ZFITTER:
Fermion-pair production with realistic cuts at LEP

Tord Riemann – DESY Zeuthen

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In collaboration with
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References:
P. Christova, M. Jack, T. Riemann: PLB 456 (1999) 264

See also: P. Christova, M. Jack, S. Riemann, T. Riemann:
DESY 98-184 (hep-ph/9812412, $\to$ Proc. Radcor98, Barcelona)

A preliminary coding:
`v600.f`, consisting of `ZFITTER` v.5.20 plus a new code `acol.f`
see: http://www.ifh.de/∼riemann/Zfitter/zf.html

Note added Sep 1999: the following updates appeared:
DESY 99-037 (hep-ph/9) for QED with acollinearity cut
DESY 99-070 (hep-ph/9) for a new `ZFITTER` description
the new Fortran package: `ZFITTER` v.6.21

The ZFITTER concept

$$\sigma \sim \int \frac{ds'}{s} \; \sigma_0(s') \; \rho(s'/s)$$

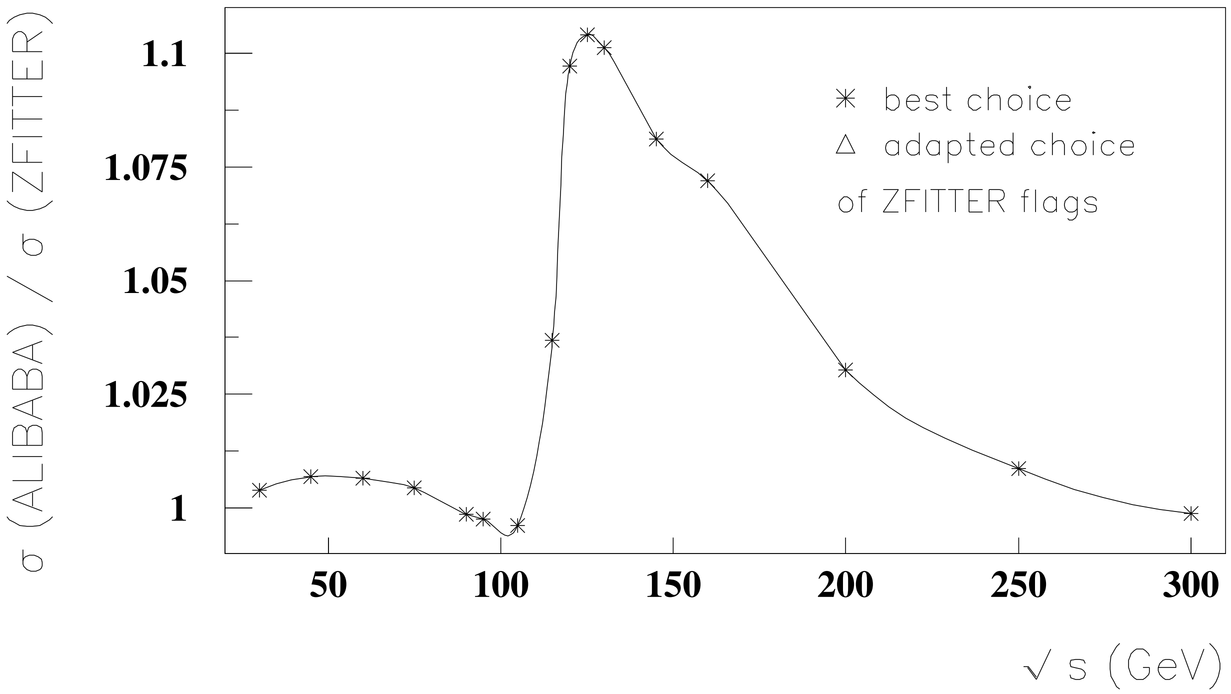
One-dimensional numeric integration for 3 treatments of photonic corr's.:

- no cut
- cut on s' and on $\cos\vartheta$
- cut on θ_{acol} and on E_{min} and on $\cos\vartheta$

Analytic effective Born $\sigma_0(s')$:

- Standard Model
- Model Independent
- others, e.g. with a heavy Z' (add code ZEFIT)

'Canonical' references for ZFITTER:
Bardin et al.:
CERN-TH. 6443/92 [hep-ph/9412201] – for ZFITTER v. 4.5
PLB 255 (1991) 290 – for QED corr's. without cut
NPB 351 (1991) 1 – for QED corr's. with cuts
ZfPC 44 (1989) 493 – for weak corr's.
http://www.ifh.de/theory/publist.html



S. Riemann, April 1992, unpublished:
Muon pair production cross section ratio with acollinearity cut – ALIBABA_1990 (v.1/2) vs. ZFITTER 4.5 (1992)

Cuts are independent of $\cos\vartheta$, but integrands (ISR and ini-fin int) depend on it.

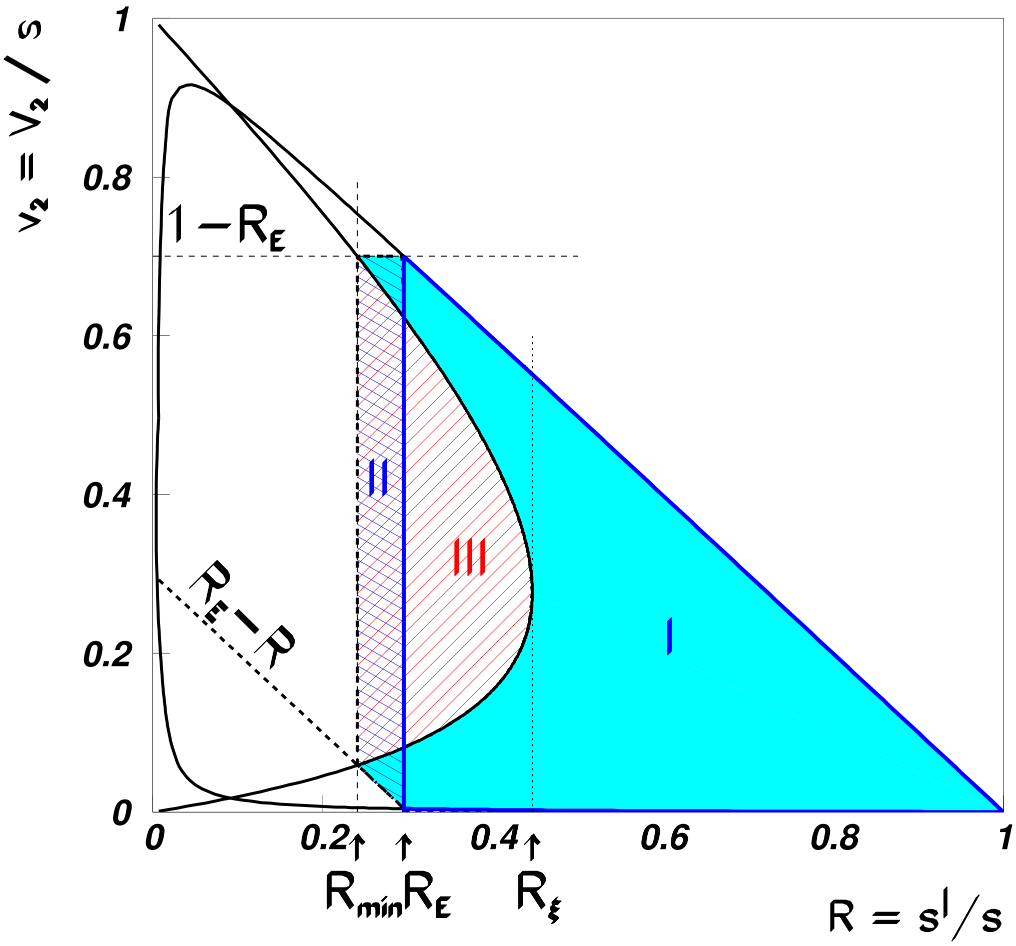


Figure 1: Phase space with acollinearity cut and (lower) muon energy cuts. See e.g.: G. Passarino, NPB 204 (1982)

Integral = I + (II - III) regions II and III contain only hard photons

help-d + phasexi_new.eps

The cross-section is a sum over three regions in phase space:

$$\sigma(s) = \left[\int_{\mathrm{I}} + \int_{\mathrm{II}} - \int_{\mathrm{III}}\right] ds' dx d\cos\vartheta \frac{d\sigma^0(A)}{ds' dx d\cos\vartheta}.$$

In the three regions, A (defines x bounds) differs:

$$\begin{aligned} A_{\mathrm{I}} &= 1, \\ A_{\mathrm{II}} &= (1+R-2R_E)/(1-R), \\ A_{\mathrm{III}} &= [1-R(1-R_\xi)^2/(R_\xi(1-R)^2)]^{1/2}, \end{aligned}$$

with

$$\begin{aligned} R_E &= 2E_{min}/\sqrt{s}, \\ R_\xi &= (1-\sin(\xi/2))/(1+\sin(\xi/2)). \end{aligned}$$

For each of the three regions, it is generically
e.g. for initial-state radiation:

$$\begin{aligned} \sigma_T(s,\xi,E_{min}) &= \frac{\alpha}{\pi} Q_e^2 \int dR\ \sigma_T^0(s')\ \rho_T(R, A(R)), \\ A_{FB}(s,\xi,E_{min}) &= \frac{\alpha}{\pi} Q_e^2 \int dR\ A_{FB}^0(s')\ \rho_{FB}(R, A(R)). \end{aligned}$$

$$\frac{4}{3}\rho_T(R,A) = \left(A + \frac{A^3}{3}\right)\frac{1+R^2}{1-R}\left(\ln\frac{s}{m_e^2} - 1\right) + (A - A^3)\frac{\mathcal{B}_T R}{1-R} \quad ,$$

with $\mathcal{B}_T = 2$.

$$
\begin{aligned}
\rho_{FB}(R; A \geq A_0) &= \frac{1+R^2}{1-R}\Big[\frac{4R}{(1+R)^2}\left(\ln\frac{s(1+R)^2}{4m_e^2 R} - 1\right) \\
&\quad - \frac{1}{(1+R)^2}\left[y_+ y_- \ln|y_+ y_-| + 4R\ln(4R)\right] \\
&\quad - (1-A^2)\left(\ln\frac{s}{4m_e^2(1+A)^2 R} - 1\right)\Big] \\
&\quad + \frac{4A(1-A)R}{1-R} + \mathcal{B}^{\geq}_{\mathcal{FB}} \quad , \\
\rho_{FB}(R; A < A_0) &= \frac{1+R^2}{1-R}\left[-\frac{y_+ y_-}{(1+R)^2}\ln\left|\frac{y_+}{y_-}\right| + (1-A^2)\ln\frac{1+A}{1-A}\right] \\
&\quad + \frac{8AR^2}{(1+R)(1-R)} + \mathcal{B}^{<}_{\mathcal{FB}} \quad .
\end{aligned}
$$

with $y_\pm = (1+R)\cdot(A_0 \pm A)$, $A_0(R) = \frac{1-R}{1+R}$,
and $\mathcal{B}^{<,\geq}_{\mathcal{FB}} = 0$.

For $A \to 1$, regions II and III do not contribute and $\rho_{T,FB}(R,A)$ approach the well-known result derived in Bonneau, Martin (1971) and Bardin et al. (1989). The coding in ZFITTER corresponds to

$$
\mathcal{B}_{\mathcal{T}} = 4/3, \qquad \mathcal{B}^{<}_{\mathcal{FB}} = \frac{(1-A)^2(1+R)^2}{(1-R)}, \qquad \mathcal{B}^{\geq}_{\mathcal{FB}} = \frac{4AR^2(1+R)}{(1-R)^2},
$$

if one looks there into the limit $c = 1$ (no acceptance cut).
The other hard flux functions: similarly compact.
With s' cut see: Bardin et al. PLB 228 (1989).

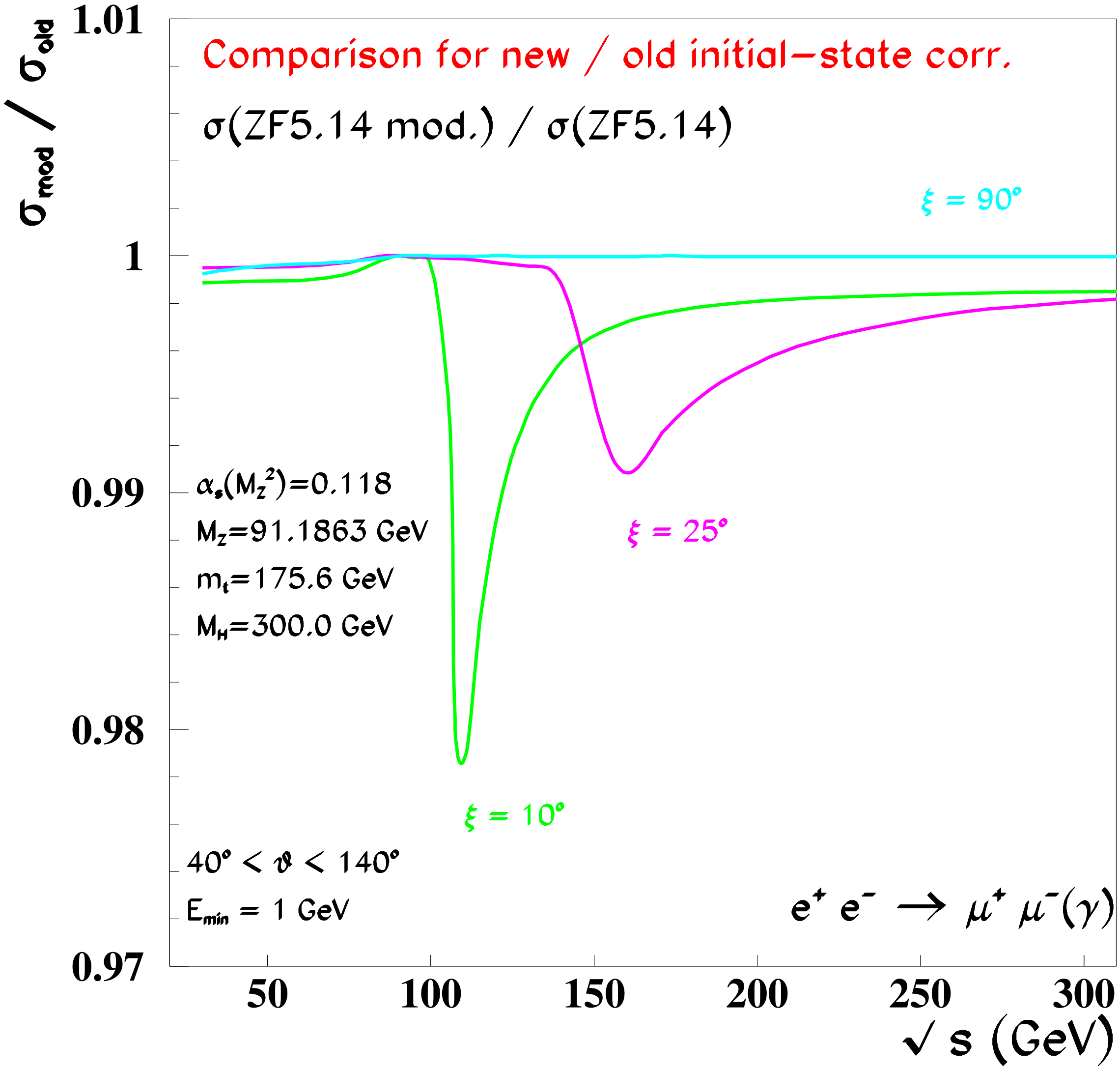


Figure 2: Numerical comparison of `ZFITTER` v.5.14 with and without new initial state corrections.

zf5_14_comp_ini

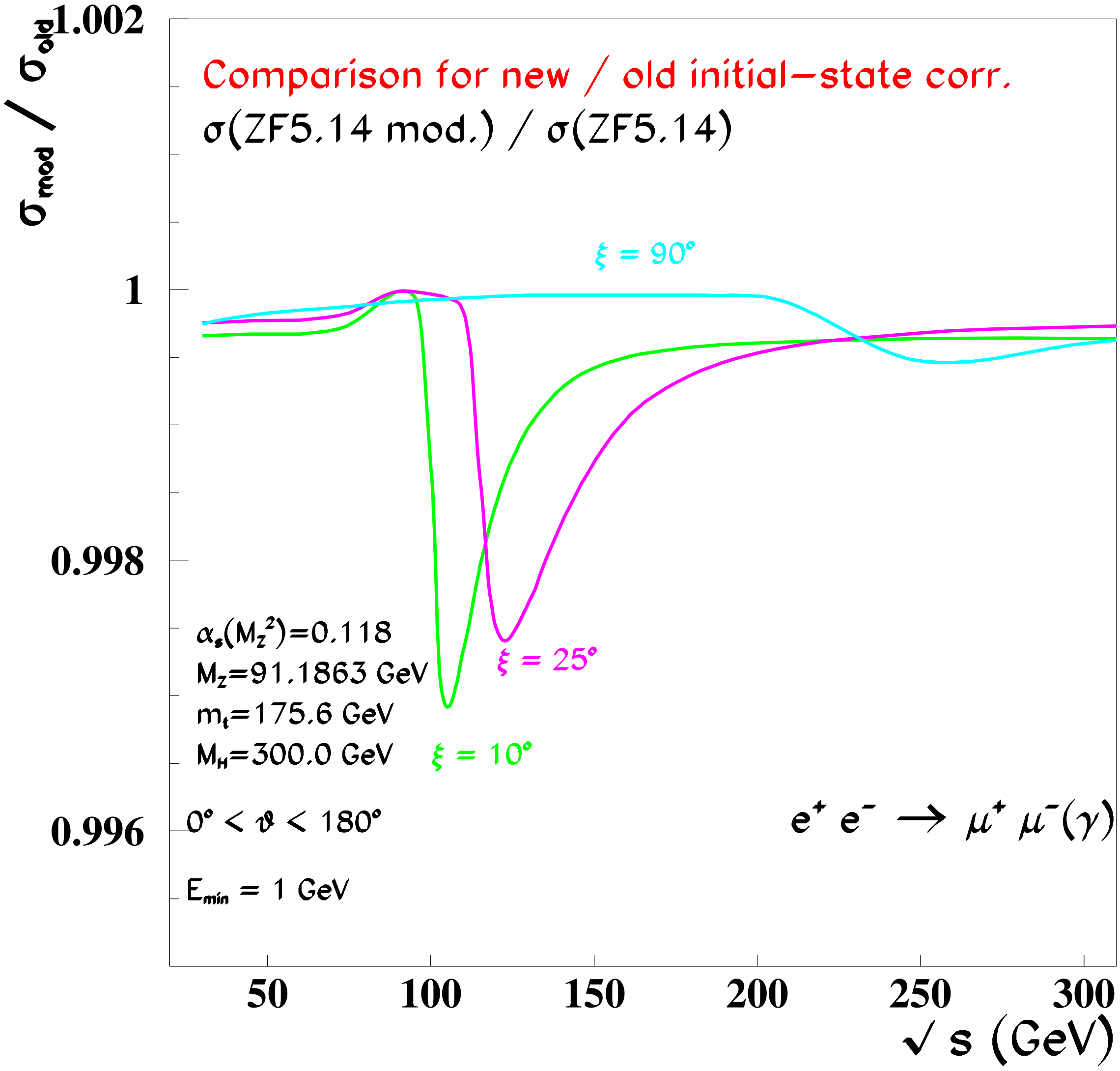


Figure 3: Numerical comparison of `ZFITTER` v.5.14 with and without new initial state corrections.

zf5_14_comp_ini_c0

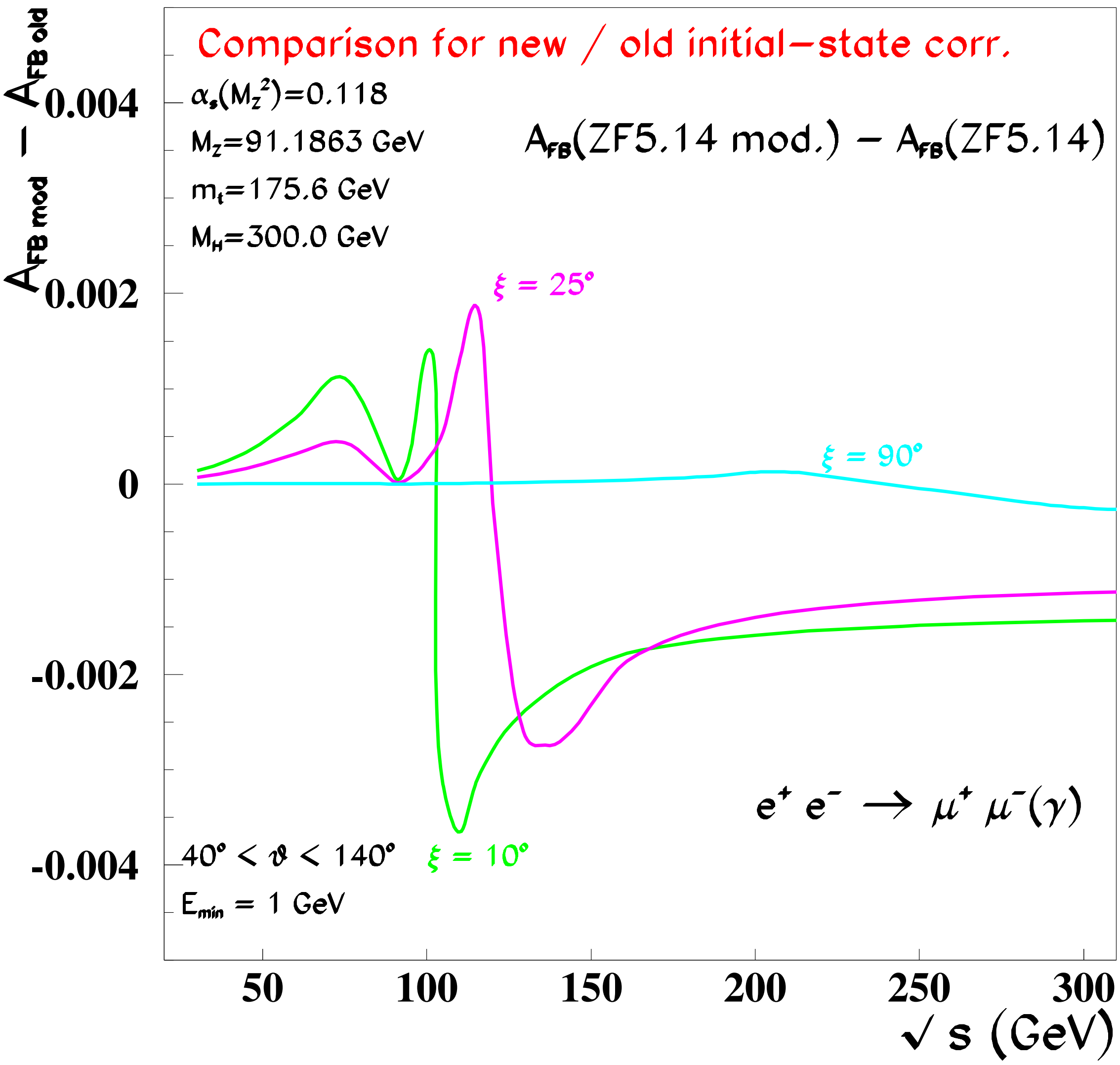


Figure 4: Numerical comparison of ZFITTER v.5.14 with and without new initial state corrections.

zf_afb_5_14_comp_ini

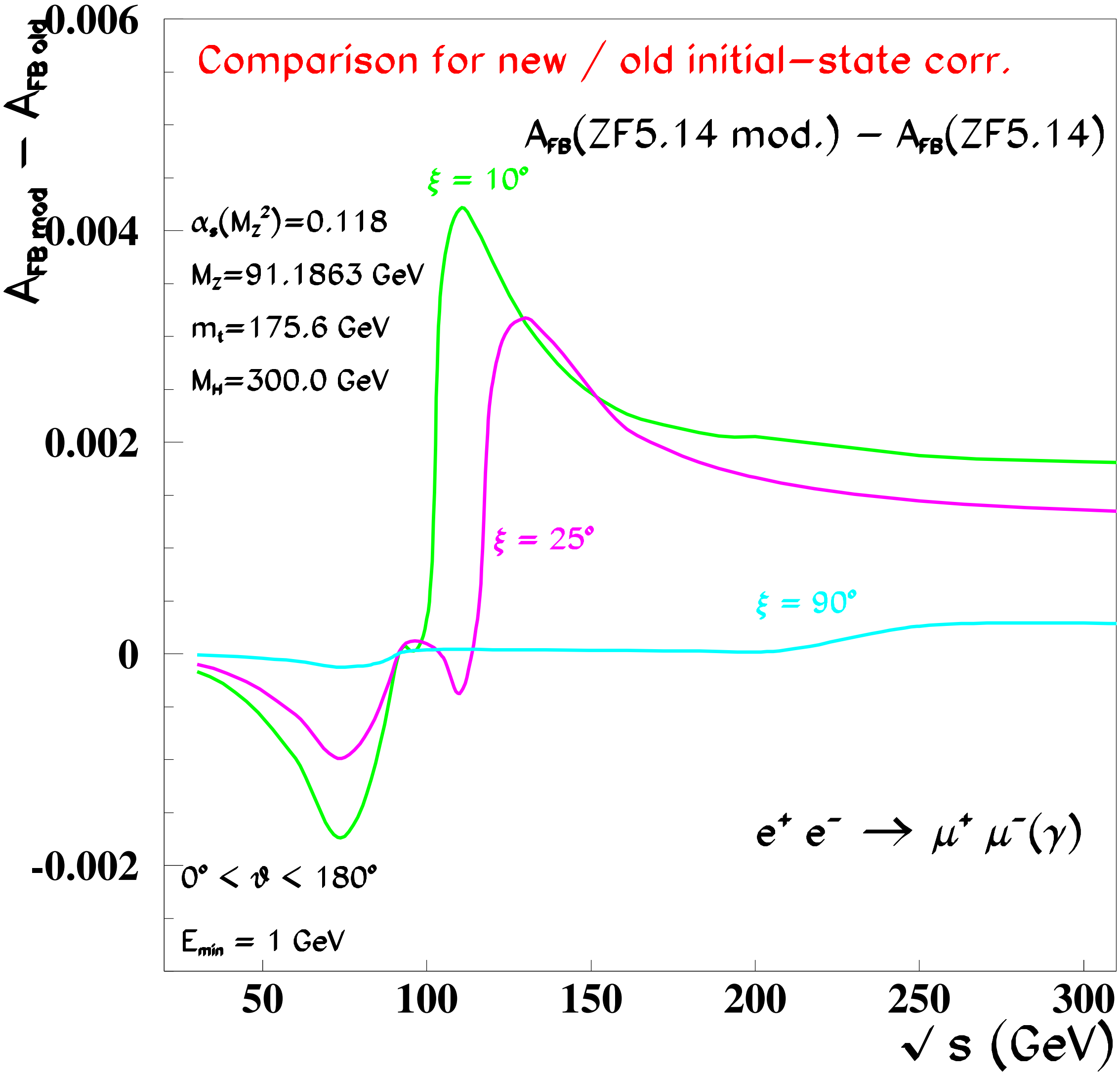


Figure 5: Numerical comparison of `ZFITTER` v.5.14 with and without new initial state corrections.

zf_afb_5_14_comp_ini_c0

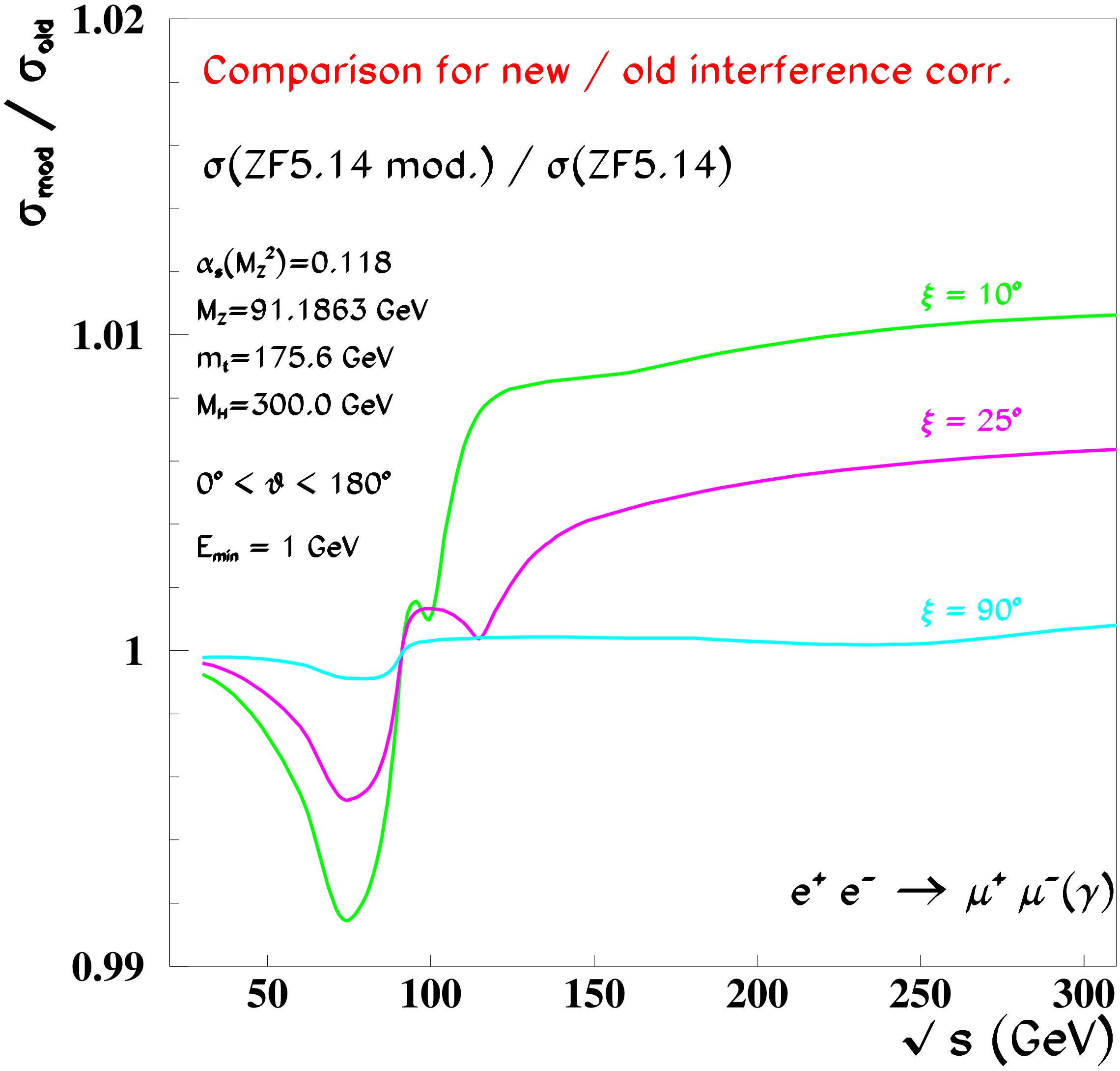


Figure 6: Numerical comparison of `ZFITTER` v.5.14 with and without new initial-final state interference.

zf5_14_comp_int

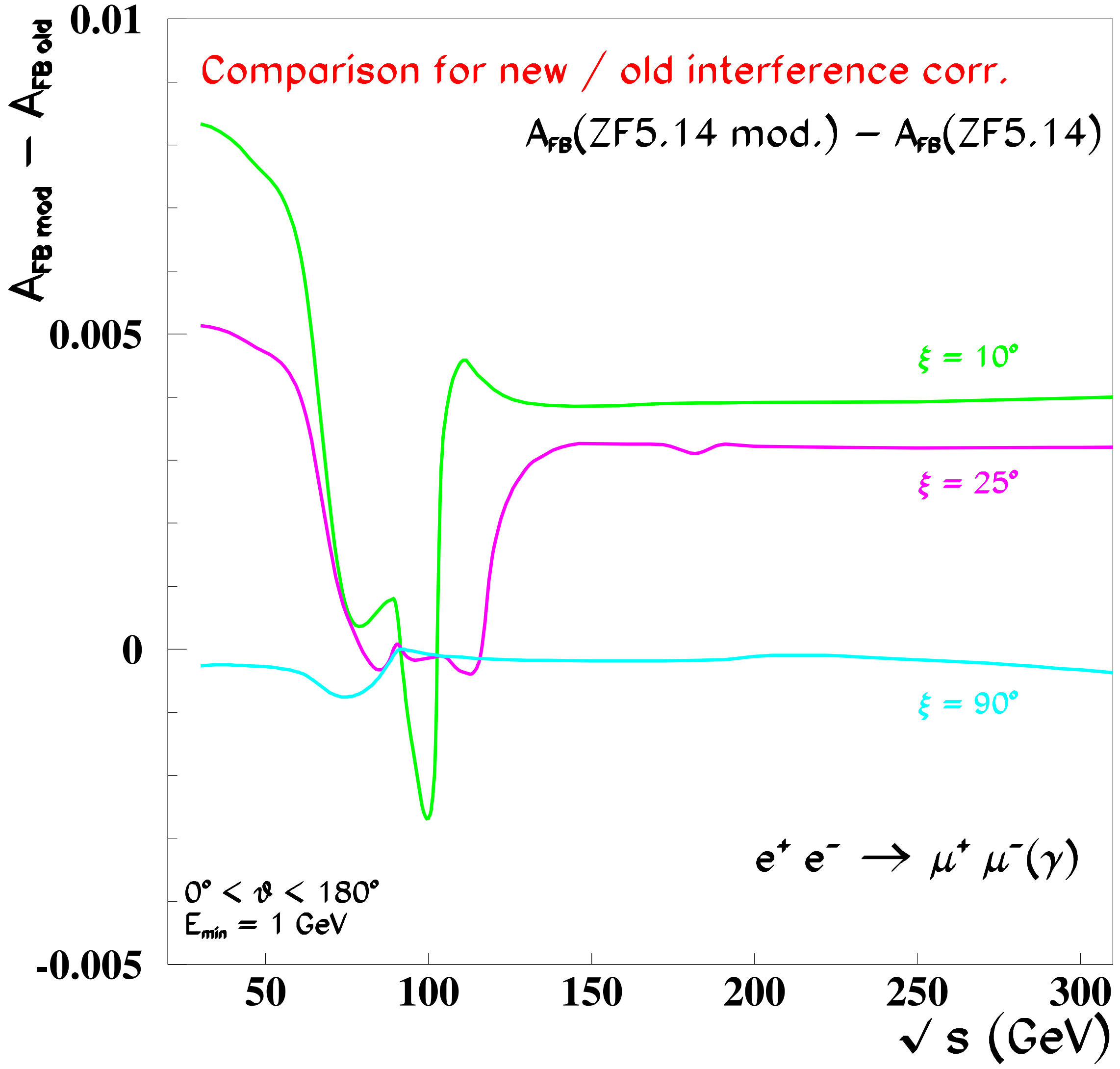


Figure 7: Numerical comparison of `ZFITTER` v.5.14 with and without new initial-final state interference.

zf_afb_5_14_comp_int

σ_μ [nb] with $\theta_{\rm acol} < 10^\circ$					
$\theta_{\rm acc}$	$M_Z - 3$	$M_Z - 1.8$	M_Z	$M_Z + 1.8$	$M_Z + 3$
0°	0.21932	0.46287	1.44795	0.67725	0.39366
TOPAZ0	0.21776	0.46083	1.44785	0.67894	0.39491
	-7.16	-4.43	-0.07	+2.49	+3.17
v.605	-7.16	-4.41	-0.02	+2.60	+3.27
0°	0.21928	0.46285	1.44781	0.67722	0.39361
ZFITTER	0.21852	0.46186	1.44782	0.67814	0.39429
v.520	-3.48	-2.14	+0.01	+1.36	+1.72
20°	0.19990	0.42207	1.32066	0.61759	0.35886
TOPAZ0	0.19873	0.42049	1.32027	0.61873	0.35973
	-5.89	-3.76	-0.30	+1.84	+2.42
v.605	-5.96	-3.80	-0.27	+1.97	+2.53
20°	0.19987	0.42205	1.32052	0.61756	0.35881
ZFITTER	0.19892	0.42075	1.32020	0.61857	0.35959
v.520	-4.78	-3.09	-0.24	+1.63	+2.17
40°	0.15034	0.31762	0.99428	0.46479	0.26989
TOPAZ0	0.14979	0.31680	0.99360	0.46514	0.27021
	-3.67	-2.59	-0.68	+0.75	+1.18
v.605	-3.88	-2.72	-0.67	+0.87	+1.32
40°	0.15031	0.31760	0.99413	0.46474	0.26982
ZFITTER	0.14978	0.31680	0.99348	0.46511	0.27016
v.520	-3.57	-2.53	-0.66	+0.80	+1.24

Table 1: `derived from Table 37 of PCP Report, D.Bardin et al., hep-ph/9902452:` `TOPAZ0`/`ZFITTER` comparison with angular acceptance cut ($\theta_{\rm acc} = 0^\circ, 20^\circ, 40^\circ$) and acollinearity cut ($\theta_{\rm acol} < 10^\circ$). First row: without IFI, second row: with IFI.
third row: relative effect of IFI in per mil IFI = ini-fin-interf.

table37PCP

A_{FB}^{μ} with $\theta_{acol} < 10^\circ$					
θ_{acc}	$M_Z - 3$	$M_Z - 1.8$	M_Z	$M_Z + 1.8$	$M_Z + 3$
T 0°	-0.28450	-0.16914	0.00033	0.11512	0.16107
	-0.28158	-0.16665	0.00088	0.11385	0.15936
	+2.92	+2.49	+0.55	-1.27	-1.71
v.605	+3.01	+2.40	+0.62	-1.04	-1.56
Z 0°	-0.28453	-0.16911	0.00025	0.11486	0.16071
	-0.28282	-0.16783	0.00070	0.11475	0.16059
	+1.70	+1.28	+0.45	-0.11	-0.12
T 20°	-0.27509	-0.16352	0.00042	0.11171	0.15645
	-0.27259	-0.16146	0.00084	0.11064	0.15499
	+2.50	+2.06	+0.42	-1.07	-1.46
v.605	+2.62	+2.02	+0.50	-0.89	-1.35
Z 20°	-0.27506	-0.16347	0.00035	0.11148	0.15616
	-0.27408	-0.16261	0.00070	0.11133	0.15594
	+0.97	+0.87	+0.35	-0.15	-0.21
T 40°	-0.24219	-0.14396	0.00054	0.09906	0.13903
	-0.24041	-0.14262	0.00078	0.09837	0.13809
	+1.78	+1.34	+0.24	-0.69	-0.94
v.605	+1.90	+1.34	+0.30	-0.57	-0.88
Z 40°	-0.24207	-0.14386	0.00050	0.09893	0.13891
	-0.24151	-0.14343	0.00069	0.09890	0.13888
	+0.55	+0.44	+0.19	-0.03	-0.03

Table 2: derived from Table 38 of PCP Report, D.Bardin et al., hep-ph/9902452: TOPAZ0/ZFITTER comparison with angular acceptance cut: ($\theta_{acc} = 0, 20, 40^\circ$) and acollinearity cut: ($\theta_{acol} < 10^\circ$). First row without IFI, second row with IFI. Third row: relative effect of IFI in per mil IFI = ini-fin-interf.

table38PCP