On Distribution of e/π Energy Losses in the CBM TRD

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Abstract

The distributions of e/π energy losses both for real measurements and GEANT simulations in the CBM TRD are analyzed and compared.

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 Transition Radiation Detector (TRD) to be used for solution of this problem is shown in Fig. 1.

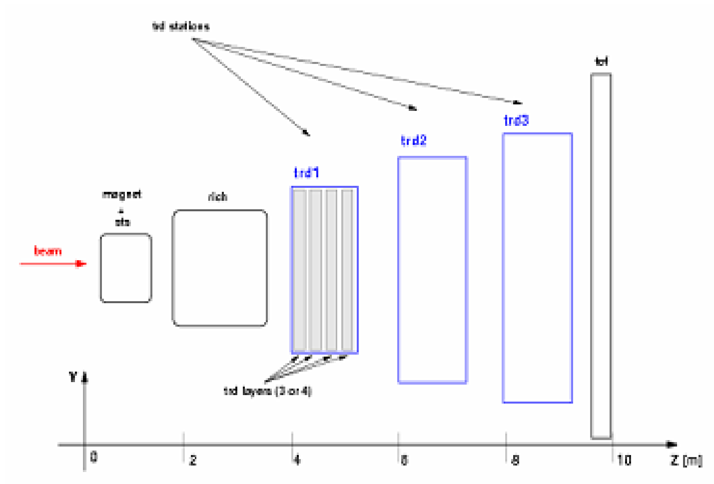

Figure 1: Schematic view of the n-layered TRD

In order to optimize the TRD geometry and estimate an optimal number n of layers, we analyze here the distributions of energy losses of e and π in the TRD. We use both real measurements obtained with the help of a one-layer TRD prototype (see Figures 2 and 3: beam-test in GSI, $p = 1.5$ GeV/c, February 2006) and GEANT simulations of the TRD realized in frames of the CBM ROOT.

We have found [1] that the distribution of pion ionization losses in the TRD prototype is quite well approximated by a log-normal function (Fig. 2)

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

σ is the dispersion, μ is the mean value, A is a normalizing factor. And the distribution of energy losses of e (ionization and transition radiation) is approximated with a high accuracy by a weighted sum of two log-normal distributions [1] (Fig. 3)

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

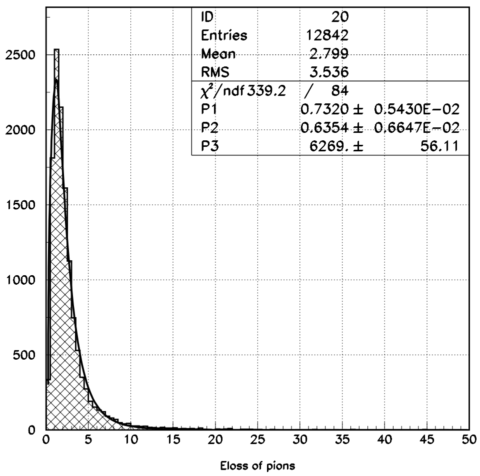

Figure 2: The distribution of pion energy losses in the TRD prototype and its approximation of the by a log-normal function (1)

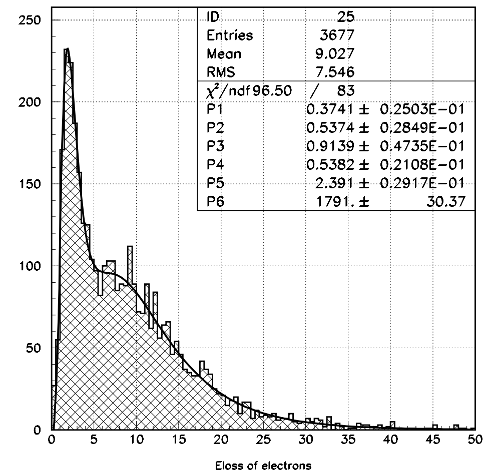

Figure 3: The distribution of electron energy losses in the TRD prototype and its approximation of the by a weighted sum of two log-normal functions (2)

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.

Such an approximation of the distribution of electron energy losses permits to extract individual contributions of ionization losses and energy losses on transition radiation.

The value of contribution of the ionization losses – the coefficient a_{exp} in the expression (2) – consists of 0.3741 (see parameter P1 in Fig. 3), and the contribution of energy losses on the transition radiation – the coefficient b_{exp} 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. 2), the root mean squared (RMS) [2] is approximately two times less.

As second set of data includes GEANT3 simulations for pions and electrons with momenta $1 \div 2$ GeV/c passing through the CBM TRD: see Figures 4 and 5 (March'07), and Figures 6 and 7 (July'07).

The comparision of distributions of energy losses in the TRD prototype with the first set of GEANT simulation 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 the mean value and RMS. At the same time, the mean value and RMS for second set of GEANT data quite well follow real data. The results of the comparison are presented in Table 1.

The distributions of GEANT simulations are also quite well approximated by log-normal distributions: see Figures 4 and 5 (March'07), and Figures 6 and 7 (July'07).

Figures 5 and 7 show that the contribution of ionization losses a_{sim} take up 0.7044 (March'07) and 0.5404 (July'07) which is approximately two times larger as compared to real measurements – $a_{exp} = 0.3741$. Parts of the losses on the transition radiation b_{sim} equal to 0.2956 (March07) and 0.4596 (July'07), which are significantly less compared to real measurements – $b_{exp} = 0.6259$.

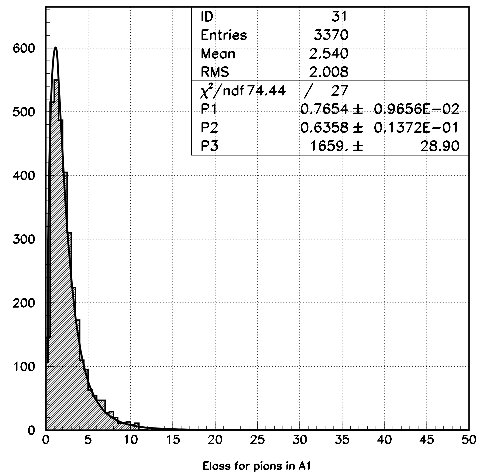

Figure 4: The distribution of pion energy losses in one layer of the TRD (GEANT simulation: March'07) and its approximation of by a log-normal function (1)

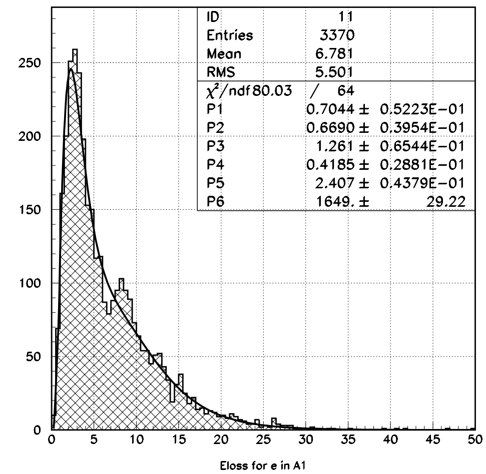

Figure 5: The distribution of electron energy losses in one layer of the TRD (GEANT simulation: March'07) and its approximation of by a weighted sum of two log-normal functions (2)

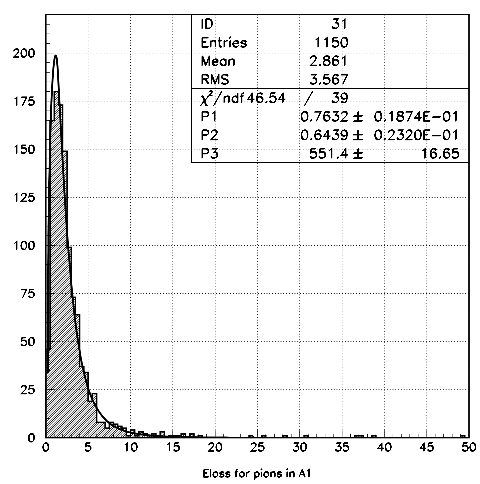

Figure 6: The distribution of pion energy losses in one layer of the TRD (GEANT simulation: July'07) and its approximation by a log-normal function (1)

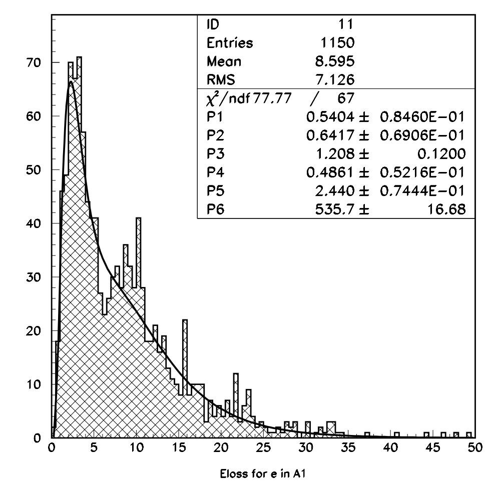

Figure 7: The distribution of electron energy losses in one layer of the TRD (GEANT simulation: July'07) and its approximation of by a weighted sum of two log-normal functions (2)

The results of this analysis demonstrate that the simulation of the energy losses for electrons in the TRD with the help of the CBM GEANT does not fit with real measurements obtained on the TRD prototype.

The problem of e/π identification using n-layered TRD consists in the following:

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

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 these energy losses.

For real measurements we have only data obtained from one-layer of the TRD prototype. To prepare a set of n "measurements", we use a subroutine HISRAN [3] that allows one to generate n random values in accordance with a given distribution. The distributions related to electrons and pions were supplied in the form of histograms using a subroutine HISPRE [3] (once for each histogram).

To estimate the efficiency of particle identification, we use a method of ratio of likelihood functions: see, for example, [1]. While applying the likelihood test to our problem, the value

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

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 a similar value for electron.

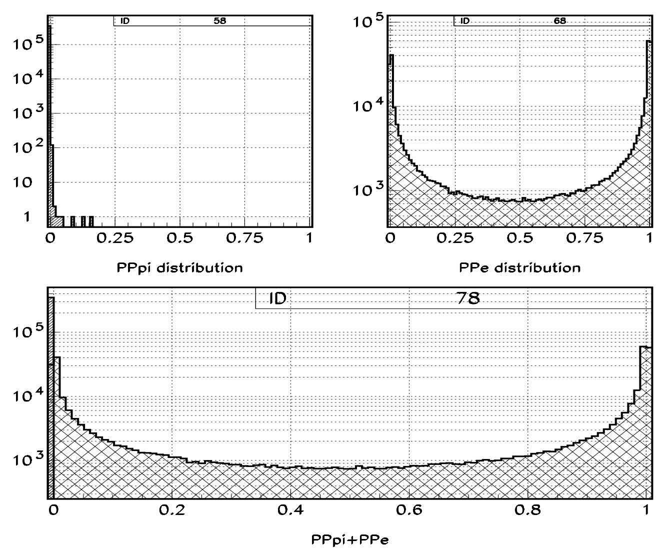

Figure 8: Distributions (for the TRD prototype) of L in cases when only pions (top left plot) or only electrons (top right plot) pass through the TRD with $n = 12$ layers; the bottom plot is the summary distribution for both particles

Figure 8 shows the distributions of the variable L for the data set generated on the basis of real measurements in accordance with the described above procedure: when only pions (top left plot) or electrons (top right plot) pass through the n-layered TRD; the bottom plot shows the summary distribution for both particles.

The corresponding distributions for GEANT data are presented in Figures 9 (March'07) and 10 (July'07).

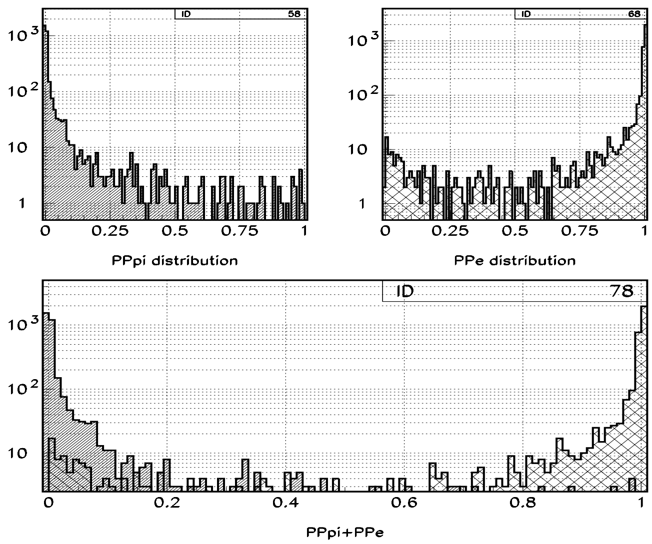

Figure 9: Distributions of L (GEANT simulation: March'07) in cases when only pions (top left plot) or only electrons (top right plot) pass through the TRD with $n = 12$ layers; the bottom plot is the summary distribution for both particles

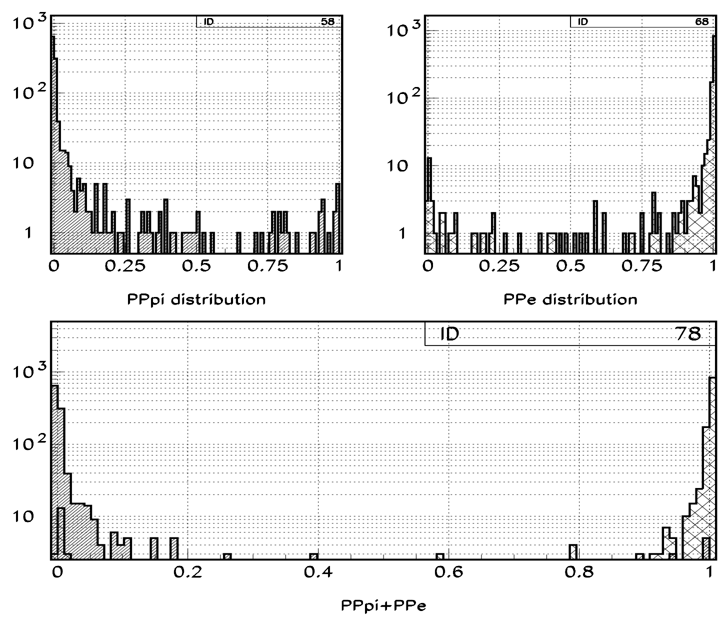

Figure 10: Distributions of L (GEANT simulation: July'07) in cases when only pions (top left plot) or only electrons (top right plot) pass through the TRD with $n = 12$ layers; the bottom plot is the summary distribution for both particles

The efficiency of registering electrons is determined by the ratio of the electrons selected in the admissible region for the preassigned significance level α to part β of pions having hit in the admissible region. In our case α value was set approximately equal to 10 %. The suppression factor of pions is equal to $100/\beta$.

In Table 2 we present the factors of pion suppression against the number n of layers in the TRD for the fixed level of α.

Table 2: Factor of pions 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

These results demonstrate that under the condition of loss $\approx$ 10 % of electrons, it is possible to achieve a reliable level of pion 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).

References

[1] E.P. Akishina, T.P. Akishina, V.V. Ivanov and O.Yu. Denisova: Distribution of energy losses for electrons and pions in the CBM TRD (to be submitted).

[2] PAW – Physics Analysis Workstation, CERN Program Library Entry Q121, Version 1.07, October 1989.

[3] F. James: CERN Computer Centre Program Library, **V150**.