Preparation to the
Lab Experiment M48:
Properties of the Z^0-Boson

ECAP and Physics Institute

at the

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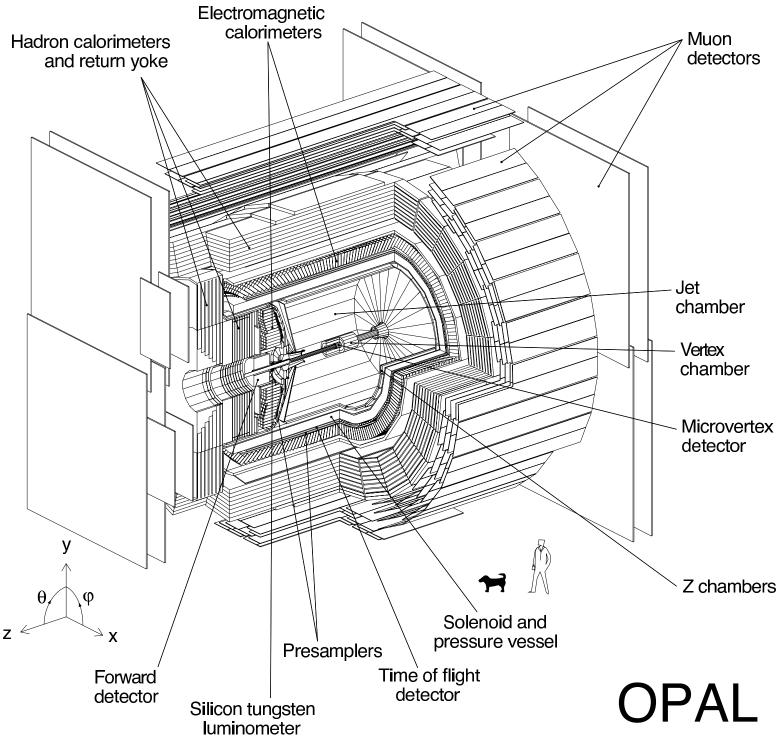

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1 Question to Prepare the Experiment

The following comprehension questions are a basis for you to check your knowledge preparing the discussion at the beginning of the lab experiment. The written preparation document can be formulated in comprehensible, clear structured keywords.

1. **Properties of the Z^0-Boson**
   a) Describe the role of the Z^0-boson within the standard model of (elementary) particle physics. Which other particles are essential, mainly in conjunction with the electro-weak interaction?
   b) Consider to which particles the Z^0 can couple, based on its (weak) properties. Accordingly, in which processes can the Z^0 be generated at large particle accelerators, what are the possible decay channels?
   c) Why can you call the Z^0 a resonant state? What physical parameters of this resonance can you identify with the three parameters of a Breit-Wigner-curve (height and position of the maximum; width)?

2. **Detection and Identification of Particles**
   a) The OPAL detector is composed of the sub-systems, including the track detector, electromagnetic and hadronic calorimeters and the myon cambers. Based on which kinds of interactions (particles/radiation with matter) does each of these systems work and which information are recorded?
   b) Describe how one can use this information to identify different types of particles and thus distinguish between the decay channels of the Z^0-boson. Consider e.g. in which aspects charged and un-charged particles or hadrons and leptons differ. Are there particles in the decay channels that cannot be detected directly by the OPAL detector?

3. **Variables and Analysis**
   a) How does the measured event (i.e. Z^0-decays) rate N_{meas} relate to the cross section σ? Accordingly, which parameter do you need to know to determine σ.
   b) What are „selection cuts“ and how do you know that a selection criterion was chosen well, i.e. what is the correlation with background, acceptance and efficiency?
   c) What is a fit, how do you perform a χ^2 fit, when is the result valid and what does ndof mean?

2 Preparation of Theoretical Aspects

The following tasks should be prepared in written form for the second lab day - at the latest. They are necessary to interpret the analysis results and have to be included into the lab journal. You do not explicitly need those for the introductory discussion on the first day.

1. Calculate the following quantities. Please use the relevant chapter on units and relations for the experiment instruction manual (Sec. 2.5) and in the supplementary material (appendix to the instruction manual).

a) partial decay widths Γ_f of the different fermion - anti-fermion decay channels:

$$Z^0 \rightarrow \mathrm{f\bar{f}};$$

b) decay widths of hadrons, charged leptons and neutral (invisible) leptons: Γ_{had}, Γ_{charged} and Γ_{invis};

c) total decay width Γ,

d) total hadronic cross section $\sigma_{\text{had}}^{\text{peak}}$ at the resonance peak;

e) partial cross sections σ_f^{peak} at the resonance peak.

2. At which percentage level would the respective widths of the Z^0 resonance change, if a decay channel into another light fermion - anti-fermion pair would open up? Break down your calculation following the different partial decay widths Γ_{u}, Γ_{d}, Γ_{e} and Γ_ν (cf. Tab. 2.2 of the instruction manual).

3. Sketch the expected angular distributions (differential cross section as function of $\cos\theta$) for the processes

$$\mathrm{e}^+ + \mathrm{e}^- \rightarrow \mathrm{e}^+ + \mathrm{e}^- \quad (1)$$

$$\text{und} \qquad \mathrm{e}^+ + \mathrm{e}^- \rightarrow \mu^+ + \mu^- \quad (2)$$

and separate the individual contributions in the (1) case.
An explanation of the angular distribution can be found in Sec. 2.3.1 („Bhabha scattering“) of the instruction manual.

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