to: LEPEWWG, 31/10/1998

from: ZFITTER team [1]

ZFITTER Status Report

presented by D. Bardin, JINR, Dubna

[1] ZFITTER–team:
DB, P. Christova, M. Jack, L. Kalinovskaya, A. Olshevsky, S. Riemann and T. Riemann.

to: LEPEWWG, 31/10/1998

from: LT–team [2]

Last Touch Status Report

presented by D. Bardin, JINR, Dubna

[2] LT–team:
DB, WH, LK, GP...

After 1994 Workshop on "Precision Calculation for Z-Resonance"

ZFITTER v. 5.10, 06/03/98

- Four Loop QCD Corrections to Running $\overline{MS}$ quantities:
  - S. Larin, T. van Ritbergen and J. Vermaseren, 1997;
  - K. Chetyrkin, B. Kniehl and M. Steinhauser, 1997.
- Nonfactorizable QCD and EW Corrections $\mathcal{O}(\alpha\alpha_S)$:
  - A. Czarnecki, J. Kühn, 1996;
  - R. Harlander, T. Seidensticker and M. Steinhauser, 1997.
- Two Loop EW Next-to -Leading Corrections $\mathcal{O}\left(G_F m_t^2 M_Z^2\right)$
  - G. Degrassi, P. Gambino, A. Sirlin, A. Vicini, 1997/98;
  - G. Degrassi, the `FORTRAN` code `M2TCOR`, 02/1988.

Reported to LEPEWWG on 16/02/1998

ZFITTER v. 5.12, 16/06/98

- Leading Log α^3 QED Corrections to Radiator Function:
  - G. Montagna, O. Nicrosini and F. Piccinini, 1996.

ZFITTER v. 5.14, 27/10/98

- Three loop QED-corrections for $\Delta\alpha_{lept}(M_Z)$:
  - M. Steinhauser, 1998.
- Two Loop QED Corrections for μ-decay:
  - T. van Ritbergen and R. Stuart, 1998.
- Release for fit of $\Delta\alpha^{(5)}_{had}(M_Z)$.

Status for LEP1:

- `TOPAZ0` and `ZFITTER` after their recent update are being used for final analysis of LEP1 data. They were used for winter and summer conferences '98.

- These codes are permanently updated to accumulate all world experience in the field and ensure the precision of theoretical computations which meets the ultimate precision of combined LEP1 data.

- Level of agreement for PO's $\sim 1 \div 2 \times 10^{-4}$.
  Update of PO's is frozen.

- Present status of RO's will be given by Giampiero.

Status for LEP2:

- Both `TOPAZ0` and `ZFITTER` teams intend to update the codes futher on for LEP2 energies. This work was started at the time of LEP2 Workshop (1995) then interrupted and has to be renewed.

- Topics of particular interest:
  - interplay of 2 fermion and 4 fermion processes at LEP2 energies (*see talk by G. Passarino at RADCOR98 in Barcelona*);
  - top mass effects through electroweak vertices and boxes at LEP2 energies (*presented by L. Kalinovskaya within last DELPHI week on 28/10/98*);
  - critical revision of realistic observables at LEP2 energies (*PC, MJ, TR, in progress*);
  - critical revision of `ZFITTER` precision at LEP2 energies (*DB and LK, in progress*).

- Comparison with `TOPAZ0` is foreseen.

- **The description...**

Improved list of I/O parameters
the leptonic masses, PDG'98:

$$\begin{aligned} m_e &= 0.51099907 \text{ MeV} \\ m_\mu &= 105.658389 \text{ MeV} \\ m_\tau &= 1.77705 \text{ GeV} \end{aligned}$$

$$\alpha(M_Z) = \frac{\alpha(0)}{1 - \Delta\alpha^{(5)}(M_Z) - \Delta_{\rm top}(M_Z) - \Delta_{\rm tb}^{\alpha\alpha_S}(M_Z)}$$

$\Delta\alpha^{(5)}(M_Z) = \Delta\alpha_{\rm lept} + \Delta\alpha^{(5)}_{\rm had}$.
Codes include the recently computed $\mathcal{O}(\alpha^3)$ terms for $\Delta\alpha_{\rm lept}$ and

$$\Delta\alpha^{(5)}_{\rm had} = 0.0280398$$

This gives $1/\alpha^{(5)}(M_Z) = 128.877$,
to which one must add the top contribution and the $\mathcal{O}(\alpha\alpha_S)$ corrections induced by the $t-b$ doublet.
leptonic contribution $10^4 \times \Delta\alpha_{\rm lept}(M_Z)$

TOPAZ0	314.97644
ZFITTER	314.97637

t contribution $10^5 \times \Delta_{\rm top}(M_Z)$

m_t [GeV]	168.8	173.8	178.8
TOPAZ0	-6.22230	-5.85844	-5.52589
ZFITTER	-6.22230	-5.85844	-5.52589

1 Results for PO

For PO we use

$$M_{_Z} = 91.1865 \text{ GeV},$$
$$m_t = 171.1 \text{ GeV},$$
$$M_{_H} = 76 \text{ GeV}, \quad \alpha_{_S}(M_{_Z}) = 0.119,$$

Martin's proposal for adding

$$\sigma_{\rm l}^0 = \frac{\sigma_{\rm h}^0}{R_l} = 12\pi \frac{\Gamma_l^2}{M_{_Z}^2 \Gamma_{_Z}^2}$$

among PO.

$\alpha_{_S}(M_{_Z})/m_t\,[\text{GeV}]$	168.8	173.8	178.8
0.116	2.00161	2.00191	2.00221
0.119	1.99893	1.99923	1.99952
		1.99948	
0.122	1.99625	1.99655	1.99685

Table 1: `TOPAZ0` (first row) / `ZFITTER` (second row) results for $\sigma_{\rm l}^0$ [nb].

Old $G_{_F}$ is $G_{_F} = 1.16639 \times 10^{-5}\,\text{GeV}^{-2}$,
new $G_{_F}$ is $G_{_F} = 1.16637 \times 10^{-5}\,\text{GeV}^{-2}$.

The correct definition of heavy quark forward-backward asymmetries should include mass effect, e.g.

$$\mathcal{A}_b = \frac{2\, g_{_V}^b g_{_A}^b}{\frac{1}{2}\,(3-\beta^2)\,(g_{_V}^b)^2 + \beta^2\,(g_{_A}^b)^2}\,\beta,$$

where β is the b-quark velocity. For $A_{\rm FB}^b$ `TOPAZ0` finds

$$0.102925 \quad \text{for} \quad m_b \neq 0,$$
$$0.102908 \quad \text{for} \quad m_b = 0,$$

with a 0.00002 difference to be compared with an experimental error of 0.0021.

$\alpha_S(m_t)/m_t\,[\mathrm{GeV}]$	168.8	173.8	178.8
0.116	0.10631	0.10589	0.10548
0.119	0.10881	0.10837	0.10795
	0.10881	0.10837	0.10795
0.122	0.11130	0.11084	0.11040

Table 2: TOPAZ0 (first row) / ZFITTER (second row) results for $\alpha_s(m_t^2)$.

$\alpha_S(M_Z)/m_t\,[\mathrm{GeV}]$	168.8	173.8	178.8
0.116	-1.08440	-1.01593	-0.95371
		-1.01593	
0.119	-1.10994	-1.03976	-0.97599
	-1.10994	-1.03912	-0.97600
0.122	-1.13536	-1.06347	-0.99816
		-1.06347	

Table 3: TOPAZ0 (first row) / ZFITTER (second row) results for $10^5 \times \Delta_{\mathrm{tb}}^{\alpha\alpha_S}(M_z)$.

$1/\alpha^{(5)}$	128.878	128.877 128.877	128.877 128.877	
M_Z[GeV](Input)	91.1865	91.1865		
m_t[GeV](Input)	171.1	171.1		
M_H[GeV](Input)	76.0	76.0		
Γ_Z [GeV]	2.4958	2.49564 2.49543	2.49559 2.49538	0.05 MeV
$\sigma^0_{\rm h}$ [nb]	41.473	41.4759 41.4743	41.4759 41.4743	-
R_l	20.748	20.7453 20.7468	20.7452 20.7467	0.0001
$A^{0,{\rm l}}_{\rm FB}$	0.01613	0.0161686 0.0161905	0.0161588 0.0161807	0.00001
$\mathcal{A}_e$	0.1467	0.146827 0.146926	0.146782 0.146882	0.0004
$\sin^2\theta^{\rm lept}_{\rm eff}$	0.23157	0.231547 0.231539	0.231552 0.231544	-0.00001
M_W [GeV]	80.37	80.3724 80.3722	80.3721 80.3718	0.4 MeV
R_b	0.2159	0.215897 0.215914	0.215898 0.215915	-
R_c	0.1722	0.172224 0.172222	0.172223 0.172222	-
$A^{0,b}_{\rm FB}$	0.1028	0.102927 0.102956	0.102895 0.102908	0.00005
$A^{0,c}_{\rm FB}$	0.0734	0.0735365 0.0736112	0.0735121 0.0735623	0.00005
$\mathcal{A}_b$	0.935	0.934678 0.934725	0.934674 0.934721	-
$\mathcal{A}_c$	0.668	0.667784 0.667788	0.667765 0.667768	0.00002

Table 4: *Table of PO, first entry is* ZFITTER*, second is* TOPAZ0*.*

Observable	TOPAZ0	ZFITTER	$\frac{T-Z}{T}10^3$
$1/\alpha^{(5)}(M_Z)$	128.877	128.877	
$1/\alpha(M_Z)$	128.887	128.887	
M_W [GeV]	80.3718	80.3721	
		80.3887	
$\sigma^0_{\rm h}$ [nb]	41.4743	41.4759	
	41.4758	41.4775	
Γ_ν [MeV]	167.177	167.202	
	167.217	167.243	-0.16
Γ_e [MeV]	83.971	83.982	
	83.995	84.007	-0.14
Γ_μ [MeV]	83.970	83.981	
	83.994	84.006	-0.14
Γ_τ [MeV]	83.781	83.792	
	83.805	83.817	-0.14
Γ_u [MeV]	300.092	300.113	
	300.220	300.242	-0.07
Γ_d [MeV]	382.929	382.959	
	383.050	383.082	-0.08
Γ_c [MeV]	300.032	300.051	
	300.159	300.180	-0.07
Γ_b [MeV]	376.149	376.142	
	376.079	376.067	0.03
$\Gamma_{\rm had}$ [GeV]	1.74212	1.74222	
	1.74255	1.74265	-0.06
$\Gamma_{\rm inv}$ [GeV]	0.50153	0.50161	
	0.50165	0.50173	-0.16
Γ_Z [GeV]	2.49538	2.49559	
	2.49599	2.49621	-0.09

Table 5: *Complete table of PO, from* TOPAZ0 *and* ZFITTER. *First row* $m_t = 171.1$ *GeV, second row* $m_t = 173.8$ *GeV.*

Observable	TOPAZ0	ZFITTER	$\frac{T-Z}{T}10^3$
R_l	20.7467	20.7452	
	20.7458	20.7442	0.08
R_b^0	0.215915	0.215898	
	0.215821	0.215802	0.09
R_c^0	0.172222	0.172223	
	0.172253	0.172255	-0.01
$\sin^2\theta_{\rm eff}^{\rm lept}$	0.231544	0.231552	
	0.231460	0.231468	-0.03
$\sin^2\theta_{\rm eff}^{b}$	0.232760	0.232845!	
	0.232726	0.232821	-0.41
$\sin^2\theta_{\rm eff}^{c}$	0.231440	0.231446	
	0.231355	0.231362	-0.03
$A_{\rm FB}^{0,{\rm l}}$	0.016181	0.016159	
	0.016328	0.016305	0.02
$A_{\rm FB}^{0,b}$	0.102908	0.102895	
	0.103389	0.103362	0.03
$A_{\rm FB}^{0,c}$	0.073562	0.073512	
	0.073929	0.073876	0.05
$\mathcal{A}_e$	0.146882	0.146782	
	0.147549	0.147445	0.10
$\mathcal{A}_b$	0.934721	0.934674	
	0.934743	0.934690	0.05
$\mathcal{A}_c$	0.667768	0.667765	
	0.668061	0.668056	0.005
ρ_e	1.00496	1.00510	
	1.00520	1.00535	-0.15
ρ_b	0.99437	0.99448	
	0.99418	0.99428	-0.10
ρ_c	1.00565	1.00579	
	1.00589	1.00604	-0.15

Table 6: *Complete table of PO, from* TOPAZ0 *and* ZFITTER.
First row $m_t = 171.1$ *GeV, second row* $m_t = 173.8$ *GeV.*