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THE ENERGY MEASUREMENT OF ELECTRONS IN A H.L.B.C.

This internal report is to be understood only as an abstract. A complete description of a total track length method for electron measurements in a H.L.B.C. will be published later.

1. BEHR-MITTNER METHOD

Electrons being light particles loose energy rapidly by radiation. So the usual method of determining the momentum of a charged particle in a magnetic field by reconstruction of the track and by measuring the curvature, does not work without application of special corrections for Bremsstrahlung losses. To have small radiation losses the measured length should be as short as possible. On the other hand, the track is distorted by multiple scattering and small angle single scattering, so that a safe average curvature measurement is only possible on a longer length.

Behr and Mittner have developed a method (BM-method) which allows one to measure the energy of electrons which do not lose more than a certain amount (cut-off used in the ν-experiment): 50 o/o) of their primary energy in a single Bremsstrahlung quantum. The frequent emission of small quanta on the measured length can be corrected by taking an average energy loss, but the occasional emission of large quanta cannot be corrected statistically. With a given Bremsstrahlung cut-off they defined an optimum measurement length on which the sum of the errors due to multiple scattering and Bremsstrahlung losses is a minimum. The B-M method gives in our liquid (CF_3Br with 11 cm radiation length) a calculated minimum error of 45 o/o of the electron energy for measurable electrons. Unseen Bremsstrahlung losses above the B-M cut-off give rise to even bigger errors in practice.

2. THE TOTAL TRACK LENGTH METHOD

Another possibility for measuring electron energies is given by the relation between the total track length (TTL) of the shower generated by an electron and its initial energy (E). For an ideal and infinite medium this relation is rather simple and nearly linear. For a finite medium one has to correct the unseen part of the shower outside the medium, which means we must consider the form of the development of the shower. We define a shower axis which is the tangent to the beginning of the electron track. The distance between this point and the chamber walls along this axis gives us the longitudinal development length of the shower in the chamber (potential length PL).

In addition one cannot measure the electrons up to their end because of the strong multiple scattering and the part where the tracks are curled up by the magnetic field. Therefore one has to apply a certain cut-off energy. Because of these effects the ideal curve $E = f\ (TTL)$ is spread out to a relation $E = f\ (TTL, PL) \pm \Delta f\ (TTL, PL)$.

There are three possible ways of finding this relation :

a) One could send electrons of know energies into the chamber, measure the generated showers in certain development lengths and reconstruct the relation $TTL = f\ (E, PL)$ point by point. This procedure was excluded by experimental difficulties and lack of accelerator time;

b) One could try to find the differential equations which describe the development of a shower. However, they have no analytic solution.

c) One could simulate experimental conditions by a Monte-Carlo program.

The presence of a large, fast computer at CERN suggested this method, which was carried out for the special case of the CERN H.L.B.C. filled with CF_3Br.

3. THE MONTE-CARLO PROGRAM

The Monte-Carlo program generates electrons of a certain energy in CF_3Br and follows each track in space and under the influence of the magnetic field in steps of 1 cm. These steps are small enough, compared with the radiation length (11 cm) and the TTL to give no big errors. All the processes which dominate in shower production were taken into account. Bremsstrahlung and pair production probabilities were obtained from the Bethe-Heitler formulae by numerical integration. The compton cross section of Klein-Nishina was used. For large angle Coulomb scattering the Rutherford formula was taken, sma l angle multiple scattering was taken into account by a randomly chosen mean scattering angle for each interval. Photo effect and the formation of tridents were not included in the calculations, the latter having a too small cross section and the photo effect only works at energies below 1 MeV. For handling the single processes the Monte-Carlo method was used.

The only free parameter remaining in the calculation is the low energy cut-off for the electrons in CF_3Br. This cut-off is mainly energy independent. An experiment with 600 MeV electrons shot into the H.L.B.C. allowed us to calibrate this parameter in our program. Agreement between experimental and simulated showers was within 5 o/o (Fig. 1). To get the distribution of TTL = f (E, PL) 200 showers were calculated for each of 100 electron energies. This distribution has been converted to the distribution 1/E = f (TTL, PL) which gives nearly symmetrical errors in 1/E. On a double logarithmic scale the resulting curves are linear, so that it is possible to give a simple formula, which can be taken into a measuring program for electrons. Compared with other errors in energy measurement, the errors introduced by measuring the shower projected onto the shower axis instead of in space are small (less than 10 o/o). This again facilitates the measurement of electrons in an experiment. The final curves are shown in Fig. 2.

4. RESULTS

The TTL-method was used to measure the neutral pions seen in neutrino events in the CERN neutrino experiment. The rest mass of the π^0 is known quite well to be 135 ± 0.015 MeV. From the decay angle between the two converted γ-rays and the measured γ-ray energies one can get the π^0 rest mass. The γ-ray decay angle is measurable with a relatively high precision. The distribution of the π^0 rest masses therefore only depends on good energy measurement of the γ's and correct combination of two γ's to form a π^0. To have mainly real π^0, only two γ events were taken. (The chance that there were four γ's of which two escaped and the remaining two formed a "wrong" π^0 is small). The restricted number of events prevented us from taking only events where the converted electrons had a PL of more than 2 radiation lengths, but already the restriction to more than 1 1/2 radiation lengths shows the value of the method (Fig. 3). As can be seen from Fig. 2, really good measurements can be expected from PL's of 2 to 3 radiation lengths upwards. So this method is suited for a big H.L.B.C. or, for smaller ones, as a good independent method supplementing the B-M method.

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Fig 1. Total tracklength (projected).

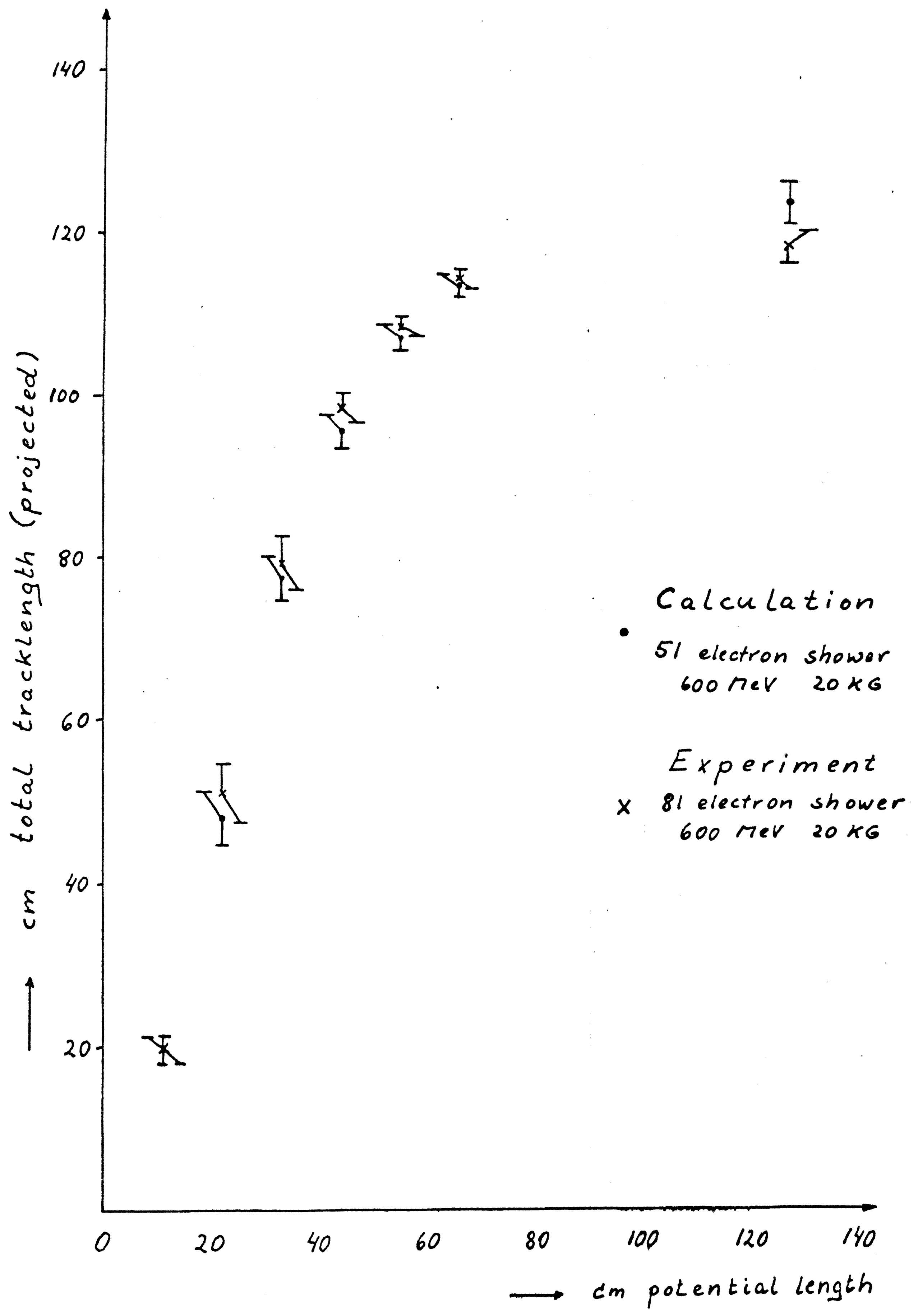


Fig. 2 a $E = f(TTL, PL)$ Mean values and 1 Standard deviation values.

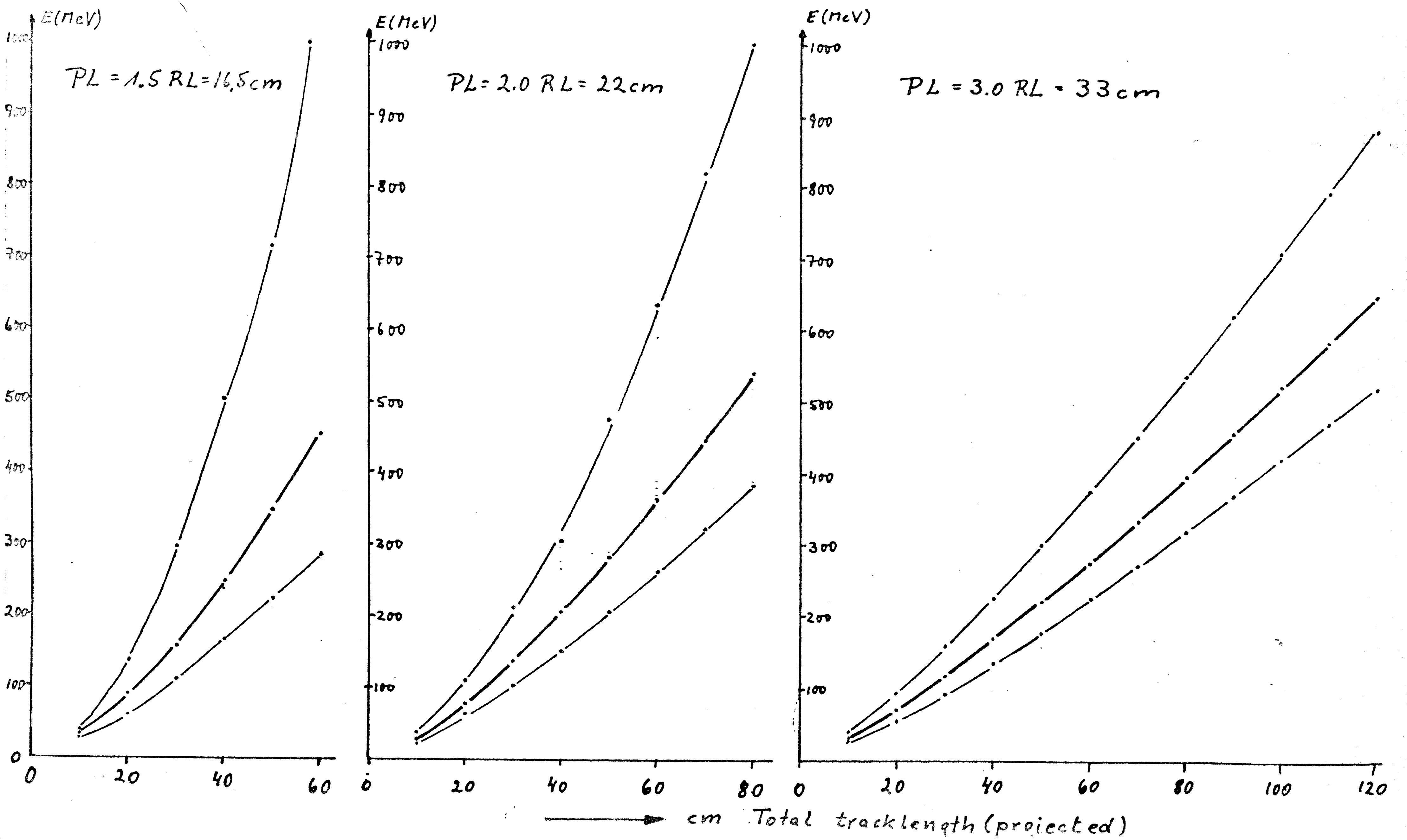


Fig. 2b $E = f(TTL, PL)$ Mean values and 1 Standard deviation values.

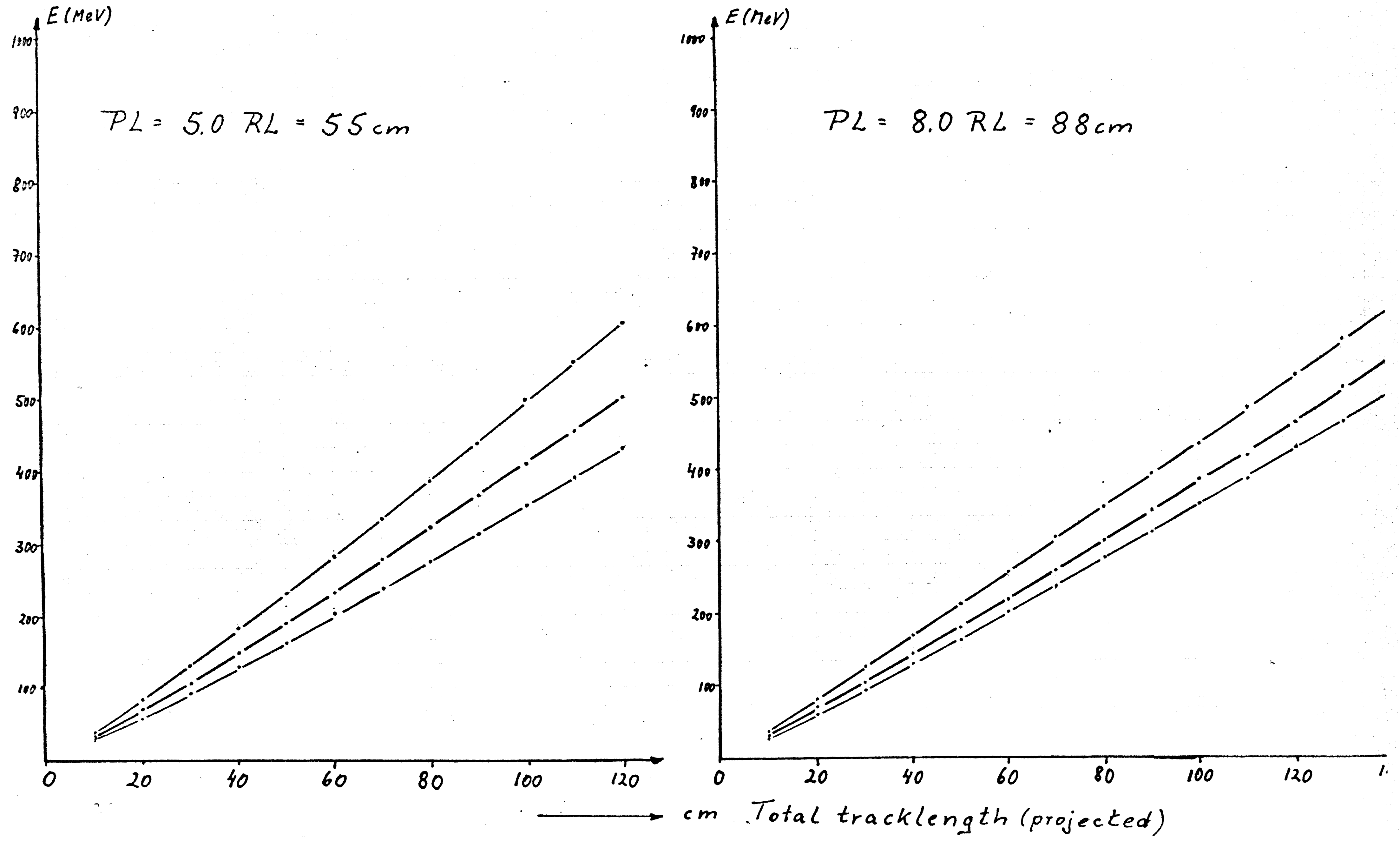
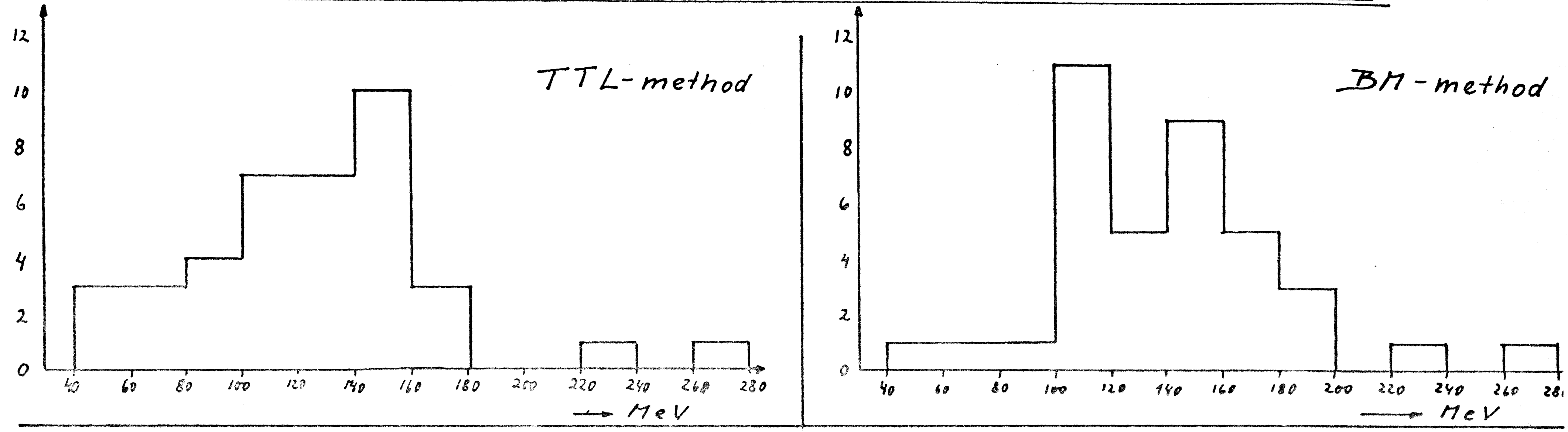


Fig. 3 2γ-events r-run 0-ii π_0-restmass.



2γ-events r-run 0-ii π_0-restmass ($PL \geq 16\,cm$)