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CERENKOV COUNTER RECONSTRUCTION FOR CLAS

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Overview

In addition to program package for GEANT simulation of Cerenkov counters (CC) in CLAS detector the program for CC reconstruction was created. The main idea of CC reconstruction is to determine that registered signal has been produced by electron or it correspond to background. For example π mesons being under the threshold of radiation of Cerenkov photons are the source of background hits when they produce electrons with velocity greater than the Cerenkov threshold.

To initialize reconstruction procedure the sample of events (about 10^5) with initial electrons with momenta 0.4 - 2.0 GeV/c has been generated using GEANT simulation package for CLAS detector [1]. The sample of events with initial π^- (0.4 - 2.0 GeV/c) consists of $\sim 1.5 \cdot 10^5$ events. Both electrons and pions were generated with polar angles from 8^o to 65^o and azimuth angles $\pm 25^o$.

Reconstruction procedure bases on the difference between signals produced by electrons and soft pions while fast pions when produce Cerenkov photons make signal analogous to electrons signal. Using this package one can decrease the number of misidentified pions. As a result the ratio π/e was determined.

Entry Point for a charged particle trajectory

In this article all coordinates are defined in detector coordinate system. Here the reconstruction procedure for sector 1 is considered. Axis z directed along beam, sector 1 middle plane is defined with axises x and z, y characterizes distance up to middle plane. Width of CC section w_{max} is the maximal value of y for given CC section. In addition to coordinates x, y, z, polar angle θ for point (x, y, z) is defined as $tg\theta = \sqrt{x^2 + y^2}/z$. For particle with momentum $\vec{p} = (p_x, p_y, p_z)$ angle θ_p is defined as $tg\theta_p = \sqrt{p_x^2 + p_y^2}/p_z$.

It is suitable to calculate coordinates of particle Entry Point in the vicinity of CC entrance window. One can determine imaginary cylindrical surface in the area between

Drift Chamber region 3 and CC. Particle Entry Point is defined as a point on the cylinder surface crossed by a trajectory of the particle (Fig.1). Between θ_{min} and θ_{max} imaginary cylinder is subdivided in 16 layers which are equidistant over $tg\theta$. Depending on the $tg\theta$ value Entry Point is characterized by integer number cci from 1 to 16:

$$cci = 1 + 16 \cdot (tg\theta - tg\theta_{min})/(tg\theta_{max} - tg\theta_{min}).$$

Program procedure

An input information should contain particle coordinates and momentum direction in the Entry Point, the hitted CC numbers, values of TDC and ADC.

Layer number on cylinder surface cci and tangent of angle ψ between particle direction and direction to the center of cci are defined in the reconstruction subroutine CRRECO ($tg\psi = tg(\theta_{cci} - \theta_p)$) (see Fig.1).

For good separation of signals produced by electrons and background events one should minimize a range of expected PMT for given input parameters cci and $tg\psi$. Instead of analysis of each fired PMT it is suitable to define mean ID number ccf as

$$ccf = \sum(ID(i)ADC(i))/\sum ADC(i).$$

The example of possible values ccf versus $tg\psi$ for electrons entering through the $cci = 14$ are shown in Fig.2a). For the comparison signals for pions entering through the same cci are shown in Fig. 2b).

Area of possible ccf could be represented as square or polygon. Common block /CRHIT/ contains values ccf corresponding to polygon areas for each input layer. If ccf belongs to interval of possible ccf numbers, the program gives answer "YES". Otherwise it gives answer "NO".

Structure of the package

The Cerenkov reconstruction sub-package CR consists of subroutines:

CRINIT - to initialize and read geometry parameters;

CREVNT - to read raw BOS bank for CC:

CRRECO - to determine possible numbers of fired PMT and to give answer "YES" if registered signal correspond to electron or "NO" in opposite case.

Input parameters

Geometry input parameters which define working volume of CC (necessary for the reconstruction) are:

R_{bc} - radius of an imaginary cylinder between region 3 and Cerenkov counter;

X_{bc}, Z_{bc} - coordinates of the axis of the imaginary cylinder (for sector 1);

$tg(\theta_{min})$, $tg(\theta_{max})$ - tangents of minimal and maximal polar angles for all set of 18 CC sections;

R^1_{bc}, R^{18}_{bc} - maximal radii for side walls of CC (sections 1 and 18); Parameters R^1_{bc}, R^{18}_{bc} are used to define Entry Point at side plane of the first section of CC or at side plane of the last section of CC.

A_0, A_1, A_2 - 3 parameters for the 2-nd order approximation of the dependence of CC width w^{max} versus $tg\theta$.

Estimation of the π/e rejection factor

The probability of the electron reconstruction P^e_{rec} was estimated for different thresholds: the number of photoelectrons in each hited PMT is equal 1, is equal 2 and the total number of photoelectrons is equal 2. Values P^e_{rec} for different momenta (inside the angular acceptance of CC) are listed in Table 1. We consider the trajectory accepted if it crosses the active volume of the CC counter.

Table 1 Probability of the electrons reconstruction

Threshold	$0.4 < p < 2.0$	$0.4 < p < 0.6$	$0.6 < p < 1.0$	$1.0 < p < 2.0$
$N_{pe} = 1$	0.996	0.993	0.997	0.997
$N_{pe} = 2$	0.946	0.929	0.946	0.961
$\sum N_{pe} = 2$	0.958	0.946	0.959	0.969

About $\sim 0.5\%$ of soft pion can make a signal in CC. These pions will be misidentified as electrons. Probabilities of the reconstruction of pions as electrons P^{π}_{rec} for different momenta are listed in Table 2.

Table 2 Probability of the reconstruction of pions as electrons

Threshold	$0.4 < p < 2.0$	$0.4 < p < 0.6$	$0.6 < p < 1.0$	$1.0 < p < 2.0$
$N_{pe} = 1$	0.43	0.33	0.47	0.53
$N_{pe} = 2$	0.28	0.19	0.32	0.33
$\sum N_{pe} = 2$	0.30	0.21	0.35	0.36

The feature of Cerenkov counters is that the bottom plane of smallest CC section is a mirror. Photons reflected on bottom mirror can give signal at large PMT numbers (see

Fig 2c). Due to this reflecting condition the area of possible fired PMT for CC sections having numbers from 1 to 3 becomes rather large. For these sections the probability of reconstruction of pions as electrons also becomes large. Table 3 shows the comparison of probabilities of reconstruction of pions entering through the smallest Entrance regions and pions entering through the other regions.

Table 3 Probability of pions reconstruction for different input sectionss

Threshold	$cci \leq 3$	$cci \geq 4$
$N_{pe} = 1$	0.61	0.40
$N_{pe} = 2$	0.41	0.26
$\sum N_{pe} = 2$	0.43	0.28

The coefficient of π/e rejection is defined as a ratio of reconstruction probabilities of pions and electrons weighted with probabilities of these particles identification

$$\pi/e = \left(\frac{N^{\pi}_{detcted} P^{\pi}_{rec}}{N^{\pi}_{accepted}}\right) / \left(\frac{N^{e}_{detcted} P^{e}_{rec}}{(N^{e}_{accepted}}\right)$$

. In Fig. 3 the dependencies of the π/e rejection coefficient on the electron reconstruction probability for different methods of reconstruction and for different thresholds are shown. A proposed reconstruction procedure reduces the value of π/e rejection coefficient by factor 2. Increasing threshold also reduces π/e rejection. On the other hand, for method of reconstruction with stronger cuts there is no significant change of the probability of electron reconstruction.

Conclusion

1. The reconstruction procedure provides the probability of electrons reconstruction more than 0.99 for threshold $N_{pe} = 1$.

2. Mirror at the bottom side of smallest CC section gives increase of the efficiency of e^- reconstruction. In that case the probability of π^- identification as electrons increases by factor 1.5.

3. The reconstruction procedure decreases the coefficient of π/e rejection by factor of 2.

Referencies

1. E.Doroshkevich, M.Kossov, A.Vlassov CLAS-NOTE 94-006, 1994

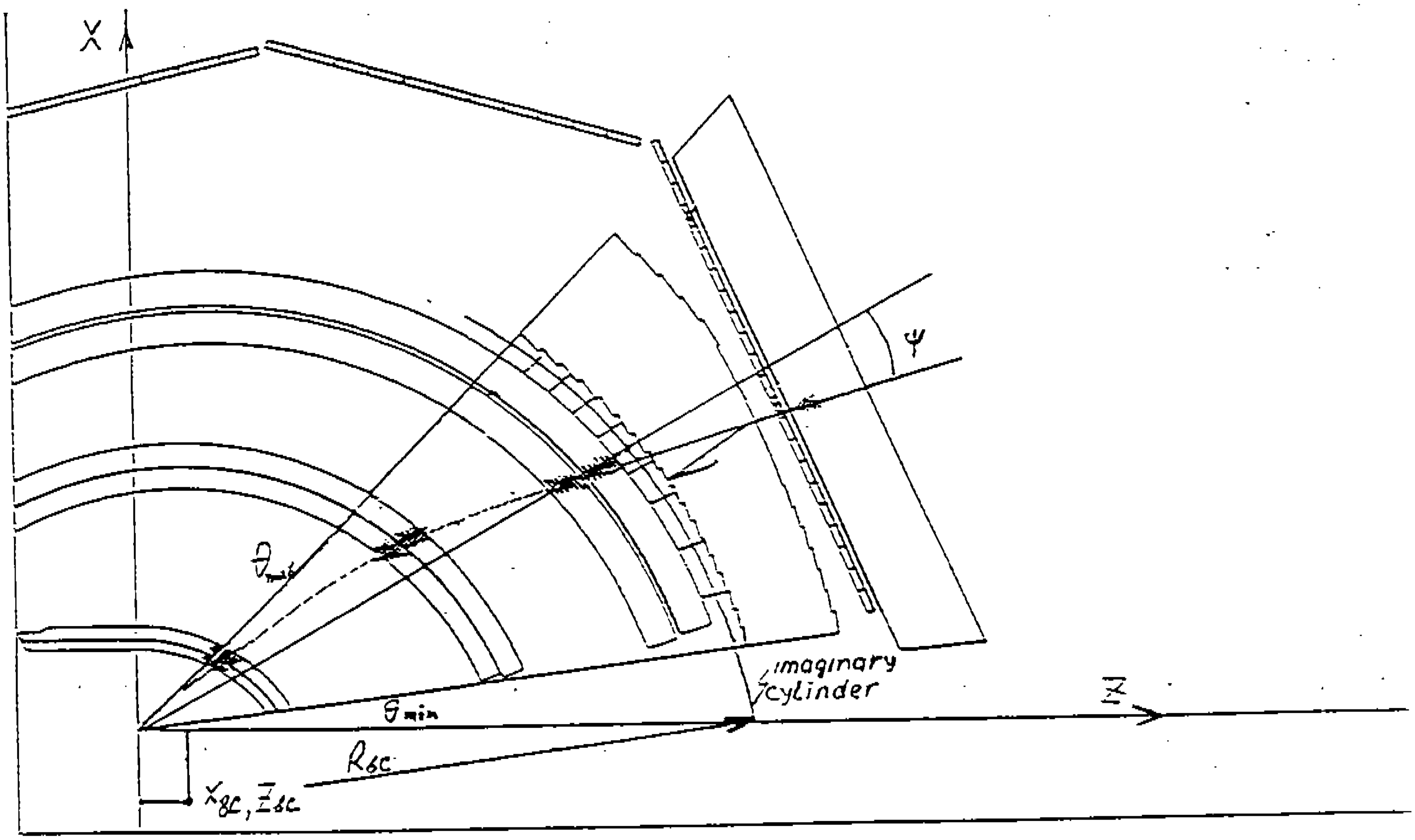
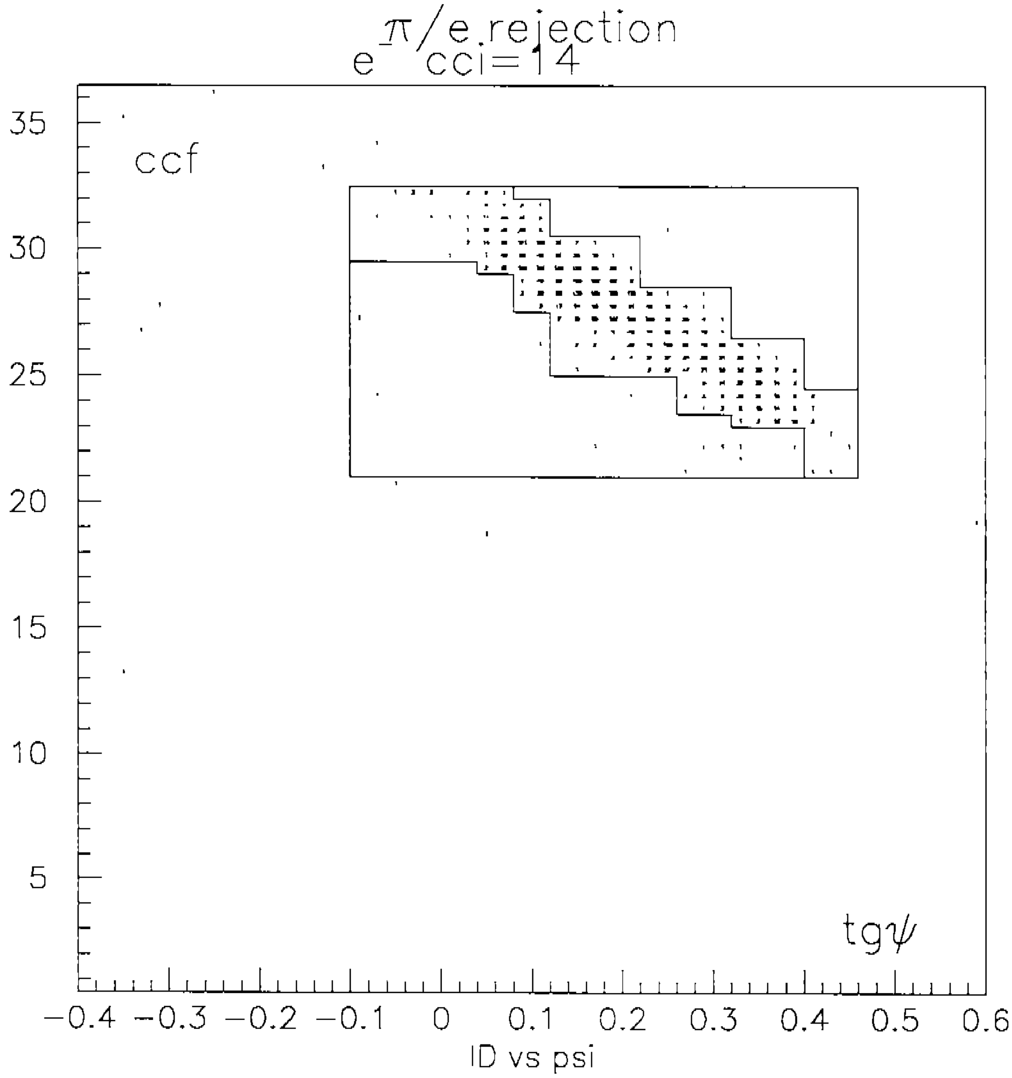
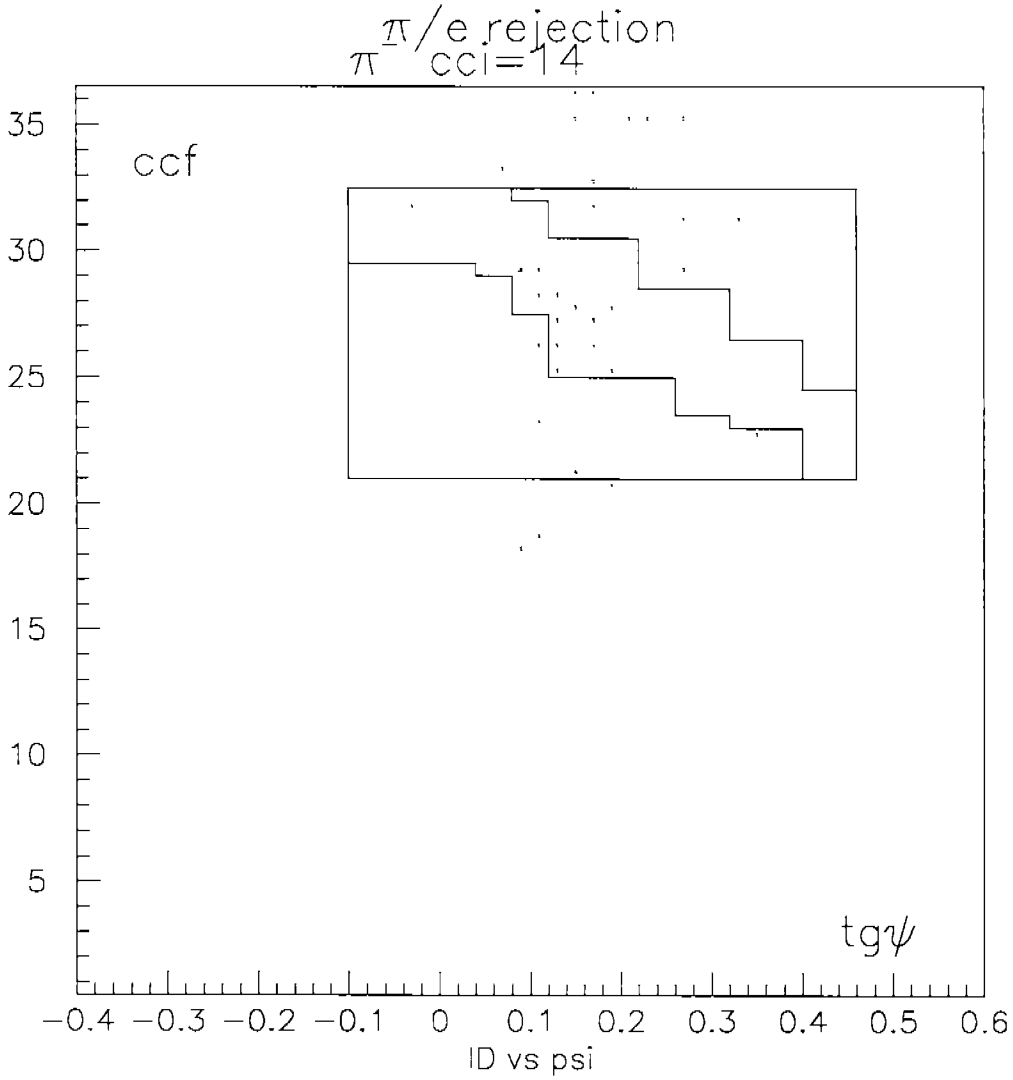


Fig. 1



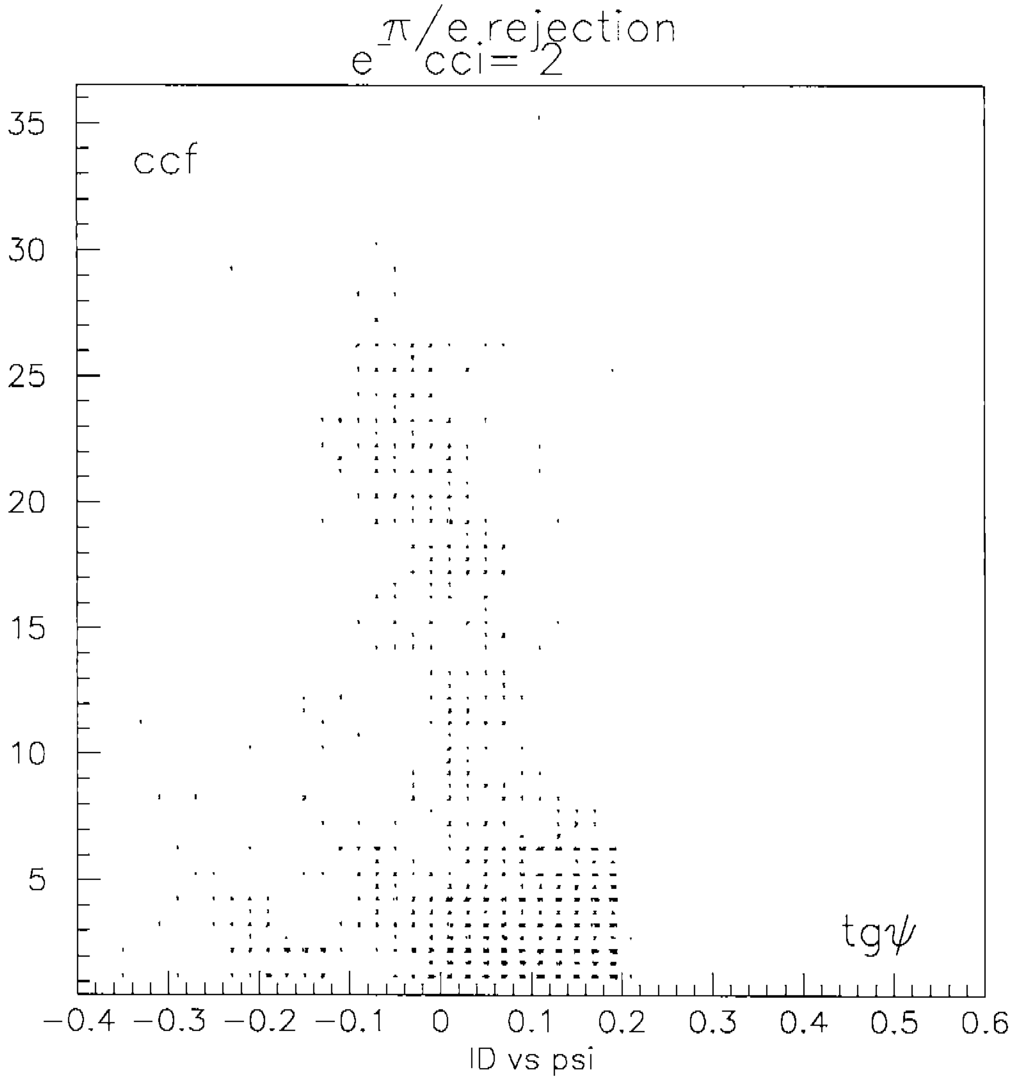
π/e rejection
e⁻ cci=14
35
30
25
20
15
10
5
ccf
tgψ
−0.4 −0.3 −0.2 −0.1 0 0.1 0.2 0.3 0.4 0.5 0.6
ID vs psi

Fig. 2a)



π/e rejection
π⁻ cci=14
ccf
35
30
25
20
15
10
5
tgψ
−0.4 −0.3 −0.2 −0.1 0 0.1 0.2 0.3 0.4 0.5 0.6
ID vs psi

Fig. 2b)



e^- π/e rejection
cci= 2
ccf
tgψ
35
30
25
20
15
10
5
−0.4 −0.3 −0.2 −0.1 0 0.1 0.2 0.3 0.4 0.5 0.6
ID vs psi

Fig. 2c)

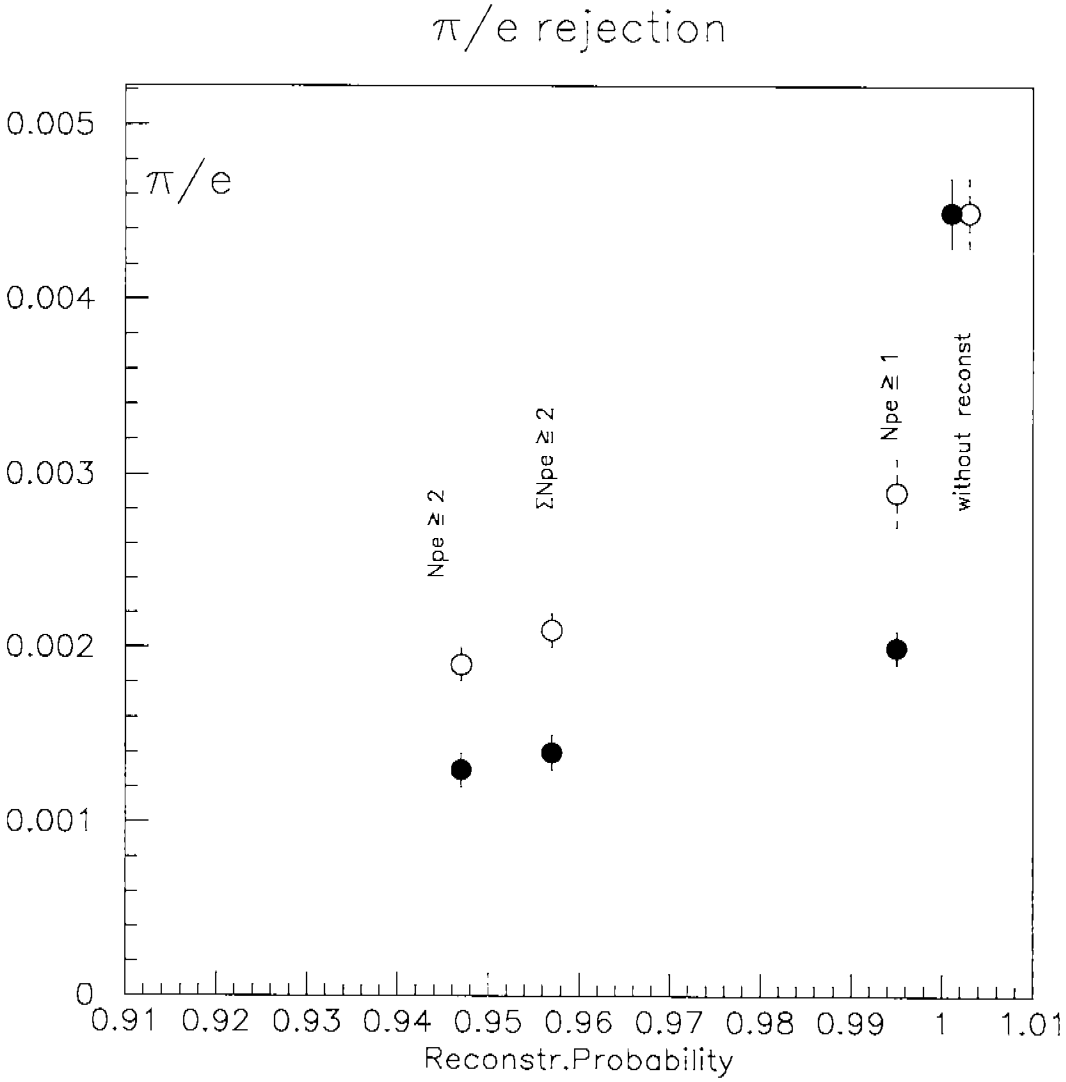

π/e rejection
π/e
0.005
0.004
0.003
0.002
0.001
0
Npe ≥ 2
ΣNpe ≥ 2
Npe ≥ 1
without reconst
0.91
0.92
0.93
0.94
0.95
0.96
0.97
0.98
0.99
1
1.01
Reconstr.Probability

Fig. 3