Cluster Statistics Study Using Garfield / Magboltz / Heed Simulation

D. Asner, G. Tatishvili

Introduction

The goal of our study is to understand the measured performance of DCH using the available software tools: Garfield, Magbolz, Heed, FastSim.

- **Simulating several gases**
- **Simulating 40 layers - hex and square cells**
- **Simulating electronic response**
- **Developing Signal extraction methods to obtain dE/dx and dN/dx**
- **Implement in FastSim to study impact of improved Particle Identification on Physics**

In this presentation we will show:

- **Several gas analysis results according to the requirements of the Cluster Counting Technique.**
- **Provide cluster time analysis for different gas mixtures.**
- **Estimate particles separation power for different gas mixtures.**
- **Very preliminary results of our cluster counting algorithm.**

Gas Mixtures

Gas mixtures were generated using Garfield / Magboltz / Heed simulation programs.

Magboltz program is used to compute for electrons, the drift velocity, the longitudinal and transverse diffusion coefficients as well as the Townsend and attachment coefficients.

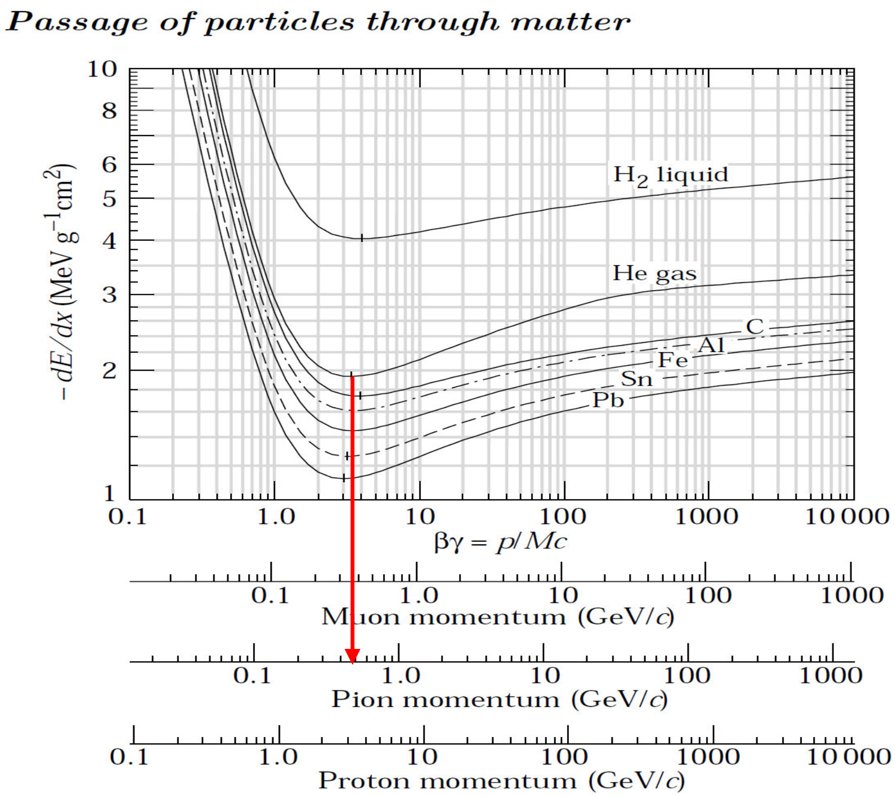
Heed program takes care of cluster generation. This program simulates the ionization of the gas molecules by a particle.

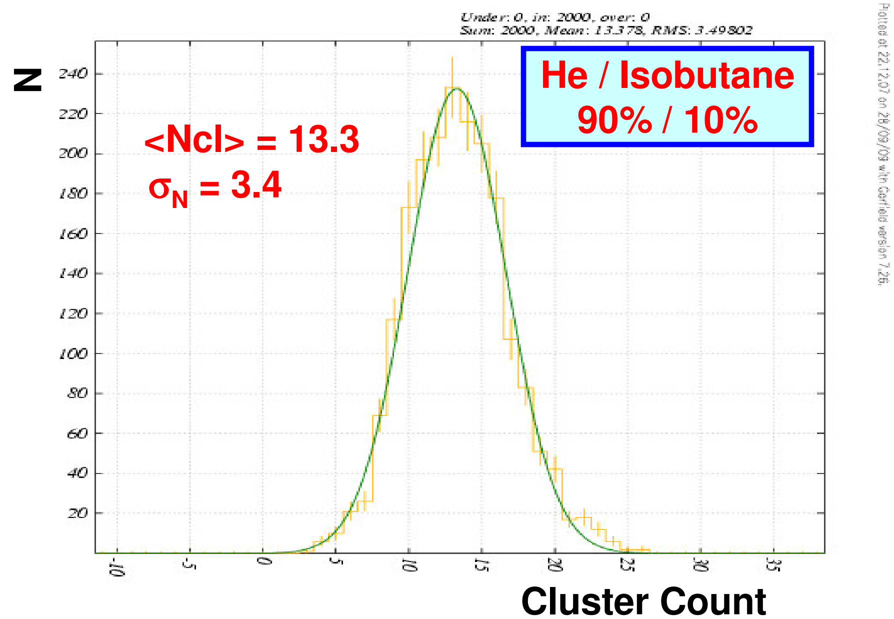
Ar/Methane, He / Isobutane, He / Propane and He / Isobutane / Freon gas files were generated.

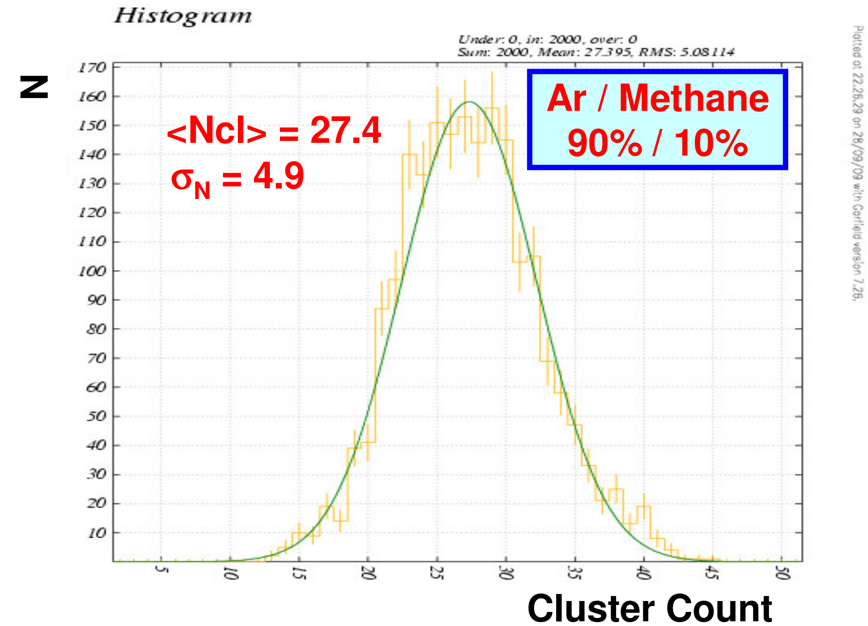
Gas Temperature and pressure were established at the level of 300°K and 1 atm.

Ar/ CH_4, %	He/ C_4H_{10}, %	He/ C_3H_8, %	He / C_4H_{10} / CF_4, %
100 / 0	100 / 0		94 / 2 / 4
99.98,97,96,95 / 01,02,03,04,05	99,98,97,96,95 / 01,02,03,04,05	95 / 05	90 / 2 / 8
90 /10	90 / 10	90 / 10	85 / 2 / 13
85 /15	85 / 15	85 / 15	80 / 5 / 15
80 /20	80 / 20	80 / 20	80 / 2 / 18
75 /25	75 / 25	75 / 25	80 / 15 / 5
70 /30	70 / 30	70 / 30	80 / 10 / 10

Cluster Statistics for Different Gas Mixtures



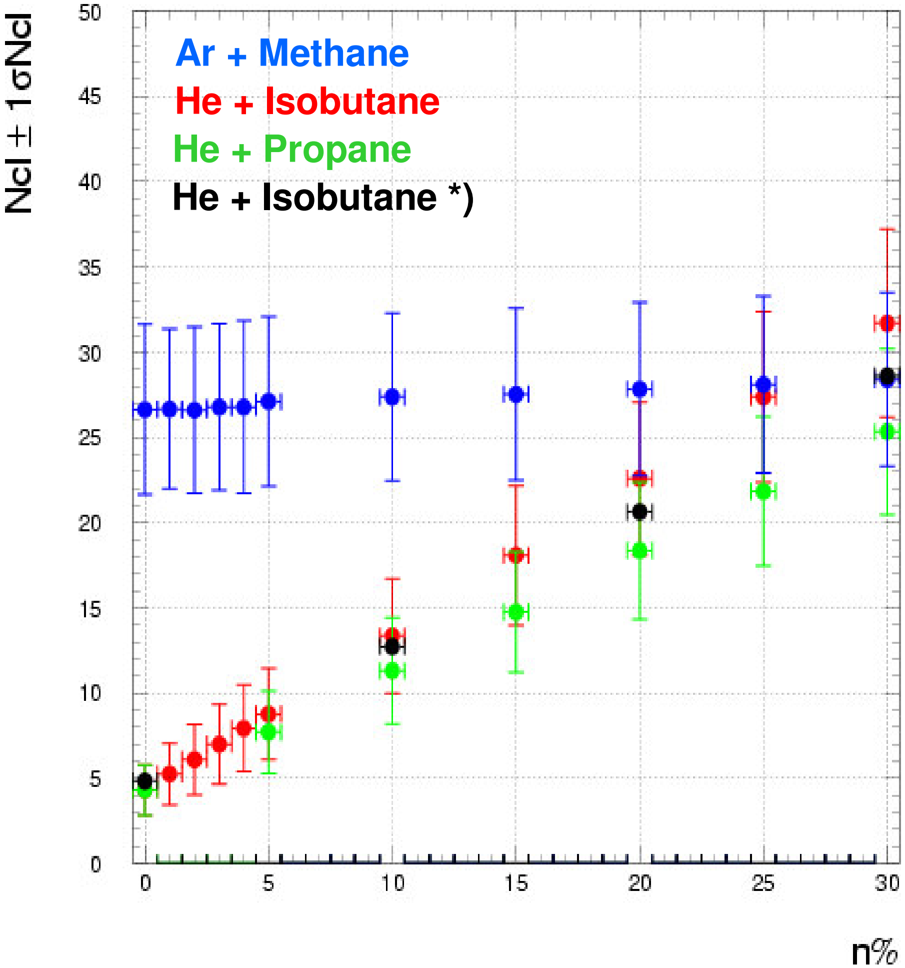




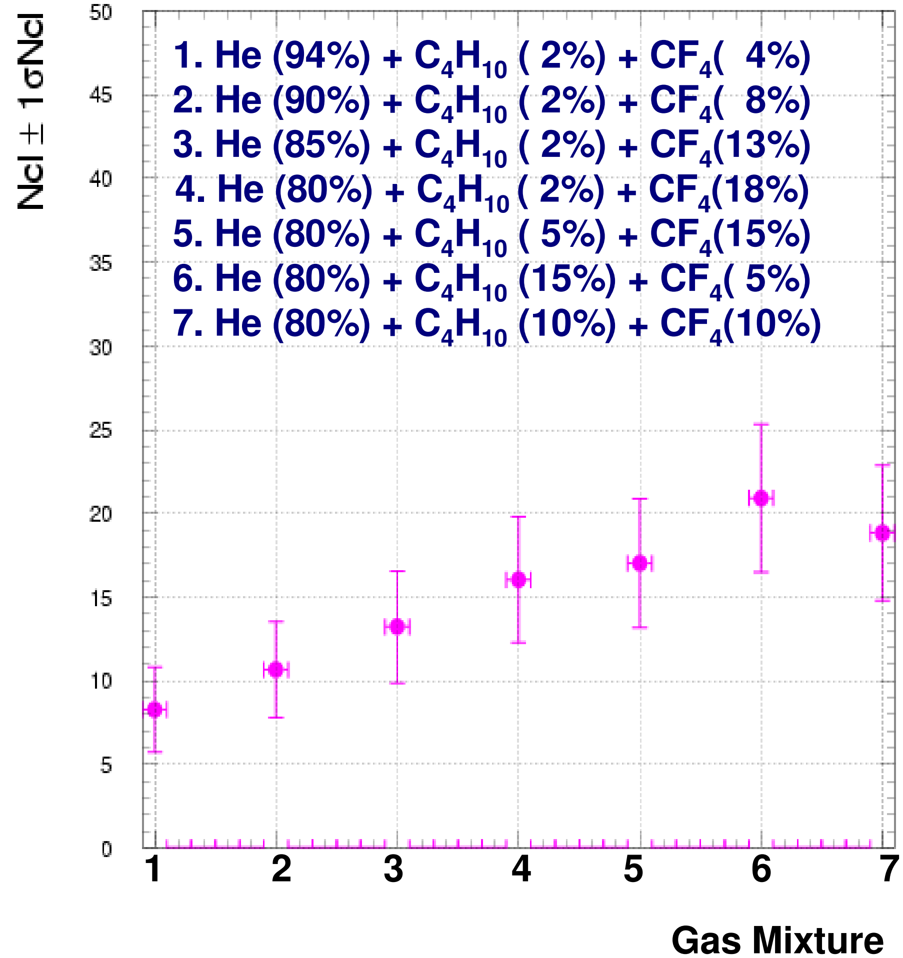
Cluster statistics are obtained for 1 cm long tracks of minimum ionizing pions (P_π = 460 MeV/c) traversing different gas mixtures.

Cluster Statistics for Different Gas Mixtures

Gas Composition: (100-n)% Basic Gas + n% 2nd comp.



Three comp. Gas Mixtures



***) Expected values by A. Sharma, F. Sauli, "Low mass gas mixtures for drift chambers operation", NIM in Physics Research A 350 (1994) 470-477.**

Comparison of Helium and Argon Based Gas Mixtures

Helium Ionization potential (24.5 eV)
> Argon Ionization potential (15.7 eV)

→

- Smaller primary and total ionization density.
- A spatial gap between consecutive clusters in Helium ~6x larger than in Argon.

Electron drift velocity in Helium is smaller than in Argon based gas mixtures.

→

Makes the counting and the timing of the individual ionization clusters easier.

Number of primary electron-ion pairs produced in Helium is less than in Argon.

→

Affects on the chamber efficiency.
Aggravate the effects of the drifting electron recombinations with the positive ions slowly drifting back.

Diffusion coefficient in pure Helium is greater than in Argon, but small amount of quencher in the gas reduces the He diffusion to the level of Argon mixtures.

Mean Number of Clusters / 1 cm for Different Gas Mixtures

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_3H_8, %	<N> Clusters	σ
100 / 0	4.28 ± 0.08	1.48 ± 0.05
95 / 05	7.67 ± 0.07	2.43 ± 0.04
90 /10	11.27 ± 0.06	3.12 ± 0.04
85 /15	14.74± 0.07	3.53 ± 0.05
80 /20	18.33 ± 0.09	4.03 ± 0.07
75 /25	21.81 ± 0.08	4.37 ± 0.06
70 /30	25.31 ± 0.10	4.88 ± 0.07

He / C_4H_{10} / CF_4, %	<N> Clusters	σ
94 / 2 / 4	8.25 ± 0.07	2.55 ± 0.05
90 / 2 / 8	10.64 ± 0.06	2.87 ± 0.04
85 / 2 / 13	13.19 ± 0.08	3.35 ± 0.06
80 / 2 / 18	16.01 ± 0.09	3.76 ± 0.06
80 / 5 / 15	17.00 ± 0.09	3.85 ± 0.06
80 / 15 / 5	20.89 ± 0.09	4.42 ± 0.07
80 / 10 / 10	18.81 ± 0.08	4.06 ± 0.06

Ar/ CH_4, %	<N> Clusters	σ
100 / 0	26.61 ± 0.11	5.00 ± 0.08
95 / 05	27.08 ± 0.10	4.98 ± 0.07
90 /10	27.35 ± 0.12	4.91 ± 0.10
85 /15	27.52 ± 0.09	5.04 ± 0.07
80 /20	27.82 ± 0.10	5.09 ± 0.07
75 /25	28.08 ± 0.10	5.18 ± 0.07
70 /30	28.38 ± 0.10	5.08 ± 0.07

Cluster counts are obtained for minimum ionizing pions (P_π = 460 MeV/c).

Requirements to the Cluster Counting Technique

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

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

Requirements of cluster counting method were discussed in several papers.

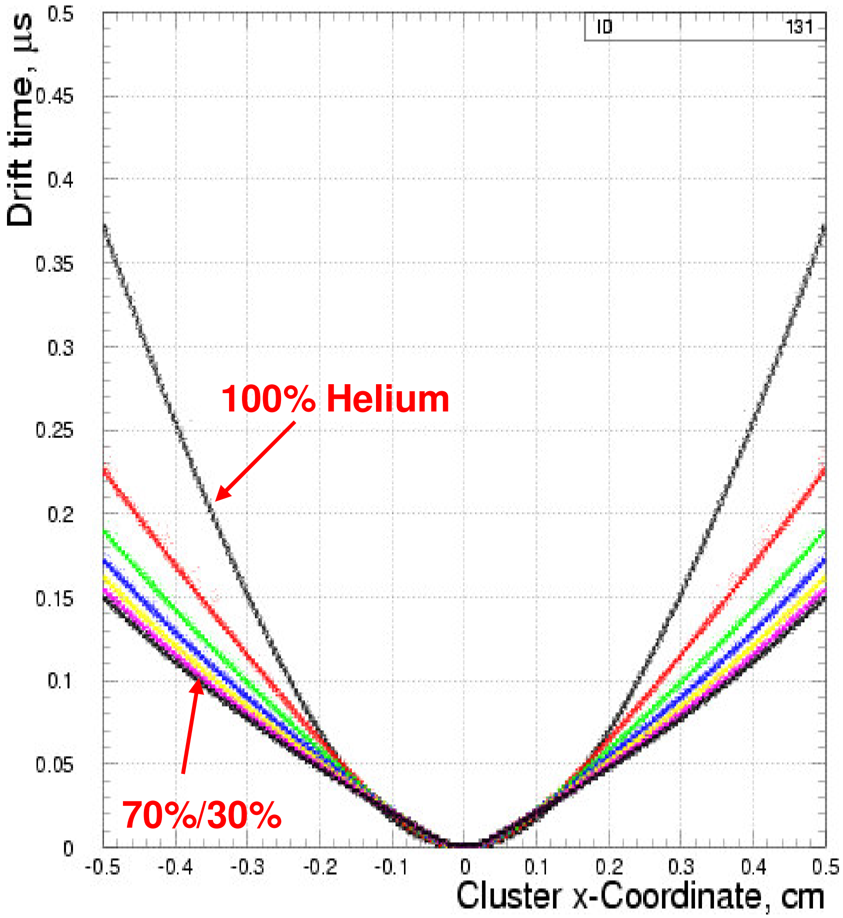
Nuclear Instruments and Methods in Physics Research A 572 (2007) 198-200

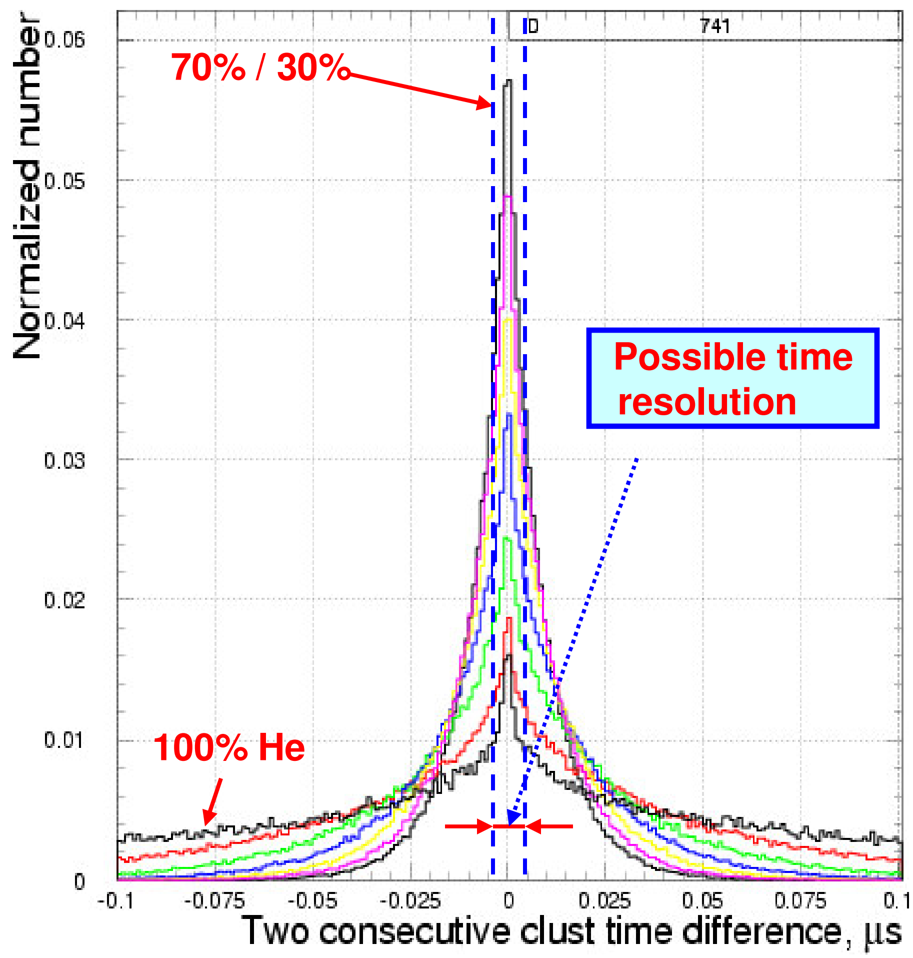
Time resolutions of order of 1 ns can be reached for:
- **A fast preamplifier 1.8 GHz, followed by an 8 bit flash ADC sampled at 2.5 GSa/s.**
- **Assuming an average hit multiplicity 100 hits per track and 10 tracks per event.**

We studied the dependence of cluster counting on the time resolution and dead time due to the limitations in the count.

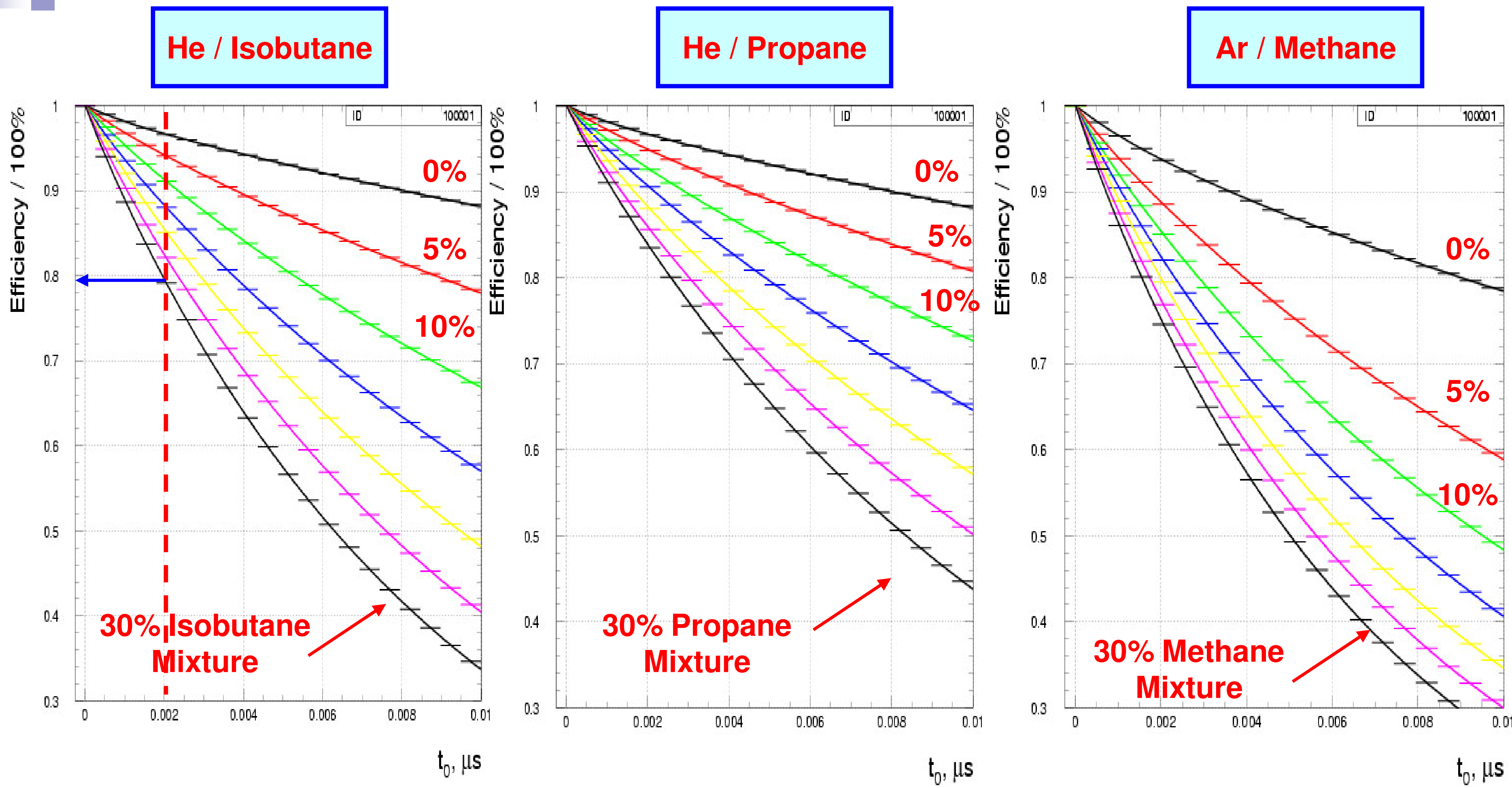
Using the Garfield simulation program we generated cluster tables for a ~$2x10^5$ 1 cm long tracks of minimum ionizing pions (and kaons with the same momentum) traversing different gas mixtures.

Cluster Analysis for He/Isobutane Gas Mixtures





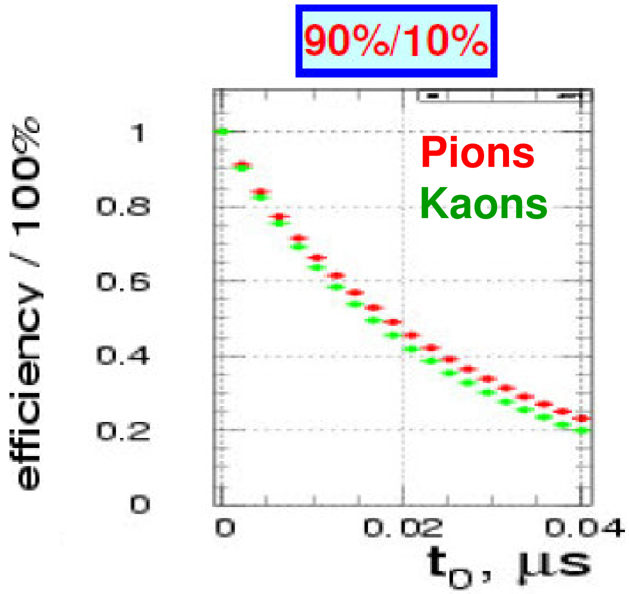
Cluster Analysis for Different Gas Mixtures

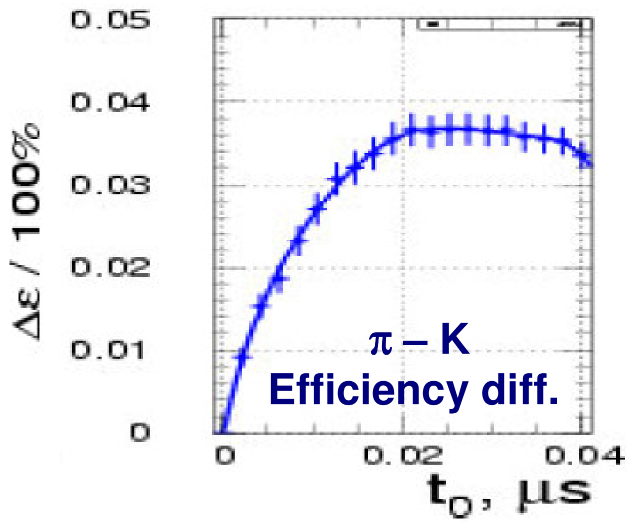


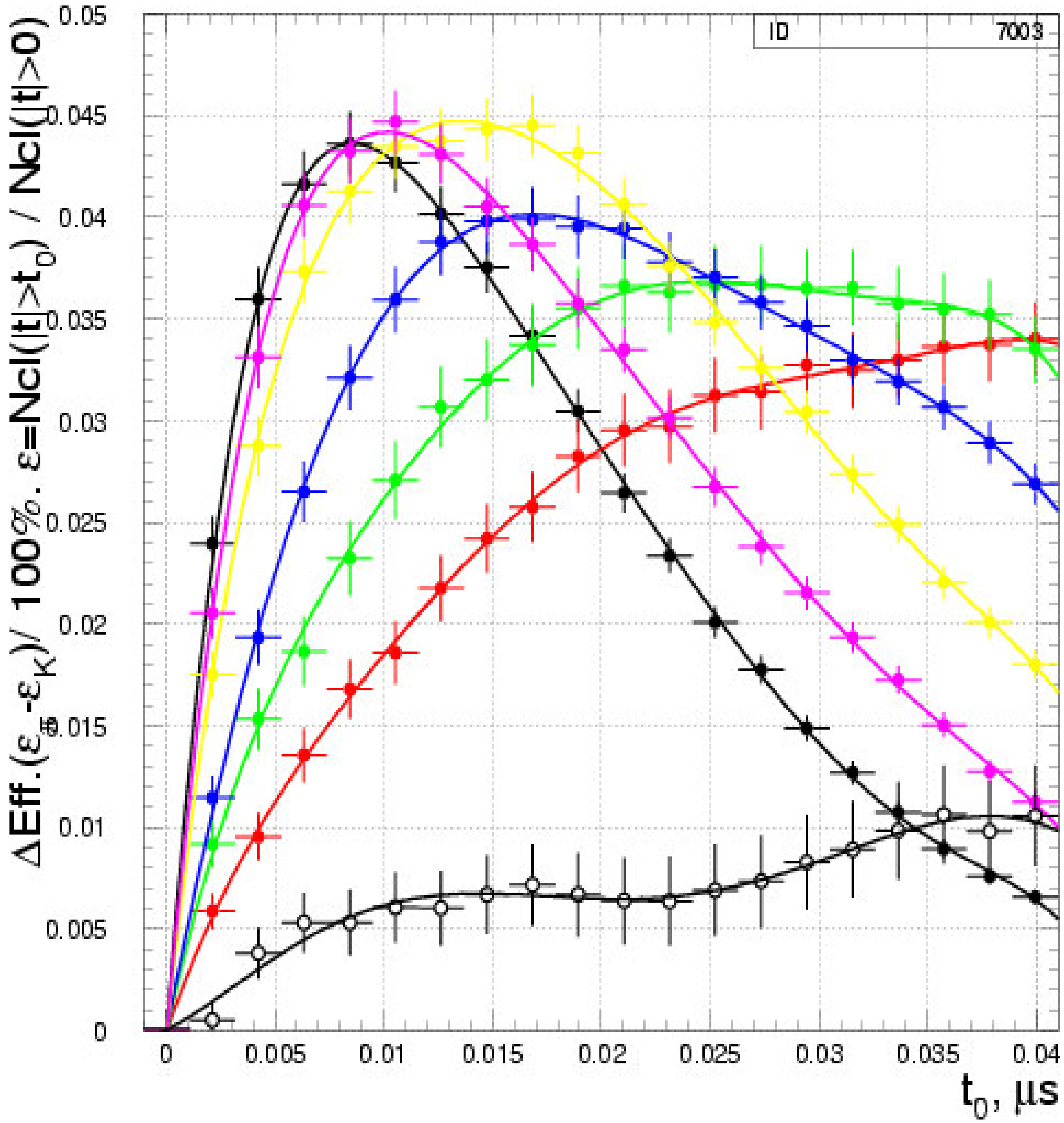
t_0 - consecutive clusters time difference.

This plot indicates that if the time resolution is 2ns and everything works perfectly ~97% of initial clusters will be detected for 100% He gas and ~80% of initial clusters - for He/Isobutane (70%/30%) gas mixture.

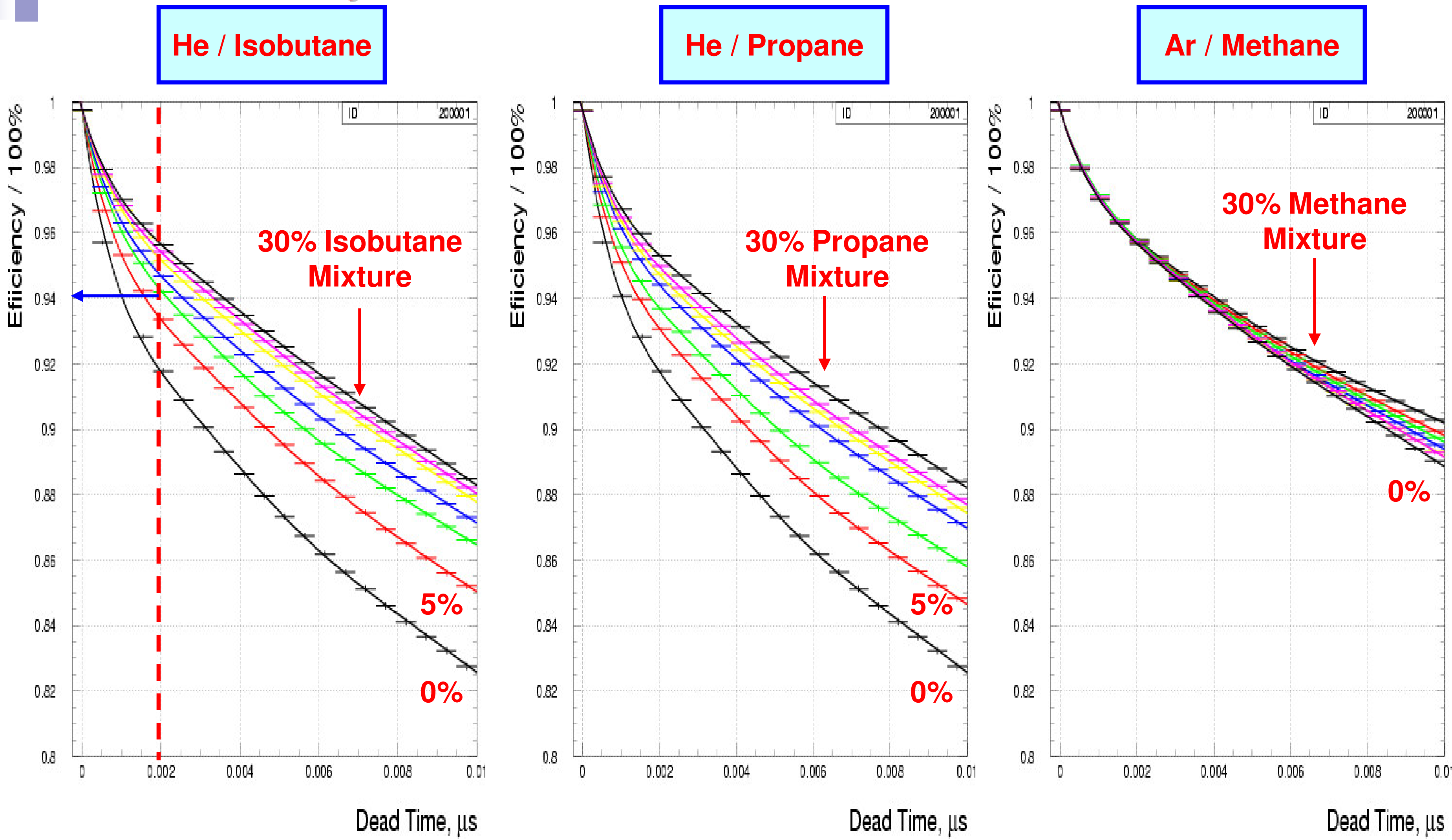
Cluster Analysis for He/Isobutane Gas Mixtures





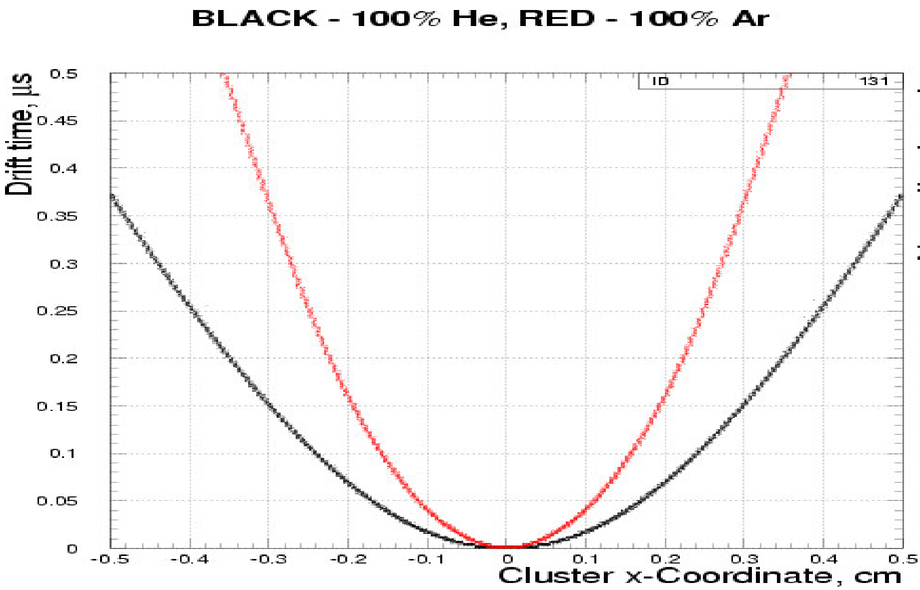


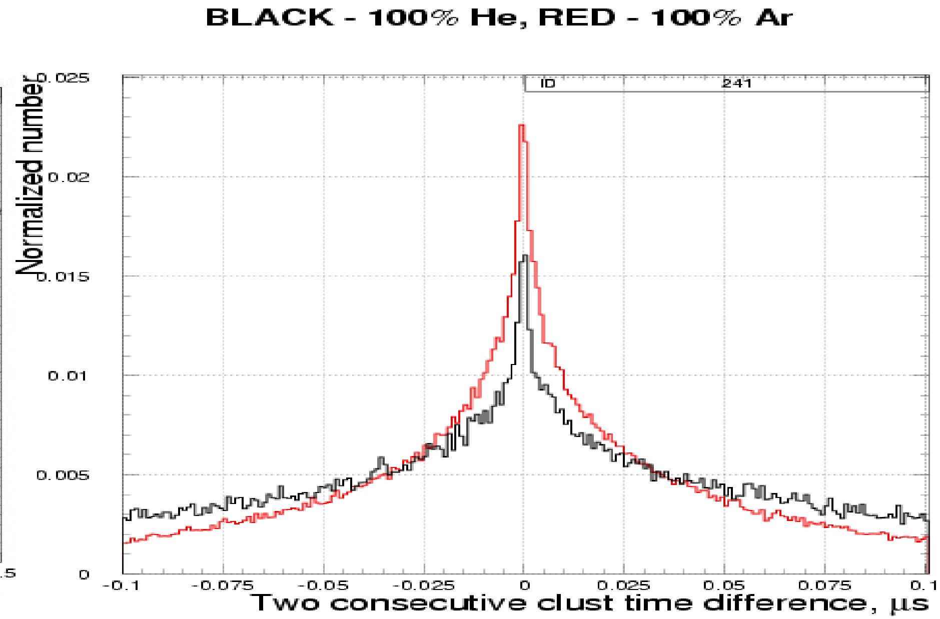
Cluster Analysis for Different Gas Mixtures

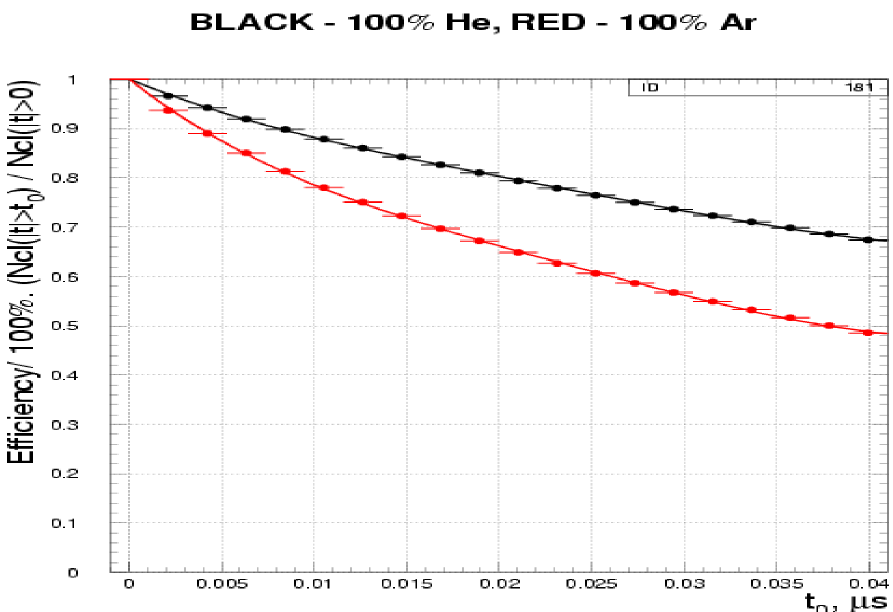


This plot indicates that if the dead time is 2ns, ~94% of initial clusters can be detected for He / Isobutane (90%/10%) gas mixture.

Cluster Analysis for He/Isobutane vs Ar/CH4



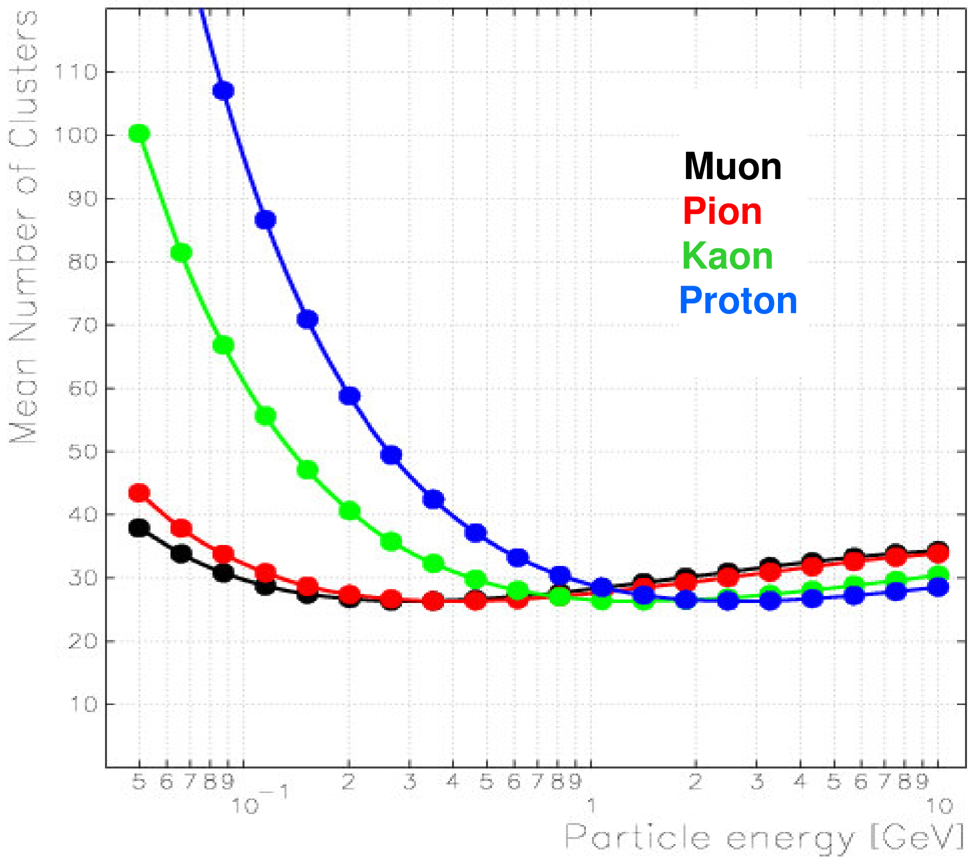




Particles Separation

2cm length samples corresponding to μ, π, K, p crossed drift tube in He (90%) and Isobutane (10%) gas mixture.

He / Isobutane (90% / 10%)



Cluster counting provides factor two better resolution compared to classical charge determination.

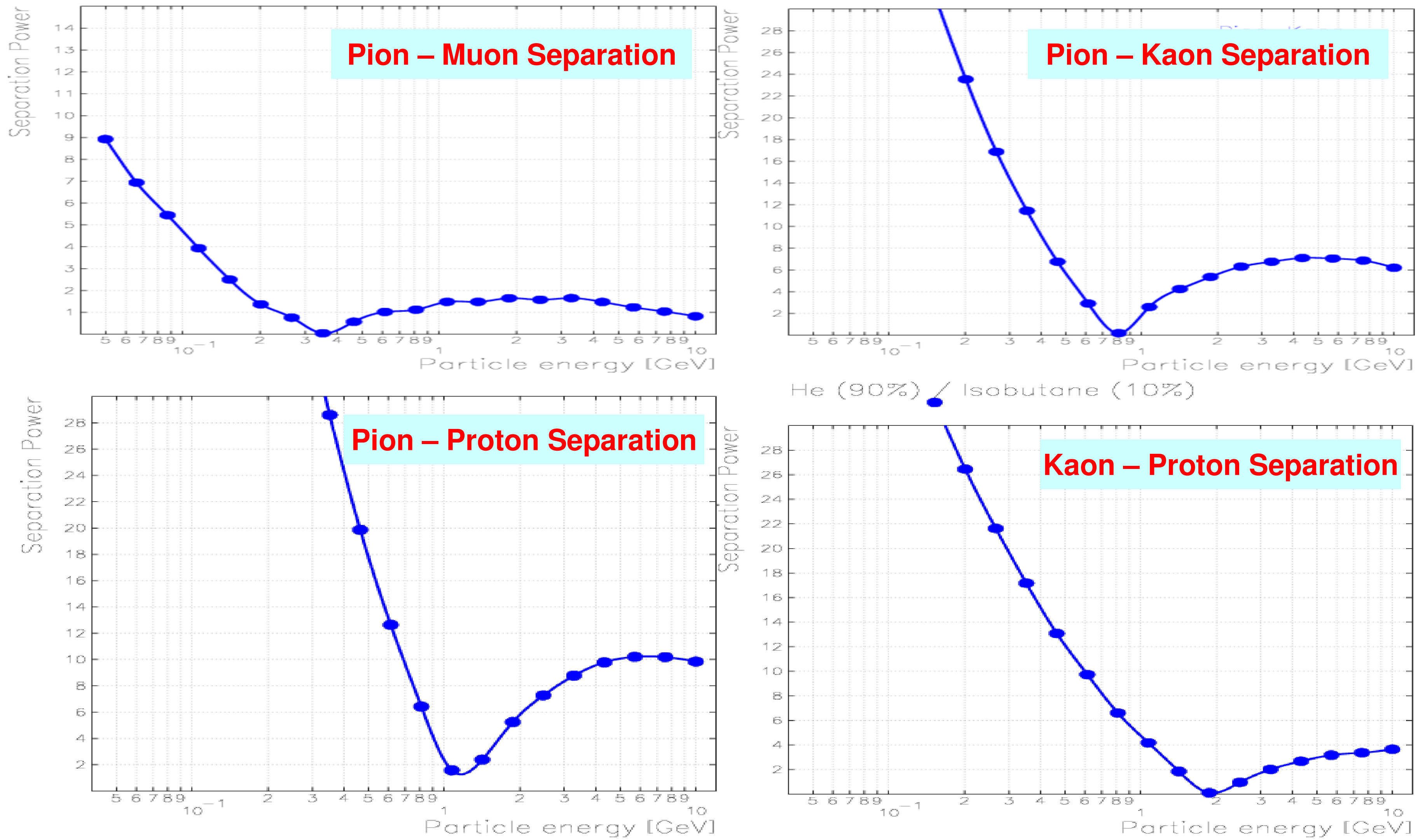
H.A. Walenta, et al., NIM, 161 (1979) 45 gives a theoretical evaluations of dE/dx resolution.

For 100 samples with sampling length (2cm) σ = 4.5%.

For pions in minimum ionizing region Ncl~13 / 1cm for 100 times sampled tracks σ ~2%.

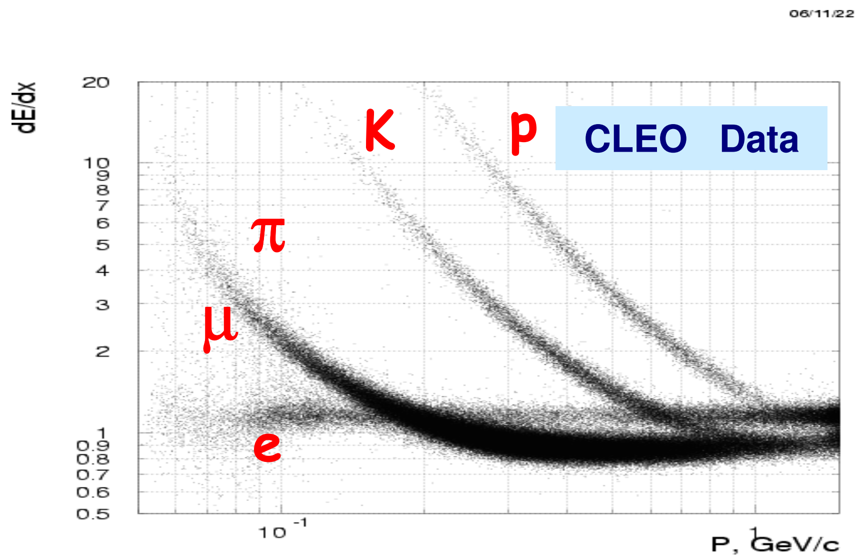
Particles Separation for Ideal Cluster Counting

He / Isobutane (90% / 10%)

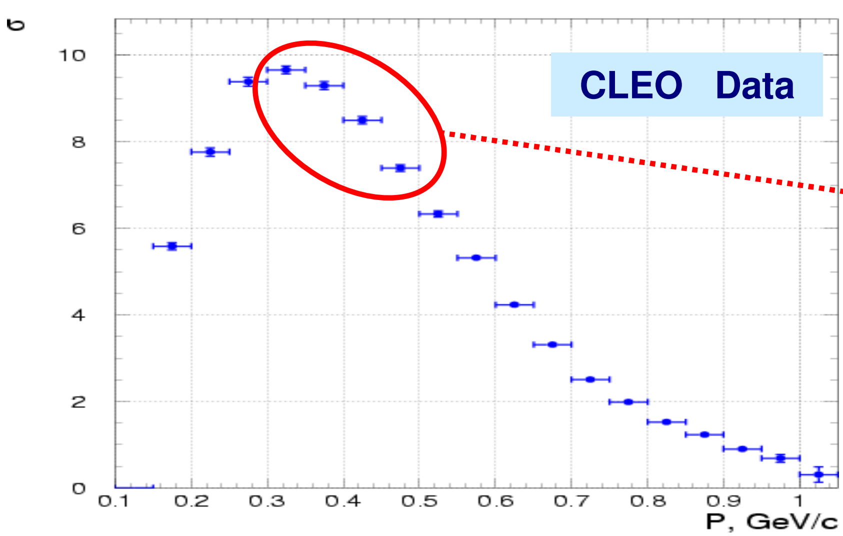


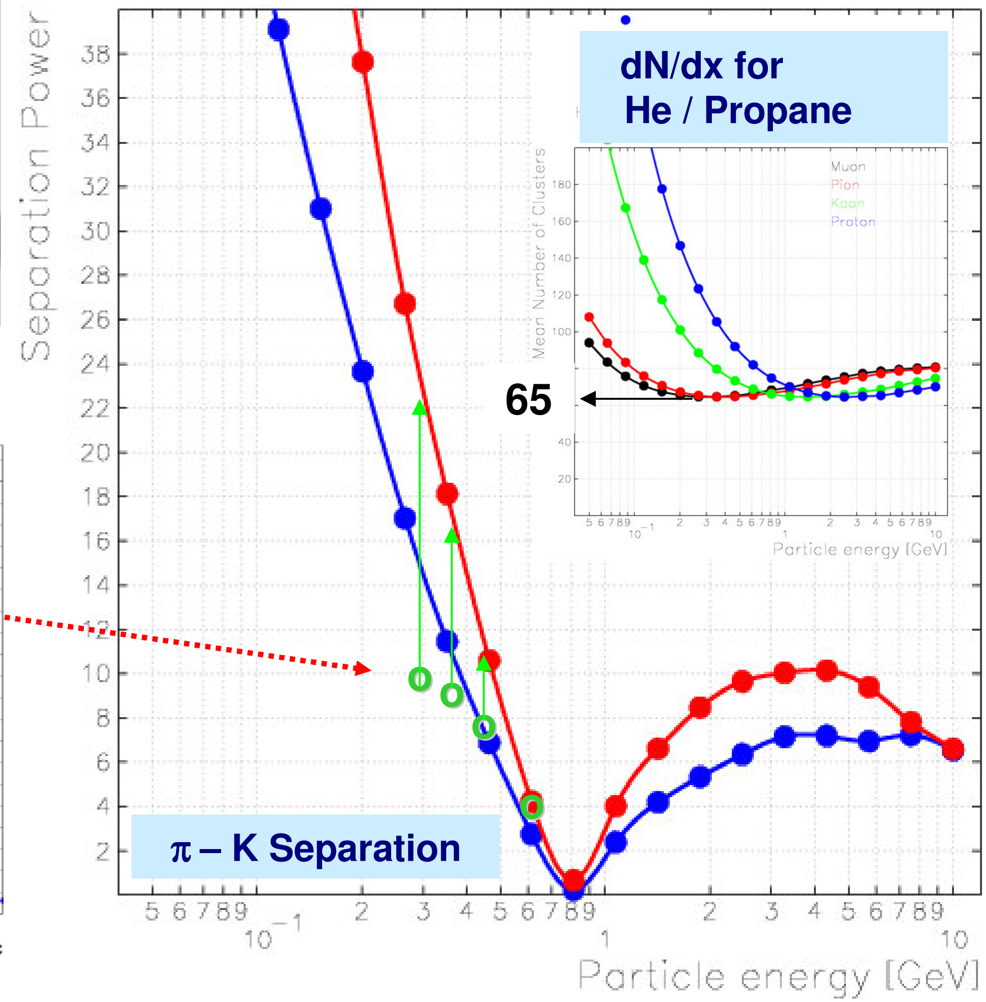
Particles Separation (Comparison)

Ideal Cluster Counting (Garfield Simulation):
CLEO Gas: He (60%) / Propane (40%)
He (90%) / Isobutane (10%)



Data42: π-K Separation





Cluster Counting Algorithm

GARFIELD SIMULATION (HEED CLUSTERING MODEL) ◄ **& SIGNAL**

▼

CLUSTER TABLES

▼

SELECTION OF TRACKS WITH GIVEN # CLSUT.

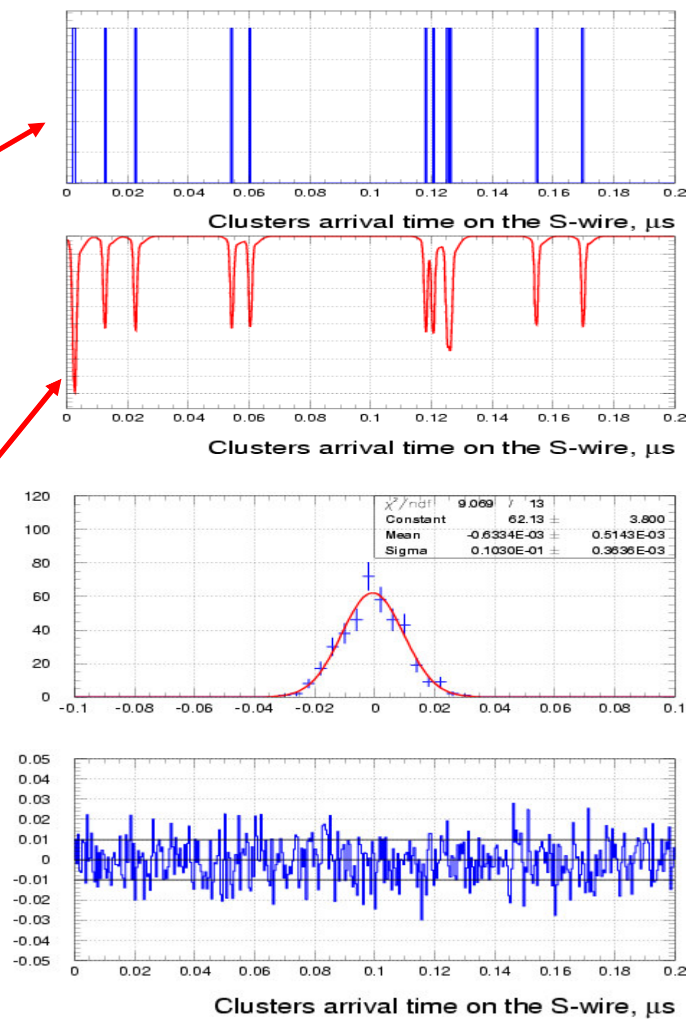
▼

SIGNAL CONSTRUCTION

Experimental Setup Functions:
TRANSFER FUNCTION
NOISE FUNCTION

▼

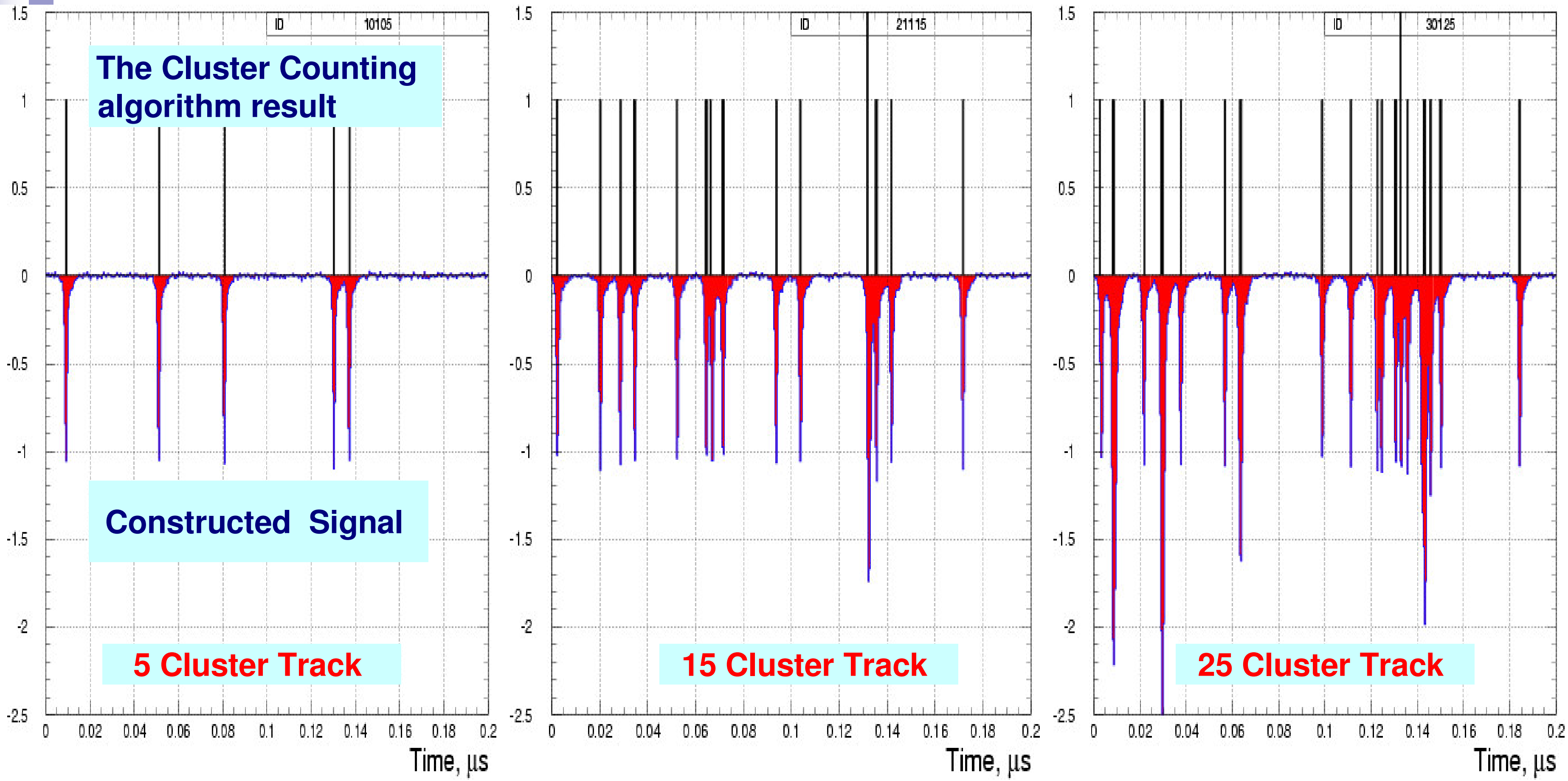
CLUSTER COUNTING ALGORITHM



As a transfer function we used a naive approximation - double Gaussian function with shifted central values.

As a noise function we used a random variable with a Gaussian distribution.

Cluster Counting Algorithm, cntd.

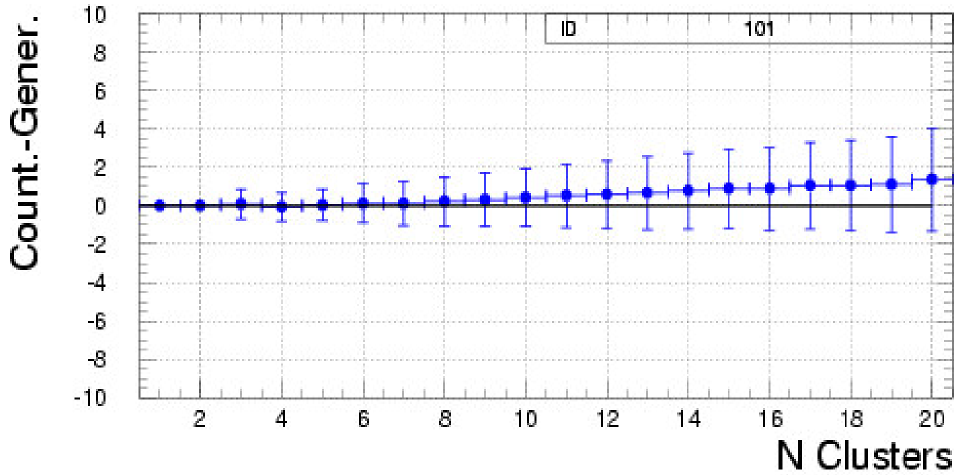


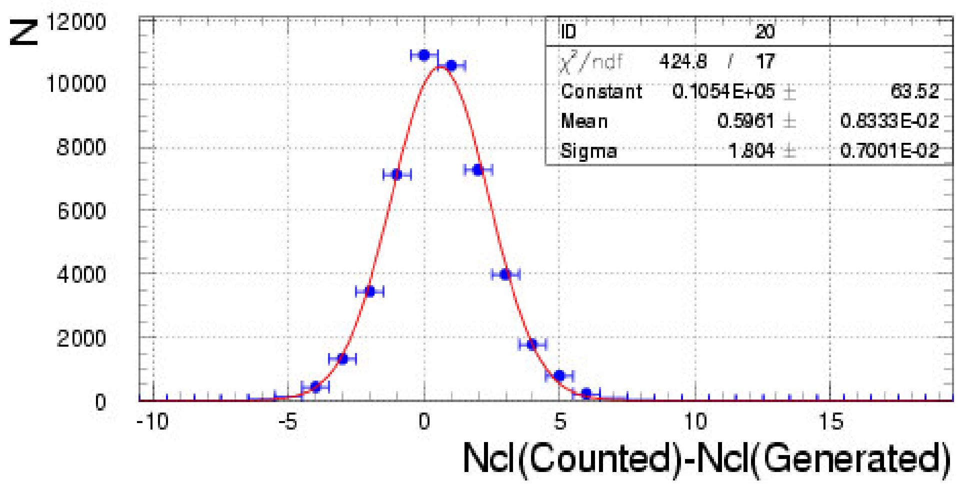
Some statements of the cluster counting algorithm:

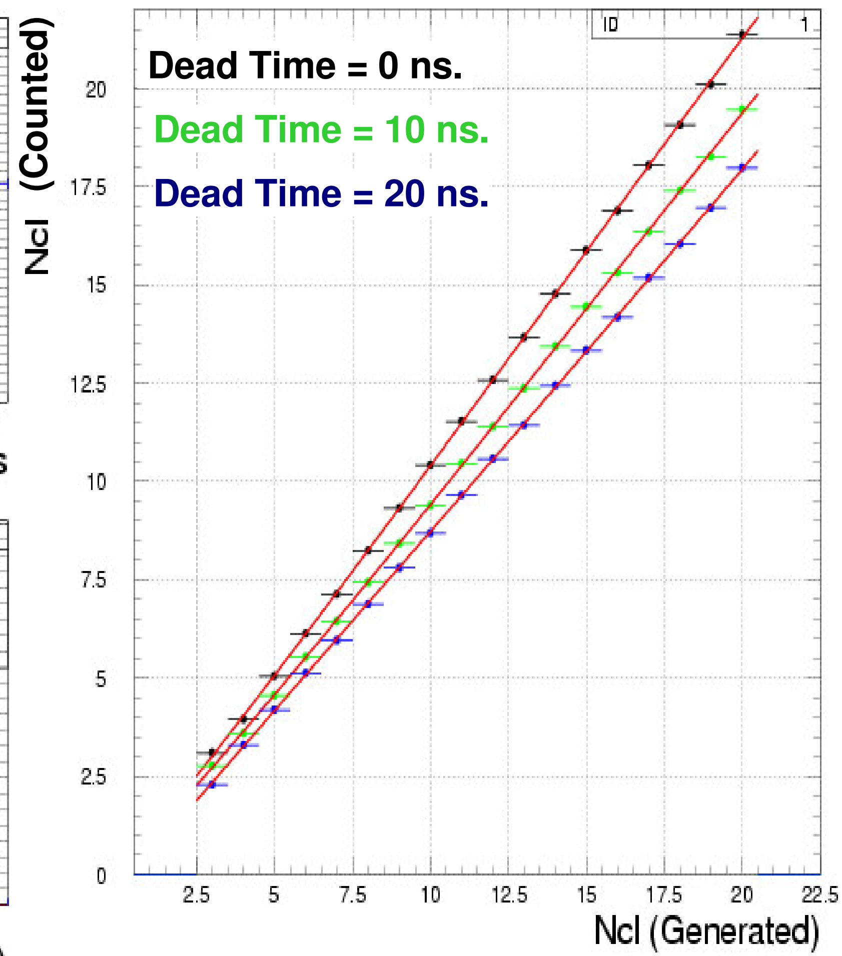
- **Transfer function shape should be the same for all clusters.**
- **Pulse heights should be larger than #σ of noise.**

We plan to study the cluster counting efficiency dependence on the noise level, pulse shape, time resolution.

Cluster Counting Algorithm, cntd.







Conclusion

- The Garfield simulation study for different gas compositions was performed.
- The simulation results fit with the expected properties of the selected gas compositions.
- Cluster analysis for different gas mixtures was performed.
- Particles separation powers for ideal cluster counting were presented.
- Preliminary result of cluster counting algorithm was presented.