H1-10/96-493

9 October 1996

Acceptance Determination of Electron Tagger (ET44) in 1995

V.Andreev

Lebedev Physical Institute, Moscow, Russia

Abstract

In the winter shutdown 1994/1995 a new electron calorimeter was installed in the HERA tunnel at the distance 44 m from the Interaction Point along electron beam. The new detector allows to extend the acceptance for tagged photoproduction events to the low y range, $0.04 < y < 0.24$. The technical design, the calibration procedure and the results of the acceptance determination for 1995 H1 Data Taking period are described.

1 Introduction

In 1994 it was proposed to build an additional electron tagger which increases the photon tagging acceptance to the low y range, $0.04 < y < 0.24$ [1]. This project was realised during shutdown 1994/1995 and H1 operated with the new electron calorimeter in 1995.

The new small calorimeter to tag electrons was installed in the HERA tunnel at the position $z \simeq -44$ m from the Interaction Point, therefore it got the name ET44. The electron beam pipe was slightly modified in this place, to allow the installation of the detector. The position of the ET44 in the HERA tunnel is shown schematically in Fig. 1.

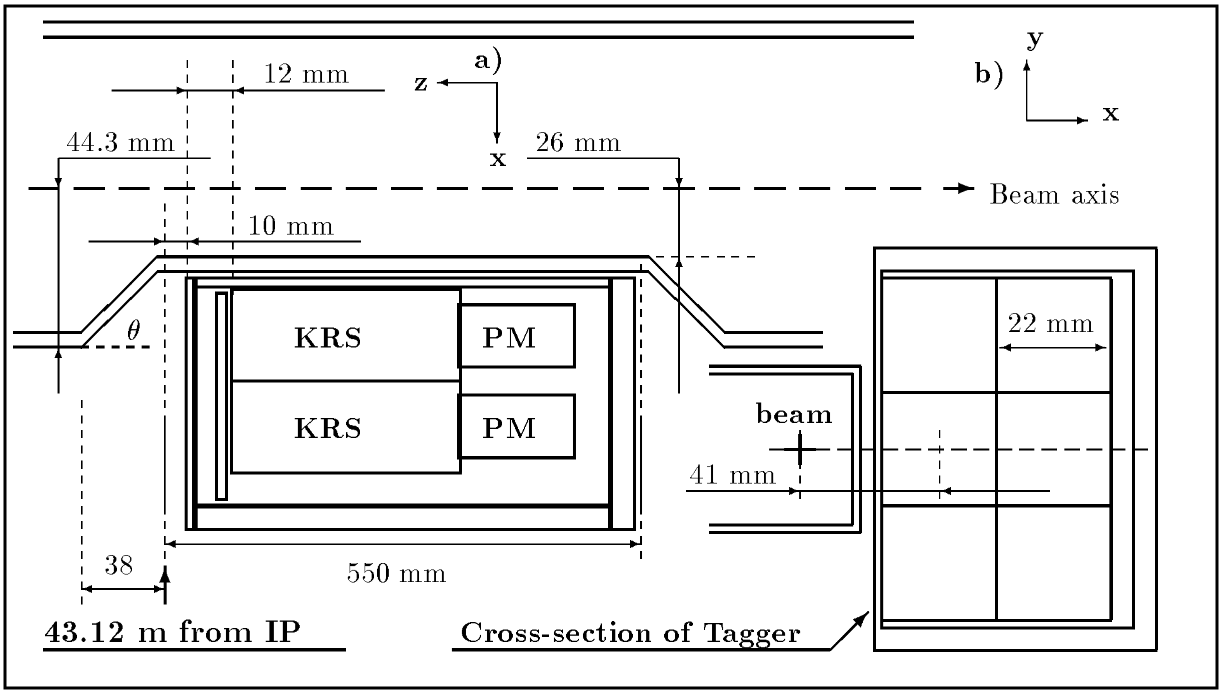

Figure 1: Sketch of the ET44 in HERA tunnel (two views). The thickness of the beam pipe near the detector is 1 mm of copper. The detector is placed in an antimagnetic iron box with a thin ($\sim$ 2 mm) wall adjacent to the beam pipe. The angle between the exit window and e-beam direction is $\theta = 30^o$.

The detector, a total absorption Čerenkov calorimeter, is built out of 6 KRS−15 crystals of the same type and size as those used in the "old" Electron Tagger. The crystals with phototubes are housed in an antimagnetic iron box with thin ($\sim$2 mm) wall close to the beam pipe. The detector was not movable in 1995 having been mounted on a fixed support. The properties of all H1 LUMI detectors are summarized in table 1. The indicated energy resolution was valid for the Electron Tagger and Photon Detector from 1992 to the middle of 1994. Afterwards the resolution started to degrade slowly to the level of $\sim 15\%/\sqrt{E}$. The energy resolution of the ET44 was $\sim 20\%/\sqrt{E}$ in 1995.

Table 1: Properties of the H1 LUMI detectors.

Parameter	unit	ET	ET44	PD
Position, $-z$	m	33.4	44.0	101.0
Aperture $x \times y$	mm^2	154×154	44×66	100×100
Lateral granularity	cells	7×7	2×3	5×5
Chemical composition		$TlCl(78\%) + TlBr(22\%)$		
Radiation length, X_0	cm	0.93		
Moliere radius, R_m	cm	2.10		
Crystal length	cm	20		
Radiation hardness	Rad	$> 6 \cdot 10^7$		
Energy resolution, σ_E/E	%	$1 \oplus 10/\sqrt{E}$, (E in GeV)		
Position resolution, $\sigma_x = \sigma_y$	mm	$0.3 - 1.2$		
Time resolution, σ_τ	ns	< 3		

The level 1 trigger element `LU_ET_44` (`TE114`) was implemented for the new electron tagger. It requires a simple condition $E_{dep}^{tot} > E_{thr}$, where E_{dep}^{tot} is total deposited energy in the calorimeter, with a typical value of $E_{thr} \simeq 10$ GeV. Such a high threshold is allowed by the accepted energy range of scattered electrons from ep-collisions and gives possibility to discriminate easily against the noise and possible low energy background. An additional γ-veto condition from the photon arm (no signal in both Photon Detector and Veto Counter) suppresses a high background from the Bethe-Heitler (BH) process $ep \to e\gamma p$ with the efficiency of 80–90 %.

2 Calibration

The Bethe-Heitler process $ep \to e\gamma p$ is used for the calibration of the H1 LUMI detectors. For all channels i in the Electron Tagger and j in the Photon Detector one requires that the following expression is fulfilled:

$$\sum_{events} \left\{ \left[\sum_i E_i(e) + \sum_j E_j(\gamma) - E_o \right]^2 \right\} = min \qquad (1)$$

where E_o is electron beam energy. The calibration procedure for the "old" Electron Tagger and for the Photon Detector is described in details in [2]. Here some specific points for the calibration of the ET44 are described. The main difficulty of the ET44 calibration comes from the poor space and energy reconstruction near the detector boundary (≤ 1 cm). Note that the majority of the accepted events have the impact point in this region.

The first step of the calibration procedure is thus to select events with an impact point in the ET44 well separated from the detector boundary. For this purpose the two energy cuts are used: the total deposited energy in the ET44 should be higher than E_{th1} = 19.1 GeV and the energy deposited in the rightmost three crystals of the detector also should be higher than E_{th2} = 0.6 GeV. Effectively these two cuts select the events with the impact point close to the center of the detector. Afterwards the standard reconstruction program is applied for these selected events.

At the next step the fact that the Photon arm has already been well calibrated together with the Electron Tagger (33 m) is exploited. The calibration coefficients for the Photon arm are fixed and then the corresponding coefficients for the ET44 are obtained using the expression (1). This procedure is illustrated in Fig. 2.

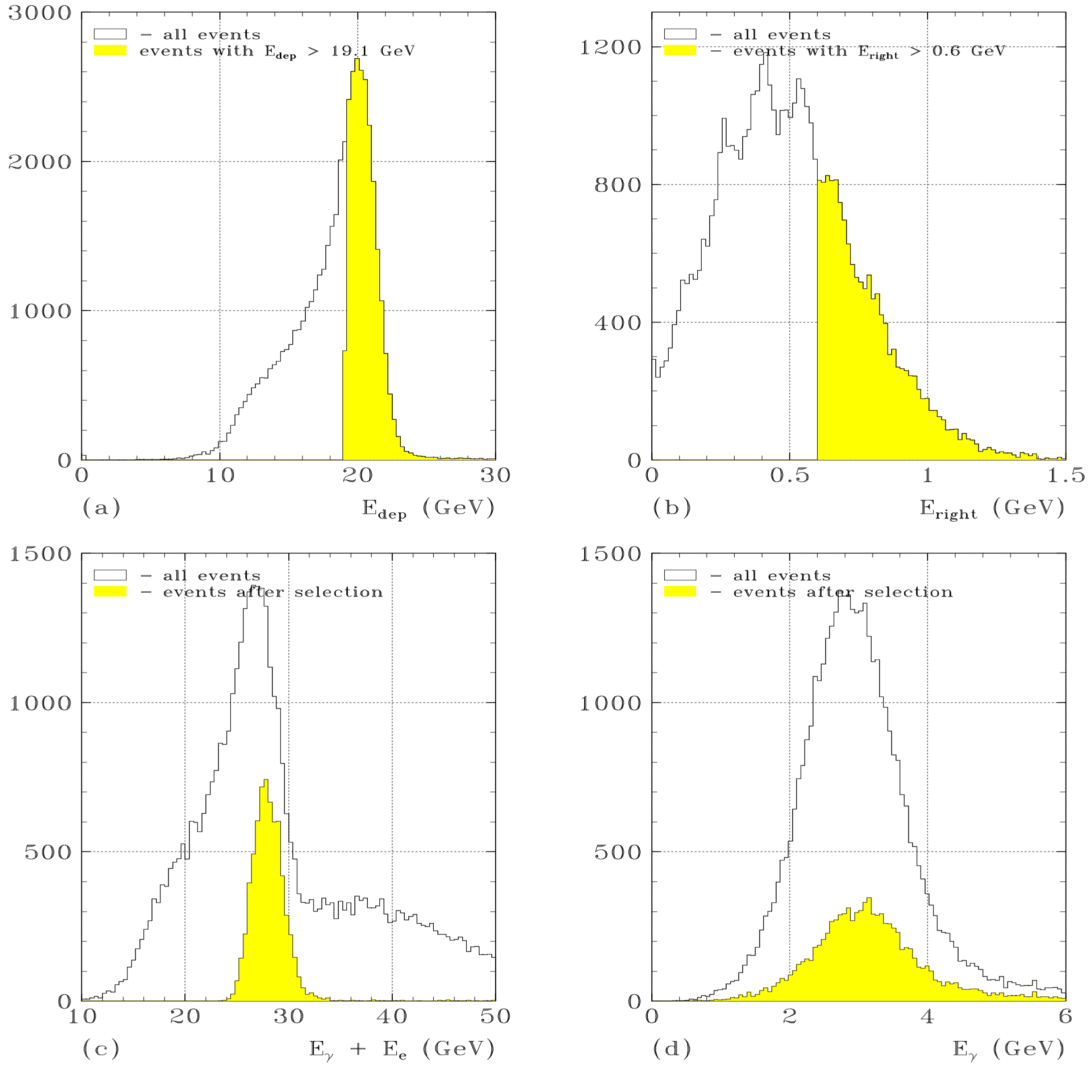

Figure 2: (a) - total deposited energy in the ET44; (b) - deposited energy in the rightmost three crystals of the ET44; (c) - sum of the reconstructed photon and electron energies for BH events; (d) - reconstructed photon energy for the bremsstrahlung events. Shaded histograms represent the distributions for the events used for the calibration.

3 Trigger efficiency

The efficiency of the ET44 trigger element `LU_ET_44` has been determined from `S93` trigger sample. The subtrigger `S93` is formed solely by the `LU_WatVet` trigger element. The efficiency is illustrated in Fig. 3(a,b).

As already mentioned above, the majority of the events accepted by the ET44 have the impact point close to the detector boundary, and as a consequence, both space and energy reconstruction are poor for these events. The deposited energy in the ET44 is always correctly determined in contrast with the reconstructed energy. For this reason the trigger efficiency for the ET44 trigger element is defined as a function of the deposited energy. And since it is not always possible to relate the deposited energy to the reconstructed energy for the individual events, the trigger efficiency is determined by averaging over a whole chosen run range.

This average trigger efficiency in 1995 is found to be in the range 0.97−0.99 for the different run periods with the error of ∼1.5 %.

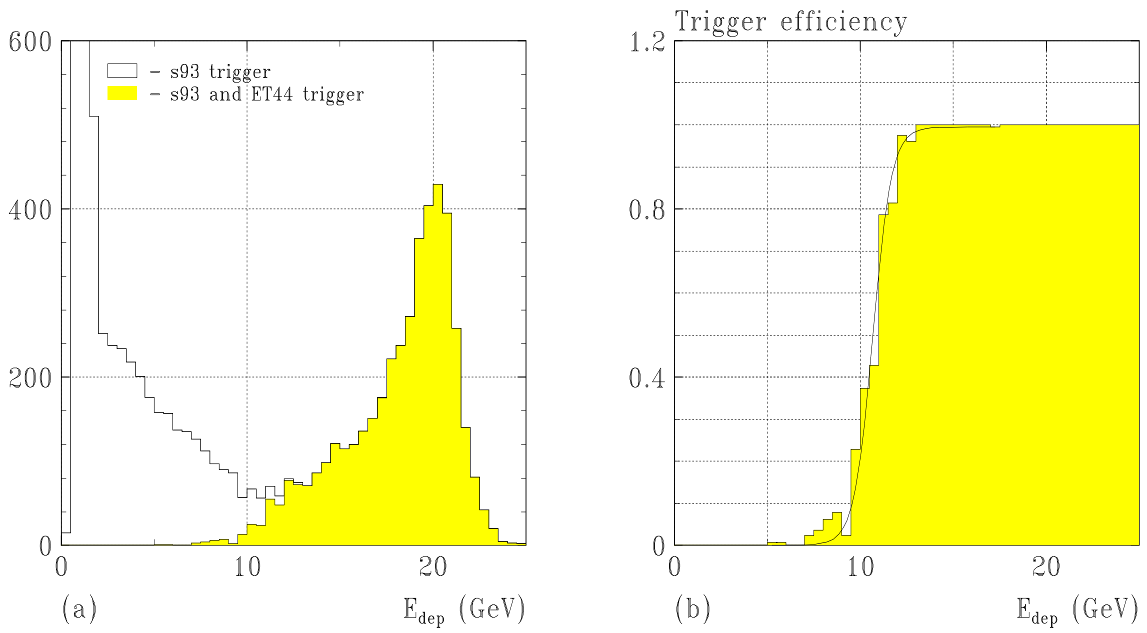

Figure 3: (a) - deposited energy in the ET44. (b) - trigger efficiency function.

4 Photon Energy Scale

The determination of the absolute energy scale of the photon arm is the most important task for the precise determination of the acceptance. This problem was considered in detail in [3] for the photon energy $E_\gamma \geq 6.0$ GeV. However, an additional investigation is necessary in case of the ET44 when the accepted photon energy for the bremsstrahlung events is $E_\gamma < 6.0$ GeV.

The energy deposited in the filter and in the Veto Counter for the low photon energies composes a noticeable part of the total photon energy. For this reason the precise knowledge of the response of the Veto Counter is very important. The quality of the VC calibration can be checked from the dependence of the average value $E_{VC}^{true} = E_o - E_{ET} - E_{PD}$ on the deposited energy in the Veto Counter. Here E_{ET} is the reconstructed energy in the Electron Tagger (33 m) and E_{PD} is the reconstructed energy in the Photon Detector alone (without VC).

An example of such correlation is shown in Fig. 4(b) for the LU_ET&LU_PD&LU_WatVet sample (subtrigger S95). For the ideal case this dependence would be linear. In the reality, some deviation from this linear dependence is observed; it is fitted by the $(a+b\cdot E_{VC}+c\cdot E_{VC}^2)$ function. The deposited energy in the Veto Counter is corrected using this expression. The photon energy distribution in the Photon Detector for the BH process with the scattered electrons accepted by the ET44, is shown in Fig. 4(c) before and after correction procedure.

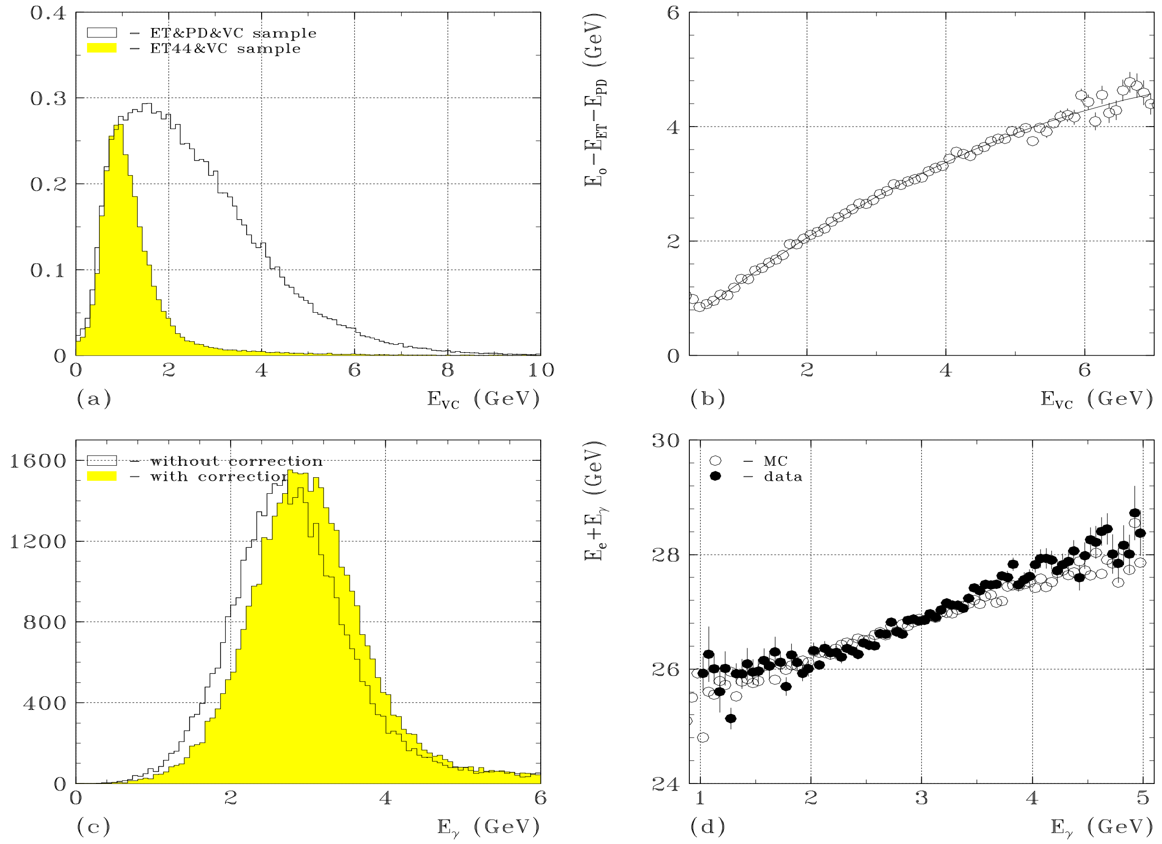

Figure 4: (a) - deposited energy in the Veto Counter; (b) - correlation between the E_{VC}^{true} and the deposited energy in the Veto Counter E_{VC}; (c) - photon energy distribution for the BH events with the scattered electrons accepted by the ET44; (d) - comparison the data with Monte Carlo.

Futher information on the non-linearity of the photon arm can be extracted from the distribution of the average value $< E_e + E_\gamma >$ versus the photon energy E_γ. At first sight, any deviation from the straight line in a such dependence would mean a non-linearity of the photon energy scale. But this simple picture is distorted by the limitations in the detectors acceptance. The comparison of Monte Carlo events having an ideal energy scale with the data can give the information about the non-linearity of the photon scale. One can see in Fig. 4(d) that the general behaviour of the data is reproduced well enough the Monte Carlo simulation. The residual difference in the region $E_\gamma > 5.0$ GeV, where the acceptance of the ET44 is small, does not exceed 4% level. This can be due to both a non-linearity of the photon energy scale at the low energy or to a non-ideal description of the ET44 acceptance by Monte Carlo. This uncertainty has to be included into the systematic error.

5 Acceptance Determination

It should be mentioned, that the ET44 acceptance calculation procedure is anologous to those used for the "old tagger", described briefly in [4].

5.1 MC calculation

The acceptance study has been performed using the fast simulation package H1LUMI [5], upgraded to include magnet elements of the electron beam line down to $z \simeq -44$ m and the new detector. Present HERA optics for the electron machine (before the installation of the spin rotator equipment) is described e.g. in [6] . The ET44 acceptance calculation for photoproduction process under the different e-beam conditions for 1995 geometry is shown in Fig. 5. Under the real conditions this acceptance can be definied with good precision from data, using BH $ep \to e\gamma p$ events. This reduces the uncertainty related to the precision with which real beam conditions can be simulated.

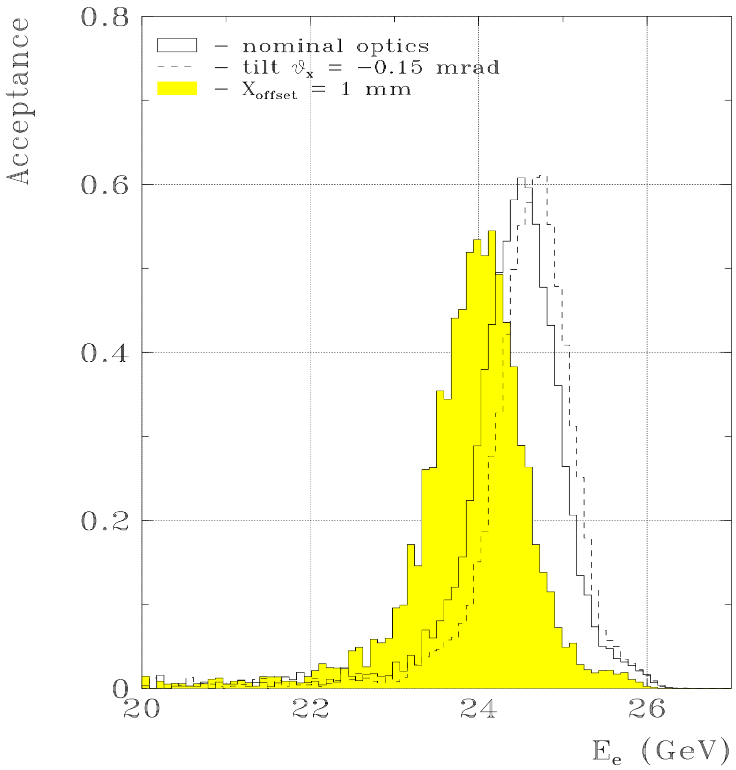

Figure 5: Acceptance of the ET44 for photoproduction process under the different e-beam conditions.

5.2 Tuning MC with experimental data

The first two electron beam parameters which influence the acceptance behaviour are the θ_x and θ_y tilt of the electron beam. Their values can be measured from the distributions of the photon impact points in the Photon Detector for the BH events. The examples of these distributions for the H1 runs 130401 – 131046 together with corresponding MC simulation are shown in Fig. 6(a,b).

Two other MC parameters, which cannot be measured directly by the H1 LUMI system are X_{off}, Y_{off} - the horizontal and vertical offsets of the electron beam at the interaction point with respect to the reference trajectory. However the dependence of the ET44 acceptance on the X_{off} is more important than the dependence on the Y_{off} and for the further analysis it is enough to determine only X_{off}. The parameter X_{off} is extracted by tuning MC to the experimental data. The energy distribution of the BH photons with the scattered electrons accepted by the ET44, is used for such tuning. One should remember a good quality of the space and energy reconstruction in the Photon Detector. Fig. 6(c) shows that Monte Carlo describes the data well.

MC parameters obtained in this way are used for the acceptance calculation for the photoproduction process. The example of this calculation is shown in Fig. 6(d).

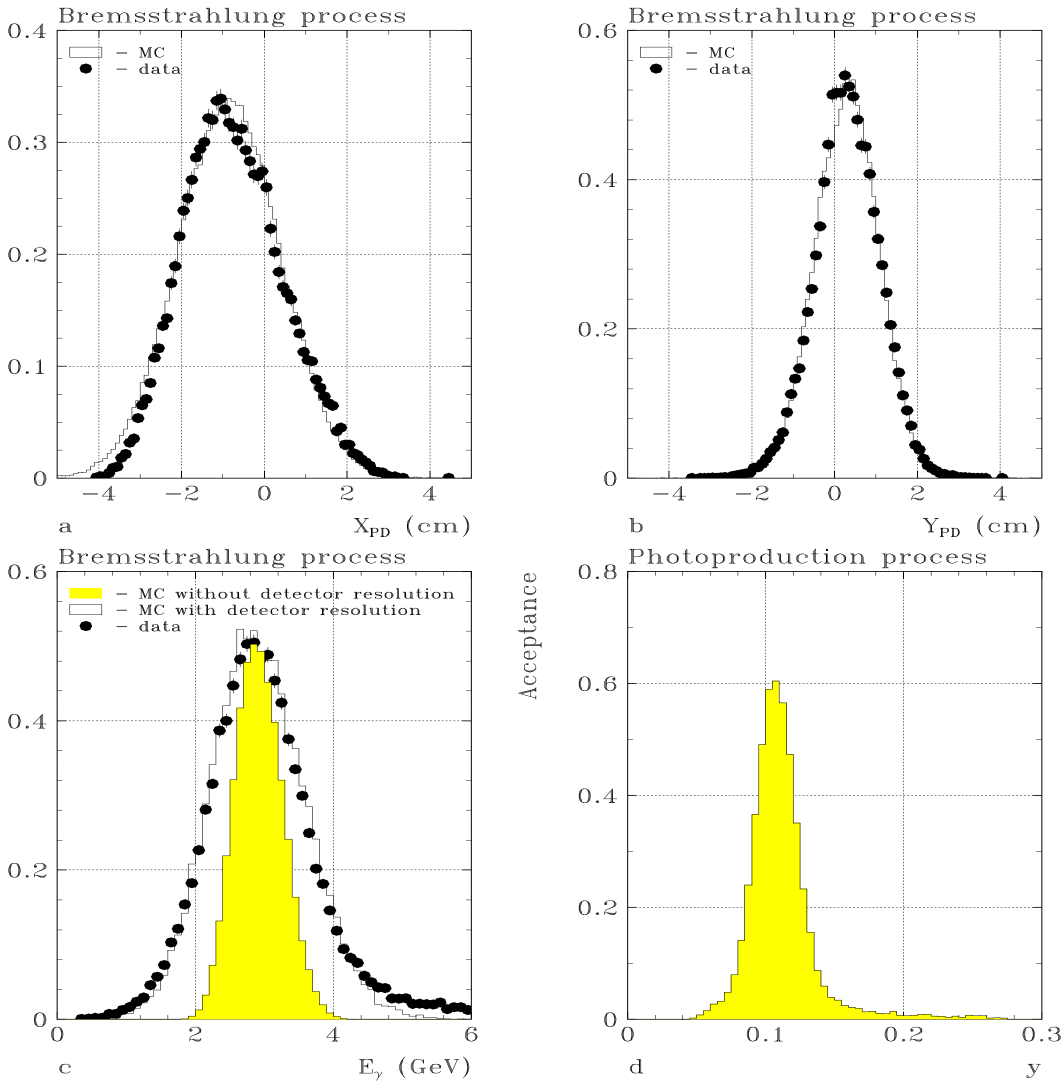

Figure 6: Tuning MC to data. (a,b) - distribution of the photon impact points in the Photon detector; (c) - photon energy distribution for the BH process; (d) - ET44 acceptance behaviour calculated by Monte Carlo for the photoproduction process as a function of y.

5.3 Offline tool for the acceptance calculation

The whole 1995 data sample was split into 16 sub-samples such that inside each sub-sample the electron beam parameters θ_x, θ_y and X_{off} do not change much. For every sub-sample the parameters of Monte Carlo were obtained with the procedure described above and the acceptance of the ET44 for the photoproduction process was calculated. These acceptance functions for the different run periods are shown in Fig. 7.

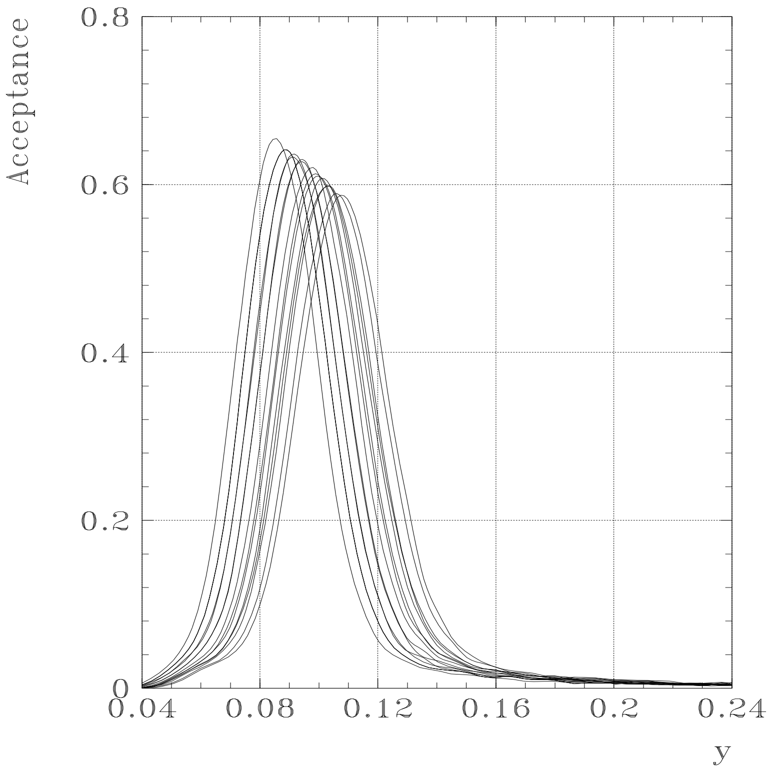

Figure 7: Acceptance of the ET44 for the photoproduction process for the 16 run periods in 1995.

The information about the acceptance dependence on y and the trigger efficiency for each sub-sample was stored in the new (run-dependent) bank LET1 in the H1 database. The structure of this bank is shown below.

```
!       BANKname BANKtype       ! Comments
!
        LET1                    ! ET44 acceptance parametrization for MC
!
!   ATTributes:
!   -----------
! COL ATT-name FMT  Min   Max   ! Comments
!
   1  EFFO      F    0.    1.   ! Trigger efficiency for the total sample
   2  PVETO     F    0.    1.   ! Gamma-arm veto level
   3  YMIN      F    0.    1.   ! Minimum y-value
   4  YMAX      F    0.    1.   ! Maximum y-value
   5  DY        F    0.    1.   ! =0.005 y-step for parametrization
   6  Y1        F    0.    1.   !
  ...                           !
 N+5  YN        F    0.    1.   !
                                !
  END TABLE
```

One important point should be made clear. As discussed above, the energy resolution is quite poor: $\sim$ 1.2 GeV. From the other hand the width of the acceptance curve is substantially less (see fig. 6(c)): $\sim$ 0.4 GeV. Therefore, the fact of tagging electron carries more information about its energy than the measured (reconstructed) value. Therefore, it would be meaningless to use the measured value in order to correct for acceptance by weighting an event with the weight equal to $1/\mathrm{A}(\mathrm{E}_e)$. Instead, one should use the acceptance value averaged (integrated) over a wide enough energy interval, which contains the region of non-zero acceptance.

The routine ACET44, which calculates the acceptance for the photoproduction process for different H1 runs is available in the H1UTIL library. The full syntax of this routine is as follows:

ACET44(IRUN,Y,MODE)

This routine can be used both for the analysis of the experimental data and for the Monte Carlo calculation. Presently, the simulation of the ET44 acceptance in H1SIM is not reproduced adequately the essential effects of HERA optics. For this reason it is recomended to stick the following procedure [4] in case of Monte Carlo:

- ignore the simulated ET44 tagger response from H1SIM (as the electron beam optics is not reproduce by H1SIM for the given run);

- in order to describe correctly the acceptance effects use ALL Monte Carlo events with corresponding (run dependent) weight W = ACET44(IRUN,Y,MODE), where Y is a generated y value $(1.-\mathrm{E}_{e'}/\mathrm{E}_e)$ from GKI bank and IRUN - run number for which the simulation is being done. The parameter MODE = 1 is used when the trigger effects (the trigger efficiency of the ET44 trigger element and γ-arm veto condition) are applied and under MODE = 0 these effects are ignored. Note: `etag_44` = `ET44&&!PD_low&&!WatVet`.
- in order to use MC statistics efficiently, one should generate a limited range in (y,Q^2)space. For the ET44 tagger this corresponds to $0.04 \leq y \leq 0.20$, $\mathrm{Q}^2 < 0.01$ GeV^2.

For the real data one should use the average acceptance as it was mentioned above. The y-range, for which the acceptance of the ET44 is valid, is measured from the experimental data. This y-range is $0.04\leq y \leq 0.24$ in 1995. The average acceptance of the ET44 can be calculated as

$$< A >= \frac{\int_{y_{min}}^{y_{max}} F(y)A(y)dy}{\int_{y_{min}}^{y_{max}} F(y)dy}$$

where $F(y)$ - photon flux, $\mathrm{A}(y)$ - acceptance function. And then all the photoproduction events from given run should be weighted with $\mathrm{W} = 1/< A >$. In the analysis of the data it is also recomended to use the $0.04\leq y \leq 0.20$ range for which the acceptance of the ET44 is greater than 1%.

5.4 Systematic error

The first source of the systematic error comes from the determination of the absolute energy scale of the photon arm at low energies and possible non-linearity of this scale. The value of this uncertainty is $\sim$ 4 % which gives $\sim$ 2 % error in the acceptance determination.

The ET44 acceptance for the photoproduction events is strongly dependent on the position of the tagger. This position is known with precision of $\sim$0.5 mm, which gives the uncertainty in the acceptance determination of $\leq$ 5.5%.

Taking into account the trigger efficiency uncertainty, the total systematic error can be estimated as

$$\delta^2 = ({\delta_1}^2 + {\delta_2}^2 + {\delta_3}^2) \leq 6.0\%.$$

6 Conclusions

It has been shown that the new electron calorimeter ET44, introduced in the H1 LUMI system operated properly in 1995.

A succesfully working calibration procedure was developed for this detector.

The acceptance for the photoproduction process is calculated for 1995 data and the H1 database has been updated with a new LET1 banks. The routine ACET44 for acceptance calculation in different run periods was created and put into the H1UTIL library.

The total systematic uncertainty for the acceptance determination for ET44 is estimated ≤ 6.0 % for 1995 data taking.

7 Acknowledgements

I am grateful to S.Levonian for the helpful remarks and discussions. I would like to thank A.Fomenko for supporting this analysis with the energy calibration and I.Sheviakov for providing a well functionning ET44 system. Special thanks are due to A.Fedotov and N.Gogitidze for correcting English. Finally, I express my gratitude to all members of Luminosity group who render assistance in this work.

References

[1] V.Andreev, S.Egli, R.Eichler, S.Levonian, Proposal for new Detectors to Increase the Photon Tagging Acceptance, H1 note, H1-09/94-383 (1994).

[2] H1 collaboration, Experimental Study of Hard Photon Radiation Processes at HERA, DESY 95-024, February 1995.

[3] N.Gogitidze and S.Levonian, An Offline Luminosity Determination for the 1995 H1 e+p Data, H1 note, H1-02/96-471 (1996).

[4] S.Levonian, Help for the e-tagger related analyses,
`http://www-h1.desy.de/~f11lev/QPETAC.html`.

[5] S.Levonian, H1LUMI - A Fast Simulation Package for the H1 Luminosity System, H1 note, H1-04/93-287 (1993).

[6] R.Brinkman, HERA Lattice and Optics Design, DESY HERA 92-07 (1992) 26.

[7] H.Bethe and W.Heitler, Proc. Roy. Soc. A146 (1934) 83.