dE/dx Study at CEPC TPC

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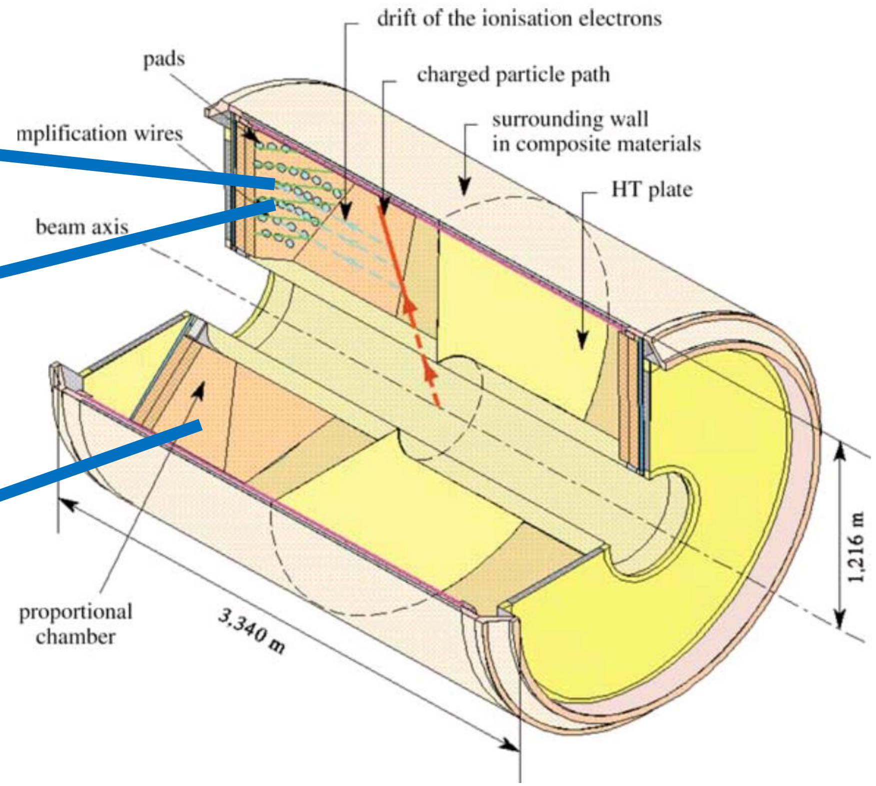
2017.02.28

dE/dx Meas. @ TPC

N_{pad}: number of pad circles

h_{pad}: pad size in the radial direction

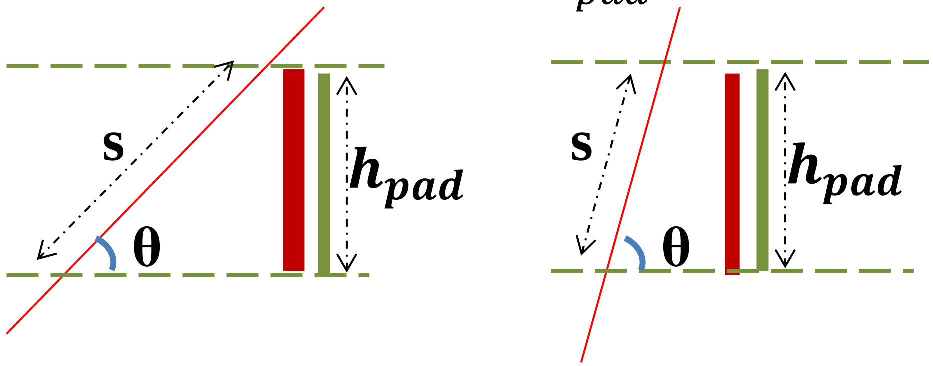
Gas density (atmosphere pressure, temperature, gas type)



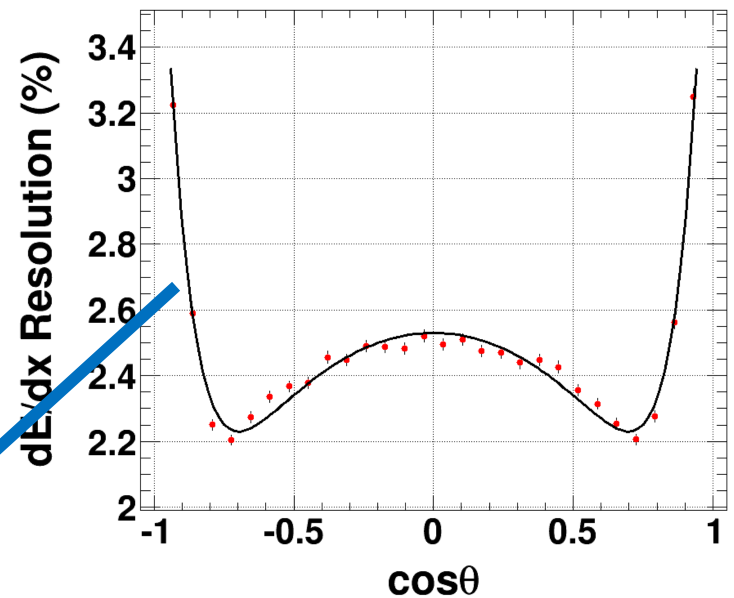
And, momentum and cosθ of the incident particle
(θ is the angle between the particle and z axis)

Space Charge Effect

$$charge\ density = \frac{dE}{dx} * \frac{s}{h_{pad}} = \frac{dE}{dx} \cdot \frac{1}{\sin\theta}$$



Smaller θ →
Larger charger density



$$\sigma_{dE/dx} = 2.53 - 0.77(cos\theta)^2 + 2.75(cos\theta)^{10}$$

N_{pad} decreases when track is parallel to Z

New 5-d Formula Based on G4

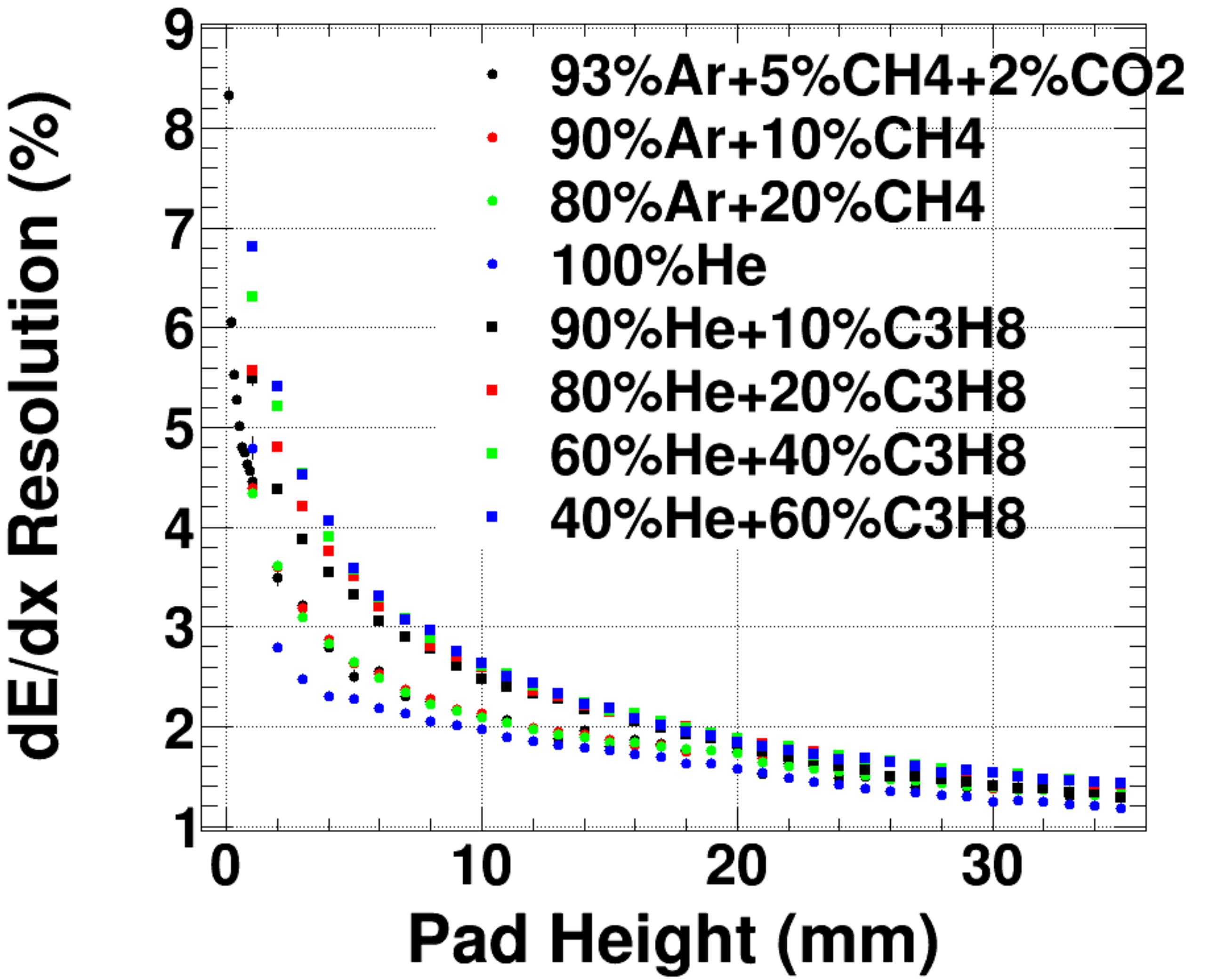
$$\frac{\sigma_{dE/dx}}{\mu_{dE/dx}} = \frac{13.66}{\sqrt{N_{pad}} * (h_{pad} \cdot \rho)^{0.3}} (2.18 + 0.30e^{-0.1p}) (2.53 - 0.77(cos\theta)^2 + 2.75(cos\theta)^{10})$$

N_{pad}: 30-350
h_{pad}(mm): 1-35
ρ(mg/cm3): 0.16~2(1-10atm)
p(GeV/c): 1-100

For He-based gas with a large fraction of hydrocarbon, the power in $(h_{pad} \cdot \rho)^{0.3}$ should be changed to $(h_{pad} \cdot \rho)^{0.45}$

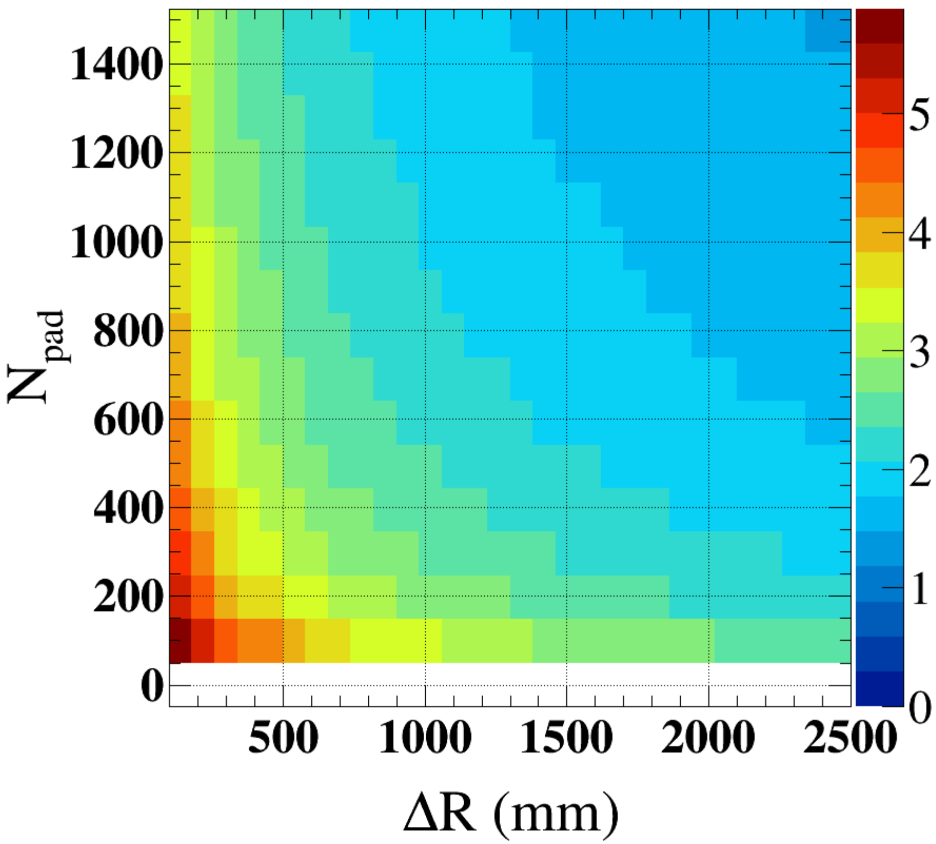
$$\frac{\sigma_{dE/dx}}{\mu_{dE/dx}} = \frac{14.61}{\sqrt{N_{pad}} * (h_{pad} \cdot \rho)^{0.45}} (2.18 + 0.30e^{-0.1p}) (2.53 - 0.77(cos\theta)^2 + 2.75(cos\theta)^{10})$$

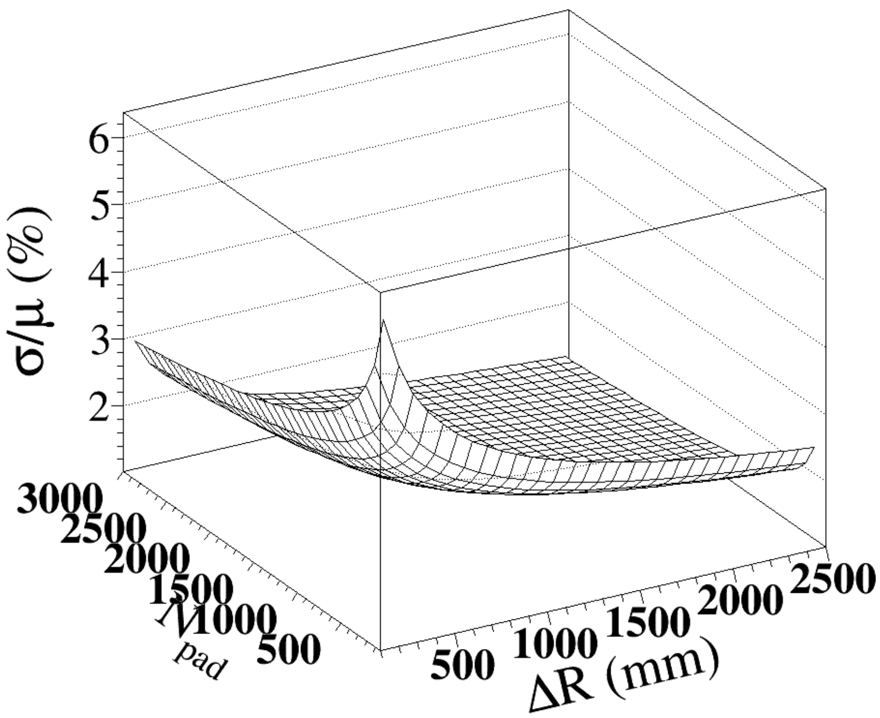
Gas Type



In order to separate the two groups with(out) much hydrocarbon, the normalization factor is different

$\sigma/\mu \sim (\Delta R, N_{pad})$





Comparison With Other Exp.

	TOPZA [1] 1987 @TRISTAN	PEP-4 [2, 3] 1981@PEP	DELPHI [4] 1990 @ LEP	ALEPH [5] 1990 @ LEP
Det. Structure	TPC	1st TPC	TPC	
Gas	90%Ar+10%CH4	80%Ar+20%CH4	80%Ar+20%CH4	91%Ar+9%CH4
Electric Field (V/cm)	353	750	187	125
Magnetic Field (T)	1	4 KG	1.23	1.5
Drift time (us)	23	21	20	
Pressure (atm)	3.5	8.6	1	1
$r_{in}(mm)$	367	200	325	300
$r_{out}(mm)$	1076	1000	1160	1800
L (mm)	3000	2000	2680	4400
mulitplicity	e^+e^- col.	e^+e^- col.	e^+e^- col.	e^+e^- col.
N_{cell}	175	183	192	344
h_{cell}	4	4	4	4
truncation	0-65%	0-65%	8-80%	8-60%
ρ (mg/ml)	1.5617	1.4624	1.4624	1.5716
Data sample (GeV)	π (0.4-0.65)	cosmic	e (45)	e/μ (45)
Exp. mea. (%)	4.6	2.80 (8.64atm) 3.56 (4.02atm) 4.65 (1.50atm)	6.5	4.5
G4 pre. (%)	2.2	1.59 / 1.95 / 2.59	2.76	2.10
Theory pre. (%)	2.25-2.55	1.56-1.77 1.96-2.23 2.64-2.99	2.82-3.21	2.07-2.34

Comparison With Other Exp.

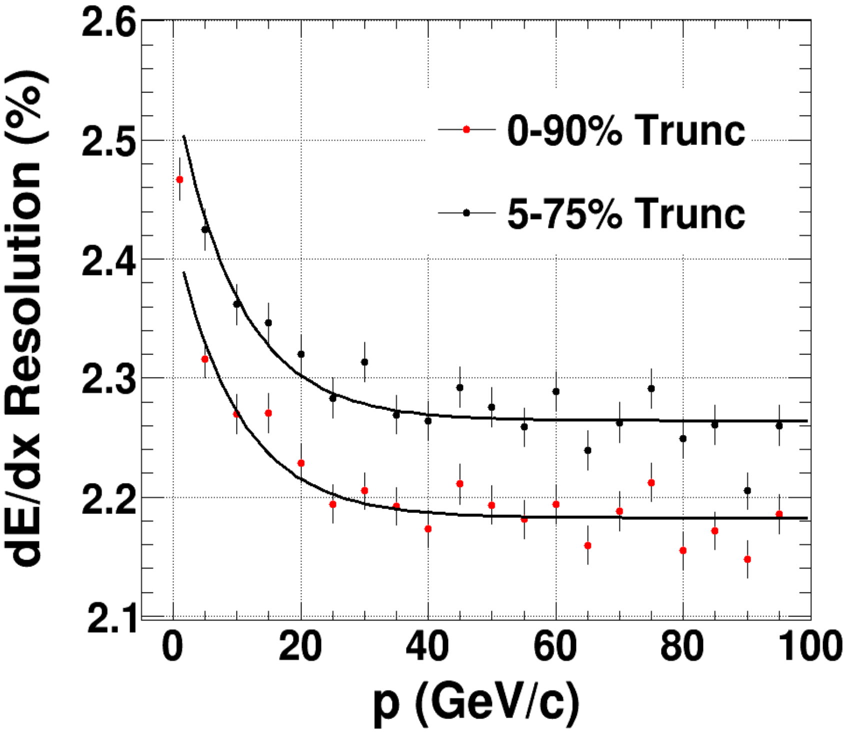
	Mark II [7] 1989 @SLAC	Babar[8] 1999@PEP-II	BESIII [9] 2009@ BEPC-II	Belle [10] @KEK
Det. Structure	Wire Chamber	Wire Chamber	Wire Chamber	Wire Chamber
Gas	89%Ar+10%CO2 +1%CH4	80%He +20%iC4H10	60%He +40%C3H8	50%He +50%C2H6
Electric Field (V/cm)	9	-	-	-
Magnetic Field (T)	-	1.5	1	1.5
Drift time (us)	-	-	-	-
Pressure (atm)	1	-	1	1
$r_{in}(mm)$	190	236	59	80
$r_{out}(mm)$	1520	810	810	874
L (mm)	2300	2800	2308	2400
mulitplicity	$e^+e^- col.$	$e^+e^- col.$	$e^+e^- col.$	$e^+e^- col.$
N_{cell}	72	40	43	53
h_{cell}	8.33	14.3	16.2	15.5
truncation	5-75%	0-80%	5-75%	0-80%
ρ (mg/ml)	1.669	0.631	0.851	0.7152
Data sample (GeV)	e (14.5)	e (1)	$\pi(0.5)$	$\pi(3.5)$
Exp. mea. (%)	7.0	6.8	6	5.0
G4 pre. (%)	3.5	4.5	4.10	3.96
Theory pre. (%)	3.7-4.2	4.7-5.3	3.76-4.26	3.63-4.11

Truncation In dE/dx Calculation

We measure the average dE/dx value of one track by removing parts of its hits (noise and Landau tail)

For 20GeV π with direction (0,1,1) in default geometry, σ/μ with different truncation:

0-1: 2.64
0-0.95: 2.24
0-0.9: 2.22
0-0.8: 2.28
0-0.65: 2.43
0.05-0.75: 2.31



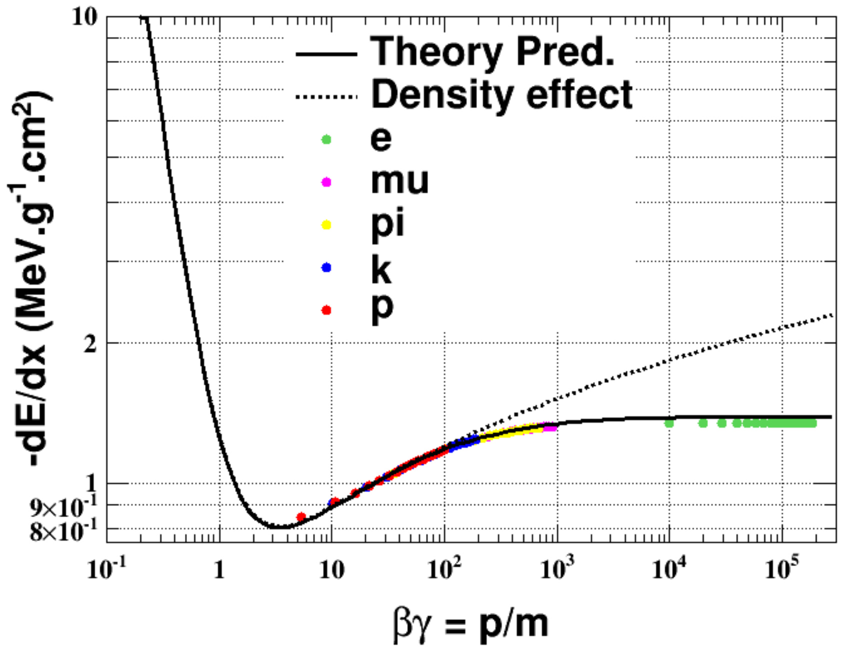
Loss of 30% hits will increase the resolution by ~4%

$\mu_{dE/dx} \sim \beta\gamma$

$$-\frac{\mathrm{d}E}{\mathrm{d}x} = 4\pi N_\alpha r_e^2 m_e c^2 z^2 (\frac{Z}{A})(\frac{1}{\beta^2}) \left[\ln\left(\frac{2m_e c^2 \beta^2 \gamma^2 E_{cut}}{I^2}\right) - \beta^2 - \frac{\delta}{2}\right]$$

$$\delta = \begin{cases} 0, & x = log_{10}(\beta\gamma) < x_0 \\ 2ln(x) - \bar{C} + a(x_1 - x)^k, & x_0 \le x \le x_1 \\ 2ln(x) - \bar{C}. & x \ge x_1 \end{cases}$$

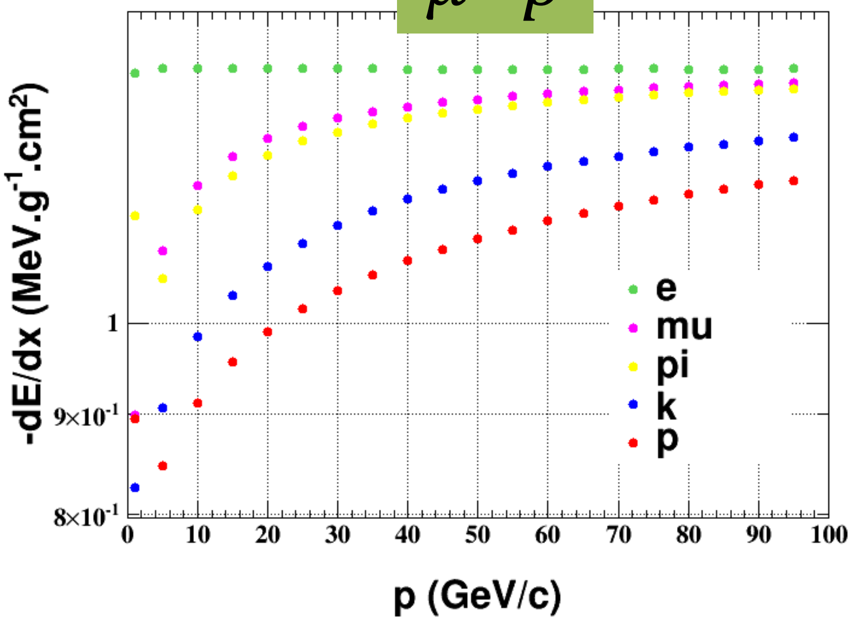
E_{cut}=851eV, determined by fitting the G4 plots



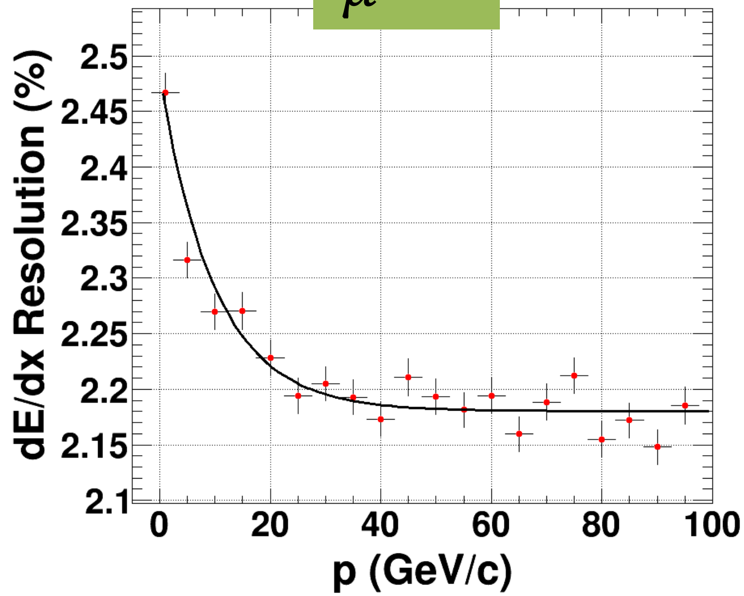
Z	A [g/mol]	ρ [g/cm^3]	I [eV]	a	k = m_s	x_0	x_1	$\bar{C}$
18 (Ar)	39.948	1.662×10^{-3}	188.0	0.19714	2.9618	1.7635	4.4855	11.9480

dE/dx For Different Particles

$\mu \sim p$

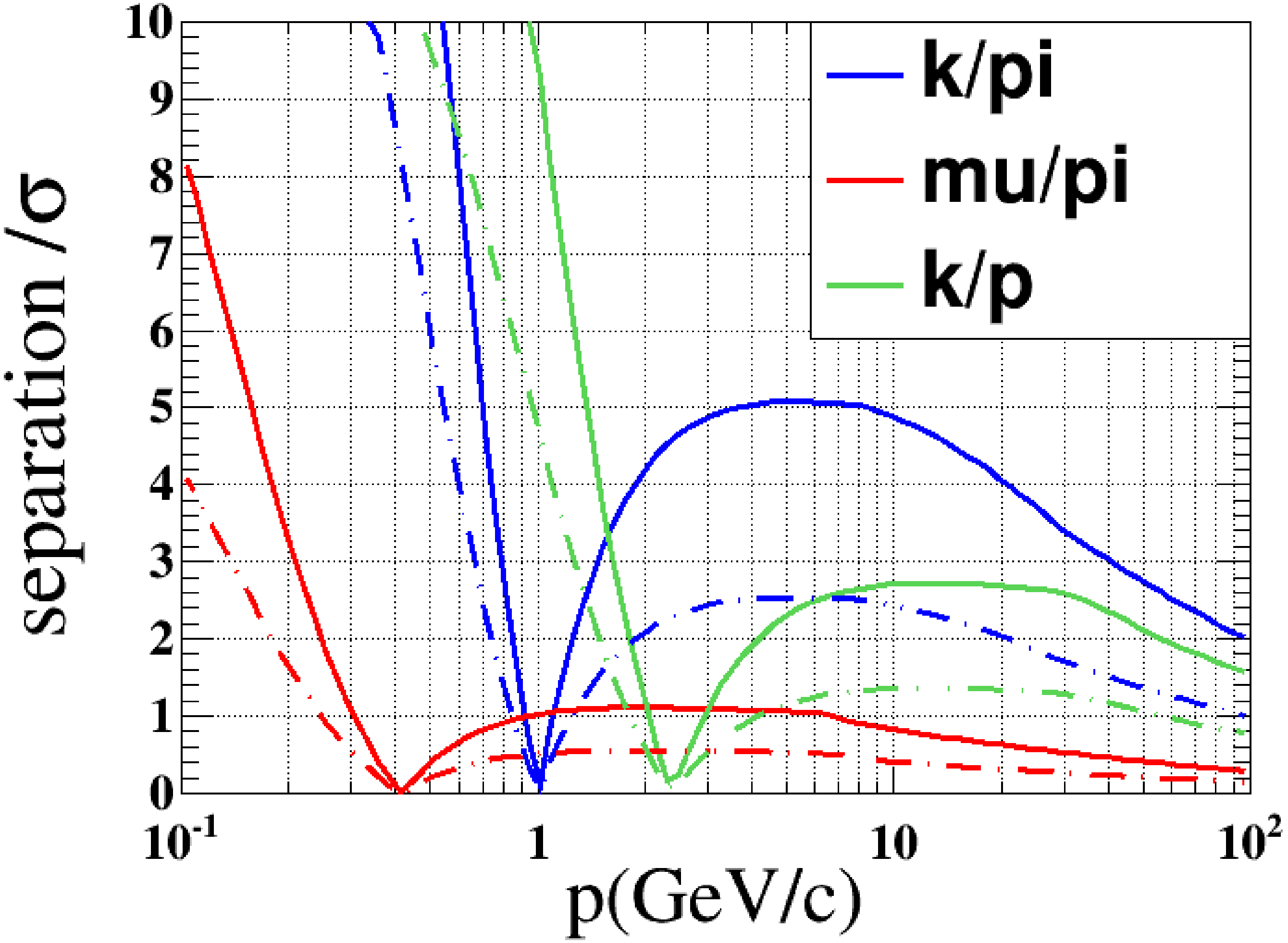


$\frac{\sigma}{\mu} \sim p$



Definition of separation ability: $\frac{\mu_1 - \mu_2}{\sqrt{\sigma_1^2 + \sigma_2^2}}$

Separation Ability



Entrance angle (0,1,1)

$\mathbf{2.4\sigma \sim 4.5\%}$ ***mis id***

$\mathbf{3.9\sigma \sim 0.3\%}$ ***mis id***

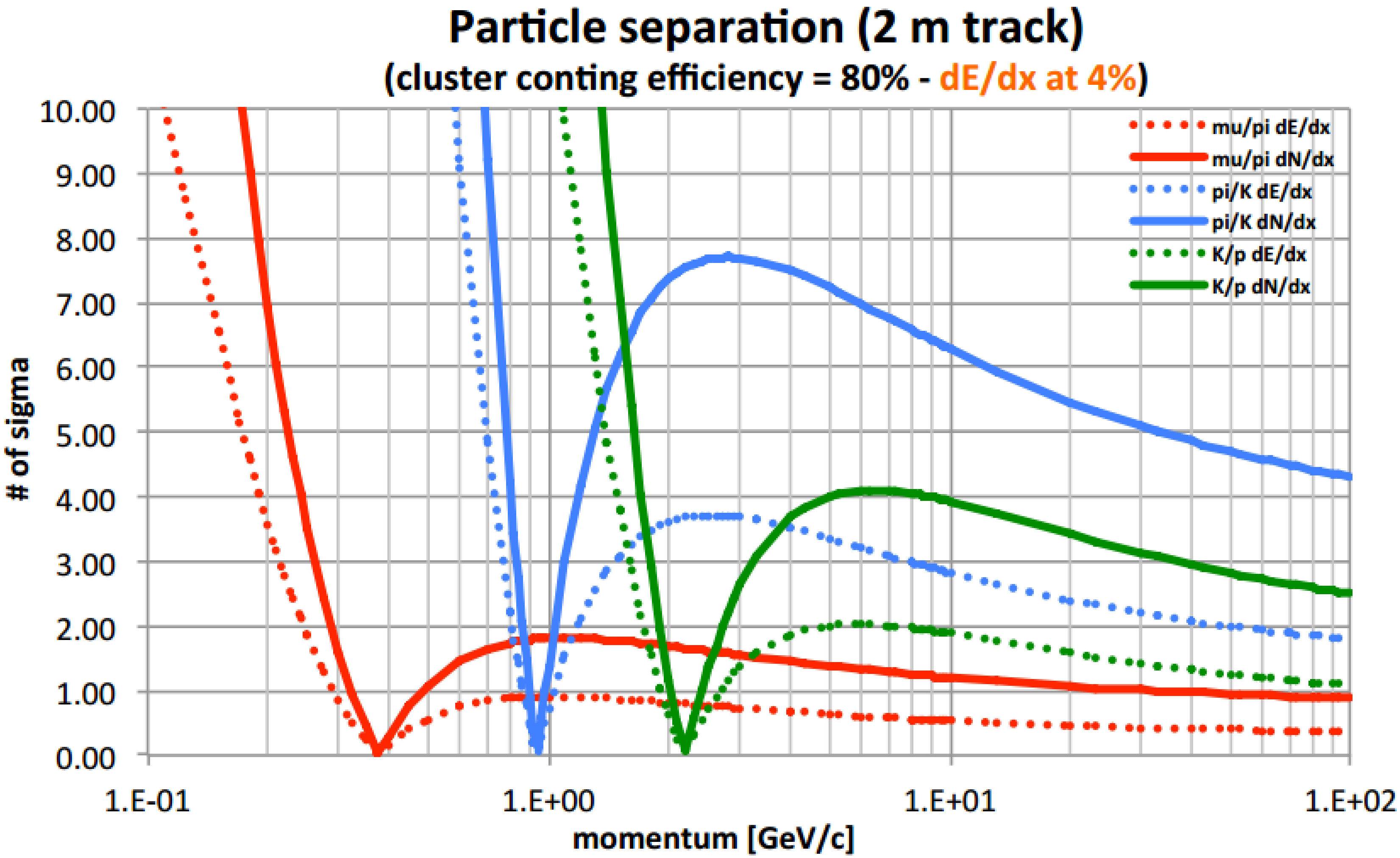
Dash-dotted line corresponds to the case I doubled the σ/μ

Summary & Outlook

- The influence of entrance angle on dE/dx is predicted, and a range of prediction is given

- Preliminary result of the separation ability is given.

A Screenshot From INFN Report



Dash-dotted line corresponds to the case using clustering counting techneque

Comparison With Other Exp.

	STAR 2000-2001 @RHIC	PEP-4 1976 @SLAC	ALICE 2008- @LHC
Det. Structure	TPC	TPC	TPC
Gas	90%Ar+10%CH4	80%Ar+20%CH4	Ne+CO2+N2
N_{layer}	45	183	159
$h_{cell}(mm)$	20*32 (12*13)	4	7.5*63, 10*64, 15*32
$r_{in}(mm)$	500	-	788
$r_{out}(mm)$	2000	1000	2580
L (mm)	4200	2000	4994
Pressure (atm)	1	8.64	1
dE/dx (%)	8 (1GeV, 0.25T)	2.8	5% (cosmic, 160 cluster)
Theory Pred. (%)	3.4-4.5	1.6-1.8	2.1-2.8