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ON THE SCALAR ELECTRON MASS LIMIT FROM SINGLE PHOTON EXPERIMENTS

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Abstract:

We discuss how the 90 % C.L. lower limit on the mass of the scalar electron, as extracted from the single photon experiments, is affected by the way the background from radiative neutrino pair production is handled. We argue that some of the results presented at the Berkeley conference are overoptimistic, and that the mass lower limit is 65 GeV rather than the advertized value of 84 GeV, for the case of degenerate scalar electrons with massless photinos.

Following the Berkeley conference, a controversy took place as to what limit on the mass of the scalar electron could actually be derived from the single photon experiments. The 90 % C.L. lower limits presented at Berkeley were the following ones [1] (two degenerate scalar electrons, massless photinos) :

ASP	66 GeV
CELLO	38 GeV
MAC	50 GeV

while the result obtained combining all experiments was [2] :

84 GeV

still at the 90 % C.L., as for all confidence levels which will be mentioned in the rest of this note.

The method used to derive these limits was the following, using as an example the case of the combined data :

From the 3 known neutrino types, one expects 4.0 'background' events.
From the observation of 2 events, one extracts an upper limit of 5.3.
An upper limit on the number of 'signal' events is then set at 1.3 (5.3 - 4.0),
from which one derives a lower limit of 84 GeV for the mass of the scalar electron.

However, suppose now that only 1 event had been observed instead of 2, the corresponding upper limit would become 3.9, and that on the number of signal events - 0.1 ! No 90 % C.L. lower limit on the mass of the scalar electron could have been derived this way in such a case...

The reason for this apparent paradox comes from ignoring the (neutrino-) background fluctuations.

To be more specific, let *a priori* (i.e. before the experiment) :

$\mathcal{P}_B(N_B)$ be the probability distribution for observing N_B background events,

$\mathcal{P}_S(N_S)$ that for observing N_S signal events,

with $\mathcal{P}_X(N)$ =, for instance, $\mathbb{P}_X(N) = e^{-X}\frac{X^N}{N!}$

The probability distribution of B is known (in our example, simply a delta function), whereas $d\mathcal{P}(S)$, the probability distribution of S, is *a priori* unknown, and it is precisely the aim of the experiment to make it 'less unknown'.

Let $N = N_B + N_S$ be the total number of events. Then, still *a priori* :

$$\mathcal{P}(N \mid S) = \sum_{N_B=0}^{N} \mathcal{P}_B(N_B)\mathcal{P}_S(N-N_B) =, \text{ for instance, } \mathbb{P}_{B+S}(N)$$

where $\mathcal{P}(A \mid B)$ stands for 'Probability of A, given B'.

The method previously described calculates S_0 such that, if N_0 events were actually observed :

$$\int_{S>S_0} \mathcal{P}(N_0 \mid S)\, dS = 10\,\% =, \text{ for instance, } e^{-(B+S_0)}\sum_{k=0}^{N_0}\frac{(B+S_0)^k}{k!}$$

It is again obvious that N_0 and B may be such that no solution exists for S_0.

However, what one really wants to determine is S_0 such that :

$$\int_{S>S_0} d\mathcal{P}(S \mid N_0) = 10\,\%$$

For that, one can apply Baye's theorem :

$$d\mathcal{P}(S \mid N) = \frac{\mathcal{P}(N \mid S)\, d\mathcal{P}(S)}{\mathcal{P}(N)} \quad \text{with} \quad \mathcal{P}(N) = \int \mathcal{P}(N \mid S)\, d\mathcal{P}(S)$$

However, $d\mathcal{P}$ (S) is not known, and this is where one has to inject some kind of prejudice. The usual way out is to assume a uniform *a priori* probability distribution for S, a prescription often referred to as Baye's postulate. Then :

$$\int_{S>S_0} d\mathcal{P}(S \mid N_0) = \frac{\int_{S>S_0} \mathcal{P}(N_0 \mid S)\, dS}{\int_{S>0} \mathcal{P}(N_0 \mid S)\, dS} = 10\,\% =, \text{ for instance, } \frac{e^{-(B+S_0)} \sum_{k=0}^{N_0} \frac{(B+S_0)^k}{k!}}{e^{-B} \sum_{k=0}^{N_0} \frac{B^k}{k!}}$$

which is the same as what had been obtained with the method previously described, except for the denominator which modifies the normalization of the background probability distribution to take into account the fact that N_B cannot have exceeded N_0 in the actual experiment.

Now, whatever the value of N_0, there is always a solution for S_0.

Using this method, the results presented at the Berkeley conference get modified as follows [3] :

ASP	57 GeV
CELLO *	38 GeV
MAC	47 GeV

with, for the combined limit from the three experiments :

65 GeV (instead of 84 GeV ...)

Although our personnal preference is for the latter method, commonly referred to as 'Bayesian', we are aware of the arbitrariness of the assumed form of $d\mathcal{P}$ (S). One could easily argue that a uniform distribution for Log(S) or, for instance, for the mass of the scalar electron would be more natural. However, in our opinion, this approach bas two strong virtues, as long as a clear statement of the underlying hypothesis is given :

- it always leads to a solution,
- it minimizes the influence of background fluctuations.

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* The CELLO result at the Berkeley conference was obtained with the method presented here. If a method similar to the one then used by ASP and MAC is used, the CELLO limit becomes 44 GeV.

References :

[1] J.S. Whitaker, Proc. of the 23^{rd} Int. Conf. on High Energy Physics, Berkeley (1986), and preprint BUHEP 86 - 10.

[2] T.L. Lavine, MAC Coll. Internal Report MAC - 748.

[3] M. Davier, Proc. of the 23^{rd} Int. Conf. on High Energy Physics, Berkeley (1986), and preprint LAL 86 - 31.
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