Searching for Heavy Quarks at NMC: 
A Simple Estimate of Background 
Muons from $\pi$ and $K$ decays

M. Thunman

Dept. of Radiation Sciences, Uppsala University, Box 535, S-751 21 Uppsala, Sweden

Abstract: New physics can be searched for in deep inelastic scattering experiments. New phenomena, like additional production mechanisms for heavy quarks, manifest themselves through production and decays of short-lived hadrons, which give additional muons in their decays. Muons from decays of light mesons can then be a severe background, especially at fixed target experiments. In order to make a first estimate of such a background a simple analytic method is here developed and applied on the muon scattering experiment NMC.

1 Introduction

Fixed target deep inelastic scattering (DIS) experiments like EMC/NMC and E665 can be used for searches of new physics, even though they are constructed for precise measurements of the structure functions. An example of such new physics is intrinsic charm \cite{1}, which have been searched for by European Muon Collaboration (EMC). They based their study on di- and trimuon events and found an upper limit of 0.6\% for the intrinsic charm probability \cite{2}, \textit{i.e.} the probability that the proton wave-function is in the intrinsic charm state $|uud\bar{c}\rangle$. The data have been reanalysed and the newer analyses confirms the conclusion of the original analyses \cite{3, 4}.

New physics like intrinsic charm and bottom would manifest themselves through the production of heavy hadrons containing these quarks. The heavy hadrons would then decay giving rise to additional muons. To extract such a signal, other sources of muons must be well understood. These sources are decays of hadrons containing perturbatively produced heavy quarks, \textit{i.e.} by perturbative QCD (pQCD), and decays of light mesons. This background has to be well understood and not too large if it should be possible to extract a signal. The perturbative production of heavy quarks is reasonable well understood, and its understanding could in fact be improved by a study of heavy quark production. The background from decays of light mesons is, besides the production mechanism, also dependent on the lay-out of the experiment. Light mesons have rather long decay lengths and could therefore be absorbed in various material before they decay. A simple analytic first estimate of the absorption effects is therefore desirable, before a full simulation of this source of muons is performed.

There are in principle two methods to reduce the background from decays of pions and kaons. Either one can build the experiments so small that the probability that meson decays between

\footnote{thunman@tsl.uu.se}
the interaction point and the detector become small enough, or one uses a larger set up with hadron absorbers to absorb the light mesons. Both EMC and NMC (New Muon Collaboration) use rather large experimental set-ups because they are designed for precise measurements of the muon momentum. Therefore, only the later method can be used.

In the mentioned intrinsic charm search at EMC a long (∼3.75 m) Fe-scintillator calorimeter was used as target. The first three meters of the calorimeter was used as target for the study, and the remaining part was used as a calorimeter/absorber (∼5 absorption lengths). This target was not used by NMC, instead different homogeneous targets of hydrogen, deuterium, carbon and different metals were used. Because of the high interaction rate in the heavier targets the number of tracks in the tracking region was expected to be unnecessarily high. The reduction of the number of tracks, both from mesons and from muons coming from light meson decays, was done by putting a calorimeter close to the beam axis in the target region and a calorimeter/absorber directly after the last part of the target (see Fig. 1). This arrangement, which was necessary for the original purpose of the experiment, also makes it useful for a search of heavy quark production in terms of additional muons from their decays.

Deep inelastic electron-nucleon scattering experiments are not as feasible as muon scattering experiments for searching of intrinsic charm. This because the scattered electron would also be absorbed together with the light mesons in the calorimeters/absorbers. Cuts in variables related to the scattered lepton are valuable to distinguish intrinsic charm events from other events, which is not possible if the electron is lost. However, by only measuring the muon rate and their energy spectrum valuable indications for intrinsic charm can still be found.

The lay-out of the paper is the following. First some general aspects of meson and muon production are discussed (section 2). Then the experimental set-up of the NMC experiment is described (section 3) and the corresponding muon flux from light meson decays is calculated (section 4). The possibility to use cuts in parameters related to secondary vertices to further reduce the background is discussed in section 5. The analysis is concluded (section 6) with some remarks.

2 General aspects of meson and muon production in DIS

The starting point of the analysis is a calculation of the muon rate from light meson decays, where attenuation of mesons in absorbing material in the experimental set-up is neglected. This calculation could either be done with a Monte Carlo, as in this study, or with an approximate analytical method. That the calculation is performed without absorption of mesons means that the mesons are allowed to decay in a distance of the size of the experiment. For a fixed target deep inelastic scattering experiment like NMC this distance is ∼20 m. The goal of the analysis is to calculate a factor which the originally calculated flux should be multiplied with in order to include absorption of mesons. This suppression factor (ξ) is the fraction of muons reaching the detectors in a set-up with absorbing material compared to without.

If the size of the experimental set-up is small compared to the decay length of the pions and kaons, decays can be neglected when calculating the development of the pion and kaon flux. Since muons of energy lower than ∼10 GeV cannot be identified in NMC, meson energies lower than ∼15 GeV are not of interest. At such low energies ∼3% of the π and ∼15% of the $K^\pm/K^0_L$ will decay in a length of 20 m ($L_{tot}$). This means that attenuation due to decays is negligible compared to the total flux, which therefore is approximately constant within the ‘empty apparatus’. The above aimed method, based on a suppression factor, is therefore applicable. Since the light meson fluxes are roughly constant within the empty parts of the apparatus, the muon production rate is also constant. A muon production rate per meter, κ, is
now defined by dividing the muon flux from the Monte Carlo with the length scale \( L_{\text{tot}} \), i.e. the number of muons produced per meter in an ‘average Monte Carlo event’.

Muon nucleon scattering is dominated by soft processes \( (Q^2 \approx 0) \), i.e. Coulomb scattering. Since typically only small amounts of energy is exchanged in such an interaction, the muon is only deflected a small angle with small energy loss. This means that muon fluxes are not attenuated by such interactions. In deep inelastic muon proton interactions, on the other hand, the momentum transfer is large, and the muon is scattered at a larger angle with sizeable energy loss. The cross section for this type of interactions is small, which implies that it does not cause any strong attenuation of the muon beam. So attenuation of beam, scattered and secondary (from decays) muons due to interactions can be safely neglected. Since the attenuation of the muon beam is neglected, the muon interaction rate and thereby the meson production rate is constant along the target (and along the calorimeter/absorber). A beam muon interaction rate is now defined, \( \zeta = 1/L \), were \( L \) is the target length (\( \zeta \) is normalised to one event per target). The meson production rate, \( \eta \), is now obtained by multiplying \( \zeta \) by the number of produced mesons in a typical deep inelastic scattering event, which is unity if \( \eta \) is given in units of ‘average Monte Carlo event’.

The pions and kaons produced in the primary interaction will interact in the target and the meson flux will therefore be attenuated when passing through the target. The meson flux will in the same way be attenuated in the calorimeter and the absorber material. The inelastic pion-proton and kaon-proton interaction cross sections are roughly the same and energy independent over the relevant energy range \( (15 - 100 \text{GeV}) \) and have the value \( \sigma \approx 20 \text{mb} \). A material independent interaction thickness is given by

\[
\lambda = \frac{\rho}{\sigma n_N} = \frac{1}{\sigma N_A} = 83 \text{g/cm}^2,
\]

where \( \rho \) is the density, \( n_N \) is the number density of nucleons and \( N_A \) is the Avogadro number. Any cross section dependence on the target number is assumed to be of the form \( A^1 \), where \( A \) is the target mass number. A material dependent interaction length is now defined

\[
\Lambda = \frac{\lambda}{\rho}.
\]

The meson flux develops in the target according to

\[
\frac{d\phi(z)}{dz} = \eta - \frac{1}{\Lambda_T} \phi(z),
\]

where \( z \) is the coordinate along the beam axes. \( \eta \) is the production term and \(-\phi(z)/\Lambda_T \) is the attenuation due to interactions in the target \((T)\). The solution is

\[
\phi(z) = \eta \Lambda_T (1 - e^{-z/\Lambda_T}),
\]

where no initial meson flux is assumed. \( \phi \) is here given in units of ‘average Monte Carlo event’. The contribution to the muon flux due to meson decays in the target is given by

\[
N_{\mu} = \int_0^L dz \kappa \phi(z) = \kappa \eta \Lambda_T (L - \Lambda_T (1 - e^{-L/\Lambda_T})),
\]

where \( L \) is the length of the target. So far it has been assumed that no particles escapes from the target through its lateral surface. This is an approximation that is going to be discussed further when the experimental set-up is specified.
In a region between a target and a calorimeter/absorber the meson flux is unaffected by absorption, but it contributes to the muon production through the pion and kaon decays. The decays give rise to the muon flux

\[ N_\mu = \kappa \ell \phi_0, \]  

(6)

where \( \ell \) is the length between the target and the calorimeter/absorber.

When the meson passes through a calorimeter or an absorber the flux is attenuated due to interactions. The meson flux develops according to

\[ \phi(z) = \phi_0 e^{-z/\Lambda}, \]  

(7)

where \( z \) is the depth in the calorimeter/absorber. Mesons will also decay in the calorimeter/absorber and therefore also contribute to the muon flux by

\[ N_\mu = \kappa \phi_0 \Lambda (1 - e^{-\ell/\Lambda}), \]  

(8)

where \( \ell \) is the length of the calorimeter/absorber.

3 The experimental set-up

The target set-up that is going to be used for the calculation is the heavy target one used by NMC in 1988. The elements relevant for the muon production will be specified whereas other elements will only be briefly discussed.

The target system consists of two complementary set of targets which are interchangeable. Each set consists of four targets (Target 1–Target 4 in Fig. 1, only one set shown). The target material is either homogeneous carbon or evenly distributed slices of different metals. The effective thickness of the different targets is roughly the same (\( \sim 145 \, \text{g/cm}^2 \)). Carbon is used as reference and two targets are always made of homogeneous carbon, target 1 and 3 or 2 and 4 in the two sets of targets, respectively. The calculation will be performed for a set-up where all targets are made of a homogeneous material, i.e. all targets made of carbon which simplifies the calculation. This is a reasonable approximation since the targets were designed to be as equivalent as possible. The lengths of each target and the distances between them are shown in Fig. 1.

Between Target 2 and 3 an iron calorimeter is placed. It consists of layers of iron and plastic scintillator with a central hole for the beam (52\( \times \)26 cm\(^2\)) and has a total thickness of 325 g/cm\(^2\). Its purpose is to measure the energy of hadrons coming from interactions in Target 1 and 2.

Figure 1: Lay out of the relevant parts of the experiment. All lengths are in cm.
Similarly, a calorimeter consisting of layers of concrete and plastic scintillator is placed after Target 4. It has a thickness of 235 $g/cm^2$, with the exception of the central part which only has a thickness of 157 $g/cm^2$. The reason for the lower thickness in the central part is that a hole ($8 \times 8 \text{ cm}^2$) is made in the calorimeter (see Fig. 1) in order to make it possible to separate muons scattered in Target 4 from those scattered in the calorimeter. A concrete absorber of thickness 460 $g/cm^2$ is placed after the calorimeter. Its purpose is to absorb hadrons in order to minimize the number of particles in the downstream muon detectors. Further downstream an iron-absorber ($\sim 400 \text{ g/cm}^2$) is placed. Its purpose is to absorb hadrons in order to ensure that only muons reach the detector planes after it.

The main parts of the experiment, besides the targets, are the analyzing magnet and a number of thin detector planes for position measurements. These elements are however not important for this calculation and therefore not included in Fig. 1. The analyzing magnet is positioned $\sim 1 \text{ m}$ after the concrete absorber. The detector planes are in three groups. The first group consists of planes before, inside and directly after the analysing magnet. The purpose of this group is to reconstruct tracks through the magnet. The second group is a set of planes directly before the iron absorber, whose purpose is, together with the first group, to measure the muon momentum with high precision. The third group is placed after the iron absorber and is used for muon identification.

4 Calculation of muon fluxes

The starting point of the analysis is a calculation of the muon flux in which absorption effects are neglected. This has been done with the Monte Carlo LEPTO 6.4 [7] which simulates deep inelastic lepton-nucleon scattering. It uses leading order matrix elements and parton showers for the perturbative QCD calculations of the partonic state, and the Lund string model [8] for the non-perturbative hadronisation of the partons. The simulation has been done with a 280 GeV $\mu^+$ beam, which is the condition under which NMC has taken most of their data. Two sets of simulations have been done, one with a minimal set of experimental cuts for NMC ($Q^2 > 2 \text{ GeV}^2, W^2 > 100 \text{ GeV}^2, 0.2 < y < 0.8$ and $E_{\mu'} > 10 \text{ GeV}$), and one with an additional set of cuts for searching for intrinsic charm ($x > 0.2$ and $y < 0.65$).

To investigate if parameters related to the production vertices, in particular the impact parameter, could be used for further discrimination, also muons from decays of charmed particles have been studied. Both the normal pQCD and the hypothetical intrinsic charmed production mechanisms are considered as sources of charmed particles. The intrinsic charm study has been performed with LEPTO, while the pQCD study has been performed with AROMA [9]. AROMA is a program based on LEPTO, but with an improved heavy quark treatment due to explicit inclusion of the heavy quark masses in the matrix element.

The muon flux gets contributions from interactions in all targets and also from interactions in the concrete calorimeter and the concrete absorber. It is assumed that it is possible to determine from which target the scattered muon originated, and that the targets therefore can be treated as independent. This is important if some of the targets must be excluded from an experimental analysis because of too high background. As mentioned earlier the interaction rate is normalised to one event per target in order to be able to compare directly with the Monte Carlo.

The situation is similar for all four targets. They all give contributions to the muon flux from decays within the target, decays in an empty section after the target and decays in a calorimeter after the empty section. After a few simplifications the muon fluxes from them can therefore be calculated with the same formula. The simplifications made are that all mesons are assumed to
Figure 2: Angular distribution of pions for different pion energy bins. Shown are both the distribution for the minimal set of cuts at NMC (dashed lines) and for the set of cuts applicable for a search of intrinsic charm (solid lines). The simulations are for a 280 GeV muon beam and the distributions are given with an arbitrary normalisation, which is the same within each of the two sets. Marked is also the minimum angle \( \theta_{\text{min}} \) a meson must make with the beam axis in order to be able to escape through the lateral surface.

miss the next target and are allowed to travel freely until they hit a calorimeter. The angle a meson must make with the beam axis in order to miss the next target is \( \sim 3^{\circ} \). From Fig. 2 one can see that many mesons make so small angle with the beam axis, especially with the minimal set of cuts, that they hit the next target. Therefore, the contributions from decays in the empty sections will be overestimated, by a factor maybe as large as 3. Secondly it is assumed that all mesons from Target 1 hit the Fe-calorimeter. Since the hole in the Fe-calorimeter is rather large, this will underestimate the muon flux in case of Target 1. It is also assumed that absorption in the Fe-calorimeter of mesons originating from Target 2 can be neglected and analogously that absorption in the first part of the concrete calorimeter of mesons originating from Target 4 can be neglected. Finally, the contributions to the muon flux from decays after the Fe-calorimeter in case of Target 1 and from decays after the concrete calorimeter in case of Target 2 and 3 are neglected. In case of Target 4, the calorimeter part is not thick enough to neglect decays after it, so decays in the concrete absorber is also taken into account, but decays after the absorber is neglected. These last simplifications will underestimate the muon flux with a few percent. Since the goal of this study is only to estimate the suppression due to absorption, the precision given by these simplifications is sufficient.

For the derivation of the formulas in section 2 it was assumed that no particles escape through the lateral surface of the targets. The approximation is valid for a wide target and will be shown to be reasonable in the case of NMC. The targets are cylinders of length \( L = 75 \text{ cm} \) and radius \( R = 4.0 \text{ cm} \). A particle produced in the beginning of the target must make an angle larger than \( 3.06^{\circ} \) with the beam axis in order to escape through the lateral surface. In Fig. 2 the angular distributions of pions for different energy bins for the two sets of experimental cuts are shown as obtained from Monte Carlo simulations. One can see that most pions in the
case of minimal cuts fulfill this criteria. For the intrinsic charm search most pions make an angle less than $6^\circ$ with the beam axis, which means that only pions produced in the first half of the target can escape through the lateral surface. These pions must travel through larger amounts of material than an average pion produced more downstream and escaping through the end-surface. The former will therefore suffer larger absorption and therefore be less important. This, together with the fact that still half of the pions makes an angle less than $3^\circ$ with the beam axis, justify the approximation even in the intrinsic charm search case.

The muon flux is now obtained by calculating the contributions from the different sections of the experiment and adding them. The contribution from meson decay within the target is

$$N_{\mu,1} = \kappa \eta \Lambda_T \left( L - \Lambda_T (1 - e^{-L/\Lambda_T}) \right),$$

(9)

where all variables have been defined earlier. The meson flux after the target is given by Eq. (4) with $z = L$,

$$\phi_M(L) = \eta \Lambda_T \left( 1 - e^{-L/\Lambda_T} \right).$$

(10)

In the empty section after the target it give rise to the contribution

$$N_{\mu,2} = \kappa \eta \Lambda_T \ell \left( 1 - e^{-L/\Lambda_T} \right),$$

(11)

where $\ell$ is the length of the empty section. Since attenuation due to decays is neglected when calculating the evolution of the flux, the same meson flux will reach the calorimeter. The contribution to the muon flux from decays in the calorimeter is

$$N_{\mu,3} = \kappa \eta \Lambda_T \Lambda_{cal} \left( 1 - e^{-L/\Lambda_T} \right) \left( 1 - e^{-\ell_{cal}/\Lambda_{cal}} \right),$$

(12)

where $\ell_{cal}$ is the length of the calorimeter. For Target 4 the contribution from decays in the absorber must also be included, which is

$$N_{\mu,4} = \phi_0 \kappa \Lambda_{abs} \left( 1 - e^{-\ell_{abs}/\Lambda_{abs}} \right),$$

(13)

where

$$\phi_0 = \eta \Lambda_T e^{-\ell_{cal}/\Lambda_{cal}} \left( 1 - e^{-L/\Lambda_T} \right)$$

(14)

is the flux at the boundary of the calorimeter and the absorber.

The relevant data for the experimental set-up are collected in Table 1. By adding the four contributing sources the total muon flux is obtained, i.e.

$$N_\mu = \sum_{i=1}^{4} N_{\mu,i}.$$  

(15)

Since the muon production rate $\kappa$ is normalised with respect to the ‘average Monte Carlo event’ (MC-flux divided by $L_{tot}$) and $\zeta$ is normalised to one event per target this is the suppression factor, i.e. $\xi = N_\mu$. The multiplicative suppression factors for the four targets are given in Table 1.

Analogous to the production within the targets, the primary muon can interact with the material in the concrete calorimeter and the concrete absorber. The analysis is similar to the target analysis but decays in the section between the concrete and the Fe-absorber must be included. For the calorimeter the flux is

$$\kappa \eta \Lambda_{cal} \left( \ell_{cal} - \Lambda_{cal} \left( 1 - e^{-\ell_{cal}/\Lambda_{cal}} \right) \right) + \Lambda_{cal} \left( 1 - e^{-\ell_{cal}/\Lambda_{cal}} \right) \left( 1 - e^{-\ell_{abs}/\Lambda_{abs}} \right) +$$

$$\ell e^{-\ell_{abs}/\Lambda_{abs}} \left( 1 - e^{-\ell_{cal}/\Lambda_{cal}} \right),$$

(16)
Target 1 | Empty section | Calorimeter | Absorber | $\xi$
--- | --- | --- | --- | ---
$75$ | $43$ | $165$ | $55$ | $21$ | $0.055$
$75$ | $43$ | $260$ | $115$ | $55$ | $0.084$
$75$ | $43$ | $120$ | $115$ | $55$ | $0.051$
$75$ | $43$ | $35$ | $80$ | $55$ | $0.033$

Table 1: Data on targets, calorimeters and absorber and the suppression factor for the final flux for the four different targets.

where the three different parts are from the decays in the calorimeter, decays in the concrete absorber and decays between the absorbers respectively. $\ell_{cal}$ is the part of the calorimeter that is in the beam (80 cm) and works as a target, and $\ell$ is the length between the concrete and the Fe-absorber. From interactions in the concrete absorber one gets the flux

$$\kappa \eta \Lambda_{abs} \left( \ell_{abs} - \Lambda_{abs}(1 - e^{-\ell_{abs}/\Lambda_{abs}}) + \ell(1 - e^{-\ell_{abs}/\Lambda_{abs}}) \right),$$

where the first part is from decays within the concrete absorber and the later part is from decays between the absorbers. In both these two cases $\eta$ is redefined compared to the target case in order to be normalised to one interaction in the ‘target’. The suppression factor for the calorimeter is 0.027 and for the absorber 0.17.

5 Impact parameter signature for secondary vertices

Since the difference in life-time between charmed particles and light mesons is large, they will typically decay at very different distances from the primary vertex. Since the heavy hadrons are very short-lived the muons from their decays will originate almost from the primary vertex ($\lesssim 1$ cm). Light mesons, on the other hand, are long lived and will typically decay far away from the primary vertex. This causes differences in distributions related to the production points of the muons. Such a distribution is the one in impact parameter. The impact parameter is the distance from the beam axis the muon track passes a plane orthogonal to the beam axis at the primary interaction point. If the difference is large enough and the distribution not smeared too much because of multiple Coulomb scattering it can be used to discriminate muons from light meson decays.

The distributions in impact parameter (without smearing due to multiple Coulomb scattering) for the muons originating from charm and light meson decays, respectively, are shown in Fig. 3 for the two sets of cuts discussed earlier. The distributions of muons from charm are shown for both charm production mechanisms. These distributions have the same shape (within the resolution), this is a reflection of properties of the charmed particle itself, that are independent of the production mechanism. The figure shows that there is a significant difference before Coulomb scattering is taken into account, which hopefully can be used to discriminate the background further.

The Coulomb scattering, which does not affect the deep inelastic interaction rate, is important when it comes to the reconstruction of the muon tracks. Both the scattered and the secondary muons will undergo multiple Coulomb scattering when they pass through calorimeters.
Figure 3: The distribution in impact parameter for muons from light meson decays (solid lines), intrinsic charm (dashed lines) and pQCD charm (dotted lines). Shown are both the distribution with a) the minimal set of cuts, and b) with the intrinsic charm search set. Decays are allowed in the distance between Target 4 and the detector planes before the magnet i.e. 3.5 m.

and absorbers and therefore deviate from their original direction. The resulting scattering angle is approximately given by Gaussian distribution having the width \[ \theta_0 = \frac{19.2 \text{MeV}}{\beta cp} \sqrt{\frac{x}{X_0}} \left[ 1 + 0.038 \ln(x/X_0) \right], \]

where \( x/X_0 \) is the thickness of the scattering material in radiation lengths.

The material that mainly causes the multiple Coulomb scattering is the concrete calorimeter and the concrete absorber. The main material in these two elements is concrete and the radiation length for concrete \((26.7 \text{g/cm}^2[5])\) is therefore used for both elements.

Muons from Target 4 must pass through 270 cm calorimeter and absorber material (neglecting target material), mainly consisting of concrete. This gives a width in the angular distribution of 0.008 rad for the lowest energy muons that are detectable \((10 \text{GeV})\). The distance between Target 4 and the first layer of the muon detector is \(\sim 3.5 \text{m} \). The muons coming from charm decays will therefore have a Gaussian distribution in impact parameter of width \(\sim 3 \text{cm} \), instead of the distribution shown in Fig. 3. This means that only muons with impact parameters larger than \(\sim 3 \text{cm} \) can be excluded, which is not an efficient cut to reduce the flux of muons from light meson decays as can be seen in Fig. 3. Since the width is decreasing with energy a tighter cut could be used if only higher energy muons where used. This is however not preferable since the rate would then be significantly decreased as can be seen from Fig. 2. An energy dependent cut in impact parameter would circumvent this problem and might be a working concept. For the more upstream targets the broadening will be even larger due to the larger distance between the target and the calorimeter/absorber. For Target 1 one must also include scattering in the iron calorimeter, which will further enlarge the broadening. So an energy and target dependent cut in the impact parameter would be the only feasible solution. This has to be further investigated with a dedicated Monte Carlo study using Geant [10], which is beyond the scope of this paper.

6 Summary

In order to search for heavy quarks by looking for additional muons in experiments like NMC the background from decays of light mesons must be well understood. In order to make an estimate
of this muon background a simple analytic technique has been developed. The technique has been applied to the heavy target set-up used by NMC. It was found that the muon flux from light meson decays is reduced to a few per cent of what it would have been without absorption. Taken all four targets together it would be 6%, but would be lower if only target 4 is considered. The possibility to use absorbers and calorimeters positioned in the beam as targets was also analysed. It was found that the calorimeter positioned before the absorber can be used as a ‘target’. The number of muons from decays of light mesons produced in interactions in the absorber was found to be a few times higher than those from the real targets, and the absorber is therefore not useable as a target. The acceptance of events in the absorber is anyhow not sufficient for using it as a target.

A further reduction of the background from decays of light mesons might be possible if vertex identification can be done with sufficient resolution. Such a reduction could be based on rejecting muons whose tracks do not point back to the primary vertex, which could be done by a cut in impact parameter. The simple analysis performed here shows that this method is not efficient because of multiple Coulomb scattering of the muons.

Acknowledgments

I am grateful to Andreas Mucklich for providing details on the NMC experiment. I would also like to thank Allan Arvidsson and Gunnar Ingelman for useful discussions and for critical reading of the manuscript.

References

[1] S.J. Brodsky, P. Hoyer, C. Peterson and N. Sakai, Phys. Lett. B93 (1980) 451.
    S.J. Brodsky, C. Peterson and N. Sakai, Phys. Rev. D23 (1981) 2745.
[2] J.J. Aubert et al., Phys. Lett. 110B (1982) 73; Nucl. Phys. B213 (1983) 31.
[3] E. Hoffman and R. Moore, Z. Phys. C20 (1983) 71.
[4] B.W. Harris, J. Smith and R. Vogt, Nucl. Phys. B461 (1996) 181.
[5] J.J. Aubert et al., Phys. Lett. 94B (1980) 96; Phys. Lett. 94B (1980) 101.
[6] Particle Data Group, Phys. Rev. D50 (1994) 1.
[7] G. Ingelman, J. Rathsman and A. Edin, LEPTO 6.4 – A Monte Carlo for Deep Inelastic Lepton-Nucleon Scattering, DESY preprint, to appear.
[8] B. Andersson, G. Gustafson, G. Ingelman and T. Sjöstrand, Phys. Rep. 97 (1983) 33.
[9] G. Ingelman, J. Rathsman and G.A. Schuler, AROMA 2.2 – A Monte Carlo Generator for Heavy Flavour Events in ep Collisions, DESY preprint, to appear.
[10] GEANT- Detector description and Simulation Tool, CERN preprint W5013, 1993.