New developments in understanding and correction of dE/dx

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1 Introduction

We shall first summarize how we treated the dE/dx calculation and how we applied various corrections before, to show what kind of "understanding "has been missing so far. We discuss low multiplicity events (less than few hundred tracks) only, where some of the hardware effects, such as long term baseline shifts and cross-talk effects are - we believe - small, and we do not apply them. We'll focus on the *rest* of the procedure. Of course, this *rest* concerns high multiplicity environment as well (there, the mentioned corrections come *in addition*).

The usual way to correct a cluster charge before using it in the calculation of the truncated mean, is

• to take into account the pulser gain calibration and krypton calibration tables

• to correct for the loss of charge due to the threshold cut (5 ADC-s) of the NA49 electronics

• to correct for the charge loss due to electron attachment to oxigen (few percent over one meter drift)

• to correct for the variable length of flight over a given padrow, which is a function of the angles of the track

• as the pressure is measured, correct for the known dependence of the gas gain on the pressure (the temperature is rather stable, unlike the pressure)

• correct for a pre-extracted time-dependence of the electronics gains, leaving a room for eventual (and certainly present) changes in the gain sector by sector, due to a not yet completely clear origin

• applying the iterative inter-sector calibration which extracts sector gains from the data, and provides relative gain constants for the TPC sectors at a given point in time. This is related to the Bethe-Bloch function which should be optimized before (discussed in previous Coll. Meetings).

The most problematic and difficult of all above is the second point, the threshold loss treatment, which we'll discuss below.

2 Origin and old treatment of the threshold loss

The reason why the cluster charges loose some fraction of their value due to threshold cut is simple: the signals coming from a timeslice-pad pixel not reaching 5 ADC-s are not added to the total cluster charge (Figure 1). If we imagine a cluster as a two dimensional histogram: ADC values as a function of pad and timeslice number, then the lost charge is on the edge of the histogram, the tails which go below threshold. This seems at first sight to be a minor loss, as the typical maxADC values are 50-60 ADC-s, an order of magnitude bigger. But actually the losses are even in the MTPC-s sizeable, an order of 10 percent, and higher in the VTPC-s.

These losses are drift length dependent, or rather, they depend on the width of the cluster. The old approach was to take a measurable and measured value of the charge losses over a meter of drift, even as a function of total charge, and apply a correction choosing a reference plane $y_0 = const.$, where the correction is zero, and otherwise is proportional to the difference $y - y_0$.

3 Problems of the old method

It is easy to see, that the proper correction method is not as simple as above: the tracks making big angles with respect to the pad direction produce elongated, widened clusters, so the losses actually depend on the track angles, which becomes a *concern* in the Vertex chambers.

Indeed, the charge loss depends on many things: on the total cluster charge, on the y position of the cluster (there is a drift length dependence, as diffusion widens the clusters), and the two angles describing the track direction, as well as the tilt angles of the pads (which vary in a huge range), on the width of the pads and timeslices (drift velocity), the gap between pad plane and sense wires, pad length, and so on.

Qualitatively, it is easily seen, that for a given total charge the loss of the above kind increases as the "width" of the cluster increases (due to big angles, drift length, bigger gap, etc.). Naturally, even clusters close to the sense wires receive the threshold loss, due to a relatively wide time response and pad response function.

The solution was a sufficiently detailed, however extremely fast *simulation* of the cluster shapes as a function of the above parameters. This is still too slow to use it on-line (run the simulation for each cluster in the data), but good enough to produce appropriate look-up tables.

4 Simulation of the cluster shapes

The simulation follows in many respect the TPC simulation algorithm of Juraj Bracinik, summarized as follows.

Using the drift constants, a cluster starting from a given y position takes a Gaussian distribution in x and y with a calculable *sigma*, and reaching the sense wires, the electron cloud produces a signal distribution in the pad plane. In the end, the cluster shape will be a convolution of a Gaussian and a pad response function (taken as reciprocal of the cosine hyperbolic function) in the x (pad) direction, and a convolution of a Gaussian and a time-response function, which is measured (including a short-term undershoot). From a technical point of view, the convolution is facilitated by an approximation: the time response and the pad response functions are approximated by sum of Gaussians, making the convolution possible even analytically. An example is shown in Fig. 2 for the signal shape.

If the track makes some angle with respect to the beam direction, the above result has to be integrated along the path of the ionizing particle above the given padrow, giving the proper elongated shapes. Now it is easy to bin our 2-dimensional cluster to a pad-timeslice grid, and calculate the loss (ADC-s below threshold) at a given total ADC value. One has to average over the actual position of the ionization in x and y, to avoid fake binning effects.

This way, we come to the prediction of the loss, and cluster shape at any given track angle and total ADC configuration, in any type of sector construction.

5 Tilted pads

So far we did not mention the difficulty of treating tilted pads; in the Vertex TPC-s, there are tilt angles up to 55 degrees. The above simulation holds for non-tilted pads, that is, rectangular pads with edge perpendicular to the padrow (sense wire) direction, but allowing any track angle. However, one can generalize this (to a good approximation) to any tilt angle. The response on the given pad segment (in reality, of course, pads are intact, but we can imagine them as metallic surfaces having many small segments which are parallel to the row direction, see Fig. 3) depends on the distance of the pad segment and the track, we can transform the pads shifting the segments so that we get the non-tilted configuration, shifting at the same time the corresponding track pieces as well. The construction of the chambers are fortunate: the pad widths are constant if measured along the padrow direction, not if measured perpendicular to the pad edge, as we move in x direction: so there is no x dependence in our look-up tables. This way (as one can derive from the above concept) one should use as parameter (γ) not the difference between the tilt angle (θ) and horizontal track angle (α), but rather:

$$tan(\gamma) = abs(tan(\theta) - tan(\alpha))$$

.

This way we can still use the tables derived for non-tilted pads. (One could worry about the total ionization over the padrow, because it changes as we transform our track to an other padrow-crossing angle. But this is not a concern here: the tables anyway treat properly each total ADC value, we are here interested only in the shape of the cluster in a grid of timeslices and pads).

Finally, we produced a table for each sector construction geometry, and these include sufficient information to make the correction as a function of y position of the cluster, the total ADC, the pad tilt angle, and the two angle parameters of the track as inputs.

6 Wire ExB effect

One could think that wire ExB effect has still to be taken into account. This effect makes clusters wider or narrower, depending on the magnetic field polarity, and horizontal track angle: the electrons arriving to a sense wire travel in a horizontal direction as well, and the magnetic field deviates them sideways (see for example Brian's thesis for details). A simple calculation was carried out to show that the effect on the cluster width is a few percent only, if the track is perpendicular to the sense wires. If it makes a slight angle, the effect almost disappears, because the pads are much longer than the 4 mm gap between the sense wires, and the deviation of the electrons is proportional to this gap. Consequently, the cluster widens out as a pure effect of the track angle, this additional ExB-widening is relatively small.

In the end, we did not include ExB effects in our simulation.

7 Comparison with data, adjustment

Of course, the most important question is how the result of the simulation (where there are practically no free parameters to change, because the necessary constants are known) compares to cluster shapes in the data. We found good agreement in every sector and TPC with a few percent fine tuning of the parameters.

We used three measures to describe the cluster shape: the number of time slices and pads hit in a cluster, and the maxADC value (all available in the p+p DST-s). Those we compared to the result of the simulation. A single example is shown in Fig 4.

The next question is, whether the tuned simulation gives the losses which are observed in the data. Now, without touching the parameters, inserting only a few percent loss of oxigen attachment, the simulation reproduces the observed quantities in the data. This is what we call better understanding of the losses of the cluster charge.

An example can be seen in Fig 5.

One has to make an important comment here concerning the strategy of this correction. These detailed angle and drift length dependent losses are not possible to extract from the data directly. What CAN be extracted is the charge loss OVER ONE METER of drift, as a function of total cluster charge, but NOT the total lost charge. As there is inherently an angle dependence in BOTH of them, which is unknown without the help of the simulation, the measured information is not sufficient to make a good job when one corrects for the threshold loss in the old way.

By adjusting the model to every possible measure given by the data, we believe, that it gives not only the measured quantities back properly (which we checked), but the other necessary quantities as well (which are not measurable, but necessary for correction). This is why the simulation was necessary.

8 Results

The motivation of the presented work was to decrease or eliminate systematic effects, like angle dependent dE/dx, which have been so far observed, leading to slight (unphysical) displacements of the dE/dx spectra at a given total momentum bin depending on the transverse momentum. The detailed checks and test phase is still in progress, as the whole work is still rather new.

We present here one example of the lost ADC value as a function of the track angle, given by our simulation (Fig. 6), and a dE/dx scatter plot which is already available, showing 100k 1999 p+p reconstructed test events (Fig. 7), and the dE/dx distribution of the total momentum bin 9-11 GeV/c (Fig. 8). The resolution for the pions is 3.05% (sigma/mean). For Pb+Pb central interactions, where the corrections are more difficult due to the high track density, a resolution of 3.7% could be achieved in the same bin (by Christof and Thomas).

9 How to go on?

There is an other interesting study going on; how to include in the truncated mean calculation several cluster charges, which have a track length of flight over the padrows varying: not only due to different pad lengths, but due to various track angles as well. To first order, dividing by the length of flight (dE/**dx**) should do; that is what is done so far. However, it is well known that the charge distribution (Landau-disribution) changes NOT by a multiplicative scaling, as we change the length of flight; for instance, it gets narrower (relatively) if the latter increases. That means, that dividing by the length of flight still results *different* distributions, and we calculate truncated mean from charges obeying different distributions, depending on the angles, pad lengths...

One general way to treat this problem would be a maximum likelihood approach, which actually provides similar precision as the simple truncated mean method.

Besides the authors, J. Bracinik, H.G. Fischer and L. Betev contributed to this work with useful consultations.

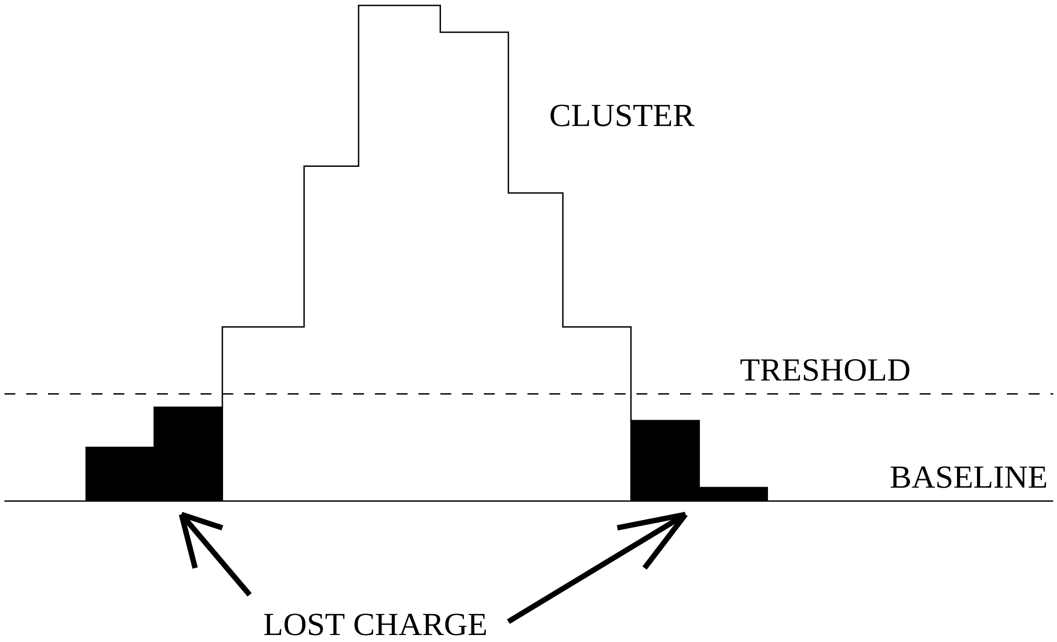

Figure 1: Example of a cluster which looses part of its charge due to threshold effect. Misleading picture: the cluster in reality is not one, but two dimensional (x and y, or: pads and timeslices)

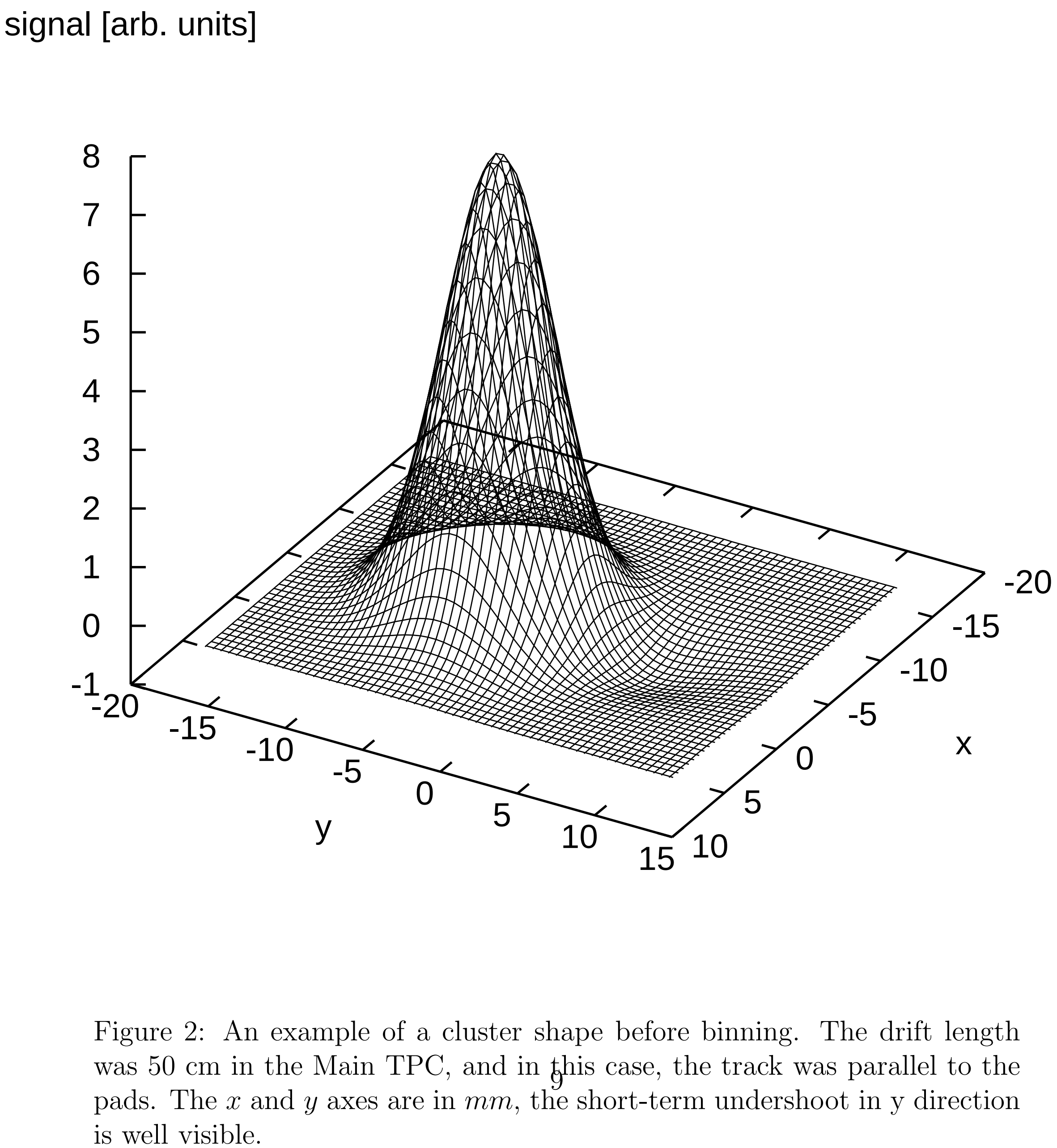

Figure 2: An example of a cluster shape before binning. The drift length was 50 cm in the Main TPC, and in this case, the track was parallel to the pads. The x and y axes are in mm, the short-term undershoot in y direction is well visible.

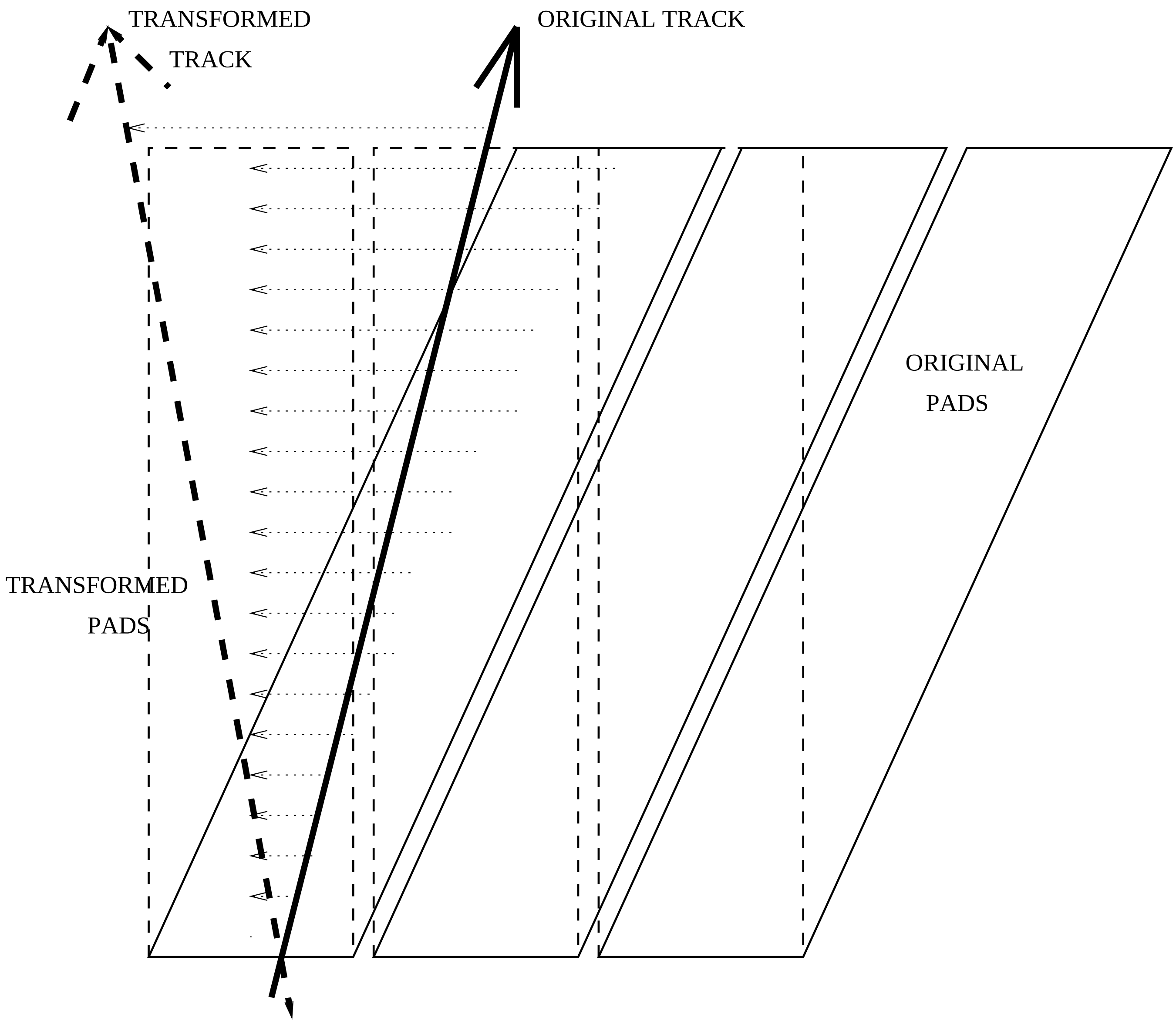

Figure 3: Transformation of tilted pads to non-tilted pads. The crossing track should be transformed as well. The aim is to treat tilted pads in a simple way, assuming that the pads are not tilted, but using an appropriate angle difference parameter (see text).

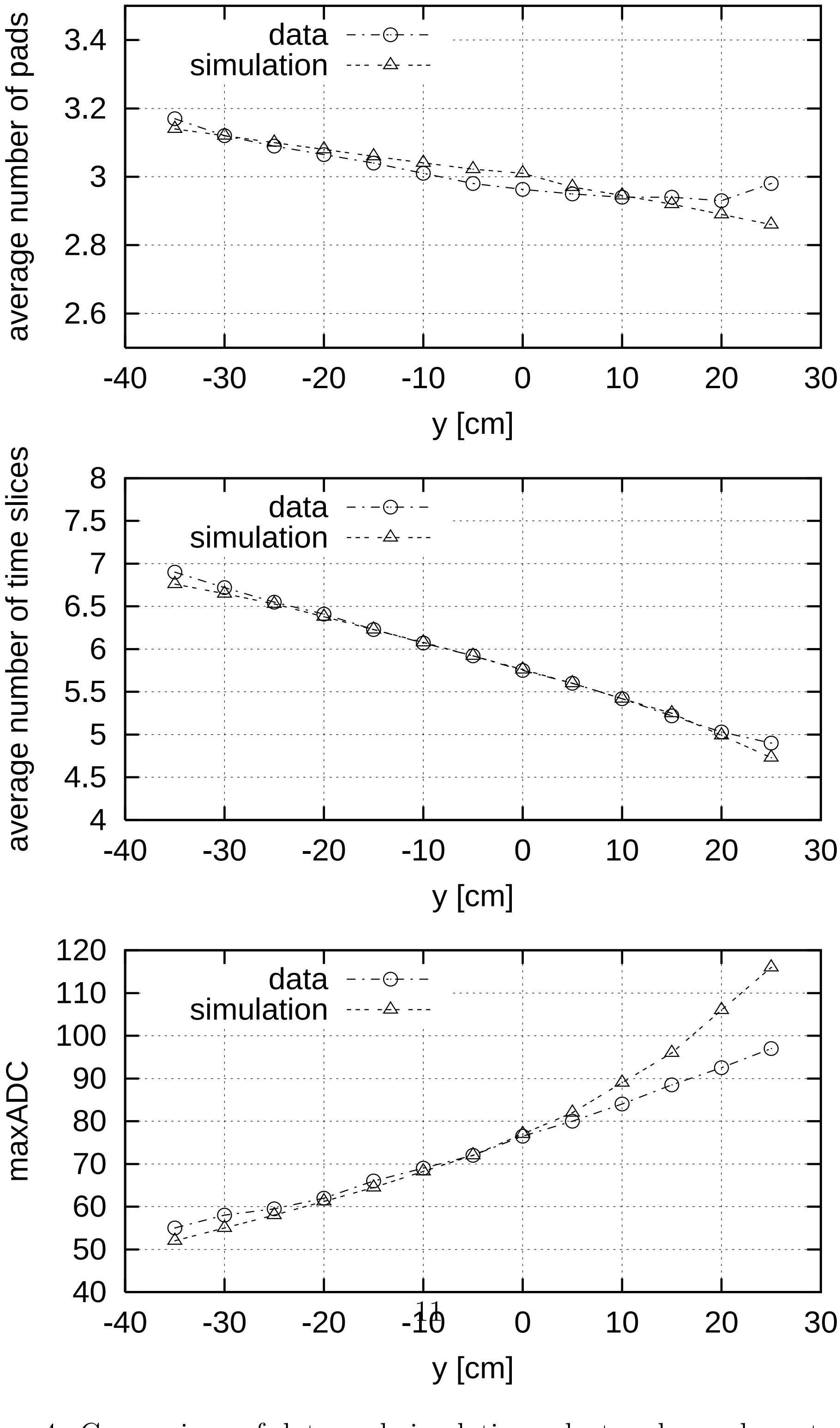

Figure 4: Comparison of data and simulation: cluster shape characteristics in Vertex-2.

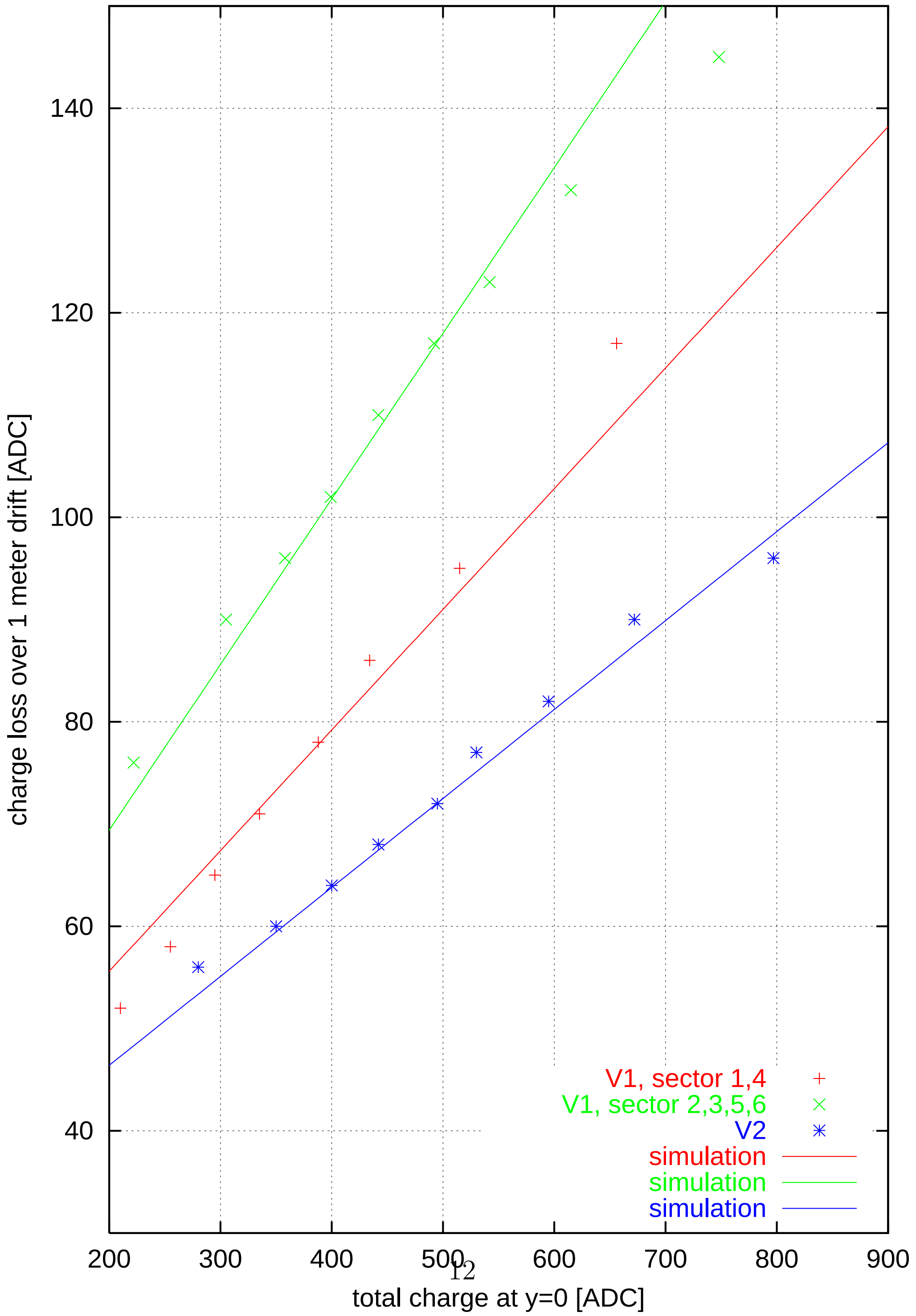

Figure 5: Comparison of data (points) and simulation (lines): drift length dependence of the charge loss in different Vertex-TPC sectors.

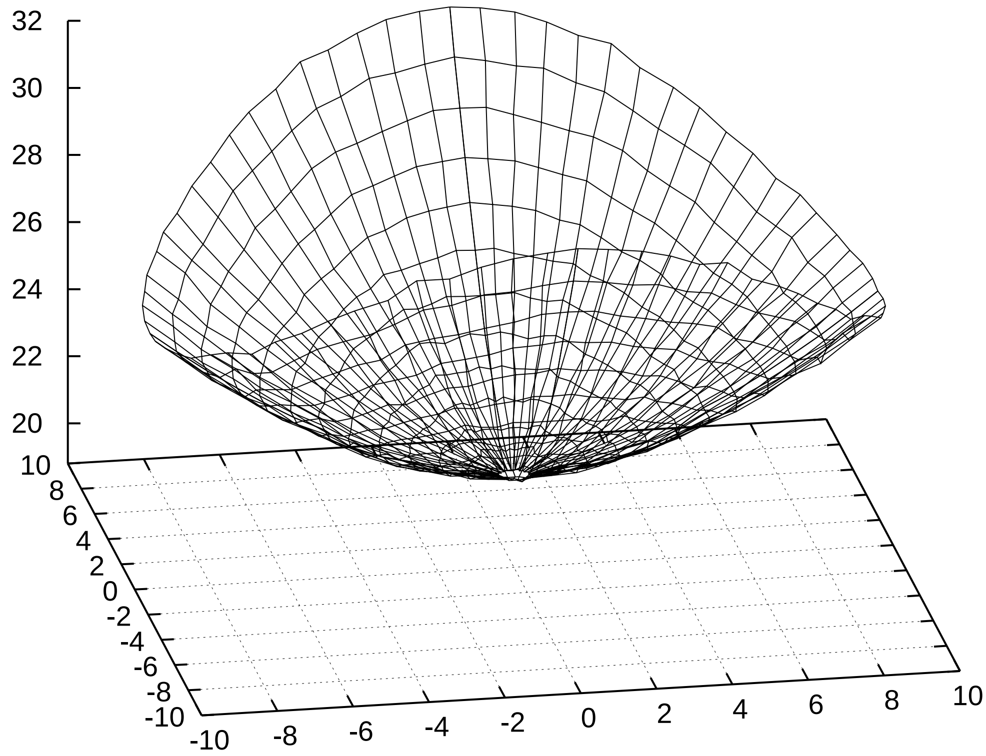

Figure 6: Example of the charge loss (in ADC-s) suffered by a Main TPC High Resolution cluster, which had 500 ADC total charge and where the track was in the mid-plane (y=0), as a function of a horizontal and dip angle of the track (degrees). Note, that as a function of dip angle, the loss increases more rapidly, because the time slice width is smaller than the pad width (2.4 and 3.6 mm, respectively).

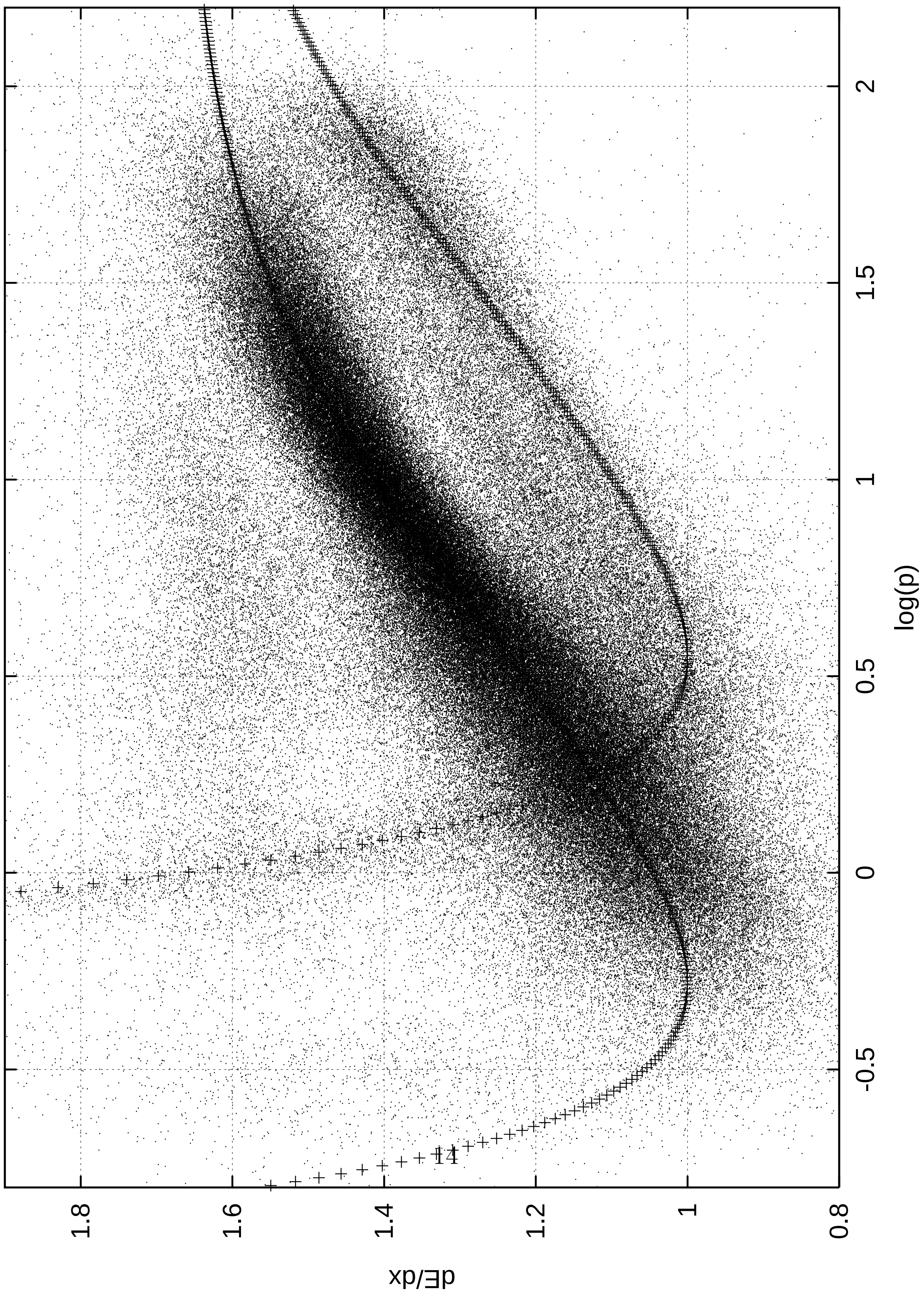

Figure 7: dE/dx as a function of the logarithm of the momentum of the track, positives and negatives together.

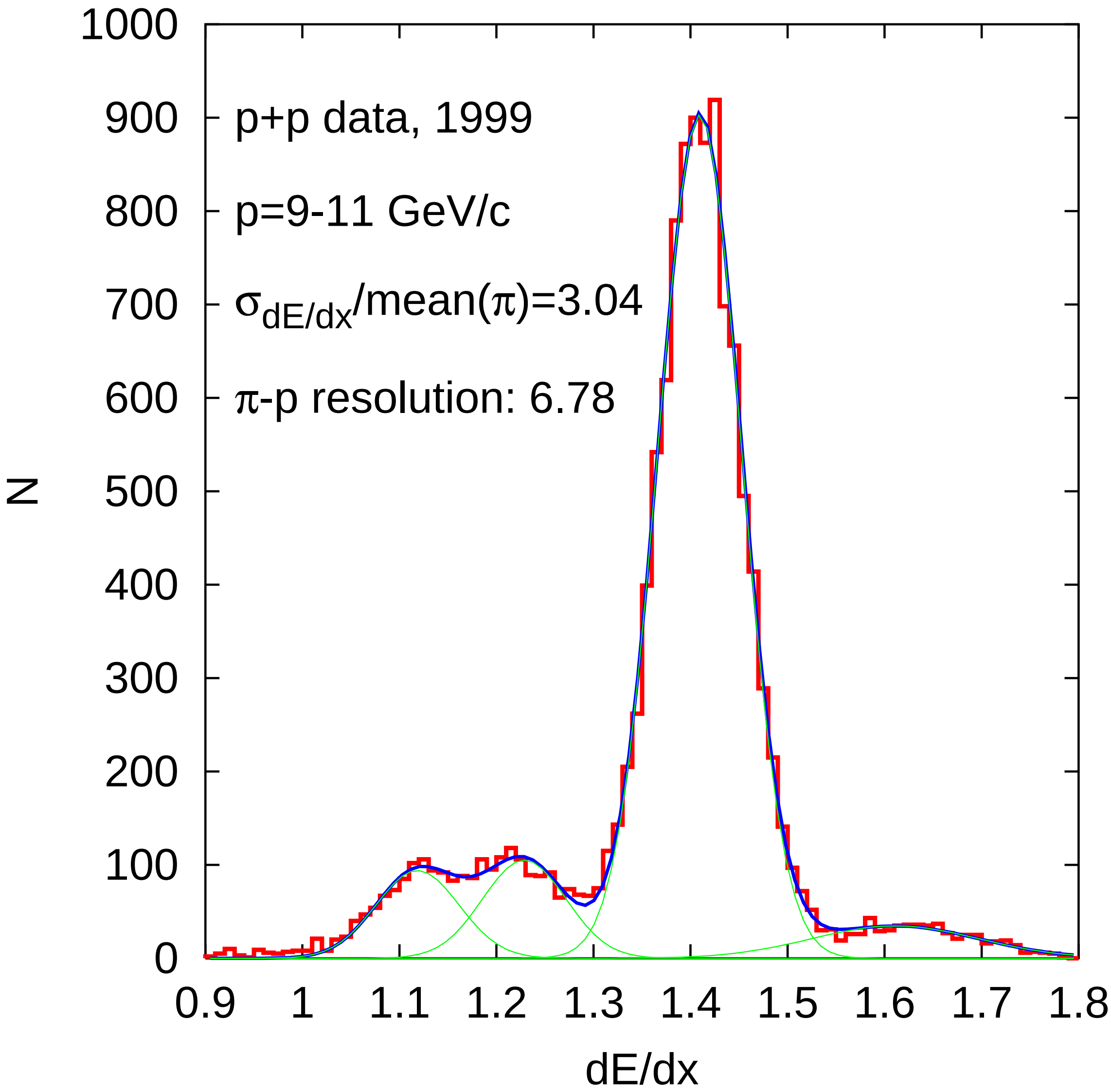

Figure 8: dE/dx distribution of the $9GeV < p < 11GeV$ momentum bin, p+p reaction.