

# Energy Loss correction in Kpi analysis

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January 26, 2009

The aim of this work is to quantify the Energy Loss in the Dirac experimental set-up for different particles : kaons, pions, protons, anti protons, and electrons. In particular for the  $K \pi$  and  $\pi^- \pi^+$  events I evaluate if this effect could explain a distortion in the reconstructed Ql variable.

## 1 Ql calculation

The calculations of the relative momentum Q of a pair in its center mass system (CMSY) and its projections Qx Qy ad Ql are extracted from the routine QVectDC in Ariane (version 402-03).

The inputs for the calculations are :

- Masses of the two particles corresponding to the reconstructed negative track (t-) and positive track (t+),  $M_{t-}$  and  $M_{t+}$ .
- Projections of laboratory momentum for the particles,  $P_x$ ,  $P_y$  and  $P_z$  for negative and positive particles.

In the routine there is first a change of coordinate system, in the Center of Mass of the pair. We get then  $p_x$ ,  $p_y$  and  $p_z$  for the two particles in their CMSY.

$$Ql = \frac{(p_z^+ - p_z^-) \times \sqrt{(E_+ + E_-)^2 - (p_z^+ + p_z^-)^2} + \frac{(M_-^2 - M_+^2) \times (p_z^+ + p_z^-)}{\sqrt{(E_+ + E_-)^2 - (p_z^+ + p_z^-)^2}}}{(E_- + E_+)} \quad (1)$$

where E is the energy of a particle.

Ql contains two terms :

- the first is proportional to the difference of  $p_z$  for the two tracks in the center of mass,  $p_z(t-)- p_z(t+)$ .
- the second is proportional to the difference of the square of the two masses,  $M_{t-}^2 - M_{t+}^2$ , and to the sum of the two  $p_z$  components.

## 2 Analysis

### 2.0.1 Ql distribution for $K^+ \pi^-$ events and $\pi^+ \pi^-$ events.

The Ql distribution for  $K^+ \pi^-$  events candidates has been obtained selecting events from the data collected in 2007 with Platinum target. The following requests have been applied:

- $K\pi$  trigger flag.
- The momenta for  $K$  and  $\pi$  :  
 $3.75\text{GeV}/c < P_K < 8\text{GeV}/c$ ,  
 $1.1\text{GeV}/c < P_\pi < 2.2\text{GeV}/c$  and  
 $5.1\text{GeV}/c < P_{K+\pi} < 10.2\text{GeV}/c$ .
- Only one valid track per arm.
- The Kaon candidate should have a valid TDC hit in the Aerogel.
- The reconstructed  $Q_t < 8\text{MeV}/c$  and  $|Q_l| < 20\text{MeV}/c$ .
- Prompt event ( $|\Delta t_{VH}| < 0.5\text{ns}$ ).

For the  $K^-\pi^+$  selection, all the cuts are kept but the request of the valid TDC in the Aerogel detector.

In fig 1 is the  $Q_l$  distribution of these events. Due to the small statistics available it is not really possible to say if the distribution is centered at 0 or shifted to the right. The effect could be large as 1 MeV/c.

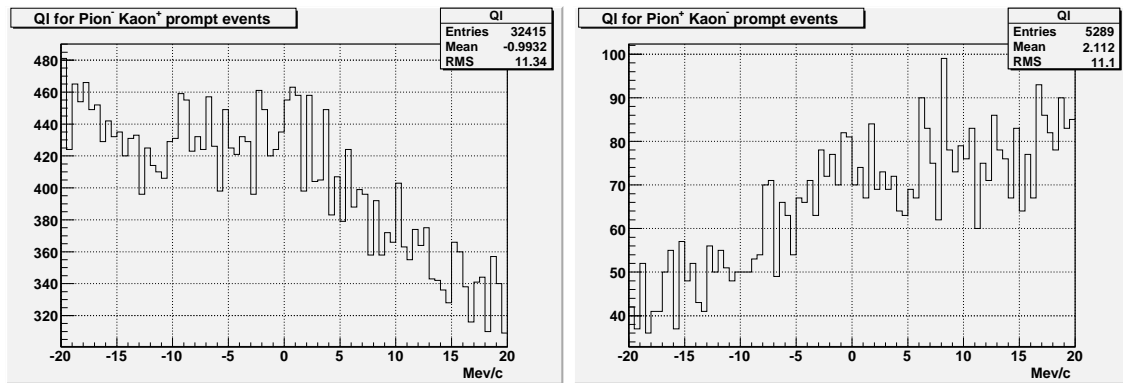


Figure 1:  $Q_l$  distribution for prompt  $K^+\pi^-$  (left) and  $\pi^+K^-$  (right) events.

For comparison, I have selected a sample of  $\pi^+\pi^-$  data. The sample comes from the same data taking, 2007 Pt target, with the requests :

- $\pi\pi$  trigger flag.
- The momenta for  $\pi^+$  and  $\pi^-$  :  
 $P_\pi^+ < 4\text{GeV}/c$ ,  
 $3\text{GeV}/c < P_{\pi^+\pi^-} < 8.6\text{GeV}/c$ .
- Only one valid track per arm.
- The reconstructed  $Q_t$  is smaller than 6 MeV/c and  $|Q_l| < 20\text{MeV}/c$ .
- Prompt event ( $|\Delta t_{VH}| < 0.5\text{ns}$ ).

In fig 2 is the  $Q_l$  distribution for these events, with the zoom of the central part of the  $Q_l$  distribution. As can be seen, the center of the distribution is at 0. There is a shift, the shift as large as 0.25 MeV/c, towards the right.

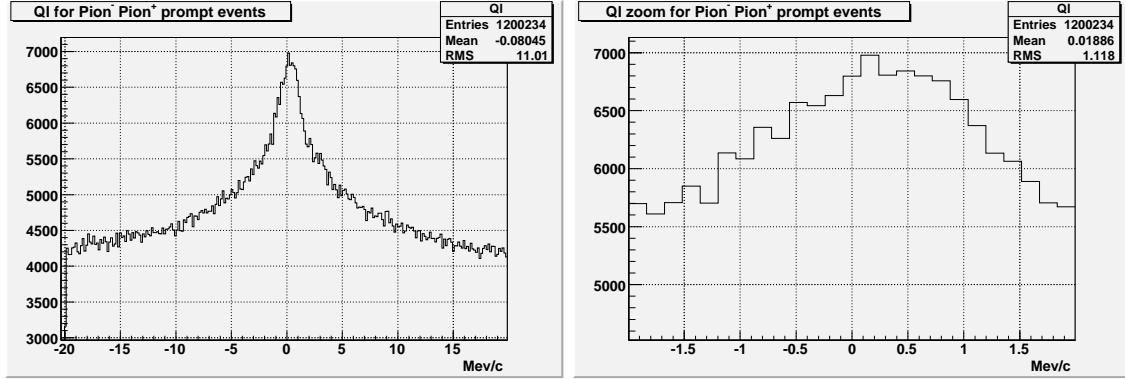


Figure 2: On the left, Ql distribution for prompt events, on the right a zoom on the central Ql distribution for  $\pi^+\pi^-$  events.

## 2.1 Monte Carlo measurement of Ql shift and of Energy Loss.

In order to evaluate the Ql shape in the Monte Carlo, I have used the generated sample of  $K^+\pi^-$  Coulomb Correlated (KP CC) <sup>1</sup> events and then let them go through Geant-Dirac (version 2.70). For every event I have stored the generated momenta for kaon  $p_{K^{in}}$  and pion  $p_{\pi^{in}}$  and calculated the  $Ql_{in}$  value.

If both tracks were present at the exit of the membrane before the magnet (740 cm from the target), I registered the corresponding momenta  $p_{\pi^{out}}$  and  $p_{K^{out}}$  and calculated the corresponding  $Ql_{out}$ .

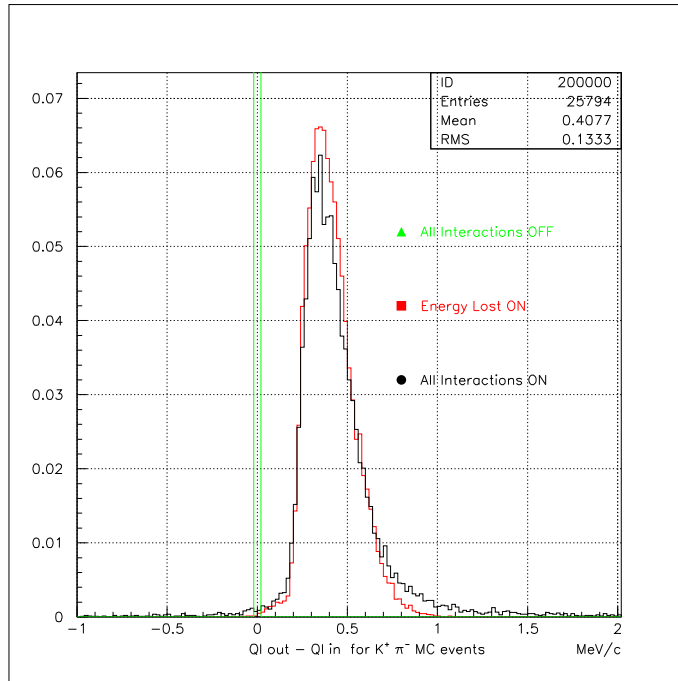


Figure 3:  $Ql_{in} - Ql_{out}$  for  $K^+\pi^-$  MC events, in Black is the MC distribution when all interactions are switched ON, in Red only the Energy Loss is ON, in Green all interactions are OFF.

In order to find out what was the cause of this shift, I have taken the same generated

<sup>1</sup>/castor/cern.ch/user/y/yallkofe/2007Pt/MC/kinebuffer/ccKpPm/kine.ccKpPm.101

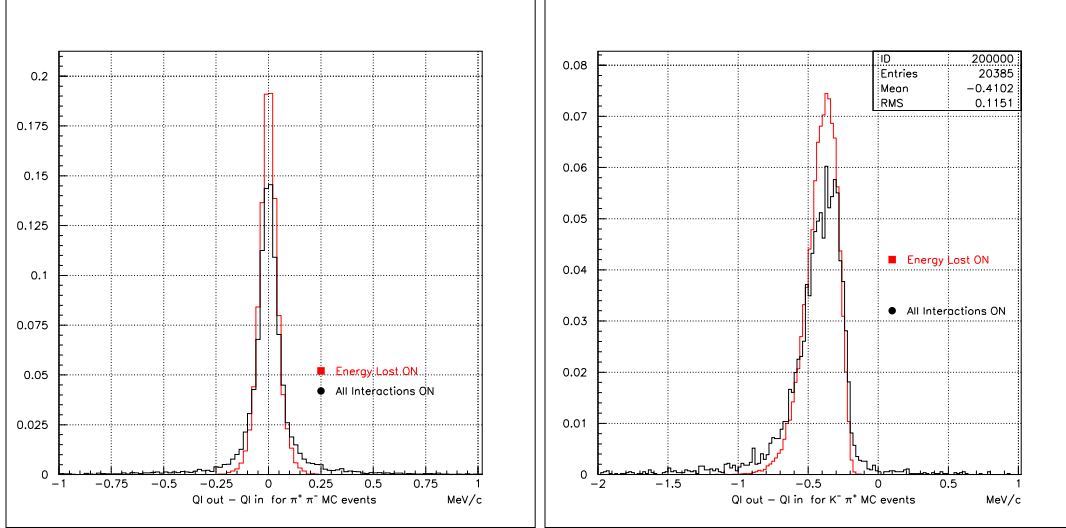


Figure 4:  $Ql_{in} - Ql_{out}$  for  $\pi^-\pi^+$ (right) and  $\pi^+K^-$ (left) MC events, in Black is the MC distribution when all interactions are switched ON, in Red only the Energy Loss is ON.

sample of  $K^+\pi^-$  and passed through Geant in different conditions. In fig 3 is shown the distribution of  $Ql_{in} - Ql_{out}$  event by event for  $K^+\pi^-$  MC data.

- All interactions ON. The shift in Ql is broad, and for  $K^+\pi^-$  events the mean is at 0.4 MeV/c.
- All interaction OFF and Energy Loss ON. The Ql shift distribution for  $K^+\pi^-$  events is a bit thinner since the tails are smaller but the peak is in the same position as in the former case.
- All interaction OFF. No Ql shift is visible.

I can conclude then that the main reason for the Ql shift is due to the Energy Loss.

For  $K^+\pi^-$ , the Ql formula contains two terms, the first equals to the  $\pi\pi$  case, then there is a second term that depends on the difference of the mass involved multiplied by the sum of the relative  $p_z$ , which is zero for  $\pi\pi$  events. Since the momenta distributions for kaons and pions are very different in Dirac and the difference in mass is important, this second term could cause a shift in Ql reconstructed with respect to the generated one if the Energy Loss is not taken into account.

Consider now a perfect tracking device, with perfect resolution, so no smearing of the momenta is possible. This is the condition I have simulated in Geant when only the Energy Loss was switched ON. During the passage in the Dirac detector the particle loses energy and the final reconstructed momenta  $P_{rec}$  is given by  $P_{rec} = P_{in} - \delta P$ , where  $\delta P$  is a positive quantity.

For the  $K^+\pi^-$  events the Ql reconstructed is then

$$Ql_{rec} = Ql_{in} + (-\delta p_z^K + \delta p_z^\pi) \times \sqrt{(\cdot)} + (-\delta p_z^K - \delta p_z^\pi) \times (M_\pi^2 - M_K^2)$$

The Ql shift in this case is then a positive quantity since the mass of the Kaon is larger than that of the pion and  $\delta p$  are positive quantities. For the  $K^-\pi^+$  events, the Ql shift becomes negative since the masses are reversed, as is shown in figure 4 (right).

In figure 4 (left) is shown the distribution of  $Ql_{in} - Ql_{out}$  event by event for  $\pi^+\pi^-$  MC data: there is no evident Ql shift. This is expected because in the determination of Ql

only the first term in the equation is present, and the momenta distributions for  $\pi^+$  and  $\pi^-$  are almost equivalent.

Since in the  $\pi\pi$  experimental data we have a small shift in the Ql distribution, maybe there is also a geometrical effect, an asymmetry in the right-left arm of the spectrometer that has to be corrected for.

In order to correct for this effect, I have run our Geant-Dirac program on different samples of events,  $\pi^+\pi^-$ ,  $K^+K^-$ ,  $e^+e^-$  and protons and anti-protons events. For each type of particle a correction function like  $\delta p = p_{in} - p_{out}$  as function of  $p_{in}$  has been evaluated, and introduced in Ariane by V. Yazkov (version 403 02). In the final part of the tracking, the measured value of p can be corrected for Energy Loss introducing in the FFreadInput the flag IonLossOn = TRUE.

In figure 5 are the 2-dimensional plots for the  $p_{in} - p_{out}$  versus  $p_{in}$  for  $K^+$ ,  $\pi^+$ , protons and electrons. The charge conjugate particle has the same distribution. In Table 1 are the mean and RMS of the energy loss distributions for the different particles.

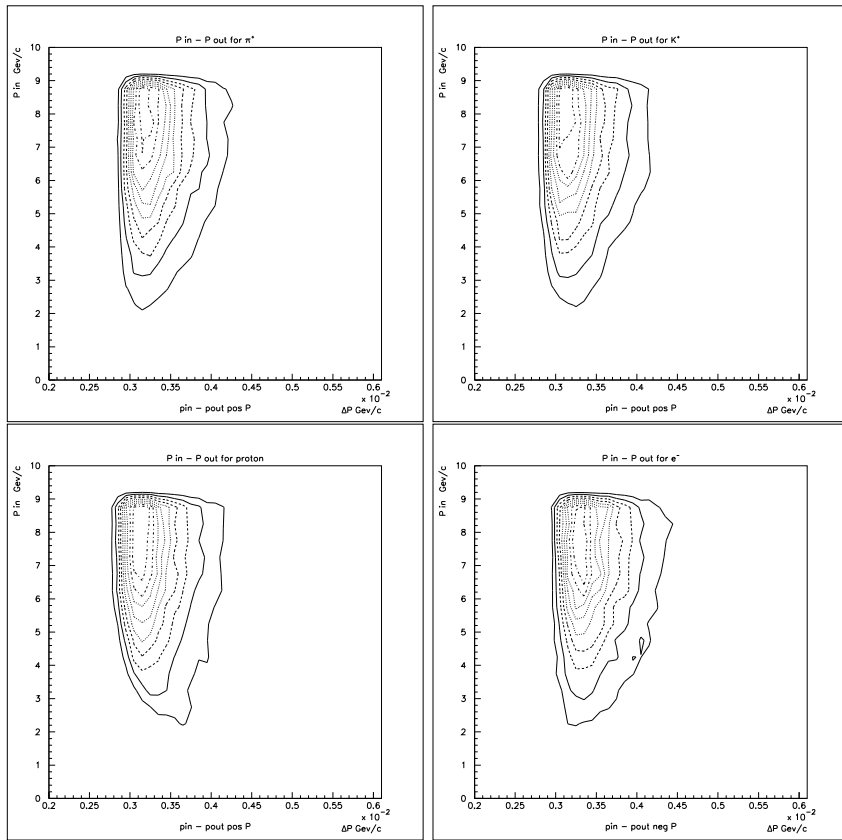


Figure 5:  $p_{\pi^{in}} - p_{\pi^{out}}$  versus  $p_{\pi^{in}}$  for  $\pi^+$ ,  $K^+$ , proton and electron tracks.

Particle type	Mean $\langle \delta p \rangle$	RMS
Kaons	$0.337 \times 10^{-2}$	$0.40 \times 10^{-3}$
Pions	$0.341 \times 10^{-2}$	$0.38 \times 10^{-3}$
Protons	$0.340 \times 10^{-2}$	$0.51 \times 10^{-3}$
Electrons	$0.348 \times 10^{-2}$	$0.39 \times 10^{-3}$

Table 1: Mean and RMS of the Energy loss distributions for different particles.

## 2.2 Conclusions

To have a shift in the reconstructed Ql is not a problem, we have just to understand it and make sure that the shift is the same in data and MC. We will verify this when all the statistics for  $K\pi$  data from 2007 and 2008 will be processed. If we want to perform the analysis in  $|Ql|$  we have to consider that the center of the distribution is not at 0. With the possibility to correct for this effect, we then should obtain a symmetric Ql distribution for the  $K\pi$  analysis.

Due to a small difference for the Ql distributions between the  $\pi\pi$  data and MC, it is important to verify the relative positions of the downstream detectors.