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J/ψ→e+e– decays selection criteria with TRD in CBM experiment

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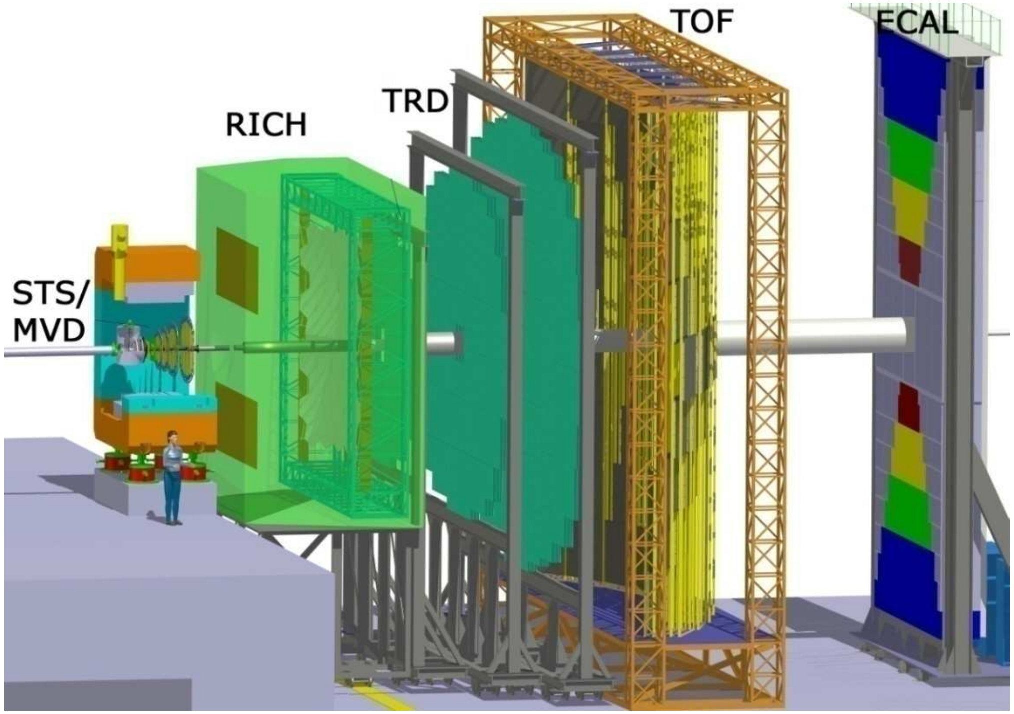
Motivation

The study of charmonium production is one of the key objectives of the CBM experiment.

Main difficulty of J/ψ→e+e- :

- extremely low yield of *J*/ψ mesons
- low probability (about 6%) of decay
- intense hadron background

Fast and efficient selection of the signal events for J/ψ→e^+e^- decays reconstruction in the real time experiment is needed



Transverse momentum p_t > 1 GeV/c

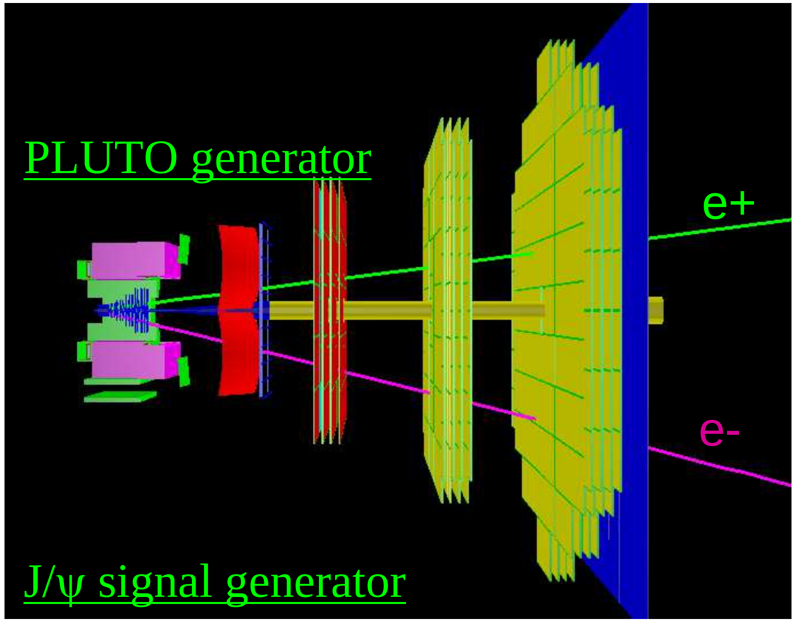
Number of hits in the TRD-track > 2

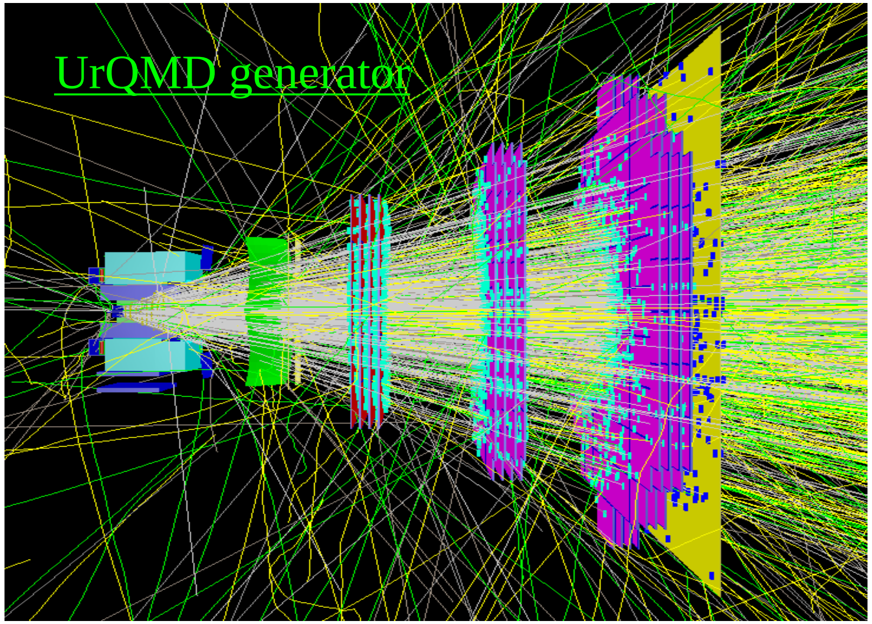
Electron identification in TRD

Electron identification in TOF

Input for simulation

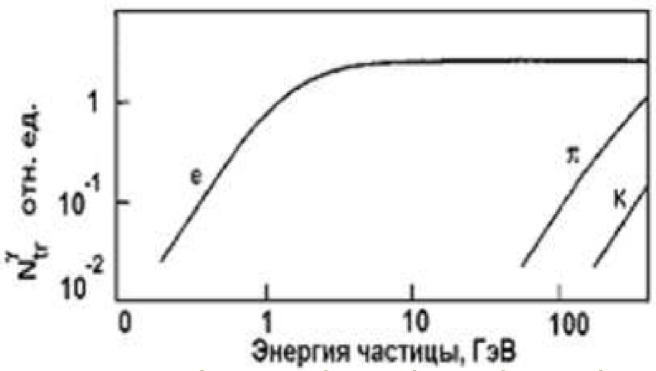
- ✓ Two sets of data:
  - electrons/positrons from J/ψ→e+e- decays (PLUTO generator)
  - background events (UrQMD)
- ✓ central AuAu collisions at 10 AGeV beam energy
- ✓ Au-target of 25 μm
- ✓ Most up-to-date realistic detector descriptions:



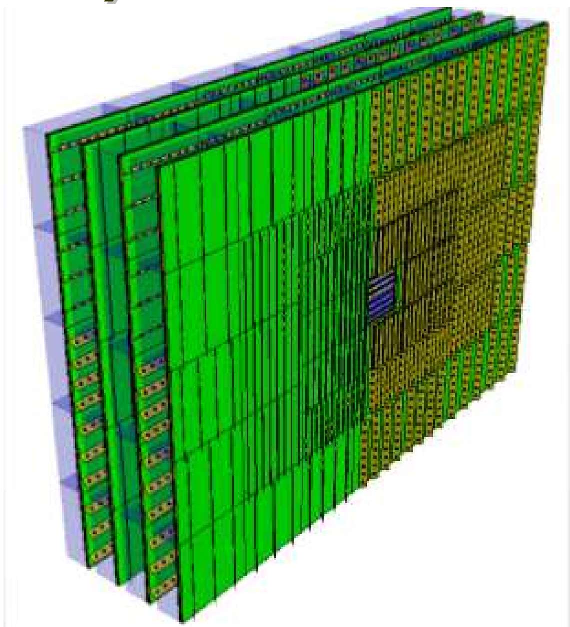


Transition Radiation Detector (TRD)

TRD detects the charged high-energy particles using the transition radiation emitted by them when crossing the interface between media with different dielectric permeability.



Dependence of number of TR photons from the particle energy



In a wide range of energies from 1 GeV to 150 GeV only electrons (positrons) generate transition radiation which is used to identify them.

<u>The main tasks of the TRD</u>:

(1) search and reconstruction of trajectories of the particles,

(2) particle identification taking into account energy losses.

Tracks reconstruction algorithm

The cellular automaton based algorithm has been developed for track reconstruction in TRD.

The following three obvious assumptions have been made to simplify and accelerate the algorithm:

1. The particle trajectories can be approximated by segments of straight lines, because the magnetic field has no influence on the area of the TRD station.

2. All tracks are close to the straight lines, crossing the target center.

3. Only those tracks are considered which have hits in all TRD stations.

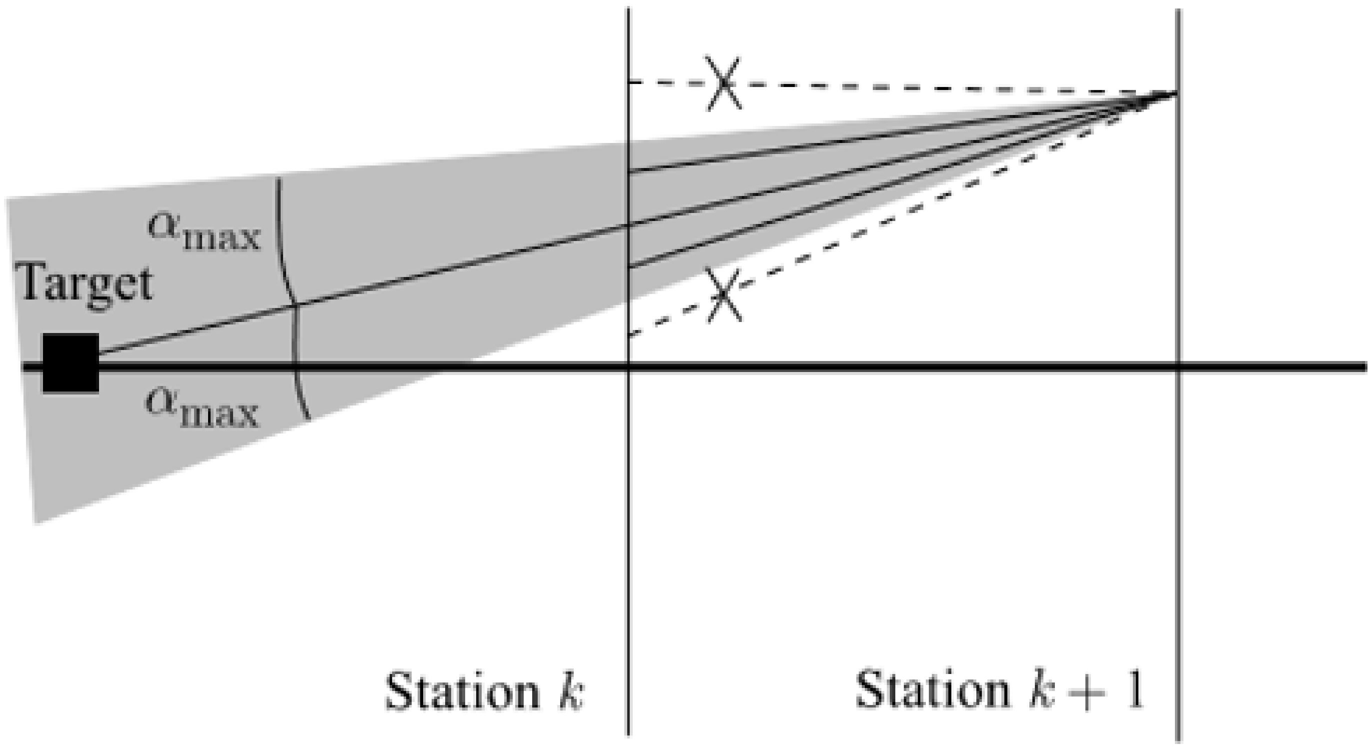
Track reconstruction algorithm includes the following stages:

1. Segment set formation; segments are elements for track building;

2 .Segments binding and track construction.

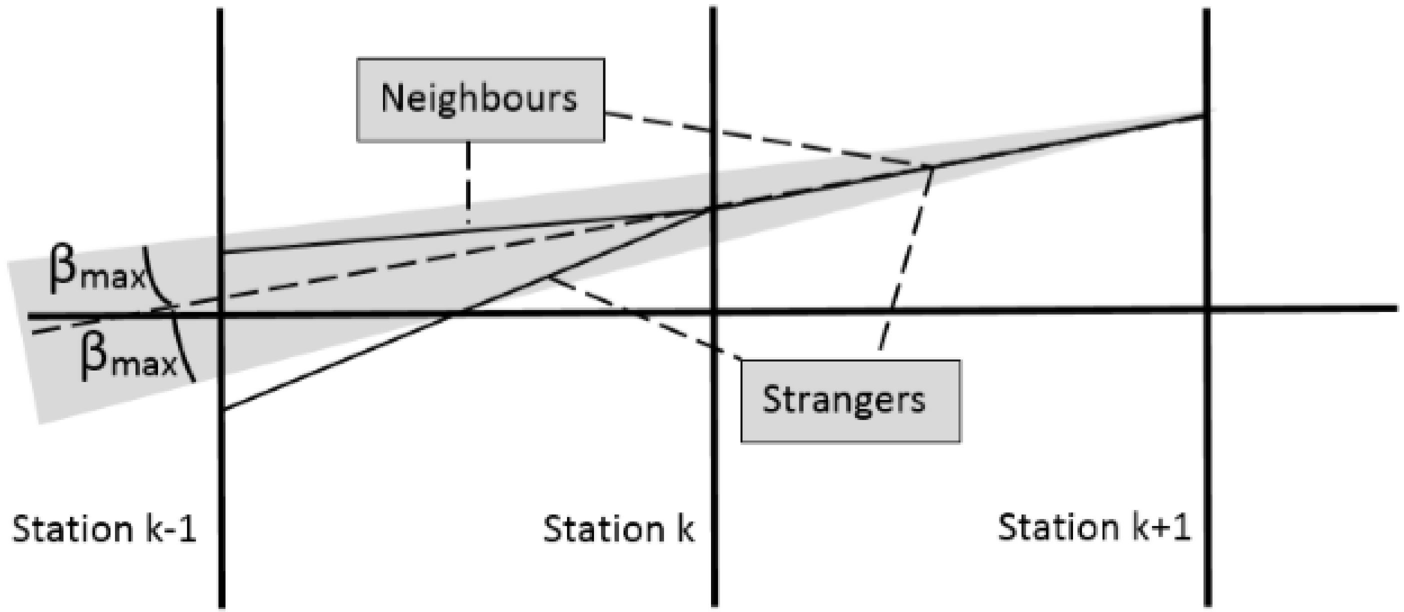
Building segments

Segments are fragments of straight lines connecting neighbour points of consecutive TRD stations. These lines do not differ much from the lines, connecting one of the segment ends and the target center. Limits for segment inclinations have been determined by Monte Carlo simulation.



Segment binding and track reconstruction

After the segments are built, consecutive segments are bound if they have a common point and the angle between them does not exceed a limit found by simulation.



Track candidate is formed from the segment sequence: from right to left (upstream the beam direction) by joining neighbour segments.

If during the track candidate building several alternatives appear, the one with minimum χ^2 is chosen.

Electron track reconstruction efficiency

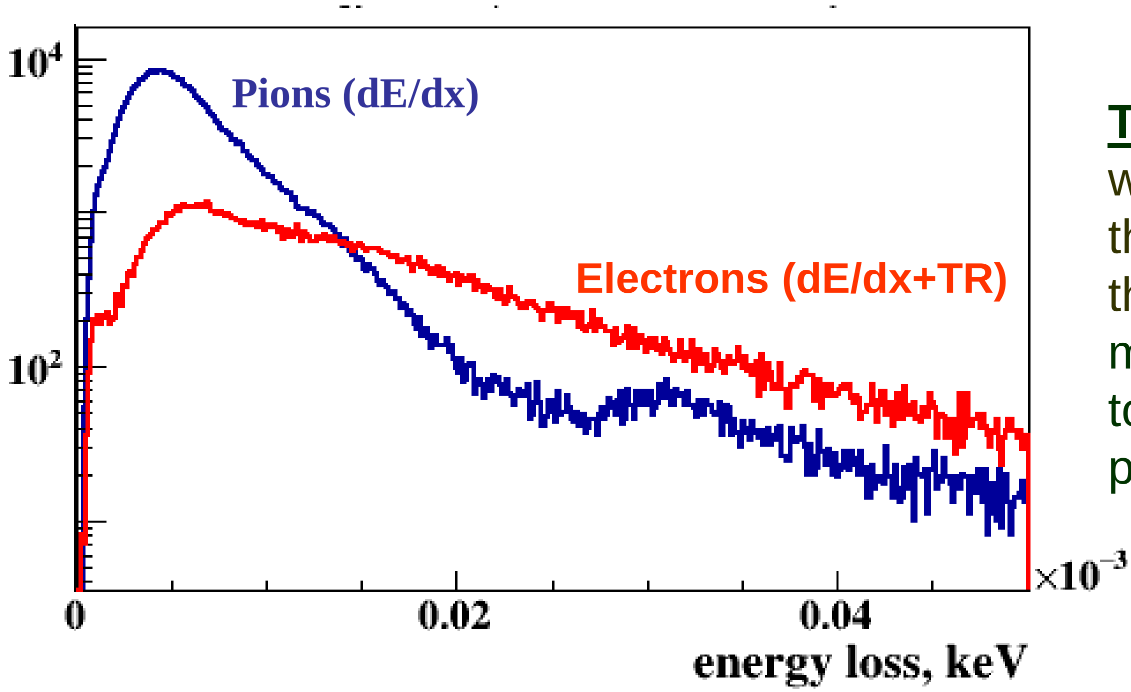
$$eff = \frac{N_{rec}}{N_{ref}} \times 100$$

N_{ref} - the number of reference tracks. The reference track is a MC-track corresponding to the electron or the positron from the J/ψ decay and which have hits in all layers of the TRD

N_{rec} - the number of reference tracks that have been matched to the reconstructed track. The track is matched if at least 3 hits of the track coincide with 3 points of the reference track.

The efficiency of the signal track reconstruction is about 92%

Electron identification



Task: each track is associated with a set of measurements of the particle energy losses. With the help of various mathematical methods, one should determine to which distribution (electrons or pions) these losses are related.

Methods:

- artificial neuron network;
- w^k_n criterion
- likelihood method

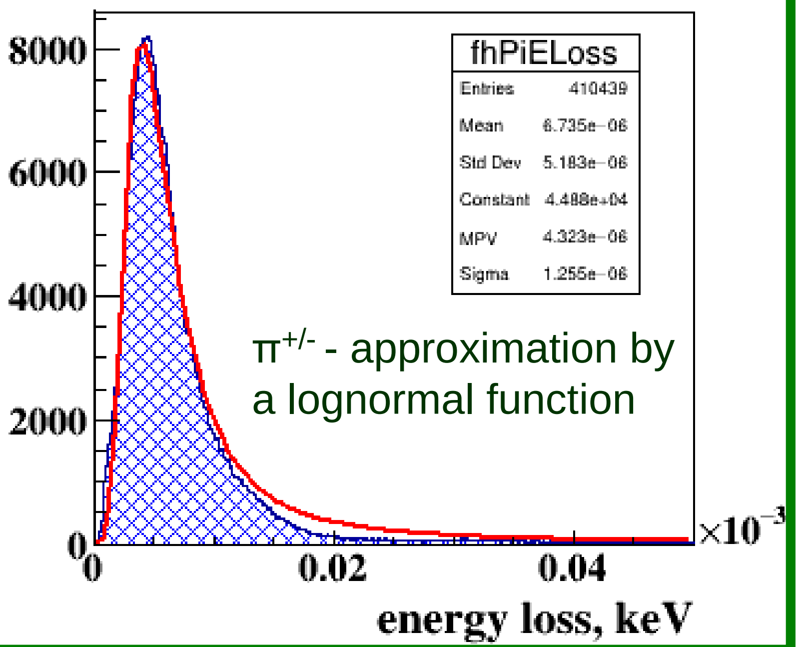
w_n^k criterion

$$\omega_n^k = -\frac{n^{\frac{k}{2}}}{k+1}\sum_{j=1}^{n}\left\{\left[\frac{j-1}{n} - \phi(\lambda_j)\right]^{k+1} - \left[\frac{j}{n} - \phi(\lambda_j)\right]^{k+1}\right\},$$

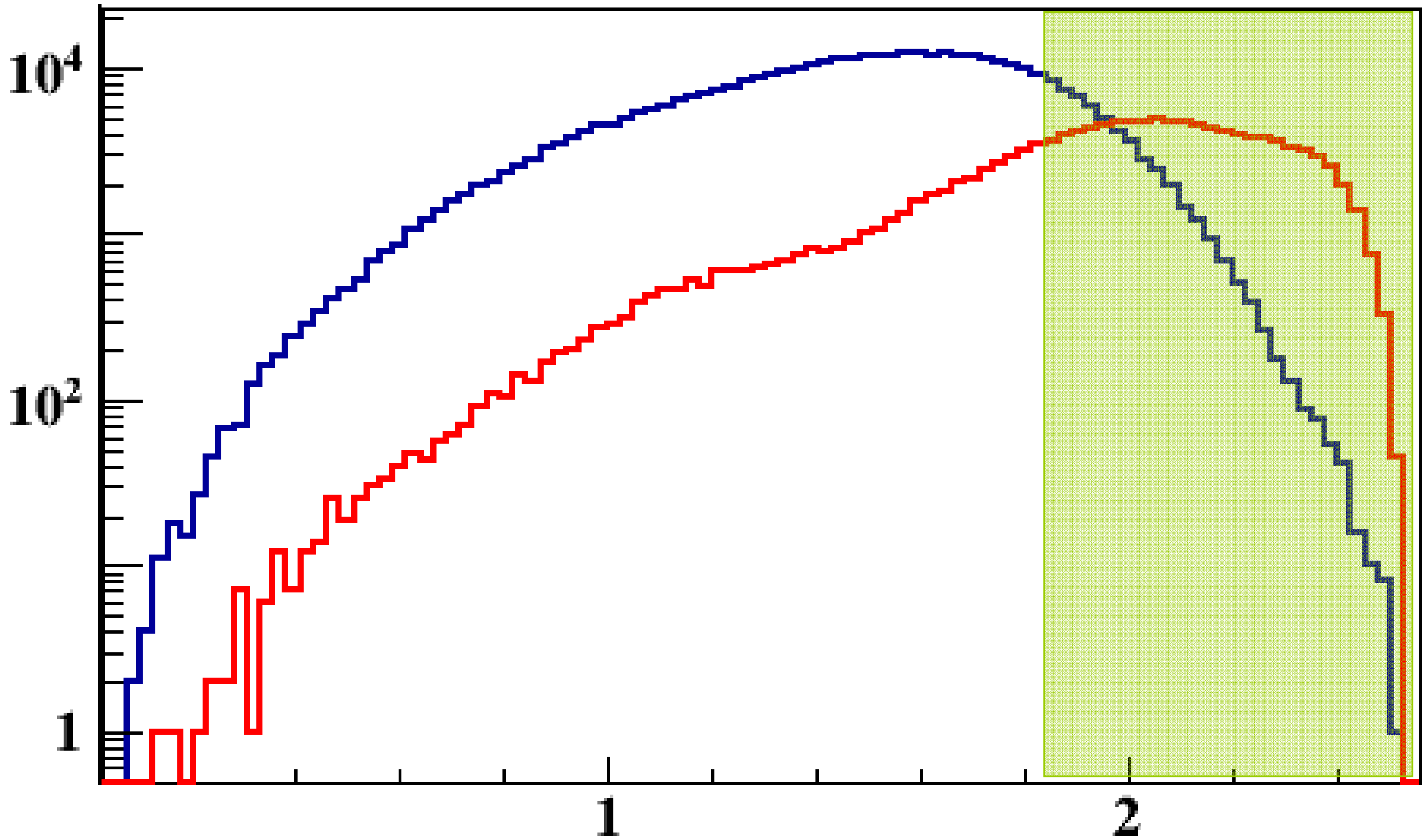
where *k* is the criterion degree,
ϕ(λ) is Landau distribution function (which describes pion energy losses) with a new variable λ:

$$\lambda_i = \frac{\Delta E_i - \Delta E_{mp}^i}{\xi_i} - 0.225, \qquad \mathrm{i} = 1,2,\ldots,\mathrm{n},$$

ΔE_i – the energy loss in the i-th TRD layer,
ΔE^i_{mp} – the value of most probable energy loss,
ξ_i =1/4.02 FWHM of distribution of the energy losses for pions,
n – number of TRD layers.



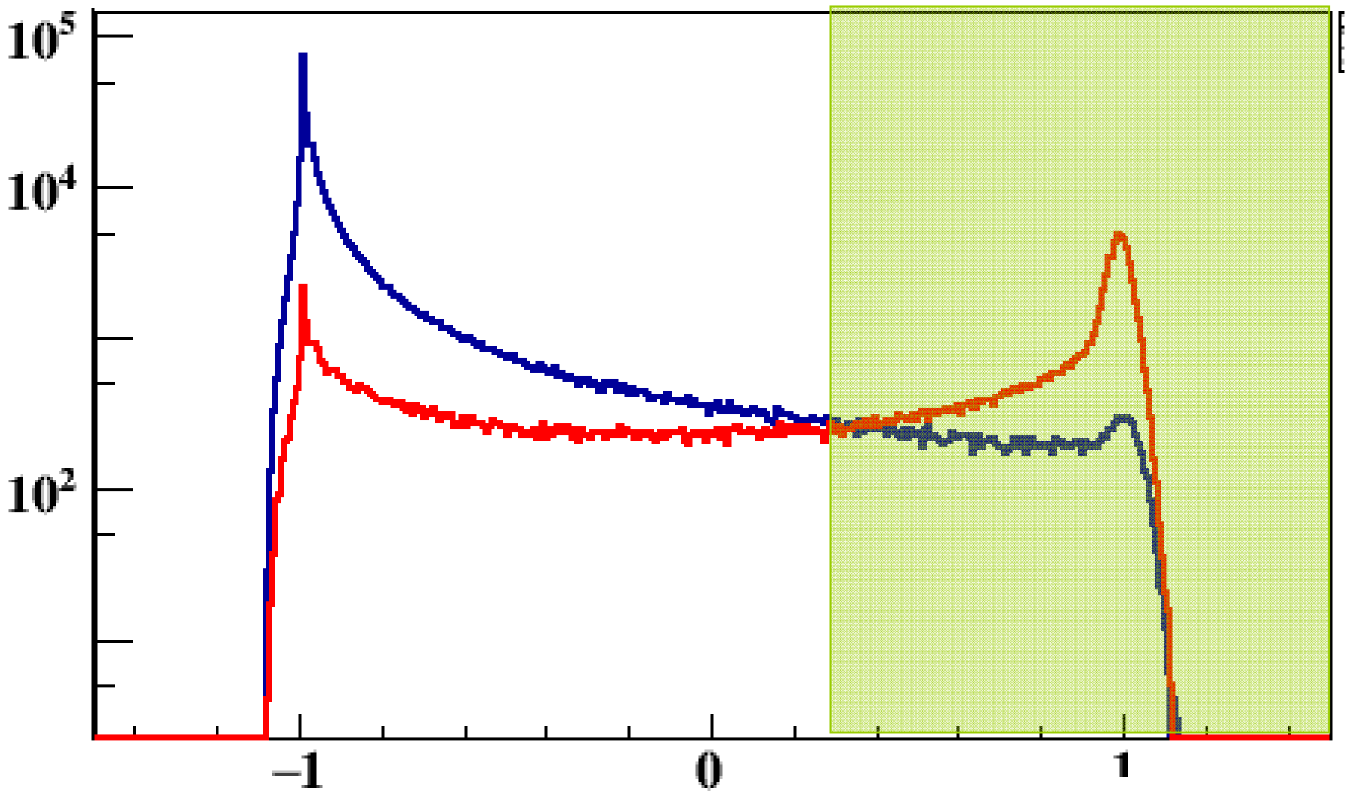
w_n^k criterion



w_3^2 for pions and electrons

Artificial neuron network (ANN)

A three-layered perceptron from the ROOT package is currently used in the CBM experiment for particle identification by the TRD.



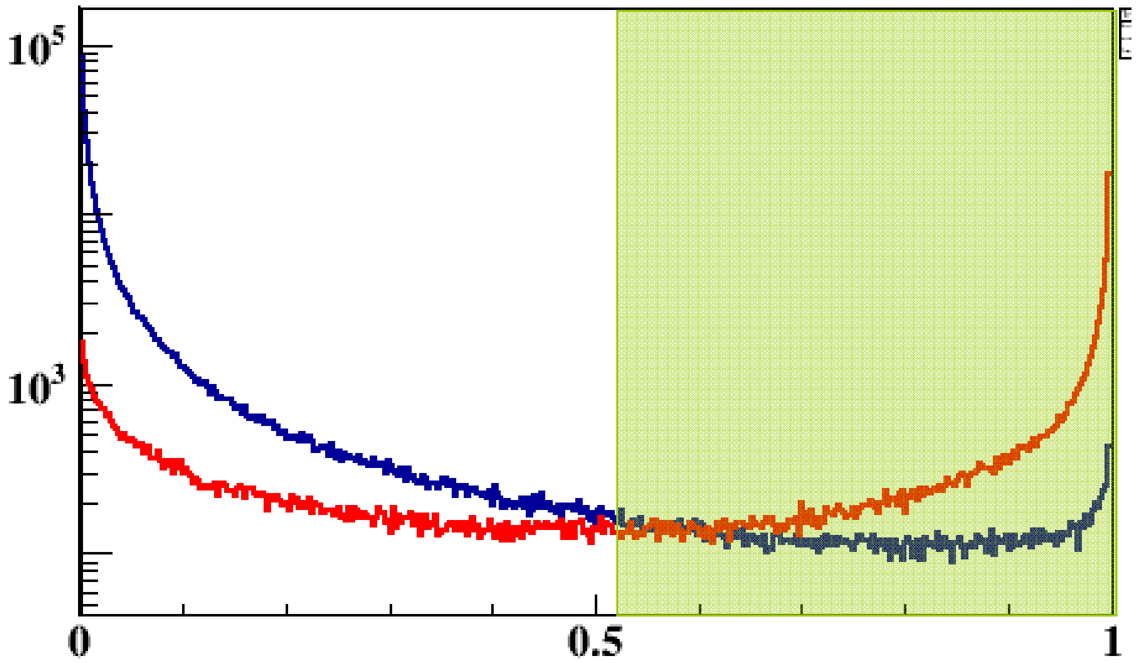
ANN output values output for pions and electrons

Likelihood method

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

$p_\pi(\Delta E_i)$ - value of the density function p_π in the case when the pion loses energy ΔE_i in the *i*-th absorber

$p_e(\Delta E_i)$ - a similar value for electron



Likelihood values for pions and electrons

Results

Suppression factor corresponding to 11% of electron losses

	pions	All bg
ω_3^2	6.5	5.35
Likelihood	17.9	8.97
ANN	18.38	9

For the likelihood test application and training of the ANN it is necessary to know the density functions of energy losses for both particles: pions and electrons.

The method based on the ω_3^2 criterion does not need this additional information, because for its application one should only know the parameters of the pion losses distribution.

Conclusions

1. The algorithm for trajectories reconstruction in TRD based on the Cellular Automaton has been developed. It shows high efficiency of signal (electron-positron from J/ψ decay) track reconstruction.

2. The comparison of the different electron identification methods has been performed.

   The best pion suppression level is achieved using:

   a) ANN with transormation of the initial energy losses in the TRD layers to a new variable typical for the ω_n^k criterion,

   b) Likelihood function ratio method.

   The bottleneck of these methods is the requirement to know the density functions of energy losses for pions and electrons.

   To apply the ω_n^k criterion one only needs the information about pions energy loss.

Thank you for your attention ☺