Summary on Error Analysis for the Second R Scan Measurement

Huang Guangshun

November 22, 2000

R is determined by the relation

$$R = \frac{N_{had}}{\sigma^0_{\mu\mu} \cdot \varepsilon_{had} \cdot \varepsilon_{trg} \cdot (1+\delta) \cdot L} \tag{1}$$

where N_{had} is the number of hadronic events, L is the integrated luminosity, $(1+\delta)$ is the correction for initial state radiation, ε_{had} and ϵ_{trg} represent the detection and trigger efficiency for the hadronic events, and $\sigma^0_{\mu\mu}$ is the $\mu\mu$ production cross section calculated by QED theory.

The systematic uncertainty of R is given by the following formula,

$$\begin{aligned}
(\frac{\Delta R}{R})_{sys.} &= \{(\frac{\Delta R}{R})^2_{had} && (2)\\
&+ [\frac{\Delta L}{L}]^2_{sys.} && (3)\\
&+ [\frac{\Delta(1+\delta)}{(1+\delta)}]^2 && (4)\\
&+ [\frac{\Delta\varepsilon_{had}}{\varepsilon_{had}}]^2 && (5)\\
&+ [\frac{\Delta\varepsilon_{trg}}{\varepsilon_{trg}}]^2\ \}^{1/2} && (6)
\end{aligned}$$

in which Eq. 2 represents the contribution from hadronic events selection, Eq. 3 luminosity, Eq. 4 initial state radiation correction, Eq. 5 hadron detection efficiency, Eq. 6 trigger efficiency.

The statistical uncertainty of R comes directly from number of observed events, mainly includes hadrons and Bhabhas which are used to determine the integrated luminosity.

$$\begin{aligned}
(\frac{\Delta R}{R})_{stat} &= \{[\frac{\Delta N_{had}}{N_{had}}]^2 && (7)\\
&+ [\frac{\Delta L}{L}]^2_{stat}\}^{1/2} && (8)
\end{aligned}$$

in which Eq. 7 represents the contribution from hadron events number, and Eq. 8 luminosity.

The similar analysis described above was done in the first R scan [1]. The work becomes a little simpler since event vertex fitting method is used so that the number of hadrons without beam-associated background N_{had} can be obtained directly.

In this analysis, we also try to divide the errors into common and point-to-point (p2p) contributions.

1 Hadron event selection

The uncertainty of hadron event selection comes from cuts used. In order to avoid correlation, every time a cut is changed, the selection program is applied to R-scan data and M.C. data, and the corresponding R value is obtained. In this way, the systematic uncertainty contribution of hadron event selection can be written as a single item $(\frac{\Delta R}{R})_{sel}$, which also includes selection relative part in Eq. 5. The relative changes of R due to variations of cuts are worked out by Derrick, and the largest contributions are tracking quality cut and geometry acceptance cut. The total error of selection is in the range of $3\% - 5\%$ for most points.

The errors come from selection are similar to all points, so most of them are in common. It is, however, very difficult to tell the amount of common and p2p. As a simple assumption, we assign 1% to p2p.

2 Luminosity

The systematic error of the luminosity arises from the selection of the cuts, the efficiency determination, the possible background contribution and the uncertainty in calculation of the cross section. The statistical error of the luminosity comes from Bhabha events number.

The geometry acceptance cut and deposited energy cut for large angle Bhabha events are selected point by point, so their contributions are regarded as p2p. While all other cuts are similar for all points, and the overall contributions are about 1.2%.

3 Radiation correction

The error sources of initial state radiative correction (ISR) are: 1. theory, 2. efficiencies and the fitting, 3. resonant parameters.

We have compared 4 schemes of ISR, and they are consistent within 1% in theory. In the calculation of ISR, efficiencies with different radiative factor k must be obtained at first. The uncertainties in the efficiencies and the error of fitting contribute to systematic error. ISR also relies on resonant parameters, we use different inputs and compare the difference of ISR factor.

Source 1 and 2 contribute common error, while source 3 has no effect in the continuum region but contributes p2p error for points in resonant region.

4 Detection efficiency

Below 3.0 GeV, we use Lund_arlw generator which is developed by R group and LUND group. Above 3.7 GeV, both Lund_charm and Lund_arlw generators are used. The final efficiency is calculated by a fitted formula.

The error sources are: 1. difference by parameters within one generator: $\sim 2\%$ for both Jetset and AreaLaw; 2. difference between generators: less than 1% at most points (we use the difference between efficiency by AreaLaw and the fitted value by Jetset to estimate the error); 3. fitting error: $0.3\% \sim 0.4\%$ for most points; and 4. hadron selection: has been taken into account already.

The error of detection efficiency is within the range of $2\% \sim 3\%$ for most points. Source 1 and 3 contribute common error, and source 2 is p2p.

5 Trigger efficiency

The trigger condition is very loose, so the trigger efficiency is very near to 100%, and the uncertainty is belived to be less than 0.5%. It is also in common.

6 Summary

We summarize the error sources in the following table, and also give a simple average of each item.

Ecm	Sel.	Lsys	ISR	Eff.	Trg.	Sys.	Hsta	Lsta	Stat	Tot.	comm	p2p
2.000	7.07	2.81	1.06	2.62	.5	8.13	2.94	1.16	3.16	8.72	7.58	4.30
2.200	5.54	2.19	1.29	3.49	.5	7.04	2.63	1.17	2.88	7.61	6.18	3.91
2.400	4.80	1.75	1.01	2.41	.5	5.76	2.71	1.19	2.96	6.47	5.44	3.51
2.500	5.19	2.47	1.30	2.32	.5	6.35	3.16	1.46	3.48	7.24	5.83	4.31
2.600	4.43	2.47	1.26	3.83	.5	6.50	2.40	1.26	2.71	7.04	5.15	4.02
2.700	3.70	2.51	1.23	2.93	.5	5.51	2.76	1.69	3.24	6.39	4.52	4.29
2.800	4.16	1.75	1.23	4.33	.5	6.39	2.61	1.14	2.85	7.00	4.89	3.81
2.900	4.26	1.75	1.29	3.43	.5	5.91	2.57	1.56	3.01	6.63	4.99	3.79
3.000	3.30	2.30	1.32	2.66	.5	5.02	2.21	1.15	2.49	5.61	4.20	3.56
3.700	2.32	1.76	1.08	2.04	.5	3.75	2.98	2.09	3.64	5.23	3.37	4.01
3.730	4.49	2.50	1.10	4.09	.5	6.68	3.29	1.82	3.76	7.66	5.12	4.85
3.750	3.49	1.82	1.04	2.57	.5	4.84	3.27	1.82	3.74	6.12	4.25	4.30
3.760	3.61	1.78	1.02	2.10	.5	4.68	3.32	1.84	3.79	6.02	4.34	4.21
3.764	6.47	3.38	1.03	4.73	.5	8.77	6.83	4.72	8.30	12.08	6.91	9.18
3.768	5.45	2.68	1.01	2.17	.5	6.55	6.78	5.36	8.64	10.84	5.96	9.07
3.770	3.23	2.54	1.04	3.39	.5	5.45	3.28	2.38	4.05	6.79	4.03	5.02
3.772	6.55	2.55	1.08	2.33	.5	7.50	6.32	4.35	7.67	10.73	6.98	8.13
3.776	3.95	2.57	1.16	3.24	.5	5.86	6.97	4.03	8.05	9.96	4.63	8.59
3.780	2.54	1.52	1.13	2.03	.5	3.80	3.09	2.04	3.71	5.31	3.50	4.01
3.790	2.36	1.72	1.07	2.07	.5	3.77	3.40	2.33	4.12	5.58	3.38	4.47
3.810	3.03	2.53	1.01	2.82	.5	4.98	3.56	2.07	4.12	6.46	3.87	4.99
3.850	3.22	2.52	1.02	3.20	.5	5.32	3.98	2.06	4.48	6.95	4.02	5.34

3.890	3.04	1.64	1.00	4.52	.5	5.80	3.81	2.04	4.32	7.23	3.87	4.99
3.930	3.38	1.78	1.07	3.76	.5	5.49	3.81	2.38	4.49	7.09	4.15	5.11
3.940	4.72	2.32	1.10	3.64	.5	6.51	3.85	2.43	4.55	7.94	5.30	5.37
3.950	3.78	2.51	1.16	3.44	.5	5.83	3.77	2.12	4.32	7.26	4.48	5.26
3.960	4.69	1.79	1.26	3.49	.5	6.26	3.92	2.08	4.44	7.68	5.27	5.09
3.970	2.52	1.56	1.36	2.06	.5	3.89	3.36	2.16	3.99	5.57	3.49	4.37
3.980	3.66	2.36	1.53	2.45	.5	5.25	3.93	2.24	4.53	6.93	4.38	5.32
3.990	4.35	2.32	1.69	2.44	.5	5.77	4.01	2.98	5.00	7.64	4.97	5.75
4.000	2.64	2.43	1.82	2.25	.5	4.64	3.61	2.59	4.44	6.42	3.57	5.33
4.010	3.97	2.59	1.99	2.12	.5	5.58	3.74	2.61	4.56	7.21	4.65	5.53
4.020	3.52	1.64	1.96	2.04	.5	4.83	3.07	2.01	3.67	6.07	4.27	4.33
4.027	3.00	1.85	1.77	2.32	.5	4.60	3.25	2.37	4.02	6.11	3.85	4.73
4.030	3.51	2.51	1.70	2.03	.5	5.09	3.60	2.62	4.45	6.76	4.26	5.25
4.033	3.52	1.83	1.62	2.62	.5	5.05	3.27	2.27	3.98	6.43	4.27	4.69
4.040	2.49	2.37	1.44	2.10	.5	4.31	3.13	2.11	3.77	5.72	3.47	4.58
4.050	3.90	2.51	1.22	2.22	.5	5.31	3.09	2.69	4.10	6.71	4.59	4.90
4.060	2.80	1.87	1.14	2.05	.5	4.13	3.30	2.35	4.05	5.79	3.70	4.47
4.070	3.25	2.37	1.16	2.08	.5	4.70	3.83	2.76	4.72	6.66	4.06	5.30
4.080	2.48	2.41	1.12	2.23	.5	4.29	4.15	2.77	4.99	6.58	3.46	5.60
4.090	2.89	2.58	1.08	2.04	.5	4.54	3.19	2.54	4.08	6.10	3.77	4.82
4.100	3.06	2.34	1.01	2.08	.5	4.52	3.38	2.22	4.05	6.07	3.90	4.68
4.110	2.98	2.49	1.01	2.79	.5	4.91	3.37	2.36	4.12	6.41	3.83	4.96
4.120	4.18	2.59	1.09	2.25	.5	5.54	4.71	3.38	5.80	8.02	4.83	6.40
4.130	2.37	2.38	1.15	2.12	.5	4.17	2.95	2.40	3.80	5.64	3.38	4.54
4.140	3.10	2.54	1.16	2.05	.5	4.67	3.36	2.17	4.00	6.15	3.93	4.76
4.150	3.20	2.36	1.09	2.06	.5	4.64	3.07	2.82	4.17	6.23	4.01	4.80
4.160	2.04	2.38	1.02	2.10	.5	3.94	3.08	2.04	3.70	5.40	3.16	4.41
4.170	3.00	2.52	1.00	2.05	.5	4.56	3.08	2.02	3.68	5.86	3.85	4.45
4.180	2.58	2.39	1.00	2.38	.5	4.39	3.06	2.79	4.14	6.04	3.53	4.86
4.190	2.10	1.61	1.01	2.05	.5	3.53	2.90	1.98	3.51	4.98	3.20	3.85
4.200	2.32	2.38	1.01	2.06	.5	4.07	3.40	2.30	4.11	5.78	3.35	4.73
4.210	3.74	2.83	1.01	2.04	.5	5.24	4.17	2.49	4.86	7.14	4.45	5.58
4.220	4.25	2.42	1.01	2.10	.5	5.44	3.13	2.76	4.17	6.86	4.89	4.83
4.230	2.72	2.88	1.01	2.06	.5	4.61	3.28	2.34	4.03	6.12	3.64	4.94
4.240	3.11	2.52	1.01	2.20	.5	4.71	3.26	2.04	3.84	6.08	3.94	4.64
4.245	3.10	2.38	1.01	2.11	.5	4.58	3.25	1.98	3.81	5.96	3.93	4.50
4.250	3.39	2.38	1.01	2.14	.5	4.80	3.80	2.17	4.38	6.49	4.17	5.00
4.255	3.85	1.56	1.01	2.10	.5	4.79	3.10	1.94	3.65	6.02	4.55	3.98
4.260	3.29	2.41	1.01	2.08	.5	4.72	3.16	2.22	3.86	6.09	4.09	4.55
4.265	2.93	2.37	1.00	2.08	.5	4.45	3.33	2.74	4.31	6.19	3.80	4.92
4.270	3.69	2.37	1.00	2.04	.5	4.96	2.92	2.02	3.55	6.10	4.41	4.22
4.280	3.44	2.52	1.01	2.06	.5	4.87	3.28	2.11	3.90	6.24	4.21	4.63
4.300	2.62	1.62	1.00	2.05	.5	3.87	3.04	2.16	3.73	5.37	3.57	4.04
4.320	3.08	2.41	1.01	2.17	.5	4.61	3.20	2.60	4.12	6.18	3.92	4.80
4.340	4.53	2.16	1.02	2.29	.5	5.63	3.94	2.59	4.71	7.34	5.14	5.24
4.350	2.82	1.85	1.03	2.05	.5	4.11	3.29	2.15	3.93	5.68	3.72	4.29
4.360	4.08	2.31	1.04	2.12	.5	5.27	3.26	2.03	3.84	6.52	4.75	4.50
4.380	3.36	2.71	1.17	2.13	.5	4.98	3.20	2.79	4.25	6.55	4.15	5.09
4.390	3.11	2.34	1.27	2.10	.5	4.63	3.37	2.94	4.47	6.43	3.95	5.10
4.400	3.05	2.67	1.35	2.23	.5	4.85	3.27	2.29	3.99	6.28	3.90	4.93

4.410	4.12	2.38	1.35	2.07	.5	5.38	3.18	2.34	3.95	6.68	4.78	4.68
4.420	2.80	2.40	1.38	2.20	.5	4.54	3.14	2.22	3.84	5.95	3.71	4.67
4.430	3.62	2.38	1.34	2.14	.5	5.04	3.36	2.29	4.06	6.47	4.36	4.81
4.440	2.76	2.43	1.31	2.10	.5	4.46	3.29	2.87	4.37	6.24	3.68	5.06
4.450	2.84	2.32	1.25	2.09	.5	4.43	3.38	2.36	4.12	6.05	3.74	4.78
4.460	2.47	2.61	1.22	2.07	.5	4.35	3.40	3.06	4.57	6.31	3.47	5.29
4.480	3.60	2.34	1.16	2.31	.5	5.04	3.61	3.11	4.77	6.94	4.35	5.40
4.500	2.60	2.36	1.10	2.06	.5	4.25	3.32	2.18	3.97	5.82	3.57	4.59
4.520	3.55	1.83	1.07	2.31	.5	4.76	3.33	2.05	3.91	6.16	4.32	4.40
4.540	3.94	2.55	1.05	2.85	.5	5.61	3.39	2.92	4.47	7.18	4.64	5.30
4.560	2.40	2.75	1.04	2.36	.5	4.50	2.99	2.15	3.69	5.81	3.43	4.68
4.600	3.11	2.38	1.05	2.40	.5	4.74	2.81	1.84	3.36	5.81	3.97	4.21
4.800	3.58	1.74	1.02	3.05	.5	5.14	2.87	2.47	3.79	6.38	4.36	4.37
average	3.5	2.3	1.2	2.5	.5	5.1	3.5	2.3	4.2	6.6	4.3	4.9
Ecm	Sel.	Lsys	ISR	Eff.	Trg.	Sys.	Hsta	Lsta	Stat	Tot.	comm	p2p

References

[1] Huang Guangshun, Final Result and Uncertainty Estimation in the First R Scan Measurement