Comparative analysis of statistical criteria for e/π identification using TRD in the CBM experiment

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Two approaches for charged particles (electron/pion) identification using the TRD detector in the CBM experiment are considered. They are based on the measurements of ionization loss of a charged particle and energy deposition of the X-rays in the n-layered TRD. In the first approach, a method of the likelihood functions ratio is used. The second approach is based on successive application of two statistical criteria: 1) the mean value method, and 2) the ω_n^k test. A comparative analysis of these approaches is presented. The data used in this study are the measurements of energy deposits in one layer TRD prototype obtained during the test-beam in the GSI, February 2006.

Outline

1. Introduction
2. Problem to be solved
3. Method of likelihood functions ratio
4. Combined method for e and π identification
5. Results and discussion
6. Conclusion

1. Introduction

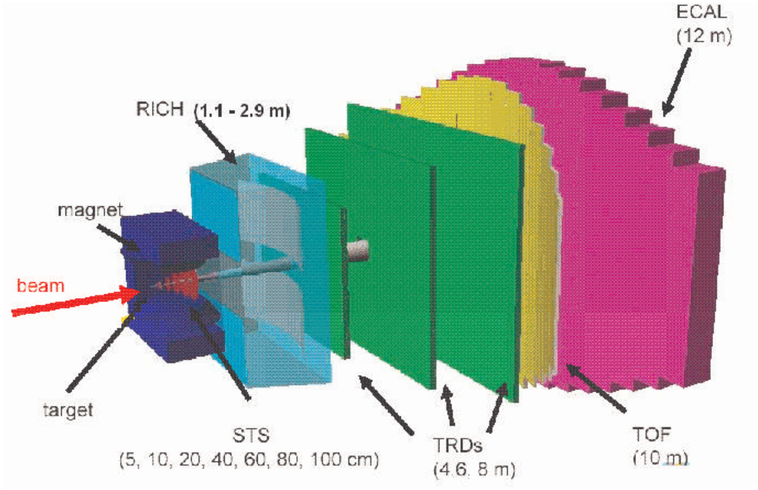

Fig. 1: CBM general layout

Figure 1 depicts a general layout of the CBM experiment. Inside the dipole magnet there is Silicon Tracking System (STS). RICH has to detect electrons. TRD arrays identify electrons with momentum above 1 GeV. TOF provides time-of-flight measurements. ECAL measures electrons, photons and muons.

2. Problem to be solved

The measurement of charmonium is one of the key goals of the CBM experiment. For detecting J/ψ meson in its dielectron decay channel the main task is the e/π separation. A schematic view of the TRD to be used for solution of this problem is shown in Fig. 2.

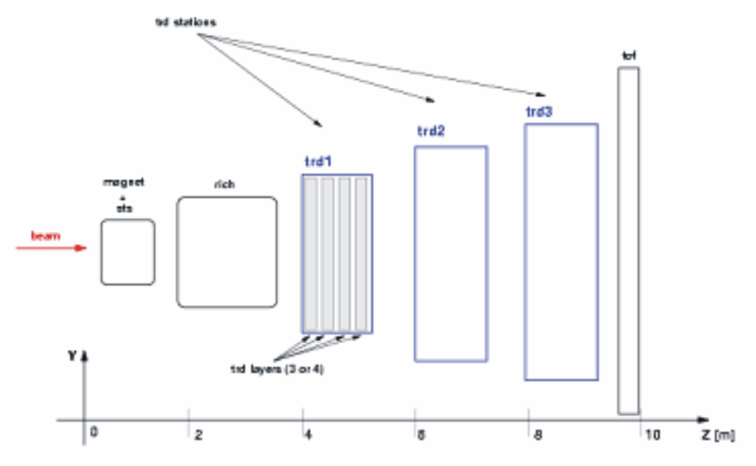

Fig. 2: Schematic view of the TRD

Figure 3 presents the mesurements of dE/dx for π (top plot) and e (bottom plot), including losses on the transition radiation, in the TRD prototype: beamtest in GSI, $p = 1.5$ GeV/c, February 2006.

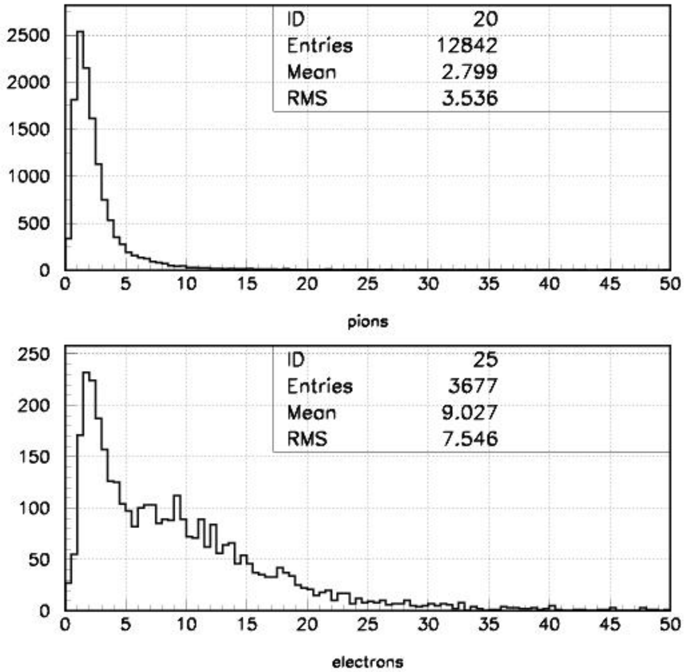

Fig. 3: Distribution of e and π energy losses in the TRD prototype: $p = 1.5$ GeV/c

These measurements have been used for simulation of energy losses by electrons and pions during their passing through n layers of the TRD.

In order to prepare a set of n "measurements" of energy losses corresponding to a particle (e/π) passing through the n-layered TRD, we used the subroutine HISRAN (CERNLIB, V-150) which permits to generate random values in accordance with a given distribution. The distributions related to electrons and pions were supplied in the form of histograms (Fig. 3) using the subroutine HISPRE (once for each histogram).

An uniform random number is generated using RNDM (CERNLIB, V-104). The uniform number is then transformed to the user's distribution using the cumulative probability distribution constructed from the user's histogram. The cumulative distribution is inverted using a binary search for the nearest bin boundary and a linear interpolation within the bin.

3. Method of likelihood functions ratio

While applying the likelihood test to the problem considered, the value

$$L = \frac{P_e}{P_\pi}, \qquad P_e = \prod_{i=1}^{n} p_e(\Delta E_i), \qquad P_\pi = \prod_{i=1}^{n} p_\pi(\Delta E_i), \tag{1}$$

is calculated for each event, where $p_\pi(\Delta E_i)$ is the value of the density function p_π in the case when the pion loses energy ΔE_i in the i-th absorber, and $p_e(\Delta E_i)$ is similar value for electron.

In order to correctly calculate the value of variable L, it is necessary to construct the density functions which must with a high accuracy reproduce the distributions of energy losses of pions and electrons (see Fig. 3).

We have found that the distribution of ionization losses of pions in the TRD prototype is well approximated by a log-normal density function

$$f_1(x) = \frac{A}{\sqrt{2\pi}\sigma x} \exp^{-\frac{1}{2\sigma^2}(\ln x - \mu)^2}, \tag{2}$$

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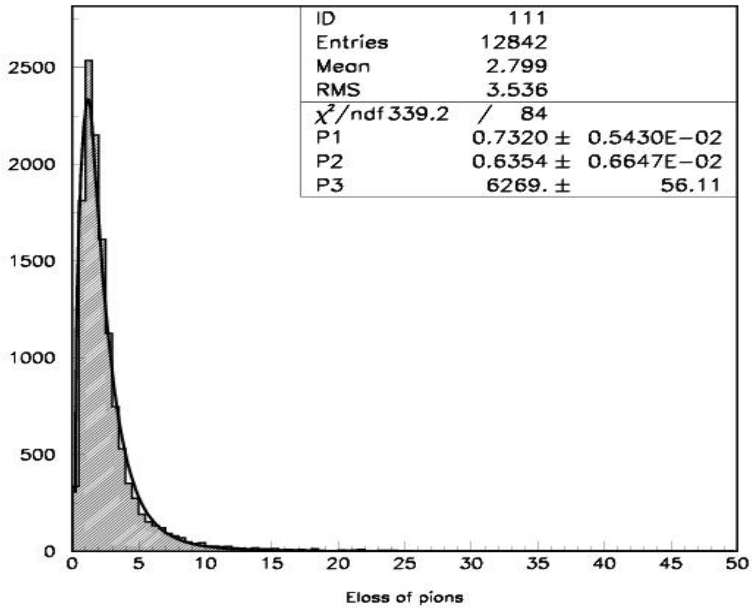

Fig. 4: Approximation of the distribution of pion energy losses in the TRD prototype by a log-normal density function (2)

σ is the dispersion, μ is the mean value, and A is a normalizing factor (see Fig. 4).

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The distribution of energy losses of electrons in the TRD prototype is with a high accuracy approximated by the density function of a weighted sum of two log-normal distributions (see Fig. 5)

$$f_2(x) = B\left(\frac{a}{\sqrt{2\pi}\sigma_1 x}\exp^{-\frac{1}{2\sigma_1^2}(\ln x-\mu_1)^2}+\frac{b}{\sqrt{2\pi}\sigma_2 x}\exp^{-\frac{1}{2\sigma_2^2}(\ln x-\mu_2)^2}\right), \tag{3}$$

where σ_1 and σ_2 are dispersions, μ_1 and μ_2 are mean values, a and $b = 1-a$ are contributions of the first and second log-normal distributions, correspondingly, and B is a normalizing factor.

The distributions of the variable L in cases when only pions (top left plot) or electrons pass through the TRD detector with n layers (top right plot); the bottom plot shows the summary distribution for both particles.

The efficiency of electrons registration is determined by the ratio of electrons selected in the admissible region for the preassigned significance level α (first order error) to part β of pions having hit in the admissible region (second order error).

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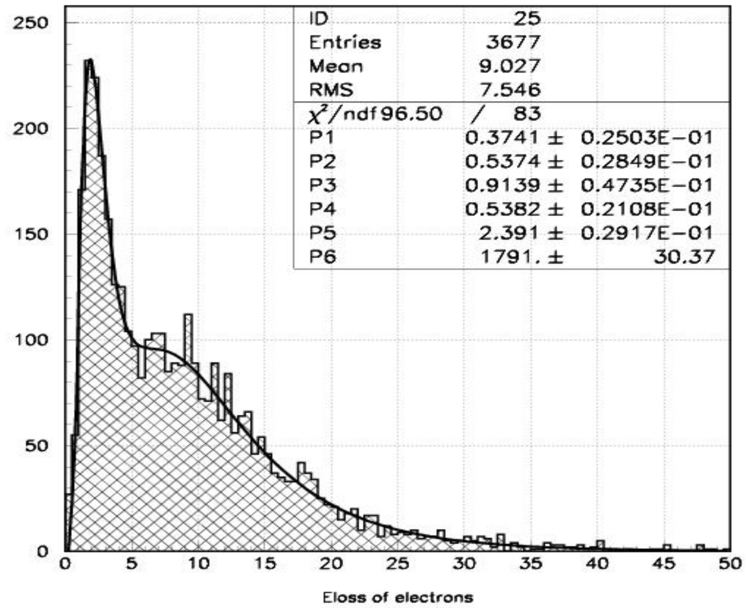

Fig. 5: Approximation of the distribution of electron energy losses in the TRD prototype by a weighted sum of two log-normal distributions

In our case α value was set equal to 10 %. In particular, the critical value $L_{cr} = 0.00035$ corresponds to the significance level $\alpha = 10.24$ %, thus, in the admissable region there will remain 89.76 % of electrons. In this

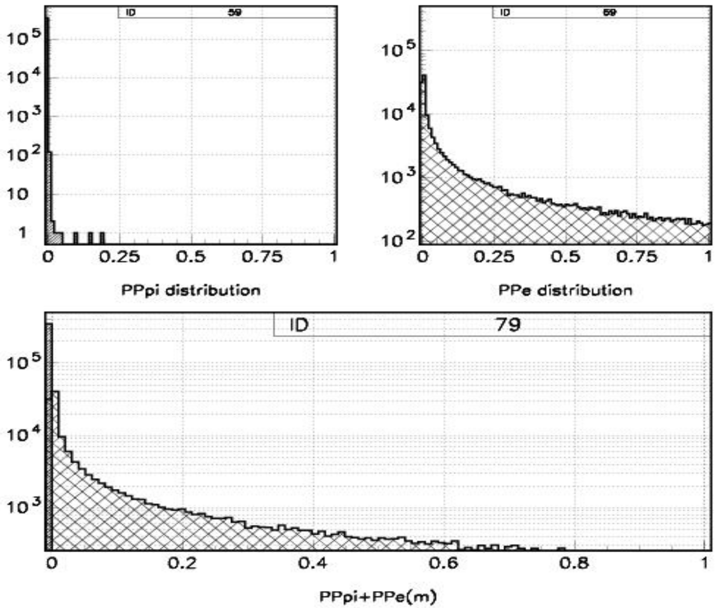

Fig. 6: Distributions of L in cases when only pions (top left plot) or only electrons (top right plot) pass through the TRD detector with $n = 12$ layers; the bottom plot is the summary distribution for both particles

case, the second order error $\beta = 0.0274\,\%$. The suppression factor of pions, which equals to $100/\beta$, will make up 3646.

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The expression (1) could be transformed to a more convenient, from a practical point of view point, form

$$L_m = \frac{P_e}{P_e + P_\pi}, \tag{4}$$

because the variable L_m changes in bounds [0,1] (see Fig. 7).

In this case, the characteristics of the modified criterion for the chosen critical value L_{cr} remain unchanged.

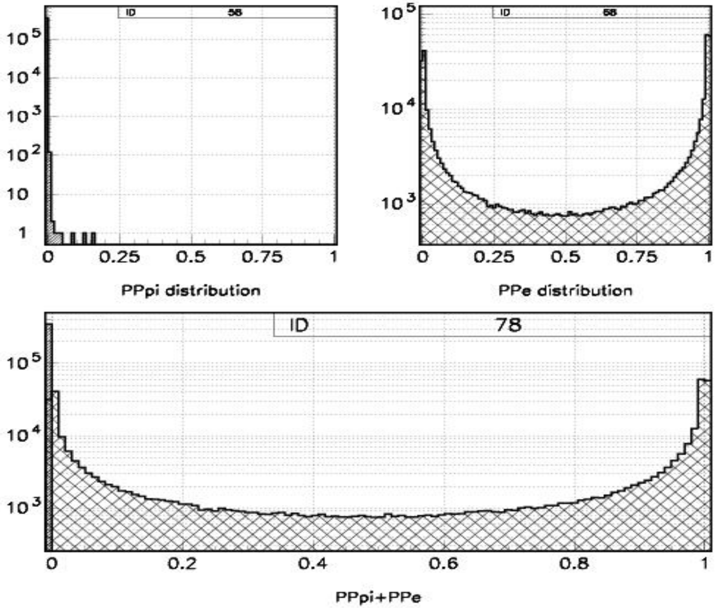

Fig. 7: Distributions of L_m in cases when only pions (top left plot) or only electrons (top right plot) pass through the TRD detector with $n = 12$ layers; the bottom plot is the summary distribution for both particles

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4. Combined method for e and π identification

Second approach is based on successive application of two statistical criteria: 1) the mean value method, and 2) the ω_n^k test.

In the mean value method a variable value is calculated:

$$\overline{\Delta E} = \frac{1}{n}\sum_{i=1}^{n} \Delta E_i, \tag{5}$$

where n is the number of layers in the TRD.

Figure 8 shows the distributions of variable $\overline{\Delta E}$ for electrons (left top plot), pions (right top plot), and the summary distribution for electrons and pions (bottom plot).

It is clearly seen that the distribution corresponding to pions is quite well separated from the electron distribution. If we set the critical value $\overline{\Delta E}_{cr} = 6.3$, then there will remain 90.62 % of electrons in the admissible region, and the second order error will form 0.055 %, and the factor of

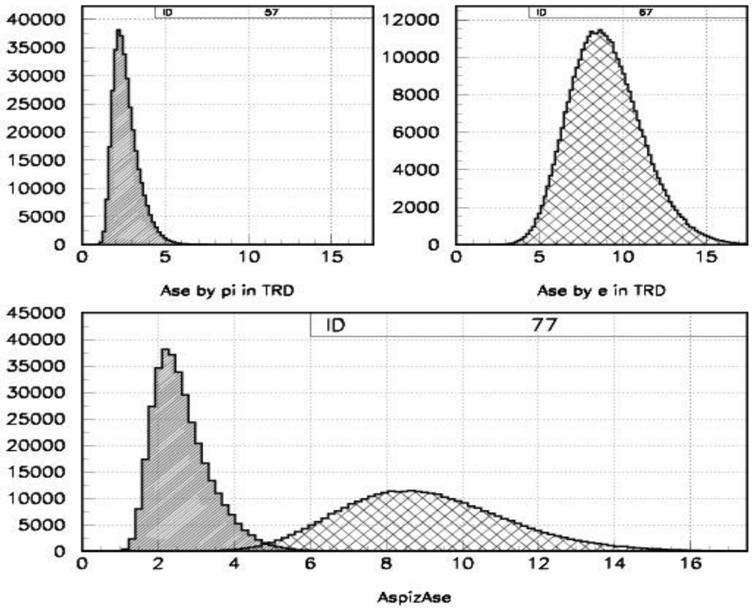

Fig. 8: Distributions of variable $\overline{\Delta E}$ for electrons (left top plot), pions (right top plot); summary distribution (bottom plot)

pions suppression will constitute 1833.

The result could be significantly improved, if we apply to the events selected in the admissible region the ω_n^k test.

This test is based on the comparison of the distribution function $F(x)$ corresponding to a preassigned hypothesis (H_0) with empirical distribution function $S_n(x)$:

$$S_n(x) = \begin{cases} 0, & \text{if } x < x_1; \\ i/n, & \text{if } x_i \le x \le x_{i+1}, \quad i = 1, \dots, n-1. \\ 1, & \text{if } x_n \le x, \end{cases} \tag{6}$$

Here $x_1 \le x_2 \le \ldots \le x_n$ is the ordered sample (*variational series*) of size n constructed on the basis of observations of variable x.

The testing statistics is a measure of "distance" between $F(x)$ and $S_n(x)$. Such statistics are known as *non-parametric*. We suggested and investigated a new class of non-parametric statistics

$$\omega_n^k = -\frac{n^{\frac{k}{2}}}{k+1} \sum_{i=1}^{n} \left\{ \left[\frac{i-1}{n} - F(x_i) \right]^{k+1} - \left[\frac{i}{n} - F(x_i) \right]^{k+1} \right\}. \tag{7}$$

The goodness-of-fit criteria constructed on the basis of these statistics are usually applied for testing the correspondence of each sample to the distribution known *apriori*.

On the basis of the ω_n^k test we developed a method for analysis of multidimensional events:

1. The sample to be analyzed is transformed ("normalized") so that the contribution of the pion distribution is described by the distribution function $F_b(x)$.
2. Each sample, composed of the values pertaining to the transformed distribution, is tested with the ω_n^k goodness-of-fit criterion for correspondence to the $F_b(x)$ hypothesis. In this process the abnormal events, which do not comply with H_0, correspond to large absolute values of the ω_n^k-statistic, resulting in their clustering in the critical region.

Energy losses for π have a form of Landau distribution. We use it as H_0

to transform the initial measurements to a set of variable λ:

$$\lambda_i = \frac{\Delta E_i - \Delta E^i_{mp}}{\xi_i} - 0.225, \qquad \text{i} = 1,2,\dots,\text{n}, \tag{8}$$

ΔE_i – energy loss in the i-th absorber, ΔE^i_{mp} – the value of most probable energy loss, $\xi_i = \frac{1}{4.02}$ FWHM of distribution of energy losses for π.

In order to determine the value of most probable energy loss ΔE^i_{mp} and the value FWHM of distribution of energy losses by π in the i-th absorber, the indicated distribution was approximated by the density function of a log-normal distribution (see Fig. 4).

The obtained λ_i, $i = 1, ..., n$ are ordered due to their values (λ_j, $j = 1, ..., n$) and used for calculation of ω^k_n:

$$\omega^k_n = -\frac{n^{\frac{k}{2}}}{k+1} \sum_{j=1}^{n} \left\{ \left[\frac{j-1}{n} - \phi(\lambda_j)\right]^{k+1} - \left[\frac{j}{n} - \phi(\lambda_j)\right]^{k+1} \right\}. \tag{9}$$

Here the values of Landau distribution function $\phi(\lambda)$ are calculated using the DSTLAN function (from the CERNLIB library).

Figure 9 shows the distributions of ω_{12}^{8} values for π (top left plot) and e (top right plot); the summary distribution is shown in the bottom plot.

Figure 10 shows the cumulative probability $F(y_t) = P_r(y < y_t)$ for events corresponding to pions, and the dependence $1 - F(y_t)$ for events caused by electrons; the summary dependence for pions and electrons is presented in the bottom plot.

The dependences 10 permit us to choose the critical limit approximately corresponding to the 10 % significance level. For instance, if we set the critical value $\omega(k,n)_{cr} = 1.5$, then there will remain 89.44 % in the admissible region, and the second order error will form 0.02857 %. Thus, the factor of pions suppression will constitute 3500.

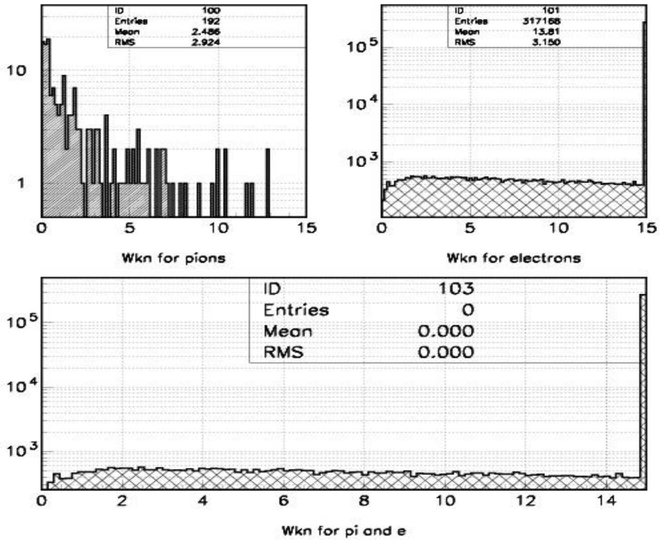

Fig. 9: Distributions of ω^8_{12} values for π (top left plot) and for e (top right plot) events; the summary distribution for π and e events (bottom plot)

5. Results and discussion

Table 1 shows the results of comparison of the given methods: α is part of lost electrons, β is the fraction of pions identified as electrons, pion

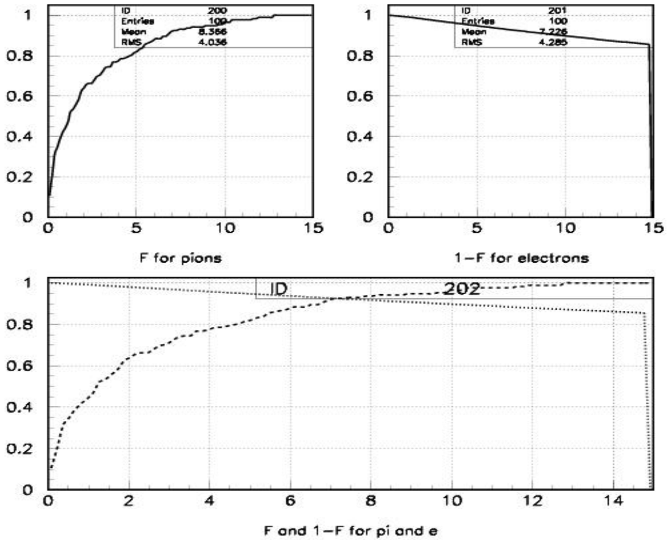

Fig. 10: The accumulated probability $F(y_t) = P_r(y < y_t)$ for π (top left plot), and the dependence $1 - F(y_t)$ for e (top right plot) events; the summary dependence for π and e (bottom plot)

suppression factor equals $100/\beta$.

The results presented in Table 1 demonstrate that under the condition of loss approximately of 1 % of electrons the application of the ω_n^k test

Таблица 1: Comparison of the given methods

method	$\alpha, \%$	$\beta, \%$	suppression of pions
likelihood	10.24	0.0274	3646
mean value	9.38	0.055	1833
mean value + ω_n^k	10.54	0.02857	3500

to the events selected in the admissible region we succeeded in almost two times pions suppression. Thus, we have achieved the result which is very close to the limit result reached by the likelihood test.

6. Conclusion

Two different approaches of electron/pion identification using ionization losses and transition radiation in the CBM TRD with n layers are presented: 1) method of likelihood functions ratio, and 2) combined approach based on the mean value method and the ω_n^k test.

The data used for this study were the measurements of energy deposits in one layer TRD prototype during the test beam in the GSI, February 2006. These measurements have been used for simulation of energy losses by electrons and pions in the TRD with $n = 12$ layers.

The application of the likelihood test requires the density functions of energy losses for both particles: pions and electrons. Our analysis of experimental data has shown that the distribution of energy losses for pions is well approximated by the lognormal function, and for electrons – by the weighted sum of two lognormal distributions. This provided a possibility to correctly calculate the values of likelihood functions for pions and electrons and to estimate the efficiency of this test – for the

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significance level $\alpha = 10.24\,\%$ the factor of pions suppression constituted 3646.

The likelihood functions ratio test could be related to Neiman-Pirson criterion which is the most powerful criterion for testing the hypothesis H_0 (in our case, the distribution of electrons) against the hypothesis H_1 (the distribution of pions). Therefore, for the given significance level $\alpha = 10.24\,\%$ the value of $\beta = 0.0274\,\%$ could be considered as minimally possible (which corresponds to the maximum factor of pions suppression).

The bottleneck of this method is that the distribution of energy losses for electrons is dependent on their momenta. At the same time the distribution of pions energy losses is weakly changing.

The second approach does not run into this issue, because for application of the ω_n^k-test, it is necessary to know only the distribution of pion energy losses. This combined approach is simpler from practical application point of view, and, as it has been demonstrated, it may provide the power close to limit value – for the significance level $\alpha = 10.54\,\%$ the value $\beta = 0.02857\,\%$, which corresponds to the factor of pions suppression equal to 3500.

Distributions of energy losses for electrons and pions in the CBM TRD

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The distributions of energy losses for e and π in the TRD detector of the CBM experiment are considered. We analyze the energy deposits in one-layer TRD prototype obtained during the test-beam in the GSI (Darmstadt, February 2006) and Monte Carlo simulations for the n-layered TRD. We show that 1) energy losses both for real measurements and GEANT simulations are approximated with a high accuracy by a log-normal distribution for π and by a weighted sum of two lognormal distributions for e, 2) GEANT simulations noticeably differ from real measurements and, as a result, we have a significant lose in the efficiency of the e/π identification. A procedure to control and correct the process of the energy deposit of e in the TRD is proposed.

Outline

1. Introduction
2. Main goals of this study
3. Energy losses for e and π in one layer of the TRD
4. Efficiency of e and π identification for real measurements and GEANT simulations
5. Results and discussion
6. Conclusion

1. Introduction

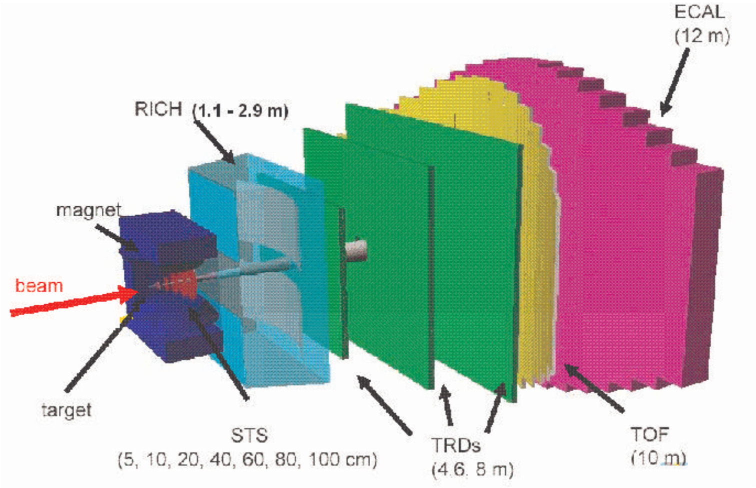

Figure 1: CBM general layout

Figure 1 depicts a general layout of the CBM experiment. Inside the dipole magnet there is Silicon Tracking System (STS): charged particle trajectory reconstruction and momentum restoration. RICH has to detect e. TRD arrays identify e with momentum >1 GeV. TOF provides time-of-flight measurements. ECAL measures e, γ and μ.

2. Main goals of this study

The measurement of charmonium is one of the key goals of the CBM experiment. For detecting J/ψ meson in its dielectron decay channel the main task is the e/π separation. A schematic view of the TRD to be used for solution of this problem is shown in Fig. 2.

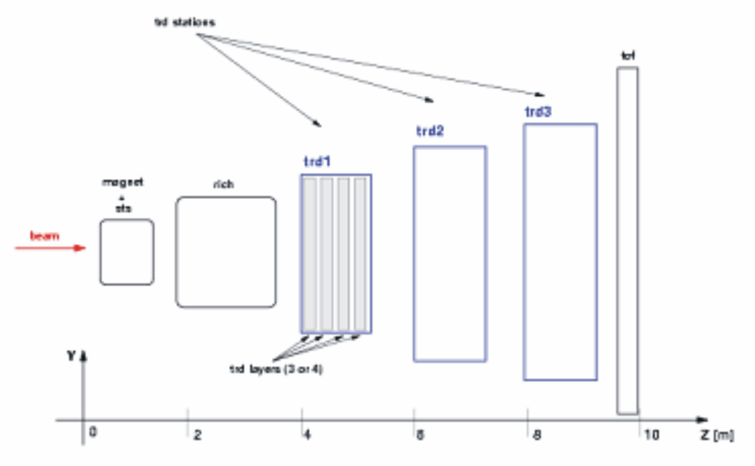

Figure 2: Schematic view of the TRD

First goal of this study is to estimate an optimal number of layers in the TRD geometry which may provide the needed levels of e identification and π suppression. In this connection, we analyze in details the distributions of energy losses for e and π in one layer of the TRD.

Another goal is to develop a procedure that may permit to control and correct the Monte Carlo simulation of the energy deposit by e in the TRD layers realized in frames of the CBM ROOT.

In our studies we use both real measurements from the TRD prototype and GEANT3 simulations of the TRD realized in frames of the CBM ROOT.

3. Energy losses for e and π in one layer of the TRD

TRD prototype

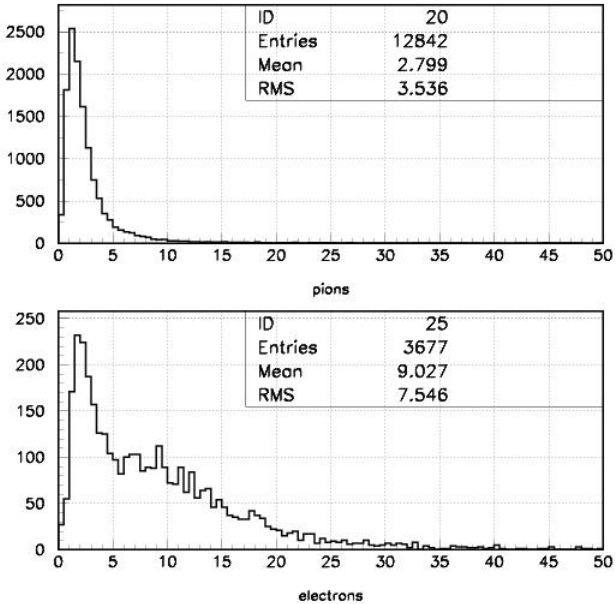

Figure 3: Distribution of dE/dx for π (top plot) and e (bottom plot), including losses on the transition radiation, in the TRD prototype: beam-test in GSI, p = 1.5 GeV/c, February 2006

We found that the distribution of dE/dx (ionization loss) for π in the TRD prototype is quite well approximated by a log-normal function

$$f_1(x) = \frac{A}{\sqrt{2\pi}\sigma x} \exp^{-\frac{1}{2\sigma^2}(\ln x - \mu)^2}, \tag{1}$$

σ is the dispersion, μ is the mean value, and A is a normalizing factor (see Fig. 4).

Moreover, the distribution of energy losses of electrons (ionization and transition radiation) is approximated with a high accuracy by a weighted sum of two log-normal distributions (see Fig. 5),

$$f_2(x) = B\left(\frac{a}{\sqrt{2\pi}\sigma_1 x} \exp^{-\frac{1}{2\sigma_1^2}(\ln x - \mu_1)^2} + \frac{b}{\sqrt{2\pi}\sigma_2 x} \exp^{-\frac{1}{2\sigma_2^2}(\ln x - \mu_2)^2}\right), \tag{2}$$

where σ_1 and σ_2 are dispersions, μ_1 and μ_2 are mean values, a and $b = 1 - a$ are the contributions of the first and second log-normal distributions, correspondingly, and B is a normalizing factor.

TRD prototype

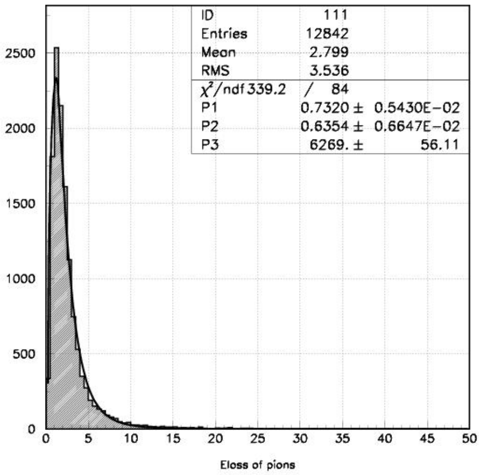

Figure 4: Approximation of the distribution of pion energy losses in the TRD prototype by a log-normal function (1)

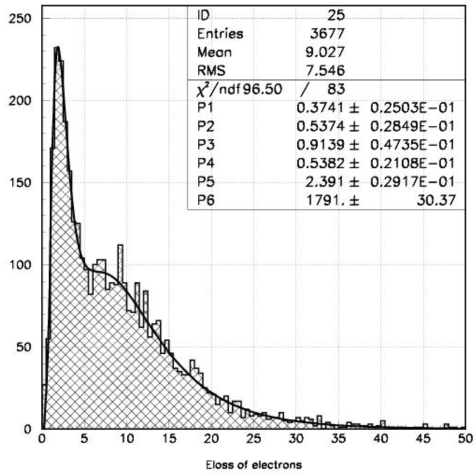

Figure 5: Approximation of the distribution of electron energy losses in the TRD prototype by a weighted sum of two log-normal functions (2)

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TRD prototype

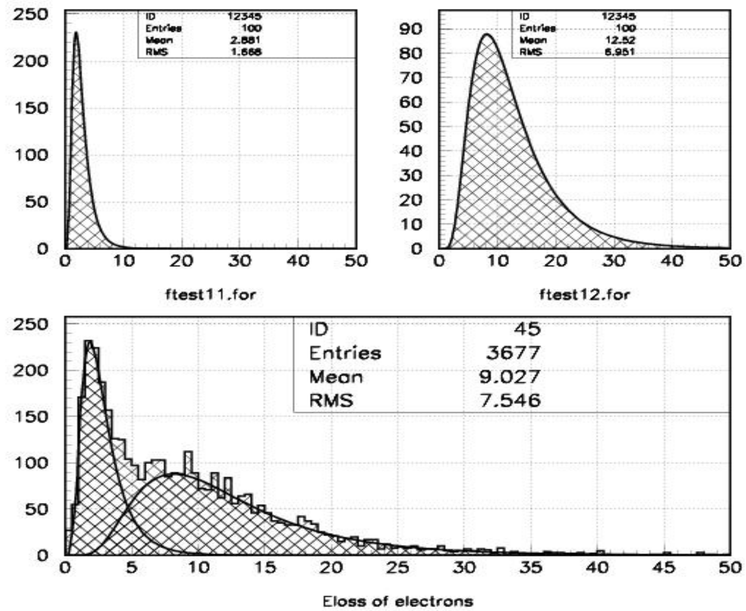

Figure 6: Approximation of the distribution of energy losses for electrons in the TRD prototype by a weighted sum of two log-normal distributions (bottom plot): contributions of dE/dx (top left plot) and transition radiation (top right plot)

The value of contribution of the ionization losses – the coefficient a_e in the expression (2) – consists of 0.3741, and the contribution of energy loss on the transition radiation – the coefficient b_e in the expression (2) – is equal to 0.6259. At the same time, the mean value of ionization losses for electrons is close to what we have for pions (see Fig. 4), the root mean squared (RMS) is approximately two times less.

Second set of data includes GEANT3 simulations for pions and electrons with momenta $1 \div 2$ GeV/c passing through the CBM TRD. Figures 7 and 8 show the distributions of energy losses of pions (top plot) and electrons (bottom plot) in one layer of the TRD for GEANT simulations in March'07 and July'07.

GEANT simulations (March'07 data)

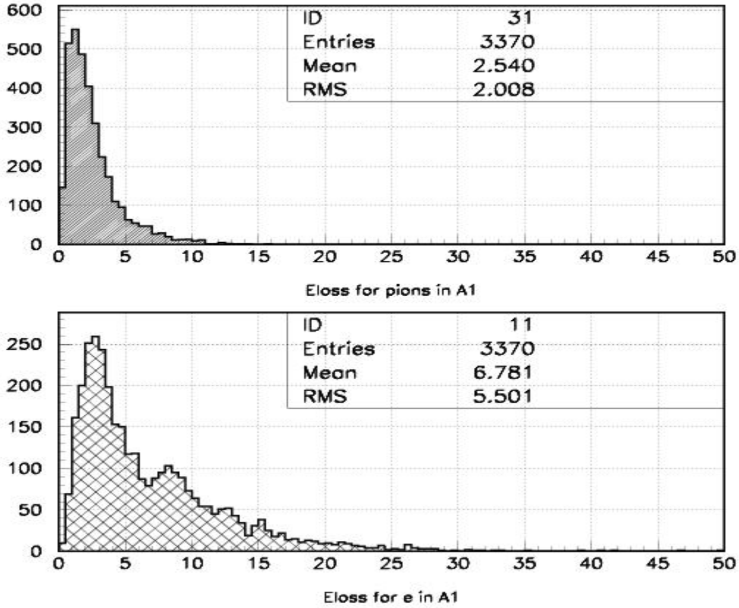

Figure 7: Distributions of energy losses for pions (top plot) and electrons (bottom plot) in one layer of the TRD using the GEANT3 simulations for pions and electrons with momenta $1 \div 2$ GeV/c

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GEANT simulations (July'07 data)

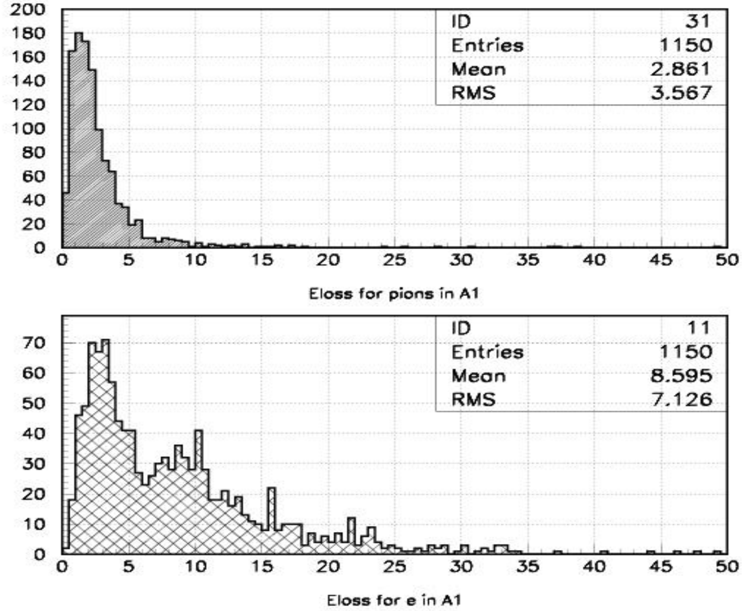

Figure 8: Distributions of energy losses for pions (top plot) and electrons (bottom plot) in one layer of the TRD using the GEANT3 simulations for pions and electrons with momenta $1 \div 2$ GeV/c

The comparision of distributions of energy losses in the TRD prototype (Fig. 3) with first set of GEANT simulations (March'07 data) (Fig. 7) shows that for both pions and electrons the main statistical characteristics (mean value and RMS) are significantly different. This distinction is noticeable especially strong for electron distributions: compare mean values and RMS. At the same time, the mean value and RMS for July'07 data (Fig. 8) quite well follow real data.

The results of the comparison are presented in Table 1.

Table 1: Comparison of mean value (m.v.) and RMS of energy deposit distributions for real measurements and GEANT simulations

type of data	m.v. (e)	RMS (e)	m.v. (π)	RMS (π)
real data	9.027	7.546	2.799	3.536
GEANT (March'07)	6.781	5.501	2.540	2.008
GEANT (July'07)	8.595	7.126	2.861	3.567

The distributions of GEANT simulations are also quite well approximated by log-normal distributions: see Figures 9, 10 and Figures 11, 12.

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GEANT simulations (March'07 data)

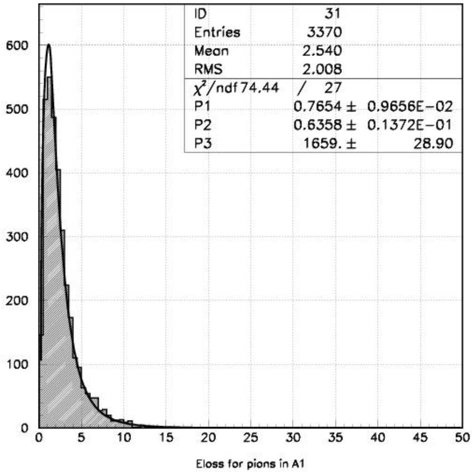

Figure 9: Approximation of the distribution of pion energy losses in one layer of the TRD by a log-normal function (1)

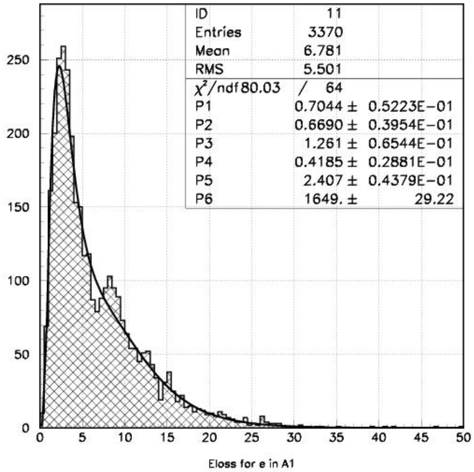

Figure 10: Approximation of the distribution of electron energy losses in one layer of the TRD by a weighted sum of two log-normal functions (2)

GEANT simulations (July'07 data)

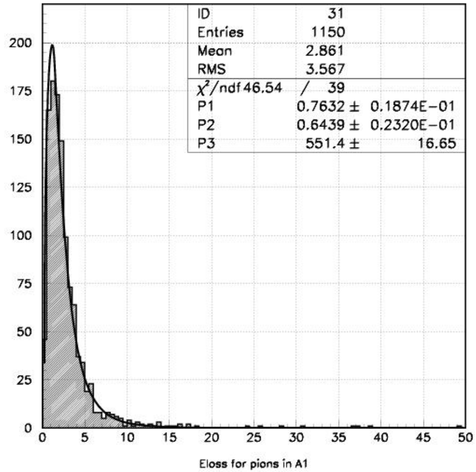

Figure 11: Approximation of the distribution of pion energy losses in one layer of the TRD by a log-normal function (1)

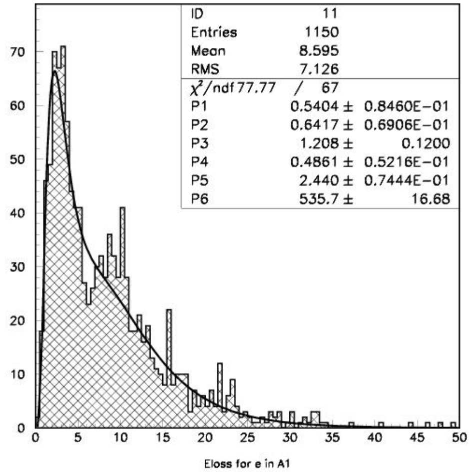

Figure 12: Approximation of the distribution of electron energy losses in one layer of the TRD by a weighted sum of two log-normal functions (2)

Figures 10 and 12 show that the contribution of ionization losses a_s take up 0.7044 for March'07 data and 0.5404 for July'07 data which is approximately two times larger compared to real measurements – $a_e = 0.3741$. Parts of the losses on the transition radiation b_s equal to 0.2956 (March07) and 0.4596 (July'07), which are significantly less compared to real measurements – $b_e = 0.6259$. Furthermore, the mean value for ionization losses of electrons significantly differs from the value obtained for pions (see Table 1 and Figures 13 and 14).

The results of this analysis demonstrate that the simulation of energy losses for electrons in the TRD with the help of the GEANT code does not fit real measurements obtained during the beam-test in the GSI on the TRD prototype.

GEANT simulations (March'07)

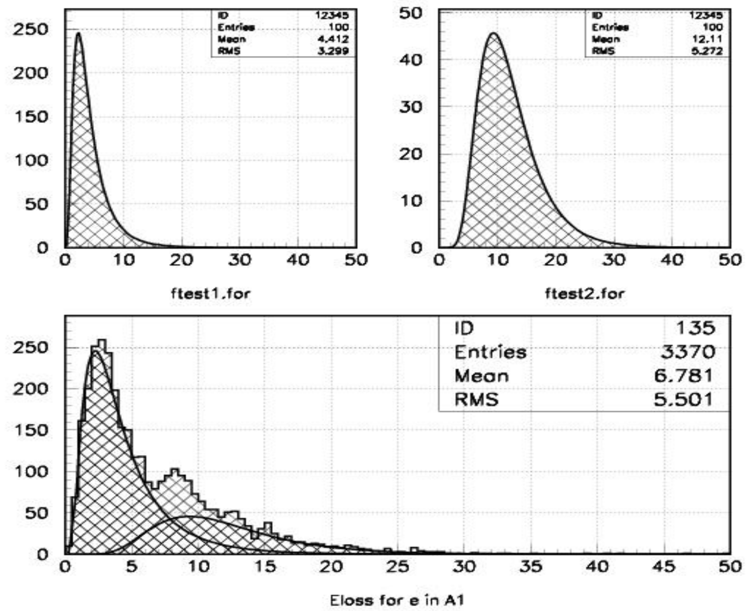

Figure 13: Approximation of distribution of the electron energy deposit in one layer of the TRD by a weighted sum of two log-normal distributions (bottom plot): contributions of dE/dx (top left plot) and transition radiation (top right plot)

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GEANT simulations (July'07)

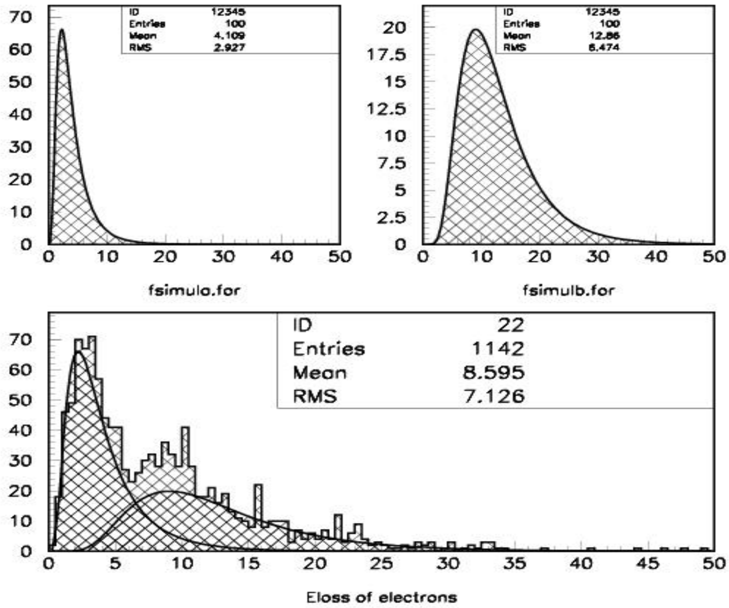

Figure 14: Approximation of distribution of the electron energy deposit in one layer of the TRD by a weighted sum of two log-normal distributions (bottom plot): contributions of dE/dx (top left plot) and transition radiation (top right plot)

4. Efficiency of e/π identification for real measurements and GEANT simulations

The problem of e/π identification using n-layered TRD consists in the following: having a set of n measurements of energy losses from n layers of the TRD, one has to determine, to what distribution (e or π) are relative the energy losses of the particle registered by the TRD.

For real measurements we have in our responsibility only energy deposits in one-layer TRD prototype. To prepare a set of n "measurements" of energy losses corresponding to e/π passing through the n-layered TRD, we use a subroutine HISRAN (CERNLib) that allows to generate n random values in accordance with a given distribution. The distributions related to e and π were supplied in the form of histograms (Fig. 3).

To estimate the efficiency of e/π identification we use a method of ratio of likelihood functions, which is the most powerful criterion for testing the null-hypothesis H_0 (in our case, the distribution of electrons) against the alternative hypothesis H_1 (the distribution of pions).

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Therefore, for a given significance level α (amount of lost e) the value of β (amount of π identified as e) could be considered as minimally possible. In our case, this corresponds to the maximum factor of pions suppression.

While applying the likelihood test to our problem under, the value

$$L = \frac{P_e}{P_e + P_\pi}, \qquad P_e = \prod_{i=1}^{n} p_e(\Delta E_i), \qquad P_\pi = \prod_{i=1}^{n} p_\pi(\Delta E_i), \quad (3)$$

is calculated for each event, where $p_\pi(\Delta E_i)$ is the value of the density function p_π (1) in the case when the pion loses energy ΔE_i in the i-th absorber, and $p_e(\Delta E_i)$ is a similar value for electron with the density function p_e (2).

Figure 15 shows the distributions of the variable L in cases when only pions (top left plot) or only electrons (top right plot) pass through the TRD with n layers; the bottom plot shows the summary distribution for both particles.

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TRD prototype

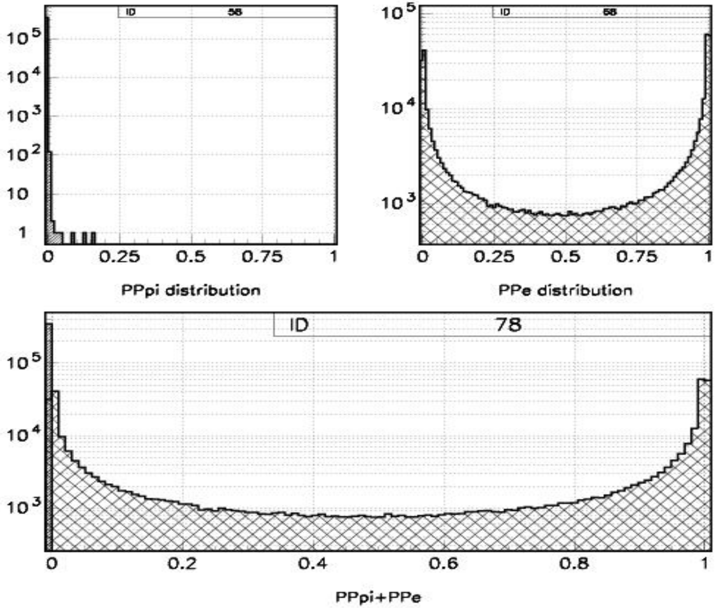

Figure 15: Distributions (for data sets based on real measurements) of L in cases when only pions (top left plot) or only electrons (top right plot) pass through the TRD detector with $n = 12$ layers; the bottom plot is the summary distribution for both particles

The efficiency of registering electrons is determined by the ratio of the electrons selected in the admissible region for the preassigned significance level α (first-order error) to part β of pions having hit in the admissible region (second-order error).

In our case α value was set approximately equal to 10 %. In particular, the critical value $L_{cr} = 0.00035$ corresponds to the significance level α $= 10.24\,\%$, thus, in the admissable region there will remain 89.76 % of electrons. In this case, $\beta = 0.0274\,\%$. Thus, the suppression factor of pions that is equal to $100/\beta$, will make up 3646.

The distributions of the variable L for the data sets based on GEANT simulations are shown in Figures 16 (March'07) and 17 (July'07).

GEANT simulations (March'07 data)

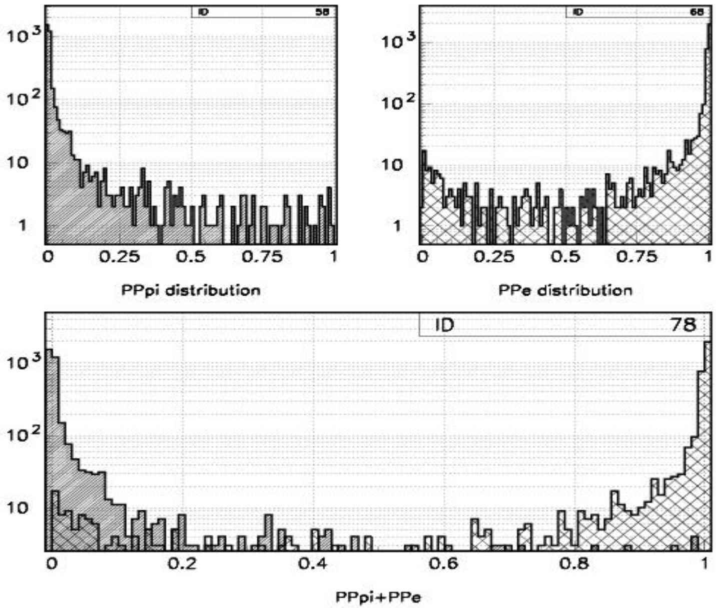

Figure 16: Distributions of L (for the data set based on GEANT simulations) in cases when only pions (top left plot) or only electrons (top right plot) pass through the TRD detector with $n = 12$ layers; the bottom plot is the summary distribution for both particles

GEANT simulations (July'07 data)

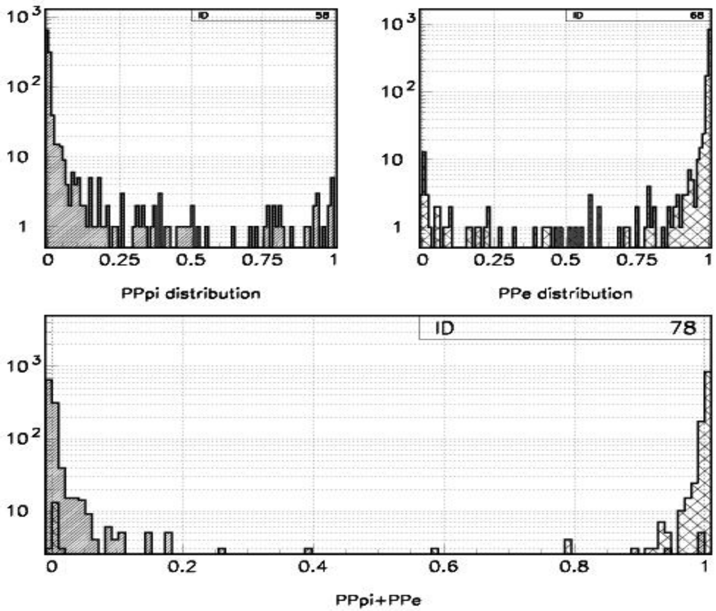

Figure 17: Distributions of L (for the data set based on GEANT simulations) in cases when only pions (top left plot) or only electrons (top right plot) pass through the TRD detector with $n = 12$ layers; the bottom plot is the summary distribution for both particles

For March'07 data the critical value $L_{cr} = 0.91$ corresponds to the significance level $\alpha = 9.97\,\%$, thus, in the admissable region there will remain 90.03 % of electrons. In this case, $\beta = 0.3561\,\%$, and the suppression factor of pions will make up 281.

For July'07 data the critical value $L_{cr} = 0.975$ corresponds to the significance level $\alpha = 10\,\%$, thus, in the admissable region there will remain 90 % of electrons. In this case, $\beta = 0.6087\,\%$, and the suppression factor of pions will make up 164.

Thus, we may conclude that the noticable difference in the distributions of energy losses of pions and electrons for the GEANT simulations compared to real measurements brought to the reduction of the pion suppression factor more than by the order of magnitude.

5. Results and discussion

The found form of the density function (2), which with a high accuracy fits the distribution of energy losses of electrons in one layer of the TRD, permits

- to decompose the result of energy losses of e on two independent physical processes: 1) the dE/dx process, and 2) the process related to the transition radiation;
- to control and correct the simulation of energy losses in the TRD in frames of the CBM ROOT (GEANT).

In Table 2 we present the factors of π suppression against the number n of layers in the TRD. These results demonstrate that under the condition of loss $\approx$ 10 % of e, it is possible to achieve a reliable level of π suppression already for n=8 (suppression factor 206 for real measurements). Approximately the same level of pion suppression for GEANT simulations is achieved only for n=11 (March'07) and n=12 (July'07).

Table 2: Factor of pion suppression against the number n of layers in the TRD

type of data set	n=8	n=9	n=10	n=11	n=12
prototype	206	384	843	1872	3646
GEANT (March'07)	50	77	135	198	281
GEANT (July'07)	46	77	144	164	164

6. Conclusion

Our analysis of e and π energy losses in the CBM TRD has demonstrated that

- energy losses both for real measurements and GEANT simulations are approximated with a high accuracy by a log-normal function for pions and by a weighted sum of two lognormal functions for electrons,
- GEANT simulations noticeably differ from real measurements and, as a result, we significantly lose in the efficiency of the electron identification and pion suppression.

We also demonstrate that under the condition of approximately 10 % loss of electrons, it is possible to reach a reliable level of pion suppression already for n=8.

The found form of density function for electrons permits to correctly decompose the energy losses of electrons on two independent processes:

- the dE/dx process, and
- a process related to the transition radiation.

This allows one to control and correct the process of simulating the energy losses in the GEANT package in frames of the CBM ROOT.