PARTICLE IDENTIFICATION USING dE/dx TECHNIQUE

J. Va'vra, S.L.A.C.

I have calculated the dE/dx particle identification prediction for two cases, one assuming that the central drift chamber has 60 samples 1 cm long operating at 1 atm gas pressure, and the other assuming a special dedicated dE/dx module with only 20 samples 1 cm long and a dedicated "dE/dx gas". The attempt was to compare standard gases with helium based gases.

To calculate this problem one needs to determine two quantities. First, the most probable energy loss (as a function of particle velocity, gas and the detector parameters), and second, the energy loss fluctuations as a function of similar parameters. The knowledge of these two quantities allows one to calculate the two particle separation in terms of a number of sigmas as a function of momentum.

There are two basic approaches to this problem:

A. A phenomenological approach leaning heavily on empirical results. For instance, the gas is represented in terms of mean ionization potential, mean density of electrons; the energy loss fluctuations are determined entirely empirically, etc.[1,2,3,4]. The main advantage of this method is that one can predict performance of any gas mixture rather easily.

B. A modern approach which correctly describes details of physics, including individual ionization potentials, photo-absorption cross-sections , etc. It requires a large Monte Carlo [5] and a data base describing a particular gas. For more insight into this problem see also [6,7,8]. This method requires a dedicated long term effort. In addition, it is not clear to me how well this method works for a variety of conditions used in the present experiments, especially if one uses some obscure gases.

In my calculation presented in this paper I used the method (A), because of its simplicity. The method has been described in reference [4] in detail. It has been successful to predict the dE/dx performance, certainly at a level of 10-20%. The most recent agreement has been demonstrated by MARK II dE/dx performance on SLC at SLAC [9]. The main points of the calculation presented in the reference [4] are as follows :

a) The most probable energy loss is taken from reference [1,2]. However the density term [4] has been obtained by extracting it from the Walenta's data[3] and fitting it with a constraint that the relativistic rise should level off. My density term parametrization [4] differs from that of Sternheimer [2], which tends to give slightly higher value of relativistic plateau. That tends to slightly exaggerate hadron-electron performance. Fig.1 shows the most probable energy loss calculation according to reference [4] for several gases.

b) The expression for the energy loss fluctuations has been obtained entirely empirically. The idea is to find some variable which would be universal for all gases and would uniquely determine the energy loss fluctuations. Fig.2 shows such an attempt which was first presented by Walenta [3]. The correlation is only approximate as one easily finds if the quantities are plotted on linear scales. This gives the main uncertainty to the dE/dx predictions. I have tried to find other correlations, for instance, plotting the measured energy loss fluctuations against an empirical estimate of number of ionization clusters. This so far did not yield any improvement. For the calculation in this paper I use the fit to Walenta's data shown in Fig. 2.

c) Finally, the last empirical dependence used in this paper is an extrapolation of the dE/dx resolution from one sample to n samples. I use n**0.43 dependence which was found empirically by several references [3,10,11]. This is valid for the truncated mean method.

Having accepted the above empirical approximations, one can now calculate the dE/dx separation in number of sigmas for various particles and gases as a function of particle momenta[4]. This is shown in Figs. 3-11. The first seven calculations are done assuming that the dE/dx would be performed in the main drift chamber, the last two calculations are done assuming it will be done in a separate device after the drift chamber. To improve the dE/dx in the nonrelativistic region one would use heavy gas like propane. Table 1 summarizes the gas dependent parameters as obtained from our calculation.

ACKNOWLEDGEMENTS

I would like to thank F.Villa for finding an error in the DME calculation which was caused by a typo in the Mathison gas reference manual. In that way he again succesfully defended the DME gas.

LITERATURE

[1] L. Landau, J.Phys. USSR 8 (44) 201.
[2] R. Sternheimer, Phys.Rev. D3 (1971) 3681.
[3] A. Walenta, Physica Scripta 23 (1981) 354
[4] J. Va'vra et.al., Nucl. Instr. and Meth. 203 (1982) 109.
[5] W. Alison and P.Wright, Exp.Tech.in High Energy Physics, Addison-Wesley Publ., 1987.
[6] D. Ritson, SLAC Summer School, 1980.
[7] R. Talman, Nucl.Instr.and Meth. 159 (1979) 189.
[8] V.K. Ermilova et.al., Soviet physics JETP, Vol.29, No.5, 1969.
[9] A. Boyarski et.al., SLAC-PUB-4956, 1989.
[10] J. Va'vra and D.Rust, SLAC-PUB-2635 (1980).
[11] Aderholz et.al., Nucl.Instr.and Meth. 118 (1977) 419.
[12] A. Seiden, private communication.
[13] W. Zimmermann et. al., Nucl. Instr. and Meth. A243 (1986) 86.

TABLE 1

Gas	ρ(NTP) at 21°C (g/cm^3)	$\bar{I}$ (ev)	$\alpha t/\bar{I}$	E_{max}/E_{min}	$FWHM(1)/E$
C_3H_8	1.88×10^{-3}	50.3	3.39	1.3	0.55
90% Ar + 10% CH_4	1.57×10^{-3}	191.2	0.58	1.67	0.96
50% Ar + 50% C_2H_6	1.46×10^{-3}	129.1	0.89	1.54	0.84
DME	1.89×10^{-3}	59.8	2.74	1.35	0.59
90% He + 10% DME [12]	3.39×10^{-4}	43.8	0.64	1.47	0.94
78% He + 15% CO_2 + 7% C_4H_{10} [12]	5.76×10^{-4}	50.0	0.93	1.43	0.83
93.8% He + 6.2% C_3H_8 [13]	2.73×10^{-4}	42.5	0.53	1.48	0.99

NOTE:

1) $E_{max}/E_{min} = dE/dx\text{-}max/dE/dx\text{-}min$ - ratio of relativistic rise to the minimum

2) $FWHM(1)/E$ - resolution of one sample divided by the most probable dE/dx value

3) $\bar{I}$ - mean ionization potential of the gas mixture

4) $\alpha t/\bar{I}$; $\alpha t = 0.153\ (Z/A)\ \rho t$ (MeV for ρt in g/cm^2), t = 1 cm in the above table.

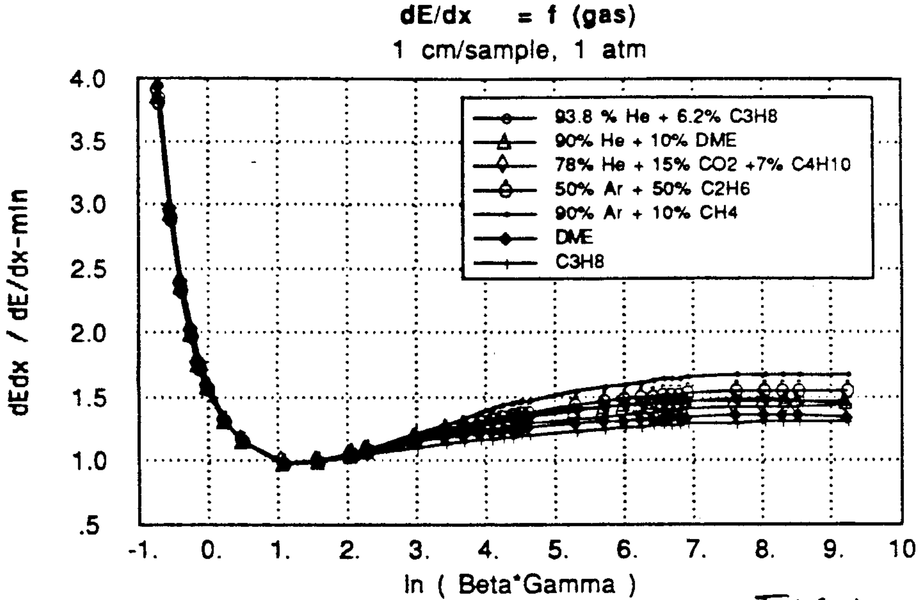

FIG.1

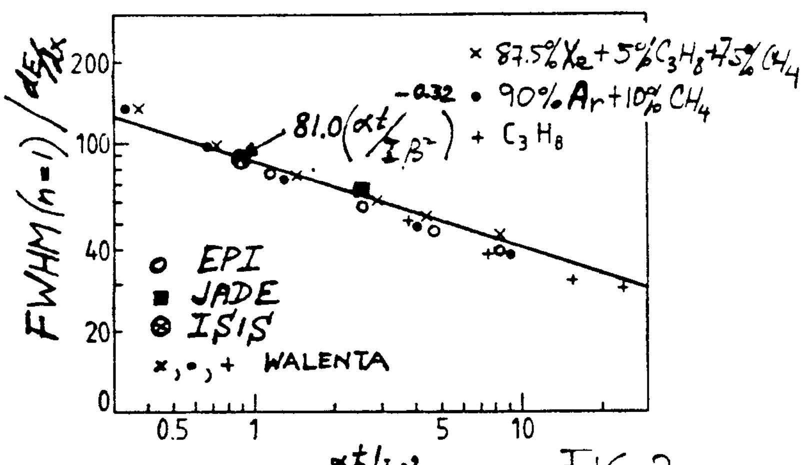

FIG.2

$\alpha t = 0.153\,(Z/A)\,\rho t$ — (MeV for ρt in g/cm^2)

I = mean ionization potential, $\beta = v/c$

dE/dx pi-K particle separation = f (gas)
1 cm/sample, 60 samples, 1 atm

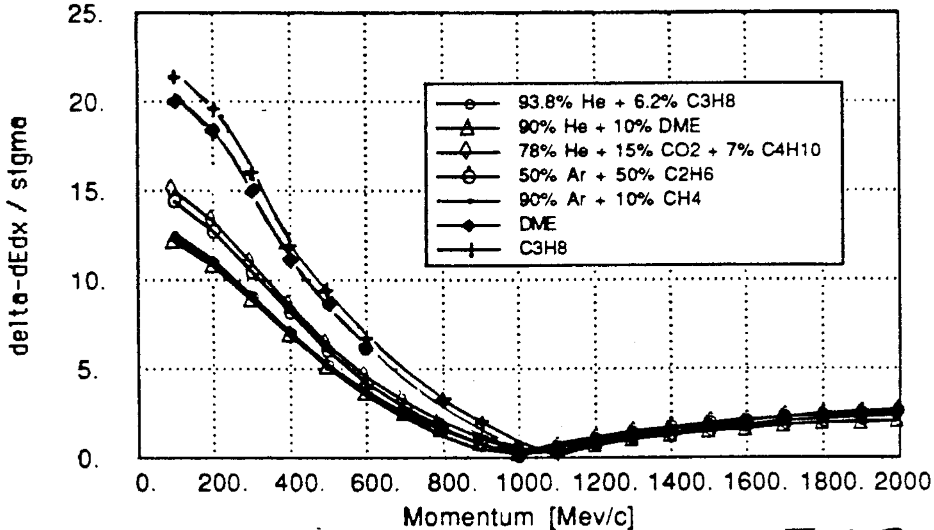

FIG.3

dE/dx pi-e particle separation = f (gas)
1 cm/sample, 60 samples, 1 atm

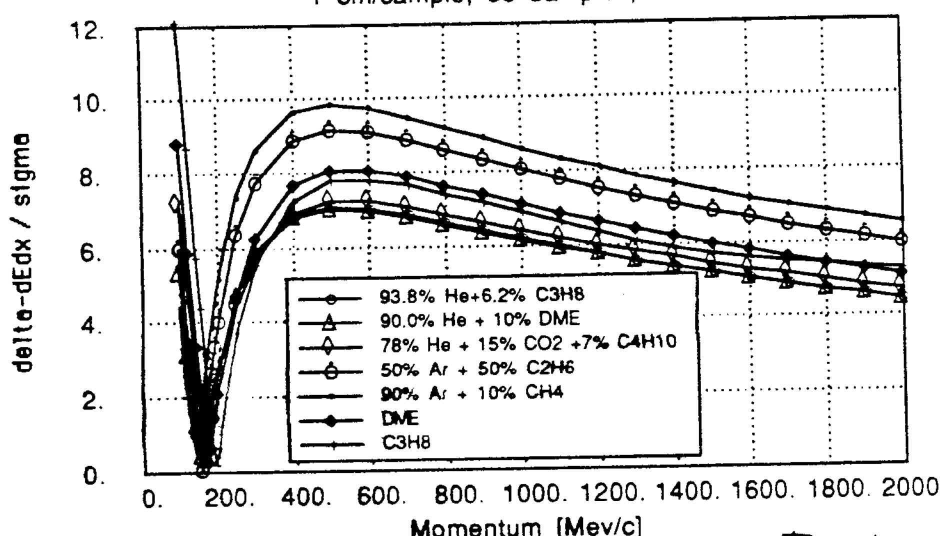

FIG.4

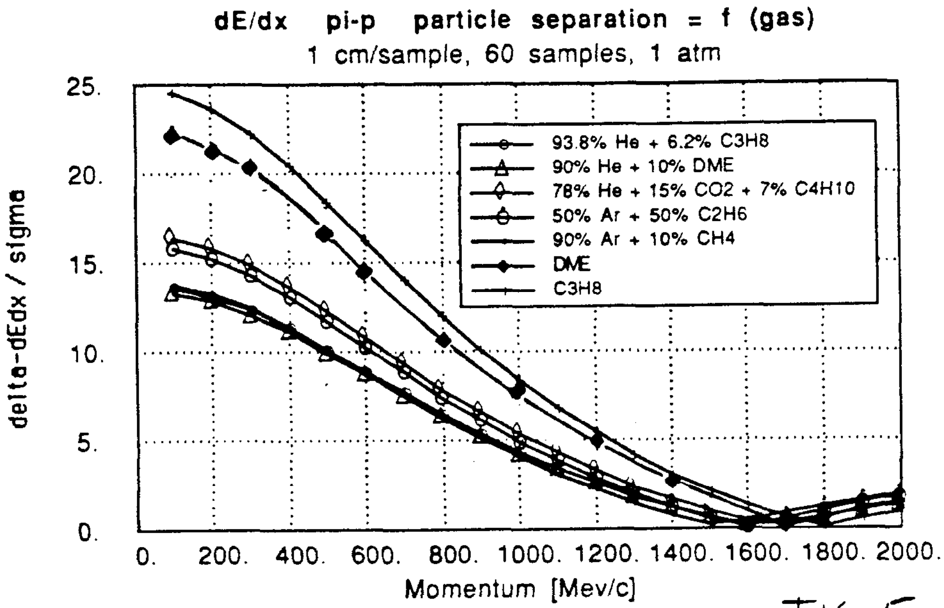
dE/dx pi-p particle separation = f (gas)
1 cm/sample, 60 samples, 1 atm
25.
20.
15.
10.
5.
0.
delta-dEdx / sigma
93.8% He + 6.2% C3H8
90% He + 10% DME
78% He + 15% CO2 + 7% C4H10
50% Ar + 50% C2H6
90% Ar + 10% CH4
DME
C3H8
0. 200. 400. 600. 800. 1000. 1200. 1400. 1600. 1800. 2000.
Momentum [Mev/c]

FIG. 5

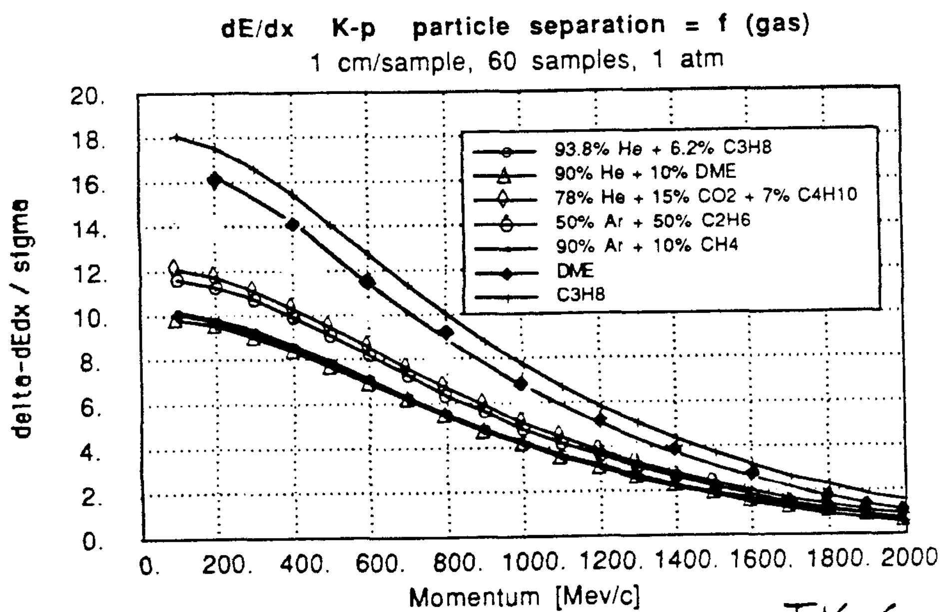
dE/dx K-p particle separation = f (gas)
1 cm/sample, 60 samples, 1 atm
20.
18.
16.
14.
12.
10.
8.
6.
4.
2.
0.
delta-dEdx / sigma
93.8% He + 6.2% C3H8
90% He + 10% DME
78% He + 15% CO2 + 7% C4H10
50% Ar + 50% C2H6
90% Ar + 10% CH4
DME
C3H8
0. 200. 400. 600. 800. 1000. 1200. 1400. 1600. 1800. 2000.
Momentum [Mev/c]

FIG. 6

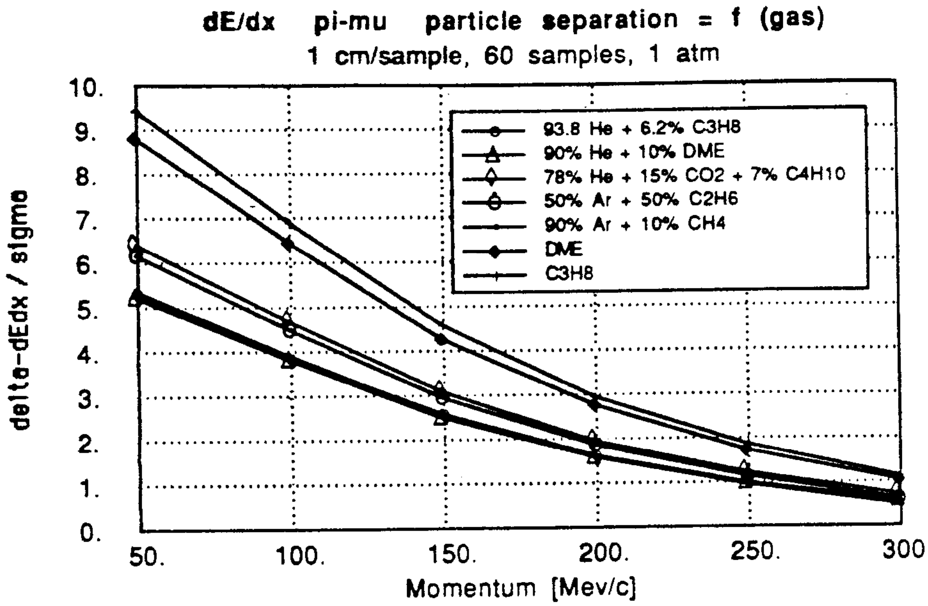
dE/dx pi-mu particle separation = f (gas)
1 cm/sample, 60 samples, 1 atm
delta-dEdx / sigma
Momentum [Mev/c]
93.8 He + 6.2% C3H8
90% He + 10% DME
78% He + 15% CO2 + 7% C4H10
50% Ar + 50% C2H6
90% Ar + 10% CH4
DME
C3H8
10.
9.
8.
7.
6.
5.
4.
3.
2.
1.
0.
50.
100.
150.
200.
250.
300.

FIG. 7

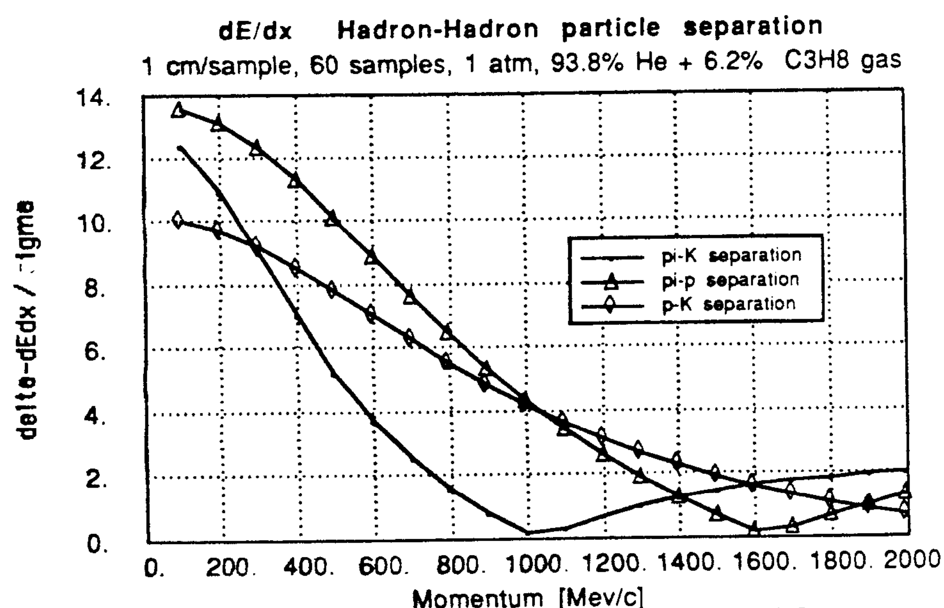
dE/dx Hadron-Hadron particle separation
1 cm/sample, 60 samples, 1 atm, 93.8% He + 6.2% C3H8 gas
delta-dEdx / sigma
Momentum [Mev/c]
pi-K separation
pi-p separation
p-K separation
14.
12.
10.
8.
6.
4.
2.
0.
0.
200.
400.
600.
800.
1000.
1200.
1400.
1600.
1800.
2000.

FIG. 8

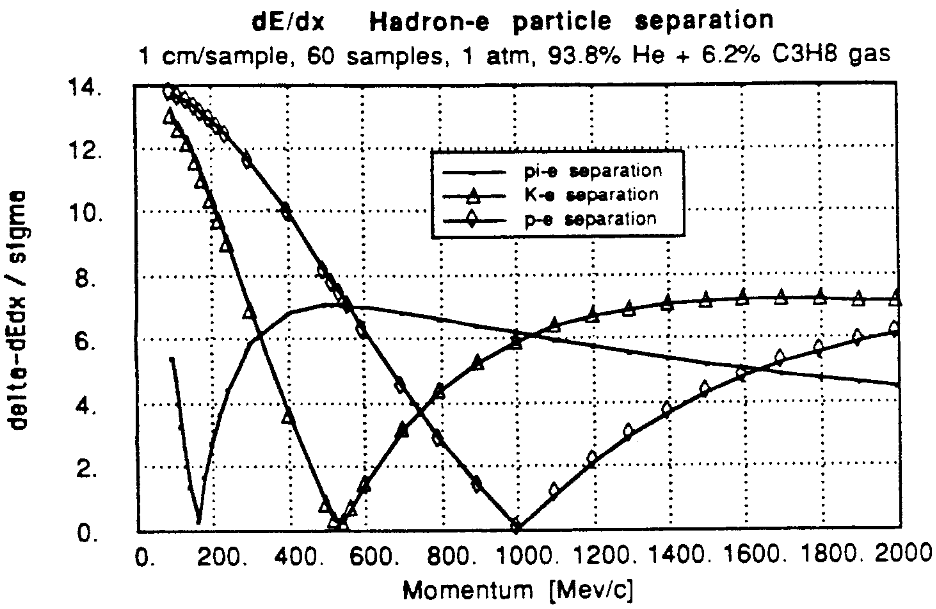
dE/dx Hadron-e particle separation
1 cm/sample, 60 samples, 1 atm, 93.8% He + 6.2% C3H8 gas
delta-dEdx / sigma
Momentum [Mev/c]
pi-e separation
K-e separation
p-e separation
0. 200. 400. 600. 800. 1000. 1200. 1400. 1600. 1800. 2000.
0. 2. 4. 6. 8. 10. 12. 14.

FIG. 9

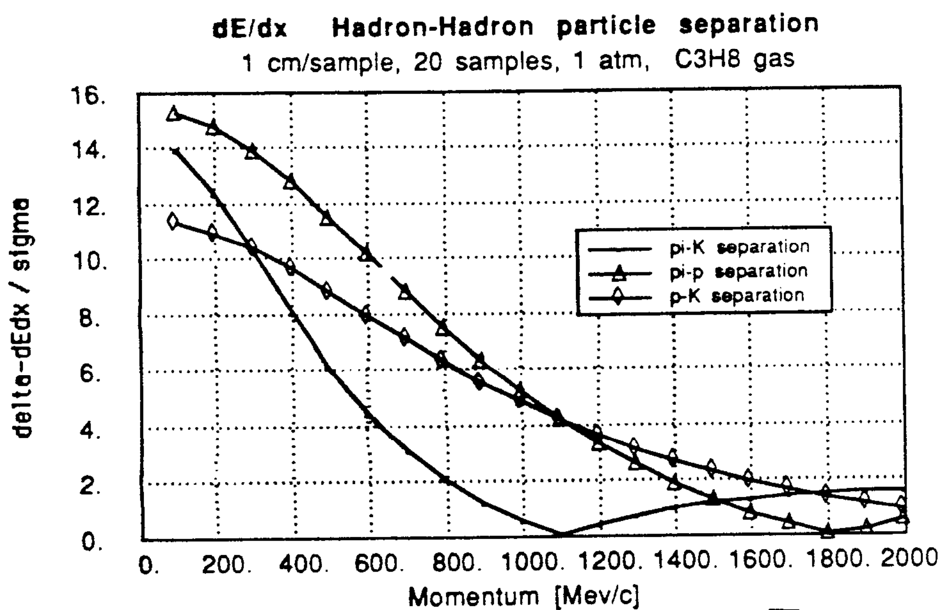
dE/dx Hadron-Hadron particle separation
1 cm/sample, 20 samples, 1 atm, C3H8 gas
delta-dEdx / sigma
Momentum [Mev/c]
pi-K separation
pi-p separation
p-K separation
0. 200. 400. 600. 800. 1000. 1200. 1400. 1600. 1800. 2000.
0. 2. 4. 6. 8. 10. 12. 14. 16.

FIG. 10

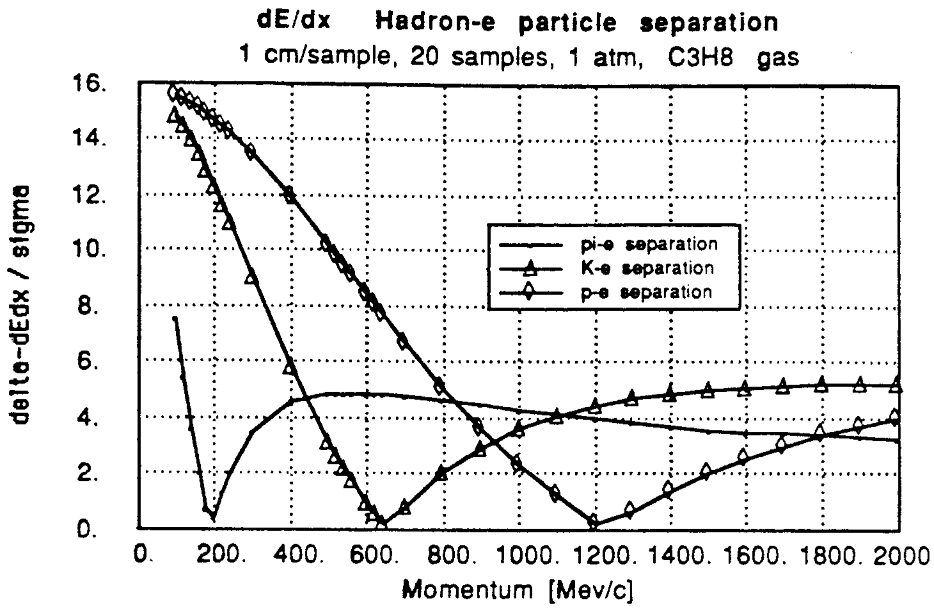
dE/dx Hadron-e particle separation
1 cm/sample, 20 samples, 1 atm, C3H8 gas
delta-dEdx / sigma
16.
14.
12.
10.
8.
6.
4.
2.
0.
0. 200. 400. 600. 800. 1000. 1200. 1400. 1600. 1800. 2000.
Momentum [Mev/c]
pi-e separation
K-e separation
p-e separation

FIG. 11