DCH Performance & Particles ID in SuperB

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Particles for dE/dx Analysis

Goals:

- **Estimation of dE/dx separation powers.**
- **dE/dx Calibration elements and dE/dx ID efficiency/fake rate measurements.**
- **Investigation of different gas mixtures using FastSim & Garfield simulation.**
- **Estimation of IP resolution.**

Using the FastSim 0.1.3 version we simulated different decays of B/Bbar to obtain a pure samples of analyzed particles covering as much as possible wide momentum range:

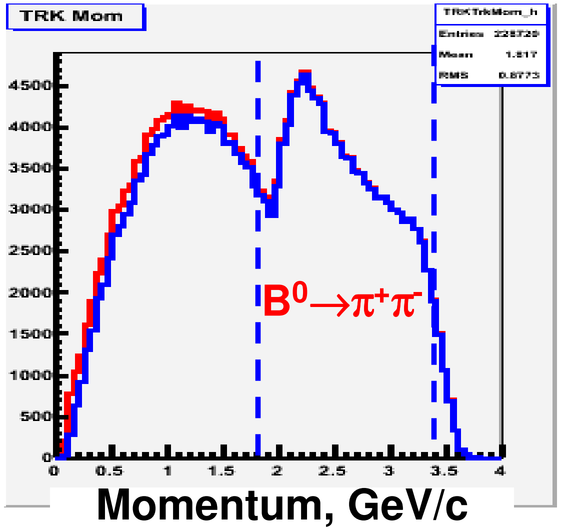
- **Electrons and Muons from J/ψ decays;**
- **Pions from B decays;**
- **Kaons from B and ϕ decays;**
- **Protons from B and J/ψ decays.**

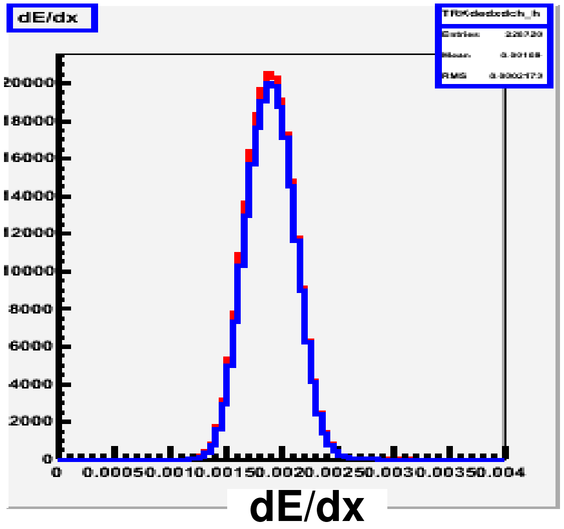
For dE/dx analysis we selected samples of electrons, muons, pions, kaons and protons without particles identification criteria.

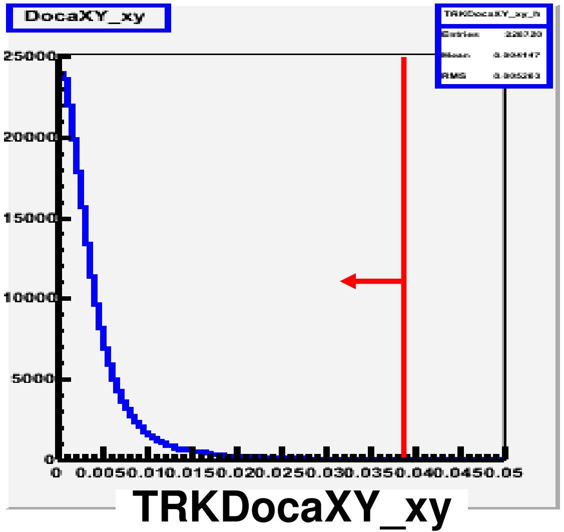
Pions Selection

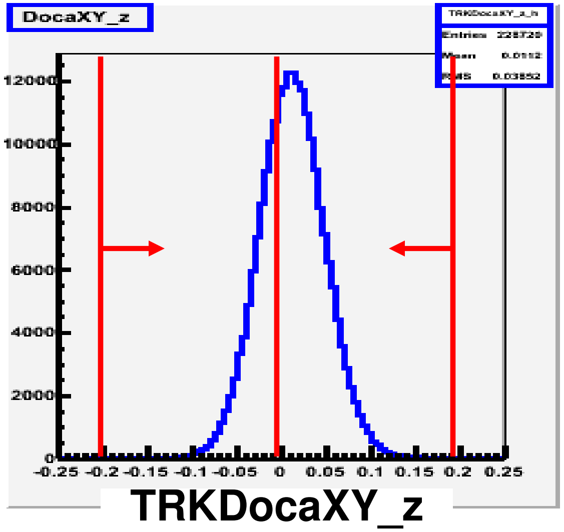
Decay: $B^0 \to \pi^+\pi^-$, B^0bar$\to \pi^+\pi^-\pi^+\pi^-$

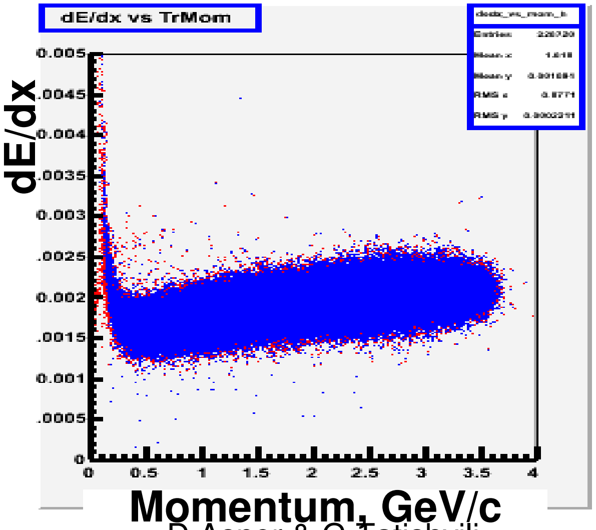
TRKDocaXY_xy < 0.04 m
|TRKDocaXY_z| < 0.2 m

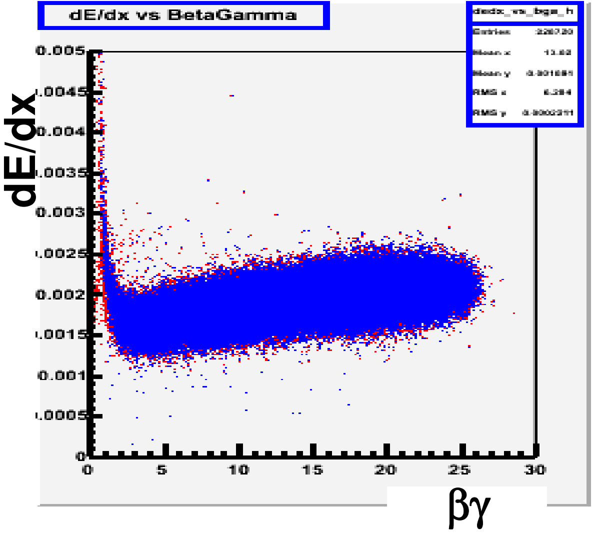






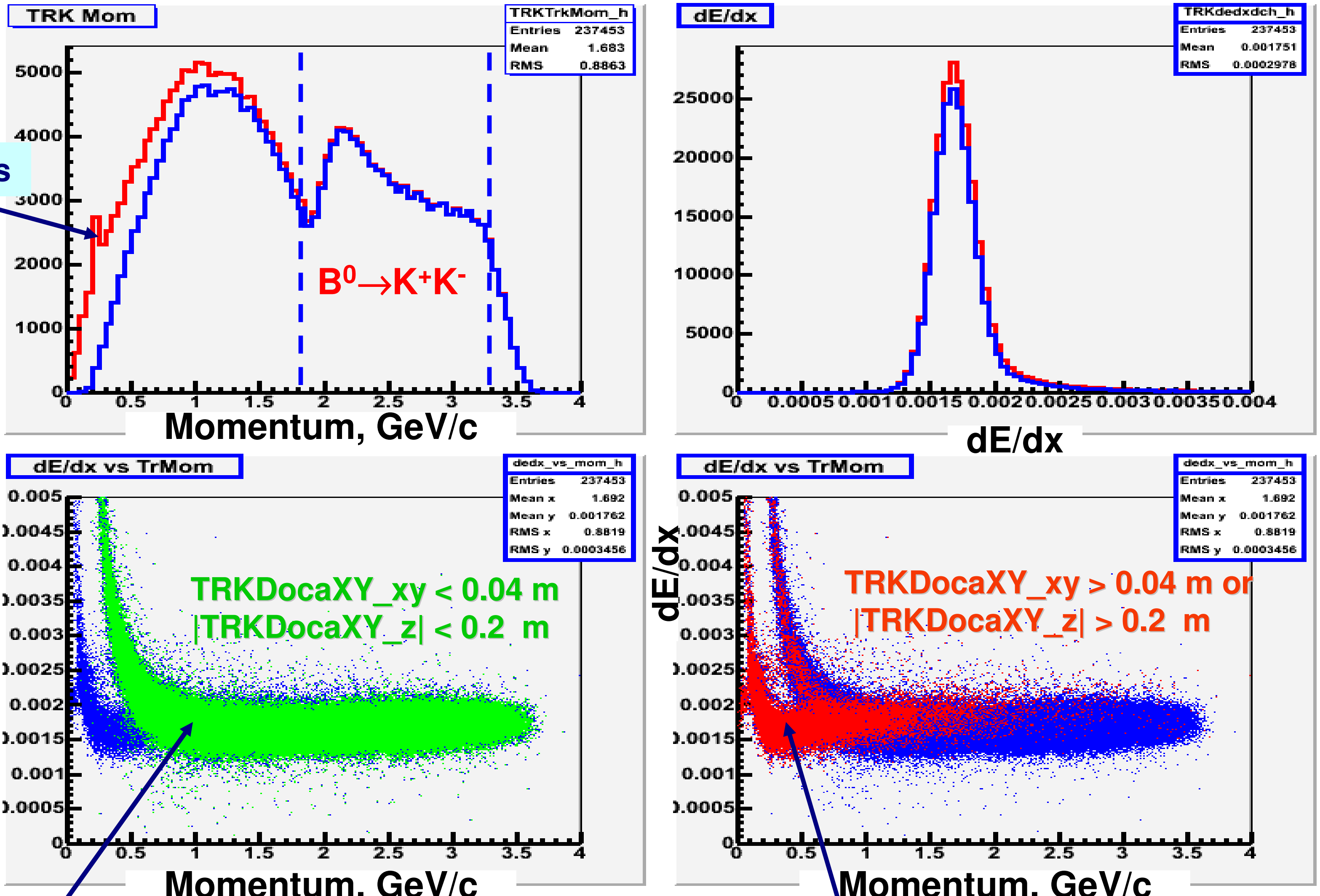






Kaons Selection

Simulation of events with “only” Kaons in the final state.



Electrons

$B^0 \to K^+K^-$

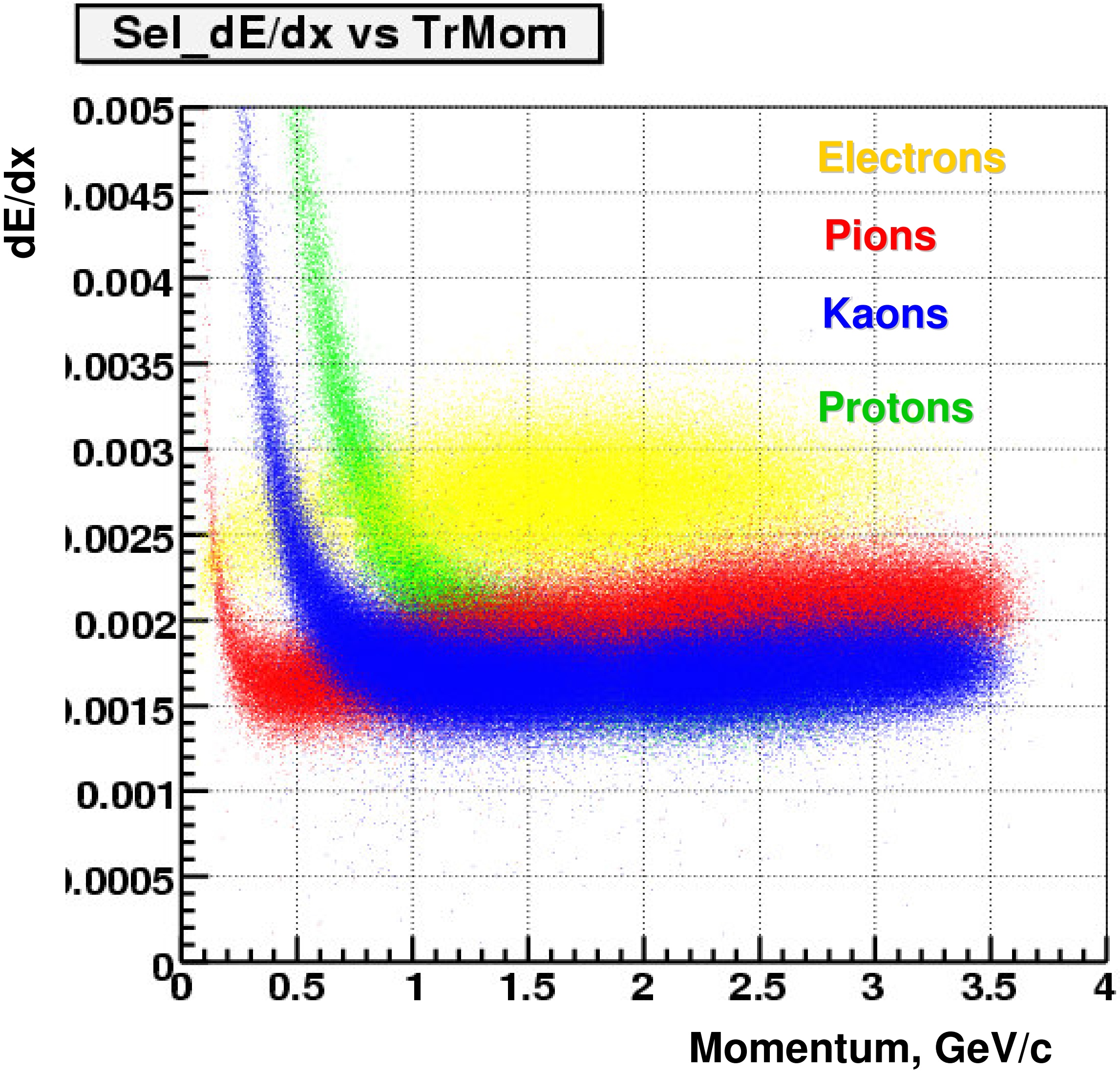
TRKDocaXY_xy < 0.04 m
|TRKDocaXY_z| < 0.2 m

TRKDocaXY_xy > 0.04 m or
|TRKDocaXY_z| > 0.2 m

Selected Kaons

Electron & Muon contamination mainly from $K \to \mu\nu$, $K \to \pi^0 e\nu$, $K \to \pi^0\mu\nu$ decays

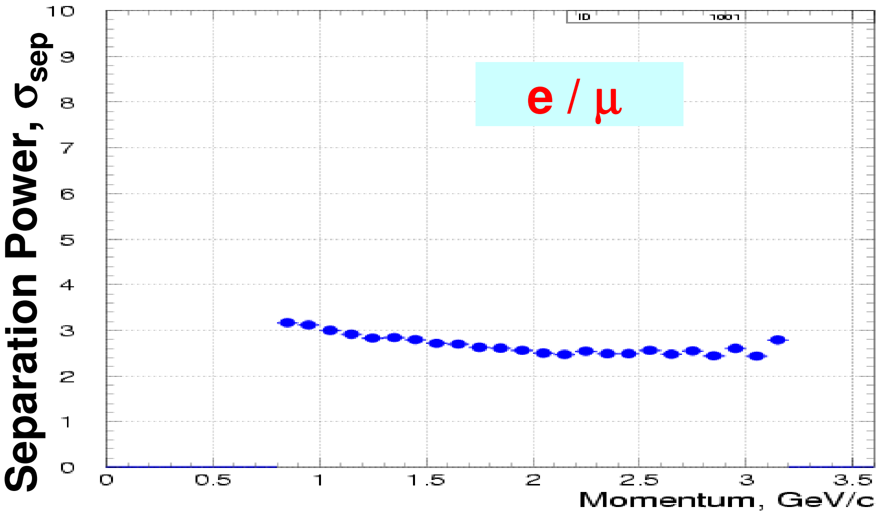
Selected Samples For dE/dx Analysis

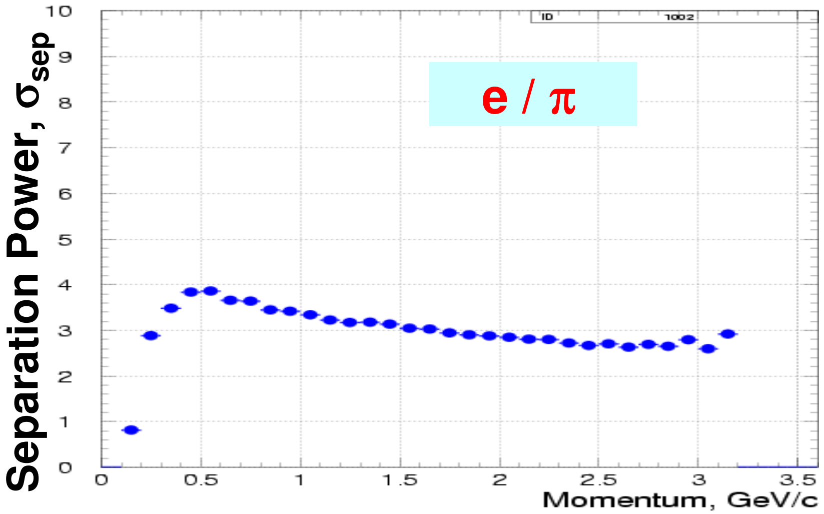


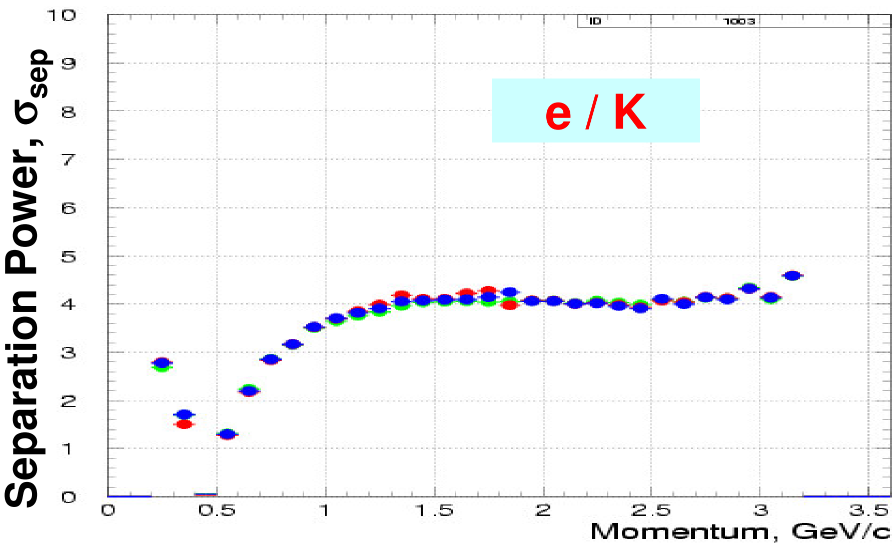
Separation powers between selected particles were calculated in each momentum bin with ΔP=100 MeV/c.

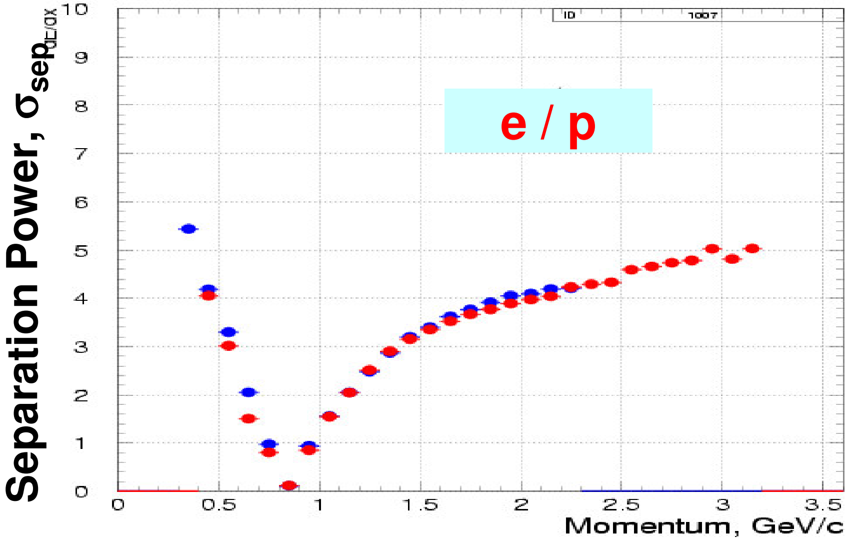
$$\sigma_{Sep.} = \frac{| M(dE/dx)_{p1} - M(dE/dx)_{p2} |}{\sqrt{\left(\sigma^2_{dE/dx\_p1} + \sigma^2_{dE/dx\_p2}\right)}}$$

Separation Powers of Electrons and Other Particles

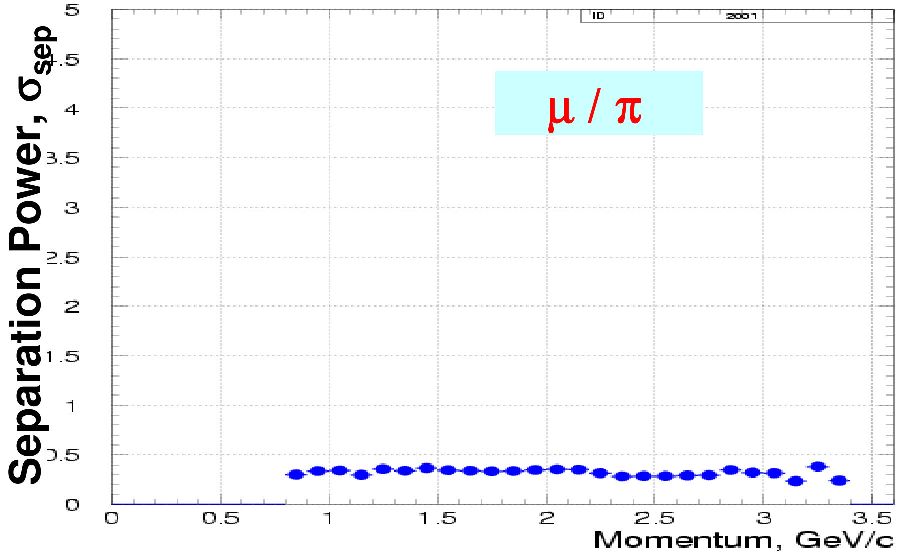


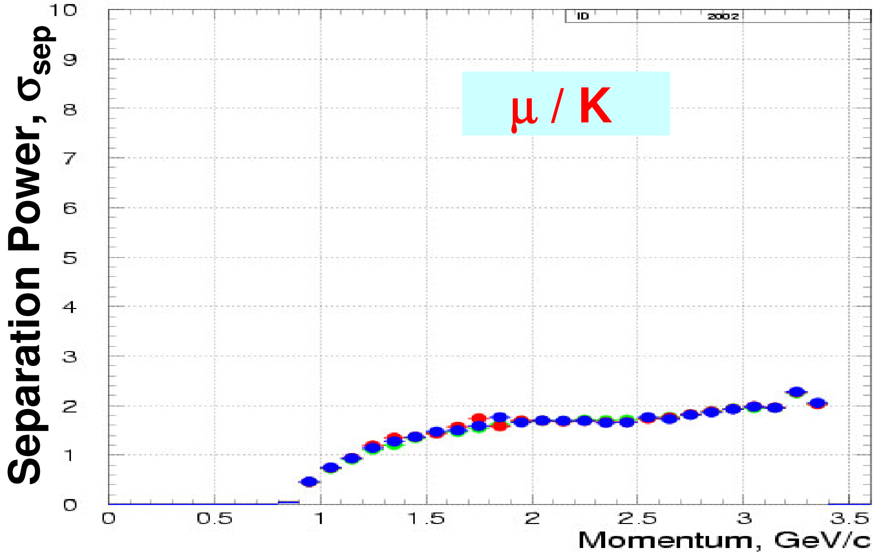


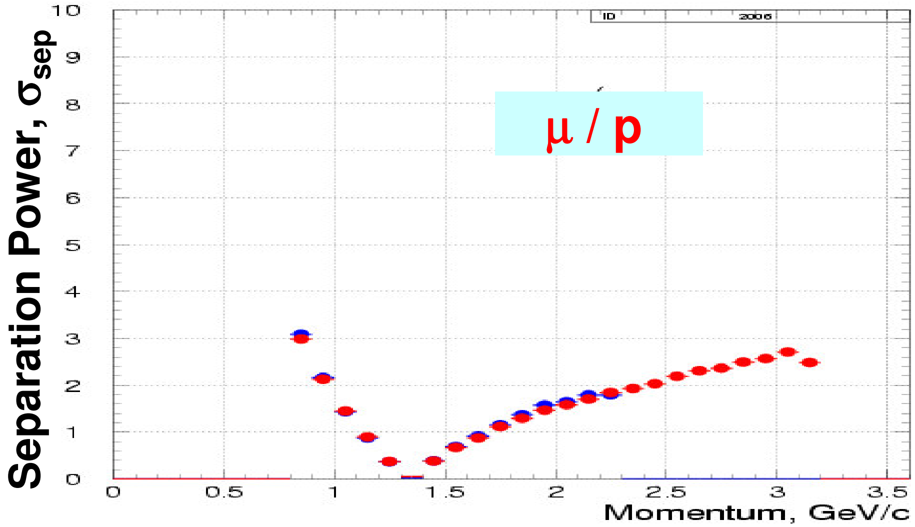




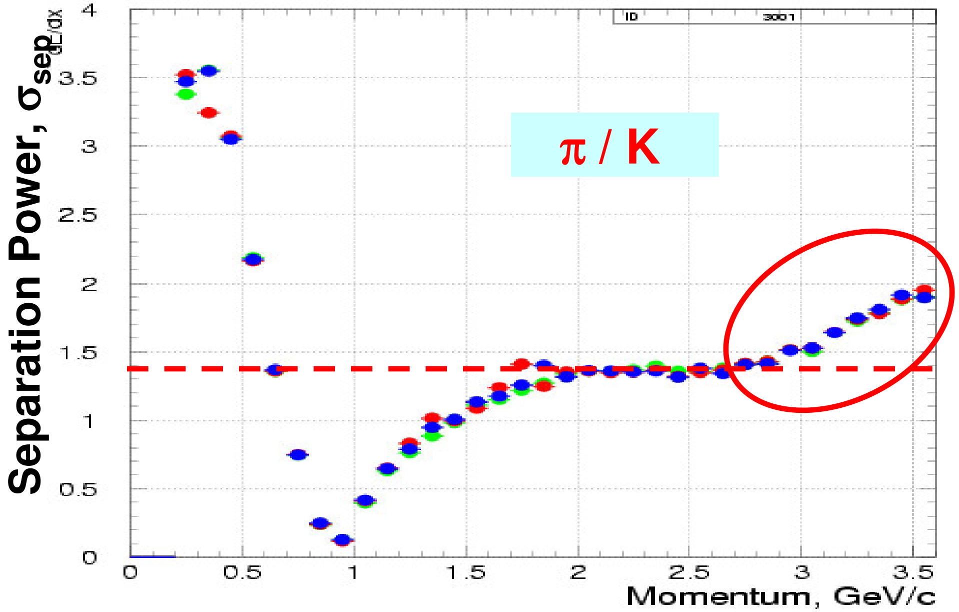
Separation Powers of Muons And Other Particles

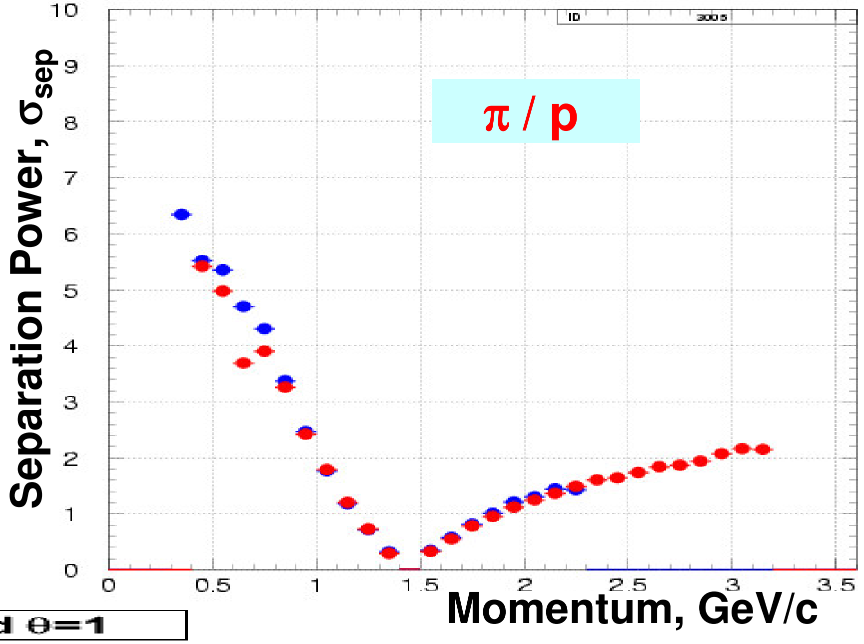


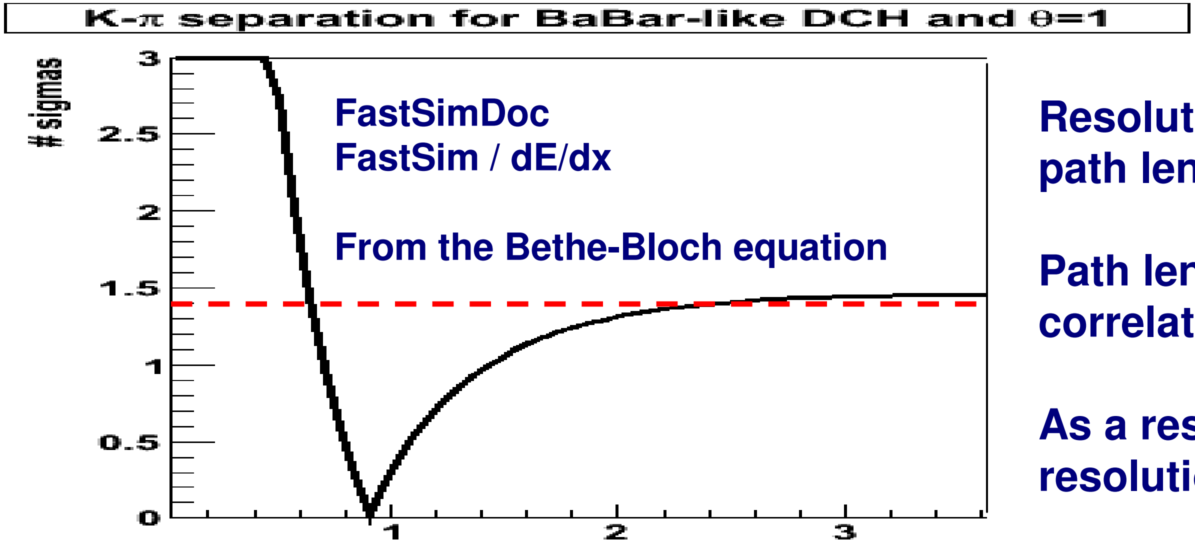




Pion / Kaon And Pion / Proton Sepatation Powers.







FastSimDoc
FastSim / dE/dx

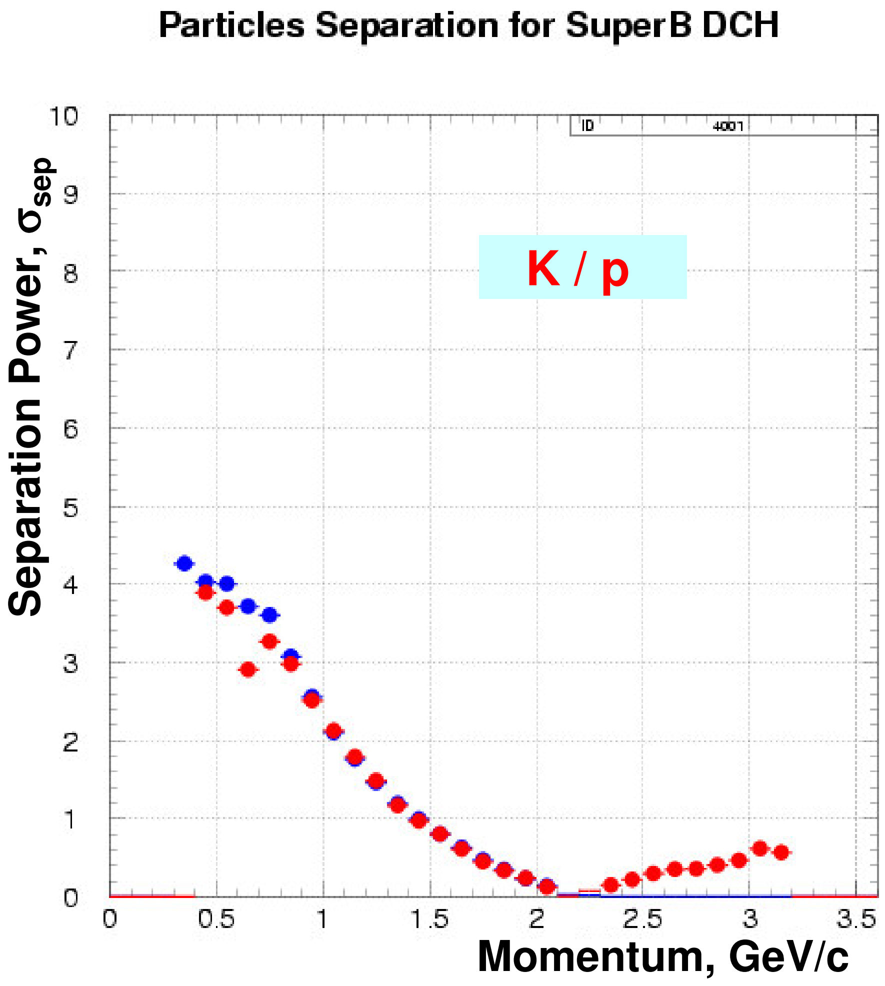
From the Bethe-Bloch equation

Resolution grows with angle (and gas path length).

Path length and momentum are correlated.

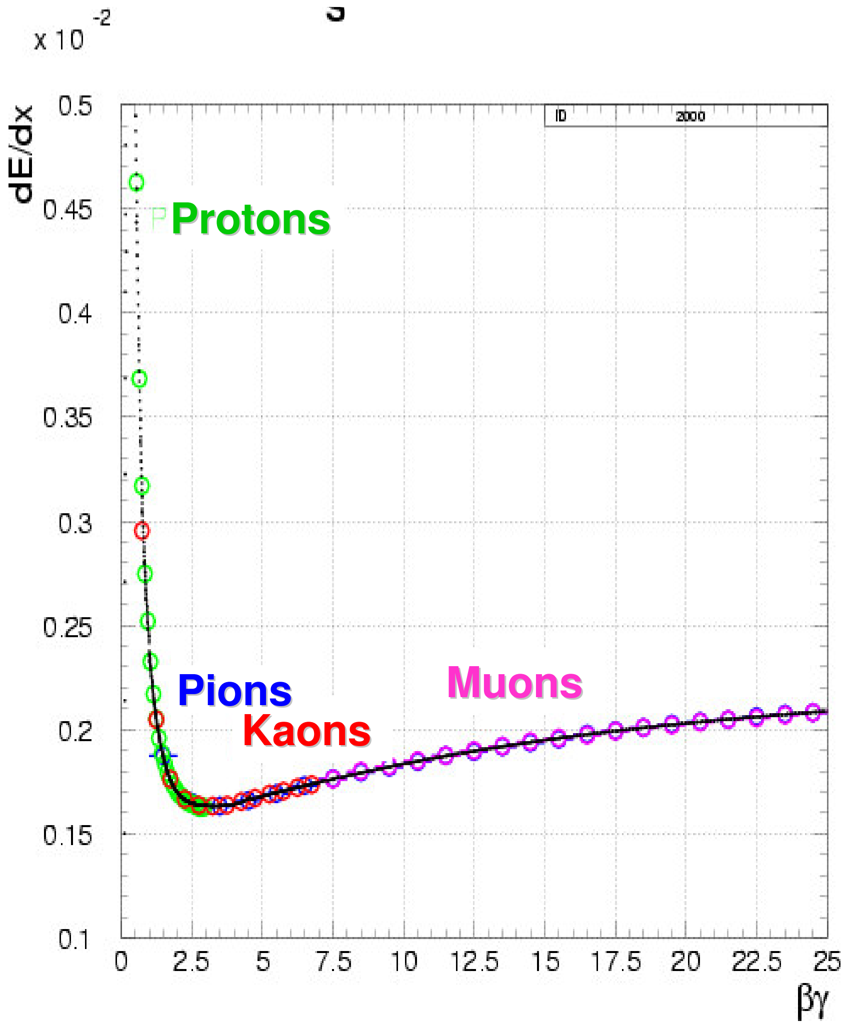
As a result We see an improvement in resolution with increasing momentum.

Kaon / Proton Separation Power



dE/dx Tuning

dE/dx Tuning is very important for data, but should be tested on MC info.



We parameterized dE/dx as a function of βγ for muons, pions, kaons and protons simultaneously.

We fit three βγ regions ([0. - 1.0], [1.0 - 4.5] and [4.5 - 50.]) to a power law + third order polinomial.

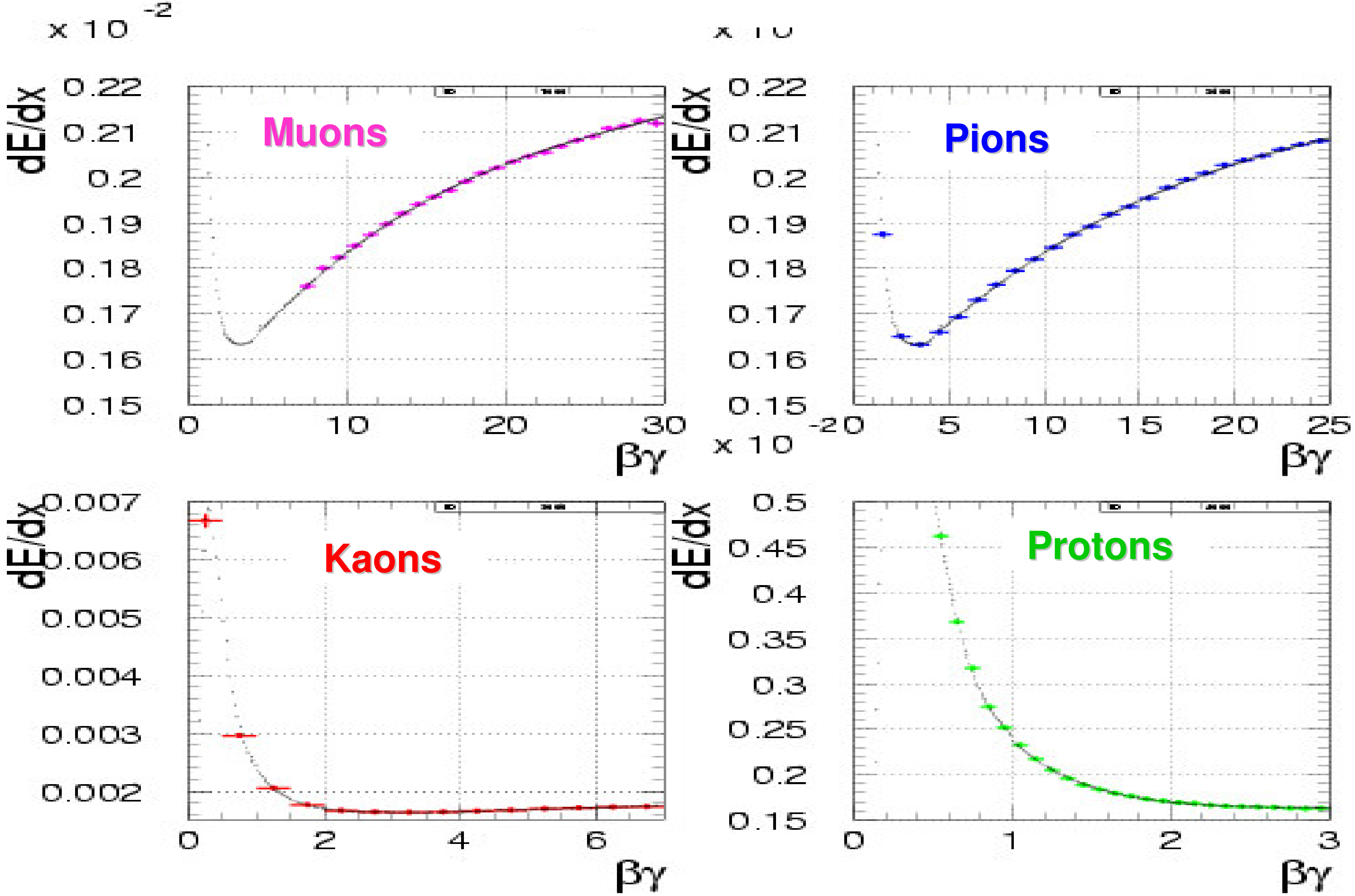
$$dE/dx(\beta\gamma) = A \cdot (\beta\gamma)^{n} + B_0 + B_1 \cdot (\beta\gamma) + B_2 \cdot (\beta\gamma)^2 + B_3 \cdot (\beta\gamma)^3$$

At very large βγ dE/dx is constant ("Fermi Plateau")

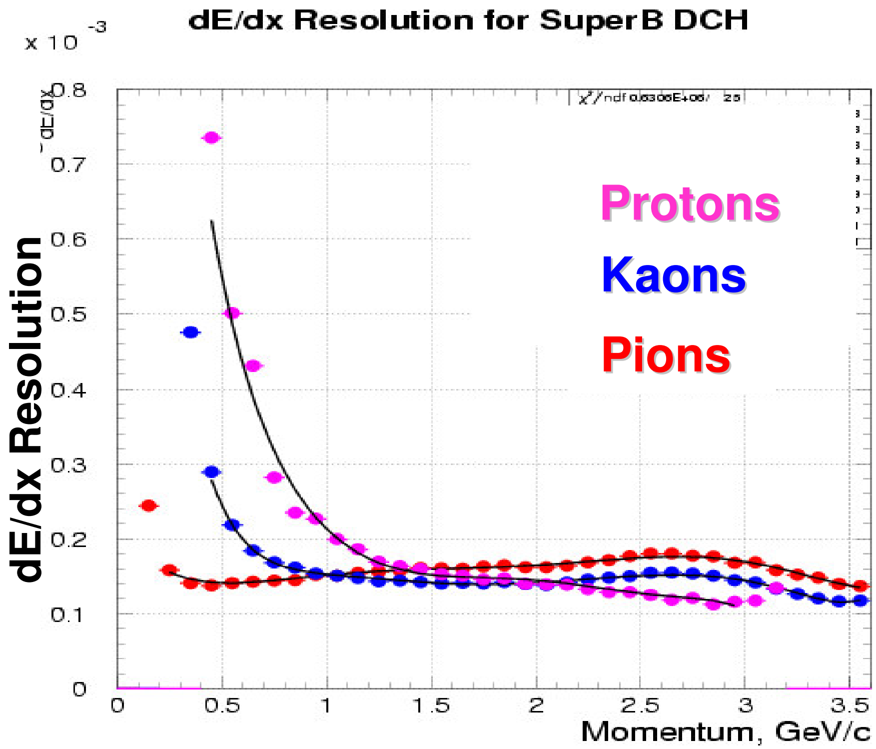
In the region βγ > 50 (electrons) for dE/dx parameterization exp-function can be used.

$$dE/dx(\beta\gamma) = C \cdot e^{D \cdot (\beta\gamma)} + E$$

dE/dx Tuning, cntd.



dE/dx Tuning, cntd.



For particle identification using dE/dx the variables σ was constructed. The value of σ is given by:

$$\sigma = \frac{(dE/dx)_{Measured} - (dE/dx)_{Expected}}{\sigma_{dE/dx}}$$

dE/dx is a function of βγ for each particle. For each type of particles (e, m, p, K, p) using βγ we find the expected value of $(dE/dx)_{Expected}$.

The track level quantity dE/dx can be thought of as the total charge (Q) deposited by the track divided by the total path length of the track.

The error on Q should be proportional to $Q^{1/2}$ and therefore the resolution of $\sigma_{dE/dx}$ should be given by equation:

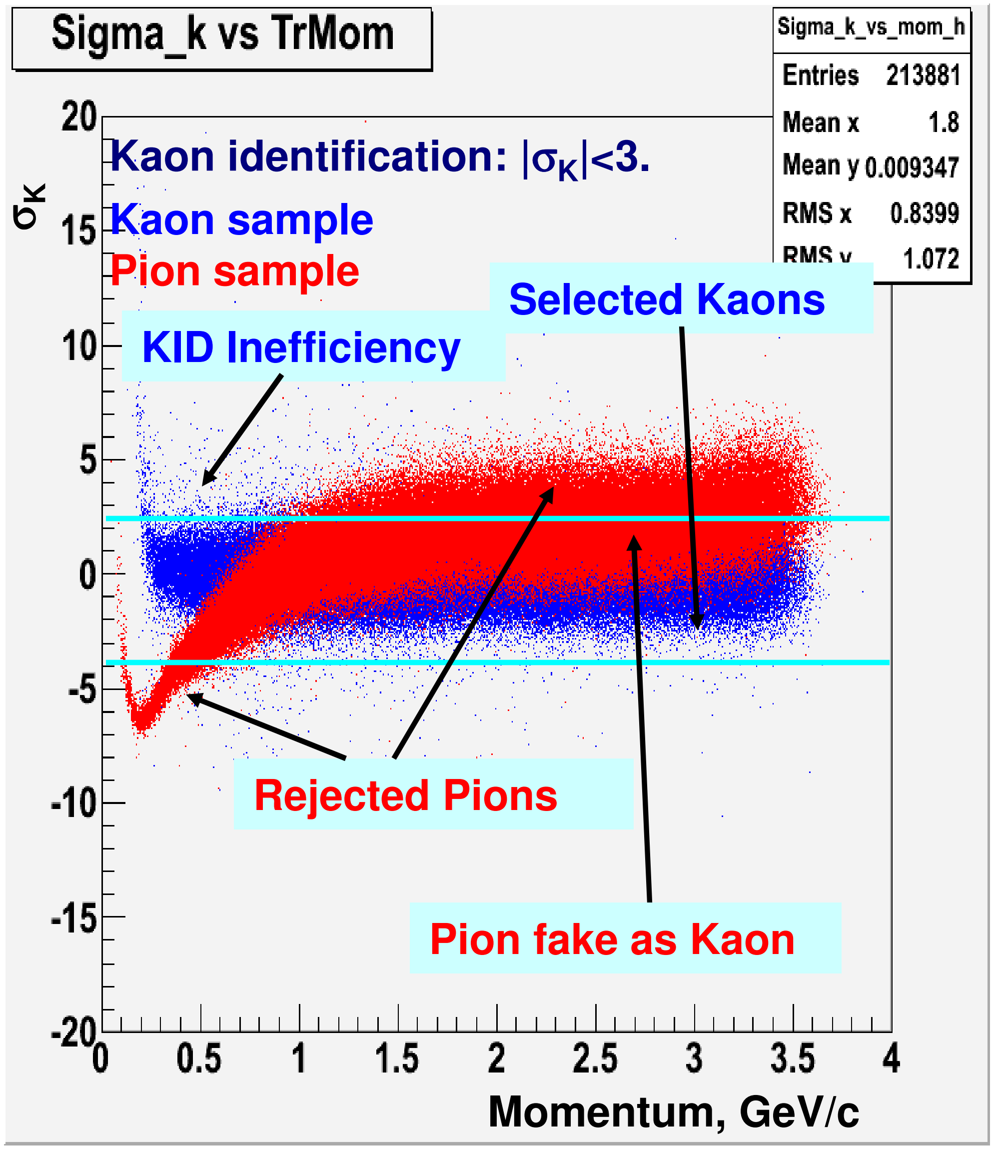
$$\sigma_{dE/dx} \approx \frac{Q^{1/2}}{L} = \frac{((dE/dx)\cdot L)^{1/2}}{L} = \frac{(dE/dx)^{1/2}_{Measured}}{L^{1/2}}$$

$L=N_{hit}/\sin(\theta)$ is a path length.

We plan to parametrize the dE/dx resolution in terms of three functions:

$$\sigma_{dE/dx} = \frac{f[(dE/dx)^{1/2}_{Measured}]}{g[N^{1/2}_{Hit}]\cdot h[1/\sin^{1/2}(\theta)]}$$

dE/dx Identification



Kaon identification: $|\sigma_K|<3$.

Kaon sample

Pion sample

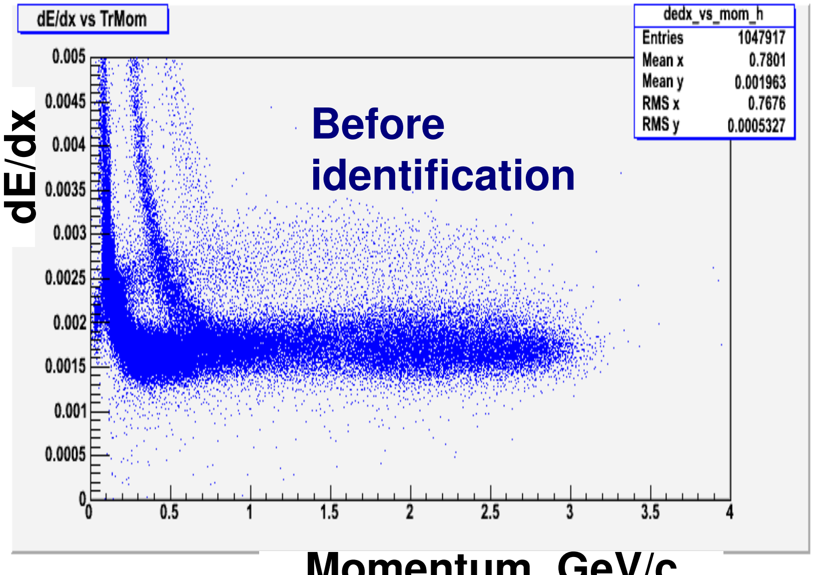
Selected Kaons

KID Inefficiency

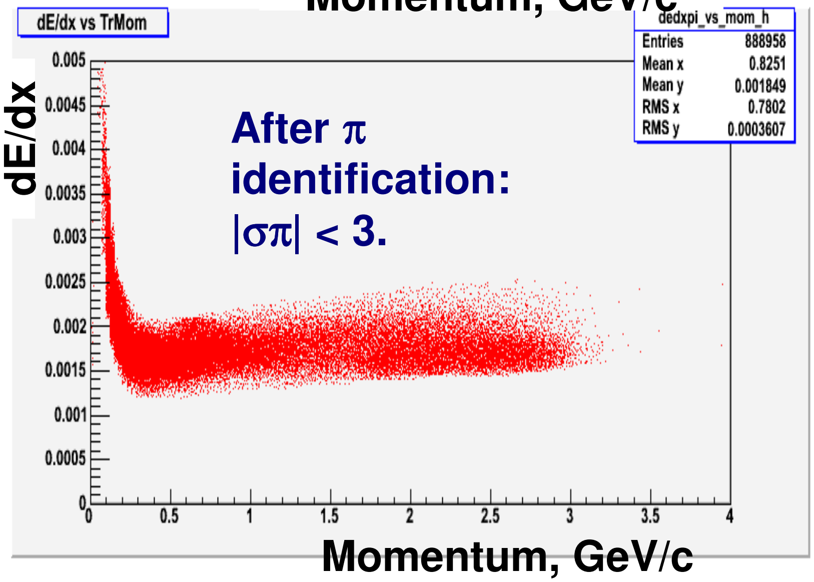
Rejected Pions

Pion fake as Kaon

Pion identification: $|\sigma_\pi|<3$.

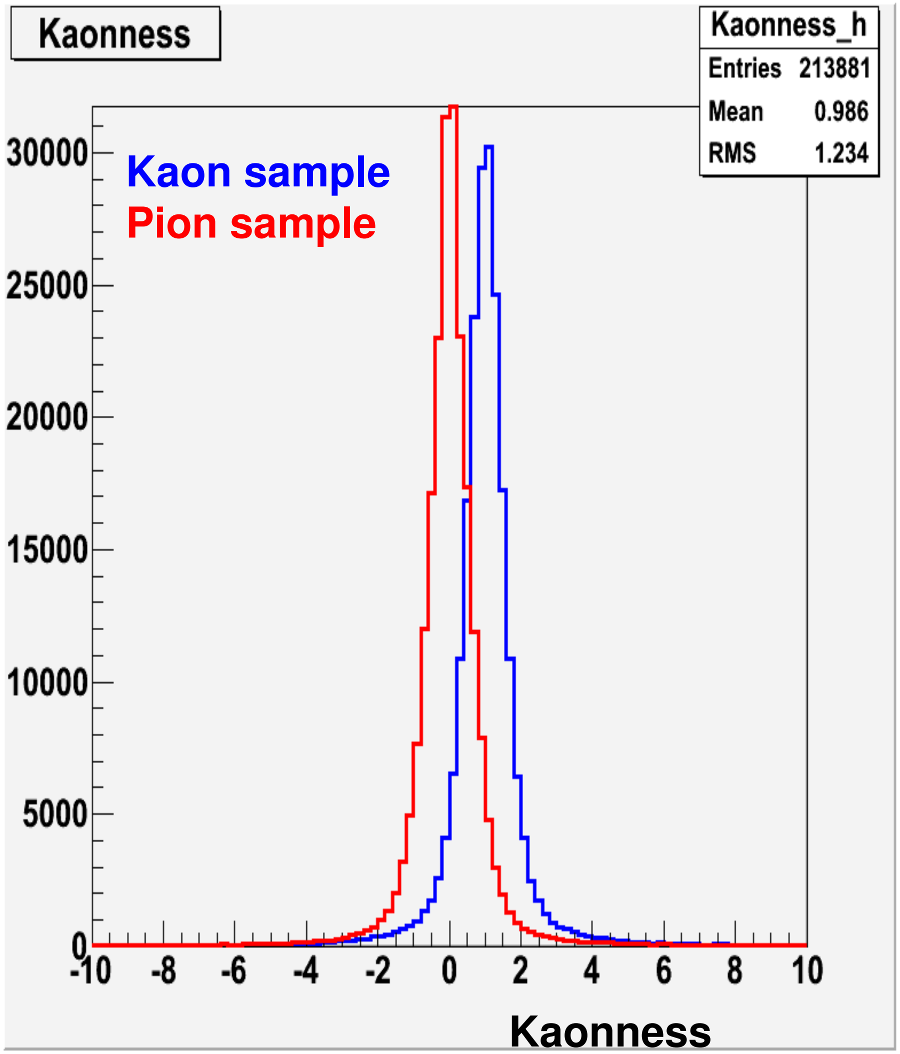


Before identification



After π identification: $|\sigma\pi| < 3$.

dE/dx Identification, cntd.



Useful quantity for π/K separation study is so called "Kaonness".

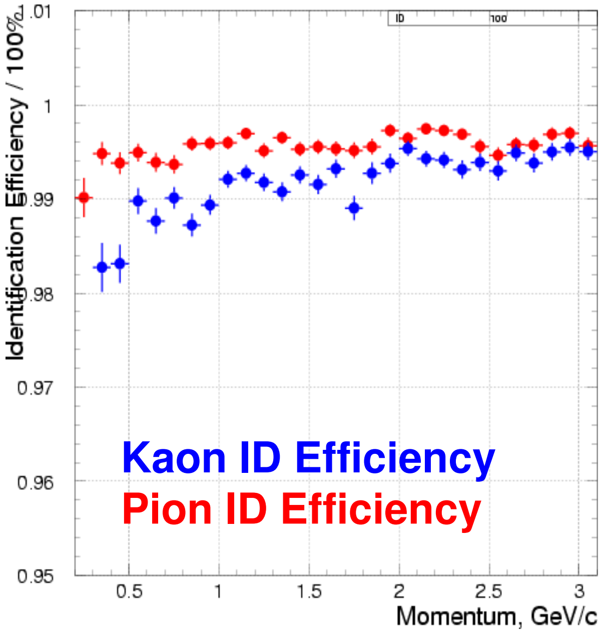
$$Kaonness = \frac{(dE/dx)_{Measured} - (dE/dx)_{Exp-\pi}}{(dE/dx)_{Exp-K} - (dE/dx)_{Exp-\pi}}$$

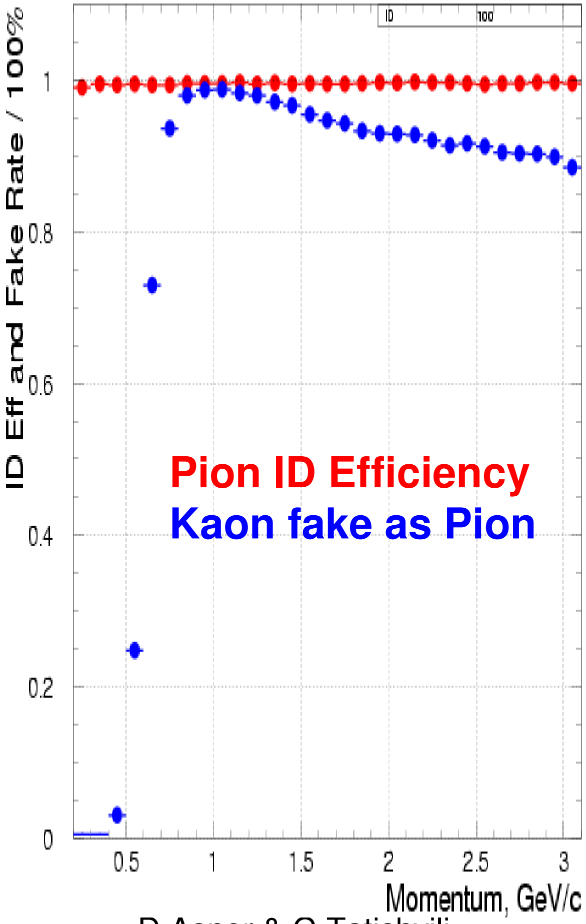
$\langle Kaonness \rangle_{Kaon} = 1$

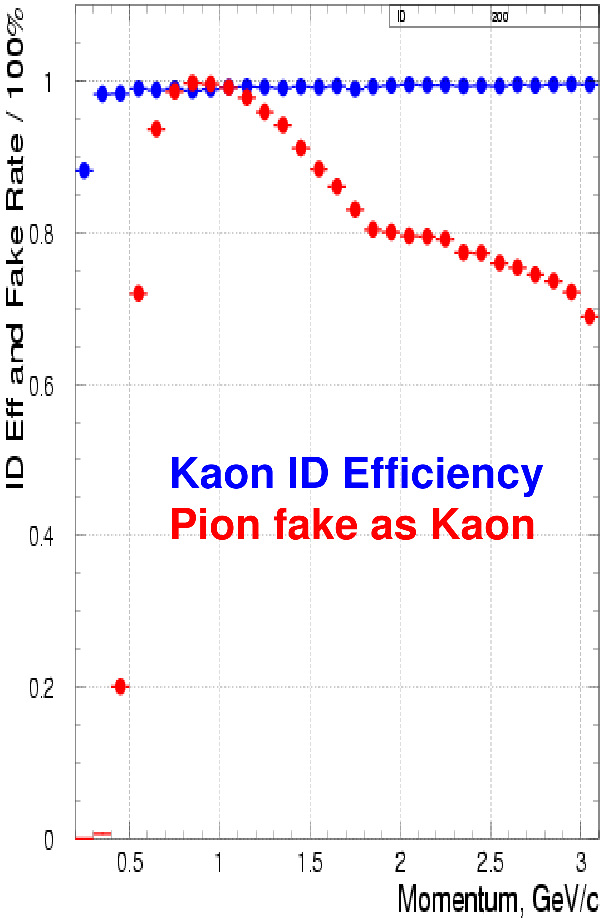
$\langle Kaonness \rangle_{Pion} = 0$

dE/dx Identification Efficiency Measurement

KID efficiency: ε = #Kaons($|\sigma_K|<3$) / #Kaons(Before ID Cut)
πID efficiency: ε = #Pions($|\sigma_\pi|<3$) / #Pions(Before ID Cut)
Fake Rate (K fake as π): f.r. = #Kaons($|\sigma_\pi|<3$) / #Kaons(Before ID Cut)
Fake Rate (π fake as K): f.r. = #Pions($|\sigma_K|<3$) / #Pions(Before ID Cut)







DCH Materials List in FastSim

Currently the folowing numbers of DCH materials are in the MaterialsList.data

	Density	Z_{eff}	A_{eff}		X0	λ_I
dch-He-Ibu	6.408E- 04	23.8	46.1	0	51.16	75.65
dch-Wires	6.237E+00	29.0	62.4	0	15.31	118.56

$$A_{Eff} = \sum_i a_i \cdot A_i$$

$$Z_{Eff} = \sum_i a_i \cdot Z_i$$

C_4H_{10}: $A_{Iso} = 4\ A_C + 10\ A_H$ $Z_{Iso} = 4\ Z_C + 10\ Z_H$

C_3H_8: $A_{Pro} = 3\ A_C + 8\ A_H$ $Z_{Pro} = 3\ Z_C + 8\ Z_H$

Atomic and Nuclear Properties of Materials
http://pdg.lbl.gov/2009/AtomicNuclearProperties/

Material	Density g/cm^3	Atomic Number, Z	Atomic Mass, A	Z/A	Rad.Len. X0, g/cm^2	Nucl.Int.L. λ_I, g/cm^2
H	-	1	1.00794	-	-	-
C	-	6	12.0107	-	-	-
He	1.66E-04	2	4.0026	0.499675	94.32	71.0
Isobutane	2.49E-03	34	58.1222	0.584974	45.23	77.1
Propane	1.87E-03	26	44.0956	0.589628	45.37	76.7

Calculation of the MaterialsList.data DCH Components

Effective Z/A ratio for gas mixtures were calculated as:

$$\left(\frac{Z}{A}\right)_{Eff} = \sum_i \omega_i \cdot \frac{Z_i}{A_i} = \sum_i \frac{f_i \cdot \rho_i}{\rho} \cdot \frac{Z_i}{A_i}$$

$$\rho = \sum_i f_i \cdot \rho_i$$

f_i – is a fraction of gas components, ρ – is the density of the mixture.
Radiation and Nuclear interaction lengths for gas mixtures were calculated as:

$$\frac{1}{X_0} = \sum_i \frac{f_i \cdot \rho_i}{\rho} \cdot \frac{1}{X_{0i}}$$

$$\frac{1}{L} = \sum_i \frac{f_i \cdot \rho_i}{\rho} \cdot \frac{1}{L_i}$$

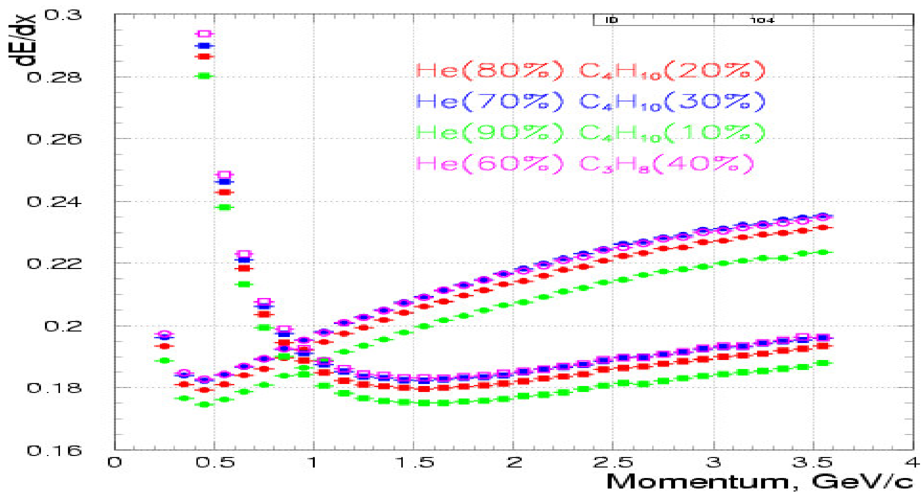
Atomic masses and Atomic Numbers for a gas mixtures were computed as:

$$A_{He/Iso} = \frac{f_{He} \cdot \rho_{He} \cdot A_{He} + f_{Iso} \cdot \rho_{Iso} \cdot A_{Iso}}{\rho_{He/Iso}}$$

$$Z_{He/Iso} = A_{He/Iso} \cdot \left(\frac{Z}{A}\right)_{Eff}$$

Gas Mixture	Density g/cm^3	Atomic Number, Z	Atomic Mass, A	Rad.Len. X0, g/cm^2	Nucl.Int.L. λ_I, g/cm^2
He(60%) & Prop(40%)	8.476E-04	22.81	39.38	48.32	75.98
He(70%) & Iso(30%)	8.632E-04	29.16	50.84	48.64	76.22
He(80%) & Iso(20%)	6.308E-04	26.50	46.73	50.80	75.73
He(90%) & Iso(10%)	3.984E-04	20.92	37.83	56.20	74.69

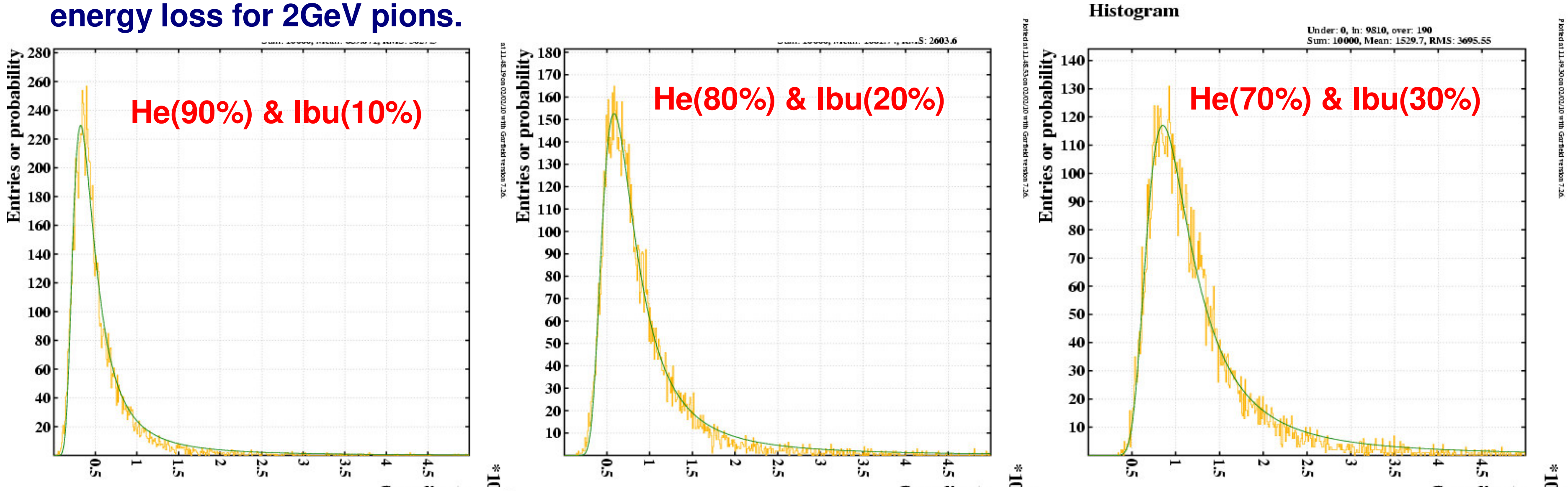
Comparison of Separation Powers for Different Gas Mixtures


FastSim

σ(dE/dx) in FastSim depends on parameters provided via XML. To get a separation powers for each gas composition “Gas_i” (Gas_i = He/Ibu(70%/30%), He/Ibu(90%/10%), He/Pro(60%/40%)) we calculated correction factors f^i based on Garfield simulation. Gas_0 is a mixture He/Ibu (80%/20%).

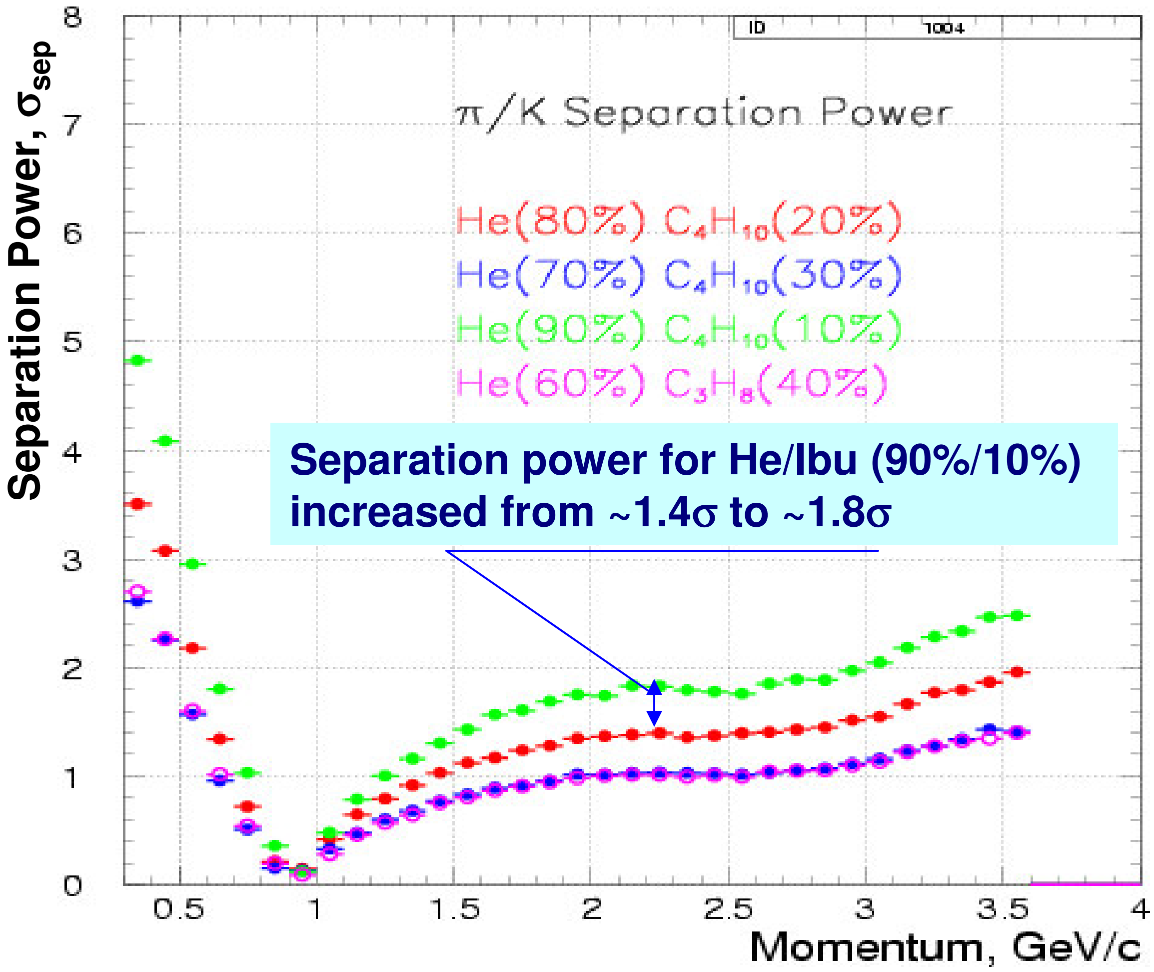
$$f^i = \frac{\sigma^{GF,Gas_i}_{dE/dx}}{\sigma^{GF,Gas_0}_{dE/dx}}$$

GARFIELD Simulation Results: Most probable energy loss for 2GeV pions.



Comparison of Separation Powers for Different Gas Mixtures

$$\sigma^{Gas_i}_{Sep.} = \frac{|\,M\,(dE\,/\,dx\,)_{p1} - M\,(dE\,/\,dx\,)_{p2}\,|}{\sqrt{\left(\sigma^{FS}_{dE\,/\,dx\,\_\,p1}\cdot f^{\,i}_{p1}\right)^2 + \left(\sigma^{FS}_{dE\,/\,dx\,\_\,p2}\cdot f^{\,i}_{p2}\right)^2}}$$



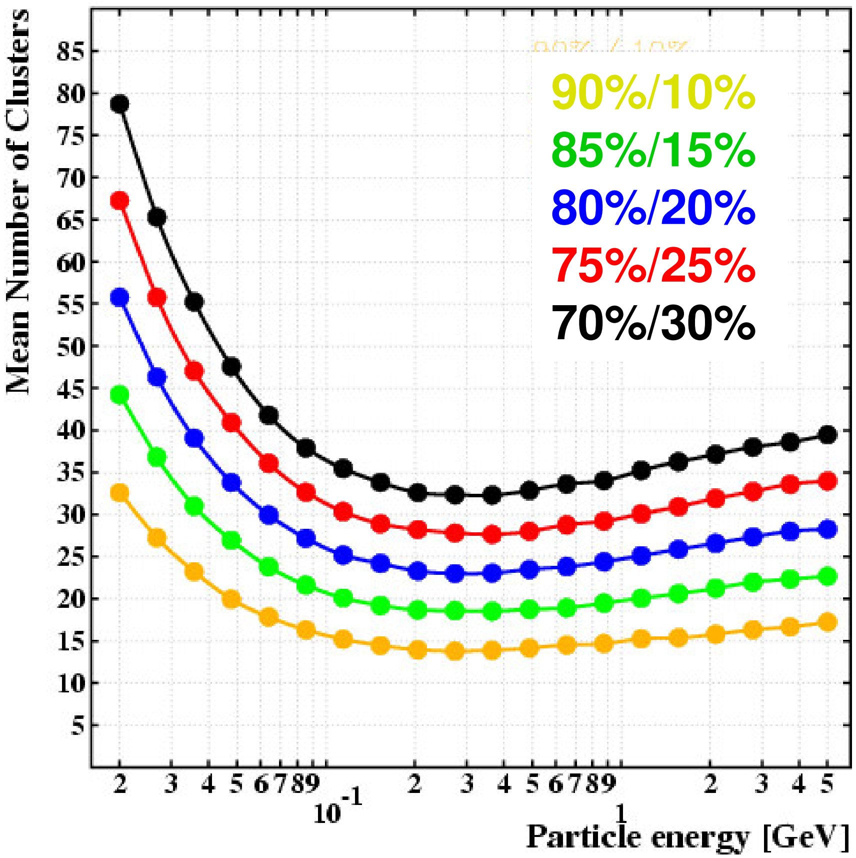
Separation power for He/Ibu (90%/10%) increased from ~1.4σ to ~1.8σ

Requirements to the dN/dx Technique

Pulses from electrons belonging to different clusters should not overlapping in time.

A low pulse density in the time gate (prevents possible overlaps).

Nclusters vs particle energy. Gas: He / C_4H_{10}



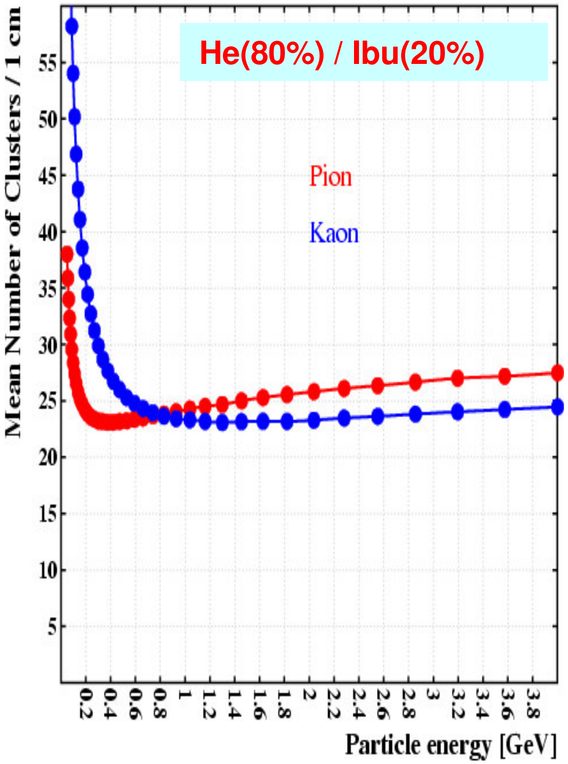
He/ C_4H_{10}, %	<N> Clusters	σ
100 / 0	4.28 ± 0.08	1.48 ± 0.05
95 / 05	8.74 ± 0.07	2.68 ± 0.05
90 /10	13.31 ± 0.07	3.36 ± 0.05
85 /15	18.05 ± 0.08	4.10 ± 0.06
80 /20	22.56 ± 0.10	4.49 ± 0.07
75 /25	27.35 ± 0.11	5.01 ± 0.08
70 /30	31.68 ± 0.10	5.52 ± 0.07

He/C_4H_{10} (90%/10%) is preferable for the Cluster Counting technique

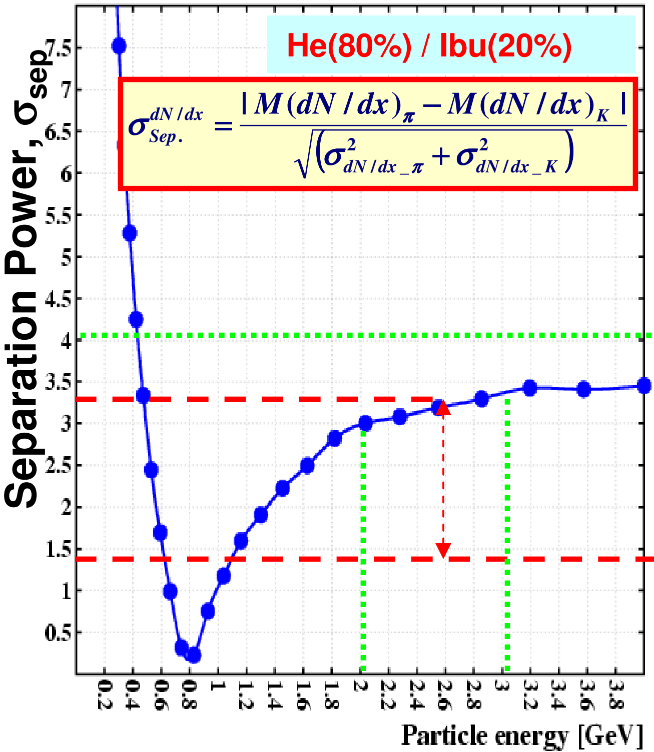
Comparison of dE/dx & dN/dx Separation Powers

Separation power for ideal cluster counting increased in respect with dE/dx method from ~1.4σ to 3.2σ (in the momentum region 2 GeV/c < P < 3 GeV/c).

Garfield Simulation
Ideal Cluster Counting



Garfield Simulation
π/K Separation by
Cluster Counting Method

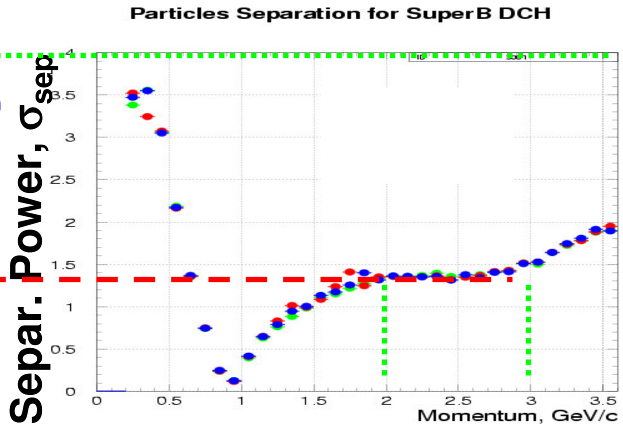


$$\sigma^{dN/dx}_{Sep.} = \frac{|\,M(dN/dx)_{\pi} - M(dN/dx)_{K}\,|}{\sqrt{\left(\sigma^2_{dN/dx\_\pi} + \sigma^2_{dN/dx\_K}\right)}}$$

Fast Simulation
π/K Separation by
dE/dx Method

He(80%) / Ibu(20%)

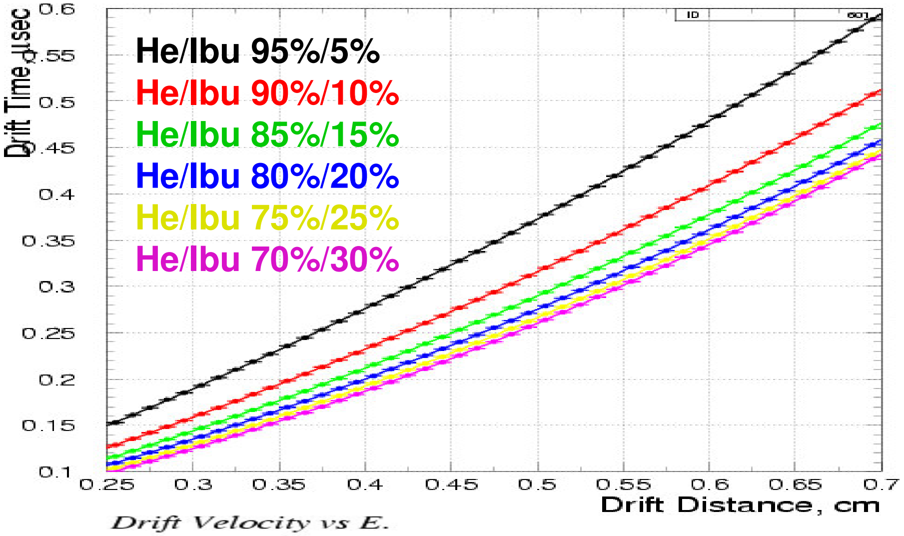
$$\sigma^{dE/dx}_{Sep.} = \frac{|\,M(dE/dx)_{\pi} - M(dE/dx)_{K}\,|}{\sqrt{\left(\sigma^2_{dE/dx\_\pi} + \sigma^2_{dE/dx\_K}\right)}}$$

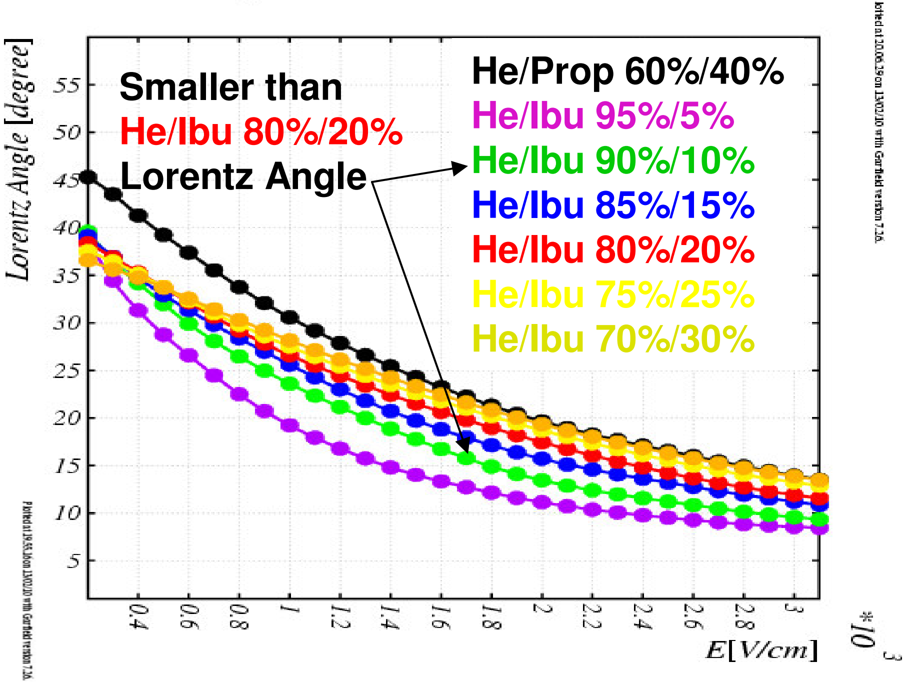


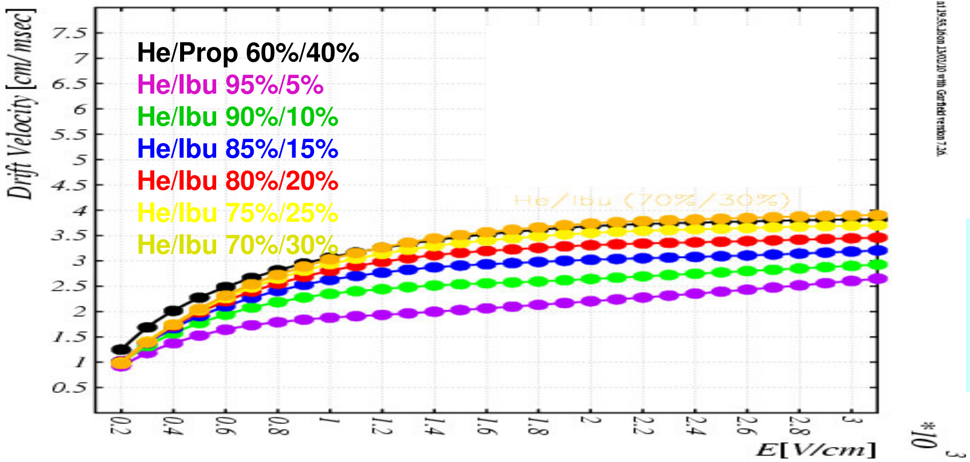
Requirements to the dE/dx Technique

Want a faster gas mixture with more primary clusters.

As Lorentz angle increases, electron drift path curvature also increases. Want to minimize Lorentz angle for straighter path and larger correlation between distance and time.



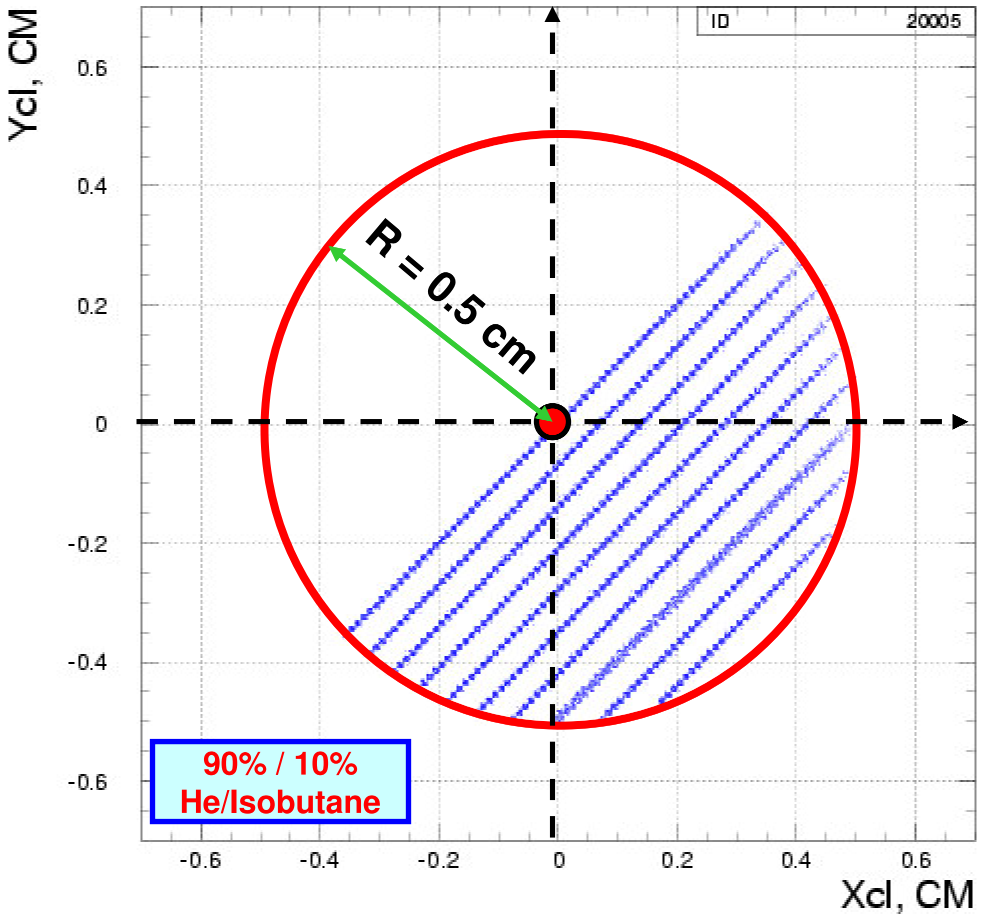

Lorentz Angle vs E.


Drift Velocity vs E.

Small Drift Velocity/Higher Drift Time for He/Ibu 90%/10% can be compensated by smaller size cells in inner layers.

Impact Parameter Resolution Estimation (Very Preliminary)

Drift Tube

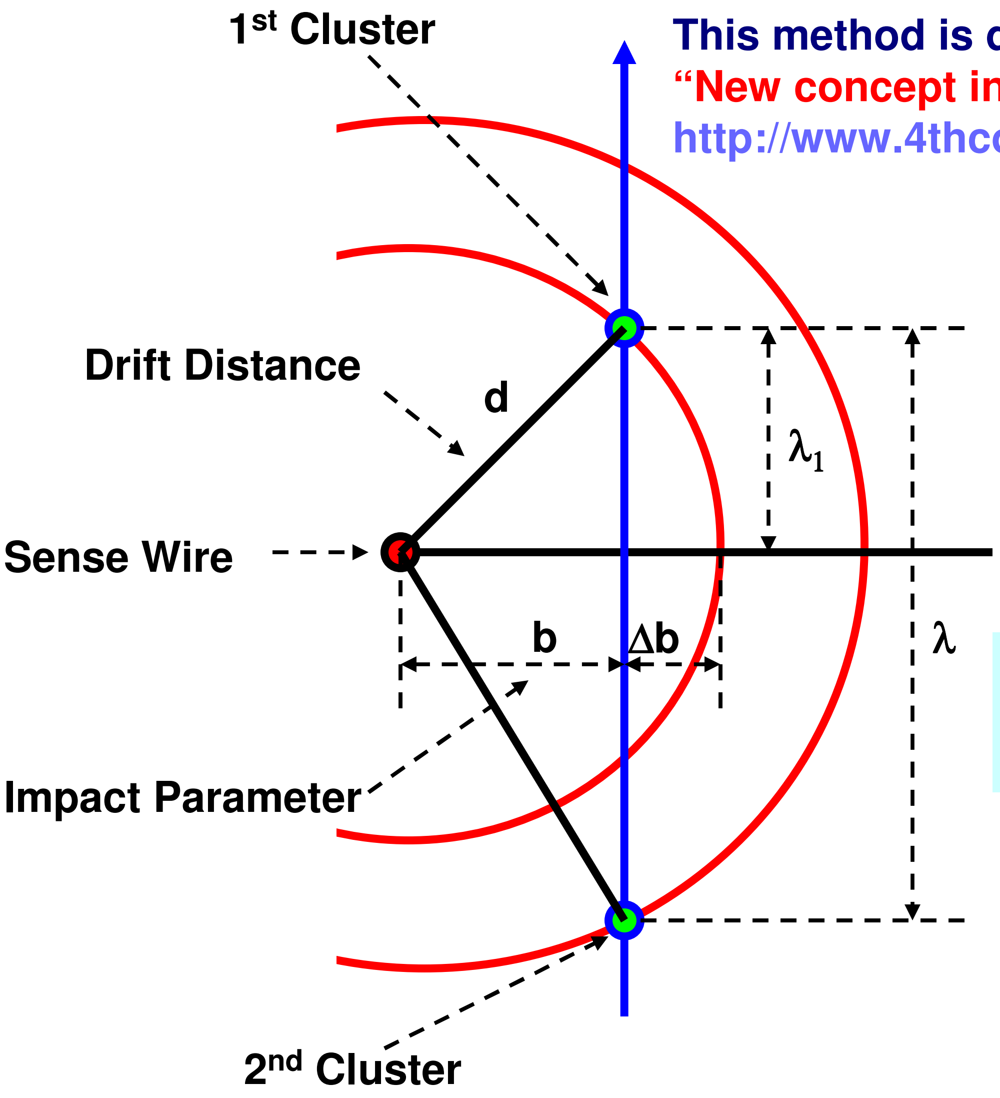


Cluster counting can contribute to reduce the impact parameters resolution for small impact parameters.

Using Garfield we simulated tracks of minimum ionizing pions crossing drift tube with the impact parameters: b=0., 0.05, 0.1, 0.15, 0.2, 0.25, 0.30, 0.35, 0.40, 0.45 cm.

For each impact parameter we simulated ~2x10^4 tracks.

Impact Parameter Resolution Estimation Method



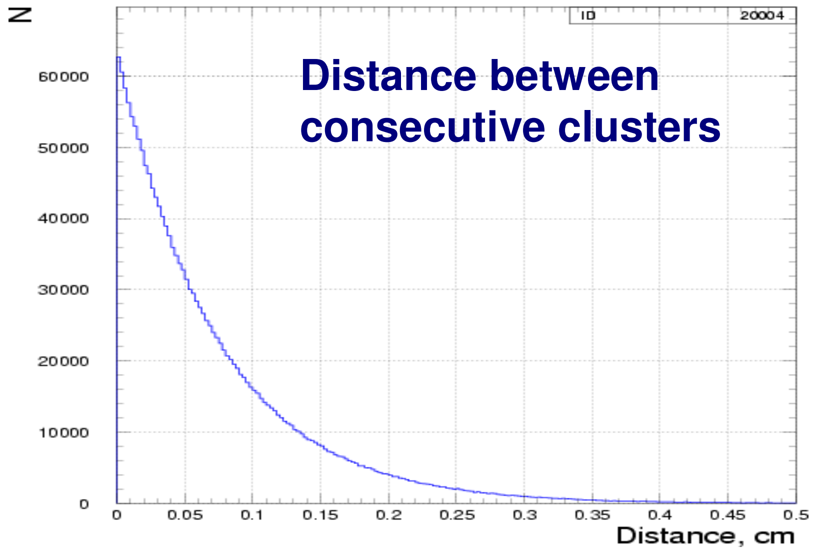
This method is described in
"New concept in high energy physics detectors (4LoI)"
http://www.4thconcept.org/

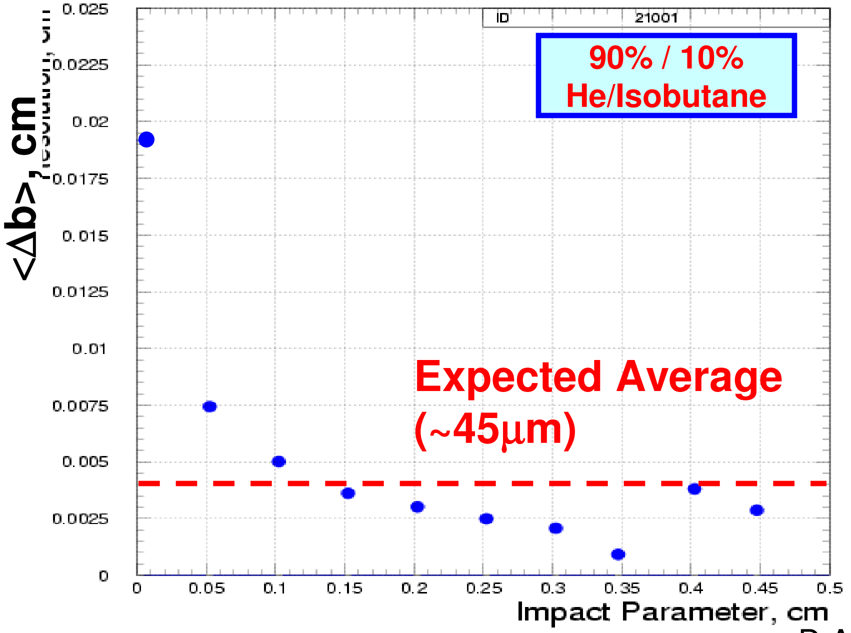
The impact parameter represents a systematic overestimate of b by the quantity Δb, usually referred to as the ionization statistics contribution to the impact parameter resolution:

$\Delta b = d - b$

We used clusters with $\lambda/4 > \lambda_1 > 0.$ cm

Impact Parameter Resolution (Very Preliminary)





Looks like that Cluster Counting method can improve spatial resolution by factor 2-3 in respect with CLEO/BaBar resolutions.

But spatial resolution needs more analysis. In particular:

According to the 4LoI, most of the improvement in impact parameter resolution is obtained by using only the first two clusters, with smaller and smaller contributions from the successive ones.

In this analysis we took into account all ionization clusters.

We need more motivated selection of clusters for estimation of the impact parameter resolution.

This work is in progress.

Summary:

- FastSim & Garfield simulation study for different gas compositions was performed.
- Particles separation powers based on FastSim were estimated.
- We performed MaterialsList calculations for different gas compositions for FastSim to estimate particles separation powers for different gas mixtures.
- We tested possible dE/dx calibration procedure in Fast Simulation: parameterized dE/dx as a function of $\beta\gamma$ for muons, pions, kaons and protons simultaneously.
- Based on FastSim we estimated dE/dx Identification efficiencies and Fake Rates for pions and kaons in wide momentum region.
- Using Garfield we estimated different gas characteristics: Drift time, velocity, Lorentz angle, etc. to compare the requirements of dE/dx and dN/dx techniques.
- Preliminary estimation of spatial resolution was presented.
- He/Ibu mixture with He fraction more that 80% and less than 90% can be considered as a candidate of SuperB DCH gas acceptable for both, dE/dx and dN/dx technique (with small size inner cells).