E213 Analysis of Z0 Decays

E213.1 Aim of the Experiment

This experiment is an introduction to modern analysis methods in high energy physics. Data collected from e^+e^- collisions with the OPAL detector at the LEP collider are analysed with a computer. The analysis strategy is optimized with the help of simulated events.

E213.2 Required Knowledge

- Elementary particles and their properties, symmetries and conservation laws, standard model, scattering reactions and their angular dependence, s- and t-channel reactions, Feynmandiagrams, unification of electromagnetic and weak interactions.
- Interaction of particles and matter, particle accelerators and detectors, (esp. the OPAL detector).
- Statistical analysis, χ^2 test, weighted mean, Breit-Wigner distribution.

E213.3 Procedure and analysis

- Part I: Graphical analysis of Z^0 decays.
  In the first part of the experiment you will get aquainted with the different decay channels of the Z^0-boson on an event-by-event basis. You are supposed to learn how to find characteristic properties which allow to distinguish between the various final states. To achieve this, the signatures of the various processes and the detector properties must be understood thouroughly.
- Part II: Statistical analysis of Z^0 decays.
  Using the knowledge achieved in the first part a large data sample is analysed. The resonance parameters of the Z^0 boson (cross section, mass, decay width) are measured in various decay channels. The Weinberg angle is measured from the forward backward asymmetry of the reaction $e^+e^- \rightarrow \mu^+\mu^-$. Lepton universality is to be verified and the number of light neutrino generations should be determined.
- The data samples for the second part were made using a preselection in data and Monte Carlo events. This has to be taken into account as a correction when determining the cross

sections. The correction factor is the ratio of the number of generated Monte Carlo events and the number of events in the corresponding n-tuple.

I.e.: for the τ Monte Carlo 100000 events were generated,
79214 events pass the preselection cuts.
correction factor: $100000/79214 = 1.262$

- There are 6 different data samples. The corresponding luminosities are listed in the table below. The data sample that you will use is chosen by the lab assistant.

E213.4 Literature

- Instructions: can be borrowed from the lab assistant
- D. Griffiths: *Elementary Particles*
- F.Halzen und A.D. Martin: *Quarks & Leptons*
- W.R. Leo: *Techniques for Nuclear and Particle Physics Experiments*
- R. Barlow: *Statistics*

Also any other text book which introduces to elementary particle physics. The instructions themselves are not sufficient for a proper introduction to particle physics.

E213.5 Assignments

- All problems from chapter 5.1 of the *instructions* should be solved.

E213.6 Appendix

- Experiment E213 counts three times and is done on two days. Appointments for the date are to be made with the lab assistant.
- The instructions should be borrowed from the lab assistant about 4 weeks before performing the experiment.
- The instructions also contain some sections on particle detectors and elementary particle physics which are necessary for the analysis. Furthermore the instructions contain some problems that are to be solved beforehand.

OPAL data n-tuple	energy (GeV)	$\mathcal{L}dt$ (nb^{-1})	**stat. error** (nb^{-1})	**sys. error** (nb^{-1})	**tot. error** (nb^{-1})
data 1	88.48021	675.8590	± 3.502185	± 4.524100	± 5.721257
	89.47158	543.6270	± 3.179205	± 3.637000	± 4.830643
	90.22720	419.7760	± 2.810879	± 2.810400	± 3.974844
	91.23223	3122.204	± 7.786547	± 20.91518	± 22.31760
	91.97109	639.8380	± 3.567344	± 4.287300	± 5.577354
	92.97091	479.2400	± 3.121618	± 3.216000	± 4.481870
	93.71841	766.8380	± 3.972102	± 5.142000	± 6.497519
data 2	88.47777	371.9800	± 2.594937	± 2.488100	± 3.595044
	89.46906	488.5300	± 3.009684	± 3.273000	± 4.446429
	90.22324	378.5461	± 2.670417	± 2.533900	± 3.681273
	91.23965	2072.793	± 6.334670	± 13.87960	± 15.25684
	91.96968	540.6800	± 3.274401	± 3.620000	± 4.881198
	92.97059	369.4000	± 2.737608	± 2.480000	± 3.693900
	93.71714	353.5000	± 2.695570	± 2.371000	± 3.589950
data 3	88.47630	403.1200	± 2.702073	± 2.700000	± 3.819843
	89.46658	545.0066	± 3.174455	± 3.650900	± 4.837999
	90.21986	542.7271	± 3.200826	± 3.637500	± 4.845275
	91.22910	2080.004	± 6.346789	± 13.92980	± 15.30755
	91.96428	493.6100	± 3.126548	± 3.302000	± 4.547362
	92.96229	340.7600	± 2.630304	± 2.284000	± 3.483555
	93.71362	622.4900	± 3.579958	± 4.180000	± 5.503499
data 4	88.47939	463.9790	± 2.902361	± 3.104100	± 4.249604
	89.46793	667.5236	± 3.521166	± 4.471900	± 5.691792
	90.22266	486.7641	± 3.033955	± 3.261500	± 4.454466
	91.22430	2246.568	± 6.603405	± 15.04780	± 16.43293
	91.96648	535.9080	± 3.265110	± 3.585300	± 4.849260
	92.96465	450.6000	± 3.027953	± 3.020000	± 4.276552
	93.71712	709.6980	± 3.819882	± 4.762000	± 6.104764
data 5	88.47939	463.9790	± 2.902361	± 3.104100	± 4.249604
	89.46957	472.6636	± 2.964559	± 3.161900	± 4.334307
	90.23120	510.2150	± 3.099458	± 3.414400	± 4.611373
	91.23193	3898.628	± 8.694719	± 26.11330	± 27.52277
	91.97322	518.6880	± 3.213012	± 3.475300	± 4.732985
	92.96836	624.5900	± 3.564113	± 4.190000	± 5.500818
	93.71712	709.6980	± 3.819882	± 4.762000	± 6.104764
data 6	88.48021	675.8590	± 3.502185	± 4.524100	± 5.721257
	89.46928	800.8436	± 3.855322	± 5.364900	± 6.606486
	90.22604	873.7021	± 4.057872	± 5.851900	± 7.121170
	91.24186	7893.498	± 12.37099	± 52.87910	± 54.30692
	91.96859	825.2780	± 4.051215	± 5.527300	± 6.852984
	92.96836	624.5900	± 3.564113	± 4.190000	± 5.500818
	93.71685	942.2280	± 4.403135	± 6.322000	± 7.704238

Radiation corrections on A_{fb}

The following table shows the radiation corrections for the measurement of A_{fb} depending on the center–of–mass energy.

$\sqrt{s}$ (GeV)	Radiation correction
88.47	0.021512
89.46	0.019262
90.22	0.016713
91.22	0.018293
91.97	0.030286
92.96	0.062196
93.71	0.093850

The radiation corrections are given for all center–of–mass energies and must be added to the measured asymmetry. E.g.: the measured value of A_{fb} at $\sqrt{s} = 91.22$ GeV is 0.002194 then 0.018293 must be added. Thus the corrected asymmetry is 0.020487.

Assuming the mass of the Z^0 is known to be $m_{\mathrm{Z}^0} = 91.1863$ GeV the radiation correction can be calculated to give the corrected asymmetry for $\sqrt{s} = m_{\mathrm{Z}^0}$. This alternative radiation correction is 0.0152 for the measurement of A_{fb} at $\sqrt{s} = 91.22$ GeV.

Best wishes for a successful experiment! Date: December 2016