Teilchenphysik II (Higgs-Physik) (SS 2016)

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Exercises Sheet 10

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Exercise 30: Uncertainty of an Efficiency Measurement (homework)

In the experiment efficiency measurements play an important role, where the efficiency (e.g. of an event selection step) is defined as the number of selected events over the number of events in the reference collection:

$$\epsilon = \frac{N_{sel}}{N_{ref}} \,.$$

In counting experiments (as in our case) the uncertainty of N counts can be assumed to be $\delta N = \sqrt{N}$ (i.e. normal distributed), while in general this does not have to be the case [1]. When propagating the uncertainty on the observed counts into an uncertainty of ϵ ($\delta\epsilon$), it has to be taken into account that e.g. N_{sel} and N_{ref} are not uncorrelated! You can easily convince yourself of this fact, since all events that have been selected must necessarily already have been part of the reference collection.
Expressed by the number of events that have been selected (N_+) and the number of events that have not been selected (N_-), ϵ can be written in terms of two genuinly uncorrelated variables:

$$\epsilon = \frac{N_+}{N_+ + N_-} \,. \tag{1}$$

From equation (1) $\delta\epsilon$ can be computed using ordinary *Gaussian* error propagation. The obtained equation for $\delta\epsilon$ holds under the assumption that N_{ref} is "sufficiently" large.

a) Calculate $\frac{\delta\epsilon}{\epsilon}$ for the general assumption of uncertainties δN_+ and δN_-, which are not necessarily normal distributed.

b) We have argued that N_{sel} and N_{ref} are not uncorrelated. What is the correlation coefficient between N_{sel} and N_{ref}?

c) Show that under the assumption of $\delta N_+ = \sqrt{N_+}$ and $\delta N_- = \sqrt{N_-}$ the term of Exercise 30 a) turns into the binomial uncertainty that you know from the lecture:

$$\delta\epsilon = \sqrt{\frac{\epsilon(1-\epsilon)}{N_{ref}}} \,.$$

d) Can you point to where the assumption of "sufficiently" large N_{ref} enters even in the general calculation?

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[1] δN could for instance be the result of a fit to the data.

Exercise 31: Transverse Mass of Massless Decay Products (presence)

In the lecture we have seen the general definition of the transverse mass:

$$M_T^2 = E_T^2 - \vec{p}_T^{\,2} \,.$$

Now we want to simplify this equation for the special case $W \to \ell\nu$. Derive a formula which depends only on the angular difference ($\Delta\phi$) between MET and the lepton transverse momentum and the absolute values of them. Insert the definition of the transverse energy ($E^2_{T(\nu/\ell)} = m^2_{(\nu/\ell)} + p^2_{T(\nu/\ell)}$) and make the transition for $m \to 0$. What is the maximum value of the transverse mass?