TRIUMF Experiment E614
Technical Note #76

Monte Carlo Simulation of Energy Loss in the Proportional Chambers near the Target for Different PC Gases.

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Abstract

Monte Carlo simulations of muon energy loss in the proportional chambers (PC5 and PC6) just upstream of the target are presented. Calculations performed for different gas mixtures. Effect of limited energy resolution taken into account in simulations.

Introduction

Information about energy deposited in proportional chambers near the target in E614 could be useful to reject muon stops which happens outside of target - in last PC's upstream of the target. Investigations of possible use of such information was started in 1998 by Monte Carlo simulations in [1] and was continued by analysis of ADC and TDC signals from PC5 and PC6 collected during summer 2002 run [3]. Present study is the continuation of Monte Carlo simulations started in [1] with analysis of some additional PC gases mixtures.

Monte Carlo Simulations

Monte Carlo simulations was performed with E614 GEANT [2] **devel** version. 29.79 MeV/c momentum polarized muon beam with momentum spread $\Delta P/P = 0.7\%$ and spot in beam focus x=1cm, y=1cm, was simulated using

PGUN E614 GEANT card. For each gas mixture muon stopping distributions was centered around Z=0 inside the target by tuning gas mixture in gas degrader. While some small fluctuations in relative number of muons stopped after the target in PC7 gases (due to not ideal centering of stopping distributions) may be seen in Tab. 1, it was not found to have any impact on presented data. In order to have coincidence between muon energy loss in PC gas with energy actually deposited in it, full Landau fluctuations without delta ray production was selected for energy loss simulations. Energy loss fluctuations in thin layers was taken into account with default in GEANT Urban model. Selection of Photoabsorption Ionization Model (PAI), which supposed to work better for thin layers, led somehow to few times less muon energy loss in chamber gas and was rejected as unrealistic. In simulations effect of energy resolution was taken into account in accordance with table 1 in [4]. From that table, using experimentally measured in [5] energy resolution for 5.9 keV and 30 keV γ's from Fe^{55} and Am^{241} sources in PC gas, one can find average dependence of energy resolution from deposited in gas energy:

$$\frac{\sigma(E)}{E} = \frac{a}{\sqrt{E}} \tag{1}$$

with a = 0.22.

May be, we have less ideal conditions in our detector then one was specially created for energy resolution measurements in [5] and also we have muons rather then γ's, these muons deposit more energy in PC gas than it did γ's in [5]. All that can have impact on energy resolution in E614 PC's. Because of that, together with simulations with energy resolution found from literature (a=0.22), simulations with two worsen energy resolutions (a=0.44 and a=0.88) was also done for each calculation in present study.

Simulations was performed for different PC gases mixtures: CF_4/ISO (80/20), Ar/ISO (40/60), DME/He(50/50), DME/He(5/95).

Results

Fig 1 present dependence of energy deposited by muon in closest to target proportional chamber - PC6 vs energy lost by the same muon in previous proportional chamber - PC5. One can see such dependence for all muons came to PC6 and with different selection criteria, like for muons stopped in

PC6 only, stopped in target only, stopped in PC6 wires only. No energy resolution effect was included in fig 1 data. The same (as in Fig. 2 and Fig. 3 from [1]) two branches with positive and negative slopes can be seen. They corresponds mainly to muons stopped in target (positive slope) and muons stopped in PC6 gas(negative slope). Right bottom part of branch with positive slope corresponds to muons stopped in PC6 wires. There is approximately 0.26% of muons stops in PC6 wire. While it is sad that we cannot select them from the muons stopped in target, we may be should not worry to much about them, because in metal wire they do not suppose to loose their initial polarization, while muons stopped in gas will loose it and is much more dangerous because of that. But they can be recognized from muon stopped in target and cut off by simple two dimensional cut, shown on figure:

$$dE6 = C1 \times dE5 + C2 \tag{2}$$

where C1 and C2 - constants, representing slope and offset in line defined by eq. (2). Values of these constants shown on presented figures.

The same data, but with more poor energy resolution shown on Fig. 2. It looks very similar and actually even the worst calculated resolution with a=0.88 (see, for instance, Fig. 4) do not take off possibility to make clear cut to separate two branches with different slopes produced by muons stopped in target and muons stopped in PC6 gas.

The impact of energy resolution in Ar/ISO (40/60) on rejection ability of cut (2) may be seen on Fig. 3. That figure and other similar figures (Fig. 5, Fig. 7, Fig. 8) was calculated without taken into account muons stopped in PC6 wires, because we anyhow cannot reject them from muons stopped in target with any cut. It looks that effect of not ideal energy resolution do not have serious influence on suggested cut inside the calculated range of energy resolutions.

The same data was calculated for gas mixture - CF_4/ISO (80:20) currently in use in PC chambers. While it is shown [4] that that gas may be not good choice for amplitude measurements, Fig. 4 and Fig. 3 show similar to Ar/ISO behavior. It can mean that situation is very similar from the point of energy loss, while differences in charge collection in different gases is not presented in GEANT yet.

It was also mentioned [6] that in lighter gas mixtures resolution between branches on dE6 vs. dE5 figures could be better then in more heavy gases. So, idea was suggested [7] to try new, more light gas mixture, such as DME/He (50/50) or even DME/He (5/95).

The corresponding calculations presented on Fig. 6 for DME/HE (50/50) gas mixture. One can see that in case we will be really able to use such gas mixture, we do not need to apply two dimensional cut to data, just simple ADC threshold could make job in case of that gas. As it seen from Fig. 6 DME/He mixture do not provide us with complicate picture with two branches with different slopes, it is why we do not need to make two dimensional cut and it is also could give possibility to make rather effective threshold like cut, even with more bad energy resolution, then was calculated in present study. Actually, because that mixture have so little muon stops in PC6, even without collecting the ADC signals we already can have effective decreasing of muons stopped in last PC, comparatively to more heavy gas mixtures (see table 1).

Conclusion

Main results summarized in table 1, from which one can see that for traditional gases mixtures like CF_4/ISO or AR/ISO with applied two dimensional cut we can suppress beam muon stops in PC6 gas up to approximately 0.02% of stops in target. For new, not tested yet, mixture DME/He with threshold like cut we can go as low as 0.003%-0.005%. Without amplitude analysis DME/He mixture provide at least factor 10 less stops in PC6 gas than traditional mixtures. No sufficient impact of energy resolution on cut effectiveness was found inside tested range (a=0.22-0.88).

References

[1] M. Grinder and D.H. Wright, An Analysis of Energy Loss in the Proportional Chambers near the Target, E614 TN-22, 31 August 1998.

[2] D.H. Wright, A Users Guide to E614 GEANT, E614 TN-29, 30 March 1999.

[3] Marc Lalancette, Report on energy Loss analysis in the Proportional Chambers near the Target, From Real Data, E614 TN-70, 30 August 2002.

[4] V.I. Selivanov, Energy Resolution Optimization of the Target PCs and t_0 Problem, E614 TN-71, 24 September 2002.

[5] I.Lehraus, R.Matthewson, W.Tejessy, M.Aderholz, NIM 153(1978)347-355

[6] R.E. Tribble, Private communication, 2003

[7] V.I. Selivanov, Private communication, 2003

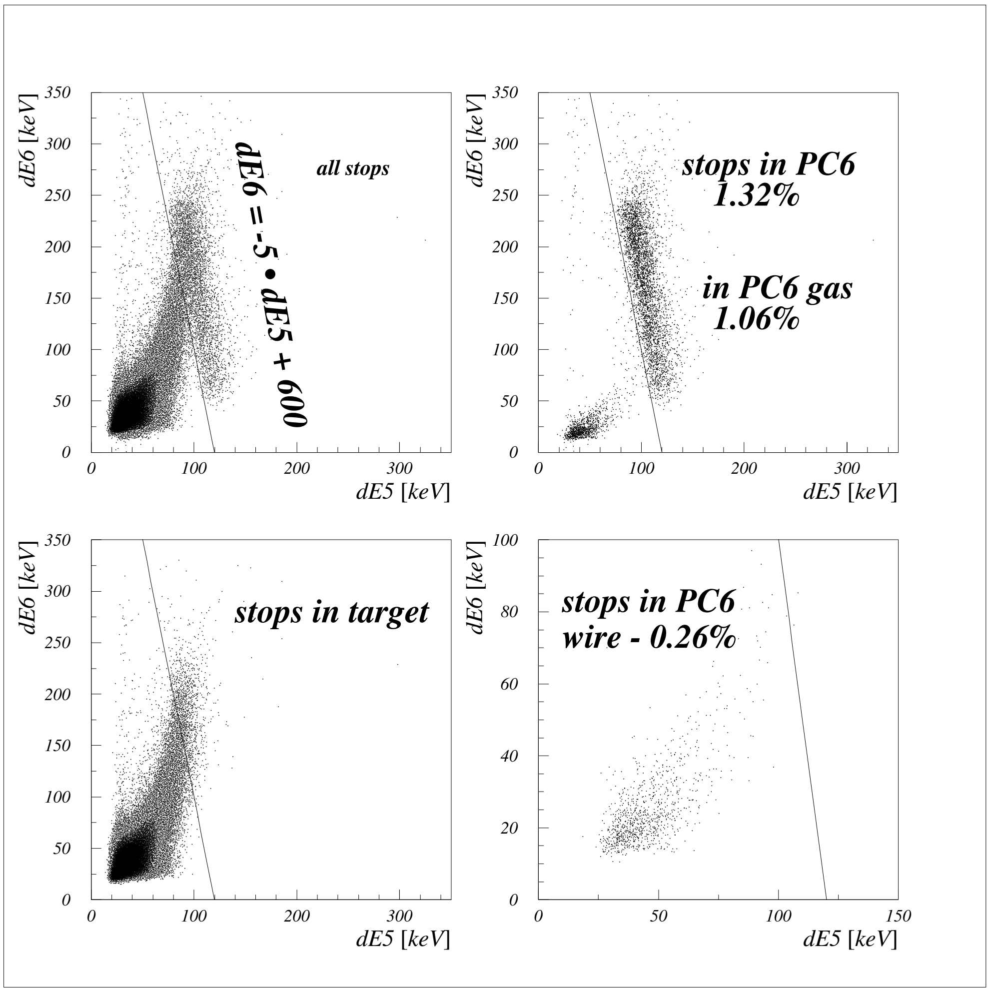

Figure 1: PC gas - Ar/ISO (40/60). Energy deposited by beam muons in PC6 (dE6) vs energy deposited by the same muon in PC5 (dE5). Left top: for all beam muons which came to PC6. Right-top: for beam muons stopped in PC6. Bottom-left: for beam muons stopped in target. Bottom-right: for beam muons stopped in PC6 wires. Two dimensional cut, separating branches with positive and negative slopes on left top figure, also shown on other figures.

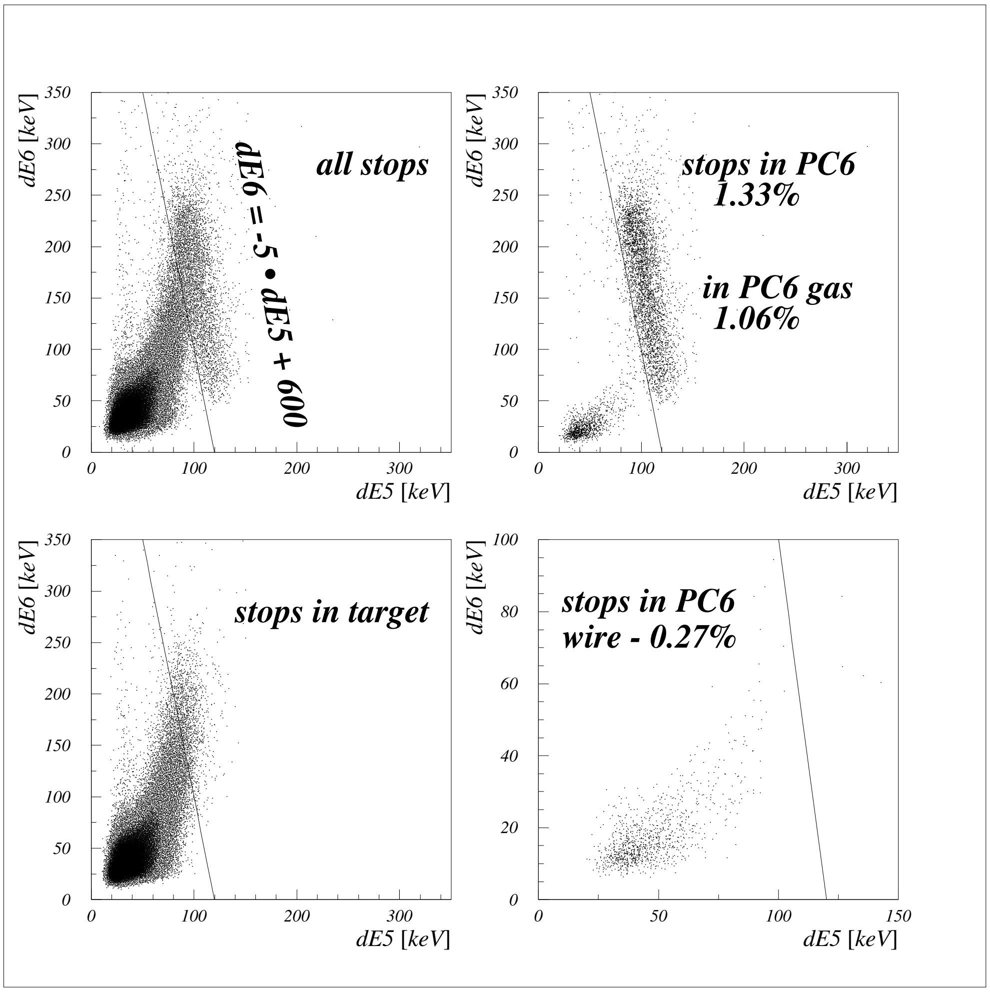

Figure 2: The same figure as Fig. 1, but with twice worsen energy resolution (a=0.44).

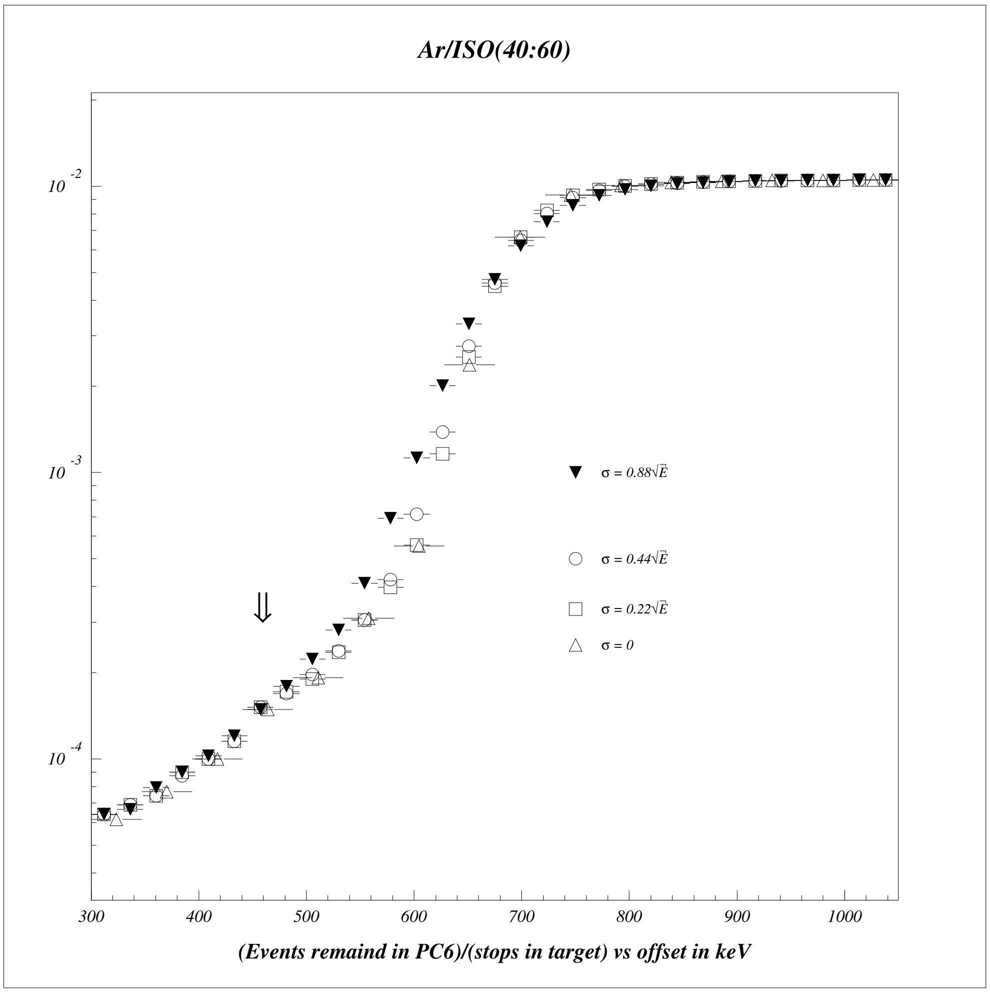

Figure 3: Rejection ability of cut (2) for different energy resolutions. Arrow show offset (C2) value, where cut (2) still survived 98% beam muons stopped in the target.

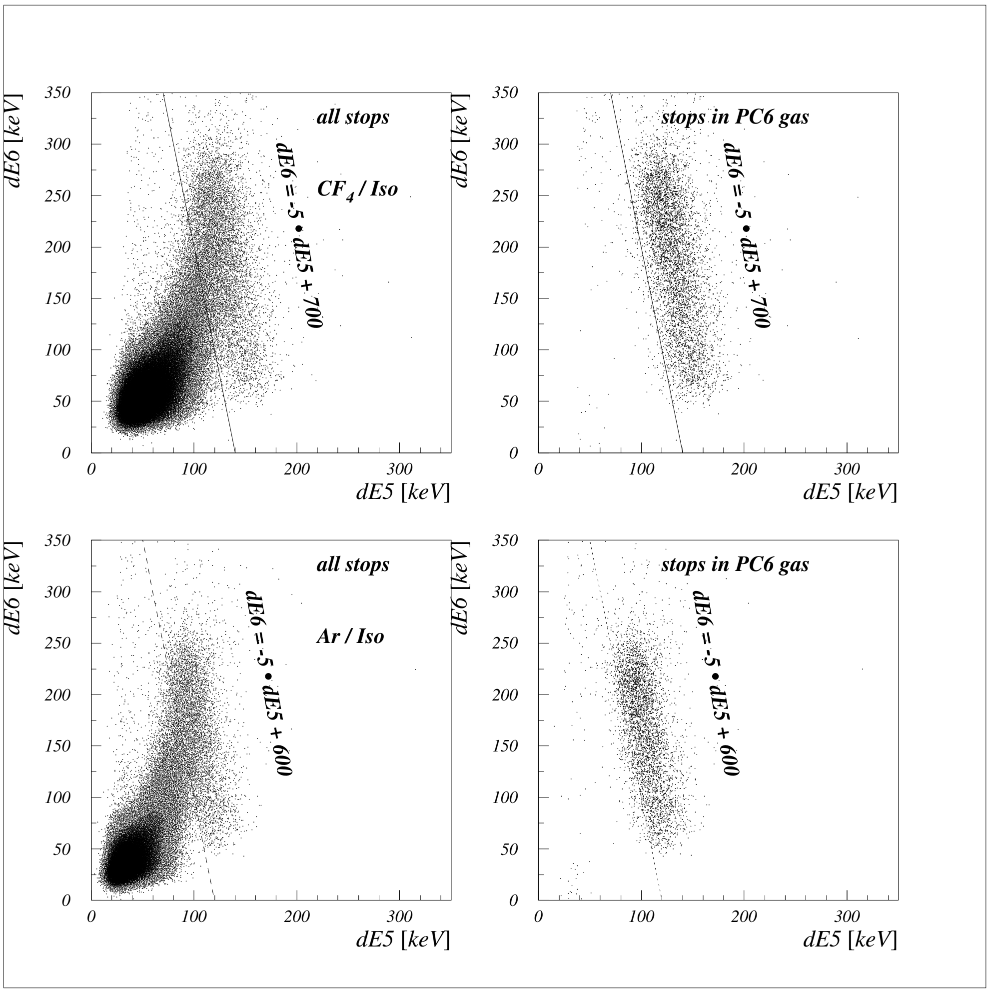

Figure 4: That figure compare two different gas mixtures: CF_4/ISO (80/20) and Ar/ISO (40/60). Worst calculated energy resolution (a=0.88) presented. Muon stops in PC6 wires do not included in figures.

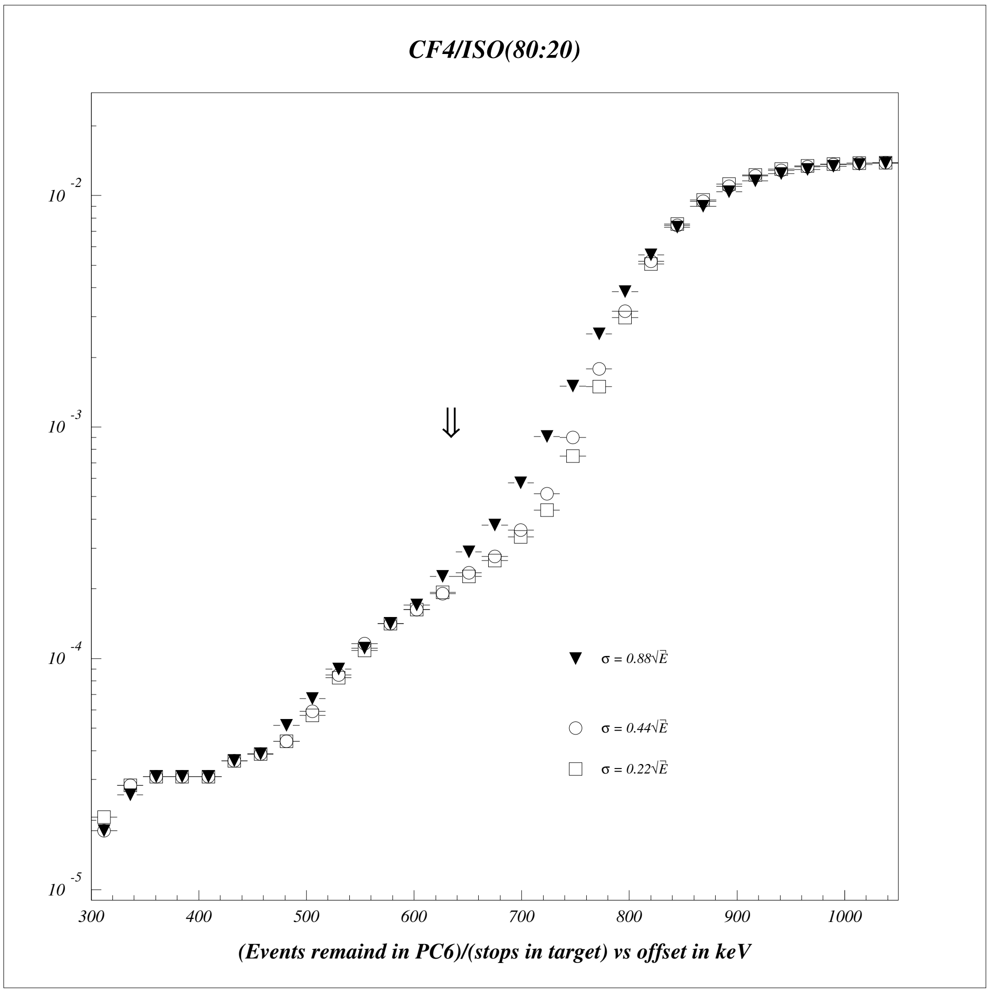

Figure 5: Rejection ability of cut 2 for different energy resolutions. Arrow show offset (C2) value, where cut (2) still survived 98% beam muons stopped in the target.

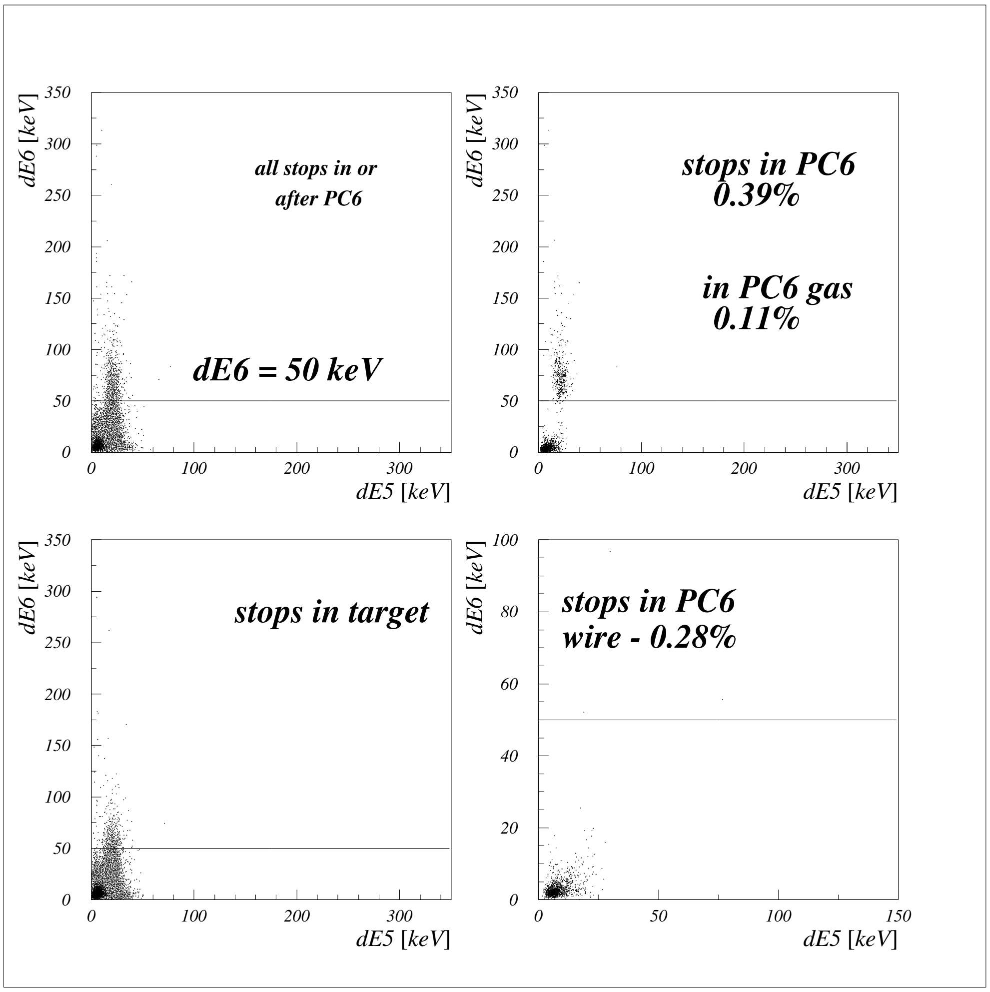

Figure 6: PC gas - DME/He (50/50). Energy deposited by beam muons in PC6 (dE6) vs energy deposited by the same muon in PC5 (dE5). Left top: for all beam muons which came to PC6. Right-top: for beam muons stopped in PC6. Bottom-left: for beam muons stopped in target. Bottom-right: for beam muons stopped in PC6 wires. Cut, separating regions with muons mainly stopped in target from muons mainly stopped in PC6 gas on left top figure, also shown on other figures.

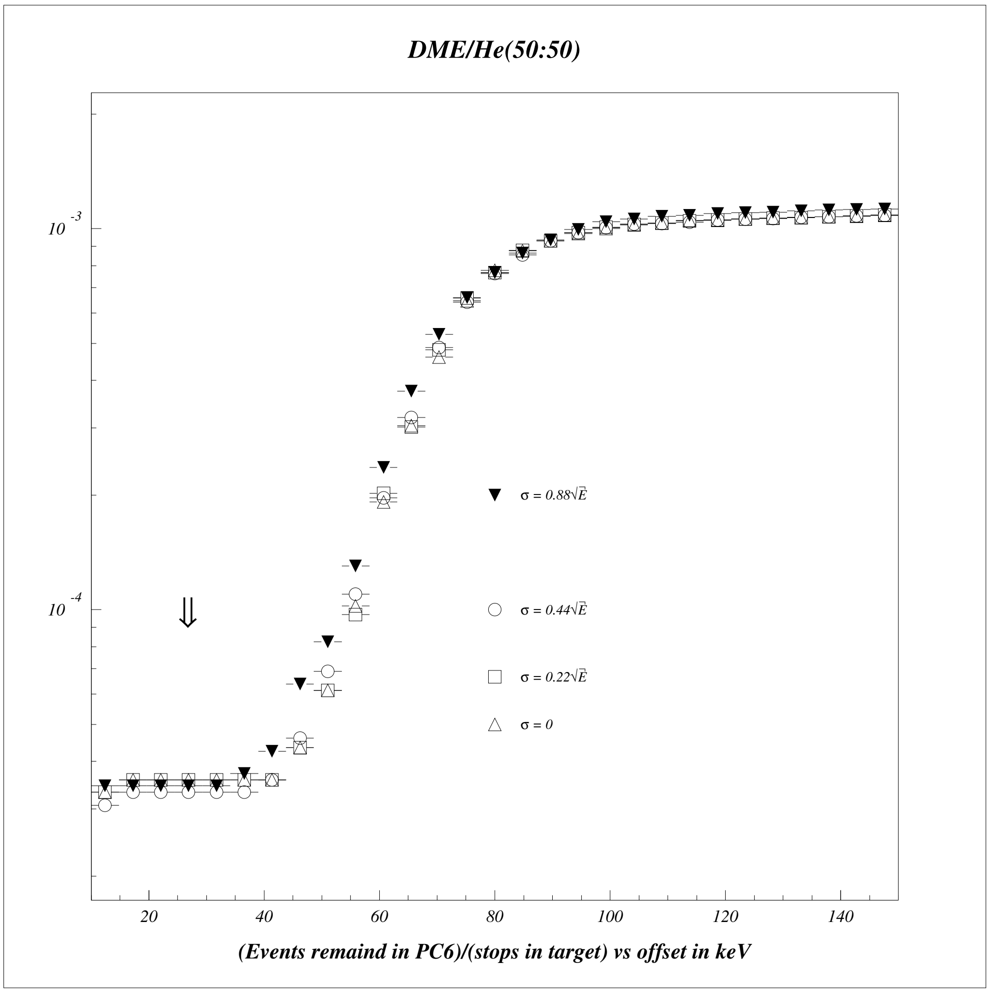

Figure 7: Rejection ability of cut ($dE6 = C2$) for different energy resolutions. Arrow show offset (C2) value, where cut still survived 98% beam muons stopped in the target.

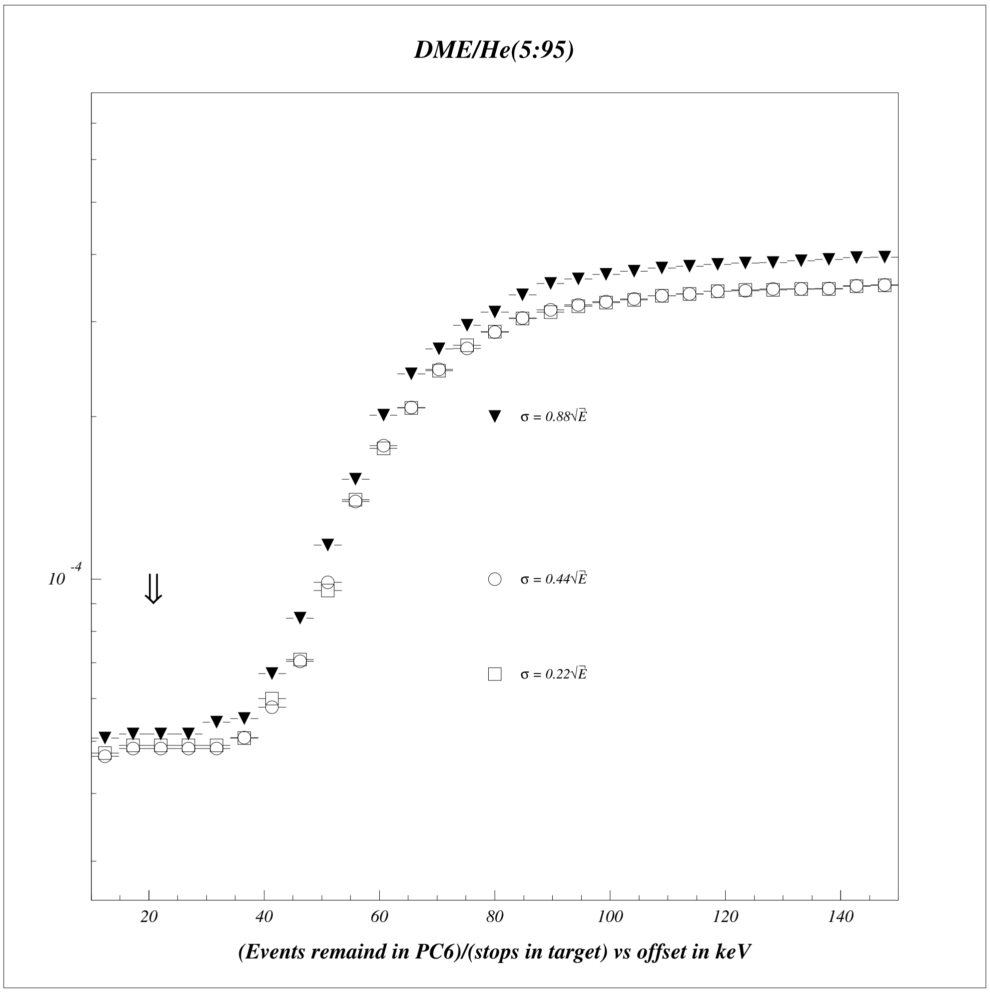

Figure 8: Rejection ability of cut ($dE6 = C2$) for different energy resolutions. Arrow show offset (C2) value, where cut still survived 98% beam muons stopped in the target.

Table 1: Beam muon stops in PC6 wire and gas, PC7 gas, normalized on beam muon stops in the target for different gases. Stops with cut shown for energy resolution a=0.44

Gas mixtures	Stops in PC6 wires	Stops in PC6 gas	Stops in PC6 gas with cut, which survive 98% stops in target	Stops in PC7 gas
CF_4/ISO (80/20)	0.26%	1.4%	0.019%	0.075%
Ar/ISO (40/60)	0.27%	1.06%	0.015%	0.11%
DME/He (50/50)	0.28%	0.11%	0.0033%	0.15%
DME/He (5/95)	0.27%	0.035%	0.0048%	0.06%