\otimes$ FSR interference $\equiv$ Electric Charge Screening effect

Solution implemented in

/afs/cern.ch/user/s/skrzypek/public/koralw-1.53.2-export.30aug.tgz

Paper still unpublished.

Example: $\mu^+\mu^- \to \mu^+\mu^-$ at 5 GeV

("Mhamha"© A. Blondel)

The complete soft one-photon emission distribution in YFS-scheme:

$$\tilde{S}_{abcd} = -\frac{\alpha}{4\pi}\left(\frac{p_a}{kp_a} - \frac{p_b}{kp_b} - \frac{p_c}{kp_c} + \frac{p_d}{kp_d}\right)^2$$

approximate ISR and FSR (no interference):

$$\tilde{S}_{ab} + \tilde{S}_{cd} = -\frac{\alpha}{4\pi}\left(\frac{p_a}{kp_a} - \frac{p_b}{kp_b}\right)^2 - \frac{\alpha}{4\pi}\left(\frac{p_c}{kp_c} - \frac{p_d}{kp_d}\right)^2$$

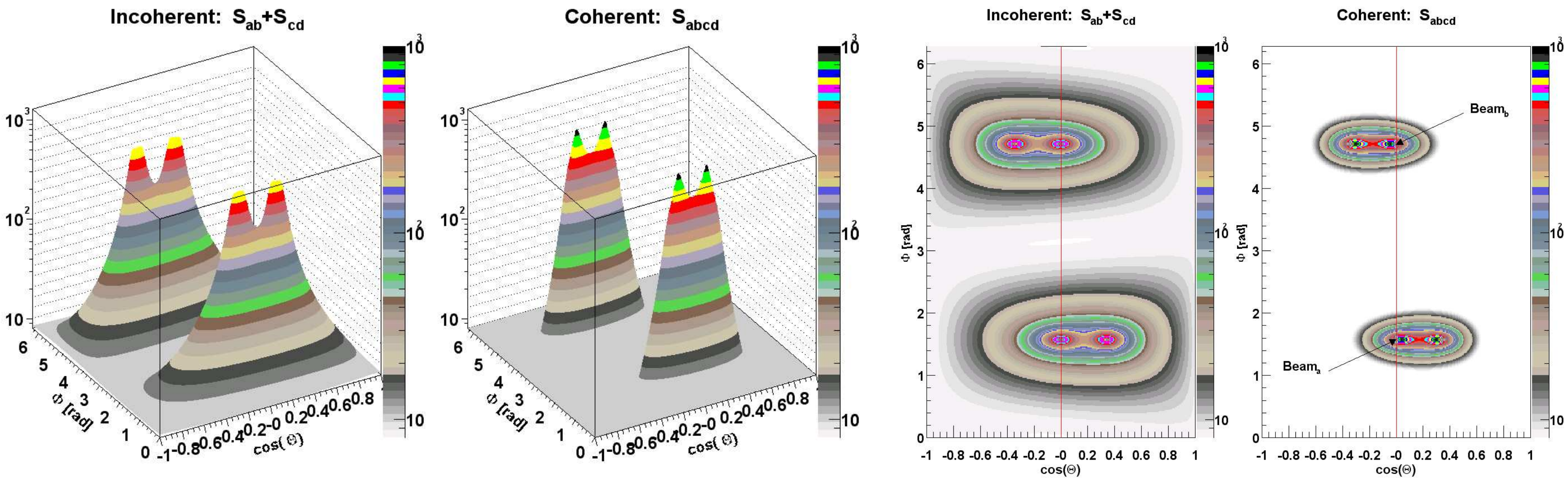
the difference $\equiv$ interference $\equiv$ ECS=Electric Charge Screening

Fig. 1: suppression of transverse photons

Complete $\tilde{S}_{abcd}$: KKMC, BHWIDE (ECS okay!)

Incomplete $\tilde{S}_{ab} + \tilde{S}_{cd}$: KoralW, KORALZ (ECS missing!)

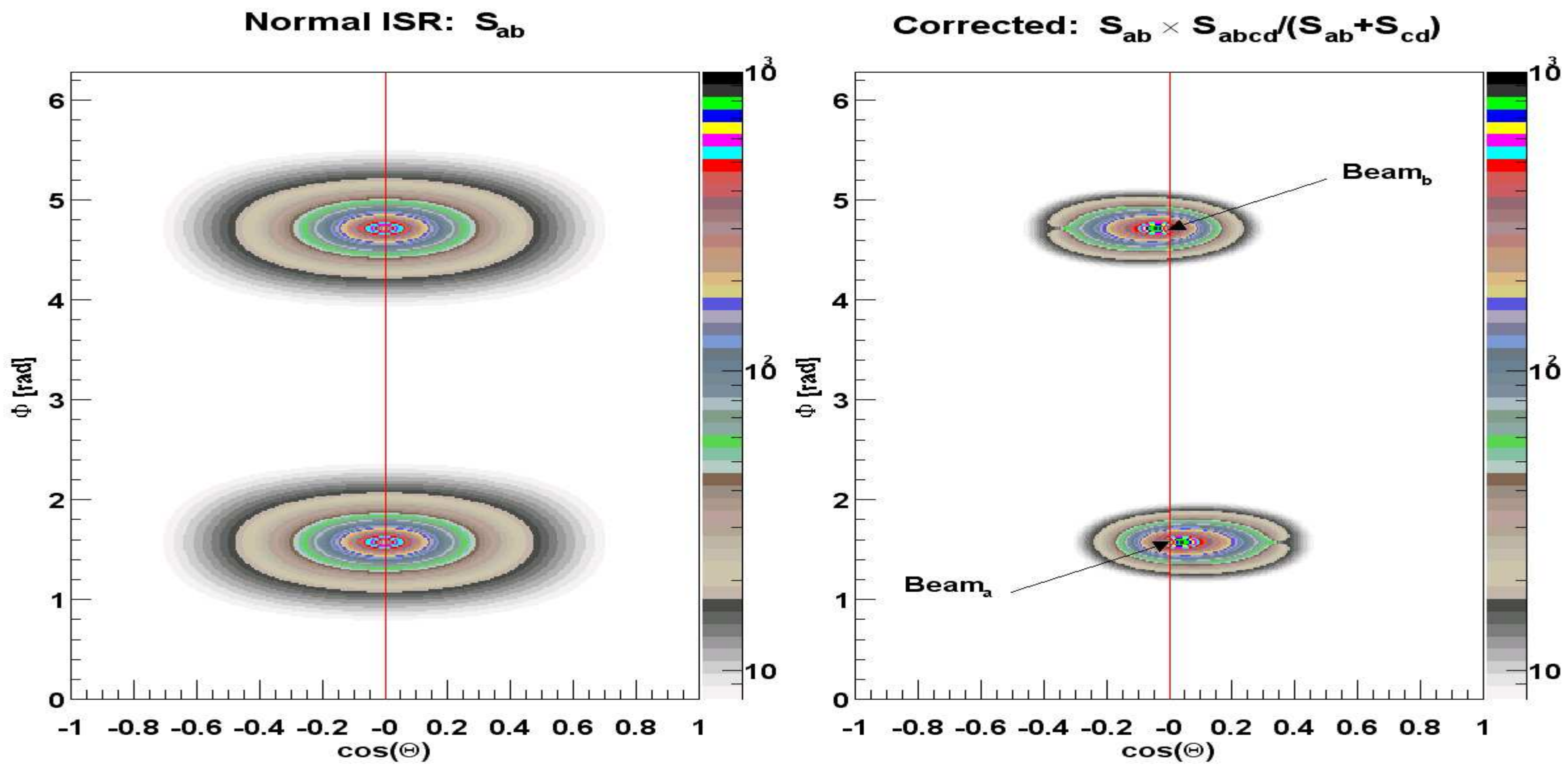
ECS in $\mu^+\mu^- \to \mu^+\mu^-$ at 5 GeV



Photon angular distribution on the sphere.

The difference between left and right hand side plots illustrates ECS effect.

ECS: correction-weight



Photon angular distribution on the sphere ISR (left) and ISR times the ECS correction-weight (right).

$$W_{\rm ECS} = \prod_{photons} \frac{\tilde{S}_{abcd}(k)}{\tilde{S}_{ab}(k) + \tilde{S}_{cd}(k)},$$

Single-W production with KoralW Monte Carlo

- Simple algorithm for introducing Electric Charge Screening effect due to ISR$\otimes$FSR interference into standard ISR-only bremsstrahlung in YFS scheme has been presented.
- The algorithm does not re-create FSR. FSR can be regarded as integrated out (calorimetric observables) or aded via PHOTOS or PYTHIA packages.
- The algorithm is done via re-weighting procedure without any modifications in the original Monte Carlo. The weights are well behaved and do not spoil Monte Carlo convergence.
- Running photon coupling constant (t-channel) is also introduced.
- The algorithm is implemented in KoralW Monte Carlo code version 1.53.2. KoralW 1.53.2 available from: /afs/cern.ch/user/s/skrzypek/public/koralw-1.53.2-export.30aug.tgz

Neutralino and chargino system parameters

S. Y. Choi, J. Kalinowski, G. Moortgat-Pick and P. M. Zerwas, “Analysis of the neutralino system in supersymmetric theories,” Eur. Phys. J. C **22**, 563 (2001)
arXiv:hep-ph/0108117

S. Y. Choi, J. Kalinowski, G. Moortgat-Pick and P. M. Zerwas,
“Analysis of the neutralino system in supersymmetric theories: Addendum,”
arXiv:hep-ph/0202039

J. Kalinowski and G. Moortgat-Pick,
“Complete reconstruction of the neutralino system,” in *Proc. of the APS/DPF/DPB Summer Study on the Future of Particle Physics (Snowmass 2001)* ed. R. Davidson and C. Quigg,
arXiv:hep-ph/0202083

J. Kalinowski and G. Moortgat-Pick,
“SUSY parameters from charginos,” in *Proc. of the APS/DPF/DPB Summer Study on the Future of Particle Physics (Snowmass 2001)* ed. R. Davidson and C. Quigg,
arXiv:hep-ph/0202084

Neutralino and chargino system parameters

Charginos $\tilde{\chi}^{\pm}$ and neutralinos $\tilde{\chi}^{0}$ in supersymmetric theories can be produced copiously at $e^{+}e^{-}$ colliders and their properties can be measured with high accuracy. Consecutively to the chargino system, in which the SU(2) gaugino parameter M_2, the higgsino mass parameter μ and $\tan\beta$ can be determined, the remaining fundamental supersymmetry parameter in the gaugino/higgsino sector of the minimal supersymmetric extension of the Standard Model, the U(1) gaugino mass M_1, can be analyzed in the neutralino system, including its modulus and its phase in CP-noninvariant theories. The CP properties of the neutralino system are characterized by unitarity quadrangles. Analytical solutions for the neutralino mass eigenvalues and for the mixing matrix are presented for CP-noninvariant theories in general. They can be written in compact form for large supersymmetric mass parameters. The closure of the neutralino and chargino systems can be studied by exploiting sum rules for the pair-production processes in $e^{+}e^{-}$ collisions. Thus the picture of the non-colored gaugino and higgsino complex in supersymmetric theories can comprehensively be reconstructed in these experiments.

Extension of KKMC to $\nu\bar{\nu}\gamma$ channel

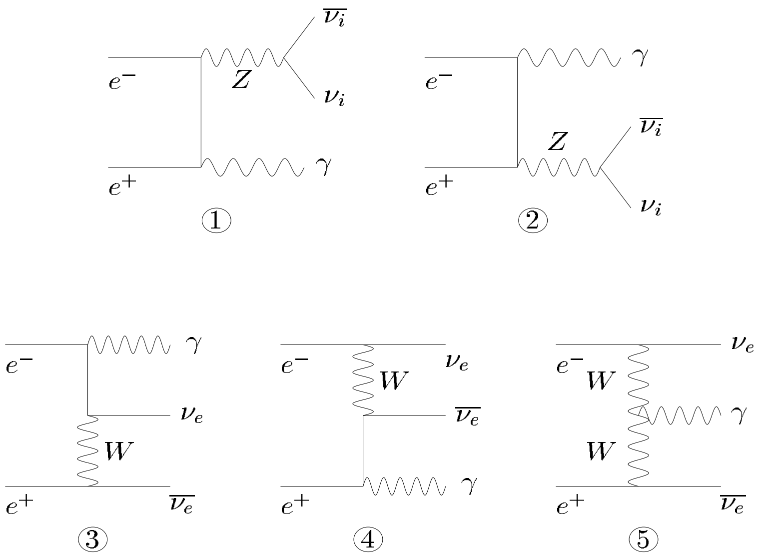
D. Bardin, S. Jadach, T. Riemann and Z. Was,

"Predictions for anti-nu nu gamma production at LEP,"

arXiv:hep-ph/0110371.

We study predictions for the reaction $e^+e^- \to \bar{\nu}\nu(n\gamma)$. The complete one-loop corrections are taken into account and higher order contributions, in particular those for the observed real photons, are added whenever necessary. The event generator $\mathcal{KK}$MC, a general-purpose Monte Carlo generator for the process $e^+e^- \to \bar{f}fn\gamma$ based on the method of exclusive exponentiation, is used as the environment. We extend its applicability to the process $e^+e^- \to \bar{\nu}_l\nu_l n\gamma, l = e, \mu, \tau$, where the observation of at least a single γ is required. The exponentiation is implemented in much the same way as for the s-channel process alone. In particular, all photonic effects present in the case of W exchange, which *cannot* be included in the s-channel exponentiation scheme, are calculated to a finite order only. The real hard photon matrix element is calculated up to $\mathcal{O}(\alpha^2)$. Leading logarithmic contributions of the two-loop corrections and one-loop photonic corrections accompanying real single photon emission are included. The electroweak corrections are calculated with the DIZET library of the ZFITTER package. Numerical tests and predictions for typical observables are presented.

Extension of KKMC to $\nu\bar{\nu}\gamma$ channel



We have extended the Monte Carlo program $\mathcal{KK}$ to the neutrino mode. The systematic error is estimated to be 1.3% for $\nu_e\bar{\nu}_e\gamma$ and 0.8% for $\nu_\mu\bar{\nu}_\mu\gamma$ and $\nu_\tau\bar{\nu}_\tau\gamma$. For observables with two observed photons we estimate the uncertainty to be about 5%.

These new improved results were obtained thanks to the inclusion of non-photonic electroweak corrections of the `ZFITTER` package and due to newly constructed, exact, single and double emission photon amplitudes in the $\mathcal{KK}$ MC for the contribution with the t-channel W exchange. The virtual corrections for the W exchange are at present introduced in the approximated form. The exponentiation scheme CEEX is the same as in the original $\mathcal{KK}$ MC program

Conclusions

- **Important effort in the polish node was devoted to WW physics in LEP2. TU in measurement of σ, M_W and TGC was imroved significantly. Certain works (1W) still unpublished.**
  It is to be stressed that these works are intensively used in the LEP2 data analysis.
- **In a series of papers chargino/neutralino parameters are analyzed.**
- **Precision calculations concerning $2f$ production at LEP2 are extended to $\nu\bar{\nu}$ channel (KKMC).**
- **Other works elaborate on various aspects of ELC and LHC physics.**